NATURAL HISTORY OF CENTRAL ASIA
VOLUME IV

THE PERMIAN OF MONGOLIA

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CENTRAL ASIATIC EXPEDITIONS

THE PERMIAN OF MONGOLIA

CENTRAL ASIATIC EXPEDITIONS
ROY CHAPMAN ANDREWS, *Leader*

THE PERMIAN OF MONGOLIA

A REPORT ON THE PERMIAN FAUNA OF THE JISU HONGUER LIMESTONE OF MONGOLIA AND ITS RELATIONS TO THE PERMIAN OF OTHER PARTS OF THE WORLD

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WITH A CHAPTER ON THE RELATIONS OF THE JISU HONGUER FORMATION TO THE GENERAL GEOLOGY OF MONGOLIA BY CHARLES P. BERKEY, PH.D., CHIEF GEOLOGIST, AND FREDERICK K. MORRIS, A.M., GEOLOGIST, OF THE CENTRAL ASIATIC EXPEDITIONS, 1922, 1923, 1925

With 72 Illustrations in the Text and
35 Plates at End of Volume

NATURAL HISTORY OF CENTRAL ASIA

VOL. IV

CHESTER A. REEDS, PH.D., *Editor*

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THE PERMIAN OF MONGOLIA

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PREFACE

The fossils described in this volume were obtained during several seasons' field work in Mongolia, by the Central Asiatic Expeditions of 1922, 1923 and 1925. They were collected chiefly by Mr. Frederick K. Morris, at Jisu Honguer in southern Mongolia (Latitude 42° 18′ N., Longitude 109° 48′ E.). The fossils all occur in limestone, much of which is crystalline, varying from coarse to fine-grained. As a rule the fossils are well preserved, but perfect specimens are not easy to extricate because of the nature of the rock, which gives the surface layers of the shell a tendency to become exfoliated. This is especially the case with the larger brachiopods, most markedly so among the Spirifers and Spiriferellas. However, when weathered out, the surface characters are well shown.

Although the strata are strongly disturbed, the fossils in the limestones have suffered almost no distortion. It is only in rare cases that compression and distortion are found.

The geology of this region is discussed at some length by Messrs. Berkey and Morris in Chapter II of this volume, where the character and succession of the several divisions of the series are given. In the field, Berkey and Morris have recognized some twelve successive divisions which have been designated by field numbers. These are given in the list at the end of Chapter II, together with the genus or species most characteristic of them, and by which they will be referred to in the descriptions of Part II.

For the benefit of the general reader, a summary of the entire subject covered in this volume is given in Chapter I.

It has been found desirable to designate the various specimens which were studied in detail, by serial numbers, which are not always, or even generally, consecutive. This has resulted from the fact that the material was described, as its preparation was completed, without reference at the time to the systematic sequence. Often the discovery of additional material, after the original description had been completed, necessitated certain additions, especially in the measurements, and such new specimens have their serial number far removed from those of the specimens previously described. At the end of the volume, a list will be found, which gives in numerical order, the names, locality numbers, catalogue numbers and present disposition of the specimens in question.

The work of preparation and description was carried on in the palæontological laboratories and work-rooms of the National Geological Survey of China, and I take this opportunity to express my appreciation to Dr. W. H. Wong, the Director of the Survey, who has given me every facility in his power and has spared no pains to secure for the Survey library the literature demanded by this work. Even so, we regret to say that it has not been possible to consult all the books and papers germane to this subject, as it has been impossible to obtain some of the rarer works, which are not in the Survey library.

To my palæontological associates on the Survey, Messrs. Sun, Chao, Tien, Hsü and Chow, I am indebted for much help, especially in the preliminary work of sorting the material and in the search for references. Mr. Chao* himself undertook the preparation of the descriptions of the Productidæ for this volume, as a part of an extensive monographic study on the Productidæ of China, which has since appeared in the *Palæontologia Sinica*. With Mr. Chao I have carefully gone over the Mongolian representatives of this group, and checked his descriptions and determinations.

The illustrations were mostly prepared by our palæontological artist, Mr. K. C. Liu, whose skill and accuracy in the delineation of fossil invertebrates is amply attested by the plates in the *Palæontologia Sinica*. A few of the illustrations were made by Mr. Wang Hao-Ting, whose color illustrations of modern animals, for the Central Asiatic Expeditions, have received such well-merited praise. To my former secretary, Miss Rachel Burer (now Mrs. Barker), I am indebted for help throughout the preparation of the descriptions. My present secretary, Mrs. Alice Woodland, has rendered me invaluable assistance in the revision of the manuscript and the preparation of the plates.

Although the figures for the plates were drawn and assembled in Peking, it was found desirable to reproduce the plates by the collotype process in New York. The illustrations in the text were redrawn from my original figures by Mr. John Germann of the American Museum staff. The illustrated types are deposited in the Museum of the Geological Survey of China, in accordance with agreement.

Finally, I wish to record here my sincere thanks to Professor Henry Fairfield Osborn, President of The American Museum of Natural History, Dr. George H. Sherwood, Director, and to Dr. Roy Chapman Andrews, the resourceful and intrepid Chief of the Central Asiatic Expeditions, as well as to Mr. Walter Granger, Assistant Chief of the Central Asiatic Expeditions, and

* Mr. Chao's recent death at the hands of bandits while engaged in field work in Yunnan, has robbed Chinese science of one of its most brilliant young geologists and palæontologists.

to its geologists, Professors Charles P. Berkey and Frederick K. Morris, for placing the interesting material of this fauna in my hands for study and description.

To Dr. Chester A. Reeds, Curator of Geology and Invertebrate Palæontology in the American Museum, I am indebted for editing the manuscript. In this work he has been assisted in turn for short periods by Misses Elizabeth R. Powell, Adela M. Pond and Clara M. Beale. Miss Jannette M. Lucas has checked the bibliographic references. I am also grateful to Dr. Reeds for sending an edited copy of the manuscript to me December 16, 1929, for reading and emendations prior to submitting it to the printer. Dr. Reeds has supervised the engraving of the illustrations and the printing of the volume, and, with the assistance of Mr. Sydney Helprin, read the various printer's proofs and prepared the index.

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Peking, March 1, 1930.

CONTENTS

TEXT-FIGURES

PLATES

THE PERMIAN FAUNA

OF THE

JISU HONGUER LIMESTONE OF MONGOLIA

PART I

GENERAL INTRODUCTION

PART I—GENERAL INTRODUCTION

CHAPTER I

THE PERMIAN OF MONGOLIA

ITS RELATIONS TO THE PERMIAN OF OTHER PARTS OF THE WORLD AND ITS BEARING ON PERMIAN GEOLOGY AND GEOGRAPHY—A GENERAL SUMMARY

INTRODUCTION

THE Permian history of Mongolia can be fully understood only in the light of those antecedent events which prepared the stage for the final scenes of the Palæozoic, and which brought the physical and faunal evolution to the point where Permian events followed as a normal sequence.

The Permian is the final period of the Palæozoic era. The Palæozoic era by itself forms a closed volume in the history of our earth; it is sharply set off from the era that precedes it and is also very distinct from the one which follows it. The Palæozoic differs from the eras which succeeded it much more strongly than do these eras from one another. Indeed, it would not put too great a strain upon our sense of relative values, if we were to unite the three post-Palæozoic eras, the Mesozoic, the Cenozoic and the Psychozoic, into a single super-era, the Neozoic, and place it in opposition to the Palæozoic. Although each is different, when viewed in detail there is a thread of continuity to be discerned, whether we view these periods in the light of their physical and geographical development, or in that of their organic evolution.

Broadly speaking, the beginning of the Mesozoic was the beginning of the earth in which we live to-day, despite the fact that tremendous physical and organic changes have marked the progress of its development. But the earth of Palæozoic time was so distinct that we cannot visualize its history in the light gained from the study of the later eras. Much evidence is accumulating which leads many students of the Palæozoic earth to consider that its axis of rotation was situated differently from that which exists to-day, thus causing tropic conditions to prevail at the present poles, and polar conditions where to-day the climate is tropical. Other evidence points to the possibility that in Palæozoic time the continents themselves were not where we find them to-day, but instead formed a more or less continuous unit which since that time has become dismembered to form the present continents and ocean basins. The most important event of this dismemberment was the westward drift of the Americas and the birth of the Atlantic Ocean. It is true that there are many geologists who neither accept the doctrine of the displacement of the earth's poles nor subscribe to the theory of the former continuity of the continents. But these have not yet succeeded in explaining the most pertinent physical events of the Palæozoic in any satisfactory way. Whether we accept or reject these broader theories of world evolution, none of us can escape the conviction that in Palæozoic time the earth was unique, both in its physical conformation and in its organic history.

Mongolia, in early Palæozoic time, was the site of an upland region of ancient rocks, which supplied the rivers flowing from it into the Irkutsk Basin of Siberia with sediments. This basin, which is roughly outlined by the Lena River on the east, and the Yenisei on the west, extended southward from the present Arctic region to the latitude of Irkutsk, and was the site of extensive sedimentation from the opening of the Palæozoic to the close of the Silurian period. It was apparently bounded throughout this time by a marginal geosyncline of horseshoe-shaped outline, with the Angara platform in the center forming a sort of medial marginal plain. The Mongolian upland on the south, and similar uplands on the east and west, formed the old-lands that supplied the sediments. Throughout much of the earlier Palæozoic, the Boreal Sea, the predecessor of the present Arctic Ocean, flooded the Irkutsk Basin, so that the strata which were forming there enclosed marine organisms of the type peculiar to that province. Most significant among these marine organisms were the reef-building corals, which apparently flourished in these waters, for portions of this ancient basin, now well within the Arctic Circle, show rocks formed of ancient coral reefs, reefs which would never have been formed had the waters of that time not been of sufficient warmth to prevent the formation of ice during any portion of the year.

At the end of Silurian time, the strata of the marginal geosyncline of the Irkutsk Basin were folded into a mountain range or series of ranges whose direction was essentially that of the original geosynclines. At the same time the bordering old-lands suffered a collapse which converted them into a new series of geosynclines parallel to the newly formed ranges. These ranges now became the old-land which supplied the newly formed geosynclines with sediments.

It is thus at the beginning of Devonian time that we meet for the first time with the great Mongolian geosyncline, an east-west trough of slow but progressive subsidence, bordered on the north by the predecessor of the present Khingan Range of which the folded ranges of the Irkutsk region formed an integral part. To the south of the Mongolian geosyncline lay the platforms of northern China, which formed the marginal plain that normally supplements the geosyncline. At first the floor of the Mongolian geosyncline was above sea-level, and the sediments, if such were formed there in Lower Devonian time, were of a purely continental type, enclosing no marine organisms. They probably form to-day a portion of the still undifferentiated graywacke series, and, if this is the case, they should be found next overlying the ancient, more or less crystalline rock, that in the period just preceding formed the earlier Palæozoic upland of Mongolia.

Middle Devonian time witnessed the great marine transgression which in Central Asia has become known as the Kwenlun transgression. At this time, the marine waters which then covered parts of central Asia and extended through the great Himalayan geosyncline, the predecessor of the Himalayan Mountains, into southern China, also transgressed northeastward and entered the Mongolian geosyncline, large portions of which were then converted into an inland sea. In this sea, Devonian corals grew in reefs, and brachiopods, trilobites and other organisms of the period flourished in abundance, as is shown by their remains, now found as fossils in the limestones, shales, and other sedimentary rocks of this period, which probably outcrop in Mongolia and are known from the bordering region in Siberia. Once established, marine conditions continued in more or less interrupted manner to the end of Devonian time, in at least some portions of this geosyncline, and they were succeeded by the marine waters of Lower Carboniferous or Dinantian time. For, although Dinantian fossil-bearing strata have been found in Mongolia in few localities, notably at Sair Usu, they are known both from regions farther west at Kusnezk, etc., and farther east in the Gasimursk ranges of Transbaikalia and other regions. All these fall within the confines of the Mongolian geosyncline. This geosyncline formed indeed the chief great waterway, through which the marine organisms of the Lower Carboniferous Sea could migrate. And that they did so migrate is shown by the fact that many species, known in the Lower Carboniferous limestone of the British Isles, and the equivalent Calcaire Carbonifère of Belgium, are found not only in the localities within the Mongolia geosyncline, but occur also in equivalent rocks of Japan and even on the western coast of North America. The interior Lower Carboniferous or Mississippian seas, as they are more generally named in North America, were, however, for the most part, quite distinct from the main Dinantian seas of Asia, which were an extension of the Pacific, while the American Mississippian was an extension of the Boreal Sea of the period. Nevertheless, it is true that this Boreal Sea also communicated with the great Eurasiatic Dinantian Sea near the western end of the Mongolian geosyncline, so that a certain amount of intermigration of the Eurasiatic Dinantian and the American Mississippian faunas was possible.

Although the Mongolian geosyncline seems to have been the chief pathway of migration of the faunas between the Pacific regions and Europe in Dinantian time, its effectiveness as a connecting waterway ceased with the opening of the succeeding Middle Carboniferous or Moscovian period, and remained inoperative to the end of Carboniferous time. This does not mean that sedimentation in this geosyncline came to a standstill, for river-borne sands from the northern uplands probably continued to be spread as alluvial deposits over the low plains. It is not yet known whether any coal deposits were forming during this period in the Mongolian region, though this was the great coal-forming period of western Europe and eastern North America.

It was approximately at this time that the region of the Indian Ocean appears to have been the center of glaciation. Traces of this glaciation are found in India, in Australia, and in Africa, with indications that the movement of the ice was both southward and northward from a region situated in the vicinity of the present equator. This has been explained by placing one of the poles, perhaps the South Pole, in latitude 20° South, Longitude 80° East, of to-day, which would bring the North Pole somewhere in the region of Tultenango, Mexico (Latitude 20° North, Longitude 100° West, of to-day). If we assume with Wegener that Africa, India and Australia were in conjunction at that time, a somewhat different position for the poles would be required to account for this ice radiation, and if South America joined Africa at that period, as is held by Wegener, the similar late Palæozoic glaciation on that continent would equally be accounted for.

While these events were proceeding in the south, western Europe and eastern North America were the sites of extensive coal swamps. We have at present no evidence that any of the marine faunas of this period were derived from the Atlantic Ocean. Indeed, so far as Palæozoic history is concerned, the Atlantic Ocean need not have been in existence at all. On the other hand, the evidence is overwhelming that the eastern border of North America was at that time margined by an extensive continent, which has been named Appalachia, and from which the rivers spread their sediments westward over the plains on which flourished the coal swamps, in which was produced much of the coal of eastern North America. A similar old-land margined Europe on the west, and its rivers spread the sands and muds that enclosed the coal beds of western Europe. If Europe and North America were in contact at that time, these two old-lands may have been part of one continental high-land situated between the two areas of river flood-plains. Much of this continent disappeared by sinking at the end of Palæozoic time, and this may have been the period when the continents broke apart and the Atlantic Ocean appeared.

There was, however, one area in which marine sedimentation was more or less continuous throughout Carboniferous time, namely, central and southern

Russia, where the marine sediments of this period are especially well-known from the Donetz Basin of southern Russia.

As given in detail in Chapter XIII of this volume, all three divisions of the Carboniferous are present in great thickness in the Donetz Basin. The middle division, known as the Moscovian, and characterized by a fauna of which the brachiopod *Spirifer mosquensis* is the leading form, has there a thickness of some 6,000 meters and is followed by 2,000 meters of Upper Carboniferous beds, in which the fauna gradually changes by the disappearance of the older forms and the advent of new types. It is suggested that the Boreal Sea of that period, the predecessor of the present Arctic Ocean, was the center of evolution of this fauna, which migrated on the one hand into the Russian basin and on the other into the Palæo-Cordilleran geosyncline of western North America. But this sea (though it may have sent an occasional arm eastward into China, to persist for a short time) was for the most part a separate water-body, and its fauna was entirely distinct from the contemporaneous fauna which then must have occupied the Pacific Ocean.

It has generally been held that the typical section of the marine Carboniferous is found in the Ural Mountains region of eastern Russia, where the Middle Carboniferous beds with *Spirifer mosquensis* are succeeded by three or four hundred meters of limestone which collectively have been named the Uralian Series.

This series has been made the type of the Upper Carboniferous of Europe, but as is shown in Chapter XI, no part of it can be placed in this division. The entire Uralian, as now understood, is a unit, from the Omphalotrochus beds, so called because of the presence there of the gastropod *Omphalotrochus whitneyi*, through the overlying Schwagerina limestone, named so because of the dominance in it of the foraminiferan shell *Schwagerina princeps*. These beds correspond to a similar series of limestones, characterized by the same *Schwagerina*, which overlies the 2,000 meters of Upper Carboniferous beds of the Donetz Basin and hereinafter designated the Bakhmout series. Moreover, the fauna of the Uralian beds is distinct from the typical Upper Carboniferous fauna of the Donetz Basin. It is the latter that must be considered the type of the Russian Upper Carboniferous, and I have suggested that the name Donetzian be made the group name of the Upper Carboniferous of Europe.

As will be seen by a careful study of the discussion of this question in Chapters XI and XIII, the Ural Mountains section and that of the Timan Range are incomplete. A great hiatus, representing nearly the whole of the Upper Carboniferous and a considerable part of the Middle Carboniferous as well, separates the Uralian beds, or at least a considerable portion of them, from the underlying limestone with *Spirifer mosquensis*, that is, the east

Russian representative of the Middle Carboniferous. This implies that while deposition of all the later Carboniferous strata went forward in the Russian Basin, the East Russian region was dry land forming the pre-Uralian old-land, against which the strata of the several divisions of the Carboniferous overlapped in a wedging-out manner.

The Uralian of East Russia is succeeded by the Artinskian, which comprises a series of sandstone, shales, etc., with a fauna which retains some of the species of the Uralian beds, together with others which are found in the typical original Permian beds which overlie the Artinskian. So long as the Uralian beds were considered to be of Upper Carboniferous age, this commingling of faunas warranted the designation of the Artinskian as Permo-Carboniferous. But when we consider that the real Carboniferous beds, the Donetzian, underlie the typical Uralian and have practically nothing in common with them, it becomes apparent that the Omphalotrochus and Schwagerina limestone faunas represent the appearance of a new and alien host of organisms in a region hitherto occupied by endemic faunas only, or by such as were at home in the Boreal Sea. This invasion, which completely changed the faunal aspect, may well be taken as coinciding with the opening of the new and final period of the Palæozoic history of the earth, that is, the Permian, and hence, in the revised classification advocated in this volume, the base of the Permian is placed at the base of the Uralian as a whole.

As will be seen by the study of the details given in Chapters XI to XV, the Uralian fauna is essentially an Indo-Pacific fauna. It represents the invasion of the sea through southern China, the Nanshan geosyncline and central Asia, to the Russian Basin, and as far north as Spitzbergen on the one hand, and into the Tethys, the predecessor of the Mediterranean, on the other. The distribution of these faunas in the Tethys is given in Chapter XVI. There we have also shown that all the available evidence points to the conclusion that the western end of the Tethys was closed in Permian time, the deposits there being of the continental type formed by the rivers which proceeded from the Atlantean continent of the period. This leads to the further conclusion that all the Permian faunas of the Tethys Basin were derived from the Indo-Pacific region by migration, in so far as they were not supplied by the Boreal Sea or were endemic, that is, developed in the region from pre-existing Carboniferous types.

For the typical succession of the Later Palæozoic beds, the student of Asiatic geology has always looked to the ancient Himalayan geosyncline or the waterway which occupied the site of the present Himalayan Mountains before these ranges arose by folding in Tertiary time. The sections which have been so well described from the Salt Range in northwest India, and whose faunas have been made known so extensively by the labors of Professor

Waagen and his palæontological associates, have always been regarded as the standard of comparison for other Asiatic sections. In the Salt Range, the glacial conglomerate, or Talchir formation, is succeeded by the Speckled sandstone, and this by the Lower Productus limestone which varies in thickness from 27 to 66 feet and is characterized by *Spirifer marcoui*. This appears to be equivalent to the lower part of the old Uralian series, that is, the beds below the Cora limestone of the Urals. These also contain *Spirifer marcoui*, and they, together with the Lower Productus limestone, most probably represent Lower Permian, the Upper Carboniferous being the period of glaciation in southern Asia. There is every reason for believing that, between the Lower and the Middle Productus limestone, there is a hiatus, similar to that indicated between the corresponding beds of the Ural region, while the Middle Productus limestone of the Salt Range, which varies in thickness from 270 to 410 feet, is the approximate correlative of the Omphalotrochus and Schwagerina limestones, or at least of the latter. For although it does not contain *Schwagerina* itself, the correspondence between the species of the other groups in the two formations is so marked that, in spite of their distance apart, they must be regarded as representing approximately equivalent horizons. This is brought out clearly by table IV in Chapter XI, and table VI in Chapter XII. Moreover, the most striking and characteristic species are common to the two.

In the past, this correspondence has been recognized, and a correlation between these two horizons has been made. The Upper Productus limestone of the Salt Range was then correlated with the Artinskian of the Ural region.

As the Russian geologists had considered the Uralian as Upper Carboniferous, not recognizing the great hiatus between it and the Middle Carboniferous in the Ural region, they insisted on referring the Middle Productus limestone to the Upper Carboniferous and the Upper Productus limestone to the Permo-Carboniferous. The Indian geologists, on the other hand, insisted on the Permian age of the Middle and Upper Productus limestone. It is now clear that this latter reference is correct, and that the Uralian as well as the Artinskian of the Ural region are likewise to be regarded as typical Permian divisions.

The Jisu Honguer limestone of Mongolia may be considered the approximate equivalent of the east Russian Uralian and of the Middle Productus limestone of the Salt Range. Like the latter, it contains no *Schwagerina*, but the fauna is otherwise of a strikingly similar character. This is brought out by Table II in Chapter IX which shows the distribution of the species of the Jisu Honguer limestone in other localities. In that chapter, this particular problem is more fully discussed.

There are many new varieties of brachiopods in the Jisu Honguer limestone. This is to be expected in a region as unique as was the Mongolian geosyncline, and as distant from the other two localities as it is readily seen to be by reference to a map. In the detailed descriptions of this fauna, given in Part II of this volume, the characters of these varieties and their relationships to the species are discussed at length, and this with the aid of the illustrations will give a complete picture of this fauna.

One important fact, however, must not be overlooked. This is the essentially dwarfed character of the Jisu Honguer faunas, for as is shown by the measurements given in the descriptive part, the average size of the Jisu Honguer forms falls considerably below that of the same or closely related species found in the Middle Productus limestone of India or the Schwagerina limestone of the Urals. A somewhat exhaustive discussion of this problem is given in Chapter XX, where the conclusion is reached that this dwarfing is due primarily to abnormal salinity of the waters, created by the large amount of fresh water that was poured into this basin by the rivers which built extensive alluvial plains, more or less comparable to that of the Yellow River of China, over large parts of the Mongolian geosyncline in Permian time. These other types of Permian deposits, which are found in the Mongolian geosynclines, are described in Chapter XVIII, from which it will be seen how extensive these non-marine deposits were.

On the other hand, as we proceed eastward from Jisu Honguer, the deposits become more markedly marine, and in the corresponding marine beds of Manchuria and Japan, *Schwagerina* again makes its appearance.

The Jisu Honguer limestone and its equivalent beds in the maritime regions of eastern Asia, the Middle Productus limestone of India, the Schwagerina beds of south China and of the Nanshan and Tianshan geosynclines of central Asia and other horizons in Tethys, as well as the typical Uralian of eastern Russia and the corresponding beds which overlie the Upper Carboniferous beds in the Donetz Basin, all represent the record of the first great invasion of the Indo-Pacific waters across Asia into Europe, and this marks the opening of Permian time. This great invasion of the eastern seas, however, did not persist, for it was followed by a breaking up of the continuous area of deposition into several distinct marine provinces. One of these was the Russian province where the higher Permian beds enclose again a distinctive fauna. This Russian sea extended westward into the great Zechstein Sea of north Germany, where these faunas were first studied. That basin suffered complete evaporation, which resulted in the formation of the anhydrite and salt beds, and the remarkable potash and other mother-liquor salts that are of such economic importance to Germany. The rest of the Russian basin, too, became separated from the Boreal Sea, and, by evaporation, gypsum and salt deposits were formed, and eventually the region was reduced to one of desert conditions, as is testified by the great extent of the Tartarian Series of "Red Beds," which terminate the Permian Series of Russia.

Isolation, followed by desiccation, with evaporation of the waters and later the deposition of continental beds, also characterized the Tethys, especially in its western portion, as is described in detail in Chapter XVI. Here it appears, however, that because of the great depth of a portion of this basin, complete drying up of the waters did not take place, but a great inland salt sea, comparable to the Caspian of to-day, remained. In this relict sea, the survivors of the late Palæozoic faunas lingered, while everywhere else these organisms became extinct, with the exception of those which had assumed a swimming or a floating life. When, in the early Mesozoic, the sea once more returned, the descendants of these survivors in the Permian Mediterranean, became a part of the early Triassic fauna, and formed a distinctive element of the Alpine Triassic fauna of that region.

The later Pacific Permian fauna is, however, found in the strata of south and central China and in some of the Permian deposits of the outlying islands of to-day, but it has not been found in Mongolia. This fauna, too, eventually became extinct, when the great physiographic changes at the end of Permian time brought the Palæozoic era to a close and caused the all but world-wide extinction of the Palæozoic marine faunas. This was due to a withdrawal of the marine waters from all the shallow seas and from the continental shelves of the oceans, a phenomenon which may have been caused by a depression of the ocean bottoms and a consequent deepening of the greater oceanic basins.

CHAPTER II

RELATIONS OF THE JISU HONGUER FORMATION TO THE GENERAL GEOLOGY OF MONGOLIA

By Charles P. Berkey and Frederick K. Morris

Geologists of the Central Asiatic Expeditions, 1922, 1923, 1925

GENERAL STRUCTURE OF MONGOLIA

Mongolia occupies the northern portion of the great compound basin of central Asia, which is the world's largest region of inland drainage. The rims of the basin are warped uplifts of mountainous height, ranging in elevation from 5,000 to 20,000 feet. The eastern margin is formed by the Great Khingan Mountains on the borders of Manchuria, and the western extreme by the Pamir and the Kashgar range, at the western end of the Tarim lowland. The northern limit lies along the Siberian border in the Tannu Ola, Khangai, and Transbaikal ranges, and the extreme southern rim is the Altyn Tag, which separates the central basin from the high platforms of Tibet.

The eastern portion is broadly open and gently warped. In the western portion many long narrow fault-block ranges of the Tien Shan, Altai, and Tannu Ola systems extend eastward from the great knots of mountains that form the western rim. These ranges enclose long, relatively narrow, semi-desert basins. The chief subdivisions of this great basin of central Asia are the Gobi in the east, and the Tarim, the Dzungaria, and the Kobdo basins farther west. Within the mountainous rims, the floor of the Gobi basin region sinks to as low as 2,800 feet above sea level. The Tarim is much lower.

The oldrock floor of the Gobi Basin is a complex of sedimentary and igneous rocks, ranging from Archæan to Jurassic in age. All are disturbed by folding and faulting, and are cut by many large and small igneous bodies. The earlier members of the complex have been heavily metamorphosed, and include gneisses, schists, crystalline limestones, and serpentines. The later members are much less affected by this kind of change, and include graywackes, sandstones, shales, slates, and limestones. The most important igneous masses are large intrusive bodies of granite, which represent the maximum encroachments of a great differentiating bathylith which underlies the region, and which, we believe, has supplied most of the stocks, dikes, and flows found in Mongolia.

Upon the peneplaned surface of the complex oldrock floor, a series of later sediments has been deposited, ranging in age from earliest Cretaceous to Recent. These later sediments lie nearly horizontally except near the mountain fronts where they are locally disturbed. They are but lightly cemented, and consist chiefly of clays and sands, with minor conglomerate members. They represent a variety of inland deposits—alluvial fans, floodplains, lake deposits, wind-borne sand and dust. A rich harvest of continental vertebrate fossils has been obtained from them.

THE GEOLOGIC COLUMN

From these general structural relations it is clear that there are two broad divisions of the rocks of central Asia—the lower, and much the greater, including the complex formations of the oldrock floor, and the upper including only the comparatively thin later sediments. Within each division there are significant breaks, marked unconformities, and disconformities, accompanied by epochs of igneous activity and of orogenic disturbance.

A summary of the geologic column for central Mongolia is given in the following table, pages 14 and 15.

LARGER GEOLOGIC HISTORY

An outline of the larger features of the geologic history as now understood in central Asia will be of some advantage as a background for the specialized discussion of the Palæozoic strata and their fossil content which forms this volume. This geologic history was presented by Charles P. Berkey and Frederick K. Morris, 1927, in much more detail and with supporting evidence in Volume II of *The Natural History of Central Asia*. It is judged to be sufficient in this connection to outline only the general picture.

The older pre-Cambrian formations

Willis and Blackwelder (1907, Vol. I, Pt. 1, pp. 19 and 109) have distinguished in China two ancient systems which they have classified as the T'ai Shan system, of Archæan age, and the Wu T'ai system, representing the early Proterozoic, using the terms previously adopted by von Richthofen in 1871 (1882–1912). Because the oldest rocks in Mongolia fall into a fairly similar twofold division, we have chosen to use the same names for them.

The Expedition was never fortunate enough to find the actual contact between formations assigned to the T'ai Shan complex and those included under the Wu T'ai. We are aware, of course, that metamorphic effects, produced by

GENERALIZED GEOLOGIC COLUMN FOR MONGOLIA

	Era	Period	Thickness (Feet)	Sediments	Igneous Activity	Disturbance
Later Sediments	Cenozoic	Recent Pleistocene Pliocene	5–100 100–1000 2000	Lake beds, valley fills, dunes, upland gravels Rubbles, sands, and silts Clays, sands, and gravels	None Volcanoes Volcanoes	Local warping Faulting, warping, and uplift Faulting, mountain growth
				Disconformity		
		Miocene Oligocene	100–1000? 100–2500	Clays, sands, and fine gravels Clays, sands, and conglomerates	None Basalt flows	None noted None noted } Mountain making in other parts of Asia
				Disconformity		
		Eocene	100–500	Clays, sands, and gravels	None noted	None noted } in the open basin country
				Disconformity		
		Paleocene	300	Clays, sands, and fine gravels	Basalt flows	None noted } in the open basin country
				Disconformity or Slight Unconformity		
	Mesozoic	Upper Cretaceous	400	Fine sands and a little clay	None noted	Warping and local faulting
				Disconformity or Unconformity		
		Lower Cretaceous	500–2000	Paper shales, clays, sands, conglomerates and, rarely, thin limestones	Basic and acid extrusive sheets	Warping and faulting

GREAT UNCONFORMITY—All formations below this line tilted, faulted and locally folded

Oldrock Floor of Central Asia		Lower Jurassic possibly including Triassic	500–10,000	Conglomerates, coarse sands, shales, tuffs, ashes	Large and small intrusive bodies, great outpouring of acid and basic lavas	Faulting, tilting, local crowding and folding
	Unconformity—Folding and faulting followed by prolonged erosion					
	Palæozoic	Permian	50–2000	Conglomerates, sandstones, shales, limestones, marine and estuarine, also ash and tuffs.	Large stocks of the Great Bathylith; sills and dikes	Folding
		Break—probably Disconformity				
		Dinantian	50–1000	Conglomerates, sandstones, shales and marine limestones	Dikes observed	Folding
	Break, extending through early Palæozoic time—Maximum advance of the Great Bathylith					
	Proterozoic	Late pre-Cambrian or Sinian?*	10,000–20,000	Graywackes, slates, and minor conglomerates; ash and tuff	Dikes, sills, veins, and large stocks	Folding, shearing, local metamorphism
		Unconformity				
		Wu T'ai system of Willis		Schists locally injected; sheared conglomerates, dolomites and crystalline limestones	Large and small intrusive bodies	Complex folding and shearing; "regional" metamorphism
	Unconformity					
	Archæozoic	T'ai Shan system of Willis		Gneisses, injected schists, marbles, crystalline limestones	Large and small intrusive bodies	Complex folding and shearing; profound regional and igneous metamorphism

*Probably includes Continental Devonian and Marine Devonian found in some portions of the Mongolian geosyncline.

diastrophism and especially by the encroachment of a large igneous mass, may cause rocks of diverse age to resemble one another. The distinction was made only where broad areas of rocks consistently displayed a given range of metamorphic effects.

Thus, the T'ai Shan complex consists of gneisses, schists, coarsely crystalline marbles, and a wide range of igneous rocks. The gneisses include (1) granites which have been sheared and reorganized; (2) schists which have been so profoundly injected by igneous materials that most of their original minerals have been destroyed or replaced by invading pegmatites; (3) various syntectic rocks. The igneous rocks include chiefly granites and diorites, with fewer basic, coarse-grained types.

The rocks of the Wu T'ai system are schists, crystalline limestones, quartzites, conglomerates, and associated igneous masses. Among the schists are found greenstones and chloritic schists, mica-schists, and schistose conglomerates. Locally the schists bear lit-par-lit injections and lens-like streaks of granite pegmatites, but nowhere are they so fully saturated with and replaced by igneous matter as are the gneisses of the T'ai Shan complex. Dolomites and crystalline, finely bedded, "ribbon" limestones are the chief carbonate rocks, and are very abundant. Many of the igneous rocks are sheared, forming augen-gneisses, but none bears evidence of as complex a history as those of the T'ai Shan.

Later pre-Cambrian rocks

At several widely separated places in its traverse of Mongolia, the Expedition passed from an area of Wu T'ai schists to an area of graywackes and argillites. In each of these localities the transition was so abrupt that a change from an older to a distinctly younger formation was confidently inferred.

The younger rocks are graywackes, shales or slates, argillites, a few jaspers, and occasional limestones. The grains of the graywackes consist of quartz, feldspar, porphyry, volcanic ash, schist, and slate, cemented chiefly with silica. The shales grade into slates and even into fine mica phyllites, especially near granite contacts. The limestones are gray, very siliceous, and much shattered, but not like the metamorphic crystalline limestones of the Wu T'ai system, nor like the richly fossiliferous calcarenites and calcilutites of the known Palæozoic series. Large areas of the graywacke-slate series are without limy members, especially in the northern borders of Mongolia. Large areas of the graywackes and slates are sheared and reorganized, developing abundant fine mica flakes. Such metamorphism was observed almost nowhere in the typically known Palæozoic rocks.

In our reports, these rocks are termed the Khangai series because large areas in the Khangai Mountains are composed of them. Tentatively the series was assigned to late pre-Cambrian age, the Sinian of Grabau, because they resemble the Sinian rocks of the Nan K'ou district, in degree of disturbance, metamorphism, and relation to igneous masses. The types of sediments are similar in the Nan K'ou and the Khangai series, but much more limestone is found at Nan K'ou and far more sandy materials in the Khangai district.

The Khangai series is invaded by a granite bathylith of immense size, estimated as underlying an area of about 500,000 square miles in central Asia. Large stocks, believed to represent the most actively upward-working portions of the bathylith, have undercut the ancient roof and stoped out great masses of the graywacke series. Along the contacts that can now be seen, the granites are crowded with xenoliths, while the graywackes and slates are metamorphosed to a schistose condition, and are cut by many dikes and sills. Farther from the contact some dikes and sills are to be seen, while large and abundant veins of white quartz suggest the activity of uprising solutions probably derived from the bathylith.

Palæozoic strata

An impressive scarcity of Palæozoic strata marked the earlier exploratory work of the Expedition. Russian geologists had reported large areas in districts farther north and east, and also from the Altai region. It was clear, therefore, either that the Gobi region was of different structure from that explored by the Russians or that a different classification of the formations was being made. With full appreciation of the problem, special attention was given to every formation which might be of Palæozoic age, but only a few limited areas were found. In subsequent work, however, especially in the season of 1925, additional Palæozoic areas were discovered, and the occurrences are now understood well enough to enable one to outline the larger structural relations.

The known Palæozoic rocks are comparatively limited in distribution, though they are locally very thick. They are invariably closely folded, standing either on edge or dipping at high angles, and are deeply eroded. All occurrences are essentially remnants, representing steeply down-folded portions of old mountain ranges or down-faulted blocks carrying folded strata down into contact with earlier series.

The general strike of the strata of Palæozoic age is essentially the same as that of the pre-Cambrian, especially the Khangai series, with which the Palæozoic strata are often closely associated. In such cases there is little evidence of a break, either in the topography or in the structural appearance, and as a consequence the true relation is readily overlooked. In fact, even at the best places, the relation cannot be established except by very careful inspection. The difficulty is increased by two important facts: (1) the non-fossiliferous condition of the graywacke series, and (2) the similar petrographic character of the typical graywacke rocks and certain portions of the Palæozoic strata. Under such conditions, even a down-faulted block of Palæozoic strata is easily overlooked. The Khangai series is clearly older than the known determinable Palæozoics, but how much older we do not know.

Only fragmentary occurrences of the Palæozoic series have been identified with certainty in the Gobi region. These localities are described farther on in this chapter. It is possible, of course, that larger areas extend beneath the later sediments, but in any event the areal proportion is small. This small areal extent need not be interpreted to mean that the Palæozoic beds originally were so limited; on the contrary, probably strata of this age covered the whole of central Mongolia.

To the best of our knowledge, the earlier Palæozoic is not represented, but the later Palæozoic is, including the Permian. Subsequent to the deposition of these strata, the whole region was closely folded, and with that orogenic movement, deformation of the close-folding type was concluded for the northern portion of central Asia. Thereafter, deformation took the form of block-faulting and crowding in the Mesozoic era, followed by faulting and simple warping in the Tertiary.

TABULAR SUMMARY OF THE
ERAS AND PERIODS CHARACTERIZED BY EMERGENCE AND SUBMERGENCE

Era	*Period*	*Formation or System*	*Sedimentation*	*Diastrophism*	*Igneous Activity*
		Erosion	Unconformity		
Palæozoic	*Permian*	Jisu Honguer Tsagan Khati Gutul Usu Dunde Saikhan Jichi Ola and other formations.	Widespread shallow flooding of Mongolian geosyncline. Deposition of conglomerates, very thick graywacke sandstones and shales, with thinner limestones. Locally thick deposits of ash and tuff (cf. igneous activity).	Folding, open in some places, intense in others.	Revival of bathylithic invasion locally sending up large stocks, but chiefly dikes, sills and quartz veins. Active surface volcanism producing ash, tuff and flows. Local metamorphism of sediments.
Palæozoic	*Pennsylvanian*	Erosion	Unconformity		
Palæozoic	*Dinantian (Mississippian)*	Sair Usu (and probably other somewhat metamorphosed sedimentary formations).	Shallow flooding of the Mongolian geosyncline. Deposition of basal conglomerates, with fossil-bearing, thick limestone beds succeeded by sands and shales.		
Palæozoic	*Devonian*	No formation-names assigned. Presence of Devonian sediments inferred from fragments in alluvium.	Shallow seas extending through much of the Mongolian geosyncline.		
		Erosion	Unconformity		

			Emergence during Cambrian, Ordovician and Silurian time.	Folding, of simpler type than is seen in the Wu T'ai and T'ai Shan complexes.	Widespread invasion of the great bathylith.
	Pre-Cambrian Sinian?	Arbun Khoyer graywackes and phyllites; Khangai series as revised.	Widespread shallow submergence probably taking place at different times in various parts of China and Central Asia. Deposition of conglomerates, sands of graywacke type alternating with clays; and with smaller thicknesses of limestones and volcanic fragmental material.		
		Prolonged Erosion		Unconformity	
EARLY PROTEROZOIC			Emergence persisting into late Proterozoic time.	Complex folding	Invasion of bathylithic magmas on a large scale.
		Wu T'ai	Widespread submergence. Deposition of conglomerates, sands, clays and limestones of great thickness over broad areas.		
		Erosion		Unconformity	
ARCHÆOZOIC			Emergence persisting into Proterozoic time	Complex folding	Invasion of magmas on a large scale.
		T'ai Shan	Widespread submergence. Deposition of clastic sediments and limestones accumulating to great thickness over broad areas. Several divisions are probably represented, but are not now separable.		

The nature of Gobia

It will be seen from this brief summary that all rock formations from the Archæan through the Palæozoic have the following common characteristics:

1. They are very thick and consist of relatively fine-grained sediments, chiefly shales and sandstones, with varying thicknesses of limestone; conglomerates are locally present but are distinctly subordinate. The sediments are probably dominantly marine or estuarine.

2. They are folded, and the folding is generally intensive, though fairly open folds prevail in the Khangai Mountains.

3. All are invaded by bathylithic igneous masses, chiefly granites, and all except the later Palæozoic strata are metamorphosed, at least locally. The late Palæozoic strata are much less modified.

Until the close of the Palæozoic, therefore, central Asia manifested a tendency to subside beneath shallow seas and to accumulate broad and thick covers of sediments.

At the close of the Palæozoic, however, after vigorous earth movements had folded the latest sediments of the Mongolian geosyncline, a new stability was attained. Thenceforward, no marine deposits are recorded between the Tethys trough on the south and the Lena embayment on the north; or between the lower Amur basin on the east, and the foot of the Urals on the west. The mid-Mesozoic rocks of Mongolia are wholly non-marine. In the post-Permian revolution, therefore, the Mongolian geosyncline was welded to Angoraland, and the continental element, Gobia, was formed.

Mountain-making has been renewed in Gobia at least twice since its origin: at the close of the early Jurassic sedimentation, and again in Tertiary time. But the essential stability of Gobia is indicated (1) by the retention of great amounts of continental sediments which were not removed by seaward-draining rivers, and (2) by the peneplanation of the post-Jurassic mountains, without any transgression of the sea.

Post-Palæozoic sediments

The Jurassic formations of Mongolia consist of conglomerates, sandstones, and shales, aggregating more than 10,000 feet in thickness, and associated locally with lava flows, tuffs, and ash. These formations occur as infaulted or infolded remnants of once larger terrains, but they were probably never continuous across the region. The predominance of coarse pebble conglomerates, sometimes thousands of feet in thickness, implies fairly rugged relief; yet the great thickness suggests that deformation continued intermittently while the sediments were accumulating. Probably, while the lowlands sank, the heights were renewed from time to time by uplift. The warping passed locally into faults, and igneous activity accompanied the faulting. The progressive movement of the block resulted in crowding the thick sediments trapped in the lowlands so that minor and local folding took place. As a consequence, the sediments are quite generally warped and tilted. In China proper some of the Jurassic formations are closely folded, but this condition is seldom seen in the interior of the continent.

Thus, the Jurassic terrains indicate a distinctly greater stability of crustal conditions than prevailed during the Palæozoic era. The formation of typical geosynclines in central Asia had come to an end with the retreat of the Palæozoic sea; but the sinking of the graben floors to receive great thicknesses of sediment indicates a more active deformation than prevailed during Cretaceous and Tertiary times. The Jurassic marks a transition between the geosynclinal habit that characterized central Asia during all pre-Jurassic periods and the high crustal stability that marked all later periods. The transition character of the Jurassic is indicated also in the type of igneous activity which accompanied the change in kind of deformation. Simple intrusions and volcanic eruptions characterize Jurassic time. These volcanic activities are in marked contrast not only with the more profound volcanism and close folding of pre-Mesozoic time, but also with the very minor volcanic eruptions, gentle warpings and faultings which prevailed during the Tertiary period.

The record of the later sediments

After the last deformation of the Jurassic conglomerate series, the sediments of Lower Cretaceous age rested everywhere upon the upturned eroded edges of older formations, ranging in age from Archæan to Jurassic. This break marks a change in the history of the inland portions of Asia, and is, therefore, referred to as the Great Unconformity, for although it probably does not cover a longer lapse of time than is covered by some of the earlier unconformities, it marks a greater change in the dynamic history of the continent. Marine Cretaceous beds record encroachment of the sea along Sakhalin and part of the Amur provinces, along the Arctic margin, in the west Siberia lowland, in western Turkestan, and in the Tethys trough—surrounding an enormous, generally low-lying continent which was never again invaded by the sea nor deformed by folding. The later disturbances of this portion of the continent have been essentially warping, uplift, and block-faulting.

The sediments are thin, and consist chiefly of sandy clays and sands, with local gravels. The greatest thickness recorded for any one period is less than 3,000 feet; few post-Jurassic formations attain 1,000 feet. They lie horizontally over large areas, and are only locally faulted and tilted. This kind of deformation is most noticeable along the fronts of Tertiary mountain ranges. Lava flows are abundantly associated with Lower Cretaceous formations, more sparingly with Paleocene and Oligocene beds. Teilhard and Licent have reported large outpourings of basalt in eastern Mongolia during the Pliocene and Pleistocene, and Pleistocene volcanics have been noted by Russian explorers, especially in the margins of the Gobi basin, and by this Expedition in the Khangai Mountains. But the Tertiary volcanism is slight in comparison with that of the Jurassic period.

During Cretaceous and Tertiary times a new cycle of mountain uplift commenced and the present systems of ranges grew up. All the ranges contain folded rocks, but the folding, in every case, belongs to the earlier revolutions. The latest folding was an accompaniment of large faulting in Jurassic time. The Tertiary uplifts, in marked contrast, are broad warped arches or abruptly rising fault blocks. The lowlands between the ranges are either down-faulted grabens or broad open down-warped basins. Thus, a marked increase in stability is indicated by the post-Jurassic record. The zones of folding have, in general, gone outward toward the margins of the continent, especially toward the eastern margin and the Tethys trough.

PALÆOZOIC AREAS

Identifiable Palæozoic sediments have been discovered by this expedition in seven different localities—Gurbun Saikhan, Sair Usu, Tsagan Khati, Jasu Jergulung, Jichi Ola, Hallong Ossu, and Jisu Honguer. Only two, Sair Usu and Jisu Honguer, proved to be abundantly fossiliferous, and only Jisu Honguer was studied in sufficient detail to warrant the extended discussion which occupies this volume. It is reasonably certain that the occurrence near Sair Usu would repay field study in much the same manner.

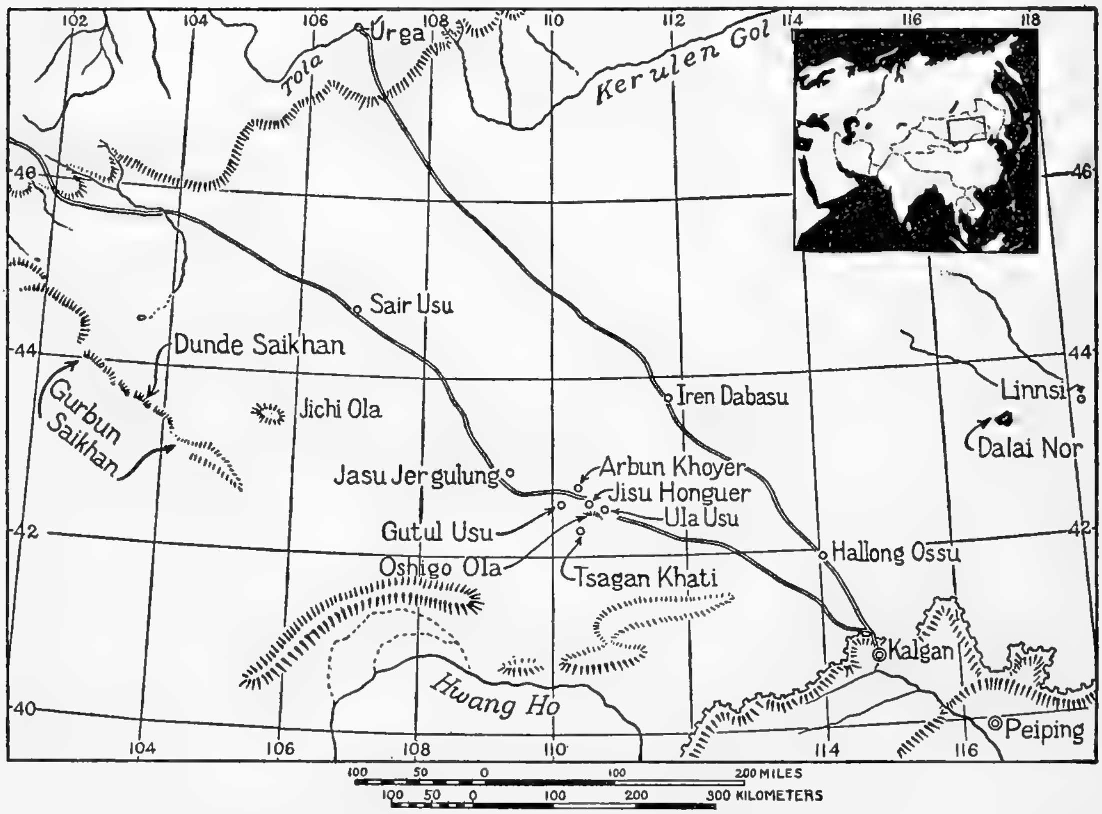

FIGURE A.—Location map of Mongolia, showing Jisu Honguer, Tsagan Khati, Gutul Usu, Jichi Ola, Sair Usu, and minor points where fossils have been found.

Gurbun Saikhan

Our first discovery of fossil-bearing rocks was made at Gurbun Saikhan, in 1922 (Fig. A.). We had traversed the range from the north front to the crest without finding fossils, all the rocks being regarded as pre-Cambrian. On the return journey, and about seven miles to the west of the previous traverse, Professor Berkey discovered a single pebble of crinoidal limestone in the dry shingle at the head of an alluvial fan. It was the only piece found, although a further search was at once made. There must be a belt of Palæozoic sediments in the Gurbun Saikhan range, but it cannot be extensive, or fragments would be less rare.

Sair Usu

Later during the same season, Palæozoic strata were discovered about nine miles east of Sair Usu. A basal conglomerate, made up chiefly of quartz pebbles, rests upon the upturned edges of older, complexly folded phyllites. The conglomerate is shattered and veined with white quartz. It is succeeded by gray and buff, massive, thick-bedded limestones, dolomites and shales of uncertain extent. Fossils are fairly abundant in the limestone, and those collected were delivered to Professor Grabau. A brief stop did not permit the measurement of a section, but the thickness cannot be less than 1,000 feet, most of it limestone. If the slates south of Sair Usu, where no fossils were found, belong to the same formation, as we suppose, the estimate of thickness must be greatly increased.

The extent of the belt could not be determined because later sediments cover the Palæozoic rocks on the southeast side of the area in the direction of our traverse. This locality, together with its possible extensions in the vicinity, is one of the most promising in central Mongolia for additional data on the Palæozoic history of the region. The occurrence of basal conglomerate and the clear-cut structural relations give this locality special significance in relation to the larger Palæozoic problem. It is on the main Sair Usu trail and readily accessible.

Tsagan Khati

Crinoidal limestones are found near the temple, Tsagan Khati in Sumu, about fifty miles southwest of Jisu Honguer. It is possible that the rocks are a continuation of the Jisu Honguer area, but an opportunity to follow along the strike of either area far enough to test this supposition was not afforded. The limestones are much shattered, and are associated with phyllites and porphyries, but the structural relations are obscured by covered ground.

Jasu Jergulung

On an unnamed hill east of the customs station, Jasu Jergulung (Fig. A), remnants of a once larger deposit of gray fossiliferous limestone were found clinging to the hillsides, which are made up mostly of argillites and silicified ash. The limestone beds are tilted at about 45 degrees to the north, and rest unconformably upon the more steeply dipping beds of argillite and ash, which dip southward. Only patches of the lowest layer of limestone were found. The structural relations in other respects are obscure, and the place deserves much more extended study.

Jichi Ola

The mountain, Jichi Ola (Fig. A), consists of thick-bedded conglomerates, massive, simple graywackes unmodified by shearing, shales, a few thin beds of calcareous material mixed with clastic sands derived from older rocks, and a few beds of dense silicified ash. The formation is closely folded, and the strata stand almost vertically, striking about N. 60° W. Fragmentary fossils were found in the lime-bearing layers, and these have been sent to Professor Grabau too recently to be included in this volume.

Hallong Ossu

On the main caravan trail between Kalgan and Urga, about eleven miles north of the Swedish mission at Hallong Ossu, a belt of limestone about twenty feet thick was found in 1925, from which a few obscure fossils, including the cross-section of a large brachiopod, were collected. The limestone is associated with fine phyllites, which are apparently conformable with it. The limestone and phyllites are both cut by granite which occupies a large area to the south. This outcrop is of interest because it is the only place where the Expedition found undoubted Palæozoic rocks cut by bathylithic granite, though a post-Palæozoic renewal of bathylithic activity had been inferred.

Jisu Honguer

Toward the end of the field season of 1922, the fossil-bearing limestones of Jisu Honguer were discovered, but the Expedition stopped for only an hour. The same ground, however, was visited again in 1923 and in 1925. The Jisu Honguer formation includes a basal conglomerate succeeded by gray sandstones, limestones, and shales, attaining a thickness of at least 2,000 feet. The strata are closely folded and lie squeezed and crumpled in a down-faulted block, crowded between older rock formations, and forming a long narrow belt extending somewhat south of west. These beds constitute the Jisu Honguer formation, and here we found the fauna described in this volume.

Linnsi

Teilhard and Licent have noted a significant group of rocks near Linnsi, which they describe thus: "A remnant of partly marmorized limestone, not exceeding a few square meters in area (we would not have seen it if the Mongols had not built a primitive limekiln there) contains some brachiopods and abundant crinoids; it is the typical Carboniferous.* Toward the southeast the limestone is succeeded by a thick series of slates, sandstones, and psammites, in vertical beds striking N. E.—S. W., which pass without a possible doubt into the phyllites of Linnsi. Since by analogy with all we know of the geology of northern China it cannot be doubted that the schistose series is later than the limestone, this locality assumes a capital importance. It permits the assertion that the phyllites of Linnsi, at least in the basin of Linnsi, are Carboniferous or post-Carboniferous." (Teilhard de Chardin, 1926, p. 20.)

On page 45 of the same report, the authors add: "For the western region of the Gobi, the American geologists arrived at conclusions which differ from ours. They recognize a sandstone slate Khangai series of pre-Cambrian age, cut by the granites of the great bathylith of pre-Carboniferous age, and followed by the Carboniferous and Permian limestones. Our series of Linnsi corresponds very well with the characteristics of the Khangai series; but we have offered our reasons for believing it to be much younger. Nevertheless, north of range XI (about 96 miles in a direction bearing 25 degrees east of north from Kalgan), it is possible that our interpretation of the terrains may yet require correction. We have written of the eruptive and sedimentary rocks of that zone, lying between the dunes and rhyolites, as belonging to the Linnsi system. Perhaps it would be well to recognize there the control of the western Gobi; the sandstones may correspond to the Khangai series; the granites may be part of the great bathylith. The limestones would then be post-granite—which would explain their excellent preservation."

THE JISU HONGUER FORMATION

The name Jisu Honguer is applied to a locality in central Inner Mongolia, near the southern boundary of the Outer Mongolian Eimak of Tushetu (Fig. A). Here the Sair Usu trail crosses a smooth, shallow depression, in which there are two wells. The western well was located as approximately Lat. 42° 38′ 15″ N., and Long. 110° 30′ 35″ E., by Major L. B. Roberts, topographer of the Expedition of 1925, by a traverse from Camp Ula Usu. At the same time its elevation was determined as 3440 feet.

Topography and general structural relations

The Jisu Honguer district lies within the broad open basin of the eastern portion of Mongolia—a region characterized as a whole by gentle warping rather than by block-faulting which is the most prominent feature of the Altai region farther west. That there is block-faulting on a smaller scale is evident, however, when conditions are favorable for determining the structure. The Jisu Honguer area is a down-faulted block.

* More probably Permian (A. W. G.).

Eastward from Jisu Honguer, a basin of Tertiary sediments extends for over sixty miles, burying the oldrock floor and forming an almost flat, gravel-covered upland, interrupted locally by large and small undrained hollows. At Jisu Honguer a narrow belt of Palæozoic rocks is stripped of this cover, exposing the most prolific strata of that age yet discovered by the Expedition. The badland scarps of Tertiary strata have yielded vertebrate fossils of Eocene and Oligocene age.

Westward for eighty miles along the trail from the known Palæozoic beds, the Expedition traversed an area of complex metamorphic and igneous rocks of undetermined age. Here the hills are low and simple-looking, but structurally they are very complex, every difference in rock quality registering in that arid country in small upstanding ridges and minor depressions, as closely packed together as it is possible for such features to be. The Mongolian peneplane originally beveled the massif so that the myriad nearly accordant minor elevations now make the whole landscape look like a much-disturbed ocean that has suddenly frozen into solid rock. This surface feature, never to be forgotten for its monotony, suggested our field name of "the Choppy Sea," for this region (Fig. B.)

Even within "the Choppy Sea," the broader belts of fine phyllites have weathered into more open lowlands as much as a mile wide, looking like parks rather than valleys. Wherever the more resistant graywackes, greenstones, and gneisses predominate, the valleys are narrower and more sharply incised, with aggraded floors of coarse arkosic or graywacke sand.

Northward from Jisu Honguer no exploration except a rapid traverse has been made, but toward the south and west several other areas of Palæozoic rocks were found, notably at Tsagan Khati and Gutul Usu, respectively about twenty and one hundred miles from Jisu Honguer. At still greater distances, lie Sair Usu and Jichi Ola (Fig. A).

The type locality of the Jisu Honguer formation lies between the Tertiary cover on the east, the graywacke-phyllite area on the west and north, and the gently rolling red granite and porphyry hills of Oshigo Ola on the south. The narrow Palæozoic belt extends in a southwesterly direction beyond the area examined by us. The area of known Palæozoic rocks is about twenty square miles. Along the western flanks of Oshigo Ola there are conglomerates which overlie the granite and the Palæozoic strata, covering the contact so that the structural relations between them could not be determined. Because the conglomerates appear to be tilted, we assigned them to the Jurassic rather than to the Tertiary.

The limestones are the resistant beds, and form the only hills and the best outcrops in the almost flat country underlain by Palæozoic strata. The most prominent landmark in the district is the limestone hill, Honguer Ola,

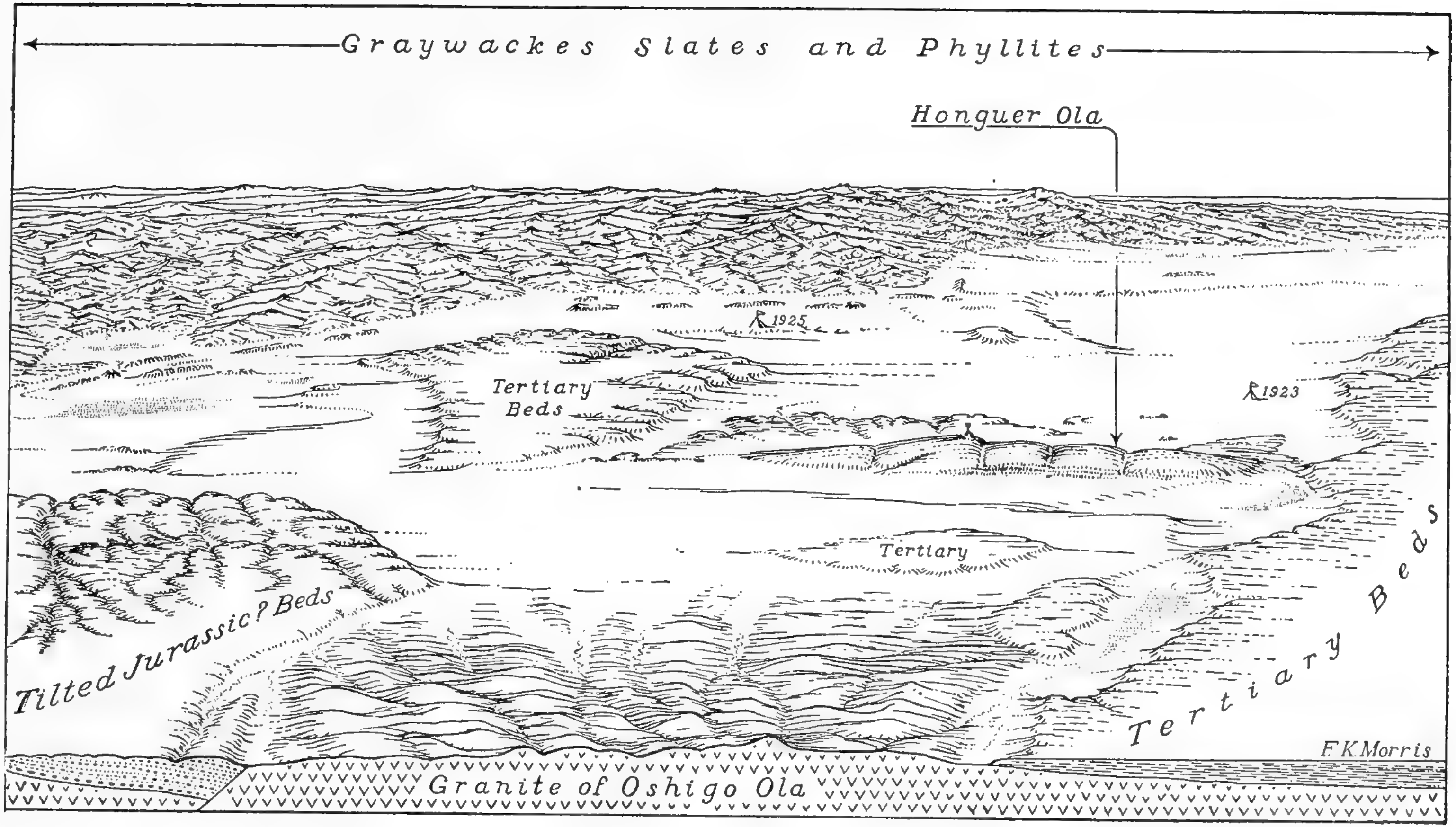

FIGURE B.—General view of the area (sketch).

which is crowned by a handsome obo, or prayer pile of stones, called Jisu Honguer Obo, from which the district takes its name. In this hill no less than 500 feet of massive, thick-bedded limestones, covering a total area of not less than a square mile, are exposed so that every detail of structure can be seen. These beds are not very prolific in fossils, the best returns coming from the thin-bedded strata lying in the plain north of the hill.

The lower contact

At Jisu Honguer, undoubted Palæozoic strata come in contact with the typical Khangai graywacke series. Thus, an opportunity is offered to study the relation in some detail. West and north of the belt of fossiliferous strata, there is a thick series of graywackes and slates, the latter grading through phyllites into fine silvery mica schists. Most of the graywackes are sheared and metamorphosed, but some have suffered little change except induration and incipient reorganization of the finer constituents. Some of the slates are not too thoroughly reorganized to retain the traces of fossils, if fossils had ever been present, but they are all barren. A few small lenses of siliceous limestone appear in the series, and these too are quite barren. Careful search, covering many miles of traverse, was made for fossils in the most promising members of the graywacke series, but without success.

The rocks are complexly folded and are cut by many dikes and vast numbers of white quartz veins. The total thickness must be several thousand feet. Our traverse extended northwestward nearly across the strike for twenty-six miles before encountering another formation. Because of the absence of fossils and because none of the known Palæozoic formations of Mongolia is so highly metamorphosed, we tentatively assign the series to the late pre-Cambrian.

Professor Grabau provisionally assigns the graywacke-slate-phyllite series to late Palæozoic age, saying, "Theoretically these graywackes should represent only the later Palæozoic from the Devonian to the Permian, being the shore deposits of these periods, formed along the northern border of the geosyncline and next to the oldland from which they were derived. Farther to the south these strata are merged into the normal beds of the later Palæozoic." (Grabau, 1924c, p. 280.)

At Jisu Honguer the area of sheared graywackes, slates, and phyllites continues without any sign of fossils to the very margin of the fossil-bearing Jisu Honguer beds. At that point there is an abrupt change in formation. The Palæozoic Jisu Honguer beds are folded but not notably metamorphosed. A few dikes of andesite and granite porphyry cut the formation, but the abundant quartz veins so characteristic of the graywacke-phyllite series are lacking. It is possible, of course, that the graywacke series is Palæozoic, but it cannot be of the same age as the Jisu Honguer formation, and is, undoubtedly, much older.

Along the contact zone, except where faulted, the Jisu Honguer formation rests directly upon the graywacke-slate series. This can be seen best at the eastern end of the area where the Palæozoic basal conglomerates have a gentle dip, averaging 15°, whereas the graywackes, exposed about 150 feet farther north, stand almost vertically. Westward, the dips of the Palæozoic beds become steeper, and the contact becomes a fault along which the sandstone member and the shale-and-limestone members of the Jisu Honguer formation come into contact with the graywacke-slate series.

Along its southern margin the Jisu Honguer area is bordered by the granite hills of Oshigo Ola; the relation is abrupt, probably a fault. A cover of Tertiary sediments extends from the east along part of the dry valley between Oshigo Ola and Honguer Ola, concealing the contact between the granite and the Palæozoic sediments. Farther west, the contact is hidden by the overlying tilted conglomerates, which are tentatively assigned to the Jurassic. In one small area, indurated conglomerates, sandstones, and dense siliceous limestones were found resting directly upon the granite. The strata are shattered and veined but not sheared or notably recrystallized. They dip westward at gentle angles and are cut by faults along which the granites reappear. No fossils were found, but the structural relations and their resemblance to some members of the typical Jisu Honguer favor the inference that these beds are Palæozoic.

At Jisu Honguer, therefore, the Palæozoic formation as a whole is formed of generally weak incompetent beds which have been down-faulted and crumpled between the thicker and stronger masses of the Oshigo Ola granites and other formations composing the older floor on the southeast, and the graywacke-slate series on the northwest. The less resistant character of these strata has led to the development of a shallow lowland of smooth surface, in striking contrast to the ruggedness of "the Choppy Sea" areas of older rocks and the still greater smoothness of the later Tertiary sediments.

Subdivisions of the Jisu Honguer formation

There are three general subdivisions of the Jisu Honguer series: a lower group, chiefly conglomerates and sandstones, an overlying group of shales and thin-bedded limestones, and a much more massive limestone member which forms the hill, Honguer Ola.

The lower group. The basal members of the lower group are found only at the northeastern end of the Jisu Honguer area, where a conglomerate lies upon the graywacke series. The pebbles in the conglomerate consist chiefly of fine, dense, silicified ash or argillite and other dark-colored sedimentary rocks, and of vein quartz, porphyries, and granite. The dips at the eastern end of the area vary considerably but average from 12° to 20° toward the south. The basal beds dip gently, and the dip increases southward until, less than a half mile from the northern margin, the strata are almost vertical. Beds of coarse arkosic sandstones, brown to gray in color, are found among the conglomerates, and increase upward until they predominate. Intercalated in the arkosic sandstones are lens-shaped beds of calcarenite which consist of broken crinoid joints and brachiopod shells, with a few fragments of bryozoans and corals mingled with the rock fragments. Lens-shaped beds of calcilutite, rich in better-preserved fossils, are present not far above the conglomerates. In general, the calcilutites lie at higher horizons than the calcarenites and graywacke beds.

The middle group of shales and limestones. The appearance of intercalated shales marks the beginning of a middle group of soft strata which weathers out to form a low flat strip of land between the conglomerates and the hill of Honguer Ola. The chief rock types are finely fissile, green and bluish clay shales, and lens-shaped, discontinuous beds of calcilutite, locally containing black chert. At the western margin of the Jisu Honguer formation the conglomerate-sandstone group is lacking; the shales and the limestones lie in faulted contact with the graywackes. The beds are closely crumpled, and are cut by small faults. The limestones, originally discontinuous, are still further broken by squeezing between the less competent shales, and by subsequent faulting, so that their present distribution is quite erratic. They resist weathering better than the shales; hence, some of them stand out as low but abrupt knobs and ridges. A chain of such knobs lies almost against the graywacke contact in the western part of the area.

In spite of the crumpling, the shales are not much metamorphosed. Phyllites, which are abundant in the underlying graywacke series, were not found in the Jisu Honguer formation. Typical slates also are lacking, although some slaty structure is developed in the greenish shales near the graywacke contact. No fossils have been found in the shales. The thickness could not be measured directly because of minor folding, but at least 500 feet must be assigned to the shale-and-limestone group.

The massive limestone group. The transition to the limestone group of Honguer Ola was observed near the eastern end of the belt, between the well and the hill. Limestone members increase and shales diminish as one goes southward toward the hill. The beds dip northward, arch up to form the anticlinal hill, and lie nearly horizontal on the rounded summit. On the southern slope the beds dip southward until a fold-thrust is reached, where the dip changes abruptly toward the north. Several cross-faults cut the ridge, causing slight offsets. Transverse valleys have developed along the zones weakened by faulting.

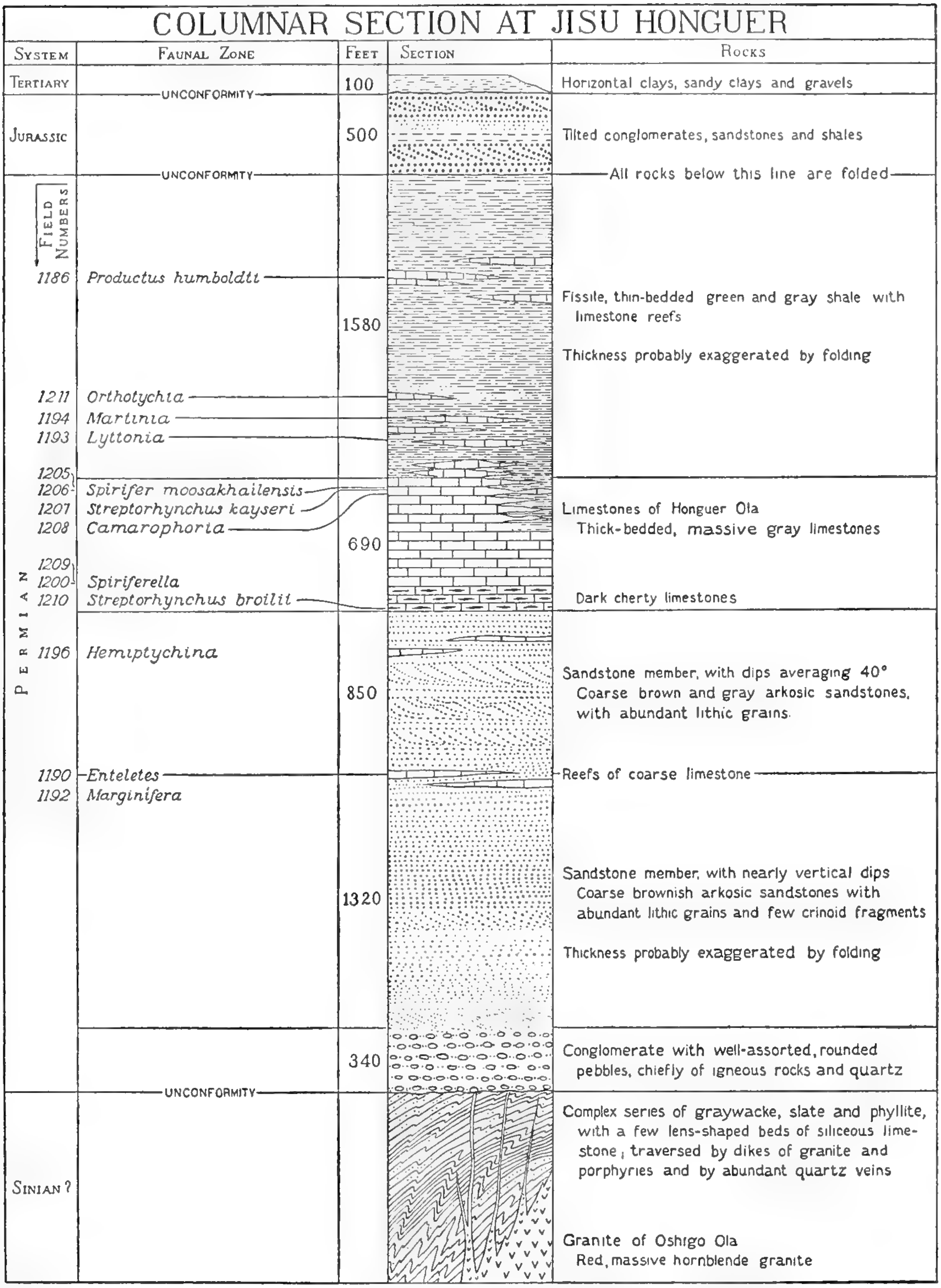

Figure C.—Columnar stratigraphic section of the Jisu Honguer formation, Mongolia.

The stratigraphic position of the Honguer Ola limestone is not accurately known. It forms an anticline and therefore may underlie the shale beds to the north. The shale clearly succeeds the sandstone stratigraphically, and exactly similar sandstones are found just beneath the limestone on the south side of the hill. The Honguer Ola limestone cannot be traced westward more than a half mile beyond the hill itself, and in that direction the limestone appears to thin out. As has been pointed out, the lens-like, discontinuous character of all the limestones in the formation is a striking feature of the formation, and it may be that the limestone of Honguer Ola is itself a reef or lens, thicker and broader than the other limestone members, but otherwise quite like them. It probably grades laterally into the shales, and is, therefore, at least partly equivalent to them in age.

The rocks of this member are gray to blue calcilutites, in beds six to eighteen inches thick, almost without shale partings, but plainly bedded. Some of the beds, especially those on the southern flank of the hill, are very cherty, and abound in large Spirifer shells.

Fossil content

The first fossil-bearing rocks were discovered by Professor Berkey and Mr. Morris in 1922. At that time a small collection of fossils was made, the general structure was noted, and the locality was recommended for subsequent study. In 1923 a second examination and a map of the locality, Fig. D, were made by Mr. Morris, and a larger collection of fossils was obtained. The district was visited again by both geologists in 1925, at which time they gave special attention to the geologic structure of the district and the relation of these strata to the graywacke series which come in contact here. The collection of fossils was delivered to Professor Grabau, and the result of his studies of the material is assembled in this volume on the palæontology of Jisu Honguer.

LOCALITY LIST, JISU HONGUER, MONGOLIA

By C. P. Berkey, F. K. Morris and A. W. Grabau

FIELD NUMBER[1] FOSSIL ZONE AND DESCRIPTION

1186. *Productus humboldti* bed. South of the Sair Usu trail, about 1.1 miles northwest of the camp of 1923. Thin reef of limestone dipping southward, striking N. 85° E. Enclosed between beds of shale.

1190. *Enteletes* bed. North of the Sair Usu trail, about 1.4 miles northwest of the camp of 1923. Thin reef of limestone, dipping vertically, striking N. 80° W., terminated at its western end by a fault contact with the older graywacke series. Enclosed between sandstones on the north and fine fissile shales on the south.

[1] For the stratigraphic position of the field numbers see columnar chart, Fig. C; for the geographical distribution and location of the field numbers see geologic map of the Jisu Honguer area, Fig. D.

1192. *Marginifera* bed. Thin reef of limestone just east of bed 1190, and offset about 4 feet toward the north from bed 1190, dipping vertically, striking N. 80° W. Enclosed between beds of gray shale.

1193. *Lyttonia* bed. About 0.2 mile south of the camp of 1923. A short reef of blue limestone, just west of the trail, dipping 70° N., striking N. 80° E. It is about 6 feet wide, and not more than 20 feet long, enclosed by green fissile shales and thin beds of sandstone.

1194. *Martinia* bed. Thin reef of limestone enclosed in shales, just north of bed 1193, dipping 70° N., striking N. 80° E.

1195. *Waagenophyllum* bed. Defined from six loose specimens; the reefs from which these corals came were not identified.

1196. *Hemiptychina* bed. About 1.3 miles northwest of the camp of 1923, near the Sair Usu trail. Thin reef of limestone enclosed by greenish fissile shales, dipping nearly vertically, striking N. 85° E., less than 0.2 mile south of bed 1190.

1200. *Spiriferella* beds. Cherty limestones near the southern base of Honguer Ola, dipping 50° N., striking nearly due E-W. See also bed 1209.

1205. *Spirifer moosakhailensis* bed. Thick-bedded massive blue-gray limestones near the northern base of Honguer Ola, toward the eastern end of the hill. Dip is 40° N., strike nearly due E-W.

The following locations, 1206, 1207 and 1208 are limestones similar to bed 1205, and are encountered successively as the northern slope of the hill is ascended.

1206. On northern slope of Honguer Ola, about 10 feet stratigraphically below bed 1205. Dip is 60° N., strike nearly due E-W.

1207. *Streptorhynchus kayseri* bed. On northern slope of Honguer Ola, about 10 feet stratigraphically below bed 1206. Dip is 50° N., strike nearly due E-W.

1208. *Camarophoria* bed. Purplish massive calcilutite, partly crystalline. It arches over the top of the anticlinal hill, Honguer Ola, near the eastern end, and descends the southern slope. Dip and strike are variable.

1209. *Spiriferella* beds. Cherty limestone on the southern slope of Honguer Ola, lying stratigraphically about 40 feet above bed 1200, but belonging to the same group of beds. Dip is 50° N., strike nearly due E-W.

1210. *Streptorhynchus broilii* bed. Cherty limestone like beds 1200 and 1209, but near the western end of Honguer Ola. This bed is the stratigraphic base of the Honguer Ola limestone member, as it lies directly upon the coarse brown arkosic sandstone member. Dip is 56° N., strike N. 85° W.

1211. *Orthotychia* bed. About 0.5 mile east of the camp of 1925. A short reef of gray limestone enclosed in shale. Dip is vertical, strike nearly due E-W. This is the reef from which the first fossils were obtained in 1922.

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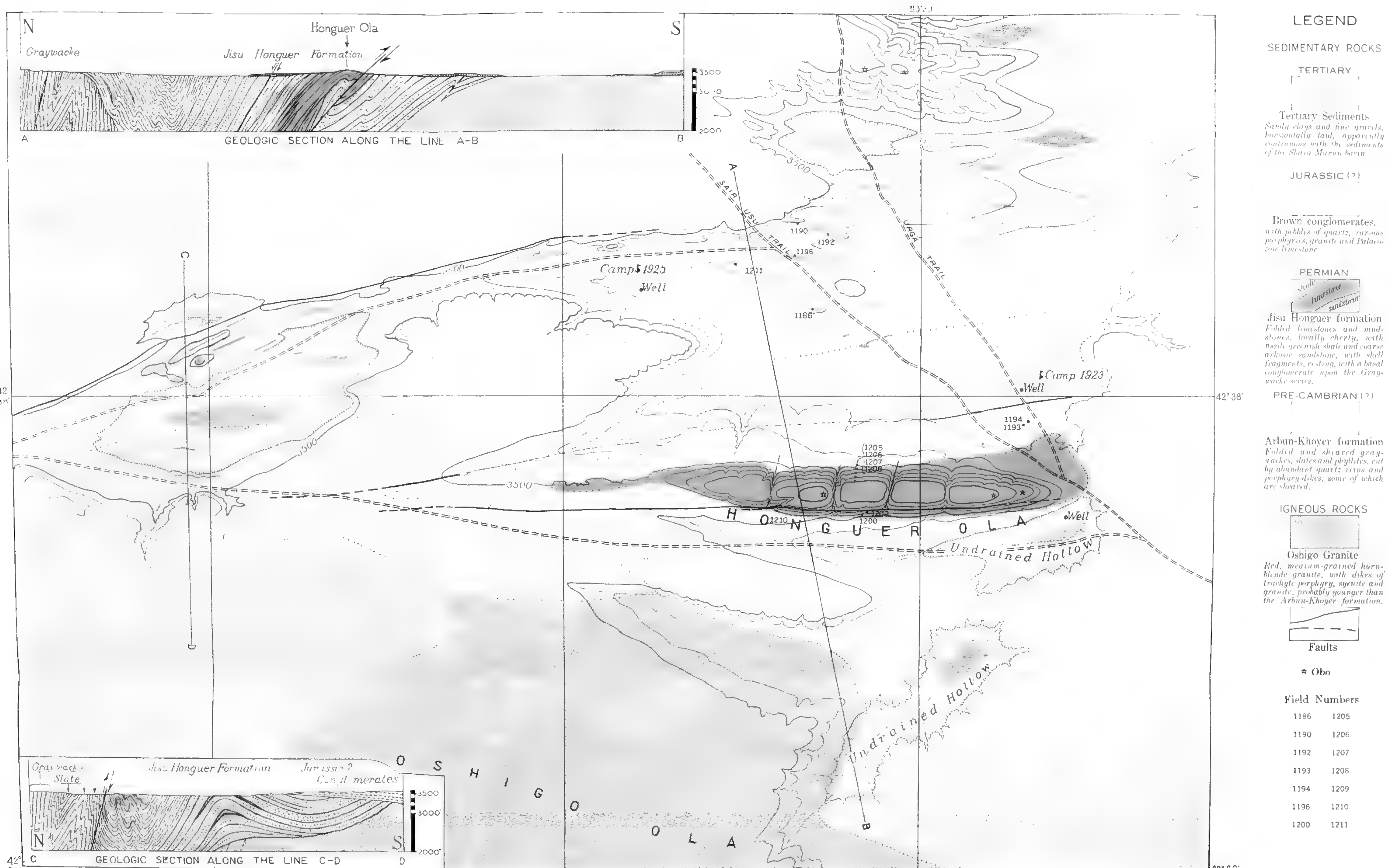
HENRY FAIRFIELD OSBORN, *President*

RECONNAISSANCE MAP OF THE JISU HONGUER AREA

THE PERMIAN OF MONGOLIA
BY A. W. GRABAU
VOL. IV, NATURAL HISTORY OF CENTRAL ASIA
FIGURE D



CENTRAL ASIATIC EXPEDITIONS
ROY CHAPMAN ANDREWS, *Leader*

Topography by Frederick K. Morris
Geology by Charles P. Berkey and Frederick K. Morris
Outcrops located by stadia
Areas without contours were examined but not surveyed

PART II

DESCRIPTION OF THE GENERA AND SPECIES OF THE JISU HONGUER LIMESTONE FAUNA OF MONGOLIA

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CHAPTER III

THE ANTHOZOA OF THE JISU HONGUER LIMESTONE

INTRODUCTION

THE Anthozoa or corals are among the rarer fossils of the Jisu Honguer limestone of Mongolia. Indeed, so far, only three genera have been obtained, one of which is represented by two species, and each of the other two by a single species. Only two of these genera have specifically determined representatives, the material of the third being insufficient for detailed discrimination. The two, however, which permit of such determination are typical representatives of Permian genera, and they show, moreover, the two extreme types of coral development in the Permian.

The genus *Polycœlia* is known only from Permian rocks, being a characteristic index fossil of the western European Zechstein, where hitherto the only typical species have been found. Other corals from other regions have been referred to this genus, but as I have shown elsewhere (*Palæontologia Sinica*, Series B, Vol. II, Fasc. 2), these species are to be referred to other genera. *Polycœlia* is a coral of primitive structure, but it is a persistent primitive type which apparently has continued into the Alpine Triassic, where the genus *Pinacophyllum* Frech appears to be one of its last derivatives.

So far as I have been able to review the corals referred to *Polycœlia*, it appears that the Mongolian species here described are its only known Asiatic representatives. One indeed shows only minor modifications from the European type, while the other is more distinctive. But that it, too, is congeneric with the European species cannot be doubted.

The other determinable corals belong to the eminently Permian family of Lonsdaleidæ. They represent merely a variety of the well-known *Lonsdaleia virgalensis* Waagen and Wentzel, which is congeneric with *L. indica* Waagen and Wentzel, the species that has been made the type of the genus *Waagenella* by Yabe and Hayasaka; but as that name was preoccupied, Hayasaka changed it to *Waagenophyllum.* This coral, of loosely aggregated corallites, represents the extreme of coral modification in the Palæozoic, especially in the development of the highly complex syncolumella, which is characteristic of the members of this family, though it is not wholly restricted to them, but occurs in some Carboniferous forms as well. As now understood, the genus and its typical species *W. indicum* and *W. virgalense*, of the latter of which our coral is a variety, are characteristic of the east Asiatic Permian rocks.

DESCRIPTION OF GENERA AND SPECIES

Class **ANTHOZOA**

Order TETRASEPTATA Grabau

Suborder PROTEROSEPTATA Grabau

Family POLYCŒLIDÆ Roemer

Genus **Polycœlia** King

1. **Polycœlia cylindrica** Grabau, sp. nov.

Plate I, Figs. 4a–b (No. 466), 5a–c (No. 468)

The corallum is long and slender for the genus, becoming for the most part cylindrical, although it may retain a slight curvature. Only fragments have been obtained.

Measurements:—The measurements of two of these are as follows:

Serial number	*466*	*468*
Catalogue number	*C.S.1487*	*C.S.1488*
Plate and figure numbers	*I, 4a-b Holotype*	*I, 5a-c*
Length of fragment	20.0 mm.	21.0 mm.
Diameter at upper end	6.3	6.5
Diameter at lower end	4.3	3.0

The epitheca shows a moderate series of concentric wrinkles as well as growth lines, while the septal grooves are well developed. The most striking character in the calicinal region is the strong development of the four primary septa, which, in the calyx, extend far into the center, though not reaching it (Pl. I, Fig. 5c). This gives the appearance of a thick-walled corallum with only four septa, but the presence of the others within the thickened wall is indicated by the septal grooves on the exterior. Below the calyx the four primary septa are seen to extend two-thirds the distance to the center, dividing the corallum into four nearly equal quadrants (Pl. I, Fig. 4b). In each quadrant there are typically five secondary septa, but it may happen that in one or two of these quadrants one of the secondary septa is incompletely, or not at all, developed, thus making the total number 23 or 22, instead of 24. It is, however, impossible to state from our material whether the retarded quadrants are cardinal or counter. The length of the secondary septa is less than half the radius. In the section (Pl. I, Fig. 4b), there is a suggestion of an additional septum on either side of one of the primary septa (cardinal?). Tertiary septa are present, as indicated by the costal grooves (septal grooves), but they do not extend beyond the thickened wall. There may be a few dissepiments, but they do not appear in the section, and if present are not very numerous.

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia; exact horizon not known. Collector, F. K. Morris.

2. **Polycœlia longiseptata** Grabau

Plate I, Figs. 1a-b (No. 462), 2a-b (No. 478), 3a-c (No. 464), 6a-b (No. 465)

1928. *Polycœlia longiseptata* Grabau, "Palæozoic Corals of China," *Palæontologia Sinica*, Ser. B., Vol. II, Fasc. 2, p. 26, Pl. I, Figs. 3a-b, Pl. VI, Fig. 15.

This is also an elongated species, but reaches nearly twice the diameter of the preceding.

Measurements:—The following are the measurements of characteristic specimens:

Serial number	*473*	*462*	*478*	*464*	*465*
Plate and figure numbers	......	*I, 1a-b*	*I, 2a-b*	*I, 3a-c*	*I, 6a-b*
Catalogue number	*American Museum 23223*	*C.S. 1484*	*C.S. 1485*	*C.S. 1486*	*C.S. 1489*
Length of fragment	36.0 mm.	38.0 mm.	33.0 mm.	24.0 mm.	20.0? mm.
Diameter at upper end	10.0 "	10.5 "	10.4 "	9.7 "	7.3 "
Diameter at lower end	6.8 "	9.4 "	7.5 "	5.0 "	6.4[1] "

The form is subcylindrical, tapering very gently, the rate ranging from 1 in 11, to 1 in 16 or 17 mm., except in the lower end, where the tapering is more rapid, as shown in specimen No. 464.

Sometimes the corallum is gently curved, and there are irregularities, due to constrictions, and irregular growth lines. Finer growth lines are abundantly shown in certain places.

The exterior is marked by pronounced costal grooves, of which there are 42 in an average specimen (No. 478). This interpreted in terms of septa suggests that this is the number comprised in the primary, secondary and

[1] At point of section. Lower half of corallum destroyed in sectioning.

tertiary cycles. Taking the primary as four, this leaves 38 for the secondary and tertiary, which we may consider divisible into 20 secondary, that is, 5 in each quadrant, and 18 tertiary, distributed between them. In section, the primary septa are seen to reach nearly to the center in the older part, though falling slightly short of it in the younger. The only other prominent septa are the secondary, of which there are seen to be no more than 5 in each quadrant, and these are of approximately the same length as the primary. The tertiary septa are short; indeed, in some cases they are hardly visible in the section, though their presence is indicated by the costal grooves. The epitheca is thin, not over 0.2 mm. in diameter, but in other cases it is thickened by secondary stereoplasm, in which the short tertiary septa are embedded. A few dissepiments are present in the earlier section (Pl. I, Fig. 1b), these becoming more numerous in some cases (Pl. I, Fig. 6b).

So far as our present material permits us to judge, there appears to be marked uniformity between the primary and secondary septa. The presence of well marked dissepiments also separates this species from others so far known. The more rapid enlargement in the young, which leads to greater diameter in the cylindrical part, is the most prominent external character, which readily distinguishes it from the associated smaller species. It may be added that in a few cases there appears the beginning of a quaternary cycle of septa, as shown by occasional fine costal grooves, between the more strongly marked ones. This is, however, of rare occurrence.

Horizon and Locality:—This species appears to be best represented in the *Enteletes* bed (1190) of the Jisu Honguer limestone, where the majority of our specimens have been found. (Nos. 462, 463, 464, 475). A single specimen showing a greater rate of tapering, however, has been obtained from the *Marginifera typica* bed (1192), Jisu Honguer, Mongolia. Collector, F. K. Morris.

Family STREPTELASMAIDÆ Grabau, emend.

1922. "Palæozoic Corals of China," *Palæontologia Sinica*, Ser. B., Vol. II, Fasc. 1, p. 28.

Genus **Amplexus** Sowerby

3. **Amplexus** ? sp.

Plate I, Figs. 7a-c (No. 477)

Several large compressed coralla appear to belong to this genus, though the preservation is such as to render a specific or even precise generic identification impossible. Two of the coralla are so closely adjoined as to suggest that they belong to a compound form, and this is shown to be the case in the section where the corallites are found to be confluent. The third is separate, but consists of crushed fragments only.

Measurements:—In form the corals appear to have been cylindrical, the greatest preserved length being about 4 cm., or a little less. Because of the compressed character, the diameter cannot be ascertained, but it may have been about 18 mm. Actual measurements of the best preserved individuals at the point sectioned (No. 477), representing two confluent individuals, give:

	(a)	(b)
Transverse diameter	9 mm.	12 mm.
Longitudinal diameter	16.3	20.5
Estimated diameter if cylindrical	13.0	16.0

The surface is covered by a wrinkled epitheca; the wrinkles, which are not very pronounced, however, occur at subregular intervals and become slightly nodose where they cross the interseptal ridges. These latter are rather narrow and far apart, being not infrequently separated by an interval of more than their own width.

The septa are in three cycles, the primary and secondary extending far to the center, though, because of the crushed character, their exact extent is not recognizable. There are about sixteen or eighteen of the longer septa in the smaller corallite, and about twenty-four or twenty-six in the larger. These are considerably thickened by stereoplasm, as is also the space between them and the tertiary septa. This gives the appearance of a very thick wall, which in the larger specimen reaches 2 mm. The septa, where they become free from this wall, have a thickness of about 1 mm., tapering rapidly to a point. The tertiary septa are only about half as thick at the point where they become free, and at a distance which only slightly exceeds the thickness of the stereoplasmic wall. The center appears to be free from all deposits, but tabulæ may be present. No indications of them, however, have been seen in our specimen. There are no dissepiments or other interseptal structures.

In spite of the crushed character, which has changed the cross-section to oval, there can be no question but that the two corallites are confluent, for the space between them, as shown in the section, is entirely devoid of a wall and is occupied by the septa. There is no reason why a compound form may not be placed under the genus *Amplexus*, for we have compound forms in other genera which are typically simple, for example, *Heliophyllum*. The generic disposition of the present specimens depends primarily upon the internal structure and especially the presence of tabulæ, but this cannot be ascertained in our material. If tabulæ are absent, which is suggested by the few sections it has been possible to make, this species may perhaps be regarded as a compound form of *Polycœlia*, or *Petraia*, though the septa are rather long for the latter form. Until sufficient material is obtained to permit the determination of the internal structure, the present species will be left under *Amplexus*.

Horizon and Locality:—In the *Marginifera typica* bed (1192) of the Jisu Honguer limestone, Jisu Honguer, Mongolia. Collector, F. K. Morris.

Family LONSDALEIDÆ Grabau, nom. nov.

Genus **Waagenophyllum** Hayasaka

(**Waagenella**[1] Yabe and Hayasaka)

This generic name is proposed for compound corals, placed under the genus *Lonsdaleia*, as aberrant types, by Waagen and Wentzel, who considered the possibility that they represented a distinct genus. They consist of cylindrical forms growing freely, without connection other than basally, each corallum being surrounded by its own epitheca. The septa are not very numerous and do not reach the center, which is occupied by a very thick columella which sometimes occupies one-third or more of the diameter of the entire corallum, is never twisted, and is more or less solid, so that it weathers out freely. It is composed of a number of dissepimental plates, which have not infrequently a cystose character, and sometimes surround a central flattened rod or lamella with finer ones radiating in all directions from it. In longitudinal sections, these structures have the appearance of vertically ascending tabulæ bending towards the center, so as to give the appearance of blunt cones. In transverse section a structure suggesting the arrangement of the threads of a spider-web is not infrequently seen. There is no inner wall, though the appearance of one is often produced by the arrangement of the dissepiments (sclerotheca).

The genotype is *Lonsdaleia indica* Waagen and Wentzel, while the only other known species is *L. virgalensis* Waagen and Wentzel, of which the Mongolian form is merely a variety. So far as at present known, the genus is restricted to the Permian strata of the Himalayan and Mongolian geosynclines, including in the former, eastern Burma (Kehsi Mansan, Northern Shan States), and Indo-China (Longson, Tonking, Laong-Prabang, Laos). Its occurrence in some of the Chinese Permian rocks is highly probable.

4. **Waagenophyllum virgalense** (Waagen and Wentzel) var. **mongoliense** Grabau, var. nov.

Plate I, Figs. 8a-d (No. 461), 9a-c (No. 474)

cf. 1886. *Lonsdaleia virgalensis* Waagen and Wentzel. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 6, p. 900, Pl. CI, Fig. 4; Pl. CXVI, Fig. 2.

The corallum is compound, composed of numerous slender, more or less cylindrical tubes which are straight or slightly curving and increase by budding

[1] This name was preoccupied, and Hayasaka changed it to Waagenophyllum.

at infrequent intervals. The tubes form a loose digitate agglomeration destitute of extraneous support, extending upwards side by side in a more or less parallel position, but at somewhat variable distances apart. The interval between the tubes is usually less than the diameter of the tubes themselves, but may be equal to it, or even exceed it by half again that diameter, rarely more. On rare occasions they are in contact. The diameter of the corallites themselves varies, though this is probably an expression of differences in age. In a single specimen (No. 461) the diameters range from 4 mm. to 5.7 mm. This appears to be the maximum. The majority of individuals falls between 4.5 and 5 mm.

The epitheca is thin and wrinkled, marked longitudinally by the costal grooves. There are thirty-four to thirty-eight long septa, rarely more, which, however, distinctly alternate in length, every second one being slightly shorter. Thus eighteen or twenty longer septa apparently represent the primary and secondary cycles, that is, the four primary and fourteen or sixteen secondary, while the slightly shorter septa apparently represent the tertiary cycle. In addition to these, there is a set of quaternary septa. These, however, are very short, and confined to the outer margin of the caliculum. Their length is always less than half the length of the tertiary septa. None of the septa extends to the center, where a space, with a diameter equal to or somewhat exceeding one-third that of the corallum, is non-septate. In a corallite 4.4 mm. in diameter, the central space has a diameter of 1.8 mm., while in another corallite in the same group, which has a diameter of 4.5 mm., that of the central space is only 1.5 mm. in diameter. The filling of this central space varies considerably: in some cases there appears to be a slightly thickened median plate, of more or less width, joined to what appear to be the two primary septa. This is surrounded by vesicular tissue, the walls of the vesicle being scarcely curved, but forming a series of irregular rectangles or rhomboids, more or less concentrically surrounding the central columella; in other cases some of these cyst-walls seem to be thickened, so that the appearance of a central cross is produced, around which the subrectangular cysts are disposed. Frequently, however, the central plate can not be distinguished. The outer row of these cyst-walls often gives the appearance of an inner wall, but such is not in reality existing, for the septa are not positively limited by it, but some of them extend slightly beyond the rim of this apparent wall. It is in reality a *sclerotheca*. Except for the fact that the cyst-walls are straight or even gently convex outward, the whole central structure or syncolumella might be considered as suggesting the spider-web appearance of the central part of *Dibunophyllum*. In some cases indeed the cyst-walls are so arranged as to give the appearance, in thin section, of several concentric rings.

The dissepiments are numerous and in places closely crowded, but have in general an essentially concentric arrangement. They are for the most part very gently convex outward, though not infrequently they appear straight and more rarely outwardly concave.

The outer ends of the septa are thickened by stereoplasm, and this, with the short quaternary septa, which is not always present, gives the appearance of a rather thick outer wall. Such a thick wall does not, however, exist.

In weathered specimens the syncolumella or inner vesiculose area may project as a thick median boss, or again, it may appear as a sunken space, distinctly surrounded by a dissepimental wall. At the same time, the epithecal wall appears thickened.

In another specimen from the same locality (No. 474, Pl. I, Figs. 9a-c), the corallites are even more irregularly disposed. A few of them are seen in contact, but only locally so, and here they appear even to interfere with one another so as to produce a slight flattening at the point of contact. Occasionally the principal septa appear to extend to within a short space of the center, but this is probably due to an accidental alignment of the radiating cyst-walls with the septa. In other corallites the septa stop short of the syncolumella, which is large and shows the spider-web character. This syncolumella in one case has a diameter of 2.5 mm., that of the corallite as a whole being 5.3 mm. A corallite sectioned through the calyx shows a median, rather solid-appearing, syncolumella 1.6 mm. in diameter, that of the corallite as a whole being 4.9 mm. The septa all stop short of the syncolumella, which is surrounded by a vacant space. This suggests that the section is through the calyx. Because of the stereoplasm and the last cycle of short septa, the outer part of the corallum appears in section like a thick solid wall, the thickness being as much as 1.2 mm., in some cases, though in another example it is only 0.7 mm. In this corallite there is a marked peculiarity, which may have some significance, namely, that the four primary septa are more prominent than the others, being thicker and extending to the syncolumella, whereas the other septa are thinner and stop short of the syncolumella. This looks like persistence of the primitive tetrameral arrangement of the septa. This feature, however, is not recognizable in the other corallites of the colony.

Remarks:—This variety differs from the typical Indian species in its more numerous dissepiments, and in the fact that short quaternary septa (the so-called septa of the third order of Waagen and Wentzel) are frequently, though not always, developed. According to Waagen and Wentzel, the typical form is never more than 4 mm. in diameter, while the syncolumella occupies a little more than one-third of the diameter of calyces. "There are eighteen to twenty primary septa (our primary and secondary septa) and as many secondary ones (our tertiary); septa of a third order (our quaternary) are never developed." The species is rare in the Productus limestone of the Salt Range and is a much smaller form than the common *Waagenophyllum indicum* (Waagen and Wentzel), the genotype.

Horizon and Locality:—In the *Waagenophyllum* bed (1195) of the Jisu Honguer limestone of Jisu Honguer, Mongolia, where it is the dominant species. Collector, F. K. Morris.

CHAPTER IV

BRYOZOA OF THE JISU HONGUER LIMESTONE

INTRODUCTION

In the Jisu Honguer limestone the Bryozoa are even more sparingly represented than are the Anthozoa. Although several bryozoan colonies have been found in these rocks, only one of them was determinable, and that belongs to a widespread and typical Permian species, represented not only in the Zechstein of Europe but in the Upper and Middle Productus limestone of India as well. It is likely that other genera and species of Bryozoa will be brought to light by future explorations in these rocks. The indications, however, point to a great rarity of this class of organisms in the Jisu Honguer limestone series of Mongolia.

DESCRIPTION OF SPECIES

Class **BRYOZOA**

Order GYMNOLÆMATA Allman

Suborder TREPOSTOMATA Ulrich

Genus **Geinitzella** Waagen

1. **Geinitzella columnaris** (Schlotheim) var. **tuberosa-sparsigemmata** Grabau, var. nov.

Plate I, Figs. 10a-b (No. 470, Holotype), 11a-b (No. 469), 12a-b (No. 479), (No. 471)

1861. *Stenopora columnaris* Schlotheim. Geinitz, Dyas, Vol. I, p. 113, Pl. XXI (with literature references and synonymy).

1886. *Geinitzella columnaris* Waagen and Wentzel. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 5, p. 882; Pl. CVI, Figs. 5, 6; Pl. CXII, Figs. 1–5; Pl. CXIII, Figs. 1–4; Pl. CXV, Fig. 1 (with synonymy).

This species is represented in our collections by an irregular subcylindrical fragment (No. 470, Pl. I, Figs. 10a-b, the holotype) and several fragments showing sections. The length of the fragment showing the external characters is 26.5 mm., and its maximum diameter is 13 mm. Zoœcial apertures are uniform, polygonal, with moderately thick walls, about 4 to 1 mm. The walls are rather thick, with minute acanthopores at irregular intervals at the juncture of a group of macropores. Mesopores appear to be absent, as are also maculæ and monticules.

A specimen showing a longitudinal section is shown in No. 469 (Pl. I, Fig. 11a-b). It has a preserved length of 20 mm. and is very nearly of a uniform width of 8.5 mm. The sides are essentially parallel, and the terminal part is regularly rounded. The zoœcial tubes arise from an imaginary median axis, pass obliquely upward and outward and then curve more strongly so as to reach the surface at a slightly oblique or almost right angle. The tubes increase in diameter from the center outward, the terminal ones reaching a diameter of 0.7 mm. The individual tubes may reach a length of about 10 mm.

Where the tubes are broken, they appear hollow for the most part. There are no sections that show diaphragms.

A third specimen (No. 479, Pl. I, Figs. 12a-b) presents a transverse fracture of a branch with a diameter of 8.3 mm. in one direction, which is slightly oblique, and 6.4 mm. in the transverse direction, which probably represents more nearly the diameter of the zoœcium. The zoœcial tubes here are smaller than in the longitudinal section, three of them occupying a space of 1.3 mm. at the point where this section is taken, which is probably near the base of the zoœcium, the tubes radiating in what appears to be almost a plane. The indications of the periodic thickening of the walls, regarded as so characteristic of the genus *Geinitzella*, are visible in a few cases.

Horizon and Locality:—In the *Hemiptychina* bed (1196), (No. 469), and from unrecorded horizons (Nos. 470, 471, 479), Jisu Honguer limestone, Jisu Honguer, Mongolia. Collector, F. K. Morris.

Remarks:—I identify our specimens with the well known European and Indian species with some reservation, since we have an insufficiency of material to permit the making of proper sections. Our form would probably agree most nearly with the one designated as variety *ramosa-sparsigemmata*, which is common to the Permian of Europe and India and is characterized by having the apertures of the full-grown zoœcia close together with only a single acanthopore at the junction points. Our specimen is somewhat more robust than the cylindrical one figured by Waagen (1879–1887, Pl. CXIII, Fig. 1a), which has a diameter of 6.5 mm., with a length of 29 mm. In form, our specimen resembles perhaps more the variety *tuberosa* of the Zechstein, figured by Geinitz, 1861, on his Pl. XXI, Fig. 10. That form is subpyriform, with a maximum diameter of 11 mm. and a length of 20 mm. That specimen, however, has many more acanthopores than are visible in our specimen.

Another specimen of this variety figured by Geinitz (1861–1862, p. 113, Pl. XXI, Fig. 7), which has a maximum diameter of 7.5 mm., also resembles our form, but here too the acanthopores appear more numerous. In this form there are about seven zoœcial apertures in 2 mm. Variety *tuberosa* has not been found in India, but is common in Europe, while the variety *ramosa* of Europe is usually more slender than that of India. It would thus seem that, whereas our form corresponds in contour and in size of zoœcial apertures to the European variety *tuberosa*, in the character of the acanthopores it corresponds to variety *ramosa-sparsigemmata* of India. This might be indicated by naming our form variety *tuberosa-sparsigemmata*, var. nov.

CHAPTER V

BRACHIOPODA OF THE JISU HONGUER LIMESTONE

INTRODUCTION

THE Brachiopoda are by far the most abundantly represented class of life in the fossil fauna of the Jisu Honguer limestone of Mongolia. Ninety-nine species and varieties of these forms are described in the following pages. The Brachiopoda seem to have occupied the waters of this region to the virtual exclusion of most other classes, and individual species and varieties often occur in such abundance as to form actual beds of shell-limestone. In fact, the brachiopod shells seem to have been the chief source of lime in the formation of this rock, though many of the crystalline grains of lime carbonate, which fill the interstices between the shells, may have resulted from the destruction of crinoid stems and plates. Only a few stem joints, however, and no calyx plates, have actually been discovered. So far as we have been able to determine, the shells of the brachiopods were not worn before entombment, nor were they broken to any undue degree, though the valves are not infrequently separated.

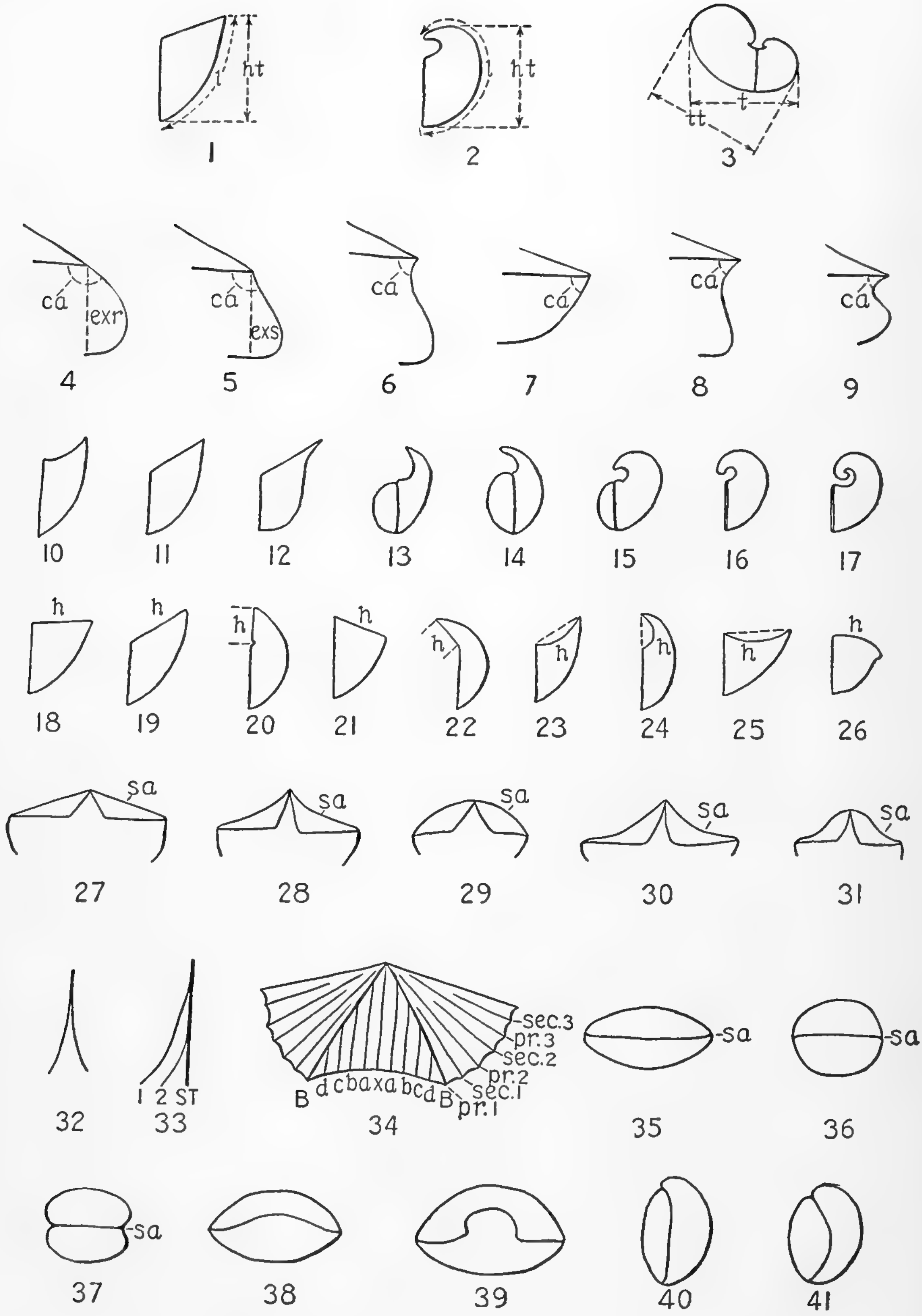
It is a noteworthy fact that almost the only brachiopods which reach their full growth are the spiriferoid and productoid types, most of the others being smaller than their representatives in the Productus limestone of the Salt Range, the Permian limestone of Timor, or the Uralian beds of eastern Russia. These facts are fully brought out by the measurements and discussions under the specific descriptions.

The significance of this fact is considered in a later chapter.

DEFINITION OF BRACHIOPOD TERMS

In the description of the Brachiopoda, it is desirable to define somewhat more precisely certain terms which have heretofore been used somewhat loosely. They may be considered under separate headings.

Dimensions:—The *height* of the valve is taken to be the vertical distance from umbo to base, the shell being so placed that the plane of contact of the valves is vertical (ht., Text-Fig. 1). This measurement may begin at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sa
31
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1 2 ST
33
sec.3
pr.3
sec.2
pr.2
sec.1
pr.1
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sa
35
sa
36
sa
37
38
39
40
41

FIGURE 1.—Diagrammatic representation of how the height (*ht.*), and the length (*l*), of a brachiopod shell are measured when the beak is the most projecting point of a valve.

FIGURE 2.—Diagrammatic representation of how the height (*ht.*), and the length (*l*) of a brachiopod shell are measured when the beak is incurved and the umbo is the highest projecting point.

FIGURE 3.—Diagrammatic representation of how the thickness (*t*), or greater thickness (*tt.*) are measured in an obese brachiopod.

FIGURE 4.—Diagrammatic representation of a portion of a brachiopod valve with an ***obtuse cardinal angle*** (*ca.*) and a shell-margin ***exceeding round*** (*exr.*).

FIGURE 5.—Diagrammatic representation of a portion of a brachiopod valve, with an ***obtuse cardinal angle*** (*ca.*), and a shell-margin ***exceeding straight*** (*exs.*).

FIGURE 6.—Diagrammatic representation of a portion of a brachiopod valve with a ***rectangular cardinal angle*** (*ca.*), and a shell-margin ***exceeding concave.***

FIGURE 7.—Diagrammatic representation of a portion of a brachiopod valve with an ***acute cardinal angle*** (*ca.*), and a shell-margin ***receding rounded.***

FIGURE 8.—Diagrammatic representation of a portion of a brachiopod valve with an ***acute cardinal angle*** (*ca.*), and a shell margin ***receding concave.***

FIGURE 9.—Diagrammatic representation of a portion of a brachiopod valve with an ***acute cardinal angle*** (*ca.*), and a shell-margin ***receding sinuate.***

FIGURES 10 and 11.—Diagrammatic representation of ***erect*** beaks of a brachiopod.

FIGURE 12.—Diagrammatic representation of a brachiopod valve with a beak which projects outward and upward and has the median longitudinal contour of the umbo concave, as in some *Streptorhynchus.*

FIGURE 13.—Diagrammatic representation of a brachiopod shell with an overarched beak curving inward and lying within the point of greatest convexity of the valve.

FIGURE 14.—Diagrammatic representation of a brachiopod shell with an overarched beak curving inward and projecting over the hinge area.

FIGURE 15.—Diagrammatic representation of a brachiopod shell with the beak of pedicle valve incurved and projecting to the plane of contact of the valves.

FIGURE 16.—Diagrammatic representation of the pedicle valve of a brachiopod with an incurved beak which overhangs and extends beyond the plane of valve contact.

FIGURE 17.—Diagrammatic representation of the pedicle valve of a brachiopod with an enrolled beak which extends to the plane of valve contact.

FIGURE 18.—Diagrammatic representation of a valve of a brachiopod with hinge area (*h*) ***horizontal*** or ***flat.***

FIGURE 19.—Diagrammatic representation of a valve of a brachiopod with hinge area (*h*) ***inclined.***

FIGURE 20.—Diagrammatic representation of a valve of a brachiopod with hinge area (*h*) ***vertical.***

FIGURE 21.—Diagrammatic representation of a valve of a brachiopod with hinge area (*h*) ***reclined*** and lying within the circumference.

FIGURE 22.—Diagrammatic representation of a valve of a brachiopod with hinge area (*h*) ***proclined,*** that is, overhanging and inclined beyond the vertical.

FIGURE 23.—Diagrammatic representation of a valve of a brachiopod with hinge area (*h*) ***inclined*** and ***concave.***

FIGURE 24.—Diagrammatic representation of a valve of a brachiopod with hinge area (*h*) ***curved vertical.***

FIGURE 25.—Diagrammatic representation of a valve of a brachiopod with hinge area (*h*) ***curved horizontal.***

FIGURE 26.—Diagrammatic representation of a valve of a brachiopod with hinge area (*h*) a proclined ***curved convex area.***

FIGURE 27.—Diagrammatic representation of a hinge area of a brachiopod, showing ***shoulder*** and ***straight shoulder angle*** (*sa.*)

FIGURE 28.—Diagrammatic representation of the hinge area of a brachiopod, showing ***shoulder*** and ***curved shoulder angle*** (*sa.*).

FIGURE 29.—Diagrammatic representation of the hinge area of a brachiopod, showing a ***convex shoulder angle*** (*sa.*).

FIGURE 30.—Diagrammatic representation of the hinge area of a brachiopod, showing a ***sinuous shoulder angle*** (*sa.*).

FIGURE 31.—Diagrammatic representation of the hinge area of a brachiopod with ***shoulder angle*** which changes from ***convex*** to ***concave.***

FIGURE 32.—Diagrammatic representation of primary ***bifurcation*** of plications with one ***furcation, primary.***

FIGURE 33.—Diagrammatic representation of the division of plications by ***branching,*** showing ***stem*** (*st.*) and ***branches,*** 1, 2.

FIGURE 34.—Diagrammatic representation of the valve of a brachiopod, showing median sinus, one pair of bounding plications (B,B), a ***median sinal plication*** (x), and ***lateral sinal plications*** (a, b, c, d), and outside branching plications, ***primary*** (pr. 1, pr. 2, pr. 3), and ***secondary*** (sec. 1, sec. 2, sec. 3).

FIGURE 35.—Diagrammatic representation of a brachiopod shell, showing ***suture*** and ***sutural angle*** (*sa.*).

FIGURE 36.—Diagrammatic representation of a brachiopod shell, showing ***flat suture, suture angle*** (*sa.*), and ***suture margin*** of 180°.

FIGURE 37.—Diagrammatic representation of a brachiopod shell, showing a ***depressed suture*** and ***suture angle*** (*sa.*).

FIGURE 38.—Diagrammatic representation of a brachiopod shell, showing ***sinuate suture*** in front.

FIGURE 39.—Diagrammatic representation of a brachiopod shell, showing pronounced sinuosity in front, usually in the pedicle valve, into which projects a ***lip*** or ***tongue*** of the opposite valve.

FIGURE 40.—Diagrammatic representation of a brachiopod shell, showing a ***straight lateral suture*** on the side of the shell which descends directly from the cardinal angle to the base or front of the shell.

FIGURE 41.—Diagrammatic representation of a brachiopod shell, showing a ***sinuate lateral suture*** where the side of one valve indents that of the opposite valve, as seen in *Dielasma.*

the beak, if that is the most projecting portion of the valve, but if the beak is incurved, the measurement is taken from the highest projecting point of the umbo (ht., Text-Fig. 2). The *length* of the valve, on the other hand, is measured on the curvature, beginning at the tip of the beak, no matter how much that is incurved, and extending to the front along the center, or to the extreme tip of the linguiform projection of the sinus if such is present (l., Text-Figs. 1 and 2). The *width* is the transverse diameter, usually measured on the plane of contact, unless this shows lateral contraction, in which case the additional measurement at the bulging sides must be taken. Sometimes it seems desirable to give the contour measurement, that is, the measurement along the curvature from margin to margin at the greatest expansion. The *thickness* of the shell should always be measured with the plane of the contact vertical (t., Text-Fig. 3), even though, as in some *Enteletes*, a greater thickness may be obtained by a measure across this plane. It may be desirable to give this latter measurement in addition to that of the thickness as above defined (tt., Text Fig. 3). Measurements of early stages may be taken when such stages are defined by stronger growth lines. In taking such measurements, the above principles should be kept in mind.

Cardinal angles and lateral margins:—A cardinal angle (ca., Text-Figs. 4-9) may be defined as the angle formed by the hinge line and the side margin of the shell. This may be *obtuse*, *rectangular*, *acute*, *mucronate*, or it may be *truncated*. When the cardinal angle is obtuse, the shell-margin is generally extended outward or *exceeding*. The side may be *exceeding round* (exr., Text-Fig. 4), or *exceeding straight* (exs., Text-Fig. 5). When the cardinal angle is rectangular, the lateral margin is at first straight and vertical. It may subsequently round regularly to the frontal margin, or expand outward again, in this way becoming *exceeding concave* (exc., Text-Fig. 6). When the cardinal angle is acute, the side commonly curves downward and inward and is then spoken of as *receding rounded* (Text-Fig. 7), but it may also be *receding concave* (Text-Fig. 8), where, for the greater distance, the curvature is outward rather than inward. Again, the side may be *receding sinuate*, when it describes, at first, a more or less abrupt concave curve, followed by a convex one, which still forms a part of the side of the shell (Text-Fig. 9). In shells with mucronate cardinal angles, the receding concave, or receding sinuate side, may be pronounced. Both exceeding and receding sides may for the most part be straight lines.

Beak:—The beak may be rounded, pointed or truncated. It is *erect* when it projects vertically upward, the median umbonal contour being for some distance parallel to the plane of the contact of the valve, that is, a straight vertical line (Text-Figs. 10, 11). In some cases, the beak may project outward as well as upward, as in the case of some *Streptorhynchus*. In that case, the median longitudinal contour of the umbo is concave (Text-Fig. 12).

More commonly the beak is *overarched*, that is, while still forming the most projecting portion of the valve in the vertical plane, it curves inward projecting over the hinge area (Text-Fig. 14), or, in any case, lying within the point of greatest convexity of the valve (Text-Fig. 13). In this case, the median longitudinal contour of the umbo is gently convex. The beak is *overhanging*, when it actually projects beyond the prolongation of the plane of contact of the valves and still forms the highest point of the valves. On the other hand, if the beak is below that point, that is, if it points downward, it is spoken of as *incurved* (Text-Figs. 15, 16), or if extreme, as *enrolled* (Text-Fig. 17). Incurvature may be simple, or it may be overhanging (Text-Fig. 16) when the beak actually extends beyond the plane of valve contact.

Hinge area:—The hinge area, when present, may be flat or curved, it may be complex, that is, curved in the young and flat in the later stages, or in exceptional cases, the reverse. When *flat*, the hinge area may be *horizontal*, that is, at right angles to the plane of valve contact, or *vertical*, that is, it may form a continuation of that plane (h., Text-Fig. 20), or if it lies between these two positions, it is *inclined* (h., Text-Fig. 19). If the hinge area slopes beyond the horizontal, that is, if it forms one side of a cone the apex of which lies within the circumference, it is said to be *reclined* (h., Text-Fig. 21). In exceptional cases the hinge area may incline beyond the vertical, this being the case when the beak is actually overhanging. Such a hinge area is called *proclined* (h., Text-Fig. 22). *Curved* areas are commonly concave. These may be *inclined*, when the line connecting the two ends of the concave curve, that is, the beak to the middle of the hinge line, lies between horizontality and verticality. If that line is vertical or horizontal, the hinge area is spoken of as *curved vertical* (Text-Fig. 24), or *curved horizontal* (Text-Fig. 25). A curved area may also be *proclined*, if the chord which subtends the arc slopes beyond the vertical. A proclined curved area, however, when it exists, is convex rather than concave (Text-Fig. 26).

Shoulder and shoulder-angle:—When the shell possesses a definite hinge area, the line along which this joins the main part of the shell, that is, the line along which the shell bends over to form the hinge area, is called the *shoulder*. This may be sharp and angular, or it may be more or less rounded. In either case, the angle which is formed by the hinge area and the shell is the *shoulder-angle* (sa., Text-Fig. 27), and is generally acute in varying degree, but may be rectangular or even obtuse. The direction of the shoulder, seen when the valve is viewed either from without or within, also varies. If it forms a straight line from beak to cardinal angle, it is spoken of as *straight* (Text-Fig. 27). More often, it is *concave* (Text-Fig. 28), and in exceptional cases *convex* (Text-Fig. 29). It may also be *sinuous*, when it changes from concave to convex or the reverse, or from straight to concave or convex, or both (Text-Figs. 30, 31).

Surface features of shell:—The surface features of brachiopod shells, the so-called ornamentations, are radial or concentric or a combination of both.

Radial markings:—The radial ornamentations, in addition to the median fold and sinus, consist of *plications*,[1] if coarse, or *striations*, if fine. These increase by *intercalation*, in the center of the widening interspace of the plicæ or striæ, when they may be designated of the second, third, etc., order, the plicæ or striæ of the first order being added progressively from the median to the cardinal-lateral regions. Striæ or plicæ may also increase by *bifurcation*, and this may be *primary*, with one furcation (Text-Fig. 32), *secondary*, when the two branches again bifurcate, and *tertiary* furcation, when some or all of the four resulting branches again divide. When the division is unequal, that is, one part remaining much larger than the other, this is spoken of as *branching*, rather than furcation, the smaller one being considered the branch and the larger the stem (Text-Fig. 33). When a plication gives off branches on the side towards the sinus, this is called branching on the inside, or the separation of inside branches. If the branches are formed on the opposite side, that is, on the side towards the cardinal angles, this is spoken of as outside branching or the formation of outside branches. The distance at which these branches appear from the beakward end of the plication determines their order, that branching off nearest to the beak being the first.

When the shell has a well-developed sinus, as in the spirifers, the first-formed of the shell plications, that is, the first shell plications, bound this sinus on either side. In that case they are also called the *bounding plications* (Text-Fig. 34, b). These bounding plications frequently give off branches in the sinus, these usually being parallel, or nearly so, to the median axis of the sinus, which may itself be occupied by a simple or bifurcating *median sinal plication* (Text-Fig. 34, x). The sinal branches of the bounding plications are spoken of, respectively, as the first, second, third, etc., lateral sinal plications, the first branching off nearest to the beak (Text-Fig. 34, a, b, c, d). All the sinal plications are generally more slender than the main plications of the shell.

Morphological significance of the radial ornamentation:—The plications or striations of the shell are a product of the rate of growth of the mantle, and as such are frequently correlated with the degree of convexity. If the interstitial or circumferential increase in the shell-building mantle is in excess of the radial increase, this excess would have to be accounted for by the folding or pleating of the mantle, which is expressed as plications or striations on the shell, according to the magnitude of the mantle-folds or pleats. If the pleats increase in number rather than in size, the shell will be striated; in the other case, plications are formed. If a few pleatings are formed and these increase in size, that is, if the interstitial growth of the mantle is uniformly

[1] These are commonly, but incorrectly, termed ribs or costæ.

distributed throughout, then the plications will remain few in number and they and the interspaces will enlarge regularly, without the formation of secondary or intercalated plications. If, on the other hand, the excess of interstitial growth is concentrated along certain radial lines, either the plications will increase in size at the expense of the interspaces, or the interspaces at the expense of the plications. In the former case, when the increase has reached a maximum, a bifurcation will take place, that is, a depression will form along the middle of the plication, or branches will be given off. In the second case, when the interspaces continue to increase at the expense of the plications, they will eventually become so broad that further increase results in the formation of a fold in their center, that is, an intercalated plication appears.

As before stated, plications may be compensatory of the degree of convexity of the shell. Thus, of two shells with the same relative rate of radial and interstitial mantle growth, the one with moderate convexity may be smooth or faintly plicated, while the other, becoming strongly convex, because of the increase in bulk of the animal matter within, would have to become plicated, because the more convex the shell, the less rapid the increase in diameter, and concomitantly the increase in growth circumference. Thus it may happen that an animal, in which there is no proportional change in the relative interstitial and radial growth of the mantle, may begin with a smooth shell of relatively slight convexity, whereas, when the convexity of the shell increases because of the excessive increase in the bulk of the animal within, this convexity will have to be compensated for by the formation of plications.

The principle is again illustrated in shells such as *Hemiptychina* (Plates II, III), where, because of a sudden increase in bulk at the front of the adult animal, the shell is abruptly deflected toward the suture, making almost a right angle with the earlier part of the shell-surface. This abrupt deflection, then, is compensated for by the formation of plications on the deflected portion. If such abrupt deflection took place without the formation of plications, it would imply a decrease in the relative rate of circumferential mantle-growth, and this would indicate that the animal has reached a stage of decline or gerontism. A similar indication of gerontism would be furnished by the disappearance of striations or plications in the frontal part of the shell, when there is no change in curvature, while both the disappearance of plications and the abrupt deflection of the margin would indicate excessive gerontism. On the other hand, the appearance of plications on a shell, where the early stages are smooth and there is no increase in convexity, would have to be interpreted as indicating either a relative increase in the rate of interstitial growth of the mantle, or a relative decrease in the rate of radial growth. If the former is the case, this will have to be interpreted as the acquisition of an excess of vitality with such a form probably representing a member of a progressively accelerated phylum.

Concentric markings:—Circumferential or concentric shell features are generally much less pronounced in the Brachiopoda than in the molluscan shell. These features comprise the lines of growth and the concentric wrinkles. In the case of the Cephalopoda and Gastropoda, the concentric wrinkles parallel to the shell mouth constitute the *ribs*, while the homologue of the striations and plications of the brachiopod and pelecypod shell forms the *spirals* of the shell of cephalous Mollusca. The homologue of the ribs of the shells of cephalous Mollusca are in the shells of Brachiopoda and Pelecypoda designated *concentric folds*, if regular, or if irregular, *concentric wrinkles*. The chief types among the Brachiopoda, in which the former are developed, are the *Productidæ*, the *Leptænas*, and *Streptorhynchus*, and related forms. They represent a periodic increase, followed by a regular decrease, in the circumference of the mantle. This feature is generally restricted to specialized, if not actually to declining, groups of Brachiopoda. Where both fine concentric undulations and radiating striæ or plications are present, the latter are interrupted or cancellated by the former, becoming nodose, or presenting a reticulated appearance. This is also produced by the lamellose development of the growth accretions, the shell surface projecting in a series of sharp edges, in place of the faintly developed concentric growth-lines.

Such projecting growth edges are the homologues of the varices of the gastropod shells, but are seldom very pronounced in the brachiopod shells. Where they cancellate the plications or striations, these assume a spinulose character. True spines may occasionally develop along such points of cancellation of striations by a varix, this being a typical feature in *Reticularia*, *Squamularia* and other genera. In the Devonian *Atrypa spinosa*, these features are often somewhat irregular. In *Productus* this irregularity is extreme. Spines are developed only at sporadic intervals in the majority of species, but they may grow to excessive lengths.

Concentric wrinkles are to be considered as irregularities of growth, probably indicating unfavorable conditions of existence. They may be sporadic, or they may develop in a regular succession in the adult stages, as is the case in some species of *Enteletes* (*vide infra*). In this case, however, the concentric wrinkles can hardly be considered as undulations, for they are step-like, and represent rather an oscillatory, abrupt contraction followed by an equally abrupt re-expansion of the shell.

Normally the growth lines are fine and uniform, but at intervals there may be stronger lines, with or without step-like modifications of the contour, or concentric wrinkles. Such strong growth lines are better spoken of as growth interruptions, and they indicate a temporary halt in the process of growth, without, however, developing a varix. In a certain sense, they may be regarded as standing in lieu of varices, especially if they are at all regularly disposed. Such growth interruptions are serviceable in the measurement of the early stages in ontogeny.

Sutures:—The term suture is here used for the line of junction of the two valves, along the side and front of the shell. The *sutural angle* is the angle across the suture, that is, the angle which the adjoining parts of the two valves make with each other (sa., Text-Fig. 35). The suture may be acute, this being the case in thin shells, whereas in the more convex ones it is either rectangular or obtuse, while in extreme cases it may become flat, that is, the shell margins join in the same plane (Text-Fig. 36). The suture margin is then 180 degrees. The suture may, however, also be depressed, as is the case in gerontic individuals, and sometimes in normal species of a declining series (Text-Fig. 37). This is due to the fact that the shell-margin, in the later stages, contracts so that the circumference is less than it was at a preceding stage. When plications reach the margin, the suture becomes a zigzag one, especially if the plications are angular. Frontally the suture is *sinuate* (Text-Fig. 38), whenever there is developed a median depression or sinus, with or without a corresponding median fold on the opposite valve. Not infrequently, the sinuosity is very pronounced when the median portion of one valve, usually the pedicle valve, projects as a *lip* or *tongue* into the opposite valve (Text-Fig. 39). The course of the lateral sutures, that is, the sutures of the side of the shell, may be straight, descending directly from the cardinal angle to the base (Text-Fig. 40), or it may be sinuous, there being a distinct curvature between the two end points as seen in the end view (Text-Fig. 41). In that case, the side of one valve *indents* that of the opposite valve, such indentation being usual by the side of the brachial valve into that of the pedicle valve. This is seen especially well in *Dielasma*.

DESCRIPTION OF SPECIES

Order TELOTREMATA Beecher

Superfamily TEREBRATULACEA Waagen

Family TEREBRATULIDÆ King

Genus **Dielasma** King

1. **Dielasma millepunctatum** Hall var. **mongolicum** Grabau, var. nov.

Plate IV, Figs. 5a-d (No. 25)

cf. 1856. *Terebratula millepunctata* Hall. Reports of explorations and surveys . . . from the Mississippi River to the Pacific Ocean, Vol. III, Pt. IV, Pl. II, Figs. 1, 2, p. 101.

cf. 1894. *Dielasma bovidens* Hall and Clarke. Natural History of New York, Pt. 6, Vol. VIII, Pt. 2; Pl. XXXI, Figs. 31–32.

cf. 1902. *Dielasma millepunctatum* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe,* Vol. XVI, No. 2, p. 456, Pl. III, Figs. 2 and 4.

cf. 1914. *Dielasma darvasicum* Tschernyschew. "Der Fauna der oberpaleozoischen Ablagerungen Darvas." Lief. I, *Mém. Com. Géol. Russe,* New Ser., Livr. CIV, p. 43, Pl. II, Figs. 5–7.

The shell is elongate with height and width as 5:3.

The pedicle valve is broadly convex in the young. At a stage where the length is 13 mm. along the curvature, the greatest width is 10 mm., this being a little in front of the mid-length. At this stage the front of the valve is nearly flat, the convexity is scarcely noticeable, and the frontal margin is regularly rounded to the point of greatest width of the shell. The shoulders are already distinctly and abruptly rounded, but there is as yet no concavity beneath the beak.

At a little later stage, when the length of the shell is 15 mm., the front begins to be slightly depressed. At this stage the shell has essentially the form and proportions of *Dielasma itaitubense* Derby, figured by Tschernyschew (1902, Pl. III, Fig. 1), from the Schwagerina limestone of Russia, though it is only about half the size of that shell.

From this point forward the valve becomes more broadly depressed and the sides of the shell more abruptly bent over until they lie at right angles to the plane of the valve. In the cardinal region the sides become depressed into a marked concavity, which is most pronounced below the beak and gradually dies away forward. The beak is moderately incurved until its truncated end is parallel to the plane of the shell-margin. The frontal curvature becomes more broadly rounded but not truncate.

The brachial valve in the half-grown individual (11 mm. long) is subspherical with the length and width as measured on the curvature equal in each case (11 mm., 11 mm.), though direct measurements because of the greater transverse convexity make the width slightly less than the length (9.5 mm.) The greatest width is a little in front of the center, and above it the sides are gently rounded, meeting at the beak in an angle of about 100°, while below the outline of the shell is a regularly rounded curve. In the full-grown shell, too, the length and width are nearly equal (22 × 21 mm.), the greatest width being about three-fifths the length of the valve from the beak. The addition of the shell-matter is scarcely marked in the upper 3 mm. or one-seventh of the length, but, from that point on, it becomes pronounced, until the adult is nearly twice as wide as the half-grown valve.

Measurements:—In our specimen, the full length of the valve is 22 mm., and the greatest width, measured on the curvature and situated 13 mm. from the beak, is 21 mm. The actual width of the shell as measured on the shell-margin is, however, only 15 mm., the difference being due to the pronounced transverse arching. This is rounded in the center while the sides are nearly flat, forming with each other an angle slightly over 90 degrees.

At the front, however, the transverse arch is a regular and gentle one.

	No. 25
Height of pedicle valve	23.3 mm.
Height of brachial valve	21.0 mm.
Maximum width	15.0 mm.
Thickness	10.0 mm.

This shell corresponds most nearly to the forms figured by Tschernyschew (1902, Pl. III, Figs. 2, 4, especially the latter) as *Dielasma millepunctatum* Hall from the Cora beds of Russia (Ufa River), though the convexity of contour of the brachial valve of our shell appears somewhat more abrupt. It is, however, distinct from the form figured by Hall and Clarke (1894, Pl. LXXXI, Figs. 31-32) under that name, which is much narrower proportionately. Hall and Clarke regard *Dielasma millepunctatum* as synonymous with *Dielasma bovidens* Morton, giving to that species a broad construction. Tschernyschew, on the other hand, holds that they should be considered distinct species. I am inclined to agree with this narrower construction, for I believe refinement in stratigraphic work is aided by such precision, even though it multiplies the number of names. As long as the general relationship of the types is recognized, the separation of distinct mutations under separate names serves the science better than the association of many varied types under one designation.

In general, our shell lies intermediate between the narrow form *Dielasma millepunctatum* Hall and the broad *Dielasma bovidens* Morton, of the upper Coal Measures of the western United States. It and the Russian specimens, referred by Tschernyschew to *Dielasma millepunctatum*, may be considered as essentially alike, but I do not think that they should be referred to either of the American species. As they are, however, nearer to *Dielasma millepunctatum*, I have felt it desirable to refer them to a variety of that species.

Horizon and Locality:—In the *Enteletes* bed, horizon 1190, of the Permian Jisu Honguer formation of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Comparison:—This shell is very similar in general form and in many of its characters to *Dielasma darvasicum* Tschernyschew from the Schwagerina beds of Darvas, but that form is much longer proportionately, this being seen even in half-grown individuals. Also the Darvas form has a sharper median depression in the pedicle valve, beginning not far from the umbonal region, whereas in the Mongolian form the shell is at first flattened and then gently and broadly depressed near the front, the depressions being flat-bottomed. The front of the Mongolian shell, too, is less pronouncedly truncate than that of the Darvas shell, and finally, the latter does not show the rather sharp deflection which bounds the crescent-shaped depressed area below the beak of the former. The measurements of an adult and a young specimen of *Dielasma darvasicum*, figured by Tschernyschew (1914), are as follows:

	Pl. II, Fig. 5	Pl. II, Fig. 7
Height of pedicle valve	31.0 mm.	16.0 mm.
Height of brachial valve	29.0 mm.	15.0 mm.
Greatest width	15.5 mm.	9.0 mm.
Thickness	13.0 mm.	6.3 mm.

It is thus seen that in the adult shell the length is nearly a third again as great, while the width is almost the same. It is, however, quite apparent that these shells are all modifications of a single type in which the extension in length is the dominent characteristic.

2. **Dielasma truncatum** Waagen var. **mongolicum** Grabau, var. nov.

Plate VII, Figs. 2a-c (No. 381), 3a-e (No. 61), (No. 383)

1882. *Dielasma truncatum* Waagen. Brachiopoda. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, p. 345, Pl. XXV, Fig. 11a-d (13a-c).

1902. *Dielasma truncatum* Waagen. Tschernyschew, "Die obercarbonischen Brachiopoden des Ural und des Timan," *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 456, Pl. I, Figs. 1a-d.

1914. *Dielasma truncatum* Waagen. Tschernyschew, "Die Fauna der oberpalæozoischen Ablagerungen des Darvas," Lief. I, *Mém. Com. Géol. Russe*, New Ser., Livr. 104, p. 43, Pl. II, Fig. 8.

A single fairly well preserved specimen of this large and peculiar species of *Dielasma* has been obtained from the Jisu Honguer limestone, but it does not entirely agree with either the Indian, Russian or Darvas forms, and is described here as a distinct variety. The shell is imperfect, the beak of the pedicle valve is broken away, but in size and general form it corresponds to the Indian species. Two other specimens are less perfect. The illustrated specimens will be described first:

Holotype (Pl. VII, Figs. 3a-e):—The pedicle valve is most convex in the umbonal region, though when the shell is viewed as a whole from the side, the maximum elevation is near the center, and the curve is a regular one from the broken beak to the front. However, the sides of the valves are abruptly deflected so that they form a right angle with the upper surface, which, for perhaps three-fourths of the length of the valve, is markedly depressed by the median sinus. The down-curving sides of the shell are distinctly depressed so as to form a concavity near and parallel to the shell-margin. This concavity is broad and pronounced near the beak and continues with but slight diminution to near the front, where it dies out. Near the shell-margin of the brachial valve it is flanked by a similar concavity, narrow near the beak but becoming broader and more pronounced towards the front of the shell, where it continues across the front, giving it a characteristic geniculated aspect. Because of these two concavities, the actual meeting of the shell margins of the two valves on the side takes place on a distinctly elevated sharp ridge, flanked on either side by the concavities of the pedicle and brachial valves respectively. In the pedicle valve the maximum width of this concave border is about 6 mm. near the beak, narrowing forward to disappearance. In the brachial valve, the maximum width of the concavity is also about 6 mm., but this is near the front, and narrows to disappearance near the beak, though still marked a short distance from it.

It is this feature of the marginal concavity which distinguishes our shell from the Indian form. In the large shell figured by Waagen, the marginal deflections, which are hardly depressed enough to form a concavity, are rather flat instead, being near the beak in both valves. They broaden forward in both, and continue around the front so that the front of both valves is geniculated, whereas in our shell this is the case in the brachial valve only. In certain aspects, however, there is a suggestion of change in curvature of the pedicle valve of the Mongolian shell about one-third the distance from the front, but this is not pronounced enough to constitute a geniculation, also it occurs much earlier than the geniculation of the front of the pedicle valve in the Indian shell. Again, our shell differs from the Indian shell in having a rather pronounced median depression for the greater length of the pedicle valve. This median depression is flanked on either side by a convex surface of about the same strength and width, the outer slope of which descends more or less abruptly to the concave marginal zone. Because of this arrangement, the frontal margin of the pedicle valve presents a distinct reversed W-shaped outline, with a rather sharp median depression of nearly rectangular form flanked on either side by an equally sharp plication. (In Fig. 3c the W is normal because the brachial valve is up.) This sharpening of the flanking ridges of the sinus until they have the appearance of plications takes place only at the front, for immediately behind this the flanking ridges are convex and become more broadly so towards the beak.

The brachial valve has a sharply elevated umbonal region, the transverse contour of which is almost roof-shaped, and the angle somewhat more than a right angle. The beak is elevated and rather sharply pointed, apparently closely appressed to the deltidial region of the pedicle valve, though this is not fully determinable because of the broken characters of the umbones. The apical angle is very large, about 147 degrees. At this angle the cardinal margins slope outward or within a short distance of the greatest width of the valve; here they curve abruptly into the lateral margins, which, from a dorsal aspect, are nearly vertical to the point where they merge into the frontal curve. This gives the valve a subtrapezoidal aspect. In reality, however, the lateral shell margin is strongly curved, as is seen in the side view, where the margin of the brachial valve is strongly convex and that of the pedicle valve correspondingly concave or indented.

As before noted, the shell margin is bordered by a concave zone which begins a short distance from the beak and thus flattens a part of the cardinal as well as the lateral margin. This part of the shell forms an abruptly deflected zone with a distinct geniculation between it and the main shell-surface. In consequence, the median transverse contour is a strongly convex arch ending laterally in the abruptly deflected concave zone. Near the front the contour is a much gentler arch, but the geniculation is more abrupt.

On the whole, the brachial valve is deeper than the pedicle, its greatest depth being in the umbonal region. From this point, very near the beak, the median longitudinal contour is a gentle and rather regular arch to the abrupt frontal deflection, where it is sharply geniculated. No distinct fold is formed on this valve, though, as already noted, the frontal suture is a zigzag one, forming a broad W when the brachial valve is uppermost. In spite of the somewhat crushed character of the front, it is apparent that the suture line is distinctly elevated as it is on the sides.

A portion of the shell over the umbonal region is exfoliated, exposing the muscle platform. This exhibits the peculiar marking shown in the enlargement (Pl. VII, Fig. 3e). It consists of a median depression which broadens forward, and from a point below the beak is divided by a rounded median ridge which also broadens forward. On either side is a series of flexed, rounded ridges separated by rounded interspaces and successively increasing in strength forward. The course of these ridges is at first forward from the median ridge to the center of the groove which bounds that ridge on either side, then sharply curving backwards with a long arm extending back at an angle of about 45° with the median ridge. These longer arms increase progressively in length as well as strength from the beak forward, while the curve between them and the likewise lengthening shorter arm become greater in the same direction. There is a slight asymmetry due probably to distortion of the shell as a whole. An analogous, though in detail not quite identical, structure of the muscle platform has been illustrated by Tschernyschew for a specimen of *Dielasma curvatum* Tschernyschew (1902, Pl. I, Fig. 5a) from the Schwagerina limestone of Russia. Others have been observed in *Dielasma bovidens, Dielasma elongatum, Dielasma giganteum,* etc. These show a certain amount of variation but a general agreement of form. In the broken beak of the pedicle valve, indications of strong dental lamellæ are seen. Other internal structures have not been ascertained.

The shell structure is very finely punctate. Lines of growth are not strongly marked.

Other specimens:—A somewhat crushed shell from these strata (No. 381, Pl. VII, Fig. 2a-c) shows the essential characters of this variety, though the deflected lateral portion of the valves is not so pronouncedly depressed as to produce a concavity as is the case in the holotype. In other respects it is, however, well marked, giving the shell a squarish aspect in umbonal view (Fig. 2b). The anterior portion is not well preserved, but apparently the downward deflection of the sides of the pedicle valve die out before reaching the front, so that that portion curves regularly to the frontal margin, as in the holotype. The frontal portion of the brachial valve, however, shows the deflection. The median depression of the pedicle valve is slightly less pronounced than in the holotype. The frontal part of the suture is not visible, but its characters are apparently the same as those of the holotype. The length of the shell is 29 mm., its maximum width 20 mm., and its maximum thickness about 19 mm.

A smaller specimen (383) from the same horizon presents the characters of this variety but apparently is immature, though in some of its characters it corresponds to the adult shell.

The beak of the pedicle valve overarches that of the brachial valve. Longitudinally the valve is arched more pronouncedly in the region of the beak and with less convexity in the median region. About one-third the height from the front is a deflection which is like that of the holotype but is more abrupt and occurs at a somewhat earlier stage. The change is inaugurated by a rather sharp geniculation below which the contour shows a slight concavity followed by a convexity and another faint concavity at the frontal margin. The distance from the geniculation to the frontal margin is slightly over 7 mm., while the height of the nongeniculated younger stage of the shell is 18.5 mm. The sides of the shell converge to the beak at an angle of about 51°; they are sharply deflected to the suture, this deflected portion having a double concavity as in the larger holotype described. Indeed, the correspondence between the two shells is perfect, except that in the smaller one this pronounced deflected portion with its double concavity is carried across the front with equal strength, whereas in the holotype this frontal portion is much less markedly differentiated from the earlier shell and less pronounced in its characters, while, as noted, it begins at a later stage than is the case in the smaller shell. The median depression of the valve begins about one-third the length of the shell from the beak or at about the point where in the holotype the apical portion is broken off. It continues to the front, where the characteristic reversed W-shaped outline of the suture is produced as the result of an additional faint depression on either side.

The brachial valve shows the slight marginal concavity found in the adult shell, but less strongly marked and narrower. As in the adult it becomes more pronounced at the front where the longitudinal contour shows a sharp geniculation. The deflected portion, however, is of less height than that of the pedicle valve. Thus at the stage in growth immediately preceding that which is marked by sudden contraction of the mantle margin resulting in the building of the contracted rim in the brachial valve, the pedicle valve had already experienced such a pronounced contraction in the shell-building mantle.

It must be noted that this geniculation of the frontal part of the brachial valve occurs at a much earlier stage than it does in the adult shell represented by the holotype. In this respect, then, the present shell can not be regarded as immature, but as a shell assuming the characters of maturity at an early stage, in other words as a dwarfed individual.

Measurements:—The following table shows the measurements of the holotype, No. 61, in column 1, and that of the young shell, No. 383, in column 2; while in column 3 are given the measurements of the adult Indian shells, and in column 4, those of the young shell, both after Waagen (1879–1887, p. 346).

	Mongolian Shells		*Indian Shells, Waagen, 1883*	
	1 (No. 61) Holotype	*2 (No. 383)*	*3 (adult)*	*4 (young)*
Height of pedicle valve	31.0 mm.	21.0 mm.	35.0 mm.	12.5 mm.
Length of pedicle valve on curvature	43.0 mm.	36.0 mm.	....	....
Height of brachial valve	24.5 mm.	18.5 mm.	29.0 mm.	11.0 mm.
Length of brachial valve on curvature	32.0 mm.	20.0 mm.	....	....
Greatest width of shell	23.0 mm.	15.0 mm.	22.0 mm.	9.5 mm.
Maximum width of pedicle valve on curvature	34.0 mm.	....	....	....
Maximum width of brachial valve on curvature	32. mm.	....	....	....
Thickness of shell	18.7 mm.	13.0 mm.	19.0 mm.	5.5 mm.
Maximum apical angle of pedicle valve	....	51°	51°	56°
Maximum apical angle of brachial valve	147°	....	63°	75°

Horizon and Localities:—The holotype was found in the *Hemiptychina* bed (1196) of the Jisu Honguer limestone of Jisu Honguer, Mongolia. The other two specimens came from the *Camarophoria* bed (1208) of the same formation.

Remarks:—The specimen figured by Tschernyschew (1902, Pl. I, Fig. 5a), under *Dielasma truncatum* from the Schwagerina limestone of Russia, differs from both the Indian and the Mongolian form in several distinct characters. In the first place the pedicle valve has a depression which becomes broad and flat near the front, where it produces a pronounced median elongation, resulting in a strong squarish emargination of the suture. In the Indian shell this frontal emargination is a gentle sinuosity, while in the Mongolian shell the suture is zigzag but otherwise without sinuosity. The sutural margin of the Russian shell shows no abrupt deflection such as is shown in the Indian, and, to a different degree, in the Mongolian shell; nor is there any marginal concavity such as is so strongly marked in the Mongolian and to a lesser extent in the Indian shells.

The shell described and figured by Tschernyschew (*loc. cit.*) under *Dielasma truncatum*, from the Permian of Tangi-Gor ravine, near Safeddaron in Darvas, agrees essentially with the shell from the Ufa River, Russia, though it is smaller. Both the Russian and the Darvas forms, then, should be referred to another species or at least to a distinct variety of the Indian form, with which they apparently agree in the immature stages. Indeed, it is not improbable that they represent the ancestral type to both the Indian and the Mongolian forms, and on this account they might be referred to as variety *antecedens*, *nom. nov.* That they come nearer the Indian than the Mongolian form will be at once apparent from a comparison of the illustrations.

3. **Dielasma** cf. **truncatum** Waagen

Plate IX, Fig. 1a-e (No. 168)

A single, somewhat imperfect specimen of a *Dielasma* from the Jisu Honguer limestone of Mongolia has the size and the general characters of the Indian shell as figured by Waagen. The beak of the pedicle valve is overarched or nearly overhanging but not incurved as is the case in the shell figured by Waagen. It is truncated by a moderate-sized and somewhat imperfect foramen. The longitudinal contour of the valve is a continuous and almost symmetrical arc with the greatest elevation in the center. Transversely the contour is sub-rectangular in the umbonal region and for some distance below. That is, the median part is so gently rounded as to be almost flat, while the sides curve over rapidly and descend abruptly nearly at right angles to the summit. These characters continue to the front with the median part becoming slightly more flattened but not depressed. The front of the specimen is imperfect, so it can not be determined if the truncation is marked, but the indications are that it is less pronounced than in the specimen figured by Waagen.

The sides are not concave, as in the variety previously described, but are essentially as in Waagen's shell. The suture is, however, raised. In outline it fully conforms to that shown in Waagen's figure.

The brachial valve is imperfect. Its longitudinal contour is very gently arched and it becomes more obese towards the front than is the case with the Indian shell. The anterior part is abruptly deflected with a rather marked geniculation. Transversely the contour is sub-regularly arcuate.

The most marked distinction of this shell, and the one in which it differs radically from the shells figured by Waagen, is the zigzag character of the frontal suture. These zigzags are of the kind found in *Hemiptychina*, being produced by a faint folding of the front which accompanies, and is apparently conditioned by, the sudden deflection of the anterior part of the shell. This feature is seen in the variety described above, but there it is an accompaniment of the median sinus.

Measurements:—The surface characters are not preserved. The measurements of the specimen gave:

	No. 168
Height of pedicle valve	32.0 mm.
Length on curvature	45.0 mm.
Height of brachial valve	26.0 mm.
Length on curvature	31.0 mm.
Greatest width	26.8 mm.
Maximum thickness	22.3 mm.

Horizon and Locality:—In the *Camarophoria* bed (1208) of the Jisu Honguer limestone (Permian) at Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

4. **Dielasma giganteum** Tschernsychew var. **anteplicatum** Grabau, var. nov.

Plate VII, Figs. 1a-c (No. 62)

1902. *Dielasma giganteum* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 455, Pl. IV, Figs. 1–3.

This shell is represented by a fragment which comprises one side of the entire shell with the two valves in conjunction. From this it can be seen that the characters correspond closely to those of Tschernyschew's species, with the exception that the frontal border has several low, sharp plications. The shell is of the type of *Dielasma truncatum* without the characteristic lateral and frontal geniculation. The entire beak of the pedicle valve is not preserved, but from what remains, it appears to have been of the blunt, slightly overhanging type characteristic of the Russian species. The most characteristic feature, and the one which at once indicates its relationship to *Dielasma giganteum*, is the curved scimitar-like marginal depression of the pedicle valve, which extends from beneath the beak, where it is broadest and most pronounced, to a short distance in front of the mid-length, tapering gradually away. This marginal depression is flat or only slightly concave and is separated from the main shell surface by a rather abrupt rounding, which is hardly to be termed a geniculation. The concavity of the marginal zone is brought out mainly by the upraised margin, which together with that of the brachial valve, forms a sharp sutural ridge similar to that seen in *Dielasma truncatum* var. *mongolicum.* This sharp ridge extends the entire length of the side as far as the frontal margin.

There is no corresponding concave marginal zone in the brachial valve, though the margin is slightly raised to form, together with that of the other valve, the sharp sutural ridge. The transverse contour of the brachial valve appears to have been a regular arch in so far as the fragment permits us to judge. On the whole, the convexity of the two valves appears to have been equal, though it varies from point to point because the lateral margin is not straight but strongly curved. The brachial valve indents the margin of the pedicle valve to a somewhat less degree than is the case in the preceding species.

In all the characters of the shell so far described the agreement with the figures of *Dielasma giganteum* is very striking, except that our shell is somewhat smaller. There is, however, this striking difference, that instead of a simple median depression of the pedicle valve, there are several rather pronounced plications near the front. Not enough of the shell is preserved to show whether or not the median depression was present in the young, though a very slight flattening of the curve remaining in the broadest part of the fragment suggests that this may have been the case. Near the front there is, however, a marked narrow depression close to the lateral frontal margin of the pedicle valve which corresponds to a sharp plication on the outside of the frontal margin of the brachial valve. Next to the lateral depression of the pedicle valve is a short pronounced plication, which though rounded at first becomes sharp at the front, forming a zigzag suture with the brachial plication. The concavity of the depression next inward of the pedicle plication, indicates that there was another plication nearer the center, though this is not preserved. So far as it is possible to judge, there were three plications in the pedicle valve and perhaps five in the brachial, though it is also possible that only one lateral plication existed on each side, on both the pedicle and the brachial valve. If we correlate the plications with the narrowing of the transverse diameter in our shell, this would account for the location of the greatest width near the mid-length of our shell, whereas in the non-plicate *Dielasma giganteum* it is from a fourth to a third of the length from the anterior end.

Compared with the preceding species, the frontal plications appear to have been more numerous, though of the same type, or else of the same number but shifted farther towards the lateral margin. In other characters the two are also quite distinct.

There is no marked change in the character of the longitudinal contour which would account for the formation of the plications by a sudden relative shortening of the circumference of the shell margin, as in the species of *Hemiptychina*, and in the case of the marked deflection of the surface of the brachial valve in *Dielasma truncatum* var. *mongolicum*. These plications may, however, be correlated with the rather marked lateral contraction of the shell as a whole, which begins at about the mid-length where the greatest width of the shell is located. In this respect it corresponds rather well with *Dielasma dubium* Tschernyschew (1902, p. 457, Pl. I, Figs. 3 a-d) from the Schwagerina limestone of the Timan. This form has, however, only two plications in the brachial valve and three in the pedicle, these plications being nearer the center than in our shell. Moreover, the Timan shell lacks the depressed zone in the pedicle valve and the sharp sutural ridge, while the indentation of the side margin of the pedicle valve by that of the brachial valve is less pronounced than in the Mongolian shell. On the other hand, *Dielasma biplex* Waagen (1879–1887, Pl. XXV, Figs. 4 and 5), though also resembling our shell, has a deeper marginal indentation, and two plications in the brachial and a median one in the pedicle valve, all extending to above the middle of the shell. Finally, *Dielasma breviplicatum* Waagen (1879–1887, Pl. XXX, Figs. 12, 13) differs from our shell in the gentler contours, absence of marginal depression, lesser convexity and fewer plications, these being confined, however, to the front as in our shell. It differs in like characters from *Dielasma acutangulum* Waagen.

On the whole, then, it would seem that our shell is a modification by specialization of the Russian *Dielasma giganteum*, and though smaller is more advanced than that form, which might perhaps be regarded as its ancestor. Definite determination of these points must await the discovery of more completely preserved material.

The structure of our shell is finely punctate, but the punctæ are somewhat larger and more readily visible than in the preceding species.

Measurements:—The few measurements which our specimen, No. 62, permits are given in column 1 below, while the measurements of two of Tschernyschew's species, as taken from his figures, are given in columns 2 and 3.

	1	2	3
	Mongolia No. 62	*Tschernyschew Fig. 2*	*Tschernyschew Fig. 3*
Height of pedicle valve	Approx. 33 mm.	about 55 mm.	45 mm.
Height of brachial valve	" 29 mm.	50 mm.	42 mm.
Greatest width	" 30 mm.	38 mm.	32 mm.
Greatest thickness	" 18.1 mm.	23 mm.	21 mm.

Horizon and Locality:—In the Jisu Honguer limestone of Mid-Permian age at Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

5. **Dielasma jisuense** Grabau, sp. nov.

Plate IV, Figs. 6a-d (No. 17)

This shell is represented by a single specimen with an imperfect pedicle valve. The shell is of medium size for the genus, elongate with the greatest width above the middle, the valves all subequally convex, non-plicate.

The pedicle valve has the umbonal region broken away, but there is enough remaining to show that it was strongly and regularly convex, curving to the cardinal margins near which the shell is depressed, forming a faint concavity and meeting the edge of the opposite valve in a sharp, slightly raised sutural margin. This depression disappears by the time the greatest width of the shell is reached. From this point, which lies behind the mid-length of the shell, the sides contract with a curvature so gentle as to be almost straight, but near the frontal margin they round more abruptly. The frontal margin is gently rounded, almost straight. The frontal suture is slightly emarginate because of the presence of a shallow broad sinus in the front of the pedicle valve. The median transverse contour is regularly arched from side to side, the sinus not appearing until after the shell has passed that point.

The brachial valve has a sharp elevated beak, not incurved but apparently appressed against the delthyrial region of the pedicle valve. The apical angle is large, about 123°, the cardinal margins sloping outward in straight lines and then rapidly curving into the sides at the point of greatest lateral expansion, which is situated about one-third the length of the valve from the beak. This gives the valve a subpentagonal outline with the angles, however, rounded. In the umbonal region the transverse contour is a subtriangular arch, but forward it becomes more regularly rounded, the arch being quite regular below the mid-length of the valve. There is no fold because there are no lateral depressions, the median frontal emargination of the suture line being permitted by the flattening of the curve of the frontal margin. All the sutures are sharp, the inter-valvular sutural angle being less than 90°. Viewed laterally, the suture forms a somewhat asymmetric curve, the brachial margin moderately indenting the margin of the pedicle valve.

The lines of growth are fine, with occasional stronger ones. The shell structure is finely punctate.

The elongate subpentagonal or shouldered appearance of the brachial valve, with the greatest width at the posterior third of the valve, is the most striking feature of this shell and distinguishes it from others of this type. It might be considered the young of *Dielasma timanicum* Tschernyschew (1902, Pl. I, Fig. 2, Pl. II, Fig. 9), if that large species were found in our rocks. It cannot be considered a dwarfed form of that shell, as in the adult the sides are nearly parallel instead of contracting as in our shell. Nor can it be considered the young of either of the two large species previously described, since the outline does not agree with that of the earlier stages of those shells as shown by the lines of growth. I have not been able to find any other shell with the adult or the young stages with which it agrees. Hence, until *Dielasma timanicum* is found in our rocks, I deem it well to retain a distinct specific term for our shell (No. 17), considering it as representing an adult.

Measurements:—The measurements obtainable of this shell are:

	No. 17
Length of brachial valve	17.3 mm.
Greatest width	15.0 mm.
Thickness	10.3 mm.

Horizon and Locality:—In the Middle Permian Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

6. **Dielasma acutangulum** Waagen var. **minor** Grabau, var. nov.

Plate VII, Figs. 4a-d (No. 14), 9a-d (No. 64), 10a-d (No. 65), 11a-c (No. 69)

1882. *Dielasma acutangulum* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, p. 353, Pl. XXVI, Figs. 1, 2.

This shell is elongate with the valves subequally convex. It is represented by a number of young and a small specimen which seems to be full-grown.

Measurements:—The following measurements show the dimensions of the different specimens.

	1	*2*	*3*	*4*	*5*
Serial Number	*No. 64*	*No. 14*	*No. 65 Holotype*	*No. 69*	*India*
Height of pedicle valve	5.3	5.8	6.7	9.4	26.5
Height of brachial valve	4.8	5.0	6.2	8.7	24.5
Greatest width	3.9	4.5	5.3	7.2	16.0
Greatest thickness	2.3	2.8	3.2	4.8	10.0
Apical angle, pedicle valve	72°	75°	72°	95°	53°
Apical angle, brachial valve	124°	118°	112°	120°	73°

The width and length of the shell vary in proportion from three to four to five to eight, the former being the more usual. In the large shell of the species figured by Waagen, the length is proportionately greater, the proportions being three to four and eight-tenths.

The beak of the pedicle valve is incurved, but not strongly overarching, and truncated by a rather large foramen. The sides curve over and then bend more abruptly to form a false area which is separated from the shell by a faint angulation. The sides slope outward to the greatest width, which is somewhat in front of the mid-length, and then curve to the front, which is more broadly rounded or even faintly flattened. In somewhat older shells the flattening on either side of the beak extends farther down the shell, but the angulation defining it is not more pronounced. Even in the largest shell in our collection (No. 69, Fig. 11), it is not very strongly marked, though the flattening extends farther on the shell.

In the young, the median longitudinal contour is moderately arched, more strongly in the umbonal than in the frontal region. The greatest convexity is in the posterior third, from which point forward the arc is a gentle one. The transverse contour is a convex arch in the umbonal region but becomes medially flattened or even depressed towards the front, there being a median flattening or very faint depression down the middle of the valve. In the holotype, which is larger in size (No. 65, Fig. 10), this depression is pronounced enough to produce a faint emargination in the frontal suture line. In our largest shell (Fig. 11), which is somewhat distorted and lengthened by a transverse calcite vein, this median depression is somewhat more pronounced, and there is the faintest indication of a central fold like that which characterizes this depression in the larger Indian shells.

The beak of the brachial valve is pointed but not incurved, being appressed against the delthyrial region of the pedicle valve. In the young the sides slope outward for about one-third the length of the valve, and then bend with an obtuse angle into the rounded outer margin which forms a regular arc to the front where the curvature becomes less or is even slightly flattened in the center. In the young the longitudinal contour may be a regular arch though even here the greater convexity may be in the umbonal region. In older shells this is usually the case, the longitudinal contour being asymmetric. The transverse contours form regular arches, which, however, become flatter near the front.

Compared with the Indian shells, the largest Mongolian specimen is less than half their size, though in other characters and in the faint development of frontal plications, the form corresponds fairly well. The apical angles of both pedicle and brachial valves are, however, larger, especially in the brachial valve.

The lines of growth are faint. Though even our largest shell (No. 69, Fig. 11) has not developed to any pronounced degree the frontal plications shown on the Indian shell, I do not think that they grow much larger in the Mongolian geosyncline. I gather that they represent the growth stages of a dwarfed form which is most nearly related in all its characteristics to *Dielasma acutangulum*. The shells are too elongated to represent the young of any of the species previously described. For these reasons, I prefer to designate our shells by a distinct varietal name.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia; six specimens. Collector, F. K. Morris.

Among the young shells in our collection is one with a broken beak, an intermediate specimen (Pl. VII, Figs. 4a-d, No. 14), the measurements of which are given above in column 2, which though proportionately somewhat broader, seems to belong here. In this specimen there is the faintest indication of the two plications near the front of the brachial valve, that are seen to be so well developed in the adult Indian form. If this shell really belongs here, it is much more accelerated than the others described above, since in the largest of our shells, which is more than a third larger, the plications are scarcely developed. In this shell too, the subumbonal depressions are somewhat more pronounced than in the others, but in the rest of the characters they correspond.

Since this shell does not seem to have the characteristics of the young of other species in the formation, I shall place it here as an accelerated individual.

7. **Dielasma elongatum** Schlotheim var. **orientalis** Grabau, var. nov.

Plate VII, Figs. 5a-d (No. 16), 7a-d (No. 68)

Cf. 1816. *Terebratula elongatus, complanatus* and *latus* Schlotheim. *Denkschr. K. Bayer. Akad. Wissen. München*, Vol. VI, p. 27, Pl. VII, Figs. 7, 9, 12, 13 and 14.

Cf. 1850. *Epithyris elongatum* (Schlotheim). King, "A Monograph of the Permian Fossils of England," Vol. I, p. 147, Pl. VI, Figs. 30–45. (*Monographs*) *Palæontographical Soc.*, Vol. III.

Cf. 1858. *Terebratula elongata* (Schlotheim). Davidson, "British Fossil Brachiopoda," Vol. II, Pt. 4, p. 8, Pl. I, Figs. 5–22, and Pl. II, Fig. 2. (*Monographs*) *Palæontographical Soc.*, Vol. X.

Cf. 1882. *Dielasma elongatum* Schlotheim. Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, p. 342, Pl. XXV, Fig. 10.

Cf. 1894. *Dielasma elongatum* Schlotheim. Netschajew, "Die Fauna der Perm-Ablagerungen des östlichen Teiles des europäischen Russlands," *Travaux, Soc. Nat. Imp. Univ. Kazan*, Vol. XXVII, Pt. 4, p. 185, Pl. V, Fig. 15.

1902. *Dielasma elongatum* Schlotheim. Tschernyschew, "Die obercarbonischen Brachiopoden des Ural und des Timan," *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 454, Pl. II, Fig. 6, Pl. IV, Fig. 9 (not Pl. IX, Figs. 5–7).

1903. *Dielasma elongatum* Schlotheim. Diener, "The Permian Fossils of the Central Himalayas." *Palæontologia Indica*, Ser. XV, Vol. I, Pt. 5, p. 41, Pl. I, Fig. 9 (not Pl. II, Fig. 4).

Cf. 1911. *Dielasma elongatum* Schlotheim. Netschajew, "Die Fauna der Perm-Ablagerungen vom Osten und vom äussersten Norden des europäischen Russlands." *Mém. Com. Géol. Russe*, New Ser., Livr. 61, p. 109, Pl. XV, Figs. 2–5.

Cf. 1914. *Dielasma elongatum* Schlotheim. Tschernyschew, "Die Fauna der oberpalæozoischen Ablagerungen des Darvas," *Mém. Com. Géol. Russe*, New Ser., Livr. 104, p. 42, Pl. II, Fig. 1.

Cf. 1916. *Dielasma elongatum* Schlotheim. Broili, "Die Permischen Brachiopoden von Timor," Palæontologie von Timor, Lief. VII, p. 63, Pl. CXXVII (13), Fig. 37 (with further literature reference).

Among the young and dwarfed shells, collected by Mr. Morris in Mongolia, are two specimens which appear to be referable to this rather cosmopolitan species. As has been remarked by others, the determination of these smooth terebratuloid shells by their external characters is all but a hopeless task, and this is particularly true of young shells or such as we have reason to believe are dwarfed.

Our specimens, though much smaller, agree fairly well with the shell figured by Tschernyschew from Darvas, where only one specimen was obtained. Our largest specimen (No. 16, the holotype, Pl. VII, Fig. 5) is elongate with the greatest width in the anterior third and the front regularly rounded. The beak of the pedicle valve, which is slightly imperfect, appears to have overarched to a moderate degree. The umbonal portion is rather elevated, and the sides curve abruptly to the hinge margin. There is a faint angulation which separates the shell surface from the marginal portion which is depressed concave. This depression extends forward for a short distance. The greatest convexity is in the posterior third, from which point the median longitudinal contour is regularly arched to the beak on the one hand and to the front on the other, the latter arc having, of course, a larger radius than the former. Transversely, the contour is almost hemispherical in the umbonal region, but becomes a much flatter arc forward without the appearance of a median flattening or depression.

Viewed ventrally, the posterior half, or more, of the shell appears strongly compressed laterally, so that the sides appear very gently concave from the beak to the point of greatest width. From this point the margin is abruptly rounded, the anterior lateral portion forming with the front a continuous curve.

The brachial valve is much less convex than the pedicle, the greatest depth, which is near the beak, being less than half that of the pedicle valve. The beak is pointed and incurved against the deltidial region of the pedicle valve; the cardinal margins slope outward in straight lines for about one-third the length of the valve, or somewhat more, then pass gradually into the rounded side and frontal curve. The longitudinal contour is very asymmetric, with a short, strong curvature to the beak and a long, gentle curvature to the front. The transverse contours, strongly arched in the umbonal region, become very gently arched toward the front. The frontal intervalve margin is straight without sinuosity. The sutural angle, which is sharp, continues as an acute angle over the side of the shell, becoming larger towards the beak but maintaining a pronounced character. The indentation of the side of the pedicle valve by that of the brachial is very slight.

The lines of growth are faint, and the punctate structure is very fine. The measurements of this specimen are given in column 2, table below.

In the smaller shell (No. 68, Pl. VII, Fig. 7) the outline and general characters are essentially the same as in the larger, but the indentation of the side of the pedicle valve by that of the brachial is more marked as a whole; this is also true, however, of the umbonal region of the larger valve when compared with the shell as a whole. The beak of the small shell is arched over, but not beyond the plane of junction of the valves. It is truncated by a rather large foramen. The measurements are given in column 1.

Measurements:—In the following table the measurements of our specimens (columns 1 and 2) are compared with those from other parts of Asia referred to this species.

Locality	*Mongolia*		*Darvas*	*Salt Range*	*Himalayas*		*Russia*
Serial Number	*No. 68*	*No. 16*	[1] *var.*	*normal*	*var.*	*normal*	*var.*
Column number	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Height of pedicle valve	4.1	6.5	13.5	18.0	25.5	14.5	16.0
Height of brachial valve	3.7	6.0	12.0	16.0	23.0	13.0	14.0
Greatest width	3.5	5.3	10.0	14.0	16.5	11.0	11.0
Greatest thickness	2.0	3.2	....	8.5	11.0	6.5	8.0
Apical angle of pedicle valve	68°	65°	51°	79°	....	....	....
Apical angle of brachial valve	93°	100°	70°	110°	....	....	....

No. 3 from Darvas and No. 5 from the Himalayas are the variety *orientalis* represented by our shells (columns 1 and 2); the others are typical *Dielasma elongatum*. No. 7 is the robust form referred by Tschernyschew to his variety from the Schwagerina bed of Russia.

Our specimens correspond more nearly to the one from Darvas than to the Indian or Timor shells. Although it is twice as large as our largest specimen, the Darvas shell has the same outline and proportions, the greatest width being in front of the middle. In the Indian shell, on the other hand, the greatest width is near the middle, and the outline is more subpentagonal than subtriangular as in the Mongolian shell, the frontal and anterolateral marginal curvature forming a less regular arc. The inequality of the valves is also less than in our shell, while the front sutural margin is slightly sinuous instead of straight as in the Mongolian shell. The Timor shell is similar to the Salt Range specimen. The shells figured by Diener from the Himalayan Permian comprise two varieties. The smaller, Diener (1903, p. 42, Pl. II, Fig. 4) says: "agrees in all its characters with the variety from the dolomites of the Middle Zechstein of Poersneck in Saxony." "Nor," says Diener, 1903, "could I perceive the smallest distinguishing feature after comparison with many specimens of that shell from Poersneck. . . ." This specimen, though widest in the

[1] Holotype.

middle, is more elongate than the shells figured by Waagen and Broili. The large specimen figured by Diener, 1903 (Pl. I, Fig. 9), resembles somewhat an elongated form figured by Geinitz from the middle Zechstein of Poersneck, or still more closely the British specimens of the narrow variety figured by King (1850, Pl. VI, Figs. 31, 35 and 39).

"Whereas the typical or normal forms of *Dielasma elongatum* are widest near the middle, in this variety the greatest breadth is situated in the anterior portion of the shell. The shell is very flat in front and provided with a sharp anterior margin. The apical region is attenuated, the ventral valve evenly curved in the transverse direction and without any trace of a mesial sinus. In the last-mentioned character, my type differs from the British types of *Dielasma elongatum* in which a gradually depressed or shallow sinus is always present, although it becomes hardly perceptible in certain middle-aged and young shells." (Diener, 1903, p. 42.)

In spite of its very large size, this appears to be the form represented by the Darvas and Mongolian shells, and since the Himalayan shell also differs from the European shells, in the absence of the sinus, though agreeing with some of them in form, it may not be amiss to designate this type by a distinct varietal name. For this purpose the name variety or mutation *orientalis* (nom. nov.) would seem to be applicable.

To this same group apparently belongs the specimen figured by Tschernyschew from the Schwagerina limestone in his 1902 monograph on Pl. II, Fig. 6, though that shell is more robust than the other specimens referred to. The large shell figured by him on Pl. IV, Fig. 9, is more doubtful but may belong here. Again the shells figured by Tschernyschew (1902, Pl. IX, Figs. 5–7) have the form and proportions of this variety but are characterized by a depression in the pedicle valve and a frontal sinuosity of the suture. Therefore they can scarcely be referred to this variety if the construction is to be taken very strictly, as I think it should.

Horizon and Localities:—Our two small specimens came from the Jisu Honguer limestone of Jisu Honguer, Mongolia, where they were collected by F. K. Morris. The other shells referred to this variety are: from the upper reaches of the River Obi-Rawnou in Darvas (column 3); from the Permian limestone of Chitichun No. 1 (Hundes) in the Himalayas (column 5); and from the Schwagerina limestone of the Felpartsch cliff on the River Sylwa, in the west Ural region of Russia.

8. **Dielasma itaitubense** (Derby)

Plate IV, Figs. 2a-e (No. 63)

1874. *Terebratula itaitubensis* Derby. "On the Carboniferous Brachiopoda of Itaituba, Rio Tapaja, Prov. of Pará, Brazil." Morgan Expeditions. *Bull. Cornell Univ.* (Science) Vol. I, No. 2, p. 1, Pl. II, Figs. 1, 3, 8, 16; Pl. III, Fig. 24; Pl. VI, Fig. 15.

1883. *Dielasma itaitubense* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 348, Pl. XXVI, Fig. 5.

1902. *Dielasma itaitubense* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan," *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 457, Pl. III, Fig. 1.

1914. *Dielasma itaitubense* Tschernyschew. "Der Fauna der oberpalæozoischen Ablagerungen des Darvas," *Mém. Com. Géol. Russe*, New Ser., Livr. CIV, p. 43, Pl. II, Figs. 2–4.

This species, described originally from South America, and later from the Salt Range and from the Schwagerina and Omphalotrochus limestone of the Ural district in Russia, appears to be represented in our collection by a very small but distinctive shell.

In form it is narrow and elongate with the valves unequally convex. The pedicle valve has a beak strongly arched and overhanging the plane of contact of the valves, its apex truncated by a rather large foramen. There is a relatively broad flattened or slightly depressed crescentic marginal region on each side of the beak which is delimited by a somewhat pronounced ridge, which, however, is not angular. The crescent extends for about half the length of the shell and is supplemented by a similar but short depressed space on either side of the beak of the brachial valve, which, however, soon disappears. The sutural margin along the pedicle crescent is sharp but not elevated. In ventral aspect the sides of the shell are very gently curved, appearing almost parallel, the greatest width being near the mid-height or slightly in front of it. Near the front the sides round rather rapidly into the frontal margin which is gently curved. The greatest convexity of the valve is behind the middle, from which point the arching to the beak is on a somewhat smaller radius than that towards the front. The transverse contour in the umbonal region is a depressed arch with abruptly deflected sides. A faint median depression begins a short distance in front of the beak and continues with but slightly more pronounced character towards the front, where it is not sufficient to produce any discernible sinuosity in the frontal suture line.

The brachial valve is somewhat less convex than the pedicle valve, the greatest depth being near the mid-length, with the median longitudinal contour a regular arch from beak to front. The indentation formed by the lateral shell margin of the brachial valve in that of the pedicle is slight and regular. The beak is closely appressed against the deltidial region of the pedicle valve, pointed but scarcely incurved. The sides slope outward at an angle somewhat less than 90° with each other, to the lateral margin where they merge into the gently arched side contours. In mid-length the shell is strongly arched, appearing more convex in frontal view than the pedicle valve. At the front there is a faint flattening in the contour corresponding to that of the pedicle valve.

The surface is smooth, with growth lines scarcely visible and punctate structure very fine.

This species resembles somewhat closely the young form figured by Tschernyschew from Darvas (1914, Pl. II, Fig. 2), but its sides are more nearly parallel. The contours, on the other hand, are more like the larger specimens (*op. cit.*, Fig. 3) than the young, especially the median longitudinal contour of the brachial valve. Again it corresponds fairly well to the much larger Russian shell figured by Tschernyschew in his earlier monograph, though again the sides of our shell are more nearly parallel. The Russian shell also shows a sinuosity in the frontal sutural margin of the adult. The same may be said in comparison with the large shell from the Salt Range figured by Waagen, but here the characters of the beak and umbonal regions of the pedicle valve correspond more nearly. Especially is this true of the pronounced crescentic depressed space on either side of the shell, which is so well marked in the Indian, but is not shown in either the Russian or the Darvas shells.

On the whole there is considerable doubt as to the exact reference of our shell, which is probably a young individual. It does not correspond exactly to either the young or adult of any species known to me.

Measurements:—In the following table the measurements of our shell and those of the young specimen from Darvas are given, the latter being taken from Tschernyschew's (1914) figure:

	Mongolian Shell	*Darvas shell Tschernyschew, 1914,*
	No. 63	*Pl. II, Fig.*
Height of pedicle valve	5.6 mm.	13.0 mm.
Height of brachial valve	4.9 mm.	11.5 mm.
Greatest width	3.5 mm.	8.5 mm.
Greatest thickness	2.8 mm.	5.0 mm.
Apical angle of pedicle valve	50°	49°
Apical angle of brachial valve	94°	70°

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Genus **Hemiptychina** Waagen

1882. *Hemiptychina* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, pp. 361–364.

1894. *Hemiptychina* Hall and Clarke. *Natural History of New York*, Pt. 6, Vol. VIII, Pt. 2, p. 299.

This generic name was introduced by Waagen for plicated terebratuloids of the Productus limestone which do not possess dental plates. Waagen did not designate a genotype, and the first species described is a smooth shell, *Hemiptychina sublævis*. He considered that the plication of the exterior "is not absolutely indispensable for the shells belonging to this genus" (Waagen, 1879–1887, p. 361). Hall and Clarke hold that "The propriety of including these plicated and smooth shells in the same genus appears, on certain grounds, open to objection; and the author's intention will undoubtedly be better interpreted by regarding the plicated shell *Terebratula himalayensis* Davidson as typical of the *Hemiptychina*, a shell of whose interior something is known, and from which it is clearly evident that the author's diagnosis was largely drawn" (Hall and Clarke, 1894, p. 299). This is, moreover, the first species figured by Waagen. For the non-plicated shell with this type of interior the name *Beecheria* was created by Hall and Clarke with *Beecheria davidsoni* Hall and Clarke from the Carboniferous limestone of Windsor, Nova Scotia, as genotype.

Hemiptychina himalayensis (Davidson)

1862. *Terebratula himalayensis* Davidson. "On some Carboniferous Brachiopoda collected in India by A. Fleming, M.D., and W. Purdon, Esq., F.G.S." *Quart. Journ. Geol. Soc. London*, Vol. XVIII, p. 27, Pl. II, Fig. 1.

1863. *Terebratula himalayensis* de Koninck. "Fossiles Paléozoiques de l'Inde," p. 32, Pl. IX, Fig. 1.

1878. *Terebratula himalayensis* Waagen. Record, Geol. Survey of India, Vol. XI, p. 286.

1884. *Hemiptychina himalayensis* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 368, Pl. XXVI, Figs. 6–10.

1894. *Hemiptychina himalayensis* Hall and Clarke. *Natural History of New York*, Pt. 6, Vol. VIII, Pt. 2, p. 299, Fig. 222.

1897. *Hemiptychina himalayensis* Diener. "The Permo-Carboniferous Fauna of Chitichun No. 1." *Palæontologia Indica*, Ser. XV, Himalayan Fossils, Vol. I, Pt. 3, p. 76, Pl. XII, Fig. 4.

This species is typical of and apparently restricted to the Permian beds of the Himalayan geosyncline.

9. **Hemiptychina himalayensis** (Davidson) var. **mongolica** Grabau, var. nov.

Plate II, Figs. 1a-e (No. 0), 2a-e (No. 1), 3a-d (No. 2), 4a-d (No. 3), 5a-d (No. 4), 6a-e (No. 5), Plate III, Figs. 2a-e (No. 384), (Nos. 21, 22, 60, 73)

This variety of the Indian species is not uncommon in the limestones of Jisu Honguer, from which more than half a dozen well preserved specimens were obtained, none of which, however, permits the preparation of the interior. Nevertheless, the external characters of this shell are so typical that there can be no doubt about the reference of our shells to this specific group.

The feature of most significance is the restriction of the plicated stage to the adult portion of the shell, the earlier periods being characterized by smoothness. Hence, if the smooth shells of this type are to be referred to the genus *Beecheria*, as advocated by Hall and Clarke, that genus must be regarded as ancestral to the present one. The fact that the type species of that genus belongs to an earlier horizon (Upper Dinantian of the Atlantic province) is in harmony with this interpretation.

Moreover, it follows that young shells of the present species are without plications, as is shown in the specimen figured on Pl. II, Fig. 1a. Adult forms of this type, with slight indentations only at the very margin of the valves, are common in the lower Productus limestone of the Salt Range of India, a horizon which may possibly be of Carboniferous, but is more likely of early Permian age. These shells have been described as *Hemiptychina sublævis* by Waagen, and they may well be ancestral to *Hemiptychina himalayensis*, as suggested by him. These are more primitive than *Hemiptychina himalayensis*, though they probably are already referable to the genus *Hemiptychina* rather than to the genus *Beecheria*. It must not be overlooked, however, that members of the genetic group to which *Hemiptychina himalayensis* belongs may remain in the *sublævis* stage as the result of retardation in development, and so occur in the same strata in which the plicated forms are normally found. This explains the finding of a few shells of the *Hemiptychina sublævis* type in the Middle Productus limestone.

It should be further noted that the young stages of our shell are characterized by a more or less pronounced sharp shell margin at the meeting point of the two valves, this being commonly less than a rectangle, though in more advanced forms it may be obtuse. It is never as flatly obtuse as in the typical adult forms where the angle may approach 180 degrees. This character of the immature shell is well seen, not only in young individuals, but it appears also from a study of the stronger growth lines of the adult shell. These show that in the less obese individuals, the valves meet in an acute angle in the neanic stage, though in the adult this angle is very obtuse. In the more obese shells, which must be considered as more strongly accelerated in development, the marginal shell angle in the nepionic stage is already obtuse, though no plications are formed.

An immature shell from the Hemiptychina bed (Locality 1196, No. 0, Pl. II, Figs. 1a-e) shows an extremely sharp shell margin. The valves are only slightly arched, the brachial less than the pedicle. The frontal angle is 55°, that of the sides 68°, while the lateral angle of Waagen's most compressed form is 74°, with the frontal angle scarcely less. The measurements of this specimen are given in column 0 in the following table.

Essentially similar characters are shown in the non-plicated species, which, as explained above, must be regarded as either primitive or retarded in development, retaining the *Beecheria* characters of the ancestral types in earlier geological time. Here, too, we find that in some individuals the shell margin is acute (Waagen 1879–1887, Pl. XXVII, Figs. 3c, d), while in others, which are more accelerated in development, the shell margin is obtuse (Waagen 1879–1887, Pl. XXVII, Figs. 1c, d), and in still others it is essentially rectangular (Waagen, 1879–1887, Pl. XXVII, Figs. 2c, d). Waagen places all these in the same species *Hemiptychina sublævis* Waagen and on this basis the three types mentioned may be considered as three mutations showing progressive acceleration, least in 3, most in 1, with 2 intermediate.

The development of the plications on the front of the shell coincides with the rather abrupt inward deflection of the shell surface. The latter, if occurring by itself, would indicate a distinct change in the relative rates of growth of the shell-building mantle in length and in circumference of the margin. In other words, it would imply a relative reduction in the rate of interstitial mantle growth, which heretofore kept pace with the rate of radial growth or growth in length. For it is evident that a sudden change in the contour of the shell by downward or inward deflection means an abrupt reduction of circumference of the shell margin over what it would be, were the contour a regular curvature. Such a reduction in the interstitial growth of the mantle and consequent deflection of the shell margin, or relative contraction of the shell margin, is a feature of individual old age or gerontism. When it is a normal characteristic of the adult of a species, it must be interpreted as indicating racial old age or phylogerontism.

On the other hand, the production of plications in the shell margin which previously was non-plicate, indicates a relative increase in the circumference of the mantle border if there is no change in contour, the interstitial growth increasing at the expense of the radial growth. Therefore, when downward deflection of the shell is accompanied by the formation of plications, these two opposing features may balance each other, the relative growth of the mantle border remaining unchanged. Such a condition may be brought about by the rapid increase in the thickness of the body of the animal, especially in the anterior region, to accommodate the increase in size of certain internal organs, this increase being in excess of the increase in size outward and forward. If the relative rates of growth of the mantle (radial and interstitial) remain unchanged, the necessary downward bending of the mantle to enclose the thickening body must inevitably result in the wrinkling of the down-bending edge as a straight close-fitting blouse must wrinkle when drawn together below an obese abdomen. This wrinkling will be expressed in the shell as plications. The more obese the shell becomes in front the more pronounced must be the plication, always pre-supposing that the relative rates of growth of the mantle are not changed.

This mode of growth in the adult is characteristic of the genotype of *Hemiptychina*, and succeeds a normal growth which produces a smooth shell of regular contour in the young—a shell character which recapitulates the adult character of the ancestral form. The direction of evolution is thus indicated, and we must consider that in forms of this genetic series it continues in the same direction, or in several directions which start from this as a necessary morphic stage. It is perfectly true that by retardation in certain forms within this group, the frontal obesity is never developed, and that consequently a smooth species may be included within this genus. It would, however, probably be impossible to determine with certainty that such a smooth species (*Hemiptychina sublævis* Waagen of the Middle Productus limestone) is not a persistent representative of the ancestral smooth type, which is referred, and appropriately so, to the genus *Beecheria*. Probably the fact that such forms are sporadic among the normal members of the generic group would serve as a valid argument that they represent retarded branches of the genetic series, throwbacks, as it were, to the ancestral type, but not to be united with it.

In any case, however, the fact remains that obesity of development with its consequent morphic shell features is a characteristic of the genus *Hemiptychina* and that in strict construction any other mode of modification from the original smooth form, which does not begin with this character, cannot be normal to species of this genetic group.

We shall later see that this rules out of this generic community a number of species which have been placed in it by some authors, expecially Tschernyschew.

The number of marginal plications in the individuals of this species from the Salt Range is, according to Waagen, from eleven to twelve, five or six of these occupying the front and three the adjoining lateral portions of the shell. The shell margins have become interlocking zigzag. Ten is the maximum number (four in the center, three on each side) found in the pedicle valve of our most obese individual, but in one from Mongolia (No. 5 of the table, Pl. II, Fig. 6), and a somewhat less obese individual (No. 4, Pl. II, Fig. 5) which, however, still compares very favorably in obesity with the plicate shells of the Salt Range, the number on either side is only two, with four in the center or eight in all. In the next less obese form (No. 3, Pl. II, Fig. 4), the number is still four in the center of the front and two on either side, the outer of these on each side being, however, extremely faint or almost obsolete. Finally, in the least obese (No. 2, Pl. II, Fig. 3) the number of frontal plications is four, and only one faint plication occurs on either side of these, or six in all. In the youngest shell (No. 1, Pl. II, Fig. 2), which might be referred to *Hemiptychina sublævis* Waagen (though it agrees in character with the immature shells of similar size in the forms with obese adult stage), the shell margins are acute; there is no downward deflection and no plications.

While this forms a regularly decreasing series corresponding to the decrease in obesity, there is an exception in the case of our largest and most obese form (No. 384, Pl. III, Fig. 2) which agrees very closely in measurements with the average shell from the Salt Range region. In this, the immature smooth stage of the pedicle valve has a height of 18.3 mm., whereas the total height of the valve is 20 mm. The deflected portion of the pedicle valve has a height of 8 mm., and there are four plications in the center, strongly marked by zigzags at the suture. On each side, however, there is only one plication, thus making the total number six, as in the smallest of the plicated series above described (No. 2, Pl. II, Fig. 3). The sides of the valve are vertical or even faintly contracted at the suture, so that the shell may be regarded as a gerontic individual.

The length of the primitive smooth stage of the brachial valve is 16 mm., and that of the deflected part 5.6 mm., to the end of the points of the zigzag suture. The sides, too, are vertical, locally slightly concave, corresponding to this feature in the pedicle valve. There are five median plications, the outside ones very faint. The lateral plications are scarcely developed. This specimen probably came from the Hemiptychina bed (1196). Agreeing in size with the Indian shells, it exceeds them in obesity and differs from them in the very moderate development of the plications.

Another feature worth noting is the change in the incurvature of the beak with increase in obesity. In the young, with acute shell margins, the beaks of both valves are elevated above the hinge line, but scarcely incurved. As the shell becomes obese and the frontal margins are separated vertically, the beaks approach more and more, coming to overhang the hinge line. This is most pronounced in the pedicle valve, the beak of which finally overhangs that of the brachial to a marked degree.

Of interest in this connection is a much smaller specimen (No. 60, not figured), which agrees, in the frontal character and the number of plications, with specimen No. 4 of the above series. Indeed, the deflection is even more abrupt than in that individual. Besides the four central plications in the pedicle valve, there are two on either side, the outermost being, however, much less strongly developed than the others. The length of this shell (pedicle valve) is only 12 mm. as compared with 17.6 mm. in No. 4, while the greatest width is 9.5 mm. as compared with 14.6 in the larger shell. Finally, the thickness appears to have been over 7 mm. (as compared with 11.2 mm. in No. 4), though this cannot be accurately determined because of the destruction of the brachial valve. The length of the deflected plicated portion is, however, 5.5 mm. as compared with only about 5 mm. in the much larger form (No. 4).

This is clearly a much accelerated individual in which the normal adult characters appear long before the shell has reached even the normal growth for these forms in this limestone. In the other shells the smooth stage is the only one shown at this size, while in the present accelerated form the smooth stage occupies scarcely more than 10 mm. of the length. The specimen comes from the Hemiptychina bed (1196), where the larger specimens were found, and indicates even better than they the tendency to dwarfing of these shells which prevailed during the formation of this limestone.

There is very little, if any, difference in the obesity of the valves, though in the immature shell the pedicle valve is more convex than the brachial. The greatest convexity of the valves lies in the posterior third, that of the brachial being, if anything, farther behind than that of the pedicle valve. In only one of our specimens is the foramen uninjured, and there it is large, circular, and lies mainly in front of the beak, which is partly truncated by it.

Measurements:—The following measurements (Nos. 0–5a) are of seven specimens showing increasing obesity, the first two being immature, non-obese and without plications. The measurements are in millimeters. Nos. 6–8 are measurements of this species from the Salt Range, after Waagen, 1882; No. 9 is this species from Chitichun, after Diener, 1903, while Nos. 10 and 11 are measurements of *Hemiptychina sublævis* from the Salt Range, also after Waagen, 1882, and No. 12 from Chitichun.

These measurements show some interesting features. In the first place, the Salt Range specimens are generally larger than the Mongolian shells, though one of our specimens agrees with them. The proportions of length and width, however, are not very different from those of the Mongolian shells, except in the case of No. 7, which is the most obese of the Salt Range shells both actually and proportionately. The proportional obesity of this shell, however, falls between Nos. 2 and 3, that is, it is only slightly greater than that of the

Hemiptychina himalayensis var. *mongolica*

	Mongolia					
Actual Measurements	*No. 0*	*No. 1*	*No. 2*	*No. 3*	*No. 4*	*No. 5*
	Pl. II, Fig. 1	*Pl. II, Fig. 2*	*Pl. II, Fig. 3*	*Pl. II, Fig. 4*	*Pl. II, Fig. 5*	*Pl. II, Fig. 6*
Length of pedicle valve	12.1	12.0	13.8	14.5	17.6	15.4
Length of brachial valve	11.1	11.1	12.0	13.5	16.2	14.0
Maximum width	11.0	10.0	11.5	11.5	14.6	13.0
Thickness	5.0	6.4	7.4	9.4	11.2	12.0
Proportions						
Length to width	1.1:1	1.20:1	1.20:1	1.26:1	1.21:1	1.19:1
Length to thickness	2.42:1	1.875:1	1.73:1	1.58:1	1.57:1	1.28:1
Width to thickness	2.2:1	1.86:1	1.55:1	1.21:1	1.30:1	1.08:1
Apical angle pedicle valve	54°	73°	73°	78°	88°	88°
Apical angle brachial valve	97°	109°	105°	105°	109°	109°

	Mongolia *No. 384*	*H. himalayensis* Salt Range			*H. himalayensis* Chitichun	*H. sublævis* Salt Range		*H. sublævis* (Diener, 1903) Chitichun
Actual Measurements	*5a*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
	Pl. III, Fig. 2							
Length of pedicle valve........	20.0	20.0	21.0	19.5	22.0	20.0	19.0	17.5
Length of brachial valve.......	17.8	18.0	18.5	16.0	18.5	17.0	16.0	15.0
Maximum width............	15.5	16.0	14.5	17.0	16.0	14.0	14.0	13.0
Thickness....................	14.5	11.5	13.0	8.0	14.0	10.0	11.0	10.0
Proportions								
Length to width..............	1.29:1	1.25:1	1.45:1	1.15:1	1.375:1	1.43:1	1.36:1	1.42:1
Length to thickness...........	1.38:1	1.74:1	1.62:1	2.44:1	1.57:1	2.00:1	1.73:1	1.75:1
Width to thickness............	1.07:1	1.39:1	1.12:1	2.12:1	1.14:1	1.40:1	1.27:1	1.30:1
Apical angle pedicle valve......	75°	75°	67°	77°	70°	66°	70°	61°
Apical angle brachial valve.....	110°	115°	110°	120°	110°	101°	104°	90°

least obese of the Mongolian shells. Again, No. 6, the next in proportional thickness, agrees essentially with No. 2, our least obese shell. Finally, No. 8 of the Salt Range shells is proportionally much less obese than any of our shells, even the young in which actual obesity has not yet been formed. Its actual thickness falls between Nos. 2 and 3, though the actual size is much greater than our largest specimens.

From this it appears that our shells are on the whole more obese than those of the Salt Range which exceed our shells in size. The proportions between width and thickness, except in the extreme form (No. 8), varies much as it does in our shells, while the proportion of total length to width varies on both sides of the average of our specimens.

In describing the character of the plication of our shell, it was noted above that four was the number of plications on the front, with a gradual increase of the number of plications on either side from one to three. In the Salt Range specimens, the number of plications on the front is five or six, while three is the usual number on the adjoining lateral margins.

Thus it is seen that our specimens are generally smaller, uniformly more obese proportionately, and have four instead of five or six frontal plications, with the number of lateral ones increasing from one to three instead of remaining essentially constant at three. Small though these differences are, they are cumulative and must probably be regarded as sufficient for the separation of our form from the Salt Range form—as a distinct mutation or geographic variety, and the designation mutation *mongolica*, mut. nov., may be applied to it. When it is realized that the localities are more than 1,600 miles apart in a straight line, such difference is not surprising.

If we now compare the young of our species, the measurements of which are shown in columns 0 and 1 of the table, with the typical specimens of *Hemiptychina sublævis* from the Lower Productus limestone of the Salt Range, the measurements of which are shown in columns 10 and 11, we note that, whereas the actual measurements of the Salt Range form greatly exceed those of our young, the proportions are not so very different, especially the proportion of thickness to length, that of our young form falling almost exactly midway between those of the two Salt Range specimens given. This would tend to confirm the suggestion made above that this species is either primitive, or produced by retardation in development of the normal type.

Horizon and Locality:—This variety has so far been found only in the *Hemiptychina* bed (horizon 1196) of the Jisu Honguer limestones at Jisu Honguer, Mongolia. The horizon is Middle Permian, corresponding to the Middle Productus limestone. In the Salt Range the species begins in the Lower Productus limestone, where it is rare in the "Chonetes bed" (2 specimens). It is still rare in the lower part of the Middle Productus limestone (Katta beds), but is most common in the upper part of the Middle Productus limestone. It also occurs, though less commonly, in the Upper Productus limestone.

Remarks:—Tschernyschew has described a small smooth shell from the Schwagerina horizon of Kasarmenskij Kamen on the Sim under the name *Hemiptychina* (*Beecheria*) *sublævis* Waagen. This shell has a length of 13 mm., a maximum width of 11 mm., and a thickness of 7 mm. These measurements are taken from Tschernyschew's figure (1902, Pl. LX, Figs. 1a-d).[1] His description is entirely in Russian and is therefore unavailable. The proportion of length to width is 1.18: 1; of length to thickness, 1.86: 1; and of width to thickness, 1.57: 1. These proportions are very unlike those recorded for typical *Hemiptychina sublævis* by Waagen, 1882 (Columns 10 and 11 of table above), showing these specimens to be first of all a much less elongated form. In this respect they agree rather closely with the young of *Hemiptychina himalayensis* mut. *mongolica* Grabau. In thickness the Russian form also agrees with our young. Indeed the Russian form is in its proportions very like the young of the Mongolian variety of *Hemiptychina himalayensis*, which it also approaches in actual measurements, being but little larger. Our young

[1] It would greatly facilitate scientific research if such valuable material could be presented in one of the three most widely known languages, English, French, or German. In this report I am recognizing only those species described in one of these languages, unless the descriptions are accompanied by illustrations sufficient to preclude doubt of their character.

shell has, however, a sharper frontal angle, this being 73°, whereas that of the specimen figured by Tschernyschew is 140°. This suggests that the Russian form is an adult, which is further indicated by the absence in these strata of typical *Hemiptychina himalayensis* with plicated front. Furthermore, there is a very gentle frontal emargination in the Russian shell with corresponding flattening of the curvature.

It would thus appear that the Russian shell is distinct from the Indian species. It apparently still represents the undifferentiated ancestral type and belongs to the genus *Beecheria*. To this I shall refer it, applying to it the name *Beecheria tscherníscheffi*, nom. nov., in appreciation of the great work of this eminent Russian palæontologist whose command of foreign languages enabled him to make his work accessible to the scientific world.

Beecheria tscherníscheffi Grabau may be considered as related to the ancestral types from which *Hemiptychina himalayensis* and other species of that generic group were derived. The Schwagerina limestone represents the first invasion of the Pacific waters across China into the Russian basin, being followed later by the invasions responsible for the Jisu Honguer and Middle Productus limestones. (See correlation chapter).

Specimens identical with the Russian forms occur in the Spiriferenkalk of Spitzbergen. Of those specimens identified by Tschernyschew, Wiman says (1914, p. 76): "Beide Schalen, besonders aber die dorsale, sind flacher als an Waagen's Figuren, stimmen aber genau mit denen Tschernyschew's überein." This agreement between the Russian and Spitzbergen shells and their difference from the Indian shells indicate the constancy of characters of this supposedly ancestral species brought in by the early Permian invasion.

Tschernyschew has also described two related species from Darvas, one of which is referable to the genus *Beecheria*, the other to *Hemiptychina*. These are *Beecheria pseudo-elongata* Schellwien, and *Hemiptychina darvasica* Tschernyschew. The former was originally described by Schellwien (1900b, p. 107, Pl. XV, Figs. 27–29) from the Trogkofelschichten of Austria, and again by Gortani (1906a, p. 45, Pl. III, Figs. 11, 12), from the Carnic Alps. The Darvas specimens figured by Tschernyschew (1914) show the following measurements taken from his figures:

Actual Measurements	*Beecheria pseudogaleata* Tschernyschew			A
	1 (Fig. 15)	2 (Fig. 16)	3 (Fig. 17)	
Height	11.5	11.5	11.0	10.5
Width	10.5	9.0	10.0	9.5
Thickness	5.0	5.5	5.0	5.0

Proportions	*Beecheria pseudogaleata* Tschernyschew			A
	1 (Fig. 15)	2 (Fig. 16)	3 (Fig. 17)	
Height to width	1.1:1	1.28:1	1.1:1	1.1:1
Height to thickness	2.3:1	2.1:1	2.2:1	2.1:1
Width to thickness	2.1:1	1.64:1	2.0:1	1.9:1
Apical Angles				
Apical angle, pedicle valve	81°	69°	73°	97°
Apical angle, brachial valve	105°	107°	116°	102°

The first three are Darvas specimens of *Beecheria pseudo-elongata* and show the subrotund character of that shell and the relative thinness, which is less than half the length. In the last column (A) are given the measurements of an early (neanic) stage of the young *Hemiptychina himalayensis* mut. *mongolica*, as shown by a strong growth cessation on both valves. Not only does this correspond very nearly in actual size, but the proportions are also identical, especially those of length and width, and length and thickness. This correspondence also extends to the apical angle, which is essentially similar in the brachial valve, though higher in the pedicle valve. These angles are, however, only approximate, as their measurements on a shell not actually young is a matter open to error. Another point of doubt lies in the measurement of the thickness, which, from the nature of the case, could not be obtained with absolute certainty, but that given is probably correct within one or two-tenths of a millimeter.

The uniformity of size and the abundance of this shell in the Darvas limestones, as reported by Tschernyschew, indicate that the shell is fully grown. Thus it represents the form and proportions and so far as can be ascertained the other external characters of the neanic *Hemiptychina himalayensis* mut. *mongolica*, and, so far as can be judged, the young of the Salt Range species as well. The only interpretation is that the present shell is in the line of ancestry of the Mongolian and perhaps also of the Salt Range species.

The specimens described by Schellwien from the Alps of southern Europe, *Hemiptychina darvasica* Tschernyschew are nearly equivalve in the young but in the adult the pedicle valve becomes much more convex; the shell also increases in length. Successive stages in development of this form, as shown in the figures by Tschernyschew, give the following dimensions:

Column Number	*Hemiptychina darvasica* Tschernyschew 1	2	3	4	5	*H. sublævis* Chitichun
Height	8.0	9.0	12.5	15.5	21.5	17.5
Width	8.0	8.0	10.5	13.5	17.0	13.0
Thickness	4.0	4.2	6.0	8.0	11.5	10.0
Proportions						
Height to width	1:1	1.125:1	1.19:1	1.15:1	1.126:1	1.42:1
Height to thickness	2:1	2.14:1	2.08:1	1.94:1	1.87:1	1.75:1
Width to thickness	2:1	1.9:1	1.75:1	1.69:1	1.48:1	1.30:1
Apical angle, pedicle valve	93°	78°	75°	71°	61°	61°
Apical angle, brachial valve	124°	110°	116°	97°	114°	90°

The young of this species also closely resembles in its proportions those of the adult *Beecheria pseudo-elongata*, though at a stage when it is only about one-third the size of that adult. In this species we again find that the adult shows a certain amount of flattening at the front, especially in the pedicle valve, with the development of 3 to 4 faintly marked plications. Tschernyschew calls attention to the fact that this shell resembles more closely the form *Hemiptychina sublævis* described by Diener from Chitichun No. 1 (1903, pp. 40, 41, Pl. II, Fig. 3), agreeing with it in the relatively greater width and the greater angle of the pedicle valve. In this respect he holds that they differ from the typical *Hemiptychina* (*Beecheria*) *sublævis* from the Lower Productus limestone. As will be seen by comparing the measurements given in the various tables, which may be taken as those of typical members of the species in the several localities, this generalization of Tschernyschew's is not entirely accurate. For while the apical angles of the pedicle valves in Darvas and Chitichun specimens appear to be the same, that of the brachial valve differs widely in the two shells. Furthermore, the proportions of length to width also differ, that of the Chitichun specimen being much greater. On the other hand, the Chitichun specimen is almost identical in this respect with one of the Salt Range specimens, while its proportion of length to thickness agrees closely with the other.

Hemiptychina darvasica Tschernyschew is certainly distinct from either of the two Salt Range species here considered, taking in a measure an intermediate position. This is further suggested by the incipient plications on the frontal margin. On the other hand, the Chitichun specimens of *Beecheria sublævis* agree fairly closely with those of the Salt Range, falling within the range of variability of that species. The Chitichun specimen of *Hemiptychina himalayensis*, however, agrees less closely in proportions with the Salt Range forms of the species. Among the species of the Productus limestone of the Salt Range, *Hemiptychina sparsiplicata* Waagen, characteristic of the lowest beds of the middle division, was regarded by that author as intermediate in character between *Hemiptychina sublævis* and *Hemiptychina himalayensis*, as it is intermediate in stratigraphic succession. This is, however, not the case for *Hemiptychina sparsiplicata*, which shows a decidedly different order of development. It is undoubtedly true that it is a derivative from the simple forms classed as *Hemiptychina sublævis*, but only from those members of that somewhat variable group which show a sharp shell angle (Waagen, 1879–1887, Pl. XXVII, Fig. 3). This is also the type ancestral to *Hemiptychina himalayensis*. The other robust forms figured by Waagen are individuals which in the period of the Lower Productus limestone developed some homœomorphic characters of *Hemiptychina himalayensis*, that is, the abruptly incurving front which means relative restriction of circumferential growth. Since, however, this is not accompanied by compensating plications (the incipient plications developed at the edge being insufficient for this), it is apparent that the rate of circumferential (interstitial) mantle growth has relatively decreased, in other words, that these forms exhibit a tendency to gerontism. Hence they cannot be in the line of ancestry of a type in which such a relative reduction in rate of growth is not obtained. I shall for convenience refer to the sharp-angled type of *Hemiptychina sublævis* (Waagen, *op. cit.*, Fig. 3) as mutation α, this form being the more primitive and the one fulfilling the requirements of an ancestral type. The others may be referred to respectively as mutation β (Fig. 1) and γ (Fig. 2), for these, too, show certain differences between them, mutation γ being more abruptly restricted in front than mutation β.

It is, then, from mutation α that *Hemiptychina sparsiplicata*, as well as *Hemiptychina himalayensis*, is derived, for the young of both agree with the adult of mutation α, as do also the young of mutations β and γ, which are likewise derivations from the common ancestral type. In the case of *Hemiptychina sparsiplicata*, however, the progress of development took a new direction, for we find that plications appear in the front of the shell, while the normal contour is still maintained. Thus the plications are not compensating, but are superadded to the primitive stage, and hence indicate a relative expansion of the mantle border or increase in circumferential (interstitial) growth. Thus on the one hand we have decrease in this growth leading to the obese non-plicate, or sparingly plicate, mutation γ, and on the other, increase, producing *Hemiptychina sparsiplicata*. Between these lies *Hemiptychina himalayensis* with apparently no change in the relative rate of growth of the mantle, but with a sudden deflection due to internal thickenings, and the development of compensating plications. Another example of growth in the direction taken by *Hemiptychina sparsiplicata* is seen in *Hemiptychina crebriplicata* Waagen from the Middle Productus limestone. In this shell the pedicle valve is not strongly, but very equally vaulted in every direction. It is "smooth for a little more than half its length, then a number of folds begin to appear which soon become very distinct and reach down to the margin of the valve. There are seven folds in the frontal region of which the middle one is distinctly stronger than the others. On each lateral part there are five folds more, so that this valve bears altogether not less than seventeen folds of which the two last lateral ones are, however, rather indistinct." (Waagen, 1879–1887, p. 374). The half-grown valve thus repeats the ancestral *sublævis* mutation α stage, while the conditions presented in the adult of *Hemiptychina sparsiplicata* here begin in the later neanic because of acceleration in development. Thus it is possible for these plications to develop to a marked degree and in great number in the adult, since the original plications of the *sparsiplicata* stage do not increase in size, but new ones develop in addition to them. In *Hemiptychina sparsiplicata* the folds of the pedicle valve appear only after the shell has reached two-thirds its full size, and the number remains few, two in the center and two or three on each side, the two median ones being very little more prominent than the lateral ones. It is not possible from Waagen's figure to determine the order of appearance of the plications on the pedicle valve of *Hemiptychina crebriplicata*, but it can be seen that at first the number is fewer than in the adult, though the order of appearance of the others lags little behind.

In *Hemiptychina sparsiplicata* the brachial valve is more strongly vaulted than the pedicle, but the plications begin later than in the pedicle valve, about three-fourths of the valve being smooth. The number of folds in the adult is three in front and three on each side, but in younger shells there is only one lateral fold. In *Hemiptychina crebriplicata* the brachial valve is not as regularly vaulted as the pedicle, being tolerably flat in longitudinal section for about two-thirds of its length, after which it bends more rapidly to the frontal margin. It is only when the shell bends down that the plications appear, an indication that the relative rate of growth is less increased circumferentially than in the pedicle valve, though there is actual increase, since the number of plications, six on the front and six on either side, is evidently more than is needed to compensate for the increased curvature.

There is still another shell of this type in the Middle Productus limestone, which belongs to this genetic series. This is *Hemiptychina inflata* Waagen (1879–1887, Pl. XXVII, Figs. 7, 8 and 9). The young of this is of the usual regularly and moderately curved type, the early stages being smooth. In some forms this smooth stage (*sublævis* mut. α stage) continues for half the length of the shell; in others, more accelerated, it begins shortly below the beak. It is clear that some form of *Hemiptychina crebriplicata*, one in which the number of plications is not so great as in the typical form of the species, is ancestral to *Hemiptychina inflata*, which in its young shows strong acceleration, in that the plications, which here also indicate increase in circumferential growth, are developed very early.

The longitudinal contour of the valve is regular and moderate only in the young, but when the shell has reached half its normal length, "a rather sudden deflection takes place, and the shell ascends more or less flatly to the frontal line." (Waagen, 1879–1887, p. 372). With this deflection, the plications increase in size, or, in other cases, one and two or more, rarely all, bifurcate towards the front. It is probable that, if the shell were flattened out, there would be seen to be a continuous relative increase in circumferential growth rather than an absence of change or even a decrease. The brachial valve is never so regularly curved as the pedicle valve, its longitudinal contour being a flat curve for about half the length, when "a more or less sudden deflection takes place, after which the valve descends either in a slightly broken or rounded curve to the frontal line, or the deflection is so strong, chiefly in the case of large and very strongly inflated specimens, that the shell bends over inward, and the valve then appears slightly shorter at the frontal line than at the place where it makes its bend." (Waagen, 1879–1887, p. 377). In transverse contour the lateral margins also become contracted in the large forms. The plications begin in this valve only near the point of deflection, the number becoming four or five in the center and four or five more on each side. This number probably more than compensates for the deflection, so that here too the relative rate of circumferential growth increases, though this begins much later than in the pedicle valve. On the other hand, when deflection becomes extreme, so that the circumference is actually less, the plications probably no longer fully compensate, since their increase in size or number is not commensurate with the increase in curvature. Thus this condition indicates a loss of the power of increased circumferential growth, and this must be considered as indicating senility, either individual or racial.

In the following table the measurements of the three species above discussed are reproduced from Waagen with the proportions added: Nos. 1–3 represent *Hemiptychina sparsiplicata*; No. 4, *Hemiptychina crebriplicata*, and Nos. 5–8, *Hemiptychina inflata*. These shells represent a distinct line of development and should be referred to a separate genus. The name *Morrisina* is here proposed. (For description see below).

	H. (Morrisina) sparsiplicata			*H. (Morrisina) crebriplicata*	*H. (Morrisina) inflata*			
Measurements	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Length of pedicle valve....	18.0	17.5	16.0	20.0	26.0	24.0	22.0	19.0
Length of brachial valve...	16.0	15.0	14.0	18.0	21.0	20.0	18.5	16.0
Width of shell............	14.5	14.0	12.0	17.0	20.0	18.0	17.0	15.5
Thickness of shell.........	10.0	10.0	8.5	11.0	21.0	18.0	16.5	14.0
Proportions								
Length to width..........	1:0.8	1:0.8	1:0.8	1:0.85	1:0.77	1:0.75	1:0.77	1:0.82
Length to thickness........	1:0.56	1:0.57	1:0.53	1:0.55	1:0.81	1:0.75	1:0.75	1:0.74
Width to thickness........	1:0.7	1:0.7	1:0.7	1:0.65	1:1.05	1:1.0	1:0.97	1:0.9
Apical angles								
Pedicle valve.............	73°	76°	69°	80°	71°	65°	72°	72°
Brachial valve............	120°	123°	111°	115°	124°	118°	118°	112°

10. **Hemiptychina morrisi** Grabau, sp. nov.

Plate III, Figs. 1a-d (No. 315), 3a-e (No. 6), 4a-e (No. 7), 5a-e (No. 8), (Nos. 9 and 9a)

This shell is of the type of *Hemiptychina himalayensis* var. *mongolica* but is strongly obese in the anterior region.

The pedicle valve has a beak overarching far beyond the plane of the junction of the valves, covering the beak of the brachial valve, which projects into the delthyrium of the pedicle valve. The foramen is large and round, up to 1 mm. in diameter, truncating the beak and the region behind it. The umbonal region is narrow, the apical angle of the young from 51° to 67°, and the sides rounded to the flattened false area which is delimited laterally by a faint angulation. In ventral aspect, the pedicle valve shows a distinct concavity of contour on each side of the umbo, below which it flares slightly and then continues in a regularly convex curve of the sides to the frontal region.

In a typical but not full-grown specimen (No. 6, Pl. III, Figs. 3a-e), the contour of the immature shell is a regular curve for a length, along the curvature from the truncated beak, of 17 mm. The vertical height of this stage of the shell is only 13.5 mm. and its width 11 mm., while the same width on the curvature is 14 mm. This represents the ancestral smooth stage with regular curvature.

The corresponding stage in the brachial valve has a width of 11 mm., the width on the curvature being 13 mm.; the vertical length of this stage is slightly over 11 mm., this being increased to nearly 12 mm. when measured on the curvature. It is at this point that the abrupt deflection takes place. The apical angle of the brachial valve at this stage is 103° in this specimen, while that of the pedicle valve is only about 51° or about one-half that of the brachial valve. These measurements agree fairly well with those of the young of *Hemiptychina himalayensis* mut. *mongolica*, given in the table above, except that for the apical angle of the pedicle valve, which in the present form is only about two-thirds that of the young *Hemiptychina mongolica*.

At the end of the smooth and simply arched young adult valve above described, the abrupt deflection takes place, and for a length of 10 mm. the shell surface is gently arched, but in a plane practically at right angles to that of the younger portion. This portion is characterized by low broad round plications nearly 1.5 mm. in width. The plications terminate in angular reentrants, while the interspaces terminate in similar projections of the margin. There are four plications in the median part and one on either side, with the merest suggestion of a second one, making six in all for the pedicle valve and seven in all for the brachial. In the brachial valve the deflection is more abrupt, being almost at once at right angles. It extends for 5 mm. to the extreme projection of the interlocking points, and for less than 4 mm. to the reentrants or ends of ribs. A slightly smaller shell (No. 2 of the measured series) has the umbonal region slightly flattened. This flattening characterizes the entire immature stage. The false area is not developed, but there is a gentle concavity on each side below the beak. The change from the immature to the deflected stage is less abrupt than in other specimens, the length of the former being 15.5 mm., and the latter 8 mm., while for the brachial valve they are 13 and 5 mm. respectively. In this specimen the plications are almost obsolete, but their position is indicated by the strong zigzag shell suture. Judged by this there are six in the pedicle valve (four median and one lateral on each side) and seven in the brachial valve (five median and one lateral on each side).

Another specimen (No. 8, Pl. III, Figs. 5a-e) has a simple, gently arched brachial valve in the immature stage with a height of 13.2 mm. and a width of 11.7 mm. Apical angle at this stage 98°, but in the very young it is only 77° and in adult 118°. The beak of the pedicle valve is broken, but the length of the young stage on the curvature is about 15 mm. The frontal thickness of the adult is 14.5 mm. The deflected portion of the brachial valve is 5 mm., that of the pedicle 8 mm. in length. The plications are low, wholly confined to the deflected portion, and end in sharp reentrants, while the interspaces project in sharp points. On the brachial valve there are nine (five median and two lateral on each side), on the pedicle valve eight (four median and two lateral on each side).

A large and very perfect specimen of this shell (the holotype, No. 315, Pl. III, Figs. 1a-e) has an immature smooth stage, 19.5 mm. in height in the pedicle, and 17 mm. in the brachial valve. The corresponding measurements on the curvature are 25.5 mm. and 18.5 mm. respectively. The direct width of this stage is 14 mm., while measured on the curvature it is 19 mm. on the pedicle and 16 mm. on the brachial valve. The apical angles of this stage are 67° and 104° respectively for pedicle and brachial valve. The deflected frontal portion has a length of 10 mm. on the pedicle valve and of 7 mm. on the brachial. There are four median plications on the pedicle valve and four lateral ones on either side, the last of which is indicated only in the suture. These are wholly confined to the deflected portion both in front and on the sides. Their maximum width is not over 2 mm., and the interspaces are narrower. Corresponding to this, the plications on the brachial valve are narrower and the interspaces wider. Their number is not over eleven, there being five in the center and three on the side.

A brachial valve (No. 9), with a height of 16.9 mm. and a width of 14.7 mm., has a frontal deflection of 6 mm., and it has eleven plications in all, five in the center and three on each side with the last one very faint.

This species is more accelerated than *Hemiptychina himalayensis* var. *mongolica*, the deflection beginning earlier, and hence the deflected portion has a greater length, and the total thickness of the shell at the front is much increased.

Measurements:—Measurements of four specimens of *Hemiptychina morrisi* gave:

	(No. 6)	*(No. 7)*	*(No. 8)*	*(No. 315) Holotype*
Height	16.0	15.5	17.3	22.0
Width	12.5	11.5	12.8	15.8
Thickness	12.3	12.3	15.0	15.4
Length of pedicle valve	24.0	23.5	26.0	36.5
Length of brachial valve	19.0	18.0	21.0	25.5
Plications in pedicle valve	6	6	8	12
Plications in brachial valve	7	7	9	11

Horizon and Locality:—This species is associated with the preceding in the *Hemiptychina* beds (1196) and the *Lyttonia* bed (1193) of Jisu Honguer. An imperfect specimen has also been obtained from Locality 1208. The species is named after Frederick K. Morris, a geologist of the Third Asiatic Expedition, who collected these fossils.

Remarks:—This shell is the homœomorph of *Hemiptychina inflata* Waagen of the Salt Range Middle and Upper Productus limestone, but as we have seen, that shell is a derivative from a partly plicated ancestor representing an independent line of development, whereas the present shell is a further modification, in the same direction, of the characters first shown in *Hemiptychina himalayensis* var. *mongolica*.

Genus **Beecheria** Hall and Clarke

11. **Beecheria sublævis** (Waagen)

Plate VIII, Figs. 1a-f (No. 59), (Nos. 66, 72)

1882. *Hemiptychina sublævis* Waagen, *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 364, Pl. XXVII, Figs. 1–3.

1902. *Hemiptychina (Beecheria) sublævis* Tschernyschew, "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 460, Pl. LX, Figs. 1–3.

1903. *Hemiptychina sublævis* Diener. *Palæontologia Indica*, Ser. XV, Himalayan Fossils, Vol. I, Pt. 5, "Permian Fossils of the Central Himalayas," p. 40, Pl. II, Figs. 3a-d.

This shell is biconvex, with the pedicle valve deepest in the umbonal region. It is elongate with rounded frontal contour and without plications. The marginal intervalve angle is less than ninety degrees.

The pedicle valve is strongly convex or even inflated in the umbonal region, with the beak curving over at right angles to the plane of contact of the valve, and actually extending beyond that for a short distance. The beak is pointed except for the truncation by the small circular foramen. The apical angle of this overhanging part of the beak is about 55°, enlarging to 63° in the neanic part of the shell, which angle is maintained in the adult. The umbonal margins curve without angulation to the hinge margin, which shows no flattening, nor are there any defined cardinal angles. In ventral aspect the sides slope outward regularly for the posterior half of the vertical height, then form with the front a regularly rounded curve. Actually the valve margin is gently curved from the cardinal region, and the point of greatest width lies somewhat in front of the mid-height; beyond this the margin forms a regular curve with the frontal margin.

The greatest convexity of the valve lies in the posterior third of the height, actually about 8 mm. from the beak along the curvature. From this point beakward the curvature is a strong arch, but from this point to the front one of much greater radius. In transverse contour the umbonal portion is approximately semicircular, while towards the front the arch becomes low but still remains regular. There is no median flattening or depression of any kind, and there are no plications.

The brachial valve is subcircular in the neanic stage, with the length only slightly greater than the width and with front and sides regularly rounded, forming an apical angle of about 103°. With further addition this angle changes to 130°. There is a distinct cardinal angle shown on either side where the margin changes, so that the lateral margins of the adult shell converge at an angle of about 70°. These angles give the umbonal region of the brachial valve a distinctly shouldered appearance. The sides slope forward to the point of greatest width, whence the rest of the marginal outline is a regular curve as in the pedicle valve.

The median longitudinal contour of the brachial valve is almost a regular flat arch from beak to front, with the greatest convexity near the middle, this, however, being only about half as deep as the umbonal portion of the pedicle valve. The transverse contour is regularly arched, deeper in the median region and becoming shallower forward, but without flattening or modification of any kind and without plicæ.

The margins of the two valves meet at an angle of 80° to 82° for the sides and about 87° for the front.

The surface is marked by growth lines and periodic growth interruptions subregularly distributed in the second half of the shell.

Measurements:—In the following table, the measurements of the only undoubted specimen, No. 59, of this species obtained are given in column 1; in columns 2 and 3 are given the measurements of the immature shell, No. 66, of *Hemiptychina himalayensis* var. *mongolicus* (*sublævis* stage) from the same strata, and in columns 4, 5 and 6 the measurements of typical *Hemiptychina sublævis* from India. In column 7 are given the measurements of a young shell which may belong to this species or to a young *Hemiptychina*.

	Beecheria sub-lævis	Young *Hemiptychina himalayensis*		*Hemiptychina sublævis* India			*H. sub-lævis,* young
Column number	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Serial number	*No. 59*						*No. 66*
Height of pedicle valve	15.5	12.1	12.0	20.0	19.0	17.5	3.6
Length on curvature	22.5	....	....	......	....	....	....
Height of brachial valve	12.8	11.1	11.1	17.1	16.0	15.0	3.3
Length on curvature	15.0	....	....	....	....	....	....
Greatest width	11.6	11.0	10.0	14.0	14.0	13.0	3.2
Greatest thickness	7.3	5.0	6.4	10.0	11.0	10.0	1.7
Apical angle of pedicle valve	63°	54°	73°	66°	70°	61°	75°
Apical angle of brachial valve	130°	97°	109°	101°	104°	90°	98°

In actual size this species falls between those of *Hemiptychina himalayen-*

sis var. *mongolicus* found in the same strata, these ranging in length from 13.8 to 17.6 mm. Though not obtaining the size of the Indian shells, this individual is placed in this species, for it is too large to be regarded as the young of *Hemiptychina himalayensis* var. *mongolicus*, being actually larger than the majority of the shells representing that more specialized species in the Jisu Honguer limestone. In proportions our shell also agrees fairly well with the Indian forms.

Horizon and Locality:—In the *Lyttonia* bed (Locality 1193) of the Jisu Honguer limestone, at Jisu Honguer, Mongolia, Mid-Permian; one specimen. Collector, F. K. Morris.

Remarks:—This shell is of the elongate type with overhanging beak comparable to Fig. 1, Pl. XXVIII, of Waagen's work (1879–1887), but is less convex. In point of convexity it corresponds more nearly to his figure 3, which is, however, a somewhat broader form. It is larger and has a more strongly overhanging beak than the form figured by Tschernyschew from the Schwagerina limestone of Russia, being at the same time less convex. From the Chitichun species figured by Diener (measurements *ante*, column 6), it differs in being less convex and in having the frontal margin straight instead of sinuous.

Genus **Morrisina** Grabau, gen. nov.

In the discussion of the species described by Waagen and Diener from the Permian beds of the Himalayan geosyncline, and referred by them to the genus *Hemiptychina*, it was shown that the three species, *Hemiptychina sparsiplicata*, *Hemiptychina crebriplicata* and *Hemiptychina inflata*, represented a distinct line of development from the ancestral form *Beecheria sublævis*, from which form the true *Hemiptychinas* were also derived. If my diagnosis of these shells is correct, it follows that these species can not be referred to the genus *Hemiptychina*, and I therefore propose for them the new generic term *Morrisina* with *Hemiptychina sparsiplicata* Waagen as the genotype. I believe that by thus collecting the group of distinctive forms under a separate name, the gain in precision more than counterbalances the difficulty arising from a multiplicity of generic names. Indeed it is becoming generally recognized that, if we are to obtain a true understanding of the relationships of the multifarious types of organisms in nature, the only proper method of attack is the genetic one. Classification of fossil shells by their adult characters only is a proceeding which has deservedly fallen into disrepute, because it leads to endless errors, ignoring as it does the principles of parallelism or homœomorphy in development. Therefore, the only reliable method to follow is that based on the ontogeny of the individual, whenever that can be ascertained, and the application of the knowledge thus gained to the correlation of the related types into generic series. And that distinct genetic series, even if they are derived from a common ancestor, demand designation by distinctive generic terms is a principle few will deny, since it is the only satisfactory method of introducing precision into our systematic descriptions.

The generic characters of *Morrisina* may be summarized as follows:

The shells are terebratuloid in form, with the young stages presenting the characters of *Beecheria*. The later stages are characterized by the formation of plications in both valves, the plications being developed without material change in the longitudinal contours of the valves, and therefore representing a progressive circumferential expansion of the mantle edge, instead of a compensatory structure demanded by an abrupt change in contour with the regular mantle growth, such as is seen in *Hemiptychina*. In primitive or non-accelerated species of this genus, the plications may appear only near the front of the shell (*Hemiptychina sparsiplicata*), which, however, continues to show the sharp sutural angle typical of the ancestral *Beecheria*. In more specialized forms the *Beecheria* stage is more restricted, the plications appearing at an earlier stage and becoming more numerous or larger. In gerontic individuals or phylogerontic species, the frontal border of one or both valves may be abruptly turned down without increase in the number or size of the plications, or even a diminution in this respect. If the number of plications increases on the deflected part, or becomes notably increased in size, the deflection must be regarded as due to thickening of the animal within, the deflection then not indicating gerontism, while the additional plications, or the marked increase in size of the original ones, are purely compensatory. Such shells are homœomorphs of the more accelerated species of *Hemiptychina*.

The generic name is given in recognition of the addition to our knowledge of the Permian fauna of Asia which has been made by the labors of my friend Mr. Frederick K. Morris, a geologist of the Third Asiatic Expedition.

12. **Morrisina sparsiplicata** (Waagen)

Plate VIII, Figs. 2a-e (No. 74)

1882. *Hemiptychina sparsiplicata* Waagen, *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 366, Pl. XXVII, Figs. 4–6.

1892. *Terebratula himalayensis* var. *sparsiplicata* Rothpletz. "Die Perm-Trias und Jura-Formation von Timor und Rotti." *Palæontographica*, Bd. XXXIX, p. 85, Pl. X, Fig. 10.

cf. 1909. *Hemiptychina himalayensis* var. *sparsiplicata* Diener. *Palæontologia Indica*, Ser. XV, Himalayan Fossils, Vol. I, Pt. 2, "The Anthracolithic Fauna of Kashmir, Kanaur and Spiti," p. 96, Pl. X, Fig. 9 (Zewan beds of Kashmir).

A moderate-sized imperfect shell, nearly reaching the size of some of the Salt Range specimens, and with the essential characters of this species, has been obtained from the Jisu Honguer limestone. The shell, No. 74, is subcircular, with the height and width nearly equal and the valves strongly and subequally convex.

The pedicle valve has a broken beak which was apparently not strongly incurved, the umbonal sides sloping away at an angle of 90° with each other. The umbonal portion rounds into the cardinal region without geniculation or sudden change in curvature, and the latter is only slightly depressed into a short concavity, not well enough defined to be termed a crescent. The transverse contour between umbonal and median portions is a regular arch from suture to suture; the frontal part is not preserved, the median longitudinal contour, so far as preserved, is a regular curve.

The brachial valve is even more subcircular than the pedicle, with the length slightly less than the greatest width. The blunt beak is scarcely incurved while the contour of the umbonal portion is rounded. The cardinal margins diverge at an angle of 111° and pass gradually into the rounded lateral margins, which in turn round regularly into the frontal margin, uniting the lateral margins without appreciable change in curvature. There is scarcely any change in the transverse contour from the median to the frontal portion. The median longitudinal contour, however, is asymmetric, the greatest elevation being about one-third the valve length from the beak. Hence the beakward slope is more abrupt than the forward slope. The greatest width of the valve is somewhat in front of the mid-length, and it is at about this point that the plications appear. They are shown on only one side of the valve, the other being crushed. At first there appear to be only the two chief plications, separated by an interval equal to or somewhat greater than their width. These plications increase in strength to the frontal margin. Between them appears a median plication, but this does not reach the strength of the other two. In this respect our shell, No. 74, shows some variation from the Indian shells, where the three median plications of the brachial valve are uniform. Shortly after the appearance of the median plications a lateral plication appears, and somewhat later a second lateral outside of this. Though shown on only one side, they evidently had their counterparts on the other. Thus there would be seven plications at the front, the median one the smallest.

On the whole, and in spite of the fact that the median plication is smaller than the others, our shell resembles fairly closely the more rotund varieties figured by Waagen (1879–1887) from the Salt Range, especially his Fig. 5 of Pl. XXVII, and I do not hesitate to refer it to that species.

Dimensions:—The following are the dimensions of our shell, No. 74, and those given by Waagen of shells from India. As will be noted, the difference in size is slight, while the proportions of our shell are nearest to the largest of the Indian form.

	Mongolia No. 74	*Salt Range Waagen (1879–1887), Pl. XXVII, p. 366*		
		Fig. 5	*Fig. 4*	*Fig. 6*
Column number	*1*	*2*	*3*	*4*
Height of pedicle valve	15.0	18.0	17.5	16.0
Height of brachial valve	13.6	16.0	15.0	14.0
Greatest width	14.0	14.5	14.0	12.0
Greatest thickness	8.8	10.0	10.0	8.5
Apical angle of pedicle valve	90°	73°	76°	69°
Apical angle of brachial valve	111°	120°	123°	111°

For further discussion of relationships, see the variety next described.

Horizon and Locality:—In the Permian Jisu Honguer limestone (Locality 1208) of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

13. **Morrisina sparsiplicata** (Waagen) var. **nana** Grabau, var. nov.

Plate VIII, Figs. 3a-e (No. 58)

A small specimen of *Morrisina* has been obtained from the Jisu Honguer limestone, No. 58, which is clearly a dwarfed form, showing the characters of *Morrisina sparsiplicata* of the Productus limestone, but attaining only half the size, or even less, of the Indian shells.

The beak of the pedicle valve is broken but was apparently overarching as in the other shells of this genus. The umbonal margins or shoulders show only a faint angulation at the bend to the hinge line, and only the faintest concavity of outline in ventral view. The greatest width, which is much less than the length, is somewhat in front of the mid-length, from which point the sides and frontal margin form a regular curve scarcely modified by the faint plications. The longitudinal contour of the pedicle valve is regularly arched, though the greatest convexity is in the posterior third. There is, however, no frontal deflection of any kind, the shell margins meeting in an acute angle both in front and at the sides of the anterior half. In this respect the shell has the characters of *Hemiptychina* (*Beecheria*) *sublævis*, but plications begin about 2.8 mm. from the front, or after a shell length of somewhat less than 6 mm. There are two median plications which become quite pronounced at the front where they form zigzag angles greater than 90° while the interspace between them is broader than the plications. On either side there is a slightly narrower concavity the outside of which passes into the shell margin without further lateral plications.

The brachial valve is slightly less convex than the pedicle, with a prominent beak appressed under that of the pedicle valve, and with rather strongly sloping hinge margins, ending in obtuse but distinct hinge angles. From this point the sides of the shell curve regularly to the frontal margin. Three plications characterize the front, a median and a lateral on each side. All three are of about the same size and are separated by broadly concave interspaces. The outer plications are separated from the lateral margin by the faintest concavity. These plications produce neither fold nor sinus in the front of the shell but are modifications of a straight frontal margin. The growth lines appear slightly stronger towards the front of each valve, but there are no marked growth interruptions.

In the typical Salt Range specimens there are two median plications in the pedicle valve covering about the anterior third of the shell, while two or three slightly less prominent plications occur on either side. These lateral plications are entirely absent in the present variety. In the brachial valve of the Salt Range shells, the plications occupy the anterior fourth and consist of three median, as in our variety, but with the addition of two or three lateral on either side, though in the young there is generally only one plication on each side. In the Mongolian specimen of the species previously described, there are two lateral plications; in our variety there are no lateral plications. This would suggest that the shell is younger than those described from the Salt Range or the young of the species as found in Mongolia, were it not for the fact that the plications appear in the Mongolian shell before it is half the size of the Salt Range form or the Mongolian form. This again would suggest acceleration, but there is no indication that our shell, No. 58, would ever reach the size of the Indian forms. It is, rather, like so many of the other shells of this group in Mongolia, a dwarfed form, and probably would not have reached a much greater size than it now possesses. The differences are well indicated by a comparison of measurements of this variety with the species from Mongolia and with the Indian shells.

Measurements:—These are given in the following table, where Column 1 (No. 58) represents this variety; Column 2 (No. 74) the Mongolian specimen of *Morrisina sparsiplicata*, and Column 3, the Indian shells (see also page 83).

	Mongolia		Salt Range	Mongolia
	Morrisina sparsiplicata nana	*Morrisina sparsiplicata*	*Waagen (1879–1887) Pl. XXVII, Fig. 6, p. 366*	*H. himalayensis mongolica*
	1 (No. 58)	*2 (No. 74)*	*3*	*4*
Height of pedicle valve	8.0 mm.	15.0	16.0	12.0
Height of brachial valve	7.2	13.6	14.0	11.1
Greatest width	6.7	14.0	12.0	10.0
Maximum thickness	4.5	8.8	8.5	6.4
Apical angle of pedicle valve	72°	90°	69°	73°
Apical angle of brachial valve	107°	111°	111°	109°

Remarks:—In Column 4 I have given the measurements of the shortest of the two young specimens of *Hemiptychina himalayensis* var. *mongolica* (No. 1 of the series of measurements on page 83), in which the shell surface is entirely smooth (*sublævis* stage), from which it will be seen that the present form is only two-thirds as long as the young of that specialized shell. The fact that plications appear while the shell is not deflected shows that these plications are not compensatory as in *Hemiptychina himalayensis* and its variety, but represent instead an expansion of the mantle margin of the animal in the later stages of growth, this being emphasized by the fact that the shell is flatter at this stage than in the earlier smooth part.

The species itself also occurs in these limestones as shown above, and besides being characteristic of the lower part of the Middle Productus limestone of India, has been recorded by Rothpletz from Ajer Mati in Timor. Broili does not record this species in his monograph on the Timor Brachiopoda, and it would appear that the three specimens obtained by Rothpletz are the only ones known from these southern regions. The dimensions of Rothpletz's figures are: Length of pedicle valve 14.5 mm., length of brachial valve 12 mm., greatest width 11 mm., greatest thickness 8.7 mm. There are two lateral plications on each side of the three median in the pedicle valve, and one lateral on each side of the three median in the brachial valve. In point of size and plications, then, the Timor shell is intermediate between the species and the variety as it occurs in Mongolia, but it is relatively more convex than the latter. The shells described by Diener from the Zewan beds of Kashmir are more elongate than either the Indian or the Mongolian shells, and probably belong to a distinct variety, if not species.

Horizon and Locality:—A single specimen of this variety was obtained by Mr. F. K. Morris from the Permian Jisu Honguer limestone of Mongolia; exact bed not recorded.

Genus **Mongolina** Grabau, gen. nov.

Genotype: **Mongolina subdieneri** Grabau, sp. nov.

These are terebratuloid shells of elongate outline and robust form, though generally small or of moderate size, with the early stages smooth, but the later plicated. The frontal portion of both valves is marked by a median depression, that of the brachial valve typically modified by a median plication, while the depression of the pedicle valve is of the nature of a sinus sometimes extending to within a short distance of the beak and defined near the front by two bounding plications. The beak of the pedicle valve is incurved; the cardinal margins below it are depressed into a crescent; the sides of the valves meet in a very obtuse angle or even in a plane. Both valves are very convex, the side of the brachial indenting that of the pedicle valve.

The internal characters are not determined but apparently are like those of *Hemiptychina* and *Morrisina*.

Distribution:—Permian of Asia, and Sosio River, Sicily. Among other described species, I would place in this genus *Hemiptychina orientalis* Tschernyschew (1902, Pl. II, Fig. 7; Pl. XLII, Figs. 1–4) from the Schwagerina limestone of Russia. The less accelerated shell referred to that species by Tschernyschew (1914, Pl. III, Figs. 6, 7) from Darvas may be considered as a primitive or retarded member of this generic series. *Hemiptychina dieneri* Gemmellaro probably also belongs to this genus, but recalls somewhat the genus *Jisuina* in its outline.

14. **Mongolina subdieneri** Grabau, sp. nov.

Plate VIII, Figs. 5a-f (No. 70); (No. 67)

1914. *Hemiptychina dieneri* Tschernyschew. "Die Fauna der oberpalæozoischen Ablagerungen des Darvas." *Mém. Com. Géol. Russe*, New Ser., Livr. 104, p. 47, Pl. III, Figs. 9–11.

1887–99. *Hemiptychina dieneri* Gemmellaro. "La Fauna dei calcari con *Fusulina* della valle del Fiume Sosio nella Provincia di Palermo." Molloscoidea, Vol. I, p. 236, Pl. XXV, Figs. 29–34.

This shell is small and robust with the valves strongly convex, the convexity of the brachial valve being greater than that of the pedicle valve.

The pedicle valve has a beak strongly arched and slightly overhanging that of the brachial valve, blunt and truncated by a large circular foramen. The umbonal region is depressed, convex in the middle, more strongly convex laterally, and bent abruptly into a flat, gently concave, false cardinal area which extends on either side of the beak as an unsymmetric crescent to beyond the mid-length of the shell. It is widest in the region of maximum arching of the beak and dies out forward. The boundary between it and the main part of the valve is a pronounced geniculation, rounded on the top, which, together with the depression it bounds, can be traced to near the point where the shell curves into the frontal margin. As a result, the ventral aspect of the shell shows the sides gradually diverging to the point of maximum breadth, which is in the anterior third of the height; thence they are gradually rounded to the frontal margin, which in this view appears straight in the median portion.

The depressed convexity of the umbonal region gradually develops forward in a gentle sinus, which is still moderate at the end of the neanic period, while the shell arches from the sinus to the lateral margin. At this point, however, which is about two-thirds the shell length from the beak, two bounding plications make their appearance by the formation of two outside depressed grooves;

these plications are rounded and increase in strength and width forward until at the front they have the strength and width of the median depression between them, while the depression on either side of them is slightly less pronounced. The longitudinal contour, which is a low arch in the median region of the shell length, is slightly more accentuated near the front, this being especially noted in the plications which bend downward rather abruptly. There is, however, no pronounced frontal geniculation as in typical *Hemiptychina*, and the plications are well developed long before the change in contour occurs.

The brachial valve is strongly arched in the umbonal region, where the blunt beak is appressed against the deltidial region of the pedicle valve and bent over slightly beyond the plane of the hinge line. From the beak the cardinal margins slope outward in nearly straight lines to a point situated about one-third the valve length from the beak, where they curve gently into the lateral margin, which in turn curves more strongly into the frontal margin. Thus the indentation formed by the margin of the brachial valve into that of the pedicle valve is very pronounced. Viewed dorsally, the sides of the pedicle valve are seen to project beyond those of the brachial almost to the point of greatest width of the shell.

The mid-longitudinal contour of the valve is an almost perfect arch modified only by the slightly more pronounced curvature (to a lesser radius) of the part at the front. There is, however, no geniculation. Before the mid-length is reached, the median portion of the valve becomes gently depressed, and almost immediately two bounding ridges are outlined by the sharpening of the median depression on either side, though the outside of these ridges is not separated from the shell by depressions but continues to remain a part of the general arch surface of the lateral slopes of the shell. Hence these ridges are unilateral and have not the characters of plications. Immediately after their inception, or even simultaneously, a median plication arises in the brachial sinus, becoming stronger and broader forward with the increase in depth of the median depression, so that at the front it has the width and depth of the parts of the median depression bounding it on either side. The lateral ridges, however, are not defined by outside depressions, so that the whole character of the valve surface is that of a median sinus divided by a central plication.

Only a few lines of growth are strong enough to be visible on the shell surface, though at the front these are somewhat more numerous. The punctate structure is not apparent under an ordinary lens.

Measurements:—In the following table the measurements of the Mongolian specimen described, No. 70, are given in column 1, while partial measurements of specimens figured from Darvas by Tschernyschew (1914, Pl. III, Figs. 10 and 11) are given in columns 2 and 3.

	1	*2*	*3*
	Mongolia No. 70	*Darvas Fig. 10*	*Tschernyschew Fig. 11*
Height of pedicle valve	9.5	12.5	12.0
Length of pedicle valve on curvature	14.0	....	....
Height of brachial valve	8.4	11.0	10.5
Length of brachial valve on curvature	11.0	....	....
Greatest shell width	7.2	9.0	8.5
Median width of pedicle valve on curvature	10.0	....	....
Median width of brachial valve on curvature	11.5	....	....
Maximum thickness of shell	6.3	8.0	8.0
Apical angle of pedicle valve	55°	73°	73°
Apical angle of brachial valve	102°	117°	116°

The shells figured by Tschernyschew from Darvas are somewhat larger than our specimen (No. 70) from Mongolia, and the outline is more rectangular, with the greatest width at or even behind the mid-length. There is some indication that our shell may be slightly distorted by pressure on one side so as to make the outline more triangular than it really is. In any case our shell appears sufficiently like the Darvas shells to make reference to the same species desirable. It is different, however, with the Sosio shell described by Gemmellaro as *Hemiptychina dieneri*. That is a shell of much more squarish outline, though probably congeneric with our own species.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Genus **Jisuina** Grabau, gen. nov.

Genotype: **Jisuina elegantula** Grabau, sp. nov.

Plate VIII, Figs. 4a-e (No. 71)

The following additional species appear to belong here:

1887–99. *Hemiptychina nikitini* Gemmellaro and *Hemiptychina genuiflexa* Gemmellaro. "La Fauna dei calcari con *Fusulina* della valle del Fiume Sosio." Molloscoidea, Vol. I, pp. 233–236, Pl. XXV, Figs. 10–17, 18–28, Pl. XXVII, Fig. 58, Pl. XXX, Figs. 33, 34.

1905. *Hemiptychina waageni* Stuckenberg. "Die Fauna der obercarbonischen Suite des Wolgadurchbruches bei Samara." *Mém. Com. Géol. Russe*, New Ser., Livr. XXIII, p. 34, Pl. VIII, Fig. 13.

1914. *Hemiptychina bokharica* Tschernyschew. "Die Fauna der oberpalæozoischen Ablagerungen des Darvas." Lief. I, *Mém. Com. Géol. Russe*, New Ser., Livr. 104, p. 46, Pl. III, Fig. 8.

This shell (No. 71), with the young stages smooth, is apparently of the type of *Beecheria*. The shell, however, becomes rapidly elongated, while the sides bend down forming a crescent in the pedicle valve. The brachial valve becomes very convex, its section being roof-shaped; and this and the abrupt deflection of the sides of the pedicle valve give the shells a narrow and elongate aspect which at once distinguishes them from *Morrisina* or *Beecheria*. The front is plicated typically, with three plications in the pedicle and two in the brachial valve, all defined by grooves on both sides. There is no frontal geniculation. The shell structure is punctate. Internal characters are not determined.

Occurrence:—In the Permian strata of Asia and the Mediterranean region (Tethys).

15. **Jisuina elegantula** Grabau, sp. nov.

Plate VIII, Figs. 4a-e (No. 71)

The shell is small and elongate, with unequal valves, the brachial much the more convex and smooth except near the front where plications appear.

The pedicle valve has its beak broken away, but apparently it was incurved over that of the brachial valve. The umbonal region is arched, but a short distance forward the median surface of the valve becomes flattened or even slightly depressed to about the middle of the length, when it disappears. About one-third the length from the front, two plications appear, and shortly after, a median plication appears between these. These plications are at first very faint but rapidly enlarge to the front where they form a zigzag suture line. The plications are defined by lateral depressions on either side, so that they are distinct from the rest of the shell surface. The median longitudinal contour is a uniform arch, highest in the center and without any marked deflection or change in radius in the plicated portion. The transverse contour, however, is less regular. In the umbonal region, and for some distance below, the median portion is flattened or depressed, while the sides bend down abruptly to the suture line. In the umbonal portion, a distinct, faintly concave crescent is formed, bounded by a geniculation on the shell-side and extending on the suture side to about the mid-length of the shell. But even in front of this, the shell margin bends down rather abruptly to the suture, so that the latter is either depressed or very obtuse along the entire lateral margin. This feature gives the shell the narrow elongate aspect which is such a distinctive feature.

The brachial valve is extremely convex, its transverse contour being roof-shaped though rounded at the top. This is most marked in the umbonal region, while about one-third of the valve length from the front the surface becomes depressed, and two median plications appear, bounded by two strong lateral grooves on the outside and divided by a shallower, narrower median groove. From the outer bounding grooves, the shell surface rises, plication-like, but at the top this surface rounds into the lateral shell margin. Thus, although near the front the valve appears to have four plications, there are in reality only two, the outer ones being only the shell portion bounding the lateral grooves.

In median longitudinal contour the shell is flat for a part of the length in the middle, then bends down somewhat abruptly but without geniculation to the plicated portion in front and to the beak behind. The margin of the valve is regularly convex, indenting that of the pedicle valve, and bringing the greatest depth of the valve near the mid-length. The beak is slightly incurved against the pedicle valve, and the cardinal margins slope out straight at a very obtuse angle to the sides, into which they curve rather abruptly. Viewed dorsally, the margin of the crescent of the pedicle valve projects beyond the shell margin of the pedicle valve.

The lines of growth are rather marked in the frontal half of the shell, less so in the earlier part. The punctate structure is rather coarse.

Measurements:—The following measurements, in column 1, are those of the type and only specimen obtained, No. 71. In column 2 are given the measurements of *Jisuina bokharica* (Tschernyschew) from the figures of Tschernyschew (1914). The descriptions and illustrations of the other species of this genus are not available.

	J. elegantula 1 (*No. 71*)	*J. bokharica* 2
Height of pedicle valve	7.7	19 mm.
Height of brachial valve	7.0	17 mm.
Greatest width	5.0	13? mm.
Greatest thickness	4.0	10 mm.
Umbonal angle of pedicle valve	80°	87°
Umbonal angle of brachial valve	114°	129°

Remarks:—This species, though smaller, is of the type of *Jisuina* (*Hemiptychina*) *bokharica* described by Tschernyschew from Darvas. That species, however, though more than twice as large as our shell, has incipient plications only at the front. The greatest width of the shell, too, is behind the mid-length instead of near it as in our shell. The strong roof-shaped form of the contour of the brachial valve and the flattening of the pedicle are as in our shell, but the Darvas shell has a more pronounced median longitudinal depression in the pedicle valve. The number of plications on the front margin is stated by Tschernyschew to be three in the Darvas form, which is the number found in the pedicle valve of our shell. In *Hemiptychina* (*Jisuina*) *nikitini* Gemmellaro, which has the same contours, there are only two in the pedicle and one in the brachial valve. The plications, moreover, begin at the mid-length in the pedicle valve and in the anterior third of the brachial, which is earlier than in our shell. In *Hemiptychina* (*Jisuina*) *genuflexa* Gemmellaro the number is more variable. On the whole our shell seems to be most closely related to *Hemiptychina* (*Jisuina*) *genuflexa* var. *quatriplicata* Gemmellaro (1899, Pl. XXV, Figs. 25, 26), but the plications in that shell, too, begin much earlier, especially on the pedicle valve.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Genus **Notothyris** Waagen

16. **Notothyris simplex** Waagen var. **mongoliensis** Grabau, var. nov.

Plate IV, Figs. 1a-e (No. 10, Holotype); Plate IX, Figs. 2a-e (No. 75)

Cf. 1882. *Notothyris simplex* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, p. 389, Pl. XXVIII, Figs. 9–11.

Cf. 1902. *Notothyris nucleolus* (Kutorga). Tschernyschew, "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 464, Pl. XLII, Figs. 8–13.

Cf. 1916. *Notothyris nucleolus* (Kutorga). Broili, "Die permischen Brachiopoden von Timor." Paläontologie von Timor, Lief. VII, p. 66 (with synonymy), Pls. CXXVI, Fig. 4, and CXXVII, Figs. 8–10, 12–15.

The holotype (Pl. IV, Fig. 1) is minute, elongate oval, biconvex and smooth except for a few incipient plications at the frontal margin.

The pedicle valve is strongly convex, regularly arched from the beak to near the frontal margin, where the deflection may be slightly more pronounced with the appearance of the incipient plications. The transverse contour is regularly and strongly arched. The beak is moderately incurved, scarcely projecting beyond the beak of the brachial valve, and truncated by a large foramen. The umbonal angle is at first 67°, then broadens out to 77°, the result being that in ventral aspect there is a faint concavity of outline between the beak and the sides, the umbo appearing slightly compressed. The marginal shell angle of the sides is about 115°. At the front the median part of the valve is abruptly elevated into a small fold, the center of which is again depressed, so that this part of the shell is really formed of two angular plications, the outside slope of each, however, being longer than the inside slope, thus giving the center the character of a duplicate fold. On either side of this central portion is a low plication which does not extend as far up the shell as the median ones.

The length of the pedicle valve along the curvature is 7.2 mm. (height 5.3 mm.), and of this the plicated part occupies about 1.5 mm., thus forming a little more than one-fifth the shell-length. As before noted, there is a somewhat abrupt change in contour but not enough to compensate for the plications. The lines of growth on this plicated part of the shell are also more pronounced than on the smooth part where they are virtually invisible.

The brachial valve is nearly as convex as the pedicle, the greatest convexity being in the posterior third, with the curvature in opposite directions somewhat unequal. Transversely, too, the contour differs, being more flatly arched in the center and more abrupt on the sides. Towards the front this median flattening becomes a faint depression with, however, a low median plication in the center. The bounding plication on either side is of about the same strength as the median one; outside of this is an additional low and short plication on either side, making five in all. The plicated part in the brachial valve is shorter than in the pedicle valve, but like that shows a faint deflection and somewhat strong growth lines.

	No. 10, Holotype	*No. 75, Paratype*
Total height of shell	5.3 mm.	4.7
Height of brachial valve	4.6 mm.	4.0
Width	3.8 mm.	3.2
Thickness	3.5 mm.	3.7

The dimensions of a second, less perfectly preserved shell, No. 75, are given in column two. Though smaller, it is somewhat more robust, as shown by the thickness, which is greater and exceeds the width. This shell resembles *Notothyris simplex* Waagen from the Katta beds of the Salt Range region, but differs in having an extra plication on either side of the center, the pedicle valve thus having four instead of two, and the brachial valve five instead of three as in the Indian shell. These lateral plications are, however, less pronounced in the smaller of our two shells. This is clearly a step further advanced in development of our species over the Indian form. Our shells, too, are smaller, the dimensions of the Indian specimens being, according to Waagen, shown in columns one and two of the subjoined table.

Measurements:—

	Indian Shells		*Mongolian Shells*	
Actual Measurements:	*1*	*2*	*No. 10*	*No. 75*
Height	7.5	8.0	5.3	4.7
Width	6.0	6.0	3.8	3.2
Thickness	5.5	4.5	3.5	3.7
Proportions:				
Height to width	1.25:1	1.33:1	1.40:1	1.47:1
Height to thickness	1.36:1	1.78:1	1.51:1	1.30:1
Width to thickness	1.09:1	1.33:1	1.09:1	0.87:1

From this it is seen that the Mongolian specimens are proportionately longer, but that the other proportions fall within the limits of those of the Indian shells.

Horizon and Locality:—In the *Enteletes* bed (1190) of the Jisu Honguer limestone (Mid-Permian) of Jisu Honguer, Mongolia; one specimen (holotype). Collector, F. K. Morris.

Tschernyschew suggests the identity of Waagen's *Notothyris simplex* with *Notothyris nucleolus* Kutorga, of which he describes a number of specimens from the Schwagerina limestone of the Ural where it is one of the most characteristic forms. Broili, too, makes Waagen's species synonymous with the *Spirifer nucleolus* of Kutorga (*Notothyris nucleolus*). He also includes under this, *Rostranteris ovalis* Gemmellaro and *Rostranteris inflatum* Gemmellaro, both of which belong to the genus *Notothyris*. Broili had about four hundred specimens of this shell from Timor and so was able to trace the variations. Still our form seems sufficiently distinct to deserve a separate designation, one distinction being the great difference in size, for our shells are only about half as large as, or less than, those figured from Timor. Nor can ours be regarded as young shells, since the frontal plications are fully developed. Moreover, our shells are proportionately narrower and thicker than the forms generally included under Kutorga's species.

None of Tschernyschew's figured specimens show as many plications as do our shells and those figured by Broili; the additional plications, when indicated, are shown in the larger shells.

17. **Notothyris berkeyi** Grabau, sp. nov.

Plate IV, Figs. 4a-d (No. 11)

The shell is large when compared with the usual forms of this genus in these rocks, and is robust with abruptly deflected frontal margin characterized by W-shaped sinuosity of suture. The pedicle valve is strongly convex, with the beak incurved over that of the brachial valve and truncated by a large foramen which is imperfect in the type specimen.

The longitudinal contour is a regular strong curve from the beak to the frontal margin, the frontal portion of this valve being scarcely separated from the rest of the shell by deflection. The transverse contour is less regular, the center somewhat flattened, the sides rather abruptly curved to the suture. The surface is smooth, except for growth lines, there being scarcely any indications of plications near the front in this valve, though the zigzag form of the frontal margin is well marked. The median elevation of the valve is faintly marked near the front, being modified by the very faint central depression, which is, however, pronounced in the sutural margin. This margin has only three prominent sharp teeth, the median one of which is greater than 90°, the lateral are approximately rectangular and project farther than the median one.

The brachial valve is less convex than the pedicle valve, with a regular curvature both longitudinally and transversely in the immature shell, whose length and width are approximately the same (about 13.8 mm.), and whose umbonal angle is 120°. The shell is abruptly deflected, especially at the front, where, turning at almost a right angle, it continues nearly flat for 6 mm. or more. Here a broad, rounded elevation appears, the center of which is indented at the margin by the center of the *W*, while the sides, which project in the two nearly rectangular notches, are faintly depressed. There are only these two projecting rectangular points corresponding to three projecting marginal points in the pedicle valve (Pl. IV, Fig. 4a), but there are no pronounced plications developed in the front of this or the pedicle valve.

Measurements:—

	No. 11
Total height	18.5 mm.
Total length on curvature	27.8 mm.
Total width	15.5 mm.
Total thickness	12.3 mm.
Height of brachial valve	14.5 mm.
Length on curvature	22.0 mm.

Horizon and Locality:—In the *Enteletes* bed of the Middle Permian of Jisu Honguer, Mongolia. Collector, F. K. Morris (locality 1190). Named in honor of Professor C. P. Berkey, Chief Geologist of the Third Asiatic Expedition.

18. **Notothyris nucleolus** (Kutorga)

Plate IV, Figs. 3a-d (No. 12), Plate VIII, Figs. 7a-f (No. 76), 8a-c (No. 77)

1842. *Spirifer nucleolus* Kutorga. "Beitrag zur Palæontologie Russland." *Verhandl. Russ.-Kaiserl. Mineral. Gesell. St. Petersburg*, p. 23, Pl. V, Fig. 7.

1902. *Notothyris nucleolus* (Kutorga). Tschernyschew, "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, pp. 44, 464, Pl. XLII, Figs. 8–13.

1909. *Notothyris nucleolus* (Kutorga). Stoyanow, A. A. "On the Character of the boundary of Palæozoic and Mesozoic near Djulfa, St. Petersburg." *Verhandl. Russ.-Kaiserl. Mineral. Gesell.*, Vol. XLVII, p. 92, Pl. VI, Fig. 1.

1911. *Notothyris nucleolus* (Kutorga). Diener, "Anthracolithic fossils of the Shan States." *Palæontologia Indica*, New Ser., Vol. III, Mem. 4, p. 53, Pl. VII, Figs. 13, 14.

1912. *Notothyris nucleolus* (Kutorga). Jakowlew, "Die Fauna der oberen Abtheilung der Paläozoischen Ablagerungen im Donez-Bassin, III, Die Brachiopoden." *Mém. Com. Géol. Russe*, New Ser., Lief. 79, p. 15, Pl. V, Fig. 15.

1916. *Notothyris nucleolus* (Kutorga) Broili. "Die permischen Brachiopoden von Timor." Paläontologie von Timor, Lief. VII, p. 66, Pl. CXXVI (12), Fig. 4; Pl. CXXVII (13), Figs. 8–10, 12–15.

The shell, No. 12, illustrated in Plate IV, Fig. 3, is a more accelerated form than No. 10 shown in Plate IV, Fig. 1. The plications of the pedicle valve begin before the shell is half grown, and consist of two rounded rather low plicæ with a broader median interspace. Forward these slowly increase in height and width. The interspace is always broader, and forms at the front of the shell a pronouncedly projecting, rounded sutural lobe. Shortly after the appearance of the main plications, two faint, broad, lateral plications appear, one on either side. These are never pronounced and form only faint broad undulations in the margin. That on the right side is somewhat broader, though scarcely more pronounced than that on the left, thus giving the shell a somewhat asymmetric aspect. The depressions which separate these lateral plications from the two median ones are stronger than the plications, and more influential on the outline of the shell margin.

The brachial valve is somewhat more convex than the pedicle, the transverse contour being more abrupt than the longitudinal, which is regularly arched. The surface is smooth for somewhat more than two-thirds the length, where the plications appear rather abruptly. Of the plications, the median one is strongest, most pronounced and rounded; the first lateral on either side are slightly less elevated with more strongly divergent sides, this divergence being somewhat greater than a right angle, while the top is also slightly more angular. Finally, there is a very faint broad elevation, not to be called a plica, on the extreme lateral margins. Asymmetry is also shown here by the somewhat broader character of the lateral plication on the right side (as seen in view).

Two young shells of this species (Pl. VIII, Figs. 7–8) show a much less robust outline. In the larger of the two (Fig. 7), the two median plications on the pedicle valve are already well developed and even the two lateral ones are indicated. In the smaller one (Fig. 8) only the two median plications are shown near the front. The cardinal region in the larger of the two young specimens is somewhat more depressed than in the adult shell, but there is no defined false area. In the smaller shell it is more rounded. The brachial valve of the young shells is subrotund, with the sides strongly indenting those of the pedicle valve. The surface is smooth, except at the front, where three distinct plications appear, these being shown on both the young shells.

In the youngest shell the lateral sutural angles are acute, but in the next larger shell they are already obtuse, though somewhat less so than in the adult. The arching of the valves is regular throughout, merely increasing in depth with increase in size.

Measurements:—In the following table the measurements of three specimens of different sizes are given:

	No. 12	*No. 76*	*No. 77*
	Pl. IV, Fig. 3 *1*	*Pl. VIII, Fig. 7* *2*	*Pl. VIII, Fig. 8* *3*
Height of pedicle valve...........	6.7 mm.	4.8 mm.	4.2 mm.
Height of brachial valve..........	5.8 mm.	4.4 mm.	3.9 mm.
Greatest width....................	5.3 mm.	4.2 mm.	3.7 mm.
Thickness.........................	4.5 mm.	3.0 mm.	2.2 mm.
Apical angle of pedicle valve.......	73°	85°	98°
Apical angle of brachial valve......	127°	135°	138°

The progressive decrease in the apical angle of both pedicle and brachial valves with increase in size is apparent. This is, of course, a concomitant of the increase in convexity.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia; three specimens. Collector, F. K. Morris.

Remarks:—This shell differs in several respects from the Timor shell referred to this species by Broili. In the first place, the brachial valve of the Mongolian adult shell is the more convex, whereas in the Timor forms it is the pedicle valve which is often gibbous and generally more convex than the brachial. In our immature shells, however, the convexity of the valves is more nearly equal, or that of the pedicle valve may be slightly the greater. The plications of the pedicle valve of our shell begin much earlier than in any shell figured by Broili, and are rounded in the adult, whereas they are sharp in the Timor form. Also the outside plications of the pedicle valve are recognizable in our adult shell but not in the Timor form. In all these characters the Timor shells agree better with our immature than with our adult shell.

19. **Notothyris nucleolus** (Kutorga), mut. α Grabau, mut. nov., aberrant form

Plate VIII, Figs. 6a-f (No. 78)

Specimen No. 78, an extremely robust shell, with irregularities of growth, appears to be an aberrant form of this species.

The pedicle valve has a strongly incurving beak truncated by a large foramen. In the nepionic stage the shell is subcircular, perhaps somewhat longer than wide and strongly arched from beak to front and from side to side. The top of the transverse arch is rather broad and low, but the sides curve abruptly to the cardinal margin, without, however, forming an angulation. The shell is smooth, except at the front, where two plications appear. At this point the shell is exfoliated and the internal mold appears, on which, however, the two plications are continued as two narrow but sharp ridges. These become somewhat obliterated near the mid-length of the shell but appear again in the forward portion as two normal rounded plications, while on either side appears an additional faint rounded plication, making four in all at the front. The abrupt change in curvature at the end of the nepionic stage is very marked, the plane of the young and that of the adult forming approximately a right angle. At this point, the abruptness is emphasized by the removal of the shell, which appears to have been unusually thick. Near the front the transverse arcuation of the shell is regular and moderate, but in the younger portion the sides bend down abruptly. The form of the shell as a whole appears elongate in ventral view, with the umbonal portion pointed and slightly contracted.

The brachial valve shows the same abnormality. The nepionic portion is subcircular with the beak concealed beneath the incurving beak of the pedicle valve. The transverse contour is arched, with the sides rather abruptly turned down, so that the young shell as a whole must have been a rather obese one. At the end of the nepionic stage, when the plications are scarcely indicated, the front is abruptly and sharply depressed, forming almost a right angle in the longitudinal contour. The median sinus begins with this deflection, which is bounded by a plication on either side and has a small median plication. The latter is distinctly marked at the point of deflection and for a short distance below, then it disappears, the sinus being flat-bottomed, but it reappears again at the front as a low, rather sharp median plication, smaller than the bounding plication of the sinus.

The side margins of the brachial valve profoundly indent those of the pedicle valve.

Measurements:—The following are the measurements of the nepionic and adult stages of shell No. 78.

	Nepionic	*Adult*
Height of pedicle valve	3.5 mm.	7.0 mm.
Length on curvature	4.0 mm. (Originally 4.5)	11.0 mm.
Height of brachial valve	3.0 mm.	5.5 mm.
Length on curvature	?3.5 mm.	8.0 mm.
Width of pedicle valve	3.4 mm.	5.5 mm.
Width of brachial valve	3.0 mm.	5.5 mm.
Greatest thickness	4.6 abt.	5.3 mm.
Apical angle of pedicle valve	95°	45°
Apical angle of brachial valve	90°	70°

The shell has the appearance of having been suddenly geniculated at the front at the end of the nepionic stage, forming a frontal deflection like that seen in *Hemiptychina himalayensis* and its congener, and, like that, plicated at the front because of the sudden deflection. After that the shell appears to have continued to grow normally like the other species of *Notothyris*, except that the sinus in the brachial valve and the fold-like aspect of the median part of the pedicle valve are more pronounced than usual.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

20. **Notothyris irregularis** Grabau, sp. nov.

Plate VII, Figs. 6a-e (No. 13, Holotype); Plate IX, Figs. 3a-e (No. 385), (Nos. 380, 386)

This shell is subequally and moderately biconvex. It is plicated only towards the front.

Measurements:—Dimensions of two specimens are as follows:

	No. 13, Holotype Pl. VII, Fig. 6	*No. 385 Pl. IX, Fig. 3*
Height of pedicle valve	6.3 mm.	5.8
Height of brachial valve	5.7 mm.	5.3
Greatest width	5.7 mm.	5.5
Greatest thickness	3.7 mm.	3.2
Angle of beak of pedicle valve	75°	93°
Angle of beak of brachial valve	104°	122°

In the holotype, No. 13, the pedicle valve has its beak elevated and projected above that of the brachial valve. It is moderately incurved and truncated by a large, round foramen. The sides curve rather abruptly, but without marked angulation, to the hinge line. No deltidial plates are visible. The longitudinal contour is a nearly regular curvature from beak to frontal margin, with the greatest convexity near the middle. The transverse contour is also regular, except near the beak, where it is subangular with the median portion flattened, and near the front, where there is a slight modification owing to the elevation of the median portion and the plications. The sides of the valves meet those of the opposite valve in an acute angle. In ventral view the sides diverge regularly at an angle of 75° from the beak to about the middle of the valve, after which they are rounded to the frontal margin, the outline of which is slightly modified by the plications but is rounded as a whole.

The upper half of the shell is perfectly smooth, except for two faint diverging ridges which appear in the exfoliated shell; the part between the ridges is flattened with a similar flattening on either side. About mid-length, or a little later, appear two median plications, one (the left) beginning a trifle earlier than the other and becoming stronger, so as to produce a slight irregularity in symmetry on the surface. This is more marked at the front where the two plications are quite dissimilar in size. Shortly after the appearance of the median plications, two others arise, one on either side, and continue to the front but remain somewhat fainter than the median. Finally, a third one appears on each side near the front, but this is not very pronounced.

The brachial valve has its beak closely appressed under that of the pedicle valve, and the sides diverge from it with a faint concavity, forming on the whole an angle of 104°. Before the mid-length is reached, the outline becomes rounded in conformity with that of the pedicle valve. The longitudinal contour is less regularly arched than that of the pedicle valve, the greatest convexity being back of the front, from which point the contour descends rather abruptly to the frontal margin.

A short distance behind the mid-length of the valve, the transverse contour becomes modified by a median flattening, this becoming more pronounced forward and forming a depression. The two bounding plications of this depression or sinus arise about the mid-length of the valve, and increase in strength forward until at the front they are equal in strength to the larger of the two median plications of the pedicle valve. An intermediate plication arises near the front, although nearer one side than exactly median. This accounts for the irregularity in the two median plications of the pedicle valve, which are determined by the division of the brachial sinus. A plication of about the same strength as the median one, appears on either side of the bounding plications near the front, thus making five well-defined plications in all in this valve, as compared with four well-defined and two very faint lateral ones in the pedicle valve.

The growth lines are faint and indistinct.

Paratypes:—A second slightly smaller specimen (No. 385, Pl. IX, Fig. 3) whose dimensions are given above has the second pair of lateral plications of the pedicle valve undeveloped, the two median being of essentially the same size. In the brachial valve the three median plications are of the same size and of essentially uniform disposition. The pair of lateral plications is very faint. In other respects, except the greater apical angles, it corresponds to the holotype. In a still younger shell (No. 386), with a length of 5.1 mm., a maximum width of 4.6 mm. and a thickness of 2.7 mm., only the two median plications of the pedicle valve are seen at the front, these being of somewhat unequal size. In the brachial valve the median portion flattens, appearing with faint bounding plications and a very faint median plication at the front. Otherwise the characters are as in the holotype.

Horizon and Locality:—Middle Permian. In the Jisu Honguer limestone of Jisu Honguer, Mongolia; several specimens. Collector, F. K. Morris.

Remarks:—This shell differs from the other small species of *Notothyris* described above, by its greater proportional width, less strongly marked convexity of valves and consequently lesser thickness, by the fact that the valves meet at an acute angle instead of an obtuse, as in *Notothyris simplex* or in nearly the same plane as in *Notothyris nucleolus*, and by the difference in the character of the plications, those in the brachial valve of the present form being marked by two strong bounding plications of the brachial sinus and a median sinal plication near the front as well as a lateral one on either side.

Superfamily SPIRIFERACEA Waagen

Family ATHYRIDÆ Phillips

Genus **Athyris** McCoy

21. **Athyris excavata** Grabau, sp. nov.

Plate VI, Figs. 5a-d (No. 124, Holotype), 6a-c (No. 174)

The shell is transverse, subpentagonally ovate, with elevated pointed beaks, rounded sides and nearly straight frontal margin. The frontal suture is broadly emarginated. The valves are about equally convex. The greatest width is in front of the mid-length.

The pedicle valve has its greatest convexity in the posterior third, the longitudinal contour being more pronouncedly arched in the umbonal than in the frontal half. The beak is arched, scarcely projecting above that of the brachial valve, with the lateral slopes slightly depressed and excavated at the meeting with the brachial valve, suggesting the existence of a hinge area, which is, however, wanting. The transverse contour of the umbonal region is a strong arch in the center with a faint concavity on either side. This concavity disappears forward, the surface sloping regularly to the shell margin. A medium depression, however, appears behind the mid-length, increasing forward to form a shallow median sinus, which produces a distinct deflection of the median frontal suture.

The brachial valve has its greatest convexity near the mid-length. The beak is also elevated and curved beneath that of the pedicle valve, there being a similar depression on either side in the lateral slopes corresponding to that of the pedicle valve. Viewed dorsally direct (Fig. 5a), the line from beak to lateral margin is a gentle concavity, slightly less pronounced than that of the corresponding line in the pedicle valve. The transverse contour of the umbonal region is, however, without the lateral concavities seen in the pedicle valve, being arched from side to side. Forward, this contour becomes a broader arch curved to a greater radius, but there is no medium elevation corresponding to the depression in the pedicle valve, not even at the front where the suture line is deflected dorsally.

The surface is apparently smooth, except near the front, where there are a few strong subregular growth wrinkles.

The interior of the shell is filled with cleavable calcite, and where this is partly broken away on the brachial valve, the spiralia are seen (Fig. 5a). These lie close to the shell in the anterolateral portion of the brachial valve, but near the center of that valve there is a calcite-filled space between them and the shell, having a thickness of 2 mm. The shell itself varies from about 0.5 to over 1 mm. in thickness. The spiral ribbon as preserved has a width of about 0.7 mm. near the center. Towards the margin, the ends of the spirals seem to coil more and more parallel to the surface of the brachial valve, so that the apex of the spiral appears to be turned dorsalwards. Other internal characters are not preserved.

Measurements:—The following are the dimensions of the Holotype, No. 124:

	No. 124
Height of pedicle valve	31.5 mm.
Length of same	45.0 mm.
Height of brachial valve	30.5 mm.
Length of same	38.0 mm.
Maximum width	37.5 mm.
Maximum thickness	23.0 mm.

Horizon and Locality:—In the *Hemiptychina* bed (1196) of the Jisu Honguer limestone at Jisu Honguer, Mongolia; one adult specimen, probably fragments of others. An imperfect young shell (Pl. VI, Fig. 6) is referred with some doubt to this species. Collector, F. K. Morris.

22. **Athyris timorensis** Rothpletz var. **mongoliensis** Grabau, var. nov.

Plate VIII, Figs. 9a-f (No. 15, Holotype); Plate IX, Figs. 4a-e (No. 79)

Cf. 1916. *Spirigera timorensis* Rothpletz. Broili (retarded varieties). "Die permischen Brachiopoden von Timor." Paläontologie von Timor, Lief. VII, p. 48 (with synonymy), Pl. CXXIII, Figs. 13–14, Pl. CXXIV, Fig. 2.

This shell, with the valves subequally convex, is of subrotund outline, smooth without fold or sinus.

The pedicle valve is slightly greater in length than the maximum breadth, which is about mid-length. The beak is strongly incurved, and overarched, extending beyond the plane of contact of the valves. The umbonal region is slightly contracted below the beak, so as to give that portion when viewed ventrally a slightly concave marginal appearance. (Pl. VIII, Fig. 9c; Pl. IX, Fig. 4c). When the shell is exfoliated, this appears more pronounced because of the thickness of the shell on either side of the rostral cavity. The cardinal margins are bordered by a narrow, slightly depressed region, which is gently concave and separated from the main shell surface by a slightly marked angulation, but this feature is not pronounced and is not seen in the young. The sides of the shell slope outward to the point of greatest width, into which they round. Thence a more abrupt rounding carries the sides into the ventral margin, which is rounded to a somewhat greater radius. The median longitudinal contour is asymmetric with the greatest convexity in the posterior third, whence the curvature is rather strong to the beak but more gentle to the frontal margin, with occasionally some slight irregularities due to inequality in rate of growth. The transverse contour is strongly arched from side to side in the region of the greatest convexity, becoming less pronounced forward though still remaining regular. The sutural angle is slightly obtuse both at the sides and the front.

The brachial valve is equal in length and breadth. The circular outline is slightly marred by the gentler arching of the sides in the cardinal region, and the stronger rounding in the region of the greatest width. The beak is obtuse and hidden beneath that of the pedicle valve, which overarches it and is slightly appressed over it. The suture line in the cardinal region is slightly wavy but straight below. There is no pronounced indentation of the sides of the pedicle by those of the brachial valve. The median longitudinal contour is a nearly regular arch, with the greatest convexity in the middle, and with regular slopes to the front and beak, except that in the latter case the beak itself turns down somewhat more abruptly. All transverse contours are regular from side to side.

The lines of growth are fine with occasional stronger ones.

The form, contours and relationships of the younger shell figured are identical with those of the larger one, except that it does not show the depressed region of the umbonal slopes of the pedicle valve near the cardinal margins. The sutural angle, too, is rectangular or slightly acute instead of being obtuse.

Measurements:—The two specimens figured have the following dimensions:

	Mongolian var.		*Timor shells*	
	Pl. VIII, Fig. 9 No. 15	*Pl. IX, Fig. 4 No. 79*	*Broïli, Pl. CXXIII, Fig. 13*	*Broïli, Pl. CXXIV, Fig. 2*
Height of pedicle valve.....	8.0 mm.	4.9 mm.	23.0 mm.	18.0 mm.
Height of brachial valve....	7.2 mm.	4.5 mm.	21.0 mm.	16.0 mm.
Greatest width............	7.2 mm.	4.7 mm.	22.5 mm.	18.0 mm.
Greatest thickness.........	4.9 mm.	3.3 mm.	11.5 mm.	9.0 mm.

Remarks:—This shell resembles the young of *Athyris capillata* Waagen (1879–1887, Pl. XLII, Figs. 1 and 3), but the adult of that shell has a marked median frontal emargination with a slight sinus in the pedicle and fold in the brachial valve. It comes near the simpler (retarded) adult varieties of *Spirigera* (*Athyris*) *timorensis* Rothpletz, figured by Broili from Timor (1916, Pl. CXXIII, Figs. 13 and 14, Pl. CXXIV, Fig. 2) in which the median frontal deflection is absent or weak. It does not correspond, however, to Rothpletz's accelerated form. The beak of our shell seems, moreover, more strongly incurved than in the Timor form, and the subumbonal cardinal depression of our shell is apparently not found in that shell. Nevertheless, our shell is near enough to that form to be considered a dwarfed variety (provided of course our largest shell is adult, which, in view of the absence of larger individuals, seems likely). A comparison of our enlarged figures with those of Broili will bring out this resemblance. The dimensions of two Timor shells, taken from Broili's figures, are given in columns three and four above.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia; not uncommon. Collector, F. K. Morris.

23. **Athyris royssii** Léveillé

Plate VI, Figs. 7a-d (No. 80), 8a-c (No. 81), (Nos. 18, 82)

1883. *Athyris royssii* Léveillé in Waagen, *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, p. 475 (with older bibliography), Pl. XL, Figs. 6 and 9.

1916. *Spirigera royssii* Broili. "Die permischen Brachiopoden von Timor." Paläontologie von Timor, Lief. VII, p. 49 (with extended bibliography), Pl. CXXIV, Figs. 3–13, especially figures 3–6 and 12.

This very variable form appears to be represented in our strata by a number of young or dwarfed forms (Nos. 18, 80–82), which correspond to the non-sinuated types figured by Waagen and Broili from Asiatic rocks as above noted. Our shells are so small that they should probably be regarded as young individuals, although no large forms of this species have been found in these rocks. From this fact one is tempted to consider them a dwarfed primitive variety of the much larger non-sinuate shells of the Salt Range and Timor.

These shells are at once distinguished from the rotund forms which represent the preceding species by their greater transverseness.

The beak of the pedicle valve is pointed and raised rather than strongly incurved as in the preceding species. The umbonal portion is more strongly contracted laterally than in the preceding form, so that the sides appear more pronouncedly concave. The umbonal slopes round to the cardinal margin, there being no depressed zone. The shell rapidly expands to the widest point which is near the mid-length. The sides are regularly rounded and pass into the frontal margin, which is rounded to a greater radius. The median longitudinal contour is less asymmetric than in the preceding species, with the greatest convexity nearer the center. Still the beakward slope is more arched than that towards the front. The transverse contours form regular arches from side to side; and the sutural angles are acute both at the side and at the front. The surface is without a sinus, the front without emargination.

The brachial valve is of about the same convexity as the pedicle valve, with the median longitudinal contour a nearly regular arch from beak to front, and the transverse contour similar to those of the pedicle valve. The beak is obtuse and incurved, but not covered by that of the pedicle valve. The side slopes outward, at first straight, then round, into the arcuate lateral margin. There is no indentation of the sides of the pedicle valve by those of the brachial valve. The surface is without a fold.

In one specimen at least (No. 18, not figured) a distinct, strong, step-like deflection or wrinkle is shown near the front of the brachial valve, which suggests senile conditions. If that is the case, the dwarfed character of these shells, as opposed to their immature condition, is corroborated.

Growth lines are rather distant and subequally spaced.

Measurements:—The following are the dimensions of four specimens of *Athyris royssii* from these strata:

Column number............	*1*	*2*	*3*	*4*
Serial number..............	*No. 81* *Pl. VI, Fig. 8*	*No. 80* *Fig. 7*	*No. 82*	*No. 18*
Height of pedicle valve.....	6.3	6.0	5.0	6.0
Height of brachial valve....	5.7	5.3	4.5	5.6
Greatest width.............	6.6	6.1	4.7	6.5
Maximum thickness........	3.7	3.6	2.8	3.7

This shows a uniformly greater width than length in the larger forms, and a more rotund outline in the smallest.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia; not uncommon. Collector, F. K. Morris.

Genus **Hustedia** Hall and Clarke

24. **Hustedia grandicosta** (Davidson)

Plate V, Figs. 6a-d (No. 26)

1862. *Retzia radialis* Phillips var. *grandicosta* Davidson. "On Some Carboniferous Brachiopoda Collected in India." *Quart. Journ. Geol. Soc. London*, Vol. XVIII, p. 28, Pl. I, Fig. 5.

1863. *Retzia radialis* Phillips var. *grandicosta* (Davidson). de Koninck, "Mémoires sur les Fossiles Palæozoique recueilles dans l'Inde," etc., p. 33, Pl. IX, Fig. 5.

Cf. 1883. *Retzia compressa* (Meek). Kayser, "Obercarbonische Fauna von Loping." In, Richthofen, China, Vol. IV, p. 176, Pl. XXII, Figs. 1-4.

1883. *Eumetria grandicosta* (Davidson). Waagen (pars), *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 491, Pl. XXXIV, Figs. 6–8 (not Fig. 12).

1916. *Retzia* (*Hustedia*) *radialis* Phillips var. *grandicosta* Davidson. Broili, "Die permischen Brachiopoden von Timor." Paläontologie von Timor, Lief. VII, p. 51, Pls. X and XI (Bibliography).

A nearly perfect specimen, No. 26, of small size (Plate V, Figs. 6a-d) presents the following characteristics.

The valves are equally convex, but of unequal length and strongly plicate. The height is greater than the width. The pedicle valve has its beak slightly incurved over the flat and rather high and prominent cardinal area. The apex was originally truncated by a foramen but is somewhat broken in the specimen. The area is triangular with sharply defined sides. Its height is about 1.5 mm., and its basal width about twice that. A distinct deltidial structure is visible on one side, about 0.4 mm. wide, and bounded by two sharp parallel lines, one of which occupies the median portion of the area. At a somewhat greater distance from the median line is a less well-marked line bounding the other side of the deltidial structure. The plications, of which there are twelve, the last on either side very faint, all begin at the truncated beak, but while the inner three on each side of the center of the valve are more or less truncated by the foramen, the outer three apparently originate just below the foramen. There is practically no difference in strength in the three plications on either side of the center, but they grow progressively shorter. The fourth plication is almost but not quite as thick as the third, and much shorter. The fifth and sixth, however, are much finer, especially the sixth, which is visible as a fine short ridge. In certain positions with reference to the light, the region of its occurrence in most positions appears as a rather broad flattened or faintly depressed area between the fifth plication and the margin of the hinge area.

The main plications are rounded at the top and separated by interspaces, which are at first of the same width but become somewhat wider towards the front, where they are strongly depressed to form the pronounced zigzag frontal margin. There is no difference in size between the median interspace and those next farther out, the median part of the valve thus being unmarked by a modified depression.

The frontal margin is sharply and pronouncedly zigzag, the angle of the individual teeth being near 60°.

The brachial valve has its beak strongly curved against the area of the pedicle valve. The median plication begins distinctly later than those next to it and is at first much smaller than they. The two plications on either side of the central one seem to be formed by the bifurcation of a single plication which begins close below the beak and before the median plication appears. Thus there are at first only two plications resulting from this original bifurcation. These bifurcate again to form four, and almost immediately after that the median plication appears between the two pairs. This rapidly increases in size, until near the front it is almost, though not quite, equal to those on either side, that is, it is not quite as high as those plications, though as broad, if not broader, and slightly more rounded on top.

Besides the five central plications, there are three others in each side, making eleven in all. These lateral plications decrease rapidly in size outward, until the outermost one near the hinge margin is only a short, fine and narrow ridge.

Both the longitudinal and transverse arching of valves is regular. Lines of growth are fine, except near the front, where there are several stronger growth interruptions, which, however, do not produce irregularity in the shell contour. The punctate structure is not visible with magnification of eight diameters.

Measurements:—The dimensions of our specimens, No. 26, are given in the following table, column (a); in column (b) the measurements of var. *lata*, No. 56, are given, and in column (c) those of a typical form from the Productus limestone of India, after Waagen.

	No. 26	*No. 56*	
	(*a*) *Pl. V, Fig. 6*	(*b*) *Pl. V, Fig. 5*	(*c*)
Height of pedicle valve	6.8 mm.	6.4 mm.	14.0 mm.
Height of brachial valve	5.5 mm.	5.7 mm.	12.0 mm.
Greatest width	5.2 mm.	7.2 ± mm.	10.0 mm.
Greatest thickness	4.3 mm.	4.2 mm.	9.0 mm.
Apical angle of pedicle valve	65°	96°	63°
Apical angle of brachial valve	105°	120°	100°

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer (1196, *Hemiptychina* bed); one specimen. Collector, F. K. Morris.

Remarks:—In the specimen described by Broili from Timor, the number of plications on the brachial valve of smaller individuals ranges from eleven to thirteen and fifteen, while in larger individuals the number is twenty-one. Often, but not always, the middle plica is somewhat less strongly developed than those on either side of it and begins somewhat below the beak as in our specimen. Also, the mid-plica lies somewhat more depressed, the median portion of the shell being slightly sunken. Broili sites a similar character in some of the shells of *Hustedia radialis* from the Belgian Carboniferous limestone, especially in the smaller individuals. According to Broili, this is shown only in youthful individuals, being recognizable in adults only in the well-preserved umbonal part. In these adults the median plica often becomes somewhat stronger near the front. That our specimen is a young or dwarfed form of *Retzia grandicosta*, rather than *Retzia indica*, is shown by the number of plications, which in the latter is seven (rarely nine) in the brachial, and eight (rarely ten) in the pedicle valve. Also the median interspace of the pedicle valve is wider and deeper in *Retzia indica*, and the median plica of the brachial valve is stronger and extends to the beak. The Timor specimens are also much larger, that figured by Broili on Plate X, figure 17, being: height 17.5 mm. (pedicle), 15.2 mm. (brachial valve), width 14.4 mm., thickness 11.6 mm. Another specimen (Pl. XI, Fig. 22) gives the height of the pedicle valve as 17 mm.; the brachial valve 13.6 mm.; the width 17 mm.; and the thickness 11 mm. Here the length and width are equal.

This species is certainly the same as that described by Broili from Timor, although our specimen, No. 26, is less than half as large as the larger Timor specimens.

In typical forms figured by Waagen from the Upper Productus limestone of Jabi, the number of plications on the pedicle valve ranges from ten to twelve, and on the brachial valve from eleven to thirteen. The measurements given of one of these agree closely in proportion with ours but are more than twice as great. There is also fairly close correspondence between the apical angles of the two valves in both specimens.

Ours might in comparison be thought a young shell, but because of the agreement of proportions it may also be considered a dwarfed variety, an interpretation in harmony with the character of the Mongolian fauna as a whole.

Kayser has figured and described a small shell from Loping, under the name *Retzia compressa* Meek. This is not very different from our shell, though it seems more robust, and the umbonal region is more compressed. The brachial valve has from nine to eleven plications and the pedicle from ten to twelve. This also agrees with our shell. The measurements of Kayser's shell are: Height of pedicle valve 10.5 mm., height of brachial valve 7 mm., width 7 mm., thickness 7.3 mm.

A comparison of specimens is needed to determine whether the Loping and Mongolian forms are conspecific.

25. **Hustedia grandicosta** mut. **lata** Grabau, mut. nov.

Plate V, Figs. 5a-e (No. 56)

A second specimen of *Hustedia grandicosta*, of about the same length as the preceding, differs from it in the strikingly greater width, which considerably exceeds the greatest length, and in the surprisingly large apical angles of both valves and in the greater number of plications. It is true that these features have commonly been regarded as variations of the form, and Broili, as well as other authors, have figured shells as broad as the present specimen, and with as many, or even more plications. But the fact remains that these types indicate divergent evolution, and though these forms may agree in the very young individuals, the difference in direction of development is quickly established, so that by the time they have reached the same size they are markedly distinct. It seems to me desirable to recognize this divergent evolution by applying distinctive names, and though there may be intermediate lines of evolution between these two, such lines are also radial divergencies from a common stock. Though in the beginning these divergencies are not very pronounced, so that for convenience they can be included in one specific designation, this designation must always be a convenience and does not express the true relationship. Each radial line of evolution, when persisted in, will lead to results of widely distinct character.

The dimensions of the present mutation, No. 56, are given in the above table under (b), where it will be seen that in all except width there is marked agreement. The plications diverge more towards the margin, in conformity with the greater width. The median plication of the brachial valve appears shortly after those flanking it on either side, but becomes of the same size towards the front, where there is no irregularity of outline. On either side are six diverging, outward-curving and progressively diminishing plications, making thirteen in all. The hinge line is extended on either side of the beak by flattened wing-like expansions without area. The beak itself is less elevated than that of the narrower form. The hinge area of the pedicle valve is wider and slightly lower than that of the narrow form, being 3.2 mm. as compared with 2.5 mm. in width, and 0.6 mm. as compared with 0.7 mm. in height. The plications of the pedicle valve also diverge more than in the narrow form, and their total number is fourteen. In other respects they are like those of the narrow form. Finally, it should be emphasized that the whole outline of the present form is more circular, whereas that of the precedent one is elongate; and that the valves meet at the sides in an angle which is slightly less than 90°, whereas that of the narrow mutation is considerably over 90°, being in fact quite obtuse.

Horizon and Locality:—The present mutation is represented by a single specimen, No. 56, from the *Orthotychia* bed (locality 1211) of the Jisu Honguer limestone (Mid-Permian) of Jisu Honguer, Mongolia. Collector, F. K. Morris.

26. **Hustedia remota** (Eichwald)

Plate VII, Figs. 8a-e (No. 27)

1883. *Eumetria grandicosta* Waagen (pars). *Palæontologia Indica,* Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, Pl. XXXIV, Figs. 12a-b (not Figs. 6–9).

1902. *Retzia remota* Eichwald. Tschernyschew, "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe,* Vol. XVI, No. 2, Pl. XLVII, Figs. 8–11.

Measurements:—The only specimen in our collection, No. 27, is small, with the following dimensions:

	No. 27
Height of pedicle valve	9.6 mm.
Height of brachial valve	8.0 mm.
Maximum width	8.7 mm.
Maximum thickness	6.4 mm.
Length of hinge line	3.2 mm.
Original height of hinge area	1.8 mm.
Apical angle of pedicle valve	80°
Apical angle of brachial valve	117°

The valves are subequally convex and both heavily and coarsely plicated. The pedicle valve has a strongly elevated beak, the apical angle of which is about 80°. It is but slightly incurved, the hinge area beneath it being very nearly in the plane of junction of the valves. The apex is truncated by a rather large circular foramen, which is, however, not perfect in the specimen. Beneath it is a well-defined, very gently concave hinge area forming a triangle, the height of which is slightly more than half the basal width, but with the apex truncated by the foramen. Its lateral margins are sharply defined by an angulation to which the shell curves on either side. The deltidial plates are large, occupying about one-half of the area.

The longitudinal contour forms an arch which is most strongly convex a little behind the middle, the stronger curvature being towards the beak. The transverse contour is regularly convex. The greatest width is somewhat in front of the mid-length, from which point the shell outline is regularly rounded.

The surface is marked by ten strong radial plications which gradually decrease in length as well as strength to the cardinal margin. All of them extend to the foraminal truncation, but the outermost on each side begins at the foramen, while the others are slightly truncated by it. The plications are at first rather sharp, but become broader towards the front with their summits rounded. The two median ones scarcely differ in size from the next adjoining on either side, but the interspace which separates them is slightly broader than that separating the others. These interspaces are deep and pronounced, but their rounded bottoms are narrower than the width of the plications on top.

The brachial valve shows a straight hinge line, the length of which is about three-eighths the width of the shell below, but there is apparently no hinge area. The beak of the brachial valve projects very little above the hinge line and is appressed against the area of the pedicle valve. In outline the valve is subcircular with the width somewhat greater than the height and the contours subregularly convex.

The median plication is very slightly larger at the front than those next adjoining but does not extend quite to the beak, beginning a very short distance below it. At the beak there are two plications which almost immediately divide when the median one appears between them. Thus are formed the five central plications of the valves, the conditions being similar to those found in *Hustedia grandicosta*. Besides these five central ones, there are three others on each side, these gradually becoming smaller and curving outward to meet the shell margin at right angles to the median axis. This valve has therefore eleven plicæ in all, as compared with the ten plicæ of the pedicle valve.

There is no median fold or sinus, the shell suture being regularly zigzag, the zigzags forming less than right angles. Lines of growth are somewhat pronounced near the front. Punctate structure is not preserved.

Compared with *Hustedia grandicosta* (No. 26), this shell (No. 27) is more robust and more subrotund in outline, with coarser and more numerous plications.

Horizon and Locality:—In the *Enteletes* bed (Locality 1190) of the Jisu Honguer series at Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—I refer the shell (No. 27) to *Hustedia remota* Eichwald, on the strength of the illustrations given by Tschernyschew (1902, Pl. XLVII, Figs. 8–10). The text is entirely in Russian and therefore unavailable, and the original work of Eichwald is not at hand. However, the form and proportions, as well as the number and character of the plications, agree with the Russian forms. The measurements, as taken from Tschernyschew's figures, are as follows (columns *b-e*), to which are added the measurements of our shell (No. 27, column *a*) and those of a shell from India (Waagen, 1879–1887), column *f:*

	Mongolia	*Tschernyschew*				*Waagen*
	a	*b*	*c*	*d*	*e*	*f*
	No. 27	*Fig. 8*	*Fig. 9*	*Fig. 10*	*Fig. 11*	*Fig. 12*
Height of pedicle valve....	9.6	11.0	12.5	7.5	6.5	14.0
Height of brachial valve...	8.0	9.5	11.0	6.0	5.5	12.0
Maximum width.........	8.7	10.0	12.0	6.5	5.5	12.5
Maximum thickness......	6.4	6.7	9.0	4.3	3.3	9.5

This shows the shells from the Russian Schwagerina limestone to be both larger and smaller than our specimens, but essentially of the same proportions.

Broili includes these shells in his synonymy of *Retzia radialis*, though he suggests that they may be designated as variety *remota*. The shells from Timor, however, do not agree with the present form but rather with the one previously described. Hence I prefer to give them distinct designation.

On the other hand, this shell (No. 27) agrees in form, proportions and number of plications with that figured by Waagen from the Middle Productus limestone of Kàfirkot, under the name of *Eumetria grandicosta* (1879–1887, Pl. XXXIV, Fig. 12*a-d*), but that shell is different in form from the others figured under that name by Waagen. The measurements of the shell taken from Waagen's work are given in the above table, column *f*. The apical angles of that shell are 80° for pedicle and 117° for brachial valve, while the corresponding angles for the normal form of *Eumetria grandicosta* in the Indian rocks are 63° and 100° respectively. The number of plications on the pedicle valve is ten, and on the brachial valve eleven, agreeing in this with our shell. The apical angles of our shell agree precisely with those of the Indian shell, being also 80° and 117° respectively.

The two forms here designated respectively as *Hustedia grandicosta* and *Hustedia remota* represent divergent lines of development, the one (*Hustedia grandicosta*) characterized by excessive addition in front, so that the height of the brachial valve is always greater than the maximum width, while in the other (*Hustedia remota*) the addition is more uniform throughout, resulting in the formation of a broader form, with the maximum width greater than the height of the pedicle valve, or at least equal to it. It seems desirable to distinguish between these two tendencies by applying distinctive names, especially as these are already in existence. Even should there be intermediate forms, as there is every reason to expect, this should not influence the fact of the diverging tendencies. I think that more is gained by laying emphasis upon these tendencies than by uniting all the forms under a common designation, even though the latter would make identification easier. In any case, the Mongolian forms, though of such limited representation, show distinctly these two diverging lines of evolution.

The American *Hustedia mormoni* Marcou, which by Broili and others is united with the European and Asiatic forms, is intermediate in form, the maximum width being equal to the height of the brachial valve, as measured on a typical specimen from Kansas City, Missouri (Hall and Clarke, 1892, Pt. II, Pl. LI, Figs. 1–8). In the number of plications it agrees with our form, as does also the actual width, but the plications themselves are less coarse.

Genus **Spiriferella** Tschernyschew

The genus *Spiriferella* was defined by Tschernyschew as a subgenus of *Spiriferina* with *Spiriferella saranæ* as the type. The internal characters are the most typical for this genus. They are described by Tschernyschew (1902, p. 523 et seq.) as follows:

"The strong hinge teeth are supported by extremely heavy dental plates which are arched along their length and broaden towards the base, enclosing the elevated gutter-like median portion of the shell. This elevated area is hidden above, under the pseudo-deltidium, with the lower surface of which it almost coalesces. Forward, however, it becomes suddenly depressed marking the beginning of a broad lancet-form muscular area. This is surrounded by sharp curving ridges, which are the continuation of the base of the dental plates and unite forward into a flat keel which dies out before reaching the frontal margin. The muscular area is divided medially by a ridge, which ends at the foot of the elevated platform into which a short median groove extends as a continuation; occasionally the median ridge continues a short distance onto the platform. The muscular area is striated longitudinally. The elevated platform is in reality a sort of spondylium (pseudo-spondylium) supported by a median septum of the type found in *Pentamerus* but greatly thickened. This septum becomes apparent in shells split along the mid-line. The septum has a deltoid section and increases from the beak forward to the front of the platform and is continued forward in the median ridge which divides the muscular area. On either side of the median pseudospondylium the rostral cavity shows ovarian pittings."

Typus **Spiriferella rajah**

27–30. **Spiriferella salteri** Tschernyschew, and its mutations. Plate XIX, Figs. 1 (No. 176); 2 (No. 219); 3 (No. 175); 5 (Nos. 204–207). Plate XX, Figs. 1 (No. 182); 2 (No. 202); 3 (No. 183); 4 (No. 185); 5 (No. 187); 6 (No. 189); 7 (No. 184); 8 (No. 188). Plate XXII, Figs. 5 (No. 220); 7 (No. 201); 8 (No. 267); 9 (No. 211); 10 (No. 261). Plate XXIII, Figs. 1 (No. 196); 2 (No. 178); 3 (No. 198); 4 (No. 200); (Nos. 197, 210, 221, 253, 258, 260, 263, 265, 268).

1902. *Spiriferella salteri* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 528, Pl. XII, Figs. 5–6.

1914. *Spiriferina draschei* Wiman. "Uber die Karbonbrachiopoden Spitzbergens und Bären Eilands." *Nova Acta R. Soc. Sci. Upsaliensis*, Ser. IV, Vol. III, No. 8, p. 38, Pl. III, Figs. 2–4, 9–11, 17–26 (*cetera exclus*).

1916. *Spirifer rajah* Broili. "Die permischen Brachiopoden von Timor." Paläontologie von Timor, Lief. VII, p. 34, Pl. CXIX (5) Figs. 1, 2, 4–7 (*cetera exclus*).

Compare also the following:

Cf. 1874. *Spirifer draschei* Toula. "Kohlenkalk Fossilien von der Südspitze von Spitzbergen." Sitzungsber. K. Akad. Wissen., Wien, Abt. 1, Bd. LXVIII, 1873, p. 239, Pl. VII, Figs. 4a-c.

Cf. 1901. *Spirifer draschei* Frech. Lethæa Geognostica, Pt. I, Vol. II, Lethæa Palæozoicum, p. 498 (Fig. 499, original of Toula's refigured).

Cf. 1902. *Spiriferella keilhavii* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, p. 527, Pl. XL, Figs. 1–4.

Cf. 1902. *Spirifer saranæ* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém.. Com. Géol. Russe*, Vol. XVI, p. 522, Pl. XII, Fig. 4.

Cf. 1916. *Spiriferella rajah* and varieties. Fredericks, "On some Upper Palæozoic Brachiopoda of Eurasia." *Mém. Com. Géol. Russe*, New Ser., Livr. CLVI, p. 80 (text chiefly Russian), Pl. V, Fig. 7 (*cetera exclus*).

The shell is transverse in the young to equidimensional in the adult. In the young the hinge line forms the greatest width of the shell. In the adult the height and width are nearly equal, and the hinge line shorter than the width of the shell below.

The pedicle valve is extremely convex, with the beak elevated and terminal in the young and submature, but incurved in the largest shells, so that it lies below the umbo when the shell is placed with the intervalve plane vertical. The area is high and arched, describing an arc of 90° or over in adult shells. It is sharply defined by the umbonal angles or shoulders and divided by a narrow delthyrium the base of which is less than its height. It is without vertical striations. None of our specimens preserve a pseudodeltidium. The cardinal angles are acute in the young, rectangular in submature shells and slightly obtuse in the largest shells. In the submature and adult shells the actual length along the curvature from beak to front is about one-fourth again as great as the vertical height, whereas in the young it is less. Approximately the height is to the length as 1 : 1.3 to 1 : 1.35 in the adult, and as 1 : 1.2 in the young or even as 1 : 1.16 in the youngest stage measured.

Measurements:—The following are some of the dimensions of different pedicle valves in the collection:

Column Number	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Serial number	*175*[1]	*186*[1]	*182*	*177*[1]	*202*	*185*	*187*	*184*	*183*	*175*	*176*	*204*
Plate and Figure	*XIX,3*	—	*XX,1*	—	*XX,2*	*XX,4*	*XX,5*	*XX,7*	*XX,3*	*XIX,3*	*XIX,1*	*XIX,5*
Height	13.3	15.5	18.5	19.5	21.0	26.0	24.0	26.0	29.±[2]	33.0	41.0	43.0
Length	15.4	19.0	24.0	26.0	31.0	33.0	34.0	33.0	35.0	42.0	55.0	57.0
Width below	X	X	X	23.0	X	X	X	X	X	33.0	40.0	47.0
Length of hinge-line	16.0	22.0	26.0	24.0	32.0	30.0	32.0	30.0	30.0	33.0	32.0	37.0
Height of hinge-area	—	—	—	—	—	—	—	—	—	10.±	—	—
Width of delthyrium	—	—	—	—	8.7	—	—	—	—	8.0	—	—

The median sinus begins at the beak and is bounded by a strong rounded plication on either side. At first these plications are simple and the bottom of the sinus is rounded, this condition continuing in different individuals for a shell length of from 5 to 8 or rarely 9 mm. or more, depending on the degree of acceleration in development of the individual. For this length of shell, then, which may be referred to the nepionic stage, the shell has the simple character of a Silurian *Spirifer*—transverse elongate with a few relatively strong simple plications, a simple smooth sinus, moderately high hinge-area, and with the

[1] Measurement on immature stage of larger specimen.
[2] Width less than length of hinge-line.

length of the hinge-line greater than the width below. The latter character is maintained until the shell is over 30 mm. in length, corresponding to a height of 25 mm. or over. Meanwhile, however, a pair of lateral sinal plications has appeared, one on the inside of each bounding plication of the sinus, from which they appear to branch off. In the least accelerated individual observed (No. 182, Pl. XX, Fig. 1, Text-Fig. 42) this begins 5 mm. from the beak and remains the only pair throughout a shell length[1] of 24 mm. They never become very pronounced.

This immature individual has a length of hinge-line of 26 mm., exceeding the width of the shell below. There are seven lateral plications, all of them simple, though they become broad towards the front.

In the majority of the individuals, a second pair of sinal plications branches off from the bounding plication at a later stage, these plications thus coming to lie between the bounding plication and the first sinal plication. This second pair would probably also have appeared in the shell referred to above, had it grown to full size, but that would have been after attaining a shell length of 24 mm.

27. **Spiriferella salteri** Tschernyschew var. **simplex** Grabau, var. nov., mut. α

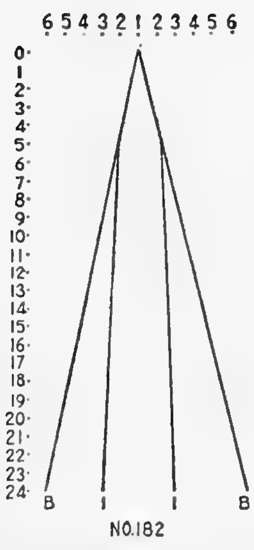
Plate XX, Figs. 1 (No. 182), 2a-b (No. 202), (Text-Figs. 42 and 44, 43 for comparison)

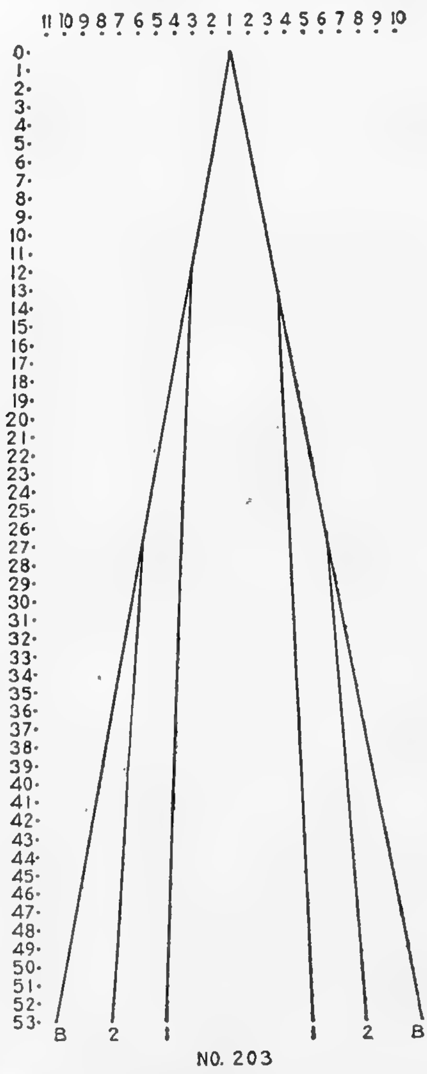
In the simplest forms, mutation α, as represented by Nos. 182 and 202, etc., there is no pronounced median plication in the shell (No. 182, Text-Fig. 42), though the center in some cases appears gently convex. This suggests the character of *Spiriferella saranæ*. It is possible that were this shell not exfoliated a median plication would be indicated, though probably this would not be pronounced. In any case this seems to be the primitive form of this species. A median plication is probably characteristic of all the normal forms in the Mongolian deposits, though it is sometimes weak and in other cases becomes divided towards the front.

A second shell of this series, No. 203, appears to be even more primitive in some respects than the one previously described, for the first pair of sinal plications does not branch off from the bounding ribs until a shell length of 11 or 12 mm. has been reached (the beak is broken and exact measurements not possible) (Text-Fig. 43). The second pair of sinal plications branch off at a shell length of 27 mm., which is a greater length than shell No. 182 (Pl. XX, Fig. 1). There is no median plication, and on this account the shell is referred to *Spiriferella saranæ* (see below), a species apparently ancestral to the present one. Another shell (No. 202, Pl. XX, Figs. 2a-b), also referable to this mutation, is more accelerated and has a median plication, which, how-

[1] Shell lengths are always measured on the curvature.

ever, does not begin until 24 mm. from the beak (Text-Fig. 44). The first pair of sinal plications begins 5 mm. from the tip of the beak, the second 15 mm. The total length of the shell is 31 mm. and its vertical height 21 mm. The length of the hinge-line, which marks the greatest width, is 32 mm. There are eight simple shell plications on either side.





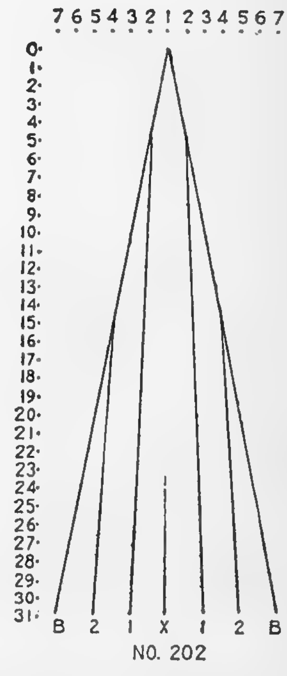


FIGURE 42.—(No. 182) Diagram of the bounding plications (B, B) and lateral sinal plications (1, 1) in *Spiriferella salteri* Tschernyschew, mut. α Grabau, mut. nov. There is no pronounced median sinal plication on the shell.

FIGURE 43.—(No. 203) Diagram of the bounding plications (B, B) and lateral sinal plications (1, 1, 2, 2), in *Spiriferella saranæ* (Verneuil).

FIGURE 44.—(No. 202) Diagram of the bounding plications (B, B), the median sinal plications (x), and lateral sinal plications (1, 1, 2, 2), in *Spiriferella salteri* Tschernyschew, mut. α Grabau, mut. nov. The beginning of a median plication (x) is noticeable near the front.

28. **Spiriferella salteri** Tschernyschew var. **mongolica** Grabau, var. nov., mut. β

Plate XX, Figs. 3 (No. 183), 4 (No. 185), 5 (No. 187), 6 (No. 189), (Nos. 177, 186, 190, 193, 250, 252); Plate XXIII, Fig. 4 (No. 200), (Text-Figs. 45–50).

The second group of these shells is characterized by the possession of a median plication in addition to the other sinal plications, while the shell plications are simple. It is not always possible to determine the appearance of the median plication with precision, because of the exfoliated character of the shells, but it can be stated with reasonable certainty that it does not appear before the first pair of lateral sinal plications. In some cases it seems to appear simultaneously with these, in others somewhat later. In some cases it is so delicate that it is scarcely visible. Ordinarily when there are only two pairs of lateral plications the median plica appears at the same time as the first lateral pair, or a little earlier, though it may be very faint at first (No. 183, Pl. XX, Fig. 3). It is quite possible, however, that if these shells grew larger, a third pair would appear, as is seen in No. 176 (mut. γ, Pl. XIX, Fig. 1), where the third pair appears 40 mm. from the beak, a length not reached by the others referred to. Taking the order of appearance of the first and second pairs of sinal plications in these shells, they can be arranged as follows:

Mutation β	*Appearance of sinal plications at a distance from beak of:*		
	1st sinal	*2d sinal*	*3d sinal*
No. 177 (Text-Fig. 45)..........	8.0 mm.	18.0 mm.	28+ mm.[1]
183 (Text-Fig. 46)..........	7.0 mm.	17.0 mm.	35+ mm.[1]
189 (Text-Fig. 47)..........	6.5 mm.	16.0 mm.	30.0 mm.
186 (Text-Fig. 48)..........	6.5 mm.	11.0 mm.	22.0 mm.
187 (Text-Fig. 49)..........	5.0 mm.	11.0 mm.	30+ mm.[1]
185 (Text-Fig. 50)..........	8.0 mm.	15.0 mm.	33+ mm.[1]

Thus there is an almost regular progression in the appearance of the sinal plications in Nos. 177, 183, 189, 186, especially the second pair, these developing successively earlier as the acceleration progresses.

The third sinal plication also appears in the same order if we interpret these shells in terms of adults. Thus, No. 177 is only 28 mm. long; a third sinal plication might have appeared had it grown larger. Judging from the order of appearance of the others, it should not form until the shell is over 40 mm. long. In No. 183 it has not yet developed at 35 mm., but might have appeared shortly afterward, had the shell grown larger. In No. 189 it appears at 30 mm. and in No. 186 at 22 mm., the shell being 30 mm. long but broken,

[1] Third sinal plicæ not shown in part preserved.

so that only the measurements on the growth line, marking a length of 19 mm., could be taken for the other dimensions.

There is more variation in the shell plications, however. In Nos. 189 (Pl. XX, Fig. 8), 185, 186 (Pl. XX, Fig. 4), and 187 (Pl. XX, Fig. 5), the first or bounding plications are simple, but in rare cases there may be an outside branch given off by the bounding plicæ, or one of the other shell plicæ may branch.

In No. 189 (Pl. XX, Fig. 6) the two sides are unequally developed. On the right side, the first and second sinal plications appear earlier than on the

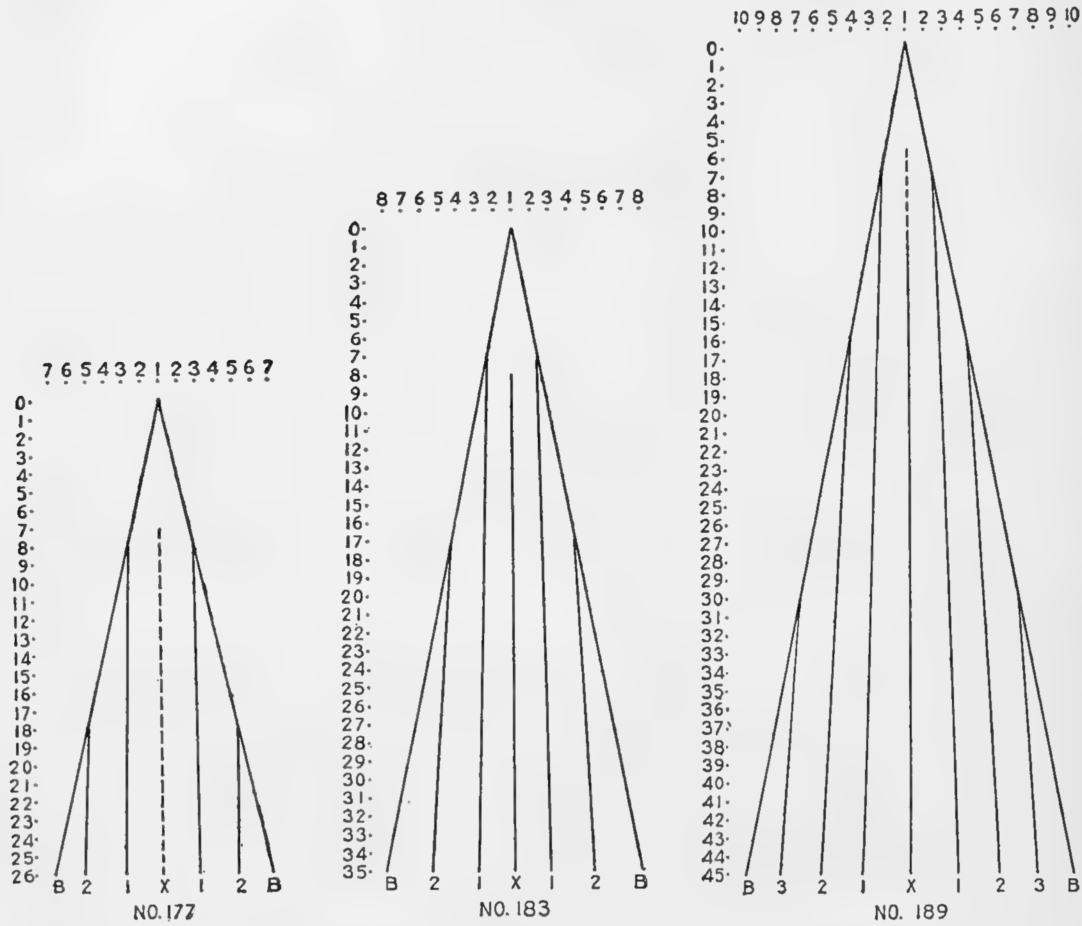


FIGURE 45.—(No. 177) Diagram of the bounding plications (B, B), the median sinal plications (x), dotted, and lateral sinal plications (1, 1, 2, 2) in *Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.

FIGURE 46.—(No. 183) Diagram of the bounding plications (B, B), the median sinal plications (x), and lateral sinal plications (1, 1, 2, 2) in *Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.

FIGURE 47.—(No. 189) Diagram of the bounding plications (B, B), the median sinal plications (x), and lateral sinal plications (1, 1, 2, 2, 3, 3) in *Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.

left, and they are stronger. There is also a third one. The bounding plication on this side is without an outside plication. On the left, however, the first and second sinal plications appear later, and the third is not shown, but there is also an outside branch of the bounding plication which appears after the first but before the second sinal plications. All the other plications are simple.

Since we may consider that the outside branch on the left bounding plication of No. 189 is compensated for by the later appearance of the inside branches or sinal plications on that side, that shell may be considered as having simple plications with an abnormal modification.

No. 187 (Pl. XX, Fig. 5) of the series presents a further modification, in that the median plication, which itself is very faint, divides toward the front into two faint parallel branches. The first sinal plication has become very

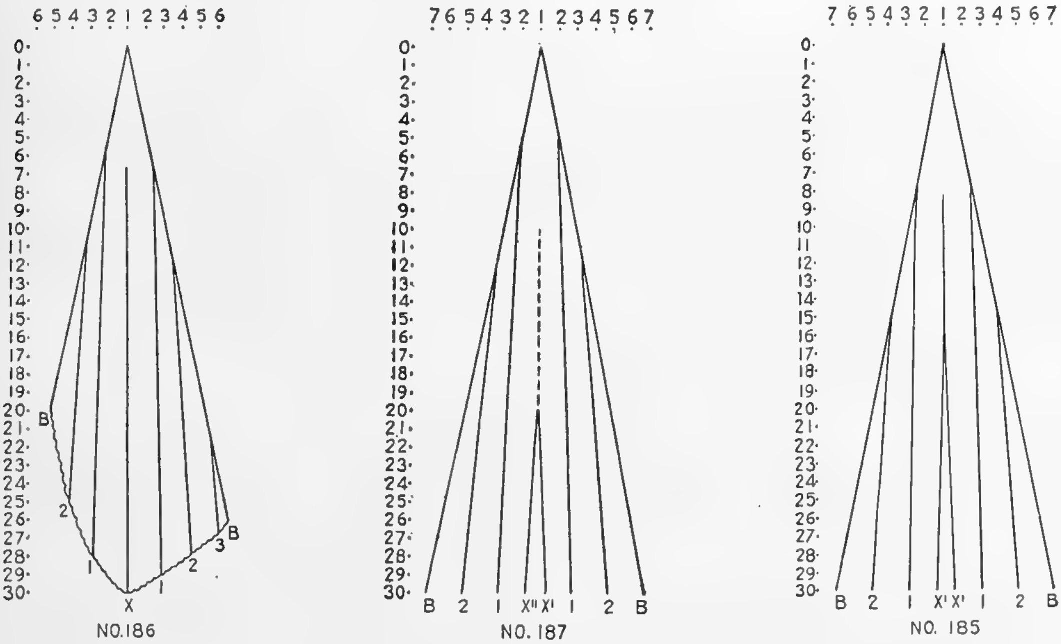


FIGURE 48.—(No. 186) Diagram of the bounding plications (B, B), the median sinal plications (x), and lateral sinal plications (1, 1, 2, 2, 3, 3), in *Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.

FIGURE 49.—(No. 187) Diagram of the bounding plications (B, B), the median sinal plications (x,′ x″), and lateral sinal plications (1, 1, 2, 2) in *Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.

FIGURE 50.—(No. 185) Diagram of the bounding plications (B, B), the median sinal plications (x′, x′), and lateral sinal plications (1, 1, 2, 2) in *Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.

strong and broad towards the front; the second is somewhat less strong, and there is no third, but the bounding plication is very broad. There is a suggestion of an inside branch near the front of the second left-hand shell plication, but otherwise these plications are simple. This is carried a step further in

No. 185 (Pl. XX, Fig. 4), where the median plication begins with the first pair of sinal plications (about 8 mm. from beak) and divides near the front. The second left shell plication is divided into two equal branches by a median groove, this beginning 15 to 17 mm. from the beak, while the fourth and fifth in the same side show the beginning each of an inside branch. The others are simple but become broadly rounded near the front.

29. Spiriferella salteri Tschernyschew (typica), mut. γ

Plate XIX, Figs. 1a-d (No. 176), 5a (No. 204), 5c (No. 206), 5d (No. 207); Plate XX, Fig. 7 (No. 184); Plate XXII, Fig. 6 (No. 255), (Nos. 256, 257); (Text-Figs. 51–52).

In the third series recognized, the lateral plications of the shell are all modified by branches, this, therefore, being a more specialized type. Arranged in order of their acceleration, we have the following for this and the next variety:

	Appearance of sinal plications at a distance from beak of:			
	1st sinal	*2d sinal*	*3d sinal*	*Plate and Figure*
(*typica*) (mut. γ)				
No. 176 (Text-Fig. 51).....	6.0 mm.	18–19 mm.	40.0 mm.	XIX, 1
184 (Text-Fig. 52).....	5.0 mm.	10.0 mm.	20.0 mm.	XX, 7
var. *wimanni* (mut. δ)				
No. 219..................	5.0 mm.	20.0 mm.	30.0 mm.	XIX, 2
175 (Text-Fig. 53).....	5.0 mm.	14.5 mm.	24.0 mm.	XIX, 3
188 (Text-Fig. 54).....	3.? mm.	10.? mm.	26.? mm.	XX, 8

In No. 176, which is an adult 57 mm. in length, the median plication, which becomes broad and strong near the front, begins at about the same time as the first pair of laterals in the sinus, 6 mm. from the beak. The second and third begin much later, the latter not until a shell length of 40 mm. has been reached. Both the first and second sinal plications become broad and flat near the front, with a faint groove along the top of the left-hand group, suggesting the division which is marked in No. 188. The right side is accelerated over the left. The bounding plication is without outside branches, but the second plication has both inside and outside branches, which is also true of the third and fourth plications, but in a much less marked degree, these appearing only near the front. On the left side, where the first or bounding plication is also simple, the second has both an inside and an outside branch, but these are very faint. The others appear to be simple.

In No. 184 (Pl. XX, Fig. 7), the median plication is faint at first, not becoming strongly defined until about 18 mm. from the beak. Near the front

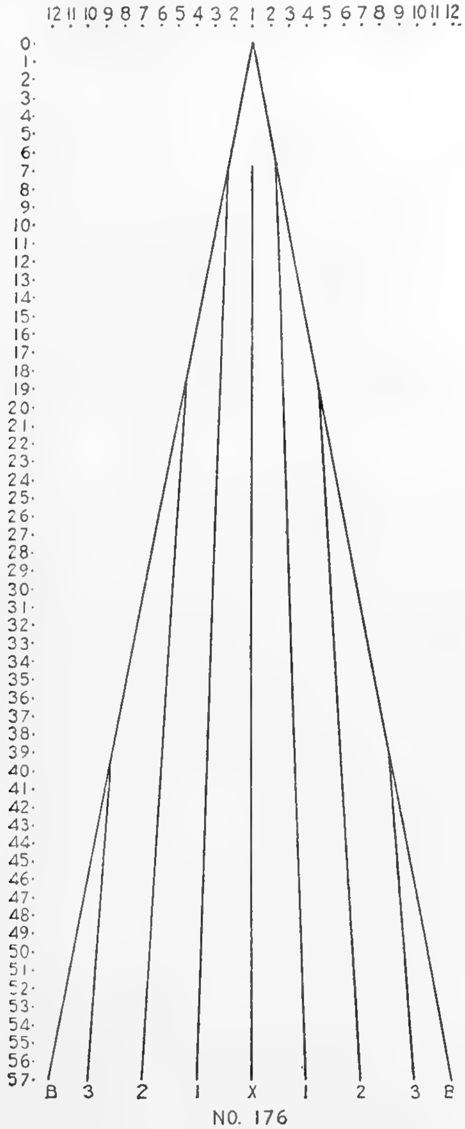


FIGURE 51.—(No. 176) Diagram of the bounding plications (B, B), the median sinal plications (x), and lateral sinal plications (1, 1, 2, 2, 3, 3) in *Spiriferella salteri* Tschernyschew (*typica*), mut. γ.

it is as strong as the other sinal plications, of which there are three pair. The first or bounding plications are simple. The second plication has both inside and outside branches, those on the right beginning about 20 mm. from the beak, those on the left much later. The third plication has both inside and outside branches, the former beginning as on the preceding, the latter at a later stage. The fourth has an inside branch, and perhaps an outside one near the front, but the shell is not perfect enough to show this with certainty. The character of the other plications can not be determined, but they may be simple.

This shell is thus much more accelerated in the sinal plications, which appear earlier, and in the shell plications, which show more pronounced branching. Other shells show these characters more or less perfectly.

30. **Spiriferella salteri** Tschernyschew var. **wimanni** Grabau, var. nov., mut. δ

Plate XIX, Figs. 2a-c (No. 219), 3a-c (No. 175, Holotype), 5b (No. 205); Plate XX, Fig. 8 (No. 188); Plate XXII, Fig. 9 (No. 211); Plate XXIII, Fig. 3 (No. 198); (Nos. 195, 199, 223, 249); (Text-Figs. 53, 54).

These characters are carried a step further in mutation δ, as shown in Nos. 219, 175, and 188, as well as others. In the holotype, No. 175, the median

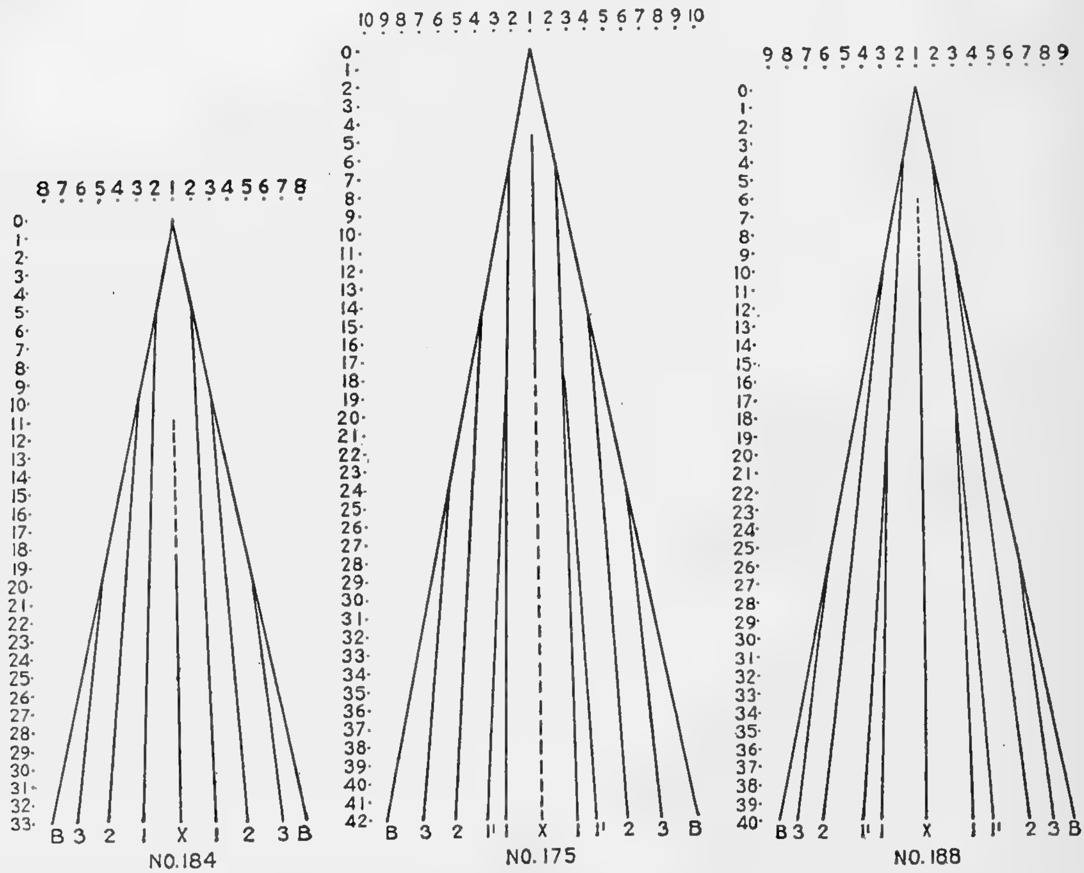


FIGURE 52.—(No. 184) Diagram of the bounding plications (B, B), the median sinal plications (x), and lateral plications (1, 1, 2, 2, 3, 3) in *Spiriferella salteri* Tschernyschew (*typica*), mut. γ.

FIGURE 53.—(No. 175) Diagram of the bounding plications (B, B), the median sinal plications (x), and lateral sinal plications (1, 1, 1′, 1′, 2, 2, 3, 3) in *Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ.

FIGURE 54.—(No. 188) Diagram of the bounding plications (B, B), the median sinal plications (x), and lateral sinal plications (1, 1, 1′, 1′, 2, 2, 3, 3) in *Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ.

plication begins apparently before the first pair of lateral sinal plications. It is poorly preserved, however, near the front, or else becomes obsolete. We may perhaps consider this as representative of a developmental branch carrying on the features first seen in No. 176 (mut. γ), for the plications of the sinus appear earlier than in that shell but later than in No. 184. However, the feature of significance is that the first sinal plication divides at a distance of 18 mm. from the beak or shortly after the appearance of the second pair of lateral sinal plications.

The shell plications are slightly more modified on the left side than on the right. On the left side the first or bounding plication has an outside branch, while the second has an inside and an outside branch, the former beginning before the latter. The third plication has an inside branch beginning shortly after the inside branch of the second plication. It can not be determined whether it has an outside branch, but the probabilities are that it has. The fourth to seventh are imperfect near the front. On the right side, the outside branch of the first or bounding plication is very indistinct. The second has both an inside and an outside branch, the latter beginning long after the former. The third has short inside branches and outside branches which are even shorter; and an outside branch is seen near the front on the fourth plication, but no inside branch; the fifth, sixth, and seventh are apparently smooth.

In No. 219 (Pl. XIX, Fig. 2), the median sinal plication begins far up in the sinus, close to the beak, and divides at about the point of appearance of the first pair of lateral sinal plicæ. These divide only near the front. The bounding plication is flattened but apparently unbranched; the 2d, 3d, and 4th have both outside and inside branches, the 5th an inside branch only. There appear to be four more simple and faint plicæ.

In No. 188 (Pl. XX, Fig. 8), the division of the first sinal plication begins earlier on the right than on the left, and the median plication is very strong. The first or bounding plication appears to be without outside branch, but the others, of which there are five preserved, have well-developed inside and outside branches, the inside branch beginning earlier than the outside one in each case, while the appearance of the branches on the successive plications is progressively later or farther from the beak.

A similar state of development is shown in No. 205 (Plate XIX, Fig. 5b), where the first sinal plication on the left divides very early, but this division is interrupted in the middle, to appear again near the front. It is again seen in a crushed shell retaining both valves (No. 195), but here the division appears only near the front. In this shell the bounding plication has an outside branch, and evidently all the others (at least six) have both inside and outside branches, this being one of the most complex of our shells. The median plication is simple, not bifurcating, a feature found in all our specimens of mutation δ except No. 214 (Pl. XIX, Fig. 2).

Brachial valves:—A number of brachial valves of different sizes have been obtained, but only one of these is associated with a pedicle valve (No. 195). The dimensions of these valves are as follows:

Serial number	*No. 200 (Text-Fig. 55)* *Pl. XXIII, 4*	*No. 178 (Text-Fig. 56)* *Pl. XXIII, 2*	*Nos. 196, 197 (Text-Fig. 57)* *Pl. XXIII, 1*	*Nos. 198, 199 (Text-Fig. 58)* *Pl. XXIII, 3*	*No. 195*	*No. 178 Neanic*
Height	22.0	22.5	29.5	37.2	38.?	15.0
Length	25.0	25.0	36.0	42.0	—	—
Greatest width	24.±	29.5	36.8	43.4±	52.?	19.5
Length of hinge-line	18.5	28.0	32.3	33.0	44.?	19.5

The width is always greater than the height, but the length of the hinge area is less than the greatest width below, making the cardinal angles obtuse. In the immature shell, however, as shown by the growth lines, the hinge line forms the greatest width of the shell, the cardinal angles being acute or sometimes even slightly mucronate. The width is also proportionately greater than the length.

The convexity of the valve is moderate, as shown by the fact that the length is only slightly greater than the height. This is especially the case in the younger shells, the convexity increasing with maturity. The mid-longitudinal contour is strongly arched at the umbo, then becomes relatively flat, until, in the mature specimens, it bends downward again at the front. Transversely, the contour is a rather sharp arch with the center elevated and the sides very gently curved. The beak is scarcely elevated, the cardinal margins on either side sloping gently but regularly to the cardinal angles. The area is relatively low and nearly vertical. It is not sufficiently exposed in any of our specimens to show its characters.

There is a single median plication or fold at the beak, flanked on either side, almost from the beginning, by a strong lateral plication which sweeps outward at a gentle curve. Almost from the beginning the median fold is characterized by a longitudinal groove which widens and deepens forward until the median part consists of two plications, which in the simpler forms remain simple (No. 200, Pl. XXIII, Fig. 4), but, in the more specialized, bifurcate near the front (No. 178). In our two largest specimens (Nos. 196, 198, Pl. XXIII, Figs. 1 and 3), the division is unequal, beginning slightly earlier on the right than on the left. The left plication is, however, slightly more prominent, which gives it the appearance of being a median plication, whereas the center is really occupied by a groove. The smaller shells have on either side of this median group (Nos. 178, 200, Pl. XXIII, Figs. 2 and 4) two additional plications, the first, nearest to the median group, beginning earlier than the second. This series of

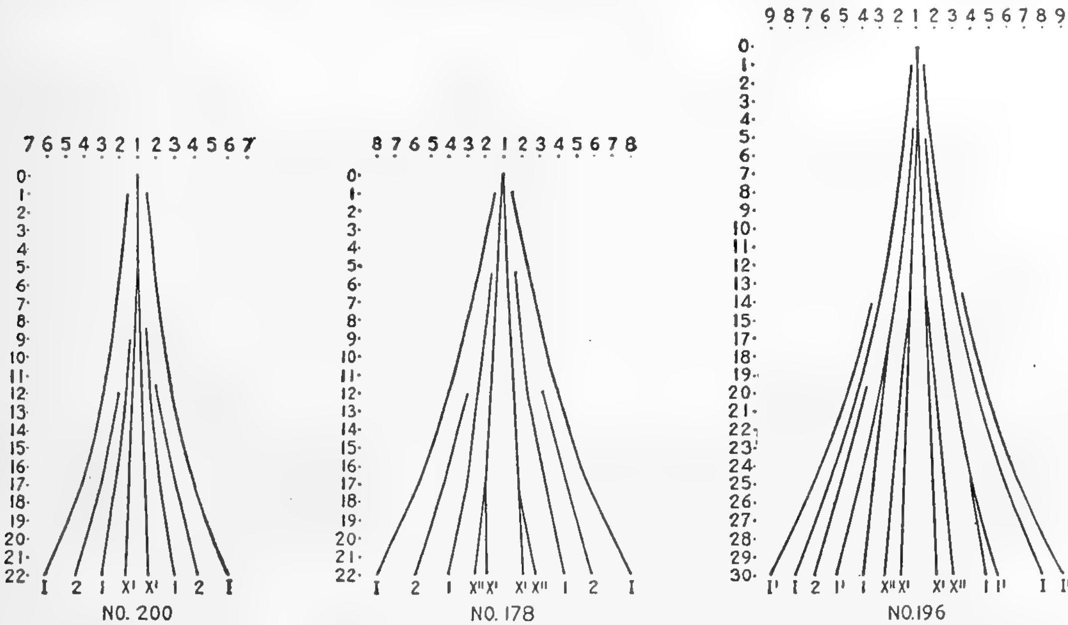


FIGURE 55.—(No. 200) Diagram of the median sinal plications (x', x'), and the lateral sinal plications (I, I, 1, 1, 2, 2) in *Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β (brachial valve).

FIGURE 56.—(No. 178) Diagram of the paired median sinal plications (x', x', x'', x'') and the lateral sinal plications (I, I, 1, 1, 2, 2) in *Spiriferella salteri* Tschernyschew (brachial).

FIGURE 57.—(No. 196) Diagram of the median sinal plications (x', x', x'', x'') and the lateral plications (I, I, 1, 1, 1', 1', 2) in *Spiriferella salteri* Tschernyschew (brachial).

plications makes up the median fold, in the youngest specimen (No. 200, Text-Fig. 55), of six plications at the front, in the next (No. 178, Text-Fig. 56), of eight plications because of the bifurcation of the median two. In both, the flanking plications are simple. In the next specimen (No. 196, Text-Fig. 57), there is an asymmetric development, the outer of the two marginal plications being suppressed, there being thus only seven plications on the fold. In this same specimen the flanking plications are also asymmetrically developed: whereas the one on the left, the accelerated side, has both an outside and an inside branch, the former of which is the longer; the right flanking plication has only an outside branch.

In the largest well-preserved specimen (No. 198, Text-Fig. 58), the two median plications (resulting from bifurcation of the original single one at the beak) not only bifurcate themselves at a very early stage, but there are three lateral plications between this group and the flanking plications, the longest on the inside, the shorter on the outside. Thus the fold in this specimen comprises a total of ten plications at the front. In this shell also each of the flanking plications has an outside and an inside branch, the latter apparently appearing

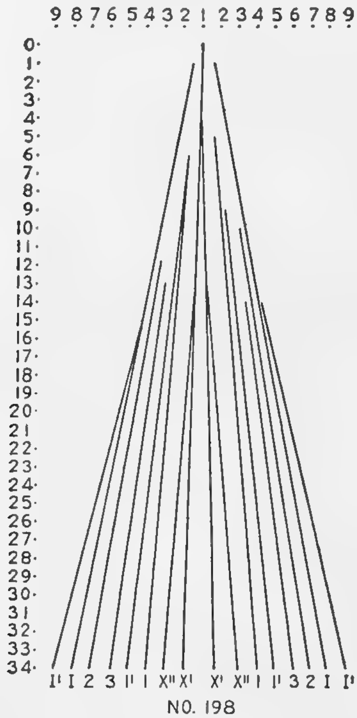


FIGURE 58.—(No. 198) Diagram of the median sinal plications (x′, x′, x″, x″) and the lateral plications (I, I, I′, I′, 1, 1, 1′, 1′, 2, 2, 3, 3) in *Spiriferella salteri* var. *wimanni* Grabau, var. nov., mut. δ.

earlier. The second main plication also has an inside and an outside branch, beginning nearer the front than in the first plication. The characters of the others can not be determined. In specimen No. 196 (Pl. XXIII, Fig. 1), however, the five recognizable plications on the left side have inside and outside branches, these appearing progressively later in the successive plications outward. On the right side only, outward plications are visible in the first, second and third main plications. The fourth, fifth and sixth appear simple.

Surface:—Little can be determined regarding the surface characters of these shells, because of the state of preservation and the general exfoliation. No punctæ have been observed, but in places an extremely fine granular structure is visible. Nor have any striæ been seen. There are seen occasionally, however, fine nodulations on the summits of the plications, and at intervals stronger lamellose projections, where a strong growth line crosses them.

Interior:—Little can be determined regarding the interior of our shells, but so far as visible this corresponds essentially to the characters given as typical for the genus. In a specimen of mutation δ (No. 211, Pl. XXII, Fig. 9), the median elevated platform is well shown, supported and surrounded by its curving dental plates. The thickness of the shell and platform here is somewhat more than 8 mm. In the internal mold (Pl. XXII, Fig. 9), the striated muscular area enclosed by the curving ridges is relatively narrow, probably because of compression; the enclosing ridges (d) are well marked, and there is a secondary ridge beginning some distance from the dental plates and extending in a curve

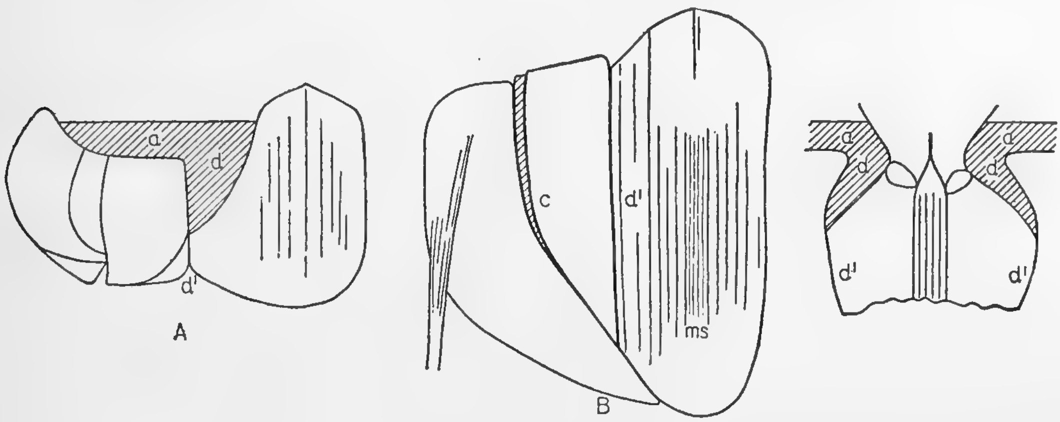


FIGURE 59.—Diagrammatic cross-sections (A, B, C) of *Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, mut. δ, x 2.

forward, finally joining the dental plate. The median septum (*ms.*, Text-Fig. 59) of the muscular area is faintly indicated by a groove (compare also Pl. XXII, Figs. 1a-e).

Horizon and Locality:—These shells are abundant in the *Spiriferella* bed (1209) of the Jisu Honguer limestone, where they are often almost the only fossil present and to which they appear to be chiefly confined. A single specimen of those described as mut. α (No. 203) was obtained from the *Marginifera typica* bed (1192).

Comparisons and Discussion:—The essential character which distinguishes this group of mutations from others with similar sinal and lateral characters of plications, is their elongate character in the adult. The hinge line occupies less than the greatest width of the shell below, and the length of the shell, if not the height, greatly exceeds the width. This is the character of the type of Tschernyschew's species *Spiriferella salteri* from the Schwagerina limestone and the Artinskian of Russia. The measurements of this form and a smaller one taken from Tschernyschew's figures are as follows:

	Tschernyschew, 1902	
	Fig. 5	*Fig. 6*
Height	32.4	25.0
Length	52.0±	40.0
Width	29.7	22.0
Hinge line	25.0	18.8

The essential character of this species, which distinguishes it from *Spiriferella saranæ*, a similar elongated form, is, as emphasized by Tschernyschew, the possession of the median fold. In his type specimen, which I take to be the one shown in his figure 5, there are three pairs of lateral sinal plications appearing in the usual order. So far as can be determined from the illustration, the smaller shell has only two pairs of lateral sinal plications. The bounding plications each have an outside branch which begins far up on the beak, while the second shell plication has both an inside and an outside branch, the former beginning earlier. The third and fourth appear to be similar. In the smaller shell the branching of the plication is less pronounced. The first sinal plication is undivided and the median plication is also simple. This corresponds therefore to the mutation γ as above defined, and this may be considered typical of the species. The simpler forms referred to as mutation β, with undivided lateral plications, may be referred to the variety *mongolica* (var. nov.). The simplest forms (No. 182), designated above as mutation α (var. *simplex*), may perhaps be referred to *Spiriferella saranæ*, though on account of the youthful stage of the shell this reference is uncertain. I am, however, quite ready to refer the larger form without median plication (No. 203) to that species; and this will be described farther on.

We may here note that the young stage of our primitive shells, especially that shown in No. 202, and in a measure also that shown in No. 182, have some of the characteristics of *Spirifer* (*Brachythyrina*) *strangwaysii* Verneuil of the Russian Mid-Carboniferous, and the var. *pankouensis* Grabau of the Taiyuan formation. This refers primarily to the relative development of the plications in the sinus, which in the older species consists of one median and generally two pairs of lateral sinal plications. The fold consists of a median plica which becomes broad and bifurcates forward and which has a strong lateral branch on either side. On the other hand, while our shells are sometimes as transverse as the older form, the number of lateral shell plications is less, these being scarcely over six in the Mongolian shell, while eight or even ten are characteristic of *Spirifer* (*Brachythyrina*) *strangwaysii* and its variety from the Taiyuan series. The hinge area also is lower in the latter shell. Finally the internal characters are quite distinct, and the two types can only be regarded as representatives of distinct genetic series, the external characters being merely homœomorphic.

A comparison of our shells with the original form of *Spirifer draschei* Toula from Spitzbergen, as refigured by Frech (Frech and Noetling, 1902, Vol. II, p. 498), shows marked differences. In that shell the sinus is very broad, the median plication is strongly developed but simple, and there are four lateral sinal plications on each side. In this respect, then, the shell is more specialized than any of our specimens, in which the number of lateral sinal plications never exceeds three on each side. None of the sinal plications divides. The bounding plication has one outside branch but the others are simple. The number of shell plications appears to be only five on each side, including the bounding plication and excluding its outside branch. In this respect it corresponds to one of the simpler forms of our mutation β (No. 189), but it differs from that in having one more sinal plication on each side, and in being more accelerated in the sinus than our shell.

Wiman (1914, p. 38, Pl. III) describes and figures a number of shells from Spitzbergen and Bear Island which he refers to Toula's species, though none of those he figures agrees wholly with Toula's type. A median plication is present on the sinus in all his figures, and he states that it is always the strongest, and in poorly preserved individuals is alone preserved. He adds that in exceptional cases even the median plication may be absent and replaced by a flat surface. In the more specialized forms the median plication is divided, this division beginning while the shell is still small (Wiman, 1914, Pl. III, Figs. 2 and 18). The total number of plications in the sinus resulting from new appearances and bifurcation, may, according to Wiman, reach fourteen, but none of his figures shows that number, ten being the maximum, that is, a bifurcated, first sinal pair, a simple second and third, and a bifurcated median plication.

Another feature characteristic of the shells from Bear Island is the bifurcation of the first lateral sinal plication. This occurs in forms with both simple and with divided median plications. This occurs generally in the anterior third of the shell but sometimes extends much farther back. As we have seen, this is characteristic of our mutation δ, which corresponds to the Bear Island shells with undivided median ribs. This correspondence, however, refers only to the sinal plications, for in those figured by Wiman, the branching of the lateral ribs is much less pronounced than in our mutation δ. In Wiman's Fig. 10, which corresponds to our mutation δ so far as sinal plications are concerned, there appears to be no outside branch on the bounding plications, and only a short inside branch on the second plication, with perhaps an indication on a third. This form might perhaps be referred to as $\delta -$, being equivalent to our mutation δ in the sinus but more primitive in the lateral plications.

On the other hand, the shells shown by Wiman (1914, Figs. 2 and 18) have their shell plications as complicated as in our mutation $\delta+$, while the sinus is more specialized in that the median plication also divides. This form may then be designated as $\delta+$. All these forms figured by Wiman belong to the mutations of the *Spiriferella salteri* series rather than to the typical form of Toula, the form of Toula differing in its relatively simple shell plication, and its sharply defined, very broad sinus, with four lateral plications and a simple median sinal plication, none of which is divided.

Since these shells are clearly a modification of the *Spiriferella salteri* type, which goes beyond the characters of the typical form, especially in the division of the first lateral sinal plication and often in that of the median plication as well, both $\delta-$ and $\delta+$ are to be included under a distinct varietal name, and I propose to call them variety *wimanni* after that versatile and eminent Swedish palæontologist and collaborator on Chinese faunas, Dr. Carl Wiman.

Under this variety we may then distinguish a further number of mutations. The simplest of these has the median plication undivided and few branches to the lateral plication (mutation ϵ). The second has a simple median sinal and strongly branched lateral shell plications (mutation ζ), the third a bifurcating median sinal and few branched lateral shell plications (mutation θ), and the fourth a bifurcating median sinal and strongly branched lateral shell plications (mutation τ). All have the first pair of sinal plications forked. Other mutations may be recognized.

Wiman states that the order of appearance of branches on the shell plications of his specimen is as follows, translated into the terms here used.

The first plication has an outside branch, the second and third each have an inside branch; in the fourth and fifth, the division is into essentially equal branches, while the sixth is simple. In exceptional cases, the broader plicæ suggest both inside and outside branches. Thus it appears that in regard to the branching of the shell plications the Spitzbergen and Bear Island shells are less specialized than the Mongolian mutation.

It must be remembered that the young of this shell is transverse with the greatest width in the hinge line. Hence the small shell figured by Wiman (1914, Pl. III, Figs. 5–8) cannot be the young of this species, since its hinge line is already much shorter than the width of the shell below, and the width is less than the height.

The brachial valves figured and described by Wiman show the median plication divided by a strong groove and three lateral supplementary plicæ on each side of them; the first, however, has the appearance of a branch or intercalated plica, being shorter than the second. The larger lateral shell plications have only a single short branch each.

Baron George Fredericks has figured a number of shells of this group from what is apparently an equivalent horizon near Vladivostok, Russia, a region which in Permian time was like the Jisu Honguer region of Mongolia, a part of the Mongolian geosyncline. Unfortunately Baron Fredericks' text is nearly all Russian, which I find indecipherable. Consequently I can make my comparisons only with his illustrations, which are for the most part satisfactory.

Fredericks refers all of his shells to *Spiriferella rajah* (Salter), which, as will be shown later, is a mistake, though some of them probably belong to that species. All of his simpler shells with the surface characters of our species, are of the transverse type, which is a primitive character, his shells in this respect being retarded, though specialized in respect to the surface features. They are, therefore, homœomorphs of the present series, but must be classed as a distinct genetic group. Forms of this type are also common in Mongolia and will be described farther on.

Several of the shells referred by Diener to *Spiriferella rajah* from Spiti, especially those figured by Diener (1903, Pl. IV, Figs. 2 and 5), may belong to this series rather than to true *Spiriferella rajah*, though the details of the pedicle valve are not determinable. In so far as the brachial valves of these two are concerned, they correspond to our simpler forms, since the median plication is divided only once (in Fig. 2) near the middle. There are indications of only two lateral plications on the fold, with the inner one the shorter (if correctly drawn). In the smaller form (Fig. 2 of Diener), there are only faint indications of branches on the lateral shell plications, while in the larger these plicæ have both an inside and an outside branch.

These shells may perhaps form transition types to the true *Spiriferella rajah*, since all these forms are phases of different degrees of acceleration. This may be taken by some as an argument for uniting them all in one species, a point of view I cannot subscribe to, unless we are willing to believe in the discontinuity of species due to sudden and abrupt appearance of specific characters. If, however, we regard evolution as proceeding by progressive modifications in definite directions, and differential acceleration in the development of the several characters along distinct genetic lines, we must select for our specific types those forms in which a distinct and sufficient developmental step has been taken, and group around these, within a certain radius, the various more or less accelerated and retarded types.

Broili (1916, Fig. 7) figures a number of large shells of this series from the Permian of Timor, referring them to *Spirifer rajah*, though they should be classed under the *Spiriferella salteri* series. These include shells with simple median plications, three pairs of lateral sinal plications, and with the second and some of the subsequent plications branched. There is a suggestion of a division of the first sinal plication on one side which would put this shell into our mutation δ, or in the form which it is proposed to designate var. *wimanni* Grabau.

The brachial valve has the two plicæ resulting from the bifurcation of the median plication, again divided into two parts, except in his largest shell (No. 4), which is of the δ type, but where these median plicæ of the brachial valve are not again divided. There are two lateral plicæ on the fold of this shell, but they are faint, while the others have both inside and outside branches. In the other shells (Figs. 1, 7a), where the two median plicæ are divided again (in 7a this division begins very early), there are also only two lateral plications on the fold, the tinier on the longer. The shell plications have outside and in some cases (Fig. 5) also inside branches.

The shell is transverse (being still immature), with the hinge-line shorter than the shell-width below. The adult shells are higher than they are wide and have the first pair of sinal plications distinctly divided, while the median plication also bifurcates in one of the specimens figured. The lateral plications are strongly branched, not divided, while the plications of the brachial valve are branched as well as divided. These shells are therefore referable to our mutation δ or the variety *wimanni*, but not to *Spiriferella rajah*. The other shells figured by Broili belong to distinct species.

It is noteworthy that the majority of the Mongolian shells, as well as those of Spitzbergen, appear to be more specialized than those of Russia, which would suggest a somewhat later horizon for the east Asiatic shells. From them, in turn, as will be shown, are derived the typical mutations of *Spiriferella rajah*, which are much more specialized than the members of the *Spiriferella salteri* series.

31. **Spiriferella rajah** (Salter)

Plate XXII, Figs. 1a-e (No. 194), 2a-b (No. 224), (No. 264), (Text-Fig. 60)

1865. *Spirifera rajah* Salter. Palæontology of Niti in the Northern Himalayas, Calcutta, pp. 59 and 111.

1866. *Spirifera rajah* Davidson. "Notes on Some Carboniferous, Jurassic and Cretaceous Brachiopoda Collected by Captain Godwin-Austin in the Mustakh Hills, Thibet." *Quart. Journ. Geol. Soc. London*, Vol. XXII, p. 40, Pl. II, Fig. 3.

1899. *Spirifer rajah* Diener. *Palæontologia Indica*, Ser. XV, Himalayan Fossils, Vol. I, Pt. 2, "Anthracolithic Fossils of Kashmir and Spiti," p. 68, Pl. IV, Figs. 1, 7, 5? (*cetera exclus*).

1916. *Spiriferella rajah* Fredericks. "On some Upper Palæozoic Brachiopoda of Eurasia." *Mém. Com. Géol. Russe*, New Ser., Livr. CLVI, Pl. V, Figs. 2, 3, 5 (*cetera exclus*).

This shell forms the other extreme of the series of which *Spiriferella salteri* and var. *mongolica* (mutations α and β) form the simpler end. Like all the typical members of this series, the center of the sinus is characterized by a median plication. The slopes of the sinus carry three pairs of lateral sinal plications, of which the first may divide. In addition, the bounding plication has an outside branch, and the main part is divided by a median groove into two equal branches. Thus the whole plication appears covered with uniformly finer plications, and the same thing is true of the sinal slopes. This is well brought out by Davidson's figure and some of those published by Diener and

Fredericks, and should be taken as the characteristic feature of this species. The same feature characterizes the other plications: there are not only inside and outside branches, but the main plication divides so that there are at least four uniformly smaller plicæ completely covering the larger one. The shell is of the elongate series, higher than it is wide, with the hinge-line shorter than the greatest width below.

This species is rare in Mongolia, only a few specimens having been obtained. No. 194, which can be referred to it and is the best specimen, is not quite typical. It is shown in Plate XXII, Figs. 1a-e, and represents an internal mold with the shell preserved in the anterior half of the pedicle valve, and over

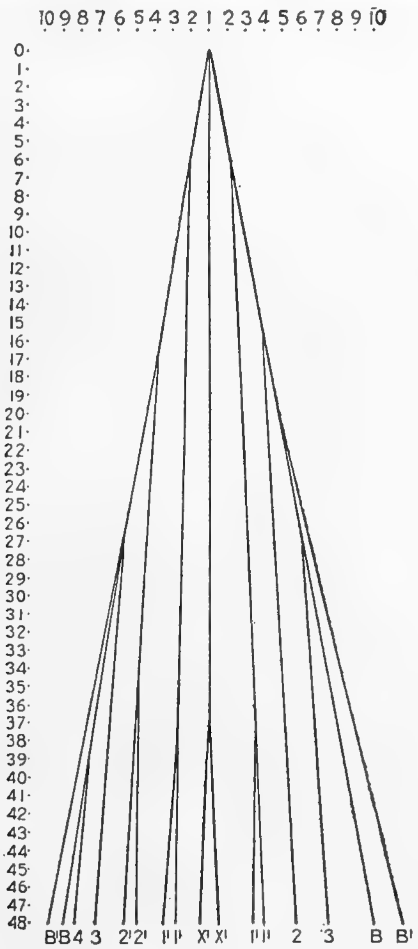


FIGURE 60.—(No. 194) Diagram of the bordering plications (B, B, B′, B′), the median sinal plications (x′, x′), and the lateral plications (1′, 1′, 1′, 1′, 2, 2′, 2′, 3, 3, 4) in *Spiriferella rajah* (Salter) (interior).

most of the brachial valve. In general appearance, the sinus is shallow and the plications are broad and low, covered with numerous subequal finer plicæ. An analysis of these gives the following result (Text-Fig. 60):

The median plication of the sinus is strong and divides near the front. The first lateral sinal plication on the right also divides at about the same time, that on the left somewhat earlier. The second sinal plication on the left also divides near the front, somewhat later than the first, but on the right it remains simple. The third is simple on both sides. The bounding plication, which is only slightly wider than the branches, has an outside branch in each case which begins earlier than the third sinal plication. On the left side the bounding plication itself shows a narrow median groove near the front, indicating the beginning of a division, but on the right side this feature is not seen. There are thus in all five sinal plications at the front on the left side and four on the right, making with the two branches of the median plication a total of eleven plicæ near the front. To these are added the three lateral branches of the bounding plication on the left and two on the right.

The second shell plication on the left has an inside branch dividing near the front and a simple outside branch; the main part of the plication also divides near the front, giving thus five finer subequal plications. A similar, slightly less pronounced condition exists on the right. The third plication shows the same five-fold character on the left, but on the right the plications do not divide, there being thus only a main and two lateral branches. In the fourth plication on the left, the main stem divides but not the branches, the number thus being four at the front, while the fifth and sixth plications have only simple branches, being three-fold at the front. On the right they appear somewhat simpler but the preservation is not so good. Summarized, the plicæ near the front of the shell are as follows:

	(Left)						sinus			(Right)					
Plica number	6,	5,	4,	3,	2,	1	sinal	center	sinal	1,	2,	3,	4,	5,	6
No. of branches	3	3	4	5	5	3	5	2	4	2	4	3	3	3	2?
				28				2				22			

Here, then, we have the complexity produced by the bifurcation of the main plications and, in some cases, that of their branches. On the left of the center of the shell, there is a total of twenty-eight smaller plications modifying the sinus and the six large plications. If the development were symmetric the total number on both sides would be fifty-six.

In the brachial valve, which is more strongly convex proportionately than in the other forms described, the characters are less well-preserved, but some of them can be determined near the front. The main median fold bifurcates near the beak, and at the front the branches appear to bifurcate again, especially on the right. There are three or perhaps four plications on the slope, but their origin is obscure. On the right the first lateral shell plication has an inside and an outside branch, while the trunk divides near the front, giving four plicæ. The second plication is like it, but in addition the outside branch forks, giving five plicæ. The third and fourth show only simple trunks with inside and outside branches or three plicæ each. There is no fifth. On the left the state of preservation does not permit analysis, but the general aspect of the plications suggests a similar complexity.

This is by far the most specialized shell in our collection, but it is seen that the specialization proceeds in a regular manner, and progressively, that is, it is purely orthogenetic. It is also seen that this shell is the terminal member, so far as at present known, of the developmental series which began with the simple mutation α of the *Spiriferella salteri* group, and that throughout every step is represented, with variations, which mark short lateral excursions in development, these being the result of differential acceleration of one developing sector or retardation of another or simultaneity of both.

The apical portion of this shell shows only the internal mold, on which are impressed the shell characters of the interior of the rostral region. The elevated median platform is recognized. Its floor is sharply convex and longitudinally striated. It is bounded by forward-converging ridges which are really the abruptly descending forward margins of the platform. The muscular area in front of it is bounded by the converging lamellæ, the point of meeting of which is still covered by shell matter. It is strongly grooved longitudinally in the mold, these grooves representing the parallel striæ; a slightly deeper groove represents the median septum. Outside of this the plications of the mold are covered by about five longitudinal striæ, each of these representing the internal expression on the shell of the division of the plications into finer plicæ as above described. This appears to have been more strongly marked on the interior than on the exterior of this part of the shell.

Measurements:—Since the preservation of the apical portion is incomplete, the shell being wanting, the measurements of the heights and lengths are much less than they would be in the perfect shell. An estimate of the original height and length is added in the second column of the table, the first giving the actual measurements of the specimen.

	No. 194	
	Actual Measurements	*Estimated Original Measurements*
Height of pedicle valve	35.0 mm.	40 mm.
Length of same	41.0 mm.	48 mm.
Height of brachial valve	35.0 mm.	36 mm.
Length of same	39.0 mm.	42 mm.
Greatest width	36.2 mm.	....
Length of hinge-line	27.3 mm.	....
Maximum thickness	22.2 mm.	....

Another much crushed and broken specimen (No. 224, Pl. XXI, Figs. 2a-b) shows the two valves in conjunction, but while the complex character of the branching and division of the plications is evident, the precise order cannot be ascertained. Both the median and the first pair of lateral sinal plications are divided at a very early state, and the second sinal appears to divide likewise. Thus there are at least twelve finer plications in the sinus at the front. The bounding plication has an outside branch and also divides, while the branching and division in the second plication produce five plicæ which extend for at least half the shell length. What is visible of the other plicæ shows similar complexity.

The brachial valve also shows pronounced division. Each of the two branches, resulting from the bifurcation of the median fold at the beak, again bifurcates at the front. There are three flanking plications on the side of the fold, the outer one of which again divides at the front. The lateral plications have both inside and outside branches, but further details are not determinable.

Horizon and Locality:—In the *Spirifer moosakhailensis* bed (1205) of the Jisu Honguer limestone of Jisu Honguer, Mongolia, and in the *Spiriferella rajah* bed (1209) of the same formation, where it is associated with other species of the *Spiriferella rajah* series. Collector, F. K. Morris.

Comparisons:—Compared with Davidson's figure (partly restored) of a Himalayan specimen of this species, we find fewer plications in the sinus, neither the median nor any of the laterals showing bifurcation in his shell. Thus there are only five plicæ in all for the lateral sinal and those of the bounding plication, instead of eight as in our shell (exclusive of the median one). The other plications, however, are subdivided much as are those of our shell, but the actual number of coarse plications is greater, being about nine as compared with five in our shell. The brachial valve of Davidson's shell is also less complicated, being more like that of *Spiriferella salteri* var. *wimanni* Grabau, with branched but not bifurcated lateral plications. The median plication is represented as undivided.

Two specimens of *Spiriferella rajah* from the Himalayas figured by Diener (1903, Figs. 1 and 7, Pl. IV) show essentially the characters of our shell. The lateral sinal plications bifurcate as does also the main stem of the bounding plication, until there are altogether seven secondary plicæ in the larger, which is nearly the same as in our shell, while in the smaller there are six. In this shell the second plication has four secondary plicæ and the third and fourth have three each. In the larger shell, on the other hand, the second, third and fourth plications have five secondary plicæ each, the others being flattened out so that only the plicæ are recognizable.

Baron Fredericks (1916) figures several pedicle valves of this type from the Permian deposits near Vladivostok. Two of these, represented by Figs.

2 and 8 of his plate V, he refers to variety *typa*, forma *magna*, nom. nov., but the exact basis of his classification is not determinable, though it may be given in the Russian text, which is indecipherable. The measurements of his larger shell (Fredericks, Pl. V, Figs. 2a-b) are as follows, according to his illustrations:

Height	65 mm.
Length on curvature (Fig. 2b), about	85 mm.
Greatest width, about	66 mm.
Length of hinge line	54 mm.

The strong median plication is divided for most of its length. The first lateral sinal plication also divides above the mid-length, and the second, which begins far up, also divides near the front. The third appears to be simple. There are thus five plications on each side of the sinus near the front and two in the middle, corresponding to our shell. The bounding plication is, however, undivided, and has no outside branch. The second lateral shell plication is divided into three parts, these parts again dividing by bifurcation into minor branches. The total number of divisions is not ascertainable with certainty but appears to be five. The third plication has at least four, if not five, secondary plicæ. The others are not determinable.

The specimen represented by Fredericks (1916, Pl. V, Figs. 8a-b) is incomplete but apparently has a length of 50 mm., with a hinge width of 45 mm. or more, and a width below of nearly 55 mm. The length on the curvature, as measured from Fig. 8b, is 63 mm. The median plication is comparatively faint, but the first and second pair of lateral sinal plications are divided medially, while the third is simple and short. The bounding plication in this case is also divided, the division beginning far above the middle, but it has no outside branch. The second shell plication is divided into three branches, each one of which bifurcates near the front, so that it gives rise to six distinct branches. The third plication is similar, though less pronounced, there being only five plicæ. The fourth plication is still more simple, while the fifth and last pair appears to be undivided. This shell is transverse for a longer period than is normally the case, and it may be a member of the transverse or retarded series with homœomorphic plical development.

A second variety described by Fredericks is var. *saranæformis* and is based on *Spiriferella saranæ* (Verneuil) Tschernyschew, though the reason for such comparison is not obvious. *Spiriferella saranæ*, as we have seen above, is a totally distinct form without median sinal plications, and with essentially simple primary plicæ, though these may develop branches.

The shells referred by Fredericks (1916) to this variety are separated into three subvarieties or forms. The first is forma *vera*, and is represented by Figs. 3 and 9 of his plate V. Fig. 3 represents an extremely elongated narrow form, the height being about 63 mm., the width on the hinge 44 mm., and the width below about 48. The length on the curvature, so far as can be ascertained from Fig. 3b, is 85 mm. This form has something of the outline and high, short hinge area of *Spiriferella saranæ*, as figured by Tschernyschew, but is more complex. The sinal plications are numerous, and at least two of them bifurcate, while the median plication is well developed. The bounding plications are also repeatedly divided, so that the total number of the secondary plicæ on the side of the sinus and on the bounding plication is at least eight. The second and third plications are divided into at least five secondary plicæ by branching and bifurcation. The others are obscure. Fig. 9 of Fredericks' plate shows only the cardinal region of a shell referred to this subvariety and therefore gives no clue to its other characters.

The second form of var. *saranæformis* is forma *lata*, shown in Fig. 6 of Fredericks' plate V. This is a broad type, so far as can be judged from the figures, with a length of about 50 mm. and a width on the hinge of about 45 mm. The width below the hinge line is slightly greater, about 54 mm. The median plication is divided for the greater part of the length, and the first pair of sinal plications divides very early. The second pair is simple, beginning far up on the shell, and the third pair is hardly developed. The bounding plications are without outside branches, but the next shell plication has both an inside and an outside branch, the former beginning earlier and being somewhat stronger than the latter. The next, that is, the third plication, is apparently similar, though the division near the front is greater, so that there are at least five resulting branches. The third plication also divides rather strongly, the details not being ascertainable from the figure. This form is probably referable to the transverse series to which *Spiriferella keilhaviiformis* belongs (see below).

The third type described by Fredericks, which he denominates forma *intermedia*, being intermediate between *lata* and *vera*, is represented by Figs. 5a-c of his plate V. This has a length of some 60 mm., a width on the hinge line of 40 mm., and a width below of 50 mm. The length on the curvature, so far as can be ascertained from Fig. 5b, is 80 mm. The median plication of the sinus is strong, as are also the other sinal plications. The first pair divides about midway of the length of the shell. The second and third pair are simple. There is a slender outside branch of the bounding plication, the latter apparently bifurcating. Thus there are seven plicæ at the side of the sinus and the bounding plication. The second plication has an inside branch beginning far up on the shell, and an outside branch beginning later and not becoming so strong. The main stem appears to divide near the front, thus making a total of four secondary plicæ for this plication. The third plication has an inside and apparently a shorter outside branch, though the details cannot be determined from the figure. The fourth is still simpler.

This appears to be one of the most primitive members of this series, but because of the splitting of the stems of the plications, it is still referable to *Spiriferella rajah*. Like the forma *vera*, it has a high arched hinge area, but this is not as short as in that form, nor is the umbonal region so compressed.

Thus three of Fredericks' shells are referable to *Spiriferella rajah*, namely, his Figs. 2a-b, 3a-c, and 5a-b, Plate V. The others must be referred to other species.

32. **Spiriferella saranæ** (Verneuil)

Plate XXII, Figs. 4a-b (No. 203), (Nos. 212, 213, 214, 215, 246, 259), (Text-Fig. 43, p. 132)

1845. *Spirifer saranæ* Verneuil. Géologie de la Russe d'Europe et des Montagnes de l'Oural, Vol. II, p. 169, Pl. V, Fig. 15.

1902. *Spiriferina* (*Spiriferella*) *saranæ* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 522, Pl. XII, Fig. 4; Pl. XL, Fig. 7 (older bibliography on p. 121).

1914. *Spirifer saranæ* Wiman. "Über die Karbonbrachiopoden Spitzbergens und Bären Eilands." *Nova Acta R. Soc. Sci. Upsaliensis*, Ser. IV, Vol. III, No. 8, p. 35.

This species, originally obtained from north Europe, appears to be sparingly represented in our rocks. Like the members of the preceding series, it is transverse in the young or at least quadrilateral, but becomes elongate in the adult. The other essential character is the absence of the median plication of the sinus, though lateral sinal plications are present, these in some very large individuals increasing to four on each side of the sinal slopes. They are, however, mostly very faint. The number of shell-plications on each side of the sinus is from six to eight, and they are typically simple, rounded, and separated by deep, sharp and narrow furrows. In exceptional cases (that is, accelerated forms) there appears in some of them an indication of the formation of an inside branch.

As previously stated, it is not possible to determine whether the simplest form of the series above described as mutation α of *Spiriferella salteri* (No. 182) is referable to that species or to the present one. As in the case of another of these shells (No. 202), the median plication may appear late (in No. 202 it does not appear until the shell has reached the size of No. 182). There is, however, little doubt in my mind that the specimen No. 203 is really referable to the present species, there being no indication of a median sinus, although the shell length (on the curvature) is 54 mm.

The beak, though broken in preparation, was strongly incurved, with a very high, strongly curved cardinal area, the height of which in the center, as nearly as can be ascertained by measurement along the curvature, was at least 25 mm. Tschernyschew says that in some cases the height may equal the length of the hinge line.

Measurements:—It is not possible to give the full measurement, because of its imperfect character, but those of an earlier stage, as shown by the growth line, may be given, and to these the estimate of the others may be added.

Pedicle valve	*No. 203*	
	Immature	*Full size*
Height	32.0 mm.	39.5 mm.
Length	48.0 mm.	54.0 mm.
Width	34.0 mm.	36.? mm.
Hinge line	27.5 mm.	32.? mm.
Height of hinge area	19.0 mm.	25.0 mm.

The sinus is pronounced, though not quite as sharp as shown in Tschernyschew's figure. The shell is exfoliated, and so the characters are not fully shown, but at least three lateral sinal plications are indicated, the first beginning about 12 mm. from the beak on the left side and somewhat later on the right, while the second begins about 27 mm. from the beak. A third is more strongly marked on one side (right) than on the other, and beginning about 34 mm. from the beak. There may be others, but if so they are very faint. There is no median plication.

The bounding plication is round but near the front has a suggestion of an outside branch. There are in all six lateral shell plications on each side of the sinus, but the sixth is very faint. They are broadly rounded and divided by narrower grooves. Some of them show a faint flattening or even a light grooving on top, and in one or two cases branching is suggested, which, however, is not pronounced. The finer surface characters and internal structure are not determinable.

What appears to be a brachial valve of this species has been obtained from these strata (No. 215). The specimen is imperfect but appears to have been elongate with the hinge line shorter than the width below. The median fold is simple, without groove, and there are at least four simple lateral shell plications, which are narrow and separated by broader round-bottomed interspaces corresponding to the narrow grooves and broad plications of the pedicle valve respectively. There are no marginal plications on the median fold, and the valve is rather strongly convex in the umbonal region.

Horizon and Locality:—In the *Marginifera* bed (1192) of the Jisu Honguer limestone of Jisu Honguer, Mongolia. One nearly perfect and a number of fragmentary pedicle valves from the *Spiriferella rajah* and *Orthotychia* beds (1209, 1211). Also an imperfect brachial valve apparently from the *Spiriferella rajah* bed. Collector, F. K. Morris. The species has been recorded from the Urals, Spitzbergen and Bear Island.

33. **Spiriferella persaranæ** Grabau, sp. nov.

Plate XIX, Figs. 4a-b (No. 179), (Text-Fig. 61)

This is a shell of the *Spiriferella saranæ* type, in which the median plication of the sinus is absent, while the form of the shell is elongate with the high hinge area and over-arching beak of the pedicle valve.

Measurements:—The measurements of the only specimen obtained, a pedicle valve which is probably immature, are as follows:

	No. 179
Height	18.5
Length	29.0
Width	20.8
Length of hinge line	19.0
Height of area	9.0±
Width of delthyrium	5.0

The area is strongly arched, and in some parts a vertical striation is visible. The delthyrium is narrower than it is high, occupying only about one-fourth of the hinge area.

The sinus is relatively narrow and rounded at the bottom, without median plication but with two pairs of lateral plications. The first pair begins 5 mm.,

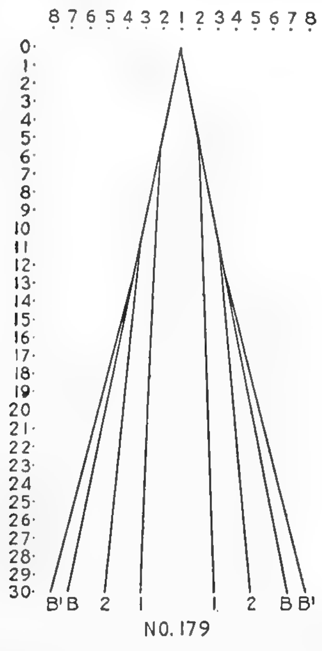


FIGURE 61.—(No. 179) Diagram of the bordering plications (B, B, B', B') and lateral sinal plications (1, 1, 2, 2) in *Spiriferella persaranæ* Grabau, sp. nov.

and the second 11 mm. from the beak (Text-Fig. 61). These plications, however, remain very weak, being scarcely visible except under a magnifier.

The bounding and lateral shell plications are, however, well marked and show a decided advance in development over the normally simple plicæ of *Spiriferella saranæ*, corresponding in character to the plicæ of *Spiriferella salteri* (mutation γ). The bounding plication has a strong outside branch, which begins about 12 mm. from the beak. The second plication has a strong inside branch, beginning a little later than the outside branch of the bounding plication, and an outside branch beginning still later. The third plication has an inside branch beginning farther forward, but the other branches are not recognizable. The fourth and fifth plications are simple, the last being much the weaker. In this shell the development of branches is chiefly confined to the shell plications, those of the sinus remaining weak, though the second pair is somewhat stronger than the first.

Horizon and Locality:—In the *Marginifera* bed (1192) of the Jisu Honguer limestone of Mid-Permian age at Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—This specimen was originally identified as *Spirifer* (*Spiriferella*) *tibetanus* Diener and was so referred to in the preliminary note on these fossils published in my Stratigraphy of China, Part I, p. 340. It differs, however, from that form by its longer hinge line and the absence of the median plication. The *Spiriferella tibetanus* series is the homœomorph of the *Spiriferella rajah* series, but is a smaller, more triangular form, which has a short hinge line at a stage when the members of the *Spiriferella rajah* series are still transverse. It runs through the same series of mutations as does *Spiriferella salteri*, though no specimens as complex as *Spiriferella rajah* have been observed. *Spiriferella tibetanus* is at present known from the Himalayan region in Tibet (Chitichun), from northern Russia and Spitzbergen (Wiman, 1914, Pl. III, Figs. 5–8), but not from Mongolia.

The **Spiriferella keilhaviiformis** Group

This series is one with a large number of mutations which parallel those of the *Spiriferella rajah* series, but the shells are transverse, even in the adult, where, however, they may become nearly quadrangular but never elongate. Thus they present a series retarded in respect to the relative mode of growth, for they retain the primitive transverse form throughout, a form which is characteristic only of the young stages in the *Spiriferella rajah* series. So far as surface plications are concerned, they probably parallel every mutation of the *Spiriferella rajah* series, and some of these on that account have been placed in the *rajah* group as transverse members. A further characteristic of this group is the relatively lower hinge area and the less strongly incurved beak of the pedicle valve.

Both this and the *Spiriferella rajah* series have a common ancestor in a simple transverse shell with median plications and simple lateral shell plications. From that ancestor probably the *Spiriferella tibetanus* series was also derived, though the *Spiriferella saranæ* series is of simpler character and probably earlier ancestry.

Baron Fredericks (1916) figured a number of these shells from Vladivostok as varieties of *Spiriferella rajah* Salter, and there is a fair representation of this type among our Mongolian shells. Tschernyschew has figured and described one member of this series from the Ural region as *Spiriferella keilhavii* v. Buch, but this figure does not seem to bear out this reference. Diener has already called attention to the fact that one of the great differences between the members of the *Spiriferella rajah* series and those of the *Spiriferella keilhavii* series is the absence of the median plication in the sinus, in the latter shells, whereas it is constantly present in the *Spiriferella rajah* series. I may add that this median sinal plication is also a constant character of our transverse series here discussed. Now it would appear from Tschernyschew's figure that his shell has a median plication, which, however, is divided into two parts from a very early stage. The first pair of sinal plications also divides earlier on the left than on the right side, and there are two other simple lateral plications which appear progressively in the usual order of succession between the first pair and the bounding plication. Thus are produced the five plications on either side, of which Tschernyschew speaks in his text, but one of these five is the branch of the median plication, while, because of the division of the first pair of lateral plications, the normal three lateral plications produce four plications at the front.

This shell in its sinal plication is therefore in the more advanced mutation stage δ of the *Spiriferella salteri* series in which the median plication is also divided. If this interpretation is correct, we can follow Baron Fredericks, who has renamed this form *Spiriferella keilhaviiformis*, though he makes it a variety of *Spiriferella rajah*. I am unable to say whether Fredericks' reasons for this change are due to his perception of the presence of a median plication, since his text is in Russian. As he figures a form from Vladivostok, however, in which a median plication exists, and refers it to *Spiriferella keilhaviiformis*, there seems to be no reason against adopting his term (based on adequate illustrations), whatever the character of Tschernyschew's type. Three types of *Spiriferella keilhaviiformis* are recognized, of which variety *vulgaris* is the simplest.

34. **Spiriferella keilhaviiformis** var. **vulgaris** Fredericks

1916. *Spiriferella rajah* var. *vulgaris* Fredericks. "On some Upper Palæozoic Brachiopoda of Eurasia." *Mém. Com. Géol. Russe*, New Ser., Livr. CLVI, Pl. V, Figs. 1a-b, 4a-b. (Text in Russian.)

This is the simplest of these transverse forms with median plication so far recognized. The specimens figured by Fredericks from Vladivostok are both pedicle valves and have the following dimensions, as nearly as these can be determined from his figures, which are presumably of natural size.

	a Fredericks Fig. 1a-b	*b* Fredericks Fig. 4a-b
Height	30.0	42.0
Length	45.0	77.0
Width (maximum)	41.0	50.5
Length of hinge line	41.0	42.0

The median sinal plication of the first of these shows a median groove, while that of the second appears to be simple. There are three pairs of lateral sinal plications in the smaller shell (*a*), none of which divide, while the larger shell has apparently only two pairs of simple lateral plications. The bounding plication has no outside branch. The second, third, fourth and fifth plications of the shell have inside branches in the first specimen, the fifth also showing indications of an outside branch on the left side, while on the right it appears to be simple. The sixth plication is weak and simple. In the larger specimen (*b*), the second, third and fourth plications have inside branches, while the others appear to be simple.

If the diagnosis here given from Fredericks' figures is correct, this form is simpler than any yet found in the Mongolian rocks. All of our shells of this type are more specialized and must be referred to the typical form of the species, or, since they do not wholly agree with that, to a mutation of the same.

Horizon and Locality:—At present known only from the Permian deposits of the Vladivostok region, Russian Far East (Fredericks).

35. **Spiriferella keilhaviiformis** Fredericks

Plate XXI, Figs. 6 (No. 216), 7 (No. 217); (Nos. 208, 218, 222)

1916. *Spiriferella rajah* var. *keilhaviiformis* Fredericks. "On some Upper Palæozoic Brachiopoda of Eurasia." *Mém. Com. Géol. Russe*, New Ser., Livr. CLVI, Pl. V, Fig. 7. (Text in Russian.)

cf. 1902. *Spiriferella keilhavii* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 527, Pl. XL, Figs. 1–4.

The specimen which Fredericks has taken for his type of this form is transverse with well-marked median plication and a complicated subdivision of the plicæ. He considers that Tschernyschew's shell also belongs to this form and not to the true *Spiriferella keilhavii*, and in this I am inclined to agree with him, if my diagnosis of Tschernyschew's shell, taken from the illustrations, is correct. The dimensions of the two forms are as follows:

	a *Fredericks* *Pl. V, Fig. 7*	*b* *Tschernyschew* *Pl. XL, Fig. 1*
Height	45	42
Length	. .	61
Greatest width	53	50+
Length of hinge line	45	48

The characters of the type figured by Fredericks are as follows, so far as can be determined from the figure, the text being indecipherable. The median sinal plication is well developed and grooved in the middle. There are three pairs of lateral sinal plications, which appear to divide near the front so as to produce four plicæ. The bounding plication has an outside branch near the front. The second plication has both an inside and an outside branch, the former beginning far up on the shell. The median part of the stem of this plication also divides at the front, thus producing four plicæ. The third and fourth plications are of similar character, each producing four plicæ near the front. The characters of the fifth are not readily determinable, but it too seems to be divided into several plicæ.

The shell figured by Tschernyschew is similar, except that the median plication is strongly divided throughout its length, and the division of the first lateral sinal plication begins early. The other two are simple. Thus the sinus has four pairs of lateral plicæ at the front, and two median ones, or a total of ten plicæ. The bounding plication has an outside branch which begins far up on the beak and becomes pronounced and strong near the front. In this respect, as in the case of the division of the median and first pair of lateral sinal plications, this shell is more specialized than that figured by Fredericks as his type. In respect to the branching and division of the shell plications, Tschernyschew's shell is also more complex, but the exact details of development can not be accurately determined from his figure. The branches of these plications appear early, and some of them become quite distinct from the main one near the front. As a result, the main plications are not determinable, the shell appearing as if covered with numerous rather unequal fine plicæ.

Among the specimens from the *Spiriferella rajah* bed (1209) of the Jisu Honguer limestone, there are several pedicle valves which are referable to this species. A fragment with the beak and one side missing (No. 216, Pl. XXI, Fig. 6) shows a median and three pairs of lateral sinal plications, the first pair rather faint. Because of the exfoliated character of the shell it can not be determined whether any division of the sinal plication occurred. The bounding plication appears to have had an outside branch, while inside and outside branches appear to have been characteristic of the other shell plications. Near the front, a part of the shell is better preserved; and here it is seen that in the third, fourth and fifth plications there are not only inside and outside branches, the former beginning far up, but the inside branch as well as the main stem divide near the front, so that there are five secondary plicæ for each of these primary plications. The sixth plication also branches, but the details can not be determined. The surface is further modified by concentric lines which produce nodulations on the secondary plicæ, as has been found characteristic for other shells of these series.

The width of this specimen is approximately 42 mm., the length of its hinge line about 40 mm. The hinge area is high and arched and shows vertical striations. The height of the shell can not be determined but is apparently less than the width.

Another specimen (No. 217, Pl. XXI, Fig. 7) shows the beak and the greater part of one side. The width is approximately 46 mm., with a height probably not over 35 mm. and a length of hinge line of perhaps 31 or 32 mm. The median plication appears to be simple, at least in the earlier part shown, and there are at least two pairs (possibly three) of lateral sinal plications. Whether division occurs near the front can not be determined. The bounding plication appears to have an outside branch (not clearly determinable). The second plication has an inside and an outside branch, the former dividing near the front. The main stem of the plication also divides, but unequally, giving the appearance of a second inside branch. Thus there are five secondary plicæ altogether, near the front of the plication, one somewhat larger than the others. The other plications show only an inside and an outside branch, the former beginning earlier than the latter. It is probable that the main stem is divided at the front, but this is not positively determinable.

Our largest pedicle valve (No. 208, not figured), has the following dimensions:

	No. 208
Height	37 mm.
Length	52 mm.
Width	59.5 mm.
Length of hinge area	50.0 mm.

The hinge area is high and strongly arched, and the beak is well incurved. The median plication is divided for practically its entire length, and there are three (?) pairs of lateral sinal plications, the first pair of which appears to be divided near the front, while the bounding plication has a short outside branch. These facts, however, are not very clearly shown, since the specimen is strongly weathered in the frontal region of the sinus. The second and third plications have each a strong inside branch which begins far up on the beak, that of the third one somewhat later than that of the second. There is also a shorter outside plication, and the third has its stem divided at the front, there being also an indication of the division of the inside branch near the front, making five secondary plicæ. Similar conditions probably are obtained in the second plication but are not shown because of weathering. The fourth plication clearly shows the division of the stem near the front and the outside branch, the inside branch is broad, but the division, if it exists, is not apparent. There are thus four plicæ, with the inside branch broad, and perhaps also divided, making five in all. The fifth plication, however, shows the division of the inside branch, and in one spot of the stem also; the rest is obscured by weathering on the left side of the shell; the division of the stem is seen far up on the plication (though obscured on the front), and the two branches also begin very early. The character of the sixth plication is not determinable.

Where best preserved, the concentric ornamentation of narrow nodules on the plications is well shown.

A brachial valve, No. 218, associated in the same rock mass with the pedicle valve just described, has the following dimensions:

	No. 218
Height	32.? mm.
Length	45.? mm.
Width	62.0 mm.
Length of hinge line	56.0 mm.

It is rather strongly arched, especially in the umbonal region, the beak being elevated above the cardinal angulations and incurved. Almost from the beginning, the median fold divides into two branches, which become strong and broadly rounded towards the front and are divided by a somewhat narrower round-bottomed groove. There are six plications on either side of the central pair, these appearing simple because the shell is entirely exfoliated. In a few cases, however, there is an indication of branching, an inside branch being clearly indicated on the second and fourth plications on the right side of the shell. There is also an indication of a finer striation on the plications, seen especially on the median pair.

Because of its apparent simplicity, this brachial valve may belong to another species, though it is highly probable that the simplicity is due only to the weathering away of the shell.

The cardinal angles are obtuse, and there is a distinct concavity on either side of the umbonal region in the transverse contour of the posterior part.

Horizon and Locality:—In the Jisu Honguer limestone of Mongolia, *Spiriferella rajah* bed (1209) (Nos. 208, 216, 217, 218, 222). Collector, F. K. Morris.

Remarks:—So far as our material permits us to judge, there seems to be pretty close agreement of characters of all the specimens with that figured by Fredericks as *Spiriferella rajah* var. *keilhaviiformis* and also with the figure of *Spiriferella keilhavii* given by Tschernyschew. The shell is nearly as complex as is typical *Spiriferella rajah*, but is readily distinguished by its transverse character, which is frequently very pronounced. When weathered, the characters are obscured and the plications often appear simple.

The species is known from the Mongolian geosyncline (Vladivostok and Jisu Honguer) and from the Ural region of Russia.

36. Spiriferella keilhavii (v. Buch)

Plate XX, Figs. 9a-c (No. 227); Plate XXI, Figs. 1 (No. 227), 2a-c (No. 226), 3 (No. 228), 4 (No. 230), 5 (No. 236), (Nos. 229, 231, 232, 233, 235, 247)

1846. *Spirifer keilhavii* v. Buch. "Uber *Spirifer keilhavii.*" *Abhandl. K. Akad. Wissen. Berlin*, Jahrg. 1846, p. 74, Fig. 2a and b.

1914. *Spirifer keilhavii* Wiman. "Uber die Karbonbrachiopoden Spitzbergens und Bären Eilands," *Nova Acta R. Soc. Sci., Upsaliensis*, Ser. IV, Vol. III, No. 8, p. 36, Pl. II, Figs. 25–30; Pl. III, Fig. 1 (other synonymic references).

This species bears the same relationship to *Spirifer saranæ* that *Spiriferella keilhaviiformis* bears to the *Spiriferella rajah* series. It is the transverse form with lower hinge area, relatively more equal convexity of valves, and with essentially the same surface structure characterized especially by the absence of the median plication. It is well represented in our collection.

Measurements:—The dimensions of a number of these are given in the following table.

	0 Spitz-bergen Shell	*1* No. 227 a	*2* No. 227 b	*3* No. 228 Pl. XXI, Fig. 3	*4* No. 230 a Pl. XXI, Fig. 4	*5* No. 230 b Pl. XXI, Fig. 4
		Pl. XX, Fig. 9 Pl. XXI, Fig. 1				
Height of pedicle valve....	37.8	20.0	29.2	33.3	21.0	33.0
Length of pedicle valve....	60.0	30.0	41.0	46.0	29.0	48.0
Height of brachial valve...	31.3	14.5	24.0	....	....	....
Length of brachial valve...	37.0	16.5	28.5	....	....	....
Maximum width..........	48.2	30.0	37.0	46.0	40.0	45.0
Length of hinge line.......	48.2	30.0	37.0	43.0?	40.0	45.0
Width of delthyrium......	....	....	7.5	....	....	....
Height of hinge area.......	....	....	7.0	....	....	....
Thickness of entire shell...	23.5	....	8.5	....	....	....

	6 No. 236 a Pl. XXI, Fig. 5	7 No. 236 b Pl. XXI, Fig. 5	8 No. 235 a	9 No. 235 b	10 No. 226 Pl. XXI, Fig. 2
Height of pedicle valve	21.5	39.0	27.0	42.0	49.0
Length of pedicle valve	26.0	49.0	39.0	63.0	67.0
Height of brachial valve	....	....	....	....	....
Length of brachial valve	....	....	....	....	....
Maximum width	41.0	64.0	52.0	54.0	78.0
Length of hinge line	41.0	64.0	52.0	54.0	68.0
Width of delthyrium	....	....	....	....	14.0
Height of hinge area	....	....	....	....	15.0
Thickness of entire shell	....	....	....	....	....

In column 0, the measurements of a typical specimen from Bear Island are given, taken from Wiman (1914, Pl. II, Figs. 25–27).

The first measurement (No. 227 a) is of an immature stage indicated by a strong growth line. The second (No. 227 b) gives the full size of the specimen.

In all the immature stages the hinge line forms the greatest width of the shell, the width being half again, and in the majority of cases nearly twice, the height of the shell at that stage. In all the better-preserved specimens in our collection, the hinge line forms the greatest width of the shell, as is stated to be the case in the shells from Spitzbergen, but our larger shells are usually proportionately wider.

In a typical small shell (No. 227), the early stage has acute cardinal angles, approaching close to 45°, while in the full-grown shell they are essentially rectangular, or only slightly acute. The two valves, which are in conjunction, are subequally convex. The pedicle is somewhat the greater in convexity, the maximum occurring in the posterior third. The beak is incurved almost as strongly as in the figure given by Wiman. The shoulder is sharp and slightly sinuous, with a marked concavity on either side of the beak. The hinge area is of moderate height, increasing at the beak to nearly twice the height on either side. It is striated vertically, two to three striæ occupying 1 mm. The delthyrium is broad, slightly higher than it is wide.

The shell is exfoliated, so that the detailed characters of the plications can not be recognized. However, the following can be made out: there is no median plication, but there are at least two pairs of lateral sinal plications, though these are only faintly visible; the bounding plication has an outside branch; the second and third shell plications have both an outside and an inside branch, while the fourth has apparently only an inside branch. The character of the other plications cannot be ascertained.

In the specimen figured by Wiman from Bear Island, there are three pairs of lateral sinal plications, the third being very short. The bounding plication, however, appears to be without an outside branch, while the second plication has a branch on either side, and this is borne out by Wiman's description.

The brachial valve has the beak slightly overarching, with the shoulders nearly straight and horizontal, except at the beak. In the young the cardinal angles are acute, becoming gradually less acute, then scarcely rectangular, or even (perhaps) slightly obtuse, but as the cardinal angles of the adult are imperfect, this is not certain. The cardinal area is very low. The median fold is simple for a short distance from the beak, after which it is divided by a median groove which becomes deeper and broader forward. The two resulting plications are equal and rounded in the first half, but become broad and more flattened towards the front. There is, however, no further bifurcation or branching, as is the case in the shell figured by Wiman, and as is seen in at least one of our larger shells. There are five lateral plications on each side, with indications of two more in the cardinal lateral region. The first and second show indications of branching, but the others are simple. In Wiman's figure all the plications are simple. There are several strong growth lines, and where they and some of the finer ones cross the plications, a sharp transverse nodulation is produced.

In a larger shell (No. 228, Pl. XXI, Fig. 3), which has a broader and more pronounced sinus, there are three pairs of lateral sinal plications, and the center of the sinus is rounded. The bounding plication is without an outside branch, but the second and third plications have each an inside and an outside branch, both beginning far up on the shell, those of the same plication appearing simultaneously, but the third group appearing later than the second. The characters of the other plications can not be determined. In a third shell of about the same size (No. 230, Pl. XXI, Fig. 4), the lateral sinal plications are not shown because of extreme exfoliation. The bounding plications, however, have a well-developed outside branch, which begins far up on the umbo. The second and third plications have each an inside and an outside branch, as in the preceding specimen, and the fourth has an outside branch near the front. In both specimens the concentric nodulation is visible in parts of the shell.

In a more transverse shell (No. 236, Pl. XXI, Fig. 5), in which the width is only somewhat less than twice the height, the lateral plications are all simple, or with a single faint branch only in a few, their number being eight in all on each side of the sinus. The sinal plications, though faint, appear to comprise three pairs of laterals. Both in the great width and in the simple character of the plications, this shell shows the effect of retardation in development, the adult characters corresponding more nearly to those of the young of other individuals, and representing the more primitive ancestral characters. Indeed, this shell, occurring in a different bed of the series (1192), may be considered as a more primitive mutation (mutation *primitiva*, mutation nov.). The next larger shell (No. 235), with three pairs of lateral sinal plications, has essentially the same characters as those found in No. 230 (Fig. 4). Finally, in our largest specimen (No. 226, Pl. XXI, Fig. 2), the greatest complexity prevails. The beak is overhanging and slightly incurved. The hinge area is high and strongly striated vertically, with the delthyrium forming an isosceles triangle. The shoulder is sharp, sloping and straight for the greater part, but somewhat concave at the beak. The cardinal angles are broken, but probably were broadly acute or at least rectangular. There are at least three pairs of lateral sinal plications, with the suggestion of a fourth, and with the center rounded. The bounding plication has a strong outside branch beginning near the beak, and there is a further suggestion of division of the stem near the front. The second plication has a well-developed inside and slightly less strongly developed outside branch. The stem is faintly grooved near the front, indicating division. The third plication has strong inside and outside branches, beginning far up on the umbo, and the fourth appears to be similar, though incompletely preserved. The rest are not preserved. This shell then suggests an approach in complexity to *Spiriferella rajah* of the medially plicated series, but is of course quite distinct from it in form and the lack of a median plication, as well as in the division of the sinal plications. It also parallels the characters of the more complex mutations of *Spiriferella keilhaviiformis*.

There is at least one other large fragmentary shell (No. 229) in our collection which shows a similar state of costal complexity.

Because of the imperfect state of preservation of our shells, in which the actual surface is always exfoliated, there must remain a certain amount of doubt as to the exact characters of the larger of these shells, and the propriety of referring them to the present species. The primary division of the plications is clearly indicated, but it is repeatedly shown, in the shells of this group, that the finer subdivision of the plicæ, when it exists, is recognizable only when a portion of the outer shell is preserved. Only in rare cases is this finer subdivision so strongly marked that it penetrates to the lower shell layers. This is the case in several of the specimens belonging to the next species to be described, and there it is seen that, although the primary plications are well marked in the exfoliated shell, and appear to be simple, they are in reality much subdivided into very many subequal, finer plications. At the same time it is to be noted that where this finer subdivision is carried to such an extreme as in the following species (referred to *Spirifer moosakhailensis* Diener) the integrity of the primary plicæ is less well maintained, these becoming either broader and less sharply defined, or else, if they remain distinct, the early branching off of the secondary plicæ is not marked. This appears to be due to the fact that the subdivision of these branches takes place so early that their integrity as unit branches never fully develops. Thus within certain limitations we may place the shells, those with well-marked primary branches (*i.e.*, strong secondary plicæ), among the more primitive members of the group of which *Spiriferella keilhavii*, as represented in our collection, is a typical member.

Horizons and Locality:—Keeping the above remarks in mind, and classifying our shells in accordance with the principle there expressed, we may record this species from the following horizons in the Jisu Honguer limestone of Jisu Honguer, Mongolia.

In the *Marginifera typica* bed (1192), the most primitive mutation (No. 236 and No. 247). In the *Spiriferella rajah* bed (1209), abundant and typical (Nos. 227, 228, 230, 231, 233, 235). Horizon not certain but probably *Spiriferella rajah* bed (1209) (Nos. 226, 229). In the *Enteletes* bed (1190), one poorly preserved fragment (No. 232), apparently of the primitive mutation.

Genus **Spirifer** Sowerby

37. **Spirifer moosakhailensis** Davidson

Plate XXIII, Figs. 5a-c (No. 180), 6 (No. 181), 7 (No. 241), 8a-b (No. 242), (Nos. 209, 225, 234, 237, 238, 239, 240, 242a, 243, 244, 245, 248, 262, 266, 269?), (Text-Fig. 62)

1862. *Spirifera moosakhailensis* Davidson. "On some Carboniferous Brachiopoda collected in India, etc." *Quart. Journ. Geol. Soc. London*, Vol. XVIII, p. 28, Pl. II, Fig. 2.

1883. *Spirifer moosakhailensis* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 512, Pl. XLV (other references).

1892. cf. *Spirifer fasciger* Schellwien. "Die Fauna des karnischen Fusulinenkalkes," I, *Palæontographica*, Bd. XXXIX, p. 42, Pl. V, Figs. 2, 3.

1892. *Spirifer musakheylensis* Rothpletz. "Die Perm-Trias und Jura-Formation of Timor und Rotti." *Palæontographica*, Bd. XXXIX, p. 79, Pl. IX, Figs. 1–2.

1897. *Spirifer musakheylensis* Diener. *Palæontologia Indica*, Ser. XV, Himalayan Fossils, Vol. I, Pt. 4, "The Permian Fossils of the Productus shales of Kumam and Gurwhal," p. 34, Pl. III, Fig. 34; Pl. IV, Figs. 1a-b, 2; Pl. V, Fig. 1 (other references).

1899. *Spirifer musakheylensis* Diener. *Palæontologia Indica*, Ser. XV, Himalayan Fossils, Vol. I, Pt. 2, "Anthracolithic Fossils of Kashmir and Spiti," p. 63, Pl. V, Figs. 3–7 (other references).

cf. 1908. *Spirifer oldhamianus* Mansuy non Waagen. "Contribution à la Carte Géologique de l'Indochine." Paléontologie, p. 60, Pl. XV, Fig. 11 (*non* Pl. XVI, Figs. 1, 2).

cf. 1911. *Spirifer musakheylensis* Frech. In Richthofen, China, Vol. V, p. 153.

cf. 1913. *Spirifer musakheylensis* Mansuy. "Faunes des Calcaires à Productus de l'Indochine." *Mém. Sérvice Géol., Indochine*, Vol. II, Fasc. 4, p. 57, Pl. V, Fig. 6.

1916. *Spirifer fasciger* Broili. "Die permischen Brachiopoden von Timor." Paläontologie von Timor, Lief. VII, p. 37, Pl. CXX, Figs. 11–13; Pl. CXXI, Figs. 1–3.

Davidson's original description: "Shell transversely subrhomboidal; valves almost equally deep or convex; hinge-line variable in length, sometimes not half as long as the breadth of the shell, while at times it is as long. Ventral area of moderate width; fissure wide and partially arched over by a pseudodeltidium. Dorsal valve sublinear; beak small and moderately incurved. In the dorsal valve there exists a wide, elevated angular fold, and in the ventral one a corresponding sinus. The entire surface of the shell is covered with numerous small ribs [plicæ], which cluster into fasciculi, seven or eight being collected into groups, which give to the valves the appearance of a double plication, many of the smaller ribs [plicæ] being due to interpolation; while the whole surface and ribs [plicæ] are closely intersected by numerous sharp, projecting, concentric, undulating laminæ, of which four or more may be counted in the breadth of a line. Dimensions very variable; a large example measures twenty-six lines in length by thirty-nine in width and eighteen or nineteen in depth."

Davidson (1862, p. 29) emphasizes the "peculiar and beautifully regular, closely disposed, sharp, projecting, concentric, undulating laminæ, which resemble so closely those of *Spirifer laminosa*, and which give to the shell its beautiful sculptured appearance" as its most characteristic feature; and this is likewise emphasized by Waagen and Diener in their descriptions of this species from the Salt Range and the Himalayan region. Waagen says (1879–1887, p. 513): "The most characteristic feature of the species is the lamellose, erect striæ of growth which, in great numbers and closely arranged, cover both valves. Besides these, there are some irregular, more strongly developed imbricating marks of growth running parallel to the margins of the valves." Diener (1897, p. 36) adds to this another distinctive character by which this species can be separated from its nearest allies, namely, "the presence of broad, flatly rounded folds, each of which corresponds to a bundle of ribs [plicæ]"; he also includes "the erect, lamellose condition of the lines of growth." He adds: "In all of my specimens, even if the shell appears to be perfectly well preserved, the ribs [plicæ] though being of very different strength, are always more or less distinctly rounded on their tops, but never sharp." This distinguishes this species from *Spirifer fasciger* (Keyserling) which has angular instead of rounded primary plications. The rounded character of the primary plications is well shown in Davidson's original figure, which must be taken as representing the holotype of the species.

Unfortunately the state of preservation of the Mongolian material is such that the concentric sculpture is not preserved or is only faintly indicated. Nevertheless, as Diener insists, the rounded character of the primary plications may be taken as a distinctive guide, provided it can be shown that associated with these are the numerous fine secondary and tertiary, etc., plications, or the "bundles of ribs" of Waagen, Diener, and others.

It is unfortunate that in none of the elaborate descriptions of this species are given the details of development of the secondary and tertiary plicæ on the primary plications and on the fold and in the sinus, a feature which I hold to be of prime importance in determining relationship. Waagen (1879–1887, pp. 512, 513) gives some suggestion along this line, when he says: "The radial striation begins at the apex of the beak, as a few strong ribs [plications] arranged on both sides of the sinus. There are generally seven ribs [plications] on each side, and three more within the sinus. Each of these ribs [plications] very soon becomes split up into three and thus gives rise to the formation of a bundle of ribs [plicæ], in which the ribs [plications] are more and more augmented as the bundle approaches the margins of the valve; so long as the bundles are distinguishable, there are rarely more than seven ribs [plications] within one bundle. The bundling disappears, sometimes at an earlier, sometimes at a later, stage of growth, quite full-grown specimens only rarely show the bundling distinctly at the margins of the valve."

In the figure of a young shell given by Waagen (1879–1887, Pl. XLV, Fig. 5b), the order of appearance of the sinal plications seems to be as follows, assuming the details to be correctly drawn. There seems to be a median divided plication, though these may be the branches of the first lateral plications. If that is the case, the first lateral divides; the second and third are simple. On the other hand, if a median double plication occurs, then there are only two lateral sinal plications, the first of which bifurcates; the second is simple. From what is known of the order of development, the first interpretation appears the normal one, though from the figure this can not be determined. In either case, however, the bounding plication bifurcates into two branches, and each of them almost immediately bifurcates again, making four secondary plications in all. Because of this extreme division of the bounding plications, it seems more probable that there are three pairs of sinal plications, of which the first pair divides, and no median plication. The first, or bounding, plication has an outside branch, and the second plication has both inside and outside branches. The former bifurcates at about the mid-length of this stage of the shell, and the latter also seems to bifurcate, while the stem remains simple and slightly broader. It may be, however, that the stem bifurcates and the outside plication remains simple. Unfortunately these details are not clear in the figure. The third plication develops in a similar manner, but the others are less complex. The dimensions of the pedicle valve at this stage are:

Height	13.7 mm.
Width	19.7 mm.
Length of hinge line	13.4 mm.

The number of primary plications on either side of the sinus is only three at this stage.

Turning now to our Mongolian specimens, which appear to be referable to this species, it must be again emphasized that the state of preservation is such as to show generally only the primary plications, while those of the secondary, tertiary, etc., groups are only occasionally shown.

Measurements:—In the following table the measurements of characteristic specimens are given:

Column No.	*1*	*2*		*3*	*4*
Serial No.	*No. 242 Text-Fig. 62 Pl. XXIII, Fig. 8*	*No. 240*		*No. 180 Pl. XXIII, Fig. 5*	*No. 181 Pl. XXIII, Fig. 6*
		a	*b*		
Height of pedicle valve	22.3	23.0	40.0	41.5	....
Length of pedicle valve	33.0	31.0	50.0	74.0	....
Height of brachial valve	20.6	....	....	31.8	....
Length of brachial valve	25.0	....	....	40.0	....
Greatest width	29.2	53.0	71.0±	72.0?	80.5?
Length of hinge line	26.0?	53.0	64.0?	72.0?	80.5?
Width of delthyrium	....	....	....	11.0	15.5
Height of hinge area	....	....	....	11.0+	16.0
Greatest thickness	17.4	....	....	28.5	....

Column No.	*5*	*6*	*7*	*8*	*9*
Serial No.	*No. 241 Pl. XXIII, Fig. 7*	*No. 209*	*Davidson type*	*Waagen largest shell*	*Diener*
Height of pedicle valve	45.0?	....	54.7	56.0	38.0+
Length of pedicle valve	....	....	....	....	....
Height of brachial valve	....	....	54.5	45.0	....
Length of brachial valve	....	....	....	....	....
Greatest width	95.0?	120.0?	80.8	88.0	80.0+
Length of hinge line	95.0?	120.0?	78.0	79.0	....
Width of delthyrium	18.0	21.3	12.7	....	....
Height of hinge area	15.0+	16.5	....	....	....
Greatest thickness	....	....	....	39.0	....

In column seven the dimensions of Davidson's type specimen are given as taken from the figures. Columns eight and nine give measurements of Indian shells after Waagen (1879–1887, p. 513) and Diener (1897, p. 38) respectively.

The smallest of our shells (No. 242, Pl. XXIII, Fig. 8) shows essentially rectangular cardinal angles, which at an earlier stage are obtusely rounded. The hinge line is somewhat shorter than the width, and the ends are subtruncate. The shoulder is gently concave and angulated. The beak is overhanging, but not incurved. The sinus is well-defined, rapidly broadening forward, margined by broad, rounded, bounding plications, while there are two other broad low plications on the side of the shell. The brachial valve has an elevated, rather sharp fold, which is especially prominent near the front. Two broad primary plications are shown on either side. None of these primary plications on either valve is very sharply defined; they have more the character of broad undulations. The entire surface of both valves is covered with fine plicæ, representing the second, third and later order of branches.

The details of development of the finer plications, so far as it can be determined, are as follows (Text-Fig. 62). The umbonal region of the pedicle

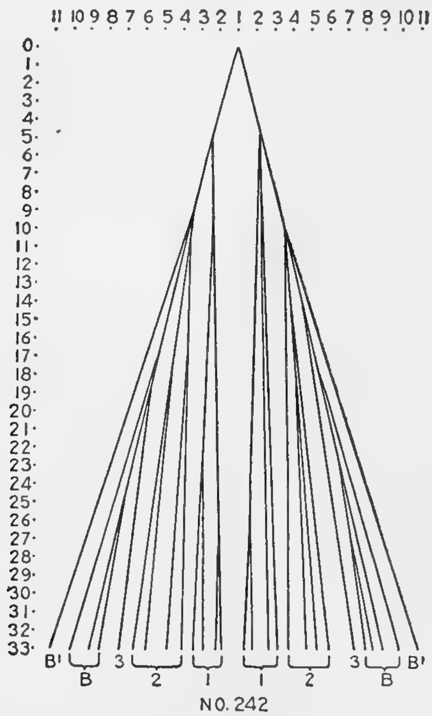


FIGURE 62.—(No. 242) Diagram of the bordering plications (B, B, B′, B′) and lateral sinal plications (1, 1, 2, 2, 3, 3) in *Spirifer moosakhailensis* Davidson (young).

valve is worn, hence the origin of the secondary plications is not shown. The first two lateral sinal plications begin early, perhaps 5 mm. from the beak or even earlier. Both divide at a very early period (10 mm. or less from the beak), and one of these, the outside one, divides again on the left side, while the other shows merely a faint median groove at the front. Each of the two inside branches shows a similar median groove. The second lateral plication divides early into two parts, each of which again divides in the anterior third of this stage of growth. The division on the right is less distinctly recognizable in the early stages than in the left. The third plication appears to be simple, but the bounding plication divides into two arms, of which the inner one on the right becomes triplicate at the front, while on the left it simply bifurcates again but only faintly so. In addition, there is an outside branch on either side. The second plication has an inside branch which divides early, and a simple outside branch, while the main stem again divides near the front, thus making five plicæ. The same is true of the third plication, which also has five plicæ, so far as can be determined. All, or nearly all, of these plications have already appeared at a shell length of 25 mm. (height 19 mm., width 23 mm.), this shell at such an early stage being fully as complicated as the adult *Spiriferella keilhavii* of the most advanced mutation. The chief difference is found in the fact that the number of primary plications is not over three in the young shell.

The fold of the brachial valve is divided at the outset by a median groove into two arms, which at the front divide again, making four plications in all. On either side comes in a small plication which produces the first lateral plica, while almost immediately another one of the same size appears between the first plica and the median fold. This intercalated plica soon divides into two arms, which shortly thereafter again bifurcate, making four. At variable intervals another bifurcation takes place, in some cases at mid-length, in others near the front, until eight fine plications are produced on the left side. These, with the four median and the eight on the right side (provided there is symmetrical development, which is not clearly determinable), would make a total of twenty fine plications in the fold near the front. Although at the outset the intercolated plica is nearly as strong as the median fold and the first plica on either side, its rapid subdivision causes it to spread and become a part of the outer slopes or flanks of the fold. The first lateral plication has an inner and an outer branch; the latter divides into two, as does also the stem of the plication, producing five plicæ for this plication. In the second plication the inner branch also divides, producing six plicæ at the front. There are only two plications at this stage in the brachial valve.

These facts show that the same law, which governs the formation of plications in all the plicated shells so far described, is followed in the present species. Only the division and branching occur so early that even in the young shell an extremely complex system of plications occurs. It is, however, clearly seen that the very young stages correspond in practically all respects with adults of the simpler types, such as *Spiriferella keilhavii*, and that the present species therefore represents a condition of acceleration in development, with the result that its own adult can assume an extremely complex character.

A nearly adult, but rather strongly crushed and partly broken shell (No. 240), has a height of approximately 40 mm. and a width of over 70 mm. The surface characters are only partly preserved, and it is seen that there are perhaps eighteen or twenty small plications in the sinus near the front, which is but little if any more than in the youthful specimen described, showing that division ceases after a certain stage has been reached. The primary plications can be seen only in the half-grown shell; in the adult they are mostly flattened out. In the half-grown shell, which has a height of 23 mm., a length of 31 mm., and a width of 53 mm., which is also the length of the hinge line, there are five plications recognizable, each with only an outside and an inside branch. Immediately after this stage, these branches begin to bifurcate, and the distinction between the plications becomes less well-marked, the first merging with the lateral slopes of the sinus. In the stage mentioned, there are only about three pairs of lateral sinal plications, but immediately after this, several bifurcate, while the subdivisions of the first plication, which flattens into the sinal slope, are added so as to produce nine or ten in all. At this advanced stage, the definition of the sinus is vague, because the plications, as a whole, are flattened out. At the front on the left side, which is alone preserved, twenty-two fine plicæ appear, these corresponding to the second and last plications. This makes from five to six divisions to a plication, from which it is seen that in this large shell the complexity is not much greater than in the small one first described. The latter, however, has only three plications, and hence the total number is less. It must be noted, however, that the half-grown stage of the present individual (No. 240) is much less complicated than is the small shell, which, though of almost the same height and length, is much narrower. Indeed, in the present shell, the half-grown stage is not any more complex than a normal adult *Spiriferella keilhavii*, though it is proportionately wider.

A somewhat larger shell (No. 180, Pl. XXIII, Figs. 5a-c) has a strongly incurved beak (imperfect), and a high hinge area with nearly parallel sides for some distance on either side of the beak. Thus the shoulder, somewhat concave at the beak, becomes straight and horizontal, then more sloping to the cardinal angles, which are acute and faintly subtruncate. The area is strongly striated vertically, a feature seen on all well-preserved shells. The striæ vary somewhat in thickness, so that sometimes two and sometimes three occupy the space of one millimeter. In this specimen the sinus and plications are pronounced and well-defined throughout, except at the very front where the shell is crushed. There are six plications on either side of the sinus, decreasing regularly outward. They are sharply rounded and appear simple, but in certain positions it can be seen that they have inside as well as outside branches, though these appear only in the half-grown shell. The bounding plication has an outside branch, but the lateral sinal plications are not preserved.

This would at first sight appear to represent a very simple elongate species, which is not referable to the complex species under which it is here placed. That is, however, due to the fact that the shell is almost entirely exfoliated, so that over large parts only the internal mold is seen. Fortunately, however, in the crushed front there is preserved a portion of the shell, and this shows the numerous fine secondary and later plicæ found in the other shells of this series. In a space equal to the frontal width of the second and third plications, there are about twenty of these smaller plicæ, which argues pronounced subdivision.

Another specimen (No. 181, Pl. XXIII, Fig. 6), which, measured on the best preserved side, had a width of over 80 mm., shows about the same character of surface with strong rounded plications with inside and outside branches; but in a few places the finer plications are suggested. On this specimen a few of the primary lateral sinal plications are shown, and they are seen to be of the normal character. In the frontal part of the sinus preserved, the finer plications are indicated to the number of eighteen or twenty. The area of this individual is very high and vertically striated as in the other shells. It is arched, and the beak is slightly overhanging, but not incurved. The delthyrium has the form of a broad isosceles triangle, and is covered by a pseudodeltidium.

Our two largest specimens, one (No. 241, Pl. XXIII, Fig. 7) with the width of approximately 95 (?) mm., the other (No. 209) in the neighborhood of 120 mm. wide, show the fine plicæ in spite of the exfoliated character of the shell, and these plicæ begin far up on the beak. The primary plications have been so subdivided that they are hardly recognizable, and the boundary of the sinus is very indefinite. This is especially true of the lesser of the two (No. 241), where the costæ with their two branches each can be seen only on the umbone, and there they are not very distinct. On the larger (No. 209, American Museum Cat. No. 23168), the plications are more distinct, except near the front, but the sinal boundaries at the front are no more distinctly defined. In the umbonal region, however, the plications are well-marked, narrow and simple at first, but quickly develop two branches and then increase by division, the first division appearing about 15 mm. from the beak, whereas the first branches appear about 10 mm. from the beak. The area is high, divided by a very broad delthyrium. The vertical striation of the area is not shown in this specimen, probably because of exfoliation. The beak overhangs slightly but is not incurved.

The specimens showing brachial valves are poorly preserved, and their reference to this species is open to question. They show only such simple characters (in the exfoliated specimens) as are seen on the broad forms referred to *Spiriferella keilhavii.*

Although in many of our specimens the lamellose concentric structure is indicated, we have none perfect enough to show it in its characteristic form. Thus determination must be based solely upon the form and the character of the plications and their finer subdivisions.

Horizon and Locality:—This species is common in the *Spiriferella rajah* bed (1209) of the Jisu Honguer limestone at Jisu Honguer, Mongolia, most of the specimens obtained having been found there (Nos. 180, 181, 237–241, 248).

It also occurs more sparingly in bed 1205 (Nos. 234, 243, 244) and in bed 1206 (No. 209), in the *Marginifera typica* bed (1192) (No. 245), in the *Orthotychia* bed (1211) (No. 266), and in bed 1210 (No. 262). The young (or dwarfed) individual above described (No. 242) has been found in the *Enteletes* bed (1190).

Elsewhere this species is known from the Salt Range and the Himalayan Permian. It is also very common in the Permian of Timor, from which island Rothpletz has described it, while subsequently Broili figured a large number of characteristic shells under the name of *Spirifer fasciger* Keyserling, of which he makes this *Spirifer moosakhailensis* a synonym. One of his specimens has a width of 165 mm., which is the largest known. According to Mansuy and Frech, it also occurs in Indo-China. The shells described and figured by Schellwien from the Karnic Fusulinenkalk (Auernigg beds), may also belong here rather than to *Spirifer fasciger*, as already suggested by Rothpletz.

Genus **Martinia** McCoy

38. **Martinia osborni** Grabau, sp. nov., holotype

Plate XIV, Figs. 1a-e (No. 45), 2a-e (No. 41), 3a-e (No. 131), 4a-d (No. 122, holotype), 5a-c (No. 120), 6a-d (No. 126), (Nos. 119, 121, 125, 134, 136, 141, 144, 147–150, 152, 153, 172)

This shell attains a large size. The pedicle valve is subtriangular to subpentagonal in the adult and characterized by a rather blunt, slightly overarching beak and a pronounced median sinus and strong anterior lip.

The earliest stage (*a*) of the pedicle valve is subcircular, with the height and breadth equal, though the length on the curvature is slightly more. At this stage the valve is uniformly convex without a sinus or flattening and without modification of the regular arc of the frontal margin. The extent of this stage varies somewhat in different individuals, as shown in the table, where it ranges from 8.2 to 12.6 mm. in height and breadth. In one individual measured, however, the sinus appears as a faint median depression at a much earlier period, so that the length of the non-sinuate stage is only about 3.5 mm., with the width slightly more (4. mm.). In this shell, however, the brachial valve, which is preserved, has its convex stage fall within the above limits. In the next stage (*b*), the sinus forms a broad shallow depression in the center of the pedicle valve, while it scarcely affects the frontal margin, which still appears as a regular arc. The length of this stage varies with the degree of acceleration. In the adult individuals, this stage ranges in length from 15.4 to 22.4 mm. It is shortest in the holotype (No. 122, Pl. XIV, Fig. 4) in which the sinus is most pronounced in the adult, and longest in those in which it is still moderately shallow in the adult. In the immature individuals measured, this stage is shorter, ranging from 13.4 to 15.2 mm. It is shortest in the shell in which the non-sinuate stage is shortest (No. 131, Pl. XIV, Fig. 3), this being thus a more strongly accelerated form. The width at this stage is usually slightly greater than the height, though much less than the length, which is usually somewhat less than half again as great as the height at that stage.

In the third stage (*c*), the shell becomes extended in front by the development of a median lip corresponding to the sinus. This is at first moderate but increases in length until it projects about 11 or 12 mm. in the adult with the deepest sinus, as in the holotype (No. 122), but only about 8 mm. or a little more in those with shallow sinus. The total height and width of the shell are nevertheless still the same, or nearly so, but the length is fully half again as great as the height.

The greatest width of the shell is always somewhat below the mid-height, more so in the younger stages than in the adult. The adult shell has a strongly triangular appearance above the mid-height, curving to the lateral contraction of the umbonal region, which is, however, convex to the margin. The frontal portion, curving to the median lip, gives, in combination with the upper part, a marked pentahedral appearance to the shell in direct ventral aspect, an appearance which is, of course, less pronounced or hardly produced in the immature shells.

The hinge area is short, but sharply defined by an abrupt angle from the shell surface, there being even a suggestion of a slight acceleration of this angle above the shell sides. In the center it is divided by a broad and high triangular fissure, to which the area forms a narrow flanking triangular platform on either side. The total length of the hinge line is always less than half the greatest width, even in immature shells, and in the only adult in which it was exposed it is considerably less than half the width of the shell. Thus in dorsal view, the curving sides of the shell are shown to a marked degree on either side of the hinge area. The greatest depth of the shell is also in the umbonal region, the longitudinal contact being thus very asymmetric.

The brachial valve is wider than it is high in all stages. In the young it is regularly and rather strongly convex, the median portion becoming more sharply arched as growth proceeds, so that towards the front of the adult it is somewhat roof-shaped in section, though the sides are never flat but are gently arched. No distinct median fold is outlined, but at the front there is an emargination which is already visible in half-grown shells but becomes more pronounced in the adult. This corresponds to the median lip of the pedicle valve and in frontal view represents a pronounced embayment in the suture line.

The beak of the brachial valve is incurved but does not extend beyond the plane of contact of the valves. The umbonal region is strongly convex, with a pronounced depression on either side, so that this part of the shell forms a distinct concavity. The cardinal line then extends nearly horizontally to the cardinal angles, which are obtuse, angular in some cases, but rounded off in others. The hinge area, which is arched and of less height than that of the pedicle valve, is thus defined above by a sharp angulation. The lateral margins are regularly rounded into the frontal margin, which in the young is gently arched but in the adult becomes sinuate. The longitudinal contour of this valve is more regular than that of the pedicle valve, though not quite symmetrical, being always more abrupt at the beak. The convexity is less than that of the pedicle valve.

The surface of the shell is marked by subregular lamellæ and is radically striated in all our specimens. These striæ are low, rounded, and separated by much wider interspaces. There are about four of these in 1 mm. in the young, and three in 1 mm. in the adult, measured from crest to crest. At the crossing of the growth lamellæ the striæ are interrupted and thickened. In some of the better-preserved portions of the surface, the striæ are seen to extend in section between the coarser growth lamellæ, stopping abruptly with the next growth interruption, and beginning again as a finer ridge on the next forward lamella. This gives the surface a reticulated appearance. Indeed, the shell layer in which this striation is shown is not the outside layer but the one just beneath, while in the deeper layers the striæ are continuous. In a few instances a fragment of the covering layer is shown, but not enough to give the true character of the surface. Nevertheless, in a few places the edges of the growth lamellæ appear to be finely noded as in *Squamularia*, but this is not general enough to be of significance.

Measurements:—In the following table the several stages of a number of individuals of different ages are given. In the pedicle valve, stage *a* is non-sinuate; stage *b* with sinus but with no anterior lip; stage *c* with lips equal in the full-sized individual. In the brachial valve, stage *a* is normally convex, stage *b* with stronger median elevation.

	Pl. XIV, Fig. 1 No. 45		*Pl. XIV, Fig. 2 No. 41+*			*No. 153*			*Pl. XIV, Fig. 3 No. 131*			*No. 125*		
	a	*b*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
Pedicle Valve														
Height	8.4	12.9	4.5	8.5	15.0	7.9	12.3	17.0	3.5	13.4	20.0	7.7	15.2	20.5
Length	10.0	17.0	5.5	11.5	22.3	9.5	16.5	24.0	4.2	18.5	29.0	8.5	19.0	29.0
Width	8.4	12.8	4.5	8.5	13.6	7.9	13.5	17.7	4.0	13.7	19.2	8.5	15.0	19.7
Brachial Valve														
Height	.....	12.4	7.0	.....	12.9	.....	.....	.....	10.5	.....	17.8	.....	.....	.....
Length	.....	14.5	13.0	.....	15.5	.....	.....	.....	11.5	.....	21.0	.....	.....	.....
Width	.....	12.8	7.5	.....	13.6	.....	.....	.....	11.3	.....	19.2	.....	.....	.....
Thickness	.....	8.9	.....	.....	10.0	.....	.....	.....	.....	.....	14.3	.....	.....	.....
Hinge line	.....	7.1	.....	.....	8.2	.....	.....	7.6	.....	.....	9.0	.....	.....	8.8

	No. 134			*Pl. XIV, Fig. 3 No. 121*			*Pl. XIV, Fig. 4 No. 122*			*Pl. XIV, Fig. 5 No. 120*			*Pl. XIV, Fig. 6 No. 126*		*No. 119*	
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*a*	*b*
Pedicle Valve																
Height.........	6.3	15.8	20.8	9.2	19.5	24.6	8.2	15.4	31.0	12.6	22.4	37.8	....	....	....	....
Length.........	7.5	23.0	33.0	10.0	28.0	37.0	10.5	21.5	45.0	13.0	29.0	53.0	....	....	....	....
Width..........	6.3	14.4	19.4	9.2	21.2	27.0	8.2	16.5	31.0	12.6	21.7	37.0	....	....	....	....
Brachial Valve																
Height.........	8.0	....	18.4	....	....	....	....	....	....	....	....	....	....	23.3	....	26.8
Length.........	9.5	....	22.0	....	....	....	....	....	....	....	....	....	....	27.5	....	28.0
Width..........	8.5	....	19.4	....	....	....	....	....	....	....	....	....	....	25.5?	....	36.0?
Thickness......	....	....	16.0	....	....	13.0?	....	....	13.0?	....	....	16.0	....	....	....	....
Hinge line......	....	....	11.2	....	....	....	....	....	....	....	....	16.0	....	....	....	....

Horizon and Locality:—This species is common in the *Lyttonia* and *Martinia* beds (1193, 1194) and occurs more rarely in the *Orthotychia* bed (1211) of the Jisu Honguer limestone of Permian age at Jisu Honguer, Mongolia; about twenty specimens. Collector, F. K. Morris.

Remarks:—This species has somewhat the form and general appearance of *Martinia triquetra* Gemmellaro (1899, Pl. XXXII, Figs. 23–28), but is more elongate proportionately and has a broader sinus and more extended anterior lip. The shell described and figured under that name by Tschernyschew from the Schwagerina beds of Russia (1902, Pl. XVI), comes nearer to it and may be conspecific. *Martinia uralica* Tschernyschew (1902, Pl. XVII, Figs. 1–5), on the other hand, lacks the triangular outline, and has a much shallower sinus without the pronounced anterior extension. The beak of the pedicle valve is also much more strongly incurved in the Russian shell.

Nearly related to the present species is the form figured by Kayser (1883, Pl. XXII, Figs. 10, 10a, 10b) as *Spirifer ellipticus*, but that shell is proportionately broader and less triangular. The measurements, taken from Kayser's figure, are: length of pedicle valve 34 mm., length of brachial valve 30 mm., greatest width 39 mm., thickness 24 mm. In my Stratigraphy of China, Vol. I, p. 363, Fig. 251, I referred this shell to *Martinia triquetra* Gemmellaro var. *lopingensis* Grabau. It has since been more fully described by Chao (1929, p. 79, Pl. X, Figs. 9–15) under the name *Martinia lopingensis* Grabau and Chao.

39. **Martinia mongolica** Grabau, sp. nov.

Plate XV, Figs. 1a-e (No. 48), 2a-e (No. 36), 3a-e (No. 29), 4a-f (No. 116); Plate XVIII, Fig. 1 (No. 143); (Nos. 39, 42, 43, 44, 49, 129, 132, 137, 142)

Cf. 1898–99. *Martinia orbicularis* Gemmellaro. "La Fauna Calcari con Fusulina della Valle del Fiume Sosio," p. 301, Pl. XXXIII, Figs. 16–22.

Cf. 1902. *Martinia orbicularis* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe,* Vol. XVI, No. 2, p. 567, Pl. XVII, Figs. 1–3; Pl. XX, Fig. 8.

This shell is subspherical, wider than it is high, with elevated beaks distant because of high hinge areas. It has a well-marked sinus in the pedicle valve, a transversely strongly arched brachial valve, and a marked frontal emargination of the suture. The surface is finely striated in the usual state of preservation.

The youngest shell referable to this species (No. 46, Pl. XV, Fig. 1) is wider than high, its thickness being about five-sevenths of the width. The beak of the pedicle valve is already well incurved and the area high and wide, so that the beaks of the two valves are distant, a feature characteristic of all stages of this species. The convexity of the valve is considerable, being greater in the posterior third, curving regularly to the front and to the inturned beak. The sides of the umbo are slightly contracted, producing a concavity in the cardinal slopes on either side. The mid-transverse contour is a strong regular arch which becomes lower towards the front without the formation of either flattening or depression. The cardinal margins are sharp or even slightly elevated, thus sharply defining the area. The cardinal angles, too, are prominent, forming slight auriculations, and are obtusely angulated.

The brachial valve is somewhat less convex than the pedicle, with a slightly elevated beak and a moderately high curving hinge area. The cardinal margins are sharp and gently sloping, with a marked concavity in front of them on either side of the beak. The general character of the longitudinal contour is similar to that of the pedicle valve. The greatest convexity is about one-third of the length from the beak. The curvature towards the latter is, however, less abrupt in this valve. The transverse contour is a curve with the sides flatter than the top.

The shell margins are acute. The suture line is not sinuate in front.

In a somewhat larger shell (No. 36, Pl. XV, Fig. 2), also wider than it is high, the sinus is not yet developed in the pedicle valve. By the time the shell has reached a length of 14 mm. (No. 43), the sinus is slightly developed, forming a gentle emargination in the frontal suture.

The holotype and largest individual in the collection (No. 116, Pl. XV, Fig. 4) is only 21.3 mm. high by 23.1 mm. wide, and has a thickness of 17.5 mm. It is a robust shell, with the beak of the pedicle valve incurved but not overarching the plane of valve contact. The hinge area is of moderate height, and the length of the hinge line is a little less than half the greatest width of the shell. The umbo is slightly compressed, giving the side slopes a concave aspect. The longitudinal contour is asymmetric, with the greatest convexity in the posterior third. The median depression is marked long before the shell is half-grown. Indeed, in the specimen in question, the median depression begins when the shell has reached a length of 9.7 mm. and a width of 10.7 mm. It becomes deeper and broader forward, and although its center is marked by a rather sharp line, its sides are gently convex and its margins ill-defined. At the front, however, this depression forms a strong subangular emargination in the suture. The sides of the shell are rather abruptly rounded from the cardinal angles to the anterolateral margin of the sinus, where the outline swerves slightly so as to give the effect of a moderate anterior lip.

The brachial valve, though on the whole slightly less convex than the pedicle, is in certain aspects more so and is especially prominent by virtue of the rather strong median elevation. The summit of this is sharply convex, while the sides at first are gently convex, then become flatter, and near the front are actually somewhat depressed. This gives the cross-section of the valve a roof-shaped appearance, the sides forming an angle of 97° with each other while the summit is abruptly rounded.

The surface of this shell is not well enough preserved to show all its characteristics, the outer shell-layer being exfoliated except on the side of the umbo of the pedicle valve, where a small portion remains; this shows fine regular concentric lines, about four to 1 mm. at this point. Faint radii are visible on these lamellæ with a suggestion of minute pustules at their frontal margin. They are, however, not prominent as in *Reticularia* and *Squamularia*. The deeper shell-layer, which still covers a large part of the shell, shows a marked radial striation, the radii narrow, round and widely spaced, so that at the front only two fall within the space of 1 mm., though at an earlier stage there are three of these in the same interval. These striæ are also visible to some extent on the internal mold, showing that they affected the inner surface of the shell. This feature is to some extent complicated by what are probably muscular grooves (appearing as ridges in the internal mold), these being of a more irregular character than the striæ.

This radial striation is visible on practically all the shells of this species in our collection whenever the outer shell layer is exfoliated. Sometimes it is strongly marked; in other cases it is fainter, but never absent. This, as shown by Chao (1929, p. 67), distinguishes *Martinia* from *Reticularia* and *Squamularia*. The internal mold, however, does not always show the effect of these striæ; indeed it is often invisible on the younger shells. When more of the shell surface is preserved, these striæ are interrupted by the concentric growth lines, so that they appear rather as aligned elongated pustules, the surface acquiring a cancellated appearance (No. 129).

In the more mature shells the growth lamellæ near the front are rather pronounced and crowded; and in our largest shell there appears a step-like contraction in each valve, a feature which strongly suggests the maturity of this specimen.

Measurements:—In the following table the measurements of characteristic specimens of this species in various stages of development are given, these ranging from the youngest stage, in which the shell is non-sinuate, to the adult.

Serial Number	*No. 48*	*No. 36*	*No. 129*	*No. 29*	*No. 143*	*No. 116*		*No. 132*
						Holotype *a*	*b*	
Plate and Figure	*Pl. XV, Fig. 1*	*Pl. XV, Fig. 2*		*Pl. XV, Fig. 3*	*Pl. XVIII, Fig. 1*	*Pl. XV, Fig. 4*		
Height of pedicle valve	6.6	8.9	15.6	15.8	14.8	9.7	21.3	20.4
Length on curvature	....	....	26.5	21.5	22.0	11.0	31.0	30.0
Height of brachial valve	6.3	7.8	13.8	15.5	....	....	19.5	19.3
Length on curvature	....	....	15.0	20.0	....	....	23.0	23.0
Greatest width	7.1	9.3	17.0	17.0	16.0	10.7	23.1	22.8
Greatest thickness	5.0	6.8	12.4	12.9	11.0	....	17.5	15.9
Length on hinge line	4.0	4.4	11.0	10.4	10.2	....	11.0	11.4
Proportion of height (P.V. = 1) to width	1.08	1.04	1.09	1.08	1.08	1.10	1.08	1.11

In No. 116, *a* is the young stage before the sinus is developed, while *b* is the adult.

This shell is readily distinguished from the immature stages of *Martinia osborni* by the relatively greater width, which always exceeds the height of the shell, whereas in the young of that species it is always much less than the height.

There is another shell in our collection which must be referred to this species (No. 143, Pl. XVIII, Fig. 1). It is imperfect but preserves most of the pedicle valve and a part of the brachial valve as well. The pedicle valve is strongly convex with the greatest convexity behind the mid-length, from which point it arches rather regularly to the front on the one hand and to the beak on the other. The latter is elevated but scarcely incurved, the hinge area below it being of slight arcuation. The umbonal sides curve over to the margins of the broad delthyrium, there being no flattening into a hinge area. Instead, the shell on either side of the delthyrium is slightly turned inward so that the margins of the delthyrium are sunken. The hinge line is straight and slightly extended, so that the cardinal angles are faintly salient.

In transverse contour the pedicle valve is regularly arcuate in the umbonal region, this contour becoming modified forward by the development of a faint median depression, which at the front of the shell, even in this stage, becomes somewhat lip-like and produces a faint but distinct emargination in the frontal suture.

The width is considerably greater than the height, the maximum width being about at mid-length. The side forms a regular and pronounced arcuation from the obtusely angular cardinal angle to the front.

The brachial valve of this specimen is too imperfect for description; but its hinge line, cardinal angles and marginal outline conform to those of the pedicle valve. The transverse contour appears to have been a regular arch and the convexity less than that of the pedicle valve.

The surface characters of this specimen are rather better preserved than in the majority of our species. The deeper shell layer is characterized by strongly marked radiating lines, while the outer shell layer shows occasionally strong subregular concentric growth lamellæ. Upon these the striæ appear as elongated, interrupted radii, which are swollen on the free margins of the lamellæ.

Horizon and Localities:—In the Jisu Honguer limestone of Mongolia, especially in the *Martinia* bed (1194), associated with *Martinia osborni*, but also more rarely in the *Lyttonia* bed (1193). It is a fairly common form.

Remarks:—This shell at first resembles *Martinia orbicularis* Gemmellaro of the Sosio limestone of Sicily. That shell, however, has a less convex brachial valve, which, moreover, lacks the roof-shaped character of that of our species; the beaks of the valves are also closer together, and the sinus of the pedicle valve and the frontal emargination are much less pronounced than in our adult shell. Indeed the Sosio shell corresponds in its essential characters more nearly to the young of our species than it does to the adult, and may represent an ancestral form. Measurements of different individuals of the Sicilian shell are given in the last four columns of the table on page 186, these being taken from Gemmellaro's text. The measurements of a shell from the Schwagerina limestone referred by Tschernyschew to Gemmellaro's species, and taken from his figure, are also given. This is proportionately longer. Both of Tschernyschew's specimens show a scarcely developed frontal emargination and no sinus, and the beaks are closer together than in our shell. The depth of the brachial valve is only about five-eighths that of the pedicle valve, and the transverse contour is rounded, not roof-shaped.

40. **Martinia orbicularis** Gemmellaro

Plate XV, Figs. 5a-f (No. 35), 6a-f (No. 46), 7a-e (No. 30), 8a-f (No. 117), (Nos. 123, 135, 139, 151)

1898–99. *Martinia orbicularis* Gemmellaro. "La Fauna Calcari con Fusulina della Valle del Fiume Sosio," p. 301, Pl. XXXIII, Figs. 16–22.

1902. *Martinia orbicularis* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, p. 567, Pl. XVII, Figs. 1-3.

The shell is transverse, wider than it is high; both valves are regularly convex, with straight frontal suture or with only a moderate sinuosity corresponding to a faint sinal depression. The beaks are more or less approximate. The surface generally shows interrupted radiating striæ.

The youngest shell referable to this species (No. 35) is 6.6 mm. high by 6.8 mm. wide, being thus slightly wider than it is long and of subcircular outline with sides and front regularly rounded. The regular outline is, however, modified by the beak of the pedicle valve, which is elevated, with the umbonal slopes compressed into slight concavities, and the sharp, nearly horizontal cardinal margins which define the hinge area above. The cardinal angles are obtuse, subangular but not auriculate. The beak is incurved over the arched area but does not reach the plane of contact of the valves. The beak of the brachial valve is slightly elevated above the cardinal margins but not incurved; the hinge area is much lower than that of the pedicle valve and not arched. The hinge line is somewhat longer than the greatest width of the shell which occurs in the mid-length.

The pedicle valve at this stage is more convex than the brachial, having its greatest convexity in the umbonal region, while that of the brachial valve is nearer the middle. In the latter, the shell arches regularly to the front, but towards the beak it is at first flatter, then more abruptly arched. The transverse contours of both valves are regular arches, that of the pedicle valve the more pronounced. There is no sinus, and the frontal margin is straight.

At this stage the shell agrees closely with the young of *Martinia mongolica* of the same size (see table p. 182; No. 48, Pl. XV, Figs. 1a-e), though the shell is slightly wider and considerably thicker, its thickness being 5 mm. as compared with 4.3 mm. in the present form. This is a difference constant through all stages of these shells.

A larger shell (No. 46, Pl. XV, Fig. 6) referred to this species, has a length of 12.1 mm. and a width of about 11.8 mm., the shell being slightly injured on one side. Nevertheless, it would appear that this specimen is subcircular with the length equal to or slightly greater than the width. The convexity is, however, moderate, that of the pedicle valve continuing to be greater than that of the brachial valve. The maximum thickness of the two valves is 7.5 mm., which is of about the same proportion to the width as is seen in the younger specimen described. The contours and outlines are as in the younger specimen, with this exception: near the front there is a faint depression, hardly more than a flattening in the surface of the pedicle valve, with a corresponding slight deviation in the frontal suture.

A larger shell (No. 30, Pl. XV, Fig. 7), 16.5 mm. high and 17.5 mm. wide, has a thickness of 11.1 mm., which again is of approximately the proportion to the width shown in the younger shells so far described. The pedicle valve is more convex than the brachial, with the greatest convexity in the posterior third. The beak is arched, barely incurved, and rises 1.8 mm. above the hinge line, which is more than one-fourth less than in a corresponding specimen of *Martinia mongolica*. The transverse contour at the end of the posterior third of the length is a sharply rounded arch, slightly less than twice as wide as high. Forward the contour becomes lower and flattened on top, and about mid-length a faint median depression appears. This becomes broader and gently deepens forward until at the frontal margin a gentle emargination appears in the suture, the depth of which is about 2.5 mm., while its width is 10 mm., the proportions being as 1:4. The hinge line is less than half the greatest width of the shell which is median. This shell is slightly more transverse, has its lateral margins therefore more strongly rounded, and has a more strongly pronounced median sinus. Otherwise it has all the characteristics of the smaller shell previously described.

One of our largest pedicle valves (No. 123, American Museum Cat. No. 23136) shows not even a flattening towards the front, though the convexity becomes considerably less. The greatest convexity is still in the posterior third, with the contour arching regularly in both directions. The umbones appear much less compressed than in the younger specimens. Over the greater part of the shell the growth lamellæ are regular, but near the front they are closely crowded and more irregular. In another, somewhat larger, specimen, however (No. 117, Pl. XV, Fig. 8), there is not only a moderate median depression, but also two faint lateral ones, outlining two very broad low fold-like undulations, one on each side of the median depression. In cardinal aspect two other such low, indistinct folds are seen, especially on the left side. They appear even more strongly marked in a certain position of the specimen than is shown in Fig. 8b, and it may be necessary to refer this shell to a distinct species, though since it is imperfect, and since the brachial valve is missing, it is left here for the present.

None of our specimens preserves the outer surface characters, but the fine radial striation of the deeper shell layers is seen in all of them. These striæ are slightly interrupted or cancellated by the concentric growth lines, but in ordinary aspect they appear continuous, though they have a somewhat nodulose aspect. There are about four striæ to 1 mm. in the younger, and three to 1 mm. in the more mature part of the shell—measured from crest to crest of the outer striæ included.

Measurements:—In the following table, measurements of characteristic specimens of this species from Jisu Honguer in various stages of development, are given in columns 1 to 5. In column 6 measurements of one of Tschernyschew's shells from the Schwagerina limestone are given, these being taken from his figures. Finally in columns 7 to 10 are given the measurements of four of Gemmellaro's specimens, as recorded by him in his text.

Column No.	*1*	*2*	*3*	*4*	*5*
Serial No.	*No. 35*	*No. 46*	*No. 30*	*No. 123*	*No. 117*
Height of pedicle valve	6.6	12.1	16.5	21.9	24.5
Length along curvature	....	....	22.0	32.0	33.5
Height of brachial valve	6.2	11.6	15.5	....	....
Length along curvature	....	....	19.0	....	....
Greatest width	6.8	11.8	17.5	23.5	25.5
Greatest thickness	4.3	7.5	11.1	....	....
Length on hinge line	3.7	6.3	7.4	17.7	12.9
Proportion of height (P.V. = 1) to width	1.03	0.98	1.06	1.07	1.04

Column No.	*6*	*7*	*8*	*9*	*10*
	Schwagerina limestone	*Sicilian shells Gemmellaro*			
	Tschernyschew Pl. XVII, Fig. 1				
Height of pedicle valve	20.8	35.0	25.0	21.0	16.0
Length along curvature	....	....	....	....	....
Height of brachial valve	18.0	....	....	....	....
Length along curvature	....	....	....	....	....
Greatest width	18.4	39.0	27.0	21.0	17.0
Greatest thickness	14.5	23.0	16.0	12.0	11.0
Length on hinge line	....	22.0	15.0	12.0	10.0
Proportion of height (P.V. = 1) to width	0.89	1.11	1.08	1.00	1.06

Horizon and Locality:—Rather common in the Jisu Honguer limestone of mid-Permian age, at Jisu Honguer, Mongolia. It has been obtained from the *Lyttonia* bed (1193), from the *Martinia* bed (1194), in which it is most abundant, and from the *Orthotychia* bed (1211). Collector, F. K. Morris.

Remarks:—There seems no reason to doubt the correctness of the reference of our shells to Gemmellaro's species, with the proportions of which, as well as the general form and relative convexity of the valves, it agrees in all essentials. Our shell No. 48 alone is an exception, but this agrees more nearly with the shell from the Schwagerina limestone referred by Tschernyschew to this species.

From *Martinia mongolica*, with the young of which it agrees, the more mature shells are easily distinguished by the greater difference in the relative convexity of the valves, the closer approximation of the beaks with lesser elevation of that of the pedicle valve, and the fainter development of the sinus which produces only a moderate frontal emargination in the suture line. Also there is no deflection of the lateral suture as is the case in *Martinia mongolica*. The contour of the brachial valve is also more normally arched in the present species.

41. **Martinia sinensis** Grabau, sp. nov.

Plate XVI, Figs. 3a-f (No. 133), 9a-c (No. 140)

Cf. 1897. *Reticularia lineata* Diener. *Palæontologia Indica*, Ser. XV, Himalayan Fossils, Vol. I, Pt. 3, "The Permo-carboniferous Fauna of Chitichun, No. 1," p. 56, Pl. IX, Figs. 8a-d (not 5–7).

The shell is elongate, pentahedral, longer than it is wide, and of extreme convexity, which is as great as or greater than the width.

The pedicle valve is strongly elevated with an incurved beak which projects to the plane of contact of the valves. The umbonal sides are rounded to the cardinal area, from which they are separated by an angulation. The hinge area is high and strongly curved, the length of the hinge line a little more than half the greatest width of the shell. The greatest convexity of the valve is in the umbonal region, with a long gently arched contour to the front and a more pronounced one of shorter radius to the beak.

In the young stage the valve is regularly convex, this stage continuing for a length of 5.5 mm. in the holotype, whose total length is 19.3 mm. (No. 133, Pl. XVI, Fig. 3). At that point the center of the valve becomes flattened and quickly depressed to a very shallow median sinus, which extends to the front, while broadening but deepening only to a very moderate degree. At the front this part is prolonged into a strong rounded lip. In the other shell of this species in our collection (No. 140, Pl. XVI, Fig. 9), which has a height of 22.5 mm., the non-sinuate stage is only 7.3 mm. high, or about one-third of the adult height (but less than one-fourth of the length). In this shell, the sinus is deeper, and the anterior lip is very greatly prolonged, projecting at least 12 mm. beyond the plane of the valve contact. In this respect No. 140 resembles the adult of *Martinia osborni*, but the sinus is much shallower in the present form and the shell is narrower and more convex.

The brachial valve is extremely convex and of nearly uniformly arched longitudinal contour, the greatest convexity being a little above the mid-length of the valve. In the young the transverse contour is a regular arch, but in the later stages it becomes more compressed, so that the sides are much less curved than the top which remains rounded. There is, however, no distinctly defined median fold. The sides of this valve meet those of the pedicle valve at an angle of about 125°.

Surface of both valves marked with fine sharp radiating striæ, separated by wider interspaces and somewhat irregular. They are coarser near the middle part of the shell and finer on the umbonal sides. They are best seen where the outer shell-layer has been exfoliated. These striæ are cancellated by the concentric growth lamellæ, which appear, however, less strongly marked except near the front where they are crowded. On this account the striæ appear continuous under a low-power lens. When, however, the outer shell-layer is preserved, the concentric growth lamellæ are the dominant element; these, though somewhat irregular where observed (they are chiefly preserved on the sides of the umbonal region), are sharply elevated and their margins marked by rather close-set, somewhat irregularly spaced, extremely fine pustules, visible only under a magnification of twenty-four diameters or more. They suggest the surface features of *Reticularia* or *Squamularia*, but are much too fine, while the radiating striæ of the deeper shell layers indicate that this shell is a *Martinia*. Near the front of the shell there are three striæ to 1 mm. as measured from crest to crest.

The characters of the interior are not determined; there are no indications of dental lamellæ.

Measurements:—The following are the measurements of the two specimens of this species obtained. In the pedicle valve, *a* is the young stage before the sinus appears, *b* the full size of the shell. In specimen No. 140 only the pedicle valve is preserved, hence the thickness given is for that valve only. The direct measurements as usual are taken with the plane of valve contact vertical. In the last two columns are given measurements of other species for comparison.

	No. 133 Pl. XVI, Figs. 3a-f		*No. 140 Pl. XVI, Figs. 9a-f*		*Tibetan* Diener	*M. uralica longa* Tschernyschew *Pl. XL, Fig. 9*
	a	*b*	*a*	*b*		
Height of pedicle valve..	5.5	19.3	7.3	22.5	23.0	30.3
Length on curvature.....	6.5	32.0	9.5	40.0	....	....
Height of brachial valve.	....	17.3	....	....	18.5	24.6
Length on curvature.....	....	20.0	....	....	....	....
Maximum width........	5.0	16.3	6.8	20.0	19.5	21.7
Maximum thickness.....	....	17.6	....	10.0[1]	15.0	21.4
Length of hinge line.....	....	8.6	....	11.0	12.0	12.0
Proportion of height (P.V.=1) to width....	0.91	0.95	0.93	0.89	0.85	0.70

[1] Pedicle valve only.

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia. The horizon of the smaller specimen described (No. 133) is not known; the larger (No. 140) comes from the *Martinia* bed (1194). Collector, F. K. Morris.

Remarks:—This species shows close affinities with *Martinia uralica* var. *longa* Tschernyschew from the Schwagerina limestone of the Ural region, but that shell is proportionally longer, while the relative convexity of the brachial valve is much less than in our species, being only two-thirds as deep as the pedicle, whereas in the present form the convexity is more nearly equal. Measurements of the Russian shell taken from Tschernyschew's figures are given in the last column of the table on page 188.

Another shell which in its external characters is very near to our species is that figured by Diener under the collective name of *Reticularia lineata* from Chitichun, Tibet (cf. Diener, 1897a, Pl. IX, Figs. 8a-e). Indeed if this were a *Martinia*, it might be considered as a slightly less accelerated mutation of our species in which the median sinus begins somewhat later, while the brachial valve is less convex and the frontal emargination less pronounced. The dimensions of this shell are given in the last column but one of the table above. It is thus of interest to note that the same type of shell is found in the north on the Chinese-Mongolian border, and on the south in the Indo-Tibetan border region.

42. **Martinia rectangularis** Grabau, sp. nov.

Plate XVI, Figs. 4a-f (No. 38)

This species is represented by a small shell of subquadrate outline and moderate convexity of valves. The peculiarity of outline is produced by the extended hinge line which is only slightly shorter than the width of the shell below.

The pedicle valve is nearly as wide as it is long, with the beak pointed, strongly elevated and incurved over the high-arched area, but not reaching the plane of the valve contact. The umbonal sides curve to the edge of the hinge area which is rather sharply demarcated by an angulation. The cardinal angles are obtuse, angular, slightly salient, because of the compression of the shell just below. Otherwise there is no concavity in the outline of the umbonal slopes. The greatest convexity is in the umbonal region, in the posterior fourth of the height, where the transverse contour is a regular arc. This becomes flatter forward, and in front of the mid-length the top is at first flat and then becomes gently depressed. This depression broadens forward but is never very pronounced, though it forms a distinct deflection in the frontal suture line.

The sides of the shell have a slight curvature, passing forward into the pronounced curves of the anterolateral margins, which unite in the more subdued frontal curve. Thus the cardinal angles are obtuse and the shell is slightly wider in the anterior third. The lines of growth, however, show that at a slightly earlier stage the sides were vertical, the cardinal angles essentially rectangles and the hinge line equal to the greatest width of the shell. This is the character in most of the earlier stages, when the hinge line formed the greatest shell width and the cardinal angles were rectangular.

The brachial valve is essentially as wide as it is high, with a strongly elevated incurved beak which overarches the arched hinge area, the height of which is only somewhat less than that of the pedicle valve, and which, like that, is defined by a strong angulation. The slopes on either side of the beak are at first pronounced, then flattened out so that a distinct though moderate concavity in outline is produced in the cardinal ends. The greatest convexity is in the cardinal region in front of which the transverse contour is a regular arch forward, becoming gradually lower. Close to the front there is the faintest lateral depression on each side of the median region, defining an incipient fold, which, however, does not become pronounced. As in the pedicle valve, the growth lines show that in the preceding and in the earlier stages, the sides were straight and the hinge line equal to the greatest width of the shell.

The radiating striæ, characteristic of all the Mongolian shells of this genus and generally seen wherever the outer shell layer is exfoliated, are obscurely shown on this shell. Where they are cancellated by the concentric growth lines they occur in the form of swellings or indefinite nodes.

Measurements:—The following are the dimensions of the type and only specimen obtained.

	No. 38
Height of pedicle valve	12.6
Length of same on curvature	17.0
Height of brachial valve	12.3
Length of same on curvature	15.8
Greatest width	12.2
Greatest thickness	8.8
Length of hinge-line	8.7

Remarks:—I have no way of determining whether this is a small species or represents the young of a much larger shell. So far, however, I have not found any shell of this genus in which the young has the characters seen in this shell, and certainly there is none among the Mongolian material. The rectangular character of the cardinal angles in all except the last stage, in which they are still prominent and only slightly obtuse, their salient aspect, the nearly equal length and breadth, and the umbonal convexity of both valves, are features which are characteristic of this form, and so far as I know, unknown in other shells of this genus.

Horizon and Locality:—In the *Martinia* bed (1194) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

43. **Martinia** cf. **distefanoi** Gemmellaro

Plate XVI, Figs. 6 (No. 155), 7 (No. 156), 8 (No. 157); Plate XVII, Figs. 1a-c (No. 155), 2a-d (No. 156), 3a-d (No. 157), (No. 158)

1898–99. *Martinia distefanoi* Gemmellaro, "La Fauna dei Calcari con Fusulina della Valle del Fiume Sosio," p. 306, Pl. XXII, Figs. 14–22.

There are a number of small specimens of *Martinia* in our collection which apparently agree best with the characters of the above-named species. The chief features of significance are the very moderately developed hinge area of the pedicle valve, and the elongated form.

Of the specimens here included, the smallest, apparently a young individual (No. 155, Pl. XVI, Fig. 6, Pl. XVII, Fig. 1) has a length of 11.5 mm. and a width of 10.0 mm. The beak of the pedicle valve is elevated but scarcely incurved over the high arched area which is mostly occupied by the large open delthyrium. The cardinal angles are imperfect. They appear to have been extended and slightly auriculate. The greatest convexity is in the umbonal region, and the longitudinal contour is an uninterrupted curve from the beak to front, the posterior portion being, however, curved to a lesser radius than the anterior. The median depression begins in the region of greatest convexity, about one-third the length of this specimen from the beak. It widens and slightly deepens forward but is not pronounced in this small shell. There is, however, a distinct frontal prolongation and an emargination in the suture line, though this latter is slight.

The brachial valve is less convex than the pedicle, with the beak blunt and elevated and only gently incurved. Longitudinally the contour is a nearly uniform arc slightly more convex in the umbonal region. Transversely the contour is strongly arched in the middle, while towards the front there is a faint depression on either side defining an incipient fold.

The surface is radiately striated in the deeper shell-layers, while in the outer layers where the radii are crossed by the subregular concentric growth lines, the striæ are interrupted and swollen at the margin of the growth lamellæ.

A larger pedicle valve (No. 156, Pl. XVI, Fig. 7, Pl. XVII, Fig. 2), with a height of 14 mm. and a width of 12 mm., shows the high, scarcely incurved beak, the rounded umbonal margins, and the broad delthyrium occupying the greater part of the space beneath the beak with only a moderately developed hinge area. The cardinal angle on one side preserves a distinct auriculation. The shell also has a well-marked though shallow sinus with a corresponding frontal extension. Except for the slight area and broad delthyrium it is not unlike the young of *Martinia osborni.*

A still larger specimen (No. 157, Pl. XVI, Fig. 8, Pl. XVII, Fig. 3) also shows the delthyrium occupying most of the space beneath the beak, and the incurved sides of the shell with only a narrow area on either side, which, however, is not well developed, and not strongly delimited from the shell margin. The cardinal extremities are extended into slight auriculations, and there is a distinct concavity below the cardinal angle preserved on one side.

Other specimens show similar characters. In all of them the sinus is well developed but not deep, and the exfoliated surface is striated. Where the outer shell is preserved, the subequal, rather distant growth interruptions near the front are the most pronounced surface markings, but they are not as a rule well marked on the earlier part of the shell. Where they interrupt the radii, their edges are beset by numerous small nodulose swellings.

Measurements:—The following are the dimensions of the specimens which appear referable to this species, all of them being probably immature, though the larger ones may represent the average adult size for this species as it occurs in these strata, these being, however, much smaller than the specimens from Sicily, measurements of some of which, taken from Gemmellaro's text, are given in the last four columns.

Column No.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Serial No.	*No. 155*	*No. 156*	*No. 157*	*No. 158*	*Gemmellaro's shells*			
Plate and Figure	*XVII, 1*	*XVII, 2*	*XVII, 3*					
Height of pedicle valve	11.5	14.0	20.7	19.4	35.0	38.0	27.0	20.0
Length of same	13.5	17.5	31.0	24.5	....	....	....	....
Height of brachial valve	10.5	....	....	....	....	....	....	....
Length of same	11.5	....	....	....	....	....	....	....
Greatest width	10.0	12.0	19.5	18.5	33.0	32.0	25.0	18.0
Thickness	7.9	....	....	....	23.0	?	18.0	13.0
Length of hinge-line	4.2	6.5	9.4	7.7	14.0	15.0	11.0	8.0
Basal width of delthyrium	4.0	6.0	6.9	5.8	....	....	....	....
Proportion of height (P. V. = 1) to width	0.87	0.93	0.98	0.95	0.94	0.84	0.93	0.90

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia, exact level not known; not uncommon. Collector, F. K. Morris.

Remarks:—I refer these shells with considerable hesitation to Gemmellaro's species, for although they agree with that species in their general character and the proportions, there are certain very marked differences. The beak of the pedicle valve in the Sicilian species is more strongly incurved, and there is greater approximation to the beak of the brachial valve than is the case in our shells. The auricular character of the hinge-area appears to be common to both, but the shoulder angles are sharper in the Sicilian than in our shells, giving the hinge-area a more definite character. Finally, the frontal emargination of the Sicilian shells is more pronounced than in those from the Jisu Honguer limestone, though that may be a matter of further development. Certainly in the specimen figured by Gemmellaro (1898–99, Pl. XXXII, Figs. 16–19) the corresponding stage appears to be no more sinuate than is our largest shell. This seems to be the specimen whose measurements are given in column 5. In Gemmellaro's figure, the exfoliated portions of the shell show radii similar in strength and disposition to those shown in our shells.

Tschernyschew has described a small shell from the Schwagerina limestone under the name *Martinia parvula* (1902, page 567, Text-Figs. 50–51, Pl. XX, Figs. 2–4) which is not unlike our smaller shell, agreeing with it in size. The Russian shell is, however, more elongate and the beak of the pedicle valve more incurved, while the convexity of the brachial valve is proportionately less than in our shell. In the development of the median depression and the frontal emargination, however, the two are very similar.

44. **Martinia distefanoi** Gemmellaro var. **spissa** Grabau, var. nov.

Plate XVII, Figs. 4a-f (No. 40)

The shell is distorted, more oblique on one side than on the other, this inequilateral development being more pronounced in the full-grown shell than in the earlier stages, where there is, however, some indication of it. This, however, in itself is not considered a distinctive character. The shell is elongate with strongly convex valves and prominent distant and projecting beak.

The pedicle valve has its greatest convexity in the umbonal region. The beak is elevated and turned over so as to overhang the high-arched cardinal area, but it is not turned downwards. In the young stage the shell is uniformly arched transversely as well as longitudinally, and almost, if not quite, symmetrical. At that stage the height is 9.2 mm., the width 8.2 mm., and the length of the hinge line 5.3 mm. The next stage, which has a height of 15.3 mm., a width of 13.4 mm., and a length of hinge area of 8.4 mm., has the cardinal angles depressed, producing a concavity in the slope of the cardinal margins. The irregularity of growth is shown in the hinge region, where the cardinal angle on the left is normally and angularly obtuse, whereas on the right there is a contraction before the cardinal angle is reached. Otherwise the addition is symmetrical, being greatest, of course, in the anterior region. In this stage there is a distinct median flattening and faint depression along the center of the pedicle valve. The final stage is added almost entirely at the front and right side, the hinge line not being added to on the left but considerably extended on the right, so that its length is 9.7 mm. The median depression is slightly more pronounced, and an irregular frontal emargination is produced in the suture.

The hinge area is narrow because of the very large triangular fissure or delthyrium which has a basal width of 6.5 mm., or $\frac{67}{100}$ of the length of the hinge line.

The brachial valve is as convex as the pedicle valve but more triangularly arched in transverse contour, with the sides nearly flat but the top rounded. The early stage is normally convex and symmetrical, the valve at this stage having a height of 7.1 mm., a width of 6.6 mm., and a length of hinge area of 6.2 mm. With the additions during the succeeding stages, the cardinal angles become depressed, so that the cardinal slopes on either side show a concavity. The asymmetric development proceeds in the same way as in the pedicle valve, though the greatest addition here is on the left side. The beak in the adult is considerably elevated and incurved over the moderately high hinge area, which is arched. The roof-like character of the transverse contour becomes less pronounced forward but there is no distinctive fold.

The surface features are poorly preserved. The deeper shell-layers are strongly and somewhat coarsely striated, but the details of the surface layer are not determinable.

Measurements:—In the following table the measurements of the several stages are summarized:

Specimen No. 40	*Adult shell*	*Pedicle valve*			*Brachial valve*	
		a	*b*	*c*	*a*	*b*
Height	....	9.2	15.3	18.5	7.1	16.1
Length	....	....	....	24.0	....	18.5
Width	....	8.2	13.4	15.7	6.6	15.7
Thickness	12.0	....	....	....	....	....
Length of hinge	....	5.3	8.4	9.7	6.2	9.7
Basal width of delthyrium	....	....	....	6.5	....	....
Proportion of height (=1) to width	....	0.89	0.87	0.85	0.93	0.98

Horizon and Locality:—In the *Martinia* bed of the Jisu Honguer limestone at Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—This shell might be considered a small specimen of *Reticularia inæquilateralis* Gemmellaro, because of its inequilateral development, but that form is usually distorted by the deflection of the beak of the pedicle valve to the right. Also that shell has a sinus which begins far up on the shell, whereas in our specimen this is scarcely developed. Moreover, that species probably belongs to the genus *Squamularia*. The distorted character may be considered an individual feature.

It is true that there are certain marked differences which separate our shell from the Sicilian species, and these may indicate complete specific distinction. On the other hand, this shell is closely related to the Mongolian shell described above as probably belonging to that species, especially to the young shell shown in Plate XVII, Fig. 1. The present variety, however, although it is a third again as large as the young shell referred to, has the median depression on the pedicle valve and the frontal emargination much less strongly developed. The brachial valve of this variety is also proportionately deeper, and its contour is more sharply roof-shaped than is that of the brachial valve of the young shell cited or that of any of the Sicilian shells.

45. **Martinia distorta** Grabau, sp. nov.

Plate XVIII, Figs. 5a-f (No. 118)

The specimen to be described under this name is peculiar because of its extreme irregularity of growth. It might be regarded as a pathological individual and so indeed it may be, but it is none the less interesting on that account, since experience has shown that the expressions in the shell of a pathological state of the individual are similar to those shown in old-age individuals and in members of a phylogerontic race. Hence under peculiar environmental conditions such as may have obtained in Mongolia at that time,[1] a race of distorted *Martinias* might arise with characters essentialy like those seen in this individual, though there may be much difference in detail.

The peculiarity of structure is already indicated in the young shell, though the characters of the very young stage are not determinable. When the pedicle valve is only 8.3 mm. high the greatest width is at or near the hinge line, that part of the shell being extended on the right side into a blunt mucro, in front of which the shell margin is concave. On the left side, however, the greatest lateral extension is much below this, being indeed near the mid-length of the shell, above which the side slopes inward to the obtuse cardinal angle. This side of the shell is marked by a pronounced concavity in the lateral umbonal slope. At this stage the shell is not unlike the young of some mutations of *Martinia polymorpha* Gemmellaro from the Sosio beds (1898–99, Pl. XXXI).

In the next stage the addition is mainly in front, so that whereas the length has increased to 11.3 mm., or a matter of 3 mm., the mid-width of the

[1] See the discussion in Chapter VIII.

shell has increased only about 0.6 mm., that is, from 8.8 to 9.4 mm. The side slopes of the shell are now distinctly concave, being nearly alike on both sides. The lateral shell margins at this stage, too, are gently concave and merge with a slight angulation into the rounded frontal margin, which is regular. The concavity of the lateral slopes continues to the adult, while at the same time the additions to the front become irregular, being greatest on the left side, so that that part of the valve is longer than the right side, producing a pronounced inequilaterality. The unequal enlargement of the shell continues to the adult, the addition to the front of the shell being much in excess of that added to the sides. Thus in the last stage the valve has increased in length from 11.3 mm. to 14.6 mm. on the right side and to 15.5 on the left, or a matter of 3.3 to 4.2 mm. The addition to the width in the middle of the shell on both sides has been only 1.3 mm., or an increase in width from 9.4 to 10.7 mm. Below this point, however, the shell widens so that the greatest width near the front is 12 mm. The length of the hinge line in the full-grown shell is 9.3 mm.

The beak of the pedicle valve is incurved but scarcely overhangs the hinge area, which is concave and of moderate height and defined by angular cardinal margins from the depressed and somewhat irregular lateral umbonal slopes. Just before the end of the first stage described, the regular transversely arched contour is interrupted by a medium depression which becomes a very shallow median sinus characterized along its center by a more sharply depressed line. This depressed line, however, becomes obsolete in the last stage, though the shallow sinus persists.

The brachial valve is somewhat less irregular. At first and up to the point where the valve is 9.7 mm. long, the greatest width is at or just in front of the hinge line, the shell margins contracting in front of this. The sides and frontal margins are straightened so that the shell has a squarish aspect, with, however, the left side most extended near the hinge line, this corresponding to the extended right side of the pedicle valve. The side slopes are also concave and continue so to the adult, which has a height of 14.4 mm. on the longer and 13.3 mm. on the shorter side. The front of the shell is rather abruptly deflected downward, especially on the shortened side.

The beak of the adult brachial valve is also incurved, overhanging the concave hinge area to a very slight extent. The latter has a height somewhat less than that of the pedicle valve and is equally defined by sharp cardinal margins near which the shell surface is depressed. The beaks of the two valves are distant.

The surface is marked by numerous irregular concentric growth lines and growth irregularities, and, in the exfoliated shell surface, by numerous regular radiating striæ more or less regularly interrupted by the growth line, giving them, under the lens, a pustulose character.

From the character of the young with its extended hinge line, the suggestion lies near that this is a form derived from *Martinia rectangularis* (Species No. 42), but the distortion gives even the early stages a distinctive appearance. It is probable that we have here a member of the *Martinia* tribe in which senescent characteristics are developed at an early stage and that like the Sicilian *Martinia polymorpha* it bears a relationship to the normal form of the genus comparable to that of the distorted members of the *Streptorhynchus*, *Meekella*, *Productus*, and other groups found in the Permian strata of this and other regions.

Horizon and Locality:—In the *Martinia* bed (1194) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

46. **Martinia rhomboidalis** Grabau, sp. nov.

Plate XVIII, Figs. 6a-f (No. 145)

Shell small, of sub-rhomboidal outline with tumid valves. It has a maximum height of 12 mm. and a maximum width of 9.7 mm. near the mid-length, the shell being distinctly elongate, with strongly convex valves whose combined thickness is 7.8 mm. The hinge line is extended, but its length is less than the width of the shell below. From the point of maximum breadth the sides converge rapidly forward, joining in an abruptly round anterior end.

The pedicle valve is slightly more convex than the brachial, with the greatest convexity in the posterior third. The umbonal region is elevated, with the beak incurved and overhanging but broken in the specimen. The umbonal sides are regularly rounded to the cardinal margins without concavity. The hinge area is highly arched, defined by pronounced angulations of the cardinal margins. The delthyrium is large, its basal width nearly equal to half the length of the hinge line. The cardinal angles are slightly salient, obtuse, but angulated with the sides diverging straight forward to the point of greatest width. This is subangular, more pronouncedly so on one side (the left) than on the other, and below it the sides slope straight forward to the front, which has a width of 3.4 mm., or slightly more than one-third the greatest shell width. The front is broadly rounded. The transverse contour is regularly arched throughout, the arch gradually becoming lower forward. There is no flattening or depression, except at the very front, where the suture shows a gentle emargination, indicating the beginning of the formation of a sinus and lip. Inside of the lateral shell margin on either side, there is, however, a marked growth contraction followed by an expansion so as to produce a step in the contour, while the lateral sutural margins are sharp and the intervalvular angle slightly acute. A corresponding contraction is seen in the brachial valve, and this might be taken to indicate that the shell has reached the end of its growth and is either the adult form of a small species or a dwarfed representative of a larger form of similar outline.

The brachial valve has its greatest convexity a short distance behind the mid-length, from which point it curves regularly to the front, and at a larger radius to the beak. This, though also slightly injured, is elevated and apparently incurved, subtending a gently arched hinge area of moderate height. The shell is slightly depressed at the cardinal angles, which are thus given a faint salient aspect. Transverse contours are regular arches, except for the marginal step-like contraction already referred to. There is no fold.

Surface finely radiate as in the other species.

Measurements:—The following are the dimensions of this shell:

	No. 145
Height of pedicle valve	12.0 mm.
Length of same	15.0 mm.
Height of brachial valve	10.3 mm.
Length of same	13.0 mm.
Greatest width	9.7 mm.
Maximum thickness	7.8 mm.
Length of hinge line	7.1 mm.

Horizon and Locality:—In the *Martinia* bed (1194) of the Jisu Honguer limestone at Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Genus **Squamularia** Gemmellaro (emend. Girty)

As emended by Girty, this generic name is now applied to all those spiriferoids which have the external characters of *Reticularia* but internally possess neither dental plates nor median septum. Thus this genus holds the same relationship to *Reticularia* as *Martinia* holds to *Martiniopsis*. It includes probably all the Permian species formerly referred to *Reticularia*.

47. **Squamularia eleganuloides** Grabau, sp. nov.

Plate XVI, Figs. 1a-f (No. 47), 2 (No. 138)

Shell transverse, wider than high, of subregular outline. Represented in our collection by a young pedicle valve and a fragmentary adult pedicle valve.

In the immature pedicle valve (No. 47), the beak is elevated but hardly incurved, and the shell is strongly inflated in the umbonal region, which is the most convex part of the shell. The sides curve regularly to the broad triangular deltidial fissure, which divides the region beneath the beak, there being in this valve no hinge area. The rounded slope which takes its place is very gently concave, as seen in the side view, rising from the hinge line to the beak (which is imperfect), while describing an arc of less than ninety degrees.

From the margins of the delthyrium, which is about two-sevenths of the greatest width of the shell, the shell margins describe a curve which is regular throughout though of slightly greater radius in front.

The median longitudinal contour describes a gentle arc from beak to front, while the transverse contours change from a very convex arc in the umbonal region to one of constantly increasing radius forward, until near the mid-length the top of the arch becomes flattened and after that gently depressed. This depression is, however, not sufficient to produce a sinus, and at the front it is marked only by the faintest deflection of the suture line dorsalward.

The surface of the shell has the appearance of being marked only by moderately strong concentric wrinkles, which increase slightly in width forward and are on the whole very uniformly disposed. These wrinkles are roof-shaped, with their sides sloping beakward on the one hand and forward on the other. The wrinkles appear perfectly smooth, even on their summits, though under a very high-powered lens the tops of the ridges are seen to be marked by exceedingly fine pustules which are evidently spine bases. No radial striation is visible, even where the shell is exfoliated.

Measurements:—The dimensions of this shell are:

	No. 47
Height of pedicle valve	15.0 mm.
Length on curvature	18.5 mm.?
Greatest width	17.2 mm.
Width of deltidial fissure	4.8 mm.
Thickness of valve at umbo	7.7 mm.

The larger shell (No. 138, Pl. XVI, Fig. 2) has a length of 26.7 mm. and a width exceeding that (approximately 33 mm., though the shell is too imperfect for precise measurements). The early stages, so far as preserved, agree in all respects with the younger, more perfect, shell described. The hinge area is absent, and the shell curves to the broad deltidial fissure. On the margin of this there is preserved on one side a deep rounded groove, which becomes gently broader and deeper forward and is impressed upon the shell as a distinct downward deflection of the shell substance, the shell below the groove being of the same thickness as that on its side.

The median flattening and gentle depression seen in the smaller shell are equally marked at the corresponding stage in the larger one. From that point the depression regularly broadens forward but becomes of scarcely greater depth proportionately, so that even in the large shell it can not be spoken of as a sinus. Nor does it produce any forward deflection of the concentric wrinkles, which form a continuous, regular arcuation across the front of the shell. The concentric wrinkles are equally strongly marked on this shell, there being about four in 3 mm. near the front, whereas there are about three in 2 mm. in the young stage. These have the same roof-shaped character throughout, and are widest in the middle, becoming more crowded on the sides. In this specimen no finer details are observable, owing to the strong exfoliation of the shell. There are no radiating striations visible on any part of the shell.

This shell seems to combine the hinge characters of *Squamularia indica* (Waagen), with the surface features of *Squamularia elegantula* (Waagen). Like the former, the pedicle valve has no hinge area, but the sides curve to the broad open delthyrial fissure. The Indian shell is, however, more nearly circular, while ours is transverse and the surface features are distinct. These in our specimen correspond closely to those described by Waagen as characteristic of *Squamularia elegantula*, to which species our shell would be referred, except for the fact that the Indian shell has a well-marked hinge area separated from the rest of the shell by a sharp cardinal angulation as in the majority of the species of this genus. The hinge line of the Indian shell is also stated to be "not very much shorter than the greatest breadth of the shell." I have chosen the specific name to indicate the rather close correspondence, otherwise, of our shell with that from the Productus limestone of the Salt Range.

Horizon and Locality:—This is a rare form in the Jisu Honguer limestone of Jisu Honguer, Mongolia, only two specimens having been obtained. The exact level at which the smaller shell (No. 47) was found is not known; the larger, however (No. 138), was found in the *Lyttonia* bed (1193). The specimens were collected by F. K. Morris.

48. **Squamularia indica** (Waagen)

Plate XVII, Figs. 5a-f (No. 162); Plate XVIII, Figs. 2a-d (No. 165), 3a-c (No. 164), 4a-c (No. 395), (Nos. 115, 127, 130, 154, 163, 159, 160, 161, 170)

1882. *Reticularia indica* Waagen. Brachiopoda. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 542, Pl. XLIII, Fig. 6, Pl. XLIV, Fig. 2 (with older literature references).

Not 1911. *Spirifer* (*Reticularia*) *indica* Frech. In Richthofen, China, Vol. V, p. 118, Pl. XXVIII, Figs. 4a-b. (This is referred by Chao to *Squamularia nodosa* Chao, *Palæontologia Sinica*, Ser. B, Vol. XI, Fasc. 1, p. 95.)

1929. *Squamularia indica* Chao. "Carboniferous and Permian Spiriferoids of China." *Palæontologia Sinica*, Ser. B, Vol. XI, Fasc. 1, p. 94 (referred to).

A single large shell of this species, comparable to the type of the species described by Waagen, though smaller, has been found in one of the horizons of the Jisu Honguer limestone, associated with *Camarophoria superstes*, *Dielasma truncatum*, etc. Besides this, a number of immature specimens apparently referable to this species have been found in other beds of this limestone series. These will be described separately.

THE ADULT SHELL

Plate XVIII, Figs. 3a-c (No. 164), 4a-c (No. 395)

The pedicle valve (No. 164) is of large size, transverse wider than it is high. Though the specimen is imperfect, the relative dimensions are determinable with a fair degree of accuracy. Compared with those of the Indian shell, the type of the species, the proportions of length and width are the same, though the Mongolian shell is not much more than two-thirds the size of the Indian shell.

Measurements:—The measurements of our two large shells (one pedicle and one brachial valve) and of the Indian shell are given in the following table.

	Mongolian shells		*Indian shell Waagen*
	No. 164 Pl. XVIII, Fig. 3	*No. 395 Pl. XVIII, Fig. 4*	
Height of pedicle valve	44.0	....	61
Length of same	55.0	....	..
Height of brachial valve	....	41.0	54
Length of same	....	46.7	....
Greatest width	46.6	44.0+	65
Thickness	14.8[1]	11.6[2]	36
Length of hinge line	25.5	22.8	26
Width of delthyrium	15.0	....	17

The beak of the pedicle valve is moderately elevated, and was apparently slightly incurved, though the apical portion is broken away. The surface rounds almost without interruption to the broad delthyrial fissure, there being no flattening or demarcation by an angulation to indicate the existence of a hinge area. At the margin of the delthyrium the sides of the shell are turned downward for a space, so that the delthyrium is actually depressed. The transverse contour of the shell is a perfectly regular arc from margin to margin, but forward that arc becomes flattened on top and then depressed into a gentle sinus which apparently is not marked by any frontal prolongation, though there is an evident sinuosity in the frontal sutural margin. The longitudinal median contour is a nearly regular curve, becoming more arcuate, however, in the umbonal region. The greatest convexity of the valve is about

[1] Pedicle valve only. [2] Brachial valve only.

one-third the height from the beak. Both sides and front are regularly rounded so that the outline appears subcircular.

The surface is mostly exfoliated, but near the margin both concentric and radiating striæ are visible. The former, marking the margins of the growth lamellæ, are about 1.5 mm. apart; the radiating striæ near the front are distant about 0.75 mm., but sometimes they are closer.

A brachial valve of a similar adult individual (No. 395, Pl. XVIII, Fig. 4) from the Marginifera bed, shows a normal characteristic for the species. The beak is slightly imperfect, but appears to have been incurved over the narrow vertical area. The umbonal region rises rather prominently above the cardinal slope, slightly modifying the otherwise circular outline of the valves. The transverse contour is a regular arch with a somewhat greater radius in the frontal than in the umbonal region. There is no median elevation of any kind, though a slight median deflection in the growth lines indicates a faint frontal emargination. Longitudinally the contour is a regular curve, with the greatest elevation in the posterior third, from which the slope to the beak is slightly more abrupt than that to the front.

The surface features are not well preserved, but the fine sub-regular growth lamellæ are readily seen in some parts. There are, however, only faint indications of the interrupted striæ as the outer shell layer is wholly exfoliated. At the end of the nepionic stage and again near the front of the adult, there are step-like interruptions in the growth.

Another brachial valve (No. 165, Pl. XVIII, Fig. 2) of smaller dimensions from another bed (1196) has the following dimensions:

	No. 165
Height	22.0 mm.
Length	30.0 mm.
Width	25.6 mm.
Thickness	8.4 mm.

which gives proportions not unlike those of the Indian shell.

The beak is elevated and pointed but scarcely incurved, and the sides and front are rounded. The transverse contour is a regular arch, and the longitudinal contour is almost regular, with the greatest convexity near the middle. The surface shows both radiating striæ and concentric growth lamellæ, but neither are very well preserved.

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia; the large pedicle valve was obtained from the *Camarophoria* bed (1208), the large brachial valve from the *Marginifera typica* bed (1192), and the brachial valve from the *Hemiptychina* bed (1196). Collector, F. K. Morris.

IMMATURE SPECIMENS

Plate XVII, Figs. 5a-f (No. 162), (Nos. 130, 154)

Several small valves of subrotund outlines, short hinge line and broad delthyrium are referred with hesitation to this species, agreeing with it in form and character of hinge, but being of very much smaller size. One of the smallest individuals referable to this species is subrotund with the width slightly greater than the height (No. 162, Pl. XVII, Fig. 5). The beak is elevated, scarcely incurved over the arched cardinal region, which is largely occupied by the delthyrium, margined laterally by a narrow area which merges into the shell on either side. The greatest convexity is in the umbonal region. The transverse contour is regularly arched to the sharp lateral margins. There is no sinus or flattening, and the front suture is straight.

The brachial valve is less convex than the pedicle, with the beak elevated but not incurved. The cardinal angles are slightly salient. The longitudinal contour is subregular, slightly more arched at the umbo. The transverse contours are regularly arcuate and have no fold. The surface is radiate where exfoliated but shows concentric lamellæ where the shell is preserved, with fine nodules on the lamellæ margins.

A larger pedicle valve, also tentatively referred to this species (No. 130), shows similar longitudinal and transverse contours, but the median depression becomes more pronounced towards the front. At the stage corresponding in size to the previously described specimen, this character is, however, equally slightly developed. The umbonal slopes around to the delthyrium, but there is a narrow flattened area on either side of the fissure. The beak is but slightly incurved. The surface characters are similar to those of the smaller specimen, but the pustulose character is preserved in a few places only. The width of this specimen is much greater than the height.

A small brachial valve (No. 154) is also referred to this species, though with even more hesitation. The valve is nearly orbicular, slightly wider than high, with strongly rounded sides. It is obtusely angulated, has slightly salient cardinal angles and a hinge line five-eighths the width of the shell in length. The transverse contour is regularly arched. The greatest convexity lies behind the mid-length. The beak is slightly elevated, not incurved, and the surface is without fold.

The deeper shell-layer shows regular fine sharp striæ, while the outer layer shows the concentric lines and pustules only slightly developed.

Measurements:—The following are the dimensions of the three specimens described:

Squamularia indica (Waagen)

Serial No.	*No. 162*	*No. 130*	*No. 154*
	Pl. XVII, Figs. 5a-f		
Height of pedicle valve	9.7	22.4	....
Length of same on curvature	....	28.0	....
Height of brachial valve	9.0	....	11.4
Length of same on curvature	....	....	12.5
Maximum width	9.8	25.0	12.0
Greatest thickness	6.8	....	....
Length of hinge line	5.4	11.2	7.5
Basal width of delthyrium	3.1	7.0	....

Remarks:—Although our shells are only from about one-third to one-fourth the size of the largest Indian shell, the general characters and proportions agree very well, especially those of the specimen first described. The sub-orbicular form, moderate convexity of valves, elevated but slightly incurved beak of the pedicle valve, the absence of a flattened area or its faint development, and the large delthyrium are characters which the Indian and Mongolian shells have in common, and which separate them from other species of this genus in the Asiatic Permian.

Horizon and Locality:—In the *Martinia* bed (1194) and more rarely in the *Lyttonia* bed (1193) and the *Orthotychia* bed (1192) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; not uncommon. Collector, F. K. Morris.

49. **Squamularia waageni** (v. Loczy)

Plate XVI, Figs. 5a-d (No. 167)

1883. *Spirifer lineatus* Kayser. Richthofen, China, Bd. IV, p. 174, Pl. XXII, Fig. 6 (*cetera exclus*).

1899. *Reticularia waageni* v. Loczy. Wissenschaftliche Ergebnisse der Reise des Grafen Bela Szechonyi, Bd. III, p. 110, Pl. IV, Fig. 1.

1911. *Spirifer* (*Reticularia*) *waageni* Frech. Richthofen, China, Vol. V, pp. 118 and 141, Pl. XXVIII, Figs. 2a-e, 3.

1929. *Squamularia waageni* Chao. "Carboniferous and Permian Spiriferoids of China." *Palæontologia Sinica*, Ser. B, Vol. XI, Fasc. 1, p. 93, Pl. XI, Figs. 7–11.

A large and rather imperfect specimen has the characters of this shell as defined by Frech, and it is apparently the only adult individual obtained from the Mongolian deposits. It is longer than it is wide, with strongly convex valves and scarcely incurved beaks.

The pedicle valve is slightly more convex than the brachial, with regularly arched surface and apparently without median sinus. The beak is elevated but scarcely incurved over the high gently arcuate area, which is not defined by angulations but represents the overcurving margins of the umbonal region of the shell. The outline is elongate, with the sides rounded, the greatest width being in front of the mid-length. The hinge line is considerably shorter than the greatest width.

The pedicle valve is the more convex, the greatest convexity being apparently near the mid-length. The beak is imperfect but appears to have been strongly elevated without pronounced incurvature. The umbonal sides are turned over to the hinge region, becoming slightly flattened but not separated from the shell by a marked angulation. Indeed, the overturned portion hardly deserves the name of hinge area. In the center is the broad delthyrium which occupies most of the cardinal space. Its sides are distinctly grooved.

The brachial valve, though less convex than the pedicle, is rather strongly arched, though towards the front it is more flattened. The beak, too, is strongly elevated and apparently was not incurved, though the specimen is imperfect. A well-marked high and nearly vertical area is present, this being separated from the rest of the shell by a pronounced angulation. The character of the median opening is not shown.

The surface is marked by subequally spaced concentric growth lamellæ or faint wrinkles, of which three occupy the space of two millimeters in the umbonal portion of the brachial valve. The wrinkles are nearly symmetrical in section, being highest in the middle and sloping in a roof-shaped manner to the sides. There are no pustules visible in this specimen, and only the faintest indication of radiating striæ. The concentric wrinkles, however, are characteristic.

Measurements:—The following dimensions are only approximate, as the specimen (No. 167) is too incomplete for full measurement. The dimensions of the perfect shell from the Djulfa beds of Armenia, figured by Frech, together with those of a specimen from the Permian of southern Kiangsu, China, after Chao, are given for comparison.

	Mongolian Shell, No. 167 Pl. XVI, Fig. 5	*Djulfa Shell*	*Chinese Shell, Chao, 20, 49, Pl. XI, Fig. 9*
Height of pedicle valve	45.5	47.3	26.0
Height of brachial valve	39.0	39.0	....
Greatest width	34.0	42.5	24.0
Greatest thickness	31.0	29.0	....
Length of hinge line	28.0	28.0	....
Basal width of delthyrium	15.0	12.0	....

Horizon and Locality:—A single specimen has been obtained in dense limestone from the *Spirifer moosakhailensis* bed (1205) in the Jisu Honguer limestone (Permian) in Mongolia. Collector, F. K. Morris.

Genus **Spiriferina** d'Orbigny

50. **Spiriferina mongolica** Grabau, sp. nov.

Plate IX, Figs. 5a-f (No. 275), 6a-f (No. 274), (No. 276)

This shell is extremely transverse in the adult with mucronate cardinal extremities and few very coarse plications.

Measurements:—The following are measurements of two characteristic specimens:

	1	*2*
	No. 274	*No. 275*
Height of pedicle valve	5.9	14.3
Length of same	8.3	18.0
Height of brachial valve	5.3	11.9
Length of same	6.6	17.0
Extreme width	8.5	23.2
Original width[1]	8.8	26.0
Length of hinge line	7.5	25.2
Greatest thickness	4.2	9.8
Height of hinge area, pedicle valve	2.0+	3.5+

Young:—The young shell (No. 274, Pl. IX, Fig. 6) shows a much less proportional width than the adult, having the cardinal angles acutely rounded instead of mucronate. The pedicle valve is much more convex than the brachial, with the greatest depth in the umbonal region. The beak slightly overarches the relatively high, gently arched hinge area, which is inclined. The shoulder is subangularly rounded and gently concave in outline. The sinus begins at the apex and is immediately bounded by two strong plications, which increase in strength forward, becoming broader but remaining rounded on top, and remain the strongest plications of the shell. The sinus is rounded and deep, but at this stage there is no anterior lip-like extension. A second plication begins a short distance below the beak on either side and becomes stronger forward but does not reach the strength of the bounding plication. The interspace between the first two plications is round-bottomed and broader than the plications. A third plication appears near the hinge line but is weaker than the others.

[1]Obtained by doubling the width of the unbroken half.

The brachial valve is gently convex with a regular median longitudinal contour from beak to front. The beak scarcely projects above the shoulder angle and is not overarching. The shoulder is straight and slightly sloping outward, and angulated in section, with the hinge area very narrow and vertical. A strong median plication, corresponding to the sinus, occupies the center of the valve. It is narrowly rounded at the top with the sides sloping outward in roof-like manner. It is the highest of the plications but is narrower than the first lateral plication on either side. These lateral plications also begin close to the beak, becoming strong forward and broader than the median plication, corresponding to the broader interspaces between the first and second plications on the pedicle valve. Outside of these on either side appears a faint second plication, corresponding to the shallow interspace between the second and third plications of the pedicle valve.

The shape of the valve is nearly semicircular, with the outline regularly curving between the cardinal angles. The suture line is strongly zigzag, with the median part an equilateral triangle, the zigzag decreasing outward.

Adult:—(No. 275, Pl. IX, Fig. 5). The beak of the pedicle valve is more strongly arched, being slightly overhanging. The hinge-area is high but still inclined and gently arched, except under the beak, where it curves strongly. The shoulder is subangularly rounded, slightly more angulated at the upper margin of the hinge-area and, longitudinally, gently concave from the beak to the cardinal angles, which are mucronate. The hinge area does not appear to extend the full length of the hinge line. The sinus remains rounded to the front, where it is abruptly deflected for about 3 mm. at an angle of 110° and continued in a rounded plication which is continuous with the similarly deflected median fold of the brachial valve. The bounding plications increase rapidly in height and also in width to a point a short distance from the front, where they decline again rather abruptly, until at the frontal margin they are much lower. The second pair of plications broadens forward until their width equals that of the first or bounding plications, but they are not high. The third pair is scarcely stronger than in the young shell, having more the character of a broad undulation. The outer part of it is continued in the mucronate cardinal extremities.

In the brachial valve of the adult, the beak projects more strongly and slightly overhangs the hinge area which is narrow and vertical on either side. The shoulder has become gently concave longitudinally but remains sharply angular in transverse section. The median fold has become very high and prominent, though remaining relatively narrow, its side still straight but diverging at a smaller angle than in the young. It widens regularly forward and its summit is regularly rounded. From a short distance in front of the beak, the crest line of the fold is straight and slightly rises forward with reference to the plane of the valve contact. Then it is suddenly deflected inwards at an angle of 83°, with the angle rounded, and continues for a distance of 3.8 mm. below the crest line of the fold. In this way a frontal fold is formed partly by the brachial and partly by the pedicle valve and with a length of 6.8 mm. This geniculation of the median fold forms the most pronounced feature of the shell in the specimen described, but whether it always is so pronounced can not be stated, since the only other adult specimen in the collection (No. 276) is imperfect in this portion. It results in giving the brachial valve a greater convexity than the pedicle valve. The first pair of lateral plications also becomes pronounced forward, but these plications attain only half the height of the median fold, though being its equal or nearly so in width. At the front they are also geniculate, though at an obtuse instead of an acute angle, the knee being rounded but the lower part straight. The amount of deflection below the summit line is about 3.5 mm., a small part of this being due to the thickening of the pedicle valve. The second plication is much shorter and lower but still fairly pronounced, also with a slight frontal thickening producing the effect of a geniculation. A small, rather indistinct, third plication continues into the mucronate cardinal extension.

The surface of the shell is coarsely and subregularly pitted, three of these pits with their two interspaces occupying, on the side of the shell, an interval of 1.2 mm. The pits are rounded, slightly varying in size, the larger ones exceeding in diameter the width of the interspace, the smaller ones equaling it or being slightly less. Where the shell is exfoliated, these pits are represented by low pustules. Strong concentric growth lines are seen at intervals, especially near the front where they are more crowded. The finer growth-lines are not apparent.

Horizon and Locality:—This species seems to be restricted to the *Hemiptychina* bed (1196) of the Jisu Honguer limestone of Jisu Honguer, Mongolia, where three specimens, two adults and one young, were obtained by F. K. Morris.

Comparisons:—The only species which I have seen that approaches our shell is *Spiriferina multipunctata* Mansuy (1913b, p. 74, Pl. VIII, Figs. 9a-c) from the Permian Productus limestone of Indo-China. This shell agrees with the Mongolian form in having the small number of coarse plications, but it does not develop the high median fold of the pedicle valve. It is also proportionately less extended transversely, is without the mucronate cardinal extremities, and has a much lower hinge-area in the pedicle valve. The punctations of the Indo-China shell, too, are much finer.

Superfamily RHYNCHONELLACEA Schuchert

Family RHYNCHONELLIDÆ Gray

Genus **Uncinulus** Bayle

51. **Uncinulus mongolicus** Grabau, sp. nov.

Plate V, Figs. 7a-d (No. 31), 8a-d (No. 32); Plate VI, Figs. 3a-e (No. 387), 4a-e (No. 388), (Nos. 57, 389)

The shell is small, transverse, wider than it is high. It is extremely ventricose in front. The pedicle valve is shallow, very gently convex on top with the sides abruptly but only slightly deflected. The beak is pointed and projecting in the young considerably above that of the brachial valve. It is very slightly incurved, but as the apical portions of adult specimens are broken, the amount at that stage can not be determined with certainty.

On either side of the beak the shell is distinctly depressed, forming a concave false area. These two depressed false areas, however, are not in the same plane and so do not give the aspect of a true hinge area. They are bounded by rather pronounced, though not sharp, shoulder angles on the shell side, which emphasize the pointed appearance of the beak. The deltidial plates are large, closing a broad triangular delthyrium.

The median longitudinal contour of the pedicle valve is regularly convex from the beak to the frontal portion, which is abruptly deflected with a rapid curvature into a median prolongation at right angles to the plane of the valve. The greatest convexity of the valve is near or above the middle of the length. The transverse contour is at first regularly arched, except for the more abruptly subtriangular cardinal margins. Below this the median surface is flattened and even faintly depressed to form the median sinus, which is, however, not pronounced at any time. The plications which bound the sinus are not larger than those within the sinus, these latter numbering usually six, but seven in the largest individual, making a total of eight or nine with the bounding plications, which also extend into the median prolongation. This latter projects beyond the middle of the frontal elevation of the shell joining the opposite valve front in a zigzag suture. Each of the six median plications is marked by a distinct, sharp, but shallow, longitudinal median groove, which extends for somewhat more than the last half of the length of the deflected frontal lip. The bounding plications are less strongly marked by these grooves, and they are barely indicated on the deflected margins of the lateral plications of this valve.

In the average shell there are at least seven of these plications on either side of the sinus, or eight including the bounding plication, thus making eight—six—eight, or twenty-two in all. In our largest shell (No. 387, Pl. VI, Fig. 3), there are nine on either side, or ten with the bounding plications; thus in this shell there are ten—seven—ten, or twenty-seven plications in all.

These lateral plications decrease somewhat to the cardinal margins, the last approximately coinciding with the angulations bounding the pseudo areas. The plications broaden rather rapidly towards the front, where they are rounded, except in the projecting lip, and are separated only by sharp narrow linear grooves. Very fine uniform concentric growth lines cover these plications.

The brachial valve is much more pronouncedly convex than the pedicle valve, and becomes obese near the front. The longitudinal contour from the beak to the frontal edge, which is abruptly bent at right angles to meet the front of the pedicle valve, is regularly arched to a somewhat smaller radius than that of the pedicle. The actual line of meeting in one specimen (No. 31) is even faintly depressed, showing a slight contraction of the shell margin, an indication of incipient senility. The transverse contour of the valve, as seen from the front, is subsemicircular or semioval. The median fold is scarcely pronounced, except close to the front, where it includes seven plications in the smaller and eight in the larger specimens, the outer or bounding ones rising only slightly above the sides of the shell and only their inner half taking part in the frontal excavation for the reception of the median tongue of the pedicle valve. These median plications extend only about half as far to the frontal suture as do the lateral plications. In the average specimens there are eight or nine of these plications on either side of the median group; these become fainter towards the cardinal margins. In the large shell there are ten. Thus there are ten—eight—ten, or twenty-eight in the largest shell; nine—seven—nine, or twenty-five in the next, and eight—seven—eight, or twenty-three in the simplest. They are flattened in the deflected part, and all, lateral as well as median, marked by a sharp linear groove down the center, which extends nearly or quite to the angle of deflection.

The beak of the brachial valve is broad and slightly elevated and appressed against the deltidial face of the pedicle valve. Near the beak the plications are all fine but broaden rapidly outwards. The growth lines are as in the pedicle valve.

On the interior there are two strong dental plates in the pedicle valve, and there is an indication of a short median septum in the brachial valve in several of our specimens. The young shell was nearly biconvex, with the convexities of the valves nearly equal.

Measurements:—Four individuals measure as follows:—

	Uncinulus mongolicus Grabau			
	No. 389	*No. 31 Pl. V, Fig. 7*	*No. 32 Pl. V, Fig. 8*	*No. 387 Pl. VI, Fig. 3*
Height of pedicle valve...	6.4 mm.	7.4 mm.	8.1 mm.	10.2 mm.
Height of brachial valve..	5.8 mm.	6.8 mm.	7.4 mm.	9.6 mm.
Maximum width.........	6.3 mm.	8.2 mm.	8.5 mm.	11.3 mm.
Maximum thickness......	4.6 mm.	6.2 mm.	5.7 mm.	8.2 mm.

Horizon and Locality:—In the crystalline limestone of Permian age at Jisu Honguer (Locality 1190, No. 31); exact horizon not determined (Nos. 32, 387, 388, 389), and four other specimens: nine specimens. Collector, F. K. Morris.

That the larger of these are adult shells is shown by the pronounced character of the frontal deflection. If they were the young of much larger shells, they would show no deflection at all. Moreover, the slight indication of senility shown by the contracting frontal border of one specimen, indicates that these shells have reached their full growth.

These shells resemble somewhat a small shell figured by Broili (1916, Pl. XII, Fig. 13) from the Permian of Timor under the name *Uncinulus jabiensis* Waagen. The Mongolian shell is, however, more transverse and has more plications. From the larger shells referred to this species by Broili, our specimens are distinct. Broili's shells also lack the median groove on the plications. The species described by Waagen (1879–1887, p. 428, Figs. 1, 2) as from the upper Productus limestone of India, *Uncinulus posterus*, comes nearer to our shell than any other known to me. It is, however, a more triangular shell in outline and has the transverse contour less quadrangular than is the case in our shells. Moreover, the early part of the Indian shell is devoid of plications, whereas in our shell they begin at the beak, though they are very fine in the young stages.

Order PROTREMATA Beecher

Superfamily PENTAMERACEA Schuchert

Family PENTAMERIDÆ McCoy

Genus **Camarophoria** King

52. **Camarophoria mutabilis** Tschernyschew

Plate IV, Figs. 7a-e (No. 34); Plate V, Figs. 1a-e (No. 54), 2a-e (No. 55), (No. 19)

1902. *Camarophoria mutabilis* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe,* Vol. XVI, No. 2, p. 491, Pl. XXII, Fig. 18; Pl. XXIII, Fig. 10; Pl. XIV, Figs. 1–15; Pl. XLVI, Fig. 14.

Shell transverse subpentagonal and subequivalve, coarsely plicated with median fold and sinus.

Measurements:—The measurements of the described specimens are:—

Serial No.	*No. 34*	*No. 54*	*No. 55*
	Pl. IV, Fig. 7	*Pl. V, Fig. 1*	*Pl. V, Fig. 2*
Height of pedicle valve	12.3 mm.	9.2 mm.	7.5 mm.
Height of brachial valve	10.8 mm.	8.1 mm.	6.5 mm.
Greatest width	16.1 mm.	10.5 mm.	7.6 mm.
Thickness	9.0 mm.	5.0 mm.	4.2 mm.
Apical angle of pedicle valve	115°	86°	85°
Apical angle of brachial valve	135°	123°	111°

In the largest of our specimens (Pl. IV, Fig. 7) the beak of the pedicle valve is but slightly incurved, though rising close to 2 mm. above that of the brachial. It is imperfect in this specimen, and the presence or absence of a foramen can not be determined. The sides of the umbonal region are slightly compressed and subangularly rounded to the hinge-margin. There is no area. A delthyrium is not determinable. In the young stages the contour of the valve is uniformly convex and neither the plications nor the sinus seem to reach the beak. Both begin rather abruptly some 4 mm. below the beak, from which point the sinus gradually becomes depressed and rounded by two plications, which become very strong towards the front, with broadly rounded top, and form the major plication of the valve. In the center of the sinus are two smaller plications which begin at about the same point as the bounding plication, with which they at first agree in strength but do not enlarge as rapidly forward. A third plication, incompletely developed, branches off from one of the bounding plications near the front. The sinus is only moderately pronounced, its definition being due largely to the strength of the bounding plications. Outside of these there are two others, on either side, beginning somewhat later than the median plication, but rapidly becoming stronger than the median plications, though their height and width at the first are only about one-half that which characterizes the bounding plications. Growth lines are more or less irregularly crowded in the anterior half of the shell.

The brachial valve of the large specimen is somewhat more convex than the pedicle valve, with the beak strongly curved under the beak of the pedicle valve and with the upper portion free from plications. The longitudinal median contour is almost regularly convex with the greatest elevation at about the mid-length. The transverse contour is also nearly regular, the median elevation being effective only towards the front. Three median plications begin a little less than one-fourth the length of the shell from the beak. They become stronger near the front than the median plications of the pedicle valve, corresponding to the broader interspaces of that valve. A short additional plication appears near the front on the same side as the additional plication on the pedicle valve, and corresponds to the depression which separates the latter from the bounding plication from which it branches. The shell thus shows a marked asymmetry of development. These plications with their interspaces form the moderately pronounced median elevation near the front of the shell, which is bounded on either side by a broad and deep, rounded depression corresponding to the large bounding plications of the pedicle valve. Outside of this are two sharp, rather widely separated plications on each side and a low third short one near the cardinal margin. This is more broadly rounded on the stronger developed side of the shell, the side with the additional median plications, and there it shows a tendency to divide near the front so as to make a very short ill-defined fourth plication. On this same side there is also a faint indication of a subsidiary plication on the outside of the second lateral plication. Lines of growth are more or less irregularly crowded in the anterior part as in the pedicle valve.

Because of the extra plication near the front on one side, the groove bounding the median fold on the opposite side is broader and deeper. This is partly compensated for by the formation, near the front, of a faint subsidiary plication on the outside of this groove or the inside of the first lateral plication. This further emphasizes the asymmetry of growth, since the extra plication on the opposite side is formed on the inside of the bounding groove, that is, next to the median fold of which it is a part.

An immature specimen (No. 54, Pl. V, Fig. 1) has a more triangular form with the frontal sinus less pronounced. The smooth umbonal area extends for about 4 or 5 mm., after which the plications gradually appear. The bounding plications of the sinus on the pedicle valve are the strongest, that on one side (right of view, Pl. V, Fig. 1b) dividing apparently near the point of its appearance, into two equal plicæ separated by a narrow interspace. That on the opposite side (left) merely increases in strength. The two median plications of the sinus appear almost as early as the bounding plications. They are uniform, but the groove separating them from the bounding plications on the right is deeper and slightly broader than that on the left, showing the prevailing irregularity of growth in this species. There are two lateral plications on either side of the valve, the outer being very short. The sinus is barely defined at this stage, producing only a slight deviation in the frontal outline.

In the brachial valve, there are three median plications slightly unequal and marking the median fold, which is, however, scarcely defined. The bounding groove on the left is broad and carries an extra smaller median plication corresponding to the groove that divides the bounding plication of the sinus on the pedicle valve (right as viewed in that valve). The other is simple. There are two well-marked, and one faint, scarcely developed plication on either side of the shell, corresponding to the two plications in the pedicle valve.

Altogether, then, there is an extra plication on one side of each valve (right in pedicle, left in brachial), due to the median division of the right bounding plication of the sinus of the pedicle valve.

Several larger imperfect shells associated with the young shell described (Locality 1211) show essentially the characters of the large shell described above (No. 34) and a similar though somewhat less pronounced irregularity of growth.

A still younger shell of the same outline (No. 55, Pl. V, Fig. 2) shows the plications only near the front, but these also have the irregularities observed in the older form. It is noteworthy that the apical angles of both valves are much less in the young than in the older shell, causing a corresponding change in outline.

Horizon and Localities:—Permian, Jisu Honguer limestone of Jisu Honguer, Mongolia. In the *Enteletes* bed (Locality 1190), one specimen (No. 34); in the *Orthotychia* bed (Locality 1211), young (No. 54) and two imperfect larger shells. Bed unknown, one young (No. 55). Collector, F. K. Morris.

Remarks:—The shell corresponds best to the specimens of this species from the Schwagerina limestone of Russia, figured by Tschernyschew (1902) on Pl. XLV of his monograph, but differs from all of them in its greater irregularity of development. Since only a few specimens are known from Mongolia, this irregularity must probably be considered an individual character. The specimen shown in Fig. 12 of Tschernyschew's plate comes nearest to our large shell both in form and size, that shell having its plications somewhat irregularly developed. Most of the Russian shells are larger than the Mongolian shells.

53. **Camarophoria superstes** (Verneuil)

Plate IV, Figs. 8a-d (No. 53); Plate V, Figs. 3a-e (No. 51), 4a-e (No. 52)

1845. *Terebratula superstes* Verneuil. Géologie de la Russie d'Europe et des Montagnes de l'Oural, Vol. II, p. 104, Pl. VIII, Fig. 5.

1883. *Camarophoria superstes* (Verneuil) Waagen, *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 445, Pl. XXXII, Figs. 12, 13.

1885. *Camarophoria superstes* (Verneuil) Tschernyschew. "Der permische Kalkstein im Governement Kostroma." *Verhandl. Russ. Kaiserl. Mineral. Gesell.*, Ser. II, Bd. XX, p. 294, Pl. XVII, Fig. 32.

1902. *Camarophoria superstes* (Verneuil) Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 504, Pl. XLVI, Figs. 4–6.

1916. *Camarophoria purdoni* Broili (not Davidson). "Die permischen Brachiopoden von Timor." Paläontologie von Timor, Lief. VII, Pl. CXXV (11), Figs. 19–23 (*cetera exclus*).

The shell is small, inequivalve, with the brachial valve the more convex. It is of subpentagonal outline, and, except for a few plications, sinuate near the front.

Measurements:—The dimensions of typical individuals are shown in the table on opposite page.

The pedicle valve is moderately and broadly convex in the umbonal region, where the transverse contour is a regular arch. The beak is elevated and moderately overarched but does not extend beyond the plane of contact of the valve. It is bluntly pointed and truncated by a minute circular foramen. The umbonal surface curves regularly to the sides, then abruptly bends inward to the hinge line, with a rather marked though blunt angulation. There is no hinge-area, but the shell surface between the hinge and the bounding angulation is slightly concave.

	Camarophoria superstes (Verneuil)		
Serial No.	*No. 51*	*No. 52*	*No. 53*
	Pl. V, Fig. 3	*Pl. V, Fig. 4*	*Pl. IV, Fig. 8*
Height of pedicle valve	6.3	5.7+	....
Length of pedicle valve on curvature	9.0	7.0+	....
Height of brachial valve	5.5	5.3	4.7
Length of brachial valve on curvature	7.0	6.5	6.0
Maximum width	6.5	6.2	4.7
Maximum thickness	5.0	3.7	3.2[1]
Height of frontal sinus	3.0	2.0	....
Width of frontal sinus	4.1	3.7	....
Apical angle of pedicle valve	84°	82°	....
Apical angle of brachial valve	103°	98°	....
Number of plications in sinus	2 faint	2	....
Number of plications on fold	3 "	3	3
Proportion of height (P.V.=1) to width	1.03	1.09	....

Slightly below the mid-length of the valve, a median flattening of the transverse contour appears, gradually developing into the median sinus, which is broadly and shallowly rounded near the front and projects into a trapezoidal lip, the outer portion of which lies at right angles to the plane of valve contact. Close to the end of the lip, but not extending its entire length, are two short, broadly rounded plications, separated by an interspace of the same width and character, which corresponds to a similar plication on the brachial valve. On the more obese shell (No. 51, Pl. V, Fig. 3), these plications are very faint, indeed hardly perceptible except at the shell margin. On the less obese shell (No. 52, Pl. V, Fig. 4), they are more pronounced. On another very convex brachial valve (No. 53, Pl. IV, Fig. 8), the three plications are well marked on the fold.

The brachial valve is extremely convex, even obese, with the greatest convexity in the posterior third, from which point the contour is regular in both directions. The transverse median contour is a regular arch, but in the umbonal region this is modified by a faint concavity on either side at the cardinal margins, while towards the front the median fold appears, but never becomes very pronounced. This fold is characterized by three low plications close to the front, though in some cases these may be very faint. The rest of the shell is smooth, but in one very obese brachial valve there is a suggestion of a lateral plication on one side near the front. The beak of the brachial valve is blunt and closely appressed under that of the pedicle valve.

In spite of its strong convexity, the actual length of the brachial valve is less than that of the pedicle valve, because of the very pronounced median lingual projection.

[1]Brachial valve only.

The growth lines are very faint.

The internal structure is not ascertained.

Horizon and Locality:—Middle Permian. In the Jisu Honguer limestone (Locality 1208?) of Jisu Honguer, Mongolia; three specimens. Collector, F. K. Morris.

Remarks:—This shell agrees in all essentials of external form with those described and figured by Tschernyschew from the Schwagerina limestone of the Ural, and the Permian limestones of other parts of Russia, but they are somewhat smaller. The dimensions of the specimens figured by Tschernyschew are as follows:

	1	2	3
Height of pedicle valve	9.3 mm.	8.2 mm.	7.4 mm.
Width	9.7 mm.	8.7 mm.	7.2 mm.
Width of sinus at front	4.4 mm.	3.7 mm.	3.0 mm.
Proportion of height to width	1.04	1.05	0.97

From this it appears that though the Russian specimens are larger, the proportions are essentially the same. These, too, are characterized by three plications on the fold and two on the sinus, and there are faint indications of lateral plications. Perhaps the convexity of the pedicle valve of the Mongolian specimens is slightly less in proportion, but this is difficult to ascertain from the figures.

Even closer is the resemblance of some of the small shells figured by Broili, 1916, from the Permian of Basleo in Timor, especially that shown in Fig. 20 of his plate. This is almost identical in form and size with one of our specimens. Broili refers these to *Camarophoria purdoni* Davidson, a large multiplicate form originally described from the Permian of India, and he also figures large specimens which may be referable to that type. A reference to Davidson's figure (1862, Pl. II) and to those of the same species given by Waagen (1879–1887, Pl. XXXII, Figs. 1–7) shows the Indian form to have numerous plications on the fold and sinus as well as on the sides. These, beginning at the beak, are four or five times as large as those on the Mongolian and Russian shells. It is true that Broili figures a very large shell from Timor with only three plications on the fold, two in the sinus, and faint plications on the side, and that he also figures others of similar markings and intermediate size, and that the shells show considerable variation in these respects. But unless Broili would consider the small shells dwarfed individuals of the larger species, I do not see how they can be united. They are certainly not young individuals, for the fold and sinus are as strongly developed proportionately as in the large shells, if not more so, whereas a corresponding stage of the large shell shows no sinus at all. I should hesitate to refer even the large shells figured by Broili to the Indian species, though I doubt not that they are genetically related to them. The much more vigorous growth of the Indian shells, shown by the numerous and pronounced plications, argues a specialization under favorable conditions, and it may very well be that they are derived by acceleration from the Timor forms, which are generally smooth in the young, and in the adult have, as a rule, less numerous and less sharply defined plications. In like manner, the smaller forms in Timor which I would refer to *Camarophoria superstes*, may be derivations from a common stock, the acceleration being in the nature of an early development of the sinus. This in itself may have put a stop to further growth in size, which could proceed only along the lines of further accentuation of the sinus, with the result that when the shell had reached the size of the larger ones, the sinus and fold would be enormously out of proportion to the rest of the shell, and the type would not be recognizable as belonging even to this generic group. Either, then, the small shells figured by Broili are dwarfed individuals, or they represent a new line of evolution and a distinct species. Since the Russian forms, though generally somewhat larger, are also of this type, I would refer them to Verneuil's species, in which I would also place the Mongolian shells as somewhat dwarfed individuals. Indeed Verneuil's original specimen is more than twice as large as our shells and nearly twice as large as those figured by Tschernyschew, having a length of 17 mm. and a width of 16 mm.

By comparing these shells with the figures and descriptions of *Camarophoria superstes* given by Waagen, we find that the Indian forms of this species are not only larger but of somewhat different proportions. The pedicle valve is proportionally more convex and the width is much less than the length. The thickness is also greater in proportion to the width. The dimensions of the two specimens figured by Waagen from the Upper Productus limestone (cephalopod bed) of Jabi in the Salt Range, are:

	1	*2*
Height of pedicle valve	16.0 mm.	12.5 mm.
Height of brachial valve	14.5 mm.	11.0 mm.
Greatest width	13.5 mm.	11.5 mm.
Greatest thickness	11.0 mm.	10.0 mm.
Apical angle of pedicle valve	99°	95°
Apical angle of brachial valve	105°	103°
Proportion of height (P.V. = 1) to width	0.84	0.92

The character of the plication and the fold and sinus are similar, but because of the difference of form the Salt Range shell should at least be regarded as a different mutation from that presented by the Mongolian, Ural, and the smaller Timor shells.

54. **Camarophoria purdoniformis** Grabau, sp. nov.

Plate VI, Figs. 1a-d (No. 390), 2a-e (No. 391)

cf. 1902. *Camarophoria crumena* Tschernyschew (non Martin, non Davidson). "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 189, Pl. XXII, Figs. 2–15.

1916. *Camarophoria purdoni* Broili (non Davidson, Waagen et al). "Die permischen Brachiopoden von Timor." Paläontologie von Timor, Lief. VII, p. 55, Pl. CXXV (11), Figs. 7, 9–11, 16, 17 (*cetera exclus*).

This shell from Timor, described by Broili, appears to be represented in our collection by a brachial valve (No. 390), which, though agreeing fairly well with the forms figured by Broili, seems to be somewhat more primitive. There is also a fragmentary specimen showing parts of both valves (No. 391).

Measurements:—The following measurements of our specimens and of typical forms from Broili's illustrations make possible a comparison.

	Mongolian		*Broili's figures, Pl. CXVIII*			
	No. 391	*No. 390*	*7*	*9*	*10*	*16*
	Pl. VI, Fig. 2	*Pl. VI, Fig. 1*				
Height of pedicle valve....	....	....	26.0	31.0	37.5	31.5
Height of brachial valve...	12.5	16.2	22.0	28.0	29.0	28.0
Greatest width............	20.8	21.3	29.0	36.0	37.0	37.0
Maximum thickness.......	10.0	13.0[1]	21.0	21.5	....	....

The brachial valve in our larger specimen (No. 390) is wider than it is high, the proportion being about as 1 to 1.3, which agrees very closely with that observed in the larger shells described by Broili, though it is less in his smaller shells. The brachial valve is extremely convex, its transverse contour being more than a semicircle. Thus, while the actual width is 21.3 mm., the length of the arc of the shell's contours is about 37 mm. Thus the longitudinal contour is much less arched. The height is 16.2 mm. The length along the curvature is only 20 mm.

The beak is prominent and overarched but does not overhang the plane of contact of the valves. The apical angle is 105°, and the cardinal slopes are very gently concave. The shell is free from plications for a length of about 8 mm., when three median plications and two lateral ones, one on either side,

[1]Brachial valve only.

begin almost simultaneously. The median plications are broad and close together. They diverge slightly, increasing in width to a moderate degree, while at the same time the interspaces increase in width but never exceed the plications. This part remains moderately arched and so becomes the elevated median fold. At a later stage a new plication branches off on the outside of each of the outer of the three plications; and these remain a part of the fold, which then has five plications at the front. These outer plications, however, do not reach the size or strength of the median three.

Most of the specimens figured by Broili from Timor are accelerated, and in them the outer plications appear much earlier and are essentially of the same size as the median ones. There is, however, some variation, and in one of the specimens only slightly larger than our shell, there are only the three median plications. There is a much broader interval between the first lateral shell plications and those of the fold. This increases rather rapidly in width forward and is rather strongly depressed. This results in the pronounced elevation of the median fold. The first pair of lateral shell plications, though increasing in width, never becomes as strong as the median plications. Some time after its appearance, a second pair of lateral plications arises but these remain separated from the first by much wider interspaces. No other plications appear, the cardinal portions remaining smooth. In the Timor shells there are usually from three to four lateral plications, much closer together than in our shell, and outwardly decreasing in length and strength. Even in the smaller of Broili's shells which I have included under this species (Fig. 11), there is an indication of a third lateral plication.

A very imperfect specimen (No. 391, Pl. VI, Fig. 2) from the Hemiptychina bed (1196) approaches more closely the Timor shells but is still much smaller than the more typical members of that species. Its brachial valve has a height of 12.5 mm. and a width of over 20 mm., the proportions being thus greater than on the other shells. The outer pair of plications of the fold appears shortly after the median three and reaches essentially the same size as these. The fold is very prominent, and there are three lateral plications on the shell, all three well developed and separated by about their own width. There are four plications in the sinus, beginning earlier than on the fold. On the side of the shell there are four distinct plications, including that bounding the sinus. These are confined to the later half of the valve, and the outermost is the shortest. Between the plications, where the shell is well preserved, rather strong regular and crowded concentric striæ are seen. The maximum thickness of this specimen, No. 391, is 10 mm.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia. The horizon of the larger shells is unknown, that of the smaller is the *Hemiptychina* bed (1196). Collector, F. K. Morris.

Remarks:—The specimen last described has essentially the characters of the shell described and figured by Tschernyschew as *Camarophoria crumena* from Russia, but I can not agree with Tschernyschew's opinion that it is the same as the *Conchyliolithus anomites crumena* of Martin, which is reproduced by Davidson (1861a, Pl. XXV, Figs. 3, 4–9), nor do I hold that it can be identified with the *Camarophoria crumena* figured by Davidson from the Carboniferous limestone of England, *loc. cit.*, Pl. XXV, Figs. 4–9. That shell, though agreeing essentially with our form in the character of the fold and sinus, is more accelerated in the lateral parts where there are generally numerous plications, though it should be noted that Tschernyschew figures some specimens with more numerous plications. From *Camarophoria pinguis* Waagen our shell differs in the much later appearance of the plications. The different character of the plications in *Camarophoria purdoni* has already been referred to (p. 219).

Superfamily ORTHACEA Walcott and Schuchert

Family SCHIZOPHORIIDÆ Schuchert

Genus **Orthotychia** Hall and Clarke

55. **Orthotychia derbyi** (Waagen) var. **nana** Grabau, var. nov.

Plate X, Figs. 1a-d (No. 33), (No. 37?)

1884. *Orthis derbyi* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 565, Pl. LVI, Figs. 2, 5, 6.

The shell is small for the genus, with the brachial valve much exceeding the pedicle in size and convexity.

Measurements:—The following are the measurements of our most characteristic specimen (No. 33), together with two of Waagen's shells, for comparison.

	O. derbyi var. *nana* Grabau, No. 33			*O. derbyi* Waagen	
	Adult	*Nepionic*	*Neanic*	*1*	*2*
Height of pedicle valve...	13.7	5.3	8.3	21.0	21.5
Length (on curvature)...	16.5	....	....	....	....
Height of brachial valve..	15.1	6.2	8.4	25.0	24.0
Length (on curvature)...	20.0	....	....	....	....
Greatest width..........	16.6	6.5	9.8	26.0	27.0
Maximum thickness.....	11.4	....	....	18.5	17.5
Length of hinge area.....	7.4	....	....	11.0	11.0

The pedicle valve is transversely suboval, with the width considerably exceeding the height. The beak is elevated, scarcely incurved, with the young portion of the hinge area approximately parallel to the plane of contact of the adult valves, while the adult portion of the hinge area is nearly at right angles to this plane. The hinge area thus forms an arc of 90°. The cardinal extremities are not angular; the sides are strongly and regularly rounded, the front more gently rounded.

The greatest convexity of the valve is in the umbonal region; it is regularly arched longitudinally and transversely in the nepionic stage, after which the median portion becomes first flattened and then gently depressed with a median sinus. This regularly broadens and deepens forward, remaining rounded in section and becoming only moderately pronounced near the front, where the deflection from the plane of contact of the valves equals only about 3.5 mm. The sinus is not quite median but is slightly deflected to one side, thus producing an irregularity which corresponds to similar irregularities in the growth of other species in this fauna. At the frontal margin of the plane of contact, the edges of the valves are thickened to form a slightly depressed band 1.8 mm. in width at the sinus, and extending over the sides of the shell, gradually thinning away before reaching the cardinal angles. This band is formed by the addition of shell layers to the edges of both valves, the circumference of which is gradually decreasing, a feature indicative of senility, since it indicates a cessation of increase in circumferential size of the mantle, while lime deposition still continues, with probable increase in length. This feature indicates that the present specimen is not an immature but a full-grown, indeed slightly senile, individual.

The longitudinal contour of the valve as a whole is not regular but is marked by a succession of convex surfaces with slight depressions between, each depression being marked on the shell by a strong concentric growth line indicating momentary cessation of growth. The whole surface of the shell is marked by fine regular rounded striæ, separated by wider interspaces. Near the front the number of these striæ is about ten in 3 mm. The increase in number appears to be due to bifurcation. The striæ, on the umbonal portion, though numerous, are much finer.

The brachial valve is more convex than the pedicle, with the greatest convexity in the posterior third. In the nepionic stage the valve is regularly convex, though more strongly so than the pedicle. A faint median elevation begins in the neanic stage, becoming regularly more pronounced by the slight longitudinal depression of the valve on either side. The strong growth lines, or lines of growth cessation at subregularly distant intervals, are seen also in this valve.

The beak of the brachial valve, in the adult, is very strongly incurved, overarching the cardinal area, which, though lower than that of the pedicle valve and less arching, projects over it. The entire umbonal region is considerably elevated above that of the pedicle valve, and the curvature of the brachial valve is much more pronounced than that of the pedicle valve. As already noted, the front margin is thickened in a senile manner similar to that of the pedicle valve and to the same amount. This thickened portion appears to be free from striæ, or they are much less strongly developed than on the surface of the shell. These striæ on the brachial valve are similar to those of the pedicle valve, but they appear to increase by intercalation.

Internal structure not determinable.

Horizon and Locality:—Middle Permian. In the *Orthotychia* bed of the Jisu Honguer limestone (Locality 1211) at Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—I refer this shell to *Orthotychia* rather than to *Schizophoria* in spite of the fact that the internal structure is not ascertainable. Already Waagen has placed his species in the group *Orthis morganiana* Derby, the genotype of *Orthotychia* because of its very close correspondence to that species. The Indian species, however, is smaller, although the shell is comparatively thicker. The carinated appearance of the brachial valve, formed by the slight flattening or depression of the shell on either side, is another diagnostic feature. All of these are characters found in our shell, but in size our form is only a little more than half the size of the Indian shell (see table of measurements). That our shell is not immature but dwarfed, is shown by the development of the full specific characters and more especially by the indications of senility above referred to. The Indian shell ranges from the middle to the upper Productus limestone.

Genus **Enteletes** Fischer v. Waldheim

56. **Enteletes andrewsi** Grabau, sp. nov.

Plate X, Figs. 2a-f (No. 83), 3a-e (No. 84), 4a-e (No. 90), 5a-g (No. 86); Plate XI, Figs. 1a-f (No. 87), 2a-f (No. 89)

The shell is of medium size or larger. The brachial valve is the more convex. Both valves are inflated, and the hinge line is much shorter than the greatest width of the shell.

The beak of the pedicle valve is moderately incurved, not overarching the plane of contact of the valves. The beak of the brachial valve is much more strongly incurved, overhanging the plane of contact of the valves.

Nepionic stage:—In this state the pedicle valve is nonplicate and without a sinus, or in the more accelerated individuals this may appear in the form of a shallow median depression at the front. The height of the valve at this stage is between 5.5 mm. and 6 mm.; the length on the curvature is much greater.

At this stage the shell is regularly arched, is marked only by fine regular and numerous radiating striæ, and has the growth lines showing only at intervals. When the shell is exfoliated the dental lamellæ and median septum are indicated. The brachial valve at this stage is of about the same convexity as the pedicle valve, regularly arched from side to side, with the beak no more incurved than that of the pedicle valve. The surface is marked only by fine striæ which end in a tubulose manner at the stronger growth lines. The hinge line is about equally arched at this stage.

Neanic stage:—With the passage into the neanic stage, the median depression of the pedicle valve and the corresponding median elevation of the brachial valve begin. The latter is defined chiefly towards the front, though sometimes visible for some distance above it. The shell surface on either side is slightly depressed. Before the end of this stage, a depression appears on either side of the median sinus of the pedicle valve, so as to outline the bounding ridges which flank the sinus on both sides. At the front a sinus and fold form a sharp zigzag in the suture line, where the incipient plications formed by the lateral depressions give a slightly wavy outline to the suture on either side of the median deflection.

At this stage the brachial valve is already more convex than the pedicle. The beak of the former arches more strongly and extends to the plane of contact of the valves. The longitudinal contour of the brachial valve is still subregular with the greatest convexity near the middle, while that of the pedicle valve is now in the posterior part.

The measurements of an individual in this stage (No. 83) are given in column 1 of the following table. The shell at this stage has essentially the characters of an *Orthotychia*, though it is relatively more convex, being practically globular, and the frontal emargination of the suture is more angular. Nevertheless this stage may be termed the *Orthotychia* stage. The shell height at this stage is somewhat over 8 mm.

Ephebic or adult period:—With the beginning of the adult period the lateral plications become outlined. In a specimen showing the beginnings of the adult characters (anaphebic) (Pl. X, Figs. 3a-e, No. 84), the depression on either side of the bounding plications of the sinus is pronounced and sharp, so that these plications are fully defined. Outside of this depression an incipient plication appears recognizable only at the front. In the brachial valve the lateral plication, on either side of the fold, is well-marked, and corresponds to the depression on the pedicle valve. It is outlined exteriorly by a depression which corresponds to the incipient lateral plication in the pedicle valve. The shell height at this stage is a little over 9 mm. (See No. 84, column 2, of the following table.) The sutural margins at this stage appear elevated in the internal mold, indicating that the thickness of the shell, on the inside, is reduced at the margin. The general form of the shell at this stage is still subglobular, but the brachial valve is much more inflated than the pedicle. The width is slightly greater and the thickness slightly less than the shell height.

As the shell increases in size, the convexity of the brachial valve becomes more pronounced, so that the umbonal portion rises above that of the pedicle valve, while the beak becomes more and more overhanging, extending beyond the plane of junction of the valves. The sinus of the pedicle valve becomes deeper and sharper, and the bounding plications more pronounced and angular. The front is extended medially as a triangular lip; the lateral plications also become pronounced and angular, though they are smaller than the bounding plications. In the brachial valve the fold becomes high and subangular, with a deep triangular reëntrant in front which receives the median extension or lip of the pedicle valve. On either side of the median fold, which now has the character of a plication, is a broad depression at first round-bottomed then becoming angular, outside of which is the fine lateral plication which is rounded at the top. This, too, is defined by a broad depression on the outside, but beyond that in the early stages no further fold occurs. In a shell of this stage (No. 90, Pl. X, Fig. 4), with a height of the brachial valve of 11.5 mm. (pedicle, 9.8 mm.), the first of a series of concentric wrinkles has appeared. These are due to a sudden contraction of the shell margin followed by an expansion and normal growth. These wrinkles are thus short steps in the shell surface at the front. In this young shell (No. 90) there is only one such step-like wrinkle on each valve. In an average immature individual, in which the shell height is about 15 mm. (No. 86, Pl. X, Fig. 5), three such contractions have occurred before the frontal margin is reached. This increases to four or even five in the adult, forming a pronounced zigzag ornamentation on both sides of the frontal suture.

The shells expand laterally as they increase in size, so that the width is always as great as, or greater than, the height and thickness.

The number of lateral plications in the valves varies somewhat with the degree of maturity and also with the degree of individual acceleration.

In a shell but little beyond the neanic stage (No. 90, Pl. X, Fig. 4), there is one moderately developed lateral plication on either side of the pedicle valve, making four in all with the bounding plications of the sinus. There is also a faint indication of a second lateral plication on one side. In the brachial valve there are two lateral plications, though not very pronounced, on either side of the fold.

In a larger shell (No. 87, Pl. XI, Fig. 1), the second lateral plication of the pedicle valve is well developed but short, while the brachial valve has two well-developed and long lateral plications with a third one fairly well developed on one side but barely indicated on the other. In a younger shell, however (No. 86, Pl. X, Fig. 5), intermediate in size between the preceding two, the pedicle valve, though showing only one lateral plication on one side, has three lateral ones clearly indicated on the other (left) side, making four in all on that side. In the brachial valve three lateral plications occur on the accelerated side (right in this case as viewed dorsally) and two on the other. Finally, in the largest shell of this species in our collection (No. 89, Pl. XI, Fig. 2), there are only two lateral plications which with the bounding plication of the sinus make three in all on the right side of the pedicle valve. The other side is broken, but judging from the condition in the brachial valve it has an additional plication. In the brachial valve, the left side (corresponding to the right side of the pedicle valve) has only two well-developed lateral plications, whereas on the right side there is a lateral which appears to have been well developed though now mostly broken away, and there may have been a fourth short one near the now broken front. It is noteworthy that nearly all the shells of this species are slightly more accelerated on one side than on the other. This is the left-hand side when viewed ventrally and the right-hand side when viewed dorsally (from brachial side).

The radiating striæ throughout are fine, sharply rounded, and close-set, covering both plications and interspaces. They increase very little in size, but their number is increased both by bifurcation and intercalation. The depressions which separate them are sharp and linear. Occasionally what appear to be tubular openings are seen on the striæ. Extremely fine growth lines, barely visible under a lens, cover them. Coarser growth interruptions occur only at rare intervals, except at the front. Here the number of wrinkle-like growth modifications is seen to increase with age or with acceleration.

Measurements:—In the following table, Nos. 83 and 84 represent shells in the neanic stage; No. 90 is a small shell at the beginning of maturity; Nos. 86 and 87 represent further stages in maturity, while No. 89 is the largest shell in the collection and may be regarded as fully mature.

	Enteletes andrewsi Grabau					
Column number	*1*	*2*	*3*	*4*	*5*	*6*
Serial number	*No. 83*	*No. 84*	*No. 90*	*No. 86*	*No. 87*	*No. 89*
Plate and Figure	*X, 3*	*X, 4*	*X, 5*	*X, 6*	*XI, 1*	*XI, 2*
Height of pedicle valve	8.0	9.0	9.8	11.7	14.4	21.0
Median length of pedicle valve on curvature	12.0	14.5	16.5	22.5	25.0	33.0+
Height of brachial valve	8.1	9.9	11.5	14.3	17.8	23.2
Length of brachial valve on curvature	11.0	13.5	14.5	22.5	27.0	35.5
Greatest width	8.1	10.5	12.7	16.4	18.6	24.8
Greatest thickness	7.6	9.3	10.8	16.0	18.8	24.1
Length of hinge line	4.2	4.6	6.5	8.3	8.9	14.8

The height and thickness measurements are made with the plane of junction of the valves perpendicular.

It will be noted that, although the height of the brachial valve is always greater than that of the pedicle valve, increasing with increase in size, yet the length of the valve along the curvature is at first less in the brachial than in the pedicle valve. This is due to the strong indentation of the front of the brachial by the lip of the pedicle valve. In a medium-sized shell (No. 86) the lengths have become equal, after which that of the brachial valve increases. This shows the progressively augmented increase in the convexity of the brachial valve.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia, in the *Enteletes* bed (1190) and the *Martinia* bed (1194). The species is fairly common. It is named after Doctor Roy Chapman Andrews, the intrepid leader of the exploring expeditions in Mongolia.

Remarks:—This species has some resemblance to *Enteletes tschernyschewi* Diener, from the Permian of Chitichun in the Himalayas, but that species is a more accelerated shell. In the first place, the plications begin much earlier, often close to the beak, while the median sinus of the pedicle valve begins only a short distance below the beak. The median plication of the brachial valve is much narrower and sharper than in our shell, where it has a broad roof-shaped character, and with the depression on either side occupies about half the width of the valve, whereas in the Himalayan species it occupies less than a third of the width. In our shell it has more the character of an angular median fold with the lateral plications much less pronounced, while in Diener's *Enteletes tschernyschewi* it is a plication only a little larger than the next one on either side. The median sinus of the pedicle valve is also much wider and deeper in our shell, with the lateral plications and their dividing depressions much less pronounced. In the Himalayan shell the median sinus is of the same kind as, and only slightly larger than, the depression between the lateral plications. Finally, the number of plications on the Himalayan shells is much greater than that on shells of corresponding size from Mongolia. The radial striæ are reported by Diener as delicate and seen only in well-preserved specimens, whereas they are a marked feature of our shells seen even on internal molds. In the adult Himalayan shell the lines of growth are irregularly crowded near the front, whereas the Mongolian shells show a regular series of equidistant, step-like wrinkles as above described. Altogether, then, our species is seen to be quite distinct from the Himalayan form, which it rivals in size, and with which it may have a common ancestor. *Enteletes tschernyschewi* Gemmellaro (Pl. XXVIII, Figs. 1–9) from Sicily is a different shell. It resembles more our immature shell, but has more and sharper plications. His *Enteletes contractus* (Pl. XXVIII, Figs. 16–24) resembles our adult shell but is much smaller and has more angular plications, and a relatively narrower fold and sinus.

57. **Enteletes angulatoplicata** Grabau, sp. nov.

Plate XI, Figs. 3a-f (No. 85), 4a-c (No. 91); Plate XII, Figs. 1a-d (No. 92), (Nos. 88, 93, 94, 95)

This is a less advanced form than the preceding, to which it is genetically related, and with which it agrees closely in the young shell stages. When the pedicle valve of a typical specimen (No. 85, Pl. XI, Fig. 3) has a height of 8.5 mm., the shell is still smooth, except for a broad round-bottomed median sinus which begins about 5 mm. from the beak. The brachial valve continues normally convex until it has reached a height of 8.5 mm., when a low sharp median fold appears. Shortly thereafter a similar sharp low fold appears on either side, the three folds dividing the shell into four approximately equal parts. The plications continue sharp and angular to the front of the shell, the median remaining the highest and most pronounced. The interspaces between it and the lateral plications are broad, subangularly rounded at the bottom and with unequal sides, those next the median angular fold being the broadest.

In this individual, which is of medium size and in which the height of the brachial valve is 16.6 mm., only these three plications occur, a median and one lateral on each side, though in the left-hand side there is a faint indication of a second lateral. In *Enteletes andrewsi* the second lateral is already well-developed before this stage is reached, and even a third lateral may occur, while all the plications are more rounded in section.

In the pedicle valve the sinus is broader in this species than in the preceding one at the same stage. It is more angular and the bounding plications are sharper. In the specimen, No. 85, a lateral plication appears on either side when the shell has reached a length of about 10.5 mm. (length on curvature about 14 mm.), these lateral and the two bounding plications being the only ones at the front in the immature shell (No. 85, Pl. XI, Figs. 3a-f), in which the height of the pedicle valve is 14 mm. The median indentation of the front of the brachial valve by the lip of the pedicle valve is acutely triangular. This shell also shows a single step-like growth interruption or concentric wrinkle in each valve at the front, being comparable in this respect to a much younger stage in the preceding species (No. 90), in which the heights of the brachial and pedicle valves are 11.5 and 9.8 mm. respectively.

In a somewhat larger specimen (No. 91, Pl. XI, Fig. 4), in which the height of the brachial valve is 18.2 mm., there are still only two lateral plications, one on either side of the median fold. The rest of the shell is regularly curved and covered only by the radiating striæ. In this individual the depressions on either side of the fold are less profound, and the lateral plications less pronounced than in the smaller shell. In consequence the width of the shell is proportionately greater. In this shell, too, there is only one step-like growth modification before the frontal margin is reached.

The largest shell in the collection (No. 92, Pl. XII, Fig. 1) is a brachial valve 22.5 mm. in height. In this individual a second lateral plication appeared on either side when the shell was about 14.5 mm. high, and these plications are well developed at the front though much smaller than the first lateral. Though flanked by a faint depression on the outside, there is no further plication, this depression rising gradually into the lateral shell surface. A new feature occurs in this shell, in that there is a very faint subsidiary plication on the right-hand slope of the median fold, appearing shortly after the appearance of the first pair of lateral plications. The subsidiary plication is, however, very faint, and visible only in certain positions of the shell with reference to the light. A similar though much fainter suggestion of such a plication is seen in specimen No. 91. Corresponding to it, and to the early developed second pair of lateral plications, the width of the shell is proportionately less in the earlier stages than in the other specimen, though in the adult the proportions are the same. This gives the umbonal region a somewhat contracted appearance. On the front there are two distinct step-like growth modifications rather more distantly spaced than in *Enteletes andrewsi*. There is also a less pronounced one at a correspondingly earlier stage.

The radiating striæ of this species are similar to those of the preceding one.

Measurements:—The following are the measurements of the specimens described and of some others in the collection.

	Enteletes angulatoplicata Grabau					
Column number...........	*1*	*2*	*3*	*4*	*5*	*6*
Serial number.............	*No. 95*	*No. 94*	*No. 85*	*No. 93*	*No. 91*	*No. 92*
Plate and figure...........			*XI, 3*		*XI, 4*	*XII, 1*
Height of pedicle valve....	12+	....	14.0	....	....	....
Length on curvature.......	....	....	24.5	....	....	....
Height of brachial valve...	13+	15.2	16.6	19.0	18.2	22.5
Length on curvature.......	....	....	22.0	28.?	27.5	30.0
Greatest width............	14.5	17.0	18.4	22.5	21.3	23.0
Maximum thickness.......	13.8	....	16.1	....	....	....
Length of hinge line.......	7.0	....	9.2	....	10.3	12+
No. plications at front of pedicle valve..........	4	2	4	....	....	....
No. plications including median at front of brachial valve.............	3	3	(1+) 3	3	3	5
No. of growth interruptions at front................	1	0	1	1	1	2

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia; common. Collector, F. K. Morris. It occurs chiefly in the *Hemiptychina* bed (1196) but also more rarely in the *Martinia* bed (1194). It has also been found more rarely in the *Camarophoria* bed (1208).

Remarks:—This species, while of the same general proportions as the preceding one, is readily distinguished from it by the uniformly smaller number of plications, their sharper more angular character, the broader slopes of the median angular fold, and the small number (one or two) of the step-like growth modifications at the front.

58. **Enteletes obesa** Grabau, sp. nov.

Plate IX, Figs. 7a-f (No. 96); Plate XII, Figs. 2a-e (No. 104), 3a-f (No. 97), 4a-f (No. 100), (Nos. 98, 99, 101, 102, 103, 392)

The shell is extremely obese, with the valves inflated so that the thickness is always greatly in excess of the height and width.

Pedicle valve:—In the nepionic stage (a), column a, table below, this shell is non-plicate but covered with radiating striæ, of which there are approximately five to 1 mm. It continues for a length of about 4.5 mm., as seen on the umbonal part of an early adult (No. 97, Pl. XII, Fig. 3) and the umbonal part of a much younger shell (No. 104, Pl. XII, Fig. 2), both of which agree in regard to the measurements of this stage, that is, length 4.5 mm., width 4.8 mm. At this point there begins a faint median depression in the center which develops into the median sinus. In the early neanic stage (b), when the shell length is 7.5 mm. and the width 8.8 mm., the sinus is still very faint, but later in the neanic stage (c), when the shell length is 11 mm. and the width 12.5 mm., the sinus is well developed, the two bounding plications being outlined by a flanking depression on the outside of each. The lateral plications are hardly indicated at this stage. This is the stage (c) reached by the young specimen (No. 104), the height of which is 10.7 mm. and the width 11.2 mm. At this stage (No. 104) the sinus is sharp, the sides flatly sloping, the anterior lip obtuse and projecting 2.5 mm., and there are three striæ to 1 mm. at the front. The lateral groove defining the bounding plication is pronounced but has existed for only a short time. It is somewhat stronger on the right side; outside of it the shell surface curves regularly to the lateral margin, there being no indication of lateral plications. The thickness of the valve at this stage is 5 mm.

While the earliest non-sinuate stage (a) is essentially of the same size, the next stage (b) varies somewhat in length, as shown in the table below. In our largest shell the lateral plications have not yet become defined at a length of 14.8 mm. and a width of 15.7 mm. Stage c, therefore, continues to this size.

In the slightly more accelerated individual of immature age (No. 97, Pl. XII, Fig. 3), the lateral plications become defined at the end of the neanic, and in stage d gradually increase in strength to the front, when the valve has reached a height of 12.5 mm., though the actual length on the curvature is 25 mm., or twice the height. The number of striations at the front is three to 1 mm., and there are three step-like growth modifications, with the front margin forming a fourth. These all belong to the early ephebic stage and are chiefly seen in the sinus. Whenever the shell is exfoliated, the two lateral and median septa are indicated, extending to about the end of stage b.

A more accelerated individual is seen in No. 96 (Pl. IX, Fig. 6). In this stage, a to c are shortened, while stage d, in which the lateral plications become defined, continues only to a shell height of 11.3 mm. (length 18.0), whereas in the preceding individual (No. 97) it continues to the end of the shell (height 12.5 mm., length 25 mm.). At this stage there is, however, only one frontal step-like growth modification. Upon this there is superadded stage e, in which the second pair of lateral septa become defined by the development of an outer flanking depression. These continue to the front of the shell (which is also immature), so that this shell shows six frontal plications (one pair of bounding and two pairs of lateral), though the actual shell height is the same as that of the less accelerated form (No. 97). The shell length is, however, a little greater, being 26 mm. as compared with 25 mm. in No. 97.

The next larger shell in the collection (No. 98) is again a retarded individual. The earliest stage (a) is not well preserved, the shell surface being destroyed, showing the septa. The second stage (b) continues longer than in the preceding shell (No. 96) but not so long as in the first two specimens (Nos. 104, 97). After that the bounding plications of the sinus become defined and these extend to the front of the valve without further development of other plications, though on the right-hand side there is an additional notch in the growth wrinkles, the front indicating an incipient development of the lateral plication. In respect to the development of plications, this shell is more retarded than the others of its size in which one or even two pairs of lateral plications are developed. This shell further suggests senility because shortly after the beginning of stage c the valve is abruptly deflected, forming almost a right angle with the earlier surface. Moreover, there are five distinct step-like growth modifications, all of which fall into stage c. They begin at the point of abrupt deflection. Although the height of this valve is only slightly greater than that of the same valve in the preceding specimens (13.2 as compared with 12.5 mm.), the length is very much greater (31 as compared with 26 or 25 mm.). This gives this shell a much greater obesity.

Another internal mold of a somewhat larger shell (No. 99) shows the curvature a regular arch with the bounding plications fairly well-developed, though not so pronounced in the internal mold. The height of the shell at this stage (c) is 9.6 mm. and the length 15 mm. The first pair of lateral plications, which appears in the next stage, is also weakly developed so that they are scarcely perceptible in the internal mold, except with certain positions of the light. The zigzag character of the growth ridges, however, indicates their presence, and at the front they are distinctly indicated by notches. The appearance of the second pair is indicated on the right side by an additional notch in the frontal margin, but nothing of the plication itself is visible on the shell mold.

In the adult shell (No. 100, Pl. XII, Fig. 4) both the sinuate stage (b) and the stage with only bounding plications (c) continue longer than in the other shells. The first pair of lateral plications is very faint and hardly distinct from the general shell surface. At the front there are three lateral notches (four with that of the bounding plication) on the right side, while those on the left can not be determined because of mutilation of the shell. There is, however, no indication in the shell-surface of plications corresponding to these notches, except the first lateral one, which, however, is exceedingly faint. There appears to be only one profound growth contraction near the front, though some others, less regular and less profound, precede it. The striæ are sharp near the front, the distance from the crest of the first to the crest of the fourth stria being one millimeter.

In another adult (No. 101), with extremely enrolled valves, the beaks of which almost touch, the earlier stages of the pedicle valve are not determinable, but at a shell length of 23 mm. from the beak (height about 17 mm.), two pairs of lateral plications are already well-developed and probably began very much earlier. These plications are well-developed and strongly marked by the concentric wrinkles, of which there are at least six besides the prominent one at the front. At the suture the three plications on either side are marked by notches, and there is a beginning of a fourth near the frontal margin, though this does not develop to a very pronounced degree.

Brachial valve:—In the smallest of our submature individuals (No. 97, Pl. XII, Fig. 3), the early stage (a) is without fold or plications, is regularly arched from beak to front and from side to side, and is characterized only by fine striations, of which there are about five to 1 mm. This stage has a length of 5.8 mm. and a width of 6.1, being longer than the corresponding non-sinuate stage of the pedicle valve. This is followed by the development of a rather abrupt median fold defined by a depression on either side, and marked in front by a rectangular reentrant. This stage (b) continues in this individual (No. 97) until it has reached a length and width of 11.8 mm., at which time stage c has already commenced in the pedicle valve. In stage c, the first pair of lateral plications appears, these being rather angular, while the lateral slopes of the median fold, which is rather pronounced, are slightly concave, though on the left side a subsidiary low, rounded, fold-like elevation occurs which extends to the front but never becomes very pronounced. This stage continues until the shell has reached a height of 12.3 mm. and a width of 13.5 mm., ending with the first step-like growth modification. Then begins the last of the adult substages, with the appearance of the second pair of lateral plications, which quickly become elevated but do not reach the size or the angularity of the first pair. The notch marking them in the frontal suture is also smaller and more obtuse than that formed by the first pair. This condition continues to the front of this shell, which, it must be remembered, is immature. In this last stage there are four step-like wrinkles, including that at the beginning of the stage and that at the front.

In the next larger shell (No. 96, Pl. IX, Fig. 6), the total number of plications at the front is seven, comprising the median fold and three pairs of lateral plications. The last pair of these is not well-defined on the outside except near the front, and is stronger on the left than on the right side. There are five step-like wrinkles, including the one at the front. The successive stages are indicated in the table.

In the next larger, though more retarded, shell, the total number of plications, including the median fold, is only three, though at the front there are notches suggesting a second pair of lateral plications and even a faint depression outlining it for a short distance.

In the retarded adult (No. 100, Pl. XII, Fig. 4), the final number of plications is five, but the last pair is defined only near the front and especially on the left side, whereas on the right it is scarcely recognizable. Only three step-like wrinkles occur, as in the pedicle valve. The indentation of the front margin by the pedicle lip is over 12 mm. Because of this the actual length on the curvature of the two valves is the same (44 mm.), though the brachial valve is much more convex and more strongly arched longitudinally, while the beak curves to within a short space of the hinge-line beyond which it extends.

In the more accelerated adult (No. 101), which is imperfect, the beaks of the two valves appear to touch, though this is not fully exposed, nor will the nature of the shell permit preparation. The beak of the brachial valve is even more strongly incurved than in the preceding shell, the revolution of the plane of valve contact from the youngest to the final stage being nearly, if not quite, 270 degrees. The shell is strongly plicate, both the first and second pair of lateral plications appearing very early and the third pair considerably before the front. Owing to the preservation of the shell, however, no accurate measurements can be made, and the lengths of the valves given in the table are only approximate. The growth interruptions or concentric wrinkles also appear early, there being at least eight of these in the brachial valve.

As the measurements of heights and thickness are made with the suture line perpendicular in each case, it follows that the brachial valve always rises much above the pedicle valve, though if the shell were placed so that the line from the center of curvature of the shell as a whole to the center of the hinge area is vertical, the difference in height is much less. In this position the maximum thickness of the shell is greater than when measured with the suture plane vertical, this being less marked, or almost non-existent in the most immature shells such as No. 97, and usually most marked in the adults. These two measurements are given in the table under the thicknesses of the entire shell, the first (*a*) being that perpendicular to the plane of contact of the valve, the second (*b*) being the maximum thickness. The universal great excess of the thickness of the shells in the various adult stages over the width and height form a ready feature by which this species can be recognized.

As the shell increases in size, the beaks become more strongly incurved and hence the actual shell-length increases more rapidly than the height. In this manner, while the height in the pedicle valve between No. 97 and No. 100 has increased only 8.5 mm., the length has increased 19 mm. In general the length in the older stages is about twice the height.

The length of the hinge area varies considerably, as shown in the table, but it is always very much less than, and generally only about half, that of the width.

Measurements:—In the following table the detailed measurements of the better-preserved specimens of this species are given, only two of these (Nos. 100 and 101) being fully adult, while the others, except the first (No. 104), are submature. The pedicle valve of the specimen represented by the first column is a shell in the neanic stage, and presents a very different aspect from

Enteletes obesa Grabau

Serial Number	*No. 104*			*No. 97*				*No. 96*					*No. 98*			
	Plate XII, Fig. 2			*Plate XII, Fig. 3*				*Plate IX, Fig. 6*								
Pedicle Valve Stages	*a*	*b*	*c*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*
Height	4.7	7.5	10.7	4.5	7.5	11.0	12.5	3.2	5.7	9.4	11.3	12.5	....	6.8	....	13.2
Length on curve	6.5	11.0	16.5	5.0	8.5	15.0	25.0	3.5	6.5	13.0	18.0	26.0	....	9.5	....	31.0
Width	4.8	8.8	11.2	4.8	8.8	12.5	17.3	3.4	5.5	9.9	10.7	16.2	....	7.4	....	18.4
Length transverse arc	....	....	16.0	....	....	....	28.0	....	....	....	....	25.0	....	....	....	30.0
Thickness	....	....	5.0	....	....	....	9.0	....	....	....	....	9.4	....	....	....	9.5
No. of plications	0	0	2	0	0	0	3	0	0	2	4	6	0	0	2	2+
No. of growth wrinkles	0	0	0	0	0	0	3	0	0	0	1	4	0	0	....	5

Enteletes obesa Grabau—(*Continued*)

Serial Number	*No. 104*			*No. 97*				*No. 96*					*No. 98*			
	Plate XII, Fig. 2			*Plate XII, Fig. 3*				*Plate IX, Fig. 6*								
Brachial Valve Stages	*a*	*b*	*c*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*
Height	....	....	....	5.8	11.8	12.3	15.8	4.8	6.0	11.2	11.8	16.8	4.8	7.9	9.5	17.1
Length on curve	....	....	....	8.5	12.5	16.0	26.5	5.0	6.5	15.5	17.0	27.0	6.0	13.0	18.0	30.0
Width	....	....	....	6.1	11.8	13.5	17.3	5.2	6.7	11.2	12.2	16.2	6.0	7.9	10.5	18.4
Length transverse arc	....	....	....	....	....	....	30.0	....	....	....	....	29.0	....	....	....	33.0
Thickness	....	....	....	....	....	....	9.0	....	....	....	....	9.3	....	....	....	11.8
No. of plications	....	....	....	0	1	3	5	0	1	3	5	7	0	1	3	3+
No. of growth wrinkles	....	....	....	0	0	0	4	0	0	0	1	4	0	0	1	4
Entire Shell Stages	*a*	*b*	*c*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*
Thickness (*a*)	....	....	....	....	....	....	18.0	....	....	....	....	18.7	....	....	....	21.3
Thickness (*b*)	....	....	....	....	....	....	18.2	....	....	....	....	19.6	....	....	....	21.7
Length hinge line	....	....	....	....	....	....	8.5	....	....	....	....	7.8	....	....	....	10.7

Serial Number	*No. 99*				*No. 100*				*No. 101*				
					Plate XIV, Fig. 4								
Pedicle Valve Stages	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*e*
Height	....	6.3	9.6	18.8	4.9	8.9	14.8	21.0	....	....	....	....	20.0
Length on curve	....	9.5	15.0	33.0	5.2	11.0	19.8	44.0	....	....	....	....	48.0
Width	....	7.0	10.6	19.4	5.2	10.0	15.7	23.8	....	....	....	....	27.0
Length transverse arc	....	....	....	30.0	....	....	....	42.0	....	....	....	....	50.0
Thickness	....	....	....	11.0	....	....	....	18.5	....	....	....	....	18.0
No. of plications	0	0	2	4	0	0	2	4	0	2	4	6	8
No. of growth wrinkles	0	0	0	4	0	0	0	3	....	....	....	....	6+
Brachial Valve Stages	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*e*
Height	....	....	....	....	3.8	8.9	16.5	27.5	....	....	....	....	29.0
Length on curve	....	....	....	....	4.5	11.5	23.0	44.0	....	....	....	....	50.?
Width	....	....	....	....	4.7	8.7	17.0	23.8	....	....	....	....	27.0
Length transverse arc	....	....	....	40.0	....	....	....	49.0	....	....	....	....	50.0
Thickness	....	....	....	13.3	....	....	....	17.0	....	....	....	....	18.3
No. of plications	0	1	3	5	0	1	3	5	0	1	3	5	7
No. of growth wrinkles	0	0	0	4?	0	0	0	3	....	....	....	....	8

Serial Number	*No. 99*				*No. 100*				*No. 101*				
					Plate XIV, Fig. 4								
Entire Shell Stages	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*e*
Thickness (*a*)	....	....	....	24.0	....	....	....	30.5	....	....	....	....	31.5
Thickness (*b*)	....	....	....	....	....	....	....	31.0	....	....	....	....	33.8
Length hinge line	....	....	....	?	....	....	....	9.7	....	....	....	....	?

that seen in the adult or even submature shells. In some cases the point of change in stages could not be ascertained with precision because of the imperfect state of preservation. Nevertheless, the measurements give a fair picture of the changes in size and character.

Horizon and Localities:—This species is one of the more abundant in the Jisu Honguer limestone of Jisu Honguer, Mongolia, at least ten characteristic specimens having been obtained by F. K. Morris from these beds. It occurs in the *Enteletes* bed (1190), where it is most common and associated with *Enteletes andrewsi* Grabau; in the *Martinia* bed (1194) associated with *Enteletes andrewsi* and *Enteletes angulatoplicata* Grabau, and in the *Hemiptychina* bed (1196) where it is associated with *Enteletes angulatoplicata* Grabau. Altogether it is the largest, most obese and most striking species of this genus in these strata.

59. **Enteletes subobesa** Grabau, sp. nov.

Plate XIII, Figs. 1a-e (No. 113), 2a-e (No. 114), (No. 114a)

Several specimens agree in a remarkable manner in the early stages with *Enteletes obesa* but do not reach the elongate shell growth so characteristic of that species. A comparison of a young stage of this species (No. 114) with the young shell referred to *Enteletes obesa* (No. 104) shows that at about the same height (10.8 mm.) the width in the present species is already much greater (14.7 mm. as compared with 11.2 mm.). This is shortly after the bounding plications of the sinus become defined by the appearance of the parallel outside depression in both the specimens in question. The non-sinuate nepionic stage in this shell also compares favorably with that of the young specimen previously referred to, being of nearly the same height (4.6 mm.) but rather wider (5.8 mm. as compared with 4.8 mm. in specimen No. 104).

In the full-grown shell (No. 114, Pl. XIII, Fig. 2), apparently an adult, judging from the numerous rather crowded growth lines near the front, the bounding plications are well developed, rectangularly rounded, and defined by deep depressions on the outside. The sinus is deep, subangular and continued in the acutely triangular anterior lip, which extends for about 7.5 mm. beyond the general shell margin. The outside of the lateral depression rises with a convex surface into the lateral slopes of the shell, which are regularly convex, there being no further depressions to outline the lateral plications. Thus at the adult stage, when the shell has a height of 20.0 mm. (length 31.0 mm.), a width of 23.1 mm. and a thickness of 12.4 mm., the pedicle valve has only two plications, that is, those bounding the sinus. This simple condition is not found in any of the specimens of *Enteletes obesa* which have attained anything like the size of this shell, the number of plications always being at least four and in one case eight. Nor is it seen in shells of *Enteletes andrewsi*, to which this species bears considerable resemblance in general form. Even in younger stages of that shell, however, the lateral plications are already defined.

A second feature in which this shell differs is the absence of the very characteristic and regular step-like growth contractions found in all the other species. Instead, this species is characterized by irregularly spaced and sometimes crowded coarse growth lines.

Finally, a comparison of shell length (measured on the curvature) with shell height (measured with the plane of contact of the valves vertical) brings out the fact that in the present species the former is much less than is the case in *Enteletes obesa*. In the adult of that species the length is always twice the height or more, and increases with increase of maturity, while in the present form it is only about half again as long. In this respect it corresponds well with the young shells of *Enteletes obesa*, that is, those only about half the height of the adult.

On the other hand, it agrees in this respect more closely with *Enteletes andrewsi* and *Enteletes angulatoplicata*, from which it, however, differs in the absence of lateral plications and the substitution of irregular growth lines for the regular step-like growth interruptions characteristic of the other two species.

A brachial valve (No. 114a), associated in the same rock fragment with the pedicle valve described, and another brachial valve (No. 113), show the same characters. The latter is the more perfect shell and is figured herewith (Pl. XIII, Figs. 1a-e).

The non-plicate stage is 4.6 mm. long, after which the obtusely rounded fold becomes outlined by lateral depressions and the margin becomes sinuate with a median reëntrant. After the shell has reached a height of 10.8 mm., or a shell length of 15.5 (to the center of the median frontal indentation), the lateral plications become feebly outlined, at first by a flattening and then by a faint depression of the shell surface on the outside. These plications are not well-defined, however, though marked by a gradually forward increasing indentation of the frontal margin, as shown by the growth lines. The total height of the valve is 16.8 mm., its length 24.5 mm., or slightly more than half again as long, and it has a width of 19.0 mm. In the young there are five and in the adult four striations to 1 mm., measured from crest to crest, or three measured on the interspaces. The striæ are rounded, somewhat narrower than the interspaces, and at intervals marked by nodes which appear to be oblique openings of the tubular striæ on the surface; coarse lines of growth are frequent especially near the front. There are no step-like interruptions.

Measurements:—Although the measurements of the two best preserved shells have already been given, they may be collected here in tabular form:

	Enteletes subobesa Grabau					
Serial number	*No. 113, Pl. XIII, Fig. 1*			*No. 114, Pl. XIII, Fig. 2*		
	Brachial valve			*Pedicle valve*		
	a	*b*	*c*	*a*	*b*	*c*
Height of valve	4.6	14.2	16.8	4.6	10.8	20.0
Length of valve	5.0	19.0	24.5	6.5	15.5	33.0
Width of valve	5.1	15.5	19.0	5.8	14.7	23.1
Thickness of valve	....	....	8.+	....	....	12.4+
Length of hinge area	....	....	8.9	....	....	11.5

Remarks:—I was disposed at first to regard this shell as a retarded form of *Enteletes andrewsi*, because of its general resemblance to that species. The non-development, or only slight development, however, of the lateral plications, and the absence of the characteristic step-like growth interruptions, which in this species are replaced by irregular coarse growth lines, have constrained me to regard it as a distinct species. The close resemblance of the early stages to those of *Enteletes obesa* indicates their derivation from a common stock, though for that matter, the early stages of all our species show more or less similar characters.

Horizon and Locality:—In the *Hemiptychina* bed (1196), of the Jisu Honguer limestone (Permian) of Jisu Honguer. One pedicle (No. 114) and one brachial valve; also from unknown bed in the same formation, one brachial valve. Collector, F. K. Morris.

60. **Enteletes nucleola** Grabau, sp. nov.

Plate XIII, Figs. 3a-f (No. 105), 4a-f (No. 106), 5a-f (No. 393), (Nos. 107, 108, 109, 110, 111, 112)

The shell is small to medium-sized and is retarded in development. The smallest specimen in the collection (No. 105, Pl. XIII, Fig. 3) is in the early neanic stage. The earliest nepionic stage is smooth without fold or sinus, but in the brachial valve the median elevation is recognizable before the corresponding depression is noticeable in the pedicle valve. In this shell the valves are subequally convex, the umbonal region of the pedicle valve being slightly more convex than that of the brachial valve. The beak of the brachial valve is already well curved in, while that of the pedicle valve is less elevated. The sinus begins about 5 mm. from the beak and is rather sharply rounded at the front, while corresponding to it in the brachial valve is the less-rounded fold which is rather sharp at the front. There are no plications at this stage. There are about five flat radial striæ to 1 mm. The length is 7.4 mm. and 12.6 mm. for the pedicle and brachial valve respectively. The width is 7.9 mm; the thickness is 5.8 mm.

A somewhat older shell (No. 106, Pl. XIII, Fig. 4), with a height of pedicle and brachial valves of 9.4 mm. and 9.7 mm. respectively, a width of 10.7 mm. and a thickness of 8.4 mm., has similar proportions, but the sinus has become more pronounced and is bounded near the front by a low round plication on either side, defined by a parallel outside depression. The indentation formed by the sinus in the frontal suture is rectangular, and the fold has become more strongly defined and is subtriangularly rounded in transverse contour. It is well defined by the parallel depression and flanked at the front by low round plications distinctly outlined by a short outside depression close to the frontal margin. Several distinct growth interruptions are seen on this shell, one strong one at the end of the nepionic smooth stage in the pedicle valve and several others near the front.

In a third somewhat larger shell (No. 107, not figured), the median fold is much more sharply angular, but the lateral plications are scarcely defined; even in the pedicle valve the bounding plications of the sinus are not defined except at the very front on one side. The brachial valve has a height of 10.5 mm. and a width of 11.5 mm. The beak of the pedicle valve is broken, showing the three well-marked septa in the rostral cavity which extend throughout the smooth or nepionic portion of the shell. The width is greater than the height, and the maximum thickness of this shell is 8.5 mm. It is a typical representative of the *Orthotychia* stage.

A submature shell, which represents our most perfect individual, may be taken as the holotype (No. 393, Pl. XIII, Fig. 5). The nepionic smooth stage is of nearly equal length and width, with elevated beaks and regularly arched surfaces. In the brachial valve, it continues a little longer than in the pedicle. In the pedicle valve the sinus begins as a gentle median depression, which does not become outlined by bounding plications until the end of the neanic stage; height 8.6. From that point onward, the bounding plications are defined by well-marked depressions on either side, but there is no additional plication outside of these. In the brachial valve, the second stage is essentially of the same height and length as the pedicle, it being characterized by a very indefinite median angulation, which is defined rather by flattening on either side. The two lateral plications are also indicated by faint angulations but are not defined by lateral depressions. Even in the final stage the slopes outside of these lateral plicæ are scarcely depressed, hardly more than flattened. The sinus-fold zigzag is a right angle, the others are obtuse. There is a single step-like contraction in the front of each valve.

In a still larger shell (No. 109, not figured) the width is also greater than the height. The beak of the pedicle valve is moderately incurved over the rather high hinge area. The greatest convexity is in the posterior third. The non-sinuate shell stage is short, not over 4 mm. high, but the succeeding stage, with only the sinus developed, continues nearly to the front of this shell, where the bounding plications become outlined by the formation of the parallel depression. The first pair of laterals is not defined, though on the left side there is a slight sinuosity in the frontal margin, indicating the commencement of the defining depression, and in certain positions this can be traced for a short distance on the surface of the shell. The sinus is subangular, with a sharply defined median line but with rounded lateral margins.

In the brachial valve the median fold is narrowly rounded, somewhat sharply elevated, and defined by broad shallow concavities on either side which laterally merge gradually into the convex shell surface. A lateral plication appears only on the right side (corresponding to the better developed left side of the pedicle valve), and only a very short distance before the frontal margin is reached.

This shell thus shows a long persistence in the *Orthotychia* stage, this being modified only at the very front by the formation of a lateral plication in each valve. This plication is chiefly defined on the side of the shell, which, as in the majority of individuals of *Enteletes* in these rocks, shows unequal acceleration of the two sides. The brachial valve in particular is least advanced in this species, as is shown in an individual (No. 112) 14.6 mm. high (25 mm. long) in which only the median fold is marked, and that not very sharply, being outlined only by the faintest lateral concavities, but characterized by a deep median reëntrant in the suture line. No lateral plications are formed even at this advanced stage.

The shells so far described, though immature (except perhaps the last one), all belong to one series, and their characteristics do not fit those of the young as shown in the other species previously described. These are the late appearance of the fold and sinus, the rather sharply elevated character of the fold with faint lateral concavities outlining it, and the shallow character of the sinus, the sides of which are gently convex and merge into the shell laterally. Finally, there is the non-development of lateral plications which even in the larger specimens are outlined only at the front and only on the more accelerated side. The width is always greater than the length in all the various stages of growth. On the whole, this is to be regarded as one of the smaller species of the genus in these rocks.

Measurements:—The following are the measurements of shells of various stages referred to this species:

Enteletes nucleola Grabau								
Serial Number...........	*No. 105 Pl. XVII, Fig. 3*		*No. 106 Pl. XIII, Fig. 4*			*No. 393 Pl. XIII, Fig. 5*		
Stages....................	*a*	*b*	*a*	*b*	*c*	*a*	*b*	*c*
Height of pedicle valve...	4.9	7.4	5.7	7.1	9.4	5.0	8.6	10.9
Length of pedicle valve...	....	9.0	....	....	14.0	5.5	11.0	15.5
Width of pedicle valve....	5.2	7.9	6.4	8.5	10.7	5.5	9.0	14.2
Height of brachial valve...	3.2	7.5	5.5	6.0	9.7	5.2	8.5	11.6
Length of brachial valve..	....	10.5	....	....	14.0	9.0	11.0	15.5
Width of brachial valve...	3.8	7.9	5.5	8.0	10.7	5.5	9.0	14.2
Thickness of entire shell....	....	5.8	....	....	8.4	....	....	10.0
Length of hinge line......	....	3.5	....	....	5.2	....	....	6.7

Serial number...........	*No. 107*	*No. 108*	*No. 109*	*No. 112*	*No. 110*
Stages..................	*Final Stage Only*				
Height of pedicle valve...	9.5	12.6	13.0	....	....
Length of pedicle valve...	15.0	....	21.0	....	....
Width of pedicle valve...	11.5	14.4	15.4	....	....
Height of brachial valve..	10.5	12.7	14.7	14.6	11.6
Length of brachial valve..	14.0	....	20.?	25.0	14.0
Width of brachial valve..	11.5	14.4	15.4	16.7	12.2
Thickness of entire shell..	8.5	10.4	12.8	10.8	....
Length of hinge line.....	5.4	....	6.4	....	....

Horizon and Locality:—In the Permian Jisu Honguer limestone in the *Orthotychia* bed (1211), the *Enteletes* bed (1190), *Martinia* bed (1194) and the *Hemiptychina* bed (1196). Though mostly represented by small specimens, the species is not uncommon. Collector, F. K. Morris.

Family STROPHOMENIDÆ King

Genus **Streptorhynchus** King

61. **Streptorhynchus kayseri** Schellwien

Plate XXIV, Figs. 1a-d (No. 288), (No. 299a)

1883. *Streptorhynchus crenistria* var. *senelis* Kayser (non Phillips). In Richthofen, China, Vol. IV, p. 178, Pl. XXIII, Fig. 1 (*cetera exclus*).

1900. *Streptorhynchus kayseri* Schellwien. "Beiträge zur Systematik der Strophomeniden des oberen Palæozoikum." *Neues Jahrb. für Mineral.* Jahrg. 1900, Vol. I, p. 6.

This species is represented in our collection by a single pedicle valve partly incomplete.

Measurements:—The measurements of this shell are as follows:

	No. 284 Pl. XXIV, Fig. 1	*Loping shell*
Height	22.3 mm.	39.0 mm.
Length	35.0 mm.	44.0 mm.
Greatest width	36.8 mm.	43.5 mm.
Length of hinge-line (approximately)	26.5 ?	31.0 mm.
Height of hinge area	24.0 mm.	12.5 mm.
Basal width of inner area	17.0 mm.	....
Thickness	26.5 mm.	15.5 mm.
Height of aperture	21.2 mm.	32.5 mm.
Apical angle	82°	91°

The pedicle valve is very deep, with a high horizontal and flat area and a gently curved shell surface. The beak is obliquely truncated, part of this being due to fracture, and a part appearing to represent a true scar of attachment. The umbonal sides are deflected inward with an abrupt rounding, passing without sharp demarcation into the hinge area, so that the shoulders proper are depressed and non-apparent, except locally on one side below the beak where there is a slight angulation. This makes it difficult to determine the exact width of the area, and consequently the length of the hinge line, the measurement given being taken at the points where the rounded shell margins pass into a horizontal edge. The area is divided into two parts, an outer, rather ill-defined part bordering the overturned umbonal surface, and an inner part. The latter is defined by two grooves which diverge from the beak forward, until they have reached a distance apart, at the hinge line, of 17 mm., which is 9.5 mm. shorter than the estimated length of the hinge line. The median part is preserved for only a short distance below the beak, where it is gently arched for some distance, while farther forward a shallow median concavity appears. There is no indication in the part preserved of a deltidium, unless the median depression represents it, and one might be tempted to consider the entire median portion as a deltidium, which would make this part of the shell occupy the maximum portion of the hinge area. Such an extreme development of the deltidium is, however, unlikely, and it is probable that, were this portion of the shell better preserved, the outline of the deltidium would be apparent.

From the cardinal angles, which are very obtuse, the sides of the shell margin at first slope outward to the point of maximum width, then continue with a regular curve to the front, which forms a continuous curve with the sides, there being no median emargination. The transverse contour, though, is a regular curve to the point of greatest width, there being no median flattening or depression. The longitudinal contour likewise is a regular, very gentle curve from beak to front, except for three growth interruptions which form step-like descents in the shell surface. The first of these is faint, the second stronger, while the third is very pronounced, having in one place a vertical height of over 3 mm., though much less in other parts.

The surface of the shell is marked by fine, sharp, somewhat unequal and unequally spaced, radiating striæ which are separated by broader concave interspaces and increase in number forward, chiefly by intercalation, but in some cases apparently by bifurcation, though this is not wholly clear. At the front there are from three to five of these striæ in the space of 1 mm. Growth-lines other than the strong growth interruptions above noted are not visible, though in some cases the striæ bear extremely fine nodulations, due apparently to cancellation by the growth lines.

Horizon and Locality:—Found in the Jisu Honguer limestone of Jisu Honguer, Mongolia, in the *Streptorhynchus kayseri* bed (1207); one specimen. Collector F. K. Morris.

Remarks:—I refer this shell to the type illustrated by Kayser from Loping for which Schellwien subsequently coined the name *Streptorhynchus kayseri*, since it agrees in all essentials. The Loping shell shows a few more concentric wrinkles than our shell and they are less pronouncedly step-like, but that is a minor detail, and one of purely individual character. Like our shell, the Loping form shows a strong cicatrix of attachment which truncates the beak, while the hinge line is shorter than the greatest width of the shell, and the outline transversely oval. In the Loping shell the hinge area is inclined instead of horizontal, but that is a feature of growth, since in a somewhat younger stage in our shell the hinge area was also inclined with reference to the plane of valve contact. The striæ are also of the same character in the two shells. The dimensions of the Loping form, as taken from the figures, is given in the second column of the table.

62. Streptorhynchus pelargonatus (Schlotheim)

Plate XXIV, Figs. 2a-e (No. 293)

1816. *Terebratula pelargonatus* Schlotheim. *Denkschr. Bayer. Akad. Wissen. München*, Vol. VI, p. 28, Pl. VIII, Figs. 21–24.

1858. *Streptorhynchus pelargonatus* Davidson. "Monograph of British Permian Brachiopoda," p. 32, Pl. II, Figs. 32–42 (*Monographs*) *Palæontographical Soc.*, Vol. XII, (with older literature references).

1882. *Streptorhynchus pelargonatus* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 579, Pl. L, Figs. 3, 4, 5, 7 (with older literature references).

1902. *Streptorhynchus pelargonatus* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, Pl. XXVI, Figs. 6–7 (description in Russian).

A single small pedicle valve occurs in the collection of fossils from Jisu Honguer.

Measurements:—Its dimensions are as follows:

Streptorhynchus pelargonatus (Schlotheim)

	Mongolian	*India—Waagen*	
	No. 293	*I*	*II*
Height	11.7	20.0	15.0
Length	13.4	....	....
Greatest width	15.4	13.5	13.0
Length of hinge line	12.2	11.0	9.0
Height of area	7.5	....	....
Basal width of deltidium	3.0	....	....
Height of aperture	11.4	13.0[1]	11.0[1]
Apical angle	73°	65°	75°

The beak is projecting and sharp without a scar of attachment. The area is high, horizontal and flat, except for the faintest upward curvature at the beak. The shoulders are sharp, nearly straight (the slight undulations due to irregularities of growth), and obtusely angular, lying just within the frame of the umbonal slopes. The hinge line is shorter than the greatest width of the shell below. The cardinal angles are obtuse. The deltidium occupies about one-fourth the area and is broadly and regularly convex. The area on either side is finely striated vertically and marked by both growth lines and coarser growth interruptions.

The outline of the valve is transversely oval with the greatest width near the mid-length. The transverse contour is a series of decreasing arches, reaching absolute flatness at the front. The median longitudinal contour is

[1]Height of brachial valve.

nearly a straight line from beak to base, except for an occasional constriction in the shell surface. One such, moderately pronounced, occurs a short distance below the beak and renders the latter somewhat asymmetric in position. Another fainter and broader constriction occurs farther forward.

The surface is marked by fine, rather flat, radiating striæ, which increase in number forward by intercalation. In some parts of the shell the primary striæ can be distinguished by their greater thickness, while between them are the secondary and tertiary striæ. Towards the front, quaternary striæ appear. The interspaces are much narrower than the striæ, being for the most part merely depressed lines. At the front where the striæ are more nearly equal, from four to five occupy the space of 1 mm. In addition to the coarse concentric wrinkles and constrictions above referred to, there are finer growth lines, but these are not uniformly well shown.

This shell might be regarded as the young of the preceding species, with which it agrees in many features, especially in the horizontal position of the hinge area, in the oval form of the shell, and in the fact that the hinge line is shorter than the greatest width of the shell below. It differs markedly, however, from that species in the well-developed sharp, though obtuse, shoulder angles, in the undivided character of the hinge area, which is vertically striated, and in the strong development of the deltidium. The striæ, too, of this shell are different, being broad and flat with narrower interspaces, instead of being sharp and separated by wider interspaces as in the preceding species. These characters are sufficient to indicate that we are dealing with a distinct species. This is also indicated by the smaller size of the shell, though this may be due to immaturity.

Horizon and Locality:—In the light crystalline limestone beds of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector F. K. Morris.

Remarks:—The Indian shells of this species are of about the same size as our shell and agree with it in most characters. The hinge area is, however, always inclined instead of being horizontal as in our shell. This gives a greater height to the pedicle valve, whereas the other dimensions are not far different from those of our shell (see table). The fact that the beaks of the Indian shells are also more irregular than that of our specimen is probably due to the individual character of our shell; other specimens, if found, may show similar irregularities. The British Permian forms figured by Davidson are also more irregular, the area in these also having an inclined position. In size these are frequently smaller than our pedicle valve, ranging in length from 9 to 10 mm. in different individuals, though in some of those figured by Davidson the length reaches 13 to 15 mm. This is, however, much less than our shell, since a large part of the height is due to the greater erection of the beak and inclination of the hinge area. The pedicle valve figured by Tschernyschew under this name from the Cora bed of the Ufa River, agrees more nearly with our specimen in that the area approaches horizontality, although it is more strongly curved than is the case in our shell. The Russian shell is larger than ours, having a vertical height of 22 mm. (?) and a height of hinge area of 14 mm., according to the figures given by Tschernyschew, which, as no statement is made to the contrary in the German text or description of the plate, is taken to be of natural size. If the horizontality or slight inclination of the Mongolian shell should prove to be a constant feature when more material is obtained, I should suggest that it be referred to a new variety (var. *conica* nov.). To this variety the Russian form might also be referred if it is found that the brachial valves of the two types agree.

Broili (1916, p. 5) calls attention to the fact that typical *Streptorhynchus pelargonatus* of the German Zechstein show clearly that the striæ, which cover the shell closely, are not of equal strength, but that, aside from the intercalated striæ which appear later near the shell margin, the striæ consist of stronger ones alternating with weaker ones. This is a distinctive feature of our shell as described, the striæ being readily separable into primary, secondary, tertiary and, near the front, quaternary groups. Broili further calls attention to the fact that in the Zechstein forms these striæ are covered by growth lines which are so crowded that in well-preserved specimens a granulation or annulation of the surface is produced. This is also seen in our shell, though the preservation is not sufficiently good to make it a pronounced character. Broili separates the Timor shells in which the striæ are coarser, and all become of the same size, even the relatively late intercalations, in which the growth lines are more distant, as *Streptorhynchus pseudo-pelargonatus* Broili. In the character and inclination of the area, the Timor shells agree better with the Salt Range and European shells than with our specimen (Broili, F., 1916, Pl. CXV, Figs. 4–5).

63. **Streptorhynchus broilii** Grabau, sp. nov.

Plate XXIV, Figs. 3a-d (No. 300), 4a-c (No. 301)

Cf. 1916. *Streptorhynchus pseudo-pelargonatus* Broili. "Die permischen Brachiopoden von Timor." Paläontologie von Timor, Lief. VII, p. 5, Pl. CXV (1), Figs. 4 and 5.

Two valves in our collection have features which separate them so markedly from other species of this genus known to me, that I hesitated for a long time before placing them in the genus *Streptorhynchus*. However, the main characters, so far as can be determined, agree with those diagnostic of the genus, and so for the present I place them under it.

Measurements:—The dimensions of the two specimens are as follows:

	Streptorhynchus broilii Grabau	
	No. 300	*No. 301*
Height	18.0	20.0
Length	23.5	25.0
Greatest width	20.0	21.5
Length of hinge line	12.0	17.?
Height of area	7.2	9.6
Thickness of valve	7.7	9.0

The beak of the pedicle valve is erect and pointed, with a strongly arched high area. In one specimen (No. 300) a rather large subcircular scar of attachment, about 5 mm. in diameter, appears behind the beak, occupying a slightly oblique position. The other appears to be without such a scar. The shoulders lie slightly within the frame of the rounded umbonal margins and have a concave outline, with sharp but obtuse angles. The hinge line is shorter than the greatest width of the shell below, which is below the mid-length, while the height is approximately from three-fourths to one-half the greatest width of the area. There appears to be a convex deltidium in the center, but this is not well exposed in our specimens. The cardinal extremities are obtusely angular.

The shell surface is regularly rounded, in the umbonal region this rounding turning inward to the shoulder angles. In the other parts of the shell the transverse contour is a regular arc from side to side, there being no median depression or flattening of any kind. The shell margins are regularly curved from the cardinal angles, the curvature being continuous with that of the anterior margin. The longitudinal contour is also a regular curve from the beak to the front, except where the scar of attachment in one of the shells makes an interruption. The greatest thickness of the valve is at the beak, from which two curves proceed, one regularly convex, forming the longitudinal contour of the shell surface, the other more strongly concave, forming the contour of the hinge area.

The brachial valve is unknown.

The surface is marked by rather coarse radiating striæ which increase in number forward by repeated intercalation, all but the last becoming of uniform size towards the front. The striæ are well defined, broadly rounded on top with steep sides and separated by rather flat depressed interspaces, which at the point of intercalation of a new stria are about twice the width of the striæ themselves. A series of rather distant concentric lines of growth faintly nodulate these striæ. Where the shell was injured in one of the specimens (No. 301) the striæ have become irregular. The interval covering two striæ and the separating interspace is a little less than 1 mm. near the middle of the shell, while the interval of 1 mm. covers three striæ, one of them a new intercalation at the front.

The interior is without septum. Other characters are unknown.

Horizon and Locality:—Of our two specimens, one (No. 301) comes from the *Camarophoria* bed (1208), while the other (No. 300) was obtained from bed No. 1210, both in the Jisu Honguer limestone of Jisu Honguer, Mongolia. Collector, F. K. Morris.

Remarks:—This shell comes nearer to Broili's *Streptorhynchus pseudo-pelargonatus*, from the Permian of Timor, than to any other species known to me. It agrees with that shell in the characters of the striæ, but differs in a number of other respects. In the first place, it is a much larger shell than that found in Timor, the largest specimen of which has a height of 16 mm. and a width of 13.5 mm. Our shell is proportionately much broader. The beak of our shell is always erect, that being the case with one of Broili's shells, where the hinge area is, however, much flatter. The other has the beak overarching and the area more concave. Finally, both of our shells are surprisingly regular in form and contour, and, except for the scar of attachment in one of the specimens, these contours and the outline are much more regular than is usual in this species. Broili's species shows greater irregularity of growth, especially his smaller shell.

Although these shells may be regarded as representative, I do not think it wise to refer this northern shell to the Timor species, or even to a variety of it, since the entire aspect indicates a marked distinctness.

64. **Streptorhynchus** sp.

Plate XXIV, Fig. 5 (Nos. 302a, 302b)

What appear to be two brachial valves of a *Streptorhynchus* occur in a rock fragment from the Enteletes bed (1190). They are not referable with certainty to any of our species, though the probabilities are that they belong either to *Streptorhynchus pelargonatus* or to *Streptorhynchus pseudo-pelargonatus*.

Measurements:—The following are the measurements of the two specimens:

	Streptorhynchus sp.	
	No. 302a	*No. 302b*
Height	11.0 mm.	7.5 mm.
Greatest width	15.0 mm.	11.6 mm.
Length of hinge line	13.5 mm.	10.3 mm.

The valves are transverse, nearly half again as wide as their height, with the hinge line shorter than the greatest width below. The shoulders are straight, nearly horizontal, with the beak scarcely elevated above them, and not prominent. The cardinal angles are obtuse. The hinge area is narrow.

The valves are faintly convex, the greatest convexity being a short distance below the beak. One of the valves (a) is more strongly arched than the other, the convexity being different on opposite sides of the center, which shows a broad ill-defined median depression. The sides are again flattened towards the cardinal angles, even becoming slightly concave. In one specimen (b), the beak is eccentric, the sides being of unequal length.

The surface is marked by sharply defined rounded striæ, which are of uniform size, but near the front are increased by intercalation of smaller striæ, which reach nearly the size of the primary ones at the frontal margin. The striæ are separated by broad, flat interspaces, twice or more the width of the striæ at the point of intercalation of new striæ. They are finely granulated by the growth lines, which are also visible in the interspaces.

The surface characters of these valves agree best with those of *Streptorhynchus pelargonatus* but they are all of one size as in *Streptorhynchus pseudopelargonatus*. They are not so coarse as those of *Streptorhynchus broilii* and not so close together. Until these valves are found in close association with pedicle valves it will not be possible to place them precisely.

Horizon and Locality:—In the *Enteletes* bed (1190) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; two specimens. Collector, F. K. Morris.

Genus **Schellwienella** I. Thomas

65. **Schellwienella regina** Grabau, sp. nov.

Plate XXV, Figs. 2a-d (No. 314)

The shell is resupinate, with the pedicle valve concave and the brachial valve convex. It is large for the genus, is thin, slender, and of graceful aspect, without distortion.

Measurements:—The dimensions of the holotype and only known specimen are as follows:

	No. 314
Height of pedicle valve	41.5
Length of same	43.5
Height of brachial valve	34.0
Length of same	37.0
Greatest width	71.5
Length of hinge line	71.0
Height of hinge area	10.5

	No. 314
Basal width of deltidium	4.5
Basal width of inner area	10.5
Maximum thickness	9.0
Maximum convexity, brachial valve	9.0
Maximum concavity, pedicle valve	5.0
Apical angle of pedicle valve	141°

The pedicle valve is gently convex in the young, for a length of slightly over 19 mm., in which stage the surface has become flat. A concavity then gradually develops, which becomes pronounced towards the front until its total depth has become 5 mm. A very faint, broad, median rise is observable towards the front of the shell. In the cardinolateral region the shell surface of the adult becomes convex again, showing a moderate deflection towards the hinge. The width is only very slightly greater than the length of the hinge line. Length to width is as 7: 12. The cardinal angles are almost 90°. The shoulders are straight, except at the ends, where they are slightly concave, slope gently and form an apical angle of 141°. The shoulder angles are sharp, 45°. The beak is pointed, erect, very slightly salient. The area is inclined flat, nearly seven times as wide as it is high. There is a narrow inner area forming an equilateral triangle, with basal width and height equal. In the center of this lies the narrow delthyrium which has a basal width of 4.5 mm. The outer, larger area is very finely striated vertically.

The brachial valve in the umbonal portion is gently concave, but quickly becomes convex, with, however, a shallow median depression in the center. The cardinolateral portions are depressed to gently concave. The shoulders are straight and horizontal, the beak slightly projecting above them. The hinge area is very narrow and linear, about 1 mm. wide, inclined at nearly the same angle as that of the pedicle valve, with which it forms practically a continuous slope.

The outline of the shell is semicircular, with a regular and continuous curvature of sides and front, the latter slightly flattened in the center. The shell margin is sharp and continuously regular, except at the front, where there is a faint emargination, corresponding to the sinus in the brachial and the incipient median elevations in the pedicle valve.

The surfaces of both valves are marked by sharp but fine and narrow radiating striæ. Those on the pedicle valve are nearly 1 mm. apart before the number is increased towards the front by intercalation of new ones. Those on the brachial valve are similar, and their number also increases by intercalation. Towards the front they are somewhat nearer together than are those of the pedicle valve, and their size is essentially uniform, whereas in the pedicle valve smaller intercalated striæ occur between most of the larger ones. All the striæ are faintly nodulated by concentric growth lines which on the striæ produce small scaly elevations. These are fairly regularly spaced and also produce a slight thickening where they occur, thus giving the striæ a somewhat beaded appearance.

The internal structure is unknown, though at the beak of the pedicle valve there appears to be a very short thin median septum, which extends, however, for only a very short distance.

Horizon and Locality:—This shell has been obtained from the *Marginifera* bed (1192) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—This species belongs to the groups to which belong the shells figured by Davidson on Pl. XXVI, as *Streptorhynchus crenistria* Phillips, that is, the thin-shelled large shells with a very small visceral cavity, and with concave pedicle and convex brachial valve. It differs, however, from the carboniferous limestone species in a number of important details. In the first place, our shell is much more transverse than the average of the British forms, being essentially semicircular. Again the curvature of our shell is more regular and more pronounced, the shoulders are more sloping, and the area is proportionately higher and more triangular. The sinus in the brachial and a faint elevation in the pedicle valves also are characters not seen in the Carboniferous limestone shells. In the matter of surface characters the two agree in all essentials. The shell originally named *Orthis caduca* by McCoy and refigured by Davidson (1861a, Pl. XXVI, Fig. 4) as *Streptorhynchus crenistria* agrees with our shell in the transverse form, but the hinge-line is shorter, the area lower, and it lacks the sinus and median elevation on the brachial and pedicle valves respectively. Finally, that shell is flat in the main part of the pedicle valve as well as in the brachial valve. The striæ, too, show more frequent intercalations than are seen in the Mongolian species. These characters mark a sufficient distinctness between the British species and the shell from Mongolia to warrant its reference to a separate species.

Genus **Orthothetina** Schellwien

This generic name was proposed by Schellwien for a species of biconvex strophomenoid shells, with the general characters of *Streptorhynchus*, but with the dental plates parallel and near together and resting on the bottom of the pedicle valve. In this respect the structure corresponds to that of *Meekella*, but the exterior is merely striated, instead of plicated and striated as in *Meekella*. Girty (1908, p. 209) adopts this name but is somewhat doubtful whether to grant it generic rank. I see no reason for denying it this rank, as it represents a distinct stage in development through which some species of *Meekella* pass while *Orthothetina* remains permanently in this stage. It is, of course, possible that the latter is not genetically related to *Meekella*, and that the similarity of internal structure presents a case of parallelism in development.

Two more or less imperfect shells of this type have been found in our Mongolian material, but these show unmistakably the characters diagnostic of the genus *Orthothetina*, as above defined.

66. **Orthothetina ruber** (Frech)

Plate XXIV, Figs. 6a-c (No. 298), 9a-c (No. 322)

1911. *Orthothetes ruber* Frech. In Richthofen, China, Vol. V, P. 174, Pl. XXVI, Figs. 4a-c.

The shell is strepthorhynchoid with the pedicle valve plano-convex and the brachial valve more or less regularly convex. The hinge line is shorter than the greatest width of the shell. The outline is distorted.

Measurements:—The dimensions of the only specimen obtained, which is with certainty referable to this species, but is imperfect (No. 298, Pl. XXIV, Fig. 6), are as follows, the estimated dimensions being given in the second column.

	Orthothetina ruber (Frech)	
	No. 298	*No. 298*
	As preserved	*Original estimate*
Height of pedicle valve	22.3	26.9
Length of same	25.0	29.8
Height of brachial valve	21.2	21.2
Length of same	31.0	31.0
Greatest width	27.2	28.0
Length of hinge line	26.8+	28.0+
Height of area (pedicle valve)	10.0	14.6
Basal width of delthyrium	5.3	5.3
Maximum thickness	15.7	15.7
Apical angle	....	90°

The pedicle valve has the erect beak turned to one side. The cardinal area is flat and inclined on one side, and is twisted to horizontality on the other. It is high, but not as high as wide. The delthyrium, which is rather broad, slowly converges upward, and is covered by a convex deltidium, which in the later stages of growth appears to divide into three parts, a narrow median and higher part, and two lateral somewhat more depressed parts. The shoulders are salient, not inframed by the umbonal slopes; sloping, but the outline is not fully preserved; acute in some and apparently obtuse in other parts.

The surface of the valve is not preserved. The central part is flat or slightly depressed medially, the depression being irregular. The sides, curving gently to the lateral margin, are continued without curvature to the front which is acute and has a salient suture line, which is straight except for the faintest median deflection.

The brachial valve is strongly convex in the umbonal region, and is abruptly curved to the beak which overarches the low hinge area. The shoulders are sloping but not pronounced. The median longitudinal contour is a regular curve from the highest point on the umbo to the front. The transverse contour is strongly arched in the umbonal region, becoming gentle forward, until near the front the center is flattened while the sides are rounded.

The surface, where it is preserved, is marked by radiating striæ, but the details of these are not determinable.

The interior of the pedicle valve has two septiform dental lamellæ, which converge slightly but remain distinct to the bottom of the valve, where they are parallel and slightly over 2 mm. apart. The interior of the brachial valve is not readily determinable, but there are indications of two diverging septal ridges and a short median septum.

Horizon and Locality:—In the *Enteletes* bed (1190) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—This species has the general form and contour of valves characteristic of *Derbya hemisphærica* Waagen (1879–1887, Pl. LIV, Figs. 1–3) with which it agrees in all essentials so far as can be determined, except in the internal characters. In the Salt Range shell there is only a median septum in the pedicle valve, the dental plates not being developed, whereas in our shell the dental plates are distinct and reach the bottom of the valve. I know of no form in the late Palæozoic which agrees with this shell in all its characters, except perhaps the poorly figured and inadequately described *Orthothetes ruber* of Frech. He cites that shell from Sung Kan in Kweitchow province. Frech also refers to this species the imperfect pedicle valve from Loping, figured by Schellwien (1900 *a*, Pl. I, Fig. 6), as *Orthothetina* without reference to a distinct species. This shows clearly the two parallel septiform dental plates similar to those seen in our shell, but the beak is less irregular. The surface of the valve is characterized by irregular concentric wrinkles, and the striæ are fine, sharply rounded, rather irregular, and increase in number by irregular intercalation. They are separated by wider interspaces. Though neither of the authors cited describes his shells adequately and Frech's figures leave much to be desired, I refer our shell to this species, chiefly on the strength of the general form and relative convexity of valves. Possibly if better material were available, our shell might prove to be distinct.

There is another imperfect shell in our collection (No. 322, Pl. XXIV,

Fig. 9), which I would refer to this species. It is a part of a pedicle valve, with high, essentially horizontal hinge area and irregularly depressed surface strongly and irregularly concave in the center, rounded convex in the lateral parts. The half-grown shell is regularly resupinate, convex in the umbonal region and flattened forward, becoming concave at the margin, after which the irregularity appears.

The beak is pointed and projecting, the hinge area flat and horizontal, its height 12 mm., while the width is 16.5 mm. when restored on one side of the center, the other being imperfect, but may have been less originally. It is divided into an irregular inner area, which is marked by fine vertical striæ, and an outer one, which is marked only by horizontal growth lines and fine pustules. The delthyrium is twisted to one side; is open in this specimen, and has a width of about 4 mm. at the hinge line. The shoulder is straight, sloping, the angle obtuse, lying within the frame of the cardinal slopes. The surface is marked by fine, sharp thread-like radiating striæ, separated by intervals several times their width, and increased at the front by intercalated striæ. A few horizontal constrictions occur, and there are a number of growth stoppages distinctly marked. The interior has two septiform dental plates which rest on the bottom of the valve; they extend parallel for a short distance, then converge and apparently meet at a point about 6.5 mm. from the beak.

67. **Orthothetina** cf. **eusarkos** (Abich)

Plate XXIV, Figs. 7a-b (No. 321)

Cf. 1878. *Streptorhynchus crenistria* var. *eusarka* Abich. Geologische Forschungen in den Kaukasischen Ländern, Vol. I, Pl. VI, Fig. 4.

Cf. 1900. *Orthothetina eusarkos* Schellwien. "Beiträge zur Systematik der Strophomeniden des oberen Palæozoikums." *Neues Jahrb. für Mineral.* Jahrg. 1900, Bd. I, Pl. I, Fig. 1.

This shell is represented by an incomplete pedicle valve, too imperfect to permit measurements with any degree of accuracy. It is transverse with the width somewhat less than twice the height, the outline roughly semicircular.

The pedicle valve is rather strongly convex with extended and distorted beak so that it occupies a position on one side of the shell. It was apparently attached, as indicated by what seems to be a rather pronounced scar. The hinge area is gently concave, slightly inclined, the inclination approaching horizontality. The delthyrium is broad, its basal width being 13 mm.; the height is probably less than 4 mm. The shoulders are gently convex, longitudinally, and rounded transversely so that the shell surfaces merge with that of the hinge area without a very pronounced demarcation. The hinge line is probably less than the greatest width of the shell. The greatest convexity is a short distance below the beak, from which point the curvature is abrupt to the beak and more gentle to the frontal margin. The transverse contour is a regular arc from side to side in the umbonal region, but becomes flattened and even slightly depressed in the middle towards the front, although there is no actual sinus formed.

The surface appears smooth, probably because of weathering, but under the lens shows faint radiating striæ, cancellated by equally ill-developed concentric undulations, which are narrow and subregular, resembling those of *Reticularia*. In a few places there are faint pustules suggestive of spine-bases.

The interior has two strong dental plates which rest upon the bottom of the shell, but because of the distortion of the beak appear rather far apart from the beginning. They diverge slightly, being about 8 mm. apart near the middle of the shell. The brachial valve is unknown.

Horizon and Locality:—In the *Streptorhynchus* bed (1207) of the Jisu Honguer limestone at Jisu Honguer; one specimen. Collector, F. K. Morris.

Remarks:—This shell is peculiar in its subdued surface markings, rounded shoulder angles, and widely separated dental plates. I have not found any other species to compare with it, and refer it with much hesitation to Abich's species. The shell is too imperfect to permit thorough diagnosis of its characters.

68. **Orthothetina** sp.

Plate XXIV, Figs. 8a-d (No. 307)

This shell is small, transverse, irregular and convex.

Measurements:—The dimensions so far as can be ascertained are as follows:

	No. 307
Height of brachial valve	10.7 mm.
Greatest width	14.0 mm.
Length of hinge line	12.5 mm.
Maximum thickness	5.5 mm.
Distance apart of dental plates	1.8 mm.

The pedicle valve is more convex, deepest in the umbonal region. The beak and hinge area are not preserved but the hinge line forms approximately the greatest width of the shell; the cardinal angles are slightly mucronate on one side, obtusely subangular on the other. The transverse contour is irregular with the greatest height on one side, from which the surface at first slopes then descends abruptly, almost at right angles, to the shell margin, which is salient. Thus the vertical lateral part appears gently concave. This gives the shell the appearance of being abruptly truncated on one side. On the other side the slope is longer, inclined, but flat to near the margin where it drops more abruptly to the shell margin, though not as abruptly as on the other side. This sudden geniculation in the shell surface is traceable all around the margin as a step-like contraction, followed by an expansion in a sharp and salient shell margin.

The brachial valve is flatly convex, deepest at about the middle, in front of which there is a gentle concavity, after which the valve rounds gently to the frontal margin. This is asymmetrical, the shell being much higher on one side (the abruptly truncated side) than on the other. The hinge area is narrow, not well preserved.

The surface is marked by coarse distant radiating primary striæ, between which somewhat finer secondary striæ are intercalated, and near the front still finer tertiary ones. A few concentric wrinkles occur, and the striæ show indications of fine nodulation.

On the interior, the pedicle valve is characterized by two septiform dental lamellæ, which rest on the bottom of the valve. At the point of fracture of the umbo, which is at the level of the hinge line, they are 1.8 mm. apart, while 3 mm. farther down they are 2.5 mm. apart, thus showing a moderate divergence. In the brachial valve, the socket plates are strongly developed and diverge at an angle greater than 90°. In the center there is a short median septum, not reaching to the beak, which divides a muscular area characterized by short irregularly diverging grooves (shown in the internal mold as ridges). Other internal characters not observed.

Horizon and Locality:—In the *Martinia* bed (1194) of the Jisu Honguer limestone at Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—This shell is too imperfect to permit designation of it as a new species, and I know of no shell of the genus with which it could be compared, though a number of species whose internal characters appear to be unknown are similar to it.

Genus **Derbya** Waagen

69. **Derbya dupliciseptata** Grabau, sp. nov.

Plate XXV, Figs. 1a-c (No. 303), (Text-Figs. 63–65)

The shell is large, robust, of subtriangular outline, planoconvex to incipiently biconvex, with the pedicle valve strongly arched and the brachial valve flat or gently and irregularly convex. The specimen is incomplete.

Measurements:—The following measurements are therefore only partly exact.

	No. 303
Height of pedicle valve	68 mm.+
Length of same	71 mm.
Height of brachial valve	42 mm.
Length of same	....
Greatest width	68 mm.
Maximum thickness	31 mm.
Length of hinge line	41 mm.
Height of hinge area	25 mm.
Basal width of deltidium	14 mm.
Apical angle of pedicle valve	116°–52°

The pedicle valve is very irregularly but strongly vaulted, with the umbonal region laterally compressed, giving the shell a subtriangular outline. The beak is erect or very slightly overarching at the tip. It is pointed in the young at a very obtuse angle, but later has the sides more nearly vertical. The hinge area is high, vertical, gently but irregularly concave, with the center formed by a pseudo-deltidium, which at the hinge line occupies about one-fourth of the entire width of the area. The hinge line is shorter than the greatest width of the shell, which is near the center. In front of the compressed umbonal portion the shell expands rapidly in breadth.

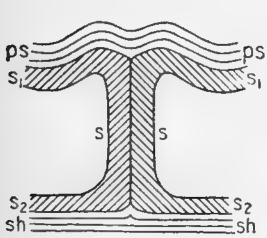
The shoulders are sharp, salient, not framed by the umbonal slopes, acutely angular and gently concave in outline in the lower major portion. The apical angle formed by this part of the shell is about 52°, but the earlier portion, incomplete in the specimen, appears to have had a very broad angle. In the inner shell layer the pseudo-deltidium is defined by two deep diverging grooves, while a groove likewise characterizes the center of the pseudo-deltidium. These grooves are filled in by shelly thickenings of the outer layers of the hinge area. As these outer layers are the first formed, the others being added successively within, it is apparent that the grooving becomes more and more pronounced with the thickening of the shell. This can be seen in related forms where the entire thickness is preserved and visible in section (see under next species). The inner shell layer shows only a lamellose character; the outer layers being exfoliated, their markings can not be determined.

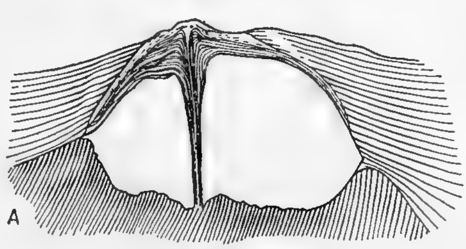
The general longitudinal contour is an irregular curve with local swelling and contraction. The transverse contours are also arched, the arch low or even flattened in the center and rather abruptly curved down on the sides. There is no median depression or sinus.

The surface of the valve is coarsely and irregularly wrinkled, these wrinkles being due to sudden contractions in the shell followed by renewed expansion. These wrinkles are seen in the internal mold as well. Where the shell is preserved it shows fine, rather sharp radiating striæ which increase by intercalation, the newer striæ remaining small for a time but eventually reaching the size of the others. Where the shell is abruptly contracted, the striæ are crowded, so that three occur in the space of 1 mm., whereas normally there are only two. The interspaces are wider than the striæ and deeply concave. Where well preserved the striæ are seen to be noded at fairly regular intervals.

The brachial valve is flat on the whole, but with local convexities and concavities, the surface being an irregular one. The beak is elevated with a low obtuse projection, above the straight and horizontal shoulders, which defines the upper edge of a narrow linear hinge area. The cardinal extremities are obtuse, and the general outline of the shell is one of irregular rounded sides and more broadly rounded form. There is neither fold nor sinus in this valve. The outer layer of the valve in the type and only specimen is exfoliated and the surface more or less modified by weathering and solution, so that the original surface markings are not preserved. It was undoubtedly radiately striate as in the pedicle valve.

The interior is only partly known. In the pedicle valve there is a median septum which extends from the bottom of the valve to the pseudo-deltidium, at least in the rostral portion. This septum consists of two distinct layers or two septa in close contact throughout. At the bottom of the valve each layer bends outward continuously with the inner layers of the shell on either side (s_2 s_2 , Text-Fig. 63).





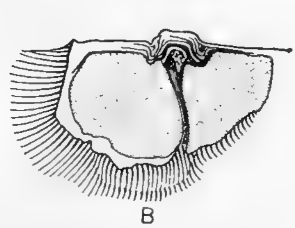


FIGURE 63.—(No. 303) Diagram of double septum of *Derbya dupliciseptata* Grabau, sp. nov. (s, s) septum; s_1, s_1, outward-bending portions of septum beneath pseudodeltidium (ps); s_2, s_2, outward-bending portions of septum to form inner shell layers, covered by true shell (sh, sh).

FIGURE 64.—Cross-section diagram of *Derbya* sp. (Timan). A.—Umbonal section showing upper ends of median septum bending outward to form inner layers of pseudodeltidium. (After Schellwien.)

FIGURE 65.—Cross-section diagram of *Derbya* sp. (Timan). B.—A section lower down than Text-Figure 64 showing the separation of the septum from pseudodeltidium. (After Schellwien.)

This double septum can be traced on the ventral side for more than half the length of the valve. At the pseudo-deltidium it also divides again, each layer bending sharply outward to form the inner layers of the pseudo-deltidium (s_1 s_1 , Text-Fig. 63). Judging from the fact that it is only the inner layers which are thus confluent with the septa, we must conclude that in the earlier stages of growth the septum ended freely without being in contact with the pseudo-deltidium. Again judging from the fact that the median depression in the inner layer of the pseudo-deltidium extends for about half the length of the latter, we conclude that the septum is in contact with the pseudo-deltidium for at least half its length from the beak.

Schellwien (1900a, p. 10, Figs. 6 and 7) has figured a section through the apical portion of an undetermined species of *Derbya* from the Timan which is here reproduced as Text-Figs. 64–65, in which a similar bending of the outer layers of the septum occurs to form the inner layers of the pseudo-deltidium. Schellwien interprets this as an indication that the septum was formed by the deltidial plates in the region of the beak, but this can not be inferred from his figure, since the outer layer, which must have been formed first, has no relation to or connection with the septum, this connection being clearly the result of subsequent deposition of layers of lime from within. The extent of the original median septum, against the sides of which the layers were deposited and finally extended to the beak, is not indicated in Schellwien's figure, unless it is represented by the white line in the center of the thickened septum. In our shell this original median septum is indicated in one place, where the shell has been removed, as a thin plate which is continued upward in a median groove between the outer thickening layers, as viewed from the bottom, and this may represent the weathered part of the original median septum. This is indicated in Text-Fig. 63 by the white space and its continuation in a black line to the beak.

A second section of the same shell, a short distance below the first, is given by Schellwien (1900a, Fig. 7). Our Text-Fig. 65 shows the end of the thickened septum free from the pseudo-deltidium. The layers of the pseudo-deltidium are not bent down in the center, even the inner ones being straight, whereas in the section showing contact with the septum these layers bend down in the center. Again, in Schellwien's section, whereas the outer layer of the pseudo-deltidium is normally convex and not separated from the hinge-area on either side by a depression, the inner layers bend down on either margin of the pseudo-deltidium, the shell being more strongly thickened at these points than elsewhere. Thus if all the layers except the inner one were removed, the pseudo-deltidium would be bounded on either side by a pronounced and rather broad concave groove, such as is shown in this layer in our specimen where all but the innermost layers have been removed.

The interior of the brachial valve is not well shown, but the diverging septate prongs of the hinge-plate are well indicated, making an angle with each other of slightly over 90° and extending for a considerable distance along the shell. There is no indication of a median septum.

Horizon and Locality:—This species is known only from a single specimen obtained from the *Enteletes* bed (1190) of the Jisu Honguer limestone of Jisu Honguer, Mongolia. Collector, F. K. Morris.

Remarks:—In certain respects this species is not unlike *Derbya nasuta* Girty (1908, p. 188, Pl. XXVI, Figs. 6, 6c) from the Delaware Mountain formation (Guadalupian) of Texas, U. S. A. It corresponds to that form especially in the character of the beak of the pedicle valve and in its area and salient sharp-angled shoulders. The pedicle valve of our shell is strongly convex in the pallial region, whereas that of the Texan form becomes flat and depressed towards the front. They have the same general type of surface characters, but the brachial valves are quite distinct, that of our species being nearly flat, while in *Derbya nasuta* the brachial valve is strongly convex. From *Derbya grandis* Waagen and similar forms our shell is distinguished by its subtriangular outline, due to the depression of the umbonal part, its similarity of height and breadth, and the flat brachial valve.

70. **Derbya(?) (Derbyina) mongolica** Grabau, sp. nov.

Plate XXV, Figs. 3a-c (No. 292), (No. 291), (Text-Fig. 66)

The shell is moderately large, robust and much distorted. Only the pedicle valve is known.

Measurements:—The pedicle valve has the following dimensions:

	No. 292
Height	33.0 mm.
Length	35.5 mm.
Greatest width	42.0 mm.
Length of hinge line	32.? mm.
Width of median area	16.0 mm.
Height of area	28.5 mm.
Height of aperture	27.0 mm.
Apical angle (young)	52°
Apical angle (adult)	86°

The beak of the pedicle valve is strongly projecting, with a high level area which is nearly as high as it is wide, and is essentially horizontal. The umbonal portion is contracted into a narrow subtriangular cone, below which the shell expands more rapidly, but irregularly. The shoulders are bluntly rounded, of undulating outline and slightly within the frame of the expanded part of the shell. The area is divided into three parts: a median (the pseudo-deltidium), and two lateral. The first is gently convex, but with a central longitudinal depression. It occupies about half the width of the area and is defined by two strong grooves, one on either side, which extend from the beak to the hinge line. The lateral parts are irregular triangles, flattened and bounded respectively by the aforementioned grooves, the shoulders and the hinge-line. At the hinge-line margin they are each about half as broad as is the median part.

This median portion is probably to be considered in the light of a pseudo-deltidium which would make this organ a very broad one. Certainly there is no other indication of a deltidium or of a median fissure or delthyrium. The sides of this median part are thoroughly united with the rest of the hinge area, and the surface is marked by fine growth lines. Similar growth lines occur in the hinge area, but they extend more nearly at right angles to the shoulder, thus giving the front of the area a convex margin, at least in the younger stages.

Below the contracted umbonal portion, the outer part of which is rounded, the shell expands in a rudely trilobate manner,—a median part which is broadly and irregularly depressed into a rude sinus, and two lateral parts which are convexly rounded, though here, too, there is considerable irregularity. The sides of the shell bend abruptly down to the shell margin.

The surface of the valve appears smooth, except for irregular growth wrinkles. This smoothness is due, however, to exfoliation of the outer shell layers, leaving only the innermost layer, which has no markings. Where, however, a little of the shell is preserved, as on one side of the sinus, irregular radiating striæ of moderate fineness are visible. These are also seen on the outside of the contracted umbonal part, which preserved the shell. In one place a distinct nodulation of these striæ is seen, this being due to cancellating growth lines. On the mold of the exterior, from which the adhering shell layers are removed, the radial striation is well indicated. The striæ are rounded and broader than the interspaces, and apparently increase, in part at least, by bifurcation. The transverse fine nodulation is also indicated in the mold.

The interior of the shell is peculiar. The valve is divided into two cameræ by a double septum, or better two septa, in contact, which extend from the bottom of the valve to the pseudo-deltidium. The dividing plane of these septa is well marked, and the septa themselves are thickened by the addition of shell layers on the side away from the median dividing plane, that is, on the inner face of the cameræ. The characters of these septa and the shell surface in contact with them are well seen on a fracture plane which separated the contracted rostral portion from the broad expanded part of the shell. The septa seem to extend only for the length of this part of the shell in contact with the inner surface of the deltidium, after which the inner edge becomes free. Around this inner edge the layers added on each side extend continuously, so that on their free edges the septa are united, and viewed from that end would appear as a single very thick septum (Text-Fig. 66B). In like manner the lamellæ turn outward at the inner face of the pseudo-deltidium, thickening it by the addition of successive layers, each continuous with a layer of the septum. The thickening of the compound septum is 1.7 mm. at the inner deltidial end. (Text-Fig. 66A.)

The thickness of the shell is considerable, especially in the region of the deltidium and hinge area. At the fractured portion of the beak this part of the

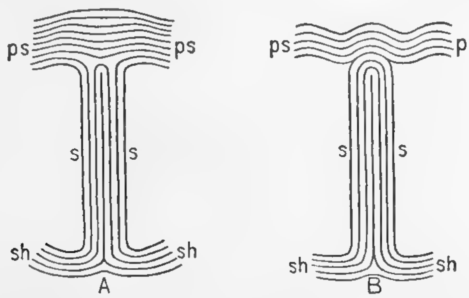


FIGURE 66.—(No. 292) Semi-diagrammatic representation of sections of the umbo of *Derbya?* (*Derbyina*) *mongolica* Grabau, sp. nov., to show the relation of median septum to shell and to pseudodeltidium. A.—In upper part of beak showing continuity of septal layers with inner layers of pseudodeltidium and shell. B.—The same specimen—somewhat lower, showing septum free from pseudodeltidium, though still in contact with it. (Much enlarged.)

shell is 4.3 mm. thick in the middle and 3.8 mm. on the side. It consists of numerous shelly layers added successively from within and having an undulating character. The innermost layer alone covers the greater part of the shell and its hinge area outside of the umbonal portion, the remainder having been separated off by exfoliation. It is noteworthy that the median broad shallow groove of the deltidium is seen only in the lowest layer, and there apparently only in the part free from the median septum. On the outer part of the shell, where preserved, in the umbonal region, the surface of the deltidium is strongly and regularly convex, while there is only an indication, in the course of the lower layers at the front of the fractured part, of the development of the median depression. On the ventral side the maximum thickness of the shell appears to be not over 1.5 mm. and is similarly composed of numerous superposed lamellæ.

This general thickening of the shell, and the character of the area, suggest to some extent what is seen on a much smaller scale in the young of some *Richthofenia* (Waagen, 1879–1887, Pl. LII, Fig. 2). Indeed the umbonal part, taken by itself, is not unlike in form some of the young *Richthofenia*. There is, however, no indication of the covering over of the hinge area as is characteristic for that form. Then, too, the sudden expansion of the shell and the broadening of the deltidium give it a different aspect in the adult. The septum, too, thickened as it is by the addition of layers on the outside, is similar to the much shorter septum of some *Richthofenia* (Girty, 1908, Pl. XXIV, Fig. 10).

Altogether it is difficult to escape from the belief that this shell is in a manner related to *Richthofenia*, though it departs widely from it in form and, to some extent, in structure. Again we might not go far wrong when we consider that this shell is less specialized, and is in a manner related to, the ancestors of *Richthofenia*, if not an actual connecting link between this form and a *Derbya*-like type of *Strophomenidæ*.

It is with some hesitation that I refer this shell to *Derbya*, and I do so only because there seems to be no other genus which has characters more nearly like those shown here. Moreover, this shell corresponds in its internal characters to *Derbya dupliciseptata* as above described, except that striæ characters are carried a step farther. It may be related to *Scacchinella* Gemmellaro of the Italian Permian (Trogkofel beds). That shell has a high flat hinge area in the pedicle valve which on its interior has a well-developed median septum.

All these characters are found in our shell, though the proportions and outline differ greatly from the south European forms.

Horizon and Locality:—In the *Hemiptychina* bed (1196) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—This unique shell carries the structural type seen in the preceding species much further in the same direction, so that the median septum is distinctly a double one, the two together having a thickness of 1.7 mm. This extreme development of the median septum and its distinctly double character, as well as the form of the hinge area and the very broad pseudo-deltidium, separate it from other forms of the genus. The peculiar pyramidal form is another diagnostic character not found in typical *Derbya*. It may be desirable to refer this shell to a new genus or at least subgenus, for which I would use the designation *Derbyina* (nom. nov.). In any case it marks an extreme type probably derived from a normal *Derbya*-like progenitor.

71. **Derbya** cf. **hemisphærica** Waagen

Plate XXV, Fig. 4 (No. 304), Fig. 5 (No. 309), (Nos. 305, 306, 309, 310, 317?, 945?)

1882. *Derbya hemisphærica* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 604, Pl. LIV, Figs. 1–3 (with older references).

1902. *Derbya* aff. *hemisphærica* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 579, Text-Figs. 56, 57.

Brachial valve:—A number of brachial valves are present in the collection from Jisu Honguer, which are referred to this species.

Measurements:—Measurements of two fairly perfect specimens gave the following dimensions:

Brachial valve	No. 304	No. 306
	Pl. XXV, Fig. 4	
Height	35.0 mm.	23.5 mm.
Length	44.0 mm.	....
Maximum width	51.0 mm.	30.6 mm.
Length of hinge line	42.0 mm.	20.0 mm.

The brachial valve is strongly convex, much wider than it is high, with the hinge line shorter than the greatest width of the shell and the cardinal angles obtusely rounded. The shoulders are straight, level or very gently inclined. The beak projects slightly beyond them and is sharply curved to the hinge. The area is narrow linear; the shoulder angles are sharp.

The greatest convexity is in the umbonal region, from which the curvature is abrupt to the beak, but gentle, almost flat, to the front. The contour is irregular because of a number of concentric wrinkles due to sharp contractions of the shell edge followed by gentler expansions. The transverse contours are strongly arched in the umbonal region, nearly flat at the front in some, but gently arched in other specimens in which the concentric wrinkles are less strongly developed.

The surface is marked by sharply rounded, strong but narrow striæ separated by pronounced interspaces of about the same width as the striæ, or wider. In the interspaces an intercalated stria soon appears between the older ones, such intercalation being common near the front and sides of the valve. In some cases there is a tertiary intercalation. The striæ are finely and rather irregularly noded where they are crossed by some of the growth lines, and on well preserved parts of the shell a very faint notching of the striæ is apparent, evidently produced by the growth lines. The spacing of the striæ is somewhat irregular, these being from two to nearly three in the interval of a millimeter near the lateral and frontal margin. Though faint when they first appear, the intercalated striæ become as strong as the others at the front, except where there is tertiary intercalation.

The interior is known only from the impressions in the internal mold. The hinge-plate appears to have been heavy, and probably bore a strong cardinal process, though this is not preserved. The socket plates are strong, slightly concave outward, moderately thick at the point of origin and diverging at an angle of 90° or over. As thin plates they extend for a considerable distance across the inner surface of the valve. In some cases they converge again to a very slight degree, so that in addition to being gently concave outward in their shorter or transverse dimension, they are gently convex outward in their longitudinal direction, at least along the line of juncture with the inner shell surface. In one of the specimens whose measurements are given above (No. 304, Pl. XXV, Fig. 4), the socket plates diverge regularly for a distance of about 10 mm. from the point of origin, then converge for some distance, enclosing a muscular area between them. Two narrower, crescentic ridges enclose an almond-shaped area between them. In this specimen the median septum is scarcely indicated, but in two others (Nos. 306, 309, Pl. XXV, Fig. 5) an impression is shown, indicating it to be rather short, thick, and of triangular section.

Pedicle valve:—A fragmentary specimen (No. 305) of a large brachial valve, which, from its general outline and contours, appears to belong here, has attached to it what appears to represent the normal pedicle valve of this species, though the features are only recognizable in section. This valve is irregularly concave, with a projecting pointed beak and a gently concave hinge area in horizontal or even reclined position. The interior space between the valves is filled with crystallized calcium carbonate, and everything except the outlines of the valves is destroyed. The center of the hinge area, which has a height of about 11.5 mm., is occupied by a thick convex pseudo-deltidium, the outline of which is partly shown in the section. The beak of the convex brachial valve appears to project for a short distance above the surface of the pseudo-deltidium.

The specimen is shattered to such an extent that preparation is not possible, and nothing further of the form and structure of the pedicle valve can be determined. The brachial valve has the contours and surface features of the others described and an impression of one of the socket ridges is seen.

Measurements:—The following are the measurements, so far as they are determinable:

	No. 305
Height of pedicle valve	34.0 mm.
Height of brachial valve	46.0 mm.
Length of same	58.0 mm.
Greatest width (approx.)	88.0 mm.
Length of hinge line (approx.)	80.0 mm.
Height of hinge area	11.5 mm.
Thickness of entire shell	17.0 mm.

Horizon and Locality:—In the *Hemiptychina* bed (1196) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; four specimens. Collector, F. K. Morris.

Remarks:—It is with some hesitation that I refer this shell to *Derbya hemisphærica* Waagen from the Upper Productus limestone of India, because the absence of a well-preserved pedicle valve makes precise, specific and even generic determination quite impossible. If the pedicle valve shown in section in specimen No. 305 is normal, it is much more concave than in the normal Indian shell, while at the same time the area of our shell is level or reclined, instead of inclined as in the Waagen species. Both these features may, of course, be due to crushing in our shell which is in a very imperfect state of preservation. The dimensions of our brachial valves agree fairly well with those given by Waagen for the Indian shell, except in the case of the large fragmentary specimen, No. 305, described, where the width seems to be excessive. That shell is, however, so fragmentary that the measurements can not be relied upon, the width and length of hinge area being measured on one side and doubled. It is, however, not possible to determine the exact center of the valve.

Genus **Meekella** White and St. John

72. **Meekella uralica** Tschernyschew

Plate XXV, Figs. 6a-d (No. 171)

1902. *Meekella uralica* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 583, Pl. LI, Figs. 1–2.

This shell is biconvex, with an irregular pedicle valve with high area, and a subregular brachial valve with linear area. The surface is plicate in front and striated throughout.

Measurements:—The following are the approximate dimensions of the only specimen in our collection which is complete. In the second column are given the measurements of Tschernyschew's type as taken from his figures.

	No. 171 Pl. XXV, Fig. 6	*Tschernyschew Pl. LI, Fig. 1*
Height of pedicle valve..................	29–30 mm. ?	37. mm.
Length of same.........................	....	....
Height of brachial valve..................	21.0	34.
Length of same.........................	27.8	....
Greatest width..........................	28.0	39.
Length of hinge line....................	21.0	22.
Height of hinge area of pedicle valve......	10.0 ?	14.
Basal width of deltidium................	1.2	4.
Maximum thickness....................	19.3	21.
Apical angle of pedicle valve.............	100°	80°

The pedicle valve has a strongly projecting convex umbonal region, and apparently an erect beak, though this is broken away. It is asymmetrical, being more strongly inclined towards one side, at which point the shell surface is concave. The shoulders are very gently concave, probably more so on the side towards which the umbo inclines, are obtusely angular but rather blunt, and lie within the frame of the umbonal sides which project slightly beyond the shoulders as seen in the dorsal or cardinal view. The hinge area is inclined, flat in the part preserved, but probably somewhat arched in the apical region. It is divided by a narrow high delthyrium, which lies on one side of the center, corresponding to the irregularity of the beak. This delthyrium is covered by a rather flat deltidium, and its sides are supported by the septiform dental lamellæ which extend to the bottom of the valve, converging slightly. Thus at the point of fracture of the umbo they are 3.5 mm. apart at the hinge area but only 2.5 mm. on the bottom of the valve. Where best preserved, the hinge area shows not only lines of growth but also vertical or nearly vertical striations. Below the umbonal region there is a sudden contraction of the shell surface, and in the remainder of the valve the center is more flatly arched, while the sides are turned down abruptly, even becoming concave on one side before reaching the suture. The front was apparently also turned down abruptly but is imperfect. In the anterior third of the shell, fairly coarse plications appear, some of which, especially near the middle, extend farther up on the shell. Where the shell is preserved it is seen to be covered by fine, sharp radiating striæ with much broader interspaces, three to four of the striæ covering an interval of 1 mm.

The brachial valve is much less convex than the pedicle, deepest in the umbonal region. The transverse contour is for the most part a fairly regular though somewhat asymmetric arc, but near the shell margin there is generally a faint concavity. The beak is nearer to one side, corresponding to the irregularity of the pedicle valve. It is moderately elevated above the hinge-line, and blunt. The shoulders are gently sloping and faintly concave, their angle rather sharp though obtuse. The hinge area is narrow and nearly vertical, and the cardinal extremities obtusely angular and slightly salient because of a concavity in the shell surface between them and the umbo. The sides and frontal margins are subregularly rounded, though unequally so on the sides. The front apparently is not strongly deflected.

The surface is plicate, some of the plications appearing for a third or less of the shell length from the beak, while others appear between them nearer the front. The plications appear rounded in the exfoliated shell, but at the front where the shell is preserved they are rather sharp with broadly rounded concave interspaces. The entire surface, including the plications and interspaces, is radially striate; the striæ are sharp and narrow with broader, concavely rounded interspaces, from three to four in the space of 1 mm. These striæ are faintly nodulated where they are crossed by the fine subregular concentric growth-lines.

Horizon and Locality:—A single specimen was obtained by F. K. Morris from the *Enteletes* bed (1190) of the Jisu Honguer limestone of Jisu Honguer, Mongolia.

Remarks:—In referring this shell to Tschernyschew's species, I am influenced by the fact that only an imperfect specimen occurs in our collection, and that the characters preserved are such as indicate general agreement rather than marked differences between our shell and the Russian form. Tschernyschew's shell shows less pronounced irregularities, the beak being essentially central and the hinge area symmetrical. The shoulder angles of his figured specimen mark the greatest expanse of the value in the umbonal region, whereas in our shell they are more contracted, so that the umbonal shell-slopes project beyond them. The deltidium in our shell is also somewhat wider and apparently less strongly convex, though this may be a matter of preservation. In the brachial valve of the Russian shell, there is a faintly marked median longitudinal depression, which is not seen in our shell. Furthermore, the plications on the brachial valve begin earlier in the Mongolian than in the Russian shell, and they are more angular instead of rounded.

It may be that in a complete shell other differences will be apparent, which, together with those mentioned, will be sufficient to demand the reference of this shell to a new species. For the present, however, I shall leave it here.

Genus **Geyerella** Schellwien

73. **Geyerella mongolica** Grabau, sp. nov.

Plate XXVI, Figs. 1a-d (No. 308), (Text-Figs. 67A-C)

This is the first Asiatic representative of a genus hitherto known only from southern Europe and southwestern North America (Guadalupian of Texas). Unfortunately it is represented by only a single pedicle valve, the apex of which is broken away, but it shows not only the external but also the internal characters on which the genus is founded.

The shell is large, robust, of subtriangular outline, strongly convex with rudely plicate surface. The plicæ are accentuated where they are crossed by the irregular concentric undulations of unequal growth.

Measurements:—The following are the dimensions of the holotype and only known specimen.

Pedicle valve	*No. 308 As measured*	*Original (estimated)*
Height	35.0 mm.	40.0 mm.
Length	35.0 mm.	48.0 mm.
Greatest width	46.0 mm.	46.0 mm.
Length of hinge line	25.5 mm.	25.5 mm.
Width of deltidium	8.5 mm.	10.0 mm.
Height of hinge area	4.5 mm. (preserved)	29.0 mm.
Thickness of valve	23.0 mm.	28.0 mm.
Apical angle	72°	72°

The estimated original length is based on the assumption that the sides slope uniformly to the beak, maintaining the same apical angle. The greatest thickness of the valve is in the region of the beak, which is not preserved, however, in our specimen. The hinge area, judging from the part still present, is flat or gently concave and essentially horizontal. The greatest width of the shell is at the anterior lateral parts, from which points the frontal margin is more or less regularly rounded. The ventral surface of the shell is moderately convex, viewed as a whole, with, however, many minor irregularities. At the sides, however, the shell is abruptly bent down and even inward, so that the transverse diameter of the aperture is less than that of the ventrolateral portion. There is no median depression or flattening in the dorsal region.

The surface of the shell is characterized by a series of coarse and more or less discontinuous radial plications, which are rounded and separated by

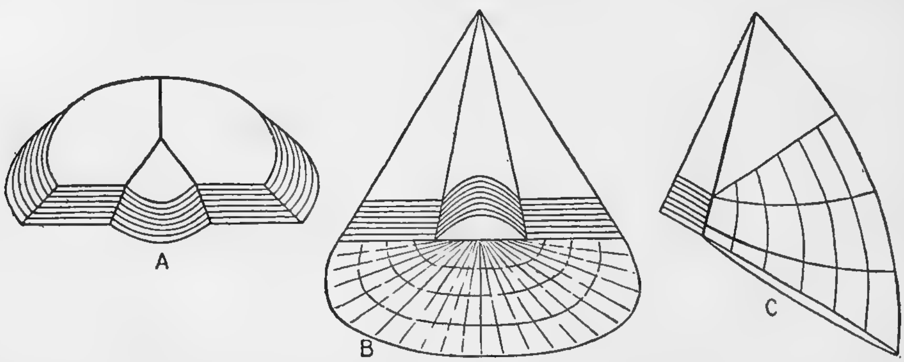


FIGURE 67.—(No. 308) Restoration of shell of *Geyerella mongolica* Grabau, sp. nov. A.—View from above the specimen, as preserved, showing truncation of apical part, thus exposing the median septum and spondylium, covered by pseudodeltidium. B, C.—Cardinal and lateral views, respectively, with original outlines restored.

intervals which near the front attain from two to three times the width of the plication. There are about ten of these plications in the ventral part of the shell, while the bent-over sides appear to be free from them. In addition, the surface is marked by numerous fine sharp radiating striæ, four or five to 1 mm. They are separated by interspaces of about equal width or slightly larger. Transversely the shell is marked by fine growth lines and by coarse concentric wrinkles of rather irregular character due to sudden contractions of the shell followed by slower expansions. The radial plications are best seen in the intervals or troughs between the wrinkles, while upon their crests they are more or less concentrated into indefinite nodular protuberances, which are, however, not very prominent.

Judging from the part preserved, the shoulders are bluntly angular, although this appears on one side only, while on the other the side merges into the hinge area, with only a faint indication of angularity. In any case these shoulders lie well within the frame of the cardinal slopes, the hinge area being not only much shorter than the greatest width of the shell, but also shorter than the width of the shell at the points opposite the cardinal angles. The center of the hinge area is occupied by a broad and very convex pseudodeltidium, which in section shows considerable thickening. From the margin of the delthyrium, the dental lamellæ converge inward, meeting at an angle of about 90°, joining the median septum which has about the same length (6.6 mm.) as the dental plates. These latter, as well as the median septum, which they join, are thin and not reënforced by secondary deposits of stereoplasm. Parts of these features are very well marked, especially one of the dental plates, and less clearly the septum. The other dental plate is not so easily distinguished from the mass of crystalline calcite which fills the visceral cavity.

The form, the high horizontal area, the radial plications, and the internal structure are sufficiently characteristic to warrant the reference of this shell to *Geyerella*. The deltidial plates meet in the center of the valve and are continued thence in the median septum to the bottom. The area of the shell is wider than that of the shells found in the Permian of southern Europe, and the shoulders are somewhat less indefinite and rounded. The radial plications, too, are much weaker, while the concentric wrinkles give the Mongolian shell a much coarser appearance. In the reduction of the plications the Mongolian shell comes nearer to *Geyerella alpina* Schellwien than to the larger *Geyerella gemmellaroi* Schellwien. From *Geyerella americana* Girty it differs in much the same measure as from the typical species of the genus. Thus this shell is not a connecting form but is rather to be regarded as a branch from the main stock to which *Geyerella gemmellaroi* and *Geyerella americana* belong.

Horizon and Locality:—In the *Enteletes* bed (1190) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Genus **Derbyella** Grabau, gen. nov.

These shells are biconvex, with the pedicle valve the deeper, and usually more or less distorted in growth, but, so far as our species show, without scar of fixation. The area is of variable height with the delthyrium covered by a convex deltidium, which is narrow when the area is high, and proportionally wider when it is low. The internal characters of the pedicle valve correspond to those of *Derbya* Waagen, a generic group which Girty refers to *Orthothetes* Fisher von Waldheim, because the original species on which that author based his genus belongs to this group, and not to that generally referred to *Orthothetes* by Hall and Clarke and by others, for which Girty proposed the name of *Schuchertella*. The chief of these characters is a well-developed median septum, which is joined by the septiform dental lamellæ, there being thus a triangular spondyliform chamber at the top of the septum, which is covered by the deltidium and normally extends to the apex, the only point where the dental lamellæ rest on the bottom of the shell. It has been suggested by Girty and Weller that the name *Derbya* be restricted to those forms in which the dental lamellæ do not unite with the median septum, this being the case in the typical species on which *Derbya* was founded.

The present group belongs to the type with a small triangular chamber at the top of the septum, as in *Orthothetes* restricted by Girty. There is also a median septum in the brachial valve, but its full extent has not been ascertained.

The most important character, however, in which *Derbyella* differs from *Orthothetes* or *Derbya* is in the external features of the shell, those of the two genera cited consisting of regular radiating striæ, whereas the present forms are marked by coarser irregular striæ, interrupted by the concentric growth lines and rendered more or less pustulose. Moreover, there are numerous distinct rounded spine-bases upon these radii in both valves, and in at least one of the shells referred to this genus, the short blunt spines are partly preserved. Externally, then, these shells have the characters of *Aulosteges*, from which, however, they are distinguished by the convex brachial valve and by the internal structure, which is like that of *Orthothetes* (*Derbya*).

Genotype:—Derbyella bureri Grabau, sp. nov., known at present only from the Permian of Mongolia.

74. **Derbyella bureri** Grabau, sp. nov.

Plate XXV, Figs. 7 (No. 285), 8 (No. 286); Plate XXVI, Figs. 2a-c (No. 286), 3a-c (No. 285), (Nos. 287, 289)

This is a shell of irregular growth, with a very high distorted pedicle valve and a gently convex brachial valve. The outline and dimensions are variable; holotype No. 286.

Measurements:—The measurements of three characteristic specimens of this species are tabulated on the following page.

A specimen representing the average size (No. 285) preserves only the pedicle valve with the hinge portion of the brachial valve. The former is of irregular growth, with erect though slightly damaged beak turned to one side. The umbonal sides are rounded and expand beyond the shoulder as seen in the cardinal or in the dorsal view. The hinge area is high and relatively narrow, the height equal to or a little higher than its basal width, gently concave and marked by irregular growth-lines and faint vertical striations. Medially it is divided by a narrow delthyrium covered by a faintly convex deltidium, the width of which is about 1.5 mm. at the base. The shoulder is concave and obtusely subangular, but not very pronounced, lying within the frame of the umbonal slopes.

	No. 285	Holotype No. 286	No. 287
	Pl. XXVI, Fig. 3	Pl. XXVI, Fig. 2	
Height of pedicle valve	28.0+	20.0	15.6
Length of same	41.0	28.0	21.0
Height of brachial valve	23.0[1]	14.3	....
Length of same	....	17.0	....
Greatest width	26.8	20.2	16.2
Length of hinge line	14.8	13.0	9.3
Height of hinge area	15.0±	8.7	9.5
Basal width of delthyrium	1.5	2.0	1.7
Maximum thickness	....	12.5	9.0+
Apical angle of pedicle valve	79°	100°, 75°	70°

The surface of the valve is very irregular, presenting several contractions followed by expansions, the most pronounced being in the apical portion. In addition to the more pronounced contractions, there are many smaller concentric wrinkles more regularly disposed. In the young the contour of the valve is rounded, but in the later stages the median part is broadly flattened, with a slight depression down the center. The sides are abruptly rounded and deflected, nearly at right angles to the shell margin.

The surface of the valve is marked by coarse radiating striæ, which are broadly rounded and separated by narrower interspaces. There are about five striæ to 2 mm. near the front. Concentric growth lines are also visible in addition to the wrinkles, and these render the striæ pustulose. In places, rather strong rounded spine-bases are seen on the striæ. Where the shell is exfoliated on the umbonal slopes,. the deeper layer appears strongly and irregularly pitted.

Only a small part of the brachial valve remains, showing, however, a faintly elevated beak with straight, nearly horizontal, shoulders and a narrow linear hinge area.

The holotype, a smaller shell (No. 286, Pl. XXV, Fig. 8, Pl. XXVI, Fig. 2) retains both valves. The apical part of this shell is very irregular, for after reaching a height of 4 mm., the shell makes a sudden geniculation, so that for the next 4 mm. its surface extends at right angles or even less than a right angle to the previous plane of growth. At this stage the apical angle is 100°, and the height of the hinge area is much less than its width, which is slightly over 8 mm., that being a little less than the maximum width of the shell at that stage. After that the shell expands again rapidly, the growth direction

[1] Approximately.

making a little more than a right angle with the preceding plane. After it has grown for about 5 mm. more, it again turns abruptly and continues, at a little more than a right angle, to the front, forming, however, three further coarse concentric wrinkles. The median part is flattened with a central depression, as in the other shell described, and the sides are deflected as abruptly, but the depth of the valve is less. The apical angle, too, has decreased to about 75°, but because of the youthful irregularities, the hinge area is not so high proportionately as in the preceding specimen. It is marked by growth lines which at intervals are strong, and also characterized by vertical striations. The deltidium is slightly wider and more convex than in the larger shell, and the shoulders are sinuous and obtusely subangular, lying within the frame of the expanded umbonal sides.

The brachial valve is gently convex at the umbo, nearly flat in front. The beak is slightly elevated above the hinge-area, which is linear, while the shoulders on either side are straight and horizontal to the obtuse cardinal extremities. The young shell is very transverse, 6 mm. high and 8.5 mm. wide, corresponding to the transverse pedicle valve in the young; its sides are rounded and its front flat and parallel to the hinge line. In the adult it is proportionately higher but still transverse, with rounded sides and a rather irregular frontal margin. Because of the median depression of the pedicle valve, there is a faint sinuosity in the frontal suture, but there is no fold on the brachial valve. The hinge line is much shorter than the greatest width of the shell. The transverse contour of the brachial valve is slightly sinuous in the umbonal region, being flatly convex in the center, then gently concave on either side, followed again near the margin by a gentle convexity. In the center the contour is a more regular, very flat curve. The longitudinal contour is a straight line, except at the beak, where it curves downward.

The surface of this shell is similarly marked by rather coarse irregular striations three or four to 2 mm. These are rounded and separated by narrower interspaces, and they are cancellated by the growth lines, so that they frequently appear pustulose. There are also many small round pustules which have the appearance of spine bases, and because of this one might be tempted to refer the shell to *Aulosteges*, were it not for the well-developed median septum and the convex brachial valve.

The largest shell, an imperfect pedicle valve (No. 289), has a maximum width of 31 mm., but its height can not be determined because of the incompleteness of the beak. The depth of this valve was at least 23 mm. The surface is similarly marked by coarse striæ and pustules, and, when exfoliated, by pittings.

A fourth young pedicle valve (No. 287) has an apical angle of 70° and an erect pointed beak and high hinge area, the height nearly equaling the length of the hinge line. The concentric wrinkles are less pronounced than in the other shells, while the coarse radiating striæ show similar interruptions. The pustulose spine bases show a rude arrangement into concentric rows.

The interior of this shell is characterized by a well-developed median septum, which rests on the bottom of the valve and extends upward to the hinge area, where it unites with the two high dental plates which support the sides of the narrow and high delthyrium. The brachial valve also has a median septum extending forward for some distance, but the full extent of this is not apparent.

Horizon and Locality:—This species appears to be confined to the *Martinia* bed (1194) of the Jisu Honguer limestone at Jisu Honguer, Mongolia, where four specimens were obtained by Mr. F. K. Morris. The species is at present unknown from other localities. It is named after Miss Rachel Burer (now Mrs. Barker) in recognition of her assistance in the preparation of this book.

75. **Derbyella subrotunda** Grabau, sp. nov.

Plate XXVI, Figs. 4a-f (No. 297)

This shell of moderate size is biconvex, of subrotund outline, with the height and width nearly equal. The hinge line is much shorter than the greatest width of the shell, and the beak of the pedicle valve is more or less irregular.

Measurements:—The dimensions of the type and only known specimen are as follows:

	No. 297
Height of pedicle valve	14.7
Length of same	....
Height of brachial valve	13.0
Length of same	....
Greatest width	15.2
Maximum thickness	8.0
Length of hinge line	8.9
Height of pedicle area	3.2
Height of brachial area	1.7–2.0
Basal width of deltidium	1.8
Apical angle	120°

The pedicle valve is more convex than the brachial, with the beak erect and only slightly elevated. The hinge area is flat and horizontal and is for the greater part gently arched only at the beak. The surface of the area is marked by growth lines and irregular vertical striæ. The length of the hinge line is slightly greater than half the maximum width of the shell, which is near the middle of the valve. The shoulder is straight or very gently concave. The angles are obtuse and blunt, not very well defined. The beak is eccentric with a faint scar of attachment, and with the greatest height and width of the area on one side of the center, so that the deltidium does not occupy the middle but lies about one-third the width of the area from one side. The sides of the delthyrium are supported by strong septiform dental plates that unite below and join with the median septum which rests on the bottom of the valve. The deltidium is strongly convex, somewhat irregular, its basal width being about 1.8 mm. The cardinal extremities are obtuse, slightly auriculate on one side. The transverse contour of the umbonal region has a strong arc in the center, the sides of which become slightly concave before reaching the margin. In the frontal area the median part is flattened, and the sides curve rather sharply downwards to the shell margin. The medium longitudinal contour is a nearly flat level line in the center, curving down rapidly to the beak on the one hand and to the front on the other.

The brachial valve has the beak depressed and a reclined area which slopes upward to meet the hinge line of the opposite valve, the slope being nearly continuous with the curvature of the shell, so that the shoulder angles, indicated only by a slight thickening, are almost obliterated. The area is very gently concave and varies in width from 1.7 mm. on one side to 2.0 mm. on the other. It is marked by lines of growth and by a strong convex cheilidium which extends from the beak to the hinge line, but is not fully apposed to the deltidium, its basal part being shifted somewhat to one side. Where the shell substance is exfoliated, the inner mold is marked by numerous fine pits, indicating fine pustules or spines on the inside of the area.

The beak is very little elevated above the shoulders, which are irregularly straight and occasionally marked by rather strong pustules, as is also the area in some parts. On either side of the beak the surface of the shell is slightly depressed into a small concavity, and the surface beyond that is also irregular, but on the whole the transverse contour is a gentle arch. Forward, the median part becomes flattened and finally gently concave, producing a slight deflection in the frontal suture line.

The surface of both valves is marked by mild concentric wrinkles, especially near the front. The entire surface is covered with irregularly disposed, sharp but low, rounded pustules or spine bases supporting short spines, which are preserved in recumbent position on some parts of the shell. These spines are rarely over a millimeter in length.

Horizon and Locality:—A single specimen was obtained by F. K. Morris in the *Martinia* bed (1194), associated with the preceding species.

76. **Derbyella minor** Grabau, sp. nov.

Plate XXVI, Figs. 5a-f (No. 316)

This is a small subglobular shell, biconvex, with deep pedicle and shallow brachial valve.

Measurements:—The dimensions of the type and only specimen known are as follows:

	No. 316
Height of pedicle valve	10.0 mm.
Length of same	17.0 mm.
Height of brachial valve	7.0 mm.
Length of same	9.0 mm.
Greatest width	9.7 mm.
Length of hinge line	6.3 mm.
Height of area	2.0 mm.+
Basal width of deltidium	3.2 mm.
Maximum thickness	7.6 mm.

The pedicle valve is productoid, strongly convex, and arched through an angle of approximately 270°. The beak is strongly incurved, so much so that it points downward, but is closely appressed to the hinge area. The contour of the shell is irregular in the umbonal region, giving an asymmetric appearance to the beak and hinge area. The shoulders are curved, very obtuse, and not strongly defined, the sides of the umbo curving over and passing with only a slightly pronounced angulation into the hinge area, which thus lies within the frame of the umbonal slopes. The area is gently concave, steeply inclined (almost vertical) and vertically striated. In the center is a very broad delthyrium. The greatest convexity is near the mid-length and on one side, the other being more depressed, making an irregular surface, and giving the frontal suture an irregular outline.

The brachial valve is gently convex for the greater part of the surface but abruptly turned down at the borders, the geniculation being marked by a slightly thickened ridge, while the turned-down border is slightly concave. The beak is somewhat elevated, not inturned. The umbonal region is slightly swollen. The shoulders are straight, nearly horizontal, the slight slope scarcely perceptible. The cardinal angles are obtusely angular. The area is extremely narrow or absent. The sides of the valve are rounded to the somewhat irregular frontal margin. The area is extremely narrow if not absent entirely.

The surface of the valves is coarsely wrinkled, especially in the pedicle valve. There is a fine radial striation observable in certain parts where the shell is not exfoliated. At the crossing they produce faint nodes, which appear to be augmented by other somewhat larger pustules, which have the character and appearance of spine bases. There is a marked resemblance between the surface of this shell and that of a species of *Aulosteges*, though the general character and internal structure distinguish it.

The interior of the pedicle valve has a well-developed median septum, which divides the entire rostral region and extends along the bottom of the valves for about half the shell-length. The septum is thin and slightly irregular. Its relation to the dental plates or deltidial margins can not be ascertained.

This species is readily distinguished from the others of this genus by its small size, strongly incurved beak, low hinge area and very broad delthyrium. That it is an adult is shown by the fact of its strong curvature, which further growth would change to spiral, and by the abrupt deflection of the margins of the brachial valve, a senile, not a youthful character.

Horizon and Locality:—In the *Martinia* bed (1194) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Genus **Aulosteges** von Helmersen

77. **Aulosteges gigantiformis** Grabau, sp. nov.

Plate XXVII, Figs. 1a-c (No. 280), 2a-c (No. 281), 3a-c (No. 282), (Nos. 943, 944)

cf. 1894. *Aulosteges gigas* Netschajew. "Die Fauna der Perm-Ablagerungen des östlichen Teils des europäischen Russlands" (in Russian). *Travaux Soc. Nat.*, Kazan Imp. Univ., Vol. XXVII, Pt. 4, p. 155, Pl. III, Figs. 1, 3; Pl. IV, Figs. 3–5, 12.

cf. 1903. *Aulosteges* cf. *gigas* Diener. *Palæontologia Indica*, Ser. XV, Himalayan Fossils, Vol. I, Pt. 5, "The Permian Fossils of the Central Himalayas," p. 182, Pl. VIII, Figs. 13, 14.

cf. 1911. *Strophalosia wangenheimi* (Verneuil). Netschajew, "Die Fauna der Perm-Ablagerungen von osten und æussersten Nord des europäischen Russlands." *Mém. Com. Géol. Russe*, New Ser., Livr. LXI, p. 146, Pl. VI, Figs. 3, 8, 9, 11; Pl. VII, Figs. 2, 6.

The shell is productiform in general appearance, with the pedicle valve strongly convex and the brachial valve gently concave to nearly flat. The development is generally somewhat irregular, and the form is elongate, with the hinge line shorter than the greatest width below.

Measurements:—The dimensions of three specimens (*a*, young, *b*, adult stage) are tabulated on the opposite page.

The pedicle valve is strongly and somewhat irregularly convex, but in general the median contour forms a fairly regular curve from beak to base, except where the former is distorted (No. 280, Pl. XXVII, Fig. 1). The hinge area is flat, except for the apical portion, which is curved so that the beak strongly overarches or even overhangs, but no incurving is shown in our specimens. The flat part of the area is steeply inclined in the shell of least thickness, vertical in the next thicker, and slightly proclined in the shell of greatest thickness in which the beak overhangs. At the base of the hinge area, just above the hinge line, there is generally a strong concavity extending the whole length of the hinge line, and produced by a strong thickening of the basal edges of the hinge area. In the holotype with inclined area (No. 280) this has a width of 3.2 mm. and a depth below the plane of the hinge area of 2 mm., while in the thickest shell with proclined area (No. 281), the width is 4 mm. and the depth is 3.5 mm. In the intermediate shell (No. 282), it is hardly developed. This thickening is due to the addition of layers of lime on the inside of the lower margin of the hinge area, these layers becoming more and more curved as the deposit thickens. The area is divided by a narrow delthyrium, which is covered by a convex deltidium. The shoulder is sharp, varying from acute to nearly rectangular, and for the most part is straight, though a tendency towards a faint concavity, or in some cases a slight convexity, is observable, depending more or less upon the irregularity of the beak.

	Aulosteges gigantiformis Grabau, sp. nov.				
Serial number	*Holotype No. 280*	*No. 281*		*No. 282*	
	Pl. XXVII, Fig. 1	*Pl. XXVII, Fig. 2*		*Pl. XXVII, Fig. 3*	
	b	*a*	*b*	*a*	*b*
Height of pedicle valve	48.5+	17.6	47.5+	14.7	....
Length of same	58.2+	19.7	69.0	16.0	....
Height of brachial valve[1]	36.0	....	33.8	....	....
Length of same	....	....	....	....	....
Greatest width	38.8	20.3	38.0	18.8	36.0
Length of hinge line	31.0	19.3	32.0	18.8	28.2
Height of area of pedicle valve	13.0+	8.4	14.4	5.8	10.0
Basal width of delthyrium	9.5	3.6	5.0	5.7	6.5
Depth of pedicle valve	16.5	....	22.5	....	21.8
Concavity of brachial valve	2.7	....	3.7	....	1.2
Apical angle pedicle valve	78°	92°	92°	....	107°

The pedicle valve is transverse in the young, wider than it is high (see No. 282a of above table), with the hinge line forming the greatest width of the shell, and even slightly mucronate in some cases. With increasing growth, however, the shell becomes wider below, so that the hinge line no longer forms the widest part of the shell. Also the length increases more rapidly, until it equals the width (No. 281a), after which the length becomes rapidly greater, until in the adult it is not far from being twice the width and more than twice

[1] Exclusive of cardinal process.

the length of the hinge line. Because of the curvature, however, the height is much less than the length. As will be seen, by comparison of the height and length of the young, the difference is comparatively slight, which is equivalent to saying that the convexity of the valve is very slight at this stage.

A general characteristic of the shell in the neanic stage (a) is the development of concentric wrinkles of the type common in certain *Producti* and in *Leptæna rhomboidalis*. These wrinkles are best developed in the shells with arched hinge area and overarched beak, and they represent the periodic decrease in the relative circumferential growth of the shell-building mantle, followed by rejuvenescence, which continues long enough to produce an expanded shell surface, after which the relative reduction in the rate of circumferential growth sets in again, producing a contraction of the shell surface. In this manner a wrinkle is formed. The successive recurrence of such wrinkles indicates periodic expansions and relative contractions of the mantle growth, or a periodic rejuvenescence followed by a declining growth. This type of development is probably in all cases to be regarded as indicating the beginning of decline in the race to which the individual possessing it belongs, and, since it may recur in any number of genetic series, presents a case of parallelism and in no way indicates relationship.

In the present shells we may count from nine to ten such concentric wrinkles in a length of 16 mm. in the best-preserved surface (No. 282). After this early stage, the wrinkles become coarser and farther apart, and then die away altogether. The entire surface of the valve in the exfoliated specimens is covered by rather large and distant pits, arranged roughly in radiating lines, representing the position of the spines. Where the shell is less exfoliated the spine-bases are still preserved as a low conical elevation (No. 281). These spines vary from 0.5 to 1.5 mm. apart, the longitudinal distance usually being greater than the transverse. The hinge-area is marked by growth lines, and in some parts spine bases have been observed. These are also shown on the deltidium (No. 281).

The transverse contour of the valve is flat or even slightly depressed in the median line, while towards the side this rounds abruptly into the lateral slopes, which, in the more convex individuals, form nearly or quite a right angle. Close to the margin the shell sometimes flares out again to a slight extent. Where exposed, the internal mold shows coarse longitudinal striæ corresponding to the muscular groovings on the interior of the valve.

The brachial valve is at first flat but in the adult becomes gently concave by the turning up of margins. Sometimes, however, the whole surface of the valve is gently concave (No. 280). The hinge area is narrow, linear, with the shoulder straight and level on either side of the beak. The cardinal process is strong and projects far beyond the hinge line. It is divided at the summit into a broad median and apparently two narrow lateral parts. In the perfect shell it is hidden by the cheilidium and deltidium. It is continued forward in a narrow and low median septum, which extends for two-thirds the length of the valve. There appear to be no hinge teeth. The surface of the valve is pitted much as is that of the pedicle valve, but there are no marked concentric wrinkles, though they are sometimes faintly indicated in the young.

In one of our specimens (No. 280), in which the umbo is swollen and circular, there is an indication of a cicatrix behind the beak suggesting that this shell was attached.

Horizon and Locality:—This species has been found only in the *Enteletes* bed (1190) of the Jisu Honguer limestone at Jisu Honguer, Mongolia; three specimens. Collector, F. K. Morris.

Comparison:—This species is related to *Aulosteges* cf. *gigas*, Netschajew, Diener, as described and figured by Diener (1903, p. 182) from the Kuling series of Spiti, but there are certain very marked differences. In the first place, the young of the Himalayan species is more strongly arched, producing a very different umbonal aspect. The shoulder is concave in outline instead of straight as in our shell; the cardinal area is arched in the Himalayan and straight in our shell except where at the beak it is suddenly curved over. Again, the Mongolian shell does not show the vertical striations seen on the hinge area of the Himalayan shell, and the delthyrium is broader and more triangular than in the Indian form, where it is very narrow. Finally, the thickening at the base of the hinge area, so marked in the Mongolian shell, does not appear to be present in the Himalayan form; at least no mention is made of it, and it is not indicated in the figures.

I have not seen the descriptions and illustrations of Netschajew's Russian shell, but the difference between that and the Himalayan shell is, according to Diener, exclusively one of ornamentation, that is, the smaller number of concentric wrinkles and the closer arrangement of the tubercles or spines in the Himalayan shell. As we have seen, however, there are marked differences in form and in the delthyrium between the Indian and the Mongolian shells. Netschajew (1911, p. 147) says that the Russian forms differ from the Himalayan types in the constant presence of the well-developed sinus and in the broader pseudo-deltidium, which in adult individuals is never less than 5 mm. wide at the base. In this latter respect our species agrees with the Russian form, but the sinus is present only in some of our forms, while it is absent in others. Until an opportunity for comparison with Russian specimens of this species is possible, I shall regard our shell as a distinct though related form. In the general form of the shell character of the shoulder, and relative convexity of the valves, our species also shows relationship to *Aulosteges wangenheimi* Verneuil as figured by Netschajew (under the name *Strophalosia wangenheimi*, 1911, Pl. VI, Figs. 8 and 9, and Pl. VII, Figs. 2a-c). That shell is, however, at once distinguished by its high hinge area, which is as high as wide, and its narrow pseudo-deltidium. It is also a longer shell relatively to the width than is our Mongolian form.

78. Aulosteges grangeri Grabau, sp. nov.

Plate XXVII, Figs. 4a-d (No. 283), 5a-d (No. 284)

The shell is subpentagonal in outline, concavoconvex, with the hinge-line less than the greatest width of the shell.

Measurements:—The following are the dimensions of two shells from Mongolia:

	1 *No. 283 Holotype*	*2* *No. 284*
	Pl. XXVII, Fig. 4	*Pl. XXVII, Fig. 5*
Height of pedicle valve	35.0	32.0+
Length of same	45.0	40.0
Height of brachial valve	28.5	26.5
Length of same	30.0	29.0
Greatest width	34.5	34.6
Length of hinge line	20.7	17.8
Height of hinge area	6.5	4.7+
Basel width of delthyrium	4.5?	4.4?
Convexity of pedicle valve	12.0+	10.4
Concavity of brachial valve	5.2	3.9
Greatest thickness	6.8	6.5
Apical angle of pedicle valve	106°	120°

The pedicle valve has an obtusely pointed, overarching beak, with the apex overhanging, and extending considerably beyond the plane of the valve contact. The area is broadly triangular, proclined, gently arcuate, more strongly so in the apical part, and with a triangular arched deltidium of moderate basal width covering the delthyrium. The surface of the area is marked by growth-lines and faint vertical striations. The shoulder is strongly inclined, straight, and sharply acutely angular, the ends merging with the lateral margins, which are at first straight, then round to the greatest width and again towards the front which is subtruncate.

The longitudinal median contour in the more convex holotype (No. 283) is an irregular arc, rising with a uniform curve from the beak to the point of greatest convexity, which is in the anterior third, and then descending in a more abrupt curve to the frontal margin. The transverse contour is a regular low arc in the umbonal region, this becoming flattened forward and depressed in the center with the appearance of the median shallow sinus which begins about one-fourth the shell length from the beak and gently increases in width and depth forward. It never becomes very pronounced and has both rounded bottom and rounded indefinite sides. In one of our two specimens (No. 284), it is not at all developed, the transverse contour remaining a regular low arc throughout, comparable to the young of the other shell. In the non-sinuate form, too, the longitudinal contour is more nearly a regular arc throughout.

The surface, where preserved, shows small, slightly elongated pustules arranged in irregular radiating lines.

The brachial valve is regularly and rather strongly concave, with a very narrow linear hinge area, straight horizontal angular shoulders, and a large median cardinal process, divided at the summit; but precise detail is not determinable. The outline conforms to that of the pedicle valve, with the faintest median elevation and a faint frontal emargination in the suture line of the holotype, which has a median sinus in the pedicle valve. These features are absent in the other shell. A few concentric wrinkles begin near the cardinal extremities but die away long before reaching the middle of the shell. This feature is also marked, but to a less extent, in the pedicle valve. The pustules or spine bases are coarser on this than on the pedicle valve, rounded and more widely scattered. Indications of radial striation are seen in one of the specimens (No. 284).

Horizon and Locality:—This species has been obtained only from the *Orthotychia* bed (1211) of the Jisu Honguer limestone at Jisu Honguer, Mongolia; two specimens. Collector, F. K. Morris.

Remarks:—This species is readily distinguished from the preceding by its gentler convexity of pedicle, and stronger, more regular, concavity of brachial valve, by its subrotund form, and its relatively low hinge area. I have not seen any other form with which it can be closely compared. The name is given in honor of Mr. Walter Granger, the well-known palæontologist of the Third Asiatic Expedition.

Family RICHTHOFENIDÆ Waagen

Genus **Richthofenia** Kayser

79. **Richthofenia lawrenciana** (de Koninck)

Plate XXVII, Figs. 6a-c (No. 296), 7a-d (No. 294); Plate XXVIII, Figs. 1a-e (No. 295), 8a-e (No. 394)?

1863. *Anomia lawrenciana* de Koninck. "Descriptions of some Fossils from India, discovered by Dr. A. Fleming of Edinburgh." *Quart. Journ. Geol. Soc. London*, Vol. XIX, p. 6, Pl. IV, Figs. 7, 8, 9.

1882. *Richthofenia lawrenciana* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 736, Pl. LXXXII, Fig. 1; Pls. LXXXII A and LXXXIII (with other literature references).

This species is represented by several more or less fragmentary parts, representing the larger of the two valves.

The shells are irregular conical bodies, the tapering of which is sometimes so slight that it appears subcylindrical, in others more pronounced. In the least rapidly tapering of our specimens (No. 296, Pl. XXVII, Fig. 6), the cross section is almost circular, more nearly so in the terminal larger portion than at the fractured smaller end, where a flattening occurs on one side near the front, at the point where the hinge area of the young shell merges into the general contour of the adult. In this specimen (No. 296), the transverse diameter at the larger (apertural) end is 22.7 mm., and the dorsoventral diameter 23 mm. At the smaller end, about 17 mm. below the upper, the transverse and dorsoventral diameters are 17.5 mm. and 18 mm. respectively. At this point the hinge area appears as a flattened surface of the dorsal surface of the shell, this flattened, or even slightly concave, area, sloping apicad at an angle of about 148° with the shell surface in front of it. The lateral margins of this depressed surface are variable, that on one side being angular with the shell surface, forming a distinct shoulder, while on the other it is less definite. The outer shell around this margin of the depressed area shows a fractured surface, as if it formerly extended across this flattened space. The interior as seen at the fractured end is filled partly with vesicular tissue, no definite arrangement being ascertainable. The surface of the shell is rugose, with strong irregular concentric growth-lines, but no spine bases are observable on this specimen. There is however, a pitted appearance shown under the lens in certain parts.

A second shell (No. 294, Pl. XXVII, Fig. 7) is more compressed dorsoventrally. Its lateral and dorsoventral diameters are 24.5 and 21 mm. respectively at the larger end, and 21.5 and 13.5 mm. respectively at the point where the flattening of the hinge area begins, approximately 21 mm. from the upper end. The hinge-area is a flattening at its outer end, but towards the apex becomes more and more strongly concave. The sides are ill-defined in this specimen, there being no shoulder angles; instead the shell surface rounds gradually into the area. If we take the growth lines as a guide and note the position of the aperture before the area disappears, it is apparent that the position of this area, with reference to the aperture, was a reclined one.

It is quite conceivable that up to this point the shell was essentially normal, that the smaller or brachial valve fitted against the larger or pedicle valve as in other brachiopods, and that some sort of hinge apparatus existed. The character of the hinge area of the larger valve at that time was somewhat like that seen in *Geyerella*, though there is no evidence of a pseudo-deltidium on either of our specimens that show this reclined hinge area. This relationship of valves is indeed indicated in a specimen figured by Waagen from the Salt Range, where the entire shell is still in the hinge area stage, and the smaller valve conforms to the frontal outline of the larger one at this stage (Waagen, 1879–1887, Pl. LXXXIII, Figs. 15a-b). The hinge area there, however, appears raised with a narrow pseudo-deltidium in the center, this having the character of a string of elongated beads or a string of short sausages.

The outer shell-layer in this specimen also does not extend continuously over the depressed area but is broken around its margins. The surface of the area is formed by an inner layer. Near the upper end it is lamellose, as if several layers had previously covered the area or a part of it. The apex is broken away; if the lateral slopes were uniform and continuous the length of the broken-away part would have been about 9 mm. At the fractured end, the transverse diameter at the hinge-area, which here is the widest part, is 11.5 mm., while the dorsoventral diameter is only 5.5 mm. The outer shell here is thick, over 2 mm. in places. The apical portion here seems to have been cut off from the rest of the shell by an oblique septum, which makes about a right angle with the hinge area, which in turn makes an angle of 143° with the shell surface in front of it. No other internal structure is observable.

The surface of this shell is even more irregularly rugose than that previously described. The growth lines are very irregular and frequently bunched into concentric wrinkles. At irregular and infrequent intervals there are pustules which appear to be the bases of hollow spines like those of *Productus*. The form of the shell also differs from that of the preceding. Instead of being cylindrical or long cone-shaped, it is steeply and roughly pyramidal, with the surfaces flattened so that in cross-section it appears rudely quadrangular.

The third specimen is still more irregular in form (No. 295, Pl. XXVIII, Fig. 1). It is roughly quadrangular in section and tapers gently from the larger to the smaller end. The transverse and dorsoventral diameters at the larger end are 26.5 and 20.5 mm. respectively, and at the smaller about 20.0 and 14.5 mm. respectively. The distance between the two ends is 23 mm., and at each end there is a thin transverse partition or tabula, which is slightly irregular and very gently concave upwards. The upper of these two partitions lies at the end of a depressed area, and might be taken for the smaller inner valve except that it shows no structure whatever such as is commonly seen in these smaller valves, and in all respects it is like the partition at the lower end. That the shell extends beyond the upper portion is clearly shown by the remaining fragment which extends for 9 mm. farther on one side, before it, too, ends in a fracture margin.

The depressed area, which extends for the entire length of the shell between the two partitions referred to (Pl. XXVIII, Fig. 1a), is evidently the hinge area. Its depth below the margins is nearly 2 mm., its surface is as irregular as that of the shell, and its width is about one-third that of the shell. On either side the upper shell surface is gently convex, bending down to the depressed area, but there is no sharp demarcation between it and the shell on either side. At the narrower end, where a part of the terminal partition is broken away, an inner shell layer is abruptly bent inward from either side, extending as two converging septa towards the middle of the shell below the depressed area. The irregular space between these septa and the surface of the area is filled partly with shelly matter, but the surface also bends down, forming an abruptly depressed apical portion suggestive of that found in the preceding specimen (No. 294) near the apex, but more abrupt and more pronounced. On one side, where the shell is partly broken, it is seen that a long and broad hollow cyst has partly thickened the shell wall (Pl. XXVIII, Figs. 1b, 1d). Other smaller cysts occur above this larger one. The surface is as rugose as that of the preceding specimen, but pustulose spine-bases are more rare. On the surface of the inner shell layer, a crude longitudinal marking is observable, this being too indefinite and irregular to be referred to as a striation.

So far as can be determined from the fragments preserved, our shell differs in a number of points from those described by Waagen from the Productus limestone of the Salt Range. In the first place, our specimens are more cylindrical than the Indian forms, which are conical, though less so than *Richthofenia sinensis*. The dividing partitions or tabulæ of our shell are also more regular, and there is no indication of the peculiar septa of the Indian form. This may, however, be simply a case of non-exposure, for our specimens are too few to warrant sacrificing any of them to the making of sections. A far more pronounced difference, however, lies in the character of the hinge area, which is long and depressed and apparently without the nummuloided deltidium seen in the Indian shell. *Richthofenia sinensis* Waagen has a similar hinge area, which, however, is much shorter. The shell itself also is more conical even than *Richthofenia lawrenciana*. In spite of these differences, I shall nevertheless refer our shell to *Richthofenia lawrenciana* until such time as more material permits the investigation of the internal structure.

Horizon and Locality:—This species has been obtained from the *Hemiptychina* bed (1196) of the Jisu Honguer limestone at Jisu Honguer, Mongolia; three specimens. Collector, F. K. Morris.

Family AULACORHYNCHIDÆ

Genus **Aulacorhynchus** Dittmar

80. **Aulacorhynchus** sp.

Plate XXVIII, Fig. 2 (No. 324)

The impression of a pedicle valve of a species of *Aulacorhynchus* occurs in a fragment of the Jisu Honguer limestone, but it is too imperfect to permit of more than generic determination. A few fragments of the shell still adhere, showing that it was very thin and fragile.

The valve is moderately convex, very transverse and low, with a long straight hinge line. In general appearance it presents almost one-half of a circular disc, curved like a watch glass. The cardinal angles are imperfect, but judging by the concentric undulations they are essentially rectangular, while the hinge line forms the greatest width of the shell. The surface is marked by fine uniform and equally spaced concentric ridges, which are separated by wider depressions, the whole ornamentation appearing very regular. These striæ extend to the hinge line without deflection, ending there abruptly. The dimensions of the shell are: height, 10.5 mm.; greatest width and length of hinge line, 20 mm.

Horizon and Locality:—In soft yellowish crystalline limestone of the *Lyttonia* bed (1193) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Family LYTTONIIDÆ

Genus **Lyttonia** Waagen

81. **Lyttonia nobilis** Waagen

Plate XXVIII, Figs. 3a-c (No. 327), 4 (No. 325a), 5 (No. 326), 6 (No. 325b)

1882. *Lyttonia nobilis* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 398; Pl. XXIX; Pl. XXX, Figs. 1, 2, 5, 6, 8, 10, 11.

1914. *Lyttonia nobilis* Mansuy. "Faunes des Calcaires à *Productus* de l'Indochine." *Mém. Service Géol., Indochine*, Ser. II, Vol. III, Fasc. 3, p. 32, Pl. VI, Figs. 7a-d; Pl. VII, Figs. 1a-c.

This characteristic Indian shell, found also in Indo-China, is represented by several specimens in the Jisu Honguer limestone of Mongolia. Of these, one (No. 327, Pl. XXVIII, Figs. 3a-c) represents the ventral valve. It is elongated, of somewhat pear-shaped outline, but incomplete and gently convex, since it is of only moderate depth, our shell being comparable in this respect to the one figured by Waagen (1879–1887, Pl. XXIX), though it is much smaller. A part of the shell is still intact, but its surface is weathered, and over much of the specimen it is entirely removed. The septa are narrow and gently curved. Their distance apart varies from two to three millimeters, while the width of the septa themselves is not over 1.5 mm. and frequently not over 1 mm. There are twelve septa preserved in a length of about 50 mm., and as the length of the shell was at least 75 mm., the total number on each side was about eighteen, which compares favorably with the Salt Range shells, where there are thirty-three in a shell 145 mm. long.

Measurements:—The dimensions of this specimen, which is imperfect, are:

	No. 327 *Pl. XXVIII, Fig. 3*
Greatest length..............................	75 mm.
Maximum width..............................	60 mm.
Thickness..................................	16 mm.

A dorsal valve is shown in another specimen, partly in the original in dorsal aspect (No. 325, Pl. XXVIII, Fig. 4), and partly in impression in the counterpart in ventral aspect (No. 326, Pl. XXVIII, Fig. 5). The fragment has a length of 50 mm. and a maximum width on one side of the center of 30 mm., giving a total width at that point of 60 mm. or more. The central part is narrow with a strong median groove. From either side of this extends the series of flat digits, sometimes called septa, which form the characteristic feature of these shells. These digits are broadly rounded, subregular, moderately curved, some of them more strongly curved upward at the outer end. They are separated by narrow slits and terminate in a rounded end which merges into a broad shelly marginal expansion without grooving or septation. The width of the digits varies from 2.5 to 3 mm., while the interspace is a millimeter or less.

Apparently the two valves are still in contact in this specimen, the internal septa of the ventral valve occupying the slits between the digits of the dorsal valve. On one side of the specimen (No. 326, Pl. XXVIII, Fig. 5) the entire shell seems to be intact, showing the flat under side of the ventral valve, with the position of the septa faintly indicated on the exterior. The other half of this specimen shows the impression of the dorsal valve, with a part of the shell matter still adhering. As indicated by this specimen, the shell was extremely thin and flat, though a part of this appearance may be due to compression.

Although so poorly preserved, these specimens are sufficient to indicate the presence of this typical Indian species in the Permian of Mongolia.

Horizon and Locality:—In the *Lyttonia* bed (1193) and the *Enteletes* bed (1190) of the Jisu Honguer limestone of Jisu Honguer, Mongolia. Collector, F. K. Morris.

82. **Lyttonia ? sp.**

cf. *Oldhamina lopingensis* Grabau

Plate XXVIII, Fig. 7 (No. 328)

Among the material of the first collection made by Messrs. Berkey and Morris in the Jisu Honguer limestone, is a fragment of a *Lyttonia* in a dark limestone (No. 328), which shows some characters not seen in other specimens of the recognized species. It is true that Baron Fredericks has described a number of species and varieties from Cape Kalonzin in Ussuriland, but his descriptions are all in Russian, which is not one of the accepted languages of descriptive science. Hence, I regard them as invalid, especially as his illustrations are inadequate to show the characters of the so-called species. In any case none of his illustrations corresponds to our fragment.

The fragment represents a part of a dorsal valve, with the central part, and portion of three to four digits, preserved on either side. The maximum length of the fragment is only 14.7 mm., with a total preserved width of 15.4 mm. The central portion has an average width of 6 mm., while the width of the best-preserved digit is 2.4 mm., this being the average width so far as the fragmentary digits show. The width of the slit between the digits is about 1.2 mm.

The most characteristic feature of the fragment is the nature of the median groove of the axis, which is interrupted by deeper oval pits, there being actual perforations of the shell along the median line. Two of these perforations have a length of 2.2 and 2.3 mm. respectively, and a corresponding maximum width of 1 and 0.9 mm., the shorter one being the broadest. These two perforations are separated by a non-perforate shell portion 1.1 mm. in width, which lies below the level of the shell surface and forms a part of the median groove. A third perforation is separated from these by an interval of 2.6 mm. and has a length of 2 mm., with a maximum width of 1 mm. These elongate oval perforations lie roughly opposite the slits between the digits but do not exactly correspond to them. The broader interspace between the last two perforations recorded is also higher, so that it seems to interrupt the median groove. Below the last noted perforation is a space about 5 mm. in length, without perforations but forming a continuous deep groove.

The digits as seen from the dorsal side at first curve forward from the median axis and then in most cases extend straight outward at right angles, though in one case the direction seems to be forward. So far as can be seen they are not curved. In some cases the shelly matter of these digits shows a crowded series of growth lines which are convex outward and apparently parallel to the outer end of the digit. These would indicate that the digits are not joined on the outer margin by a continuous shell expansion, or at any rate that they were not so joined in the immature shell.

The chief peculiarity of this shell is, as noted, the perforated axis. There is in the collection of the Geological Survey of China a specimen of a new species of *Oldhamina* to which the name of *Oldhamina lopingensis* Grabau has been given. This will be described and illustrated with other Loping species in a forthcoming monograph. But we may note in this connection that the median axis of the internal mold of the strongly convex ventral valve shows a similar series of oval pittings, which would indicate the existence of a row of elongate median tubercles on the inside of the ventral valve, instead of a continuous septum as in other species. It is not impossible that our fragment from Mongolia represents a part of the dorsal valve of this mid-Chinese Permian species, though there is no way of determining their relationship with our present material. In general character and size of digits and interspaces, the Mongolian fragment corresponds fairly well to the interspaces and septa on the interior of the Loping shell.

Horizon and Locality:—The single fragment, No. 328, was obtained by Professors C. P. Berkey and F. K. Morris from the Jisu Honguer limestone of Jisu Honguer, Mongolia. The rock is a dark gray calcilutite not observed again among the material of the later collection. It received the serial number, No. 691, at the time of collecting.

Family PRODUCTIDÆ Gray

(By Y. T. Chao[1])

Genus **Productus** Sowerby

83. **Productus (Linoproductus?) mammatus** Keyserling

Plate XXIX, Figs. 10a-b (No. 965), 11 (No. 963), 12 (No. 964), 13a-b (No. 966), 14 (No. 336)

1902. *Productus mammatus* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe,* Vol. XVI, No. 2, p. 631, Pl. XXXV, Figs. 4–6.

1906. *Productus mammatus* Keidel. "Geologische Untersuchungen in sudlichen Tienschan." *Neues Jahrb. für Mineral.* Beilage-Bd. XXII, p. 367, Pl. XII, Fig. 5.

1927. *Linoproductus? mammatus* Chao. "Productidæ of China, Pt. I, Producti." *Palæontologia Sinica,* Ser. B, Vol. V, Fasc. 2, p. 146, Pl. XV, Figs. 10–14.

The shell is below medium size, very transverse in outline, with the hinge-line marking the greatest width of the shell.

The pedicle valve is moderately inflated, with the curve very unequal in the longitudinal direction. The shell remains almost flat in the visceral portion but becomes abruptly geniculated downwards beyond it, rounding so that the frontal part is at right angles to the earlier part of the shell. Transversely the apical region projects but slightly above the ears, but towards the front the strongly impressed median portion falls rapidly along the main flanks to the lateral margins. The beak is low and insignificant, neither turned over nor projecting beyond the hinge line. The hinge line is straight, always exceeding the width of the body of the shell below. The ears are large and flat,

[1] These descriptions of Mongolian Productidæ were prepared for the present volume by the late Mr. Chao of the Chinese Geological Survey. He also wrote a monograph on the Productidæ of China, which appeared in the Palæontologia Sinica, Ser. B., Vol. V, Fasc. 2 (1927), Fasc. 3 (1928). Mr. Chao's recent death at the hands of bandits while engaged in field work in Yunnan has robbed palæontology of one of its coming men and China of one of its most brilliant young scientists.—A. W. Grabau.

forming an acute angle at the cardinal extremities. They are sharply marked off from the remainder of the shell by a shallow concavity which is sometimes quite pronounced. This concavity terminates anteriorly in the steeply falling lateral slopes of the shell. The median sinus begins not far from the beak. In the visceral portion it remains rather insignificant and appears only as a slight depression; but as soon as it reaches the geniculated part, it suddenly develops into a broad and deep sinus of considerable magnitude down to the anterior margin, imparting to that part of the shell a bilobed appearance.

The surface is marked by numerous fine radiating striæ which increase in number towards the front by intercalation. There are generally nine to ten striæ within a space of 5 mm. Concentric wrinkles are entirely absent, but a few strong spines occur rather regularly in certain parts of the shell. When the ends are well preserved there is seen a strong spine at each end of the hinge line, projecting obliquely outward. On each side of the median sinus in the anterior part, two strong spines are also likely to occur.

The brachial valve is represented by several external folds. It is flattish in the visceral portion, geniculated vertically downwards towards the front, following the curve of the opposite valve. Thus there remains a very thin visceral cavity between them. The median fold, represented in the casts by a depression, is low in the posterior but becomes strong and high from the geniculated part onwards. The surface is marked by the same kind of fine radiating striæ which in one of the specimens show a slight convergence towards the mesial fold. Spines are entirely absent.

The median septum is represented in the interior of a brachial valve. A part of the brachial ridge can also be more or less recognized.

Measurements:—Dimensions of characteristic specimens:

	Pedicle valves			*Brachial valve*
	No. 963	*No. 964*	*No. 965*	*No. 966*
Plate and Figure	*XXIX, 11*	*XXIX, 12*	*XXIX, 10*	*XXIX, 13*
Height of shell	19.8	17.8	18.9	18.3
Length on curvature	22.5	29.0	25.5	23.5
Length of hinge line	32.0+	32.0+	29.0	24.0+

Remarks:—Our shell is characterized by its very transverse outline, fine radiating striæ, pronounced median sinus, constantly distributed spines, and particularly by its depressed visceral portion, which unites with the straight anterior part in a blunt geniculation.

Tschernyschew neither gave any descriptions of the species from Ural and

Timan, nor did he state its relations with other species in the German text. But the species is so characteristic that, comparing with Tschernyschew's figures only, one will not hesitate in identifying our Mongolian shells with the Russian species.

Horizon and Locality:—The original specimens of this species were obtained from Russia. Tschernyschew got his shells from the Schwagerina-Kalk of the Ural and the Timan. Keidel described this species from the "Upper Carboniferous" (Lower Permian) bed of the Kukurtuk valley in the Tien Shan. Our specimens (Nos. 963–966) were obtained by Professor F. K. Morris from the Jisu Honguer limestone of Jisu Honguer, Mongolia. (Locality 1192, *Marginifera* bed.)

84. **Productus (Striatifera)** cf. **ischmensis** Tschernyschew

Plate XXIX, Fig. 5 (No. 332)

cf. 1902. *Productus ischmensis* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 641, Text-Fig. 80.

1927. *Striatifera* cf. *ischmensis* Chao. "Productidæ of China, Pt. I, Producti." *Palæontologia Sinica*, Ser. B, Vol. V, Fasc. 2, p. 97, Pl. XV, Fig. 5.

In the collection of Professor Morris from Mongolia, there is a single rather fragmentary shell which agrees fairly well with *Productus ischmensis* Tschernyschew from Timan, though our specimen is imperfect and does not show all the characters of the species.

The shell is of medium size, about as long as it is wide, and roughly circular in outline.

The pedicle valve is very sparingly inflated in the longitudinal direction. Near the front it is abruptly geniculated as in the type, this geniculation being accentuated, though not produced, by crushing. Transversely, the elevated median portion in the frontal region falls abruptly on either side to the ears in the umbonal region, but forms a rounded to subangular cross section. The beak is broken off. The ears are preserved only in part, but they are apparently large and defined by a rather strong concavity on either side of the umbo. The surface is marked by radiating striæ, which increase in number by intercalation, and spread out in such a manner as to meet the margins always at right angles. There are generally six or seven striæ within a space of 5 mm. The surface is also marked by many concentric wrinkles that are rather indistinct in our shell due to weathering.

The muscular impressions of the pedicle valve are fairly well represented in our shell. The adductors are elongated in outline, dendritic, one on each side of the median line from the beak. Outside of and anterior to them are the diductors, which are roundish and longitudinally striated.

Remarks:—Gröber (1908, Pl. XXX, Fig. 1) found a shell in the Viseen limestone of the Tien Shan which he regarded as identical with Tschernyschew's *Productus ischmensis* from the Lower Permian of Timan. He considered that species a variety of *Productus striatus*, but it is rather doubtful whether a shell with ears vertically bent down can still have a perfectly straight hinge line, as that illustrated by Gröber's figure. The always vertical bending down of the ears in *Productus ischmensis*, and the horizontal spreading out in *Productus striatus* must mean something more than a mere ordinary variation within the species. To me, it seems better to regard them as distinct, as one does not find a series of imperceptible gradations between them.

Productus ischmensis differs from *Productus striatus* chiefly in the vertically bent down ears. In the type, according to Tschernyschew, the ears retain a horizontal position from the hinge line, to a somewhat greater extent than in *Productus compressus*, after which they bend at right angles as in the Indian form and maintain a vertical position with reference to the dorsal (brachial) valve. The concentric growth lines extend only over the horizontal part of the ears; on the vertical part they are wanting, but there are numerous fine spines which arise at right angles to the surface of the ears. This deflected part of the ears is not shown in our specimen, where the umbonal portion is broken away. But the contour of the sides of that part of the umbo remaining suggests that such deflection may have been present in the perfect shell. This character suggests *Productus compressus* and *Productus mongolicus*, but our shell is distinguished from either of them by its much broader outline, larger ears, less distinct and regular concentric wrinkles, and much coarser radial striations.

Horizon and Localities:—The species was originally described by Tschernyschew from the "Upper Carboniferous" (Lower Permian) bed of Ural and Timan. The specimen here described was obtained from the *Marginifera* bed (1192) of the Permian Jisu Honguer limestone at Jisu Honguer, Mongolia.

85. **Productus (Striatifera) compressus** Waagen var. **corniformis** Chao, var. nov.

Plate XXIX, Figs. 6 (No. 342), 7 (No. 345), 8a-b (No. 344), 9a-b (No. 343)

1862. *Productus striatus* Davidson non Fisch. "On some Carboniferous Brachiopoda collected in India." *Quart. Journ. Geol. Soc. London*, Vol. XVIII, p. 31, Pl. I, Fig. 16.

1884. *Productus compressus* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 710, Pl. LXXXI, Figs. 1–2.

1884. *Productus mytiloides* Waagen. *Ibid.*, p. 711, Pl. LXXX, Fig. 4.

1927. *Striatifera compressa* var. *corniformis* Chao. "Productidæ of China, Pt. 1, Producti." *Palæontologia Sinica*, Ser. B, Vol. V, Fasc. 2, p. 101, Pl. XV, Figs. 6–9.

The shell is exceedingly elongated, horn-shaped, with an acuminated beak and a rounded front, a hinge line in the true sense being absent.

The pedicle valve is moderately inflated. The shell is very regularly and uniformly inflated in the early stages to about the anterior third of the shell, where it bends a little more abruptly but smoothly to the anterior margin. The beak is pointed, strongly incurved at the extremity and increasing in width very gradually towards the front. It is strongly compressed laterally, with the lateral flanks sometimes even curving inward, imparting a terebratuloid appearance to it. The beak is further compressed, often irregular and curved to one side of the central line of the shell as if it were originally twisted by anchorage as in *Aulosteges*. This strong laterally compressed character of the shell remains pronounced from the young to the adult. The ears are extremely small, defined by the presence of several spines and vertically bent down, leaving a triangular space beneath the beak and no room for the hinge line. The median sinus is entirely absent.

The surface sculpture consists of radiating striæ and concentric wrinkles. The radiating striæ are extremely fine, delicate and thread-like, nine to twelve of them generally occupying a space of 2 mm. They augment in number towards the front by intercalation and spread out radially from the apex of the beak. The newly intercalated striæ remain rather slender and indistinct for a considerable distance before they reach the size of the older ones, and hence the striæ appear to be separated by wide interspaces. Generally the striæ are fairly straight and regular throughout, while in other cases they are flexuous and waving in certain parts of the shell. The concentric wrinkles are more or less irregular but always well defined. They are rounded on top and separated by shallow depressions. Sometimes some of the concentric wrinkles may gradually disappear; in other cases two of them become confluent. As a rule they are most prominent upon the median portion of the shell. They are not unlike the wrinkles on the epitheca of a tetraseptate coral. Several spines arise from the rudimentary ears, but besides these no spines whatever have so far been observed upon the median portion of the valve.

The brachial valve is unknown.

Measurements:—

Serial Number	*No. 342*	*No. 343*	*No. 344*	*No. 345*
Plate and Figure	*XXIX, 6*	*XXIX, 9*	*XXIX, 8*	*XXIX, 7*
Height of pedicle valve	26.0 mm.	30.5 mm.	26.0 mm.	23.0 mm.
Length along curvature	33.0 mm.	39.0 mm.	33.0 mm.	29.0 mm.
Greatest width at anterior part	21.0 mm.	21.5 mm.	16.5 mm.	22.5 mm.
Depth	12.0 mm.	20.0 mm.	12.5 mm.	10.0 mm.

Remarks:—On the whole, the Mongolian shells are most nearly related to *Productus compressus* of India, with which they agree in the general outline and surface sculptures. But our shells never attain the size of the Salt Range species and are much narrower, and the sides are more incurved, giving the shell a characteristic horn-shaped appearance. The constantly smaller size and the stronger lateral compression seem to me quite sufficient for the establishment of a new variety.

The variety is not unlike the figures of *Productus prinadai* Fredericks and *Productus pinniformis* Girty in form and in size. But it can easily be distinguished from either of them by its more compressed outline and more concentric wrinkles.

Horizon and Localities:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia. *Enteletes* bed (1190, three specimens) and *Spiriferella rajah* bed (1209, one specimen). Collector, F. K. Morris.

86. **Productus (Linoproductus) lineatus** (Waagen)

Plate XXIX, Figs. 25 (No. 331), 26 (No. 329), 27a-b (No. 330)

1884. *Productus lineatus* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 673, Pl. LXVI, Figs. 1–2.

1914. *Productus lineatus* Wiman. "Über die Karbonbrachiopoden Spitzbergens und Bären Eilands." *Nova Acta R. Soc. Sci. Upsaliensis*, Ser. IV, Vol. III, No. 8, p. 70, Pl. XIII, Figs. 14–15.

1922. *Productus cora* Hayasaka. "Palæozoic Brachiopoda from Japan, Korea and China, Part I." *Sci. Rept. Tohoku Imp. Univ.*, Ser. II (Geol.), Vol. VI, No. 1, p. 68, Pl. V, Figs. 3–4 (see especially for synonymy).

1927. *Linoproductus lineatus* Chao. "Productidæ of China, Pt. I, Producti." *Palæontologia Sinica*, Ser. B, Vol. V, Fasc. 2, p. 129, Pl. XV, Figs. 25–27.

There has been recently a growing tendency among investigators to consider that no essential differences exist between *Productus cora* d'Orbigny and *Productus lineatus* Waagen, the one being connected by imperceptible gradations with the other. Consequently the specific circumscription of *Productus cora* has been greatly enlarged, and *Productus lineatus* designated a synonym of d'Orbigny's species.

Productus cora was originally described by d'Orbigny from material obtained from South America, partly from the vicinity of Pataponi Village, on an island in Lake Titicaca, and partly from Yarbichambi, on the same lake. It has recently been redescribed and figured in great detail by R. Kozlowski (1914, p. 48, Pl. IV, Fig. 19; Pl. V, Fig. 5; Pl. VI, Figs. 1–10), from material obtained from the type locality and elsewhere in Bolivia. Much difference of opinion has existed regarding the latitude of variation of this species, which has been described as one of the characteristic forms of the Russian Carboniferous (or Permian), being especially characteristic of the so-called Cora beds of the Ural country. There can be no question that forms of this general type are widespread in Eurasia as well as in America, but is remains to be determined whether all the forms placed under this species are members of one genetic group. This can be settled only by a study of the ontogeny of the various types, and for this our material is too imperfect. It is to be deplored that Kozlowski did not make an attempt at tracing out the ontogenetic history of the species from the type locality, since he had such excellent material to work with. The distinction of species has generally been based on a few adult characters. Thus the presence of a well-developed sinus is taken by Waagen as distinguishing *Productus lineatus* from *Productus cora*, but a sinus sometimes occurs in the specimens of *Productus cora* from Bolivia. Nevertheless we can not but feel that, when study is sufficiently discriminating, it will be found that many of the European and Asiatic types identified with *Productus cora* are distinct, their similarity to the South American form being due to parallelism in development. In the first place, it does not seem likely that a South American brachiopod, apparently living in an extension of the Pacific, should be represented by an identical form on the opposite side of the Pacific or that in its migrations it should reach Europe in an unchanged condition. In the second place, it does not seem likely that a species should survive all the vicissitudes of the mid-Carboniferous and the Permian without specific change. This may have occurred, but we need better proof than the mere similarity of adult forms—the early stages must show that these forms are cospecific, and until these stages are carefully studied, the question of identity must remain in abeyance.

One thing seems certain, that the sinus of the pedicle valve is subject to acceleration in development in the different forms. Thus, in the typical *Productus cora* from Bolivia, it is the merest depression at the front; other specimens, however, show this condition when the shell is still quite young and this median depression increases as the shell grows in size. Thus in the adult the sinus is well developed. But the form of the shell is still the same as in the non-sinuate shell which is essentially triangular, the sides of the umbonal region diverging rather strongly. In *Productus lineatus* of the Permian Productus limestone, on the other hand, the form is more nearly rectangular, with the sides nearly parallel. The manner of growth differs from that of the Bolivian form, so far as can be judged from illustrations, but the precise formulation of this difference must be based on measurements of stages in development in many individuals of both species.

So far as our imperfect material permits us to judge, it shows more nearly the characters of *Productus lineatus* of India than of *Productus cora* of Bolivia, and we prefer to place it for the present under the name of the Asiatic form. One of our specimens (No. 329, Pl. XXIX, Fig. 26) shows the elongated form, with the sides parallel and with the early development of the shallow sinus characteristic of the Indian species. The height of the shell is at least 37 mm., while its width is only about 29 mm. The striæ are sharply defined, rounded, narrow, and separated by interspaces about equal to them in width. There are about nine of these striæ in 5 mm. in this specimen, though in another (No. 331, Pl. XXIX, Fig. 25) there are only seven. In a third (No. 330, Pl. XXIX, Fig. 27), representing a young stage, there are nearly twelve striæ to 5 mm., but only eight in the more advanced. This latter might be more readily taken for a *Productus cora*, especially in the young stage, the sinus in this case being only faintly developed, while the form at this time corresponds more nearly to that of *Productus cora*. This suggests that *Productus cora* might be ancestral to *Productus lineatus*, a fact also suggested by the more pronounced development of the sinus in the latter form, this indicating greater acceleration.

The auricular extremities are wrinkled, this being a character found in both the Bolivian and the Indian forms.

Indications of spines are extremely rare in our specimens, only one or two being found in a specimen. This is a feature of the Indian shell, the Bolivian forms having typically more numerous indications of spines. It must, however, be borne in mind that both the character of the striæ and the frequency and disposition of spines, are features which may be subject to independent development in parallel genetic series.

Whether the broad forms described by Tschernyschew as *Productus cora* from Russia are to be referred to that species, or belong to an independent series possibly derived from a *cora* ancestor, must be determined by the study of the ontogeny of these shells. They are certainly different from our shells.

On the whole our shells are probably nearer to those described and figured as *Productus lineatus* by Wiman from the Upper Carboniferous (Permian?) of Spitzbergen and Beeren Island.

Horizon and Localities:—In the mid-Permian Jisu Honguer limestone of Jisu Honguer, Mongolia. Specimens have been obtained from the *Camarophoria* bed (1208) and the *Spiriferella rajah* bed (1209). Collector, F. K. Morris.

87. **Productus** cf. **porrectus** Kutorga

Plate XXX, Figs. 10a-b (No. 333), 11 (No. 334), 12 (No. 335)

1902. *Productus porrectus* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe,* Vol. XVI, No. 2, p. 634, Pl. XXXII, Fig. 4; Pl. LV, Fig. 1; Pl. LVI, Fig. 4; Pl. LXII, Fig. 2.

The species appears to be represented by several individuals, all of which are rather fragmentary and poorly preserved. The shell is of large size.

The pedicle valve appears to be strongly inflated and characterized by a pronounced median sinus. From the rather strongly accentuated sinal boundaries the sides descend abruptly with very little rounding. The surface is marked by numerous, irregular, rather discontinuous striæ of varying width, which swell out at intervals into pustular spines, and less strongly by concentric wrinkles. From five to six striæ generally occupy a space of 5 mm. The auricular parts are marked by many coarse tuberculations corresponding probably to spines in the actual shell.

The brachial valve is flattish in the visceral portion but geniculated at the margins. Not far from the beak commences a median fold which becomes very high and broad anteriorly. The interior of the brachial valve is represented by two specimens, only one of which (No. 334, Pl. XXX, Fig. 11) shows the characters well. The median septum is very long, extending to the geniculation of the valve. The surface is marked by numerous pustular spines which are especially pronounced on the auricular extremities.

The general outline of the shell, the pronounced median sinus of the pedicle valve, the fold of the brachial valve, and the surface sculpture as well as the long and thin median septum in the brachial valve, give our Mongolian shells a marked resemblance to *Productus porrectus* Kutorga, as illustrated by Tschernyschew from Ural and Timan. But our only specimen (No. 335, Pl. XXX, Fig. 12), in which the surface sculpture is sufficiently well preserved, shows a little finer striation. Because of the fragmentary nature of our Mongolian specimens, no attempt is made at certain identification.

Horizon and Localities:—In the Middle Permian Jisu Honguer limestone of Jisu Honguer, Mongolia. (Localities 1192, 1207, 1209.) Collector, F. K. Morris.

88. **Productus (Baxtonia)** cf. **juresanensis** (Tschernyschew)

(No. 346)

1902. *Productus juresanensis* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 620, Pl. XXIX, Figs. 1–2; Pl. XLVII, Figs. 1–2; Pl. LIII, Fig. 4.

1912. *Productus juresanensis* Yakowlew. "Die Fauna des oberen Abtheilungen der Palæozoischen Ablagerungen in Donez-Bassin Brachiopoda." *Mém. Com. Géol. Russe*, Nouv. Ser., Livr. LXXIX, p. 31, Pl. IV, Figs. 1–2.

1913. *Productus juresanensis* Mansuy. "Faunes des Calcaires à Productus de l'Indo-Chine." *Mém. Service Géol., Indochine*, Vol. II, Fasc. 4, p. 35, Pl. II, Figs. 13a-i.

1914. *Productus juresanensis* Tschernyschew. "Die Fauna der oberpalæozoischen Ablagerungen des Darwas." *Mém. Com. Géol. Russe.*, Nouv. Ser., Livr. CIV, p. 62, Pl. IX, Figs. 1a-d.

1927. *Baxtonia juresanensis* Chao. "Productidæ of China, Part I, Producti." *Palæontologia Sinica*, Ser. B, Vol. V, Fasc. 2, p. 81, Pl. VIII, Figs. 4–8.

1928. *Juresania juresanensis* Chao. Ibid., Pt. II, Ibid., Fasc. 3, p. 55.

The species is represented by a single pedicle valve from Mongolia. The general outline and the more or less preserved surface sculpture suggest in every respect the well-known and widespread species *Productus juresanensis* Tschernyschew, but as the shell is poorly preserved we prefer to make the identification a tentative one.

The approximate measurements of our specimen are: height 31 mm.; length 44 mm.; maximum width 37.5 mm. From this it is seen that the valve is transverse in appearance, that is, when the height is considered in proportion to the width. The actual length is, however, much greater. The umbonal part is strongly compressed, with the sides falling nearly vertically and diverging at an angle of 70°. There is an abrupt flattening out to the auricular extremities, which are, however, not fully shown. Even in the very young stage the summit appears to be flattened so that we have here an accelerated form so far as the median sinus is concerned. This becomes stronger and wider forward, being perhaps slightly more pronounced than in Tschernyschew's figure. From the center of the sinus the sides slope upward on either side to a rounded summit and then gradually slope to the lateral margin, the contour being concave in the umbonal region, flat in the center and barely rounded near the front. The young shell is marked by distant, sharp, much elongated pustules and the sinus is well developed before the first constriction occurs. There are also indistinct concentric wrinkles formed in reality by transversely arranged elongated pustules. The concentric constrictions in growth are characteristic of the species and occur at subregular intervals. They are brief, the shell after a short interval expanding again. Thus where the expanded part is 3 mm. wide, the depression between is only 0.8 mm. The expanded ridges were apparently pustulose, but the shell is too much weathered to show this positively.

Horizon and Locality:—Permian, in the Jisu Honguer limestone of Jisu Honguer, Mongolia. (Locality 1192, *Marginifera* bed.) Collector, F. K. Morris.

89. **Productus (Waagenoconcha)** cf. **purdoni** Davidson

Plate XXIX, Figs. 4a-b (No. 942)

1862. *Productus purdoni* Davidson. "On some Carboniferous Brachiopods collected in India by A. Fleming . . . and W. Purdon." *Quart. Jour. Geol. Soc. London*, Vol. XVIII, p. 31, Pl. II, Fig. 5.

1884. *Productus purdoni* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 4, p. 705, Pl. LXXIII, Figs. 1–3.

1897. *Productus purdoni* Diener. *Palæontologia Indica*, Ser. XV, Himalayan Fossils, Vol. I, Pt. 4, "Permian Fossils of the Productus shales of Kumaon and Garhwal," p. 21, Pl. II, Figs. 1a-c, 2a-c.

cf. 1914. *Productus purdoni* Wiman. "Über die Karbonbrachiopoden Spitzbergens und Bären Eilands." *Nova Acta R. Soc. Sci. Upsaliensis*, Ser. IV, Vol. III, No. 8, p. 68; Pl. XIV, Figs. 8, 9; Pl. XV, Figs. 1–2; Pl. XVI, Figs. 1–4.

1927. *Waagenoconcha* cf. *purdoni* Chao. "Productidæ of China, Pt. I, Producti." *Palæontologia Sinica*, Ser. B, Vol. V, Fasc. 2, p. 89, Pl. XV, Fig. 4.

The species is represented by a single specimen from Mongolia. The preserved part shows all the essential characters of *Productus purdoni*, but the shell is too fragmentary for certain identification.

The pedicle valve is strongly enrolled in the apical region where it is also characterized by steep cardinal slopes and a strong hinge line, apparently shorter than the width of the shell below. Towards the front, the valve becomes less inflated, the strongly impressed median portion falling more gradually along the main slopes to the lateral margins. The beak is pointed, rapidly expanded towards the front. The median sinus is pronounced, commencing not far from the beak. The surface is marked by numerous tubercles arranged in a regular quincunx.

Our shell agrees more closely with that of the type figured by Davidson than with the majority of the shells figured by Waagen, which appear to have a less definitely pronounced sinus. The shell is very elongate in the adult, but in the young stages, as indicated by growth lines, it is most transverse. Our specimen, which preserves a height of about 35 mm. and a maximum width of perhaps 45 mm., is not unlike in this respect the immature stage of the type figured by Davidson. The full height of the type is 60 mm., and its maximum width near the base 54 mm. The height of the brachial valve is 51 mm. The large shells figured by Wiman probably belong to a distinct species.

From the preserved part alone, our shell is not unlike *Productus humboldti* d'Orbigny, but even this preserved part is still much larger than any of the shells of *Productus humboldti* so far recorded, and the marginal zone of small spines is absent, which would be represented in that part of the shell if it were really to belong to the last-mentioned species.

The general outline and surface sculpture suggest an immature *Productus purdoni* Davidson, but unfortunately the anterior part of the shell is imperfect, and positive identification has to be postponed.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia. (Locality 1196.)

90. **Productus (Waagenoconcha) humboldti** d'Orbigny

Plate XXIX, Figs. 2 (No. 279), 3 (No. 278)

1902. *Productus humboldti* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 620, Pl. LIII, Figs. 1–3.

1914. *Productus humboldti* Kozlowski. "Les Brachiopodes du Carbonifère Supérieur de Bolivie." *Annales de Paléontologie*, Vol. IX, p. 40, Text-Fig. 9; Pl. VII, Figs. 7–9.

1927. *Waagenoconcha humboldti* Chao. "Productidæ of China, Pt. I, Producti." *Palæontologia Sinica*, Ser. B, Vol. V, Fasc. 2, p. 86, Pl. XV, Figs. 2–3.

The species is represented by two pedicle valves, the anterior part of which is broken off in both.

In the early stages, the pedicle valve is strongly arched with steep cardinal and umbonal flanks. With increasing age, it becomes less strongly inflated, and the much impressed median portion also falls less steeply along the main slopes to the lateral margins. The beak is pointed, incurved, but not turned over the hinge line. It increases in width very rapidly towards the front. The hinge line is straight, a little less than the greatest width of the shell. The ears are moderately developed, marked off from the remainder of the shell by a concavity. The median sinus, commencing a little below the beak, becomes very broad and strong anteriorly. The great prominence of the median sinus in the larger specimen may be accentuated by compression.

The most characteristic feature of the species is the surface sculpture. This consists of numerous slender, elongated tubercles arranged in a regular quincunx. These tubercles are separated by narrow interspaces, three to four of them generally occupying a space of 3 mm. upon the mid-part of the shell. They are extremely elongated, reaching a length of 3 mm. in the larger specimen. These tubercles, however, appear to be smaller and more closely crowded in the smaller specimen, recalling more nearly the *Productus humboldti* described by Tschernyschew from the Ural and Timan.

From the preserved part alone, one might reasonably assume that these shells were representatives of the young stages of *Productus purdoni* Waagen, but our shells are much less strongly enrolled in the early stages than the latter species, and so far as can be judged from our imperfect specimens they are also much broader in outline. The curvature of the early stages, the general outline and the characteristic surface sculptures, on the other hand, agree with *Productus humboldti* completely.

Horizon and Localities:—In the *Enteletes* bed (Locality 1190) and also Locality 1186 of the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia. Collector, F. K. Morris.

91. **Productus (Echinoconchus) fasciatus** Kutorga

Plate XXIX, Figs. 1a-c (No. 277)

1902. ***Productus fasciatus*** Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 631, Text-Figs. 72–74, Pl. XXXI, Fig. 7, Pl. XXXIV, Figs. 5, 6.

1927. *Echinoconchus fasciatus* Chao. "Productidæ of China, Pt. I, Producti." *Palæontologia Sinica*, Ser. B, Vol. V, Fasc. 2, p. 70, Pl. XV, Fig. 1.

The species is represented only by a single specimen with the umbonal region broken off and the surface strongly deteriorated by weathering.

The shell is a little below medium size, elongate-oval, with a hinge line less than the greatest width of the shell.

The pedicle valve is strongly inflated, with the sides diverging, but very gradually, from the beak to the anterior margin. The early stages are strongly enrolled and highly elevated, this strong curvature becoming gradually less prominent towards the front. The median portion is flattened, with the cardinal, umbonal, and main slopes falling abruptly and vertically to the ears and lateral margins, forming a characteristic rectangular cross-section from the young to the adult. The hinge line is a little less than the greatest width of the shell. The ears are small, sharply marked-off from the highly elevated visceral portion by a concavity. The median sinus appears as a flattening from the very young to the adult. The surface is strongly deteriorated by weathering, but is apparently marked by numerous prominent, obtusely angulated, concentric folds. These latter are most prominent and more widely spaced in the middle portion of the valve, becoming narrowed and crowded together towards the lateral parts and the frontal margins. There are generally four to five folds in a space of 10 mm. upon the middle portion of the valve. In typical species the posterior slope of the concentric folds is marked by numerous, closely crowded, roundish spine-bases. These latter, however, are only indistinctly represented in the left anterolateral corner of our valve, due to the bad state of preservation.

The brachial valve is flattish, with a slightly depressed umbonal region. The ears are small, flattish and marked off from the remainder of the valve by a blunt ridge. The median fold is ill-defined, appearing as a low but broad elevation. The surface is marked by numerous, regular concentric ridges. Other sculptures are not preserved.

Measurements:—The dimensions of our only specimen are as follows:

	No. 277
Height of pedicle valve	23 mm.
Length of curvature	....
Length of hinge line	26 mm.
Width of shell	33 mm.
Height of brachial valve	23 mm.
Thickness between two valves	17 mm.

Remarks:—Although the surface sculptures of our specimen are not so well preserved, yet the peculiar outline makes its reference to *Productus fasciatus* Kutorga, as described by Tschernyschew from the Ural and Timan, beyond doubt. At first sight, the species may be thought to bear some resemblance to *Productus punctatus* and its allies, but it can be easily distinguished from the latter by the highly elevated median portion which is flattened on top and has vertical flanks. The constancy of small size always shown by this species, as well as the characters of the concentric folds and the spine-bases, form other significant differences.

Horizon and Locality:—In the *Enteletes* bed (1190) of the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia. Collector, F. K. Morris.

92. **Productus** sp. A

(Nos. 337, 338, 339)

This species is represented by three strongly crushed specimens. The pedicle valve (No. 337) is broad and characterized by a very broad and pronounced median sinus which occupies five-eighths the width of the shell. The umbonal region is sharply compressed, with the sides, which diverge at right angles, descending abruptly. A part of the abruptness is, however, due to crushing. The surface is marked by two kinds of sculptures. The radiating striæ are rather delicate and slightly wavy, five to six of them generally occupying a space of 5 mm. The concentric sculpture is strong and regular, confined only to the visceral portion of the shell. There are generally four concentric ridges within a space of 5 mm. Upon the radiating striæ arise here and there strong spines, and where the longitudinal and concentric sculptures intersect, a very regular series of pustules is produced, which gives that part of the shell a very pronounced character. The height is about 42 mm. The greatest width, which is at the hinge line, is 47 mm.

The brachial valve referred to this form (No. 338) is so gently concave in the visceral region as to appear almost flat. At the sides and front it is abruptly turned up, forming a geniculation which is nearly rectangular. There is a faint median fold-like elevation which continues through the geniculated portion. The broad sinus and peculiar sculpturing of the umbonal part are characteristic points of our Mongolian shell, and these characters distinguish it from all other forms known to me. Our specimens are, however, too strongly crushed to enable us to determine their true character or give them specific rank.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia. From the *Marginifera* bed (1192). Collector, F. K. Morris.

93. **Productus** sp. B

(No. 340)

The species is represented only by a large external mold of the brachial valve. The mold is flattish in the visceral portion, abruptly geniculated downward towards the front. The median fold is well-defined but low. The surface is marked by radiating striæ and concentric undulations. The latter are about the same size as the former and are confined only to the flattish visceral portion, giving that part of the shell a very neat reticulation. There are generally three or four striæ within a space of 5 mm., and as many as five concentric ridges are counted in the same space.

The shell suggests a member of the *semireticulatus* group but is too fragmentary for exact determination.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia. *Marginifera* bed (1192). Collector, F. K. Morris.

94. **Productus** sp. C

(No. 341)

This is the largest *Productus* so far known from Mongolia. It is much broader than it is high and characterized by a pronounced sinus. The hinge line is somewhat less than the greatest width of the valve.

The pedicle valve is strongly inflated with a blunt geniculation at about the posterior third. The beak is broad, rapidly expanded towards the umbonal region and marked by steep flanks. The median sinus begins in the vicinity of the beak and becomes very broad and strong towards the front, giving the shell a bilobed appearance. The surface sculpture is almost entirely destroyed. The auricular parts seem to be marked by many coarse tuberculations. A large, longitudinally striate diductor scar is more or less represented in the umbonal region of the valve. The vertical height is about 52 mm., the length on the curvature is 90 mm., the greatest width 75 mm.

Its affinity with other species is not clear at present.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia (Locality 1205, *Spirifer moosakhailensis* bed).

Genus **Proboscidella** Oehlert

95. ' **Proboscidella** cf. **lata** Tschernyschew

Plate XXX, Figs. 13a-b (No. 271), 14 (No. 272), (No. 273)

1902. *Proboscidella lata* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 642, Pl. XXXI, Fig. 4; Pl. LIX, Fig. 7.

1906. *Proboscidella* cf. *lata* Keidel. "Geologische Untersuchungen im südlichen Tian-Schan, etc." *Neues Jahrb. für Mineral.*, Beilage-Bd. XXII, p. 369.

1927. *Proboscidella* cf. *lata* Chao. "Productidæ of China, Part I, Producti." *Palæontologia Sinica*, Ser. B, Vol. V, Fasc. 2, p. 148.

The species is represented by three fragmentary specimens. The ears are broken off, and the surface sculpture is only partially preserved. The general shape is elongate with an incurved beak and a laterally compressed front.

The pedicle valve is strongly inflated with the curve more pronounced in the posterior part. The valve is characterized by rather steep flanks from the young to the adult. The beak is pointed, strongly incurved and rapidly expanded towards the visceral portion. From the latter part onward, the shell again becomes narrowed, laterally compressed, and forms a tube-shaped prolongation characteristic of the genus *Proboscidella*.

The surface sculpture is not so well preserved, but it consists apparently of radiating striæ and concentric ridges. The radiating striæ are rather delicate and rounded; five of them generally occupy a space of 5 mm. in the anterior part, but only three are counted within the same space in the umbonal region. They are flexuous and wavy, at least in the frontal part of the shell, where they are broken up into elongated pustules. The concentric sculpture is faint and indicated only by the arrangement of the pustules, which are confined to the posterior portion of the valve. In the internal mold of the pedicle valve, the umbonal region is marked by numerous elongate tubercles arranged in a cross-lineation. Several strong spines frequently occur where the shell begins to be compressed. Of other spines, none has been observed, due to the strong deterioration of the surface.

The brachial valve is unknown.

Among the three species of *Proboscidella* described by Tschernyschew from the Ural and Timan, our Mongolian shell seems to be most nearly related to *Proboscidella lata* Tschernyschew, the two agreeing in the general outline and type of radiating striæ, though the sinus of our shell is broader and flatter. Further examination of well-preserved specimens will probably prove them distinct.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia (Locality 1192, *Marginifera* bed). Collector, F. K. Morris.

Genus **Marginifera** Waagen

96. **Marginifera jisuensis** Chao

Plate XXIX, Figs. 15a-c (No. 348), 16a-c (No. 355), 17a-c (No. 350), 18a-c (No. 351), 19a-c (No. 347), 20a-c (No. 349), 21a-c (No. 352), 22 (No. 23), 23 (No. 353), 24 (No. 354); Plate XXX, Figs. 15a-b (No. 348), 16a-c (No. 128), 17a-b (No. 50), 18a-b (No. 24), 19 (No. 23), (No. 28)

cf. 1902. *Marginifera juresanensis* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe*, Vol. XVI, No. 2, p. 652, Pl. LX, Fig. 18 (*cetera exclus*).

1927. *Marginifera jisuensis* Chao. "Productidæ of China, Pt. I, Producti." *Palæontologia Sinica*, Ser. B, Vol. V, Fasc. 2, p. 149, Pl. XV, Figs. 15-24.

The species is the most abundant among those of the genus so far obtained from the Permian beds of Mongolia. It is represented by more than one hundred individuals, ranging in size from specimens only 7 mm. in height to those twice as large.

The shell is of small size, elongate-ovate in outline, with the hinge line a little less than the greatest width of the shell in the immature shell but much less in the mature. In immature shells the width exceeds the height, but when mature the height is greater.

The pedicle valve is strongly inflated. The curve is tolerably strong but rather regular in the posterior part with the visceral portion projecting high above the hinge line. Anteriorly, the shell gradually becomes less strongly vaulted and forms a broad curve down to the anterior margin. The length along the curvature is nearly twice the height of the shell. Transversely, the curve is very regular, forming a semicircular cross-section in the immature shells, but in the mature individual the slightly convex median portion generally falls more or less abruptly and often essentially vertically to the lateral margins. The beak is pointed and prominent, strongly incurved and overhanging the hinge line at its extremity. The hinge line is straight, always shorter than the greatest width of the shell and more strongly so in the adult. The ears are usually broken off along the internal marginal ridge of the brachial valve. When preserved, they appear to be small, flattish and sharply marked off from the remainder of the shell. A median sinus is entirely absent. In a few specimens, however, a median flattening commences not far from the beak and extends to the anterior margin.

The surface is marked by numerous spines and imbricating concentric striæ of growth. As a rule, the spine bases are more numerous and roundish in the posterior part, but become gradually decreased in number and at the same time increased in strength towards the anterior part. Here the spine-bases are also a little elongated. In some well-preserved specimens (No. 348, Pl. XXIX, Fig. 15), a low and short elevation is seen to appear both before and after the occurence of a spine, that is, the spine base is elongated in longitudinal direction, giving the anterior part of the shell an interruptedly striate appearance. Spines are again very abundant on the sides of the shell, and there they are disposed into a double row of closely crowded spines a little above the ears. In some specimens (Nos. 353, 354, Pl. XXIX, Figs. 23–24), some of the spines are seen still adhering to the sides of the shell. Although their extremities are all broken off, yet their preserved length is only a little less than the height of the shells. If complete, their length must be still greater. The direction of the spine is always perpendicular to the surface of the shell.

When the external shelly layer is split off, the shell appears to be smooth. The anterior part, however, is marked by a conspicuous band corresponding to the internal ridge of the brachial valve, along which the trail is often broken off.

The brachial valve is moderately concave and follows the curve of the opposite valve. The visceral cavity between the two valves is considerable, reaching a thickness of 5 and 5.3 mm. in shells measuring respectively 12.7 and

13.6 mm. in height. In the less strongly inflated young shell, however, it is comparatively thin, being only 3.4 mm. thick in a shell of about 9.8 mm. in height, and 2.5 in one 8.5 mm. in height. The ears are flat and sharply marked off from the concave visceral portion. A median fold is entirely absent.

The surface of the brachial valve is characterized by numerous roundish pustule-pits which appear as rounded pustules in the external molds, and by many undulating concentric sculptures which are more pronounced upon the ears.

Internally, the surface is marked by numerous microscopic pustules. The characteristic marginal ridge is well represented in some of the specimens. Other characters are not observed.

Measurements:—The following are the dimensions of a series of characteristic shells of this species (columns 1–6) together with the measurements of *Marginifera juresanensis* taken from Tschernyschew's figure (column 7).

Column Number	1	2	3	4	5	6	7
Serial Number	*No. 352*	*No. 349*	*No. 348*	*No. 347*	*No. 351*	*No. 350*	*M. juresanensis* Tschernyschew
Plate and Figure	*XXIX 21*	*XXIX 20*	*XXIX 15*	*XXIX 19*	*XXIX 18*	*XXIX 17*	*LX 18*
Height of pedicle valve	8.5	9.8	11.3	12.7	13.6	15.0	14.0
Length of same on curvature	11.0	17.0	20.0	23.0	26.5	27.0	22.0
Height of brachial valve	6.8	8.5	....	9.2	8.8	....	11.5
Greatest width of shell	8.8	11.2	11.5	11.3	11.7	13.8	15.0
Depth of pedicle valve	3.8	....	7.0	6.3	6.8	8.2	....
Thickness between valves	2.5	3.4	....	5.0	5.3	....	....
Length of hinge line	7.5	....	8.0	6.3	9.8	10.4	14.0

Remarks:—The ovate outline, small size, strongly inflated pedicle valve, the absence of a median sinus, and spinose ornamentation are characters which can be easily used to distinguish it from all the other species of the genus.

As a rule, the small young individuals are comparatively broader in outline and less strongly inflated, with a relatively thin visceral cavity between the two valves. In this respect they resemble closely the adult of Tschernyschew's species, which, however, is much larger. The large adult ones, on the other hand, are very elongate-ovate and tolerably strongly inflated, forming a thick visceral cavity between them. With these two extremes at either end, they are connected by many insensible gradations, representing different stages of growth.

Comparing now our shells with *Marginifera juresanensis* as figured by Tschernyschew, one will immediately be convinced that shells of approximately the same size as Tschernyschew's type-figure, are more strongly inflated than it, and that the height is greater than the width, while those a little inferior in size possess essentially the same curvature, the greater width, longer hinge line and smaller interval between valves. Those still smaller are even less strongly inflated than the Russian shell. Based upon this consideration, the Mongolian shells seem to be a little more advanced in the evolutionary scale, if the only figure given by Tschernyschew really represents the most common form from Ural and Timan. The Mongolian species may be regarded as a derivative from a type similar to the Russian form, agreeing with it in the young, but becoming more convex and more elongate in the adult. It is accordingly a more specialized shell.

Horizon and Localities:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia. Common in the *Hemiptychina* bed (1196), *Martinia* bed (1194), *Lyttonia* bed (1193), and the *Enteletes* bed (1190); and rare in the *Camarophoria* bed (1208). Collector, F. K. Morris.

97. **Marginifera typica** Waagen var. **septentrionalis** Tschernyschew

Plate XXX, Figs. 6 (No. 357), 7a-c (No. 356), 8 (No. 359), 9 (No. 361), (Nos. 358, 360, 362)

1902. *Marginifera typica* Waagen var. *septentrionalis* Tschernyschew. "Die obercarbonischen Brachiopoden des Ural und des Timan." *Mém. Com. Géol. Russe,* Vol. XVI, No. 2, p. 646, Pl. XXXVI, Figs. 10-12; Pl. LVIII, Figs. 13-16.

1906. *Marginifera typica* Waagen var. *septentrionalis* Keidel. "Geologische Untersuchungen in südlichen Tien-Schan, etc." *Neues Jahrb. für Mineral.,* Beilage-Bd. XXII, p. 371, Pl. XII, Fig. 4.

1927. *Marginifera typica* var. *septentrionalis* Chao. "Productidæ of China, Pt. I, Producti." *Palæontologia Sinica,* Ser. B, Vol. V, Fasc. 2, p. 163, Pl. XVI, Figs. 34-37.

The shell is below medium size, wider than it is long, with the hinge line forming the greatest width of the shell.

The pedicle valve is strongly inflated. The curve is rather unequal in the longitudinal direction. The shell is moderately inflated in the visceral portion but becomes strongly geniculated anteriorly. After this geniculation, it is only slightly vaulted down to the anterior margin. Transversely the apical region is characterized by moderately steep cardinal flanks, while forward the shell surface is rounded to the steep lateral and frontal slopes. The beak is pointed, incurved at the extremity but not turned over the hinge line. The hinge line is straight, equaling the greatest width of the shell. The ears are well-developed, forming a slightly acute or nearly right angle at the cardinal extremities, flat and sharply marked off from the remainder of the shell by a row of spines, though this may not always be preserved. Not far from the beak a median depression commences, which develops rapidly into a pronounced sinus of uniform strength to the anterior margin. Its center is often a sharply defined depressed line.

The surface sculptures are nearly all destroyed among our specimens, and these deteriorated shells appear to be smooth. But from the remnant of the external shell adhering to some of them, we still can see that it is marked by many rounded, low radiating striæ. There is always a row of spines on the division line between the ears and the visceral portion of the shell and a single strong spine near each end of the hinge margin. A few other spines also occur upon the anterior portion of the shell. When the external shell is split off, the inner layers are seen to be covered with numerous fine forward-projecting pustular spines and pustule-pits.

The internal structure of the pedicle valve is shown in several internal molds. The surface of the mold is marked by numerous pustular pits corresponding to pustular spinules in the interior of the actual shell. The muscular impressions are well shown. The adductors lie as two elongated depressions, one on each side of the median line, not far from the beak. Anterior and outside of them, come the diductors which are flabellate and longitudinally striated.

The brachial valve is concave in the visceral portion, geniculated towards the front, following the curve of the opposite valve. The visceral cavity between the two valves appears to be comparatively thin, reaching a thickness of only about 3 mm. in a shell 25 mm. or more (No. 360) in width. The ears are flat, marked off from the remainder of the shell. The median fold is well pronounced. The surface is marked by many faint radiating striæ, and the interior by distant, regularly disposed, fine spinulose elongated pustules.

Internally, the marginal ridge is well shown in specimen No. 361 (Pl. XXX, Fig. 9). It is bordered on its outside in the auricular parts by a shallow groove which serves apparently for the reception of the ridge in the opposite valve. The median septum is long but not high, extending nearly to the marginal ridge in the frontal region. The brachial ridge is partly preserved. It appears to be strong and thick, forming a heart-shaped reëntrant at its frontal margin just as in typical *Marginifera typica*, but is a little larger. The internal surface is covered with numerous fine pustules. The latter are more numerous and stronger on the auricular parts outside of the marginal ridge. In the frontal part within the marginal ridge there exist a few strong spines.

Measurements:—

Serial Number	*No. 356*	*No. 357*
Plate and Figure	*XXX, 7*	*XXX, 6*
Height of pedicle valve	21.8 mm.	15.7 mm.
Height of pedicle valve from beak to anterior margin	21.0 mm.	14.0+ mm.
Length of pedicle valve along curvature	35.0+ mm.	29.0+ mm.
Length of hinge line	27.4+ mm.	24.4+ mm.
Width of pedicle valve	26.0 mm.	22.5 mm.

Remarks:—The presence of a strong spine at either end of the hinge line and of a regular row of spines on the lateral parts, as well as the general outline and surface sculptures, agree completely with Tschernyschew's typical variety from the Ural and the Timan. The only difference between them lies in the shape of the brachial ridges in the brachial valve, which, instead of forming a broad curve as in var. *septentrionalis*, are really filiform and simply hook-shaped as in typical *Marginifera typica*. But the external characters between them are so alike that I have little hesitation in identifying the Mongolian shells with the Russian variety.

The difference between *Marginifera typica* and its variety *septentrionalis* is very slight. It lies chiefly in the fact, as pointed out by Tschernyschew, that in the Russian variety there is always a strong spine with sometimes a thinner one on each end of the hinge line, and the spines on the lateral parts are less in number than in the Indian species.

Horizon and Locality:—In the Permian Jisu Honguer limestone of Jisu Honguer, Mongolia. *Marginifera* bed (1192). (Nos. 356–362). Collector, F. K. Morris.

98. **Marginifera gobiensis** Chao

Plate XXX, Figs. 1a-b (No. 367), 2 (No. 371), 3a-b (No. 368), 4 (No. 370), 5a-c (No. 363), (Nos. 364, 365, 366, 369)

cf. 1897. *Marginifera himalayensis* Diener. *Palæontologia Indica*, Ser. XV, Himalayan Fossils, Vol. I, Pt. 3. "The Perm-Carboniferous Fauna of Chitichun No. 1," p. 35.

cf. 1899. *Marginifera himalayensis* Diener. *Palæontologia Indica*, Ser. XV, Himalayan Fossils, Vol. I, Pt. 2, "Anthracolithic Fossils of Kashmir and Spiti," p. 39, Pl. II, Figs. 1-7; Pl. VI, Figs. 1-2.

1927. *Marginifera gobiensis* Chao. "Productidæ of China, Pt. I, Producti." *Palæontologia Sinica*, Ser. B, Vol. V, Fasc. 2, p. 165, Pl. XVI, Figs. 29-33.

This interesting shell is represented by sixteen specimens. It stands very near to the Himalayan species. Indeed, it is distinguished from the latter only by very subordinate characters.

The shell is a little below medium size, transverse to subquadrate in outline, with the hinge line marking the greatest width of the shell.

The pedicle valve is strongly inflated. The curve is rather unequal in the longitudinal direction. The apical region is low and flatly rounded, after which the shell becomes broadly but strongly geniculated downward at a place where the visceral portion meets the anterior part. After this geniculation, the curve becomes very moderate towards the anterior margin. Transversely the apical region is characterized by gentle cardinal slopes, but towards the front the impressed median portion turns a round angle at first and then falls steeply to the lateral margins. The beak is pointed, low and not turned over the hinge line. The latter is straight and always marks the greatest width of the shell. The ears are not well preserved, but appear to be not very large. They are flat and sharply marked off from the remainder of the shell by a row of spines. At variable distances from the beak a median sinus commences which varies somewhat in strength in different individuals but is always well-defined. In some specimens it appears to be broad and shallow, while in others it is narrow and deep. As a rule, it is most pronounced in the vicinity of the geniculated part but becomes shallower again towards the front.

The surface is marked by numerous radiating striæ which increase in number towards the front chiefly by bifurcation and intercalation upon the lateral parts. There are generally six striæ within a space of 5 mm. The striæ remain parallel for their entire length. Only in one shell do we see a very slight convergence of several striæ towards the mesial sinus. In well-preserved shells, the apical region is seen to be crossed by many concentric rib-like wrinkles which extend as far as the geniculated part and with the striæ produce a reticulation on the earlier part of the shell. The concentric undulations have about the same strength as the radiating striæ, but they are separated by broader interspaces. In the weathered specimens, however, the concentric undulations are very faint and appear as if they are entirely absent, though indications of their occurrence are generally seen on close examination. Besides these two kinds of sculptures, the surface is also marked by infrequent scattered spines. There is always a row of spines at the limit line between the ears and the remainder of the shell. Their exact number is not ascertainable, due to the splitting away of the shell, but it seems not to be very great, probably four to five. A few other strong spines are also likely to occur on the sinus-bounding lobes in the venter. So far as our specimens permit us to judge, there is not the slightest trace of spines in the apical region, except the two lateral rows of spines which are very constant.

The brachial valve is represented by several external molds. These are flattish in the apical region but become bluntly geniculated anteriorly, following the curve of the opposite valve. There is left thus only a very thin visceral cavity between them. The beak is prominent and slightly elevated. The ears are flat and fairly well differentiated from the remainder of the shell. The median fold commences in some cases not far from the beak, in others at the point of geniculation; it varies in strength among different individuals but is always well-defined. In some specimens, it is broadly rounded, in others rather sharp.

The surface is marked by the same kind of sculptures as the opposite valve, but the concentric element is more strongly pronounced. The radiating striæ increase rapidly in number by bifurcation, chiefly on the geniculated parts, and show a slight convergence towards the mesial fold (sinus on the interior of the valve). The concentric wrinkles cover more than one-half of the entire surface. They are far more prominent and coarser than the radiating striæ and are separated by deep valleys. As a result, the concentric wrinkles appear to be the dominant type of sculpture in the posterior portion of the shell, with only faint indications of the radiating system on top of them.

The internal structures are shown in a single individual (No. 371, Pl. XXX, Fig. 2). The marginal ridge can be clearly recognized in the left-hand posterior lateral corner of the valve. The median septum is long, extending to where the shell is geniculated, but it is not very pronounced. The brachial ridges are fairly well preserved and are apparently of the same type as in *Marginifera typica.* The muscular impressions are strongly deteriorated by weathering and can hardly be differentiated. From the small patches of actual shell adhering here and there upon the molds, the internal surface seems to be marked by numerous roundish pustules.

Measurements:—

	No. 363 (Pl. XXX, Fig. 5)
Height of pedicle valve..............................	22 mm.
Height of pedicle valve from beak to anterior margin....	20 mm.
Length of pedicle valve along the curve................	33 mm.
Length of hinge line................................	30 mm.

Remarks:—The Mongolian shell is just intermediate in character between *Marginifera typica* Waagen and *Marginifera himalayensis* Diener, but is distinct from either of them. The general outline of the shell and particularly the surface characters of the brachial valve resemble closely those of *Marginifera himalayensis* Diener, but the Mongolian shell differs from it in having a regular row of spines on each side of the lateral parts and some additional ones scattered here and there upon the surface. The latter characters bring it very near to *Marginifera typica* and its variety *septentrionalis*; from the former, however, it differs in the smaller number of spines and particularly in the presence of the prominent concentric sculpture and the absence of the marginal grooves in the brachial valve; from the latter, it is distinguished only by the prominent reticulation of the brachial valve and the non-depressed apical region.

Horizon and Locality:—This species seems to be rather common in the *Spiriferella rajah* bed (1209) of the Jisu Honguer limestone of Jisu Honguer, Mongolia, where it was collected by Mr. F. K. Morris. It has not been obtained from other layers.

99. Marginifera morrisi Chao

Plate XXIX, Figs. 28a-c (No. 376), 29a-c (No. 377), 30 (No. 372), (Nos. 373, 374, 375, 378, 379)

1927. *Marginifera morrisi* Chao. "Productidæ of China, Pt. 1, Producti." *Palæontologia Sinica,* Ser. B, Vol. V, Fasc. 2, p. 152, Pl. XV, Figs. 28-30.

The shell is below medium size, rectangular in outline, with the hinge line marking the greatest width of the shell.

The pedicle valve is strongly inflated. The curve is rather unequal in the longitudinal direction. The shell is only moderately inflated in the visceral portion and then curves rapidly through an angle of more than 270°. After this curvature, which in the final part sometimes approaches a geniculation, it is only slightly vaulted and forms a very insignificant curve down to the anterior margin. Transversely the apical region is provided with rather steep cardinal slopes, while still farther forward the sides fall vertically along the umbonal and main slopes to the lateral margins, forming a somewhat rectangular cross-section. The beak is pointed and prominent, overhanging the hinge line at its extremity. It is rapidly expanded towards the umbonal region, from whence forward the shell assumes a parallel growth along both sides, producing the characteristic rectangular outline of the shell. The ears are flat, sharply marked off from the remainder of the shell by a regular row of spines. Not far from the beak a median depression commences, which, as soon as the geniculated part is reached, develops rapidly into a narrow though well-defined sinus of uniform strength down to the anterior margin.

All our specimens have the external shell exfoliated. These deteriorated specimens appear to be perfectly smooth. But in one of the specimens (No. 372) (Locality 1208), the umbonal region is marked by faint but distinct and rather distant concentric wrinkles. Slightly above the ears upon the lateral parts are distributed several spines generally disposed in a regular row. Spines are also present here and there upon the whole surface of the shell. Another specimen (No. 374) shows faint radiating striæ, especially in the frontal region. They number on the average three to 1 mm.

The brachial valve is strongly concave in the visceral portion, following the curve of the opposite valve. The ears are flattish, sharply marked off from the remainder of the shell. The median fold is faint and low. The surface sculpture is not preserved, but the interior is coarsely pustulose.

The characteristic, thickened marginal ridge in the brachial valve is well represented in the frontal part of one of our specimens (No. 376, Pl. XXIX, Fig. 28). Upon this ridge a row of elongated pustules can be clearly observed.

Measurements:—

Serial Number	*No. 378*	*No. 377*	*No. 379*
Plate and Figure		*XXIX, 29*	
Height of shell	16.0 mm.	17.5 mm.	13.2 mm.
Height of shell from beak to anterior margin	13.0 mm.	14.3 mm.	12.0 mm.
Length of shell along the curve	31.0 mm.	38.0 mm.	20.0 mm.
Length of hinge line	20.0 mm.	17.4 mm.	16.0 mm.
Distance between two valves	6.5 mm.	....	....

*Remarks:—*In its general characters our species is the most nearly related to *Marginifera involuta* as described by Tschernyschew from the Ural and Timan. It agrees with this in the strongly geniculated pedicle valve, the characteristic rectangular outline, and the narrow but well-pronounced median sinus. But our shells differ from it in the presence of a regular row of spines upon the lateral parts, which is, according to Tschernyschew, absent in *Marginifera involuta*, and in the presence of some other spines upon the visceral portion and anterior part of the shell. If the surface sculpture is well preserved, there may be other points of difference.

*Horizon and Localities:—*This is a fairly common shell in the Jisu Honguer limestone of Jisu Honguer, Mongolia, occurring in the *Hemiptychina* bed (1196), in the *Camarophoria* bed (1208), and more rarely in the *Martinia* bed (1194). It was collected by Professor F. K. Morris, in whose honor it is named.

CHAPTER VI

PELECYPODA OF THE JISU HONGUER LIMESTONE

INTRODUCTION

THE Pelecypoda, or bivalve mollusks, cannot be considered as sparingly represented in the Jisu Honguer limestone, where 15 species have been found. Their number, however, in both species and individuals, falls so far short of that of the Brachiopoda that they are very easily overlooked, especially since few are of large size, and they are seldom well preserved. They are mostly, however, of types which are well represented in Permian strata elsewhere, and, although more than half of the species described are new, their relationship is close to other Permian species. On the whole, this fauna, too, is of an eastern aspect, although some types long known from the western European Permian deposits are present or are represented by closely related species.

Class **PELECYPODA** Goldfuss

Order HOMOMYARIA Zittel

Suborder HETERODONTA Neumayr

Family TRIGONIIDÆ Lamarck

Genus **Schizodus** King

1. **Schizodus subquadratus** Grabau, sp. nov.

Plate XXXI, Figs. 1a-d (No. 400)

This shell is represented by a left valve which is of approximately subquadrate outline, with the length slightly exceeding the height. The measurements of the holotype are: length 22.8 mm., height 21 mm., length of hinge line behind the beak 10.8 mm.

The valve is moderately convex with the beak incurved over the hinge line and lying slightly more than one-third the length of the shell from the anterior end. In front of the beak there is a lunuloid excavation, rather pronounced just below the beak, and dying away as a gentle concavity forward. There is, however, no actual demarcation of a lunule. The anterior margin descends rather abruptly. It is only slightly curved in front, but rounds more regularly into the basal margin, which is again only very gently arcuate as far as the posterior basal extremity, which is angulated. The posterior margin is straight, ascending with slight obliquity to the hinge line, with which it makes an obtuse angle.

The posterior part of the shell is strongly demarcated by the umbonal ridge, which extends obliquely from the beak to the posterior basal margin, forming a straight line. The triangular posterior part thus separated off is gently concave in the lower part but rather pronouncedly so in the umbonal region. The hinge line is straight, extending behind the beak to within a point anterior to the greatest posterior basal projection. The hinge structure is not determinable.

The surface is covered with regular, fine, elevated, concentric ridges, very narrow and rounded, with flat interspaces of much greater width, which are most prominent in the anterior half of the shell. In this part of the shell three of these ridges occupy one millimeter. On the anterior umbonal part they are more crowded, and frequently unite while others die out, having the character of intercalated ridges. On the posterior portion they are much more subdued, being especially faint behind the umbonal ridge.

Horizon and Locality:—In the *Hemiptychina* bed (1196) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Comparison:—This species resembles somewhat *Dolabra equilateralis* McCoy (1844, p. 65, Pl. XI, Fig. 14) from the Carboniferous limestone of Ireland. That species as figured by McCoy agrees with our form in the similarity of length and height, in the general outline, and in the straight umbonal ridge, but, according to Hind (1896–1905, p. 246), who refers it to the genus *Protoschizodus*, the type figured by McCoy is an imperfect shell, and quite unlike McCoy's figure, judging from the refigured type specimen (Hind, 1896–1905, Pl. XX, Fig. 7). The more perfect shells figured and described by Hind have the beak in the anterior third, but the shell is much longer than high, and the umbonal ridge is curved. Altogether, as judged from the figures given by Hind, the Carboniferous limestone species is quite distinct from our form. From *Schizodus truncatus* King, the type of the genus found in the Magnesian limestone (Permian) of Sunderland, England, and in the German Zechstein, it differs in the proportions, the European shell being longer in proportion to the height, while the posterior margin is rounded instead of straight as in our shell.

From the species of the Productus limestone of India our shell differs in the form, proportions, and in the straight umbonal ridge. Nor are there any similar species of this genus in the Guadalupian fauna.

The genus *Protoschizodus* was instituted by de Koninck for *Schizodus*-like shells occurring in the Carboniferous limestone (Dinantian), in which the left valve has two teeth situated anteriorly, the posterior and larger immediately below the umbo, while the right valve has a single tooth in front, with a fossa on each side for the reception of the teeth of the opposite valve. In *Schizodus*, on the other hand, there are three teeth in each valve, only one of these being a cardinal tooth, the anterior and posterior being lateral teeth. In our shell the teeth are not visible and hence the precise generic reference might be considered in doubt. Since, however, *Protoschizodus* is primarily a Dinantian genus, while *Schizodus* is chiefly Permian, though with Dinantian species, it seems safe to refer our shell to typical *Schizodus*.

2. **Schizodus elongatus** Grabau, sp. nov.

Plate XXXI, Figs. 2a-c (No. 401)

This species is represented by a single left valve of moderate size. It is slightly longer than it is high, the dimensions being, length 10.9 mm., height 10 mm., length of hinge line 8.3 mm. The umbonal region is elevated and the beak arched over but not incurved. It is laterally compressed and very prominent, rising above the straight hinge line which projects for perhaps 8.5 mm. behind the beak, but as the shell is broken at this point, the exact length cannot be ascertained. The longitudinal contour of the shell is a slightly asymmetric, rather strongly arched, curve from the beak to the posterior basal margin, the arching being somewhat more pronounced in the umbonal region than in the basal half. The greatest convexity is a short distance above the middle. In front of the beak the shell shows a slight excavation, but there appears to be no distinct lunule. Behind the beak the shell is abruptly depressed, the posterior dorsal slope being slightly concave to the hinge line. There is no umbonal ridge, but the rather abrupt depression of the posterior dorsal slope gives a suggestion of an appearance in that direction. Anteriorly the surface curves regularly but rapidly from the umbo to the anterior shell margin below the lunular excavation. If we place the shell with the hinge line in a horizontal position, the anterior margin below the excavation curves regularly backward with a moderate curvature, merging into the somewhat more strongly curved basal margin. The posterior slopes are rounded below but apparently subtruncate above, although because of the imperfection of the shell, this outline cannot be definitely ascertained.

The surface is apparently smooth, though faint radial striations are suggested on the internal mold, which is nearly all that is preserved of this species. Even the lines of growth are but obscurely indicated.

Horizon and Locality:—In the *Enteletes* bed (1190) of the Jisu Honguer limestone of Permian age, Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—This shell differs from the preceding in having the beak nearer the anterior end; in the stronger backward curve of the frontal margin which in *Schizodus subquadratus* is practically vertical, the result being a greater obliquity of the outline of the present shell; and in the undeveloped umbonal ridge or angulation, which is pronounced in the preceding species, where the posterior dorsal shell surface is also more strongly concave than in the present form. The beak of the present species is also more compressed and more elevated above the hinge line than in *Schizodus subquadratus.* There is no species in the Salt Range Permian which agrees with our form. At present I know of no form with which to compare it.

Family CONOCARDIIDÆ Neumayr

Genus **Conocardium** Bronn

3. **Conocardium jisuensis** Grabau, sp. nov.

Plate XXXI, Figs. 3a-d (No. 407), (No. 406)

This shell is represented by a single right valve (No. 407) of which the anterior part and the tubular prolongation are destroyed. Nevertheless the characters are sufficiently well preserved to permit description. Another imperfect shell (No. 406) may also belong here. The shell is of medium size for the genus, and the valve is very strongly convex.

Measurements:—The following are the measurements of the specimen described:

	No. 407
Dorso-ventral	15.0 mm.
Antero-posterior (length)	15.3 mm.
Length of anterior part in front of beak	14.0 mm.
Maximum thickness of valve	8.0 mm.
Height of posterior flattening	6.0 mm.

The beak is submarginal, with apparently a slight inclination toward the anterior end. It is strongly incurved, lying below the plane of greater elevation of the umbo. From beak to base the longitudinal contour is a regular curve of much shorter radius in the umbonal than in the basal region. Transversely the umbonal region is very strongly convex, while the anterior portion is separated from it by a very faint concavity, the anterior portion forming the greater part of the preserved length of the posterior part. The shell is, however, imperfect in the frontal region, so that the full extent in this direction is not determinable. The outline, too, is broken, but apparently it extended as an oblique slope to the basal margin, with probably a slight emargination in the line of the frontal sulcus. The basal margin is rather regularly and strongly rounded to the posterior end, which is truncate for a distance of one-third the height of the shell below the beak. This posterior truncation is not defined by an abrupt angulation, but rather by one of the shell plications. It is nearly at right angles to the plane dividing the valves, and is gently concave, not marked by striations, though there is a suggestion of a plica-like elevation near the margin. Just below the beak there is a semicircular excavation 1.7 mm. in diameter, which, if a similar excavation exists in the opposite valve, would mark the circular aperture from which the tubular posterior prolongation projects. The margin of this truncation is slightly elevated to produce a sharp suture.

The surface is marked by twenty-five or more fine radial plicæ. On the median part of the shell these are divided into two groups, a broadly rounded or nearly flat-topped plication alternating with one about half its width or less, while the interspaces between the plicæ are gently concave and of about the same width as the broader plications. Both sets of plications extend far up on the beak, and it is not possible to determine which of the two are primary, though on *a priori* grounds one would consider the broader plicæ to be primary. The last of the broad plications appears to unite beakward with the narrower one next posterior to it; that is, the two plicæ are formed by the unequal division of a primary one, and it may be that that is the origin of the other unequal plications as well, but this cannot be determined from our specimen. This double plication already lies far down on the posterior margin of the shell, and behind it are two more narrow plications which also seem to unite beakwards into a single one. It is the last of these which bounds the truncated posterior area. In the anterior part of the shell the plicæ are of more nearly equal size, that is, that of the narrower plicæ on the main shell surface. They become finer forward, especially in front of the ill-defined anterior sulcus.

In this anterior portion the striations or plicæ are cancellated by strong, sharp, concentric depressions; this results in furnishing the plicæ with a close-set regular series of subspinous nodes, giving this part of the shell a very distinctive appearance. It is in this part alone that the outer shell layer is preserved, which is probably the reason why the plications elsewhere appear essentially smooth, since over the greater part of the shell this layer has been removed. It is, however, to be noted that in the anterior part of the shell, where the lower part is denuded of the outer shell layer, the plications still contain some indication of the nodulation which is seen in their upper part where the shell-layer is present. On the other hand, the plicæ over the greater part of the shell scarcely show such nodulation, or at least show it only sporadically and intermittently; hence we may conclude that the anterior part of the shell is more strongly marked by these nodulated plications than any other part.

Horizon and Locality:—In the *Martinia* bed (1194) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris. Another specimen (No. 406) from the *Enteletes* bed (1190) seems to belong here, though the characters are so poorly preserved that the details cannot be determined.

Remarks:—This species seems to be distinct from those so far described from Permian rocks of Europe and America. Its chief characteristics appear to be the small size of the cardiform posterior region, the absence of a defining angulation, the alternating coarse and finer plications, and the strong cancellation of the plicæ of the anterior part.

Suborder DESMODONTA Neumayr

Family SOLENOPSIDÆ Neumayr

Genus **Sanguinolites** McCoy

4. **Sanguinolites modiomorphoides** Grabau, sp. nov.

Plate XXXI, Figs. 4a-c (No. 418), 5a-d (No. 480), (No. 416)

This shell is represented by a nearly perfect left valve (No. 418), from which the shell is partly destroyed by weathering, and by a second crushed and imperfect left valve preserving some parts of the shell in an unweathered condition (No. 416).

The shell is elongate, modiomorphoid in form, and divided into two parts by a very prominent and sharp umbonal ridge, which extends from the beak to the posterior lateral margin. In contour this ridge describes a nearly regular curve, somewhat more strongly arched in the umbonal region. When the shell is viewed laterally (Pl. XXXI, Figs. 4a-c), this ridge makes a strong curve across the umbonal region, but appears nearly straight on the greater part of the shell. For the most part, the angle of the ridge is about 99°, but it flattens out toward the posterior basal region and becomes rounded and rather strongly obtuse. The part of the shell below this angulation is moderately convex in the anterior region, but becomes almost flat posteriorly. Between the flat posterior and the convex anterior portion, there is a faint, broad and hardly perceptible oblique sulcation. The beak is incurved but not prominent, and the shell extends in front of it for a short distance, but because of the fact that both specimens are broken at this point, the full extent of the anterior projection is not determinable. The part above the angulation is gently concave, but is divided near the middle by another, broader, but less well-defined ridge, extending from near the beak to the posterior lateral margin. This ridge divides the upper part of the shell into two concave slopes, narrow at the beak but increasing in width posteriorly, and together with the dividing ridge forming the full height of the posterior part of the shell.

The margin of this portion is obliquely truncated. Above, it forms apparently an obtuse angle with the hinge line, though probably if the shell were complete, this would be seen to approach a right angle. If that is the case the upper of the two concavities is broader than the lower. Ventrally the posterior border rounds rather abruptly into the gently curved or nearly straight basal margin of the shell, which rises obliquely to the rounded anterior border. The surface of the shell appears smooth, even the growth-lines being obliterated by weathering. The character of the hinge line is not determinable.

Measurements:—The dimensions of this specimen are as follows:

	No. 418
Antero-posterior or length..............................	49.5 mm.
Height in the region of the beak:.......................	20 mm.
Posterior height, about.................................	31 mm.
Length of hinge line behind the beak (about)............	33 mm.

In the second specimen (No. 416) the umbonal ridge is rounded for a greater length, and the part below it is somewhat less flattened; otherwise the characters are essentially similar in the two specimens.

Horizon and Locality:—The more perfect specimen described (No. 418) was obtained from the *Lyttonia* bed (1193) and the other (No. 416) from the *Hemiptychina* bed (1196) of the Jisu Honguer limestone of Jisu Honguer, Mongolia. Collector, F. K. Morris.

Remarks:—In the sharpness of the umbonal angulation this shell resembles somewhat the specimen of *Sanguinolites visetensis* figured by Hind (1896–1905, Pl. XLIII, Fig. 3), but the ridge is more curved in the umbonal region in our shell, and the shell is as a whole more elongate. Moreover, other specimens of this species figured by Hind do not show this angulation to the same extent. In general form and outline, our shell resembles some of the specimens figured by Hind as *Sanguinolites striato-lamellosus* (1896–1905, Figs. 8 and 10) but the angulation of our shell is much more pronounced, and the concavity of the upper part much stronger. There is also some resemblance to *Sanguinolites striatus* (Hind, *loc. cit.*, Pl. XLVI, Figs. 1 and 2), but again the difference in the angle between the two parts is more pronounced in our shell. So far as I have been able to find, none of the described species has the pronounced characteristics of our shell, and I therefore make it the type of a new species.

5. **Sanguinolites** cf. **modiomorphoides** Grabau

Plate XXXI, Figs. 5a-d (No. 480)

An internal mold, with a little of the shell adhering, shows the general outline and the chief characteristics of the preceding species. At the same time, there are certain minor differences, which if the specimen were more complete might appear sufficient to separate it as a distinct species.

Measurements:—The following are the dimensions of this specimen:

	No. 480
Antero-posterior or length	39.3 mm.
Height at beak	14.2 mm.
Posterior height	23.3 mm.
Thickness of combined valves	23.6 mm.

The beaks are subanterior, depressed and apparently closely incurved. There is a very faint depression beneath them but not pronounced enough to be called a lunule. Behind the beak, the dorsal margin rises toward the posterior end, but this is very imperfect. The umbonal ridge begins at the beak, describes a gentle upward and outward curvature and then extends to the posterior basal margin, essentially as in the preceding specimen, but it is somewhat less sharply angulated. The surface below it is almost flat, but interrupted by several strong growth undulations and a faint sulcus, extending obliquely from near the beak to about the center of the ventral margin. In front of this sulcus, the shell is gently rounded to the frontal margin, the valves meeting in a very broadly obtuse angle, to form almost a flat surface. The dorsal portion of the shell above the umbonal ridge is also nearly flat, although close to the umbonal ridge there is a pronounced concavity which, however, is less intense than that of the preceding shell. The oblique ridge which divides this posterior portion is also less prominent than is that of the preceding shell, but otherwise is quite similar. The posterior end is imperfect, so that the outline cannot be determined.

A small portion of the shell remains around the beak, showing coarse irregular and rather sharply angular growth ridges, which are crowded beneath the beak, but extend in essentially parallel manner to the umbonal ridge, beyond which they are not preserved. These angular ridges are separated by much broader interspaces. No radial ornamentation is shown.

Horizon and Locality:—In the Jisu Honguer limestone, Mongolia. Exact level not known. (Cat. G. S. C. 1435; No. 480); one specimen. Collector, F. K. Morris.

Remarks:—The generic reference of this and the preceding shell is by no means above suspicion. They may indeed be referable to the genus *Sphenotus*, rather than to *Sanguinolites*, but since the hinge character is not shown precise determination is not possible.

6. **Sanguinolites olseni** Grabau, sp. nov.

Plate XXXII, Fig. 14 (No. 483)

Shell represented only by a right valve, which, however, is nearly complete, though it does not show the hinge structure. On that account the generic reference must be considered provisional.

Measurements:—The following are the measurements of the holotype and only specimen known.

	No. 483
Greatest length (anterior-posterior)	38.? mm.
Length of crescence line (beak to posterior ventral margin)	31.0 mm.
Height of valve at beak	15.5 mm.
Height at posterior end	14.0 mm.
Length of hinge line	29.0 mm.
Length of hinge line in front of beak	4.2 mm.
Thickness of valve (approximately)	5.0 mm.

The shell is elongate, more than twice as long as high, with the umbo rising above the elongated hinge line and the beak moderately incurved. Hinge line straight, extending for the greater part behind the beak and terminating in the abruptly truncated posterior margin. The short anterior portion ends in an obtuse angle, from which the shell rounds regularly to the antero-basal margin. There is a faint concave sulcus, which defines the anterior portion as a distinct auriculation.

A distinct, but somewhat rounded, umbonal ridge extends from the beak to the postero-basal margin. The shell surface above this ridge is almost flattened or very gently convex, becoming concave towards the beak, where the umbonal ridge becomes most prominent. There is no indication of a second ridge in this part of the shell, though there is a distinct deflection near the hinge, faintly suggestive of that seen in *Arca*, though there is no such defined hinge area. The shell below the umbonal ridge is more or less uniformly convex, though the rather strong concentric growth wrinkles modify that convexity. These growth wrinkles are especially marked in the internal mold and are rather irregular, especially towards the base of the shell. There is no sulcus, the basal margin continuing as a gentle curve from the rounded anterior margin to the postero-basal extension of the umbonal ridge, at which point it meets the posterior oblique truncation with a sharp rounded curve.

Only a small portion of the shell is preserved in front of the beak. This shows somewhat irregularly spaced but strongly elevated concentric laminæ, which are rather sharp and cancellated by radial elements, with the result that they are broken up into a series of rather strongly sub-spinose nodes. On the stronger lamellæ, these are distinctly in two series, a larger alternating with a smaller one.

Horizon and Locality:—In the *Martinia* bed (1194) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris. Named after Mr. George Olsen, preparator of the field staff of the Central Asiatic Expeditions.

Remarks: This species resembles somewhat the *Paralleloden* (?) *subtilistriatus* of C. Wanner (1922, page 72, Pl. CLIV, Figs. 14a-b) with which it agrees very closely in outline and proportion, though that shell is only about two-thirds the size of our shell. It has, moreover, a faint sulcus and the surface characters are distinct, the radial elements being continuous instead of broken into spinose nodes. The two species are probably congeneric.

7. **Sanguinolites** sp.

(No. 417)

An impression of the umbonal and upper part of the shell (No. 417) appears to represent a distinct form of *Sanguinolites*, in which the shell was elongate, with the umbonal angulation rather sharp in the anterior, but weak in the posterior part, and defining a rather strongly concave upper portion, which is comparatively narrow and without an additional ridge. The lines of growth show that this part is truncated very obliquely.

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia. Exact horizon not determined. Collector, F. K. Morris.

Order ANISOMYARIA Neumayr

Family AVICULIDÆ Lamarck

Genus **Pseudomonotis** Beyrich

Subgenus **Aviculomonotis** Grabau, subgen. nov.

8. **Pseudomonotis (Aviculomonotis) mongoliensis** Grabau, sp. nov.

Plate XXXI, Figs. 6a-c (No. 403), 7 (No. 405), 9a-c (No. 409)

cf. 1903. *Aviculopecten interstitialis* (Phillips). Hind, "A Monograph of the British Carboniferous Lamellibranchiata," Vol. II, p. 94, Pl. XIV, Figs. 16-21. (*Monographs*) *Palæontographical Soc.* (with older literature references).

This species is represented by three left valves, the shells of which have mostly been destroyed, but still show sufficient characters to permit diagnosis.

The largest of these specimens (Pl. XXXI, Fig. 6) has a height of 68.3 mm. and a length (anteroposteriorly) nearly the same, though it is impossible to give exact figures because of the imperfection of the shell. The valve is extremely convex at the umbo, which is laterally compressed so that the ears are separated by very pronounced concave sulci. The posterior side is the longer, thus giving the shell a rather marked obliquity of crescent line. The beak is overarching, but not markedly incurved, rising but slightly above the hinge line. The longitudinal contour from beak to base is an asymmetric curve, pronounced in the umbonal region, but rather gentle in the basal half. The umbonal sides are steep, the summit narrowly rounded. The anterior ear is not fully preserved, but appears to have been defined by a slightly less prominent sulcus than that defining the posterior ear. The latter is perfectly flat, making a right angle with the posterior umbonal slope, though the sulcus itself is rounded. The full extent of the posterior ear or wing is not ascertainable, but it seems to have been nearly as great as the maximum width of the shell. Towards the base, the transverse contour of the shell becomes broader, and the sulcus defining the posterior ear is less pronounced. The surface of the shell, so far as preserved, is marked only by eight or nine strong, distant, and rather narrowly rounded radiating plications which apparently begin at the beak, where, however, they are more closely crowded. Near the base of the shell the distance between their summits is from 6 to 7 mm., though the width of the plicæ themselves is only slightly over 2 mm. No finer striations or lines of growth are shown on this specimen, though at intervals there appear what seem to be stronger growth interruptions. The posterior ear is perfectly smooth except for indications of growth lines. The character of the anterior ear is not determinable, but in the case of both ears, only the internal mold is preserved.

Another specimen from the same locality (No. 405, Pl. XXXI, Fig. 7) has a height of 32.5 mm., and a maximum length, so far as can be determined, of 37 mm. It represents an internal mold from which the shell has been entirely removed. The posterior wing is strongly defined by a pronounced sulcus, the posterior slope of the shell and the surface forming essentially a right angle in the mold. It was probably less strongly pronounced in the actual shell-surface. The anterior ear is not preserved. The beak was rather strongly incurved, but is broken away. Beneath it, however, is seen the evidence of a triangular, rather strongly impressed, cartilage pit, curved longitudinally, but flat with sides depressed transversely. On either side the ears were characterized on the interior by a pronounced groove parallel to the hinge line, represented by a rounded fold in the mold, this groove having a width of about 1.3 mm. on the posterior wing but becoming broader towards the center. The anterior portion of this groove is only partly indicated, as most of the anterior ear is broken away.

The posterior muscular scar is well shown, being in the form of an elongated or irregularly oval, moderate elevation on the mold, indicating the form and depth of the scar.

The surface of the mold is apparently somewhat weathered, which has destroyed most of the impressions of the radii, but several of these are still faintly indicated near the middle of the shell. They were apparently of the same character as in the larger shell described.

When compared with the earlier stages of the shell, the convexity in vertical contour is scarcely less marked, but in anteroposterior contour it appears somewhat less, the umbonal region being less strongly compressed than in the larger shell. This difference, however, may be one of modification in fossilization.

A young shell of this species (No. 409, Pl. XXXI, Fig. 9) has a height of 18.2 mm., and a maximum length of perhaps 17 mm., the anterior part being imperfect. It is strongly convex, with the sides of the umbo compressed and abruptly descending to the ears, this being somewhat more pronounced in the posterior than in the anterior part. Both ears, though imperfect, are seen to be large and marked by fine radiating striæ, which are nodose and more closely crowded on the anterior than on the posterior ear. The coarser radii are also nodose, but only partly preserved as the shell is mostly destroyed.

Measurements:—The measurements of the three specimens may be summarized in the following table, though, because of the imperfections of the specimens, the measurements are largely approximate.

Serial Number........................	*No. 403*	*No. 405*	*No. 409*
Height................................	68.3 mm.	32.5 mm.	18.2 mm.
Length (anteroposterior)...............	69.? mm.	37.0 mm.	17.0 mm.
Thickness of left valve................	25.0 mm.	12.5 mm.	8.? mm.
Umbonal angle (about)..................	70°	74°	73°
Angle of crescens line with hinge (about)..	84°	82°	78°

Horizon and Locality:—All three specimens were obtained from the *Enteletes* bed of the Jisu Honguer limestone, Jisu Honguer, Mongolia. Collector, F. K. Morris.

Remarks:—This shell resembles to a marked degree the specimens of *Aviculopecten interstitialis* (Phillips) described and figured by Hind from the Carboniferous limestone of Great Britain, the two shells having almost identical form, though our large specimen is nearly twice the size of the British form. The maximum dimensions of the latter are 35 and 32 mm. for the anteroposterior and dorsoventral dimensions respectively. The British species has the same type of surface markings, but there are only six coarse plications with three finer ones between each pair, whereas in our shell the number is eight or nine. Moreover, the plicæ of the British shells are less closely nodulated. The reference of our species to the genus *Pseudomonotis* is questionable; probably it and the British form, as well as the two following species, should both be referred at least to a distinct subgenus, for which the name *Aviculomonotis* Grabau (subgen. nov.) is here proposed with *A. mongoliensis* as the genotype.

9. **Pseudomonotis (Aviculomonotis) kazanensis** (de Verneuil)

Plate XXXI, Fig. 8 (No. 404)

1881. *Pseudomonotis kazanensis* Verneuil. Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, p. 281, Pl. XXII, Fig. 3. (Older literature references.)

A single imperfect specimen agrees in all respects with the shell figured and described by Waagen. It is a left valve, with a length along the crescens line of about 37 mm. This is also the approximate width. The vertical height is only very slightly less, thus making the shell essentially equidimensional. The length and width of Waagen's shell are 42 and 40 mm. respectively. The beak, though imperfect, is seen to be scarcely compressed laterally, while the posterior ear is less strongly defined than in the preceding species; indeed, it is scarcely separated from the main part of the shell. The anterior ear, on the other hand, is more strongly defined, the shell being rather abruptly depressed in front of the umbo, producing a rather marked concavity at the beginning of the ear. The longitudinal contour has its greatest convexity in the dorsal third. The transverse contour is a nearly regular arch in the umbonal regions, except for the anterior abrupt depression. Ventrally the contour becomes flatter and more regular.

The surface characters are similar to those of the preceding species, characterized by eight, or nine, strong, but narrow, sharp, radiating plicæ which are separated by somewhat unequal interspaces. In the most distantly spaced the interval between the crests is about 5.5 mm. near the base of the shell, but the next adjoining interval is only 4 mm. The width of the plicæ is slightly less than 2 mm., and their summits are rounded, while the interspace between adjoining plicæ is very gently concave. These interspaces are characterized by three or four finer radiating striæ, about 1 mm. apart and distinctly noded, and between these, in some cases, still finer tertiary striæ are visible. The larger or primary striæ are also regularly noded at intervals of somewhat over a millimeter between the nodes.

The posterior ear is marked by fine radiating striæ, which likewise appear to be noded, but are more crowded than the finer striæ in the interplical spaces of the main part of the shell. The coarser plicæ are, however, absent from the ears. The character of the hinge is not determinable in our specimen.

Horizon and Locality:—In the *Enteletes* bed (1190) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris. Waagen's single specimen came from the Upper Productus limestone of the Salt Range. This species appears to be common in the Permian of Russia.

10. **Pseudomonotis (Aviculomonotis) matthewi** Grabau, sp. nov.

Plate XXXII, Figs. 1a-c (No. 402)

This species is represented by a single left valve with its counterpart in rock. The valve is extremely convex and only moderately oblique, the crescens line forming an angle of 70° with the hinge line. The length of the valve along the crescens line is 28.8 mm., while the vertical height is 27.2 mm. The width of the valve in the widest part below the ears is 23.6 mm., while the width at the ears is 26.8 mm. Of this, 16.3 mm. represents the distance from the beak to the tip of the posterior ear or wing, while 10.5 mm. represents the distance from the beak to the tip of the anterior ear. The beak rises considerably above the hinge line and is overarched and moderately incurved. It is strongly compressed laterally, both the anterior and posterior ears being separated off by strong concavities. The sides of the umbo diverge at an angle of 68°. The greatest convexity of the valve is about one-fourth of the height from the beak, from which point the longitudinal contour curves gently to the base, but is strongly arched to the beak. In the umbonal region the transverse contour is a high arch, with nearly vertical sides, but towards the base it becomes a regular and moderate curve. The anterior ear is tongue-shaped with a rounded end, and projects strongly in front of the beak. Below it the anterior margin of the shell is strongly excavated, so that the ear appears quite distinct from the shell as a whole. The outer half of the ear is flat and projects at right angles to the umbonal side of the shell. The wing is somewhat less strongly defined, especially towards the ventral part of the shell. Its posterior end is formed by an acute angle which does not project as far as the maximum extension of the shell below.

Between the posterior angle of the wing and the posterior margin of the shell there is a short but rather strong excavation. The posterior shell-margin is very gently rounded, the rounding becoming more pronounced towards the base where it merges into the general rounded surface of the basal part of the shell. The anterior margin is nearly straight and vertical to the excavation beneath the ear.

The surface is marked by numerous rather strong and somewhat irregular radial striæ of which there are from four to five in the space of 2 mm. near the base. These striæ are slightly flat-topped and separated by somewhat wider interspaces. They increase by intercalation of new ones toward the base.

Growth-lines are scarcely marked, but occasionally the radii appear faintly and irregularly nodose. There are also a few concentric, rather faint constrictions but no distinct sulci. The interior mold appears nearly smooth, though showing locally faint indications of the primary striæ. On the whole, however, the interior of the shell appears to be perfectly smooth.

Horizon and Locality:—In the *Hemiptychina* bed (1196) of the Jisu Honguer limestone of Jisu Honguer, Mongolia. This species is named in honor of the late Doctor W. D. Matthew, distinguished palæontologist of the University of California, formerly of the American Museum of Natural History.

Remarks:—In the obliquity of the crescens line, the compression of the sides of the umbo, the angle of divergence of the umbonal sides, the sharply demarcated ear, and the general pronounced convexity of the valve, this shell closely resembles our largest specimen of *Aviculomonotis mongoliensis*, previously described. Imperfect internal molds of these two forms would probably be indistinguishable. When the shell surface is intact, however, the character of the striæ readily distinguishes them, and even in the internal mold of the latter species, the small number of coarse plications is recognizable. The characters of the ears, too, when well preserved, will serve to distinguish these shells.

11. **Pseudomonotis furcoplicatus** Grabau, sp. nov.

Plate XXXII, Figs. 2a-b (No. 410), 3a-c (No. 411)

cf. 1881. *Pseudomonotis inversa* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 3, p. 284, Pl. XXII, Figs. 4a-b.

cf. 1893. *Aviculopecten plicatus* (Sowerby). Hind, "A Monograph of the British Carboniferous Lamellibranchiata." Vol. II, Pt. 2, p. 73, Pl. XII, Figs. 5, 6, 8 and 9. (*Monographs*) *Palæontographical Soc.* (with further synonymy).

This species seems to be represented by two small fragmentary specimens from the Jisu Honguer limestone. The larger of the two, a left valve (No. 410, Pl. XXXII, Fig. 2), is the most complete and shows the beak in an essentially central position, and apparently projecting slightly above the hinge line, although it is broken in our specimen. The sides of the beak diverge at an angle of nearly 90°; the ears on either side are defined by strong sulci, the ears themselves being essentially flat. The shell itself is only moderately convex, more so in the umbonal than in the basal region, but even in the umbo the transverse contour is a nearly regular arch, though slightly modified in front by a somewhat more abrupt depression, the sulcus defining the anterior ear, being deeper than that defining the posterior ear. The longitudinal contour is a subregular arch somewhat more strongly curved in the umbonal than in the basal region. The margin of the posterior ear is straight throughout the greater length, merging into the shell-margin about two-thirds of the shell-length from the beak. Upward, it curves outward to form the falcate margin which terminates in the acute end of the posterior ear, which, however, in our specimen is broken.

The anterior ear is imperfect but appears to have been small. The anterior shell slope facing it is flattened, becoming slightly concave at the ear. The frontal margin is regularly rounded.

The surface is marked by regularly rounded primary plications that begin at the beak and gradually increase in strength forward. At a very early stage some of these appear to divide into two nearly equal parts that usually remain closer together than do the simple striæ. This division of striæ appears to be irregularly distributed, the specimen in question showing three examples of it in the anterior half and two at least in the posterior part. In addition to this, secondary striæ appear in the interspaces, but these always remain much smaller than the primary striæ. Even tertiary striæ are indicated in one or two places. Near the base of the shell, the distance between the crests of five of the primary striæ is 4.5 mm., but there is a slight variation, the distance between crests of adjoining striæ being in some cases slightly more, in others slightly less than 1 mm. The striæ appear to be crossed by concentric lines, but these are only imperfectly indicated. Where shown, they produce a faint nodulation upon the striæ.

Measurements:—The length of the specimen described (No. 410) is 18 mm. The maximum width, which is below the middle, is somewhat over 16 mm., originally about 18 mm. The length of the hinge line is approximately 8 mm.; of this, 6.5 mm. extends behind the beak.

The smaller of the two specimens (No. 411, Pl. XXXII, Fig. 3) is very imperfect, and little can be said of it, except that the primary striæ more frequently show the division into two equal parts, and the striæ appear to be somewhat sharper than in the larger shell. The secondary striæ are fine and sharp. The specimen is too imperfect to permit measurement, but the divergence of the umbonal sides seems to be at a somewhat lesser angle.

The measurements of specimen No. 411 are: height 9 mm., length 9 mm., length of hinge behind the beak 1.3 mm., total length of hinge 3.3 mm.

Horizon and Locality:—The larger of the two specimens was obtained from the *Orthotychia* bed (1211); the smaller from the *Enteletes* bed (1190) of the Jisu Honguer limestone, Jisu Honguer, Mongolia. Collector, F. K. Morris.

Remarks:—This shell has the general form and character of Sowerby's *Aviculopecten plicatilis* from the Carboniferous limestone of the British Isles, but the angle of divergence of the umbo is less in our shell than in the English and Irish forms, where it ranges from 116° to 123°. The bifurcation of the striæ is seen in the illustrations of some of the Irish shells, but it seems to be less striking than in our form, the two branches not retaining the same association that they do in our species. Furthermore, the secondary striæ increase in size more rapidly in the British form. While it is possible that better preserved material will show other characters in which our shell is distinct from the British species, the fact remains that it is very closely related to it.

Genus **Deltopecten** Etheridge

12. **Deltopecten** cf. **subquinquelineatus** (McCoy)

Plate XXXII, Figs. 4a-b (No. 419)

cf. 1847. *Pecten subquinquelineatus* McCoy. "On the Fossil Botany and Zoölogy of the Rocks Associated with the Coal of Australia." *Ann. and Mag. Nat. Hist.*, Ser. I, Vol. XX, p. 298, Pl. XVII, Fig. 1.

cf. 1906. *Deltopecten subquinquelineatus* Etheridge and Dun. "A Monograph of the Carboniferous and Permo-Carboniferous Invertebrata of New South Wales," Vol. II, Pt. 1, p. 26, Pl. III, Fig. 2; Pl. IX, Figs. 1-5; Pl. XII, Figs. 2 and 3; Pl. XIII, Figs. 2 and 8; Pl. XIV, Fig. 1. *Mem. Geol. Survey of New South Wales*, Pal., No. 5.

This shell appears to be represented in our collection by a single crushed specimen, apparently a right valve. Though much compressed, it appears to have been of moderate convexity only, and although very imperfect it permits of at least approximate measurements.

Measurements:—Those obtained are as follows:

	No. 419
Total height	39.4 mm.
Height, beak to base	37.5 mm.
Maximum transverse diameter	43.7 mm.
Length of hinge line	24.5 mm.
Height of hinge area	2.0 mm.
Basal width of triangular cartilage pit	11.0 mm.
Length of anterior ear from beak	14.8 mm.
Length of posterior ear from beak	11.4 mm.
Depth of anterior auricular sinus	6.2 mm.
Frontal width of broadest striæ	1.7 mm.
Frontal width of narrow striæ	0.5 mm.
Umbonal angle	91°

The shell is represented merely by an impression in the rock, which, however, shows well the broadly triangular hinge area, and the central subumbonal chondrophore, which distinguishes *Deltopecten* from *Aviculopecten*. The chondrophore, however, is more broadly triangular than is usually the case in this genus, though a specimen of *Deltopecten subquinquelineatus* figured by Etheridge and Dun (1906, Pl. XIV, Fig. 1) comes near it. The hinge area is rather coarsely striated parallel to the hinge line, whereas the chondrophore shows in addition, fine diagonal striæ, which, however, are not parallel to its sides but make an angle of nearly 45° with the hinge line, whereas the angle between the side of the chondrophore and the hinge line is only about 17°.

In size and form our specimen corresponds most nearly to the right valve figured by Etheridge and Dun (*loc. cit.*, Pl. XI, Fig. 5), but the anterior ear of our specimen is narrower and does not show these striations. Its anterior end is rather squarely truncate, and the sinus beneath it is deep and large. The posterior ear forms essentially a right angle with the hinge line, and then is rounded to the lateral umbonal margin, producing an emargination of moderate amount. In the internal mold the umbonal slopes facing the ears are abrupt, in places vertical and even concave, and sharply angulated at the point of departure from the shell surface. From the general aspect of the internal mold it would appear that the umbonal part was rather convex, though the main part of the valve is rather flat. The striæ are very irregular; sometimes there are two strong, rounded, or flat-topped striæ with a much broader concave interspace. Between these pairs of coarser striæ there are finer ones, three of which take up about the space occupied by the larger two. New striæ arise by intercalation in the intervening areas, or by the bifurcation of the flat-topped striæ. Some of the striæ show an obscure nodulation, but as the shell is not preserved the extent of this is not determinable.

Horizon and Locality:—In the *Marginifera* bed (1192) of the Jisu Honguer limestone, Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—In identifying this specimen with McCoy's species, I am actuated by a desire not to give a new name to an imperfect specimen, rather than convinced of the absolute identity of our shell with the European form. There is, however, enough resemblance of our specimen to the smaller forms, described and figured by Etheridge and Dun from the Permo-Carboniferous of Australia, to consider it at least representative of that general type. The Australian form is perhaps a little more flattened in the right valve, the left valve being more strongly concave. The hinge plates or cardinal areas of the Australian forms are densely grooved with fine resilium furrows, whereas in our shell only a few of these are recognizable. The chondrophore in the right valve of the Australian specimens is described as "very large, semicircular and deeply furrowed," and "concentrically furrowed by a continuation of the resilium furrows." The distinction of primary, secondary and tertiary striæ, possible in the Australian shells, can hardly be made in our shell where bifurcation is more frequent than intercalation.

Family PECTINIDÆ Lamarck

Genus **Euchondria** Meek

13. **Euchondria (?) englehardti** (Etheridge and Dun)

Plate XXXII, Figs. 5a-c (No. 396), 6a-c (No. 397), 7a-c (No. 398), 8a-c (No. 399), (No. 481)

1906. *Aviculopecten englehardti* Etheridge and Dun. "A Monograph of the Carboniferous and Permo-Carboniferous Invertebrata of New South Wales," Vol. II, Pt. I, p. 17, Pl. IX, Figs. 6, 7, 8, 9. *Mem. Geol. Survey of New South Wales*, Pal., No. 5 (*cetera exclus*).

Measurements:—Measurements of characteristic specimens are as follows:

Serial Number	*No. 396 left*	*No. 397 right*	*No. 398 right*	*No. 399 left*
Plate and Figure	*XXXII, 5*	*XXXII, 6*	*XXXII, 7*	*XXXII, 8*
Length	20.8	15.6	19.3	21.2
Height	20.7	16.1	19.4	21.2
Thickness	6.1	3.5	5.5	6.0

This is a shell with length and height equal. It is subequivalve, and moderately convex. The valves are very inequilateral with the posterior end the shorter.

A characteristic left valve (No. 396, Pl. XXXII, Fig. 5) has the beak situated about five-sevenths of the length of the shell from the anterior end. It is acute and slightly pointed forward, with the umbonal slope in front of it rather strongly concave and steeply descending to the anterior ear, which is strongly depressed and distinctly marked off by the abrupt depression of the umbonal slope. The ear itself is not well preserved, and its exact outline cannot be ascertained, but it appears to be large, with a straight upper margin ending in an acute anterior point.

The anterior shell-margin is strongly and regularly rounded and is continued without change into the ventral margin which also is regularly rounded, but to a slightly greater radius. The posterior margin also is rounded, but to a much larger radius, the rounding being continuous and regular from the beak to where it merges into the ventral margin. The posterior umbonal slope is somewhat more strongly depressed than the anterior, but the posterior ear is also strongly marked off by this depression. The posterior ear is not well preserved, but it was much smaller than the anterior, not extending beyond the posterior border of the valve.

The longitudinal contour is almost a regular moderately convex curve, slightly more pronounced at the beak than at the front. The transverse contours are strongly convex, with abruptly descending sides in the umbonal region, more gently and uniformly arched in the lower part, the curve not being symmetrical because the greater convexity is in the posterior third.

A somewhat smaller right valve (No. 398, Fig. 7) has the beak in essentially the same position, but the convexity of the umbonal region is slightly more pronounced. The anterior umbonal slope is concave as in the left valve and descends as abruptly, but the anterior ear appears to be more strongly depressed, so that the ear forms with the anterior umbonal slope a continuous gently concave surface. It should, however, be remarked that this part of the shell is imperfect, and it is not possible to say with certainty that the form of the ear, as described, is wholly correct.

The outlines correspond in all respects to that of the left valve, but the posterior ear is not shown in this specimen, nor is it positively recognizable in a still smaller right valve (No. 397, Fig. 6).

The surface of the shell is marked by fine regular growth-lines, of which in the left valve (No. 396, Fig. 5) there are five or six to 1 millimeter. On the anterior umbonal slope of the right valve (No. 398, Fig. 7) are seen fine subdued radiating striæ, about five to 1 mm., and they are again visible on the posterior umbonal slope, where, however, they appear to be somewhat finer. The anterior ear also seems to have been striated, somewhat more coarsely, but this is not definitely ascertained because of the imperfection of this part of the shell. The main part of the valve does not show these striæ, nor are the concentric growth-lines well shown. In the smaller right valve (No. 397, Fig. 6), the striæ are shown in the posterior part of the shell and faintly indicated in other parts where the shell is slightly exfoliated. There appear to be no striæ on the left valve; at least they are not preserved in our best specimen (No. 396, Fig. 5), though in another one (No. 399, Fig. 8) there is a suggestion of them near the front.

Horizon and Locality:—In the *Enteletes* bed (1190) and the *Hemiptychina* bed (1196) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; not rare. Collector, F. K. Morris.

Comparisons:—The shells described and figured by Etheridge and Dun from the "Permo-Carboniferous" (probably Permian) of New South Wales under the name *Aviculopecten englehardti* Etheridge and Dun (1906, Pl. IX, Figs. 8 and 9), are very variable in size and form. The two shells most nearly resembling our form have lengths of 19 and 26 mm. and heights of 22 and 27 mm. respectively, being thus slightly longer than they are high. The anterior obliquity is strongly marked, but the beak seems to be somewhat less eccentric than in our shells. Some of the other shells figured by these authors have a more central beak, and may not belong to the same species. The largest shell figured by Etheridge and Dun has a length of 46 mm. and a height of

44 mm. and shows the characteristic anterior obliquity and slightly concave anterodorsal margin of our shells. If we take this, and the right valves shown in figures 8 and 9, as typical, we can refer our shells to this species, for they have not only essentially the same form, but also the surface features of fine, close and regular concentric, and still finer radiating striæ. The distant latilamellæ are, however, not marked in our shells.

Etheridge and Dun refer to the figure of an *Aviculopecten* sp. from the Zewan beds, given by Diener (1899, Pt. 2, Pl. I, Fig. 3), which they consider "indistinguishable from *Aviculopecten englehardti.*" I am, however, obliged to differ from their view, if the strongly oblique shells described by the Australian authors are to be regarded as typical of the species. Not only is Diener's shell much less oblique, with a much less eccentric beak than in the Australian and in our Mongolian shells, but the anterior dorsal margin is straight in the Himalayan shell, whereas in the Mongolian specimens, and those of essentially similar size from New South Wales (Etheridge and Dun, 1906, Pl. IX, Figs. 8 and 9), this margin is concave.

Waagen figures a small shell from the Upper Productus limestone of the Salt Range, which has some of the characters of our shell, though the beak is nearly central on the valve and the height is only three-fourths of the length. It has, however, the forward-pointing beak, the projecting anterior end and the concave anterodorsal margin of our specimen. Waagen refers this shell to Meek's genus *Euchondria* under the name *Euchondria subpusilla* Waagen. The surface of this shell is quite smooth, fine regular growth lines being detectable only with difficulty under the lens. There are also faint traces of radiating sculpture on the wing.

While it is, of course, distinct specifically, Waagen's shell is without much doubt congeneric with our shells. That these can not be retained in the genus *Aviculopecten* is evident, nor, as pointed out by Waagen and by Etheridge and Dun, can they be referred to *Streblopteria* McCoy. Waagen holds that, though the posterior wing of *Pecten neglectus* Geinitz (the genotype of Meek's genus *Euchondria*) "is somewhat larger than the anterior one, yet the Permian species like *Pecten pusillus* Schlotheim, etc. might far better be united with *Euchondria* than with *Streblopteria.*"

Pecten pusillus Schlotheim of the north European Zechstein is also a small shell, with the beak subcentral and with the anterior ear larger than the posterior. Its anterodorsal margin, however, is not concave, or not perceptibly so.

It will probably be necessary to create a new genus for the Australo-Asiatic Permian shells here described, but at present the material is too incomplete and imperfectly preserved to warrant such a procedure. As I am unwilling to leave these shells under the much-embracing generic designation

Aviculopecten, I shall for the present, though with a query, refer them to Meek's genus *Euchondria*.

Girty (1908, p. 433, Pl. IX, Figs. 3, 3a) has described and figured a left valve from the Capitan formation (Guadalupian) of Guadalupe Mountain, under the name *Camptonectes* (?) *papillatus* Girty, which agrees in all respects with our shell, though it is smaller, being scarcely more than half the size of our shell, but of exactly the same outline and proportions. The surface characters of his shell are, however, of a nature which appear to separate it from our specimens. He describes the surface as "marked with papillæ which increase in size proportionately to the dimensions of the shell. Over the upper half they are small, and the surface appears to be almost smooth. They have a sort of quincunx arrangement, such that they tend to form two sets of curved lines intersecting at an acute angle. These lines are concave toward the anterior and posterior sides of the shell. Their curvature is greatest near the margins, especially near the lateral margins. In this region also the linear arrangement is more strongly marked, and tends to develop into connected ribs [striæ]. The papillæ appear to have been the bases of small spines pointing radially and almost tangentially to the surface." This feature seems to be wholly wanting in our left valve, where the concentric growth lines are the only ornamentation, but in the less perfect specimen (No. 399, Fig. 8), there is one spot near the base where the growth lines are interrupted by the radii producing a papillation, but this is not nearly so pronounced as in Girty's shell. Nor is this structure shown in any of the right valves, where the radii, when shown at all, are continuous. If it were not for these surface features, however, we should have to refer our shells to a large form of Girty's species. I do not, however, feel that these shells are referable to *Camptonectes*, under which Girty himself placed them doubtfully.

Genus **Pseudamusium** Klein

14. **Pseudamusium auriculatum** Grabau, sp. nov.

Plate XXXII, Figs. 9a-b (No. 408), 10 (No. 443)

cf. 1908. *Camptonectes* (?) *asperatus* Girty. "The Guadalupian Fauna." *U. S. Geol. Survey Professional Paper* No. 58, p. 434, Pl. IX, Figs. 1, 2.

This species is represented by the internal mold of two right valves of somewhat imperfect character. In the first of these (No. 408, Pl. XXXII, Fig. 9), the shell is somewhat higher than wide, with a pointed beak, and the sides of the umbo diverge at an angle of 78°, which increases at a later stage to 86°. The anterior umbonal margin is gently concave in outline, while the posterior is as gently convex. This gives the beak a decidedly forward-pointing aspect, though it is situated near the center of the shell. The transverse contour of the umbonal portion is gently convex, with the sides abruptly turned down so that the ears are defined by a pronounced sulcus on either side. At the point of greatest transverse diameter of the shell, which is a short distance below the mid-height, the contour is gently and regularly convex from side to side. The convexity is so moderate that the shell at first glance appears almost flat. The frontal and side margins of the shell, to the points of greatest width, form a regular curve, almost a semicircle.

The anterior ear is large, defined by a deep and strong emargination; the lower and outer margins form a regular curve, while the superior extremity appears to describe a rectangle, though part of it is broken. The ear is flat except for a faint submedian uparching. It is separated by a sharp sulcus from the umbonal part of the shell. The posterior ear is not fully preserved. The hinge line is straight, projecting somewhat beyond the beak. Above it appears another narrow shell-band, which, along the anterior half of the hinge line, is in contact with it. (This is omitted in the figures.) At the point of contact, both the hinge margin of the ear and that of the shell-band above it show fine vertical denticulations such as those in *Crenipecten*, but finer. The posterior continuation of this contact is interrupted by a fracture. It is difficult to determine whether this shell-band is a part of the hinge of the valve or is that of the opposite valve spread out flat in the same plane with the right valve. The distinct line of demarcation, where the two come in contact, and the marginal crenulation suggest the latter alternative.

The surface of the internal mold is smooth except for occasional coarse but very gentle concentric undulations, indicating irregularity of growth. A small fragment of the shell-surface is, however, preserved in one spot, and this shows flat, uniform, concentric laminæ, separated by sharply incised grooves. There are about four of these concentric laminæ in one millimeter. They are of the same elevation, and so flat and so uniform, that the surface is perhaps better described as characterized by a succession of regularly spaced, fine, but sharply incised concentric grooves.

The largest specimen (No. 443, Pl. XXXII, Fig. 10) agrees in all essentials with the one described, except that the longitudinal contour is slightly more convex and the anterior ear larger. The umbonal sides are gently concave in the front and convex behind, with the same abrupt depression of the sides to the flat ears seen in the smaller shell. The posterior ear, which here seems complete, is small, and terminates almost in a rectangle, whereas in the smaller specimen this is slightly obtuse. No surface characters are preserved.

Measurements:—The measurements of the two specimens obtained are as follows:

	Holotype No. 408	*No. 443*
Plate and Figure	*XXXII, 9*	*XXXII, 10*
Entire height of shell	20.7	25.0
Height from beak to base	18.8	24.4
Distance from beak to point of greatest length	10.9	14.5
Maximum length (antero-posterior)	17.1	23.0
Length of hinge line	14.0	10.0?
Length of anterior ear from beak	6.8	9.5
Width of anterior ear	4.2	4.0?
Apical angle	78°–86°	75°–86°

Horizon and Locality:—In the *Enteletes* bed (1190) of the Jisu Honguer limestone of Jisu Honguer, Mongolia; two specimens. Collector, F. K. Morris.

Remarks:—The non-radiate surface of the shell and the general form and character would indicate that this shell is referable to the genus *Pseudamusium*, to which Hind has referred a number of species from the Carboniferous limestone of the British Isles. Our shells differ, however, from the species described by Hind in the more acute apical angle, the larger ears, both anterior and posterior, and in the regular concentric groovings which characterize the surface. The forward-turned beak suggests somewhat the species of the genus *Obliquipecten* Hind, but this curvature is less pronounced in our shell than in the species from the Carboniferous limestone, and the ears of our specimens are more pronounced, especially the posterior one, which is wanting in the typical species of that genus. This makes the hinge line much shorter in *Obliquipecten* than in the shells here described.

In general form this shell is not unlike *Camptonectes* (?) *asperatus* Girty (1908, p. 434, Pl. IX, Figs. 1–2), but the apical angle of that shell is very much larger, reaching 103° in the early part and increasing to considerably more than that in the later part. The American shell also lacks the abrupt downward deflection of the umbonal sides so characteristic of our shell, and its surface is characterized by the two sets of diverging, radiating striæ, whereas in our shell the surface marking is concentric. The American specimens also are much smaller and apparently more convex than our specimens. The genus *Camptonectes*, according to Verrill, "is generally regarded as only a section of *Pseudamusium*."

15. **Pseudamusium cf. auriculatum Grabau**

Plate XXXII, Figs. 11 (No. 412), 12 (No. 413), 13 (No. 299b)

Two small smooth pectiniform shells (Nos. 412, 413) appear referable to this genus, but not enough is shown of their characters to make exact specific diagnosis possible.

Measurements:—They show the following dimensions, to which are added those of a third shell (No. 299), described below:

	No. 412	*No. 413*	*No. 299*
Plate XXXII, Figure	*11*	*12*	*13*
Dorso-ventral diameter	14.2 mm.	12.9 mm.	9.0 mm.
Antero-posterior diameter	11.7 mm.	11.5 mm.	7.9 mm.
Length of hinge line	6.0 mm.	....	3.6 mm.
Divergence of umbonal sides	72°	77°	80°

The first two shells are both left valves, and they are very gently convex, becoming almost flat towards the base. The umbonal sides are abruptly turned down, more strongly so in the anterior side. The sides diverge at an acute angle. The outline of the anterior portion is very gently concave, and the posterior one similarly convex. These curvatures are, however, so slight that the sides appear to form straight lines. The anterior ear is large, flat and well defined, its outer edge rounded and forming essentially a rectangle with the hinge line. The posterior ear is also well defined, but much smaller.

The greatest width of the shell lies below the mid-height, from which point the margin is regularly rounded across the base.

As the specimens are internal molds without fragments of shell adhering, they appear perfectly smooth. There are, however, suggestions of a concentric grooving as in the preceding species, and in certain positions there appear to be shown fine radial lines, which are, however, so indistinct that it is not possible to say whether these represent actual striations.

Horizon and Locality:—In the *Enteletes* bed (1190), of the Jisu Honguer limestone, Jisu Honguer, Mongolia; two specimens. Collector, F. K. Morris.

Remarks:—It is possible that these shells represent the young of the left valve of the preceding species with which they agree in most respects, unless it should appear that the present shells are striated, when they will have to be referred to another species. They occur associated with the type form in the *Enteletes* bed.

A third, somewhat smaller shell (No. 299), also a left valve, likewise appears referable to this species, although it is more convex than the preceding two described. The convexity, however, is not greater on the whole than that of the adult shells of the species to which this is referred. There is, however, one marked difference, and that is, that the umbonal region is more convex and the beak more strongly incurved than in the other shells.

In proportion this shell agrees with those previously described, and there is the same abrupt deflection of the umbonal sides to the flat ears. The anterior ear is largest, with its terminal angle very slightly obtuse and its outer border nearly vertical, but not projecting as far as the body of the shell below. The posterior ear appears to be small, but it is not well preserved.

The beak is essentially central, with the sides diverging at an angle of about 80°, but there is scarcely any difference in the outline of the umbonal sides, both being nearly straight. The rest of the outline of the shell is rounded, the greatest diameter being below the middle. The surface of the shell is smooth except for subregular concentric growth-lines. There is also a very faint indication on the shell, which is mostly preserved, of indistinct radial striæ. The measurements of this shell, No. 299, are given in column three of the table above.

The indications of radiating striæ in the lower shell layers, though faint, are unmistakable, and this would indicate that the shell belongs to a distinct species. This is also suggested by the somewhat greater convexity of the umbonal regions and the stronger incurvature of the beak. For the present, however, I prefer not to give it a separate designation.

Horizon and Locality:—This shell (No. 299) was also found in the *Enteletes* bed (1190) of the Jisu Honguer limestone of Jisu Honguer, Mongolia. Collector, F. K. Morris.

Family MYALINIDÆ Frech

Genus **Myalina** de Koninck

16. **Myalina falcata** Grabau, sp. nov.

Plate XXXIII, Figs. 1a-d (No. 414)

The shell is subpyriform in outline, equivalve, and depressed convex. The valves are extremely inequilateral. The beak is anterior, pointed, with the hinge line behind forming a nearly straight line for about half the length of the shell, behind which line the shell margin curves into the regularly rounded posterior margin of the shell. The ventral margin has a curvature, continued for about the same distance or somewhat less, after which it becomes a nearly straight line forming a very gentle concavity as it slopes upwards to the anterior beak. Where the margins are rounded, in the posterior third, they form a very sharp edge, because the valves in this portion are almost flat. Forward, however, the shell becomes thickened because of the increase in the convexity of the shell, and here both dorsal and ventral margins present a thickened edge, while behind the beak the dorsal margin becomes depressed into an elongated escutcheon, which extends the entire length of the hinge line.

On the ventral side there seems to be a corresponding depression bounding the byssal opening. Thus the valve margins, while expanded in the posterior part of the shell, are distinctly contracted in the anterior part, this becoming more marked towards the beak where the vertical distance below the shell margins is distinctly less than the vertical height of the shell. Both the dorsal and ventral borders of the shell in the anterior part round into the depression, there being no sharp angulation.

At the beak, the sides of the valves are gently convex from the dorsal to the ventral depression, but in the posterior three-fourths of the shell this convexity is confined to the dorsal half of the valve, the ventral half being flattened or depressed; this is especially shown in the internal mold, where a distinct depressed area, bounded dorsally by a falcate or sickle-shaped, ridge-like rounding, characterizes the ventral portion (see Pl. XXXIII, Fig. 1a). Where the shell is present this area appears merely as a flat surface.

The shell itself is rather thick, especially in the ventral depressed area where it attains a thickness of 3 mm. or more. It is thinner in other parts, probably not more than half that thickness over the convex dorsal part of the valve.

The surface of the shell is characterized by rather coarse irregular growth-lines, and apparently also by subdued concentric wrinkles, though this is not ascertainable with certainty because of its weathered condition. The internal mold is smooth, except for the irregularities of contour. The ovoid posterior adductor scars are faintly indicated in the mold. They lie some distance below the dorsal margin and beyond the end of the hinge line. The anterior adductor scar lies near the anterior end of the depressed area.

Measurements:—The following are the dimensions of the holotype and only known specimen:

	No. 414
Antero-posterior; length	66 mm.
Dorso-ventral; height (maximum)	41 mm.
Maximum thickness of mold (representing depth between valves)	17.8 mm.
Length of hinge (approximate)	46 mm.

Horizon and Locality:—In the *Martinia* bed (1194), of the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—This species appears to be unlike any I have seen described from Carboniferous or Permian rocks. Its most distinctive feature is the falcate ridge which bounds the depressed area of the internal mold.

17. **Myalina** cf. **verneuili** (McCoy)

Plate XXXIII, Figs. 2a-b (No. 415)

cf. 1897. *Myalina verneuili* (McCoy). Hind, "A Monograph of the British Carboniferous Lamellibranchiata," Vol. I, Pt. II, p. 115, Pl. III, Fig. 6; Pl. IV, Figs. 3-8. (*Monographs*) *Palæontographical Soc.*, Vol. LI (with older synonymy).

This is represented by an internal mold only. The shell is equivalve, extremely inequilateral, of subtriangular outline, with the dorsal and ventral margins nearly straight, and diverging at an angle of about 57°. The posterior border is broadly rounded. The beaks are anterior, spreading in the internal mold, rounded, with the inner shell-margins contracted both above and below so as to produce a distinct depression in the dorsal as well as in the ventral border of the internal mold. The hinge line is straight, extending for the greater part of the length of the shell behind the beak, and marked on the internal mold by a distinct depression or escutcheon. It forms an obtuse angle with the posterior border. The ventral border is straight with the byssal opening narrow, elongate, and lying in the depressed ventral area. The lateral surfaces of the shell curve abruptly inward to the ventral margin, this curvature being rounded, not angulated. This incurved portion gradually dies away towards the posterobasal margin, where it merges into the sharp posterior shell-border. In like manner the dorsal portion of the shell curves over abruptly, but without angulation, to the hinge line. At the posterior end the valves meet to form a thin wedge, but forward they expand so that the thickest part of the mold (and presumably, within bounds, that of the shell as well) lies in the anterior third. The surface of the internal mold is rather irregularly undulating, which may be the result of weathering. Only faint lines of growth are indicated.

Measurements:—The dimensions of the rather imperfect internal mold (No. 415) are noted below in column one, the measurements given being approximate because of the imperfection of the specimen. The measurements are made with the hinge line in a horizontal position. In columns two and three, measurements of *Myalina verneuili* from the British Carboniferous limestone are given:

	Mongolia No. 415	*Carboniferous Limestone, Hind, Pl. IV*	
	Pl. XXXIII, Fig. 2	*Fig. 5*	*Fig. 8*
Antero-posterior (length)	41.0 mm.	35.0 mm.	31.0 mm.
Dorso-ventral (height)	28.0 mm.	24.0 mm.	27.0 mm.
Length of hinge line	33.5 mm.	28.0 mm.	25.0 mm.
Greatest oblique length	39.0 mm.	39.0 mm.	37.0 mm.
Maximum thickness	13.5 mm.	14.0 mm.	....
Apical angle	51°	51°	58°

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia (exact horizon lost); one specimen. Collector, F. K. Morris.

Remarks:—In so far as may be judged from the characters of the internal mold, our specimen agrees closely with some of the forms from the British

Carboniferous limestone referred to *Myalina verneuili.* In columns two and three of the above table, the measurements of two shells figured by Hind are given, these being taken from his figures. It will be seen that the correspondence is very close, and indeed it would be difficult to point out permanent differences. The British species occurs in the Upper Carboniferous limestone, the Millstone grit, and other Carboniferous beds.

CHAPTER VII

GASTROPODA OF THE JISU HONGUER LIMESTONE

INTRODUCTION

THE Gastropoda, like the Pelecypoda, form a subordinate division of the fauna of the Jisu Honguer limestone. The number of species of Gastropoda, however, is slightly larger. Among these are several characteristic Productus limestone species, but the most distinctively marked forms belong not only to new species but to genera not heretofore obtained in Asiatic rocks. Nevertheless, their totality may be taken as indicative of a Permian horizon. It is worthy of note that those gastropods which represent Productus limestone species are as a rule dwarfed individuals.

Class **GASTROPODA**

Order PROSOBRANCHIA Cuvier

Suborder ASPIDOBRANCHIA Schweigger

Family BELLEROPHONTIDÆ McCoy

Genus **Bellerophon** Montfort

1. **Bellerophon squamatus** Waagen var. **mongoliensis** Grabau, var. nov.

Plate XXXIII, Figs. 3a-d (No. 425), 4a-b (No. 422), (No. 424)

1880. *Bellerophon squamatus* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. II, p. 138, Pl. XII, Fig. 9.

This variety is represented by a number of imperfect individuals.

Measurements:—The following are the measurements of the more perfect specimens, those given in the last two columns representing the species as it occurs in the Productus limestone of India (Waagen, 1879–1887, p. 139).

	Mongolia		India	
	No. 425	No. 422	I	II
	Pl. XXXIII, Fig. 3	Pl. XXXIII, Fig. 4		
Maximum diameter of shell	11.6 mm.	20.5 mm.	50.0 mm.	40.0 mm.
Transverse diameter at aperture	9.6 mm.	18.5 mm.	40.0 mm.	23.0 mm
Thickness of shell at umbilicus	7.4 mm.	10.9 mm.	....	....
Height of aperture	3.8 mm.	6.4 mm.	18.0 mm.	19.0 mm.
Diameter of umbilicus	1.6 mm.	2.2 mm.	....	11.0 mm.
Width of keel	1.1 mm.	0.7 mm.	2.2 mm.	....
Number of growth squamæ in 5 mm.	14	13	2.5	....

The form is oval, with the maximum diameter of the shell greater than the transverse diameter of the aperture. The whorls are regularly rounded in the young, becoming slightly depressed in the later stages, so that the transverse curvature of the whorl decreases, this giving the appearance of a flattening of the dorsum. In this respect the shell differs from the typical *Bellerophon squamatus*, which retains the curvature of the young individual into the adult.

The coiling is completely involute, so that the shell is devoid of an umbilicus. An umbilical depression is, however, shown in the internal mold when the shell is removed, and the measurements given in the table are thus obtained. The center of the whorl is marked by a faintly elevated ridge of keel, which is flat-topped and varies somewhat in width, being proportionately wider in the young shell than in the later stages. In some states of preservation this keel is defined merely by two sharp depressed lines, and shows scarcely any elevation, but whenever the shell surface is well preserved it forms a distinct median ridge. The lines of growth are strongly marked and squamose. In our youngest specimen (No. 425) they average nearly three to a millimeter and curve upward from the umbilical region, arching over the side with a very gentle curvature, and becoming very gently deflected at the keel, forming with it an angle of about 65° and producing a moderately pronounced sinuation at the frontal margin at this stage (Pl. XXXIII, Figs. 3a-d).

In a larger specimen (No. 422, Pl. XXXIII, Fig. 4), they are nearly straight and produce only a very slight sinuosity. In this respect the young shell corresponds more nearly to *Bellerophon jonesianus* Waagen, but the proportions are those of *Bellerophon squamatus* rather than those of the more subglobose species next described. The growth squamæ of our larger specimen are very crowded, being but little more widely spaced than in the young (thirteen in 5 mm.), whereas in the Indian species, which reaches a size of more than twice that of our largest specimen, they are widely spaced, there being about five of them in the space of 10 mm., that is, only about one-fifth as many in a given space as in our variety. The outline, however, corresponds in our shell with those of the Indian shell. The keel of our larger shell is also much narrower, having a width of only 0.7 mm., which is less than the width (10 mm.) of the specimen referred here to the young. In the Indian shell the width of the keel is more than three times that of our shell (2.2 mm.). The reference of the small shell (No. 425) to this variety is, of course, open to criticism, but I believe it is defensible since there is no other adult form in these strata to which it can be referred. It is certain that there are changes in character in the stages of growth of the individual, but what they are, and the order of their succession in the individual, cannot be determined from the material in hand.

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia. Exact level unrecorded (Nos. 422, 424, 425). Collector, F. K. Morris.

2. **Bellerophon jonesianus** de Koninck

Plate XXXIII, Figs. 5a-c (No. 426), 6a-c (No. 423), 7a-c (No. 421), (No. 427)

1880. *Bellerophon jonesianus* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. II, p. 135, Pl. XIII, Figs. 1, 2 (with other literature references).

This species is represented in our collections by an adult and several immature individuals.

Measurements:—The measurements of these shells are as follows, those of two extreme examples cited by Waagen (1879–1887, Pl. XIII, Fig. 2; immature shell), from the Productus limestone of India being added in the last two columns.

	Mongolia			*India*	
Serial Number	*No. 426*	*No. 423*	*No. 421*	*I*	*IV*
Pl. XXXIII, Figures	*5a-c*	*6a-c*	*7a-c*		
Maximum diameter of shell	11.3	20.5	32.4	55.0	11.0
Transverse diameter at aperture	10.8	19.4	32.2	53.0	9.0
Thickness of shell at umbilicus	8.0	13.8	20.5	41.0	7.0
Height of aperture	4.4	....	....	18.0	4.0
Diameter of umbilicus	1.7	4.4	6.5	....	....
Width of keel	1.1	1.2	....	2.0	1.0
Number of growth squamæ in 5 millimeters	6	4.5	....	2.5	....

The shell is subglobose; its maximum diameter and the transverse diameter at the aperture are almost the same. This is true of the youngest individual as well as of the adult, and the same may be said for the typical forms described by Waagen, except in the case of his youngest individual (see above, column IV), which agrees almost exactly with the young shell (No. 425), which I have placed under the preceding species, chiefly because there is among our material a young shell (No. 426, Pl. XXXIII, Fig. 5), of the same maximum diameter but of much greater width, and therefore more in harmony with the measurements of the adult of the present shell. If Waagen is correct in placing the narrower shell as the young of the present species, our small shell (No. 425), placed under the preceding species, would in reality belong to *Bellerophon jonesianus*. In that case the small shell here included (No. 426) belongs to a distinct species. In view of the marked agreement, however, of this young shell with the larger forms of this species, I feel justified in placing it here as a representative of the young stage.

The surface of the last whorl is regularly and broadly rounded, there being only a faint median interruption by the slightly elevated keel. The sides turn inward rather abruptly, but there is no real angulation, though an indication of such a one is shown on one side of the aperture. The shell is not completely involute, but shows an umbilicus of moderate size, which is somewhat over one-sixth of the diameter of the whorl. The surface is perfectly smooth, even the growth-squamæ, which are rather distant (see table above), being only faintly indicated.

In the next larger shell (No. 423, Pl. XXXIII, Fig. 6), essentially the same conditions prevail, though the umbilicus here is larger. In this shell it would appear that the inner apertural layer, that is, the inner lip, covers a considerable portion of the preceding whorl in advance of the outer lip, though the amount of this extension cannot be determined because of the imperfection of the shell. In this specimen the squamose lines are seen to arch gently across the side of the shell from the umbilicus to near the keel, where they bend abruptly backwards before crossing it, thus making a rather pronounced emargination.

The angle made by the squamæ with the keel is about 65°, which is that seen in the typical specimens from India. It is also to be remarked that this angle agrees with the character of the growth-lines in the young specimen (No. 425, Pl. XXXIII, Fig. 3) referred to the preceding species because of its proportions, and if that is actually the young of that shell, it would seem as if the two species were derivatives from a common ancestor.

Our largest shell (No. 421, Pl. XXXIII, Fig. 7), represents merely an internal mold showing no characters whatever. The form of the whorls, the proportions of shell diameter, its transverse apertural diameter, and the well-developed umbilicus indicate that it belongs to this species.

In describing his youngest specimen, which is about the same size as our youngest shell, Waagen calls attention to the fact that, in addition to the proportionally greater shell-diameter, "the whorls are nearly entirely involute, no umbilicus, properly speaking, being present, only a slight groove in its place." He further remarks that the growth striæ pass "in a very regular low arch from the umbilicus to the peripheral part of the whorls, forming an angle of about 60° with the keel." All these features agree thus very closely with the young shell (No. 425, Pl. XXXIII, Fig. 3) placed under the preceding species, and also, except for its greatest width of aperture, with the young (No. 426, Pl. XXXIII, Fig. 5) referred to the present species. In the later stages, when the shell has reached a diameter of about 20 mm., which, therefore, corresponds to our specimen (No. 423, Pl. XXXIII, Fig. 6), the growth striæ become more distant and straighter, while the deflection at the keel forms an angle of 65°.

The width of the keel at this stage in the Indian species is just one millimeter, while in the younger shell it is slightly less, this, too, agreeing with our two young specimens. Between 20 and 40 mm. the keel becomes more or less obsolete, being replaced by a flat slit-band in the plane of the shell surface. There is also some variation in the distance between the striæ or growth lines. In the adult shell, the characters change rather markedly, the growth striæ becoming strong, irregular folds, especially in the umbilical region, while the umbilicus, which was closed in the earlier stages by an expansion of the inner lip, again becomes a narrow open slit. The outer lip is strongly expanded in the umbilical region, and this is true of the inner lip as well. The keel has again appeared in these later stages. None of our specimens attains to this full development.

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia, obtained from the *Enteletes* bed (1190) (No. 421); from the *Hemiptychina* bed (1196) (No. 423); and from unrecorded horizons (Nos. 426 and 427). Collector, F. K. Morris.

Family PLEUROTOMARIIDÆ d'Orbigny

Genus **Luciella** de Koninck

3. **Luciella planoconvexa** Grabau, sp. nov.

Plate XXXIII, Fig. 8 (No. 428); Plate XXXIV, Figs. 1a-b (No. 428), 2a-b (No. 429)

This species is represented by two moderately complete individuals, the larger of which (No. 428, Pl. XXXIV, Fig. 1) has an apical angle of 54.5°, while that of the smaller, less perfect specimen (No. 429, Pl. XXXIV, Fig. 2) is more slender, being only 50°.

Measurements:—The complete measurements of the two specimens as far as obtainable are as follows:

Serial Number	*No. 428*	*No. 429*
Plate XXXIV, Fig.	*1a-b*	*2a-b*
Entire height of shell	16.7	14.5?
Basal diameter	15.5	10.3
Vertical height of last whorl	5.8	4.3
Vertical height of fourth whorl from base	2.0	1.6
Apical angle	54.5°	50°
Shoulder angle of body whorl	79°	73°
Number of whorls preserved (about)	7	5[1]

In the larger of the two specimens (No. 428) the apical whorls are worn so that the details of form cannot be determined. There are, however, four whorls including the body whorl which preserved the shell, the upper one of which is the shallowest with its shoulder strongly and regularly rounded. As the whorls all embrace to the shoulder angle, the latter and the form of the side of the whorl cannot be determined, while, because of the rounding of the whorls, the suture is rather strongly impressed. There are apparently six simple spirals present, one just above the lower and another just below the upper sutures, and the others are distributed regularly between.

These spirals are of about uniform size, nearly uniformly spaced, and separated by slightly wider interspaces. The lower two appear to bound the slit-band, which lies just above the suture.

In the next whorl below this, the vertical height has increased and the convexity is somewhat less. The shoulder angle is distinctly visible where a part of the succeeding whorl is broken away, and so far as we can judge the bottom part of the whorl forms nearly a rectangle, or at least a very obtuse angle with the axis of coiling. The slit-band is narrow and lies just above the shoulder-angle. It is depressed and bounded by two slightly raised spirals. A faint spiral is also visible below the upper suture, and there is an indication of an additional spiral above the slit-band, but on the whole the spirals have become almost obsolete on this whorl. There are shown, however, strong oblique growth-lines, which extend backwards in a straight line at an angle of 33° with the suture-band, after crossing which they again turn forward. In the next lower whorl, that is, the one immediately above the body-whorl, more of the shoulder angle is exposed because the embracing by the body-whorl is somewhat less. Where the shell is broken away on the body-whorl even more of the base of the next higher whorl is seen. The slit-band is still narrow,

[1] Apex imperfect; at least two whorls are missing.

having a width of 0.6 mm. and lying at a somewhat greater distance above the obtuse shoulder angle. It is bounded by two distinct but low spirals, which are the only two visible spirals on this whorl. Here, however, as on the preceding whorl, the oblique growth-lines are strongly marked, being subregularly spaced, about three of them occupying the space of one millimeter. The angle of deflection is the same as in the preceding whorl, but the lines curve slightly upwards to the sutural margin above. The whorl is still convex and is higher than the preceding one. In the last part of the final whorl the shoulder has become flat or nearly so, though in some places a slight curvature is observable just above the slit-band which lies immediately above the somewhat rounded acute shoulder angle. The width of the slit-band on this whorl is a trifle less than 1 mm., and as in the other cases it is bounded by sharp, low, spirals. The oblique growth-lines make an angle of 32° with the slit-band, bending upwards to the suture rather more strongly than in the preceding whorls. No other surface ornamentation is visible on the shoulder. The base is nearly flat, extending about at right angles to the axis of coiling, and is marked by numerous fine spiral lines.

In the second specimen (No. 429, Pl. XXXIV, Fig. 2) practically nothing of the shell is preserved, the specimen being an internal mold. As a result, the sutures seem more deeply impressed than is the case where the shell is present. The last whorl and a part of the preceding one have their shoulders quite flattened, but above that the exposed part of the whorl is convex. Faint indications of the band and the oblique growth-lines are visible on the last whorl. The shoulder of this whorl is rounded, the base being flat or nearly so and thus forming an acute angle with the shoulder of the whorl. The aperture is oblique and vertically compressed, being wider than it is high.

The outer lip is gently arched and recedes behind the inner lip. The umbilicus is of moderate size, having a diameter of about 1.5 mm., while the diameter of the whorl is 10.7 mm. As shown in the table, this specimen has a higher apical angle, and is hence a more slender-spired shell, than the first specimen described, but I do not think it wise to separate it even as a variety, since all the other characters are alike in the two specimens.

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia. Exact horizon not ascertained; two specimens. Collector, F. K. Morris.

4. **Luciella elongata** Grabau, sp. nov.

Plate XXXIV, Figs. 3a-b (No. 438)

This species is represented by a single individual together with its impressions in the rock.

Measurements:—The following are the measurements of the specimen:

	No. 438
Entire height of shell (about)	15 mm.
Basal diameter	9 mm.
Vertical height of last whorl	4 mm.
Vertical height of fourth whorl from base	1.7 mm.
Apical angle	36°
Shoulder angle of body whorl	53°
Number of whorls preserved (about)	8

The shell is high-spired, slender, with the sutures deeply impressed. The whorls gradually increase in height and more slowly in diameter. The early whorls are rounded, the last three angulated, the shoulder gradually becoming flattened until in the final whorl it is entirely flat in the lower two-thirds and only gently rounded below the suture. The embracing of the whorls reaches to the base of the shoulder, which projects slightly beyond it, thus producing the impressed suture. This is much more pronounced on the internal mold than on the shell itself. The band is narrow, situated at the shoulder angle and defined by two sharp spirals. Above this, on the shoulder, there are two strong spirals and apparently also a number of weaker ones, though this cannot be definitely ascertained in our shell. There are apparently no transverse ridges or ribs, but because the shell adheres to the rock, the surface characters cannot be observed except in so far as they impress the internal mold. The shell is relatively thick, the base flatly rounded and apparently with an elevated marginal spiral. The aperture is oblique, acute in the outer margin. The umbilicus is of moderate size, apparently covered to some extent by the extension of the inner callus.

Compared with the preceding species, this is a much higher and more slender form, with a much lower apical angle. It has apparently the same obliquely deflected growth-lines while the other characteristics are also very similar; hence the chief distinction lies in the more slender spire of the present shell.

Horizon and Locality:—In the *Martinia* bed (1194) of the Jisu Honguer limestone, Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

5. **Luciella perlimbata** Grabau, sp. nov.

Plate XXXIV, Figs. 4a-b (No. 432)

This species is represented by a single specimen in the Mongolian material. The spire is broad, low, and of few whorls, with deeply impressed sutures, and a strongly deflected, nearly flat basal part.

Measurements:—The dimensions of the only specimen obtained are as follows:

	No. 432
Entire height of shell (about)	11.3 mm.
Basal diameter	10.3 mm.
Vertical height of last whorl	4.0 mm.
Vertical height of 2nd whorl from base	2.2 mm.
Apical angle	60°
Shoulder angle of body whorl	87°
Number of whorls preserved (about)	4

The whorls are rounded in the early stages, but towards the end of the last whorl the shoulder is nearly flat, though for the greater part of that whorl it is broadly rounded, the rounding being most pronounced a short distance below the suture. At this point the whorl is marked by a series of rounded nodes, 0.7 mm. in average diameter, and 1.4 mm. apart. There are about fifteen of these to a whorl, and they form the most prominent and characteristic feature of the shell. Below this row of nodes, at a distance equal to the distance which the nodes are from the suture, is a strong though subdued spiral, which produces a marked angulation in the shoulder, where it occupies nearly the center of the shoulder-width. Between it and the shoulder angle is a finer spiral, appearing to form the upper boundary of the slit-band, which is rather deeply depressed and near the mouth of the shell has a width of about 0.6 mm. The shoulder angle is marked by a rather thick and prominent rounded keel, below which the base is abruptly deflected so as to appear almost flat. The aperture is strongly oblique.

The low conical form, high apical angle, row of strong nodes, and keeled shoulder angle, form the distinctive characters of this species.

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Genus **Worthenia** de Koninck

6. **Worthenia nana** Grabau, sp. nov.

Plate XXXIV, Figs. 5a-b (No. 433)

This species is represented by a small internal mold, which, however, possesses distinctive characters.

Measurements:—The following are the measurements of the specimen:

	No. 433
Height of last three whorls preserved	7.7 mm.
Original height, perhaps	9.0 mm.
Maximum diameter of last whorl	5.8 mm.
Entire height of last whorl at aperture	4.4 mm.
Height of exposed part of third whorl from base	1.6 mm.
Diameter of this whorl	3.0 mm.
Apical angle	39°
Number of whorls preserved	3

The earliest whorl preserved, the third from the base, is rounded, but the one succeeding it has a well-marked shoulder angle having the form of a flattened keel which apparently bears the band. The space below it is at first concave and then marked by a second broadly rounded angulation. Normally the latter is covered by the succeeding whorl, but in the present specimen there is a distortion so that this lower angulation is exposed on one side. In any case, however, the whorls are deep, the whorls not embracing to the ambitus. In the last whorl the shoulder is very flat, and the keel pronounced and flattened on top where the band is situated. The growth-lines are very oblique, the apertural notch formed by them extending about one-third the circumference of the whorl. The concave depression below the keel is pronounced, while the rest of the whorl below it is broadly rounded to form a second keel-like elevation; below, it is flatly curved to the umbilicus, which is moderate. There appear to have been fine spiral striæ on the basal part, but these are not well preserved.

Horizon and Locality:—In the *Enteletes* bed (1190) of the Jisu Honguer limestone, Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Genus **Solenospira** Ulrich (?)

7. **Solenospira (?) mongolica** Grabau, sp. nov.

Plate XXXV, Figs. 13a-b (No. 417a)

This species is represented by a single incomplete specimen which, however, shows part of the shell preserved. Three whorls are preserved; the first of these is sub-rounded, while the second and last become sub-angular from the flattening of the shoulder. There is, however, no sharp shoulder angle, that part of the shell being rounded, while both above and below, the surface is flattened. Below the rounded shoulder angle lies a broad well-defined band, bounded on either side by a strong spiral and itself marked by 4 or 5 finer spirals. Above the band on the last whorl are 9 uniform prominent spirals, separated by somewhat greater interspaces, about 5 of these occupying the flattened shoulder, the other 4 covering the rounded shoulder angle. All appear to be primary spirals separated by wider interspaces. Below the band, there are from 4 to 5 similar spirals, the last one at the suture, but on the body whorl, where the inward deflection is rather sudden, other similar spirals occupy the lower portion of the shell. The umb licus seems to be closed but our specimen is not perfect enough to make accurate determination.

The most striking feature of our shell is the loose-coiled deep-sutured aspect of the spire as a whole, with the sub-angular whorls, marked by the strong uniform spirals and the finer spiralled band on the body of the whorl.

In the internal mold, the whorls appear rounded. There are fine lines of growth which, however, are barely visible under a lens. They seem to cross the whorls at right angles and show only the slightest deflection or emargination in the band.

Measurements:—The dimensions of the holotype and only specimen are as follows:

	No. 417
Length of fragment	15.0 mm.
Original length of shell (approximately)	25.5 mm.
Height of body whorl near aperture	5.8 mm.
Exposed height of third whorl from bottom	3.5 mm.
Diameter of body whorl	9.3 mm.
Diameter of third whorl from bottom	5.4 mm.
Width of band on body whorl	1.3 mm.
Apical angle	33°

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia. Exact horizon not ascertained. One specimen. Collector, F. K. Morris. (No. 417, Cat. G. S. C. 1482.)

Remarks:—This specimen differs from the late Palæozoic shells previously referred to the genus in the large number of uniform spirals on the shoulder. It might be questioned whether it is referable to this genus, which is typically a lower Palæozoic one. But for the present, because of the incomplete state of our specimen, it is not advisable to separate it under a distinct genus. I know of no Permian form comparable to it.

Family EUOMPHALIIDÆ de Koninck

Genus **Euomphalus** Sowerby

8. **Euomphalus simuloides** Grabau, sp. nov.

Plate XXXIV, Figs. 6a-c' (No. 434)

cf. 1861. *Straparollus similis* Meek and Worthen. "Description of New Palæozoic Fossils from Illinois and Iowa." *Proc. Acad. Nat. Sci., Phila.*, Vol. XIII, p. 145, and *Geol. Survey of Illinois*, Vol. II, p. 285.

cf. 1899. *Euomphalus similis* Whitfield. "List of Fossil Types and Figured Specimens, used in the Palæontological Work of R. P. Whitfield, etc." *Ann. New York Acad. Sci.*, Vol. XII, pp. 139–186.

cf. 1909–10. *Euomphalus similis* Grabau and Shimer. "North American Index Fossils," Vol. I, p. 660, Fig. 909.

This is represented by a single specimen in the collection. The shell is small, of about three volutions, low-spired, with rounded carinated whorls and large open umbilicus.

Measurements:—The measurements of the specimen are as follows:

	No. 434
Entire height of shell	5.3 mm.
Greatest diameter of body-whorl	7.6 mm.
Height of body-whorl at aperture	3.9 mm.
Height of body-whorl, half a volution behind the mouth	3.2 mm.
Width of keel at aperture	1.2 mm.
Total number of whorls preserved	3

The earliest whorl seems to be rounded and apparently without the differentiation of the keel, but this appears soon afterward by a flattening of the whorl below the suture and a constriction below this flattened area, thus giving the whorl an appearance of a flat bowl with a constricted mouth, furnished with a flattened, slightly expanded rim. This flattening becomes more pronounced in the last whorl, where it is actually depressed to form the revolving band. This band does not occupy the entire width of the rim, but is bounded by narrow spirals both on the inside and the outside, the rounded margin of the rim expanding beyond this. This rim forms a marked projection on the last whorl, because the shell below it is rather strongly constricted before expanding again and is regularly rounding to the periphery, and thence more flatly to the large umbilicus. The embracing of the whorls extends to the ambitus in the last part, but somewhat above it in the early part, thus producing a sunken suture and a very low spire. The aperture is oblique but imperfect in our specimen. The lines of growth and depth of the notch cannot be determined.

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—This shell is of the size and general character of *Euomphalus similis* (Meek and Worthen) of the Upper Mississippian of North America (See Grabau and Shimer, p. 659), but that shell has the outer bounding spiral of the band more strongly elevated, while the constriction below the rim is less strongly marked. Moreover the umbilicus is margined by a spiral.

9. **Euomphalus mongolicus** Grabau, sp. nov.

Plate XXXIV, Figs. 7a-b (No. 436), 8a-b (No. 437)

cf. 1843. *Euomphalus catilloides* de Koninck (non Conrad 1842). "Description des Animaux fossiles qui se trouvent dans le terrain carbonifère de la Belgique," p. 429, Pl. XXV, Fig. 3.

cf. 1881. *Euomphalus catilliformis* de Koninck. Faune du calcaire Carbonifère de la Belgique, Pt. III, Gastropodes, p. 146 (with synonymy), Pl. X, Figs. 39-41, Pl. XII, Fig. 7, Pl. XIX, Figs. 4-6. *Ann. Mus. R. Hist. Nat. Belgique,* Ser. Pal., Vol. VI.

This is represented by two imperfect specimens. The shell is coiled almost in a plane, with a sunken spire and deep suture.

Measurements:—The dimensions of the specimens so far as they can be ascertained are as follows:

	No. 436	*No. 437*
Plate XXXIV, Figures	*7a-b*	*8a-b*
Greatest diameter of the shell	33.0 mm	35.5
Diameter of last whorl near aperture	8.5	8.0
Diameter half a volution from aperture	5.4	....
Height of whorl at latter point	6.6	....
Height at aperture	....	9.3

The whorls are rounded, somewhat compressed and moderately impressed where in contact. The lower side is regularly rounded. The upper side is rounded except for an incipient low keel which lies about one-third of the diameter of the whorl from the outer margin and forms a faint elevated spiral ridge. The lines of growth on the upper surface of the shell have a sigmoid flexure; beginning at the umbilicus they arch forward and then backward to the keel, this part forming a regular arc. On crossing the keel they are deflected forward again, thus producing a concave sinuosity, with the keel at the center of the concavity.

On the outer margin they arch rather strongly forward at first, to about the center of the mid-height of the whorl, and then turn as sharply backward, thus forming a projecting outer lip, sharply arched in contour, and extending beyond the convexity in the upper surface of the whorl. When they have returned to the point opposite the keel, they curve forward again, thus producing a second concavity on the under side, followed by a second convexity before reaching the suture.

Remarks:—This shell resembles to a considerable degree the figure of *Euomphalus catilliformis* given by de Koninck (1881, Pl. XIX), but differs from that shell in the greater depression of the spire and more especially in the fact that the faint keel is situated in the outer third of the volution instead of near its suture. The lines of growth also show a stronger, more asymmetric sigmoid flexure on the upper side of the whorl, and a stronger forward-arching on the outer side, than is seen in de Koninck's species. Moreover, the keel of our shell is less strongly pronounced than in the case of the Belgian species. These characters seem to be sufficient to separate our shell from de Koninck's species, a separation which is, moreover, emphasized by the difference in geological age. There is also considerable similarity between our shell and *Euomphalus parvus* Waagen (1879–1887, Pl. IX, Fig. 2), from the Salt Range of India, but that shell is very small, being less than one-fourth the size of our shell, and having, moreover, a very broad keel near the center of the upper whorl, instead of a fine sharp one in the outer third. Finally, the lines of growth of the Indian shell do not have the strong curvature characteristic of the Mongolian shell.

Horizon and Locality:—In the *Marginifera* bed (1192) of the Jisu Honguer limestone, Jisu Honguer, Mongolia. Collector, F. K. Morris.

Genus **Phymatifer** de Koninck

10. **Phymatifer** cf. **coroniferus** de Koninck

Plate XXXIV, Fig. 9 (No. 439)

cf. 1881. *Phymatifer coroniferus* de Koninck. Faune du Calcaire Carbonifère de la Belgique, Pt. III, Gastropodes, p. 150, Pl. XIII, Figs. 1-3. *Ann. Mus. R. Hist. Nat. Belgique*, Ser. Pal., Vol. VI.

This species appears to be represented by a small incomplete shell embedded in rock, of which, however, not enough is preserved to make exact identification possible. The shell is moderately high-spired as seen in section. So far as it is possible to determine from the section, the upper part of the whorl shows a marginal carina, but whether this is noded or not cannot be determined. Inside of this carina the whorls appear to be flattened. The lateral margin is rounded to the basilateral angulation, which is very strongly noded, the nodes being broad, somewhat flattened projections, with an interval of about 2 mm. from tip to tip. The inside of the whorl descends rather abruptly to the umbilicus, the base and umbilical slope forming almost, but not quite, a right angle. Within the umbilicus, the inner whorls are seen with their basal lateral nodes only partly concealed. The maximum diameter of the shell is 12 mm.

This shell is of the type of *Phymatifer coroniferus* de Koninck from the Dinantian of Belgium, but differs from it in several important details, the most noted of which is the flattened base, with its abrupt descent to the umbilicus, and the row of strong subspinose basolateral nodes. In the Belgian shell, the basal part of the whorl is rounded and marked by a submedian nodose keel. Altogether our shell is quite distinct, but the material is insufficient for a full diagnosis. Nevertheless it is recognized that a distinct species is here represented.

Horizon and Locality:—In the Jisu Honguer limestone, Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Family TROCHIDÆ Adams

Genus **Flemingia** (de Koninck), emend. Zittel

11. **Flemingia tepeeformis** Grabau, sp. nov.

Plate XXXIV, Figs. 10a-b (No. 430), 11a-c (No. 431)

This species is represented by one complete specimen (No. 430) and a fragment of a body whorl (No. 431). The shell is tepeeform, with flat shoulders, which form a continuous slope. The sutures are scarcely impressed, and the bases of the whorls are flat with a deep and broad umbilicus.

Measurements:—The dimensions of the two specimens are as follows:

Serial Number	*No. 430*	*No. 431*
Plate and Figure	*Pl. XXXIV, Fig. 1*	*Pl. XXXIV, Fig. 2*
Entire height	11.5 mm.	....
Diameter of body whorl	14.5 mm.	11.1 mm.
Height of body whorl	4.2 mm.	3.0 mm.
Number of whorls shown (about)	5.0 mm.	....
Apical angle	80°	70°
Shoulder angle of body-whorl	56°	62°
Diameter of umbilicus	8.8 mm.	6.0 mm.

The very early whorls are not shown in our specimens, but in the earliest exposed the shoulder is already flat at the basal angle, approximately as in the adult, with the suture scarcely impressed. The preantepenultimate whorl, that is, the fourth from the end, shows six simple broad spirals on the shoulder, one of which is just above the lower suture, and another just below the upper suture. The spirals are sharp, narrow, rounded on top, and separated by broad interspaces, somewhat less than half a millimeter in width. The shell is not preserved on the later whorls, but the mold shows a somewhat broad median depression, which, however, is very shallow with a suggestion of a spiral in the center, while there are indications of two spirals above the three below. Neither growth lines nor transverse ornamentations are visible, though on the fourth whorl from the end the spirals in certain positions appear faintly cancellated by transverse grooves. The basal angle is very sharp, the base itself being flat for about one-fourth of the diameter, when it begins to slope inward with a gentle curve to the umbilicus. The upper angle of the whorl is also sharp, the shell inside of it being concave. The aperture appears to have a somewhat subrhomboidal outline.

Horizon and Locality:—In the *Hemiptychina* bed (1196) of the Jisu Honguer limestone, Jisu Honguer, Mongolia; two specimens. Collector, F. K. Morris.

12. **Flemingia gigas** Grabau, sp. nov.

Plate XXXV, Figs. 1a-b (No. 440)

This is represented by a single specimen, showing the body-whorl and a part of the preceding whorl. The shell is large, with sloping flat shoulders, sharp basal angle, flat base, and deep umbilicus.

Measurements:—The following are the measurements:

	No. 440
Total height, probably	50.0 mm.
Basal diameter	72.5 mm.
Height of body whorl	22.5 mm.
Diameter of umbilicus, about	29.0 mm.
Apical angle, approximately	70°
Shoulder angle of body-whorl	72°
Angle formed by base with side slope of the shell	55°

This specimen is largely a mold of the interior, except that part of the shell is preserved on the base. The shoulder angle of the body-whorl is very sharp, but, because of the slight rounding of the shoulder surface, the actual angle is greater than that which the base makes with the side slope of the shell. In the mold the suture between the body-whorl and the preceding one is somewhat impressed, but this was probably much less the case in the shell surface itself. There are still indications on the mold of rather strong and broad spirals, of which there seem to have been ten or twelve in all, separated by wider interspaces. On the basal part of the body-whorl there appear to have been about thirty of these spirals, somewhat unequally spaced, with two interspaces near the middle of the base having about double the width seen in the others. The actual interval occupied by these two interspaces with their dividing spiral is 2.5 mm., while that occupied by two adjoining interspaces with their dividing spiral is only 1.2 mm. The lines of growth on the basal part are straight, passing obliquely outward from the umbilicus without flexure to the margin. They cross the spirals somewhat obliquely, outlining with them a series of rhomboids. The base is practically flat in the outer part of the whorl, then curves regularly downward to the broad and deep umbilicus. The aperture is subrhomboidal with the sides rather unequal. The fragment of the succeeding whorl preserved shows characters similar to those of the body-whorl, the shoulder in the mold being also gently convex. There appears to have been a rather strong spiral near the lower suture, and there are indications of other fine and distantly spaced spirals.

Horizon and Locality:—In the *Hemiptychina* bed (1196) of the Jisu Honguer limestone, Jisu Honguer, Mongolia; one specimen. Collector F. K. Morris.

Comparisons:—This shell has somewhat the characters of *Flemingia carbonaria* (Meek and Worthen) from the Chester group of North America and the Dinantian of Belgium. As described and figured by de Koninck (1881, p. 300, Pl. XX, Figs. 1 to 9) this shell reaches a height of 30 mm. with a basal diameter of 57 mm., an apertural height of 5 mm., and an apical angle of

96°. It consists of seven volutions which in the mold are very gently convex of shoulder with very faintly impressed sutures, but in the shell show a strong median angulation on the shoulder, produced by a sharp spiral, with a flattening of the whorl on either side. The shoulder-angle itself is sharp and the base is flat. The lines of growth are very oblique on the upper shell-surface. Though there appears to be some similarity, our shell is nevertheless quite distinct.

Family NERITOPSIDÆ Fischer

Genus **Naticopsis** McCoy

13. **Naticopsis khoovensis** Waagen

Plate XXXV, Figs. 2a-c (No. 445), 3a-c (No. 444), 4a-b (No. 443), 14a-b (No. 448), (No. 446)

1879. *Naticopsis khoovensis* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. II, p. 100, Pl. IX, Fig. 10.

This species is represented by a number of individuals in our collection which have essentially the characteristics shown by the Indian species described by Waagen.

Measurements:—The following are the dimensions of some of our specimens, with those of Waagen's type given in the last column:

Serial number	*No. 443*	*No. 444*	*No. 445*	*No. 446*	*No. 448*	*Waagen type*
Plate XXXV	*Figs. 4a-b*	*Figs. 3a-c*	*Figs. 2a-c*		*Figs. 14a-b*	
Total height of shell	16.7	20.5	21.5	19.2?	18.0	33.0 mm.
Greatest diameter of last whorl	17.0	19.2	21.3	19.0	17.0	30.0 mm.
Height of body-whorl at aperture	14.4	17.8	19.0	17.2	15.8	30.0 mm.
Width of aperture	....	....	10.5	11.8	9.0	30.0 mm.
Apical angle	131°	115°	120°	120°	120°	116°

The shell is globose, the height sometimes equal to the diameter, sometimes slightly less or slightly more. The number of volutions is about three, forming a very depressed spire and rapidly increasing in size, so that the height of the last whorl nearly equals its diameter and forms all but a very small part of the height of the shell. This last whorl embraces somewhat less strongly than the earlier, the embracing at the aperture being approximately at the ambitus of the preceding whorl, while that whorl embraces the earlier one to considerably above the ambitus. At the suture the last whorl is often faintly flattened, thus producing a very marked depression. In other cases, however, the shell slopes steeply away from the suture, the posterior apertural angle being acute. The inner lip is much thinner than the outer lip and forms a thin coating over the columellar region.

Anteriorly the outer lip meets the columella at a rather broad angle, the latter being slightly thickened. The aperture is, however, perfectly rounded anteriorly. The growth lines extend from the upper suture in a gentle curve, obliquely backward to the ambitus and then descend straight to the basal margin. There is no trace of an umbilicus.

Though smaller than the Indian species, which is represented by a single specimen, our shell agrees with it in all its characteristics, and I have no hesitancy in referring our specimens to Waagen's species.

Horizon and Locality:—In the *Enteletes* bed (1190) (No. 443, 448), and in the *Hemiptychina* bed (1196) (Nos. 444, 445, 446), Jisu Honguer limestone, Jisu Honguer, Mongolia; six specimens. Collector, F. K. Morris.

Suborder CTENOBRANCHIA Schweigger

Family STROPHOSTYLIDÆ Grabau and Shimer

Genus **Strophostylus** Hall

14. **Strophostylus indicus** (Waagen)

Plate XXXV, Figs. 5a-b (No. 442), 6a-b (No. 441), (Nos. 447, 450, 451, 452)

1879. *Platystoma indicum* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. II, p. 105, Pl. XI, Fig. 1.

This species is represented by two adult and several young individuals, the majority of which have preserved the shell.

Measurements:—The measurements of characteristic individuals give the following dimensions:

Serial number	*No. 452*	*No. 450*	*No. 447*	*No. 441*	*No. 442*	*Waagen's type*
Plate XXXV	....	....	....	*Figs. 6a-b*	*Figs. 5a-b*	....
Total height of shell	6.3	9.4	16.5	26.0	29. +	40.0 mm.
Greatest diameter	4.7	9.3	19.1	26.4	31.1	56.0 mm.
Height of body-whorl at aperture	5.2	7.0	14.1	21.3	24.0	37.0 mm.
Width of aperture	3.4	5.0	12.1	....	21.7	35.0 mm.
Apical angle	71°	93°	122°	100°	110°	138°

The adult shell is subglobose, consisting of about three volutions, very rapidly increasing in size, with the last volution forming the largest part of the shell. The spire of the young shell is rather high, the whorls embracing to the ambitus. In the later whorls the coiling becomes less pronounced, the embracing being below the ambitus; hence the spire of the shell as a whole is rather high. The whorls are rounded and without angulation, but anteriorly the apertural part is slightly extended, without, however, forming a canal or notch. Thus the outer lip becomes rather elongated, while the inner lip is closely appressed to the columella. In the young shell the greatest diameter is less than the height, but in the adult it is greater. The aperture is subcircular, being, however, modified by the anterior extension, which produces an irregularity in the outline and increases the height over the width. In the perfect adult specimen (No. 442, Pl. XXXV, Figs. 5a-b), the last part of the body whorl meets the preceding whorl at an acute angle, there being a slight concavity in the shell-surface below the suture; thus a rather marked anterior canalicution is produced. This is not marked in the young shell. There is no trace of an umbilicus. The shell is thin, and the surface is smooth, except for the lines of growth, which appear as a regularly spaced series of rather strong transverse striations, from eight to nine of them occupying 5 mm. in the center of the body-whorl. Finer lines of growth between the coarser ones are visible with a high-power lens. The shell also appears to have an extremely fine punctation. The lines of growth proceed from the suture almost at a right angle, but then curve very rapidly backwards, so that at the center they are nearly a third of a volution behind the point of origin at the suture. Thence they descend almost regularly to the umbilical region.

Although our shell is somewhat less ventricose than is the case in Waagen's type, I am inclined to consider that it is a representative of the Indian species. Our shell appears proportionately higher, as can be seen by a comparison of the measurements with those of the Indian species. The acute angle which the lip forms at the posterior suture is also not shown in Waagen's shell, but it must be remembered that that shell represents mainly an internal mold. While recognizing the difference in the two forms, I do not think it wise at present to refer our shell to a distinct species.

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia. *Enteletes* bed (1190) (Nos. 442, 451), *Hemiptychina* bed (1196) (No. 447), *Spirifer moosakhailensis* bed (1205) (No. 441). Horizon unrecorded (Nos. 450, 452); six specimens. Collector, F. K. Morris.

Family SCALARIIDÆ Broderip

Genus **Holopella** McCoy

15. **Holopella** cf. **trimorpha** Waagen

Plate XXXV, Fig. 7 (No. 435)

cf. 1880. *Holopella trimorpha* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. II, p. 94, Pl. X, Figs. 2, 3.

I should refer to this Indian species, a fragment of an internal mold of a high-spired shell, the only one of its kind so far found in the Mongolian strata. The shell retains only two whorls, which are round, except at the suture, where there is a slight flattening or incipient concavity, the whorl at this point being acutely angular. Nevertheless, as the embracing is considerably below the ambitus, the whorls are distinct and the sutures appear rather depressed. There are no spirals, though there is the faintest indication on the last whorl of a slightly elevated spiral ridge. This is, however, so indistinct as to be scarcely noticeable. The lines of growth are only faintly marked and appear to extend essentially in a straight line from suture to suture.

Measurements:—The measurements of the part preserved are as follows, with those of the Indian species given in the last column:

	No. 435	*Indian shell*
Total height preserved	15.0	27.0
Original length, approximately	33.5	....
Maximum diameter of last whorl	10.5	4.5
Last whorl at aperture	7.8	2.9
Width of aperture	6.0	....
Apical angle	18°	12.5°

Horizon and Locality:—Jisu Honguer limestone, Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—Our shell is larger than that described by Waagen, the last whorl being more than twice as high and wide as the measurements given for Waagen's shell. Nevertheless, the proportions appear to be very similar, especially to those of the specimen from Khura (Waagen, 1879–1887, Pl. X, Figs. 3a-c). In that shell there appears to be the same modification of the whorl by slight flattening at the suture, and though the whorl appears to be a trifle more elongate proportionately, the difference is not a very pronounced one. As Waagen has remarked, there is great difficulty in the satisfactory determination of these shells, and specific distinctions can be made only with well preserved material. It may be noted that at about a third of a volution below the aperture of our shell there is a swelling which produces a sort of pseudo-rib, not defined enough to be regarded as such, or distinct enough to be considered a varix. It may represent merely a pathological modification.

Family SUBULITIDÆ Lindström

Genus **Macrocheilina** Bayle

16. **Macrocheilina (Sphærodoma) avellanoides** (de Koninck)

Plate XXXV, Figs. 8a-b (No. 453)

1863. *Macrocheilus avellanoides* de Koninck. "Mémoires sur les Palæozoiques recueilles dans l'Inde . . . ," p. 13, Pl. IV, Fig. 4.

1863. *Macrocheilus avellanoides* de Koninck. "Descriptions of some Fossils from India, discovered by Dr. A. Fleming of Edinburgh." *Quart. Journ. Geol. Soc. London*, Vol. XIX, p. 10.

1879. *Macrocheilus avellanoides* Waagen. *Palæontologia Indica*, Ser. XIII, Salt Range Fossils, Vol. I, Productus Limestone Fossils, Pt. 2, p. 97, Pl. IX, Figs. 6-9 (with other literature references).

A single specimen of this species has been obtained from our rocks. It reaches only about half the size of the typical Indian shell, but otherwise agrees with it in general form and characters. In form the shell is somewhat elongate-ovate, rather ventricose, with the spire forming less than half of the shell.

Measurements:—The dimensions of our shell are given in column one of the following table, while the other three columns give dimensions of three specimens after Waagen.

	Mongolian Shell (No. 453)	*Indian shells, after Waagen*		
Column number	*1*	*2*	*3*	*4*
Height preserved	17.6 mm.	......	......	......
Total original height of shell	18.0 mm.	40.0	39.0	30.0
Maximum diameter	13.0 mm.	27.0	26.0	19.0
Height of body-whorl at aperture	12.3 mm.	27.0	25.0	21.0
Greatest width of aperture	6.6 mm.	11.0	11.0	8.0
Apical angle	82°	82°	82°	87°

The apical whorl of our specimen is broken away but apparently was very small. Including it, there are about four volutions which rapidly increase in size and all of which are rounded. The embracing extends to slightly above the ambitus, the whorl being rather suddenly rounded at the suture, which thus is moderately impressed. At the aperture the posterior part ends in an acute angle, but there is no concavity in the whorl, the outline being a regular arc to the base, where there is a slight flexure, but neither callosity nor umbilical depression is visible. There is no anterior notch, though the shell is slightly extended and twisted with the production of an anterior columellar fold, which, however, is not well preserved in our specimen.

The surface is smooth, no spirals having been observed on any of the whorls. The lines of growth are obsolete, though occasionally stronger ones are visible. These extend in an almost straight arc from suture to base.

Horizon and Locality:—In the *Enteletes* bed (1190) of the Jisu Honguer limestone, Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

17. **Macrocheilina (Sphærodoma) transitoria** Grabau, sp. nov.

Plate XXXV, Fig. 9 (No. 454)

This shell is represented by a single specimen which differs from the preceding in its more elongate form and small apical angle. The apex of the specimen, too, is slightly imperfect, but, making allowance for this, the following measurements are obtained:

Measurements:—

	No. 454
Total height of shell	21.0 mm.
Maximum diameter	14.5 mm.
Height of body-whorl at aperture	14.2 mm.
Greatest width of aperture	8.2 mm.
Apical angle	64°

Allowing for the broken apex, there are approximately four whorls preserved in this shell, all of which are rounded and embrace to just below the ambitus. This gives a moderately impressed suture, though the outlines of the whorls are irregular and not more abrupt at the suture as is the case in the preceding shell. The aperture is acute posteriorly, and slightly extended anteriorly, as in the preceding specimen. The surface is smooth except for faint lines of growth which descend from the suture to the base. Altogether this shell represents merely a more slender and elongate mutation of the preceding species, but since it is intermediate in form between that and the next shell it seems to deserve a separate specific designation.

Horizon and Locality:—In the *Hemiptychina* bed (1196) of the Jisu Honguer limestone, Jisu Honguer, Mongolia; one specimen. Collector, F. K. Morris.

Remarks:—I have referred this and the preceding shell to the genus *Sphærodoma* of Keyes because of their rather thick and more or less globular form with very convex body-whorl. This type of shell is common in the American Carboniferous, and is also most characteristic of the Upper Productus limestone of India. There are very few shell characters on which to base specific designation other than the form and proportions of the shell, the convexity of the body-whorl, the height of the spire, and the apical angle. In the genus *Soleniscus*, on the other hand, to which the next species is referred, the shell is elongate with a higher spire, and with the whorls more flattened. It is likewise a common genus in the American Carboniferous, but has not been reported from the Productus limestone of India.

Genus **Soleniscus** Meek and Worthen

18. **Soleniscus mongolicus** Grabau, sp. nov.

Plate XXXV, Figs. 10 (No. 455), 11a-b (No. 458), 12 (No. 459), (Nos. 456, 457, 460)

This species is represented by several imperfect specimens, which, however, show the characteristics of the genus and appear not to be referable to any known species. Our largest shell is imperfect at both ends, the remaining portion, which consists of the two last volutions only, having a height of 23.5 mm. Restoring the apical portion would add another 12.5 mm., while the basal part would add perhaps 3 mm. more. This would give a total height of the shell of 39 mm.

Measurements:—The following are measurements of this and several young specimens:

Serial number	*No. 459*	*No. 458*	*No. 455*
Plate XXXV	*Fig. 12*	*Figs. 11a-b*	*Fig. 10*
Total height of shell	6.1	11.0?	39.0?
Actual height of fragment	....	....	22.0
Maximum diameter	3.3	5.6	12.6?
Height of body-whorl at aperture	4.2	8.7	19.7?
Greatest width of aperture	....	3.4	....
Apical angle	55°	67°	26°

The apical angle given in the third column is really the angle of convergence of the last two whorls, which may be much more acute than the angle of the younger whorls, as is indeed shown by the apical angles of the other specimens referred to this species. That the younger shells belong here seems to be indicated by the canaliculate anterior end, which is much more produced than is the case in any of the preceding shells. In consequence, the spire of the young shell is much less elevated than that of the adult, being at most, half the length of the body-whorl. In these earlier stages, except for the strong anterior extension, the young shell might easily be referred to *Sphærodoma*, and probably to one of the preceding species, but the extended canal forbids such a reference.

In general appearance the young shell is more fusiform, with a well-marked anterior canal which is slightly twisted and characterized by a slight thickening. The posterior part of the aperture is acute as in the preceding species. The whorls are rounded with the body-whorl ventricose and the embracing extending to a short distance above the ambitus. The suture is scarcely impressed. The surface is smooth except for lines of growth which are often quite distinct and subregularly spaced; they descend in a slightly flexuous curve from the suture to the base.

In the last two whorls in the larger specimen, the only part preserved, the sides of the shell are very much flattened, though they always maintain a faint convexity. The sutures are scarcely impressed and the whole appearance of the shell seems to be spatulate. The aperture is long and drawn-out anteriorly into a slightly twisted canal. The lines of growth appear to extend forward at first, then curve gently backward and finally turn back more pronouncedly to the anterior canal. No other surface characters are visible.

Horizon and Locality:—In the Jisu Honguer limestone of Jisu Honguer, Mongolia. *Hemiptychina* bed (1196) (Nos. 455 and 456). Horizon unknown (Nos. 457 to 460); six specimens. Collector, F. K. Morris.

Remarks:—The young shell is not unlike *Soleniscus typicus* Meek and Worthen, of the North American Coal Measures, that shell showing a similar anterior canaliculation, but the characters of the adult shell are distinct from those of any other species with which I am acquainted.

PART III

STRATIGRAPHIC AND FAUNAL RELATIONS OF THE JISU HONGUER LIMESTONE TO THE PERMIAN FORMATIONS OF OTHER REGIONS

PART III—STRATIGRAPHIC AND FAUNAL RELATIONS OF THE JISU HONGUER LIMESTONE TO THE PERMIAN FORMATIONS OF OTHER REGIONS

CHAPTER VIII

GENERAL COMPOSITION OF THE FAUNA OF THE JISU HONGUER LIMESTONE

INTRODUCTION

THE fauna of the Jisu Honguer limestone is in many respects a peculiar one. In the first place, it should be noted that there is a vast preponderance of brachiopods, a total of almost one hundred species, varieties and mutations having been obtained, as compared with seventeen of pelecypods, eighteen of gastropods, four corals, and two bryozoans. It is to be noted that trilobites, cephalopods, and echinoderms are nearly or quite absent, except in so far as the latter are represented by scattered crinoid stems. Corals and bryozoa are rare, and their distribution is strictly limited to definite horizons. Indeed the reef-building type *Waagenophyllum virgalense* var. *mongoliense* is confined to one stratum (1195), in which so far no other fossils have been found. The other corals, and the bryozoans, represent rare and sporadic occurrences. The mollusca, too, are sparingly represented, occurring chiefly as single individuals; except the pecteniform types among the pelecypods; the bellerophontid and naticoid types, and the macrochilinids among the gastropods, these types being present in a number of individuals. Among the brachiopods, *Dielasma* is characteristic, there being eight species, several of which are represented by a number of individuals. Members of the *Hemiptychina* and *Notothyris* groups are also well represented, but athyrids and rhynchonelloids are rare.

The spiriferoids, on the other hand, are well represented, chiefly by the genera *Spiriferella* and *Martinia*, while *Squamularia* is less abundant. Among the other well represented generic types may be mentioned *Enteletes*, with five species and many individuals, and the streptorhynchoid group, including besides *Streptorhynchus* itself, the genera, *Schellwienella*, *Orthothetina*, *Derbya*, *Derbyella*, *Meekella*, and *Geyerella*, with a total of sixteen species. Next in abundance are the productoids, including the genera *Productus*, *Proboscidella*, and *Marginifera*, this series comprising fourteen determined and several undetermined species. Finally, it should be noted that the genera *Aulosteges*, *Richthofenia* and *Lyttonia* are represented by characteristic species which link these deposits with the Middle Productus limestone of India and the Loping formation of central China.

Taking into account varieties and mutations, the total number of brachiopods recorded is 99, of which seven are given only generic designation, leaving ninety-two species, varieties, and mutations. Of these, seven are not positively identified with the species to which they are referred, thus leaving a total of eighty-five well-determined forms. Of these, thirty-two have been named previously and described, leaving a total of fifty-three species, varieties, and mutations, or over 62 per cent., of the determined brachiopod fauna represented by new forms. If we add to these the seven doubtfully identified forms, the total number of species previously named is thirty-nine out of the ninety-two determined forms, or 42.4 per cent. This statement is, however, somewhat misleading, for some of the other forms are also known from other localities. In reality there are only twenty-three of the fifty-three species, varieties, and mutations, described as new, which have not been found elsewhere than in Mongolia, while twenty-five others are either varieties of species elsewhere known or are represented by related or analogous species in various late Palæozoic formations of other regions. In the following Table I, the distribution of the species, etc., in the Jisu Honguer limestone is given:

TABLE I. DISTRIBUTION OF THE SPECIES IN THE JISU HONGUER LIMESTONE

(x = present; r = rare; c = common)

		Not Recorded	*1186*	*1190*	*1192*	*1193*	*1194*	*1195*	*1196*	*1205*	*1207*	*1208*	*1209*	*1210*	*1211*
	ANTHOZOA														
1	*Polycœlia cylindrica* Grabau	x													
2	*P. longiseptata* Grabau			x	x										
3	*Amplexus* sp				x										
4	*Waagenophyllum virgalense* (Waagen and Wentzel) var. *mongoliense* Grabau							x							
	BRYOZOA														
1	*Geinitzella columnaris* (Schlotheim)								x						
2	Gen. et sp. undetermined											x			
	BRACHIOPODA														
1	*Dielasma millepunctatum* var. *mongolicum* Grabau			x											
2	*D. truncatum* var. *mongolicum* Grabau								r			x			
3	*D.* cf. *truncatum* Waagen											r			
4	*D. giganteum* var. *anteplicatum* Grabau	x													
5	*D. jisuense* Grabau	x													
6	*D. acutangulum* var. *minor* Grabau	x													
7	*D. elongatum* var. *orientalis* Grabau														x
8	*D. itaitubense* (Derby)											x			
9	*Hemiptychina himalayensis* var. *mongolica* Grabau								x						
10	*H. morrisi* Grabau					x	x		x						
11	*Beecheria sublævis* (Waagen)			x		x									
12	*Morrisina sparsiplicata* (Waagen)								x			x			
13	*M. sparsiplicata* var. *nana* Grabau														x
14	*Mongolina subdieneri* (Grabau)	x													
15	*Jisuina elegantula* Grabau	x													
16	*Notothyris simplex* var. *mongoliensis* Grabau			x											
17	*N. berkeyi* Grabau			x											
18	*N. nucleolus* (Kutorga)	x													
19	*N. nucleolus* (Kutorga), mut. α Grabau	x													
20	*N. irregularis* Grabau	x													
21	*Athyris excavata* Grabau								x						
22	*A. timorensis* var. *mongoliensis* Grabau	x													
23	*A. royssii* Léveillé	x													
24	*Hustedia grandicosta* (Davidson)								x						
25	*H. grandicosta* mut. *lata* Grabau														x
26	*H. remota* (Eichwald)			x											
27	*Spiriferella salteri* mut. α												x		
28	*S. salteri* var. *mongolica* mut. β									x			c		
29	*S. salteri* var. *typica* mut. γ												c		
30	*S. salteri* var. *wimanni* mut. δ									x			c		
31	*S. rajah* (Salter)									x			x		
32	*S. saranæ* (Verneuil)				x					x			x	x	x
33	*S. persaranæ* Grabau				x										
34	*S. keilhaviiformis* var. *vulgaris* Fredericks	x													

TABLE I. (*Continued*)

		Not Recorded	1186	1190	1192	1193	1194	1195	1196	1205	1207	1208	1209	1210	1211
35	*Spiriferella keilhaviiformis* Fredericks												c		
36	*S. keilhavii* v. Buch			x	?								c		
36a	*S. keilhavii* v. Buch, mut. *primitiva* Grabau				x										
37	*Spirifer moosakhailensis* Davidson			x	x					x			c	x	x
38	*Martinia osborni* Grabau					c	c					x			x
39	*M. mongolica* Grabau					x	x								
40	*M. orbicularis* Gemmellaro					x	x								
41	*M. sinensis* Grabau						x								
42	*M. rectangularis* Grabau						x								
43	*M.* cf. *distefanoi* Gemmellaro	x					x								
44	*M. distefanoi* mut. *spissa* Grabau	x					x								
45	*M. distorta* Grabau						x								
46	*M. rhomboidalis* Grabau						x								
47	*Squamularia elegantuloides* Grabau					x									
48	*S. indica* Waagen	x			x	x	x		x						
49	*S. waageni* v. Loczy									x					
50	*Spiriferina mongolica* Grabau								x						
51	*Uncinulus mongolicus* Grabau			x											
52	*Camarophoria mutabilis* Tschernyschew			x											x
53	*C. superstes* Verneuil											x			
54	*C. purdoniformis* Grabau								x						
55	*Orthotychia derbyi* var. *nana* Grabau								x						x
56	*Enteletes andrewsi* Grabau			x			x								
57	*E. angulatoplicata* Grabau						x		x			x			
58	*E. obesa* Grabau			x			x		x						
59	*E. subobesa* Grabau								x						
60	*E. nucleola* Grabau			x			x		x						x
61	*Streptorhynchus kayseri* Schellwien										x				
62	*S. pelargonatus* (Schlotheim)	x													
63	*S. broilii* Grabau											x		x	
64	*S.* sp.			x	x										
65	*Schellwienella regina* Grabau				x										
66	*Orthothetina ruber* (Frech)			x											
67	*O.* cf. *eusarkos* (Abich)										x				
68	*O.* sp.	x													
69	*Derbya dupliciseptata* Grabau			x											
70	*D.* (*Derbyina*) *mongolica* Grabau						x		x						
71	*Derbya* cf. *hemisphærica* Waagen								x						
72	*Meekella uralica* Tschernyschew			x											
73	*Geyerella mongolica* Grabau			x											
74	*Derbyella bureri* Grabau						x								
75	*D. subrotunda* Grabau						x								
76	*D. minor* Grabau						x								
77	*Aulosteges gigantiformis* Grabau			x											
78	*A. grangeri* Grabau														x
79	*Richthofenia lawrenciana* de Koninck			x					x						
80	*Aulacorhynchus* sp.					x									
81	*Lyttonia nobilis* Waagen			x		x									

TABLE I. (*Continued*)

		Not Recorded	1186	1190	1192	1193	1194	1195	1196	1205	1207	1208	1209	1210	1211
82	*L.* cf. *oldhaminiformis* Grabau	...	...	...	...	x	...	...	...	...	...	...	...	...	...
83	*Productus mammatus* Keyserling	...	...	...	x	...	...	...	...	...	...	...	...	...	...
84	*P.* cf. *ischmensis* Tschernyschew	...	...	...	...	...	...	...	...	...	x	...	...	...	...
85	*P. compressus* Waagen var. *corniformis* Chao	...	...	x	...	...	...	...	...	...	...	...	x	...	...
86	*P. lineatus* Waagen	...	...	...	...	...	...	...	...	...	...	x	x	...	...
87	*P.* cf. *porrectus* Kutorga	...	...	...	x	...	...	...	...	...	...	...	...	...	...
88	*P.* cf. *juresanensis* Tschernyschew	...	...	...	x	...	...	...	...	...	...	...	...	...	...
89	*P.* cf. *purdoni* Davidson	...	...	...	...	...	...	...	x	...	...	...	...	...	...
90	*P. humboldti* d'Orbigny	...	x	x	...	...	...	...	...	...	...	...	...	...	...
91	*P. fasciatus* Kutorga	...	x	...	...	...	...	...	...	...	...	...	...	...	...
92	*P.* sp. A	...	...	...	x	...	...	...	...	...	...	...	...	...	...
93	*P.* sp. B	...	...	...	x	...	...	...	...	...	...	...	...	...	...
94	*P.* sp. C	...	...	...	...	...	...	...	...	x	...	...	...	...	...
95	*Proboscidella* cf. *lata* Tschernyschew	x	...	...	...	...	...	...	...	...	...	...	...	...	...
96	*Marginifera jisuensis* Chao	...	...	x	...	x	c	...	x	...	...	x	...	...	...
97	*M. typica* var. *septentrionalis* Tschernyschew	...	...	...	c	...	...	...	...	...	...	...	...	...	...
98	*M. gobiensis* Chao	...	...	...	...	...	...	...	...	...	...	...	x	...	...
99	*M. morrisi* Chao	...	...	...	...	...	x	...	x	...	...	x	...	...	...
	PELECYPODA														
1	*Schizodus subquadratus* Grabau	...	...	...	...	...	...	...	x	...	...	...	...	...	...
2	*S. elongatus* Grabau	...	...	x	...	...	...	...	...	...	...	...	...	...	...
3	*Conocardium jisuensis* Grabau	...	...	x	...	...	x	...	...	...	...	...	...	...	...
4	*Sanguinolites modiomorphoides* Grabau	...	...	...	...	x	...	...	x	...	...	...	...	...	...
5	*S.* cf. *modiomorphoides* Grabau	x	...	...	...	...	...	...	...	...	...	...	...	...	...
6	*S.* sp.	...	...	...	...	...	x	...	...	...	...	...	...	...	...
7	*S.* sp.	x	...	...	...	...	...	...	...	...	...	...	...	...	...
8	*Pseudomonotis* (*Aviculomonotis*) *mongoliensis* Grabau	...	...	x	...	...	...	...	...	...	...	...	...	...	...
9	*P.* (*A.*) *kazanensis* de Verneuil	...	...	x	...	...	...	...	...	...	...	...	...	...	...
10	*P.* (*A.*) *matthewi* Grabau	...	...	...	...	...	...	...	x	...	...	...	...	...	...
11	*P. furcoplicatus* Grabau	...	...	x	...	...	...	...	...	...	...	...	...	...	...
12	*Deltopecten* cf. *subquinquelineatus* (McCoy)	...	...	...	x	...	...	...	...	...	...	...	...	...	...
13	*Euchondria? engelhardti* Etheridge and Dunn	...	...	c	...	...	...	...	x	...	...	...	...	...	...
14	*Pseudamusium auriculatum* Grabau	...	...	x	...	...	...	...	...	...	...	...	...	...	...
15	*P.* cf. *auriculatum* Grabau	...	...	x	...	...	...	...	...	...	...	...	...	...	...
16	*Myalina falcata* Grabau	...	...	...	...	...	x	...	...	...	...	...	...	...	...
17	*M.* cf. *verneuili* (McCoy)	x	...	...	...	...	...	...	...	...	...	...	...	...	...
	GASTROPODA														
1	*Bellerophon squamatus* Waagen var. *mongoliensis* Grabau	...	...	...	...	...	...	...	...	...	...	x	...	...	...
2	*B. jonesianus* de Koninck	...	...	x	...	...	...	...	x	...	...	...	...	...	...
3	*Luciella planoconvexa* Grabau	x	...	...	...	...	...	...	...	...	...	...	...	...	...
4	*L. elongata* Grabau	...	...	...	...	...	x	...	...	...	...	...	...	...	...
5	*L. perlimbata* Grabau	x	...	...	...	...	...	...	...	...	...	...	...	...	...
6	*Worthenia nana* Grabau	...	...	x	...	...	...	...	...	...	...	...	...	...	...
7	*Solenospira? mongolica* Grabau	x	...	...	...	...	...	...	...	...	...	...	...	...	...

TABLE I. (*Continued*)

		Not Recorded	*1186*	*1190*	*1192*	*1193*	*1194*	*1195*	*1196*	*1205*	*1207*	*1208*	*1209*	*1210*	*1211*
8	*Euomphalus simuloides* Grabau	x													
9	*E. mongolicus* Grabau				x										
10	*Phymatifer* cf. *coroniferus* de Koninck	x													
11	*Flemingia tepeeformis* Grabau								x						
12	*F. gigas* Grabau								x						
13	*Naticopsis khoovensis* Waagen			x					x	x					
14	*Strophostylus indicus* (Waagen)			x					x	x					
15	*Holopella* cf. *trimorpha* Waagen								x						
16	*Macrocheilina* (*Sphærodoma*) *avellanoides* (de Koninck)			x											
17	*M.* (*S.*) *transitoria* Grabau								x						
18	*Soleniscus mongolicus* Grabau	x							x						

CHAPTER IX

OCCURRENCE OF THE SPECIES OF THE JISU HONGUER LIMESTONE IN OTHER REGIONS

INTRODUCTION

TURNING now to the details of the distribution of the species in other countries, we find that twenty-four are also represented in the Schwagerina limestone, but of these eight also occur in India, three in other parts of Europe, especially Spitzbergen, and three more both in India and Europe, thus making a total of fourteen species, widely distributed geographically. By far the larger number of these also occur in Timor. This leaves only ten species, so far known only from the Schwagerina limestone of Russia and the Jisu Honguer limestone of Jisu Honguer, Mongolia. The Productus limestone of India has nineteen species in common with the Jisu Honguer limestone, eight of which also occur in Russia and three more in other parts of Europe, leaving eight species restricted to the Productus limestone of India and the Jisu Honguer limestone of Mongolia. Some of these are, however, also found in Timor. Altogether, then, the relation to the Schwagerina limestone is slightly more marked than that to the Productus limestone. Nevertheless, it is true that the species of the Productus limestone are the more characteristic and numerically best represented, while the species represented by related forms in the Productus limestone are more numerous than those represented in the Schwagerina limestone. This would throw the balance of relationship to the side of the Indian formation. So far, the number of species in common between the Jisu Honguer limestone and the Permian of China is small, but that is chiefly due to the fact that the Chinese forms have not yet been studied to any great extent.

Turning to the other groups, we find that among the corals one of the Indian species only is represented in our rocks, by a distinct variety. Our only specifically identified bryozoan is, however, a species of world-wide distribution, occurring in the European Zechstein, as well as in the Indian Productus limestone.

Of the seventeen pelecypods in our fauna, only sixteen are specifically determined, and of these, four are doubtfully identified, leaving a total of twelve described species. Of these, one occurs in the Salt Range as well as in Russia, and another is characteristic of the Permian deposits of Australia. Of the doubtfully identified forms, one is referred to an Australian and the other to a European species. Twelve, therefore, of the sixteen, or 76.6 per cent., are known only from Mongolia. The gastropods tell a similar story. Of the eighteen species recorded, one is doubtfully identified with an Indian form, while four others are referred to Indian species, and one is a variety of an Indian form. Finally, one species is doubtfully identified with a European form. This leaves a total of ten new species restricted to the Jisu Honguer limestone, to which may be added one new variety. In so far as our species have any outside representation, their affinity is entirely with the Productus limestone species. In the following, Table II, the distribution of the species in other localities is given:

TABLE II, DISTRIBUTION OF THE SPECIES OF THE JISU HONGUER LIMESTONE IN OTHER LOCALITIES

The species restricted to this formation are omitted. The following notations are used: × = identical species: + = occurrence of a species which in Mongolia is represented by a variety: O = related species.

		Ural and Timan					Spitzbergen and Bear Island				Eastern Alps		Other European Localities				Darvas		Salt Range, India			Other Asiatic Localities									America	
		Omphalotrochus beds	Cora beds	Schwagerina beds	Artinskian-Kungurian	Samara-Kostroma	Cyathophyllum beds	Cora beds, Bear Island	Spirifer beds	Productus beds	Auernigg beds	Trogkofel	Zechstein	Sosio limestone	Permian Donetz Basin	Djulfa Series	Safeddaron group	Obirawnou group	Lower Productus beds	Middle Productus limestone	Upper Productus limestone	Himalayan Permian	Burma (Shan States)	Timor	Australia	Indo-China	China	Japan	Vladivostok	Tien Shan	Texas, North America	South America
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	ANTHOZOA:																															
1	*Waagenophyllum virgalense* (Waagen and Wentzel) var. *mongoliense*, Grabau																			+												
	BRYOZOA:																															
1	*Geinitzella columnaris* (Schlotheim)			×		×							×							×	×		×									
	BRACHIOPODA:																															
1	*Dielasma millepunctatum mongolicum*		+																													
2	*D. truncatum mongolicum*			+	+												+		+													
3	*D.* cf. *truncatum*			×	×												×		×													
4	*D. giganteum anteplicatum*			+																												
5	*D. jisuensis*			O										O																		
6	*D. acutangulum minor*																				+	+										
7	*D. elongatum orientalis*			×	+	+							+					+		+		×		+								
8	*D. itaitubense*	×		×		×		×									×			×												×

		Ural and Timan					Spitzbergen and Bear Island				Eastern Alps		Other European Localities				Darvas		Salt Range, India			Other Asiatic Localities									America	
		Omphalotrochus beds	Cora beds	Schwagerina beds	Artinskian-Kungurian	Samara-Kostroma	Cyathophyllum beds	Cora beds, Bear Island	Spirifer beds	Productus beds	Auernigg beds	Trogkofel	Zechstein	Sosio limestone	Permian Donetz Basin	Djulfa Series	Safëddaron group	Obirawnou group	Lower Productus beds	Middle Productus limestone	Upper Productus limestone	Himalayan Permian	Burma (Shan States)	Timor	Australia	Indo-China	China	Japan	Vladivostok	Tien Shan	Texas, North America	South America
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
9	*Hemiptychina himalayensis mongolica*																		+	+	+	+		+								
11	*Beecheria sublævis*			O					O			O						O	×	×		×		×								
12	*Morrisina sparsiplicata*																		×	×				×								
13	*M. sparsiplicata nana*																		+	+				+								
14	*Mongolina subdieneri*													O			O															
15	*Jisuina elegantula*													O			O															
16	*Notothyris simplex mongoliensis*			O										+						+				+								
18	*N. nucleolus*			×	×						×	×			×	×	×			×		×		×					×			
19	*N. nucleolus* (α)			+	+						+	+			+	+	+			+		+		+								
22	*Athyris timorensis mongoliensis*																							+			+					
23	*A. royssii*							×												×	×	×	×	×		×	×					
24	*Hustedia grandicosta*																		×	×	×			×			×					
25	*H. grandicosta lata*																		+	+	+			+			+					
26	*H. remota*		×	×					×	×		×							×	×	×								×			
27	*Spiriferella salteri*, α																							×								O
28	*S. salteri mongoliensis*, β			+					+																							
29	*S. salteri* (*typica*), γ			×	×				×													O										
30	*S. salteri wimanni*, δ							×	×	×														×								
31	*S. rajah*																					×		O					×			

32	*S. saranæ*		×	×	×			×	×	×																			×			
35	*S. keilhaviiformis*			×																									×			
36	*S. keilhavii*								×	×																						
37	*Spirifer moosakhailensis*		O	O	O			O	O	O	×	O							×	×	×	×		×		×	×					
38	*Martinia osborni*			O										O													O					
39	*M. mongolica*			×								O						×				×		×								
40	*M. orbicularis*													×																		
41	*M. sinensis*																					×										
43	*M.* cf. *distefanoi*													×																		
44	*M. distefanoi spissa*													+																		
47	*Squamularia elegantuloides*																			O												
48	*S. indica*															×				×	?					×	×					
49	*S. waageni*															×											×					
50	*Spiriferina mongolica*																									O						
51	*Uncinulus mongolicus*																				O			O								
52	*Camarophoria mutabilis*			×	×				×	×									O	O	O											
53	*C. superstes*			×	×	×														×	×			×					O			
54	*C. purdoniformis*	×	×	×	×	×			×	×												O		×					O			
55	*Orthotychia derbyi nana*																			+	+											
56	*Enteletes andrewsi*																					O										
61	*Streptorhynchus kayseri*																										×					
62	*Streptorhynchus pelargonatus*			×	×							×	×						×	×				O								
63	*S. broilii*																							O								
66	*Orthothetina ruber*															?											×					
67	*O. eusarkos*															×											?					
71	*Derbya* cf. *hemisphærica*																				×											
72	*Meekella uralica*			×								O																				
77	*Aulosteges gigantiformis*					O																O										
79	*Richthofenia lawrenciana*																		×	×				×			O		×			
81	*Lyttonia nobilis*																	×		×		×				×	O					
83	*Productus mammatus*			×					×																×							
84	*P.* cf. *ischmensis*				×														O	O	O											
85	*P. compressus corniformis*																			+	+											
86	*P. lineatus*		×	×	×		×				O							×	×	×	×		O					×				
87	*P.* cf. *porrectus*		×	×	×				×																							
88	*P.* cf. *juresanensis*	×	×	×											×		×									×						
89	*P.* cf. *purdoni*								×												×	×							×			
90	*P. humboldti*				×	×														O												×
91	*P. fasciatus*	×	×	×	×				×		O	O					×															
95	*Proboscidella* cf. *lata*			×	×																									O		

TABLE II—*Continued*

		Ural and Timan					Spitzbergen and Bear Island				Eastern Alps		Other European Localities				Darvas		Salt Range, India			Other Asiatic Localities									America	
		Omphalotrochus beds	Cora beds	Schwagerina beds	Artinskian-Kungurian	Samara-Kostroma	Cyathophyllum beds	Cora beds, Bear Island	Spirifer beds	Productus beds	Auernigg beds	Trogkofel	Zechstein	Sosio limestone	Permian Donetz Basin	Djulfa Series	Safeddaron group	Obirawnou group	Lower Productus beds	Middle Productus limestone	Upper Productus limestone	Himalayan Permian	Burma (Shan States)	Timor	Australia	Indo-China	China	Japan	Vladivostok	Tien Shan	Texas, North America	South America
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
96	*Marginifera jisuensis*			×																												
97	*M. typica septentrionalis*		×	×	×				×											×	×	O							O	×		O
98	*M. gobiensis*																			O	O	O										
99	*M. morrisi*		O	O																												
	PELECYPODA:																															
9	*Pseudomonotis* (*Aviculomonotis*) *kazanensis* de Verneuil					×															×											
12	*Deltopecten* cf. *subquinquelineatus* (McCoy)																								×							
13	*Euchondria ? englehardti* Etheridge and Dun.																								×						+	
17	*Myalina* cf. *verneuili* (McCoy)[1]																															
	GASTROPODA:																															
1	*Bellerophon squamatus* Waagen																			×												
2	*B. jonesianus* de Koninck																			×	×											
10	*Phymatifer* cf. *coroniferus* de Koninck[2]																															
13	*Naticopsis khoovensis* Waagen																			×												
14	*Strophostylus indicus* (Waagen)																			×												
15	*Holopella* cf. *trimorpha* Waagen																				×											
16	*Macrocheilina* (*Sphærodoma*) *avellanoides* de Koninck																			×	×											

[1] Upper Carboniferous of Western Europe.
[2] Lower Carboniferous of Western Europe.

CHAPTER X

AGE RELATIONS OF THE FAUNA OF THE JISU HONGUER LIMESTONE

STATEMENT OF THE PROBLEMS

As we have seen, the nearest relationship of our fauna is with that of the Middle Productus limestone on the one hand, and the Schwagerina limestone on the other. The Middle Productus limestone is commonly considered to be of Permian age, whereas the Russian geologists have generally followed Tschernyschew and considered the Schwagerina limestone as of Upper Carboniferous age. That the two formations have many species in common cannot be questioned, and some of these appear to be among the most diagnostic of horizon markers. In table V, on a subsequent page, are given the species common to these two localities. From the close similarity between the fauna of the Productus limestone and the fauna recognized to be of Permian age in the Chinese succession—partly from the stratigraphic succession of the beds in which it occurs, and partly because of their intimate association with strata bearing plants of Permian age—we confidently refer this Chinese fauna and, with it, the Middle Productus limestone fauna, to the Permian. This would automatically determine the age of the Jisu Honguer fauna, its undoubted correlative, as Permian. This, however, raises again the question concerning the age relation of the Schwagerina limestone. In this connection two lines of argument might be investigated. In the first place, it may be argued that the Schwagerina limestone is older than the Middle Permian, belonging essentially to the Upper Carboniferous, the Permian beginning with the Artinskian. This is the correlation recently advocated by Fredericks who considers the Lower Permian absent in the Ural region. In that case, the fauna of the Schwagerina limestone must be regarded as a prenuncial one, representing the first appearance of the species, which later invaded the more eastern and more southern territories as members of the subsequent Permian fauna. This would imply that these members originated in the Boreal region, from the pre-existing Carboniferous faunas of that region.

If that were the case, we should expect to find this fauna in the corresponding deposits of North America, that is, those of the Palæo-Cordilleran geosyncline, which also was an extension of the Boreal sea, in late Carboniferous and

Permian time. Up to the present, the species in question are, however, not known from that region, although related types are found in the Guadalupian fauna of Texas, which I believe to be distinct from the contemporaneous faunas of the Palæo-Cordilleran trough, the Guadalupian deposits having been formed in an embayment from the Pacific. (See palæo-geographic map in Grabau, 1921, Vol. II, p. 519, Fig. 1436).

The other alternative would be to consider the Schwagerina limestone as of Permian age, and regard it as either contemporaneous in origin with the Middle Productus limestone of India, and the Jisu Honguer limestone of Mongolia, or as representing an earlier invasion of the Permian fauna. In that case, instead of being natives of the Boreal sea, the characteristic species of these deposits must be considered as originating in the Indo-Pacific Ocean of Permian time. This latter supposition is in conformity with the general eastern character of the fauna and is greatly strengthened by the extensive development of this fauna in the Permian deposits on the Island of Timor, as well as in the eastern end of the Mongolian geosyncline at Vladivostok, and so far as some of its most striking types are concerned, for example, *Lyttonia*, *Richthofenia*, etc., in Japan, and eastern China.

I have elsewhere (1923–1924, Vol. I, p. 502) suggested that all the available evidence points to two centers of origin of the Permian fauna of Eurasia and North America. The first of these was the Boreal realm, the fauna originating there being perhaps most typically represented in the Zechstein of northern Europe. This is the fauna which would extend southward in the Palæo-Cordilleran geosyncline of western North America. The other center of origin was the Indo-Pacific realm, whence the fauna wandered into the Himalayan and Nanshan geosynclines and extended westward into the Tethys, which apparently was not in connection with the Atlantic. That ocean, if it existed at that time, was separated from the Tethys by land barriers. This southern basin was at least temporarily connected with the northern one, by way of Turkestan and the Kirghiz steppes (Grabau, 1923–1924, p. 325, Fig. 229, and polar map, p. 326, Fig. 231). This latter district also marks the point of junction of the Russian sea and the Mongolian geosyncline. If the Schwagerina limestone were contemporaneous with the Jisu Honguer limestone, we might consider the fauna of the latter as primarily of Pacific origin, with possibly certain additions of the Boreal element from Russia. The Pacific element of the Schwagerina limestone was in that case derived either by further migration westward from the Mongolian geosyncline, or by northward[1] migration from the Himalayan geosyncline, through the Turkestan straits, or by some other route.

[1] This refers, of course, to compass points of to-day. If, as held by some, the poles in Permian time had a different position, these directions differed correspondingly.

CHAPTER XI

THE PERMIAN AND UPPER CARBONIFEROUS SUCCESSION IN RUSSIA AND ADJOINING DISTRICTS

INTRODUCTION

It may be well in this connection to consider briefly the stratigraphic relationships of the Schwagerina limestone and the overlying later Permian deposits of Russia in their most typical region, namely, the Ural and Timan ranges of European Russia. We will first consider the succession in the Timan Range. This has been described in some detail by Tschernyschew (1902), who has given a number of characteristic sections of which the following are condensed summaries.

THE TIMAN REGION

In the Timan, the succession is as follows, in the descending order:

SUPERFORMATION (Quaternary beds)

Hiatus and Unconformity

URALIAN SERIES:

5. SCHWAGERINA LIMESTONE ($C3_3$)..60 meters

Reddish, light gray, to white limestone, and light gray dolomites, with interbedded layers and nodules of chert, abounding in brachiopods and corals. Mollusca subordinate. Among the species found also in the Jisu Honguer limestone are: *Dielasma elongatum*, *Notothyris nucleolus*, *Camarophoria mutabilis*, *Spiriferella saranæ*, *S. salteri*, *Productus fasciatus*, *P. mammatus*, *P. porrectus*, and *Marginifera typica* var. *septentrionalis*. Locally the limestones and dolomites are crowded with *Schwagerina princeps* and *Fusulina verneuili*.

4. CORA LIMESTONE ($C3_2$)..70 meters

Light gray, oölitic limestone and greenish gray glauconitic limestone, rarely with chert nodules, and dark gray bituminous limestone, with large *Fusulinas*. This horizon is also characterized by brachiopods, corals and bryozoans. Among the species also found in the Jisu Honguer limestone are the following: *Dielasma elongatum*, *Spiriferella saranæ*, *Productus humboldti*, *P. juresanensis*, *P. lineatus* and *P. fasciatus*.

In the section on the Indiga River, Tschernyschew states (1902, p. 435) that "Towards the base, the white platey oölite passes into calcareous sandstone, with plainly indicated diagonal bedding, and into limestone breccias, with inclusions of white and greyish chert." This rests upon the *Omphalotrochus* beds. It would seem almost certain that we have here a disconformity, which, if the Cora beds are of Permian age, separates them from the underlying Upper Carboniferous or earliest Permian beds. This, however, has not been recognized in the other sections.

3. Omphalotrochus Beds ($C3_1b_2$)....................?

White oölitic limestone, alternating with light gray yellow and platey limestones, which are plastered with green and red clay on the bedding planes. The beds are locally filled with a small spherical *Fusulina*, and contain numerous chert nodules. Besides *Omphalotrochus whitneyi* Meek, this bed contains brachiopods, corals and bryozoans. It is apparently an older horizon than anything represented at Jisu Honguer.

2. Parting sandstone ($C3_1b_1$)....................1–2 meters

Rose-red and white, thin-bedded, arkose sandstone, with distinct cross-bedding. This evidently marks a period of change in sedimentation, and indicates a hiatus of unknown length. The Omphalotrochus beds, therefore, are distinctly separated from the underlying *Spirifer marcoui* beds by a disconformity.

Hiatus and Disconformity

1. Gschellian Series, Spirifer marcoui Beds (C3, a)....................?

Light gray and reddish concretionary dolomitic limestone, not infrequently with large cavities, calcite geodes, and chert nodules. Wherever well developed, this horizon is characterized by corals and brachiopods, among the latter of which *Spirifer marcoui* Waagen is the leading form.

Combined thickness of numbers 1–3 about 70 meters.

Hiatus and Disconformity

Subformation: Moscovian limestone with Spirifer mosquensis

In the section of Cape Beloje Stschelje north of the mouth of the Volonga, the Omphalotrochus beds rest unconformably upon sericite shales.

In the Petschorskaja Pishma syncline, the *Spirifer marcoui* beds rest disconformably upon white limestones with *Spirifer mosquensis*, which in turn rests unconformably on sericite shales or eroded Devonian shales.

In only one section, namely, that on the Myla River above the village of Wanjutschkowa, is the series succeeded by red sandstones of later Permian age, but these rest directly upon the *Productus cora* beds, the Schwagerina limestone being absent. Where the latter is present in other sections, it is followed unconformably by horizontal marine beds of post-Pliocene age.

THE UFA PLATEAU OF THE URALS, AND THE TYPICAL PERMIAN SECTION

The most complete succession of the Upper Palæozoic strata of northern Russia is that found in the Ufa plateau region of the southern Urals, to the south of the village of Perm, and west of the southern Urals. The plateau itself is formed of the great limestone series to which the name Uralian has been given by the Russian geologists.

On the western border of the Plateau, which is here bounded by the Ufa River, the limestones are succeeded by the Artinskian shales and marls, named from the small village of Artinsk on the Ufa River in this region, and these are in turn succeeded by the Kungurian dolomitic series of limestone, which Murchison originally placed in his Permian, but which, together with the Artinskian, are classed by most Russian geologists as Permo-Carboniferous. They and the Artinskian beds are also well exposed east of the limestone area of the Ufa plateau.

Succeeding these Kungurian dolomitic rocks is the series of shales, sandstones and dolomitic beds which are so well exposed on the Kama River. This river begins north of Latitude 60°, runs parallel to the western border of the Urals to the village of Perm, and thence continues southwestward and westward to its junction with the Volga, south of Kazane or nearly in latitude 55°. We shall here use the name KAMA SERIES for these beds, which in a sense are the typical members of Murchison's Permian. They are in turn succeeded by the Red Beds, which constitute the Tartarian Series, and which are classed by some Russian geologists as Permo-Triassic. We may summarize this succession in the following table:

TABLE OF THE PERMIAN SUCCESSION OF EASTERN RUSSIA

UPPER PERMIAN

Tartarian Series (P.T.) or (P_3)
Kama Series (P) or (P_2 and P_1)

MIDDLE PERMIAN

Kungurian dolomites and limestones (C.P.c)
Artinskian shales, marls and sandstone (C.P.g)

Hiatus (?)

LOWER PERMIAN

Uralian limestone Series (C_3)
Tastuba or Schwagerina limestone ($C3_3$)
Cora limestone ($C3_2$)

Possibly small Hiatus and Disconformity

Omphalotrochus beds ($C3_1$ b)

Hiatus and Disconformity

UPPER CARBONIFEROUS

Spirifer marcoui beds—Gschellian ($C3_1$a)

Hiatus and Disconformity

MIDDLE CARBONIFEROUS—Moscovian

THE UPPER PERMIAN

A number of sections may be given to show the detailed character of the formation.

I. SECTION FROM SAMARA TO UFA

(VII Intern. Geol. Cong., Guide II, p. 22.)

Summary:—The general character and subdivisions of the Upper Permian in this region are as follows:

P_3 OR TARTARIAN SERIES

The Tartarian series is divisible into two parts.

(b) The Upper (P_3b) is a group consisting of red sandstones and argillaceous sandstones, with intercalations of shales and of marls, and calcareous beds of the same color, rarely greenish or bluish.

(a) The lower division (P_3a) is a group consisting of rose-colored marls and variegated clays (reddish, bluish and greenish), with intercalations of sands of the same color and of greenish limestone beds.

The series is non-marine, and in both divisions are found beds with fresh-water pelecypods (*Anthracosia, Najadites, Palæomutela*) (Amalitzky, 1892). Salt and gypsum are not infrequently found in this series.

THE TYPICAL PERMIAN OR KAMA SERIES:

This has the following subdivisions between Ufa and Samara, in descending order:

P_2 OR SAMARA BEDS

Group f (P_2c part). Brown sandstones, marls and limestones enclosing some pelecypods (*Allorisma elegans* King, etc.).

Group e (P_2c part). Calcareous sandstones, shales and marls with intercalated friable sandstones. This series is rich in pelecypods and gastropods, including *Macrodon kingianum, Osteodesma kutorgana, Modiolopsis pallasi,* *Murchisonia subangulata*, *Leda speluncaria*, *Turbonilla altenburgensis*, etc. Ostracods of the genera *Bairdia* and *Estheria* also occur. The brachiopods are represented by *Lingula orientalis*, and the fish by *Palæoniscus* and *Acrolepis*.

Group d (P_2b). Sandstones and calcareous grits, more or less cupriferous. They contain a rich brachiopod fauna, including such forms as *Spirifer regulatus*, *Productus cancrini*, *Dielasma elongata*, *Athyris pectinifera*, *Spiriferina cristata*, *Productus hemisphericus*, and *Strophalosia horrescens*, and some pelecypods and corals.

Group c (P_2a). Red sandstones, more or less argillaceous, with intercalations of clays and marls, of yellowish, brownish and reddish colors. Fossils found only in the upper beds, including *Productus cancrini*, *Athyris pectinifera*, *Dielasma elongata*, *Allorisma elongata*, *Macrodon kingianum*, etc.

P_1 OR UFA SERIES

Group b (P_1b). Argillaceous limestones and marls of variegated colors, red, brown, blue, greenish; barren of fossils.

Group a (P_1a). Gypsiferous beds: limestones, gypsum, clays; no fossils.

The lower two groups (a) and (b) constitute the lower division of Netschajew's section given below, representing P_1a and P_1b, respectively. To these the name UFA SERIES is here applied, because of their satisfactory exposure in and around the town of Ufa on the river of that name. The remainder of the beds (groups c to f) are commonly known as the eastern phase of the Zechstein, and will here be referred to as the SAMARA BEDS. The upper division constitutes the well-known TARTARIAN SERIES.

The general succession at Samara is summarized by Netschajew as follows, the succession here being given in descending order, with the names here used, and the correlation with the preceding general section indicated:

C—UPPER DIVISION OR TARTARIAN SERIES (P_3):—about 175 meters or more.

(P_3b) Red-colored clays and marls, and sandstone layers.

(P_3a) Rose-colored marls with limestone layers.

B—MIDDLE OR SAMARA SERIES (P_2):—75–100 meters.

(P_2c) Complex of gray marls and marly limestones with gastropods and pelecypods (equals horizons *e* and *f* of Nikitin's section).

(P_2b) Yellowish and white marly limestones with brachiopods, and complex of marls and dolomites with gypsum layers (equals horizon *d* of Nikitin's section).

(P_2a) Complex of gray sandstones and gray marls with a brachiopod fauna (equals horizon *c* of Nikitin's section).

A—Lower or Ufa Series (P_1):—about 200 meters.

(Subdivisions not given by Netschajew, equals horizons *a* and *b* of Nikitin's section). The lower part of this division (P_1a) is well exposed in the city of Ufa, where the gypsiferous beds have an exposed thickness of 86 meters, and probably exceed 100 meters in thickness. We may roughly take the entire thickness of the two divisions of the Ufa series as 200 meters.

LOCAL SECTIONS

5 I a Nikefur:—About 170 versts southwest of Ufa, near the village of Nikefur (about 54° 45′ east longitude, 53° 50′ north latitude). On the banks of a tributary of the Dioma, and on that river, good exposures are found in cliffs 140 feet high. (Murchison, Verneuil and Keyserling, 1845, Vol. I, p. 151). The succession is as follows, in descending order:

(P_2a) at the summit of the section, are limestone beds, with *Productus cancrini* and *P. horrescens*, etc., intercalated with plant-bearing sandy beds . . . . about 30 ft.
(P_1b) Grits, marls, sandstones, with some limestone beds . . . . 100 ft.

5 I b Metaftamak:—About 80 versts to the north, or about 150 versts in a direct line from Ufa to Samara, lies the village of Metaftamak (22 versts from Belebei). Here the following section occurs: (Murchison, Verneuil and Keyserling, *loc. cit.*).

(P_3) White marlstones, flaggy limestones, marls and sandstone, 400 to 500 ft.
(P_2) Limestones and calcareous grits and sandstones, often made up of shells of *Productus cancrini*, etc., and whitish and greenish marls with *Modiolæ* . . . . 150 to 200 ft.
(P_1) Argillaceous beds . . . . 80 ft.

Base not exposed

5 I c Karlinski Plateau:—About 20 versts west of the preceding locality, a section was made by Murchison, *et al*, extending from the Kidash River, near its confluence with the Ilk, to the summit of the Plateau of Karlinski (Murchison, Verneuil and Keyserling, 1845, Vol. I, p. 155, Fig. 25). The total thickness of the strata here exposed is at least 500 ft.

The following subdivisions are shown in descending order, with the classification added:

Tartarian Series (P_3)

Horizon g.

White marlstone, with red and green argillaceous marl or shale.

Horizon f.

Dingy red and green incoherent sands, with some green marl and a little copper.

Horizon e.

White marlstones of great thickness with stems of fossil plants and shells of *Unio* or *Anodonta*. (These are probably *Anthracosia*, etc.)

SAMARA SERIES (P_2):

Horizon d.

Yellowish, calcareous shelly beds, ten to fifteen inches thick, with white, red, and green-colored marls. These beds break into large rhombs or septarian masses, and the separating fissures are filled with shale. The chief bed is made up of a multitude of broken shells and is divided from the marlstones above and below by a thin pellicle of shale.

Horizon c.

Thin-bedded white marlstone, passing into tufaceous limestone.

Horizon b.

Gray sandstone and grit.

Horizon a.

Shale and calcareous flagstone, with *Productus cancrini* and other fossils.

This section apparently includes the whole of the Samara series (P_2) and at least the lower part of the Tartarian series (P_3).

5 I d Sergiefsk:—On the banks of the river Sok at Sergiefsk, and at the Imperial Baths, eight miles east of that town, white and yellowish magnesian limestones are exposed in cliffs 100 to 120 ft. in height. These are divided into beds from four to ten inches in thickness, and they are the limestones of the Samara series, which have become thicker and purer as we proceed westward toward Samara, and away from the Uralian oldland, the source of the clastic material of the later Palæozoic. At the Sulphur Baths, the lower beds are whitish limestones, with an abundance of *Productus cancrini* and *Pseudomonotis kazanensis.* Higher up, the series consists of gypsum, limestone, sulphur, and dolomite tufa, and above these occur marlstones and white limestones.

II THE KAMA RIVER SECTIONS

The sections exposed along the Kama River extend from the city of Perm on the western flanks of the Ural Mountains for a distance of 720 kilometers in a straight line to Nijni Novgorod, on the Volga River, or over 900 kilometers along the Kama and Volga Rivers. These furnish the type exposures of the Permian System of Russia. The general succession as summarized by Netschajew (1894) is as follows, the succession being given in descending order, with the formation names here used, and the approximate thicknesses as estimated from the sections added thereto:

C UPPER OR TARTARIAN SERIES (P_3):—About 120 meters.

(P_3 b) Complex of red-colored clays and marls interstratified with red limestones.

(P_3 a) Complex of rose-colored marls interbedded with grayish white limestones.

B MIDDLE OR SAMARA SERIES (P_2):—About 40 meters.

(P_2 c) Complex of heavy-bedded limestones and gray marls.

(P_2 b) Complex of gray sandstones, with strata of clay limestones and marly clay.

(P_2 a) Gray marly clay, with clayey limestones.

A LOWER OR UFA SERIES (P_1):—About 200 meters.

(P_1 b) Clayey, sandy, red-colored complex, with intercalations of gypsum.

(P_1 a) Complex of red sandstones and conglomerates with interstratified beds of red clay.

The Middle or Samara series seems to be absent in its normal phase in the eastern part, gradually increasing in thickness, until beyond Nijni Novgorod it becomes the most important member, constituting the Russian Zechstein or KOSTROMA SERIES. (See below).

5 II A. SECTIONS BETWEEN PERM AND SARAPOUL

The first set of sections which we shall review lies between Perm, where the base of the series is exposed, and Sarapoul, where the Kama beds pass under the Tartarian series. The distance in a straight line between these two points is 210 kilometers, and the direction is southwestward.

The Ufa beds (P_1 a and P_1 b) are seen a short distance above Perm, showing their normal super-position in Mount Tchourbina, opposite the confluence of the Tchoussowai River with the Kama. Beyond this point the upper division (P_1 b) is alone exposed at intervals, being more or less cupriferous. As the beds are very gently inclined, are indeed, according to Murchison (1845, Vol. I, p. 144), "as near as possible horizontal," the successive outcrops found as we pass down the river may be added one to the other, giving us in this way a fairly good estimate of the total thickness. The successive sections are as follows, beginning with the easternmost, which shows the lowest members (VII International Geological Congress, guide XI, Stuckenberg):

At Mouth of Nytywa	12 meters
At Okhansk	16 meters
At Ossa	slight exposure
At Wotkinsky and below	72 meters
At Sarapoul	27 meters
Total exposed thickness of (P_1 b)	127 meters

At the last point, the beds pass under the Tartarian series (P_3). Only fossil plants are recorded from this series, these including *Calamites kutorgæ.*

Evidently the Samara beds (P_2) are absent from this section, and this needs explanation. Either there is a disconformity and hiatus between the Ufa beds and the Tartarian series, cutting out the Samara beds (P_2), or these are here represented by continental beds of the Ufa (P_1) type, and included in the above succession. Or it is possible that the series referred to the Tartarian (P_3) may be in part at least the continental equivalent of the Samara series (P_2). It is of course to be expected that the calcareous beds would disappear in the direction of the oldland, but in that case, they should be represented by continental beds, which, however, would be readily included in one of the continental series which bound it above and below. Again, it is conceivable that the thickness of 127 meters, obtained by adding the successive sections, is less than the actual thickness of the entire series, the dip being greater than assumed, so that the other members occur between the sections but show no exposures. In the absence of palæontological zones it is of course impossible to make correlations, and the total thickness could be obtained only by borings in the Sarapoul regions. If such there are, I am not aware of their existence. If, then, the series here designated (P_1) is much thicker, it includes the continental equivalent of the Samara beds. A part of these is represented by the exposures at Sarapoul, where they are followed by the Tartarian beds.

5 II B. TIKHIA GORY TO KAMA MOUTH

The next set of outcrops down the Kama River extends from Tikhia Gory to the confluence of the Kama with the Volga, a distance due west of about 175 kilometers. Here the series appears again from beneath the Tartarian series and seems to be a descending series, though, since the beds are practically horizontal and the section is along the fall of the river, it is possible that repetitions occur in the successive outcrops.

6 1 Tikhia Gory:—Here the Samara series (P_2) makes its appearance.

The upper beds are red clays with gray and green sandstones interstratified, becoming calcareous downward. About seven meters below the top is a limestone, one meter thick with *Pseudomonotis garforthensis*, *Modiolopsis teplofi*, *Productus cancrini*, *Dielasma elongata*, etc. Half a meter lower is a limestone 3.5 meters thick, with *Lingula orientalis*, etc. Another meter of limestone lies below, and below that are twelve meters of red clay, etc. Total exposure..24.75 meters.

6 2 Elabouga:—Farther down stream at Elabouga, beds of the Samara series (P_2) are again exposed. They consist of limestones with *Productus cancrini*, *Allorisma elegans*, etc., at the top and with beds carrying *Lingula orientalis* in the lower part.

Total thickness.. 14 meters.

Total exposure of (P_2) in two sections.................. 38.75 meters.

In the last section, the Samara beds rest on clays and sandstones belonging to the upper Ufa series (P_1 b), with a total exposure of..........23.25 meters.

6 3 Santiaki:—In this section, the beds of the Tartarian series (P_3) are shown, consisting of red clays, sandstones and conglomerates, with interstratified limestone beds, and of shells and marls with plant remains, and near the base with fish scales. Total exposure of (P_3)..............98.75 meters.

This rests on gray limestone, with *Productus cancrini*, *Modiolopsis pallasi*, etc., representing horizon (P_2). Total exposure................ 15 meters.

6 4 Tchistopol:—At this section, as described in detail by Murchison (1845, Vol. I, p. 156), the beds are slightly inclined, as shown in the figure in that volume.

Here, resting on grits with fossil plants—possibly Ufa beds (P_1 b)—is a limestone 2.5 meters thick, with *Productus cancrini*, *Pseudomonotis kazanensis*, etc., succeeded by a thin coal bed and sandstones, representing the upper division of (P_2). Overlying this are Quaternary sands. The total thickness of P_2 here exposed is.................................... 25.25 meters.

III. KAZAN REGION

In the Kazan region, the Permian beds are exposed on the right bank of the Volga, for a distance of 30 kilometers above the mouth of the Kama. Both the Tartarian and Samara series (Kazan stage) are exposed in essentially horizontal beds, the thickness of the latter not exceeding 20 meters.

From ten kilometers below, to 1.5 kilometers above, the mouth of the Svivaga River (Murchison, Verneuil and Keyserling, Vol. I, p. 162, Fig. 28), the banks of the Volga show the following exposure of Permian beds:

(P_3) Tartarian series.................................... 36 meters.

(P_2) Samara series (Kazan stage)

(P_2c) Siliceous limestone, grading into a dolomitic oölite, with the pelecypods and gastropods found in horizon *e* of the Samara section (page 386).

(P_2b) Alternations of gray or white limestone, tending to become siliceous and largely covered by talus or alluvium. In dolomitic limestone near the water level, are found the fossils of horizon *d* of the Samara section (page 387).

Beyond this to Nijni Novgorod, only red and variegated marls, etc., of the Tartarian (P_3) are exposed. The following are the outcrops:

1. TCHEBOKSARY, exposure of (P_3)..27.75 meters.

In the lower beds occur Anthracosian pelecypods (*Palæomutela solenoides, P. semilunulata, Oligodon zitteli*, etc.)

2. KOZMODEMIANSK, (P_3) Upper Beds..62 meters.
(P_3) Lower Beds..28 meters.
(P_3) in 1 and 2, if continuous[1]..117.75 meters

FOSSILS OF THE SAMARA BEDS (KAZAN STAGE)

The following species of Bryozoa, Gastropoda and Pelecypoda have been obtained among others from the Samara beds of the several sections in this region.[2]

FROM THE UPPER LIMESTONES (P_2b):

Turbonilla altenburgensis, Murchisonia subangulata, Macrodon kingianum, Astarte permocarbonica, A. vallisneriana, Bakewellia cerathophaga, B. antiqua, B. sulcata, Pleurophorus pallasi, P. simplex, Schizodus obscurus, S. rossicus, Pseudomonotis speluncaria and the bryozoan *Geinitzella columnaris.*

FROM THE LOWER LIMESTONE (P_2a):

In addition to the Brachiopoda, the following may be noted as characteristic Bryozoa: *Fenestella retiformis, Orbipora crassa;* Pelecypoda: *Pseudomonotis speluncaria, Schizodus obscurus.*

The Brachiopoda of the Samara beds of the Kama series, that is, the so-called Zechstein (P_2) of the east Russian region, comprise the following species, according to Netschajew (1911). In this list the following notations are introduced: a, b, c, signify the lower, middle and upper divisions respectively; when not so marked horizon is doubtful. P = Middle Permian of Pinega and Culoj Rivers, north Russia; z = Zechstein of west Europe; p_1, p_2; p_3 signify, respectively, lower, middle, and upper Productus limestone of the Salt Range,

[1] Murchison, Vernueil and Keyserling give a thickness of 150 to 200 feet to these beds in this region (Geol. Russia, Vol. I, p. 163), which form division *c* of their section (p. 162). Below them are (*b*) gray colored harder limestone preceded by impure limestone and shale, both strong-bedded and flag-like. These beds rise to a height of seventy or eighty feet above the Volga in the cliffs at Verkin Uslon opposite the point where the Kazanka (from Kazan) enters the Volga. From these beds are reported *Productus cancrini, Pseudomonotis kazanensis* Verneuil, *Bakewellia ceratophaga* Schlotheim, *Modiola pallasi* Verneuil. These beds are preceded by gypsum in thick subconcretionary bands and, with this, courses of fossiliferous limestone, shown at the base of the cliff. These still belong to the Samara series (P_2), which thus has a thickness here of eighty feet or more.

[2] For complete lists see Netschajew (1894).

and *h* signifies Upper Palæozoic of the Himalayas. An asterisk (*) preceding the name indicates that the species has come up from the underlying horizon, that is, the Kungurian-Artinskian or the "Uralian" of this region.

1 *Lingula orientalis* Golowkinsky (*a-c*)
2 *L. lawrskyi* Netschajew (*c*)
3 *L. credneri* Geinitz (*a-b*, *z*)
4 *Orbiculoidea koninckii* Geinitz (*a*, *z*)
5 *O. papula* Eichwald (*a*)
6 *Crania orientalis* Netschajew (*b*)
*7 *Productus koninckianus* Keyserling (*a-c*, *P*)
8 *P. dieneri* Netschajew (*a-b*, *P*)
*9 *P. cancrini* Verneuil (*a-c*, *P*, *z*, *h*)
10 *P. pyramidalis* Netschajew (*a-b*)
11 *P. tenuituberculatus* Barbot-de Marny
12 *P. hemisphærium* Kutorga (*a-b*, *P*)
13 *P. plano-hemisphærium* Netschajew (*a*)
14 *P. tschernyschewi* Netschajew (*P*)
15 *P. latus* Netschajew (*a*)
16 *P. belebejicus* Netschajew (*a*)
17 *P. hemisphæroidalis* Netschajew (*a*)
18 *Strophalosia horrescens* Verneuil (*a-c*, *P*)
19 *S. fragilis* Netschajew (*a-b*, *P*, p_2)
20 *S. longa* Netschajew (*a*)
21 *S. wangenheimi* Verneuil (*a-c*, *P*)
22 *S. tholus* Keyserling (*a*, *P*)
23 *S. gigas* Netschajew (*a*, *P*)
24 *Spirifer schrenki* Keyserling (*a-b*, *P*)
25 *S. acutiapicalis* Netschajew (*a*)
26 *S. latiareatus* Netschajew (*a-P*)
27 *S. planus* Netschajew (*a*, *P*)
28 *S. rugulatus* Kutorga (*a-b*, *P*)
29 *S. curvirostris* Verneuil (*a*, *P*)
30 *S. stuckenbergi* Netschajew (*a-b*, *P*)
31 *S. lahuseni* Netschajew (*a*, *P*)
32 *S. grewingki* Netschajew (*P*)
33 *S. blasii* Verneuil (*a-b*, *P*)
34 *S. multiplicicostatus* Netschajew (*a*)
35 *S. asinuatus* Netschajew (*a*)
36 *S. keyserlingi* Netschajew (*P*)
37 *S. culojensis* Netschajew (*P*)

38 *Ambocœlia nucella* Netschajew (*a-b*)
39 *A.* (*Martinia*) *clannyana* King (*a-c*, *z*)
40 *Spiriferina multiplicata* Sowerby (*a*, *P*, *z*, p_{2-3})
41 *S. subcristata* Netschajew (*a-c*, *P*)
42 *S. parvula* Netschajew (*a*)
*43 *Athyris royssiana* Keyserling (*a-c*, *P*)
*44 *A. pectinifera* Sowerby (*a-c*, *P*, *z*, p_{2-3})
45 *A. semiconcava* Waagen (*a-b*, *P*, p_1)
46 *A. stuckenbergi* Netschajew (*a*, *P*)
47 *A. bajtuganensis* Netschajew (*a*)
48 *A.* cf. *grossula* Waagen (*P*, p_3)
*49 *Rhynchopora geinitziana* Verneuil (*a*, *P*, *z*)
*50 *R. nikitini* Tschernyschew (*a*)
51 *Camarophoria culojensis* Netschajew (*P*)
52 *C. humbletonensis* Howse (*a*, *z*, p_2)
*53 *C. purdoni* Davidson (*a*, p_{2-3}, *h*)
54 *C.* cf. *schlotheimi* v. Buch (*a*, *z*)
*55 *C. superstes* Verneuil (*a-b*)
56 *C. waageni* Netschajew (*a*, p_{2-3})[1]
*57 *C. globulina* Phillips (*a*, *z*, p_3)
*58 *Dielasma elongata* Schlotheim (*a-c*, *z*, P^2, p_2, *h*)
59 *D. angusta* Netschajew (*a*)
60 *D. elliptica* Netschajew (*a*)
61 *D. nikitini* Netschajew (*a*)
*62 *D. itaitubense* Derby (*a*, p_2)
*63 *D. jurcsanense* Tschernyschew (*a*)
64 *D. rara* Netschajew (*a*)
65 *D. jakowlewi* Netschajew (*a*)

From the outcrops in the valleys of the Oka and the Kliasma Rivers southwest and west of Nijni Novgorod, Yakowlew has described the following species:

a_1 From the lowest limestone (P_2 a); Gastropoda: *Pleurotomaria kingi* Yakowlew, *Euomphalus fratuberculatus* Yakowlew; Brachiopoda: *Productus cancrini* Verneuil, *Strophalosia horrescens* Verneuil, *Dielasma elongata* Schlotheim, *Athyris pectinifera* Sowerby, *Athyris royssii* Léveillé, *Spirifer rugulatus* Kutorga(?), *Spiriferina cristata* Schlotheim, *Martinia clannyana* King.

[1] *Camarophoria superstes* Waagen (1883, p. 445 Pl. XXXII, Figs. 12, 13 = *C. waageni* Netschajew).
[2] Listed for this region by Yakowlew.

a_2 From the succeeding brachiopod limestone (P_2 a_2) he described the following Gastropoda: *Pleurotomaria baranowkæ* Yakowlew, *P. antrina* Schlotheim, *P. kingi* Yakowlew, *Murchisonia subangulata* Verneuil, *M. biarmica* Kutorga, *M. multilineata* Netschajew, *Omphalopychia permiana* Yakowlew, *Promathildia* aff. *kasanensis* Netschajew, *Tretospira divesuralica* Golowkinsky.

b_1 From the pelecypod and gastropod limestones (P_2 b_1) he describes the gastropods: *Wortheniopsis netschajewi* Yakowlew, *Murchisonia multilineata* Netschajew, *M. imparlineata* Netschajew, etc.

Palæontologically the lower part of the Samara beds (P_2 a), with Brachiopoda and Bryozoa predominating, is correlated with the lower part of the Lower Zechstein of Germany, while the upper beds (P_2 b and P_2 c) are correlated with the upper part of the lower and with part of the middle Zechstein of Germany.

THE KOSTROMA DOLOMITES

In western Russia, in the Government of Kostroma (Tschernyschew, 1885), the calcareous facies of the Middle Permian, that is, the Russian Zechstein, is well developed, underlying the variegated marls of the Tartarian. As this is a more extensive series than the Samara beds, corresponding more nearly to the whole of the Kama series, we shall speak of it here as the Kostroma Dolomites. The formation is well seen at Soligalitsch on the banks of the Selma (about latitude 59° N., longitude 42° 15′ E.) and again at Puschtesch on the Volga. The fauna of these beds comprises thirty-eight identified species, of which twenty-one, or 55 per cent., also occur in western Europe. Among these, the following are the more important: *Temnocheilus freieslebeni* (Geinitz), *Turbonilla volgensis* Golowkinsky, *Straparollus permianus* King, *Murchisonia subangulata* Verneuil, *Allorisma elegans* (King), *Edmondia murchisoniana* King, *Astarte permocarbonica* Tschernyschew, *Pleurophorus costatus* Brown, *Solemya biarmica* Verneuil, *Leda speluncaris* Geinitz, *Macrodon kingianum* Verneuil ?, *Bakewellia cerathophaga* Schlotheim, *Aviculopecten kokscharofi* Verneuil, *Pecten pusillus* Schlotheim, *Pseudomonotis speluncaria* Schlotheim, *Dielasma elongatum* Schlotheim, *Athyris pectinifera* Sowerby, *A. royssiana* Keyserling, *Spiriferina cristata* Schlotheim, *Camarophoria superstes* Verneuil, *Strophalosia horrescens* Verneuil, *Aulosteges wangenheimi* Verneuil, *A. gigas* Netschajew, *Rhynchopora geinitziana* Verneuil, and *Productus cancrini* Verneuil.

It is evident that this fauna is wholly distinct from the Indo-Pacific type represented in the Himalayan, Chinese and Mongolian deposits, and we must regard this fauna as essentially of Boreal origin. It is probably a younger fauna than that of the Jisu Honguer limestone, corresponding in a general way to the Upper Productus limestone of India, and the Loping and perhaps part of the Maping beds of China, whereas the Jisu Honguer limestone is the essential equivalent of the Middle Productus limestone.

In the Alexandrowskaja bore-hole within the city of Totma (Lat. 60° N., Long. 42° 30′ E.), the drill entered the marine limestone of the series at a depth of 111 meters. These showed intercalated gypsum and sandstone layers and continued to a depth of 267 meters, showing a thickness of 156 meters for this series. Some of the gypsum beds are very thick. From specimens obtained at a depth of 226 meters (115 meters below top), Licharew (1925, p. 147) has identified *Camarophoria superstes* Verneuil. In the bore-hole at Petrowskaja, a series of Upper Permian fossils have been found at essentially the same depth.

THE UPPER PERMIAN OF ARCTIC RUSSIA

The Permian Beds of West Russia can be traced northward into the Arctic region, where they can be followed from the shores of the Arctic Ocean, in the Gulf of Mezen, up the rivers which enter into it, and along the Pinega and Dvina Rivers and the basin of the Waga until they disappear under the Quaternary sands and clays, only to reappear in the Kostroma region already discussed. The beds throughout this region are almost horizontal, so that the same formations are exposed over long distances. Since the formations can hardly be considered the exact equivalents of those previously discussed, although corresponding to them in a general way, we shall use distinctive names, at least for the lower two series, using DVINA BEDS for the lower gypsiferous series, and WAGA FORMATION for the succeeding fossiliferous beds, which in a general way correspond to the Samara (or Kazan) beds of Eastern Russia, but to only a portion of the Kostroma beds farther south. The value of the use of such local names lies in the precision which it gives to the discussion and the greater facility which it affords in instituting comparisons between the different regions. Since these beds represent only a portion, and often a very small portion, of the German Zechstein, it is not advisable to continue the use of that term for these Russian deposits, except in very general discussions. I realize, of course, that it would be more proper to leave the naming of their formations to the Russian geologists themselves,[1] but until they do so I consider it desirable to use preliminary formation names, even though the students of the individual section should find it desirable to substitute other names which at some future time may be more appropriate, a substitution which I shall gladly subscribe to.

The following is a generalized succession in this region, modified from Netschajew, with additions from the geology of Russia, etc. The succession is given in descending order:

[1] The names Waga limestone and Upper Permian beds of Waga basin have been used by Licharew.

PERMIAN SERIES:

III Upper or Tartarian Red Bed series (P3)

II Middle or Waga series (P2), a complex of gray and yellowish-brown sandstones and clays, with intercalated gray limestones. Fossiliferous (P2).

I Lower or Dvina series (P1)

1 *b* Complex of red beds, consisting chiefly of red clays and marls, with intercalated gray and red limestones.

1 *a* Thick complex of gypsum beds, with subordinate limestone beds at various levels.

Disconformity

Subformation: Carboniferous limestones.

These sections are extremely significant from the fact that these later Permian or Kama beds rest directly upon the Carboniferous limestones, the Kungurian and Artinskian being absent, as well as the beds of typical Uralian age, that is, the Schwagerina, Cora and Omphalotrochus limestone horizons of the Ural and Timan region. For the Carboniferous limestones, subjacent to the Dvina gypsum beds of this region, are either Middle Carboniferous, or else early Upper Carboniferous, that is, of the age of the Donetzian beds to be discussed later. Murchison, Verneuil and Keyserling (1845, Vol. I, p. 174), have noted this section, which clearly shows the gypsum beds, resting upon these Carboniferus limestones; for, although the actual contact is covered by alluvium, the horizontality of the beds forbids the assumption of any great interval between the two series. The fossils recorded from these Carboniferous beds include: *Spirifer mosquensis*, *S. rotundatus*, *Chonetes hardrensis*, *Productus punctatus*, *P. antiquatus*, *Orthothetes arachnoides*, *Euomphalus calyx*, etc.

These limestones appear a hundred miles above the mouth of the Dvina at Archangel, where typical Middle Carboniferous fossils, *Martinia glaber*, *Enteletes lamarcki*, *Productus scabriculus* and *P. antiquatus*, are found. In spite of the presence of many typical Lower Carboniferous limestone species, these Archangel limestones, and those farther up on the Dvina and on the Pinega, are to be regarded as either Middle or possibly early Upper Carboniferous, for, as will be shown later, *Spirifer mosquensis*, and *Enteletes lamarcki*, and other Middle Carboniferous fossils continue through a considerable portion of the early Upper Carboniferous, or Donetzian beds, of Russia. In any case, however, these beds cannot be younger than mid-Upper Carboniferous, that is, mid-Donetzian (see below).

Similar beds containing some of the same shells, together with the corals *Lithostrotion floriforme* and *Harmodites parallelus*, extend for a short distance up the river Pinega, followed farther up by other bands of limestone with Carboniferous fossils, but apparently of no very great thickness. Succeeding these are beds of brilliantly white alabaster, which form cliffs, and alternate with courses of limestone. These constitute the basal part of the Permian system of this region, and, according to the very definite statement of Murchison *et al*, there is no other formation between these two. Hence it is very evident that there is here a pronounced hiatus and indication of land conditions during the period of deposition of the Uralian, Artinskian and Kungurian beds of other parts of Russia. The gypsum deposits themselves, with their interstratified limestones, are probably primary sediments and as such indicate that the land interval in this region was followed, at the beginning of the Kama period of the Permian, by lagoonal conditions on the borders of a sea which lay to the south and east.

On the banks of the river, above the city of Pinega, the cliffs show the following section of the lower Dvina beds, in descending order (Murchison, Verneuil, and Keyserling, 1845, Vol. I, p. 173).

6. Red and argillaceous sandstone, with small intermixed concretions of gypsum.
5. Red crystalline gypsum.
4. White gypsum.
3. Band of limestone, two or three feet thick.
2. Gypsum with some thin courses of marly limestone.
1. Ten to twelve feet of thin bedded limestone, the bottom beds of which are charged with Turritellæ, Aviculæ, *Turbo*[1] and other forms dissimilar from Carboniferous fossils.

Beds of gypsum, with thin courses of limestone similar to those of the Pinega, are found on the Dvina River, separated from the outcrops of the Carboniferous limestone, by an alluvium-covered interval. Beginning as red and white gypsum, they continue up the river for 15 versts, where they form cliffs 40 to 50 feet in height, consisting of pure white gypsum. This alabaster gorge of the Dvina continues for a distance of more than 20 versts.

The gypsum beds are succeeded by red and green marls, which continue up the river to the vicinity of Ust-vaga, where they are succeeded by the middle division here called the Waga series. This includes white limestones, impure sandy limestones, dark green calcareous sandstones, and dirty gray limestones, with *Productus horrescens* and other Zechstein fossils. From strata of this series, at Kulogory, on the Pinega River, a considerable number of fossils have been obtained. The brachiopods which were described by Netschajew are listed with those of the Samara limestone, where they are distinguished by the capital letter *P* after the name. The mollusks were described by Yakowlew and Tschernyschew, and comprised the following PELECYPODA: *Modiolopsis pallasi* Verneuil, *Bakewellia antiqua* Münster, *B. cerathophaga* Schlotheim; GASTROPODA: *Murchisonia tschernyschewi* Yakowlew; *Trepospira* cf. *tumida* Meek & Worthen, *Tuberculiplura kutogoræ* Yakowlew; CEPHALOPODA: *Temno-*

[1] These do not, of course, belong to those genera.

cheilus pernodosis Tschernyschew, *T. grewingki* Tschernyschew, *T.* cf. *crassus* Hyatt, *Pteronautilus* (?) sp.

The fossiliferous beds are succeeded by the red beds of the Tartarian series, which continue to form the remainder of the outcrops on the Dvina and its branches and which reappear on the Volga. It must, however, be understood that the base of the series in one section is not necessarily homochronic with that in another section, especially one far removed. Continental sedimentation probably began at different times in different regions, and while it was taking place in one district, marine sediments continued to be formed in another.

A section through the basin of the Waga River (the beds here dipping very gently to the southeast), gives the following succession in descending order, from southeast to northwest. On the southeast are the marls and marly sands, which represent the highest or Tartarian division. These are not seen in contact with the fossiliferous limestones of the Waga, but are separated from them by a covered interval. The Waga limestones lie chiefly to the west of the river of that name, and after another interval, the gypsiferous beds, which underlie them, are exposed in a parallel line of outcrops. On the Schultus and the Konoscha Rivers are exposed some limestones, which either underlie the gypsum or are intercalated in it. These contain the following identified species. Those marked with a dagger (†) occur in the Kostroma beds farther south, and those marked by an asterisk (*) also occur in the Kazan stage (Samara beds) of east Russia: VERMES: 1, **Serpula obscura* King. BRACHIOPODA: 2, †*Productus velensis* Licharew; 3,†* *P. cancrini* Verneuil; 4, var. *globularis* Licharew; 5,†* *Rhynchopora geinitzi* Verneuil; 6, *R. depressa* Licharew. PELECYPODA: 7,†* *Pseudomonotis kasanensis* Verneuil; 8,†* *Pseudobakewellia krasnowidowoensis* Netschajew; 9, *Lima krotowi* Stuckenberg; 10,†* *Pseudamusium pusillus* Schlotheim; 11,* *Aviculopecten* cf. *ovalis* Netschajew; 12,* *Netschajewia* cf. *elongata* (Netschajew); 13,* *N.* cf. *globosa* Netschajew; 14,* *Modiola modiclæoidea* Netschajew; 15,†* *Lithodomus consobrinus* Eichwald; 16,†* *Pleurophorina simplex* Keyserling; 17,* *Pleurophorus* cf. *costatus* Brown; 18,* *Nucula wymmensis* Keyserling; 19,†* *Parallelodon kingi* Verneuil; 20, *Schizodus dubiformis* Waagen (Upper Productus Limestone); 21,* *S.* cf. *rossicus* Verneuil; 22,†* *Astarte permocarbonica* Tschernyschew; 23, *Psammobia* ? cf. *subpapyracea* King (Zechstein); 24,* *Sanguinolites bicarinatus* var. *lævigatus* Licharew; 25,* *S.* ? cf. *lunulata* Keyserling; 26,†* *Edmondia murchisoni* King; 27, var. *elongata* Howse; 28,* *Goniomya* (?) *kasanensis* Verneuil; 29,†* *Solemya biarmica* Verneuil; 30, *S. parallela* Beede and Rogers (Kansas); 31,†* *Alula kutorgi* (Verneuil); 32, gen. and sp. nov. GASTROPODA: 33,* *Murchisonia golowkinskji* Yakowlew.

All but eight of these forms are known either from the Kostroma dolomite or the Kazan beds, and three of these are otherwise accounted for as indicated. Three are new.

Of these thirty-three species, twelve, or 36.36 per cent., are also found in the Middle Permian of Russia, but twenty-seven, or about 82 per cent., are characteristic of the Waga limestone which overlies the gypsum. It is thus apparent that these limestones are still to be classed with the Upper Permian, and this probably shows that the gypsum series as well is referable to the Upper Permian, and is the essential equivalent of the lower Kama or Ufa beds of the Ural region. As these beds are exposed within a short distance of the outcrops of the Middle or early Upper Carboniferous limestones, it is apparent that there is here a great hiatus in succession and that the later Carboniferous as well as the Lower and Middle Permian beds are absent.

Elsewhere, too, in this region, the limestone beds interbedded in the gypsum carry an abundance of *Productus cancrini*, *Rhynchopora geinitzi* and other characteristic Upper Permian fossils.

In the Timan these higher fossiliferous Permian beds appear to be absent, the red Tartarian beds resting disconformably on the Schwagerina limestones as shown in the section of Kamennougolnaja Griada on the Myla near the village of Wanjutschkowa. (Tschernyschew, 1902, p. 438.)

COMPARISON OF THE SECTIONS

If we now compare the sections of the Upper Permian from east to west, it becomes apparent that we have a gradual change in facies, and in thickness as well. It must be borne in mind that the region of the Ural Mountains was a geosyncline within the old-land lying on the east, while the marginal plain on the west was formed by the Russian platform. Within the Uralian geosyncline, the strata of the group were all clastic and probably altogether non-marine. We have at present no estimate of the thickness of these beds, within the geosynclinal region, but the sections given by Murchison *et al* of the steeply inclined Permian strata at Orenburg, in the southern Ural, show that they were of great thickness. Over the marginal plain, that is, the main Russian region, the corresponding deposits are much thinner, as is normally the case in such regions. Far to the west lay the nearly enclosed Zechstein Sea of northern Germany, and here these Upper Permian deposits are represented by the marine Zechstein, though that was interrupted by the Salt period. These marine beds extend eastward across the marginal plain, forming a progressively thinning series as the geosycline is approached, while at the same time the lithic character underwent a progressive change, from purely calcareous to prevailingly terrigenous. The same change seems to have taken place northward, where the marine series is relatively thin, while at the same time a land barrier apparently confined these waters on the north, and lagoonal conditions in that region permitted the deposition of the gypsum beds. That connection with the boreal waters was finally established during the period of maximum transgression is indicated by the presence of certain elements of the Zechstein fauna in the Permian of North America which was formed in an extension from this boreal sea into the Cordilleran geosyncline.

From the facts now available it would seem as if the Upper Permian sea of Russia, of which the German Zechstein basin was an extension, was itself essentially an inland water body, with only slight or temporary connection with the boreal sea. That at this period no pronounced connection existed with the southern waters, or with those which covered the Chinese region, is suggested by the distinctness of the fauna.

THE MIDDLE PERMIAN

THE KUNGURIAN SERIES (C Pc)

The Kungurian series (C Pc), which underlies the Kama beds in eastern Russia, consists of limestones and dolomites, gypsum and anhydrite, with an abundant brachiopod and pelecypod fauna, but without cephalopods, which are so characteristic of the underlying Artinskian. The land plants are occasionally represented by *Ullmannia biarmica*. The brachiopods are largely types which have passed upward from the Schwagerina horizon. Tschernyschew lists sixty-one species for the Kungurian and Artinskian, not separating these two divisions in his table. Only two of the sixty-one, namely *Productus anomalus* Keyserling and *P. ischmense* Tschernyschew, are restricted to this horizon, the others also occurring in the Schwagerina limestones and lower beds. Ten of the species common to the Schwagerina and these overlying beds, pass upward into the Kama series, and an additional one is there represented by a related species.

Stuckenberg has determined eighty-six species of mollusks from the Kungur Beds of the Kama River region. Of these, forty occur in the Schwagerina limestone and below (Uralian). Nineteen are of the Zechstein type, and twenty-seven are restricted to this and the Artinskian horizons, or are not specifically determined. Among the typical Zechstein species are *Pecten pusillus* Schlotheim, *Lima permiana* King, *Bakewellia antiqua* Martin, *Leda speluncaris* Geinitz, *Schizodus truncatus* King, *Macrodon verneuilianum* de Koninck, *Pleurophorus pallassi* Verneuil, etc. This and the underlying division, the Artinskian, are commonly classed by the Russian geologist as Permo-Carboniferous, because of the transition character of the fauna, between the Schwagerina and the Zechstein series, the former being classed by the Russian geologist as Upper Carboniferous primarily because of its stratigraphic position. If, however, we recognize that the North Russian section is incomplete, the typical Carboniferous being largely wanting, while the Schwagerina limestone corresponds essentially to the Middle Productus limestone of the Salt Range, then we are compelled to place the Schwagerina limestone together with the Cora and Omphalotrochus limestones, that is, the typical Uralian of the Russian geologist, in the Permian system. These represent the Lower Permian, and the Artinskian and Kungurian may be regarded as representing the Middle Permian. Further light on this question is furnished by the succession in the Donetz Basin of southern Russia, which will be considered in a later section.

From the Kungurian beds at Schustowa and Denjatins in the basin of the Oka and Kljasma rivers southwest and west of Nijni Novgorod, Yakowlew lists the following species: GASTROPODA: *Wortheniopsis kyschertianæformis* Yakowlew, *W. denjatinensis* Yakowlew, *Rhaphistomella subdecussata* Geinitz, *Pleurotomaria præplatypleura* Yakowlew, *P. ? sibirtzewi* Yakowlew, *Portlockia rotundata* Yakowlew, *Trachydomia wheeleri* Swallow, *Loxonema* aff. *quadricarinatum* Worthen, *Tuberculopleura anomala* (Meek and Worthen), *Promathildia barroisi* Yakowlew. BRACHIOPODA: *Productus* cf. *konincki* Verneuil and Keyserling, *P.* cf. *cora* d'Orbigny, *Chonetes* cf. *uralica* Müller, *Dielasma* aff. *sacculus* Martin, *D. elongata* Schlotheim, *Martinia clannyana* King, *Athyris planosulcata* Phillips, *A.* cf. *pectinifera* Sowerby, *Orthothetes crenistria* Phillips.

THE ARTINSKIAN SERIES (C Pg)

The Artinskian division is rich in plant remains, which permit its correlation with at least a part of the Rothliegendes of western Europe. The Brachiopoda, as we have seen, are essentially the same as those of the Kungurian, but the most distinctive element of the fauna is seen in the goniatites and related cephalopods. The following are the more important species: *Gastrioceras jossæ, G. suessei, Paralegoceras tschernyschewi, Agathiceras stuckenbergi, A. krotowi, Popanoceras sobolewskianum, P. kingianum, Thalassoceras gemmelaroi, Pronorites præpermicus, P. postcarbonarius, Medlicottia artiensis, M. orbignyana* and *Propinacoceras sakmaræ.*

From fine-grained marls of the series, Sochkine (1925, Pls. I–III, pp. 76–104) has described the following species of corals: 1, *Lytvolasma asymetricum* Sochkine (rr)[1]; 2, *Stereolasma minus* Sochkine (rc); 3, *Tachylasma rizoides* Sochkine (c); 4, *T. lata* Sochkine (rr); 5, *Lophophyllum proliferum* McChesney (r); 6, *Amplexus coralloides* var. *permocarbonica* Sochkine (r); 7, *Cyathaxonia cornu* Michel (rr); 8, *Pleurophyllum tenuiseptatum* Sochkine (c); 9, *P. artiense* Sochkine (r); 10, *Phryganophyllum karpinskyi* Stuckenberg (r); 11, *Campophyllum schrenki* Stuckenberg (r); 12, *C. nikitini* Stuckenberg (rr); 13, *Thysanophyllum tschernowi* Sochkine (c).

From this horizon Krotow (1888, pp. 451, 452) has listed one trilobite (*Phillipsia grunewaldii* Möller), twelve cephalopods, thirty-five gastropods,

[1] rr = very rare; r = rare; rc = fairly common; c = common; cc = very common.

thirty-four pelecypods, thirty-four brachiopods, five bryozoans, and one each of *Serpula*, *Archæocidaris*, *Polycœlia* and *Fusulina* (*F. verneuili* Möller), together with nine plants, or a total of one hundred and thirty-four species. It would seem, however, as if many of these determinations are in need of revision.

Lithologically it is mostly a clastic formation. It begins with conglomerate, sandstone, and intercalated limestone, which rest with a slight disconformity on the Schwagerina beds, while its relation to the overlying Kungurian seems to be a perfectly conformable one.

In the Central Russian area, where the Artinskian fauna is rich in ammonoids, the material is of a finer and more uniform character.

THE LOWER PERMIAN

THE URALIAN LIMESTONE SERIES

In the Ural Mountain region this division comprises the Tastuba or Schwagerina limestone above, and the Cora limestone below, and represents essentially the typical Uralian of the Russian geologists. Since, however, this term has been used as equivalent to Upper Carboniferous in most of the literature on the European and Asiatic Upper Palæozoic, it would lead to endless confusion were it again employed in any but a strictly local way for the beds for which it was originally coined. We shall consider the several members, as well as the underlying beds of the Upper Carboniferous, in descending order:

LOWER PERMIAN:

5. TASTUBA OR SCHWAGERINA LIMESTONE (C 3_3):—50 meters.

White and light gray limestones, with a rich fauna, including trilobites (*Griffithides*), goniatites (*Agathiceras*, *Pronorites*), pelecypods, brachiopods, corals, bryozoans and Foraminifera: *Schwagerina princeps*, *Fusulina longissima* and *F. verneuili*. The Foraminifera locally make up most of the rock. Among the species also found in the Jisu Honguer limestone are the following: *Dielasma elongatum*, *D. giganteum*, *D. truncatum*, *D. itaitubense*, *Beecheria sublævis*, *Notothyris nucleolus*, *Camarophoria mutabilis*, *C. superstes*, *Hustedia remota*, *Spiriferella saranæ*, *Spiriferella salteri*, *Spiriferella keilhavii*, *Streptorhynchus pelargonatus*, *Meekella uralica*, *Productus humboldti*, *P. juresanensis*, *P. fasciatus*, *Proboscidella lata*, *Marginifera typica* var. *septentrionalis*, and *Geinitzella columnaris*.

4. CORA LIMESTONE (C 3_2):—100 meters.

Gray, not infrequently siliceous limestone, with interbedded layers of yellow-gray marl and thin-bedded oölites, with subordinate layers of bituminous shales in the lower part. It is extremely rich in *Productus cora* and other brachiopods, as well as in pelecypods. The following species occurring here are also found in the Jisu Honguer limestone: *Dielasma millepunctatum, Hustedia remota, Streptorhynchus pelargonatus, Productus lineatus, P. fasciatus, P. porrectus, Marginifera typica* var. *septentrionalis. Fusulina verneuili* is the leading foraminiferan.

Disconformity ?

3. OMPHALOTROCHUS BEDS (C_3 b):—12 meters.

Coral limestone, with species of *Petalaxis, Columnaria* and *Syringopora*, and with numerous *Omphalotrochus whitneyi*, together with *Spirifer marcoui* and other brachiopods.

2. (NOT RECORDED).

Hiatus and Disconformity

UPPER CARBONIFEROUS:

1. SPIRIFER MARCOUI BEDS (C_3 a):—about 50 meters.

Limestones with *Spirifer marcoui* and other brachiopods and corals. (Gschellian.)

Basal beds not exposed.

CHARACTER AND RELATIONSHIPS OF THE FAUNA OF THE SCHWAGERINA LIMESTONE

In order that we may arrive at an understanding of the relationship of the Schwagerina limestone with the Jisu Honguer limestone of Mongolia and the Productus limestone of India, we will consider the fauna of the first somewhat more in detail.

One of the marked faunal characteristics of the Schwagerina limestone of Russia is the abundance of *Schwagerina princeps*[1] and *Fusulina verneuili* which are often rock-forming. So far, these are wholly unknown in the Jisu Honguer limestone, and Schwagerina is likewise not known from the deposits of the Himalayan geosyncline. They are, however, known from higher Permian beds in China (see below). Another feature in which the fauna of the Schwagerina limestone differs from that of the Jisu Honguer limestone is the abundance of corals in the former, and their rarity in the latter formation. The brachiopods, which have been studied in such detail by Tschernyschew, admit of a closer comparison. In the following table a list of genera is given with their representation in number of species in the Indian, Mongolian, Ural-Timan and Darvas regions. From this the general character of the faunas may be ascertained.

[1] See the more recent statement by Fredericks quoted below.

TABLE III. NUMBER OF SPECIES OF UPPER PALÆOZOIC BRACHIOPODA IN THE SALT RANGE, MONGOLIA, THE URAL-TIMAN REGION, AND IN THE DARVAS SECTIONS

		Salt Range				Jisu Honguer limestone	Ural-Timan						Darvas		
		Total	Lower Productus	Middle Productus	Upper Productus		Total	Omphalotrochus	Cora limestone	Schwagerina limestone	Artinskian-Kungurian	Kama	Total	Safeddaron	Obirawnou
1	*Dielasma* King	10	2	6	2	8	14	2	4	13	5	1	5	4	1
2	*Dielasmina* Waagen	1	....	1	1	....	....	....	....	....	....	....	1	1	....
3	*Hemiptychina* Waagen[1]	4	3	4	2	7	4	....	....	4	....	....	4	3	1
4	*Notothyris* Waagen	7	....	7	2	5	3	....	....	3	1	....	2	2	....
5	*Aulacothyris* Douville	....	....	....	....	....	2	....	1	2	1	....	2	2	....
6	*Waldheimia* King	....	....	....	....	....	1	....	....	1	....	....	....	....	....
7	*Lyttonia* Waagen	3	....	3	....	2	....	....	....	....	....	....	1	....	1
8	*Keyserlingia* Tschernyschew	....	....	....	....	....	2	....	....	2	....	....	1	1	....
9	*Oldhamina* Waagen	1	....	1	1	....	....	....	....	....	....	....	....	....	....
10	*Terebratuloidea* Waagen	4	....	4	....	....	2	....	....	2	....	....	....	....	....
11	*Pugnax* Hall and Clarke	....	....	....	....	....	8	....	....	8	....	....	....	....	....
12	*Uncinulus* Bayle	3	....	2	3	1	1	....	....	1	....	....	3	3	....
13	*Rhynchonella* Fischer von Waldheim	3	1	2	1	....	3	....	....	3	1	....	1	1	....
14	*Rhynchopora* King	....	....	....	....	....	3	3	2	2	2	2	....	....	....
15	*Camarophoria* King	5	....	4	3	3	15	3	4	14	6	3	2	2	....
16	*Spiriferella* Waagen	10	1	7	8	....	....	....	....	....	....	....	....	....	....
17	*Athyris* McCoy	10	4	5	6	3	4	1	3	4	3	2	1	....	1
18	*Hustedia* (*Eumetria*)	2	1	2	1	3	2	....	1	2	....	....	....	....	....
19	*Uncinella* Waagen	1	....	1	....	....	....	....	....	....	....	....	....	....	....
20	*Spiriferina* d'Orbigny	5	1	3	4	1	8	....	2	8	2	1	2	2	....
21	*Spiriferella* Tschernyschew	....	....	....	....	10	4	....	1	4	3	....	....	....	....
22	*Spirifer* Sowerby	8	5	4	2	1	24	2	6	21	4	....	2	2	....
23	*Martiniopsis* Waagen	2	1	....	1	....	7	....	....	7	1	....	....	....	....
24	*Martinia* McCoy	5	1	4	1	9	14	1	....	13	....	....	6	6	....
25	*Squamularia* Gemmellaro[2]	3	1	3	1	3	4	1	1	4	1	....	3	3	....
26	*Ambocœlia* Hall	....	....	....	....	....	2	....	....	2	....	....	1	....	1
27	*Enteletes* Fischer von Waldheim	7	....	6	1	5	....	....	....	....	....	....	3	2	1
28	*Orthotychia* Hall and Clarke	2	....	2	....	1	1	....	....	1	....	....	1	....	1

TABLE III—*Continued*

		Salt Range					Ural-Timan						Darvas		
		Total	Lower Productus	Middle Productus	Upper Productus	Jisu Honguer limestone	Total	Omphalotrochus	Cora limestone	Schwagerina limestone	Artinskian-Kungurian	Kama	Total	Safeddaron	Obirawnou
29	*Schizophoria* King	2	1	2	...	...	2	...	1	2	1	...	...	...	...
30	*Rhipidomella* Oehlert	3	1	2	...	...	2	...	1	1	...	...	...	...	...
31	*Streptorhynchus* King[3]	5	1	6	2	5	3	...	1	2	1	...	...	...	...
32	*Derbya* Waagen[4]	7	1	4	5	3	3	2	2	2	...	...	...	...	...
33	*Orthothetes* Fischer von Waldheim[5]	1	...	...	1	3	1	...	...	1	...	...	...	...	...
34	*Meekella* White and St. John	...	...	...	...	1	7	3	5	2	...	...	...	...	...
35	*Geyerella* Schellwien	...	...	...	...	1	...	...	...	...	...	...	...	...	...
36	*Derbyella* Grabau	...	...	...	...	3	...	...	...	...	...	...	...	...	...
37	*Leptæna* Dalman	1	...	1	...	...	...	...	...	...	...	...	...	...	...
38	*Chonetes* Fischer von Waldheim	14	1	8	7	...	11	...	5	11	3	...	...	...	...
39	*Aulacorhynchus* Dittmar	...	...	...	...	1	...	...	...	...	...	...	...	...	...
40	*Strophalosia* King	8	4	3	2	...	...	...	...	...	...	...	...	...	...
41	*Chonetella* Waagen	1	...	1	1	...	...	...	...	...	...	...	...	...	...
42	*Aulosteges* Helmersen	2	1	1	...	2	1	1	1	1	...	1	2	1	1
43	*Productus* Sowerby	20	5	12	15	12	43	10	22	39	22	1	8	5	3
44	*Proboscidella* Oehlert	...	...	...	...	1	3	...	...	3	2	...	1	1	...
45	*Marginifera* Waagen	6	4	1	2	4	8	2	4	8	2	...	2	2	...
46	*Richthofenia* Keyserling	1	1	1	1	1	...	...	...	...	...	...	...	...	...
47	*Tegulifera* Schellwien	...	...	...	...	...	1	...	...	1	...	...	...	...	...
48	*Cardinocrania* Waagen	1	?	1	1	...	...	...	...	...	...	...	...	...	...
	TOTAL	168	42	114	77	99	213	31	67	194	61	11	54	43	11

[1] Includes *Beecheria, Morrisina, Mongolina and Jisuina.*

[2] Includes all the species formerly referred to *Reticularia,* which is not a Permian genus.

[3] Includes *Schellwienella.*

[4] Includes *Derbyina.*

[5] Includes *Orthothetina.*

SUMMARY

The genus *Dielasma* is represented by thirteen species in the Schwagerina limestone. Two of these occur in the Jisu Honguer limestone, while four others are represented by varieties and one by a related species. Three of these thirteen species occur in the Productus limestone of India, and three others are represented by related species.

The genus *Hemiptychina* (including *Beecheria*, *Morrisina*, *Mongolina* and *Jisuina*) is represented by four species in the Schwagerina limestone, none of which occurs in Mongolia, though one species of the Schwagerina limestone, *Beecheria tschernyscheffi* Grabau (= *Hemiptychina sublævis* Tschernyschew, non Waagen), which also occurs at Darvas, is related and possibly ancestral, to both the Mongolian and the Himalayan species. None of the typical Indian species occurs in the Schwagerina limestone.

There are three species of *Notothyris* in the Schwagerina limestone, only one of which, *N. nucleolus*, occurs in the Jisu Honguer limestone. This also occurs in the Productus limestone, which has another species in common with the Schwagerina limestone.

The genus *Aulacothyris* is represented by two species in the Schwagerina limestone and the genus *Waldheimia* by one. None of these is found either in Mongolia or in the Productus limestone of India. The genus *Keyserlingia*, which is related to *Lyttonia*, has two species in the Schwagerina limestone, but is unknown in either the Jisu Honguer or the Productus limestones.

The genus *Terebratuloidea* has two species in the Schwagerina limestone, neither of which occurs in the Jisu Honguer or Productus limestone, though there is a related species in the latter. The same is true of *Rhynchonella*, which has three species, none of which is known from Mongolia or India. *Uncinulus* has one species, and *Rhynchopora* two species in the Schwagerina limestone, but none of these is known from either Mongolia or India, while *Pugnax*, with eight species, has only one represented by a related species in the Productus limestone. Of the two species of *Rhynchopora* in the Schwagerina limestone, none is found either in Mongolia or India.

Camarophoria, on the other hand, is represented by fourteen species in the Schwagerina limestone and by an additional one in the Cora limestone. Three of these occur in Mongolia, and one of the latter, together with two others, in the Productus limestone. All three of our species continue upward into the marls and dolomites overlying the Schwagerina limestone. The genus *Athyris* has four species in the Schwagerina limestone, three of which occur also in India, one in the Lower, one in the Middle, and one in the Upper Productus limestone. None of the Russian species is known from the Jisu Honguer limestone. *Hustedia* is represented by two species in the Schwagerina limestone, both of which occur also in the Productus limestone, but only one, *H. remota*, in the Jisu Honguer limestone.

There are eight species of *Spiriferina* in the Schwagerina beds, three of which occur in the Productus limestone, but none of them in the Jisu Honguer limestone. *Spiriferella* has four species in the Russian beds. Three of these occur in the Jisu Honguer limestone, two of them continuing into the Artinskian beds of the Urals. None of the Russian species occurs in the Indian beds. The genus *Spirifer* is represented by twenty-four species, though three of these do not extend above the Cora beds. None of these occurs in the Jisu Honguer limestone, though one of our species, *S. moosakhailensis*, is represented in the Schwagerina limestone by the related *S. fasciger*. Four of the twenty-four, including *S. fasciger*, extend into the Artinskian beds. Six of the twenty-four species occur in the Productus limestone of India, but one of these is found only in the Lower Productus limestone. A seventh is represented by a related species in the Middle Productus limestone.

The genus *Martiniopsis* is represented by seven species and *Martinia* by thirteen species in the Schwagerina limestone. None of these is found in the Jisu Honguer limestone where allied but distinct species of *Martinia* occur. Only one of the species of *Martinia* occurs in the Middle Productus limestone of India, though two others are represented by allied species, one of them in the Lower Productus limestone only. The genus *Reticularia* has four species in the Schwagerina limestone, but these are probably referable to *Squamularia*. One of these does not extend above the lower Productus limestone of the Salt Range, while a second occurs in the Permian beds of the Himalayan region. A third one of the Russian species is represented by an allied form in the Productus limestone. Of the two species of *Ambocœlia* in the Schwagerina limestone, neither is known from Mongolia or India.

Streptorhynchus has three species, two of them in the Schwagerina beds, but only one of these, the widely distributed *S. pelargonatus*, occurs in the Jisu Honguer limestone and the Indian Productus limestone as well. In the Urals, it extends into the Artinskian beds. Another of the three Russian species is represented by an allied form in the Productus limestone of India. There are two species of *Derbya* in the Schwagerina beds, both of which also occur in the Productus limestone of India. A third species is restricted to the Omphalotrochus and Cora beds of Russia. None of these three occurs in Mongolia. *Meekella* has seven species in the Ural-Timan succession, but only two of these occur in the Schwagerina beds, one of them, *M. uralica*, also occurring in the Jisu Honguer limestone. There are five species in the Cora beds, three of which also occur in the Omphalotrochus bed. None of them, however, is known from the Productus limestone of the Salt Range, though at least one of them, *M. striatocostata*, has a wide distribution elsewhere.

A single species of *Orthothetes* occurs in the Schwagerina limestone, but this is unknown in Mongolia and in the Productus limestone. The genus *Rhipidomella* has one species in the Cora bed and one in the Schwagerina bed, the latter also occurring in the Lower Productus limestone. Neither is known from

Mongolia. Of the two species of *Schizophoria*, one extends into the Artinskian and is represented by an allied form in the Middle Productus limestone.

Orthotychia is represented by *O. morganiana*, a South American species, a variety of which occurs in the Permian of China and of Darvas. This species is not found in the Jisu Honguer, or in the Productus limestones, but in both formations another species, *O. derbyi*, takes its place.

One of the most remarkable features of the Jisu Honguer limestone is the total absence of *Chonetes*, a genus represented by fourteen species in the Productus limestone and by eleven in the Schwagerina limestone. Of the latter, three extend into the Artinskian and five into the Cora beds. Two of the eleven species also occur in the Productus limestone, while two others are represented by allied species, one in the Lower and one in the Upper Productus limestone. The single species of *Aulosteges* of the Schwagerina limestone also occurs in the middle Productus limestone but not in Mongolia.

Of *Productus*, there are thirty-nine species in the Schwagerina limestone and four additional ones in other horizons: one only in the Omphalotrochus bed, one in the Cora bed and two in the Artinskian-Kungurian beds, making the total number forty-three. Moreover, twenty of the Schwagerina limestone species extend into the Artinskian-Kungurian beds, but only one of them into the higher Permian beds. Twenty-one of the Schwagerina limestone species also occur in the Cora beds, eight of these also extending into the Omphalotrochus beds. Only three of the forty-three species actually occur in the Productus limestone of the Salt Range, though eight others are represented by allied species in that formation. Of the nine more or less definitely identified species in the Jisu Honguer limestone, six also occur in the Schwagerina bed (several of these in other beds as well) and one other in the Artinskian. One of the six and two others also occur in the Productus limestone of the Salt Range. The genus *Proboscidella* is represented by three species; two of these extend into the Artinskian, one of the latter also occurring in the Jisu Honguer limestone. None of the species is known from the Productus limestone. There are eight species of *Marginifera* in the Schwagerina limestone. Of these, one, *M. uralica*, ranges from the Omphalotrochus beds to the Artinskian-Kungurian; another, *M. typica* var. *septentrionalis*, from the Cora beds to the Kungurian. This also occurs in the Jisu Honguer limestone and in the Middle and Upper Productus limestones. A third species ranges from the Omphalotrochus to the Schwagerina beds, and a fourth merely extends down into the Cora bed. Four are restricted to the Schwagerina bed. Besides the single species, occurring in the Jisu Honguer limestone, there are two other Russian forms, represented by allied species. None of the other Russian forms, however, occurs in the Productus limestone. Finally, *Tegulifera uralica* is restricted to the Schwagerina limestone.

Altogether, then, of the one hundred and ninety-four species of brachiopods, thirty-four, or 17.5 per cent., also occur in the Productus limestone (five in the Lower Productus limestone only), while twenty-six are represented by allied species (three of them in the Lower Productus limestone only). Thirty of the Ural-Timan brachiopods either occur in the Jisu Honguer limestone or are represented there by varieties. This is 15.5 per cent. of the Russian brachiopod fauna, but 31.3 per cent. of the Mongolian brachiopod fauna. Six of the Mongolian species are represented by allied forms in the Russian succession.

Finally of the thirty-one species of Brachiopoda listed by Tschernyschew for the Omphalotrochus horizon, only three, or less than 10 per cent., are not found in the higher beds, this indicating the unity of the early Permian fauna. Of the sixty-seven species of Brachiopoda listed for the Cora beds, twelve, or about 18 per cent., do not occur in the higher beds. This shows a greater distinctness, in so far as indicated by the brachiopods, between the Cora and the Schwagerina beds than between the Cora and Omphalotrochus beds, though caution is necessary not to over-emphasize the significance of this difference.

SUMMARY OF THE PERMIAN SERIES OF EASTERN RUSSIA

From the foregoing discussion it would appear that the Uralian series, that is, the Omphalotrochus, Cora and Schwagerina limestones, properly belong in the Permian system. That there is a distinct series of Upper Carboniferous formations, which is older than any of these divisions and is typically represented in the Donetz Basin, we shall see in a later section. The Gschellian with *Spirifer marcoui*, appears to represent a local development of a portion of this Upper Carboniferous series, most of which in eastern Russia is unrepresented. Furthermore, it is possible that the Uralian beds do not represent the base of the Permian, since we know that in the Chinese region there is an older Permian horizon, the CHIHSIA LIMESTONE, with *Tetrapora* and other characteristic early Permian types. This underlies the beds with *Lyttonia* and is probably equivalent to the Lower Productus limestone series. Since, however, none of its species is represented in the Uralian of Russia, this earliest Permian is apparently undeveloped there, the Uralian representing an overlapping series of the invading Pacific Sea.

George Baron Fredericks has recently published a revision of the Uralian (1929, p. 549) as the result of recent work in the Ural region. In this he brings out the fact that fifty per cent. of the faunas and localities restricted by Tschernyschew to the Schwagerina horizon belong to the Omphalotrochus horizon, and about twenty per cent. to the Cora horizon. From this it follows that *Schwagerina* is characteristic of the Omphalotrochus horizon and occurs only incidentally in the Schwagerina horizon, of which this foraminiferan is not characteristic. He divides the Uralian into the following four members, which are here given in descending order.

C d/3 Krasnoufimskian division:

Fine to coarse-bedded limestones, with occasional marls. It contains the following most characteristic forms: *Scheia tuberosa* Tschernyschew, *Zygopleura ryazancevi* Fredericks, *Aviculopecten uralicus* Fredericks, *Pseudamusium krasnoufimskensis* Fredericks, *Thrincoceras uralicum* Fredericks, *Pronorites præpermicus* Karpinsky, *Medlicottia artiensis* Grabau, *Gastrioceras, Stacheoceras, Fenestellæ,* some brachiopods.

C c/3 Ssarginian division:

Massive white and dark limestone, rich in fossils at certain levels. Most characteristic for this division are the following: *Productus genuinus* Kutorga, *Cora simensis* Tschernyschew, *Martiniopsis orientalis* Tschernyschew, *M. aschensis* Tschernyschew, *M. lutugini* Tschernyschew, *Pugnax uta* Marcou, *P. conivens* Eichwald, *P. granulum* Tschernyschew, *Keyserlinginæ*, etc.

C b/3 Irginian division:

(Cora horizon). Marls and coarse-bedded, often silicified, limestone. These Foraminifera are almost confined to this horizon in the Ural region. In the upper part of this division are interbedded clay-sandstones or sandy clay-shales. The most characteristic species of this horizon are: *Fusulina verneuili* Möller, *F. longissima* Möller, Silicispongiæ, some Fenestellidæ, *Productus moelleri uralicus* Tschernyschew, *Spiriferella saranæ* Verneuil.

C a/3 Tschernoryetschenakian division:

(Omphalotrochus beds). Massive, unstratified or coarsely stratified limestones with the following characteristic species: Schwagerinæ (*S. robusta* Krotow), Fusulinæ, *Palæoaplisina laminæformis* Krotow, *Omphalotrochus whitnei* Meek, *Productus batycolpos* Schellwien, *Cora* aff. *corrugata* M'Coy (= *Productus prattenianus* Girty non Norwood), *Marginifera pusilla* Schellwien, *M. timanica* Tschernyschew, *Tegulifera deformis* Schellwien, *Scacchinella gigantea* Schellwien, *Spirifer* (?) *fritschii* Schellwien, *Enteletes*, etc.

The lowest of these divisions C a/3 is evidently the Omphalotrochus horizon, while the species of the second division C b/3 are those previously ascribed to the Cora horizon. The upper two divisions apparently represent the old

Schwagerina limestone, though this is not positively stated in Fredericks' paper. The evidence adduced by him, however, clearly indicates the unity of the Uralian. Fredericks still follows the old correlation and regards the Uralian as Upper Carboniferous, but he assumes a marked hiatus between the Uralian and Artinskian and considers that the Lower Permian is entirely absent in the Ural region. The Middle Permian he begins with the Artinskian which consists of fine-grained sandstones, marls, calcareous clay and tuffogene sandstones, with the following fauna: ECHINODERMATA (*Monobrachiocrinus*, *Indocrinus*, *Hemiindocrinus*, *Timoroblastus*, etc.); AMMONOIDEA (*Pronorites*, *Parapronorites*, *Propinacoceras*, *Medlicottia*, *Gastrioceras*, *Agathiceras*, *Adrianites*, *Popanoceras*, *Stacheoceras*, etc.), etc.

The upper part of the Middle Permian he calls the UFIMSKIAN DIVISION. It consists (a) of limestones and dolomites, (b) of dolomites and gypsum (300 meters), (c) of tuffogene sandstones, clays and red beds. This latter subdivision contains a Gondwana flora.

As Upper Permian, he identifies the KUNGURIAN BEDS, consisting of (1) limestone and dolomites with a marine fauna, and (2) of dolomites with gypsum and anhydrite and rock salt. As a second phase of the Upper Permian, he cites the KAZAN STAGE, with transgression of the Kazan sea, with a brachiopod fauna. This is followed by the disappearance of the sea and development of a pelecypod fauna, then a marsh period and finally definite drying up of the land, succeeded by semi-desert conditions (Tartarian) which he refers to the Lower Trias.

Unless we have here extensive dislocations of an orogenic nature, Fredericks' divisions do not seem to correspond to the sections previously recognized, and given in the preceding pages. Still, whatever the correlation of the higher divisions eventually will come to be, it does not affect the question of the Lower and Middle Permian. It is evident that Fredericks' correlation of the Artinskian as Middle Permian, is that which I had arrived at, before I had become acquainted with Fredericks' work. But I cannot follow him in his correlation of the Uralian, which as the preceding and succeeding discussion will show, clearly represents the invasion of the Pacific sea, with its characteristic fauna, into the alien Russian Basin, at the opening of Permian time. In this matter of correlation I am quite at one with Beede and Knicker (1924) who from a careful analysis of the Schwagerina fauna, unhesitatingly referred it to the Permian, although they too recognized that a small percentage of the species represents holdovers from the Upper Carboniferous faunas of the Russian (Boreal) Basin.

With this correlation established, and with the higher Permian interpreted on the basis of the preceding discussion, I give the following tentative classification of the Permian of east Russia.

TENTATIVE CLASSIFICATION OF THE PERMIAN FORMATIONS OF RUSSIA

Upper Permian

Tartarian series (P_3) .... 150 meters
Kama series
Samara beds (P_2).............................75 to 100 meters
Ufa beds (P_1)..................................... 200 meters

Middle Permian

Kungurian series (C Pc) .... ? meters
Artinskian series (CPg)................................ ? meters

Lower Permian

Uralian series
Schwagerina limestone (C 3_3)........................ 50 meters
Cora limestone ($C3_2$)................................ 100 meters
Omphalotrochus beds ($C3_1$)........................ 12 meters

Hiatus and Disconformity

Upper Carboniferous

THE BEAR ISLAND AND SPITZBERGEN EXTENSION

The Ural-Timan Permian series is extended northward to Bear Island and Spitzbergen. On the latter, the general succession is as follows, according to Nathorst:

a. Spitzbergen Section—

Lower Triassic Beds, *Myalina* shales, with *M. degeeri, Pecten mordenskiöldi*, etc.

Hiatus and Disconformity

Upper Permian (incomplete)

Horizon e: Hustedia limestone and Pseudomonotis shale................ 2.7 meters
Horizon d: Unfossiliferous shales and sandstone with Myalina shales in the center .... 310 meters

Middle Permian, Kungurian ? and Artinskian

Horizon c: Productus shales series.................................. 166 meters

Siliceous shales and cherts, with *Productus cancriniformis* Tschernyschew, *P. postcarbonarius* Tschernyschew, *Derbya robusta* Hall?, *Spirifer alatus* Schlotheim, etc., and numerous sponge-spicules in the lower part.

Lower Permian

Horizon b: Spirifer limestone.. 38 meters

Massive white limestone, with numerous fossils, especially in the lower 10 ft., mostly identical with those of the Schwagerina limestone of Russia.

Horizon a: Cyathophyllum limestone.............................. 460 meters

Mostly white limestone, with *Productus timanicus*, *P. cora*, *P. lineatus*, *P. konincki*, with a thin layer of Fusulina limestone 340 meters below the top.

Hiatus and Disconformity

MIDDLE CARBONIFEROUS, Limestone with *Spirifer mosquensis* and basal conglomerate

Hiatus and Disconformity

SUBFORMATION, Lower Carboniferous red shales and sandstones, with plants and coal

b. Bear Island Section—

On Bear Island the succession is as follows:

LOWER (AND PART OF MIDDLE?) PERMIAN

3	Spirifer limestone	71 meters
	Hiatus and Disconformity	
2	Cora limestone and Cora sandstone	? meters
	Hiatus and Disconformity	
1	Fusulina limestone	? meters
	Hiatus and Disconformity	

MIDDLE CARBONIFEROUS

2	Sandstone without fossils	? meters
1	Sandstone with Ambigua limestone carrying *Athyris ambigua*	? meters
	Hiatus and Disconformity	

SUBFORMATION

Upper Devonian (Lower Carboniferous?) Ursa sandstone (continental) with plant remains.

c. Detailed Discussion—

The Cyathophyllum limestone of Spitzbergen has the following composition, according to Wiman (1914), at Cape Anser in Billen Bay.

SUPERFORMATION: Spirifer limestone, about	10 meters
CYATHOPHYLLUM LIMESTONE	460 meters
F. Limestone (talus-covered)	20 meters
E. Cyathophyllum limestone alternating with impure gypsum	110 meters
D. Light gypsum with bed of Cyathophyllum limestone	91 meters
C. Pure Cyathophyllum limestone	119 meters
B. Fusulina limestone	0.5 meters
A. Cyathophyllum limestone, with white and discolored gypsum beds	120 meters

Hiatus and Disconformity

SUBFORMATION: Lower Carboniferous (Culm)

C.	Red Culm sandstone	75 meters
B.	Dark shales with coal	10 meters
A.	Light sandstone, about	10 meters

The Fusulina limestone (B) bed of the above section carries, besides other Foraminifera, *Schwagerina princeps*, which seems to appear somewhat earlier here than in Russia.[1] Holtedahl has shown the presence of Moscovian beds, with *Spirifer mosquensis*, above a basal conglomerate, at the base of the Cyathophyllum limestone of King's Bay, Spitzbergen, and Wiman thinks this horizon may also be found on the Ice Fjörd. Elsewhere Nathorst reports gypsum at the base of this limestone.

The higher Permian beds are shown in a section on the south shore of Sassen Bay, given by C. Wiman (1914, p. 14), which is as follows in descending order:

II. PRODUCTUS BEDS, etc. (Artinskian):

I.	Limestone with siliceous beds	3 meters
H.	Glauconite sandstone with *Lingula*	28 meters
G.	Limestone	5 meters
F.	Siliceous beds	5 meters
E.	Limestones	5 meters
D.	Siliceous beds	5 meters
C.	Limestones	5 meters
B.	Productus beds, siliceous, about	95 meters
A.	Black clay slate, Bryozoa and sponges	15 meters
	Total: Productus series	166 meters

I. SPIRIFER BEDS (Wiman's classification):

C.	Glauconite sandstone	8 meters
B.	Limestone, about	20 meters
A.	Spirifer limestone, about	10 meters
	Total: Spirifer beds	38 meters

Wiman proposes to draw the line between the Spirifer limestone and the Artinskian at the base of the Bryozoa sponge shales (II A), because that is the formation in which the Artinskian sponges appear for the first time. At the Ice Fjörd, these sponges are rock-forming at this horizon.

In the 20-meter limestone bed (I B) of the above section, is found an abundance of *Streptorhynchus kempii*, a species which characterizes the lower

[1] According to Fredericks, however (1929), the Schwagerinæ appear in the Omphalotrochus beds.

part of the Spirifer limestone of Bear Island and seems to be restricted to this horizon. The entire Spirifer limestone of Spitzbergen is a shallow-water formation, and conglomeritic beds, in which the pebbles are rolled shells of *Spiriferina* (*Spiriferella*), are not infrequent. The greater thickness of this formation farther south on Bear Island, where it attains to 71 meters, would indicate that the Spitzbergen beds represent an incomplete development of the series and probably comprise only the lower part of that formation as developed on Bear Island.

The Cyathophyllum limestone of Spitzbergen is comparatively poor in species, but the Cora limestone of Bear Island includes more. In the following table are shown the brachiopods. Those also found in the Middle Carboniferous are preceded by an asterisk (*).

TABLE IV. BRACHIOPOD FAUNA OF THE "CYATHOPHYLLUM" BEDS OF SPITZBERGEN AND THE "CORA" BEDS OF BEAR ISLAND

		Spitzbergen and Bear Island					Ural-Timan Region (Tschernyschew)[1]				
		Cyathophyllum bed, Spitzbergen	Cora bed, Bear Island	Spirifer bed, Spitzbergen	Spirifer bed, Bear Island	Siliceous limestone, Spitzbergen	Omphalotrochus bed	Cora bed	Schwagerina bed	Artinskian-Kungurian	Kama series
1	*Dielasma plica* Kutorga	....	×	×	....	×	....	....	×	×	....
2	*D. itaitubense* Derby	....	×	....	....	....	×	....	×	....	×
3	*Pugnax osagensis* Swallow	....	×	....	?	....	....	....	×	....	....
4	*Rhynchopora nikitini* Tschernyschew	....	×	×	....	....	×	×	×	×	×
5	*Camarophoria crumena* Martin	....	×	×	....	×	×	×	×	×	×
6	*Athyris royssii* Léveillé	....	×	....	....	....	....	....	....	....	....
7	*A. royssiana* Tschernyschew	×	....	×	....	×	....	×	×	×	×
8	*A. planosulcata* Phillips	×	....	×	....	....	×	×	×	×	....
9	*Hustedia remota* Eichwald	×	....	×	....	×	....	×	×	....	....
10	*Spiriferina expansa* Tschernyschew	....	×	×	....	×	....	×	×	×	....
11	*Spiriferella saranæ* Verneuil	....	×	×	....	×	....	×	×	×	....
12	*S. draschei* Wiman (= *S. wimanni* Grabau)	....	×	×	....	×	....	....	....	....	....
13	*S. polaris* Wiman	....	×	×	....	×	....	....	....	....	....
14	*Spirifer cameratus* Morton	....	×	×	....	....	....	×	×	×	....
15	*S. fasciger* Keyserling	....	×	×	×	×	....	×	×	×	....
16	*S. marcoui* Waagen	×	....	....	×	....	×	×	....	....	....

[1] According to Fredericks (1929) the distribution of the species in the several divisions of the Uralian is subject to revision.

TABLE IV. BRACHIOPOD FAUNA OF THE "CYATHOPHYLLUM" BEDS OF SPITZBERGEN AND THE "CORA" BEDS OF BEAR ISLAND (*Continued*)	Spitzbergen and Bear Island					Ural-Timan Region (Tschernyschew)[1]				
	Cyathophyllum bed, Spitzbergen	Cora bed, Bear Island	Spirifer bed, Spitzbergen	Spirifer bed, Bear Island	Siliceous limestone, Spitzbergen	Omphalotrochus bed	Cora bed	Schwagerina bed	Artinskian-Kungurian	Kama series
17 *S. supramosquensis* Nikitini	×	....	....	....	....	×	×	....	....	....
18 *S. fritschi* Schellwien	×	....	×	....	....	....	....	×	....	....
19 **Reticularia lineata* Martin[2]	×	×	×	×	?	×	×	×	×	....
20 *Chonetes variolata* d'Orbigny	×	....	×	....	×	....	×	×	×	....
21 **Productus boliviensis* d'Orbigny	....	×	×	....	×	....	×	×	×	....
22 *P. multistriatus* Meek var.	×	....	×	....	....	....	×	×	....	....
23 *P. inflatus* McChesney	×	....	×	×	×	×	×	×	×	....
24 **P. irginæ* Stuckenberg	....	×	×	....	×	....	×	×	×	....
25 *P. cora* d'Orbigny	×	×	×	....	....	×	×	×	×	....
26 *P. lineatus* Waagen	×	....	....	....	....	....	×	×	×	....
27 *P. aagaardi* Toula	×	....	×	....	×	....	×	×	×	....
28 *P. konincki* Verneuil	×	×	×	×	×	×	×	×	×	....
29 *Marginifera involuta* Tschernyschew	....	×	....	....	....	....	×	×	....	....
	14	18	22	5	15	10	22	24	18	4

[1] According to Fredericks (1929) the distribution of the species in the several divisions of the Uralian is subject to revision.

[2] Probably *Squamularia asiatica* Chao or a related form.

From the Spirifer limestone of Spitzbergen, fifty-six species of brachiopods have been obtained. The Spirifer limestone of Bear Island, on the other hand, has furnished only thirteen species of Brachiopoda, all but two of which are also found in the Spirifer limestone of Spitzbergen.

In the following table these fifty-eight species are given with their distribution through other beds of this region and those of the Ural Mountains region:

TABLE V. BRACHIOPOD FAUNA OF THE SPIRIFER LIMESTONE OF SPITZBERGEN AND BEAR ISLAND

		Spitzbergen and Bear Island					Russia, Ural and Timan Regions				
		Cora beds, Bear Island	Spirifer beds, Bear Island	Spirifer limestone, Spitzbergen	Productus beds, Spitzbergen	Hustedia beds, Spitzbergen	Omphalotrochus beds	Cora beds	Schwagerina beds	Artinskian-Kungurian	Kama beds
		1	2	3	4	5	6	7	8	9	10
1	*Dielasma moelleri* Tschernyschew	....	....	×	....	....	×	×	×	×	....
2	*D. plica* Kutorga	×	....	×	×	....	....	....	×	×	....
3	*Beecheria sublævis* (Waagen)	....	....	×	....	....	....	....	×	....	....
4	*Rhynchopora nikitini* Tschernyschew	×	....	×	....	....	×	×	×	×	×
5	*R. variabilis* Stuckenberg	....	....	×	....	....	×	×	×	×	×
6	*Camarophoria crumena* Martin	×	....	×	×	....	×	×	×	×	×
7	*C. mutabilis* Tschernyschew	....	....	×	×	....	....	....	×	×	....
8	*C. plicata* Kutorga	....	....	×	....	....	....	....	×	×	....
9	**Athyris royssiana* Tschernyschew	....	....	×	×	....	....	×	×	×	×
10	**A. planosulcata* Phillips	....	....	×	....	....	×	×	×	×	×
11	**Hustedia remota* Eichwald	....	....	×	×	×	....	×	×	....	....
12	*Spiriferina cristata* Schlotheim	....	....	×	....	....	×	×	×	×	×
13	*S. expansa* Tschernyschew	×	....	×	×	....	....	×	×	×	....
14	*Spiriferella saranæ* (Verneuil)	×	....	×	×	....	....	×	×	×	....
15	*S. keilhavii* (v. Buch)	....	×	×	×	....	....	....	×	....	....
16	*S. salteri* Tschernyschew	....	....	×	....	....	....	....	×	×	....
17	*S. draschei* Wiman (non Toula) (= *S. wimanni* Grabau)	×	....	×	×	....	....	....	....	....	....
18	*S. polaris* Wiman	×	....	×	×	....	....	....	....	....	....
19	*Spirifer cameratus* Morton	×	....	×	....	....	....	×	×	×	....
20	*S. fasciger* Keyserling	×	×	×	×	....	....	×	×	×	....
21	*S. ravana* Diener	....	×	×	....	....	....	....	×	×	....
22	**S. marcoui* Waagen	....	×	....	....	....	×	×	....	....	....
23	*S. tastubensis* Tschernyschew?	....	×	....	....	....	....	....	×	....	....
24	*S. dieneri* Tschernyschew	....	....	×	....	....	....	....	×	....	....
25	**S. fritschi* Schellwien	....	....	×	....	....	....	....	×	....	....
26	*S. loveni* Wiman	....	....	×	....	....	....	....	....	....	....
27	**Reticularia lineata* Martin†	×	×	×	....	....	×	×	×	×	....

TABLE V—*Continued*

		Spitzbergen and Bear Island					Russia, Ural and Timan Regions				
		Cora beds, Bear Island	Spirifer beds, Bear Island	Spirifer limestone, Spitzbergen	Productus beds, Spitzbergen	Hustedia beds, Spitzbergen	Omphalotrochus beds	Cora beds	Schwagerina beds	Artinskian-Kungurian	Kama beds
		1	2	3	4	5	6	7	8	9	10
28	*Streptorhynchus macrocardinalis* Toula	....	....	×	....	....	....	....	....	....	....
29	*S. triangularis* Wiman	....	....	×	....	....	....	....	....	....	....
30	*S. kempii* Andersson	....	×	×	....	....	....	....	....	....	....
31	*Derbya grandis* Waagen	....	....	×	....	....	....	....	×	....	....
32	*Chonetes* cf. *geinitzi* Waagen	....	....	×	....	....	....	....	×	×	....
33	*C. capitolinus* Toula	....	....	×	....	....	....	....	....	....	....
34	**C. variolata* d'Orbigny	....	....	×	×	....	....	×	×	×	....
35	*C. granulifera* Owen	....	....	×	....	....	....	×	×	....	....
36	*C. moelleri* Tschernyschew	....	....	×	....	....	....	....	×	....	....
37	*Productus boliviensis* d'Orbigny	×	....	×	×	....	....	×	×	×	....
38	**P. multistriatus* Meek var.	....	....	×	....	....	....	×	×	....	....
39	*P. weyprechti* Toula	....	×	×	....	....	....	....	....	....	....
40	*P. uralicus* Tschernyschew	....	....	×	×	....	....	×	×	×	....
41	**P. inflatus* McChesney	....	×	×	×	....	×	×	×	×	....
42	*P. pseudoaculeatus* Krotow	....	....	×	....	....	....	×	×	×	....
43	*P. purdoni* Davidson	....	×	×	....	....	....	....	....	....	....
44	*P. irginæ* Stuckenberg	×	....	×	×	....	....	×	×	×	....
45	**P. cora* d'Orbigny	×	....	×	....	....	×	×	×	×	....
46	**P. aagaardi* Toula	....	....	×	×	....	....	×	×	×	....
47	**P. konincki* Verneuil	×	×	×	×	....	×	×	×	×	....
48	*P. loveni* Wiman	....	....	×	....	....	....	....	....	....	....
49	*P. mammatus* Keyserling	....	....	×	×	....	....	....	×	....	....
50	*P. fasciatus* Kutorga	....	....	×	....	....	×	×	×	×	....
51	*P. porrectus* Kutorga	....	....	×	....	....	....	×	×	×	....
52	*P. elegans* McCoy	....	....	×	....	....	....	....	....	....	....
53	*P. longus* Meek	....	....	×	×	....	....	×	....	....	....
54	*P. pseudohorridus* Wiman	....	....	×	×	....	....	....	....	....	....

TABLE V—*Continued*

		Spitzbergen and Bear Island					Russia, Ural and Timan Regions				
		Cora beds, Bear Island	Spirifer beds, Bear Island	Spirifer limestone, Spitzbergen	Productus beds, Spitzbergen	Hustedia beds, Spitzbergen	Omphalotrochus beds	Cora beds	Schwagerina beds	Artinskian-Kungurian	Kama beds
		1	2	3	4	5	6	7	8	9	10
55	*P. timanicus* Stuckenberg	....	×	×	....	....	×	×	×	....	....
56	*P. impressus* Toula	....	×	×	....	....	....	×	....	....	....
57	*Marginifera typica* Waagen var. *septentrionalis* Tschernyschew	....	....	×	....	....	....	×	×	×	....
58	*Marginifera? bicarinata* Wiman	....	....	×	×	....	....	....	....	×	....
		14	13	56	22	1	13	31	42	31	6

* Also in Cyathophyllum limestone of Spitzbergen.
† May be *Squamularia asiatica* Chao or a related species.

ANALYSIS OF THE FAUNAS

The analysis of these faunas shows some very pronounced characteristics. Considering first the Cyathophyllum bed of Spitzbergen, we find that of the total number of fourteen species of brachiopods, thirteen, or 93 per cent., also occur in the Cora bed of the Urals, while twelve, or 84.5 per cent., also occur in the Schwagerina or Tastuba limestone of the Urals. From this it would seem that the Cyathophyllum limestone of Spitzbergen is essentially equivalent to the Cora beds of the Urals, with a large percentage of the Schwagerina fauna. It must be remembered that *Schwagerina princeps* itself occurs 340 meters below the top of the Cyathophyllum limestone, which is more than twice the combined thickness of the Schwagerina and Cora beds of the Urals. Moreover, the Cora beds of Bear Island cannot be considered the equivalent of the Cyathophyllum limestone, having only three species out of eighteen in common with it, and these long-ranging species. On the other hand, the Spirifer limestone of Spitzbergen has forty-one out of its fifty-six species, or 73+ per cent., in common with the Schwagerina limestone of the Urals. All but three of the fourteen species recorded from the Cyathophyllum bed also occur in the Spirifer bed, the excepted ones being *Spirifer marcoui*, *Spirifer supramosquensis*, and *Productus lineatus*. Thus it would appear that the Cyathophyllum and Spirifer horizons are not as strongly differentiated in Spitzbergen as are the Cora and Schwagerina beds in the Urals[1], and that the Schwagerina limestone type of sedimentation continued longer in the Spitzbergen region than it did in the Urals. The succeeding Productus beds would then be the essential equivalent of the Artinskian as is commonly held.

On the other hand, the Bear Island section is less complete and apparently represents interrupted sedimentation. Andersson has found a hiatus between the Spirifer and Cora beds of Bear Island, and according to Wiman, there is another hiatus below the Cora beds, separating them from the underlying Fusulina limestone. Wiman in his table (1914, p. 10) apparently makes the Cora limestone of Bear Island the equivalent of the Fusulina limestone and some of the underlying beds of Spitzbergen, and he also makes the two Spirifer limestones equivalent and correlates both with the Schwagerina limestone of Russia.

The brachiopod faunas, however, do not seem to bear out this correlation. Thus, of the eighteen species recorded from the Cora beds of Bear Island, only three also occur in the Cyathophyllum bed. These are *Reticularia lineata* (= *Squamularia asiatica?*), *Productus cora* and *Productus konincki*, and all are long-ranging species. [On the other hand, fourteen of the eighteen species, or 77.8 per cent., also occur in the Spirifer limestone of Spitzbergen, to which these Bear Island Cora beds would therefore seem to be equivalent. Moreover, we have seen that the Spirifer bed of Spitzbergen is essentially equivalent to the Schwagerina limestone, which would correlate the Cora limestone of Bear Island with the Schwagerina limestone of Russia, fifteen of the eighteen species, or 83 per cent. of the Cora brachiopod fauna of Bear Island, occurring in the Schwagerina limestone of Russia. This would make the Spirifer limestone of Bear Island a younger formation than the Spirifer limestone of Spitzbergen. And this is borne out by the fact that the most characteristic index fossil of these beds, that is, *Streptorhynchus kempii* Andersson, is found in the lower beds of the Spirifer limestone of Bear Island and in the upper beds of the Spirifer limestone of Spitzbergen, being restricted to these two horizons. If this indicates uniformity of level, then the greater part of the 71 meters of the Spirifer limestone of Bear Island must be referred to the horizon of the Productus beds of Spitzbergen.

The highest Permian beds show the following succession in descending order, according to Nathorst:

SUPERFORMATION: Triassic sandstones and shales

PERMIAN BEDS:

5.	*Hustedia* beds	1.2 meters
4.	*Pseudomonotis* shale and limestone	1.5 meters

[1] This is based on Tschernyschew's tables. According to recent work of Fredericks (1929) the faunal difference is less pronounced.

3.	Unfossiliferous shale and sandstone	130 meters
2.	*Myalina* shale	25–30 meters
1.	Unfossiliferous shale and sandstone	140–150 meters
	Total	297.7 to 312.7 meters

The following twelve species have been described by Lundgren. Of these, eight are new, and four, marked by an asterisk, are known elsewhere. Three of these have a rather extensive range throughout this Upper Palæozoic series, and only *Bakewellia antiqua* appears to be a typical Permian species: 1, *Geinitzella columnaris* (Schlotheim), 2, *Orbiculoidea spitzbergensis* Lundgren, 3,* *Streptorhynchus pelargonatus* Schlotheim, 4,* *Hustedia remota* Eichwald (*Retzia nathorsti* Lundgren), 5, *Pecten nordenskioldi* Lundgren, 6, *Aviculopecten lindströmi* Lundgren, 7, *Aviculopecten toulai* Lundgren, 8, *Aviculopecten? borealis* Lundgren, 9, *Aviculopecten ? pygmæus* Lundgren, 10, *Pseudomonotis bjona* Lundgren, 11, *Bakewellia** *antiqua* Münster, 12, *Myalina degeeri* Lundgren.

From a limestone on Axel's Island in Bell Sound, Högbom has obtained the following species: *Orbiculoidea spitzbergensis* Lundgren, *Hustedia remota* Eichwald (both rare), *Aviculopecten toulai* Lundgren, and *Aviculopecten lindströmi* Lundgren (common), *Aulacothyris* cf. *uralica* Krotow, extremely abundant. These beds are probably to be correlated with one of the divisions of the Kama series, perhaps the Samara beds, of which they represent the northernmost extension.

CHAPTER XII

THE PRODUCTUS LIMESTONE OF THE SALT RANGE IN INDIA AND ITS FAUNA

THE Productus limestone of the Salt Range of northwestern India must always be regarded as the type of the Permian succession in Asia. Its detailed subdivision, chiefly according to Waagen, is as follows:

SUPERFORMATION: Triassic Ceratite marls.

Hiatus and Disconformity

PERMIAN

UPPER PRODUCTUS LIMESTONE:—130 feet or less.
- c. CHIDERU BEDS, marls and sandstones.
- b. JABI BEDS (or cephalopod beds), sandy limestones, with cephalopods.
- a. KHUNDGHAT BEDS (Lower and Middle Divisions of Upper Productus limestone).

MIDDLE PRODUCTUS LIMESTONE:—270 to 410 feet.
- b. KALABAGH (Upper Division of Middle Productus) Crinoidal limestones, marls and dolomites.
- a. VIRGAL BEDS. (Middle Division of the Productus limestone).

Hiatus and Disconformity (?`

LOWER PRODUCTUS LIMESTONE:—27 to 70 feet.
- b. KATTA BEDS (formerly Lower Division of Middle Productus limestone) Arenaceous limestone, marls and dolomites.
- a. AMB BEDS (Upper speckled sandstone).

PENDSCHAB SERIES. Speckled sandstone (Middle and Lower). 400 to 600 feet.
- b. WARCHA GROUP (Noetling) Lavendal. Clay and speckled sandstone.
- a. DANTOTE GROUP (Noetling). Olive green sandstone.

Hiatus and Disconformity

UPPER CARBONIFEROUS

TALCHIR GROUP (Noetling). Boulder clay, glacial boulders, in a fine matrix. 100 to 200 feet.

Hiatus and Unconformity

SUBFORMATION: Lower Cambrian.

Noetling and Frech place the entire Productus limestone in the Permian and consider that it is in depositional continuity with the overlying Triassic series, which Noetling regards as characterized only by a complete change in fauna. I have elsewhere (Grabau, 1923–1924, Vol. II, pp. 18–28; 77–88), discussed this question at length and pointed out the fallacy of Noetling's argument. There can be no doubt that a hiatus of considerable extent separates the Permian Productus limestone and the Lower Triassic Otoceras beds. Indeed, my conviction is growing that the interval, which is here unrepresented by sediments, is one of great duration, long enough to permit the complete development of a new pelagic fauna from Palæozoic survivors. I conceive the succession of events to have been essentially as follows:

At the close of the Permian, the strata of the Mongolian and Tsingling geosynclines were folded, accompanied by complete withdrawal of the marine waters, not only from the geosynclines but from the continental shelves as well. This phenomenon affected not only Asia but all the other continents, and was probably the chief cause for the all but universal extermination of the littoral Palæozoic fauna. The Himalayan geosyncline was affected by this withdrawal, as were all the other geosynclines which had previously been filled by marine waters. Even the Tethys was largely drained, though there is reason to believe that in the center of this water body, there was a residual sea in which the Palæozoic brachiopods and other types had some survivors, which reappeared in modified form in the Alpine Triassic.

The survivors in the open sea, especially the Pacific Ocean, the subsidence of the bottom of which was probably the chief cause of the withdrawal of the waters, were primarily the pelagic forms, though certain littoral types may by that time have become adapted to the deeper waters so that they could survive in the bathyal district. The main pelagic types appear to have been the fish, the goniatites and the foraminiferans, and it was from these, together with a few brachiopods, corals and echinoid survivors, that the chief elements of the Mesozoic fauna were derived. But a sufficient time must be allowed for the surviving Palæozoic goniatites to give rise to a considerable number of genetic lines in which the ceratite structure was developed, before the fauna again entered the geosynclines on the renewal of marine transgression, for we find many such lines of evolution already in existence at the beginning of Triassic sedimentation. It is true that the Lower Triassic of the Himalayan geosyncline, in my view, represents only the upper portion of the Lower Triassic as developed in some other regions, but even where this division is more fully developed, the fauna, when it appears, is already highly specialized, so that we probably nowhere find a transition series from the Permian to the Trias. This might imply that the Permian of the Himalayan geosyncline is itself incomplete and that the Chideru beds do not represent the highest Permian, and this is probably the case, as will be shown in the discussion of the Chinese Permian.

During the Permo-Triassic interval, extensive land connections existed, for not only was India united to Pal-Asia by the emergence of the Himalayan geosyncline, but Cathaysia and Australia were undoubtedly united into one continuous mass. This permitted free migration of the floras, as well as the land animals, between Australia, India and Africa, without necessitating the existence of a Gondwana land. Such a condition of land connection as outlined had existed before the close of Permian time, certainly during the Middle Carboniferous, and again probably at some time during the Upper Carboniferous or before the opening of Permian time. Thus, ample opportunity for the wide migration of the *Glossopteris* flora and the late Palæozoic vertebrates was afforded, though there was probably a more restricted opportunity for the migration of the animals of the rivers and of other continental waters.

Thus, while the argument for the Permian age of the Middle and Upper Productus limestone cannot be based on stratigraphic continuity with the Triassic sediments of the Himalayan geosyncline, I hold, nevertheless, that these limestones are certainly to be referred to the Permian. Tschernyschew (1902, p. 728), on the other hand, has argued for the Carboniferous age of the greater part of this series.[1] He makes the following correlations between the Salt Range and the Ural-Timan sediments: the Upper Productus limestone, about 100 meters[2] in thickness, he parallelizes with the supra-Schwagerina beds, comparing the Chideru beds with what he regards as the Lower Permian deposits of European Russia, and the Jabi and Khundghat beds with the Kungurian limestone and dolomite horizon (*C.p.c.*) and the Artinskian marls (*C.p.g.*), his so-called Permo-Carboniferous. The Middle Productus limestone, about 100 meters in thickness, in which he includes the Katta beds, he parallelizes with the Schwagerina beds, 50 to 60 meters in thickness, and the Cora beds, 70 to 100 meters in thickness. The Lower Productus limestone, about 66 meters in thickness, under which he comprises only the Amb beds, he parallelizes with the Omphalotrochus beds, 60–70 meters thickness. Finally the Pendschab series, about 200 meters in thickness, he correlates with the Middle Carboniferous, parallelizing the Warcha series with the *Spirifer mosquensis* beds.

I am quite willing to accept this correlation in part, provided the Schwagerina limestone, the Cora limestone, and the Omphalotrochus beds are placed in the Permian. The correlation of the Omphalotrochus beds of Russia with these formations seems to be established by the occurrence of *Spirifer marcoui* in both. As above noted, these beds are separated from the *Spirifer mosquensis* beds by a well-marked hiatus, while another hiatus, though of less magnitude, seems to separate them from the Cora beds. That they do not represent the Upper Carboniferous seems certain. Indeed it is quite possible that these beds are in reality the earliest Permian, and are

[1] Fredericks seems to follow him in this.

[2] This and the following thicknesses assumed by Tschernyschew are too great, as the table on a preceding page shows.

separated by a time interval from the Cora beds which mark a renewed invasion of the sea. If these correlations are correct, we should expect to find the Productus limestone series incomplete in itself, for it is scarcely conceivable that less than 200 meters of limestone and sandstone should represent the whole of the Permian series, which elsewhere, as in the case of the Wushan limestone of China, is represented by nearly 2,000 meters. There is indeed some evidence for the belief that the Lower and Middle Productus limestones have a disconformable relation, with an intervening hiatus of undetermined length, as indicated in the table above. It must be noted that the Lower Productus limestone is mostly a sandstone, and one of its striking characteristics is its great variation in thickness. Thus at Amb, the type locality where it is most fossiliferous, it has a thickness of only 27 feet, while at Katta it has a thickness ranging from 55 to 66 feet. The Katta beds, which overlie the Amb beds, have a thickness of only 6 to 10 feet and are characterized by *Fusulina cattænsis*. These are placed by Noetling at the base of the Middle Productus limestone, while Waagen considered that they should be classed with the Upper Speckled sandstone, as Lower Productus limestone, though in his table he also placed them at the base of the Middle Productus limestone. If these beds are of only local occurrence, they may belong to the series below the hiatus, having been removed elsewhere by subsequent erosion. If, however, they extend widely, being present with little variation in all the sections, they probably represent the first products of the reinvasion of the sea which followed the period of erosion after the deposition of the Amb beds.

At the base of the series lies the great Talchir conglomerate, representing a period of glaciation. This was supposed by Tschernyschew to correspond to an early period in Carboniferous time, or it may be of early Upper Carboniferous age following the period of *Spirifer mosquensis* deposition and corresponding to the period of emergence which followed that epoch. There is nothing in the very meager fauna of the Dandote group to indicate its correspondence to the Middle Carboniferous. These beds consist of olive-green sandstone, enclosing two marine zones, that of *Eurydesma globosa* below and that of *Conularia lævigata* above. The fossils of this formation, indeed, are similar to those of the so-called Permo-Carboniferous of Australia, which occur in beds immediately overlying a similar glacial boulder clay, the Muree glacial formation, which is probably also of Upper Carboniferous age. In both regions the fossiliferous beds mark the return of the sea after the glacial conditions had disappeared, though there may have intervened a period of non-deposition of greater or less duration. That the marine invasion was, however, temporary in the Himalayan geosyncline is shown by the fact that the succeeding beds consist of cross-bedded sandstones 300 to 500 feet in thickness and interbedded with red shales (Speckled sandstone). The succeeding Lower Productus limestone marks the reinvasion of the sea, probably in early Permian time. It consists mostly of soft calcareous sandstone, with coal partings in the lower part (Amb series), while the Katta beds are chiefly crinoidal. The fauna is quite distinct from that of the underlying Pendschab series. It is especially characterized by numerous *Producti*, of which *Productus cora*, *Productus lineatus*, *Productus semi-reticulatus* and *Productus spiralis* are the leading types. These are long-ranging types, and may indicate either very late Carboniferous or Permian. Other characteristic species are *Spirifer marcoui*, *Chonetes ambiensis* Waagen, *Aulosteges medlicottianus* Waagen, *Marginifera ovalis* Waagen, *Richthofenia lawrenciana* Waagen, and *Beecheria sublævis*. These last two species link the fauna rather closely with that of the Middle Productus limestone as well as the Permian of China and Mongolia, and suggest that the formation is at least early Permian, and that it might be even Lower Middle Permian. The great abundance of *Aulosteges*, *Marginifera* and *Fusulina* further characterizes the Amb beds, as does also the absence of ammonoids. The Katta beds, the precise position of which is in doubt, are characterized especially by *Fusulina kattænsis*. Ammonoids are absent from this bed.

The Middle Productus limestone is the thickest and most characteristic member of this series. It consists mainly of blue or gray limestones, which are prominent cliff-formers in the Salt Range. White or cream-colored dolomite layers and marls are frequent members of the series, and it is from the latter that most of the fossils have been obtained. The number of species of fossils from this horizon is very large, especially among the Brachiopoda. Thirty-six of these brachiopods also occur in the Schwagerina beds of Russia, and twenty-two occur in the Jisu Honguer limestone or are there represented by dwarfed varieties. These species include such characteristic types as *Lyttonia nobilis*, also found in the Jisu Honguer limestone, and *Oldhamina decipiens*, which occurs also in the Permian of China. Both of these types are widespread in eastern Asia but have a limited vertical range, and so serve as good index fossils of this horizon.

The species of brachiopods which the Middle Productus limestone has in common with the Russian beds, especially the Schwagerina limestone, are indicated in table VI, below, while those it has in common with the Jisu Honguer limestone are shown in table II, page 377. Among the corals in this horizon are *Wentzelella salinaria*, *Waagenophyllum indica* and *W. virgalensis* which last is represented by a variety in the Jisu Honguer limestone. The only ammonite found in this horizon is *Xenaspis carbonaria* Waagen, a form with ceratitic sutures.

The Upper Productus limestone, which even Tschernyschew places in the Permian, is prevailingly arenaceous, consisting of sandstones with carbonaceous shales and with subordinate beds of limestone and dolomite. Yellow and rusty-brown colors prevail. Fossils are abundant, ammonoids predominating in the upper beds where they are associated with numerous pelecypods but with few brachiopods. Among ammonoids, especially noteworthy are those with complicated ceratitic and even ammonitic sutures (*Medlicottia*, *Cyclolobus*, and *Popanoceras*). The gastropods are represented chiefly by bellerophontids, at least one of which is found also in the Jisu Honguer limestone. Among the brachiopods are fifteen species also found in the Schwagerina limestone, and fourteen species found in the Jisu Honguer limestone or represented there by dwarfed varieties. These are given in Tables II and VI, on pages 377 and 430 respectively. *Oldhamina decipiens* also continues into the Upper Productus limestone.

The brachiopod fauna of the Productus limestone is snown in Table III. This table also shows the number of species of these genera found in the Jisu Honguer limestone of Mongolia and in the Ural-Timan region. The total number of species of brachiopods found in the Productus limestone is one hundred seventy-eight, of which seventy-seven occur in the upper, one hundred fourteen in the middle, and forty-two in the lower division. Of these one hundred seventy-eight, thirty-four, or 19.1 per cent., are actually found in the Ural and Timan regions as shown in Table VI. All but one of these, *Spirifer marcoui*, occur in the Schwagerina limestone. Sixteen extend into the Artinskian and Kungurian, seven continue into the higher Permian. Thirty-one, or 18 per cent., of the Indian brachiopod fauna either occur in the Jisu Honguer limestone or are represented there by varieties. Though this is only a small percentage of the Indian fauna, it must be remembered that it is 31.3 per cent. of the Mongolian brachiopod fauna of ninety-nine species, varieties and mutations, whereas the thirty-four in common with the one hundred ninety-four species in the Schwagerina beds represent only 17.5 per cent. of that fauna. Thus it appears that from the point of view of the two northern faunas, the Mongolian and the Russian, the former, with 31.3 per cent., has about twice as many Indian species as the latter with 17.5 per cent. Considering, however, the Mongolian fauna by itself, we find that the two alien faunas are almost equally represented, for this fauna contains thirty-one Indian species, this constituting 31.3 per cent. of the Mongolian fauna, and thirty Russian species, or 30.3 per cent. of the brachiopod fauna. Thus the Mongolian brachiopod fauna is intermediate between the Indian and Ural-Timan fauna, being about equally related to each.

The following table shows the distribution of the species of brachiopods which are common to the Salt Range and the Ural-Timan region.

TABLE VI. DISTRIBUTION OF THE SPECIES OF BRACHIOPODA IN COMMON BETWEEN THE SALT RANGE AND THE URAL-TIMAN REGION

	Ural-Timan Region						Salt Range of India		
	Omphalotrochus bed	Cora beds	Schwagerina beds	Artinskian and Kungurian dolomites	Higher Permian beds		Lower Productus limestone	Middle Productus limestone	Upper Productus limestone
	a	*b*	*c*	*d*	*e*		*1*	*2*	*3*
1	....	....	×	×	×	*Dielasma elongatum* Schlotheim	....	×	....
2	....	....	×	×	....	*D. truncatum* Waagen	×	....	....
3	×	....	×	....	....	*D. itaitubense* Derby	....	×	....
4	....	....	×	....	....	*Notothyris nucleolus* Kutorga	....	×	....
5	....	....	×	....	....	*N. warthi* Waagen	....	×	×
6	....	....	×	×	×	*Camarophoria superstes* Verneuil	....	×	×
7	....	....	×	....	....	*C. netschajewi* Tschernyschew	....	....	×
8	....	....	×	×	×	*C. globulina* Phillips	....	....	×
9	....	×	×	×	×	*Athyris pectinifera* Sowerby	....	×	×
10	....	×	×	×	×	*A. royssiana* Keyserling	×	....	....
11	....	....	×	....	....	*A. gerardi* Diener	....	×	....
12	....	×	×	....	....	*Hustedia remota* Eichwald	×	×	×
13	....	....	×	....	....	*H. indica* Waagen	....	×	....
14	....	....	×	....	....	*Spiriferina ornata* Waagen	....	....	×
15	....	×	×	×	×	*S. cristata* Schlotheim	×	×	×
16	....	....	×	....	....	*S. panderi* Moeller	×	....	×
17	....	....	×	....	....	*Spirifer striatus*	×	....	....
18	....	×	×	×	....	*S. fasciger* Keyserling	×	×	×
19	....	....	×	×	....	*S. ravana* Diener	....	×	....
20	×	×	....	....	....	*S. marcoui* Waagen	×	×	....
21	....	....	×	....	....	*S. dieneri* Tschernyschew	....	×	....
22	....	....	×	×	....	*S. tibetanus* Diener	....	×	....
23	....	....	×	....	....	*Martinia semiplana* Waagen	....	×	....
24	....	....	×	×	....	*Streptorhynchus pelargonatus* Schlotheim	×	×	....
25	×	×	×	....	....	*Derbya regularis* Waagen	×	×	....
26	....	....	×	....	....	*D. grandis* Waagen	....	×	×
27	....	....	×	....	....	*Rhipidomella pecosi* Marcou	×	....	....

TABLE VI. DISTRIBUTION OF THE SPECIES OF BRACHIOPODA IN COMMON BETWEEN THE SALT RANGE AND THE URAL-TIMAN REGION

(*Continued*)

	Ural-Timan Region						Salt Range of India		
	Omphalotrochus bed	Cora beds	Schwagerina beds	Artinskian and Kungurian dolomites	Higher Permian beds		Lower Productus limestone	Middle Productus limestone	Upper Productus limestone
	a	*b*	*c*	*d*	*e*		*1*	*2*	*3*
28	....	....	×	....	....	*Chonetes morahensis* Waagen	....	×	×
29	....	....	×	....	....	*C. trapezoidalis* Waagen	....	....	×
30	×	×	×	....	+	*Aulosteges dalhousi* Davidson	....	×	....
31	×	×	×	×	....	*Productus cora* d'Orbigny	×	×	×
32	....	×	×	×	....	*P. lineatus* Waagen	×	×	×
33	....	....	×	×	....	*P. cancriniformis* Tschernyschew	....	×	....
34	....	×	×	×	....	*Marginifera typica* var. *septentrionalis* Tschernyschew	....	×	×
34	5	11	33	16	6+1	Total	12	26	15

× = identical; + = related.

CHAPTER XIII

THE UPPER CARBONIFEROUS AND PERMIAN FORMATIONS OF THE DONETZ BASIN

INTRODUCTION

SINCE the age of the typical Uralian beds, that is, the Schwagerina and Cora limestones and the Omphalotrochus beds of the Ural Mountain region, is in question, it cannot be regarded as the standard for the Upper Carboniferous for Europe as has generally been done. Hence, we are constrained to seek a new standard for the European Upper Carboniferous, one that, if possible, gives a complete succession, is bounded above and below by the next younger and older formations respectively, and carries a fauna which permits of no doubt as to its proper position in the stratigraphic and biologic sequence. Probably the only locality in Europe where a section is found which satisfies all these requirements is in the Donetz Basin of southern Russia. This lies only a short distance north of the Sea of Azov and is limited on the north and east by the valley of the Donetz River, a tributary of the Don, which flows into the northeastern end of the Sea of Azov. Roughly speaking, the basin is bounded on the west and east by the longitudes of 37° 45′ and 40° 45′ respectively, and on the south and north by latitudes 47° 30′ and 49° 50′ respectively. The central portion is formed by the Upper Carboniferous, while the lower beds are exposed on its southern margins. Its northwestern portion is formed by the subordinate Bakhmout (Bachmut) Basin in which the Permian strata overlie the Upper Carboniferous.

The Upper Carboniferous series of this basin consists of some 2,000 meters of marine limestone and clastic beds, with only subordinate coal-bearing layers. This series rests on several thousand meters of limestones and coal-bearing beds; the series throughout carries the *Spirifer mosquensis* fauna and probably represents the most extensive and most complete section of the Middle Carboniferous series extant. It in turn rests upon several thousand meters of mostly marine Lower Carboniferous limestones.

The fauna of this Upper Carboniferous group, to which the group name DONETZIAN should be applied, is a purely endemic fauna, and like the preceding

Moscovian, of which it is largely a derivative, was undoubtedly at home in the boreal ocean of late Palæozoic time. If this was the center of distribution, the fauna migrated on the one hand into the Russian Basin and on the other into the Palæo-Cordilleran geosyncline of North America. That this was most probably the case is shown by the remarkable similarity of the Upper Carboniferous fauna of these two regions.

The more important members of the Donetzian, or the Upper Carboniferous fauna of the Donetz Bazin, are given in Table VII with a distribution in the several members of the series elsewhere. This list is confessedly incomplete, and large elements like those of the corals and bryozoans are omitted altogether. It represents, however, according to Tschernyschew and Loutouguin (1897), a general view of the fauna. See also N. Lebedew (1926).

STRATIGRAPHIC SUCCESSION OF THE PERMIAN AND UPPER CARBONIFEROUS BEDS OF THE DONETZ BASIN

In descending order, we meet with the following subdivisions:

SUPERFORMATION:—Jurassic series.

Hiatus and Unconformity

PERMIAN:

UPPER OR MIDDLE PERMIAN:—

Red and green clays and marls and friable sandstones with subordinate beds of gypsum and anhydrite as well as thick beds of rock salt interstratified between the layers of limestone and anhydrite. These beds may correspond to the Tartarian series but probably are older.—about 250 m.

LOWER PERMIAN: (Bakhmout Series).

BAKHMOUT DOLOMITES:

Upper:

Dolomitic limestones and sandstone characterized by large numbers of *Productus laplayi* Verneuil and *Schwagerina princeps* Ehrenberg, the shells of which sometimes make up the rock. Shells of nautiloids (*Temnocheilus*, *Asymtoceras*, etc.), are often found (for list of species see Table IX).

Middle and Lower:

Dolomites with a fauna recalling in part that of the underlying bed, but including some Zechstein species as well as many found in North America (for list of species see Table IX).

SUB-BAKHMOUT SERIES:—SHALES AND LIMESTONE:

Limestones, shales and sandstone with marine faunas (see Table IX) and with occasional thin coal beds and plant-bearing shales. The latter include the following species: (3_3)[1] *Asterophyllites equisetiformis* Brongniart, (3_3) *Annularia longifolia* Brongniart, *Palæostachya arborescens* Sternberg, (3_3) *Pinnularia columnaris* Lindley and Hutton, *Sphenophyllum majus* Schellwien, (3_3) *Sphenophyllum erosum* Lindley and Hutton, (3_3) *Sphenophyllum saxifragæfolium* Sternberg, *Sphenophyllum schlotheimi* Brongniart, *Sphenophyllum angustifolium* Seyras, (3_3) *Pecopteris arborescens* Schellwien, *Cordaites principalis* Geinitz, *Semaropsis fluitans* Weiss.

The subdivisions of the series are as follows:

Horizon l

Gray to grayish-green sandstone containing locally minerals of copper oxide. Also red and green clays and sandy shales of different colors.

Horizon k

Argillaceous limestone, with calcite geodes.

Underlying the limestone is a great series, composed of thick beds of arkose, red, green and gray argillites, with intercalations of thin beds of gray argillaceous limestone. Fossils have been found chiefly in the uppermost beds, where *Productus cancrini* and other brachiopods and mollusks characterize it. (See Table IX.)

Horizon i

Sandy, argillaceous shales, arkoses, and gray, green and red argillaceous shales.

Horizon h

Limestone passing into calcareous sandstone, with a great abundance of *Productus inflatus* and many other species of brachiopods, pelecypods and gastropods listed in Table IX.

Horizon g

Argillaceous shales, passing upward into sandstones and containing a bed of limestone composed entirely of shells of *Myalina*.

Horizon f

Compact limestone of dark brown color, 1 to 1½ meters in thickness, riddled with shells of *Fusulina verneuili* and *Fusulina longissima*.

Horizon e

Gray-white or red argillaceous shales, with thick intercalated coal-seams, succeeded by friable sandstones with lenticular concretions of calcareous

[1] (3_3) also in Upper Carboniferous ($C3_1$).

sandstone and gray, greenish and red argillaceous shales with similar concretions, and thin coal-seams in the upper part.

Horizon d

Very compact ferruginous sandy limestones, with *Productus nebrascensis*, nautiloids of the *tuberculati* group, and numerous pelecypods and gastropods.

Horizon c

Argillaceous shales passing into friable schistose sandstones and containing ovoid concretions of calcareous sandstone.

Horizon b

Light yellow dolomitic limestones with *Enteletes hemiplicatus*, *E. carnicus* and other fossils (see Table IX), including *Spirifer supramosquensis*.

Horizon a

Argillaceous shales and thick arkoses containing numerous crinoid joints, followed by argillaceous shales and sandy argillites of various shades, and finally a schistose graywacke. The basal crinoid-bearing beds rest directly upon the upper bed of the Donetzian series.

CARBONIFEROUS FORMATIONS:

UPPER CARBONIFEROUS OR DONETZIAN:

III. SUPERIOR DIVISION ($C3_3$):

Barren division, with no workable coal beds, those that occur being extremely thin, thickness exceeding 1,000 meters. It shows the following subdivisions in descending order:

Horizon 1

Argillaceous shales with concretions of sphærosiderite superposed on a limestone 1–3 meters in thickness, abounding in *Productus* and other fossils as listed in Table VII.

Horizon 2

Argillaceous sands and friable arkoses.

Horizon 3

Thick limestone beds, interstratified with red calcareous clay. In places the limestone is entirely made up of corals. Brachiopods are common and with them *Fusulina prisca*, *Fusulina verneuili*, etc. (See Table VII).

Horizon 4

Friable arkoses, with beds of red and green clay.

Horizon 5

Limestone with *Productus nevadensis, Fusulina*, etc. (see Table VII).

Horizon 6

Micaceous sandstones, argillaceous sandstones and friable arkoses, and gray or red clays. All alternating frequently.

Horizon 7

Limestone with *Fusulina verneuili* and brachiopods (see Table VII).

Horizon 8

Friable arkoses and sandy argillaceous shales.

Horizon 9

Compact dolomitic limestone, with *Productus punctatus* and other brachiopods (see Table VII) and with *Fusulina ventricosa*.

Horizon 10

Argillaceous shales, with thin coal seams and argillaceous sphærosiderite, also with interstratified limestone bands with *Productus semireticulatus, Marginifera, Spirifer fasciger, Rhipidomella pecosi*, etc.

Horizon 11

Argillaceous sandy shales, sometimes gray, sometimes red, covered by friable arkoses, with beds of violet or green clay.

Horizon 12

Limestone about 1.7 meters in thickness, in places entirely composed of *Fusulina verneuili* and *Fusulina longissima* accompanied by *Productus nevadensis* and *Marginifera* cf. *pusilla*.

Horizon 13

Argillaceous shales, with concretions and beds of argillaceous limestone, and containing *Productus nevadensis, Productus semireticulatus, Spirifer fasciger, Rhipidomella pecosi*, etc.

Horizon 14

Light gray limestone, with chert containing an abundance of *Fusulina verneuili* besides *Productus cora* and numerous other brachiopods, etc., some of which are listed in Table VII. This limestone, which is made the base of the upper division, has a remarkable constancy throughout the region and forms an easily recognizable horizon marker between the upper and middle divisions.

From the roof shales of the coal beds of this division ($C3_3$), the following plant remains have been obtained: *Asterophyllites equisetiformis* Brongniart, *Calamostachys germanica* Schenk, (2) *Annularia longifolia* Brongniart, *Stachannularia tuberculata* Weiss, (2) *Annularia sphenophylloides* Brongniart, (2) *Calamites cistii* Brongniart (?), *Calamites gigas* Brongniart (?), *Pinnularia columnaris* Lindley and Hutton, (2) *Sphenophyllum erosum* Lindley and Hutton, (2) *Sphenophyllum saxifragæfolium* Sternberg, *Sphenophyllum emarginatum* Brongniart, *Sphenopteris böckongiana* Weiss, *S.* (*Diplothema*) *m'ladeki* Stur, *Pecopteris arborescens* Schellwien, *P. arguta* Sternberg, *P. unita* Brongniart, *P. oreopteridea* Schellwien, *P. abreviata* Brongniart (?), *Collipseridium dawsonianum* Lesquereux (?).

Those marked (2) also occur in the Middle Carboniferous.

II. Middle division ($C3_2$).

This division is very distinct from the underlying ($C3_1$). It contains only two or three beds of coal, especially in the lower horizon, which are thick enough to warrant exploitation. The other coal beds are very thin; *Sigillaria scutellata* Brongniart has been obtained from some of these beds. With regard to the fauna, this series is interesting because of the preponderance among the fossils of types characteristic of the Upper Carboniferous and continuing into the Lower Permian of the Urals and the Timan, and of characteristic North American species. The following horizons are distinguishable in descending order.

Horizon 15

Argillaceous shales, locally carbonaceous; arkoses and micaceous sandstones, covered by yellow ochery and gray argillaceous shales; intercalated among the shales are thin beds of limestone, containing large *Fusulinas*.

Horizon 16

Argillaceous shales of a vivid red or bright green, with beds of calcareous sandstone and red argillaceous limestone. Here are found *Productus semireticulatus*, *Productus cora*, *Marginifera* sp., and numerous corals, bryozoans and crinoid stems.

Horizon 17

Argillo-arenaceous shales and clays with very thin beds of limestone carrying *Productus semireticulatus*, *Marginifera* sp., *Reticularia lineata*, *Allorisma subcuneata*, and *Spirifer mosquensis*. This is the highest horizon at which this last, the typical Middle Carboniferous (Moscovian) *Spirifer*, has been recorded. Its association with the American species of *Allorisma* is noteworthy.

Horizon 18

Argillaceous shales and friable arkoses.

Horizon 19

Limestone bed 0.7 meters in thickness resting on an arenaceous sandstone. Both are rich in fossils, including *Productus cora* and other brachiopods together with pelecypods and gastropods, all of them characteristic North American Carboniferous species. This is separated from the next underlying horizon by a finely foliated grit and by argillaceous shales and sandstones. The shales sometimes enclose a workable coal bed.

Horizon 20

Greenish-gray, friable arkoses, sandy argillaceous shales, and clay shales of different colors. The latter are interstratified with marls, carrying *Pseudomonotis radialis* Meek (non Phillip), *Bellerophon percarinatus* Conrad, *Orbiculoidea missouriensis* Schumard, *Schizodus*, etc.; all of them are American Carboniferous types.

Horizon 21

Light gray limestone filled with small gastropods, foraminifera (*Fusulina gracilis*, a characteristic American species, *Bradyina nautiliformis*) and brachiopods, among which *Spirifer kleinii* is very abundant (see Table VII).

Horizon 22

Argillaceous shales and friable arkoses, with intercalations of grits and red and green argillites. In the arkoses are found numerous stems of *Araucaria*. The shales carry a bed of coal.

I. Lower division ($C3_1$).

This division contains numerous exploitable coal beds. In these, remains of the following Lycopodiales have been found: **Lepidodendron aculeatum* Sternberg, **Lepidodendron dichotomum* (Sternberg) Zeiller, **Lepidodendron rimosum* Sternberg, **Lepidodendron grigoriewi* Zalessky (1904), **Lepidodendron veltheimi* Sternberg, **Lepidodendron lycopodioides* Sternberg, *Bothrostrobus olryi* Zeiller, **Sigillaria camptotænia* Wood, *Sigillaria transversalis* Brongniart, *Syringodendron alternans* Sternberg. Those marked by an asterisk (*) have passed upward from the Middle Carboniferous.

This division consists of the following horizons in descending order.

Horizon 23

Limestones in several beds, separated by layers of calcareo-argillaceous shales.

The limestones contain numerous chert concretions. The total thickness of the bed is 11 meters, and it forms a distinctly recognizable horizon throughout the region, separating the lower from the middle division. It contains numerous fossils, among them *Productus cora*, *Spirifer supramosquensis*, *Spirifer strangwaysi* (a typical Middle Carboniferous form) and other brachiopods (see Table VII). Also large numbers of the American Carboniferous trilobite, *Griffithides scitula* Meek and Worthen, and many pelecypods, gastropods, corals and bryozoans.

Horizon 24

Gray, green and red argillaceous shales, overlain by schistose arkoses.

Horizon 25

Gray and red argillaceous shales overlain by a bed of coal 0.35 meters thick.

Horizon 26

Gray limestone, about 1 meter thick, very dense and containing *Productus semireticulatus*, *Spirifer mosquensis*, *Bucania decussata;* and Foraminifera (*Bradyina nautiliformis*, *Fusulina ventricosa*, an American type), etc.

Horizon 27

Gray to violet argillaceous shales and dark gray limestone, about 0.5 meters in thickness, shaly graywackes.

Horizon 28

Argillaceous shales, like those next below, with a coal bed 0.7 meters thick.

Horizon 29

Sandy, argillaceous shales, with beds of gypsum and spathic iron, and carbonaceous clay shales, followed by a bed of coal 0.45 meters in thickness.

Horizon 30

Yellow ochery and gray argillaceous limestone, with intercalated shales. The limestone contains *Productus*, *Spirifer mosquensis*, *Schizophoria resupinata* and other brachiopods (see Table VII), as well as numerous pelecypods and gastropods.

Horizon 31

Argillaceous shales, with a bed of coal 0.45 meters thick, and layers of gypsum.

Horizon 32

Dolomitic limestones with numerous *Productus cora* and other species, as well as *Meekella striatocostata*, a common American form, and the Middle Carboniferous *Spirifer mosquensis* (see Table VII).

Horizon 33

Limestone 0.7 meters in thickness with *Spirifer mosquensis* and other brachiopods (see Table VII), and with *Bradyina nautiliformis* and *Schwagerina* sp., etc. This is overlain by violet clay-shale, and clay-shale with coal bed and graywackes. Underlying it are schistose graywackes and clay-shales with concretions of spathic iron.

Horizon 34

Gray or yellowish-gray argillaceous limestones, interstratified with shales containing *Productus*, *Spirifer mosquensis* and other brachiopods (see Table VII), and numerous pelecypods, gastropods, and bryozoans.

Horizon 35

Clay-shales, changing in places to shaly graywackes, with two subordinate coal beds, one 0.25 meters and the other 0.35 meters in thickness. These beds are succeeded by argillaceous shales with concretions of argillaceous limestone, gypsum and iron ore. These beds contain *Spirifer mosquensis*, *Rhipidomella pecosi*, *Productus semireticulatus*, *Marginifera* sp.

Horizon 36

Clay-shales and shaly graywackes with intercalations of coal, followed by thick limestones with intercalations of clay-lime-shales carrying coal beds. Some of the limestone beds are white or ochery yellow, others are dark gray. These limestones contain an abundant fauna of brachiopods, including the Middle Carboniferous *Spirifer mosquensis* and *Enteletes lamarcki*, and vast numbers of the American *Fusulina ventricosa*, besides an abundance of Bryozoa and corals.

Horizon 37

Limestone, interstratified with argillaceous lime-shales, in which are found a number of species of *Productus*, together with *Spirifer mosquensis* and other brachiopods (see Table VII) as well as numerous pelecypods, gastropods and corals.

Horizon 38

Arkoses, shaly sandstones and clay-shales, with intercalations of 0.15 meters of coal.

Horizon 39

Clay-shales and graywackes surmounted by a bed of coal, the roof shale of which abounds in well preserved plant remains.

Horizon 40

Shaly graywackes and impure coal beds 0.7 meters in thickness.

Horizon 41

Clay-shales and coarse-grained arkoses.

Horizon 42

This division has at the summit a limestone of about 5 meters thickness which passes upward into ochery yellow shales; underlying it is a coal bed, sometimes attaining a sufficient thickness for exploitation. Underlying it are shales and below that a dark gray limestone bed, often crystalline, from two to three meters in thickness and containing besides other species found below, a profusion of large specimens of *Mentzelia* cf. *corculum* (Kutorga) and *Spirifer supramosquensis* Nikitin. Underlying this are shales, with intercalated coal beds, and at the base a compact dark gray limestone, partly argillaceous and ochery yellow, and containing an abundant fauna, which, besides including many species which have passed up from the underlying Moscovian, such as *Spirifer mosquensis*, *Schizophoria resupinata*, and *Enteletes lamarcki*, is also characterized by the first appearance of the new Upper Carboniferous types, such as *Spirifer cameratus*, etc. (see Table VII). In addition to the brachiopods, there are fragments of *Conularia* and numerous corals.

In the roof shales of the various coal beds of this entire division ($C\ 3_1$) as well as in other shales, are found the following species of plants: *Sphenopteris obtusiloba* Brongniart, *Pecopteris nervosa* Brongniart, *Pecopteris cyathea* Brongniart, *Pecopteris muricata* Sternberg, *Neuropteris gigantea* Sternberg, *Neuropteris rarinervis* Bunbury, *Neuropteris heterophylla* Brongniart, *Alethopteris grandini* Brongniart, *Alethopteris lonchitica* Unger, *Calamites succowi* Brongniart, *Lepidodendron lycopodioides* Sternberg, *Sphenophyllum emarginatum* Brongniart, *Sphenophyllum saxifragæfolium* Goeppert, *Sphenophyllum erosum* Lindley and Hutton, *Sigillaria sentellata* Brongniart, *Sigillaria elegans* Brongniart, *Sigillaria transversalis* Brongniart, *Sigillaria comulata* Weiss var. *striata* Weiss, *Cordaites principalis* Geinitz, *Cardiocarpus* cf. *boulayi* Zeiller, *Trigonocarpus næggerathi* Brongniart, *Lepidostrobus variabilis* Brongniart, *Lepidophyllum lanceolatum* Brongniart.

Middle Carboniferous or Moscovian (C 2).

An immense succession (some 7,000 meters) of shales, limestones and coal beds, divisible into six series and numerous horizons, containing the typical *Spirifer mosquensis* fauna, which begins abruptly in the basal layers and continues throughout the entire series. This division also contains many coal beds and an abundant flora of ferns, *Annularia*, *Calamites*, *Lepidodendron*, *Sigillaria* and *Stigmaria*. It rests in turn upon an enormous thickness of Lower Carboniferous limestones, with the typical Carboniferous limestone fauna of western Europe.

THE DONETZIAN FAUNA

The fauna of the Upper Carboniferous bed or the *Donetzian division* has been only partially published, the chief types listed being the Foraminifera and brachiopods. In Table VII, a list of seventy-five species of fossils is given and their distribution in the various horizons, but it must be remembered that this is only a very partial record of the entire fauna.

One of the striking features of this fauna as a whole is the number of species, which have passed up from the lower horizon, that is, the Moscovian or the underlying Dinantian. Out of the fifty-eight species of brachiopods listed, there are at least twelve, or 20.7 per cent., that are characteristic Middle Carboniferous species. Most notable among these is *Spirifer mosquensis* which occurs in nearly every fossiliferous bed of the lower division of the Donetzian and continues to near the top of the Middle Division. Another is *Enteletes lamarcki*, which occurs in both the Upper and Lower Divisions, and others are *Productus konincki* and *Productus semireticulatus* as well as *Productus punctatus*, the last two also occurring in the Dinantian of the Donetz Basin.

Another feature of this fauna is the marked American element, that is, the presence of species widely distributed in the Upper Carboniferous of the Palæo-Cordilleran geosyncline and the interior basins of North America. Of the fifty-eight species of brachiopods, at least seventeen, or 29.3 per cent., are typical American Carboniferous forms, and at least two others are represented by closely related species. Among these are such typical forms as *Hustedia mormoni*, *Spiriferina octoplicata*, *S. cristata*, *Spirifer cameratus*, *Spirifer opimus* (*S. rockymontanus*), *Rhipidomella pecosi*, *Meekella striatocostata*, *Productus nevadensis*, *Orbiculoidea missouriensis* and others. Two of the most abundant Foraminifera are American forms, namely, *Fusulina ventricosa* and *Fusulina gracilis*.

Only four species of the abundant pelecypod fauna have been listed, but three of these are American forms, including *Pseudomonotis radialis* Meek and *Allorisma subcuneatum* Meek and Worthen. Of the five gastropods recorded, four also occur in the Upper Carboniferous of North America.

The only trilobite recorded, *Griffithides scitula*, is also an American form.

Ural-Timan					Salt Range			Darvas		Germany etc.	North America			
Omphalotrochus	*Cora*	*Schwagerina*	Artinskian-Kungurian	Kama	Lower *Productus*	Middle *Productus*	Upper *Productus*	Safeddaron	Obirawnou	Zechstein	Mississippian	Carboniferous	Permian	
....	....	....	....	....	....	....	....	....	....	....	....	×	....	1
....	....	....	....	....	....	....	....	....	....	....	....	×	....	2
....	×	×	....	....	....	....	....	....	....	....	....	....	....	3
....	....	×	....	....	×	....	....	....	....	....	....	....	....	4
....	....	....	....	....	....	....	....	....	....	....	....	....	....	5
....	....	....	....	....	....	....	....	....	....	....	....	....	....	6
....	....	....	....	....	....	....	....	....	....	....	....	....	....	7
....	....	×	×	....	....	....	....	....	....	....	....	....	....	1
....	....	×	×	....	....	....	....	....	....	....	....	....	....	2
×	×	×	×	×	....	....	....	×	....	....	....	....	....	3
....	....	×	×	×	....	×	×	....	....	....	....	....	....	4
....	....	....	....	....	....	×	×	....	....	....	....	....	....	5
....	....	×	×	....	....	....	....	....	....	....	....	....	....	6
....	....	....	....	....	....	....	....	....	....	....	....	....	....	7

TABLE VII. PARTIAL LIST OF THE DONETZIAN FAUNA

× = Identical species
\+ = Related species

Species	Donetz Basin: Lower Carboniferous	Donetz Basin: Middle Carboniferous	Donetz Basin: Upper Carboniferous	Lower Division 42	37	36	35	34	33	32	30	26	23	Middle Division 21	20	19	17	16	14	Upper Division 13	12	10	9	7	5	3	1	Bakhmout Basin Permian b	d	f	h	k	l	m	Ural-Timan: Omphalotrochus	Cora	Schwagerina	Artinskian-Kungurian	Kama	Salt Range: Lower Productus	Middle Productus	Upper Productus	Darvas: Safeddaron	Obirawnou	Germany etc.: Zechstein	North America: Mississippian	Carboniferous	Permian	
FORAMINIFERA:																																																	
1 *Fusulina ventricosa* Meck			×			×						×											×																							×		1
2 *F. gracilis* Meek			×											×																																×		2
3 *F. verneuili* Moeller			×																×		×			×	×	×										×	×											3
4 *F. longissima* Moeller			×																		×																×			×								4
5 **F. prisca* Ehrenberg			×																							×																						5
6 **Schwagerina* sp.			×						×																																							6
7 **Bradyina nautiliformis* Moeller		×	×						×			×		×																																		7
BRACHIOPODA:																																																	
1 *Dielasma plica* Kutorga			×			×							×																																			1
2 *Notothyris nucleolus* Kutorga			×										×													×																						2
3 *Rhynchopora nikitini* Tschernyschew																			×																													3
4 *Camarophoria superstes* Verneuil			×	×																																												4
5 *C. pinguis* Waagen			×			×																																										5
6 *C. plicata* Kutorga			×																																		×											6
7 **Metzelia* cf. *corculum* Kutorga			×	×																																												7
8 *Athyris (Cliothyris) royssii* Léveillé				×																											×																	8
9 *Hustedia mormoni* Marcou			×										×																																			9
10 *Spiriferina octoplicata* Schlotheim			×																																													10
11 *S. cristata* Schlotheim			×																																													11
12 **Spirifer mosquensis* Fischer			×		×	×	×	×	×	×	×	×																																				12
13 *S. cameratus* Morton			×																				×																							×		13
14 *S. supramosquensis* Nikitin			×										×																																			14
15 **S. okensis* Nikitin			×	×																																												15
16 *S. striatus* Martin			×			×																																								×		16
17 *S. rectangulus* Kutorga			×			×							×													×																						17
18 **S. strangwaysi* Verneuil		×	×										×																																			18
19 **S. trigonalis* var. *lata* Schellwien			×										×																																	+		19
20 **S.* cf. *kleini* Fischer		×	×											×																																		20
21 *S. fasciger* Keyserling			×																																					+								21
22 *S. opimus* Hall (*S. rockymontanus* Marcou)			×																																											×		22
23 *Reticularia lineata* Martin					×					×							×																															23
24 **Enteletes lamarcki* Fischer			×	cf		×																	×	cf																								24
25 *E. carnicus* Schellwien			×																				×																									25
26 *Schizophoria resupinata* (Martin)	×			×							×																																					26
27 *Rhipidomella pecosi* Marcou							×																																							×		27
28 *Orthotheles crenistria* Phillips				×				×																																								28
29 **O. caducea* McCoy																																																29
30 **O. arachnoides* Phillips	×									×																																						30
31 *Derbya grandis* Waagen						cf																																										31
32 *D. regularis* Waagen			×							×	cf																																					32
33 **D. senilis* Phillips			×																																													33
34 *Meekella striatocostata* Cox			×							×									×							×																				×		34
35 **M. eximiaeformis* Toula			×																																+	+												35
36 *Chonetes granulifera* Owen			×	×		×																																								×		36
37 **C. laguesi* de Koninck			×	×									×																																			37
38 **C. dalmanoides* Nikitin						×		×		×																																						38
39 *C. uralica* Moeller													cf																																			39
40 **C. [illegible] variolata* Keyserling																																														+		40
41 *Productus koninckii* Verneuil		×		×	×	×		×			×																																					41
42 *P. scabriculus* Martin	×	×	×																																											×		42
43 *P. semireticulatus* Martin	×	×	×	×	×	×	×	×	×	×	×	×	×	×			×	×		×		×	×		×																					×		43
44 *P. pyxidiformis* de Koninck	×		×		×																																									×		44
45 *P. aculeatus* Martin			×		×																																							×					45
46 *P. cora* d'Orbigny		cf	×			×				×			×	×		×		×	×				×				×								×	×	×			×	×	×	×				×		46
47 *P. nevadensis* Meek			×			×														×	×			×	×																					×		47
48 *P. punctatus* Martin	×	×	×																				×												×											×		48
49 *P. tenuistriatus* Verneuil			×																				×	×																								49
50 *P. alternatus* Norwood and Pratten			×																																										×			50
51 *P. praepermicus* Tschernyschew			×																																													51
52 *P. artiensis* Tschernyschew			×																																													52
53 *P. lineatus* Waagen			×																																	×	×					×		×					53
54 *P. abichi* Waagen			×																																													54
55 *Proboscidella genuina* (Kutorga)			×																							×											×											55
56 **Marginifera pusilla* Schellwien			×										×	×							×																											56
57 *M. uralica* Tschernyschew			×																×							×									×	×	×									×		57
58 *Orbiculoidea missouriensis* Schumard			×												×																															×		58
PELECYPODA:																																																	
1 *Pseudomonotis radialis* Meek			×												×																															×		1
2 *Allorisma subcuneata* Meek and Hayden			×														×							×	×																					×		2
3 *Aviculopecten ivanitskii* Verneuil			×								×																																			×		3
4 *Myalina nessus* Walcott			×													×																														×		4
GASTROPODA:																																																	
1 *Bellerophon percarinatus* Conrad			×												×																															×		1
2 *B. crassus* Meek and Worthen			×																				cf		×																					×		2
3 *Bucania decussata* Fleming, n.sp.?	×											×																																		×		3
4 *Trachydomia wheeleri* Swallow			×													×																														×		4
5 *Euphemus carbonaria* Cox		×	×													×											×						×													×		5
6 *E. urii* Fleming			×																																													6
7 *Macrocheilina (Sphaerodoma) medialis* Meek and Worthen			×										×			×																														×		7
TRILOBITAE:																																																	
1 *Griffithides scitula* Meek and Worthen			×										×																																	×		1

*Restricted to Donetz basin or of Boreal type.

COMPARISONS OF THE BRACHIOPOD FAUNAS OF THE DONETZIAN, "URALIAN" AND PRODUCTUS LIMESTONE FORMATIONS

On comparing this brachiopod fauna, so far as recorded, with that of the beds above the *Spirifer mosquensis* horizon in the Urals and Timan, we find the following relationship.[1] Of the fifty-eight species, the total number in common between the two series is twenty-seven, or about 46.5 per cent., with two others represented by related species. Nine, or 15.5 per cent., of the fifty-eight are also found in the Omphalotrochus bed, while an additional one is represented by a related species. Fifteen, or 26 per cent., are found in the Cora beds, and two others are represented by related species. Twenty-five, or 43 per cent., are found in the Schwagerina beds, with an additional one represented by a related species. Seventeen, or 29.3 per cent., are found in the Artinskian-Kungurian horizons, and three, or 5.2 per cent., are found in the Kama beds. The relation to the Productus limestone is equally slight. Nine of the fifty-eight species, or 15.5 per cent., are found in the lower Productus and the same number in the Middle Productus, and eight, or 13.8 per cent., in the Upper Productus limestone. In each, there is, moreover, one species represented by a related form. Analyzing these species, which the Donetzian has in common with the Ural and Timan we find that eight of the species are also found in North America, while a ninth, found in the Productus limestone only, is also an American form.

These are the following:

1. (11). *Spiriferina cristata*, Cora to Kama, also Lower, Middle and Upper Productus limestone.
2. (13). *Spirifer cameratus*, Cora to Kungurian, unknown in Salt Range.
3. (16). *Spirifer striatus*, Schwagerina limestone, Lower Productus bed.
4. (27). *Rhipidomella pecosi*, Schwagerina limestone, Lower Productus beds.
5. (34). *Meekella striatocostata*, Omphalotrochus to Cora beds. Absent in Salt Range.
6. (36). *Chonetes granulifera*, Cora to Schwagerina. Absent in Salt Range.
7. (46). *Productus cora*, Omphalotrochus to Kungurian, Lower, Middle and Upper Productus limestone.
8. (48). *Productus punctatus*, Omphalotrochus to Schwagerina.
9. (43). *Productus semireticulatus*, absent in Ural-Timan, Lower Productus, Mississippian and Pennsylvanian of North America.

These may be considered persistent boreal types. Eliminating these eight from the twenty-seven in common between the Donetzian and Uralian faunas, there remain nineteen, or nearly 32.8 per cent., of the Donetz fauna. These with their distribution are given in the annexed Table VIII.

[1] It is of course quite possible that detailed study of the Donetzian fauna will greatly alter this relationship.

TABLE VIII. NON-AMERICAN SPECIES OF BRACHIOPODA IN COMMON BETWEEN THE DONETZIAN AND URALIAN

			Beds in Donetz Basin	Ural-Timan					Salt Range		
				Omphalotrochus beds	Cora beds	Schwagerina beds	Artinskian-Kungurian	Kama series	Lower Productus limestone	Middle Productus limestone	Upper Productus limestone
1	(1)	*Dielasma plica*	36, 23	....	....	×	×	....	....	....	....
2	(2)	*Notothyris nucleolus*	23, 3	....	....	×	×	....	....	....	....
3	(3)	*Rhynchopora nikitini*	14	×	×	×	×	×	....	....	....
4	(4)	*Camarophoria superstes*	42	....	....	×	×	×	....	×	×
5	(5)	*C. pinguis*	36	....	....	....	....	....	....	×	×
6	(6)	*C. plicata*	3	....	....	×	×	....	....	....	....
7	(14)	*Spirifer supramosquensis*	42, 23, 3	×	×	....	....	....	....	....	....
8	(17)	*S. rectangulus*	36, 23, 3	....	....	×	....	....	....	....	....
9	(21)	*S. fasciger*	14 to 1	....	×	×	×	....	....	....	....
10	(23)	*Reticularia lineata* (Lower and Middle Carboniferous)	Throughout to 14	×	×	×	×	....	×	....	....
11	(25)	*Enteletes carnicus*	9, 3, 1	....	....	....	....	....	×	....	....
12	(31)	*Derbya grandis*	36 (cf. only)	....	....	×	....	....	....	×	×
13	(32)	*D. regularis*	32, 30 (cf.)	×	×	×	....	....	×	×	....
14	(39)	*Chonetes uralica*	14, 9, 7, 3	....	×	×	....	....	....	....	....
15	(41)	*Productus konincki* (Middle Carboniferous)	47 to 23, 7, 1	×	×	×	×	....	....	....	....
16	(49)	*P. tenuistriatus* (Lower Carboniferous)	9, 7	....	....	×	×	....	....	....	....
17	(51)	*P. præpermicus*	1 only	....	....	×	×	....	....	....	....
18	(52)	*P. artiensis*	1 only	....	....	×	×	....	....	....	....
19	(53)	*P. lineatus*	1 only	....	×	×	×	....	×	×	×
20	(54)	*P. abichi*	1 only	....	....	....	....	....	....	×	×
21	(55)	*Proboscidella genuina*	3 only	....	....	×	×	....	....	....	....
22	(57)	*Marginifera uralica*	14, 3, 1	×	×	×	×	....	....	....	....

ANALYSIS OF THE LIST

Analyzing this list, we find that three of the nineteen have passed into this series from the Lower or Middle Carboniferous of the Donetz Basin. These are No. 10, *Reticularia lineata;* No. 15, *Productus konincki,* and No. 16, *Productus tenuistriatus.* The first two[1] of these range from the Omphalotrochus bed to the Kungurian in the Ural region. Four other species appear in the Omphalotrochus bed, namely, No. 3, *Rhynchopora nikitini;* No. 7, *Spirifer supramosquensis;* No. 13, *Derbya regularis,* and No. 22, *Marginifera uralica.* These, together with the species first mentioned, may be considered as endemic, or as members of the boreal fauna, and their continuance into the Schwagerina limestone must be regarded as a case of persistence. Again we may note that five of these species are found only in the highest division of the Donetzian, that is, beds 3 and 1. These are in bed 3, No. 6, *Camarophoria plicata,* and No. 21, *Proboscidella genuina.* Both of these are restricted to the Schwagerina and the Artinskian-Kungurian of the Ural region. The three species found only in the highest bed (1) of the Donetzian are No. 17, *Productus præpermicus,* No. 18, *Productus artiensis,* and No. 19, *Productus lineatus.* The first two of these three are also restricted to the Schwagerina and Artinskian-Kungurian horizons. The third occurs also in the Cora bed, and ranges through the three divisions of the Productus limestone of the Salt Range. These five species might perhaps be considered Indo-Pacific types, with which this region was in communication towards the close of Upper Carboniferous and the opening of Permian time, that is, during the period of deposition of the Lower Productus limestone of the Salt Range and the Omphalotrochus and perhaps the *Spirifer marcoui* beds of the Ural region. On the other hand, at least four of them may be endemic types, this being suggested by the fact that they are not found in the Salt Range, where, however, the fifth one, that is, *Productus lineatus,* is characteristically developed.

Finally, it should be noted that one species, No. 12, *Derbya grandis,* is only doubtfully identified from the Donetzian horizon. Thus there are in all thirteen of these nineteen species which may be eliminated because they are clearly endemic, or are found only in the highest strata, only one of the latter suggesting an Indo-Pacific origin. This leaves only six species to be still accounted for. One of these is the widespread *Notothyris nucleolus,* which is probably also endemic in the Russian region. Another is *Spirifer fasciger,* No. 9, which is apparently a derivative from the typical boreal *Spirifer cameratus,* and which, moreover, is often confused with *Spirifer moosakhailensis,* so that statements of the occurrence of this form are not always reliable. Eliminating these two, there remain only the following four species which begin some distance down in the Donetzian and make their first appearance in the Schwagerina, or in one case, No. 14, in the Cora horizon. These are No. 1, *Dielasma plica;* No. 4, *Camarophoria superstes;* No. 8, *Spirifer rectangulus,* and No. 14, *Chonetes uralica.* This is only 7 per cent. of the recorded

[1] As Chao has pointed out, the Permian shells commonly identified as *Reticularia* belong to the genus *Squamularia.*

brachiopod fauna of the Donetzian series. Only one of these, No. 4, *Camarophoria superstes*, is also reported from the Middle and Upper Productus limestone, and this might therefore be considered an Indo-Pacific type, while the others may be endemic in the Russian or the boreal basin. But, unfortunately, the species in question occurs far down, indeed in the very basal bed only of the Donetzian, and can therefore scarcely be considered as originating in the far distant Indo-Pacific region. The explanation probably is to be found in the fact that the determination is very loosely made, that the Donetzian and Uralian specimens are not conspecific and that neither is probably the form found in the Salt Range. Indeed the latter is quite evident on comparing the figures given by Tschernyschew with those given by Waagen.

If we now consider those of the twenty-two species given on Table VIII, which occur also in the Salt Range, we may at once eliminate those which we have already discussed in connection with their occurrence in the Urals, namely, Nos. 4, 10, 12, 13 and 19. That leaves only three species: No. 5, *Camarophoria pinguis;* No. 20, *Productus abichi*, and No. 11, *Enteletes carnicus*. The last of these occurs only in the Lower Productus limestone, but is a well represented species in the deposits of the Tethys sea of Europe, where it was described from the Auernigg beds.

In the Donetz Basin, *Enteletes carnicus* appears to be restricted to the upper half of the upper division, that is, beds 9, 3, and 1. Although this may be a derivative from a Middle Carboniferous or early Upper Carboniferous species, and so belong to the group of endemic types, it may also be an early invader from the Indian Ocean into the Tethys and thence into the Russian Basin. Of the other two, which are characteristic of the Middle and Upper Productus limestone of the Salt Range, the first, *Camarophoria pinguis*, occurs far down in the Donetzian, that is, Horizon 36. And here again we may perhaps be entitled to reasonable doubt as to the correctness of the identification of the early Donetzian species with Waagen's Salt Range type. As to the other, *Productus abichi*, it need merely be said that this species is found only in the highest horizon of the Donetzian, that is, Horizon No. 1.

So far, then, as the relation of the Schwagerina limestone fauna of the Urals, and the Upper and Middle Productus limestone faunas, to those of the Donetzian is concerned, we may conclude from the evidence now at hand that it is exceedingly meagre, if not entirely problematical.

We need, therefore, have no hesitancy in declaring that there is no valid evidence for the correlation of the Schwagerina limestone with the whole or even a part of the Donetzian. The latter, from its stratigraphic superposition on, and intimate faunal relation to, typical Moscovian beds, must therefore represent the Upper Carboniferous, whereas the typical Uralian must be considered a younger horizon, the Donetzian interval being represented in the Ural region by great gaps, which is indeed indicated structurally by the evident disconformities below, and to a lesser degree above, the *Omphalotrochus* and *Spirifer marcoui* beds. The last one of these alone may possibly represent a stratigraphic equivalent to the later Donetzian, though it is not impossible that even it represents a post-Donetzian horizon.

Of the fifty-eight species of brachiopods listed in Table VII, fifteen appear to be restricted to the Donetz Basin. These are marked by an asterisk (*). Five of these are continued from lower horizons; the others are probably boreal types.

Taking the total fauna as listed, we have seventy-five species divided into: seven Foraminifera, fifty-eight brachiopods, four pelecypods, five gastropods and one trilobite. Of these, two Foraminifera, seventeen brachiopods, three pelecypods, four gastropods and the one trilobite, or twenty-seven species in all, also occur in the Carboniferous of North America. In other words, 36 per cent. of the Donetzian fauna occurs in the Carboniferous of North America.

THE BAKHMOUT SERIES OF THE DONETZ BASIN

(BACHMUTIAN OR BAKHMOUTIAN)

This includes the highest of the Palæozoic strata of the Donetz Basin, and as we have seen, is found in the western part, that is, the subordinate Bakhmout Basin. This series is divisible into the Lower or SUB-BAKHMOUT limestone, shale and sandstone series, with marine fossils and plant remains, and an upper or BAKHMOUT DOLOMITE series, with marine fossils, followed in turn by a red-bed continental series. The latter has often been referred to the Tartarian, but there is no evidence that it belongs there, as it may be the continental equivalent of the Kama or even the Kungurian if not Artinskian division of the Ural region, for it is quite within the range of possibility that continental sedimentation began earlier in the southern part of the Russian Basin than in the northern.

The lower division rests apparently with conformity on the Upper Carboniferous (Donetzian), but there may be a break between this lower series and the Bakhmout dolomite, in which case the lower division should receive a distinctive name. Until a better one is proposed we will designate them SUB-BAKHMOUT SERIES. A break in continuity of deposition is indicated by the continental Red Beds, which separate the two series.

THE LOWER OR SUB-BAKHMOUT SERIES

Tschernyschew and Loutouguin have listed a fauna of thirty-eight species from this division distributed through five beds. These are listed in Table IX. It consists of fourteen brachiopods, thirteen pelecypods, nine gastropods, and two foraminiferans. Of these, seven brachiopods, eight pelecypods, and six gastropods, or twenty-one in all, are American Carboniferous species, eleven ranging into the Permian and one of these occurring in the Lower Carboniferous or Mississippian. This makes a total of over 55 per cent. of the listed fauna.

Of the other seventeen, seven are brachiopods, three of which, *Enteletes carnicus*, *Spirifer supramosquensis* and *Notothyris nucleolus*, have come up from the Upper Carboniferous fauna. A fourth, *Dielasma hastata*, occurs in the Lower Carboniferous of Europe and Asia. The others with their distribution elsewhere are as follows:

	Zechstein (Lower)	Omphalotrochus beds	Cora beds	Schwagerina bed	Artinskian-Kungurian bed	Kama bed	Lower Productus bed	Middle Productus bed	Upper Productus bed
No. 12 *Productus cancriniformis*	......	......	......	×	×	......	......	×	......
No. 23 *Martinia clannyana*	×	......	......	......	×	×	......	......	......
No. 32 *Dielasma elongata*	×	......	......	×	×	×	......	×	......

So far as No. 12 is concerned, it seems to be a new introduction into this fauna, and since it occurs in the Middle Productus limestone, as well as in the Schwagerina limestone, it may be regarded as a Permian element introduced from the Indo-Pacific region. No. 23 is a Zechstein form and unknown in either the Productus or the Schwagerina limestones, but occurs in the higher Permian of Russia. *Dielasma elongata*, on the other hand, is a form difficult to evaluate, because of its wide distribution in Permian strata, occurring not only in the beds above indicated, but in the Upper Darvas beds and on Timor as well, and is furthermore represented by a variety in the Jisu Honguer limestone. If all the shells thus identified with Schlotheim's *Terebratula elongata* from the German Zechstein are identical with that species, which is by no means certain, it must probably be regarded as an Indo-Pacific type which has made its ultimate way into the Zechstein sea of north Europe, where it continued through the Lower and Middle Divisions. So far as the brachiopods listed, then, are concerned, the three species given above constitute the sole Permian element of this fauna. The others are boreal types continuing from the Upper Carboniferous. Of the three, one at least belongs to the boreal fauna, while two may be emigrants from the Indo-Pacific basin.

Taking next the pelecypods listed for this fauna, we have a total of twelve species, all of which are listed from horizon h, one of them continuing to horizon k.

Of these, eight, or 61.5 per cent., are also known from the Upper Carboniferous of North America, and these therefore may be considered boreal types. One of these, No. 16, *Nucula beyrichi*, is a typical Lower Zechstein species. Three others, not known from North America, namely: No. 30, *Allorisma elegans;* No. 11, *Bakewellia bicarinata*, and No. 27, *Edmondia murchisoni*, are typical Lower Zechstein species, and together with No. 16 constitute the Permian pelecypod element, which makes one-third, or 33.3 per cent., of this fauna. No. 19, *Cyrtodontarca bakewellioides*, is restricted to this basin. This leaves only one to be accounted for, namely, No. 4, *Pseudomonotis kazanensis*, first described from the Kungurian of Russia, and also found in the Upper Productus limestone of the Salt Range and in the Jisu Honguer limestone. It is true that the Donetz shell is only doubtfully identified, but should the determination be proved correct, this may be regarded as another Permian element, though whether of Indo-Pacific or of boreal origin would be difficult to determine at present. Thus the pelecypods, with one possible exception (No. 4), are all boreal elements of the fauna, being partly hold-overs from the Upper Carboniferous and partly new Permian elements.

The Gastropods, so far as determined, are represented by nine species, six of which are found in horizon h, and three in horizon k. Of these, six are found in the Upper Carboniferous of North America and therefore represent boreal types. The others are: No. 1, *Bellerophon pachtussovi* Tschernyschew, and No. 26, *Palyphemopsis* (*Bulimorpha*) *dimorpha* Krotow, both of them Russian forms whose distribution at present is only partly known, but which may represent Permian elements; and No. 2, *Bucania decussata* Fleming, a European Coal Measure species. Thus, so far as we have the facts, the gastropod element, too, seems to be of boreal type.

Finally, the two foraminiferans found in this fauna, namely, *Fusulina verneuili* and *Fusulina longissima*, both occur in the Donetzian, and are likewise known, the first from the Cora and Schwagerina, the second from the Schwagerina and Lower Productus limestone. They therefore represent Upper Carboniferous forms which continue into the Permian as here understood. Taking, then, the fauna as a whole, we find that, of the thirty-eight species, twenty-one, or 55 per cent., also occur in the North American Carboniferous. One of the pelecypods also occurs in the Zechstein. In addition to this, five others, or six in all, that is, about 15.8 per cent., occur in the Zechstein, namely, two brachiopods and three (all together four) pelecypods. Four of the seven brachiopods which pass up from the lower beds do not occur in North America, and the two foraminifera and one of the gastropods also pass up. Thus thirty-three out of the thirty-eight species, or about 86.8 per cent., are boreal types, or types derived from the lower horizons. Of the remaining five species, four, that is, two pelecypods (Nos. 4 and 19) and two gastropods (Nos. 1 and 26), appear to be endemic, while the fifth, a brachiopod (*Productus cancriniformis*), is probably a Pacific type, which may also be the case with one of the Zechstein brachiopods (No. 32), and one of the pelecypods referred to as endemic (No. 4).

Not only, then, is this fauna, as we now know it, not inherently related to that of the Schwagerina limestone, having, in common with that formation, only two species not known from older horizons, but it has no relationship, or only the most meagre, with the Indo-Pacific fauna. Four of the six species that it has in common with the Schwagerina limestone (two brachiopods and two Foraminifera) are contributions to the Schwagerina fauna from within, that is, species which have held over from an earlier horizon. This may also be true of the species referred to above as of Indo-Pacific origin. The proper interpretation of these beds seems to be that they are early Permian with a Permo-Carboniferous character or fauna, that is, a fauna composed of residual Carboniferous and of new Permian forms. It is possible that these beds may be the equivalent of the Omphalotrochus beds, or they may occupy a position below these beds. Finally it may be added that of the twelve plants listed from the different beds of this series, six, or 50 per cent., occur in the underlying Upper Carboniferous beds of this region.

THE BAKHMOUT DOLOMITE

As has been stated previously, this series is separated from the underlying one by red and green sandstones with masses of concentrated iron oxide, and by red and variegated clay shales. These beds mark apparently a period of exposure, with possibly a formation of bog-iron-ore. The duration of this period is not determinable, but it was apparently longer than the periods of coal formation, which interrupted the deposition of the earlier series, since in their case there was little or no change in the character of the marine fauna. Such a change in fauna is, however, very marked between the lower beds and the Bakhmout dolomites, since of eighty-one species described for this fauna by Yakowlew, or recorded in addition by Tschernyschew and Loutouguin, only ten, or about 12.4 per cent., occur in the preceding series, though at least another six are also found in Carboniferous beds. Twenty of the eighty-one species, or about 24.6 per cent., also occur in the higher beds of North America, that is, beds generally referred to the Upper Carboniferous or the Permian of the Cordilleran geosyncline or the interior of the North American region.

At present, comparison with the other European or Asiatic beds is possible only in the case of the brachiopods, since full descriptions of the pelecypods or gastropods of even the Schwagerina or Cora beds are not as yet available.

Eleven of the twenty-one species of brachiopods, or nearly 50 per cent., are found in the Schwagerina horizon, though only four are restricted to it. Five begin in the Omphalotrochus beds, two of these not occurring above the

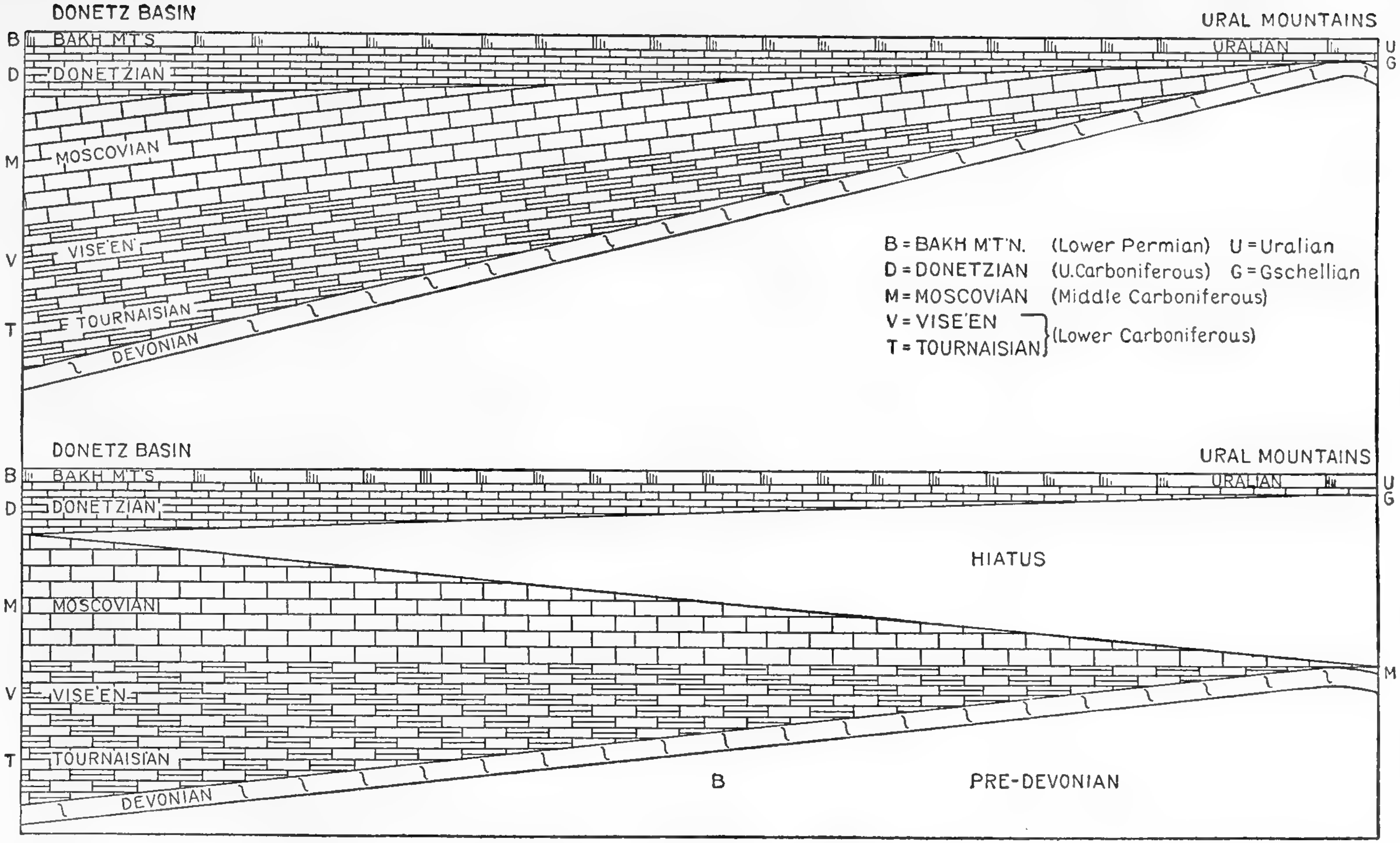


FIGURE 68.—Diagram showing the overlap relationship of the Lower, Middle and Upper Carboniferous and the Lower Permian between the Donetz Basin of South Russia and the Ural Mountains district (original). A.—The strata in their relationship before disturbance and erosion. B.—The same in horizontal position, showing magnitude of hiatus.

Schwagerina horizon, while three also occur in the Artinskian-Kungurian horizon. Six species begin with the Schwagerina horizon, four of them being restricted to this horizon, while the other two also occur in the Artinskian-Kungurian and one of them continues to the Kama beds. Finally, two species are recorded only from the Artinskian-Kungurian, one from Artinskian-Kama, and one only from the Omphalotrochus and Cora horizons. Thus, there are fourteen species in common between the Bakhmout dolomite on the one hand and the Schwagerina or higher beds on the other, but of these, eight are known either in the preceding horizon or in lower beds. That leaves only six of the twenty-one species, or about 28.6 per cent., as characteristic of the Bakhmout and the Schwagerina or higher beds of the Ural region. To this, however, should be added the abundant development of *Schwagerina princeps*, a species not known below the Bakhmout dolomite in the Donetz region or the Schwagerina limestone in the Ural region. This foraminiferan is literally rock-making in both these regions, and although not known in the Productus limestone of the Salt Range or the Himalayan section, or at Darvas, it is abundant in the Permian beds of China, Indo-China and in Manchuria and other parts of the eastern end of the Mongolian geosyncline, though it appears to be entirely wanting in the Jisu Honguer limestones.

Yakowlew correlates the Bakhmout dolomite with the Artinskian and possibly the Kungurian, referring them to the Permo-Carboniferous of the older classification. This is the term that has commonly been applied to the Artinskian, and by Tschernyschew and others to the Upper Productus limestone of the Salt Range. This was justifiable, so long as the Uralian was considered to be Upper Carboniferous, for many of the Uralian species continue, as we have seen, into these higher horizons. When, however, we take as our standard of the Upper Carboniferous the Donetzian of southern Russia, it becomes apparent that the Schwagerina limestone is a younger formation, and since it marks the invasion of the Indo-Pacific Permian elements, we are, it seems to me, constrained to place these Uralian beds in the lower part of the Permian system. This, then, clears away any stratigraphic objection to the correlation of the Bakhmout dolomite with the Schwagerina horizon, a correlation indicated by palæontology, for in both formations we find the indications of the advent of the Indo-Pacific fauna, none the least of the elements of which is *Schwagerina princeps*. This foraminiferan, then, must be regarded as indicating a Lower Permian horizon, and its center of origin is probably to be sought in the Pacific waters of the period.

TABLE IX. PARTIAL LIST OF THE FAUNA OF THE BAKHMOUT SERIES WITH DISTRIBUTION ELSEWHERE

			Western Europe		Donetz Basin			Bakhmout Basin: Sub-Bakhmout Stages						Bakhmout Basin: Bakhmout Dolomite Stages					Ural-Timan					Salt Range			Darvas		Germany			North Russia		North America				Eastern Alps				
			Lower Carboniferous	Middle Carboniferous	Lower Carboniferous	Middle Carboniferous	Upper Carboniferous	Total	b	d	f	h	k	Total	l	m	u	Lower Permian, Central Russia	Omphalotrochus	Cora	Schwagerina	Artinskian-Kungurian	Kama	Lower Productus	Middle Productus	Upper Productus	Safeddaron	Obirawnou	Lower Zechstein	Middle Zechstein	Upper Zechstein	Lower Kostroma	Upper Kostroma	Mississippian	Carboniferous	Permian	Sosio-Sicily	Auernigg	Trogkofel	Bellerophon	Djulfa	
		PROTOZOA:																																								
(1)	1	*Fusulina verneuili* Moeller					×	×			×									×	×																					1
(2)	2	*F. longissima* Moeller					×	×			×										×			×																		2
(3)	3	*Schwagerina princeps* Ehrenberg												×		×					×																					3
		TOTAL						2						1																												
		ANTHOZOA:																																								
(4)	1	*Lophophyllum proliferum* McChesney												×		×																			×	×						1
(5)	2	*Michelinia abichi* Waagen and Wentzel												×											×																×	2
(6)	3	*M. eugenæ* White												×																											×	3
		TOTAL						0						3																												
		BRACHIOPODA:																																								
(7)	1	*Orbiculoidea donetzensis* Yakowlew												×																												1
(8)	2	**Derbya crassa* Meek and Hayden						×				×	×						×	×															×	×						2
(9)	3	*Meekella eximia* Eichwald (=*M. striatocostata* Cox)					×							×	×	×	×		×	×															×	×						3
(10)	4	*Chonetes carbonifera* Keyserling												×	×	×	×	×																								4
(11)	5	*Productus leplayi* Verneuil												×		×													×													5
(12)	6	**P. inflatus* McChesney						×				×	×	×	×	×			×	×	×	×													×							6
(13)	7	*P. elegans* McCoy	×											×			×																									7
(14)	8	*P. punctatus* Martin	×	×										×					×	×	×														×	×						8
(15)	9	**P. konincki* Verneuil				×	×							×	×			×	×	×	×	×																				9
(16)	10	*P. pseudomedusa* Tschernyschew												×		×					×																					10

TABLE IX.
(Continued)

			Western Europe: Lower Carboniferous	Western Europe: Middle Carboniferous	Donetz Basin: Lower Carboniferous	Donetz Basin: Middle Carboniferous	Donetz Basin: Upper Carboniferous	Bakhmout Basin, Sub-Bakhmout Stages: Total	Sub-Bakhmout: b	Sub-Bakhmout: d	Sub-Bakhmout: f	Sub-Bakhmout: h	Sub-Bakhmout: k	Bakhmout Basin, Bakhmout Dolomite Stages: Total	Bakhmout Dolomite: l	Bakhmout Dolomite: m	Bakhmout Dolomite: u	Lower Permian, Central Russia	Ural-Timan: Omphalotrochus	Ural-Timan: Cora	Ural-Timan: Schwagerina	Ural-Timan: Artinskian-Kungurian	Ural-Timan: Kama	Salt Range: Lower Productus	Salt Range: Middle Productus	Salt Range: Upper Productus	Darvas: Safeddaron	Darvas: Obirawnou	Germany: Lower Zechstein	Germany: Middle Zechstein	Germany: Upper Zechstein	North Russia: Lower Kostroma	North Russia: Upper Kostroma	North America: Mississippian	North America: Carboniferous	North America: Permian	Sosio-Sicily	Eastern Alps: Auernigg	Eastern Alps: Trogkofel	Eastern Alps: Bellerophon	Djulfa	
		Brachiopoda: (Continued)																																								
(17)	11	*P. juresanensis* (= *P. mexicanus*) Tschernyschew												×		×			×	×	×																					11
(18)	12	**P. cancriniformis* Tschernyschew						×					×								×	×			×																	12
(19)	13	**P. semireticulatus* Martin	×		×	×	×	×	×	×														×										×	×	×						13
(20)	14	**P. nevadensis* Meek					×	×	×																										×							14
(21)	15	**P. nebrascensis* Owen						×		×		×	×						×																×	×						15
(22)	16	**P. cancrini* Verneuil																×				×	×						×			×										16
(23)	17	**Enteletes carnicus* Schellwien					×	×	×																		×												×			17
(24)	18	**E. hemiplicatus* Hall						×	×																										×	×						18
(25)	19	*Camarophoria semiplicata* Gemmellaro												×		×																					×					19
(26)	20	*Spiriferina fastigata* Schellwien												×		×																						×				20
(27)	21	*Ambocœlia planoconvexa* Shumard												×		×					×														×	×						21
(28)	22	**Spirifer supramosquensis* Nikitin					×	×	×										×	×																						22
(29)	23	**Martinia clannyana* King						×					×	×	×			×				×	×						×													23
(30)	24	*Reticularia lineata* Martin	×											×		×			×	×	×	×		×			×															24
(31)	25	**Athyris royssii* Léveillé			×		×	×				×												×	×	×								×								25
(32)	26	*Pugnax granum* Tschernyschew												×		×					×																					26
(33)	27	*Uncinulus timorensis* Beyrich												×		×						×			×	×																27
(34)	28	**Notothyris nucleolus* Kutorga					×	×	×					×		×					×	×																				28
(35)	29	*N. mediterranea* Gemmellaro												×								×			×												×	×	×	×		29
(36)	30	*Beecheria sublævis* Waagen												×							×			+	+																	30
(37)	31	**Dielasma hastata* Sowerby	×					×	×	×																																31
(38)	32	**D. elongata* Schlotheim						×					×	×	×			×			×	×	×		×			×	×	×												32
		TOTAL						14						21																												

		PELECYPODA:																																								
(39)	1	*Entolium aviculatum* Swallow												×																				×	×						1
(40)	2	*Streblopteria* cf. *sericea* Verneuil												×																											2
(41)	3	*Pseudomonotis* sp.												×																											3
(42)	4	*P.* cf. *kazanensis* Verneuil						×				×	×	×	×							×	×			×															4
(43)	5	*P. garforthensis*												×	×								×																		5
(44)	6	*Aviculopecten carboniferous* Stevenson												×																				×							6
(45)	7	*Lima krotowi* Stuckenberg												×																											7
(46)	8	**Lima retifera* Shumard						×				×																						×							8
(47)	9	**Bakewellia cerathophaga* Schlotheim												×	×													×	×												9
(48)	10	*B. nikitowkensis* Yakowlew												×																											10
(49)	11	**B. bicarinata* King						×				×																	×												11
(50)	12	**Myalina swallowi* McChesney						×				×		×	×																			×	×						12
(51)	13	**Modiolopsis* cf. *teplofi* Verneuil												×	×								×																		13
(52)	14	*Nuculana* cf. *bellistriata* Stevens												×																				×	×						14
(53)	15	**N. bellistriata* var. *attenuata* Meek						×				×																						×	×						15
(54)	16	**Nucula beyrichi* v. Schauroth						×				×																	×						×	?						16
(55)	17	*Macrodon* aff. *striatum* Schlotheim												×																											17
(56)	18	*M. naliwkini* Yakowlew												×																											18
(57)	19	*Crytodontarca bakewellioides* Yakowlew						×				×		×																											19
(58)	20	*Schizodus wheeleri* Swallow						×				×		×	×												×							×	×						20
(59)	21	*S. rossicus* Verneuil												×																											21
(60)	22	*Pleurophorus subcuneatus* Meek and Hayden												×																					×						22
(61)	23	*P. oblongus* Meek and Hayden												×																				×	×						23
(62)	24	**P. subcostatus* Meek and Hayden						×				×																						×	×						24
(63)	25	*Astarte permocarbonica* Tschernyschew var. *adentiula* Yakowlew												×	×																										25
(64)	26	*Edmondia nebrascensis* Geinitz												×																				×	×						26
(65)	27	**E.* aff. *murchisoni* King (=*E. elongata* House)						×				×																	×	×											27
(66)	28	**Clinopristha radiata* Hall						×				×																×							×	×						28
(67)	29	**Monopteria longa* Geinitz						×				×																						×	×						29
(68)	30	**Allorisma elegans?* King						×				×		×									×						×							+						30
		TOTAL				13								22																											
		GASTROPODA:																																								
(69)	1	**Bellerophon pachtussovi* Tschernyschew						×					×																												1
(70)	2	**Bucania decussata* Fleming		×				×					×																												2

TABLE IX.
(*Continued*)

			Western Europe: Lower Carboniferous	Western Europe: Middle Carboniferous	Donetz Basin: Lower Carboniferous	Donetz Basin: Middle Carboniferous	Donetz Basin: Upper Carboniferous	Bakhmout Basin, Sub-Bakhmout Stages: Total	Bakhmout Basin, Sub-Bakhmout Stages: b	Bakhmout Basin, Sub-Bakhmout Stages: d	Bakhmout Basin, Sub-Bakhmout Stages: f	Bakhmout Basin, Sub-Bakhmout Stages: h	Bakhmout Basin, Sub-Bakhmout Stages: k	Bakhmout Basin, Bakhmout Dolomite Stages: Total	Bakhmout Basin, Bakhmout Dolomite Stages: l	Bakhmout Basin, Bakhmout Dolomite Stages: m	Bakhmout Basin, Bakhmout Dolomite Stages: u	Lower Permian, Central Russia	Ural-Timan: Omphalotrochus	Ural-Timan: Cora	Ural-Timan: Schwagerina	Ural-Timan: Artinskian-Kungurian	Ural-Timan: Kama	Salt Range: Lower Productus	Salt Range: Middle Productus	Salt Range: Upper Productus	Darvas: Safeddaron	Darvas: Obirawnou	Germany: Lower Zechstein	Germany: Middle Zechstein	Germany: Upper Zechstein	North Russia: Lower Kostroma	North Russia: Upper Kostroma	North America: Mississippian	North America: Carboniferous	North America: Permian	Sosio-Sicily	Eastern Alps: Auernigg	Eastern Alps: Trogkofel	Eastern Alps: Bellerophon	Djulfa	
		GASTROPODA: (Continued)																																								
(71)	3	*B. makatikhæ* Yakowlew												×																												3
(72)	4	*Euphemus* aff. *nodocarinatus* Hall												×																					×							4
(73)	5	*Wortheniopsis kyschertianæformis* Yakowlew												×				×																								5
(74)	6	*W. burtasorum* Golowkinski												×																												6
(75)	7	*W. denjatinensis* Yakowlew												×				×																								7
(76)	8	*Pleurotomaria (Rhaphistomella) subdecussata* Geinitz												×				×																	×	×						8
(77)	9	**P. dimorpha* Krotow												×	×																											9
(78)	10	*Rhineoderma nikitowkensis* Yakowlew												×																												10
(79)	11	*Murchisonia golowkinskii* Yakowlew												×																												11
(80)	12	*M. (Glyphodeta) permiana* Yakowlew												×																												12
(81)	13	**M. subangulata* Verneuil												×	×			×												×												13
(82)	14	*Straparollus luturguini* Yakowlew												×																												14
(83)	15	*Sosiolites (?) vassilievkensis* Yakowlew												×																												15
(84)	16	**Trachydomia wheeleri* Swallow					×							×	×																				×							16
(85)	17	*Naticopsis tschernyschewi* Yakowlew												×																												17
(86)	18	**N. (Strophostylus)* cf. *nana* Meek and Worthen						×				×		×	×																				×	×						18
(87)	19	*Loxonema peonense* Worthen												×																					×							19
(88)	20	*L.* aff. *quadricarinatum* Worthen												×				×																	×							20
(89)	21	**L. multicostata* Meek and Worthen						×				×																							×							21
(90)	22	**Aclisina robusta* Stevens						×				×																							×							22

(91)	23	**Orthonema salteri* Meek and Worthen						X				X																							X							23
(92)	24	*Zygopleura bakhmouthinensis* Yakowlew												X																												24
(93)	25	*Macrocheilina intercalaris* Meek and Worthen												X																					X	X						25
(94)	26	**M.* (*Sphærodoma*) *medialis* Meek and Worthen						X					X																						X							26
(95)	27	**Polyphemopsis* (*Bulimorpha*) *dimorpha* Krotow						X				X																														27
(96)	28	**P.* aff. *inornata* Meek and Hayden						X				X																							X							28
(97)	29	*Tuberculopleura anomala* Yakowlew												X				X																								29
(98)	30	*Promathilda biseriatuberculata* Yakowlew												X																												30
(99)	31	*P. barroisi* Yakowlew												X				X																								31
(100)	32	*Turbonellina nowosselowkensis* Yakowlew												X																												32
(101)	33	*Portlockia kamenkinsis* Yakowlew												X																												33
		TOTAL						9						25																												
		CEPHALOPODA:																																								
(102)	1	*Metacoceras tschernyscheffi* Twetchachew												X	X																											1
(103)	2	*M. variabilis* Yakowlew												X																												2
(104)	3	*M. trigonotuberculatus* Yakowlew												X																												3
(105)	4	*Temnocheilus pernodosus* Tschernyschew												X																												4
(106)	5	*T. grewingki* Tschernyschew												X																												5
(107)	6	*T.* aff. *crassus* Hyatt												X																												6
(108)	7	*Asymtoceras korulkensis* Yakowlew												X																												7
(109)	8	*Discites nikitowkensis* Yakowlew												X																												8
(110)	9	*Orthoceras kodinæ* Yakowlew												X																												9
		TOTAL						0						9																												
		GRAND TOTAL						38						81																												

*Listed by Tschernyschew and Loutouguin.
× = identical species.
\+ = related species.

Before discussing this problem further we will note the characters of the highest Permian beds of the Bakhmout basin.

THE HIGHER CONTINENTAL PERMIAN BEDS OF THE DONETZ BASIN

The Dekonskaia formation.—The Bakhmout dolomite of the Donetz basin is concordantly followed by a great thickness of red beds which have commonly been referred to the Tartarian, but which, in view of the new correlation here presented, are probably to be regarded as the continental equivalents of the Artinskian and succeeding beds of the Ural region. They comprise, in general, red and green clays and marls, and friable sandstones underlying gypsum, anhydrite, and rock salt. The rock salt is exploited near the town of Dekonskaia, which name might perhaps be applied provisionally to this entire continental formation. Drilling has revealed the following succession in this region:

		Thickness	
		Feet	Inches
1	Surface soil	2	0
2	Yellow argillaceous sand	3	6
3	Loose sand	21	0
4	Clay	6	6
5	Gypsum	1	6
6	Red clay	8	6
7	Calcareous sandstone	24	0
8	Gypsum with intercalated clay	27	8
9	Anhydrite	2	10
10	Gypsum and clay	22	0
11	Brown gypsiferous clay	1	9
12	Gypsum	7	3
13	Anhydrite	43	0
14	Variegated clay	12	6
15	Gypsiferous marl	2	0
16	Rose gypsum	0	4
17	Marls with interstratified anhydrite	4	2
18	Anhydrite	9	5
19	Brown saliferous clay	11	6
20	Marly clay, with layers of dolomite and anhydrite	14	5

		Thickness	
		FEET	INCHES
21	Saliferous anhydrite	16	8
22	Brown saliferous clay	11	3
23	Rock Salt	4	7
24	Brick clay, with layers of gypsum	18	4
25	Anhydrite	21	4
26	Rock salt interstratified with gypsum	23	0
27	Granular rock salt	117	2
28	Smoke-colored gypsiferous clay	4	8
29	Bluish saliferous anhydrite	34	4
30	Dolomite	33	2
31	Rock salt	17	6
32	Dolomite	9	11
33	Rock salt with clay	6	0
34	Dolomite	13	2
35	Rock salt	50	5
36	Dolomite	7	5
37	Rock salt	17	1
38	Dolomite	11	1
39	Rock salt	32	0
40	Dolomite	6	3
41	Rock salt	37	5
42	Dolomite	5	2
43	Rock salt, to bottom of boring	55	6
	Total, beds 5 to 43	736	3

These beds are known only in the western part of the Donetz Basin, that is, the subordinate Bakhmout Basin, and they have been disturbed, with the other Palæozoic strata of this region. They are unconformably succeeded by strata of Jurassic age. It is evident that this constituted a region of lagoons, such as we find in the Kungurian of the Ural border, with which they are approximately synchronous, and similar to those which occurred in a later epoch in the Archangel region of northern Russia. Such deposits, occurring in widely distant regions, are not necessarily synchronous; they represent a gradual disappearance of the sea from the region, which may be contemporaneous with a transgression in other regions at various periods.

CHAPTER XIV

THE EASTWARD EXTENSION OF THE SCHWAGERINA BEDS

INTRODUCTION

Since the Schwagerina limestone marks essentially the first great invasion of the new fauna, it becomes necessary to trace the pathway along which this invasion and the migration of the fauna proceeded. Since *Schwagerina* itself is absent from the Himalayan geosyncline, as well as from the Mongolian geosyncline, it is evident that neither could represent the pathway of migration. These deposits are, however, found in the Nanshan geosyncline in the region of Lake Kukunor, and in the western extension of that geosyncline in the Tianshan Mountains. They are again to be found in southern China and in Indo-China, and these occurrences are sufficient to determine the general route of the migration of the faunas, which will no doubt be found in the future at many intermediate points. In this chapter we shall discuss the localities which have been investigated in the regions mentioned.

THE NANSHAN GEOSYNCLINE

Tian-Shan: The presence of the Schwagerina beds in regions intermediate between the Chinese basin and the eastern end of the Mongolian geosyncline, on the one hand, and the Ural-Timan region on the other, is demonstrated by the sections in the Central Tian-Shan. Thus, in the upper valley of the Kukurtuk, northwest of Utsch-turfan (approximately Long. 78° 59′ E., Lat. 41° 28′ N.), the Lower Carboniferous limestone is followed disconformably by strata with the typical fauna of the Schwagerina limestone. These beds have also been found in a number of other localities in this region, and frequently they are separated from the underlying Lower Carboniferous limestone by clastic beds, including a conglomerate which contains rolled fragments of the corals from the lower horizon.[1]

The higher limestones of this overlying series are especially characterized

[1] Norin has recently discovered at some places in the Tian-Shan a distinct glacial tillite between the Lower Carboniferous beds and the Schwagerina limestones of this region, which clearly corroborates the conclusions drawn from other evidence, that the late Palæozoic glaciation of Asia fell in Upper Carboniferous time. A preliminary note of this discovery will appear in the Bulletin of the Geological Society of China.

by *Schwagerina princeps* which occurs in great abundance. Associated with it, and extending throughout the series, is a rich fauna, of which the following forty-two species have been described by Keidel. In this list an asterisk (*) indicates that the species is also known from the Schwagerina limestone of Russia, while the following notations are used for its occurrence in other horizons: p. 1, p. 2, p. 3 signify Lower, Upper and Middle Productus limestone respectively; *a* signifies Artinskian and Kungurian; *b* signifies Bakhmout dolomite; *s* signifies the Samara beds or their equivalent.

FAUNA OF THE KUKURTUK LIMESTONE OF THE TIAN-SHAN

FORAMINIFERA:

1, **Schwagerina princeps* Ehrenberg.

BRACHIOPODA:

1, **Notothyris nucleolus* Kutorga (p. 2); 2, **Productus* cf. *grünewaldti* Krotow; 3, **Productus uralicus* Tschernyschew (p. 1); 4, **Productus inflatus* McChesney; 5, *Productus gratiosus* Waagen (p. 2–3); 6, *Productus subcostatus* Waagen (p. 2–3); 7, *Productus aculeatus* Martin; 8, **Productus curvirostris* Schellwien; 9, **Productus pustulatus* Keyserling; 10, **Productus cora* d'Orbigny; 11, **Productus lineatus* Waagen (p. 1–3); 12, **Productus simensis* Tschernyschew (p. 2); 13, **Productus tenuistriatus* Verneuil; 14, **Productus cancriniformis* Tschernyschew (p. 2); 15, **Productus mammatus* Keyserling; 16, **Productus punctatus* Martin; 17, **Productus fasciatus* Kutorga; 18, *Productus elegans* McCoy; 19, **Proboscidella* cf. *lata* Tschernyschew; 20, *Marginifera pusilla* Schellwien; 21, **Marginifera typica* Waagen var. *septentrionalis* Tschernyschew (p. 2–3); 22, **Marginifera involuta* Tschernyschew; 23, **Marginifera clarkei* Tschernyschew; 24, **Rhypidomella pecosi* Marcou (p. 1); 25, *Schizophoria resupinata* Martin; 26, **Schizophoria supracarbonica* Tschernyschew; 27, **Orthotichia* cf. *morganiana* Derby; 28, *Enteletes kayseri* Waagen (p. 2); 29, *Enteletes tschernyscheffi* Diener (Him.); 30, *Enteletes hemiplicata* Hall; 31, *Enteletes œhlerti* Gemmellaro; 32, *Enteletes merzbacheri* Keidel; 33, **Spiriferina cristata* Schlotheim (p. 1–3); 34, **Spirifer* cf. *fasciger* Keyserling (p. 1–3); 35, **Spirifer lyra* Kutorga; 36, **Spirifer tibetanus* Diener (p. 2); 37, **Spirifer supramosquensis* Nikitin; 38, *Martinia glabra* Martin (p. 1–3); 39, **Martinia corculum* Kutorga; 40, **Reticularia lineata* Martin (= ? *Squamularia asiatica* Chao) (p. 1); 41, *Reticularia* cf. *dieneri* Gemmellaro; 42, **Reticularia rostrata* Kutorga.

Analysis of this fauna shows that twenty-eight of the brachiopods also occur in the Schwagerina limestone. This, with *Schwagerina princeps*, makes twenty-nine species out of a total of forty-three, or nearly 70 per cent. Five other species occur in the Productus limestone, all but one of them in the

Middle or Upper Productus limestone. Of the twenty-nine species also occurring in the Schwagerina bed, ten also occur in the Productus limestone, all but three of these occurring above the Lower Productus limestone. Thus, there is a total of fifteen species, or nearly 35 per cent., of the Tian-Shan fauna, which is also found in the Productus limestone. The total number found in the Middle and Upper Productus limestone is eleven, or 25.6 per cent. of the fauna. Two species were originally described by Gemmellaro from Sicily, and one, *Enteletes merzbacheri*, is restricted to these beds. Six species occur in the lower horizons (Upper Carboniferous, etc.), these including *Spirifer supramosquensis*.

It is thus evident that the Kukurtuk limestone of the Tian-Shan is equivalent to the Schwagerina limestone of eastern Russia and the Bakhmout dolomite of southern Russia, and essentially equivalent to the Middle Productus limestone of India and the Jisu Honguer limestone of Mongolia. These two, however, were deposited under conditions which either were unfavorable to the existence of the *Schwagerina*, or at any rate prevented their entrance into the same region. It may also be that the *Schwagerina princeps* beds are slightly older, but this would not explain the absence of other *Schwagerina* in these limestones, for, as we shall see, in the Pacific border regions there are a number of horizons marked by different species of *Schwagerina*. Hence the Pacific region was characterized throughout Permian time by the existence of these Foraminifera.

Kukunor:—Coming farther east, we find the Schwagerina limestones again well developed in Kukunor. In this region, especially in the Semenow Mountains, we find the following succession in descending order.

3. Pale red and gray limestones, the latter with occasional *Doliolina*.
2. White oölitic limestone without fossils.
1. Massive gray limestone, with *Neoschwagerina craticulifera*, *Verbeekima verbeeki*, and *Schwagerina princeps*, and with *Fusulina* and *Fusulinella*.

These *Doliolina* beds are concordantly succeeded by Lower Triassic strata, from which they are, however, separated by a hiatus, which cuts out some of the later Permian beds.

On the southern slope of the Semenow Mountains occurs a gray limestone with *Pinna* sp., *Camarophoria* sp., *Richthofenia* sp., *Spiriferina* cf. *subcristata*, *Enteletes carnicus*, etc. This apparently represents the Lower Permian horizon.

These deposits were evidently formed in the Nanshan geosyncline which, as we shall see, formed the line of connection between the inner Asiatic and the Pacific border region. That this may have been closed in later Permian time, or at least partially so, is suggested by the character of the TALAPAI FORMATION of Kansu, which will be noted farther on.

The Schwagerina limestone is again found in Yunnan, in Indo-China, in the Malaysian Archipelago, Japan, Korea and Manchuria, while it is also known from many parts of China proper. These occurrences may now be discussed seriatim.

THE SOUTHERN CHINESE BASIN

Yunnan:—Here the succession of beds, referred by Frech to the Lower Permian, but by Deprat to the Upper Carboniferous, is as follows, according to the latter authority.[1]

UPPER PERMIAN:

e. Labradoritic rock (eruptive).
d. Gypsiferous sands and marls.
c. Heavy conglomerates.
b. Calcareous beds, with *Neoschwagerina multiseptata* Deprat.
a. Limestones, with *Neoschwagerina globosa* Yabe, *Sumatrina annæ* Volz, *Doliolina pseudolepida* Deprat, *Schwagerina douvillei* Deprat, *Fusulina exilis* Schwager, and *F. margheritii* Deprat.

MIDDLE PERMIAN:

b. Limestone, with *Schwagerina verbeeki* Geinitz (dominant). *Fusulina richthofeni* Schwager, *Fusulina mansuyi* Deprat, *Fusulina minima*, etc.
a. Beds with *Spirifer blasii* Verneuil, *Martiniopsis inflata* Waagen, *Athyris angulata* Mansuy, *Spiriferella grandis* Waagen, *Camarophoria globulina* Phillips, *Naticopsis piriformis* Mansuy (this is called Lower Permian by Deprat).

LOWER PERMIAN (Frech) (Upper Uralian, Deprat):

h. Zone of *Neoschwagerina multicircumvoluta* Deprat.
g. Zone of *Neoschwagerina craticulifera* (Schwager).
f. Zone of *Schwagerina princeps* (Ehrenberg).
e. Zone of *Fusulina incisa* Schellwien.
d. Zone of *Fusulina multiseptata* Schellwien and *Doliolina aliciæ* Deprat.
c. Zone of *Doliolina claudiæ* Deprat.
b. Zone of *Productus* cf. *compressus* Waagen.
a. Zone of *Fusulina kattænsis* Waagen.

UPPER CARBONIFEROUS:

b. Zone of *Fusulina tchengkiangensis* Deprat and *Fusulina regularis* Schellwien.

[1] This is subject to revision.

a. Zone of *Fusulina brevicula* Schwager and *Fusulina regularis* Schellwien.

Disconformity

Subformation: Middle or Lower Carboniferous

Western Yunnan:—At Talishao in western Yunnan (about Long. 99° 22′ E., Lat. 25° 15′ N.), the Ordovician limestones, etc., are followed by decomposed andesitic and diabasic lavas and tuffs, and by fossiliferous calcareous shales and limestones of Permian age. From these the following known species were identified by Cowper Reed, besides a number which are new: Anthozoa: *Michelinia yunnanensis* Reed; *Syringopora ?* sp.; *Plerophyllum* aff. *timorense* (Gerth); *Tachylasma* cf. *cha* Grabau; *Dibunophyllum* (*Verbeekiella*) aff. *australie* (Beyrich). Crinoidea: *Poteriocrinus* cf. *maschatensis* Romanowski; crinoid stems (*Poteriocrinus?*), 4 types. Bryozoa: *Fenestella assumpta* Reed; *F. elusa* Reed; *F.* sp.; *Rhombopora?* (2 species); *Thamniscus orientalis* Reed; *Cœlocaulis?* sp. Brachiopoda: *Derbya* cf. *grandis* Waagen; *Productus* cf. *hemisphærium* Kutorga; *P.* aff. *simensis* Tschernyschew; *Marginifera semigratiosa* Reed; *M. concrescens* Reed; *M.* cf. *clarkei* Tschernyschew; *Septoproductus abichi* (Waagen); *Productus* sp.; *Strophalosia proxima* Reed; *Aulosteges* aff. *poyangensis* Kayser; *Chonetes pseudovariolata* var. *yunnanensis* Reed; *C.? molengraaffi* Broili; *C.* cf. *geinitziana* Waagen; *C.* aff. *transitionis* Krotow; *C.* sp.; *Athyris* cf. *roissyana* Keyserling; *A.* sp.; *Composita derbyi* Waagen; *Spirifer fasciger* Keyserling; *S. peregrinus* Reed; *S. rajah* Salter var.; *S.* aff. *strangwaysi* de Verneuil; *S.* cf. *lydekkeri* Diener; *S.* aff. *musakheylensis* Davidson; *Martiniopsis talishaoensis* Reed; *M.* sp.; *Martinia* cf. *semiplana* Waagen; *Reticularia sublineata* Reed; *Notothyris* sp.; *Rhynchopora* cf. *nikitini* Tschernyschew; *R. emerita* Reed; *R.* aff. *wynnei* Waagen. Pelecypoda: *Aviculopecten m'coyi* Meek and Hayden var.; *A. hiemalis* Salter var. *alta* Reed; *A.?* aff. *katwahiensis* Waagen; *Streblopteria?* cf. *deprati* (Mansuy); *Palæolima scabrosa* Reed; *Modiola yunnanensis* Reed; *Parallelodon* cf. *subtilistriatus* Wanner; *P.* cf. *multistriatus* Girty; *Schizodus* sp. Gastropoda: *Euomphalus* sp.; *Bellerophon* sp.

Indo-China:—The Productus limestone of Tonking and Laos, in Indo-China, is also characterized by *Schwagerina princeps* at Houei-Poung, Upper Laos, and represents this Lower Permian horizon. Somewhat higher beds with *Lyttonia* have been found at Hongay, in Haiphang, and other beds carry the fauna of the Maping limestone of south China. In the Langson quadrangle of Tonking, the limestone with *Waagenella indica* (Waagen) is known, representing the horizon of the Middle Productus limestone of the Salt Range, and essentially our Jisu Honguer limestone. At Hoei-tumm-tac, in Upper Laos, beds with *Pseudomonotis garforthensis* King, represent late Middle or Upper Permian. Beds with the Middle Productus fauna, but without *Schwagerina*, are found in Cambodia, southern Indo-China. These, in addition to many new species, include: *Steinmannia gemina* Waagen and Wentzel, *Wentzelella salinaria* (Waagen and Wentzel), *Geinitzella crassa* Waagen and Wentzel, *Productus abichi* Waagen, *Productus boliviensis* d'Orbigny, *Productus inflatus* McChesney, *Productus gratiosus* Waagen, *Productus sumatrensis* Roemer, *Productus cora* d'Orbigny, *Strophalosia rarispina* Waagen, *Uncinulus timorensis* Beyer, *Squamularia indica* (Waagen), *Squamularia inæquilateralis* (Gemmellaro), *Schizophoria juresanensis* Tschernyschew, *Spirifer fritschi* Schellwien, *Spiriferina insculpta* Phillips, *Hustedia remota* Eichwald, *Athyris planosulcata* Phillips, *Notothyris warthi* Waagen mut. *cambodinensis* Mansuy, and *Lyttonia nobilis* Waagen.

Mansuy holds that the Productus limestone of Tonking and Laos shows closer affinity with the Uralo-Permian beds of the Ural Mountains than with those of the Himalayas or the Salt Range. Brachiopods predominate in the fauna, comprising one hundred fifteen species out of a total of one hundred thirty-five forms described. Of these, some 65 per cent. are related to, or identical with, late Uralian species of Russia. While several horizons seem to be represented, the greater portion of the series belongs to the zone of *Schwagerina princeps*. The following is a partial list of the species of these beds, those described as new and doubtfully identified being omitted (Mansuy, 1919, pp. 95–97). BRACHIOPODA: 1, *Productus uralicus* Tschernyschew; 2, *Productus boliviensis* d'Orbigny; 3, *Productus grünewaldti* Krotow; 4, *Productus transversalis* Tschernyschew; 5, *Productus inflatus* McChesney; 6, *Productus pustulosus* Phillips; 7, *Productus elegans* McCoy; 8, *Productus tartaricus* Tschernyschew; 9, *Productus gratiosus* Waagen; 10, *Productus tuberculatus* Moeller; 11, *Productus curvirostris* Schellwien; 12, *Productus pustulatus* Keyserling; 13, *Productus juresanensis* Tschernyschew; 14, *Productus tenuistriatus* Verneuil; 15, *Productus konincki* Verneuil; 16, *Productus cancriniformis* Tschernyschew; 17, *Productus tschernyschewi* Netschejew; 18, *Productus pseudomedusa* Tschernyschew; 19, *Productus jakowlewi* Tschernyschew; 20, *Productus cora* d'Orbigny; 21, *Productus porrectus* Kutorga; 22, *Productus timanicus* Stuckenberg; 23, *Productus punctatus* Martin; 24, *Proboscidella kutorgæ* Tschernyschew; 25, *Chonetes variolata* d'Orbigny; 26, *Meekella striatocostata* Cox; 27, *M. eximia* Eichwald; 28, *Spirifer striatus* Martin; 29, *Spirifer cameratus* Morton; 30, *Spirifer fasciger* Keyserling; 31, *Spirifer moosakhailensis* Davidson; 32, *Spirifer tastubensis* Tschernyschew; 33, *Spirifer dieneri* Tschernyschew; 34, *Spirifer lyra* Kutorga; 35, *Spirifer tibetanus* Diener; 36, *Spirifer interplicatus* Rothpletz; 37, *Spirifer nikitini* Tschernyschew; 38, *Spirifer fritschi* Schellwien; 39, *Spirifer rectangulus* Kutorga; 40, *Spirifer panduriformis* Kutorga; 41, *Spirifer uralicus* Tschernyschew; 42, *Spirifer sokolovi* Tschernyschew; 43, *Spirifer quadriradiatus* Verneuil; 44, *Spirifer ussensis* Stuckenberg; 45, *Spiriferina* *ornata* Waagen; 46, *Spiriferina laminosa* McCoy mut. *sterlitamakensis* Tschernyschew; 47, *Spiriferella artiensis* Stuckenberg; 48, *Martinia triquetra* Gemmellaro; 49, *Martinia corculum* Kutorga; 50, *Martinia simensis* Tschernyschew; 51, *Martiniopsis uralica* Tschernyschew; 52, *Martinia orientalis* Tschernyschew; 53, *Martinia baschkirica* Tschernyschew; 54, *Reticularia lineata* Martin (= ? *Squamularia asiatica* Chao); 55, *Reticularia* (*Squamularia?*) *rostrata* Kutorga; 56, *Ambocœlia planoconvexa* Shumard; 57, *Athyris gerardi* Diener; 58, *Uncinulus timorensis* Beyrich; 59, *Camarophoria crumena* Martin; 60, *Camarophoria mutabilis* Tschernyschew; 61, *Camarophoria superstes* Verneuil; 62, *Pugnax osagensis* Shumard; 63, *Pugnax granum* Tschernyschew; 64, *Dielasma vesiculare* de Koninck; 65, *Dielasma mœlleri* Tschernyschew; 66, *Dielasma curvatum* Tschernyschew; 67, *Dielasma bovidens* Morton; 68, *Dielasma plica* Kutorga; 69, *Dielasma itaitubense* Derby; 70, *Dielasma juresanense* Tschernyschew; 71, *Hemiptychina dieneri* Gemmellaro; 72, *Notothyris mediterranea* Gemmellaro.

The highest Permian beds known from Indo-China occur at Luang-Prabang, in Upper Laos. The succession here is as follows, in descending order, according to Deprat and Mansuy.

Division C. Limestone, graywackes and carbonaceous shales, with plant impressions. These beds have furnished *Productus nystianus* de Koninck, *Modiola palasi* Verneuil, and other incompletely identified forms.

Division B. Graywackes, with *Lyttonia nobilis* Waagen, *Productus nystianus* de Koninck, *Productus cora* d'Orbigny, etc.

Division A. Compact black limestone, very thick and containing *Neoschwagerina globosa* Yabe, *Sumatrina annæ* Volz, *Fusulina exilis* Schwager, *Wentzelella indica* (Waagen), *Lyttonia* cf. *tenuis* Waagen, and a number of new species. This is evidently equivalent to horizon (a) of the Upper Permian of Yunnan.

The other Permian sections of China will be given later. Enough has been said to show the wide distribution of the *Schwagerina princeps* beds and their close association with faunas typically of Permian age. There seems thus little doubt that not only the Bakhmout dolomites but the beds with *Schwagerina princeps* elsewhere all belong to the same horizon. In the Donetz region, they are not only preceded by Supra-Carboniferous beds of considerable thickness (the Sub-Bakhmout series), to which alone the name Permo-Carboniferous could be applied, if that term itself were not an undesirable one, but there is also a quite apparent disconformity and hiatus of unknown length between these lowest Permian beds, with a Permo-Carboniferous or transition fauna, and the Bakhmout dolomites.

CHAPTER XV

THE PERMIAN SUCCESSION IN OTHER EAST-ASIATIC LOCALITIES

INTRODUCTION

Having traced the general course of migration of the Lower Permian fauna across Asia, we shall discuss in this chapter the Permian deposits known at present from other East-Asiatic localities. These include the deposits that mark the eastward extension of the Mongolian geosyncline.

MALAY ARCHIPELAGO

Sumatra:—In western Sumatra (Djambi district) two distinct series of Permian rocks have been identified, these having been brought into close relation by large overthrusts. One series consists of various types of igneous rocks and their tuffs with lenses and layers of fossiliferous limestone (Brouwer, 1925, p. 14). These latter are characterized by the Foraminifera *Verbeekina verbeeki, Neoschwagerina craticulifera* and *Sumatrina annæ*, together with species of *Fusulina* and *Bigenerina*. These beds are evidently to be referred to the higher Permian, being probably the correlatives of the Middle Permian of Indo-China and possibly equivalent to the Upper Productus limestone if not actually younger than that.

The second of the two series in western Sumatra also consists largely of volcanic rocks and their tufaceous sandstones, together with thick beds of conglomerate in which the pebbles are of the same volcanic rock. The thickness of this series is at least 1,400 meters, and in its lower part Fusulinidæ and *Productus* have been found, which suggest this part to be equivalent to the Middle Productus limestone of the Salt Range. Locally, thin coal beds occur in the lower part. The upper part may be Mesozoic in age.

In the Highlands of Padang, the following succession is recognized in descending order.

SUPERFORMATION: Tertiary Beds (Eocene, etc.).

Hiatus and Unconformity

PERMIAN SERIES:

2. Limestone with rare shale intercalations, mostly light to dark-gray and brown, dark at the base, with rich fauna; about........300 meters.

1. Shales without fossils, rarely with intercalated limestones; about ....200 meters.

Hiatus and Unconformity

SUBFORMATION:

Pre-Carboniferous slates, without fossils and with gold-bearing quartz-veins.

From horizon 2, a fauna of fifty-nine species has been obtained, seventeen of which, however, are not specifically identified, or only doubtfully so, leaving forty-two identified species. Of these, ten, or 24.3 per cent., occur in the Moscovian of Russia, four of them also in the Carboniferous of Europe, and three in America. These four, however, also occur in the lower Productus limestone or in the Loping fauna or both. More specifically, five out of eleven brachiopods, or 45.5 per cent., occur in the Middle Carboniferous; five of the seventeen gastropods, or nearly 30 per cent., are Middle Carboniferous; four gastropods, or 23.5 per cent., are identified with American forms; twenty-two, or more than half, are known only from these beds.

Fliegel considers that these beds are Upper Carboniferous and older than the Loping beds of China. Others, however, regard them as Permian. They may be older than the Middle Productus limestone and the Jisu Honguer limestone. On the other hand, according to Brouwer, they are to be correlated with the higher Permian beds of Sumatra previously noted.

The following definitely identified species are listed by Fliegel from the Padang limestones, those marked (*) also occurring in the Moscovian of Russia, while those preceded by (+) also occur in the Carboniferous beds of North America:

FORAMINIFERA:—1, *Fusulina granum-avenæ* F. Roemer; 2, *Schwagerina* (*Mœllerina*) *verbeeki* Geinitz.

BRACHIOPODA:—1, *Dalmanella frechi* Fliegel; 2, *Orthothetes politus* Fliegel; 3, **Productus lineatus* Waagen; 4, *+ *Productus semireticulatus* Martin; 5, *Productus sumatrensis* F. Roemer; 6, *Productus longispinus* Sowerby; 7, *Productus ovalis* Waagen; 8, *+ *Productus punctatus* Martin; 9, *+ *Reticularia lineata* McCoy (= ? *Squamularia asiatica* Chao); 10, *Spirifera damesi* Fliegel; 11, *Spirifera pseudodielasma* Fliegel.

PELECYPODA:—1, *Aviculopecten waageni* Fliegel; 2, *Aviculopecten verbeeki* Fliegel; 3, *Pinna richthofeni* Fliegel; 4, *Conocardium uralicum* Verneuil; 5, *Conocardium sumatrense* F. Roemer; 6, *Allorisma padangense* F. Roemer.

GASTROPODA:—1, *Patella anthracophila* F. Roemer; 2, **Bellerophon asiaticus* F. Roemer; 3, **Bellerophon subcostatus* Fliegel; 4, **Bellerophon convolutus* von Buch; 5, *Bellerophon roemeri* Fliegel; 6, *Euomphalus* (*Phymatifer*) *sumatrensis* F. Roemer; 7, + *Euomphalus* (*Phymatifer*) *pernodosus* Meek; 8, *Pleurotomaria orientalis* F. Roemer; 9, *Pleurotomaria nikitini* Fliegel; 10, *Pleurotomaria obliqua* Fliegel; 11, *Murchisonia padangensis* Fliegel; 12, *Trochus? anthracophilus* F. Roemer; 13, **Naticopsis sumatrensis* F. Roemer; 14, *Naticopsis trautscholdi* Fliegel; 15, *Naticopsis elegantula* Fliegel; 16, + *Naticopsis subovata* Meek and Worthen; 17, *Macrocheilus intercalare* Meek and Worthen var. *pulchella* Meek; 18, + *Polyphemopsis nitidulum* Meek and Worthen.

CEPHALOPODA:—1, *Orthoceras orientale* Fliegel; 2, *Temnocheilus* (*Metacoceras*) *hayi* Hyatt; 3, *Pleuronautilus sumatrensis* Fliegel; 4, *P. loczyi* Fliegel

TRILOBITA:—1, *Griffithides sumatrensis* F. Roemer.

This gives a total of two Foraminifera, eleven brachiopods, six pelecypods, eighteen gastropods, four cephalopods, one trilobite, or forty-two in all.

Timor:—The Permian strata of this island have yielded the most extensive fauna yet known from any deposit in Asia. The beds are strongly folded and faulted, and consist of tuffs, tufaceous marls, limestones and basic effusive rocks. The fossils are best preserved in the tufaceous marls, where the most striking element of the fauna is formed by the crinoids and blastoids. Of the former, two hundred thirty-nine species have been described, belonging to at least seventy genera, fifty-nine of which have been definitely determined. Of these, forty-two genera are so far known only from Timor. The blastoids are fewer in species, but are represented by vast numbers of individuals which belong mostly to the genus *Schizoblastus.*

The cephalopods are represented by more than fifty species, most of which are new. Their closest relation is with the species of the Val Sosio in Sicily, with the Artinskian of Russia, and with the Upper Productus limestone of the Salt Range. On the basis of the cephalopod distribution, the following classification of the deposits of the more important localities is made.

AMARASSI BEDS. Upper and Middle Productus limestone.

SOMOHOLE BEDS. Lower Artinskian series.

BASTES, BITAUNI AND ASTABE BEDS. Upper Artinskian series.

Of seventy-nine[1] specifically identified brachiopods, twenty-one identical and eight related forms occur in the Middle Productus limestone, while the Middle and Upper Productus limestone together have forty-one (thirty identical and eleven related) species, or 52 per cent. of the Timor brachiopod fauna. On the other hand, there are only twenty identical and eight related species in common with the Schwagerina limestone, and eighteen identical and seven re-

[1] According to the tables of Dr. Beotr Hamlet, 1928, 2nd Nederlandsche Timor Expeditie.

lated with the Artinskian. With the Jisu Honguer limestone this fauna has nineteen species in common, but six of these are represented by varieties in the Jisu Honguer limestone.

The coral fauna is likewise represented by numerous species and many new genera, many of which show transitional characters between types known from the Palæozoic and those from the Mesozoic.

According to Brouwer, "The nearest relatives of all the Permian faunas investigated up to the present time are to be found in the Permian of the Alps, of Sicily, of the Urals, of the Salt Range and in the Himalayas, while the Permian sediments of Timor also correspond to a marked degree with the Wichita formation of North America, but a certain independence appears in the development of the faunas." Compared with all the known Chinese faunas, this Timor fauna appears to be somewhat younger than the Jisu Honguer fauna.

Fossiliferous Permian beds have also been found on the islands of Savu, Rotti, Letti, Luang and Babber. On Letti, east of Timor, the Permian beds are graywackes, shales and sandstones, containing brachiopods, ammonites, crinoids and Fusulinidæ. These are referred to the Lower Permian. The ammonites are closely related to, if not identical with, species found in the Irwin River coal field in western Australia. The brachiopods, according to Broili (1914), comprise the following species: 1, *Productus cora* d'Orbigny; 2, *Productus spiralis* Waagen; 3, *Chonetes strophomenoides* Waagen; 4, *Spirifer fasciger* Keyserling; 5, *Spiriferella rajah* Salter; 6, *Reticularia lineata* Martin (=? *Squamularia asiatica* Chao); 7, *Martinia nucula* Rothpletz; 8, *Hustedia grandicosta* Davidson, and species of *Dielasma* and *Notothyris*. With *Spiriferella rajah*, Broili includes a form more probably referable to *Spirifer tibetanus* Diener.

THE CENTRAL CHINESE BASIN

The marine Permian beds are probably more extensively developed in Central and South China than in any other Asiatic region. In the gorge of the Yangtze they are represented by the great Wushan limestone, which has a thickness of nearly two thousand meters. The lower hundred meters are the equivalent of the Chihsia limestone of the Nanking Hills region, a formation which, since the days of von Richthofen, has been regarded as Lower Carboniferous or Dinantian. Recently, however, Hayasaka has called attention to the fact that the typical species of coral of this limestone is not of the genus *Syringopora*, but referable rather to a new genus *Tetrapora* Yabe and Hayasaka. Finding what seemed to be a section of *Schwagerina* in the same limestone, Hayasaka suggests that the age may be Permian rather than Dinantian, and this is now the accepted classification.

The subdivisions now recognized for the Permian of the Yangtze valley are as follows:

SUPERFORMATION:

Triassic or Jurassic.

Hiatus and Disconformity

UPPER PERMIAN...about 700 meters

Tayeh limestone.
Paoan shale (Zone of *Girtyites* and *Anderssonoceras*).

MIDDLE PERMIAN...about 1000 meters

Hsuanchin coal series.
Hsiaochiang formation (Zone of *Kiangsiella tingi*).
Changsing limestone (Zone of *Oldhamina*).
Loping beds (Zone of *Lyttonia*).

LOWER PERMIAN...about 100 meters

Chihsia limestone (Zone of *Tetrapora*).

Hiatus and Disconformity

SUBFORMATION:

Silurian or Devonian.

Chihsia limestone:—This formation, formerly regarded as of Dinantian age, is now definitely placed at the base of the Permian. The type locality is Chih-Hsia-Shan, one of the Nanking Hills, from which it was first described by von Richthofen. Here it rests disconformably on the great Wutung sandstone of Silurian or Devonian age, and carries *Girvanella nankinensis* Grabau in the basal layers. The formation is widely distributed in the eastern provinces of the Yangtze valley, and in the Yangtze Gorges it forms the first 100 meters of the great limestone series which there rests disconformably on Silurian beds. The fauna is distinctive, comprising the following species so far determined: FORAMINIFERA: *Schwagerina* sp.; *Fusulinella* (*Nankinella*) *gigas* (Mansuy) Grabau; *F. multivoluta* Lee; *F. verbeekinoides* Lee; *F. sphærica* Abich; *F.* sp. ANTHOZOA: *Tetrapora elegantula* Yabe and Hayasaka; *T. nankinensis* Yoh; *T. halysitiformis* Yoh; *T. syringoporoides* Yoh; *T. laxa* Yoh; *Monilopora dendroidea* Yoh; *Michelinia favositoides* Girty; *M. microstoma* Yabe and Hayasaka; *M.* cf. *placenta* Waagen and Wentzel; *M. multicystosa* Yoh; *Allotropiophyllum sinense* Grabau; *Lonsdaleia chinensis* Girty; *L. chihsiænsis* Yoh; *L. kiangsiensis* Yoh. BRYOZOA: *Fistulipora waageniana* Girty; *F. chinensis* Yoh; *Geinitzella chinensis* Girty. BRACHIOPODA: *Spirifer blackwelderi* Girty; *Spiriferella pentagonalis* Chao; *Dalmanella indica* (Waagen); *Orthotychia morgiana* var. *chihsiænsis* Chao; *Kiangsiella pectiniformis* Davidson var. *nankinensis*

Grabau; *Schuchertella* cf. *semiplana* (Waagen); *Derbya* sp.; *Chonetes* sp.; *Marginifera obscura* Chao; *Productus nankinensis* (Frech); *Productus richthofeni* Chao.

From this it will be seen that those types which are not entirely new are related to Permian species found elsewhere in eastern Asia. That the Chihsia limestone represents the first invasion of the Permian sea in southern China can no longer be doubted. The same formation is widely distributed in South China and will be referred to again in the discussion of the South Chinese deposits.

Loping series:—This is the longest known of the Permian formations of China, is rather widespread in the Yangtze valley, occupying what has been designated as the Loping geosyncline (Grabau, 1923–1924, Vol. I, p. 472, Fig. 299). It usually rests disconformably upon older Palæozoic beds, or unconformably upon the pre-Palæozoics. It has a thickness of more than 500 feet in the type locality in Kiangsi Province and is generally overlapped on the margins of the geosyncline by the later formations. Among its most characteristic fossils are *Lyttonia richthofeni*, *Richthofenia sinensis*, *Enteletes kayseri*, *Martinia lopingensis*, etc. The fauna is shown in the subjoined table, where those in common with the Jisu Honguer limestone are indicated. The formation is widely developed in south China, but the fauna has not yet been studied in detail.

Changsing limestone:—This formation is intercalated between coal beds, and while its fauna has many features in common with the Lyttonia beds, it is believed to be a distinct horizon overlying the Loping series. Nevertheless, it is not impossible that it represents merely a phase of the Loping beds, as the two have not actually been found in superposition. The most characteristic species of this limestone is *Oldhamina decipiens*, a species typical of the Middle and Upper Productus limestone of the Salt Range. In the Yangtze gorges, this horizon is found in the Wushan limestone, 685 meters above its base, or about 585 meters above the Chihsia limestone. *Lyttonia richthofeni* is associated with *Oldhamina* in these limestones, which may indicate that the fauna is a unit. The species so far obtained from the Changsing limestone are given in the table.

TABLE X. FAUNA OF THE LOWER MIDDLE PERMIAN OF THE YANGTZE VALLEY

		Loping beds	Changsing beds	Jisu Honguer limestone	Lower Productus limestone	Middle Productus limestone	Upper Productus limestone	Schwagerina limestone
	FORAMINIFERA:							
1	*Fusulina* sp.	×						
	ANTHOZOA:							
2	*Lophophyllum proliferum* McChesney	×						
3	*Sinophyllum pendulum* Grabau	×						
4	*Tachylasma aster* Grabau		×					
5	*Tachylasma lopingensis* Grabau	×						
	BRYOZOA:							
6	*Rhombopora lepidodendroides* Meek	×						
	BRACHIOPODA:							
7	*Dalmanella subquadrata* Fliegel	×						
8	*D. indica* Waagen var.	×			×	×		
9	*Enteletes kayseri* Waagen	×				×		
10	*E. meridionalis* Gemmellaro	×						
11	*Streptorhynchus kayseri* Schellwien	×		×				
12	*S. pelargonatus* Schlotheim	×		×	×	×		
13	*S. subpelargonatus* Fliegel	×						
14	*Orthothetes circularis* Fliegel	×						
15	*O. kayseri* (Jaekel)	×						
16	*Orthothetina eusarkos* Abich	×	×	×				
17	*O. ruber* Frech	×		×				
18	*Derbya* cf. *grandis* Waagen	×				×	×	
19	*D. schellwieni* Keyserling	×						
20	*Meekella kayseri* Jaekel (*sens. strict.*)	×						
21	*Chonetes tenuilirata* Chao	×						
22	*C.* cf. *barnsiensis* Davidson	×						
23	*C. soochowensis* Chao	×						
24	*Productus gratiosus* Waagen	×	×			×	×	
25	*P. yangtzeensis* Chao	×	×					
26	*P. abichi* Waagen	×	×			×	×	

TABLE X—*Continued*

		Loping beds	Changsing beds	Jisu Honguer limestone	Lower Productus limestone	Middle Productus limestone	Upper Productus limestone	Schwagerina limestone
27	*P. palliata* Keyserling	×	×	...	...	...	...	...
28	*P. mongolicus* Diener	×	×	...	...	×	×	...
29	*P. chonetoides* Chao	×	...	...	...	...	...	...
30	*P. kayseri* Chao	×	...	...	...	...	...	...
31	*P. subplicatilis* Frech	×	...	...	...	...	...	...
32	*P. kiangsiensis*	×	...	...	...	×	×	...
33	*Marginifera helicus* Abich emend. Frech	×	...	...	...	...	...	...
34	*M. lopingensis* Keyserling	×	×	...	...	...	...	...
35	*M. spinulocostatus* var. *ciliata* Arthaber	×	...	...	...	...	...	...
36	*Strophalosia horrescens* Verneuil	×	...	...	...	...	...	×
37	*Aulosteges poyangensis* Kayser	×	...	...	...	...	...	...
38	*Lyttonia richthofeni* (Kayser)	×	...	+	...	×	...	...
39	*L. oldhaminiformis* Grabau	×	...	?	...	...	...	...
40	*Oldhamina decipiens* Waagen	...	×	...	...	×	×	...
41	*Squamularia asiatica* Chao	×	...	...	×	...	...	...
42	*S. waageni* Loczy	×	×	×	...	...	...	...
43	*S. osborni* Grabau var. *lopingensis* Grabau	×	×	+	...	...	...	...
44	*S. nodosa* Chao	×	...	+	...	+	...	...
45	*Martinia lopingensis* Grabau and Chao	×	...	+	...	+	...	...
46	*Spirifera globularis* Phillips	×	...	...	...	...	...	...
47	*Hustedia grandicosta* (Davidson)	×	...	×	×	×	×	...
48	*Dielasma acutangulum* Waagen	×	...	×	...	...	×	...
	PELECYPODA:							
49	*Aviculopecten maccoyi* Meek and Worthen	×	...	...	...	...	...	...
50	*A. pseudoctenostreon* Waagen	×	...	...	...	...	×	...
51	*Pseudomonotis* cf. *garforthensis* (King)	×	...	...	...	×	...	×
52	*Oxytoma* aff. *lævicostata* Netschajew	×	...	...	...	...	...	×
53	*Gervilleia* (*Angustella*) *præangusta* Frech	×	...	...	...	...	...	...
54	*Myalina trapezoidalis* Kayser emend. Frech	×	...	...	...	...	...	...
55	*Libea sinensis* Frech	×	...	...	...	...	...	...

TABLE X—*Continued*

		Loping beds	Changsing beds	Jisu Honguer limestone	Lower Productus limestone	Middle Productus limestone	Upper Productus limestone	Schwagerina limestone
56	*L. indica* Waagen	×	......	......	×	......	......	......
57	*Pinna confitsiana* Kayser	×	......	......	......	......	......	......
58	*Schizodus truncatus* (King)	×	......	......	......	......	......	......
	GASTROPODA:							
59	*Bellerophon* cf. *jonesianus* Waagen	×	......	×	......	......	......	......
60	*Platyceras producti* Frech	×	......	......	......	......	......	......
	CEPHALOPODA:							
61	*Orthoceras obliqueannulatum* Waagen	×	......	......	......	......	......	......
62	*O.* cf. *bicinctum* Abich	×	......	......	......	......	......	......
63	*Tainoceras orientale* Kayser	×	......	......	......	......	......	......
64	*T. mingshanense* Kayser	×	......	......	......	......	......	......
65	*T.* sp.	......	×	......	......	......	......	......
66	*Gastrioceras richthofeni* Frech	×	......	......	......	......	......	......
	TRILOBITÆ:							
67	*Griffithides obtusicauda* Kayser	×	......	......	......	......	......	......

× = identical, + = related.

Hsiaochiang formation:—This formation is known at present from several localities in the Yangtze valley, the two principal ones occurring in the southern margin of the Loping geosyncline, about 370 miles apart.

The one is situated in northeastern Chekiang, where it is included in the FEILAIFONG FORMATION, the other in southwestern Kiangsi, at the type locality. In both cases they overlap the Loping and Changsing formations, resting upon older rocks or on continental formations. The following species have so far been obtained from this horizon.

Productus punctatiformis Chao, *Productus chihanensis* Chao, *Productus gratiosus* Waagen, *Productus cora* d'Orbigny, *Schizophoria chihanensis* Grabau, *Orthotychia morganiana* (Derby) var. *sinensis* Grabau, *Kiangsiella tingi* Grabau, *Kiangsiella anderssoni* Grabau, *Kiangsiella anderssoni* mut. *heterostriata* Grabau, *Orthothetes carinostriata* Grabau, *Orthothetes carinostriata* mut. *sinuosa* Grabau, *Spiriferina chuchuani* Grabau, *Squamularia asiatica* Chao, *Ambocœlia* cf. *planoconvexa* Shumard.

The Hsiaochiang formation is directly succeeded by the Fengtien series, which in its lower part represents the Hsuanchin coal series and in its upper part carries the Paoan fauna. This, farther north, is represented by the Paoan shale, which has been traced from the eastern Yangtze valley to the Szechuan border-line. It is everywhere characterized by goniatites, the leading species being *Gastrioceras* (*Girtyites*) *zitteli* Gemmellaro, a species originally described from Sicily; *G. liui* Grabau, and *Glyphioceras* (*Anderssonoceras*) *anfuense* Grabau. Associated with these in the typical region are: *Productus gratiosus* Waagen and *Productus compressus* Waagen. In Anhui, Hayasaka has found continental beds with *Gigantopteris dentata* 140 meters above the *Gastrioceras zitteli* horizon.

In the Yangtze gorges, this horizon occurs in the Wushan limestone about 1,100 meters above its base, or 1,000 meters above the assumed base of the Permian. In the Choutien district of northern Szechuan, these pyroschists, with *Gastrioceras zitteli* Gemmellaro and *Agathiceras* cf. *suessi* Gemmellaro, are both preceded and succeeded by limestones with *Squamularia waageni* (Loczy), and associated with *Productus subplicatilis* Frech, *Solemya biarmica* Verneuil, *Lima dieneri* Frech, *Aviculopecten coxanus* Meek and Worthen var. *sinensis* Frech, *Macrodus* cf. *tenuistriatus* Meek and Worthen, *Ambocœlia planoconvexa* Shumard.

These Gastrioceras beds are at present the highest known fossiliferous Permian beds with marine fauna that are generally traceable throughout the Yangtze valley, for neither the Tayeh limestone, which occupies the upper 800 meters of the Wushan limestone group over part of this area, nor the upper part of the Wushan, has so far furnished fossils. In the equivalent Peishan limestone, however, in northwestern Kiangsi, numerous specimens of *Squamularia* cf. *asiatica* Chao and a species of *Agathiceras* (*A. kinshanense* Grabau) have been found. Associated with this goniatite are small specimens of *Carbonicola wangsoweni* Grabau, a species which has also been found with other pelecypods of this group in the Hukou shale of Fukien. A small *Conularia* (*C. simplicosta* Grabau) also occurs in these Peishan beds of Hupeh.

What may be the equivalent of these beds in Fukien is the Hukou shale, 300 meters in thickness, resting upon a conglomerate 100 meters in thickness, which in turn lies about 1,100 meters above the granite. The age of the lower beds is probably late Palæozoic, though no fossil zones have been found. A limestone full of *Schwagerina* and a shale with a variety of *Productus cora* have been obtained, but their exact position in the series is undetermined.

The Hukou shale carries fresh-water pelecypods, among which the following have been identified: *Anthracomya wardiformis* Grabau, *Anthracomya modiomorphoides* Grabau, *Carbonicola wangsoweni* Grabau, *Carbonicola ovalis*

Grabau, *Carbonicola* cf. *subrotunda* Brown, and the ostracod *Estheria fukienensis* Grabau.

Associated with these pelecypods and crustaceans are numerous trunk fragments, branches and leaf impressions of *Neocalamites fukienensis* Chow related to *Neocalamites hœrensis* Schimper of the Swedish Rhætic, and to *Schizoneura carrerei* Zeiller, from the Rhætic of Tongking. These plants indicate very late Permian age.

In the Lipakou coal basin of Hunan, pelecypods have been found in strata interbedded with the beds carrying *Gigantopteris nicotinæfolia* and which apparently represent Middle Permian. Frech has described the following species from these beds: *Pseudomonotis radialis* Waagen, *Aviculopecten coxanus* Shumard var. *sinensis* Frech, *Leda præacuta* Waagen, *Nucula beyrichi* Schaur, *Pleurophorus subovalis* Waagen, *Pleurophorus* cf. *acuteplicatus* Waagen, *Schizodus pinguis* Waagen, *Schizodus compressus* Waagen, *Astarte ambiensis* Waagen, *Allorisma* cf. *subelegans* Meek, *Edmondia* cf. *nebrascensis* Geinitz, *Edmondia tieseni* Frech, *Bellerophon* sp.

THE SOUTH CHINESE PERMIAN

The marine succession in the Permian of south China is as follows:

UPPER PERMIAN:

Maping limestone.

MIDDLE PERMIAN:

Holo coal-bearing series (Zone of *Lyttonia*).

LOWER PERMIAN:

Chihsia limestone Series (Zone of *Tetrapora*).

Hiatus and Disconformity or Unconformity

SUBFORMATION:

Older Palæozoic.

Chihsia limestone:—This is known from Kwangsi and Yunnan provinces and probably occurs in Kwantung and Kweichow provinces as well. From Yunnan, Mansuy has described the typical Chihsia foraminiferan *Fusulinella* (*Nankinella*) *gigas* (Mansuy) Grabau. In Kwangsi, Mr. Yoh has found *Tetrapora* widely distributed, the species being those found in the Yangtze valley. Other corals also occur. From these beds Mr. Yoh has obtained several specimens of a new species of *Daviesiella* (*D. lochengensis* Grabau) which suggest Viséen affinities, but probably represent a persistence of this productoid type in the Pacific realm, its original home. The details of the fauna still await determination.

Holo coal-bearing series:—This is the essential equivalent of the Middle Permian of the Yangtze valley, especially the Loping horizon as indicated by the presence of *Lyttonia*, but it may also cover other members of the Middle Permian succession. Only a part of the fauna has so far been studied, but it proves of considerable interest. What appears to be a leading type, apparently confined to a definite horizon, is the new spiriferoid genus, *Lochengia* Grabau, with *L. holoensis* Grabau as the genotype. These shells are very suggestive of the Russian *Spirifer ufensis* Tschernyschew and *S. supracarbonaria*, but all the specimens so far obtained prove to be without hinge-area. Besides the type species *Lochengia holoensis* Grabau, the following have been obtained: *Lochengia enteleteformis* Grabau, *Lochengia anormalis* Grabau, and *Lochengia aplicata* Grabau. The other fossils of this horizon have not yet been determined.

Maping limestone:—This is a thick and mostly pure limestone of grayish color and wide distribution which caps the hills in many places and rests either conformably upon the Middle Permian or by overlap on older Palæozoic rocks. It has furnished to date a fauna of about 80 species, a great proportion of which are new. The previously known species have been obtained from other Permian beds of south China, especially the *Wangchiapa limestone* of West Kweichow, which may be its equivalent or may be an older Permian formation; and from the "Productus limestone" of Indo-China. There is just enough relationship shown in the fauna to the Uralian of Russia to emphasize the Pacific origin of the bulk of the latter.

Three divisions are recognizable in the Maping limestone, the lower with corals predominating, the middle, chiefly characterized by brachiopods; and the upper characterized by Foraminifera. The following is the list of species so far described from the two lower divisions (Grabau, 1930):

ANTHOZOA: *Syringopora mapingensis* Grabau and Yoh; *Multethecopora grandis* Grabau; *Chætetes pachythecalis* Grabau and Yoh; *Diphiphyllum ultimum* Grabau; *Amygdalophyllum minor* Grabau and Yoh; *Amygdalophyllum obscurum* Grabau and Yoh; *Paliphyllum lamniscatum* Grabau and Yoh (gen. et spec. nov.); *Paliphyllum mapingense* Grabau and Yoh; *Aulophyllum permicum* Grabau and Yoh.

BRACHIOPODA: *Productus porrectus* Kutorga; *Productus gruenewaldti* Krotow; *Productus subspiralis* Grabau and Yoh (also in the "Productus limestone" of Indo-China); *Productus* cf. *mammatus* Keyserling; *Productus graciosus* Waagen; *Buxtonia kweichowensis* Chao; *Buxtonia mapingensis* Grabau and Yoh; *Linoproductus lineatus* (Waagen); *L. lineatus* var. *crassus* Grabau and Yoh; *Linoproductus cancriniformis* var. *rugato-striatus* Grabau and Yoh; *Striatifera striatus* var. *suppressus* Grabau and Yoh; *Striatifera mapingensis* Grabau and Yoh; *Marginifera* cf. *lopingensis* Kayser; *Marginifera chuchuahuani* Grabau and Yoh; *Marginifera? gaominensis* Grabau and Yoh; *Marginifera gobiensis*

Chao; *Plicatifera chaoi* Grabau and Yoh (also in "Productus limestone" of Indo-China); *Schuchertella semiplana* (Waagen); *Orthothetes sphænæformis* Grabau; *Orthotychia magnifica* Grabau; *Orthotychia elongata* Grabau; *Orthotychia derbyana* (Waagen) var. *dubia* Grabau; *Enteletes variabilis* Mansuy; *Enteletes* cf. *intermedia* Mansuy; *Camarophoria uniplicata* Grabau; *Pugnax* cf. *connivens* Eichwald; *Terebratuloidea elongata* Grabau; *Terebratuloidea triplicata* Kutorga; *Terebratuloidea? senex* Grabau; *Spirifer panduriformis* Kutorga; *Spirifer mignon* Grabau; *Spirifer rectanguloides* Grabau and Yoh; *Spirifer rectangulus* Kutorga; *Spirifer fasciger* var. *simplex* Grabau and Yoh; *Martinia semiplana* var. *lata* Grabau; *Martinia semiplana* var. *asinosa* Grabau; *Martiniopsis cathaysiensis* Grabau; *Martiniopsis mapingensis* Grabau; *Martiniopsis tachysinosus* Grabau; *Squamularia nucleolus* Grabau; *Squamularia nucleolus* var. *sinosus* Grabau; *Squamularia asiatica* Chao; *Squamularia asiatica* var. *elegantula* Grabau; *Squamularia* sp.; *Athyris expansa* var. *kwangsiensis* Grabau; *Athyris acutirostris* Grabau; *Athyris acutirostris* var. *pygopeoides* Grabau; *Athyris girardi* Diener; *Dielasma mapingensis* Grabau; *Dielasma dieneri* Grabau and Yoh; *Dielasma rudis* Grabau; *Dielasma* sp.; *Uncinella geniculata* Mansuy var. *magna* Grabau.

PELECYPODA: *Palæostrea sinensis* Grabau; *Pseudomonotis daonelliformis* Grabau; *Aviculopecten mapingensis* Grabau; *Aviculopecten janus* Gemmellaro; *Aviculopecten laosensis* Mansuy; *Pterinopecten* sp.; *Streblopteria deprati* Mansuy; *Streblopteria magnini* Mansuy; *Bakewellia* sp.; *Septifer? curvirostris* Grabau.

GASTROPODA: *Bellerophon* sp.; *Euomphalus khemerianus* Mansuy; *Euconospira permiana* Grabau; *Naticopsis* sp.; *Capulus* sp.; *Anomphalus minutus* Grabau; *Holopella latispira* Grabau.

TRILOBITA: *Neoprœtus sinensis* Grabau; *Phillipsia* sp.

The fauna of the highest member of the Maping series is primarily a foraminiferan fauna. Professor J. S. Lee of the National Research Institute has identified the following species: 1. *Fusulina* (*Schellwienia*) *longissima* Moeller; 2. *Fusulina* (*Schellwienia*) *tschernyschewi*, var. nov.; 3. *Fusulina* (*Schellwienia*) *exilis* Schwager; 4. *Fusulina* (*Schellwienia*) *acuta* Lee; 5. *Fusulina* (*Schellwienia*) *alpina* Schellwien; 6. *Fusulina* (*Schellwienia*) *incisa* (Schellwien); 7. *Schwagerina* aff. *princeps* Ehrenberg; 8. *Climacammina antiqua* Brady; 9. *Lunucammina? permiana* Spendel; 10. *Cribrostomum*, sp. nov.; 11. *Cribrogenerina* sp. ind.; 12. *Bigenerina* sp.; 13. *Textularia* sp.; 14. *Textularoides* sp. ind.

This foraminiferan fauna is remarkable, as noted by Lee, because of the absence of the higher forms of the Fusulinidæ from it, and because of the presence of many forms found in the Taiyuan series of north China, and the Uralian of other districts. Among these, *Fusulina longissima* is the most widely distributed in the Taiyuan series, and in Russia it ranges from the

Omphalotrochus beds to the Artinskian. In the Carnic Alps, Nos. 5 and 6 occur in the Auernigg beds, and No. 9 ranges from the Permian to the Triassic, but lacks full determination. The other species of non-Fusulinas are also common Permian forms.

It need not be matter for surprise, that these Foraminifera linger in the Pacific basin throughout Permian time, and that their first invasion of Europe marks their only occurrence there. As we have seen, other forms among the Productidæ and Spiriferidæ seem to persist throughout the Permian of this region, occurring both in the highest and the lowest divisions. Nor need we assume that the first appearance of these forms in the east Asiatic region is entirely contemporaneous with their first appearance in Europe for if the Pacific was the center of their evolution, as we believe it was, they probably appeared at a time when the majority of older types of brachiopods, etc., still persisted, and therefore in pre-Permian time. This may be an explanation of their occurrence in the Taiyuan series of north China, which is therefore not necessarily to be classed as a Permian formation.

THE PERMIAN OF NORTH CHINA

In north China, the Permian strata are chiefly continental. The succession in Shansi, where it is most typically developed, is as follows according to Norin.

Younger Permian:

Shichienfeng series:..700 meters.
    B. Sandstone zone..................................500 meters.
    A. Gypsiferous marl............................150–200 meters.

Lower Permian:

Shihhotse series...450 meters.
    Upper Shihhotse...280 meters.
    Ginkgo zone..120 meters.
    Gigantopteris zone..160 meters.
    Lower Shihhotse, with Rothliegende flora.............170 meters.
Shansi series..65 meters.
?Taiyuan series (*sens. lato*).

Hiatus and disconformity

Subformation:

Middle Ordovician.

Taiyuan series:—This consists of a series of plant-bearing shales and sandstones with intercalated beds of limestone. In Shansi, where it has been studied in great detail by Norin, it is the lower coal-bearing series, and is followed by the Shansi series, which is definitely referred to the Permian and constitutes the upper coal-bearing series. (For a series of sections and their location, see Grabau, Stratigraphy of China, Vol. I, p. 254). Other sections are found in Kansu, Chihli, and elsewhere in north China. (For these sections, see Grabau, Stratigraphy of China, Vol. I, pp. 455–464). The various limestones have been given distinctive names and some of these are noted in the subjoined tables.

Formerly, the Taiyuan series was referred to the Lower Carboniferous or Dinantian but it was recognized that it was a post-Viséen formation. From a study of the Foraminifera by Professor J. S. Lee, and of the Productidæ, Spiriferidæ, and the pelecypods, by the late Mr. Y. T. Chao, these investigators have come to the conclusion that the old Taiyuan admits of a two-fold subdivision: A lower, to which they have given the name PENCHI series, and which they refer to the Moscovian, because of the presence of *Spirifer mosquensis*, *Enteletes lamarckii* and many Moscovian Foraminifera; and a higher division to which they restrict the name TAIYUAN series and which is approximately equivalent to Gschellian, if not to the Uralian. In the subjoined table (XI) are given the brachiopods and pelecypods of the Taiyuan series so far as determined by Mr. Chao. In Table XII the Foraminifera of the Taiyuan and higher beds of north China are given after Prof. J. S. Lee, with their distribution elsewhere. Those of the Penchi series are omitted. While these tables show certain affinities with the Uralian, that is, the Lower Permian, as now understood, especially so far as the Foraminifera are concerned, it is by no means a foregone conclusion that this indicates that this is the age of the Taiyuan series, *sens. strict.*, since, as we have already pointed out, these species must have appeared earlier in the Pacific region, and hence an invasion of the region in pre-Permian time would bring with it the precursors of the Permian fauna. It may very well be that the Taiyuan series proper represents an invasion of north China by the Pacific waters, while the Moscovian faunas still persisted in the Russian basin. For the Moscovian fauna was wholly excluded from the Pacific region after the temporary eastward extension during the formation of the Penchi series (if indeed the Penchi fauna does not represent the early development of the *Spirifer mosquensis* fauna, from Viséen ancestors, in the isolation of the Chinese basin. The Moscovian fauna subsequently migrated into the Russian basin, where it flourished during the entire period of the Middle Carboniferous and the early part of the Upper Carboniferous, as seen in the Donetz basin section. If that is the case, the Taiyuan as well as the Penchi series may well represent Middle Carboniferous, there being no break between them, but the former carries the Pacific fauna, the partial continuance with modification of the early Viséen fauna which appears also to have had its home in the Pacific. The early development of the Foraminifera which continued through Permian time may well have been the dominant characteristic of the post-Viséen fauna.

The group of plicated Spirifers in the Taiyuan fauna, referred to in the preliminary lists as *Spirifer bisulcatus*, has been subdivided by Chao into a number of distinct species, none of which represents the true Viséen species of *Spirifer bisulcatus* but all of them evident derivatives of that species. The first of those noted, *Spirifer* (*Choristites*) *trautscholdi* Stuckenberg, is rare in the Taiyuan, occurring only sporadically in the lowest members. It is common, however, in the underlying Penchi series. The second species, *Spirifer* (*Choristites*) *pavlovi* Stuckenberg, is the most typical and the one most nearly like the true *Spirifer bisulcatus*. It was formerly described under the name *Spirifer taiyuanensis* by Mr. Chao who later referred it to the Russian species. It is absent from the Penchi series but confined to the lowest horizon of the Taiyuan series. In the higher horizons it is entirely replaced by *Spirifer* (*Choristites*) *norini* Chao. None of these species extends into the Shansi series which as seen from Table XII. has few species in common with the Taiyuan series, those occurring in the higher beds being long-lived species. It is noteworthy that the leading Spirifers of the Taiyuan series occur in the Samara beds of the Volga elbow, a horizon which I regard as high up in the Russian Permian. With the Wanchiapa limestone of western Kweichow province the Taiyuan has only two Producti in common. That formation represents at least the Schwagerina horizon and may actually be the equivalent of the Maping limestone with which it has its most characteristic species in common.

TABLE XI. BRACHIOPODA AND PELECYPODA OF THE TAIYUAN FORMATION OF NORTH CHINA
(So far as described).

				Shansi				Europe			
		Penchi	Taiyuan	Paotechou	Tumen	Tungtayao	Wangchiapa	Auernigg	Uralian	Artinskian	Samaran
		1	2	3	4	5	6	7	8	9	10
	BRACHIOPODA:										
1	*Chonetes carbonifera* Keyserling	×	×	×	....	....	....	....	×	....	....
2	*C. graseulifera* var. *asiatica* Chao	×	×	....	....	....	....	....	×	....	....
3	*C. yuscgchangensis* Chao	....	×	..	....	....	....	....	....	....	....
4	*C. pygmæa* Loczy	×	×	....	....	....	....	....	....	....	....
5	*C. latesinuata* Schellwien	....	×	....	....	....	....	....	....	....	....
6	*C. latesinuata* var. *maokouensis* Chao	....	×	....	....	....	....	....	....	....	....
7	*Aulacorhynchus paotechouensis* Grabau and Chao	....	×	×	....	....	....	....	....	....	....
8	*Echinoconchus elegans* (McCoy)	×	×	....	....	....	×	....	....	....	....
9	*E. punctatus* (Martin)	×	×	....	....	....	×	....	×	×	....
10	*Productus* (*Juresania*) *juresanensis* Tschernyschew	×	×	×	×	×	....	....	×	....	....
11	*P.* (*Avonia*) *echidniformis* Grabau and Chao	×	×	....	....	....	....	....	....	....	....
12	*P. semireticulatus* Martin	×	×	....	....	....	....	....	....	....	....
13	*P. taiyuanfuensis* Grabau	....	×	×	×	×	....	....	....	....	....
14	*P. uralicus* Tschernyschew	....	×	....	....	....	....	....	×	....	....
15	*P. manchuricus* Chao	....	×	....	....	×	....	....	....	....	....
16	*P. gratiosus* var. *occidentalis* Schellwien	×	×	....	....	....	....	×	....	....	....
17	*Marginifera orientalis* Chao	....	×	....	×	....	....	....	....	....	....
18	*M. pusilla* Schellwien	....	×	....	....	....	....	×	....	....	....
19	*Linoproductus cora* (d'Orbigny)	×	×	×	....	×	....	....	×	....	....
20	*Spirifer fasciger* Keyserling	×	×	....	....	....	....	×	×	....	×
21	*S.* (*Choristites*) *trautscholdi* Stuckenberg	×	×	....	....	....	....	....	....	....	×
22	*S.* (*C.*) *pavlovi* Stuckenberg	....	×	....	....	....	....	....	....	....	×
23	*S.* (*C.*) *norini* Chao	....	×	....	....	....	....	....	....	....	....
24	*S.* (*Brachythyris*) *shansiensis* Chao	×	×	....	....	....	....	....	....	....	....
25	*S.* (*B.*) *strangwaysi* Verneuil	×	×	....	....	....	....	....	....	....	....
26	*S.* (*B.*) *strangwaysi* var. *lata* Chao	×	×	....	....	....	....	....	....	....	....
27	*Martinia semiglobosa* Tschernyschew	....	×	×	....	....	....	....	×	....	....
28	*M. manchuriensis* Chao	....	×	....	....	....	....	....	....	....	....
29	*Squamularia echinata* Chao	×	×	×	×	×	....	....	....	....	....

TABLE XI. BRACHIOPODA AND PELECYPODA OF THE TAIYUAN FORMATION OF NORTH CHINA
(So far as described).

(*Continued*)

				Shansi				Europe			
		Penchi	Taiyuan	Paotechou	Tumen	Tungtayao	Wangchiapa	Auernigg	Uralian	Artinskian	Samaran
		1	2	3	4	5	6	7	8	9	10
	PELECYPODA:										
30	*Nuculopsis anthraconeiloidas* Chao	×	×	....	....	....	....	....	....	....	....
31	*Parallelodon chihliensis* Chao	....	×	....	....	....	....	....	....	....	....
32	*P. tieni* Chao	....	×	....	....	....	....	....	....	....	....
33	*Cucullopsis quadrata* Chao	....	×	....	....	....	....	....	....	....	....
34	*Astartella adenticulata* Jakowlew	×	×	....	....	....	....	....	×	....	....
35	*Cypricardinia sinensis* Chao	....	×	....	....	....	....	....	....	....	....
36	*C. subelegans* Chao	....	×	....	....	....	....	....	....	....	....
37	*Palæolucina carbonaria* Chao	....	×	....	....	....	....	....	....	....	....
38	*Conocardium norini* Chao	....	×	....	....	....	....	....	....	....	....
39	*C. nobilis* Chao	×	×	....	....	....	....	....	....	....	....
40	*Lima striatoplicata* Chao	....	×	....	....	....	....	....	....	....	....
41	*Aviculopecten alternatoplicatus* Chao	....	×	....	....	....	....	....	....	....	....
42	*A. manchuricus* Chao	....	×	....	....	....	....	....	....	....	....
43	*Pterinopecten nodostriatus* Chao	....	×	....	....	....	....	....	....	....	....
44	*Acanthopecten shansiensis* Grabau	....	×	....	....	....	....	....	?	....	....
45	*Deltopecten giganteus* Chao	....	×	....	....	....	....	....	....	....	....
46	*D. multistriatus* Chao	....	×	....	....	....	....	....	....	....	....
47	*Streblopteria plana* Chao	....	×	....	....	....	....	....	....	....	....
48	*S. granosostriata* Chao	....	×	....	....	....	....	....	....	....	....
49	*Entolium aviculatum* Swallow	....	×	....	....	....	....	....	+	....	....
50	*E. ostusum* Grabau	....	×	....	....	....	....	....	....	....	....
51	*Myalina swallowi* McChesney	....	×	....	....	....	....	....	×	....	....

× = identical species
\+ = related species

TABLE XII. LOWER PERMIAN FORAMINIFERA OF NORTH CHINA

× = dominant
+ = other occurrences
O = represented by varieties

		Kansu			West Shansi	Shansi E. Hills Tay'n	Shansi W. Hills Taiyuan		Pinting-Shansi					Shantung		Shansi		Honan		Liu-ho-kou, Honan					Tzu-chou, Chihli					Chihli		Fengtien	Europe Urals	Europe Carnic Alps			Russian Turkestan	Japan
		Yaokou	Hsinho	Hungshanyao	Paoteh, 10 m.	Chienlao, 1.3 m.	(a) Miaokou, 5–12 m.	(d) Tungtayao, 3 and 4 m.	(a) Yaokou, 0.8 m.	(b) Suchieh, 1.8 m.	(c) Kushi, 3 m.	(d) Chienshi, 1.5 m.	(e) Honshi, 2 m.	Yihsien Shantung	Changchiu (b), 4 m.	Kaishiu	Linfen	Shenhsien	Hsinan	(a) Taching, 6 m.	(b) Hsiaoching, 1.4 m.	(c) Fuching, 1.6 m.	(d) Shanching, 2.5 m.	(e) Yehching, 2.8 m.	(a) Tachingi, 5.2 m.	(b) Hsiaoching, 1.8–2 m.	(c) Fuching, 2.5–4.3 m.	(d) Shanching, 1.3 m.	(e) Yehching, 1.5 m.	Shaho (a), 4 m.	Lincheng (c) Peiching, 1.2 m.	Wuhutsui (b) Yangshakou, 1 m.	Uralian and other Permian	Auernigg, etc.	Schwagerina bed	Trogkofel	Darvas	Akiyoshi limestone, Nagato
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
	Schwagerina:																																					
47	*princeps* Ehrenberg													+				+															×		×	×		×
46	*tinvenkiang* Lee																	+								+												
45	*wongwenhao* Lee																				+					+												
44	*moungthensis* Deprat																																					×
43	*fusulinoides* Schellwien		×						?																											×		
	Schellwienia:																																					
42	*longissima* Moeller	?		+				×	+						×	×	×			×					×				+	×			×					
42a	var. *tenuis* Schellwien			+														×		×			+		×				×	×								
42b	var. *compacta* Lee			+																																		
42c	var. *phaseolus* Lee			+																									×	×								
41	*erucaria* (Schwager)										×								×																			
40	*pailensis* (Schwager)									+									×																			
39	*pusilla* (Schellwien)				×														×																			

TABLE XII. LOWER PERMIAN FORAMINIFERA OF NORTH CHINA—(*Continued*)

× = dominant
\+ = other occurrences
O = represented by varieties

		Kansu			West Shansi	Shansi: E. Hills Tay'n	Shansi: W. Hills	Shansi: Taiyuan	Pinting-Shansi					Shantung		Shansi		Honan		Liu-ho-kou, Honan					Tzu-chou, Chihli					Chihli		Fengtien	Europe: Urals	Europe: Carnic Alps			Russian Turkestan	Japan
		Yaokou	Hsinho	Hungshanyao	Paoteh, 10 m.	Chienlao, 1.3 m.	(a) Miaokou, 5–12 m.	(d) Tungtayao, 3 and 4 m.	(a) Yaokou, 0.8 m.	(b) Suchieh, 1.8 m.	(c) Kushi, 3 m.	(d) Chienshi, 1.5 m.	(e) Honshi, 2 m.	Yihsien Shantung	Changchiu (b) 4 m.	Kaishiu	Linfen	Shensien	Hsinan	(a) Taching, 6 m.	(b) Hsiaoching, 1.4 m.	(c) Fuching, 1.6 m.	(d) Shanching, 2.5 m.	(e) Yehching, 2.8 m.	(a) Tachingi, 5.2 m.	(b) Hsiaoching, 1.8–2 m.	(c) Fuching, 2.5–4.3 m.	(d) Shanching, 1.3 m.	(e) Yehching, 1.5 m.	Shaho (a), 4 m.	Lincheng (c) Peiching, 1.2 m.	Wuhutsui (b) Yangshakou, 1 m.	Uralian and other Permian	Auernigg, etc.	Schwagerina bed	Trogkofel	Darvas	Akiyoshi limestone, Nagato
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
	SCHELLWIENIA: (*Continued*)																																					
38	*subnathorsti* Lee						+			×											×	?				×		+			+							
37	*nathorsti* Staff and Wedekind						×			×	×	+																										
37a	var. *laxa* Lee						+			+		×																			×							
36	*oblonga* Ozawa		+																												+							×
35	*alpina* (Schellwien)																	×															O	O	O	O		
34	*plicata* Lee		+																										×			×						
33	*richthofeni* (Schwager)		×			×	×		+				×									×	×				?	×				×						×
33a	var. *speciosa* Lee																				×																	×
32	*complicata* (Schellwien)		×			×	×		+				×		×				×																			×
31	*japonica* (Gümbel)					+			+				×														×	×	×									×
31a	var. *hayasakai* Lee																				+																	
20	*expansa* Lee			+			+						+												×													
29	*acuta* Lee																					×					×											
28	*cervicalis* Lee																						×				×	×										

27	cf. *lutugini* (Schellwien)								+																								×					×
26	*verneuili* var. *evidensis* Lee																					+											O					
25	*verneuili* var. *obtusa* Lee																														×		O					
24	*valida* Lee								+					×					?																			
24a	var. *exigua* (Schellwien)		+			+								×																							×	
23	*vulgaris* (Schellwien)										?			×											×					×							×	×
23a	var. *fusiformis* (Schellwien), emend. Lee		+											+																+							×	
23b	var. *globosa* (Schellwien)													×																							×	×
23c	var. *watanabii* Ozawa, emend. Lee			+										×																								
23d	var. *minor* Lee													×																								
23e	var. cf. *kozui* (Deprat)													×																								
22	*anderssoni* (Schellwien)																	×															×					
21	*nobilis* Lee																							×								+						
20	*arctica* (Schellwien)								+		+											×																
19	*regularis* (Schellwien)						?		+		?																							×		×		
18	*prisca* (Ehrenberg)	+	+						×																								×					×
17	*incisa* (Schellwien)		+																															×				×
16	*parvula* (Schellwien)		+						×																													
15	*simplex* (Schellwien)	×																															×					
15a	var. *minuta* Lee	×				×			+																+													
	NEOFUSULINELLA:																																					
8	*chaoi* Lee [1]																															+						
	BOULTONIA:																																					
2	*willsi* Lee						+																									×						

[1] Also in Penchi series.

Shansi series:—The Shansi series consists of shales, sandstones and thin coal seams, with some thin marine beds at the base. In central Shansi this is the Tungtayao limestone, 3 to 4 meters thick, while in western Shansi, the main coal seam, which here probably forms the base of the series, is succeeded by the Paotechou limestone, 10 meters thick, abounding in fossils. Somewhat higher, and separated from the Paotechou limestone by a coal bed and shale 0.4 meters thick, lies the Tumen formation, 14 meters thick, consisting of shales at the bottom and capped by a mass of limestone and a shale with limestone nodules. The fauna is especially rich in gastropods, among which *Euphemus wongi* Grabau is the dominant form.

In the Kaiping coal basin a fossiliferous horizon occurs in the base of the Shansi series at a point about 35 meters above the Tangshan limestone (Penchi) in a fine massive argillutite. Though mostly distinct in character, several of the characteristic species of the Shansi series are found. In beds not associated with marine organisms, and probably somewhat higher, a specimen of *Eurypteris chinensis* Grabau was obtained by Dr. Andersson. The series has been named the Chaokouchuang series. It is followed by the coal-bearing beds. In the following table is given the fauna of the three limestone series and the Chaokouchuang beds so far as determined. Some of these determinations are provisional.

TABLE XIII. FAUNA OF THE SHANSI SERIES

		Paote-Chou	Tumen	Tung-toyao	Chaokou-chuang
	FORAMINIFERA:				
1	*Fusulina pusilla* Schellwien	×	....	....	....
2	*F. longissima* (Moeller)	....	×	....	....
	BRYOZOA:				
3	*Polypora* cf. *koninckiana* Waagen and Pechel	....	....	....	×
	BRACHIOPODA:				
4	*Orbiculoidea* sp.	....	....	×	....
5	*Productus taiyuanfuensis* Grabau	×	×	....	cf.
6	*P.* cf. *semireticulatus* Martin	....	....	....	×
7	*P.* (*Juresania*) *juresanensis* Tschernyschew	×	×	×	....
8	*P. cora* d'Orbigny	×	×	....	×
9	*P.* cf. *kiangsiensis* Kayser	....	....	....	×
10	*P. cora* var. *rarispina* Grabau	×	×	....	....
11	*P. manchuricus* Chao	....	....	×	....
12	*Marginifera longispina* var. *orientalis* Chao	....	×	....	....

TABLE XIII.—*Continued*

		Paote-Chou	Tumen	Tung-toyao	Chaokou-chuang
	BRACHIOPODA: (Continued)				
13	*Orthothetes crenistria* Phillips	×	×	....	×
14	*O. crenistria senilis* Phillips	×	....	....	....
15	*Chonetes carbonifera* Keyserling	×	....	....	....
16	*C. tungtoyaoensis* Grabau	....	....	×	....
17	*C.* sp.	....	....	....	×
18	*Aulacorhynchus paotechouensis* Grabau and Chao	×	....	....	....
19	*Meekella kayseri* Jaeckel	×	....	....	....
20	*Dalmanella* cf. *indica* Waagen	....	....	....	×
21	*Enteletes kayseri* Waagen	×	....	cf.	....
22	*E. læviusculum* Waagen	×	....	....	....
23	*E. paotechouensis* Grabau	×	....	....	....
24	*Squamularia inaequilateralis* Gemmellaro	....	....	....	×
25	*S. echinata* Chao	×	×	×	×
26	*Martinia semiglobosa* Tschernyschew	×	....	....	....
27	*Spiriferina chuchuani* Grabau	×	....	....	×
28	*S. cristata* var. *octoplicata* Sowerby	×	....	×	....
29	*Athyris royssii* var. *orientalis* Grabau	....	×	....	....
30	*Pugnax* sp.	....	×	....	....
31	*Rhynchopora* cf. *wynnii* Waagen	....	....	....	×
	PELECYPODA:				
32	*Myalina swallowi* McChesney	×	×	....	....
33	*Entolium aviculatum* Swallow	×	....	....	....
34	*Aviculopecten* sp.	×	....	....	....
35	*Pseudomonotis mathieui* Grabau	....	....	....	×
36	*P. shansiensis* Chao	....	×	....	....
37	*Allorisma regularis* King	×	×	....	....
38	*Schizodus shansiensis* Chao	....	×	....	....
39	*Bakewellia* (?) sp.	....	....	....	×
40	*Edmondia nyströmi* Chao	....	×	....	....
	GASTROPODA:				
41	*Bellerophon anderssoni* Grabau	×	....	....	....
42	*B. calamitoides* Grabau	....	×	....	....

TABLE XIII.—*Continued*

		Paote-Chou	Tumen	Tung-toyao	Chaokou-chuang
	GASTROPODA: (Continued)				
43	*Euphemus wongi* Grabau	....	×	....	....
44	*Gyronema ? altispiralis* Grabau	....	×	....	....
45	*Mourlonia* cf. *propinqua* Mansuy	....	×	....	....
46	*Soleniscus syncamoides* Mansuy	....	×	....	....
47	*S.* cf. *brevis* White	....	×	....	....
48	*S.* sp.	....	×	....	....
49	*Sphærodoma subglobosa* Grabau	....	×	....	....
50	*Aclisina* sp.	....	×	....	....
51	*Meekospira* sp.	....	×	....	....
52	*Naticopsis* cf. *ventricosa* Norwood and Pratten	....	×	....	....
53	*N.* sp.	....	×	....	....
54	*Euomphalus* sp.	....	....	....	×
	CEPHALOPODA:				
55	*Huanghoceras simplicostatum* Grabau	×	....	....	....
56	*Remeleoceras subquadrangularis* Grabau	×	×	....	....
57	*Temnocheilus asiaticus* Grabau	×	....	....	....
58	*Metacoceras* sp.	×	....	....	....
59	*Orthoceras* sp.	×	....	....	....
	MEROSTOMATA:				
60	*Eurypterus* (*Anthraconectes?*) *chinensis* Grabau	....	....	....	×
	ECHINODERMATA:				
61	*Cyathocrinus* sp. 1	....	....	....	×
62	*C.* sp. 2	....	....	....	×
	VERMES? :				
63	*Spirorbis ?* sp.	....	....	....	×

The lower SHIHHOTSE series is comprised of marls, shales, sandstone and coals, with a Lower Permian or Rothliegende flora, including *Tæniopteris*, *Pterophyllum*, etc. The lower division of the Upper Shihhotse contains the *Gigantopteris* flora, both at the bottom and at the top, while *Ginkgophyes* occurs in the upper zone. From a consideration of the flora which includes *Sphenophyllum thonii*, one of the most distinctive Permian species, Halle concludes that the Upper Shihhotse series falls within the limits of the Lower Permian or the Rothliegende of central Europe. Zechstein species are wanting, and the flora on the whole has a distinctive character of its own, as might be expected from the isolated character of the Asiatic continent. The Upper Shihhotse is in general the equivalent of the Leipakou series of Hunan, before noted. In both localities, *Annularia maxima* Schenk is associated with *Gigantopteris nicotinæfolia* (Schenk). The SHICHIENFENG series, which is entirely of continental character, probably represents the Middle and part of the Upper Permian of Europe.[1]

THE PERMIAN OF WESTERN CHINA

In this connection may be noted the great continental series of Permian beds, developed within the Nanshan geosyncline, and which may belong to a higher division than the Schwagerina and Doliolina limestone of the Semenov Mountains, before noted. If, as seems likely, these continental beds extended over the whole of the geosyncline, they would effectively bring to an end the connection between the Russian and the central Asiatic regions which existed during the forming of the Schwagerina limestone series. The succession, as developed south of the Alaskan range and some 50 miles north of Lanchoufu in Kansu, is as follows (according to Wong and Hsieh):

SUPERFORMATION:

Mesozoic conglomerates.

Unconformity

PERMIAN:

b. TALAPAI FORMATION..1,000 meters

White and reddish sandstone, often coal-bearing, with layers of fossiliferous limestone and black shale near the coal.

a. SOHANPU FORMATION..600 meters

Red shales with some sandstone beds rich in gypsum. Base not exposed.

At Talapai, the fossiliferous beds are only about 12 meters thick, are interbedded with coal seams, and lie in the middle of the great sandstone series. The fossiliferous beds contain small nodules of gray limestones, in which are found the young and, more rarely, imperfect adult shells of *Gastrioceras wongi* Grabau. With these occur *Productus hemisphæricus* Kutorga, a characteristic fossil of the Samara beds of the Russian Upper Permian, and *Trepospira* (?) *kansuensis* Grabau. The black shale also contains numerous young specimens of *Gastrioceras wongi*, besides a great abundance of pelecypods.

[1] See the recently published monograph on the flora by Halle (Pal. Sinica, Ser. A, Vol. II).

The following species have been determined: *Pterinopecten papyraceus* Sowerby, which is a characteristic upper Coal Measure species; *Posidoniella yuani* Grabau, allied to *P. vetusta* Sowerby, of the Carboniferous limestone of England; *Posidoniella* cf. *pyriformis* Hind, apparently the British Carboniferous limestone species; and *Aviculopecten kansuensis* Grabau, resembling somewhat *Aviculopecten losseni* von Koener, of the Pendleside and Culm of Europe. With these is not infrequently found *Lingula credneri* Geinitz, a characteristic Zechstein species of Europe.

In spite of the similarity of the pelecypods to Carboniferous species of Europe, the presence of the two typical Upper Permian species of brachiopods, *Productus hemisphæricus* and *Lingula credneri*, indicates an Upper Permian age for the Talapai formation. *Gastrioceras wongi* also suggests later Permian, for it is of the type of *Gastrioceras jossæ* of the Artinskian of Russia.

THE PERMIAN OF THE PACIFIC REGION

That the Schwagerina fauna was at home in the Pacific as well as in the Indian Ocean of Permian time is shown by its occurrence in Japan, Korea and southern Manchuria.

Japan:—In Japan two series of limestones have generally been recognized: an upper with *Schwagerina* (*Verbeekina*) *verbeeki* Geinitz, *Neoschwagerina globosa* Yabe, etc., and a lower with *Verbeekina verbeeki*, *Doliolina lepida*, *Schwagerina* (*Neoschwagerina*) *craticulifera*, and *Fusulina japonica*.

In the Kitakami Mountains, the Permian beds overlying the Dinantian disconformably begin with clay slates, sandstones and crinoidal limestones, followed by clay slates and sandstones, with *Lyttonia richthofeni* Kayser, *Richthofenia*, *Productus flemingi* de Koninck, *Productus horridus* Sowerby, *Productus vishnu* Waagen, *Spiriferina cristata* Schellwien, *Dielasma* cf. *biplex*, and *Camarophoria humbletonensis* Howse. A Fusulina limestone in the clay slate and sandstone contains *Fusulina amedæi* Deprat, *Mizzia* cf. *velevitina* Schubert, etc.

In the Oni district, near Toyama, a limestone, said to be about 2 kilometers thick, carries the Lower Carboniferous (Dinantian) fauna in the lower and middle division, and the Permian fauna in the upper. The lower division carries the *Syringothyris cuspidata* fauna (Tournaisian) while the middle carries the *Productus giganteus* fauna (Viséen). The Permian is represented by the upper division, which apparently succeeds the Dinantian disconformably. It contains *Fusulina brevicula* Schwager, *Fusulina* cf. *japonica* Gümble, *Schwagerina* (*Verbeekina*) *deprati* Yabe, *Doliolina lepida* Schwager, *Neoschwagerina craticulifera* Schwager.

In the Hida Plateau, Fusulina limestone occurs at Akasaka, near Gifu. Here the following succession is recognized:

8. White crystalline limestone, without fossils.
7. Hard compact gray limestone, rich in fossils. *Fusulina japonica* and pelecypods abundant.
6. Dark gray limestone, hard and compact, large *Fusulina* rare.
5. White limestone, rich in fossils, including large *Fusulina*, *Pleurotomaria*, corals, two crinoids, and a small *Bellerophon*.
4. Black limestone, traversed by small veins of calcite, poor in fossils, rarely with crinoids; *Fusulina* and *Schwagerina* in certain parts.
3. Black earthy limestone, with *Schwagerina* distributed throughout, and corals at certain horizons.
2. Black marble, containing *Bellerophon*, *Murchisonia*, etc.
1. Brecciated limestone, composed of fragments of the limestone below it.

Among the fossils found in these several beds, the following are listed by Ogura (1926).

FORAMINIFERA: *Fusulina japonica* Gümble, *Fusulina exilis* Schwager, *Schwagerina* (*Verbeekina*) *verbeeki* Geinitz, *Schwagerina craticulifera* Schwager, *Fusulinella* sp., *Lingulina* sp., *Tetrataxis conica* Ehrenberg, *Endothyra* cf. *crassa* Brady, *Climacammina protenta* Schwager, *Climacammina cribrigera* Schwager, *Trochammina* sp., *Textularia* sp. ECHINOIDEA: *Archæocidaris* sp., *Pteriocrinus* sp., *Pentacrinus* sp. ANTHOZOA: *Favosites* sp. BRACHIOPODA: *Lyttonia richthofeni* Kayser, *Reticularia lineata* Martin (= *Squamularia asiatica* Chao?), *Squamularia waageni* (Loczy), *Squamularia* cf. *inæquilateralis* (Gemmellaro), *Schacchinella* sp. GASTROPODA: *Pleurotomaria* sp., *Bellerophon* aff. *hiulcus* Sowerby.

In Akiyoshi, northwestern Yamaguchi, in Chugoku Province, Fusulina limestone forms the most prominent limestone plateau in Japan, in which erosion has developed a karst topography. According to the investigations of Ozawa (1925) this limestone contains a rich fauna distributed through seven horizons. Those described comprise 3 species of plants, 67 species of Foraminifera, 13 species of corals, 5 of Bryozoa and 2 of Brachiopoda, a total of ninety species. The Foraminifera also found in north China are indicated in Table XII, Col. 37.

Korea:—In Korea, the HEIAN SYSTEM, largely a terrestrial formation, is divided into the following four series, according to Kawasaki (1926).

4. GREEN SERIES:

Green shale and sandstone, no coal and no fossils....... 1000 meters.

3. KOBOSAN SERIES:

Shale and sandstone, generally with thin coal seams, regarded as equivalent to the Shihhotse series of China, with plant remains .... 364–580 meters.

2. Jido Series:

Sandstone, shale and workable coal seams, Permian plants........ ....80–150 meters.

1. Koten Series:

Red shale, sandstone, limestone and, rarely, thin coal seams, with plants and marine animals........................80–270 meters.

The limestones of the Koten Series generally occur in thin beds or lenses, varying in thickness and number up to five. From the middle of the series, Yabe has recorded *Schwagerina princeps* Ehrenberg, *Chætetes asiaticus* Yabe and Hayasaka, *Caninia muratai* Yabe and Hayasaka, *Cystophora dubia* Yabe and Hayasaka, *Cystophora kikkawai* Yabe and Hayasaka, *Archnastræa coreanica* Yabe and Hayasaka, and species of *Productus*, *Spirifer*, *Uncinulus* and *Dalmanella*.

From a limestone, probably of the same horizon, Konno has recorded *Productus cora*, *Tetrataxis* cf. *maxima* Schellwien, and *Fusulina*.

From higher beds, Yabe and Konno have recorded *Fusulina* aff. *richthofeni* Schwager, *Fusulina subcylindrica* Deprat, and *Schwagerina* sp. Finally, Ozawa has described *Fusulinella konnoi* Ozawa from this series. This apparently represents the Lower Permian Schwagerina limestone.

The Jido Series is rich in anthracite seams and carries the following flora, which comprises a mixture of Carboniferous and Permian plants. It has been correlated with the Shansi series of China.

Mariopteris muricata Schlotheim, *Pecopteris candollei* Brongniart, *Pecopteris polymorpha* Brongniart, *Pecopteris oreopterida* Schlotheim, *Pecopteris cyathea* Schlotheim, *Pecopteris orientalis* Schenk, *Lonchopteris alata* Kawasaki, *Callipteridium koraiensis* (Tokunaga), *Callipteris conferta* Schlotheim, *Tæniopteris multinervis* Weiss, *Mixoneura subcrenata* Rost, *Calamites cisti* Brongniart, *Sphenophyllum emarginatum* Geinitz, *Sphenophyllum oblongifolium* Germar et Kaufman, *Sphenophyllum macrophyllum* Tokunaga, *Sphenophyllum thoni* Mahr., *Annularia inæquifolium* Tokunaga, *Lepidodendron oculis-felis* Abbado, *Lepidostrobus* sp., *Sigillaria* sp., *Stigmaria ficoides* Sternberg, *Cordaites principalis* Germar, *Cordaites* sp., *Nœggerathia acuminifissa* Krasser, *Nœggerathia kikkawai* Tokunaga, *Pterophyllum carbonicum* Schenk, *Lagenospermum* cf. *oblongum* (Kidston), and others.

The Kobosan Series is likewise a terrigenous formation, with generally thin coal seams. It carries the Gigantopteris flora, the following species having been identified.

Pecopteris integra Andræ, *Pecopteris orientalis* Schenk, *Tæniopteris spatulata* McClelland, *Sphenophyllum speciosa* (Royle), *Sphenophyllum sino-corean-*

um Yabe, *Annularia inæquifolia* Tokunaga, *Annularia papilioides* Kawasaki, *Annularia mucronata* Schenk, *Annularia maxima* Schenk, *Annulariopsis inopinata* Zeiller, *Schizoneura heianensis* Kodaira, *Neocalamites meriani* (Brongniart), *Gigantopteris nicotianæfolia* Schenk, *Gigantopteris rarinervis* Konno, *Gigantopteris elongata* Kawasaki, *Gigantopteris dentata* Yabe, *Chiropteris reniformis* Kawasaki, *Thinnfeldia* cf. *incisa* Sapper, *Conchophyllum richthofeni* Schenk.

This is a mixture of Upper Palæozoic and Triassic types and indicates a late Permian age, but not necessarily the youngest Permian. The GREEN SERIES consists of sandstones and shales and is unfossiliferous. It is thought to be of Triassic age, but may still be referable to the Permian. It is unconformably succeeded by Liassic or younger beds.

Southern Manchuria:—Although southern Manchuria falls within the eastern end of the Mongolian geosyncline, the faunas of its Permian sediments are so closely related to those of Korea and Japan that they are best considered in this connection, while those of the Vladivostok region may be noted later on.

In the Hon-Kee-Ko, Yentai and other coal fields of southern Manchuria, the Cambrian or Ordovician beds are disconformably succeeded by a thin complex of shales and sandstones, with a marine fauna in small lenticular masses of limestone. A portion of this may represent the Taiyuan series, but a part of it at least is referable to the Lower Permian, as shown by the following Permian species: *Marginifera timanica* Tschernyschew, *Spirifer jigulensis* Stuckenberg, *Spirifer nikitini* Tschernyschew, *Spirifer tschernyscheffi* Stuckenberg, *Spirifer supramosquensis* Nikitin, *Spirifer winnii* Waagen, *Martinia semiplana* Waagen, and *Martiniopsis baschkirica* Tschernyschew. With the exception of *Spirifer supramosquensis*, which occurs in the Cora or lower horizons, these species are characteristic of the Schwagerina and higher beds of Russia, and the Productus limestones of India. With these occur the following corals, which are either identical with, or related to, species in the Koten series of Korea: *Arachnastræa manchurica* Yabe and Hayasaka, *Cystophora manchurica* Yabe and Hayasaka, *Chætetes asiaticus* Yabe and Hayasaka, and *Syringopora reticulata* Goldfuss. This is evidently the Schwagerina fauna, as developed in Korea.

In the Yentai coal field, these *Honkeiko* beds are succeeded by the continental Yentai or lower coal series. This is more than 1,000 feet thick and consists of shales and sandstones, alternating with coal beds of which there are eleven, three of them, each 5 feet thick, being important producers.

There are two plant horizons, one from 150 to 180 feet above the Honkeiko marine beds and the other 420 feet above these beds. The latter contains the *Gigantopteris nikotinæfolia* flora, which Yabe refers to the lower Permian. Associated with *Gigantopteris nikotinæfolia* Schenk, in this upper coal-bearing horizon of the Yentai series, are *Odontopteris reicheana* Gutbier, *Neuropteris scheuchzeri* Hoffmann, *Callipteridium* cf. *pteridium* Schlotheim, *Calamites* cf. *suckowi* Brongniart, *Annularia inæquifolia* Tokunaga, *Sphenophyllum oblongifolium* Germar and Kaufman, *Lepidodendron oculis-felis* Abbado, *Stigmaria ficoides* Sternberg, etc. Zalessky, Yokoyama and Yabe refer this flora to the uppermost Stephanian. It thus represents a late Carboniferous flora, extending into the Permian, unless indeed a part of the Stephanian is referable to the Permian. The upper coal series in the Yentai field is 267.7 feet thick and consists of shales and sandstones with four coal seams, varying up to 7 feet in thickness. No floras have been discovered in this series. This upper coal series is succeeded by a thick sandstone, with intercalations of shale.

SUMMARY OF THE DISTRIBUTION OF THE SCHWAGERINA BEDS

We have thus seen that the Schwagerina beds, especially those with *Schwagerina princeps*, which we regard as one of the lowest Permian horizons, are widely distributed in the Indian and Pacific border regions. These deposits are, however, absent from the Himalayan geosyncline and from the strata of the main part of the Mongolian geosyncline, being so far unknown in the Jisu Honguer limestone. Since they are so well developed in the Russian basin, we must seek for a connection between that and the Indo-Pacific region by another path than by these two geosynclines. As already indicated, this line of connection was probably by way of the Nanshan geosyncline, where these Foraminifera now occur in the Semenoff Mountains. This pathway may have been open somewhat before the opening of the Himalayan and Mongolian geosynclines, or migration along this path may have been determined by special physical conditions. As before noted, the Talapai formation indicates that this pathway was probably closed in later Permian time. First, we shall review the deposits of the Tethys going westward, and those of the Himalayan geosyncline from west to east, excepting those of the Salt Range already noted. Then we shall follow these by the other deposits of the Mongolian geosyncline from west to east.

CHAPTER XVI

THE PERMIAN DEPOSITS IN THE TETHYS

INTRODUCTION

ALTHOUGH the Permian deposits of the Tethys, or Ancient Mediterranean Sea, belong in large part to southern Europe, it is, nevertheless, important for an understanding of Permian stratigraphy that we should summarize them here. This is all the more imperative because of the fact, which they help to emphasize, that a large part of the faunal element of these deposits is of eastern origin, marking the southwestward migration of the Indo-Pacific fauna. In this region, however, there is a certain amount of intermingling of boreal elements, thus making the fauna a more complex one. Finally, there may be an endemic element in this fauna, though in the present state of our knowledge it may not be possible to evaluate it. We shall begin with the sections in the eastern region, that of Darvas in Bokhara, and continue westward to the western end of the Tethys.

THE DARVAS SECTION

In the Darvas Mountains of Bokhara, we find a great series of limestones resting unconformably upon the pre-Devonian rocks and representing the Carboniferous and Permian series. Lower Carboniferous or Dinantian is entirely wanting, as is also the entire Middle and at least a part of the Upper Carboniferous.

Safeddaron beds:—The lower part of the series is formed by the Safeddaron beds, which consist mainly of light gray, occasionally dark Fusulina limestone of considerable thickness. The Foraminifera are frequently rock-forming, and in comparison with them, the other fossils occupy a subordinate position. From the collections made by Edelstein (1908), the following species of Foraminifera have been identified by Dyhrenfurth (1909):

Fusulina contracta Schellwien, *Fusulina vulgaris* Schellwien var. *globosa* Schellwien, var. *fusiformis* Schellwien, var. *exigua* Schellwien and *Fusulina kraffti* Schellwien.

The brachiopods have been described by Tschernyschew (1914), but the remainder of the fauna is still undescribed.

The species in common between this horizon and the Jisu Honguer limestone are shown in Table II, page 377. Tschernyschew gives a table to the distribution of the Darvas species in the more important Upper Palæozoic horizons, including the Ural, Timan, and the Salt Range. From this we may draw the following summary. The total number of brachiopods in the Safeddaron formation is forty-three species. Of these, twenty-two, or 51 per cent., occur in the Schwagerina limestone of Russia. Eight, or 18.6 per cent., in the Cora beds, and five, or 11.6 per cent., in the Omphalotrochus beds. Most of the species which occur in the Omphalotrochus or Cora beds, however, occur also in the Schwagerina beds. The species which occur in the Cora and Omphalotrochus beds are mostly long-lived, as well as widely distributed species.

Four of the species range from the Omphalotrochus to the later Permian beds. One occurs in the Omphalotrochus and Schwagerina, one ranges from the Cora to the later Permian, and three occur in both the Cora and Schwagerina beds. Of the remainder, two occur in the Schwagerina and higher beds, one is confined to the higher beds, and the remainder occur only in the Schwagerina limestone.

Compared with the fauna of the Productus limestone, we find that two of the Safeddaron species or 4.65 per cent., occur in the Lower Productus limestone only. Seven, or 16.3 per cent., occur in the Middle Productus limestone only, and one is known from the Upper Productus limestone only. One ranges from the middle to the upper, and one ranges through all three divisions, thus making ten in all, or 23.30 per cent., of the Darvas species found in India, as compared with thirty-one, or 72 per cent., found in northeastern Russia. Seven of the forty-three Safeddaron species or 16.3 per cent., of that fauna, occur in the Jisu Honguer limestone of Mongolia. Thus the relationship of the Safeddaron fauna is much closer to that of the Russian deposits, especially to that of the Schwagerina limestone, and even to that of the Productus limestone, than to the Jisu Honguer limestone. Its relationship is closer with the Middle Productus limestone than to the other members. *Schwagerina* is absent, but *Fusulina* is represented by six species or varieties.

Obirawnou series:—The Safeddaron series is followed by a great series of marly and sandy calcareous sediments with alternating beds of tuffs; frequently with Fusulinas, and with conglomerates and sandstones and clays. Slate and gypsum predominate in the upper part. The highest members are sandstones, with mollusks, brachiopods and bryozoans (*Mypophoria darvasana*, *Clidophorus* sp., *Avicula* sp., *Martinia kraffti* (?) and *Spirifera* sp.). An impression of a Ceratite, referable to *Medlicottia* or to *Propinacoceras*, was found in a pebble in Tertiary conglomerate, having probably been derived from these beds. The lower part (Lower Obirawnou division) contains a rich fauna of Fusulinas, bryozoans, corals, cephalopods and brachiopods. Eleven species of brachiopods have been described by Tschernyschew. One of these, *Orthotychia morganiana*, occurs in the Schwagerina limestone and is represented by a variety in the Middle Permian of China. A second, *Dielasma elongata*, ranges from the Schwagerina limestone into the overlying higher Permian series, while a third, *Productus lineatus*, ranges in the Ural-Timan region, from the Cora beds to the higher Permian.

Two of the Obirawnou species are, in India, confined to the Middle Productus limestone. These are *Dielasma elongatum* and *Lyttonia nobilis*. One of the species of these higher Darvas beds, namely, *Productus gratiosus* Waagen, ranges from the upper to the Middle Productus limestone, and one, *Productus lineatus*, ranges from the Upper to the Lower Productus limestone.

Compared with the fauna of the Jisu Honguer limestone, Mongolia, we find that it and the Obirawnou formation have only four species in common. These are shown in Table II.

The Obirawnou formation is succeeded by Triassic strata, representing the Scythian division. The beds are concordant, but there is probably a disconformity and a hiatus, representing a time interval of unknown length.

Before continuing with the section farther east, we may briefly note several localities farther west, which have some significance in this connection. These are: the Elburz Mountains of Persia, the Djulfa region, the eastern Alps, the Sosio region of Sicily, and the western end of the Tethys.

THE ELBURZ MOUNTAINS REGION

In the eastern Elburz Mountains of Persia, Tietze found Schwagerina limestone at Sahra-i-Mudchen near Shahrud. From those beds Moeller determined *Schwagerina princeps* Ehrenberg, *Fusulina* cf. *verneuili* Moeller, *Tetrataxis conica*, and *Fusulinella sphærica* Abich. With these occurs *Productus semireticulatus*. This appears to be the Schwagerina limestone fauna. These beds rest apparently on Lower Carboniferous (Dinantian) beds.

THE DJULFA SECTION

About 8 kilometers west of Djulfa, a series of fine exposures of the late Palæozoic and the early Mesozoic beds are seen in the gorge of the Araxes River, which here forms the boundary between Russia and Armenia.

The Upper Palæozoic beds comprise a series of marly limestones, which contain a fauna that in character is intermediate between the Indian and European Permian. These beds have been called the DJULFA BEDS, and have been referred to the lower Neo-dyas, or approximately the Middle Permian, comparable to the Zechstein of Europe and the Upper Productus limestone of India. The fauna consists largely of brachiopods and mollusks, especially cephalopods, of which more than half the number appear to be peculiar to the

Permian. In the fauna listed by Frech (1902) there are twenty-seven brachiopods. Of these, sixteen, or 59.26 per cent., are either found in the Productus limestone, chiefly the upper and lower, or are represented there by related forms. There are a number of species connected with those of the Sosio series of Sicily, the Bellerophon limestone of the Southern Alps, and the Zechstein formation of Germany. Only four of the brachiopods, or about 15 per cent. of the total, are found in the Jisu Honguer limestone. The peculiarity of the fauna may indicate a distinct horizon, and it is not impossible that we have here a very late Permian fauna, which may be the time equivalent of the Tartarian stage of Russia, and which may have existed also in the Himalayan region in formations which were removed again by erosion during the Permo-Triassic interval.

THE CRIMEA

Still farther west, at Simferopol in the Crimea, limestones with *Schwagerina princeps* are known, forming the connection between the Persian and the eastern Alps region. It is of course possible that the Simferopol region is an extension of the Donetz basin region, which lies a comparatively short distance to the northeast. Indeed it is not impossible that that was the line of connection between the Russian basin and the Alpine region to the west, which would explain the absence of the Schwagerina horizon in the Araxes valley region, should such on further investigation be found to be the case.

THE EASTERN ALPS

In the Carnic Alps of the Tyrol, and the Karawanken range of the Ukraine, the Upper Palæozoic beds are preserved in infaulted erosion remnants. The general classification of these beds in this region is as follows:

Superformation:

Triassic, Werfen beds.
(Probable disconformity and hiatus, though possible continuity of deposition).

Permian Series:

Bellerophon limestone series.
Grödener series.

Disconformity and Hiatus (with local faulting and lava flows)

Trogkofel beds (Artinskian, probably in part Uralian).
Schwagerina beds.
Auernigg beds (in part at least representing Gschellian and Lower Uralian, with a thickness of 280–300 meters.)

Hiatus and Unconformity

SUBFORMATION:

Older Palæozoic (folded and eroded strata, ranging from Ordovician to Dinantian).

Auernigg beds.—These are typically developed in the Auernigg Alps and in the "Krone" in the Carnic Alps. The classical sections lie a short distance west of Pontafel about longitude 13° 18′ East, latitude 46° 30′ North.

The basal beds are not well exposed, but apparently begin with heavy conglomerates, resting on an old erosion surface. This is followed by a series of quartzites, shales, etc., of no great thickness, which in turn are succeeded by thick graywacke shales, with a rich brachiopod fauna. This is bed No. 6 of the section of the Krone given by Suess, and it is from this bed and the so-called *Spirifer bed* of the Auernigg Alps, which is regarded as its equivalent, that the brachiopods described by Schellwien (1892) from this region were largely obtained. The actual position of the Spirifer bed in the Auernigg section has not been located, but Schellwien believes that it lies below the heavy conglomerate (bed *a*, 60 meters) with which Frech's Auernigg section begins. The following are the definitely identified species from these beds:

1, *Marginifera pusilla* Schellwien; 2, *Productus lineatus* Waagen; 3, *Productus cancriniformis* Tschernyschew; 4, *Productus semireticulatus* Martin; 5, var. *bathykolpos;* 6, *Productus gratiosus* var. *occidentalis* Schellwien; 7, *Productus longispinus* Sowerby; 8, *Productus aculeatus* Martin var.; 9, *Productus curvirostris* Schellwien; 10, *Chonetes papilionacea* var. *rarispina* Schellwien; 11, *Chonetes lobata* Schellwien; 12, *Chonetes latesinuata* Schellwien; 13, *Chonetes obtusa* Schellwien; 14, *Orthothetes semiplanus* Waagen; 15, *Derbya waageni* Schellwien; 16, *Derbya expansa* Schellwien; 17, *Rhipidomella pecosi* Marcou; 18, *Enteletes kayseri* Waagen; 19, *Enteletes carnicus* Schellwien; 20, *Reticularia lineata* Martin (probably *Squamularia asiatica* Chao); 21, *Martinia semiplana* Waagen; 22, *Martinia frechi* Schellwien (?); 23, *Martinia carinthiaca* Schellwien; 24, *Spirifer fasciger* Keyserling; 25, *Spirifer fritschi* Schellwien; 26, *Spirifer carnicus* Schellwien; 27, *Spirifer zitteli* Schellwien and variety; 28, *Spiriferina coronæ* Schellwien; 29, *Camarophoria alpina* Schellwien; 30, *Rhynchonella confinensis* Schellwien; 31, *Rhynchonella grandirostris* Schellwien; 32, *Dielasma toulai* Schellwien.

Few of these are eastern forms. No. 2 occurs in the Lower, Middle and Upper Productus limestones, No. 5 in the Lower, No. 14 in the Upper, No. 17 in the Lower, No. 18 in the Middle, No. 20 in the Lower, No. 21 in the Middle, No. 24 in all three. Of these, Nos. 17, 20 and 24 are of little significance in this connection.

The typical Auernigg section begins with a heavy conglomerate, 60 meters in thickness, which is believed to overlie the Spirifer bed, followed by beds which are roughly divisible into four groups, two chiefly marine and two chiefly continental. Including with this the lower beds just mentioned, we have the following six groups in descending order.

6. Upper Marine Series:

Or main Fusulina bed. (Bed s of Frech's section). . . . . 8 meters.

5. Upper Continental Series:

Shales with some Fusulina limestone, conglomerates and clays, shales and graywackes, with plant remains (*Calamites*, *Pecopteris*, *Sigillaria*). (Beds o to r of Frech) . . . . 42 meters.

4. Middle Marine Series:

Or Lower Fusulina limestone, consisting, in descending order, of:
Bed n. Conocardium bed . . . . 10 meters.
Bed m. Graywacke and shale . . . . 8 meters.
Bed l. Dark Fusulina limestone . . . . 8 meters.
Beds h to r. Shales, Fusulina limestone and conglomerates . . 43 meters.
Bed g. Dark Fusulina limestone and Fusulina shale in upper part . . . . 6 meters.
Total g to n . . . . 75 meters.

3. Middle Continental Series:

This constitutes the basal part of Frech's section, beginning with a quartz conglomerate (bed *a*, 60 meters), followed by graywackes, cross-bedded sandstone, conglomerates and shales, and by graywackes with plants and some animal remains, and including some subordinate conglomerates (beds a to f of Frech's section) . . . . 150 meters.

2. Lower Marine or Spirifer Bed:

Equals bed 6 of Krone section . . . . ?

1. Lower Continental Series:

Shales, graywackes and basal conglomerate . . . . ?

Among the species obtained from the several beds of this series are the following:

TABLE XIV. FAUNA OF THE AUERNIGG BEDS

		Beds				
		Spirifer bed and bed 6	g	l	n	s
	FORAMINIFERA:					
1	*Fusulina alpina* var. *antiqua* Schellwien	......	×	......	......	......
2	*F. alpina* var. *fragilis* Schellwien	......	......	......	......	×
3	*F. alpina* var. *communis* Schellwien	......	......	×	......	×
4	*F. multiseptata* Schellwien	×	......	......	......	......
5	*F. regularis* Schellwien	......	......	......	......	×
6	*F. incisa* Schellwien	......	......	......	......	×
7	*F. tenuissima* Schellwien	......	......	......	×	......
8	*Fusulinella lævis* Schellwien	......	......	......	......	×
9	*Endothyra* aff. *bowmani* Phillips	......	......	......	......	×
10	*Stacheia polytrematoides* Brady	......	......	......	......	×
11	*Psammophis inversus* Schellwien	......	......	......	......	×
12	*Hemidiscus carnicus* Schellwien	......	......	......	......	×
13	*Textularia textulariformis* Moeller	......	......	......	......	×
14	*Bigenerina elegans* Moeller	......	......	......	......	×
15	*Tetrataxis maxima* Schellwien	......	......	......	......	×
	ANTHOZOA:					
16	*Lonsdaleia floriformis* mut. *carnica* Frech	......	......	......	×	......
	BRACHIOPODA:					
17	*Orthothetes semiplanus* Waagen	×	×	......	......	......
18	*Productus semireticulatus* Martin	×	×	......	......	......
19	*P. lineatus* Waagen	×	×	......	......	......
20	*Chonetes latesinuata* Schellwien	×	×	......	......	......
21	*Spirifer fasciger* Keyserling	×	......	......	×	......
22	*S. trigonalis* Martin var. *lata* Schellwien	......	......	......	×	......
23	*Martinia carinthiaca* Schellwien	×	......	×	×	......
24	*M. frechi* Schellwien	×?	×	......	......	......
25	*Reticularia lineata* Martin (?)	×	......	×	......	......
26	*Athyris* cf. *planosulcata* Phillips	......	......	×	......	......
27	*Rhynchonella grandirostis* Schellwien	×	......	......	×	......
28	*Dielasma? toulai* Schellwien	×	......	......	......	......
29	*D. carinthiacum* Schellwien	......	......	×	......	......

TABLE XIV. FAUNA OF THE AUERNIGG BEDS—(*Continued*)

		Beds				
		Spirifer bed and bed 6	g	l	n	s
	Pelecypoda:					
30	*Conocardium uralicum* Verneuil	....	....	....	×	....
31	*C.* sp.	....	....	....	×	×
	Gastropoda:					
32	*Trachydomia* aff. *wheeleri* Shumard	....	....	....	×	....
33	*Naticopsis* sp.	....	....	×	....	....
34	*Phymatifer pernodosus* Meek	....	....	....	×	....
35	*Macrocheilos* aff. *subulitides* Gemmellaro	....	....	×	....	....
36	*Bellerophon* sp.	....	....	×	×	....
37	*Murchisonia* sp.	....	....	×	×	....
38	*Loxonema* sp.	....	....	×	....	....
	Trilobita:					
39	*Griffithides scitula* Meek	....	....	....	....	×

These Auernigg beds are correlated with the Gschellian or the horizon of *Spirifer supramosquensis* of Russia. Though the number of species in common between this series and the Lower Productus limestone is small, it is probably nevertheless essentially equivalent to it, being the result of the first invasion of the Indo-Pacific waters into the Himalayan geosyncline and the Tethys in late Upper Carboniferous or early Permian time. Many of the species, however, are probably of boreal origin, and others are endemic, being derived from the older Carboniferous faunas of the Russian basin. It is, of course, not impossible that a part of these Auernigg beds represents early Permian and that they are in part equivalent to the Cora beds of the Urals and the sub-Bakhmout beds of the Donetz region.

Schwagerina beds:—This series is not fully exposed in the eastern Alps region, where it has been largely destroyed by subsequent erosion and is now represented chiefly by pebbles and fragments. At Neumarktl in upper Ukrainia, however, it is more or less intact as dark Schwagerina limestone. The foraminiferan fauna of this series comprises the following species: *Schwagerina princeps* Ehrenberg, *Fusulina alpina* var. *communis* Schellwien, *Fusulina multiseptata* Schellwien, *Fusulina tenuissima* Schellwien, *Bigenerina* sp., *Tetrataxis maxima* Schellwien, *Tetrataxis maxima* var. *depressa* Schellwien.

This is probably to be regarded as the exact equivalent of the Schwagerina or Tastuba limestone of the Urals, and the Bakhmout dolomite of the Donetz basin, though at present it is impossible to say how complete the representation is.

Trogkofel series:—This comprises the highest marine beds of the Carnic Alps, being developed as reddish limestones around the Trogkofel Peak, as well as in the Karawanken Mountains of Ukrainia. In some cases these beds are also found included as pebbles in the Triassic conglomerates. The Foraminifera of the Schwagerina beds continue into this division, but with these appear many types not known previously, but equally characteristic of the Sosio limestones of Sicily. Among these is the peculiar brachiopod *Scacchinella*, a genus related to *Richtofenia* and also found in the Sosio limestone of Sicily and the Uralian of the Urals. The fauna likewise shows many affinities with the Artinskian of Russia, this being found especially in the Karawanken ranges. Fredericks (1929), on the other hand, holds that it is more closely related to the Uralian, since many of the species restricted to the Uralian are found in it. That this fauna shows the eastern influence more strongly than the boreal is evident and expectable, and this would explain the closer faunal analogy with the Uralian than with the boreal Artinskian fauna, of which it may nevertheless be the time equivalent. About eighty species have so far been recognized, among which the following are some of the most striking forms:

FORAMINIFERA: *Fusulina regularis* Schellwien, *Fusulina alpina* var. *communis* Schellwien, *Bigenerina elegans* Moeller, *Schwagerina fusulinoides* Schellwien, *Schwagerina princeps* Ehrenberg. ANTHOZOA: *Steinmannia variabilis* Waagen and Wentzel. BRACHIOPODA: *Productus cancrini* Verneuil, †*Productus curvirostris* Schellwien, *Productus gratiosus*, *Productus semireticulatus*, *Productus aculeatus*, *Productus spinulosus*, *Productus cora* d'Orbigny, *Productus cancriniformis* Tschernyschew, †**Chonetes strophomenoides* Waagen, †*Chonetes sinuosus* Schellwien, *Streptorhynchus pelargonatus* Schellwien, ‡*Meekella procera* Schellwien, ‡*Meekella depressa* Schellwien, *Meekella irregularis*, ‡*Geyerella distorta* Schellwien, ‡*Tegulifera deformis* Schellwien, ‡*Scacchinella gigantea* Schellwien, ‡*Camarophoria nucula* Schellwien, **Enteletes œhlerti* Gemmellaro, *Enteletes carnicus* Schellwien, ‡*Enteletes suessi* Schellwien, **Spirifer wynnei* Waagen, †*Spirifer carnicus* Schellwien, †*Spirifer quadriradiatus* Murchison, Verneuil and Keyserling, *Spirifer fasciger*, **Spirifer tibetanus* Diener, *Spirifer supramosquensis* Nikitin, *Spirifer trigonalis*, **Squamularia dieneri* (Gemmellaro), *Squamularia* cf. *asiatica* Chao, **Rhynchonella retifera* Gemmellaro, **Rhynchonella wynnei* Waagen, †*Rhynchonella confinensis* Schellwien, *Notothyris exilis* Gemmellaro, *Hemiptychina* (*Mongolina*) *dieneri* Gemmellaro, *Hemiptychina tschernyschewi* Schellwien, ‡*Hemiptychina carniolica* Schellwien. CEPHALOPODA: **Thalanoceras microdiscus* Gemmellaro, *Popanoceras* sp.

An analysis of this fauna shows, according to Frech, that twenty-one of the eighty species are already known from the older Permian. The more important of these are marked in the preceding list by an asterisk (*). Other new species of *Enteletes*, *Streptorhynchus*, *Meekella*, *Scacchinella*, *Geyerella*, *Spirifer*, *Spiriferella*, *Terebratuloidea*, and *Hemiptychina* have their nearest relatives in the Mediterranean, that is, Sicilian deposits.

Nine of the species have so far been found in the older Permian, especially the Auernigg beds. Some of the more important of these are included in the preceding list, where they are preceded by a dagger (†).

Still other species are isolated and are therefore to be regarded as localized forms. These include the species marked in the preceding list by a double dagger (‡). Finally, there is a considerable number, that is, about thirty species, or 37.5 per cent., which are of little stratigraphic significance, because of their long range. The fauna is in need of revision.

Grödener series:—In the Carnic Alps, the Grödener sandstone rests unconformably on older folded strata, including the Dinantian, while the Auernigg to Trogkofel beds likewise rest unconformably on the same series. It is probable that, between the Grödener sandstone and the Trogkofel beds, there is only a disconformity, and that there was not a second period of folding after the deposition of the Trogkofel beds. Frech says that the interruption at this horizon is characterized more by faultings and massive eruptions than by folding.

The basal part of the Grödener series is formed by a conglomerate containing pebbles of the older rock, with *Schwagerina fusulinoides* and *Fusulina regularis*, both characteristic of the Trogkofel beds. This indicates an erosion interval following the deposition of the Trogkofel beds. This hiatus may represent most of the mid-Permian period, the Grödener series itself probably marking the beginning of Upper Permian time.

The Grödener series admits of the following subdivision in descending order:

3. Grödener Sandstone:—

Heavy-bedded red micaceous sandstones of coarse grain, with subordinate marls, clays and dolomite concretions arranged in layers. Sometimes blue clay and gypsum occur. In the upper part of the series, not far below the horizon of the Bellerophon limestone, a flora has been found among which the most frequent types are the cones (*Carpolithus*) of coniferous trees, branches of *Volzia hungarica* Heer, *Baiera digitata* Heer, *Ullmannia bronni*, and *Ullmannia geinitzi*, besides *Equisetites* and dissociated fish scales.

2. Tregioro Shales:—

Bituminous shales of local development, but reaching in places a thickness of 200 meters. These contain plant remains, including the following:—*Walchia piniformis* Schlotheim, *Walchia filiciformis* Schlotheim, *Ullmannia frumentaria* Schlotheim, *Ullmannia* cf. *selaginoides* Brongniart, *Baiera digitata* Brongniart. This indicates a curious conjunction of species, which are elsewhere distinct, for in Germany *Ullmannia* is characteristic of the Kupferschiefer, and *Walchia* of the Rothliegende. This would place the beds near the top of the latter division.

1. Grödener Conglomerate:—

This contains pebbles of the older formations, including the Trogkofel beds, and locally contains plant-bearing beds with species found in the middle Rothliegende. These include *Walchia piniformis* Schlotheim, *Walchia filiciformis* Schlotheim, *Sphenopteris fasciculata* var. *zwichawiensis* Gutbier, *Sphenopteris* (*Ovopteris*) *oxydata* Goeppert, *Sphenopteris suessi* Geinitz, etc. This conglomerate constitutes the Verrucano of the Italian Alps. In other sections it is replaced by the Borzen quartz-porphyry, or encloses flows of it.

Bellerophon limestone:—This overlies the Grödener sandstones and is covered by the Triassic Werfen sandstone. It consists mostly of dark, bituminous limestone, dolomites, porous dolomites, ash, and gypsum. In the central, western and northern Alps, it is absent as a marine formation and sometimes replaced by gypsum deposits. In general, it corresponds to the Middle and Upper Zechstein.

In the Laibach Plain (about Longitude 14° 30′ East, Latitude 46° 5′ North), the Bellerophon limestone consists of dark limestones and dolomites, the former with sections of *Bellerophon*. In these beds Kossmatt and Schellwien found a fauna of brachiopods, corals and foraminifera, strongly suggesting the Indian Productus limestone fauna. These include the following species: *Richthofenia* cf. *lawrenciana* de Koninck, *Productus indicus* Waagen, *Productus abichi* Waagen, *Marginifera ovalis* Waagen, *Lonsdaleia* (*Waagenophyllum*) *indica* Waagen and Wentzel.

In a highly instructive article on the Bellerophon limestone fauna, Dr. George Caneva of Padua (1906) gives a list of some fifty genera, exclusive of the pelecypods, which he has obtained from this formation. Many of these are new and represented by a large number of species. He considers that the Bellerophon limestone is of Permian age, but because of the peculiarity of the fauna, and the fact that only a few species are identical with the species of the Productus limestone and the Djulfa limestone, though many of them are related types, he considers that the *Bellerophon* fauna is much younger. In this he is undoubtedly correct, but holding to the old idea that the series in the Salt Range is a continuous one, he suggests the possibility that the Bellerophon limestone is the chronological equivalent of the Ceratite limestone of India, which he would therefore place in the Permian.

Recognizing, as we do, the existence of a break and a hiatus in the Indian section, we can readily place the Bellerophon limestone in the higher Permian as a horizon unrepresented in the Indian succession, where the Permo-Triassic hiatus covers a part of the interval. Such higher marine beds are represented by the Maping limestone of south China. Of the general character of the Bellerophon fauna, Caneva says: "The impression which this complex produces leads to the belief that we are dealing here with a fauna which, so to speak, has been directly developed from that of the Orient. It appears to us a declining fauna, a true fauna of the *Fin de Siècle*, and partly a connecting fauna between that of the Orient and that of the European Zechstein, and in part as a fauna heralding the new period." It may be well here to give a list of the species originally described by Stache (1877–1878) from the Bellerophon limestone. Many of these are subject to revision; others have been added since the date of his publication. The complete fauna of this formation still requires monographic treatment. CEPHALOPODA: *Nautilus* (*Metacoceras*) *hœrnesi* Stache, *Nautilus crux* Stache, *Nautilus sebedinus* Stache, *Nautilus* (*Pleuronautilus*) *fugax* Mojsisovics, *Nautilus* sp. GASTROPODA: (Symmetrical forms): *Bellerophon vigilii* Stache, *Bellerophon cadoricus* Stache, *Bellerophon* sp., *Bellerophon jacobi* Stache cf. *hiulcus* Sowerby, *Bellerophon peregrinus* Laube, *Bellerophon ulrici* Stache, *Bellerophon* sp. (Unsymmetrical species): *Bellerophon sextensis* Stache, *Bellerophon gümbeli* Stache, *Bellerophon fallax* Stache, *Bellerophon janus* Stache, *Bellerophon comelicanus* Stache, *Bellerophon pseudohelix* Stache, *Bellerophon mojsvari* Stache, *Pleurotomaria* sp., *Murchisonia tramontana* Stache, *Turbonilla* (*Chemnitzia*) *montis crucis* Stache, *Turbonilla* sp., *Catinella depressa* Gümbel, *Natica comelicana* Stache, *Natica cadorica* Stache (cf. *Natica neritina* Münster), *Natica pusiuncula* Stache. PELECYPODA: *Hinnites crinifer* Stache, *Entolium* (?) *tirolense* Stache, *Vola* (?) *præcursor* Stache, *Pecten pardulus* Stache, *Aviculopecten* cf. *coxanus* Meek and Worthen, *Aviculopecten trinkeri* Stache, *Aviculopecten comelicanus* Stache, *Aviculopecten gümbeli* Stache, *Avicula* (?) *cingulata* Stache, *Avicula* (?) *striatocostata* Stache, *Avicula filosa* Stache, *Avicula* (?) sp., *Bakewellia ladina* cf. *bicarinata* King, *Bakewellia* cf. *ceratophaga* Schlotheim, *Bakewellia* (?) sp., *Gervillia* (?) *peracuta* Stache, *Cassianella?* sp., *Aucella* cf. *hausmanni* Goldfuss (*Mytilus squamosus* Sowerby), *Nucula?* sp., *Nucula* cf. *beyrichi* Schaur, *Nucula?* sp. (new genus?), *Schizodus?* cf. *truncatus* King, *Arca?* sp., *Clidophorus?* sp., *Leptodomus* (*Sanguinolites*) sp., *Anthracosia ladina* Stache, *Cardinia?* sp., *Pleurophorus jacobi* Stache, *Pleurophorus?* sp., *Edmondia* cf. *radiata* Hall, *Edmondia* cf. *rudis* McCoy, *Conocardium?* sp., *Allorisma? tirolense* Stache, *Allorisma?* sp. BRACHIOPODA: *Spirifer vultur* Stache, *Spirifer ladinus* Stache, *Spirifer? insanus* Stache, *Spirifer mega-*

lotis Stache, *Spirifer haueri* Stache, *Spirifer cadoricus* Stache, *Spirifer dissectus* Stache, *Spirifer crux* Stache (cf. *Spirifer striofer* Quenstedt), *Spirifer?* (*Spirigera*) *concors* Stache, *Spirifer sextensis* Stache, *Spirifer?* sp., *Spirigera janiceps* Stache, *Spirigera papilio* Stache, *Spirigera aquilina* Stache, *Spirigera peracuta* Stache, *Spirigera bipartita* Stache, *Spirigera pusilla* Stache, *Spirigera confinalis* Stache, *Spirigera? archimedis* Stache, *Spirifer?* sp., *Spirifer* (*Martinia*) cf. *glaber* Martin, *Spirifer* (*Reticularia*) cf. *lineatus* Martin, *Spirifer* sp., *Spirifer?* cf. *duplicosta* Phillips, *Cyrtia?* sp., *Spirigera? faba* Stache, *Orthis? ladina* Stache, *Streptorhynchus tirolensis* Stache, *Streptorhynchus pichleri* Stache, *Strophomena* sp., *Strophomena* (*Leptæna*) *alpina* Stache, *Productus cadoricus* Stache, *Productus* cf. *cora* d'Orbigny, *Productus?* sp., *Productus stotteri* Stache, *Spirifer? impar* Stache, *Rhynchonella?* sp., *Lingula?* sp.

Other forms cited are: *Diplopora bellerophontis* Rothpletz, *Paraceltites sextensis* Diener, etc.

If our contention that the Tethys became a closed relict sea at the end of Permian time is correct, and that it remained so during the Permo-Triassic interval, when all the epeiric seas and continental shelves were laid bare, we can understand that the fauna of the deposits in this relict sea would not only reappear at the opening of Triassic time in the modified Alpine Triassic fauna, but we can also see a reason for the many peculiarities of these latest of Permian faunas.

THE PERMIAN OF SICILY

In the valley of the Sosio River, in the province of Palermo, several isolated masses of Permian limestone project through the filling of Eocene strata in this valley. These Permian beds show no connection with older or younger formations, but because of their rich fauna they have become a classic deposit. Two divisions are recognizable, as follows:

2. Upper porous limestone (*Calcare grossolano*).
1. Lower white or gray Fusulina limestone (*Calcare compatta*).

Among the many fossils obtained from these deposits the following may be cited: CEPHALOPODA: *Hyattites geinitzi*, *Popanoceras* (*Stacheoceras*) *globosum*, *Popanoceras* (*Stacheoceras*) *karpinskyi*, *Popanoceras* (*Stacheoceras*) *mediterraneum*, *Popanoceras perspectivum*, *Popanoceras daræ*, *Popanoceras tietzei*, *Popanoceras benedictinum*, *Popanoceras* (*Hyattites*) *tugidium* Abich, *Agathiceras suessi*, *Agathiceras kingi*, *Agathiceras distefanoi*, *Agathiceras elegans*, *Agathiceras insigne*, *Agathiceras ensiferum*, *Agathiceras* (*Hoffmannia*) *hoffmanni*, *Medlicottia verneuili*, *Medlicottia bifrons*, *Medlicottia schopeni*, *Medlicottia marcoui*, *Prosageceras beyrichi*, *Prosageceras galilæi*, *Prosageceras affine*, *Prosageceras mojsisovicsi*, *Parapronorites konincki*, *Pronorites* (*Darælites*) *meeki*, *Thalassoceras phillipsi*, *Thalassoceras subreticulatum*, *P. microdiscus*, *Paraceltites hœferi*.

Among the brachiopods may especially be mentioned: *Enteletes waageni* Gemmellaro, *Enteletes tschernyschewi* Gemmellaro, *Enteletes œhlerti* Gemmellaro, *Geyerella gemmellaroi* Schellwien, *Reticularia convexiuscula* Gemmellaro, *Reticularia pulcherrima* Gemmellaro, *Martinia polymorpha* Gemmellaro, *Martinia aviformis* Gemmellaro, *Martinia lamellosus* Gemmellaro, and *Martinia variabilis* Gemmellaro. The last four comprise a group of forms which some authors would unite under the first of the names given. Other brachiopods described by Gemmellaro, but referred by Frech and others to species from Himalayan regions or elsewhere, are: *Uncinulus siculus* Gemmellaro (referred to: *Uncinulus timorensis* Beyrich and *Uncinulus theobaldi* Waagen), *Camarophoria acuminata* Gemmellaro (referred to *Camarophoria humbletonensis* House and *Camarophoria multiplicata* King), *Martinia semiramis* Gemmellaro (referred to *Martinia acutomarginalis* Diener), *Martinia cornelia* Gemmellaro (referred to *Martinia acutomarginalis* Diener), *Martinia distefanoi* Gemmellaro (referred to *Martinia elegans* Diener), *Martinia acuminata*, Gemmellaro (referred to *Martinia? elegans* Diener), *Martinia rupicola* Gemmellaro (referred to *Martinia ? nucula* Rothpletz), *Reticularia affinis* Gemmellaro (referred to *Reticularia waageni* Loczy), *Spirifer siculus* Gemmellaro (referred to *Spirifer wynnei* Waagen), *Enteletes elegans* Gemmellaro (referred to *Enteletes tschernyschewi* Diener, non Gemmellaro); also *Richthofenia communis* Gemmellaro and *Richthofenia sicula* Gemmellaro. It may be remarked here that there is not much virtue in uniting forms which show palpable differences of character, unless this is done on a genetic basis, when the progress of modification in one or more directions should be indicated. Even then it is best to distinguish the various modifications by mutational names. Frech's work is not specially characterized by painstaking attention to genetic principles, having too much of an autocratic flavor, and until these Sosio forms have been restudied after modern methods, it is just as well to keep Gemmellaro's names for the various modifications. Altogether Gemmellaro has described over 83 species of brachiopods, 48 species, of pelecypods (7 in the lower and 45 in the upper horizon), 79 species of gastropods (29 in the lower and 63 in the upper horizon), and 72 species of cephalopods, most of them from the lower horizon.

THE WESTERN END OF THE TETHYS

The westernmost exposure of the marine Permian in the Tethys basin is known from the Pyrenees of Ariege in southern France (Caralp, 1903). At Saint Girons, Carboniferous shales without fossils are concordantly followed by Permian beds which comprise in ascending order the following members:

1. a. Fossiliferous non-calcareous shales and argillites of vivid green color, weathering into a yellow clay. These are characterized by ammonoids, crinoids, and brachiopods; thickness 30–35 meters.

1\. b. Brownish to grayish sandstones, the quartz grains often cemented by calcareous cement and yielding as high as 24 per cent. $CaCO_3$.

1\. c. Greenish shales and argillites, locally reddish with small calcareous nodules; percentage of $CaCO_3$ ranges from 0 to 30.

Thickness of b and c exposed, about 50 meters. This is unconformably succeeded by Middle Permian beds, which in ascending order comprise the following:

2\. a. Sandstones and conglomerates 7–8 meters thick.

2\. b. Reddish shales and marls, 10 meters thick, followed by greenish-gray micaceous beds half a meter in thickness.

2\. c. Red clays and marls 20–30 meters. These beds are covered unconformably by the Triassic, the Upper Permian being absent though developed elsewhere. All the beds except 1 a appear to be of continental type, but this lowest division, which may be designated the SAINT GIRONS SERIES, contains a poorly preserved fauna found in this as well as in other localities. This fauna includes the following recognized species:

Daraëlites sp. aff. *Daraëlites meeki* Gemmellaro (Sicily), *Daraëlites* sp. 2.
Gastrioceras sp. 1. cf. *Gastrioceras zitteli* Gemmellaro (Sicily).
Gastrioceras sp. 2. cf. *Gastrioceras sosiense* Gemmellaro (Sicily).
Gastrioceras sp. 3. aff. *Gastrioceras suessi* Karpinsky (Artinskian of Russia).
Gastrioceras sp. 4. aff. *Gastrioceras rœmeri* Gemmellaro (Sicily).
Pronorites sp. cf. *Pronorites ouraliensis* Karpinsky (Artinskian of Russia).
Agathiceras cf. *suessi* Gemmellaro (Sicily).
Adrianites cf. *haueri* Gemmellaro (Sicily).
Thalassoceras sp.
Paraceltites sp.

In addition to these there are species of *Paraceltites*, *Gastrioceras* and *Daraëlites* unlike those of Sicily or the Artinskian of the Urals. Other types represented are a species of *Griffithides*, a large *Euomphalus*, and several of *Leiopteria*. According to Haug, the Artinskian age of these beds is established. No other marine Permian faunas are known from this part of France or from the Iberian peninsula; nor are any known from northwestern Africa. It is highly probable that the Tethys basin was closed on the west by land in Permian time, this being either a part of the continent of Atlantica or the eastern end of the Appalachian old-land of North America, if Wegener's contention that Europe and America were one continental mass at that time is correct. The presence of a land-mass is indicated by the fact that the Permian of the western end of the Tethys is represented by red sandstones and plant-bearing beds, and that in many cases the Middle Permian continental beds lie unconformably upon the folded older Palæozoic. Such conditions are found in Andalusia, while in the Atlas Mountains of Morocco, a great series of red beds lies discordantly on Carboniferous or older Palæozoic formations. If this interpretation is correct, it follows that the Permian fauna of the Tethys is derived in part from the Indo-Pacific Ocean and in part from the Boreal Ocean, the Atlantic Ocean, if it existed at that time, furnishing no contribution. A part of the fauna is of course endemic, being developed from preëxisting Carboniferous faunas of the Russian basin and elsewhere.

On the whole, Middle and Upper Carboniferous formations play only a small part in the deposits formed in the Tethys and Himalayan geosyncline. Only the late Upper Carboniferous beds are present in this zone, these resting as a rule unconformably upon Dinantian or older beds. It thus appears that the first invasion of the Indo-Pacific waters, with their distinctive fauna, occurred in late Upper Carboniferous time and became dominant in the Lower Permian, when the Schwagerina limestone of the Tethys, of the Russian basin, of the central Asiatic region, and of China was formed. In Artinskian time, the boreal influence was again marked and continued so through Kungurian time, after which there occurred a widespread disturbance which affected especially the Tethys region, where it was accompanied by the outpouring of igneous material. In the Russian basin, on the other hand, it was largely marked by the contraction of the seas and the formation of gypsum. In the eastern Alps the disturbance was mainly faulting followed by erosion, but farther west actual folding took place. This was followed by the continental sedimentation of the Grödener beds and the final expansion of the relict sea in which the *Bellerophon* fauna was developing.

We will next turn our attention eastward and review some of the other important sections of the Himalayan geosyncline.

CHAPTER XVII

THE PERMIAN OF OTHER SECTIONS OF THE HIMALAYAN GEOSYNCLINE

INTRODUCTION

Although the Salt Range section is the best-known and most important of those studied in the Himalayan geosyncline, there are a number of others, extending from Kashmir on the west to Burma on the east, which are of significance in this study. They will be considered here *a seriatim*, beginning in the west.

THE KASHMIR DISTRICT

In the mountains of Kashmir the following section has been determined by the geologists of the Indian Survey at Zewan:

SUPERFORMATION:

Meekoceras beds of the Lower Triassic.

Hiatus and Disconformity

PERMIAN SERIES:

ZEWAN SERIES:..490 feet.

4. *Xenaspis carbonaria zone:* Shales and thin-bedded limestone ....100 feet.
3. *Marginifera himalayensis zone:* Dark arenaceous shales, micaceous and carbonaceous, with limestone intercalations at the base ....300 feet.
2. *Protoretepora zone:* Shales and limestones..............30 feet.
1. *Hemiptychina zone:* Dark-gray limestone with shaly partings ....60 feet.

GANGAMOPTERIS BEDS:..800 feet.

Shales and sandstones with a basal conglomerate. Near the middle of the series, a bed enclosing remains of the Lower Gondwana flora with species of *Glossopteris*, *Psygmophyllum*, *Gangamopteris*, *Vertebraria*, etc., and with fish remains (*Amblypterus*) and labyrinthodonts (*Archægosaurus*). These beds are correlated with the Talchir glacial formation of the Salt Range.

Disconformity

CARBONIFEROUS SERIES:

UPPER CARBONIFEROUS: . . . . ?

PANJAL, VOLCANIC SERIES:

Panjal traps . . . . several thousand feet.
Panjal pyroclastic slates (agglomerate slates) . . . . several thousand feet.

MIDDLE CARBONIFEROUS:

MOSCOVIAN?

Fenestella shales . . . . 2000 feet.

Probable Hiatus and Disconformity

LOWER CARBONIFEROUS:

LOWER DINANTIAN.

Syringothyris limestone series . . . . 1000 feet.

Hiatus and Disconformity

SUBFORMATION:

Muth quartzite (Silurian?) . . . . 3000 feet.

The Zewan series is the essential equivalent of the Middle and Upper Productus limestone of the Salt Range.

(1). The lowest division is characterized by *Hemiptychina himalayensis*, *Productus purdoni*, *Productus cora*, *Spirifer moosakhailensis*, etc.
(2). The second zone is so named from the abundance of the bryozoan *Protoretepora ampla* Lonsdale. It contains *Lyttonia nobilis* and some other brachiopods.
(3). The third zone, characterized throughout by *Marginifera himalayensis*, is divisible into three subzones as follows, beginning with the lowest:
    (3a). Subzone of *Productus indicus*. Chiefly limestones, characterized by the predominance of *Producti* belonging to the *semireticulatus* group. Among other species characteristic of this division are: *Productus abichi* Waagen, *Productus cancrini* de Verneuil,

Productus cf. *cancriniformis* Tschernyschew, *Marginifera himalayensis* Diener, *Spirifer rajah* Diener, *Athyris royssii* Léveillé, *Camarophoria purdoni* Davidson, *Dielasma biplex* Waagen, *Dielasma acutangulum* Diener, *Hemiptychina himalayensis* Waagen, etc.

(3b). Main *Marginifera* subzone. The chief character of this subzone is the absence of the *Productus* of the *semireticulatus* group. Among the characteristic species are: **Productus waagenianus* Girty, *Productus abichi* Waagen, *Productus gangeticus* Diener, **Marginifera himalayensis* Diener, *Lyttonia nobilis* Waagen, *Spirifer fasciger* Keyserling, **Spirifer rajah* Salter, *Spiriferina fastigata*, and *Camarophoria purdoni* Davidson.

The three leading species of this zone are indicated by an asterisk (*).

(3c). Subzone of *Spirifer rajah*. This species predominates, though it is by no means restricted to the zone. *Spirifer fasciger*, *Productus abichi* and *Productus gangeticus* are other species present.

(4). The highest zone of the Zewan series is that of *Xenaspis carbonaria*. It is quite distinct from those underlying it, and besides the zone fossil it contains many pelecypods, though the species of *Productus* from the lower zone, as well as *Marginifera himalayensis* and other types, continue into it. Among the brachiopods, *Productus waagenianus* Girty is especially noteworthy, being characteristic of the Guadalupian Permian fauna of Texas, from which it was first described. The peculiar character of this fauna is the total absence of *Fusulina*, though these occur in the Salt Range and in the Permian beds of Afghanistan and Burma. Corals are rare, but crinoids are well represented by their stem joints.

Taking the brachiopod fauna of the Zewan beds as a whole, we find that eighteen out of thirty-four species, or about 53 per cent., also occur in the Salt Range, two of them only in the Lower Productus limestone and sixteen in the Middle and Upper Productus limestone. Sixteen species, or 47 per cent. of the brachiopod element, is new. This includes such typical species of the fauna as *Dielasma latouchii* Diener, *Spirifer nitiensis* Diener, *Spirifer rajah* Salter, *Chonetes limarensis* Diener, and *Marginifera himalayensis* Diener, all of which are also found in the Productus shales (including the Kuling shales) of the central Himalayas. It is not impossible that the Zewan series presents a somewhat higher horizon than even the Upper Productus limestone, to which, however, it may be in part equivalent. Some of the lower beds of the Salt Range are those represented in Kashmir by the non-marine Gangamopteris beds.

THE SPITI REGION

Lipak series:—The most complete development of late Palæozoic beds known in the Himalayan Mountains is found at Spiti in the northwestern part of the range, near the Tibetan border. In the vicinity of Muth, where the pre-Carboniferous Muth quartzite has a thickness of about 500 feet, it is followed by a few hundred feet of gray flaggy limestones, the Lipak series and this in turn is followed by the Kuling shales, which consist of a great series of shales and sandstones with a fauna of Permian age essentially equivalent to that of the Productus shales of the central Himalaya. Between the Kuling shales and the flaggy limestone is a pronounced disconformity, the higher series beginning with a thin bed of conglomerates.

Kuling shales:—Three divisions have been recognized in the Kuling series as follows:

C. Black shales, with limestone partings (Productus shales or Kuling shales proper).
B. Calcareous sandstone.
A. Unfossiliferous grits and conglomerates.

Disconformity

SUBFORMATION:

P_0 series or Lipak limestones.

The Kuling shale is succeeded by the Otoceras beds of the Triassic, from which they are probably separated by a hiatus, though sedimentation appears to be uninterrupted.[1]

The calcareous sandstone (B) has a fauna rich in number of individuals, though poor in species. The following have been definitely identified. Those also occurring in the Productus shales of Byans or the Lyssar valley are preceded by an asterisk (*), and those occurring in the Zewan beds are preceded by a dagger (†). Other notations are P_1, P_2, P_3—Lower, Middle, and Upper Productus limestones, respectively; P, higher Permian beds of Russia.

BRACHIOPODA:

1. *†*Dielasma latouchi* Diener
2. *†*Athyris gerardi* Diener
3. *Spirifer marcoui* Waagen (P_1–P_2)
4. *†*Spirifer moosakhailensis* Davidson (P_{1-3})
5. **Spirifer nitiensis* Diener
6. *Spirifer distefanoi* Gemmellaro

[1] This question has been discussed at length in my Stratigraphy of China, Pt. II, Chapter X.

7. *Streptorhynchus* cf. *pectiniformis* (Davidson) (P_2–P_3)
8. *Aulosteges* cf. *gigas* Netschajew (P)
9. *Oxytoma laticostatum* Netschajew (P)

Only two species, Nos. 2 and 7, are typical Productus limestone species, the third, No. 4, being equally characteristic of the Productus shales and the Zewan beds, to both of which this fauna is more closely related than to the Productus limestone of the Salt Range. Noteworthy are the two elements of the higher Russian Permian, Nos. 8 and 9.

The Kuling shale proper (C) contains a more numerous fauna, of which two species, *Marginifera himalayensis* Diener and *Spirifer rajah* Salter, are the most abundant and characteristic, these being, moreover, widely distributed species, as they, or closely allied forms, occur in the Jisu Honguer limestone. The following is a list of the species obtained from these shales, the notations being the same as in the preceding list:

BRACHIOPODA:

1. *†*Athyris gerardi* Diener
2. *Athyris proteus* var. *alatus* Abich
3. *†*Spirifer moosakhailensis* Davidson (P_{1-3})
4. *†*Spirifer rajah* Salter
5. *†*Chonetes lissarensis* Diener
6. *†*Productus* cf. *gangeticus* Diener
7. *†*Marginifera himalayensis* Diener

PELECYPODA:

8. *Modiolopsis teplofi* Verneuil (P)
9. *Solemya biarmica* Verneuil (P)
10. *Conocardium* aff. *secula* Gemmellaro
11. *Oxytoma laticostatum* Netschajew (P)
12. *Goniomya* aff. *kasanensis* Gemmellaro
13. *Myophoria kraffti* Diener

GASTROPODA:

14. *Bellerophon* cf. *vigilii* Stache

CEPHALOPODA:

15. *Cyclolobus* cf. *oldhami* Waagen (P_3)
16. †*Xenaspis* cf. *carbonaria* Waagen (P_3) Chitichun
17. *Cyclolobus insignis* Diener
18. *Cyclolobus* (*Krafftoceras*) *kraffti* Diener
19. *Cyclolobus* (*Krafftoceras*) *haydeni* Diener

Aside from *Spirifer moosakhailensis* and the two cephalopods, which are not positively identified (Nos. 15 and 16), this fauna shows no relationship to the Productus limestones of the Salt Range, but appears to be a younger fauna. Its relationship to the fauna of the Productus shales of the central Himalayas and to that of the Zewan beds is evident in the brachiopods, while the pelecypods show the presence of the higher Permian element of the Russian basin. It also has some affinities with the Maping limestone of south China.

In other sections of this region, the Kuling shale is disconformably preceded by the P_0 series of grits and conglomerates, passing down into several alternating shales and quartzites. In the lower Spiti valley, where the flaggy limestones (Lipak series) and the Muth quartzite are not exposed, this section has a thickness of at least 3,000 feet and perhaps much greater.

Three fossiliferous horizons are recognized in the P_0 series. These are situated respectively at about 500, 1,000 and 1,500 feet below the Kuling series. The upper two are called the Fenestella beds, because of the abundance of that bryozoan, while the lowest or *Thabo* division contains only undeterminable plant remains.

From the Fenestella beds, the following definitely identified species have been obtained: *Productus undatus* Defrance, *Productus scabriculus* Martin, and var. *spitiensis* Diener, *Productus nystianus* var. *lopingensis* Keyserling, and *Protoretepora ampla* Lonsdale. *Productus nystianus* var. *lopingensis* was originally described from the Permian Loping beds of China, and it is probable that the P_0 series is in part of early Permian age, though a part of it may represent the Middle Carboniferous, mainly in continental phase. The underlying Lipak series abounds in Dinantian fossils.

In Johar and Painranda, the Lyssar valley, and Byans, the Kuling shales are represented by the Productus shales.

SECTION IN LYSSAR GANGA AND DHARMA GANGA, CENTRAL HIMALAYAS

The following section of the Productus shales of the Lyssar and Dharma valleys is given by Diener (1897, Vol. I, Pt. 4, page 4).

SUPERFORMATION, LOWER TRIASSIC:

Dark limestones in thin beds, with dark shales alternating, fossils of the *Otoceras* stage.

Hiatus and Disconformity

PRODUCTUS SHALES:..185 feet.

i. Black crumbling shales, with ferruginous concretions in irregular partings..85 feet.

h. Micaceous and calcareous sandstone with fucoid markings, with shaly partings and irregular thickness, about .... 2 feet.
g. Micaceous dark shales, which weather in bright colors, with ferruginous concretions; shales show fucoid markings .... 7 feet.
f. Same as h; with brachiopods .... 3 feet.
e. Micaceous dark shales, which weather in bright colors, with ferruginous concretions; shales show fucoid markings ...... 51 feet.
d. Dark limestone with indistinct plant remains .... 8 inches.
c. Dark micaceous shales, with fucoid impressions .... 26 feet.
b. Argillaceous limestone in thicker beds .... 8 feet.
a. Earthy shales with fucoid impressions .... 3 feet.

CARBONIFEROUS (?):

WHITE QUARTZITE SERIES.

The fauna of these Productus shales includes the following species, those preceded by an asterisk (*) also being known from the Kuling shales or (and) the calcareous sandstone underlying them, while those preceded by a dagger (†) also occur in the Zewan beds.

FAUNA OF THE PRODUCTUS SHALES OF BYANS AND THE LYSSAR VALLEY

BRACHIOPODA:

1. *†*Dielasma latouchei* Diener
2. *†*?Athyris gerardi* Diener
3. *†*Spirifer moosakhailensis* Davidson (P_{1-3})
4. *†*Spirifer nitiensis* Diener
5. *†*Spirifer rajah* Salter
6. *Spirifer* cf. *ravana* Diener
7. *Spirifer bambahurensis* Diener
8. *Spirifer joharensis* Diener
9. *†*Chonetes lissarensis* Diener
10. *Chonetes* cf. *uralica* Moeller
11. †*Productus cancriniformis* Tschernyschew (P)
12. *†*Productus* cf. *gangeticus* Diener
13. †*Productus* cf. *purdoni* Davidson (P_2–P_3)
14. *†*Marginifera himalayensis* Diener

PELECYPODA:

15. *Liebea* aff. *hausmanni* Goldfuss

GASTROPODA:

16. *Pleurotomaria* cf. *punjabica* Waagen (P_{1-3})

CEPHALOPODA:

17. *Hyattoceras* aff. *cumminsi* White
18. *Gastrioceras* aff. *marianum* Verneuil
19. *Nomismoceras smithi* Diener

Aside then from the species peculiar to these beds, the fauna of the Productus shales is that of the Kuling shales and Zewan beds, and, like these, probably represents a younger horizon than the Productus limestones of the Salt Range, corresponding probably to the Kama (typical Permian) series of the east Russian region, and the Maping limestone of China in part, while the Middle and Upper Productus limestones correspond to the Schwagerina, Artinskian and perhaps Kungurian.

PERMIAN BEDS OF BURMA

Permian rocks are known from the Shan states of Burma, where they constitute the Upper Plateau limestone which rests disconformably on Eifelian beds of the Devonian. The Upper Plateau limestone is partly dolomitic and brecciated and in the main unfossiliferous. It is disconformably followed by the Napeng beds of Rhætic age. The lower part of the limestone may include beds of Dinantian age, but the greater part is probably Permian. The fossils, which have been found at four different localities, represent approximately the horizon of the Middle and Upper Productus limestone of the Salt Range. Out of forty-seven species definitely determined, thirty, or about 64 per cent., are identical with, or closely allied to, the species found in the Salt Range. These include such characteristic forms as *Waagenophyllum indica* (Waagen and Wentzel), *Oldhamina decipiens* de Koninck, *Chonetes grandicosta* Waagen, etc. The fauna is clearly a part of the Himalayan unit. The Permian of China and Indo-China has already been discussed.

CHAPTER XVIII

OTHER PERMIAN DEPOSITS OF THE MONGOLIAN GEOSYNCLINE

INTRODUCTION

Although Lower Carboniferous beds, abounding in marine organisms, are found in a number of localities throughout the Mongolian geosyncline, Permian beds with marine faunas were scarcely known before the discovery of the Jisu Honguer limestone, except in the extreme eastern or Vladivostok portion of the geosyncline, and one or two scattered localities in the west. Continental beds of Permian age are, however, widespread in this region and they belong to the graywacke series described by Berkey and Morris in Volume II of this set. The basal part of these continental Permian beds often contains marine intercalations, with a more or less depauperate fauna, which has frequently been referred to the Carboniferous, but which, from the association of Permian plants, must be regarded as Permian. Thus in Mongolia as in south China, and in many parts of the Tethys, there is a pronounced hiatus between the Lower Carboniferous and the Permian, involving the whole of the Middle and Upper Carboniferous, which as we have seen is most typically developed in the Donetz region of Russia.

THE KIRGHIZ STEPPES

We will begin our discussion of the deposits of this geosyncline with those of the Kirghiz Steppe, which forms the western end of this geosyncline. The facts have largely been brought together by Obrutschew in his important and timely work "Geologie von Sibirien."

The Lower Carboniferous marine limestones of this region are mostly referable to the Tournaisian. They are disconformably succeeded by coal-bearing shales and sandstones, with a Permian flora, including *Neuroganga-mopteris cardiopteroides*, *Lepidodendron kirghisicum* Zalessky and *Cœnodendron primævum* Zalessky, which show their relationship to the Kusnezk flora.

In the Manrak range and the adjoining region of the Mongolian border, the succession, according to Stoyanow, is as follows in descending order.

PERMIAN BEDS:

3. Extensive flows of gray aphanite.
2. White, yellow, gray, brown and reddish tuffites, sandstones, sometimes with poorly preserved plant remains, alternating with clayey sandstones and containing a coal-bearing horizon 15 meters thick, with the following plant remains: *Neurogangamopteris cardiopteroides*, *Rhacopteris potanini*, and *Noeggerathiopsis æqualis*. Elsewhere this horizon contains conglomerates, coarse sandstones, quartzites and sandy shales sometimes with coal beds. These contain, in addition to the above species, *Dicranophyllum lusitanicum* and *Phyllotheca*. East of Saissan, black shales with concretions, probably of this horizon, contain well-preserved fish remains of the genus *Acrolepis*, associated with the above-mentioned plants.
1. Light oölites, with *Posidionella elongata* and *Posidionella variabilis*. Near the northwestern termination of the range, a thick series of hard, white, reddish and yellow calcareous sandstone contains fish remains in the lower portion, while the middle part is filled with shells of *Posidionella lævis* Bronn, and *Posidionella elongata* Phillips. The Upper beds contain beautifully preserved specimens of *Noeggerathiopsis æqualis* Goeppert.

Hiatus and Disconformity

LOWER CARBONIFEROUS:

Modiola shales.

The outstanding facts shown by this section are: first, that the Permian strata of this region rest disconformably on the Lower Carboniferous or Dinantian, and that, unless a part of these higher series is to be classed as Upper Carboniferous, neither Middle nor Upper Carboniferous is represented in this region. From the nature of the flora, it seems necessary to class these higher beds as belonging to the Permian. The second significant fact is that the pelecypod fauna of these beds is confined to the lower division, and that it consists of species which apparently represent coastal and probably brackish-water conditions. The fauna is essentially of the type of that found in the Talapai formation of the Nanshan geosyncline, the last of the Permian faunas of that section. Here, as there, the fauna heralds the disappearance of marine conditions, and the encroachment of terrigenous sands and muds, with the development of coal swamp conditions. But it is probable that the fauna in the Manrak region is an older one than that of the Talapai, representing essentially the basal part of the Permian. Located as it is along the southern margin of the Mongolian geosyncline, it would seem to indicate that marine conditions continued for only a comparatively short period of time, in the western part of this geosyncline. For though the southern marginal plain of the geosyncline may have furnished some of the sediments, the bulk of them, if our interpretation is correct, must have been derived from the old-land on the north, in which case, strata of this kind must have been continuous across the entire geosyncline. This does not exclude the possibility that older marine Permian strata were deposited in the center of this basin, prior to and at the time when the *Posidionella* beds were forming on its southern margin. Up to the present, however, few such deposits have been discovered in this part of the geosyncline.

DZUNGARIA

One such locality was found by Klemenz in the Gobi desert of Dzungaria, south of the Gobi Altai, at Nursu, about Longitude 91° East, Latitude 43° 30′ North, and one was found in the region between Longitudes 91° to 92° East, and more than 100 versts east-northeast of Gutschen. Near marls and sandstones with coal beds, he obtained, in loose ash-gray sandstones and conglomerates, a fauna which was determined by Tschernyschew as comprising the following species: *Productus purdoni*, *Productus asperulus?*, *Productus mexicanus?*, *Chonetes transitionis*, *Rhynchopora nikitini*, *Reticularia lineata* (= ? *Squamularia asiatica* Chao), *Martinia semiglobosa*, *Spirifer cameratus*, *Bairdia curta*, *Stenopora collunnaris* vars. *camosa* and *multigemmata*. This fauna, though suggestive to some extent of the Artinskian of the Urals, may represent the westward extension of the Jisu Honguer fauna. These beds probably rest upon marine Lower Carboniferous beds, which are widely distributed in the Altai region and the mountains of Dzungaria. These Lower Carboniferous beds are chiefly the bearers of the Tournaisian fauna, no true Viséen having been definitely established in this region. In the mountains of Dzungaria, that is, in the Urkaschur, Semistai, Barlyk, and Indili-Dschir Mountains, Permian beds of the type of those found in the Manrak-Tarbagatai and Saur ranges are found. These consist of light and dark sandstones, sometimes calcareous, sometimes clayey and including tuffites; of siliceous or calcareous shales; of conglomerates often very coarse; and of porphyry-tuffs and breccias. More rarely dark limestones occur, carrying traces of corals. Lenses and beds of poor coal with plant remains also occur, the only one of which so far determined is *Equisetites mirabilis*. Effusive rocks also occur. This series rests disconformably upon marine Tournaisian.

THE KUSNEZK BASIN

Passing now to the northern border of the geosyncline in this region, we find, some kilometers due north, the deposits of the Kusnezk coal basin, northwest of Minuzinsk, approximately in Longitude 85° East, Latitude 55° North. The succession determined here is as follows in descending order:

H. 6. Krassnoiarsk Series...1,590 meters.

Chiefly sandstones, often arkosic and clayey; coal beds are few and usually thin, totaling not more than 7 meters. The plant remains include, according to Borissiak, *Gangamopteris*, *Schizoneura*, *Sphenopteris*, *Odontopteroides*, etc.

H. 5. Suprakemerow Series:...1,166 meters.

Sandstones, alternating with clayey and sandy shales, with numerous plant remains; lower part consisting chiefly of black shales with thin coal beds, totaling not over 5 meters.

H. 4. Kemerow Series:...106 meters.

Coarse sandstones, followed by three to four workable coal beds, which have a total thickness of 16 meters.

H. 3. Subkemerow Series:...2,330 meters.

Chiefly sandstones, with clay-shales and coal beds in the upper part and clay-shales with sphærosiderite, marls and many coal beds in the lower part. The clay-shales and marls, and more rarely the sandstones, contain plant remains. Among those determined from this and the overlying horizon (H–4) are: *Baiera pulchella*, *Cordaites æqualis*, *Neurogangamopteris cardiopteroides*, etc. A peculiarity of this series is the presence of numerous stems of *Mesopitys tschichatschewi*. These sometimes still stand upright; sometimes they form accumulations in the sandstones.

In the thinly laminated black shales of this series occur shells of pelecypods regarded by Stoyanow as of brackish-water habitat. He has determined the following species, which in Britain are found at various horizons in the Carboniferous beds. *Aviculopecten murchisoni*, *Sanguinolites tricostatus*, *Anthracomya minima*, *Anthacomya lævis*, *Anthracomya phillipsi*, *Scaldia benediana*, *Edmondia vesali*, *Edmondia punctatella*, *Carbonicola virti* and *Parallelodon angustus*. Though this has been regarded as an Upper Carboniferous fauna, there is nothing intrinsically antagonistic to the view that it may belong in the Permian, a view held by some.

H. 2. Non-productive Series:...1,270 meters.

Alternating yellowish gray or green sandstones, and sandy and, more rarely, clayey shales with layers and lenses of yellowish and brownish marls, passing into sphærosiderite or limy beds with cone-in-cone structure. Coal beds rare and thin, totaling only 2 meters. Plant remains rare and poorly preserved.

H. I. BALACHONKA SERIES:..1,270 meters.

Sandstones alternating with shales and subordinate coal beds in the upper, and sandstones and pyritiferous shales in the lower part. The sandstones are mostly medium-grained, yellowish to ochery, and concretionary. The sandy shales are gray, and the clay-shales are black, often fissile and carrying plant remains in abundance; these include: *Phyllotheca equisetoides*, *Cordaites æqualis*, *Callipteris* aff. *crassinervis* and *Pecopteris angustifolia*. There are no less than twenty coal beds with a total thickness of 23 meters. Wenyukow cites from these beds the following: PELECYPODS: *Posidonomya becheri*, *Carbonicola carbonaria*, *Anthracosia* several species, and small *Ostracoda*. Because of these, the beds have been considered as the upper part of the Lower Carboniferous, but even if the species are correctly determined, the flora rather indicates Lower Permian age, in which horizon it is placed by a number of investigators. The basal portion of this series is formed by a conglomerate up to 21 meters in thickness, with small quartz and flint pebbles, or locally by a uniform sandstone.

Total thickness of the Kusnezk series:.............7,525 meters.

Hiatus and Disconformity

SUBFORMATION: LOWER CARBONIFEROUS MARINE BEDS

Chiefly Tournaisian, but in part perhaps Viséen.

Zalessky has figured the flora of the Kusnezk series, his material being derived from the Krassnoiarsk, Kemerow and Subkemerow series. He considers the entire series as Permian, an interpretation in harmony with our understanding of the history of deposition in this part of the Mongolian geosyncline.

OTHER OCCURRENCES IN WESTERN MONGOLIA, ETC.

The Upper Palæozoic beds are again exposed in the Urianchai basin, southeast of the Kusnezk basin. The coal-bearing series begins with yellow sandstone and clay shale followed by sandstones and clay shales with coal beds. The plants found in these were formerly regarded as Jurassic types, but the recent restudy has shown them to be more probably Permian. They rest on beds with a Lower Carboniferous flora, and these are in turn preceded by beds of Devonian age.

In northwestern Mongolia, south of the Tannuola Range, beds of similar age are exposed. In the valley of the Charatarbagatai on the southern slopes of the Tannuola, dark-gray sandy clay shales contain plant remains, which Schmalhausen originally determined as Lower Carboniferous types but which subsequent revision by Zalessky has shown to be species of Permian type. Farther to the southwest in Mongolia, Klemenz found, in strongly dislocated clay-slates along the trail from the Barmen Pass to Lake Atschitnur in the Buku-buren Steppe, a flora which indicates various Permian horizons of Europe, together with a Gondwana type of *Gangamopteris*. The flora is essentially the same as that of the Kusnezk basin, and includes the following species according to Zalessky's revision: *Callipteris murenensis* Zalessky, *Psygmophyllum mongolicum*, *Neurogangamopteris cardiopteroides*, *Dicranophyllum lusitanicum*, *Noeggerathiopsis æqualis*, *Phyllotheca* sp., *Samaropsis* sp.

The Permian of the Siberian type appears thus to be well developed in northwestern Mongolia, with essentially the same flora throughout. These deposits are traceable as far south as Dzungaria, where marine members are found locally at least in the lower part. Throughout, these beds appear to rest disconformably on the Lower Carboniferous, either the marine Tournaisian or its continental equivalent, the Ursa stage. Middle and Upper Carboniferous seem to be entirely wanting in this part of the Mongolian geosyncline, or if they are represented by continental strata, they have not yet been positively identified. In any case, so far as marine sedimentation is concerned, there is a complete hiatus between the Tournaisian or Viséen and the Lower Permian.

CENTRAL AND EASTERN PARTS OF THE MONGOLIAN GEOSYNCLINE

Urga Region:—Turning now to the central and eastern parts of the Mongolian geosyncline, we find that in several localities north of Jisu Honguer the old graywacke series includes beds with Lower Carboniferous, and others with Permian fossils. Thus, on the road from Kiachta to Urga, Obrutschew found on the Charagol near Urmuchtu, bryozoans and corals in greenish and gray clay and calcareous shales. Later Tschernow found brachiopods in these beds which Tschernyschew identified as the types found in the Gasimursk fauna, now considered to be Lower Carboniferous. Farther northwest on the Upper Selenga and on the Telgirmurin in the Khangai Mountains of northern Mongolia, Tolstichin found a succession of sandstones, conglomerates and clay slates with coal and poorly preserved plants, indicating essentially the Permian horizon of Siberia.

Gasimursk Range:—In the Gasimursk range of the Transbaikal Mountains, near the Mongolian border, late Palæozoic sediments have long been known. The principal marine fauna here is of Tournaisian age, while others of Devonian age are known. Beds which may represent the late Palæozoic, presumably Permian, continental deposits, are found in southwest Transbaikalia.

Amur Land, etc.—Upper Palæozoic deposits are also known from Amur Land, a small and interrupted band being found along the railroad on the upper reaches of the Uruscha, Newer, Oldoi, and Urka Rivers. On the Urka, black shales and arkoses carry plant remains, suggesting Permian age. Between the Uruscha and the Newer Rivers, marls are exposed carrying a Tournaisian fauna. Farther east, on the Tynda and Urkan, in the basin of the Seja, occur dark gray slaty and clayey sandstones with beds of black limestone, with a fauna indicating the Gasimursk horizon.

In the Birja basin of the lower Amur, and in the hills on the right bank of the Amur, opposite the city of Khabarowsk, occur slightly metamorphosed conglomerates, breccias, arkoses, clayey and siliceous shales, graphitic shales, sericite shales, calcareous sandstones and crystalline limestones, and more rarely coal shales. These beds contain Radiolaria, Foraminifera (*Neoschwagerina*) and crinoidal remains, which indicate early Permian age and correspond to the Japanese and Korean deposits already discussed.

Vladivostok Region:—Near Vladivostok is found one of the better-known upper Palæozoic deposits of the eastern end of the Mongolian geosyncline. The succession in descending order is as follows:

2. Light gray, coarsely crystalline, hard limestones, rarely with clayey layers, but becoming more clayey and siliceous downward, with limestone only in thin layers........................25 meters.
1. Green calcareous sandstone and siliceous shales with basal conglomerate or breccias....................................25 meters.

The clayey layers have furnished bryozoans, crinoid stems, corals and *Productus cora*, while the limestones are characterized by brachiopods and large fusulinas. Tschernyschew has determined twenty-two species, including the following: *Hemiptychina inflata*, *Notothyris nucleolus*, *Camarophoria purdoni*, *Hustedia remota*, *Hustedia indica*, *Spiriferina cristata*, *Spiriferella keilhavii*, *Spirifer fasciger*, *Reticularia lineata*, *Reticularia rostrata*, *Productus purdoni*, *Productus irginæ*, *Productus asperulus*, *Productus wallacei*, *Productus weyprechti*, *Marginifera typica*, *Marginifera ovalis*.

On the Sutschan River, where the limestones are especially well-developed and have been traced for a distance of 45 kilometers, *Richthofenia lawrenciana* has been found, while *Thamniscus timanicus* and *Lyttonia tenuis* have been found on the west coast of Amur Bay.

On the Mangugai River, 20 kilometers from its mouth, the same limestone has reached a thickness of 120 meters and contains in part the same fauna, together with *Spiriferella saranæ*, *Spirifer hardmani* and *Productus porrectus*.

Tschernyschew found that of the twenty-seven forms determined, sixteen, or 59.3 per cent., also occur in the *Schwagerina* fauna of the Ural and Timan. Eleven are also found in the Virgal beds and nine in the Kallabagh beds of the Indian Productus limestone. Thus these beds are essentially equivalent to these horizons and represent the eastern extension of the Jisu Honguer limestone. Calcareous sandstones of ash-gray color crop out between Chatunitschi and Innogoudobnaja and contain the molds of *Productus purdoni*, *Productus* aff. *subquadratus* and *Spirifer fasciger*. These may represent the same or a somewhat higher horizon. In the valley of the Sutschian River, these limestones rest directly upon deformed granites which sometimes pass into granite-gneiss. The limestone is 126 meters in thickness and contains in addition to the species before mentioned, *Camarophoria margaritowi* and *Productus cora*.

More recently, Baron Fredericks has restudied these faunas and found Indian types well represented. He refers the former to a Lower Permian age as Permo-Carboniferous and describes many species of the *Spiriferella* group. To these, reference has already been made in the descriptive part of our text. Unfortunately Fredericks' descriptions and discussions are all in Russian, and hence it is not possible for me to make a critical evaluation of his work. I give his lists of species here but regard his new genera and species as *nomina-nuda* until they are redescribed in a language accessible to all workers in the field. Hence I omit them here. From near Vladivostok he lists the following species: *Productus inflatus* McChesney, *Productus aagaardi* Toula (mut.), *Productus cora* d'Orbigny, *Productus boliviensis* d'Orbigny, *Productus weyprechti* Toula, *Productus cancriniformis* Tschernyschew, *Productus koninckianus* Verneuil, *Productus palliatus* Keyserling, *Productus juresanensis* Tschernyschew, *Productus wallacianus* Derby, *Productus asperulus* Waagen, *Productus humboldti* d'Orbigny, *Productus irginæ* Stuckenberg, *Productus purdoni* Davidson, *Productus porrectus* Kutorga, *Marginifera typica* Waagen, *Marginifera ovalis* Waagen, *Chonetes* cf. *compressa* Waagen, *Richthofenia lawrenciana* de Koninck, *Streptorhynchus pelargonatus* Schlotheim, *Enteletes hemiplicatus* Hall (mut.), *Orthotychia morganiana* Derby, *Hustedia remota* Eichwald, *Hustedia indica* Waagen, *Cliothyris* cf. *royssii* Léveillé, *Athyris subexpansa* Waagen, *Spiriferina biplicata* Schlotheim, *Spiriferina cristata* Schlotheim, *Spiriferella ravanæ* Verneuil, *Spiriferella rajah* Salter,[1] *Spirifer striatus* Davidson, *Spirifer marcoui* Waagen, *Spirifer cameratus* Morton, *Spirifer moosakhailensis* Davidson, *Spirifer ambiensis* Waagen, *Spirifer alatus* Schlotheim, *Squamularia perplexa* McChesney, *Reticularia rostrata* Kutorga (or *Reticularia pulcherrima* Gemmellaro), *Camarophoria margaritowi* Tschernyschew, *Camarophoria* cf. *purdoni* Davidson, *Rhynchopora nikitini* Tschernyschew, *Uncinulus theobaldi* Waagen (?), *Notothyris nucleolus* Kutorga, *Hemiptychina inflata* Waagen, *Parallelodon tenuistriatum* Meek and Worthen. This list evidently needs revision,

[1] See revision of some of Fredericks' forms in text.

since it includes a mixture of types, which, without full and convincing demonstration, can not be accepted as occurring together.

Fredericks' second paper is in Russian and the origin of his fauna is not stated in another language, excepting in the title. Hence I cannot make full use of it in this work. I give his list of Brachiopoda from Cape Kalonz in Ussuriland, again omitting the new species. It would be of great value if this entire work were translated into one of the better-known languages.

Chonetes vishnu Salter, *Chonetes rothpletzi* Broili, *Chonetes æquicostatus* Waagen (var.), *Chonetes molengraffi* Broili, *Marginifera* cf. *typica* Waagen, *Marginifera* cf. *echinata* Waagen, *Lyttonia tenuis* Waagen, *Productus mytiloides* Waagen (var.), *Productus gallatinensis* Girty, *Productus cancriniformis* Tschernyschew, *Productus weyprechti* Toula, *Productus humboldti* d'Orbigny, *Productus irginæ* Stuckenberg, *Productus purdoni* Davidson, *Productus waageni* Rothpletz, *Productus gangeticus* Diener, *Productus* cf. *abichi* Waagen, *Reticularia pulcherrima* Gemmellaro, *Spirifer moosakhaïlensis* Davidson, *Spiriferina cristata* Schlotheim, *Spiriferella rajah* Salter, *Spiriferella vercheri* (?) Waagen, *Hustedia remota* Eichwald, *Cliothyris royssii* Léveillé, *Pugnax uta* Marcou, *Pugnax swallowiana* Shumard, *Pugnax osagensis* Swallow.

The American forms above cited are probably erroneous identifications, which remark may also apply to some of the others.

On the north coast of the island of Ruski, coal-bearing Permian strata were found by Eliaschewitsch. They consist of gray and black arkoses and sandy clay shales, and, in the upper part, of clay shales and siderite layers which are plant-bearing. Among the plants, the following have been obtained as verified by Krischtofowitsch: *Cordaites æqualis, Glottophyllum* cf. *cuneatum, Glottophyllum* sp., *Sphenopteris emarginata, Phyllotheca* sp., *Schizoneura* sp.

Similar beds are found in other parts of this region, and the thickness of these beds in some sections appears to be very great.

In general, then, we find in the Vladivostok region and in the southern part of the Sichota-Alin, the upper Palæozoic represented by limestones with a Lower Permian marine fauna, followed by higher continental beds with coal and an Upper Permian flora of the Angara type. The series rests disconformably on Lower Carboniferous, or unconformably on older beds, and is disconformably succeeded by Triassic strata. The limestone is probably the exact equivalent of the Jisu Honguer limestone.

CHAPTER XIX

SUMMARY OF THE PERMIAN STRATIGRAPHY OF EURASIA

From the foregoing discussion of the distribution of the Permian beds and faunas, it becomes apparent that we must recognize three distinct centers of origin for the latter. These are:

1. Endemic in the Russian Basin.
2. Boreal.
3. Pacific.

The endemic fauna appears to have been developed primarily in the south Russian basin, where the Upper Carboniferous or Donetzian is well developed and is characterized by a fauna which itself has been derived, in part at least, from the earlier Middle Carboniferous fauna of that region. This is the fauna found in the sub-Bakhmout series, which alone of the Russian faunas deserves the name of Permo-Carboniferous. Some of the elements of this fauna may reappear in the Auernigg beds of the eastern Alps. The full extent of this endemic fauna may be difficult to determine, because a part of it may have been developed in the boreal realm. On the other hand, we have seen that there is much evidence that the boreal region was separated from the Russian basin, if not completely, at least to a very great extent, for, so far as we know, the Permian of the northwestern region begins with gypsum and salt deposits indicating lagoonal conditions and nearby land, but formed at a period near the beginning of Upper Permian time only. Upper Carboniferous and Lower Permian are represented throughout the Dvina region or northern Russia by a hiatus. This is true of many of these deposits in the Timan and Ural region, where only late Upper Carboniferous, showing Pacific influence, and Lower Permian of the same character are represented, the greater part of the Upper Carboniferous being cut out by a hiatus. If there was a connection between the Russian basin and the boreal sea, its location must have been between the Timan and the region of the Dvina and the Pinega Rivers, or approximately between 45° and 48° East Longitude. That a part of the Upper Carboniferous of the Ural and Timan region was derived from the fauna of the southern Russian basin is very probable, though at present we are not in a position to evaluate it. A large part probably was derived directly from the boreal province, while the foreign element of the fauna of the *Spirifer marcoui* and *Omphalotrochus whitneyi* beds was introduced from the Indo-Pacific province. This appears to have been the source of *Spirifer marcoui* itself, which is characteristic of the Lower Productus limestone of the Himalayan geosyncline, although even this may possibly be a boreal element which extended its migration to northwestern India. Whether *Omphalotrochus whitneyi*, the leading fossil of the Omphalotrochus beds, is of Pacific or boreal origin is likewise undetermined, though this species was originally described from corresponding beds in California, which may have been part of the Pacific province. If, however, these beds were formed in the Palæocordilleran geosyncline, the species in question must be considered a member of the boreal fauna, as must also be all other species which the deposits of this west American geosyncline have in common with the Upper Carboniferous and Permian deposits of the European region. A number of these species have already been designated as such in the earlier part of this stratigraphic discussion.

The first of the Indo-Pacific faunas to enter the Central Asiatic and Russian regions was that of the Lower Productus limestone. This invasion proceeded through the Himalayan geosyncline following the epoch of glaciation in the Indian Ocean region. The influence of this invasion is seen as far west as the eastern Alps, for a part of the fauna of the Auernigg beds appears to have been derived in this way. It is probable that this had only a slight influence on the deposits of the Russian basin; indeed it may not have modified that fauna at all, its chief modifying influence being in the Ural and Timan geosynclines.

It is possible that this was an epoch marked by oscillatory marine and continental conditions in the Chinese basin, and if the evidence supplied by the Fusulinidæ is reliable, it may be represented in north China by the later Taiyuan formation.

Apparently this first invasion from the Indo-Pacific region was terminated by a retreat of the sea, not only from the Russian basin but also from the Himalayan geosyncline. In the former we have the evidence of such retreat in the continental beds which separate the Sub-Bakhmout from the Bakhmout formation in the south, and the Omphalotrochus beds from the Cora beds in the north and east. Whether a similar retreat is indicated in the region of the eastern Alps cannot now be determined, because of the slight development and poor preservation of the Schwagerina beds of that region. Judging from the marked change in fauna, however, it appears likely that such a non-marine interval even there separates the two series.

The second marine invasion from the Indo-Pacific region occurred in early Permian time. In north China, it may have been preceded by the formation of the marine members of the Shansi series, which are believed to be the lowest Permian deposits of Asia and whose fauna may have been of Pacific origin.

The second invasion of the Pacific waters proceeded either through the Loping geosyncline of central China or through Indo-China and southern China from the Indo-Pacific waters. This invasion brought with it the Schwagerina fauna of which *Schwagerina princeps* is the leading type. Apparently the only pathway by which this fauna could pass into Central Asia and thus into the Ural and south Russian basins, was by way of the Nanshan geosyncline, where the fauna is found in the Semenow Mountains of to-day. The other pathway of communication with the European region seems not to have been available, since *Schwagerina* is absent from the deposits in the Himalayan geosyncline and from Darvas, as well as from those of the Mongolian geosyncline, except in the region of its extreme eastern end. It is difficult to understand the reason for this absence, unless it is to be accounted for on purely bionomic principles, that is, that there were some features of the environment, such as depth of water, salinity, temperature, currents, or the like, which prevented the entrance of these Foraminifera into the Himalayan geosyncline at least. For even if we assumed that the *Schwagerina princeps* horizon is an older one than any represented in the Productus limestone, or that it occurs in the interval between the Lower and Middle Productus limestone, we must still account for the absence of other species of *Schwagerina*, *Neoschwagerina*, *Doliolina* and *Sumatrina*, all of which occur in the Permian beds of the Indo-Pacific region. Moreover, the fauna of the Schwagerina limestone and that of the Middle Productus limestone have so many species in common that we must consider them essentially contemporaneous. We can better understand the absence of these Foraminifera from the Mongolian region and the fact that the Mongolian geosyncline could not have been a passageway for the migration of these types, when we realize that the Jisu Honguer limestone was deposited under conditions of diminished salinity, while the western end of the geosyncline was characterized only by shallow and to a large extent brackish-water deposits.

That the Schwagerina limestone of the Ural and Timan regions, and probably the Cora limestone with it, also the Bakhmout dolomite of the Donetz basin and finally the Schwagerina limestone of the eastern Alps actually do represent an invasion from the Indo-Pacific region, seems to be beyond doubt, and is clearly brought out by the distribution of this fauna in many sections throughout Asia, as reviewed in the preceding pages. That this invasion occurred at, or shortly after, the opening of Permian time seems also beyond doubt. As we have seen, the boreal fauna is of a distinctive type, and while it was in evidence during Upper Carboniferous time in the Russian basin, it was temporarily replaced by the invading fauna of the east. In the Artinskian sediments, however, we find the evidence of its readvance, this probably corresponding to a closure of, or an unfavorable change in, the Nanshan geosyncline.

There is much evidence that the boreal region was the home and the center of dispersal of the goniatite fauna, which becomes so marked a type in the Artinskian sediments, and which is also so well developed in the corresponding deposits of parts of North America. From this point, it extended not only to the Ural region, but to south Europe as well, probably by a roundabout way, as shown by its presence in the Trogkofel beds of the eastern Alps and the Sosio limestone of Sicily. Again we find it in the Upper Productus limestone of the Salt Range and in extreme richness in the Permian of Timor. Here, however, it is quite possible that many new types had developed in the Pacific, from early migrants into this basin, in Carboniferous and preceding eras, and that these had become mingled with the new migrants sent out from the boreal realm in Artinskian time (Grabau, 1923–1928, Vol. II, p. 84).

In the eastern Alps, the Boreal-Artinskian element is not developed to its full strength, since the members of the Schwagerina fauna still continue into the Trogkofel beds, the older fauna being modified only by the incoming boreal elements. In the Sosio beds, on the other hand, farther to the southwest, the Artinskian element is much stronger, as is also the oriental element or that of the Productus limestone. But, even here, where the water was apparently more open and communication more direct, the fauna has an individualistic character. It probably includes the Kungurian horizon as well, while the Upper Productus limestone is in part at least its equivalent. It was probably at this time that the Pacific sea had its greatest extension, reaching as far west as the eastern Pyrenees where the marine St. Girons beds of Ariege were forming, though these were shortly replaced by continental sediments.

This period of expansion of the seas was followed by one of rather widespread withdrawal. In the western Tethys in Ariege the older strata were folded and became subject to erosion. In the region of the eastern Alps, dislocation was the first effect of deformation, but this was accompanied by extensive volcanic eruptions. In the Himalayan geosyncline the final emergence seems to have taken place, the region hereafter, until the invasion by the Lower Triassic sea, remaining exposed except for a brief submergence recorded in the Productus or Kuling shales. This may represent a reinvasion from the Pacific, at the time of the formation of the Maping beds of China, during the period of the Zechstein sea. In the Darvas sections continental sediments follow upon the last of these marine incursions.

This period of interruption in sedimentation is apparently marked in the Chinese basin by the widespread Hsuanchin coal horizon, of the Yangtze valley, and the equivalent Holo coal-bearing series of south China, indicating swamp and partial land conditions. In the Russian basin it is marked by the withdrawal of the waters and their evaporation, with the formation of the Kungurian gypsum deposits and the gypsum and salt beds which succeed the Bakhmout dolomites in southern Russia.

In the Russian basin, the early gypsum-forming period, at the close of the Kungurian period, was followed by renewed expansion of the marine waters of the boreal region, these forming the Zechstein sea of Russia, with its circumscribed Lower Zechstein basin in the north German region. This deposition began with the copper-bearing deposits of the Ufa series in the Ural region, and the similar Kupferschiefer in the north German depression. That these copper minerals owe in some way their formation, or at least separation, to the physical conditions which characterized the arid period just preceding, is suggested, though their precipitation may have been due to the peculiar characters of the waters as they first expanded. In the north German basin it is known that these first entered the river valleys of the old Rothliegende desert basin, bringing with them *Productus cancrini* and some other boreal species. It was this first invasion that was apparently responsible for the sudden killing of vast numbers of the river-inhabiting fish of that region, whose bodies are now preserved in such perfection in the Kupferschiefer of this region.

In the Tethys basin the interruption in sedimentation was followed by outpourings of lavas (Bozen porphyrite), and this in turn was followed by the formation of the Grödener beds, which are of purely continental origin. The basal beds of this series correspond essentially in age to the Kupferschiefer of north Germany and the Ufa beds of the Urals. The formation as a whole probably corresponds to the Lower Zechstein and perhaps to a part of the Middle as well. It was this period which is probably represented in northern Russia by the Dvina gypsum series and in southern Russia by the post-Bakhmout red bed series with salt and gypsum. Within the Russian basin it was succeeded by the Zechstein sea, which, as we have seen, represents an advance of the boreal waters. It was at that period that the North German desert basin was fully invaded by the Russian sea, which extended into eastern England, where the Magnesian limestone represents the westward continuation of the Lower Zechstein. It is not yet certain whether the period of interruption in sedimentation in the Zechstein basin of northern Germany, so forcibly displayed by the lower anhydrite and salt series, with its famous mother-liquor deposits, has left any trace in the main Upper Permian marine series of the Russian basin. It is certain that this period can not correspond to the beginning of Tartarian sedimentation, for that marks the final withdrawal of the marine waters from that basin, and we know that there was a second incursion of the marine waters from the Russian region into the Zechstein basin after it had become fully desiccated by complete evaporation of the older waters. This second incursion resulted in the formation of the Upper Zechstein, and it must be represented by more normal marine deposits in northern Russia, though the faunal distinction of this late deposit in the larger basin may not have been very great when compared with that of the preceding epoch.

The second closing of the north German Zechstein basin and the commencement of the evaporation which resulted in the formation of the upper anhydrite and salt series, may coincide with the final withdrawal of the marine waters from the Russian basin and the beginning of the formation of the Tartarian continental series. Whether this period corresponded to the expansion of the Tethys relict sea, and the formation of the Bellerophon limestone of the Alps, cannot be positively stated. That expansion may coincide with the second incursion of the waters into the north German Zechstein basin or may belong to a later period, that is, the Tartarian continental epoch of the Russian basin. All that we can say at present is that the Bellerophon limestone probably represents the latest deposit of a salt-water type which we know from the Permian and that it may include the very latest Permian sediments and bridge the Permo-Triassic interval. But that it was not a normal marine deposit seems likewise certain, for there is no equivalent marine deposit which connects it with the Indo-Pacific sea of the period, the only conceivable center of dispersion of the marine faunas of the Tethys in the closing stages of the Permian period. For there seems to be no escape from the conclusion so strongly emphasized by Caneva that the fauna of the Bellerophon limestone belongs to a later epoch than any represented in the Himalayan geosyncline. It is true that the fauna of the Productus (Kuling) shales of the central Himalayas has an Upper Permian character and is most probably younger than that of the Upper Productus limestone of the Salt Range, which we conceive as corresponding essentially to the Artinskian and Kungurian of the European Permian. But at best these can represent only the horizon of the lower Kama (the Ufa or lower Samara beds), and therefore correspond more nearly to the epoch of the Grödener beds of the Tethys region. The horizon of the Bellerophon limestone is undoubtedly represented by at least a part of the interval of non-deposition which separates the latest Permian of the Himalayan geosyncline from the oldest Triassic deposited in that region. Thus we are brought to the conclusion that the Bellerophon limestone is the product of deposition in an enclosed body of salt water not very unlike the Caspian Sea of to-day, in truth a typical relict sea left behind in the Tethys basin on the withdrawal of the waters from the Himalayan geosyncline and the Russian basin, and that it had no connection with the open sea. This relict sea probably existed farther to the south, that is, somewhere in the region of the present Mediterranean Sea, during the epoch of deposition of the Grödener sandstone in the Alpine district of to-day, and it was probably in the more restricted relict sea of that epoch that many of the peculiar types characteristic of the Bellerophon limestone were developed from survivors of the Sosio fauna, if indeed a part of that fauna itself does not represent the epoch of the more restricted relict sea.

There can be little question, I take it, that the types of brachiopods, corals, etc., which give the Alpine Trias its peculiar Palæozoic character, are derivatives from Palæozoic survivors in the Mediterranean relict basin. As I read the history of the period, we have in this region the only known transition between Palæozoic and early Mesozoic types, though the actual connecting epoch may not be represented by sediments in any now accessible portion of the geological column. As I have explained at length elsewhere (Grabau, A. W., 1923–1928, Vol. II, p. 82), the only rational explanation which we can at present advance for the all but universal extinction of the Permian fauna, is the complete withdrawal of the marine waters from all the geosynclines and continental shelves of the period, at the close of Permian time, a phenomenon best explained as a result of over-deepening of the basin of the Pacific Ocean. Such an event would bring with it the complete extinction of all the littoral benthonic types, leaving survivors only in a few deep inland basins, such as we believe the Tethys to have been in what is now the Mediterranean region. These relict basins, if of sufficient size and sufficiently supplied with drainage to prevent their desiccation, would maintain a relict fauna such as we find to-day in the Caspian Sea. But these would be the only survivors of the more ancient types of benthonic organisms, with the exception of those which have become adapted to a life on the bathyal slopes of the ocean basin. The types which would survive such a withdrawal of the shallow waters are the pelagic organisms, both planktonic and nektonic, and it is from these that the dominant types of the succeeding fauna are developed. I consider the goniatites to have been of such pelagic types. They formed the most prominent element of the surviving faunas at the close of Palæozoic time. Though they may have originated in the boreal realm, they had by this time become very prominent members of the Indo-Pacific fauna, and many of them had advanced far into the ceratite stage of development. It is these survivors which gave rise to the various phyla of ceratitic ammonoids which appear so abruptly in the oldest deposits formed within the geosynclines after their reflooding by the readvance of the sea, in Lower Triassic time.

CHAPTER XX

BIONOMIC RELATIONS OF THE FAUNA OF THE JISU HONGUER LIMESTONE

It has been pointed out that the fauna of the Jisu Honguer limestone is to a large extent a brachiopod fauna, and that many groups, such as the crustaceans, cephalopods, and echinoderms, are unrepresented. The same thing may be said of the Foraminifera, for although a considerable number of thin sections have been made by Professor J. S. Lee, he was unsuccessful in finding any of these organisms in the Mongolian rocks. The corals, too, as we have seen, are poorly represented, the only important colonial form being restricted to a single horizon. Bryozoa likewise are relatively rare, though, because of their poor state of preservation, they may have been more numerous than we now realize. While further collections from these limestones may modify these statements, it is not likely that they will materially alter the picture as a whole. A further detail must be added here, namely, that in the great majority of cases where the species of the Jisu Honguer limestone are identical with those of the Indian or Russian forms, or where our forms are varieties of Russian or Indian species, they are almost invariably much smaller, often not more than half the size of the species found elsewhere. Nevertheless, in the great majority of cases there is evidence that the Mongolian species, to which reference is here made, are adults, for in this discussion the young individuals are left out of consideration. Indeed, in the case of many of our new varieties, their most important difference is one of size, this being especially the case with the varieties of the Indian species. It thus becomes evident that our fauna has many of the characteristics of a dwarf fauna, and this is emphasized by the fact that now and then an individual is found approaching more nearly in size that of the normal Indian forms. But such occurrences are extremely rare. In one group of shells, however, namely, that of the *Spirifers* and *Spiriferellas*, the majority of the individuals are developed to the full size characteristic of the same or related species elsewhere. Indeed, in some cases, our shells may actually exceed in size those found in other localities.

If we look for an analogous example in the modern fauna, we seem to find it in the case of Pechili Bay, in China, that nearly enclosed epeiric body of water which is bounded by the Liao-Tung peninsula on the east, by Chihli Province on the west, and by Shantung on the south, and which communicates with the Yellow Sea by a comparatively narrow opening. This shallow sea receives the waters of the Yellow River, which, because of its abundant load of sediment, rapidly builds its delta forward into the sea. It has been calculated that this river pours, on the average, 3,285 cubic meters of water per second into the gulf of Pechili, and that the material carried by it into this gulf during the year amounts to 472,500,000 cubic meters (Grabau, 1924a, p. 248). An analysis of the water, from the vicinity of Peitaiho, showed that the salinity is only 25.54 per mille, while that of the Yellow Sea is more nearly the normal for ocean water, that is, about 35 per mille. Moreover, the water of the Pechili gulf is very high in magnesium salts, these being far beyond the normal for ocean water.[1]

When we turn to the fauna of Pechili Bay, we find it to possess a distinctive character, inasmuch as certain groups of organisms which usually abound in the open sea waters are rare, if not wholly wanting. Thus hydroids are scarcely ever found, which may be in part accounted for by the fact that the rock weed is rarely present on this coast. Barnacles, too, though abundant on some of the submerged ledges, are usually of diminutive size, while brachiopods, fairly common on the coast of Japan, are represented only by an occasional *Lingula*. A few small detached corals have been obtained, but a species of lime-secreting coralline bryozoan is very abundant, while other types seem to be rare. Crustacea are numerous, but the number of genera and species seems to be restricted. Among the echinoderms, starfish are fairly abundant in certain localities, though only two species seem to be common. Ophiurans are very rare, but holothurians are represented by one or more common species. Only two echinoids have so far been obtained, one regular Arbaceoid type, and one irregular, belonging to the genus *Echinocardium*. Both of these are represented chiefly by exceedingly minute individuals, though on the southern coast of the bay, at Chefoo, etc., beyond the opening of Pechili Bay, where the influence of the outer waters is more markedly felt, they grow to a very much larger size.

The chief element of the invertebrate fauna of Pechili Bay is formed by the shelled Mollusca, that is, the pelecypods and gastropods, but the shell-less cephalopods are also represented by numerous individuals though few species. Chief among these is a small *Octopus* which is extensively used as bait by the fishermen. The other common form is the cuttlefish, *Sepia*, of which many individuals find their way into the bay from the more open waters, but in addition many of them apparently breed within the bay, for their eggs are of

[1] See the analysis given in Grabau and King (1928). I may mention that the percentage of NaCl is only 52.16% as compared with 77.76% for normal sea water, while that of $MgCl_2$ is 32.59% and $MgSO_4$ 9.46% as compared with 10.88% and 4.74% respectively for normal sea water.

common occurrence. It is a noteworthy fact, however, that the majority of specimens taken by the fishermen within the bay are of much smaller size than those found farther east or near the opening of the bay, or in the open water outside, the length of those within the bay seldom exceeding six inches, exclusive of their long arms.

Of shelled Mollusca, one hundred twenty-seven species have so far been determined from Pechili Bay, these being about equally divided between the pelecypods and gastropods. Some of the former occur in vast abundance, forming the bulk of the shelly deposit upon the beaches; but it is notable that these shells seldom reach the size attained by those of the same species on the opposite shore at Dairen or at Wei-hai-wei, the two localities on the opposite sides of the opening of Pechili Bay into the Yellow Sea. Thus, one of these abundant types on the Peitaiho shore, *Ostrea talianwahnensis*, is usually not much over two inches in length, though occasionally reaching a length of four inches. On the opposite shore, however, at Dairen (Talianwahn), where the influence of the open waters is felt, the length of this species is commonly six inches or more. *Arca*, which is also common on the Peitaiho coast, is, however, usually only half the size of the full-grown species found on the outside or near the bay opening, though occasionally large individuals are found on the west coast of the bay; these, however, are rare. The shell of *Rapana tomasiana*, one of the largest and commonest of the gastropod species in the bay, rarely exceeds four inches in length, but in the open waters on the Japan coast this species not infrequently has a length of seven inches or even more. Similar observations have been made on most of the other species found in this bay and occurring likewise on the Japanese shores, the open China coast, or the coast of the Philippines.

The suggestion may be made that the waters of the Mongolian geosynclines, in which we have seen that the fauna was similarly dwarfed, were also of subnormal salinity, that is, having a salt content less than that of the normal sea. Such conditions would be brought about by extensive inpouring of fresh water into a basin where circulation was more or less imperfect. That such influx of fresh waters actually occurred in Permian time is indicated by the enormous mass of graywackes and other terrigenous sediments, which in this region represent material supplied by the rivers. As seen from the review of the deposits of the Mongolian geosyncline in the preceding pages, continental sediments are more widespread than the marine, the latter being restricted chiefly to the southern border and to the eastern end of the geosyncline. This would indicate that over the greater part of the geosynclinal region the river-borne sediments were supplied from the north, and as is clearly shown by the sequence of events in the formation of this geosyncline, it is there that the old-land lay. Indeed the region of limestone deposition was probably to a large extent over the marginal plain on the south, where the influence of the river sediments was less marked, though the influence of the inpouring fresh water was felt in the reduction of salinity.

That the fauna of the Jisu Honguer limestone accumulated under the conditions just outlined would seem to admit of little doubt, and we are thus furnished with a satisfactory cause for the dominant dwarf character of this fauna. That it was an extension of the Pacific fauna of the time is clearly indicated by the presence of essentially the same fauna in the limestones formed in the eastern end of this geosyncline. All the evidence so far available indicates that these waters did not extend westward throughout the geosyncline at this time, for not only have all the sediments of the western region a strongly continental character with an almost complete absence of marine faunas, but when such faunas do occur, they are shallow-water mud faunas, or such as to suggest a brackish-water habitat. The absence of the Foraminifera in the fauna of the Jisu Honguer limestone is readily explained by the subnormal salinity of the waters in which these deposits were formed.

PART IV

APPENDICES

PART IV—APPENDICES

LIST OF SPECIMENS USED IN THE DESCRIPTION OF THE JISU HONGUER LIMESTONE FAUNA OF MONGOLIA

In the following list the specimens which were used in the description of the Jisu Honguer limestone fauna are given, with their serial number, locality number, and catalogue number of the collections in which they are deposited. A. M.—American Museum of Natural History, New York. C. S.—Museum of Geological Survey of China, Peking. The kinds of types are also indicated, and when the specimen is illustrated, this is stated. (See the remarks in the Preface.)

Serial No.	Locality No.	H —Holotype—Single specimen selected as *the* type C —Cotype—One of a group of equal type and value Pa—Paratype—Described in addition to holotype Pl —Plesiotype—Specimen used in further description of an already described species	a Type	b Museum	c Catalogue No.	d Plate	e Figures
		Brachiopoda:					
0	....	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov.	Pa	CS	1250	II	1a-e
1	1196	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov.	Pa	CS	1251	II	2a-e
2	1196	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov.	Pa	CS	1252	II	3a-d
3	1196	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov.	Pa	CS	1253	II	4a-d
4	1196	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov.	H	CS	1254	II	5a-d
5	1196	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov.	Pa	CS	1255	II	6a-e
6	....	*Hemiptychina morrisi* Grabau, sp. nov.	Pa	CS	1256	III	3a-e
7	....	*Hemiptychina morrisi* Grabau, sp. nov.	Pa	CS	1257	III	4a-e
8	....	*Hemiptychina morrisi* Grabau, sp. nov.	Pa	CS	1258	III	5a-e
9	....	*Hemiptychina morrisi* Grabau, sp. nov.	Pa	AM	23101	....	....
9a	....	*Hemiptychina morrisi* Grabau, sp. nov.	Pa	AM	23102	....	....
10	....	*Notothyris simplex* var. *mongoliensis* Grabau, var. nov.	H	CS	1259	IV	1a-e
11	....	*Notothyris berkeyi* Grabau, sp. nov.	H	CS	1260	IV	4a-d
12	....	*Notothyris nucleolus* (Kutorga)	Pl	CS	1261	IV	3a-d
13	....	*Notothyris irregularis* Grabau, sp. nov.	H	CS	1262	VII	6a-e
14	....	*Dielasma acutangulum* Waagen var. *minor* Grabau, var. nov.	Pa	CS	1263	VII	4a-d
15	....	*Athyris timorensis* Rothpletz var. *mongoliensis* Grabau, var. nov.	H	CS	1264	VIII	9a-f
16	....	*Dielasma elongatum* Schlotheim var. *orientalis* Grabau, var. nov.	H	CS	1265	VII	5a-d
17	....	*Dielasma jisuense* Grabau, sp. nov.	H	CS	1266	IV	6a-d
18	....	*Athyris royssii* Léveillé	Pl	AM	23103	....	....
19	1211	*Camarophoria mutabilis* Tschernyschew	Pl	AM	23104	....	....

Serial No.	Locality No.	H —HOLOTYPE—Single specimen selected as *the* type C —COTYPE—One of a group of equal type and value Pa—PARATYPE—Described in addition to holotype Pl —PLESIOTYPE—Specimen used in further description of an already described species	a Type	b Museum	c Catalogue No.	d Plate	e Figures
		BRACHIOPODA: (Continued)					
20	....	....	....	....	....	....	....
21	1196	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov.	Pa	AM	23105	....	....
22	1196	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov.	Pa	AM	23106	....	....
23	1194	*Marginifera jisuensis* Chao	Pa	CS	1536	XXIX XXX	22 19
24	1194	*Marginifera jisuensis* Chao	Pa	CS	1548	XXX	18a-b
25	....	*Dielasma millepunctatum* Hall var. *mongolicum* Grabau, var. nov.	H	CS	1267	IV	5a-d
26	1196	*Hustedia grandicosta* (Davidson)	Pl	CS	1268	V	6a-d
27	1190	*Hustedia remota* (Eichwald)	Pl	CS	1269	VII	8a-e
28	1194	*Marginifera jisuensis* Chao	Pa	CS	1567	....	....
29	1194	*Martinia mongolica* Grabau, sp. nov.	Pa	CS	1270	XV	3a-e
30	1194	*Martinia orbicularis* Gemmellaro	Pl	CS	1271	XV	7a-e
31	1190	*Uncinulus mongolicus* Grabau, sp. nov.	H	CS	1272	V	7a-d
32	....	*Uncinulus mongolicus* Grabau, sp. nov.	Pa	CS	1273	V	8a-d
33	1211	*Orthotychia derbyi* (Waagen) var. *nana* Grabau, var. nov.	H	CS	1274	X	1a-d
34	1190	*Camarophoria mutabilis* Tschernyschew	Pl	CS	1275	IV	7a-e
35	1194	*Martinia orbicularis* Gemmellaro	Pl	CS	1276	XV	5a-f
36	1194	*Martinia mongolica* Grabau, sp. nov.	Pa	CS	1277	XV	2a-e
37	1194	*Orthotychia* sp.	....	CS	1589	....	....
38	1194	*Martinia rectangularis* Grabau, sp. nov.	H	CS	1278	XVI	4a-f
39	1194	*Martinia mongolica* Grabau, sp. nov.	Pa	AM	23107	....	....
40	1194	*Martinia distefanoi* var. *spissa* Grabau, var. nov.	H	CS	1279	XVII	4a-f
41	1194	*Martinia osborni* Grabau, sp. nov.	Pa	CS	1280	XIV	2a-e
42	1194	*Martinia mongolica* Grabau, sp. nov.	Pa	AM	23108	....	....
43	1194	*Martinia mongolica* Grabau, sp. nov.	Pa	AM	23109	....	....
44	1194	*Martinia mongolica* Grabau, sp. nov.	Pa	AM	23110	....	....
45	1194	*Martinia osborni* Grabau, sp. nov.	Pa	CS	1281	XIV	1a-e
46	1194	*Martinia orbicularis* Gemmellaro	Pl	CS	1282	XV	6a-f
47	....	*Squamularia elegantuloides* Grabau, sp. nov.	H	CS	1283	XVI	1a-f
48	....	*Martinia mongolica* Grabau, sp. nov.	Pa	CS	1284	XV	1a-e
49	1194	*Martinia mongolica* Grabau, sp. nov.	Pa	CS	1588	....	....
50	1194	*Marginifera jisuensis* Chao	Pa	CS	1549	XXX	17a-b
51	1208?	*Camarophoria superstes* (Verneuil)	Pl	CS	1285	V	3a-e

52	1208	*Camarophoria superstes* (Verneuil)	Pl	CS	1286	V	4a-e
53	....	*Camarophoria superstes* (Verneuil)	Pl	CS	1287	IV	8a-d
54	1211	*Camarophoria mutabilis* Tschernyschew	Pl	CS	1288	V	1a-e
55	....	*Camarophoria mutabilis* Tschernyschew	Pl	CS	1289	V	2a-e
56	1211	*Hustedia grandicosta* (Davidson) mut. *lata* Grabau, mut. nov	H	CS	1290	V	5a-e
57	....	*Uncinulus mongolicus* Grabau, sp. nov	Pa	AM	23111	....	....
58	....	*Morrisina sparsiplicata* (Waagen) var. *nana* Grabau, var. nov	H	CS	1291	VIII	3a-e
59	1193	*Beecheria sublævis* (Waagen)	Pl	CS	1292	VIII	1a-f
60	....	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov	Pa	AM	23112	....	....
61	1196	*Dielasma truncatum* Waagen var. *mongolicum* Grabau	H	CS	1293	VII	2a-e
62	....	*Dielasma giganteum* Tschernyschew var. *anteplicatum* Grabau, var. nov	H	CS	1294	VII	1a-c
63	....	*Dielasma itaitubense* (Derby)	Pl	CS	1295	IV	2a-e
64	....	*Dielasma acutangulum* Waagen var. *minor* Grabau, var. nov	Pa	CS	1296	VII	9a-d
65	....	*Dielasma acutangulum* Waagen var. *minor* Grabau, var. nov	H	CS	1297	VII	10a-d
66	....	*Beecheria sublævis* (Waagen)	....	CS	1587	....	....
67	....	*Mongolina subdieneri* Grabau, sp. nov	Pa	AM	23113	....	....
68	....	*Dielasma elongatum* Schlotheim var. *orientale* Grabau, var. nov	Pa	CS	1298	VII	7a-d
69	....	*Dielasma acutangulum* Waagen var. *minor* Grabau, var. nov	Pa	CS	1299	VII	11a-c
70	....	*Mongolina subdieneri* Grabau, sp. nov	H	CS	1300	VIII	5a-f
71	....	*Jisuina elegantula* Grabau, sp. nov	H	CS	1301	VIII	4a-e
72	....	*Beecheria sublævis* (Waagen)	Pl	AM	23114	....	....
73	1190	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov	Met.	AM	23115	....	....
74	1208	*Morrisina sparsiplicata* (Waagen)	Pl	CS	1302	VIII	2a-e
75	....	*Notothyris simplex* var. *mongoliensis* Grabau, var. nov	Pa	CS	1303	IX	2a-e
76	....	*Notothyris nucleolus* (Kutorga)	Pl	CS	1304	VIII	7a-f
77	....	*Notothyris nucleolus* (Kutorga)	Pl	CS	1305	VIII	8a-c
78	....	*Notothyris nucleolus* (Kutorga) mut. α Grabau, mut. nov	H	CS	1306	VIII	6a-f
79	....	*Athyris timorensis* Rothpletz var. *mongoliensis* Grabau, var. nov	Pa	CS	1307	IX	4a-e
80	....	*Athyris royssii* Léveillé	Pl	CS	1308	VI	7a-d
81	....	*Athyris royssii* Léveillé	Pl	CS	1309	VI	8a-d
82	....	*Athyris royssii* Léveillé	Pl	AM	23116	....	....
83	1194	*Enteletes andrewsi* Grabau, sp. nov	Pa	CS	1310	X	2a-f
84	1194	*Enteletes andrewsi* Grabau, sp. nov	Pa	CS	1311	X	3a-e
85	1194	*Enteletes angulatoplicata* Grabau, sp. nov	H	CS	1312	XI	3a-f
86	1190	*Enteletes andrewsi* Grabau, sp. nov	Pa	CS	1313	X	5a-g
87	1190	*Enteletes andrewsi* Grabau, sp. nov	H	CS	1314	XI	1a-f
88	1190	*Enteletes andrewsi* Grabau, sp. nov	Pa	AM	23117	....	....
89	1190	*Enteletes andrewsi* Grabau, sp. nov	Pa	CS	1315	XI	2a-f
90	....	*Enteletes andrewsi* Grabau, sp. nov	Pa	CS	1316	X	4a-e
91	1196	*Enteletes angulatoplicata* Grabau, sp. nov	Pa	CS	1317	XI	4a-c

Serial No.	Locality No.	H —HOLOTYPE—Single specimen selected as *the* type C —COTYPE—One of a group of equal type and value Pa—PARATYPE—Described in addition to holotype Pl —PLESIOTYPE—Specimen used in further description of an already described species	a Type	b Museum	c Catalogue No.	d Plate	e Figures
		BRACHIOPODA: (Continued)					
92	....	*Enteletes angulatoplicata* Grabau, sp. nov.	Pa	CS	1318	XII	1a-d
93	1190	*Enteletes angulatoplicata* Grabau, sp. nov.	Pa	AM	23118	....	....
94	....	*Enteletes angulatoplicata* Grabau, sp. nov.	Pa	AM	23119	....	....
95	....	*Enteletes angulatoplicata* Grabau, sp. nov.	Pa	AM	23120	....	....
96	1194	*Enteletes obesa* Grabau, sp. nov.	Pa	CS	1319	IX	7a-f
97	1190	*Enteletes obesa* Grabau, sp. nov.	Pa	CS	1320	XII	3a-f
98	....	*Enteletes obesa* Grabau, sp. nov.	Pa	AM	23121	....	....
99	1194	*Enteletes obesa* Grabau, sp. nov.	Pa	AM	23122	....	....
100	1190?	*Enteletes obesa* Grabau, sp. nov.	H	CS	1321	XII	4a-f
101	1194	*Enteletes obesa* Grabau, sp. nov.	Pa	AM	23123	....	....
102	1196	*Enteletes obesa* Grabau, sp. nov.	Pa	AM	23124	....	....
103	1196	*Enteletes obesa* Grabau, sp. nov.	Pa	CS	....	....	....
104	....	*Enteletes obesa* Grabau, sp. nov.	Pa	CS	1322	XII	2a-e
105	....	*Enteletes nucleola* Grabau, sp. nov.	Pa	CS	1323	XIII	3a-f
106	1211	*Enteletes nucleola* Grabau, sp. nov.	Pa	CS	1324	XIII	4a-f
107	....	*Enteletes nucleola* Grabau, sp. nov.	Pa	AM	23126	....	....
108	....	*Enteletes nucleola* Grabau, sp. nov.	Pa	AM	23127	....	....
109	1190	*Enteletes nucleola* Grabau, sp. nov.	Pa	AM	23128	....	....
110	1190	*Enteletes nucleola* Grabau, sp. nov.	Pa	AM	23129	....	....
111	1194	*Enteletes nucleola* Grabau, sp. nov.	Pa	AM	23130	....	....
112	1196?	*Enteletes nucleola* Grabau, sp. nov.	Pa	AM	23131	....	....
113	....	*Enteletes subobesa* Grabau, sp. nov.	C	CS	1325	XIII	1a-e
114	1196	*Enteletes subobesa* Grabau, sp. nov.	C	CS	1326	XIII	2a-e
114a	1196	*Enteletes subobesa* Grabau, sp. nov.	C	AM	23132	....	....
115	....	*Squamularia indica* (Waagen)	Pl	AM	23133	....	....
116	1194	*Martinia mongolica* Grabau, sp. nov.	H	CS	1327	XV	4a-f
117	1194	*Martinia orbicularis* Gemmellaro	Pl	CS	1328	XV	8a-c
118	1194	*Martinia distorta* Grabau	H	CS	1329	XVIII	5a-f
119	1194	*Martinia osborni* Grabau, sp. nov.	Pa	AM	23134	....	....
120	1208	*Martinia osborni* Grabau, sp. nov.	Pa	CS	1330	XIV	5a-c
121	1193	*Martinia osborni* Grabau, sp. nov.	Pa	AM	23135	....	....
122	1208	*Martinia osborni* Grabau, sp. nov.	H	CS	1331	XIV	4a-d
123	....	*Martinia orbicularis* Gemmellaro	Pl	AM	23136	....	....

124	1196	*Athyris excavata* Grabau, sp. nov.	H	CS	1332	VI	5a-d
125		*Martinia osborni* Grabau, sp. nov.	Pa	AM	23137		
126	1194	*Martinia osborni* Grabau, sp. nov.	Pa	CS	1333	XIV	6a-d
127	1208	*Squamularia indica* (Waagen)	Pl	AM	23138		
128	1194	*Marginifera jisuensis* Chao	Pa	CS	1550	XXX	16a-c
129	1193	*Martinia mongolica* Grabau, sp. nov.	Pa	AM	23139		
130	1193	*Squamularia indica* (Waagen)	Pl	AM	23140		
131	1194	*Martinia osborni* Grabau, sp. nov.	Pa	CS	1334	XIV	3a-e
132	1194	*Martinia mongolica* Grabau, sp. nov.	Pa	AM	23141		
133		*Martinia sinensis* Grabau, sp. nov.	H	CS	1335	XVI	3a-f
134	1194	*Martinia osborni* Grabau, sp. nov.	Pa	AM	23142		
135	1193	*Martinia orbicularis* Gemmellaro	Pl	AM	23143		
136	1194	*Martinia osborni* Grabau, sp. nov.	Pa	AM	23144		
137	1211	*Martinia* cf. *mongolica* Grabau, sp. nov.	Pa	AM	23145		
138	1193	*Squamularia elegantuloides* Grabau, sp. nov.	Pa	CS	1336	XVI	2
139	1194	*Martinia orbicularis* Gemmellaro	Pl	AM	23146		
140	1194	*Martinia sinensis* Grabau, sp. nov.	Pa	CS	1337	XVI	9a-c
141	1194	*Martinia osborni* Grabau, sp. nov.	Pa	AM	23147		
142	1194	*Martinia mongolica* Grabau, sp. nov.	Pa	AM	23148		
143	1194	*Martinia mongolica* Grabau, sp. nov.	Pa	CS	1338	XVIII	1a-e
144	1194	*Martinia osborni* Grabau, sp. nov.	Pa	AM	23149		
145	1194	*Martinia rhomboidalis* Grabau	H	CS	1339	XVIII	6a-f
146	1194	*Martinia osborni* Grabau, sp. nov.	Pa	CS	1496		
147	1193	*Martinia osborni* Grabau, sp. nov.	Pa	AM	23150		
148	1193	*Martinia osborni* Grabau, sp. nov.	Pa	CS	1497		
149	1193	*Martinia osborni* Grabau, sp. nov.	Pa	CS	1498		
150	1193	*Martinia osborni* Grabau, sp. nov.	Pa	CS	1586		
151	1211	*Martinia orbicularis* Gemmellaro	Pl	AM	23151		
152	1193	*Martinia osborni* Grabau, sp. nov.	Pa	AM	23152		
153	1211	*Martinia osborni* Grabau, sp. nov.	Pa	AM	23153		
154	1211	*Squamularia indica* (Waagen)	Pl	CS	1500		
155	1194	*Martinia* cf. *distefanoi* Gemmellaro	Pl	CS	1340	XVI	6
						XVII	1a-e
156		*Martinia* cf. *distefanoi* Gemmellaro	Pl	CS	1341	XVI	7
						XVII	2a-d
157		*Martinia* cf. *distefanoi* Gemmellaro	Pl	CS	1342	XVI	8
						XVII	3a-d
158		*Martinia* cf. *distefanoi* Gemmellaro	Pl	AM	23154		
159	1194	*Squamularia indica* (Waagen)	Pl	AM	23155		
160	1194	*Squamularia indica* (Waagen)	Pl	AM	23156		

Serial No.	Locality No.	H —Holotype—Single specimen selected as *the* type C —Cotype—One of a group of equal type and value Pa—Paratype—Described in addition to holotype Pl —Plesiotype—Specimen used in further description of an already described species	a Type	b Museum	c Catalogue No.	d Plate	e Figures
		Brachiopoda: (Continued)					
161	1193	*Squamularia indica* (Waagen)	Pl	AM	23157		
162		*Squamularia indica* (Waagen)	Pl	CS	1343	XVII	5a-f
163		*Squamularia indica* (Waagen)	Pl	CS			
164	1208	*Squamularia indica* (Waagen)	Pl	CS	1344	XVIII	3a-c
165	1196	*Squamularia indica* (Waagen)	Pl	CS	1345	XVIII	2a-d
166	1208						
167	1205	*Squamularia waageni* (v. Loczy)	Pl	CS	1346	XVI	5a-d
168	1208	*Dielasma* cf. *truncatum* Waagen	Pl	CS	1347	IX	1a-e
169							
170	1208	*Squamularia indica* (Waagen)	Pl	AM	23159		
171	1190	*Meekella uralica* Tschernyschew	Pl	CS	1414	XXV	6a-d
172	1193	*Martinia* cf. *osborni* Grabau, sp. nov		AM	23160		
173	1194	*Enteletes* sp.		CS			
174		*Athyris excavata* Grabau, sp. nov.	Pa	CS	1348	VI	6a-c
175	1209	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ.	H	CS	1349	XIX	3a-c
176	1209	*Spiriferella salteri* Tschernyschew (*typica*), mut γ	Pl	CS	1350	XIX	1a-d
177	1209	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.	Pa	CS			
178	1209	*Spiriferella salteri* Tschernyschew	Pl	CS	1351	XXIII	2
179	1192	*Spiriferella persaranæ* Grabau, sp. nov.	H	CS	1352	XIX	4a-b
180	1209	*Spirifer moosakhailensis* Davidson	Pl	CS	1353	XXIII	5a-c
181	1209	*Spirifer moosakhailensis* Davidson	Pl	CS	1354	XXIII	6
182	1209	*Spiriferella salteri* Tschernyschew var. *simplex* Grabau, var. nov., mut. α.	Pa	CS	1355	XX	1
183	1209	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.	Pa	CS	1356	XX	3
184	1209	*Spiriferella salteri* Tschernyschew (*typica*), mut. γ.	Pl	CS	1357	XX	7
185	1209	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.	Pa	CS	1358	XX	4
186	1209	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.	Pa	AM	23163		
187	1209	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.	H	CS	1359	XX	5
188	1209	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ.	Pa	CS	1360	XX	8
189	1209	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.	Pa	CS	1361	XX	6
190	1209	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.	Pa	CS			
191	1209	=177?					
192	1209	=179?					
193		*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β.	Pa	CS			

194	1205	*Spiriferella rajah* (Salter)	Pl	CS	1362	XXII	1a-e
195	1209?	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, mut. δ	Pa	CS	1501		
196	1209	*Spiriferella salteri* Tschernyschew	Pl	CS	1363	XXIII	1
197	1209	*Spiriferella salteri* Tschernyschew (counterpart of No. 196)	Pl	CS			
198	1209	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ	Pa	CS	1364	XXIII	3
199	1209	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ	Pa	AM	23167		
200	1209	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β	Pa	CS	1365	XXIII	4
201	1209	*Spiriferella salteri* Tschernyschew	Pl	CS	1366	XXII	7
202	1209	*Spiriferella salteri* Tschernyschew var. *simplex* Grabau, var. nov., mut. α	H	CS	1367	XX	2a-b
203	1192	*Spiriferella saranæ* (Verneuil)	Pl	CS	1368	XXII	4a-b
204	1209	*Spiriferella salteri* Tschernyschew (*typica*), mut. γ	Pl	CS	1369	XIX	5a
205	1209	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ	Pa	CS	1369	XIX	5b
206	1209	*Spiriferella salteri* Tschernyschew (*typica*), mut. γ	Pl	CS	1369	XIX	5c
207	1209	*Spiriferella salteri* Tschernyschew (*typica*), mut. γ	Pl	CS	1369	XIX	5d
208	1209	*Spiriferella keilhaviiformis* Fredericks	Pl	CS	1373	XXII	3
209	1206	*Spirifer moosakhailensis* Davidson	Pl	AM	23168		
210	1209?	*Spiriferella salteri* Tschernyschew	Pl	AM	23169		
211	1209	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ	Pa	CS	1374	XXII	9
212	1211	*Spiriferella saranæ* (Verneuil)	Pl	CS			
213	?	*Spiriferella saranæ* (Verneuil)	Pl	AM	23171		
214	1209	*Spiriferella saranæ* (Verneuil)	Pl	AM	23172		
215	?	*Spiriferella saranæ* (Verneuil)	Pl	AM	23173		
216	1209	*Spiriferella keilhaviiformis* Fredericks	Pl	CS	1375	XXI	6
217	1209	*Spiriferella keilhaviiformis* Fredericks	Pl	CS	1376	XXI	7
218	1209	*Spiriferella keilhaviiformis* Fredericks (with No. 208)	Pl	CS	1585		
219	1209	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ	Pa	CS	1377	XIX	2a-c
220	1209	*Spiriferella salteri* Tschernyschew	Pl	CS	1378	XXII	5
221	1209	*Spiriferella salteri* Tschernyschew	Pl	CS	1502		
222	1209	*Spiriferella keilhaviiformis* Fredericks?	Pl	AM	23174		
223	1209	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, mut. δ	Pa	AM	23175		
224	1209	*Spiriferella rajah* (Salter)	Pl	CS	1379	XII	2a-b
225	1209	*Spirifer moosakhailensis* Davidson	Pl	AM	23176		
226	?	*Spiriferella keilhavii* (v. Buch)	Pl	CS	1380	XXI	2a-c
227	1209	*Spiriferella keilhavii* (v. Buch)	Pl	CS	1381	XX XXI	9a-c 1
228	1209	*Spiriferella keilhavii* (v. Buch)	Pl	CS	1382	XXI	3
229	?	*Spiriferella keilhavii* (v. Buch)	Pl	AM	23177		
230	1209	*Spiriferella keilhavii* (v. Buch)	Pl	CS	1383	XXI	4
231	1209	*Spiriferella keilhavii* (v. Buch)	Pl	AM	23178		
232	1190	*Spiriferella keilhavii* (v. Buch)	Pl	AM	23179		

Serial No.	Locality No.	H —HOLOTYPE—Single specimen selected as *the* type C —COTYPE—One of a group of equal type and value Pa—PARATYPE—Described in addition to holotype Pl —PLESIOTYPE—Specimen used in further description of an already described species	a Type	b Museum	c Catalogue No.	d Plate	c Figures
		BRACHIOPODA: (Continued)					
233	1209	*Spiriferella keilhavii* (v. Buch)	Pl	AM	23180		
234	1205	*Spirifer moosakhailensis*? Davidson	Pl	AM	23181		
235	1203	*Spiriferella keilhavii* (v. Buch)	Pl	AM	23182		
236	1192	*Spiriferella keilhavii* (v. Buch) mut. *primitiva* Grabau, mut. nov.	H	CS	1384	XXI	5
237	1209?	*Spirifer moosakhailensis* Davidson	Pl	AM	23183		
238	1209	*Spirifer moosakhailensis* Davidson	Pl	AM	23184		
239	1209	*Spirifer moosakhailensis* Davidson	Pl	AM	23185		
240	1209?	*Spirifer moosakhailensis* Davidson	Pl	AM	23186		
241	1209?	*Spirifer moosakhailensis* Davidson	Pl	CS	1385	XXIII	7
242	1190	*Spirifer moosakhailensis* Davidson	Pl	CS	1386	XXIII	8a-b
242a	1190	*Spirifer moosakhailensis* Davidson (counterpart of No. 242)		CS			
243	1205	*Spirifer moosakhailensis* Davidson	Pl	AM	23188		
244	1205	*Spirifer moosakhailensis* Davidson	Pl	AM	23189		
245	1192	*Spirifer moosakhailensis* Davidson	Pl	AM	23190		
246	1210	*Spiriferella saranæ* (Verneuil)	Pl	AM	23191		
247	1192	*Spiriferella keilhavii* (v. Buch)?	Pl	AM	23192		
248	1209	*Spirifer moosakhailensis* Davidson	Pl	AM	23193		
249	1205	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, mut. δ and counterpart	Pa	CS			
250	1205	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β?	Pa	AM	23195		
251	1205	*Spiriferella saranæ* Tschernyschew?	Pl	CS			
252	1209	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β	Pa	AM	23196		
253	1209	*Spiriferella salteri* Tschernyschew	Pl	AM	23197		
254	1205	?					
255	1209	*Spiriferella salteri* Tschernyschew (*typica*), mut. γ	Pl	CS	1387	XXII	6
256	1209	*Spiriferella salteri* Tschernyschew (*typica*), mut. γ	Pl	AM	23198		
257	1209	*Spiriferella salteri* Tschernyschew (*typica*), mut. γ	Pl	AM	23199		
258	1209	*Spiriferella salteri* Tschernyschew	Pl	CS			
259	1209	*Spiriferella salteri* Tschernyschew (*typica*), mut. γ	Pl	AM	23200		
260	1209	*Spiriferella salteri* Tschernyschew	Pl	CS			
261	1209	*Spiriferella salteri* Tschernyschew	Pl	CS	1388	XXII	10
262	1210	*Spirifer moosakhailensis* Davidson	Pl	AM	23201		
263	1209	*Spiriferella salteri* Tschernyschew	Pl	AM	23202		
264	1200	*Spiriferella rajah* (Salter)	Pl	AM	23203		

265	1209	*Spiriferella salteri* Tschernyschew	Pl	CS			
266	1211	*Spirifer moosakhailensis* Davidson	Pl	AM	23204		
267	1209	*Spiriferella salteri* Tschernyschew	Pl	CS	1389	XXII	8
268	1204	*Spiriferella salteri* Tschernyschew, mut.? (Text-Fig. 59)	Pl	CS	1503	XXII	3
269	1209?	*Spirifer* sp.		CS	1583		
270	1200	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β	Pa	AM	23205		
271	1192	*Proboscidella* cf. *lata* Tschernyschew	Pl	CS	1545	XXX	13a-b
272	1192	*Proboscidella* cf. *lata* Tschernyschew	Pl	CS	1546	XXX	14
273	1192	*Proboscidella* cf. *lata* Tschernyschew	Pl	CS	1547		
274	1196	*Spiriferina mongolica* Grabau, sp. nov.	Pa	CS	1390	IX	6a-f
275	1196	*Spiriferina mongolica* Grabau, sp. nov.	H	CS	1391	IX	5a-f
276	1196	*Spiriferina mongolica* Grabau, sp. nov.	Pa	AM	23206		
277	1190	*Productus* (*Echinoconchus*) *fasciatus* Kutorga	Pl	CS	1515	XXIX	1a-c
278	1190	*Productus* (*Waagenoconcha*) *humboldti* d'Orbigny	Pl	CS	1517	XXIX	3
279	1189	*Productus* (*Waagenoconcha*) *humboldti* d'Orbigny	Pl	CS	1516	XXIX	2
280	1190	*Aulosteges gigantiformis* Grabau, sp. nov.	H	CS	1420	XXVII	1a-c
281	1190	*Aulosteges gigantiformis* Grabau, sp. nov.	Pa	CS	1421	XXVII	2a-c
282	1190	*Aulosteges gigantiformis* Grabau, sp. nov.	Pa	CS	1422	XXVII	3a-c
283	1211	*Aulosteges grangeri* Grabau, sp. nov.	H	CS	1423	XXVII	4a-d
284	1211	*Aulosteges grangeri* Grabau, sp. nov.	Pa	CS	1424	XXVII	5a-d
285		*Derbyella bureri* Grabau, sp. nov.	Pa	CS	1415	XXV XXVI	7 3a-c
286	1194	*Derbyella bureri* Grabau, sp. nov.	H	CS	1416	XXV XXVI	8 2a-c
287	1194	*Derbyella bureri* Grabau, sp. nov.	Pa	AM	23207		
288	1207	*Streptorhynchus kayseri* Schellwien	Pl	CS	1370	XXIV	1a-d
289	1194	*Derbyella bureri* Grabau, sp. nov. (two parts)	Pa	AM	23208		
290							
291	1194	*Derbya(?)* (*Derbyina*) *mongolica* Grabau, sp. nov.	Pa	CS	1582		
292	1196	*Derbya* (?) (*Derbyina*) *mongolica* Grabau, sp. nov. (Text-Fig. 66)	H	CS	1409	XXV	3a-c
293	?	*Streptorhynchus pelargonatus* (Schlotheim)	Pl	CS	1371	XXIV	2a-e
294	1196	*Richthofenia lawrenciana* (de Koninck)	Pl	CS	1426	XXVII	7a-d
295	1196	*Richthofenia lawrenciana* (de Koninck)	Pl	CS	1427	XXVIII	1a-e
296	1196	*Richthofenia lawrenciana* (de Koninck)	Pl	CS	1425	XXVII	6a-c
297	1194	*Derbyella subrotunda* Grabau, sp. nov.	H	CS	1418	XXVI	4a-f
298	1190	*Orthothetina ruber* (Frech)	Pl	CS	1403	XXIV	6a-c
299a		*Streptorhynchus kayseri* Schellwien	Pl	CS	1452		
299b		*Pseudamusium* cf. *auriculatum* Grabau	Pa	CS	1452	XXXII	13
300	1210	*Streptorhynchus broilii* Grabau, sp. nov.	C	CS	1372	XXIV	3a-d
301	1208	*Streptorhynchus broilii* Grabau, sp. nov.	C	CS	1401	XXIV	4a-c

Serial No.	Locality No.	H —Holotype—Single specimen selected as *the* type C —Cotype—One of a group of equal type and value Pa—Paratype—Described in addition to holotype Pl —Plesiotype—Specimen used in further description of an already described species	a Type	b Museum	c Catalogue No.	d Plate	e Figures
		Brachiopoda: (Continued)					
302a	1190	*Streptorhynchus* sp. }	....	....	....	....	....
302b	....	*Streptorhynchus* sp. }	....	CS	1402	XXIV	5
303	1190	*Derbya dupliciseptata* Grabau, sp. nov.	H	CS	1407	XXV	1a-c
304	1196	*Derbya* cf. *hemisphærica* Waagen	Pl	CS	1410	XXV	4
305	1196	*Derbya* cf. *hemisphærica* Waagen	Pl	CS	1411	....	....
306	1196	*Derbya* cf. *hemisphærica* Waagen	Pl	AM	23209	....	....
307	1194	*Orthothetina* sp.	....	CS	1405	XXIV	8a-d
308	1190	*Geyerella mongolica* Grabau, sp. nov. (Text-Figs. 67a-c)	H	CS	1417	XXVI	1a-d
309	....	*Derbya* cf. *hemisphærica* Waagen	Pl	CS	1413	XXV	5
310	1196	*Derbya* cf. *hemisphærica* Waagen	Pl	AM	23210	....	....
311	....	*Streptorhynchus* sp.	....	CS	1580	....	....
312	1207	*Orthothetes* sp.	....	CS	1581	....	....
313	1193	....	....	....	....	....	....
314	1192	*Schellwienella regina* Grabau, sp. nov.	H	CS	1408	XXV	2a-d
315	1193	*Hemiptychina morrisi* Grabau, sp. nov.	H	CS	1392	III	1a-e
316	1194	*Derbyella minor* Grabau, sp. nov.	H	CS	1419	XXVI	5a-f
317	1190	*Derbya* sp.	....	CS	1576	....	....
318	1194	*Orthothetes?* sp.	....	CS	1577	....	....
319	1192	*Streptorhynchus?* sp.	....	CS	1578	....	....
320	....	*Streptorhynchus?* sp.	....	CS	1579	....	....
321	1207	*Orthothetina* cf. *eusarkos* (Abich)	Pl	CS	1404	XXIV	7a-b
322	....	*Orthothetina ruber* (Frech)?	....	CS	1406	XXIV	9a-c
323	1207	*Squamularia indica* (Waagen)	Pl	AM	23211	....	....
324	1193	*Aulacorhynchus* sp.	....	CS	1426	XXVIII	2
325a	1193	*Lyttonia nobilis* Waagen	Pl	CS	1427	XXVIII	4
325b	1193	*Lyttonia nobilis* Waagen	Pl	CS	1427	XXVIII	6
326	1193	*Lyttonia nobilis* Waagen (counterpart of No. 325a)	Pl	CS	1428	XXVIII	5
327	1193	*Lyttonia nobilis* Waagen	Pl	CS	1427	XXVIII	3a-c
328	691[1]	*Lyttonia?* sp. (cf. *Oldhamina lopingensis* Grabau)	....	CS	1429	XXVIII	7
329	1208	*Productus* (*Linoproductus*) *lineatus* (Waagen)	Pl	CS	1540	XXIX	26
330	1209	*Productus* (*Linoproductus*) *lineatus* (Waagen)	Pl	CS	1541	XXIX	27a-b
331	1208	*Productus* (*Linoproductus*) *lineatus* (Waagen)	Pl	CS	1539	XXIX	25

[1] Berkey and Morris, 1927, p. 181.

332	1192	*Productus* (*Striatifera*) cf. *ischmensis* Tschernyschew	Pl	CS	1519	XXIX	5
333	1192	*Productus* cf. *porrectus* Kutorga	Pl	CS	1564	XXX	10a-b
334	1192	*Productus* cf. *porrectus* Kutorga	Pl	CS	1565	XXX	11
335	1207	*Productus* cf. *porrectus* Kutorga	Pl	CS	1566	XXX	12
336	1192	*Productus* (*Linoproductus?*) *mammatus* Keyserling	Pl	CS	1528	XXIX	14
337	1192	*Productus* sp. A		CS	1571		
338	1192	*Productus* sp. A		CS	1572		
339	1192	*Productus* sp. A		CS	1573		
340	1192	*Productus* sp. B		CS	1574		
341	1205	*Productus* sp. C		CS	1575		
342	1190	*Productus* (*Striatifera*) *compressus* Waagen var. *corniformis* Chao, var. nov.	C	CS	1520	XXIX	6
343	1190	*Productus* (*Striatifera*) *compressus* Waagen var. *corniformis* Chao, var. nov.	C	CS	1523	XXIX	9a-b
344	?	*Productus* (*Striatifera*) *compressus* Waagen var. *corniformis* Chao, var. nov.	C	CS	1522	XXIX	8a-b
345	1209	*Productus* (*Striatifera*) *compressus* Waagen var. *corniformis* Chao, var. nov.	C	CS	1521	XXIX	7
346	1192	*Productus* (*Juresania*) cf. *juresanensis* (Tschernyschew)	Pl	CS			
347	1194	*Marginifera jisuensis* Chao	Pa	CS	1533	XXIX	19a-c
348	1194	*Marginifera jisuensis* Chao	H	CS	1529	XXIX	15a-c
						XXX	15a-b
349	1194	*Marginifera jisuensis* Chao	Pa	CS	1534	XXIX	20a-c
350	1196	*Marginifera jisuensis* Chao	Pa	CS	1531	XXIX	17a-c
351	1196	*Marginifera jisuensis* Chao	Pa	CS	1532	XXIX	18a-c
352	1194	*Marginifera jisuensis* Chao	Pa	CS	1535	XXIX	21a-c
353		*Marginifera jisuensis* Chao	Pa	CS	1537	XXIX	23
354	1194	*Marginifera jisuensis* Chao	Pa	CS	1538	XXIX	24
355	1194	*Marginifera jisuensis* Chao	Pa	CS	1530	XXIX	16a-c
356	1192	*Marginifera typica* Waagen var. *septentrionalis* Tschernyschew	Pl	CS	1512	XXX	7a-c
357	1192	*Marginifera typica* Waagen var. *septentrionalis* Tschernyschew	Pl	CS	1511	XXX	6
358	1192	*Marginifera typica* Waagen var. *septentrionalis* Tschernyschew	Pl	CS	1555		
359	1192	*Marginifera typica* Waagen var. *septentrionalis* Tschernyschew	Pl	CS	1513	XXX	8
360	1192	*Marginifera typica* Waagen var. *septentrionalis* Tschernyschew	Pl	CS	1556		
361	1192	*Marginifera typica* Waagen var. *septentrionalis* Tschernyschew	Pl	CS	1514	XXX	9
362	1192	*Marginifera typica* Waagen var. *septentrionalis* Tschernyschew	Pl	CS	1557		
363	1209	*Marginifera gobiensis* Chao	C	CS	1510	XXX	5a-c
364	1209	*Marginifera gobiensis* Chao	C	CS	1551		
365	1209	*Marginifera gobiensis* Chao	C	CS	1552		
366	1209	*Marginifera gobiensis* Chao	C	CS	1553		
367	1209	*Marginifera gobiensis* Chao	C	CS	1506	XXX	1a-b
368	1209	*Marginifera gobiensis* Chao	C	CS	1508	XXX	3a-b
369	1209	*Marginifera gobiensis* Chao	C	CS	1554		
370	1209	*Marginifera gobiensis* Chao	C	CS	1509	XXX	4

Serial No.	Locality No.	H —HOLOTYPE—Single specimen selected as *the* type C —COTYPE—One of a group of equal type and value Pa —PARATYPE—Described in addition to holotype Pl —PLESIOTYPE—Specimen used in further description of an already described species	a Type	b Museum	c Catalogue No.	d Plate	e Figures
		BRACHIOPODA: (Continued)					
371	1209	*Marginifera gobiensis* Chao	C	CS	1507	XXX	2
372	1208	*Marginifera morrisi* Chao	Pa	CS	1544	XXIX	30
373	1208	*Marginifera morrisi* Chao	Pa	CS	1558		
374	1208	*Marginifera morrisi* Chao	Pa	CS	1559		
375	1208	*Marginifera morrisi* Chao	Pa	CS	1560		
376	1196	*Marginifera morrisi* Chao	H	CS	1542	XXIX	28a-e
377	1196	*Marginifera morrisi* Chao	Pa	CS	1543	XXIX	29a-c
378	1196	*Marginifera morrisi* Chao	Pa	CS			
379	1194	*Marginifera morrisi* Chao	Pa	CS	1561		
380		*Notothyris irregularis* Grabau, sp. nov.	Pa	AM	23212		
381	1208	*Dielasma truncatum* Waagen var. *mongolicum* Grabau, var. nov.	Pa	CS	1393	VII	2a-c
382		See No. 168					
383	1208	*Dielasma truncatum* Waagen var. *mongolicum* Grabau, var. nov.	Pa	CS	1504		
384	1196?	*Hemiptychina himalayensis* var. *mongolica* Grabau, var. nov.	C	CS	1394	III	2a-e
385		*Notothyris irregularis* Grabau, sp. nov.	Pa	CS	1395	IX	3a-e
386		*Notothyris irregularis* Grabau, sp. nov.	Pa	AM	23213		
387		*Uncinulus mongolicus* Grabau, sp. nov.	Pa	CS	1396	VI	3a-e
388		*Uncinulus mongolicus* Grabau, sp. nov.	Pa	CS	1397	VI	4a-e
389		*Uncinulus mongolicus* Grabau, sp. nov.	Pa	AM	23214		
390		*Camarophoria purdoniformis* Grabau, sp. nov.	C	CS	1398	VI	1a-d
391	1196	*Camarophoria purdoniformis* Grabau, sp. nov.	C	CS	1399	VI	2a-e
392	1190	*Enteletes obesa* Grabau, sp. nov.	Pa	AM	23215		
393		*Enteletes nucleola* Grabau, sp. nov.	H	CS	1400	XIII	5a-f
394	1196	*Richthofenia?* sp. or *Scacchinella?* sp.		CS	1430	XXVIII	8a-e
395	1192	*Squamularia indica* (Waagen)	Pl	CS	1401	XXVIII	4a-c
		PELECYPODA:					
396	1196	*Euchondria* (?) *englehardti* (Etheridge and Dun)	Pl	CS	1444	XXXII	5a-c
397	1190	*Euchondria* (?) *englehardti* (Etheridge and Dun)	Pl	CS	1445	XXXII	6a-c
398	1190	*Euchondria* (?) *englehardti* (Etheridge and Dun)	Pl	CS	1446	XXXII	7a-c
399	1190	*Euchondria* (?) *englehardti* (Etheridge and Dun)	Pl	CS	1447	XXXII	8a-c
400	1196	*Schizodus subquadratus* Grabau, sp. nov.	H	CS	1431	XXXI	1a-d
401	1190	*Schizodus elongatus* Grabau, sp. nov.	H	CS	1432	XXXI	1a-c

402	1196	*Pseudomonotis* (*Aviculomonotis*) *matthewi* Grabau, sp. nov.	H	CS	1440	XXXII	1a-c
403	1190	*Pseudomonotis* (*Aviculomonotis*) *mongoliensis* Grabau, sp. nov.	H	CS	1436	XXXI	6a-c
404	1190	*Pseudomonotis* (*Aviculomonotis*) *kazanensis* (de Verneuil)	Pl	CS	1438	XXXI	8
405	1190	*Pseudomonotis* (*Aviculomonotis*) *mongoliensis* Grabau, sp. nov.	Pa	CS	1437	XXXI	7
406	1190	*Conocardium jisuensis* Grabau, sp. nov.	Pa	AM	23216	....	....
407	1194	*Conocardium jisuensis* Grabau, sp. nov.	H	CS	1433	XXXI	3a-d
408	1190	*Pseudamusium auriculatum* Grabau, sp. nov.	H	CS	1448	XXXII	9a-b
409	1190	*Pseudomonotis* (*Aviculomonotis*) *mongoliensis* Grabau, sp. nov.	Pa	CS	1439	XXXI	9a-c
410	1211	*Pseudomonotis furcoplicatus* Grabau, sp. nov.	H	CS	1441	XXXII	2a-b
411	1190	*Pseudomonotis furcoplicatus* Grabau, sp. nov.	Pa	CS	1442	XXXII	3a-c
412	1190	*Pseudamusium* cf. *auriculatum* Grabau	Pa	CS	1450	XXXII	11
413	1190	*Pseudamusium* cf. *auriculatum* Grabau	Pa	CS	1451	XXXII	12
414	1194	*Myalina falcata* Grabau, sp. nov.	H	CS	1453	XXXIII	1a-d
415	....	*Myalina* cf. *verneuili* (McCoy)	Pl	CS	1454	XXXIII	2a-b
416	1196	*Sanguinolites modiomorphoides* Grabau, sp. nov.	Pa	AM	23217	....	....
417	....	*Sanguinolites* sp.	....	CS	1482	....	....
418	1193	*Sanguinolites modiomorphoides* Grabau, sp. nov.	H	CS	1434	XXXI	4a-c
419	1192	*Deltopecten* cf. *subquinquelineatus* (McCoy)	Pl	CS	1443	XXXII	4a-b
420 =323	1207	*Pseudomonotis?* sp.	....	CS	1590	....	....
443	1190	*Pseudamusium* (*Euchondria*) *auriculatum* Grabau, sp. nov. (with *Naticopsis*)	Pa	CS	1449	XXXII	10a-b
		GASTROPODA:					
421	1190	*Bellerophon jonesianus* de Koninck	Pl	CS	1459	XXXIII	7a-c
422	....	*Bellerophon squamatus* Waagen var. *mongoliensis* Grabau, var. nov.	C	CS	1456	XXXIII	4a-b
423	1196	*Bellerophon jonesianus* de Koninck	Pl	CS	1458	XXXIII	6a-c
424	....	*Bellerophon squamatus* Waagen var. *mongoliensis* Grabau, var. nov.	C	AM	23218	....	....
425	....	*Bellerophon squamatus* Waagen var. *mongoliensis* Grabau, var. nov.	C	CS	1455	XXXIII	3a-d
426	....	*Bellerophon jonesianus* de Koninck	Pl	CS	1457	XXXIII	5a-c
427	....	*Bellerophon jonesianus* de Koninck	Pl	CS	....	....	....
428	....	*Luciella planoconvexa* Grabau, sp. nov.	H	CS	1460	XXXIII XXXIV	8 1a-b
429	....	*Luciella planoconvexa* var. *acuta* Grabau	H	CS	1461	XXXIV	2a-b
430	1196	*Flemingia tepeeformis* Grabau, sp. nov.	H	CS	1469	XXXIV	10a-b
431	....	*Flemingia tepeeformis* Grabau, sp. nov	Pa	CS	1470	XXXIV	11a-c
432	....	*Luciella perlimbata* Grabau, sp. nov.	H	CS	1463	XXXIV	4a-b
433	1190	*Worthenia nana* Grabau, sp. nov.	H	CS	1464	XXXIV	5a-b
434	....	*Euomphalus simuloides* Grabau, sp. nov.	H	CS	1465	XXXIV	6a-c
435	....	*Holopella* cf. *trimorpha* Waagen	Pl	CS	1476	XXXV	7
436	1192	*Euomphalus mongolicus* Grabau, sp. nov.	C	CS	1466	XXXIV	7a-b

Serial No.	Locality No.	H —Holotype—Single specimen selected as *the* type C —Cotype—One of a group of equal type and value Pa—Paratype—Described in addition to holotype Pl —Plesiotype—Specimen used in further description of an already described species	a Type	b Museum	c Catalogue No.	d Plate	e Figures
		Gastropoda: (Continued)					
437	1192	*Euomphalus mongolicus* Grabau, sp. nov.	C	CS	1467	XXXIV	8a-b
438	1194	*Luciella elongata* Grabau, sp. nov.	H	CS	1462	XXXIV	3a-b
439	....	*Phymatifer* cf. *coroniferus* de Koninck	Pl	CS	1468	XXXIV	9
440	1196	*Flemingia gigas* Grabau, sp. nov.	H	CS	1471	XXXV	1a-b
441	1205	*Strophostylus indicus* (Waagen)	Pl	CS	1475	XXXV	6a-b
442	1190	*Strophostylus indicus* (Waagen)	Pl	CS	1474	XXXV	5a-b
443	1190	*Naticopsis khoovensis* Waagen and	Pl	CS	1449	XXXV	4a-b
....	....	*Pseudamusium auriculatum* Grabau, sp. nov.	Pa	....	....	XXXII	10
444	1196	*Naticopsis khoovensis* Waagen	Pl	CS	1473	XXXV	3a-c
445	1196	*Naticopsis khoovensis* Waagen	Pl	CS	1472	XXXV	2a-c
446	1196	*Naticopsis khoovensis* Waagen	Pl	CS	....	....	....
447	1196	*Strophostylus indicus* (Waagen)	Pl	AM	23219	....	....
448	1190	*Naticopsis khoovensis* Waagen	Pl	AM	23220	XXXV	14a-b
449	....	....	....	....	....	....	....
450	....	*Strophostylus indicus* (Waagen)	Pl	CS	1568	....	....
451	1190	*Strophostylus indicus* (Waagen)	Pl	CS	1569	....	....
452	....	*Strophostylus indicus* (Waagen)	Pl	CS	1570	....	....
453	1190	*Macrocheilina* (*Sphærodoma*) *avellanoides* (de Koninck)	Pl	CS	1477	XXXV	8a-b
454	1196	*Macrocheilina* (*Sphærodoma*) *transitoria* Grabau, sp. nov.	H	CS	1478	XXXV	9a-b
455	1196	*Soleniscus mongolicus* Grabau, sp. nov.	H	CS	1479	XXXV	10a-b
456	1196	*Soleniscus mongolicus* Grabau, sp. nov.	Pa	AM	23221	....	....
457	....	*Soleniscus mongolicus* Grabau, sp. nov.	Pa	AM	23222	....	....
458	....	*Soleniscus mongolicus* Grabau, sp. nov.	Pa	CS	1480	XXXV	11a-b
459	....	*Soleniscus mongolicus* Grabau, sp. nov.	Pa	CS	1481	XXXV	12
460	....	*Soleniscus mongolicus* Grabau, sp. nov.	Pa	CS	....	....	....
417a	....	*Solenospira* (?) *mongolica* Grabau, sp. nov.	H	CS	1482	XXXV	13a-b
		Anthozoa and Bryozoa:					
461	1195	*Waagenophyllum virgalense* (Waagen and Wentzel) var. *mongoliense* Grabau, var. nov.	H	CS	1491	I	8a-d
462	1190	*Polycœlia longiseptata* Grabau	H	CS	1484	I	1a-b
463	1190	*Polycœlia longiseptata* Grabau	Pa	AM	23223	....	....
464	1190	*Polycœlia longiseptata* Grabau	Pa	CS	1486	I	3a-c

465	....	*Polycœlia longiseptata* Grabau, sp. nov.	Pa	CS	1489	I	6a-b
466	....	*Polycœlia cylindrica* Grabau, sp. nov.	H	CS	1487	I	4a-b
467	....	....	....	....	....	....	....
468	....	*Polycœlia cylindrica* Grabau, sp. nov.	Pa	CS	1488	I	5a-c
469	1196	*Geinitzella columnaris* (Schlotheim) var. *tuberosa-sparsigemmata* Grabau, var. nov.	Pa	CS	1494	I	11a-b
470	....	*Geinitzella columnaris* (Schlotheim) var. *tuberosa-sparsigemmata* Grabau, var. nov.	H	CS	1493	I	10a-b
471	....	*Geinitzella columnaris* (Schlotheim) var. *tuberosa-sparsigemmata* Grabau, var. nov.	Pa	AM	23224	....	....
472	1196	....	....	....	....	....	....
473	1192	*Polycœlia longiseptata* Grabau	Pa	CS	....	....	....
474	1195	*Waagenophyllum virgalense* (Waagen and Wentzel) var. *mongoliense* Grabau, var. nov.	Pa	CS	1492	I	9a-c
475	1208	*Bryozoan* (gen. and sp. indet.)	....	CS	1591	....	....
476	1192	*Amplexus* ? sp.	....	AM	23225	....	....
476a	1192	*Amplexus* ? sp.	....	CS	1592	....	....
477	1192	*Amplexus* ? sp.	....	CS	1490	I	7a-c
478	1190	*Polycœlia longiseptata* Grabau	Pa	CS	1485	I	2a-b
479	....	*Geinitzella columnaris* (Schlotheim) var. *tuberosa-sparsigemmata* Grabau, var. nov.	Pa	CS	1495	I	12a-b
		Additional Pelecypoda:					
480	....	*Sanguinolites* cf. *modiomorphoides* Grabau	Pa	CS	1435	XXXI	5a-d
481	1211	*Euchondria ? englehardti* (Etheridge and Dun)	Pl	AM	23226	....	....
482	1190	....	....	CS	1594	....	....
483	1194	*Sanguinolites olseni* Grabau	H	CS	1505	XXXII	14a-b
		Additional Brachiopoda:					
942	1196	*Productus* (*Waagenoconcha*) cf. *purdoni* Davidson	Pl	CS	1518	XXIX	4a-b
943	1190	*Aulosteges*	....	CS	1595	....	....
944	1190	*Aulosteges*	....	CS	1596	....	....
945	....	*Derbya?*	....	CS	1597	....	....
963	1192	*Productus* (*Linoproductus?*) *mammatus* Keyserling	Pl	CS	1525	XXIX	11
964	....	*Productus* (*Linoproductus?*) *mammatus* Keyserling	Pl	CS	1526	XXIX	12
965	....	*Productus* (*Linoproductus?*) *mammatus* Keyserling	Pl	CS	1524	XXIX	10a-b
966	....	*Productus* (*Linoproductus?*) *mammatus* Keyserling	Pl	CS	1527	XXIX	13a-b

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PLATE I

(DRAWINGS BY K. C. LIU)

			PAGE
FIG.	1.	*Polycœlia longiseptata* Grabau	39
	1a,	Part of a corallum of the holotype, natural size;	
	1b,	section of the same, enlarged × 4.	
		Enteletes bed (1190), No. 462, Cat. G.S.C. 1484.	
FIG.	2.	*Polycœlia longiseptata* Grabau	39
	2a,	Lateral view of a corallum showing tapering;	
	2b,	median section of the same, enlarged × 4 (paratype).	
		Enteletes bed (1190), No. 478, Cat. G.S.C. 1485.	
FIG.	3.	*Polycœlia longiseptata* Grabau	39
	3a,	Lateral view of a fragment of a corallum, natural size, paratype;	
	3b,	natural section of lower end, natural size;	
	3c,	the same, enlarged × 4.	
		Enteletes bed (1190), No. 464, Cat. G.S.C. 1486.	
FIG.	4.	*Polycœlia cylindrica* Grabau, sp. nov.	38
	4a,	Lateral view of a fragment of a corallum, natural size;	
	4b,	section of the same, enlarged × 4.	
		Jisu Honguer limestone, Holotype, No. 466, Cat. G.S.C. 1487.	
FIG.	5.	*Polycœlia cylindrica* Grabau, sp. nov.	38
	5a,	Lateral view of a fragment of a corallum, natural size;	
	5b,	another higher portion of the same corallum × 2;	
	5c,	view of the calyx showing the 4 primary septa, enlarged × 4. Paratype.	
		Jisu Honguer limestone, No. 468, Cat. G.S.C. 1488.	
FIG.	6.	*Polycœlia longiseptata* Grabau, sp. nov.	39
	6a,	A fragment of a corallum, paratype, natural size;	
	6b,	thin section of the same, enlarged × 4.	
		Jisu Honguer limestone, No. 465, Cat. G.S.C. 1489.	
FIG.	7.	*Amplexus?* sp.	40
	7a,	Lateral view of a crushed specimen, showing parts of 2 corallites (one crushed) closely associated;	
	7b,	a section, showing the crushed corallites and the septa, natural size;	
	7c,	half of the section, enlarged × 2.	
		(7b and 7c reversed with reference to 7a.)	
		Marginifera bed (1192), No. 477, Cat. G.S.C. 1490.	
FIG.	8.	*Waagenophyllum virgalense* (Waagen and Wentzel) var. *mongoliense* Grabau, var. nov.	42
	8a,	View of a thin section of part of the holotype showing numerous corallites (redrawn from photograph), natural size, cotype;	
	8b,	the same enlarged × 4 (redrawn from photograph);	

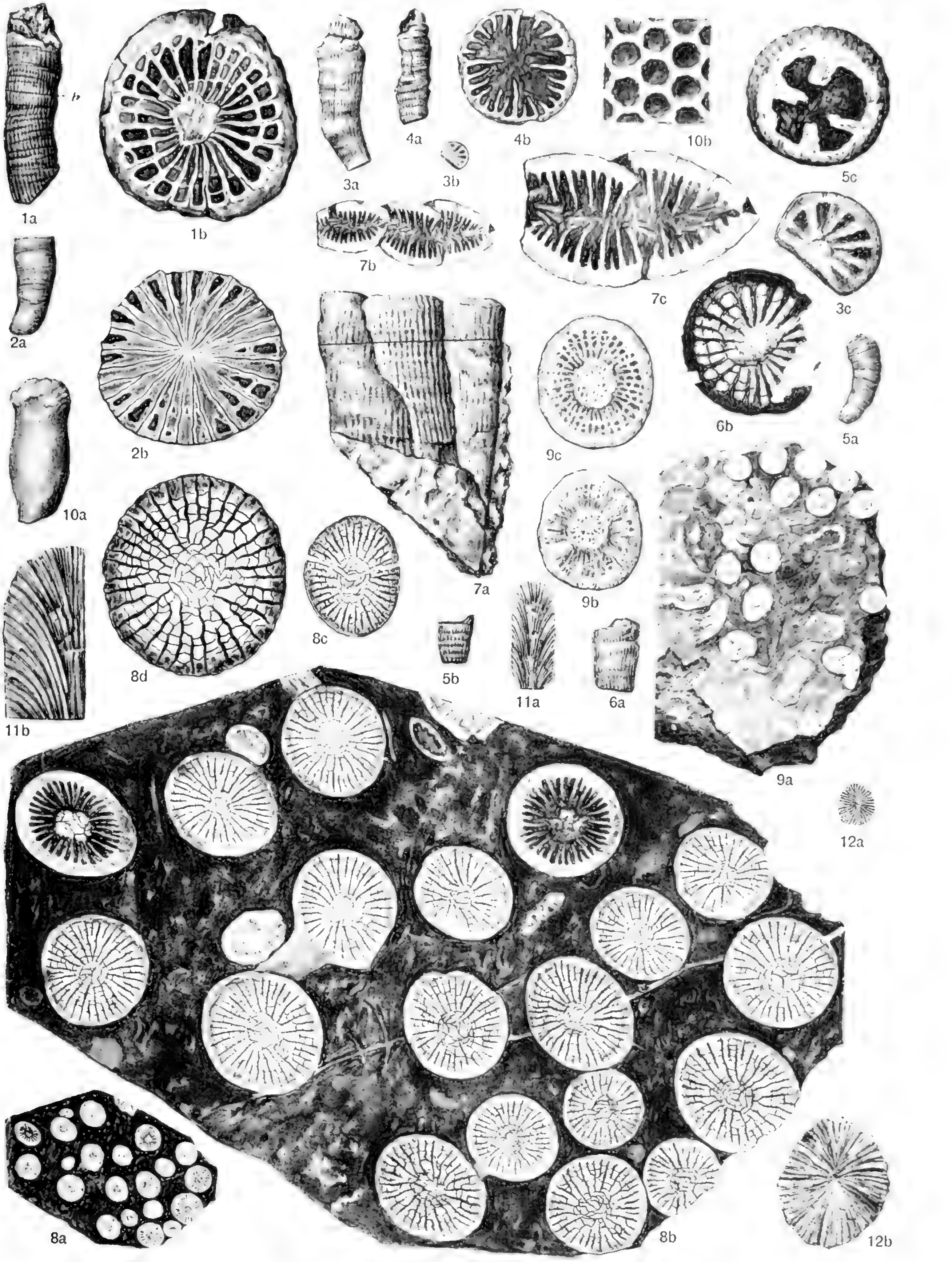
8c and 8d, 2 corallites of another thin section of the same corallum, enlarged: 8c × 4, 8d × 8. (Redrawn from a photograph.)
Waagenophyllum bed (1195), No. 461, Cat. G.S.C. 1491.

FIG. 9. *Waagenophyllum virgalense* (Waagen and Wentzel) var. *mongoliense* Grabau, var. nov. 42
9a, A polished slab showing the disposition of the corallites, natural size, paratype;
9b and 9c, polished sections of two of the corallites, enlarged × 4.
Waagenophyllum bed (1195), No. 474, Cat. G.S.C. 1492.

FIG. 10. *Geinitzella columnaris* (Schlotheim) var. *tuberosa-sparsigemmata* Grabau, var. nov. 46
10a, A zoœcium, natural size, holotype;
10b, a part of the surface of the same, enlarged × 20, to show the thick-walled, close-set cells.
Jisu Honguer limestone, No. 470, Cat. G.S.C. 1493.

FIG. 11. *Geinitzella columnaris* (Schlotheim) var. *tuberosa-sparsigemmata* Grabau, var. nov. 46
11a, Natural section of a specimen, showing the arrangement of the zoœcial tubes, natural size;
11b, half of the section, enlarged × 3 (paratype).
Hemiptychina bed (1196), No. 469, Cat. G.S.C. 1494.

FIG. 12. *Geinitzella columnaris* (Schlotheim) var. *tuberosa-sparsigemmata* Grabau, var. nov. 46
12a, A natural cross-section of a specimen, natural size;
12b, the same enlarged × 3 (paratype).
Jisu Honguer limestone, No. 479, Cat. G.S.C. 1495.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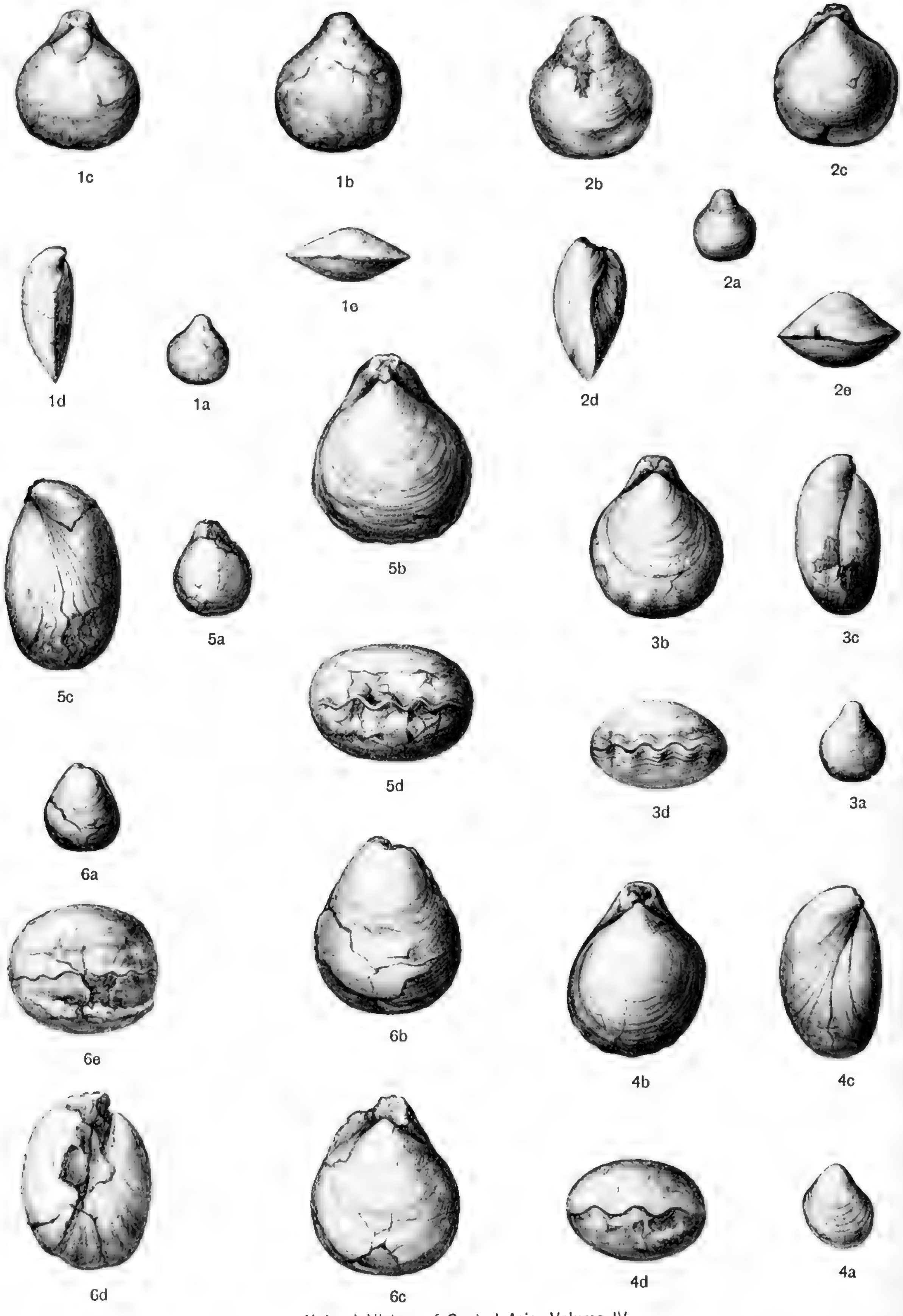
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PLATE II

(DRAWINGS BY K. C. LIU)

			PAGE
FIG.	1.	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov. .	78
	1a,	A young shell in the *Beecheria* stage, paratype, natural size, pedicle view;	
	1b,	pedicle; 1c, brachial; 1d, lateral; 1e, frontal,* views of the same shell enlarged × 2.	
		Jisu Honguer limestone, No. 0, Cat. G.S.C. 1250.	
FIG.	2.	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov. .	78
	2a,	Pedicle view of a somewhat larger shell still in the *Beecheria* stage, natural size, paratype;	
	2b,	pedicle; 2c, brachial; 2d, lateral, and 2e, frontal,* views of the same specimen, enlarged × 2.	
		Hemiptychina bed (1196), No. 1, Cat. G.S.C. 1251.	
FIG.	3.	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov.	78
	3a,	A submature individual, showing the beginning of the frontal deflection and plication, pedicle view, natural size, paratype;	
	3b,	brachial; 3c, lateral; 3d, frontal†, views of the same, enlarged × 2.	
		Hemiptychina bed (1196), No. 2, Cat. G.S.C. 1252.	
FIG.	4.	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov. .	78
	4a,	Slightly more advanced specimen, somewhat distorted, natural size, paratype;	
	4b,	brachial; 4c, lateral; 4d, frontal,* views of the same specimen, enlarged × 2.	
		Hemiptychina bed (1196), No. 3, Cat. G.S.C. 1253.	
FIG.	5.	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov. .	78
	5a,	Still more advanced specimen, natural size, holotype;	
	5b,	brachial; 5c, lateral; 5d, frontal,* views of the same specimen, enlarged × 2.	
		Hemiptychina bed (1196), No. 4, Cat. G.S.C. 1254.	
FIG.	6.	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov. .	78
	6a,	A very obese specimen, with numerous fine plications confined to the suture, natural size, paratype;	
	6b,	pedicle; 6c, brachial; 6d, lateral; 6e, frontal, views of the same specimen, enlarged × 2.	
		Hemiptychina bed (1196), No. 5, Cat. G.S.C. 1255.	

* Brachial valve uppermost.

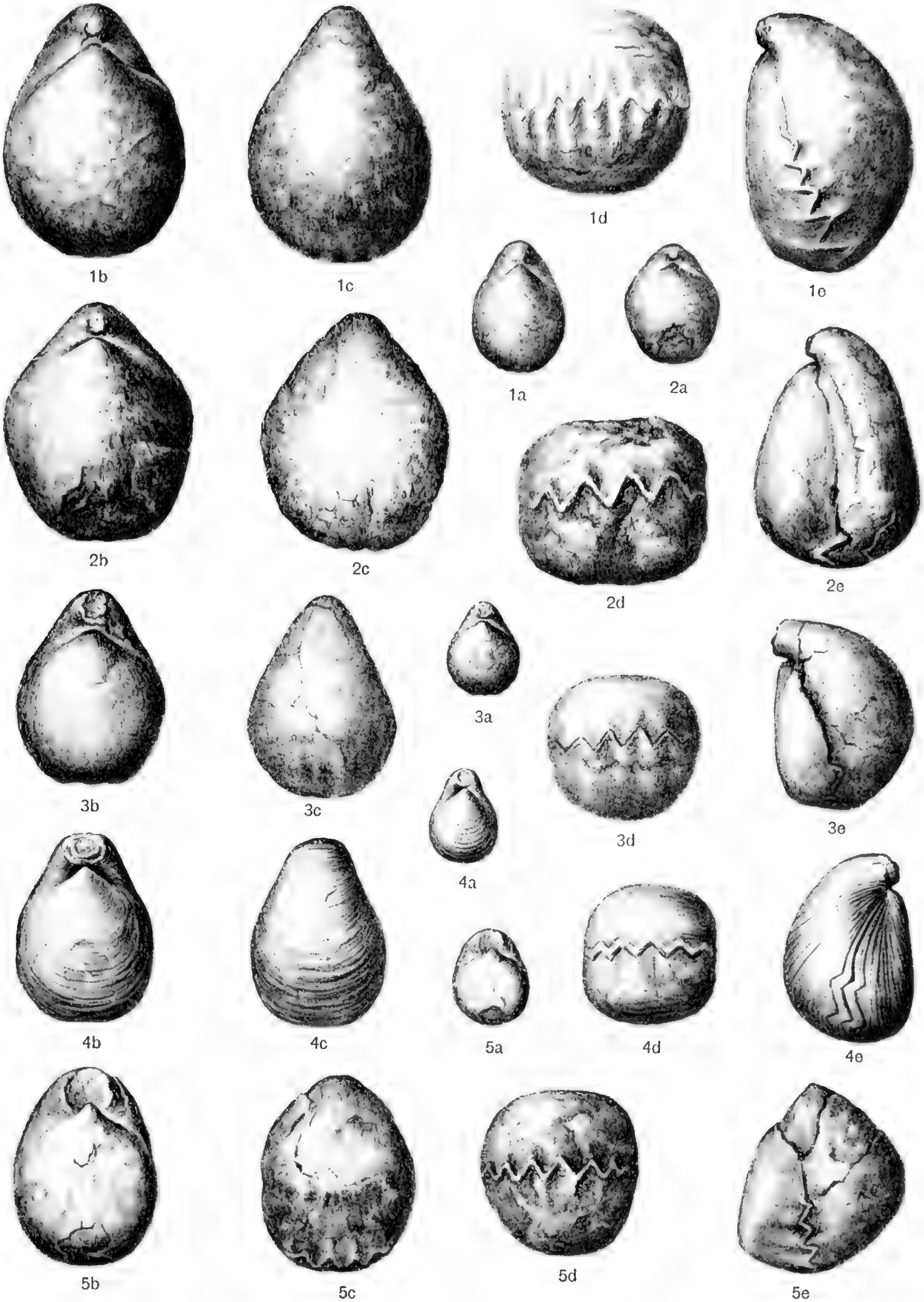
† Pedicle valve uppermost.

PLATE III

(DRAWINGS BY K. C. LIU)

			PAGE
FIG.	1.	*Hemiptychina morrisi* Grabau, sp. nov.	92
	1a,	Dorsal or brachial view, natural size;	
	1b,	the same, × 2; 1c, ventral or pedicle view, × 2; 1d, frontal* view, × 2; 1e, side view, × 2. Holotype.	
		Lyttonia bed (1193), No. 315, Cat. G.S.C. 1392.	
FIG.	2.	*Hemiptychina himalayensis* (Davidson) var. *mongolica* Grabau, var. nov. .	78
	2a,	Brachial view, natural size;	
	2b,	same, × 2; 2c, pedicle view, × 2; 2d, frontal* view, × 2; 2e, side view, × 2. Paratype.	
		Hemiptychina bed (?) (1196?), No. 384, Cat. G.S.C. 1394.	
FIG.	3.	*Hemiptychina morrisi* Grabau, sp. nov.	92
	3a,	Brachial view, natural size;	
	3b,	same, × 2; 3c, pedicle view, × 2; 3d, frontal* view, × 2; 3e, side view, × 2. Paratype.	
		Probably Hemiptychina bed (1196), No. 6, Cat. G.S.C. 1256.	
FIG.	4.	*Hemiptychina morrisi* Grabau, sp. nov.	92
	4a,	Brachial view, natural size; 4b, same, × 2; 4c, pedicle view, × 2; 4d, frontal* view, × 2; 4e, side view, × 2. Paratype.	
		Probably Hemiptychina bed (1196), No. 7, Cat. G.S.C. 1257.	
FIG.	5,	*Hemiptychina morrisi* Grabau, sp. nov.	92
	5a,	Brachial view, natural size; 5b, same, × 2; 5c, pedicle view, × 2; 5d, frontal† view, × 2; 5e, side view, × 2. Paratype.	
		Probably Hemiptychina bed (1196), No. 8, Cat. G.S.C. 1258.	

*Brachial valve up.
†Pedicle valve up.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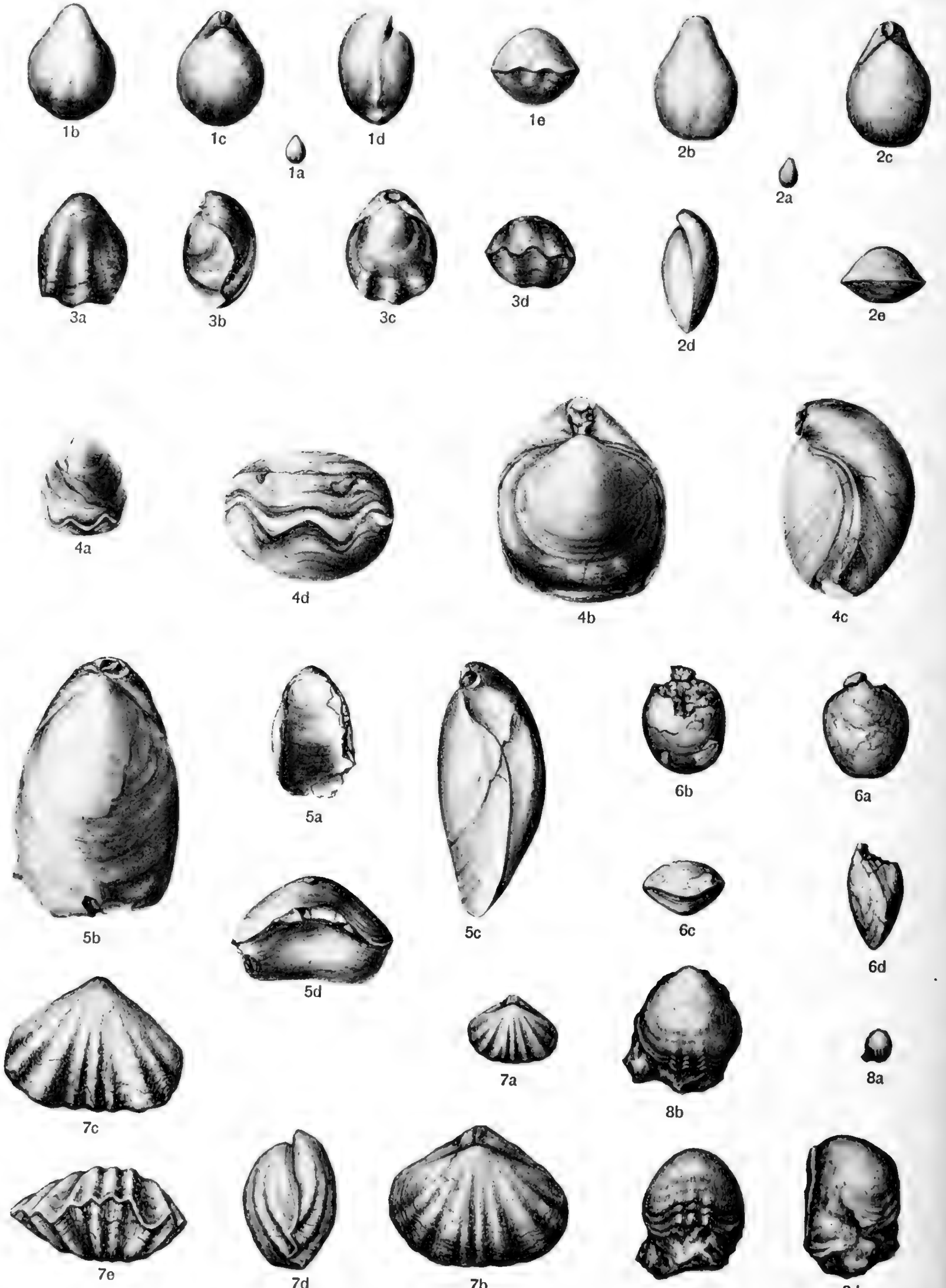
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PLATE IV

(DRAWINGS BY K. C. LIU)

PAGE

FIG. 1. *Notothyris simplex* var. *mongoliensis* Grabau, var. nov. 108

1a, Pedicle view of the holotype, natural size; 1b, pedicle; 1c, brachial; 1d, lateral; 1e, frontal†, views of the same specimen, enlarged × 4.
Jisu Honguer limestone, No. 10, Cat. G.S.C. 1259.

FIG. 2. *Dielasma itaitubense* (Derby) 75

2a, Pedicle view of a very young shell, natural size; 2b, pedicle; 2c, brachial; 2d, lateral; 2e, frontal,* views of the same specimen, enlarged × 4.
Jisu Honguer limestone, No. 63, Cat. G.S.C. 1295.

FIG. 3. *Notothyris nucleolus* (Kutorga) 111

3a, Pedicle; 3b, lateral; 3c, brachial; 3d, frontal,* views of a small but characteristic specimen, enlarged × 3.
Jisu Honguer limestone, No. 12, Cat. G.S.C. 1261.

FIG. 4. *Notothyris berkeyi* Grabau, sp. nov. 110

4a, The holotype, pedicle view, natural size; 4b, brachial; 4c, lateral; 4d, frontal,* views of the same specimen, enlarged × 2.
Jisu Honguer limestone, No. 11, Cat. G.S.C. 1260.

FIG. 5. *Dielasma millepunctatum* Hall var. *mongolicum* Grabau, var. nov. . . 57

5a, The holotype, pedicle view, natural size; 5b, brachial; 5c, lateral; 5d, frontal,* views of the same specimen, enlarged × 2.
Jisu Honguer limestone, No. 25, Cat. G.S.C. 1267.

FIG. 6. *Dielasma jisuense* Grabau, sp. nov. 69

6a, Pedicle; 6b, brachial; 6c, frontal†; 6d, lateral, views of the holotype, with imperfect beak, natural size.
Jisu Honguer limestone, No. 17, Cat. G.S.C. 1266.

FIG. 7. *Camarophoria mutabilis* Tschernyschew 211

7a, The largest specimen, brachial view, natural size; 7b, brachial; 7c, pedicle; 7d, lateral; 7e, frontal,* views of the same specimen, enlarged × 2.
Enteletes bed (1190), No. 34, Cat. G.S.C. 1275.

FIG. 8. *Camarophoria superstes* (Verneuil) 214

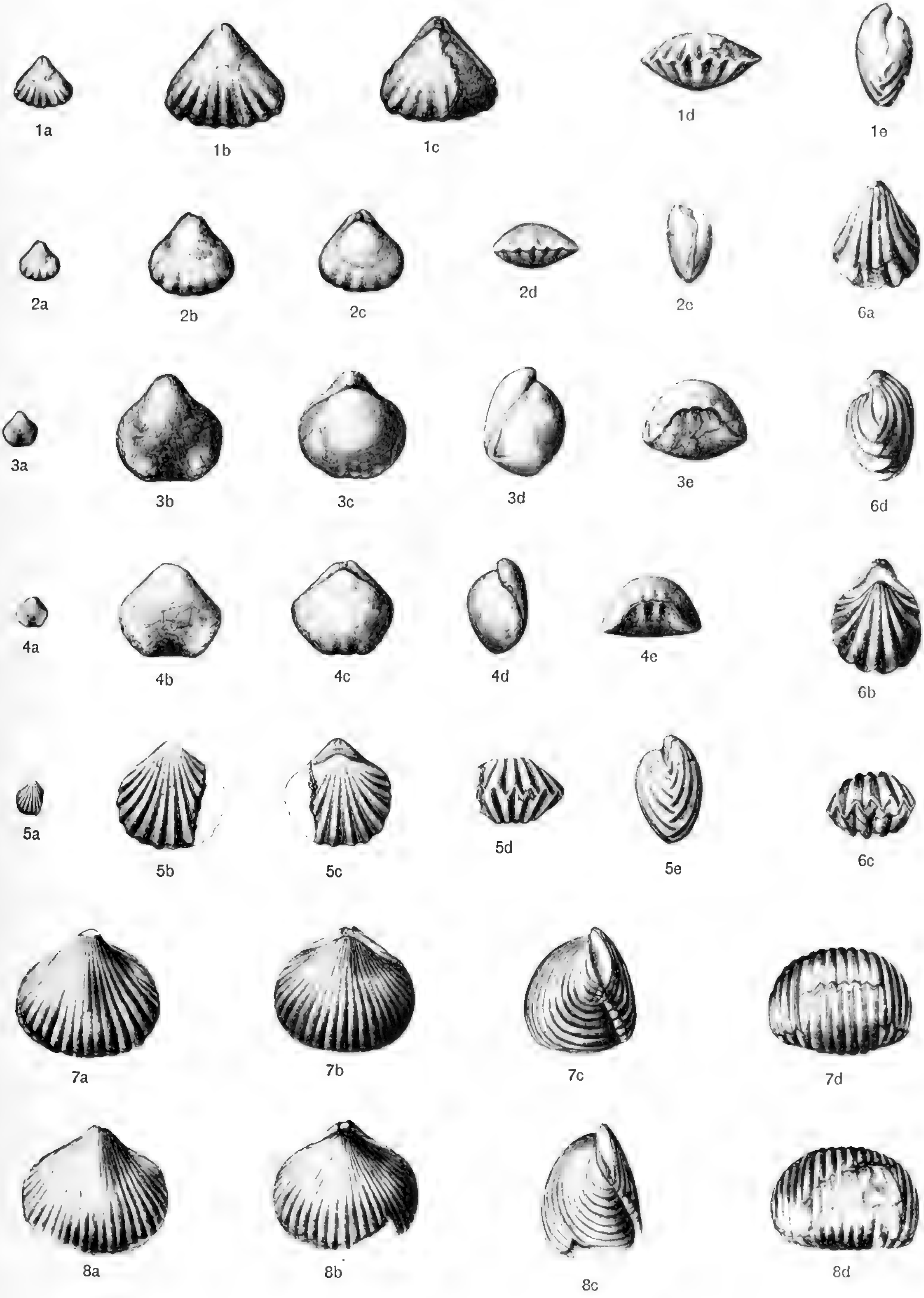
8a, A small brachial valve, referable to this species, natural size; 8b, the same, enlarged × 4; 8c, frontal*; 8d, lateral views of the same, enlarged × 4.
Jisu Honguer limestone, No. 53, Cat. G.S.C. 1287.

*Brachial valve up.
†Pedicle valve up.

PLATE V

(DRAWINGS BY K. C. LIU)

			PAGE
FIG.	1.	*Camarophoria mutabilis* Tschernyschew	211
	1a,	Pedicle view of a small shell, natural size: 1b, pedicle; 1c, brachial; 1d, frontal; 1e, lateral, views of the same specimen, enlarged × 2. Orthotychia bed (1211), No. 54, Cat. G.S.C. 1288.	
FIG.	2.	*Camarophoria mutabilis* Tschernyschew	211
	2a,	Pedicle view of a still younger shell, natural size; 2b, pedicle; 2c, brachial; 2d, frontal; 2e, lateral, views of the same shell, enlarged × 2. Jisu Honguer limestone, No. 55, Cat. G.S.C. 1289.	
FIG.	3.	*Camarophoria superstes* (Verneuil)	214
	3a,	Pedicle view, small but characteristic shell, natural size; 3b, pedicle; 3c, brachial; 3d, lateral: 3e, frontal, views of the same specimen, enlarged × 3. Camarophoria bed? (1208?), No. 51, Cat. G.S.C. 1285.	
FIG.	4.	*Camarophoria superstes* (Verneuil)	214
	4a,	A slightly smaller shell, natural size; 4b, pedicle; 4c, brachial; 4d, lateral; 4e, frontal, views of the same shell, enlarged × 3. Camarophoria bed (1208), No. 52, Cat. G.S.C. 1286.	
FIG.	5.	*Hustedia grandicosta* mut. *lata* Grabau, mut. nov.	124
	5a,	Pedicle view of the holotype, partly imperfect, natural size; 5b, pedicle; 5c, brachial; 5d, frontal; 5e, lateral, views of the same shell, enlarged × 3. Orthotychia bed (1211), No. 56, Cat. G.S.C. 1290.	
FIG.	6.	*Hustedia grandicosta* (Davidson)	121
	6a,	Pedicle; 6b, brachial; 6c, frontal; 6d, lateral, views of a small but characteristic specimen, enlarged × 3. Hemiptychina bed (1196), No. 26, Cat. G.S.C. 1268.	
FIG.	7.	*Uncinulus mongolicus* Grabau, sp. nov.	209
	7a,	Pedicle; 7b, brachial; 7c, lateral; 7d, frontal, views of the holotype, enlarged × 3. Enteletes bed (1190), No. 31, Cat. G.S.C. 1272.	
FIG.	8.	*Uncinulus mongolicus* Grabau, sp. nov.	209
	8a,	Pedicle; 8b, brachial; 8c, lateral; 8d, frontal, views of another, somewhat less robust paratype, enlarged × 3. Jisu Honguer limestone, No. 32, Cat. G.S.C. 1273.	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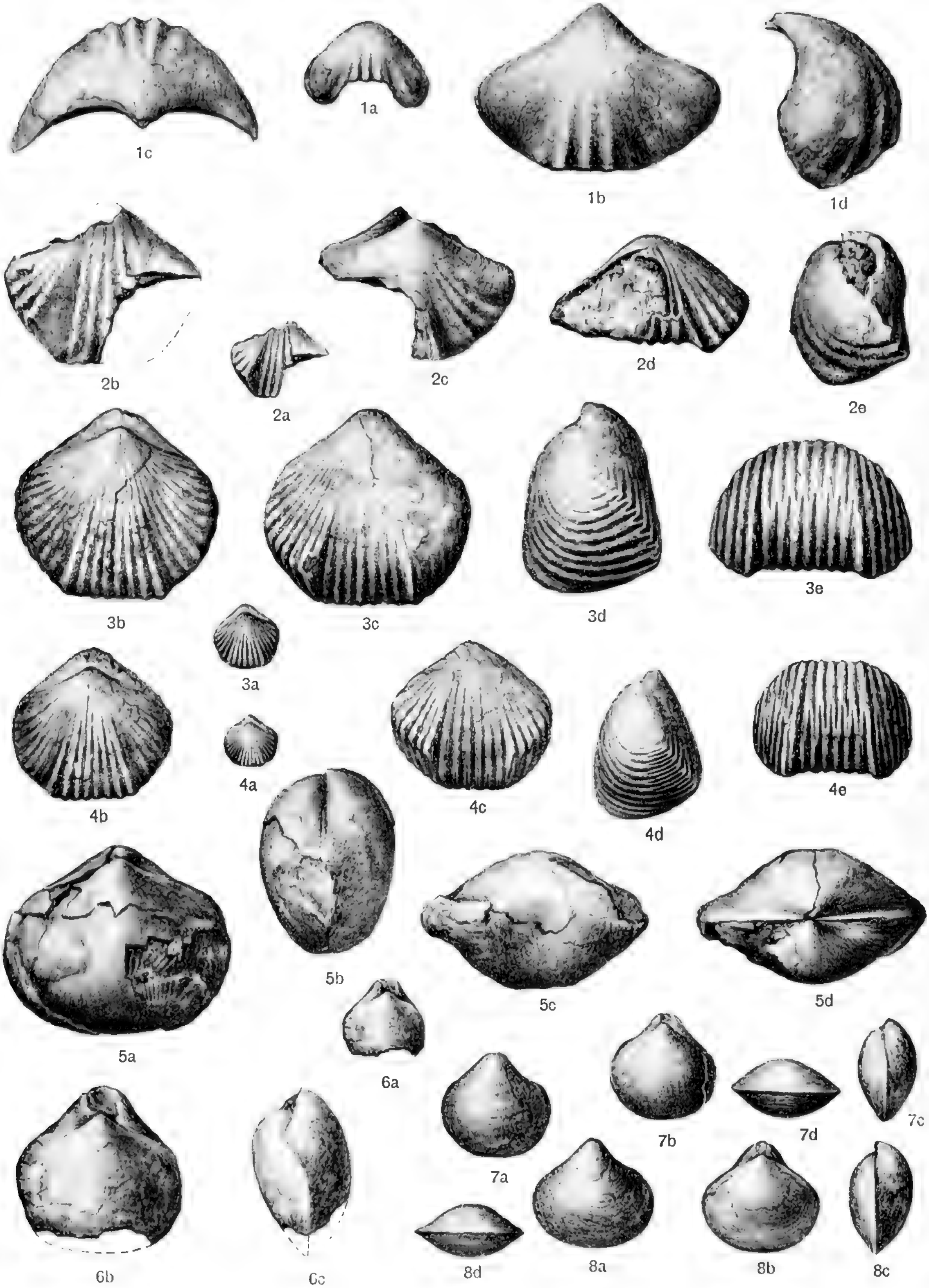
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8d
8a
8b
8c

PLATE VI

(DRAWINGS BY K. C. LIU)

PAGE

FIG. 1. *Camarophoria purdoniformis* Grabau, sp. nov. 218

1a, A brachial valve, sub-anterior view, natural size; 1b, same, dorsal view, × 2; 1c, cardinal view of same, × 2; 1d, lateral view of same, × 2. Cotype.

Jisu Honguer limestone, No. 390, Cat. G.S.C. 1398.

FIG. 2. *Camarophoria purdoniformis* Grabau, sp. nov. 218

2a, An imperfect shell, pedicle view, natural size; 2b, the same, × 2; 2c, the same, brachial view, × 2; 2d, frontal view, × 2; 2e, side view, × 2. Cotype.

Hemiptychina bed (1196), No. 391, Cat. G.S.C. 1399.

FIG. 3. *Uncinulus mongolicus* Grabau, sp. nov. 209

3a, Brachial view of a typical shell, natural size, paratype; 3b, same, × 3; 3c, pedicle view, × 3; 3d, lateral view, × 3; 3e, frontal view, × 3.

Jisu Honguer limestone, No. 387, Cat. G.S.C. 1396.

FIG. 4. *Uncinulus mongolicus* Grabau, sp. nov. 209

4a, Brachial view of a somewhat shorter and more robust form, natural size; 4b, the same, × 3; 4c, pedicle view of the same, × 3; 4d, side view, × 3; 4e, frontal view, × 3. Paratype.

Jisu Honguer limestone, No. 388, Cat. G.S.C. 1397.

FIG. 5. *Athyris excavata* Grabau, sp. nov. 117

5a, The holotype, with the shell partly exfoliated, natural size; 5b, the same, side view, × 1; 5c, the same, frontal* view, × 1; 5d, the same, umbonal† view, × 1.

Hemiptychina bed (1196), No. 124, Cat. G.S.C. 1332.

FIG. 6. *Athyris excavata* Grabau, sp. nov. (?) 117

6a, A young, somewhat imperfect shell, doubtfully referred to this species, brachial view, natural size; 6b, the same, × 2; 6c, side view of same, × 2.

Jisu Honguer limestone, No. 174, Cat. G.S.C. 1348.

FIG. 7. *Athyris royssii* Léveillé 120

7a, A young or dwarfed shell, pedicle view, × 3; 7b, the same specimen, brachial view, × 3; 7c, the same, side view, × 3; 7d, the same, frontal* view, × 3.

Jisu Honguer limestone, No. 80, Cat. G.S.C. 1308.

FIG. 8. *Athyris royssii* Léveillé 120

8a, Another small shell, pedicle view, × 3; 8b, the same, brachial view, × 3; 8c, the same, side view, × 3; 8d, the same, frontal* view, × 3.

Jisu Honguer limestone, No. 81, Cat. G.S.C. 1309.

*Brachial valve up.
†Pedicle valve up.

PLATE VII

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PAGE

FIG. 1. *Dielasma giganteum* Tschernyschew var. *anteplicatum* Grabau, var. nov. . 66
1a-c, Lateral, pedicle and frontal† views of the holotype, natural size.
Jisu Honguer limestone, No. 62, Cat. G.S.C. 1294.

FIG. 2. *Dielasma truncatum* Waagen var. *mongolicum* Grabau, var. nov. . . 60
2a-c, Pedicle, umbonal† and lateral views of a paratype, natural size.
Camarophoria bed (1208), No. 381, Cat. G.S.C. 1393.

FIG. 3. *Dielasma truncatum* Waagen var. *mongolicum* Grabau, var. nov. . . 60
3a-d, Brachial, pedicle, frontal* and lateral views of the holotype, natural size; 3e, muscular platform × 2.
Hemiptychina bed (1196), No. 61, Cat. G.S.C. 1293.

FIG. 4. *Dielasma acutangulum* Waagen var. *minor* Grabau, var. nov. . . . 70
4a-d, Brachial, pedicle, frontal* and lateral views of a somewhat accelerated shell, enlarged × 3. Paratype.
Jisu Honguer limestone, No. 14, Cat. G.S.C. 1263.

FIG. 5. *Dielasma elongatum* Schlotheim var. *orientalis* Grabau, var. nov. . . 72
5a-d, Brachial, pedicle, frontal† and lateral views of the holotype, × 3.
Jisu Honguer limestone, No. 16, Cat. G.S.C. 1265.

FIG. 6. *Notothyris irregularis* Grabau, sp. nov. 115
6a, Brachial view of the holotype, natural size; 6b-e, brachial, pedicle, frontal* and lateral views of the same, enlarged × 3.
Jisu Honguer limestone, No. 13, Cat. G.S.C. 1262.

FIG. 7. *Dielasma elongatum* Schlotheim var. *orientalis* Grabau, var. nov. . . 72
7a-d, Brachial, pedicle, frontal* and lateral views of a young specimen, paratype.
Jisu Honguer limestone, No. 68, Cat. G.S.C. 1298.

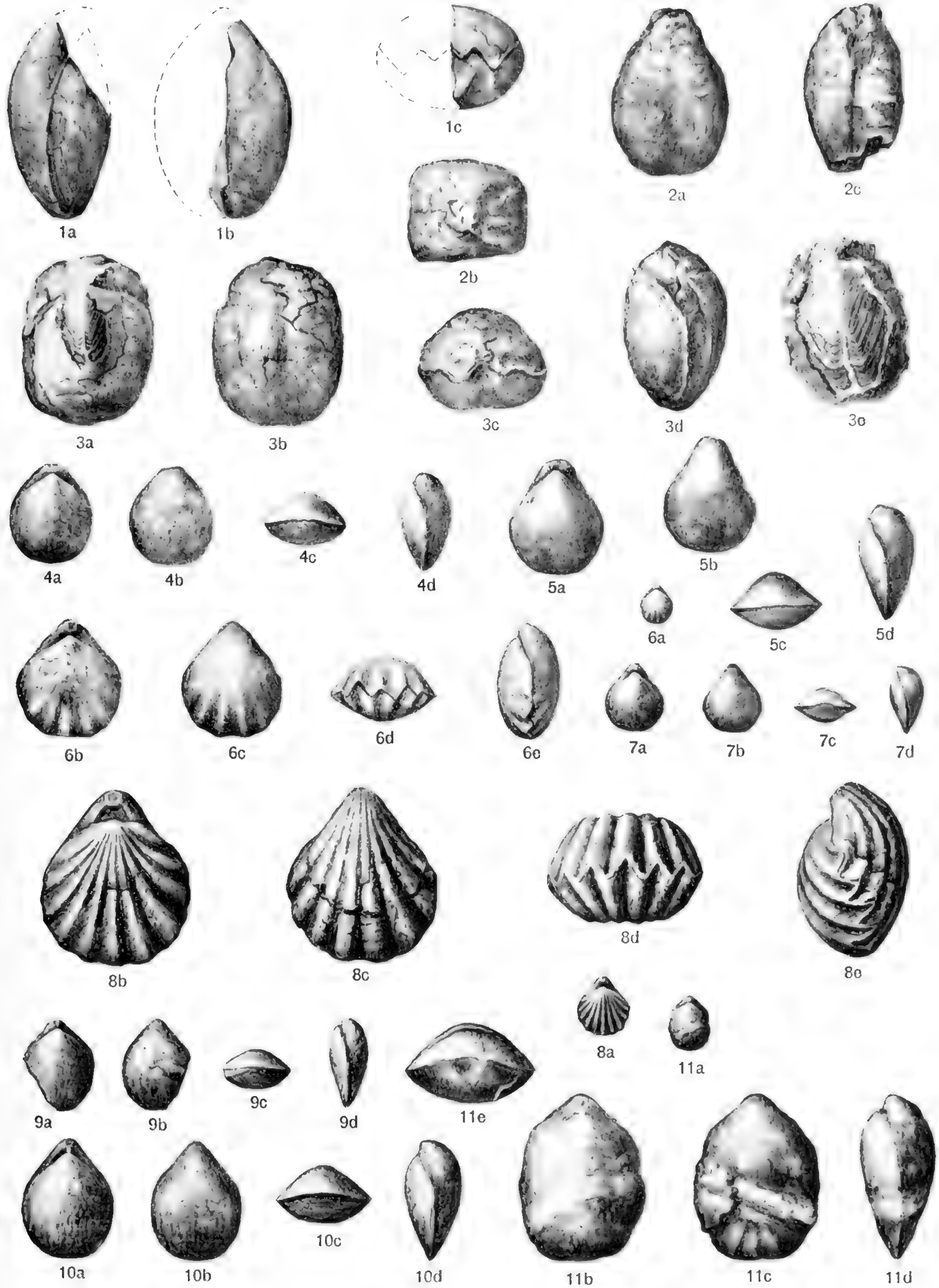
FIG. 8. *Hustedia remota* (Eichwald) 125
8a, Brachial view of the specimen, × 1; 8b-e, brachial, pedicle, frontal* and lateral views of the same, × 3.
Enteletes bed (1190), No. 27, Cat. G.S.C. 1269.

FIG. 9. *Dielasma acutangulum* Waagen var. *minor* Grabau, var. nov. . . . 70
9a-d, Brachial, pedicle, frontal* and lateral views of an imperfect shell, paratype, × 3.
Jisu Honguer limestone, No. 64, Cat. G.S.C. 1296.

FIG. 10. *Dielasma acutangulum* Waagen var. *minor* Grabau, var. nov. . . . 70
10a-d, Brachial, pedicle, frontal* and lateral views of the holotype, × 3.
Jisu Honguer limestone, No. 65, Cat. G.S.C. No. 1297.

FIG. 11. *Dielasma acutangulum* Waagen var. *minor* Grabau, var. nov. . . . 70
11a, Brachial view of a shell of rectangular appearance, with short but pronounced plications near the front, natural size; 11b-e, brachial, pedicle, lateral and frontal* views of the same, enlarged × 3. Paratype.
Jisu Honguer limestone, No. 69, Cat. G.S.C. 1299.

*Brachial valve up.
†Pedicle valve up.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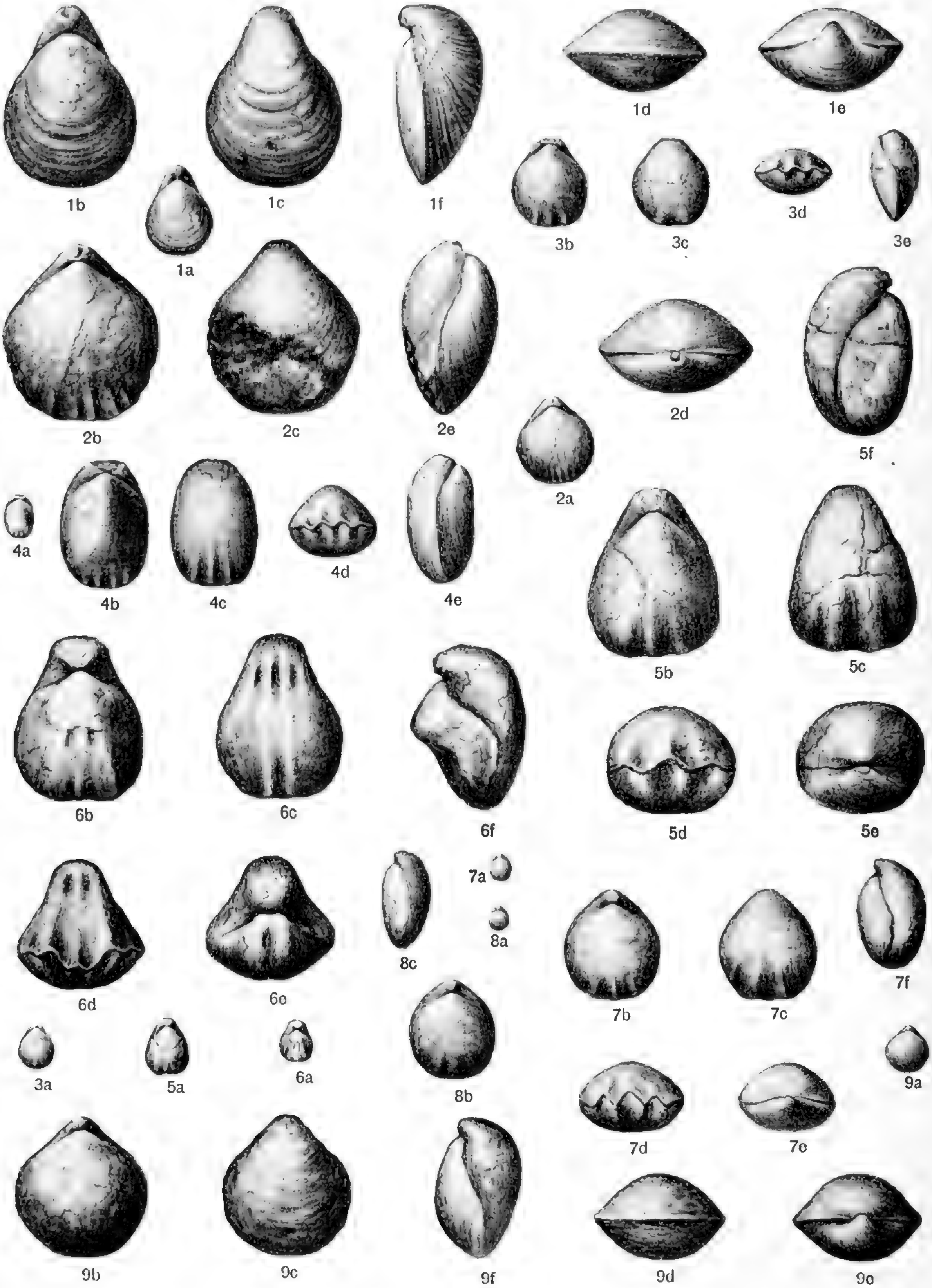
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PLATE VIII

(DRAWINGS BY K. C. LIU)

PAGE

FIG. 1. *Beecheria sublævis* (Waagen) 95

1a, A characteristic specimen, brachial view, natural size; 1b, brachial; 1c, pedicle; 1d, frontal*; 1e, umbonal,* and 1f, lateral, views of the same specimen, enlarged × 2.

Lyttonia bed (1193), No. 59, Cat. G.S.C. 1292.

FIG. 2. *Morrisina sparsiplicata* (Waagen) 98

2a, A typical but imperfect specimen as it occurs in Mongolia—brachial view, natural size; 2b, brachial; 2c, pedicle; 2d, umbonal*; 2e, lateral, views of the same specimen, enlarged × 2. Somewhat restored.

Camarophoria bed (1208), No. 74, Cat. G.S.C. 1302.

FIG. 3. *Morrisina sparsiplicata* (Waagen) var. *nana* Grabau, var. nov. . . . 100

3a, The holotype, brachial view, natural size; 3b, brachial; 3c, pedicle; 3d frontal*; and 3e, lateral, views of the same, enlarged × 2.

Jisu Honguer limestone, No. 58, Cat. G.S.C. 1291.

FIG. 4. *Jisuina elegantula* Grabau, sp. nov. 106

4a, The holotype, and genotype, brachial view, natural size; 4b, brachial; 4c, pedicle; 4d, frontal,* and 4e, lateral, views of the same shell, enlarged × 2.

Jisu Honguer limestone, No. 71, Cat. G.S.C. 1301.

FIG. 5. *Mongolina subdieneri* Grabau, sp. nov. 103

5a, The holotype, brachial view, natural size; 5b, brachial; 5c, pedicle; 5d, frontal*; 5e, umbonal, and 5f, lateral, views of the same specimen, enlarged × 3.

Jisu Honguer limestone, No. 70, Cat. G.S.C. 1300.

FIG. 6. *Notothyris nucleolus* (Kutorga), mut. *α* Grabau, mut. nov. 113

6a, A remarkable aberrant form produced by interruption and change of growth, brachial view, natural size: 6b, brachial; 6c, pedicle; 6d, frontal*; 6e, umbonal,* and 6f, lateral, views of the same specimen, enlarged × 4.

Jisu Honguer limestone, No. 78, Cat. G.S.C. 1306.

FIG. 7. *Notothyris nucleolus* (Kutorga) 111

7a, A young shell, brachial view, natural size; 7b, brachial; 7c, pedicle; 7d, frontal*; 7e, umbonal,* and 7f, lateral, views of the same specimen, enlarged × 4.

Jisu Honguer limestone, No. 76, Cat. G.S.C. 1304.

FIG. 8. *Notothyris nucleolus* (Kutorga) 111

8a, A very young shell, brachial view, natural size; 8b, brachial, and 8c, lateral, views of the same specimen, enlarged × 4.

Jisu Honguer limestone, No. 77, Cat. G.S.C., 1305.

FIG. 9. *Athyris timorensis* Rothpletz var. *mongoliensis* Grabau, var. nov. . . . 118

9a, The holotype of this variety, brachial view, natural size; 9b, brachial; 9c, pedicle; 9d, frontal*; 9e, umbonal,* and 9f, lateral, views of the same specimen, enlarged × 3.

Jisu Honguer limestone, No. 15, Cat. G.S.C. 1264.

*Brachial valve up.

PLATE IX

(DRAWINGS BY K. C. LIU)

PAGE

FIG. 1. *Dielasma* cf. *truncatum* Waagen 65

1a, Brachial view of a specimen with the essential characters of this species, natural size; 1b, pedicle; 1c, frontal*; 1d, cardinal,* and 1e, lateral, views of the same specimen, natural size.

Camarophoria bed (1208), No. 168, Cat. G.S.C. 1347.

FIG. 2. *Notothyris simplex* var. *mongoliensis* Grabau, var. nov. 108

2a, Brachial view of a young shell, paratype, natural size; 2b, brachial; 2c, pedicle; 2d, frontal,* and 2e, lateral, views of the same specimen, enlarged × 4.

Jisu Honguer limestone, No. 75, Cat. G.S.C. 1303.

FIG. 3. *Notothyris irregularis* Grabau, sp. nov. 115

3a, Brachial view of paratype, natural size; 3b, brachial; 3c, pedicle; 3d, frontal,* and 3e, lateral, views of the same specimen, enlarged × 3.

Jisu Honguer limestone, No. 385, Cat. G.S.C. 1395.

FIG. 4. *Athyris timorensis* Rothpletz var. *mongoliensis* Grabau, var. nov. . . 118

4a, Brachial view of a young specimen, paratype, natural size; 4b, brachial; 4c, pedicle; 4d, frontal, and 4e, lateral, views of the same specimen, enlarged × 3.

Jisu Honguer limestone, No. 79, Cat. G.S.C. 1307.

FIG. 5. *Spiriferina mongolica* Grabau, sp. nov. 206

5a, Pedicle view of the holotype, natural size; 5b, pedicle; 5c, brachial; 5d, frontal*; 5e, cardinal,* and 5f, lateral, views of the same specimen, enlarged × 2.

Hemiptychina bed (1196), No. 275, Cat. G.S.C. 1391.

FIG. 6. *Spiriferina mongolica* Grabau, sp. nov 206

6a, Pedicle view of a young specimen, paratype, natural size; 6b, pedicle; 6c, brachial; 6d, frontal*; 6e, cardinal,* and 6f, lateral, views of the same specimen, enlarged × 4.

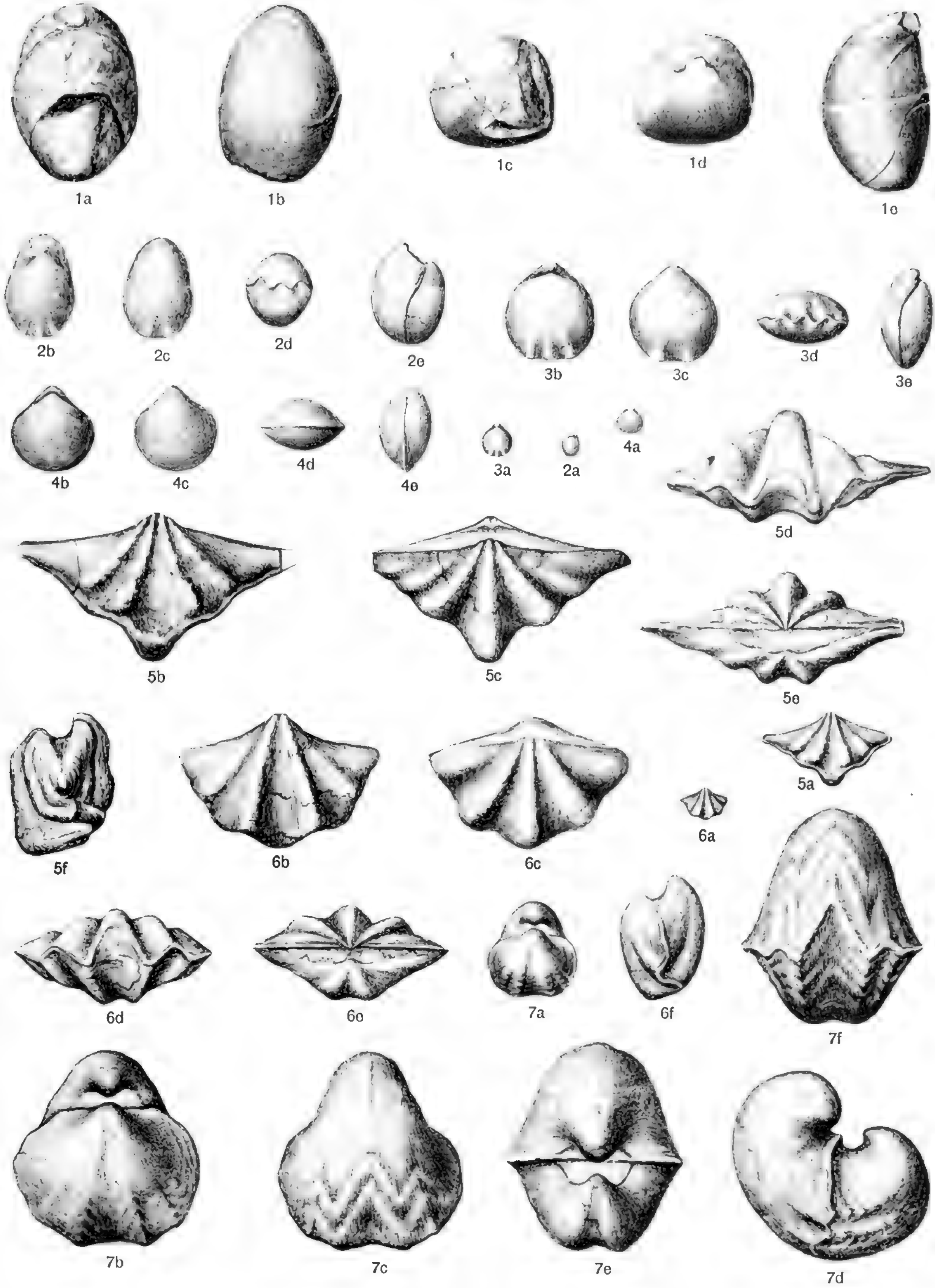
Hemiptychina bed (1196), No. 274, Cat. G.S.C. 1390.

FIG. 7. *Enteletes obesa* Grabau, sp. nov. 229

7a, Pedicle view of an immature shell (paratype), natural size; 7b, pedicle; 7c, brachial; 7d, lateral; 7e, cardinal,* and 7f, frontal,* views of the same specimen, enlarged × 2.

Martinia bed (1194), No. 96, Cat. G.S.C. 1319.

*Brachial valve up.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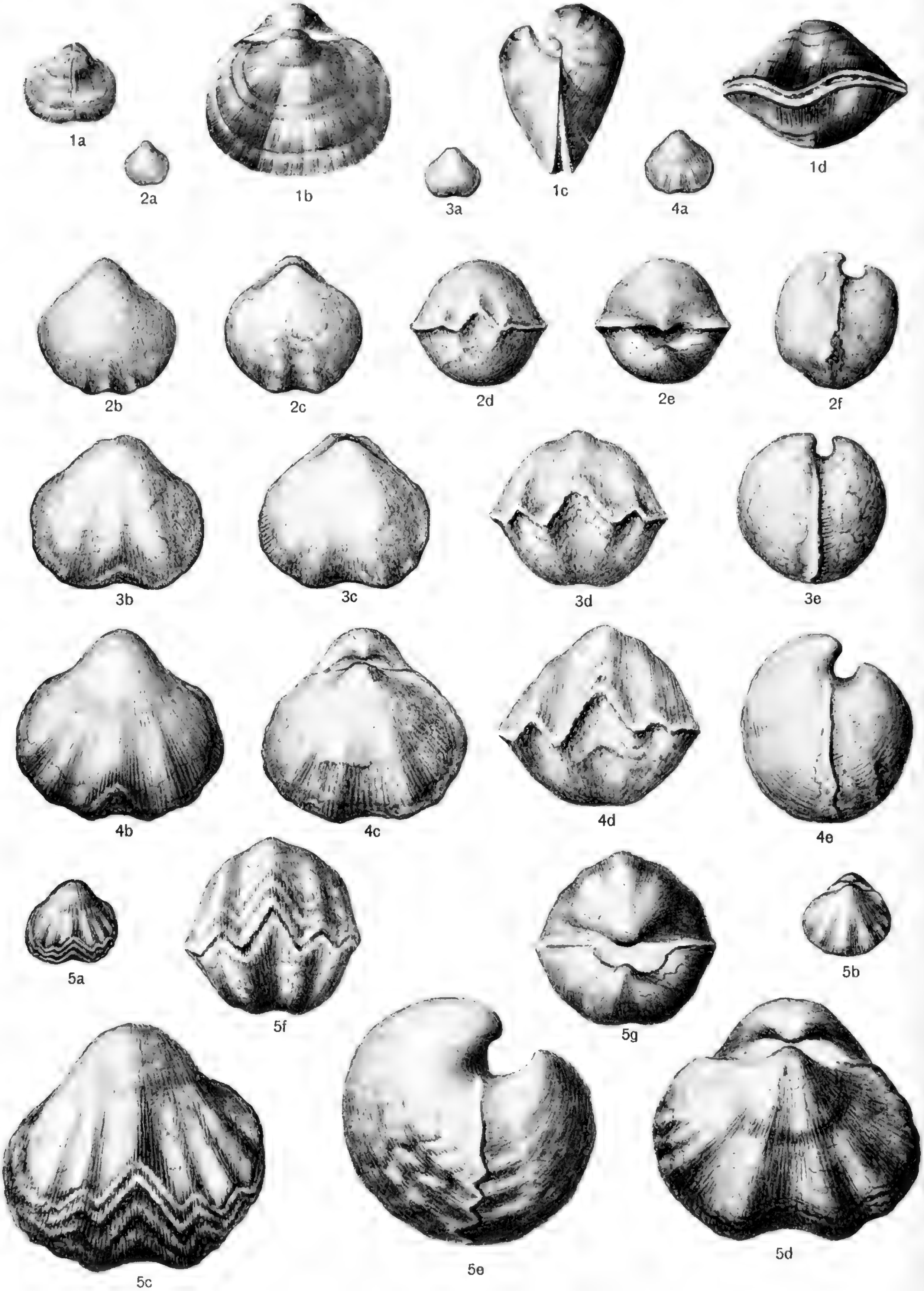
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PLATE X

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PAGE

FIG. 1. *Orthotychia derbyi* (Waagen) var. *nana* Grabau, var. nov. 220

1a, Pedicle view of the holotype, natural size; 1b, brachial; 1c, lateral, and 1d, frontal,* views of the same specimen, enlarged × 2.

Orthotychia bed (1211), No. 33, Cat. G.S.C. 1274.

FIG. 2. *Enteletes andrewsi* Grabau, sp. nov. 222

2a, Brachial view of a young specimen, paratype, natural size; 2b, brachial; 2c, pedicle; 2d, frontal*; 2e, cardinal*; and 2f, lateral, views of the same specimen, enlarged × 3.

Martinia bed (1194), No. 83, Cat. G.S.C. 1310.

FIG. 3. *Enteletes andrewsi* Grabau, sp. nov. 222

3a, Brachial view of a slightly older shell, paratype, natural size; 3b, brachial: 3c, pedicle; 3d, frontal*; 3e, lateral, views of the same specimen, enlarged × 3.

Martinia bed (1194), No. 84, Cat. G.S.C. 1311.

FIG. 4. *Enteletes andrewsi* Grabau, sp. nov. 222

4a, Brachial view of a somewhat larger immature shell, paratype, natural size; 4b, brachial; 4c, pedicle; 4d, frontal*; 4e, lateral, views of the same specimen, enlarged × 3.

Jisu Honguer limestone, No. 90, Cat. G.S.C. 1316.

FIG. 5. *Enteletes andrewsi* Grabau, sp. nov. 222

5a, Brachial; 5b, pedicle, views of an immature accelerated individual, natural size; 5c, brachial; 5d, pedicle; 5e, lateral, views of the same individual, enlarged × 3; 5f, frontal,* and 5g, cardinal, views of the same individual, enlarged × 2. Paratype.

Enteletes bed (1190), No. 86, Cat. G.S.C. 1313.

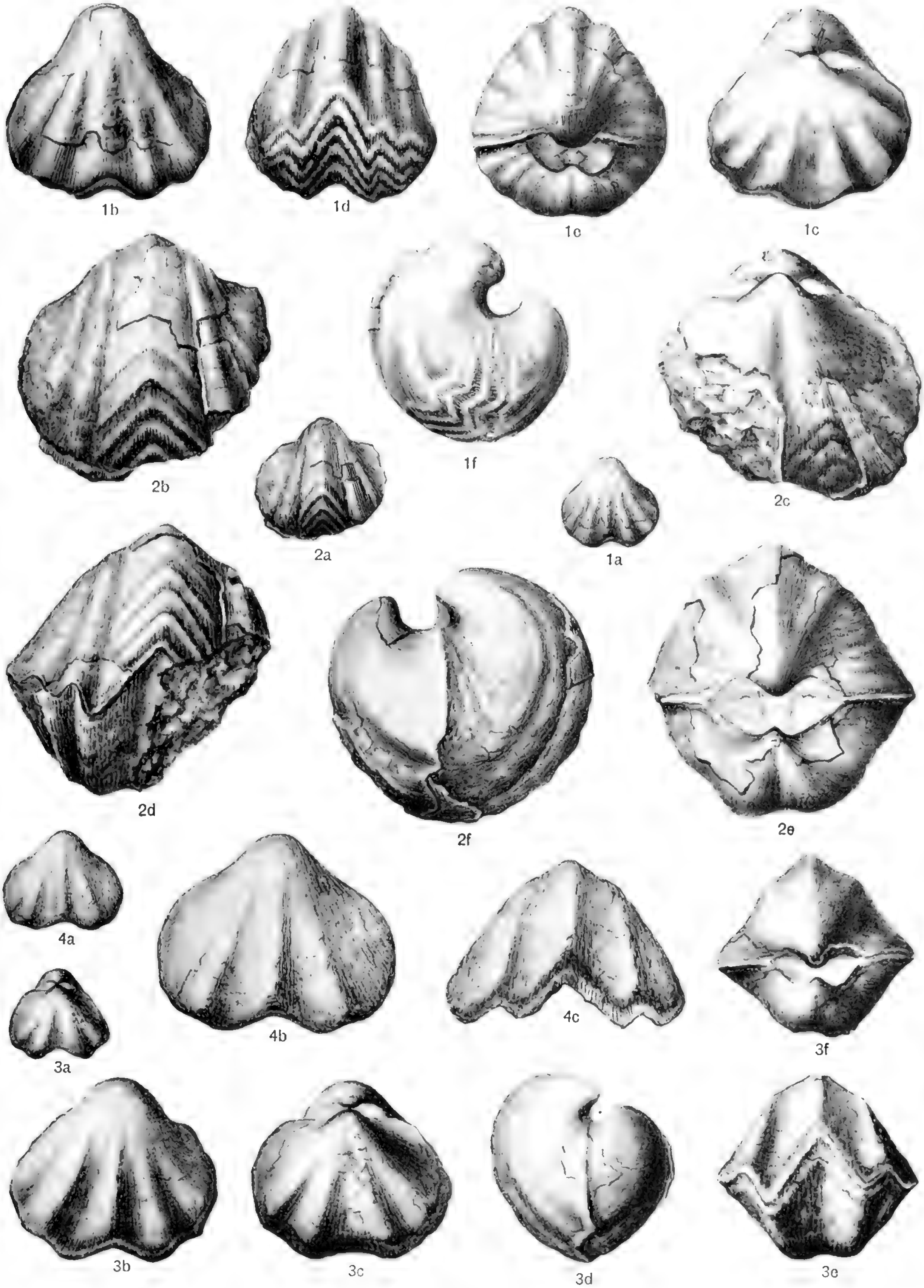
*Brachial valve up.

PLATE XI

(DRAWINGS BY K. C. LIU)

			PAGE
FIG.	1.	*Enteletes andrewsi* Grabau, sp. nov.	222
	1a,	Brachial view of a characteristic, nearly mature, individual, holotype, natural size; 1b, brachial; 1c, pedicle; 1d, frontal*; 1e, cardinal,* and 1f, lateral, views of the same individual, enlarged × 2. Enteletes bed (1190), No. 87, Cat. G.S.C. 1314.	
FIG.	2.	*Enteletes andrewsi* Grabau, sp. nov.	222
	2a,	Brachial view of a mature but imperfect shell, paratype, natural size; 2b, brachial; 2c, pedicle; 2d, frontal; 2e, cardinal, and 2f, lateral, views of the same shell, enlarged × 2. Enteletes bed (1190), No. 89, Cat. G.S.C. 1315.	
FIG.	3.	*Enteletes angulatoplicata* Grabau, sp. nov.	227
	3a,	Pedicle view of a submature individual, holotype, natural size; 3b, brachial; 3c, pedicle; 3d, lateral; 3e, frontal, and 3f, cardinal, views of the same individual, enlarged × 2. Martinia bed (1194), No. 85, Cat. G.S.C. 1312.	
FIG.	4.	*Enteletes angulatoplicata* Grabau, sp. nov.	227
	4a,	A separate brachial valve of a mature individual, paratype, natural size; 4b, the same, enlarged × 2; 4c, frontal view of the same, enlarged × 2. Hemiptychina bed (1196), No. 91, Cat. G.S.C. 1317.	

*Brachial valve up.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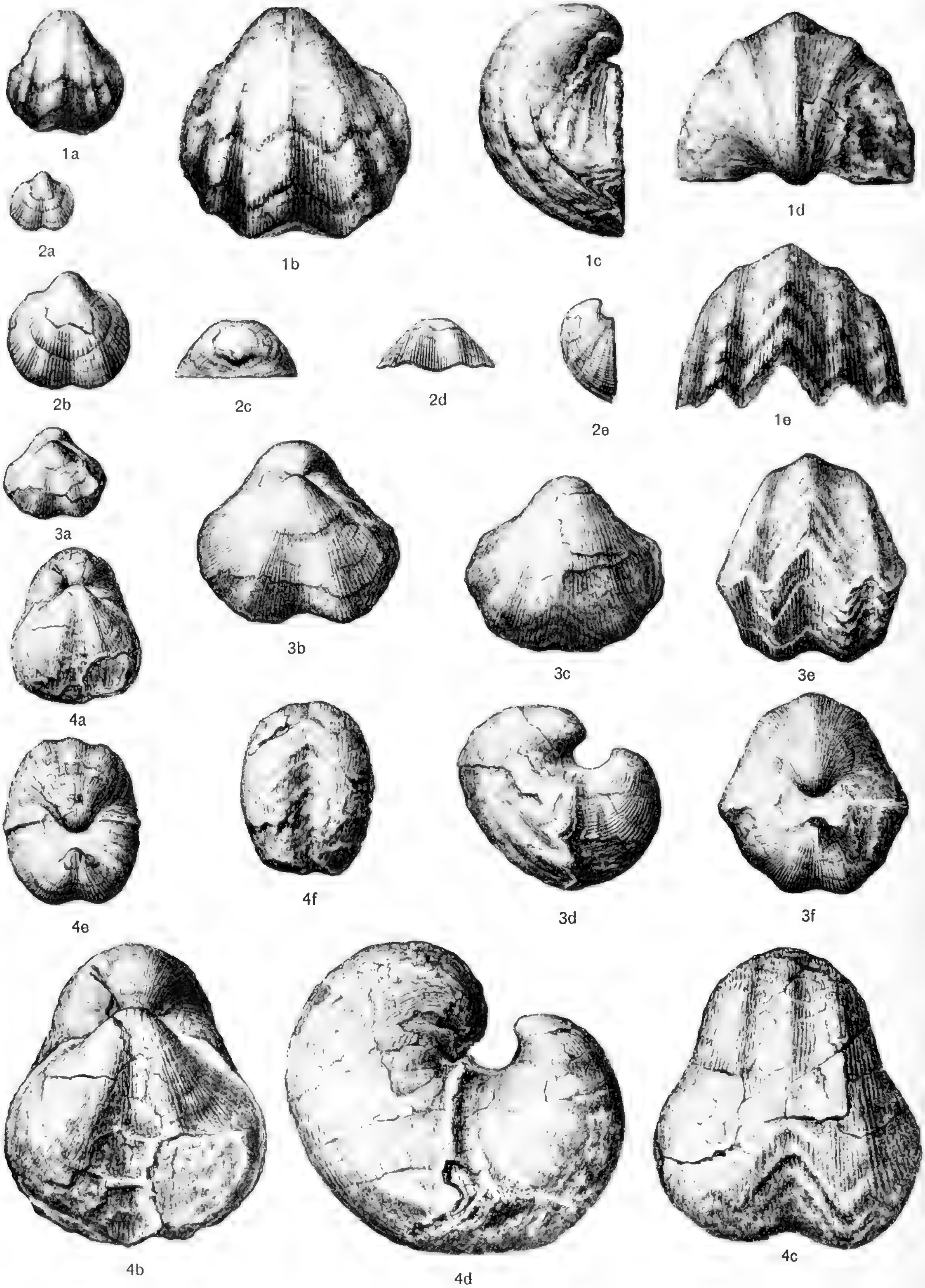
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PLATE XII

(DRAWINGS BY K. C. LIU)

PAGE

FIG. 1. *Enteletes angulatoplicata* Grabau, sp. nov. 227

1a, A characteristic brachial valve of an adult individual, paratype, natural size; 1b, the same, enlarged × 2: 1c, lateral; 1d, cardinal, and 1e, frontal, views of the same, enlarged × 2.

Jisu Honguer limestone, No. 92, Cat. G.S.C. 1318.

FIG. 2. *Enteletes obesa* Grabau, sp. nov. 229

2a, A young pedicle valve, paratype, natural size; 2b, the same, enlarged × 2; 2c, cardinal; 2d, frontal, and 2e, lateral, views of the same, enlarged × 2.

Jisu Honguer limestone, No. 104, Cat. G.S.C. 1322.

FIG. 3. *Enteletes obesa* Grabau, sp. nov. 229

3a, Pedicle view of nearly mature shell, paratype, natural size; 3b, pedicle; 3c, brachial; 3d, lateral; 3e, frontal,* and 3f, cardinal,* views of the same individual, enlarged × 2.

Enteletes bed (1190), No. 97, Cat. G.S.C. 1320.

FIG. 4. *Enteletes obesa* Grabau, sp. nov. 229

4a, Pedicle view of a typical adult individual, holotype, natural size; 4b, pedicle; 4c, brachial; 4d, lateral, views of the same individual, enlarged × 2; 4e, cardinal,* and 4f, frontal,* views of the same individual, natural size.

Enteletes bed? (1190?), No. 100, Cat. G.S.C. 1321.

*Brachial valve up.

PLATE XIII

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PAGE

FIG. 1. *Enteletes subobesa* Grabau, sp. nov. 235

1a, A typical brachial valve, imperfect, cotype, natural size; 1b, the same, enlarged × 2; 1c, lateral; 1d, frontal; 1e, cardinal, views of the same, enlarged × 2.

Jisu Honguer limestone, No. 113, Cat. G.S.C. 1325.

FIG. 2. *Enteletes subobesa* Grabau, sp. nov. 235

2a, A characteristic pedicle view of a somewhat larger individual than 1a, cotype, natural size; 2b, the same, enlarged × 2; 2c, lateral; 2d, frontal, and 2e, cardinal, views of the same, enlarged × 2.

Hemiptychina bed (1196), No. 114, Cat. G.S.C. 1326.

FIG. 3. *Enteletes nucleola* Grabau, sp. nov. 237

3a, Pedicle view of a young shell, paratype, natural size; 3b, pedicle; 3c, brachial; 3d, frontal*: 3e, cardinal,* and 3f, lateral, views of the same shell, enlarged × 3.

Jisu Honguer limestone, No. 105, Cat. G.S.C. 1323.

FIG. 4. *Enteletes nucleola* Grabau, sp. nov. 237

4a, Pedicle view of a probably mature individual, paratype, natural size; 4b, pedicle; 4c, brachial; 4d, frontal*; 4e, cardinal,* and 4f, lateral, views of the same individual, enlarged × 3.

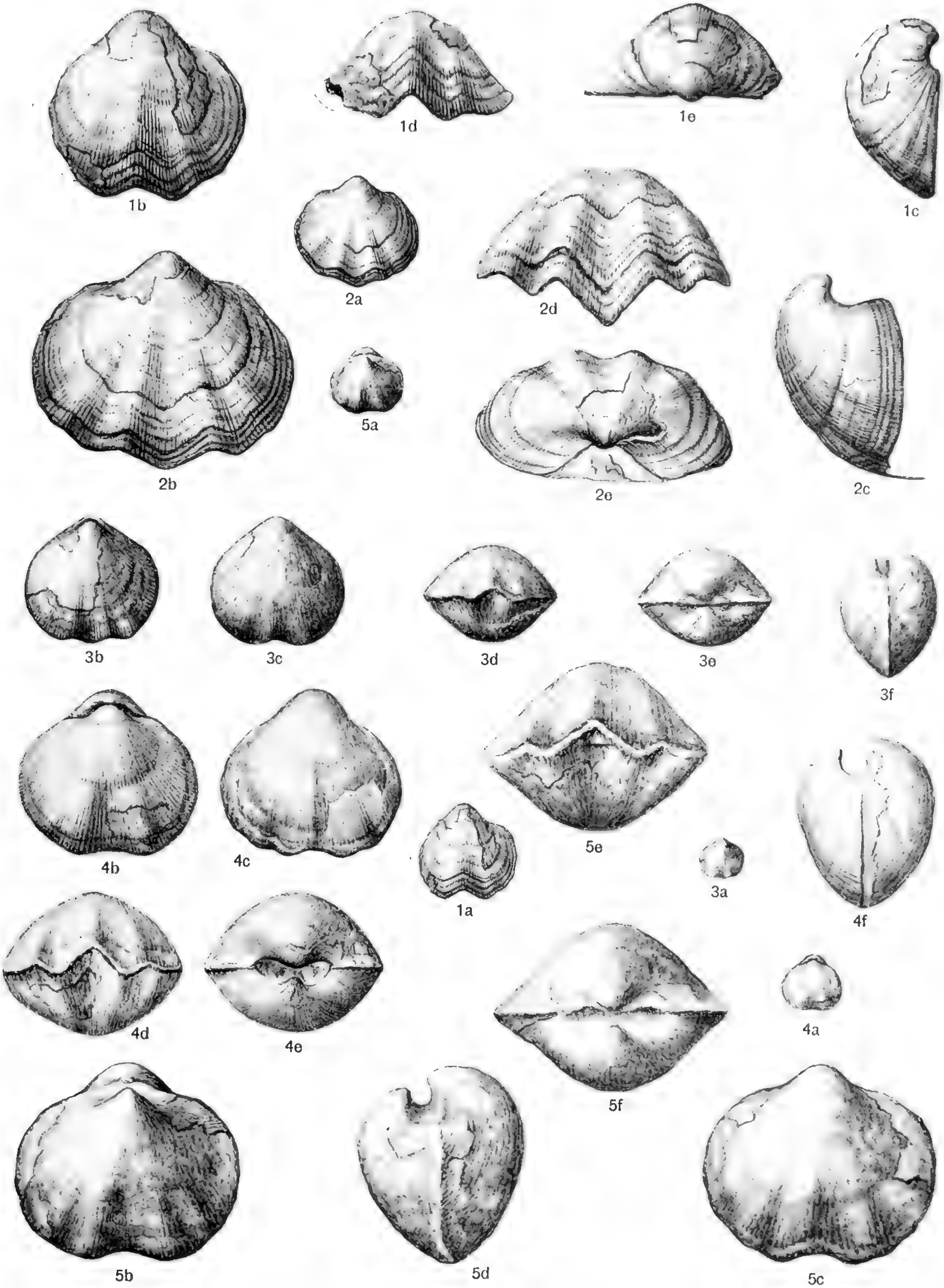
Orthotychia bed (1211), No. 106, Cat. G.S.C. 1324.

FIG. 5. *Enteletes nucleola* Grabau, sp. nov. 237

5a, Pedicle view of holotype, a mature individual, natural size; 5b, pedicle; 5c, brachial; 5d, lateral; 5e, frontal,* and 5f, cardinal,* views of the same shell, enlarged × 3.

Jisu Honguer limestone, No. 393, Cat. G.S.C. 1400.

* Brachial valve up.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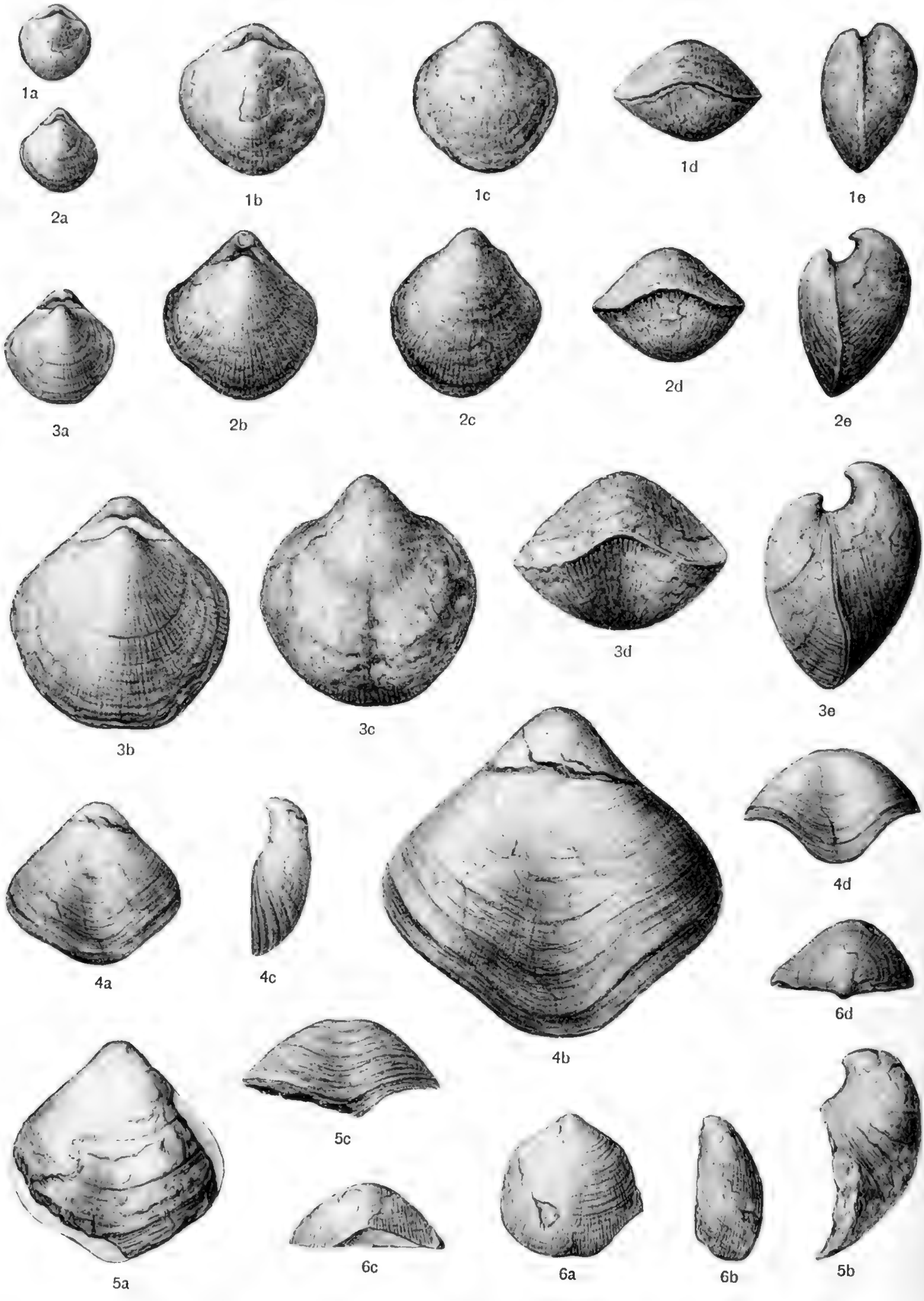
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PLATE XIV

(DRAWINGS BY K. C. LIU)

PAGE

FIG. 1. *Martinia osborni* Grabau, sp. nov. 176

1a, Brachial view of a young shell, paratype, natural size; 1b, brachial; 1c, pedicle; 1d, frontal; 1e, lateral, views of the same individual, enlarged × 2.

Martinia bed (1194), No. 45, Cat. G.S.C. 1281.

FIG. 2. *Martinia osborni* Grabau, sp. nov. 176

2a, Brachial view of a somewhat more elongated young individual, paratype, natural size; 2b, brachial; 2c, pedicle; 2d, frontal,* and 2e, lateral, views of the same individual, × 2.

Martinia bed (1194), No. 41, Cat. G.S.C. 1280.

FIG. 3. *Martinia osborni* Grabau, sp. nov. 176

3a, Brachial view of a typical, but immature shell, paratype, natural size; 3b, brachial; 3c, pedicle; 3d, frontal*; 3e, lateral, views of the same individual, enlarged × 2.

Martinia bed (1194), No. 131, Cat. G.S.C. 1334.

FIG. 4. *Martinia osborni* Grabau, sp. nov. 176

4a, A characteristic mature pedicle valve, holotype, natural size; 4b, the same, enlarged × 2; 4c, lateral; 4d, frontal, views of the same individual, natural size.

Camarophoria bed (1208), No. 122, Cat. G.S.C. 1331.

FIG. 5. *Martinia osborni* Grabau, sp. nov. 176

5a, An imperfect, slightly large pedicle valve, natural size; 5b, lateral, and 5c, frontal, views of the same, natural size. Paratype.

Camarophoria bed (1208), No. 120, Cat. G.S.C. 1330.

FIG. 6. *Martinia osborni* Grabau, sp. nov. 176

6a, A submature brachial valve of this species, somewhat crushed, cotype, natural size; 6b, lateral; 6c, frontal; and 6d, cardinal, views of the same, natural size.

Martinia bed (1194), No. 126, Cat. G.S.C. 1333.

* Brachial valve up.

PLATE XV

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PAGE

FIG. 1. *Martinia mongolica* Grabau, sp. nov. 180

1a, Brachial view of a young shell, paratype, natural size; 1b, brachial; 1c, pedicle; 1d, frontal, and 1e, lateral, views of the same shell, enlarged × 2.

Jisu Honguer limestone, No. 48, Cat. G.S.C. 1284.

FIG. 2. *Martinia mongolica* Grabau, sp. nov. 180

2a, Brachial valve, of a somewhat older shell, paratype, natural size; 2b, brachial; 2c, pedicle; 2d, frontal; and 2e, lateral, views of the same, enlarged × 2.

Martinia bed (1194), No. 36, Cat. G.S.C. 1277.

FIG. 3. *Martinia mongolica* Grabau, sp. nov. 180

3a, Pedicle view of what is apparently a submature shell of this species, paratype, natural size; 3b, brachial; 3c, pedicle; 3d, frontal; 3e, cardinal, and 3f, lateral views of the same individual, enlarged × 2.

Martinia bed (1194), No. 29, Cat. G.S.C. 1270.

FIG. 4. *Martinia mongolica* Grabau, sp. nov. 180

4a, Brachial view of a larger, probably adult and somewhat more transverse shell, cotype, natural size; 4b, brachial; 4c, pedicle; 4d, lateral; 4e, frontal, and 4f, cardinal, views of the same, enlarged × 2.

Martinia bed (1194), No. 116, Cat. G.S.C. 1237.

(See also Plate XVIII, Fig. 1.)

FIG. 5. *Martinia orbicularis* Gemmellaro 183

5a, Brachial view of young shell, natural size; 5b, brachial; 5c, pedicle; 5d, frontal; 5e, cardinal; 5f, lateral, views of the same, enlarged × 2.

Martinia bed (1194), No. 35, Cat. G.S.C. 1276.

FIG. 6. *Martinia orbicularis* Gemmellaro 183

6a, Brachial view of a somewhat larger young shell, natural size; 6b, brachial; 6c, pedicle; 6d, frontal; 6e, cardinal; 6f, lateral, views of the same shell, enlarged × 2.

Martinia bed (1194), No. 46, Cat. G.S.C. 1282.

FIG. 7. *Martinia orbicularis* Gemmellaro 183

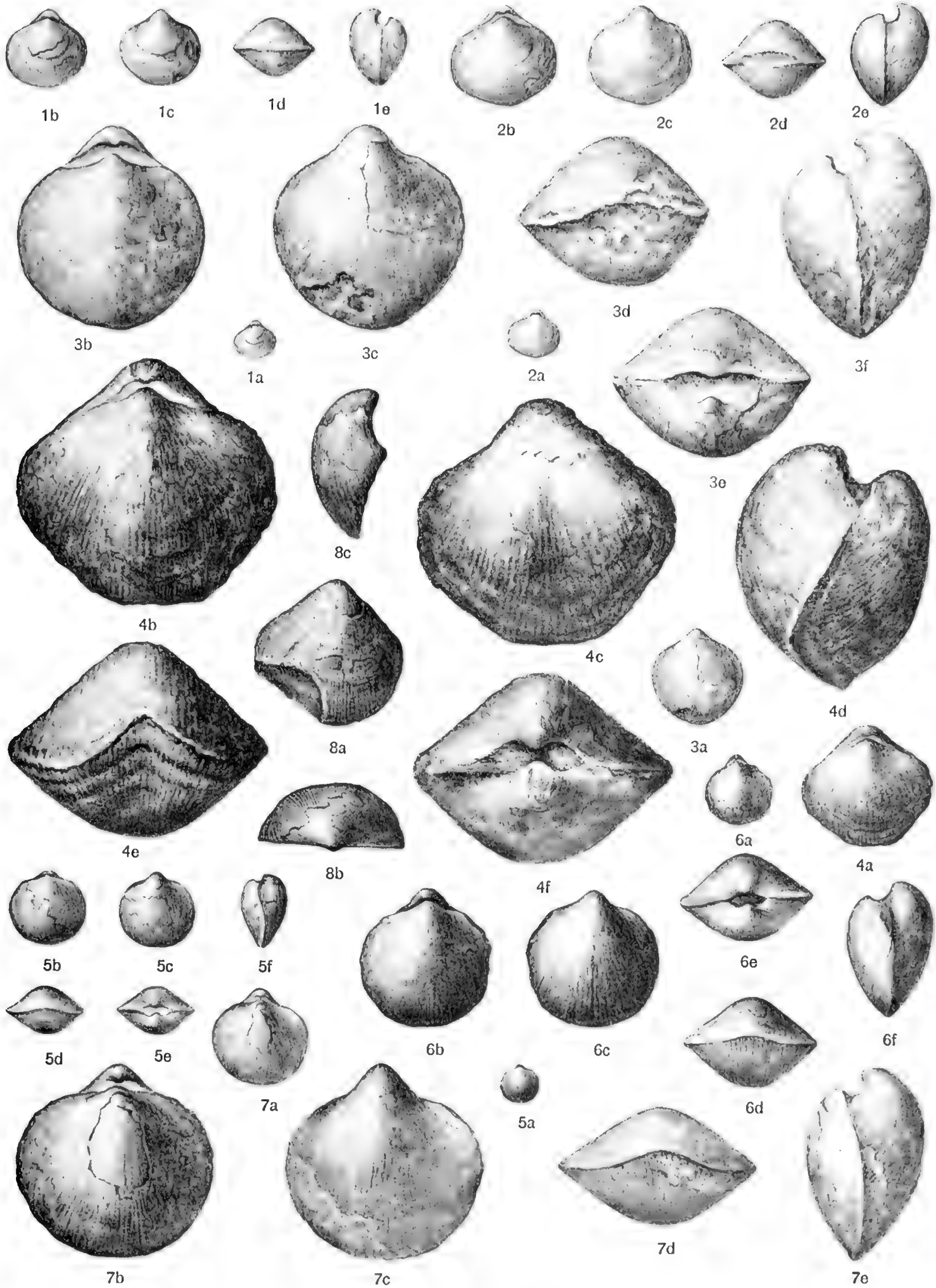
7a, Pedicle view of a specimen representing the average size of the adult individuals in this strata, natural size; 7b, brachial; 7c, pedicle; 7d, frontal; 7e, lateral, views of the same shell, enlarged × 2.

Martinia bed (1194), No. 30, Cat. G.S.C. 1271.

FIG. 8. *Martinia orbicularis* Gemmellaro 183

8a, An imperfect pedicle valve of unusual size for these strata; 8b, cardinal; 8c, lateral, views of the same shell; natural size.

Martinia bed (1194), No. 117, Cat. G.S.C. 1328.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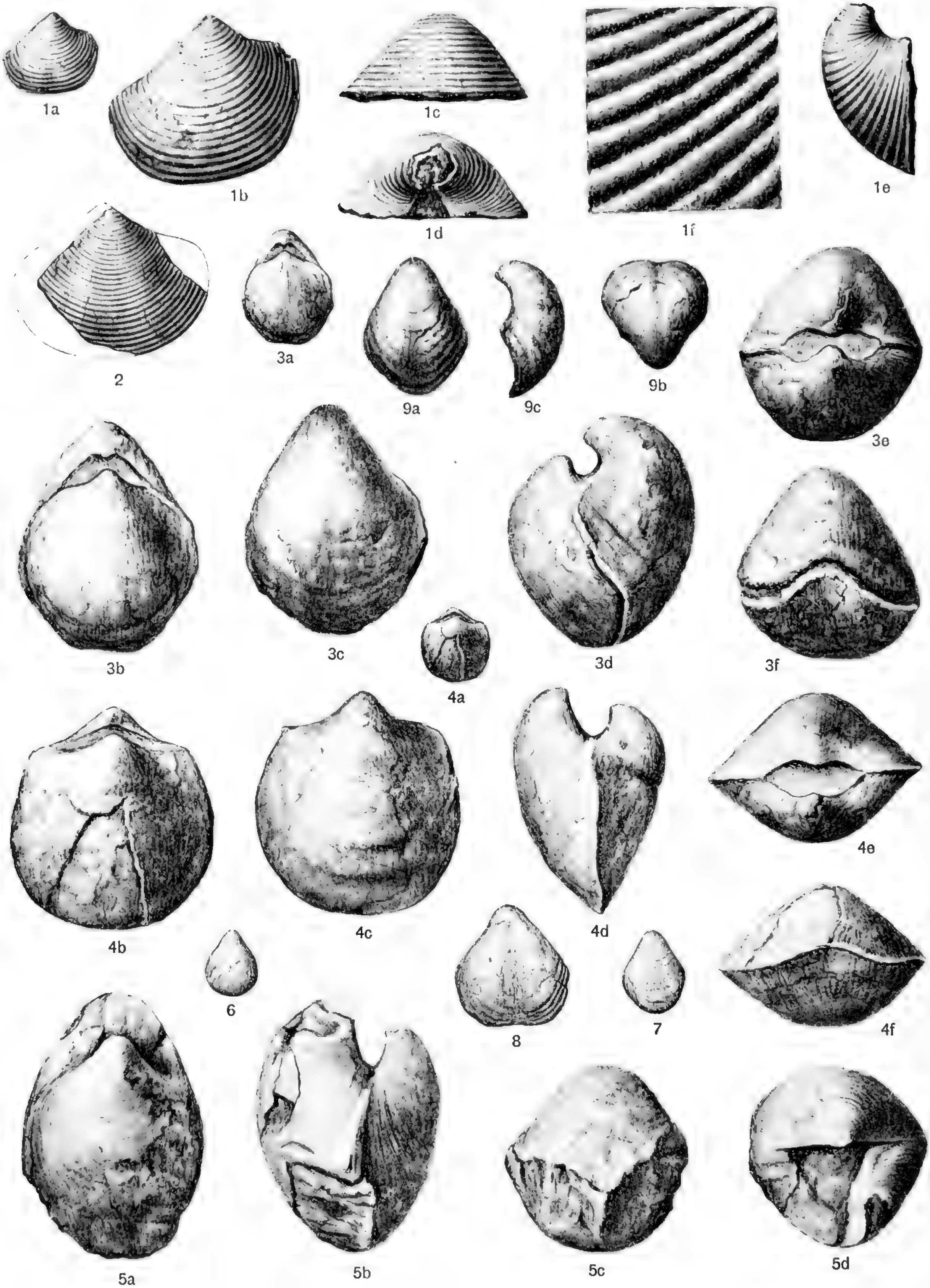
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PLATE XVI

(DRAWINGS BY K. C. LIU)

PAGE

FIG. 1. *Squamularia elegantuloides* Grabau, sp. nov. 198

1a, A characteristic pedicle valve of an immature individual, holotype, natural size; 1b, the same, enlarged × 2; 1c, frontal; 1d, cardinal, and 1e, lateral, views of the same, enlarged × 2; 1f, portion of the surface, enlarged × 5.

Jisu Honguer limestone, No. 47, Cat. G.S.C. 1283.

FIG. 2. *Squamularia elegantuloides* Grabau, sp. nov. 198

A fragment of a pedicle valve, probably representing the adult, natural size, paratype.

Lyttonia bed (1193), No. 138, Cat. G.S.C. 1336.

FIG. 3. *Martinia sinensis* Grabau, sp. nov. 187

3a, Brachial view of the holotype, natural size; 3b, brachial; 3c, pedicle; 3d, lateral; 3e, cardinal, and 3f, frontal, views of the same specimen, enlarged × 2.

Jisu Honguer limestone, No. 133, Cat. G.S.C. 1335.

FIG. 4. *Martinia rectangularis* Grabau, sp. nov. 189

4a, Brachial view of the holotype, natural size; 4b, brachial; 4c, pedicle; 4d, lateral; 4e, cardinal, and 4f, frontal, views of the same specimen, enlarged × 3.

Martinia bed (1194), No. 38, Cat. G.S.C. 1278.

FIG. 5. *Squamularia waageni* (v. Loczy) 204

5a, Brachial; 5b, lateral; 5c, frontal; 5d, cardinal, views of an adult imperfect specimen partly restored, natural size.

Spirifer moosakhailensis bed (1205), No. 167, Cat. G.S.C. 1346.

FIG. 6. *Martinia* cf. *distefanoi* Gemmellaro 191

Pedicle view of a young individual, natural size (see Pl. XVII, Fig. 1).

Martinia bed (1194), No. 155, Cat. G.S.C. 1340.

FIG. 7. *Martinia* cf. *distefanoi* Gemmellaro 191

Pedicle view of a somewhat larger individual, natural size (see Pl. XVII, Fig. 2).

Jisu Honguer limestone, No. 156, Cat. G.S.C. 1341.

FIG. 8. *Martinia* cf. *distefanoi* Gemmellaro 191

Pedicle view of a half-grown individual, natural size (see Pl. XVII, Fig. 3).

Jisu Honguer limestone, No. 157, Cat. G.S.C. 1342.

FIG. 9. *Martinia sinensis* Grabau, sp. nov. 187

9a, A somewhat larger pedicle valve than the holotype (Fig. 3), natural size, paratype; 9b, oblique cardinal; 9c, lateral, views of the same, natural size.

Martinia bed (1194), No. 140, Cat. G.S.C. 1337.

PLATE XVII

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PAGE

FIG. 1. *Martinia* cf. *distefanoi* Gemmellaro 191

1a, Brachial; 1b, pedicle; 1c, cardinal; 1d, frontal, and 1e, lateral, views of the young shell shown in Pl. XVI, Fig. 6, enlarged × 3.

Martinia bed (1194), No. 155, Cat. G.S.C. 1340.

FIG. 2. *Martinia* cf. *distefanoi* Gemmellaro 191

2a, Pedicle; 2b, cardinal; 2c, frontal, and 2d, lateral, views of the same specimen (pedicle valve) shown in Pl. XVI, Fig. 7, enlarged × 3.

Jisu Honguer limestone, No. 156, Cat. G.S.C. 1341.

FIG. 3. *Martinia* cf. *distefanoi* Gemmellaro 191

3a, Pedicle; 3b, cardinal; 3c, frontal, and 3d, lateral, views of the half-grown pedicle valves, shown in Pl. XVI, Fig. 8, enlarged × 2.

Jisu Honguer limestone, No. 157, Cat. G.S.C. 1342.

FIG. 4. *Martinia distefanoi* Gemmellaro var. *spissa* Grabau, var. nov. . . . 193

4a, Brachial view of the holotype, natural size; 4b, brachial; 4c, pedicle; 4d, lateral; 4e, cardinal, and 4f, frontal, views of the same shell, enlarged × 2.

Martinia bed (1194), No. 40, Cat. G.S.C. 1279.

FIG. 5. *Squamularia indica* (Waagen) 200

5a, Brachial view of a young individual, natural size; 5b, brachial; 5c, pedicle; 5d, cardinal; 5e, frontal, and 5f, lateral, views of the same specimen, enlarged × 3.

Jisu Honguer limestone, No. 162, Cat. G.S.C. 1343.

PLATE XVIII

(DRAWINGS BY K. C. LIU)

			PAGE
FIG.	1.	*Martinia mongolica* Grabau, sp. nov.	180
	1a,	Brachial view of an immature shell, imperfect and restored, natural size, paratype; 1b, brachial; 1c, pedicle; 1d, cardinal, and 1e, lateral, views of the same specimen, restored and enlarged × 2.	
		Martinia bed (1194), No. 143, Cat. G.S.C. 1338.	
FIG.	2.	*Squamularia indica* (Waagen)	200
	2a,	A half-grown brachial valve, natural size; 2b, lateral; 2c, cardinal, and 2d, frontal, views of the same, natural size.	
		Hemiptychina bed (1196), No. 165, Cat. G.S.C. 1345.	
FIG.	3.	*Squamularia indica* (Waagen)	200
	3a,	An adult pedicle valve, imperfect and restored, natural size; 3b, lateral, and 3c, cardinal, views of the same, natural size.	
		Camarophoria bed (1208), No. 164, Cat. G.S.C. 1344.	
FIG.	4.	*Squamularia indica* (Waagen)	200
	4a,	An adult brachial valve, natural size; 4b, lateral; 4c, cardinal, views of the same, natural size.	
		Marginifera bed (1192), No. 395, Cat. G.S.C. 1401.	
FIG.	5.	*Martinia distorta* Grabau, sp. nov.	195
	5a,	Brachial view of the holotype, natural size; 5b, brachial; 5c, pedicle; 5d, cardinal; 5e, frontal, and 5f, lateral, views of the same shell, enlarged × 2.	
		Martinia bed (1194), No. 118, Cat. G.S.C. 1329.	
FIG.	6.	*Martinia rhomboidalis* Grabau, sp. nov.	197
	6a,	Brachial view, natural size; 6b, brachial; 6c, pedicle; 6d, cardinal; 6e, frontal, and 6f, lateral, views of the same shell, enlarged × 3.	
		Martinia bed (1194), No. 145, Cat. G.S.C. 1339.	

PLATE XIX

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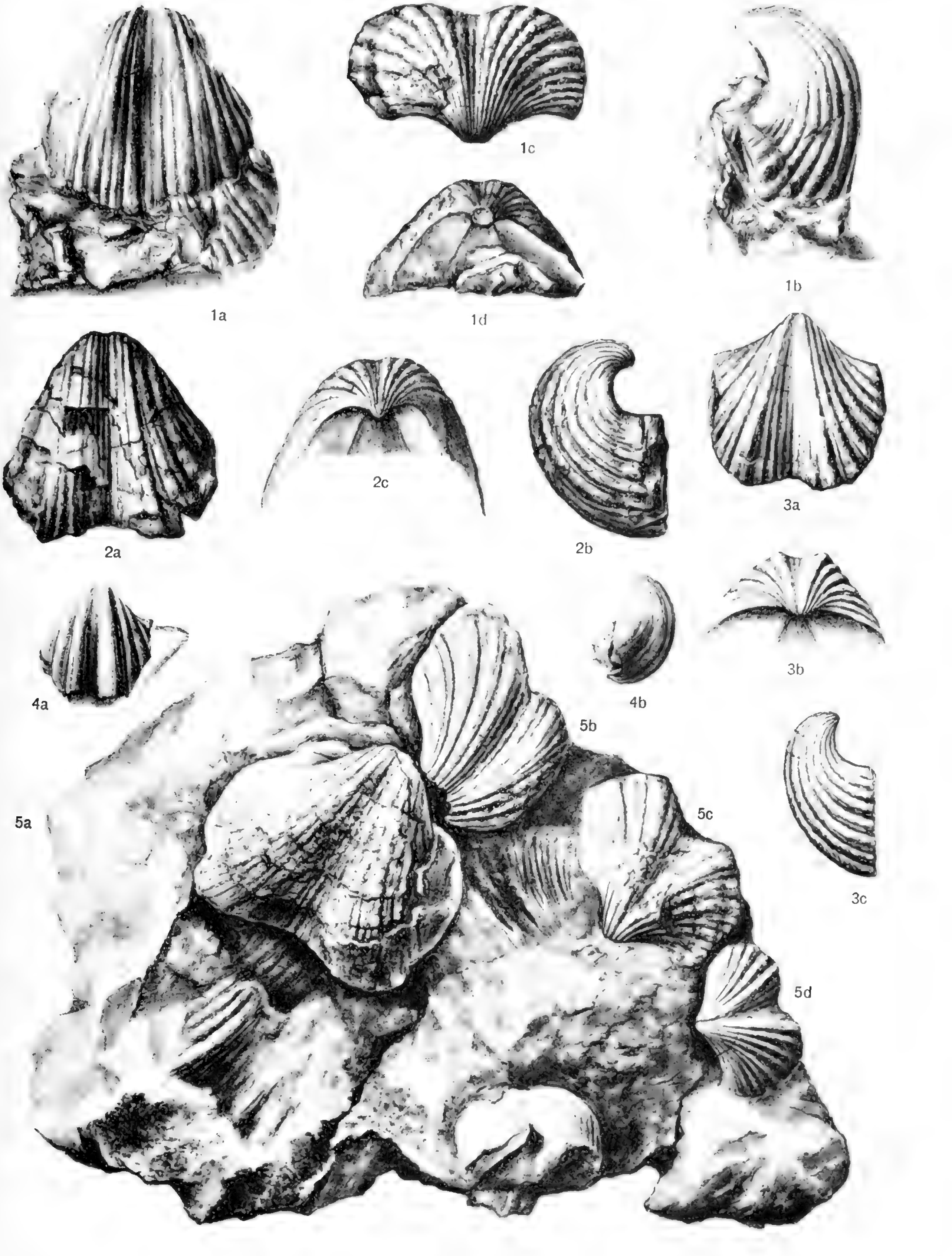
			PAGE
FIG.	1.	*Spiriferella salteri* Tschernyschew (*typica*), mut. γ	136
	1a,	Characteristic pedicle valve, natural size; 1b, lateral; 1c, umbonal; 1d, cardinal, views of the same, natural size.	
		Spiriferella bed (1209), No. 176, Cat. G.S.C. 1350.	
FIG.	2.	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ	138
	2a,	Characteristic pedicle valve, natural size, paratype; 2b, lateral; 2c, cardinal, views of the same, natural size.	
		Spiriferella bed (1209), No. 219, Cat. G.S.C. 1377.	
FIG.	3.	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ	138
	3a,	A nearly mature pedicle valve, holotype, natural size; 3b, cardinal; 3c, lateral, views of the same, natural size.	
		Spiriferella bed (1209), No. 175, Cat. G.S.C. 1349.	
FIG.	4.	*Spiriferella persaranæ* Grabau, sp. nov.	156
	4a,	Pedicle; 4b, lateral, views of the holotype, a pedicle valve, partly restored.	
		Marginifera bed (1192), No. 179, Cat. G.S.C. 1352.	
FIG.	5.	*Spiriferella salteri* Tschernyschew	136, 138
		A limestone block, showing several varieties of this species, natural size.	
	5a,	(*typica*), mut. γ, No. 204.	
	5b,	variety *wimanni* Grabau, var. nov., mut. δ, No. 205.	
	5c,	(*typica*), mut. γ, No. 206.	
	5d,	(*typica*), mut. γ, No. 207.	
		Spiriferella bed (1209), Nos. 204 to 207, Cat. G.S.C. 1369.	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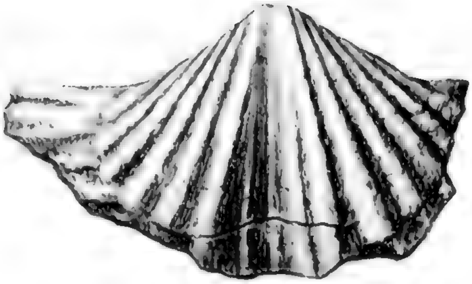

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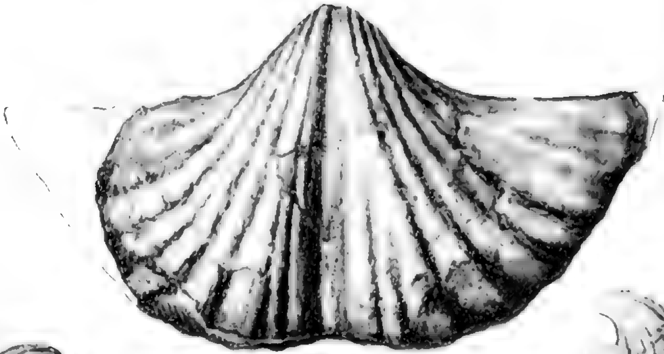

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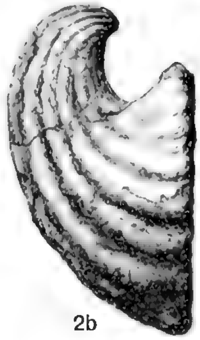

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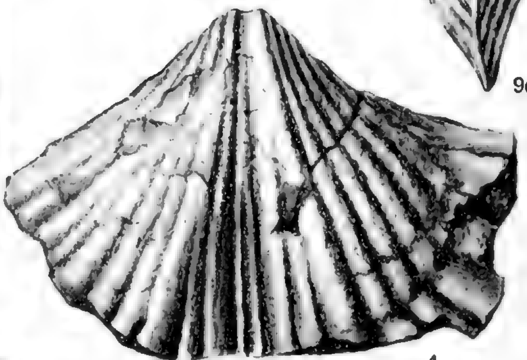

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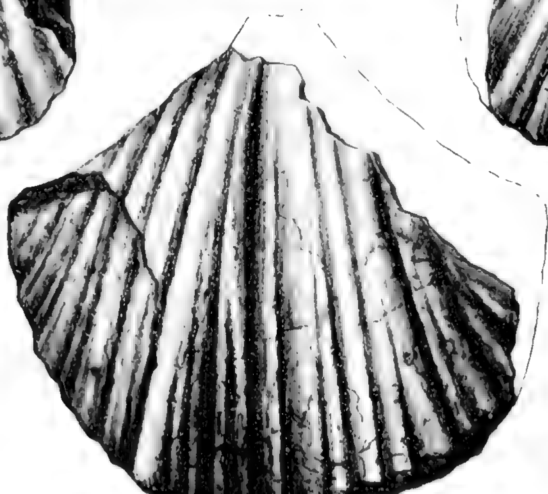

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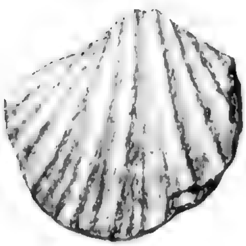

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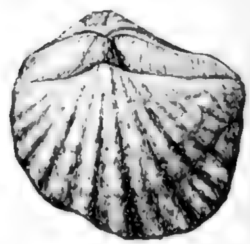

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PLATE XX

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			PAGE
FIG.	1.	*Spiriferella salteri* Tschernyschew var. *simplex* Grabau, var. nov., mut. α . An immature fragmentary pedicle valve, enlarged × 2; paratype. Spiriferella bed (1209), No. 182, Cat. G.S.C. 1355.	131
FIG.	2. 2a,	*Spiriferella salteri* Tschernyschew var. *simplex* Grabau, var. nov., mut. α . A somewhat larger pedicle valve, enlarged × 2, holotype; 2b, side view of the same, enlarged × 2. Spiriferella bed (1209), No. 202, Cat. G.S.C. 1367.	131
FIG.	3.	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β A fragmentary pedicle valve, restored, enlarged × 2, paratype. Spiriferella bed (1209), No. 183, Cat. G.S.C. 1356.	133
FIG.	4.	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β. A characteristic pedicle valve enlarged × 2, paratype. Spiriferella bed (1209), No. 185, Cat. G.S.C. 1358.	133
FIG.	5.	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β. A fairly perfect pedicle valve, enlarged × 2, holotype. Spiriferella bed (1209), No. 187, Cat. G.S.C. 1359.	133
FIG.	6.	*Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β. A somewhat larger imperfect pedicle valve, enlarged × 2, paratype. Spiriferella bed (1209), No. 189, Cat. G.S.C. 1361.	133
FIG.	7.	*Spiriferella salteri* Tschernyschew (*typica*), mut. γ. . . . . . A fragmentary pedicle valve, restored, enlarged × 2. Spiriferella bed (1209), No. 184, Cat. G.S.C. 1357.	136
FIG.	8.	*Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ Paratype, enlarged × 2. Spiriferella bed (1209), No. 188, Cat. G.S.C. 1360.	138
FIG.	9. 9a,	*Spiriferella keilhavii* (v. Buch) . . . . Brachial; 9b, pedicle; 9c, lateral, views of a specimen showing the typical form, natural size. (See Plate XXI.) Spiriferella bed (1209), No. 227, Cat. G.S.C. 1381.	164

PLATE XXI

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PAGE

FIG. 1. *Spiriferella keilhavii* (v. Buch). 164

Pedicle view of the same shell (shown in Pl. XX, Fig. 9b), enlarged × 2.

Spiriferella bed (1209), No. 227, Cat. G.S.C. 1381.

FIG. 2. *Spiriferella keilhavii* (v. Buch). 164

2a, A large but imperfect pedicle valve, probably adult, natural size; 2b, cardinal, and 2c, lateral, views of the same, natural size.

Jisu Honguer limestone, No. 226, Cat. G.S.C. 1380.

FIG. 3. *Spiriferella keilhavii* (v. Buch). 164

A fragmentary pedicle valve of somewhat more complex structure enlarged × 2.

Spiriferella bed (1209), No. 228, Cat. G.S.C. 1382.

FIG. 4. *Spiriferella keilhavii* (v. Buch). 164

A more nearly complete, accelerated pedicle valve, enlarged × 2.

Spiriferella bed (1209), No. 230, Cat. G.S.C. 1383.

FIG. 5. *Spiriferella keilhavii* (v. Buch), mut. *primitiva* Grabau 164

A rather poorly preserved pedicle valve, showing the simple character of this primitive mutation, natural size, holotype.

Marginifera bed (1192), No. 236, Cat. G.S.C. 1384.

FIG. 6. *Spiriferella keilhaviiformis* Fredericks 160

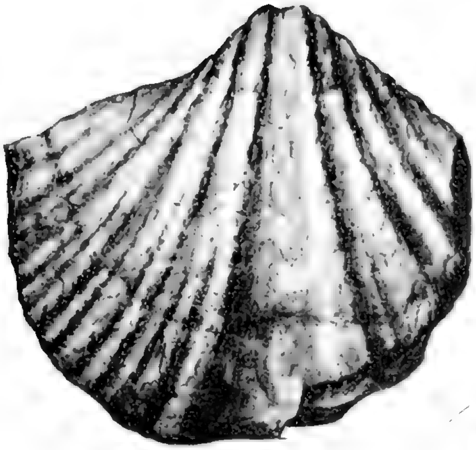
A fragment of a pedicle valve, referred to this maritime province species, enlarged × 2.

Spiriferella bed (1209), No. 216, Cat. G.S.C. 1375.

FIG. 7. *Spiriferella keilhaviiformis* Fredericks 160

Another fragment of a pedicle valve, referred to this species, enlarged × 2.

Spiriferella bed (1209), No. 217, Cat. G.S.C. 1376.



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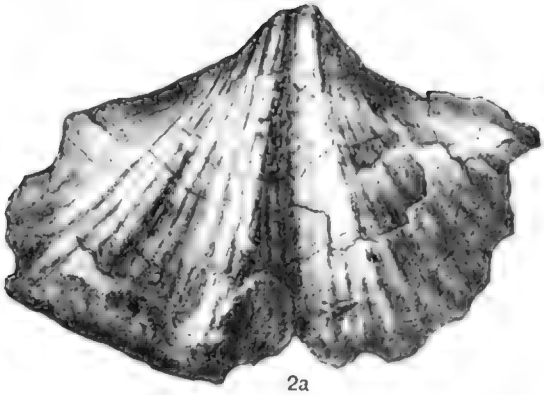

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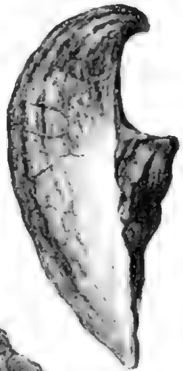

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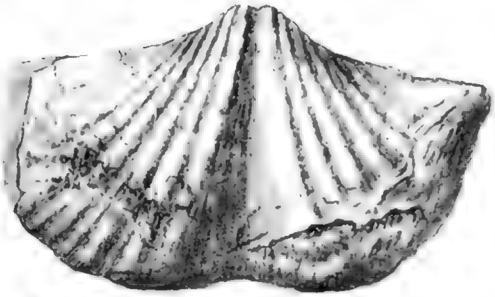

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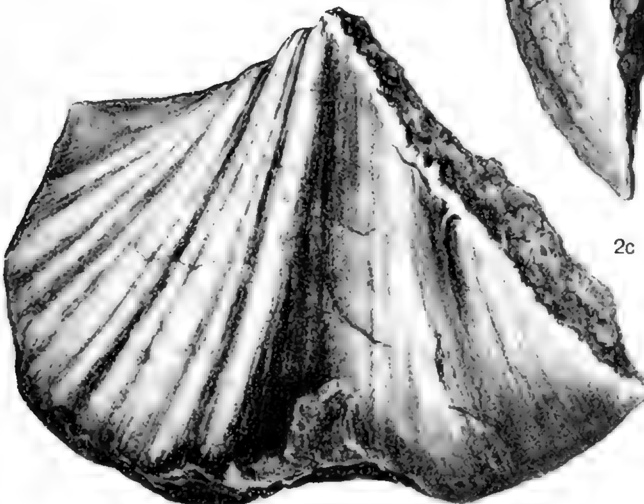

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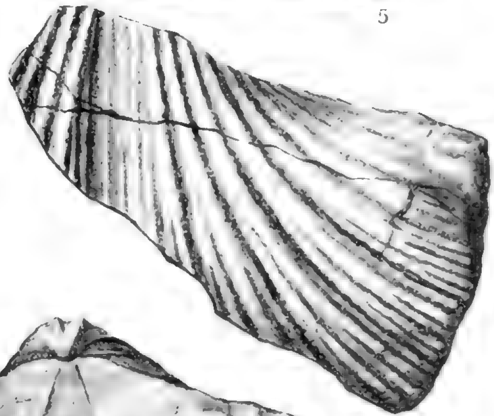

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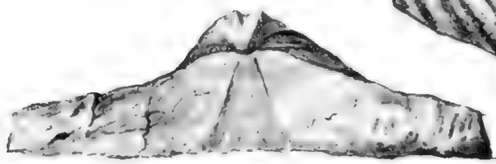

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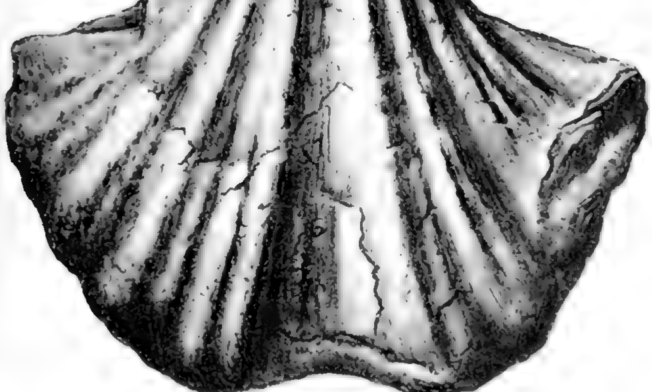

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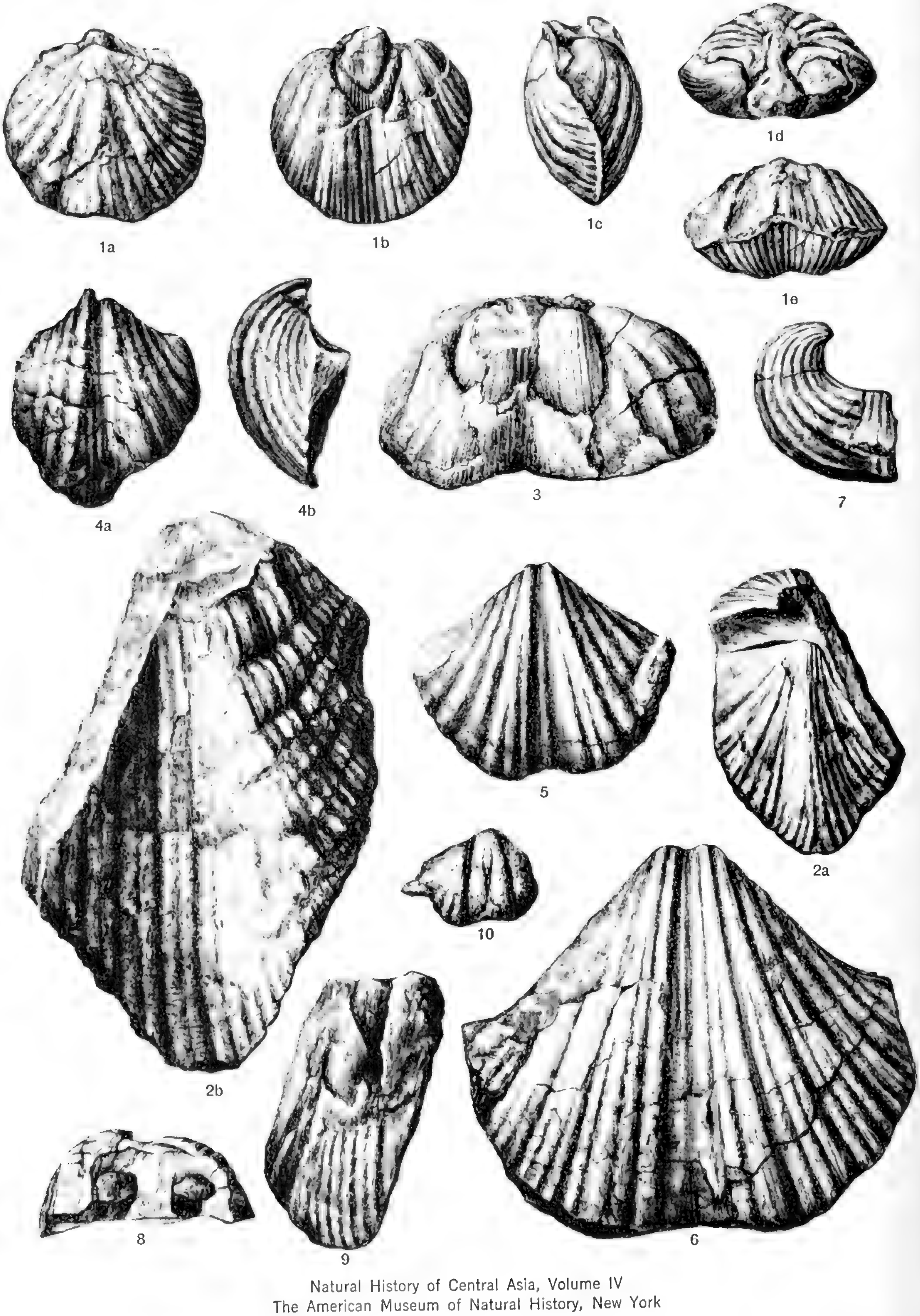

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PLATE XXII

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PLATE XXIII

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PAGE

FIG. 1. *Spiriferella salteri* Tschernyschew 129
Brachial valve of an undetermined mutation, natural size.
Spiriferella bed (1209), No. 196, Cat. G.S.C. 1363.

FIG. 2. *Spiriferella salteri* Tschernyschew 129
A smaller distorted brachial valve of an undetermined mutation, natural size.
Spiriferella bed (1209), No. 178, Cat. G.S.C. 1351.

FIG. 3. *Spiriferella salteri* Tschernyschew var. *wimanni* Grabau, var. nov., mut. δ. 138
A fragmentary brachial valve, with part of hinge area of pedicle valve attached, natural size, paratype.
Spiriferella bed (1209), No. 198, Cat. G.S.C. 1364.

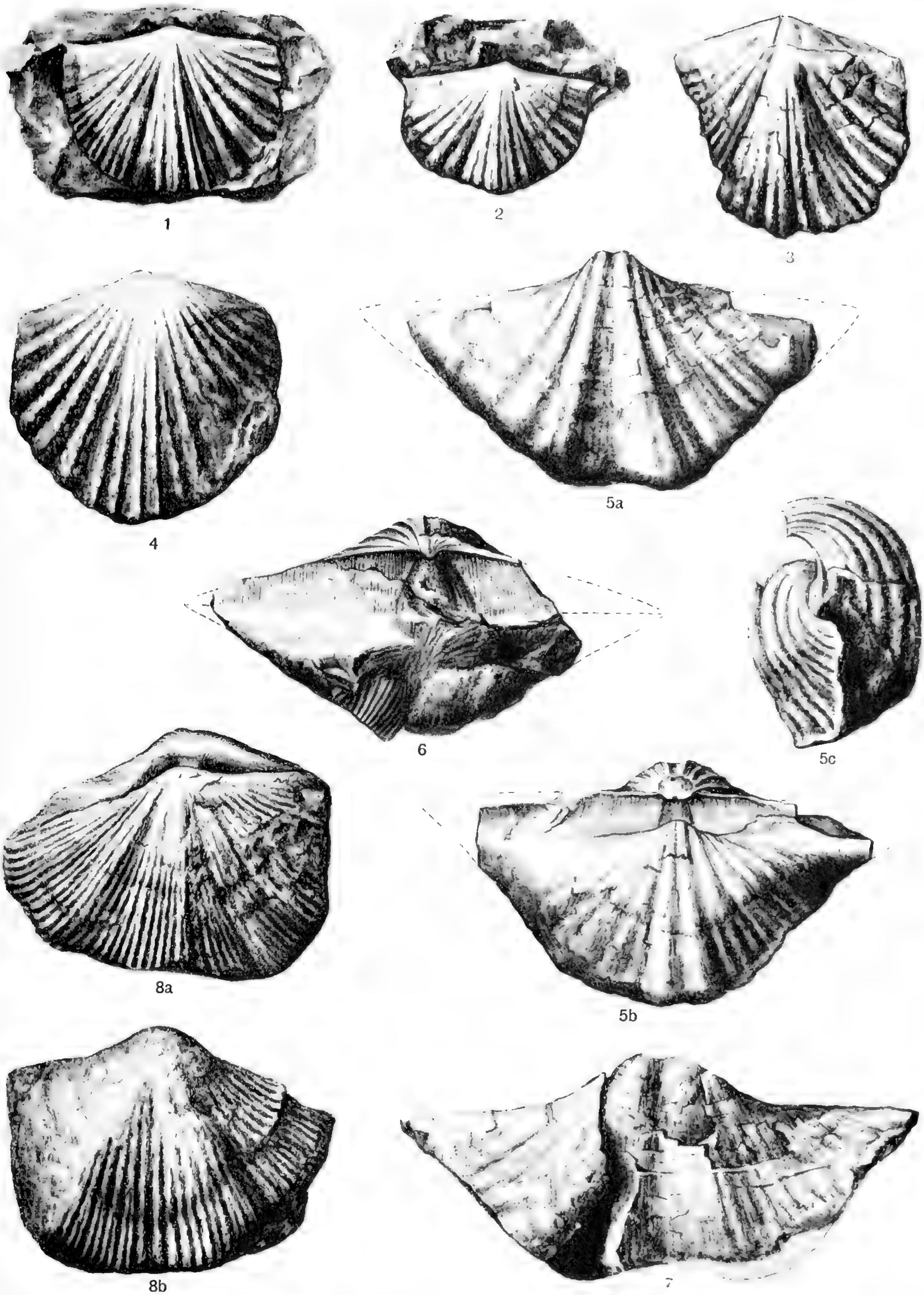
FIG. 4. *Spiriferella salteri* Tschernyschew var. *mongolica* Grabau, var. nov., mut. β. 133
A brachial valve, enlarged $\times$ 2, paratype.
Spiriferella bed (1209), No. 200, Cat. G.S.C. 1365.

FIG. 5. *Spirifer moosakhailensis* Davidson 168
5a, Pedicle view of a nearly perfect but somewhat exfoliated specimen, natural size; 5b, brachial, and 5c, lateral, views of the same, natural size.
Spiriferella bed (1209), No. 180, Cat. G.S.C. 1353.

FIG. 6. *Spirifer moosakhailensis* Davidson 168
Cardinal view of an imperfect pedicle valve, natural size.
Spiriferella bed (1209), No. 181, Cat. G.S.C. 1354.

FIG. 7. *Spirifer moosakhailensis* Davidson 168
Internal mold of the pedicle valve, showing mold of muscular impressions and with part of the shell surface preserved, natural size.
Spiriferella bed?, No. 241, Cat. G.S.C. 1385.

FIG. 8. *Spirifer moosakhailensis* Davidson 168
8a, Brachial, and 8b, pedicle, views of a somewhat imperfect young shell, showing multiple divisions of the plications, enlarged $\times$ 2 (see Text-Fig. 62).
Enteletes bed (1190), No. 242, Cat. G.S.C. 1386.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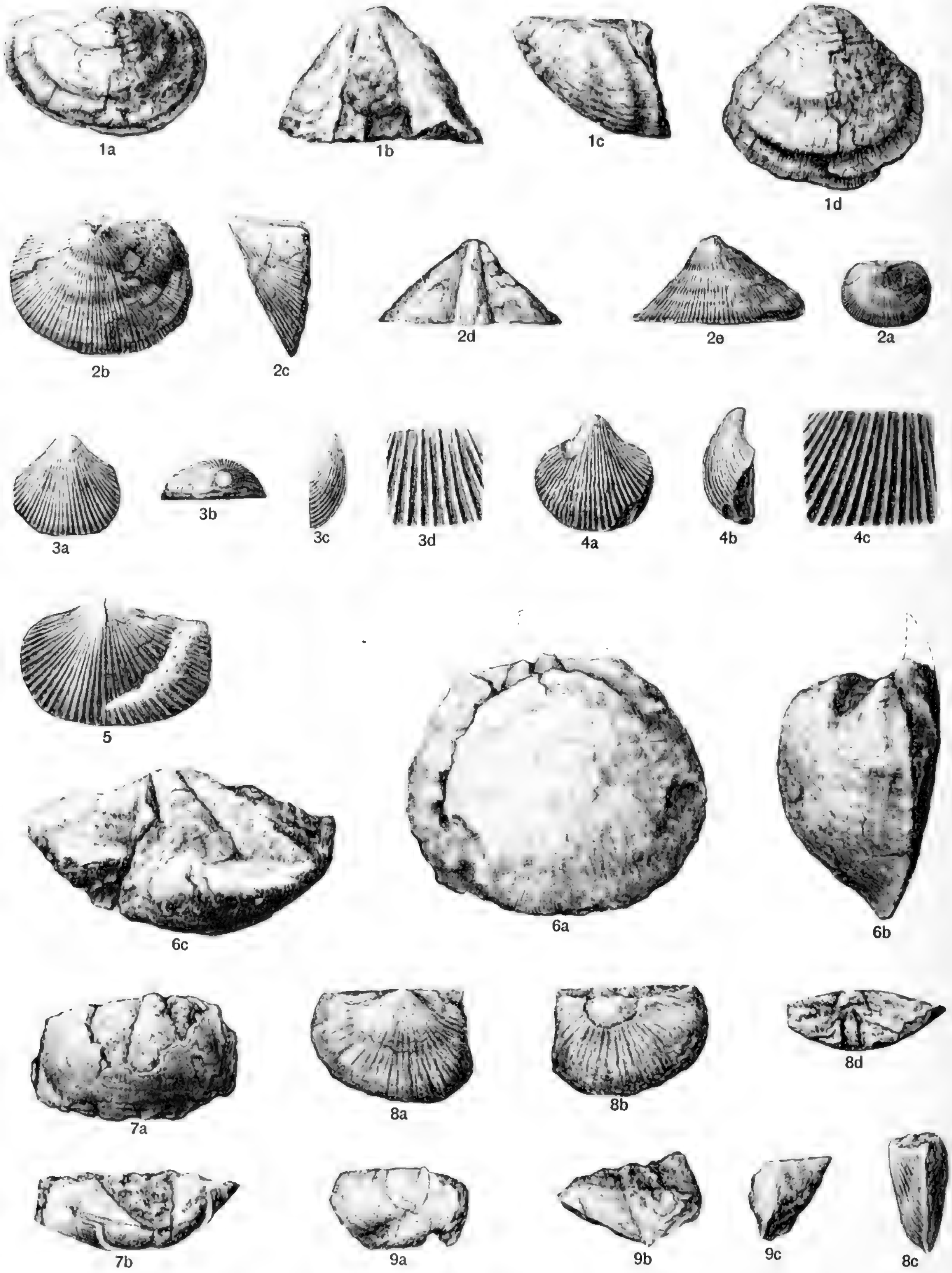
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PLATE XXIV

(DRAWINGS BY K. C. LIU)

			PAGE
FIG.	1.	*Streptorhynchus kayseri* Schellwien	241
	1a,	Pedicle; 1b, cardinal; 1c, lateral; and 1d, oblique, views of a somewhat imperfect pedicle valve, natural size.	
		Streptorhynchus kayseri bed (1207), No. 288, Cat. G.S.C. 1370.	
FIG.	2.	*Streptorhynchus pelargonatus* (Schlotheim)	243
	2a,	Direct view of a small, characteristic pedicle valve, natural size; 2b, pedicle; 2c, lateral; 2d, cardinal; 2e, frontal, views of the same shell, enlarged × 2.	
		Jisu Honguer limestone, No. 293, Cat. G.S.C. 1371.	
FIG.	3.	*Streptorhynchus broilii* Grabau, sp. nov.	245
	3a,	Pedicle; 3b, cardinal; 3c, lateral, views of a pedicle valve, cotype, natural size; 3d, enlargement of the surface of the same to show the characteristic striæ, × 4.	
		Streptorhynchus broilii bed (1210), No. 300, Cat. G.S.C. 1372.	
FIG.	4.	*Streptorhynchus broilii* Grabau, sp. nov.	245
	4a,	Pedicle; 4b, lateral, views of another pedicle valve, cotype, natural size; 4c, enlargement of surface to show the striæ, × 4.	
		Camarophoria bed (1208), No. 301, Cat. G.S.C. 1401.	
FIG.	5.	*Streptorhynchus* sp.	247
		One of the brachial valves described, × 3.	
		Enteletes bed (1190), No. 302b, Cat. G.S.C. 1402.	
FIG.	6.	*Orthothetina ruber* (Frech)	251
	6a,	Brachial; 6b, lateral, and 6c, cardinal, views of a somewhat imperfect specimen, enlarged × 2.	
		Enteletes bed (1190), No. 298, Cat. G.S.C. 1403.	
FIG.	7.	*Orthothetina* cf. *eusarkos* (Abich)	253
	7a,	Pedicle; 7b, cardinal, views of a very fragmentary pedicle valve, showing the characters of this species, natural size.	
		Streptorhynchus kayseri bed (1207), No. 321, Cat. G.S.C. 1404.	
FIG.	8.	*Orthothetina* sp.	254
	8a,	Brachial; 8b, pedicle; 8c, lateral, views of a specimen from which the beak and hinge areas have been broken away, enlarged × 2; 8d, view of the broken cardinal surface, showing the 2 septa in each valve, enlarged × 2.	
		Martinia bed (1194), No. 307, Cat. G.S.C. 1405.	
FIG.	9.	*Orthothetina ruber* (Frech) (?)	251
	9a,	Pedicle; 9b, cardinal; 9c, lateral, views of a very imperfect pedicle valve, somewhat doubtfully referred to this species.	
		Jisu Honguer limestone, No. 322, Cat. G.S.C. 1406.	

PLATE XXV

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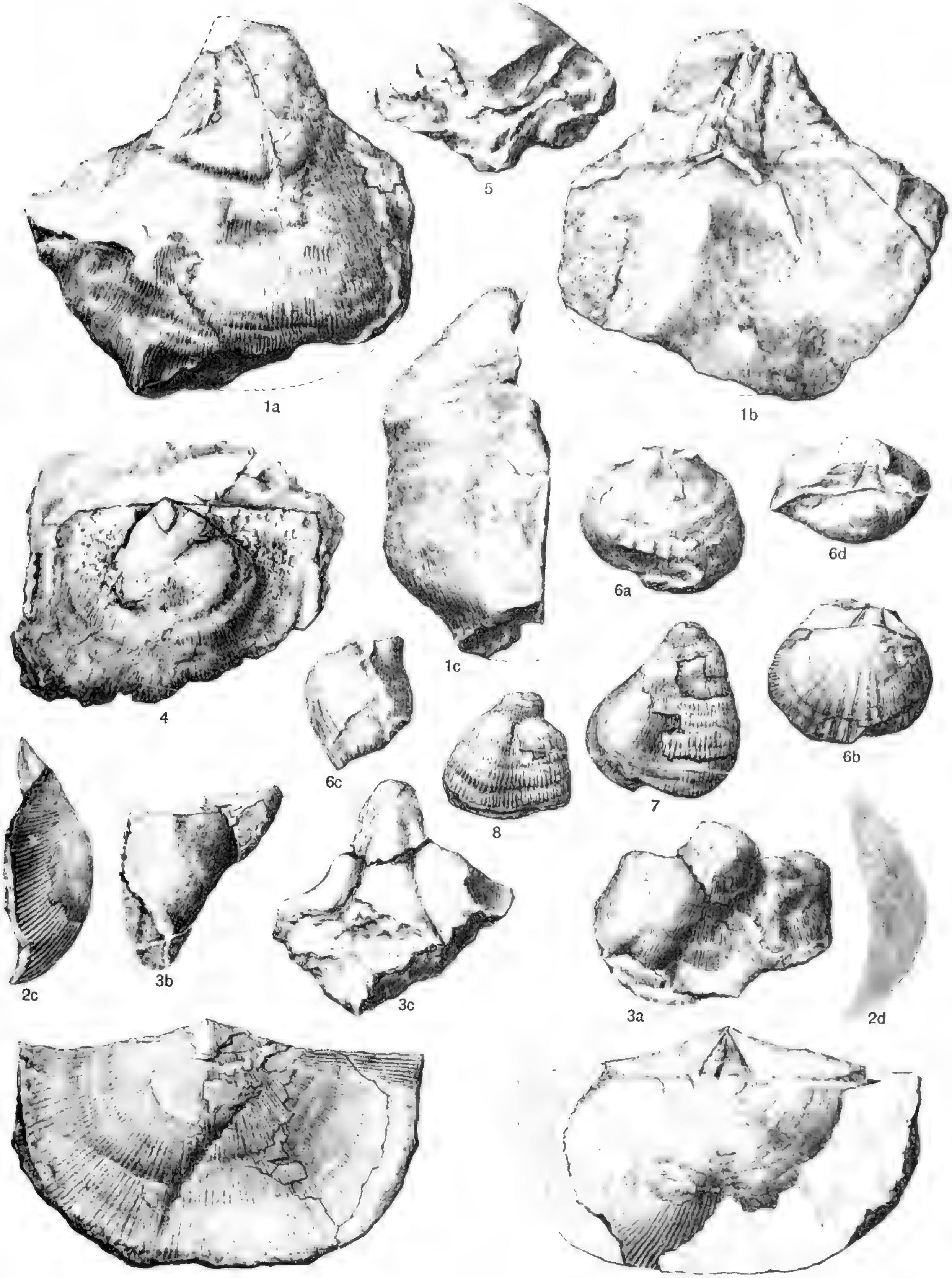
			PAGE
FIG.	1.	*Derbya dupliciseptata* Grabau, sp. nov.	255
	1a,	Pedicle; 1b, brachial; 1c, lateral, views of the holotype, a rather worn specimen, natural size (see Text-Fig. 63).	
		Enteletes bed (1190), No. 303, Cat. G.S.C. 1407.	
FIG.	2.	*Schellwienella regina* Grabau, sp. nov.	248
	2a,	Pedicle; 2b, brachial; 2c, lateral, views of the holotype, natural size; 2d, median section of the same, natural size.	
		Marginifera bed (1192), No. 314, Cat. G.S.C. 1408.	
FIG.	3.	*Derbya* (?) (*Derbyina*) *mongolica* Grabau, sp. nov.	259
	3a,	Pedicle; 3b, lateral; 3c, cardinal, views of the holotype, an imperfect pedicle valve, natural size (see Text-Fig. 66).	
		Hemiptychina bed (1196), No. 292, Cat. G.S.C. 1409.	
FIG.	4.	*Derbya* cf. *hemisphærica* Waagen.	262
		A very fragmentary brachial valve, with part of a shell preserved and showing muscular impressions.	
		Hemiptychina bed (1196), No. 304, Cat. G.S.C. 1410.	
FIG.	5.	*Derbya* cf. *hemisphærica* Waagen.	262
		Internal mold of a brachial valve, showing the mold of muscular impressions, cardinal view.	
		Jisu Honguer limestone, No. 309, Cat. G.S.C. 1413.	
FIG.	6.	*Meekella uralica* Tschernyschew	265
	6a,	Pedicle; 6b, brachial; 6c, lateral; 6d, cardinal, views of a somewhat imperfect shell referred to this species, slightly restored, natural size.	
		Enteletes bed (1190), No. 171, Cat. G.S.C. 1414.	
FIG.	7.	*Derbyella bureri* Grabau, sp. nov.	270
		Pedicle view of a large paratype, natural size (see Pl. XXVI, Fig. 3).	
		Jisu Honguer limestone, No. 285, Cat. G.S.C. 1415.	
FIG.	8.	*Derbyella bureri* Grabau, sp. nov.	270
		A pedicle view of a smaller shell, holotype, natural size (see Pl. XXVI, Fig. 2).	
		Martinia bed (1194), No. 286, Cat. G.S.C. 1416.	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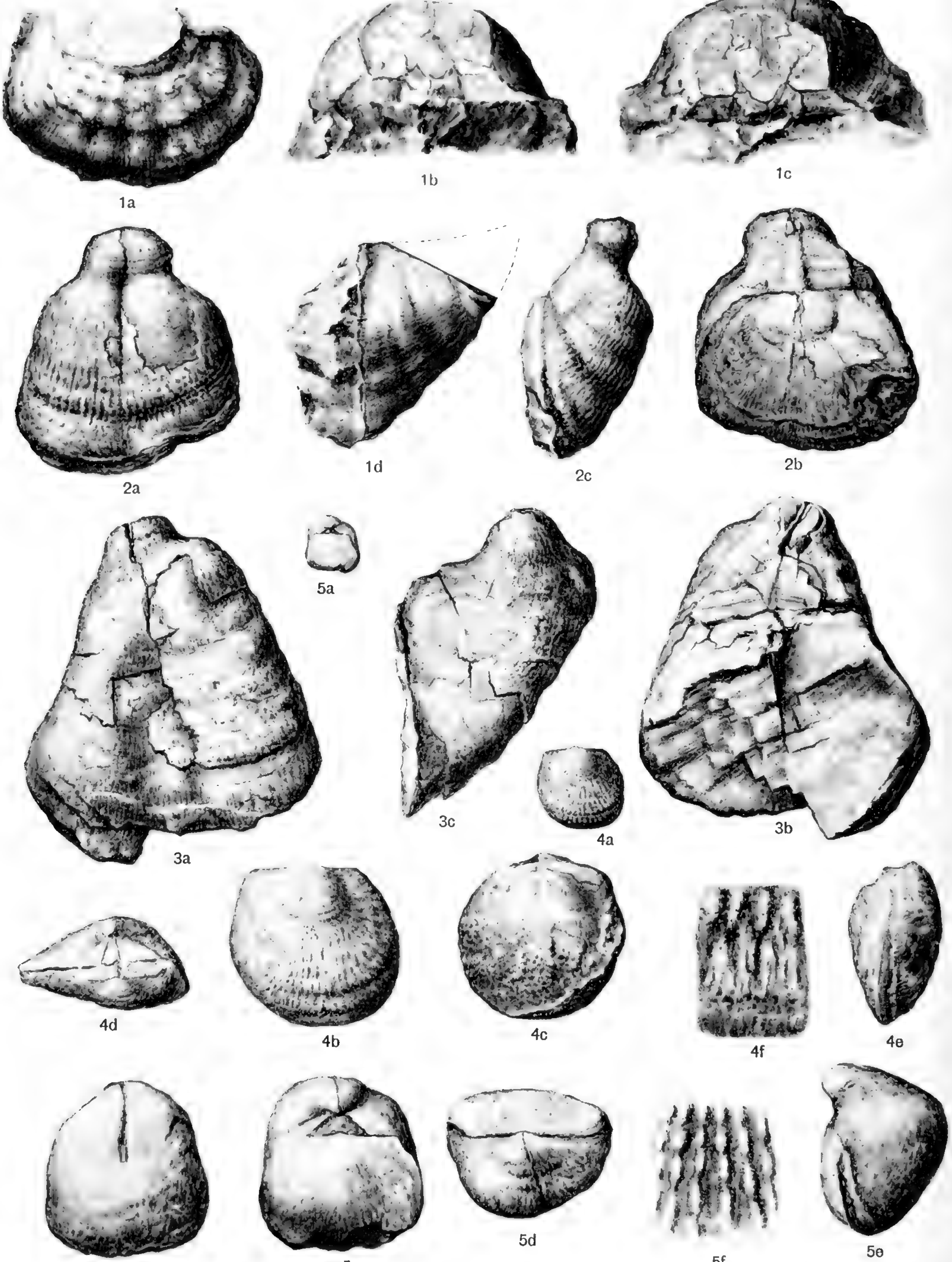
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PLATE XXVI

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PAGE

FIG. 1. *Geyerella mongolica* Grabau, sp. nov. 267

1a, Pedicle; 1b, umbonal; 1c, apical; 1d, side, views of the holotype, natural size (see Text-Fig. 67 a to c).

Enteletes bed (1190), No. 308, Cat. G.S.C. 1417.

FIG. 2. *Derbyella bureri* Grabau, sp. nov. 270

2a, Pedicle; 2b, brachial; 2c, lateral, views of the holotype, enlarged × 2 (see Pl. XXV, Fig. 8).

Martinia bed (1194), No. 286, Cat. G.S.C. 1416.

FIG. 3. *Derbyella bureri* Grabau, sp. nov. 270

3a, Pedicle; 3b, brachial; 3c, lateral, views of the paratype, enlarged × 2 (see Pl. XXV, Fig. 7).

Jisu Honguer limestone, No. 285, Cat. G.S.C. 1415.

FIG. 4. *Derbyella subrotunda* Grabau, sp. nov. 273

4a, Pedicle view of the holotype, natural size; 4b, pedicle; 4c, brachial; 4d, apical; 4e, lateral, views of the same specimen, × 2.

4f, portion of the surface, enlarged × 5, to show the pustules and spine-basis.

Martinia bed (1194), No. 297, Cat. G.S.C. 1418.

FIG. 5. *Derbyella minor* Grabau, sp. nov. 275

5a, Brachial view of the holotype, natural size; 5b, pedicle; 5c, brachial; 5d, apical; 5e, lateral, views of the same specimen, enlarged × 3; 5f, portion of the surface, enlarged × 6, to show the spine-basis.

Martinia bed (1194), No. 316, Cat. G.S.C. 1419.

PLATE XXVII

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PAGE

FIG. 1. *Aulosteges gigantiformis* Grabau, sp. nov. 276
1a, Pedicle; 1b, brachial; 1c, lateral, views of holotype, natural size.
Enteletes bed (1190), No. 280, Cat. G.S.C. 1420.

FIG. 2. *Aulosteges gigantiformis* Grabau, sp. nov. 276
2a, Brachial; 2b, pedicle; 2c, lateral, views of paratype, natural size. In 2c a part of the pedicle valve is broken away showing inside of thick brachial valve.
Enteletes bed (1190), No. 281, Cat. G.S.C. 1421.

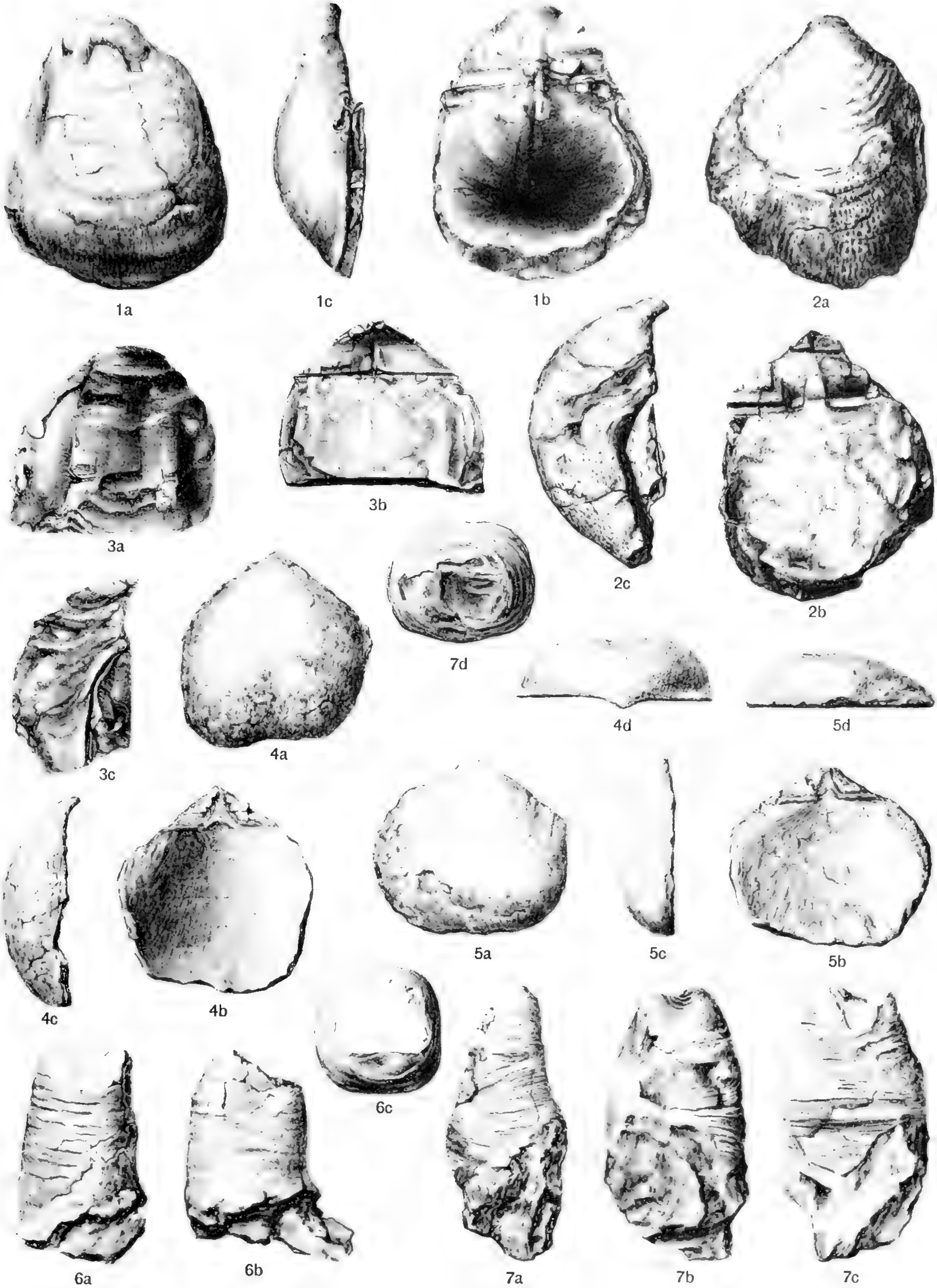
FIG. 3. *Aulosteges gigantiformis* Grabau, sp. nov. 276
3a, Pedicle; 3b, brachial; 3c, lateral, views of an imperfect cotype, natural size.
Enteletes bed (1190), No. 282, Cat. G.S.C. 1422.

FIG. 4. *Aulosteges grangeri* Grabau, sp. nov. 280
4a, Pedicle; 4b, brachial; 4c, lateral; 4d, apical, views of holotype, showing a median depression in the pedicle valve, natural size.
Orthotychia bed (1211), No. 283, Cat. G.S.C. 1423.

FIG. 5. *Aulosteges grangeri* Grabau, sp. nov. 280
5a, Pedicle; 5b, brachial; 5c, lateral; 5d, apical, views of paratype without the median sinus, natural size.
Orthotychia bed (1211), No. 284, Cat. G.S.C. 1424.

FIG. 6. *Richthofenia lawrenciana* (de Koninck) 281
6a, Brachial?; 6b, lateral; 6c, summit, views of a characteristic specimen of the Mongolian variety, natural size.
Hemiptychina bed (1196), No. 296, Cat. G.S.C. 1425.

FIG. 7. *Richthofenia lawrenciana* (de Koninck) 281
7a, Lateral; 7b, brachial?; 7c, ventral; 7d, summit, views of a more conical specimen from these rocks, natural size.
Hemiptychina bed (1196), No. 294, Cat. G.S.C. 1426.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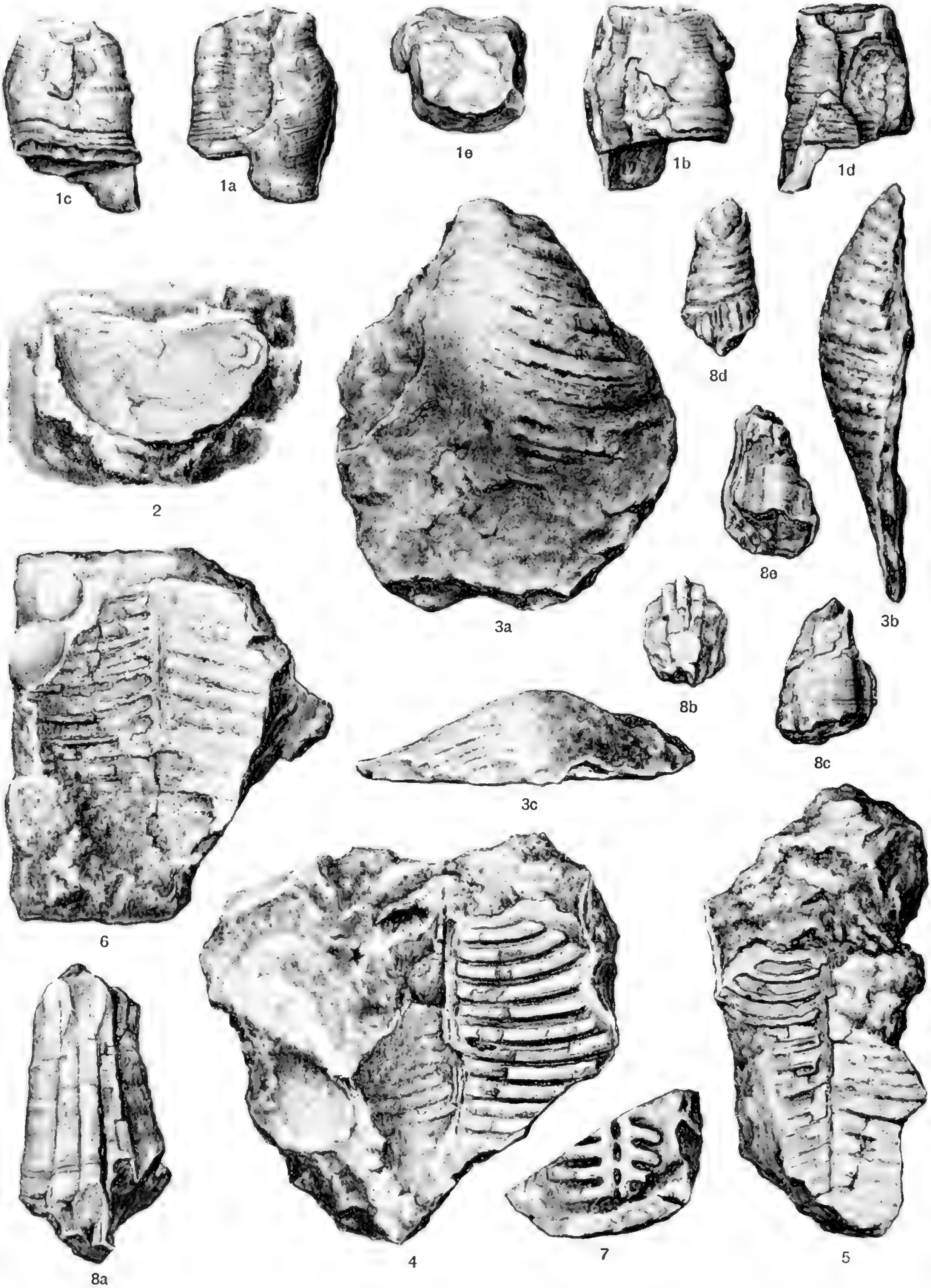
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PLATE XXVIII

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			PAGE
FIG.	1.	*Richthofenia lawrenciana* (de Koninck)	281
	1a-d,	The four sides of a fragment with epitheca partly removed; 1e, summit view of the fragment; all natural size. Hemiptychina bed (1196), No. 295, Cat. G.S.C. 1427.	
FIG.	2.	*Aulacorhynchus* sp.	284
		An imperfect specimen on the rock surface, enlarged × 2. Lyttonia bed (1193), No. 324, Cat. G.S.C. 1426.	
FIG.	3.	*Lyttonia nobilis* Waagen	285
	3a,	Ventral; 3b, lateral; 3c, apical, views of a ventral valve, natural size, showing part of the septa. Lyttonia bed (1193), No. 327, Cat. G.S.C. 1427.	
FIG.	4.	*Lyttonia nobilis* Waagen	285
		Interior of the ventral valve, showing the septa and the outer border, natural size. Lyttonia bed (1193), No. 325a, Cat. G.S.C. 1427.	
FIG.	5.	*Lyttonia nobilis* Waagen	285
		Counterpart of a specimen, Fig. 4, natural size. Lyttonia bed (1193), No. 326, Cat. G.S.C. 1428.	
FIG.	6.	*Lyttonia nobilis* Waagen	285
		Another impression from the same rock with specimen, Fig. 4, natural size. Lyttonia bed (1193), No. 325b, Cat. G.S.C. 1427.	
FIG.	7.	*Lyttonia?* sp. (cf. *Oldhamina lopingensis* Grabau)	286
		A fragment of a specimen which has some of the characteristics of *O. lopingensis* from the Loping Beds of China, natural size. Lyttonia bed (691[1]), No. 328, Cat. G.S.C. 1429.	
FIG.	8.	*Richthofenia?* sp. or *Scacchinella?* sp.	281
	8a,	View of the apical portion of a specimen, showing the narrow, long, elevated hinge area with sharply defined lateral margins and long narrow pseudo-deltidium. The exact reference of this form is very doubtful. It may be the hinge portion of a *Richthofenia* with the epitheca removed, or it may be a new species of *Scacchinella* or some other type; enlarged × 2; 8b and 8c, lateral views of the opposite sides of the specimen, natural size; 8d, view of the side opposite to the hinge area, natural size; 8e, another lateral view of the specimen, natural size. Hemiptychina bed (1196), No. 394, Cat. G.S.C. 1430.	

[1] Berkey and Morris, 1927, p. 181.

PLATE XXIX

(PHOTOGRAPHS, NATURAL SIZE, BY Y. T. CHAO;

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PAGE

FIG. 1. *Productus (Echinoconchus) fasciatus* Kutorga 299
1a, Pedicle view of a specimen with surface strongly deteriorated by weathering; 1b, lateral; 1c, brachial, views of the same specimen.
Enteletes bed (1190), No. 277, Cat. G.S.C. 1515.

FIG. 2. *Productus (Waagenoconcha) humboldti* d'Orbigny 298
Pedicle view of a small specimen, showing quincuncial arrangement of tubercles.
Productus humboldti bed (1189), No. 279, Cat. G.S.C. 1516.

FIG. 3. *Productus (Waagenoconcha) humboldti* d'Orbigny 298
A fragmentary pedicle valve of a larger specimen.
Enteletes bed (1190), No. 278, Cat. G.S.C. 1517.

FIG. 4. *Productus (Waagenoconcha)* cf. *purdoni* Davidson 297
4a, Pedicle view of a specimen with the anterior part broken off; 4b, side view of the same.
Hemiptychina bed (1196), No. 942, Cat. G.S.C. 1518.

FIG. 5. *Productus (Striatifera)* cf. *ischmensis* Tschernyschew 290
A broken and crushed pedicle valve referred to this species.
Marginifera bed (1192), No. 332, Cat. G.S.C. 1519.

FIG. 6. *Productus (Striatifera) compressus* Waagen var. *corniformis* Chao, var. nov. 291
A somewhat crushed pedicle valve embedded in rock.
Enteletes bed (1190), No. 342, cotype, Cat. G.S.C. 1520.

FIG. 7. *Productus (Striatifera) compressus* Waagen var. *corniformis* Chao, var. nov. 291
A pedicle valve of slightly different form, attached to rock.
Spiriferella bed (1209), No. 345, cotype, Cat. G.S.C. 1521.

FIG. 8. *Productus (Striatifera) compressus* Waagen var. *corniformis* Chao, var. nov. 291
8a, A pedicle valve, somewhat more compressed laterally; 8b, side view of the same with rock attached.
Jisu Honguer limestone, No. 344, cotype, Cat. G.S.C. 1522.

FIG. 9. *Productus (Striatifera) compressus* Waagen var. *corniformis* Chao, var. nov. 291
9a, Side view of a rather strongly arched pedicle valve of a somewhat larger size; 9b, ventral view of the same valve.
Enteletes bed (1190), No. 343, cotype, Cat. G.S.C. 1523.

FIG. 10. *Productus (Linoproductus?) mammatus* Keyserling 288
10a, A fairly well preserved pedicle valve; 10b, side view of the same.
Jisu Honguer limestone, No. 965, Cat. G.S.C. 1524.

FIG. 11. *Productus (Linoproductus?) mammatus* Keyserling 288
Top view of a slightly larger distorted pedicle valve.
Marginifera bed (1192), No. 963, Cat. G.S.C. 1525.

PAGE

FIG. 12. *Productus (Linoproductus?) mammatus* Keyserling 288
A top view of a distorted pedicle valve.
Jisu Honguer limestone, No. 964, G.S.C. 1526.

FIG. 13. *Productus (Linoproductus?) mammatus* Keyserling 288
13a, Anterior view of an imperfect pedicle valve; 13b, top view of the same.
Jisu Honguer limestone, No. 966, Cat. G.S.C. 1527.

FIG. 14. *Productus (Linoproductus?) mammatus* Keyserling 288
Interior of a brachial valve.
Martinia bed (1194), No. 336, Cat. G.S.C. 1528.

FIG. 15. *Marginifera jisuensis* Chao 303
15a, Pedicle view of the holotype, showing characteristic surface sculpture; 15b, brachial, and 15c, lateral views of the same specimen.
Marginifera bed (1192), No. 348, Cat. G.S.C. 1529.

FIG. 16. *Marginifera jisuensis* Chao 303
16a, Pedicle; 16b, brachial; 16c, lateral, views showing spines.
Martinia bed (1194), paratype, No. 355, Cat. G.S.C. 1530.

FIG. 17. *Marginifera jisuensis* Chao 303
17a, Pedicle; 17b, lateral; 17c, brachial, views of a specimen with surface sculpture preserved in the apical part. Note the double row of spines in the lateral part of 17b and the incipient plication in 17a; paratype.
Hemiptychina bed (1196), No. 350, Cat. G.S.C. 1531.

FIG. 18. *Marginifera jisuensis* Chao 303
18a, Pedicle; 18b, lateral, and 18c, brachial, views of a specimen with shell entirely broken off, paratype.
Hemiptychina bed (1196), No. 351, Cat. G.S.C. 1532.

FIG. 19. *Marginifera jisuensis* Chao 303
19a, Pedicle; 19b, lateral; 19c, brachial, views of a specimen with the shell entirely broken away, paratype.
Martinia bed (1194), No. 347, Cat. G.S.C. 1533.

FIG. 20. *Marginifera jisuensis* Chao 303
20a, Pedicle; 20b, lateral; 20c, brachial, views of an immature shell, paratype.
Martinia bed (1194), No. 349, Cat. G.S.C. 1534.

FIG. 21. *Marginifera jisuensis* Chao 303
21a, Pedicle; 21b, lateral, and 21c, brachial, views of a still younger shell, paratype.
Martinia bed (1194), No. 352, Cat. G.S.C. 1535.

FIG. 22. *Marginifera jisuensis* Chao 303
Top view of external mold of brachial valve, with internal marginal ridge still preserved in the anterior part; paratype.
Martinia bed (1194), No. 23, Cat. G.S.C. 1536.

FIG. 23. *Marginifera jisuensis* Chao 303
Pedicle valve, showing spines; paratype.
Jisu Honguer limestone, No. 353, Cat. G.S.C. 1537.

PAGE

FIG. 24. *Marginifera jisuensis* Chao 303
A smaller pedicle valve, showing spines; paratype.
Martinia bed (1194), No. 354, Cat. G.S.C. 1538.

FIG. 25. *Productus* (*Linoproductus*) *lineatus* (Waagen) 293
Pedicle view of a medium-sized shell, somewhat distorted.
Camarophoria bed (1208), No. 331, Cat. G.S.C. 1539.

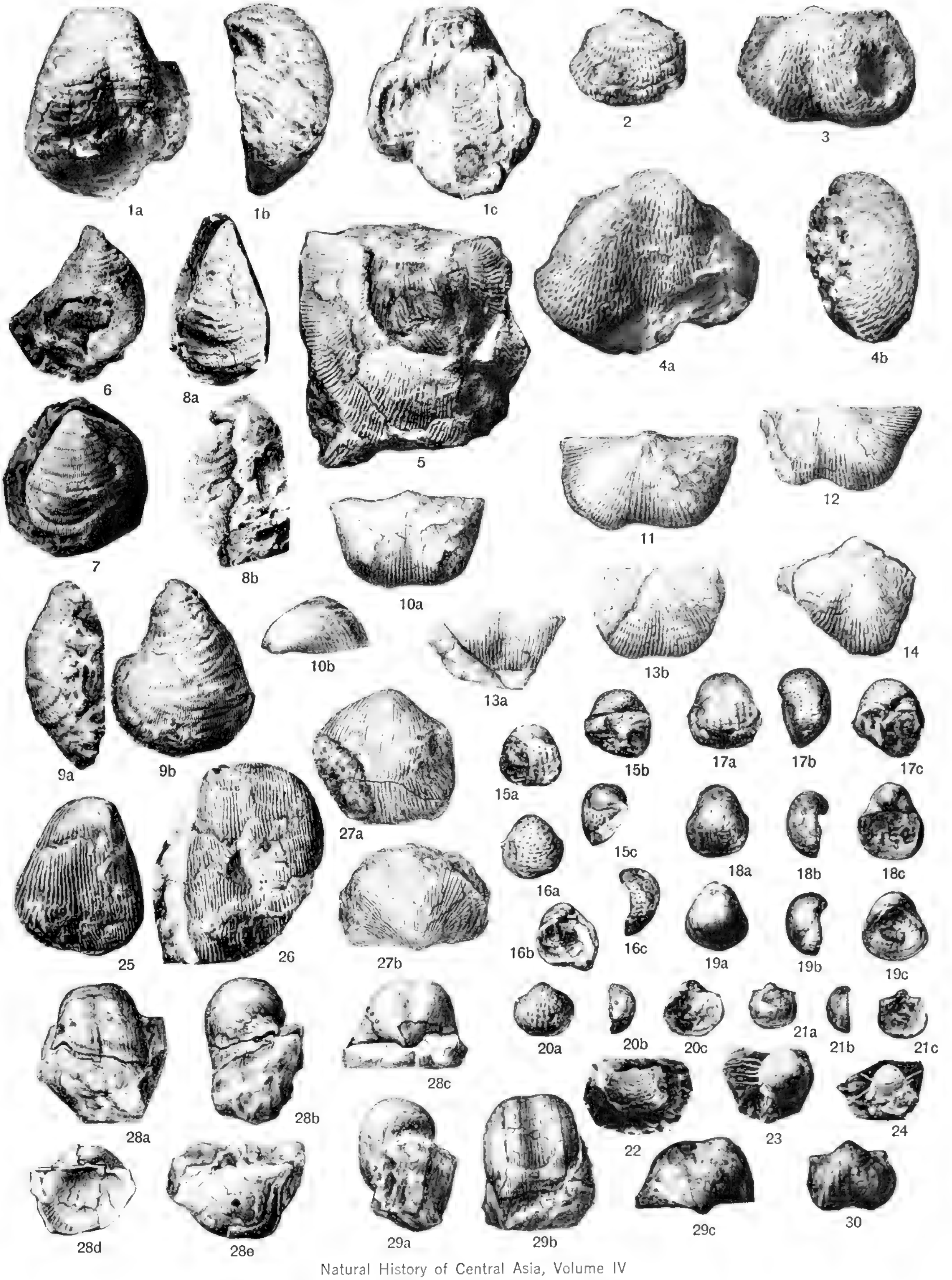
FIG. 26. *Productus* (*Linoproductus*) *lineatus* (Waagen) 293
A larger, imperfect pedicle valve.
Camarophoria bed (1208), No. 329, Cat. G.S.C. 1540.

FIG. 27. *Productus* (*Linoproductus*) *lineatus* (Waagen) 293
27a, A pedicle valve of rather transverse outline; 27b, umbonal view of the same.
Spiriferella bed (1209), No. 330, Cat. G.S.C. 1541.

FIG. 28. *Marginifera morrisi* Chao 311
28a, Pedicle; 28b, lateral; 28c, umbonal, views of the holotype; 28d, brachial view of the same specimen separated from the rock; 28e, rock with part of brachial valve attached, showing interior, with broad marginal ridge on the interior brachial valve.
Hemiptychina bed (1196), No. 376, Cat. G.S.C. 1542.

FIG. 29. *Marginifera morrisi* Chao 311
29a, Lateral; 29b, frontal; 29c, umbonal, views of a characteristic paratype.
Hemiptychina bed (1196), No. 377, Cat. G.S.C. 1543.

FIG. 30. *Marginifera morrisi* Chao 311
Ventral view of a small pedicle valve, characterized by concentric wrinkles in the umbonal part; paratype.
Camarophoria bed (1208), No. 372, Cat. G.S.C. 1544.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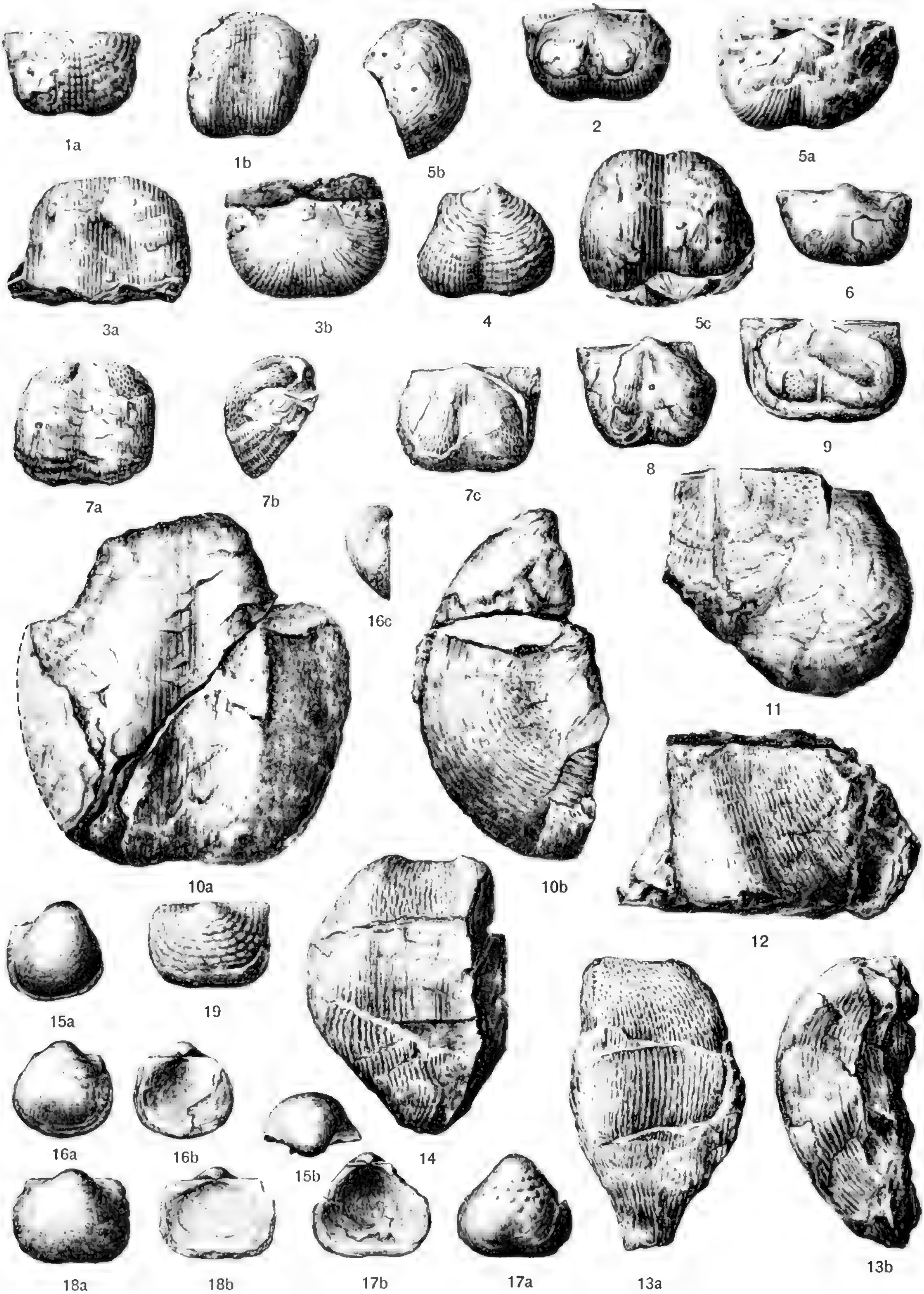
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PLATE XXX

(Drawings by K. C. Liu, natural size except where noted)

PAGE

Fig. 1. *Marginifera gobiensis* Chao 308

1a, Top view of a pedicle valve, showing concentric undulations and reticulations; 1b, the deflected frontal part of the same individual; cotype.

Spiriferella bed (1209), No. 367, Cat. G.S.C. 1506.

Fig. 2. *Marginifera gobiensis* Chao 308

Interior of brachial valve, showing the rather poorly preserved marginal ridge and brachial ridges; cotype.

Spiriferella bed (1209), No. 371, Cat. G.S.C. 1507.

Fig. 3. *Marginifera gobiensis* Chao 308

3a, Frontal view of another, larger, pedicle valve, somewhat crushed; 3b, top view of the same; cotype.

Spiriferella bed (1209), No. 368, Cat. G.S.C. 1508.

Fig. 4. *Marginifera gobiensis* Chao 308

Top view of a characteristic mold of a brachial valve, showing strong concentric wrinkles in the older or posterior part; cotype.

Spiriferella bed (1209), No. 370, Cat. G.S.C. 1509.

Fig. 5. *Marginifera gobiensis* Chao 308

5a, Top view of a pedicle valve, showing the beginning of a deep median sinus; 5b, side view of the same, showing the extreme curvature; 5c, frontal view of the same specimen, showing a well-developed sinus; cotype.

Spiriferella bed (1209), No. 363, Cat. G.S.C. 1510.

Fig. 6. *Marginifera typica* Waagen var. *septentrionalis* Tschernyschew . . . 306

Top view of a pedicle valve, showing the lateral row of spines.

Marginifera bed (1192), No. 357, Cat. G.S.C. 1511.

Fig. 7. *Marginifera typica* Waagen var. *septentrionalis* Tschernyschew . . . 306

7a, Frontal view of a pedicle valve, with the shell split off; 7b, lateral view of the same; 7c, top view of the same.

Marginifera bed (1192), No. 356, Cat. G.S.C. 1512.

Fig. 8. *Marginifera typica* Waagen var. *septentrionalis* Tschernyschew . . . 306

Top view of a pedicle valve, showing strong spine-base near cardinal angle.

Marginifera bed (1192), No. 359, Cat. G.S.C. 1513.

Fig. 9. *Marginifera typica* Waagen var. *septentrionalis* Tschernyschew . . . 306

Interior of a brachial valve.

Marginifera bed (1192), No. 361, Cat. G.S.C. 1514.

Fig. 10. *Productus* cf. *porrectus* Kutorga. 295

10a, Ventral view of a very imperfect valve referred with some doubt to this species; 10b, side view of the same. 295

Marginifera bed (1192), No. 333, Cat. G.S.C. 1564.

PAGE

FIG. 11. *Productus* cf. *porrectus* Kutorga 295

Interior of a brachial valve, one side of which is perfect, showing the strongly developed median septum, the other half of the valve being mostly broken away.

Marginifera bed (1192), No. 334, Cat. G.S.C. 1565.

FIG. 12. *Productus* cf. *porrectus* Kutorga 295

Part of a pedicle valve referred with doubt to this species, showing the surface characters.

Streptorhynchus kayseri bed (1207), No. 335, Cat. G.S.C. 1566.

FIG. 13. *Proboscidella* cf. *lata* Tschernyschew 302

13a, Ventral view of a long but rather imperfect pedicle valve; 13b, lateral view of the same specimen.

Marginifera bed (1192), No. 271, Cat. G.S.C. 1545.

FIG. 14. *Proboscidella* cf. *lata* Tschernyschew 302

Ventral view of a fragment of another pedicle valve, showing the long frontal part, and surface characters.

Marginifera bed (1192), No. 272, Cat. G.S.C. 1546.

FIG. 15. *Marginifera jisuensis* Chao 303

15a, Pedicle view of the holotype, shown in Pl. XXIX, Fig. 15a-c, enlarged × 2; 15b, umbonal view of the same specimen, enlarged × 2.

Martinia bed (1194), No. 348, Cat. G.S.C. 1529.

FIG. 16. *Marginifera jisuensis* Chao 303

16a, Pedicle view of a characteristic specimen, enlarged × 2; paratype; 16b, brachial view of the same, × 2; 16c, lateral view of the same, × 2.

Martinia bed (1194), No. 128, Cat. G.S.C. 1550.

FIG. 17. *Marginifera jisuensis* Chao 303

17a, Pedicle view of a specimen with strongly elevated beak and short hinge-line, enlarged × 2, paratype; 17b, brachial view of the same specimen, enlarged × 2.

Martinia bed (1194), No. 50, Cat. G.S.C. 1549.

FIG. 18. *Marginifera jisuensis* Chao 303

18a, Pedicle view of a small specimen of a transverse character, enlarged × 3; paratype; 18b, brachial view of the same specimen, enlarged × 3.

Martinia bed (1194), No. 24, Cat. G.S.C. 1548.

FIG. 19. *Marginifera jisuensis* Chao 303

Top view of an external mold of the brachial valve, with the internal marginal ridge still preserved in the anterior part, enlargement × 2, of the specimen shown in Fig. 22, Pl. XXIX. Paratype.

Martinia bed (1194), No. 23, Cat. G.S.C. 1536.

PLATE XXXI

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PAGE

FIG. 1. *Schizodus subquadratus* Grabau, sp. nov. 313

1a, The left valve of the holotype, natural size; 1b, dorsal view of the same, natural size; 1c, the left valve, enlarged × 2; 1d, posterior view of the same, enlarged × 2.

Hemiptychina bed (1196), No. 400, Cat. G.S.C. 1431.

FIG. 2. *Schizodus elongatus* Grabau, sp. nov. 315

2a, Left valve of the holotype, natural size; 2b, the same, enlarged × 4; 2c, posterior view of the same, enlarged × 4.

Enteletes bed (1190), No. 401, Cat. G.S.C. 1432.

FIG. 3. *Conocardium jisuensis* Grabau, sp. nov. 316

3a, View of the right valve, with the posterior tubular prolongation broken away, natural size, holotype; 3b, the same, ventral view, natural size; 3c, the same valve, enlarged × 2; 3d, posterior view, showing the narrow flattened area and the opening where the tubular prolongation is broken away, enlarged × 2.

Martinia bed (1194), No. 407, Cat. G.S.C. 1433.

FIG. 4. *Sanguinolites modiomorphoides* Grabau, sp. nov. 318

4a, the left valve of the holotype, natural size: 4b, summit; 4c, posterior view of the same valve, natural size.

Lyttonia bed (1193), No. 418, Cat. G.S.C. 1434.

FIG. 5. *Sanguinolites* cf. *modiomorphoides* Grabau 320

5a, Left side; 5b, right side; 5c, dorsal view; 5d, frontal view of an internal mold, with the shell partly preserved and with the general characters of this species. The specimen is somewhat imperfect. An attempt at restoration has been made on the assumption that it belongs to this species. All figures natural size.

Jisu Honguer limestone, No. 480, Cat. G.S.C. 1435.

FIG. 6. *Pseudomonotis* (*Aviculomonotis*) *mongoliensis* Grabau, sp. nov. . . . 322

6a, The left valve of the largest specimen obtained, somewhat fragmentary, holotype; 6b, posterior view; 6c, dorsal view of the same; all natural size.

Enteletes bed (1190), No. 403, Cat. G.S.C. 1436.

FIG. 7. *Pseudomonotis* (*Aviculomonotis*) *mongoliensis* Grabau, sp. nov. . . . 322

A small left valve, natural size, paratype.

Enteletes bed (1190), No. 405, Cat. G.S.C. 1437.

FIG. 8. *Pseudomonotis* (*Aviculomonotis*) *kazanensis* (de Verneuil) 325

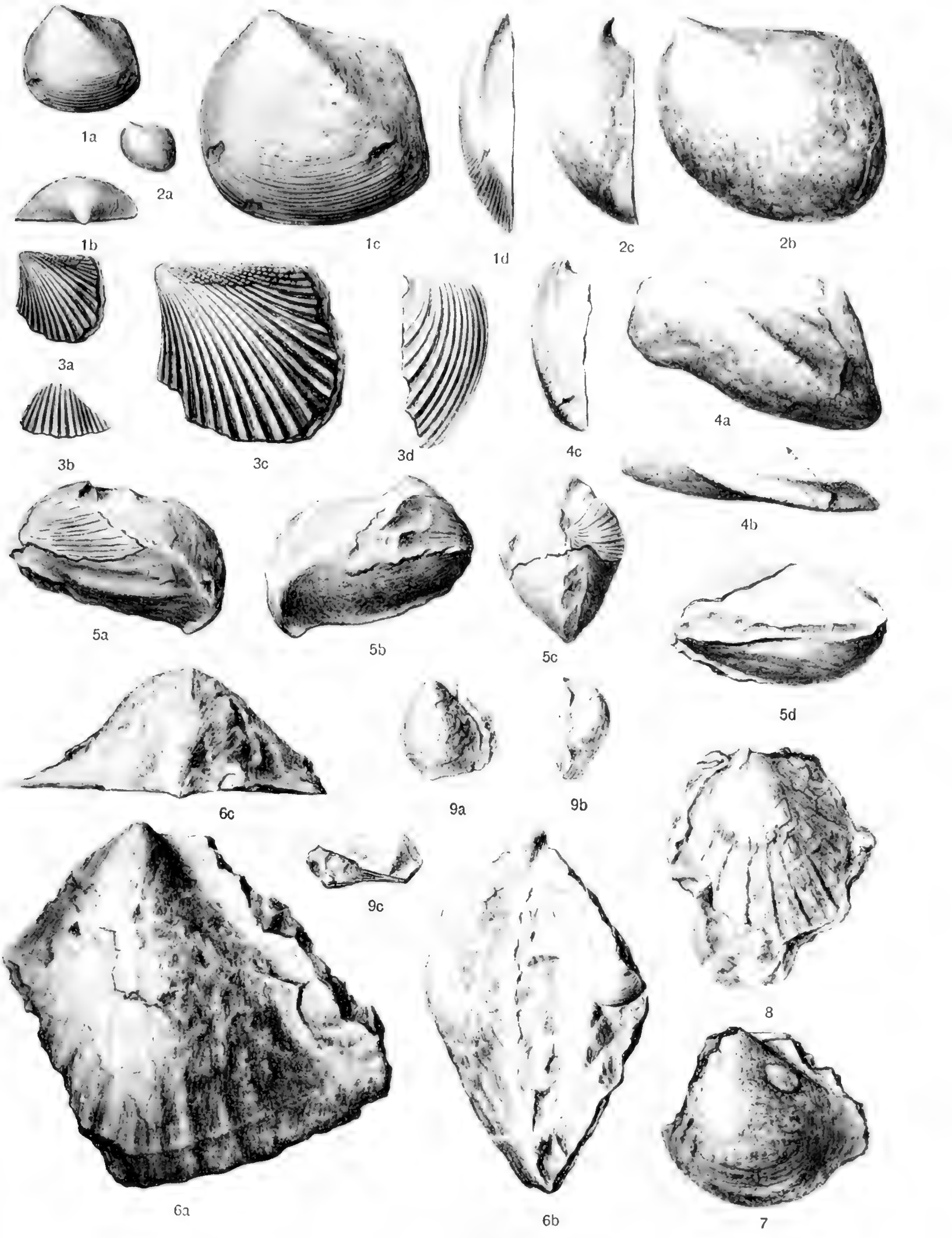
A left valve, with the characters of this species; fragmentary, natural size.

Enteletes bed (1190), No. 404, Cat. G.S.C. 1438.

FIG. 9. *Pseudomonotis* (*Aviculomonotis*) *mongoliensis* Grabau, sp. nov. . . . 322

9a, A left valve of a young specimen, paratype, natural size; 9b, anterior; 9c, dorsal, views of the same specimen, natural size.

Enteletes bed (1190), No. 409, Cat. G.S.C. 1439.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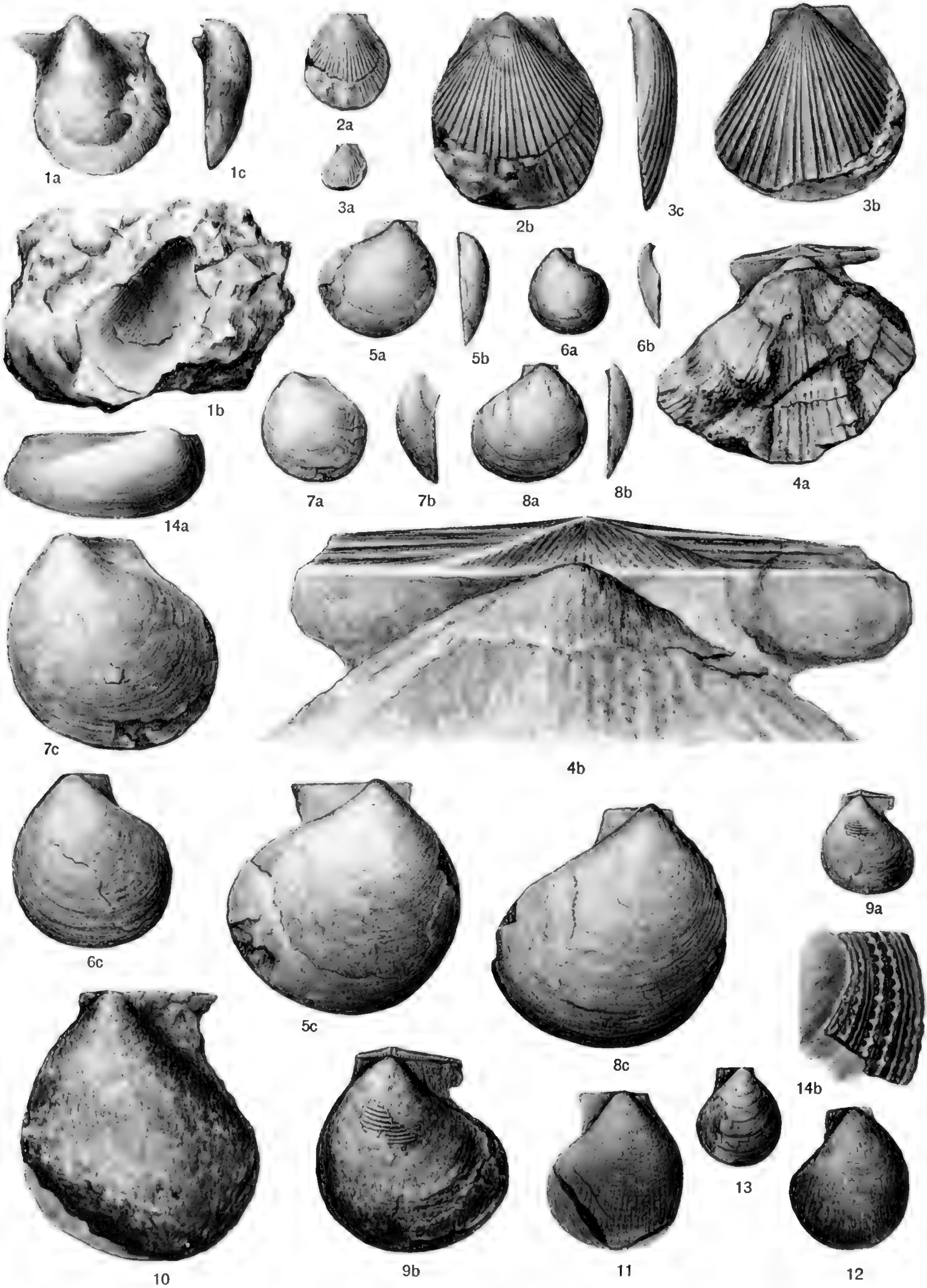
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PLATE XXXII

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PAGE

FIG. 1. *Pseudomonotis (Aviculomonotis) matthewi* Grabau, sp. nov. 326

1a, Left valve, the holotype, natural size; 1b, impression of the same in the rock retaining most of the shell, natural size; 1c, frontal view of the specimen, natural size.

Hemiptychina bed (1196), No. 402, Cat. G.S.C. 1440.

FIG. 2. *Pseudomonotis furcoplicatus* Grabau, sp. nov. 327

2a, Left valve, natural size, holotype; 2b, the same, enlarged × 2.

Orthotychia bed (1211), No. 410, Cat. G.S.C. 1441.

FIG. 3. *Pseudomonotis furcoplicatus* Grabau, sp. nov. 327

3a, Left valve, natural size, paratype; 3b, the same, enlarged × 4; 3c, frontal view of the same, enlarged × 4.

Enteletes bed (1190), No. 411, Cat. G.S.C. 1442.

FIG. 4. *Deltopecten* cf. *subquinquelineatus* (McCoy) 329

4a, Internal mold of a somewhat crushed and fragmentary right valve, with impression of the surface striæ, natural size; 4b, the mold of the cardinal area enlarged × 4, showing the mold of the broad resilifer and the striated hinge area.

Marginifera bed (1192), No. 419, Cat. G.S.C. 1443.

FIG. 5. *Euchondria (?) englehardti* (Etheridge and Dun) 331

5a, Left valve, natural size; 5b, frontal view of the same, natural size; 5c, the same, enlarged × 2.

Hemiptychina bed (1196), No. 396, Cat. G.S.C. 1444.

FIG. 6. *Euchondria (?) englehardti* (Etheridge and Dun) 331

6a, The right valve of a smaller specimen, natural size; 6b, frontal view of the same, natural size; 6c, the same valve, enlarged × 2.

Enteletes bed (1190), No. 397, Cat. G.S.C. 1445.

FIG. 7. *Euchondria (?) englehardti* (Etheridge and Dun) 331

7a, Right valve, natural size; 7b, frontal view of the same; 7c, the same valve, enlarged × 2.

Enteletes bed (1190), No. 398, Cat. G.S.C. 1446.

FIG. 8. *Euchondria (?) englehardti* (Etheridge and Dun) 331

8a, Left valve, with much depressed anterior ear, natural size; 8b, frontal view of the same, natural size; 8c, the same valve, enlarged × 2.

Enteletes bed (1190), No. 399, Cat. G.S.C. 1447.

FIG. 9. *Pseudamusium auriculatum* Grabau, sp. nov. 334

9a, Right valve of the holotype, with a small portion of the shell preserved, natural size; 9b, the same, enlarged × 2.

Enteletes bed (1190), No. 408, Cat. G.S.C. 1448.

FIG. 10. *Pseudamusium auriculatum* Grabau, sp. nov. 334

A larger right valve, syntype, enlarged × 2.

This specimen is associated with *Naticopsis khoovensis* Waagen.

Enteletes bed (1190), No. 443, Cat. G.S.C. 1449.

PAGE

FIG. 11. *Pseudamusium* cf. *auriculatum* Grabau 336
A fragmentary left valve, probably representing this species; syntype?, enlarged × 2.
Enteletes bed (1190), No. 412, Cat. G.S.C. 1450.

FIG. 12. *Pseudamusium* cf. *auriculatum* Grabau 336
Another left valve, referred with some doubt to this species, enlarged × 2, syntype?
Enteletes bed (1190), No. 413, Cat. G.S.C. 1451.

FIG. 13. *Pseudamusium* cf. *auriculatum* Grabau 336
A small left valve, which may belong to this species but is probably distinct. Associated with *Streptorhynchus kayseri* Schellwien, No. 299a, enlarged × 2.
Jisu Honguer limestone, No. 299*b*, Cat. G.S.C. 1452.

FIG. 14. *Sanguinolites olseni* Grabau, sp. nov. 321
14a, View of the right valve of the holotype, natural size; 14b*, detail of the same(?), enlarged × 4(?).
Martinia bed (1194), No. 483, Cat. G.S.C. 1505.

* Caption entered by Editor; missing in manuscript.

PLATE XXXIII

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PAGE

FIG. 1. *Myalina falcata* Grabau, sp. nov. 338

1a, View of left side of an internal mold, showing the falcate umbonal ridge, holotype, natural size; 1b, the same, showing the right side, from which the umbonal part is broken away, but which preserves a fragment of the shell, natural size; 1c, posterior view of the same specimen, natural size; 1d, dorsal view of the same specimen, natural size.

Martinia bed (1194), No. 414, Cat. G.S.C. 1453.

FIG. 2. *Myalina* cf. *verneuili* (McCoy) 339

2a, View of the right side of an internal mold, natural size; 2b, anterior view of the mold, natural size.

Jisu Honguer limestone, No. 415, Cat. G.S.C. 1454.

FIG. 3. *Bellerophon squamatus* Waagen var. *mongoliensis* Grabau, var. nov. . 342

3a, Frontal view of a young specimen, cotype, natural size; 3b, frontal; 3c, dorsal; 3d, lateral view of the same specimen, enlarged × 3.

Jisu Honguer limestone, No. 425, Cat. G.S.C. 1455.

FIG. 4. *Bellerophon squamatus* Waagen var. *mongoliensis* Grabau, var. nov. . 342

4a, A larger specimen, possibly an adult, frontal view, cotype, natural size; 4b, the same, enlarged × 3.

Jisu Honguer limestone, No. 422, Cat. G.S.C. 1456.

FIG. 5. *Bellerophon jonesianus* de Koninck 344

5a, Frontal view of a young specimen, natural size; 5b, dorsal, and 5c, lateral, views of the same specimen, enlarged × 3.

Jisu Honguer limestone, No. 426, Cat. G.S.C. 1457.

FIG. 6. *Bellerophon jonesianus* de Koninck 344

6a, Frontal; 6b, dorsal; 6c, lateral, views of a larger specimen, retaining part of the shell, natural size.

Hemiptychina bed (1196), No. 423, Cat. G.S.C. 1458.

FIG. 7. *Bellerophon jonesianus* de Koninck 344

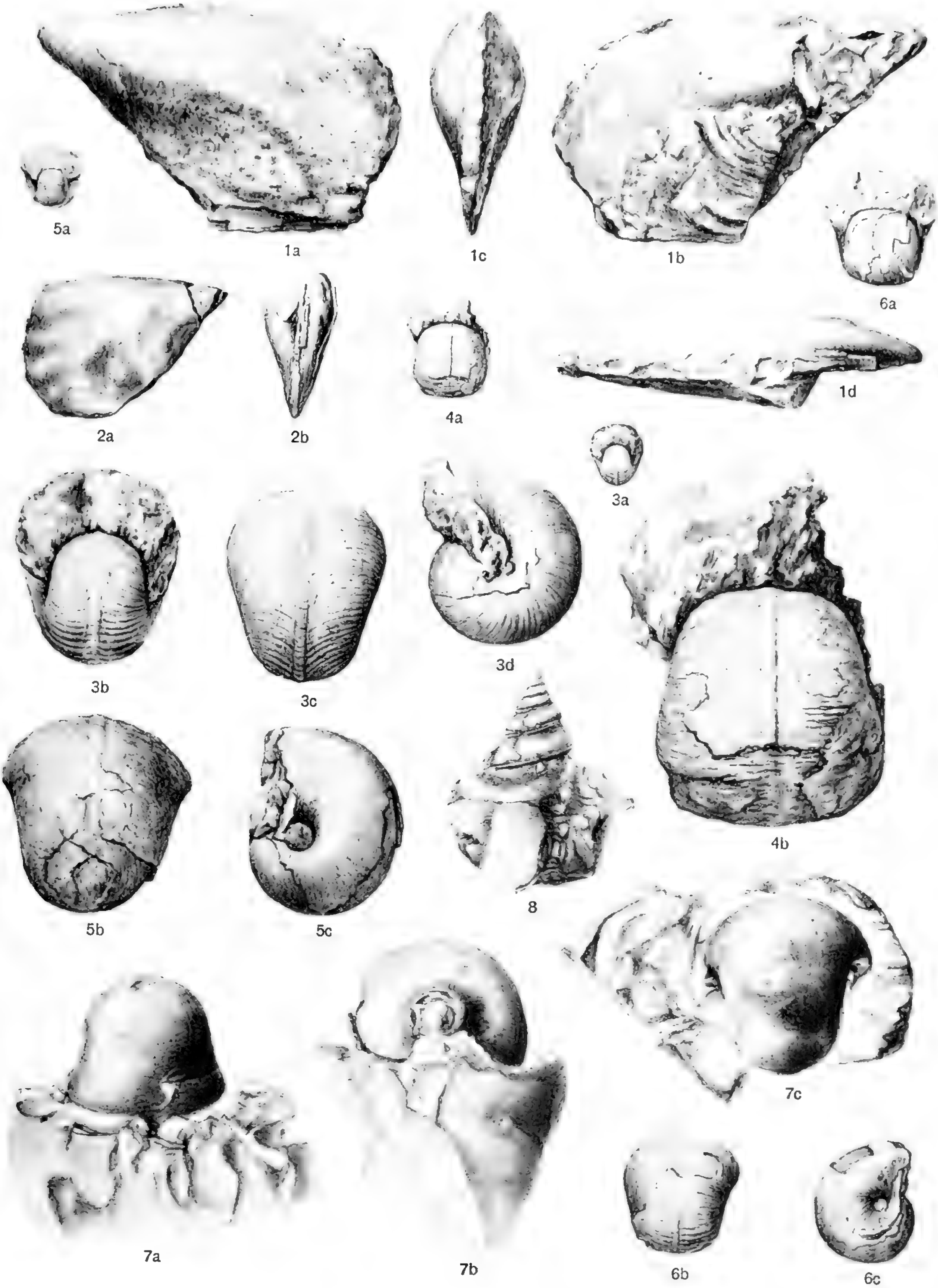
7a, Posterior; 7b, lateral; 7c, dorsal, views of a large internal mold attached to rock probably representing the adult.

Enteletes bed (1190), No. 421, Cat. G.S.C. 1459.

FIG. 8. *Luciella planoconvexa* Grabau, sp. nov. 346

View of the holotype, attached to rock, natural size (see Pl. XXXIV).

Jisu Honguer limestone, No. 428, Cat. G.S.C. 1460.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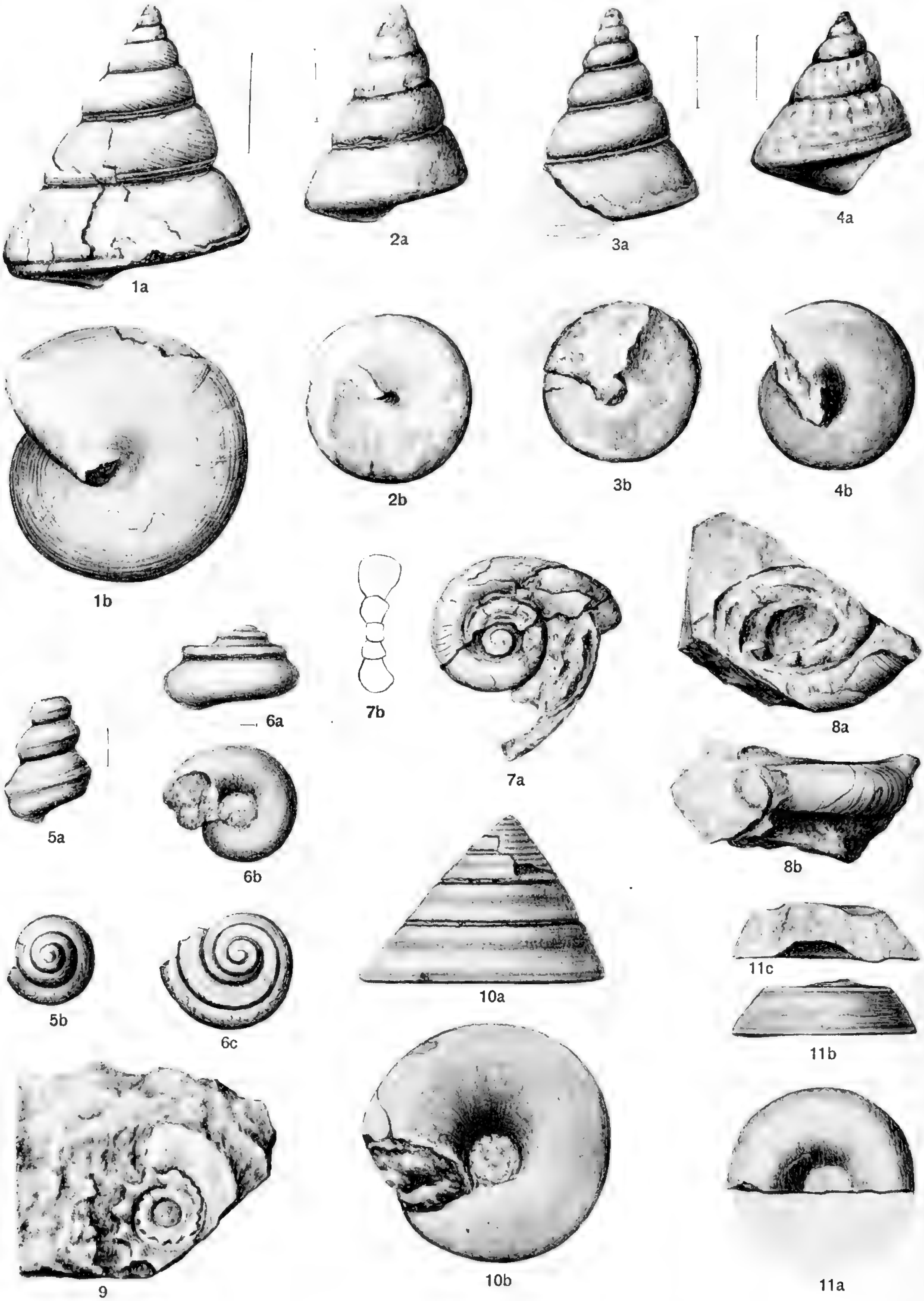
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PLATE XXXIV

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PAGE

FIG. 1. *Luciella planoconvexa* Grabau, sp. nov. 346
1a, The holotype, shown in Pl. XXXIII, Fig. 8, enlarged × 3; 1b, basal view of the same, enlarged × 3.
Jisu Honguer limestone, No. 428, Cat. G.S.C. 1460.

FIG. 2. *Luciella planoconvexa* Grabau, sp. nov. 346
2a, A specimen of a somewhat more slender type than the preceding, transitional to the next species; holotype, enlarged × 3; 2b, basal view of the same, enlarged × 3.
Jisu Honguer limestone, No. 429, Cat. G.S.C. 1461.

FIG. 3. *Luciella elongata* Grabau, sp. nov. 348
3a, The holotype with the apex restored, enlarged × 3; 3b, basal view of the same, enlarged × 3.
Martinia bed (1194), No. 438, Cat. G.S.C. 1462.

FIG. 4. *Luciella perlimbata* Grabau, sp. nov. 349
4a, View of the holotype, with the apex restored, enlarged × 3; 4b, basal view of the same, enlarged × 3.
Jisu Honguer limestone, No. 432, Cat. G.S.C. 1463.

FIG. 5. *Worthenia nana* Grabau, sp. nov. 350
5a, A fragmentary internal mold, with the apex restored; holotype, enlarged × 3; 5b, summit view of the same, enlarged × 3.
Enteletes bed (1190), No. 433, Cat. G.S.C. 1464.

FIG. 6. *Euomphalus simuloides* Grabau, sp. nov. 352
6a, Side view of the holotype, enlarged × 3; 6b, basal; 6c, apical, views of the same specimen, enlarged × 3.
Jisu Honguer limestone, No. 434, Cat. G.S.C. 1465.

FIG. 7. *Euomphalus mongolicus* Grabau, sp. nov. 353
7a, Apical view of a somewhat broken specimen, much of the shell preserved, cotype, natural size; 7b, transverse section of the same, showing the arrangement of whorls.
Marginifera bed (1192), No. 436, Cat. G.S.C. 1466.

FIG. 8. *Euomphalus mongolicus* Grabau, sp. nov. 353
8a, Summit view of an imperfect, somewhat distorted shell on rock, cotype, natural size; 8b, side view of the same, natural size.
Marginifera bed (1192), No. 437, Cat. G.S.C. 1467.

FIG. 9. *Phymatifer* cf. *coroniferus* de Koninck 355
View of a fragmentary specimen embedded in rock as seen from the under side of the specimen, showing the characteristic noded margin, enlarged × 2.
Jisu Honguer limestone, No. 439, Cat. G.S.C. 1468.

FIG. 10. *Flemingia tepeeformis* Grabau, sp. nov. 355
10a, The holotype, enlarged × 3; 10b, basal view of the same.
Hemiptychina bed (1196), No. 430, Cat. G.S.C. 1469.

PAGE

FIG. 11. *Flemingia tepeeformis* Grabau, sp. nov. 355

11a, Fragment representing half of internal mold of the last whorl with the characteristic features of this species, basal view restored, showing the large umbilicus, paratype, enlarged × 3; 11b, side view of the fragment, enlarged × 3; 11c, view of the natural median section of the same, enlarged × 3.

Jisu Honguer limestone, No. 431, Cat. G.S.C. 1470.

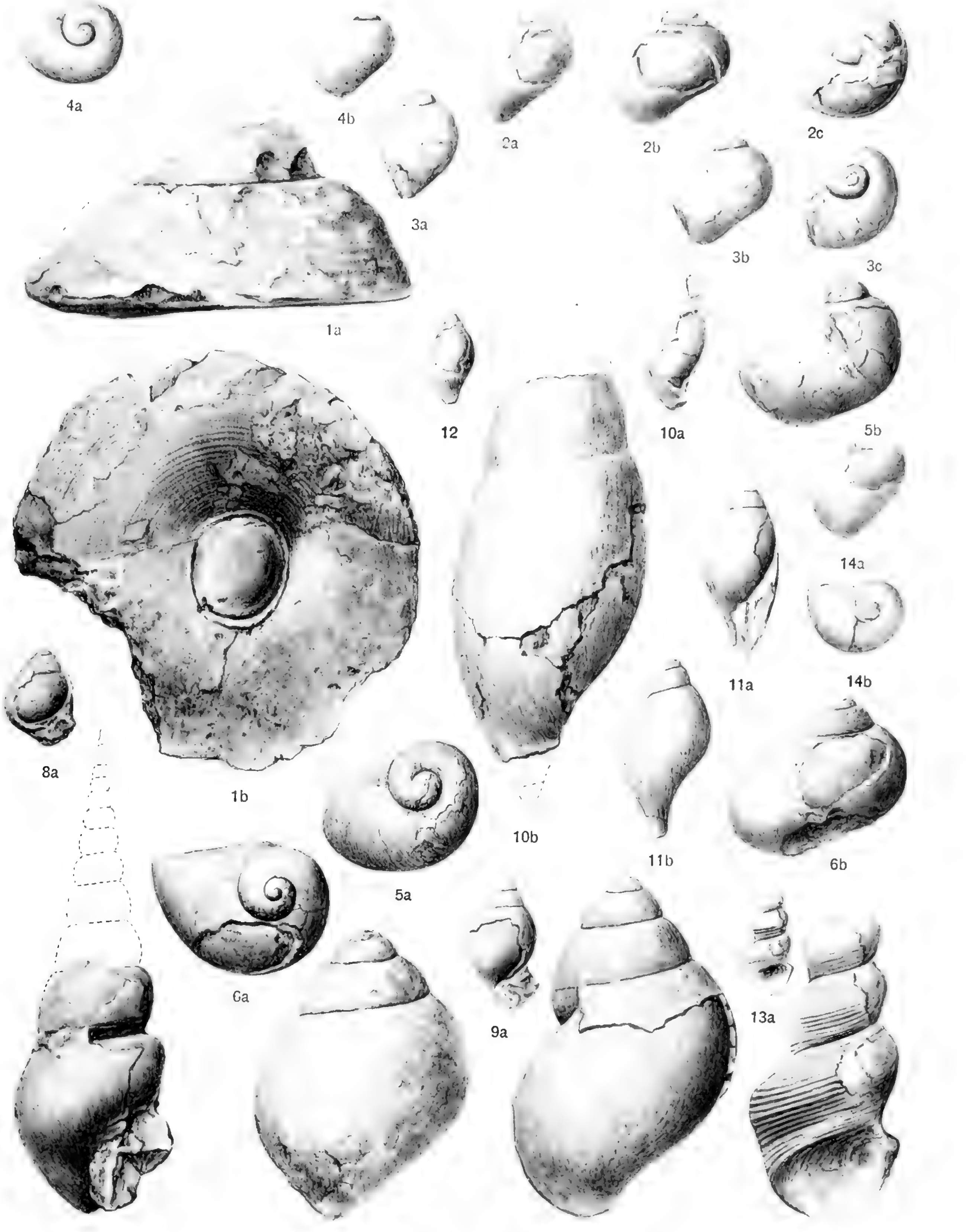
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PLATE XXXV

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		PAGE
FIG. 1.	*Flemingia gigas* Grabau, sp. nov.	356
1a,	Lateral view of the holotype with the outline restored, natural size; 1b, basal view of the specimen, natural size.	
	Hemiptychina bed (1196), No. 440, Cat. G.S.C. 1471.	
FIG. 2.	*Naticopsis khoovensis* Waagen	358
2a,	A characteristic specimen of this species, showing apertural margin, natural size; 2b, lateral, and 2c, apical, views of the same, natural size.	
	Hemiptychina bed (1196), No. 445, Cat. G.S.C. 1472.	
FIG. 3.	*Naticopsis khoovensis* Waagen	358
3a and 3b,	Lateral, and 3c, apical, views of another specimen of this species, natural size.	
	Hemiptychina bed (1196), No. 444, Cat. G.S.C. 1473.	
FIG. 4.	*Naticopsis khoovensis* Waagen	358
4a,	Apical; 4b, lateral, views of a smaller, but characteristic specimen, natural size.	
	Enteletes bed (1190), No. 443, Cat. G.S.C. 1449.	
FIG. 5.	*Strophostylus indicus* (Waagen)	359
5a,	Apical; 5b, lateral, views of the largest specimen in the collection, natural size.	
	Enteletes bed (1190), No. 442, Cat. G.S.C. 1474.	
FIG. 6.	*Strophostylus indicus* (Waagen)	359
6a,	Summit; 6b, lateral, views of another, smaller but equally characteristic specimen, natural size.	
	Spirifer moosakhailensis bed (1205), No. 441, Cat. G.S.C. 1475.	
FIG. 7.	*Holopella* cf. *trimorpha* Waagen	361
	The only specimen obtained, with the apical whorls restored, enlarged × 3.	
	Jisu Honguer limestone, No. 435, Cat. G.S.C. 1476.	
FIG. 8.	*Macrocheilina* (*Sphærodoma*) *avellanoides* (de Koninck)	362
8a,	Apertural view of a characteristic specimen, representing this species, natural size; 8b, view of the opposite side of the same, enlarged × 3.	
	Enteletes bed (1190), No. 453, Cat. G.S.C. 1477.	
FIG. 9.	*Macrocheilina* (*Sphærodoma*) *transitoria* Grabau, sp. nov.	363
9a,	Apertural view of the holotype from which the shell has been partially broken away, natural size; 9b, view of the opposite side of the same, enlarged × 2.5.	
	Hemiptychina bed (1196), No. 454, Cat. G.S.C. 1478.	
FIG. 10.	*Soleniscus mongolicus* Grabau, sp. nov.	364
10a,	The holotype; natural size; 10b, the same, with the basal part of the apical parts restored, the latter representing two restorations, one on the basis of the apical angle as indicated by the slopes on the sides of the shell, the other on the supposition that the small shells shown in Fig. 11 represent the young of this species; enlarged × 3.	
	Hemiptychina bed (1196), No. 455, Cat. G.S.C. 1479.	

PAGE

FIG. 11. *Soleniscus mongolicus* Grabau, sp. nov. 364

11a, Apertural; 11b, opposite, views of a young shell, assumed to be the young of this species; paratype, enlarged × 3.

Jisu Honguer limestone, No. 458, Cat. G.S.C. 1480.

FIG. 12. *Soleniscus mongolicus* Grabau, sp. nov. 364

A still younger shell of the same type as that shown in Fig. 11, enlarged × 3.

Jisu Honguer limestone, No. 459, Cat. G.S.C. 1481.

FIG. 13. *Solenospira (?) mongolica* Grabau, sp. nov. 351

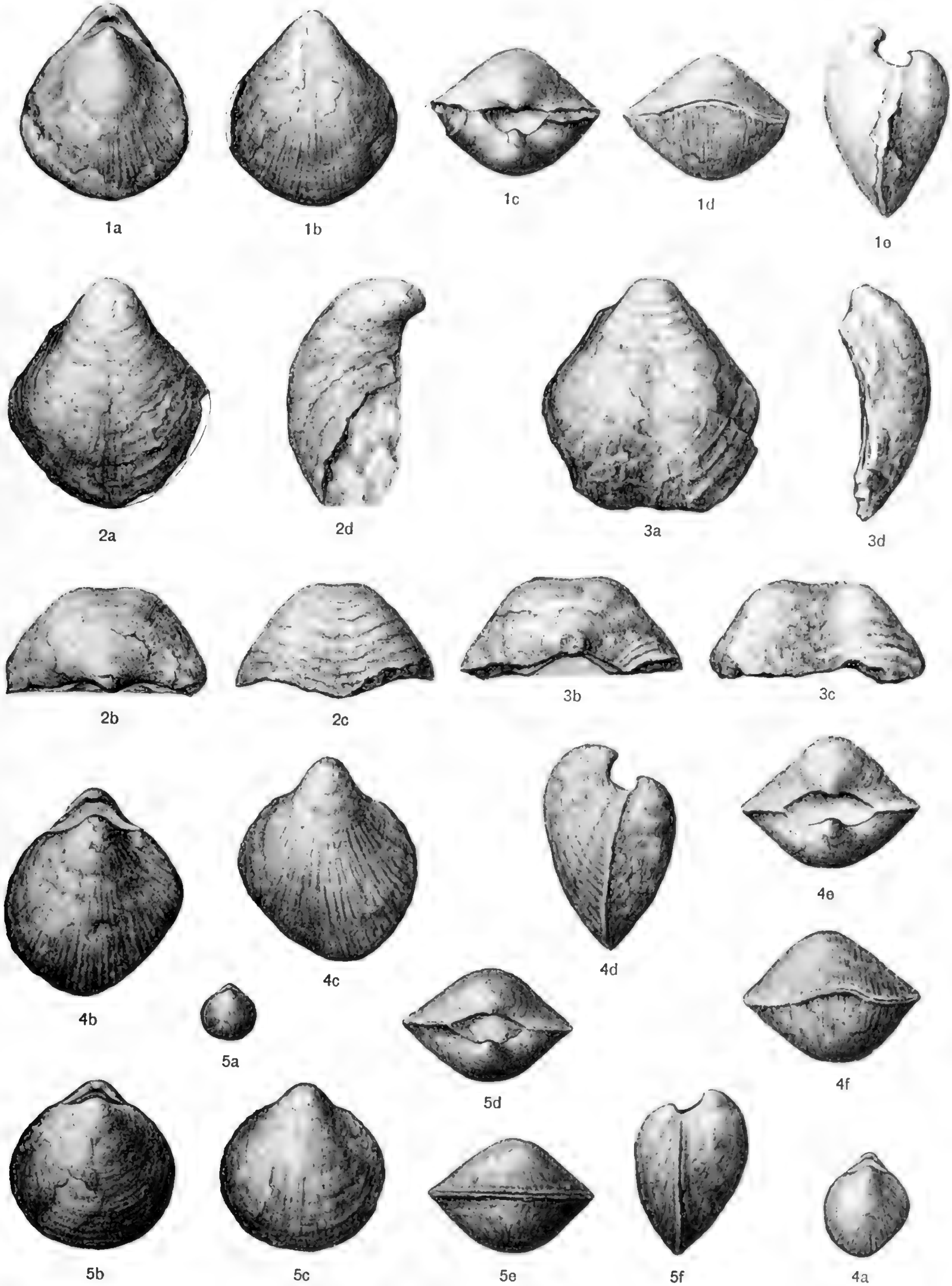
The holotype; 13a, natural size; 13b, enlarged × 3.

Jisu Honguer limestone, No. 417a, Cat. G.S.C. 1482.

FIG. 14. *Naticopsis khoovensis* Waagen 358

14a, Lateral; 14b, summit, views of a typical specimen with the shell partly broken away, natural size.

Enteletes bed (1190), No. 448, Cat. G.S.C. 1483.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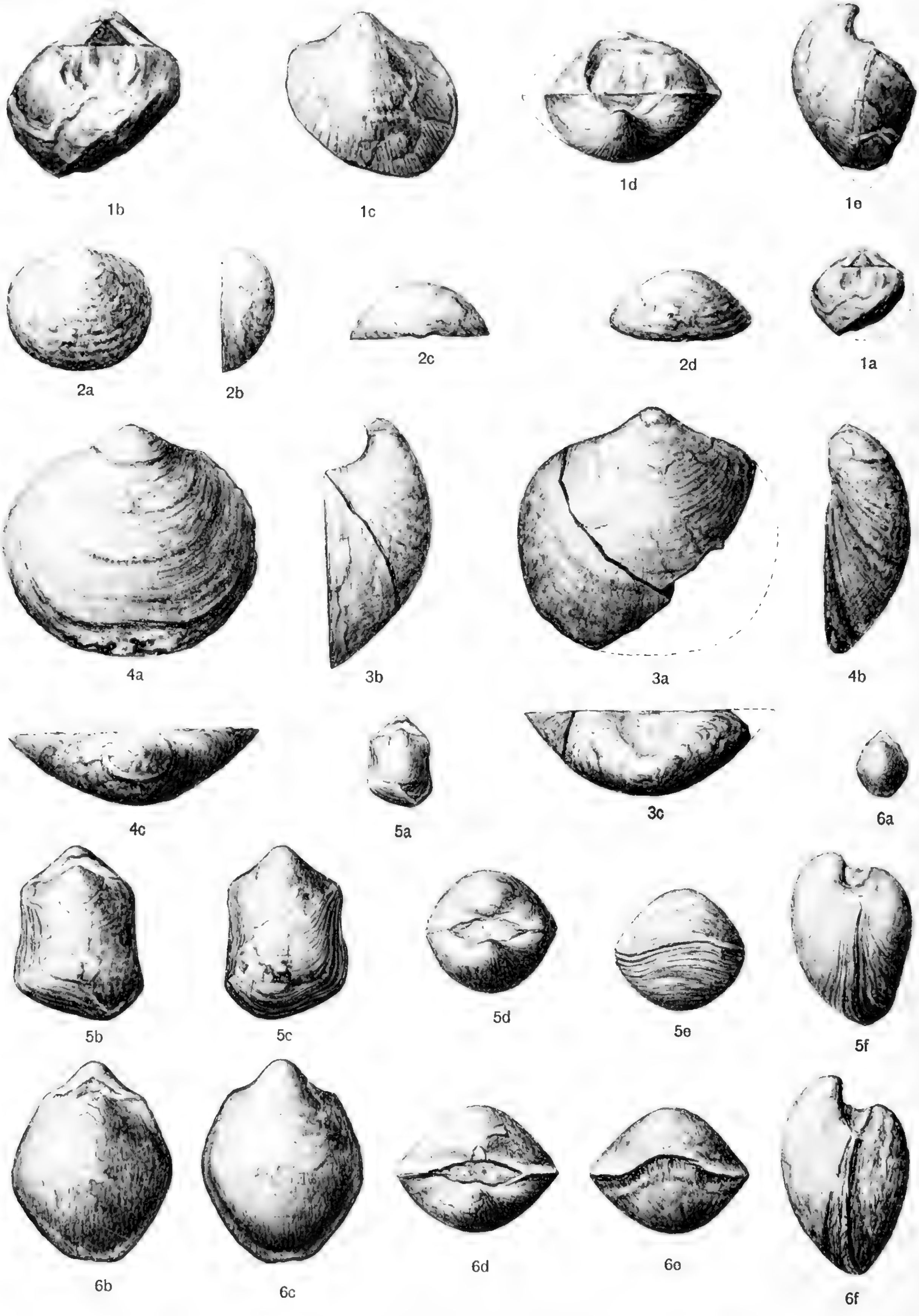
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INDEX

Names in *italic* are synonyms. Figures in **heavy type** refer to descriptions of fossils or horizons. Figures in *italic* denote references to illustrations.