MEMOIRS

OF THE

SCIENCE DEPARTMENT,

TOKIO DAIGAKU.

(University of Tokio.)

No. 4. -6

GEOLOGY

OF THE

ENVIRONS OF TOKIO.

BY

DAVID BRAUNS, Ph. D., M. D.

Professor of Geology in Tokio Daigaku.

PUBLISHED BY TOKIO DAIGAKU.

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PREFACE.

The geology of the environs of Tokio is a subject which has undoubtedly a very high interest for visitors and residents of Tokio or Yokohama, but above all for the Japanese students of geology to whom it offers some difficulties which no one, as far as I know, has tried to obviate. Unfortunately, I have not at hand Professor *Rein's* last publication about Japan, the only one I have before me being his paper on the Fuji-no-yama contained in the 25th volume of Petermann's 'geographische Mittheilungen'; but as the problems which form the main subject of this memoir are chiefly of a paleontological character, the author of the Japanese geography can scarcely have alluded to those difficulties. Although Dr. *E. Naumann's* paper concerning the Tokio plain, contained in the same volume of the 'geographische Mittheilungen,' makes also no allusion to them, yet I have been obliged, in treating the same subjects, to advance opinions, as it will be seen, partly agreeing with, partly diverging from those of Dr. Naumann. A paper about the fossil *elephants* of Japan being under preparation by the same author, I preferred not to recur to the preliminary notices given by Dr. Naumann on this subject in the periodical of the 'Ostasiatische Geselltchaft.'

By far the greatest difficulty was the determintion of the fossil shells mentioned in chapters 4 to 7, a difficulty increased by the want of several of those books which ought to have been consulted. This circumstance is also the reason why I could *not* give a fuller account of all the organic remains, and confined myself to giving descriptions only of the Mollusca contained in the pliocene beds of Tokio and Yokohama. Of these, however, a few species were also excluded whose condition would not admit of an exact determination. From the molluscous fauna the conclusions concerning the horizon and nature of the strata were drawn. As a similar way has been followed by other authors in a great many instances, I think I have committed no error in doing the same in a case which was not only of great importance, but also did not promise to yield other means of solving the problem.

The books mostly consulted were *Lischke's* japanische Meeres-conchylien, contained in three volumes, published by Fischer, Cassel, in the years 1869 and 1874-1875. This work, richly illustrated and critically written, mentions (and mostly describes) 429 species of Japanese mollusca, and so made up for the want of other books, e. g. *Dunker's* and *Schrenck's* works on Japanese Mollusca. The local fauna besides was partly given in *Gould's* Otia conchologica, or, descriptions of shells and mollusca, from 1839 to 1862, Boston 1862, to which the Plates of the Mollusca from Wilke's exploring expedition, by the same author, were a highly welcome addendum. Pacific shells are besides described by *Carpenter* in the Proceedings of the California Academy of natural sciences, whilst *Gould's* publications, except those already mentioned, are chiefly contained in the Boston Proceedings of the society of natural history, quoted in some instances in this memoir.

As the nature of the fauna described will show, the comparison with Atlantic shells was of a much greater importance than, perhaps, could have been expected. This was done chiefly with the aid of *Forbes* and *Hanley's* british Mollusca, 4 volumes, London, 1853, of *Jeffreys* british Conchology, 4 volumes London, 1867 (year of last publication), but also of *Gould-Binney's* report on the Invertebrates of Massachusetts, 2d ed., Mollusca, Boston 1870, *Stimpson's* revision pp. Boston 1857, *Tryon's* American marine Conchology, Philadelphia 1873, *Weinkauff's* Conchylien des Mittelmeeres, 2 volumes, 1867 and 1868. But it was quite as important to compare the shells in question with other fossil shells; and for this purpose the 'Crag-Mollusca,' described (and figured) by *S. Wood* in the reports of the Paleontological Society of London (in two sections, one contained in 3 different numbers, with two supplements, the first of which has also 2 parts, the whole published within the years 1847-1879) were most essential. The subapennine fauna could not be consulted in the original publications; but this was the case again with a great part of the German papers on the fossil beds of Mayence, Vienna, Cassel, Soellingen, on the Mecklenburg tertiary layers, &c., as well as with Nyst's accounts of Belgian fossils. *Goldfuss'* Petrefacta Germaniæ—of course—were sometimes of great use.—As the Brachiopoda were added to the true mollusca, the papers of *Davidson*, above all his paper on Japanese recent Brachiopoda, from the 'proceedings of the Zoological Society of London,' April 18th, 1871, page 300-312, and pl. 30 and 31, were consulted.

With the aid of all these books—and many others used on different occasions, all of which need not be mentioned—I feel I have only made a preliminary step in an investigation which, though offering very great difficulties, is of such importance that it seemed to me to require immediate treatment. A further delay would, above all, have been disadvantageous to the students of the Daigaku; I need, therefore, make no apology for this Memoir.

I cannot omit to call the attention of the reader to the clever way in which the Japanese artist, Mr. H. Hirauchi, has done his work in designing the illustrations, and chiefly a certain number of the pliocene shells. Though—among the more frequent, or otherwise important species—only such specimens were selected, as were well preserved, yet the task set to him was so entirely new, that the difficulties he was to surmount are not to be underrated. Much of whatever is excellent in the appearance of the book is due to the successful execution of his work. As to the printing &c, it may be called in this case as well as in the preceding memoirs 'surprisingly elegant and correct.' I seize this opportunity of expressing my best thanks for all the aid given me in this direction by the Presidents of the Daigaku.

I offer likewise my thanks to the director of the Zoological department for the kindness with which he opened to me all those parts of the Daigaku collections under his care.

Finally I add my thanks to my assistants, past and present, for the aid given me in making these researches, Messrs Sekino, Kato, Kochibe and Nishi, to whom I must add the names of two of the students of the Daigaku, Mr. Yamashita and Mr. Fujitani.

Tokio, December 1880.

The Author.

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CHAPTER I.

INTRODUCTION.

The environs of Tokio, the capital of the Japanese Empire and, at the same time, the place in which most of the collections, colleges and schools of Japan are united and in which therefore also the university or Daigaku has been founded, exhibit, geologically, a much smaller number of rocks and formations than we might wish for. This is the more to be regretted as these environs are part of a vast plain everywhere constructed on the same plan and showing essentially the same formations, so that, in order to reach rocks and strata of a different kind, the student of geology is always obliged to make long and rather tiresome trips in a country which, it must be admitted, has but imperfect roads and means of conveyance, and offers but very few comforts to travellers. Moreover, the mountains encircling the large plain of Tokio—the largest in fact of the Japanese Empire, and for that reason most likely selected for the site of the capital—present little variety. In almost every direction we find rocks of a similar character and origin on leaving behind us the formations of the plain—those diluvial plateau-like heights intersected by rivers and rivulets, and more or less broad alluvial valleys, which we are to describe in the first chapters of this paper. Those rocks of the adjacent hills and mountains, forming as it were a vast quadrant, to which the small isolated district of Uraga is to be added, are indeed mostly crystalline sedimentary or schistose rocks, micaschists, calcareous micaschists, chlorite-schists, intermixed with quartzites, crystalline limestones, and cipollines, in a few instances passing over to gneissic rocks, in other instances (N. and N.W. of Tokio) to quartzitic conglomerates or to limestones containing few kinds of recognizable organic remains—crinoïds, belonging to the tesselate ones, orthocerata, and fusulinæ—, all proving that these rocks are at least of a palaeozoïc age. In some parts, as for instance in the Tsukuba-mountains, which, from the northern and northeastern side, project somewhat farther into the plain than the rest of the neighboring heights, or in some parts of the Chichibu district and farther to the west, or in the mountains which northward from Mito verge nearly to the sea-side, we find granites, diorites and other plutonic rocks of a rather ancient origin; whilst in a few localities, especially in the southern part, along the coast, recent volcanic rocks with their tufas are widely spread. These tufas indeed pass gradually into the formations of the plain and especially into the neogene tertiary rocks which may be said to be the most attractive formation of it. These volcanic rocks have their highest level on the top of the Fuji-no-yama, that well known normal volcanic cone of gigantic dimensions which is situated to the W.S.W. of Tokio at a distance of about 65 miles, and whose crater, now nearly filled with barren ashes and lapilli, forms a hollow cone not more than about five hundered feet below the high and sharp ridge encircling it. The volcanic 'action has totally ceased on the high top of the giant-cone,—the last eruption, nearly two centuries ago, having affected only a side-cone, the Hoyei-san, about half way up from the western base—, and we see but slight traces of it in the environs of Hakone, at a direct distance of about 12 miles from the top of the Fuji-mountain, so that it seems to have retreated to the sea. Indeed it seems to have its main centre now in the volcano of the island of Oshima, nearly SSW from Tokio. Not only the last vigorous eruption—about a century ago,—but also smaller ones seen and described and partly pictured by European geologists, and, as it becomes obvious from a great many dates of the seismoscopical offices, a part at least of the earthquakes so frequently occurring at Yokohama and Tokio, point to this fact; whilst on the other hand, the volcanic phaenomenon of the districts in the north of Tokio, especially on the Asama-yama, whose last great eruption is recorded to have taken place 6 years after that of Oshima, is now apparently less vigorous and not much above that degree of intensity which is exhibited by the hot springs and the sulfurous exhalations near Hakone. As for the sedimentary rocks overlying the older crystalline sediments, they are, as far as they are known in this vicinity, all very young, being partly tertiary, partly quaternary. The tertiary rocks, though very thick and developed in different shape, as shale, conglomerate and sandstone, are not, or not much, older than the tertiary rocks which we shall find in the plain, and form indeed one and the same system, rich throughout in such species of mollusca, as still survive in the Japanese seas. These rocks form sometimes beds and basins encircled by the micaceous schistose rocks, partly large, as for instance that which extends between Nigawa and Minano in the district of Chichibu, partly smaller, as one which has been discovered in the environs of Sukegawa, in the north of Mito and near the eastern coast. Other parts of those tertiary strata are spread along the boundaries between the crystalline system and the quaternary soil of the plain, as for instance between Mito and the mountains in the north of that town, or in the district of Komagori, or westward from Yokohama. The rocks constituting this part of the country, which though not perfectly contiguous, may be called a belt encircling the plain, are mostly sandstones, sometimes rather impure and frequently passing into conglomerates and tufaceous rocks. In the latter case they contain sometimes fragments of pumice, in the former, they are rich in small and worn fragments of crystalline rocks, representing all the different kinds occurring in the adjacent mountains. The species of fossils found in the sandstones—unluckily very often mere casts or moulds—are of course of great importance. We shall, therefore, be obliged to recur to them in the following pages. It may suffice here to mention among them Nassa livescens Phil., Columbella scripta L., Mya. arenaria L., Cyclina Sinensis Gmel., Mactra veneriformis Desh , Dosinia Japonica Reeve, whose identity, however, with the true

Dosinia exoleta L. will be proved in the following pages, and Cardium muticum Reeve, all of which have been found frequently and in more than one locality, and serve to illustrate sufficiently, what has been said about the character of these strata.

The quaternary formation looses the character which it exhibits in the plain, whenever we ascend a few hundred feet above the level which it has near the sea side, in the environs of the bay of Tokio. The valleys of the rivers are terraced also there, but the differences between the true diluvial and the true alluvial formation disappear, and instead of them, a formation is developed containing large pebbles, shingle and sand mixed with loose, impure soil, such as we frequently find along the slopes of steep hills or mountains. As this formation passes insensibly into very recent deposits, there can scarcely be any doubt about its being partly of recent origin, and corresponding to the undoubtedly alluvial deposits of the lower part of the river valleys. But this cannot be said of the totality of these loose quaternary conglomerates, as there is evidence of organic remains in them which belong to extinct mammals. Though the species could not be always ascertained there can be no doubt about the genus Elephas (v. Chapter 3.) occurring not unfrequently in the beds described above, which, as scarcely needs be mentioned, cover unconformably all the other formations, palaeozoic or tertiary, with a coat which sometimes has many metres of thickness, whilst, in other instances, it is partly or entirely eroded and taken off by the waters, or even may have been prevented by them from being deposited at all. As good examples of such deposits we may mention again the districts of Chichibu and Komagori, the latter exhibiting moreover the passage between the abovementioned conglomerates and the more clayish soils forming the upper part of the deposits of the plain, a passage gradually appearing just beyond Hanno. Having thus encircled the large plain of Tokio and characterized the mountains in its circumference, upon which, therefore, its deposits are somewhat dependent, we may proceed to describe the plain itself and the parts into which it is to be divided.

Of course the difference is most obvious between the river-valleys themselves and the parts of the plain in which the valleys are cut. The smaller valleys and side-valleys, and on the other hand all the innumerable smaller or larger portions of the higher plain left between the rivers and rivulets, exhibit a similar if not identical character. This uniformity in character of both of these formations relieves us from enumerating all those rivers, which in a very great number descend from the water-ridges towards the plain and reach the sea, partly in the bay of Tokio, partly in the adjacent parts of the ocean. The largest of all those rivers, the Tonegawa, is renowned for the partitions which take place about 40 miles from the mouth. Some of its arms run into the open sea, the largest of them forming a sort of lagoon-district barred from ocean by sand-banks, similar also in some respect to the Nehrung which severs the mouths of the Baltic rivers called Haffs, from the open sea. Besides the lagoons themselves a large fresh-water lake, the Kasumiga-Ura, is to be mentioned, not more than about 8 feet above the level of the sea and, as it were, a repetition of the lagoons in a somewhat higher level. The other arms, among which the Yedogawa—a little eastward from Tokio, and from the arm which almost touches the capital, the Nakagawa—is most important and is used not only by common boats but also by steamboats. In their lower part, these arms have branches communicating with the stream which runs through Tokio, the Sumidagawa; and also in its upper course this river sends tributary arms to the system of the Tonegawa. The same river, called Arakawa in the upper part of its course and running through the district of Chichibu, divides, in its lower part, Tokio itself (Asakusa) from the suburb of Mukojima. Together with the western arms of the Tonegawa, it forms a sort of delta which we may call the delta of Tokio. Of course, we are to confine this name to the environs of Tokio, and cannot call delta the whole space between the western and eastern arms of the Tonegawa, nor, as is obvious from what is said above, any part of the region of the mouths of the eastern arms. It may be added, that the other river-mouths in the Tokio-bay, among which that of Kawa-saki between Tokio and Yokohama is the most important, have the same character as the Tokio-delta, whilst the river-mouths as well of the eastern coast bordering the open ocean, as of the southern coast to the west of Yokohama are more or less similar to that of the eastern arms of Tonegawa.

It may be added that, as a rule, the soil of the latter is sandy, sometimes intermixed with other minerals, among which magnetic iron sand may be mentioned, in the north of the north-eastern Tonegawa arms, whilst in the bay it is mostly clayish. In the first case, we may also notice that the bluffs and cliffs, mostly formed of sandstone or tufaceous rocks, are much oftener projecting far into the sea, whilst in the bay, we find such projecting rocks only in the southern part. The interior or northern part of the bay generally exhibits a broad margin of low, mostly clayish lands, the bluff line being situated at some distance from the sea.

As stated above, the parts of the plain which are not cut deep by rivers or by the waves of the sea are considerably higher, even in the closest vicinity of the sea. We find the level of this higher plain, or plateau, about 28 metres above the sea at Tokio, and nearly equally high, nay even a little above 30 metres, at Yokohama and its environs. The surface of the higher plain given by strata which, near the surface, are always nearly horizontal, is more regular than the alluvial deposits themselves which not only follow the slope of the valleys but are also disposed in a somewhat different way in the same cross-section of the valley. In such a cross-section the riverline itself may be grooved rather deep into the other alluvial layers, and terraces may often be seen which always divide younger and older alluvial deposits, the youngest alluvial strata being always found in furrows cut deep into the older ones, exactly in the same way, as the totality of the alluvial formations is cut into the diluvial, or even into any other older formation. Thus it comes, that all the diluvial parts of the plain appear as isles or peninsulas, divided from one another by all those river-valleys and side-valleys of tributary rivers and rivulets, down to the most minute undulations of the ground or ravines and torrent-beds.

It is to be mentioned, that this division of the surface of the plain is of the highest importance for agriculture, the rice-fields being in most instances confined to the lower or alluvial tracts, and generally filling them, whilst on the higher level we find the barley, wheat, millet, Indian corn, the many kinds of beans, the nasu, satsuma-imo and sato-imo, and at the same time the plantations of tea, of the mulberry-tree, and also most of the small forests; whilst the villages and towns with their bamboos and garden-trees and shrubs are indifferently spread over both sorts of localities. It will appear from the following pages that the geological constitution of all these originally contiguous and only posthumously intersected higher parts of the plain is also geologically identical or nearly identical, the surface being almost always formed of iron-ochre coloured sandy clays or loams, and that they are always widely different from the deposits of the river-valleys imbedded between them.

The level of these higher parts of the plain does not, of course, show great differences. In the vicinity of the capital 30 metres are—as above stated—the average height wherever the formations are completely developed, the more elevated heights which occur not exceeding about 45 metres. But even at some distance, e. g. near Tsukuba, or Odawara, scarcely any difference is to be observed. In the neighbourhood of the mountains, however, we get levels of 70 to 150 metres above the sea, and of course the river-beds themselves exhibit a corresponding increase of level. Generally speaking, we have a very uniform plain or, as we may call it and have called it above, in spite of its rather low level, a *plateau* widely spread around Tokio, which must have been deposited by the sea and under its surface, and therefore must have risen above the level of the sea since the diluvial epoch in which it was formed.

The act of elevation itself which is believed to continue to the present day, and which has been the object of a paper 'Ueber die ebene von Yedo'—lately published in the' geographische Mittheilungen 'of Petermann—by Dr. E. Naumann, will be discussed in the concluding chapter. I therefore proceed to point out some remarkable features of the country as it now appears.

The very first objects which strike the new arriver at Yokohama and at Tokio are the steep bluffs which appear, as has been said, at different distances from the sea, but form an almost continual, though very irregular line. The identity of these bluffs—of the Bluff on the southern side of Yokohama, of those of Kanagawa, Shinagawa, of some parts of Tokio, of Oji is indeed obvious, and we may say without any doubt that the deep cuttings of river-valleys and ravines into the plateau-formations of the inland are also precisely of the same nature and origin. We find, therefore, comparatively the steepest and highest slopes next to the sea-side; for the water-courses, which necessarily run down according to the well known parabolic law and which, as we have seen, are cut through a nearly horizontal plateau, must be most strongly opposed to the plateau-surface next to their mouths, and the very highest precipices must, at all events, be found next to the sea side. Consequently we see the best exposures and geological openings, and above all those which give the most perfect sections, in the vicinity of Tokio and Yokohama and other places near the shore. It is not, therefore, at of all astonishing, that chiefly at Tokio, Kanagawa, Yokohama we find those openings and steep slopes which exhibit the lower parts of the plateau-formations.

The higher of them—if we deduct the less important alluvial deposits on the very top of the diluvial layers of the plateau—are undoubtedly *diluvial*, and may be taken as a sort of base for further investigation. Now there is everywhere a series of more or less thick strata, which often uniformly, or conformably, succeed the uppermost deposits and, as scarcely needs be mentioned, are always horizontal. These strata, partly clayish, partly sandy, sometimes tufaceous and very often intermixed with thick layers of round pebbles, sometimes fill up the total height from the level of the sea or the deepest point to be observed in the sections, whilst in many other cases they are only some metres thick. But in both cases a line of uncomformability is below them, and indeed this line is always more or less clearly to be seen whenever we have the second case in which the diluvial formations described above do not reach the lowest part of the section. The strata below that line of uncomformability are sometimes nearly horizontal; but in many other cases they are more or less strongly inclined. We may therefore assume that they are different in age and formation from the upper ones. Indeed they are to be determined without any prejudice and without excluding them a priori from any formation belonging to or older than the diluvial era. It is not altogether excluded, that they might belong to the older part of the, 'Diluvium' or quaternary epoch; they might be, on the other hand, of a very old origin, and it is not without a deeper study of all their peculiarities of structure , and above all of their organic remains, that we are allowed to draw a conclusion about their nature. Now it has been already mentioned that a great part of their organic remains, especially of the fossil mollusca, belongs to recent species, and this fact shows that, if not diluvial, they are of a very recent—or neogene—tertiary origin. Whether the one or the other case is before us, will appear, as has been already hinted, in the following pages. It may be noticed before-hand that the conclusion drawn from the mollusca found at Oji, Shinagawa, Yokohama &c, viz. that the deposits must be tertiary and not quaternary ones, is confirmed by the strictness with which the line of uncomformability appears, and by the strongly marked differences in the angle of dipping between the two series of strata—either above or below that line—, which are often to be observed. Instances of both facts will be given in the detailed descriptions of the sections of Shinagawa, Kanagawa, Yokohama, Takigashira, Surugadai and Oji. Thus, both the architecture of the formations and the paleontological character tend to prove that the shell-layers below the line of uncomformability, which very often form the very top of the deeper formation, are indeed a very young and high part of a system which includes all the abovementioned tertiary beds and basins of the slopes and within certain excavations of the old sedimentary rocks of the mountains encircling the vast plain which is the object of this memoir.

This system is indeed a unit and does not exhibit uncomformabilities, nor even very striking lines of partition. We are well enabled to point out younger and older strata in the thick succession of layers which it includes, but only by the very fact that they overlie one another. The connexion of the shell-beds of Tokio and its environs, with those of the environs of Sukegawa and other places in the north of Mito, can also be very nicely traced along the road from Tokio to Mito and farther northward.

It deserves to be noticed that in no part of the plain of Tokio is any trace of glacial deposits to be seen nor any trace of gracial action on any of the formations. Of course we could not expect, from what we know of other countries, to find such traces in any but the diluvial formation, but even in this formation we look for them in vain. This fact is fully admitted by the author of the above-quated paper, Dr. E. Naumann; he adds, however, that there are certain signs of a lower temperature having existed during that formation. I do not think those signs really exist. The Elephas, or Mammoth, which is mentioned in Dr. Naumann's paper, is not Elephas primigenius Blumenbach (see chapter 3rd), and so falls rather short of proving this abatement of temperature, and the presence of a few mollusca in the *tertiary* beds which are now confined to the seas round the isle of Yesso—or even farther to the north—gives of course still less evidence of a lower temparature during the *diluvial* epoch. Indeed this fact must be explained in a thoroughly different way since other fossils of the tertiary beds would rather seem to indicate a higher temperature of the tertiary age. I have been always of opinion that it is a little rash to draw conclusions from the presence of this or that species of fossil plant or animal on the climate of past ages. In most instances we do not know the animals or plants themselves and are to form our conclusions on the assumption of more or less strict affinity between them and surviving species, and the case of Elephas primigenius and Rhinoceras tichorrhinus ought to have shown sufficiently how erroneous such conclusions may turn out. But even when we know the plants and animals, we are not allowed to derive any definite dates from their actual geograhical distribution. Professor Fraas, of Stuttgart, one of the best German Geologists and well versed in researches of deposits of many formations and climes, found on studying the prehistoric fauna of southern Germany—about 50° of northern latitude—a complex of animals which reminded him of the collections made for show, or in a zoological garden, lions, hyaenas and other animals of southern latitudes cast together with reindeer, and other animals of frigid climates, and with horses, stags, bears and many other animals existing nowadays in the same latitudes. All these species are asserted to have been strictly contemporaneous. Now it is obvious that the reindeer has retreated just as far to the North as the lion has retreated to the South, and if we should infer from the former that the climate has been colder than it now is, we should be obliged by the presence of the lion on the other hand to assume that it must have been warmer than it actually is. The whole set of facts referring to this theme is fully explained if we keep in mind that any species of plants or animals may have been restricted to a smaller area by the struggle of life to which it was subjected. Species better adapted to a cold climate persisted there but were restricted from the southern part of their area, whilst the reverse took place with those species which were better adapted to a warm climate. Without admitting this fact, we should be indeed at a perfect loss how to explain the majority of facts connected with the study of tertiary floras and faunas, and it obliges us much more than it is the custom among paleontologists, to restrict our conclusions and statements on the temperature of the different continents and oceans. Indeed the area over which the majority of species are spread is far larger and includes a far greater variety of climates than is generally admitted; and the range of latitude, which a given species may have, or may have had in the course of geological ages, is very often undoubtedly a much larger one.

Making an application of these views to the matter in question, we may say that the climate of the latest tertiary times may have been a little warmer—or a very little colder—than it is now, but that it may just as well have been exactly the same.

Still less may we form any conclusions on the temperature of Japan during the diluvial era, whose fauna we know but imperfectly, and whose flora to a necessity was the same as that of both the youngest tertiary age and the present time, and which does not exhibit those glacial phaenomena which give such a high interest to the study of the quaternary formations of England, Scandinavia, Germany and Switzerland. During this period, which so strongly divides the genial climate of the miocene era of Europe from the less warm but also fertile present era of the same part of the world, we find in southern latitudes, such as that of Tokio and its environs, nothing but a deposit of detritus indicating a smaller extension of the land than we have now, and no proofs of a climate differing from that of the present age, the only reasons for admitting a lowering of the temperature being derived from the observations made in higher latitudes.

In fact the absence of the glacial phænomenon is exactly what might have naturally been expected. The latitude of Tokio, similar to that of Gibraltar or Damascus, together with the absence of Alpine mountains, would be scarcely in accordance with the presence of inland-ice, such as has been proved to have existed in the above-named European districts. The absence of any traces of it relieves us from pointing out such heavy changes in the configuration of the land and its surface as could be reconciled with the glacial phænomenon. It is true, indeed, that the above mentioned German geologist, Fraas, is of opinion that exactly in the same latitudes, and even a little father to the south, viz. in the southern prolongation of the Jordan-valley beyond the Dead Sea and on the

Sinaïtic peninsula, glaciers have existed; but his opinion, which as far as we know has never been shared by any other geologist, is neither proved to a certainty, nor even recurred to by the author himself. and the only argument given by him, the configuration of the surface of the hills and valleys, may be equally well explained in a different way.

Whether the diluvial era, which at all events, in the main, represents a state of things intermediate between the tertiary and recent time, but which locally and temporally may be opposed to either, brought indeed a colder temperature than that of the present day to Japan and the adjacent parts of Asia, can not be explained by the data given us by Japanese geology. Thus, the answer to this question depends upon the answer which geology will give to the important question, to what degree did the influence of the increase of northern ice and cold, which undoubtedly took place at least during a part of the diluvial era and caused its temperature to be somewhat like that of the southern hemisphere of the present age, extend towards the aequator. However probable it may seem that such an influence has been felt in a similar way as the influence of the heat of the Sahara-desert and of the winds arising from it is to be felt in a great part of Europe, and as the influence of the moist and warm monsoon of eastern India is nowadays felt in Japan:—we are not able to assert that it took place, and much less are we able to speak about any degree of it. At any rate there seems to have taken place a slight and gradual alteration of our climates since the tertiary period, and if the degree of abatement was, in the average, not very high—as there are many reasons to believe—, we cannot deny a strong change of our climates in another way, namely, that the seasons became more distinct and opposite, and that with an abatement of the temperature of winter there is most likely to notice an increase of warmth of summer. This change seems to have gradually begun towards the end of the tertiary period.

Indeed the assumptions and views here stated are quite sufficient to explain, in connexion with the theory of natural selection, all the facts connected with the changes of our faunas and floras since the miocene time.

We find indeed, that Japan has not only at that period but down to a much more recent date had its share of the palæarctic faunas and floras, which to a certainty have been in connection with the living fauna. The continental archipelago, whose centre and most important part is the main island of Nippon, has indeed preserved some features which have disappeared elsewhere; and we find here a corroboration of that law, which so strongly confirms Darwin's theory, that isolated parts of faunas and floras escape the severest consequences of the struggle of life and of natural selection, and may preserve certain characters even long after they have disappeared elsewhere. In some cases, such remnants of ancient floras and faunas are likewise preserved in other countries, though very often on the continents they are pushed much farther to the south.

As examples of such remnants of old floras and faunas may be quoted Gingko biloba L., a plant known from the miocene and pliocene European floras under the name of Gingko or Salisburia adiantoides Heer, and the Japanese giant-salamander belonging to the genus Sieboldia whose nearest allies are found in miocene deposits of Europe.

Of course it would lead me too far, if I would go through the recent fauna or flora of Japan, in order to elucidate these theses more in detail. It may suffice to have pointed out here their general and most striking features, and to apply the laws thus derived to that portion of the faunas, which is imbedded in the strata which constitute the formations of the plain of Tokio, and which therefore will be the object of the following chapters.

CHAPTER II.

THE ALLUVIAL DEPOSITS.

It might seem perhaps that the *alluvial* deposits are comparatively of little consequence and, therefore, less interesting than the rest of the stratified formations. Inconsistant as this mode of viewing things is with true science, it turns out to be perfectly erroneous whenever we enter more deeply into the subject. Not only is the agricultural importance of the alluvial deposits of the river-valleys and of the deep plains along the sea-side very great, but also a minute investigation of all these deposits is of utmost consequence theoretically, for any studies of prehistoric remains.

I need not dwell upon this point, as another Memoir of the Daigaku, 'The Shell Mounds of Omori' (by Edward S. Morse (Vol. I, part 1 of the memoirs) shows sufficiently the great importance which these researches have especially for the district whose geology we are treating here. This importance calls for the greatest precaution with reference to those shell-mounds, the more so as there are a great many difficulties to be overcome. It would be preposterous to call every larger accumulation of shells a shell-mound; many of them are produced by nature and not by men; other are accumulated by men in more recent (historic) times. But a great many of these deposits are indeed the products of human action in a remoter period. The characters belonging to such artificial shell mounds are, of course, easily determined—those mounds are never overlaid by any but recent alluvial deposits—they are accumulated and not arranged in layers or strata—and moreover they are, if not always, yet almost always intermixed with products of human art and industry, with waste of cookery, bones of animals &c. The nature of the products of art as well as the character of the human bones occasionally found within the mounds gives always the best intimations of the age to which they belong.

All these objects having been carefully taken into consideration, we may indeed safely accept the result of the above quoted author concerning the prehistoric character of the mound of Omori—and also that of Onomura, province of Higo, mentioned by Morse in the chapter about the platycnemic tibiæ—, though we may omit a further discussion about the exact era of its construction.

Of course in a country where people are eating daily a very large quantity of shell-fish, we have shell-heaps or deposits of any date up to the present day, and as those heaps are almost always accumulated next to the human dwellings, they may be very easily mistaken for shell-mounds by any one who is not well versed in anthropological researches. Wherever such accumulations are found next to the doors of existing houses, or within a village, or next to the landing-places of fishermen, there is indeed scarcely any danger of a mistake being made; but whenever they are found in a comparatively desert place and at a larger distance from the sea, we are indeed forced to reserve our verdict until an accurate investigation of the mound has been made, and a thorough knowledge of all remnants of pottery and other branches of industry contained in it has been obtained. There may be cases where even native tertiary shell-layers are not easily distinguished from artificial shell-heaps. This difficulty is greatest whenever we are to deal with such parts of those shell-layers as have been washed away by the recent sea and therefore, though of tertiary origin, are no longer contained in tertiary strata, but in alluvial strata, into which they have been newly and posthumously imbedded. This, indeed, is the case with a great many accumulations of shells along the base of the ancient bluff-line at Uyeno, Oji, and other parts of Tokio and its suburbs, where we find shells of the same description and of the same species as in the more ancient and deep shell layers of Oji, Surugadai &c., under the soil of the rice-fields, spread along the base of the diluvial hills. This origin of the shell-deposits found in those places is indeed rendered obvious by the occurrence of undoubtedly tertiary layers in their close vicinity and by the absence of any other cause which could afford the shells. But in such localities, as for instance on the southern side of the Yokohama-bluffs, where the waves of the sea come actually into close contact with the base of the bluff, or at least very near it, it is sometimes impossible to draw a certain distinct limit between recent shells and tertiary shells deposited in a secondary way by the torrents, breakers and waves of the present age. We may add, however, that in such cases this distinction is generally of slight importance and serves only to make still more evident the necessity of utmost accuracy in all those researches which concern alluvial shell-deposits.

If we try to classify the alluvial formation, we may proceed in two ways, either arranging them simply according to their chemical and mineralogical qualities, or according to their geological age or comparative antiquity. In the first case, we are to separate the clayish and sometimes somewhat calcareous deposits of comparatively calm and stagnant water, together with the peat-deposits made in perfectly stagnant water, from the sand deposits of rivers running with some rapidity, or of the shore of a rougher sea. We may say indeed, that the minerals contained in the rocks from whose destruction the alluvial deposits have been formed, are not without influence on the nature of these deposits (the magnetic-iron sands of the eastern coast being a striking example of this influence), yet the minerals forming the greater part of those sediments—quartz and common clay together with some lime—occur in almost every kind of rocks and are scarcely wanting in any locality. We see, therefore, that modifications produced by the action of water are of the greatest importance for the constitution of any sediment, and serve above all to sever the different sorts of bulk and weight, causing in one instance coarse sands or even conglomerates, in another fine-grained, or impure sands, in a third clayish parts to be gathered and deposited together. Thus, we see along the coast surrounding the plain of Tokio, sands and clayish soils alternating and often occurring close to one another, according to the degree of exposure or protection of the part of the strand to which they belong. Thus, sandy deposits prevail along the open coast, especially along the eastern coast, but there are also parts of the shore of the Tokio-Bay which are sandy in consequence of their being exposed to the direct influence of the waves of the sea. One of these places is to be seen along the road from Yokohama to Odawara, and is one of the best examples of this kind. Another kind of soil, which is not very frequently met with near Tokio, is also found near Yokohama—the peat and peaty soil. Near Takigashira-mura we have the following section in those parts which cover the strata to be mentioned in one of the following chapters, and which at the same time are situated nearer to the sea:

1 Meter	of sandy clay, blackish and intermixed with peat.
0.6—	peaty substance.
0.5—	impure sand, coloured dark by peaty admixtures.
0.2—0.3	loose conglomerate (rounded pebbles with dark and somewhat peat-coloured soil between).
0.4—	impure sand mixed with pebbles.

Under this layer we have that line of umcomformability, which separates the quaternary beds from the tertiary deposits, and which we shall discuss hereafter. The layer next to that line is a shell-layer of a similar importance and of the same character, mostly also containing the very same species, as that of Oji. As to it, we refer to the 6th chapter, and add here only, that clayish soil, always a little sandy, is widely dispersed through the bay near Takigashira, in which we find a profusion of such species of shells which seem to be typical for calm and shallow water, e. g. the Lampaniæ (L. multiformis Lischke and zonalis Lamck). It is therefore not astonishing to find near this part of the coast, on the low grounds which are cut by the canal joining the bay with the harbour of Yokohama, those alluvial deposits which indicate the calmest and most stagnant waters. Of course these peat-deposits are truly alluvial, as is clearly shown by the underlying pebbles, to some of which recent oysters are attached, which however in their origin have been certainly diluvial. Most of these pebbles at least form a diluvial layer which only in its upper parts seems to have been greatly affected by alluvial waters. The lower parts of the river-beds are likewise more clayish—and in some instances peaty—within the bay than on the eastern coast, where sands prevail often to some distance from the sea. This cannot be well explained by any difference between the river-courses themselves, but it is perfectly accounted for on the supposition that the same causes acted upon the land before it reached its present extension, at a time when the shore was situated nearer to the base of the bluffs, but when the elevated bluffs were already in existence and opposed to the low-level-plain. This period, of course, belongs to an earlier part of the recent or alluvial age.

This fact which will be treated in the concluding chapter of this memoir, leads us to consider the difference exhibited by the alluvial sediments according to their age. It may be said, however, that a distinction between older and younger deposits of this kind cannot be made everywhere—just as we have seen already in the introduction that on the slopes of the mountains encircling the plain of Tokio we cannot draw a certain line even between the two main divisions of the quaternary age, the diluvial and alluvial formation. Indeed the distinction of old and new alluvial deposits is confined to broader river-valleys, whenever they show the phenomenon of *terraces*, slight as their height and importance may be. By examining our river-beds, we shall very often recognize such terraces, and it would be perfectly erroneous if we should confine that name to the very large, nay gigantic terraces of some of the river-valleys of North America. In any part of the European continent, for instance, we find terraces along the river-banks of a few metres of height, and this seems to be indeed the rule, whilst those very high terraces apparently have an exceptional character.

The phenomenon is moreover in perfect conformity with all the laws which concern the action of water, erosion &c, the water of any river always tending to cut into the soil and to flatten and lower the parabolic line which as a rule is formed by any freshwater-course. Wherever the land is rising, and the level of the upper part of a river-course is raised above the level of the mouth, of course the phenomenon is rendered more obvious. I have already mentioned, and shall recur to this fact, that such is the case in Japan, or at least in the environs of Tokio. We may not be astonished, therefore, to find terraces along many of the larger rivers mentioned in the first chapter, among which the Tonegawa may be said to be a good example, although terraces are formed along the banks of almost all the rivers of the Tokio plain.

Of course the deep incisions made by the rivers in the middle and upper part of their valleys do not strictly, at least not exclusively, belong to the formation of terraces, and this is easily seen from the very slow but unvarying deepening of the river-beds themselves within the broader parts of the valleys. We cannot deny, however, that a part of this action at least belongs to the terrace-period. Most likely in the upper parts of the valleys this action began already at a time anterior to the alluvial era, continued during all its earlier part, or during the terrace-era, and continues still during the later part of the alluvial age.

In such cases where we may trace the limits of the terrace formation, we shall be very often aware of lithological, or mineralogical, differences between its deposits and those anterior and subsequent to it. During the diluvial age conglomerates are of frequent occurrence—as the following chapter will also elucidate—alternating with sands and clays. This is sometimes, but comparatively seldom, the case also in the terrace-formation, in which *sands* are more common. It differs by this character also from the more recent deposits which are richer in clay, peat and calcareous layers, and this difference is well explained by the more uniform movement of the waters which made those older deposits. Though in the average the velocity of the waters was not greater—perhaps somewhat smaller—at that time than it is now, yet the want of stagnant parts of the river-courses and the comparative uniformity of the slope as well as of the breadth of the valleys could but have such consequences. They are, however, less conspicuous in the plain of Tokio than in many other countries, for instance in the plain of northern Europe, where the bulk of the older alluvial deposits (corresponding to the American Terrace- or Champlain-period) is almost entirely built up by the so-called 'Thal-Sand,' or sand of the valleys.

CHAPTER III.

THE DILUVIAL DEPOSITS.

In the introductory chapter we have already sketched the mode in which the very important older quaternary strata have been deposited under the surface of the sea at a period anterior to the present (or alluvial) age. These strata contain in some cases remains of extinct animals, but in Japan do not betray any traces of glacial origin. Owing to the horizontal position maintained by these strata from the beginning, they have been cut through by rivers and rivulets; and along the banks of the streams, as well as in road-cuttings and banks along the sea, we have geological sections through these diluvial strata which sometimes expose their whole extent. In many cases, which have already been alluded to, and which will be mentioned in the following chapters, these sections are of the highest value for our investigation; whilst, in other instances, we have the slopes made less steep by superficial waters which always tend to sweep down parts of the soil and to obliterate any sharp contrasts of level in the surface of the earth. In consequence of this action there are also cases in which the upper parts of the diluvial formation have been sliding down along a sloping hill; as a rule, however, the upper strata only cover the surface of the higher plain.

A few instances, moreover, are to be noted where the lower part of the formation is, as it were, a little swollen, and therefore appears at the surface. This is mostly the case where sands prevail, and we may say, that in such localities the upper part of the diluvial deposits is wanting or reduced to a very thin layer scarcely to be perceived in a geological section and often entirely mixed up with the fertile and humose soil supporting the vegetation. It is also impossible to say whether fossil remains found in such localities really belong to the upper part of the diluvial formation, even if they are found directly under the fertile soil—as this has been the case with one or two of the remains of elephants to be mentioned below. As all those remains, about which we have more accurate information, have been either found in deeper cuttings or have been dug out under water, it will be safer to refer all the elephants' remains to the lower part of the diluvial formation.

The *upper part* of the diluvial deposits is surprisingly uniform, and the contributes much to the even character of the surface of the upper plain. In the cuttings we see almost invariably a stratum of 3 to 6 meters thickness overlying the rest of the diluvial formation.

This upper stratum is a somewhat coarse clayish sand of a reddish brown color. An analysis made under the direction of Professor Atkinson, of the Daigaku, by one of the students, gave the following result.

COMPOSITION OF THE LIGHTER PORTION OF SAMPLE AFTER LEVIGATION.

24,40 percent of the whole.

Siliceous acid, Si O_2	65.15 %
Sesquioxyd of aluminium, Al_2 O_3	19,20
d° of Iron, Fe_2 O_3	7,76
Lime, Ca O	1,49
Magnesia, Mg O	0,12
Phosphoric acid, P_2 O_5	0,20
Loss on ignition	6,03
Total	99,95 %

It is remarkable that 'alkalis appear to be wanting'—a fact which in itself serves to refute the notion that there is a small amount of phosphoric acid in the Japanese soils. The superficial diluvial layer, often overlying very loose sand or conglomerates, and always subjected to a degradation by the rain-water which is mostly kept for a long while on or near its surface—the soil being but little pervious to water—, has lost its alkali-salts, and yet a tolerable amount of phosphates is left in it. It may be added that not all such soils are free from alkalis, the amount of carbonate of potash being sometimes more than one half percent and that of carbonate of Soda at least more than 2 per mille. The sand, comprising the *coarser parts* and (amounting to 75,52 percents of the whole, contains

Siliceous acid, Si O_2	69.885
Sesquioxyd of aluminium Al_2 O_3	15.285
d° of Iron, Fe_2 O_3	8.645
Lime, Ca O	1.875
Magnesia, MgO	traces
	95.690

and therefore contains decomposed silicates together with quartz, the silicates having chiefly furnished already clay and limonite. The presence of a larger quantity of this last-mentioned substance is shown also by the color of the soil.

The stratum which does *not quite conformably* overlie the lower part of the diluvial deposits shows clearly that there was a gradual and gentle passing from one part of the formation to the other. It may be remarked that slight unconformabilities often occur within the diluvial formation. Though they are by far less numerous and less important here than in all those places where we are to assume a glacial action, yet they are to be observed, and, at the same time, are in perfect agreement with the nature of the diluvial formation. For this formation is one of rather quick destruction and turbulent deposition of soils in comparatively shallow seas and near the shores—a fact which accounts for their being spread chiefly along the present shores or at least in wide and low plains bordering the sea on one side. The unconformability in question, however, is more striking and appears so often and so strongly that we are indeed obliged to divide more sharply the upper from the lower diluvial layers.

The mode of deposition explains also fully the great *variety* which we find among the *lower* diluvial deposits even within narrow limits, all of which may be determined as a mixture of conglomerates, sands, clayish sands and clays, of which sometimes the one and sometimes the other prevail.

Now the uniformity of the uppermost layer gives another reason for separating this deposit from the rest, and one more may be derived from a striking character, the want of any traces of true stratification *within* it. This want may be explained in a different way; but by far the most probable explanation seems to be that those uppermost diluvial deposits, though they correspond exactly, lithologically, to the *loam*, and differ from the true, '*loess*' of the Europeans by not having a sufficiently large amount of lime, have had an origin analogous to that of the large deposits of loess found by Baron von Richthofen in Eastern Asia.

Those loess-deposits had accumulated by the action of *wind*, according to theory of von Richthofen, and though this theory, which points out the *subaërial character* at least of a very great part of the loess, is a very new one, yet it has been discussed already most copiously and may now be regarded as fully confirmed.

Far as I am from assuming an exclusively subaërial origin of any loess, and ready as I am to admit that there are loess parts, e. g. the lowest strata around the larger basins filled by it, which do *not* exhibit any signs of subaërial origin and are undoubtedly stratified (showing alternate layers of loess and conglomerates, or of loess containing many loess-shells, and other parts devoid of them), yet the majority of the loess-deposits remains, and corroborates the above-mentioned theory. Slight as the upper diluvial deposits of Japan are if compared with those of China and Mongolia, it is scarcely possible not to admit an analogous origin, and this assumption moreover is in perfect accordance with the *age* of the analogous European deposits which we know to a certainty were formed at the conclusion of the diluvial epoch.

The want of lime, which (as the analysis shows) is not a complete one, is of course much less important than the fact of the analogous mode and period of deposition.

This want of lime may be explained either by a comparative scarcity of rocks furnishing lime by their detrition and decomposition, or by a subsequent loss of it which has very often been observed in such diluvial deposits as are placed next to the surface and therefore have been exposed for a long time to the action of atmospheric water. All the minute researches on the superficial, and above all on the superficial quaternary sediments confirm this theory most completely, a theory which as far as I know was first published by a German author Professor Dr G. Berendt at Berlin (as well in his papers published by the 'Geologische Landes-Anstalt' at Berlin, as in some papers contained in the periodical of the 'deutsche geologische gesellschafit'). I have had many opportunities when surveying and mapping in the Province of Brandenburg, Germany, to observe the correctness of this theory. In many instances only an upper layer, of irregular extent, and limited by an undulating line at a little distance from the surface of the soil, has lost its lime; but in some other instances, where the thickness of the marly soil was not very great, and where sands or conglomerates pervious to water were underlying it, it is seen to be completely deprived of lime.

It needs scarcely be added that the *loess* is very often subjected to the same law and very often has, in its superficial parts, lost that higher percentage of lime which is always found in normal loess. Now moreover we find in such soils, out of which the lime has been washed by the atmospheric water, a certain degree of accumulation of clay in the lower and a comparatively small amount of it in the upper part. This, of course, is also quite natural, as, in the process of outwashing, the soil becomes loose and the clay can also be washed out of it to a certain degree, and thus carried down and, in many instances, accumulated in the lower part of the outwashed soil. In other cases it may be even taken down into loose sands &c. underlying the smaller layers of marly and afterwards loamy soil.

That the sandy clayish soil of the upper part of the diluvial formation of the Tokio plain has no lime and a higher percentage of clay than other soils of an analogous origin and of the same geological age, cannot be surprising, even if we do not take into consideration that all the true loess, at least that of Europe, has been derived from rocks worn and ground by glacier action.

Rocks thus reduced to powder would be much less exposed to loss than rocks converted into detritus by the action of water alone. Both causes combine to diminish the amount of lime and to increase the amount of clay, the first being about 14 % in the loess as well as in the glacial marly mud (bond-moraines of the Swedish authors) covering a great part of the surface of the northern European plain, and only about 2 % in the upper diluvial deposits of Japan, whilst the sesquioxyd of aluminium, about 8 % in the loess &c., rises to the double amount in the latter. In the other substances, especially in the amount of silica and iron, there is no essential difference.

For instance, we have 62½ percent of siliceous acid in the loess and 65 in the Japanese soil. The only difference still to be noticed is the presence of a small percentage of alkalis (2.3 totally) in the loess—a difference which, as has been already stated, is doubtlessly due to the dissolving action of atmospheric water just as well as the small amount of lime.

The soil in question is practically of a very great importance. It renders the plain of Tokio fertile even in those parts which are not situated in river-valleys and depressions (filled with the alluvial deposits sketched in the foregoing chapter); although not all of the higher plains are cultivated, yet their vegetation is almost everywhere a copious nay luxuriant one. The tree-plantations and the woods are thriving, the groups of trees round the villages and temples are quite as richly developed as those in the lower grounds, and even the bamboo is scarcely inferior to that of the marshy djungles. The Matsu- and Sugi trees are very often met with in large and beautiful specimens. But above all the fields containing barley, wheat, buckwheat, the various kinds of millet, beans, Sato- and Satsuma-potatoes and other vegetables are very fertile and contribute in a high degree to the almost luxuriant crops which Japan enjoys in spite of its singular and, as a rational agronomist ought to say, not quite correct system of husbandry. Indeed except that quite correct idea of confining the rice-farming to the low grounds, which is said to be a divine suggestion, the author must confess to have seen nothing praiseworthy in the agricultural system of the Japanese, although much that deserves praise in the zeal and skill exhibited by the workmen themselves. It may be safely said that even this diligence and industrial cleverness of the farming people would not suffice to provide them with good crops if the soil was not fertile in itself. Among those sorts of soil which are to be highly valued, the upper diluvial soil is one of the best and at the same time one of the most widely spread, as it covers a very large portion of the Tokio plain. Valuable, however, as this soil is in respect to farming, it is rather unfavorable to civil engineering; and to a great part the very bad state of the roads of the environs of Tokio is due to the same cause. Indeed it is surprising to see, in the very neighbourhood of a capital of the largeness and importance of Tokio, the roads so bad and, I may say, so primitively constructed that any large rainfall, any thaw in winter unvariably makes them nearly impassable. This would, perhaps, not be the case, if the roads did not cross, in the Tokio-plain, very often and for long distances the sandy clay of the upper diluvial formation, which is impervious to water. In dry weather, the roads made of this soil are tolerable, and so the inhabitants are led to believe erroneously that the roads are not very bad and that the weather is the cause of those disasters and hindrances in travelling which—as is well worthy of notice—occur not only in side-roads, but in the most important high roads. Indeed some of the governors of provinces and districts especially in the north of Tokio have begun to improve the roads partly by digging out ditches and moats for drainage and to correct the road itself by the addition of gravel and pebbles or fragments of stones. But even such primitive improvements are far from being frequently made, and wherever they are not, the roads on the high-level plain between the valleys are equally bad with those on the embankments between the rice-fields or on the small dikes crossing the low grounds or running along the river-banks.

The lower part of the diluvial formation is practically far less important, though it has, as a rule, a much greater thickness. It may be added also that it varies much more lithologically and contains either impure conglomerate or sand or clay, and sometimes even an admixture of tufaceous parts. Very seldom, however, is it uniform in its totality, for we very often see the inferior part of it to be clayish whilst the upper part is formed of conglomerate. As a rule, we may say that conglomerates predominate. In many places we see 6—8 meters filled up entirely by them and it is very seldom that they are entirely wanting.

Even where clay prevails, small layers of conglomerate are inserted between it, and pebbles or other coarser objects are often intermixed with the sands or clays. We may besides add that these sands and clays, together with the conglomerates, are always *stratified;* the stratification of sands and conglomerates often passing over into those undulating layers so often seen in them, whilst the clays are perfectly horizontal and exhibit many smaller and larger strata.

Though it seems very difficult, after all, to give a good idea and a picture of the diluvial strata, we add a small sketch of the bluff next to the railway station of Kanagawa (NE from it). It exhibits the horizontal surface of the upper plain, the upper diluvial sandy clays unconformably overlying the lower diluvial strata of clay, conglomerate and sand, which are not of a very great thickness at that place and unconformably overlie the sedimentary rocks described in the following chapter. (Pl. I fig. 1).

The practical use of the lower diluvial deposits is confined mainly to the *conglomerates*, which, if tolerably pure, are frequently dug out for engineering purposes. Less important is the use of some of the clays for making bricks, or tiles, or even—in small layers of purer quality—for making pottery in villages whose inhabitants are accustomed to draw the materials required for it from their neighbourhood.

The admixture of the lower diluvial strata with the tufas belonging to the volcanic rocks of the southern coast near Yokohama etc. is not to be omitted, although, within the limits of quaternary rocks, it is by far less extensive than in the tertiary formation. It may be said to be almost fully explained by parts of the tertiary tufaceous rocks being destroyed and deposited again by the diluvial sea. Although the outbreak of ashes and lapilli continued through the present era, and must necessarily have brought some material of that kind between the sediment of quaternary origin, yet by far the greater part of that admixture seems to be a secondary deposit and carried over from tertiary tufaceous strata to the quaternary ones. The volcanic energy, indeed, must have begun to abate long before the present era, and most likely about the end of the tertiary and before the very beginning of the diluvial epoch.

The organic remains of the diluvial formation of Tokio and its environs are not very numerous.

First we must mention the fragments of wood, half decomposed or even entirely converted into brown coal, which frequently occur in sandy or clayish diluvial beds, especially near their lower limit. Prints of leaves are but sparely distributed among those fragments of stems, or of roots, all of which belong to recent species. This is of course to be expected as even most of the youngest tertiary fossil plants do not belong to other than surviving species. The leaves occuring most frequently are oak—and ash-leaves, those of maples, chestnuts, whilst the fragments of wood belong to the sugis or cryptomerias and other coniferous plants now living in Japan.

The molluscous shells, which may be divided into land-and fresh-water shells (mostly Helix, Melania and Cyrena) on one side, and marine shells on the other, also belong mostly to surviving Japanese species. This may be even exclusively said of the land-and fresh-water shells, but not so exclusively of the marine shells, because among these there are some which have been washed out of tertiary beds and redeposited. In this case, of course, the preservation of the shells is inferior to that of the shells of the tertiary layers themselves; fragments prevail, and that sort of fresh lustre which is very often found in alluvial shell-deposits of any origin, is entirely wanting, just as it is only exceptionally seen in the tertiary beds. The same may be said of course about crabs and crayfish, star-fish, corals and bryozoa, whilst reef-building corals, as scarcely needs be mentioned, are wanting in all the quaternary deposits.

Among the terrestrial animals we have only mammals, and even among these the number of species is rather limited. Stag's antlers have been found, but it has not been ascertained whether they belong to Cervus Sika Sieb. or to some other species extinct in Japan, so that it would not be allowable to speak of the existence of any such species. A great many vertebrae of Cetacea have been collected, and as far as may be concluded from the descriptions of the localities, partly in diluvial strata; for whilst in some instances it is reported that they have been found in deep valleys, yet in other cases the reverse is asserted. The species they belong to, could be only very imperfectly determined; in one case a skull was dug out which belongs to Phocaena globiceps Cuv. whilst in another one the teeth which had been found are those of Phocaena Orca L. Several other species will no doubt be added to this incomplete list.

Last, not least, the Elephant-teeth and jaws are to be mentioned, which belong to *two* different species.

FIRST SPECIES.

1) Four branches of the jaws of one—apparently young—animal have been found not exactly within the limits of the district we are describing, but are well worth mentioning in other repects. The number of plates is comparatively small; the teeth moreover, in spite of being very large, are undoubtedly milk-molars. There are two in every branch, and the posterior one is not ground at all, but has the ridges or plates rather prominent. I count 5 plates and one (posterior) talon in the anterior teeth of the lower jaw, four plates and one (posterior) talon in the anterior teeth of the upper jaws; the anterior side is much worn and partly destroyed. The length of the lower teeth is 66 millim., that of the upper 50 m'm, the breadth of both is 38 mm. The posterior teeth are not fully grown out of the sockets, and their posterior end is not visible. The number of the plates visible is 5 in the lower jaw, with one (anterior) talon. In the upper jaw there is one plate less. In both jaws one plate, or perhaps one plate and a talon, must be added to the number of the visible plates. The length is 50 mm.

The small number of plates is remarkable in so large teeth (whose entire height, however, is comparatively small; it is visible in the posterior part of the left upper jaw, and by this circumstance alone the teeth are proved to be milk-teeth). This fact excludes every possibility of regarding this specimen as belonging to the second species to be mentioned, viz. E. antiquus. Besides, the solidity, and the little deviation from the oblong form exhibited by the plates and the ridges corresponding to them, together with the form of the mandibles, as far as they are preserved, make it certain that we are dealing with *Elephas meridionalis* Nesti. This species has been establisted by Nesti in the Ann. Mus. d. Firenze, vol. 1, p. g, pl. 1, f 1 and 2, and the name is synonymous with E. Malbattu and with 2 names given also by Nesti, viz E. minutus and E. minimus, ib. pl. 2, f. 1. The latter of these two names is not to be confounded with an E. minimus Giebel, which is nothing but a young E. primigenius Blmb. The comparatively large size of the jaws of the very young animal, and, as I said, the form of the lower jaws attest also this relationship. The mandible could be directly compared with a plaster copy of one of the standard specimens of Elephas meridionalis, and showed no difference in any proportion, being only as much smaller in all dimensions as may be fully explained by the young age of the individual. The so-called gutter is of the normal size, the angle of the branches of the mandible equal to 115°. The entire mandible is 390 mm long. 300 mm wide at the posterior end. The first 215 mm open more slowly (the interval reaching only 70 mm, whilst the breadth of the bones is 100); the anterior extremity is 70 mm broad (in the median line).

The locality in which this specimen was found is in the neighbourhood of the Biva-lake, province of Omi. Further details about the way in which the bones were found and how they were deposited, I have not been able to ascertain.

2) As this first specimen, though the completest of all I have seen in Japan, does not belong to an adult animal, another one is of importance, though topographically still farther separated from our area. It has been found in the province of Iyo, in the island of Shikoku, and is a huge last molar tooth colored very dark brown, almost black, with all the lustre of the fresh tooth, but covered in a few places by serpulae and small oyster-shells. It belongs to the right branch of the mandible and has a total length of 200 millimeters, a breadth of 90 and reaches a height of 110. It contains 8 plates, the two last of which are small, the penultimate worn very little and the last one not at all. The crowns are broad, highly elevated and conically ascending; their length reaches 75 millimeters.

3) The third specimen of Elephas meridionalis Nesti is a lower jaw found in the year 1868 near Yokosuka (Sagami), which therefore belongs to the district in question. It was taken to Paris by Dr. Savatier, and is mentioned by Antonio Stoppani in his 'Corso di Geologia,' vol. 2, p. 677 (Milano 1873). Together with the remains of the next species it proves the coëxistence of these *two* species of Elephas not only in Japan but also in the environs of Tokio, just

as in Italy and other parts of Europe.

The definition of the beds in which this remain of Elephas meridionalis was found, as an 'alluvione' (l. c. in Stoppani's Corsa) seems to indicate that we have to deal with those quaternary deposits which are contemporaneous with the alluvial as well as the diluvial era, and which have been discussed in the introductory chapter. At all events the expression which Stoppani uses on this occasion, viz., 'terreno glaciale,' or glacial bed, is not founded on any strict observation, and means nothing but what we call the *diluvial* age of those beds. It may be observed that Stoppani assumes far too much in referring all these beds to a glacial origin.

SECOND SPECIES.

1) A tooth of 11 plates and 2 talons, 45 to 50 millimeters broad and 100 millim. long with a height of 125 mm in maximo, is a true molar, though not the last one, of the upper jaw of a comparatively large, though not perfectly full-grown animal. The narrowness of the crown together with the rather large number of plates, and the slight dilatation of the plates in the median line of the tooth, which in spite of the oblong (nearly linear) shape of the plates is distinctly to be seen, makes it quite certain that we have to deal with Elephas *antiquus* Falconer. The comparatively less solid and much folded enamel-coats of the plates give a further difference from E. meridionalis Nesti, which is chiefly distinguished by the smaller number of plates; E. primigenius Blumenbach, on the other hand, has no dilatation of the plates in the central part of the tooth, though in other respects its characters are quite similar.

This specimen has been recently found in the Province of Kishiu, not far from the southern extremity of the main-island, south of Osaka. Although, like the first specimen of E. meridionalis, it does not properly belong to the district we are describing, yet the distance of the locality in which it was found is not so great, that it need be excluded from our list, which is far from being a long one.

2) The second specimen which undoubtedly represents an upper last molar of a somewhat older individual, is 140 mm long and 50 mm broad with 125 of height in maximo, and has 14 plates. A part of the tooth (anteriorly) being broken off, we cannot say what has been the real number of plates. Most likely, there were but very few more. The plates exhibit all the characters of *Elephas antiquus* Falconer; the enamel-layers are still more folded and comparatively weak.

This specimen has been found at Kibara Mura, a village bordering the above-mentioned lake, the Kasumiga-Ura, north of Tokio (Province Hidachi), and is said to have been found under the surface of the water.

3) The third specimen, a mandible, found in a deep cutting—according to what is added, most likely a gravel-cutting—near Yokosuka (Province of Sagami)

is still more suited to confirm the determination of the foregoing specimens. Its crown is narrow, 45 to 55 millim., whilst the tooth is 165 mm long and has 14 plates of the same nearly oblong form with a marked, though not very large dilatation in the middle.

4) If the last mentioned specimen belongs already to the Tokio-plain, the fourth one has been found in the metropolis itself near Yeddonbashi, in the diggings made for the construction of the post-office situated in the neighbourhood of this bridge. It is a right upper first true molar, not very large, 183 millim. long, 55 broad (crowns measuring up to 50, but mostly not more than 40 mm), and has a triangular shape in the profile-view, the highest part reaching 140 millim. The number of plates is 11, with 2 talons (the posterior of which is more distinctly visible than the anterior one); the enamel is often and deeply plaited.

Altogether, these 4 specimens leave no doubt whatever about their belonging to the true Elephas antiquus Falconer, a species formerly confounded with the mammoth, but separated from it for sufficient reasons.

This was chiefly done by Falconer in an essay published after his death, 1865, which is mostly referred to by A. Leith Adams in a paper published by the Paleontological Society of London, 1877.

These Proboscidean remains show, I dare say, to a certainty, that during the diluvial age there were Elephants in Japan which belong to palæarctic quaternary forms.

They seem to have been rather abundantly spread at least in the central part of the main-island, but they do not show close relationship with the Siberian elephants, as they do not belong to truly boreal forms indicating a very cold climate. Elephas antiquus, though found in localities not far distant from the area of the mammoth (e. g. in Thuringia) and sometimes even within its area (in England), has not been found in any truly glacial deposit. Still less this is the case with Elephas meridionalis.

The elephants of the diluvial deposits of Japan form, after all, a valuable link between the tertiary and recent faunae, and confirm what is said in the first chapter about the close resemblance of the western and eastern part of the palæarctic region.

As to the relations to American elephants, the Elephas americanus might be compared, which also belongs to a warmer climate. It is at all events very closely allied to Elephas antiquus; but its enamel plates are asserted to be less crowded. As the discussion about this object would lead us too far, I do not enter it; the less so, as we may quite safely refer all the Japanese specimens to palæarctic diluvial species, and moreover to such as belong nearly to the same latitudes.

It has been already said that there is no sufficient reason for extending the era of the Japanese Elephants beyond the reach of the *lower* diluvial deposits, to which the same species mostly, if not totally, are also confined in Europe.

CHAPTER IV.

THE TERTIARY DEPOSITS OF OJI.

In the introductory chapter, I have already alluded to the remarkable fact, that there is a great difference between the diluvial beds and the strata beneath them. As a rule, these diluvial beds are also divided; we can often very easily find a line which separates the upper diluvial loam from the lower diluvial beds, and which is truly a line of *uncomformability.* This is quite natural, as the upper diluvial formation—according to what is said in the preceding chapter—has been deposited in a perfectly different way. The lower diluvial strata, not intermixed with any products of glacial action, are eminently conformable. Thus another line of partition, another true line of *uncomformability* becomes highly important. It is formed at some distance from the surface of the soil, although, of course, that distance varies and is often so great that the lower strata are not exposed. The appearance of this line is very nicely exhibited in some of the localities which I am to mention, e. g., at Oji, Fig. 4 and at Kanagawa, Fig. 2 & 3.

At Oji, the very lowest part of the exposure shows the line of position and the strata below it in a similar way, as they are seen in deep cuttings. At Kanagawa, the line of unconformability appears much higher, as it does also in a great part of the bluffs near Yokohama. Those at Kanagawa, a portion of which I have designed, are very near the Kanagawa station, and between the railway and the sea. They give perhaps the best idea of the true nature of that line, which here takes an undulating course, and so becomes very clear, although there is no visible difference in the angle of dipping between the two formations. In other instances we can very easily recognize such a difference: for instance, in the bluff of the sea-side south-west of Yokohama. The difference is more than 4 degrees, and amounts up to 6 degrees, the lower strata being inclined to the west whilst the upper strata continue to be horizontal. This difference would be indeed perfectly sufficient to prove that this unconformability is more than what is usually seen between two subordinate divisions of a formation, even if the angles of dipping of the inferior strata was not sometimes greater. At Sukegawa and between this place and the town of Mito, it is very often about 10°, and never below 8°, whilst in some places it rises to 14°, the direction of dipping being here nearly or exactly north. Thus we find the lower formation undulating throughout, and its upper limit is quite irregular in consequence of the erosive action of water during a subseqnent period, after which another sedimentary formation was deposited.

If we do not confine ourselves to the plain of Tokio, we find even higher angles of dipping within the formation immediately underlying the quarternary deposits. In the province of Chichibu, the sandstone, conglomerate and shale, mentioned in the introductory chapter, have an angle of dipping mostly of 30°, or rather from 30° to 40°, directed towards W 30° E; in a few instances, near the borders of the basin filled by those strata, it amounts to 55° or even a little above, the direction changing to due North. As it has been already stated and will be discussed below, the fossils contained in these beds are to so great an extent the same as those of the strata which in the Tokio-plain appear directly below the above-defined line of unconformability, that there can be no doubt about all these layers belonging to one and the same formation.

This, of course, could not be affirmed without some deeper study of the fossils, and I think, it is quite necessary for the advancement of our knowledge of this highly important formation to give the results of the observations thus far made upon it, without attempting for the present to make them quite complete. Indeed, it does not seem advisable, to extend at once those researches to other animals than mollusca, or to the fossil plants occasionally found in these *uppermost tertiary* deposits of the environs of Tokio, as we may call them quite safely. Although we find almost always fragments of stems of monocotyledous, dicotyledous and gymnospermous plants, and although a few nice small specimens of corals, some sea-urchins, as e. g. Echinocyamus and Scutella found at Oji, and even occasionally, for instance in the province of Mino (Togari and Tsukiyoshi) some crabs or fish may be found between the remains of mollusca, yet the number of the latter so far exceeds that of other organisms, that we may now confine our attention advantageously to an analysis of the mollusca.

In giving the list of the fossil shells, I think it advisable first to separate them according to the localities. I hope thus not only to leave no doubt whatever about the uniformity of all those localities and shell layers, but also to give a full account of all the facts peculiar to each of them.

The locality first to be mentioned is Oji, see fig. 4, a village in the neighbourhood of Tokio, situated beyond that part of the town which is called Hongo, and nearly N.N.W. from the centre of the town. The distance of Oji from Nihonbashi is about 2 Ri., from the centre of Hongo about 1 Ri (one Ri being nearly equal to 4 kilometres).

Arriving at Oji, we see first a cutting containing sandy conglomerates of the lower diluvial formation under a cover of the upper diluvial loam, next to the road descending from the height of the plateau down to the rivulet passing through the village. After crossing the river and ascending the plateau on the other side, we have the same formation, viz., upper and lower diluvial strata. We see here, however, some clayish layers between the conglomerates and sands. Passing on a little more to the west, we find the deep cutting in which a corn-mill is situated, and in this cutting, very near its bottom, are those shell layers, which are richer in shells, individuals as well as species, than any of the other localities to be mentioned. It is obvious from the very first glance at the place or at its figure (Pl. I. fig. 4) that we cannot possibly have to deal here with any accumulation of shells made by men; the thickness of the diluvial deposits, here still more clayish, being not less than 7.3 meters. Of this thickness, 3 meters belong to the upper diluvial loam (which itself is covered by 0.5 to 1.5 meters of soil), and 4.3 meters to the different parts of the lower diluvial formation (2.3 clay, 0.3 conglomerates and 1.7 clay again, measured from above.)

The shell-layers are found immediately below the line of unconformability which is sufficiently undulating to be recognized; they slowly pass into impure dark clayish strata, somewhat poorer in organic remains, and in the lowest part containing almost none at all. Those clays are visible in a thickness of 3 meters measured from the shell-layer, which, in the average, is not thicker than 0.5 meters, though sometimes rising to nearly 1 m. The difference it exhibits from the—unconformable—diluvial deposits, is of course much sharper, and above all we do not find any well preserved shells above the line of partition. There are only a few casts, apparently belonging to shells of the same species as those of the layer, imbedded in them together with fragments of wood etc. The shell layer is not confined to the mill, but extends to the north and west. Here it is repeatedly intersected by cuttings made for canals, and sometimes also it appears in the banks of the river itself. But it is not uniformly rich, as we may see in many of those places, some of which seem to have been in some instances mistaken for remains of shell-mounds. The true shell-mounds, alluded to by Professor Morse in his memoir, are, however, quite different and situated both sides of the road from Tokio to Oji, near this place, but next to a village named Nishiga-Hara-Mura. At a larger distance from the mill, the number of shells is rapidly decreasing, at least as far as the investigation of the layer could be carried on; and as all the species found in the other places are included within the number of those found next to the mill (in the steep slope seen behind the mill seen in the sketch, along the small canal, and in the tunnel to the right), I may confine myself to the following list of species found in this locality.

THE SHELLS OF THE LAYER AT OJI.

Gasteropoda.

Neptunea arthritica Valenciennes. Plate II fig. 1 (comptes rendus de l'acad. des sciences nat. 1858, vol. 46, page 761. Bernardi, Journal de Conch. vol. 6, Page. 386, plate 12, of 3. Schrenck, Tritonium arthriticum, Nordjap. Moll. page 421. Lischke, Japanische Meeresconch. v. 1, page 37.)

Not very frequent at Oji. Recent at Hakodate; as to the generic denomination, I think it best to adopt Lovén's genus.

Trophon Gunneri Lovén.

(Index Moll. Scand. page 12. No. 84. Wood, Crag Mollusca. Suppl. page 27, t. 3, fig. 18.)

This species, recent from the boreal seas, fossil from the glacial beds and according to S. V. Wood from the Norwich Crag of England, has been very rarely found at Oji. I have before me only 1 specimen with 5 whorls, 2 of which are smooth, and the last of which has 11 to 12 frondiculated rib's. It is 7 mm. long and 3 mm. thick.

Nassa Japonica Adams.

(Genera Moll. vol. 1, p. 120, Caesia Japonica ; id. in Ann. and Mag. Nat. History 1870, vol. 5, p. 426.—Lischke, Japan Meeres-conch. III, p. 37, pl. 2, f. 20-23.—Non Nassa Japonica Reeve, Demoulea Japonica Adams, in Reeve; Icon. Nassa, pl. 29, f. 192).

Without trying to criticize the statements made by Lischke, I confine myself here to identifying with his species one which is very frequently found at Oji, though almost exclusively in very small specimens. The turreted shape and the nice transverse striæ with broad, somewhat convex interstitional lines, go almost uniformly over the costæ and give to the surface a much less granular character than in the (equally elongated) N. granulata J. Sow. The somewhat convex and rounded form of the whorls makes this identification perfectly certain.

Nassa livescens Philippi.

(Zeitscher für Malacozool. 1848, p. 135, as Buccinum.—Dunker, Moll. Japon. p. 7 Lischke, Japan. Meeres-Conch. II, page 52, pl. 4, f. 1-3).

The same is to be said about another species of Nassa, which occurred but rarely at Oji, broader, thicker, with less convex whorls, and with coarser and more oblique ribs.

Columbella scripta. Linné.

(Syst. Nat. ed. XII, P. 1225, as Murex scriptus.—Blainville, Faune française, p. 208, pl. 8, f. 20-12, as Columbella conica.—Philippi, Enum. Moll. Sicil. vol. I, p. 225 and 227, as Buccinum Linnæi.—Kiener, Coqu. viz. p. 48, pl. 16, f. 56, as Buccinum corniculatum.—Sowerby, Thes. Conch p. 127, pl. 38, f. 101, as Columbella corniculata.—Deshayes in ed. Lamarck, vol. X, P. 175, same name.—Philippi, En. Moll. Sic. vol. II, p. 190 and 193, as Buccinum scriptum Chemnitz, Conch. cab. second ed. p. 41, pl. 8, f. 19-22, same name.—Weinkauff, Conch. d. Mittelm. vol. II, p. 36. d'Orbigny, Prodr. vol. III, p. 175, as Columbella pseudo-scripta.-Hoernes, Mollusken des Wiener Beckens, v. 1, p. 116, pl. 11, f. 12.14.—Beyrich, Zeitschr. d. geol. Ges. Tert. Moll. p. 107, pl. 6, f. 8.).

This shell known from Nagasaki and mentioned by Dunker, Lischke (Jap. Meeres-conch. I, p. 57 and 58) and others agrees with fossil and recent specimens of the species, which is eminently mediterranean. The specimens of Oji are tolerably numerous, nearly as large (15 m. m. long, 6 of which belong to the aperture, 6 m. m. broad) and of the same proportions as the European.

Olivella consobrina Lischke.

(Japan. Meeres-conch II, p. 62, pl. 5, f. 10 and 11.).

A few specimens entirely corresponding with Lischke's figure—only the coloring being deficient in the fossil shell—have been met with at Oji.

Ringicula arctata Gould.

(Otia Conch. p. 122.-Lischke, Jap. Meeresconch, v. 2, p. 78, pl. 5, fig. 16. 17.).

Small specimens of this kind were the most frequent gasteropoda at Oji, being nearly equalled in number only by the Nassa Japonica and Odostomia, and surpassed only by some of the conchifera (Tellina nasuta, Solen grandis, Dosinia exoleta, Lucina borealis, Diplodonta trigonula).

Size, proportion, callosity and narrowness of the aperture, together with the 2 folds and 1 tooth above them, and with the pointed apex, are the properties which suffice together with the proportions (length to breadth 4 : 3) and with the number of the whorls (5-½) to leave no doubt about the identity of the species found living at Hong Kong and Nagasaki. The transverse striæ, not very conspicuous even in the recent shells, are but seldom well preserved in the fossil. It seems doubtful, whether the pliocene fossil shells, which S. Wood described 1848 from the british crag under the names of Ringicula buccinea and ventricosa (Crag Moll. I, p. 22, pl. IV. f. 182) belong to the same species or not. They are much larger, the length of the largest specimens of England being at least 70% greater than that of the largest Japanese. The proportions, however, the details of sculpture and form, the teeth and folds, and the thick outer lip together with the narrow aperture do not differ. In this respect, it may be mentioned that the folds are placed comparatively lower in the average in the adult and more developed specimens, in which moreover the outer margin is more thickened. Thus, though Wood says he did not see any intermediate forms, we may assume that R. ventricosa is only the full grown stage of R. buccinea, and must be erased as a species. The analogous differences we find in the younger and older shells of Oji, only—both of them—in smaller dimensions. As for the sculpture, it is quite natural to see it better preserved in the more robust specimens, in England as well as at Oji, than in the less developed specimens. Thus, it does not appear either in the figure or in the diagnosis and description of R. buccinea Wood. To a certainty, we may say that the species of the Crag, which by some authors have been already united, are at least very nearly akin to our species. This, as Gould says, is also closely allied to 2 recent Pacific species (R. caron and propinquans), which I have had no occasion to examine.

Ficula reticulata Lamarck.

(Hist. Nat. des Anim. s. vert. 2nd ed. Vol. IX, p. 510.—Phil. En. Moll. Sic. Vol. II, p. 186.—S. Wood. Crag Moll. I, p. 42, pl. 2, f. 12.—Lischke, Jap. Meeres-Conch, v. I, p. 40.—Reeve, Icon., Ficula I, 1).

One small specimen found at Oji.

Natica Lamarckiana Reeve.

(Conch. Icon. Natica, pl. 2, f. 6.—Lischke Japan. Meeres-Conch v. 1, p. 80.—Morse, Shell-Mound of Omori, pl. 18, f. 8).

Very frequently found at Oji, sometimes in rather large specimens, of 60 mm. in diameter and 50 mm. in height and even larger. Smaller specimens are rather common; they are not so typical in outlines, less broadened and flattened, but readily recognized as belonging to the same species when compared with the adult form. The adult specimens have not been found in sufficient number for comparison with the Omori-Mound-specimens. They are, in the average, between the two figures given by Morse, but nearer to the older form.

Scalaria clathratula Montague (Turbo).

(Test. Brit. Vol. II p. 297, and suppl. p. 124.—Sowerby, Thes. Conch, vol. I, pl. 33, f. 47.—S. Wood, Crag Moll. I, p. 94, pl. 8, f. 19.—Forbes and Hanley, Brit. Moll. III. p. 209, pl. 70, f. 384.—Jeffreys, Brit. Conch IV, p. 97.).

The shell, which (as e. g. Weinkauff states in the Conchylien des Mittelmeeres v. 2, p. 238) has not always been correctly determined, seems not to differ from S. Trevelyana (Leach) Sow., Thes. I, p. 100, pl. 35, f. 129. Compare S. Wood's Crag Moll. l. c. f. 20 and Supplement, p. 58, pl. IV. f. 6. The differences are not given uniformly by the British authors, S. Trevelyana being not constantly more elongated, nor S. clathratula having the ribs less angulated at the upper end. The aperture is also obliquely elliptic in both. The small specimens found at Oji do not differ at all from the Crag specimens. As for the mediterranean and fossil Viennese specimens, I leave the question unsettled.

Scalaria cancellata Brocchi.

(Coqu. Subapenn. p. 377, pl. 7. f. 8.—S Wood, Crag-Moll. I, p. 95, pl. 8, f. 22, and Suppl. p. 59, pl. 4, f. 2.).

Although I can not compare the very scarce Oji-specimens with Brochi's figure, or subapennine originals, there can be no doubt about their belonging to the same species with the Crag-specimens. The margin of the lower volution, the slight convexity of the whorls, which is quite obvious in spite of the rather deep suture, the large number of ribs and transverse striæ producing the reticulated surface, all agree. The size is very little above that which Wood indicates (reaching 12 m.m. in length and nearly 4 in breadth).

Monoptygma puncticulata Gould.

(Otia conchologica, p. 149.—Syn.? Monoptygma eximia Lischke, Malakozool. Bl. vol. 19, p. 103, June 1873, and Japan. Meeres Conch. v. 3, p. 59, pl. 3, f. 4-6.).

A few small fragmentary specimens of this subulated shell (length to breadth as 3 : 1), with flat, transversely grooved whorls, deep suture and small aperture, have been found at Oji. Though a little imperfect, they show complete identity with Gould's diagnosis and description. Whether the above named species of Lischke's is identical, I leave undecided.

Monoptygma striata Gray.

(Sowerby Thes. Vol. II, p. 816, pl. 172, f. 18.).

This species is thicker, less slender (length to breadth nearly as 5 : 2) and has an obtuse apex, a little less crowded transverse lines, a wider aperture, and a more conspicuous twisting of the columella. It must be, therefore, separated from the foregoing species, though it has the same smooth embryonal whorls and is also very similar in appearence. It has been still more rarely met with at Oji.

Odostomia planata Gould.

(Otia conchol. p. 148).

The comparatively large, elongated and pyramidal species (I measure it up to 7.5 mm. in length, and 2 mm. in diameter, 40% of the axis equalling the aperture with a little more than 8 whorls) is found in abundance at Oji, though mostly of considerably smaller size. Just as the characters given by Gould require, it is smooth, the whorls are flat, the aperture is oval, the lip sinuated, the columellar fold strong, and the basis perforated.

Odostomia subplanata Gould.

(Otia Conch. p. 148).

The species, like the foregoing one found living at Hongkong, was also, though not so frequently, found at Oji. It is much smaller and not perforated, the whorls more convex, less numerous and more quickly tapering to the apex. The size of the fossil specimens of Japan is exactly that which Gould notes, viz., 2.7 mm. in length or somewhat above, 1 mm. in diameter.

Eulima subulata Donovan.

(Brit. shells, vol. 5, pl. 172.—Forbes and Hanley, brit. Moll. v. 3. p. 235, pl. 92, fig. 788.—Jeffreys, brit. Conch. v. 3, p. 208.—Philippi, Moll. Sicil. Vol. II, p. 134. S. Wood, Crag Moll. I, p. 97 pl. 19, f. 3 and Suppl. p. 66.—Koch and Wiegmann, Moll.-Fauna. d. Sternberger Gestines in Mecklenburg p. 95. pl. 3, f. 4.).

The long, subulated, almost cylindrical form of the shell, together with the flatness of the whorls, which have in fact but a very narrow belt in their lower part tapering towards the suture, distinguish this species, which is very rarely (and scarcely ever in entire specimens) found at Oji, from all the other species described from the Pacific coasts, and other localities. The shell is said by Philippi, Merian, Speyer and other authors to occur in the German upper oligocene (lowest miocene) strata.

Chemnitzia elegantissima Montague.

(Test. brit. Vol. II, p. 293, pl. 10, f. 2, and Suppl. p. 124.—Philippi. Moll. Sicil. Vol. II, p. 136.—Forbes and Hanley Brit. Moll. v. 3, p. 283, pl. 93, f. 1. 2.—Syn. Odostomia lactea Jeffreys, Brit. Conch. IV, p. 164; Turbonilla elegantissima. Mont. in Weinkauff's Conch. d. Mittelm. Vol. II, p. 207; ? Ch. Jeffreysii S. Wood, Crag Moll. add. pl. f. 14, Suppl. p. 184;—? Koch and Wiegmann, Moll. Fauna d. Sternberger Gest. p. 103, pl. 3, f. 9.).

The shell, as large and nicely scruptured as from any other lacality, has the longitudinal, more or less straight and strong ribs, moderately convex whorls and elongated form belonging to the species. The specimens from Oji vary greatly in all those points which led Koch and Wiegmann, and as they record, Jeffreys, to separate the Turbonilla Jeffreysii from our species; but I think it doubtful, whether this separation is correct or not. Still more doubtful is the identification of a crag-shell with this Turbonilla Jeffreysii which the author himself, S. Wood, declares to be uncertain. I may add besides, that there are specimens with quite as many varices as Koch and Wiegmann's Turbonilla variculosa, l. c., p. 106, pl. 3, f. 8, exhibits, and on the whole, I can not but agree with Forbes and Hanley who think several species, e. g. Ch. gracilis and pusilla of Philippi, to be separated from Ch. elegantissima without sufficient reason. I leave it open, whether this is also the case with Ch. elegantior S. Wood (Crag Moll. I. p. 81, pl. 10, f. 5. suppl. p. 61.), originally called Ch. elegantissima.

Cerithiopsis rugosa Gould.

(Otia Conchol. p. 143).

The highly typical, particular and nice Sculpture, together with size and dimensions (15 mm. in length and 4 in diameter) prove the identity of one of the Oji shells (one specimen) with the living Chinese species of Gould.

Pleurotoma tigrina Lamarck.

(Hist. nat. des anim. s. vert.—1856 Gould, U. S. Exploring Exp. of Wilke., p. 249, pl. 18, f. 311.).

A few specimens were found at Oji, belonging to the turreted, sharp-keeled form with long curved Sipho and a minor carina just above the suture.

Drillia reciproca Gould.

(Otia. Conchol. p. 135).

Long, fusiform, with 10 convex whorls, on which there are 4 or 5 transverse carinæ, the middle one of which is a little stronger and somewhat granular. The intervals are obliquely striated, the obliqueness being in different direction according to the position above or below the sinus. Sinus deep and broad, lip produced, canal short, broad and twisted; aperture only about ¼ of the total length. The largest specimens attain nearly the length noted by Gould, 12 mm.. with the same proportion in diameter, viz. ⅓ of the axis. This shell which does not agree with any other but the species of Gould to which I unite it, was frequently met with at Oji. The recent specimens were found at Oshima.

Mongelia striolata (Scacchi). Phil.

Moll. Sicil. Vol. II, p. 168, pl. 26, f. 7.—Forbes and Hanley, brit. Moll. Vol. III, p. 483, pl. 114 A, f. 1 and 2.—Jeffreys, brit. conch. v. 4, p. 376. S. Wood, Crag Moll. Suppl. p. 179 and Addendum-pl., f. 2.

Not as frequently found at Oji, as the foregoing shell; apex somewhat obtuse, canal lengthened, aperture narrow, whorls with a prominent angle near the apical side. Longitudinal ribs, about 9 or 10, also shouldered and often a little oblique, are crossed by transverse striæ. The characters do not differ in any particular from the British specimens, fossil or recent. Among all the species mentioned by Gould, only M. semiassa, Ot. conch. p. 137, might be identical; but its whorls have their elevated part nearly in the middle.

Terebra bipartita Gould.
(Otia Conchologica p. 126.).

This species was rarely found at Oji, the specimens having up to 18 mm. in length, and nearly 5 mm. in diameter. The number of longitudinal ribs is 13 to 16; in their intervals, we see very finely punctated transverse lines mentioned by Gould, one of which is stronger, and placed at ⅔ of each whorl from the lower, ⅓ from the upper or posterior suture. The specimens show very weak traces of the differences of color seen in the recent shells from Japan.

Trichotropis (Iphinoë) coronata Gould.
(Otia Conchol. p. 121.).

The very curious and elegant species, as Gould says, has been rarely found at Oji. The specimens are much smaller than those which Gould mentions from the Arctic Seas (Straits of Semiavine). For the latter are said to have little more than 6 whorls and 25 mm. in length by 18 mm. in diameter, whilst the fossil in Oji specimens with 5 whorls, have only 10 mm in length and 6 in diameter. The dimensions, however, and the very typical form and sculpture (one strong keel on an angulated margin, above or behind which the shell is quite even and horizontal, whilst it is also smooth, but rotundated, below or anteriorly, the wide and deep umbilicus with its sharp margin, the simple lip and ovately triangulated orifice), so perfectly agree that a specific separation seems quite untenable. Moreover, the number of the whorls in the larger specimens may be diminished by resorption, as Gould's statement: anfr. 6 ÷ etc.; seems likewise to indicate. At the utmost, the Japanese fossil form could be distinguished as a dwarfish variety.

Trochus argyrostomus Gmelin.
(Syst. Nat. Linn. ed. 13, p. 3583.—Chemnitz, conch. cab. vol. 5, pl. 165, f. 1562 & foll., and ed. nov. Trochus pl. 6, f. 1.2. Lischke, Jap. Meeres-Conch. vol, p. 96, pl. 7, f. 3-5).

Some fragmentary specimens of the obtuse conical species (with closed umbilicus) suffice to give evidence of the existence of this species (peculiar to the East-Asiatic shores and continental isles from Korea to the Phillipines) within the compass of the formation of Oji.

Tornatia exilis Dunker.
(Moll. Japan. p. 25, pl. 2, f. 14.-Lischke, Jap. Meeres-Conch. vol. p. 105.).

Very seldom at Oji, the shell is nearly cylindrical, rounded at the ends; the spire slightly elevated with mammillated—sinistral—apex. The aperture is narrow in the upper part, somewhat broader below, with a feeble fold on the columella.—These characters coincide with those which S. Wood gives for his Bulla Lajonkaireana Basterot (Crag Moll. I, p. 178, pl. 21, f. 5), rectius Bulla mammillata Philippi. Enum. Moll. Sic. v. 1, p. 222, pl. 7, f. 20, and Weinkauff, Conch. d. Mittelm. vol. 2, p. 201, Forbes and Hanley, pl. 114 C, f. 4 and 5, so that I regret very much not to have any specimens, living or fossil, at hand. The size—$\frac{1}{7}$ of an inch in the Crag specimens and 4 millim in those of Oji, with 2 in diameter—agrees also. The only difference is the surplus of diameter which is to be seen in the upper part of B. mammillata (or Lajonkaireana), and of which the specimens of Oji do not show any trace. From Wood's remarks, however, it appears that this character is not quite constant and Forbes and Hanley's figure represents another deviation from the cylindrical form, namely a reduction of the diameter in the middle of the shell. If all these characters were really variable, there would be no reason whatever to separate these 2 species.

Bulla (Cylichna) cylindracea Pennant.

(Brit. Zool. vol. IV, pl. 70, f. 85. S. Wood, Crag Moll. I, p. 175, pl. 22, f. 1.—Forbes and Hanley brit. Moll. pl. 114 B, f. 6.—Jeffreys, brit. Conch. v. 4, p. 415. Weinkauff, Conch d. mittelmeeres. v. 2, p. 194).

The cylindrical form and the perfectly hidden spire together with the dimensions and proportions (10 mm. of axis, 3.5 of diameter) show that the few bullæ found at Oji belong to B. cylindracea. As to Bulla parallela Gould Otia Conch. p. 98, moll. of Wilke's expl. Exped. pl. 15, f. 267, it is excluded by its transverse striæ on both ends of the shell which are totally wanting in the Oji specimens.

SOLENOCONCHÆ.

Dentalium octogonum Lamarck.

(Hist. nat. d. anim. s. vest. 2d. ed. vol. V. 3, p. 701,—Sowerby, Thes. Conch. vol. V. p. 102, pl. 223, f. 9.—Lischke, Jap. Meeres-Conch vol. 2, p. 103, vol 3, p. 75, pl. 5, f. 1-3.).

The octagonal outline of the cross-section divides this species sharply from the following one, even from its ribbed varieties. I omit to discuss the question whether D. hexagonum Gould, Otia conch. p. 119, Sow. l. c f. 10, Lischke Vol. 3, p. 174, pl. 5, f. 4-7, is really a good species, though I think this is not the case. The few specimens found at Oji all belong to the typical octagonal form.

Dentalium entale Linné.

(Syst. Nat. p. 1263.—Philippi, En. Moll. Sic. Vol. II, p. 206.—S. Wood, Crag Moll. I, p. 189, pl. 20, f. 2, and Suppl. p. 92, pl. 6, f. 20, add. pl. f. 12.—Forbes and Hanley, brit. Moll. Vol. 2, p. 451, pl. 67, f. 12.—Syn. D. Tarentinum Lamarck, anim. s. vert. vol. V. p. 345, Weinkauff, Conch. d. Mittelm. v. 2, p. 416; Jeffreys, brit. Conch. v. 3, p. 195.).

The specimens of Oji, small, smooth, thin and moderately curved, can not be united with the species found living near the Japanese coast, e. g. D. octogonum.

CONCHIFERA.

Solen grandis Dunker.

(Novitates conchol. II, p. 71, pl. 24, f. 5.—Lischke, Japan Meeres-conch. vol. I, p. 141.).

Straight, with parallel margins, obliquely truncated in front and rounded behind, moderately slender (length to height 1 : 4 or 1 : 5) solens found in great number at Oji are not different from the shell which by the above mentioned Authors has been described from the Philippine islands and Nagasaki, but which also is found at Yenoshima. The hinge, having but one tooth in each valve, quite close to the anterior margin in the right and a little behind in the left valve, suffices to distinguish this true solen from species similar in appearance (S. gladiolus Gray, also S. siliqua, which is besides a little more slender), whilst the pacific species belonging to the same group are all excluded by their different outlines (e. g. Solen sicarius Gould, Otia conch. p. 74, by its greater height and curved inferior margin; S. gracilis. Gould, or Solen Gouldii Conrad in Amer. Journ. of conch. Vol. III. 1867, App. p. 28 and Lischke, Jap. Meeres-conch. v. 2, p. 123, and also S. strictus Gould and S. corneus Lamck. by their much smaller height).

It is to be added, however, that S. sicarius, according to the figure given in the Atlas of Moll. &c. of Wilke's Exped. pl. 33, f. 501, may be less different than the diagnosis seems to indicate.

Saxicava arctica Linné (Mya).

(Syst. Nat. ed. 12, p. 1113, Gmelin, Linn. syst. nat. ed. 13, p. 3226.—Phil. Enum. Moll. Sic. vol. 2. p. 19.—Forbes and Hanley, brit. Moll. I. p. 141, pl. 6, f. 4-6 and pl. F, 6.—Jeffreys, brit. conch. v. 3, p. 81, as S. rugosa var. arctica. S. Wood, Crag moll. II. p. 287, pl. 29, f. 4.—Weinkauff, Conch. des Mittelm, vol. I, p. 20.—Lischke, Japan. Meeres-Conch, v. 1, p. 134, v. 2, p. 122 & 165. v. 3, p. 100.).

The variable, world-wide species, which is also very often found in Tertiary deposits, occurs abundantly at Oji. It is mostly small, but in a few instances reaches 18 mm. in length and 11 in height.

Panopaea generosa Gould.

(Otia conch. p. 165 and Atlas of Moll. & shells of Wilke's Expl. Exp. pl. 34, f. 507.).

Exactly corresponding to the description and figure of Gould, the specimens of Oji are determined accordingly. They are not very numerous and not much above 100 mm. in length, and 65 in height, umbones being at 45 mm. distance from the anterior margin. It is not the place here to discuss whether and how far Gould's species deserves to be kept; from Panopæa Faujasii M. de la Groye (Ann. du Mus. vol 9, p. 131. pl. 12, 1807; Basterot. Foss. de Bordeaux, p. 95: Phil., En. Moll. Sic. vol. 1, p. 7, pl. 2, s. 3.; Goldfuss, Petr. Germ. vol. 2, p. 274, pl. 159, f. 1; Sow, Min. Conch. pl. 611, f. 3 & 4; Weinkauff, Conch. d. Mittelm. vol. 1, p. 22 as P. glycimeris Born; Wood, Crag Moll. II, p. 283, pl. 27, f. 1), Lamarck's Panopaea Aldrovandi, I do not find any constant difference. For straightness of the upper margin and nearly equal broadness of the posterior and anterior part of the shell are also found among the specimens of P. Faujasii, and even the direction of the lines of growth (and of the irregular, somewhat coarse folds or concentrical ribs which in both species are parallel to these lines of growth) are sometimes nearly parallel to the upper part of the shell in both the P. generosa and Faujasii, and the deviations from that direction (in P. Faujasii, as e. g. Goldfuss' very good figure exhibits, more convergent to the posterior side of the upper margin; in P. generosa, as Gould's figure shows, divergent from it) seem neither to become very great, nor to be always of the same nature. The hinge and the pallial sinus do not exhibit any peculiar characters.

The shell is found recent in the northern part of the Pacific, and if the identification with P. Faujasii is tenable, in the Mediterranean and near the Atlantic coasts of Spain and Portugal. The boreal form of the Atlantic Sea is widely different, and even supposed to belong to another genus. The Yesso shell described by Gould as P. fragilis and identified with P. Japonica Adams by Lischke (Japan. Meeres Conch. III, p. 104) is different in size (2 by 1.5 inches instead of 6 by 4), has a fissure of the upper margin near the base of the tooth and a very thin shell.

Lyonsia (Pandorina) flabellata Gould.
(Otia Conch. p. 162.).

Two very small specimens are found at Oji, not larger than 1 and 3 millim., but in all characters (ratio of length to height about 17 : 10, thickness very slight, rounded anterior part and much truncated, obliquely and feebly folded hind part, beaks at ⅓ of length from the anterior margin, straight upper margin, very feeble hinge and nacreous interior) perfectly resembling this Arctic species of the Pacific Ocean. I feel obliged to mention them in spite of their scarcity and of the minuteness of the specimens of a form attaining much larger dimensions, as they seem to be not unimportant as to the character of the fauna.

Myadora fluctuosa Gould.
(Otia conchol. p. 161.).

To Gould's diagnosis (small, thin, concentrically striated or rather folded, nearly equilateral shell, posteriorly a little smaller, triangular with somewhat truncated end, right valve convex, length to height as 8 to 7) the few specimens found at Oji give some additional points. The largest specimen of a right valve has 15 millim. in length and 13 millim. in height, nearly the double size of

Gould's specimen which was dredged at Kagoshima. Among the specimens there is one left valve, which Gould has not, quite flat and a little smaller, but corresponding in shape to the right valve. The concentrical undulations are spread over nearly the entire surface in most of the Oji specimens; but one of them exhibits them only in the middle part of the surface. We may therefore assume the difference of sculpture mentioned by Gould (undulis concentricis circ. 20 ad marginem haud protractis ornata) to be an individual deficiency which does not exclude our specimens from the above mentioned species.

Lutraria Nuttalli Conrad. Pl. IV, f. 16.

(Journal of Acad. Nat. Sc. Philad. vol. 7, 1837, p. 235 pl. 18. f. 1.—Lischke, Japan. Meeres-Conch. v. 1, p. 136.—Non Mactra Nuttalli Reeve, Conch. Ic. Mactra, pl. 21, f. 125.—Syn. L. Maxima Middendorf, Beiträge zu einer Malacozool. Rossica, vol. 3, p. 66, pl. 19, f. 1-4, 1849; and Reeve, Conch. Icon. Lutraria, pl. 5, f. 18, and Mactra, pl. 1, f. 4; also Adams, Genera etc. vol. 2, p. 381, pl. 101, f. 1., Chenu, Manual, vol. II, p. 59, f. 243. Syn. also L. capax Gould, Wilkes Expl. Exp. Moll. pl. 34, f. 508 and Otia Conch. p. 76 and 245.).

In denominating this important species found in tolerably great number and large specimens at Oji (reaching 130 millim. in length, 90 in height and 62 in thickness), I follow Lischke l. c. The name L. maxima, according to his statements, l. c. p. 138, is duly to be applied to another shell, L. maxima Jonas—also a Japanese and Chinese shell of nearly the same length, but much smaller height and thickness—and therefore Gould's denomination ought to be accepted if not the same shell had been already described and figured by Conrad.—The hinge—hinge-tooth broad, with appendix and plicated, narrow lateral teeth—is well preserved and quite typical, the shell covered with concentrical striæ and moderately thick. The large umbones, the large, tongue-shaped pallial sinus, the anterior rounding and posterior truncation and oblique folding are all present.

Mactra veneriformis Deshayes. Pl. IV, f. 17.

(Proc. Zool. S. oc. 1853, p. 15.—Reeve Icon. Conch. Mactra, pl. 1, f. 2.—Lischke, Japan. Meeres Conch. v. 1, p. 133, v. 2, p. 121. pl. 9, f. 7 and 8).

This species, common in the Tokio-Bay, has been found at Oji, but less frequently than in other localities of the pliocene formation, e. g. Takigashira Mura. The specimens, rather oblique, obtusely carinated and moderately thick, agree perfectly with the living ones.

Mactra Sachalinensis Schrenck.

(Moll. d. Amurlandes u. d. Nord-Japan. Meeres, p. 515, pl. 23, f. 3-7.—Lischke, Jap. Meeres-Conch, v. 1, p. 132.—Syn. M. Ludorfii Dkr., Novit. Conch. II, p. 60, pl. 20, f. a-c).

The shell which occurs frequently near the coasts of Sachalin and Yesso, has an elongated, nearly equilateral outline and a nearly straight upper margin. The proportion of length and height is given as 100 to 75 in the elongated varieties. A great many small shells agree perfectly in outline with the latter, and moreover show a perfect identity of the hinge with its rather straight line and its two duplicated lateral teeth. I omit the discussion whether M. spectabilis Lischke (l. c. v. 2. p. 120, pl. 11, f. 1 and 2) whose height is said to be about 0.79 of the length, and whose hinge is exactly the same, is not merely a very large variety of M. Sachalinensis.

Tellina Yeddoënsis Lischke.
(Japan. Meeres-Conch. v. 3, p. 92, t. 9, f. 1-3.).

From all the other small Tellinæ this species, somewhat inequilateral, shorter and a little pointed behind, with fold, with hinge-teeth and lateral teeth in the right valve, is sufficiently distinguished by the last character. (Cf. Lischke.) It is not very frequent at Oji.

Tellina nitidula Dunker.
(Malakozool. Bl. Vol. 6, p. 236, Moll. Japon. p. 27, pl. 3, f. 14.—Lischke, Japan. Meeres-Conch. v. 1, p. 129, v. 2, p. 113, pl. 10, f. 10 and 11).

This species, which is also not very abundantly found at Oji, seems to be separated into many species by Martens, Lischke &c. without sufficient reason, and really to be somewhat variable in outline and proportions. The absence of posterior lateral teeth distinguishes it from the foregoing, the outline and the presence of an anterior (small) lateral tooth in the right valve from the following species.

Tellina nasuta Conrad. Pl. IV, f. 18.
(Journal of Acad. Nat. Sc. Philad. Vol. 7, pt. 2d, 1837, p. 238.—Sowerby, Thes. Conch., Vol. 1, p. 314, pl. 64. f. 224.—Reeve, Icon. Conch. Tellina, pl. 9, f. 40.—Lischke, Jap. Meeres-Conch. v. 2, p. 115, pl. 10, f. 15-17.).

There being no doubt left about the majority of Tellinæ found at Oji belonging to this rather inequilateral, strongly folded, posteriorly short, pointed and arcuated species, I omit a further discussion on it and on its synonymy, stating only that it belongs to the most frequent shells of that locality and constitutes a considerable portion of the shell-layer.

Tapes rigidus Gould. Pl. V, f. 19.
(Otia Conch. p. 85.—Moll. of Wilke's exploring Exp. pl. 37, f. 538.).

Gould's diagnosis says: shell solid, transverse, ovate and ventricose, inequilateral, covered with concentrical laminated lines and radiating broad striæ, both of which together leave, in the anterior part of the shell, only deep points, whilst behind the intervals are short perpendicular lines; umbones high, touching one another, lunulæ broad; anterior side narrower and rounded, posterior one broad and obliquely truncated; lower margin crenulated and upper margin not much convex; 2 bifid hinge-teeth in the right valve, one bifid tooth in the left valve. This and the figure leaves no doubt about the determination of this species, which was tolerably frequent at Oji, but mostly fractured.

The largest specimens have 70 mm. in length and 60 in height.—The genus is denominated according to Gould's statement in his Index (Otia Conch. p. 256) in spite of the crenulated margin, because all the other characters agree with those of Tapes. The species has also been found living at Hakodate.

Saxidomus purpuratus. Sowerby. Pl. V, f. 20.

(Thes. Conch. vol. 2, p. 692, pl. 150, f. 124 and 125.—Deshayes, Catal. of conchifera of Brit. Mus. p. 188.—Adams, Ann. Mag. Nat. Hist. 1869, vol. 3, p. 235.—Lischke, Japan. Meeres-Conch. v. 1, p. 127, t. 9. f. 4 & 5.—Syn. S. Nuttalli Schrenck, Nordjapan. Moll, p. 253, and S. giganteus Martens, preuss. Exped. n. Ost-Asien, Zool. vol. 1, p. 140.).

As Lischke undoubtedly is right in identifying this species with the figure and description given by Sowerby, I follow him in omitting a comparison with Gould's species from the Pacific coast of America, though it is quite possible that one—if not more—of the latter are identical with the shell which has been described from Japan, Tokio as well as Hakodate, and which most likely occurs in many more places of the Japanese coasts. Lischke's supposition, Kunachee to be in fact a Japanese, not an Indian locality, seems to be confirmed by similar names occurring in Japan. The specimens found not unfrequently and of large size (105 mm. by 80 mm.) at Oji, exhibit the posterior bifid tooth of the right valve and the deep pallial sinus, which seem to indicate that Saxidomus is more akin to Tapes than to Venus proper; the concentrical striæ are numerous and sharp, the posterior side is long, very obtusely carinated and more rounded than truncated. The inferior margin is smooth.

Venus (Mercenaria) Stimpsoni Gould. Pl. V, f. 21.

(Otia Conch. p. 169.).

This Hakodate species, which I could compare directly with authentical specimens from that locality, has been found only once in a complete and large specimen at Oji. The oblique shell with the acute umbones placed near the anterior end, deep lunula, convex dorsal margin, pointed posterior end, with broad hinge, shallow pallial sinus and numerous concentrical laminæ, measures 97 by 78 millim. (Recent specimens reach 105 by 87 mm.) Smaller specimens and fragments have been found in tolerably large number; they measure mostly about 15 by 12.5 millim. and have the shape of the larger; the umbones are placed at 4.6 millim. from the anterior end, the surface is covered with foliaceous concentrical ribs; the intervals are broad and longitudinally striated. The marginal crenulation is always sharp and fine.

Dosinia exoleta Linné. Pl. VI, f. 22.

(Syst. nat. ed. XII, p. 434, as Venus exoleta.—Chemnitz, Conch. Cab. vol. 6, p. 48, pl. 38, f. 104, do.—Gmelin, Syst. nat. Linn. ed. XIII, p. 3284, do.—Montagne, test. brit. p. 116, do.—Lamarck, hist. nat. pp. vol. 5, p. 512, and id. second. ed. by Deshayes, vol. 6, p. 314, as Cytherea.—Philippi, Enum. Moll. Sic. vol. 2, p. 32, and abbild. I, p. 171, do.—Reeve, Conch. Ic. Artemis, pl. 5, f. 29—Forbes and Hanley, Brit. Moll. vol. 1, p. 428, pl. 23, f. 3, 4.—Sowerby, Thes. Conch. p. 658, pl. 1 & 1, f. 12-14.—Jeffreys, brit. Conch. vol. II, p. 327, as Venus.—Weinkauff, Conch. d. Mittelm. vol. 1, p. 120.—Goldfuss, Petref. German. vol. 2, p. 241, pl. 149, f. 18, as Cytherea.—Hoernes, Foss. Moll. des Wiener Beckens, vol. 2, p. 143, f. 16, f. 2,—Syn. D. lentiformis (Venus) Sowerby, Min. Conch. pl. 203 and Wood, Crag Moll. II, p. 215, pl. 20, f. 7. Syn. also D. Japonica Reeve, Conch. Icon. Artemis, pl. 3, f. 17, Sowerby Thes. vol. 2, p. 669, pl. 143, f. 60, Roemer, Dosinia, p. 60, pl. 11, f. 4, Lischke, Japan. Meeres-Conch. v. 1, p. 127, v. 3, p. 88, and Morse, Shell-mound of Omori, p. 28, pl. 18, f. 7. Syn. also Dosinia Troscheli Lischke, Japan. Meeres-Conch. III, p. 89, pl. 8, f. 1-3).

The most minute details of the hinge being exactly the same, there can be no doubt about the Dosiniae, which I got from Oji in an unexpectedly rich supply and which were indeed the most common shells of this locality, belonging to the same species as Dosinia exoleta L., from which also D. lentiformis was quite unnecessarily separated. Outline and area, as well as pallial sinus, exhibit, in the Oji-specimens, all the variations indicated under all the above quoted names and by any of the mentioned authors. Especially the character of the stronger demarcation of the area, supposed to be typical for D. Troscheli, passes so gradually into the common form, and is not at all constantly connected with any shape of the pallial sinus or of the outline, or even of the coloring, that in fact—as I convinced myself in examining the Tokio collections—a great many of the Japanese specimens could not be strictly assigned to either of the forms.

Indeed the shell varies much, and as the large number of specimens from one locality and formation, viz. Oji, demonstrates, this variability can not be explained as a stage of evolution, or as a local modification. We must accept it as a property of the species, which, on the other hand, seems to be well distinguished from the species of the same genus, e. g. D. lincta Pulteney, close as this form is allied, or D. (Artemis) lambata Gould in Otia Conch. p. 84 and Atlas of Wilke's Exp. pl. 37, f. 536. Dosinia exoleta L. therefore must be considered as one of the truly palaearctic forms of which indeed already a certain number has been generally admitted. We may add that the range of the variations is not essentially increased by all the other Japanese localities, fossil or recent.

Considering these variations, we must indeed reject the conclusions of Morse, who l. c. gives the average of the proportion of length to height in the recent shells as 0.939, in the shells from the mounds as 0.952. The Oji shells have a range in this respect from 1 down to .927, which may include almost any proportions observed anywhere. At least I found only some of the so called D. Troscheli going down a little below 0.92. As for the size, it is quite true that the Oji shells surpass as well the recent as the mound specimens, and not rarely have 80 mm. of diameter, or 80 of length to a little less height. But as the number of specimens measured by Morse is so very small (10 recent and 9 mound-specimens), especially when compared with the many hundreds dug out at Oji, this fact loses very much of its importance, and scarcely justifies any conclusion on a gradual diminution of the size of this species which, at first sight, it seems to support.

Indeed, an examination of the Tokio collections of recent shells gave, at its very beginning, the maximum length of recent Dosiniæ (both labelled as D. Troscheli and as D. Japonica) equal to 75-77 millim., the height being in the first case, equal to the length, viz. 75 millim, in the second 71, (ratio of height to length being about 0.92).

Cardium Californiense Deshayes.

(Revue par la Soc. Cuvier. 1839. p. 360.—Middendorff, Malacozool. Rossica, vol. 3, p. 40, pl. 15, f. 23-25.—Lischke, Japan. Meeres-Conch. v. 1, p. 144, and v. 2, p. 125.—Syn. C. blandum Gould, Otia Conch. p. 83. and Atl. Wilke's Expl. Exp. pl. 36, f. 534. Syn. also C. pseudofossile Reeve, Conch. Icon. Cardium, pl. 10, f. 52.).

The numerous ribs (often 40) are separated by narrow intervals and crossed by feeble, undulating concentrical lines; the shell is nearly equilateral and but slightly elongated. Most of the specimens of Oji have less than 17 mm. in length and 15 in height; only one is considerably larger, but broken. They are not very numerous, and do not allow any serious approach to the question about the relation of this species to C. Islandicum Linné (Syst. Nat. 12th ed. p. 1124; Gould-Binney, Rep. on Inv. of Mass. p. 139), with which Gould in the Otia declares it to be analogous, and to which it seems quite akin.

Cardium muticum Reeve.

(Conch. Icon. Cardium, pl. 6, f. 32.—Lischke, Japan. Meeres-Conch. vol. I, p. 144.—Syn. C. japonicum Dunker, Moll. Japon. p. 28. pl. 3. f. 16.).

According to Lischke, this species is not synonymous with C. papyraceum Chemn., Conch. cab. vol. 6. p. 190. pl. 18. f. 184, though Schrenck (Nord Jap. Moll. p. 517) unites them. At all events I can confirm one of the statements given by Lischke, viz. that C. muticum, a large, comparatively thin-shelled species with somewhat broad ribs and intervals, is always a little transversely elongated. The largest of the unbroken specimens (which are far from being frequent), has 75 millim. in height, and 85 in length. They are obliquely elongated behind.

The species, though not frequent at Oji, is not uninteresting as one of the species occurring in the sandstones of the north eastern coast of Japan.

Laevicardium bullatum H. and A. Adams.

(Genera of recent shells, vol. 2, p. 437. Moerch, as Cardium, Cat. Conch. Yoldi, vol. 2, p. 33.).

According to Lischke (Japan. Meeres-Conch., v. 3, p. 106), this species is not synonymous with Cardium bullatum Lamarck, and of Reeve, but to C. rugatum of these authors quoted by the fŏrmer in his Histoire Naturelle pp., 2d ed, vol. 6, p. 393, and figured by the latter in the Icon. Conch., Cardium, pl. 12, f. 63. It has been given, as Lischke says, under the same name by Meuschen in the Zoophylacium Gronovianum vol. 3, p. 266, no 1125, pl. 18, f. 5, and by Lischke. Without entering into this question, I mention only the few specimens, mostly broken, which were found at Oji. They are thin, subspherical, nearly circular in outline, not much elongated behind. The surface is very delicately radiated and concentrically striated. Fulvia centifilosa Carpenter, perhaps only a variety of Cardium (Lævicardium) modestum, differs by having weaker radii behind, whilst our species does not show any difference between both ends of the shell.

Lasaea rubra Montague.

(Test. brit. p. 83, pl. 27, f. 4, as Cardium.—Forbes and Hanley, Brit. Moll. vol. 1, p. 94, pl. 36, f. 5-7, as Poronia rubra, and pl. O, f. 3.—Jeffreys, brit. Conch. vol. 2, p. 219.—Woodward, Manual of Conch. pl. 19, f. 13, as Kellia, subgenus Poronia.—Weinkauff Conch. d. Mitteln. vol. I, p. 177, as Poronia.—Wood, Crag-Moll. II, p. 125, pl. 11, f. 10.—Lischke, Japan Meeres-Conch. vol. II, p. 137.).

The small species, rounded, not quite equilateral, a little elongated behind, covered with strong concentrical striæ and a very fine and minute radial striation and with the typical hinge of the genus, has been already identified by Lischke. The diagnoses of the numerous species of this genus given by Gould are all different. A few specimens only were found at Oji, but at Shinagawa the species was met with in a larger number of specimens.

Kellia suborbicularis Montagne.

(Test. brit. p. 38 and 564, as Mya.—Forbes and Hanley, brit. Moll., vol. 2, p. 87, pl. 18, f. 9.—Jeffreys, brit. Conch. vol. 2, p. 225.—Wood, Crag Moll. II, p. 119, pl. 12, f. 8.—Weinkauff, Conch. d. Mittelm. vol. 1, p. 174.).

The same may be said about the distribution of the very smooth, ventricose shell which also exhibits the typical hinge of its genus. A separation from the British and Mediterranean—recent and fossil—specimens is the more to be rejected as the shell is known to be variable, and as the fossil Japanese specimens do not go beyond the limits pointed out by the above mentioned authors, either in their form or in their size.

Lucina borealis Linné. Pl. VI, f. 24.

(Syst. nat. ed. 73, p. 1184, as Venus.—Forbes and Hanley, brit. Moll. vol. II, p. 46, pl. 35, f. 5.—Jeffreys, brit. Conch. vol. II, p. 242.—Hoernes, Foss. Moll. des Wiener Beckens, vol. II, p. 299, pl. 33, f. 4.—Wood, Crag Moll. II, p. 139, pl. 12, f. 1.—Weinkauff's Conch. d. Mittelm vol. 1, p. 162).

The most minute examination of form, outline, internal and external sculpture and hinge has not revealed the slightest difference between a Lucina, found very often, though mostly in small specimens at Oji, and the fossil and recent European Lucina borealis. The strong concentrical striæ, the deep lunula, the flat, circular shape, the slight internal ridge before the posterior muscular impression (almost, though not quite constant), the oblique central furrow of the inside:—all these, and in fact, all the other characters perfectly agree.

The largest specimens of Oji are 25 mm. in length and 23 mm. in height.

Diplodonta trigonula Bronn. Pl. VI, f. 25.

(Ital. Tert. Geb. p. 96, pl. 3, f. 2.—Philippi, Enum. Moll. Sic. vol. II. p. 24.—Hoernes. Foss. Moll. des Wiener Beckens, vol. II, p. 218, pl. 32, f. 4.—Weinkauff Conch. des Mittelmeeres, vol. I, p. 158.—Syn. D. apicalis Phil., l. c. vol. I, p. 31, pl. 4, f. 6, and vol. 2, p. 24, younger form. Syn. also D. astartea Nyst, Coqu. foss. belg. p. 121, pl. 6, f. 4, and Wood, Crag Mollusca II, p. 146, pl. 82, f. 2.).

The obliqueness, the triangular form with obliquely descending hinge-margin, and with posterior elongation, together with the simple concentrical lines and folds of the surface, prove the identity of the above-quoted species and of one of the shells found frequently in the layer of Oji. The hinge exhibits some difference from D. orbella Gould (Otia Conch. p. 212, Lischke, v. 2, p. 133) as there is a posterior lateral tooth, though somewhat indistinct (except at the end of the area, where it becomes more distinctly visible); but this species is still more decidedly excluded by its equilateral, rounded and globose form. Our specimens reach 20 mm. in length, 25 in height and 12 in thickness. The umbones are at $\frac{1}{3}$ to $\frac{2}{5}$ of the length from the anterior end.

Arca inflata Reeve.

(Conch. Icon. Arca, pl. 5, f. 30, Lischke, Japan. Meeres-Conch. vol. I, p. 146, and vol. II. p. 144. Morse, shell-mound of Omori, p. 26, pl. 18, f. 5.—Syn. II. Broughtoni Schrenck, Moll. des Amerlandes u. des Nord-Jap. Meeres. p. 578, pl. 24, f. 1-3.).

This shell is found frequently at Oji, 90 mm. in length, 74 in height and 60 in thickness, with 38 to 45 ribs. The posterior part is a little narrower, the lower margin, being bent upwards, and obtusely pointed. As for the synonyms, I refer to Lischke.

The shell being very common at Tokio, it is indeed striking that it is so rarely met with at Omori.

The specimens described by Morse as having an unusually broad hinge area are possibly exceptionnally developed; the Oji-specimens do not differ from the living.

Arca subcrenata Lischke.

(Japan. Meeres-Conch. vol. I, p. 146, pl. 9, f. 1–3, and vol. II, p. 144.—Morse, shell-mound of Omori, p. 25.).

Of this species (differing from the foregoing by a much smaller number of ribs, viz. 30 to 33, instead of about 42, by their crenulation and by the characters of the sub-genus Scapharca), some small specimens have been found at Oji which perfectly agree with Lischke's diagnosis and figure and with recent specimens. They are neither numerous nor large enough to allow any remarks about deviations from the Omori or recent form, like those described by Morse.

Pectunculus glycimeris Linné. Pl. VI, f. 26.

(Syst. nat. ed. 12, p. 1143, as Arca.—Forbes and Hanley, brit. Moll. vol. 2, p. 245, pl. 46, f. 4-7.—Jeffreys, Brit. Conch. vol. 2, p. 166.—Weinkauff, Conch. d. Mittelm. vol. I, p. 183.—Wood, Crag Moll. II, p. 66, pl. 9, f. 1, and second Suppl. p. 43, pl. 6, f. 5.—Schrenck, Moll. des Amurlandes u. Nord-Japans, p. 580.—Syn. P. nummarius Brocchi, conch. foss. subap. p. 483, pl. 2, f. 8, auctore S. Wood.—Syn. also P. pilosus? Linné, Lamarck, hist. nat. vol. 6, 1, p. 49, No. 2, Philippi, En. Conch. Sic. vol. 2, p. 44, and vol. I, p. 62.—Syn. also T. variabilis Nyst. Coq. foss. belg. Vol. 2, p. 2 and 9, pl. 20, f. 1.—Syn. also P. albo-lineatus Lischke, Japan. Meeres-Conch. vol. III, p. 108, pl. 9, f. 11 and 12.).

Authors generally unite the two Linnaean species, whilst Weinkauff gives like Born the name P. pilosus to the P. bimaculatus of Poli. He also excludes the P. insubricus Brocchi, which is united to P. glycimeris by some, and gives that name to the species better known under the Lamarckian name of P. violascens or violacescens.—The best list of synonyms is generally said to be that of S. Wood. l. c., to which I add only the P. albolineatus of Lischke, as I could not find any constant differences between the Japanese and European specimens. At all events, the punctures on which Lischke lays some stress are to be seen in most of the Oji specimens, and, at the same time, they do not differ from what is seen in many of the European shells of this species. As for the coloring, it is known to be variable in P. glycimeris, and the white radiating lines can scarcely be of any importance in a shell which has radial ribs.

The specimens found at Oji are—like all the fossil specimens of the other localities to be mentioned—mostly small, seldom exceeding 50 mm. in length, 48 in height, and 30 in thickness. They belong to the transverse or circular variety, not to the elongated one. Their number is, though decidedly inferior to the

Solen, Mactra sachalinensis, Tellina nasuta, to the Lucina and Diplodonta, and above all to the Dosiniæ, yet by no means small.

Nucula Cobboldiæ Sowerby. Pl. VI, f. 28 and 28 a.
(Min. Conch. pl. 180, f. 2. 1818.—Lyell, Elem. of Geol. p. 299, f. 113, in the 2nd ed. 1841.—Wood Crag Moll. II, p. 82, pl. 10, f. 9, and suppl. p. III, pl. 10, f. 2.—Woodward Manual of Moll. pl. 17, f. 18.—Syn. N. mirabilis Hinds, Adams and Reeve.—Syn. also N. insignis Gould, Otia Conch, p. 175. Syn. also N. Lyalli Bell, Ann. and Mag. Nat. Hist, 1871, ? cett.).

There can be no doubt about the fact, that the Japanese Nuculæ of the type of N. Cobboldiæ (genus Acila) have only been separated in consequence of so few specimens having been examined. The localities in which this shell is found fossil, supplying to a great extent this want, the identification, so much doubted and objected to by the author of the highly valuable monograph on the Crag-Mollusca, becomes unavoidable. The specimens found at Oji, tolerably numerous and well preserved, answer, on the whole, to Gould's diagnosis and description as well as to the figure given of N. mirabilis. According to Gould himself, N. insignis is almost identical with this shell, and it differs only in two trifling points, viz., the angle formed by the inferior margin with the smaller, straight side margin (an angle very variable in the different specimens), and in the angular markings at the extremities, which appear in Hind's figure, and which sometimes, but not often, are also seen in the Oji specimens. On the other hand, there is no difference whatever from the true N. Cobboldiæ. Especially the larger specimens found not at Oji, but at Shinagawa, Kanagawa, Yokohama and in the province of Mino—specimens to which however some of the Oji specimens approximate—are perfectly similar to the larger specimens of N. Cobboldiæ. The posterior part (Gould's anterior one) is elongated, rounded at the extremity; the anterior one (Gould's posterior side) is truncated, often concave, sometimes provided with a prominent rounded keel; and sometimes next to this keel, there is in some specimens even a slight furrow which makes the angle appear still sharper. As for the sculpture, I dare say that the zigzag lines, diverging from the central axis of the side-face, always cover either the whole surface or at least the greater part of it. In this respect, indeed an important objection to the identification would be the remark of Wood (in his supplement) about a smooth belt in very large Crag-specimens, if I had not succeeded in finding it also in some of the Kanagawa and Shinagawa specimens. I figure it, fragmentary as the specimen is, and may add that indications of this belt are not unfrequent in other specimens. For instance one more of the Mino specimens has a distinct belt on the anterior and posterior side (especially the latter) and would show it most likely entirely, if the central portion was not fractured. Another Kanagawa specimen has a rather broad belt (2 mm.) behind, but it is smaller in the anterior part of the shell. This specimen has only 27 mm. in length and 20 in height (like the one which is figured): the other one which is belted has 37 millim. in length and 28 in height. British specimens, of 21 and 25 millim. in length, with 17 and 18 millim. in height, have a smooth belt; others again do not show it. At Oji, the shells are always below 20 mm. in length, the largest I have before me measuring 17.5 millim. in length, and 13 in height. It is the only one which has a slight trace of a belt. The proportion of length to height changes from $\frac{3}{4}$ to $\frac{4}{5}$. The number of teeth is much more variable than I find it noted. It sometimes goes down to 8 anterior teeth (posterior according to Gould) and 16 posterior (Gould's anterior). The shells quoted by Wood, Crag Moll. II, p. 83, in order to prove the wide vertical and topographical range of the group Acila, viz. a recent species dredged off the Cape of Good Hope, and the cretaceous N. bivirgata and ornatissima, have—as Wood himself says—no specific relationship with our shell. Their existence, therefore, cannot have any value in deciding the question under consideration. As to N. Lyalli, the identity of Bell's specimen with N. Cobboldiæ is affirmed by Wood himself in the supplement, p. 112. The Pacific shell originally called so must, therefore, be very much like our species. The characters added by Wood (ib. p. 115) as belonging to the Pacific shells are indeed not to be seen in the recent Hakodate specimens, nor in the fossils I had before me except in the very large and fullgrown fossil specimens mentioned above.

N. Cobboldiæ is decidedly quaternary in England, as Wood remarks in his supplement, and did not die out there before the latter part of the glacial period.

Leda confusa Hanley.

(Sowerby, Thes. vol. 3, p. 119, pl. 228, f. 85.—Reeve Conch. Icon. Læda, pl. 5, f. 24, bis.—Lischke, Jap. Meeres-Conch. vol. III, p. 109.—Syn. Nucula pella. Sow. Conch. ill. Nucula, f. 4, non. cett.).

The shell, posteriorly narrow and a little shorter than in the rounded anterior portion, concentrically striated, is very rarely found at Oji.

Yoldia arctica Broderip. Pl. VI, f. 29.

(Broderip and Sowerby Zool. Journal No. 15, p. 359, pl. 15, f. 1.—Middendorf, Mém. de l'Acad. de Petersb., p. 544.—Syn. Nucula lanceolata Sow, non Lamarck: Wood Crag Moll. II. p. 88, pl. 10. f. 16, and suppl. p. 115; and sowerby, 1817, Min. Conch. pl. 180, f. 1.).

Without entering upon the question of the correctness of the denomination, I reject the name differently used by Lamarck and Wood and give the usual name to the shell, a few specimens of which, reaching 34 mm. in length and 18 in height, were found at Oji. These specimens, widely differing from all the Pacific species mentioned by Gould, Stimpson etc., have the oblique undulating sculpture and transversely elongated, posteriorly shortened and narrow, anteriorly elongated and rounded form belonging to the species. All the other characters (smoothness of the part next to the posterior upper margin, solidity of hinge etc.) are present.

Pecten (Pseudamussium) plica Linné. Pl. VII, f. 30.

(Syst. nat. ed. 12, p. 1145.—Sowerby, Thes. vol. I, p. 65, pl. 20, f. 237—239.—Reeve. Conch. Icon. Pecten, pl. 3, f. 16.—Lischke, Japan. Meeres-Conch. vol. 2, p. 160, vol. 3, p. 113.).

This radially ribbed and strongly folded species is the most frequent of all the Pectines of Oji.

Pecten (Vola) laqueatus Sowerby. Pl. VII, f. 31 and 31 a.

(Thesaurus Conch. vol. I, p. 46, pl. 15, f. 101.—Reeve, Conch. Icon. Pecten, pl. 30, f. 135.—Lischke, Japan. Meeres-Conch. vol. 1, p. 167, vol. 2, p. 157, pl. 12, f. 1 and 2.).

Nearly circular with about 13 broad and rectangular ribs, broader than the intervals in the convex valve, smaller in the flat one, with concentrical striæ, this shell—thinner than the allied species generally are—is found rarely at Oji. More numerous and a little larger specimens will be mentioned from Shimagawa.

Pecten (Vola) Yessoënsis Jay.

(Report. on the shells coll. by Perry's Exped., p. 293, pl. 4, f. 1 and 2, pl. 3, f. 3 and 4.—Dunker, Novit. Conch. p. 61, pl. 21.—Schrenck, Moll. des Amurlandes u. nordjapan. Meeres, p. 484, pl. 20, f. 1-4.—Lischke, Japan Meeres-Conch. vol. 1, p. 165, pl. 10, f. 3-4, vol. 2, p. 157, pl. 13.).

Many rounded and not very broad radiating ribs cover the surface of the shell. They are not radially striated, but show only the lines of growth. The shagreen-like epidermis of the flat valve, seen in all the recent specimens from Hakodate, are not preserved in the fossil specimens, which do not show neither the overlapping of the concave valve, and, on the whole, are not at all frequent. Especially from Oji I have got only fragments, sufficient however to give doubtless evidence of the presence of this species in the tertiary layers of the environs of Tokio.

Ostrea gigas Thunberg.

(Kong. Vetenskaps akademiens nya handlingar, vol. 14, 1793, p. 140, pl. 6, f. 1-3.—Lischke Japan. Meeres-Conch. vol. I, p. 174, vol. 2, pl. 14, f. 182, p. 160, vol. 3, p. 114.—Syn. O. Laperousii Schrenck, Nordjap. Moll. p. 475, pl. 19, f. 1-6, auct. Lischke).

Like Lischke, I confine myself to identify the shell which in the fossil state has been met with at Oji and in most of the localities to be mentioned in the following chapters somewhat more rarely than it is now found. It is eminently elongated, has a strong shell, somewhat laminated, pointed in the lower valve, the upper being shorter and flat.

Anomia patelliformis Linné. Pl. VII, f. 32.
(Syst. Nat. 12th ed. p. 1151.—Forbes and Hanley, brit. Moll. pl. 56, f. 5 and 6.—Jeffreys, brit. Conch. Vol. II, p. 34.—Weinkauff Conch. d. Mittelmeeres, vol. 1, p. 282.—S. Wood, Crag-Moll. II, p. 10, pl. I, f. 4.—Syn. A. striata Lovén, Forbes and Hanley, brit. Moll. pl. 55, f. 1 and 6, and pl. 53 f. 6, vol. 2, p. 336.—Lovén, Ind. Moll. Scand. p. 29.—Wood, Crag-Moll. II, p. 11, pl. 2, f. 3, 1st suppl. p. 100, 2nd suppl. p. 41. pl. 6, f. 3.).

The properties of Anomiæ found in the tertiary shell-layers leave no doubt about the determination. The thin shells, covered with irregular, undulating, small round ribs and undulating striæ, exhibit sometimes traces of reddish or purple color. The muscular scars (3 of the upper valve, sometimes confluent, the lowest being smaller snd placed to the left side of the spectator), exactly correspond to the figures given by Forbes and Hanley, and S. Wood. I think it very probable that the shells mentioned by Lischke (Japan. Meeres-Conch. vol. 1, p. 80) as different from his A? laqueata, to which I may add specimens abundantly found at Yokohama, also belong to this species which is known from many places of the Pacific Coast. It was very rare, however, at Oji.—

As the results to be derived from this list of mollusca may better be given after it has been completed by the addition of the species from other localities, I pass to the next places of exposure.

CHAPTER V.

THE TERTIARY DEPOSITS WITHIN THE PRECINCTS OF TOKIO.

One locality alluded to in the second chapter, situated at the foot of the ridges between Oji and that part of Tokio which is called Uyeno, and containing only such tertiary fossils as have been redeposited in alluvial layers, has furnished a certain number of specimens of shells mentioned above (Tellina nasuta Conr., Dosinia exoleta L., Ostrea gigas Thunb., Saxidomus purpuratus Sow., Arca inflata Reeve), but no species which is not contained in the Oji layers, and therefore it may be dismissed here. Another exposure shown to me and situated in the north-western part of Tokio, and said to have formerly exhibited the shell-layer, does not show any trace of it now, deep though the cutting of the road is which in this place leads down from the plateau to one of the tracts of low ground. Similar is the case of the well-diggings often mentioned and almost always reaching the tertiary shell-bed. The only locality therefore, which remains to be mentioned in the northern parts of Tokio, is Surugadai.

SURUGADAI.

Between Surugadai and Seido, at a short distance from Nihon-Bashi to the north, there is a very deep cutting through which the canal of Kandagawa goes. This cutting and the canal itself separate Surugadai from the rest of the diluvial plateau and isolate this projecting part of it. The entire hill of Surugadai is said by some authors to have been the result of the construction of the canal which took place in the 17th century. This assumption is improbable on account of the great extent and height of the hill, which exactly equals the plateau on the other side of the canal: and it becomes entirely untenable after an examination of the steep slopes of the canal-cutting. For there we see native rocks outcropping on the banks of either side which perfectly correspond to one another. The deeper layers are uncomformably covered by horizontal strata rich in pebbles, but partly clayish, which are themselves covered by the upper diluvial loam. The thickness of both of these parts of the diluvial formation and their distance from the upper margin is, of course, by no means uniform; the following measurement, made in that part of the northern slope where the lower strata are richest in fossil shells, may be taken as an average. The soil, however, has been removed there to some extent near the upper margin, a road being led over the height and deepened under the original surface. Below the level of the road, I found 5 meters of the upper diluvial loam; 4 meters of lower diluvium with pebble-strata; 5 meters of clay containing shells. Under this part of the slope, a less steep portion it filled up with detritus and soil broken off from the upper parts, measuring (vertically) 2 meters. Below the surface of the water, a boring was made which gave the same clay for at least 2 meters more. The strike and dip of the strata could not be measured exactly, but they seem to have a very slight dip to SE. They are clayish, but impure, and resemble very much the Oji strata. An accumulation of shells in one layer, like that of Oji, however, is not observed, and the clay contains some shells or fragments almost in every part which is exposed. I can only notice a maximum about the middle of the abovementioned 5 meters. The number of the shells collected would have been large enough, if they had not been mostly broken.

Great care was to be taken not to mix recent shells—or shells imbedded in the embankment at the period of its construction, like those mentioned by Morse in his Memoir on Omori, p. 35—with the fossils, and no specimen was collected or noted which was not dug out by myself or in my presence. Thus I obtained the following Oji species:

Nassa japonica Lischke.
Columbella scripta L.
Natica Lamarckiana Recluz.
Cerithiopsis rugosa Gld.
Dentalium entale L.
Solen grandis Dkr.
Saxicava arctica L.
Panopaea generosa Gld.
Mactra veneriformis Desh.
Mactra Sachalinensis Schrenck.
Tellina nasuta Cour.
Tellina Yeddoënsis Lischke.
Dosinia exoleta L.
Cardium Californiense Desh.
Laevicardium bullatum Ad.
Arca inflata Reeve.
Arca subcrenata Lischke.
Ostrea gigas Thunb.
Anomia patelliformis L.

To those 19 species, the following 6 are to be added which have not been found at Oji.

Rapana bezoar Linné. Pl. II. fig. 2.
(Syst. nat. ed. 12, p. 1204, as Buccinum.—Lamarck, Hist. nat. &c. second ed. v. 9, p. 514, as Pyrula.—Reeve, Conch. Icon. Pyrula, pl. 4, f. 15,6.—Lischke. Japan. Meeres-Conch. v. 1, p. 51.—Morse, Shell-mound of Omori, p. 34.).

Lischke describes quite correctly the Tokio specimens (with bulky, but somewhat elevated spire, long and curved canal and rather wide umbilicus) as belonging to the variety called Rapana Thomasiana by Crosse (Journal de Conch., v. 9, p. 176 and 268, pl. 9, 10). The fossil specimens are perfectly alike; they are not at all numerous in any of the tertiary deposits, and very few only occurred at Surugadai.

Lampania zonalis Lamarck. Pl. II. fig. 12.

(Hist. nat. sec. ed. vol. 9, p. 299, as Cerithium.—Sowerby, Thes. Conch. v. 2, p. 884, pl. 185, f. 264 and 265.—Adams, Genera of shells, v. 1, p. 289, pl. 30, f. 5 and 5a.—Reeve, Conch. Icon. Lampania, pl. 1, f. 5a-c.—Lischke, Japan. Meeres-Conch. v. 1, p. 73, pl. 6, f. 15 and 16, and v. 2, p. 69.).

Turreted, with the proportion of axis to diameter nearly as 3 to 1, with many plain whorls covered by some spiral ribs and by curved longitudinal ribs which make the former appear granulated, with a broad outer lip and a deep and broad notch in it, the species is easily to be recognized. From Lampania multiformis Lischke, the only other species which is important for this paper, L. zonalis differs first by the deeper notch of the lip, then by the straighter and wider canal. The other differences—stronger sculpture and tendency to graduated whorls in L. zonalis—are not constant.—I leave it undecided whether those two characters suffice to characterize L. multiformis as a species. From Takigashira-mura (v. next chapter), where the Lampaniæ are very frequent, I have among many specimens provided with a deep notch, some without it, and yet a few of the latter have comparatively strong ribs and a graduated spire. Lischke (v. 2, p. 69, pl. 5, f. 23 and 24) pronounced them a variety. Other specimens show an intermediate size of the notch; and even the canal which is comparatively the best character, shows, in one or two instances, an intermediate shape. At any rate, the specimens of Surugadai, by far less numerous than those of Takigashira, all have the characters of L. zonalis Desh. They reach the same size which is mostly seen at Takigashira, viz. 34 mm. in height and 12 in diameter.

Globulus superbus Gould.

(Otia conchol. p. 156.—Lischke, jap. Meeres-conch. v. 2, p. 83, pl. 5, f. 18-21.).

Some specimens of Surugadai corresponding—in their rather elevated spire, in their spiral furrows, in size, 15 mm. in height and 20 in diameter with 7 whorls, in the sick umbilical callus and ovate aperture—exactly to Gould's diagnosis and to Lischke's figures, I cannot but identify them. I omit to discuss the question, left also unsettled by Lischke, whether Gould's species is really a good one. The number of specimens from Yokohama and Takigashira is much larger, and moreover some of them show different characters, viz. those of Globulus monilifer Lamarck; but even there I do not find any intermediate form. I therefore think it best to separate them provisorily. At Surugadai mostly fragments are found, some of them with nice pearly lustre and with traces of colour-markings on some parts of the shell.

Cytherea meretrix Linné.

(Syst. nat. ed. 12, p. 1132.—Schrenck, nordjapan. Moll. p. 545 to 550.—Lischke, jap. Meeres-Conch. v. 1, p. 122, and v. 2, p. 108.).

Omitting the discussion about the limits of this species, most unhappily divided into a great many so-called species and varieties, and referring, like Lischke, to Schrenck's statements on this matter, I classify the Cythereæ of the tertiary beds of the environs of Tokio according to these authors. I add, however, that according to other authors the name of the frequent Japanese Cythereæ, which are identical with the fossil ones, would be C. lusoria Chemnitz (Conchyl.—Cabinet v. 9, p. 337; Lamarck, hist. nat. 2d. ed. v. 6, p. 297; Roemer, Monographie d. Mollusken-Gattung Venus p. 30, pl. 12, f. 1), of which also 'sub-varieties' have been largely established. The triangular, posteriorly elongated form, the smoothness, the typical hinge and not very thick shell, in some instances also slight colour-marks, are common to all the fossil shells. A few of them, though very small or broken, were found at Surugadai.

Cyclina sinensis (Linné) Gmelin. Pl. VI. fig. 23.

(Syst. nat. Linn. ed. 13, p. 3285.—The name was altered into chinensis by Lamarck, hist. nat. 2d. ed. vol. 6, p. 291, Reeve, Conch. Icon. Artemis, pl. 1, f. 6, Sowerby, Thes. Conch. v. 2, p. 661, Lischke, japan. Meeres-Conch. v. 1, p. 126, v. 2, p. 111, and Morse, Shell-mound of Omori, p. 27, pl. 18, f. 1.).

The height is a little greater than the length, the surface covered with fine radiating striæ crossing the lines of growth. Besides, the species is easily recognized by its crenulated inner margin and by its flat lunula. It is by far more frequent in the Tokio-Bay than it was formerly supposed to be, but it does not occur frequently in any of the tertiary deposits, and the specimens, not reaching the size of the living ones, are in every respect so much like them that there seems to be no necessity for discussing here the value of the statements of Mores concerning the smaller size and comparatively smaller length of the recent shells. The differences given by Morse—viz. 1 to 1.057 as proportion of the length to the height of shell-mound specimens, and 1 to 1.042 for the same dimensions of the recent ones—are but slight, and so the case may possibly be as in Dosinia exoleta L.

Tapes decussatus Linné.

(Syst. nat. ed. 12, p. 1135, as Venus.—Gmelin, syst. nat. L. ed. 13, p. 3294, no. 35, with varieties sub no. 57, 64 and 99, as Venus.—Lamarck, hist. nat. 2d. ed. v. 6, p. 375, as Venus.—Forbes and Hanley, brit. Moll. pl. 25, f. 1, and v. 1, p. 379.—Sowerby, Thes. Conch. v. 2, p. 693, pl. 150,

f. 115 and 116.—Jeffreys, brit. Conch. v. 2. p. 359.—Weinkauff, Conch. d. Mittelm. v. 1, p. 97.—S. Wood, Crag-Mollusca, v. 2, p. 327, Suppl. p. 145, pl. 10, f. 4.—Dunker, Mollusca Japonica p. 26.—Schrenck, nord-japon. Moll. p. 533.—Syn. Tapes Philippinarum Adams and Reeve, Zool. of the voyage of H. M. S. Samarang, Moll. p. 79, pl. 22, f. 10; Sowerby, Thes. conch. v. 2, p. 694, pl. 151, f. 146 and 147; Reeve, Conch. Icon. Tapes, pl. 11, f. 56; Lischke, japan. Meeres-Conch. v. 1, p. 115, v. 2, p. 108 and v. 3, p. 78, pl. 10, f. 4, the last representing a variety called Tapes ducalis by Roemer, Monogr. der Moll.-Gatt. Venus, v. 2, p. 82, pl. 28, f. 3.).

It seems strange, indeed, that Lischke rejects the determinations of Dunker and Schrenck, and also of Jay, based upon a scrupulous examination of hundreds of specimens, and that he tries to point out differences which do not correspond to what is really seen in the East-Asiatic specimens. They are indeed far from being always thicker, or shorter, than the European ones. The posterior dorsal margin is very often just as straight in the Japanese shells as in the European, and the differences seen in one part of the globe recur in the other. As for the sculpture, the variability of the European specimens may have even a little wider range. One of Lischke's reasons for giving T. Philippinarum as a distinct species seems to be that T. decussatus is not an arctic shell. But arbitrary as it undoubtedly is to reject the wide distribution of a species on this account, this reason is also much weakened by the occurrence of T. decussatus not only in the British seas, but also in the diluvial post-glacial beds of North-Britain.—The species is not uncommon in other Japanese localities containing tertiary beds, but only rarely met with at Surugadai. It reaches here 36 mm. in length, 25 in height and 16 in thickness.

SHINAGAWA.

The next place to be mentioned is a deep railway-cutting in the southwestern part of Tokio itself, next to the station of Shinagawa. It is very near the sea, but does not belong to the bluff-exposures mentioned in the following chapter.

The railway-cutting dissects, in its northeastern part, tertiary beds unconformably covered by lower diluvial strata. As far as the vegetation allows to see, both formations are horizontal. The unconformability, however, is obvious. The limit is undulated and slopes so rapidly, that, in the southwestern part of the same cutting, only diluvial strata, mostly formed of gravel, are exposed, and they fill up the whole cutting from the top to the very bottom. The best place for digging out shells is a few yards beyond the bridge leading over the cutting, at a short distance from the station, and 1 to 2 meters above the railway-level. This digging being kindly allowed by the authorities, I obtained here the following species already mentioned from one or both of the foregoing localities.

Neptunea arthritica Valenc.—(See Oji.)
Nassa japonica Adams.—(do. and Surugadai.)
Ringicula arctata Gould.—(See Oji.)
Columbella scripta. L.—(See Oji and Surugadai.)
Natica Lamarckiana Recluz.—(See Oji and Surugadai.)
Chemnitzia elegantissima Mont —(See Oji.)
Odostomia planata Gould.—(do.)
Lampania zonalis Lamarck.—(See Surugadai.)
Globulus superbus Gould.—(See Surugadai.)
Dentalium entale L.—(See Oji and Surugadai.)
Panopaea generosa Gould.—(do.)
Saxicava arctica L.—(do.)
Lutraria Nuttalli Conr.—(See Oji.)
Mactra veneriformis Desh.—(See Oji and Surugadai.)
Mactra Sachalinensis Schrenck.—(do.)
Venus (Mercenaria) Stimpsoni Gould.—(See Oji.)
Saxidomus purpuratus Sow.—(do.)
Dosinia exoleta L.—(See Oji and Surugadai.)
Cardium Californiense Desh.—(do.)
Laevicardium bullatum Ad.—(do.)
Lasaea rubra Mont.—(See Oji.)
Kellia orbicularis Mont.—(do.)
Lucina borealis L.—(do.)
Pectunculus glycimeris L.—(do.)
Nucula Cobboldiæ Sow.—(do. Of this species some large specimens have been found at Shinagawa.)
Pecten laqueatus Sow.—(See Oji.)
Ostrea gigas Thunb.—(See Oji and Surugadai.)
Anomia patelliformis L.—(do.)

To these 28 species the following 8 (one of which is a brachiopod, whilst 4 are gasteropoda and 3 conchifera) are to be added.

Fusus inconstans Lischke.

(Japan. Meeres-Conch. v. 1, p. 34, pl. 2, f. 1-6, v. 2, p. 26, pl. 3, f. 1-5.)

Leaving the responsibility for the species to the author, I simply note the presence of a few specimens corresponding entirely to Lischke's description, diagnosis and figures at Shinagawa. We shall meet with the species once more in the 7th chapter.

The shell is elongated, fusiform, with a long canal, strong ribs on the elevated spire, which become much weaker on the last whorls, and spiral striæ one of which, in the middle of the upper whorls, is often placed upon an elevated carina. This character is lost in the smaller variety which occurs almost exclusively in the fossil state. It is about 80 mm. long and has a diameter of 27 mm. As for the differences from other species provided with a long canal, e. g. F. nodosoplicatus Dkr (Novit. conch. II, pl. 33, f. 3 and 4) from Japan, F. spectrum Ad. and Reeve (conch. Icon. Fusus, pl. 18, f. 68), also a Japanese form and mentioned as such by Schrenck (Nordjapan. Moll. p. 417), and F. Novae Hollandiae Reeve (l. c. f. 70) which Schrenck says is synonymous with F. Spectrum, I refer to Lischke, without entering into the above-mentioned question, for whose discussion the material provided by the tertiary layers in question is evidently not sufficient.

Neptunea (Sipho) gracilis da Costa.

(Brit. Conch. p. 124, pl. 6, f. 5.—Jeffreys, brit. Conch. v. 4, p. 335.—S. Wood, Crag Moll. I, p. 46, pl. 6, f. 10, perhaps only partly; second suppl. p. 7, pl. 2, f. 4.—Syn. Fusus islandicus Forbes and Hanley, brit. Moll. v. 3, p. 416, pl. 103, f. 1 and 3 and pl. SS, f. 2.).

The differences between Neptunea islandica, which has a bulbiform apex, N. propinqua, which has a smaller number of spiral elevated lines on the upper whorls, and N. gracilis are but slight. The latter is chiefly said to have a shorter canal and to be smaller than N. islandica Chemn.; but perhaps S. Wood may be quite right in saying (in his 2d supplement) that all these forms—together, perhaps, with Sipho tortuosus, ventricosus, Sarsii and Leckenbyi—may be only 'inconstant varieties of Sipho islandicus.'—One specimen from Shinagawa has the characters of N. gracilis.

Purpura lapillus Linné.

(Syst. nat. ed. 12, p. 1202.—Forbes and Hanley, brit. Moll. v. 3, p. 350, pl. 102, f. 1-3 and pl. LL., f. 4.—Jeffreys, brit. Conch. v. 4, p. 276.—S. Wood, Crag.-Moll. I, p. 36, pl. 4, f. 6; 2d Suppl. p. 5, pl. 1, f. 13.—Gould, Rep. on the invertebr. of Mass., 2d ed. by Binney, Moll., p. 360.).

The shell, variable as it is frequent, is but seldom found in the Japanese tertiary deposits. One fragment, belonging to the common form with strong spiral ribs and somewhat elongated in outline, has been found at Shinagawa.

Cemoria noachina Linné.

(Mantissa, p. 551, as Patella.—Lowe, zoological Journal, v. 3, 1828, p. 77, as Puncturella.—Gould, Rep. on the invert. of Mass. 2d ed. p. 276, f. 537.).

Oblong (diameters as 5 to 3), radially ribbed, with a small fissure near the apex, this small shell, about 7 mm. long, has been once found at Shinagawa. The number of the ribs is 20; concentrical striæ and mostly one very feeble rib in the middle of the interval are to be seen between them. The form and sculpture of the shell correspond exactly with the quoted figures and make it impossible to identify it with the Puget-Sound and Orange-Harbour species mentioned in Gould's Otia conchol. p. 14. The outline, especially the very different angle of divergence, and the difference of the plate distinguish this shell from Puncturella Cooperi Carpenter (Desc. of new marine shells from California, Proceedings of the Ca. Acad. of Nat. sc. v. 3.).

Limopsis aurita Brocchi. Pl. VI fig. 27.

(Conch. foss, Subapenn. p. 485, pl. 11, f. 9. as Arca.—Defrance, Dict. Scient. pl. 39, p. 224.—Goldfuss, Petrefacta German. v. 2, p. 163, pl. 126, f. 14.—Philippi, Enum. Moll. Sic. v. 1, p. 63, and v. 2, p. 45. All these authors apply the generic name of Pectunculus.—S. Wood, Crag-Moll. II, p. 70, pl. 9, f. 2 and Suppl. p. 117.—Jeffreys, brit. Conch. v. 2, p. 161.).

This species, as far as I know, has never been found living in the Pacific Ocean or in its bays, nor in the East-Indian Sea, and even the genus seems to be wanting except in the very remotest corner of this part of the ocean, in the Red Sea. The shells, not rare at Shinagawa, are easily distinguished from Pectunculus by their sharp and smooth margin. Besides, they are mostly more oblique, and their ribs are a little sharper. The cancellated surface, on which the radiating ribs prevail, is exactly the same as in the European fossil specimens, and the only difference which could be found is the number of teeth which according to Jeffreys is about a dozen. This does not correspond to the Shinagawa specimens which are partly large, reaching 17 mm. in height and 18 in length, and mostly very well preserved. They have never less than 14 teeth and often 18, or 9 on each side of the cartilage pit, and in a few instances, one—or in the posterior side even 2—may be added. But all the figures and Wood's description prove to a certainty that the normal number of teeth is indeed 18, and that a smaller number indicates either an obliteration or an imperfect stage of development. The vertical range of the species is comparatively great, as it is found in the Falun-like miocene deposits of North-Germany as well as in the Subapennine formation. It is also found in the crag and is said to occur in the glacial beds (where it may be derivative). Jeffreys and others say that it still exists near the northwestern coast of Britain.

Pecten laetus Gould.

(Otia conchol. p. 177.—Carpenter, Rep. II, p. 587; Cuming and Lischke, v. i., exclude, however, the specimens from New Zealand, mentioned by Gould l. c. p. 95 and figured in Atl. of Moll. of Wilke's Expl. pl. 42, f. 571; they unite the latter to P. Dieffenbachii Gray.—Lischke, Japan. Meeres-Conch. v. 1, p. 169, pl. 12, f. 6 and 7; vol. 2, p. 157.).

Omitting, in this case also, a critical investigation whether the species is really good or not, I identify the shells from Shinagawa with it and particularly with Lischke's figure 6 l. c. They are few in number, mostly broken. One is entire but smaller than the mentioned figure; it has 10 strong ribs with foliated projections, and the number of the intermediate ribs is mostly 3, sometimes 4 or 2. The outline is nearly circular, the length almost as great as the height. The species to be compared are P. senatorius L., but also P. hastatus Sow. (Gould's hericius), a very variable species which verges towards P. rubidus Hinds (of Alashka) as well as towards P. islandicus Muell.

Ostrea denselamellosa Lischke.

(Japan. Meeres-Conch. v. 1, p. 177, pl. 13, f. a and b, pl. 14, f. 1 and v. 3, p. 114.).

This species may be said to be still more doubtful and resembles indeed very much those forms which Wood represents (Crag. Moll. II, p. 17, pl. 1, f. 1 and pl. 2, f. 2) under the name of Ostrea princeps, or Nyst (not Sowerby) as O. undulata (Coqu. foss. de Belgique, p. 324, pl. 24, f. 7^a and pl. 25, f. 7^b.). Some large and good specimens were, together with many fragments, found at Shinagawa.

Waldheimia Grayi Davidson.

(Proceed. of Zool. Soc. London, 1852, p. 76; ibid. 1871, April, p. 304, pl. 31, f. 7 and 8.—Adams, Ann. Mag. Nat. Hist. 2d-series. v. 11, p. 99.).

Though only one lower valve of this species—abundantly occurring in Japan—has been found at Shinagawa, it has some importance as the only specimen of Brachiopoda of the Tokio layers. It is easily recognized by its rounded triangular ribs (about 15) and moderately transverse shape.

By the addition of the new species from Surugadai and Shinagawa the total amount becomes 76. This number is again increased by the localities near Yokohama which are to follow in the next chapter.

CHAPTER VI.

THE TERTIARY DEPOSITS OF THE ENVIRONS OF YOKOHAMA.

KANAGAWA.

The bluffs near the station of Kanagawa (the first from Yokohama in the direction to Tokio) give a very good idea of the strata in question and of the way in which they are unconformably covered by the quaternary beds, and therefore have been represented not only in the above-quoted figure, but also in figure 2 and 3, plate I; yet they are not rich in fossils. The high, nearly vertical bluffs are almost everywhere composed of tufaceous, grayish-green rocks, mostly a little soft, and separated into thick strata. They are, of course, limited above by an undulating line, near which, in the strata themselves, sometimes a few shells appear. This is also the case in some parts of the lower strata, but the number of the specimens is always small, and they are scattered over the slope of the tufaceous and sandy clay.

The greater part of the Mollusca found are large and small specimens of *Nucula Cobboldiae* Sow., which, though mostly breaking into small fragments when taken out of the native rock, yet in a few instances were good and always helped to make out the characters of the interesting species. It was here that the specimen (Pl. VI, f. 28a) with the smooth inferior belt of 2.6 millimeters in breadth was found. Next to be mentioned is *Mya arenaria* Linné which will be discussed with other species found at Takigashira-Mura where it is abundant. To finish the list of Conchifera, I have only to add *Ostrea gigas* Thunb., ***Pecten plica*** L. ***Arca subcrenata*** Lischke, ***Dosinia exoleta*** L. and ***Tapes decussatus*** L. Gasteropoda are not found except two *Neptuneae*, one of which is *N.* ***gracilis*** da Costa, whilst the other turns out to be the true *N.* ***islandica*** Chemn. (Conchyl.—Cabinet. v. 4, p. 150, pl. 141, f. 1312 and 1313; Jeffreys, brit. Conch. v. 4, p 333). It differs from the foregoing, as has been said above (vide chapter 5, Shinagawa), by a more obtuse, bulbiform and upturned apex; besides, it has a more elongated spire, whilst the transverse striae on the whorls do not differ from those af N. gracilis.

YOKOHAMA BLUFF, EASTERN PART.

From Kanagawa station the steep and high bluff-line retreats to a considerable distance and thus forms a bay between this place and Yokohama. This portion offers no remarkable localities in which fossils are to be found. The next place in which this is the case is the Yokahama Bluff in the south of the town, now covered with villas. At the point where the bluffline reaches the sea, the tertiary strata are seen to contain a shell-layer, not very much above the level of the sea and sinking nearer and nearer to it beyond the coal-stores and other industrial establishments which are here built between the strand and the bluff. For a short distance, the layer descends nearly to the strand, whilst blocks of tertiary rocks tumbled down are scattered along the shore. Here I collected, partly in these blocks, but mostly in the native shell-layer, a small number of shells, taking of course very great care not to mistake recent shells, for instance oysters which cover some of the blocks, for tertiary ones. It may be remarked, however, for this and for many other localities, that the state of preservation mostly sufficed to prevent such a mistake; for excellent as it sometimes was (exhibiting in many cases even traces of color, or nacreous lustre), yet all the tertiary shells were unequivocally fossil, resembling in every respect certain European tertiary shells, e. g. the Viennese, Antwerp and Touraine miocene shells, or those of Grignon, but above all the subapennine fossils.—The diluvial rocks—which also descend very low, just above the shell layer—do not contain any well preserved shells (indeed scarcely any shells at all), and are so different from the tertiary tufaceous clays and shell-beds that there is no difficulty in distinguishing the blocks.

LIST OF SPECIES.

Neptunea arthritica Valenciennes.—(See Oji, Shinagawa.)
Nassa japonica Adams.—(do.)
Purpura lapillus L.—(See Shinagawa.)
Lampania zonalis Lamarck.—(See Surugadai, Shinagawa.)
Panopaea generosa Gould.—(See Oji, Surugadai, Shinagawa.)
Tellina nasuta Conrad.—(See Oji, Surugadai, Shinagawa.)
Dosinia exoleta L.—(See Oji, Surugadai, Shinagawa and Kanagawa.)
Cardium Californiense Desh.—(See Oji, Surugadai, Shinagawa.)
Laevicardium bullatum Ad.—(do.)
Arca inflata Reeve.—(See Oji, Surugadai.)
Arca subcrenata Lischke.—(See Oji, Surugadai and Kanagawa.)
Pectunculus glycimeris L.—(See Oji, Shinagawa.)
Pecten laqueatus Sow.—(See Oji, Shinagawa.—Found frequently in the eastern part of the Bluff.)
Ostrea gigas Thunberg.—(See Oji, Surugadai, Shinagawa and Kanagawa.)

To these species mentioned already from Tokio two more are to be added:

Dolium luteostomum Küster.

(2d ed. of Chemnitz, Conchyl.—Cab. v. 3, Abth. 1, pt. 2, p. 66, pl. 58.—Lischke, Japan. Meeres-Conch. v. 1, p. 65 and v. 2, p. 57.—According to this author, the species is synonymous to D. japonicum Dunker, Novit. conchol. v. 2, p. 104, pl. 35 and 36; and to D. variegatum Küster, l. c. p. 74, and Schrenck, nordjapan. Moll. p. 401, *non* Lamarck.)

The bulky, deeply furrowed shell—on whose surface and mould broad ribs with narrow intervals appear, much flatter on the mould than on the shell itself—has been found rarely in the blocks and shell-layer of the Yokohama Bluff. Though mostly only moulds, the specimens, on being compared with recent Dolia, left no doubt whatever about their identity with the above-mentioned species.

Tapes euglyptus Philippi.

(Zeitschrift für Malacozool. 1847, p. 89, and Abbildungen etc. v. 3, p. 76, Venus, d. 7, f. 3.—Sowerby, Thes. Conch. v. 2, p. 680, pl. 145, f. 17. Lischke, japan. Meeres-Conch. v. 1, p. 119, and v. 3, p. 80, pl. 6, f. 8—11.)

The species which belongs to the group of Tapes papilionaceus L. shows sculpture, pallial sinus and outline doubtlessly to be identical with some specimens at Yokohama. One of them represents the variety figured by Lischke.

SOUTH WESTERN PART OF THE YOKOHAMA BLUFF.

Crossing the bluff in its western part from N. to S., we find a broad and well constructed footpath leading down to the sea-side and to the fishermen's houses placed next to the sea. This way is deeply cut into the rock and, as it crosses the line which divides the quaternary and the tertiary strata with the shell-layer, here fully developed below that line, a great many shells are dug out and spread over a part of the road, some being also visible in their native rocks on the sides of the road. Thus, though now no clear idea of the nature and position of the strata is given by this exposure, yet I was able to make here some additions to the collection of fossils. The number of species, however, which I can assign with certainty to the tertiary formation, is very small and includes nothing that has not been found also in other places. The largest number of specimens is furnished by *Mactra veneriformis* Desh., next to it by *Globulus superbus* Gould. Some specimens of *Lampania zonalis* Lamarck, a single one of *Lampania multiformis* Lischke (vide below, Takigashira Mura), on whose relation to L. zonalis I have made already some remarks when treating the latter one (from Surugadai), one specimen of *Tapes decussatus* L. and some of *Ostrea gigas* Thunb. are to be added.

TAKIGASHIRA MURA.

At the southern mouth of the canal which leads from Yokohama-harbour along the Bluff-slope and its western prolongation and at last turns to the south and reaches the sea again, the village or Mura of Takigashira is situated. Going along the canal, soon after having left the small part of the Bluff which is intersected by the canal, and on getting to the open low ground beyond, we reach a gravel-deposit which is used for engineering purposes, and is covered by unquestionably alluvial deposits. They have been described in the second chapter as mostly peaty; the lowest part of them is impure, dark-coloured sand, 0.5 meter in thickness. The pebble-stratum itself must have been exposed to the action of the sea during some part of the alluvial era, as before mentioned; but neither the admixtures of peaty and humose substance, nor the recent oysters covering some of the pebbles prove at all an alluvial origin of the entire pebble layer. For those oysters are all confined to the superficial pebbles, and the whole stratum is evidently a continuation of the layer which appears next to the limit of the tertiary deposits in the bluff-slope between Takigashira Mura and Yokohama. The section seen there gives

6 metres upper diluvial loam mixed with humose soil near the surface.
9 m. grayish clay, mostly in thick strata, but sometimes alternating with thin layers of sandy soil
0.5 to 1.5 m. grayish Conglomerate.
(line of unconformability.)
18 m. (in max.) clayish and tufaceous pale greenish-gray strata, tolerably hard.
6 m. (in the average) sandy soil, also greenish-gray.

As the conglomerate-layer very gradually slopes down to the level of the lower plain, and as it is exactly like the conglomerate-layer mentioned above, there can be no doubt about the latter belonging to the same geological horizon, viz. to the lower diluvial formation.

Below this layer and the line of unconformability, we find at Takigashira the same clayish soil which is the thickest part of the section given above. Half-way between the bluff and the place where the gravel is dug, a large quantity of shells appears, only surpassed by that of Oji. This shell-layer was afterwards found to extend from the slope of the bluff of the gravel field, though the richest development is confined to the first-mentioned place. It scarcely needs be added that only such specimens were admitted as were undoubtedly found in the strata below the gravel, and anything not found in the native soil of this part of the geological section was rigorously excluded. I found the following fossils mentioned already from other localities:

Fusus inconstans Lischke.—(See Shinagawa.)
Nassa japonica Adams.—(See Oji, Shinagawa, Yokohama.)
Nassa livescens Phil.—(See Oji. This species occurred abundantly at Takigashira.)
Rapana bezoar L.—(See Surugadai.)
Columbella scripta L.—(See Oji, Surugadai, Shinagawa.)
Ringicula arctata Gould.—(See Oji, Shinagawa. Seldom at Takigashira.)
Natica Lamarckiana Recluz.—(See Oji, Surugadai, Shinagawa.)
Odostomia planata Gould.—(See Oji, Shinagawa.)

Drillia reciproca Gould.—(See Oji.)

Lampania zonalis Lamarck.—(See Surugadai, Shinagawa, Yokohama.)

Lampania multiformis Lischke, Japan. Meeres-Conch. v. 1, p. 74, pl. 6, f. 1-10 and v. 2, p. 69, pl. 5, f. 23 and 24.—Though I expressed, when speaking about the foregoing species, some doubts about the value of the specific characters, yet the presence of all the marks given by Lischke (viz. obliqueness of the canal, and size of the notch; the flatness of the whorls, the slighter sculpture and the less elevated spire being not constant) obliges me to quote also L. multiformis from Takigashira as well as from the western part of the Yokohama-Bluff. In both places together, only a few specimens were found among a multitude of L. zonalis.

Trochus argyrostomus Gould.—(See Oji.)

Globulus superbus Gould.—(See Surugadai and eastern part of Yokohama-Bluff.)

Tornatina exilis Dunker.—(See Oji.)

Dentalium entale L.—(See Oji, Surugadai, Shinagawa.)

Solen grandis Dunker.—(See Oji, Surugadai.)

Mya arenaria Linné, Syst. nat. ed. 12, p. 1112; Forbes and Hanley, brit. Moll. v. 1, p. 168 and pl. 10, f. 4-6; Jeffreys, brit. Conch. v. 3, p. 64; Wood. Crag Moll. II, p. 279, pl. 28, f. 2; Lischke, Jap. Meeres-Conch. v. 1, p. 138; Morse, Shell-mound of Omori, p. 30, pl. 18, f. 4; syn. Mya japonica Jay, Rep. on Moll. of Perry's Exp. p. 292, pl. 1, f. 7 and 10.—The elongated form, bulbose anteriorly, obtusely pointed behind, the typical hinge etc. leave, as is universally admitted, no doubt about the identity of the recent Japanese specimens with the European, recent and fossil. There is no difference whatever between the recent Japanese shells or those of the mounds (which Morse states not to differ at all), and those found at Takigashira. The shell has not been found in Tokio, but at Kanagawa; more abundantly, than at this place or at Takigashira, it occurs in the upper tertiary sandstones of Mino (See Chapter 7.)

Mactra veneriformis Desh.—(See Oji, Surugadai, Shinagawa, western part of Bluff. At Takigashira, this species is much more numerous than the following one.)

Mactra Sachalinensis Schrenck.—(See Oji, Surugadai, Shinagawa.)

Tellina nasuta Conr.—(See Oji, Surugadai, Shinagawa, eastern part of Bluff.)

Tapes decussatus L.—(See Surugadai, western part of Bluff.)

Saxidomus purpuratus Sow.—(See Oji, Shinagawa.)

Cytherea meretrix L.—(See Surugadai. Frequently found at Takigashira.)

Dosinia exoleta L.—(See Oji, Surugadai, Shinagawa, Kanagawa, eastern part of Bluff. Rare at Takigashira.)

Cyclina sinensis Gmel.—(See Surugadai.)

Kellia suborbicularis Mont.—(See Oji, Shinagawa.)

Lasaea rubra Mont.—(See Oji, Shinagawa.)

Lucina borealis L.—(See Oji, Shinagawa.)

Arca inflata Reeve.—(See Oji, Surugadai, eastern part of Bluff.

Arca subcrenata Lischke.—(See Oji, Surugadai, eastern part of Bluff.)

Pecten laetus Gould.—(See Shinagawa. Not frequent at Takigashira.)

Ostrea gigas Thunb.—(See Oji, Surugadai, Shinagawa, Kanagawa, western and eastern part of Bluff.)

Besides these 33 species found also in other places, 7 more have been collected at Takigashira which are still to be discussed:

Eburna japonica Reeve. Pl. II, f. 5.

(Conch. Icon. Eburna, pl. 1. f. 3.—Sowerby. Thes. Conch. v. 3, p. 70, pl. 215, f. 11.—Lischke, Japan. Meeres-Conch. v. 1, p. 67, and vol. 2, p. 58.—Morse, Shell-Mound of Omori, p. 30, pl. 18, f. 9.)

Of this shell not at all uncommon in the Tokio Bay and often brought to the market, only a single specimen has been found fossil at Takigashira. It is small and has the angle of divergence equal to 60°, being in this respect nearer to Morse's specimens from Omori than to the recent. It is typically developed, with the deep notch below, the ovate aperture, the smooth surface, and has even some slight traces of colour.

Purpura luteostoma Chemnitz.

(Conch. Cab. v. 11, p. 83, pl. 187, f. 1800 and 1801. Nov. ed. Küster, Buccinum, pl. 19, f. 7 and 8.—Reeve, Conch. Icon. Purpura, pl. 8, f. 35.—Lischke, Jap. Meeres-Conch. v. 1, p. 54.—Morse, Shell-mound of Omori, p. 33.)

One specimen of 37 millimeters in height and 24 in diameter, together with a few fragments, gives evidence of the existence of this species in the tertiary beds. It is typical and has broad spiral rows of big tubercles the largest of which are placed near the upper suture; a concave spiral groove is seen next to the latter.

Chemnitzia scalaris Philippi.

(Moll. Sicil. v. 1, p. 157, pl. 9, f. 9, as Melania, afterwards as Chemnitzia.—Forbes and Hanley, brit. Moll. v. 3, p. 251, pl. 94, f. 5 and pl. FF, f. 5.—Jeffreys, brit. Conch. v. 4, p. 160.—Weinkauff, Conch. d. Mittelm., v. 2, p. 212, as Turbonilla.)

The description of Jeffreys and the figure of Forbes and Hanley perfectly agree with some specimens found at Takigashira. They are small, only 6 millimeters long and 2 broad, turreted, with shouldered whorls, which are covered with 16 strong longitudinal ribs and with many small transverse striae appearing chiefly in the intervals.

This shell belongs to the warmer part of the temperate Atlantic region; but a variety, of elongated form, (see Jeffreys l. c. and Forbes and Hanley, ib. f. 1, Ch. rufescens) is more boreal, and to this variety one of the specimens may be assigned. The remark of Weinkauff, that the species has not been found fossil, seems not to be perfectly true, as Jeffreys mentions one specimen found in the Crag.

The exact resemblance of the British shells and those of Takigashira does not allow us to give them any other name in spite of the wide distance of habitat and the scarcity of the species in strata older than quaternary. Perhaps the wide Atlantic distribution, which includes the Mediterranean from Gibraltar to the Ægean Sea, and New England on the other hand, may account for the occurrence of the species on the opposite side of the palæarctic continent.

Vermetus imbricatus Dunker

(Malacozool. Bl. v. 6, p. 240. 1860, and Mollusca Japon. p. 17, pl. 2, f. 18.—Lischke, Japan. Meeres-Conch. v. 1, p. 83.—Non Sandberger, Conch. d. Mainzer Beckens, p. 112.—Syn. Serpulus Adamsii Moerch in Adams, Ann. Mag. Nat. Hist., 1864, p. 141, Schrenck, nordjap. Moll. p. 601, and Moerch, Suppl. notes to Review of Vermetidæ in Proc. Zool. Soc. 1865, p. 99.)

In regard to this species, found in congregated masses on pebbles &c. abundantly in the alluvial layers and living, but rarely and only fractured in the tertiary deposits of Takigashira, I follow the denomination adopted by Lischke.

Globulus monilifer Lamarck.

(Hist. nat. 2d ed, v. 9, p. 118, as Rotella.—Lischke, Japan. Meeres-Conch. v. 1, p. 64.)

The true Globulus monilifer, flat and covered with its sharply circumscribed, flat tubercles, has been found in small numbers together with a great many of G. superbus Gld. It has been already mentioned that I did not find any intermediate forms.

Diplodonta orbella Gould.

(Proc. Boston Soc. Nat. Hist., v. 4, 1851, p. 90; Boston Journal Nat. Hist., v. 6, p. 395, pl. 15, f. 3; Otia Conch. p. 212.—Carpenter, Proc. Boston Zool. Soc., 1856, p. 202 and 218.—Lischke, Japan. Meeres-Conch., v. 2, p. 133.).

The diagnosis of Gould leaves no doubt about the identity of one entire valve—and some fragments—from Takigashira, with his Diplodonta orbella. The valve in question is 18 millimeters long, 17 high, and the total thickness of both valves would have been 15. The concentrical striæ are irregular, not very strong; the outline is more regularly rounded than in D. rotundata. The lateral tooth is much more obliterated than in D. trigonula, described above.

Arca granosa Linné.

(Syst. nat. ed. 12, p. 1112.—Reeve, Conch. Icon. Arca, pl. 3, f. 15.—Lischke, Japan. Meeres-Conch. v. 1, p. 145.—Morse, Shell-mound of Omori, p. 26.)

This shell has comparatively few—I count 18—ribs most of which, especially the anterior ones, are granulated. The outline, obliquely quadrangular and rounded at the edges, especially at the obtuse anterior. inferior edge, the hinge etc. do not present any peculiar characters. The specimens of Takigashira are very few in number, but they are partly well preserved and give unequivocal evidence of the existence of this species in the tertiary layers of central Japan. Their proportions are exactly the same as those from Nagasaki and from the Omori mound, but they are smaller (28 millim. long and 22 high). The number of ribs being like the minimum of Omori, the tertiary fossil specimens are of course much nearer akin to the latter than to the recent ones from Nagasaki.—

The total number of species from Takigashira Mura is therefore 40, and this place is superior to the other localities near Yokohama in the same way as Oji is to the other places in Tokio. Of the 53 species found altogether in the environs of Yokohama, three fourths belong to Takigashira.

The large number of species common to the layers both of Yokohama and Tokio would be sufficient to prove the identity of the formation, even if this was not geologically evident. Of 53 species 41 are identical with Tokio species.

As there are 75 species from all the places about Tokio altogether, and 2 from Kanagawa, 3 from the Bluff and 7 from Takigashira, the total number of species is 87.

CHAPTER VII.

THE TERTIARY DEPOSITS OF OTHER PARTS OF JAPAN.

Turning to the south from Yokohama, we enter the province of Sagami before we come to the place named already in the third chapter, Yokosuka, and before we arrive at the cape which forms the southwestern extremity of the Tokio-Bay. Here, thick and tolerably hard tufaceous rocks, mixed with middle- and fine-grained quartz-sand, of greenish gray color, appear on the bluff-sides, and they are often quarried. Nevertheless, the amount of organic remains exhibited by them has been trifling, and except Nucula Cobboldiæ Sow., Ostrea gigas Thunb., Dosinia exoleta L., I know nothing to mention but a few specimens of badly preserved and undeterminable gasteropoda.

A similar result is obtained in the vicinity of Hakone, where the tertiary deposits are to be seen in a great many places and are developed in the way pointed out in the introductory chapter as being typical for the mountains round the Tokio plain. Hard sandstone, conglomerate and shale alternate, and though not a complete series of strata is exposed, yet the tertiary character is evident from the similarity with the Chichibu formation. Besides, in one place, a little northeast of Otogitome, rocks have been found with a few species of shells, Dosinia exoleta, L., Cyclina sinensis Gmel., Panopaea generosa Gould, Mactra veneriformis Desh.

A much better result is obtained when we go farther to NW. and N. and enter the province of Shinshiu or Shinano, which borders Musashi—the province containing Tokio and Yokohoma—in the west, and the western end of the Musashi-province itself, the district of Chichibu.

CHICHIBU.

Several places in the valley of the Aragawa (or upper Sumidagawa), for instance Minano and a small village named Hinô between Omiya and Nigawa, or in the valley of another branch, a little farther to the north, for instance Otagawa, have furnished tertiary beds and fossils. The latter are contained in hard sandstones, or in hard sandy and marly layers between the dark shale mentioned in the introductory chapter. For miles all those rocks, which fill a wide basin amidst schistose crystalline rocks, do not show any organic remains, and only in the places mentioned above are they found in tolerably good number. Besides the specimens of fossil wood (the species of which cannot be determined) are found the following shells:

Nassa livescens Phil.
Columbella scripta L.
Dentalium entale L.
Panopaea generosa Gould.
Mya arenaria L.
Mactra veneriformis Desh.
Tapes rigidus Gould
Venus (Mercenaria) Stimpsoni Gould.
Dosinia exoleta L.
Cyclina sinensis Gmel.
Cardium Californiense Desh.
Lucina borealis L.
Leda confusa Hanl.
Pecten laqueatus Sow.
Pecten plica L.
Pecten Yessoënsis Jay.
Ostrea gigas Thunberg.
Ostrea denselamellosa Lischke.
Lima squamosa Lamarck.
Terebratulina caput serpentis L.

All of them, except the two last species, have been described above; they prove at the same time the very young age of the entire system of rocks, and the identity of the character of its organic remains with that of Oji, Surugadai, Shinagawa, Kanagawa, Yokohama and Takigashira. This conclusion is, of course, not altered by the two additional shells both of which live in the Japanese sea. As they are also found at Sukegawa, north of Mito, in the province Hidachi, they will be more conveniently discussed below.

SHINSHIU PROVINCE.

The rocks found here are partly tufaceous and covered also by quaternary tufaceous rocks spread chiefly round the Asama-Yama. Among the rocks belonging to the latter formation I mention, by the way, an alunite-breccia found in the neighbourhood of the solfatara of Tadayama. The fossils to be mentioned are:

Natica Lamarckiana Reeve.
Turritella communis Risso (to be discussed below.)
Mya arenaria L.
Aulus pulchellus Dunker (also to be discussed below.)
Lutraria Nuttalli Conr.
Tellina nasuta Conr.
Venus (Mercenaria) Stimpsoni Gould.

Saxidomus purpuratus Sow.
Dosinia exoleta L.
Cyclina sinensis Gmel.
Diplodonta trigonula Bronn.
Lucina borealis L.
Cardium Californiense Desh.
Arca inflata Reeve.
Pectunculus glycimeris L.
Nucula Cobboldiæ Sow.
Pecten laqueatus Sow.
Pecten Yessoënsis Jay.
Pecten laetus Gould.

Among these 19 species, there are again only 2 which have not been mentioned in the foregoing chapters; one of them is a living Japanese specices.

MINO-PROVINCE.

In this province the same system of sandstone and shale is developed as in Chichibu, and the amount of fossils is larger than in any of the districts mentioned in this chapter. As for the other animals, I refer to what I said above. The mollusca, partly well preserved, belong to the following species:

Fusus inconstans Lischke. Chiefly found at Tsukiyoshi.
Neptunea islandica Chemnitz. d°.
Neptunea arthritica Valenc. Found at Tsukiyoshi and Togari.
Buccinum leucostoma Lischke (discussed below). From Togari.
Dolium luteostomum Küster. d°.
Eburna japonica Reeve. From Tsukiyoshi.
Natica Lamarckiana Recluz. From Tsukiyoshi.
Natica pyriformis Recluz. (discussed below) d°.
Cerithiopsis rugosa Gould. d°.
Lampania zonalis Lamarck. d°.
Turritella communis Risso (discussed below.) From Tsukiyoshi and Togari, frequent.
Vermetus imbricatus Dunker. From Togari.
Globulus superbus Gould. From Tsukiyoshi.
Mya arenaria L. From Tsukiyoshi and Togari.
Solen grandis Dunker. From Togari.
Soletellina Boeddinghausii Lischke (discussed below). From Tsukiyoshi and Togari.
Mactra veneriformis Desh. From Tsukiyoshi.
Tellina nasuta Conr. From Togari.
Dosinia exoleta L. Both places, frequent and in great variety.

Cyclina sinensis Gmelin. Also from Tsukiyoshi and Togari.

Saxidomus purpuratus Sow. From Togari.

Cardium muticum Reeve. Both places.

Cardium Californiense Desh. d°.

Lucina borealis L. d°.

Diplodonta trigonula Bronn. d°.

Arca inflata Reeve. From Tsukiyoshi.

Nucula Cobboldiæ Sow. Some large specimens, both from Tsukiyoshi and Togari.

Pecten plica L. Also from Tsukiyoshi and Togari.

Pecten Yessoënsis Jay. From Tsukiyoshi. Not frequent.

Ostrea gigas Thunb. From Tsukiyoshi and Togari.

Besides these shells, which entirely confirm what is said above, I cannot omit to mention the rich flora of the shale and the tufas which is nowhere found better than near Tsukiyoshi. As for the determination, I add simply that not one belongs to a species foreign to the actual Japanese flora; Acer palmatum seems to occur most frequently.

HIDACHI.

The mountains in the north of the Tokio plain, bordering the sea, are next to be mentioned. The exposures of tertiary beds are chiefly found along the coast at some distance from Mito. In a few places brown coal occurs, as it seems, under the beds described here, and it is said to extend even into the sea. The fossiliferous strata belong to a very thick system of partly hard, partly softer sandstones, sometimes a little tufaceous, but much oftener somewhat marly and intermixed with small rounded grains of rocks from the neighbouring crystalline mountains. In one instance, these tertiary rocks are enclosed within the schistose crystalline rocks and form a separate basin; this is the case upwards, or west, of Sukegawa. In all the other cases, for instance east of Sukegawa, or at Tagagori, Miyaku, they form the very last solid rocks next to the sea. They are covered by diluvial strata much in the same way as at Tokio, and it is worthy of notice that these diluvial strata are always horizontal, whilst the dip of the tertiary strata, as has been stated above, is mostly between 8° and 15°.

The fossils themselves are numerous but very often too badly preserved to be determined. It seems the less to be necessary to describe them here completely, as they will be the object of another paper prepared by Mr. Kochibe, graduate and ex-assistant of the Daigaku, now appointed at the Geological Surveying-Office of Tokio. But in order to give a correct idea of the fauna in its relation to that one which I described in the foregoing chapters, I give the following preliminary list containing the most important species.

SPECIES FOUND ALSO IN THE TOKIO PLAIN.

Fusus inconstans Lischke.
Neptunea islandica Chemnitz.
Neptunea arthritica Valenc.
Nassa livescens Phil.
Purpura lapillus L.
Eburna japonica Reeve.
Dolium luteostomum Küster.
Natica Lamarckiana Recluz.
Vermetus imbricatus Dunker.
Dentalium entale L.
Mya arenaria L.
Panopæa generosa Gould.
Solen grandis Dunker.
Mactra Sachalinensis Schrenck.
Tellina nasuta Conr.
Tapes rigidus Gould.
Tapes decussatus L.
Saxidomus purpuratus Sow.
Dosinia exoleta L.
Cyclina sinensis Gmel.
Cardium muticum Reeve.
Cardium Californiense Desh.
Lucina borealis L.
Arca inflata Reeve.
Arca subcrenata Lischke.
Pectunculus glycimeris L.
Nucula Cobboldiæ Sow.
Yoldia arctica L.
Pecten laqueatus Sow.
Pecten Yessoënsis Schrenck.
Pecten plica L.
Pecten lætus Gould (specimens from Sukegawa exactly corresponding to Lischke's fig. 6. l. c.)
Ostrea gigas Thunb.
Ostrea denselamellosa Lischke.
Anomia patelliformis L.
Waldheimia Grayi Davidson.

This list adds 7 species (Purpura lapillus L., Mactra Sachalinensis Schrenck, Tapes decussatus L., Arca subcrenata Lischke, Yoldia arctica L., Anomia patelliformis L. and Waldheimia Grayi Dav.) to the number of those which are common to the tertiary formation of the Tokio plain, and that of other districts.

SPECIES NOT FOUND IN THE TOKIO PLAIN.

Voluta megaspira Sowerby.
(Thes. Conch. v. 1, p. 208, pl. 48, f. 31 and 32.—Reeve, Conch Icon. Voluta, pl. 20, f. 49.—Schrenck, nordjapan Moll. p 443.—Lischke, Jap. Meeres-Conch. v. 2, p. 167 and v. 3, p. 43.).

Many moulds and fragments occur in all the localities of Hidachi where sandstones are exposed.

Buccinum leucostoma Lischke.
(Japan. Meeres-Conch. v. 3, p. 38, pl. 1. f. 7 and 8.).

Not frequent, neither at Sukegawa, nor in the province of Mino, at Togari (vide supra). The specimens agree perfectly with the quoted figure.

Natica pyriformis Recluz.
(Proc. Zool. Soc. 1843, p. 211.—Chemnitz, Conch. Cab., 2d ed. by Kuster, Natica, p. 60, pl. 5, f. 16.—Lischke, Japan. Meeres-Conch. v. 2, p. 169, and v. 3, p. 53.).

The specimens are partly well preserved, especially those from Tsukiyoshi, province of Mino (vide supra).

Turritella communis Risso.
(Hist. nat. des pr. produits de l'Europe mérid., v. 4. p. 106, pl. 4, f. 37.—Philippi, Enum. moll. Sicil., v. 2, p. 160, and v. 1, p. 192 as T. terebra. This name is also adopted by Sowerby, Min. Conch. pl. 565, f. 3, by Jeffreys, brit. Conch. v 4, p 80, and by Brocchi. Turbo terebra, non L., in Conch. foss. subapenn v. 2. p. 374, pl. 6. f. 8.—Forbes and Hanley, as T. communis, in brit. Moll. v. 3. p. 173, pl 89, f 1-3.—S. Wood, do, Crag Moll. I, p. 74, pl. 9, f. 9.).

Numerous specimens from the province of Mino (especially Togari, but also Tsukiyoshi) enable me to identify the Japanese fossil shells which were less frequent in Hidachi, with the well known palæarctic species, whilst they differ from the living Japanese and Oriental species.

Crepidula aculeata Gmelin.
(Syst. nat. Linn. ed. 13, p. 3693.—Lamarck, hist. nat. 2d ed. v. 7, p. 642.—Reeve, Conch. Icon. Crepidula, pl. 4. f. 22 and pl. 5, f. 27.—Lischke Japan. Meeres-Conch. v. 2. p. 76.)

One specimen only was found at Tagagori, Hidachi.

Haliotis gigantea Chemnitz.
(Conch. Cab. v. 10, p. 315, pl. 167. f 1610 and 1611.—Reeve, Conch. Icon. Haliotis, pl. 6, f. 19.—Lischke, Jap. Meeres-Conch. v. 1, p. 101, and v. 2, p. 91.—Syn. H. Kamtschatkana Jonas, Reeve l. c. pl. 3, f. 8.)

A few but partly excellently preserved specimens were found at Sukegawa, Hidachi.

Patella amussitata Reeve.

(Conch. Icon. Patella, pl. 33, f. 83.—Schrenck, nordjapan. Moll. pl. 14, f. 4 and 5.—Lischke, Jap. Meeres-Conch. v. 1, p. 109 and v. 2, p. 100, pl. 5, f. 7-11.)

The species, rather variable, has been found in tolerably large specimens, some of which were well preserved, in several places along the coast of Hidachi.

Aulus pulchellus Dunker.

(Novit. Conch. II, p. 20, pl. 6, f. 4 and 5.—Lischke, Jap. Meeres-Conch. v. 1, p. 124.—Syn. Aulus costatus junior Schrenck, nordjapan. Moll. p. 590, Middendorf, Reise &c. v. 2, first portion, p. 269; Aulus costatus Say, from the Atlantic coast of America.).

Without entering upon the question of the identity of these two species, answered in an opposite sense by Schrenck and Lischke, I mention the specimens from Hidachi and Shinshiu, tolerably numerous and belonging undoubtedly to the same species as those of Dunker.

Soletellina Boeddinghausii Lischke.

(Japan. Meeres-Conch, v. 2, p. 118, pl. 9, f. 9.).

In all the localities of the provinces of Hidachi and Mino moulds of this species are found; the shells themselves were less frequent.

Lima squamosa Lamarck.

(Hist. nat. 2d ed. v. 7, p. 113.—Lischke, Japan. Meeres-Conch. v. 1, p. 162.—Syn. Ostrea lima Linné, Syst. nat. ed. 12, p. 1147 and Sowerby, Thes. Conch. v. 1, p. 84, pl. 21, f. 1.)

This nearly world-wide species about which Lischke's discussion may be referred to, has been chiefly found in the Brachiopoda-beds near Sukegawa which will be mentioned below; but it occurs also in other places of Hidachi and in the district of Chichibu.

Mytilus edulis Linné.

(Syst. nat. ed. 12, p. 1157.—Forbes and Hanley, brit. Moll. v. 2, p. 170, pl. 48, f. 1, 3 and 4.—Reeve, Conch. Icon. Mytilus. pl. 8, f. 33.—Jeffreys, brit. Conch. v. 2, p. 104.—Weinkauff, Conch. d. Mittelm. v. 1, p. 224.—Philippi, En. moll. Sicil. v. 1, p. 73 and v. 2, p. 53.—S. Wood, Crag Moll. II, p. 52, pl. 8, f. 9 a-c, and p. 55, pl. 8, f. 10 as M. hesperianus.)

Omitting to mention all the varieties, I only add that the recent Mytili of Japan—not all of them like Mytilus Dunkeri Reeve (Conch. Icon. Mytilus, pl. 5, f. 17; Lischke, Japan. Meeres-Conch. v. 1, p. 153, pl. 10, f. 7 and 8) or like the other forms described by Lischke and other authors—must be, mostly at least, united with the true M. edulis L., whose variability is indeed almost universally acknowledged. The same is the case with the shells and moulds from the Hidachi sandstones, whose number, however, is but small.

Modiola flabellata Gould.
(Otia conchol. p. 93. Atlas of Mollusca of Wilke's Exped. pl. 40, f. 561.)

This Oregon species is doubtlessly represented by a few of the moulds of the Sukegawa sandstones.

Terebratulina caput-serpentis L.
(Syst. nat. 12th ed. p. 1153, as Anomia; excl. syn.— Ib. p. 1151, as Anomia retusa.—Lamarck, hist. nat. &c. 2d ed. v. 7, p. 332, as Terebratula caput-serpentis.—Forbes and Hanley, brit. Moll. v. 1, p. 353, pl. 56, f. 1—4, also as Terebratula. Reeve.—Conch. Icon. pl. 4, f. 19; also in Monogr. of recent Brachiopoda.—Jeffreys, brit. Conch; v. 6, p. 69, as Terebratula.—Sowerby, Min. Conchol. v. 6, p. 69, as Terebratula striatula.—Philippi, Enum. Moll. Sicil. v. 1, p. 96 and v. 2, p. 66; do.—Weinkauff, Conch. d. Mittel-meeres v. 1, p. 285.—Adams, Ann. Mag. Nat. Hist. 3d series, v. 11, p. 68, with varieties T. japonica and T. Cumingii.—Davidson, Proc. Zool. Soc. 1871, p. 303, pl. 30, f. 7, 8 and 9.).

Though the outline and size—as this is often the case with Brachiopoda and especially with Terebratulinae—are somewhat different from the typical specimens, those of Hidachi reaching 34 millimeters in height and 32 in length, yet the characters, for instance the sculpture, agree so perfectly that they cannot be referred to different species. Even as a variety this fossil form cannot be separated from the recent Japanese specimens, since the latter, from Hakodate, have the same—and in some instances a little larger—size and exactly the same proportions.—The specimen mentioned above from Chichibu is much smaller.

Rhynchonella psittacea Gmelin.
(Syst. nat. Linn. 13th ed., 3318, as Anomia.—Lamarck, Hist. nat. etc. v. 6, 1st div., p. 248.—Davidson, Proc. Zool. Soc. London, 1871, p. 309, pl. 31, f. 12.—Adams, Ann. Mag. Nat. Hist. 3d series, v. 11, p. 100, established a variety as Rh. Woodwardi.)

Specimens corresponding perfectly to the description and figure of Davidson, but reaching 30 millim. in height add 34 in length—in one case even 36—, have been found exclusively in the isolated basin west of Sukegawa. They were associated with the foregoing species, which occurred also abundantly and almost exclusively at this place.

The sandstone and marly conglomerate filling the valley encircled by crystalline rocks, and overlying unconformably mica-schist, calcareous mica-schist, cipolline and other crystalline limestones, might be indeed called the 'Sukegawa

Brachiopoda-beds' from the frequency of those two species. This is the more striking as other fossils are comparatively rare and belong only to 5 species, viz. Pecten laetus Gould, Lima squamosa Lamarck, Ostrea gigas Thunberg, Ostrea denselamellosa Lischke and Anomia patelliformis Linné. The identity of the formation, however, is evidently proved by the similarity of the rocks to those near the coast, and by the species of shells; for they are all recent Japanese and with one exception found also at Oji, Takigashira &c.

Among the other fossils some sea-urchins might be mentioned, and some fragments of fossilized wood partly reaching huge dimensions. Unfortunately, they are all too badly preserved to be of any importance.

In concluding the remarks about Hidachi, I have to mention a locality on the road from Tokio to Mito, near the Tonegawa and next to the village of Kogone. This locality is included within the compass of the Tokio environs, but its formations are intermediate between those of Tokio and those of Hidachi. They consist of a tufaceous sandstone, very much like that of Sukegawa, only a little softer. It is covered by diluvial strata, mostly also sandy. From the tertiary strata Mactra veneriformis Desh., Cytherea meretrix L., Arca inflata Reeve were brought to me.

LOCALITIES ON THE ISLAND OF KIUSIU.

The thick and varied system of sandstones, tufas, conglomerate and shale which is seen along the coast on both sides of the Tokio plain as well as in the hills surrounding it, is, of course, not limited to central Japan. I am fully convinced that it will be discovered almost along the whole eastern and southern shore, and probably it does not end there. To the south and west, this may be said to a certainty; for in the island of Kiusiu several places are already known and have been explored which doubtlessly contain the same formation.

At Amakusa, tufaceous rocks, somewhat fine-drained, contain a great many moulds of bivalves—Tellina nasuta Conr., Tapes rigidus Gould, Pecten plica L., Mactra Sachalinensis Schrenck, Diplodonta trigonula Desh., Arca granosa L., Cardium Californiense Desh., Saxidomus purpuratus Sow.—and moulds and shells of Turritella communis Risso.

In the ken of Kagoshima the amount of tertiary fossils is still larger, though we cannot include in this formation *all* the layers of plants frequently found in this part and in other districts of the island; for some of them are quaternary and belong to very modern fresh-water deposits. The fossil shells are Nassa livescens Phil., Natica pyriformis Recluz, Lampania zonalis Lamarck, Tellina nasuta Conr., Mactra veneriformis Desh., Cytherea meretrix L., Cardium Californiense Desh., all the three Arcæ described above and both species of oysters.

Near Bungo, on the northeastern corner of the island, blocks with Dosinia exoleta L., Mactra veneriformis Desh., Saxidomus purpuratus Sow. and Cardium Californiense Desh. are found.

NORTHERN LOCALITIES.

Similar rocks have been brought from Rikuson, a little NE. of Sendai, containing Pecten plica L., Dosinia exoleta L., Panopaea generosa Gould and Saxicava arctica L.; whilst at Hakodate not only similar rocks have been seen, but also smaller and well preserved fossil shells, much like those of Oji or Shinagawa, have been dredged. The most important of them is Limopsis aurita Brocchi, of which a few specimens, doubtlessly in a fossil state, are in the zoological collections of the Daigaku.

Another locality is situated between Sendai and Hidachi, in the province of Yuwashirô. The pliocene rocks, greenish tufaceous sandstones, have been found in tunnelling through a range of low hills south of Yuwashirô-su (Munaita-sawa, Asakagori). Here Cardium muticum Reeve, large and typical, Lucina borealis L., Mactra veneriformis Desh., Tellina nasuta Conr., Pecten laqueatus Sow and stems and leaves of plants (Cryptomeria japonica, and a Carpinus) are found.—

The tertiary beds beyond the Tokio plain, in their totality, have furnished 60 species, 46 of which are also contained in the Tokio- and Yokohama-layers, and only 14 (about 23 percent) are new; but these are all recent and with two exceptions Japanese. Only one of them does not occur in the Pacific.

The different localities do not differ much in their proportion, Chichibu having 20 species with 2 new ones, Shinshiu 19 with two new ones, Mino 31 with 4 new species; Hidachi with 50 species has, however, 14 new ones, whilst the other localities in which only a few species are found, have no new ones. The largest number of new species, therefore, belongs to Hidachi, where the 'face' of the formation is also modified. The modification, however, and the number of new forms is not very great, and the character of the fauna, in its totality, is not altered.

CHAPTER VIII.

SUMMARY.

It would be perfectly clear, I believe, even without the assistance of the facts contained in the foregoing chapter, that the shell-layers which are the subject of the 4th, 5th, and 6th chapter, though they are very young, yet belong to the tertiary formation. For the Tokio-and Yokohama-exposures exhibit an *unconformability* which separates the bulk of the diluvial formation (divided in itself by another line of unconformability) from an underlying formation, and the latter contains a molluscous fauna comprising living species, many of which are not now found in the neighbourhood of Japan nor even in the Pacific. Besides, in some localities within the Tokio plain, the strata below the same line of unconformability have a dip of 5 to 6 degrees, whilst the diluvial strata are horizontal.

To illustrate the character of the fauna, I resume that in the upper tertiary deposits of the environs of Tokio and Yokohama 87 species have been determined. Two of them, Dentalium octogonum Lamarck and D. entale L., belong to the Solenoconchæ; one of them is recent and Japanese, the other exclusively found in the Atlantic. A third species belongs to the Brachiopoda and is recent and Japanese. The rest are 41 Gasteropoda and 43 Conchifera. Among the former, 9 are neither Japanese nor Chinese; if we include the species described by Gould from Hongkong or its vicinity, e. g. Cerithiopsis rugosa, Monoptygma puncticulata, the two Odostomiae, as indigenous in the neighbouring seas, the number of the indigenous species is 52. The rest includes only one boreal univalve of the Pacific Ocean, Trichotropis coronata Gld, not found hitherto further south than the strait of Semiavine. The remaining species are Atlantic, and though none of them are really extinct, they are geographically separated by a wide interval from the living Japanese fauna. Most of them are very often found in a fossil state, just as a certain number of the other 32 gasteropoda, especially those which at present are common to the Atlantic and Pacific Ocean, e. g. Columbella scripta L., Purpura lapillus L., Chemnitzia elegantissima Mont.— Among the 43 Conchifera there are only 7 which are not living in the Japanese sea, and among them we find 2 boreal Pacific species, Panopaea generosa Gould and Lyonsia flabellata Gould. the former going southward to Oregon but not to the East-Asiatic temperate coasts. But the other 5 are important species, viz. Kellia suborbicularis Mont., Lucina borealis L., Diplodonta trigonula Desh., Yoldia arctica L., an important arctic form. and above all Limopsis aurita Brocchi, which belongs to a *genus* whose next locality is the Red Sea. Limopsis aurita itself was, until very lately, said to be extinct. Deep-sea dredgings may indeed, as has been the case with this species, reduce the number of really extinct tertiary forms; but this is a fact which is applicable to all the younger tertiary deposits. It proves indeed that an extinct fauna must be considered as such even if it does not contain any other but living species, whenever a larger part of these species does not belong to the recent fauna of the same zoogeographical province or region.

Of course we find also in the class of Conchifera many species which are Atlantic as well as Pacific. Two of the bivalves, Saxicava arctica L. and Mya arenaria L., are circumpolar; one, Lasaea rubra Mont., is cosmopolitan. A great many are also fossil, especially of those common to both the western and eastern ocean, and I think it will not appear a very paradoxical result that—aided by a rich supply of specimens—I added to their number Dosinia exoleta L. and Nucula Cobboldiæ Sow. and replaced to it Tapes decussatus L., known from the Japanese coast as Dosinia japonica and Troscheli, as Nucula mirabilis and insignis, and as Tapes Philippinarum. In this respect, I am indeed fully convinced that in Japan exactly the reverse will take place of what Lischke says to be commonly the case, viz. that in every fauna which is imperfectly known a further revision will probably reduce the number of the *foreign* forms, or of those species which are said to be identical with forms of another part of the globe. Lischke himself has shown by too many examples that the marine molluscous fauna of Japan is—just as the fauna of other classes of animals—palæarctic. Perhaps it would appear still more so if we knew the real distribution and geographical range of some genera and species now mostly confined to southern latitudes, as for instance Myadora. At all events, we have in the fauna of Oji, Tokio, Kanagawa, Yokohama, Takigashira elements which do not agree with the actual Japanese fauna, and the number and importance of these elements is so great as to remove all possibility of their ever being effaced by discoveries of recent Japanese shells. I need scarcely add that some of the species which are extinct on the East-Asiatic coast, occur very frequently in the tertiary layers, e. g. Lucina borealis, Diplodonta trigonula, Limopsis aurita.

In these as well as in many other respects the Japanese shell-layers discussed above have the greatest resemblance to the *Crag*, and next to it with the younger Subappenine deposits, whilst the rocks resemble very closely the European *Faluns*, a formation, by the way, not at all limited to the western coast of France. Glacial deposits have no more affinity with the Oji deposits than with the English Crag itself, and it would be very easy to match the 'arctic' species undoubtedly contained in these deposits by others—Cyclina sinensis, Arca granosa, Monoptygma, Myadora, or even Diplodonta trigonula—which point more to the south. And thus we should at last be obliged to recur to the explanations given above on this subject.—

If, however, all these reasons should not seem to give sufficient evidence of these views, the localities described in the seventh chapter will do so in a perfectly satisfactory manner.

All these strata of shale, sandstone, hard and loose conglomerate have, as is repeatedly stated, an enormous thickness and yet a perfectly uniform fauna. And this fauna is eminently the same as at Oji, Takigashira etc.

The results given at the end of the 7th chapter show that in the localities first mentioned, Chichibu, Shinano, Mino, altogether 44 species have been found which belong to the fauna of Oji, Takigashira &c., and that there are only 7 new species; whilst in Hidachi 36 species from Oji, Takigashira etc. and 14 new ones have been found. But Hidachi, on the other hand, is closely connected with the other localities by the identity of 30 of the former and 7 of the latter species, and thus, only 7 species remain peculiar to Hidachi. These 7 species are all of them living in the Japanese sea, and it is a remarkable fact that the separate basin near Sukegawa, richest comparatively in such species as do not belong to the fauna of Oji and Takigashira (3 among 7), has not one species which is not found living near Japan. All the other localities, and the more distant places, have proportionally very few species (if any) not belonging to the Tokio fossil fauna; and all of them together with Hidachi have only *one* species which is neither found in the fossil fauna of Oji etc., nor among the living shells of Japan, viz. Turritella communis Risso. As the proportion of fossil Tokio shells belonging to the living Japanese marine fauna to those which are extinct in Japan is 69 to 18, the latter being 21 percent, the presence of one further species of the latter description with 13 new species living in the neighbourhood would rather serve to prove a younger age of the sandstone, conglomerate, marl and shale. As this cannot be admitted, the Tokio layers being undoubtedly one of the higher, if not of the very highest parts of the younger tertiary formation of Japan, we are forced to regard both layers as most intimately united.

A further division of the entire system cannot be made, at present, palæontologically; we must confine ourselves to separating it into upper and lower strata simply according to their relative position.

There can be no doubt about its very young age, and the *Pliocene Era*, or the Crag-division of the tertiary formation, is the only one to which we can assign it. If the question should arise whether we should assume that it belongs to the miocene formation, this is answered in the negative by the absence of a somewhat larger number of extinct shells, by the scarcity of typical miocene species (though there are some present, for instance Columbella scripta, Chemnitzia elegantissima, Eulima subulata, Dentalium entale, Lucina borealis, Diplodonta trigonula, Pectunculus glycimeris, to which perhaps some other, for instance Panopaea generosa and the Tornatina might be added), by the close resemblance to the Crag and by an approach which those layers make towards the diluvial deposits.

With these, however, they cannot be identified for the reasons given at the beginning of this chapter—character of fauna, high percentage of species foreign to the present marine fauna of Japan, line of unconformability between them and doubtless lower diluvial strata—, and besides for those reasons which result from the identity of the Tokio pliocene strata and the system of sandstone, shale &c. amounting at least to some hundred meters in thickness. This very thickness, clearly shown by the Chichibu-layers as well as by those of Hidachi and other provinces, and still more the *high angle of dipping* often observed, forbids the inclusion of these strata within the compass of the quaternary formation. Now, not being able to claim a quaternary age for these large systems of rocks, we cannot do so for the Oji rocks and their parallels in the Tokio plain.

The solution of this problem is of the highest importance for Japanese geology. The strata in question occur almost everywhere; at least in almost all the provinces and districts which thus far have been explored. We find them, with or without other sedimentary or volcanic or crystalline rocks, not only along the coast, but often far into the interior. Their geological age ascertained, we have a fixed point from which we may advance, and without which we should scarcely have a sufficient basis for observation anywhere. This is true as well in regard to the underlying strata, tertiary, for instance brown coal, mesozoic, palæozoic or azoïc, as to all the eruptive formations and to the overlying quaternary strata which give the surface-formation of wide districts. The largest of these is the plain of *Tokio*, whose geology could never be fully understood without a strict determination of the fossiliferous deeper layers of its environs.—

This point being settled, I may add a few remarks about the geological changes which, since the origin of those oldest deposits of the Tokio plain, are to be observed within this district.

The character of the fauna may be dismissed after all that has been said about it here and in the introductory chapter. I repeat only that the marine fauna also gives evidence to a highly satisfactory degree of its *palaearctic* character. The molluscous fauna of Japan is much more closely connected with the European fauna than we should have ever expected without recurring to the faunæ of past ages. This connection is much too intimate to be accounted for by the small number of 'circumpolar' species contained in the Japanese fauna; but it is well explained by the close affinity which the pliocene fauna reveals with the European. It has, therefore, a far greater importance than it would have if it was an isolated faunula and not—as it is—a part of a very large fauna which, in certain respects, has been better preserved in Japan than in the other parts of the palæarctic region. I need but call the reader's attention to the important fact that the pliocene Nucula Cobboldiæ actually exists in the ocean encircling Japan.

As the question about the temperature has also been settled in the first chapter, I may proceed to the last object of these pages, to the question concerning the changes of the level of the sea.

Of course there can be no doubt whatever about the fact that since the deposition of the pliocene strata the land has been slowly elevated above the level of the sea. This movement of the entire mass of land forming the Japanese archipelago, has, to a certainty, not gone on quite regularly and must have been at times interrupted; but, on the whole, it has continued from the last period of the tertiary age to the present day. The interval between the pliocene layers and the diluvial strata, causing that line of unconformability often mentioned, may have been filled up by an extent of land greater than at present; and the occurrence of two of the palæarctic species of elephants seems to point to the same fact. But soon after the beginning of the diluvial era another submersion must have taken place to which another elevation succeeded. And this elevation has doubtlessly continued up to the present time.

This seems to be proved, if not with certainty, yet with some probability, by the Omori shell-mound. A mound of such a size is likely to have been heaped next to the sea; and I think the discoverer of this mound is perfectly right in laying some stress upon this matter.

On the other hand, it seems scarcely possible to make any calculations concerning the *amount* of the increase of land, or the rapidity with which the soil of Japan is elevated above the level of the sea. Much greater precautions must be taken, in this respect, than has generally been the case. If we should, for instance, compare the result of the soundings in the bay of Tokio made at different periods, we might perhaps, at a short distance from the shore, perceive a comparatively great diminution of the depth of the bay, and yet the real amount of the elevation might be trifling. For a large mass of detritus is daily brought into the sea by the rivers, by the sea itself, by men; and this mass is distributed mostly along the coast. We are not allowed, therefore, to draw any conclusions concerning a rising of the entire mass of land from soundings made next to the shore, especially in the harbours, and above all in the harbour of Tokio. Just as untenable are the results derived from the increase of land in the precincts of the town itself. Swamps extending along the coast may have been made artificially accessible to men, and therefore they are said now to be land, whilst on the old maps and in the old traditions they are said to belong to the sea. To this increase of land, which must be declared to be strictly local, the stagnations produced by weirs—above which always a large bulk of detritus is retained and accumulated—add of course a great deal, and this has been evidently the case in some parts of Tokio.

I am far, therefore, from sharing the views contained on this subject in Dr. Naumann's paper on the Tokio plain. Especially do I think that his estimate of years is incorrect. The very short time assigned for the formation of the plain of Tokio, viz. 45000 years—given, it is true, as a minimum—seems to be quite inconsistent with the amount of time which we really must assume for our geological periods.

Still less tenable, of course, is the view that within historical time the Tokio plain has ever been covered by the sea. This is not only the case with the higher parts of the plain formed by diluvial strata, but also for the lower or alluvial parts. Man may have previously existed (as he has been proved to be contemporaneous not only with the cave-bear and the mammoth, but also with Elephas antiquus in Europe); but he can only have existed as a prehistoric race similar to the man of Enghis and of Neanderthal.

The rising of the land seems to be independent of the volcanic phenomena. We find indeed such elevations in any part of the world, with or without volcanic action, and the question is a very complicated one, whether—or how far—this action may be the cause of the rising of land. On the other hand, this rising seems to have an influence on the volcanic phænomena, namely, that it tends to mitigate them and causes them to withdraw from certain parts. The volcanoes seem to be dependent upon the presence of water, and thus a diminution and retreat of volcanic action in Japan is perfectly accounted for.

It has been said above, that we are not entitled to assume a heightened degree of volcanism during the quaternary age; and when we consider the large layers of quaternary conglomerates, which even in volcanic districts cover tufaceous rocks, without being tufaceous themselves, this conclusion cannot but be confirmed. The level which, in such instances, is reached by quaternary layers, is sometimes very high. In the district of Hakone it is decidedly above 700 meters. But we do not know whether these strata are not fresh-water deposits kept up in a high level much like the present lake of Hakone.

The volcanic action, not very intense, after all, at present in Japan, seems —as above stated—to have had its maximum about the same period at which the youngest tertiary deposits were made, as is proved indeed by the large amount of tufas found among these rocks, and the more so, the nearer we are to the volcanic centres pointed out in the first chapter.—

With these remarks founded upon minute investigation I conclude the sketch of the 'Geology of Tokio,' by which I hope to give some impulse to, and some basis for, further observations and studies.

EXPLANATION OF PLATES.

PLATE I. GEOLOGICAL SECTIONS.

Fig. 1. Section of the diluvial and tertiary strata of the steep Bluff NW. of Kanagawa-Station. Vide p. 21.

Fig. 2 and 3. Sections of the same strata, from the Bluff between the railway and the shore, next to Kanagawa-Station. Vide p. 26.

Fig. 4. Section of the diluvial and tertiary strata near the corn-mill at Oji, N. of Tokio. Vide p. 26.

PLATE II. FOSSILS FROM THE PLIOCENE DEPOSITS.

GASTEROPODA.

Fig. 1. Neptunea arthritica Valenciennes. From Oji. V. p. 28.
— 2. Rapana bezoar L. From Surugadai. V. p. 51.
— 3. Nassa japonica Lischke. From Oji. V. p. 29.
— 4. Nassa livescens Philippi. Do. V. p. 29.
— 5. Eburna japonica Reeve. From Takigashira. V. p. 64.
— 6. Columbella scripta L. From Oji. V. p. 29.
— 7. Odostomia planata Gould. Do. V. p. 32.
— 8. Cerithiopsis rugosa Gould. Do. V. p. 33.
— 9. Drillia reciproca Gould. Do. V. p. 33.
— 10. Mangelia striolata Sow. Do. F. p. 33.
— 11. Terebra bipartita Gould. Do. V. p. 34.
— 12. Lampania zonalis Lamarck. Specimen from Takigashira. V. p. 52.

PLATE III. FOSSILS FROM THE PLIOCENE DEPOSITS.

CONCHIFERA.

— 13. Solen grandis Dunker. From Oji. V. p. 36.
— 14. Panopæa generosa Gould. Do. V. p. 36.
— 15. Mya arenaria L. From Takigashira. V. p. 59 and 63.

PLATE IV. Do. CONTINUED.

— 16. Lutraria Nuttalli Conr. From Oji. V. 38.
— 17. Mactra veneriformis Desh. Specimen from Takigashira. V. p. 38.
— 18. Tellina nasuta Conr. From Oji. V. p. 39.

PLATE V. Do. CONTINUED.

— 19. Tapes rigidus Gould. From Oji. V. p. 39.
— 20. Saxidomus purpuratus Sow. Do. V. p. 40.
— 21. Venus (Mercenaria) Stimpsoni Gould. Do. V. p. 40.

PLATE VI. Do. CONTINUED.

— 22. Dosinia exoleta L. (var.) From Oji. V. p. 41.

— 23. Cyclina sinensis Gmel. Specimen from Takigashira. V. p. 53.

— 24. Lucina borealis L. From Oji. V. p. 44.

— 25. Diplodonta trigonula Bronn. Do. V. p. 44.

— 26. Pectunculus glycimeris L. Do. V. 45.

— 27. Limopsis aurita Brocchi. From Shinagawa, V. p. 57.

— 28. Nucula Cobboldiae Sow. From Oji. V. p. 46.

— 28[a] The same, specimens from Kanagawa. V. p. 46, and p. 59

— 29. Yoldia arctica Broderip. From Oji. V. p. 47.

PLATE VII. Do. CONTINUED.

— 30. Pecten plica L. From Oji. V. p. 48.

— 31. Pecten laqueatus Sow. Do. V. p. 48.

— 32. Anomia patelliformis L. Specimens from Shinagawa. V. p. 49.

PLATE VIII. SKETCH MAP OF THE ENVIRONS OF TOKIO. Scale 1 : 100000.

ADDENDA AND ERRATA.

Page	29.	Line	3.	Add:	Pl.	II,	f.	3.
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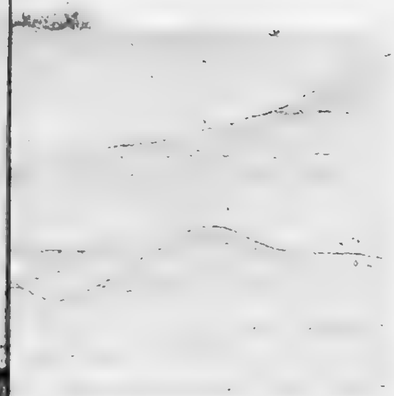
Pl. I.



anagawa Bluff
Diluvial Dep.

th Diluvial & Tertiary Dep.

Geology of Tokio.

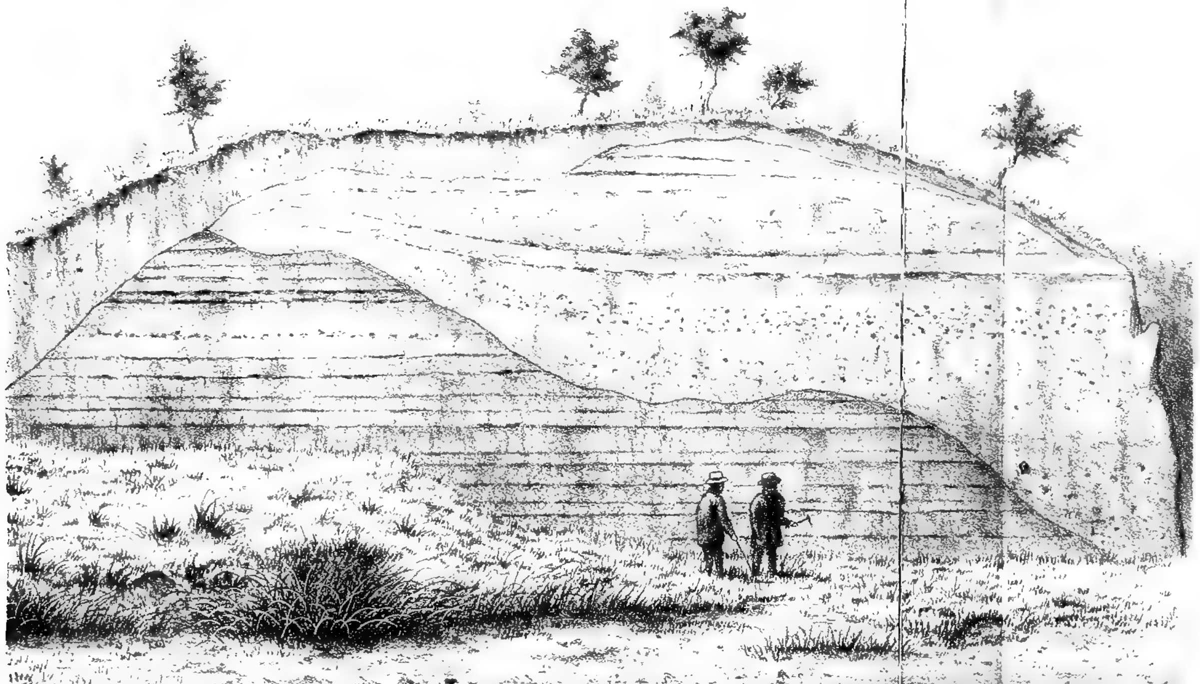


fig 2. Bluff at Kanagawa
with Tertiary, Low & up Diluvial Deposits

fig 1. Slope of the Plateau E from Kanagawa Station
with Tertiary, Low & Up. Diluvial Deposits.

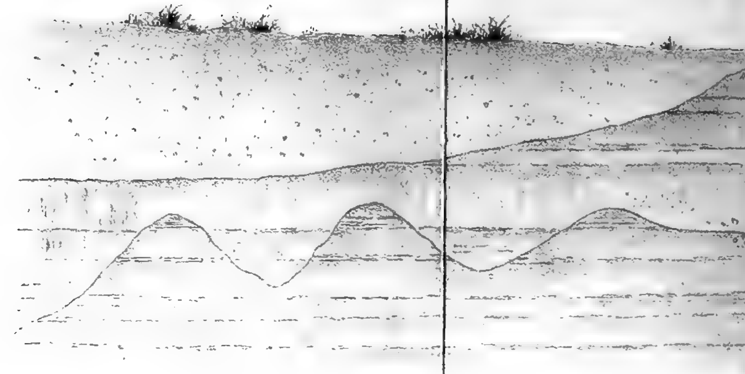


fig 3. Western side of Kanagawa Bluff
with Tertiary Low & up Diluvial Dep.

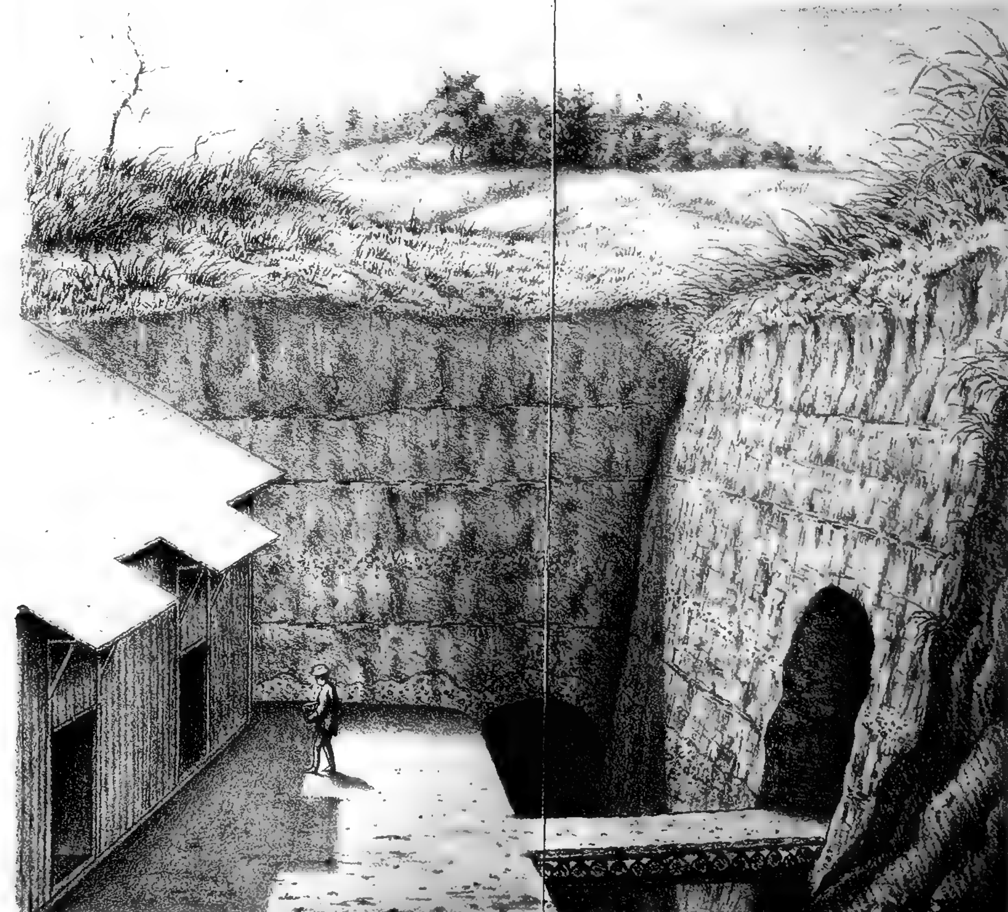
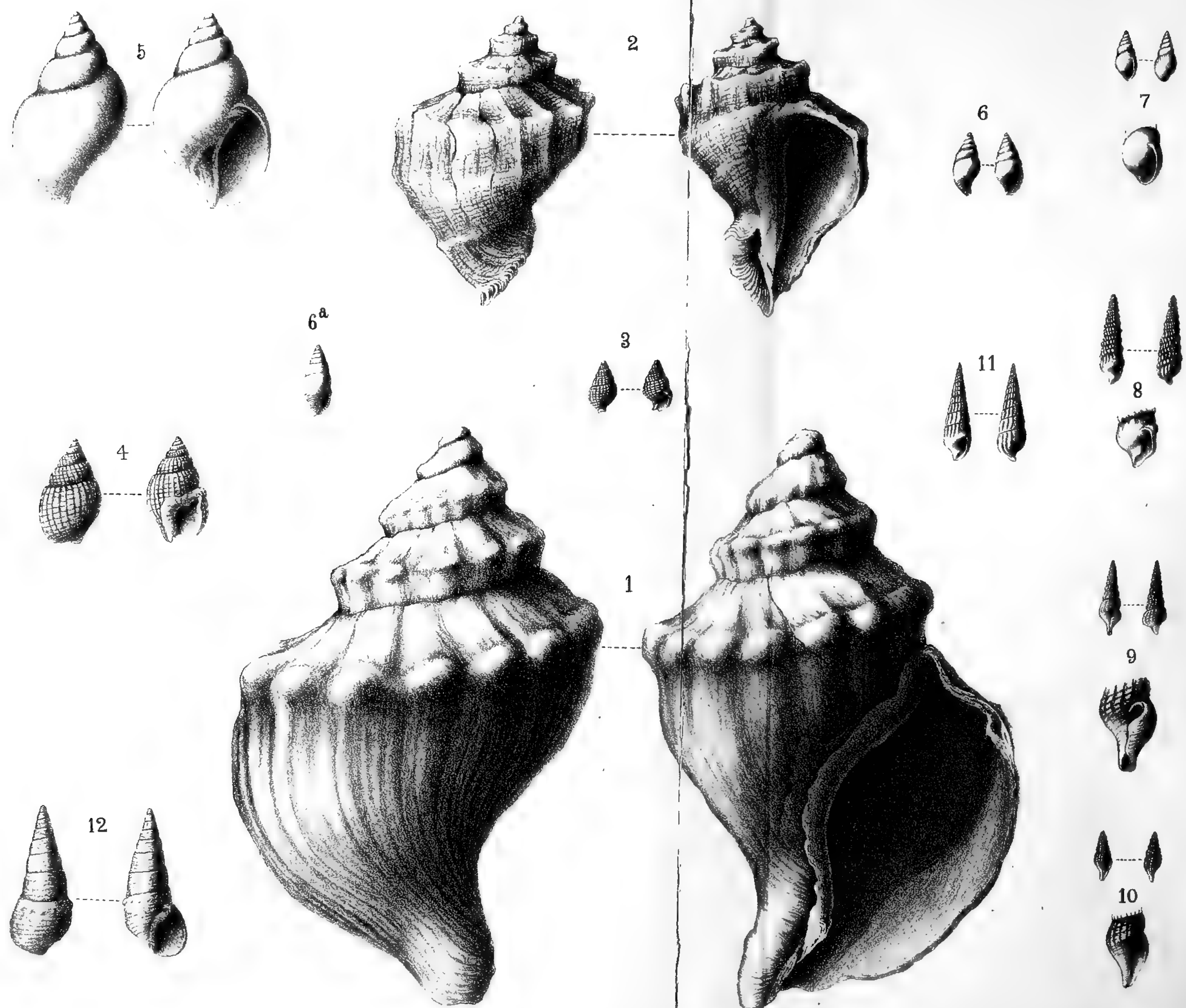
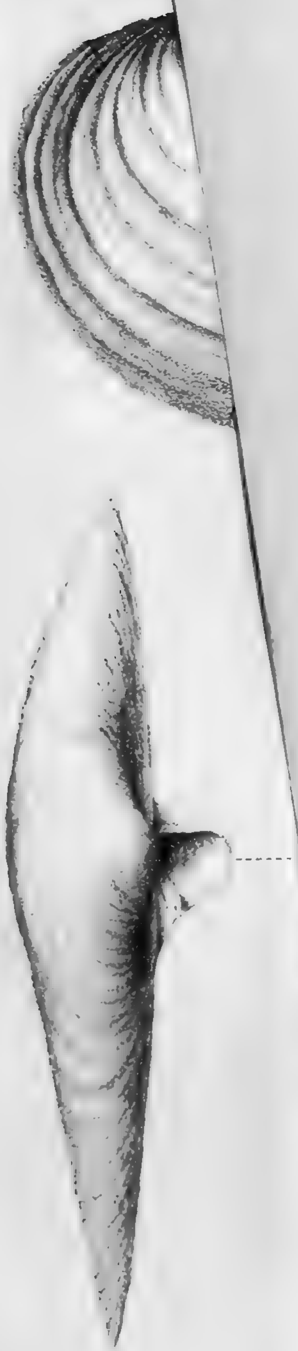


fig 4. Oji Cutting near Corn Mill with Diluvial & Tertiary Dep.

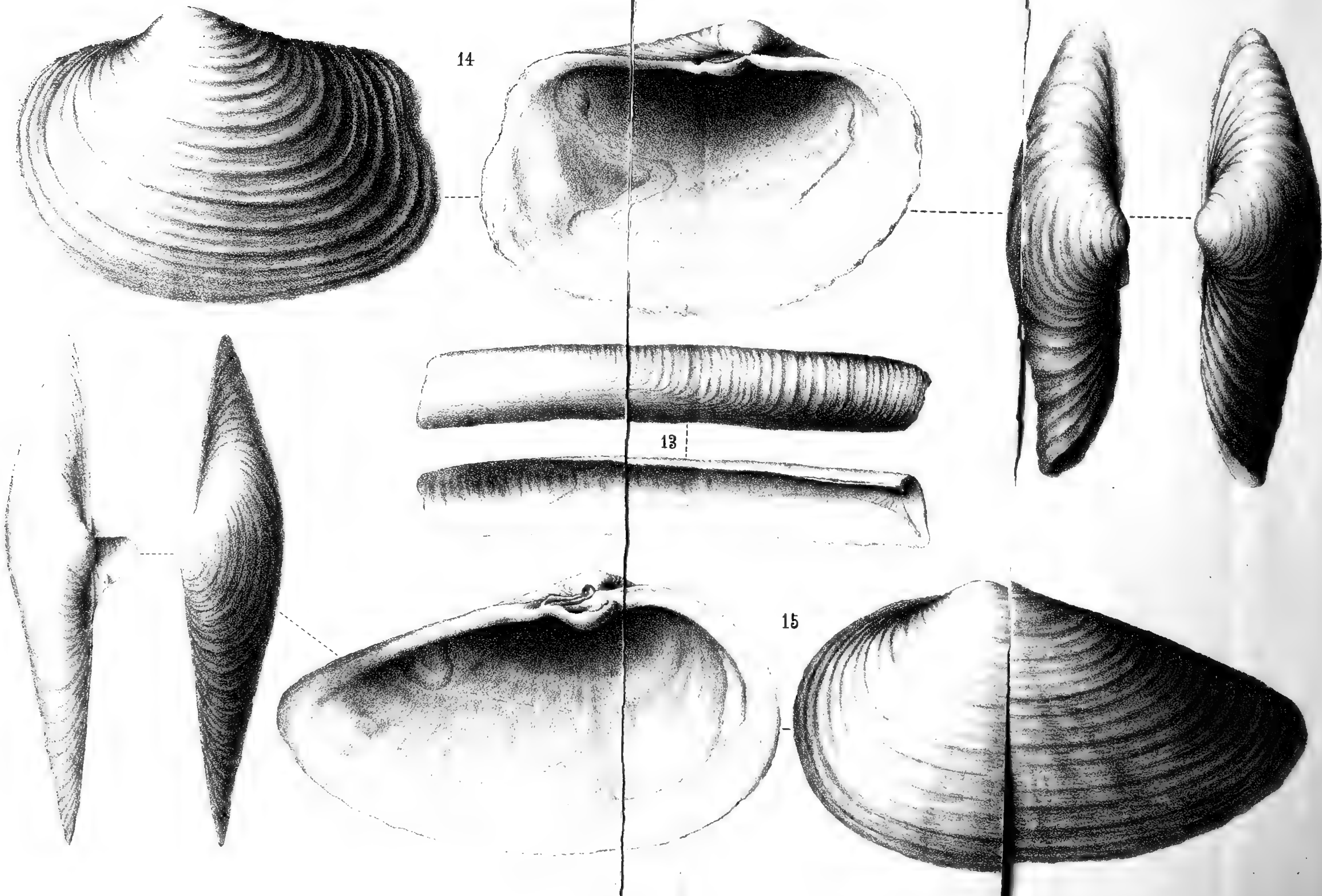
Geology of Tokio. Pl. II.



1. Neptunea arthritica. Valenciennes. 2. Rapana bezoar Linné. 3. Nassa Japonica. Reeve.
4. Nassa livescens. Philippi. 5. Eburna Japonica. Reeve. 6. Columbella scripta. Linné.
7. Odostomia planata. Gould. 8. Cerithiopsis rugosa. Gould. 9. Drillia reciproca. Gould.
10. Mangelia striolata. Phil. 11. Terebra bipartita. Gould. 12. Lampania zonalis, Lamarck.



13. Solen gra



13. Solen grandis. Dunker. 14. Panopæa generosa. Gould. 15. Mya arenaria. Linne.

PL.IV.

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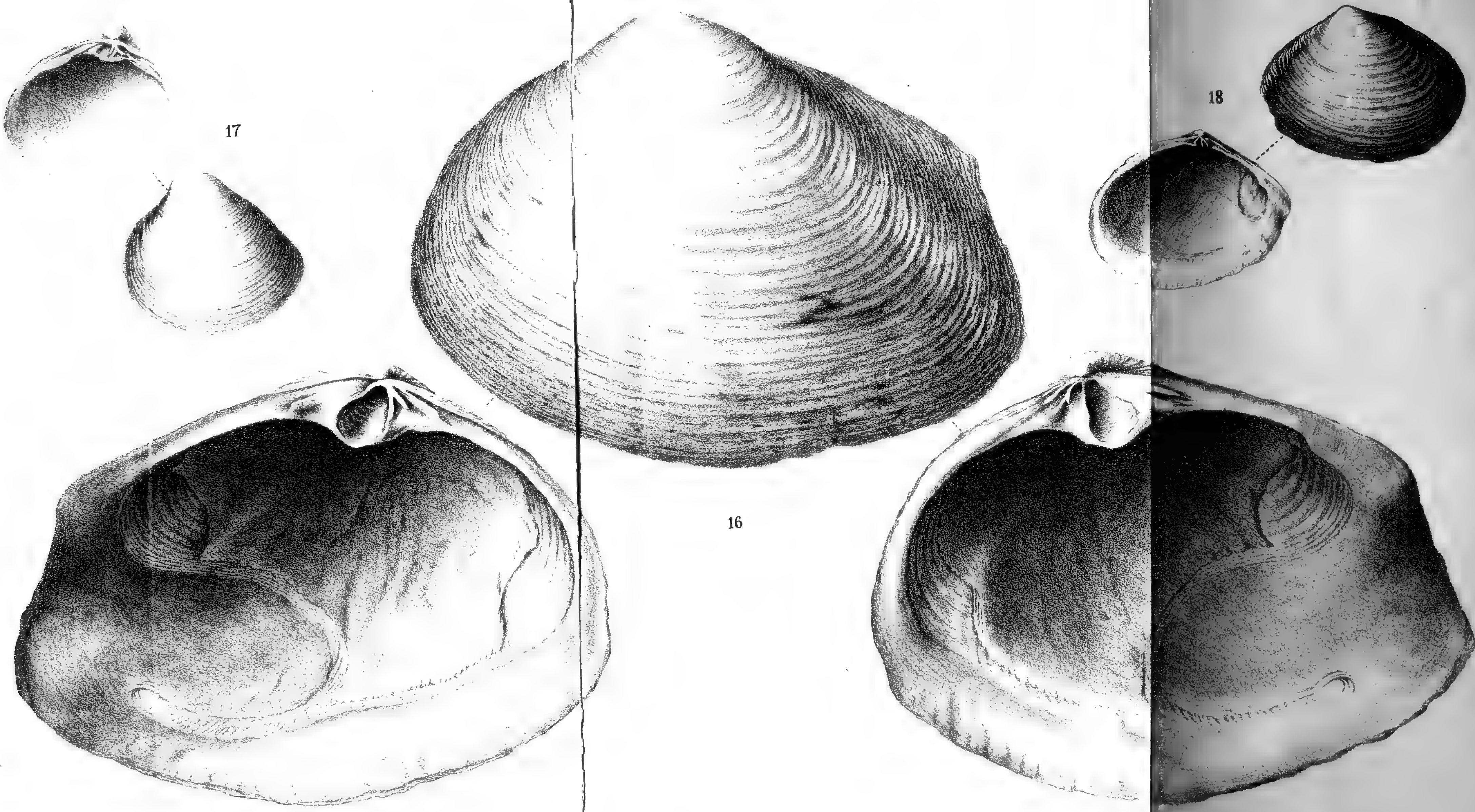
asuta. Conrad.



16. Lutraria Nuttali. Conrad. 17. Mactra veneriformis. Deshayes. 18. Tellina nasuta. Conrad.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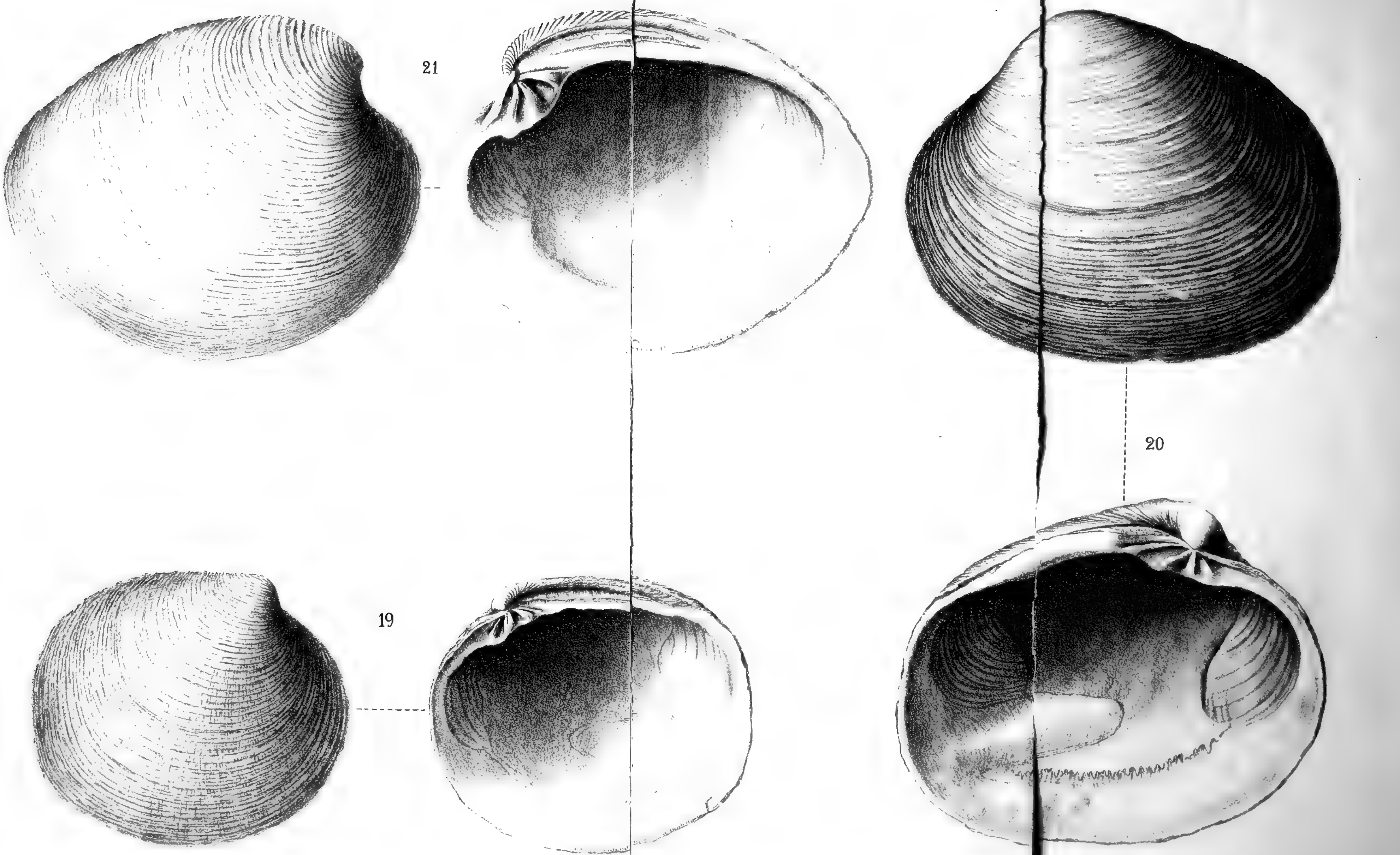
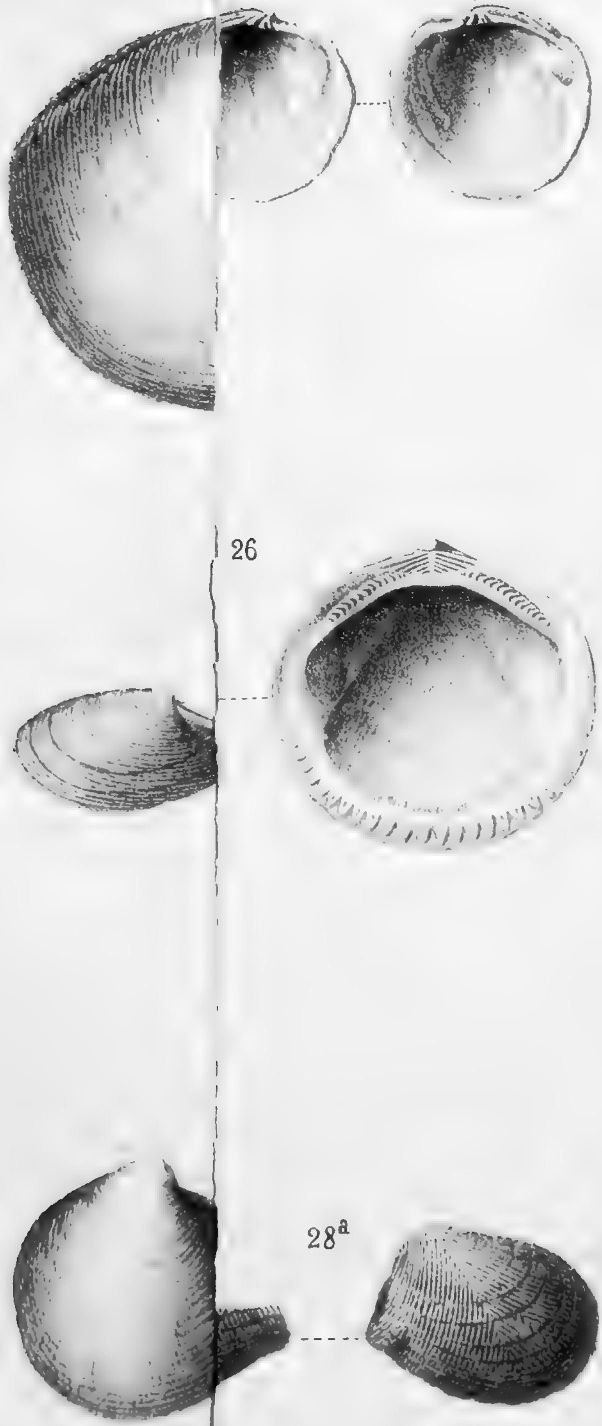
Geology of Tokio. Pl.V.



19. Tapes rigidus. Gould. 20. Saxidomus purpuratus. Sowerby.
21. Venus (Mercenaria) Stimpsoni Gould.

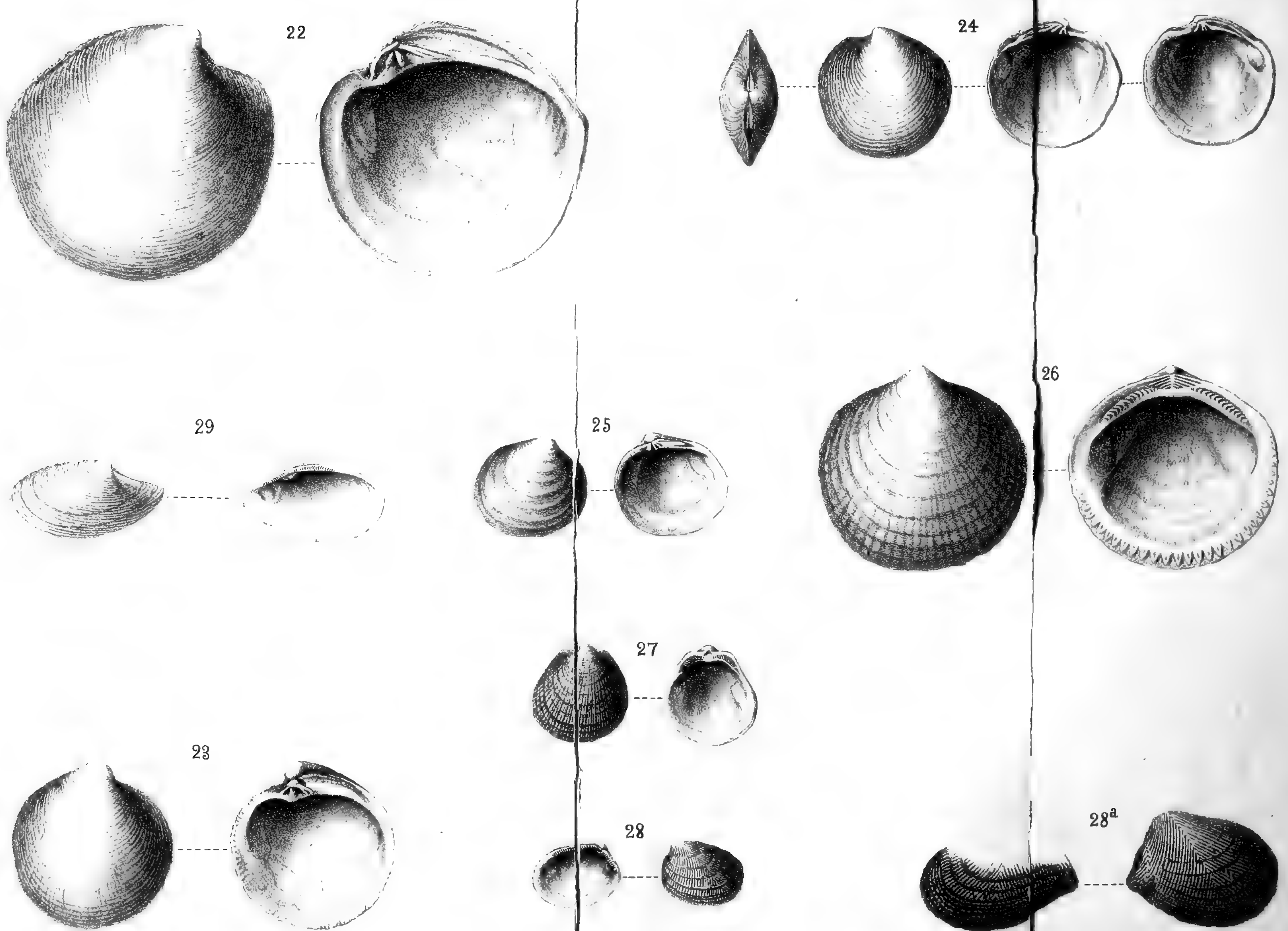
Pl.VI.



22. Dosinia exoleta 24. Lucina borealis. Linné.

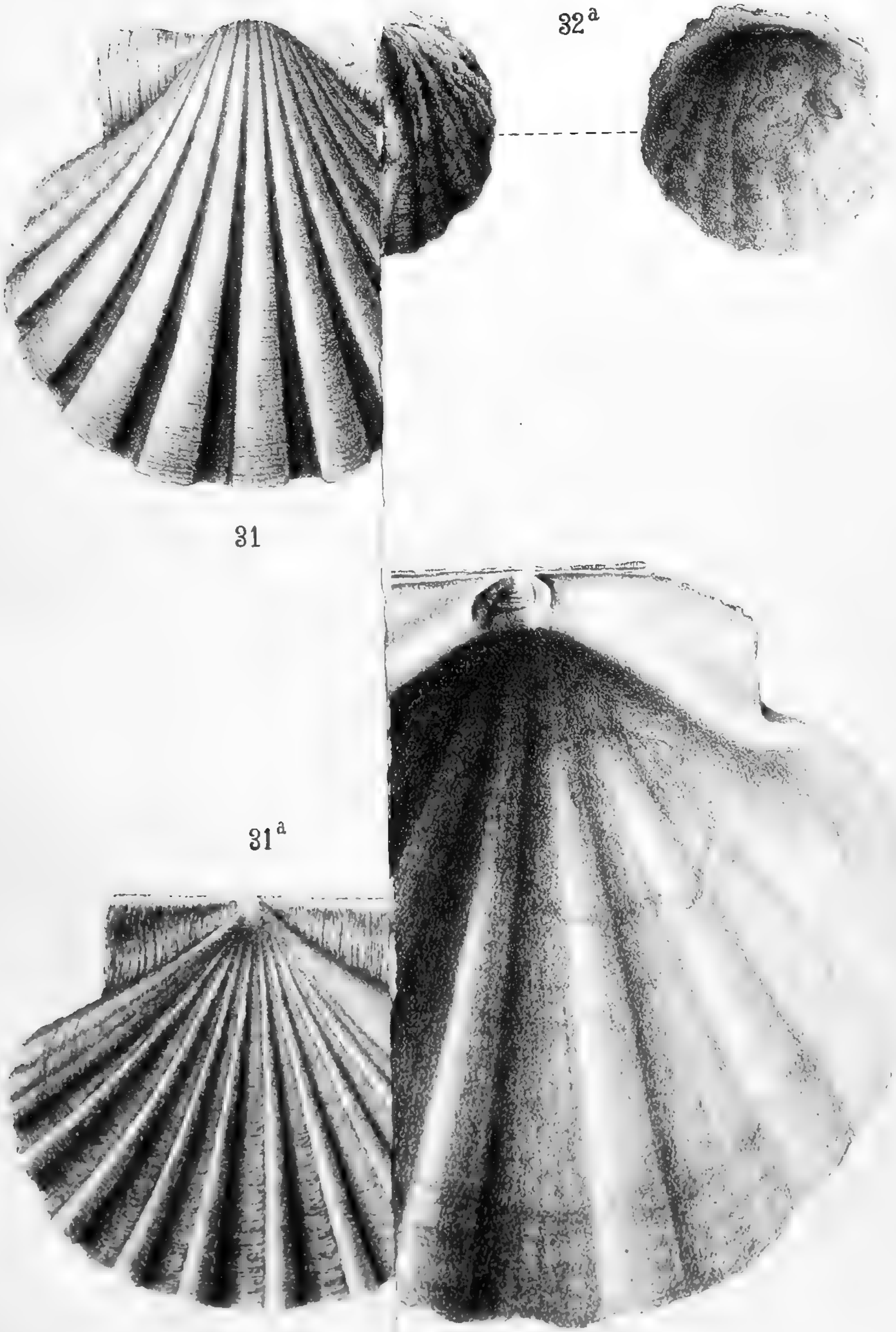
25. Diplodonta r Limopsis aurita. Brocchi.

& Sowerby.

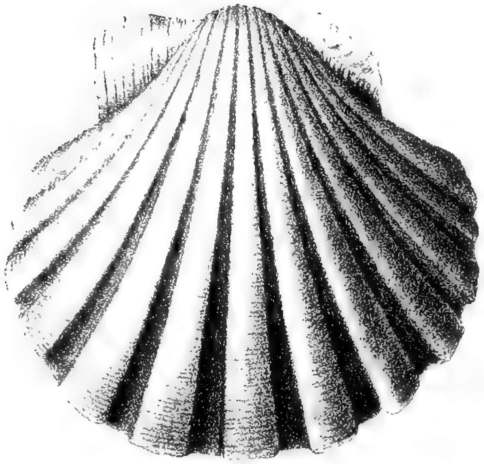


22. Dosinia exoleta Linné {var. Troscheli Lischke} 23 Cyclina sinensis. Gmelin. 24. Lucina borealis. Linné.
25. Diplodonta trigonula. Deshayes. 26. Pectunculus glycimeris. Linné. 27. Limopsis aurita. Brocchi.
28 & 28a Nucula Cobboldiae Sowerby. 29. Yoldia arctica. Broderip & Sowerby.

Pl. VII.

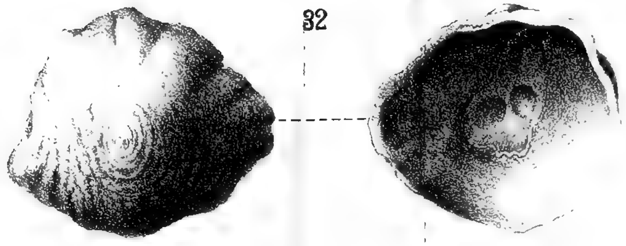


30. Pecten Pymia patelliformis.

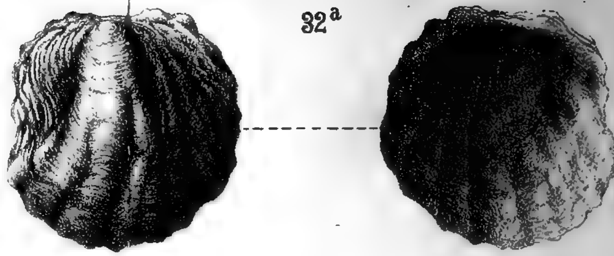


31

32



32[a]



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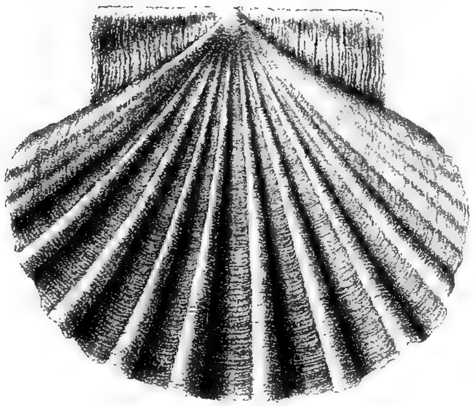
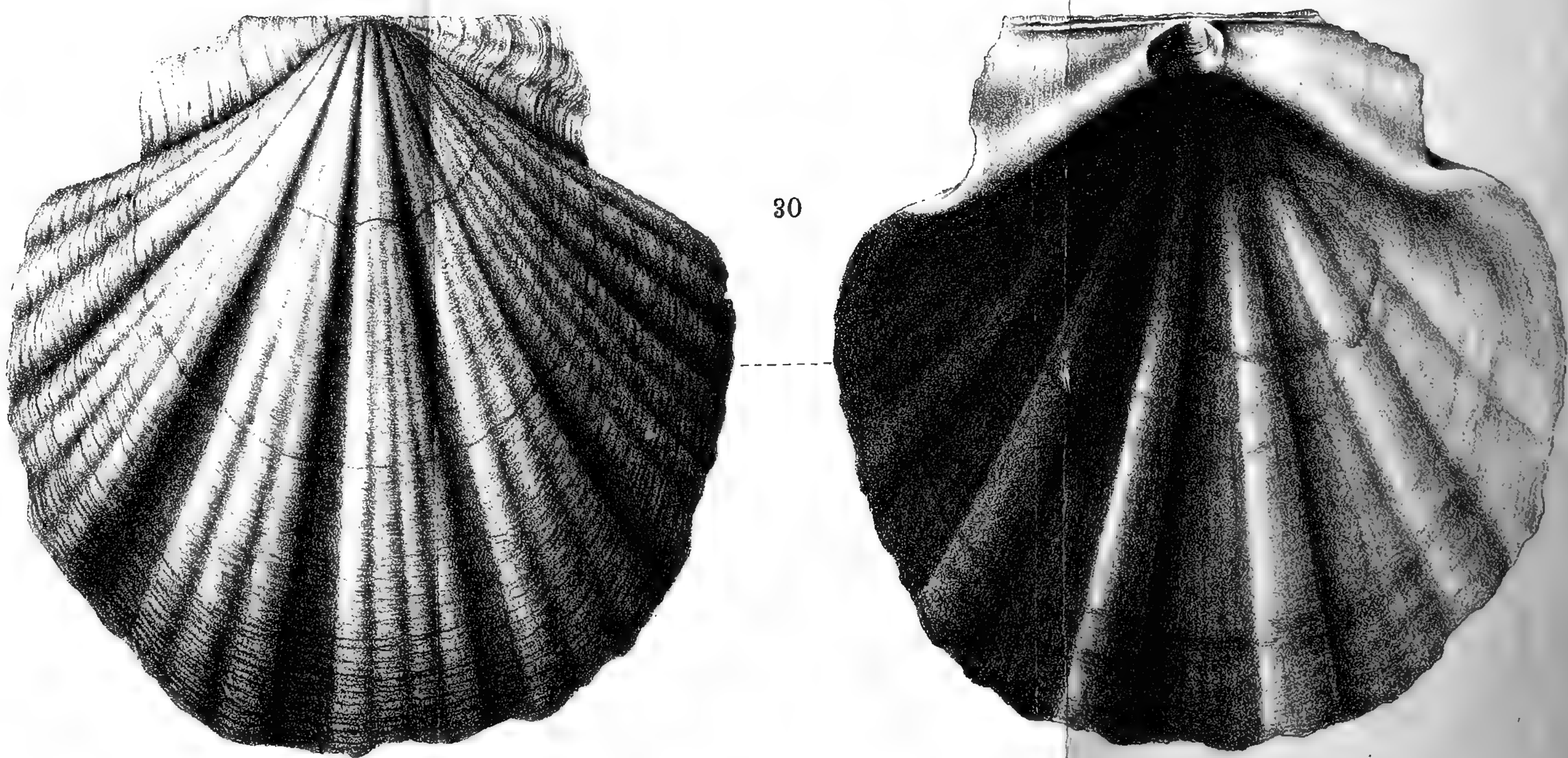
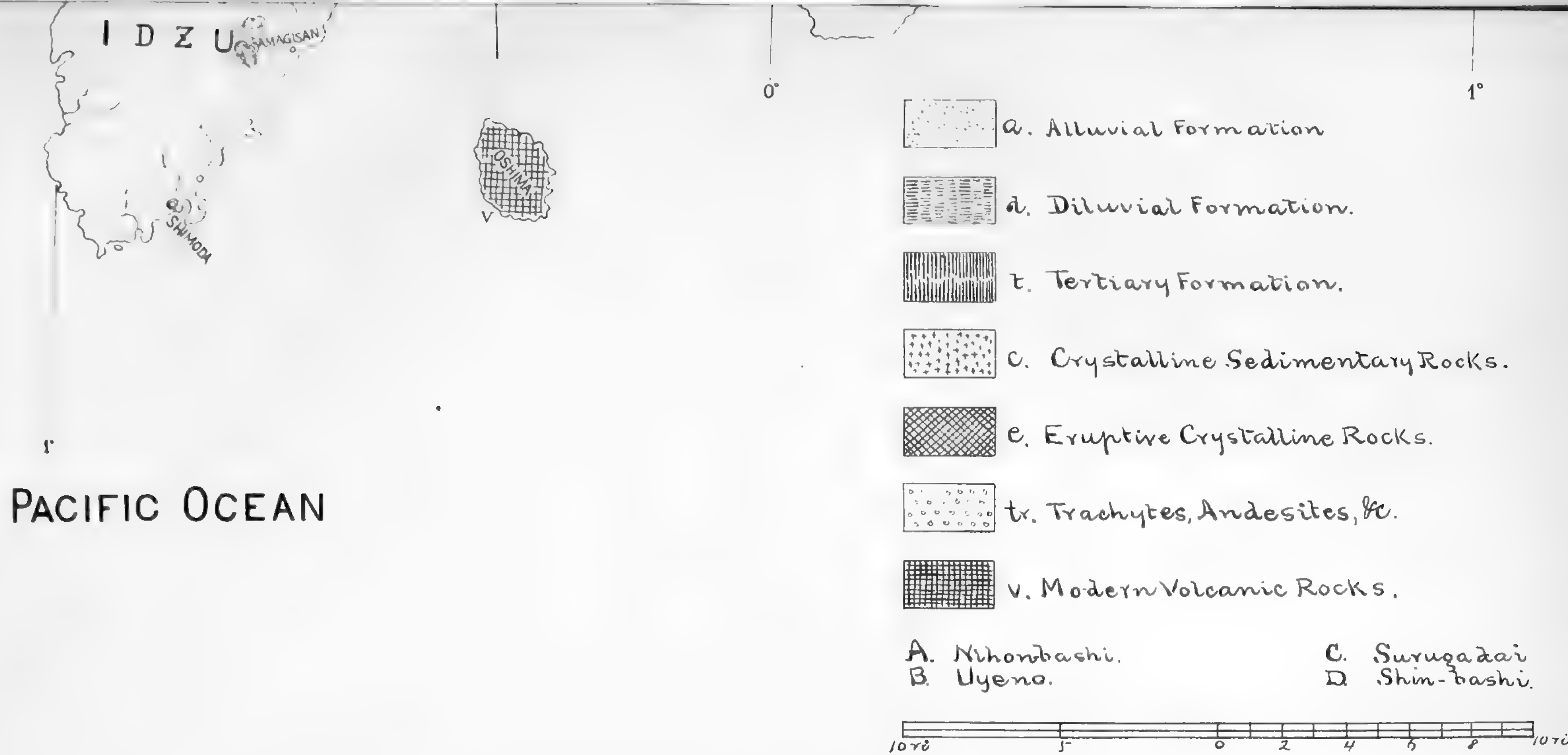


30



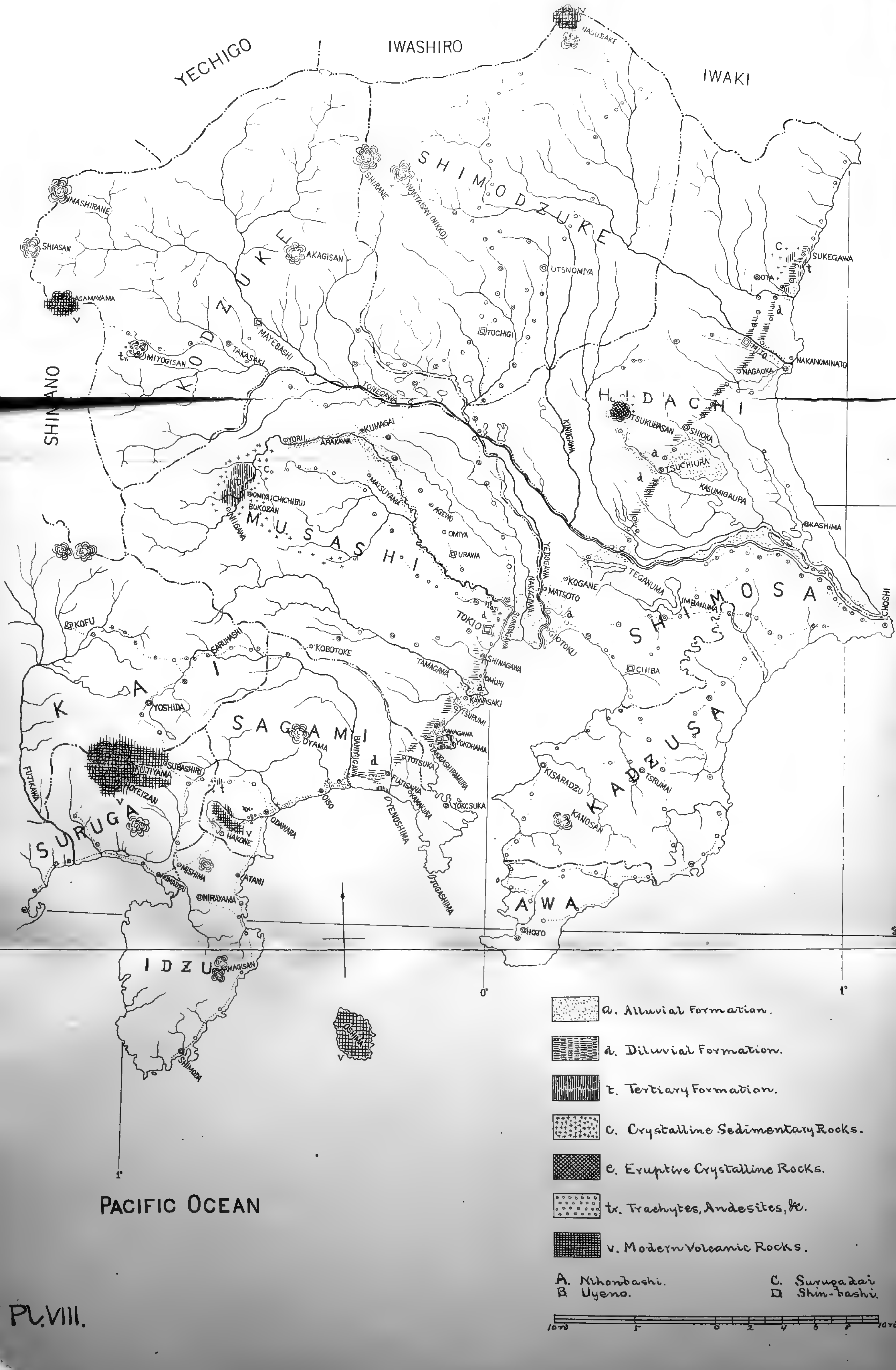
30. Pecten plica Linné. 31. & 31ª Pecten laqueatus Sowerby. 32 & 32ª Anomia patelliformis.



IDZU
AMAGISAN
SHIMODA
OSHIMA
0°
1°
PACIFIC OCEAN
a. Alluvial Formation
d. Diluvial Formation.
t. Tertiary Formation.
c. Crystalline Sedimentary Rocks.
e. Eruptive Crystalline Rocks.
tr. Trachytes, Andesites, &c.
v. Modern Volcanic Rocks.
A. Nihonbashi.
B. Uyeno.
C. Surugadai
D. Shin-bashi.
10 ri
5
0
2
4
6
8
10 ri

PL.VIII.

Sketch Map of the Environs of Tokio.



PL. VIII.

MEMOIRS

OF THE

SCIENCE DEPARTMENT,

TOKIO DAIGAKU.

(University of Tokio.)

No. 5.

MEASUREMENTS

OF THE

FORCE OF GRAVITY

AT

TOKIO AND ON THE SUMMIT

OF

FUJINOYAMA.

BY

T. C. MENDENHALL, Ph. D.

Professor of Experimental Physics in Tokio Daigaku.

PUBLISHED BY TOKIO DAIGAKU.

TOKIO:

2541 (1881.)

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PREFACE.

Concerning the following brief memoir, a few things ought to be said which belong more appropriately in a preface than elsewhere.

I have already expressed my indebtedness to various persons who have contributed to a greater or less extent to the success of the experimental investigation herein described; but I wish to make special mention in this place of the invaluable assistance rendered by Messrs. Tanakadate and Tanaka, to whom was assigned the task of making the pendulum vibrations both in Tokio and on the summit of Fujinoyama. These experiments and the reduction of the results involved a far greater amount of labour than is at first apparent. The determination of the actual periods of vibration from the chronogroph sheets was made, in all cases, by Messrs Tanakadate and Tanaka although, in many instances, I have repeated the measurements, only, however, to verify the results which they had obtained. The faithfulness and skill with which they performed every assigned duty justified great confidence in their results

I am indebted to all of the members of the party upon the summit of the mountain, for aid rendered in very many ways and I ought particularly to mention Mr. Yamada who took upon himself the care and responsibility of transporting the instruments from the University to the summit of the mountain and back again.

I must also express my thanks to the Directors of the University, Mr. Kato and Mr. Hattori, who kindly granted the use of these instruments and who aided the undertaking in every way in their power.

A considerable portion of the first part of this memoir, on the Tokio determination, was published, in substance, in the American Journal of Science, for August 1880, and a portion of the second part, on the Fujinoyama determination, in the same journal for February 1881.

Finally, it seems only justice to call attention to the fact that the printing of the memoir has been done entirely by native workmen, who are at once unfamiliar with the language in which it is written and unacquainted with the methods of "making up" which are so well understood in every western printing office. This fact, together with the difficulty and in some cases, impossibility of obtaining perfectly suitable type for the representation of mathematical formulæ, will be sufficient excuse for any shortcomings in the mechanical execution of the pamphlet.

T. C. M.

Tokio-Japan. January 1881.

I

THE ACCELERATION

DUE TO

THE FORCE OF GRAVITY

AT

TOKIO-JAPAN.

Experiments for determining the value of the acceleration due to the force of gravity at Tokio were begun in the Physical Laboratory of the Imperial University in the month of February 1880 and were continued at intervals during the succeeding two or three months. The task of making the pendulum vibrations and the necessary measurements was assigned to Messrs. Tanakadate and Tanaka, two special students in the Department of Physics. Much time was given to preliminary experiments and time determinations in order to familiarize these students with the use of the apparatus and also to develop the most desirable method of reaching accurate results.

A considerable series of experiments was made in the beginning with a Kater's reversible pendulum belonging to the physical laboratory, the results of which were only useful as furnishing an approximate value. Indeed the investigation by this method was not carried to any degree of accuracy on account of the impossibility of obtaining an accurate measure of the length of the pendulum, as the University possessed no standard measure with which it could be compared, as well as on account of the difficulty of determining certain corrections for the influence of the atmosphere. It was resolved, however, to attempt a more precise determination by means of a so-called simple pendulum which had been ordered from Salleron in Paris and which arrived in time for the completion of the experiments in May.

THE PENDULUM.

The pendulum was of the well known form used by Borda and many others and generally known as "Borda's pendulum". It consists of a spherical ball of metal attached by a thin wire to a small and short cylinder in which the knife-edge is fixed at right-angles to its axis. On a portion of this cylinder projecting above the knife-edge were the adjusting screws by means of which this part of the apparatus, exclusive of the wire and ball, could be made to vibrate in a period closely approximating to that of the pendulum as a whole.

It was found by trial that this adjustment might be considerably disturbed without sensibly altering the period of the pendulum, but it was, nevertheless, carefully attended to in all of the experiments. The advantage of making it is, of course, that it greatly simplifies the calculation of the reduced length of the pendulum.

LOCATION AND SUSPENSION OF THE PENDULUM.

The pendulum was swung in one of the small rooms of the physical laboratory which is so protected from sudden changes of temperature and from currents of air as to be especially suitable for the purpose. In this room is a large stone pier about 60 cm. square in section, built upon a solid foundation and extending to a height of about 2 metres. A heavy bar of iron about 70 cm. in length and having a cross-section of about 11 cm. by 2.5 cm. was placed on the top of this pier and was secured in its place by means of heavy blocks of stone which were placed upon it. The end of the iron bar projected just far enough to allow a resting place for the plane upon, which the pendulum was swung. The location of the pendulum was approximately as follows;—

Latitude—N.-35°-41′
Longitude—E.-139°-46′
Height above sea level........5 metres.

According to the original plan of this pendulum the ball is to be attached to the wire by means of a small cup the inside of which is ground to a radius equal to that of the ball. The cup is first fastened to the wire through a perforated screw head, and then a little tallow being spread over the inside of the cup the ball adheres to it very readily. This is a very useful device in that it makes it easy to attach the ball in various positions in order that any lack of uniformity in its structure may be detected. Having served this purpose, however, the cup was rejected, thus simplifying the calculations and lessening the probability of error in the linear measurements. The ball was finally fastened to the suspending wire by means of a small drop of solder which was fused to the end of the wire and afterwards brought in contact with the ball while the latter was heated. A number of different suspending wires were tried and that at last made use of was of platinum .35 mm. in diameter which was of sufficient strength to insure, after a few day's suspension, a pendulum of invariable length during the time of the experiment, subject, of course, to slight changes due to variation in temperature and the low co-efficient of expansion of platinum reduces these changes to a minimum. The knife-edge of the pendulum, which was of steel, rested on a pair of agate plates which were firmly secured in a plate of brass and which were accurately leveled by means of four leveling screws, after which the plate was firmly clamped to the iron bar upon which it rested so as to prevent lateral motion and render the support as rigid as possible.

The measuring apparatus was also by Salleron and was of the form used by Borda. The rod was of iron and its length was read by means of a vernier and microscope to hundredths of a millimetre. There was also a metallic thermometer attached for giving the temperature of the bar.

A strong plat-form was firmly secured to the stone pier immediately below the lower end of the pendulum and upon this was placed the small circular plane table which, in the process of making a measurement, was elevated by means of a screw until it was tangent to the lower surface of the pendulum ball. When this was done the pendulum was removed from its place and the measuring rod substituted. The deflection of the pendulum support, due to the excess of the weight of the measuring rod over that of the pendulum itself was measured and found to be .02 mm. and this correction was applied to the indicated length as was, also, the proper correction for temperature. For the purpose of verifying the length of the rod we were enabled, through the kindness of the officials of the Imperial Treasury, to compare it with a standard metre by Deleuil in the possession of that Department. The result of this comparison was that a correction of .04 mm. was made upon the length of the measuring rod at 0°.—Very recently another standard has been received by the same Department, which is certified to be a copy of the standard at the Conservatoire des Arts et Metiers and the necessary corrections for it have been furnished. The previous standard has been carefully compared with this and the agreement is so close as not to demand any further correction for the pendulum metre. In all the observations the temperature was recorded as read from a thermometer hanging very near to the middle point of the pendulum and the metallic thermometer connected with the measuring rod was also read and recorded at each measurement of length.

As the apparatus was arranged it was very easy to make a measurement of the length of the pendulum and this was done at very short intervals, always both before and after a series of vibrations. It was found, however, that when the temperature was constant the length remained sensibly the same.

The arc of vibration was measured by means of a scale placed immediately behind the suspending wire and a telescope placed about five metres away. The mean arcs of vibration varied in the different experiments from 40′ to 70′.

DETERMINATION OF THE TIME OF A SINGLE VIBRATION.

The method of determining the period of a pendulum which has been most generally used is known as the "method of coincidences." A serious objection to this method is that as the exact moment of coincidence cannot be accurately ascertained the total time of swinging must be long in order to secure a high degree of accuracy in the resulting period of a single vibration. If a chronograph and break-circuit clock or chronometer be made use of, there seems to be no doubt that better results than by the method of coincidences may be obtained in several ways. Assistant C. S. Peirce of the U. S. Coast Survey in his recent elaborate series of pendulum experiments at initial stations in Europe and America, has made use of a Chronograph by telegraphing the transits of a point on the pendulum over the wires of a telescope. Making a pendulum record or count its own vibrations electrically has also been accomplished by various devices. Many of these are objectionable on account of the friction exerted against the motion of the pendulum.

In the plan adopted in these experiments it is believed that this objection to an automatic record was entirely removed. It involves the use of a chronograph, a break-circuit clock or chronometer, and an arrangement by means of which the experimental pendulum could be made to break the circuit at any desired vibration. In the beginning the whole number of seconds required for a given number of vibrations may be determined by letting it break the circuit at every vibration, or, better, at every sixtieth or hundredth vibration, which can easily be accomplished by counting and raising the break-circuit apparatus to its proper position underneath the pendulum at the right moment. In our arrangement this apparatus consisted of a very small and light "trip-hammer" made of fine wire, which was so adjusted that by pressing upon a button it was brought up to such a point that it would be just "thrown" by the pendulum in its passage through the lowest point of its arc. Although the resistance offered to the pendulum can be made extremely small, yet it is so great as to interfere quite perceptibly with its motion if the pendulum is obliged to operate the break-circuit at each beat, as experiment has proved. But it may be rejected after the first two or three trials, not only on account of the resistance which it introduces but also because it is not necessary to continue its use. The whole number of seconds required for a given number of vibrations being known, it only remains to determine the fractional part of a second as accurately as possible. It is therefore only necessary to cause the pendulum to break the circuit twice, once at the beginning of the period and once again at the end. By this means all objection to the process on account of resistance is removed. Indeed it is in the possibility of determining these fractional parts of a second at the beginning and at the end, that the merit of this method consists. The chronograph used in these determination is by Alvan Clark and Sons, and for uniformity of speed it is everything that could be desired. The line made by the pen is sharp and clear. The length of one second on the sheet is about 8 mm., so that it can be easily measured with a microscope of low power with a micrometer eye piece. It will easily be seen that even if the total time during which the pendulum is made to swing be not great, its value can be ascertained within a very small fraction of itself. By this process, therefore, it becomes possible to make the duration of the experiment extremely short compared with that required in the method of coincidences and yet to reach the same degree of accuracy. As a proof of this it may be stated that in numerous instances in which the duration of the experiment was only twenty minutes, three independent measurements of the total time, made from the chronogroph sheet, did not differ among themselves by more than one sixty-thousandth part of the whole. The advantages in thus reducing the whole duration of the experiment from hours to minutes are many. All of the conditions may be maintained nearly constant during the whole time of the swing, and this is especially important in regard to temperature and arc of vibration, the latter being also made much smaller to begin with than would otherwise be possible. Again, the method eliminates "judgment" to a great extent as the pendulum marks for itself the beginning and the end of the period of time. Another important gain is that the use of the clock may be dispensed with, and, without loss of accuracy, the break-circuit chronometer substituted, thus rendering the whole apparatus for such a determination easily portable.

Time was obtained from a break-circuit sideral chronometer Negus 1629. The chronometer remained in the transit room of the astronomical observatory which is nearly two miles distant from the physical laboratory but a telegraph line connects the two points so that the chronometer could at any moment be made to record its beats upon the chronograph in the laboratory. The rate of the chronometer was determined by star transits observed for several nights in succession before and after the vibration experiments. In the results given the periods of vibration are stated in mean solar time, corrected for chronometer rate and also for arc of vibration.

Besides these corrections applied to the period, the final results must be corrected for the effect of the atmosphere; in other words, they must be reduced to a vacuum. Aside from simply lessening the actual effect of gravity upon the pendulum, a portion of air is carried with the vibrating body in its motion so that it may be said that its real density is less while in motion than while at rest. This fact seems first to have been noticed by Du Buat, who made some investigations concerning it in the latter part of the last century, but it was not recognized by more recent observers until its re-discovery by Bessel. It has been made the subject of extensive experiment by Baily and has been discussed analytically by several mathematicians. The quantity of air carried by the pendulum is found not to depend on the material of which it is composed or on its density but solely upon its form. In a mathematical analysis by Green the general equation for the effect upon ellipsoids is developed. From this it is shown that in the case of a sphere the ordinary correction for the air should be increased by one half. This factor has been used in correcting the results of these experiments.

Mr. Peirce of the U. S. Coast Survey has recently discussed the correction due to the flexure of the support of the pendulum. Although attention was not given to this at the time of making these experiments the pendulum support has been since examined for flexure, by means of a microscope with micrometer eyepiece which was mounted upon the stone pier upon which the support was secured. No flexure was discovered which would sensibly alter the results obtained.

It is hardly necessary to refer to the well known formula by means of which the length of the equivalent simple pendulum was obtained. The following are the dimentions and massess of the various parts of the pendulum.

Total length of the pendulum....................	1014.18	mm.
Distance from knife-edge to wire................	46.50	"
Length of wire..	931.62	"
Diameter of wire	.35	"
Radius of ball	18.03	"
Weight of ball...	198.951	grm.
" " wire	1.913	"
Density of ball..	8.0	"

From these quantities the length of the equivalent simple pendulum is found to be;—

$$l = 994.59 \text{ mm.}$$

Below will be found the results of eleven time determinations made on two successive days in May. On both days during the time of vibration, all of the conditions were sensibly constant and the same, and in addition to this the nights were favorable for the determination of the chronometer rate. Each of the results is based upon an experiment of twenty minutes' duration, the time of vibration in each case being the mean of two or three independent measurements of the chronograph record made by different persons. These include all of the determinations made upon those two days, none having been rejected.

Time of a single vibration.

May 26.—	1.00103
	1.00100
	1.00103
	1.00104
	1.00103
May 27.—	1.00101
	1.00102
	1.00101
	1.00103
	1.00101
	1.00100

Combining these results with the value of l given above and making the necessary air correction the following corresponding values of "g" are obtained;

Corresponding value of "g."

May 26.—	9.7982 meters.
	9.7988 "
	9.7982 "
	9.7980 "
	9.7982 "
May 27.—	9.7986 meters.
	9.7984 "
	9.7986 "
	9.7982 "
	9.7986 "
	9.7988 "

Mean of all results—

$$g=9.7984$$

On comparing this result with those obtained by the use of the generally accepted formulæ for the calculation of the value of "g" for any latitude, it will be found to be slightly greater than any of them.

The absolute determination of the force of gravity at any point to any great degree of precision is a matter involving many difficulties and this is especially true under circumstances in which the facilities for doing the work are certainly not of the best. Aside from the experimental difficulties, there are numerous sources of possible, indeed probable, error which can only be investigated and properly disposed of under exceptionally favorable conditions. Undoubtedly, therefore, more trustworthy results are to be expected from comparative determinations by measuring the periodic time of the same pendulum vibrated at different stations, the corrections to be applied having been carefully investigated and its period determined at some fundamental station. In accordance with this view it is proposed in the immediate future to undertake a careful determination of the periodic time of such an "invariable pendulum" and afterwards to send the same to be vibrated at some point in America or Europe.

PREVIOUS DETERMINATIONS.

Up to about the time of the conclusion of these experiments I was not aware that any previous attempt had been made to determine the value of the force of gravity at this point. Upon the arrival of the Philosophical Magazine for April 1880, however, it was found to contain a paper by Messrs Ayrton and Perry on a "Determination of the Acceleration of Gravity for Tokio, Japan"—which was based on experiments made by the Authors at the College of Engineering in this city in 1878. An examination of this paper will show that there are serious objections to the method pursued by Messrs. Ayrton and Perry besides numerous and fatal errors committed in the reduction of their results.

The pendulum used by Messrs. Ayrton and Perry was nearly ten meters in length. There are serious objections to the use of a long pendulum. Borda, in his celebrated determinations made at Paris, used a pendulum about four meters long, but one which approximates in length to a seconds pendulum has been almost universally made use of since. The great objection to the use of a long pendulum is the difficulty of measuring it *in place*. Messrs. Ayrton and Perry measured their pendulum by placing it in a horizontal position, and stretching it by allowing the end near the ball to hang over a wheel with very little friction. The length was obtained by comparison with a bar one meter long, and as this bar must be placed ten times to cover the whole length, it is plain that any great degree of accuracy must have been difficult to obtain, and this is especially true when the measurement of that portion of the wire which hangs over the wheel is considered. Their 26th experiment was made on the 25th of January, and the 53d on the 21st of February, from which we may infer that the entire time of suspension was at least two months. As only one measurement is spoken of, it is probable that it was measured at the conclusion of the series of experiments, and it seems hardly likely that its length would have remained constant during that length of time. In getting the time of vibration the first method used was what might be termed the method of coincidences by electricity, and which, so far as I know, was first described by Professor Pickering, in his excellent "Physical Manipulations." This was afterward rejected, however, and the vibrations were counted by means of a Morse instrument. The authors speak of measuring the fraction of a vibration, but evidently this could not be done with accuracy by the use of such an arrangement, and there is also the objection that the pendulum was obliged to do the work of breaking the circuit at every vibration. Messrs. Ayrton and Perry give the time of vibration of their pendulum for only three experiments, and it is a little difficult to understand exactly how these were obtained. The time, taken from the chronometer, is given and also the number of vibrations. The only way to make these consistant with each other is to assume an extraordinary and rapidly fluctuating clock rate and even then it is impossible to deduce the periodic time which they use in their calculations which is considerably greater than that of either of the three experiments given. In applying the air correction they have failed to take account the air dragged by the pendulum in its motion although in a subsequent paper in the same journal they have applied this correction. They have also omitted to correct for the arc of vibration although this was considerable in their experiments. In consideration of these facts it does not seem that the result which they obtained is entitled to great weight, notwithstanding its close agreement with the calculated value for this latitude when the proper corrections are introduced.

II

DETERMINATION

OF

THE FORCE OF GRAVITY

ON THE

SUMMIT OF FUJINOYAMA.

The expedition to the summit of Fujinoyama for the purpose of making pendulum experiments at that point was undertaken during the first part of the month of August 1880. The writer was fortunate in securing the interest and co-operation of W. S. Chaplin Esq. Professor of Civil Engineering in the University, who accompanied the party to the summit of the mountain and rendered great assistance throughout taking special charge of the determination of the rate of the chronometer. In addition to Professor Chaplin and the writer, the party consisted of four special students in physics in the University, Messrs. Tanakadate, Tanaka, Fujisawa and Kumamoto, and Mr. Yamada, assistant in the Department of Physics. Mr. Nobutani of the Meteorological Observatory was with the party a portion of the time as were also, Messrs. Wada and Nakamura from the Surveying Department.

To Messrs. Tanakadate and Tanaka was assigned the task of making the pendulum vibrations as they had, in making the Tokio determination, acquired a knowledge of all of the details of the work. Mr. Fujisawa determined the vibration periods of two magnets which he had previously vibrated in the physical laboratory at Tokio and he also assisted Mr. Kumamoto in keeping up the meteorological observations.

Mr. Nakamura also carried on a series of meteorological observations during his entire stay upon the summit which were accompanied by simultaneous observations at the foot of the mountain by Mr. Wada. These observations, together with all of the meteorological work done, will be found in the second report from the Meteorological Observatory of the University,—Memoirs of the Science Department of the University of Tokio. No. 7.—"Meteorology of Tokio for the Year 1880."

The following is the list of the principal instruments and appliances carried to the summit of the mountain.

Two pendulums.
Supports for same with break-circuit arrangement &c.
Chronograph.
Break-circuit chronometer (Negus. 1629).
Small Alt-azimuth instrument.
Mercurial barometer.
Maximum and Minimum Thermometers.
Hygrometer.
Thermometers.
Magnets & Case for swinging.

With batteries and other miscellaneous articles necessary to the success of the undertaking.

Considerable difficulty was anticipated in getting the apparatus safely to the top of the mountain. The two pendulums were packed together in one box so that injury to either in transportation would hardly be possible. The chronograph was separated into parts and packed in different boxes. It was thought best to carry the alt-azimuth in its case as a whole and, after some difficulty, a man was found who undertook to carry it to the summit. Everything reached the top of the mountain in good condition and on the afternoon of August 4th the chronograph was mounted and the pendulum vibrations were commenced. Considerable trouble was experienced in finding a suitable place in which to conduct the experiments. A small tent had been sent up for the use of the party but it was at once seen that, owing to the high winds which are so frequent upon the summit and which are likely to occur at any time, it would be impossible to carry out the experiments safely in that. There are several small stone huts upon the top of the mountain which are used as temples or as resting places for the pilgrims who visit the mountain annually, during the months of July and August, in great numbers. Through the kindness of Mr. Kinoshita a priest in charge of some of these small temples we were permitted to take possession of one of them and to mount our instruments within it. It proved to be admirably suited to our purposes, its heavy stone walls affording us at once complete protection from the wind and a firm mounting for the support upon which our pendulums vibrated.

To secure, as far as possible, against any possibility of entire loss of results from accident two pendulums were carried to the mountain. As it was impossible to procure just what was desirable in the way of pendulums, it was necessary to make the best of the material at hand.

To this end a Kater's reversible pendulum by Negretti and Zambra of London was made use of, after removing one of its knife-edge, its "tail-pieces" and all of the unnecessary movable parts. The heavy brass cylinder was secured at the lower end in such a way that it could hardly, by any possibility, be moved from its position and a small adjusting slide-piece was secured in a like manner upon the short piece of the bar which extended above the knife-edge. The total length of the pendulum was 135 cm.; the bar was 38 mm. wide and 4.2 mm. thick; the flat cylinder was 10 cm. in diameter and 19 mm. thick and its centre was approximately 110.5 cm. from the knife-edge.

The wooden pendulum consisted of a thin flat bar of what was thought to be well seasoned wood, having the knife-edge which had been removed from the brass pendulum inserted at a distance of 19.5 cm. from one end and at the other was attached a heavy brass cylinder 6.5 cm. long and 5.4 cm. in diameter.

Both of these pendulums had been vibrated in the physical laboratory of the University before carrying them to the mountain and both were vibrated in the same place immediately after the return of the expedition. The mode of conducting the experiment was similar to that already described as in use in the Tokio determination. The chronograph sheets were carefully lettered and numbered and the reduction of the work was made after the return of the party to Tokio. The weather during the stay upon the mountain was everything that could be desired, the nights being clear and the winds moderate. The work was finished by the afternoon of August 6th and it was extremely fortunate that this was the case as on the following morning there began a storm of rain and wind which would have rendered its continuance extremely difficult.

In the results given below only those obtained from the brass pendulum are included.

The wooden pendulum is not rejected on account of any particular discrepancy between its work and that of the brass pendulum, but because we have no means of making any correction for the effect of moisture upon it. From experiments since its return from the mountain it is clear that its rate is affected by the humidity of the air in which it swings, as, indeed, was anticipated. The results which it gives differ but slightly from those of the brass pendulum but owing to this uncertainty they are not made use of. The pendulum served a useful purpose, however, as a check upon the other.

A great many groups of vibrations were recorded both on the mountain and at Tokio before and after the mountain work, the total time of each series being in general thirty minutes. Without quoting the individual results it will be sufficient to say that they agree among themselves slightly better than the series of vibration periods given in the paper on the Tokio determination. The vibrations at Tokio were all made under nearly the same conditions and, for convenience, they were reduced to the common temperature of 23°.5, at which most of them were made, and barometer 30 inches. The time of vibration of the pendulum under these conditions, the mean of all of the results, was.—

$$t_1 = .999834 \text{ seconds.}$$

On the summit of the mountain, during the time of making the experiments, the barometer was tolerably constant at about 19.5 inches and the temperature 8°.5 and to these conditions the results were reduced, after correcting for arc and chronometer rate.

Finally the mean of all is reduced to the Tokio conditions as to temperature and pressure.

CORRECTIONS.

The corrections for arc of vibration have been made by means of well known formulæ. The mean arc of vibration in both the Tokio and Fujinoyama experiments was about one degree and a half In making the correction for temperature the co-efficient of expansion has been assumed to be .0000187 as no means were at hand for determining it precisely. This is a commonly accepted co-efficient for brass and a comparison of the vibration periods of the pendulum under different temperatures indicates that it can not be far from correct.

The correction for difference of barometric pressure is the most difficult to determine. Were it possible to vibrate the pendulum at the same place under pressures widely differing it might be determined experimentally. Lacking this, I was fortunately able to refer to a recent elaborate and exhaustive discussion of the whole subject, from an experimental as well as a theoretical standpoint, by C. S. Peirce Esq. of the United States Coast Survey.* In this valuable memoir Mr. Peirce gives a graphical representation of the periods of vibration of his pendulum, under various pressures, from 30 inches down to practically a vacuum. By interpolation the period for any pressure can be very closely ascertained, as also the correction in going from one pressure to another. There are important differences between the pendulum used by Mr. Peirce and that in use here, the principal being the difference in the shape of the cylindrical weights and the fact that in our pendulum only one cylinder was attached. Nevertheless a fair approximation to the proper correction may be taken from his curve showing the results with "heavy end down" and observing that the differences in the two pendulums are such as to make the correction for our pendulum considerably less than for that of the Coast Survey. In this way and by considering these differences the correction used in the reduction was reached. After it had been established I was fortunate in finding in this country a volume of the Philoso-

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* Measurements of Gravity at Initial Stations in America and Europe-Appendix No. 15 U. S. Coast Survey Report of 1876.—

phical Transactions of the Royal Society for 1832 containing Mr. Baily's memoir in which a series of elaborate experiments to determine this correction are described. Among the many pendulums which he used, was one, "No 22" which, in form and dimensions, resembles that used here much more closely and the results of his experiments with it confirm the accuracy of the assumptions made. It will be remembered that, as all results are reduced to the Tokio conditions, the correction is to be made for only about one third of an atmosphere so that, although important, it is less so than if the reduction had been to a vacuum. It is believed, therefore, that the correction applied is not far wrong.

The corrected time, therefore, is obtained as follows:—

time on the summit of Fujiyama, temperature 8°.5—barometer 19.5 inches,—

$$t = 1.000146$$

$$\text{temperature correction} = .000140$$

$$\text{air correction} = .000050$$

corrected time.—

$$t_2 = 1.000336$$

Now letting t_1, t_2 and g_1, g_2 represent the time of vibration and force of gravity at Tokio and on the summit of Fujinoyama respectively, we have,—

$$g_2 = \frac{g_1 t_1^2}{t_2^2}$$

Assuming the force of gravity at Tokio to be, as previously determined,—

$$g_1 = 9.7984$$

it follows that on the summit of Fujinoyama

$$g_2 = 9.7886$$

An interesting and valuable application of this result, were it entirely trustworthy and were the other necessary facts in our possession, would be the determination of the density of the earth. While many of the circumstances are extremely favorable to this end, many of the data are, unfortunately, somewhat uncertain. It was originally intended to undertake at the same time a complete trigonometrical survey of the mountain in order to obtain the necessary data concerning its volume and form as accurately as possible. This, however, we were obliged to defer but it is hoped that it may be made, at some future time. The following is offered as, perhaps, the most approximate solution of the problem possible under the circumstances.

Fujinoyama is an extinct volcano whose height is known to be 2.34 miles, very closely. It is renowned for its almost perfect symmetry of form and for the fact that it rises solitary and alone out of a plain of considerable extent. Thus there is not much to consider except the attraction of the mountain itself. To determine this, is, of course, a matter of considerable difficulty but it is believed that a result, not far out of the way, is reached by the following assumptions.

Without any great error the mountain may be assumed to be a cone. The angle of this cone has been obtained by making careful measurements upon a large number of photographs of the mountain, taken from many different points of view. The mean of many measurements, which do not differ greatly among themselves, gives for this angle;—

$$A = 138^{\circ}.-$$

Another point of vital importance is the mean density of the mountain. The rock, as far as can be discovered, is quite uniform in its composition throughout. It is a part of Japanese tradition, for it can hardly be called history, that the mountain was produced in a single night in the year B. C. 286. Many geologists are of opinion that it is mainly the result of a single eruption. A number of specimens from the surface have been examined and it is found that when the air is retained in the pores the density is about 1.75, but when it is ground into a powder and freed from air it is 2.5.

These facts were communicated to five geologists, at present employed in Japan, Messrs. Milne, Lyman, Brauns, Nauman and Netto, most of whom had considerable knowledge of the mountain from personal examination. They were requested to give an opinion as to what was its most probable mean density. These opinions, which were based on various suppositions concerning the internal structure of the mountain, were kindly furnished and I am greatly indebted to these gentlemen for the interest which they exhibited in the problem submitted.

The mean of these results gave for the density of the mountain;—

$$d = 2.12$$

which is assumed to be correct in computing the result and it also happens to be very nearly the mean of the two densities given above.

The time of a single vibration of the pendulum at the level of the sea at Fujinoyama was not determined experimentally but it may be deduced from the Tokio result with sufficient accuracy by the application of the ordinary formula.

The difference of latitude between Tokio and Fujinoyama is about 19′ and from this we obtain for the period at the sea level at the foot of the mountain,

$$t_3 = .999847$$

From this it is easy to calculate what the force of gravity would be at the height of the summit, if the mountain did not exist. It is,—

$$g_3 = 9.7865$$

and

$$\frac{g_2}{g_3} = 1.00021$$

that is,—

Attraction of Mountain = .00021 Attraction of Earth.

The attraction exerted by a cone on a particle at its vertex is,—

$$4\pi dh \sin^2 \frac{a}{2}$$

in which d represents the density of the cone, h its height and a its semi-vertical angle.

Substituting in this formula the values of the quantities given above there results for the attraction of the mountain;—

$$A_m = 20.072$$

The volume of the earth is very approximately

$$2594 \times 10^8 \text{ cubic miles}$$

and if its density be represented by D, its attraction will be found to be;—

$$A_e = 16556\,D$$

Combining this with the equation given above we find,—

$$D = 5.77$$

This result is somewhat greater than the generally accepted density, but considering the great uncertainty of some of the data, its close agreement must be regarded as remarkable.

It is believed that the density of the mountain is the most uncertain of all the factors involved in the calculation, and it will be of interest to reverse the problem and, assuming the well established density of 5.67, according to Baily, determine the mean density of the mountain by combining this with the results of the pendulum experiments. When this is done the result is,—

$$d = 2.08$$

Now when the influence of the pressure to which much of the rock is subjected is considered, it seems highly probable that, if the mass of the mountain were continuous throughout, its mean density would be much higher than 2.08 and that it might, indeed, be higher than 2.5. Even after allowing for considerable errors in the pendulum experiments and in the measurement of the mountain, the results seem to indicate that the mountain is deficient in attraction and they may thus serve a useful purpose in throwing some light on the possible internal structure of the volcano.

Note. Since the printing of the above, Professor Chaplin has completed a discussion of the height of Fujinoyama, based upon all observations yet made which may be considered reliable, both barometrical and trigonometrical. The result of this discussion gives for the height of the mountain 3792 metres, or 12441 feet, which is slightly more than 2.35 miles. The details of this discussion will be found in No 7 of the Memoirs of the Science Department of the Tokio Daigaku,—"Meteorology of Tokio for the Year 1880."

MEASUREMENT

OF THE

FORCE OF GRAVITY

AT

SAPPORO

(YESSO),

BEING

AN APPENDIX

TO

MEMOIR No. 5

OF THE

SCIENCE DEPARTMENT,

TÔKIÔ DAIGAKU

(UNIVERSITY OF TÔKIÔ)

BY

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REPORT

ON

A DETERMINATION

OF

THE FORCE OF GRAVITY

AT

SAPPORO.

An expedition to Sapporo for the purpose of determining the force of gravity there was undertaken by us with the permission of the University authorities during the month of August 1881. We here express our heartiest thanks to W. S. Chaplin Esq., Professor of Civil Engineering in the University, who accompanied us for the purpose of taking charge of the rating of the chronometer, and to whom we are indebted for much invaluable advice. Our thanks are also due to H. M. Paul Esq., Professor of Astronomy, who kindly furnished us with the chronometer rate during our Tokio experiments.

As regards the instrumental appliances and the method of experiment we have followed the example set by Professor T. C. Mendenhall in his determination of gravity at the summit of Fujinoyama. The method consisted essentially in determining the time of vibration of a so-called invariable pendulum at the two localities, at which the intensities of gravity were to be compared. Two brass pendulums were made by the Seirensha for the University and were marked A and B respectively. The pendulum A after being vibrated at Tokio was taken to America by Prof. Mendenhall to be vibrated there, so as to bring Tokio into direct gravity connection with the initial stations in Europe and America, while the pendulum B together with an old Kater's pendulum were selected for our purpose.

The pendulum B consisted of a hollow brass cylinder whose outer diameter was 2.5 c. m., with a knife-edge at a distance of 11.0 c. m. from one end and a heavy disc of the same metal weighing 2398 grammes attached at the other. Its total length was 121.5 c. m. The Kater's reversible pendulum (by Negretti and Zambra) was made use of after removing one of the knife-edges and all the unnecessary movable parts. The movable bob, consisting of a heavy brass cylinder was secured at the lower end in such a way as to keep it rigidly in one position, and another small bob was secured in a similar manner upon the short part of the bar which extended above the knife-edge, for the purpose of making the pendulum have a half-period of nearly one second. The total length of the pendulum was 135 c. m.; the bar was 3.8 c. m. wide and .42 c. m. thick; the cylindrical bob was 10 c. m. in diameter and 1.9 c. m. thick, and its centre was approximately 110.5 c. m. from the knife-edge.

Both of these pendulums were vibrated at Tokio in the physical laboratory of the University both before and after the observations at Sapporo. The following description applies to the Tokio experiment.

Position and suspension of the pendulum.—The pendulum was swung in one of the small rooms occupying the south wing of the physical laboratory, which is well protected from sudden changes of temperature and from currents of air. In this room there is a large stone pier about 60 c. m. square in horizontal section, built upon a solid foundation and extending to a height of two metres above the ground. A heavy bar of iron about 70 c. m. in length and having a cross section of about 11 c. m. by 2.5 c. m. was placed on the top of this pier and was secured by means of heavy blocks of stone placed above it. The end of the iron bar projected just far enough to allow a resting place for a stout iron plate which was carefully levelled and upon which the knife-edge was made to rest. The position of the pendulum was approximately as follows:—

Latitude .... 35° 42′ N.
Longitude .... 139° 46′ E.
Height above sea level .... 5 metres.

Determination of the time of vibration.—Time was obtained from a break circuit sidereal chronometer (Negus 1629). The chronometer remained in the transit room of the astronomical observatory and its beats were received through a telegraph line which connects the two places. It is immaterial in the present experiment what unit of time we use, and it was found convenient to use sidereal time throughout the experiments. The chronograph used was by Alvan Clark and Sons, the same instrument as was used in the Fujinoyama expedition. As to its uniformity of speed and other desirable characteristics we have only to confirm the remarks made by Prof. Mendenhall in his report on the Fujinoyama expedition. A simple arrangement similar to that used by Prof. Mendenhall was applied to the pendulum so that it could be made to break the circuit through the chronograph magnet at any desired vibration. The pendulum, after being caused to break the circuit once, was swung freely during 20 to 40 minutes generally, and was then again caused to break the circuit. These two breaks, together with seconds marks during the whole interval, were recorded on the chronograph. The whole number of seconds required for a given number of vibrations being known from preliminary experiments (which had shown that the time of a single vibration of both pendulums was nearly one second), it only remained to determine two fractional parts of a second at the beginning and end of the interval. The measurement of these, reduced by the chronograph to a linear measurement, was made with a microscope provided with a micrometer eye-piece.

Having completed our experiments at Tokio, we started for Sapporo early in the month of August. All the instruments hitherto used, including the two pendulums, the chronograph, the break circuit chronometer, and a portable transit instrument, were carried with us. The method of experiment having been the same as at Tokio, it is only necessary to specify the position of the observing station at Sapporo. Through the kindness of Governor Dzusho we were allowed the use of a small transit room belonging to the Geographical Bureau of the Colonization Department. There were two stone pillars in the room, on one of which there was already set up a small transit instrument. Upon the other two additional stone blocks were laid, from which the pendulums were swung in the manner already described. The position of the pendulum was approximately as follows:—

Latitude ....43° 3′ 54″ N.
Longitude ....141° 22′ 4″ E.
Height above sea level..............................21 metres.

Everything went on smoothly, the nights being clear for transit observations. Having finished our experiments in the course of a week we immediately left Sapporo. On our return to Tokio the same series of observations were repeated.

REDUCTIONS.

The numerical data of the experiments are given in full in the accompanying tables. The correction for the reduction to infinitely small arcs has been calculated from the well known formula which, with the usual notation, may be written

$$t \frac{1}{4} \sin^2 \frac{A}{2}.$$

A millimeter scale was placed under the pendulum and the extent to which the lower end of the pendulum swung was read on this scale at the beginning and at the end of each experiment. The mean of these two readings in m. m. is given in the 7th column under the heading "Mean Arc." The semi-angle of vibration has been computed from this column combined with the length of the pendulum below the axis of rotation. The mean total arc of vibration in both the Tokio and Sapporo experiments was about one degree and a half.

The next correction is that depending on the temperature of the pendulum. The discordance in the coefficients of expansion given by different authorities as well as the difficulty of exactly identifying the quality of the metal on which they experimented shows that it would have been desirable to determine the temperature corrections by swinging the pendulums at different temperatures, other things remaining the same. Want of time did not enable us to undertake such a series of experiments and the commonly accepted coefficient of expansion for brass, .0000187 per degree centigrade, was assumed; which we think will be sufficiently accurate for our present purpose. A thermometer was hung near the pendulum and the readings were taken at the beginning and end of each experiment. The mean of the two readings is given in the 9th column under the heading "Mean Temperature." The temperature was sensibly constant during any one experiment. In making out the correction 25° C. was taken as the temperature of reference as it happened to be about midway between the extreme temperatures. The correction is

$$t\frac{a}{2}(T-25)$$

where t is the time of a vibration uncorrected, a the coefficient of expansion (.0000187), and T the observed mean temperature. This correction is given in the 10th column.

The correction for the chronometer rate has been computed from the daily rate obtained by transit observations. The daily rate got from transit observations on two successive nights is of course no more than the mean rate during the day. In making out this correction we have however supposed the rate to be uniform throughout each day, for, although this may introduce a slight error into the individual results, yet in the mean of a number of experiments continued during a whole day the error thus introduced will eventually be very small.

The further corrections for the statical buoyancy and the viscous resistance of the air will appear in the form $c\rho t$,* where c is some constant depending upon the form of pendulum, ρ the density of the air divided by that of the pendulum, and t the time of vibration after the other corrections have been applied. Using the suffixes t and s to denote ρ and t at Tokio and Sapporo respectively, the ratio of the values of the acceleration due to gravity at the two localities when thus corrected will become

$$\left(\frac{t_t}{t_s}\right)^2\left(\frac{1+c\rho_t}{1+c\rho_s}\right)^2=\left(\frac{t_t}{t_s}\right)^2\left\{1+2c(\rho_t-\rho_s)\right\}$$

neglecting higher powers of small quantities. Now taking the density of brass to be 8.47 the temperature of the air 25° C. and the barometric pressure 76.0 c.m.

[illegible] $\rho = .000140$

c has been computed by Poisson to be $\frac{3}{2}$ † in the case of a sphere attached to a thin rod. In the present case, the pendulum consisted of a very oblate ellipsoid attached to a bar as already described, and vibrated in the plane of its longer axis, so that we may safely assume c to have been something not far from the above. Further, since the barometric readings were sensibly the same during both the

* Bessel,—Berl. Akad. 1826.

† Airy, Treatise on Sound. Art. 54.

Tokio and Sapporo experiments, the error arising from this source will be approximately eliminated in the mean of different observations.

We regret to say that an accident occurred to the pendulum B in the course of transportation from Tokio to Sapporo: a brass cap at its upper end was pressed in a little. For this reason, out of the two sets of observations at Tokio, only the one made after returning from Sapporo was used in the case of pendulum B. Nevertheless the earlier observation is of some use, as showing that the change produced in the time of vibration was very small.

The eleventh column gives the time of a single vibration, that is, a half-period, reduced to an infinitely small arc and to the temperature 25° C. The results stand as follows:—

PENDULUM B

Time of single vibration at Tokio	1.000197 sec	± .0000042
" " " " Sapporo	.999869 "	± .0000071

KATER'S PENDULUM

Time of single vibration at Tokio (before)....	1.000103 sec	± .0000031
" " " " " (after)	1.000104 "	± .0000047
" " " " " (mean)	1.000103 "	± .0000026
" " " " Sapporo	.999758 "	± .0000117

The ratio of the acceleration due to gravity at Sapporo to that at Tokio comes out as follows:—

(1) By Pendulum B...	1.000656	± .000017
(2) " Kater's Pendulum	1.000690	± .000024

As to the way of combining the two results obtained from the two pendulums, a few remarks seem to be necessary. It will be seen from the magnitudes of the probable errors, that result (1) should have about twice as much weight as (2): but on account of the accident already described, we have been able to utilize only one series of Tokio vibrations for (1). Hence it appears proper on this account to diminish the weight of (1) and we have concluded that simply to take the arithmetical mean will be a not inappropriate way of combining the two results.

The mean of the ratio is 1.000672. The value of g* at Tokio is known to be 979.84 c. m. per sec. per sec. Hence we have finally for the acceleration due to the force of gravity at Sapporo

980.510 c. m. per sec. per sec.

* Memoir No. 5 of the Science Department of Tokio Daigaku.

The above result is slightly greater than that obtained by the use of generally accepted formulas for the calculation of the value of g in any latitude (as was also the case in the Tokio value of g). Thus the formula

$g = 980.6056 - 2.5028 \cos 2\lambda - .000003\, h$ (Prof. Everett's C. G. S. System).

makes g in the latitude of Sapporo

980.43 c. m. per. sec. per. sec.

In the Astro. Nach., No. 2228, Prof. Listing gives the following formula

$$g = 978.0728 + 5.0875 \sin^2 \phi$$

which gives

g = 980.44 c. m. per sec. per sec.

Again the formula

$$g = 980.63 - 2.553 \cos 2\lambda$$

given by Major Herschel in the Philosophical Magazine for June 1879 gives

980.46 c. m. per sec. per sec.

As however the above formulas are only to be regarded as giving an approximate value of g in any latitude, they afford but little test on our special result. It will be perhaps more interesting to compare the value of g found from actual experiment at other stations in nearly the same latitude. The only place we can find for this purpose is Toulon on the southern coast of France,—one of the stations in an elaborate series of pendulum experiments made by Captain Duperry. Its latitude is 43° 7′ 20″ N, so that it differs from that of Sapporo by 3′ 26″. Duperry's result is given in terms of the number of vibrations in a day made there by a London seconds pendulum [2]. The value of g at London is 981.157, and the value of g at Toulon comes out to be 980.412 which is somewhat less than the Sapporo value although the latitude of Toulon is three and a half minutes higher. From this it is to be inferred that in the same latitude the value of g here is slightly greater than on other meridians. So far as the Sapporo observation is concerned, the difference cannot be attributed to local causes as Sapporo is situated in a vast plain at a distance of a few miles from the sea.

In the article referred to above a great number of results of pendulum experiments made at various localities are given, among which we find a determination made at the Bonin Islands by Captain Leutke. From the combined result of all the observations there recorded, Mr. Baily deduced a formula from which the numbers of vibrations at the respective localities were calculated, and these are given under the heading "Computed". From these it may be seen that the difference between the observed and computed numbers is greater in the case of the Bonin Islands than at any other station. In other respects as well as in geographical position, the Bonin Islands stand isolated from the rest. The following are the figures given.

2 [illegible] Vol. IX. Art. [illegible] of the Earth.

Latitude	Number of vibrations per day of a London seconds pendulum	
	Observed	Computed
Bonin Island 27° 4′ 12″ N	86322.06	86310.81

From these we have calculated

	Observed	Computed
g at Bonin Island	979.388	979.132

Computed from Professor Everett's formula g comes out to be 979.139. Thus it will be seen that the observed value is greater than the computed, contrary to what we might expect in view of the isolated position of the islands, rising as they do out of the deep basin of the Pacific Ocean.

In the case of the Tokio and Sapporo results, as any error in the Tokio value would affect the Sapporo value with a similar error, the coincident excess of g as observed over the calculated value might have been predicted. But now combining the results of the Bonin, Tokio and Sapporo experiments, we venture to say that the acceleration due to gravity is probably slightly greater in the neighborhood of Japan than at other places in the same latitude. Further determinations will however be necessary before a definite decision can be come to on this point.

MAGNETIC EXPERIMENTS.

On account of the imperfection of the magnetometric apparatus at our disposal, we were obliged to content ourselves with a relative determination of the horizontal intensities of terrestial magnetism at Tokio and at Sapporo.

The method consisted in vibrating in a horizontal plane at the two localities a magnet which was permanent enough to undergo no appreciable change in the process of transportation. The method of observing the time of vibration was the same as that used by one of us on the summit of Fujinoyama; it is described on page 55 of Memoir No. 7 of the Science Department of this University (Report on the Meteorology of Tokio for 1880, by Prof. Mendenhall), but it will not be out of place here to recapitulate the most important features.

The magnet was suspended by means of a silk fibre, whose torsion was found to be negligeable, and was swung in a glass case, which protected it from currents of air. On the glass case there was pasted a graduated scale by which the arc of vibration was read off. The temperature at the time of swinging was shown by a thermometer inserted in this glass case. As, however, small variations of the magnetic moment due to variations of temperature could not be conveniently ascertained, and as, moreover, the extreme variations scarcely exceeded 2 or 3 degrees, it was considered unnecessary to introduce any allowance for this in the time of vibration. The exact adjustment of the horizontality of the magnet being a matter of some difficulty, several observations were made with a re-adjustment of the level before each, other things remaining the same.

The time of transit of a mark in the middle of the end of the magnet across a vertical line traced on the glass case was observed by a telescope placed some metres distant and was recorded on the chronograph. In the measurement of the time from the chronograph sheet usually from 80 to 150 complete vibrations were taken, so that the error due to this is believed to fall far short of those arising from other sources.

Three magnets were carried, two of which were kindly lent us by the authorities of Kobu Daigakko. A comparison of the magnetic moments before and after the Sapporo excursion shows that two of the three magnets had settled into a very stable magnetic state. Each of the magnets was provided with a holder to which the suspending fibre could be fastened.

The observations are arranged in the following tables:

OBSERVATIONS AT TOKIO BEFORE GOING TO SAPPORO.

Mag.	Date	Time (uncorrected)	Mean Arc	Time (corrected)	Mean Temp.
1	July 31	13.3123	4°.8	13.3109	28°.9
..	Aug. 1	13.3253	6°.7	13.3224	30°.0

2	July 28	13.2635	6°.4	13.2610	27°.5
,,		13.2641	5°.0	13.2625	27°.5
,,		13.2652	6°.2	13.2628	27°.7
3	July 31	11.6994	18°.0	11.6809	30°.0

OBSERVATIONS AT SAPPORO.

Mag.	Date	Time (uncorrected)	Mean Arc	Time (corrected)	Mean Temp.
1	Aug. 18	14.1165	30°.0	14.0562	27°.5
2	,,	14.0603	10°.1	14.0524	28°.0
,,	,,	14.0150	7°.7	14.0111	27.°6
,,	,,	14.0178	17°.0	13.9985	27°.5
,,	,,	14.0150	17°.0	13.9957	27°.5
,,	,,	14.0095	13°.0	13.9983	27°.5
3	,,	12.7706	25°.0	12.7326	27°.5

OBSERVATIONS AT TOKIO AFTER THE SAPPORO EXCURSION.

Mag.	Date	Time (uncorrected)	Mean Arc	Time (corrected)	Mean Temp.
1	Aug. 31	13.3083	6°.5	13.3056	28°.4
,,	,,	13.3097	8°.3	13.3053	30°.0
,,	,,	13.3103	10°.6	13.3031	29°.8
2	Aug. 28	13.2600	9°.6	13.2541	29°.5
,,	29	13.2672	9°.5	13.2614	28°.5
3	Sept. 2	12.0440	10°.0	12.0382	29°.0

No. 1 and No. 2. were cylindrical in form and both of the same dimensions:
length 17.5 c. m. diameter 0.8 c. m.
weight 73.8 grms.

No. 3. was a rectangular rod:
length 12.0 c. m. section 1.0 c. m. by 0.5 c. m.
weight 68·8 grms.

A summary of the results is given below:—

	Before Sapporo.	Sapporo	After Sapporo
1.	13.3167	14.0543	13.3046
2.	13.2621	14.0009	13.2578
3.	11.6809	12.7326	12.0382

In the reduction of the results, the mean of the times of vibration before and after Sapporo is taken.

The ratio of the two intensities is equal to the square of the inverse ratio of the times of vibration, whence we get for the ratio of H at Sapporo to H at Tokio;—

$$\text{by No. 1.} \quad \left(\frac{13.3167}{14.0543}\right)^2 = .8970.$$

$$\text{by No. 2.} \quad \left(\frac{13.2600}{14.0009}\right)^2 = .8970$$

$$\text{by No. 3.} \quad \left(\frac{11.8596}{12.7326}\right)^2 = .8676.$$

From the preceding tables it will be seen that magnet No. 3. suffered considerable change during the excursion, and therefore the result given by it can hardly be relied upon.

Prof Mendenhall took the value .299 expressed in the Centi-metre-Gramme-Second system of units, as the most probable value of the horizontal component of the earth's magnetic force at Tokio, after a careful examination of the results obtained by Mr. Schutt, Commander Sampson, and others, during the summer of 1880. If in the absence of any later determination we accept this as the present value for Tokio, we obtain

0.268

as the value of the Horizontal Intensity at Sapporo.

THE END.

OBSERVATIONS AND REDUCTIONS

OF

PENDULUM EXPERIMENTS

FOR THE

DETERMINATION OF THE VALUE OF *G*

AT SAPPORO.

Aug. 1881.

OBSERVATIONS WITH PENDULUM B. AT

Date 1882		Reference No.	Number of Minutes	Fraction of Second	Time of single vibration (uncorrected) Sd. Sec.	Mean arc (mm.)
July	23rd	1	82	.851	1.000183	16.9
	"	2	80	.333	1.000185	16.5
	24th	1	42	.446	1.000177	17.4
	"	2	46	.481	1.000174	16.8
	25th	1	64	.591	1.000154	16.3
	"	2	42	.409	1.000162	16.8
	26th	1	81	.885	1.000201	16.9
	"	2	82	.411	1.000213	18.5
	"	3	22	.271	1.000205	18.9
	"	4	89	.440	1.000188	16.0
	"	5	88	.888	1.000196	20.0
	"	6	21	.281	1.000186	16.5
	"	7	85	.872	1.000177	16.0
	"	8	28	.281	1.000167	15.3
	"	9	86	.375	1.000174	16.5
	27th	1	86	.847	1.000160	16.5
	"	2	80	.299	1.000166	18.4
	28th	1	81	.818	1.000169	18.5
	"	2	81	.804	1.000168	18.3
	29th	1	88	.851	1.000177	18.5
	"	2	88	.885	1.000169	17.1
	"	3	81	.419	1.000225	17.7
	31st	1	27	.301	1.000186	19.7
August	1st	1	52	.578	1.000185	17.4
	"	2	88	.352	1.000178	18.3

TOKIO BEFORE THE SAPPORO EXCURSION.

Correction for arc (to be subtracted)	Mean Temp. °C	Correction for Temperature	Correction for chronometer rate (to be added)	Time of single vibration (corrected) Sid. Sec.	Residuals
.000015	25.6	—.000006	.000012	1.000174	+ 8
.000014	26.0	—.000009	.000012	1.000174	+ 8
.000015	25.6	—.000006	.000012	1.000168	+ 2
.000015	25.9	—.000008	.000012	1.000163	— 3
.000014	25.0	—.000000	.000012	1.000152	—14
.000015	25.0	—.000000	.000012	1.000159	— 7
.000015	25.2	—.000002	.000012	1.000196	+30
.000018	25.4	—.000004	.000012	1.000203	+37
.000018	25.7	—.000006	.000012	1.000193	+27
.000013	26.0	—.000009	.000012	1.000178	+12
.000020	26.2	—.000011	.000012	1.000177	+11
.000014	26.6	—.000015	.000012	1.000169	+ 3
.000013	26.6	—.000015	.000012	1.000161	— 5
.000012	26.7	—.000016	.000012	1.000151	—15
.000014	26.8	—.000017	.000012	1.000155	—11
.000014	26.0	—.000009	.000012	1.000149	—17
.000018	26.1	—.000010	.000012	1.000150	—16
.000018	26.1	—.000010	.000012	1.000153	—13
.000017	26.5	—.000014	.000012	1.000144	—22
.000018	26.1	—.000010	.000012	1.000161	— 5
.000015	26.5	—.000014	.000012	1.000152	—14
.000016	27.0	—.000019	.000012	1.000202	+36
.000020	28.0	—.000028	.000012	1.000150	—16
.000016	27.4	—.000023	.000012	1.000158	— 8
.000017	27.6	—.000024	.000012	1.000149	—17
			Mean	1.000166	
				±.0000024	

OBSERVATIONS WITH PENDULUM B. AT

Date 1882	Reference No.	Number of Minutes	Fraction of Second	Time of single vibration (uncorrected) Sid. Sec.	Mean arc (mm.)
September 12th	1	30	.311	1.000173	18.1
,,	2	30	.308	1.000171	18.1
14th	1	30	.382	1.000212	18.0
,,	2	31	.388	1.000205	18.3
,,	3	30	.389	1.000216	18.0
16th	1	29	.345	1.000198	18.1
,,	2	32	.350	1.000182	18.2
,,	3	29	.419	1.000241	19.1
17th	1	30	.456	1.000253	18.1
19th	1	34	.548	1.000239	18.7

OBSERVATIONS WITH PENDULUM

August 16th	1	28	.201	.999880	17.3
,,	2	28	.220	.999869	16.8
,,	3	28	.221	.999870	17.5
,,	4	25	.184	.999875	17.8
,,	5	30	.224	.999876	17.3
,,	6	31	.206	.999889	17.6
18th	1	40	.489	.999796	16.0
,,	2	24	.148	.999807	18.0
,,	3	22	.154	.999883	17.0
,,	4	33	.412	.999792	17.2
,,	5	26	.317	.999797	17.1
,,	6	31	.228	.999878	16.8
,,	7	30	.181	.999900	18.0
,,	8	32	.250	.999870	18.5
,,	9	31	.321	.999827	18.0
,,	10	20	.194	.999838	18.2

TOKIO AFTER THE SAPPORO EXCURSION.

Correction for arc (to be subtracted)	Mean Temp. °C	Correction for Temperature	Correction for chronometer rate (to be added)	Time of single vibration (corrected) Sid. Sec.	Residuals
.000017	23.2	+.000017	.000012	1.000185	—12
.000017	23.1	+.000017	.000012	1.000183	—14
.000017	26.7	—.000016	.000012	1.000191	— 6
.000017	26.6	—.000015	.000012	1.000185	—12
.000017	26.4	—.000013	.000012	1.000198	+ 1
.000017	25.1	—.000001	.000012	1.000192	— 5
.000017	25.4	—.000004	.000012	1.000173	—24
.000018	25.8	—.000007	.000012	1.000228	+31
.000017	26.5	—.000014	.000013	1.000235	+38
.000018	28.2	—.000030	.000012	1.000203	+ 6
			Mean....	1.000197	
				±.0000042	

B AT SAPPORO.

.000015	21.3	+.000035	.000005	.999905	+36
.000015	21.6	+.000032	.000005	.999891	+22
.000015	21.8	+.000030	.000005	.999889	+20
.000017	22.3	+.000025	.000005	.999888	−19
.000015	22.7	+.000022	.000005	.999888	+19
.000016	23.4	+.000015	.000005	.999893	+24
.000013	27.3	—.000022	.000028	.999789	—80
.000017	27.3	—.000022	.000028	.999886	—17
.000015	27.3	—.000022	.000028	.999874	— 5
.000015	27.5	—.000024	.000028	.999781	—88
.000015	27.2	—.000021	.000028	.999789	—80
.000015	26.5	—.000014	.000028	.999877	+ 8
.000017	25.3	—.000003	.000028	.999908	— 39
.000018	23.0	+.000019	.000028	.999899	30
.000017	22.0	+.000028	.000028	.999866	— 3
.000017	21.9	+.000029	.000028	.999878	— 9
			Mean	.999869	
				±.0000071	

OBSERVATIONS WITH KATER'S PENDULUM AT

Date 1882		Reference No.	Number of Minutes	Fraction of Second	Time of single vibration (uncorrected) Sid. Sec.	Mean arc (min.)
July	30th	1	19	.194	1.000170	18.3
	,,	2	29	.198	1.000111	17.6
	,,	3	25	.203	1.000185	17.3
	,,	4	27	.201	1.000124	17.1
	,,	5	29	.156	1.000130	18.1
	,,	6	43	.368	1.000143	18.7
	,,	7	34	.240	1.000117	16.5
	,,	8	50	.316	1.000105	15.9
	31st	1	27	.220	1.000136	17.0
	,,	2	29	.227	1.000131	17.4
	,,	3	36	.291	1.000135	17.5
	,,	4	25	.221	1.000147	18.6
	,,	5	57	.431	1.000127	16.4
	,,	6	31	.281	1.000151	18.3

TOKIO BEFORE THE SAPPORO EXCURSION.

Correction for arc (to be subtracted)	Mean Temp. °C	Correction for Temperature	Correction for chronometer rate (to be added)	Time of single vibration (corrected) Sid. Sec.	Residuals
.000015	27.3	—.000022	.000012	1.000145	+42
.000014	27.8	—.000026	.000012	1.000083	—20
.000014	28.3	—.000031	.000012	1.000102	— 1
.000013	28.1	—.000029	.000012	1.000094	— 9
.000015	28.2	—.000030	.000012	1.000097	— 6
.000016	28.1	—.000029	.000012	1.000110	+ 7
.000012	28.1	—.000029	.000012	1.000088	—15
.000012	28.0	—.000028	.000012	1.000077	—26
.000013	27.9	—.000027	.000012	1.000108	+ 5
.000014	28.0	—.000028	.000012	1.000101	— 2
.000014	28.1	—.000029	.000012	1.000104	+ 1
.000015	28.2	—.000030	.000012	1.000114	+11
.000012	28.2	—.000030	.000012	1.000097	— 6
.000015	28.2	—.000030	.000012	1.000118	+15
			Mean....	1.000103	
				±.0000031	

OBSERVATIONS WITH KATER'S PENDULUM AT

Date 1882		Reference No.	Number of Minutes	Fraction of Second	Time of single vibration (uncorrected) Sid. Sec.	Mean arc (mm.)
Sept.	27th	1	27	.238	1.000147	18.6
	,,	2	33	.289	1.000146	17.1
	,,	3	30	.240	1.000133	16.8
	,,	4	30	.201	1.000112	17.9
	,,	5	31	.202	1.000108	17.0
	,,	6	32	.088	1.000046	16.2
	,,	7	30	.081	1.000045	16.5
	,,	8	38	.229	1.000101	16.7
	29th	1	32	.155	1.000083	16.9
	30th	1	31	.097	1.000053	17.8
	,,	2	36	.121	1.000056	17.3
Oct.	1st	1	31	.121	1.000065	16.3
	,,	2	32	.155	1.000081	16.5
	4th	1	33	.140	1.000070	16.8
	,,	2	30	.132	1.000078	19.2
	19th	1	29	.073	1.000043	16.9
	,,	2	29	.033	1.000019	18.2
	,,	3	31	.020	1.000012	17.8
	,,	4	26	.040	1.000026	18.1
	20th	1	30	.000	1.000000	17.1

TOKIO AFTER THE SAPPORO EXCURSION.

Correction for arc (to be subtracted)	Mean Temp. °C	Correction for Temperature	Correction for chronometer rate (to be added)	Time of single vibration (corrected) Sid. Sec.	Residuals
.000015	22.5	+.000023	.000012	1.000167	+63
.000018	23.0	+.000019	.000012	1.000164	+60
.000013	23.4	+.000015	.000012	1.000147	+43
.000015	23.6	+.000015	.000012	1.000124	+20
.000013	24.3	+.000006	.000012	1.000113	+ 9
.000012	24.8	+.000002	.000012	1.000048	—56
.000012	24.9	+.000001	.000012	1.000046	—58
.000012	25.2	—.000002	.000012	1.000099	— 5
.000013	21.6	+.000033	.000012	1.000115	+11
.000014	20.7	+.000040	.000012	1.000091	—13
.000014	20.9	+.000038	.000012	1.000092	—12
.000012	20.8	+.000039	.000012	1.000104	± 0
.000012	20.9	+.000038	.000012	1.000119	+15
.000013	22.8	+.000021	.000013	1.000091	—13
.000016	23.5	+.000014	.000013	1.000084	—20
.000013	17.0	+.000075	.000010	1.000115	+11
.000015	16.8	+.000077	.000010	1.000091	—13
.000014	17.0	+.000075	.000010	1.000083	—21
.000015	17.1	+.000075	.000010	1.000096	— 8
.000013	15.8	+.000087	.000012	1.000086	—18
			Maen....	1.000104	
				±.0000047	

OBSERVATIONS WITH KATER'S

Date 1882		Reference No.	Number of Minutes	Fraction of Second	Time of single vibration (uncorrected) Sid. Sec.	Mean [illegible]
Aug.	16th	1	30	.500	.999722	17.3
	..	2	31	.543	.999708	16.5
	..	3	26	.405	.999740	17.3
	..	4	30	.426	.999763	18.2
	..	5	31	.485	.999730	17.6
	17th	1	31	.620	[illegible]	16.5
	..	2	31	.613	.999671	17.1
	..	3	31	.530	.999714	18.6
	..	4	30	.537	.999668	16.2
	..	5	33	.625	.999683	17.1
	..	6	30	.404	.999775	17.3
	..	7	32	.263	.999803	16.5
	..	8	31	.327	.999824	17.7
	18th	1	40	.500	.999792	16.6
	..	2	33	.395	.999801	16.3
	..	3	30	.231	.999872	17.4
	..	4	23	.169	.999878	17.8

PENDULUM AT SAPPORO.

Correction for arc (to be subtracted)	Mean Temp. °C	Correction for Temperature	Correction for chronometer rate (to be added)	Time of single vibration (corrected) Sid. Sec.	Residuals
.000014	25.0	+.000000	.000005	.999713	— 45
.000012	25.0	+.000000	.000005	.999701	— 57
.000014	24.7	+.000004	.000005	.999735	— 23
.000015	24.2	+.000008	.000005	.999761	+ 3
.000014	24.0	+.000009	.000005	.999739	— 19
.000012	24.8	+.000002	.000028	.999680	— 78
.000013	25.6	—.000006	.000028	.999680	— 78
.000015	27.9	—.000026	.000028	.999701	— 57
.000012	28.0	—.000028	.000028	.999686	— 72
.000013	27.6	—.000024	.000028	.999674	— 84
.000014	28.4	—.000032	.000028	.999757	— 1
.000012	26.8	—.000017	.000028	.999862	—104
.000014	25.4	—.000004	.000028	.999834	+ 96
.000012	25.1	—.000001	.000028	.999807	+ 49
.000012	26.1	—.000010	.000028	.999807	+ 49
.000014	26.5	—.000014	.000028	.999872	+114
.000015	26.5	—.000014	.000028	.999877	+119
			Mean....	.999758	
				±.0000117	

APPENDIX

TO THE

MEMOIR No. 5

OF

TÔKIÔ DAIGAKU
(TÔKIÔ UNIVERSITY).

MEASUREMENT

OF THE

FORCE OF GRAVITY

AT

NAHA (Okinawa) AND KAGOSHIMA

BY

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Students of Physics, Department of Science.

PUBLISHED BY TÔKIÔ DAIGAKU.

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2544 (1884.)

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NAHA AND KAGOSHIMA.

According to the direction of the university authorities, an expedition to Naha (Okinawa-ken) was undertaken by the physical students, during the summer of 1882, with the principal object of making a comparison of the force of gravity there with that at Tokio. The determinations of the force of gravity at different localities in the Pacific Ocean has of late become of peculiar interest, as the determinations hitherto made tend to show that the intensities at places near Japan are decidedly greater than those calculated from the usual formulæ. To furnish data which might aid in finally deciding this point formed, therefore, the principal object of the expedition.

The party consisted of Messrs. Yamaguchi, Yamada, Tanakadate and myself. The magnetic observations, which were made along with the pendulum experiments, were conducted by Mr. Yamaguchi. Mr. Yamada, who acted as treasurer of the party, undertook, besides other duties, the transportation and the general charge of the instruments. Mr. Tanakadate, who had been previously on a similar expedition to Sapporo, took upon himself the task of chronometer rating and latitude observations, as being the only one of the party who had had experience in practical astronomy. The transit instrument used for time observations was the property of the Surveying Bureau. We take the opportunity of thanking the Director, Mr. Arai, for his kindness in granting us the use of it. This instrument not being suitable for latitude observations, we employed for this purpose a sextant belonging to the university.

The mode of experiment was essentially similar to that used by Prof. Mendenhall in his Fuzinoyama experiment, and followed by Mrss. Tanakadate, Tanaka and Fujisawa in the expedition to Sapporo during the summer of 1881. The method is fully described in memoir No. 5 of the university, and its Appendix; and consequently but a brief account will here suffice.

Two pendulums were used, called for convenience B and C. These had similar forms, but different somewhat in construction. The B pendulum consisted of a hollow brass cylinder, 121·6 centimetres long and closed at both ends. Near the one end was the steel knife-edge on which the pendulum rested when oscillating; and near the other was fixed a flat oblate-spheroidal disc whose diameter was about 18·5 centimetres. The lower end bore a small wedge, whose edge, when desired, could be brought to bear upon the extremity of a delicate spring, the slight displacement of which was sufficient to break the circuit of the electric chronograph. Thus the precise instant at which the extremity of the pendulum swept past the end of the spring could be recorded. The form of the C pendulum was exactly similar to that of B; but its bob, instead of being a solid brass spheroid, was made of a hollow brass shell of the same outward form but filled with lead. The modification thus introduced was not originally intended, but arose from the misapprehension of the instrument maker.

When C was made, another pendulum exactly similar was constructed. The time of oscillation of this latter pendulum (called D) had been determined by Mr. Tanakadate and sent to America to supply the place of A* which had been previously sent, but injured during transportation.

The B pendulum had also been injured during the Sapporo expedition; and its upper brass disc, which was the injured portion, was now replaced by a new one, so that its time of oscillation was slightly changed, as will be seen on comparing the old and the new results.†

In previous expeditions Kater's reversible pendulum had been used together with B pendulum. But the former, having been always found to give unsatisfactory results,‡ it was now abandoned, and the C pendulum was used instead.

Two series of experiments were made in the physical laboratory before and after the expedition, so that any injuries done to the two pendulums during the expedition might be readily detected by comparing the two sets of results.

The experiments at Tokio were made in the pendulum room of the laboratory. The pendulum was hung from a massive stone pillar erected in the room. The approximate position of this pillar was

35° 42′ 40″ north latitude, and
139° 45′ 45″ east of Greenwich.

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* See "Appendix to memoir No. 5."

† Compare Tables I and III at the end of this paper with the tables in the "Appendix to memoir No. 5."

‡ See memoir No. 5 and its Appendix.

The height of the knife-edge of the pendulum rested on a steel plate about 11·5 cms. square and about 2 cms. thick. This plate was clamped tightly by means of two screws to a heavy iron bar 75 cms. long, 7·5 cms. broad, and 2 cms. thick. This was placed on the pillar and kept in position by a large block of stone resting upon it. The pendulum was passed through a hole in the middle of the plate, which was first carefully levelled. The levelling of this steel plate was quite a difficult task; it was never accomplished in less than an hour, while at times it took more than three or four. Levelling with two screws is indeed a mere matter of chance, and it would certainly be an improvement if the plate were provided with three levelling screws standing in V's, so that it might be clamped geometrically to the heavy iron bar by the weight of the pendulum itself. This plan had been thought of before the expedition, but want of time prevented us carrying it out.

The time of oscillation was measured with a break-circuit sidereal chronometer of Negus construction. Its rate was compared every morning by telegraphic communications with another Negus chronometer in the astronomical observatory; and the rate of the latter was determined by Mr. Tanakadate from transit observations made on every clear night during the progress of the experiments. The pendulum usually continued to vibrate for twenty to forty minutes, except in some few cases in which, from special circumstances, longer continuation was necessary. The interval between the beginning and end of each set of oscillations was measured in the way above described. Since the pendulum had been previously adjusted so that its time of oscillation was very nearly one second, the total number of seconds between the beginning and end of a set of oscillations was to a first approximation the same as the number of oscillations during the whole interval. The correction applied to this estimate could be readily deduced from chronographic records by microscopic measurement.

The amplitudes of oscillations were measured with a small millimetre scale fixed horizontally near the lower end of the pendulum, and readings were taken at the beginning and end of each series of oscillations.

The temperature of the room was measured with a good Saleron thermometer, hung near the pendulum.

The first series of experiments at Tokio having been completed, we started for Naha on the seventeenth of July.

During our stay at Kagoshima while waiting for the despatch of steamer, we found ample time to make a series of experiments. Through the kindness of Mr. C. Watanabe, the *Kagoshima-ken-rei*, a small building in the *kencho* was put at our disposal, and there the experiments were conducted. The chronometer and the chronograph were placed in the same building; and astronomical observations were made in the garden just in front of the building. A large cylinder of stone about 1.5 metres long and 0.7 metres in diameter, was erected upright on the ground inside the building; and on this stone the iron bar was set. The adjustments and measurements were carried out as usual. Owing to the fickleness of the weather, peculiar to the meteorology of the southern summer of this country, much inconvenience was felt in making the astronomical observations.

The height of the knife-edge of the pendulum above the level of the sea was found to be about 6.6 metres and the latitude of the place was determined by Mr. Tanakadate to be about

$$31^\circ\ 35'\tfrac{1}{2}\ \text{north.}$$

According however to the map published by the Naval Department, the same place is situated at

$$31^\circ\ 31'\ 2''\cdot8\ \text{north latitude.}$$

This difference of about $4'\frac{1}{2}$ is far too great to be tolerated in such determinations. The data from which the Navy map had been compiled seems to have been furnished by the officers of "His Majesty's Ship, Teibokan". But in spite of the determination having been made by professional men, we are inclined to think that their result is not very trustworthy. At any rate it is quite irreconcilable with our determination as obtained with the aid of the Berlin Jahrbuch.

We arrived at Kagoshima on the 27th of July and after a successful series of observations proceeded to Naha which we reached on August 18.

At Naha, through the kindness of the Director of the Normal School, we obtained a room in every way well fitted for our perpose, except that it was freely traversed by currents of air and sensitive to atmospheric changes of temperature. The former evil was easily remedied; and the latter was of little account as the temperature change for a whole day even was only a few degrees.

The pendulum, the chronograph and the chronometer were all set up in this room.

Several rectangular blocks of stone of nearly one metre in length and some 30 centimetres in breadth and thickness were piled up firmly, to the height of about $1\frac{1}{2}$ metres. On this rough but solid pillar the iron bar was placed, and the experiments were made in the usual manner.

The astronomical observations were taken in the yard in front of the room, where a similar but smaller pillar had been erected. The weather was showery and unsettled and rendered the operations very difficult.

The latitude of the place was determined by Mr. Tanakadate to be $26^\circ\ 12'\ 6''$ north. The height of the position of the pendulum from the sea level was not accurately determined, although it was certainly not more than 6 metres. Any correction due to such a small height is far within the errors of experiment and may be neglected.

Every thing went on as well as could be expected, and after completing the experiment, we left Naha on the 23rd of August.

REDUCTION.

The method of calculation was similar to that used in the previous expedition. The complete numerical data are arranged in tables at the end of the paper.

The correction for arc was deduced from Captain Basevi's formula*

$$\text{Correction} = -\frac{t}{64}\left\{(\alpha+\beta)^2-\tfrac{1}{3}(\alpha-\beta)^2\right\},$$

in which t is the observed time of oscillation, and α and β are respectively the initial and the final semi-arcs of the corresponding set of oscillations.

In making the temperature correction, we assumed the value of the coefficient of expansion to be 0.0000187 per degree centigrade, which is a fair average of the determinations hitherto made on brass. From want of time and also from other considerations the direct measurement of the coefficient of expansion could not be made; but in all probability the error arising from any inaccuracy in the value of the expansion coefficient must be very small.

The correction for temperature was applied so as to reduce the observed time of oscillation to the time of oscillation at 25° C. This temperature is a convenient one as being approximately the average temperature for all the experiments at Tokio, Kagoshima and Naha.

If ΔT is the difference between the actual temperature and 25°, and t the observed time of oscillation, the necessary correction as calculated from the expression

$$\tfrac{1}{2}\, t\, a\, \Delta T$$

is very nearly

$$\frac{a}{2}\,\Delta T = 0.00000935\ \Delta T$$

as t differs very slightly from unity.

The chronometer correction was calculated from the mean daily rate, any slight error so arising being minimised over the whole series of observations by a suitable distribution in time of the different sets of pendulum observations. In cases of bad weathers, the determination of the average rate for two or three days only was possible. This was not of course very good: but in the long run individual errors would probab'y balance. It may be remarked that the chronometer was carefully protected and carefully managed, and its rate in any one locality tolerably uniform.

The corrections due to the buoyancy and the resistance of air have been neglected, as was the case in the reduction of results in the previous expeditions.†

* The Great Trigonometrial Survey of India, vol. V.

† See memoir 5 and also its appendix.

With the above corrections the results are as follows :

Time of single oscillation at Tokio, before the expedition,	of pendulum B $= 1.000733$ sec. ± 0.0000016 of pendulum C $= 0.999896$ sec. ± 0.0000023
Time of single oscillation at Tokio, after the expedition	of pendulum B $= 1.000735$ sec. ± 0.0000027 of pendulum C $= 0.999904$ sec. ± 0.0000012
Time of single oscillation at Kagoshima	of pendulum B $= 1.000875$ sec. ± 0.0000024 of pendulum C $= 1.000058$ sec. ± 0.0000020
Time of single oscillation at Naha	of pendulum B $= 1.001078$ sec. ± 0.0000023 of pendulum C $= 1.000260$ sec. ± 0.0000015

Taking the mean of the two sets of results for Tokio, we have for the B pendulum, the time of a single oscillation

$$t = 1.000734 \text{ sec.} \pm 0.0000016$$

and for the C pendulum

$$t = 0.999900 \text{ sec.} \pm 0.0000013$$

Now the value of g for Tokio according to Prof. Mendenhall's determination is 979.854 ± 0.0014, the units being the centimetre and the mean solar second. From the data thus furnished, we have deduced the following values of g for Naha and Kagoshima :

For Naha	$g=979{\cdot}181$ C. G. S. $\pm 0{\cdot}0070$ with B pendulum, and $g=979{\cdot}149$ C. G. S. $\pm 0{\cdot}0059$ with C pendulum. Mean, $g=979{\cdot}165$ C. G. S. $\pm 0{\cdot}0055$.
For Kagoshima	$g=979.578$ C. G. S. ± 0.0072 with B pendulum, and $g=979.545$ C. G. S. ± 0.0064. Mean $g=979.561$ C. G. S. ± 0.0057.

The above results are both of them slightly greater than those obtained by calculation from approximate formulæ.

Thus, from the formula

$$* \; g = 980.605 - 2.5028 \cos 2\lambda - 0.000003\,h$$

we get

for Naha, $g = 979.04$ cms. per sec. per sec.,
for Kagoshima, $g = 979.49$,, ,, ,,

The formula

$$\dagger \; g = 980{\cdot}63 - 2{\cdot}553 \cos 2\lambda$$

gives nearly the same results as above.

Again the formula

$$\ddagger \; g = 978{\cdot}0728 + 5{\cdot}0875 \sin^2\phi$$

gives

for Naha, $g = 979{\cdot}06$ cms. per sec. per sec.,
for Kagoshima, $g = 979{\cdot}47$,, ,, ,,

Again the formula

$$\S \; g = 32{\cdot}088(1 + 0{\cdot}005133 \sin^2\lambda)$$

which is in terms of the British absolute units gives, in terms of the French units,

for Naha, $g = 979{\cdot}00$ cms. per sec. per sec.,
for Kagoshima, $g = 979{\cdot}39$,, ,, ,,

Now all these values are slightly smaller than those actually obtained from experiments. Such discrepancies however, cannot much detract from the merit of the experimental work, since the formula are all of them only approximate, and the comparisons of the values must be considered as the test of the formula rather than the test of the work.

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* Prof. Everett's System of Units.

† Major Herschell, Phil. Mag. vol. IX, p. 417.

‡ Prof. Listing, Astro. Nach., No. 2228.

§ Thomson and Tait's Natural Philosophy, § 222.

OBSERVATIONS

OF

MAGNETIC ELEMENTS

BY

E. YAMAGUCHI.

I accompanied the expedition for the purpose of making magnetic observations. The instrumental appliances were very imperfect and the results necessarily rough.

The determinations of the horizontal intensity were only relative, the method being exactly similar to that adopted by Mr. Fujisawa in the expedition to Fujinoyama and Sapporo. The method consisted in the determination of the time of vibration of a horizontally suspended magnet. The magnet was suspended by a silk fibre about 30 cm. long, in a glass case on which was pasted a scale for measuring the arc of vibration. Silk fibres were also fixed vertically on the outside of the glass case near the middle of the scale. The transits with reference to one of three fibres of a convenient point on the end of the oscillating magnet could be easily observed, and when necessary simultaneous records made on the chronograph, which was being used in the gravity experiments. The adjustment of the magnet in the horizontal position was done by suspending it close over a wooden surface already levelled. The reading on the glass case did not give at once the true arc; but this could be easily deduced as the diameter of the glass case and the length of the magnet were known.

Two magne tswere used. The one (named A) was cylindrical in form, having a length of 17.3 cm. and a diameter of .8 cm. Its mass was 63.8 gm. It was one of the two magnets kindly lent by the Kobu Daigakko and used by Mr. Fujisawa at Sapporo. The other one had changed so much in magnetic moment, that it was considered not worth using. The second magnet (named B) was a rectangular block of square section, 11.2 cm. long and 1.2 cm. square. Its mass was 139.3 gm. Each of the magnets rested in a brass or copper stirrup to which the silk fibre was fastened.

At Kagoshima a few observations were made in the Kencho building, which from the shakiness of the floor proved unsuitable. Accordingly a stone block was erected on the outside of the building with a shelter to protect it from the sun's rays. The time of vibration observed there differed from that observed in the building. Observations were then made at two other places; and again the results were discordant. But before the cause of these discrepancies could be investigated the party were on the point of leaving Kagoshima. The results given below are deduced from the mean of all the observations made outside of the building.

At Naha, the magnet B was accidentally exposed to the sun's direct rays for a short time. The temperature, as indicated by the thermometer in the glass case rose to about 50°C, and produced a great change in the magnetic moment. Therefore as regards magnet B the intensity observed at Kagoshima is compared with the previous determination at Tokio, while the intensity observed at Naha is compared with the subsequent determination at Tokio. The results of magnet A are more trustworthy.

The means of the times of vibration are found to be :—

At Tokio before the excursion	
Magnet A	13.6138
B	10.7070
At Kagoshima	
Magnet A	13.2334
B	10.3965
At Naha	
Magnet A	12.7857
B	10.4916
At Tokio after the excursion	
Magnet A	13.5874
B	11.8131
The mean of the two observations at Tokio	
Magnet A	13.6003.

The intensity being inversely proportional to the square of time of vibration, the ratios of the horizontal intensities at Kagoshima and Naha to that at Tokio are as follows :—

Kagoshima.

Magnet A ... ... $\left(\frac{13.6003}{13.2334}\right)^2=1.0563$

B ... ... $\left(\frac{10.7070}{10.3965}\right)^2=1.0606.$

Naha.

$$\text{Magnet A} \ldots \ldots \ldots \left(\frac{13.6003}{12.7857}\right)^2 = 1.1315$$

$$\text{B} \ldots \ldots \ldots \left(\frac{11.8131}{10.4916}\right)^2 = 1.2678$$

The declinations were taken with a declination theodolite of ordinary construction. The diameter of the circle, on which the needle was mounted, was 14.5 cm. The graduation was only to half-degrees. The circle together with the telescope was movable about a vertical axis. This motion was effected by a tangent screw, and could be read to 10′ by means of a vernier.

At Kagoshima the direction of north was deduced from time observations combined with azimuth observations of the sun's position. The azimuth of the telescope was successively changed by 10′ and the contacts of the sun's disk were observed six times with the preceeding limb and six times with the succeeding limb. The successive positions of the magnet relatively to the circle, which moved in azimuth with the telescope, were read at intervals. Two such series of observations were taken. The magnetic declinations so obtained are as follows:—

1st series...	3° 20′.5 W
2nd "	3° 17′. W
Mean	3° 18′.7 W.

At Naha Mr. Tanakadate from transit observations made meridian marks on two distant objects one to the north and the other to the south. The transit instrument was then dismounted and the theodolite set in its place. The magnetic declination so observed was:—

2° 25′.5 W.

The determinations of the dip were also rough, and were obtained by a comparison of the horizontal and vertical intensities of the magnetic field due to the earth. A solenoid was formed by winding insulated copper wire upon a glass tube 31.5 cm. in length and .9 cm. in diameter. The wire was wound in two layers, the total number of coils being about 1030. The resistance of the wire was 6.07 ohms. Near one end of this solenoid, which could be fixed either horizontally or vertically, a small-mirror magnetometer was set. To intensify the magnetic field within the solenoid a soft-iron wire of nearly the same length was inserted. When the soft-iron wire was in position and a current flowing through the solenoid, the iron wire was under the influence of two distinct magnetisations, that due to the earth, and that due to the current. The strength and the direction of the current were then adjusted until the magnetometer deflection was made equal to that which the current in the solenoid alone would produce. The external magnetic effect of the current alone was always very small. The current strengths necessary to balance in this way the vertical and horizontal components of the earth's induction were thus measured; and their ratio gives the tangent of the angle of dip. The results were as follows:—

	Kagoshima.
	45° 24′.
	44° 12′
	44° 56′
	45° 12′
Mean	44° 56′

	Naha.
	38° 54′
	37° 44′
Mean	38° 19′.

	Hor. Intensity.	Declination.	Dip.
Tokio	1.0000		
Kagoshima	1.0563	3° 18′.5 W	44° 56′
Naha	1.1315	2° 25′.5 W	38° 19′

RESULTS OF PENDULUM EXPERIMENTS.

TABLE I.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM B AT TOKIO, BEFORE THE EXPEDITION.

DATE.	Number.	Number of minutes.	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation, unreduced. Unit, sidereal second.	Initial* semi-arc of oscillation in mm.	Final* semi-arc of oscillation in mm.	Mean temperature in degree C.	Correction for arc.	Correction for temperature.	Correction for chronometer rate.	Time of a single oscillation, reduced. Unit, sidereal second.	Residual.
July 6	1	31	1.342	1.000722	18.5	15.3	22.6	-15×10^{-6}	$+22\times10^{-6}$	$+\ 2\times10^{-6}$	1.000731	$-\ 2\times10^{-6}$
"	2	36	1.563	1.000724	18.2	14.5	23.0	−14	+19	"	1.000731	− 2
"	3	35	1.513	1.000721	16.8	12.7	23.3	−11	+16	"	1.000728	− 5
"	4	42	1.827	1.000725	18.5	12.5	23.3	−12	+16	"	1.000729	− 4
"	5	37	1.596	1.000719	17.2	11.3	23.5	−10	+14	"	1.000723	−10
"	6	41	1.771	1.000720	16.5	11.7	23.4	−10	+15	"	1.000727	− 6
"	7	40	1.748	1.000728	16.0	11.7	23.3	−11	+16	"	1.000735	+ 2
"	8	29	1.238	1.000711	15.0	12.0	23.1	−11	+18	"	1.000720	−13
"	9	34	1.523	1.000747	16.0	12.3	23.1	−10	+18	"	1.000757	+24
"	10	27	1.161	1.000716	18.1	14.2	23.1	−14	+18	"	1.000722	−11
"	11	36	1.579	1.000731	16.5	12.5	23.2	−11	+17	"	1.000739	+ 6
"	12	45	1.969	1.000729	16.5	11.8	23.0	−10	+19	"	1.000740	+ 7
July 7	1	56	2.359	1.000702	16.9	10.8	21.8	−10	+30	$+\ 6\times10^{-6}$	1.000728	− 5
"	2	37	1.636	1.000737	17.9	13.5	22.1	−13	+27	"	1.000757	+24
"	3	30	1.331	1.000739	17.5	14.9	24.4	−14	+ 6	"	1.000737	+ 4
"	4	35	1.526	1.000727	16.1	12.3	24.3	−10	+ 7	"	1.000730	− 3
"	5	32	1.392	1.000725	19.0	14.5	23.8	−15	+11	"	1.000727	− 6
"	6	32	1.396	1.000727	18.4	14.8	24.6	−14	+ 4	"	1.000723	−10
"	7	28	1.231	1.000733	17.1	13.5	24.4	−12	+ 6	"	1.000733	0
										MEAN	= 1.000733 ± 0.0000016	

* Distance of the scale from the knife-edge = 110.0 cms.

TABLE II.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM C AT TOKIO, BEFORE THE EXPEDITION.

DATE.	Number.	Number of minutes.	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation, unreduced. Unit, sidereal second.	Initial* semi-arc of oscillation in mm.	Final* semi-arc of oscillation in mm.	Mean temperature in degree C.	Correction for arc.	Correction for temperature.	Correction for chronometer rate.	Time of a single oscillation, reduced. Unit, sidereal second.	Residual.
July 9	1	29	0.151	0.999913	18.8	15.9	24.6	-16×10^{-6}	$+4\times10^{-6}$	$+1\times10^{-6}$	0.999902	$+6\times10^{-6}$
"	2	29	0.201	0.999884	19.2	15.4	24.8	−16	+ 2	"	0.999871	−25
"	8	28	0.221	0.999868	18.3	15.0	24.8	−14	+ 2	"	0.999857	−39
"	4	29	0.153	0.999912	19.3	15.9	24.9	−16	+ 1	"	0.999898	+ 2
"	5	36	0.197	0.999909	18.1	14.2	24.9	−14	+ 1	"	0.999897	+ 1
"	6	37	0.264	0.999881	17.8	13.8	24.9	−13	+ 1	"	0.999870	−26
"	7	36	0.180	0.999917	19.2	15.1	28.8	−15	+ 2	"	0.999905	+ 9
"	8	59	0.354	0.999900	17.3	12.0	24.7	−11	+ 3	"	0.999893	− 3
"	9	31	0.172	0.999907	18.9	15.4	25.0	−15	0	"	0.999893	− 8
"	10	30	0.146	0.999919	18.0	14.8	25.0	−14	0	"	0.999906	+10
"	11	25	0.118	0.999922	19.2	16.3	25.0	−16	0	"	0.999907	+11
"	12	40	0.175	0.999927	19.5	14.9	24.8	−15	+ 2	"	0.999915	+19
"	13	27	0.160	0.999902	17.8	14.5	24.8	−15	+ 2	"	0.999890	− 6
July 10	1	43	0.298	0.999884	18.9	13.9	23.7	−14	+12	$+3\times10^{-6}$	0.999885	−11
"	2	38	0.199	0.999913	18.3	14.5	23.9	−14	+10	"	0.999912	+16
"	3	35	0.187	0.999911	17.6	14.8	24.0	−13	+ 9	"	0.999910	+14
"	4	38	0.211	0.999908	18.4	14.5	24.3	−13	+ 7	"	0.999905	+ 9
"	5	37	0.241	0.999892	18.7	14.3	24.5	−14	+ 5	"	0.999886	−10
"	6	32	0.165	0.999914	18.8	15.5	24.9	−15	+ 1	"	0.999901	+ 5
"	7	34	0.189	0.999907	18.8	15.1	25.1	−15	− 1	"	0.999894	− 2
"	8	33	0.243	0.999926	19.5	15.3	25.3	−16	− 3	"	0.999910	+14
										MEAN	= 0.999896 ± 0.0000023	

* Distance of the scale from the knife-edge = 109.7 cms.

TABLE III.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM B AT TOKIO, AFTER THE EXPEDITION.

DATE.	Number.	Number of minutes.	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation, unreduced. Unit, sidereal second.	Initial* semi-arc of oscillation in mm.	Final* semi-arc of oscillation in mm.	Mean temperature in degree C.	Correction for arc.	Correction for temperature.	Correction for chronometer rate.	Time of a single oscillation, reduced. Unit, sidereal second.	Residual.
Sept. 14	1	30	1·274	1.000708	17.5	13.5	24.7	-12×10^{-6}	$+3\times10^{-6}$	-8×10^{-6}	1.000691	-44×10^{-6}
Sept. 15	1	46	2.024	1.000733	20.5	13.2	23.1	−15	+18	"	1.000728	− 7
"	2	46	2.032	1.000736	21.1	13.6	23.0	−18	+19	"	1.000739	+ 4
"	3	30	1.350	1.000750	21.0	16.2	23.5	−18	+14	"	1.000738	+ 3
"	4	31	1.378	1.000741	21.0	15.6	23.7	−17	+12	"	1.000728	− 7
"	5	39	1·756	1·000750	21.3	15.7	23.8	−18	+11	"	1.000735	0
Sept. 16	1	59	2·553	1.000721	17.5	10.0	21.0	−10	+37	"	1.000740	+ 5
"	2	38	1·689	1.000741	20.7	15.3	21.0	−17	+37	"	1.000753	+18
"	3	34	1·491	1.000731	21.7	16.0	21.3	−18	+34	"	1.000739	+ 4
"	4	34	1·544	1.000757	22.3	16.8	21.5	−20	+33	"	1.000762	+27
"	5	38	1·634	1.000717	20.5	14.3	21.9	−16	+29	"	1.000722	−13
"	6	32	1·389	1.000723	19.2	14.4	22.1	−15	+27	"	1.000727	− 8
"	7	33	1·425	1.000720	20.3	13.9	22.2	−15	+26	"	1.000723	−12
"	8	41	1·758	1.000715	20.1	16.5	22.4	−17	+24	"	1.000714	−21
Sept. 18	1	41	1·789	1.000727	21.1	14.4	20.0	−16	+46	"	1.000749	+14
"	2	46	1·937	1.000702	20.9	13.4	19.6	−15	+50	"	1.000729	− 6
"	3	41	1·778	1.000723	20.3	13.6	19.5	−15	+51	"	1.000751	+16
"	4	35	1·491	1.000710	22.1	16.6	19.6	−19	+50	"	1.000733	− 2
Sept. 19	1	43	1.897	1.000735	22.9	15.4	19.2	−19	+53	-4×10^{-6}	1.000765	+30
									MEAN	....	= 1.000735 ± 0.0000027	

* Distance of the scale from the knife-edge = 110.0 cms.

TABLE IV.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM C AT TOKIO, AFTER THE EXPEDITION.

DATE.	Number.	Number of minutes.	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation, unreduced. Unit, sidereal second.	Initial* semi-arc of oscillation in mm.	Final* semi-arc of oscillation in mm.	Mean temperature in degree C.	Correction for arc.	Correction for temperature.	Correction for chronometer rate.	Time of a single oscillation, reduced. Unit, sidereal second.	Residual.
Sept. 19	1	38	0.260	0.999886	19.8	14.9	19.3	-15×10^{-6}	$+53\times10^{-6}$	-4×10^{-6}	0.999920	$+6\times10^{-9}$
"	2	45	0.326	0.999879	22.5	15.5	19.3	−19	+53	"	0.999909	+ 5
"	3	35	0.241	0.999885	21.8	17.0	19.4	−20	+52	"	0.999913	+ 9
"	4	53	0.384	0.999879	22.7	15.9	19.4	−19	+52	"	0.999907	+ 3
"	5	36	0.262	0.999879	21.6	15.9	20.3	−19	+44	"	0.999901	− 3
"	6	36	0.284	0.999868	19.6	14.8	20.3	−15	+44	"	0.999893	−11
Sept. 20	1	41	0.289	0.999882	21.6	14.9	19.8	−17	+48	-14×10^{-6}	0.999899	− 5
"	2	25	0.149	0.999901	22.6	18.4	20.5	−22	+42	"	0.999907	+ 3
"	3	32	0.211	0.999890	22.2	17.8	21.7	−21	+31	"	0.999886	−18
"	4	47	0.232	0.999918	24.0	16.5	22.0	−21	+28	"	0.999911	+ 7
"	5	49	0.249	0.869915	23.4	16.6	22.7	−21	+21	"	0.999901	− 3
"	6	40	0.220	0.999908	19.9	15.8	23.0	−16	+19	"	0.999897	− 7
"	7	32	0.149	0.999922	19.6	15.8	23.0	−16	+19	"	0.999911	+ 7
"	8	35	0.227	0.999892	19.6	15.1	21.4	−16	+33	"	0.999895	− 9
"	9	37	0.221	0.999901	19.5	14.3	21.7	−15	+31	"	0.999903	− 1
"	10	38	0.154	0.999922	18.1	14.8	22.5	−14	+28	"	0.999917	+13
"	11	33	0.158	0.999920	20.0	15.3	23.4	−16	+15	"	0.999905	+ 1
"	12	31	0.168	0.999910	20.2	16.7	23.7	−18	+12	"	0.999890	−14
"	13	40	0.185	0.999923	20.8	16.5	23.6	−18	+13	"	0.999904	0
Sept. 22	1	50	0.311	0.999896	18.8	13.5	22.0	−15	+28	-12×10^{-6}	0.999897	− 7
"	2	33	0.186	0.999906	19.0	15.3	22.0	−15	+28	"	0.999907	+ 3
										MEAN	0.999904 ±0.0000012	

* Distance of the scale from the knife-edge = 109.7 cms.

TABLE V.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM B AT KAGOSHIMA.

DATE.	Number.	Number of minutes.	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation, unreduced. Unit, sidereal second.	Initial* semi-arc of oscillation in mm.	Final* semi-arc of oscillation in mm.	Mean temperature in degree C.	Correction for arc.	Correction for temperature.	Correction for chronometer rate.	Time of a single oscillation, reduced. Unit, sidereal second.	Residual.
July 30	1	40	2.158	1.000899	16.8	10.0	29.3	-9×10^{-6}	-40×10^{-6}	$+6 \times 10^{-6}$	1.000856	-16×10^{-6}
"	2	33	1.843	1.000831	18.8	11.7	29.5	−12	−42	"	1.000883	+ 8
"	3	35	1.931	1.000919	20.1	13.1	29.1	−14	−38	"	1.000873	− 2
"	4	29	1.551	1.000891	17.2	12.7	28.1	−12	−29	"	1.000856	−19
"	5	30	1.678	1.000932	16.4	12.9	27.7	−11	−25	"	1.000902	+27
"	6	32	1.743	1.000908	18.2	13.6	27.7	−13	−25	"	1.000876	+ 1
"	7	40	2.261	1.000942	18.5	13.8	28.3	−13	−30	"	1.000905	+30
July 31	1	31	1.668	1.000896	18.3	13.6	28.1	−13	−29	"	1.000860	−15
"	2	26	1.427	1.000917	18.1	14.2	28.9	−14	−36	"	1.000873	− 2
"	3	29	1.571	1.000903	17.3	12.9	29.3	−12	−40	"	1.000857	−18
"	4	36	1.991	1.000922	16.7	12.0	29.4	−11	−41	"	1.000876	+ 1
"	5	45	2.427	1.000899	17.5	11.8	29.0	−12	−37	"	1.000856	−19
"	6	29	1.628	1.000936	18.5	14.4	29.4	−14	−41	"	1.000887	+12
"	7	38	2.074	1.000910	18.5	17.4	29.4	−17	−41	"	1.000858	−17
"	8	34	1.911	1.000937	18.4	13.8	29.1	−13	−38	"	1.000892	+17
"	19	26	1.432	1.000918	16.3	12.9	28.9	−11	−36	"	1.000877	+ 2
"	10	30	1.655	1.000919	16.3	12.1	28.3	−10	−31	"	1.000884	+ 9
"	11	25	1.374	1.000916	17.5	13.9	28.2	−13	−29	"	1.000880	+ 5
August 1.........	1	36	1.993	1.000923	18.3	12.6	29.3	−12	−40	"	1.000877	+ 2
									Mean		= 1.000875 ± 0.0000024	

* Distance of the scale from the knife-edge = 110.0 cms.

TABLE VI.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM C AT KAGOSHIMA.

DATE.	Number.	Number of minutes.	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation, unreduced Unit, sidereal second.	Initial* semi-arc of oscillation in mm.	Final* semi-arc of oscillation in mm.	Mean temperature in degree C.	Correction for arc.	Correction for temperature.	Correction for chronometer rate.	Time of a single oscillation, reduced. Unit, sidereal second.	Residual.
August 1	1	45	0.240	1.000089	19.0	14.0	29.7	-14×10^{-6}	-44×10^{-6}	$+\ 6\times10^{-6}$	1.000037	-21×10^{-6}
"	2	35	0.241	1.000115	18.2	14.2	29.6	−14	−43	"	1.000064	+ 6
"	3	33	0.172	1.000087	17.5	13.7	29.7	−13	−44	"	1.000036	−22
"	4	33	0.184	1.000098	18.5	14.0	29.9	−14	−46	"	1.000039	−19
"	5	34	0.206	1.000101	17.6	18.8	29.4	−13	−41	"	1.000053	− 5
"	6	38	0.160	1.000070	18.5	14.0	26.8	−14	−17	"	1.000045	−13
August 2	1	31	0.208	1.000109	18.5	15.1	27.8	−15	−21	"	1.000079	+21
"	2	48	0.258	1.000090	19.7	14.0	27.8	−15	−26	"	1.000055	− 3
"	3	30	0.199	1.000110	19.1	15.8	28.6	−16	−33	"	1.000067	+ 9
"	4	29	0.216	1.000124	18.9	15.4	29.0	−15	−37	"	1.000078	+20
"	5	27	0.202	1.000124	18.7	15.7	29.6	−15	−43	"	1.000072	+14
"	6	31	0.201	1.000108	18.9	15.1	28.6	−15	−33	"	1.000066	+ 8
"	7	32	0.201	1.000105	19.3	15.5	28.5	−16	−33	"	1.000062	+ 4
"	8	25	0.193	1.000129	19.5	16.2	28.5	−17	−33	"	1.000085	+27
"	9	37	0.228	1.000108	19.2	15.0	28.4	−15	−32	"	1.000062	+ 4
August 3	1	27	0.135	1.000083	18.9	15.4	28.3	−15	−31	$+\ 7\times10^{-6}$	1.000044	−14
"	2	34	0.225	1.000111	19.3	14.4	28.7	−15	−34	"	1.000069	+11
"	3	41	0.236	1.000096	18.7	18.8	29.0	−14	−37	"	1.000052	− 6
"	4	23	0.160	1.000116	19.8	16.8	29.3	−17	−40	"	1.000066	+ 8
"	5	26	0.141	1.000091	19.5	15.6	29.4	−16	−41	"	1.000041	−17
"	6	31	0.189	1.000102	18.5	14.5	29.5	−14	−42	"	1.000053	− 5
"	7	48	0.308	1.000107	19.1	12.5	29.6	−13	−43	"	1.000058	0
										MEAN	= 1.000058 ± 0.0000026	

* Distance of the scale from the knife-edge = 109.7 cms.

TABLE VII.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM B AT NAHA.

DATE.	Number.	Number of minutes.	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation, unreduced. Unit, sidereal second.	Initial* semi-arc of oscillation in mm.	Final* semi-arc of oscillation in mm.	Mean temperature in degree C.	Correction for arc.	Correction for temperature.	Correction for chronometer rate.	Time of a single oscillation, reduced. Unit, sidereal second.	Residual.
August 20	1	43	2.879	1.001116	17.9	12.3	28.9	-12×10^{-6}	-32×10^{-6}	$+9\times10^{-6}$	1.001081	$+3\times10^{-6}$
"	2	45	2.993	1.001109	18.5	12.1	29.4	−12	−41	"	1.001065	−13
"	3	34	2.238	1.001097	18.2	13.4	29.7	−13	−44	"	1.001049	−29
"	4	35	2.321	1.001105	19.5	14.6	29.1	−15	−38	"	1.001061	−17
"	5	37	2.486	1.001120	18.5	11.5	28.1	−12	−29	"	1.001088	+10
"	6	41	2.736	1.901112	20.6	11.5	27.3	−13	−21	"	1.001087	+ 9
"	7	37	2.467	1.001111	18.2	10.5	27.0	−10	−19	"	1.001091	+13
"	8	44	2.981	1.001129	18.7	10.5	27.3	−11	−21	"	1.001106	+28
"	9	39	2.614	1.001117	20.4	14.5	27.3	−16	−21	"	1.001089	+11
"	10	40	2.632	1.001097	20.0	13.7	27.1	−15	−20	"	1.001071	− 7
"	11	30	1.986	1.001103	18.3	14.0	27.0	−14	−19	"	1.001079	+ 1
"	12	29	1.928	1.001108	20.5	15.5	27.2	−17	−20	"	1.001080	+ 2
August 21	1	31	2.065	1.001110	19.2	13.5	27.1	−14	−20	"	1.001085	+ 7
"	2	40	2.663	1.001110	17.6	11.8	27.9	−11	−27	"	1.001081	+ 3
"	3	32	2.144	1.001117	16.6	11.7	28.2	−10	−30	"	1.001086	+ 8
"	4	34	2.290	1.001123	18.6	12.7	28.9	−13	−36	"	1.001083	+ 5
"	5	38	2.537	1.001113	20.9	12.8	29.0	−15	−37	"	1.001070	− 8
"	6	38	2.507	1.001100	18.7	12.0	29.2	−12	−39	"	1.001058	−20
"	7	33	2.160	1.001091	18.4	13.0	28.8	−13	−35	"	1.001052	−26
"	8	42	2.853	1.001106	20.4	15.3	25.1	−16	− 1	"	1.001097	+19
										MEAN	= 1.001078 ± 0.0000023	

* Distance of the scale from the knife-edge = 110.0 cms.

TABLE VIII.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM C AT NAHA.

DATE.	Number.	Number of minutes.	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation, unreduced. Unit, sidereal second.	Initial* semi-arc of oscillation in mm.	Final* semi-arc of oscillation in mm.	Mean temperature in degree C.	Correction for arc.	Correction for temperature.	Correction for chronometer rate.	Time of a single oscillation, reduced. Unit, sidereal second.	Residual.
August 21	1	35	0.569	1.000271	17.1	13.4	27.3	-12×10^{-6}	-21×10^{-6}	$+9 \times 10^{-6}$	1.000247	-13×10^{-6}
"	2	40	0.718	1.000299	18.8	14.8	27.2	−14	−20	"	1.000274	+14
"	8	88	0.584	1.000295	18.9	15.8	27.2	−15	−20	"	1.000269	+ 9
"	4	86	0.619	1.000287	16.0	12.7	27.0	−11	−19	"	1.000266	+ 6
"	5	37	0.629	1.000283	19.1	14.5	28.6	−15	−33	"	1.000244	−16
"	6	37	0.652	1.000294	19.2	14.8	28.7	−15	−34	"	1.000254	− 6
"	7	33	0.562	1.000284	17.2	13.3	28.8	−12	−35	"	1.000246	−14
"	8	38	0.603	1.000305	19.1	14.9	29.4	−15	−41	"	1.000258	− 2
"	9	30	0.560	1.000311	21.6	17.6	29.1	−20	−38	"	1.000262	+ 2
"	10	30	0.534	1.000297	16.8	13.6	29.5	−12	−42	"	1.000252	−10
"	11	33	0.603	1.000305	17.0	13.5	29.5	−12	−42	"	1.000260	0
"	12	48	0.857	1.000297	18.2	12.8	28.8	−12	−35	"	1.000259	− 1
August 22	1	30	0.529	1.000297	18.8	15.3	28.6	−15	−33	"	1.000258	− 2
"	2	37	0.647	1.000291	18.5	14.9	28.2	−14	−30	"	1.000256	− 4
"	3	40	0.731	1.000304	20.8	12.6	26.6	−14	−15	"	1.000284	+24
"	4	28	0.462	1.000275	18.9	15.5	25.2	−15	− 2	"	1.000267	+ 7
August 28	1	35	0.572	1.000273	17.9	14.5	25.3	−14	− 3	"	1.000265	+ 5
"	2	39	0.167	1.000279	19.8	15.2	26.4	−12	−13	"	1.000263	+ 3
"	3	31	0.514	1.000277	17.0	14.0	27.2	−12	−20	"	1.000254	− 6
"	4	44	0.757	1.000287	19.0	14.2	27.8	−14	−26	"	0.000256	− 4
									MEAN		= 1.000260 ± 0.0000015	

* Distance of the scale from the knife-edge = 109.7 cms.

APPENDIX

TO THE

MEMOIR No. 5

OF

TÔKIÔ DAIGAKU

(TÔKIÔ UNIVERSITY).

MEASUREMENT

OF THE

FORCE OF GRAVITY

AND

MAGNETIC CONSTANTS

AT

OGASAWARAJIMA

(BONIN ISLAND)

REPORTED BY

A. TANAKADATE,

Assistant to the Professor of Physics,
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DETERMINATION

OF THE

FORCE OF GRAVITY

AT

OGASAWARAJIMA.

An excursion to Ogasawarajima (Bonin) for determining the force of gravity was undertaken by the physical students of Tokio University during the summer vacation of 1884. The opportunity was taken advantage of for making determinations of some of the magnetic constants for the island.

The object of the excursion was to train, during the summer vacation, these physical students in making precise measurements. It was hoped, at the same time, that the result might be of value as a contribution to science, since the force of gravity near Japan shows a slight excess over the values obtained from ordinary formulae, and remarkably so at Ogasawarajima (Bonin) according to Capt. Leutke's observations and consequent reduction by Baily.*

The other members of the party were Messrs. Sawai, Hayasaki and Saneyoshi, students in the physical section of the university. The pendulum experiments for the determination of the force of gravity were conducted by Mr. Sawai, both at Tokio and Ogasawarajima, except a few which were performed by myself as a check upon his operations; magnetic constants were determined by Messrs. Hayasaki and Saneyoshi; and the chronometer rating was conducted by me both at Tokio and Ogasawarajima.

* Encyclopædia Britanica. Eighth Ed. Vol. IX, Art. "Figure of the Earth."

The determination of the force of gravity was a differential one, and consisted in comparing the times of a single oscillation of invariable pendulums at the two places, Tokio and Ogasawarajima. The method of determining the times of a single oscillation was the same as that described in the Memoir No. 5 and its Appendices, and our equipments were the same as those employed in the previous excursion to Naha (Leo Choo) and Kagoshima in 1882. A few improvements, however, were made on the former method of working.

The iron bar which was used for hanging the pendulum in previous experiments was found to be slightly flexible. This was detected by attaching a mirror to the end of the bar and sighting the reflected image of a scale, placed at a distance of three metres from the mirror, with a telescope. This bar was tested by Prof. Mendenhall in 1880 with a micrometer and was found to be rigid enough for the pendulum then employed. But this could not be assumed in the present case, since the pendulums were more than ten times heavier. A new bar of iron 54 cm. long with a section of 11.5 cm. by 2.5 cm. was cast. This had three screws, two near the stage from which the pendulum hung and one near the other end of the bar. A lead weight of 50 kilog. was placed over the middle of this bar and the level of the stage was adjusted by these screws; this gave sufficient stability and rigidity as observed by the reflected image.

We made also a wooden case for protecting the pendulum from air currents consequent on approach of the observer. This case was 36 cm. by 27 cm. in section and 148 cm. in length, and it had four glass windows for observing the level of the pendulum stage, temperature and arcs of oscillation. A small trap-door was made near the bottom of the case on one side. In manipulating the break circuit arrangement for giving automatic signals, the observer put his hand through this door.

PENDULUMS.

Three pendulums were employed called B, C, E, for convenience. It may be remarked that A and D were sent to America for comparing the determination of the force of gravity here with that there. B and C were the which ones taken to Naha and Kagoshima in 1882. E was a new one, which differed from the others by having the knife-edge at the upper end in the form of a T-square instead of a cross. This pendulum fitted the agate plane stage which was made by Salleron of Paris and was used in making absolute determinations in 1880. The stage, with its four leveling screws, was mounted on the iron bar already mentioned. Two of the screws rested in V-shaped grooves cut in the bar, and the other two on the plane surface of the bar; while the stage as a whole was fixed to the same by a couple of brass clamps.

For the sake of convenience the dimensions of the pendulums are given in the following tabular form.

PENDULUM.	B.	C.	E.
Total length........................	122.0 cm.	122.2 cm.	111.0 cm.
Distance between knife-edge and end of pendulum......	111.0 ,,	115.1 ,,	110.0 ,,
Diameter of bob	12.5 ,,	12.3 ,,	12.0 ,,
Thickness of bob	4.2 ,,	4.1 ,,	4.0 ,,
Diameter of cylindrical stem	2.5 ,,	2.5 ,,	2.1 ,,
Total mass	3574. gr.	4356. gr.	2834. gr.

CORRECTIONS.

Corrections for the arc of oscillation, temperature, and chronometer rate, were applied as on the previous occasions. For the arc, Basevi's formula — $t/64.\ (\overline{\alpha+\beta}^2 - \frac{1}{3}\overline{\alpha-\beta}^2)$ was employed. To save the labours of computation, tables of corrections for each pendulum were made with two arguments, the mean arc of oscillation and the difference of the arcs of oscillation. Temperature correction was applied so as to reduce all the observations to that at 25° C which was about the mean for all the experiments, the coefficient of expansion of brass being taken as 0.0000187 per degree. With regard to the chronometer correction as only the average rate between the two times of observation could be obtained, care was taken to distribute, as far as possible, the pendulum experiments throughout the full period for which this average rate was applied. Observations were made twice every 24 hours when feasible; and from these observations the average rates for night and day were determined. Gauss's method of determining the azimuth, collimation, and clock error from 6 to 12 star observations was followed.

We began experiments at Tokio in the middle of July in the Pendulum Room of the Physical Laboratory of Tokio University, and having completed our preparations, we left Tokio on the 5th of August reaching the island on the 10th of the same month. As the ship was expected to stay only for about 10 days, we took with us a prepared set of masonry and wooden piles to lose as little time as possible in building stone piers for pendulum, transit instrument, magnetometer and declinometer.

Through the kindness of Mr. T. Minami the Governor of the Island, we were furnished with a building, in the village of Ogiura, for our experimental station. This building was used for keeping boats, and had no floor. Stone piers were set up in this house for pendulum and magnetometer. The transit instrument was set near the house in open ground with a temporary shelter of sail cloth as a protection from rain. We began our work on the night of the 13th, and finished on the morning of the 18th of August. Leaving the Island on the 19th, we reached Tokio on the 31st. A check series of experiments was made between the 5th and 9th of September.

CO-ORDINATES OF THE TWO PLACES.

Tokio.

Lat.	35°	42′	40″	N.
Long.	139°	45′	45″	E.
Height above the sea level			5	metres

Ogasawarajima. (Bonin.)

Lat.	27°	4′	11″	N.
Long.	142°	11′	54″	E.
Height above the sea level ...			2.2	metres

RESULTS OF THE PENDULUM EXPERIMENTS.

B

	s
Time of a single oscillation at Tokio (before)... ...	1.000708 ± *.0000012
" " " " " (after)	1.000729 ± .0000030
" " " " " (mean)... ...	1.000718
" " " " Ogasawarajima ...	1.000906 ± .0000016

C

Time of a single oscillation at Tokio (before)... ...	0.999891 ± .0000007
" " " " " (after)	0.999897 ± .0000012
" " " " " (mean)... ...	.999894
" " " " Ogasawarajima ...	1.000087 ± .0000014

E

Time of a single oscillation at Tokio (before)	1.000088 ± .0000013
" " " " (after)	1.000089 ± .0000011
" " " " (mean)	1.000089
" " " Ogasawarajima... ...	1.000271 ± .0000021

* A reference to the reduction sheets will show that these are not, strictly speaking, probable errors in as much as the chronometer rate is supposed to be constant throughout the time for which only an average rate is determined. Again, if the figure of the pendulum suffer a slight deformation during the transportation there is no means of judging whether that happened in going or returning. From these considerations, we abandon the former plan of giving weights to the before and after results inversely proportional to the squares of the probable errors, and we believe that the simple arithmetical mean gives a better approximation to the truth.

The ratio of the force of gravity at Ogasawarajima to that at Tokio is as follows.

$$\text{By B, ...} \left(\frac{1.000718}{1.000906}\right)^2 = .999624$$

$$\text{,, C, ...} \left(\frac{.999894}{1.000087}\right)^2 = .999614$$

$$\text{,, E, ...} \left(\frac{1.000089}{1.000271}\right)^2 = .999636$$

If we take "g" at Tokio to be 979.84 the values at Ogasawarajima come out as follows:

	979.472	(C. G. S. unit)	from B
	979.462	,,	,, C
	979.483	,,	,, E
Mean	979.472	,,	

From Leutke's observation and Baily's reduction, "g" at Ogasawarajima should be 979.388.* Leutke's values for the co-ordinates are

†Lat.	27°	4′	12″	N.
Long.	142°	0′		E.

thus differing 1″ N and 11′ 54″ W from the values for our station.

Computed from the formulae.

$g = 980.6056 - 2.5028 \cos 2\lambda - .000003\ h$ (Everett)

$g = 978.0728 + 5.0875 \sin^2 \lambda$ (Listing)

$g = 980.63 \quad - 2.553 \quad \cos 2\lambda$ (Major Herschel)

g at 27° 4′ 11″ has the corresponding values

979.139

979.126

979.135

all of which fall short of the value we obtained by about .034 per cent.

In the spring of 1883 the pendulums used in the Indian Operations were brought to Tokio University by Messrs. Smith and Prechet of U. S. Coast Survey, and had their vibration numbers per day determined. When these results are published, we shall be able to get a better value for Tokio, and therefore for Ogasawarajima, Sapporo, Kagoshima and Naha, for all of which places relative determinations have now been made.

* See Appendix of Memoir No. 5 (Sapporo excursion).

† G. T. Survey of India Vol. V.

Remark.—On our return from the excursion, we found that the wedge-shaped appendage for the break circuit arrangement of the E pendulum had been slightly scraped by one of the screw nails used to fix the lid of its box. This of course is awkward: but if we suppose it to be a mere loss of mass unaccompanied by any further change, we may apply the following correction.

Let I = moment of inertia about the knife-edge of the pendulum,
K = radius of gyration about the knife-edge,
L = length of simple equivalent pendulum,
$\bar{x}$ = distance of the centre of mass from the knife-edge,
m = mass of the pendulum,
M = $m\bar{x}$ the moment of mass,
δm = mass scraped off,
ρ = distance of the scraped portion from the knife-edge.

Then

$$t=\pi\sqrt{\frac{L}{g}} \text{ to first approximation.}$$

$$\frac{\delta t}{t}=\frac{1}{2}\frac{\delta L}{L}$$

but $$L=\frac{I}{M}$$

Therefore by differentiation and reduction

$$\frac{\delta L}{L}=\frac{\delta I}{I}-\frac{\delta M}{M}$$

but $$\delta I=\rho^2\,\delta m$$

and $$\delta M=\rho\,\delta m$$

whence $$\frac{\delta L}{L}=\rho^2\frac{\delta M}{I}-\rho\frac{\delta M}{M}$$

$$=\rho\,\delta m\left(\frac{\rho}{mK^2}-\frac{1}{m\bar{x}}\right)$$

but $$K^2=L\bar{x}$$

Hence $$\frac{\delta L}{L}=\frac{\rho}{\bar{x}}\frac{\delta m}{m}\left(\frac{\rho}{L}-1\right)$$

$$\frac{\delta t}{t}=\frac{1}{2}\frac{\rho}{\bar{x}}\frac{\delta m}{m}\left(\frac{\rho}{L}-1\right)$$

Had we accurately weighed the pendulum before packing it up, we might have determined δm by reweighing it. Supposehowever that δm is .1 gr. which is certainly an over-estimate. Then, since

ρ = 110. cm.
$\bar{x}$ = 87. „ determined experimentally by balancing the pendulum horizontally.
L = 98.1 cm. estimated from t and g.
M = 2824 gr.

we have $$\frac{\delta t}{t}=\frac{1}{2}\,\frac{110}{87}\,\frac{.1}{2824}\left(\frac{110}{98.1}-1\right)$$

$$=.0000027$$

which is within the errors of experiments, as will be seen by comparing the times of a single oscillation before and after the excursion.

DETERMINATION

OF

MAGNETIC CONSTANTS.

The magnetic constants determined were the horizontal component (H) of the terrestial field and the declination. The dip was not attempted from the want of instrumental appliances.

DETERMINATION OF H.

The method of measuring H was essentially that of Gauss, and consisted in determining the product and ratio of H and M, M being the moment of the bar magnet used. We took four bar magnets called A, B, C, D. A and B had circular sections, and C and D square sections. They were carefully made to fulfil the geometrical conditions as nearly as possible. The following table gives their dimensions at 20° C.

Magnet.	A.	B.	C.	D.
Length	10.020 cm.	7.016 cm.	10.012 cm.	7.988 cm.
Diameter or breadth	.805 „	.821 „	.793 „	.794 „
Mass	39.684 gr.	28.903 gr.	50.880 gr.	39.324 gr.
Moment of inertia	334.58 in c. gr.	120.52 in c. gr.	427.72 in c. gr.	211.40 in c. gr.

In determining their lengths, the bar was brought in contact with an iron scale graduated to $\frac{1}{2}$ mm. and the positions of the ends of the bar were read with a micrometer. Four measurements were made along different longitudinal sections of the bar. The cross section was determined by means of a screw micrometer, ten readings at different portions of the bar giving a fair average.

For determining the time of oscillation, the magnet was set in vibration in a wooden case with four glass sides, one of which could be opened at pleasure. The magnet was suspended by two loops of silk fibre, which were united into a single fibre of the same material at a distance of about 5 cm. from the magnet, the length of the single fibre being about 20 cm. To bring the magnet into the horizontal position, the floor of the case was first levelled by means of three levelling screws belonging to the case: the magnet was then lowered close to the floor and was made parallel thereto by sliding adjustment of one of the silk loops. The bar was now raised by winding the suspending fibre at the top of the case.

When the bar was settled in its adjusted position, it was set in vibration by bringing a piece of iron outside the case at nearly the same level as the bar. The oscillation was observed by sighting a reflected image of a scale placed at a distance of 50 cm. from the magnet, whose polished end was used as the reflector. One line in the scale was marked, and when the image of that line passed the wire of the telescope the observer pressed the break-circuit-key, which was in connection with the chronograph. From ten to twenty successive signals were thus given and the magnet was left to vibrate for about five minutes, when another series of ten to twenty signals was made. From the ten successive marks in the chronograph sheet the time of a single oscillation was roughly determined, and the number of oscillations in five minutes was inferred as in the pendulum experiments.

The determination of $\frac{M}{H}$ was by the tangent method. The magnetometer, of the ordinary small mirror reflecting form, was set upon a tripod stand. The deflecting magnet slid along a groove cut in the upper surface of a brass rod, which was specially constructed to suit the apparatus (see Fig. 1). This brass rod rested on the telescope supports of a theodolite stand, which was truly centred with the magnetometer tripod, but had no contact therewith. The line of supports was adjusted to the direction of magnetic east and west by an electro-magnetic method, which will be described below in the account of the Declination Experiments. When this adjustment was effected, the brass rod was laid in position. Through a circular hole cut out from the centre of the rod, the magnetometer passed; and the mirror with its attached magnets was carefully adjusted to the proper level. The V-groove in the brass rod was graduated from the centre in both directions. The bar magnet was mounted on this V at two distances r_1 and r_2, whose ratio was approximately 1 : 1.32, this being according to Maxwell the best ratio to take.

To measure the angle of deflection a wooden arc of radius 85 cm. was graduated to minutes and was placed to one side of the theodolite on a wooden tripod support. The reflected image of the scale was observed in a telescope mounted upon the graduated arc. To take account of possible heterogeneity of distribution, the magnet was inverted and reversed in each of its positions as determined by the value of r; so that for any one numerical value of r there were eight magnetometer readings taken, four with the magnet to the east, and four with it to the west of the magnetometer.

CORRECTIONS.

Corrections were applied for temperature, arc of oscillation, torsion of the suspending fibre, and induction on the magnet.

Temperature correction was applied to the moment of inertia by assuming the coefficient of expansion for steel to be 0.000011 per degree C.. In the experiment for determining $\frac{M}{H}$ a like correction was applied to the scale reading of the distance of the magnet from the magnetometer, the coefficient of expansion for brass being taken as 0.000019.

The arc of oscillation was measured by means of the image of a scale reflected from the polished end of the magnet. The scale was so graduated as to give arcs in radians by direct reading.

The torsion of the suspending fibre was determined by turning the torsion head attached to the upper end of the fibre through five complete revolutions and observing the deflection thereby produced on the reflected image. This gave torsion in terms of the product MH for the magnet used, and the correction was applied accordingly. The mirror magnetometer, being suspended by a spider thread, which proved to have a very small torsional rigidity, was not corrected for torsion.

The chronometer rate as determined for the pendulum experiments was found to be outside the errors of experiment: and the times of a single oscillation were reduced from sidereal to mean solar seconds.

To correct the result for the induced magnetism on each of the bar magnets, the induction for a given value of field was determined in the following way. The bar magnet was placed in the same position as it was in determining $\frac{M}{H}$ and a solenoid which was about twice as long as the bar magnet was slid over it and the V-groove on which it lay. A known current was passed through the solenoid, and the magnetometer reading was taken. Thus the field inside the solenoid was known; and δM the increment of the moment of bar magnet could be calculated. The curve obtained by plotting the increments of moment against the field in the solenoid was very nearly straight and was quite the same whether the field was increasing or decreasing. The maximum field used was 0.6 (C. G. S. unit). From these data the induction effect was computed, and the corresponding correction applied to the values of H both at Tokio and Ogasawarajima.

The following are the values of H thus determined.

TOKIO (Before Excursion.)

Date and Time.	H	Magnet.	Observer.*
August 1st 8½ A.M.	.2964	B	S
,, 1½ P.M.	.2972	D	H
,, 2 ,,	.2971	D	S
,, 3 ,,	.2958	B	H
,, 4 ,,	.2940	A	S
August 2nd 10 P.M.	.2977	B	S
August 3rd 7 ,,	.2967	B	H
Mean	.2964		

TOKIO (After Excursion.)

Date and Time.	H	Magnet.	Observer.
September 5th 2 P.M.	.2947	D	H
,, 4 ,,	.2948	B	H
September 6th 9½ A.M.	.2948	B	H
,, 11 ,,	.2965	D	H
,, 11½ ,,	.2948	B	S
,, 12½ P.M.	.2956	A	S
,, 1½ ,,	.2950	B	H
,, 2½ ,,	.2965	D	H
,, 4½ ,,	.2942	D	S
,, 6 ,,	.2968	C	S
,, 8½ ,,	.2952	D	H
,, 11 ,,	.2945	B	H
September 7th 9½ A.M.	.2953	B	S
,, 11 ,,	.2963	A	S
,, 2 P.M.	.2932	D	S
,, 4 ,,	.2969	C	S
September 8th 12 M.	.2967	D	H
,, 2 P.M.	.2936	B	H
,, 8½ ,,	.2940	B	H
,, 9½ ,,	.2960	D	H
Mean	.2955		

* H stands for Hayasaki and S for Saneyoshi.

OGASAWARAJIMA.

Date and Time.	H	Magnet.	Observer.
August 15th 4 P.M.	.3198	B	S
" 7 "	.3133	D	S
August 16th 9½ A.M.	.3184	C	S
" 1½ P.M.	.3155	A	S
August 17th 8¾ A.M.	.3177	B	H
" 2 P.M.	.3164	A	S
" 3 "	.3154	D	H
" 3½ "	.3199	C	S
" 4½ "	.3129	D	S
" 11½ "	.3169	B	S
Mean	.3166		

DECLINATION.

Declination experiments were carried out by means of an electro-magnetic declinometer (see Fig. 2). This instrument essentially consists of three parts, a theodolite, a coil, and a magnetometer.

The theodolite is one of the ordinary kind, and forms the base of the instrument. Its azimuth-circle reads to 5."

The coil* is wound on a rectangular bronze frame in two parts with an open space in the center. The hollow pivots are of the same diameter as those of the theodolite telescope and project at right angles to the axis of the coil, which is disposed symmetrically about their line of collimation. Two narrow slits in the middle of the ends of the coil approximately define the median plane of the coil. About 700 turns of a fine insulated copper wire are wound in this frame in two layers, and the ends of the wire are led off from the same point in the coil. The two leading wires are twisted together and terminate in a twin-plug. In order to prevent the leading wires from being easily cut they are tied to the frame by an elastic string. The total weight of the coil approximately equals that of the telescope belonging to the theodolite.

The magnetometer is an ordinary small reflecting one. It stands upon an independent tripod nearly centred with the theodolite and projects through the open space in the center of the coil. A small mirror magnet is suspended

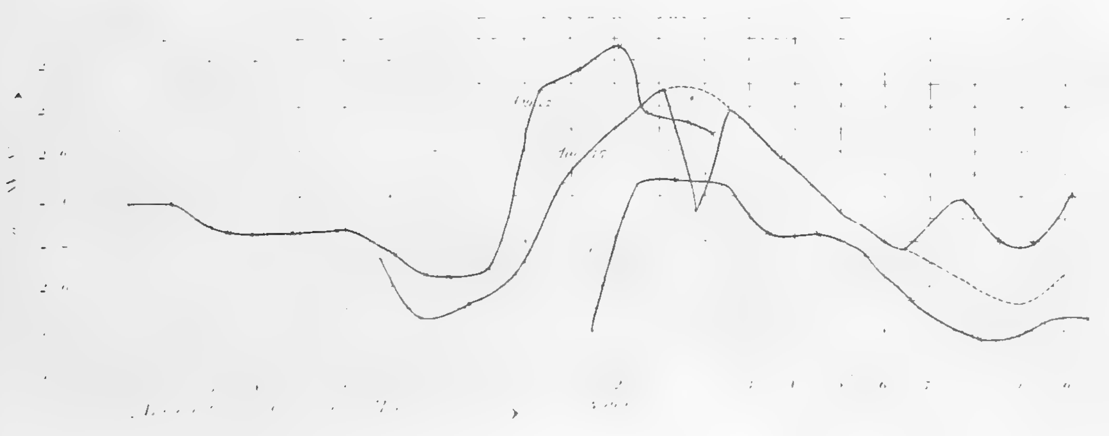
* For the discussion of the proper proportion of the shape of the coil see Proc. R. S. E. Vol. XII (1883-4).

by a single spider thread whose torsional rigidity was found to be about $\frac{1}{710}$ of that of a single silk fibre. The upper end of this thread is fixed to the stem of a fan-shaped horn damper. The top part of the magnetometer case is a brass tube and can be slide up or down by loosening a jam-nut. The upper end of this tube is plane and has in its center a triangular hole through which the stem of the damper passes. The damper can be geometrically fixed by means of a small screw pressing it up against the corner of the triangular hole. As a protection from air-currents a small glass cap is fitted to the brass tube. The lower part of the case is also a brass tube, which is furnished with four glass windows, two square and two rectangular. The mirror hangs with its face parallel to the two square ones while the rectangular ones are just large enough to allow the mirror to be viewed through them edge-on. One of the two square windows is a thin convex lens and the other is plane, so that the magnetometer can be made to suit either the lamp or the telescope method. Directly below the mirror, there is a small brass vice whose jaws are lined with chamois skin and which is worked by a screw from outside the case. To take off the initial torsion of the suspending fibre, the top part of the magnetometer is slipped down until the mirror can be caught by the vice, and the whole case is inverted and re-set on the tripod stand. The small screw which bears against the stem of the damper is unscrewed, and the top part of the magnetometer is slipped further along, so that the damper hangs free with the spider thread passing through the triangular hole. When the damper comes to rest the operations are gone through in the reversed order, and the magnetometer is thus suspended free from initial torsion. The magnetometer can be transported safely by having the mirror magnet clamped in the vice.

To work with this instrument, the theodolite stand is set in the astronomical meridian by any of the ordinary processes. The telescope is dismounted without disturbing the base of the instrument, the magnetometer is placed in its center, and the coil is mounted on the Y's. The magnetometer is adjusted to the central position by means of four screws working horizontally in the circular socket on which the base of the magnetometer case rests. It is brought into the north and south axis by sighting the edge of the mirror through the slits in the ends of the coil, and to the east and west axis by sighting the face of the mirror through one of the hollow pivots and making clearance equal all round. A scale is now placed at a proper position with reference to the magnetometer, and the reflected image of a scale division which coincides with the wire of the telescope is observed. A current from a Daniell cell, which is running steadily through a high resistance of an ordinary resistance-box, is shunted through the declinometer coil by inserting the terminal twin-plug of the leading wires into the plug hole of the high resistance. The current is made so as to produce in the center of the coil a field which has the same direction as that due to the earth. This is easily determined by observing the rate of vibration of the reflected image. The coil is now turned by means of a tangent screw until the reflected image is brought back to where it was when no current was passing. The current is then reversed by turning the twin-plug half-way round and its strength is adjusted, if necessary, by means of the resistance coils so that the resultant magnetic field is not reversed. The image will again be displaced on account of inefficiency of the previous adjustment. The position of the coil is readjusted to zero deflection of the image and the angle reading on the azimuth circle taken. The coil is now lifted up carefully from the Y's and replaced in the reversed position, after the usual fashion of collimating a telescope. The observations are repeated with this new position of the coil, and the mean of the two readings is taken as the mean magnetic bearing between the two times of setting. This subtracted from the meridian reading of the azimuth circle gives the declination required.

It will be seen that if we take the mean of the two observations thus made, the value obtained will be free from what may be called the error of magnetic collimation, that is, the error arising from the axis of the pivots not being strictly perpendicular to the direction of the electro-magnetic field. This error is half the difference of the two observations, provided the configuration of the coil and the declination remain constant throughout the whole series of operations. When the instrument was in order, the observations could be made in about three minutes, and the so called magnetic collimation was pretty nearly constant, being about 7″. This obviously gives a check on any accidental mistake on the angle reading.

The following curve shows the variation of magnetic declination at Ogasawarajima as determined in this way.



* This dip in the curve looks like an accidental error in angle reading.

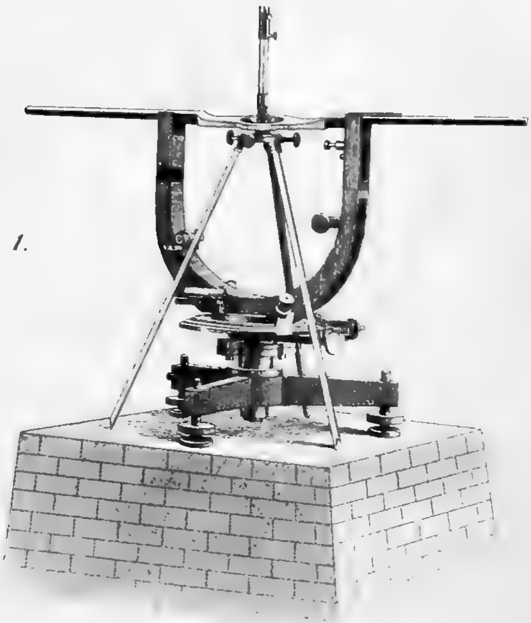
† This is probably due to a displacement of the base since a downward shift of the succeeding portion fits in well with the rest of the curve.

The mean of all the observed values is

2° 3′ 8″ W.

The maximum west declination observed is	2° 10′ 42″
The minimum „ „ „	1° 57 36″
difference	13′ 6″

Fig. 1.



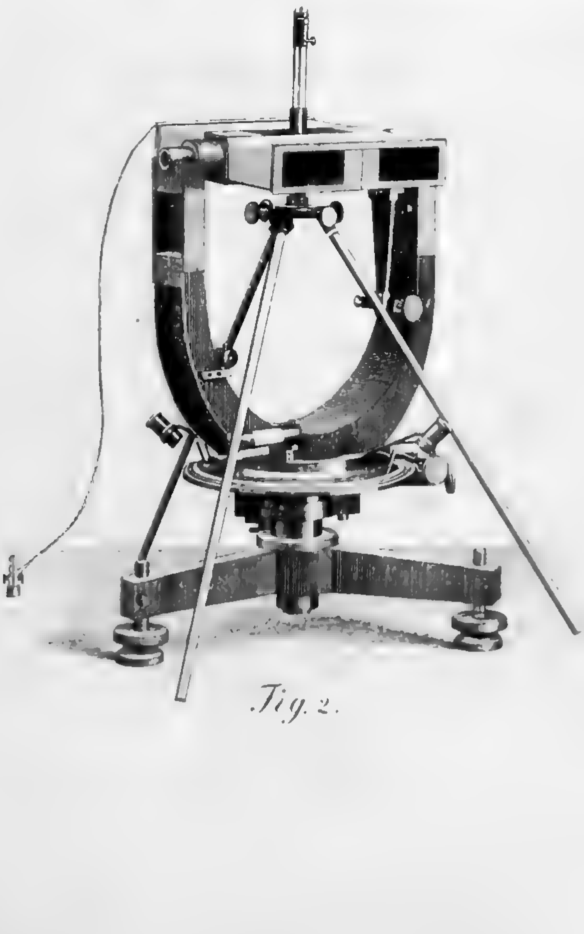


Fig. 2.

RESULTS

OF

PENDULUM EXPERIMENTS.

TABLE I.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM B AT TOKIO, BEFORE THE EXCURSION. *(For continuation see next page.)*

DATE.	Number	Beginning of Experiment. (local sidereal.)	Number of minutes.	Semi-arc of oscillation in mm. Initial.	Final.	Mean.	Temperature in degrees C. Initial.	Final.	Mean.	Mean Temp. —25°	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation in sidereal seconds. Unreduced.	Corrections in 10^{-6} sidereal seconds for Arc.	Temp.	Chro^r rate.	Time of a single oscillation in sidereal seconds.	Residual.
July 9	1	5h. 32m.	29	9.3	7.2	8.3	24.5	24.4	24.5	− .5	1.316	1.000756	− 4	+ 5	−39	1.000718	+10
„	2	8 9	25	9.6	7.9	8.8	25.2	25.4	25.3	+ .3	1.108	1.000739	− 4	− 3	−39	1.000693	−15
„	3	8 48	24	11.6	9.6	10.6	25.5	25.3	25.4	+ .4	1.087	1.000755	− 6	− 4	−39	1.000706	− 2
„	4	9 18	50	11.9	8.2	10.1	25.4	25.4	25.4	+ .4	2.218	1.000739	− 5	− 4	−39	1.000691	−17
„	5	10 27	56	10.1	6.7	8.4	25.5	25.3	25.4	+ .4	2.488	1.000741	− 4	− 4	−39	1.000694	−14
„ 10	1	4 50	58	12.3	8.1	10.2	23.5	23.6	23.6	−1.4	2.538	1.000729	− 5	+13	−37	1.000700	− 8
„	2	5 52	44	14.2	9.9	12.1	23.6	23.5	23.6	−1.4	1.925	1.000732	− 8	+13	−37	1.000700	− 8
„	3	6 50	$56\frac{3}{60}$	16.5	10.8	13.6	23.5	23.7	23.6	−1.4	2.485	1.000740	−10	+13	−37	1.000706	− 2
„	4	7 54	60	16.1	10.2	13.2	23.8	23.9	23.9	−1.1	2.649	1.000736	− 9	+10	−37	1.000700	− 8
„	5	9 12	$57\frac{2}{60}$	18.1	11.3	14.7	24.1	24.2	24.2	− .8	2.549	1.000745	−11	+ 7	−37	1.000704	− 4
„	6	10 20	49	15.0	12.2	13.6	24.3	24.4	24.4	− .6	2.205	1.000750	−10	+ 6	−37	1.000709	+ 1
„ 11	1	7 38	41	18.9	13.5	16.2	24.2	24.1	24.2	− .8	1.915	1.000778	−14	+ 7	−36	1.000735	+27
„	2	8 27	53	15.6	10.2	12.9	24.3	24.5	24.4	− .6	2.422	1.000762	− 9	+ 6	−36	1.000723	+15
„	3	10 54	39	16.4	12.0	14.2	24.8	24.8	24.8	− .2	1.766	1.000755	−10	+ 2	−36	1.000711	+ 3
„	4	11 42	90	15.5	7.8	11.7	24.9	24.9	24.9	− .1	4.036	1.000747	− 7	+ 1	−36	1.000705	− 3
„ 12	1	4 14	57	18.2	11.5	14.9	23.8	23.9	23.9	−1.1	2.515	1.000735	−11	+10	−36	1.000698	−10
„	2	5 20	39	18.6	13.5	16.1	24.1	24.0	24.1	− .9	1.730	1.000739	−13	+ 8	−36	1.000699	−19
„	3	6 11	74	18.3	10.2	14.3	24.2	24.5	24.4	− .6	3.234	1.000728	−11	+ 6	−36	1.000687	−21
„	4	8 49	82	13.0	4.5	8.8	24.2	25.4	24.8	− .2	3.663	1.000745	− 4	+ 2	−36	1.000707	− 1
„	5	10 11	28	14.5	11.8	13.2	25.6	25.2	25.4	+ .4	1.284	1.000764	− 9	− 4	−36	1.000715	+ 7
„	6	10 49	63	19.2	12.6	15.9	25.4	25.4	25.4	+ .4	2.944	1.000779	−13	− 4	−36	1.000726	+18
„	7	11 57	53	19.5	12.7	16.1	25.5	25.5	25.5	+ .5	2.403	1.000787	−13	− 5	−36	1.000733	+24

DATE.	Number.	Beginning of Experiment. (local sidereal.)	Number of minutes.	Semi-arc of oscillation in min. Initial.	Final.	Mean.	Temperature in degrees C. Initial.	Final.	Mean.	Mean Temp —25°	Sum of fractions of second at beginning and end of oscillations	Time of a single oscillation in sidereal seconds. Unreduced.	Corrections in 10^{-6} sidereal seconds for Arc.	Temp.	Chror. rate.	Time of a single oscillation in sidereal seconds.	Residual
July 13	1	4h. 0m.	60	18.8	11.8	15.3	24.2	24.2	24.2	— .8	2.743	1.000762	—12	+ 7	—37	1.000720	+12
„	2	5 3	48	18.0	12.2	15.1	24.3	24.2	24.3	— .7	2.179	1.000755	—12	+ 7	—37	1.000713	+ 5
„	3	7 5	46	21.0	14.3	17.7	24.3	24.2	24.3	— .7	2.109	1.000764	—16	+ 7	—37	1.000718	+10
„ 14	1	3 25	55	18.6	12.1	15.4	23.4	23.3	23.4	—1.6	2.456	1,000744	—12	+15	—39	1.000708	± 0
„	2	4 23	54	19.7	12.3	16.0	23.4	23.4	23.4	—1.6	2.405	1.000712	—13	+15	—39	1.000705	— 3
„	3	5 35	67	18.5	10.9	14.7	23.6	23.6	23.6	—1.4	2.952	1.000731	—11	+13	—39	1.000697	—11
„	4	6 44	41	19.3	14.8	17.1	23.8	23.8	23.8	—1.2	1.808	1.000735	—15	+11	—39	1.000692	—16
„ 27	1	7 10	35	19.8	14.1	17.1	26.5	26.8	26.7	+1.7	1.661	1.000791	—15	—16	—46	1.000714	+ 6
„	2	7 46	39	19.2	13.6	16.4	26.8	27.2	27.0	+2.0	1.861	1.000795	—14	—19	—46	1.000716	+ 8
„	3	8 58	45	20.2	13.7	17.0	27.3	27.3	27.3	+2.3	2.131	1.000789	—15	—22	—46	1.000706	— 2
„	4	9 45	33	20.5	15.2	17.9	27.4	27.5	27.5	+2.5	1.573	1.000794	—17	—23	—46	1,000708	± 0
„	5	10 20	32	20.1	15.2	17.7	27.5	27.4	27.5	+2.5	1.522	1.000793	—16	—23	—46	1.000708	± 0
„	6	11 18	40	20.3	13.9	17.1	28.0	27.5	27.8	+2.8	1.940	1.000808	—15	—25	—46	1.000721	+13
„	7	11 59	43	20.2	13.9	17.1	27.6	27.6	27.6	+2.6	2.091	1.000793	—15	—24	—46	1.000708	± 0
„	8	12 45	30	20.4	15.7	18.1	27.7	27.5	27.6	+2.6	1.428	1.000793	—17	—24	—46	1.000706	— 2
„	9	13 22	42	20.4	14.0	17.2	27.6	27.4	27.5	+2.5	1.967	1.000781	—15	—23	—46	1.000697	—11
„	10	14 6	43	20.0	13.8	16.9	27.4	27.1	27.3	+2.3	2.019	1.000783	—15	—22	—46	1.000700	— 8
													Mean............			1.000708	
																± .0000012	

TABLE II.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM B AT TOKIO, AFTER THE EXCURSION.

DATE.	Number	Beginning of Experiment (local sidereal.)	Number of minutes.	Semi-arc of oscillation in mm. Initial.	Final.	Mean.	Temperature in degrees C. Initial	Final.	Mean.	Mean Temp. 25°	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation in sidereal seconds. Unreduced.	Corrections in 10^{-6} sidereal seconds for. Arc.	Temp.	Chro° rate.	Time of a single oscillation in sidereal seconds	Residual.
Sept. 6	1	10h.37m.	$46\frac{4}{60}$	19.4	13.5	16.5	23.2	22.8	23.0	−2.0	2.165	1.000783	− 14	+ 19	− 58	1.000730	+ 1
"	2	11 28	$43\frac{30}{60}$	19.9	14.0	17.0	23.5	23.2	23.4	−1.6	2.051	1.000779	− 15	+ 15	− 58	1.000721	− 8
"	3	12 26	41	20.3	14.1	17.4	23.3	23.3	23.3	−1.7	1.933	1.000786	− 16	+ 16	− 58	1.000728	− 1
"	4	13 12	$36\frac{5}{60}$	19.9	14.8	17.4	24.0	23.5	23.8	−1.2	1.757	1.000810	− 16	+ 11	− 58	1.000747	+ 18
"	5	13 53	$25\frac{33}{60}$	19.6	15.7	17.7	23.9	23.7	23.8	−1.2	1.256	1.000807	− 16	+ 11	− 58	1.000744	+ 15
"	6	14 55	$42\frac{38}{60}$	19.0	13.6	16.3	24.4	24.0	24.2	− .8	2.107	1.000817	− 14	+ 7	− 58	1.000752	+ 23
"	7	16 19	$33\frac{18}{60}$	15.9	12.4	14.2	24.5	24.0	24.3	− .7	1.592	1.000800	− 10	+ 7	− 58	1.000739	+ 10
"	8	17 12	$43\frac{14}{60}$	19.1	13.8	16.5	24.7	24.1	24.4	− .6	2.042	1.000787	− 14	+ 6	− 58	1.000721	− 8
"	9	18 1	29	20.0	15.6	17.8	24.6	24.2	24.4	− .6	1.397	1.000803	− 16	+ 6	− 58	1.000735	+ 6
"	10	18 33	31	21.8	16.9	19.4	24.3	24.2	24.3	− .7	1.422	1.000764	− 19	+ 7	− 65	1.000687	− 42
"	11	19 21	38	19.8	14.6	17.2	24.5	24.2	24.4	− .6	1.814	1.000795	− 15	+ 6	− 65	1.000721	− 8
"	12	20 4	$32\frac{6}{60}$	20.5	15.7	18.1	24.4	24.2	24.3	− .7	1.524	1.000793	− 17	+ 7	− 65	1.000718	− 11
"	13	20 46	30	19.5	15.2	17.4	24.2	24.1	24.2	− .8	1.425	1.000792	− 16	+ 7	− 65	1.000718	− 11
"	14	21 25	$33\frac{1}{60}$	20.8	15.8	18.3	24.2	24.0	24.1	− .9	1.619	1.000817	− 17	+ 8	− 65	1.000743	+ 14
													MEAN........................			=1.000729	
																± .0000030	

TABLE III.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM B AT OGASAWARAJIMA.

DATE.	Number.	Beginning of Experiment (Local sidereal.)	Number of minutes.	Semi arc of oscillation in mm.			Temperature in degrees C.			Mean Temp. −25	Sum of fractions of seconds at beginning and end of observations	Time of a single oscillation in sidereal seconds. Uncorrected.	Corrections in 10^{-9} sidereal seconds for.			Time of a single oscillation in sidereal seconds.	Residual.
				Initial.	Final.	Mean.	Initial.	Final.	Mean.				Arc.	Temp.	Clock rate.		
Aug. 15	1	9h.25m	42	19.9	14.2	17.1	28.7	28.7	28.7	+3.7	2.510	1.000996	−15	−35	−47	1.000899	− 7
„	2	10 9	31[illegible]	19.1	14.7	16.9	28.7	28.8	28.8	+3.8	1.914	1.000999	−15	−36	−47	1.000901	− 5
„	3	10 57	33	19.4	14.8	17.1	28.9	29.0	29.0	+4.0	1.984	1.001002	−15	−37	−47	1.000903	− 3
„	4	11 31	32	20.1	15.2	17.7	29.0	29.0	29.0	+4.0	1.908	1.000994	−16	−37	−47	1.000894	−12
„	5	12 4	42	19.9	14.2	17.1	29.0	28.9	29.0	+4.0	2.498	1.000991	−15	−37	−47	1.000892	−14
„	6	12 51	27	20.1	16.2	18.2	29.0	29.0	29.0	+4.0	1.638	1.001011	−17	−37	−47	1.000910	+ 4
„	7	13 38	39	19.6	14.3	17.0	29.0	28.9	29.0	+4.0	2.337	1.000999	−15	−37	−47	1.000900	− 6
„	8	14 56	36.[illegible]	20.0	14.7	17.4	28.6	28.8	28.7	+3.7	2.221	1.001030	−16	−35	−47	1.000932	+26
„	9	15 31	34	19.8	14.8	17.1	28.8	28.6	28.7	+3.7	2.058	1.001009	−15	−35	−47	1.000912	+ 6
„	10	16 14	43	20.3	14.3	17.3	28.5	28.1	28.3	+3.3	2.587	1.001003	−15	−31	−47	1.000910	+ 4
„	11	16 59	33	20.4	15.4	17.9	28.1	27.8	28.0	+3.0	1.987	1.000996	−17	−28	−47	1.000904	− 2
„	12	17 33	34	20.2	15.3	17.8	27.8	27.4	27.6	+2.6	2.037	1.000998	−16	−24	−47	1.000911	+ 5
„	13	18 23	42	19.9	13.9	16.9	27.3	27.0	27.2	+2.2	2.497	1.000991	−15	−21	−49	1.000906	± 0
„	14	19 6	38	19.9	14.7	17.3	26.9	26.7	26.8	+1.8	2.259	1.000991	−15	−17	−49	1.000910	+ 4
„	15	19 46	39	19.7	15.1	17.4	26.7	26.6	26.7	+1.7	1.785	1.000992	−16	−16	−49	1.000911	+ 5
													MEAN........................			1.000906 ± .000016	

TABLE IV.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM C AT TOKIO, BEFORE THE EXCURSION. *For continuation see next two pages.*

DATE.	Number.	Beginning of Experiment. (Local sidereal.)	Number of minutes.	Semi-arc of oscillation in mm.			Temperature in degrees C.			Mean Temp. −25°	Sum of fractions of second at beginning and end of oscillations	Time of a single oscillation in sidereal seconds. Unreduced.	Corrections in 10^6 sidereal seconds for.			Time of a single oscillation in sidereal seconds.	Residual.
				Initial.	Final.	Mean.	Initial.	Final.	Mean.				Arc.	Temp.	Chron. rate.		
July 15	1	6h. 6m.	58	19.2	13.0	16.1	23.8	23.8	23.8	−1.2	.245	.999930	−13	+11	−42	.999886	− 5
,,	2	7 14	$60\frac{5}{60}$	19.7	13.1	16.4	23.6	23.6	23.6	−1.4	.281	.999922	−14	+13	−42	.999879	−12
,,	3	8 16	49	19.3	13.2	16.3	23.6	23.6	23.6	−1.4	.210	.999929	−14	+13	−42	.999886	− 5
,,	4	9 16	$60\frac{4}{60}$	19.8	13.3	16.6	23.6	23.7	23.7	−1.3	.230	.999936	−14	+12	−42	.999892	+ 1
,,	5	10 20	51	20.3	14.3	17.3	23.8	23.8	23.8	−1.2	.213	.999930	−15	+11	−42	.999884	− 7
,,	6	11 22	50	19.6	14.2	16.9	23.8	23.8	23.8	−1.2	.183	.999939	−15	+11	−42	.999893	+ 2
,,	7	12 17	64	20.1	13.2	16.7	23.8	23.8	23.8	−1.2	.251	.999935	−14	+11	−42	.999890	− 1
July 16	1	4 34	$50\frac{5}{60}$	19.1	13.4	16.3	23.9	23.9	23.9	−1.1	.169	.999944	−14	+10	−39	.999901	+10
,,	2	5 32	49	19.7	13.8	16.8	23.9	23.7	23.8	−1.2	.149	.999949	−15	+11	−39	.999906	+15
,,	3	6 35	66	19.9	12.9	16.1	24.0	23.8	23.9	−1.1	.259	.999935	−14	+10	−39	.999892	+ 1
,,	4	7 43	47	19.4	14.5	17.0	24.0	23.8	23.9	−1.1	.168	.999940	−15	+10	−39	.999896	+ 5
,,	5	8 41	61	19.7	13.5	16.6	24.2	23.8	24.0	−1.0	.199	.999946	−14	+ 9	−39	.999902	+11
,,	6	9 45	48	19.9	14.5	17.2	24.0	24.0	24.0	−1.0	.162	.999944	−15	+ 9	−39	.999899	+ 8
,,	7	10 41	33	20.3	15.2	17.8	24.4	24.0	24.2	− .8	.118	.999940	−16	+ 7	−39	.999892	+ 1
,,	8	11 15	40	19.4	14.9	17.2	24.0	24.2	24.1	− .9	.156	.999935	−15	+ 8	−39	.999889	− 2
,,	9	12 0	47	19.0	13.2	16.1	24.4	24.0	24.2	− .8	.184	.999935	−13	+ 7	−39	.999890	− 1

DATE.	Number.	Beginning of Experiment. (Local sidereal)	Number of minutes	Semi-arc of oscillation in mm. Initial.	Final.	Mean.	Temperature in degrees C. Initial.	Final.	Mean.	Mean Temp. − 25°	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation in sidereal seconds. Unreduced.	Corrections in 10^{-6} sidereal seconds for. Arc.	Temp.	Chron. rate.	Time of a single oscillation in sidereal seconds.	Residual.
July 17	1	6h.45m	45	19.5	14.7	17.1	23.2	23.2	23.2	−1.8	.170	.999937	−15	+17	−39	.999900	+ 9
,,	2	7 32	48 [illegible]	19.4	15.4	17.4	23.2	23.1	23.2	−1.8	.227	.999921	−16	+17	−39	.999883	− 8
,,	3	8 28	68	20.2	13.0	16.6	23.2	23.1	23.2	−1.8	.298	.999927	−14	+17	−39	.999891	± 0
,,	4	9 40	41	19.9	15.1	17.5	23.2	23.1	23.2	−1.8	.189	.999929	−16	+17	−39	.999891	± 0
,,	5	10 32	57 [illegible]	20.0	13.7	16.9	23.2	23.1	23.2	−1.8	.236	.999932	−15	+17	−39	.999895	+ 4
,,	6	11 35	51 [illegible]	13.7	9.9	11.8	23.2	23.2	23.2	−1.8	.249	.999920	− 7	+17	−39	.999891	± 0
July 18	1	4 46	62	19.7	13.1	16.4	23.0	22.9	23.0	−2.0	.226	.999939	−14	+19	−43	.999901	+10
,,	2	6 2	47 [illegible]	20.5	14.7	17.6	23.0	23.0	23.0	−2.0	.223	.999922	−16	+19	−43	.999882	− 9
,,	3	7 3	54	19.6	13.6	16.6	23.1	23.2	23.2	−1.8	.232	.999928	−14	+17	−43	.999888	− 3
,,	4	8 0	52	19.6	13.8	16.7	23.3	23.5	23.4	−1.6	.201	.999936	−14	+15	−43	.999894	+ 8
,,	5	9 2	74	20.9	13.0	17.0	23.7	24.2	24.0	−1.0	.309	.999930	−15	+ 9	−43	.999881	−10
,,	6	10 17	34 [illegible]	19.9	15.5	17.7	24.2	24.1	24.2	− .8	.124	.999941	−16	+ 7	−43	.999889	− 2
,,	7	11 0	59 [illegible]	19.6	13.0	16.3	24.3	24.3	24.3	− .7	.169	.999952	−14	+ 7	−43	.999902	+11
July 19	1	5 2	58	18.2	12.6	15.4	23.7	23.5	23.6	−1.4	.287	.999917	−12	+13	−42	.999876	−15
July 25	1	11 33	24 [illegible]	18.3	15.2	16.8	27.2	27.1	27.2	+2.2	.089	.999939	−15	−21	−26	.999877	−14
,,	2	13 7	41	19.7	14.4	17.1	27.2	27.2	27.2	+2.2	.144	.999941	−15	−21	−26	.999879	−12
,,	3	13 55	31 [illegible]	20.2	15.9	18.1	27.2	27.0	27.1	+2.1	.100	.999946	−17	−20	−26	.999883	− 8
"	4	16 31	37	19.0	14.6	16.8	26.9	26.8	26.9	+1.9	.072	.999968	−15	−18	−46	.999889	− 2

July 25	5	17h. 10m	34	18.8	14.9	16.9	26.9	26.7	26.8	+1.8	.075	.999963	−15	−17	−46	.999885	− 6
,,	6	18 35	36 [illegible]	19.2	11.6	16.9	26.5	26.4	26.5	+1.5	.072	.999967	−15	−14	−46	.999892	+ 1
July 26	1	6 35	51	18.7	13.4	16.1	25.9	26.0	26.0	+1.0	.103	.999966	−13	− 9	−44	.999900	+ 9
,,	2	7 34	38 [illegible]	20.7	16.0	18.4	26.2	26.4	26.3	+1.3	.078	.999968	−17	−12	−44	.999895	+ 4
,,	3	8 14	46 [illegible]	19.4	13.9	16.7	26.5	26.8	26.7	+1.7	.067	.999976	−14	−16	−44	.999902	+11
,,	4	9 7	34 [illegible]	20.7	16.0	18.4	26.9	27.1	27.0	+2.0	.059	.999971	−17	−19	−44	.999891	± 0
,,	5	10 17	51 [illegible]	19.7	13.7	16.7	27.4	27.4	27.4	+2.4	.064	.999979	−14	−22	−44	.999899	+ 8
,,	6	15 7	33	19.0	14.9	17.0	27.4	27.3	27.4	+2.4	.058	.999971	−15	−22	−43	.999891	± 0
,,	7	15 41	33 [illegible]	20.1	16.0	18.1	27.3	26.8	27.1	+2.1	.053	.999974	−17	−20	−43	.999894	+ 3
,,	8	16 17	43	19.8	14.9	17.4	26.9	26.7	26.8	+1.8	.064	.999975	−16	−17	−43	.999899	+ 8
,,	9	17 6	35	19.9	15.6	17.8	27.0	26.7	26.9	+1.9	.066	.999969	−16	−18	−43	.999892	+ 1
,,	10	17 44	36	19.3	15.3	17.3	26.8	26.7	26.8	+1.8	.065	.999970	−15	−17	−43	.999895	+ 4
,,	11	18 25	38	19.6	15.3	17.5	26.8	26.6	26.7	+1.7	.091	.999960	−16	−16	−43	.999885	− 6
															Mean	.999891 ±.0000007	

TABLE V.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM C AT TOKIO, AFTER THE EXCURSION.

DATE.	Number.	Beginning of Experiment Local sidereal	Number of minutes	Semi-arc of oscillation in mm.			Temperature in degrees C.			Mean Temp.	Sum of fractions of second at beginning and end of oscillation	Time of a single oscillation in sidereal seconds Uncorrected	Corrections in 10^{-6} sidereal seconds for			Time of a single oscillation in sidereal seconds	Residual.
				Initial.	Final.	Mean.	Initial.	Final.	Mean.				Arc.	Temp.	Coeff. rate.		
Sept. 7	1	8h.35m.	36 [illegible]	20.7	16.3	18.5	22.8	22.6	22.7	−2.3	.018	.999978	−18	+22	−75	.999907	+10
"	2	9 27	37	21.2	15.6	18.4	22.7	22.7	22.7	−2.3	.064	.999971	−17	+22	−75	.999901	+ 4
"	3	10 11	35	19.5	15.3	17.4	23.0	22.8	22.9	−2.1	.079	.999962	−16	+20	−75	.999891	− 6
"	4	10 49	31	20.3	16.0	18.2	22.9	22.8	22.9	−2.1	.070	.999966	−17	+20	−75	.999894	− 3
"	5	11 33	38	20.0	15.4	17.7	23.0	22.9	23.0	−2.0	.055	.999976	−16	+19	−75	.999904	+ 7
"	6	12 14	43	20.4	15.3	17.9	23.0	23.0	23.0	−2.0	.080	.999969	−17	+19	−75	.999896	− 1
"	7	12 57	23	20.0	16.9	18.5	23.3	23.2	23.3	−1.7	.050	.999964	−18	+16	−75	.999887	−10
"	8	13 34	41	17.3	13.3	15.3	23.2	23.2	23.2	−1.8	.097	.999961	−12	+17	−75	.999891	− 6
"	9	14 20	36 [illegible]	18.8	14.7	16.8	23.6	23.3	23.5	−1.5	.050	.999977	−15	+14	−75	.999901	+ 4
"	10	14 57	33	20.4	16.2	18.3	23.4	23.4	23.4	−1.6	.046	.999977	−17	+15	−75	.999900	+ 3
"	11	15 44	44	20.2	14.6	17.4	23.9	23.4	23.7	−1.3	.049	.999981	−16	+12	−75	.999902	+ 5
"	12	16 31	38 [illegible]	20.7	15.3	18.0	23.5	23.4	23.5	−1.5	.056	.999976	−17	+14	−75	.999898	+ 1
"	13	17 42	63 [illegible]	20.9	13.1	17.0	23.7	23.2	23.5	−1.5	.167	.999956	−15	+14	−75	.999880	−17
"	14	18 50	37 [illegible]	19.4	15.0	17.2	23.3	23.2	23.3	−1.7	.086	.999961	−15	+16	−75	.999887	−10
"	15	19 38	30 [illegible]	18.9	15.2	17.1	23.4	23.2	23.3	−1.7	.066	.999978	−15	+16	−75	.999904	+ 7
"	16	20 15	39 [illegible]	20.3	15.5	17.9	23.2	23.0	23.1	−1.9	.065	.999973	−17	+18	−75	.999899	+ 2
"	17	21 5	36 [illegible]	19.4	15.2	17.3	23.0	22.8	22.9	−2.1	.069	.999968	−15	+20	−75	.999898	+ 1
													MEAN...............			.999897	
																± .0000012	

TABLE VI.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM C AT OGASAWARAJIMA.

DATE.	No.	Beginning of Experiment (local sidereal.)	Number of minutes.	Semi-arc of oscillation in mm.			Temperature in degrees C.			Mean Temp. −25°	Sum of fractions of second at beginning and end of oscillations	Time of a single oscillation in sidereal seconds. Unreduced.	Corrections in 10⁻⁶ sidereal seconds for:			Time of a single oscillation in sidereal seconds.	Residual
				Initial.	Final.	Mean.	Initial.	Final.	Mean.				Arc.	Temp.	Chron. rate.		
Aug. 16	1	6h.31m.	39	19.6	14.8	17.2	26.3	26.9	26.6	+1.6	.436	1.000186	−15	−15	−49	1.000107	+20
,,	2	7 13	38	19.9	15.2	17.6	27.5	27.7	27.6	+2.6	.396	1.000174	−16	−24	−49	1.000085	− 2
,,	3	7 55	33	20.3	15.9	18.1	27.8	28.1	28.0	+3.0	.400	1.000202	−17	−28	−49	1.000108	+21
,,	4	8 37	46 [illegible]/60	19.7	14.2	17.0	28.2	28.6	28.4	+3.4	.526	1.000187	−15	−32	−49	1.000091	+ 4
,,	5	9 26	31 [illegible]/60	20.0	15.9	18.0	28.6	28.8	28.7	+3.7	.361	1.000189	−17	−35	−49	1.000088	+ 1
,,	6	9 59	34 [illegible]/60	20.0	15.6	17.8	28.8	28.9	28.9	+3.9	.392	1.000187	−16	−36	−49	1.000086	− 1
,,	7	10 43	57	19.8	13.6	16.7	28.9	29.0	29.0	+4.0	.643	1.000188	−14	−37	−49	1.000088	+ 1
,,	8	11 53	53	19.7	13.8	16.8	29.0	29.0	29.0	+4.0	.599	1.000188	−15	−37	−49	1.000087	± 0
,,	9	12 56	39	19.8	15.2	17.5	29.0	29.0	29.0	+4.0	.436	1.000186	−16	−37	−49	1.000084	− 3
,,	10	13 39	27	20.2	16.7	18.5	29.0	29.0	29.0	+4.0	.309	1.000190	−18	−37	−49	1.000086	− 1
,,	11	14 27	32 16/60	19.4	15.3	17.4	29.1	28.9	29.0	+4.0	.363	1.000188	−16	−37	−49	1.000086	− 1
,,	12	15 0	60 6/60	19.8	12.8	16.3	28.7	28.1	28.4	+3.4	.644	1.000179	−14	−32	−49	1.000084	− 3
,,	13	17 12	36 [illegible]/60	19.1	15.0	17.1	27.8	27.5	27.7	+2.7	.396	1.000183	−15	−25	−49	1.000094	+ 7
,,	14	17 51	37	20.4	15.5	18.0	27.5	27.2	27.4	+2.4	.376	1.000169	−17	−22	−49	1.000081	− 6
,,	15	18 29	31 [illegible]/60	19.9	15.7	17.8	27.3	27.1	27.2	+2.2	.319	1.000167	−16	−21	−49	1.000081	− 6
,,	16	19 16	26 [illegible]/60	19.3	15.7	17.5	27.1	27.0	27.1	+2.1	.273	1.000169	−16	−20	−49	1.000084	− 3
,,	17	19 45	34 6/60	19.7	15.4	17.6	27.1	26.8	27.0	+2.0	.319	1.000156	−16	−19	−49	1.000072	−15
,,	18	20 22	37	19.2	15.2	17.2	26.8	26.5	26.7	+1.7	.354	1.000159	−15	−16	−49	1.000079	− 8
															Mean........	1.000087	
																±.0000014	

TABLE VII.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM E AT TOKIO, BEFORE THE EXCURSION.

DATE.	Number.	Beginning of Experiment. (local sidereal.)	Number of minutes.	Semi-arc of oscillation in mm.			Temperature in degrees C.			Mean Temp. - 25°	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation in sidereal seconds. Unreduced.	Corrections in 10^{-6} sidereal seconds for.			Time of a single oscillation in sidereal seconds	Residual
				Initial.	Final.	Mean.	Initial.	Final.	Mean.				Arc.	Temp.	Chron. rate.		
Aug. 1	1	6h.35m.	63 [illegible]/60	19.8	11.8	15.8	26.1	26.2	26.2	+1.2	.611	1.000159	−13	−11	−48	1.000087	− 1
,,	2	7 42	41	19.7	14.0	16.9	26.3	26.4	26.4	+1.4	.385	1.000157	−15	−13	−48	1.000081	− 7
,,	3	8 35	38 [illegible]/60	20.4	14.7	17.6	26.4	26.5	26.5	+1.5	.364	1.000158	−16	−14	−48	1.000080	− 8
,,	4	9 15	31	20.6	15.6	18.1	26.6	26.7	26.7	+1.7	.307	1.000165	−17	−16	−48	1.000084	− 4
,,	5	10 3	40	20.7	14.7	17.7	26.9	26.9	26.9	+1.9	.402	1.000168	−16	−18	−48	1.000086	− 2
,,	6	10 45	38	20.6	14.9	17.8	26.9	27.0	27.0	+2.0	.351	1.000154	−16	−19	−48	1.000071	−17
,,	7	11 24	31 [illegible]/60	20.3	15.6	18.0	27.0	27.0	27.0	+2.0	.816	1.000168	−17	−19	−48	1.000084	− 4
,,	8	12 3	40	20.4	14.5	17.5	27.1	27.1	27.1	+2.1	.415	1.000173	−16	−20	−48	1.000089	+ 1
,,	9	12 47	73	20.0	10.9	15.5	27.2	27.1	27.2	+2.2	.755	1.000172	−12	−21	−48	1.000091	+ 3
,,	10	14 8	67	20.4	11.6	16.0	27.1	27.0	27.1	+2.1	.683	1.000170	−13	−20	−48	1.000089	+ 1
,,	11	16 11	40 [illegible]/60	20.3	14.5	17.4	27.2	27.1	27.2	+2.2	.357	1.000148	−16	−21	−48	1.000063	−25
,,	12	16 55	31 [illegible]/60	19.9	15.2	17.6	27.1	27.0	27.1	+2.1	.319	1.000171	−16	−20	−48	1.000087	− 1
,,	13	18 22	36	20.6	15.2	17.9	27.2	27.0	27.1	+2.1	.355	1.000164	−17	−20	−40	1.000087	− 1
,,	14	19 4	36 [illegible]/60	20.2	14.4	17.3	26.9	26.8	26.9	+1.9	.360	1.000166	−15	−18	−40	1.000093	+ 5
,,	15	19 42	40 [illegible]/60	20.9	14.8	17.9	26.7	26.6	26.7	+1.7	.372	1.000153	−17	−16	−40	1.000080	− 8
,,	16	20 26	26	20.8	15.5	18.2	26.6	26.5	26.6	+1.6	.224	1.000144	−17	−15	−40	1.000072	−16

Aug. 2	1	7	39	40	20.8	14.8	17.8	26.2	26.1	26.2	+1.2	.356	1.000148	−16	−11	−41	1.000080	− 8
,,	2	8	20	28	20.1	15.6	17.9	26.1	26.3	26.2	+1.2	.238	1.000141	−17	−11	−41	1.000072	−16
,,	3	9	40	29	18.9	15.0	17.0	26.4	27.1	26.8	+1.8	.263	1.000154	−15	−17	−41	1.000081	− 7
,,	4	10	14	52	20.0	13.3	16.7	27.2	27.0	27.1	+2.1	.515	1.000165	−14	−20	−41	1.000090	+ 2
,,	5	12	22	43	19.4	13.6	16.5	27.4	27.3	27.4	+2.4	.437	1.000169	−14	−22	−41	1.000092	+ 4
,,	6	13	7	32	20.7	15.8	18.3	27.4	27.3	27.4	+2.4	.326	1.000170	−17	−22	−41	1.000090	+ 2
,,	7	14	20	40	20.2	13.9	17.1	27.2	27.1	27.2	+2.2	.416	1.000174	−15	−21	−41	1.000097	+ 9
,,	8	15	3	55	19.6	12.5	16.1	27.2	27.0	27.1	+2.1	.602	1.000182	−13	−20	−41	1.000108	+20
,,	9	16	1	48$\frac{4}{60}$	19.9	13.2	16.6	27.0	27.0	27.0	+2.0	.504	1.000175	−14	−19	−41	1.000101	+13
,,	10	16	50	33$\frac{4}{60}$	20.6	15.6	18.1	27.1	27.0	27.1	+2.1	.332	1.000167	−17	−20	−41	1.000089	+ 1
,,	11	17	25	36	19.3	14.3	16.8	27.0	26.9	27.0	+2.0	.361	1.000167	−15	−19	−41	1.000092	+ 4
,,	12	18	6	44$\frac{9}{60}$	19.5	13.3	16.4	26.9	26.9	26.9	+1.9	.438	1.000166	−14	−18	−41	1.000093	+ 5
,,	13	18	51	52$\frac{30}{60}$	20.1	12.9	16.5	26.9	26.9	26.9	+1.9	.564	1.000178	−14	−18	−41	1.000105	+17
,,	14	19	46	31$\frac{40}{60}$	19.9	15.0	17.5	26.9	26.9	26.9	+1.9	.344	1.000181	−16	−18	−39	1.000108	+20
,,	15	20	23	44$\frac{10}{60}$	20.3	13.9	17.1	26.9	26.8	26.9	+1.9	.475	1.000179	−15	−18	−39	1.000107	+19
Aug. 3	1	9	14	35	18.9	13.8	16.4	26.8	26.7	26.8	+1.8	.344	1.000164	−14	−17	−39	1.000094	+ 6
																Mean..................	1.000088 ±.0000013	

TABLE VIII.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM E AT TOKIO, AFTER THE EXCURSION.

DATE.	Number.	Beginning of Experiment. (local sidereal.)	Number of minutes.	Semi-arc of oscillation in mm.			Temperature in degrees C.			Mean Temp. −25	Sum of fractions of second at beginning and end of oscillations.	Time of a single oscillation in sidereal seconds. Unreduced.	Corrections in 10^{-6} sidereal seconds for			Time of a single oscillation in sidereal seconds	Residual
				Initial	Final.	Mean.	Initial.	Final.	Mean.				Arc.	Temp.	Chro^r rate.		
Sept. 5	1	10h25m	41	19.0	13.4	16.2	23.6	23.5	23.6	−1.4	.391	1.000159	− 14	+ 13	− 73	1.000085	− 4
,,	2	11 14	55	19.2	12.2	15.7	23.7	23.7	23.7	−1.3	.526	1.000159	− 13	+ 12	− 73	1.000085	− 4
,,	3	12 20	$37\frac{18}{60}$	19.7	13.9	16.8	23.7	23.8	23.8	−1.2	.369	1.000162	− 15	+ 11	− 73	1.000085	− 4
,,	4	13 5	$31\frac{7}{60}$	20.2	15.6	17.9	24.4	23.9	24.2	− .8	.304	1.000163	− 17	+ 7	− 73	1.000080	− 9
,,	5	13 42	$31\frac{23}{60}$	18.8	14.9	16.9	24.4	24.1	24.3	− .7	.323	1.000169	− 15	+ 7	− 73	1.000088	− 1
,,	6	14 38	31	19.3	15.1	17.2	24.2	24.1	24.2	− .8	.302	1.000162	− 15	+ 7	− 73	1.000081	− 8
,,	7	15 13	$36\frac{13}{60}$	20.2	15.2	17.7	24.1	24.1	24.1	− .9	.392	1.000180	− 16	+ 8	− 73	1.000099	+ 10
,,	8	15 53	28	20.5	16.2	18.4	24.4	24.2	24.3	− .7	.300	1.000179	− 17	+ 7	− 73	1.000096	+ 7
,,	9	16 31	$42\frac{10}{60}$	18.8	13.2	16.0	24.4	24.1	24.3	− .7	.407	1.000161	− 13	+ 7	− 73	1.000082	− 7
,,	10	17 18	$29\frac{13}{60}$	20.6	16.2	18.4	24.3	24.1	24.2	− .8	.299	1.000170	− 17	+ 7	− 68	1.000092	+ 3
,,	11	17 53	30	20.8	16.3	18.6	24.3	24.1	24.2	− .8	.317	1.000176	− 18	+ 7	− 68	1.000097	+ 8
,,	12	18 42	$35\frac{17}{60}$	19.5	14.5	17.0	24.2	23.9	24.1	− .9	.346	1.000163	− 15	+ 8	− 68	1.000088	− 1
,,	13	19 23	$28\frac{8}{60}$	20.4	16.0	18.2	23.9	23.8	23.9	−1.1	.265	1.000157	− 17	+ 10	− 68	1.000082	− 7
,,	14	19 58	36	19.8	14.6	17.2	23.9	23.6	23.8	−1.2	.389	1.000180	− 15	+ 11	− 68	1.000103	+ 19
Sept. 8	1	10 6	$46\frac{18}{60}$	13.9	18.0	16.0	22.0	22.1	22.1	−2.9	.423	1.000152	− 13	+ 27	− 76	1.000090	+ 1
,,	2	10 55	$46\frac{8}{60}$	21.7	14.7	18.2	22.2	22.2	22.2	−2.8	.444	1.000161	− 17	+ 26	− 76	1.000094	+ 5
,,	3	11 52	$30\frac{8}{60}$	20.5	16.0	18.3	22.5	22.3	22.4	−2.6	.324	1.000179	− 17	+ 24	− 76	1.000110	+ 21

Sept. 8	4	12h25m	$47\frac{2}{60}$	21.3	14.4	17.9	22.4	22.4	22.4	−2.6	.448	1.000159	− 17	+ 24	− 76	1.000090	+ 1
,,	5	13 17	$33\frac{4}{60}$	20.5	15.4	18.0	23.0	22.6	22.8	−2.2	.320	1.000161	− 17	+ 21	− 76	1.000089	± 0
,,	6	14 55	$41\frac{5}{60}$	19.3	13.6	16.5	22.9	22.8	22.9	−2.1	.402	1.000163	− 14	+ 20	− 76	1.000093	+ 4
,,	7	16 17	$61\frac{44}{60}$	21.3	12.6	17.0	22.7	22.6	22.7	−2.3	.562	1.000152	− 15	+ 22	− 76	1.000083	− 6
,,	8	18 7	$39\frac{14}{60}$	20.7	14.8	17.8	22.6	22.4	22.5	−2.5	.301	1.000128	− 16	+ 23	− 55	1.000080	− 9
,,	9	18 57	$56\frac{38}{60}$	18.3	11.5	14.9	22.5	22.4	22.5	−2.5	.436	1.000127	− 11	+ 23	− 55	1.000084	− 5
,,	10	20 1	$51\frac{20}{60}$	20.2	13.2	16.7	22.7	22.3	22.5	−2.5	.396	1.000129	− 14	+ 23	− 55	1.000083	− 6
															Mean..................	1.000089	
																±.0000011	

TABLE IX.

RESULTS OF EXPERIMENTS MADE WITH PENDULUM E AT OGASAWARAJIMA.

DATE.	Number.	Beginning of Experiment. (Local sidereal)	Number of minutes.	Semi-arc of oscillation in mm.			Temperature in degrees C.			Mean Temp. −25°	Sum of fractions of second at beginning and end at oscillations	Time of a single oscillation in sidereal seconds. Unreduced.	Corrections in 10^{-9} sidereal seconds for.			Time of a single oscillation in sidereal seconds	Residual
				Initial.	Final.	Mean.	Initial.	Final.	Mean.				Arc.	Temp.	Chrof rate		
Aug. 14	1	5h23m	39	19.4	14.1	16.8	27.0	27.1	27.1	+2.1	.842	1.000360	− 15	− 20	− 46	1.000279	+ 8
,,	2	6 5	35 [illegible]/60	21.0	15.4	18.2	27.2	27.7	27.5	+2.5	.756	1.000356	− 17	− 23	− 46	1.000270	− 1
,,	3	6 42	36	19.6	14.4	17.0	27.8	28.4	28.1	+3.1	.769	1.000356	− 15	− 29	− 46	1.000266	− 5
,,	4	7 24	37	20.0	14.8	17.4	28.5	28.9	28.7	+3.7	.805	1.000363	− 16	− 35	− 46	1.000266	− 5
,,	5	8 0	35 [illegible]/60	20.2	14.9	17.6	28.9	29.1	29.0	+4.0	.773	1.000359	− 16	− 37	− 46	1.000260	− 11
,,	6	8 41	39	19.7	14.4	17.1	29.1	29.3	29.2	+4.2	.831	1.000355	− 15	− 39	− 46	1.000255	− 16
,,	7	9 29	42	19.8	13.8	16.8	29.4	29.5	29.5	+4.5	.915	1.000363	− 15	− 42	− 46	1.000260	− 11
,,	8	11 43	40	19.8	14.0	16.9	29.9	29.8	29.9	+4.9	.870	1.000362	− 15	− 46	− 46	1.000255	− 16
,,	9	12 27	25 [illegible]/60	18.4	14.8	16.6	29.8	29.8	29.8	+4.8	.560	1.000370	− 14	− 45	− 46	1.000265	− 6
,,	10	13 0	50	19.7	12.9	16.3	29.8	29.4	29.6	+4.6	1.095	1.000365	− 14	− 43	− 46	1.000262	− 9
,,	11	14 56	30 [illegible]/60	19.7	15.3	17.5	29.1	28.9	29.0	+4.0	.679	1.000376	− 16	− 37	− 46	1.000277	+ 6
,,	12	15 29	28 [illegible]/60	19.8	15.5	17.7	28.9	28.8	28.9	+3.9	.641	1.000369	− 16	− 36	− 46	1.000271	± 0
,,	13	16 34	29	19.3	15.1	17.2	28.5	28.2	28.4	+3.4	.633	1.000364	− 15	− 32	− 46	1.000271	± 0
,,	14	17 4	41 [illegible]/60	18.9	13.2	16.1	28.2	28.0	28.1	+3.1	.939	1.000373	− 13	− 29	− 46	1.000285	+ 14
,,	15	17 48	16	20.4	17.5	18.9	28.1	28.0	28.1	+3.1	.361	1.000376	− 18	− 29	− 46	1.000283	+ 12
,,	16	18 24	43 [illegible]/60	20.6	14.1	17.4	28.0	27.8	27.9	+2.9	1.145	1.000439	− 16	− 27	− 46	1.000350	+ 79

Aug. 14	17	19h13m	42$\frac{38}{60}$	20.7	14.1	17.4	28.1	27.8	28.0	+3.0	.911	1.000353	− 16	− 28	− 46	1.000263	− 8
,,	18	20 14	36	20.3	15.2	17.8	27.8	27.7	27.8	+2.8	.754	1.000349	− 16	− 26	− 46	1.000261	− 10
,,	19	20 52	28	20.9	16.1	18.5	27.7	27.6	27.7	+2.7	.593	1.000353	− 18	− 25	− 46	1.000264	− 7
,,	20	22 23	37	20.3	14.9	17.6	27.7	27.3	27.5	+2.5	.795	1.000358	− 16	− 23	− 44	1.000275	+ 4
Aug. 17	1	5 20	39	19.0	13.5	16.3	27.3	27.1	27.2	+2.2	.860	1.000368	− 14	− 21	− 44	1.000289	+ 18
,,	2	6 8	41	21.0	14.0	17.5	27.3	27.7	27.5	+2.5	.898	1.000365	− 16	− 23	− 44	1.000282	+ 11
,,	3	7 45	40	19.5	14.0	16.8	28.3	28.7	28.5	+3.5	.870	1.000362	− 15	− 33	− 44	1.000270	− 1
,,	4	9 1	62$\frac{58}{60}$	23.0	12.0	17.5	29.0	29.0	29.0	+4.0	1.386	1.000367	− 16	− 37	− 44	1.000270	− 1
,,	5	10 17	41	25.0	17.0	21.0	29.3	29.2	29.3	+4.3	.934	1.000380	− 22	− 40	− 53	1.000265	− 6
,,	6	11 7	36$\frac{58}{60}$	20.7	15.3	18.0	29.2	29.2	29.2	+4.2	.798	1.000360	− 17	− 39	− 53	1.000251	− 20
,,	7	11 46	48	19.4	13.2	16.3	29.2	29.2	29.2	+4.2	1.057	1.000367	− 14	− 39	− 53	1.000261	− 10
,,	8	12 40	67	22.4	12.9	17.7	29.3	28.2	28.8	+3.8	1.459	1.000363	− 16	− 36	− 53	1.000258	− 13
,,	9	21 33	40	19.8	14.3	17.1	26.0	25.9	26.0	+1.0	.841	1.000350	− 15	− 9	− 53	1.000273	+ 2
,,	10	22 16	51	19.7	12.8	16.3	25.9	25.6	25.8	+ .8	1.064	1.000348	− 14	− 7	− 53	1.000274	+ 3
															Mean	1.000271	
																±.0000021	

MEMOIRS

OF THE

SCIENCE DEPARTMENT,

TOKIO DAIGAKU.

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No. 6.

THE CHEMISTRY

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CONTENTS.

PART I. KÔJI.

PART II. SAKÉ BREWING.

PREFACE.

Previous to the year 1878 no scientific account of the brewing of saké had appeared, the principal papers which had been published being a translation by Professor J. J. Hofmann, of Leyden, of an article from the Japanese Encyclopædia, 1714, and a paper in the transactions of the German Asiatic Society of Japan by Dr. Hofmann, then Professor in the Medical School of the University of Tókiô. In December, 1878, Mr. O. Korschelt published an elaborate paper on the subject in the same transactions, in which he gave a detailed description of two processes used in Tôkiô, and the results of special experiments made by himself, after which it seemed that very little more could be said. But continued study of the brewing-process has yielded results which enable us to explain with greater accuracy the chemical changes involved in the manufacture, and although much yet remains to be achieved, the present essay will, I trust, be accepted as another rung in the endless ladder of scientific investigation.

In carrying out this research I have been assisted in very various ways by a number of friends, all of whom it would be impossible to mention individually, but I should with reason incur the charge of ingratitude did I not put in the front rank Mr. Kato, President, and Mr Hattori, Vice-President, of the University, to whom indeed the very existence of this memoir is owing. My thanks are also due to Mr. Jihei Kamayama and to Mr. Tobei Iizuka, of Yûshima, Tòkiô, Proprietors of the kóji and saké works respectively; to Mr. Mansuké Izumi, of Nishinomiya, and to Mr. Shinyemon Konishi, of Itami, to all of whom I owe much valuable information.

To M. Pasteur I am indebted for permission, to make use of plates XVII, XVIII, and XIX, taken from his "Études sur le Vin". Without the cordial coöperation of my assistant, Mr. Nakazawa, my task would have been much more difficult, and thus publicly I desire to acknowledge my indebtedness to him. Plate XVI. I owe to Professor Ewing, and Professor Cooper has with the greatest kindness looked over the proofs for me.

The substance of Part I of this memoir was communicated to the Royal Society of London in a Paper read on 10th March. 1881.

The printing of the memoir was carried out at the Government Printing Office (Insetsu Kiyoku), and the plates were engraved by the Gengendo Engraving Company.

The accompanying French and English equivalents of the Japanese weights and measures used in the text will prove of assistance to those who are not familiar with them.

1 kuwamme (kw.)	= 3.75 kilos.	= 8.28 lbs.
1 shaku	= 0.30303 metre	= 0.9942 ft.
1 chô (= 10 tan)	= 0.99174 hectare	= 2.45 acres.

1 koku (= 10 tô = 100 sho = 1000 go) = 180.39 litres {= 4.963 bushels. / = 39.7 gallons.}

1 yen (paper) (= 100 sen) = about 2s-6d.

R. W. A.

University of Tôkiô, Japan.
May, 1881.

INTERIOR OF SAKÉ BREWERY.

(Reduced from Nihon-san-kai-mei-san-zuye 1799.)

INTRODUCTION.

It is probably impossible now to ascertain when the art of brewing first became known to the Japanese. Tradition ascribes its introduction to some emigrants from Korea about the end of the third century, who doubtless obtained the knowledge from China where it had long been practised. How improvements were introduced we can only surmise, but it is known that about the end of the XVth century, the two districts of Itami and Ikeda had established their superiority over all others, a position which, together with Nishinomiya, they hold to this day. About 300 years ago a very important improvement was effected relating to the preservation of the saké which, in the hot months of summer very quickly became undrinkable. This consisted in heating the saké to such a temperature that the hand could not bear it, but, although answering the purpose for a time, it did not suffice in the manner in which the heating was carried out to permit the liquid to be kept for any lengthened period. Nor has any important alteration in the process of manufacture been introduced since that time notwithstanding the trouble entailed upon the brewer by the repeated heating of the saké which is necessary, but it is hoped that the suggestions made in this memoir may have the effect of directing attention to the important and efficient process introduced by M. Pasteur for preserving wine.

I am indebted to Mr. Shigetoshi Yoshiwara, Vice-Minister of Finance, for the following statement of the quantity of the various kinds of alcoholic liquids produced in the year ending September 30th, 1880.

	Tax per koku	No. of koku	Revenue in yen
Ordinary saké (seishû)	1 yen	5,015,084	5,015,084
Turbid saké (nigorizake)	0.3 „	65,494	19,648
White saké (shiro-zake)	2 „	1,500	3,000
Sweet saké used for cooking (mirin)	2 „	38,569	77,138
Liqueur (meishû)	3 „	3,615	10,845
Spirit (shôchû)	1.5 „	83,708	125,562
		5,207,970	5,251,277

Fees from sale of licences to brewers and retail dealers..	1,208,293
Total revenue derived from alcoholic liquors..........	6,459,570 yen

The estimated amount of revenue from alcoholic liquors for the year ending September 30th, 1881 is 10,795,025 yen, the total estimated revenue being yen. 56,616,907. The former estimate is much greater than the actual yield of the past year, owing to the considerable changes which have been made both in the amounts and in the mode of collecting the taxes.* The amount of the different kinds of saké given in the table above is 5,207,970 koku, or 206,756,409 gallons., but this number does not express the total quantity consumed, for without any doubt, much saké which is not taxed, is prepared in private houses in the country. Taking into consideration only the amount of ordinary saké used, say 5 million koku, or 198 million gallons, the consumption corresponds to 6 gallons per head per annum reckoning the population at 33 millions. If it were diluted twice so as to be about the same strength as beer, the consumption would be doubled, that is 12 gallons a head, whilst the consumption of beer in England averages 34 gallons per head, nearly three times as much as in Japan. The brewing of saké is, therefore, relatively of less importance than that of beer in England, and this is doubtless to be ascribed to the enormous consumption of tea, which serves at all times, in summer and in winter, as the national beverage.

The study of the chemical reactions involved in the brewing process described in the following pages has brought to light a fact of some importance relating to the physiology of plants, viz. that the growth of a mould over the surface of perfectly dead rice grains causes a change in the character of the albumenoid matter of the grain resembling that which results from the germination of the embryo of similar grains. I cannot omit here to draw attention to the mutual advantage to be derived from an association of workers in industrial and in pure science; the coöperation cannot but be of the greatest utility on the one hand, by suggesting new subjects for research to the theoretical worker, and on the other, in aiding the practical man to attain the best results possible. The student of science in Japan has a wide field before him; that system of isolation which has prevented the introduction of Western knowledge till within the last quarter of a century has not been entirely fruitless, for it has resulted in the development of industrial processes which are as novel and interesting to the European as those of the latter are to Japanese. The scientific students of the university and colleges of Japan need not, therefore, look very far in order to find subjects that require investigation and explanation, and this search will, without doubt, add largely to the sum total of existing knowledge.

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* The estimated revenue derived from the production and sale of alcoholic liquors given above differs greatly from that which appears in the Estimates of the Minister of Finance for the year ending June 30th, 1881. The number there given is yen 5,965,029, or very little more than one-half the estimates for the year ending three months later. The explanation of the difference lies in the fact that since the Estimates of the Minister of Finance were published the taxes have been doubled.

PART I. KOJI.

SECTION. 1.

RICE.

The grain from which alcohol is produced in Japan is the same as that which forms the staple article of diet for all classes, viz. rice, and its cultivation employs the labour of the greater number of the population. According to the Official Catalogues of the Japanese Exhibits at Philadelphia, in 1876, and at Paris, in 1878, the total area of paddy land is 1,611.130 chô (3,947,268 acres), and the yield of rice amounts to 28,000,000 koku (138,964,000 bushels), giving an average yield of a little more than 35 bushels per acre. The numbers given by General LeGendre in his work, "Progressive Japan," are larger than these, but are said to have been obtained from the Finance department, being the results of more recent surveys. He says "According to recent surveys (1874-78) the area of rice fields in Japan is 2,539,090 chô and 47 tan, and the area of other fields (Miscellaneous cultures) is 1,732,449 chô and 73 tan (Figures procured at the Okura-Sho)."* Further on he gives the total quantity of rice produced as 34,394,787 koku, a number also furnished by the Okura-Sho (Finance Department.), and from these the average yield of rice is calculated to be a little more than 27 bushels per acre. These numbers include rice of all kinds, several hundred varieties, but of these there are only three which are sufficiently well marked to particularize. One variety is called *Okabo*, and is grown in dry fields, whilst the two others, common rice (*uruchi*), and glutinous rice (*mochigome*) are grown in paddy fields. It is said that the upland rice (*okabo*) is well suited for brewing purposes because it leaves very little residue, but I have had no experience of its use for that purpose, that which is almost universally employed being the common rice (*uruchi*). Glutinous rice is never used for the brewing of saké, the reason given being that the liquid prepared from it would rapidly putrefy, but another possible reason is its greater cost.

The best qualities of rice come from Mino, Higo, Ise, Owari, Tôtômi, and Hizen. The next best are from Boshiu, Tamba, Tajima, and the third quality from Kadzusa, Shimôsa, Musashi, and Kaga.

The following analyses of the two kinds of rice were made in the University laboratory.

* Progressive Japan. Note at the foot of the table given at the end.

TABLE I. ANALYSES OF HULLED RICE OF VARIOUS YEARS.

		Common Rice.							Glutinous Rice.		
		Ise 1877	Mino 1877	Banshiu 1877	Ise 1879	Mino 1879	Sendai 1879	1880	Koshigaya 1877	Kazai 1877	1879
	Water	11.96	13.02	12.86	11.79	11.54	12.68	11.96	12.41	12.60	10.56
Soluble in water.	Sugar and dextrin	3.22	3.52	6.45	1.49	2.60	3.94	1.99	4.78	4.40	4.06
	Ash	.72	.87	1.12	1.17	1.22	.88	.58	1.46	1.06	1.12
	Albumenoids	} 4.79	} 5.07	} 5.18	1.04	.98	} 5.60	1.76	} 4.30	} 4.30	.74
Insoluble in water.	Albumenoids				5.74	4.99		5.42			5.62
	Starch	74.69	72.52	69.28	73.31	73.73	72.54	73.31	72.86	72.81	70.15
	Cellulose	2.08	3.18	3.27	2.50	2.54	2.85	3.68	2.79	2.07	3.63
	Fat	.90	1.21	1.85	1.27	1.57	.94	1.07	1.80	1.18	2.48
	Ash	.74	.06	.09	.14	.10	.54	.22	.16	.99	.38
		100.00	100.00	100.00	98.51	99.27	99.51	99.99	100.00	100.00	98.71

No essential difference in chemical composition between the two kinds of rice is disclosed by the foregoing analyses, but the two grains can be distinguished at the first glance after removing the husk, the common rice being translucent, whilst the glutinous rice is white and opaque. The name "glutinous rice" is given to the latter, doubtless, from the peculiarity it possesses of forming, when steamed and beaten, pasty lumps of great tenacity, a property which is not shared by the common rice. It is a similar property to that possessed by wheaten flour, and in that grain is due to the presence of a peculiar nitrogenous body called "gliadin" which is not present to any marked extent in other grains. This substance is soluble in hot alcohol and if it were present in glutinous rice might be expected to be found in the alcoholic solution, but experiments made for that purpose have not shown any great difference between the two kinds of rice in the proportion of albumenoids dissolved by alcohol. Nor is there any difference in the amounts soluble in cold water; the only essential difference I have been able to detect is in the action of iodine solution upon the flour, that of common rice being coloured deep blue, like starch, and that of the glutinous variety red, like dextrin. The cause of this difference more probably lies in the nature of the albumenoids than in the proportions of dextrin.

The weight of a given bulk of rice varies considerably according to the way in which it is packed, and in calculating the weights of rice used in saké-brewing from the volume, I have taken what may be considered a fair average, viz. 40 *kuwamme* per *koku*. This is founded upon the following direct [illegible]

One *shô* of the specified kinds of rice was loosely placed in the measure, and without shaking, carefully levelled: each number is the mean of seven weighings.

		Weight of one *shô*	Weight of one *koku*
Common rice	Kazai	1391 grams	37.03 *kuwamme*
	Sendai	1346 ,,	35.83 ,,
	Mino	1379 ,,	36.72 ,,
	Ise	1401 ,,	37.30 ,,
Glutinous rice	Kazai	1394 ,,	37.12 ,,
		Mean	36.80 ,,

When the rice was tightly packed, that is, after being well shaken down, the average weight of one *koku* was 42 *kuwamme*, and as a rough average between the weights when loosely and when tightly packed, 40 *kuwamme* per *koku* will not be far from the truth.

The rice grain is a complex structure formed of a great many distinct parts, some of which can be readily parted by ordinary mechanical appliances, whilst others can only be separated by special means. Of the former is the hard outer coat, itself composed of several different parts, which is generally removed by the farmer as chaff before the rice is sent into the market. The hulled grain, in the form in which it is bought for food consists of three easily discernible parts, a thin, yellowish skin on the outside (the testa), within this the white starchy matter which constitutes the nutritious part of the grain (the endosperm), and at the lower end a portion of a different appearance, usually horny and shrivelled looking (the embryo). Immediately below the testa the cells of the endosperm do not differ in general appearance from those in the interior, but the greater part of the albumenoid matter of the endosperm is accumulated in these cells. An excellent test for the presence of albumenoids is mercuric nitrate; if a section of a grain of rice be steeped in such a solution those portions which contain albumenoid matter become coloured red, whilst the rest of the grain remains uncoloured. When a thin slice of the unwhitened grain is thus treated the cells forming the testa have a somewhat greenish colour and can be sharply distinguished from the layer immediately within, which is deeply coloured red. This coloration extends inwards for a distance a little greater than the thickness of the testa, but the form of the cells thus coloured does not appear to be different from the remainder of those forming the endosperm, and which assume no coloration. In a similar section of whitened rice the outer layer of greenish, square cells is not seen, and the edges present a jagged appearance, but the outer cells are as strongly coloured red as before, showing that only a small portion, if any, of the cells containing nitrogenous matter has been removed. In fact, the thickness of the layer coloured red cannot be said to have perceptibly diminished. The red coloration is not uniform but is distributed over numerous points, being stronger near the testa and becoming fainter away from it; under a high power distinct *points* of red matter can be distinguished; these are the aleurone grains.

When the rice grain is whitened the testa is removed by beating, and analyses show that the bran so obtained contains much more nitrogen than the average of the entire hulled grain. The two following analyses are taken from a paper on "The Agricultural Chemistry of Japan" by Prof. Kinch.*

COMPOSITION OF BRAN (*nuka*).

	A.	B.
Water	10.96	11.05
Ash	9.11	9.22
Oil	13 20	15.50
Fibre	7.66	8.60
Albumenoids	13.41	13.55
Soluble carbohydrates	45 66	42.08
	100.00	100.00

These analyses show that the ash, oil, fibre, and albumenoids are contained in large proportion in the bran. Together with the testa, which is mainly fibre, or cellulose, the embryo is removed, and it is from that source that most of the fat and nitrogenous matter is derived. Notwithstanding the large percentage of albumenoid matter contained in the bran, that in the whitened rice has not very greatly diminished: thus in one specimen which contained 7.4 per cent. before cleaning, afterwards 6.9 per cent. was found, the proportion of moisture being the same in each. As the bran contains so much nitrogenous matter it might have been expected that the grain after whitening would have shown a marked diminution; that it does not do so is owing to the fact that the whitened grains are selected, those which are unbroken being separated from those which have been much broken. Thus there result on the one hand grains broken into minute portions containing very little nitrogen, and sold to the *ame* maker, on the other, the unbroken, whitened grains containing still almost all the protein matter of the endosperm, and deprived of testa and embryo which together form the bran (*nuka*), and contain the largest percentage of albumenoids.

The following analyses of the whitened rice grain are given because from them the samples of *kôji*, the composition of which is given afterwards (p. 12) were prepared. A is the rice used for making *kôji* at the Yûshima works; B is the rice used at the Tôkiô brewery in the operations described in Part II.

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* Trans. Asiat. Soc. Japan. VIII. 393.

COMPOSITION OF WHITENED RICE DRIED AT 100° C.

		A.			B.		
Insoluble in water.	Starch	82.27		per cent.	82.14		per cent.
	Cellulose	4.79		,,	3.02		
	Fat	.49		,,	1.12		
	Ash	.46		,,	.16		
Soluble in water.	Albumenoids.	7.50	9.45			8.82	
	Albumenoids.	1.95					
	Dextrose and Dextrin	1.91		,,	3.97		
	Ash	.63		,,	0.77		
		100.00		,,	100,00		
	Water	12.70		,,	12.19		

SECTION. 2.

PREPARATION OF KÔJI.

Starch is a substance insoluble in water and incapable of undergoing fermentation directly, that is, of being converted into alcohol. In beer-making countries the conversion of the starch into a sugar from which alcohol can be produced is effected by the use of malt, a body formed by allowing the embryo of the barley grain to become partially developed, by which a change in the character of the grain occurs, as the result of which it becomes possessed of certain properties attributed to the existence of a hypothetical substance known as "diastase." The peculiarity of "diastase" is that it is a body containing nitrogen and having the power of rendering thick starch-paste liquid owing to the formation from it of the sugar maltose together with dextrin.. Other kinds of "diastase" occur, as for example in the saliva, and in the pancreas, and these forms. although they resemble in some respects the diastase contained in malt, differ from it in other particulars. Thus, the diastase of malt is not able to cause maltose to take up water and so be converted into dextrose, but both the diastase of the saliva and of the pancreas effect the hydration of maltose and change it into dextrose. It is evident, therefore, that different kinds of "diastase" exist, and that it is not one substance only which possesses these properties. As the material "koji" is employed in the manufacture of *saké*, and as it is used for the same purpose as malt in beer-breweries it becomes necessary to examine it in some detail that we may ascertain how far it agrees with, and how far it differs from other similar bodies

Koji is prepared both in breweries and in special works, as it is used for various purposes besides *saké* making. It will be most convenient for us to examine the mode of manufacture in the special kōji works, as there will be found the conditions essential to its successful production more readily than in the *saké* breweries. I am especially indebted to Mr. Jihei Kamayama, of Yûshima, Tōkiō, for much information as well as for permission to investigate at his works the whole process of manufacture.

The essential part of the process is carried out in long narrow passages cut in the solid clay about 15 or 20 feet below the surface of the ground. The object of this is to have a chamber which being once heated will not easily lose its heat either by radiation or by conduction. That this result is produced by cutting the chambers in the clay is shown by the constancy of temperature which they are found to possess even when considerable changes take place in the temperature of the outer air. Clay is a very bad conductor of heat, and it is practically impossible for heat to be communicated either to or from these passages through the clay. The passages are about 25 or 30 feet in length, and each set is reached through a very low and narrow one—made so for the purpose of preventing as much as possible an exchange between the outer and the inner air. The opening passage is not more than between 3 and 4 feet high, and about 4 feet wide, and is usually closed with mats. It is approached by descending a shaft from the ground above, and at the other end it opens into a passage of somewhat larger dimensions, from which two others branch off nearly at right angles. It is in these innermost parts that the highest temperature is maintained. In the saké-breweries the warm chambers are less carefully constructed, being built near the surface of the ground of wooden planks coated with mud and thickly covered over with straw mats. This is evidently a less perfect method of keeping in the heat than that adopted in the kōji works proper. Having described the apparatus used we may now consider how the rice is treated. It is brought to the works husked but not cleaned, and the process of cleaning or whitening, is done by the manufacturers. This consists in removing that thin outer skin, the testa, which, as we have seen, contains a large proportion of cellulose and mineral matter. It is removed by the brewers, as they say, because it would render the liquid brewed very liable to putrefy. In removing the bran the rice suffers a considerable loss of weight, owing, not only to the loss of the testa, but also to the fact that many of the grains become broken and are rejected on that account. In most places the cleaning is effected by human labour. The rice to be cleaned is placed in a wooden mortar sunk in the ground, and a heavy wooden hammer supported upon a fulcrum is so arranged that on pressing down the side of the lever away from the mortar and then removing the pressure, the heavy end of the lever falls by its own weight into the mortar. As it falls it causes the grains of rice to rub against one another and so the skin becomes scraped off. The loss of weight varies according to the degree to which the cleaning is carried; that which is used for the preparation of kōji and of moto (called *moto-mi*) loses from 30 to 40 per cent. of its volume, whilst the *kake-mi*, used in the stages designated *soye*, *naka*, and *shimai*, is not so thoroughly cleaned and loses only about 25 per cent. of its volume. The numbers given are, of course, only approximate for, in every operation the percentage of loss must be different. The pounded mass is separated into three portions—the whole grains—the broken grains, and the bran. The whole grains are employed in the manufacture of kôji and saké, the broken grains are sometimes made into an inferior kind of kôji, but generally, like the bran, are sold to other persons. The amount of bran obtained is said to be about 3 kuwamme (25 lbs.) for every *koku* (4.96 bushels) of rice cleaned.

In some works (saké-works) steam power is employed to work the cleaners, and in other places water power is used.

The rice is next placed in a tank, covered with water, and from time to time trodden upon by the workmen, the water being frequently changed. The fine dust which was adherent to the grain is carried away by the water, but the amount of matter thus lost, although sufficient to make the water milky is not known. After this washing the grain is left in steep for one night by which it becomes quite soft and is ready for steaming. The object of the steeping is merely to render the grain soft so that the subsequent steaming may be as short as possible. It is therefore, not analogous to the steeping of the barley-grain in making malt, an operation which is required to promote the germination of the embryo. In the case under consideration, indeed, the embryo has been completely destroyed by the rough beating, and no subsequent germination is possible. It is important to remember this, so that it may be clearly understood in what respects the manufacture of kôji differs from that of malt. But even were the embryo not removed by the process of cleaning, it would be completely killed by the next operation, that of steaming. The soaked rice is placed in a large tub which is provided with a false bottom covered with cloth; the tub is then fixed upon an iron boiler full of water. When the water boils the steam passes through an opening in the true bottom of the tub, and as it ascends through the rice which is placed upon the cloth covering the false bottom, it heats the grain and causes the starch to become gelatinized. The grains of steamed-rice are flexible and of a horny appearance, and must be the same throughout. In this state the rice is called *mi*. It is now spread out upon mats to cool, and during this time the workmen prevent the grains cohering by rubbing them between their hands. When the temperature has fallen to about 29° C. the foreman mixes with the rice a small quantity of *tane*, a yellowish powder consisting of the spores of a fungus described by the late Mr. Ahlburg under the name of Eurotium oryzeæ. (Ahlb.)* The quantity employed is not exactly the same in different works, but averages about 3 c. c. to 4 *tô* (72 litres) of rice.

The subsequent operations vary a little in different works but not in any essential particulars. I shall, therefore, only describe them as carried out in the kôji works at Yûshima, Tôkiô.

* Mittheilungen der deutschen Gesellschaft für Natur- und Völkerkunde ostasiens. 16tes. Heft. 1878.

The spores are in the first place thoroughly mixed with [illegible] three handfuls of the rice, and this mixture is then scattered over the whole quantity of steamed rice; the corners of the mats are turned up so as [illegible] the whole into a heap in the middle which is afterwards again spread out, and these operations are repeated several times to ensure that the spores shall be uniformly distributed. The rice mixed with fungus spores is then carried below to the front part of the chambers where the temperature is not high, and is there allowed to remain one day covered with mats. On the second day the temperature of the mass is about 25 or 26° C. so that it is rather lower than when the spores were mixed with it. About noon of the second day (calling that on which the admixture with spores took place the first day) the rice is put into baskets and carried above where it is sprinkled with water. In the evening of that day the mixture is spread out in thin layers upon wooden trays called *kōji-buta* which are carried to the innermost part of the subterranean passages and placed upon the floor underneath the benches which bear the koji of the third day. The trays are allowed to remain in this position from about 5 p. m. on the second day until about 5 a. m. on the third day, by which time the previous batch of koji on the benches has been removed, and the new batch is then put in its place. The mixture of rice and spores which was previously spread out in a thin layer over the tray is at this time (5. a. m. third day) collected into a heap on each tray and left until between 9 and 10 a. m. During this time the temperature rises considerably and, by the vegetation of the fungus, the grains are bound together. In order to prevent the temperature rising so high as to injure the vitality of the plant, the workman cools the mass by spreading it out in a thin layer and leaving it for some time. After it has become somewhat cooler he again collects it into heaps and leaves it until about 1 p. m. at which time it has once more attained a temperature nearly as high as at 9 or 10 a. m. after which it is spread out and repeatedly worked with the hands during the rest of the day. Between 8 o'clock in the evening of the third day and 5 a. m. of the fourth day the fungus still continues to grow, sufficiently to bind the whole mass together and to the tray. At 5 a. m. it is removed from the chamber and preserved on the trays until required for use.

In the manufacture of kōji for saké making the sprinkling with water on the second day is omitted, and the product is then called *ki kōji* (raw kōji).

The formation of kōji is an illustration of the growth of the mycelium of a fungus which uses the starch of the rice grain as food. In plants which possess chlorophyll and develop in sunlight two processes go on, assimilation and respiration. The former is accompanied by a fixation of carbon contained in carbonic acid under the influence of the sun's rays, and by the simultaneous liberation of oxygen. In this way the majority of plants add to their substance. At the same time the second process, respiration, goes on, but to a smaller extent than the former: it consists of an oxidation of the tissues of the plant, carbonic acid being liberated. This is the only process which goes on in plants destitute of chlorphyll, the green colouring matter of plants, and it can be well observed to take place in the growth of the *kôji* fungus. This process of respiration, or oxidation, as a chemist might call it, is accompanied by a remarkable development of heat sufficient to keep the temperature of the kôji and of the chamber very high. The following temperature observations will show this—the first series was made in spring when the amount of kôji being made was very small, and the outside temperature not very much below that of the chamber. In the second series of observations, made in December, the differences are much greater, the temperature of the outside air being very low, and that of the kôji much higher. During the month in which these observations were made the amount of material produced is very large, and the chambers are kept fully worked: it is owing to this circumstance that the differences of temperature between the kôji and that of the chamber are so much more marked than in May.

TABLE II. TEMPERATURES OF KOJI AND CHAMBER IN MAY.
KOJI OF THE THIRD DAY ONLY.

Date	Hour	Temperature of the outer air.	Temperature of kôji chamber		Temperature of the kôji (3rd day)
			Minimum	Maximum	
May 18th	8 a. m.	55.3° F.	72° F.	76° F.	No kôji
„ „	6 p. m.	61.8	72	74°	„
„ 19th	7 a. m.	59.0	72	77	89.6° F.
„ „	8 p. m.	64.0	74	76	„
„ 20th	8 a. m.	57.7	76	77	84.2
„ „	9 p. m.	64.6	75	77	„
„ 21st	7 a. m.	60.5	75	76	„
„ „	9 p. m.	65.0	74	76	86°
„ 22nd	9 a. m.	63.6	75	77	86
„ „	9 p. m.	60.0	76	79	89.8
„ 23rd	7 a. m.	65.5	77	83	„
„ „	8 p. m.	65.0	79	82	95°
„ 24th	7 a. m.	64.0	80	81	102°
„ „ .. .	8 p. m.	66.5	78	80	86°

TABLE III. TEMPERATURES OF KOJI AND CHAMBER IN DECEMBER.

KOJI OF THE THIRD DAY ONLY.

Date	Hour	Temperature of outer air	Temperature of air in chamber.			Temperature of kōji (3rd day)
			Minimum	Maximum	Observed	
December 5th	8 a. m.	40.7° F	—	—	82° F	104.8° F
„ „	2 p. m.	49.5	82° F	83° F	82	91.9
„ „	8 p. m.	42.5	81	83	81	83.8
„ 6th	8 a. m.	41.5	80	83	83	106.6
„ „	10 a. m.	44.7	81.6	82	81.6	101.0
„ „	1 p. m.	50.0	81	82.5	81.5	104.
„ 7th	9 a. m.	38.5	80	82.5	81.5	104.2
„ „	2 p. m.	51.0	80.5	82	81.5	93.6
„ 8th	8 a. m.	37.5	79	82.5	80	100.0

A careful examination of the second series of temperature observations will enable us to trace the growth of the fungus very clearly. The temperatures of the kōji at various times in the day have been arranged and are given in Table IV.

TABLE IV. TEMPERATURE OF KOJI ON THIRD DAY.

Hour.	December 5th	Dec. 6th	Dec. 7th	Dec. 8th
	° F	° F	° F	° F
8 a. m. ..	104.8	106.6	—	100.0
9 a. m. ..	—	—	104.2	—
10 a. m. ..	—	101.0	—	—
1 p. m. .	—	104.0	—	—
2 p. m. ..	91.9	—	93.6	—
8 p. m. ..	88.8	—	—	—

Until 1 p. m. in every case the temperature of the kōji is above 100° F., and after 1 p. m. in every case it falls below that point. The period of most active growth is, therefore, in the morning, and corresponds with the time during which the material is heaped up in masses. The effect of opening out the masses of kōji will be best seen in the temperatures taken on Dec. 6th. At 8 a. m. the temperature was 106.6° F. and it continued to rise a little until between 9 a. m. and 10 a. m. when the workman broke open the heaps and spread them out. The temperature taken at 10 a. m. shows that the mass had cooled down 5.6° F. After this the mixture was again made up into heaps and at 1 p. m. the temperature had again risen, though not quite so high as at 8 a. m. After the heaps have been broken down between 1 p. m. and 2 p. m. the rice continues to cool; on the 5th the temperature at 2 p. m was 91°.9 and at 8 p. m. had fallen to 88.8° F. The object, therefore, of the working of the mass is not so much to prevent the grains becoming too much matted together as to regulate the activity of the growth of the plant. If the grains were allowed to remain heaped up during the whole time, there would be a danger of the temperature rising to too high a point, and perhaps rendering the product useless, whilst if the grains were never collected into heaps, the temperature would not rise sufficiently high to allow the growth to go on vigorously.

The amount of heat generated during the growth of the fungus is remarkable, and will be best appreciated from the observations made in December. At that time the temperature of the open air in the shade varied between 38° and 51° F, whilst in the subterranean chamber the temperature of the air was very nearly constant and very much higher than that of the open air. The growing chamber is not artificially heated except at starting—that is, after having been disused for a considerable time. It is then heated by the introduction of barrels containing hot water, but after that, all the heat it receives is derived from the growing plant. In December the difference between the outer and inner temperatures amounts to as much as 4? or 45° F, but in May the difference is not more than 10 or 12° F. Not only is the heat generated during the growth of the plant sufficient to keep the chamber hot, but it also raises the temperature of the rice on the trays about 23° F above the maximum temperature of the chamber. All this heat must be derived from the combustion of the rice, and the liberation of its carbon and hydrogen in the form of carbonic acid and water. That carbonic acid is formed in large quantity is shown by the rapid removal of the oxygen from a confined portion of air by the actively growing plant. A handful of the mixture on the trays was put into a bottle holding about 3 litres of air, and the bottle was then tightly closed with a cork through which tubes passed by means of which a sample of the air in the bottle could be forced out and collected for analysis. During the time the bottle remained in the chamber the ends of these tubes were closed with caoutchouc tubes and pinch-cocks. The bottle was allowed to remain at the temperature of the chamber for four hours, at the end of which time it was found that the whole of the oxygen in the three litres of air had been replaced by carbonic acid. The grains of rice in the bottle remained loose, whilst those on the trays exposed to the free air of the chamber were matted together. From this it may be inferred that the quantity of oxygen contained in the bottle was insufficient to generate the heat required by the fungus for its growth, which, therefore, ceased as soon as all the oxygen was consumed.

The oxidation which goes on during the growth of the fungus, and by which the heat is generated, is effected mainly at the expense of the starch contained in the cells of the grain. Plate I represents a section of a grain of kôji cut perpendicularly to the long axis, and shows that the cellular divisions at the circumference are almost lost, whilst in the centre they are pretty distinct. Very few grains of starch, however, can be distinguished, only those which have resisted gelatinization during the operation of steaming: the starch is there, but cannot be distinguished, on account of its homogeneity. The following analyses of kóji (A and B.) will indicate its general composition, although as will be explained later on, the amount of the soluble matter varies under different treatment even with the same specimen a fact which accounts for the large percentage of starch in one specimen and the small amount in the other. The composition is given of the material after deducting the percentage of moisture lost by drying at 100°C.

COMPOSITION OF KOJI DRIED AT 100° C.

		A.		B.	
Soluble in water (A). 37.76%.... (B). 69.45%....	Dextrose	25.02 per cent.		58.10 per cent.	
	Dextrin	3.88		4.41	
	Soluble ash	.52		.54	
	Soluble albumenoids	8.34	9.84%	6.40	8.23 %
Insoluble in water (A). 62.22%.... (B). 30.51%....	Insoluble albumenoids	1.50		1.83	
	Insoluble ash	.09		.04	
	Starch	56.00		26.2	
	Cellulose	4.20		1.94	
	Fat	.43		.50	
		99.98		99.96	
	Water in original kóji	25.82%		28.10%	

Comparing these with the analyses of whitened rice given on a former page (p. 5) it will be observed that the amount of starch present is much reduced. This is due to its conversion into dextrose and dextrin, which has been mainly effected during the solution in water, owing to an active agent contained in the kóji of which more will be said hereafter. The percentage of starch which would correspond to the dextrose, dextrin, and starch given in the first analysis is 82.4%, a number very closely agreeing with that which the rice dried at 100° C. actually contained. The actual loss of material during the growth of the fungus cannot be determined, therefore, by an analysis of the koji, although the increase in the total amount of albumenoids indicates that there has been a loss of some of the other constituents of the grain. The large proportion of soluble albumenoids will strike every one, but as this is connected with the existence of a kind of "diastase" contained in the koji, it will be referred to in connection with the properties of that body.

The loss of material caused by the growth of the fungus is evident when we consider the weight of koji formed from a given weight of rice. Mr. Jihei Kamayama was kind enough to make careful weighings of the rice used and of the resulting kóji. The result obtained was that 3 *lb* of whitened rice which weighed

PLATE I.

SECTION OF THE Kōji GRAIN PERPENDICULAR TO THE LONG AXIS. × 361.

11.43 kuwamme yielded 12.38 kuwamme of kôji, or 100 parts by weight of the rice gave 108.3 parts by weight of kôji. The rice contained 14.2% of water, and the kôji contained 29.5%, therefore, deducting the water from each, we find that 85.8 parts of dry rice gave 76.4 parts of dry kôji, equal to 89%, or in other words, 11% of material was lost by the dry rice. This loss is probably nearly all starch, and if so, every 100 parts of rice converted into kôji would evolve nearly 18 parts of carbonic acid. Now 107 lbs. of dry rice are converted into kôji every day in each chamber, and thus evolve 19.2 lbs. of carbonic acid measuring 2240 litres. The total capacity of each chamber cannot be more than 20000 litres, and therefore in order to remove the carbonic acid formed a constant circulation of air is necessary. If this were not provided for the air would not only become irrespirable by the workmen, but would also become unfit for the growth of the plant which requires a supply of oxygen. At the same time care has to be taken that the current of fresh air is not sufficiently rapid to lower the temperature of the air within the chamber. The mode of ventilation depends upon the difference in temperature between the inner and the outer air, the inner air being warmer rises up a square shaft at the front end of the series of passages, whilst the cold air bringing fresh oxygen enters and flows along the floor of the chambers, until in its turn it is warmed and rises through the shaft to the air above. This method is amply sufficient during winter when the difference of temperature between the air outside and inside is about 40° F, but when, as in the spring and early summer the difference becomes less than 10° F., frequent stoppages occur. This, perhaps, might be remedied by burning a small fire at the foot of the shaft, and thus artificially causing a draught, but as a smaller quantity of kôji is required in summer, it is not of so much importance.

In the germination of barley Day* has shown that an amount of oxygen is absorbed by the grain greater than is required to produce the carbonic acid liberated and he concludes that this increased absorption of oxygen is not connected with the liberation of the carbonic acid. Whether a similar absorption occurs in the present case is not known, but if, as is not improbable, it does occur, the amount of starchy material lost by the rice during the conversion into kôji will be even greater than that given above. The amount of carbon oxidized during the germination of the barley grain is said by Day to be about 2.5 per cent., and he finds that there is a pretty constant relation between the carbon oxidized and the water formed, which averages 12 carbon to 18.28 water. Thus for every atom of carbon oxidized one molecule of water is liberated, a ratio which would agree with the formula for dextrose $C_6H_{12}O_6$, or in its simplest form CH_2O. Possibly a similar relation may be observed in the case of kôji; that a large liberation of water does occur is evidenced by the increased percentage contained by the kôji compared with that in the rice, and also by the moisture of the atmosphere in the chamber. If however, a fixed relation were to exist it would

* Journal Chem. Soc. 1880. Trans. p. 650

be hidden owing to the moistening of the rice which takes place on the second day; in the instance just discussed the ratio between the weight of carbon burnt and water contained by the kôji in excess of that contained in the rice at starting is very nearly 12 : 24 or 3 atoms of carbon to 4 molecules of water; an amount of water greater than corresponds to the formula for dextrose.

SECTION 3.

ACTIVE PROPERTIES OF KÔJI.

In the preparation of saké the kôji itself is added to the steamed rice and water, and the solution, mixed with the insoluble residue of starch and cellulose, then acts upon the steamed rice. To study this action more readily it is more convenient to make use of a filtered aqueous extract of kôji, for it has been ascertained that the active property of the kôji, the "diastase," is dissolved out by contact with water. And first as to the nature of the solution. A sample of kôji when powdered or rubbed down in a porcelain mortar and then digested with water for a short time gives, after filtration, a yellow liquid which contains dextrin, dextrose, albumenoid matter, and a small quantity of mineral matter The proportions which the three first of these constituents bear to one another depend upon two things—1°. The quantity of water used in proportion to the kôji. 2°. The duration of the digestion, whilst 3°. the temperature at which the digestion is effected affects the amount of the total matter dissolved and the rapidity with which it enters into solution. The following table (p. 15) giving the results of experiments made at the ordinary temperature of the air will show the truth of the first two of these statements.

In column II the volume of water used to dissolve the soluble matter of 100 grams of kôji is given; in III, the time during which the water and the kôji remained in contact; in IV, the number of grams of solid matter dissolved from 100 grams of kôji by the amount of water mentioned; column V gives the average percentage of solid matter in the experiments indicated; column VI gives the percentage of dextrose contained in the solid matter; column VII, the specific rotatory power of the solution, and VIII, the average specific rotatory power of the solutions indicated. In experiments 2 to 12 the amount of water used for 100 grams of kôji was 1000 c.c. and these experiments include three differing periods of digestion, but there is no evidence that the time of digestion has much influence upon the quantity of matter dissolved, at least at the temperature 10-15° C. The average percentage of solid matter dissolved is 27.0 Experiments 14 to 17 show how much solid matter is dissolved when the amount of water used is 2500 c.c. to 100 grams of koji; the average percentage being 31.4. We see, therefore, that when a larger quantity of water is used the amount of solid matter obtained in solution is greater. It is not possible to draw

TABLE V. AMOUNT OF SOLID MATTER DISSOLVED BY WATER FROM 100 GRAMS OF KÔJI AT 10—15° C.

I	II	III	IV	V	VI	VII	VIII
No.	Volume of water used	Time	Weight of solid matter in solution	Average weight of solid matter	Percent. of dextrose in solid matter	Specific rotatory power	Average specific rotatory power.
	c. c.	hrs.					
1	500	12	17.7		60.0	65°	
2	1000	18	25.7			61°	
3	"	"	24.2			55.7	57°.6
4	"	"	23.0			56.0	
5	"	12	33.3		49.0	65.3	
6	"	"	33.3		50.9	65.4	
7	"	"	29.4	27.0	45.0	62.9	
8	"	"	28.6		46.5	67.7	64°.6
9	"	"	26.8		53.0	61.4	
10	"	"	22.5		53.0	64.5	
11	"	"	22.2		54.0	65.0	
12	"	4	28.0			61.4	
13	2000	3	31.1		68.0	78.0	
14	2500	"	32.2		58.0	68.1	
15	"	"	32.5	31.4	70.0	65.2	69°.3
16	"	"	30.7		65.0	73.8	
17	"	"	30.1		68.0	70.2	
18	5000	24	30.0		47.0	64.5	
19	10000	"	40.0		66.0	60.5	

any definite conclusions from single experiments, but the very large percentage dissolved when 100 grams of koji were digested with 10000 c.c. of water, bears out the above observations.

We have next to consider the influence of time upon the nature of the soluble matter. We have seen that it does not after 3 or 4 hours at the ordinary temperature affect very much the total amount of solids dissolved. But column VIII, which gives the average specific rotatory power of three series of experiments lasting respectively 18, 12, and 3 hours, shows that at 18 hours the specific rotatory power is smaller than at 12 hours, and at 12 hours less than at 3 hours. What is the meaning of this variation? The specific rotatory power of the solution is made up of three factors. The specific rotatory power of dextrin is 216°, that of dextrose is 59°. If these were the only two substances present the specific rotatory power of the solution would lie between these two numbers having a value proportionate to the amount of each present. It will be seen however, that the average of the experiments at 18 hours is less than 59°, and this shows that something else is present which tends to lower the value of the specific rotatory power. The albumenoids which are held in solution have been ascertained by nitrogen determinations to have an average value of $-40°$, and it is owing to their presence that the specific rotatory power is so low as it is. The composition of the liquid in experiment 6, for example, will illustrate this more clearly. 100 c c. of the solution contained 1.695 gram dextrose, 0.723 gram dextrin, and 0.914 of albumenoids (calculated by multiplying the nitrogen found by 6.3). This gives a composition in 100 parts —

Dextrose	50.9	per cent.
Dextrin	21.7	,,
Albumenoids	27.4	,,
	100.0	,,

The observed specific rotatory power was 65°.4. The calculated specific rotatory power was obtained in the following way —

$$(.509 \times 59) + (.217 \times 216) + (.274 \times -40) = 30.031 + 46.872 - 10.96$$
$$= 65.94.$$

The calculated number thus agrees very well with the observed number and we may, therefore, assume the specific rotatory power of the albumenoids to be expressed by the number—40°.

Taking the series of experiments which lasted for 3 hours we find that the average specific rotatory power is 69°.3, about 10° higher than that of pure dextrose; the average specific rotatory power of those at 12 hours is 64°.6, about 5° higher than that of dextrose, and that of the experiments at 18 hours 57°.6, about 1°.4 lower than that of pure dextrose. This diminution occurs because the amount of albumenoids in solution is greater when the specific rotatory power is less, their left handed rotation partially neutralizing the right handed rotation of the dextrin and dextrose. But why is it that the amount of albumenoids is greater when the treatment with water is longer continued? The most probable explanation is that as the albumenoids exist in the kóji, they are not entirely soluble; a portion is already soluble in water, but the rest is only brought into solution by the action of the water itself. and perhaps also, through the agency of the albumenoids at first dissolved. It is in fact a chemical reaction which takes time for its completion, and probably, if sufficient time were allowed, the whole of the nitrogenous matter of the rice would be degraded and brought into solution. This is a point of importance to brewers of saké, for we shall see that the power which the kóji possesses of transforming rice into dextrose, capable of undergoing alcoholic fermentation, is due to the presence of these albumenoids in solution.

The effect of heating a mixture of kôji and water is to bring the matter into solution much more rapidly than at a low temperature.

TABLE VI. ACTION OF WATER AT HIGHER TEMPERATURES UPON 100 GRAMS OF KÔJI.

Exp.	Time and Temperature	Cub. cent. of water per 100 gr. kôji	Solid matter dissolved	Dextrose percent. of solid matter	Specific rot. power
1	2 hours at 50° + 18 hrs. at 15°C.	1700	51.80	68.0	68°
2	½ hour at 45°C	2000	31.80	84.9	76°.1
3	2 hours „ „ „	2000	61.6	68.5	53°.5
4	½ hour at 50°...............	5000	37.2	66.0	63°.2
5	24 hrs. at 15° + 2 hrs. at 100°	10000	49.2	58.	73°.8

With the exception of Exp. 2, the percentage of matter dissolved by the water is greater than in the experiments conducted at a lower temperature, and as a rule the percentage of dextrose in the solid matter is also greater. We shall, however, learn something by comparing experiments 2 and 3 with an experiment made at the ordinary temperature with the same sample of kôji. In every respect the conditions of the three experiments were the same except as regards time and temperature.

TABLE VII. ACTION OF WATER ON KÔJI.

Exp.	Time and Temperature	Cub. cent. of water per 100 gr. kôji	Solid matter dissolved	Dextrose per cent. of solid matter	Specific rot. power
1	18 hrs. at 10-12°	2000	29.2	69.3	66°.3
2	½ hr. at 45°	2000	31.8	84.9	76°.1
3	2 hrs. at 45°	2000	61.6	68.5	53°.5

The above comparison shows that the amount of solid matter dissolved when the contact between koji and water is for 18 hours at a low temperature and for ½ hr. at a high temperature is very nearly the same, but the percentage of dextrose and the specific rotatory power of the solution indicate that the proportions in which the three ingredients are present are very different. If we assume the specific rotatory power of the albumenoids to be = − 40° we may ascertain the composition of the solid matter, and referring it to a fixed amount of dextrose, we get per 100 parts of dextrose

TABLE VIII. COMPOSITION OF THE SOLID MATTER PER 100 PARTS OF DEXTROSE.

Exp.	Time and Temperature	Dextrin	Albumenoids
1	18 hours at 10-12° C.	21.2	23.10
2	½ hr. at 45°	14.7	3.06
3	2 hrs. at 45°................	14.6	25.80

After 18 hours at a low temperature the amount of dextrin is 21.2 parts for every 100 parts of dextrose, but after both ½ hr. and 2 hours at 45°, it remains practically the same and about two-thirds of the amount in the former case. The most interesting fact to be observed is the variation in the amount of the albumenoids; after 18 hours at 10-12°C. it is very little different from the amount dissolved out in 2 hours at a temperature of 45°C., but after only ½ hour at 45°C. the quantity in solution is only about one-eighth as much as in the two other experiments. This bears out the observations made at lower temperatures, viz. that the amount of albumenoid matter dissolved is mainly affected by the duration of the experiment. It is not only dependent upon that, for we see the influence of a higher temperature in dissolving the albumenoids more rapidly, 2 hours at 45°C. being more than equivalent to 18 hours at 10-12°C. Thus we are again led to the conclusion that the greater part of the nitrogenous matter in kōji is insoluble in water, but that it is in such a state that the prolonged contact with water renders it soluble.

Although the effect of heat upon the mixture of kōji and water is thus marked, when the clear solution has been separated by filtration from the undissolved grains it is not so rapidly changed either by exposure to heat or by longer standing at the ordinary temperature of the air. It is important for us to examine the change in composition of the solution on heating, as in the experiments upon starch-paste to be presently described it is the filtered solution of kōji which is used. The following table (p. 19) gives the results of a number of experiments made by Watanabe Yuzuru, graduate, on the effect of heating filtered solutions of kōji for one hour at the specified temperatures, the same solution being examined for comparison after standing at the ordinary temperature for the same time.

Below 45°C. the change in the composition of the liquid is so small that it may practically be neglected, but between 45°C. and 60°C. the effect is much more marked. An increase in the amount of solid matter and in the dextrose occurs, accompanied by a decrease in the specific rotatory power. These results are caused by an absorption of water by the dextrin which is converted into dextrose and thus the amount of solid matter in a given volume of the liquid is increased which, together with the smaller specific rotatory power of the dextrose, lowers the specific rotatory power of the solution.

TABLE IX. ACTION OF HEAT ON FILTERED SOLUTIONS OF KÔJI.

Temperature	Solid matter in 100 c. c. of solution			Dextrose in 100 c. c. of solution			Specific rotatory power		
	Unheated	Heated	Increase	Unheated	Heated	Increase	Unheated	Heated	Decrease
30°C.	4.88	—	—	2.97	3.015	0.045	—	—	—
35°	4.88	—	—	2.97	3.062	0.092	—	—	—
40°	4.89	—	—	2.98	3.079	0.099	—	—	—
45°	4.92	4.98	0.06	2.92	3.412	0.494	74°.0	70°.	4°
50°	4.95	5.02	0.07	2.793	3.285	0.492	70°.	67°.1	2°.9
55°	4.92	5.00	0.08	2.918	3.463	0.545	74°.	68°.9	5°.1
60°	4.95	5.02	0.07	2.793	3.30	0.507	70°.	67°.8	2°.2
65°	4.89	—	—	2.98	3.081	0.101	—	—	—
70°	4.89	—	—	2.98	3.075	0.095	—	—	—

The alteration is greatest at the temperature of 55°C. above which it rapidly diminishes. At 65° and at 70°. the effect produced is very much the same as at ordinary temperatures, so far as the composition of the liquid itself is concerned, but a very great change in the active properties of the liquid is brought about by heating it to these temperatures. The liquid becomes turbid, so much so that its specific rotatory power cannot be determined with any accuracy. an effect caused by the precipitation of a certain proportion of the albumenoids which have been rendered insoluble by heating. We shall see that at some temperature between 60°C. and 70°C. the liquid loses its power of transforming starch into sugar, and reasons will appear connecting this loss of activity with the precipitation of the albumenoids.

SECTION 4.

ACTION OF KÔJI EXTRACT UPON SOME CARBOHYDRATES.

The solution which is prepared by digesting kôji in water possesses certain active properties which cause it to resemble in general character the aqueous solution of malt, so carefully experimented upon by Messrs. Brown and Heron. It is of interest and importance to compare the action of kôji extract upon the principal carbohydrates in order to establish an identity or a difference between the two species of "diastase." From the mode of production there is no reason to suppose that they will be found to be identical, and experiments to be hereafter described will prove that, though they agree in some points, they differ in yet others. The carbohydrates which have been subjected to the action of kôji extract are cane-sugar, maltose, dextrin, and gelatinized starch.

ACTION UPON CANE-SUGAR.

Brown and Heron have shown that when an aqueous solution of malt is allowed to remain in contact with a solution of cane sugar, a change takes place by which the cane-sugar is made to take up water and is thereby converted into invert sugar, a mixture of dextrose and levulose. The "diastase" of malt is said by them to exert its maximum effect upon sugar at 55° C.; its action is considerably weakened at 60°C. and almost destroyed at 66°C.

Experiment shows that the extract of kóji also possesses the property of causing cane-sugar to become inverted, but I am not able to define the limits of its action. The two following experiments will suffice to prove this point.

Experiment 1. 1.974 gram of dry cane-sugar was dissolved in 25 c. c. of kóji extract, then diluted with water to 100 c. c. The amount of rotation was found to be 15.8 divisions, and the calculated number 15.5. div.

1.974 grm. cane sugar dissolved in 100 c.c. give rotation =	12.1	div.
25 c.c kóji solution diluted to 100 c c..........................	3.4	"
	15.5	"

After being allowed to stand for 18 hours at about 10 to 12° C. the rotation was found to have diminished to 5 div., and the solution contained 1.67 grm. of glucose. Deducting 0.36 gram contained in 25 c.c. of kóji solution, the amount, formed from the cane-sugar was 1.31 gram, equivalent to 1.2445 grm. cane-sugar and hence 0.7294 gram of unaltered cane-sugar was present. We thus find the calculated number of divisions rotated by the inverted solution to be + 5.43 against 5 div. actually observed.

Unaltered cane sugar (0.7294 grm. in 100 c.c.).............	+ 4.4	div.
Kóji extract (25 c c. in 100 c.c. of water).........................	+ 3.4	"
Invert sugar formed..	— 2.37	"
	+ 5.43	"

Calculated in degrees of arc the specific rotatory power of the cane-sugar has been reduced from 74° to 10°.

Experiment 2. A solution of cane-sugar containing 5.41 grams in 100 c c., and giving a rotation in a 200 m.m. tube of 33.1 div., equal to $[\alpha]_j = 74°$, was employed. 75 c.c. of this solution were mixed with 25 c.c. of a solution of kóji which contained in 100 c.c. 1.46 grm. of solid matter, 1.0125 grm. of glucose. and which gave in a 200 m m. tube an optical rotation of 8 divisions. It may be remarked that from this and other experiments made with the same solution of kóji, it was found to be exceptionally weak in its converting power. The observations are as follow, after deducting the optical rotation due to the presence of the kóji solution:—

	Optical rotation.	Specific rotatory power.
At starting	24.8 div.	74°.0
After $1\frac{1}{2}$ hours at 15°C	23.7 ,,	70°.6
,, $20\frac{1}{4}$,, at 10-12°C	21.0 ,,	62°.6
,, $\frac{3}{4}$ hr. more at 40°C	20.2 ,,	60°.2

50 c.c. of this mixture and 25 c.c. of kôji were treated as below. The numbers given are corrected for the kôji present.

After $1\frac{1}{4}$ hrs. at 40°C	11.2 ,,	50°
,, 2 ,, ,, 45°-50°	4.0 ,,	17°.8

The experiment was not carried further than this. At low temperatures the converting action of this particular extract of kôji is very slow, but at higher temperatures, and especially at from 45° to 50°C. it is much more rapid. In this respect, therefore, kôji extract resembles malt extract.

ACTION UPON MALTOSE.

So recently as 1872 Mr O'Sullivan † directed attention to the nature of the sugar formed when malt extract is made to act upon gelatinized starch, and his experiments conclusively established the existence of a new sugar, previously however, pointed out by Dubrunfaut, which is now known as *maltose*. In composition it agrees with cane-sugar, but differs from it in having a specific rotatory power of 150°, and in forming dextrose and not invert sugar when boiled with acids or otherwise hydrated. It also differs in its reducing action upon oxide of copper from either cane-sugar or dextrose, for the former has no reducing action upon cupric oxide, whilst maltose reduces only 61 to 63 per cent. of the amount reduced by the same weight of dextrose. Messrs Brown and Heron* have shown that a solution of malt is not able to convert maltose into dextrose, and that it is quite without action upon it. The following experiments will, however, show that the solution of kôji possesses the property of hydrating maltose and converting it into dextrose. This will be rendered evident by the change which the solution of maltose undergoes under the influence of kôji extract both as regards the weight of oxide of copper reduced by a given weight of the solid, and as regards the specific rotatory power of the product.

The maltose employed was obtained from *ame*, a kind of sweetmeat prepared by the action of malt in solution upon the starch contained in millet or in rice. Various specimens of *ame* contained from 68 to 94 per cent of maltose, which was separated according to the process described by O'Sullivan.‡ The specimens employed were in the crystalline state, and contained water sufficient to reduce the specific rotatory power from 150° to 144°.5.

† Journ. Chem. Soc. 1872. p. 579.

‡ Journ. Chem. Soc. 1876. ii. p. 127.

* Jour. Chem. Soc. 1879. Trans. p. 621.

Experiment 3. 100 c.c. of a solution of maltose containing 1.324 grm. of solid matter, and the equivalent of 0.855 grm. glucose, were mixed with 100 c.c. of a kòji solution containing 3.572 grams of solids and 2.14 grms. glucose, and heated for 2½ hours to 35-40°C. The liquid after heating (the kòji being deducted) gave in 100 c.c. 1.374 gram solids and 1.348 gram glucose. It is evident, therefore, that the solution of maltose had been completely converted into dextrose. The proportion of kòji solution used in this experiment was very large.

Experiment 4. A solution of maltose was prepared containing 2.68 grams of solid matter in 100 c.c., and giving an optical rotation in a 200 m.m. tube of 32.1 divisions, equal to a specific rotatory power $[\alpha]_j = 144°.5$. 100 c.c. of this solution were mixed with 100 c.c. of kóji extract containing 2.3 grms. of solid matter in 100 c.c. and giving in a 200 mm. tube an optical rotation of 10.5 divisions. This mixture was heated to 60°C. for 2½ hrs. on the water-bath, then cooled and diluted to 250 c.c. at 15°C. It contained 2.03 grams of solid matter in 100 c.c. and gave an optical rotation of 11.5 divisions. Deducting the amount of solids due to 100 c.c. of kòji extract in 250 c.c. we get as the result of the action upon the maltose—

Solid matter..2.775 grains.
Optical rotation.......................................7.3 divisions.
$[\alpha]_j$..79°.6,

The action of kóji extract in reducing the specific rotatory power of maltose is thus very marked. The explanation of the reduction of course, is, that 2.68 grams of maltose having a specific rotatory power equal to 144°.5 have taken up 0.095 gram water forming dextrose having a specific rotatory power equal to 59°. The number 79°.6 shows that the hydrating action was not quite complete, and this is confirmed by the quantity of water absorbed, which for 2.68 grams of maltose ought to have been 0.14 gr.

The following experiment will allow us to trace the gradual action of the kóji solution upon the maltose taking as the standard of comparison the specific rotatory power.

Experiment 5. 100 c.c. of the same solution of maltose as was used in the last experiment were mixed with 100 c.c. of a freshly prepared extract of koji, which contained 2.424 grams of solid matter in 100 c.c. and which gave an optical rotation in a 200 mm. tube of 11 divisions. The mixture of maltose and kòji solutions was diluted to 500 c.c. at 15°C., and after standing at that temperature for 10 minutes a sample was withdrawn for analysis. The remainder was placed in a water bath heated to 45°C. and samples were taken after the lapse of 30 min., 1 hr., and 2 hrs.

CURVE SHOWING THE ACTION OF KÔJI EXTRACT UPON MALTOSE.

Temp. 45°C.

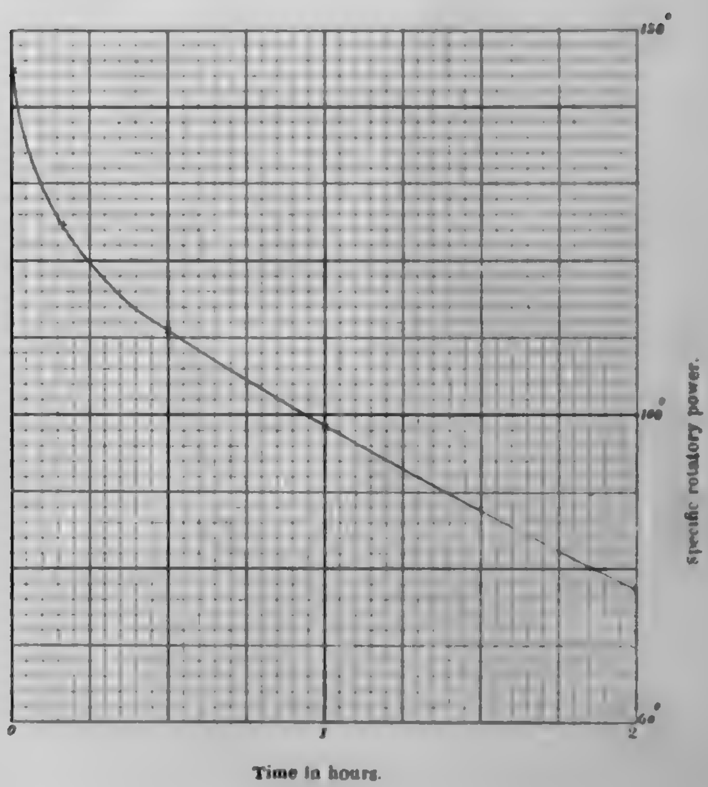

TABLE X. ACTION OF KÔJI EXTRACT UPON MALTOSE.

Time.	Solid matter in 500 c.c. after deducting kôji.	Rotation after deducting kôji.	Specific rotatory power of maltose products.
10 min............	2.823	5.8 div.	124°.2
30 ,, ...		5.3 ,,	111°.1
1 hr............	2.886	4.7 ,,	98°.5
2 ,, ...		3.7 ,,	77°.6

The specific rotatory power therefore, fell from 144°.5 to 77°.6 in 2 hours, and would doubtless have fallen to 59° if the solution had not been used up after 2 hours. The action may be represented in the form of a curve using time and specific rotatory power as abscissæ and ordinates respectively. (See Pl. II)

The curve shows very clearly how regular the action is, and leaves no doubt about the power of extract of kôji to effect the hydration of maltose. It is especially important to establish this, because this property marks in the sharpest manner the difference between malt extract and kôji extract. Brown and Heron's experiments leave no doubt about the inability of malt extract to convert maltose into dextrose, and these experiments, I think, establish conclusively the ability of kôji extract to do this.

ACTION UPON DEXTRIN.

The action of kôji extract upon dextrin is to cause it slowly to combine with water and form dextrose, as the following experiment shows.

Experiment 6. 100 c.c. of a solution of commerical dextrin containing 5.56 grams of solid matter were diluted to 250 c.c. and then gave a specific rotatory power $[\alpha]_j = 174°$. It was, therefore, impure, and contained a considerable percentage of dextrose.

50 c.c. of this solution were mixed with 50 c.c. of a solution of kôji and heated to 45°C. for 1½ hour. After being diluted to 250 c.c. the solution contained 4.145 grams of solid matter in 250 c.c., and deducting 1.285 gram contained in the 50 c c. of kôji solution added, we get 2.86 grams of solids formed from the 50 c.c. of dextrin solution, instead of 2.78 grams originally present. After making allowance for the rotation caused by the kôji solution, the specific rotatory power of the dextrin products was 92°, instead of 174° that of the substance at starting. The kôji solution had become exhausted, because when an additional amount of kôji solution was added, and the mixture heated for a longer time, the specific rotatory power further diminished to 85°. This experiment leaves no doubt concerning the gradual absorption of water by dextrin under the influence of solution of kôji.

SECTION 5.

ACTION OF KÔJI EXTRACT UPON GELATINIZED STARCH.

From the point of view of the saké-brewer the change which kôji solution produces in the nature of starch is of the utmost importance, and it will on that account be needful to enter into somewhat minute details concerning its action under varying conditions of time and temperature. That a remarkable change does take place will be evident to any one who adds a few cubic centimetres of a filtered solution of kôji to a quantity of thick starch-paste, especially if the latter be at a temperature of about 45° or 50°C. Within a very short time, a few minutes at most, the paste or jelly which before would not have moved on inverting the vessel containing it, will become as liquid as water, and, if the flocks of cellulose be allowed to settle, as transparent as water. This cannot be observed in the ordinary process of manufacture, but the change takes place, it is only disguised by the presence of a considerable quantity of insoluble matter. In order, therefore, to understand the chemical reactions involved in saké-brewing, the first point is to ascertain the composition of the clear, transparent solution obtained as above described.

Using malt extract instead of kôji extract a similar change would be observed, and the nature of the resulting solution has been very thoroughly examined by O'Sullivan*, and more recently by Brown and Heron†. The result of their investigations has been to prove that dextrin and maltose are the only products of the solution of starch by malt extract, and that the change may be represented by definite chemical equations, which are different according to the temperature at which the conversion takes place. Thus according to O'Sullivan when the malt solution is allowed to act upon gelatinized starch at the ordinary temperature of the air, or at any temperature whatever below 63°C, the reaction is represented by his equation A.

$$\text{A.}\quad \underset{\text{Soluble starch}}{6\,(C^{12}H_{20}O_{10})} + 4\,H_2O = \underset{\text{Maltose}}{4\,C^{12}H_{22}O_{11}} + \underset{\beta\text{-dextrin iii.}}{2\,C^{12}H_{20}O_{10}}$$

That is to say that the products of the reaction contain 67·8 per cent of maltose and 32·2 per cent. of dextrin, and have a specific rotatory power, $[\alpha]_j = 170°·6$.

Between the temperatures 64° and 66°C. the reaction is represented by the B′ equation

$$\text{B}'.\quad \underset{\text{Soluble starch}}{6\,(C^{12}H_{20}O_{10})} + 3\,H_2O = \underset{\text{Maltose}}{3\,C^{12}H_{22}O_{11}} + \underset{\beta\text{-dextrin ii.}}{3\,C^{12}H_{20}O_{10}}$$

Between 67° and 70°C. equation B represents the reaction:

$$\text{B.}\quad \underset{\text{Soluble starch}}{6\,(C^{12}H_{20}O_{10})} + 2\,H_2O = \underset{\text{Maltose}}{2\,C^{12}H_{22}O_{11}} + \underset{\beta\text{-dextrin i.}}{4\,C^{12}H_{20}O_{10}}$$

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* Journ. Chem. Soc. 1876, vol. II. p. 125 &c. also, 1879, Trans. p. 770

† Ibid. 1879, Trans. p. 596, &c.

and between 70°C. and the point at which the activity of the malt diastase is destroyed, the reaction is expressed by equation C.

$$\text{C.}\quad \underset{\text{Soluble-starch}}{6\,(C^{12}H_{20}O_{10})} + H_2O = \underset{\text{Maltose}}{C^{12}H_{22}O_{11}} + \underset{\alpha\text{-dextrin.}}{5\,C^{12}H_{20}O_{10}}$$

Brown and Heron agree with O'Sullivan in finding only maltose and dextrin as the products of the action of malt extract upon starch, but their experiments lead them to represent the proportions formed at different temperatures a little differently. There is also a difference in their theoretic views as to the weight of the molecule of soluble starch and the nature of the dextrins, but we may leave that aside. They imagine that the conversion of starch into maltose and dextrin is to be represented by nine different equations in the following manner.

(1) $10\,(C^{12}H_{20}O_{10}) + H_2O = C^{12}H_{22}O_{11} + 9\,C^{12}H_{20}O_{10}$ (Erythro-dextrin α)

(2) $10\,(C^{12}H_{20}O_{10}) + 2\,H_2O = 2\,C^{12}H_{22}O_{11} + 8\,C^{12}H_{20}O_{10}$ (,, ,, β)

(3) $10\,(C^{12}H_{20}O_{10}) + 3\,H_2O = 3\,C^{12}H_{22}O_{11} + 7\,C^{12}H_{20}O_{10}$ (Achroo-dextrin. α)

(4) $10\,(C^{12}H_{20}O_{10}) + 4\,H_2O = 4\,C^{12}H_{22}O_{11} + 6\,C^{12}H_{20}O_{10}$ (,, ,, β)

The series is continued through the intermediate equations.

(8) $10\,(C^{12}H_{20}O_{10}) + 8\,H_2O = 8\,C^{12}H_{22}O_{11} + 2\,C^{12}H_{20}O_{10}$ (Achroo-dextrin ζ)

(9) $10\,(C^{12}H_{20}O_{10}) + 9\,H_2O = 9\,C^{12}H_{22}O_{11} + C^{12}H_{20}O_{10}$ (,, ,, η)

Of these the most stable is No. 8 which represents the manner in which the reaction takes place at and below 63°C. They consider also that they have definite evidence of the existence of equations 4,3, and 2, and indications of 5 and 6.

It will be seen that the weight of maltose formed at low temperatures is always greater than at high temperatures, a circumstance which has to be carefully attended to in the process of making beer, because it depends upon the proportion of sugar in the wort whether the brewed liquid will contain much or little alcohol.

The above mentioned observers have been able to obtain definite chemical equations because of the absence of any hydrating action of malt extract upon maltose. As, however, it has been shown in Section 4 of this Memoir that the solution of kōji hydrates maltose, we cannot expect, even if that sugar is formed, to obtain results of the same sharpness as where the products first formed are unacted upon.

We have, therefore, in the first place to ascertain whether maltose is one of the products of the action of koji extract upon starch paste, and that it is so, will be shown by the following experiments.

To prove this an indirect method is resorted to, on account of the difficulty of isolating small quantities of maltose in a pure state from solutions containing much dextrin. The method adopted consists in determining the reducing action of the solution upon oxide of copper, and from the amount of cuprous oxide precipitated by a given weight of the starch products in solution (calculated from the specific gravity of the liquid) to find the weights of maltose and dextrin, assuming these to be the products. If no other substance is formed, the specific rotatory power of the solution calculated from the percentages of maltose and dextrin present will agree with the specific rotatory power of the solution actually observed. If they do agree the solution must contain the bodies assumed to be present, because if others were there, the specific rotatory powers would differ from one another. A detailed description of one experiment will render this more intelligible.

Experiment 7. A kōji solution was prepared by digesting for a short time 25 grams of a freshly prepared sample of kōji in about 100 c.c. of water. The liquid was then filtered, the residue digested with a fresh quantity of water, and the whole thrown upon the filter and washed until the filtrate amounted nearly to 500 c.c. The solution was then diluted exactly to 500 c.c. at 15°C. The filtration occupied three or four hours even with the assistance of a filter-pump on account of the slimy nature of the insoluble matter. The solution so made contained in 100 c.c. 1.46 gram of solid matter calculated from the specific gravity (using the divisor 3.86), 1.0125 gram glucose, and caused an optical rotation of 8 divisions in a 200 m.m. tube. This gives a specific rotatory power

$$[\alpha]_j = \frac{8 \times 0.242}{2 \times 0.0146} = 66^\circ.3$$

5 grams of starch, previously dried at 100°C., were gelatinized with about 75 c.c. of water, the paste allowed to cool to 40°C., then mixed with 25 c.c. of the kōji solution, and left for 25 minutes till it was quite clear. It was then rapidly heated to boiling, cooled, and diluted to 250 c.c. 100 c.c. of this solution, after filtration, contained 2.15 grams of solid matter, and 0.63 gram glucose, determined by weighing the reduced cuprous oxide after ignition. The optical rotation in a 200 m.m. tube was 32.4 divisions.

As the kōji solution contained in 250 c.c. of the starch products was 25 c.c. (*i. e.* one-tenth) we must deduct the weight of solid matter and glucose contained in 10 c.c. of the kōji extract from the weights above found in 100 c.c. of the liquid. The optical rotation must also be diminished by one-tenth the amount caused by the kōji solution alone. We thus get:—

Solids in 100 c.c. formed from starch....	2.15	—	0.146	=	2.004 grams.
Sugar, calculated as glucose,..............	.63	—	.101	=	.529 "
Optical rotation....................................	32.4	—	0.8	=	31.6 divisions.

$$\text{Thus } [\alpha]_j \text{ observed} = \frac{31.6 \times 0.242}{2 \times 0.02004} = 190^\circ.8$$

The percentage of sugar calculated as glucose is 26.39, and the maltose corresponding is $\frac{26.39}{0.61} = 43.28$ per cent., and the dextrin, therefore, 100 — 43.28 = 56.72. If we calculate the specific rotatory power which a mixture of maltose and dextrin in these proportions ought to have we find it to be

$[\alpha]_j$ calculated $= 216 \times 0.567 + 150 \times 0.433 = 187^\circ.4.$

There is a difference between the two results of 3.°4, which is not more than might be caused by errors of experiment. If we assumed the solution to contain dextrin and dextrose, the specific rotatory power would be only 174°, a difference of nearly 17°. This experiment, therefore, shows that maltose and not dextrose, is formed.

Experiment 8. 5 grams of starch were gelatinized and after cooling to 40°C. mixed with 25 c.c. of the same kōji extract and kept at that temperature for ¾ hour. An additional 25 c.c. of kōji was then added and the whole allowed to remain at 40°C. for 15 min. longer, then boiled and diluted to 250 c.c. After filtration the solution contained, deduction having been made for the kōji added,

Solid matter....................	2.035 grams in 100 c.c.
Sugar (calcd. as dextrose).	.888 „ „ „
Optical rotation.............	28.5 divisions
Hence $[\alpha]_j$ observed =	169°.5

The composition of the solution, assuming the sugar to be maltose, is

Maltose............................	71.54 per cent.
Dextrin............................	28.46 „ „
	100.00

The specific rotatory power calculated for this mixture is 168°.8, which agrees very closely with the observed number.

Experiment 9. With a solution prepared from different kōji, using 50 c.c. of the kōji solution containing 1.206 gram of solid matter per 100 c.c., the following results were obtained from 5 grams of gelatinized starch kept for 2 hrs. at 10-15°C.

Maltose............................	70.00 per cent.
Dextrin............................	30.00 „ „
	100.00

Specific rotatory power, observed = 174°.0
„ „ „ calculated = 169°.8

The two last experiments give results which correspond nearly with Brown and Heron's equation, No. 7.

$$10\,(C^{12}H_{20}O_{10}) + 7\,H_2O = 7\,C^{12}H_{22}O_{11} + 3\,C^{12}H_{20}O_{10}$$

which requires 70.9 per cent. of maltose, and $[\alpha]_j$ calculated = 169°.2

Solutions in which maltose can be detected can only be obtained by making use of dilute solutions of kōji and in comparatively small quantity. In by far the greater number of experiments the maltose which is at first formed is hydrated to dextrose by the excess of "diastase" present in the kōji solution, and as in the brewing operations a very large excess of kōji is used, the brewer of saké has practically nothing to do with maltose, but only with dextrose. In this respect the brewing process in Japan differs from beer-brewing in Europe and America, where the alcohol is fermented for the most part from maltose.

The following experiments will serve to illustrate the production of dextrose and dextrin only. The mode of recognising the nature of the products is the same in principle as that used to identify maltose, viz. a comparison of the observed specific rotatory power with the number calculated from the percentages of sugar and dextrin, assuming in this case the sugar to be dextrose with a specific rotatory power $[\alpha]_j = 59°$.

Experiment 10. 20 grams of dry starch gelatinized and 200 c.c. of a solution of kōji (prepared from 50 grams in 500 c.c. of water), diluted to one litre were heated at 40°C. for 6 hours, then allowed to stand for 2 hours at 15°C. The solution contained in 100 c.c., (deduction having been made for the kōji extract) 1.96 gram of solid matter and 1.68 gram glucose, with a rotation of 12.8 divisions. This gives

Dextrose	85.7 per cent.
Dextrin	14.3 ,, ,,
	100.0

Specific rotatory power, observed = 79°

,, ,, ,, calculated = 81°.4

Experiment 11. 4 grams of gelatinized starch and 96 c.c. of kōji solution (20 grams of kōji in 500 c.c. water) were heated at 45°C for 3½ hours, then evaporated to about 200 c.c. and diluted to 250 c.c. The composition of the solid matter in solution, after deducting that due to the kōji extract, was

Dextrose	86.00
Dextrin	14.00
	100.00

Specific rotatory power, observed, = 85°.7

,, ,, ,, calculated, = 81°

In both experiments, therefore, dextrin and dextrose are the only products.

Experiments were next directed towards ascertaining the degree of rapidity with which the conversion of starch into dextrose took place at different temperatures. For this purpose it was necessary to allow the mixture of starch and kōji solution to react for some time, and to ascertain the composition of the solution, or its specific rotatory power, at different stages. Setting out in one direction the duration of the digestion, and in a direction at right angles to this the specific rotatory power of the solution at stated intervals, the progress of the action can be represented by a curved line, using the specific rotatory power as a measure of the change which has occurred in a given time.

The first series of experiments was carried out at the temperature of the air, which at that time varied between 4° and 10°C.

Experiment 12. 450 c.c. of starch-paste containing 11.43 grams of dry starch were mixed with 50 c.c. of kôji extract. The whole was allowed to stand at this temperature with an occasional shaking, and samples were withdrawn after 48, 120, 192, and 240 hours respectively. After making a deduction for the 50 c.c. of kôji solution used, the amount of solids in 500 c.c. and the optical rotation were found to be as follow:—

TABLE XI. ACTION OF KÔJI EXTRACT UPON STARCH AT 4-10°C.

11.43 grams starch to 10 grams kôji.

Time.	Total starch products in solution (kôji deducted)	Specific rotatory power of starch products.
48 hours	9.714 grams.	109°.6
120 ,, ...	9.904 ,,	100°.2
192 ,, ...	10.369 ,,	90°.4
240 ,, ...	10.450 ,,	80°.4

The curve illustrating this series of experiments is seen in fig. 1, Plate. III. The action upon the starch, as indicated by the fall in the specific rotatory power, is more rapid at the beginning of the experiment, but afterwards proceeds in a regular and continuous manner during the remainder of the experiment.

The second set of experiments was conducted at the same temperature, different proportions of kôji and starch being used.

TABLE XII. ACTION OF KÔJI EXTRACT UPON STARCH AT 4-10°C.

5 grams of starch to 20 grams of kôji.

Time.	Total starch products in solution (kôji deducted)	Specific rotatory power of starch products.
68 hours	4.638 grams.	100°.4
164 ,,	4.816 ,,	75°.8

In this series the same specific rotatory power, 100°.4, is attained in 68 hours, which it took 120 hours in the former series to arrive at, and the reduction is greater in the last series in 164 hours, than in 240 hours of the former. The reason of this lies in the larger proportion of koji used in the second than in the first series of experiments but although four times as much koji was used, the rapidity of the action appears to be only about twice as great

The third and fourth series of experiments were made at a temperature varying between 10° and 15° C., but otherwise they were conducted as before.

TABLE XIII. ACTION OF KOJI [illegible]

10 grams of starch to 10 grams of kōji.

Time.	Total starch products in solution (kōji deducted)	Specific [illegible] power of starch products.
½ hour	10.61 grams.	172°.8
2 hours	10.46 „	155°
21½ „	10.56 „	131°
26 „	10.65 „	130°.4
46 „	10.51 „	[illegible]

TABLE XIV. ACTION OF [illegible]

10 grams of starch to 10 grams of kōji.

Time.	Total starch products in solution (kōji deducted)	Specific rota[illegible] power o[illegible] starch products.
1 hr.	9.705	[illegible]
48 hrs	9.925	121°
2[illegible]	[illegible]	[illegible]

Fig. 2 Plate III [illegible] that although [illegible] appearance under [illegible] power [illegible] the second [illegible] different [illegible] it may be that, although the [illegible] the average temperature of [illegible]. That this might [illegible] Plate III in which the inclination [illegible] the average. This [illegible] limits [illegible] time if an examination of the liquid had [illegible] mentioned this sudden drop would [illegible] inclination from the beginning [illegible] greater. In the same way if the temperature [illegible] experiments [illegible] C. [illegible] the latter.

Fig. 1. Curve showing the action of Kôji extract upon gelatinized starch at 4–10°C.

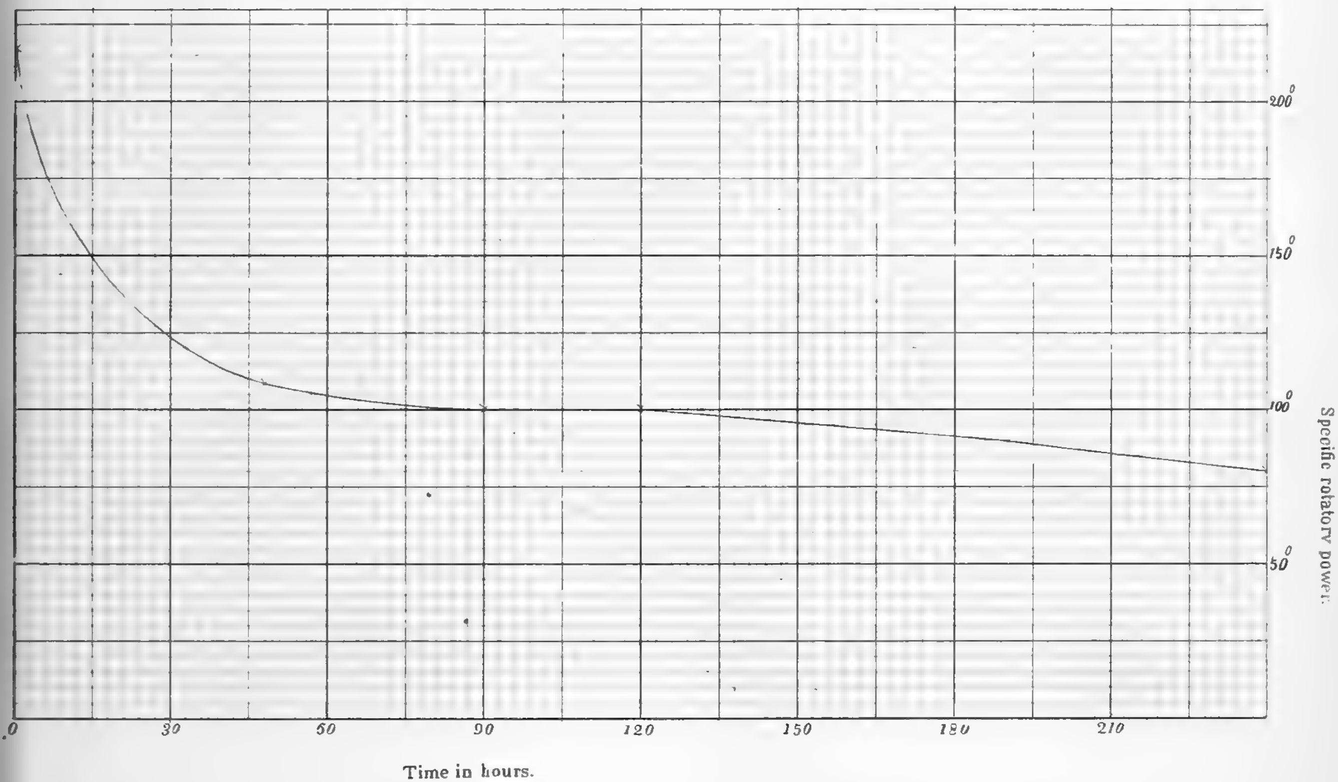
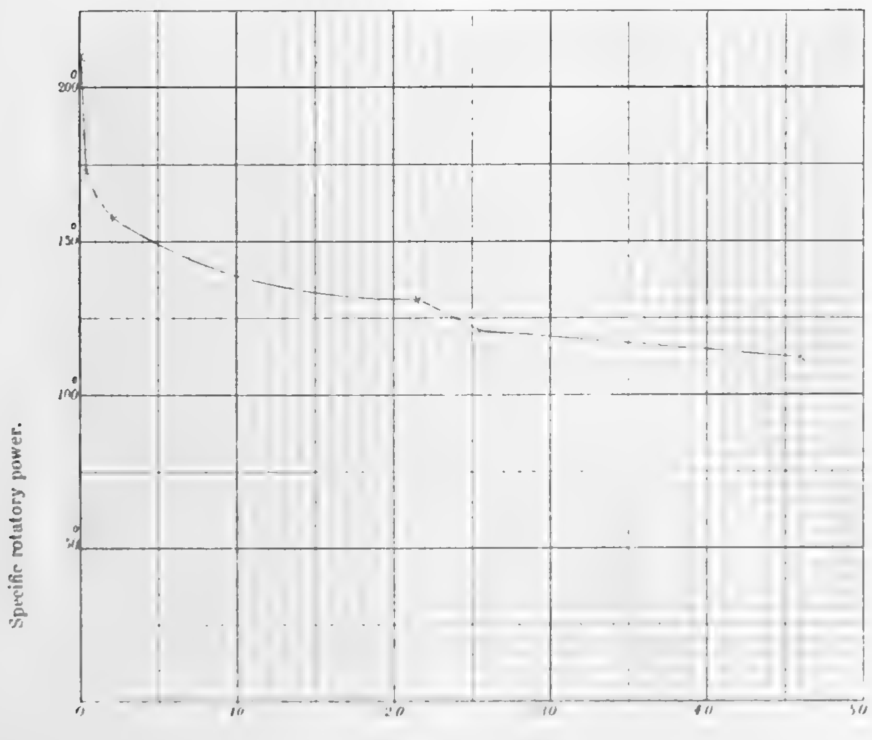


Fig. 2. Curve showing the action of Kôji extract upon gelatinized starch at 10–15°C.



From these experiments we may understand what occurs during the mashing operations in saké making. At first they are conducted at even a lower temperature than 4°C., and this is interesting because it shows that the activity of the diastase in kôji is not destroyed at low temperatures, even at 0°C.

At a higher temperature the reduction in the specific rotatory power of the solution goes on more rapidly, and although the saké-brewer never uses temperatures so high as those of the succeeding experiments, it is of scientific interest to complete the record at all temperatures below that at which the "diastase" of kôji is rendered inactive.

The experiments at higher temperatures were conducted in the following manner. The flask containing the mixture was immersed in a water-bath and kept at the specified temperature, samples being taken at stated intervals. The portion used for determining the total solid matter in solution from its specific gravity was rapidly cooled by means of ice, and another portion in which the specific rotatory power was to be determined, was poured into a dry flask containing a little salicylic acid, as recommended by Brown and Heron,* and also rapidly cooled. Deduction was made for the amount of kôji solution added as in the previous experiments.

The two next series of experiments were conducted at 40°C. and only differ in the relative proportions of starch and kôji used.

TABLE XV. ACTION OF KÔJI EXTRACT UPON STARCH AT 40°C.

10 grams of starch to 5 grams of kôji.

Time.	Total starch products in solution (kôji deducted)	Specific rotatory power of starch products.
25 min	10.08 grams.	167°
4 hours	10.08 ,,	127°
+92 hrs. at 15°C........	10.25 ,,	106°

TABLE XVI. ACTION OF KÔJI EXTRACT UPON STARCH AT 40°C.

10 grams of starch to 10 grams of kôji.

Time.	Total starch products in solution (kôji deducted)	Specific rotatory power of starch products.
⅓rd hour	9.64	148°.1
1 ,, ...	9.64	127°
2 hours	9.64	115°
3 ,, ...	9.65	106°
4½ ,, ...	9.67	88°
6 ,, ...	9.69	86°
+ 20 hrs. at 15°C.	9.79	80°

* loc. cit. 1879. Trans. p. 680.

In fig. 1 Plate IV. these results are represented in a graphic manner. The difference between the two sets lies in the fact that in the latter twice as much kōji is used as in the former, and the result is that at any given time the diminution in the specific rotatory power is greater in the latter. Further, the general form of the two curves is similar, and there is no evidence of any sudden break in the curve, such as in Brown and Heron's experiments indicates a definite chemical equation. Such a break could not be expected, seeing that the action of kōji solution upon maltose would tend to disguise such reactions, by rubbing down the corners, as it were.

Table XVII. gives the results of a similar experiment made at 45° C.

TABLE XVII. ACTION OF KOJI EXTRACT UPON STARCH-PASTE.

10 grams of starch to 10 grams of koji.

Time.	Total starch present in solution (kōji deducted)	Specific rotatory power of starch products.
5 min.	9.48 grams.	142.°6
25 ,,	9.98 ,,	126.°2
1 hr.	9.98 ,,	106.
1½ ,,	—	106.6
2 ,,	9.98 ,,	106.
3 ,,	9.98 ,,	106.8
4 ,,	—	106.2
¼th more kōji added.		
4½ hrs.	10.18 ,,	88.

In the curve fig. 2 Plate IV., which represents these results graphically, it will be noticed that during the first five minutes the fall in the specific rotatory power is very rapid until it arrives at $[\alpha]_j = 142°.6$ after which it proceeds in very nearly a straight line till the specific rotatory power equals 106°, after which it remains almost the same, until after a fresh addition of kōji, which causes a reduction to 88°. As the rate of reduction after the addition of a fresh quantity of koji is very nearly the same as at first (as is shown by the similarity in the inclinations of the curve), it is evident that the kōji first added had been nearly exhausted when the specific rotatory power of 106° was attained.

At a higher temperature, 60° C., the activity of the koji solution is very soon exhausted, as will be seen from the following results, and from the curve Plate V.

Fig. 1. Curve showing the action of Kôji extract upon gelatinized starch at 40°C.

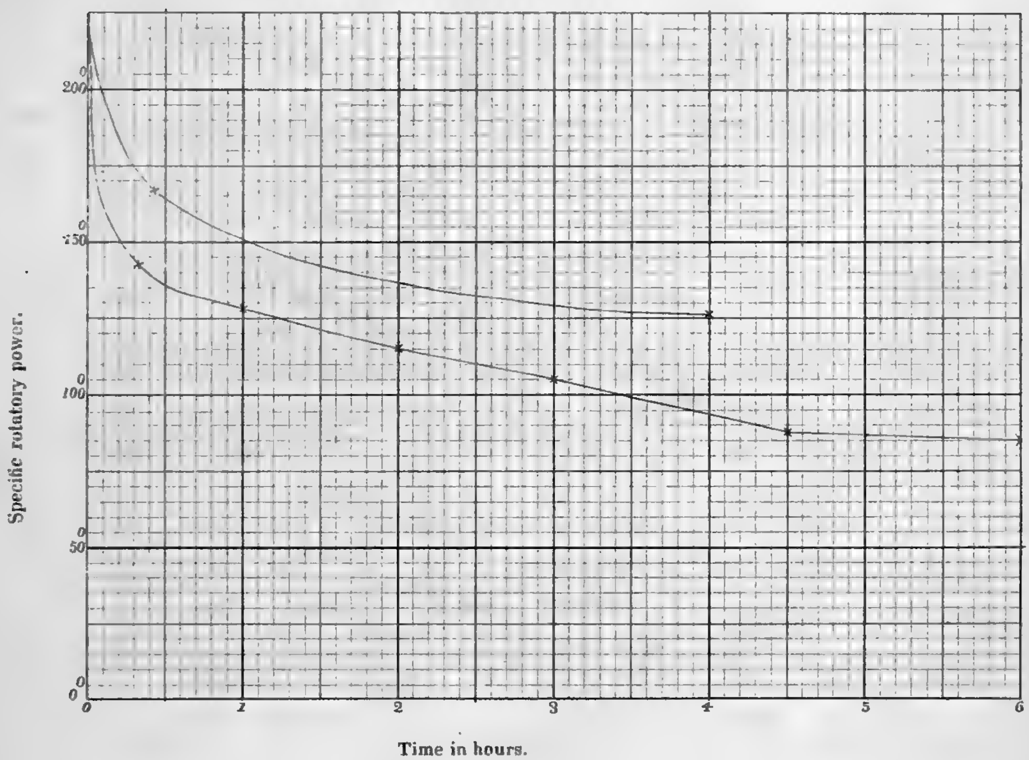
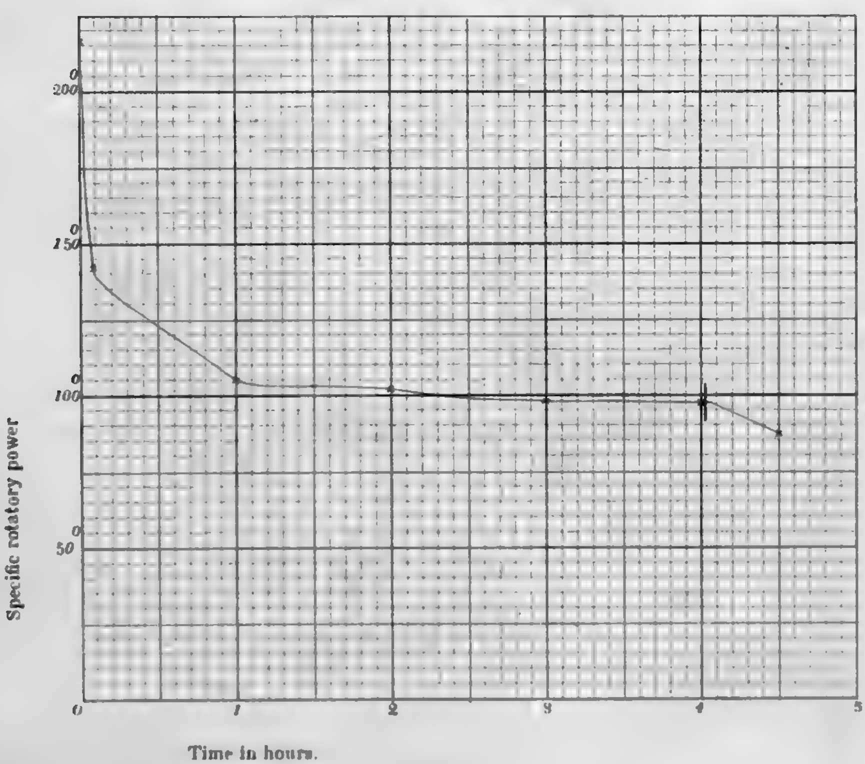
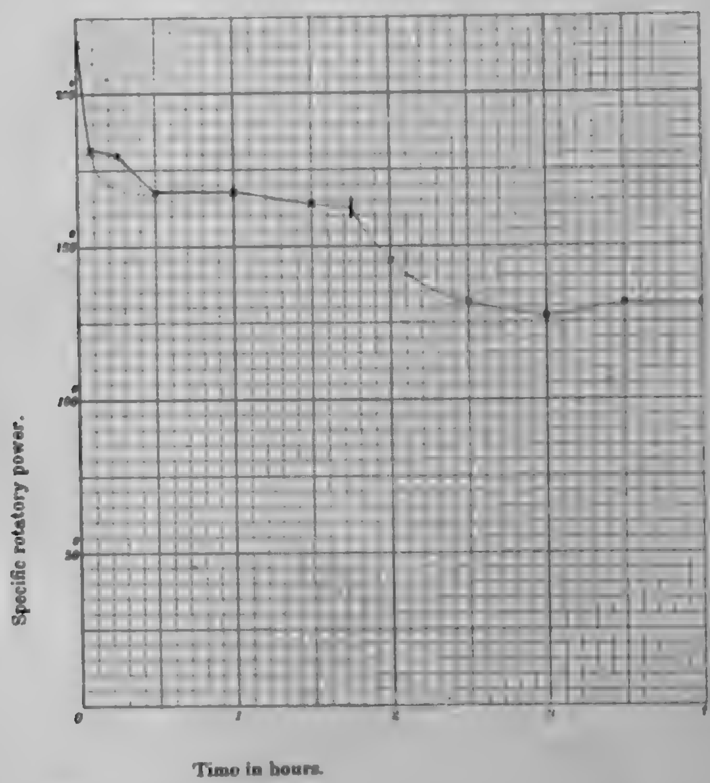


Fig. 2. Curve showing the action of Kôji extract upon gelatinized starch at 45°C.



(The vertical black line indicates the time at which a further addition of Kôji solution was made.)

CURVE SHOWING THE ACTION OF KÔJI EXTRACT UPON GELATINISED STARCH AT 60°C



(The vertical black line indicates the time at which a further addition of Kôji solution was made.)

TABLE XVIII. ACTION OF KŌJI EXTRACT UPON STARCH AT 60°C.

10 grams of starch to 10 grams of kōji.

Time.	Total starch products in solution (kōji deducted)	Specific rotatory power of starch products.
5 minutes	9.70 grams.	182°.1
15 „	„ „	180°.2
30 „	„ „	168°
1 hour.	„ „	168°
1½ „	„ „	164°.6
1¾ hr. Fresh addition.		
2 hrs.	10.19 „	145°.8
2½ „	„ „	131°.8
3 „	„ „	128°.2
3½ „	„ „	131°.8
4 „	10.19 „	131°.8

The number found at 15 min. is doubtless incorrect. After half-an-hour had elapsed, and the specific rotatory power had diminished to 168°, the action appeared to cease, until a fresh addition of kōji was made, when it fell at a similar rate, and for nearly the same time as at first. The high temperature, therefore, very quickly renders the "diastase" of kōji inactive.

At a temperature of 70°C. practically no solution of starch took place, from which it may be concluded that a temperature between 60° and 70°C. renders it completely inert. The "diastase" of malt is not killed until between 80° and 81°, which constitutes another point of difference between the two. The two bodies resemble one another in this, that the loss of activity is accompanied by the appearance of a distinct precipitate, consisting of albumenoid matter that has been coagulated by heat. Messrs. Brown and Heron state that "Every stage in the coagulation of malt-extract by heat is attended with a distinct modification of its starch-transforming power; and conversely, we have never been able to discover any modification in starch-transforming power which is not attended with distinct coagulation. In addition to this, at 80°—81°, the point at which the diastatic power of malt-extract is destroyed, nearly the whole of the coagulable albumenoids have been precipitated. We are consequently led to conclude that the diastatic power is a function of the coagulable albumenoids themselves, and is not due, as has been generally supposed, to the presence of a distinctive transforming agent."*

* Brown & Heron, loc. cit. p. 651.

We have already seen that the principal change which rice undergoes in its conversion into kôji is the alteration in the nature of the albumenoid matter which becomes more easily degraded and soluble in water; taking this in connection with the destruction of the active properties of the solution at a temperature corresponding to that at which the albumenoid matter becomes coagulated, we are led to the conclusion that there is a similar connection between the presence of soluble albumenoids and the activity of the solution of kôji which seems to hold in the case of malt extract.

PART II. SAKÉ BREWING.

SECTION. 1.

PREPARATION OF MOTO.

The process of preparing saké followed in the large breweries of Itami and Nishinomiya is very nearly the same, and may be easily divided into distinct periods, but saké is also very frequently prepared in much smaller establishments, in which case, properly speaking, only two divisions can be noticed, viz. the preparation of *moto*, and the principal process. The chemical changes which occur will be very easily understood after the details which have been given in the preceding part, but it will not be found possible to make a distinct separation between the solution of the starch and the actual fermentation as can be done in beer-brewing. In that industry the starch is converted into sugar and dextrin during the operation of mashing, after which the diastase is destroyed by boiling before the fermentation is allowed to begin, but in the manufacture of saké these two processes go on at the same time, except during the first few days. In this respect, therefore, the brewing of saké differs from that of beer, and it may, perhaps, be one of the reasons why the former liquid is so much more alcoholic than the latter.

As carried out at Itami and Nishinomiya saké-brewing consists of the following series of processes:—

1. Preparation of *Moto*
2. Preparation of *Soye* } The principal process.
3. Preparation of *Naka* } The principal process.
4. Preparation of *Shimai* } The principal process.
5. Filtration and clarification.

Of these that which requires most care and is most liable to fail is the first, the preparation of *moto*.

MOTO.

In the preparation of *moto* steamed rice, kōji, and water are used in proportions which differ slightly in different works. The term *moto* is used to express not only the product of this operation, but also a definite amount—thus the workmen speak of one moto—two and a half moto, and so on. At Itami, the most famous district, the proportions for one moto are:—

Steamed rice	0.5	koku
Kóji	.2	,,
Water	.6	,,
	1.3	,,

It may be remarked that the numbers indicating the amount of steamed rice and kóji used refer, not to the finished products, but to the quantity of rice taken to form them.

At Nishinomiya, another very celebrated saké-making district, the proportions are as follow:—

Steamed rice	0.5	koku
Kóji	.2	,,
Water	.63	,,
	1.33	

At a brewery in Tókio at which I had the opportunity of watching the whole process from beginning to end and of making analyses of the mash at different periods, the proportions for one moto were:—

Steamed rice	0.40	koku
Kóji	.16	,,
Water	0.40	,,
	0.96	

To find the percentages of dry rice and water in the last mixture we proceed as follows. The weight of one koku of water is 48 kuwamme (B. S. Lyman, Geological Survey. Report. Progress. 1878-79), and we have already seen that the weight of one koku of rice is on the average 40 kuwamme, hence the weight of one moto is

Rice (for steaming)	16.0	kw.
Rice (for making into kóji)	6.4	,,
Water	19.2	,,

After steaming the rice used was found to contain 38.8 % of water, hence the original rice, which contained 14 per. cent. of water, had taken up in addition 40 per. cent. of its weight of water. 16 kuwamme of rice will thus take up 6.4 kw. of water, which, together with the 14 per. cent. already present, will give $6.4 + 2.24 = 8.64$ kw. of water and 13.76 kw. of dry rice.

By the conversion of rice into kōji 100 parts of common rice form 108 parts of kōji containing 30 per cent. of water (see p. 13), thus 6.4 kw. of rice will form 6.9 kw. of kōji, containing 4.83 kw. dry rice and 2.07 kw. of water.

The total dry rice, therefore, is 13.76 + 4.83		18.59 kw.
The water taken up is 8.64 + 2.07 = 10.71	}	29.91 ,,
The water subsequently added 19.2	}	

or in percentages

Dry rice	38.3	per cent. (containing 32.17 of starch.)
Water	61.7	,, ,,
	100.0	

The quantity taken for 1 moto is mixed and divided into six equal parts, each of which is placed in a shallow wooden tub called *hangiri*, of a capacity of 0.267 koku. The mass is thoroughly mixed by hand for two hours, any lumps which are formed being broken down. At first the mixture of rice, kōji, and water is so thick that it would hardly fall out if the vessels were inverted, but in a short time it loses its stiffness and becomes thin. After 24 hours have elapsed stirring with paddles (*kai*) begins, and when this is finished the whole is thrown into a larger tub (*moto-oroshi*), provided with a cover cut in two to facilitate the inspection of its contents, and covered with matting for the purpose of diminishing loss of heat as much as possible. The preceding operations have been carried on at a low temperature, from 0°C. to 9 or 10°C. at the highest, and the chemical change which occurs during this period will be easily understood from the account already given of the action of kōji upon gelatinized starch. The rice-grains having been steamed are of course in the gelatinized state, but, owing to the greater compactness of the grain, the action is much less rapid than in the experiment carried out at 4 to 10°C. as described on page 29. Doubtless the mixture at first contains a certain proportion of maltose, as well as dextrose and dextrin, but it will be gradually changed into dextrose. The duration of this simple digestion in the cold differs in the different works and even in the same place. At Nishinomiya, an interval of one day after transference into one vessel is allowed before the mixture is warmed; at Itami it is sometimes heated at once, and sometimes kept for five or six days. At the Tōkiō brewery the mash was heated at 3 p.m on the fifth day after mixing, and the two following analyses show its composition before that event took place.

	Third day, 8 a.m.	Fifth day, 8 a.m.
Dextrose	7.35	12.25
Dextrin	5.12	5.69
Glycerin, ash, albumenoids, &c	trace	.48
Fixed acid	0.017	0.019
Volatile acid	—	.008
Water (by difference)	87.513	81.553
	100.000	100.000

Specific rotatory power	124°	106°
Specific gravity of mash	1.15	1.18
Temperature of mash	13°C	10°C
Starch undissolved	20.43%	15.46%

The effect thus far has been to increase the amount of dextrose at the expense of the starch: at the same time a fresh proportion of dextrin is no doubt formed, but this increase is obscured by the fact that there are two actions going on, formation of dextrin by a splitting up of the starch, and a disappearance of dextrin by the hydrating action of the koji, and the result of these two actions is to leave the dextrin very nearly what it was on the third day. It is important to observe that even so early as the third day only dextrose, and no maltose, is present in solution; the observed specific rotatory power is 124°, and that calculated for dextrose and dextrin in the observed proportions is 123°.4. The specific gravity of the mash has increased a little owing to the larger amount of solid matter in the solution, and the specific rotatory power has diminished, the proportion of dextrose to dextrin being greater on the fifth day than on the third day. The composition of the mash as given on the fifth day may probably be looked upon as the usual composition just before heating; this sample was taken at 8 a.m. and the heating commenced at 3 p.m. on the same day. If no change had occurred the mash would have contained 32.17 per cent. of starch. The dextrose and dextrin on the third day correspond to 11.735, which leaves 20.43% of starch undissolved, and in the same way the starch undissolved on the fifth day amounts to 15.46%.

The heating is effected in all establishments in the same way. A closed tub called *nukume* or *daki* of a somewhat conical form, 18 inches high, 12 in. at its upper diameter and 9 to 10 inches in diameter at the lower part, is filled with boiling water and tightly closed. It is supported by means of a handle formed by a cross bar fastened to two ears which project upwards from opposite sides; in this way it is let down into the thick mash contained in the large tub, and the mixture is agitated by moving the heater about. As a rule one heater is allowed to remain in the mash for half a-day, and is then replaced by a fresh one which is left in for the same time, but the number of heaters used depends to some extent upon the temperature of the air. During the 13 days required for the completion of the moto at Itami from 5 to 9 heaters are employed, and at Nishinomiya from 10 to 13 are used in the same time. It is found undesirable to raise the temperature of the mash too rapidly, probably because a too high temperature at first would allow the acid ferments to become developed to the exclusion of the alcoholic ferments.

In the Tôkiô brewery the heaters were allowed to remain in the mash for a much shorter time. Introduced on the fifth day at 3 p.m. the liquid was transferred back from the large tub into the shallow pans on the eighth day at 7 a.m. and was allowed to cool as much as possible until the fourteenth day at 11 a.m.

when a fresh addition of rice and koji was made, the commencement of the main process.

The heating of the mash has the effect of inducing alcoholic fermentation to set in with great vigour. On the seventh day, when the next sample was taken, gas was rising rapidly through the mash and on coming to the surface burst with a slight, explosive noise. At the same time a very strong, sharp odour was perceptible, whilst a foam covered the surface. The following analyses give the composition of the moto from the seventh to the fourteenth day, after which the main process began. The mash was again placed in the shallow *hangiri* at 7 a.m. on the 8th day.

TABLE XIX. COMPOSITION OF THE MOTO FROM THE SEVENTH TO THE FOURTEENTH DAY.

	7th day.	10th day.	12th day.	14th day.
Alcohol	5.2 p. c.	8.61 p. c.	9.41 p. c.	9.20 p. c.
Dextrose	5.4 ,,	.99 ,,	.49 ,,	.50 ,,
Dextrin	7.0 ,,	2.81 ,,	2.72 ,,	2.57 ,,
Glycerin, ash, albumenoids, &c.	1.14 ,,	2.82 ,,	2.35 ,,	1.93 ,,
Fixed acid	.31 ,,	.24 ,,	.31 ,,	.30 ,,
Volatile acid	.15 ,,	.11 ,,	.05 ,,	.03 ,,
Water (by difference)	80.80 ,,	84.42 ,,	84.67 ,,	85.47 ,,
	100.00	100.00	100.00	100.00
Specific rotatory power	135°	100°.7	111°.6	116°
Specific gravity of mash	1.08	1.05	1.06	1.04
Temperature of mash	23°C.	14°C.	10°C.	9°C.
Starch undissolved	10.68%	12.46%	11.55%	12.05%

The alcoholic fermentation set in somewhat rapidly, for between 3 p. m. on the fifth day and 8 a. m. on the seventh day 5 per cent. of alcohol was formed, and the dextrose diminished from 12.25 per cent. to 5.4 per cent. The amount of dextrin increased in that time, but the increase is probably only apparent, caused by the loss of matter in the form of carbonic acid. The solution of starch during this stage does not appear to have gone on very actively; there is a discrepancy in the numbers calculated on the seventh to the fourteenth days, which probably arises from the difficulty of taking an average sample of the mash. The percentages given are calculated upon the original weight of the mash.

From the seventh day to the fourteenth day the alcohol steadily increases; the dextrose is very quickly removed, there being less than one per cent. on the tenth day, and between the seventh day and the tenth the dextrin is reduced from 7 per cent. to 2.8 per cent. about which it remains during the rest of the time, owing probably, to the kōji having lost its activity.

When the liquid was heated by the introduction of hot water barrels the temperature attained was 23° in the Tókió brewery, and 25°C. at Nishinomiya. As soon as the mash was transferred to the shallow tubs, however, it began to cool down, the activity of the fermentation not being sufficient to keep up the temperature; the composition of the liquid indeed, shows that this result must follow inasmuch as there is not enough food left in the liquid in the form of sugar and dextrin to allow the active growth of the ferment to continue. Hence on the tenth day the temperature fell to 14°C., on the twelfth day to 10°C., and on the fourteenth day to 9°C.

A sample of the finished moto obtained from the brewery at Nishinomiya had the following composition, which agrees very well with that obtained in Tókió, from which it may be inferred that different specimens of moto will not differ in composition to any marked extent.

FINISHED MOTO FROM NISHINOMIYA.

Alcohol	10.5 %
Dextrose	.2
Total acid	.56
Starch and cellulose	16.58
Water (by difference)	72.16
	100.00

The chemical changes which go on in the production of moto are sufficiently easily explained in general terms. During the first days, whilst the mixture is kept at a low temperature, the kōji is acted upon by the water and the solution then attacks the starch according to the reactions already indicated. This results in the production of a saccharine and dextrinous liquid forming a suitable food for the ferment which subsequently establishes itself in the liquid on warming. How the ferment appears will be discussed in a later section. Whilst the yeast is growing and converting the sugar into alcohol, the solution of starch and the hydration of dextrin by the kōji still continue so long as the latter retains its activity, but that appears to be destroyed some time before the moto is completely finished. At the end of this stage the yeast ferment though not vigorous, is well formed and only requires a fresh addition of food to commence growing with renewed activity. It may, indeed, be said that the preparation of moto has for its main object the production of a healthy ferment, so that the use of the moto in the subsequent operations answers very nearly to the yeast added to the wort in beer-brewing.

The saké-brewer judges of the progress of the moto by the vigour of the fermentation and by the taste of the liquid. At Itami it is said to require 13 days to obtain the proper taste; after three days the taste is sweet owing to the presence of much dextrose; after six days it is astringent, on the seventh day it is slightly alcoholic, and finally it becomes sour. When finished the brewer is able to distinguish five tastes, respectively sweet, sour, bitter, astringent, and alcoholic, and of these the sour, bitter, and astringent are most pronounced. The formation of the acid appears to take place between the fifth and the seventh days, and is partly succinic acid formed during the fermentation; a little lactic acid is also formed during the time the mash is allowed to cool in the shallow vessels, although its amount cannot be very large seeing the great development which the yeast has taken. The bitter and astringent tastes are due to the presence of the yeast, though the nature of the substances giving rise to them is unknown.

SECTION 2.

THE PRINCIPAL PROCESS.

In the chief fermentation process as carried out at Itami and Nishinomiya there are three stages, called respectively *soye*, *naka*, and *shimai*, although they do not differ from one another in any essential particular. In the Tôkiô brewery it is not so easy to distinguish these stages, and it will, therefore, be most convenient to describe the former methods first, reserving the latter and the analyses of the product at different times until the others have been disposed of.

At Itami the proportions used to one moto are the following—

Moto	1.30	koku
Steamed rice	1.30	,,
Kôji	.35	,,
Water	1.30	,,
	4.25	,,

and at Nishinomiya the following quantities are used:—

Moto	1.33	koku
Steamed rice	1.05	,,
Kôji	.35	,,
Water	1.15	,,
	3.88	,,

This mixture is placed in a large tun called *sanjaku-oke* (or three-foot tub) which holds about 8 koku, and which is, therefore, only about half-filled. The mixture is stirred every two hours, and, after 42 hours at Itami, and 3 days at Nishinomiya the first stage (soye) is finished, and the product is divided into two parts preparatory to the second stage. During this period fermentation sets in and the temperature rises, that of one batch examined at Itami being 20°C. the temperature of the air at the same time being 11°C. An odour, strong, pungent, and fragrant arose from the mash. A sample of the mash from Nishinomiya had the following composition.

COMPOSITION OF SOYE FROM NISHINOMIYA.

Alcohol	11.00	per. cent.
Dextrose	.18	,,
Total acid	.36	,,
Starch	17.52	,,
	29.06	

The amount of dextrose present is very small, a fact which is probably accounted for by the continuous growth of the ferment between the time when the sample was taken and the time of its analysis. The alcohol on that account is doubtless higher than in the mash at the end of this stage.

As soon as the first stage is finished the mash is divided into two parts each of which is placed in a three-foot tub, and a fresh amount of steamed rice, kóji, and water added in the following proportions, using the whole of the soye.

At Itami they use—

Soye	4.25	koku
Steamed rice	2.00	,,
Koji	.65	,,
Water	3.00	,,
	9.90	,,

At Nishinomiya the following mixture is made—

Soye	3.88	koku
Steamed rice	1.80	,,
Kóji	.60	,,
Water	2.40	,,
	8.68	,,

The stirring is continued every two hours as in the soye stage so that the grains of rice may not fall to the bottom, and get beyond the action of the kóji. The mixture is left for 24 hours by which time the *naka* stage is finished. At Itami the temperature observed was lower than in the soye stage, but the observation was made soon after mixing so that the fermentation had not then had time to fully develop itself; the temperature observed was 15°.5 C. that of the air being 11° C. This mash also possessed a pungent, fragrant odour though not so powerful as in the case of the soye.

After the lapse of 24 hours, that is at the end of the second (naka) stage, the quantity of material in each tub is again divided into two, so that each of these parts now contains only one-fourth of the original moto. To the whole a fresh admixture of steamed rice, kôji, and water is made—at Itami in the following proportions:—

Naka	9.90	koku
Steamed rice	3.30	,,
Kôji	1.00	,,
Water	4.20	,,
	18.40	,,

And at Nishinomiya.—

Naka	8.68	koku
Steamed rice	3.60	,,
Kôji	1.20	,,
Water	6.20	,,
	19.68	,,

The quantity of water added at this stage (shimai) depends upon the alcoholic strength required. At first the whole quantity is divided amongst four tubs, but after standing for about 3 days the mixture is collected by degrees into one large tub called *roku-shaku-oke*, holding about 24 or 25 koku. In this the fermentation goes on more vigorously for two or three days after which it gradually ceases—the froth sinks, and the liquid is now strongly alcoholic and ready for filtration. The time during which it is allowed to stand before filtration varies, but is not a matter of much importance.

It may be useful to collect together the amounts of each material used:—

ITAMI.

Stages.	Rice for steaming.	Rice for kôji.	Water.
Moto	0.5 koku	0.2 koku	0.6 koku
Soye	1.3 ,,	.35 ,,	1.8 ,,
Naka	2.0 ,,	.65 ,,	3.0 ,,
Shimai	3.3 ,,	1.00 ,,	4.2 ,,
	7.1 ,,	2.2 ,,	9.1 ,,
	284 kw.	88 kw.	436.8 kw.

284 kuwamme of rice contain 244.24 kw. of dry rice and 39.76 kw. of water. It also takes up in addition, by steaming, 113.6 kw. of water—hence the total weight of water is 153.36 kw.

88 kuwamme of rice after being converted into kôji weigh 95.04 kw. and the kôji contains 66.53 kw. of dry rice and 28.51 kw. of water.

We have, therefore,

	Dry rice	Water
Steamed rice	244.24 kw.	153.36 kw.
Kōji	66.53 ,,	28.51 ,,
Water		436.80 ,,
	310.77 ,,	618.67 ,,

or in percentages

Dry rice	33.4	per cent. (containing 28.05 starch)
Water	66.6	,, ,,
	100.0	

In a similar way we find the percentages of dry rice and water used at Nishinomiya to be

Dry rice	32.3	per cent. (containing 27.13 starch)
Water	67.7	,, ,,
	100.0	

We may now consider the method of brewing followed in Tōkiō. One feature is that the frequent subdivision of the mash does not take place as in Itami and Nishinomiya, but after the moto has been finished, it is transferred to a large tub (*rokushaku oke*) and the subsequent additions are made to it in the same vessel. This must result in a saving both of material and of labour, and at the same time the temperature required for the active growth of the ferment is better maintained as will be seen from the observations which will be recorded presently.

In the description of the preparation of moto the last analysis given of the mash was at 8 a. m. on the fourteenth day. The next sample was taken at 8 a. m. on the seventeenth day, when the main process was already entered upon. To the quantity of material in one moto the following amounts of rice and kōji were added at 11 a. m. on the fourteenth day.

Steamed rice	1.0 koku
Kōji	.3 ,,
Water	1.2 ,,
Moto	.96 ,,
	3.46 ,,

A second addition was made at 11 a. m. on the sixteenth day, amounting to

Rice	1.2 koku
Kōji	.36 ,,
Water	1.44 ,,
Already mixed	3.46 ,,
	6.46 ,,

Supposing that no alteration had taken place in the mixture, the quantities of dry rice and water present in the mash, including the first addition, would be:—

Dry rice	34.9 % (containing 29.32 starch)
Water	65.1 %
	100.0

A sample of the mash taken on the seventeenth day from the commencement had the following composition—

Alcohol	5.800 per cent.
Dextrose	2.060
Dextrin	3.890
Glycerin, albumenoids, &c.	.043
Fixed acid	.015
Water	88.192
	100.000
Undissolved starch and cellulose	12.814 per cent.
Specific rotatory power	160°
Specific gravity of mash	1.03
Temperature of mash	19°C.

The specific rotatory power of the solution is as high as 160° because the percentage of dextrin in the solid matter is so large, amounting to 65 per cent of the total solid matter in solution. The number calculated for

Dextrin	65.00
Dextrose	34.36
Inactive matter	0.64
	100.00

is 160°.7. Hence at this stage also no maltose is present in solution, that first formed having been converted into dextrose.

The two additions of steamed rice, kōji, and water on the fourteenth and sixteenth days respectively may, perhaps, be regarded as indicating the division of the main process into the stages *soye* and *naka*. If this be so the third addition which is made on the eighteenth day at noon, will correspond with the commencement of the stage called *shimai* at Itami and Nishinomiya. The last addition consisted of—

Rice	1.40	koku
Kōji	.42	,,
Water	1.68	,,
Already present	6.46	,,
	9.96	

and the weights and percentages of dry rice and water present, if no change had taken place, would be

	Weight.	Percentage.
Dry rice..........	175.1 kw.	34.7 (containing 29.15 % starch)
Water............	329.03 ,,	65.3
	504.13 ,,	100.0

The temperature of the mash at this stage rises considerably owing to the very active growth of the alcoholic ferment; thus on the seventeenth day the temperature rose to 19°C, on the nineteenth day to 25°C, and on the twenty-first day to 26°C., by which time the fermentation was for the most part finished, and the temperature then fell to 20°C. on the twenty-fourth day and to 12°C. on the twentyeighth day. During this time the temperature of the air was never above 12°C. and, for most of the time, far below that point. The composition of the mash during this the last stage of the main process will be seen from the accompanying analyses.

TABLE XX. COMPOSITION OF THE MASH DURING THE PRINCIPAL PROCESS.

	19th day.	21st day.	24th day.	28th day.
Alcohol........................	9.44	11.88	12.41	13.23
Dextrose	1.16	.27	.27	0
Dextrin	2.74	1.42	.47	.41
Glycerin, albumenoids. &c.	1.09	1.98	1.68	1.99
Fixed acid	.08	.058	.086	.107
Volatile acid	....	.029	.086	.061
Water	85.54	84.413	84.998	84.202
	100.00	100.000	100.000	100.000
Specific rotatory power..........	132°.8	88°.8	48°.2	36°
Specific gravity of mash	1.017	0.994	0.990	0.988
Temperature of mash	25°C.	26°C.	20°C.	12°C.
Undissolved starch	7.85 %	5.534 %	5.40 %	4.18 %

A glance at the numbers given in this table will show how far the fermentation has been carried. After the addition made on the eighteenth day, the mash was left to itself except for the stirring which was continued as before about every two hours. During this time a vigorous growth of ferment went on, gas escaped rapidly, and a pungent odour was spread throughout the chamber.

On the nineteenth day the effervescence was very strong, and it rose to a maximum between that day and the twentyfirst day when, although the temperature was higher, the amount of effervescence was perceptibly less. The taste of the mash was bitter and strongly alcoholic. On the twentyfourth day the effervescence was very slight, and the odour was strongly ethereal, but, although, the effervescence had diminished greatly, formation of alcohol still went on, as between the twentyfourth and twentyeighth days the percentage increased from 12.41 to 13.23%. How much further the process might have been carried is doubtful; at this time the undissolved matter was separated from the alcoholic solution and the analyses could not be continued, but from the analysis of the mixture on the twenty-eighth day compared with that on the twentyfourth day it appears that the diastase of the kōji was not yet destroyed. The amount of dextrose and dextrin which disappeared in that interval was not sufficient to account for the increase in the amount of alcohol, which must, therefore, have been formed by the solution of a fresh quantity of starch.

From the numbers giving the percentage of undissolved starch it will be seen that it suffers a constant diminution, a change which shows that the solution of the starch under the influence of the kōji is a continuous process, going on concurrently with the fermentation of the sugar formed. Indeed it would appear that the conversion of the sugar into alcohol is a more rapid process than the production of sugar from starch, as, if it were otherwise, we might expect the sugar to increase at first, or at any rate, to remain more nearly constant than it does.

A point of interest is the increase in the amount of fixed acid from the nineteenth day onwards. The numbers given are calculated for sulphuric acid, although the acid present is for the most part succinic acid, but even in the last analysis its amount is much less than was found during the preparation of *moto*. In that stage, however, owing to the greater surface exposed to the air, and the lower activity of the alcoholic fermentation, other organisms are present, lactic acid ferments especially, and these contribute to the larger amount of fixed acid in the moto.

SECTION 3.

FERMENTATION OF THE MASH.

In the previous sections we have seen that the sugar formed by the action of the koji upon the starch of the rice grain undergoes fermentation, that is, is converted into alcohol, carbonic acid, and some other products in smaller quantity. It is now generally admitted that the production of these bodies is the result of the growth of some form of organism, which, in the majority of cases, is a species of the genus Saccharomyces. In beer-brewing the yeast ferment is added to the wort after cooling, and then finding the necessary food present it goes on growing and budding rapidly, producing, in addition to the substance of the newly formed cells, alcohol and carbonic acid as the results of its growth. These cells when examined under the microscope have the appearance (shown in fig. 1 Plate VI) of small spherical or oval cells, having a longer diameter of about one-hundredth of a millimetre, and frequently with small bubbles in the interior. They grow by a process of budding, that is, a small protuberance forms at the side of a full grown cell, gradually becoming larger, and when it has attained the size of the first cell, it breaks away, and then acts on its own account. In the fermentation of beer the most important species of alcoholic ferment is the one just alluded to, Saccharomyces cerevisiæ.

In the manufacture of wine no ferment is directly added to the must, but it has been found that germs of the alcoholic ferments which subsequently grow and produce the wine adhere to the outside of the skin and stalks of the grape and in that way enter the liquid when the grapes are crushed. The common ferment of wine is Saccharomyces ellipsoideus, but other species are also found, such as S. pastorianus, S. exiguus, S. conglomeratus, and Carpozyma apiculatum. The following are the average dimensions of these species :—

	Long diameter	Short diameter
Saccharomyces ellipsoideus	0.006 m.m.	0.004-0.005 m.m.
" Pastorianus	.006 " "	variable
" exiguus	.003 " "	.0025 m.m.
" conglomeratus	.006 " "	
" mycoderma	.006 " "	.004 m.m.
Carpozyma apiculatum	.006 " "	.003 " "

The ferment of beer, therefore, is much larger than any of these species, and although the full-grown specimens vary a little in size, they never fall below 0.008 m.m. in diameter. M. Pasteur has, however, shown that under certain conditions S. Pastorianus may assume very different forms and sizes.

Besides these special alcoholic ferments there are other forms of fungi which are capable of yielding alcohol when they are caused to grow submerged in a saccharine solution. Such are especially the Mucor mucedo and the Mucor racemosus which have been examined by Fitz. They however, never yield a liquid containing more than from 2 to 4 per cent. of alcohol.

Before considering the nature and origin of the ferment which is found in saké-breweries, it will be convenient to describe the microscopic appearances presented by the mash at the periods at which the chemical analyses described in the last section were made.

On the first and second days after mixing no appearances of any special interest were to be observed, but on the third day, together with fragments of broken mycelium filled with granulations, isolated cells of ferment were to be seen as represented in figure 1 Plate VII: the largest of these were only 0.0075 millimetre in diameter. The temperature of the mash at that time was 13°C.,

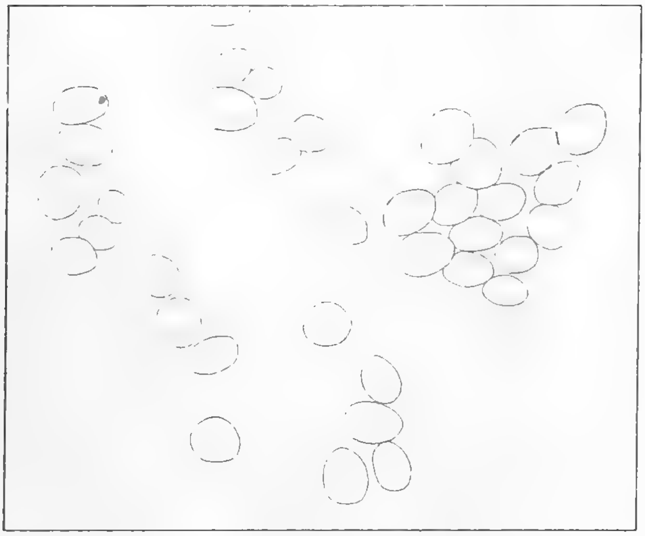


Fig. 1. Cells of Saccharomyces cerivisiæ. Sakurada beer brewery. Tôkio. × 700.

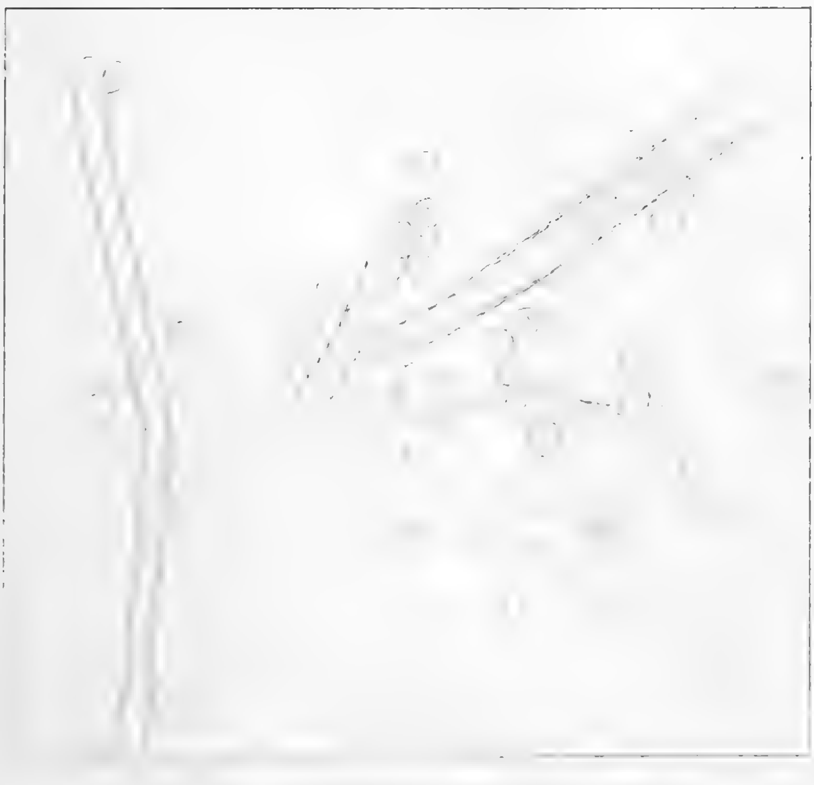


Fig. 2. Cells of saké ferment formed in a Kôji mash after nine days. × 748.

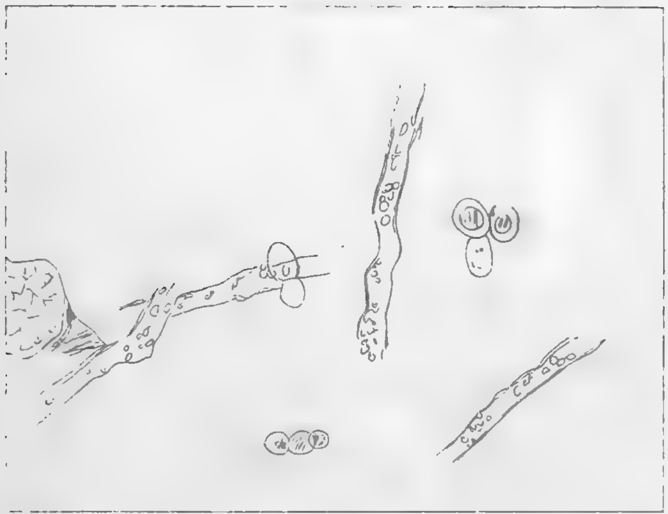


Fig. 1. Mash of third day. × 740

Fig. 2. Mash of third day after standing 3 days. × 740

Fig. 1. Mash of fifth day. × 740

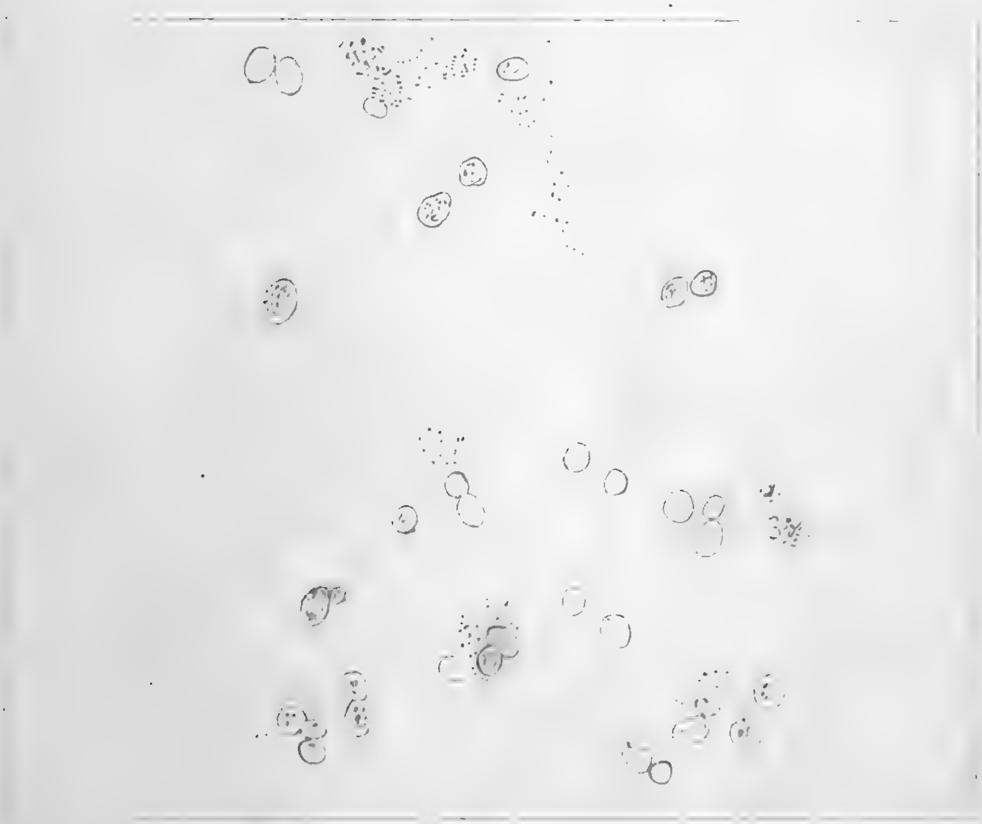


Fig 2. Mash of seventh day. × 720

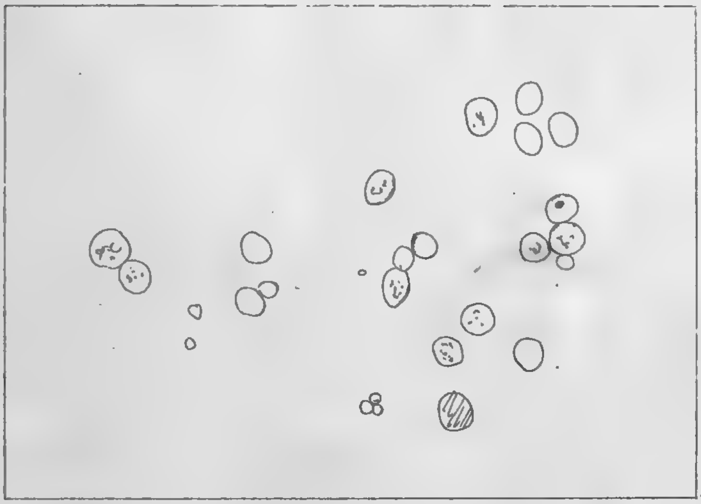


Fig. 1. Mash of tenth day. × 730

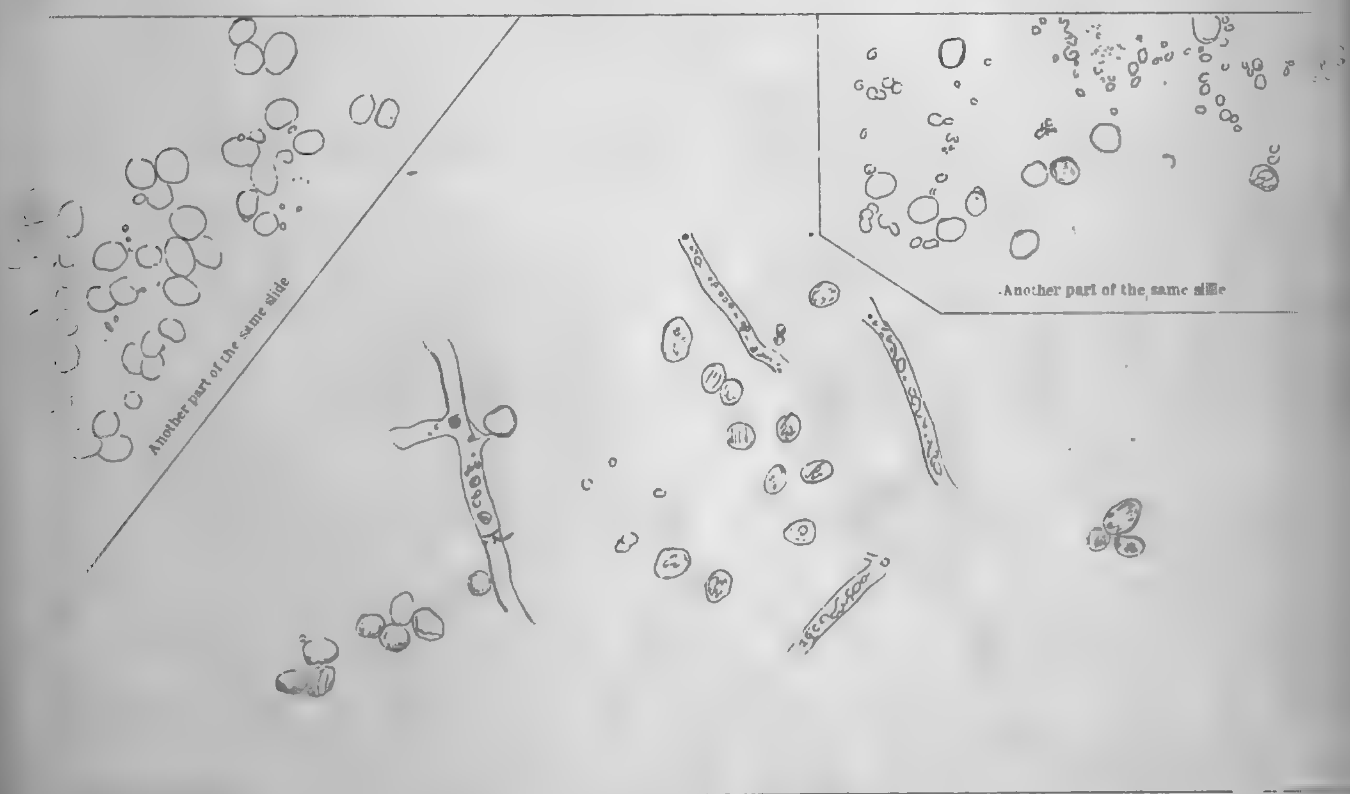


Fig. 2. Mash of twelfth day. × 700

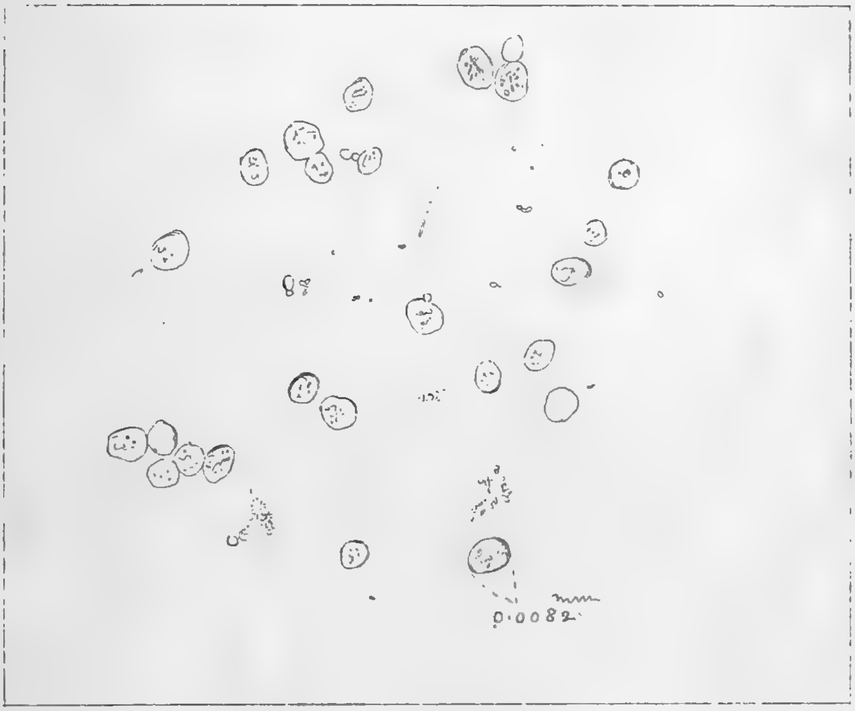


Fig. 1. Mash of fourteenth day. × 730

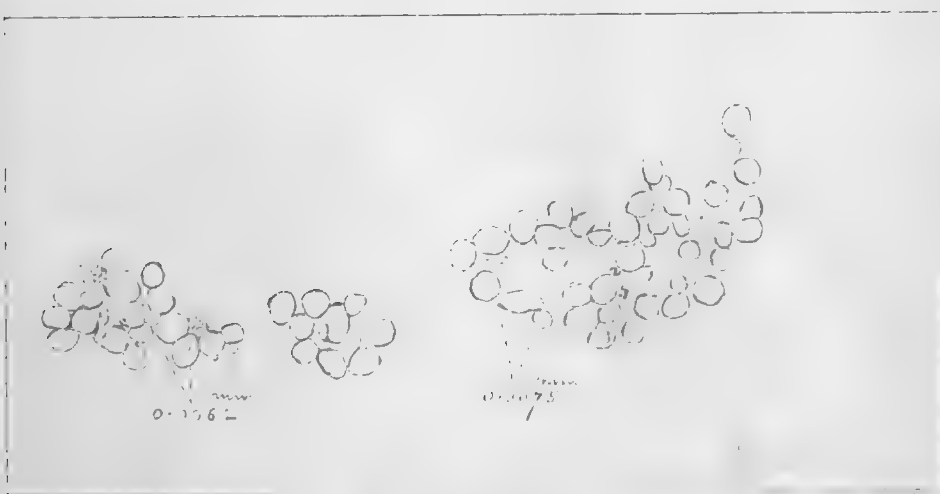


Fig. 2. Mash of seventeenth day. × 730

but it contained no appreciable amount of alcohol. The existence of these cells, however, at this very early stage is of considerable interest, and that they were capable of developing rapidly when placed under the proper conditions is shown by the appearance of a sample which was placed near a stove and left till the following day; represented in fig. 2, Plate VII. In this case large numbers of ferment cells are to be seen, of two kinds, one nearly spherical the largest measuring 0.0081 mm. in diameter, and the other longer and almost cylindrical. The appearance was that of an actively growing yeast.

The mash which was left under the usual conditions did not alter thus in appearance. A few more cells may be observed associated with fragments of mycelium, and with others apparently bursting and scattering a fine dust, but there was no active growth, nor did analysis indicate the formation of any alcohol. The appearance of the mash on the fifth day is shown in fig. 1, Plate VIII.

After the last sample was taken the moto was heated, and almost immediately a great development of the ferment cells took place. On the seventh day the temperature was 23°C. and the microscopic appearance (fig. 2, Plate VIII) shows that the cells were budding and growing with considerable activity, and chemical analysis at the same time indicated the existence of 5.2 per cent. of alcohol. The diameter of the largest cell was 0.0083 millimeter and the average size 0.0076 mm. The mash on the tenth day had a very similar appearance to that on the seventh, and on the twelfth, although the temperature was then only 16°C., the cells still appeared fresh and vigorous as in the left of fig. 2, Plate IX. At the same time fragments of the mycelium were to be seen as well as a number of very minute cells, the functions of which are not known. On the fourteenth day the cells had much the same character as before, the largest still measuring about the same, i.e. 0.0082 mm.

The next sample examined was that taken on the seventeenth day, after the further addition of rice and kōji, and when the temperature had risen to 19°C. sufficiently high to promote the very active growth of the yeast. Fig. 2 Pl. X shows the appearance of the ferment on that day, and it will be noticed that the size of the cells is rather less, the largest being only 0.0075 mm., perhaps because they were not fully grown. By the nineteenth day they were again in active growth, and the largest again had a long diameter of 0.0082 mm. The temperature at that time was 25°C. and the amount of alcohol increased from 5.8 per cent. on the seventeenth day to 9.44 per cent. on the nineteenth. The growth of the yeast continued, the temperature of the mash on the twentyfirst day being 26°C., but there are to be observed in the figure of this mash other ferment cells, small straight or curved filaments which are the cause of the future deterioration of the saké. They resemble very closely the filaments which are found in "turned" beer and wine, and are also to be found in enormous numbers in saké which has become spoilt. (See figs. 1 and 2 Plate XV.)

I have drawn also a filament of mycelium to show that it was still present, although as the ferment cells were very numerous and collected at the surface of the mash, the filaments appeared to be not so numerous as at first. The same remark applies to Plate XII which represents the appearance of the mash on the twentyfourth day, the last sample of the series which was examined. By this time the temperature had fallen to 20°C., but the fermentation still went on as the increase in the percentage of alcohol proved.

We have here a process of fermentation which resembles the wine fermentation in the fact that no ferment has been knowingly added by the brewer, and which belongs to the class called "spontaneous fermentations." By that term of course it is not meant that the living organisms have been generated spontaneously, without any forefathers, but only that they have appeared without intentional sowing. As the theory that living organisms are produced without the intervention of previous life has no basis of reality we are driven to enquire from what source these small particles of ferment have been derived. This has been discussed by Mr. Korschelt* in a paper read before the German Asiatic Society, and he very rightly says that we may conceive of their introduction in three different ways. In the first place he says that the grains of koji may carry upon their surface germs of the yeast in the same way that the grapes carry into the fermentation vat the cells which afterwards effect the conversion of sugar into alcohol. Or the germs of the yeast may in the second place fall into the vats from the atmosphere. To both explanations he considers that the sudden commencement of the fermentation is sufficient objection, for, as will be remembered, between the time of heating of the vat, and the time of taking the first sample afterwards, a period of 41 hours, more than 5 per cent. of alcohol had been formed. Mr. Korschelt, therefore, inclines to the third possibility, viz., that the mycelium fibres of the kōji fungus have been changed into the ferment cells, and he bases this supposition upon the observations made by De Bary and Rees that the mycelium of the two species of Mucor, M. mucedo and M. racemosus, have the property under certain conditions of forming cells which are able to convert sugar into alcohol.

The question is one of very great scientific interest, and no apology is therefore required for entering into a somewhat minute investigation of it. For a long time it was supposed that such common air fungi as Penicillium glaucum, and Aspergillus glaucus might, under suitable conditions, be transformed into the ordinary alcoholic ferment, and in that state go on converting sugar into alcohol. M. Pasteur† has put this theory to most rigorous tests, and has proved in the most conclusive manner the absence of any evidence whatever of such a transformation. He has shown that if proper care be taken to exclude every germ but the one being experimented upon, no conversion of that spore into any other species takes place. Thus a spore of Penicillium or of Aspergillus, or of Mycoderma vini will grow in ordinary wort so long as it has sufficient air to

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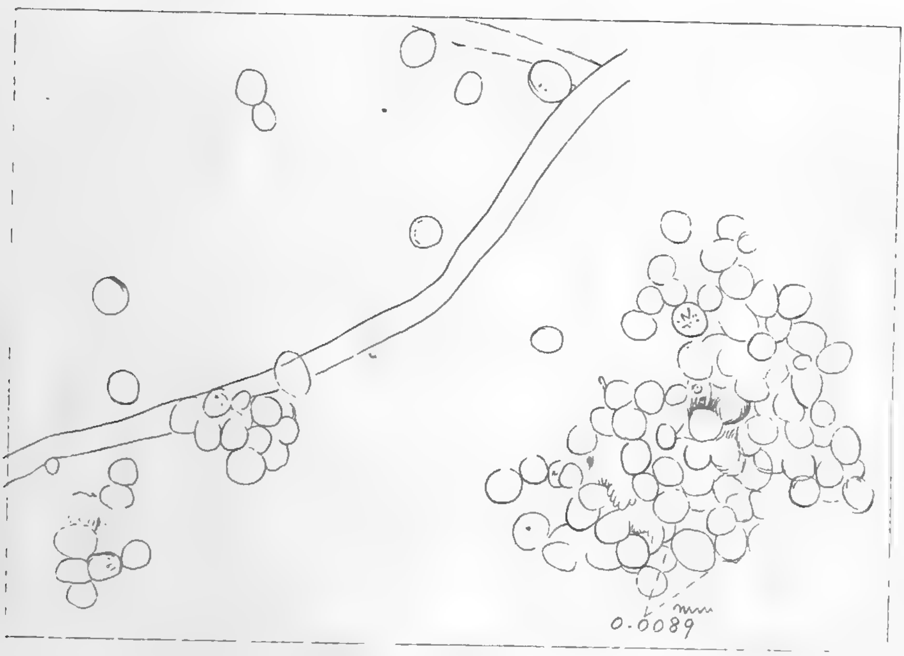
* Mitt. der Deutsch. Gesells. 16tes Heft. p. 253.

† Études sur la Bière. 1876. p. 86. &c. English Translation, p. [illegible]



Mash of twentyfourth day. × 730

breathe and is provided with sufficient food, but it is never converted into what is usually termed an alcoholic ferment. At the same time if the air be excluded he finds that the plant will go on growing for a longer or shorter time after the exclusion of the oxygen, but that its life is then carried on under abnormal conditions, which is evidenced by a change in the form of the mycelial fibres, and by the fact that a certain amount of alcohol is produced. The mycelium becomes swollen and contorted, and shows a tendency to break up into small cells attached end to end, and it is only in this state that the plant is capable of forming alcohol, but it does this without the presence of a single cell of the common yeast. If the swollen mycelium-cells be again allowed to grow under the usual conditions, that is with plenty of food and air, they reproduce the normal form of the plant from which the spores were originally taken. It may in fact be taken that while the fungus is healthy, growing under normal conditions, it consumes sugar, converting it into water and carbonic acid without producing any alcohol whatever, but that as soon as it no longer meets with the requisite quantity of free oxygen, still remaining in presence of sugar, it falls ill, and in that diseased condition it lives for a longer or a shorter time, producing alcohol as a pathological product. All fungi are not so easily killed, some may produce a very large quantity of alcohol before they die, and may even go on reproducing fresh cells. The Mucor mucedo, for instance, according to Fitz is killed when the liquid contains more than 1 % of alcohol, whilst the Mucor racemosus is more tenacious of life, and is not killed until the liquid contains from 2 to 4½ per cent. according to different observers.* There may be all variations in the case of different fungi, and although no case is at present known of one of the common air fungi yielding a greater percentage of alcohol than that given by the Mucor racemosus, there is no inherent improbability in the supposition that some fungi may yield much more. In fact the chemical difference between what are usually termed ferments and the ordinary fungi, seems to be their power of living out of contact with free oxygen, deriving that which they require from sugar, and thus causing it to spiit up into various other products in the manner shown by some such equations as the following:—

$$1^\circ.\ \underbrace{C^6H_{12}O_6}_{\text{Dextrose}} = \underbrace{2\,C_2H_6O}_{\text{Alcohol}} + 2CO_2$$

$$2^\circ.\ \underbrace{4\,C^6H_{12}O_6}_{\text{Dextrose}} + 3\,H^2O = \underbrace{C^4H_6O_4}_{\text{Succinic acid}} + \underbrace{6\,C^3H_8O_3}_{\text{Glycerin}} + 2\,CO_2 + O \text{ (Monoyer)}$$

Mr. Korschelt's supposition that the mycelium of the kōji fungus itself breaks up and goes on living as a ferment would be remarkable, therefore, only in the fact that the cells were able to live in a liquid containing as much as fifteen per cent. of alcohol, a very much higher percentage than the common beer yeast can exist in: But the question naturally arises whether the conditions under which the fermentation is carried on are such as would permit a fungus

* 4½ per cent. (Brefeld) 8.3 to 3.4 per cent. (Pasteur) 2.3 to 2.7 per cent. (Fitz.)

which ordinarily grows in air to live with such results immersed in a liquid. M. Pasteur has shown that in proportion as the fungus is provided with air it grows without producing alcohol, and, if the conditions are such that the plant can get plenty of free oxygen, no alcohol will be formed. Even the ordinary brewer's yeast at the beginning of the fermentation process grows in a vigorous manner but without producing alcohol, because it is at that time living upon the free oxygen dissolved in the wort, but by that means it acquires a freshness which enables it to grow at a later period with great vigour at the expense of the sugar contained in the wort. M. Pasteur thus explains the custom of aerating the wort followed in distilleries and in works for the manufacture of yeast. Are not the same conditions to be found in the manufacture under discussion? During the first few days the mixture of rice, kōji, and water, divided as it is amongst a number of small vessels, exposes a large surface which allows it to become perfectly saturated with air, so that, when the whole quantity of liquid is collected in one large tub and heated the ferment is enabled to grow vigorously, and as soon as the air has been used up, to produce alcohol at the expense of the sugar formed in the previous stage. We can readily understand that these conditions would be suitable for the growth of such a form of ferment as beer-yeast, which shows very little tendency to assume the air form (aerobian), but they appear to be less suited to the growth of a mycelium, such as that of the Eurotium. In fact until the mass is collected into the single vat, if the mycelium grows at all, it will form long, thin filaments, which will not produce alcohol, and it will only be when all the oxygen has been exhausted that any alcohol will be produced. Before very long, however, the mash is allowed to cool down by being again spread out in shallow vessels, and during this time, as a large surface is exposed to the air, the mash will again become charged with oxygen, and no more alcohol should be formed. What do we actually find? The heating in the large tub lasted in the brewing operation, described in section 1. Part II, from 3 p.m. on the fifth day till 7 a.m. on the eighth day, after which the mixture was transferred to the shallow vessels. Yet even after the tenth day the amount of alcohol increased, not much it is true, because the temperature conditions were unfavorable, but enough to show the fermentative activity of the yeast. If we had to do with an air-fungus, it would not be expected that the formation of alcohol would go on under such conditions, but it is quite what would be expected from the growth of a common yeast.

Again, during the main process, the mash is continually aerated by repeated beating, and we can hardly reconcile this with the production of the large amount of alcohol if the ferment were like the submerged mycelial fibres of a Penicillium or an Aspergillus. Such treatment, however, would be quite compatible with the active growth and fermentative activity of a species of saccharomyces, and would indeed answer to the aeration of the wort practised by distillers.

Further, in the drawings illustrating the microscopic appearance of the ferment during the fermentation, portions of mycelium will be observed at all stages,

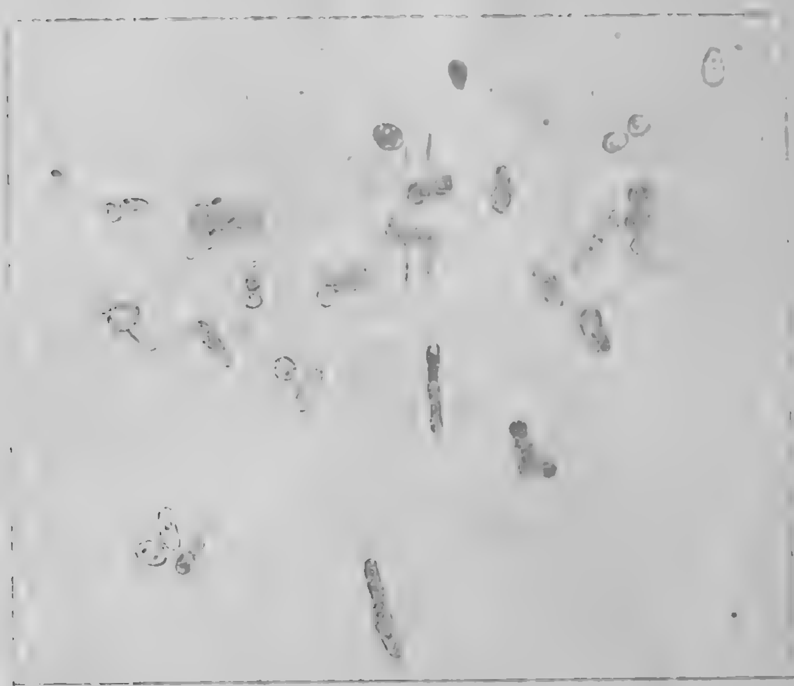


Fig. 1. K8JI in water left for two days. × 730

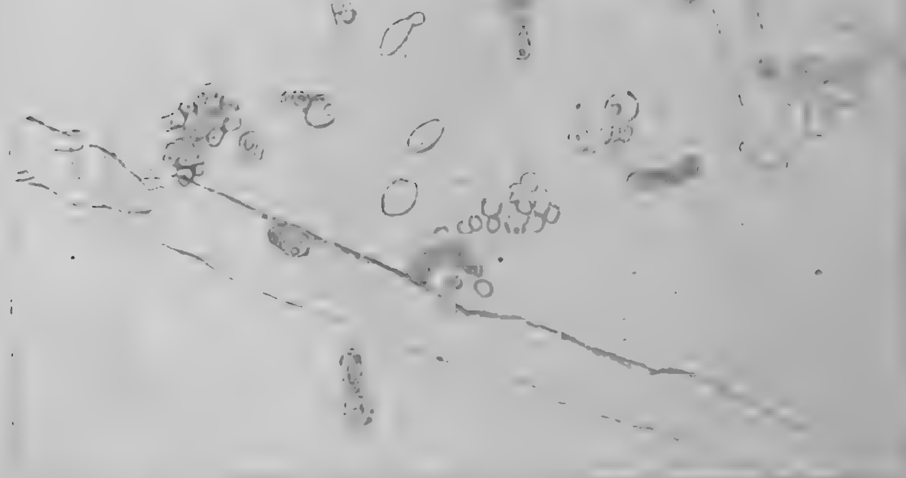


Fig. 2. same as last left in warm place for two days longer

and yet in no case was there observed any thickening such as M. Pasteur has figured in figs. 20 and 21 (Engl. Ed.) in the case of Aspergillus glaucus and Mucor racemosus, and in Plate VI. and fig. 24. of Mucor mucedo.* The mycelium remained of the same form throughout the series of observations made at the brewery and only changed in appearance from the presence of minute granulations, probably some form of foreign organism which found a resting place within the fibres. Mr. Korschelt has referred to this appearance, as well as to the more frequent crossings in the mycelium, as one of the reasons for supposing that the ferment cells observed are actually different forms of the original mycelium. I have not been able to satisfy myself that the crossings of the mycelium are more frequent after the plant has been submerged for some time than at first, but even if it were so, it does not seem that it would necessarily have any bearing upon the question. Nor am I able to agree with Mr. Korschelt when he says that there is a marked difference in the abundance of the mycelium at the beginning and the end. The point upon which most stress is laid is the suddenness of the fermentation, and that it does appear suddenly is a matter about which no one can have any doubt; but is there not a very simple explanation of it apart from the transformation of the mycelium into ferment cells? The fermentation appears immediately after the warming of the mash, which has already been exposed to the air in shallow vessels for several days before being gathered into a single vessel. It is also allowed to remain in the tub for several hours before heating, during which time we may suppose that a large part of the dissolved oxygen has been absorbed by the ferment. By heating the temperature is raised to about 25°C. and that we know is very favourable for the growth of yeast. Knowing how rapidly the yeast plant buds under the conditions, it does not appear to be necessary to invoke the transformation of the mycelium into ferment cells in order to account for the sudden appearance of the fermentation, and to my mind the simple and natural explanation is that the fermentation is spontaneous, that the germs are found either on the kôji used, or attached to the vessels in which the operations are performed. Mr. Korschelt has referred to the fact that on one occasion, before the fermentation had properly developed itself, I observed some completely cylindrical cells. Unfortunately I did not take sketches of these cells at the time, but it is probable that they were some species of mycoderma, introduced accidentally. I have repeatedly digested kôji with water without observing any change in the appearance of the mycelium. The successive changes usually seen are represented with sufficient clearness in the three figures on plates XIII and XIV. A quantity of kôji was placed in a flask with some water, the flask corked and provided with a delivery tube leading into water, and then left near a stove. After two days a drop withdrawn and examined under the microscope appeared as shown in the first figure Pl. XIII, enlarged

* I have grown the "tane" (spores) in boiled malt wort, and though the mycelium produced was kept submerged, no change in its form resulted, nor did any cells of alcohol ferment make their appearance.

730 diameters. Any one comparing this drawing with either fig. 10 or fig. 11 of M. Pasteur's work "Sur la Bière", which represent alcoholic ferments directly derived from the atmosphere, will see the close resemblance they bear to one another, and will hardly entertain any doubt concerning their atmospheric origin. On allowing this flask to remain for two days longer, there was a slight difference observable, the number of cells of alcoholic ferment had increased, and after three days more fermentation was very active, and an apparently pure specimen of yeast was obtained. Comparing these three stages of fermentation, can any one doubt that the germs of the alcoholic ferment were originally present in the kôji, and on being subjected to the proper conditions developed.

It is, of course, a matter of great difficulty to prove any proposition of this kind, but the probability appears to my mind to be very greatly in favour of the hypothesis that the germs have been either air-sown or were adherent to the grains of kôji before use.

The average size of the fully grown ferment cell is about 0.0082 millimeter, that is, between that of the ordinary wine ferment, and that of the beer yeast. From the many different appearances which the Saccharomyces Pastorianus puts on, it is difficult to say whether this ferment cell agrees in species with any of the European ferments, but from the large proportion of alcohol in the liquid in which it can exist, it appears to differ from beer yeast. The ferment of wine may produce a liquid containing as much as 15 per cent of alcohol, and from this resemblance as well as from the origin of the fermentation, saké making approaches more nearly the wine than the beer manufacture.

SECTION 4.

FILTRATION OF SAKÉ AND YIELD OF ALCOHOL.

At the end of the fermentation the mash is very thin and consists mainly of alcohol and water with a small quantity of the unaltered rice grains suspended in the liquid. The subsequent processes are essentially the same everywhere and it will not be necessary to refer in detail to the methods followed in different breweries. The separation of the liquid from the suspended matter is effected by the use of a wooden press called *fune*, a sketch of which is given in the woodcut at the beginning.

It consists of a wooden box covered on the top by a wooden plate of rather smaller size which is pressed down upon the mass beneath by means of a long lever weighted at the free end with about 12 to 18 hundred pounds, and hinged at the other end to a post firmly dug into the ground. At the bottom of the front part of the press there is an aperture through which the filtered liquid escapes, flowing thence down a gently inclined surface into a receptacle placed below.

Same as two last left for three days more. × 730

The mash (*moromi*) is put into long, hempen bags which have been strengthened by being soaked in *kaki-no-shibu*, the juice of the unripe persimmon.*

Each bag is filled about two-thirds full and then contains about 3½ *shô*; the open end is folded over and tied, and from 300 to 500 bags are piled up in the press according to its size. At Itami there are four presses in use, two of which hold 400 bags, and the other two 342. At Nishinomiya the press holds 500 bags. At first the weight put upon the lever is very small, otherwise the liquid would run through turbid, but afterwards the weights are increased to 12 or 18 hundred pounds. The pressure is kept up for 12 hours after which the weights are removed, the bags turned over, and the pressure renewed for twelve hours longer. The filtrate is slightly turbid and, before use, requires clearing.

At the Tôkiô brewery one half of the whole quantity of liquid was filtered on the twenty-seventh, and the remainder before the thirty-second day. A sample of the filtered liquid taken on that day had the following composition:—

Alcohol	11.14	per cent.
Glycerin, resin and albumenoids	1.992	,,
Fixed acid	.13	,,
Volatile acid	.02	,,
Water (by difference)	86.718	,,
	100.000	
Specific gravity	0.990	

Compared with the mash on the twenty-eighth day it will be observed that the percentage of alcohol is considerably less, a difference caused by the addition to the mash before filtering of the water used by the brewer for the purpose of rinsing out the tuns.

The composition of the pressed residue (*kasu*) was found to be

Soluble solid matter	1.43	per cent
Starch and cellulose	32.07	,,
Ash	.70	,,
Alcohol	6.00	,,
Water	59.80	,,
	100.00	

The alcohol which is unavoidably left in the residue is extracted at a later period by a process of distillation which will be described on a subsequent page.

The amount of saké obtained by the brewer from the quantities given above for one moto was 6.86 koku of sp. gr. 0.99, therefore weighing 326 kw., and the weight of the residue was 58 kuwamme. We are now in possession of all

* For an explanation of the action of this liquid upon cloth and paper, see Ishikawa. Chem. News, Dec. 3rd 1880. Transactions of the Asiatic Soc. of Japan. IX. 86.

the data required to calculate the efficiency of the brewing process as regards the conversion of the starch used into alcohol.

As the saké contained 11.14 per cent. of alcohol by weight, the total weight of absolute alcohol contained in 326 kw. was 36.32 kw. The 58 kw. of residue, also, contained 6 per cent., amounting altogether to 3.48 kw.; the total quantity of alcohol, therefore, which the brewer obtained was 39.8 kw.

We have already seen (p. 46) that the materials used for one moto amounted to:—

Dry rice................	175.1	kw.
Water..................	329.03	„
	504.13	

The dry rice contains on an average 84 per cent of starch, which, if it were completely converted into alcohol would furnish 80 kw. As the amount actually obtained was only 39.8 kw. we see that the yield is not quite one half of that which is theoretically obtainable. In accurate numbers it is 49.75 per cent. That the loss of material during the preparation of the saké is considerable will be evident when the number of transferences from one vessel to another is considered. Two other sources of loss also are very important, the loss of matter by the rice first, during the process of cleaning and washing, and secondly, during the filtration.

The following calculation will furnish us with some guide to the quantity of material lost in these operations. Allowance is made for the carbonic acid evolved by assuming that it amounts to 98 per cent. of the alcohol formed. This number is the result of experiments made by many former observers upon the ratio of carbonic acid to alcohol formed during ordinary fermentation. Any difference between it and the truth will be too small to affect the conclusions

Total weight of saké obtained..................................	326	kw.
„ „ „ residue „	58	„
„ „ „ carbonic acid lost..................................	39	„
	423	„*

As 504.13 kw. of dry rice and water were used at starting the total quantity accounted for is only 84 per cent. The weight of dry rice given above was corrected for the loss of weight during the conversion of a part of it into kóji, so that the loss of 16 per cent. is over and above that experienced during the formation of kóji. And, indeed, this is not the whole loss because no account is taken of the additional water used in cleaning the vessels, amounting to about 18 kuwamme, which would raise the loss to 19 per cent.

The yield of alcohol obtained at Itami is rather higher than that found in the Tôkiô brewery. The quantity of saké obtained is 13.32 koku, which will contain

* The escaping carbonic acid must be saturated with water, and will also cause the evaporation of more or less of the alcohol formed, but it is not possible to estimate the amount of this loss with any approach to accuracy, and it is, therefore, included in the total loss of 16 per cent.

75.9 kw. of alcohol. 75 kw. of residue are also obtained containing 3.8 kw. of alcohol, which altogether amounts to 79.7 kw. The weight of dry rice used we have seen to be 310.77 kw., containing 260.4 kw. of dry starch and ought to produce 140.3 kw. of alcohol. The actual yield is, therefore, 56.8 of that which theory indicates.

At Nishinomiya the weight of dry rice used is 310.1 kw. and it ought to produce as at Itami 140 kw. of alcohol. The yield of saké for one moto is 14.1 koku, which, together with 80 kw. of residue would contain 77.7 kw. of alcohol, and the actual percentage of alcohol obtained is thus 55.5 per cent. of that theoretically possible.

There is a very general agreement between the actual yield of alcohol in the three breweries mentioned; although that found by myself as the result of the brewing operation in Tôkiô is less than that calculated from the numbers given to me at Itami and Nishinomiya. We may assume that the percentages obtained at Itami and Nishinomiya are the best results, as they ought to be considering the long experience which the brewers of those districts have had. The operations at Tôkiô on the other hand are conducted on a much smaller scale and it is scarcely to be expected that the brewers will possess the same skill as those in the great centres of saké production.

Mr. Korschelt, in the paper on saké* already referred to, has mentioned that the actual yield of alcohol according to information from one brewer is only 50 per cent of that theoretically possible, and he expresses the opinion that in any case it is too little, and that the production must reach nearly 100 per cent, because the conversion of starch into sugar is so complete.

I do not consider that the process followed at the Tôkiô brewery is a very satisfactory one, but that practised at Itami may be regarded as the one which is carried out with the greatest degree of skill, and yet even there the yield is not more than 57 per cent. of that which might be obtained. The case in which Mr. Korschelt says he obtained 80.5 per cent. must be exceptional, and I am inclined to think that he has overrated the percentage of alcohol contained in the saké produced. At Itami the strongest saké does not contain, even before dilution, more than 14 per cent. of alcohol, and it is not probable that the percentage in a Tôkiô brew will be greater. In the process which Mr. Korschelt examined in Tôkiô, and of which he gives details, the actual yield of saké is 67 per cent. of the theoretical yield. The mash, which consisted of

2.9	koku	of	moto
3.2	„	„	kôji
12.0	„	„	rice
13.9	„	„	water

contained 475.4 kw. of starch and ought to have yielded 256 kw. of alcohol. The mash just before filtering measured, according to Mr. Korschelt 25 koku, and contained 14.5 per cent. of alcohol. If we assume that the specific gravity

* Mittheilungen der deutschen Gesellschaft. 16tes Heft. p. 256.

of the mash was 0.99 (as I found in a similar brew), the total weight of the mash would be 1187.5 kw. and would contain 172 kw. of alcohol, that is 67 per cent. of the theoretical yield. This yield is certainly greater than the average yield in other breweries, and may have been the result of especial precautions on the part of the brewer, but even in this case, only two-thirds of the alcohol was obtained.

In an earlier part of his paper Mr. Korschelt has calculated the theoretical composition of the moto, and also of the mash at the end of the principal fermentation, comparing it with the amounts of extract and alcohol actually found. He arrives at the conclusion that the whole of the starch used enters into solution, at any rate in one of the examples he brings forward. In the case of moto he gives the theoretical percentage of extract as 35.46, whilst in one batch of moto he finds 34.86 per cent. In none of the other examples does the percentage arrive at such a high point, being as a rule from 26 to 28 per cent.

The method of calculating the results adopted by Mr. Korschelt appears to be affected by the existence of errors for which it is difficult to make allowance. Some of these errors act in one direction and some in the opposite one, so that perhaps, the final result is not so far from the truth, but it is nevertheless desirable to eliminate them as far as possible, or to adopt another method of comparison which is not so liable to their presence.

The amount of water contained in freshly made kōji, as used by the brewer, varies from 25 to 30 per cent. and never falls so low as 15 per cent. which Mr. Korschelt assumes it to contain. The correction for this will cause an increase in the amount of water given in his paper (loc. cit. p. 250) from 2.925 kw. to 6.32 kw. Again, acting on the assumption that the sugar present in the mash is maltose, the weight of water taken up by the starch in conversion to sugar is calculated only as $\frac{1}{18}$, whereas, dextrose being present, as I have shown, it should be twice as much, that is instead of being 2.6 kw. it will really be 5.2 kw. This correction acts in the opposite direction in two ways, first by adding to the weight of the extract, and by taking away from the weight of the water.

Further the assumption is made that the matter other than starch dissolved from the rice will amount only to 2 per cent. of the rice, but in reality at least 12 per cent. is dissolved. I have found that the presence of the diastatic ferment of kōji has the property of rendering the insoluble albumenoids of the rice soluble, and Messrs Brown and Heron * have shown that in the case of malt a certain proportion of the cellulose is held in solution. This will, therefore, add greatly to the concentration of the mash, and, finally, the percentage of extract is increased by the removal of water and of carbonic acid during the fermentation. Mr. Korschelt allows two per cent. for the former, but he omits all correction for the latter. As we have seen however, the weight of carbonic acid evolved is about 98 per cent. of the total weight of alcohol formed, in consequence of which

* loc. cit. p. 627.

the total weight of the mash is diminished by that amount. Hence if the composition of the mash calculated on the supposition that the starch is completely converted into sugar is compared with the actual quantity of extract calculated from solid matter in solution and from alcohol, it is evident that the former will appear too low, and that therefore, the apparent solution of the starch will appear too favourable. This makes a very important item in the calculations, and its non-correction diminishes greatly the accuracy of the results obtained by Mr. Korschelt. The following method of calculating the results avoids the errors which have been pointed out, and shows that the whole of the starch is *not* brought into solution as Mr. Korschelt supposes.

The composition of the mash was given on p. 57, and we saw that it contained 475.4 kuwamme of pure starch. The weight of the whole brew before filtering was 1187.5 kw. This contained 172 kw. of alcohol, which is equivalent to $1.856 \times 172 = 319.6$ kw. of dry starch. The mash also contained 6.5 per cent. of extract, which we may assume to be entirely dextrin (although this assumption is in favour of the perfection of the method) and would thus weigh $0.065 \times 1187.5 = 77.2$ kw. The sum of the two numbers, $319.6 + 77.2 = 396.8$ kw., is the total weight of starch which has been brought into solution. We see, therefore, that only 83.5 per cent. of the total starch used has been dissolved.

So far, therefore, from being able to agree with Mr. Korschelt that the "process of saké brewing is so complete, that important improvements cannot be made in it, unless we would alter the ultimate product to such an extent that it would no longer be saké"* we ought to conclude from the evidence given in his own paper that it is still capable of being much improved. And this conclusion is borne out by all the evidence as to yield which I have been able to obtain, even from the oldest and best managed breweries.

SECTION 5.

PRESERVATION OF SAKÉ.

Clearing. The liquid which has passed through the press is turbid and requires clarification before being used. This is effected by collecting the saké in large tuns which have two holes near the bottom one above the other, and closed by means of plugs. (See Frontispiece.) After the lapse of about 15 days the suspended matter has settled to the bottom, and the greater part of the clear liquid may then be drawn off by removing the upper plug, and collecting the

* "Das Verfahren beim Sake Brauen ist an sich so vollkommen, dass bedeutende Verbesserungen darin nicht gemacht werden können, wenn man nicht das schliessliche Product so dadurch verändern will, dass so eben nicht mehr Sake ist." (loc. cit. p. 257. English translation from Japan Mail, August 1878.)

liquid in proper vessels. The remainder is allowed to stand for a longer time, and the clear part is separated by opening the lower hole. What remains is termed *ori* and is added to another brew just before filtering.

Heating. The clear saké so produced would not keep for more than a few days in the warm weather without being subjected to some further process. At Itami and at Nishinomiya the heating of the saké is carried out on the 88th night called *hachijû-hachiya*, which usually occurs between the 24th and 25th of the fourth month of the old calendar. The operation is a very simple one. A large iron pan is built in the ground, so that the upper part is only about 5 or 6 inches above the surface; on one side the ground is cut away, and a fire-place arranged below the pan, the opening being some distance below the floor. The bottom of the pan is heated directly by the flame from a wood fire, and the heating is continued until the liquid is so hot that a workman can just dip in his hand three times in succession without feeling much inconvenience. At some works thermometers have been introduced, and the temperature indicated varies from 120° F to 130° F. Whilst still hot the saké is transferred to the store vats, large tuns holding about 40 koku, made of *sugi* (cryptomeria japonica) or *hinoki* (chamaecyparis obtusa). They are closed by lids and the interval pasted round with paper fastened by means of a kind of glue made from seaweed (*funori*). In these tuns the liquid will keep without alteration so long as the weather remains cold, but as soon as the summer sets in, the saké has to be frequently examined in order to detect any change. When any signs of alteration are apparent it has to be taken out of the tun, and again heated, after which it is returned to the store vat.

In the following table are given analyses of several kinds of saké obtained from the districts of Itami and Nishinomiya. They were in most cases obtained directly from the respective brewers, and may be regarded as pure and unadulterated samples.

The samples of saké of which analyses are given in table XXI were brewed in the winter of 1879-80, and had been subjected to the operation of heating only once. As will be seen there is not a very great variation in their composition, the percentage of alcohol not passing beyond the limits 11 to 14. The quantities of dextrose and dextrin are very small, and in this circumstance, as well as in the larger percentage of alcohol, lies the essential difference between saké and beer. Connected with the absence of the two latter bodies also is the freedom from carbonic acid, for the saké is quite as "still" as the most fermented wine. When newly prepared it possesses a pale straw colour, and has a peculiar, unripe taste, but on keeping, and especially after heating, the colour darkens and the taste becomes more matured. During the hot weather it is impossible to prevent the saké "turning" without frequent heating, and as this is a very laborious operation any improvement would be welcomed by the brewer. Several samples which have undergone this change have been examined; it appears to be accompanied by the formation of butyric acid, ammonia, and a volatile,

TABLE XXI. COMPOSITION OF VARIOUS SPECIMENS OF SAKÉ FROM ITAMI AND NISHINOMIYA.

	Itami				Nishinomiya				
Name of Sake	"Gaika"	"Hatsuhikage"	"Shirayuki"		"Irozakari"	"Tairiyo"	"Sakigake"	"Kômeichi"	"Zuiichi"
Name of Brewer.	Konishi Shinyemon	Konishi Shinyemon	Konishi Mote		Idzumi Mansuke	Tatsu Gonuske	Tatsu yasu	Tatsuma Kijiro	
Alcohol	12.30	12.15	12.15	13.10	13.73	11.20	12.83	11.00	13.50
Dextrose	.62	.312	.44	.56	.404	—	.82	.20	1.41
Dextrin	.255	.256	.30	.05	.18	.16	.22	.14	.39
Glycerin, ash* and albumenoids	1.530	2.15	1.857	1.46	1.833	1.81	1.22	1.58	2.02
Fixed acid	.145	.13	.123	.32	.143	.12	.32	.13	.24
Volatile acid	.015	.01	.032	.03	.026	—	.014	.014	.013
Water (by difference)....	85.135	84.992	85.098	84.48	83.684	86.71	84.576	86.936	82.427
	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Specific gravity	0.991	0.992	0.992	0.993	0.989	0.990	0.990	0.991	0.994
Specific rotatory power ..	36°	25°.6	33°	19°.7	24°	16°.4	37°	20°.6	41°.6
Sign of Saké	凱歌印	初日影印	白雪印	⬠印	いろ盛印	大漁印	魁印	光明印	瑞一

ill-smelling substance, whilst at the same time a portion of the alcohol disappears. One sample which had been allowed to stand from the spring of 1879 till June 1880 contained 11.4 per cent. of alcohol and 0.316 per cent. of total acid, of which 18 per cent. was butyric acid. As the original saké was not completely analyzed I cannot give it for comparison. Two samples of those already given were kept and analyzed after standing in bottles corked in the usual way from February 5th 1880 until January 17th, 1881, and November 1st 1880, respectively. The composition of the original saké is repeated alongside for convenience of comparison.

* The ash consists mainly of the phosphates of calcium and magnesium.

TABLE XXII. COMPOSITION OF ITAMI SAKÉ "GAIKA" BEFORE AND AFTER STANDING.

	Before standing Feb. 5th 1880.	After standing Jan. 17th 1881.
Alcohol	12.8	11.90
Dextrose	.62	—
Dextrin	.255	.225
Glycerin, ash &c	1.58	1.667
Fixed acid	.145	.300
Acetic acid	.015	.062
Butyric acid	—	.006
Water	85.135	85.780
	100.000	100.000

TABLE XXIII. COMPOSITION OF NISHINOMIYA SAKÉ "IROZAKARI" BEFORE AND AFTER STANDING.

	Feb. 5th 1880.	Nov. 1st 1880
Alcohol	13.73	12.48
Dextrose	.404	—
Dextrin	.180	1.92
Glycerin, ash &c	1.883	
Fixed acid	.148	.335
Acetic acid	.026	.023
Butyric acid	—	.053
Water	83.684	85.189
	100.000	100.000

In both cases a diminution in the percentage of alcohol took place after keeping, and at the same time the small quantity of dextrose present in the original saké disappeared. The principal apparent change is the large increase in the percentage of fixed acid, whilst at the same time a small quantity of butyric acid is also formed. It is the presence of this acid together with the volatile body before mentioned which causes the disgusting smell possessed by such "turned" saké, notwithstanding the very small percentage contained in the liquid, but the sour taste of spoilt saké is due to the fixed acid, mainly lactic acid. The quantities of alcohol and dextrose which have disappeared are much greater than the weights

Fig. 1. Ferment cells in spoilt saké from Sakai. × 720.

Fig. 2. Ferment cells in another specimen of spoilt saké × 720

of acid formed, a circumstance which shows that a combustion occurs resulting in the formation of carbonic acid and water. In fact the liquid which has been kept over a summer will be found to be highly charged with carbonic acid, whereas unaltered saké contains none.

At the bottom of the vessel in which the saké has been kept is a thick deposit consisting almost entirely of minute cells some of which are represented in the accompanying figures, Plate XV. The organisms in fig. 1. resemble those found in putrid beer, and those in fig. 2, are almost identical with the filaments which produce "turned" beer. The former are more commonly met with, and doubtless, by their growth give rise to the unpleasant odour characteristic of spoilt saké. It is for the purpose of destroying these organisms that the saké is heated, but as, after heating, no precaution is taken to prevent the contact of the liquid with fresh germs repeated heatings are necessary. Indeed during the hot months from June till September, the saké must be heated at least once a month and very often more frequently.

It is an important and interesting fact that the process of heating the saké for the purpose of preserving it has been in use in Japan for about 300 years, and it is all the more remarkable, that having discovered the beneficial effect of this operation, the brewer should not have made it lasting by taking precautions against subsequent contamination. Instead of doing this, however, the liquid after having been heated is returned to the same store vats in which it was formerly kept, and the sides of which still retain particles of the ferment attached. When the still hot liquid is put into the vat, it is possible that the high temperature will kill all those germs adhering to the sides of the tun so far as the liquid rises. But above the level of the liquid they will remain untouched, and as, during the subsequent standing of the saké, the alcohol is drawn up the sides of the tun and runs back again in the form of "tears," the germs will in that way be carried down into the saké, will slowly develope, and in a comparatively short time will render it undrinkable.

The Japanese brewer has been credited with the discovery of the method of preserving alcoholic liquids which has made the name of M. Pasteur so widely known, but when we consider that in Japan, the heated liquid is allowed to become inoculated with the germs of its disease, even at the time of its so-called preservation, we see that he has omitted a part of the process which M. Pasteur truly regards as vital. When an alcoholic liquid has been "pasteurized", as the expression is, it will keep for an indefinite time, because the germs of disease which were already present have been killed by the high temperature of the liquid, and care is subsequently taken that no fresh germs find access to it. A wine thus treated not only does not deteriorate but actually improves by keeping, because it is allowed to "age" without the danger of any malady being set up which would spoil it. The Japanese wine, saké, is not allowed to improve in this way; I have in vain endeavoured to get samples which have been preserved for several years. As a rule, even at the most extensive breweries in Itami and

Nishinomiya, the whole of the winter's production is consumed within a year, and the reason is evident; it is impossible that the repeated heatings which the saké requires during the summer months in order to prevent it going utterly to decay should be without effect upon its quality. Further the liquid is not heated until the brewer detects an incipient spoiling, which means the already considerable development of ferment with the production of butyric acid, and although a portion of the latter is probably driven away on heating, some is sure to remain. By repeated fermentation and heating, therefore, the amount of butyric constantly increases, and thus in time, the saké must become undrinkable.

A process simple and effective, which will preserve the saké is evidently greatly desired by brewers, as is shown by the many attempts which have been made to use salicylic acid for this purpose. Mr. Korschelt wrote a pamphlet advocating the use of this antiseptic, and succeeded in persuading many large brewers to try it, but so far as I can learn, the success of the experiment has not been such as to satisfy the expectations raised. Salicylic acid has been introduced in Europe of late years as a means of preventing the deterioration of wine and beer, and when employed in sufficient quantity appears to answer the purpose in the climates of England and Germany. Prof. Kolbe mentions that "salicylic acid added to new wine entirely prevented after-fermentation. It appears also to prevent wine kept in half empty bottles becoming stale and sour. The quantity of the acid found sufficient for the purpose was 0.2 gram. (or 0.1 gram. salicylic acid and 0.1 gram acid potassium sulphate) per bottle". He also gives experiments showing the influence of the presence of differing quantities of salicylic acid upon a light, English beer, which would usually keep for about four months. The quantities added were to 100 litres of the beer.

BEER BREWED IN JANUARY 1875.*

Weight of salicylic acid added to 100 litres of beer.	Examined in August 1875.	Examined in December 1875.
0	Sour	—
2.5 grams	Not good tasted	Sour.
5 "	Good tasted and in good condition.	Good tasted.
10 "	Good, sparkling, and clear; of good taste and aroma.	Good in every respect.
20 "	Good, sparkling, clear and full-bodied.	Clear, sparkling and of good aroma. Excellent in every respect.
40 "	Rather too new in taste. Very good.	Like the foregoing, but fuller-bodied and very sparkling.

* Abstracts in Journal of the Chem. Society. London 1876. vol. 1. p. 992. From J. pr. Ch. [2] xiii. 106.

The evidence of the experiments quoted above goes to show that when from 10 to 20 grams of salicylic acid are added to 100 litres of beer, or to about 110000 grms., *i. e.* 1 or 2 in say, 10000, the preservation is perfect during summers such as we are accustomed in Europe. How far the higher temperature experienced in this country will modify the results we have no means of knowing. The only direct experiments I am acquainted with, besides those of Mr. Korschelt, are mentioned by Prof. Kinch in the Transactions of the Asiatic Society of Japan.* He says, "Numerous experiments were made last summer with salicylic acid as an antiseptic agent for saké, and it was found that used in the ratio of 1 : 10000 it preserved saké in imperfectly closed vessels for about a month, and when used in the ratio of 1 : 5000 it preserved the saké through the whole of the summer even under very trying circumstances." This evidence corroborates that offered by Prof. Kolbe, and we must probably look to the quantities used by the brewers for an explanation of their want of success. One of their complaints was the expense of the material, and though I do not know in what proportions it was used, it may readily be imagined that they would err on the side of deficiency rather than on the opposite side.

Although the evidence is in favour of the action of salicylic acid in arresting the change of alcoholic liquids, experiments have been conducted only for a comparatively short time, and there is nothing to show that the effect is a permanent one. Indeed from the chemical properties of salicylic acid, and especially from the readiness with which it is converted into salicylic ether in presence of alcohol and an acid, it may be regarded as certain that when a solution of the acid in saké is allowed to remain for a considerable time, especially at the summer temperature, it will be transformed into salicylic ether, and as this body probably does not possess the same antiseptic properties as the acid, the preservative effect of the acid will thus prove to be only temporary. Moreover the wood of the vessel in which such liquids are kept has been shown gradually to absorb the acid and thus destroy its utility. These circumstances will however, only necessitate the more frequent addition of salicylic acid, and as Prof. Kinch has shown that 1 part in 5000 of saké is sufficient to prevent the liquid spoiling during a whole summer it is only necessary that this amount should be added each spring to make the process successful. So long, however, as the price of salicylic acid is as high as it is at present in Japan, it will probably be more economical to heat the saké with such modifications in the form of the apparatus as will presently be described.

It is not necessary to wait until salicylic acid falls in price sufficiently to make its use economical; the brewer has at hand all the appliances needful for making his brew keep as long as he pleases, and without any additional expense further than that required to alter the shape of some of his vessels. I have pointed out that the weak point of the present method is that the liquid after

* Vol. VIII. p. 407.

having been heated is poured back into the same vessel in which it had formerly become spoilt, and that the vessel is *not completely filled.* With the present form of vat used for storing saké it would be difficult, if not impossible, to completely fill it, and be sure that it was also perfectly tight, but if, instead of using the large, upright tuns which are covered by large, flat plates, 6 or 8 feet in diameter, and closed round the edges by means of paper and glue, a vessel were used with only a small bung hole at the upper side which would permit of being easily and securely fastened, the brewer need hardly wish for any other means of preserving saké. At present even at the largest brewery in Itami not much more than 1000 koku, (180000 litres) of saké are prepared in one season, but if proper means of preservation were employed, that amount might be largely increased, say to one million litres or 5500 koku. If the saké were distributed into small barrels holding, say 1 koku each, the number required in one brewery would not be greater than the space would admit of, with this advantage, that even if one barrel went bad the rest of the brew would not be affected. That the heating and preservation of the saké under the conditions mentioned above suffice to prevent the liquid spoiling has been shown by direct experiments with two sorts of saké, one from Itami, "Gaika" and the other from Nishinomiya "Irozakari". Five bottles of each were heated in a vessel of water until the temperature of the contents rose to 60 C. and were then tightly corked and sealed. At the end of twelve months the saké remained clear and brilliant, and had in no way deteriorated, whilst the same saké kept in a bottle closed in the ordinary way was completely spoilt, the change being indicated by the analyses given on p. 62. This is evidence, although quite unnecessary, that the process applied to wines is likewise capable of application to saké.

An arrangement for heating saké which would be neither expensive to erect nor liable to get out of order is represented in Plate XVI, kindly furnished by Prof. Ewing. It consists of a long, wrought-iron box A, about six feet long, three feet deep, and three feet broad, made of boiler plate rivetted together, and built over a small fireplace with flues circulating beneath and on both sides so that the whole of the vessel is pretty equally heated by the hot gases before they escape to the chimney. Fig. 1 is a section taken through the furnace some distance beyond the fireplace; the flue beneath is made broader than it would be at the fireplace and to prevent the front part of the wrought-iron vessel burning away too rapidly it would be necessary to protect it from immediate contact with the flame by brickwork, which, however, is not represented in the drawing, and need only extend a short distance from the fireplace. In order to support the heating vessel it would be advisable to build up brick pillars in the middle of the flue, but it would not be necessary to make them very broad. The vessel is provided with a lid which can be removed when it is required to clean the inside; it has in the centre a long opening, somewhat larger at one end, which is usually covered with wooden plates. The larger square opening *b* is for the introduction of the saké to be heated; the

Fig. 1. *Section* Fig. 2. *General view.*

A. Wrought iron vessel.
B. Barrel for storing Sake.
M. Lid of heater.
b. Wide opening in the lid.
c. Opening in the lid for the stirrer.
s. Under flue.
s'. Side flue.
t. Stopcock.

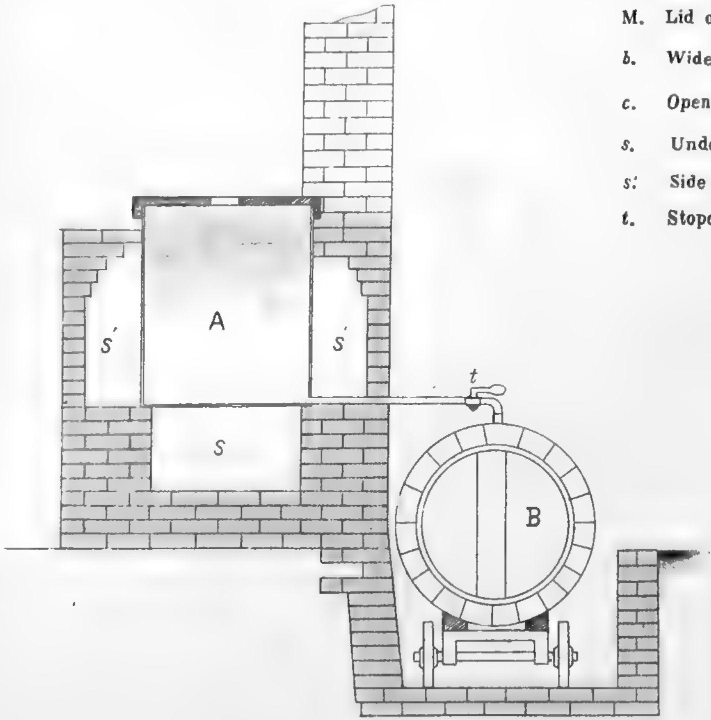


Fig. 1.

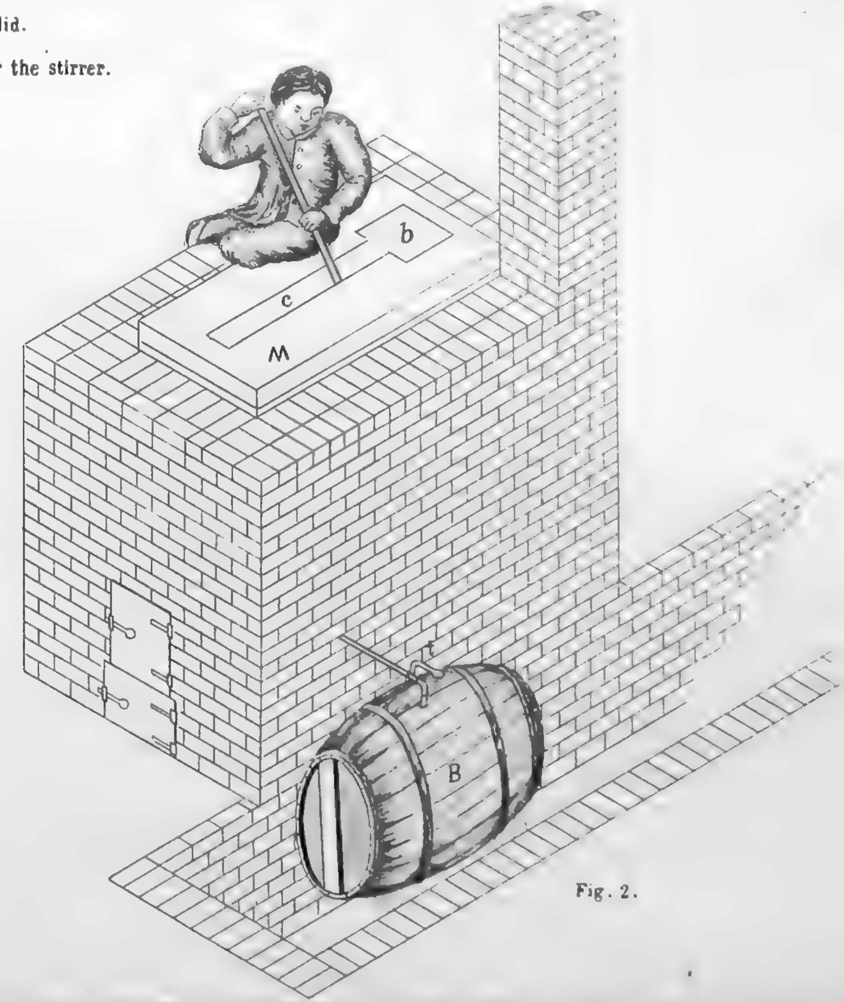


Fig. 2.

ROSSIQUEL'S APPARATUS FOR HEATING WINE

longer one *c* for the purpose of stirring the liquid in order to equalize the temperature as much as possible. That there may be no danger of the iron becoming burnt by the exposure of its sides to the action of the hot air when there is no liquid within to protect it, it will always be found advisable to withdraw the fire from the grate before removing the heated saké. A vessel of the size given will hold about 8 koku of hot saké. To permit of the withdrawal of the saké and its introduction into proper vessels which may be completely filled with it while still hot, a pipe is led through the brickwork and reaches some distance beyond it ending in a stopcock and a curved neck, the vertical portion being made to slide up and down so that it may allow of the passage under it of a barrel in the way shown in the diagram. At the side of the furnace a depression in the ground is made in such a way that the barrel, resting upon a small barrow, can be wheeled down an inclined plane on one side and be brought right under the tap, and when filled can be pushed forward, and its place taken by a fresh one, and so on until the greater part of the liquid has been stored. As soon as the barrel is filled it is, of course, tightly closed in the usual way. The barrels which would be suitable for this purpose are such as are used in beer-breweries, and some very good examples are shown by the Kai taku shi (Colonization Department) in the present National Exhibition (1881).

In plate XVII. a form of apparatus for heating wine, devised by M. Rossignol is shown, taken, by kind permission of the author, from M. Pasteur's work on wine. p. 232. (Ed. of 1873). The following is a translation of the description which accompanies the drawing. "This apparatus consists of three parts: 1°. a furnace F, which does not differ from any ordinary furnace; 2°. a broad, copper boiler C. provided with a cover soldered to it, and prolonged into a straight tube H, open at the end: the apparatus is filled with water half up the tube, and serves as a water-bath. 3°. a wooden trough or barrel T, the bottom of which is sawn off, and which rests upon the edge of the lid of the boiler and is firmly fastened to the cover by a simple arrangement: the edge of the cover *a* extends beyond the boiler for 3 or 4 centimetres; below it is a ring of wrought iron, and above a washer of caoutchouc, upon which rests the edge of the barrel; an iron ring encircles the edge of the barrel and is provided with straps of iron *e* which are fastened to the lower ring by strong bolts. The interval between the outside of the boiler and the inside of the barrel is filled with the wine, and all that portion of the boiler with which the wine comes in contact is tinned. A thermometer *t* indicates the temperature of the wine: a vessel E with tube allows the apparatus to be completely filled and the wine to expand on heating.

A simple glance at the figure will explain how the apparatus works. It heats 6 hectolitres (3.3 koku) in 1 hour, uses 10 *centimes* (10 sen) of fuel per hectolitre, and costs 140 francs."

This apparatus like the one before mentioned, has the disadvantage of being intermittent. The following description applies to the apparatus of M. Terrel des Chênes, shown in plate XVIII, also taken from M. Pasteur's "Études sur le vin"

p. 245 &c. Plate XIX shows the arrangement of casks and heating apparatus at work. "The heat generator consists of:—

1°. a central fire box F in the form of a truncated cone; the fire occupies the lower part. The fuel is introduced at first through the side opening P, and when the apparatus is at work, through the small door P′ made in the chimney. A register moderates the draught.

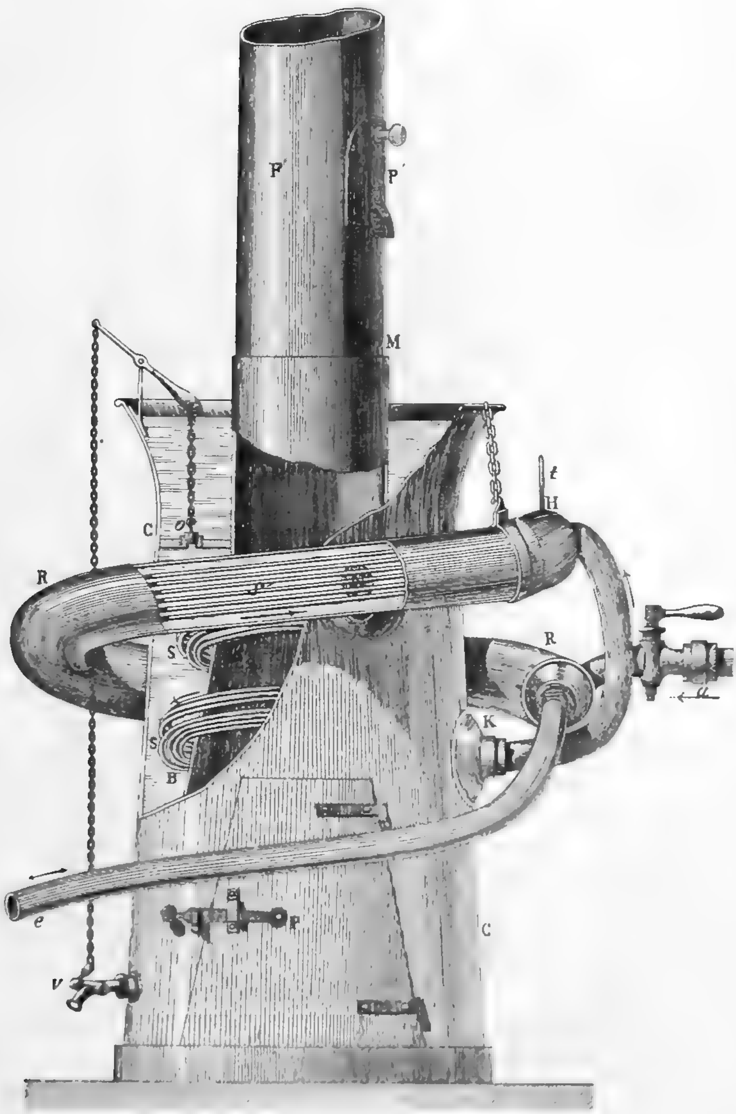
2°. a water bath B, which occupies the whole of the interval between the fire box and the outer cylinder. *r* is a clearing cock. Above the bath is a reservoir open to the air, constantly full of water, separated from the water bath by means of a horizontal partition, and communicating with it by a valve *o* attached to a lever. The lever itself is connected with the stopcock *v* by means of a chain; when from any accidental cause the temperature of the bath rises too high, the vapour escapes through *o*, the water enters and the bath is brought back to the normal temperature and is fed at the same time. If, for any reason, the apparatus has to be stopped for any time and the temperature of the bath rises too much, the same result is attained by opening the stopcock *v* which raises the valve *o*, the cold water which is always kept in the open reservoir enters the bath and cools it.

3°. a worm *ss*, through which the wine flows: this consists of 40 small copper tubes, 4 millimetres in internal diameter, which open at one end at the mouth N, at the other at K, after having made nearly two turns in the water bath. The cooler R R is formed of a very large pipe surrounding the heat-generator, containing inside 40 small parallel tubes *s*, 4 millimetres in diameter, like those within the bath. They open at one end into a box H, in which a thermometer dips to indicate the temperature, and at the opposite end of the wide tube into a cavity, R.

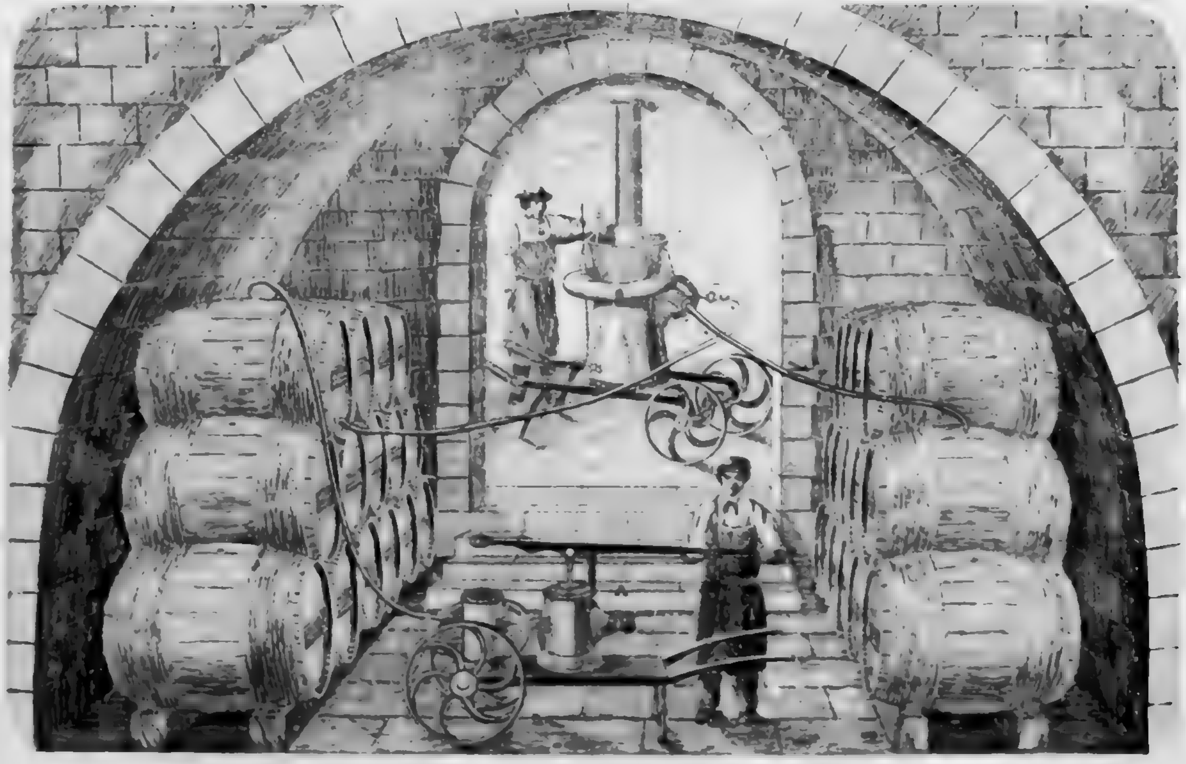
When in action the wine flows in the following way through the apparatus. The cold wine enters by the tube *a* into R in the wide gland which forms the cooler, circulates on the outside of the small tubes in R R, and leaves at N′ by a tube passing at once into the heat-generator: traverses the 40 tubes *ss* of the apparatus, leaves it at K and enters the cooler by the tube *l*, flows through the 40 small tubes *s′s′* (cooled by the newly arrived cold wine) and finally leaves the heating apparatus by the tube *c*. Plate XIX presents a perspective view of the complete apparatus and the mode of using it. It is represented by B at the opening of the cellar: it is borne upon a barrow and may be moved by one man; an air pump A, also supported upon a barrow, is used to compress the air in the upper part of the cask T, the wine contained in which is to be heated; a pipe inserted in the lower part of the cask brings the wine to *e* in the heating apparatus B; another pipe S conducts the heated wine into an empty cask T′.

To set the whole at work the water bath is filled, the wine is forced into the apparatus by working the pump; and when the water is hot enough, the stopcock S is slightly opened: the thermometer rises; when it reaches 60°, for example, the stopcock is opened more, and then only is the wine received into the

TERREL DES CHÊNES' APPARATUS FOR HEATING WINE



[illegible] FOR HEATING WINE. — GENERAL VIEW.



empty cask. One man works the pump, while another takes charge of the heating apparatus and regulates the flow of the wine by means of the stopcock, watching the thermometer all the time.

When, the operation ended, the apparatus has to be cleaned, the valve *o* is unscrewed, and in its place the extremity of the tube *e* is inserted; a current of steam then passes through the apparatus in a direction opposite to the flow of the wine, and drags away the deposit which has formed in the tubes.

The following data will give an idea of the economical results of this apparatus:

	Price, with all the requisites	Number of hectolitres heated per hour to 60°
Large apparatus	1200 fr.	10
Medium sized ,,	450 ,,	5
Small ,,	220 ,,	less than 1

The large apparatus receiving the wine at 15°C. raises it to 60° and cools it to 32°C. It requires 5 kilos. of coal per hour, costing 1½ centime per hectolitre; its diameter at the base is 0.50 metre, its total height 2 metres. The total weight with pump and other requisites does not exceed 230 kilos."

At present as the saké cannot be preserved without alteration for any length of time, the beneficial results of "ageing" have not been experienced, and a decided improvement in the quality of the liquid may be looked forward to by the adoption of the process of heating and preserving in well-closed, wooden barrels. One effect would be that a quantity of air would diffuse through the wood and would mature the wine without the danger of any disease germs accompanying it. The influence of oxygen upon wine cannot be better described than in M. Pasteur's own words* "In my opinion it is oxygen which *makes* the wine; it is by its influence that the wine ages; it modifies the bitter constituents of new wine, and causes the bad taste to disappear; it is the same agent which induces the formation of deposits of good character in casks and in bottles, and far, indeed, from an absorption of a few cubic centimetres of oxygen per litre of wine spoiling it, removing from it its "bouquet" and weakening it, I believe that wine has not come to its proper state, and should not be bottled, so long as it has not absorbed an amount of oxygen much greater than that."

SECTION 6.

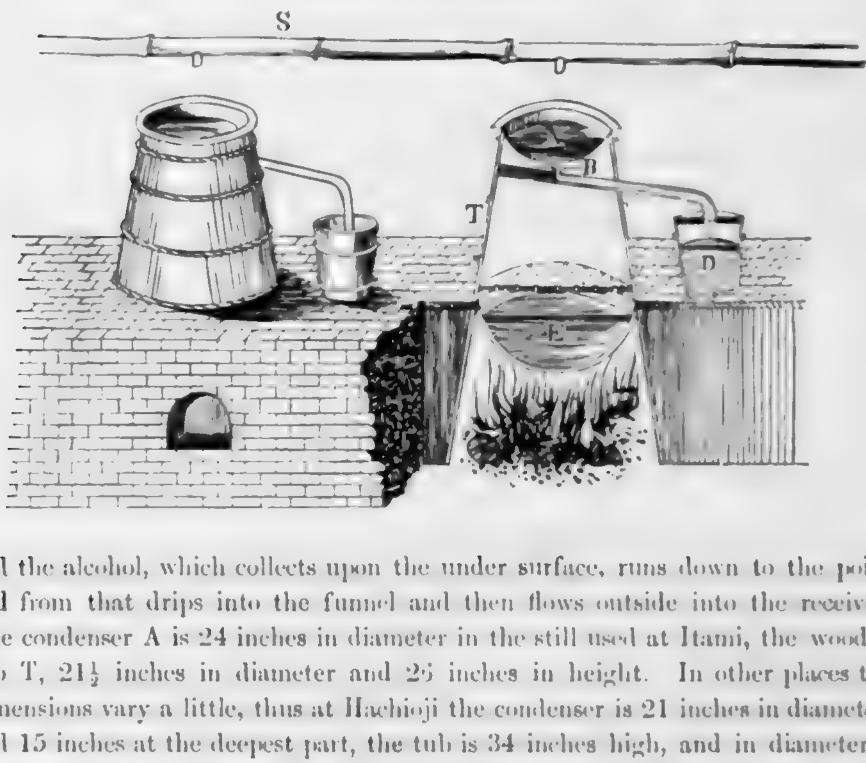
SHÔCHÛ AND MIRIN.

In a former section it was mentioned that the residue of undissolved starch and cellulose, left behind after pressing the mash, contained about six per cent. of alcohol, and that the brewer made use of a method which enabled him to recover the greater part of it. This is effected by a process of distillation whereby a kind of spirit called *shôchû* is obtained, which contains, according to certain

* Études sur le vin. 1873. p. 85.

variations in the treatment, from 20 to more than 40 per cent. of absolute alcohol. The apparatus used is represented by the accompanying woodcut, and is in principle the same as the small earthenware still, here called *rambiki*, much used in pharmacy. It consists of a shallow, iron basin built over a common fireplace in which wood is burnt, and provided with a flange upon which a wooden cylinder with a perforated bottom rests. Upon the top of this cylinder or tub there is fitted an iron basin terminating below in a point immediately above a kind of flat funnel, the tube of which bends away at an angle, and leads outside the tub to a receiver. The iron basin, when filled with cold water, serves as a condenser

DISTILLING APPARATUS.



and the alcohol, which collects upon the under surface, runs down to the point and from that drips into the funnel and then flows outside into the receiver. The condenser A is 24 inches in diameter in the still used at Itami, the wooden tub T, 21½ inches in diameter and 25 inches in height. In other places the dimensions vary a little, thus at Hachioji the condenser is 21 inches in diameter, and 15 inches at the deepest part, the tub is 34 inches high, and in diameter a little less than the condenser. About five of these stills are placed side by side, and the water required for cooling is obtained from a bamboo pipe S leading from a cistern, and having a hole closed by a plug for each condenser. 10 kuwamme of the residue (*kasu*) are mixed with 1.1 kw. of the husk of rice; the quantities used are, however, not usually weighed, but are measured in a wooden tub 20 inches in diameter and 13 inches high, two of which hold 10 kuwamme. The mixture is then placed in the tub upon a hempen cloth which covers the perforated bottom; the boiler is filled with water and the tub is then placed in position, the junction being made tight by means of a straw ring. The condenser is then placed upon the top of the tub, and is filled with water by withdrawing the plug from the bamboo pipe S. The fire is lighted, and as soon as the water boils the vapour rises through the mixture of residue and husk, the latter being used for the purpose of keeping the whole porous. The heat is so regulated that when the water boils, that in the condenser never does more than simmer, and the condensed water and alcohol drop onto the funnel and are collected outside. The water in the condenser is changed several times during an operation lasting one hour, and according to the number of times the water is changed does the strength of the distilled liquid vary; this gives the name to the spirit produced which may be *san jô dori* (collected in three shô), *go jô dori*, or *shichi-jô-dori* (collected in five and seven *shô* respectively). For the preparation of the first named spirit, the water is removed 2½ times, for the second 3 times, and 4½ times for the third; for the production of the latter the fire is not urged so much, so that the operation is somewhat prolonged, and of course, more water condenses.

When any of the saké which has been brewed becomes spoilt, the alcohol which it contains is recovered by putting it into the boiler instead of water, and the process of distillation is then conducted in the way above described.

The following are the percentages of alcohol and the specific gravities of some specimens from various places; the liquids contained mere traces of soluble solid matter.

TABLE XXIV. ANALYSIS OF SPIRIT. (SHÔCHÛ).

	Kansei from Iyo	Awomori	Hachiôbori	Itami 3-shô-dori	Itami 5-shô-dori
Alcohol, per cent.......	50.2	36.99	43.47	41.5	26.00
Specific gravity	0.918	0.942	0.937	0.941	0.964

The residue left after distilling off the alcohol is sold for use as a manure.

The principal use to which this spirit is put is in the preparation of *mirin* a kind of liqueur, which is much drunk at the New Year, and is also largely used for cooking purposes.

The following table gives the composition of a good many different kinds of *mirin* from different parts, each having a distinctive character: the majority retain merely the aroma received in the ordinary process of manufacture, others, however, are flavoured with special materials such as plum juice, and the leaves of certain scented herbs.

TABLE XXV. COMPOSITION OF VARIOUS KINDS OF MIRIN (LIQUEUR).

	Seven year *mirin*	Homei-shû	Kuwa-zake Iyo	Yoroshû Iyo	Kanro shû	Nagare-yama	Ume-shû	Shisso-shû
Alcohol	11.4	12.25	12.50	12.85	13.20	10.00	13.18	18.50
Dextrose	19.32	21.91	17.80	22.50	19.32	30.10	17.92	19.45
Dextrin, &c......	4.04	5.67	2.32	3.06	10.54	4.96	1.91	.79
Volatile acid	—	—	—	—	—	—	.005	—
Fixed "	—	—	—	—	—	—	.14	.004
Water	65.21	60.17	67.38	61.59	56.94	54.94	66.845	61.256
	100.00	100.00	100.00	100.00	100.00	100.00	100.000	100.000
Specific gravity ..	1.0801	1.0876	1.0651	1.0877	1.1076	1.1383	1.0613	1.0565
Japanese name and symbol	七年味淋	保命酒	桑酒	養老酒	甘露酒	流山味淋	梅酒	紫草酒

Most of the above specimens were yellow, thick, somewhat oily liquids, having a sweet, alcoholic taste, and with a peculiar aroma. The two last were specially flavoured, the *u'meshû* possessed a pleasant, acid taste, and a smell of plums, both given to it by digesting the liqueur with sour plums. The *shisso-shû* had a flavour somewhat resembling that of cinnamon, given to it by digestion with the leaves of the Perilla arguta, called in Japanese *shisso*.

The mode of preparation of *mirin* depends upon the principles laid down in the first part of this mémoir as to the influence of kōji upon starch, but the process differs from that followed in the making of saké, inasmuch as, owing to the presence of the large quantity of alcohol contained in *shochû* fermentation does not set in, and the chemical changes, therefore, are limited to the solvent action upon starch.

At Itami the following mixture is made :—

Steamed *mochigome* (glutinous rice)........	9.0	koku
Koji	3.3	"
Shochû (5-sho-dóri)	14.0	"
	26.3	"

The mixture is put into a large tub and stirred every two days for a period of twenty days, after which a fresh quantity of *shochû*, amounting to 0.70 koku, is added; the whole is allowed to stand for two days more, stirred, allowed to settle, the clear liquid decanted, and the residue passed through filtering bags. The total quantity of *mirin* obtained is 21 koku, and the residue amounts to

180 kuwamme, so that, assuming the specific gravity of the *mirin* to be 1.07, the total weight of *mirin* and residue will be 1258.5 kw. The total weight of mochigome, kôji, and shôchu used, including the water taken up during steaming amounts to 1313 kw., thus there is a deficiency of 54.5 kw. This may in part be accounted for by the necessity of using average numbers in the calculation as for the weight of rice, the specific gravity of mirin, &c. At Ozaka the process is quite similar, but the proportions of the materials used differ somewhat; the following are the amounts:—

Steamed *mochigome*	7.00	koku
Koji	2.50	„
Shochû	18.40	„

This quantity is allowed to stand for 15 or 20 days and is stirred every three days. 24 koku of mirin are obtained and 120 kw. of residue, altogether weighing 1352 kw. while the materials used weigh, according to calculation, 1340 kw., a sufficiently close agreement considering the necessity of guessing more or less at the numbers. If we calculate the percentage of alcohol which should be contained in the mirin on the assumption that the shochû used contained 25 per cent. by weight of alcohol, and that 6 per cent. remained in the residue, the percentage in the Itami *mirin* ought to be 16%, and in that made at Ôzaka, 16.6 per cent. As the average percentage is much less than this it shows that the strength of the shochû used must be less than that found for gô-sho-dori, and secondly, that there can be no fermentation in the process, as indeed could be seen from the strength of the spirit used. The change which does occur is the conversion of the starch of the rice into dextrose and dextrin: if the whole of the starch contained in the rice used at Ôzaka were converted into dextrose, it would form 300 kw. which would yield a liquid containing 24.3 per cent. dextrose, a number which is not far from those actually found in many specimens.

THE END