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HUGH GWYN OWEN

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CONTENTS

SYNOPSIS

Much new information on the stratigraphy of the Middle Albian substage gained from sections in England and France is recorded, and where possible previous knowledge is revised, sufficient to stabilize the Ammonite Zonal scheme in the Anglo-Paris Basin ; d'Orbigny's type area of the Stage. The succession in England is compared in detail with that of northern France by reference to sections in the Pas de Calais, Meuse, Marne, Haute Marne, Aube, Yonne, Pays de Bray, and Pays de Caux, several misconceptions being eliminated. The ammonite zonal scheme is discussed in detail to provide the basis for international agreement of a zonal scheme for the faunal province, here termed the hoplitinid ammonite faunal province, of which the Anglo-Paris Basin is but a part. A brief review is made of the faunal links between the hoplitinid province, covering much of Europe, and neighbouring ammonite faunal provinces. These links occur essentially in the *lyelli* Subzone near the base of the Middle Albian, and in the *cristatum* Subzone at the base of the Upper Albian. The palaeogeographical implications of the distribution of the faunal provinces are mentioned briefly. A study of the conditions of Middle Albian deposition in England shows that it tends to follow the pattern of Lower Albian and Aptian sedimentation in direct contrast to that of the Upper Albian where a different pattern prevailed. A review of the ammonite fauna terminates the work.

RÉSUMÉ

L'auteur présente des nouvelles informations sur la stratigraphie de l'Albien moyen de l'Angleterre et de la France, afin d'établir le plan zonale des ammonites dans le bassin anglo-parisien, qui est la région typique de l'étage de d'Orbigny. Les couches de l'Angleterre sont comparés en détail avec ceux-là de la France septentrionale. L'auteur donne tous les détail du plan zonale des ammonites, afin d'établir une province faunistique des ammonites hoplitinidés. L'auteur discute les liens faunistique entre la province des hoplitinidés et les provinces faunistique avoisinantes des ammonites. Ces liens ont bien surtout dans la sous-zone de *lyelli* auprès de la base de l'Albien moyen, et la sous-zone de *cristatum* à la base de l'Albien supérieur. Une étude de la môde de déposition de l'Albien moyen en Angleterre montre qu'elle imite la déposition de l'Albien inférieur et Aptien, non pas celle-là de l'Albien superieur. L'auteur finit en passant en revue la faune des ammonites.

I. INTRODUCTION

THE Albian Stage terminating the Lower Cretaceous has been divided into Lower, Middle, and Upper Substages. In England, the Lower Albian is represented within the top beds of the Lower Greensand and its junction with the overlying clays of the Gault ; the Middle Albian within the Gault, and by the Lower Gault where this division is recognisable ; and the Upper Albian by the Upper Gault and the contiguous Upper Greensand. Both the Middle and Upper Albian are represented within the Red Chalk facies. In northern France and the Paris Basin there is a similar lithological sequence, excluding a Red Chalk facies but including local lithological units in various areas such as the Sables de Puisaye flanking the northern area of the Massif of Morvan. This essentially common sequence reflects the closely comparable depositional environment which existed in the area of the Anglo-Paris Basin during Albian times.

This Basin extended from the area of the Massif Central and the Vosges in the south to the English Midlands (text-fig. 51). It was flanked on the west by the Variscan massifs of Armorica and Cornubia, and on the east and north east by those of the Rhine State Mountains and the Ardennes. Late Jurassic—early Cretaceous deformation provided the basic structural pattern for Lower Cretaceous sedimentation which achieved its greatest geographical extent during Albian times. Middle Albian sedimentation followed this earlier pattern, but this changed in the Upper Albian due to tectonic disturbances at its start. The Basin was linked with the surrounding shelf seas north of the Ardennes, and with Tethys by means of the Morvano-Vosges strait. These sea-ways provided important migration routes for the fauna.

In terms of absolute radiometric dates, the Albian is taken by Casey (1964 ; 199) to commence at 106 *my* B.P., and is considered to have had a duration of 6 million years. However, as that author clearly states, this is purely an arbitrary figure, the Cretaceous being divided into twelve equal time units corresponding to the twelve Stages. At present, therefore, there is no alternative but to use the relative units of time implied in the zonal schemes based on the faunal succession. Of these schemes, that based on the ammonites is the one which has been most thoroughly investigated, and the one that has led to much difference of opinion both national and international. A good deal of this disagreement is due to insufficient knowledge of the succession, despite the considerable number of papers which have been published.

Within the lengthy bibliography on the English Albian two major works stand out ; the Memoir by Jukes-Browne (1900), and the Monograph by Spath on the Albian Ammonoidea (1923–43). The work carried out before 1900 in certain cases was truly excellent. For example, that of De Rance (1868) and Price (1879, 1880) at Folkestone, Newton (1897) at Okeford Fitzpaine, Dorset, and Keeping (1868) at Upware, Cambridgeshire. All this earlier work is ably summarised by Price and

Jukes-Browne and it is unnecessary to repeat it here. Jukes-Browne's memoir included almost all the stratigraphical information then available obtained either by earlier workers, or by himself and William Hill for the Geological Survey. He provided a good picture of the stratigraphy of the Albian in England, and extended his study to make a brief examination of the Paris Basin. The accuracy of some of his and Hill's field observations can still be demonstrated, and their reading of certain sections now long since vanished can be interpreted in the light of recent information with reasonable confidence.

The first part of Spath's Monograph appeared twenty-three years after the publication of Jukes-Browne's memoir, and it was completed over a period of twenty years. Its coverage was not complete, however, a fact which it is important to bear in mind. It consists of the description of ammonite faunas from the comparatively few localities that Spath himself collected from, or that were represented in museum collections upon which he largely worked. Other sections, although available during this period, were not apparently collected from by him and so, important parts of the ammonite fauna were not described. Nonetheless, this very important work provided the basis and stimulus for the detailed stratigraphic work that was carried out during that period largely by officers of the Geological Survey, and the work that has been carried out since. The final part, published in 1943, contains a useful review of the stratigraphic work carried out in the period since 1900. Since the completion of his Monograph, a great deal of new information has been obtained about Albian sediments in England. Contributions to our knowledge have been made by a number of authors, particularly by Casey and C. W. & E. V. Wright. Their papers and many others are listed in the bibliography and are discussed in the appropriate part of the text.

In France, before Jukes-Browne's Memoir was published, Charles Barrois wrote three important papers on the French Albian (1875a, 1875b, 1878). These, in association with d'Orbigny's *Paléontologie Française*, provided a good picture of the stratigraphy and fauna of the Albian deposits of the Paris Basin. Barrois followed Hébert (e.g. 1875a) and others in including sediments, now classified as Upper Albian, within the Cenomanian. It is significant to note that Barrois already appreciated the magnitude of the break in the succession between what we now consider to be Middle and Upper Albian deposits in areas of the Paris Basin some 50 years before Kitchin & Pringle (1922a) recognised it in England. In his papers Barrois incorporated the results gained by earlier workers such as Michelin, Leymerie, Raulin, Buvignier, Cornuel, Ebray, Hébert, Delatour, and others, and a comprehensive bibliography is given by him (1878 ; 230–238). English workers such as Hopkins (1845), Topley (1868), Jukes-Browne & Hill (1896) and Jukes-Browne (1900) carried their researches into France, the latter authors providing new information particularly about the sequence in Normandy described previously by Lennier (1867).

Much useful information was published in the period of 30 years which separated Barrois' work from the publication of an important thesis by Jacob (1908). This thesis greatly increased our knowledge of the Aptian and Albian stratigraphy of the French Alpine area and adjacent Switzerland, the site of the Morvano-Vosges strait. In the following two decades, however, only a few papers were published. Of these, Lemoine (1910) on the Yonne, Aube, and Haute-Marne, Ciry (1927) on the Côte d'Or, and Stieler (1922) on the coastal sections at Petit Blanc Nez, may be mentioned. In the period from 1930 until the war interrupted work, much new information was contributed by authors such as Breistroffer working in the French Alps (1931, 1933, 1936, 1940), P. & J-P. Destombes at Wissant (1938a) and in the Pays de Bray (1938b), Larcher (1937), Houdard (1933, 1940) and Marie (1939, 1941a) working in the Aube, Yonne, Marne, and Haute-Marne. Marie's work on the Albian foraminifera and their zonal value included studies of sequences in the Pays de Bray (1941b) and Wissant (1941c).

After the war, and with Spath's Monograph completed, Breistroffer (1947) presented an important discussion of the ammonite zones of the Albian in France and England. Since then papers on various aspects of French Albian stratigraphy have been published. This more recent work is summarised, and much new information added, in the report of the Colloque sur le Crétacé inférieur held at Lyon in 1963 (1965).

Of necessity the foregoing review is very brief, and only the more important works have been mentioned including those which give comprehensive bibliographies of earlier work. However, the relevant papers on the Albian of the Anglo-Paris Basin are discussed at the appropriate place in the text. Recent papers published in France and England show that disagreement exists on various aspects of the zonal scheme, and even the litho-stratigraphy. This disagreement is both national and international ; a serious state of affairs rendering distant correlation difficult (e.g. Young 1966). It is even more serious when one realises that here we are dealing with d'Orbigny's " type area " for the Albian Stage.

An agreed zonal scheme can only be based on a detailed accurate account of the succession throughout a whole province, and inter-provincial correlation can only be accurately made once the stratigraphical successions are fully known. The object of the present work is to attempt to give this detailed information. Its presentation is the more urgent now that recent geophysical work indicates the closer proximity of Greenland, North America, and Europe in Albian times (e.g. Carey 1955, 1958, 1963, Bullard *et al.* 1965), and the need to be able to compare in detail sequences in these areas with that of our own.

The first part of this work, therefore, consists of the description and correlation of sections in England and France, and this contains much new information. The sections are shown graphically for easy reference. This descriptive part is subdivided into convenient geographical areas. The second part consists of a detailed discussion of the ammonite zonal scheme given in Table 1 (p. 10), preceded by an historical introduction. This is followed by a review of the links between the European ammonite faunal province and other areas, and in turn by a discussion of the conditions of deposition in England. The work is terminated by a brief review of the ammonite fauna, with descriptions of three new species of stratigraphic utility.

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III. DESCRIPTION AND CORRELATION OF SECTIONS

A good deal of stratigraphic information can be displayed to advantage in the form of diagrams, and so all the lithological sections are presented as text-figures. Correlation charts, however, cannot provide the necessary accuracy when used alone, and require an accompanying text. Only the critical ammonites are mentioned in this section as a more detailed list and its stratigraphical distribution is given later. For ease of description the account is divided into convenient geographical areas to which no structural significance should be attached : depositional controls on sedimentation will also be discussed later. The sections in the Weald are described first, then the Isle of Wight, Dorset coast, and the outcrop from Devon to the Leighton Buzzard area of Bedfordshire. The Albian sediments of the Leighton Buzzard area and of East Anglia are to be described elsewhere, but in no way do they affect the stabilising of the Albian Zonal scheme. Borehole evidence in southern England is then considered before attention is turned to the Paris Basin. A detailed comparison is made between the sections at Folkestone and Wissant (Pas de Calais). Selected sections in the Meuse, Marne, Haute Marne, Aube, Yonne, and in the Pays de Bray, are described followed by a comparison of sections in the Pays de Caux with the Isle of Wight. The ammonite zonal and subzonal scheme employed in this account is given in Table 1 above.

TABLE 1

Ammonite zonal scheme of the Middle Albian adopted here and discussed in detail on pages 118–130.

Substage	**Zone**	**Subzone**
Upper Albian (part)	*Mortoniceras inflatum* (part)	*Hysteroceras orbignyi* *Dipoloceras cristatum*(1)
Middle Albian	***Euhoplites lautus***	***Anahoplites daviesi*** ***Euhoplites nitidus***
	***Euhoplites loricatus*(2)**	***Euhoplites meandrinus*** ***Mojsisovicsia subdelaruei*** ***Dimorphoplites niobe*** ***Anahoplites intermedius***
	Hoplites (H.) dentatus	***Hoplites (Hoplites) spathi*** ***Lyelliceras lyelli*(3)** ***Hoplites ('Isohoplites') eodentatus***
Lower Albian (part)	*Douvilleiceras mammillatum* (part)	*Protohoplites puzosianus*(4) *Otohoplites raulinianus*

(1) Formerly included in the *lautus* Zone *sensu* Spath (e.g. 1941 ; 668).
(2) First recognised by Owen (1958 ; 162).
(3) Approximately equivalent to the *benettianus* Subzone of Spath *non* De Rance (1868).
(4) In better developed sequences in France (Pays de Bray, Aube), this index fossil does not range up to the base of the *eodentatus* Subzone.

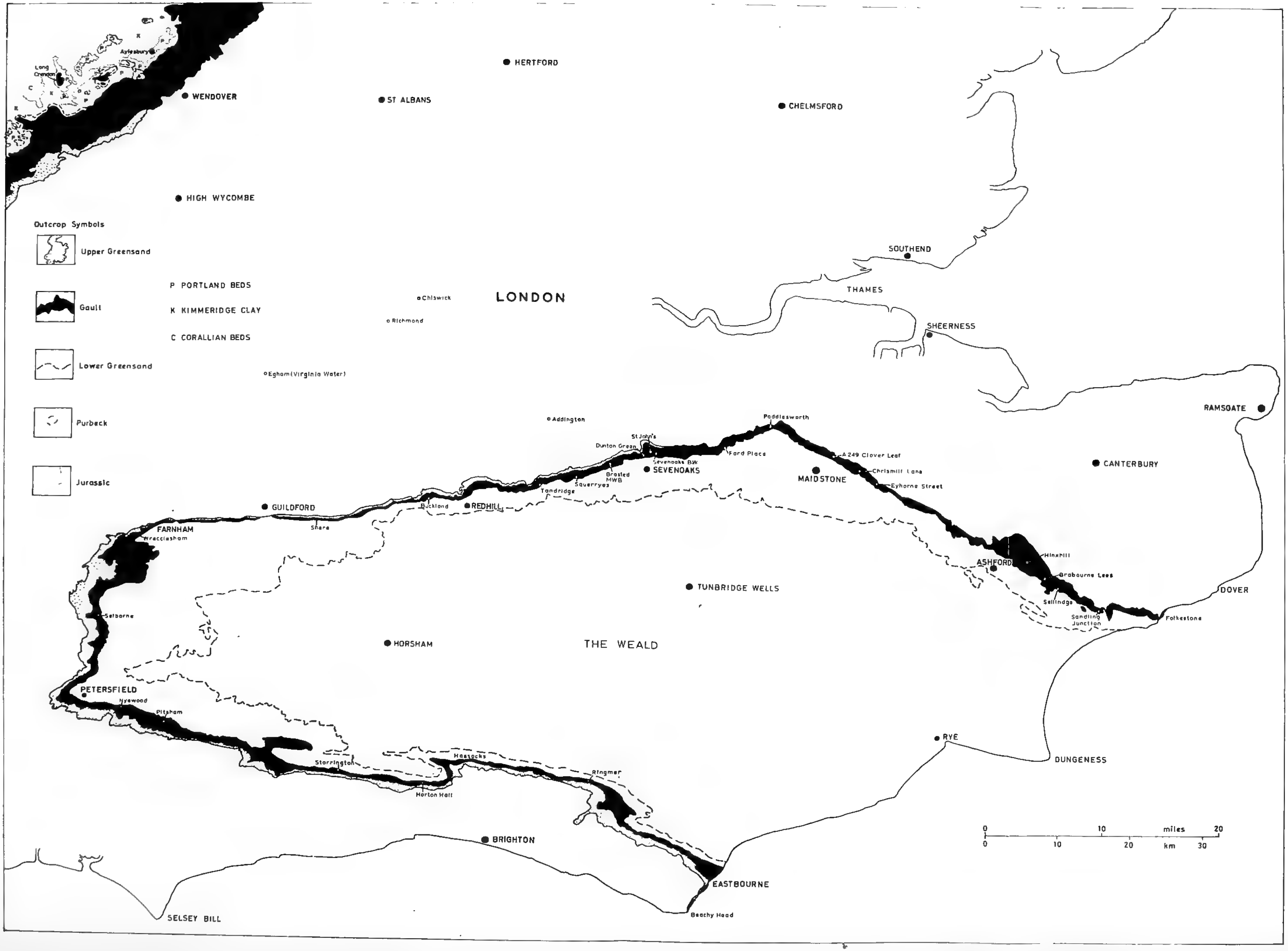


FIG. 1. Sketch map of the Weald and adjacent areas showing positions of sections and boreholes discussed in the text.

A. Weald

The Gault describes a narrow outcrop at the foot of the Downs from Folkestone in the east, around the northern, western and southern borders of the Weald to reach the sea again at Eastbourne (text-fig. 1). Deposits of Middle Albian age are present throughout and reach their greatest known thickness in Sussex. No section has yet provided a complete and relatively uncondensed sequence. Although the greatest degree of representation is to be found in the Folkestone area of Kent and between Steyning and Ringmer in Sussex, even at these localities condensation at certain horizons is very marked. Fortunately, further west in the northern Weald some condensed horizons are greatly expanded, but this is offset by truncation westwards of deposits of the higher subzones of the Middle Albian due to tectonic movements and associated erosion within the *cristatum* Subzone.

(i) FOLKESTONE

In response to the general north-easterly dip, the Gault appears above the Folkestone Beds at the top of East Cliff, where it overlooks the harbour, and declines to the shore in East Wear Bay. Copt Point is the promontary at the NE. end of East Cliff at the entrance to East Wear Bay, and it was shortly after a substantial cliff-fall in 1959 that the section given in text-fig. 2 was measured. By far the bulk of the fossils, for which the Folkestone Gault is famous, were collected from the foreshore exposures in East Wear Bay (East Weir Bay of early authors), but due to cliff and shore stabilising work carried out by British Railways, these sections are now hidden beneath beach-sand (see Bisson in Smart *et al.* 1966 ; 293–296). It is worth recording that in the period between 1948 and 1956 when remedial work obscured the sections, a large slice of Gault extending from the top of Bed III to the base of Bed X could be seen from the area now covered by the western half of the Toe-weighting to about 100 yds west of it. This slice was not greatly disturbed within itself, but at the line shown by Bisson (Smart *et al.*, 1966 ; fig. 17, p. 294) the dip was in the order of 70°–80° landwards.

The Folkestone Gault has attracted the attention of many workers because of the intrinsic beauty of its fossils. The early history of research is ably summarised by Price (1879, 1880) whose bed notation is still broadly used today. De Rance (1868), however, was the first to divide the Gault into Lower and Upper Divisions and to subdivide them further into eleven Beds. Price (1874, 1875) accepted De Rance's Upper and Lower Gault and also recognised eleven Beds but these did not coincide with those of De Rance. De Rance later (*in* Topley 1875 ; 146) accepted the bed notation of Price but they do not coincide lithologically. Jukes-Browne subsequently modified Price's account, and it is his reading of the section which has been accepted by subsequent workers (1900 ; 69–83). Spath (1923–43) drew heavily on the well preserved ammonite fauna of this locality, and indeed, the degree of representation in his Monograph is largely a reflection of the high degree of representation within the section itself. Spath (1923a, b, c ; 1926b), like Jukes-Browne (1900 ; 45), expressed his zonal scheme for the Middle and Upper Albian essentially in terms of the lithological sequence at Folkestone.

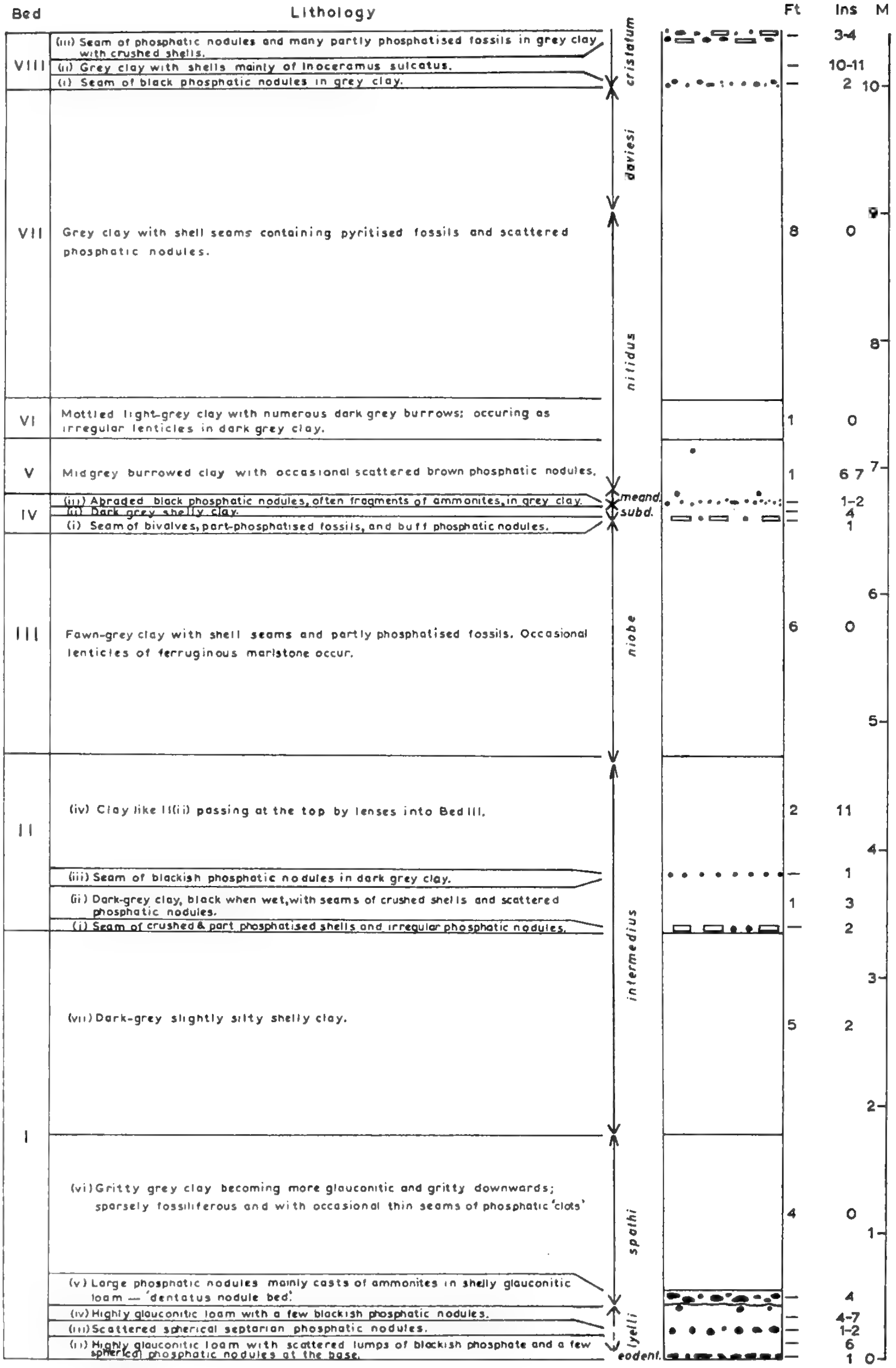


FIG. 2. Cliff section of Lower Gault a few yards NE of the sewer, Copt Point, Folkestone, Kent.

Since Spath completed his Monograph, our knowledge of the Lower Gault at Folkestone has been increased by Casey (1950) and the author (Owen 1958 ; 1963a). Bisson (*in* Smart, Bisson & Worssam 1966 ; 56–58) has given an account of the section, but this is based essentially on Jukes-Browne. The revised section of the Lower Gault, given in part by me in 1963 (1963a ; 36–38) and in full in text-fig. 2, is the first new account since Price (1880). It is slightly thicker than that of Price, but this is probably due to his section being further out from the modern cliff-line, the seaward slope of the land at Copt Point producing a slightly thinner sequence due to creep at the cliff of Price's day.

Casey (1950 ; 272–3) divided Bed I into four sub-divisions corresponding to (i) the ' Sulphur Band ', (ii) the ' Greensand Seam ', (iiia) the *dentatus* nodule bed, and (iiib) the remainder of the clays. He classified the whole of the ' Greensand Seam ' with the *inaequinodum* Subzone, later (e.g. *in* Worssam *et al.* 1963 ; 59) replaced by the index *Hoplites* (*Isohoplites*) *eodentatus*. The *dentatus* nodule bed and the lower part of the overlying clays were, following Spath, classified with the *spathi* Subzone, and the upper part of Bed I with the *intermedius* Subzone. He concluded that the *benettianus* Subzone (i.e. the *lyelli* Subzone) was probably absent (see also *in* Worssam *et al.*, 1963 ; 59).

Subsequent work has shown that Casey's subdivisions are too broad and a more detailed notation is given by me (Owen 1963a ; 36–38, 49) and in text-fig. 2.

Fossils are rare in the ' Greensand Seam '. The specimens of *Hoplites* (*Isohoplites*) in the Institute of Geological Sciences (GSM 83165–6 Spath Coll.) are angular fragments like the nodules of I(ii) which is here classified with the *eodentatus* Subzone. Bed I(iii) has not yielded fossils to me, but in I(iv) at a depth of 2 inches (0·05 m.) beneath the *dentatus* nodule bed, I have collected, apart from the specimen of *Hoplites* (*H.*) cf. *baylei* Spath figured by me (1963a ; 37, pl. 3, fig. 3), a fragment of *Beudanticeras* sp. indet. together with one specimen of *Neohibolites minimus* (Miller) and a few indigenous and very delicate bivalves. The association of *Hoplites* (*Hoplites*) and *Beudanticeras* indicates the *lyelli* Subzone. From a knowledge of the *lyelli* Subzone successions at Small Dole (p. 35), Swindon (p. 61) and the Aube (p. 91), the writer is firmly convinced that the specimens of *Hoplites* (*H.*) aff. *benettianus* which occur rarely in the spherical phosphatic nodules immediately beneath the *dentatus* nodule bed (Owen 1963a ; 37, pl. 3, figs. 1a, b ; 2a, b) are of late *lyelli* Subzone age. The presence of this Subzone at Folkestone is not surprising because it is well represented in the Gault of the Guilford (Waldeshire) Colliery shaft (p. 76) about 7 miles (11·25 km.) from Copt Point, and in the Aycliff boring (p. 78).

The classification of the remainder of Bed I has been discussed by the writer already (Owen 1963a ; 37–38, 49), and it is only necessary to question one statement made by Casey (*in* Hancock 1965 ; 247) that *Anahoplites intermedius* comes in a foot or two above the *spathi* nodule bed as a minority element in a fauna still dominated by *Hoplites*. If this were the case, then the Folkestone section would be unique. Species of *Hoplites* (*H.*) occur crushed in Bed I (vi) up to a height of 3 feet 2 inches (0·96 m.). Higher up, ammonites are absent or very rare until one reaches the base of I (vii), at which level *Anahoplites intermedius* appears. At Folkestone, as at most other localities in the Weald, there is a gap in the ammonite fauna between undoubted deposits of *spathi* and *intermedius* Subzone age. There is no break apparent in sedimentation, but the only common fossils are large *Inoceramus concentricus*. At localities such as Petersfield (Sussex p. 34), Osmington (Dorset p. 51), Devizes (Wiltshire p. 60), and to a point also in the southern part of the Paris Basin (pp. 88, 93, 97) this gap in the Weald sequence is filled. There is indeed the association of *Anahoplites* and *Hoplites* (*H.*) but the forms of *Anahoplites* are very distinct and include *A. grimsdalei* sp. nov. and *A. osmingtonensis* sp. nov. ; forerunners of the *evolutus-intermedius-praecox* group. *Hoplites* (*H.*) continues on into the *intermedius* Subzone but is a very subordinate element in the fauna.

The classification of the remainder of the Lower Gault at Folkestone by Spath has seen only a few modifications (Owen 1958 : 1960 ; 376–7). Spath pointed out (1926b; 421) that the divisions between Subzones do not always coincide with the junction between beds. The details of Bed I (vi–vii) given by the writer in 1958 were taken from what are now obviously disturbed sections, but were then the best available, and should be discounted. The account given in 1963 was taken from a perfect section. Bed I (vii) and the whole of Bed II up to a level 3 inches (0·70 m.) below its top, are classified with the *intermedius* Subzone. The bulk of the ammonites are crushed and consist essentially of species of *Anahoplites* such as *A. intermedius*, *A. praecox*, and *A. mantelli*. Partly phosphatised ammonites occur in Bed II (i) and pyritic specimens occur very sparingly among the numerous crushed fossils in II (ii). The fauna of these three subdivisions is very uniform, but in II (iii) we see the introduction of a particularly coarse development of *A. praecox*, and in II (iv), where ' solid ' pyritic fossils are more common, *Euhoplites pricei* Spath is a very characteristic form.

Dimorphoplites niobe Spath, already present in the *intermedius* Subzone, becomes common in the shell seam about 3 inches (0·076 m.) below the base of Bed III at which level *Anahoplites* of the *praecox-intermedius* group quite suddenly ceases to be important. *D. niobe*, together with *A. planus* and *A. splendens* then characterises the whole of Bed III, within the upper 2 to 3 inches (0·051–0·076 m.) of which, part or wholly phosphatised fossils with the nacreous shell occur sparingly. Bed IV (i) does not mark a great break in the sequence although semi-derived phosphatic fragments of fossils do occur. *D. niobe*, *A. planus* and *A. splendens* still occur but the fauna becomes more diversified and *Mojsisovicsia subdelaruei* *M. remota* and *M. spinulosa* (Spath) appear as infrequent but highly characteristic species. These species of *Mojsisovicsia* occur indigenous in both IV (i) and (ii) which are classified with the *subdelaruei* Subzone (Owen 1960 ; 376). Bed IV (iii) marks a greater period of erosion and its characteristic ammonite fauna was listed by Owen (1958 ; 157). This bed, together with the basal 2 inches (0·051 m.) of Bed V which contains the same fauna is classified with the *meandrinus* Subzone. Casey (*in* Smart, Bisson & Worssam 1966 ; 109) and in effect Milbourne (*in* Hancock 1965 ; 247) state that *Euhoplites meandrinus* Spath occurs outside Bed IV (iii) and the basal part of Bed V. However, the author has never seen a specimen, either in the field or in the collections, from any other bed. Spath's original (BMNH, C 32306) was a pyritic specimen, now decomposed, which with very little doubt came from the basal part of Bed V, as Spath thought likely (1930b ; 271).

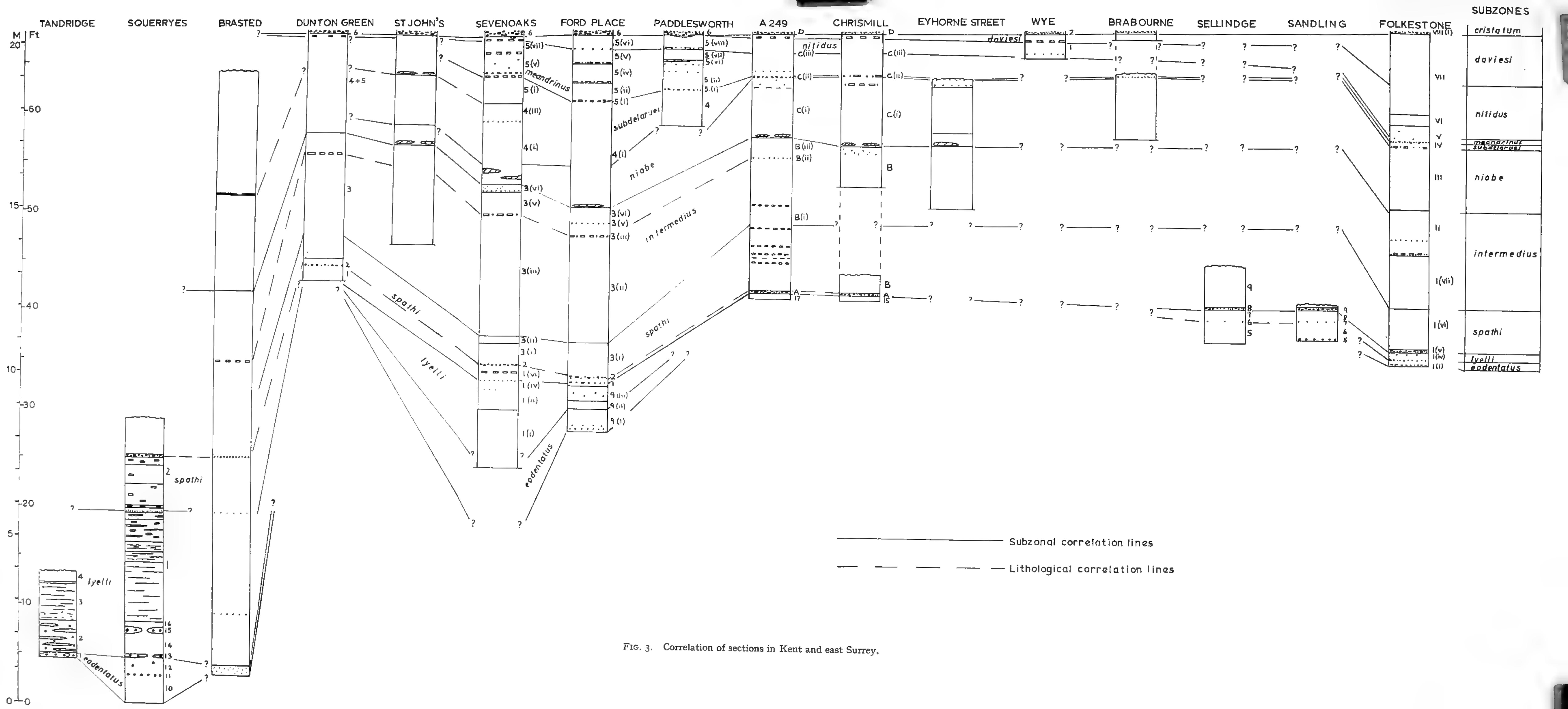


Fig. 3. Correlation of sections in Kent and east Surrey.

The sudden change from a deeply sulcate to a channelled venter in *Euhoplites* which occurs at a height of 2 inches (0·051 m.) up from the base of Bed V was taken by the writer to mark the base of the *nitidus* Subzone and the *lautus* Zone (Owen 1958 ; 157–8, 162). There are a few scattered phosphatic nodules at this level and a small break in deposition is further suggested by the sequence at Ford Place, Trottiscliffe (p. 22). The remainder of Bed V together with Bed VI are classified with the *nitidus* Subzone and yield a typical fauna. Apart from the highly burrowed nature of the clay, Bed VI is also characterised by particularly tuberculate examples of *Dimorphoplites* of the *parkinsoni* type. The lower part of Bed VII, previously classified with the *daviesi* Subzone, in fact still contains a *nitidus* Subzone fauna and must be classified with that Subzone (Owen 1960 ; 376). *Anahoplites daviesi* does not appear in the sequence until a height of about 5 feet (1·524 m.) is reached, and this and closely related forms characterise the remainder of these clays of Bed VII which are classified with the *daviesi* Subzone.

Bed VIII at the summit of the Lower Gault was classified by Spath and subsequent authors with the *cristatum* Subzone here included in the Upper Albian (*inflatum* Zone). The depositional history of Bed VIII is complex. The lower nodule bed VIII (i) represents a moderate break in deposition, and its fauna includes the bivalves *Inoceramus concentricus*, *I. sulcatus subsulcatus* and *I. sulcatus*, and the ammonites *Dipoloceras bouchardianum* (d'Orbigny) and *Beudanticeras beudanti* (Brongniart). At Wissant (p. 85) on the French coast 22 miles from Folkestone, the equivalent of Bed VIII (i) is represented by the clays of Bed 12 (v) in which a coarse form of *I. concentricus* at the base soon passes into the *subsulcatus* stage to achieve the *sulcatus* form at the top. This bed also yielded the holotype of *D. bouchardianum* and *B. beudanti* also occurs. It is, however, apparent that some material of late *daviesi* Subzone age is also present in the remanié fauna of Bed VIII (i) at Folkestone. This element can be demonstrated by the occurrence of very coarse developments of *Anahoplites* of the *daviesi* group and typical *I. concentricus*.

A detailed discussion of Bed VIII and its fauna is out of place here but it is essentially of *cristatum* Subzone age. The uncondensed sequence at Wissant indicates that the incoming of the typical fauna of the *cristatum* Subzone was quite rapid. This fauna continues on into the basal few feet of Bed IX which will also have to be classified with the *cristatum* Subzone. Bed VIII is in all truth a junction bed as the early workers recognised.

(ii) FOLKESTONE TO THE MEDWAY

No complete sequence in the Lower Gault has been seen between Folkestone and Chrismill Lane, Thurnham, on the Maidstone By-Pass, a distance of 29 miles (46·67 km.). What little information is available is ably presented by Smart, Bisson & Worssam 1966 (Folkestone to Westwell), Worssam *et al.*, 1963 (to a few miles W. of Maidstone), and Dines, Holmes & Robbie 1954. A little additional information is given here, and the correlation of the sections is shown in text-fig. 3.

It is apparent that the sequence seen at Copt Point has changed already by Elenden Gardens, Cheriton (Spath 1923c ; 141–2) but unfortunately no precise details of this section were recorded. Bisson *in* Smart *et al.* (1966 ; 100) has described the Folkestone Brickworks section at Cheriton (TR 205376) in which I suspect that the lowest 2 feet 6 inches (0·762 m.) recorded as 'Dark-grey slightly micaceous blocky clay with occasional phosphatic nodules', underlying the basal *cristatum* nodule bed, is of *daviesi* Subzone age as at Copt Point, and at Wye near Ashford. However, I did not see this part of the succession.

At Sandling Junction (text-fig. 4) the fauna of Bed 9 classified with the *spathi* Subzone is identical to that of Division A in the Maidstone By-Pass (Owen 1960 ; 372), and so, the age of the *dentatus* nodule bed has already changed at the outcrop within 5 miles (8·05 km.) of Copt Point (Owen 1963a; 49–50). No fossils have yet been found in the underlying glauconitic loams of Beds 4–8. Bed 8 (of Worssam 1966 ; 99) at File's pit in Swan Lane, Sellindge (TR 11853915) is the equivalent of Bed 9 at Sandling, and Bed 6 yielded the specimen of *Hoplites* ? recorded by Worssam.

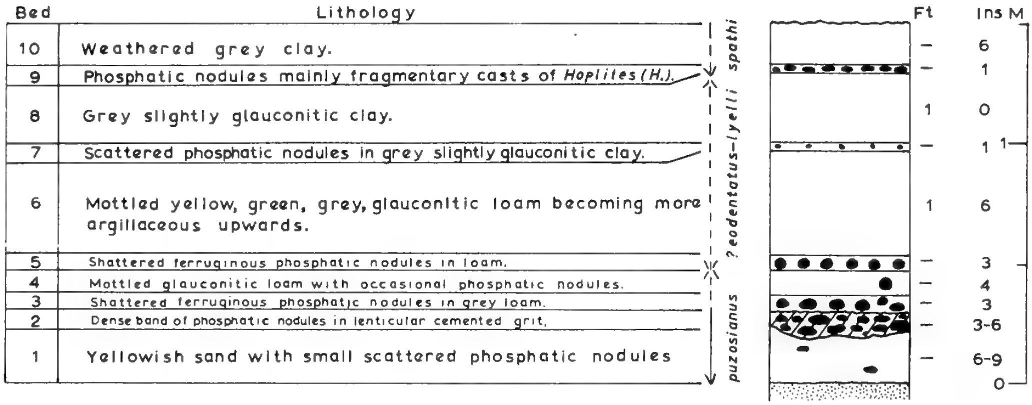


FIG. 4. Section in Gault-Lower Greensand junction beds at Folkestone Quarries Ltd's Sandling Sandpit, *c.* 150 yds. NW. of Sandling Junction railway station, Saltwood, Kent (TR 14703690).

This specimen (GSM., CW 855) is a definite *Hoplites* (*H.*) but there is no other indication of the age of the sediments overlying the *puzosianus* Subzone sediments. The principle bed of phosphatic nodules in the *spathi* Subzone sediments at the Granary Court Sand pit at Brabourne (TR 09004005) is also on the same horizon as that of Bed 9 at Sandling. At Brabourne, in the area where Hill (*in* Jukes-Browne 1900 ; 84) records a section, the former Ashford & Naccolt Brick, Tile & Potteries Ltd., dug shallow pits in higher beds of the Lower Gault about 800 yards (731 m.) a little north of west from Park Farm (TR 08904065). About 8 feet (2·43 m.) of weathered brownish clay streaked with ferruginous matter was to be seen beneath superficial deposits. Towards the top of the clays a disturbed seam containing phosphatic nodules yielded fragments of the following :—

Anahoplites planus (Mantell), *A. pleurophorus* Spath, *Dimorphoplites* aff. *niobe*, *D.* cf. *doris* Spath, *Euhoplites* cf. *subtuberculatus* Spath late mutation, *E. microceras*

Spath late mutation, *Hamites tenuicostatus* Spath, *Inoceramus concentricus* Parkinson.

The assemblage indicates the *subdelaruei* Subzone as restricted here and by the writer in 1960, which coincides with the term ' lower *subdelaruei* Subzone ' given by Smart (*in* Smart, Bisson & Worssam 1966 ; 98). The age of the underlying clay was not determinable, but the whole sequence is similar to that of the Maidstone By-Pass (text-fig. 3). Smart records *cristatum* Subzone fossils from a similar shallow working 300 yds (274 m.) to the NNW.

In the Ashford Brickworks Ltd pit (formerly the Ashford & Naccolt Brick, Tile & Potteries Ltd) situated 700 yds NW. of Sillibourne Farm and about 110 yds ENE. of Blackwall Farm, Wye (TR 04954445) the upper beds of the Lower Gault have recently been exposed (text-fig. 5). This is the pit recorded by Cornes (*in* Dewey *et al.*, 1925 ; 263–4) as ' New Nackholt ', and by Smart at TR 049445 (1966 ; 98).

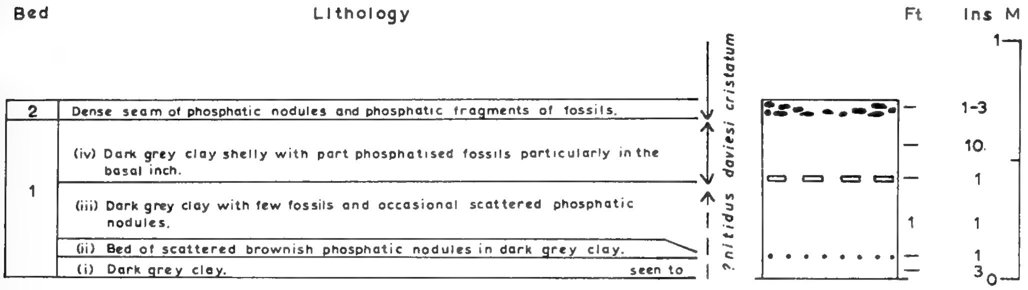
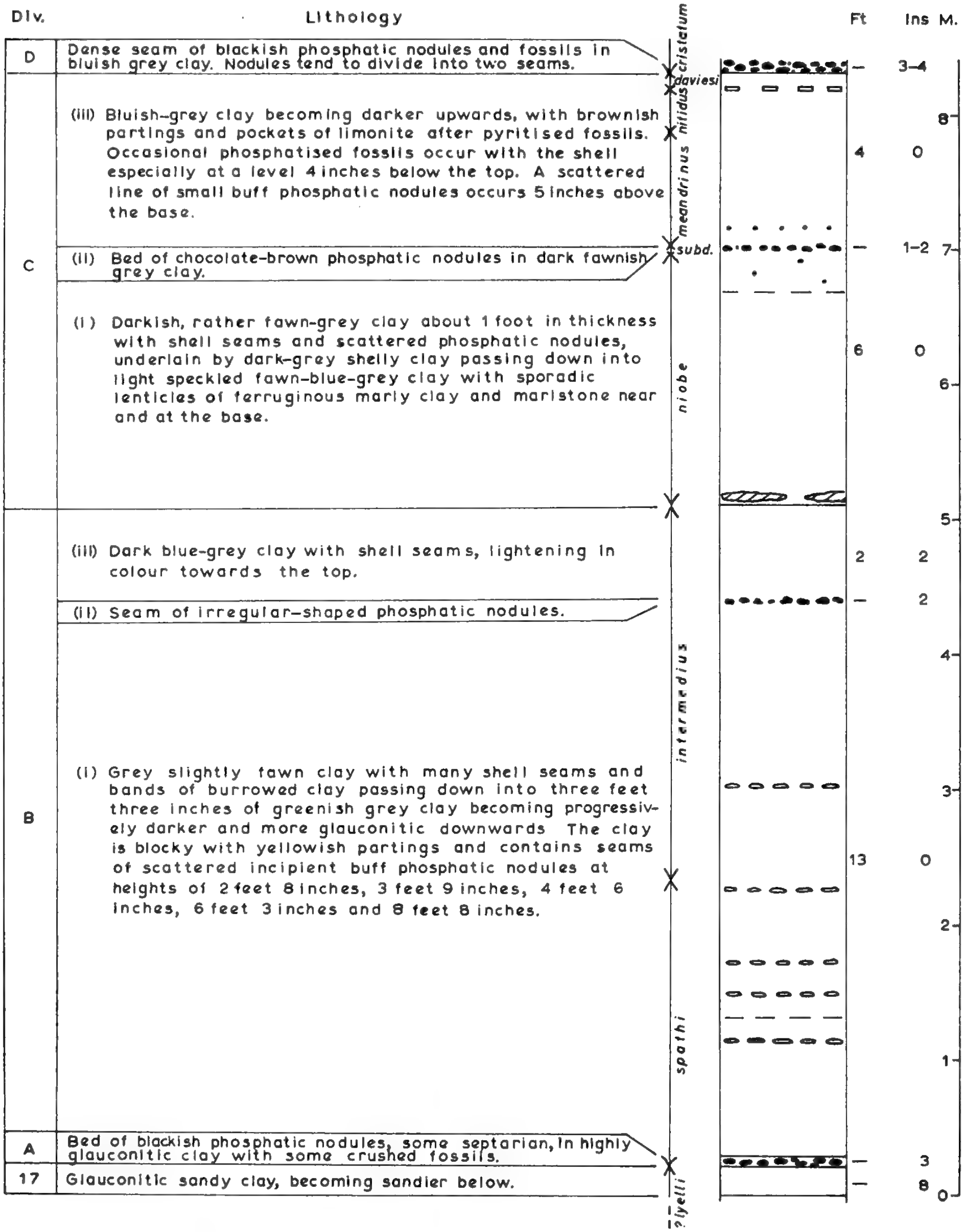


FIG. 5. Upper beds of Lower Gault at Naccolt Brick Works (Ashford Brickworks Ltd), 700 yds NW. of Sillibourne Farm and *c.* 1100 yds ENE. of Blackwall Farm, Wye, Kent (TR 04954445).

Anahoplites daviesi and *A. daviesi ornata* appear at a depth of 10 inches (0·254 m.) below bed 2, the *cristatum* nodule bed, and the remainder of the clay up to bed 2 is classified with the *daviesi* Subzone. Whether the lower part of the exposed clays of bed 1 is also of *daviesi* Subzone age is not certain. Only a single nodule bed (bed 2) here represents Bed VIII at Folkestone and its character and fauna is almost identical to that of Division D in the Maidstone By-Pass (Owen 1960 ; 374). The section recorded by Hill (*in* Jukes-Browne 1900 ; 84) at Kennington, the ammonites from which were re-determined by Casey (*in* Smart *et al.*, 1966 ; 97), apparently showed some Lower Gault, but it is at present impossible to interpret the sequence.

Unfortunately the sections recorded between Wye and Hollingbourne are insufficient to determine the succession. The preservation of the ammonites from Westwell Leacon and Kennington preserved in the Institute of Geological Sciences suggests nodule beds about the same horizon as beds C (ii) and D in the Maidstone By-Pass. The pit at Eyhorne Street, Hollingbourne, described by Hill (*in* Jukes-Browne 1900 ; 85) was alleged to show beds spanning the Lower Gault-Upper Gault junction. However, Casey (in Worssam *et al.*, 1963 ; 59) has re-determined the fossils collected from this pit and demonstrated that the section was wholly in the Lower Gault and that Hill's reading of it was incorrect. If one compares the section given



Div.	Lithology	Ft	Ins
D	Dense seam of blackish phosphatic nodules and fossils in bluish grey clay. Nodules tend to divide into two seams.	—	3–4
C	(iii) Bluish-grey clay becoming darker upwards, with brownish partings and pockets of limonite after pyritised fossils. Occasional phosphatised fossils occur with the shell especially at a level 4 inches below the top. A scattered line of small buff phosphatic nodules occurs 5 inches above the base.	4	0
	(ii) Bed of chocolate-brown phosphatic nodules in dark fawnish grey clay.	—	1–2
	(i) Darkish, rather fawn-grey clay about 1 foot in thickness with shell seams and scattered phosphatic nodules, underlain by dark-grey shelly clay passing down into light speckled fawn-blue-grey clay with sporadic lenticles of ferruginous marly clay and marlstone near and at the base.	6	0
B	(iii) Dark blue-grey clay with shell seams, lightening in colour towards the top.	2	2
	(ii) Seam of irregular-shaped phosphatic nodules.	—	2
	(i) Grey slightly fawn clay with many shell seams and bands of burrowed clay passing down into three feet three inches of greenish grey clay becoming progressively darker and more glauconitic downwards The clay is blocky with yellowish partings and contains seams of scattered incipient buff phosphatic nodules at heights of 2 feet 8 inches, 3 feet 9 inches, 4 feet 6 inches, 6 feet 3 inches and 8 feet 8 inches.	13	0
A	Bed of blackish phosphatic nodules, some septarian, in highly glauconitic clay with some crushed fossils.	—	3
17	Glauconitic sandy clay, becoming sandier below.	—	8

FIG. 6. Lower Gault sections at NW. quadrant of A 249 clover leaf, Maidstone By-Pass (East Section) M 20, extending from a point 585 yds NE. of the Chiltern Hundreds public house to the A 249, Boxley, Kent (TQ 77805745).

by Hill with that of the Maidstone By-Pass (Owen 1960 ; 369–371 and text-fig. 6 herein) it can be seen that the sequence exposed at Eyhorne Street included parts of the equivalent of Divisions B and C which appear to be identical to that of the By-Pass.

There is nothing further to add to my account of the sections exposed during the construction of the Maidstone By-Pass motorway (M20) (Owen 1960), except for an unfortunate omission of a complete sentence in my reply to the discussion of my paper by Gray (1962 ; 469). The missing sentence read, ' As seen in the sections, the Tertiary faulting affects the beds [in the A 249 clover-leaf] in the following manner.' Without this sentence there is the implication that the faulting is intra-Albian which it certainly is not. The correlation of the sections is shown in text-fig. 3, and it can be seen that the stratigraphical succession is very uniform.

(iii) MEDWAY TO TROTTISCLIFFE

(a) Paddlesworth

West of the Medway, the outcrop changes direction through an arc of about 12° but no complete sequence is seen until one reaches the Ford Place clay-pit, Trottiscliffe, where the Middle Albian sequence is thicker than at the Maidstone By-Pass. However, in the early months of 1968 the Associated Portland Cement Manufacturers clay pit at Paddlesworth, which has for many years shown an important Upper Gault sequence, was cut further south exposing the higher part of the Lower Gault. The Middle Albian sequence is shown in text-fig. 7, and its correlation with the Maidstone By-Pass and Ford Place in text-fig. 3. The basic similarity with the sequence at Ford Place from the middle of Division 4 permits the use of the same divisional enumeration.

By analogy with Ford Place, the 3 feet 6 inches (1·067 m.) of clays at the top of Division 4 at Paddlesworth are almost certainly of *subdelaruei* Subzone age. They contain numerous *Inoceramus concentricus* and *Hamites tenuicostatus* as at Ford Place, but no specimens of *Mojsisovicsia* are yet to hand. These clays represent an expansion of nodule bed C (ii) at the Maidstone By-Pass. Bed 5 (i) contains a typical *meandrinus* Subzone fauna and the sediments up to the top of 5 (vii) are also classified with this Subzone. 5 (i) corresponds exactly to 5 (i) at Ford Place but does not contain phosphatised fossils with the shell preserved as at the latter locality. 5 (ii–vi) correspond to 5 (ii–iv) at Ford Place and 5 (vii) is the direct equivalent of 5 (v). In general the sequence is slightly thinner at Paddlesworth than at Ford Place, but it is much thicker than that seen at the Maidstone By-Pass where the equivalent sediments are but 2 feet 7 inches (0·787 m.) thick.

The sediments of *lautus*-Zone age at Paddlesworth 5 (viii) are 2 inches (0·051 m.) thicker than at Ford Place 5 (vi), and 1 inch (0·025 m.) thinner than at the Maidstone By-Pass. Part phosphatised fossils occur at the base of 5 (viii) and the species of *Euhoplites* indicate the *nitidus* Subzone, although the commonest ammonite is *Dimorphoplites biplicatus* (Mantell). Crushed *Anahoplites planus* occur in the top few inches, and there are a few uncrushed *Euhoplites truncatus* in the uppermost inch.

Whether the *daviesi* Subzone is represented at this height is uncertain. Sediments of *daviesi* Subzone age are 4 inches (0·101 m.) thick in the Maidstone By-Pass.

The nodule bed Division 6 is of *cristatum* Subzone age, and it is interesting to note that there is a tendency for this bed to divide a little into two, a feature seen in Division D in Sections 2 and 4 of the Maidstone By-Pass (Owen 1960 ; 371). There is no question of there being two distinct nodule beds, but the feature is of interest in connection with the tectonic disturbance and associated erosion of the upper surface of the Lower Gault in *cristatum* Subzone times (p. 72).

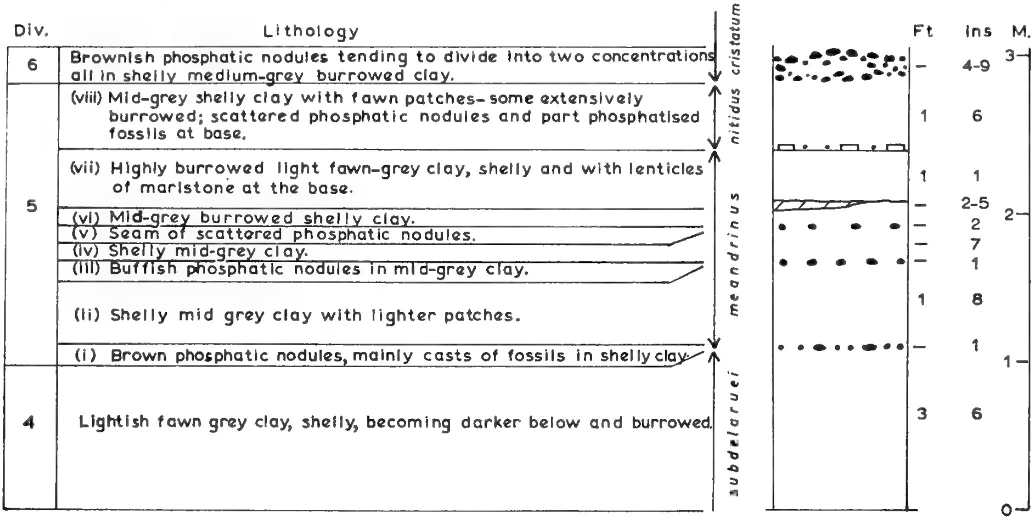
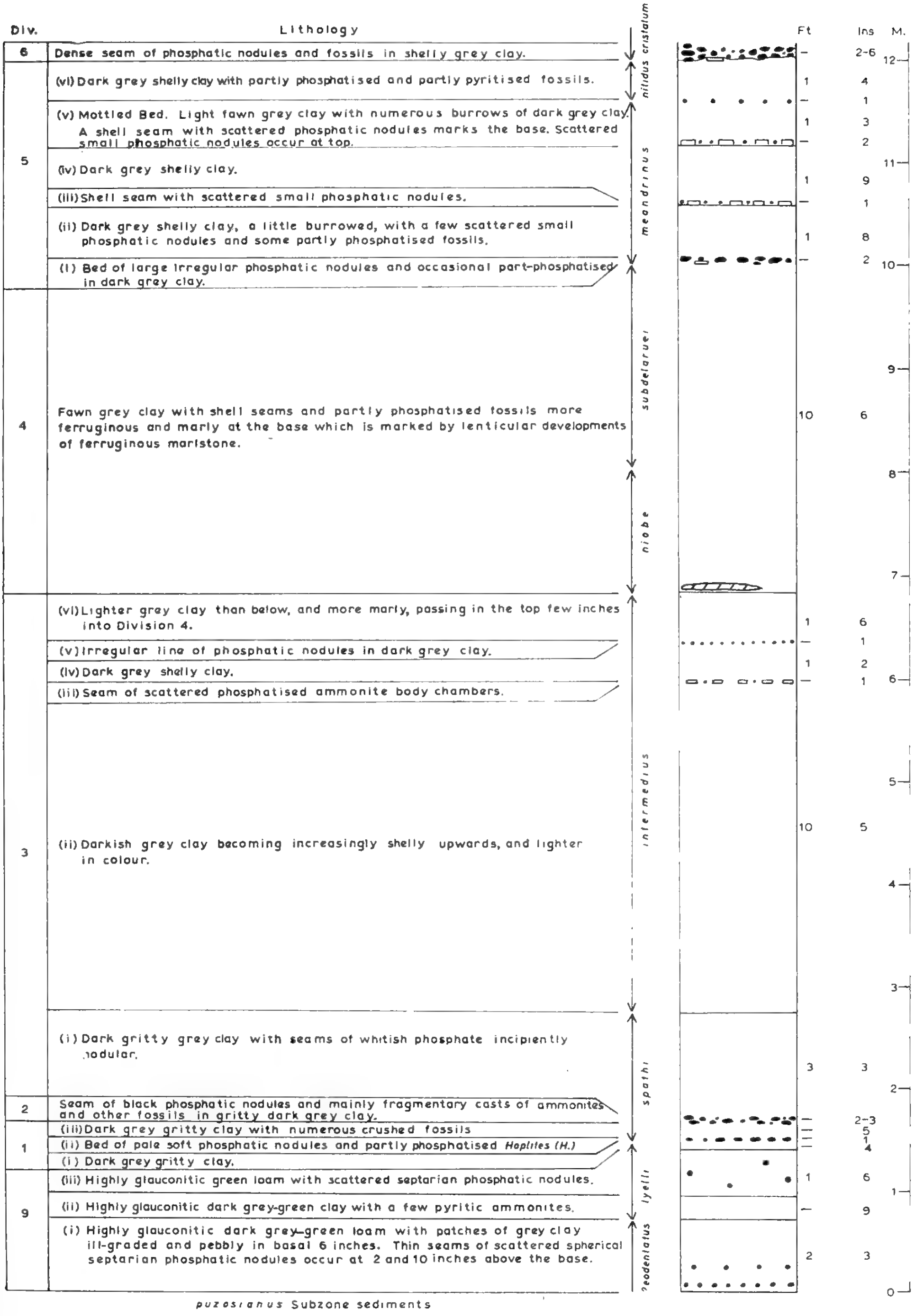


FIG. 7. Section in Lower Gault at southern side of the Associated Portland Cement Manufacturers' Holborough clay pit, 880 yds SE. of Paddlesworth, Snodland, Kent (TQ 69156165).

(b) Trottiscliffe

The sequence exposed in the Rugby Portland Cement Co's Ford Place Clay pit extends from the middle of the Folkestone Beds up to the *varicosum* Subzone of the Upper Gault. The Middle Albian sediments are shown graphically in text-fig. 8. Casey (1959) has given a brief account of the whole section, and a detailed account of the Gault-Lower Greensand junction beds (1961a ; 545). The upper part of the junction beds and the Gault have been described by Milbourne (1963) but his account is inaccurate both in lithological detail and in its subzonal classification. The writer has described the sequence in the *spathi* Subzone (1963a ; 38), but in view of Milbourne's account of this section it is necessary to redescribe the sequence in the Lower Gault (text-fig. 8).

Bed 9 of Casey (1961a ; 545) was stated to have a thickness of 3 feet (0·914 m.) and by Milbourne (1963 ; 58) as 5 feet (1·524 m.) : it is capable of subdivision (text-fig. 8). Bed 9 (ii) has yielded pyritic *Hoplites* (*H.*) spp. and *Beudanticeras* sp. and I follow Milbourne in classifying this horizon with the *lyelli* Subzone. Whether the *eodentatus*



Div.	Lithology	Zone	Ft	Ins
6	Dense seam of phosphatic nodules and fossils in shelly grey clay.	*nitidus cristatum*	–	2-6
5	(vi) Dark grey shelly clay with partly phosphatised and partly pyritised fossils.		1	4
			–	1
	(v) Mottled Bed. Light fawn grey clay with numerous burrows of dark grey clay. A shell seam with scattered phosphatic nodules marks the base. Scattered small phosphatic nodules occur at top.	*meandrinus*	1 –	3 2
	(iv) Dark grey shelly clay.		1	9
	(iii) Shell seam with scattered small phosphatic nodules.		–	1
	(ii) Dark grey shelly clay, a little burrowed, with a few scattered small phosphatic nodules and some partly phosphatised fossils.		1	8
	(i) Bed of large irregular phosphatic nodules and occasional part-phosphatised in dark grey clay.		–	2
4	Fawn grey clay with shell seams and partly phosphatised fossils more ferruginous and marly at the base which is marked by lenticular developments of ferruginous marlstone.	*subdelaruei* *niobe*	10	6
3	(vi) Lighter grey clay than below, and more marly, passing in the top few inches into Division 4.	*intermedius*	1	6
	(v) Irregular line of phosphatic nodules in dark grey clay.		–	1
	(iv) Dark grey shelly clay.		1	2
	(iii) Seam of scattered phosphatised ammonite body chambers.		–	1
	(ii) Darkish grey clay becoming increasingly shelly upwards, and lighter in colour.		10	5
	(i) Dark gritty grey clay with seams of whitish phosphate incipiently nodular.	*spathi*	3	3
2	Seam of black phosphatic nodules and mainly fragmentary casts of ammonites and other fossils in gritty dark grey clay.		–	2-3
1	(iii) Dark grey gritty clay with numerous crushed fossils		–	5
	(ii) Bed of pale soft phosphatic nodules and partly phosphatised *Hoplites (H.)*	*lyelli*	–	1
	(i) Dark grey gritty clay.		–	4
9	(iii) Highly glauconitic green loam with scattered septarian phosphatic nodules.		1	6
	(ii) Highly glauconitic dark grey-green clay with a few pyritic ammonites.		–	9
	(i) Highly glauconitic dark grey–green loam with patches of grey clay ill-graded and pebbly in basal 6 inches. Thin seams of scattered spherical septarian phosphatic nodules occur at 2 and 10 inches above the base.	*?eodentatus*	2	3

puzosianus Subzone sediments

FIG. 8. Section in Lower Gault at the Rugby Portland Cement Co. Ltd's Ford Road clay pit, 450 yds N. of Ford Place House, and *c.* 1100 yds SSW. of Trottiscliffe on W. side of Ford Road, Trottiscliffe, Kent (TQ 63605910).

Subzone is represented in 9 (i), or whether 9 (iii) is of *lyelli* Subzone age, in the absence of fossils cannot be determined at present. The Lower Gault can be divided into six broad lithological divisions corresponding to those recognised by the author in the Sevenoaks area (1958 ; 152 and text-figs. 3, and 9 herein), and the correlation of these with Paddlesworth and the four divisions seen in the Maidstone By-Pass is shown in text-fig. 3. Division 1 (i) has not yielded fossils, but 1 (ii) to the top of 3 (i) are classified with the *spathi* Subzone. Division 1 (ii–iii) contain the same species of *Hoplites* (*H.*) that occur in the *dentatus* nodule bed at Folkestone. Division 2 is the ' upper *dentatus-spathi* nodule bed ' and contains the same ammonites that were recorded by the writer from bed 4 in the Lower Gault of the Buckland Sand & Silica Co. pit (Owen 1958 ; 151).

No ammonites have been obtained from Division 3 (i), but at the base of 3 (ii) crushed *Anahoplites intermedius* and *A. praecox* appear in the succession, marking the base of the *intermedius* Subzone sediments, and range up through the remainder of Division 3. The coarse development of *A. praecox* known to occur in Bed II (iii) at Folkestone is found in the condensed bed 3 (iii), and *Euhoplites pricei* ranges through 3 (iv) to the base of Division 4 (Milbourne 1963 table 1). The lower 4 feet 2 inches (1·321 m.) of Division 4 contains crushed examples of *Dimorphoplites niobe*, and these sediments are classified with the *niobe* Subzone. As Milbourne has demonstrated, *Mojsisovicsia subdelaruei* and its contemporaries range throughout the remainder of Division 4. The *meandrinus* Subzone is represented within the sequence from Division 5 (i) to the top of 5 (v). The clays of 5 (i) to 5 (iv) contain the same fauna as Bed IV (iii) and the basal 2 inches (0·151 m.) of Bed V at Folkestone (Owen 1958 ; 157). However, 5 (v) was probably deposited at Trottiscliffe during a minor phase of non-deposition at Folkestone. The marked change in the ventral aspect of species of *Euhoplites* which occurs suddenly 2 inches (0·051 m.) above the base of Bed V at Folkestone is not so abrupt at Trottiscliffe. In Division 5 (v) the peripheral aspect is transitional from the sulcate to the channelled state. Nonetheless, the characteristic species are more closely allied to the *meandrinus* Subzone rather than the *nitidus* Subzone.

Division 5 (vi) contains a typical *nitidus* Subzone fauna but at the top, immediately beneath the *cristatum* nodule bed (Division 6), there are to be found the occasional part-phosphatised examples of *Anahoplites daviesi*. Division 6 contains numerous usually fragmentary fossils in a matrix containing crushed or partly phosphatised fossils of *cristatum* Subzone age. There are well preserved phosphatised ammonites with the shell which are of *daviesi* or *nitidus* Subzone age which have just been caught up into the phosphatic debris of the nodule bed from the clays beneath. Nonetheless, the clay sediment of Division 6 is of *cristatum* Subzone age. The phosphatic debris contains ammonites indicating the *daviesi* Subzone, but essentially the *cristatum* Subzone.

At Trottiscliffe, therefore, as at Paddlesworth at least in part, we see an expansion of the sequence found at the Maidstone By-Pass, but virtually all sediments of *daviesi* Subzone age have been removed by the *cristatum* Subzone transgression. This expansion of the sequence reaches its known maximum in this area at the Sevenoaks Brick Works Ltd's pit at Otford.

Part of Division 5 and Division 6 were exposed during the excavation of the reservoir for the Mid Kent Water Board some 600 yds ENE. of the centre of the Ford Place Clay pit (TQ 64055920). The lower part of the Gault was also exposed in the now long-abandoned Pascall's pit at Wrotham (TQ 62155780) about 2100 yds SW. of the Ford Place Clay pit and was described very briefly by H. J. W. Brown (1924 ; 79, 81). Nothing can be concluded from his account, but it is unlikely that the sequence has changed much from that at Trottiscliffe.

(iv) SEVENOAKS AREA

This area has been an important centre for the manufacture of bricks and tiles for over a century. Pits have been opened near Kemsing Station (H.J.W. Brown 1924 ; 80), Greatness Lane, Otford (Austin Browne 1949 : Khan 1952 : Casey 1954a : Milbourne 1956, 1962, 1963 : Owen 1958, 1963a, b), St. John's, Sevenoaks (Jukes-Browne 1900 : H. J. W. Brown 1924), Dunton Green (C. W. Wright 1947 : Khan 1952 : Casey 1954a : Owen 1958) and Chevening (Lobley 1880). These sections, with the exception of the last, together with borehole evidence has given a very good picture of the Lower Gault in this area. Brown (1924 ; 80) records the occurrence of the nodule bed (Division 6) at the top of the Lower Gault just N. of the railway line at Kemsing Station, but there is no other information available about the succession between Wrotham and Otford, a distance of 6½ miles. Today, the only section available is that exposed in the Sevenoaks Brick Works Ltd., pit at Otford.

(a) **Sevenoaks Brick Works Ltd., Greatness**

The sequence in the Lower Gault at the Sevenoaks Brick Works Ltd pit at Greatness Lane, Otford, is shown in text-fig. 9. It was first described by Khan who discussed the foraminiferal sequence (1952), then in part by Casey (1954a) when describing the distribution of *Falciferella*. Milbourne has described the succession (1956, 1962) but his reading of it was questioned by the writer (1958, 1963a). The six broad lithological divisions seen at Ford Place reach their maximum development here (text-figs. 3 & 9).

A combination of evidence provided by several boreholes together with surface mapping shows that the Gault-Lower Greensand Junction beds are over 13 feet 6 inches (4·11 m.) thick at Greatness. Division 1 (i) apparently is the transitional bed linking the Junction beds with the Gault. The writer reported (1963a ; 39) that the clays of 1 (ii) to (iv) probably represent the upper part of the *benettianus* (i.e. *lyelli*) Subzone, and so the bulk of the Subzone is probably present in 1 (i) and, together with the *eodentatus* Subzone, in the sediments below. The species of *Protanisoceras* (*P.*) in 1 (ii–iv) include *P.* (*P.*) *barrense* (Buvignier) a characteristic *lyelli* Subzone ammonite. In comparison with Ford Place, it can be seen that clay sedimentation commenced earlier at Greatness. The *spathi* Subzone is represented by Divisions 1 (v–vi), 2, and 3 (i–ii). Division 2 is the ' Upper *dentatus-spathi* nodule bed ' as at Ford Place, and so, the *spathi* sediments of Division 1 are slightly thicker at Great-

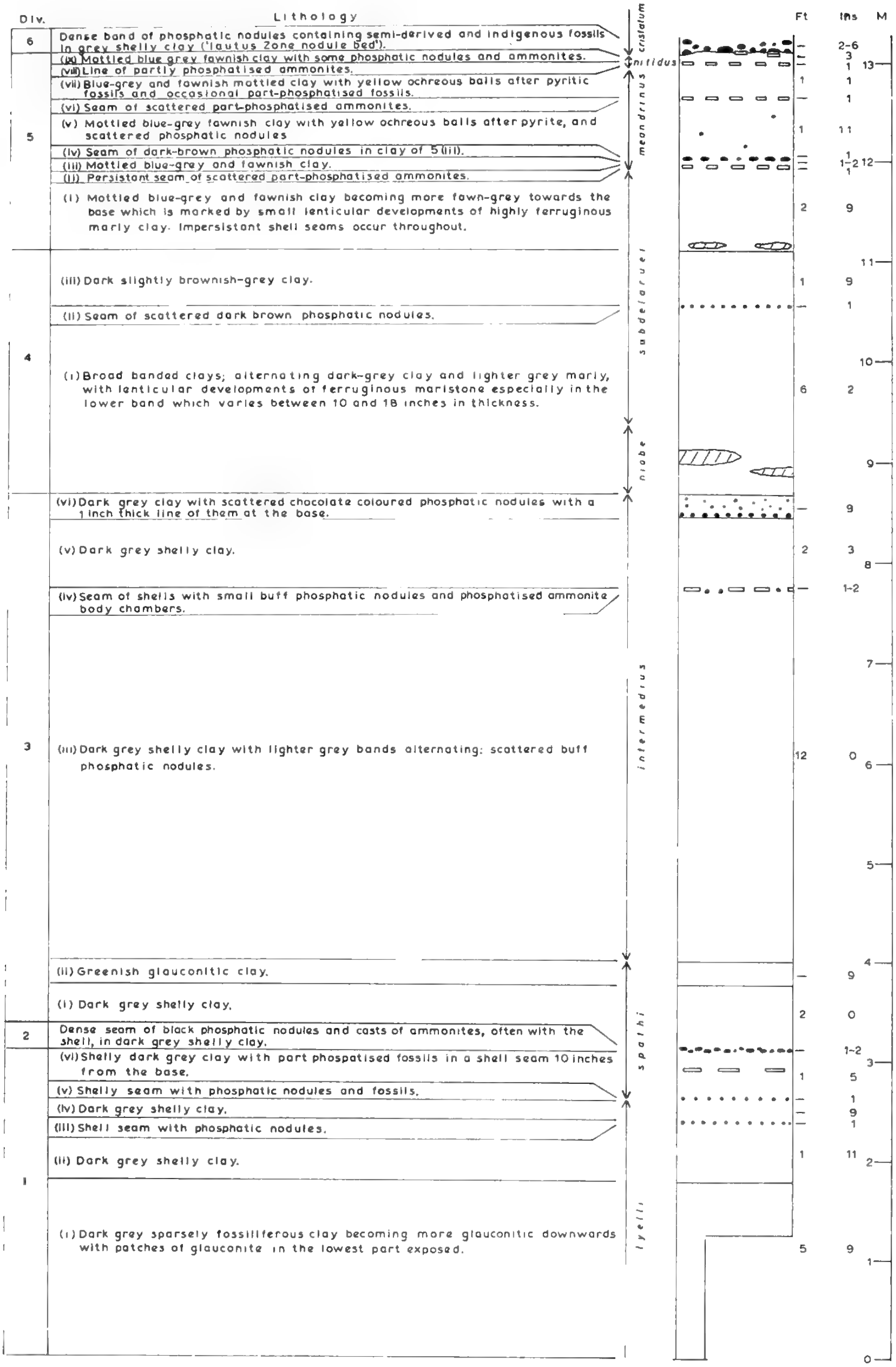


FIG. 9. Lower Gault section at the Sevenoaks Brick Works Ltd's pit, 1300 yds NNE. of Bat & Ball railway station, 150 yds S. of the Otford-Kemsing railway line, and 150 yds W. of Greatness Lane, Otford, Kent (TQ 53605780).

ness. Division 3 at both localities is closely comparable in thickness and character except at its base, where 3 (i) at Ford Place has become finer in character and shelly by Greatness and is represented in 3 (i–ii). Ammonites that occur in 3 (i) at Greatness consist almost exclusively of species of *Hoplites* (*H.*), the fauna being identical to that of the indigenous element of Division 2 itself which contains rarities such as *Oxytropidoceras* but no examples of *Anahoplites* were found by the writer. At Greatness, 3 (ii) contains a few large *Inoceramus concentricus* but no ammonites.

At the base of 3 (iii), *Anahoplites intermedius* and *A. praecox* appear in the sequence and this is taken by the author to mark the base of the *intermedius* Subzone. They range up to the top of Division 3 as at Ford Place. The thin seam of ' solid ' phosphatised ammonite body chamber fragments containing the coarse form of *A. praecox* is also present at Greatness (3 iv), and above this *Euhoplites pricei* and its close relatives are characteristic as at Ford Place. Division 4 is thinner than at Ford Place, and only the basal 2 feet 2 inches (0·66 m.) can be classified with the *niobe* Subzone in contrast to the 4 feet 2 inches (1·27 m.) at Ford Place. At the level 2 feet 2 inches (0·66 m.) above the base of Division 4 at Greatness there is a thin bedding plane (bed 10 of Milbourne 1956 ; 236) which contains species of *Mojsisovicsia* including *M. subdelaruei* (Spath). This marks the base of the *subdelaruei* Subzone which is here 8 feet 7 inches (2·616 m.) thick, and is, therefore, thicker than at Ford Place. *M. remota* (Spath) has been obtained from 4 (iii) ; and 5 (i) has yielded species of *Dimorphoplites* which indicate the *subdelaruei* Subzone rather than the *meandrinus* Subzone although *Mojsisovicsia* has not yet been found in it. It is important to note that lithologically the base of Division 5 at Ford Place does not correspond to the base of the same lithological Division at Greatness. The *meandrinus* Subzone commences with 5 (ii) which has yielded *Euhoplites meandrinus* Spath, *E.* aff. *aspasia* Spath, *Dimorphoplites* spp. and large partly crushed *Anahoplites planus* (Mantell). No ammonites were recovered from 5 (iii) but the nodules of 5 (iv) have yielded fragmentary abraded *Dimorphoplites* and *Euhoplites*. At Greatness 5 (ii) to (iv) can be correlated with 5 (i) at Ford Place. Division 5 (v) to (vi) at Greatness also contains a *meandrinus* Subzone ammonite fauna, but 5 (vii) did not yield ammonites to me and probably represents 5 (v) at Ford Place which contains an ammonite fauna which shows some affinity with the *nitidus* Subzone above.

The *nitidus* Subzone without doubt commences at the base of 5 (viii) at Greatness and includes 5 (ix). Together they have yielded a typical *nitidus* Subzone fauna and measure 4 inches (0·102 m.) in thickness in comparison with the 1 foot 4 inches (0·406 m.) of 5 (vi) at Ford Place. Division 6, the '*lautus* Zone nodule bed', as the author demonstrated in 1958 contains a fauna including elements of the *nitidus* and *daviesi* Subzones as well as of *cristatum* Subzone age. Here, as at Ford Place, the age of the clay in which the phosphatic debris is embedded is of *cristatum* Subzone age.

It is worth revising here the stratigraphical positions of the samples studied by Khan (1952) from the Sevenoaks Brick Works.

Sample S1	5 ft 6 ins down from the top of Division 3 ; *intermedius* Subzone as Khan recorded.
Sample S2	6 ins down from the top of Division 3 ; *intermedius* Subzone as Khan recorded.

Sample S3	1 ft 6 ins below the top of Division 4 ; *subdelaruei* Subzone not *niobe* as recorded.
Sample S4	6 ft below the top of Division 5 ; *subdelaruei* Subzone not *niobe* as recorded.
Sample S5	4 ft below the top of Division 5 ; *subdelaruei* Subzone.
Sample S6	2 ft below the top of Division 5 ; *meandrinus* Subzone.
Sample S7	2 ins below the top of Division 5 ; *nitidus* Subzone not *subdelaruei* Subzone as recorded.
Sample S8	‘ *lautus*-Zone nodule bed ’ Division 6 ; *cristatum* Subzone.

(b) St. John's Brickyard

The brickpit owned by Durtnell and known in the literature as St. John's Brickyard, or the ‘Bat & Ball ’ pit, is now overgrown. It was situated about 900 yards NNW. of the Bat & Ball railway station, 100 yds W. of Otford Road, Otford (TQ 52805755), and 900 yds towards the WSW. of the Greatness pit. The section was first described by Hill (*in* Jukes-Browne 1900 ; 85) and additional information was given by H. J. W. Browne (1924) and by Spath (e.g. 1925 ; pl. XII, fig. 4). It showed a sequence (text-fig. 3) intermediate in thickness between that of the Greatness pit and the Dunton Green section described next.

(c) Dunton Green

The Dunton Green Brick, Tile and Pottery Works Ltd pit was situated about 1650 yds WSW. from the St. John's Brickyards. The section is now obliterated. It was first described in detail surprisingly late in its history by C. W. Wright (1947 ; 315–318) although it had been mentioned in the literature as early as 1880 (Lobley 1880). Spath recorded ammonites from it (1923–43) and Khan (1952) and I (1958) have referred to it briefly. Unfortunately, I saw only the sequence up to the basal part of Division 4, and the dotted portion in text-fig. 10 is taken from the account by Wright.

Text-fig. 3 shows the extent to which the sequence is attenuated in comparison with that at Greatness to the ENE. and the Brasted borehole to the WSW. (not ESE. as given in Casey 1954 ; 266) discussed below.

The exposed portion of Division 1 at Dunton Green was seen to be identical to the corresponding portion of Division 1 at Greatness. Division 2 contains the same fauna as at Greatness but the phosphatised material is devoid of the shell. Division 3 (i) contains ‘solid ’ pyritised *Hoplites* (*H.*) with the nacreous shell, including *H.* (*H.*) *dentatus densicostata* Spath and *H.* (*H.*) *escragnollensis* Spath. This bed corresponds to 3 (i) at Greatness. The basal 2 feet 3 inches (0·686 m.) of 3 (ii) at Dunton Green consists of a glauconitic clay, immediately above which *Anahoplites intermedius* appears in the sequence and ranges up through the remainder of the Division. Although the sequence is much more condensed, the thin bed of phosphatised body

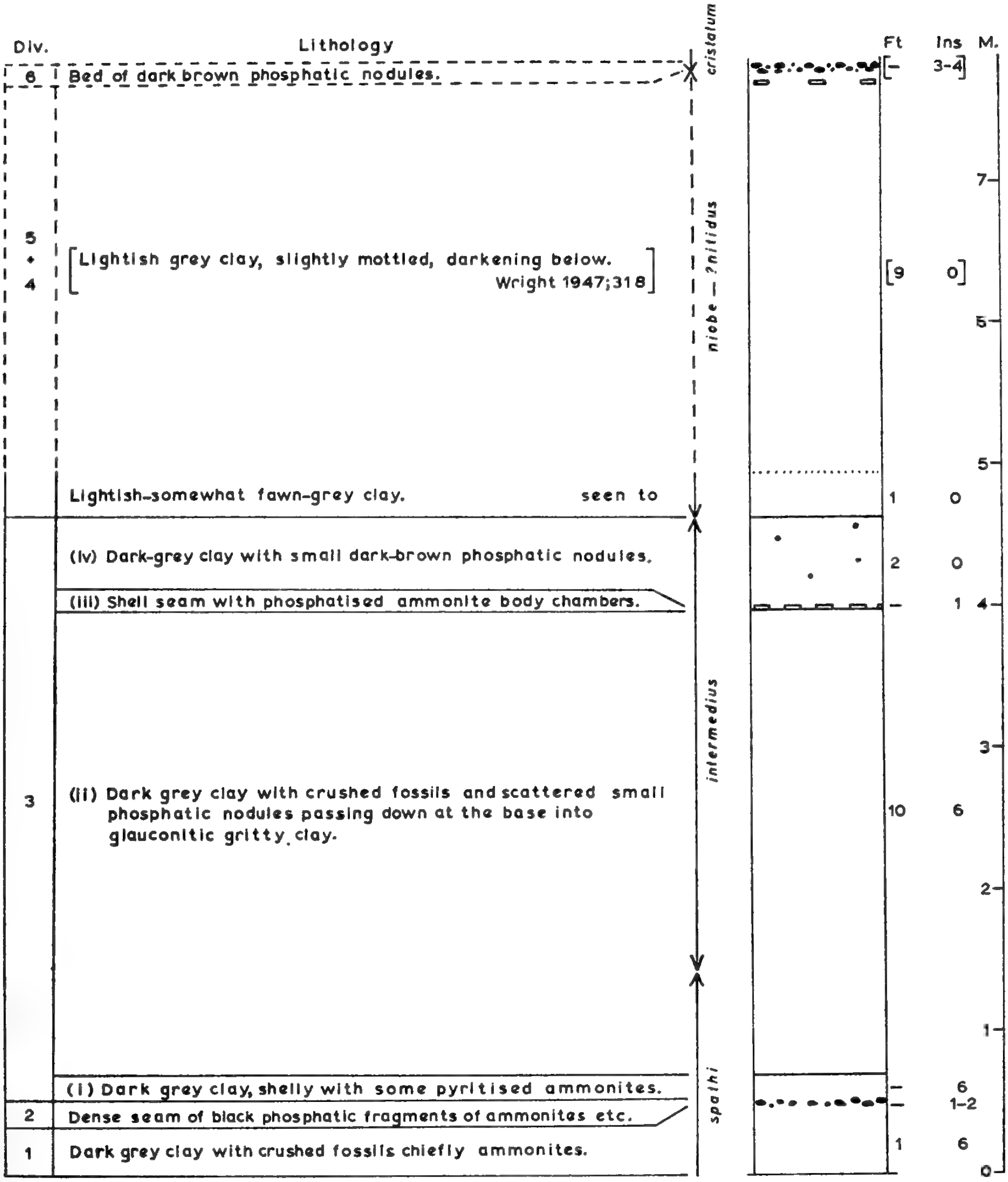


FIG. 10. Section in Lower Gault at the Dunton Green Brick, Tile & Pottery Works Ltd's pit, *c.* 550 yds S. of Dunton Green railway station on E. side of railway line, Longford, Dunton Green, Kent (TQ 515570). The dotted portion is completed from the account by Wright (1947).

chambers of ammonites 3 (iii) occurs, and may be correlated with 3 (iv) at Greatness. 3 (iii) at Dunton Green has yielded the coarse form of *A. praecox* figured by Spath (1925 ; 132, text-fig. 35e) according to its preservation. Only a foot of Division 4 was seen clear by the writer, and for the remainder of the sequence Wright's account is available.

(d) **Brasted**

The Metropolitan Water Board well at Brasted has been described by Casey (1954a ; 266 : 1961a ; 544–5) and is displayed in text-fig. 11. Its relationship to the sections at Dunton Green and Squerryes is shown in text-fig. 3. The sequence in the higher part of the well is similar to that of Dunton Green and Greatness. Unfortunately, the top of the Lower Gault bisects the ground surface further to the north of the site of the well, and the boring commenced at an unknown depth below the base of the Upper Gault.

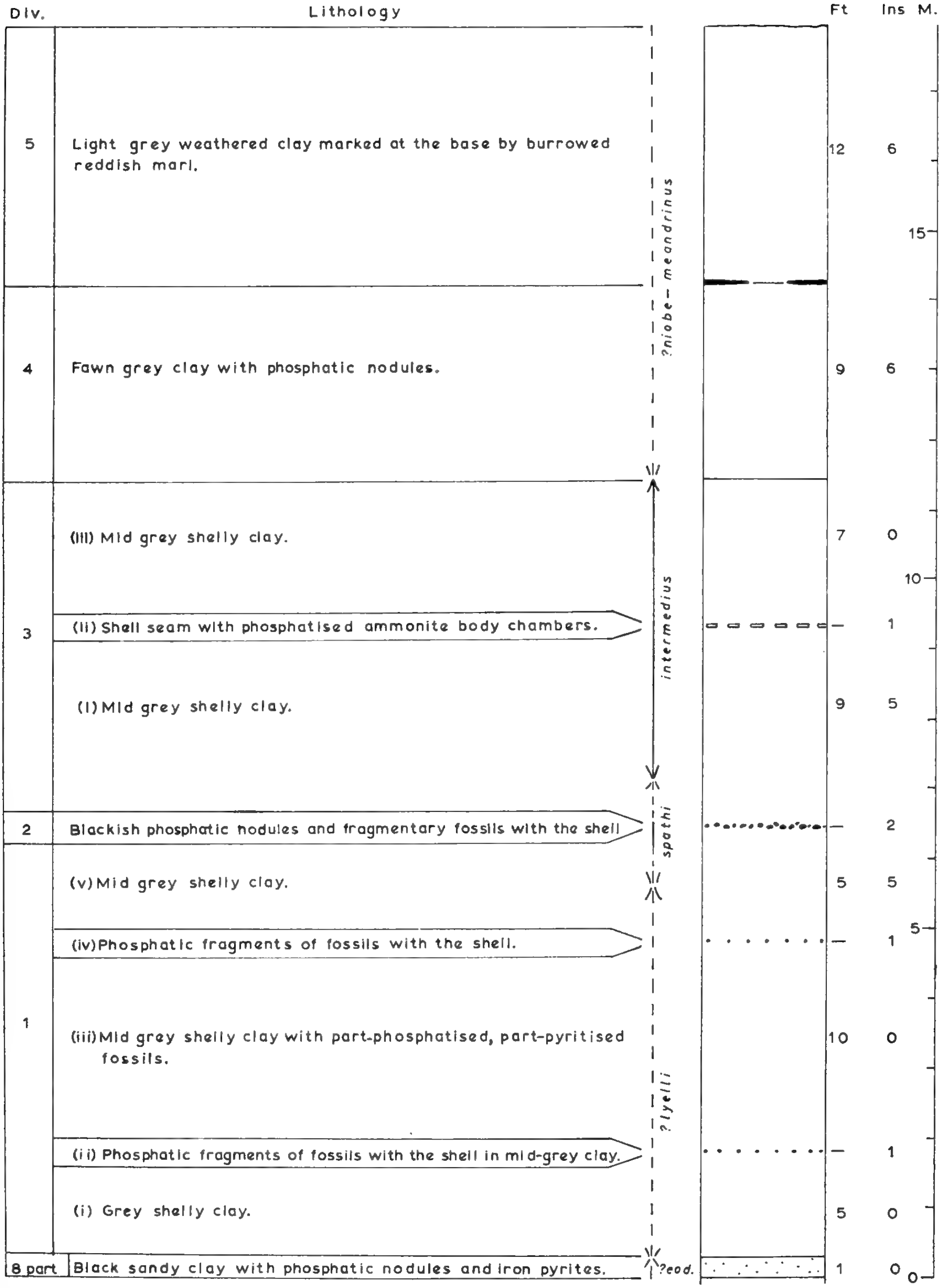
At a depth of 12 feet 6 inches (3·81 m.) the reddish burrowed marl suggests a correlation with the base of 5 (i) at Greatness. The only two ammonites preserved in the collection of the Institute of Geological Sciences (GSM) are Ca 339, *Euhoplites* sp. from a depth of about 8 feet (2·438 m.), of either *subdelaruei* or *meandrinus* Subzone age, in the preservation typical of the lower part of Division 5 at Greatness. The other, Ca 340 from a depth of 10 feet (3·048 m.), is of no diagnostic value. Together they neither confirm nor deny a *subdelaruei* Subzone age. The dividing line between Divisions 4 and 3 occurs between a depth of about 22 feet and 25 feet (6·706–7·62 m.) where the lithological change from fawn-grey clay to mid-grey clay occurs. The equivalent of 3 (iii) at Dunton Green occurs at a depth of 29 feet (8·839 m.) and yielded *Anahoplites praecox* (GSM Ca 364–6) and *Hoplites* (*H.*) sp. (GSM Ca 367). At a height of 1 foot 6 inches (0·457 m.) above Division 2 a phosphatised fragment of a coarsely ribbed *Anahoplites* with the nacreous shell preserved was recovered.

Division 2, the ' upper *dentatus-spathi* nodule bed ' was struck at a depth of 38 feet 6 inches (9·296 m.). Below this level the sequence departs markedly from that of Dunton Green and Greatness. The 20 feet 6 inches (6·248 m.) of mid-grey clay below Division 2 contains *Hoplites* (*H.*) spp. throughout. No definite indication of the *lyelli* Subzone is seen, but a boring encompasses only a very small lateral area and the possibility that part of this succession is of *lyelli* Subzone age should not be discounted. There was also no evidence of the *eodentatus* Subzone although this may be present below 59 feet (17·983 m.) depth.

(v) **BRASTED TO BUCKLAND**

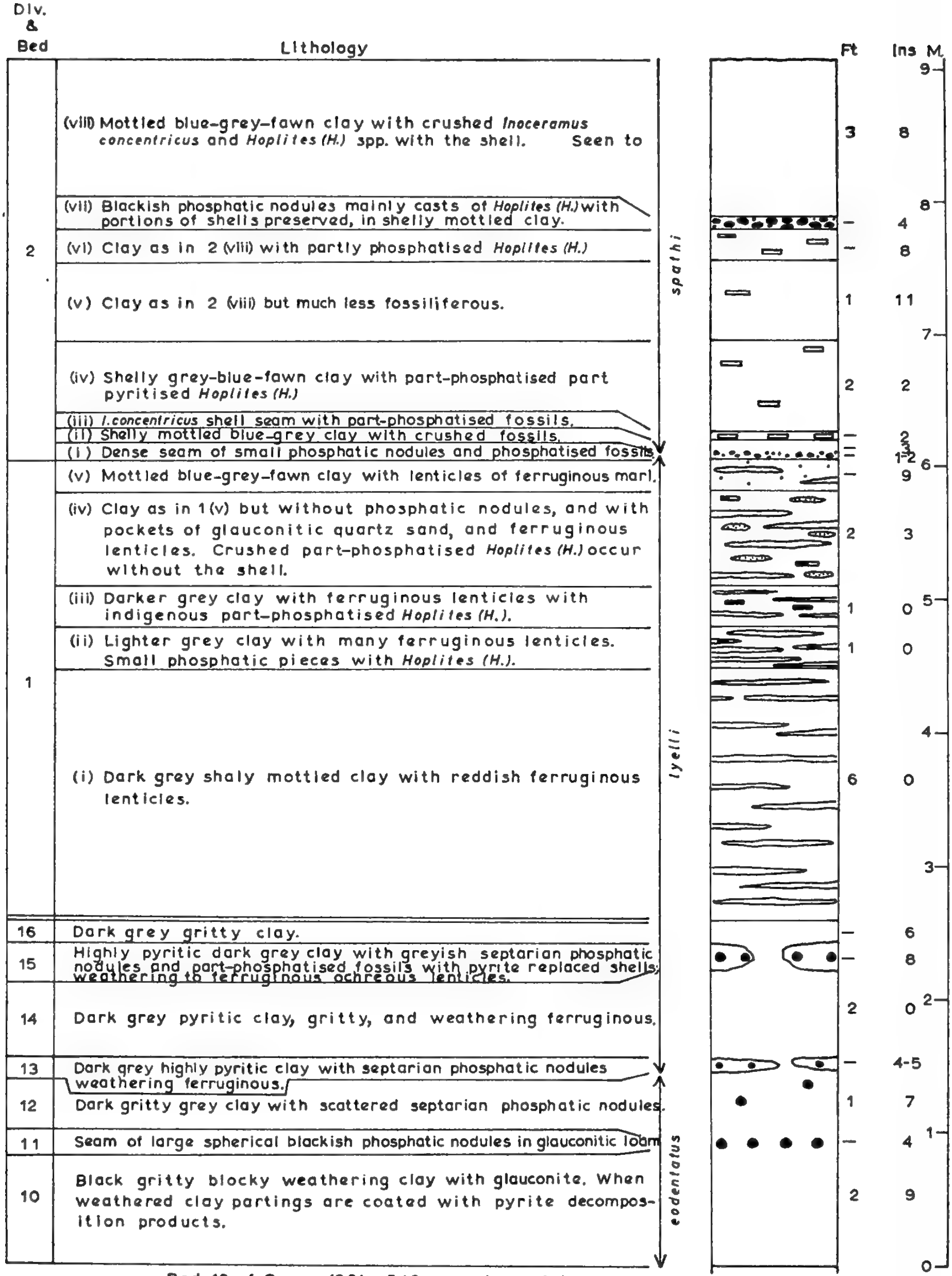
(a) **Westerham**

The northern face of the Squerryes Estate Sand pit situated 2¼ miles SW. of the Brasted Well was cut back in 1964 and provided the section given in text-fig. 12. The sequence of well-marked lithological divisions seen in the lower part of the Lower Gault in the Sevenoaks area, already indistinct at Brasted, becomes even less distinct at Squerryes. Here, two clear-cut divisions are immediately apparent and



Remainder of Bed 8 of Casey 1961a; 545.

FIG. 11. Vertical section of Middle Albian sediments in the Metropolitan Water Board well, 1000 feet NE. of St. Martins Church, to the E. of Station Road Brasted, Kent (TQ 47095574).



Div. & Bed	Lithology	Ft	Ins
2	(viii) Mottled blue-grey-fawn clay with crushed *Inoceramus concentricus* and *Hoplites (H.)* spp. with the shell. Seen to	3	8
	(vii) Blackish phosphatic nodules mainly casts of *Hoplites (H.)* with portions of shells preserved, in shelly mottled clay.	–	4
	(vi) Clay as in 2 (viii) with partly phosphatised *Hoplites (H.)*	–	8
	(v) Clay as in 2 (viii) but much less fossiliferous.	1	11
	(iv) Shelly grey-blue-fawn clay with part-phosphatised part pyritised *Hoplites (H.)*	2	2
	(iii) *I. concentricus* shell seam with part-phosphatised fossils.	–	2
	(ii) Shelly mottled blue-grey clay with crushed fossils.	–	3
	(i) Dense seam of small phosphatic nodules and phosphatised fossils	–	1-2
1	(v) Mottled blue-grey-fawn clay with lenticles of ferruginous marl.	–	9
	(iv) Clay as in 1 (v) but without phosphatic nodules, and with pockets of glauconitic quartz sand, and ferruginous lenticles. Crushed part-phosphatised *Hoplites (H.)* occur without the shell.	2	3
	(iii) Darker grey clay with ferruginous lenticles with indigenous part-phosphatised *Hoplites (H.)*.	1	0
	(ii) Lighter grey clay with many ferruginous lenticles. Small phosphatic pieces with *Hoplites (H.)*.	1	0
	(i) Dark grey shaly mottled clay with reddish ferruginous lenticles.	6	0
16	Dark grey gritty clay.	–	6
15	Highly pyritic dark grey clay with greyish septarian phosphatic nodules and part-phosphatised fossils with pyrite replaced shells; weathering to ferruginous ochreous lenticles.	–	8
14	Dark grey pyritic clay, gritty, and weathering ferruginous.	2	0
13	Dark grey highly pyritic clay with septarian phosphatic nodules weathering ferruginous.	–	4-5
12	Dark gritty grey clay with scattered septarian phosphatic nodules.	1	7
11	Seam of large spherical blackish phosphatic nodules in glauconitic loam	–	4
10	Black gritty blocky weathering clay with glauconite. When weathered clay partings are coated with pyrite decomposition products.	2	9

Bed 12 of Casey 1961a; 543 *puzosianus* Subzone

FIG. 12. Middle Albian sediments at the Squerryes Estates Sand Pits' pit, *c.* 150 yds N. of Covers Farm, Westerham, Kent (TQ 43305395).

their correlation is shown in text-fig. 3. The sequence is, however, thinner than at Brasted.

The 9 feet 2 inches (2·794 m.) of Division 2, excluding bed (i), contains a typical *spathi* Subzone fauna, the ' upper *dentatus-spathi* nodule bed ' being represented in 2 (vii). Bed (i) is the highest level in which *Protanisoceras* (*P.*) *moreanum* (Buvignier) occurs, and this is taken to mark the top of the *lyelli* Subzone sediments. The underlying 11 feet (3·353 m.) of Division 1 represents the uppermost part of the *lyelli* Subzone as developed at Horton Hall, Sussex (p. 35). However, the typical development of this Subzone occurs within beds 13–15 of the Gault-Lower Greensand Junction. Bed 15 has yielded the following ammonites:

Protanisoceras (*P.*) *moreanum* (Buvignier), *Beudanticeras laevigatum* (J. de C. Sowerby), *B. sanctaecrucis* (Bonarelli), *B. albense* Breistroffer, *Hoplites* (*H.*) *dentatus* (J. Sowerby), *H.* (*H.*) *bullatus* Spath, *H.* (*H.*) *baylei* Spath, *Lyelliceras lyelli* (d'Orbigny), *Brancoceras versicostatum* (Michelin *non* d'Orbigny, *nec* Douvillé), ' *Oxytropidoceras* ' cf. *evansi* (Spath).

Bed 13 has yielded *Beudanticeras laevigatum*, *Hoplites* (*H.*) spp., ? *Otohoplites* sp. ind., *Lyelliceras* sp. Beds 10–12 contain *Hoplites* (*Isohoplites*) spp., including *H.* (*I.*) *eodentatus* (Casey 1961a ; 543).

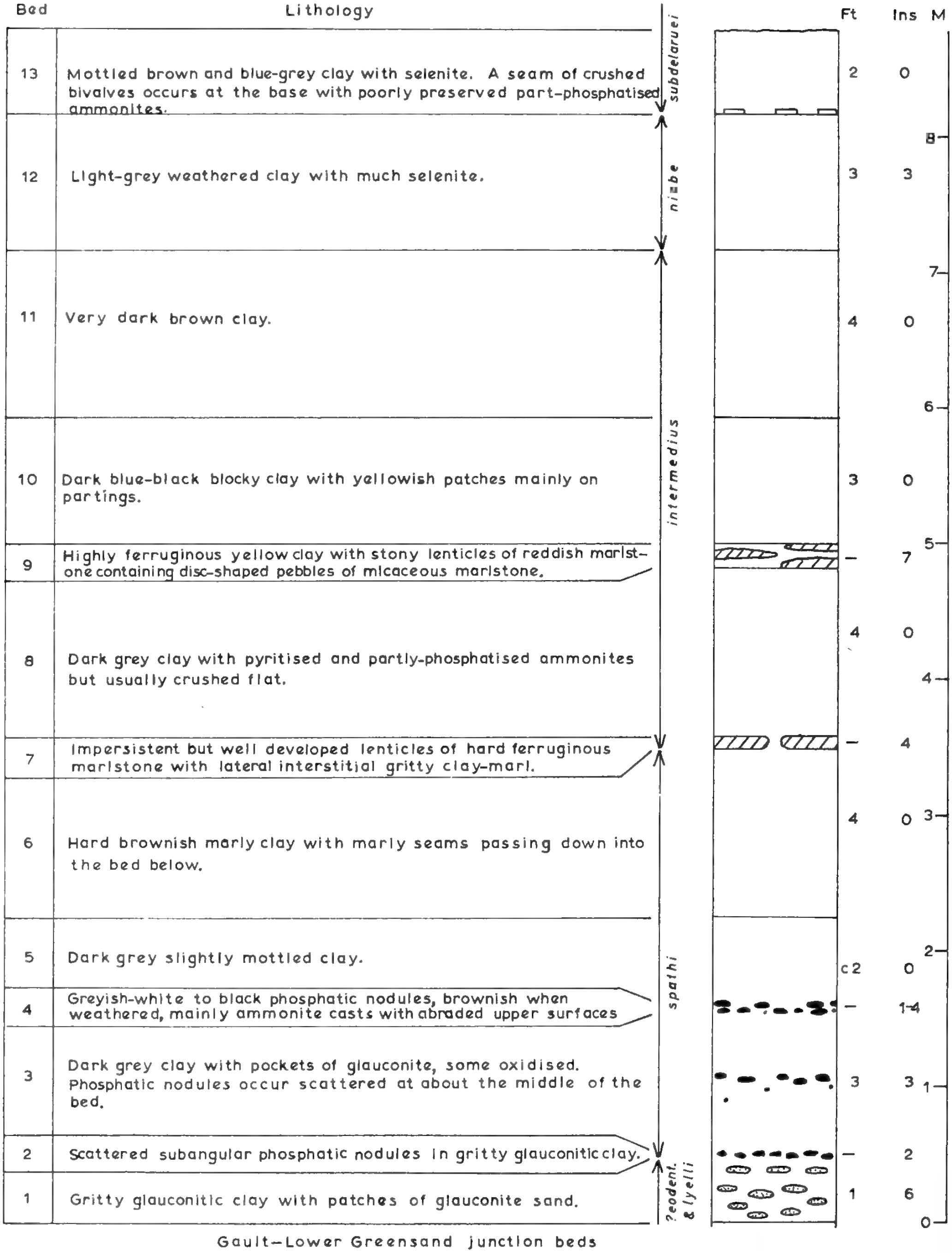
(b) **Tandridge**

The Coney Hill Sand-pit, Barrow Green (TQ 37755250), situated about 3½ miles WSW. from Squerryes, has already been described by the author (1963a ; 39). It is apparent that the sequence has become thinner (text-fig. 3). Between Tandridge and Buckland, a distance of 9 miles, there is no information concerning the sequence at the outcrop.

(c) **Buckland**

The Buckland Sand & Silica Co's pit at Buckland (TQ 231512) was described by the author in 1958 (1958 ; 149–152), however, a certain amount of revision is now necessary. The sequence (text-fig. 13) is not unlike that of Ford Place, a fact already recognised in the Gault-Lower Greensand Junction Beds by Casey (1961a ; 552). Whether the *eodentatus* and *lyelli* Subzones are present in the upper part of the Gault-Lower Greensand Junction as at Ford Place is at present unknown (p. 20). The *spathi* Subzone is represented within beds 2–6. Bed 2, tentatively classified with the *benettianus* Subzone in 1958, was later included in the *spathi* Subzone (Owen 1963a ; 47–48). It contains the same ammonites as Division 1 (ii) at Ford Place. Bed 3 is the obvious correlative of 1 (iii), and Bed 4 is the equivalent of Division 2, the ' upper *dentatus-spathi* nodule bed '. Bed 4 has yielded the best preserved fauna yet known from this horizon, and the effect of strong erosive currents on the sea-bottom is demonstrated by the effaced nature of the upper surface of the nodules.

Beds 5–11 probably represent Division 3 at Ford Place but the character of the clay is very different. In general the sediments are gritty clays with intercalated beds of ferruginous marlstone, and the fossils have shells replaced by pyrite. Beds 5 and 6



Bed	Lithology		Ft	Ins
13	Mottled brown and blue-grey clay with selenite. A seam of crushed bivalves occurs at the base with poorly preserved part-phosphatised ammonites.	*subdelaruei*	2	0
12	Light-grey weathered clay with much selenite.	*niobe*	3	3
11	Very dark brown clay.	*intermedius*	4	0
10	Dark blue-black blocky clay with yellowish patches mainly on partings.		3	0
9	Highly ferruginous yellow clay with stony lenticles of reddish marlstone containing disc-shaped pebbles of micaceous marlstone.		–	7
8	Dark grey clay with pyritised and partly-phosphatised ammonites but usually crushed flat.		4	0
7	Impersistent but well developed lenticles of hard ferruginous marlstone with lateral interstitial gritty clay-marl.	*spathi*	–	4
6	Hard brownish marly clay with marly seams passing down into the bed below.		4	0
5	Dark grey slightly mottled clay.		c2	0
4	Greyish-white to black phosphatic nodules, brownish when weathered, mainly ammonite casts with abraded upper surfaces		–	1-4
3	Dark grey clay with pockets of glauconite, some oxidised. Phosphatic nodules occur scattered at about the middle of the bed.		3	3
2	Scattered subangular phosphatic nodules in gritty glauconitic clay.		–	2
1	Gritty glauconitic clay with patches of glauconite sand.	*?eodent. & lyelli*	1	6

FIG. 13. Section of Lower Gault in the Buckland Sand & Silica Co's sandpit extending from a point 2100 yds WNW. of Reigate railway station to a position *c.* 250 yds SW. of Dowdes Farm, and 50 yds S. and roughly parallel to the Dorking-Redhill railway line, Buckland, Surrey (TQ 232512).

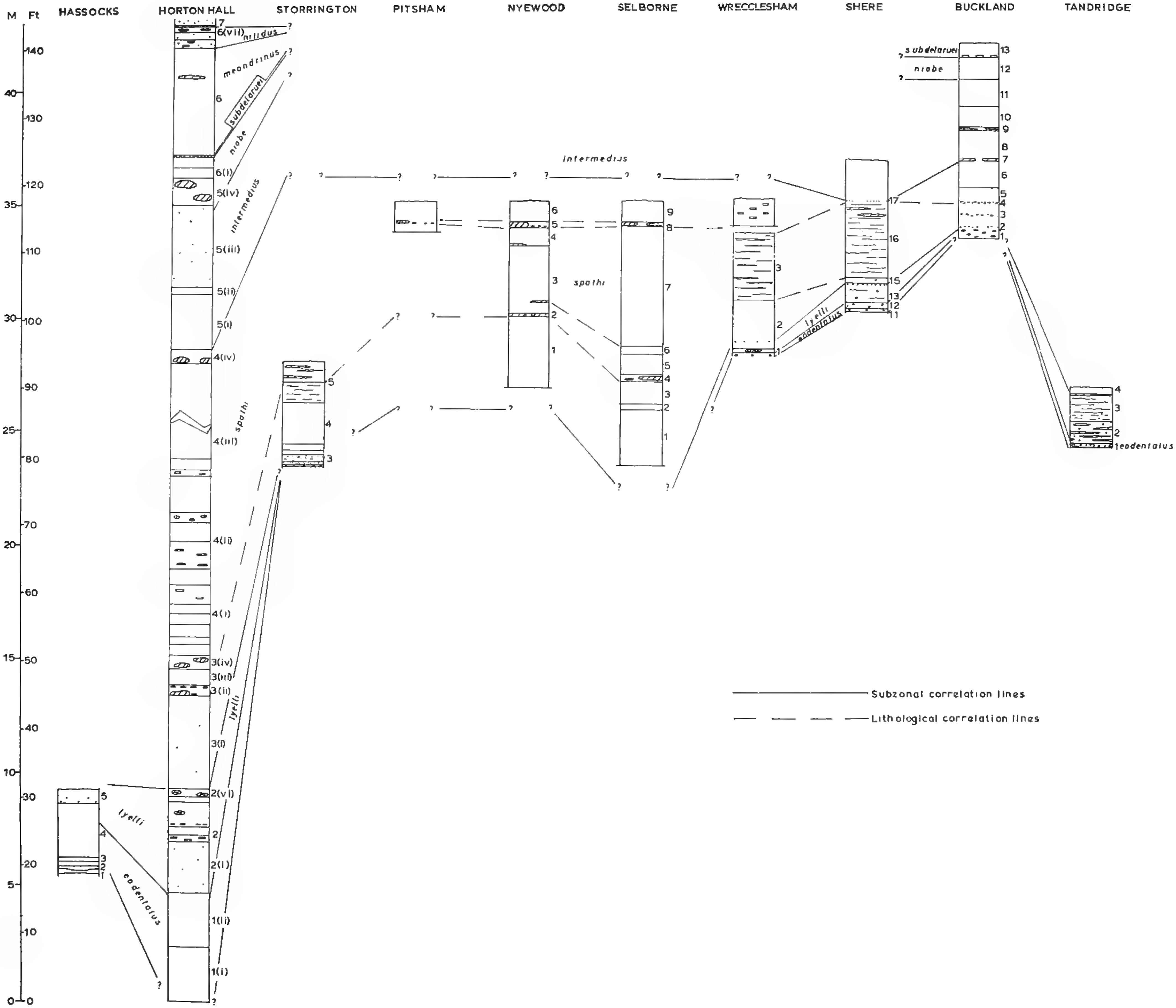


FIG. 14. Correlation of sections in Surrey, Hampshire, and Sussex, at the outcrop.

are classified with the *spathi* Subzone, Beds 7–11 with the *intermedius* Subzone. The siltier nature of the sediments of the *intermedius* Subzone heralds the sequence seen further west at such localities as Winchester (p. 69), Didcot (p. 63), and Devizes (p. 60). The *niobe* Subzone is probably present in the top of these sediments and possibly in the light grey clay of Bed 12 which can be correlated with the base of Division 4 at Ford Place. A re-examination of the ammonites from Bed 13 indicates that it should be classified with the *subdelaruei* Subzone as the writer considered possible in 1958.

The presence of higher Middle Albian subzones in the sequence is at present uncertain. Gossling (1929 ; 251) reported, from Spath's determinations of the ammonites found in the Merstham trench, that here the Upper Gault rests directly upon the *dentatus* Zone. However, Gossling did not give a detailed account of the succession and, moreover, the trench was only 4 feet (1·219 m.) deep. In the Buckland Sand & Silica Co. pit large distorted blocks of pale-grey clay were seen in the superficial deposits. These blocks contain *orbignyi* Subzone fossils and the bed from which they were torn cannot be far to the northward. However, in the foundations of Wray Common County Primary School at the N. end of Kendal Close, Reigate (TQ 26975092), the '*lautus* Zone nodule bed' was located. The fauna obtained indicated that its character was closely comparable to that of Division 6 in the Sevenoaks area.

(vi) **BUCKLAND TO UPPER BEEDING** (text-fig. 14)

There is very little information available at the outcrop between Buckland and Shere, a distance of 10½ miles, except that given by Dines & Edmunds (1933). The sections exposed during the cutting of the Shere By-Pass road have been described by the writer (Owen 1963a). There is very little doubt that the outcrop here is affected by a strike fault with a substantial northerly throw as Kirkaldy concluded (1958 ; 18). The structure illustrated by the author (1963a ; 41, text-fig. 1), the greatly attenuated width of the outcrop, the far greater thickness of the Gault in the West Clandon Waterworks boring, and the sequence at Albury (Edmunds *in* Dines & Edmunds 1929 ; 41–2) all support the presence of such a fault. The true degree of representation in the Lower Gault in this area is, therefore, uncertain, and will not be determinable until a cored borehole is drilled to the north of the disturbed ground.

The notable feature in the lower part of the Lower Gault between Shere and Shalford is the development of the *eodentatus* and *lyelli* Subzones (Owen 1963a, Wright & Wright 1948). Whether this development continues west to Whiteacre Copse on the Guildford-Godalming By-Pass road is unknown (Lea 1932 ; 320–1 ; Owen 1963a ; 50). There is a similar dearth of information further west. However in the Institute of Geological Sciences there is a small suite of specimens from the Gault exposed in a gravel pit off the Farnham to Runfold road at about 1 mile ENE. of Farnham and immediately W. of the railway bridge (SU 85854755) GSM. He 2337–45, which indicates the presence of *lautus* Zone sediments in this area.

The sections at Wrecclesham, Selborne, and Nyewood, have all been described by the writer (Owen 1963a). Text-fig. 14 shows that the sequence in the *spathi* Subzone expands south of Wrecclesham to reach its greatest known thickness in this area at Selborne. It then thins southwards towards Nyewood, and between this locality and Storrington the Gault rests directly upon the oxidised indurated ' iron grit ' at the eroded top of the Folkestone Beds. How much more of the Middle Albian is represented in the higher beds of the Gault is uncertain. I expressed the qualified opinion (1963a ; 51) that at Selborne it appeared that the *cristatum-orbignyi* Subzone transgressions had cut down to the *spathi* Subzone, a view disputed by Milbourne (*in* Hancock 1965 ; 250).

Osborne White (1910 ; 17) followed Jukes-Browne's interpretation of the ' interruptus ' Zone (see p. 111). He records at Bradshott Hall (1910 ; 20) 2 feet (0·609 m.) of clay with phosphatised ' Hoplites interruptus ' separated by 3 feet (0·914 m.) of deposits from sediments containing *Inoceramus sulcatus* indicative of the lower part of the Upper Albian. Unfortunately, this material has not been traced. The lowest part of the *intermedius* Subzone with *Anahoplites osmingtonensis* nov. is present at the outcrop in the Petersfield area (e.g. BMNH, C 35482–3). Further information has been provided by borings carried out for the Gas Council by the British Petroleum Co. in the Winchester area in the deeper part of the Wessex basin (p. 69). There, sediments of the *intermedius* Subzone are present above the *spathi* Subzone, and the *orbignyi* Subzone is also represented within the silty clay facies.

Between Petersfield and Storrington only three sections are available, all in the *spathi* Subzone ; Nyewood, Pitsham, and Sullington (Owen 1963a). Recently, Mr. C. J. Wood of the Institute of Geological Sciences recognised in the Brydone Collection the material recorded by Jukes-Browne (1900 ; 112) from a well to the N. of Graffham village. The specimen recorded as *Hamites punctatus* ? is here referred to *Protanisoceras* (*P.*) *barrense* (Buvignier) and is preserved in lilac-grey silty clay, the shell originally having been replaced by pyrite. It is accompanied by *Inoceramus concentricus* in the same preservation. The ammonite indicates the *lyelli* Subzone. The specimen of *Hamites attenuatus* is indeed of that species, but is preserved in weathered yellowish pale-grey tough silt. It is of either *loricatus* or possibly *lautus* Zone age.

Osborne White (1924 ; 26) described a well section examined by Templeman situated on the W. side of the lane to Barns Farm, 300 yds S. of its junction with the Washington-Storrington A283 road (TQ 10501345). Below 10 feet (3·048 m.) of clay containing an Upper Gault fauna, about 40 feet (12·192 m.) of Lower Gault was proved including the *cristatum* and the upper part of *intermedius* Subzones. In a well bored at Wiston Hall between Washington and Steyning 176 feet (53·644 m.) of Gault was proved (Osborne White 1924 ; 25). It seems likely, therefore, that in this area the succession in the post *spathi* Subzone sediments is closely comparable to that described below exposed in the Horton Clay pit.

(vii) **UPPER BEEDING**

The Lower Gault section exposed in the British Portland Cement Manufacturers Ltd's Horton Clay pit is shown in text-fig. 15, and its relationship to sections west and east is shown in text-fig. 14. The pre-war workings were described by Osborne White

(1924 ; 27–8), and the current sections have been described in part by Milbourne (1961 ; 135–7), Casey (1961a ; 558), and Owen (1963a ; 46). It shows the thickest sequence yet known in the Lower Gault of England, and is undoubtedly the most important. The clays contain finely disseminated pyrite, and their silty nature allows the deep penetration of weathering agents ; this obscures the bedding for at least 12–14 feet (3·658–4·267 m.) from the surface, but fortunately there is a dip of 8° S. present. In the fresh condition, the clays are seen to be fairly uniform throughout, and the Divisions adopted here are based upon cycles of sedimentation. Each cycle commences with relatively rapid sedimentation and terminates with partly arrested deposition indicated by marly seams and cementstone nodules. Individual units display an alternation of dark-grey and more fawn-grey bands. That this is an original feature is occasionally shown by the fauna ; there being often a more diverse benthos in the fawn-grey bands.

Casey has described the boreholes drilled over the area of the northern field situated to the E. of Horton Wood (1961a ; 558). The subsequent excavation of this field commenced in 1964 at the northern boundary, and the sequence is now being cut down dip. There is unfortunately a small gap in the observed sequence as shown in text-fig. 14, between this new field and the older workings.

Eodentatus & basal lyelli Subzones

About 13 feet (3·962 m.) of glauconitic sandy clay and loam (1 (i) & (ii)) classified with these Subzones occurs below the lowest level seen in the excavations (Casey 1961a ; 558).

lyelli Subzone

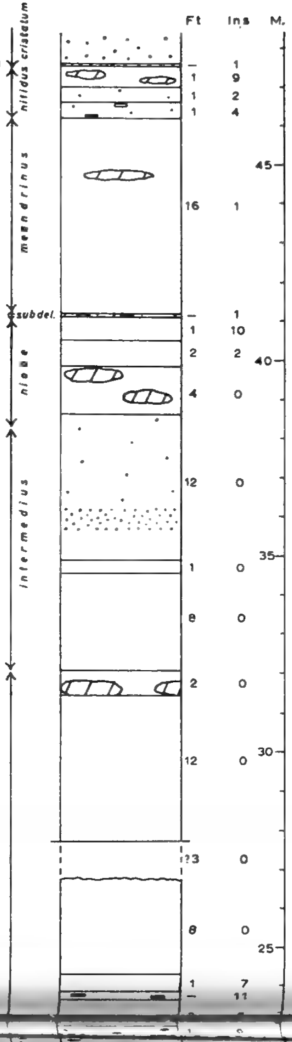
Divisions 1 (ii) to the top of 2 (vi) are classified with this Subzone. As this is the first time that such a faunal sequence has been described in England, it is discussed in detail. The top 3 feet 8 inches (1·117 m.) of 1 (ii) is seen in the excavations, but only the upper foot is fossiliferous and this has yielded *Hoplites* (*H.*) spp. and the ubiquitous *Inoceramus concentricus*, among other fossils. The shell seam that marks the base of 2 (i) has yielded the following :—

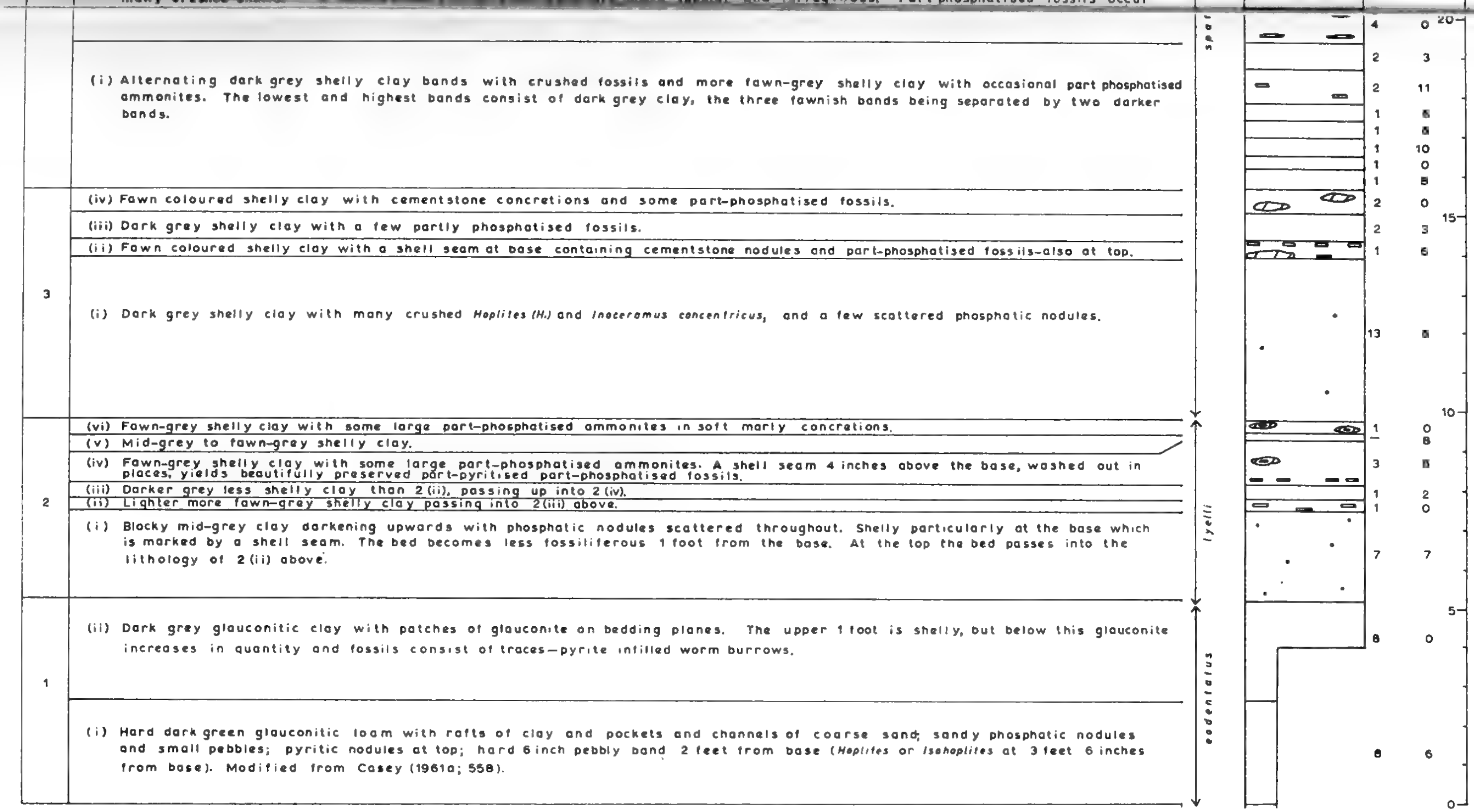
Protanisoceras (*Protanisoceras*) *nodoneum* (Buvignier). *P.* (*P.*) *barrense* (Buvignier), *P.* (*P.*) *alternotuberculatum* (Leymerie), *Beudanticeras laevigatum* (J. de C. Sowerby), *B. albense* Breistroffer, *Hoplites* (*H.*) spp., *Lyelliceras* aff. *lyelli* (d'Orbigny), *Brancoceras* (*Brancoceras*) sp., *Neohibolites minimus* (Miller), *I. concentricus* Parkinson, *Acila* (*Truncacila*) *bivirgata* (J. de C. Sowerby), *Natica* sp.

A comparable fauna occurs throughout the remainder of 2 (i). In 2 (ii) the benthonic element of the fauna increases in importance and one of the characteristic fossils is a solitary caryophyllid coral. The ammonites consist essentially of species of *Hoplites* (*H.*) and *Protanisoceras* (*P. barrense* & *P. nodoneum*) ; *Lyelliceras* is not common. The benthonic element is much reduced and the nekton to a lesser extent in 2 (iii). The ammonites include the following :

H. (*H.*) *dentatus* (J. Sowerby), *H.* (*H.*) spp. common ; *P.* (*P.*) *barrense, Lyelliceras lyelli* (d'Orbigny) the lowest definite occurrence of the typical form, *Beudanticeras* sp., accompanied by *I. concentricus*.

Div.	Lithology	Ft	Ins
7	(i) Thin seam of brown phosphatic nodules in very dark grey clay.	—	1
6	(vii) Fawn grey marly clay with cementstone nodules showing cone in cone.	1	9
	(vi) Dark grey clay with scattered phosphatic nodules.	1	2
	(v) Fawnish grey shelly clay with scattered phosphatic nodules and part-phosphatised part-pyritised fossils	1	4
	(iv) Dark grey clay with lighter bands some of which contain very scattered cementstone nodules. Shell seams occur throughout.	16	1
	(iii) Sporadic phosphatic nodules and part-phosphatised fossils in fawn clay.	—	1
	(ii) Fawn-grey shelly marly clay with a few cementstones.	1	10
	(i) Mid-grey clay with scattered shells passing at top into 6(ii).	2	2
5	(iv) Fawn grey shelly marly clay with large cementstone nodules showing cone in cone.	4	0
	(iii) Dark grey slightly micaceous shelly clay with scattered phosphatic nodules, and a more concentrated band 1 foot 9 inches thick commencing 2 feet 6 inches from the base. Crushed fossils occur throughout and the bed passes by lenses into 5(iv)	12	0
	(ii) Fawn marly seam weathering ferruginous.	1	0
	(i) Dark grey slightly micaceous shelly clay with numerous shell seams.	8	0
4	(iv) Tough blocky fawn grey marl with cementstone lenticles in the lower half.	2	0
	(iii) Dark grey slightly micaceous shelly clay with scattered shell seams. Slightly lighter bands alternate and contain part phosphatised fossils. This subdivision is not yet fully seen and in the northerly working has been seen only in a weathered state. One lighter band is indicated here at a height of 5 feet 2 inches from the base.	12 ?3 8	0 0 0
		1	7
		—	11





3

(i) Alternating dark grey shelly clay bands with crushed fossils and more fawn-grey shelly clay with occasional part phosphatised ammonites. The lowest and highest bands consist of dark grey clay, the three fawnish bands being separated by two darker bands.

(iv) Fawn coloured shelly clay with cementstone concretions and some part-phosphatised fossils.

(iii) Dark grey shelly clay with a few partly phosphatised fossils.

(ii) Fawn coloured shelly clay with a shell seam at base containing cementstone nodules and part-phosphatised fossils–also at top.

(i) Dark grey shelly clay with many crushed *Hoplites (H.)* and *Inoceramus concentricus*, and a few scattered phosphatic nodules.

2

(vi) Fawn-grey shelly clay with some large part-phosphatised ammonites in soft marly concretions.

(v) Mid-grey to fawn-grey shelly clay.

(iv) Fawn-grey shelly clay with some large part-phosphatised ammonites. A shell seam 4 inches above the base, washed out in places, yields beautifully preserved part-pyritised part-phosphatised fossils.

(iii) Darker grey less shelly clay than 2 (ii), passing up into 2 (iv).

(ii) Lighter more fawn-grey shelly clay passing into 2 (iii) above.

(i) Blocky mid-grey clay darkening upwards with phosphatic nodules scattered throughout. Shelly particularly at the base which is marked by a shell seam. The bed becomes less fossiliferous 1 foot from the base. At the top the bed passes into the lithology of 2 (ii) above.

1

(ii) Dark grey glauconitic clay with patches of glauconite on bedding planes. The upper 1 foot is shelly, but below this glauconite increases in quantity and fossils consist of traces—pyrite infilled worm burrows.

(i) Hard dark green glauconitic loam with rafts of clay and pockets and channels of coarse sand; sandy phosphatic nodules and small pebbles; pyritic nodules at top; hard 6 inch pebbly band 2 feet from base (*Hoplites* or *Isohoplites* at 3 feet 6 inches from base). Modified from Casey (1961a; 558).

FIG. 15. Section of Lower Gault at British Portland Cement Manufacturers' Horton Clay pit situated in the area 850 yds W. 35° S. from the Fox & Hounds public house, Small Dole, and 750 yds N. 15° W. of Horton Hall, Upper Beeding, Sussex (TQ 20751230).

A much more diverse fauna appears in 2 (iv). A thin bedding plane 4 inches (0·101 m.) above the base, sometimes washed out, has yielded one of the best preserved ammonite faunas yet known from the *lyelli* Subzone. The fossils are part-phosphatised and part pyritised. Some ammonites are in a ' death rest ' position ; that is, they are vertically orientated resting on the venter. The amount of distortion permits the compaction ratio of the clay to be deduced. The fauna includes :

P. (*P.*) *nodoneum*, *P.* (*P.*) *barrense*, *Pseudhelicoceras argonnensis* (Buvignier), *P.* sp., *Beudanticeras laevigatum*, *B. albense* Breistroffer, *B. sanctaecrucis* Bonarelli, *Hoplites* (*H.*) *baylei* Spath, *Hoplites* (*H.*) spp. *Douvilleiceras* sp. juv., *Oxytropidoceras evansi* (Spath), *O.* sp., *Lyelliceras lyelli* (d'Orbigny), *L. gevreyi* (Jacob), *L.* sp., *Brancoceras senequieri* (d'Orbigny), *B. versicostatum* (Michelin non d'Orbigny nec Douville) *B.* spp., *Inoceramus concentricus*, *Semisolarium moniliferum* (Michelin). ' *Auricula* ' *acuminata* Deshayes. *Hemiaster* sp.

This list shows a preponderance of lyelliceratid ammonites over the hoplitids which are greatly subordinate in actual numbers. The fossils are mainly crushed flat in the remainder of 2 (iv) and (v) but there is no significant difference in the fauna. Large uncrushed or partly crushed fossils occur in 2 (vi) and include :

P. (*P.*) *barrense*, *Beudanticeras sanctaecrucis*, *H.* (*H.*) *benettianus* (J. Sowerby), *H.* (*H.*) spp., *Lyelliceras lyelli*, *Brancoceras* spp. *Eutrephoceras* sp.

At this level *Hoplites* occurs in roughly equal numbers to the non-hoplitid genera combined. Some of the ammonites are also in a vertical 'death rest ' position and these, like those in 2 (iv), have a common orientation indicating a current direction coming from what is now 210° Magnetic.

spathi Subzone

Divisions 3 and 4 are classified with this Subzone. There is a sharp change in the ammonite fauna at the base of Division 3, the ammonites consisting essentially of *Hoplites* (*H.*) spp. At the commencement of the *spathi* Subzone, deposition of sediments increased rapidly and the bulk of the remainder of the Lower Gault, although very fossiliferous, yields little but crushed material except at a few horizons. Sedimentation during the *spathi* Subzone was particularly thick. At least 56 feet 9 inches (19·812 m.) of clays have been observed and the gap in the sequence between the northern field and the main workings is probably only a few feet.

Division 3 (i) contains numerous *I. concentricus* and crushed *Hoplites* (*H.*) the bulk of which possess *dentatus*-like ribbing : a few pyritic nuclei occur. *Protanisoceras* (*P.*) spp. have been obtained from Division 4 (i) but otherwise the heteromorph ammonites are almost exclusively species of *Hamites*. A beautifully-preserved fauna occurs in 3 (ii)–(iv) consisting mainly of ammonites and almost entirely of species of *Hoplites* (*H.*) identical to that of the well preserved element in the *dentatus* nodule bed at Folkestone (p. 13). Some specimens reach a diameter of 9 inches (0·228 m.). A loose block certainly from either 3 (ii) or (iv) contains an example of *Mojsisovicsia delaruei* (d'Orbigny). Division 4 (i) has a fauna closely comparable to that of 3 below. However 4 (ii) contains species of *Hoplites* (*H*). transitional from those seen below to those characteristic of the upper part of the *spathi* Subzone. They are of the grade well represented condensed in Division A of the Maidstone

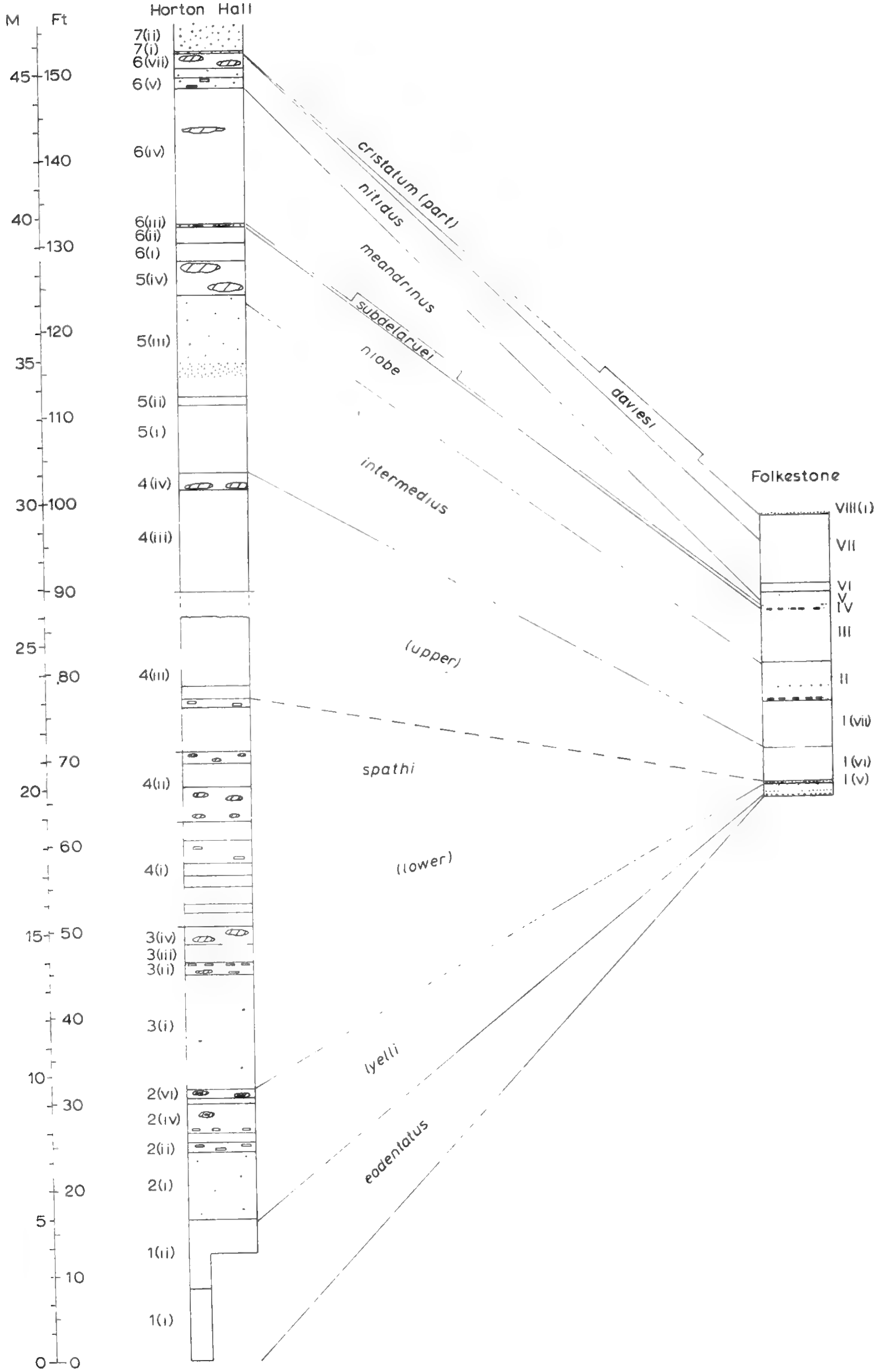


FIG. 16. Correlation of Lower Gault sections at Horton Hall and Folkestone.

By-Pass. Division 4 (iii) contains species of *Hoplites* (*H.*) that are found in the upper part of the *spathi* Subzone, and condensed in the ' upper *dentatus-spathi* nodule bed ' in the northern Weald.

In the most northern cut of the old W. field, situated S. of Horton Wood, the top of the *spathi* Subzone was seen in 4 (iii). This consists of 1 foot 6 inches of shelly clay containing numerous crushed *Hoplites* (*H.*) some with well developed lautiform ribbing. The remainder of 4 (iii) in this cut contains numerous *Inoceramus concentricus* but no ammonites were found by the author either in these clays or in 4 (iv). *Anahoplites intermedius* appears in 5 (i) and this level is taken to mark the base of the *intermedius* Subzone.

Before describing the remainder of the Lower Gault here, the correlation of the *spathi* Subzone sediments with the sequence at Selborne (Owen 1963a ; 43–4) will first be considered (text-fig. 14). Division 3 (i) at the Horton Clay pit contains the same fauna as Beds 1–3 at Selborne. On faunal and lithological grounds, 3 (ii) may be correlated with Bed 4, 3 (iii) with Bed 5, and 3 (iv) with Bed 6 at Selborne. Division 4 at the Horton Clay pit represents Beds 7–9 and the remainder of the sediments of the *spathi* Subzone not yet exposed at Selborne. The correlation of the Folkestone and Horton Clay pit sections is shown in text-fig. 16.

intermedius Subzone

The sediments from the base of 5 (i) to approximately 1 foot (0·305 m.) below the top of 5 (iii), a total thickness of 20 feet (6·096 m.), contain a typical *intermedius* Subzone fauna. The ammonites are quite often of good size (up to 4–5 inches (0·127 m.) in diameter) but crushed flat. *Anahoplites intermedius, A. praecox, A. mantelli* and *A. planus* are common to within 6 feet (1·829 m.) of the top of 5 (iii) but then decline in numbers above, with *Inoceramus concentricus* becoming the dominant fossil.

niobe Subzone

At a level about 1 foot (0·305 m.) below the top of 5 (iii), *Dimorphoplites niobe* appears sparingly together with *Anahoplites planus, Hamites tenuicostatus* and numerous *I. concentricus*. In 5 (iv) partly crushed ammonites and bivalves occur in the cement-stone nodules, and crushed fossils occur in the interstitial clays ; the stony lenticles are original sedimentary features. The ammonites include *Anahoplites planus, Dimorphoplites niobe, D.* spp. The same fauna occurs in 6 (i) and (ii). The *niobe* Subzone is represented, therefore, by 9 feet (2·743 m.) of sediments.

subdelaruei Subzone

This subzone appears to be represented only within 6 (iii) and has yielded species of *Mojsisovicsia* including *M. subdelaruei* and *M. remota.*

meandrinus Subzone

Division 6 (iv) contains shell seams which, near the top, yield pyritised fossils. The fauna is typically that which occurs in Bed IV and the basal few inches of Bed V at Folkestone classified with the *meandrinus* Subzone. Three shell seams at depths of approximately 2 feet 4 inches (0·711 m.), 3 feet 4 inches (1·016 m.), and 4 feet 4 inches

(1·321 m.), from the top of 6 (iv) have yielded ammonites suggesting a correlation with the basal 2 inches (0·051 m.) of Bed V at Folkestone.

nitidus Subzone

A typical *nitidus* Subzone fauna has been obtained from 6 (v) (Owen 1963a, 46) preserved in a manner identical to that of Bed V at Folkestone. No diagnostic ammonites were found by the author in 6 (vi) or (vii) and it is still uncertain whether these sediments are of *nitidus* or *daviesi* Subzone age.

? *daviesi Subzone*

In 1963, the author stated that the *daviesi* Subzone was absent. However, a few phosphatic nodules from the top of 6 (vii) have yielded ammonites including *Anahoplites planus* and *Euhoplites truncatus* together with *I. concentricus*. These occur immediately below the basal *cristatum* nodule bed at the base of Division 7. In the absence of *Anahoplites daviesi* it is not yet possible to determine whether these deposits represent this Subzone or not.

(viii) HASSOCKS TO EASTBOURNE

The only section in the Lower Gault now available east of Small Dole is to be seen above the Folkestone Beds in Messrs Hudsons Ltd's pit at Hassocks (text-fig. 17).

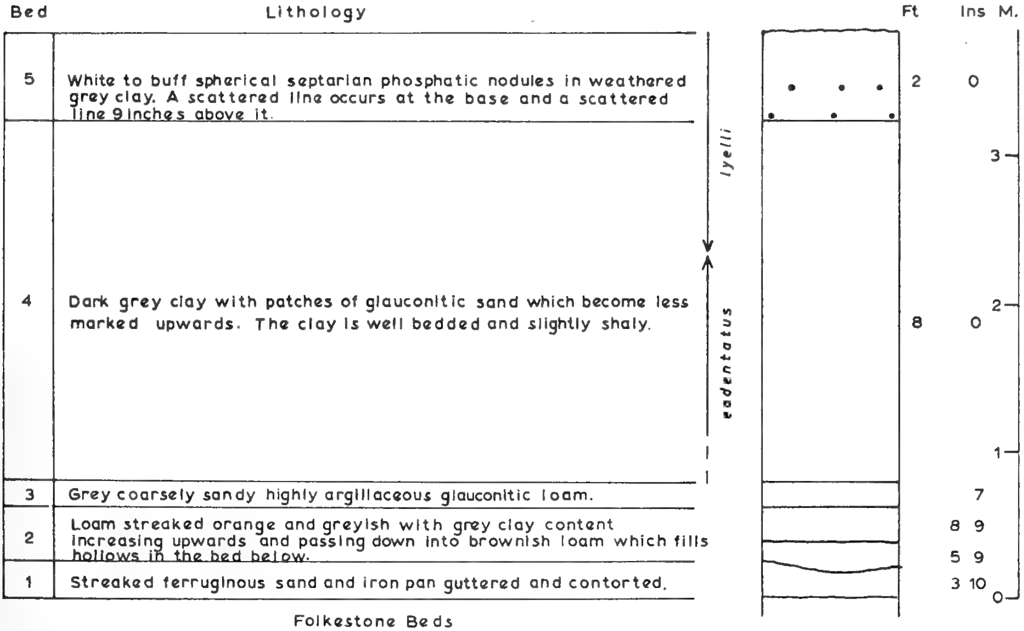


FIG. 17. Basal Gault and Gault-Lower Greensand junction beds at Hudsons Ltd's Hudsons Red Sand pit, 1400 yds W. of Hassocks railway station and 350 yds S. of the B 2116 road, Hurstpierpoint, Sussex (TQ 29121552).

This section has been discussed by Osborne White (1924 ; 29) Kirkaldy (1935 ; 526) and Casey (1961a ; 559–560). The *eodentatus* Subzone is present within Bed 4, and the *lyelli* Subzone within beds 4 and ?5.

Further east in Sussex there is very little information about the Lower Gault other than that recorded by Clement Reid (1898), Jukes-Browne (1900) and Osborne White (1924 & 1926). Spath demonstrated that at Ringmer the *daviesi* Subzone is represented (1926a ; 154) and it seems from the well records (Edmunds 1928) that the Middle Albian sediments probably maintain the thickness seen at Small Dole and may well thicken a little. The major increase in thickness of the Gault eastward is mainly explained by the change in facies from Upper Greensand to Gault. This is certainly the case in the Lewes area where the proven Upper Gault is very thick.

The discovery of a nodule bed of *spathi* Subzone age in the sea-bed ESE. of Beachy Head was used by the writer as evidence of an attenuation of deposits of this age in that area (Owen 1963a ; 46, 48, text-fig. 2). However, phosphatised *Hoplites* (*H.*) occur in Division 4 at the Horton Clay Pit where the sequence is very thick, and the record of the Eastbourne Waterworks well given by Jukes-Browne (1900, 118) is probably misleading.

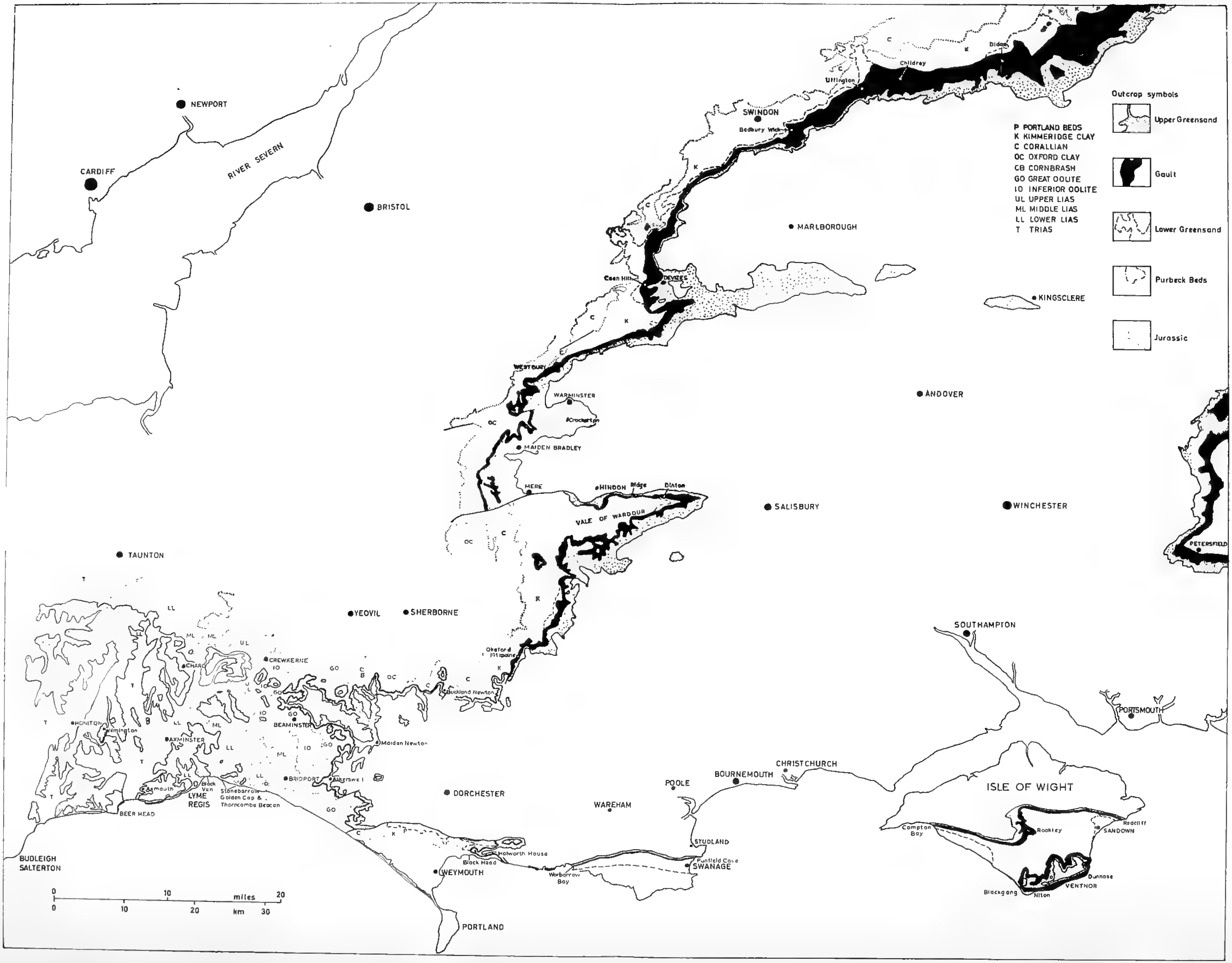
B. Isle of Wight, and Dorset Coast

This section deals with the outcrops in the Isle of Wight, from Punfield to Osmington, and from near Seatown to the Devon border (text-fig. 18). Of necessity the account is very incomplete for the exposures are seldom good and the facies is such that ammonites are uncommon except at a few horizons in the various localities. For this reason no correlation diagram is given on this occasion. Despite the difficulties, useful results have been obtained.

(i) ISLE OF WIGHT

The Carstone, and the overlying Gault (aptly named the ' Blue Slipper ') describe, except in the centre of the Island, narrow outcrops from Redcliff near Culver in the east to Compton Bay in the west. This is in response to the high dip on the northern limb of the Sandown and Brighstone anticlines respectively. Where the two axes meet in the centre of the Island there occurs a structural ' no-man's land ' with comparatively gentle northerly dips and thus a broader outcrop. An outlier of Chalk and Upper Greensand in the southern part of the island is fringed by outcrops of Carstone, and Gault dipping gently south. The Carstone and Gault have been described in stratigraphical detail notably by Bristow *et al.* (1889), Jukes-Browne (1900 ; 126–130), Osborne-White (1921), Kitchin & Pringle (1922a ; 160–161), Spath (1943 ; 741–743), and Casey (1961a ; 512–515), but there are many other references to them in the literature. The Gault is responsible for the major landslips on the southern coastline, and much of the outcrop is obscured by slipping, sludging, and deep weathering. The sections that are available are not always easy to work and fossils are far from plentiful.

FIG. 18. Sketch map showing positions of sections in South West England discussed in the text.


Outcrop symbols
Upper Greensand
Gault
Lower Greensand
Purbeck Beds
Jurassic
P PORTLAND BEDS
K KIMMERIDGE CLAY
C CORALLIAN
OC OXFORD CLAY
CB CORNBRASH
GO GREAT OOLITE
IO INFERIOR OOLITE
UL UPPER LIAS
ML MIDDLE LIAS
LL LOWER LIAS
T TRIAS
NEWPORT
CARDIFF
RIVER SEVERN
BRISTOL
SWINDON
Badbury Wick
Uffington
Childrey
Didcot
MARLBOROUGH
Caen Hill
DEVIZES
KINGSCLERE
WESTBURY
WARMINSTER
Crockerton
ANDOVER
MAIDEN BRADLEY
MERE
HINDON
Ridge
Dinton
VALE OF WARDOUR
SALISBURY
WINCHESTER
PETERSFIELD
TAUNTON
YEOVIL
SHERBORNE
CREWKERNE
CHARD
Okeford Fitzpaine
Buckland Newton
SOUTHAMPTON
PORTSMOUTH
HONITON
Wimington
AXMINSTER
BEAMINSTER
Maiden Newton
BRIDPORT
Abbotsbury
Seaton
Black Ven
LYME REGIS
Stonebarrow Golden Cap & Thorncombe Beacon
BEER HEAD
DORCHESTER
POOLE
BOURNEMOUTH
CHRISTCHURCH
WAREHAM
ISLE OF WIGHT
Compton Bay
Rookley
Redcliff
SANDOWN
STUDLAND
Holworth House
Black Head
Punfield Cove
SWANAGE
WEYMOUTH
Worbarrow Bay
Dunnose
VENTNOR
Blackgang
Niton
BUDLEIGH SALTERTON
PORTLAND
0 10 miles 20
0 10 20 km 30

Bristow *et al.* (1889), Jukes-Browne (1900), and Osborne-White (1921) all give a roughly uniform thickness of 100 feet (30·48 m.) for the Gault throughout the Island. However, this is certainly not correct for although the thickness is about 100 feet (30·48 m.) at Redcliff, it is reduced to about 65 feet (19·81 m.) at Compton Bay, and may be over 100 feet (30·48 m.) in the southern part of the Island. Kitchin & Pringle (1922 ; 160–161) recognised that Middle Albian sediments of the ' interruptus Zone ' were present at Culver and in the south of the Island, but they considered that the Gault in Compton Bay was wholly Upper Gault. They based their conclusion on the old record of *Inoceramus sulcatus* (Norman 1887 ; 70), but it will be shown below that this argument together with their view that the ' —so-called " Carstone " of this locality— ' did not represent the true top of the Lower Greensand, is completely fallacious. Spath (1926b ; 422, and *in* Jackson 1939 ; 74) considered that the Gault represented only the *dentatus* Zone and that the ' lower *benettianus* (=*inaequinodum*) zone ' passed into the Carstone beneath. This latter conclusion was confirmed by Casey (1961a ; 515) based on material collected by C. W. Wright and the author.

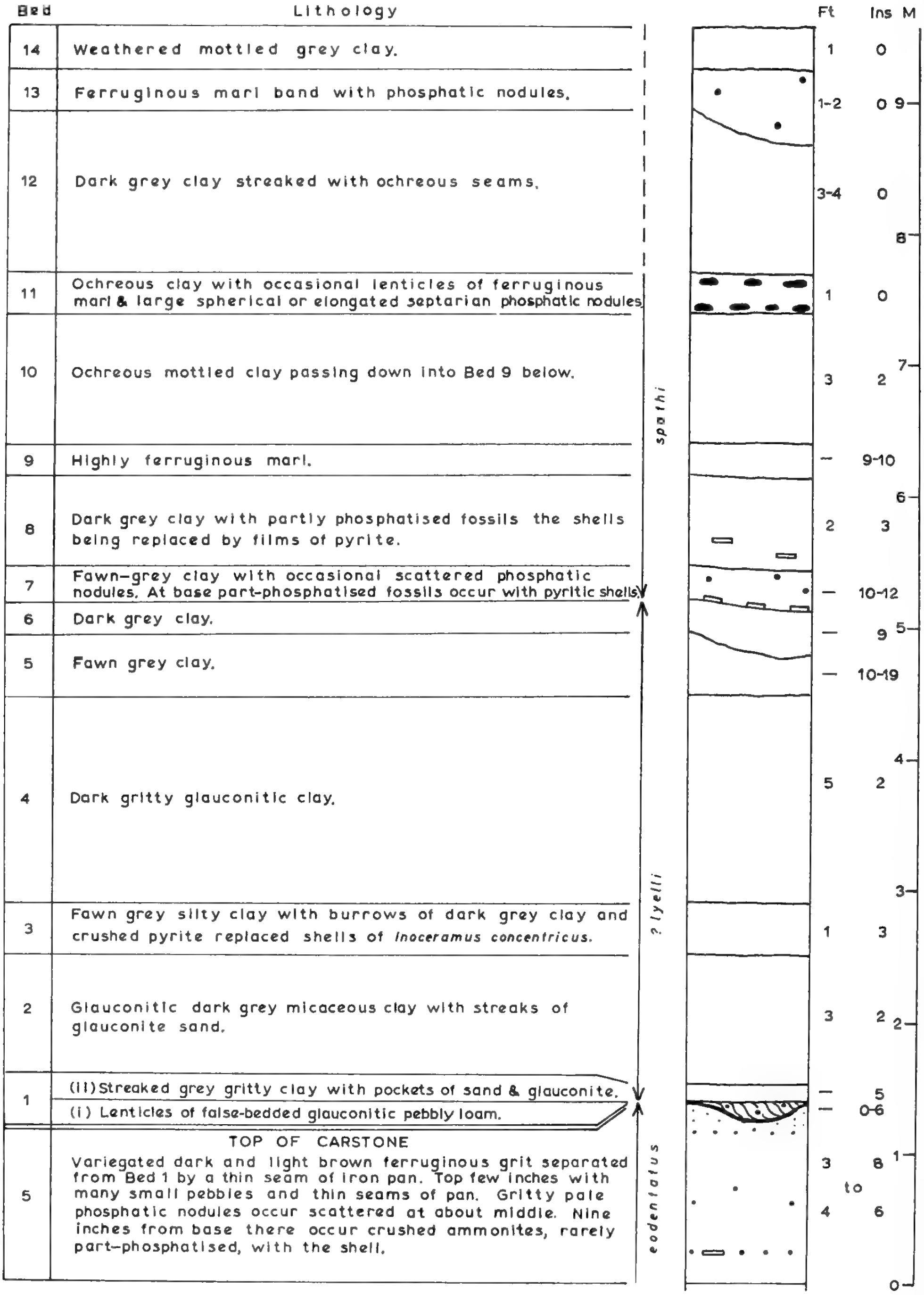
(a) **Redcliff**

The Gault in the hollow between Redcliff and the Upper Greensand face at the W. end of Culver Down (SZ 62758550) is badly slumped and overgrown. However, from time to time exposures of a few feet of clay dipping steeply NE. have been seen near the top and the base of the Formation. The Gault is here about 100 feet (30·48 m.) thick but it is impossible at this time to obtain an accurate measurement. From sections exposed near the base it can be seen that there is a fawn band within six feet (1·828 m.) of the junction with the underlying pebbly Carstone. This fawn band contains crushed *Hoplites* (*H.*) spp. with pyritic films replacing the shells, together with a few part-phosphatised specimens. On the basis of the ammonites so far seen, a basal *spathi* Subzone age is indicated. However, a similar unit at Bonchurch has yielded rare but definite *lyelli* Subzone fossils.

Mr. J. McA. Hart collected a pyritised *Euhoplites* of Upper Gault aspect from a small exposure near the top of the Gault and below Jukes-Browne's Division A. This indicates that at Redcliff the lower part of the Upper Albian is within the clay facies.

(b) **Rookley**

Perhaps the most important section available in the Isle of Wight at this time is exposed in the extensive workings of Island Bricks Ltd., at Rookley. The sequence extends from well down in the Carstone up into the Gault and is shown graphically in text-fig. 19. It has never been described in detail but has been mentioned by Pritchett & Jackson (1941). The pit is cut by an E.-W. fault down-throwing to the south, and the southern part of the section is tectonically disturbed. The sequence north of the fault dips NW. at 6° and shows variations in the thickness of certain beds which cannot be ascribed to a later tectonic cause. These are here considered to be due to slumping before consolidation of the sediment.



Bed	Lithology	Ft	Ins
14	Weathered mottled grey clay.	1	0
13	Ferruginous marl band with phosphatic nodules.	1-2	0
12	Dark grey clay streaked with ochreous seams.	3-4	0
11	Ochreous clay with occasional lenticles of ferruginous marl & large spherical or elongated septarian phosphatic nodules	1	0
10	Ochreous mottled clay passing down into Bed 9 below.	3	2
9	Highly ferruginous marl.	—	9-10
8	Dark grey clay with partly phosphatised fossils the shells being replaced by films of pyrite.	2	3
7	Fawn-grey clay with occasional scattered phosphatic nodules. At base part-phosphatised fossils occur with pyritic shells	—	10-12
6	Dark grey clay.	—	9
5	Fawn grey clay.	—	10-19
4	Dark gritty glauconitic clay.	5	2
3	Fawn grey silty clay with burrows of dark grey clay and crushed pyrite replaced shells of *Inoceramus concentricus*.	1	3
2	Glauconitic dark grey micaceous clay with streaks of glauconite sand.	3	2
1	(ii) Streaked grey gritty clay with pockets of sand & glauconite.	—	5
	(i) Lenticles of false-bedded glauconitic pebbly loam.	—	0-6
5	TOP OF CARSTONE Variegated dark and light brown ferruginous grit separated from Bed 1 by a thin seam of iron pan. Top few inches with many small pebbles and thin seams of pan. Gritty pale phosphatic nodules occur scattered at about middle. Nine inches from base there occur crushed ammonites, rarely part-phosphatised, with the shell.	3 to 4	8 6

Fig. 19. Middle Albian sediments at Island Bricks Ltd's Rookley Brickworks, situated 600 yds ESE. of the school, Rookley, and 150 yds NW. of the A 3020 road, South Arreton, Isle of Wight (SZ 51338395).

Bed 5 of the Carstone contains crushed filmy shells of ribbed ammonites. Very rarely these are partly phosphatised and can be identified as *Hoplites* (*Isohoplites*) spp. including *H.* (*I.*) *eodentatus* (e.g. BMNH., C 73358 author's colln., figured Casey 1965 ; 538, text-fig. 202 g.h.) indicating an *eodentatus* Subzone age. Beds 1–6 of the Gault have not yielded fossils and may represent the *lyelli* Subzone known to be present in the Ventnor area to the south. Beds 7–11 can definitely be classified with the *spathi* Subzone. Bed 7 contains crushed pyritic ammonites, some partly phosphatised, including the typical *H.* (*H.*) *spathi* and *H.* (*H.*) *dentatus* marking the base of the *spathi* Subzone. Bed 8 also contains crushed *Hoplites* (*H.*) spp. with pyritic tests which decompose very rapidly on exposure. Beds 9–10 have not yielded fossils, but Bed 11 has yielded a few fragments of large *Hoplites* (*H.*) which still suggest the lower part of the *spathi* Subzone. No fossils were found in Beds 12–14.

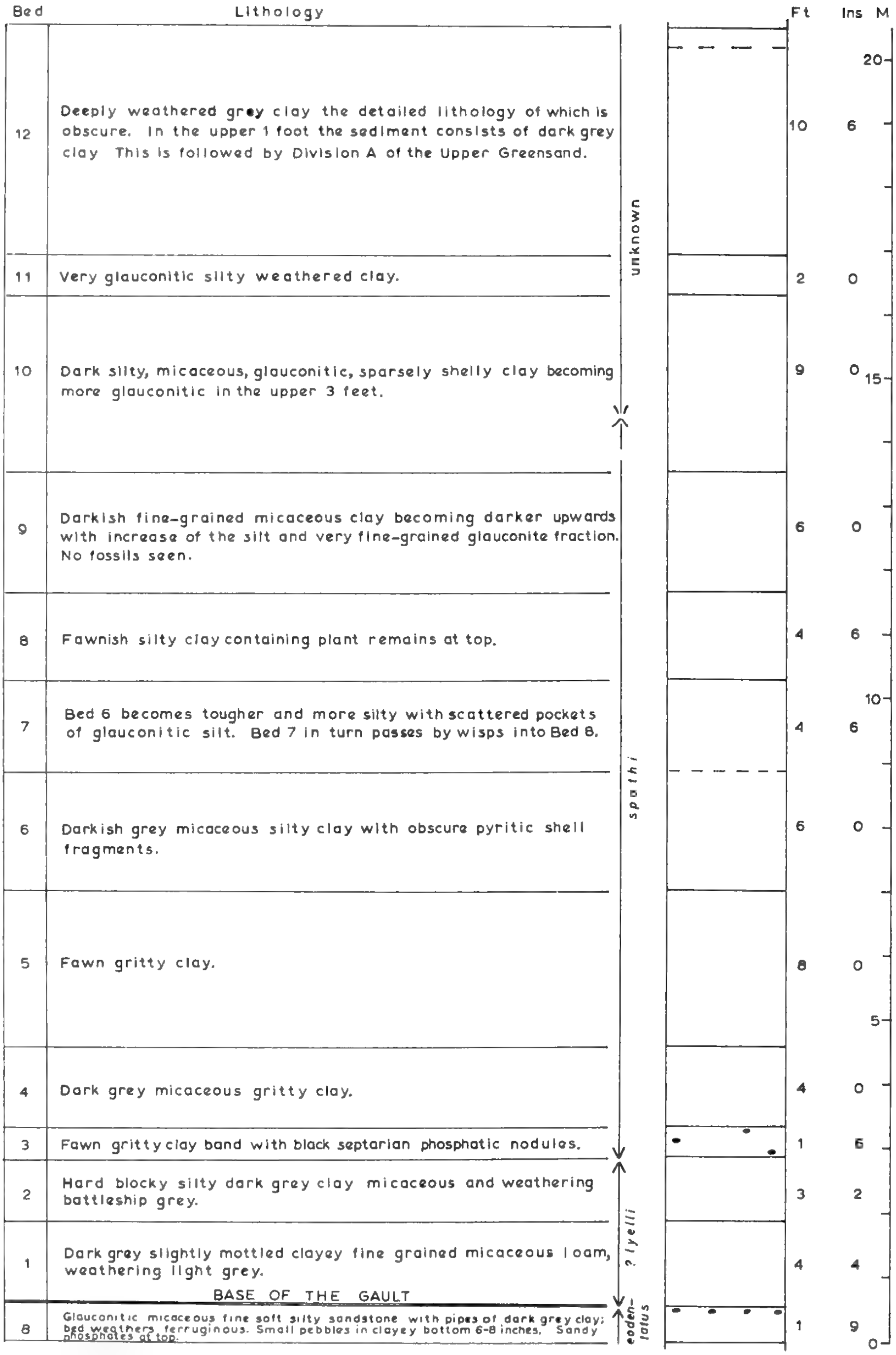
(c) **Compton Bay**

In view of Kitchen & Pringle's statement that no Lower Gault is present in Compton Bay (1922 ; 161) it was particularly fortunate that a good section has been exposed during recent years. The true Gault here was stated by Strahan (*in* Bristow *et al.* 1889 ; 63) to be 95 feet (28·956 m.) thick excluding the passage beds to the Upper Greensand but this is far in excess of the true figure. The very high angle of true dip seen in the cliff, levels off sharply at no great depth below beach level due to a slight flexure and change in direction of apparent dip. On a very accurate measurement based on the detailed sequence given in text-fig. 20, the thickness is little more than 65 feet (19·812 m.).

The phosphatic nodules at the top of Bed 8 of the Carstone have yielded *Hoplites* (*Isohoplites*) *eodentatus* indicating that Subzone. No ammonites have been found in either Beds 1 or 2 of the Gault and their exact Subzonal age is unknown. However, the species of *Hoplites* (*H.*) in Bed 3 indicate the basal part of the *spathi* Subzone and it is possible that both Beds 1 and 2 are of *lyelli* Subzone age. Apart from Bed 3, the only other ammonites found were crushed *Hoplites* (*H.*) sp. at the base of Bed 10, at which point a shelly facies appears. One is tempted to compare this junction between the pyritic facies below and the shelly facies above, with a similar junction in the *spathi* Subzone sequence in the Nyewood-Wrecclesham area of the outcrop in the Weald. However, such a correlation may well be more apparent than real. Beds 3 to the base of Bed 10 can, therefore, be classified with the *spathi* Subzone. How much of the overlying sediments belong to the *spathi* Subzone is not yet known, as also whether any other Middle Albian Subzones are represented. However, there is no doubt that there is a substantial thickness of ' Lower ' Gault present at Compton Bay.

(d) **Ventnor to Niton**

A complete section of the Carstone is exposed in the sea-cliff extending from Dunnose south-westwards to the esplanade at Bonchurch ; the stretch of coast named



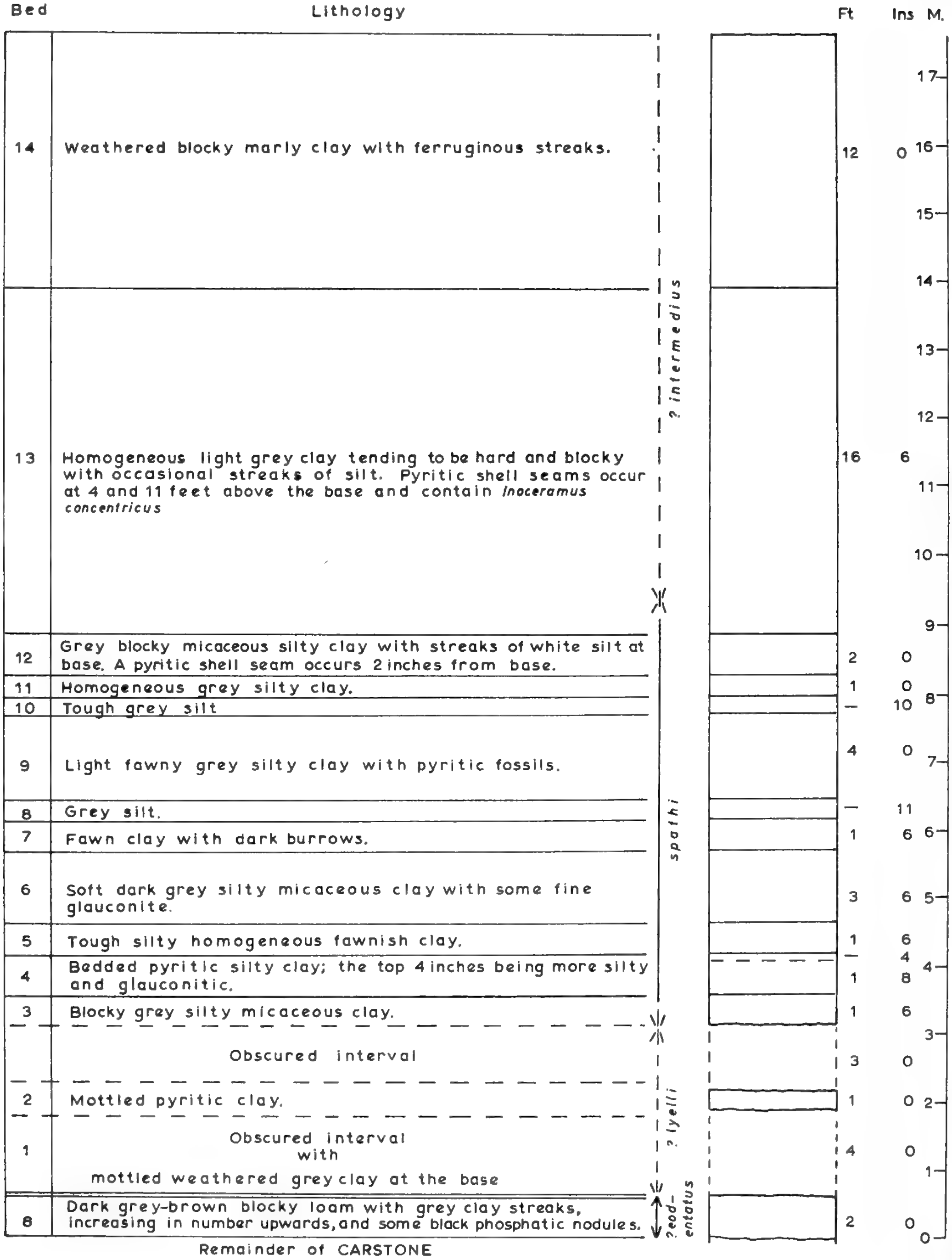
Bed	Lithology	Ft	Ins
12	Deeply weathered grey clay the detailed lithology of which is obscure. In the upper 1 foot the sediment consists of dark grey clay This is followed by Division A of the Upper Greensand.	10	6
11	Very glauconitic silty weathered clay.	2	0
10	Dark silty, micaceous, glauconitic, sparsely shelly clay becoming more glauconitic in the upper 3 feet.	9	0
9	Darkish fine-grained micaceous clay becoming darker upwards with increase of the silt and very fine-grained glauconite fraction. No fossils seen.	6	0
8	Fawnish silty clay containing plant remains at top.	4	6
7	Bed 6 becomes tougher and more silty with scattered pockets of glauconitic silt. Bed 7 in turn passes by wisps into Bed 8.	4	6
6	Darkish grey micaceous silty clay with obscure pyritic shell fragments.	6	0
5	Fawn gritty clay.	8	0
4	Dark grey micaceous gritty clay.	4	0
3	Fawn gritty clay band with black septarian phosphatic nodules.	1	6
2	Hard blocky silty dark grey clay micaceous and weathering battleship grey.	3	2
1	Dark grey slightly mottled clayey fine grained micaceous loam, weathering light grey. BASE OF THE GAULT	4	4
8	Glauconitic micaceous fine soft silty sandstone with pipes of dark grey clay; bed weathers ferruginous. Small pebbles in clayey bottom 6-8 inches. Sandy phosphates at top.	1	9

FIG. 20. Section of the Gault exposed in the sea-cliff about 200 yds NW. of Compton Chine, Compton Bay, Freshwater, Isle of Wight (SZ 36708524).

Monks Bay. Above this, the basal beds of the Gault are occasionally well exposed at the top of the cliff, but the remainder of the Gault is badly slumped in the Undercliff itself. Other sections are known from Ventnor, Steephill, and from Reeth Bay, Niton and round St. Catherine's Point and are mentioned below. An ammonite described by Spath as *Anahoplites mimeticus* (1925 ; 131, pl. X, fig. 7a, b) was alleged to have come from the 'Carstone' of Niton, Isle of Wight. However, the preservation of the holotype BMNH., C 30535 indicates that it is definitely not from the Carstone but from an horizon in the Gault possibly above the *spathi* Subzone sediments ; it is possibly a species of *Hoplites* (*H.*) with a smooth outer whorl. The specimen figured by Casey (1966 ; 547, text-fig. 207a, b, C. W. Wright Colln., 9983) as *Anahoplitoides mimeticus* Spath which he states came from the top of the Carstone (*eodentatus* Subzone), of Bonchurch, is preserved in a manner quite unlike any of the material from the top of the Carstone and C. W. Wright has informed me that it was picked up loose. It must come from a higher horizon in the Gault than the proved *spathi* Subzone sediments. However, *Hoplites* (*Isohoplites*) *eodentatus* does occur in the top part of the Carstone at Bonchurch but the preservation is the typical sandy phosphate. It might be mentioned here that the specimen of *Hoplites vectensis* from the Carstone near Niton mentioned by Spath (1925a ; 128 L.F. Spath Colln. No. 238 = BMNH., C 30555) is indeed from the Carstone and is an external mould without the peripheral area. Nonetheless, it is almost without doubt a specimen of *H.* (*Isohoplites*).

The few feet of Gault immediately overlying the Carstone at Monks Bay has yielded, from a fawn band, crushed and partly phosphatised *Hoplites* (*H.*) spp., specimens of which are in the British Museum (Nat. Hist.) L. F. Spath Colln. An external mould of a *Beudanticeras* sp. in an identical matrix is preserved in the Institute of Geological Sciences (GSM., Zn 1483 also L. F. Spath Colln.) and indicates the presence of the *lyelli* Subzone. A pyritic specimen of *Lyelliceras* is in fact known from this locality and was figured by Spath (1931 ; 320 pl. XXXIII, fig. 15a–c, BMNH., C 32845). Further evidence of the presence of sediments of *lyelli* Subzone age is provided by ammonites from the basal Gault near the Gas House, Gas House Hill, Ventnor (SZ 56857747) preserved in the Sedwick Museum. These consist of black brittle phosphate steinkerns without the shell, typical of the lower fawn band, and include *Beudanticeras sanctaecrucis* and *Hoplites* (*H.*) spp., one of them (B 42586) with pyritic inner whorls like that of the *Lyelliceras* mentioned above. C. W., & E. V. Wright have recorded *Protanisoceras moreanum* from west of Luccomb Chine (1942 ; 286).

More definite information about the higher part of the Gault is provided by the section in the cliff SW. of Steephill Cascade, Ventnor (SZ 55467707). Here the Gault dips seaward becoming much steeper in the foreshore landward of an old slipped mass. Dark grey gritty pyritic clay with rolled pieces of phosphatised *Hoplites* (*H.*) spp. occurs along the axis of the 'fold' and is overlain by sparsely shelly clay in which ammonites have yet to be found. The cliff behind these foreshore exposures is deeply weathered at this time.



Bed	Lithology	Ft	Ins
14	Weathered blocky marly clay with ferruginous streaks.	12	0
13	Homogeneous light grey clay tending to be hard and blocky with occasional streaks of silt. Pyritic shell seams occur at 4 and 11 feet above the base and contain *Inoceramus concentricus*	16	6
12	Grey blocky micaceous silty clay with streaks of white silt at base. A pyritic shell seam occurs 2 inches from base.	2	0
11	Homogeneous grey silty clay.	1	0
10	Tough grey silt	—	10
9	Light fawny grey silty clay with pyritic fossils.	4	0
8	Grey silt.	—	11
7	Fawn clay with dark burrows.	1	6
6	Soft dark grey silty micaceous clay with some fine glauconite.	3	6
5	Tough silty homogeneous fawnish clay.	1	6
4	Bedded pyritic silty clay; the top 4 inches being more silty and glauconitic.	— 1	4 8
3	Blocky grey silty micaceous clay.	1	6
	Obscured interval	3	0
2	Mottled pyritic clay.	1	0
1	Obscured interval with mottled weathered grey clay at the base	4	0
8	Dark grey-brown blocky loam with grey clay streaks, increasing in number upwards, and some black phosphatic nodules.	2	0

Remainder of CARSTONE

FIG. 21. Gault section in cliff below old coast road 50 yds NW. of Cliff Cottage and 360 yds SSE. of Blackgang Hotel, Blackgang, Chale, Isle-of-Wight (SZ 48877644).

(e) **Blackgang**

The section in the Carstone and Gault at Blackgang shows that the sequence has changed fairly considerably in the mere 4½ miles from Ventnor. The section given in text-fig. 21 exposed below Cliff Cottage, Blackgang, shows that the sediments are generally coarser in grade. It is exposed at the summit of a cliff of Sandrock Series and in wet weather is dangerous.

Bed 8 of the Carstone is probably of *eodentatus* Subzone age, but *Hoplites* (*Isohoplites*) has not yet been found here. Unfortunately, the lower 8 feet (2·438 m.) of the Gault is not clearly exposed but it certainly contains at least one fawn pyritic clay band which has not yet yielded fossils. The only ammonite seen in Bed 3 was a crushed *Hamites* (*H.*) sp. 4 inches (0·101 m.) below the top which indicates the *spathi* rather than the *lyelli* Subzone. Bed 12 has also yielded crushed *Hoplites* (*H.*) spp. which indicate the *spathi* Subzone. No other ammonites have been found higher in the section but *I. concentricus* still occurs 11 feet (3·352 m.) up in Bed 13.

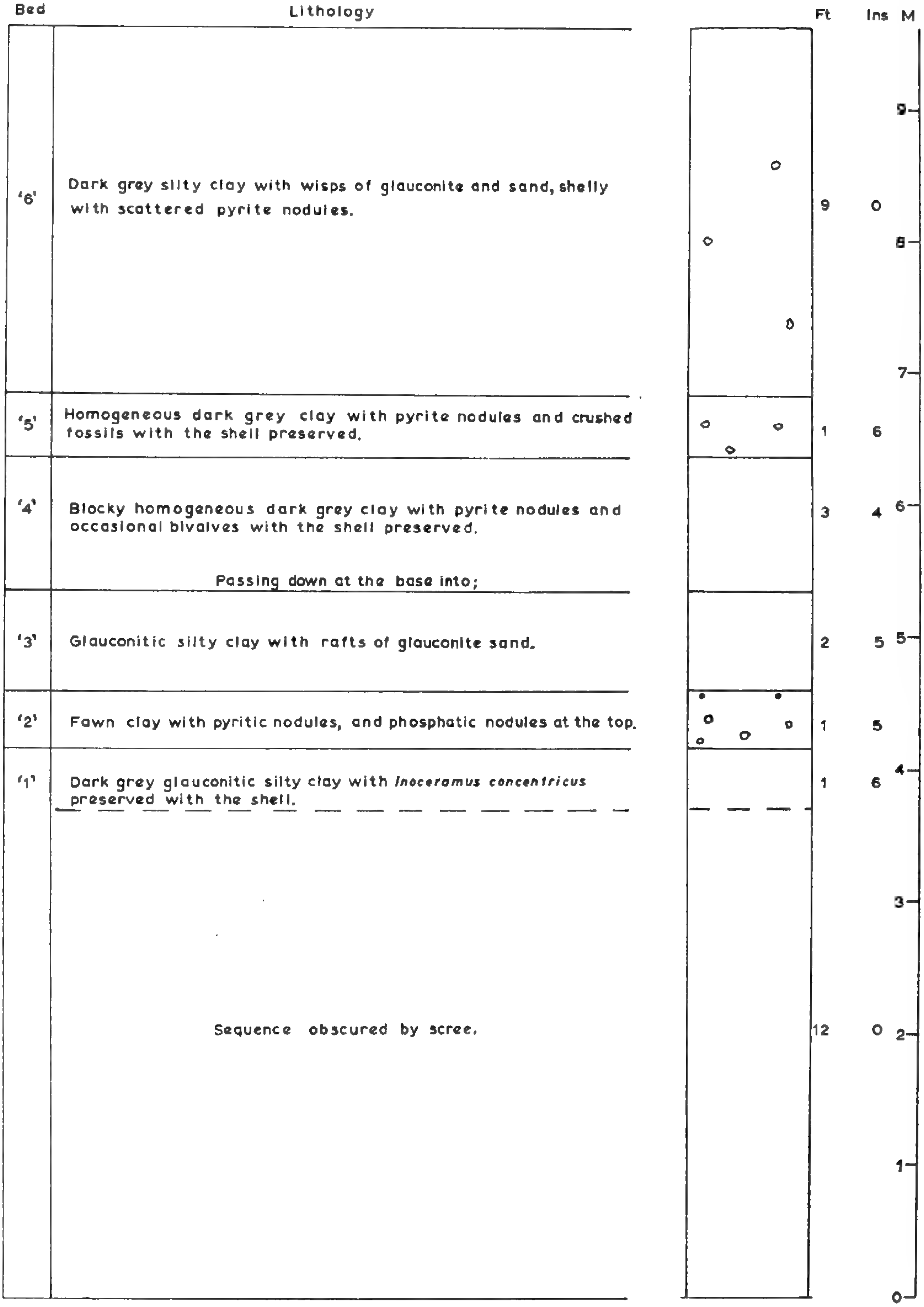
A section below Gore Cliff about 825 yards SE. of Cliff Cottage shows higher Gault (text-fig. 22). Unfortunately the two sections probably do not overlap although there is an obscured interval of 12 feet (3·657 m.) at the base of the Gore Cliff sequence. *I. concentricus* is present in the top 1 foot 6 inches (0·457 m.) of ' Bed 1 ' showing it to be still of Middle Albian age, but no other age indicative fossils are yet known from this section.

Certainly some of the lower part of the Gault here is of *spathi* Subzone age. However, the specimen of *Hoplites* aff. *vectensis* recorded by Spath (1925 ; 128, BMNH., C 890) and said to be from Blackgang is in fact identical in preservation to specimens from the top of the *spathi* Subzone at Osmington, Dorset, from whence it undoubtedly came.

(ii) BALLARD CLIFF TO OSMINGTON

The early accounts of the Gault in this coastal area of Dorset were given by Strahan (1898) and Jukes-Browne (1900). This work was revised by Wright (*in* Arkell 1947b ; 178–194), and there is no new information to add to his lithological account for the sections have deteriorated considerably. However, his Subzonal classification of the basal beds requires revision. Wright redescribes, as far as it is possible, the sections at Punfield Cove, Swanage (SZ 03878110), Flower's Barrow, Worbarrow Bay (SY 86388045), Lulworth Cove (East SY 82867988, West SY 82427988), Durdle Cove (SY 80578028), White Nothe, and Black Head, Osmington, covering in all a distance of 35 miles (text-fig. 18).

Beds 1 and 2 at Flower's Barrow, Worbarrow Bay, are apparently of the same age as the ferruginous clay with concretions at Black Head, Osmington, as Wright stated. However, the fauna from these sediments at Black Head, first recorded by Cunnington (1929) is not of ' benettianus ' Subzone age as Spath originally thought (Wright *in* Arkell 1947b ; 181) for all the species of *Hoplites* (*H.*) which occur, such as *H.* (*H.*) *dorsetensis* and *H.* (*H.*) *vectensis*, can be matched in the highest part of the *spathi* Subzone in the Weald and elsewhere. Even Spath was to change his mind about the Subzonal age of these two species, placing them in the *intermedius* Subzone (1942 ;



Bed	Lithology	Ft	Ins
'6'	Dark grey silty clay with wisps of glauconite and sand, shelly with scattered pyrite nodules.	9	0
'5'	Homogeneous dark grey clay with pyrite nodules and crushed fossils with the shell preserved.	1	6
'4'	Blocky homogeneous dark grey clay with pyrite nodules and occasional bivalves with the shell preserved. Passing down at the base into;	3	4
'3'	Glauconitic silty clay with rafts of glauconite sand.	2	5
'2'	Fawn clay with pyritic nodules, and phosphatic nodules at the top.	1	5
'1'	Dark grey glauconitic silty clay with *Inoceramus concentricus* preserved with the shell.	1	6
	Sequence obscured by scree.	12	0

FIG. 22. Cliff section of Gault at top of undercliff below Gore Cliff, 480 yds ESE. of South View House, Blackgang, Chale, Isle of Wight (SZ 49437590).

675). In this, he was very nearly right, for the concretions at Black Head yield, albeit very rarely, early forms of *Anahoplites* of the *intermedius* group. These include the specimen figured by Spath as *A. mimeticus* (1927 ; 188, pl. XVII, fig. 8a, b) which belongs to *A. osmingtonensis* sp. nov., and *A. grimsdalei* sp. nov. which is the direct forerunner of *A. evolutus* a form found at the base of the *intermedius* Subzone. These early *Anahoplites* are associated with the usual species of *Hoplites* (*H.*) of this bed, however, it is important to note Cunnington's remark (1929 ; 126) : '*Anahoplites*—are scarcer, but wherever one is found there are almost always others or fragments of others in the same block '. I have not yet found *Anahoplites* in this line of concretions containing an upper *spathi* Subzone fauna. This might be purely a collecting error, for the matrix and mode of preservation of the specimens of *Anahoplites* is identical to that of the other fossils of this bed and this is very distinctive. From a morphological point of view these are unquestionably earlier than the basal *intermedius* Subzone species of this genus, e.g. *A. evolutus* (p. 151). Equally certain, they are not earlier than the high *spathi* Subzone concretions ; that is, they are not of *lyelli* Subzone age. The sections in this area are shown in Arkell (1951 ; Fig. 4).

Deposits of *lautus* Zone age are also present in this area (Cunnington 1929 ; 129 : Spath 1943 ; 743 : Wright *in* Arkell 1947 ; 193) but the position in the section of the material picked up loose has yet to be determined.

(iii) THORNCOMBE BEACON TO BLACK VEN

The account of the sections on Golden Cap, and Black Ven, given by Jukes-Browne (1900 ; 182–189) was followed fourteen years later by the very important detailed account by Lang (1914) who also discovered the formation on Stonebarrow. To this, additional information was added in Lang & Thomas (1936), and these sections together with that on Thorncombe Beacon east of Seatown have more recently been described by Welch (*in* Wilson, Welch, Robbie & Green 1958 ; 139–150). Here again, there is nothing to add to the lithological account but a re-examination of the ammonites has provided a little, but important, additional information. The sediments classified with the Gault are much thinner in this area of the coast.

Bed 1 of Lang (1914) yielded *Anahoplites praecox* both at Black Ven and Stonebarrow (1936 ; 310). Bed 2 on Stonebarrow has also yielded *A. praecox* including one specimen BMNH., C 15661 which is very close indeed to the neotype of '*Dimorphoplites*' *alternatus*, which is in reality a very coarse development of *A. praecox* (p. 153). *A. praecox* also occurs at Charton Goyle in a matrix which is almost certainly the unweathered representative of Bed 2 (BMNH., C 68394–6). Beds 1 and 2 definitely belong to the *intermedius* Subzone. According to Spath (e.g. 1943 ; 744), Bed 3 contains both *intermedius* Subzone and *varicosum* Subzone ammonites. This is untrue. BMNH., C 41035 from Bed 3, recorded by Spath as *Epihoplites* aff. *trifidus*, is in reality an early transition between *Hoplites* (*H.*) and *Dimorphoplites* consistent with an *intermedius* Subzone age. The '*Idiohamites* of the *turgidus* group' (BMNH., C 41038) is a *Protanisoceras* (*H.*) cf. *nodosum*, also indicating an *intermedius* Subzone age. Another specimen BMNH., C 41035 from Bed 3 is here identified as *Anahoplites* cf. *intermedius*.

There is, therefore, no evidence of the presence of Upper Albian sediments in Lang's Bed 3 and this is consistent with the distribution of *Inoceramus concentricus* and *I. sulcatus*. *I. concentricus* is known from Beds 1, 2, and 3 (e.g. Lang Colln., BMNH., L 55076 from Black Ven) both on Black Ven and Stonebarrow. Specimens of *I. sulcatus* are known from Black Ven (e.g. BMNH., L 55368–71 Grimsdale Colln.) preserved without the shell in glauconitic sandstone which suggests Lang's Bed 10, certainly no lower horizon. The record of *Anahoplites planus* from Lang's Bed 10 by Spath (1943 ; 744) is an error. The Middle-Upper Albian boundary falls somewhere between the top of Bed 3 and ?the base of Bed 10.

The above indicates that Kitchin & Pringle's statement that no Lower Gault exists at Black Ven is quite fallacious (1922 ; 163). This statement is the more incredible when one realises that they had never examined the section and apparently had overlooked Lang's paper of 1914. There may well be a non-sequence in these sections but at this time there is no evidence to indicate its extent.

No sections further west on the Devon Coast have been examined by the writer.

(iv) CONCLUSION

The poor state of the sections in the Isle of Wight and on the Dorset Coast are particularly tantalising, nonetheless, some results can be drawn from this incomplete information. It is apparent that in the Isle of Wight the *eodentatus* Subzone is represented at the summit of the Carstone ; the *lyelli* Subzone is represented in the lower part of the Gault at least in the southern part of the island ; and the *spathi* Subzone sediments are well developed. The *intermedius* Subzone is probably represented but the conclusive proof is not yet to hand.

By Worbarrow Bay and Osmington the fossiliferous concretions very near the base of the Formation are of uppermost *spathi* Subzone age, and there is evidence of *lautus* Zone sediments near the top of the Gault in the Osmington-White Nothe area. In the sea-truncated outliers between Seatown and Lyme Regis the lowest fossiliferous sediments are of *intermedius* Subzone age. As one proceeds westwards from the Isle of Wight, therefore, the lowest fossiliferous sediments become later in age (text-fig. 23). The *intermedius* Subzone is widely represented by sediments in the deeper parts of the Wessex Basin ; for example in the Petersfield and Winchester districts, Hampshire (p. 69), at Didcot, Berkshire (p. 63), Devizes, Wiltshire (p. 60), and possibly at Okeford Fitzpaine, Dorset (p. 56). Its presence in the Isle of Wight, and in the Dorset coast sections as far west as Osmington should not be discounted. Across the Channel at Cauville on the French coast NE. of Le Havre, there occurs, above a *remanié* bed of basal *dentatus* Zone age, even later sediments of *niobe* Subzone age (p. 107).

C. **The outcrop from Devon to Bedfordshire**

There is no information available about Middle Albian sediments inland in the area W. of the River Axe. Neither is there any further stratigraphical information available at the outcrop from the valley of the Axe to Okeford Fitzpaine, N. Dorset, other than that recorded by Jukes-Browne (1900 ; 163–4), Welch and Robbie (in Wilson, Welch, Robbie & Green 1958 ; 148–152)[1], Reid (1903 ; 34–35), Osborne-White (1923 ; 49–50) and Smart (1955 ; 43–4). It is apparent that Middle Albian sediments occur north-eastwards from the area of Beaminster for although ammonites have not been found, *Inoceramus concentricus* has been recorded from a number of sections and in this context definitely indicate a Middle Albian age. From the coast between Thorncombe Beacon and Black Ven (p. 51), Middle Albian sediments thin markedly inland in places to less than 10 feet (3·04 m.) to thicken again in the area of Toller Porcorum (SY 562974) S. of Evershot, and also in the outcrop N. of Evershot eastwards from West Chelborough (Welch and Robbie *in* Wilson *et al.*, 1958). The Gault continues to thicken eastwards and in the region between Alton Pancras and Ansty, Smart records a thickness ranging from 25–35 feet (1955 ; 42–4). The increasing thickness is maintained up to Okeford Fitzpaine.

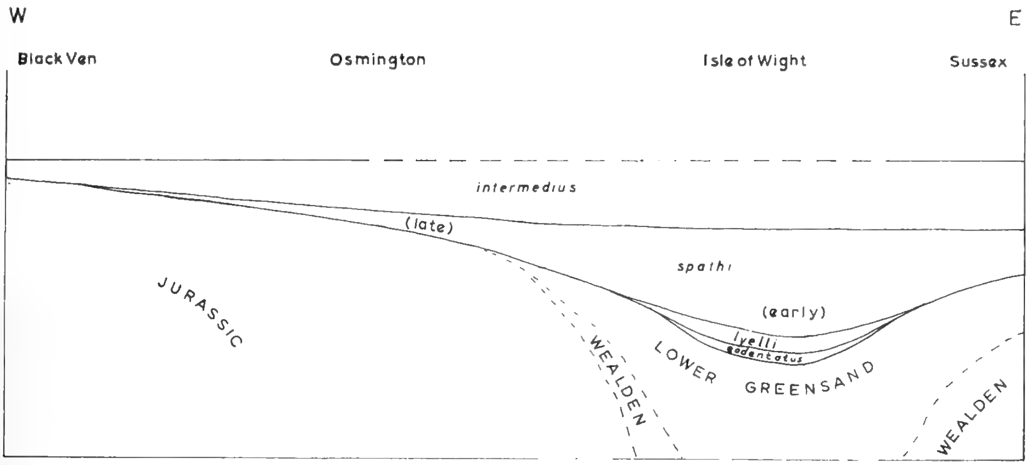


FIG. 23. Sketch section, from W. to E. across the Late Jurassic-early Cretaceous modified Wessex basin in the area of the south coast, demonstrating the transgressive nature of the Middle Albian sediments and the diachronous nature of the base.

It is very regrettable that no good sections are now available throughout this long strip of outcrop (text-fig. 18). The sequence seen on the coast between Thorncombe Beacon and Black Ven, with its development of the *intermedius* Subzone of the *loricatus* Zone has passed in the area of Okeford Fitzpaine to a sequence showing the development of the *eodentatus*, *lyelli* & *spathi* Subzones of the *dentatus* Zone. In this latter area it is underlain by deposits of *mammillatum* Zone age absent at the coastal section to the SW. This difference in sequence is made somewhat significant by a comparison with the sections in the Pays de Caux in northern France (p. 101), and is discussed later in the section dealing with the conditions of deposition (p. 142).

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[1] It is worth stating here that the stream and river sections described by the Survey officers are only well visible in periods of drought (cf. Dewey 1934 ; 42).

(i) OKEFORD FITZPAINE (DORSET)

The section at the Okeford Brick & Tile Works situated about ½ mile E. of the village of Okeford Fitzpaine on the road to Shillingstone is no longer visible. It was first described by Newton (1896 ; 198 : 1897 ; 66–68) from notes and material provided by the Misses Forbes and Lowndes, then by Jukes-Browne (1900 ; 162), Reid 1903 ; 34–35), and Osborne White (1923 ; 48). Text-fig. 24 is taken from the account given by Newton (1897, 67–8) with additions from Jukes-Browne. Spath (1925 ; 73 pl. V, fig. 6) figured one of Newton's specimens of '*Acanthoceras mammillatum*' as *Douvilleiceras inaequinodum* (Quenstedt) so demonstrating the presence of the *inaequinodum* Subzone to which Casey assigns the base of the Gault here (1961a ; 565) ; now included in the *eodentatus* Subzone. Spath also demonstrated the presence of the *benettianus* Subzone (i.e. *lyelli* Subzone) by the occurrence of *Hoplites* (*H.*) '*pseudodeluci*' Spath (type locality, 1925a ; 120) and forms close to *H.* (*H.*) *benettianus* (J. de C. Sowerby) (1925a ; 117–8), together with *Beudanticeras* probably *laevigatum* and '*Anahoplites* of *mimeticus* type' (1926a ; 147).

The material described by Newton is in the British Museum (Nat. Hist.). A re-examination of the fossils and a careful reading of Newton's account (1897) has provided the following important stratigraphical information. All the specimens were undoubtedly indigenous and not semi-derived. The three fragments (BMNH., C 6856–8) recorded by Newton as *Acanthoceras mammillatum* described by Spath as *Douvilleiceras inaequinodum* could well belong to one partly phosphatised individual. The nacreous shell was clearly preserved and the matrix adhering to it consists of the bluish grey micaceous clayey sand with glauconite of Bed 3. The specimen could not, therefore, have come from Bed 2. The specimens of *Ostrea leymeriei* (BMNH., L 11579 figured specimen, L 11591) have traces of the same sediment adhering to them as that of the specimen of *D. inaequinodum.* Moreover, internally there is the same blackish phosphate. It would seem also that these come from Bed 3 and not Bed 2 (cf. Newton 1897 ; 68).

If this is the case then Bed 2, which Jukes-Browne (1900 ; 163) considered to be a separate lithological unit and from which he records no fossils, together with Bed 1 may correspond to sediments at Dinton in the Vale of Wardour which have yielded a *kitchini* Subzone fauna (Casey 1956 ; 231, 1961a ; 564). Jukes-Browne considered that these two beds should possibly be grouped with the Lower Greensand. My reading differs from that of Casey (1961a ; 565) who states that the Gault here rests directly upon the Kimmeridge Clay.

Two fragments of large specimens of *Hoplites* (*H.*) spp. (BMNH., C 6859–60) identified by Newton as *Hoplites benettianus* (1897 ; 70), one of which he figured, are preserved one with and the other without the nacreous shell in a ferruginous brown (weathered) and grey micaceous clayey sandstone. Bearing in mind Newton's remarks (1897 ; 67–8) this lithology indicates the upper part of Bed 4. The specimen figured by Newton (1897 ; 70, pl. 2, fig. 1, BMNH., C 6860) was subsequently made the holotype of *Hoplites pseudodeluci* by Spath (1925a ; 120–123) but due to its crushed state and lack of inner whorls the true nature of it is impossible to determine. Moreover, a specimen from Bed 5 at Badbury Wick shows a closely comparable outer

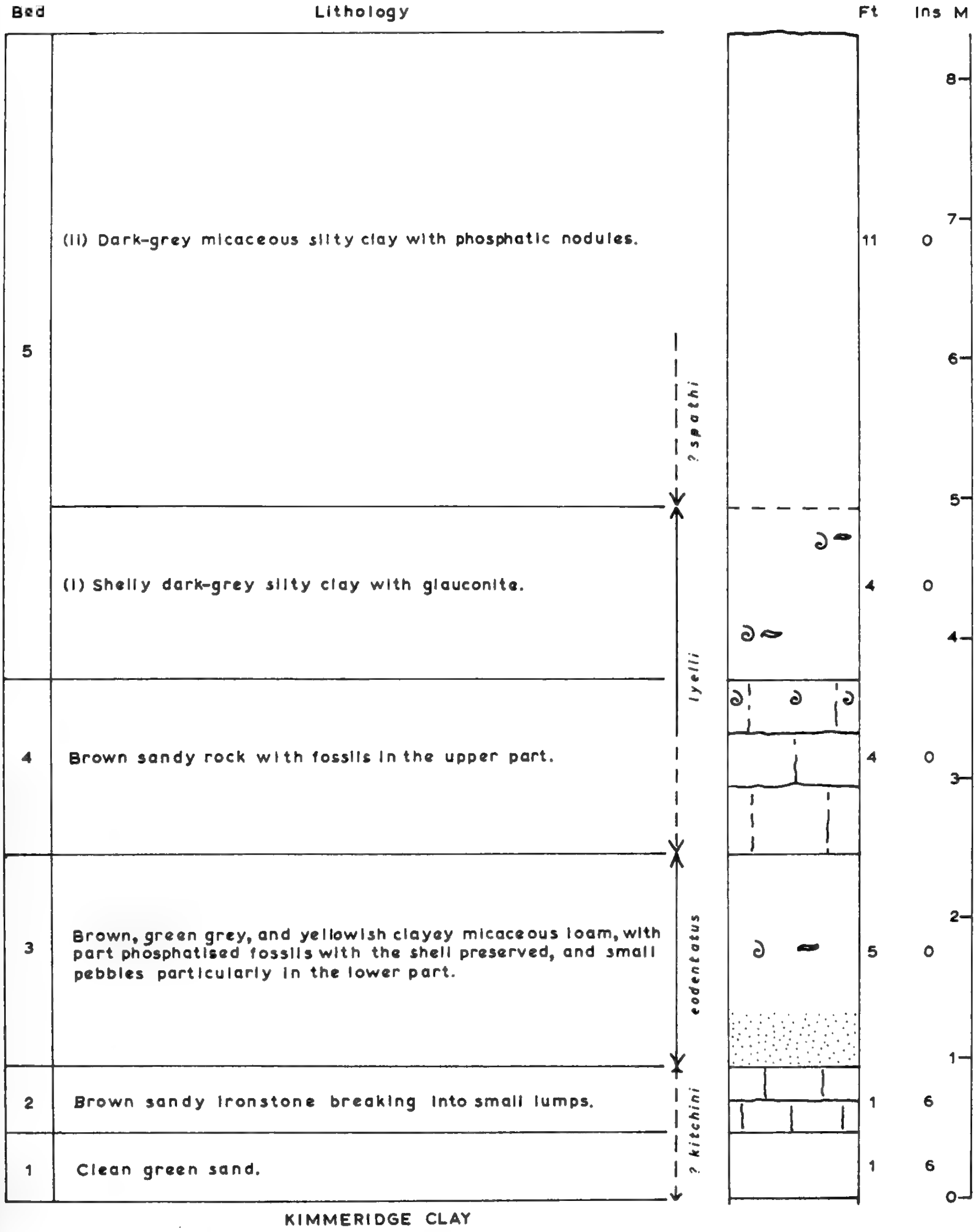


FIG. 24. Section in Albian sediments (after Newton 1897, Jukes Browne 1900, & Osborne White 1923) formerly exposed at the old Okeford Brick & Tile Works, immediately S. of the Okeford Fitzpaine to Shillingstone road, 800 yds E. of St. Andrew's Church, Okeford Fitzpaine, Dorset (ST 81501080).

whorl but the inner whorls are those of *H.* (*H.*) *bullatus* Spath. Bed 4 can definitely be classified with the *lyelli* Subzone even if no specimens of *Lyelliceras, Beudanticeras* or *Protanisoceras* have been preserved. A more typical *lyelli* Subzone fauna was recovered from the lower part of Bed 5. The ammonites described by Newton are preserved in two distinct lithologies, although they all possess remains of the nacreous shell and, except for one, are preserved as partly crushed clay steinkerns. They were re-identified by Spath as follows, to which my own comments are added.

Hoplites interruptus Bruguière

(1) *Hoplites pseudodeluci* Spath (BMNH., C 6864) figured by Spath (1925a ; 121, pl. X, fig. 6) which is preserved in an identical manner to those of Bed 4 from which it probably came.

(2) *Hoplites* sp. transitional between *benettianus* & *paronai* (BMNH., C 6863) according to Spath (1925a ; 115, 118). This specimen which has pyritic inner whorls is crushed ventrally, having come to rest on the sea floor on its venter. It is preserved in fawn clay with glauconitic loam filled burrows. It is specifically indeterminate.

(3) *Hoplites* sp. *benettianus, baylei* group (BMNH., C 6862) (1925a ; 118) probably does not belong to either of these two species.

(4) Newton's figured specimen (BMNH., C 6861), identified by Spath as *Hoplites dentatus* (J. Sowerby) (1925a ; 118), is preserved crushed in glauconitic sandy dark grey clay.

Hoplites splendens J. Sowerby

(5) The two small specimens (BMNH., C 6866–7) were identified by Spath as *Beudanticeras* probably *laevigatum.* They are preserved in exactly the same type of matrix as (2) above.

(6) The larger specimen (BMNH., C 6865) was identified by Spath (1926a ; 147) as *Anahoplites* resembling *A. mimeticus.* It certainly is an *Anahoplites,* preserved in the same type of matrix as (4) above, and its occurrence is discussed below.

Hamites sp.

(7) In his description of *Hamites attenuatus* Spath (1941 ; 611 footnote) referred to the two specimens indicating that they might have been tuberculate and, therefore, generically distinct. A close examination shows that they are both *Protanisoceras* sensu-stricto, one of them (BMNH., C 6868) being *P.* (*P.*) *barrense,* the other (BMNH., C 6869) closely comparable to that species. They are both preserved in the same lithology as (2).

The specimens (Nos. 2, 5, & 7 above) preserved in fawn clay with darker glauconitic burrows are certainly a *lyelli* Subzone assemblage. The two specimens (Nos. 4 & 6) preserved in glauconitic sandy dark grey clay suggest, however, a high *spathi* Subzone age. It has been suggested above (p. 47) that the type of *Anahoplites mimeticus* is a *spathi* Subzone species of *Hoplites* (*H.*) and certainly did not come from the Carstone, of the Isle of Wight. The association of *Anahoplites* of the *osmingtonensis-grimsdalei* group with species of *Hoplites* (*H.*) in the Osmington area of Dorset which Spath

(1926b ; 422) considered to be of *benettianus* Subzone age in fact marks the extreme summit of the *spathi* Subzone (p. 51). This association is also to be seen at the summit of the *spathi* Subzone at Caen Hill, Devizes (p. 60) and probably also at Dilton Marsh.

(ii) VALE OF WARDOUR TO DEVIZES (WILTSHIRE)

(a) Vale of Wardour

No sections in Middle Albian sediments are now to be seen in the Vale of Wardour. A brickyard was worked throughout much of the 19th Century near Ridge and was first described by Fitton (1836 ; 247) and was listed by d'Orbigny (*in* Geinitz 1849) as ' Rudge '. Jukes-Browne (1900 ; 230), Reid (1903 ; 32, 39), and Andrews (*in* Andrews *et al.*, 1903 ; 158) provided further information about this section. Fitton's ' Ammonites rhotomagensis ' suggests *Lyelliceras lyelli* indicating the *lyelli* Subzone but the specimen has not been traced. Both Fitton and Jukes-Browne record *Inoceramus sulcatus* as well as *I. concentricus* from this area and the *varicosum* Subzone is certainly present in marls at the Watercress beds Fovant (Mottram 1957 ; 166, 1961).

The only other sections are a well at Dinton described by Jukes-Browne & Andrews (1891 ; 292 & 1900 ; 228 : and *in* Reid 1903 ; 31, 38), and an exposure of the basal beds in Wardour Park (Reid 1903 ; 34, Mottram 1957 ; 161). Casey demonstrated (1956 ; 231, 1961a ; 565) that the lower part of the sequence in the Dinton well was of *kitchini* Subzone (Lower Albian) age and was overlain non-sequentially by clays of *dentatus* Zone age. However, no fossils have been preserved from the clays and it is impossible to determine their subzonal position. At the present time it is not possible to correlate these three sections with each other, or any section south or north of the Vale.

(b) Maiden Bradley to Devizes

No sections now exist in this area of the outcrop, although brick pits formerly existed at Redford Water, Flintford, Crockerton, and Westbury, all described by Jukes-Browne (1900 ; 235–6). From his account of them it is possible to gain some idea of the lithological sequence in the lower part of the Gault in this area (text-fig. 25).

The Crockerton section was worked in the early part of the 19th Century and yielded to Miss Benett the holotypes of *Ammonites benettianus* and *Ammonites laevigatus* described by J. de. C. Sowerby. It also probably yielded the specimen of *Ammonites monile* mentioned by Fitton (1836 ; 258) and a good deal of the English *lyelli* Subzone ammonites in the various collections used by Spath in his Monograph of the Ammonoidea of the Gault. Until the late 1930's it was the only section known in England to have exposed sediments definitely containing *Lyelliceras lyelli*. There is now a factory on the site.

Unfortunately, there are no detailed accounts either of this section or the others mentioned above. However, Jukes-Browne's account (text-fig. 25) suggests that the sequence is fairly uniform. It appears that ' Division ' 3 definitely yielded *lyelli*

Subzone fossils and by comparison with Caen Hill, Devizes (p. 60), probably was the source of some *spathi* Subzone ammonites also known from Crockerton.

In the Westbury area, the Eden Vale Brickyard described by Jukes-Browne (1900 ; 236) is no longer exposed, but the pit worked by the Westbury Potteries Ltd., has shown sections of the basal beds of the Gault from time to time. Casey (1956 ; 233 : 1961a ; 564) has referred to this section as the Bremeridge pit demonstrating the presence of the *kitchini* Subzone overlain non-sequentially by the basal beds of the Gault of *dentatus* Zone age. This pit is presumably the source of the specimen of '*Anahoplitoides*' from Dilton (Ponsford Colln.) illustrated by Casey (1966 ; 547 text-fig. 207c).

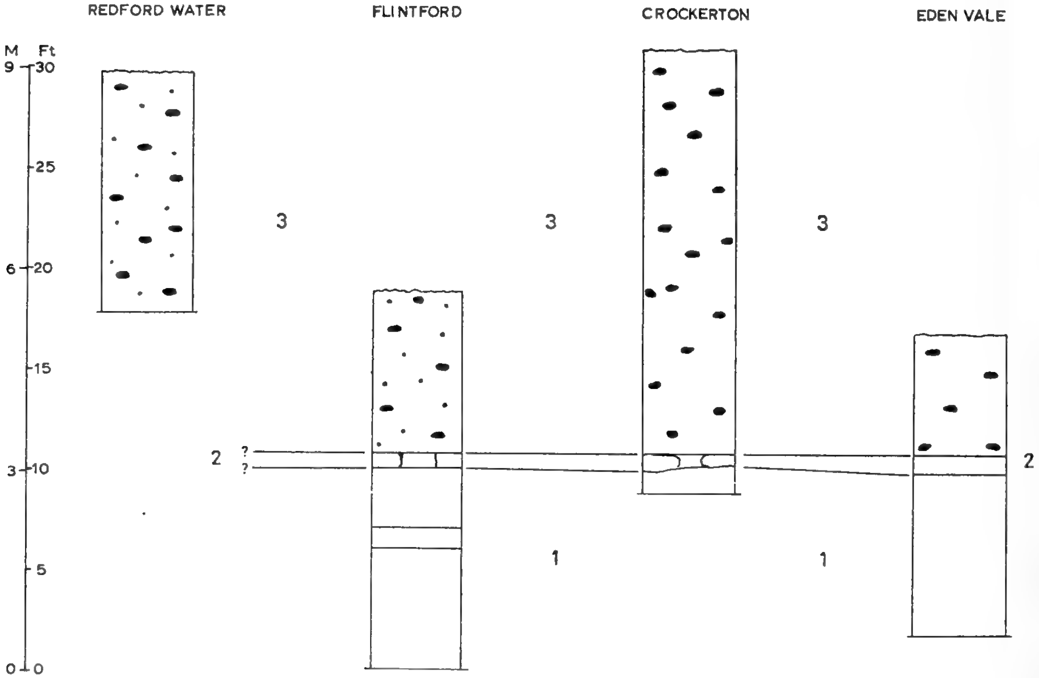
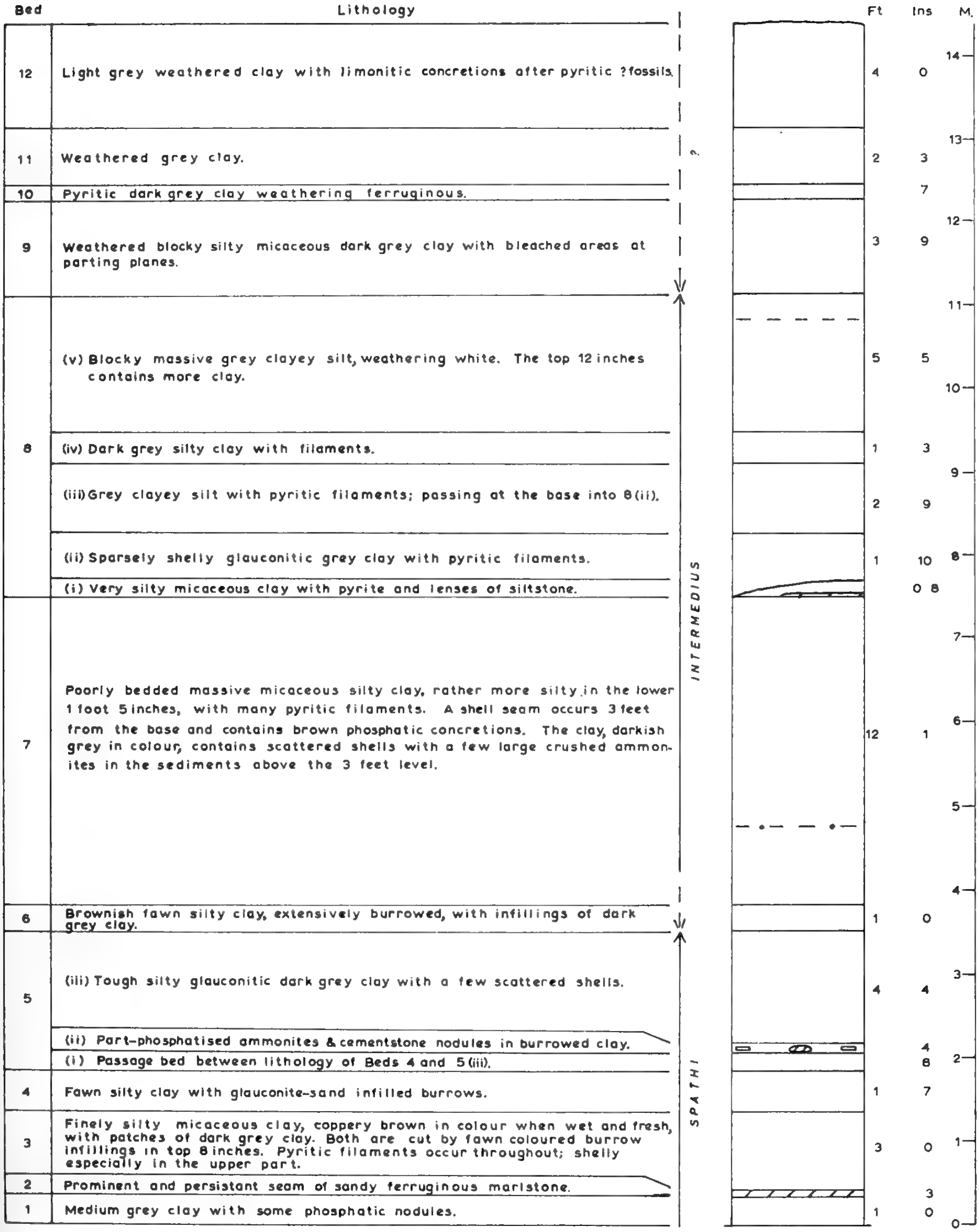


FIG. 25. Possible correlation of sections in the Warminster area of Wiltshire described by Jukes-Browne (1900 ; 235–6).

(c) **Caen Hill, Devizes**

The area W. of Devizes has been a centre of brick and tile production since the latter half of the last century. The sections then exposed at Caen Hill and Dunkirk were described by Jukes-Browne (1892 : 1900 ; 249–250, 252 : 1905 ; 15–16) and Osborne-White (1925 ; 39). Old collections in the British Museum (Nat. Hist.) and Institute of Geological Sciences indicate the presence of the ?*eodentatus*, *lyelli* & *spathi* Subzones in this area, and some of the ammonites were described by Spath (1923–1925).



Bed	Lithology	Ft	Ins
12	Light grey weathered clay with limonitic concretions after pyritic ?fossils.	4	0
11	Weathered grey clay.	2	3
10	Pyritic dark grey clay weathering ferruginous.		7
9	Weathered blocky silty micaceous dark grey clay with bleached areas at parting planes.	3	9
8	(v) Blocky massive grey clayey silt, weathering white. The top 12 inches contains more clay.	5	5
	(iv) Dark grey silty clay with filaments.	1	3
	(iii) Grey clayey silt with pyritic filaments; passing at the base into 8(ii).	2	9
	(ii) Sparsely shelly glauconitic grey clay with pyritic filaments.	1	10
	(i) Very silty micaceous clay with pyrite and lenses of siltstone.		0 8
7	Poorly bedded massive micaceous silty clay, rather more silty in the lower 1 foot 5 inches, with many pyritic filaments. A shell seam occurs 3 feet from the base and contains brown phosphatic concretions. The clay, darkish grey in colour, contains scattered shells with a few large crushed ammonites in the sediments above the 3 feet level.	12	1
6	Brownish fawn silty clay, extensively burrowed, with infillings of dark grey clay.	1	0
5	(iii) Tough silty glauconitic dark grey clay with a few scattered shells.	4	4
	(ii) Part-phosphatised ammonites & cementstone nodules in burrowed clay.		4
	(i) Passage bed between lithology of Beds 4 and 5(iii).		8
4	Fawn silty clay with glauconite-sand infilled burrows.	1	7
3	Finely silty micaceous clay, coppery brown in colour when wet and fresh, with patches of dark grey clay. Both are cut by fawn coloured burrow infillings in top 8 inches. Pyritic filaments occur throughout; shelly especially in the upper part.	3	0
2	Prominent and persistant seam of sandy ferruginous marlstone.		3
1	Medium grey clay with some phosphatic nodules.	1	0

FIG. 26. Section in Gault at Messrs Hills of Swindon Ltd's Caen Hill brickyard, *c.* 180 yds ENE. of the Olive Branch Inn, in the W. side of Caen Hill, Rowde, Wiltshire (ST 98246135).

The presence of the *eodentatus* Subzone is suggested by *Cleoniceras*? *devisense* Spath (1923a ; pl. IV, fig. 7a, b) and *Hoplites cunningtoni* Spath (1923a ; 109, pl. VIII, fig. 8a, b). Specimens of *Cleoniceras* (*C.*) are known from the *eodentatus* Subzone in France but they are very rare and Mrs. P. Jennings has obtained one undoubted *lyelli* Subzone example from Badbury Wick. *Hoplites cunningtoni* is a late *Otohoplites*, a genus also known to occur in the *eodentatus* Subzone elsewhere in southern England and in France. The *lyelli* Subzone is indicated by ammonites such as *Beudanticeras laevigatum* and *Hoplites* (*H.*) *baylei*, and the *spathi* Subzone sediments are still exposed. The most important result of the present study is the discovery of a reasonably thick sequence of sediments of *intermedius* Subzone age at Caen Hill. This occurrence and that at Didcot (p. 63) represents the first time that the subzone has been recorded in this area of the outcrop in Wiltshire and Berkshire.

Spath (1943 ; 745) followed Osborne-White (1925 ; 39) in considering that the *lautus* Zone was present in the Gault of the Devizes area. This opinion was based on material obtained by Cunnington from the long since vanished brickpit at Dunkirk. However, Jukes-Browne (1900 ; 252, 1905 ; 16) lists *Inoceramus sulcatus* as well as *I. concentricus* and it is quite possible that this indicates the *orbignyi* Subzone. This particular record of the *lautus* Zone should be treated at this time with caution.

The brick pit at Caen Hill is still in work. It was formerly owned by the Devizes Brick & Tile Co. Ltd., but now by Messrs Hills of Swindon Ltd. It is situated on the W. side of Caen Hill and has been worked eastwards into the hill exposing the section given in text-fig. 26. A dip of 3° towards the E. is present. The *lyelli* Subzone sediments are seldom exposed now, and no satisfactory section has been seen by the writer. It is possible that 'Division' 4 (text-fig. 25) of the Warminster-Devizes area is the same as Bed 2 of my section. If this is the case then the pre-*spathi* Subzone sediments are thick at Caen Hill.

Beds 1 to 5 contain *Hoplites* (*H.*) spp., such as *H.* (*H.*) *dentatus* and *H.* (*H.*) *maritimus*, indicating the *spathi* Subzone together with a good benthonic fauna of bivalves and gastropods. A shell seam 3 feet (0·914 m.) above the base of Bed 7 contains crushed evolute *Anahoplites* of *grimsdalei* type and ribbed forms comparable to *A. evolutus* and *A. osmingtonensis* together with occasional specimens of *Hoplites* (*H.*). This association continues through part of the remainder of Bed 7, and these sediments are here considered to be a little later than the concretions in the Osmington area, Dorset (p. 51) which are classified with the uppermost part of the *spathi* Subzone and may be represented at Devizes by Bed 6 and the basal 3 feet of Bed 7. However, at Devizes in Bed 7 the situation is reversed, *Hoplites* (*H.*) being here subordinate to *Anahoplites*, and so these clays are classified with the basal part of the *intermedius* Subzone. This level is, therefore, closely comparable to the basal part of the *intermedius* Subzone in the Départements of the Meuse (p. 88) and Aube (p. 93). In the Weald, this interval does not contain ammonites.

The remainder of Bed 7, and particularly 8, contains a typical *intermedius* Subzone fauna with crushed *Anahoplites praecox* and *A. intermedius*. No fossils were obtained from Beds 9–11 and their subzonal classification is, therefore, unknown at this time.

(iii) DEVIZES TO THAME (OXON)

(a) **Badbury Wick (Wiltshire)**

There is no information available at the outcrop between Devizes and the Swindon area, a distance of about 18 miles (text-fig. 18). Messrs Hill's of Swindon Ltd's pit at Badbury Wick has shown a section in *spathi* Subzone sediments for some years, but in 1967 the pit was deepened and exposed sediments of *lyelli* Subzone age. The sequence now exposed is shown in text-fig. 27. Although this is the first time in this century that a *lyelli* Subzone sequence has been well exposed in Wiltshire, it is apparently different from that of Caen Hill and further south-west (text-figs. 26 & 25). A working near the present pit was mentioned by Ramsey, Aveline & Hull (1858 ; 33).

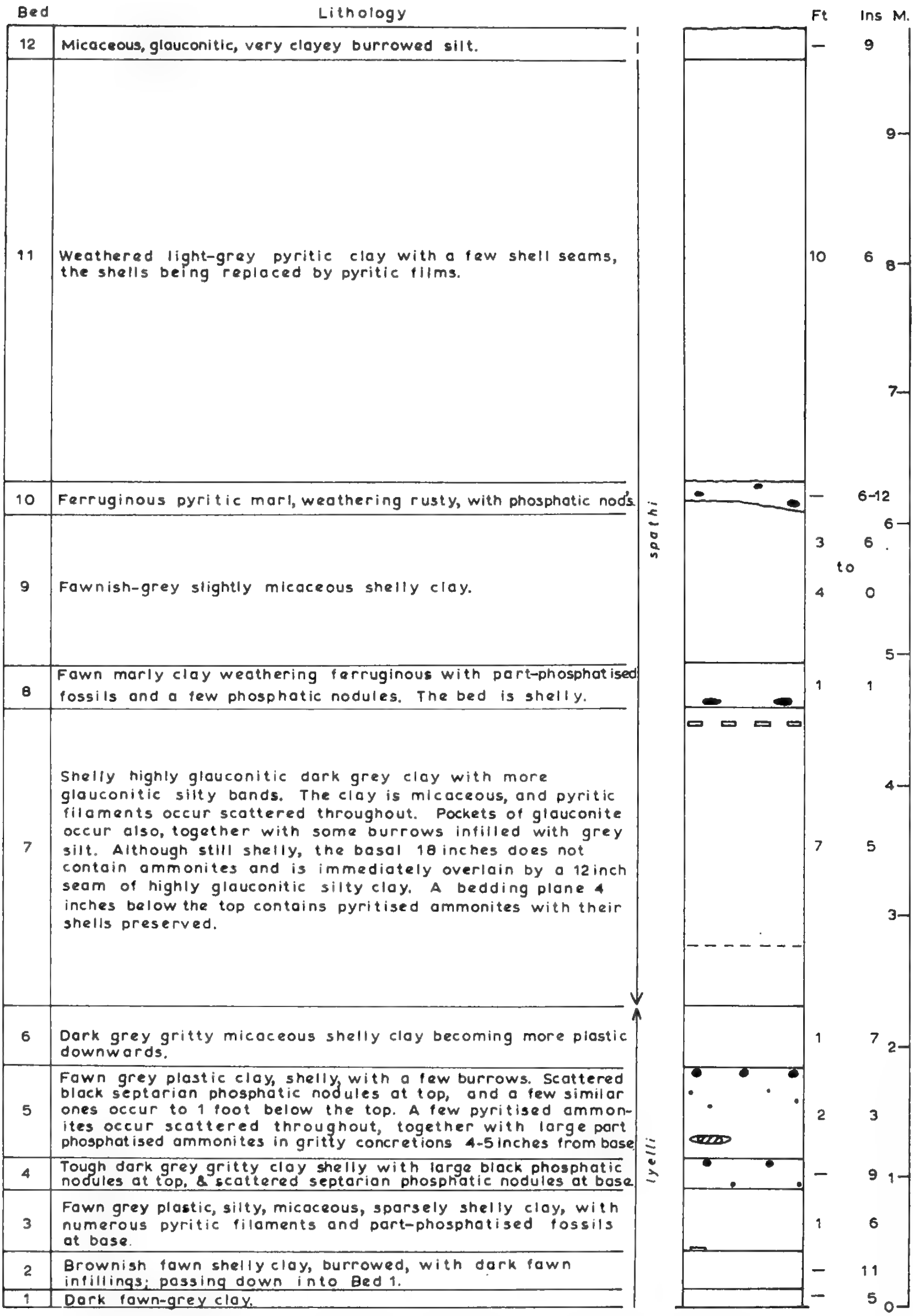
Beds 1 to 6 contain a typical *lyelli* Subzone fauna but in contrast to Small Dole (p. 38) *Lyelliceras lyelli* and *Brancoceras* spp. occur only infrequently and the bulk of the fossils are crushed. The commonest ammonites are the heteromorphs such as *Protanisoceras* (*P.*) *barrense* and *P.* (*P.*) *alternotuberculatum* together with *Beudanticeras laevigatum*, and *Hoplites* (*H.*) spp. The facies is a shelly one, albeit sparsely in places, with in general a better developed benthos than that seen in Sussex. Ammonites are apparently rare in Bed 6 which otherwise contains very well preserved but fragile bivalves and gastropods. That it still belongs to the *lyelli* Subzone is indicated by the occurrence of *Beudanticeras* spp. as well as *Hoplites* (*H.*) spp.

Beds 7 to 11 are classified with the *spathi* Subzone. Bed 7 shows the major change in the ammonite fauna which marks the base of the *spathi* Subzone, and these now consist of species of *Hoplites* (*H.*) such as *H.* (*H.*) *dentatus* and *H.* (*H.*) *maritimus* sp. nov. associated with the bivalve *Inoceramus concentricus* in shell seams. The benthonic fauna is very reduced in comparison with the *lyelli* Subzone sediments below. Bed 8 contains the same fauna with individuals partly phosphatised with the shell, while in Bed 9 the fossils are again crushed flat. In Beds 10 and 11 the shells are replaced by pyrite and the non-ammonite element of the fauna becomes uncommon. No fossils have been found in Bed 12 and its age is uncertain.

The lithological sequence in the *spathi* Subzone is quite different from that of Caen Hill, Devizes (text-fig. 26), where there is no pyritic facies in any part of the *spathi* Subzone sequence and a good benthos is present throughout. The sequence at Badbury in this Subzone is surprisingly reminiscent of that exposed in the Nyewood-Selborne area of the western margin of the Weald (Owen 1963a). However, there, the situation is somewhat reversed, the pyritic facies encompassing the sediments up to and including the two ferruginous marly bands, the shelly facies prevailing in the higher beds.

(b) **Badbury to Thame**

The Gault outcrop in the Vale of White Horse (Berkshire) has been discussed principally by Hull & Whitaker (1861), Jukes-Browne (1900 ; 268) and Arkell (1947a ; 167–9). No sections now exist either at Uffington or in the area N. of Childrey. Arkell recorded the discovery of specimens of *Dimorphoplites* by Mr. C. W. Wright in



Bed	Lithology	Ft	Ins
12	Micaceous, glauconitic, very clayey burrowed silt.	—	9
11	Weathered light-grey pyritic clay with a few shell seams, the shells being replaced by pyritic films.	10	6
10	Ferruginous pyritic marl, weathering rusty, with phosphatic nods.	—	6-12
9	Fawnish-grey slightly micaceous shelly clay.	3 to 4	6 0
8	Fawn marly clay weathering ferruginous with part-phosphatised fossils and a few phosphatic nodules. The bed is shelly.	1	1
7	Shelly highly glauconitic dark grey clay with more glauconitic silty bands. The clay is micaceous, and pyritic filaments occur scattered throughout. Pockets of glauconite occur also, together with some burrows infilled with grey silt. Although still shelly, the basal 18 inches does not contain ammonites and is immediately overlain by a 12 inch seam of highly glauconitic silty clay. A bedding plane 4 inches below the top contains pyritised ammonites with their shells preserved.	7	5
6	Dark grey gritty micaceous shelly clay becoming more plastic downwards.	1	7
5	Fawn grey plastic clay, shelly, with a few burrows. Scattered black septarian phosphatic nodules at top, and a few similar ones occur to 1 foot below the top. A few pyritised ammonites occur scattered throughout, together with large part phosphatised ammonites in gritty concretions 4-5 inches from base.	2	3
4	Tough dark grey gritty clay shelly with large black phosphatic nodules at top, & scattered septarian phosphatic nodules at base.	—	9
3	Fawn grey plastic, silty, micaceous, sparsely shelly clay, with numerous pyritic filaments and part-phosphatised fossils at base.	1	6
2	Brownish fawn shelly clay, burrowed, with dark fawn infillings; passing down into Bed 1.	—	11
1	Dark fawn-grey clay.	—	5

FIG. 27. Section in Gault at Messrs Hills of Swindon Ltd's Badbury Brickworks, W. of Day House Lane, 200 yds SW. of Badbury Wick House, Chiseldon, Wiltshire (SU 18828160).

the Childrey section (1947a ; 169) and I have been kindly allowed to re-examine them. They are, as identified by Mr. Wright, a specimen of *Dimorphoplites biplicatus* (C.W.W., 9762) and a specimen of *D. glaber* (C.W.W., 9761). Together they indicate an horizon somewhere between the base of the *meandrinus* and the top of the *daviesi* Subzones.

Nine miles ENE. of the Childrey brickyard is the famous section at Culham (Oxon). This pit situated approximately 200 yds. N. of the River Thames, 425 yds. E. of the road bridge over Culham Cut and 700 yds. SSW. of Culham College, Culham, Oxon (SU 51159487) was in work from the middle of the last century until the late 1940's. It has been described by Phillips (1860 ; 548–550, 1871 ; 426–428), Jukes-Browne (1900 ; 268–9, 1908 ; 13–14), Osborne-White (1904 ; 300–304), Treacher (1908 ; 548–550) Pringle (1926 ; 101–2), and Arkell (1947a ; 169–170). Osborne-White's account paved the way for the more detailed description given by Pringle, but the section is now badly degraded and overgrown and it is not possible to confirm or deny Pringle's subzonal grouping repeated by Spath (1943 ; 745–6). Neither is it possible to make a direct comparison with the sequence at Badbury Wick. From the list of fossils collected by Osborne-White (Jukes-Browne & Osborne-White 1908 ; 14) from Bed 3 (= Bed 1 of Pringle 1926) it seemed possible that either the *mammillatum* Zone was present or possibly the *eodentatus* Subzone. *Douvilleiceras* does range up into the *lyelli* Subzone but is rare in that Subzone in England except at Shere. Casey, who has revised the identification of the ammonites, is in favour of a basal *dentatus* Zone age (1961a ; 565), and it is significant that Osborne-White records ' Hoplites interruptus ' just above Bed 2 (1904 ; 304). Beds 2 and 3 of Pringle were classified by him with the ' *benettianus* Subzone ', and Beds 4 and 5 with the *spathi* Subzone. From the ammonites preserved in the various collections it is apparent that both the *lyelli* & *spathi* Subzones are present.

It is interesting to note that in the remnant of Gault formerly exposed at the abandoned Chawley Brickyard, Hurst Hill (SP 47550420), Cumnor, Pringle (1926 ; 98, 103) recorded ammonites which he considered to be characteristic of Bed 4 at Culham. This section was situated 7 miles NNW. of Culham and has also been discussed by Arkell (in Richardson, Arkell & Dines 1946 ; 104). If the equivalents of Beds 1 to 3 are truly absent in this outlier, this is of some palaeogeographic significance.

The only other useful information yielded by this area is provided by two borings, Nos 6 and 21, drilled for the new Central Electricity Generating Board Didcot Power Station (SU 51289174 & 51339194 respectively). Together, the fragments of these two cores show the following features in the sequence. The *orbignyi* Subzone is in a Gault facies, indicated in Boring No. 21 by a fragment of core containing *Inoceramus sulcatus* preserved in mid-grey micaceous silty clay with lighter coloured burrows from a height of 122 feet 6 inches (37·34 m.) above the base of the Gault. The *intermedius* Subzone is also present at a height of 68 feet (20·73 m.) above the base of the Gault in Boring No. 6 where the core yielded a crushed specimen of *Anahoplites praecox* preserved with a pyrite-replaced shell in silty brownish grey clay (cf. Bed 8 ii at Caen Hill, Devizes, p. 60). Boring No. 21 shows that the *spathi* Subzone with *Hoplites* (*H.*) spp. is certainly present in the sequence between 42 feet 6 inches and 17 feet 6 inches (12·95–5·33 m.) above the base of the Gault. The pieces of core preserved are from 42 feet 6 inches, 35 feet, 32 feet 6 inches, 30 feet and 22 feet 6 inches above the base of the Gault and the lithology consists essentially of dark fawn-grey silty clay with shelly fossils. There is no need to emphasise that the cores are very incomplete and that no Subzonal limits can be deduced.

Sections in the Gault were formerly exposed in the area of Thame (Oxon) and mentioned by Davies (1899b ; 160). The only information about the zonal stratigraphy is the comment by Spath that at Priestend (SP 691055) the lower Gault, which was exposed for at least 40 feet (12·16 m.), contained plentiful impressions of ammonites of the *dentatus* Zone often of unusually large size (1943 ; 746).

(iv) THAME TO LEIGHTON BUZZARD (BEDFORDSHIRE)

The published information on the stratigraphy of the Gault between Thame and Leighton Buzzard, a distance of about 19 miles is again not particularly satisfactory. This is due mainly to the paucity of good exposures and, to a certain extent, to the controversies which have tended to colour the accounts. It is apparent that deposits of Middle Albian age are present throughout the area, although they are greatly reduced in thickness in comparison with the alleged sequence at Thame. The Gault rests in this area either upon the Kimmeridge Clay, Portland, Purbeck, or Lower Greensand deposits.

(a) Long Crendon (Bucks.)

No section in the Gault now exists at Long Crendon, which is situated about 2½ miles towards the NW. of Thame, but sections in this outlier were described by Jukes-Browne (1900 ; 277), Davies (1899a ; 22), Lamplugh (1922 ; 40–44), and Kitchin & Pringle (1922 ; 164–5). The sequence has also been discussed by Kitchin & Pringle (1921a ; 62 : 1922 ; 284-5), Spath (1943 ; 746) and Casey (1961a ; 569). Kitchin & Pringle (1921a ; 62 : 1921b ; 174 see also Spath 1943 ; 746) considered that the Upper Gault rested directly upon Purbeck Beds here but the detailed evidence to substantiate this conclusion was not given.

On three counts it appears certain that Lower Gault is present. It is important to note that Davies (1899a ; 22 : 1899b ; 161) recorded *I. concentricus* from the 8 feet of Gault then exposed, but no ammonites were discovered and, therefore, the exact age still remains uncertain. In the main outcrop to the S., the lower part of the Upper Albian is quite fossiliferous with *orbignyi* Subzone ammonites and the ubiquitous *Inoceramus sulcatus*. Also Lamplugh (1922 ; 40–44) demonstrated that a thin development of Shenley Limestone was present below the Gault (see also Casey 1961a ; 569). It seems probable, therefore, that Davies' record of *I. concentricus* is correct, that these clays are of Middle Albian age, and that there is no overlap of Upper Gault in this area as Kitchin & Pringle held.

(b) Haddenham (Bucks)

Although no section exists in the main outcrop between Thame and Aylesbury, two ammonites are preserved in the Buckinghamshire Country Museum, Aylesbury, which are labelled Haddenham. Although the circumstantial evidence indicates that this is the Buckinghamshire Haddenham, this locality is not on the Gault whereas the Cambridgeshire locality is. With this reservation in mind these ammonites (W. J. Welford Colln., accession No. 176–24) are here identified as *Euhoplites* aff. *meandrinus* and *Dimorphoplites* aff. *niobe* (the late mutation known from the upper nodule bed of Bed IV at Folkestone). Both are preserved as incomplete blackish phosphatic casts without the shell, and indicate a distinct nodule bed or clays with scattered nodules of late *loricatus* Zone age within the Gault of this area.

Davies (1899a ; 55–56) disputes that the Gault was exploited S. of Haddenham Low situated about 1½ miles NE. of Haddenham (See also Balance 1964 ; Map 2). The main outcrop, however, is at no great distance to the E. of Haddenham. No information has been published about Middle Albian sediments in the 6 mile tract of country between Haddenham and Aylesbury, although Balance (1964 ; 396) has reported the Lower Gault to be present throughout the area.

(c) **Aylesbury (Bucks)**

The basal part of the Gault was formerly exposed in the Walton Cutting on the Metropolitan railway line (L.T.E.). The cutting extends SSE. from the bridge (SP 823130) carrying the B 4443 (Stoke Road) over the railway line, Walton, Aylesbury. It was described by Pringle & Chatwin (*in* Sherlock 1922 ; 9) who reported that the basal bed of the Gault rests directly upon the Portland Beds. No

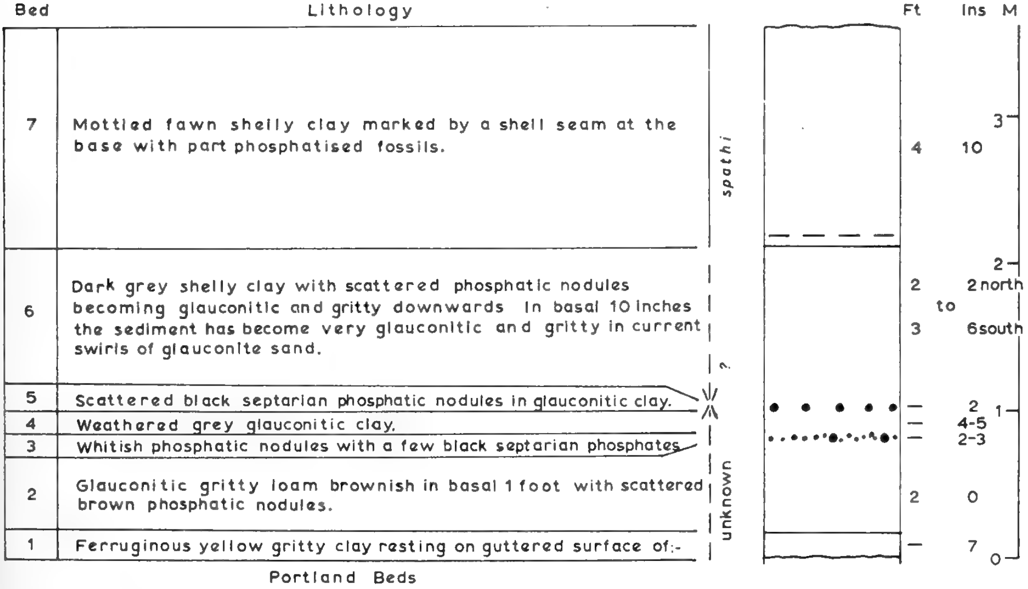


FIG. 28. Section exposed in trench dug by Messrs S. A. Leach & Co. along the field boundary extending for about 150 yds from SP 8235012425 to SP 8245012333, approximately midway between the B 4443 Stoke Mandeville road and the L.T.E. Metropolitan railway line from Aylesbury to Stoke Mandeville, Aylesbury, Buckinghamshire.

fossils were found, and indeed, the only fossils recorded from the lower part of the Gault in this area were obtained from a nodule bed stated to occur at about 10 feet (3·04 m.) above the base of the formation (Pringle & Chatwin *in* Sherlock 1922 ; 9). This bed has yielded an upper Albian fauna (Jukes-Browne 1900 ; 278 whose inclusion of this horizon in the Lower Gault was an error : C. W., & E. V. Wright 1939 ; 115–116 : Spath 1943 ; 746). Kitchin & Pringle took this fact to confirm an extreme conclusion, stating that the Lower Gault had been overstepped by the Upper Gault in this area (1922 ; 164–5). Pringle & Chatwin (*in* Sherlock 1922 ; 8) were more objective in that they pointed out that there was no evidence at that time for the presence of the Lower Gault. Spath (1943 ; 746) although vague was a little more cautious.

Important new information, demonstrating the presence of the *spathi* Subzone in the lower beds of the Gault, was obtained by the writer from a trench dug by Messrs. S. A. Leach & Co., during the laying of sewer pipes in January 1967. This very temporary section was situated only a few hundred yards S. of the Walton Cutting and the sequence is shown graphically in text-fig. 28.

No fossils were obtained from Beds 1–5 and their exact age is uncertain. Bed 6 yielded a small bivalve fauna consisting mainly of a small *Ostrea* and a few specimens of *Nucula* together with a single example of *Neohibolites minimus*. The shell seam at the base of bed 7 contains numerous *Inoceramus concentricus* and some partly-phosphatised *Hoplites* (*H.*) with simple *dentatus* ribbing, all with the nacreous shell. The species include *H.* (*H.*) *dentatus* and *H.* (*H.*) cf. *maritimus* some being quite large —6 to 8 inches in diameter, and the specimens of *I. concentricus* are also of large size. A few specimens of *Dentalium* and *Nucula* also occur. This same faunal assemblage occurs in the remainder of Bed 7 but it is crushed flat. The ammonites indicate the lower part of the *spathi* Subzone, and it is unfortunate that no higher levels were exposed at this locality.

Another ‘ cut and fill ’ trench exposing higher beds was excavated in February 1967 in the area approximately 1475 yds a little S. of E. of the trench described above. This trench was dug to a depth of 6 feet and extended from a point about 600 yds NNE. of Stoke Grange to a point about 400 yds. ENE. of Stoke Grange (SP 8357512340 to SP 83801190), to the NE. of the A 413 (Wendover Road), Aylesbury. The trench was apparently cut in the direction of strike and exposed weathered dark blue-grey clay with small buffish phosphatic nodules and patches. No determinable fossils were found except at the field boundary (SP 83621225) where two very badly preserved fragments of ammonites were seen. One was comparable to *Dimorphoplites*, the other an equally poor fragment of *Euhoplites*. Together they suggest an horizon below that exposed in the trenches along the A 41 in the Aston Clinton area described by Wright & Wright (1939) which at certain points yielded an *orbignyi* Subzone fauna.

There is no doubt that the thickness of sediments below the *orbignyi* Subzone nodule bed in the Aylesbury area exceeds 10 feet (3·04 m.) and it is likely that there is a good deal more.

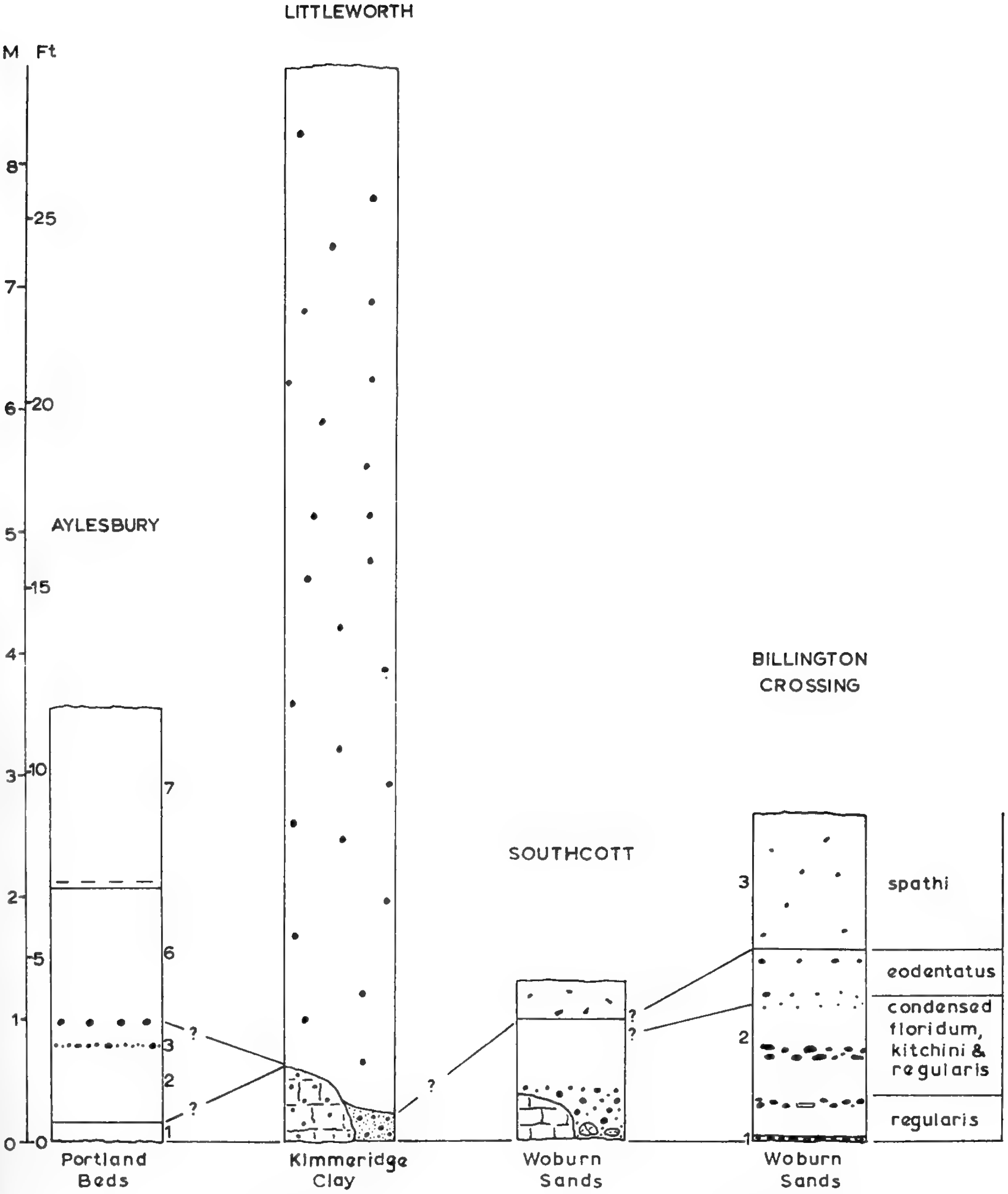


FIG. 29. Correlation of sections between Aylesbury and Leighton Buzzard.

(d) **Aylesbury to Leighton Buzzard (Beds.)**

At the outcrop between Aylesbury and Leighton Buzzard, a distance of about 10 miles, there is very little information about the stratigraphy of the Gault except for borehole records e.g. Jukes-Browne (1900). A brickyard at Littleworth (SP 881233), Wing, Buckinghamshire, described by Jukes-Browne (1900 ; 278), Davies (1901 ; 140, 1915 ; 92) and Lamplugh (1922 ; 89–90), is now badly degraded, Lamplugh (1922 ; 40) records *Inoceramus concentricus* from the ' 10 to 15 feet of shattery dark-blue Gault . . . ' which was estimated to lie at about 10–12 feet (3·04–3·65 m.) above the Gault basement bed. Specimens from the Lamplugh Collection are preserved in the British Museum (Nat. Hist.) (BMNH L 59863–8) and indicate that these sediments are of Middle Albian age. There is, therefore, over 27 feet (8·22 m.) of Middle Albian sediments in this area resting upon a thin development of Shenley Limestone which in turn rests upon Kimmeridge Clay. It is significant that *Neohibolites minimus* is apparently plentiful here, in contrast to the Aylesbury area.

In the short distance (1⅓ miles) between Littleworth and Southcott, Buckinghamshire (SP 90052452), the Woburn (or Leighton) Sands intervenes below a similar development of Shenley Limestone (Lamplugh 1922 ; 38). Moreover, the Shenley Limestone lenticle forms the base of a 2 to 3 foot bed of loam with phosphatic nodules below the Gault. These phosphatic nodule beds form an important feature at the base of the Gault at Leighton Buzzard, Bedfordshire, where they are essentially of late *tardefurcata* and early *mammillatum* Zone age, with the *eodentatus* Subzone of the Middle Albian at the top. The equivalent of the Lower Gault represents the *spathi*, *intermedius*, and *niobe* Subzones. A description of the Albian sediments in the Leighton Buzzard area is to be presented elsewhere, and at a later date, an account of the Middle and Upper Albian sediments of East Anglia will also be given. This region flanking the London platform and the North Sea area, although of considerable stratigraphical interest, does not contribute any fundamentally new knowledge to the ammonite zonal sequence of the Anglo-Paris Basin, the stabilization of which is the main purpose of this paper.

E. **Borehole Evidence**

There are now a great number of deep boreholes in southern and eastern England drilled principally in the search for water, oil and gas, and in Kent, for coal. To this number can be added a few purely exploratory borings. These have provided a good picture of the post Tertiary configuration of the Palaeozoic surface, and of the stratigraphy of the Mesozoic sediments which have buried it (e.g. Kent 1949, Falcon & Kent 1960). It is now apparent that Albian sediments underlie the Chalk throughout the area covered by that formation in England. In this work, the Wessex basin, and the area of the London Basin, Essex, and East Kent only will be considered. Borings in these areas have yielded important new information, including strong indications of post Jurassic to basal Upper Albian faulting along part of the Thames axes, certainly E. of London (Owen, *in press*).

(i) HAMPSHIRE BASIN

(a) Winchester District

The only borings through the Gault which have yielded information of zonal value are situated in the Winchester area and were drilled for the Gas Council by the British Petroleum Co.

Winchester No. 1 Chilcomb, Hants. (SU 50172830)

The division between the Upper Greensand and Gault is taken at a depth of 310 feet (94.48 m.) and the Gault is 250 feet (76·2 m.) thick. Coring was not continuous and neither the thickness of Upper Albian sediments nor the exact Subzonal boundaries in the Middle Albian sediments could be determined. Nonetheless, the fragments of core show that between 426 feet 6 inches and 438 feet (128·16 m.–133·50 m.) the essentially dark-grey silty and shelly micaceous clays contain *Inoceramus sulcatus* indicating a lower Upper Albian age (*cristatum* or *orbignyi* Subzones). There is then a gap of 41 feet (12·49 m.) in cored samples.

At 479 feet (146 m.) depth, the mid-grey shelly silty micaceous clays are of Middle Albian, *intermedius* Subzone age, and the sequence contains *Anahoplites* of the *intermedius* group to a depth of 490 feet 2 inches (149·40 m.), a level 69 feet 10 inches (21·28 m.) above the base of the Gault. The *spathi* Subzone with crushed *Hoplites* (*H.*) spp. is certainly present at a depth of 501 feet 1 inch (152·73 m.), and the sediments from this level to a depth of at least 513 feet 3 inches (156·43 m.) consist of alternating fawn and mid-grey, silty micaceous shelly clay bands. At 521 feet (158·80 m.) the nacreous shells are found to be completely replaced by pyritic films, and this pyritic facies is a feature of the sequence down to the base of the Gault at 560 feet (160·68 m.). Crushed *Hoplites* (*H.*) spp., are present in the predominantly fawn-grey silty micaceous clay of the lower part of the Gault to a depth of 526 feet (160·32 m.) but no ammonites have been found in the remaining 34 feet (10·36 m.). The basal 5 feet (1·52 m.) of the Gault is very pebbly, becoming a pebbly loam at 559 feet (170·38 m.) depth. The Lower greensand underlies the Gault.

Winchester No. 4 Itchen Valley, Hants. (SU 51133001)

This boring produced only poor chip and core returns during its traverse of the Gault. *Hoplites* (*H.*) sp. with *dentatus* ribbing was found at 11 feet 6 inches (3·50 m.) above the base of the Gault, at a depth of 1258 feet 6 inches (383·43 m.). This was preserved in an identical manner and lithology to that seen at the same level in Winchester No. 1.

Winchester No. 5 Twyford, Hants. (SU 50252712)

Only a few cored samples were recovered from the chipped sequence. At a depth of 963 feet 8 inches (293·52 m.) only 7 feet 4 inches (2·235 m.) above the base of the Gault, a crushed heteromorph ammonite with indications of lateral spines was found. This is almost certainly a *Protanisoceras* (*P.*) and indicates the *lyelli* Subzone.

(b) Relationship of Winchester to Portsdown, the Weald, and the Isle of Wight

The correlation of the Gault sequence in the Winchester No. 1 boring with those of Selborne, Nyewood, and Compton Bay, is shown as far as is possible in text-fig. 30. The lithological succession shown by the Winchester borings is comparable to that of the outcrop at Selborne on the western border of the Weald. They both show in the *spathi* Subzone sediments a lower pyritic facies overlain by clays in which the shells are preserved and in which a good benthos is present (Owen 1963a ; 43–44). Moreover, at Bradshott Hall clays of basal Upper Albian age were seen by Osborne-White (1910 ; 20) to overlie clays classified with the ' interruptus Zone ' in Jukes-Browne's sense. The lower clays could be of *intermedius* Subzone age (Owen 1963a ; 51).

From the map given in text-fig. 18, it is apparent that the borings at Winchester and Portsdown, and the natural exposure at Culver Cliff in the Isle of Wight all lie roughly on the same NNW–SSE. line. The total thickness of the Gault at Winchester No. 1 is 250 feet (76·2 m.) compared with 163 feet (49·68 m.) at Portsdown situated 15 miles to the SSE., and just over 100 feet (30·4 m.) at Culver Cliff. No information on the degree of ammonite subzonal representation in the chipped sequence of the British Petroleum Portsdown boring in known (Taitt & Kent 1958), but, in Hampshire, West Sussex, and in the Isle of Wight, there is a similar change in facies within the *spathi* Subzone from pyritic clays below to shelly clays above. Superficially it seems that as one proceeds SSE. from Winchester the decreasing thickness of the sediments suggests the shallowing of a basin in this direction. However, at Winchester the lower part of the Upper Albian is represented by at least 128 feet (39·01 m.) of silty Gault, more than the total thickness of the Gault at Culver Cliff in which the lower part of the Upper Albian is also represented (p. 43). The decrease in thickness of Middle Albian sediments from Winchester to Culver Cliff is, therefore, not particularly well marked. It is also apparent that the detailed lithological sequence in the *spathi* Subzone sediments which is recognisable for a distance of over 35 miles at the outcrop in the south western part of the Weald is totally different from that of the Isle of Wight (text-fig. 30). The common distribution of the pyritic facies reflects the presence of a common sea environment which affected different depositional areas, and it is apparent from the pre-Albian sequence at Portsdown that this area formed a ridge separating the area of the south western Weald from that of the Isle of Wight.

The Lower Greensand in the south-western area of the Weald thins rapidly towards Portsdown (Falcon & Kent 1960). Continuing SW. into the Isle of Wight the Lower Greensand as a whole thickens from Redcliff NE. of Sandown to reach a known maximum in the southern part of the Island and this increase in thickness can be correlated with an increase in finer grade sediments. It is apparent from the distribution of *lyelli* and *spathi* Subzone sediments that the Portsdown ridge affected Middle Albian sedimentation. By Middle Albian times this submarine feature consisted of an elongated swell (text-fig. 52), and its extent can be determined by the presence of the ' Iron Grit ' beneath the Gault and the absence of *tardefurcata* and *mammillatum* Zone phosphatic nodule beds. The *Lyelli* Subzone sediments are

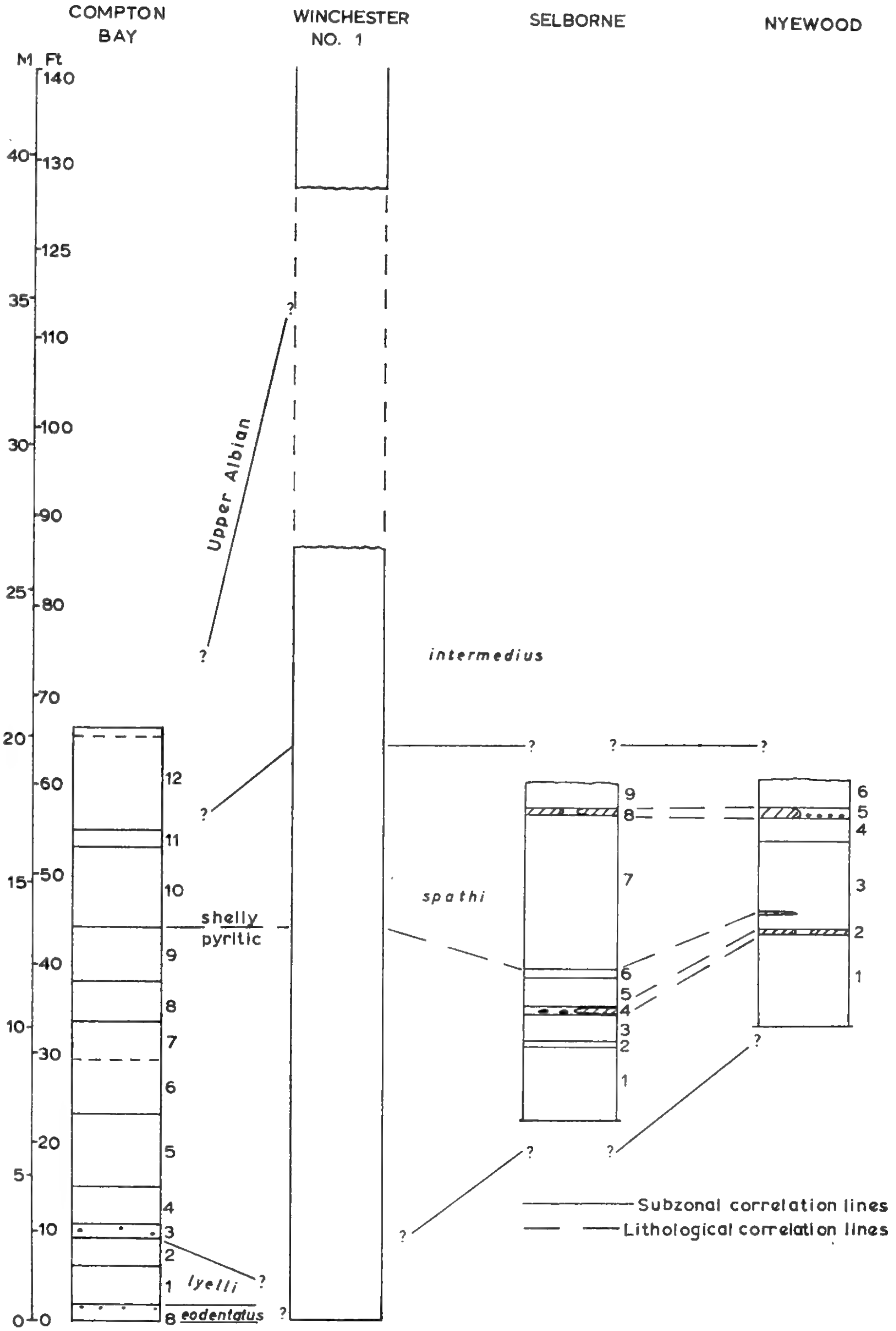


FIG. 30. Provisional comparison of the Winchester No. 1 boring with the outcrop to the south and east.

probably present at Winchester, and may well be present in the unexposed lowest part of the Gault at Selborne in the western Weald in view of the close similarity which exists in the detailed lithological sequence between this locality and the Horton Clay pit, Upper Beeding (text-fig. 14). Sediments of this Subzone are known to intervene between the ' Iron Grit ' and the *spathi* Subzone sediments along the outcrop between Nyewood and Storrington, but they are thin and gritty (p. 34). In the southern part of the Isle of Wight, however, sediments of this age are again comparatively well developed. The *spathi* Subzone sequence recognised at Selborne thins southwards to Nyewood but lithologically it remains the same (Owen 1963a & text-fig. 30). In the Isle of Wight, however, the sediment sequence is quite different. In the absence of sections it is not possible at this time to determine whether the Portsdown swell affected deposition during later Middle Albian Subzones.

It is becoming apparent that the thinning of the Lower Greensand and the Gault at Compton Bay relates to yet another ' swell ', probably that indicated by the Ringwood gravity high, evidence of which is provided by the British Petroleum Co., borings at Fordingbridge, Hants (Falcon & Kent 1960 ; 48–49), and Bere Regis, Dorset (Falcon & Kent 1960 ; 7), in which the Gault was found to rest directly upon the Kimmeridge and Oxford Clays respectively.

(ii) LONDON BASIN, EAST ANGLIA, AND KENT

(a) London Basin, S. Essex & N. Kent

Borings north of the Thames at Canvey Island (Smart, Sabine & Bullerwell *et al.*, 1964) Fobbing (Dewey *et al.*, 1925) Beckton Gasworks No. 4 (Barrow & Wills 1913), Essex ; Tottenham Court Road (Prestwich 1878, Judd 1884), Willesden No. 1 (Falcon & Kent 1960 ; 15), London ; and Bushey, Hertfordshire, provide evidence that the Upper Gault rests directly upon either the Palaeozoic rocks of the Mesozoic floor or upon a thin development of Jurassic or Lower Greensand sediments. However, in the Gas Council Cliffe group of borings encompassing the area of the East Tilbury Marshes, Essex, and across the Thames in the Cliffe and Higham parishes of Kent, Middle Albian sediments are represented in a sequence closely comparable to that seen in the Lower Gault of the Maidstone By-Pass (p. 18), and, moreover, they show no sign of either a land area or submarine cliff only a few miles to the north.

The Lower Gault of the Cliffe group of borings rests upon a thin development of Lower Greensand which in turn rests upon Oxford Clay preserved in a late Jurassic-early Cretaceous graben structure, or in the case of the two most southerly borings upon Devonian sediments as at Canvey Island and Fobbing situated to the north of the graben. The stratigraphy of these borings, the structure of the area, and its tectonic history, are discussed more fully elsewhere (Owen *in press*). In this work it is concluded that the absence of Lower Gault over much of the area north of the Thames in London and South Essex, is due to a further movement of the northern fault of this graben in early Upper Albian times.

Further west in northern Surrey, three borings have yielded information about Middle Albian sediments. These are located at Addington, Richmond and Egham

(Virginia Water), but the information is very incomplete, and in the case of the last boring mentioned it is highly suspect. The location of the borings is shown in text-fig. 1.

Addington

The boring at the Croydon Waterworks, Addington Pumping Station on the E. side of Featherbed Lane (TQ 371628) yielded a core, parts of which are preserved in the Institute of Geological Sciences. The Upper Gault-Lower Gault junction consists of a phosphatic nodule bed with *cristatum* Subzone fossils and was reached at about 879 feet (267·91 m.) depth. This is underlain by grey shelly clay represented by fragments of core from between 880 and 882 feet (268·22–268·83 m.) and which yield *Inoceramus concentricus* and poorly preserved ammonites which could indicate either a *loricatus* or *lautus* Zone age. No further core fragments have survived from the remainder of the Lower Gault sequence which has a total thickness of 22 feet (6·70 m.). This boring is situated 9½ miles WNW. of the section at Dunton Green at the outcrop (p. 26) and indicates that the thin development of Lower Gault there continues along the WNW. direction.

Richmond

The boring at the old Richmond Vestry Waterworks, Water Lane, Richmond (TQ 17657470) was first described by Judd and Homersham (in Judd 1884) and subsequently by Whitaker (1889 ; 214–217). Spath (1926a ; 151, 1930a ; 294) demonstrated the presence of the *Euhoplites inornatus* band at the base of the *orbignyi* Subzone (Upper Gault) and that the Lower Gault is also present.

The Gault core was stored in the British Museum (Nat. Hist.) for many years before being transferred to the Institute of Geological Sciences and is, unfortunately, in a dirty state. *I. sulcatus* is still present at a depth of 1116 feet (340·15 m.), and by 1119 feet (341·07 m.) *I. concentricus* is present. The Upper Gault-Lower Gault junction occurs, therefore, between these two depths. The base of the Gault was located at a depth of 1139 feet 6 inches (347·16 m.) and so the Lower Gault is between 20 feet 6 inches (6·25 m.) and 23 feet 6 inches (7·16 m.) thick. No subzonally diagnostic ammonites are present in the Lower Gault core. The base of the Gault rests upon 10 feet (3·04 m.) of sediments tentatively classified with the Lower Greensand which in turn rests upon Jurassic sediments. In the Griffin Brewery boring at The Mall, Chiswick, 3¼ miles to the NE. of the Richmond boring, the Gault rests directly upon Devonian sediments of the London Platform. The age of the base of the Gault at Chiswick is, however, unknown.

Egham (*Virginia Water*)

This boring situated at the Holloway Sanatorium, Egham (TQ 002685), was described by Dewey (*in* Dewey *et al.*, 1925 ; 128). He records a band crowded with *I. sulcatus* between depths of 1358–1360 feet (415·91–414·52 m.) some 67 feet (20·42 m.) above the base of the Gault. From the basal nodule beds, Templeman collected ammonites which led Chatwin to conclude (*in* Dewey *et al.*, 1925 ; 130, 132) that the base of the Gault was of Upper Gault age providing another example of overlap.

Now, *Inoceramus sulcatus* is characteristic of and restricted to the *orbignyi* and *cristatum* Subzones and yet the ammonites recorded from the nodule bed at 1424 feet (434·03 m.) depth include material of *varicosum* Subzone age.

A re-examination of the material stated to have come from this nodule bed shows that it includes ammonites from various Upper Gault horizons. The specimen of *Prohysteroceras* (GSM. AT 3787) is indeed correctly identified. It is, however, a form of the *varicosum* Subzone preserved in an identical manner to those of the basal *varicosum* nodule bed in the Leighton Buzzard area indicating a southerly extension of that bed. As it was found below the lowest recorded occurrence of *I. sulcatus* at 1400 feet (426·72 m.) depth, the only possible explanation is that it must have fallen from the side of the hole together with the other phosphatic fragments during the collapse of the hole reported by Dewey (*in* Treacher & Dewey 1925 ; 450).

Material acquired later from Templeman is preserved in the Palaeontology Department of the Institute of Geological Sciences and shows that the Lower Gault underlain by *mammillatum* Zone sediments was in fact traversed by this boring. These specimens, unfortunately, have no depth measurements recorded against them, but include *Euhoplites* cf. *opalinus* (GSM. AT 4800) indicating the *lautus* Zone ; *Euhoplites* of the *meandrinus* group (GSM. AT 4799) indicating the upper part of the *loricatus* Zone ; and *spathi* Subzone *Hoplites* (*H.*) spp. (GSM. AT 4801–4) preserved in pebbly gritty greyish phosphate.

Unfortunately, this boring is now stratigraphically suspect, but if one disregards the so-called phosphatic nodule bed at 1424 feet depth then it is possible to reinterpret the lower part of the hole. The last record of *Inoceramus sulcatus* was at 1400 feet (426·72 m.) depth about 27 feet (8·23 m.) above the base of the Gault. This figure of 27 feet is not an unreasonable one for the Lower Gault when one considers the geographical position of the boring. The highest record of *I. sulcatus* is at 1358 feet (413·91 m.) boring depth which indicates that the combined thickness of the *cristatum* and *orbignyi* Subzone sediments is at least 42 feet (12·80 m.) thick. This is a thick, but not impossibly thick, sequence.

(b) **The area of the Kent Coalfield**

Despite the large number of borings and various colliery shafts which penetrated through the Gault in the search for Coal Measures in Kent, only a small fraction has yielded information on the stratigraphy of the Gault. Financial costs dictated that boring through the Mesozoic rocks should be as rapid as possible and the sequence was often chipped. However, at the following seven localities shown on text-fig. 31, useful information has come to light and it is apparent that *eodentatus* and *lyelli* Subzones sediments are of widespread occurrence.

Chislet Colliery

In the downcast shaft of the Chislet Colliery situated 3020 yds N. 54° 30′E. of the North Shaft (TR 232657) an exposure of approximately 12 feet (3·65 m.) was seen of Lower Gault resting on the basal conglomerate of *mammillatum* Zone age which in turn rests unconformably on Coal Measures (Casey 1961a ; 535). A phosphatised fragment of *Hoplites* (*Isohoplites*) sp. (GSM. Ca 1416) was obtained by Dr. R. Casey from 1 foot 6 inches (0·457 m.) above the basal conglomerate indicating the *eodentatus* Subzone. From 2–4 feet (0·60–1·21 m.) above the conglomerate there occur glauconitic gritty darkish grey clays with fossils in which the shells have been replaced by pyrite. Ammonites from this bed collected by Dr. Casey include *Lyelliceras* cf. *lyelli* (GSM. Ca 1423–4) and *Hoplites* (*H.*) spp. including *H.* (*H.*) *baylei* (GSM. Ca 1426), and *Beudanticeras* cf. *albense* (GSM. Ca 1431). A specimen of *Protanisoceras* (*P.*) cf. *barrense* (GSM. Ca 1437) preserved in the same manner was picked up from the tip. This assemblage indicates the *lyelli* Subzone. One specimen (GSM. Zn 2472) is a *Hoplites* (*H.*) sp. preserved partly phosphatised in mid-grey shelly clay and is stated to have come from a height of about 12 feet (3·65 m.) above the basal conglomerate ; it indicates the *spathi* Subzone.

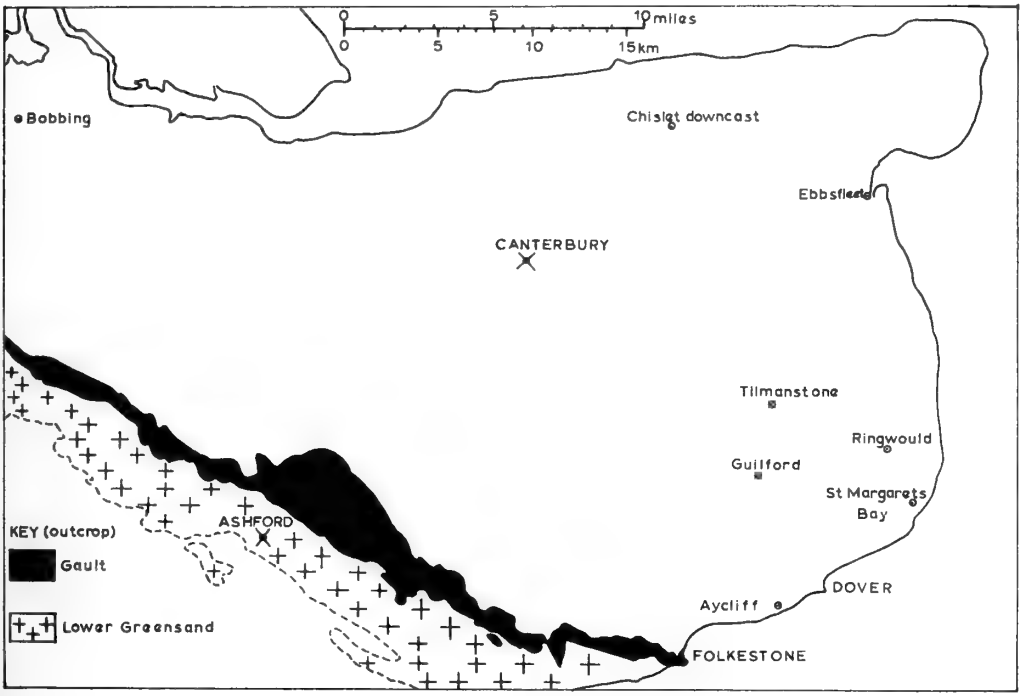


FIG. 31. Locality map of borings yielding subzonal information in the Kent coalfield.

Ebbsfleet

Fragments of the core preserved in the Institute of Geological Sciences from this boring, situated 495 yds S. 5°E. of Ebbsfleet House, Eastry (TR 337619), about 7¾ miles E. of the Chislet Colliery, shows that the Lower Gault was entered at between depths of 977 and 978 feet (297·79–298·1 m.) and is about 27 feet thick (8·23 m.) (Lamplugh, Kitchin & Pringle 1923 ; 178). *Loricatus* Zone sediments are definitely present at 12 feet 6 inches (3·81 m.) above the base of the Gault (GSM., Pl. 3854), and at 7 feet 6 inches to 7 feet (2·286 to 2·133 m.) above the base crushed *Hoplites* (*H.*) spp., occur with the shell, indicating the *spathi* Subzone.

Tilmanstone

The original manuscript accounts of the succession shown in the Shafts Nos. 1, 2 and 3 of the Tilmanstone Colliery are preserved in the Institute of Geological Sciences. The collecting was carried out by Burr and Griffiths. Griffiths, then employed as the Survey fossil collector, knew the stratigraphical value of *Inoceramus sulcatus* and *I. concentricus* and it is possible to state with some confidence from the Log that the junction between the Upper and Lower Gault occurs at a depth of 870 feet (265·17 m.) in the No. 1 Shaft (TR 288505) and that the Lower Gault is 62 feet 4 inches (18·99 m.) thick. From the account of the No. 2 Shaft (TR 288504), however, the Lower Gault appears to be only about 52 feet (15·85 m.) thick. The possible explanation of this difference in thickness is provided by the No. 3 Shaft (TR 288505) which showed the Gault to be affected by faulting. Whether this faulting is a posthumous movement of the Tilmanstone Fault which affects the Palaeozoic rocks and earlier Mesozoic rocks is not clear. Nonetheless, it is readily apparent that the Lower Gault at the Tilmanstone Colliery is very thick. Very little material has been preserved from these shafts but one specimen (GSM. Zm 5153) is of considerable interest. It is an early form of *Lyelliceras* known to occur in the *eodentatus* Subzone in France, but unfortunately no depth has been recorded against the specimen. It is interesting to note that in No. 2 shaft at a height of 21 feet 8 inches (6·60 m.) from the basal conglomerate a ' 3 inch band of Ammonites interruptus ' was recorded. This might indicate a considerable expansion of the *dentatus* Zone sediments in this area. Further evidence of this is provided by the material from the Shaft of the old Guilford Colliery (TR 281469) 2¼ miles SSW. of Tilmanstone.

Guilford Colliery

The shaft of the Guilford Colliery, situated near the south-western end of Waldershare Park, Coldred (TR 281469) is now disused. Fossils collected from the Gault during the sinking of the shaft are preserved in the Institute of Geological Sciences (presented by the Kent County Education Authority), and in the collection of Brigadier G. Bomford to whom I am particularly indebted for permitting me to examine his material. Unfortunately, the depths indicated for the individual specimens presented by the Kent County Education Authority is suspect. It seems, however, that at about 851 feet (259·38 m.) depth, the *lautus* Zone nodule bed at the top of the Lower Gault was reached. This contains material of *daviesi* Subzone age as well as of *cristatum* Subzone age, and is, therefore, comparable to the nodule bed at the outcrop to the west. If this depth of 851 feet (259·38 m.) is correct then the Lower Gault is 59 feet (17.98 m.) thick, a little thinner than the No. 1 shaft at Tilmanstone.

The only definite information about the Lower Gault here is provided by Brigadier Bomford's collection made from the tip heap of the shaft. This includes material from a nodule bed of *lyelli* Subzone age which yielded *Lyelliceras lyelli* (GB. 5443, 5447, 5446), *L. radenaci* (Pervinquiere) (GB. 5445), *Protanisoceras* (*P.*) *buvignieri* (GB.

5465), together with species of *Hoplites* (*H.*) of both the *lyelli* and *spathi* Subzones. This *dentatus* Zone sequence in the central area of the Kent Coalfield thins considerably in a south westerly direction towards the outcrop, and there is evidence to suggest that it thins also eastwards towards the Kent coast.

Ringwould

The Mesozoic rocks traversed by the boring for the National Coal Board made in 1955 and situated 760 yds W. 14°S. of St. Nicholas's Church, Ringwould (TR 35294812), has been described by Bisson (*in* Bisson *et al.*, 1967 ; 111–114), and fossils from the Gault were identified by Casey. The Upper-Lower Gault junction consists of a phosphatic nodule bed and was met at a depth of 839 feet 4 inches (255·83 m.). The top of the tough phosphatic rock bed of the type seen elsewhere at the base of the Gault was reached at a depth of 876 feet 11 inches (267·28 m.). The Lower Gault, therefore, has thinned to 37 feet 3 inches (11·35 m.) and the basal few inches in fact may well be of *mammillatum* Zone age. A re-examination of the fragments of the core preserved in the Institute of Geological Sciences has yielded the following additional information.

Crushed *Dimorphoplites* comparable to *D. tethydis* Spath non Bayle occur at depths of 842 feet 3 inches (256·71 m.) and 845 feet 1 inch (257·58 m.) and indicate either the top of the *meandrinus* Subzone, or the *lautus* Zone. At 860 feet 5 inches (262·25 m.), a specimen of *Hamites tenuicostatus* together with a juvenile *?Dimorphoplites niobe* at 862 feet 2 inches (262·79 m.) suggest the presence of the *niobe* Subzone. The *intermedius* Subzone is certainly represented at 866 feet 8 inches (264·16 m.) and 867 feet 9 inches (264·49 m.) by crushed examples of *Anahoplites intermedius*. The presence of the *spathi* Subzone is indicated by crushed specimens of *Hoplites* (*H.*) at 871 feet 11 inches (265·76 m.) to 872 feet 1 inch (265·82 m.) in dark grey clay. At 873 feet (265·25 m.) the clays become glauconitic, and at 875 feet 10 inches (266·95 m.) they become sandy for the remaining 1 foot 1 inch (0·33 m.) before the basal rock bed is reached.

The sequence in the lower part of the Middle Albian sediments is demonstrably thinner than at Tilmanstone where ' dark sandy Gault ' commences some 21 feet (6·4 m.) above the base. An even thinner sequence may be present in the next boring mentioned here.

St. Margaret's Bay.

The National Coal Board boring at St. Margaret's Bay situated 1030 yds E. 30°N. of St. Margaret's Church, St. Margaret's at Cliffe (TR 36654533), has been described by Bisson and Melville (*in* Bisson *et al.*, 1967 ; 105–110). The bulk of the sequence was chipped, but at a depth of 800 feet (243·84 m.) cores were taken for 2 feet (0·61 m.), at 830 feet (252·98 m.) a 1 foot (0·30 m.) core was taken, and a 3 feet 8 inch (1·12 m.) core from 840 feet (256·03 m.) and the base of the Gault at 843 feet 8 inches (257·15 m.). The only ammonite recorded was a specimen of a mortoniceratid ammonite, probably *Prohysteroceras*, said to have come from a depth of 830 feet (252·98 m.). What is probably a portion of the same ammonite is stated to have come from a depth of 830 feet 3 inches (253·05 m.). Casey considers that its position only 13 feet 8 inches (4·16 m.) above the base of the Gault is anomalous and should not be accepted. However, the portion from 830 feet 3 inches (253·05 m.) is not apparently derived and even if the specimen had come from the core between 800-802 feet (243·84 m.) this still suggests a thinner Lower Gault sequence than at Ringwould. These records need to be verified in any future boring in this area, but the possibility of early Upper Albian faulting here of the type seen in the region of the Thames E. of London should not be excluded (Owen *in press*). The Gault as a whole on the E. coast of Kent thins considerably northwards. In the Segas Deal Gas Works boring (TR 374533) it is 86 feet (26·21 m.) thick and in the Thanet Water Board Well, Margate (TR 365701), it is only 67 feet 6 inches (20·57 m.) thick.

Aycliff

The increased thickness of the Lower Gault seen in the Tilmanstone and Guilford Collieries is maintained in the Dover area. Lamplugh & Kitchin (1911 ; 8) considered from an examination of the Dover Colliery shafts that this was due to an expansion of the higher beds of the Lower Gault, but the exploratory borings in the Dover area for the Channel Tunnel show in fact that the reverse is the case. There are phosphatic nodule beds in the *cristatum* Subzone comparable to those at Folkestone within Bed VIII. The Gault in one of these borings, Dover No. 1 (Aycliff) (TR 294395), has been described lithologically by Bisson (*in* Smart, Bisson & Worssam 1966 ; 101), and the Lower Gault sequence is shown in text-fig. 32.

The *lautus* Zone is indicated in Bed 11 by the presence of a *Dimorphoplites* sp. of the *chloris-biplicatus* group, and in another boring by *Euhoplites opalinus*. It is considerably attenuated in comparison with Beds V–VII at Folkestone. Bed 10 has yielded a crushed *Dimorphoplites niobe* which might indicate either the *meandrinus, subdelaruei*, or *niobe* Subzones. Neither Bed 9 nor the bulk of Bed 8 yielded any zonally significant ammonites but crushed *Falciferella* occurs in the lower 6 inches (1·828 m.) of Bed 8 which suggest the *intermedius* Subzone or possibly the *niobe* Subzone. *Anahoplites* of the *intermedius* group occur from 1 foot (0·304 m.) above the base of Bed 7, and in Bed 6, definitely indicating the presence of the *intermedius* Subzone. No subzonally diagnostic ammonites are known from Beds 5 and 4, but Bed 3 contains phosphatised fragments of *H.* (*H.*) *persulcatus* and *H.* (*H.*) of the *paronai* group. This is the direct equivalent of Bed I (v) at Folkestone, the *dentatus* nodule bed, classified with the *spathi* Subzone. It is highly probable that Bed 4 above is the equivalent of Bed I (vi) at Folkestone (p. 12).

The particularly interesting feature of the sequence occurs in Bed 2. This bed is classified with the *lyelli* Subzone, and contains species of *Protanisoceras* (*P.*) at only 12 and 15 inches (0·304–0·381 m.) below Bed 3, and species of *Hoplites* (*H.*) occur throughout. This sequence bears comparison with the lower part of the Gault in the Guilford, and Chislet Collieries where the *lyelli* Subzone is also well developed. At Folkestone, the *lyelli* Subzone is very condensed and is represented within Bed I (iv). Whether the *eodentatus* Subzone is represented within the higher part of Bed 1 is uncertain in the absence of ammonites but it is highly likely when one considers the development of the *lyelli* Subzone here. The lower part of Bed 1 is probably equivalent to the ' Sulphur ' Band at Folkestone.

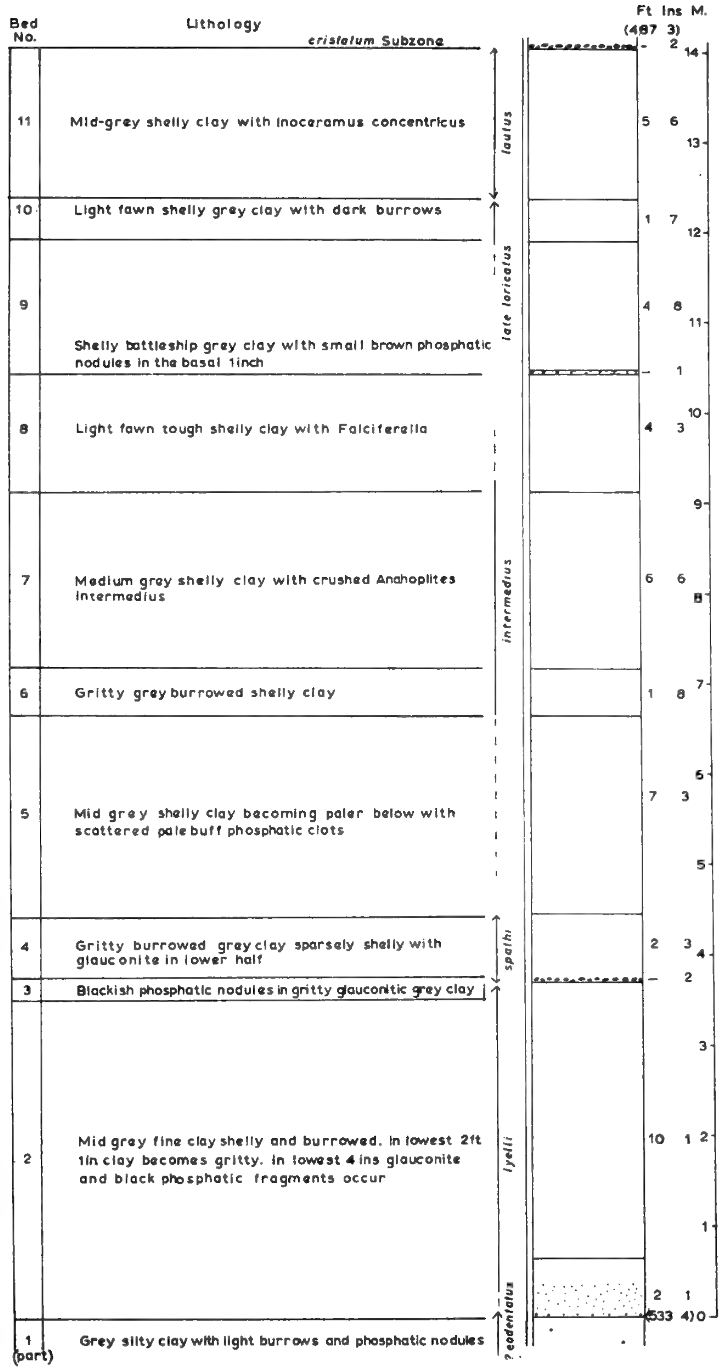


FIG. 32. Lower Gault sequence in the Dover No. 1 (Aycliff) boring, Kent (TR 294395).

These borings in the area of the Kent Coalfield show that the sequence in the Lower Gault expands considerably eastwards from the outcrop between Folkestone and Maidstone. In this trough area the *eodentatus* and *lyelli* Subzones are well developed. The whole sequence thins towards the coastal margin of Kent from the Isle of Thanet to St. Margaret's Bay northeast of Dover.

F. **Selection of sections in France**

It is not possible here to describe the Middle Albian stratigraphy of northern and central France in the same detail as the English sections. The French sections require just as long and careful study, and must include temporary sections seldom available on a chance visit and which are thus the prerogative of our colleagues in France. The purpose of this portion of the work is to make a comparison of the English sequence with a representative selection of sections of four regions ; (i) the Boulonnais ; (ii) the outcrop extending from the River Ornain (Meuse) to the River Armance (Yonne) which includes also parts of the Départements of Meuse, Marne, Haute-Marne, Aube and Yonne ; (iii) the Pays de Bray ; and (iv) the Pays de Caux (text-fig. 33).

(i) COMPARISON BETWEEN WISSANT & FOLKESTONE

The Albian deposits of the Boulonnais describe a narrow outcrop at the foot of the Chalk escarpment extending from the coast at Petit Blanc Nez south-eastwards to Lottinghen and then roughly westwards towards the coast to disappear beneath the dunes at Hardelot Plage. The deposits rest upon Aptian sediments at Wissant, but inland they may rest directly upon Aptian, ' Wealden ', Jurassic, and, near Caffiers, on Palaeozoic rocks. The exposures in the shore and in the cliffs between Wissant and Petit Blanc Nez are indicated in text-fig. 34.

The Gault of the Wissant area was briefly described by Barrois (1873, 1875, 1878, but particularly 1879 ; 27–28), Price (1879, 1880 ; 34 etc.) and Jukes-Browne (1900 ; 378–381), but it was not until 1938 (a 98–121) that a good detailed description was given by J.-P. & P. Destombes. Barrois had considered that the sequences at Folkestone and Wissant were not comparable in detail, a conclusion with which the present writer agrees. Destombes & Destombes, however, followed Price in considering that the Wissant succession is comparable to that of Folkestone, although reduced in thickness ; a view accepted by Spath (1943 ; 721).

P. & P.-J. Destombes have written an emended account of the Wissant sequence (1965 ; 257–260), the lithological accuracy of which can be confirmed by the writer's own examination of the section. However, their subzonal classification of 1938 and the implied classification of 1965 requires some revision at certain levels as also does the account by Marie (1965 ; 280–284, table 1). In April 1967 the writer observed good clean sections in the Lower Gault both in the cliffs and in the foreshore, and from the study of these the graphical section (text-fig. 35) has been drawn. The primary bed numbers employed are those used by Destombes & Destombes (1965 ; 258), and the correlation with Folkestone is shown in text-fig. 36.

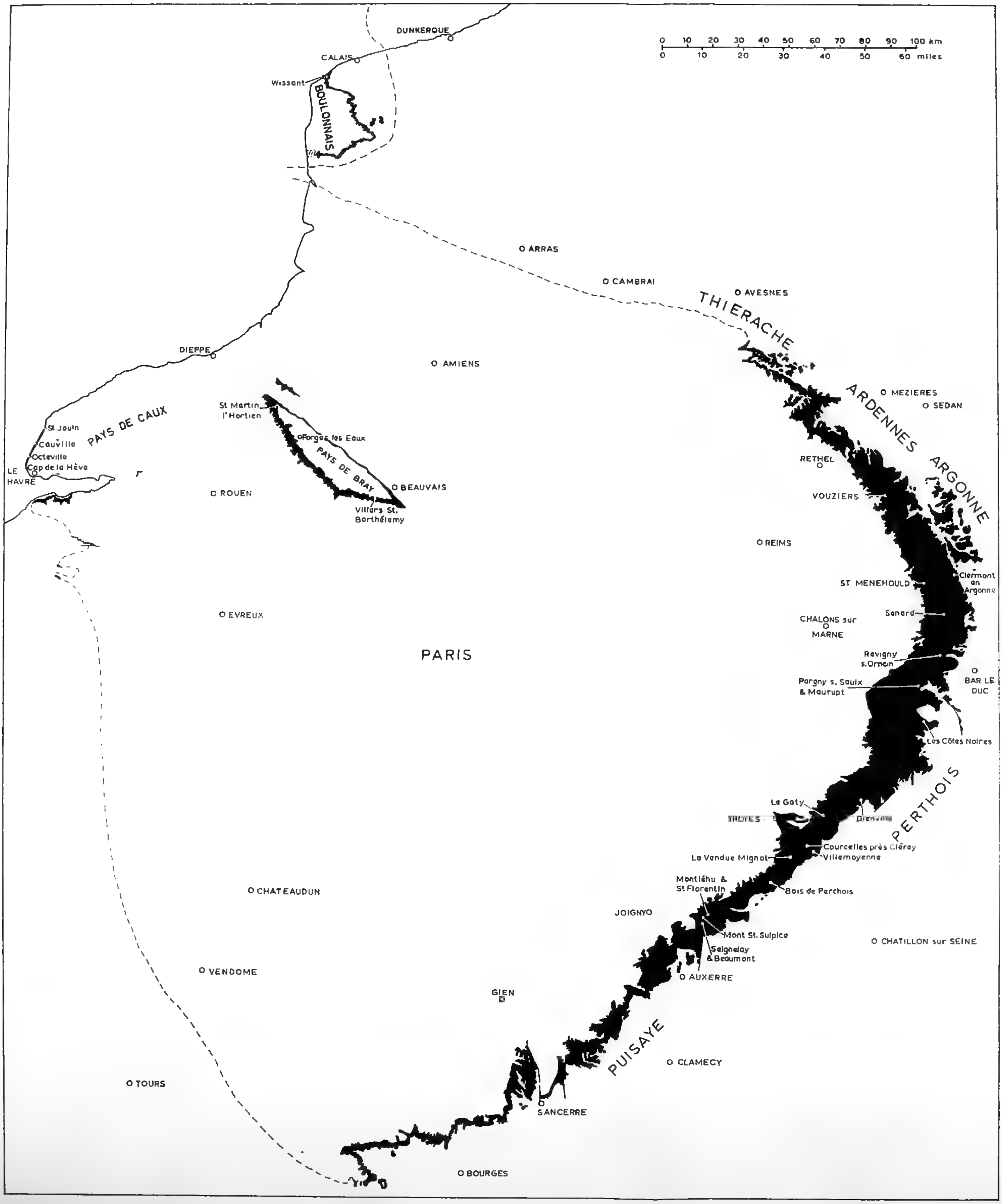


FIG. 33. Sketch map of the outcrop of Albian sediments in the Paris Basin showing the positions of the sections mentioned in the text. The pecked line represents the approximate margin of Albian sediments buried beneath overlapping Upper Cretaceous sediments.

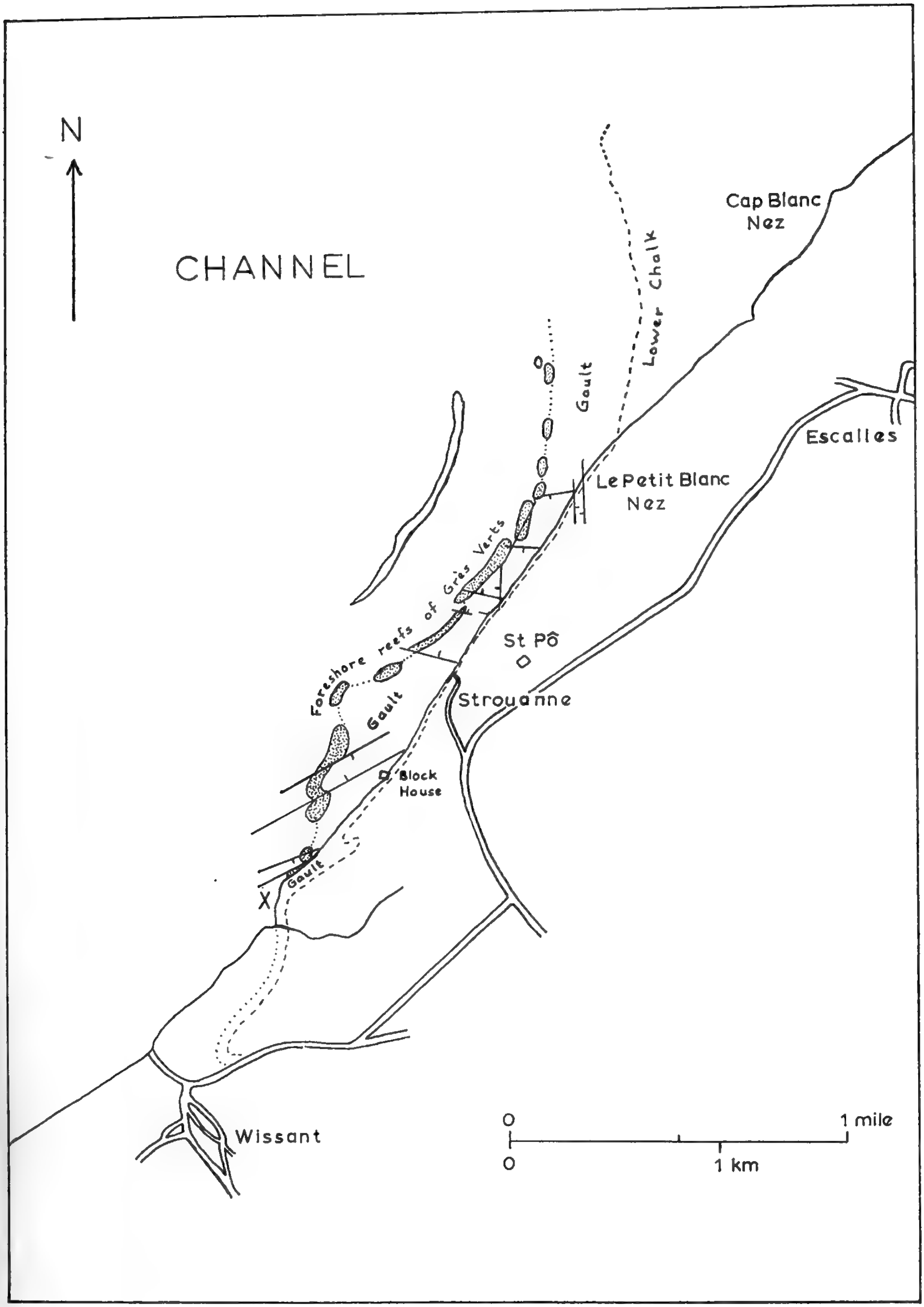


FIG. 34. Sketch map of the coast between Wissant and Cap Blanc Nez, Pas de Calais (modified from J-P. & P Destombes 1963).

At the point marked X on the sketch-map (text-fig. 34) a vertical section normally buried within the dune sands showed a sequence from the Argiles d'*Ostrea Leymerii* (Upper Aptian) up into the lower part of the Lower Gault[1]. Price (1879, 1880 ; 34) had stated that at Wissant the '*Ammonites-mammillaris* Zone and the *A.-interruptus* zone (Bed I) are mixed together, so much so that it is difficult to divide them; but the fossils from the former have the greensand matrix——'. Now, in Bed 7 in the section mentioned above, a magnificent fauna of *puzosianus* Subzone age was collected by the writer preserved in exactly the manner described by Price and associated with a *spathi* Subzone fauna. The large *puzosianus* Subzone nodules had obviously stood

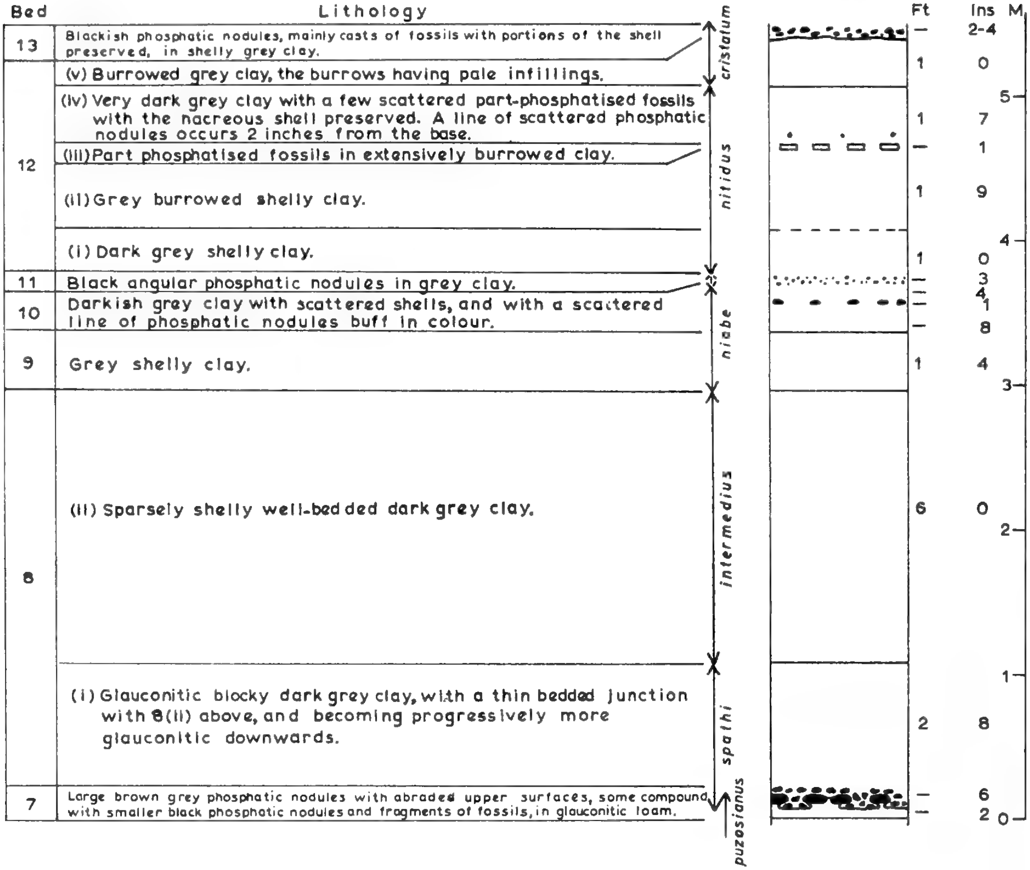


FIG. 35. Section in Lower Gault in the sea-cliff extending from point X on the sketch map (FIG. 34) up to the old german block-house 0.4 km SW. of Strouanne, Wissant, Pas de Calais.

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[1] It appears to be the first time this century that this section has been seen. It was described by Gaudry (1860). Le Hon (1864 ; 14–16), and Barrois (1879). The section examined by Dutertre, in company with Kirkaldy (1938 ; 121–2), was situated in the cliffs near the farm of Saint Pô. I can confirm the accuracy of Barrois' section from a point about 4 ft. (1·21 m.) below the top of the Argiles d'*Ostrea Leymerii* up to the top of the Sables Vert.

up as a hard-ground on the *spathi* Subzone sea floor for their upper surfaces are strongly eroded (text-fig. 35). The currents had scoured out the sandy matrix from around the nodules, and, subsequently, phosphatic fragments from a later *spathi* Subzone period of erosion accompanied by a gritty clay sediment were forced into the crevices between and even underneath the nodules of *puzosianus* age. J.-P. & P. Destombes record ' *Protohoplites raulinianus* ' from this bed (1938a ; 102).

In the foreshore to the NE. up to Strouanne, these *puzosianus* Subzone phosphatic nodules are still present but are scattered and much more rolled : they have not yielded fossils. In the reef on the foreshore in front of Petit Blanc Nez a few putty-coloured gritty well-rolled smaller phosphatic nodules of *puzosianus* Subzone type still occur mixed in with the predominantly *spathi* Subzone debris. It can be seen, therefore, that the degree of reworking increases north-eastwards from the cliff section near Wissant. In this respect it is important to note that the Palaeozoic floor rises sharply off-shore (J.-P. & P. Destombes 1963 ; 53 text-fig. 3).

There is no evidence of the presence of an *eodentatus* or *lyelli* Subzone element in Bed 7, and the *spathi* element is strongly reminiscent of the fauna in Division A in the Maidstone By-Pass (p. 38) which indicates that the earliest part of the *spathi* Subzone may not be represented either. The equivalent of the Greensand Seam and the basal *spathi* Subzone element of the *dentatus* nodule bed at Folkestone is, therefore, absent at Wissant.

It is not easy to make out the complete sequence between Bed 7 and Bed 11 and it is possible that these clays might be somewhat thicker than has been previously recorded. Nonetheless, for the purpose of this account, the general sequence given by P. & J.-P. Destombes will be the one considered. *Hoplites* (*H.*) occurs crushed in the matrix of Bed 7 and in the lower 3 inches of Bed 8 (i), and these sediments are classified with the *spathi* Subzone. The base of the *intermedius* Subzone has not been satisfactorily defined but probably commences at the base of 8 (ii). Scattered crushed examples of *Anahoplites intermedius* & *A. praecox* occur throughout the bulk of 8 (ii) and P. Destombes records *Falciferella* in the uppermost 8 inches (20 cms) (1962 ; 196–7). Bed 8 (ii) is, therefore, classified with the *intermedius* Subzone, however, as can be seen from the section and the general nature of the fauna it differs greatly from the upper part of Bed I and Bed II at Folkestone. P. Destombes (1962) classifies the bed later numbered 9 with the *niobe* Subzone and this must also include Bed 10.

Bed 11 has yielded a remanié fauna of ammonites including *Mojsisovicsia subdelaruei* & *M. remotum* indicating the *subdelaruei* Subzone, *Euhoplites* of the *meandrinus* group indicating that Subzone, and also fragments of *Euhoplites lautus* and *E. nitidus* indicating the *nitidus* Subzone. The degree of condensation at Wissant is, therefore, greater than that represented by Bed IV at Folkestone and includes material also found in the *nitidus* Subzone sediments of Bed V.

The *nitidus* Subzone is well developed in Bed 12 (i–iv) and the preservation of the fossils particularly in 12 (iii) is identical to that of Bed V–VI at Folkestone. It is possible that 12 (iv) may represent the equivalent of the lower part of Bed VII below the base of the *daviesi* Subzone but there is no certain evidence for this. However, it is certain that there is an important break in the sequence between 12 (iv) and (v),

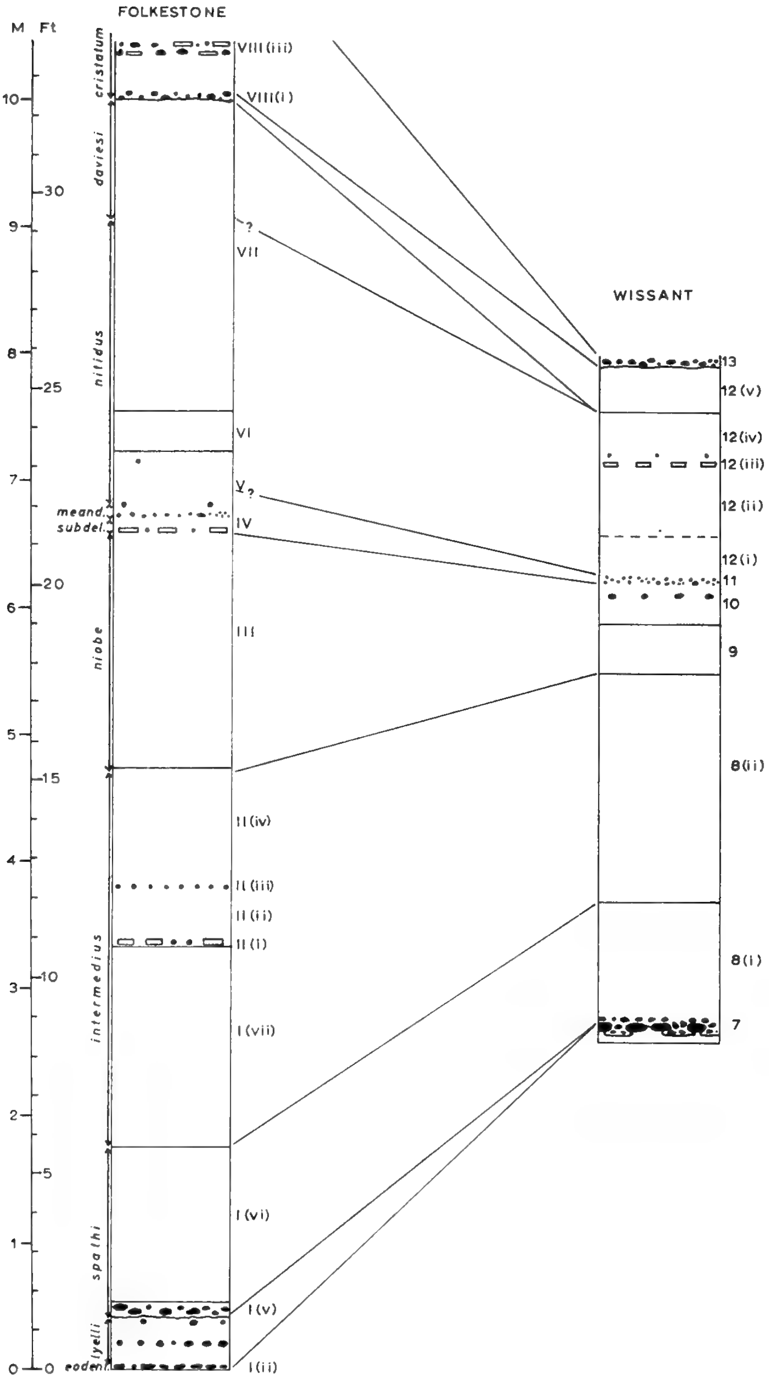


Fig. 36. Correlation of Lower Gault sections at Folkestone and Wissant.

and that the *daviesi* Subzone is absent at Wissant. At the base of Bed 12 (v) *Inoceramus concentricus* is present but as one works up through the bed it passes through a *subsulcatus* stage to achieve the form of *I. sulcatus* just below the *cristatum* nodule bed 13 (cf. P. & J.-P. Destombes 1965 ; 260). *Beudanticeras beudanti* also occurs partly crushed with its shell, and it should be borne in mind that d'Orbigny's holotype of *Dipoloceras bouchardianum* is from Wissant and is pyritic with the shell ; it almost certainly came from 12 (v). *Anahoplites daviesi* and its close relatives are absent and in fact the fauna is that which occurs in the lower nodule bed of Bed VIII at Folkestone minus the late *daviesi* Subzone element (p. 15) absent at Wissant. Therefore, the lower part of the *cristatum* Subzone is represented at Wissant by these clays of 12 (v) and this is the only proven section known to the writer where the basal part of the Upper Albian is represented by an uncondensed sequence. Bed 12 (v) certainly does not belong to the *daviesi* Subzone as Marie (1965 ; 279) has indicated.

It is worth recording here that Bed 13 at Wissant contains a remanié ammonite fauna which indicates that it represents Bed VIII (ii & iii) at Folkestone together with the clays of Bed IX up to the level at which *Hysteroceras orbignyi* becomes common. The *Euhoplites inornatus* level, which provides a useful indicator horizon in the lower part of the Upper Albian, is caught up within Bed 13. This bed represents, therefore, the bulk of the *cristatum* Subzone together with what has been considered previously to be the lower part of the *orbignyi* Subzone (see also p. 126).

The original account by Barrois (1875a) of the succession between the Wissant area of the Boulonnais and the Département of the Meuse has had very little added to it. This area includes the Ardennes where Barrois demonstrated the major stratigraphic break which exists between the *spathi* Subzone and the sediments of Upper Albian age classified by him with his ' Zone of Ammonites inflatus ' which he included in the Cenomanian. The sequence in the *dentatus* Zone is itself incomplete, reflecting the proximity of the area to the Variscan massifs to the east. In the Département of the Meuse, the Middle Albian sediments begin to thicken and it is at Revigny-sur-Ornain that the more detailed account of the sequence in the southern part of the Paris Basin commences.

(ii) THE OUTCROP FROM THE RIVER ORNAIN (MEUSE) TO THE RIVER ARMANCE (YONNE)

The outcrop of the Albian sediments in the southern part of the Paris Basin is shown in text-fig. 33. This strip of country is the classic area for the study of the French Albian ; the name Albian stems from the Roman province of Alba, now the Département of the Aube. It includes the portions of the Départements of the Meuse, Marne, Haute Marne, Aube and Yonne, divided into the old regions of the Argonne (part), then Perthois, and part of the Puisaye. The succession and its facies changes at the outcrop can be demonstrated by brief descriptions of the following seven sections (a) Revigny-sur-Ornain (Meuse) ; (b) Pargny-sur-Saulx (Marne) ; (c) Les Côtes-Noires près de Moëslain (Haute-Marne) ; (d) Courcelles près Clérey (Aube) ; (e) La Vendue Mignot (Aube) ; (f) St. Florentin area (Yonne).

These sections demonstrate the important development of the *dentatus* Zone and in particular of the *eodentatus* and *lyelli* Subzones in this area. The clay facies of the *dentatus* Zone passes rapidly in the St. Florentin area to a predominately sandy facies characteristic of the succession in the Puisaye-Yonne, Nièvre, Cher, indicating the proximity of the Variscan massif of Morvan. In the whole area under consideration the proved sediments of *loricatus* Zone age represent only the *intermedius* Subzone and in the Puisaye these are largely remanié. Sediments of *lautus* Zone age have not yet been detected.

This area has been studied by many French Cretaceous workers. One of the earliest papers written was by Michelin (1838) on the sequence at Gaty, près Geraudot (Aube). Leymerie (1841, 1842) then described the Gault in the Aube but, unfortunately, d'Orbigny (1841) just antedated Leymerie's description of *Ammonites lyelli* one of the most characteristic fossils. This was followed by a similar description of the Gault in the Département of the Meuse by Buvignier (1852). Various papers on individual localities were then published but the next important work before Barrois was that of Ebray (1863) who attempted to coordinate the sequence in the various Départements.

Barrois made the first attempt to tie in the apparently different sequences of the Boulonnais, Ardennes, and the strip of country from the Meuse to the Nièvre (1875). Unfortunately, two very inaccurate attempts were made to correlate the succession in the Aube with that of Folkestone (Price & Delatour *in* Price 1879 ; 1880 ; 37–40, Jukes-Browne 1900 ; 388–390). The result completely obliterated Barrois's work in English minds, and eventually led to a great deal of uncertainty as to the stratigraphical position of the clays containing *Ammonites lyelli* in relation to the sequence known in England. This uncertainty was not completely settled even by Spath (e.g. 1926b ; 1943, 722). It was not until Wright & Wright demonstrated the occurrence of *Lyelliceras* in the '*benettianus*' Subzone in Surrey (1948), and the stratigraphical position more definitely indicated by Casey (1961a) that the question was put beyond doubt in English minds.

The first general account of the Albian in this area of France to appear after Barrois was a paper by Lemoine (1910). Larcher (1937) subsequently produced a very interesting paper in which the fauna of the broad lithological units were listed accurately for the first time. However, it was not until 1965 that a more detailed picture of the sequence and its facies changes could be obtained. Four very important papers were presented to the Colloque sur le Crétacé inférieur held in Lyon in 1963. These were published in 1965 and written by :— Larcher, Rat, & Malapris ; P. & J.-P. Destombes ; Marie ; and Ciry, Rat, Malapris & Nicolas. Of these, the paper by P. & J.-P. Destombes is of paramount importance. Recently, Lauverjat (1969) has described the broad lithological sequence and facies changes shown by deep borings through the Chalk along two lines, parallel to the Albian sediment outcrop, from the area of Troyes (Aube) south west to the river Loing (Yonne).

(a) **Revigny-sur-Ornain (Meuse)**

Barrois demonstrated (1878), that in the northern part of the Argonne (part of the Départements of the Ardennes, Meuse, and Marne) sediments now included in the

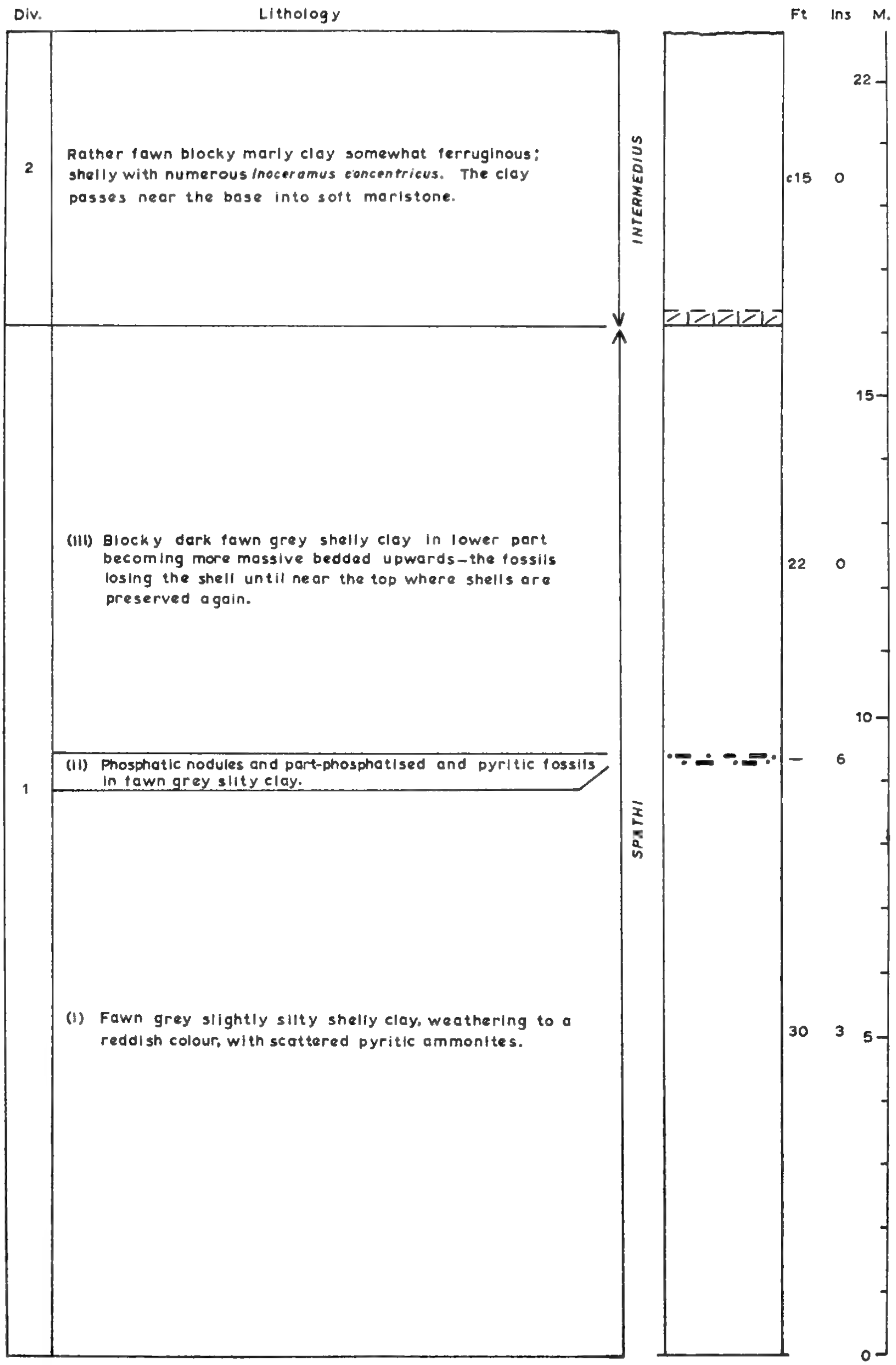


FIG. 37. Section in Gault at the claypit of the Société B.H.T.P. on the SE. side of the Marne-Rhine canal, about 2 km S. of the centre of Revigny-sur-Ornain, Meuse.

Middle Albian appear and thicken southwards. Deposits of *lyelli* Subzone age, although no longer exposed, are present in this area. Buvignier (1852 ; 525–6 & pl. explanation p. 45) lists *lyelli* Subzone fossils from as far N. as Clermont-en-Argonne, 31 kms NNE. of Revigny-sur-Ornain. These include *Pseudhelicoceras argonnenis* (type locality), *Brancoceras versicostatum* and *Lyelliceras lyelli* (although he states on p. 521 that the only locality at which this species had been found was at Senard about 17 kms a little E. of N. of Revigny-sur-Ornain). From Revigny-sur-Ornain itself, and, in the case of the last-named species below, between here and Mussey (presumably from the excavation for the Marne-Rhine Canal) he records *Nucula bivirgata, Protanisoceras* (*P.*) *alternotuberculatum, P.* (*P.*) *moreanum* (type locality), *P.* (*P.*) *nodoneum* (type locality) and *P.* (*P.*) *barrense* (type locality).

Approximately 2 kms S. of the centre of Revigny-sur-Ornain, and to the SE. of the N 395, the Société B.H.T.P. have a large brick and tile works with an extensive clay pit on the SE. side of the Marne-Rhine canal. The pit is worked in two stages by multi-bucket excavators and a sketch section is given in text-fig. 37. Deposition of sediment here was apparently fairly constant and there is an almost perfect transition from the lithology seen at the base to that seen at the top. The only sign of slight condensation occurs approximately 30 feet (9·14 m.) above the base of the section where part-phosphatised and pyritic fossils are more common.

The fossils are essentially crushed flat, and at the base of the sequence the ammonites consist of *Hoplites* (*H.*) spp. including *H.* (*H.*) *dentatus* and *Metahamites sablieri* (d'Orbigny) indicating the *spathi* Subzone. A higher *spathi* Subzone fauna ranges up into the top few feet of Division 1, and the band of phosphatised and pyritised fossils about 30 feet (9·14 m.) from the base has yielded ammonites including *H.* (*H.*) aff. *dorsetensis* Spath, *H.* (*H.*) *pretethydis* Spath, and *H.* (*H.*) *canavariformis* comparable to those found in the upper part of the *spathi* Subzone in the Weald.

Anahoplites praecox and *A. intermedius* appear at the base of Division 2 and range up through the remainder of the measured sequence. In Dr. P. Destombes' collection there is a single example of the sulcate form of *A. praecox* which indicates the lower part of the *intermedius* Subzone and was probably derived from the top few feet of Division 1.

The *spathi* Subzone is represented in this section, therefore, by about 50 feet (15·24 m.) of sediments, and the base of the Subzone has not yet been reached. The top of the *intermedius* Subzone has not been reached either, and the exposed portion of sediments belonging to this Subzone is about 15 feet (4·57 m.) thick.

(b) **Pargny-sur-Saulx (Marne)**

In the area of Pargny-sur-Saulx and Maurupt, situated approximately 12 kms SW. of the section at Revigny-sur-Ornain, there is an important centre of brick and tile production. Houdard (1940 ; 625–636) has recorded the distribution of the fauna collected from the Gault (Argiles Tégulines) in this area but there are no details of the sections. From his lists it is apparent that the *lyelli* and *spathi* Subzones are definitely present, and probably the *intermedius* Subzones as at Revigny. His record of '*Acanthoceras*' *camatteanum* and '*Parahoplites*' *steinmanni* from Pargny suggested that the *eodentatus* Subzone might also be present. The section between Pargny-sur-Saulx and Maurupt described below provides new information on the basal part of the Middle Albian in this area.

The extensive clay pit belonging to the brick and tile works of the Hugenot Freres, situated a few hundred yards E. of the D61, 1 km NNW. of Maurupt, has been deepened and shows the lithological sequence given in text-fig. 38. Bed 1 did not yield ammonites to the writer but bivalves are common. It is possible, although by no means certain, that it is of uppermost *mammillatum* Zone age. Bed 2 has yielded phosphatised or pyritised *Hoplites* (*Isohoplites*) *eodentatus*, *H.* (*I.*) sp., *Beudanticeras albense*, *B. sanctaecrucis*, *Otohoplites* sp., *Lyelliceras camatteanum* (d'Orbigny), *Brancoceras* sp., indicating the *eodentatus* Subzone, and its top is an erosion surface. The sediments of Bed 3 contain crushed fossils including ammonites, some quite large, such as *Hoplites* (*H.*) spp., *Lyelliceras* of *lyelli* Subzone appearance, and *Douvilleiceras* sp., and can be classified with the basal part of the *lyelli* Subzone.

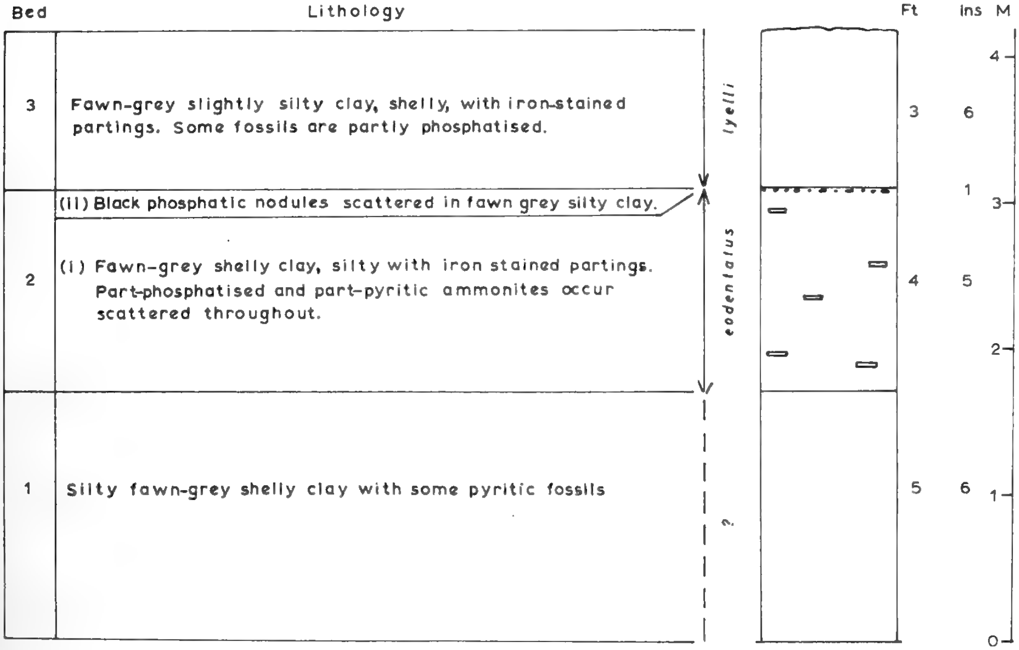


FIG. 38. Section in basal Gault exposed in the claypit of the Hugenot Freres, situated a few hundred yards E. of the D 61 road, 1 km NNW. of Maurupt, and 1·4 km S. of Pargny-sur-Saulx, Marne.

(c) Les Côtes Noires (Haute Marne)

Approximately 15 kms SSE. of the section described above is the natural river cliff of Les Côtes Noires situated on the W. bank of the River Marne 1 km to the W. of Moëslain, near St. Dizier. This magnificent natural section can only be safely worked in reasonably dry weather and is approached by way of the summit of the

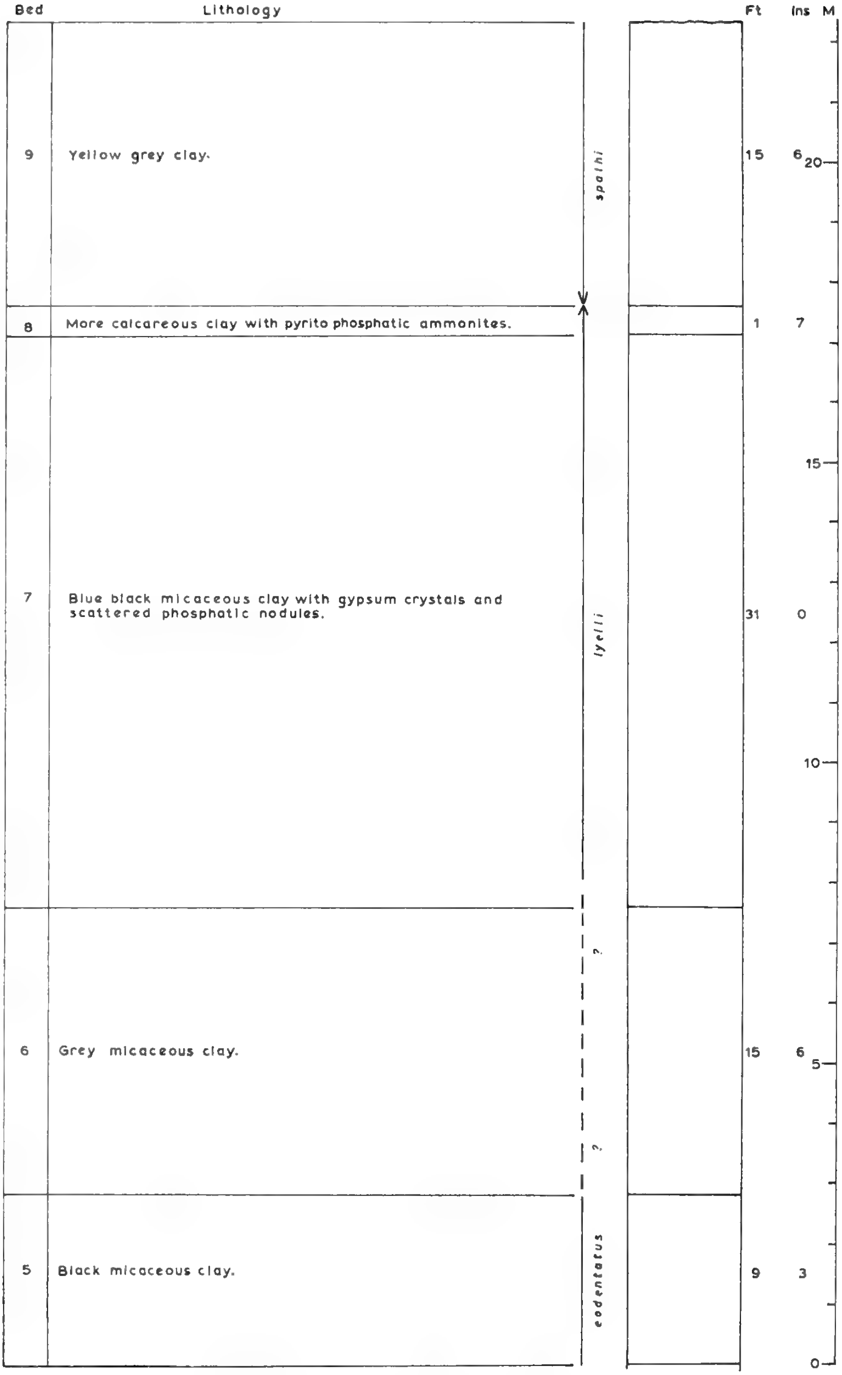


FIG. 39. Section in Middle Albian sediments (largely after P. & J-P. Destombes 1965) at Les Côtes Noires, 1 km W. of Moeslain on W. bank of the river Marne (Haute Marne).

cliff from the D196 between St. Aubin and Laneuville-au-Pont. The section has recently been described by P. & J.-P. Destombes and is quoted in text-fig. 39. It forms one of the original localities cited by d'Orbigny when defining the stage (1842 ; 404) and is doubly important because it shows a complete sequence from the *mammillatum* Zone to the *spathi* Subzone of the *dentatus* Zone.

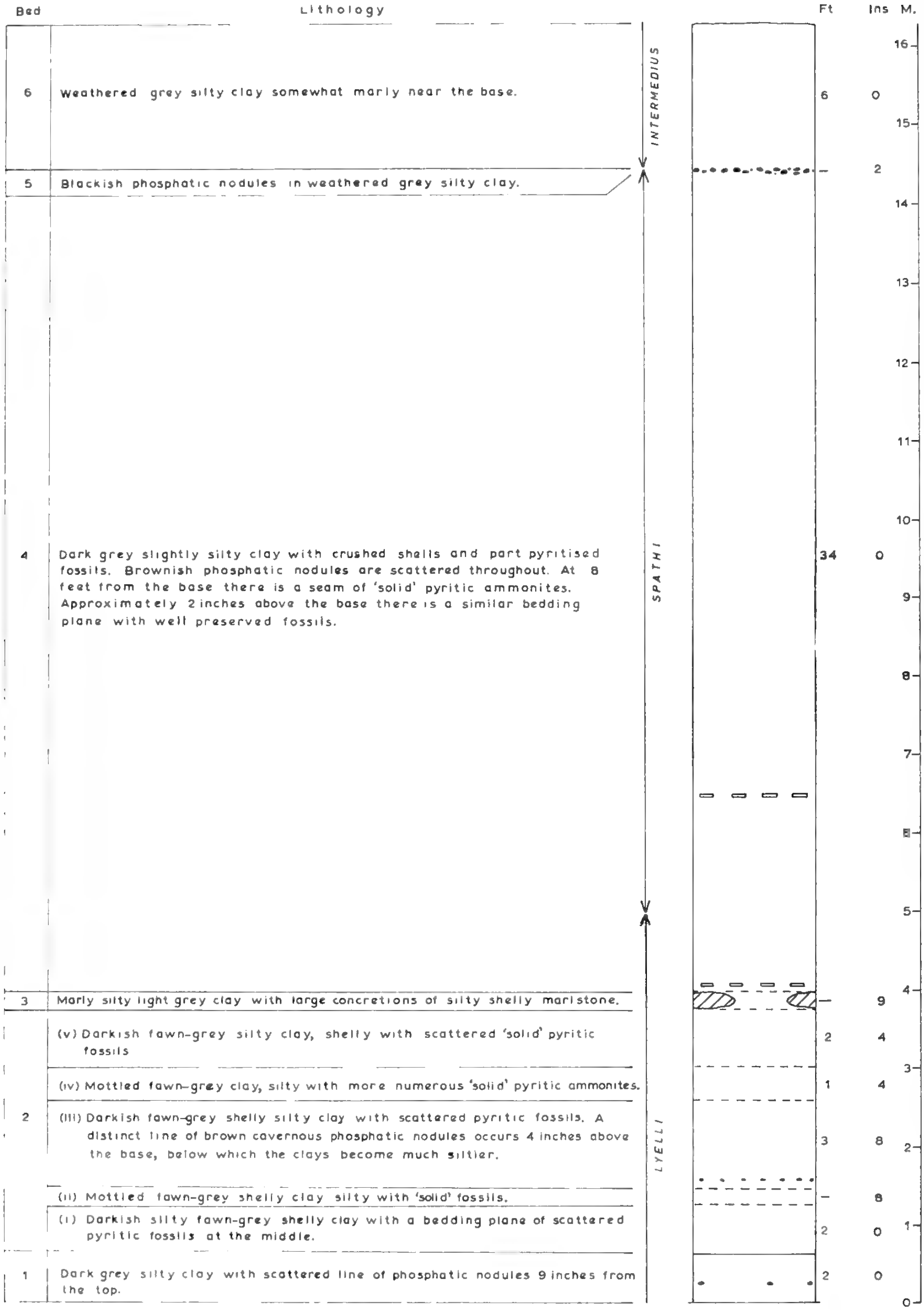
The outline classification of the sequence is as follows. The *eodentatus* Subzone is definitely represented within Bed 5 and may include 6 and the basal part of 7. The remainder of Bed 7 together with 8 contains a *lyelli* Subzone fauna, Bed 8 lithologically represents the NE. extension of a marker horizon recognisable at the top of the *lyelli* Subzone in the Gault of the Aube and in the St. Florentin area of the Yonne (text-fig. 43). Bed 9 contains a *spathi* Subzone fauna.

(d) **Courcelles près Clérey (Aube)**

This clay pit, No. 3 of the Tuileries de St. Parres les Vaudes, is situated to the E. of the river Seine on the eastern side of the D 49 about 2·5 kms SE. of Clérey. It now forms the most important section available in the Middle Albian sediments in the Aube, and is typical of the sequence formerly exposed at such famous localities as Dienville on the River Aube, and Gaty-près Géraudot in the Forêt d'Orient (Larcher, Rat & Malapris 1965 ; 246). It is very close to the old section at Courcelles figured by Leymerie (1846 ; pl. 3, fig. 4). The section is given in text-fig. 40, and its correlation with sections to the NE. and SW. in text-fig. 43. It has been described briefly by P. & J.-P. Destombes (1965 ; 262), and is particularly important in that it permits a direct comparison to be made with the sequence in the Horton Clay pit, Small Dole, Sussex (p. 35).

Bed 1 to a metre above the base of Bed 4, are classified with the *lyelli* Subzone, and the following list of ammonites is certainly not exhaustive and represents material collected strictly *in situ*. Bed 1 is not very fossiliferous but has yielded *Hoplites* (*H.*) *bullatus*, *H.* (*H.*) *dentatus* group, *Beudanticeras albense*, *Lyelliceras pseudolyelli* (Parona & Bonarelli), *L.* aff. *gevreyi*. Bed 2 (i) *Beudanticeras santaecrucis*, *Brancoceras* sp., and on a bedding plane 1 foot (0·3 m.) from the base, *Desmoceras latidorsatum* is not uncommon and this horizon has also yielded a single example of *Hypophylloceras*. Bed 2 (ii) *Brancoceras* sp., *Pseudhelicoceras argonnense*. Bed 2 (iii) *Lyelliceras lyelli*, *Brancoceras* sp., *Eubrancoceras aegoceratoides* (Steinmann), '*Oxytropidoceras*' *evansi*. Bed 2 (iv) *Desmoceras latidorsatum*, *Beudanticeras laevigatum*, *B. sanctaecrucis*, *B. albense*, *Hoplites* (*H.*) sp. *dentatus* group, *Lyelliceras gevreyi*, *Brancoceras* spp., *Protanisoceras* (*P.*) *alternotuberculatum*, *P.* (*P.*) *barrense* *P.* (*P.*) *nodoneum*. Bed 2 (v) *Beudanticeras laevigatum*, *Hoplites* (*H.*) *baylei*, *H.* (*H.*) sp. *dentatus* group, *P.* (*P.*) *alternotuberculatum*, *Pseudhelicoceras argonnense*. Bed 3 *Douvilleiceras clementinum*, *Hoplites* (*H.*) *dentatus*, *H.* (*H.*) *baylei*, *H.* (*H.*) spp. Bed 4 basal 1 metre is characterised by *Hoplites* (*H.*) spp. but P. & J.-P. Destombes record *Douvilleiceras* up to this height, and it is here included in the *lyelli* Subzone.

In comparison with the Horton Clay pit, Small Dole, the fauna listed above shows the following important features. Bed 1 must be close to the underlying *eodentatus* Subzone for *Lyelliceras pseudolyelli* is directly transitional from *Lyelliceras camatteanum*



Bed	Lithology	Ft	Ins
6	Weathered grey silty clay somewhat marly near the base.	6	0
5	Blackish phosphatic nodules in weathered grey silty clay.	—	2
4	Dark grey slightly silty clay with crushed shells and part pyritised fossils. Brownish phosphatic nodules are scattered throughout. At 8 feet from the base there is a seam of 'solid' pyritic ammonites. Approximately 2 inches above the base there is a similar bedding plane with well preserved fossils.	34	0
3	Marly silty light grey clay with large concretions of silty shelly marlstone.	—	9
2	(v) Darkish fawn-grey silty clay, shelly with scattered 'solid' pyritic fossils	2	4
	(iv) Mottled fawn-grey clay, silty with more numerous 'solid' pyritic ammonites.	1	4
	(iii) Darkish fawn-grey shelly silty clay with scattered pyritic fossils. A distinct line of brown cavernous phosphatic nodules occurs 4 inches above the base, below which the clays become much siltier.	3	8
	(ii) Mottled fawn-grey shelly clay silty with 'solid' fossils.	—	8
	(i) Darkish silty fawn-grey shelly clay with a bedding plane of scattered pyritic fossils at the middle.	2	0
1	Dark grey silty clay with scattered line of phosphatic nodules 9 inches from the top.	2	0

FIG. 40. Gault section at the No. 3 claypit of the Tuileries de St. Parres les Vaudes at Courcelles près Clérey on E. side of the river Seine, and to the E. of the D 49 road 2·5 km SE. of Clérey, Aube.

of the *eodentatus* Subzone to *Lyelliceras lyelli* of the typical development of the *lyelli* Subzone. Beds 2 and 3 contain a closely comparable fauna to that of the English *lyelli* Subzone except that in England the Tethyan element represented by *Desmoceras* and *Hypophylloceras* is absent. *Douvilleiceras clementinum* is common in Bed 3 at Courcelles but this genus is very uncommon in the *lyelli* Subzone in England. The species of *Brancoceras* are somewhat different to those found in England and they frequently show a tendency to a zig-zag arrangement of the ribs as they sweep across the venter. The occurrence of *Eubrancoceras aegoceratoides* in Bed 2 (iii) is very important for long-range correlation (p. 135).

The beautifully preserved fauna of Bed 3 includes also bivalves, gastropods, and corals, and it is this horizon that has yielded many of the fine specimens of *Hoplites* (*H.*) spp., and *Douvilleiceras clementinum* from such localities as Dienville, Gaty, or just Aube, found in museum collections.

The remainder of Bed 4 contains a typical *spathi* Subzone fauna consisting essentially of species of *Hoplites* (*H.*) together with *Metahamites sablieri* and *Inoceramus concentricus*. At a height of 8 feet (2·438 m.) from the base of Bed 4 there is a small thickness of clay with scattered pyritised ammonites and this has yielded to the author a single example of *Mojsisovicsia delaruei compressa* (Spath).

Bed 5 probably represents much of the higher part of the *spathi* Subzone sediments seen at Revigny-sur-Ornain (text-fig. 37), for the species of *Hoplites* at the top of Bed 4 are not particularly high forms. Bed 6 above contains *Anahoplites* sp. indicating the extreme base of the *intermedius* Subzone.

Larcher, Rat & Malapris (1965 ; 246) considered that the section at Villemoyenne (No. 1 of the Tuileries of St. Parres-lès-Vaudes) showed a *mammillatum* Zone sequence. However, P. & J.-P. Destombes (1965 ; 263) and Marie (1965 ; table 1) indicated that there was overlap between the sequence exposed at Villemoyenne and that of Courcelles. The pit is extensive and the dip appears to be negligible. It is situated less than 2 kms SE. of the section at Courcelles and 0·5 km along the road from Villemoyenne to Le Ht. Villeneuve. An examination of the sequence has convinced the writer that it is wholly of high *mammillatum* Zone age, a conclusion which Dr. P. Destombes has also arrived at (personal communication).

(e) **La Vendue Mignot (Aube)**

The Tuilerie Le Clerc, situated about 200 yds W. of the D1 and a few hundred yards S. of the D108 roads at La Vendue Mignot, has been nominated as the type section of the Subzone of *Lyelliceras lyelli* & *Hoplites benettianus* by P. & J.-P. Destombes (1965 ; 262, 266). The section is very shallow, like many of the smaller terriers in this region of France, but with the combination of a northerly 3° dip and the slope of the ground surface, approximately 16 feet of weathered clays are exposed (text-fig. 41). The section is situated about 9 kms WSW. of that of Courcelles près Clérey, and the sequence although well weathered in its upper part is apparently the same.

Bed 1 was seen to a depth of 7 feet (2·133 m.) but yielded no ammonites to the writer. At 2 inches (0·050 m.) above the base of 2 (i) a single example of *Desmoceras latidor-*

satum (Michelin) was found *in situ* enabling a direct correlation to be made with Courcelles. Bed 2 (ii) at La Vendue Mignot corresponds to 2 (ii) at Courcelles, but yields a somewhat higher percentage of part-phosphatised fossils. The remainder of Bed 2 is too deeply weathered to permit the recognition of the remaining subdivisions seen at Courcelles, although its fauna *grosso modo* is the same as that listed above. In the soil at about the middle of the northern face of the pit, there are pieces of well weathered sandy marlstone yielding the fauna of Bed 3 at Courcelles.

Although this is the nominated type section of the *lyelli* Subzone proposed by P. & J.-P. Destombes it shows neither the relationship with the *eodentatus* Subzone below or the *spathi* Subzone above. Neither does it show a complete sequence in the *lyelli* Subzone itself.

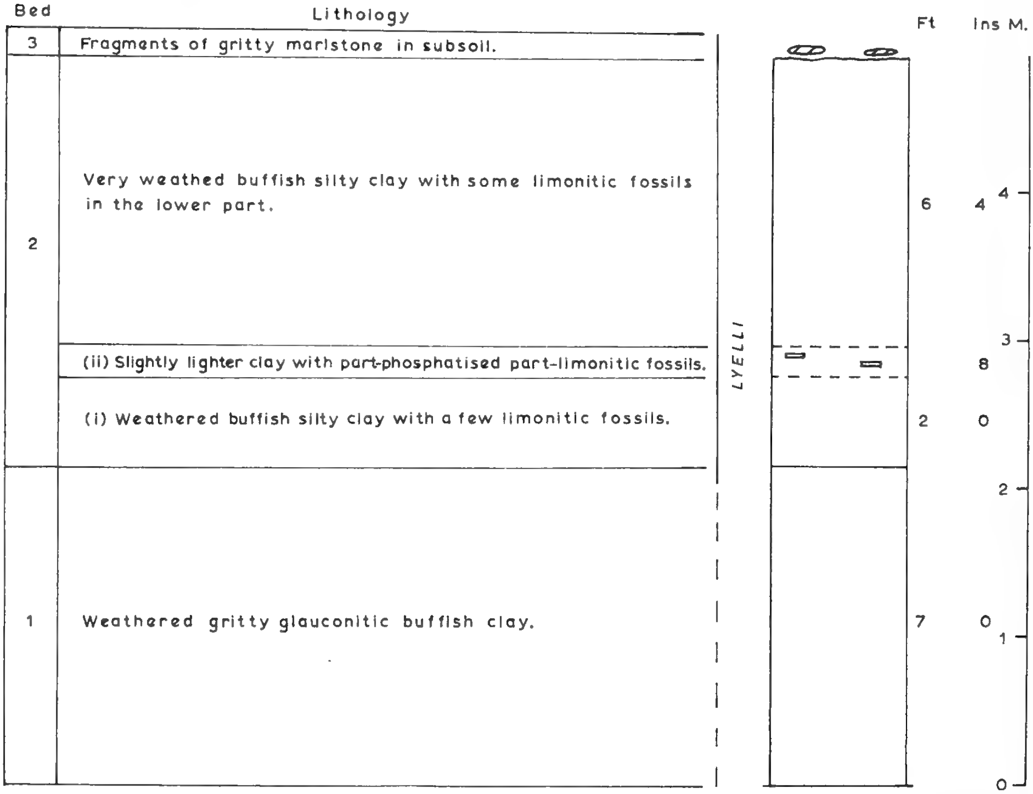


FIG. 41. Section in Gault at the Tuilerie Le Clerc, *c.* 200 yds W. of the D 1 road and a few hundred yards S. of the D 108 road, at La Vendue Mignot, on the N. side of the Foret d'Aumont, Aube.

(f) St. Florentin area (Yonne)

The early work of Ebray (1863) and Hébert (1863) did not present a true picture of the Albian succession in the area of St. Florentin, and Lambert (1894, 1913) was the first worker to give a more correct sequence. Lambert's sequence was the one quoted subsequently by Lemoine (1910). Houdard (1933) confirmed Lambert's observations and presented accurate and important new information. More recently P. & J.-P. Destombes (1965 ; 264–265) have reinterpreted the sequence indicating a facies change certainly within the *spathi* Subzone between St. Florentin and Montléhu a distance of barely 1 km. In this area the clay facies of the Perthois (the strip of country flanking the Chalk and including portions of the Départements of the Haute Marne, Aube, and Yonne) gives place to the predominantly sandy facies of the Puisaye (the similar strip of country stretching from the River Armance to the Loire).

No sediments of *eodentatus* Subzone age have been proved in this area. Although known to occur, *lyelli* Subzone sediments are no longer exposed, but from sections which existed formerly at St. Florentin, and to the SW. near Mont St. Sulpice, Seignalay and Beaumont, it is readily apparent from the old collections that the equivalent of Bed 3 at Courcelles is present. The fauna is the same but it is preserved in a much grittier and pebbly matrix. Two sections in sediments of *spathi* Subzone age exist in this area today.

Montléhu

The Tuilerie Montléhu is situated immediately S. of the N77 at the village of that name. It exposes about 18 feet (5·48 m.) of weathered grey clays with crushed *Hoplites* (*H.*) spp., and *Inoceramus concentricus*, and is classified without doubt with the *spathi* Subzone.

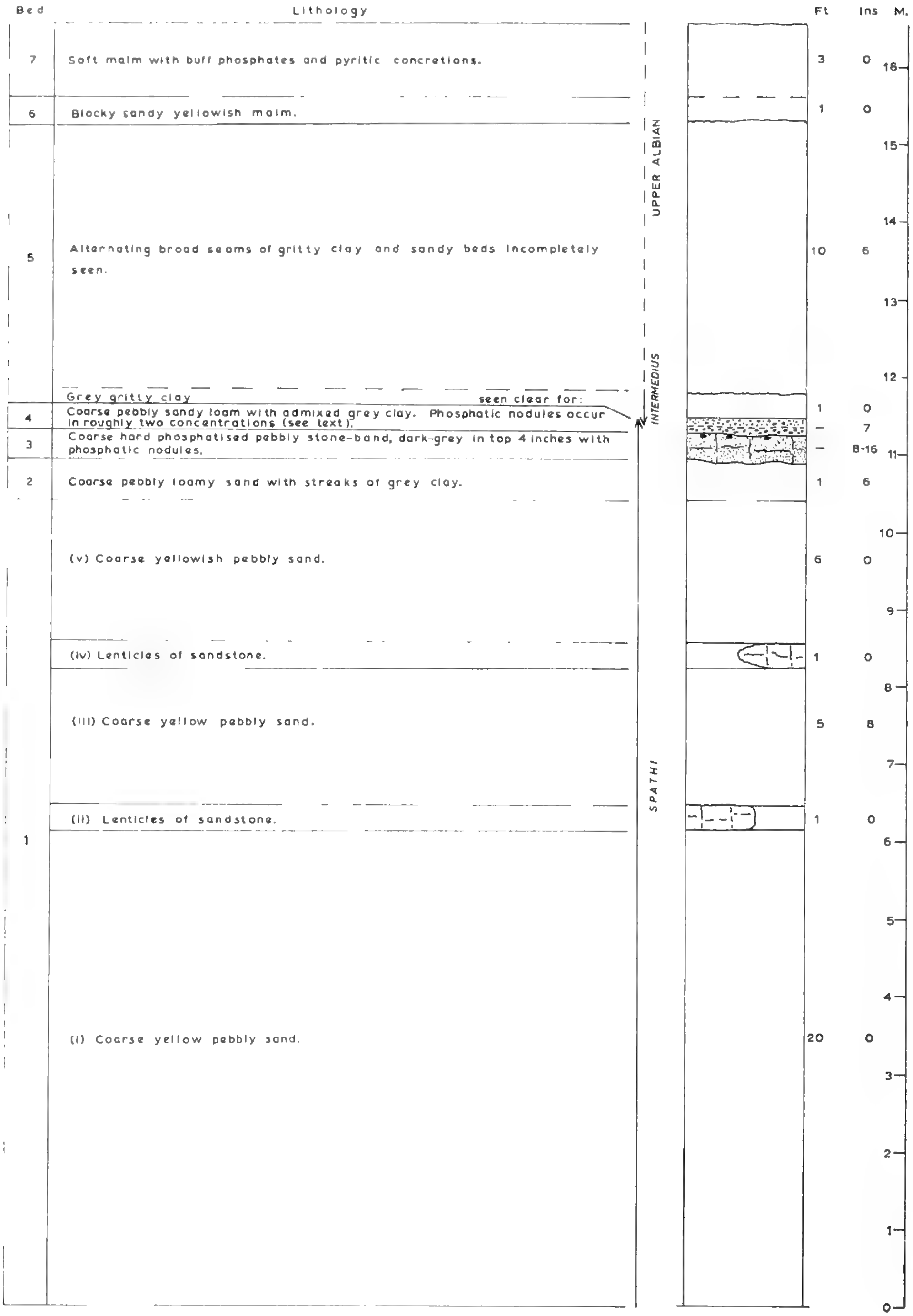
As one proceeds SW. the topography changes quickly, and St. Florentin is built upon the high ground formed by the essentially sandy deposits of both Middle and lower-Upper Albian age.

Sablière Binot

This disused sandpit in the Sables de Frecambault at the SE. end of the town of St. Florentin is situated on the same quarried escarpment as that described by Houdard (1933 ; 47). The pit, which is now being filled in, shows sediments of Middle & Upper Albian age (text-fig. 42). It has been mentioned by P. & J.-P. Destombes (1965 ; 264), and Marie (1965 ; table opp. p. 286) who includes additional information on the other sections in the area.

Bed 1 has not yielded fossils but it lies above the equivalent of Bed 3 at Courcelles (*lyelli* Subzone), known to be present in this area. It is almost certainly of *spathi* Subzone age and is considered to be the equivalent of the clays exposed at Montléhu. Bed 2 shows the incoming of clay sediment and it seems to the writer that this part of the sequence is more likely to have been deposited at the same time as the clays at Montléhu. However, the only fossils found are phosphatised bivalves. Dr. P. Destombes has informed me that large *Hoplites* (*H.*) were obtained from Bed 3 during the quarrying operation.

Bed 4, the Bed VII Graviers à *Opis glareosa* of Lambert, is of considerable interest. It can be divided into two very irregular subdivisions. A lower dark grey subdivision with *Hoplites* (*H.*) spp., derived from the *spathi* Subzone, and an upper



Bed	Lithology	Ft	Ins
7	Soft malm with buff phosphates and pyritic concretions.	3	0
6	Blocky sandy yellowish malm.	1	0
5	Alternating broad seams of gritty clay and sandy beds incompletely seen.	10	6
	Grey gritty clay seen clear for:	1	0
4	Coarse pebbly sandy loam with admixed grey clay. Phosphatic nodules occur in roughly two concentrations (see text).	–	7
3	Coarse hard phosphatised pebbly stone-band, dark-grey in top 4 inches with phosphatic nodules.	–	8-16
2	Coarse pebbly loamy sand with streaks of grey clay.	1	6
	(v) Coarse yellowish pebbly sand.	6	0
	(iv) Lenticles of sandstone.	1	0
	(iii) Coarse yellow pebbly sand.	5	8
	(ii) Lenticles of sandstone.	1	0
1	(i) Coarse yellow pebbly sand.	20	0

FIG. 42. Section in the Sables de Frecambault at the Carriere Binot, on the escarpment at the SW. end of St. Florentin, a few hundred yards N. of the lane leading to Crécy, Yonne.

lighter coloured subdivision which contains some material scoured out from the *spathi* Subzone sediments, and a predominant element derived from sediments of *intermedius* Subzone age. Indigenous *Anahoplites intermedius* and *Inoceramus concentricus* occur in the upper subdivision indicating that it is undoubtedly of *intermedius* Subzone age. The derived *intermedius* Subzone material includes species of *Anahoplites* which occur at the extreme top of the *spathi* Subzone and basal part of the *intermedius* Subzone in England.

Bed 5 is still pebbly in its lower 1 foot (0·30 m.) but it has not yielded fossils to the writer. Marie indicates that at about the middle of Bed 5 at the base of an argillaceous member the Upper Albian commences.

(g) **Summary**

The sections described briefly above provide a picture, albeit very imperfect, of Middle Albian sedimentation across the basin of deposition extending from the Kimmerian modified Palaeozoic massifs of the Ardennes on the NE. side to those of Morvan to the SW. (text-fig. 43).

The only information available about the sediments of *eodentatus* Subzone age come from the sections near Maurupt and Les Côtes Noires, in the NE. It is a curious fact that as yet it has not been detected in the Aube or Yonne. This must be due to a lack of exposures for the sequence in the *mammillatum* Zone in the area of the Bois de Perchois (Aube) is very thick and the Middle Albian sediments here are also apparently of considerable thickness. In England deposits of *eodentatus* Subzone age are in general very condensed and ammonites are not common except at a very few localities. Species of *Hoplites* (*Isohoplites*) form the majority of the ammonite fauna, and its usual associate in France *Lyelliceras* of the *camatteanum* group, is exceedingly rare in England.

Deposits of *lyelli* Subzones age already proven at Clermont-en-Argonne are also apparently thicker at Les Côtes Noires than in the Aube, but the lithological sequence is comparable from Les Côtes Noires to the St. Florentin area (Yonne).

At Revigny-sur-Ornain it is obvious that the *spathi* Subzone is represented by thick sediments especially the upper part. Unfortunately, the top of the Subzone has not been exposed at Les Côtes Noires, but at Courcelles the upper part of the Subzone is represented by a single nodule bed. No information is available about the sequence until the St. Florentin area is reached where, between Montléhu and St. Florentin itself, there is a change from the argillaceous facies of the Aube to the sandy facies of the Puisaye.

The *intermedius* Subzone is now known from five localities. It is quite thick at Revigny-sur-Ornain and the top of the Subzone was not determined in the sequence. *Intermedius* Subzone ammonites were determined by Breistroffer at Montierender (Haute Marne) and Le Plessis (Aube) (P. & J.-P. Destombes 1965 ; 262). Only the basal part of the Subzone has as yet been determined at Courcelles. At St. Florentin and at other localities in the Puisaye, the Subzone is represented within condensed deposits. No other Middle Albian Subzones are as yet known in this area.

Very little information is available about the stratigraphy of the Gault between

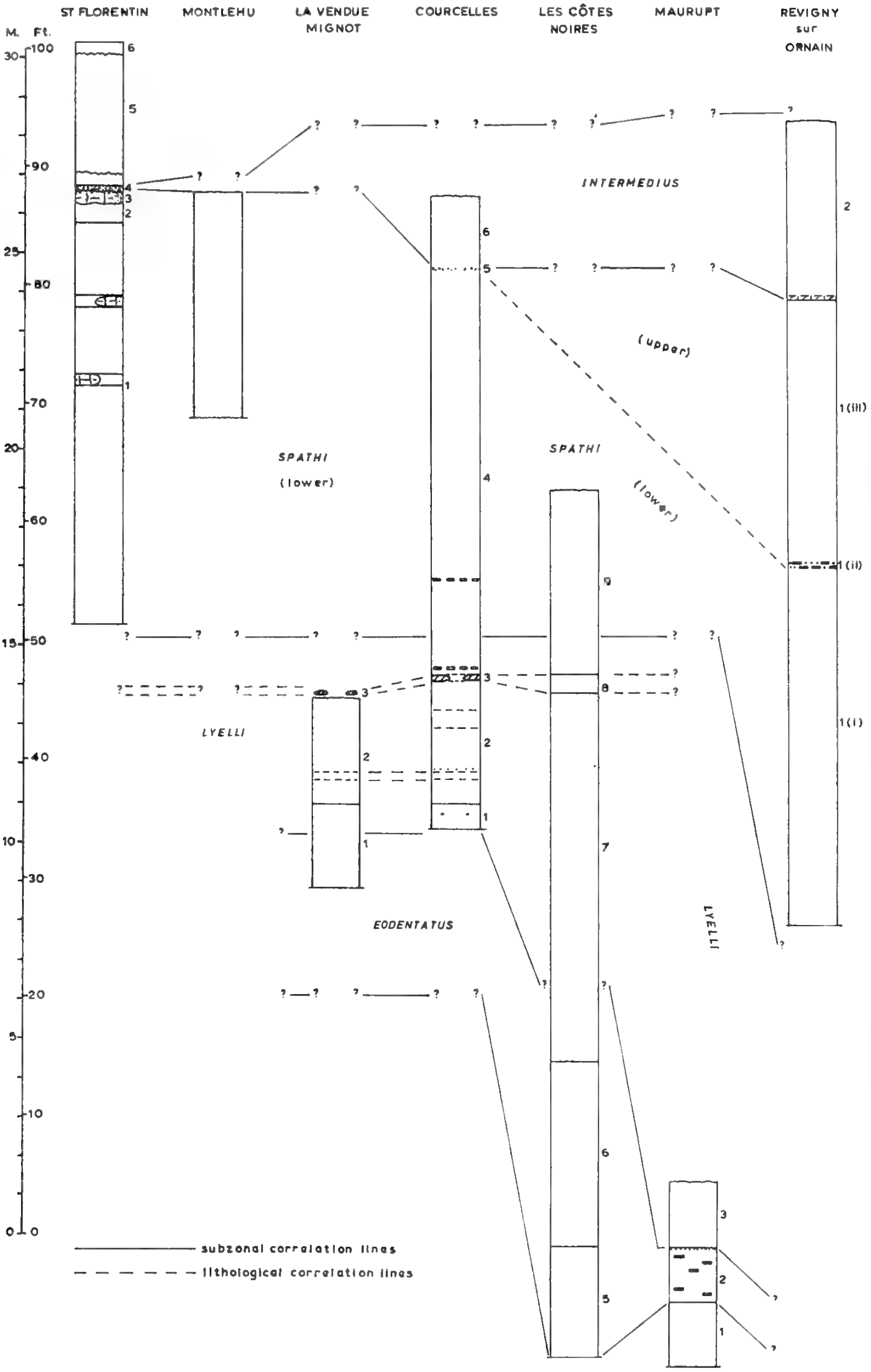


Fig. 43. Correlation of Middle Albian sections from the Meuse to the Yonne.

this area and the Pays de Bray. However, a comparison between the succession shown by the La Chapelle boring at St. Denis, Paris (Jukes-Browne 1900 ; 397) and that of St. Florentin (Yonne) and Villers St. Barthélemy in the Pays de Bray below shows that the predominantly sandy beds in the Yonne, fringing the massif of Morvan, give way to clays under Paris, but the sequence is thinner. The sequence thickens again northwards from Paris, and in the Pays de Bray the Middle Albian is represented by clays, and the Upper Albian by an Upper Greensand facies. The clay facies extends down to include at least the top of the *mammillatum* Zone towards the NW. end of the Bray.

(iii) **PAYS DE BRAY**

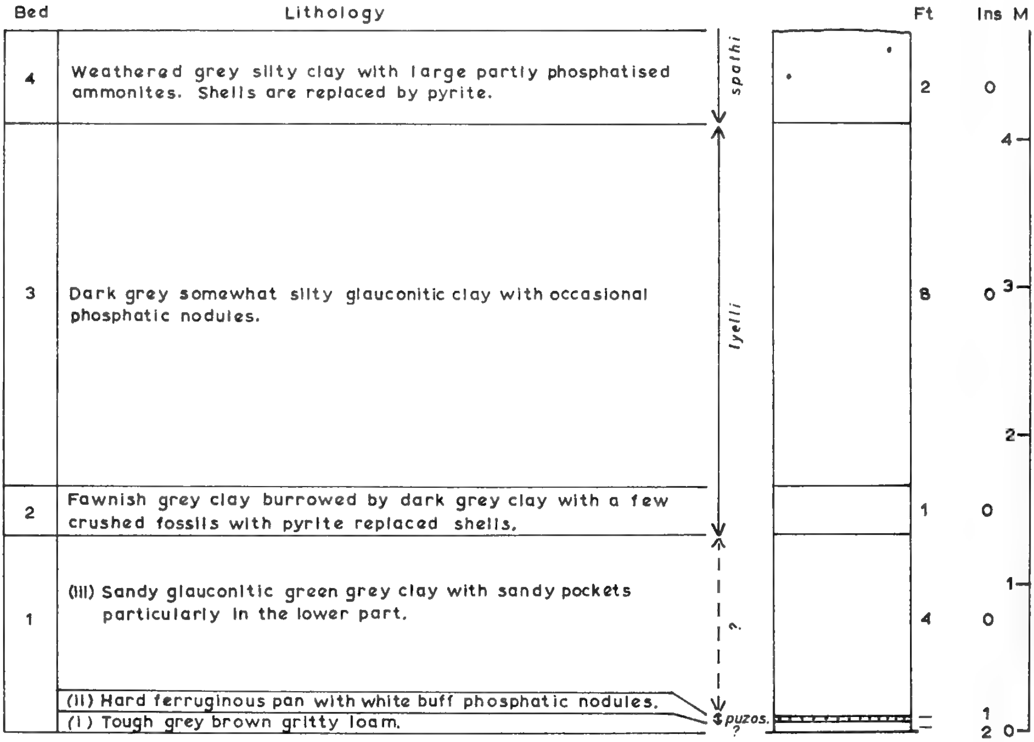
The Pays de Bray both geologically and scenically resembles the Weald (text-fig. 33). The NE. side of the Bray dips very steeply beneath the Chalk and there is no information on the sequence on this side. However, at the NW. end and along the whole of the south western side the dip is much more gentle and brick-pits in the Gault have been opened at a number of places. Usable information has been obtained from only four of these : Briqueterie Ledoict, St. Martin, at the NW. end of the Bray (P. Destombes 1970 and *in* Pomerol & Feugueur 1968) ; a section near Forges-les-Eaux (P. Destombes 1958) ; and two sections in the area of Villers St. Barthélemy (J.-P. & P. Destombes 1938b). The position of these sections is indicated on text-fig. 33.

The most detailed information on the Middle Albian sequence in this region yet published is contained in the two papers already cited by J.-P. & P. Destombes (1938b) and P. Destombes (1958). They demonstrate the presence of the *eodentatus, lyelli, spathi* and *intermedius* Subzones all in a clay facies. The *niobe* Subzone is indicated as being represented by sandy deposits (P. Destombes 1958) but no definite evidence has been published to support this. This is followed by a break in the sequence involving the remainder of the Middle Albian.

(a) **Villers St. Barthélemy**

Two sections were described by J.-P., & P. Destombes in this area (1938b ; 122, 123). Their section 1 is no longer exposed but showed deposits of both the *spathi* and *intermedius* Subzones which together are over 30 feet thick (9·15 m.). Section 2 is now well exposed and shows the sequence given in text-fig. 44.

Bed 1 (ii) contains *Otohoplites* spp. including *O. destombesi, Beudanticeras* spp. and *Douvilleiceras* spp., indicating the uppermost part of the *mammillatum* Zone. No fossils were seen in the lower part of 1 (iii) and it is not possible to say whether it is of *eodentatus* or basal *lyelli* age: the top of 1 (iii), however, contains crushed *Hoplites* (*H.*) spp. Bed 2 contains a good bivalve fauna but only a few crushed specimens of *Beudanticeras* cf. *laevigatum, Protanisoceras* (*P.*) sp. cf. *barrense,* and in Dr. P. Destombes' collection, a few examples of *Lyelliceras lyelli.* This bed definitely can be classified with the *lyelli* Subzone, as also can Bed 3 on the occurrence of a few crushed *Beudanticeras* at about the middle of the sequence. The basal part of Bed 4 however, contains large crushed *Hoplites* (*H.*) including *H.* (*H.*) cf. *dentatus* and *H.* (*H.* cf. *maritimus* sp. nov. indicating the lower part of the *spathi* Subzone. How much of this sequence overlaps that of section 1, if at all, cannot be determined. Unfortunately, during 1967 this section was rapidly expanded, and the higher part of the sequence seen in a rise has now been quarried away.



Bed	Lithology
4	Weathered grey silty clay with large partly phosphatised ammonites. Shells are replaced by pyrite.
3	Dark grey somewhat silty glauconitic clay with occasional phosphatic nodules.
2	Fawnish grey clay burrowed by dark grey clay with a few crushed fossils with pyrite replaced shells.
1	(III) Sandy glauconitic green grey clay with sandy pockets particularly in the lower part.
	(II) Hard ferruginous pan with white buff phosphatic nodules.
	(I) Tough grey brown gritty loam.

FIG. 44. Section in Gault in a claypit 0·8 km N. of the village of Villers St. Barthélemy, *c.* 150 yds E. of the D2 road, Pays de Bray.

(b) Forges-Les-Eaux, & St. Martin

Further north in the Pays de Bray, the *eodentatus* and *lyelli* Subzones sediments expand considerably and consist of shelly clays. The section in the Briqueterie Ledoict near St. Martin l'Hortien situated at the NW. end of the Pays de Bray has been described by P. Destombes, who introduced the writer to it. It shows a good development of clays of *eodentatus* Subzone age overlying high *mammillatum* zone clays (see P. Destombes 1970 & *in* Pomerol & Feugueur 1968 ; 129–130, where the locality is given as Bully).

The *lyelli* Subzone is known from a section west of Forges-Les-Eaux where Fortin collected phosphatic and pyritic *Lyelliceras* with the shell, now in the Muséum d'Histoire Naturelle, Rouen, which were recorded by P. Destombes (1958 ; 309).

However, no detailed information on the sedimentary sequence in this Subzone in the northern area of the Bray has as yet been recorded.

(iv) COMPARISON BETWEEN THE PAYS DE CAUX AND THE ISLE OF WIGHT

The expansion of the sequence towards the NW. end of the Pays de Bray apparently increases further to the NW., for the deep boring at Puys, near Dieppe, showed a very considerable thickness of clay (Jukes-Browne 1900 ; 398). However, an unknown thickness of this clay must be of Upper Albian age, representing a facies change from the Upper Greensand sequence seen in the Pays de Bray. Jukes-Browne is probably wrong (1900 ; 398) in classifying only the lowest 6·7 feet (2 m.) of sandy black clay of the core with the Lower Gault, but in the absence of palaeontological evidence, the boring cannot be interpreted. In the Pays de Caux a somewhat different facies is seen reflecting the proximity of a marginal area of Middle Albian deposition.

The Albian sediments of the Pays de Caux (Seine Maritime) are well exposed in the cliffs between St. Jouin and Le Havre. The Upper Albian Gaize rises from sea-level at the base of the Chalk cliffs to the N. of St. Jouin followed quickly by the Gault, and the top of the underlying Poudingue ferrugineux. Below these pebbly beds are sands of Upper Aptian age. In the area between Octeville and St. Adresse these sands are seen to rest upon Kimeridgian sediments, and in this area the whole sequence of Lower Cretaceous sediments can be seen sandwiched between the Chalk and the Kimmeridge Clay. However, along the entire coast from St. Jouin to Cap de la Hève a large number of rock falls tend to obscure the lower part of the Albian sequence in particular, nonetheless, it is possible to make out the succession at many points.

Lennier (1867) first described the succession and provided the foundation upon which subsequent stratigraphic work has been based. His is still the only published section of the sequence at Cauville (1867 ; plate 4). The early history of research was summarised by Jukes-Browne & Hill (1896) who made the first major attempt to correlate Upper Albian and Cenomanian sediments in the Pays de Caux with those of southern England. Hill also provided some information on earlier Albian sediments and gave the first detailed accounts of the Albian sequence seen between Octeville and Ste. Adresse. Jukes-Browne (1900 ; 395–401) reviewed the Albian sediments in this area, presenting a useful picture but without any real detail. Subsequent stratigraphic work has tended to concentrate on the sequence at Cap de la Hève, as for example the recent important studies by P. Destombes (1958), Cayeux (1960), and Rioult (1962). Destombes (1958 ; 306–308) sets out to describe the Albian sediments between Le Havre and St. Jouin but, and this is important, he bases his account of the stratigraphy on the sequence seen at Cap de la Hève and Octeville. His classification of these sediments gives a good picture of the zonal sequence in this area. Cayeux (1960 ; 21–25) quotes large extracts from Destombes' paper, but adds to this important new information pointing out that the sequence in the Poudingue at Cauville shows marked lithological variation to those seen elsewhere. The account by Rioult (1962 ; 39–42) of the section at Cap de la Hève is very useful and he also presents a comparison with the Albian sequence in the Isle of Wight and the Dorset and Devon coastal area. All three papers ably summarise the earlier literature.

As Cayeux (1962 ; 2) has pointed out, the stratigraphy of the Albian sediments between Cap de la Hève and St. Jouin needs revision. Such a revision requires patient study because of the rarity of age diagnostic fossils. The following account is quite obviously incomplete but it adds some new information on the succession and provides a much more accurate foundation for the correlation of the sediments seen in the Pays de Caux with those of the Isle of Wight. In this section of the work the full exposed sequence of the Aptian and Albian sediments up to the base of the Gaize is recorded. The terms ' Poudingue ferrugineux ', & ' Argiles du Gault ' of Lennier (1867) cannot be accurately delimited in all the sections.

It is essential that these sections are worked with the greatest care particularly in the early spring months. Winter frosts and the general freezing of ground water cause the shattering of the Chalk in the cliffs and large blocks can be dislodged merely by the ringing note of a hammer or by the slight vibration of a heavy surf. Major cliff falls are not infrequent during the early months of the year, but the collecting is far better at these times !

The sections described below indicate that the cliffs between St. Jouin and Cap de la Hève present a cross section through a depositional trough. The Lower Albian sediments are slightly comparable to those of the Isle of Wight, but those of the Middle Albian are quite different.

(a) **St. Jouin**

The section described in text-fig. 45 is exposed about 300 yds S. of the cliff-top car park west of St. Jouin. It has not previously been described, and includes Lower, Middle and Upper Albian sediments up to the base of the Gaize. Unfortunately no age diagnostic Middle Albian fossils have been found here by the writer and the correlation of this section with that of Cauville (text-fig. 49) is based purely on the lithology, and is, therefore, suspect in detail.

(b) **Cauville**

From approximately 50 yds SW. of the waterfall to about 300 yds NE. of it there are good sections interrupted by cliff falls (text-fig. 46). As Cayeux has indicated (1960 ; 23), there are striking variations in the Poudingue, the sediments of the *mammillatum* and *?tardefurcata* Zones, in this area. This is well shown in the four sections described here for the first time, however, the Middle and Upper Albian sediments remain reasonably constant.

Beds 1–9 are of Lower Albian, essentially *mammillatum* Zone, age. In the Bucaille collection in the Muséum d'Histoire Naturelle, Rouen, there are three specimens of *Hoplites* (*Isohoplites*) and one specimen of *Hoplites* (*H.*) which come from Cauville. They are preserved in blackish phosphate with traces of the inner nacreous layer of the shell preserved, and with evidence of pyritic inner whorls and glauconitic loamy

Bed	Lithology	Ft	Ins
16	First concretionary stone band of the Gaize.		
15	Tough blocky grey sandy malm with scattered pale phosphatic nodules.	3 to 4	0 0
14	Argillaceous dark grey silty glauconitic sediment resting on the guttered upper surface of Bed 13 below, becoming more of a clay upwards, then passing into about 6 inches of hard shaley grey shelly clay.	11	6
13	Highly glauconitic blackish loam resting on a guttered surface of Bed 12 below. Pyritic concretions occur throughout.	2	3
12	Highly glauconitic very dark grey loam a bit pebby passing down by rafts into sparsely shelly loam resting on guttered surface of Bed 11 below.	3	0
11	Tough fawn sandy clay with brown phosphatic nodules with dark interiors, septarian at the top.	1	0
10	Very pebbly grey loam with crushed bivalves.	1	6
9	Dark grey less pebbly clay than Bed 8 with intercalations of dirty yellowish sand. Scattered nacreous shells occur.	1	2
8	Pebbly dark grey ill-graded fossiliferous sandy clay with nacreous shells preserved.	1	5
7	Hard gritty concretions in tough grey pebbly clayey matrix.	–	8
6	Tough ill graded ferruginous loam with phosphates & grit.	–	4-6
5	Ferruginous pebbly sand with some streaks of grey clay. Lenticles of grit occur near the top.	3	0
4	Scattered sandy phosphatic nodules in brown pebbly sandy loam.	–	9
3	Rather pebbly streaked grey loamy clay and brown sand.	1	0
2	Mottled grey sandy clay-loam, and brown sand less pebbly than Bed 1 into which it passes.	2	3
1	Pebbly dark grey green loam with streaks of brown sand becoming fewer downwards. In the top of the bed there occur pebbly concretionary sandstone lenticles 4-5 inches thick.	2	6

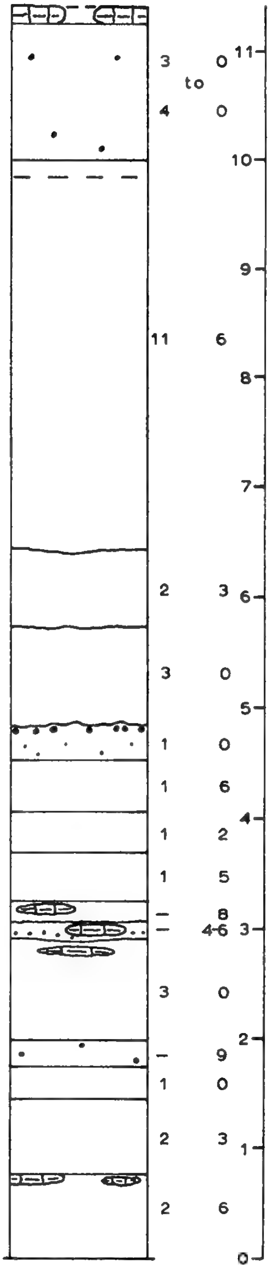


FIG. 45. Sequence in the Poudingue and Gault in the sea-cliff, *c.* 150 yds SW. of the cliff path exit, St. Jouin Bruneval, Pays de Caux.

<table>
<tr><th>Bed</th><th colspan="2">Lithology</th><th></th></tr>
<tr><td>16</td><td colspan="2">Hard light-grey concretionary sandstone. Basal bed of the Gaize.</td><td></td></tr>
<tr><td>15</td><td colspan="2">Light-grey cross-bedded sandy marly clay with a few concretions.</td><td></td></tr>
<tr><td>14</td><td colspan="2">Grey glauconitic clay-loam with black, buff-rinded, phosphatic nodules at top and bottom</td><td></td></tr>
<tr><td>13</td><td colspan="2">(v) Dark grey glauconitic slightly pebbly loam.</td><td></td></tr>
<tr><td></td><td colspan="2">(iv) Thin seam of irregular blackish light-rinded phosphatic nodules in loam.</td><td></td></tr>
<tr><td></td><td colspan="2">(iii) Lighter grey glauconitic sparsely shelly loam.</td><td></td></tr>
<tr><td></td><td colspan="2">(ii) Thin seam of scattered blackish light-rinded phosphatic nodules in loam.</td><td></td></tr>
<tr><td></td><td colspan="2">(i) Darkish grey glauconitic shelly loam.</td><td></td></tr>
<tr><td>12</td><td colspan="2">Very shelly gritty glauconitic fawny pebbly loamy clay with rolled fragments of fawn clay in the basal few inches, pebbly patches at the top, and a few concretions.</td><td>EOD- NIOBE</td></tr>
<tr><td>11</td><td colspan="2">Streaked dark green glauconitic sandy pebbly loam, with a few phosphatic nodules.</td><td></td></tr>
<tr><td>10</td><td colspan="2">Black clay channelled into the bed below.</td><td>ENT.</td></tr>
<tr><td>9</td><td colspan="2">Irregular bed of pebbly ferruginous sand with large quartzite pebbles and phosphatic nodules.</td><td></td></tr>
<tr><td>8</td><td colspan="2">Grey greenish glauconitic loam with a 4 inch thick oxydised zone at the top. In the two end sections there is a single bed of grey pebbly sandy concretions, very hard, with phosphatic nodules in the lower part. Between the two end sections, an upper bed of less pebbly grey green sandstone lenticles appears in the sequence. The lower lenticles are underlain by dark grey pebbly glauconitic loam with gritty and pebbly phosphatic nodules at the base.</td><td></td></tr>
<tr><td>7</td><td>190 yds NE of waterfall</td><td>Between path and waterfall</td><td>KITCHINI</td></tr>
<tr><td></td><td>(v) Grey green pebbly glauconitic loam with patches of pure quartz sand, the whole extensively burrowed in places.
(iv) Fawnish pebbly loam.
(iii) Very pebbly grey-green loam.
(ii) Bed of pebbles with a few gritty phosphatic nodules.
(i) Dark grey gritty glauconitic micaceous clay with a few pyrite nodules and wisps of white sand, together with brown phosphatic nodules.</td><td>(vi) Tough mottled brown-dark grey loam becoming coarser and darker upwards with pebbles at top.
(v) Dark grey sandy clay and yellowish sand with line of irregular gritty phosphatic nodules at top and small hard placquettes at the base.
(iv) Variegated greenish grey-brownish loam.
(iii) Coarse glauconitic loam.
(ii) Thin ferruginous pale-hearted fine-grained concretions.
(i) Coarse glauconitic loam.</td><td></td></tr>
<tr><td>6</td><td colspan="2">(ii) Mixture of ferruginous sand and blackish clay in streaks.</td><td></td></tr>
<tr><td></td><td colspan="2">(i) Coarse dirty yellow sand.</td><td></td></tr>
<tr><td>5</td><td colspan="2">(v) Concretions of massive ferruginous pebbly grit, with interstitial yellow sand.</td><td></td></tr>
<tr><td></td><td colspan="2">(iv) Yellowish sand.</td><td></td></tr>
<tr><td></td><td colspan="2">(iii) Slightly cemented ferruginous pebbly grit passing into 5 (iv) above.</td><td></td></tr>
<tr><td></td><td colspan="2">(ii) Coarse yellowish sand grading into 5 (iii).</td><td></td></tr>
<tr><td></td><td colspan="2">(i) Ferruginous pebbly cemented grit grading up into 5 (ii).</td><td></td></tr>
<tr><td>4</td><td colspan="2">Grey sandy clay and dirty yellow sand mixed together in a mottled loam.</td><td></td></tr>
<tr><td>3</td><td colspan="2">Yellowish bedded sand with glauconite: some thin-bedded and cross-bedded units. Nodules of phosphatised grit occur scattered throughout.</td><td></td></tr>
<tr><td>2</td><td colspan="2">Irregular shaped masses of ferruginous pebbly grit.</td><td></td></tr>
<tr><td>1</td><td colspan="2">Dirty yellow sand with glauconite.</td><td></td></tr>
</table>

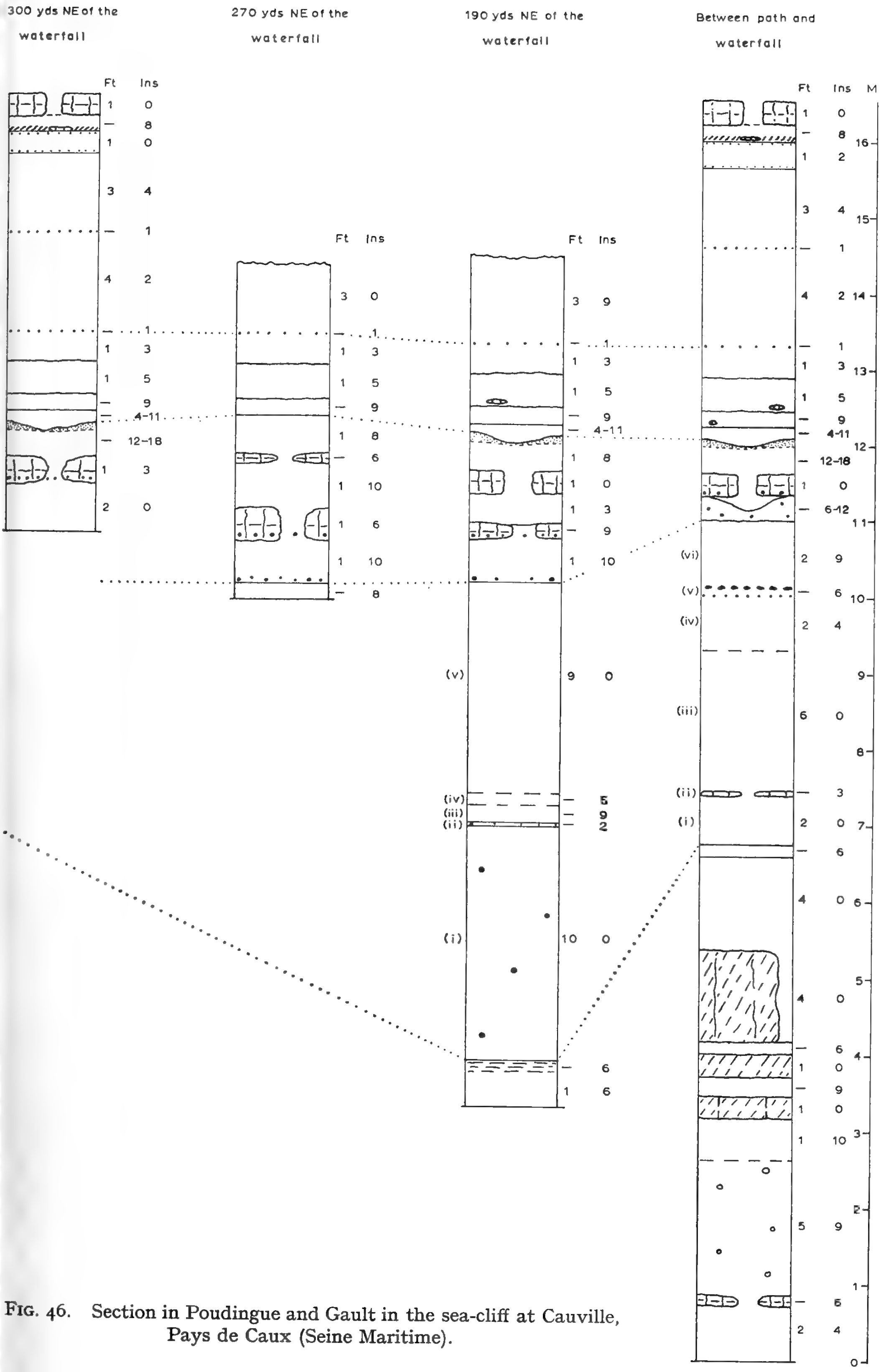


FIG. 46. Section in Poudingue and Gault in the sea-cliff at Cauville, Pays de Caux (Seine Maritime).

Bed	Lithology	Ft	Ins
11	First concretionary stone band of the Gaize.		
10	Silty glauconitic mid-grey clay at base becoming siltier and lighter in colour upwards as clay content decreases. Phosphatic and pyritic nodules occur scattered throughout. Definite break in sequence at the base.	6	0
9	Tough mid-grey, sparsely shelly slightly glauconitic clay, silty at base, becoming progressively less silty upwards. Scattered shells occur throughout.	5	0
8	Dark grey-greenish glauconitic loam with scattered shells. Thin seams of light-rinded brown phosphatic nodules occur as shown. The basal line contains gritty phosphatic nodules, the uppermost line contains septarian phosphatic nodules.	— 3 — — — — — 1 —	2 4 1 6 1 10 1 0 1
7	Dark grey-black greenish tinged glauconitic loam; a little pebbly with very scattered gritty phosphatic nodules, and shells. Definite break in sequence at the base.	4	0
6	Dark grey-green glauconitic loam with small phosphatic nodules, and shells.	1	1
5	Transitional bed with dark grey sandy clay content increasing upwards. Dark brown phosphatic nodules at top and bottom.	—	10
4	Brownish sand with a 1–2 inch bed of pure running grit at the base. The sand is slightly glauconitic in the lower half, but upper half is seamed with glauconitic wisps.	3	5
3	Hard dark brown very pebbly indurated grit with a few phosphatic nodules.	2	0
2	Mottled brown and dirty yellowish sand with a few brownish clay wisps, becoming ferruginous in the upper foot or so.	4	2
1	Heavily bioturbated mottled loam consisting of a churned-up mass of grey sandy clay brown and dirty white sand in wisps and pockets. Bed becomes more sandy downwards, and contains scattered soft buff phosphatic nodules.	6	4

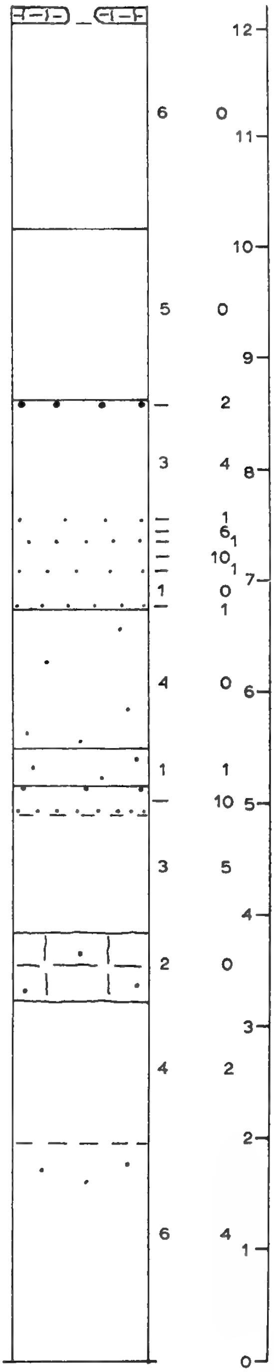


FIG. 47. Section in Poudingue and Gault in the sea-cliff immediately to the NE. and below the cliff-top car-park, Octeville, Pays de Caux.

matrix. This matrix is very similar to Bed 11. Bed 12 at the base shows angular pieces of clay indicating heavy erosion of previously deposited clay sediment. The bed itself is sandy and contains very fragile but well preserved *Inoceramus concentricus*, *Anahoplites planus*, *A. splendens*, and *Dimorphoplites niobe*, indicating the *niobe* Subzone not previously recognised in the Pays de Caux. The loams of Bed 13 also contain *I. concentricus* in the lower 1 foot 3 inches (0·38 m.) but apparently no ammonites. Post *eodentatus* Subzone Middle Albian sediments are, therefore, present in this area. The Upper Albian sediments probably commence at some level within Bed 13.

(c) **Octeville**

This section (text-fig. 47) also has not yielded age diagnostic Middle Albian fossils to the writer. It is situated in the cliff immediately to the NE. of the cliff-top car park, and again has not previously been described in detail. The lithological correlation with the sequence at Cap de la Hève and Cauville is, however, more definite than that of St. Jouin and Cauville (text-fig. 49).

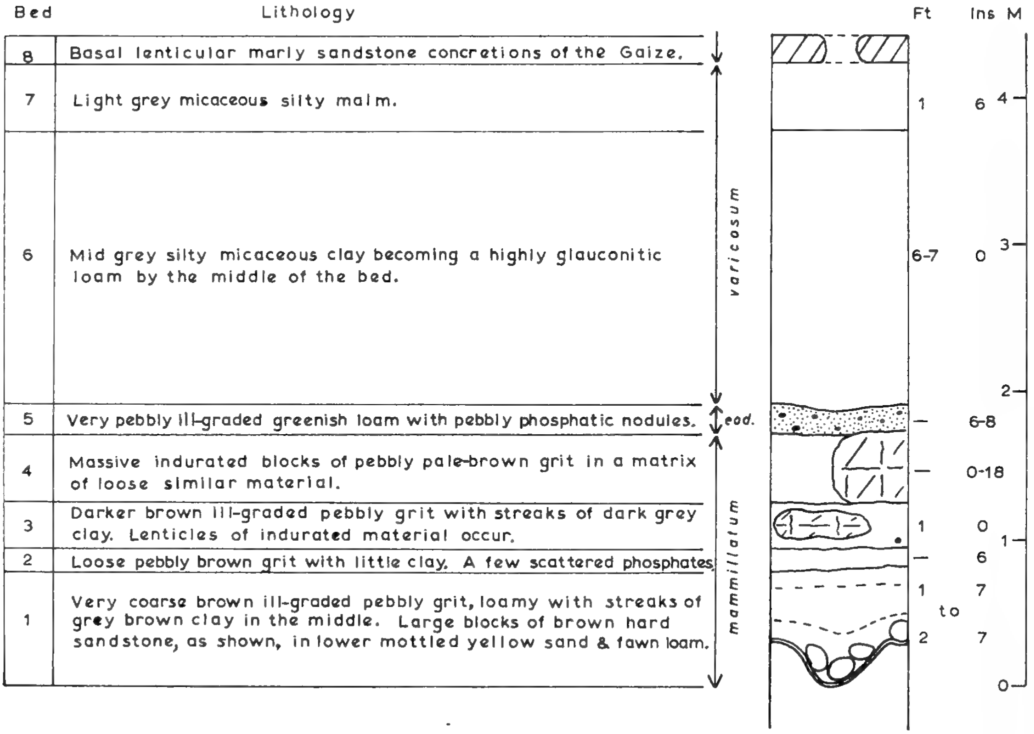
(d) **Cap de la Hève**

This famous section can be seen high in the cliff on the northern side of the Cap (text-fig. 48). It has been studied by a number of workers, but the best recent description of the sequence is that given by Rioult (1962 ; 39–42). Cayeux (1960 ; 25) has recorded *Goodhallites goodhalli* from the base of the bed here numbered 6, and Bed 4 is of *mammillatum* Zone age. In the Bucaille collection at Rouen, there is a single example of *Hoplites* (*H.*) preserved in blackish, gritty phosphate stated to have come from Cap de la Hève. The preservation is identical to fossils found occasionally in Bed 5 which, therefore, probably contains *eodentatus* and possibly basal *lyelli* Subzone fossils in *remanié*.

(e) **Summary, and comparison with the Isle of Wight**

The lithological correlation of the sections described above is shown in text-fig. 49. It can be seen that Lower and Middle Albian sediments reach their maximum development in the area of Cauville. *Eodentatus* Subzone sediments are present at all localities with the possible exception of St. Jouin where it has not been proved. At Cauville, the *eodentatus* Subzone is apparently less condensed, and is followed by sediments of the *niobe* Subzone. To what extent higher Middle Albian sediments are present, if at all, is unknown at this time. At Cap de la Hève it appears that Upper Albian sediments rest directly upon the residue of basal *dentatus* Zone age.

Even if the classification of these sections is unsatisfactory, it is immediately apparent that all previous correlations of the ' Argiles du Gault ' of the Pays de Caux with the Gault of the Isle of Wight are no longer tenable (p. 42). It appears that the sequences in the Isle of Wight and the Pays de Caux are truly out of phase. In the Isle of Wight the *kitchini* Subzone of the *mammillatum* Zone (Lower Albian) is represented *remanié* in the basal pebble bed of the Carstone ; in the Pays de Caux it is well developed at Cauville. The *eodentatus* Subzone is represented at the top of the Carstone by sediments containing indigenous *Hoplites* (*Isohoplites*) ; in the Pays de Caux it is present but very condensed even at Cauville. The major difference, however, occurs in the Gault. In the Isle of Wight the clays are of *lyelli*, *spathi*, and probably *intermedius* Subzones age, followed possibly directly by some *orbignyi* Subzone sediments (Upper Albian) ; the bulk of the *loricatus* and the whole of the *lautus* Zone being absent. In the Pays de Caux no sediments of any of the Subzones mentioned above have yet been detected. However, the *niobe* Subzone is present at Cauville, although absent in the Isle of Wight, and the lowest Upper Albian Subzone yet proved is *varicosum*.



Bed	Lithology	Ft	Ins
8	Basal lenticular marly sandstone concretions of the Gaize.		
7	Light grey micaceous silty malm.	1	6
6	Mid grey silty micaceous clay becoming a highly glauconitic loam by the middle of the bed.	6-7	0
5	Very pebbly ill-graded greenish loam with pebbly phosphatic nodules.	—	6-8
4	Massive indurated blocks of pebbly pale-brown grit in a matrix of loose similar material.	—	0-18
3	Darker brown ill-graded pebbly grit with streaks of dark grey clay. Lenticles of indurated material occur.	1	0
2	Loose pebbly brown grit with little clay. A few scattered phosphates	—	6
1	Very coarse brown ill-graded pebbly grit, loamy with streaks of grey brown clay in the middle. Large blocks of brown hard sandstone, as shown, in lower mottled yellow sand & fawn loam.	1 to 2	7 7

FIG. 48. Section in Poudingue and Gault in the sea-cliff on the N. side of Cap de la Hève, 100 yds N. of the lighthouse, Ste Adresse, Le Havre, Pays de Caux.

It is probable that the Isle of Wight and the Pays de Caux belong to two separate depositional troughs (p. 142) and do not form one area of deposition as implied by previous workers. The sediment of the 'Argiles du Gault' is a sandy loam rather than a clay and small pebbles are present. This together with the Poudingue below indicates the close proximity of a shoreline but outcrop and borehole information indicate that this could hardly be to the south (see p. 142).

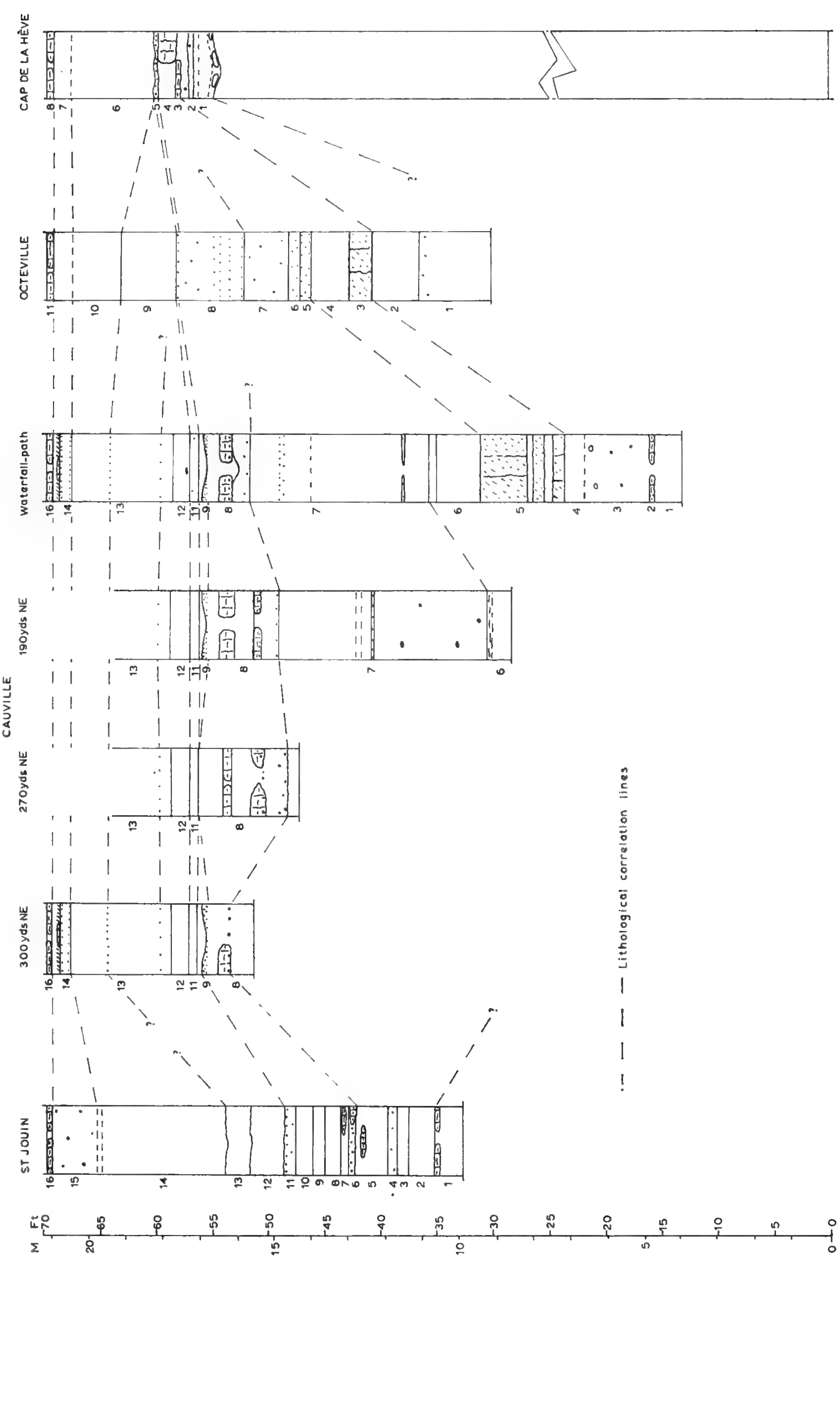


FIG. 49. Correlation of sections in the sea-cliffs of the Pays de Caux, Seine Maritime.

With the completion of the description of the individual sections in England together with a brief review of those in France, it is now possible to consider in detail the Zonal and Subzonal scheme of the Middle Albian. It is instructive and sobering to examine also the history of the development of this particular scheme, not atypical of many zonal schemes. There are workers who would insist that zonal schemes should be fixed for all time with little regard to future detailed work, or whether the scheme is based upon firm foundations.

IV. DEFINITION OF THE MIDDLE ALBIAN SUBSTAGE AND ITS ZONAL SCHEME IN THE ANGLO-PARIS BASIN

A. **Historical background**

The Formation name Gault was accepted in much the same sense by English and French geologists within the first half of the 19th Century. The history of its use in England was given by Jukes-Browne (1900 ; 14–31). D'Orbigny took William Smith's concept, that individual formations could be determined by their fossil content, a major step forward when he recognised that fossils characteristic of one lithological unit occurred in different lithologies and that these, although deposited at different localities, were formed at the same time. He erected, therefore, a series of chronostratigraphic stages to include these diverse lithologies. Apart from the localities mentioned by d'Orbigny (1842 ; 404–5) in his definition of the Albien stage (latinized to Albian), he recorded others in 1849 (*in* Geinitz 1849 ; 6–7). Pictet & Campiche adopted d'Orbigny's stage name when they commenced their description of the Cretaceous fauna of Ste Croix, Vaud, Switzerland, subdividing it into Albien infériur, moyen and supérieur (1858 ; table facing p. 27).

De Rance (1868 ; 163–171) was the first worker to describe the Gault section at Folkestone in detail. He accepted d'Orbigny's term Albian and divided it into lower and upper divisions drawing the boundary between them at what is now known as the junction between Beds VIII and IX. The lower division corresponds approximately, therefore, to Pictet & Campiche's Albien moyen. He recognised eleven beds in the Folkestone Gault and referred each to a zone based on its characteristic fossil ; employing essentially the characteristic ammonite. Later Price (1874 ; 342–368) revised De Rance's description but neither of these workers on these occasions attempted to apply their zonal scheme to sections other than at Folkestone.

Barrois (1875b ; 707–714) was the first geologist to formally define a zonal scheme for the Albian of the Anglo-Paris Basin in the sense that we use today. This idea of the application of an index fossil denoting a segment of time and represented by different types of sediment, or none at all, differed from that of De Rance & Price who used them merely in a local sense for an actual lithological unit. However, the idea crystallised by Barrois for the Albian is implicit in the writings of earlier French workers including d'Orbigny. Barrois recognised a tripartite division into:—

Zone à Ammonites inflatus
Zone à Ammonites interruptus
Zone à Ammonites mammillare

Of these only the lower two zones were included in the Albian, the Zone à Ammonites inflatus being included by him in the Cenomanian. Nonetheless, the terms ' Zone of Ammonites mammilare ' and ' Zone of Ammonites interruptus ' were first used by De Rance (1868) at Folkestone. Barrois stated that the type area of the interruptus Zone was the Aube but he recognised that in this area there was a mixture of what he thought to be the fauna of the mammillare Zone (e.g. *Douvilleiceras* of the *clementinum* group) and that of the interruptus Zone in the clays classified with the latter Zone. In 1878 (265, footnote) it was obvious that Barrois was worried by this admixture for he states that possibly Ammonites lyelli might have been preferable as the index of this zone ; this species being characteristic of the clays of the Gault classified with the interruptus Zone from the Aisne to the Yonne.

Price & Delatour (1879 ; 38–42) concluded that all the beds of the Lower Gault at Folkestone had their representatives in the Gault of the Aube, but neither of these workers had seen the sections on the opposite side of the Channel. Price and Barrois knew each other, and it is significant that Price also refers to a Zone of Ammonites lyelli and places it above the Zone of Ammonites mammillaris. Barrois, like many of his contemporaries in France, when considering the zonal scheme, was strongly influenced by the very full development of the *mammillatum* Zone, and the *eodentatus* and *lyelli* Subzones in the Gault of the southern part of the Paris Basin. Although Barrois knew the sections at Wissant and Folkestone, and realised that there was a break in the succession below the sediments of the inflatus Zone, he does not appear to have fully grasped the extent of this gap in the observed sequence in the Aube and, therefore, the reason why the sequence in the Aube appeared so different from those on each side of the Channel. The observed gap in the southeastern area of the Paris Basin involves the equivalent of the greater part of the Lower Gault at Wissant and Folkestone, and includes all from the top of the *intermedius* Subzone to the base of the *cristatum* Subzone. Whether there is a total absence of deposits of this age in this area is uncertain (p. 97).

Jukes-Browne (1900 ; 45) adopted the Zone of Ammonites interruptus but restricted it to beds of equivalent age to that of Bed I at Folkestone, the interruptus Zone of De Rance in part and Price. This reading, excluding the equivalent of the ' Sulphur Band ' brought the English interpretation more into line with the known sequence in the Aube. He realised that the remainder of the Lower Gault at Folkestone could not be classified with the interruptus Zone, and he proposed that Beds II to VII and their lateral equivalents be included in a Zone of Ammonites lautus. He excluded Bed VIII from both the lautus and rostratus zones (the latter being the equivalent of Barrois ' Zone a Ammonites inflatus) treating it as a junction bed.

Because Barrois had classified his Zone à Ammonites inflatus with the Cenomanian, Jukes-Browne felt that he could not accept d'Orbigny's name Albien for the stage. He had proposed the name Devisian to encompass the Gault and Upper Greensand of England (1892 ; 266), but this name clashed with the earlier Oxfordian substage name Divesian and the term was replaced by Selbornian (1900 ; 30–31). In reality there was no need for a new name and the terms Devisian and Selbornian are synonyms of d'Orbigny's Albian. Jukes-Browne's zonal scheme and stage name (1900) were employed in England until Spath commenced work on the nomenclature of the Albian (1921).

Kilian (1907 ; 62, 67) presented the following scheme influenced probably by the work of his pupil Jacob.

Gault stufe (Albien D'ORB.)	4 Zone der *Schloenbachia* (*Mortoniceras*) *inflata* Sow. sp. (mit zwei Subzonen)
	3 Zone des *Hoplites dentatus* Sow. sp. und *Acanthoceras lyelli* Leym. sp.
	2 Zone des *Hoplites tardefurcatus* Leym. sp. und *Hoplites regularis* Brongn. sp.
	1 Zone des *Parahoplites Nolani* Seunes sp. (sog. Milletianusschichten) und *Douvilleiceras nodosocostatum* D'ORB. sp., *D. Bigoureti* Seunes sp.

For the first time *Lyelliceras lyelli* is used formally in a zonal scheme. Jacob's thesis was completed in 1907 but not published until the following year (1908 ; 208–590, pls. I–VI) when he presented the stratigraphical results of his study of the middle part of the Cretaceous of the French Alps and adjoining regions. He divided the Albian into the four zones which appear in Kilian's work but in a simplified form. His scheme is as follows (1908 ; 296).

VIb	Sous-Zone à *Mortoniceras inflatum* Sow. sp. et *Turrilites bergeri* Brong.
VIa	Sous-Zone à *Mortoniceras hugardianum* d'Orb. sp.
V	Zone à *Hoplites dentatus* Sow. sp.
IV	Zone à *Hoplites* (*Leymeriella*) *tardefurcatus* Leym. sp.
III	Zone à *Douvilleiceras nodosocostatum* d'Orb. sp. et *Douv. Bigoureti* Seunes sp.

The Clansayes horizon (Kilian's Zone 1, Jacob's Zone III) is, therefore, added to the Albian. Jacob could not accept Barrois' zone à Ammonites mammillaris because he considered that this form was equally abundant in the following horizon (i.e *dentatus* = interruptus Zone), mistaking forms such as *Douvilleiceras clementinum* (d'Orbigny) for ' Ammonites mammillaris '. So, he renamed the zone ' Zone IV à *Hoplites* (*Leymeriella*) *tardefurcatus* ' (= Zone of *Hoplites tardefurcatus* and *Hoplites regularis* in Kilian). Kilian and Jacob correct the specific name of the interruptus zone to that of *dentatus*, but Jacob does not adopt the index *Acanthoceras lyelli*. When revising the section at Sainte Croix, Vaud, Switzerland, Jacob indicates (1908 ; 291) that Zone IV = l'Albien inférieur, V = l'Albien moyen, and VIb = l'Albien supérieur of Pictet & Campiche (1858).

Jacob seems to have misread Jukes-Browne (1900) for it was not the term Gault that Jukes-Browne could not accept, but the term Albian in the sense of Barrois (Jacob 1908 ; 584). The re-inclusion of the Zone à Ammonites inflatus of Barrois (Kilian's Zone 4, Jacob's Zone VI) in the Albian, a return to d'Orbigny's original definition in terms of lithology, removed the cause of Jukes-Browne's objection to the term Albian. Neither Jacob nor Kilian accepted or even mentioned Jukes-Browne's Zone of Ammonites lautus. This is understandable when one considers that they were strongly influenced by the succession in the Aube (1908 ; 547), with which Price & Delatour had given a completely inaccurate correlation of the beds at Folkestone

(1879 : 1880 ; 38–42). Moreover, the time span represented by Beds II to VII at Folkestone are represented in the Alpine area of France and adjoining Switzerland by very condensed deposits in which many horizons are not represented at all. At that time the only description of any detail of the section near Wissant was a poor one by Barrois (1879 ; 27–28) an abridged version of which was given by Jukes-Browne (1900 ; 378–381). Although Barrois had been unable to recognise exactly at Wissant the equivalents of the beds numbered by Price at Folkestone, Price stated definitely (1879 : 1880 ; 34) that they held good at Wissant. So, according to Price, the numbered sequence at Folkestone could be correlated not only with the Aube but also with Wissant. The gravity of this error can be judged from the stratigraphical account of the French sections given above (p. 80) where it is apparent that a major part of the Middle Albian sequence in the Aube is not represented at Wissant and *vice versa*. Although Jukes-Browne agreed with Barrois that the exact equivalents of the Beds at Folkestone could not be recognised at Wissant, he perpetuates Price & Delatour's erroneous correlation between Folkestone and the Aube (1900 ; 388–9). There is no doubt that this strongly influenced subsequent work on both sides of the Channel, and this is the reason why French geologists of that period considered that the beds at Folkestone included by Jukes-Browne in his Zone of Ammonites lautus were of the same age as part of the clays in the Aube included by them correctly in the interruptus (dentatus) zone. This led to the time spans, which I now label *mammillatum*, *loricatus* and *lautus* Zones, being not recognised at all in Kilian or Jacob's zonal schemes. The historical background to the zonation of the Middle Albian only will now be considered below. That of the Lower Albian has been discussed by Casey (1961a ; 492–499) and the Upper Albian will be discussed elsewhere.

In Germany the term ' Gault ' included clays of Aptian as well as Albian age (see for example Kilian 1907–13). It had been divided into lower, middle and upper Gault within the first half of the 19th Century and the question of nomenclatorial priorities has been discussed by Spath (1942 ; 670–671). Stolley (1908 ; 246–7) recognised in the 'Oberen Gault ' of north Germany the zones already well established in France. The ' Zone des Hoplites interruptus ' No. 6 is represented by the Minimus Tone and is followed above by the ' Zone der Schloenbachia inflata und Puzosia planulata ' No. 7 to include the Flammenmergel. Jacob's scheme continued to be used in France (e.g. Tomitch 1918, Ciry 1927, Houdard 1940).

Spath's work on the classification of the Albian commenced with the following arrangement (1921a, 32).

Gault	Up. & Mid. Albian	Zones 7 & 6 of Stolley (1908)
Mammillatus Bed	Lower Albian	,, 5 ,, ,, (1908)

Later in the same year, Spath amplified this classification (1921b ; 311).

Upper Albian	Hor. IX–XIII (Folkestone)	Hor. 7 (Stolley)
	(Upper Gault)	VI (Jacob)
Middle Albian	Hor. I–VIII (Folkestone)	Hor. 6 (Stolley)
	(Lower Gault)	V (Jacob)
	mammillatum bed	

The *mammillatum* Zone is, therefore, now included in the Middle Albian. In 1922

Spath produced a scheme of ammonite horizons which foreshadowed the zonal scheme which appeared the following year (1922 ; 96). He was far too critical of the previous work on the Albian and certainly misread Jukes-Browne, and so in 1923 he discarded the broad zonal classification of previous workers in favour of the scheme shown in Table 2. This zonal scheme was strongly influenced by the sequence at Folkestone which Spath had examined in detail (1923a ; 73 : 1923b ; 4 : and see also 1923c). Unfortunately, in England the sequence between the ' *mammillatus* Zone ' and the '*dentatus* Zone ' was at that time very imperfectly known. The ' *inaequinodus* Zone ' formed a very uncertain taxon, and the ' *benettianus* Zone ' was particularly ill-founded for Spath had no idea of the exact stratigraphical position of the *lyelli* fauna (1923c : 142, see 1926b ; 422), and he was later to classify even high *spathi* Subzone sediments with that Subzone. De Rance had already used the term ' benettianus Zone ' in a different sense, and it is unfortunate that Spath ignored the sequence in the southern part of the Paris Basin. In effect he restricted the *dentatus* Zone to exclude much of what the French workers understood by this term. He also discarded Jukes-Browne's lautus zone replacing it with zones of *intermedius*, *delaruei* and *cornutus*, but added a *cristatus* zone for Bed VIII and its lateral equivalents. It was unfortunate that this scheme should have been presented before Spath had fully studied the species he had used as indices. In the following two years he had to alter this zonal scheme (1924 ; 505 : 1925b ; 31–36), and the year after (1926b ; 421–2, 425) saw the extensive modification shown in Table 2 (p. 116).

In 1926 Spath first renamed the lower part of his *cornutum* Zone, the Zone of *Euhoplites alphalautus* (1926a ; 154 footnote 1), and then later recognised that this species was a form found in the *varicosum* Zone. The major change in the scheme given by him later that year (1926b ; 421–2, 425) was the relegation of his zones to the rank of subzones in the Table on p. 421. However, the presentation shows several inconsistencies for he refers to these subzones in the text as zones. In the table he groups the subzones into the ' old zones ' which are in fact those used by Jukes-Browne, the names being corrected where necessary. Spath included the *intermedius* Subzone in the *dentatus* [olim interruptus] Zone, but Jukes-Browne had in fact included Bed II at Folkestone in his lautus zone. Spath recognised, however, that the zonal schemes which had been used in Europe were of provincial value only, and this was a significant step forward.

The zonal scheme was further modified during the course of publication of successive parts of Spath's Monograph, and one saw the firm readoption of the broader zones. He formally presented the various emendations to his earlier scheme in 1941 (1941 ; 668) and discussed them briefly the following year (1942 ; 671–673) : these are given in Table 2. His ' zones ' of 1923 are now emended and reduced to the status of Subzones which are grouped into three Zones. The *mammillatum* Zone is much the same as that of Barrois and Jukes-Browne, however, the *dentatus* and *lautus* Zones do not correspond with the views of earlier workers despite Spath's comment (1942 ; 672 footnote 3). Is the arrangement given by Spath an improvement ? The junction between the *dentatus* and *lautus* Zones was placed by Spath at a level where there is no significant change in the fauna and the arrangement is quite arbitrary.

The older zonal grouping of French and English workers such as Barrois and Jukes-

Browne was based on a comprehensive knowledge of all the sections then available. Even if they did not consider the detail essential to modern work to be of great importance, they possessed a broader picture than many later workers, some of whom had never examined the sections in the country separated from them by the Channel. Superficially Spath's early stratigraphic work appears to have given far greater precision to the zonation of the Albian, but this was not so. His zonal scheme was introduced without sufficient initial research and suffered greatly by the early need for radical alteration, and in the end his zonal boundaries were ill-chosen. He appears not to have examined the French sections (1943 ; 722–3), which is most unfortunate as it is absolutely essential to have some first-hand knowledge of them. There is no question, however, of the immense value of his contribution. Without his work on the Albian ammonites the progress made in the study of the stratigraphy during the last 25 years would have been very slow indeed.

Breistroffer (1947) made the first revision to Spath's zonal scheme in an important paper comparing essentially the French with the English succession. In this work he includes the *mammillatum* Zone in the Lower Albian and the *cristatum* Subzone in the Upper Albian (1947 ; and Table 2 herein). Casey (1950 ; 270) noted Breistroffer's reading of the *mammillatum* Zone but followed Spath in including it in the Middle Albian. Khan (1952 ; 73) produced a useful emendation when he included the *subdelaruei* Subzone in Spath's sense, in the *dentatus* Zone ; thus placing the junction between the *dentatus* and *lautus* Zones at a point where there is some significant change in the ammonite funa. Casey, however, again followed Spath in terminating the *dentatus* Zone at the top of the *niobe* Subzone (1954a ; 264). Milbourne (1956 ; 241) could not accept a separate *subdelaruei* Subzone in Spath's sense. He included the lower part of Bed IV and its lateral equivalents in the *niobe* Subzone, and the upper nodule bed of Bed IV and its lateral equivalents in the *lautus-nitidus* Subzone recognising that these probably fell within a distinct Subzone.

The writer in 1958 reviewed briefly the zonal scheme of the Middle Albian, placing the zonal boundaries at levels where significant changes in the ammonite fauna occurred (1958 ; 160–164). At the same time I drew attention to the difficulties that existed in accepting Breistroffer's emendations of Spath's zonal scheme for the *dentatus* and *lautus* Zones ; except for the position of the *cristatum* Subzone, these have not changed. Subsequently, I proposed formally that the time span represented at Folkestone by the upper nodule bed of Bed IV and the basal few inches of Bed V and their lateral equivalents be recognised as the Subzone of *Euhoplites meandrinus* (1960 ; 373, 376). The zonal grouping suggested by the author in these two papers is shown in Table 1, p. 10.

In 1961 Casey produced his important revision of the zonal scheme for the Aptian and Lower Albian (1961a ; 492–499). He now follows Breistroffer in including the *mammillatum* Zone in the Lower Albian with the exception of Spath's *inaequinodum* Subzone. For this Subzone he proposes a new index, *Hoplites* (*Isohoplites*) *eodentatus*, and includes it in the *dentatus* Zone of the Middle Albian, pointing out that this species is the most characteristic ammonite at this horizon in England and France. The division between the *mammillatum* and *dentatus* Zones and thus the Lower and Middle Albian now falls at a distinct change in the ammonite fauna.

TABLE 2

Changes in the Zonation of the Middle Albian between 1923 and 1947.

	Spath 1923	Spath 1926b		Spath 1943		Breistroffer 1947	
	Zones	' Old Zones '	Subzones	Zones	Subzones	Zones	Subzones
Anahoplitan	*cristatus*	*lautus*	*cristatum*	*lautus*	*cristatum*	*nitidus-subdelaruei*	
			daviesi		*daviesi*		*daviesi*
	cornutus		*lautus-nitidus*		*lautus-nitidus*		*nitidus-equicostatum*
	delaruei		*delaruei*		*subdelaruei*		*subdelaruei spinulosum*
			niobe	*dentatus*	*niobe*	*dentatus-mimeticus*	[*niobe*]
	intermedius	*dentatus*	*intermedius*		*intermedius*		*intermedius-praecox*
Hoplitan	*dentatus*		*dentatus*		*dentatus-bonarellii*		*dentatus-spathi*
	benettianus		*benettianus*		*benettianus*		*benettianus-pseudodeluci*
	inaequinodus	*mammillatum*	*inaequinodum*	*mammillatum*	*inaequinodum*		
	mammillatus		*mammillatum*		*monile*		

Milbourne (1963 ; 58) places the division between the *dentatus* and *lautus* Zones above his *niobe* Subzone (which also includes the *subdelaruei* Subzone of Spath in part). He finds my Subzone of *Euhoplites meandrinus* unacceptable and substitutes for it a Subzone of *Dimorphoplites doris* and *Euhoplites neglectus*. He places the subzone in the *lautus* Zone and so once more the boundary between the two zones is placed at a level where there is no significant change in the ammonite fauna. The differences of opinion between Milbourne and myself led to a skilful review of the zonal scheme by Hancock (1965). Unfortunately two errors were overlooked when preparing Table I of Hancock's paper (1965 ; 245). The *eodentatus* Subzone was not recognised by me in 1958 but by Casey (1961), and Spath's *lautus-nitidus* Subzone did not include the time span referred by me to the *meandrinus* Subzone. The *meandrinus* Subzone formed part of the *subdelaruei* Subzone in Spath's sense and it is important to make this point absolutely clear.

In 1963 a colloquium on the Lower Cretaceous was held in France ; two very important papers being contributed by P. & J.-P. Destombes, and Breistroffer, on the zonal scheme of the Albian. These were published in 1965. P., & J.-P. Destombes propose the following arrangement (1965 ; 266).

Zone	Sous-zone	Localité-type
LYELLICERATIEN	2—*Lyelliceras lyelli* et *Hoplites benettianus*	La Vendue-Mignot
	1—*Tegoceras camatteanum* *Isohoplites eodentatus*	Cotes Noires de Moeslains niv. 5

This proposition is interesting as it shows in the case of *Lyelliceras lyelli* an independent return to the older view expressed by Barrois, Price, and Kilian, although it should be noted that Collignon has also used this index (1963 ; 2). P. & J.-P. Destombes use a hemeral name for the zone. The use of these terms particularly by Spath and Breistroffer, is not supported here for they are far too nebulous to have any really precise application. Breistroffer's paper (1965 ; 311 & table) presents an emendation of his zonal scheme of 1947 and he accepts P. & J.-P. Destombes subzonal arrangement for the basal part of the Middle Albian. The scheme given by Collignon (1965b) is quite unacceptable.

The history of this zonal scheme, like that of any other, has been one of progressive refinement as knowledge of the succession has improved. Unfortunately, the Albian in particular has suffered greatly because of arbitrary decisions concerning the fixing of ammonite zonal and subzonal boundaries. These boundaries have been placed sometimes without sufficient initial research and have been upheld later purely on rather dubious ' historical ' grounds ignoring whether or not there is a significant change in the ammonite fauna. A zonal scheme must remain sufficiently flexible to take account of new discoveries and better developed sequences. To bang in a ' golden stake ' at a convenient level in a so-called permanent type-section might help the theorist but in reality it only hinders progress towards accurate international correlation, and the knowledge of events in the evolution of the Earth that will stem from it.

(B) The Zonal Scheme of the Middle Albian in the Anglo-Paris Basin

(i) DEFINITION OF THE BASE OF THE MIDDLE ALBIAN

Towards the top of the *mammillatum* Zone (*puzosianus* Subzone) in the Anglo-Paris Basin the ammonite genus *Pseudosonneratia* (s.s. non Casey[1]) develops as a minority element subordinate to such hoplitid genera as *Protohoplites* s.s., *P.* (*Hemisonneratia*), *Otohoplites*, and *Sonneratia* as well as the common element consisting of *Douvilleiceras*, *Beudanticeras* etc. The lyelliceratids are represented by very rare specimens of *Tegoceras*.

Pseudosonneratia of the *pusosianus* Subzone is the direct forerunner of the simple-ribbed non-lautiform species of *Hoplites* of the *dentatus* group. Casey (1954b ; 112, 1961a ; 599) has separated off those species which are transitional between these two genera as a subgenus *Hoplites* (*Isohoplites*). They are characterised by a partial interruption in the strength of each rib along the siphonal line as it sweeps across the venter, but no general *en echelon* offsetting of the ventro-lateral rib terminations occurs although the tendency towards this is often apparent. Casey has demonstrated that *Hoplites* (*Isohoplites*) characterises an horizon above the development of the typical *mammillatum* Zone fauna and corresponds approximately to Spath's *inaequinodum* Subzone (Casey 1961a ; 498 : Spath 1923b ; 73). He included the Subzone in the *dentatus* Zone and subsequent work in France (P., & J.-P. Destombes 1965 : and herein) and England support this reading.

The junction between the *mammillatum* Zone and the *eodentatus* Subzone has not yet been seen in an uncondensed sequence in England. Sediments spanning the zonal boundary have, however, been exposed in France at St. Martin in the Pays de Bray (p. 100) and at Les Côtes Noires in the Haute Marne (p. 91). At both localities there is a marked change in the ammonite fauna with the virtual disappearance of *Otohoplites* at the top of the *mammillatum* Zone, and the appearance in bulk of *Hoplites* (*Isohoplites*) at the base of the *eodentatus* Subzone above. In England the available exposures of the sequence at this level show only condensed phosphatic nodule beds in which the sudden change in the character of the ammonite fauna is probably accentuated. The base of the Middle Albian in the Anglo-Paris basin is marked, therefore, by the appearance of the genus *Hoplites*, and as is shown below by the appearance of *Lyelliceras*.

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[1] Dr. P. Destombes has collected a very fine ammonite fauna from two localities in the Bois de Perchois, Aube, which I have visited in company with him. It is apparent from the material he has shown me that *Pseudosonneratia iserensis* figured by Casey (1965 ; 541 text-fig. 203e, f) is associated in a very little condensed sequence—the ' Red Bed '—at Perchois Ouest with species of *Cleoniceras* (*Neosaynella*) and *Cleoniceras* s.s., indicating a *floridum* Subzone age. It contains species of *Otohoplites* earlier than any yet known in England, showing morphological gradations to the *Pseudosonneratia*-like forms which accompany them in the same bed. The collection also contains species of *Sonneratia* with distinct *kitchini* Subzone affinities, although higher in the succession, as well as *Douvilleiceras*, *Beudanticeras* and *Protanisoceras*. The fauna of Perchois Est, although preserved in a similar manner, occurs higher in the *mammillatum* Zone sequence. The very important fauna obtained from these two sections is to be described in due course by Dr. P. Destombes (see also Destombes 1965). The area is also of interest in that at Perchois Ouest the grey clays above the ' Red Bed ' contains an ammonite fauna of distinct tethyan aspect.

(ii) THE SUBZONAL SEQUENCE (Table 1, p. 10)

(a) Subzone of *Hoplites (Isohoplites) eodentatus*

Recognised by Casey (1961a ; 498), although few details were given on that occasion, this index replaces the Subzone of *Douvilleiceras inaequinodum* of Spath (1923a ; 4 : 1923b ; 73 : 1941 ; 668). In England, the Subzone is represented in a fossiliferous uncondensed state in the Isle of Wight (p. 52) and at Okeford Fitzpaine, Dorset (54). Elsewhere, the known sections exhibit either unfossiliferous sediments which probably represent this time span, or *remanié* phosphatic nodule beds. Future deepening of the section at Small Dole, Sussex (p. 35) and at Badbury Wick, Wiltshire (p. 61) may provide a fossiliferous little-condensed sequence from which a direct comparison can be made with the succession at St. Martin (p. 100). Maurupt (p. 89) and Les Côtes Noires (p. 91) in France. Nowhere in England are the sections at the outcrop in this subzone particularly fossiliferous.

In England, the ammonite fauna consists essentially of species of *Hoplites* (*Isohoplites*) of which *H.* (*I.*) *eodentatus* is typical. It is necessary to bear in mind that the tendency to produce the peripheral rib pattern of a typical *Hoplites* (*H.*) mentioned already, can be so well advanced that a fragment or even a complete individual would have to be referred to *Hoplites* (*H.*). This fact alone shows the artificial nature of the subgenus *Isohoplites*. However, these are associated with species in which the *Pseudosonneratia* ventral aspect is still well developed. Apart from the forms derived from *Pseudosonneratia*, there are other *Hoplites* derived from *Otohoplites* and possibly *Protohoplites*, and in fact rare specimens of *Otohoplites* still occur. The associated ammonites include *Beudanticeras* such as *B. laevigatum*, *B. albense*, and *B. santaecrucis*, together with *Douvilleiceras* spp. including *D. inaequinodum*.

Lyelliceras of the *camatteanum* type, which stands rather in the same relationship to *Tegoceras* on the one hand and *Lyelliceras* of the *lyelli* type on the other, as does *Isohoplites* in the hoplitinids, is a great rarity in England. In France it is a reasonably constant and characteristic companion of *Hoplites* (*Isohoplites*) and the other ammonites mentioned above, and this has led P. & J.-P. Destombes to recommend that the Subzone be defined as that of *Tegoceras camatteanum* and *Isohoplites eodentatus* (1965 ; 265–6). They indicate a type locality, Les Côtes-Noires près de Moeslain, where the subzone is represented by clays in an apparently unbroken sequence from the top of the *mammillatum* Zone to the base of the *lyelli* Subzone. In the lower clays classified with the *eodentatus* Subzone there is the association of *Hoplites* (*Isohoplites*) *eodentatus* and *Lyelliceras camatteanum* as there is also at Maurupt and St. Martin. If one wishes to use a double index then this emendation proposed by P. & J.-P. Destombes should be adopted. However, as *H.* (*I.*) *eodentatus* is common to this time span throughout the Anglo-Paris basin, the writer employs this index only.

(b) Subzone of *Lyelliceras lyelli*

P., & J.-P. Destombes (1965 ; 265–7) have formally proposed that the *benettianus* Subzone in Spath's sense should be redefined as the Subzone of *Lyelliceras lyelli* & *Hoplites benettianus*. So, the tentative suggestion of Barrois, the bald statement of

Price, the formal proposal of Kilian and the employment of the name by Collignon (1963 ; 2) given precision by P., & J.-P. Destombes, has at last taken root. *H.* (*H.*) *benettianus* is not a satisfactory subzonal index for in the strict interpretation it may be restricted to only a comparatively narrow horizon within the Subzone that it is supposed to represent. They have proposed a type locality for this Subzone, the Tuilerie Clerc at La Vendue-Mignot, Aube (p. 95), where the *Lyelliceras* fauna is considered to be in the pure state without risk of contamination (in terms of collecting fossils that is). In fact the section does not show the relationship between either the *eodentatus* Subzone below or the *spathi* Subzone above, and there are other objections already mentioned.

The *benettianus* Subzone was defined without precision by Spath (1923a ; 4, 1923b ; 73, 1926b ; 422), and was used by him for a range of sediments some of which are truly *lyelli* in age but others have subsequently proved to be of *spathi* age. It would be far more satisfactory if the proposal of P., & J.-P. Destombes were adopted modified to a single index of *Lyelliceras lyelli*.

In France, the finest section now available in sediments of this Subzone is certainly that of Courcelles près Clérey, Aube (p. 91), although that at Les Côtes Noires is probably the most completely displayed in terms of sediments. The best development seen in England was exposed at the Horton Clay pit near Small Dole, Sussex (p. 35). A comparison of these two sections brings out the nature of the ammonite fauna and the differences to be found between them. *Lyelliceras camatteanum* and its related species of the *eodentatus* Subzone is connected with *Lyelliceras lyelli* by a series of morphological transitions. Intermediate forms such as *Lyelliceras pseudolyelli* (Parona & Bonarelli *non* Spath), *Lyelliceras huberianum* (Pictet) and *L. hirsutum* (Parona & Bonarelli) form such transitional species. These show the transition from the extreme *en-echelon* arrangement of the ventro-lateral rib terminations and non-tuberculate siphonal line characteristic of *Tegoceras*, to the single ribs commencing at the umbilical margin and sweeping without break straight across the periphery and bearing mid-lateral, ventro-lateral and siphonal clavi typical of *Lyelliceras lyelli*. These transitional forms occur right at the base of the *lyelli* Subzone both at Courcelles and to a limited extent at Small Dole, and on balance it seems that the time span in which they existed was of comparatively short duration. Uncondensed basal *lyelli* Subzone sediments are also apparently well developed in the Côte d'Or (e.g. Ciry 1927 : Ciry, Rat, Malapris & Nicolas 1965).

It is apparent that ecological conditions have a marked effect upon the ammonite fauna. In deposits of the *lyelli* Subzone containing a benthonic fauna, the heteromorph ammonites *Protanisoceras* (*P.*) *barrense* and *P.* (*P.*) *alternotuberculatum* are common (e.g. Small Dole, and Courcelles) and are as equally characteristic of this time span as is *Lyelliceras lyelli*. Where no benthos is present, or it is very reduced in numbers, the heteromorph ammonites are absent or very rare (e.g. the Isle of Wight). *Lyelliceras lyelli* is also affected by ecological conditions in that in beds containing abundant *Hoplites* (*H.*), *Lyelliceras* is not common. Casey has already noted the tendency to mutual exclusiveness between the earlier members of these two families (1957 ; 43–44), although this could in part be due to the hoplitids being able to withstand more adverse conditions in the seas of that time. However, the distribution of *Beudanticeras laevigatum, B. sanctaecrucis* and *B. albensis* is not affected by either of these two factors. In fact the *lyelli* Subzone may be recognised in areas in which sea-bottom conditions produced a sulphide facies in the sediments, by the association of *Hoplites* (*H.*) spp. and these three species of *Beudanticeras*. The distribution of *Douvilleiceras* is also not constant. It is rare at Small Dole, although very common at the top of the *lyelli* Subzone at Courcelles. It was also not uncommon in Bed 14 at Shere (Owen 1963a ; 42).

The uppermost part of the *lyelli* Subzone and its junction with the overlying *spathi* Subzone cannot alone be determined by the abrupt disappearance of *Lyelliceras lyelli*. In England, at Small Dole, Sevenoaks (p. 23), and Westerham (p. 31), and at Courcelles (Aube), there are clays just below the *spathi* Subzone which still contain *lyelli* Subzone species of *Beudanticeras, Douvilleiceras* (Courcelles only), and *Protanisoceras* (*P.*), but *Lyelliceras* is absent. It is recommended that these sediments be included in the *lyelli* Subzone for the significant change in the ammonite fauna occurs at the top of them where all the non-*Hoplites* (*H.*), *lyelli* Subzone ammonite species vanish abruptly from the sequence. In the English and French sections mentioned here there is no apparent break in deposition and no change in facies. *Protanisoceras* (*P.*) still occurs in the *spathi* Subzone but it is very rare, and, in effect, the heteromorphs are almost exclusively species of *Hamites* (*H.*) with subordinate *Metahamites*. There is no major change in the species of *Hoplites* (*H.*) in the transitional period between the *lyelli* and *spathi* Subzones. The transitional sediments at the top and bottom of the *lyelli* Subzone are of no great thickness in well developed sequences. Even slight condensation produces an apparent sharp change in the ammonite fauna at the subzonal boundaries.

(c) **Subzone of *Hoplites (Hoplites) spathi***

H. (*H.*) *spathi* in its typical form occurs in this subzone but it is not very common, although there is no dearth of closely related forms. It is possible that Spath selected this species (1941 ; 668 : 1942 ; 672, under the preoccupied name *bonarellii*) because in terms of ornament it stands mid-way between the more discoidal finer ribbed species of the *dentatus* type and the inflated coarsely ornamented forms of the *maritimus-rudis* group. The name *dentatus-spathi* Subzone is in any case too well established in the recent literature both sides of the Channel to justify altering it, except to reduce it to a single index of *H.* (*H.*) *spathi*.

The Subzone is well developed in England and the section at Small Dole is particularly important as it shows in a very fossiliferous little condensed sequence the junction with the *lyelli* Subzone below and, albeit imperfectly, the *intermedius* Subzone above. In France, the junction with the *lyelli* Subzone is seen in an uncondensed sequence at Courcelles, and the junction with the *intermedius* Subzone again in an uncondensed sequence at Revigny-sur-Ornain (p. 88). The ammonite fauna consists very largely of species of *Hoplites* (*H.*) of which the general evolutionary characteristics of stratigraphical value have been given by me (Owen 1963a ; 49). The very small percentage minority element in the fauna provides a good list of genera and species (p. 152) some of which are of value in correlation with other faunal provinces.

The division between the *lyelli* and *spathi* Subzones has been discussed above. The sediments representing the transitional period between the *spathi* and *intermedius* Subzones do not contain ammonites in the area of the Weald except at Petersfield (p. 34). At present it cannot be demonstrated in any one section in England, however, the section at Osmington (p. 51), Dorset, and Caen Hill, Devizes (p. 60) show the extreme top of the *spathi* Subzone and the extreme base of the *intermedius* Subzone respectively. Bed 2 at Osmington contains abundant high *spathi* Subzone *Hoplites* (*H.*) together with rare early forms of *Anahoplites* of the *intermedius* group such as *A. osmingtonensis* and *A. grimsdalei* spp. nov. In Bed 7 at Caen Hill, *Hoplites* (*H.*) has become very subordinate to slightly later forms of *Anahoplites* such as *A. evolutus* which are in turn earlier than *Anahoplites intermedius* and its contemporaries. *A. evolutus* is also known from Bed C at Hunstanton. These sediments containing *A. evolutus* are here considered to mark the base of the *intermedius* Subzone.

In France, fragments of *Anahoplites osmingtonensis* and *A. evolutus* occur in Bed 4 at St. Florentin (p. 97), a phosphatic nodule bed containing *en melée* material derived from both the *spathi* and *intermedius* Subzones. At Revigny-sur-Ornain (p. 88) these transitional sediments are uncondensed but the ammonites are mainly crushed flat. At Wissant sediments deposited during this period have not yielded ammonites.

There is no difference between this interpretation of the *spathi* Subzone and the views of French geologists (e.g. Breistroffer 1965 ; 313). From this account it is now obvious that the parochial view expressed by Milbourne (see Hancock 1965 ; 246–7), fixing the top of the *spathi* Subzone at an horizon of condensation in a comparatively small area of the outcrop in the northern Weald, is totally unacceptable. The record of *Anahoplites intermedius* a foot or two above the *spathi* nodule bed at Folkestone (Bed I (vi)) by Casey (in Hancock 1965 ; 247) is here considered to be a misidentification of the finely-ribbed *H.* (*H.*) *dentatus densicostata* Spath which is just as common in the higher part of the Subzone.

(d) Subzone of *Anahoplites intermedius*

Although there is some condensation at Folkestone, this section (p. 14) provides the best sequence yet known in this Subzone recognised by Spath in 1923. The sequence at Small Dole is the least condensed and also shows, albeit imperfectly, the junction with the *spathi* Subzone below, and also the junction with the *niobe* Subzone above ; however, the fauna is crushed flat. The junction with the *spathi* Subzone has been discussed above. The lowest part of the Subzone with *Anahoplites evolutus* has not yet been discovered in the Weald and so at Folkestone the earliest *intermedius* Subzone sediments containing ammonites yield *Anahoplites intermedius* and *A. praecox*. In France the section at Wissant shows an imperfect development of sediments representing this Subzone, but at Revigny-sur-Ornain, and at Courcelles the lower part is well developed.

The characteristic ammonites of this time span are the group of *Anahoplites* typified by *A. intermedius*. The ammonite fauna of the Subzone as a whole is more diverse than that of the *spathi* Subzone below. *Hoplites* (*H.*) is greatly subordinate to the other genera, but the group which had produced rare *Euhoplites* by the top of the *spathi* Subzone is well represented by forms such as *E. loricatus, E. microceras, E. subtabulatus* and *E. pricei*. Early forms of *Dimorphoplites* including *D. niobe* (*praemutation*) occur sparingly, and some of these show a tendency to the lautiform ribbing not generally developed again in the genus until the *meandrinus* Subzone. Heteromorphs are not uncommon and consist not only of *Hamites* (*H.*) spp., but also of species of *Protanisoceras* (*Heteroclinus*). The early binneyitid *Falciferella milbournei* can be abundant at certain horizons. Apart from the endemic forms, there is a much rarer element represented by specimens of *Uhligella, Tetragonites, Desmoceras, Eubrancoceras* and *Pseudhelicoceras* (e.g. *P. subcatenatum* Spath.)

The upper limit of the Subzone is marked by the quite sudden decline of *Anahoplites* of the *intermedius* group, which do not extend into the *niobe* Subzone above.

(e) **Subzone of *Dimorphoplites niobe***

The Subzone was recognised by Spath (1924 ; 505), it having previously formed part of his *intermedius* Zone (1923a, b). It has been considered to be of local value (Spath 1942 ; 672) but in fact it is of widespread occurrence. Sediments of this time span are relatively uncondensed at Folkestone and to a lesser extent at Small Dole. Elsewhere in the Weald the sequence is somewhat condensed, where indeed it has escaped basal Upper Albian planation. Outside the Weald, it is developed in the Leighton Buzzard district. In France, the Subzone may be developed at Wissant (p. 83), but the only locality at which it can be proved with certainty is Cauville, Seine Maritime (p. 107). The restricted development of the *niobe* Subzone led Breistroffer in effect to include it in the *intermedius* Subzone (1947 ; 44, 1965 ; table opposite p. 312) but his view was probably also influenced by Spath (1942 ; 672).

The ammonite fauna is a curious one in that it has no species restricted to it, yet it is distinctive. *Anahoplites intermedius* and its allies have gone, and *Dimorphoplites niobe, A. planus* and *A. splendens* are the characteristic species. The upper limit of the Subzone occurs immediately below the appearance of *Mojsisovicsia* in the sequence.

(f) **Subzone of *Mojsisovicsia subdelaruei***

Originally indexed by Spath (1923a ; 4, b ; 73) using '*Dipoloceras*' *delaruei*. He realised later that this species did not occur in this time span, and it has been found subsequently in the *spathi* Subzone. The Subzone as originally defined included sediments now classified with the *meandrinus* Subzone. The Subzone is represented by uncondensed deposits at Ford Place, Wrotham (p. 22) and at Sevenoaks (p. 25), but elsewhere in England where deposits of this age are preserved they are condensed. In France, they are known only in a condensed state (e.g. Bed 11 at Wissant).

Apart from the species of *Mojsisovicsia*, a genus which last made its appearance in the Anglo-Paris basin in the *spathi* Subzone, and which in the *subdelaruei* Subzone shows marked evolutionary changes, the hoplitinid fauna shows more diversity of form than in the *niobe* Subzone below. *Mojsisovicsia subdelaruei* appears at the base of the Subzone and evolves to *M. remota* at the top. The occurrence of *Dimorphoplites niobe* led Milbourne to unite this time span with the *niobe* Subzone (1956 ; 241, 1963 ; 64), but on balance this incursion of keeled ammonites into the Anglo-

Paris basin dictates that it be kept separate. The species of *Euhoplites* show little difference to those of the *niobe* Subzone below, but *Dimorphoplites* commences to differentiate towards the forms seen in the *meandrinus* Subzone above.

The upper limit of the Subzone coincides with the last appearance of *M. remota*. However, *Mojsisovicsia* is not at all common at this height and it is necessary to use the grade of development shown by the species of *Euhoplites* and *Dimorphoplites* at the base of the *meandrinus* Subzone, discussed below.

(g) **Subzone of *Euhoplites meandrinus***

This time span, included by Spath in his *subdelaruei* Subzone, was indexed by the writer (Owen 1960 ; 373, 376). Its separate nature was recognised by Milbourne (1956 ; 241), who included it provisionally in the *nitidus* Subzone, and by the author (Owen 1958 ; 162). Unfortunately, there is an error in Hancock (1965 ; 245 Table I) for this Subzone was not included by me in the *nitidus* Subzone, that is, in the basal Subzone of the *lautus* Zone as restricted by me in 1958. Milbourne (1963 ; 65) indexed this Subzone with his ' species ' *Euhoplites neglectus* (which on examination of the type material proves to be a synonym of *E. meandrinus*) together with *Dimorphoplites doris*. My objections to this emendation were set out in Hancock (1965 ; 247) and this clash of opinion led to a mistake in the zonal scheme given by Kaye (1965 ; 220).

The Subzone is characterised by *E. meandrinus* and closely related forms such as *E. cantianus*, *E. loricatus* (late mutation), and *E. beaneyi* which still possess the deeply sulcate venter characteristic of the genus in the preceding subzones. The late mutation of *E. subtuberculatus* tends to show the development of the channelled venter characteristic in the *lautus* Zone on its outer whorl, but the inner whorls are still sulcate. The pattern of ribbing on most of these species is transitional to that of the typical *lautus* Zone species. *Dimorphoplites* has become more diverse in form and apart from the typical *meandrinus* Subzone species such as *D. doris* and *D. pinax*, there are the early mutations present of the species which occur commonly in the *lautus* Zone above but they are greatly subordinate in numbers. *Mojsisovicsia* is absent from this time span.

In England, the *meandrinus* Subzone is present in an uncondensed sequence at the Horton Clay Pit, Small Dole (p. 40). At the Sevenoaks Brick Works (p. 25) and further east in Kent, the sediments are condensed to a variable extent. Its known representation is confined to eastern England. In France, the only locality at which the Subzone is known to be represented at this time is at Wissant in Bed 11 which also contains material derived from *subdelaruei* Subzone sediments and *nitidus* Subzone sediments as well.

At Small Dole, and at Ford Place, in particular, the sudden change from a sulcate to a channelled venter in the species of *Euhoplites* can be well seen in sediments which are uncondensed. This marks the base of the overlying *nitidus* Subzone.

(h) **Subzone of *Euhoplites nitidus***

Spath originally included Beds V–VII at Folkestone in a zone of *Dipoloceras cornutum* (1923a ; 4, b ; 73) but having realised the rarity of that species he divided this zone into two ; the zone of *Euhoplites alphalautus* (1926a ; 154 footnote 1) to include Beds V and VI, and that of *Anahoplites daviesi* to include Bed VII (see also 1925b ; 34–35). Within a few months he realised that *E. alphalautus* was a form of the *varicosum* Subzone, and substituted for it *Euhoplites lautus* and *E. nitidus* (1926b ; 425). Breistroffer (1965 ; table opp. 312) has grouped the *nitidus* and *daviesi* Subzones as Subzone of *nitidus* + *cornutum* + *daviesi*. This view is probably influenced by the section near Wissant where the *daviesi* Subzone was thought to be present, but where it is now known to be absent (p. 85).

In England, the best known development is at Folkestone where the relationship with the *meandrinus* Subzone below and the *daviesi* Subzone above is well seen (p. 15). In France, the Subzone is well represented at Wissant but the sediments there are marked by erosion levels at the base and the top (p. 84). The Subzone is not known to be represented elsewhere in France at this time. The base of the Subzone is marked by the general adoption of a channelled venter by the various species of the genus *Euhoplites*. The ammonite fauna of the Subzone has been discussed by Owen (1958 ; 154) and Hancock (1965 ; 246) and there is nothing further to add except that the top of the Subzone is now drawn at Folkestone at the level within Bed VII immediately below the first appearance of *Anahoplites daviesi* in the sequence.

(i) Subzone of *Anahoplites daviesi*

This Subzone recognised by Spath (1925b ; 35, 1926a ; 153–4) is characterised by *Anahoplites* of the *daviesi* group. There is virtually no difference in the accompanying ammonite fauna in England, but these very characteristic species of *Anahoplites* have a wide geographical range in this time span, and on this point alone the Subzone should remain separate from that of *E. nitidus*. Breistroffer's grouping (1965 ; table opp. 312) is not acceptable, and the British reading should be adhered to (e.g. Owen 1958 and Hancock 1965 ; 245, 246).

The Subzone is best developed at Folkestone although it is present in uncondensed sediments elsewhere in Kent and Sussex (Ringmer). However, at Folkestone there are clays representing horizons higher than any known elsewhere outside the U.S.S.R. Even at Folkestone the top of the clays of Bed VII representing this Subzone are planed-off and the basal nodule bed of Bed VIII contains material of late *daviesi* Subzone age. At Wissant, the lower part of the *cristatum* Subzone (the partial equivalent of Bed VIII (i) at Folkestone) is represented by clays. Unfortunately these rest non-sequentially upon sediments of *nitidus* Subzone age (p. 85) and neither at Wissant nor elsewhere in France at this time have sediments of *daviesi* Subzone age been proved. The development of the Subzone in Russia is mentioned later (p. 132).

The upper limit of the Subzone can, however, be determined by reference to Bed 12 (v) at Wissant which contains no *Anahoplites* of *daviesi* type but in which *Dipoloceras bouchardianum* and *Beudanticeras beudanti* make their appearance marking the base of the *cristatum* Subzone. In this bed also there occurs the morphological transition from *Inoceramus concentricus* to the shell form *I. sulcatus* (p. 85).

(iii) THE POSITION OF THE SUBZONE OF *DIPOLOCERAS CRISTATUM*

The junction of the Lower with the Upper Gault at Folkestone is marked by two seams of phosphatic nodules separated by a few inches of clay (p. 15). This junction bed (Bed IV of De Rance 1868, and Bed VIII of Price 1879, 1880, Jukes-Browne 1900 and subsequent workers) has always been included in the Lower Gault. However, it has long been recognised that the fauna is a transitional one containing elements characteristic of the beds below and above. The bed formed the zone of Ammonites beudantii of De Rance, and that of Ammonites cristatus of Price. Jukes-Browne (1900 ; 45) did not include the time span represented by Bed VIII in his zone of Ammonites lautus. Spath, however, placed his *cristatum* ' zone ' in the Middle Albian (1923a, b) and later relegated it to subzonal rank and included it in the *lautus* Zone in his sense (1926b ; 425). This classification has been followed by later English workers (e.g. in Hancock 1965 ; 245, 246). Breistroffer (1947 ; 48, 68) included the Subzone in the Upper Albian where it stood in isolation. The author stated that more research would have to be carried out before a final decision could be made on the position of the *cristatum* Subzone (1958 ; 164). However, in the meantime, Breistroffer's recommendation (see also 1965 ; table) has been accepted by other workers such as Collignon (1963 ; 2) for the sequence in the Malagasy Republic, and Young (1966 ; 15) for the succession in Texas, and in England by Melville (*in* Smart *et al.*, 1964 ; 7).

Although Bed VIII contains a fauna which on balance links it with the Upper Albian, its lower nodule bed includes an important Middle Albian element derived from sediments of *daviesi* Subzone age. One of the principle objections to placing the *cristatum* Subzone in the Upper Albian is that hitherto it has meant placing the Middle-Upper Albian junction at a level of erosion. However, it is now known that the basal part of the *cristatum* Subzone is represented in an uncondensed sequence in Bed 12 (v) near Wissant. This fact removes any objection that the writer might formerly have held against placing the Subzone in the Upper Albian, and I now recommend that it be included in the Upper Albian to form the basal Subzone of the *inflatum* Zone.

In Bed 12 (v) at Wissant we can see the incoming of a basal Upper Albian fauna in an uncondensed sequence (p. 85). The change in *Inoceramus* from a *concentricus* to a *sulcatus* form has already been mentioned. *Beudanticeras beudanti* appears together with *D. bouchardianum*. These forms are all known from Bed VIII (i) at Folkestone. Bed 13 at Wissant contains *en melée* material derived from the equivalent of Bed VIII (ii) & (iii) at Folkestone together with the lower part of Bed IX up to and including the horizon of *Euhoplites inornatus*. In truth Bed 13 at Wissant forms the base of the Upper Gault in our sense as well as that of our French colleagues. However, they consider it to be the direct equivalent of Bed VIII, whereas it is in fact the product of one period of erosion which occurred at Wissant later in the *cristatum* Subzone, while at Folkestone there were essentially two phases of erosion at earlier dates within this Subzone. It has been, up to now, the view of our French colleagues that all the Gault below Bed 13 of Destombes was of Middle Albian age, but it must now be recognised that Bed 12 (v) below is in fact of basal *cristatum* Subzone age.

The fauna of the *cristatum* Subzone on balance, bearing in mind that a late *daviesi* Subzone element is present in Bed VIII (i), has its most important faunal link with the beds above rather than those beneath. The very characteristic lower Upper Albian bivalve form *I. sulcatus* develops in the basal part of the *cristatum* Subzone and ranges up to the top of the *orbignyi* Subzone. Towards the top of the Middle Albian *daviesi* Subzone, extreme forms of *Anahoplites* of the *daviesi* group occur which are close to, but still generically distinct from *Epihoplites* (including *Metaclavites*). At the same point in time species of *Euhoplites* and *Dimorphoplites* modify towards those of the *cristatum* Subzone. The hoplitinids are almost completely dominant, the only Mojsisovicsiinid being *Dipoloceras cornutum* which is very rare. In the *cristatum* Subzone above we see the introduction of an important non-hoplitinid element in the ammonite fauna. In fact many of the subfamilies last well-represented in the Anglo-Paris basin in *lyelli* Subzone times appear once again in consort, and as before are subordinate to the hoplitinids.

Euhoplites is well represented but the species are essentially different to those of the Middle Albian below, and are, moreover, more closely linked to those of the *orbignyi* Subzone. This genus survives until the *auritus* Subzone and it is interesting to find that a largely unfigured *varicosum* Subzone fauna in the Leighton Buzzard area contains forms which are morphologically closer to those species of Bed V–VII at Folkestone than to those of Bed VIII. *Dimorphoplites* in the strict sense does not survive the *cristatum* Subzone, its nitch being filled by *Epihoplites* (including *Metaclavites* Casey). It is quite possible that the ecologic factors which caused *Inoceramus concentricus* to develop the strengthened shell from of *I. sulcatus*, also brought about changes in the morphology of the endemic hoplitinids during the clearly unsettled physical conditions in the *cristatum* Subzone sea.

The non-hoplitinid element in the ammonite fauna is subordinate but highly characteristic of this Subzone and foreshadows the major development of the brancoceratinid and mortoniceratinid ammonites which occurs at the base of the *orbignyi* Subzone in the sense used here. *Hysteroceras* is represented by *H. pseudocornutum*, *H. capricornu*, and *H. simplicicosta*, forms which are transitional from the earlier *Eubrancoceras*. An early mutation of *H. orbignyi* does in fact occur in the *cristatum* Subzone, but the only species of *Mortoniceras* known is *M. rigidum* although the generic position given it by Spath is uncertain. *Dipoloceras* itself, the characteristic genus of this time span, probably gave rise to *Mortoniceras* but the picture is not clear at this time. The Lyelliceratidae is represented by *Neophlycticeras* which also ranges into the *orbignyi* Subzone but it is rare. *Beudanticeras* represented in the *cristatum* Subzone by the type-species *B. beudanti* and forms such as B. *subparandieri*, also continued on into the *orbignyi* and higher Upper Albian Subzones.

The *cristatum* Subzone must also include the time span represented within the sediments of the basal part of Bed IX at Folkestone up to the level at which *Hysteroceras* and *Mortoniceras* characteristic of the *orbignyi* Subzone suddenly became dominant. This just excludes the horizon of *Euhoplites inornatus* which is of widespread occurrence in England and forms a good marker for the base of the *orbignyi*

Subzone. The *cristatum* Subzone as here defined, therefore, includes sediments grouped with the Upper Gault.

As Breistroffer has pointed out (1947 ; 48–50), *Dipoloceras cristatum* and the other contemporary species of this genus are of widespread occurrence. They are known in sequences as far removed from each other as the Anglo-Paris basin, the Malagasy Republic and Zululand, Russia and Texas, that is, in more than one ammonite faunal province. The well-marked period of erosion of Middle Albian sediments in the Anglo-Paris basin which occurred during the *cristatum* Subzone, is just as well marked in the Malagasy Republic (Besairie & Collignon 1956). Although not specifically stated by Young (1966) there are signs of a similar break in Texas. It is also possible that there is a break in the sequence in Peru (Benavides-Caceras 1956). In an entirely different faunal province still, the occurrence of *Gastroplites cantianus* in Bed VIII at Folkestone and in the lower part of the *Gastroplites* Zone in Canada is extremely important (e.g. Jeletsky 1964 ; Table 1, 1968). In Canada there is a definite break in the ammonite sequence although apparently not in the sedimentary sequence (Jeletsky *in litt.*), for the *mcconneli* Zone which contains genera such as *Arcthoplites*, *Cymahoplites* and *Cleoniceras*, both known from the *mammillatum* Zone of the old world (Casey 1961c ; 167) is definitely of Lower Albian age. A similar ammonite faunal gap involving the whole of the Middle Albian appears to exist in Alaska (Imlay 1960 : 1961) and California. Imlay's *Cleoniceras* (*Grycia*) presents no difficulty here because it does not possess umbilical bullae and almost certainly belongs to Beudanticeratinae. In effect, by taking the base of the Upper Albian to coincide with the base of the *cristatum* Subzone and its provincial equivalents, it is possible to arrive at a common point of division between the two substages capable of recognition in the local successions of each country.

(iv) THE ZONAL GROUPING (Table 1, p. 10)

(a) The Zone of *Hoplites (H.) dentatus*

As defined here this Zone comprises the Subzones of *H.* (*I.*) *eodentatus*, *L. lyelli* and *H.* (*H.*) *spathi*. This represents virtually the total range of the closely related morphological group of *Hoplites* represented by the index species *H.* (*H.*) *dentatus*. In the *eodentatus* Subzone, this species is not typically developed, but in fact *H.* (*I.*) *eodentatus* is a direct transition between the earlier *Pseudosonneratia* and *H.* (*H.*) of the *dentatus* group. This group dies out at the top of the *spathi* Subzone, although *Hoplites* (*H.*) continues onwards into the *loricatus* Zone above. With some modification, this is almost a return to the old concept of the interruptus Zone in Barrois' and Jukes-Browne's sense.

The Zone is geographically widespread represented in sediments both condensed and uncondensed. The hoplitinid faunal province by the *spathi* Subzone can be shown to have extended from the western border of asiatic Russia, south to the northern margin of Tethys now represented in the Caucasus mountains. The boundary then runs along the northern side of Tethys westwards to France. The land area flanking the east side of the Atlantic rift system which existed at this time (cf. Carey 1958) apparently formed the western boundary, although the situation in Greenland is not yet clear. In a similar manner the primitive Arctic Ocean may have formed the northern boundary, for *Hoplites* is not yet known from Canada, Alaska or Japan. The province, therefore, consists of the shelf seas of Europe. In the *lyelli* Subzone especially, there are important links with adjoining ammonite faunal provinces in which *Hoplites* (*H.*) is as yet unknown. These links are discussed in greater detail below.

(b) The Zone of *Euhoplites loricatus*

This Zone comprises the Subzones of *A. intermedius*, *D. niobe*, *M. subdelaruei* and *E. meandrinus*. It is almost the total range of *E. loricatus* which is typical of the group of *Euhoplites* with sulcate rather than channelled venters seen late in the *lautus* Zone. Deposits of this Zone, with the exception of the basal part of the *intermedius* Subzone, are of very limited occurrence in the European province. This is probably due to erosion in the early part of the Upper Albian which apparently produced a fairly general hiatus involving the *loricatus* and *lautus* Zones throughout much of Europe except in the deeper basins. It could be argued that there is no point in dividing Jukes-Browne's original *lautus* Zone into two parts, but the morphological change in *Euhoplites* is quite striking at the level at which the writer has drawn the base of the *lautus* Zone. Although the change in the remainder of the ammonite fauna is not quite so clear cut, nonetheless it does occur at about the same point in time. The ammonite fauna of the *loricatus* Zone is *grosso modo* sufficiently distinct for it to be capable of definite recognition at zonal rank. Spath placed the division between the *dentatus* and *lautus* Zones in his sense at the top of the *niobe* Subzone where in fact there is no significant change in the ammonite fauna. This quite arbitrary and meaningless arrangement is firmly rejected here.

The *intermedius* Subzone has as great a geographical range as the *spathi* Subzone of the *dentatus* Zone but known sediments of the *niobe*, *subdelaruei* and *meandrinus* Subzones are preserved in only a very limited area, that of eastern England and northern France. Links with other ammonite faunal provinces are very few and mainly with the tethyan belt.

(c) The Zone of *Euhoplites lautus*

The *lautus* Zone as now defined consists of two Subzones ; that of *Euhoplites nitidus* and that of *Anahoplites daviesi*. It is essentially the total range of *Euhoplites lautus*, and the contemporary species of this genus with their well-marked clean cut ventral channel. The base of the Zone as indicated above is defined by the quite sudden change in the peripheral aspect of *Euhoplites*. The top is defined by the appearance of *Dipoloceras bouchardianum* and *Beudanticeras beudanti* indicating the base of the *cristatum* Subzone.

Deposits of the *nitidus* Subzone are of very limited known geographical extent. They are known from eastern England and northern France, and apparently occur also in Poland, but these are probably only remnants which survived the basal Upper Albian erosional movements. The *daviesi* Subzone can definitely be identified in Russia (Mangyshlak Peninsula) but this is the only area outside the eastern Weald of England that deposits of this Subzone have as yet been recognised. Russian workers (e.g. Glasunova 1953a ; 18) have recognised above the *dentatus* Zone, which in effect is equivalent only to the *spathi* Subzone, a Subzone of *Anahoplites asiaticus*. It is apparent that this is, in part, of *intermedius* (e.g. Kopet Dagh, Mangyshlak), and in part of *daviesi* Subzone age (e.g. Mangyshlak). *Anahoplites asiaticus* and *A. transcaspius* Glasunova (1953a) look like early *intermedius* Subzone *Anahoplites* comparable to, although perhaps not specifically identical with species known in the uppermost *spathi* and basal *intermedius* Subzones of England and France. A somewhat different scheme has been proposed by Sokolov (1966) and this is discussed below (p. 132).

V. LINKS WITH OTHER FAUNAL PROVINCES

The following is a brief review of the known links between the hoplitinid and other faunal provinces at certain levels in the Middle Albian. A vast amount of work still remains to be done to determine the degree of representation of Middle Albian sediments throughout the whole surface of the Earth and so to determine accurately the boundaries of the various faunal provinces. It is becoming apparent, however, that sediments of Middle Albian age are far more restricted in occurrence than those of the Upper Albian, and in many areas where they both occur, there is often evidence of a hiatus between them. Basal Upper Albian sedimentation in widely scattered places on the Earth commenced after a period of erosion (e.g. Europe, and the Malagasy Republic), or they transgress onto very much older surfaces (e.g. Africa). The fauna itself shows evidence of unstable conditions at the base of the Upper Albian (p. 127). Whether Middle Albian sediments were deposited over a widespread area of the Earth only to be removed largely by subsequent erosion is a matter of conjecture. Here, however, we are concerned only with an outline sketch of the boundaries of our province and at what definite levels it is possible to correlate with adjoining provinces.

A. **The boundaries of the hoplitinid province** (text-fig. 50)

The westward boundary of the hoplitinid province during the Middle Albian was formed by the massifs of Morvan and Armorica. These separate the European shelf-sea from the narrow sea-way connected with the Tethyan belt which was then the 'Atlantic' (Carey 1958 ; Bullard *et al.*, 1965). No species of *Hoplites, Euhoplites, Anahoplites* or *Dimorphoplites* have yet been found in the United States of America and Canada. However, there are tantalising references to a typical hoplitinid fauna in argillaceous sediments in the coastal area N. of Scoresby Sound, E. Greenland (Spath 1946 : Donovan 1949, 1953) which demonstrate that this area also is to be included in the province. If E. Greenland is brought back to its apparent middle Cretaceous position, the coast N. of Scoresby Sound is approximately opposite the northern outlet of the present day North Sea basin.

At the present time no information is available about Middle Albian sediments in the North Sea Basin, but the evidence from the eastern margin of England and from deep borings in Holland suggest that sediments of Middle Albian age thicken towards at least the south central part of the Basin. The Middle Albian sediments of Ger-

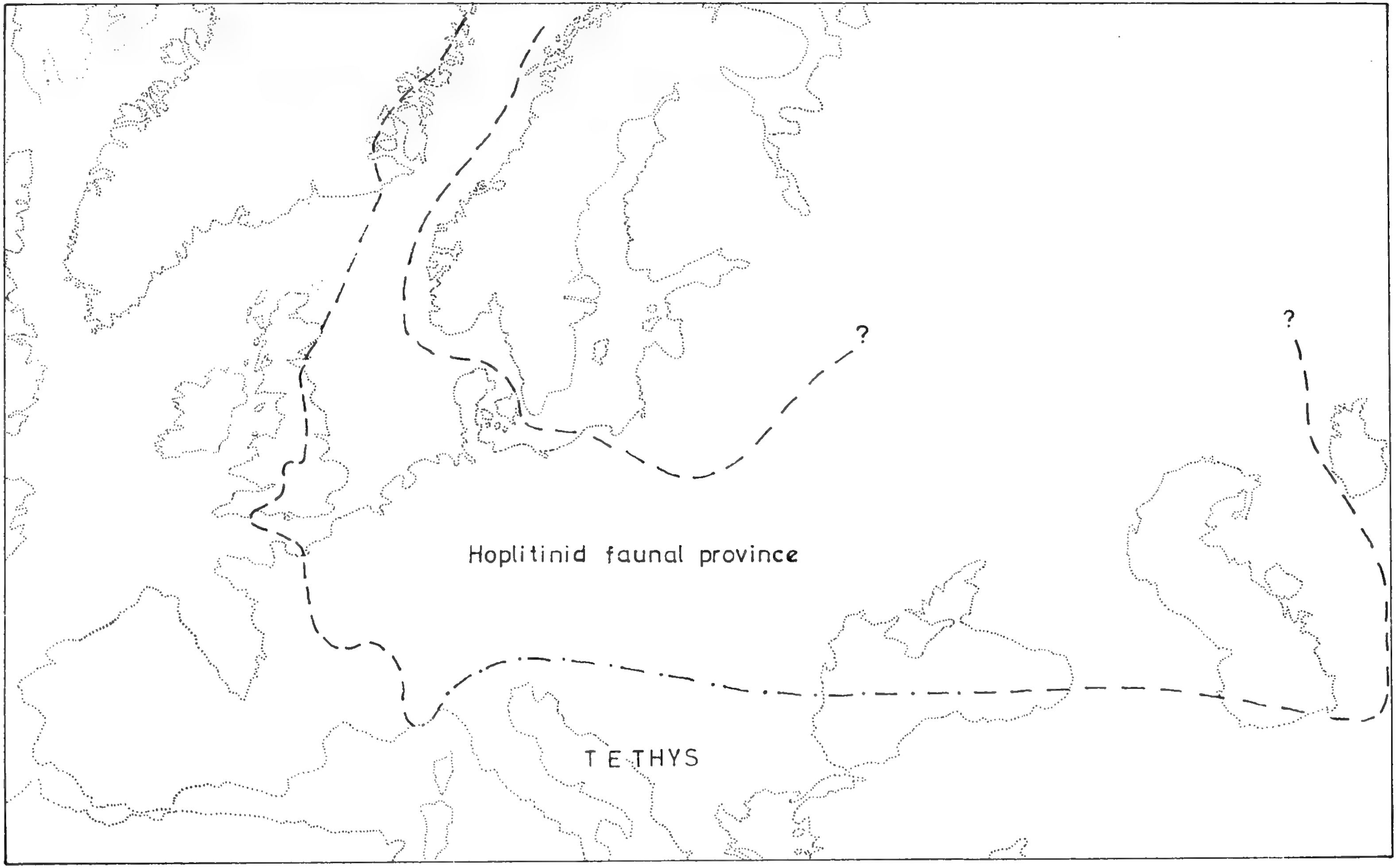

FIG. 50. Approximate boundary of the Middle Albian hoplitinid ammonite faunal province indicated by pecked line. The area of connections with the Tethyan province is indicated by dotted insertions.

many belong to the hoplitinid province and these extend through Poland (e.g. Cieślinski 1959) into Russia, although they are largely concealed by later rocks. In this respect it is interesting to note that Ravn (1925) has figured ammonites from the Cenomanian basal conglomerate on the Baltic Island of Bornholm. These indicate not only that elements derived from the *tardefurcata* and *mammillatum* Zones are present *en melée* with Cenomanian ammonites but also his *Sonneratia Baylei* (pl. III, fig. 6a, b) looks like an *Anahoplites* suggesting the possibility of Middle Albian material also being represented in the deposit. This paper seems to have escaped the attention of previous English workers (see also Ødum 1928 ; 44–5), and throws light on the provenance of the glacial erratics described by Skeat & Madsen (1898) from the Jutland drift.

The hoplitinid province in the Middle Albian may not include all of Russia in Europe, but it certainly extends as far east as the southern Urals and the eastern border of the Caspian Sea south to the Kopet Dagh in the border region with Iran. The area of Daghestan flanking the western side of the Caspian, and the area between the Mangyschlak Peninsula and the Kopet Dagh is of considerable interest. From the ammonites figured by Semenov (1899), Sinzov (1909 : 1915) and Glazunova (1953a, b) together with the recent stratigraphical work carried out by Sokolov (1966) it is apparent that Middle Albian sediments are well developed in this area. Sediments of *lyelli* Subzone age appear to be absent, but there is a good fauna of *Hoplites* (*H.*) spp. indicating the *spathi* Subzone (the *dentatus* Zone of Sokolov). The *intermedius* Subzone is also definitely represented including the basal part with *Anahoplites* of *evolutus* type. The next horizon which can definitely be correlated with the sequence in the Anglo-Paris basin are Sokolov's zones of '*Anahoplites*' *rossicus* (Sinzov) and '*A.*' *uhligi* (Semenov). These forms can be matched in the *cristatum* Subzone of Kent, and are descended directly from *Anahoplites* of the *daviesi* group, which together with its 'variety' *ornata*, are also known from this region of the U.S.S.R. Spath (1943 ; 732) was quite incorrect in comparing '*A.*' *uhligi* with *A. daviesi* ; the two are quite distinct although closely related.

Between the Zone of '*Anahoplites*' *rossicus* and that of *A. intermedius* Sokolov recognises in ascending order a Zone of *Daghestanites daghestanensis* Glasunova and a Zone of *Anahoplites kelendensis* sp. nov. (of Sokolov which appears to be undescribed). *Daghestanites daghestanensis* Glasunova has not yet been recognised outside the Soviet Union, and *Anahoplites kelendensis* in the absence of figures cannot be compared. Undoubtedly the most striking feature of the Middle Albian sequence in this area is the apparent total absence of *Euhoplites* so prolific in the area of Western Europe and present also in Greenland. In Siberia the Albian is represented in a continental facies.

The *spathi* and *intermedius* Subzones are certainly represented on the northern margin of the tethyan belt in northern Bulgaria (Zakharieva-Kovatcheva 1957, Nikolov 1965, 1970). Seitz (1930) has figured a definite *spathi* Subzone fauna on the same margin in the Rhaetic Alps at Vorarlberg, Austria. From there westward the southern boundary of the province follows the margin through Switzerland and into France. The Albian ammonite fauna of the tethyan belt is quite distinct in character from that of the European shelf seas and the hoplitinids are absent from Albian sequences south of it. The alleged occurrence of *Hoplites* (*H.*) in Mexico has not yet been substantiated by illustrations.

B. **Links with the sequences of other countries**

There are two rather fortuitous major links between the hoplitinid faunal province and other faunal provinces. The first of these comes in the *lyelli* Subzone near the base of the Middle Albian, the other in the *cristatum* Subzone at the base of the Upper Albian. Between the two there are very few links known.

(i) WEST PAKISTAN

Spath (1930b) described an Albian fauna from the area of Hazara, now Abbotabad, in W. Pakistan. The ammonites come from a condensed deposit which yielded possibly *mammillatum* Zone, and definitely *lyelli* Subzone fossils. The *lyelli* Subzone is indicated by the occurrence of *Lyelliceras lyelli*, *L. cotteri*, species of *Oxytropidoceras* (*sensu lato*) and *Brancoceras*. However, no species of *Hoplites* (*H.*) have been recorded. No direct comparison can yet be made with the sequence in the U.S.S.R. where this Subzone has not yet been detected, and in fact in the hoplitinid province the Subzone is not represented E. of the western area of Switzerland. No other Middle Albian links are known from Pakistan, although the *cristatum* Subzone is definitely represented. The two specimens of *Oxytropidoceras* figured by Spath (1934b ; 18–21, 30, pl. vi, figs. 1, 2) from the Attock district are of Middle Albian age, but cannot be assigned to a subzone at this time.

(ii) TETHYAN BELT

As yet very little knowledge exists on the degree of Zonal and Subzonal representation in the Middle Albian sediments of the part of the tethyan belt stretching westwards from W. Pakistan through Iran and Asia Minor, the Mediterranean countries to reach the proto-Atlantic on the W. coast of Spain. It is clear that the phylloceratids, some lytoceratids, and desmoceratids, where they occur, are too long time-ranging to be of even zonal value. *Desmoceras latidorsatum*, for example, occurs in the *mammillatum* Zone, as well as in the *lyelli* and *intermedius* Subzones in the Middle Albian hoplitinid province. From the discussion of the American sequences it seems that *Oxytropidoceras* sensu lato may also include long time-ranging species. However, the mojsisovicsiinids, and in particular the engonoceratids may eventually aid correlation with the provinces to the north and south of Tethys. In this respect the distribution of *Platiknemiceras* is of significance (Casey 1961b). The stratigraphic range of this genus as indicated by Casey can in two instances be narrowed. It is associated with an example of *Lyelliceras gevreyi* at Hamiran, Iran (BMNH., C 68410) cited by Spath (1931 ; 315) and recorded as *Prolyelliceras* by Casey (1961b ; 354). This specimen shows the extra-intercalated siphonal crenules and tendency to en-echelon ventro-lateral crenules characteristic of forms which occur at the base of the *lyelli* Subzone. *L. flandrini crenulata* discussed below is of the same age and is also associated with *Platyknemiceras*.

(iii) ALGERIA

Although it is in need of revision, the work of Dubourdieu (1953 : 1956 ; 185–228) indicates that at least the equivalent of the lower part of the *lyelli* Subzone is well represented by sediments in the Monts du Mellègue, Djebel Ouenza, Djebel Def, the environs of the Djebel Hameima, and the Djebel Bou Khadra. The ammonites include *Lyelliceras flandrini* Dubourdieu and *L. radenaci* (Pervinquiére). *L. flandrini* has extra-intercalated siphonal crenules indicating the lower part of the *lyelli* Subzone, and this is confirmed by *L. flandrini crenulata* (1953 ; pl. III, figs. 25–35) which is closely comparable to the inner whorls of the grade reached by *L. gevreyi* (Jacob) in Bed 1 at Courcelles (Aube). *L. radenaci* occurs also in the *lyelli* Subzone of the Guilford Colliery, Kent (p. 76).

(iv) SOMALIA

Tavani (1949) has described and figured what appears to be a lyelliceratid under the name *Somalites vertebralis*. This is associated with *Brancoceras* and they may well indicate the equivalent of the *lyelli* Subzone. However, *Somalites* has not been found outside its type locality.

(v) MADAGASCAR

Collignon has demonstrated recently that the *lyelli* Subzone is represented without question in the Middle Albian sediments of the Malagasy Republic (1963, 1965a) and he employs the term Zone à *Lyelliceras lyelli*. *Lyelliceras lyelli* and close relatives were found by him at Khomihevitra (1963 ; pl. 315, figs. 1333–5). It should also be noted that the fauna of brancoceratids described by him (1949) from d'Ambaramaninga could well indicate a basal Middle Albian age for the sediments which contain them. The species of *Pseudosonneratia* from the same bed certainly do not belong to that genus. *Dipoloceras cristatum*, and contemporary species of this genus, marking the unconformable base of the Upper Albian sediments, occur at Andranofotsy (e.g. Collignon 1963 ; 2). At present it is not possible to correlate the intervening Middle Albian sediments, referred to a Zone à *Oxytropidoceras acutocarinatum* and *Manuaniceras jacobi* in the Malagasy Republic, with those of Europe or America.

(vi) SOUTH AMERICA

Ammonites of Middle Albian age have been well illustrated from Colombia and in particular Peru, and for the purpose of the present comparison these only will be considered. Important Middle Albian faunas are also known from other South American countries such as Venezuela and Brazil but these have not yet been figured in full.

(a) Colombia

In Colombia, Gerhardt (1897 ; 168–170, pl. IV, figs. 8a, b) described an ammonite which he named *Acanthoceras prorsocurvatum* from Ubaque (Cundinamarca) and considered it to be of Aptian age. Douvillé (1906) recognised it to be of Albian age and figured a fragment (1906 ; pl. II, figs. 1, 1a) which Spath (1930b ; 65 footnote) later renamed *Prolyelliceras peruvianum*, the type species of his ' genus '. Riedel (1934 ; pl. 9, figs. 9–11) figured another specimen as *Prolyelliceras*? *lobatum* confirming a Middle Albian age for these forms, because they are associated with *Lyelliceras* of the *lyelli* type also figured by him. From specimens in the British Museum (Nat. Hist.) e.g. BMNH C 74786 J. V. Harrison Colln., from the road between Viola and Portillo, it is apparent that these so-called ' *Prolyelliceras* ' are in fact large specimens of *Lyelliceras* of *lyelli-ulrichi* type, the ornament of which modifies at diameters which are as yet unknown in the old world. *Prolyelliceras* is considered here to be a junior subjective synonym of *Lyelliceras*, and the *lyelli* Subzone is apparently well represented in Colombia.

(b) **Peru**

In the last twenty years our knowledge of the Middle Albian zonal stratigraphy of Peru has been greatly increased by the work of Knetchel (in Knetchel *et al.*, 1947) and Benavides Cáceras (1956). It is apparent that the *lyelli* Subzone is well represented in the Pariatambo, Crisnejas and Chulec formations classified by Benavides Cáceras with the Zone of *Oxytropidoceras carbonarium*. These sediments, between 100 and 200 metres thick, have yielded ammonites such as *Desmoceras latidorsatum*, *Lyelliceras lyelli*, *L. ulrichi* and *Eubrancoceras aegoceratoides*, all known from localities in the Anglo-Paris basin, especially at Courcelles (Aube). It is interesting to see that Benavides-Cáceras records *Lyelliceras pseudolyelli* from Bed 20 of the Crisnejas locality classified by him with the underlying *Knemiceras raimondii* Zone. It is also instructive to compare the sequence of Zones recognised in Peru with that of Algeria. As yet *Mojsisovicsia* has not been found in the *lyelli* Subzone in the Anglo-Paris Basin but it does occur in the overlying *spathi* Subzone where it is represented by *M. delaruei* and subspecies. The genus is represented in Peru by the type species of *Mojsisovicsia*, *M. ventallinensis* (Gabb) whose exact Subzonal age is uncertain (Douglas 1921). It is also uncertain at present whether there are any higher Middle Albian sediments than those of the *lyelli* Subzone preserved in Peru, but it appears that the Subzonal sequence is incomplete reflecting the break in sedimentation seen elsewhere in the World.

(vii) **TEXAS**

Young (1966) has presented an extremely important work on the ammonite zonation of the Fredericksburg Division of the Texas Albian and on the mojsisovicsiinid ammonites contained in it. He presents a correlation of the Texas zonal sequence with that of Europe. Following a discussion of the faunal sequence both in Texas and elsewhere outside the United States, he examines four possible conclusions raised because of an apparent anomaly which exists between the *carbonarium* Zone of Peru and that of Texas. In Peru the *carbonarium* Zone of Benavides Cáceras contains *Lyelliceras* and it is here correlated with the *lyelli* Subzone of the

European Subzonal sequence. In Texas, Young's *carbonarium* Zone does not contain *Lyelliceras* and the possible conclusions that he poses are as follows (1966 ; 18).

> ' 1. We do not understand yet the taxonomy and ranges of species of *Lyelliceras*. After all, the entire family Lyelliceratidae is still little known.
>
> 2. The rocks between the *dentatus* and *nitidus* subzones are greatly condensed in Peru, Venezuela, and Colombia.
>
> 3. The beds in Texas without diagnostic ammonites (Upper Glen Rose and lower Walnut Formations) are to be correlated with the *dentatus* and *benettianus* subzones, and the zones of *salasi* and *carbonarium* are condensed and represent all of the Folkestone section between the *dentatus* and *cristatum* subzones (= beds II–VII, inclusive). " *O.* " *carbonarium* is interpreted with such latitude that it could include forms of the *salasi* zone of Texas.
>
> 4. The ammonite zones are migrating against each other. In other words, *Lyelliceras* is younger in South America than in Europe, and *Manuaniceras carbonarium* is younger in Texas than in South America. This possibility will be distasteful to orthochronologists, but it is a factor that cannot be overlooked and is supported by the occurrence of *Inoceramus concentricus* with *Lyelliceras* (Benavides, 1956, p. 414).
>
> I am inclined to look with favor on the first explanation, but it is a personal preference. In the final analyses, some combination of two or more of these explanations may seem preferable. I must point out, however, that Benavides' (1956) section descriptions do not indicate condensation.'

Unfortunately it is necessary to point out that the evidence for his correlation of the Texas Middle Albian zonal sequence with that of the Anglo-Paris basin is nonexistent. The only direct correlation that can be made between the two areas is in the *cristatum* Subzone. *Dipoloceras fredericksburgense* and *D. cristatum* are known from the upper part of the Goodland Limestone in Tarrant Co. Texas. *Inoceramus subsulcatus* was figured by Böse (1927; 189–193, pl. XVIII, figs. 1–5) from the Edwards Limestone which is of the same age. But perhaps the most significant link is provided by *Oxytropidoceras cantianum* Spath (1931 ; 350–1, pl. 32, fig. 5) which is almost identical to the specimen of ' *Manuaniceras carbonarium* transitional to *M. peruvianum multifidum* (Steinmann) ', figured by Young (1966 ; pl. 17, fig. 6) and which is also from the upper part of the Goodland Limestone (= *cristatum* Subzone). The only other possible link is provided by *Dipoloceras* of the *cornutum* group also known from the Goodland Limestone (e.g. Spath 1931 ; 363 text-fig. 118). Now we have the measure of the problem. *Oxytropidoceras* in the wide sense occurs in the Anglo-Paris basin in the *mammillatum* Zone (Lower Albian), in the *lyelli* and *spathi* Subzones (Middle Albian), and in the *cristatum* Subzone (Upper Albian) ; it is, therefore, a very long-ranging group.[1] The development of the genus *Lyelliceras* is now well known both in the hoplitinid province and outside it, and the evidence indicates that the beds containing it in Pakistan, Madagascar, Algeria, Colombia, and Peru are of the same age as those containing *Lyelliceras* in the Anglo-Paris basin. Therefore, the specimens of ' *Oxytropidoceras* ' *carbonarium* from the *lyelli* Subzone sediments of the Pariatambo Formation of Peru cannot be of the same age as those

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[1] It is now known from the *Loricatus* Zone of north Kent (Owen *in press*).

occurring in the Goodland Limestone of Texas where they are associated with *Dipoloceras* of the *cristatum* Subzone. It now becomes apparent that certain species of the group typified by *Oxytropidoceras*, like other tethyan genera, may be very long time-ranged. Unlike the hoplitinids which show a great deal of morphological differentiation, *Oxytropidoceras* and its closely allied genera show comparatively little such differentiation. On their own, it might prove very difficult, except in a few cases, to use them for the fine subdivision of which the hoplitinids have in particular proved capable.

As yet no attempt has been made to compare the species of *Oxytropidoceras* (s.lat.) which are known from the *lyelli* and *spathi* Subzones of the Anglo-Paris basin with those occurring outside the hoplitinid province. It might well prove possible eventually to correlate the *spathi* Subzone with the tethyan succession (including Texas) on the basis of certain species of *Oxytropidoceras* (s.lat.). At the moment the *intermedius* and *niobe* Subzones have no exact zonal links with Tethys although long ranged tethyan forms are known from both time spans. *Mojsisovicsia* in the *subdelaruei* Subzone should be a renewed tethyan incursion, but none of the species from this Subzone or the *lautus* Zone have yet been recognised elsewhere. So, at this time it is not possible to correlate the Zones recognised in Texas with those of the Anglo-Paris basin. It is however, apparent from Texas and Madagascar that sediments characterised by the group typified by *Oxytropidoceras* occur between the *lyelli* and *cristatum* Subzones. Although sedimentary breaks can be difficult to detect in carbonate-marl sequences it seems to the writer that Young's *salasi* and *carbonarium* Zones are high Middle Albian as he states.

(viii) **CANADA**

The zonal scheme of the Canadian Albian has recently been ably reviewed by Jeletzky (1968), but although this represents a refinement on his earlier review of 1964 it is still open to criticism. In 1964 Jeletzky indicated that the Zone of *Arcthoplites mcconnelli* contained *Cleoniceras* and *Cymahoplites*. If these ammonites are correctly assigned generically then together they indicate a Lower Albian, *mammillatum* Zone age in the sense of Casey (1961a ; Table 1) and herein. *Cymahoplites* occurs in the *mammillatum* Zone of Europe (Casey 1961c ; 165–169, Pl. XXIX, figs. 1a–d), and although *Cleoniceras* (*C.*) ranges from the *tardefurcata* Zone (*regularis* Subzone) to the basal Middle Albian *eodentatus* Subzone, the weight of evidence, from the associated ammonites indicates a *mammillatum* Zone age. There is no evidence at this time to indicate that the Subzones of *Lemuroceras irenense* and *L. mcconnelli* are the correlatives of the European Subzone of *Douvilleiceras inaequinodum* (Jeletzky 1968 ; Fig. 1) now the basal Middle Albian Subzone of *Hoplites* (*Isohoplites*) *eodentatus*.

The *Gastroplites* Zone has been equated by Jeletzky (1968 ; Fig. 1) with both the *daviesi* Subzone (Middle Albian) and the *cristatum* Subzone (Upper Albian). However, *G. cantianus* Spath which occurs in the *Gastroplites* Zone in Canada occurs also in Bed VIII at Folkestone its type locality. It is undoubtedly of *cristatum* Subzone age, and there is no evidence for correlating the *daviesi* Subzone with any part of the *Gastroplites* Zone at this time.

Between the *Gastroplites* Zone marking the base of the Upper Albian and the *mcconnelli* Subzone is a thick interval of shales which have not yet yielded ammonites. Jeletzky has classified these sediments with a Zone F which he considers to include part or all of the time span between the *mammillatum* 'Subzone' and the *cristatum* Subzone (1968 ; 17–18, Fig. 1). If there are any Middle Albian sediments in Canada then they are contained in these shales of Zone F. At the moment, however, no Middle Albian ammonites are known from Canada. It is worth noting that the alleged *Cleoniceras* associated with a gastroplitinid ammonite fauna in Alaska (Imlay 1961) does not stand up after examination. *Cleoniceras* (*Grycia*) *sablei* Imlay which is known from crushed material does not appear to possess umbilical bullae and is here considered to be a member of Beudanticeratinae. The gastroplitinid Upper Albian province included the area that is now the western cordillera of North America stretching from Alaska to California.

(ix) **GREENLAND**

Our knowledge of the Albian sediments of the area between Traill Ø. and the Wollaston Foreland on the E. coast of Greenland N. of Scoresby Sound, is due to the work of Spath (e.g. 1946 ; 8–10) and Donovan (1949 ; 6–7 : 1953, 35–37, 50–51). It is tantalising in its incompleteness for it seems that in this area we have the boundary between the European Albian province and that of the area of Canada and the western cordillera of N. America. Both Spath and Donovan record Lower Albian ammonites which occur in both provinces ; Middle Albian ammonites such as *Hoplites* and *Euhoplites* which are characteristic of the European hoplitinid province ; and Upper Albian ammonites which may also link the two provinces.

(x) **CONCLUSION**

The foregoing very brief review indicates that a considerable amount of work now requires to be done on Middle Albian sequences outside the Anglo-Paris Basin along the lines attempted here. The object of this review is to stimulate such research. Superficially, it seems that there is in many parts of the Earth a major break in sedimentation, particularly at the top of the Middle Albian. General sedimentation occurred once again in early Upper Albian times. There is evidence of this even in the area of Kent and Sussex, wherein the *loricatus* and *lautus* Zones are apparently the most completely represented by sediments. Breaks of such an extensive nature in the Cretaceous, must be due to major events in the Earth's crustal development, for there is no evidence of unusual climatic conditions of sufficient magnitude to reduce sea-level by a significant amount.

There has always been a tendency to equate movements on a regional scale in Europe with various periods of deformation in the Tethyan belt. Until recently the development of the Atlantic, Arctic and Pacific ocean basins has been largely ignored and yet with recent geophysical work we are now beginning to see the important effect that initial faulting must have had even on Cretaceous sedimentation. The

Royal Society's Symposium on Continental Drift posed many new questions for the stratigrapher and challenged many long held concepts. The important reviews by Wilson (1965 ; 228–251), and Maack (1969) on the formation of the ocean basins drew particular attention to the role and effect of initial major rift, block and transcurrent faulting in the Jurassic and Cretaceous before the pulling apart of the old continents to the positions of the new within the Tertiary. The evidence of faulting and igneous activity indicate that the pulling apart of the continental masses bordering the present day Atlantic commenced earlier in the southern Atlantic (e.g. Maack 1969). In the northern Atlantic the vulcanism commenced in the Tertiary.

The major faulting must at times have had a profound effect on the distribution and depth of water, and thus the depositional and erosional conditions, in the continental shelf seas. This would produce characteristics quite distinct from the pressure of the African continent against Europe which in the Tertiary culminated in the Alpine ' storm '. During the Albian there is good evidence of the effect of this faulting, associated with the separation of Africa and South America, in and around Africa (e.g. Furon 1963). Even in southern England faulting occurred during *cristatum* Subzone times associated with marked erosion of Middle Albian sediments. This is but one symptom of one short period of crustal instability which is apparent in both the sediments and fauna in a number of areas in the World and points to a significant event in the development of the Earth.

The old idea of a Jurassic and Cretaceous North Atlantis continent now foundered below the N. Atlantic was not so far off the mark. However, this ancient land mass was the continental area which is now Greenland and Canada, long before it was broken up and pulled away from Europe since the Tertiary to the present day. It is apparent that the boundary between the Albian ammonite provinces of the depositional areas that is now Europe, and that of Canada and the Western Cordillera of N. America, occurred in the sea-way represented by the sediments in E. Greenland.

VI. CONDITIONS OF DEPOSITION IN ENGLAND

From the stratigraphical account of the Middle Albian sediments given above it is possible to obtain some idea of the conditions which influenced their deposition in England. Before commencing the discussion of these it is essential to consider first two factors which provide a key to the interpretation of the field evidence.

It is apparent that the early Upper Albian (*cristatum* and *orbignyi* Subzones) tectonic movements caused the planing-off of the upper surface of the Middle Albian sediments throughout England. This period of erosion, although not as great as Kitchin & Pringle held (1922a), removed a considerable amount of sediment, including marginal deposits. Within a reasonably narrow limit the resulting surface was probably plane, and for the purpose of this study it is taken so to be. From this datum level, by comparing both the surviving thickness and the lithological sequence from place to place, it is possible to make out the configuration of the surface upon which the Middle Albian sediments were deposited.

It appears that there were only comparatively minor regional tectonic movements within Middle Albian times. These seem to have consisted of minor shifting of the axes of older folds indicated below, causing condensation or increased sedimentation.

The main factor governing sedimentation appears to have been the pattern of parallel ridges and troughs produced initially in late *tardefurcata* Zone times by a comparatively mild folding phase. Casey from the field evidence afforded by largely *remanié mammillatum* Zone deposits interpreted these troughs as ' dimples ' (1961a), but the Middle Albian sediments have provided far more definite information on the trend of these structures (text-fig. 52).

Although the ridges were not obviously active structures the sediments thin across them due to water-current activity, and probably to some gravitational movement of clay particles down-slope. During minor periods of current erosion the degree of condensation is greater in the area of the ridges as one would expect.

(a) **The Margins of the depositional basin in England and Northern France** (text-fig. 51)

To what extent the Brabant massif and the London Platform acted as positive areas in Middle Albian times is far from certain. Nothing is yet known of the Gault sequence in the area of the North Sea adjacent to the shores of Kent, Essex, Suffolk and Norfolk. There certainly is no evidence made available at this time of the land area suggested in this region by Jukes-Browne's frontispiece map (1900). It is also apparent from the borings in the Cliffe area of Kent (Owen in press), that renewed movements along late Jurassic or early Cretaceous faults in the area of what is now the Thames estuary, caused strong current action which removed Middle Albian sediments over the southern part of Essex. This disturbance contributed to, and was associated with other movements which planed-off the upper surface of the Lower Gault throughout the Anglo-Paris Basin. How much sediment and the areal extent that has been removed is at present unknown, but in Kent, and in Cambridgeshire and Norfolk, where Middle Albian sediments are preserved, there is no evidence in the sequence of an area of Palaeozoic rocks actively undergoing erosion to the east.

A shoal area existed in north-west Norfolk and in the area of the Lincolnshire and Yorkshire Wolds and to an unknown extent in the adjacent area of the North Sea. Its position is indicated by the pebbly development of Bed C of the Hunstanton Red Rock (Wiltshire 1869 ; 185–188) of Middle Albian age, and its lateral equivalents in the Red Chalk with its shallow-water fauna. To the south and east in Norfolk, Bed C is replaced by clays of the contiguous Lower Gault. This shoal area probably flanked the Palaeozoic massif of the Pennines and its southerly extension of the Peak District and a possible positive area in the adjacent North Sea (Collette 1968 ; 20). Gault clay probably existed south of the Pennine massif because derived Albian fossils are known from the glacial boulder clay as far north as Chellaston, Derbyshire, as well as elsewhere in the Midlands.

On the balance of evidence the writer is inclined to doubt that the Middle Albian sea extended into the Cheshire lowlands but this could prove to be incorrect. The clays of the *lyelli* and *spathi* Subzones at Swindon (Badbury Wick) and at Devizes are very silty. Those of the *intermedius* Subzone at Devizes and Didcot are even coarser in grade. These examples do not necessarily indicate the proximity of a marginal area but equally they do not suggest an extensive basin area to the north west.

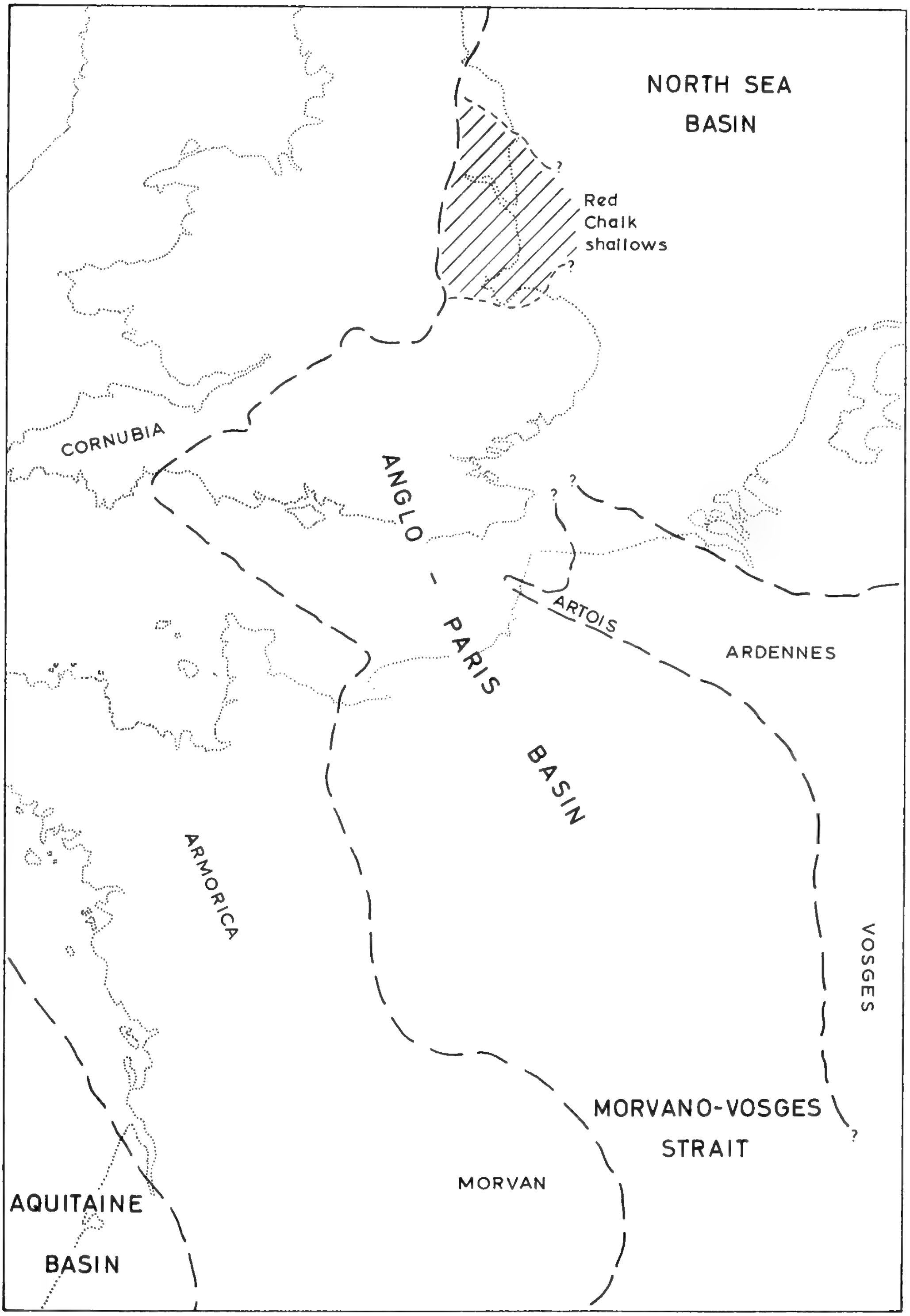

FIG. 51. Palaeogeographic map of the Anglo-Paris Basin in the Middle Albian showing links with the North Sea Basin, and Tethys via the Morvano-Vosges Strait. The Aquitaine Basin is linked with Tethys via the proto-Atlantic.

Nonetheless, the outcrop from Aylesbury (Bucks.) to Okeford Fitzpaine (Dorset) shows a section across a basin in which the *lyelli* Subzone in particular is well developed, and apparently the *intermedius* Subzone as well. Whether the margin of the Middle Albian depositional area ever reached Palaeozoic rocks in the Welsh borders is unknown. However, it seems more probable that the margin flanked a land area of Jurassic rocks from the nature of the sediments of the Gault in this area (compare the relationship seen in the Ardennes). There is no doubt that a considerable volume of clay sediment was carried eastwards into the depositional area throughout Middle Albian times (p. 147) (cf. Jones 1955).

It has been shown (p. 53) that as one proceeds westwards along the south coast from the Isle of Wight to the Devon border the basal fossiliferous bed and presumably the underlying pebble beds become later in age. In the deeper part of the Wessex Basin in the Isle of Wight, fine grade *lyelli* Subzone sediments rest upon coarsely-graded marginal *mammillatum* Zone Carstone. By Lyme Regis, the lowest fossiliferous sediments are of *intermedius* Subzone age consisting of very gritty clays, and rest upon a pebble bed which is of uncertain Subzonal age but probably not older than *spathi*. The evidence indicates marked diachronism of the base of the Middle Albian sediments, and the progressive transgression of the sea westwards across Jurassic sediments particularly during the *spathi* Subzone. The furthest margin in the extreme west probably followed the eastern boundary of the Mendip Hills and across to the area of what is now the Blackdown Hills. There is no evidence of any Middle Albian sediments in the western half of the English Channel.

On the northern coast of France, Middle Albian marginal sediments probably flanked the Palaeozoic rocks north of the Cotentin Peninsula. They are certainly present in the Pays de Caux where sediments of the *eodentatus* and *niobe* Subzones consist of very coarse pebbly loams with a high clay content. However, the available evidence from the outcrop and boreholes indicates that the land margin was not to the south-west, south, or south-east, and it is necessary to look for a ridge which underwent active erosion during the Middle Albian in the Baie de la Seine. There seems no doubt that the western margin of the Middle Albian Paris Basin was flanked by Jurassic sediments fringing the Armoricain Massif (text-fig. 33).

In the Artois, the eastern margin of the Middle Albian sea was formed by the Brabant Massif. In the Boulonnais at Caffiers, and in borings in the area of the Franco-Belgian border, Albian sediments rest upon Palaeozoic rocks on the fringe of the Massif. Of particular interest here, especially in connection with the thinning of Middle Albian sediments in the extreme east of Kent, is the marked rise in the Palaeozoic floor in the region of the Quenoc off-shore from Cap Blanc Nez (p. 83).

In general, therefore, it is apparent that in England and in France a progressive transgression over earlier Cretaceous and on to wide areas of Jurassic sediments occurred between the *eodentatus* and *niobe* Subzones. Whether this continued later into the *loricatus* and *lautus* Zones is uncertain because early Upper Albian erosion has removed the evidence. From this definition of the margin of the northern part of the Anglo-Paris Basin, it is now possible to look at the structures within the depositional area in England.

(b) **The Structural Controls on Deposition in southern England** (text-fig. 52)

The Variscan Wessex Basin of Kent (1949 ; 99) and its continuations into the Weald and across the Channel into France subsided fairly steadily throughout the Jurassic roughly in pace with the sediments which infilled it. At the end of the Jurassic and at the opening of the Cretaceous Period, a strong phase of folding and faulting occurred which in Dorset must have included fold amplitudes of well over 1000 feet (>305 m.). The resulting basin of sedimentation was very greatly reduced in area in comparison with that of the Jurassic. The history of Lower Cretaceous sedimentation in southern England is the progressive erosion of the resulting land area of Jurassic sediments and their redeposition within the basin. This basin was by now restricted to the area of the Weald proper and eastern Hampshire, and the English Channel flanking the Isle of Wight and Sussex. That the deformation was essentially early Cretaceous is indicated by the distribution and character of the Purbeck Beds and contiguous deposits. The marine Cinder Bed within the Purbeck Beds of Dorset and equivalent horizons elsewhere are considered by Casey to mark a marine incursion from the direction of the North Sea Basin (1963). The sea did not invade southern England again until the early Aptian. It is also important to note that in the Speeton area it is the top of the Kimmeridge Clay which is eroded and that heavy clay sedimentation did not commence again until after the start of the Neocomian.

The depositional history of the Lower Greensand has been discussed by Casey (1961a ; 499–501). At the end of the *tardefurcata* Zone (Lower Albian) there occurred the last of a number of minor folding phases which Casey has demonstrated affected sedimentation during the formation of the Lower Greensand. This last phase produced a number of parallel ridges and troughs trending between NW. and SE. to WNW.–ESE., the axes of which were slightly modified during *mammillatum* Zone times and again later in *loricatus* Zone times. These, together with a general subsidence of the whole Basin both in England and France *or* a rise in sea-level, set the stage for Middle Albian sedimentation. The positions of the axes of the structures are shown diagrammatically in text-fig. 52.

The Middle Albian sequence under Dover shows a good development of the *lyelli* Subzone overlain by a nodule bed of lower *spathi* Subzone age. By Folkestone the *lyelli* Subzone sediments are greatly reduced in thickness but the overlying *dentatus* nodule bed is of exactly the same age as at Dover. The rest of the Lower Gault sequence also is thinner at Folkestone, where it rests upon a *mammillatum* Zone sequence in which all four Subzones are represented.

At Sandling Junction, the basal Gault rests upon *puzosianus* Subzone sediments as at Folkestone, but these in turn rest directly on an eroded surface of early *tardefurcata* Zone sediments. Here, the *dentatus* nodule bed contains species of *Hoplites* (*H.*) transitional between those of the *dentatus* nodule bed at Folkestone and Dover, and those which occur in the ' upper *dentatus-spathi* nodule bed ' in the northern Weald. From Sandling to Maidstone, *puzosianus* Subzone sediments rest upon either *tardefurcata* or *jacobi* Zone Folkestone Beds, and the *dentatus* nodule bed in the basal Gault

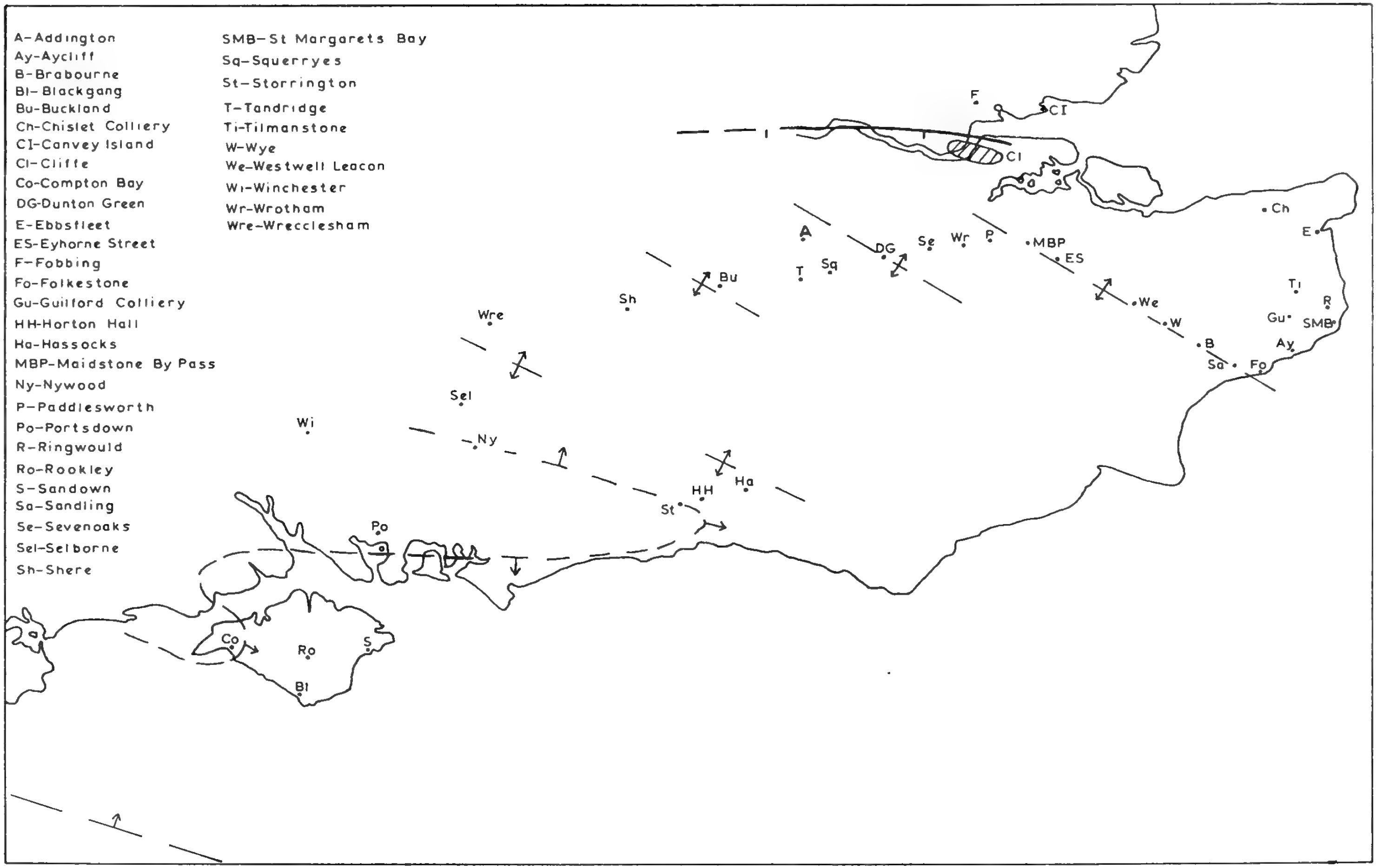

FIG. 52. Sketch map of South East England showing the structural axes influencing Middle Albian sedimentation.

has exactly the same degree of representation as at Sandling. There is strong evidence to indicate that in lithological sequence and Subzonal representation the remainder of the Gault sequence is uniform between Brabourne and the A 249 Clover Leaf on the Maidstone By-Pass, and they are certainly identical from Hollingbourne to the A 249.

In the area of the Kent Coalfield to the east, the pattern is not so clear but the *eodentatus* and *lyelli* Subzones sediments are well developed to the N. and NW. of Dover in the Guilford, Tilmanstone, and Chislet collieries. The Lower Gault as a whole is much thicker here than at the outcrop, but further east, on the Thanet and E. Kent coast, the Gault in its entirety thins rapidly.

At the valley of the Medway north of Maidstone, the outcrop swings westwards through an arc of about 12°. The change in the lithological sequence is striking (text-fig. 3, p. 14) as the outcrop turns away from the line parallel to an axes to one that cuts across the structural trend. From the four-division sequence in the Maidstone By-Pass, the Lower Gault expands into the six-division sequence recognisable from Paddleworth near Snodland westwards at least as far as Dunton Green. The central area of this Middle Albian trough seen in section at the outcrop occurs roughly in the position of the Sevenoaks Brick Works but it migrated slightly NE. during Middle Albian times. At Sevenoaks, the top of the Folkestone Beds contain developments of soft sandstone in regular beds. This is overlain by a comparatively thick development of the *mammillatum* Zone sediments. The top of *lyelli* Subzone and the lower part of the *spathi* Subzone are represented by fine clays in contrast to glauconitic clays or loam at Ford Place on the one side and at Dunton Green on the other. The overlying 'upper *dentatus-spathi* nodule bed' contains an ammonite assemblage identical to that seen in all sections from Parsons Corner, Snodland, to the Shere By-Pass. The remainder of the Lower Gault Divisions at Sevenoaks when compared with Ford Place show the offset of the trough axes towards the NE.

The whole Middle Albian sequence thins from the Sevenoaks Brick Works towards Dunton Green. Further west, the *eodentatus*, *lyelli*, and *spathi* Subzones at least, expand and are well developed in the area between Brasted and Covers Farm west of Westerham. Unfortunately the rest of the Lower Gault is not exposed although from the Brasted well it also is expanding west of Dunton Green. This boring also demonstrates that the *mammillatum* Zone troughs do not always correspond to those of the Middle Albian sediments, for here the *mammillatum* Zone sediments are much thicker than those to the east and west and are little condensed. In the Addington Pumping Station situated 9½ miles WNW. of Dunton Green the Lower Gault is of much the same thickness and probably lies near a common ridge axis, running NW. from Dunton Green.

At the Buckland Sand & Silica Co's pit together with Wray Common, at Reigate, the sequence although in general thicker and the sediments coarser, shows a similar succession to that seen at Ford Place. At Shere, however, the *eodentatus*, *lyelli* and basal *spathi* Subzones are again relatively well developed, but from here westwards to Farnham the information is either poor or of uncertain value. Moreover, the outcrop is faulted over much of this stretch of country.

From the foregoing brief description, the evidence for NW. to SE. trending ridges and troughs is not conclusive, but is very strong. However, in the southern Weald and the Isle of Wight three pieces of evidence, in the writer's opinion, tip the balance strongly in favour of the interpretation here given.

The *spathi* Subzone sequence expands southwards from Wrecclesham to reach a known maximum thickness at Selborne. From there it thins southwards towards Nyewood, but the lithological sequence in detail remains the same. Although there is a partial facies change and the sediments are coarser in E. Hampshire and W. Sussex, the sequence in the *spathi* Subzone at Selborne lithologically is remarkably close to that of the Horton Clay Pit, Upper Beeding (text-fig. 14, opp. p. 42) where it is underlain by a thick development of the *lyelli* Subzone. Yet this sequence at Horton Hall is quite different to that seen at Storrington where the *lyelli* Subzone sediments have not been proved and if present at all are very thin and pebbly. In the opposite direction, at Hassocks, the *eodentatus* and *lyelli* Subzones sediments are still well developed but are grittier and more glauconitic and here as at Storrington the Gault rests upon an 'Iron-grit' which forms the indurated top of the sands of the Folkestone Beds. At Horton Hall, however, the *tardefurcata* Zone is represented within clays and loams, totally different to that of Hassocks and Storrington.

Along the WNW.-ESE. trending outcrop at the base of the South Downs from Storrington to Petersfield, the Gault rests upon the 'Iron-grit' (Kirkaldy 1935), below which are normal loose sands of the Folkestone Beds. This sequence is seen at Portsdown where the pre-Gault Lower Cretaceous sediments are greatly attenuated. This area in which the 'Iron-grit' is present at the base of the Gault marks a long swell on the pre-Middle Albian sea-floor which apparently increased in amplitude towards the ESE. (p. 34). The sequence on the other side of the trough at Hassocks has already been mentioned, and from what little is known of the Lower Albian sequence near Eastbourne, and the Middle Albian sequence at Ringmer, the trough extended ESE. from Upper Beeding towards Eastbourne. The sedimentation remains very thick along this axis and if one projects the line through Selborne into Wiltshire it again coincides with a broader area of thick *dentatus* Zone sedimentation.

On the other, southern, side of the Storrington-Portsdown swell the lithological sequence in the *eodentatus*, *lyelli*, and *spathi* Subzones in the Isle of Wight is totally different from that of the Ringmer-Selborne trough. It is possible therefore, that yet another WNW.-ESE. trending trough exists in the English Channel and which includes the Isle of Wight. Both the *mammillatum* Zone sequence and the Lower Gault increase in degree of representation towards the southern part of the Island. The diachronous base of the Gault along the Dorset Coast can be explained if one considers this line to be a diagonal section across the trough, the *intermedius* Subzone sediments in the Charmouth area being near the southern bounding ridge which may have flanked a positive area in view of the sequence in the Pays de Caux.

In the E. and NE. part of the Weald the axes of the parallel ridges and troughs trend as far as it is possible to judge in a NW. to SE. direction and they are with the possible exception of the Kent Coalfield fairly closely set and linear (text-fig. 52). The apparent opening-out of the troughs in the northern Weald W. of Dunton Green is due partly to the fact that the outcrop tends to swing more parallel to the axes. In the southern Weald the axes have swung WNW.-ESE. and the structures are more open. These structures have what is normally considered to be an Armorican trend, and the Middle Albian is the last time that such closely lineated structures are fully identifiable in the depositional environment.

(c) **Source of the Middle Albian Sediments**

Middle Albian sediments ranging in age from the *eodentatus* Subzone to the *intermedius* Subzone rest, outside the area of the Weald and the eastern part of Hampshire, the Isle of Wight and part of Purbeck, and the area extending NE. of Aylesbury, directly upon Jurassic rocks. These Jurassic rocks had been folded and faulted in the late Jurassic-early Cretaceous to become land. Below the London area and N. Kent the Lower Gault, when present, rests upon thin Lower Greensand which is underlain by either Jurassic or Palaeozoic rocks. The Middle Albian sea, therefore, was clearly transgressive far outstripping the depositional area of the Lower Greensand which itself oversteps the Wealden and both of which derived their sediments from the Jurassic land area. It is evident from the cobbles and blocks included in the *mammillatum* Zone sediments of Kent that Palaeozoic rocks of the London Platform were by then undergoing active erosion. From the borings in N. and E. Kent there is no evidence, however, that the London Platform contributed any large quantity of sediment during the deposition of the Lower Gault. This probably consisted only of the silty fraction which is mixed with a fine clay fraction.

In general as one moves west from the Kent coast the Middle Albian clays coarsen in particle size and increase in the quantity of admixed silt and sand. This is readily apparent if one compares for example in succession the sediments of the *intermedius* Subzones at Folkestone, Buckland, in the Winchester borings, Devizes, and on the Dorset coast in the Charmouth area. This suggests a main sediment source from the western and north western margins of the sea, and possibly also from the south in the area of the English Channel.

On the coast in the Isle of Purbeck and towards Weymouth and in the Charmouth area the diachronous base of the Gault can be seen to rest directly upon extensive areas of Jurassic clays such as the Kimmeridge Clay, Oxford Clay, and the Lias (text-fig. 23). In the area of the Hampshire Basin, British Petroleum Co., borings at Bere Regis near Wareham (Dorset) and at Fordingbridge (Hants) show the Gault to rest directly upon Oxford Clay and Kimmeridge Clay respectively. Along the northern outcrop the position is much the same (text-fig. 18), with Middle Albian sediments resting upon the Lias in the far west and then eastwards upon an eroded surface of folded Jurassic sediments in which the Oxford and Kimmeridge Clays bulk large. Now this is the state of affairs within the area of the depositional basin itself already having undergone erosion since early Cretaceous times. Moreover, this is the depositional basin which extended rapidly during *spathi* Subzone times to its greatest known Middle Albian extent in the *intermedius* Subzone. Without any question the originally far greater depositional area of the Jurassic clays must have undergone active erosion during this period, and the Middle Albian sea may well have extended further during later Subzones. In the writer's opinion all the evidence points to a source in the clays of the Jurassic, west of the London Platform, for the sediment which was redeposited as the Lower Gault.

A Jurassic source to the west in Wales is suggested by the work of Jones (1955 ; 348–50), and by the borings at Port More, Antrim (Robbie & Manning 1966), and Mochras, Merioneth (Wood & Woodland 1969) in which Lias is preserved. At Port More, the incomplete remnant of Lower Lias is overlain by Upper Chalk indicating a major intra-Mesozoic hiatus, the exact nature and extent of which is uncertain at present.

Much the same state of affairs existed in the Paris Basin and it is an interesting fact that here also the Middle Albian sediments are coarser in the west and finer in the eastern areas of the Basin.

(d) The *cristatum* Subzone disturbance

After the commencement of the *cristatum* Subzone, a major disturbance affected the whole of the Anglo-Paris Basin and adjoining areas. In fact a break in sedimentation associated with erosion occurs widely throughout the Earth at about this time, and is sometimes accompanied by folding. The disturbance caused the partial planing-off of Middle Albian sediments over the whole area of the Anglo-Paris Basin.

The writer considered (1960 ; 377) that the planing-off of the upper surface of the Lower Gault in southern England was due to a tilting movement up towards the west. This may be true for the eastern half of England where definite early Upper Albian faulting has been proved (Owen *in* press), but it is not necessarily the explanation for the southern part of the country as a whole. In France, there is some evidence of a similar tilting movement towards Morvan and Armorica. Although the effects on the sediments is readily apparent, the main cause is much more obscure and may be connected with faulting at the margin of Europe and America before the later development of the Atlantic Ocean (p. 138).

Tectonic features are few in number, and there is certainly no evidence of anything but a slight broad warping of the Basin as a whole, except for the faulting mentioned above which removed Lower Gault sediments at least from the southern part of Essex. The turbulent water conditions are reflected in the nektonic fauna ; for example *Inoceramus concentricus* quite rapidly develops the far stronger *sulcatus* form, and does not revert back to a *concentricus* form until the *varicosum* Subzone when thick, little condensed sequences are seen again.

On the resulting planed-off Middle Albian surface Upper Albian sediments were laid down in an entirely different pattern to that seen in the Middle Albian. Moreover, there are two intergrading facies ; the Upper Greensand and the Upper Gault. This change in pattern renders meaningless isopachyte maps based on the sediments of the whole Stage (Wooldridge & Linton 1938). It appears at present that the Upper Albian depositional pattern is more closely related to that of the Upper Cretaceous.

VII. REVIEW OF THE AMMONITE FAUNA

The foregoing stratigraphical account has drawn heavily upon the evidence of relative ages provided by the ammonites. For the purpose of this Bulletin the subzonal distribution of the ammonite fauna of the Middle Albian, will be considered only. Of the other stratigraphically useful fossils, some have been mentioned in the text, but the foraminifera and ostracods require careful revision based on accurate collecting. The two plates of zonal ammonites should be used in conjunction with Spath's Monograph (1923–43).

A. Description of new species

In order to stabilize the new taxa used in this Bulletin, brief descriptions are given of one species of *Hoplites* (*H.*) and two species of *Anahoplites*.

Family **HOPLITIDAE** Douvillé 1890
Subfamily **HOPLITINAE** Douvillé 1890
Genus ***HOPLITES*** Neumayr 1875
Subgenus ***HOPLITES*** Neumayr 1875

Hoplites (Hoplites) maritimus sp. nov.

(Pl. 1, figs. 3a, b)

1925a *Hoplites rudis* Parona & Bonarelli (pars) ; Spath : 108, pl. 8, fig. 10c, d.

Derivation of name. *Hoplites* :—heavily armoured soldier, *maritimus* : — of the sea.

Diagnosis. *Hoplites* (*Hoplites*) with stout well-rounded whorl section bearing coarse projecting tuberculate bullae about 10 per whorl, each buttressed by short umbilical rib stemming from umbilical suture. Each bulla gives rise to two short coarse ribs terminating above ventrolateral margin in coarse projecting clavi arranged en-echelon each side of venter : intercostal areas merging onto venter. Ribs simple to about 40 mm. diameter, thereafter there is tendency to develop occasional lautiform ribs. Above 100 mm. ornament decreases in strength. Septal suture similar to *H.* (*H.*) *dentatus.*

Type material. *Holotype* BMNH. C 862a (J. S. Gardner Coll.) from Bed I (v) at Folkestone.

Dimensions. 53 ·42 ·52 ·32.

Remarks. Like all species of this genus, *H.* (*H.*) *maritimus* shows variation among individuals. Specimens of this form are, however, common in the lower part of the *spathi* Subzone taking descent from the *lyelli* Subzone *H.* (*H.*) of the *baylei-benettianus* group. At the base of the Subzone the ribbing is usually simple, but higher up occasional intercalated ribs occur which produce a lautiform effect. Later still, lautiform ribbing becomes well developed producing direct transitions to *H.* (*H.*) *canavarii* Parona & Bonarelli of the upper part of the *spathi* Subzone.

When found in condensed phosphatic nodule beds, this species shows a bewildering series of morphological transitions to other coarsely ornamented species of *Hoplites*. Most of these transitions are more apparent than real, in that coarse members of a number of indirectly related offshoots which developed at slightly different times have been collected together *en melée* in the same bed. To Spath it appeared that this species belonged to Parona & Bonarelli's *Hoplites rudis* but was not typical of it (1925a ; 108). *H.* (*H.*) *rudis* does occur in England in the upper *dentatus-spathi* nodule bed in the northern Weald, however, in the writer's opinion it represents a coarse end member of a different development of *Hoplites* (*H.*).

HORIZON & LOCALITIES. The species occurs throughout the *spathi* Subzone and is ubiquitous in the Anglo-Paris basin.

Genus ***ANAHOPLITES*** Hyatt 1900

Anahoplites osmingtonensis sp. nov.

(Pl. 1, figs. 1a, b)

1925a *Anahoplites mimeticus* Spath (pars) ; Spath : 142.
1927 *Anahoplites mimeticus* Spath (pars) ; Spath : 188, pl. 17, figs. 8a, b.

DERIVATION OF NAME. From Osmington, Dorset, the type locality.

DIAGNOSIS. *Anahoplites* of the *intermedius* group : discoidal, compressed, evolute, with excentric umbilicus. Umbilical wall steep in early whorls becoming rounded in outer whorl. Umbilical margin marked by faint comma-shaped bullae giving rise to faint striate ribs on gently curving whorl flank, terminating on ventro-lateral shoulders at faint clavi absent on body chamber. Venter subtabulate slightly sulcate. Suture line like *A. planus*, but symmetrical across venter and highly interlocked.

TYPE MATERIAL. *Holotype* BMNH., C 68385 (T. F. Grimsdale Coll.). Uppermost *spathi* Subzone between Osmington Mills and Black Head, Dorset. *Paratypes* BMNH., C 26595 same collection, horizon, and locality as Holotype. BMNH., 37604 (Astier Coll.) condensed Middle Albian phosphatic bed, Escragnolles, Alpes Maritimes, France.

DIMENSIONS.

C 68385	[107]	·39	·25	·33	(Holotype is slightly crushed)
37604	107	·40	·28	·30	

REMARKS. This species differs from *Anahoplites planus* (Mantell) in its marked excentric umbilicus, slightly sulcate venter which becomes broadly rounded on the body chamber, and the symmetrical arrangement of the suture line each side of the venter. The elements of the suture line are closely interlocked resembling specimens of *A. planus* from the *cristatum* Subzone. It is, however, probably not directly related to *A. planus*, an early mutation of which occurs in the same bed (e.g. Spath 1927 ; 188, pl. 18, figs. 7a, b), but is very near the stem from which *A. grimsdalei*, *A. evolutus*, *A. intermedius*, *A. mantelli*, *A. praecox*, and *A. alternatus* sprang.

Spath referred the paratypes of *A. osmingtonensis* to *A. mimeticus*. However, the type of *A. mimeticus* (BMNH. C 30535, 1925 ; 131, pl. 11, figs. 7a, b) shows that the inner whorls are strongly costate with well developed umbilical bullae quite unlike *A. osmingtonensis* and in fact probably does not belong to *Anahoplites* at all. The stratigraphical horizon of the Holotype of *A. mimeticus* has been discussed above (p. 47), and it is not considered here to belong to the *mammillatum* Zone genus *Anahoplitoides* (Casey 1966 ; 547–8).

HORIZON & LOCALITIES. *A. osmingtonensis* occurs at the extreme top of the *spathi* Subzone both in the Osmington area of Dorset, and the Petersfield area, Hampshire (BMNH. C 35483). It is also present in the condensed *spathi, intermedius* Subzones assemblage of Bed 4 at the Carrière Binot, St. Florentin (Yonne), and also at Escragnolles (Alpes Maritimes).

Anahoplites grimsdalei sp. nov.

(Pl. 1, figs. 2a, b)

DERIVATION OF NAME. After Mr. T. F. Grimsdale.

DIAGNOSIS. *Anahoplites* of the *intermedius* group ; discoidal, compressed, evolute. Umbilical wall rounded, marked at margin by 20 comma-shaped bullae on outer complete whorl. Each bulla gives rise to primary rib which bifurcates either just above it or near middle of whorl flank. Ribs sickle-shaped, faint on inner whorls terminating at ventro-lateral margins in distinct clavi arranged en-echelon each side of tabulate slightly sulcate venter. Occasional short intercalated ribs stem from primary ribs, one for each primary, on ventro-lateral shoulder to end at ventro-lateral margin in intercalated clavi. Suture line as in *A. intermedius*.

TYPE MATERIAL. *Holotype* BMNH. C 31702 (Lt. Col. R. H. Cunnington Coll.) Uppermost *spathi* Subzone, between Osmington Mills and Black Head, Dorset.

DIMENSIONS. 93 ·40 ·20 ·30 (slightly crushed laterally)

REMARKS. This species differs from *A. evolutus* of the basal part of the *intermedius* Subzone, to which it is closely related, by possessing fainter and more distant ribbing but which are more regularly bifurcating. Although the Holotype is slightly crushed it is probably more compressed than *A. evolutus*. The short intercalated ribs on the ventro-lateral shoulders, absent in *A. evolutus*, are reminiscent of those seen in the much later *Semenovites gracilis* (Spath) of the *varicosum* Subzone (Upper Albian). These are taken to an extreme development in a form which occurs in the basal part of the *intermedius* Subzone at Caen Hill, Devizes (Bed 7). Nonetheless, *A. grimsdalei* in fact links *A. osmingtonensis* and *A. evolutus*.

HORIZON AND LOCALITY. Extreme top of the *spathi* Subzone in the Osmington area of Dorset, and at Petersfield, Hampshire (BMNH. C. 35482).

B. Stratigraphical List

To conserve space, Subzones are numbered consecutively. (1) *eodentatus*, (2) *lyelli*, (3) *spathi*; (4) *intermedius*, (5) *niobe*, (6) *subdelaruei*, (7) *meandrinus*; (8) *nitidus*, (9) *daviesi*. p = praemutation.

	1	2	3	4	5	6	7	8	9
Phylloceratidae									
Hypophylloceras sp.		X							
Lytoceratidae									
Pictetia astieriana (d'Orbigny)			X						
Tetragonitidae									
Tetragonites kitchini (Krenkel)				X					
Hamitidae									
Hamites (*Hamites*) *attenuatus* J. Sowerby			X	X	X	X	X		
,, ,, *rotundus* J. Sowerby			X	X	X	X	X	X	
,, ,, *tenuicostatus* Spath				X	X	X	X		
,, ,, *compressus* J. Sowerby				X	X	X	X	X	X
,, ,, ,, *gracilis* Spath				X	X	X	X	X	X
,, ,, *gibbosus* J. Sowerby				X	X	X	X	X	X
,, ,, *subrotundus* Spath						X	X	X	X
,, ,, *maximus* J. Sowerby								X	X
,, ,, *tenuis* J. Sowerby								X	X
,, ,, ,, *subacuaria* Spath								X	X
Anisoceratidae									
Protanisoceras (*Protanisoceras*) *alternotuberculatum* (Leymerie)		X							
,, ,, *barrense* (Buvignier)		X							
,, ,, *nodoneum* (Buvignier)		X							
,, ,, *moreanum* (Buvignier)		X							
,, ,, spp.	X	X	X						
,, (*Heteroclinus*) *nodosum* (J. Sowerby)				X					
,, ,, *flexuosum* (d'Orbigny)				X					
Metahamites sablieri (d'Orbigny)			X						
,, spp.		X	X						
Turrilitidae									
Proturrilitoides densicostatus (Passendorfer)								X	
Pseudhelicoceras argonnensis (Buvignier)		X							
,, *subcatenatum* Spath				X					
Binneyitidae ?									
Falciferella milbournei Casey				X	X				
Desmoceratidae									
Puzosia (*Anapuzosia*) *provincialis* (Parona & Bonarelli)				X					
Uhligella derancei Casey				X					
,, ,, *erugata* Casey				X					
Beudanticeras laevigatum (J. de C. Sowerby)	X	X							
,, *sanctaecrucis* Bonarelli	X	X							
,, *albense* Breistroffer	X	X							
Desmoceras (*Desmoceras*) *latidorsatum* (Michelin)		X		X					

	1	2	3	4	5	6	7	8	9
Douvilleiceratidae									
Douvilleiceras inaequinodum (Quenstedt) .	X								
,, *clementinum* (d'Orbigny) . .		X							
Engonoceratidae									
Engonoceras iris Spath					X				
Hoplitidae									
Cleoniceras (*Cleoniceras*) *devisense* Spath .	X	X							
Otohoplites spp.	X								
,, ? *cunningtoni* Spath . . .	X								
Hoplites (*Isohoplites*) *steinmanni* (Jacob) .	X								
,, ,, *eodentatus* Casey . .	X								
,, ,, spp.	X								
,, (*Hoplites*) *dentatus* (J. Sowerby) .		X	X						
,, ,, ,, *robusta* Spath .		X	X						
,, ,, ,, *densicostata* Spath		X	X						
,, ,, ,, *sulcata* Seitz .			X						
,, ,, *baylei* Spath . . .		X							
,, ,, *bullatus* Spath . . .		X							
,, ,, *benettianus* (J. de C. Sowerby)		X							
,, ,, *spathi* Breistroffer . .			X						
,, ,, *persulcatus* Spath . .			X						
,, ,, *paronai* Spath . . .			X						
,, ,, *maritimus* Owen nov. .			X						
,, ,, *mirabiliformis* Spath . .			X						
,, ,, *obtusus* Spath . . .			X						
,, ,, *pringlei* Spath . . .			X						
,, ,, *similis* Spath . . .			X						
,, ,, *mirabilis* Parona & Bonarelli			X						
,, ,, *vectensis* Spath . . .			X						
,, ,, *latesulcatus* Spath . .			X						
,, ,, *escragnollensis* Spath .			X						
,, ,, *rudis* Parona & Bonarelli .			X						
,, ,, *dorsetensis* Spath . .			X						
,, ,, *canavarii* Parona & Bonarelli			X						
,, ,, *canavariformis* Spath .			X	?X					
,, ,, *pretethydis* Spath . .			X	?X					
,, ,, *dentatiformis* Spath . .				X					
,, ,, spp.	X	X	X	X	X	X			
Anahoplites osmingtonensis Owen nov. . .			X						
,, *grimsdalei* Owen nov. . . .			X						
,, *evolutus* Spath			X						
,, *mimeticus* Spath			X						
,, *intermedius* Spath . . .				X					
,, *mantelli* Spath				X					
,, *praecox* Spath				X					
,, *alternatus* (Woodward) . .				X					
,, *planus* (Mantell) . . .				X	X	X	X	X	X
,, ,, *compressa* Spath . .				X	X	X	X	X	X
,, ,, *inflata* Spath . . .				X	X	X	X	X	X
,, ,, *discoidea* Spath . .				X	X	X	X	X	X
,, ,, *sulcata* Spath . . .						X			
,, ,, *gracilis* Spath . . .								X	X

	1	2	3	4	5	6	7	8	9
Anahoplites splendens (J. Sowerby) . .				X	X	X	X	X	X
,, *pleurophorus* Spath . . .							X		
,, *daviesi* Spath									X
,, ,, *ornata* Spath . . .									X
,, ,, *elegans* Spath . . .									X
,, sp.									X
Dimorphoplites niobe Spath				X	X	X	X		
,, *doris* Spath						X	X		
,, *pinax* Spath						Xp	X		
,, ,, *elegans* Spath . .							X		
,, *biplicatus* (Mantell) . .						Xp	X	X	X
,, *hilli* Spath							X		
,, *perelegans* Spath . . .							X		
,, *crassa* Spath							?X		
,, *parkinsoni* Spath . . .							X	X	X
,, *tethydis* (Bayle) . . .								X	X
,, ,, Spath non Bayle .								X	X
,, *glaber* Spath . . .								X	X
,, *chloris* Spath . . .								X	X
Euhoplites subtabulatus Spath . . .				X					
,, *pricei* Spath				X	X				
,, *loricatus* Spath				X	X	X	X		
,, *subtuberculatus* Spath				X	X	X	X		
,, *aspasia* Spath				X	X	X	X		
,, *microceras* Spath				X	X	X	X		
,, *meandrinus* Spath							X		
,, *cantianus* Spath							X		
,, *bilobus* Spath							X		
,, *beaneyi* Milbourne							X		
,, *truncatus* Spath								X	X
,, ,, *quadrata* Spath . .								X	X
,, *lautus* (J. Sowerby) . . .								X	X
,, ,, *duntonensis* Spath . .								X	X
,, *nitidus* Spath								X	X
,, *opalinus* Spath								X	X
,, *proboscideus* (J. Sowerby) . .								X	X
,, ,, *intermedia* Spath .								X	X
,, *bucklandi* Spath								X	X
Lyelliceratidae									
Lyelliceras camatteanum (d'Orbigny) . .	X								
,, *pseudolyelli* (Parona & Bonarelli) .	X								
,, *hirsutum* (Parona & Bonarelli) .	X								
,, *huberianum* (Pictet)	X								
,, *lyelli* (d'Orbigny)		X							
,, *radenaci* (Pervinquiere) . . .		X							
,, *cotteri* Spath		X							
,, *gevreyi* (Jacob)		X							
Brancoceras (*Brancoceras*) *senequieri* (d'Orbigny)		X							
,, ,, *versicostatum* (Michelin)		X							
,, ,, spp.	X	X							

	1	2	3	4	5	6	7	8	9
Eubrancoceras (*Eubrancoceras*) *aegoceratoides* (Steinmann)		X							
,, ,, *cricki* Spath				X	X				
,, ,, spp.		X	X	X	X				
Mojsisovicsiidae									
Oxytropidoceras evansi Spath		X							
,, *roissyanum* (d'Orbigny)			X						
,, *mirapelianum* (d'Orbigny)			X						
,, cf. *carbonarium* (Gabb)			X						
,, spp.		X	X						
Mojsisovicsia delaruei (d'Orbigny)			X						
,, ,, *compressa* Spath			X						
,, *subdelaruei* Spath						X			
,, *remota* Spath						X			
,, *spinulosa* Spath						X			
,, *equicostata* Spath								X	
Dipoloceras cornutum (Pictet)								X	X
Falloticeras proteum (d'Orbigny)			X						

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PLATE 1

Anahoplites osmingtonensis sp. nov.

FIGS. 1 a, b. Lateral and peripheral views of holotype (BMNH. C 68385) X 1. Uppermost *spathi* Subzone, between Osmington Mills and Black Head, Dorset.

Anahoplites grimsdalei sp. nov.

FIGS. 2 a, b. Lateral and peripheral views of holotype (BMNH. C 31702) X 1. Uppermost *spathi* Subzone, between Osmington Mills and Black Head, Dorset.

Hoplites (Hoplites) maritimus sp. nov.

FIGS. 3 a, b. Lateral and peripheral views of holotype (BMNH. C 862a) X 1. *Spathi* Subzone, Lower Gault Bed I (v), Folkestone, Kent.

2 b

1 b

1 a

2a

3 a

b

PLATE 2

Dentatus Zone Indices

Hoplites (Isohoplites) eodentatus Casey

FIGS. 1 a, b. Lateral and peripheral views X 1 of an example from Bed 1, *eodentatus* Subzone, Coney Hill Sand pit, Tandridge, Surrey. (BMNH. C 76480)

Lyelliceras lyelli (d'Orbigny)

FIGS. 2 a, b. Lateral and peripheral views X 1 of an example from Division 2 (iv), *lyelli* Subzone, Horton Clay Pit, Upper Beeding, Sussex. (BMNH. C 76481)

Hoplites (Hoplites) spathi Breistroffer

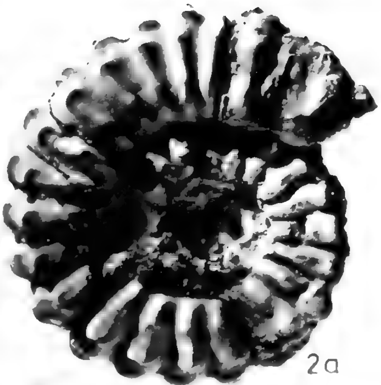
FIGS. 3 a, b. Lateral and peripheral views X 1 of a late mutation from Bed 4, upper part of the *spathi* Subzone, Buckland Sand & Silica Co. pit, Reigate, Surrey. (BMNH. C 76483)

Hoplites (Hoplites) dentatus (J. Sowerby)

FIGS. 4 a, b. Lateral and peripheral views X 1 of a late mutation from the same bed and locality as FIGS. 3 a, b. (BNMH. C 76482)

(All specimens author's coll.)

a 1 b



2a

2 b

3 a

b

b

4 a

PLATE 3

Loricatus and Lautus Zone Indices

Euhoplites loricatus Spath

FIGS. 1 a, b. Lateral and peripheral views X 1 of a late form from Division 5 (ii), *meandrinus* Subzone, Sevenoaks Brick Works, Otford, Kent. (BMNH. C 76484)

Anahoplites intermedius Spath

FIGS. 2 a, b. Lateral and peripheral views X 1 of a body chamber fragment from Division 3 (iv), *intermedius* Subzone, same locality as FIGS. 1 a, b. (BMNH. C 76485)

Dimorphoplites niobe Spath

FIGS. 3 a, b. Lateral and peripheral views X 1 of an example from 4 inches below the top of Bed III, *niobe* Subzone. Folkestone, Kent. (BMNH. C 76488)

Mojsisovicsia subdelaruei Spath

FIG. 4. Two immature crushed individuals in a block of clay from 2 feet 2 inches above the base of Division 4, *subdelaruei* Subzone, Sevenoaks Brick Works, Otford, Kent. (BMNH. C 76486)

Euhoplites meandrinus Spath

FIGS. 5 a, b. Lateral and peripheral views X 1 of a typical fragment from Bed IV (iii), *meandrinus* Subzone, Folkestone, Kent. (BMNH. C 76489)

Euhoplites nitidus Spath

FIGS. 6 a, b. Lateral and peripheral views X 1 of an example from Bed V, *nitidus* Subzone, Folkestone, Kent. (BMNH. C 76490)

Euhoplites lautus (J. Sowerby)

FIGS. 7 a, b. Lateral and peripheral views X 1 of a wholly septate phosphatic steinkern from the condensed '*lautus* Zone nodule bed' Division 6, Sevenoaks Brick Works, Otford, Kent. (BMNH. C 76487)

Anahoplites daviesi Spath

FIGS. 8 a, b. Lateral and peripheral views X 1 of an involute form from the upper part of Bed VII *daviesi* Subzone, Folkestone, Kent. (BMNH. C 76491)

(All specimens author's coll.)


1a
1b
2
a
b
a
3
b
5b
5a
4
a
6
b
8a
8b
a
7
b

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EARLY TERTIARY OSTRACODA OF THE FAMILY TRACHYLEBERIDIDAE FROM WEST PAKISTAN

BY

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EARLY TERTIARY OSTRACODA OF THE FAMILY TRACHYLEBERIDIDAE FROM WEST PAKISTAN

By Q. A. SIDDIQUI

CONTENTS

SYNOPSIS

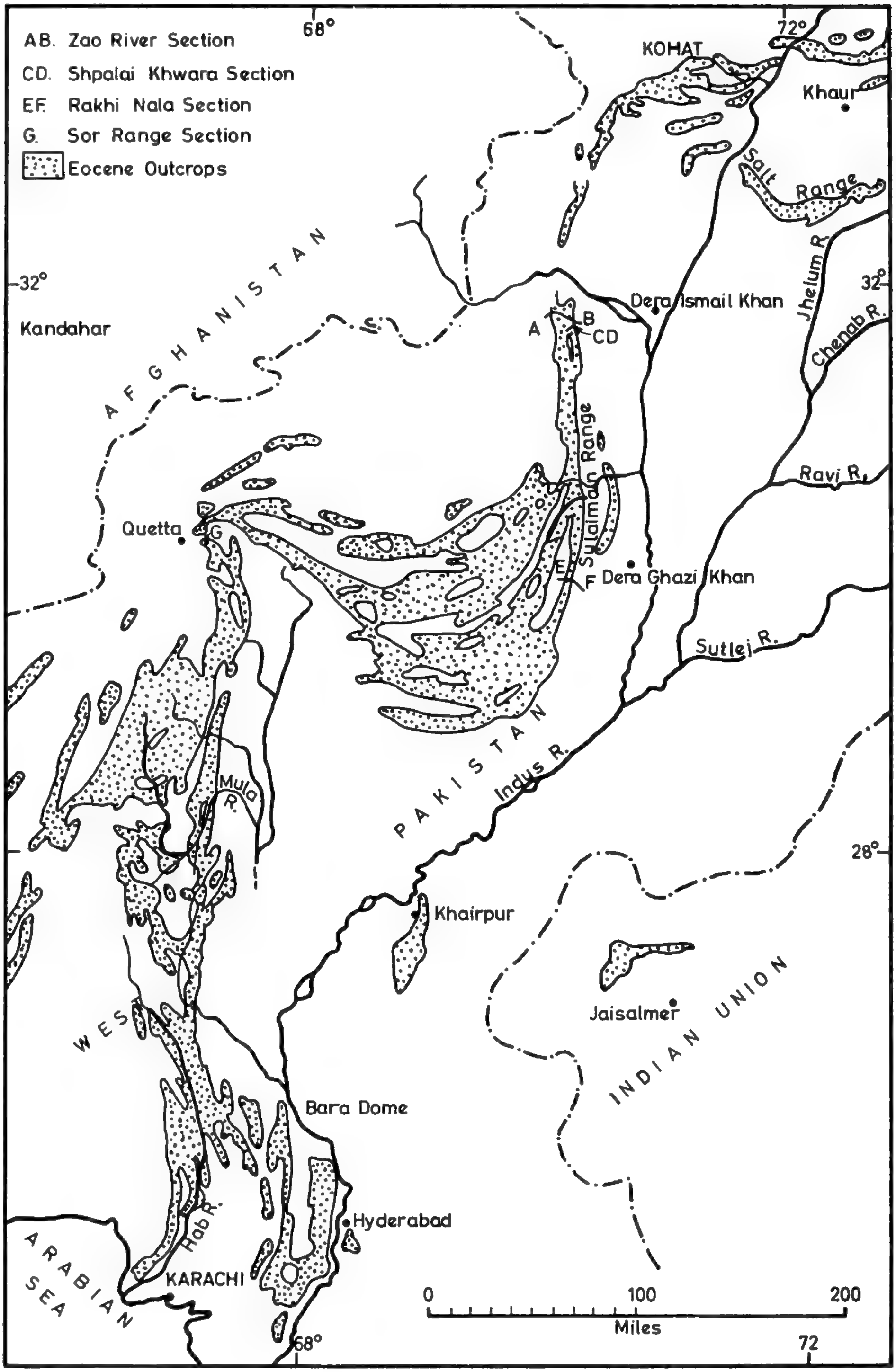
Ostracoda from the Palaeocene of the Sor Range and from the Palaeocene and Eocene of the Rakhi Nala, Zao River and Shpalai Khwara sections, Sulaiman Range, West Pakistan, have been examined. The family TRACHYLEBERIDIDAE has been studied in detail. It is represented by fourteen genera, four subgenera and fifty-nine species. Four new genera (*Alocopocythere*, *Gyrocythere*, *Phalcocythere* and *Stigmatocythere*) and two new subgenera (*Paracosta* and *Scelidocythereis*) are proposed. Out of the fifty-nine species described, fifty-four are new. Two species belonging to the genus *Phalcocythere* one from the Paris Basin and the other from Tanzania are also described.

The Palaeocene and Eocene of the Rakhi Nala section are divided into five ostracod biostratigraphic units. The biostratigraphic units IV and V of the Rakhi Nala are represented in the Zao River section and have almost identical ostracod faunas. The biostratigraphic unit IV of the Rakhi Nala is also represented in the Shpalai Khwara section. The Equations of Correlation between the Rakhi Nala and Zao River sections for biostratigraphic unit V (i. e. Middle-Upper Eocene) have been calculated by means of ranges of ostracod species common to the two sections. The standard errors of estimate for the Equations of Correlation have also been calculated. The boundaries between the Palaeocene-Lower Eocene, Lower-Middle Eocene and Middle-Upper Eocene in the Sulaiman Range are discussed.

I. INTRODUCTION

THE most comprehensive work so far published on the area is that of Eames (1952 ab). Most of his lithological subdivisions for the Eocene succession of the Rakhi Nala and Zinda Pir areas occur in the northern Sulaiman Range, i.e. in the Zao River and Shpalai Khwara sections. These can easily be distinguished on the basis of lithology and microfauna. Eames' terminology of the rock units is therefore adopted here. Bayliss (1961) and Latif (1961 and 1964) are other recent workers who have contributed to our knowledge of the Palaeocene and Eocene in the Rakhi Nala section. However, they used a different terminology for the rock units to that used by Eames, and Fig. 2 shows the correlation between these workers along the Rakhi Nala section.

The samples from the Rakhi Nala section examined for ostracods were the same as used by Bayliss and Latif, who worked on larger and pelagic foraminifera respectively. These samples were collected by Bayliss. The sample numbers as given by the collector are used in this paper. Latif altered the sample numbers after 3200 by subtracting two hundred, i.e. his sample no. 3201 is the same as collector's no. 3401, and so on.



Outcrops of Eocene rocks of part of West Pakistan. (After Eames 1952.) Sections described are indexed.

FIG. 1

Correlation between Eames, Bayliss and Latif along the Rakhi Nala

Eames (1952, p.162-163)

	*	Succession	Thickness in feet	Sample no. as used in present paper
Upper Eocene	Tapti	Pellatispira Beds	60	3666 3657
		Upper Chocolate Clays (Upper part)	425-495	3656 ↑ 3628
Middle Eocene	Kirthar	Upper Chocolate Clays (Lower part)	420-490	3627 ↑ 3604
		White Marl Band	40	3603 3600
		Lower Chocolate Clays	930	3499 ↑ 3478
		Platy Limestone	70	3477 3474
Lower Eocene	Laki = (Ghazij) **	Shales with Alabaster	750	3473 ↑ 3439
		Rubbly Limestones	410	3438 ↑ 3413
		Green and Nodular Shales	850	3412 ↑ 3171
		Upper Rakhi Gaj Shales	1620	3170 ↑ 3140
		Lower Rakhi Gaj Shales. (Topmost portion only = Irregularis Limestone.	60	3667 ↑ 3668
Paleocene	Ranikot	Lower Rakhi Gaj Shales (Max pars)	775	+3667-3672 3139 ↑ 3116
		Gorge Beds	470	3115 ↑ 3110
	CARDITA BEAUMONTI BEDS +	Venericardia Shales	95	
UPPER CRETACEOUS		Pab Sandstones		

Bayliss & Samanta (in press)

Succession		Thickness in feet & sample nos.
Kirthar	Mid-Upper Eocene	2212 3666 ↑ 3453
Ghazij	Lower Eocene	3607 3452 ↑ 3140
Dunghan	Lower Eocene # Paleocene	759 3667 ↑ 3116
Ranikot	# Paleocene	553 3115 3110
Pab	UPPER CRETACEOUS	

Latif (1961, p. 33-36, 1964, p. 31)

Thickness in feet & sample nos.	Zones	Succession	
110 3664 ↑ 3651	Globigerina cf. trilocula	Chharat – Tapti	Upper Eocene
20 3650	Chiloquembelina victoriana	Chharat – Tapti	Upper Eocene
425 3644 3624	Hastigerina micra	Chharat – Tapti	Upper Eocene
140 3623 3616	Chiloquembelina aff martini	Chharat	Middle Eocene
170 3615 3607	Catapsydrax unicavus	Chharat	Middle Eocene
160 3606 ↑ 3498	Globigerina yequaensis	Chharat	Middle Eocene
900	No Pelagic foraminifera	Kirthar	Lower Eocene
100 3464 3460	Globorotalia sp. 3	Kirthar	Lower Eocene
1160 3459 ↑ 3198	Globorotalia sp. 4	Ghazij	Lower Eocene
670 3195 ↑ 3166	Globigerina esnaensis	Ghazij	Lower Eocene
1840 3165 ↑ 3141	Hastigerina pseudoiota	Ghazij	Lower Eocene
30 3140	Globigerina sp. 5	Ghazij	Lower Eocene
100 3669 3137	Globorotalia rex	Ranikot	Paleocene
100 3136 3133	Globorotalia (T) crater	Ranikot	Paleocene
240 3132 3125	Globorotalia angulata	Ranikot	Paleocene
850	No Pelagic foraminifera	Ranikot	Paleocene
	Pab		UPPER CRETACEOUS

* Probable equivalents of Eames, 1952.

** Eames, personal communication.

+ Danian according to Nagappa, 1959, which he regards as basal Paleocene.

? Paleocene.

FIG. 2

Samples from the Zao River and Shpalai Khwara sections were taken by S. M. Ahmed and W. A. Zuberi and those from the Sor Range section by J. A. Reinemund.

All specimens with the prefix Io. are in the Department of Palaeontology, British Museum (Natural History). Those with the prefix GSP BM are in the Museum of the Geological Survey of Pakistan, Quetta.

II. ACKNOWLEDGMENTS

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I should like to thank Dr. F. T. Banner (University College, Swansea) for examining some of the smaller foraminifera from the Rakhi Nala and Sor Range sections ; Dr. C. G. Adams (British Museum, Natural History) for his help in identifying the genus *Pellatispira* from the Zao River ; and Mr. J. A. Reinemund (U.S. Geological Survey) for the information on the Sor Range locality.

For the loan of samples, I am indebted to the following : Standard Vacuum Oil Company, Karachi ; The Director, Geological Survey of Pakistan, Quetta ; Dr. I. Strachan, Birmingham University ; Dr. D. D. Bayliss, Robertson Research Ltd. I would like to acknowledge the following persons for comparative material : Mr. E. S. Pinfold, Geological Adviser of the Attock Oil Co. Ltd. ; Dr. F. E. Eames, lately Chief Palaeontologist of the British Petroleum Co. Ltd. ; Mr. I. G. Sohn, U.S.A. ; Professor A. Wood, Aberystwyth ; The Director, Oil and Gas Commission, India ; Dr. W. A. van den Bold, U.S.A. ; Dr. W. D. I. Rolfe, of the Hunterian Museum, Glasgow ; Dr. N. Grekoff, France ; Dr. R. C. Whatley, Aberystwyth ; Dr. J. E. van Hinte, Holland ; and Professor G. Ruggieri, Italy.

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III. LITHOLOGICAL UNITS

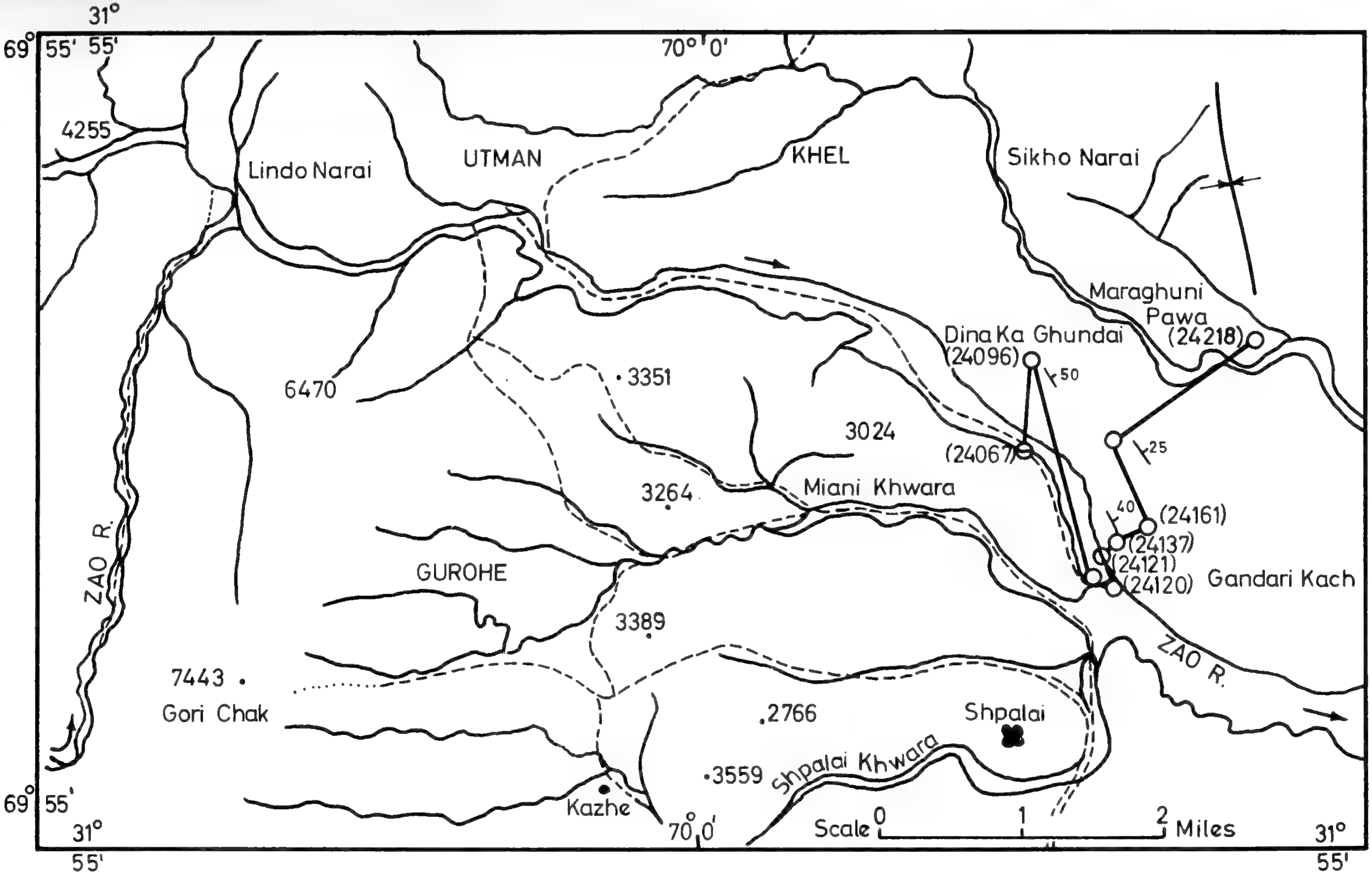
Sulaiman Range. The lithological units of the Rakhi Nala section have been described in detail by Eames (1952, pp. 162–165), Bayliss (1961) and Latif (1961, p. 32). Fig. 2 shows the succession, and the formation names give some idea of the lithology ; for a fuller description, see the authors mentioned above. The Eocene succession in the Zao River and Shpalai Khwara sections (Fig. 3) is very similar to that of the Rakhi Nala section. A detailed lithological description of rocks exposed along the Rakhi Nala, Zao River and Shpalai Khwara sections is given by means of two charts.

			ZAO RIVER		SHPALAI KHWARA	
		Succession	Thickness in feet	Sample nos.	Thickness in feet	Sample nos.
Upper Eocene	Upper Kirthar (= Tapti of Eames)	Upper Chocolate Clays (Upper part)	1796	24210 24161	NOT EXPOSED	
Middle Eocene	Lower Kirthar (Kirthar s.s. of Eames)	Upper Chocolate Clays (Lower part)	910	24160 24138		
		White Marl Band	86	24137 24134		
		Lower Chocolate Clays	754	24133 24120		
		Platy Limestone	178	24119 24114	40	24696 24694
Lr. Eoc (U.pt)	Ghazij (U.pt)	Shales with Alabaster	at least 332	24113 24097	at least 320	24693 24675

Part of the Eocene Succession in the Northern Sulaiman Range.

FIG. 3

Sor Range. Samples were collected from the " Claystones " which are overlain by fifty feet of conglomerates. The Ghazij Shales overlie the conglomerates. A chart showing these lithological units is given (Fig. 6), and a detailed succession is given in Appendix 1. " The locality is in Lease 58 on the north slope of the Sor Range, about eight miles by road east of Quetta (Survey of Pakistan Topo.Sheet No. 34 N/4, co-ordinates 30° 11′20″ N., 67° 10′ E, grid reference P 125210). Samples were collected from a road cut along the main access road that crosses the lease approximately parallel with the outcrop and along the contour of the slope ; structurally the locality



Map of the Zao River and Shpalai Khwara sections.
Numbers in brackets refer to samples. (After Ahmed & Zuberi)
FIG. 4

is near the northern end of the Sor Range syncline, which is the major structural feature of the Sor Range-Danghari coalfield." (Reinemund, personal communiication 1966).

Dr. F. T. Banner of University College, Swansea, was kind enough to examine smaller foraminifera from sample 460-i. He has dated this horizon as the Upper Palaeocene (*pseudomenardii* Zone).

IV. SYSTEMATIC DESCRIPTIONS

Subclass *OSTRACODA* Latreille 1806

Order PODOCOPIDA Müller 1896

Suborder PODOCOPINA Sars 1866

Superfamily ***CYTHERACEA*** Baird 1850

Family ***TRACHYLEBERIDIDAE*** Sylvester-Bradley 1948

DIAGNOSIS. Cytheracea with heavily calcified carapace, often highly ornamented with more or less conspicuous eye-tubercle. Muscle scar pattern basically consisting of four adductor scars (one or more vertically divided in some genera) with a frontal scar which may be simple, V-Shaped, U-shaped or multiple. Posterior characteristically sub-triangular or auricular, but in some genera produced to form a caudal process. Subcentral-tubercle present or absent.

REMARKS. The classification adopted here is to retain the trachyleberids and the hemicytherids in the family Trachyleberididae. Although in general trachyleberids possess a subcentral-tubercle and a V-shaped frontal scar whilst hemicytherids possess divided frontal and adductor scars, an auricular posterior end but lack the subcentral-tubercle there still remain a large number of genera which tend to overlap, thus making it impossible to clearly define the groups at the present time. Hazel (1967) identified two families, the Trachyleberididae having six podomeres in the antennule and the Hemicytheridae with five podomeres. This morphological character is useless palaeontologically and considering the number of trachyleberids which share hemicytherid characters (e.g. divided frontal scars) and hemicytherids having a subcentral-tubercle it would appear optimistic to expect the number of podomeres in the antennule to be so unique as to be restricted to only one group when other, equally good morphological characters obviously are not.

Pokorny (1964) considered the Hemicytherinae to be a group having a horizontal classification, and the situation at the present time has not been effectively clarified.

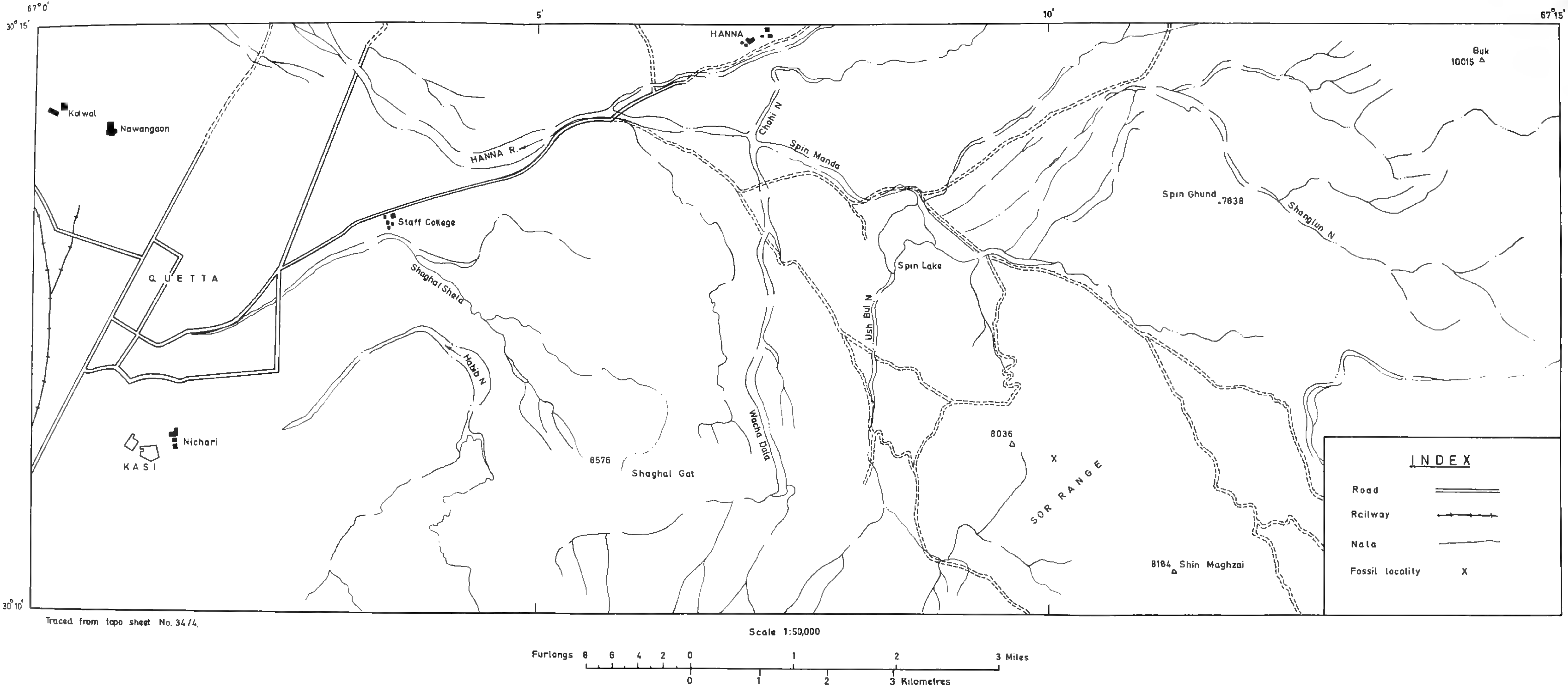
Genus ***ACTINOCYTHEREIS*** Puri 1953

TYPE SPECIES. *Cythere exanthemata* Ulrich and Bassler 1904

Actinocythereis? quasibathonica sp. nov.

(Plate 1, figs. 1–3, 6, 7, 10–13)

DERIVATION OF NAME. Latin *quasibathonica*, "simulating Bathonian" ; with reference to the resemblance to the Middle Jurassic (Bathonian) genus *Oligocythereis*.



Traced from topo sheet No. 34/4.

MAP OF PART OF SOR RANGE SHOWING FOSSIL LOCALITY, QUETTA DIVISION, WEST PAKISTAN.

FIG. 5

SOR RANGE SECTION

Measured by John A. Reinemund

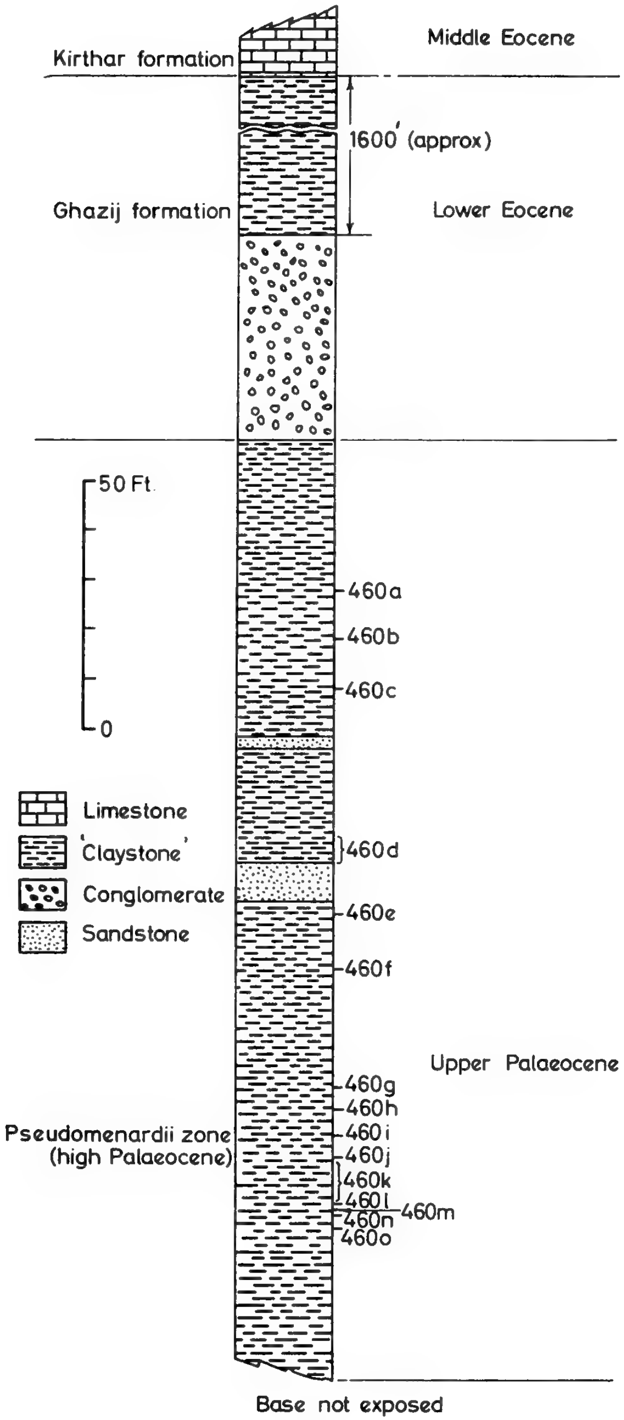


FIG. 6

DIAGNOSIS. Medium size, thick shelled. High and distinct anterior marginal rim with posterior ornamentation. Surface sparsely punctate. Subcentral tubercle prominent and rounded.

HOLOTYPE. Io. 4311, a female carapace (Pl. 1, Figs. 2, 3, 11, 12).

PARATYPES. Io. 4260 + Io. 3100–1.

MATERIAL. 29 specimens from the Rakhi Nala section from 8 horizons (sample nos. 3610, to 3615, 3617, 3618 and 3620). 10 specimens from the Zao River section from two horizons (sample nos. 24150 and 24154). GSP BM 2506–7.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 3611.

DESCRIPTION. Sexual dimorphy moderate, the females are higher and wider than the males. *Carapace* sub-rectangular, medium size and thick shelled. Anterior margin broadly rounded, postero-dorsal margin slightly concave, posterior extremity and postero-ventral margin somewhat rounded. Dorsal and ventral margins almost straight, slightly tapering towards the posterior. In lateral view the dorsal ornamentation over-reaches the dorsal margin. Valves almost equal. In dorsal view the greatest width passes through the sub-central node. *Eye-tubercle* rounded, prominent and situated below and slightly anterior to a well-developed anterior cardinal angle. Anterior marginal rim high. Ventral and posterior marginal rims less high. *Sub-central tubercle* prominent, rounded and distinct. Surface sparsely punctate (punctation is not distinct in some specimens), with an alate ventral ridge which slightly slopes upwards towards the posterior. The postero-dorsal process is a blade-like projecting ridge over-reaching the dorsal margin and extending vertically below for a short distance. A prominent mid-dorsal tubercle with a small tubercle present in front. There is also a small tubercle posterior and at some distance from the sub-central node. About 12 short marginal spines anteriorly, partly concealed in external lateral view by the anterior marginal rim, and 5–6 spines posteriorly. *Radial pore canals* few, simple and straight. *Inner margin* and *line of concrescence* coincide. *Duplicature* moderately wide. *Selvage* well marked lying sub-peripheral in left valve, but at some distance from the outer margin in right valve. There is a fairly well-developed *flange groove* in right valve. *Muscle scars* unknown. *Hinge* holamphidont with the details given below :

Hinge element	Left Valve	Right Valve
Anterior	Socket	Conical projecting tooth
Anteromedian	Subconical tooth having a straight anterior and a convex posterior in dorsal view	Deep socket
Posteromedian	Denticulate bar	Shallow locellate groove
Posterior	Slightly elongate socket, open on venter.	Pessular tooth

DIMENSIONS (mm).

		L	H	W
Io. 4260	Carapace male	0·51	0·29	0·27
Io. 4311	Carapace female (holotype)	0·52	0·32	0·29
Io. 3101	Left valve male	0·51	0·29	—
Io. 3100	Right valve male	0·51	0·29	—

REMARKS. This species is tentatively assigned to the genus *Actinocythereis*. It differs from the type species of the genus in having a continuous rather than a broken ventral ridge. In addition, the present species is much smaller, has a pitted surface and fewer radial pore canals.

Genus *ALOCOPOCYTHERE* nov.

DERIVATION OF NAME. Greek *alokos*, = furrow, *opos* = eye ; with reference to the furrow behind the eye-tubercle + *cythere*.

DIAGNOSIS. Trachyleberididae in which the eye-tubercle is confluent with both the elevated marginal rim and a short almost vertical ridge, delimited posteriorly by a deep furrow. Anterior and posterior cardinal angles protruding in left valve, only anterior cardinal angle protruding in right valve. Posterior cardinal angle of right valve over-reached by protruding cardinal angle of left valve. Dorsal margin humped.

TYPE SPECIES. *Alocopocythere transcendens* sp. nov.

DESCRIPTION. Dimorphic, the males are proportionally longer than the females. Carapace sub-rectangular to sub-quadrate in shape. Dorsal margin in lateral view sinuous, dominated by protruding anterior and posterior cardinal angles, with a hump between, ventral margin evenly curved or almost straight. Anterior margin broadly rounded, posterior straight or very slightly concave in postero-dorsal margin (between posterior cardinal angle and posterior extremity) ; posterior extremity rounded, postero-ventral region rounded or straight. Valves almost equal in size. Sub-central tubercle and eye-tubercle more or less distinct. Surface ornamentation either reticulate (with or without superimposed lineations or with superimposed papillae) or papillose. A marginal rim always present, usually upstanding anteriorly, less high along venter and posterior. Anterior and posterior margins ornamented with small spines or denticles. Normal pores simple, widely spaced. Radial pore canals simple, almost straight, often slightly inflated towards the middle, tending to occur in groups of two or three, often apparently crossing one another, about 32–35 anteriorly and 18–20 posteriorly. Inner margin and line of concrescence coincide. Duplicature of moderate width. Selvage well-marked—sub-peripheral in left valve but at some distance from the outer margin in the right valve. Right valve with a deep flange groove on the centre and anterior. Muscle scar pattern consists of four adductors in a vertical row situated on the posterior margin of the muscle scar pit and an oval frontal scar with two more or less rounded mandibular scars below. Hinge holamphidont. Right valve with highly projecting, stirpate anterior tooth, postjacent socket, posteromedian locellate groove and a pessular posterior tooth ; left valve with anterior socket, anteromedian sub-conical tooth, postero-median denticulate bar and a deep posterior socket.

COMPARISON. This genus differs from *Echinocythereis* in having a short vertical ridge below and a furrow behind the eye-tubercle, also there are two frontal scars in *Echinocythereis*, but only one in *Alocopocythere*. *Stigmatocythere* has a curved ridge joining the eye-tubercle and the sub-central tubercle, whereas in *Alocopocythere* a short, almost vertical ridge joins the eye-tubercle and is delimited posteriorly by a furrow. *Henryhowella* has three longitudinal plications in the posterior half of the valve and an anterior vestibule, not present in *Alocopocythere*. Moreover, the frontal scar in *Henryhowella* is V-shaped, while *Alocopocythere* has an oval frontal scar.

REMARKS. In addition to the species described here, the Miocene species *Trachyleberis fossularis* Lubimova and Guha (1960, p. 40, pl. 3, fig. 7), which Guha in 1961 (p. 4, figs. 5, 9) transferred to the genus *Echinocythereis* should be ascribed to *Alocopocythere*.

Alocopocythere transcendens sp. nov.

(Plate 1, figs. 4, 5, 8, 9 ; Plate 2, figs. 1–4, 6, 7)

DERIVATION OF NAME. Latin, *transcendens*, rising above ; with reference to the stratigraphic position in relation to *A. abstracta*.

DIAGNOSIS. Strongly reticulate *Alocopocythere* with rounded postero-ventral margin, sub-central tubercle more or less distinct, eye-tubercle distinct, marginal rim well marked.

HOLOTYPE. Io. 4315, a female left valve (Pl. 2, figs. 1, 6).

PARATYPES. Io. 4261 + Io. 3104–6.

MATERIAL. 263 specimens from the Zao River section from 7 horizons (sample nos. 24127, 24131, 24132, 24145, 24147, 24148 and 24151). Approximately 600 specimens from the Rakhi Nala section from 46 horizons (sample nos. 3168, 3198, to 3200, 3401 to 3405, 3407, 3409, 3410, 3418, to 3422, 3424, 3426, 3428, 3429, 3432, 3434, 3435, 3438, 3457 to 3459, 3498, 3499, 3607, 3614, 3615, 3617 and 3618). GSP. BM. 2508.

TYPE LOCALITY. Zao River section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 24148.

DESCRIPTION. *Carapace* sub-rectangular to sub-quadrate in lateral outline. Sexual dimorphism rather marked, the females being shorter, higher and wider than the males. Dorsal margin sinuous with protruding anterior and posterior cardinal angles, ventral margin almost straight in the right valve but evenly curved in the left valve. Anterior margin broadly rounded, postero-dorsal margin very slightly concave particularly in the right valve, posterior extremity rounded, postero-ventral margin rounded. Valves almost equal in size. *Eye-tubercle* distinct, rounded and polished. *Sub-central tubercle* more or less distinct. Shell surface strongly reticulate. Antero-dorsal furrow deep, bounded anteriorly by a short almost vertical ridge joining the eye-tubercle. Anterior marginal rim high, continuing as a less high rim round the venter and posterior. Anterior margin ornamented with 8–10 short spines, posterior with a postero-ventral spine, although these are preserved in a few specimens only. *Duplicature* moderately wide, 0·073 mm. anteriorly in right valve female. *Selvage* prominent in both valves, situated in the outer third of the duplicature in right valve but sub-peripheral in left valve. Along the venter it is markedly concave antero-medially. Right valve has well-developed ventral and anterior *flange grooves*. *Normal pore canals* simple, small. *Radial pore canals* more or less straight, simple, some in groups of two or three, frequently crossing each other. There are approximately 35 radial pore canals in the anterior and 20 in the posterior. *Line of concrescence* and *inner margin* coincide throughout. *Muscle scars* consist of sub-vertical row of four adductors, situated on the posterior margin of the muscle scar pit, with an oval frontal scar and two somewhat rounded mandibular scars below. *Hinge* holamphidont with the following details :

Element	Left valve	Right valve
Anterior	Deep socket confluent with ocular sinus, bounded on all sides.	Highly projecting stirpate tooth, ocular sinus lies below it.
Anteromedian	Subconical tooth with straight anterior and convex posterior in dorsal outline.	Deep rounded socket opening into posteromedian groove
Posteromedian	Denticulate bar	Locellate groove
Posterior	Deep slightly elongate socket open on ventral side.	Pessular tooth, high on posterior tending towards reniform.

DIMENSIONS (mm).

		L	H	W
Io. 3104	Carapace male	0·72	0·43	0·42
Io. 4315	Left valve female (holotype)	0·63	0·44	—
Io. 3105	Right valve female	0·64	0·39	—
Io. 4261	Left valve female	0·59	0·39	—
Io. 3106	Right valve male	0·63	0·38	—

COMPARISON. *Alocopocythere abstracta* sp. nov. is a very closely related species, but is more elongate, and has a straight rather than rounded posteroventral margin and less deep reticulations. *Alocopocythere transcendens* is perhaps ancestral to *Alocopocythere transversa* sp. nov. but is smaller, and lacks the posterior concentric ridges and a short ridge in the anteroventral area. *Alocopocythere fossularis* (Lubimova and Guha) (1960) from the Miocene of Kutch is a similar species but which differs however, in the lateral outline of the carapace.

REMARKS. Specimens of *A. fossularis* (Lubimova and Guha) from the type locality in Kutch were not available for comparison.

Alocopocythere rupina sp. nov.

(Plate 2, figs. 5, 8–10 ; Plate 3, figs. 1–4)

DERIVATION OF NAME. Latin, *rupina*, " chasm " ; with reference to the anterodorsal furrow and associated ridges.

DIAGNOSIS. *Alocopocythere* in which anterodorsal furrow is delimited anteriorly by a short almost vertical ridge and posteriorly by the anterior part of the dorsal ridge. Surface reticulate with seven longitudinal ridges. Anterior and posterior plains almost smooth.

HOLOTYPE. Io. 4314, a male carapace (Pl. 2, figs. 5, 8–10).

PARATYPE. Io. 4262.

MATERIAL. 41 specimens from the locality below from one horizon (sample no. 3111). GSP BM 2509–10.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Gorge Beds, sample no. 3111.

DESCRIPTION. Sexual dimorphism strong, the males are longer than the females. *Carapace* subrectangular in lateral view. Dorsal margin sinuous, ventral margin slightly concave in front of the middle, anterior margin broadly rounded, posterior narrowly rounded. Anterior cardinal angle protruding particularly in right valve, posterior cardinal angle less well-developed. Left valve slightly over-reaches right valve at anterior cardinal angle and in the region of posterodorsal corner. *Eye-tubercle* rounded and distinct. *Subcentral-tubercle* well-developed. Surface ornamentation with seven longitudinal ridges ; the dorsal ridge begins above and very slightly to the anterior of the subcentral-tubercle and is convex in the middle culminating in the posterior quarter. The four ridges below the dorsal ridge are almost confined posterior to the subcentral-tubercle, the second ridge from the centre is the longest and is slightly curved ; it commences above the anteroventral corner and slopes obliquely upwards towards the posterior ending in the posterior quarter. The ventral ridge is confined in the posterior part of the carapace and is intercalated between the ventral margin and the second ventral ridge, to which it is almost parallel. Anterodorsal furrow well-developed, delimited on the anterior by a short almost vertical ridge, and on the posterior by the anterior portion of the dorsal ridge. Anterior and posterior platforms almost smooth, compressed. Anterior marginal rim elevated, ventral and posterior marginal rims less high. *Radial pore canals* not detectable. *Duplicature* moderate. *Selvage* well-marked ; it is submarginal in left valve but in the outer third of the duplicature in right valve, which also has well-developed anterior and ventral *flange grooves*. *Hinge* holamphidont with stirpate anterior tooth in right valve.

DIMENSIONS (mm).

		L	H	W
Io. 4314	Carapace male (holotype)	0·68	0·37	0·34
Io. 4262	Carapace female	0·59	0·37	0·34

COMPARISON. *A. rupina* can easily be differentiated from other known species of

Alocopocythere by its anterodorsal groove, which is not only delimited by an anterior ridge but by a posterior ridge as well.

REMARKS. This is so far the oldest known species of the genus *Alocopocythere*. It occurs abundantly in one horizon (sample no. 3111) of the Gorge Beds of the Rakhi Nala section, the male to female ratio being 1 : 3.

Alocopocythere abstracta sp. nov.

(Plate 3, figs. 5–11 ; Plate 4, fig. 1)

DERIVATION OF NAME. Latin *abstractus*, separated, referring to the difficulty in separating this species from *A. transcendens* because of the many intermediate forms.

DIAGNOSIS. A reticulate *Alocopocythere* with straight postero-ventral margin in lateral outline. Subcentral-tubercle present but not prominent.

HOLOTYPE. Io. 4312, a female carapace (Pl. 3, figs. 9–11) ; (Pl. 4, fig. 1).

PARATYPE. Io. 4263.

MATERIAL. Over 2600 specimens (including adults and juveniles) from the Rakhi Nala section from 69 horizons (sample nos. 3147, 3152, 3153, 3157 to 3180, 3183, 3184, 3186 to 3191, 3193 to 3194, 3197 to 3200, 3401 to 3405, 3407, 3409, 3410, 3415 to 3424, 3426, 3428, 3429, 3432, 3434, 3435, 3438, 3443 and 3445). 5 specimens from the Zao River section from one horizon (sample no. 24127). GSP BM 2511–2512.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Upper Rakhi Gaj Shales, sample no. 3163.

DESCRIPTION. *Carapace* subrectangular in side view. Sexual dimorphism rather pronounced ; the males are longer than the females. Dorsal margin sinuous, ventral margin nearly straight. Anterior margin broadly and evenly rounded, postero-dorsal margin very slightly concave ; posterior extremity rounded ; postero-ventral margin straight. Anterior and posterior cardinal angles protruding. Valves more or less equal. *Eye-tubercle* distinct. *Subcentral-tubercle* present but not pronounced. Surface reticulate. Anterodorsal furrow deep, bounded anteriorly by a short almost vertical ridge diagnostic of the genus. Anterior and posterior margins denticulate, although the denticles are only present in a few specimens. Internal details not known.

DIMENSIONS (mm).

		L	H	W
Io. 4263	Carapace male	0·66	0·38	0·34
Io. 4312	Carapace female (holotype)	0·63	0·39	0·35

COMPARISON. *Alocopocythere coarctata* sp. nov. is smaller than the present species and has a combination of reticulations and weak ridges and a more sinuous dorsal margin. *Alocopocythere radiata* sp. nov., however, is larger, has deeper reticulations and a better developed subcentral-tubercle having posterior radial ridges.

A. abstracta has already been compared with *Alocopocythere transcendens* sp. nov.

Alocopocythere coarctata sp. nov.

(Plate 4, figs. 2–9)

Derivation of name. Latin *coarctatus*, " pressed together " ; with reference to the carapace.

Diagnosis. *Alocopocythere* in which carapace in lateral outline appears to be compressed ; dorsal and ventral margins tapering towards the posterior end, subcentral-tubercle distinct, anterior marginal rim high, surface finely reticulate (with superimposed weak longitudinal ridges).

Holotype. Io. 4313, a female carapace (Pl. 4, figs. 6–9).

Paratype. Io. 4264.

Material. 49 specimens from the below locality from five horizons (sample nos. 3432, 3434, 3435, 3458 and 3459). GSP BM 2513–4.

Type locality. Rakhi Nala section.

Type horizon. Shales with Alabaster, sample no. 3458.

Description. *Carapace* subrectangular to subquadrate in lateral view. Sexual dimorphism strong ; the females are shorter than the males. Anterior margin broadly and evenly rounded, posterodorsal margin straight, particularly in the left valve, posterior extremity rounded, posteroventral margin rounded. Dorsal margin sinuous with a hump between the protruding anterior and posterior cardinal angles, ventral margin slightly concave in the middle. Both dorsal and ventral margins taper towards the posterior. Valves almost equal. Surface finely reticulate with superimposed weak longitudinal ridges. *Subcentral-tubercle* distinct, *eye-tubercle* more or less distinct. Marginal rim present, elevated in the anterior, less elevated round the venter and posterior. Anterodorsal furrow fairly distinct and is bounded anteriorly by a short almost vertical ridge. Anterior and posterior margins denticulate. Internal characters not known.

Dimensions (mm).

		L	H	W
Io. 4264	Carapace male	0·51	0·27	0·27
Io. 4313	Carapace female (holotype)	0·50	0·32	0·29

Comparison. Unlike *A. coarctata*, *Alocopocythere rupina* sp. nov. has better developed longitudinal ridges and coarser reticulation. In addition, these two species differ in lateral outline, particularly the male dimorphs. *Alocopocythere transcendens*, sp. nov. is larger, has a less well-developed hump between the protruding anterior and posterior cardinal angles and lacks longitudinal ridges.

Alocopocythere longilinea sp. nov.

(Plate 4, figs. 10–13 ; Plate 5, figs. 1–3, 6)

Derivation of name. Latin *longi*, longitudinal + *linea*, line.

Diagnosis. A small *Alocopocythere* in which surface ornamentation is reticulate, the reticulae being arranged in longitudinal lines with weak ridges in between, subcentral-tubercle indistinct, marginal rim low, anterior marginal area compressed.

HOLOTYPE. Io. 4318, a male carapace (Pl. 4, figs. 10–13).

PARATYPE. Io. 4265.

MATERIAL. Nearly 670 specimens (including adults and juveniles) from the Rakhi Nala section from 10 horizons (sample nos. 3438, 3440, 3443 to 3445, 3448, 3450, 3451, 3457 and 3458). One specimen from the Shpalai Khwara section from one horizon (sample no. 24683). GSP BM 2515–6.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Shales with Alabaster, sample no. 3443.

DESCRIPTION. *Carapace* ovate in lateral outline and slightly tapering towards the posterior. Sexual dimorphism marked ; the males are longer in proportion than the females. Anterior margin broadly and obliquely rounded, somewhat compressed, posterior almost straight, posteroventral margin slightly curved. Dorsal margin sinuous, ventral margin evenly curved. Valves nearly equal. *Subcentral-tubercle* indistinct. *Eye-tubercle* low. Surface ornamentation consists of a combination of reticulations and weak ridges. Anterodorsal furrow deep with a short more or less vertical anterior ridge characteristic of the genus. Marginal rim low. Internal characters unknown.

DIMENSIONS (mm).

		L	H	W
Io. 4318	Carapace male (holotype)	0·54	0·32	0·25
Io. 4265	Carapace female	0·46	0·30	0·24

COMPARISON. The present species differs from *Alocopocythere abstracta* sp. nov. and *Alocopocythere transcendens* sp. nov. in being smaller and having weak longitudinal ridges. Moreover, *A. longilinea* has a low marginal rim and an indistinct subcentral-tubercle. *Alocopocythere coarctata* sp. nov. is about the same size but has a high marginal rim, well-developed subcentral-tubercle and more sinuous dorsal margin.

REMARKS. *A. longilinea* occurs in the lower part of the Shales with Alabaster of the Rakhi Nala section and at several horizons it is very abundant. It is very rare in the Shpalai Khwara section.

Alocopocythere transversa sp. nov.

(Plate 5, figs. 4, 5, 7–10 ; Plates 6–8 ; Plate 9, figs. 1–5)

DERIVATION OF NAME. Latin *transversus*, transverse ; with reference to the posterior ridges.

DIAGNOSIS. A species of the genus *Alocopocythere* with three posterior transverse concentric ridges. A short ridge in the anteroventral area runs obliquely from the anterior towards the venter, a shallow groove on the dorsal side of the ridge. Surface reticulate (with or without superimposed papillae) or papillose.

HOLOTYPE. Io. 4316, a female carapace (Pl. 5, figs. 8, 10) ; (Pl. 6, figs. 1, 2).

PARATYPES. Io. 4266–9 + Io. 3107–12.

MATERIAL. Over 800 specimens from the Zao River section from 20 horizons (sample nos. 24131, 24155, 24157, 24159, 24170, 24173 to 24178, 24180, 24181, 24183 to 24188 and 24195). Approximately 300 specimens from the Rakhi Nala section from 20 horizons (sample nos. 3624 to 3626, 3630, 3631, 3634, 3640 to 3642, 3645, 3646, 3648 to 3653, 3658 and 3660). GSP BM 2157–8.

TYPE LOCALITY. Zao River section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 24155.

DESCRIPTION. Sexual dimorphism rather marked, the males are more elongate than the females. *Carapace* subrectangular in lateral view. Dorsal margin sinuous, ventral margin straight or evenly curved. Anterior margin broadly rounded, posterodorsal margin very slightly concave, posterior extremity rounded, posteroventral margin rounded or almost straight. Anterior and posterior cardinal angles well-developed and protruding. Valves nearly equal. *Eye-tubercle* distinct, polished and rounded. *Subcentral-tubercle* distinct. Surface either reticulate (with or without superimposed papillae) or papillose. There are three posterior transverse concentric ridges approximately parallel to the posterior margin with grooves in between. There is a short ridge in the anteroventral area running obliquely from the anterior towards the venter, with a groove on the dorsal side. Anterodorsal groove fairly deep and bounded on the anterior by a short almost vertical ridge running from the eye-tubercle. The marginal rim is high in the anterior but less high on the venter and posterior. Anterior and posterior margins ornamented with short spines, only present in some specimens and approximately 20 anteriorly and 10 posteriorly. *Normal pore canals* simple, small and numerous. *Radial pore canals* numerous, simple, nearly straight, some in groups of two or three, often apparently crossing one another. *Duplicature* moderately wide. *Selvage* pronounced in the outer third of the duplicature in the right valve but sub-marginal in the left valve. Right valve with deep ventral and anterior *flange grooves*. *Line of concrescence* and *inner margin* coincide. *Muscle scars* consist of four adductors in a vertical row with an oval frontal scar and two almost rounded mandibular scars below. *Hinge* holamphidont :

Element	Left valve	Right valve
Anterior	Deep rounded socket bounded on all sides, confluent with ocular sinus.	Strongly projecting stirpate tooth (ocular sinus situated below and slightly anterior to it).
Anteromedian	Subconical projecting tooth with a straight anterior and convex posterior in dorsal view.	Deep socket.
Posteromedian	Denticulate bar	Locellate groove
Posterior	Deep elongate socket unbounded on venter	Pessular tooth with a tendency towards reniform, higher on posterior.

COMPARISON. *Alocopocythere radiata* sp. nov. is similar and perhaps related but lacks the posterior concentric ridges. Moreover, *A. radiata* has ventral inflation culminating in a ventral ridge and the longitudinal ridges radiate from the posterior of a subcentral-tubercle.

The present species has already been compared with *Alocopocythere transcendens* sp. nov.

REMARKS. This species may be divided into the following morphotypes, which may represent the chronological subspecies of *A. transversa*. However, because of the difficulty in separating these from one another and also owing to the fact that the reticulate forms recur in the Upper Eocene succession of the Rakhi Nala and Zao River sections, these are here considered as morphotypes.

MORPHOTYPE A

(Pl. 5, figs. 4, 5, 7–10 ; Pl. 6, figs. 1–4)

This has a reticulate surface. The reticulae are usually without any superimposed papillae but in some specimens a few small papillae at the junction of reticulae are present. The posteroventral margin in lateral outline is curved in the male but straight in the female.

DIMENSIONS (mm).

		L	H	W
Io. 4266	Carapace male	0·76	0·44	0·44
Io. 4316	Carapace female (holotype)	0·71	0·45	0·44
Io. 3107	Right valve male	0·85	0·46	—

MORPHOTYPE B

This comprises the transitional forms which fall between Morphotype A and Morphotype C. It has slightly papillose reticulae. Specimens Io. 5004–5 from sample 24155.

MORPHOTYPE C

(Plate 6, figs. 5–8 ; Plate 7, figs. 1–4 ; Plate 8, fig. 4)

This is similar to Morphotype B, but has a combination of reticulations and papillae and a curved posteroventral margin in both male and female.

DIMENSIONS (mm).

		L	H	W
Io. 4267	Carapace male	0·78	0·46	0·44
Io. 4268	Carapace female	0·76	0·46	0·44
Io. 4269	Right valve male (broken)	0·80	—	—

MORPHOTYPE D

This includes the intermediate forms between Morphotype C and Morphotype E. Specimens Io. 5006–7 from sample 24175.

MORPHOTYPE E

(Plate 7, figs. 5–8 ; Plate 8, figs. 1–3, 5)

This is similar in all characters to Morphotype A and Morphotype C but has a papillose surface. It has a curved posteroventral margin in the male and female dimorphs as in Morphotype C. There is a smooth, shallow groove on the dorsal side of the ventral ridge.

DIMENSIONS (mm).

		L	H	W
Io. 3110	Carapace male	0·80	0·46	0·46
Io. 3111	Carapace female	0·74	0·46	0·45

MORPHOTYPE F

(Plate 8, figs. 6–9 ; Plate 9, figs. 1–5)

This has a small carapace. The surface is ornamented with slightly papillose reticulae. There is a rim behind the anterior marginal rim and almost parallel to it with reticulations in between. It originates from the eye-tubercle and fuses ventrally with a short, oblique ventral ridge. It is likely that these forms may be juveniles of Morphotype A or Morphotype C or may even belong to a distinct species.

DIMENSIONS (mm).

		L	H	W
Io. 3109	Carapace male	0·68	0·39	0·39
Io. 3108	Carapace female	0·64	0·39	0·38
Io. 3112	Right valve female	0·59	0·37	—

Alocopocythere radiata sp. nov.

(Plate 9, figs. 6–9 ; Plate 10, figs. 1–4)

DERIVATION OF NAME. Latin *radiatus*, rayed ; with reference to the ridges radiating from the subcentral-tubercle.

DIAGNOSIS. A coarsely reticulate *Alocopocythere* with longitudinal ridges radiating from the posterior of a well-developed subcentral-tubercle. Eye-tubercle distinct, marginal rim high, ventral inflation ends in a marked ridge, almost parallel to the ventral marginal rim.

HOLOTYPE. Io. 4317, a male carapace (Plate 9, figs. 6, 8 ; Plate 10, figs. 1, 2)

PARATYPE. Io. 4270.

MATERIAL. 14 specimens from the locality below from one horizon (sample no. 3652). 8 specimens from the Zao River section from one horizon (sample no. 24173). GSP BM 2519–20.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 3652.

DESCRIPTION. Sexual dimorphism distinct ; the females are shorter than the males. *Carapace* subrectangular in lateral view. Dorsal margin sinuous with protruding anterior and posterior cardinal angles ; ventral margin almost straight. Anterior margin broadly and evenly rounded, posterior extremity rounded, posterodorsal margin very slightly concave, posteroventral margin curved in the male dimorph but almost straight in the female. Valves more or less equal. *Eye-tubercle* rounded and distinct. Surface ornamentation consists of coarse reticulations with superimposed ridges radiating from the posterior of a well-developed subcentral-tubercle. The ventral inflation culminates in a marked ventral ridge almost parallel to the ventral marginal rim. There are two ridges which join the eye-tubercle, one a short more or less vertical ridge bounded posteriorly by a deep anterodorsal furrow which is better seen in dorsal view, and the other a high anterior marginal rim which continues along the venter and around the posterior as a less high rim. Anterior and posterior margins decorated with numerous very short and delicate spines.

DIMENSIONS (mm).

		L	H	W
Io. 4317	Carapace male (holotype)	0·72	0·42	0·42
Io. 4270	Carapace female	0·68	0·42	0·40

COMPARISON. *Alocopocythere transcendens* sp. nov. shows some resemblance and is perhaps ancestral to the present species ; but *A. transcendens* has a less well-developed subcentral-tubercle without radial ridges and lacks a ventral inflation ending in a ridge. *Alocopocythere coarctata* sp. nov. is much smaller, has a carapace which tapers towards the posterior end and has a less deep surface reticulation.

Genus " *ANOMMATOCYTHERE* " Sohn

TYPE SPECIES. " *Anommatocythere microreticulata* " Sohn.

REMARKS. This is a new genus erected by Sohn whose paper is in press. The two species described below are provisionally assigned to the genus but their final designation will depend on the publication of Sohn's paper.

" *Anommatocythere* " *laqueata* sp. nov.

(Plate 10, figs. 5–10)

DERIVATION OF NAME. Latin *laqueatus*, fluted ; with reference to the ornamentation of the anterior rim.

DIAGNOSIS. Anterior rim ornamented with seven small more or less rectangular depressions. Carapace subtriangular with a gently convex dorsal margin.

HOLOTYPE. Io. 4320, a female carapace (Plate 10, figs. 8–10).

PARATYPE. Io. 4271.

MATERIAL. 32 specimens from the locality below from three horizons (sample nos. 3403, 3405 and 3466). Two specimens from the Zao River section from one horizon (sample no. 24107). GSP BM 2521–2.

Type locality. Rakhi Nala section.

Type horizon. Green and Nodular Shales, sample no. 3403.

Description. Sexual dimorphy rather apparent ; the males are longer in proportion than the females. *Carapace* subtriangular in lateral view. Dorsal margin gently convex, ventral margin almost straight, anterior margin broadly rounded, posterior with a caudal process. Greatest length lies below mid-point, greatest height at anterior cardinal angle. Anterior and posterior cardinal angles more or less rounded, somewhat better developed in the left valve. Left valve very slightly larger than the right valve, over-reaching it in the anterodorsal corner and posterodorsal slope. *Subcentral-tubercle* indistinct. *Eye-tubercle* distinct but low. Surface reticulate, the reticulae being arranged in lines separated by longitudinal ribs. Anterior marginal rim ornamented with seven small rectangular depressions like a scallop or bivalve mollusc. Internal characters not observed.

Dimensions (mm).

		L	H	W
Io. 4271	Carapace male	0·66	0·37	0·32
Io. 4320	Carapace female (holotype)	0·66	0·39	0·34

Comparison. "*Anommatocythere*" *confirmata* sp. nov. differs from the present species by having a thick-shelled and ventrally inflated carapace, a convex rather than straight ventral margin in lateral view, and no ornamentation of the anterior rim.

Remarks. Specimens from the Shales with Alabaster show fainter longitudinal ribs. This is perhaps due to the form of preservation.

"*Anommatocythere*" *confirmata* sp. nov.

(Plate 10, figs. 11, 12 ; Plate 11 ; Plate 12, figs. 1, 2)

Derivation of name. Latin *confirmatus*, "strengthened" ; with reference to the variation in the strength of the longitudinal ribs.

Diagnosis. Carapace ventrally inflated and with a short caudal process. Ventral longitudinal ribs are curved and better developed. Anterior and posterior cardinal angles well-marked.

Holotype. Io. 4319, a male carapace (Pl. 10, figs. 11, 12) ; (Pl. 11, figs. 1, 2)

Paratype. Io. 4272 + Io. 3102–3.

Material. 70 specimens from the Rakhi Nala section from five horizons (sample nos. 3499, 3611, 3613–3615). 53 specimens from the Zao River section from six horizons (sample nos. 24145, 24147, 24148, 24150 to 24152). GSP BM 2523–4.

Type locality. Rakhi Nala section.

Type horizon. Upper Chocolate Clays, sample no. 3611.

Description. Sexual dimorphism rather marked, the females are shorter and wider in proportion than the males. *Carapace* plump, thick-shelled and with ventral inflation. Dorsal margin slightly convex particularly in the right valve, ventral margin anteromedially concave but is convex in lateral outline due to the ventral inflation ; anterior margin broadly rounded, posterior with a short caudal process. Anterior and posterior cardinal angles well-developed particularly in the left valve. Left valve slightly over-reaches the right at the anterodorsal and posterodorsal corners. *Subcentral-tubercle* present but not distinct. *Eye-tubercle* rounded, shiny and distinct and lies below and slightly anterior to cardinal angle. Surface ornamentation consists of reticulations and longitudinal ribs. There is a variation in the strength of the longitudinal ribs, those on the ventral surface are stronger and curved convexly downwards in the middle. Marginal rim narrow and low. Anterior and posterior margins denticulate. Valves deep in internal view. *Normal pore canals* fairly numerous and perhaps each reticule has one normal pore canal. *Radial pore canals* simple, straight, sparse, irregularly spaced, few crossing one another, approximately 20 anteriorly and 8 posteriorly. *Line of concrescence* and *inner margin* coincide—no *vestibule*. *Duplicature* fairly wide—0·073 mm. anteriorly, 0·055 mm. on the posterior extremity. *Selvage* distinct and subperipheral ; situated in the right valve on the outer sixth of the anterior margin. Right valve with a ventral *flange groove* between selvage and flange. *Muscle scar* pattern with four adductor scars in an almost vertical superposition at the posterior margin of the muscle scar pit and two more or less rounded frontal scars. *Hinge* holamphidont with the following details of the hinge elements :

Element	Left valve	Right valve
Anterior	Deep socket bounded on all sides, eye-socket lies almost in the middle of it.	Strongly projecting stirpate tooth.
Anteromedian	Conical tooth, projecting slightly towards anterior.	Deep socket narrowing posteriorly into a long groove.
Posteromedian	Denticulate bar	Locellate groove, the anterior part deeper than posterior.
Posterior	Deep and elongate socket unbounded on ventral side.	Large bilobate tooth, the anterior lobe lower than the posterior.

Dimensions (mm).

		L	H	W
Io. 4319	Carapace male (holotype)	0·66	0·39	0·39
Io. 4272	Carapace female	0·63	0·42	0·44
Io. 3102	Left valve male	0·64	0·39	—
Io. 3103	Right valve male	0·63	0·37	—

Comparison. This species has already been compared with " *Anommatocythere* " *laqueata* sp. nov.

Remarks. The vertical range of the present species in the Rakhi Nala and Zao

River sections is 286 ft. and 378 ft. respectively. Hence, it is a very useful species as a horizon marker in the region.

Adult specimens in the two sections vary in size and in the strength of ornamentation.

Genus ***BRADLEYA*** Hornibrook 1952

Type species. *Cythere arata* Brady 1880.

Bradleya ? voraginosa sp. nov.

(Plate 12, figs. 3–9)

Derivation of name. Latin *voraginosus*, full of pits.

Diagnosis. A species provisionally placed in the genus *Bradleya* with subparallel dorsal and ventral margins, projecting anterior cardinal angle, truncated posterior, coarsely and deeply reticulate surface.

Holotype. Io. 4321, a male carapace (Pl. 12, figs. 3, 5, 7, 8).

Paratype. Io. 3115.

Material. 10 specimens from the locality below from two horizons (sample nos. 24159 and 24161). GSP BM 2525.

Type locality. Zao River section.

Type horizon. Upper Chocolate Clays, sample no. 24161.

Description. *Carapace* subrectangular in lateral outline. Valves ventrally inflated. Dorsal and ventral margins almost straight and subparallel, anterior margin broadly rounded, posterior truncated, posterodorsal slope very slightly concave particularly in the right valve. Anterior cardinal angle projecting, posterior cardinal angle rather prominent (approximately 110°). Valves almost equal. *Eye-tubercle* rounded and distinct and situated just below the anterior cardinal angle. *Subcentral-tubercle* more or less distinct. A marginal rim runs around the anterior, ventral and posterior margins. It is fairly well-developed anteriorly and posteriorly but is not so prominent along the venter. Surface ornamentation consists of coarse, deep reticulations and dorsal and ventral ridges.

The dorsal ridge is ill-defined in the anterior half, slightly arched upward in the posterior third culminating in a short horn-like posterodorsal process. The ventral ridge is better developed and slightly alate posteriorly. Anterior margin finely denticulate, posteroventral margin ornamented with 4–5 short spines. Internal details not very well displayed. *Duplicature* fairly wide. *Selvage* in the left valve is subperipheral and less well-developed than in the right valve where it is at some distance from the outer margin. It has a deep *flange groove*, particularly in the venter. *Hinge* holamphidont ; left valve with a deep almost rounded anterior socket which is bounded on all sides, a conical projecting anteromedian tooth, an apparently denticulate bar and a deep elongate posterior socket which is bounded on the venter. Hinge of right valve not clearly seen.

DIMENSIONS (mm).

		L	H	W
Io. 4321	Carapace male (holotype)	0·76	0·42	0·42
Io. 3115	Carapace female	0·73	0·40	0·42

COMPARISON. *Bradleya ? cornuelina* (Bosquet) Keij (1957) is similar to *B ? voraginosa* in lateral view but has three rather than two longitudinal ridges. Further, it has a less well-developed anterior cardinal angle. *Bradleya approximata* (Bosquet) Keij (1957) has a different posterior and larger posteroventral spines.

Genus ***BUNTONIA*** Howe 1935

TYPE SPECIES. *Buntonia shubutaensis* Howe 1935.

Buntonia devexa sp. nov.

(Plate 13, figs. 1–5)

DERIVATION OF NAME. Latin *devexus*, sloping ; with reference to the tapering lateral outline.

DIAGNOSIS. A species of *Buntonia* in which carapace is elongate, subrectangular in lateral view ; surface ornamented with 9–11 longitudinal ribs in posterior three-fifths of carapace.

HOLOTYPE. Io. 4322, a female carapace (Pl. 13, figs. 2, 4, 5).

PARATYPE. Io. 3113.

MATERIAL. 8 specimens from the locality and horizon below.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Gorge Beds, sample no. 3111.

DESCRIPTION. Sexual dimorphism rather pronounced ; the males are longer and less wide than the females. *Carapace* sub-triangular in lateral view, tapering towards the posterior. Anterior margin broadly and obliquely rounded, posterior narrowly rounded, dorsal and ventral margins almost straight, dorsal margin slopes downwards towards posterior. Greatest length passes through the midpoint, greatest height in the anterior third and greatest width in the posterior two-fifths. Anterior cardinal angle rounded. Left valve slightly larger than the right valve. Surface ornamentation consists of 9–11 longitudinal ridges, which are more or less confined in the posterior three-fifths. Anterior marginal rim distinct.

DIMENSIONS (mm).

		L	H	W
Io. 3113	Carapace male	0·80	0·39	0·24
Io. 4322	Carapace female (holotype)	0·73	0·35	0·27

COMPARISON. *Buntonia virgulata* Apostolescu (1961) has punctae between longitudinal ridges and a less elongate carapace. *Cythere* cf. *costellata* (Roemer) Latham (1938) is similar and may even be conspecific. However, her figure, which appears to be drawn upside down, shows longitudinal ridges continuing in the anterior part of the carapace.

REMARKS. *Cythere costellata* (Roemer) is now regarded as a species of the genus *Cytheretta*. Because of the imperfect preservation, it has not been possible to observe whether the present species has any eye-tubercles.

Buntonia Sp.A

(Plate 13, figs. 6, 7, 9)

FIGURED SPECIMEN. Io. 3114.

MATERIAL. Two specimens from the locality and horizon below.

LOCALITY. Rakhi Nala section.

HORIZON. Lower Rakhi Gaj Shales, sample no. 3133.

DESCRIPTION. *Carapace* small, almost triangular in lateral outline. Greatest length lies below mid-point, greatest height in anterior third. In dorsal view the carapace is widest just posterior to the middle and tapers towards anterior and posterior ends ; posterior pointed. Anterior end broadly and obliquely rounded, posterior narrow and somewhat rounded ; dorsal and ventral margins taper towards the posterior. Anterior cardinal angle rounded and well-developed. Left valve larger than right valve. Surface ornamented with some ten longitudinal ridges.

DIMENSIONS (mm).

		L	H	W
Io. 3114	Carapace	0·50	0·27	0·32

COMPARISON. *Buntonia devexa* sp. nov. (Pl 13, figs. 1–5) is much larger, has a less triangular carapace with a gentle slope on the dorsal margin. Further, *B. devexa* has a rounded rather than pointed posterior in dorsal view and has longitudinal ridges which do not continue towards the anterior.

Genus ***COSTA*** Neviani 1928

DIAGNOSIS. Trachyleberididae in which ornamentation is dominated by three or four longitudinal ridges, the median or second ridge running back from the subcentral-tubercle towards posterodorsal corner in anterior two-thirds of length, then curving sharply down towards posteroventral corner in posterior third of length.

TYPE SPECIES. *Cytherina edwardsii* Roemer 1838.

Subgenus ***COSTA*** sensu stricto

DIAGNOSIS. *Costa* with three longitudinal ridges.

Subgenus ***PARACOSTA*** nov.

DERIVATION OF NAME. Greek *para*, near ; with reference to the strong resemblance to the subgenus *Costa*.

DIAGNOSIS. *Costa* with a fourth ventral ridge intercalated between third ridge and ventral margin.

TYPE SPECIES. *Costa* (*Paracosta*) *declivis* sp. nov.

REMARKS. The subgenus *Paracosta* is so far only known from the Rakhi Nala section. It is represented by two species in the Upper Chocolate Clays and one species in the Pellatispira Beds.

Costa (Paracosta) declivis sp. nov.

(Plate 13, figs. 8, 10–14 ; Plate 14, figs. 1, 2)

DERIVATION OF NAME. Latin *declivis*, sloping downward ; referring to the direction of the ridge running anteroventrally from the subcentral-tubercle.

DIAGNOSIS. A small species of *Paracosta* in which longitudinal ridges are well-developed, median or second ridge runs anteroventrally from subcentral-tubercle.

HOLOTYPE. Io. 4325, a male carapace (pl. 13, figs. 8, 10–12).

PARATYPES. Io. 4273—Io. 3116.

MATERIAL. 34 specimens from the Rakhi Nala section from four horizons (sample nos. 3661 to 3664). GSP BM 2526–7.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Pellatispira Beds, sample no. 3662.

DESCRIPTION. Sexual dimorphism marked, the males are longer than the females. *Carapace* elongate, subrectangular in lateral view with greatest height at anterior cardinal angle. Dorsal and ventral margins almost straight, subparallel, anterior end broadly rounded, posterior subtriangular. Valves almost equal. Anterior cardinal angle rounded, posterior cardinal angle obtuse. Greatest width in the posterior third. *Subcentral-tubercle* distinct. *Eye-tubercle* rounded and distinct. Ornamentation consists of reticulations dominated by four longitudinal ridges. The dorsal ridge commences just above the subcentral-tubercle and is slightly arched upward (in lateral view over-reaching dorsal margin), the median or second ridge runs almost diagonally from anteroventral margin towards posterodorsal corner, then bending down towards posteroventral margin ; the ventral or fourth ridge (better seen in ventral view) lies between the third ridge and the ventral margin and is not as well-developed as the other three. Anterior and posterior marginal rims high. Anterior margin ornamented with 15–18 small spines, posteroventral margin with 5–6 relatively large spines. Internal characters unknown.

DIMENSIONS (mm).

		L	H	W
Io. 4325	Carapace male (holotype)	0·83	0·39	0·37
Io. 4273	Carapace female	0·77	0·39	0·37
Io. 3116	Carapace female	0·77	0·39	0·37

COMPARISON. This species differs from *Costa* (*Paracosta*) *disintegrata* sp. nov. in having well-developed longitudinal ridges and a different outline. *Costa* (*Paracosta*) *compitalis* sp. nov. is larger, lacks well-developed longitudinal ridges and has a ridge running from the eye-tubercle to the subcentral-tubercle.

Costa (Paracosta) compitalis sp. nov.

(Plate 14, figs. 3–10)

DERIVATION OF NAME. Latin *compitalis*, pertaining to a cross-roads ; referring to the nexus of the ridges running from the subcentral-tubercle.

DIAGNOSIS. A large, strongly reticulate species of the subgenus *Paracosta* in which longitudinal ridges are moderately developed, subcentral-tubercle prominent, joined by three ridges—dorsal, median and a ridge running from eye-tubercle.

HOLOTYPE. Io. 4323, a female carapace (Pl. 14, figs. 5, 6, 9, 10).

PARATYPE. Io. 4274.

MATERIAL. 14 specimens from the locality below from one horizon (sample no. 3604). GSP BM 2528–9.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 3604.

DESCRIPTION. *Carapace* subrectangular in lateral outline. Sexual dimorphism rather pronounced ; the females are shorter and higher than the males. Dorsal margin slightly curved in lateral view because of over-reaching by the dorsal ridge ; ventral margin straight, anterior broadly and evenly rounded, posterodorsal margin very slightly concave, posterior extremity slightly subtriangular, posteroventral margin rounded. Greatest height at anterior cardinal angle, greatest length through the mid-point and greatest width in posterior third. Anterior cardinal angle well-developed with a concavity behind. Left valve slightly larger than right valve, over-reaching at posterodorsal margin and in the region of anterior cardinal angle. *Eye-tubercle* rounded and distinct and confluent with the anterior marginal rim and a ridge running from the subcentral-tubercle. The prominent *subcentral-tubercle* lies more or less in the anterior third. Surface coarsely reticulate. There are four longitudinal ridges ; the dorsal ridge commences at the subcentral-tubercle and is curved convexly upward, the median or second ridge stretches back from the subcentral-tubercle towards posteroventral margin, the third ridge slightly slopes upward towards the posterior end and the ventral ridge is almost parallel to the ventral margin and is intercalated between the third ridge and the ventral margin. Anterior and posterior marginal rims distinct. Anterior and posterior margins ornamented with numerous small spines. Internal details not known.

DIMENSIONS (mm).

		L	H	W
Io. 4274	Carapace male	0·98	0·51	0·46
Io. 4323	Carapace female (holotype)	0·93	0·51	0·44

COMPARISON. *Costa* (*Paracosta*) *disintegrata* sp. nov. is smaller than the present species, has ill-defined longitudinal ridges and a carapace tapering towards the posterior end.

Costa (Paracosta) disintegrata sp. nov.

(Plate 14, figs. 11 ; Plate 15, figs. 1–6)

DERIVATION OF NAME. Latin *disintegratus*, " broken down " ; referring to the relict nature of the ridges characteristic of *Costa*.

DIAGNOSIS. *Paracosta* of medium size with weakly developed longitudinal ridges. Carapace tapering towards posterior end in lateral view.

HOLOTYPE. Io. 4324, a male carapace (Pl. 14, figs. 11 ; Pl. 15, figs. 3, 4).

PARATYPE. Io. 4275.

MATERIAL. Four specimens from the locality below from two horizons (samples no. 3621 and 3622). GSP BM 2530–31.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 3622.

DESCRIPTION. Sexual dimorphy moderate ; the males are longer in proportion than females. *Carapace* subrectangular, tapering to posterior in side view. Dorsal and ventral margins almost straight, anterior margin broadly and evenly rounded, posterior subtriangular. Anterior cardinal angle rounded, posterior cardinal angle obtuse—well-developed in left valve. Left valve over-reaches the right slightly at the anterior cardinal angle and in the region of the posterodorsal slope. A distinct *eye-tubercle* lies just below the anterior cardinal angle. *Subcentral-tubercle* well-developed. Anterior and posterior marginal rims high. Surface coarsely reticulate (some reticulae being slightly papillose). There are four ill-defined longitudinal ridges ; the dorsal ridge commences just behind the subcentral tubercle and is curved convexly upward ; the second ridge stretching back from the subcentral-tubercle towards the posterodorsal corner in the anterior two-thirds and then bends sharply round towards the posteroventral corner ; the third ridge commences below the subcentral-tubercle and slopes upward towards the posterior end ; the fourth ridge (better seen in ventral view) is more or less parallel to the third ridge and lies between the ventral margin and the third ridge. Anterior and posterior margins spinose.

DIMENSIONS (mm).

		L	H	W
Io. 4275	Carapace male	0·83	0·42	0·32
Io. 4324	Carapace female (holotype)	0·85	0·44	0·37

COMPARISON. This species falls between *Costa* (*Paracosta*) *compitalis* sp. nov. and *Costa* (*Paracosta*) *declivis* sp. nov. in size and stratigraphical position and has already been compared with these species.

Genus ***ECHINOCYTHEREIS*** Puri 1954

DIAGNOSIS. Trachyleberididae with or without ventral ridges. Carapace often inflated and with curved posteroventral margin, particularly in right valve. Surface ornamented with papillae, nodes, reticulations (or combination of these—concentrically arranged in some species) or almost smooth. Muscle scars are in a vertical column of four adductors with two frontal scars.

TYPE SPECIES. *Cythereis garetti* Howe and McGuirt 1935.

Subgenus ***ECHINOCYTHEREIS*** sensu stricto

DIAGNOSIS. *Echinocythereis* without ventral ridges.

Echinocythereis (Echinocythereis) contexta sp. nov.

(Plate 15, figs. 7, 8, 10, 13)

DERIVATION OF NAME. Latin *contextus*, joined together ; from the ornamentation of the papillae joined by the walls of the reticulae.

DIAGNOSIS. A species of the subgenus *Echinocythereis* in which posterior end is obliquely rounded towards posterodorsal corner, eye-tubercle prominent, surface reticulate with superimposed papillae.

HOLOTYPE. Io. 4326, a female carapace (Pl. 15, figs. 8, 13).

PARATYPE. Io. 4276.

MATERIAL. Five specimens from the Sor Range section from four horizons (sample nos. 460-f, 460-i, 460-j and 460-o). GSP BM 2532–3.

TYPE LOCALITY. Sor Range section.

TYPE HORIZON. Upper Palaeocene, sample no. 460-i.

DESCRIPTION. Sexual dimorphism rather strong ; the *carapace* is subrectangular in the male and subquadrate in the female. Dorsal margin in lateral outline undulating because of ornamentation, ventral margin almost straight, anterior broadly and evenly rounded. Greatest length passes above the mid-point, greatest height in the anterior fourth and greatest width behind the middle. Anterior and posterior cardinal angles well-developed. Left valve larger than the right, over-reaching it at the anterior, ventral and posterodorsal margins. *Eye-tubercle* rounded and prominent, standing out from the shell surface in lateral and dorsal views. *Subcentral-tubercle* more or less distinct. Surface ornamentation consists of slightly papillose reticulae which are concentrically arranged near the margins. Anterior and posterior margins are set with a double row of papillae ; those on the posterior are larger, and in some specimens become short spines. Internal details not seen.

DIMENSIONS (mm).

		L	H	W
Io. 4276	Carapace male	0·78	0·44	0·37
Io. 4326	Carapace female (holotype)	0·71	0·46	0·42

COMPARISON. Unlike *E.* (*E.*) *contexta* sp. nov. *Echinocythereis* (*Scelidocythereis*) sp.A has a straight rather than curved posterodorsal margin and less prominent eye-tubercles. Moreover, it has a weak ventral ridge and a short horn-like posterodorsal process. *Echinocythereis* (*Echinocythereis*) *elongata* sp. nov. also differs by possessing a very elongate carapace and a better developed subcentral-tubercle.

Echinocythereis (Echinocythereis) elongata sp. nov.

(Plate 15, figs. 9, 11, 12, 14 ; Plate 16, figs. 1, 2)

DERIVATION OF NAME. Latin *elongatus*, elongate ; with reference to the carapace.

DIAGNOSIS. An elongate species of the subgenus *Echinocythereis* in which posterior end is rounded towards posterodorsal corner, subcentral-tubercle distinct, surface ornamented with reticulae and papillae.

HOLOTYPE. Io. 4327, a female carapace (Pl. 15, figs. 12, 14 ; Pl. 16. fig. 1).

PARATYPE. Io. 3130.

MATERIAL. Nine specimens from the Rakhi Nala section from three horizons (sample nos. 3404, 3409 and 3416). GSP BM 2534.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Rubbly Limestones, sample no. 3416.

DESCRIPTION. *Carapace* elongate, subrectangular in lateral outline. Sexual dimorphism rather prominent in dorsal view ; males longer and less wide than females. Anterior margin broadly rounded, posterior narrowly rounded towards posterodorsal corner particularly in the left valve, dorsal margin irregular due to ornamentation, ventral margin more or less straight. Greatest length lies above the middle, greatest height at the anterior cardinal angle and greatest width in front of the middle. Valves almost equal. *Subcentral-tubercle* distinct. *Eye-tubercle* fairly distinct, but worn in some specimens. Surface ornamentation a combination of reticulations and papillae. The reticulae are in the anterior and ventral regions and the papillae in the middle and posterior. The papillae are perhaps revealed by the removal of an upper layer of reticulae. The decorated papillae show normal pore canals and nexus of reticulae, which are smaller than the anterior and ventral ones. *Normal pore canals* are situated between the papillae. Anterior and posterior margins denticulate, although the denticles are not preserved in some specimens. Internal characters unknown.

DIMENSIONS (mm).

		L	H	W
Io. 3130	Carapace male	0·73	0·39	0·29
Io. 4327	Carapace female (holotype)	0·71	0·38	0·34

COMPARISON. This species can easily be separated from the other known species of the subgenus *Echinocythereis* by its much more elongate carapace.

Subgenus ***SCELIDOCYTHEREIS*** nov.

DERIVATION OF NAME. Greek *skelis*, rib ; with reference to the development of the ventral ridges.

DIAGNOSIS. *Echinocythereis* with ventral ridges.

TYPE SPECIES. *Echinocythereis* (*Scelidocythereis*) *multibullata*. sp. nov.

Echinocythereis (Scelidocythereis) multibullata sp. nov.

(Plate 16, figs. 3–9 ; Plate 17, figs. 1, 2, 7)

DERIVATION OF NAME. Latin *multus*, much + *bullatus*, knobbed ; with reference to the ornamentation.

DIAGNOSIS. A species of the subgenus *Scelidocythereis* with a prominent subcentral-tubercle consisting of 4–5 small nodes. Surface nodose or tuberculate. Right valve over-reaches left valve anteriorly but is over-reached by the latter at anterior and posterior cardinal angles.

HOLOTYPE. Io. 4328, a male carapace (Pl. 16, figs. 3, 5, 6 ; Pl. 17, fig. 7).

PARATYPES. GSP BM 2558–Io. 3133–4 + Io. 4277.

MATERIAL. 76 specimens from the Zao River section from five horizons (sample nos. 24154, 24156, 24159, 21461 and 24183). 28 specimens from the Rakhi Nala section from three horizons (sample nos. 3621, 2624 and 2625). GSP BM 2535–6.

TYPE LOCALITY. Zao River section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 24161.

DESCRIPTION. Sexual dimorphism rather marked ; presumed females shorter, higher and wider than presumed males. *Carapace* subrectangular in lateral view. Anterior margin broadly and evenly rounded in both valves. In the right valve the posterodorsal corner is very slightly concave, whilst the posterior extremity and the posteroventral margins are rounded ; in the left valve the posterior end is truncated. Dorsal margin intricate in lateral view because of ornamentation ; ventral margin slightly incurved anterior to the middle in the right valve but curved convexly downward in the left valve. Greatest length passes through the middle, greatest height at the anterior cardinal angle and greatest width in front of the middle (i.e. at the subcentral-tubercle). Anterior cardinal angle protruding. Right valve over-reaches the left at the anterior margin and posteroventral margin ; but left valve over-reaches the right in the region of the anterior and posterior cardinal angle. *Subcentral-tubercle* prominent and is composed of 4–5 small nodes. *Eye-tubercle* rounded and distinct. Surface ornamented with nodes, or tubercles, those nearest the ventral margin being the larger. There are three small ventral ridges, the two near the ventral margin are smaller and almost confined to the anteroventral and mid-ventral regions. Anterior and posterior margins are denticulate. Viewed internally the valves are deep. *Duplicature* fairly wide, 0·11 mm. at the posterior extremity (Pl. 16, fig. 9). *Selvage* well-developed, subperipheral in the left valve but almost at the outer third in the right valve. A deep *flange groove*, better developed at the venter, lies between the selvage and flange in the right valve. *Radial pore canals* fairly numerous, simple, almost straight, few occurring in groups of two or three. *Inner margin* and *line* of *concrescence* coincide. *Muscle scars* (best seen in weathered specimens from the outside) are in an almost vertical column of four adductors and two more or less rounded frontal scars. Hinge holamphidont:

Element	Left valve	Right valve
Anterior	Deep, almost rounded socket bounded on all sides.	Highly projecting pessular tooth.
Anteromedian	Projecting subconical tooth.	Socket opening into posteromedian groove.
Posteromedian	Slightly projecting denticulate ridge (denticles are seen only in nicely preserved specimens).	Locellate groove.
Posterior	Deep elongate socket unbounded on venter.	Large subpessular tooth, less high on anterior.

DIMENSIONS (mm).

		L	H	W
Io. 4328	Carapace male (holotype)	0·85	0·50	0·45
Io. 3134	Carapace female	0·83	0·51	0·48
Io. 3133	Left valve female	0·84	0·54	—
Io. 4277	Right valve female	0·83	0·50	—

COMPARISON. *Echinocythereis* (*Scelidocythereis*) *sparsa* sp. nov. is smaller than the present species, has a different lateral outline, distinct marginal rims and scattered tubercles as surface ornamentation. In addition to this, it has an indistinct rather than prominent subcentral-tubercle.

REMARKS. This species occurs in the Upper Chocolate Clays of the Zao River and Rakhi Nala sections. It has a short vertical range and hence can be used as an index marker.

Echinocythereis (Scelidocythereis) **sp.A**

(Plate 17, figs. 3, 4, 8, 9)

FIGURED SPECIMEN. Io. 3129.

MATERIAL. Two specimens from the locality and horizon below.

LOCALITY. Sor Range section.

HORIZON. Upper Palaeocene, sample no. 460-i.

DESCRIPTION. *Carapace* short, subquadrate in lateral view. Dorsal margin slightly irregular due to surface ornamentation, ventral margin almost straight, anterior broadly and evenly rounded, posterodorsal margin straight, posterior extremity somewhat rounded, posteroventral margin curved. Greatest length lies below mid-point, greatest height in the anterior third and greatest width behind the middle. Anterior and posterior cardinal angles well-developed. Valves almost equal. *Eye-tubercle* rounded, polished and distinct. *Subcentral-tubercle* present but not well-developed. Surface reticulate with superimposed papillae. A weak ventral ridge at some distance from the ventral margin slopes obliquely upwards towards the posterior end. The posterodorsal process is a short horn-like ridge slightly anterior to the posterior cardinal angle. A marginal rim runs along anterior, venter and posterior margins.

DIMENSIONS (mm).

		L	H	W
Io. 3129	Carapace	0·59	0·39	0·34

COMPARISON. This species has already been compared with *Echinocythereis* (*Echinocythereis*) *contexta* sp. nov.

Echinocythereis (Scelidocythereis) rasilis sp. nov.

(Plate 17, figs. 5, 6, 10 ; Plate 18, figs. 1–3, 5, 7)

DERIVATION OF NAME. Latin *rasilis*, smoothed ; with reference to the carapace.

DIAGNOSIS. Carapace subreniform. Dorsal margin arched with a slight concavity behind the protruding anterior cardinal angle. Surface smooth with two ventral ridges.

HOLOTYPE. Io. 4329, a female carapace (Pl. 17, figs. 6 ; Pl. 18, figs. 2, 3).

PARATYPES. Io. 4278 + Io. 3131–2.

MATERIAL. 17 specimens from the Rakhi Nala section from three horizons (sample nos. 3499, 3614 and 3617). 41 specimens from the Zao River section from seven horizons (sample nos. 24145, 24147, 24148, 24150, 24152 and 24157). GSP BM 2537–8.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Lower Chocolate Clays, sample no. 3499.

DESCRIPTION. *Carapace* subreniform in lateral outline, with the greatest height at the anterior cardinal angle. Dorsal margin arched with a slight concavity behind the anterior cardinal angle, ventral margin incurved anterior of the middle, particularly in the right valve ; anterior margin broadly rounded, posterodorsal slope very slightly concave, posterior extremity rounded, posteroventral margin curved or straight. In dorsal view the greatest width lies almost at the middle. Anterior and posterior marginal areas compressed. Anterior cardinal angle protruding, Right valve over-reaches left valve along the anterior and posteroventral margins. Left valve over-reaches right valve slightly in the regions of the anterior cardinal angle and posterodorsal slope. Surface smooth. There are two ventral ridges, the one nearest the ventral margin being smaller. *Eye-tubercle* more or less distinct and situated below the anterior cardinal angle. Anterior margin finely denticulate (20–25 small denticles), posterior with 6–8 larger denticles. *Duplicature* fairly wide, 0·073 mm. anteriorly. In the right valve the *selvage* and *flange groove* are well-developed particularly in the anteroventral and ventral regions. In the left valve the *selvage* is well-marked but the *flange groove* is somewhat less well-developed. *Radial pore canals* not clearly visible but would seem to be simple, straight and numerous. No *vestibule*. *Hinge* not determinable.

DIMENSIONS (mm).

		L	H	W
Io. 4278	Carapace male	0·59	0·46	0·37
Io. 4329	Carapace female (holotype)	0·56	0·45	0·37
Io. 3131	Carapace male	0·76	0·49	0·37
Io. 3132	Carapace female	0·78	0·49	0·42

COMPARISON. *Hemicythere sahnii* Tewari and Tandon (1960) appears to be a closely related species. Specimens of this were not available for comparison but from the description and figures given by these authors it does not seem to have the concavity behind the anterior cardinal angle which is present in *E*(*S*.) *rasilis*, sp. nov.

REMARKS. The marginal denticles are not preserved in all specimens.

Echinocythereis (Scelidocythereis) sparsa sp. nov.

(Plate 18, figs. 4, 6, 8, 9)

DERIVATION OF NAME. Latin *sparsus*, scattered ; with reference to the papillae.

DIAGNOSIS. A species of *Scelidocythereis* with subrectangular carapace, dorsal margin slightly arched, ventral margin incurved in front of the middle. Surface ornamented with scattered papillae and two ventral ridges. Anterior and posterior marginal rims distinct. Left valve larger than right.

HOLOTYPE. Io. 4330, a female carapace (Pl. 18, figs. 8, 9).

PARATYPE. Io. 4279.

MATERIAL. 43 specimens from the locality below from three horizons (sample nos. 24159, 24181, and 24183). GSP BM 2539–40.

TYPE LOCALITY. Zao River section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 24159.

DESCRIPTION. Sexual dimorphy moderate, the males are longer in proportion than the females. *Carapace* subrectangular in side view with greatest height at the anterior cardinal angle. Dorsal margin slightly arched, ventral margin sinuated anterior to the middle. Anterior margin broadly rounded, posterior somewhat rounded. Right valve larger than left valve, which it over-reaches along the anterior and ventral margin. Anterior cardinal angle rounded. *Subcentral-tubercle* indistinct, *eye-tubercle* rounded and distinct. Surface ornamentation consists of sparsely distributed papillae. There are two ventral ridges ; the top ridge bifurcates posteriorly but the bottom ridge is shorter. Anterior and posterior marginal rim fairly well-developed. Anterior margin ornamented with small and numerous denticles, posterior with 6–8 larger denticles. *Duplicature* moderately wide with a prominent *selvage* and *flange-groove* in the right valve particularly in the ventral and anteroventral regions. *Radial pore canals* simple, almost straight, irregularly spaced, 25–30 anteriorly and 12–15 posteriorly. *Hinge* holamphidont : right valve with anterior tooth—conical and projecting, followed by postjacent socket, shallow posteromedian groove and posterior reniform tooth. *Muscle scar* pattern consists of four adductors in a vertical superposition and two more or less rounded frontal scars.

DIMENSIONS (mm).

		L	H	W
Io. 4279	Carapace male	0·78	0·45	0·37
Io. 4330	Carapace female (holotype)	0·76	0·49	0·39

COMPARISON. *Echinocythereis* (*Scelidocythereis*) *rasilia* sp. nov. although smaller than the present species may be ancestral but has a smooth rather than a papillose surface. Moreover, it has a concavity behind the anterior cardinal angle and lacks the distinct marginal rims.

REMARKS. *Echinocythereis* (*Scelidocythereis*) *sparsa* has so far only been found in the Upper Chocolate Clays of the Zao River area.

Genus ***GYROCYTHERE*** nov.

DERIVATION OF NAME. Greek *gyros*, circle ; with reference to the concentric arrangement of the ornamentation + *cythere*.

DIAGNOSIS. Reticulate Trachyleberididae with three or four longitudinal ridges, the dorsal ridge distinct from the eye-tubercle, arcuate, sloping down towards anterior and terminating below the eye-tubercle ; the third ridge more or less distinct in different species.

TYPE SPECIES. *Gyrocythere exaggerata* sp. nov.

DESCRIPTION. Sexual dimorphism rather pronounced ; the females are shorter, higher and wider than the males. Carapace subrectangular to subquadrate in lateral view. Valves almost equal. Eye-tubercle and subcentral tubercle present, more or less pronounced. Surface reticulate. Three to four longitudinal ridges present ; the dorsal ridge commences anteriorly below the eye-tubercle and is arched convexly upwards ; the second ridge stretches backwards from the subcentral-tubercle and is also arched convexly upwards, its continuation in front of the subcentral-tubercle being less pronounced ; the third ridge situated below the subcentral-tubercle slopes obliquely upwards towards the posterior and is curved convexly downward towards the anterior and the ventral ridge is confined to the posterior two-thirds of the carapace and culminates in a slight alar expansion in the posterior, almost obsolete or absent in some species. Normal pores simple, fairly numerous. Radial pore canals simple, irregularly spaced, more or less straight, a few seem to bifurcate, approximately 25 anteriorly. Inner margin and line of concrescence coincide. Duplicature moderately wide. Selvage well-marked, submarginal in left valve but at some distance from the outer margin in right valve. Ventral and anterior flange grooves well-developed in right valve. Hinge holamphidont with stirpate anterior tooth in right valve. Muscle scar pattern consists of four adductor scars in an almost vertical row and a U-shaped frontal scar, which opens to the anterodorsal angle.

COMPARISON. This genus differs from the genus *Costa* in having an arcuate dorsal ridge and in the less evident anterior marginal rim. Further, the subcentral-tubercle in *Costa* lies more towards the anterior. *Hermanites* has only two longitudinal ridges and has a concave posterodorsal slope. *Gyrocythere* lacks the very wide duplicature seen in *Paracytheretta.*

Gyrocythere exaggerata sp. nov.

(Plate 18, figs. 10–14 ; Plate 19, Plate 20, fig. 5)

DERIVATION OF NAME. Latin *exaggeratus*, exaggerated ; with reference to the well-developed longitudinal ridges.

DIAGNOSIS. A species of the genus *Gyrocythere* with prominent eye-tubercle, bilobate subcentral-tubercle and well-developed longitudinal ridges.

HOLOTYPE. Io. 4331, a female carapace (Pl. 19, figs. 1–4).

PARATYPES. Io. 4280 + 3122–3128

MATERIAL. 39 specimens from the Zao River section from six horizons (sample nos. 24145, 24147, 24148, 24150 24152). Eight specimens from the Rakhi Nala section from two horizons (sample nos. 3613 and 3614). GSP BM 2541–2.

TYPE LOCALITY. Zao River section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 24151.

DESCRIPTION. *Carapace* subrectangular in the male dimorph and subquadrate in the female. Anterior margin broadly and evenly rounded, posterior narrow, almost rounded in left valve but slightly subangular in the right valve. Dorsal and ventral margins almost concealed in lateral outline by the dorsal and ventral ridges. Greatest height in the ocular region, greatest length passes through the mid-point. Anterior cardinal angle prominent with a concavity behind in lateral view. Valves almost equal. *Eye-tubercle* prominent, rounded and polished, stands out in lateral view. *Subcentral-tubercle* distinct and bilobate. Surface coarsely reticulate. Reticulae are slightly papillose in some specimens. There are four well-developed longitudinal ridges ; the dorsal ridge begins below the eye-tubercle anteriorly and is convex upwards, whilst the median or second ridge runs from the subcentral-tubercle posteriorly and is convex upwards, its extension anterior to the subcentral-tubercle is less well-marked. A third ridge is intercalated between the median and the ventral ridges. It slopes obliquely upwards towards the posterior and is convex downwards in its anterior part. The ventral ridge is restricted to the posterior two-thirds of the carapace. It ends in a slight alar expansion in the posterior third of the carapace. Anterior margin denticulate, posteroventral margin with short spines present in some specimens. *Normal pore canals* simple, numerous (Pl. 19, figs. 6, 7). *Radial pore canals* not very well-displayed due to the form of preservation, but appear to be simple, almost straight, irregularly spaced (few seem to bifurcate), with some 25 at the anterior margin. *Line of concrescence* and *inner margin* coincide. *Duplicature* of moderate width, 0·07 mm. anteriorly. *Selvage* pronounced in both valves ; it is in the outer third of the duplicature in right valve but submarginal in left valve. Right valve with well-developed *flange groove*, particularly on the venter. *Muscle scars* are in a vertical row of four adductors and a U-shaped frontal scar opening towards the anterodorsal corner. *Hinge* holamphidont:

Element	Left valve	Right valve
Anterior	Rounded socket, confluent with ocular sinus, seen in a few specimens.	Projecting stirpate tooth.
Anteromedian	Subconical tooth which has straight anterior but convex posterior in dorsal view.	Deep rounded socket opening into posteromedian groove.
Posteromedian	Denticulate bar.	Locellate groove.
Posterior	Deep, slightly elongate socket.	Pessular tooth, but subrectangular in lateral view.

DIMENSIONS (mm).

		L	H	W
Io. 3125	Left valve male	0·81	0·49	—
Io. 3127	Right valve male	0·83	0·49	—
Io. 4331	Carapace female (holotype)	0·78	0·49	0·46
Io. 3126	Left valve male	0·76	0·46	—
Io. 3124	Right valve female	0·71	0·44	—
Io. 3128	Right valve female	0·71	0·44	—
Io. 4280	Left valve male	0·77	0·46	—
Io. 3120	Right valve female	0·72	0·44	—
Io. 3122	Right valve male	0·79	0·44	—

COMPARISON. This species resembles *Gyrocythere perfecta* sp. nov. (Pl. 22, figs. 1–10) but differs from it in being larger and having more prominent longitudinal ridges and an eye-tubercle. Moreover, the subcentral tubercle in *G. exaggerata* is distinctly bilobate.

REMARKS. The occurrence of this species ranges through 390 ft. in the Zao River section and 15 ft. in the Rakhi Nala section. It seems likely that it will prove a useful horizon marker.

Gyrocythere parvicarinata sp. nov.

(Plate 20, figs. 1–4, 6–8, 12)

DERIVATION OF NAME. Latin *parvus*, little + *carinatus*, ridged; with reference to the longitudinal ridges.

DIAGNOSIS. A strongly reticulate species of the genus *Gyrocythere* with three longitudinal ridges, median ridge ill-defined, posterior subtriangular, eye-tubercle distinct, subcentral-tubercle well-developed.

HOLOTYPE. Io. 4334, a male carapace (Pl. 20, figs. 1, 2, 6, 7).

PARATYPE. Io. 4281.

MATERIAL. Over 100 specimens from the Rakhi Nala section from 25 horizons (sample nos. 3153, 3168 to 3172, 3179, 3180, 3185, 3192, 3193, 3199, 3200, 3401 to 3405, 3407, 3409, 3410, 3415 and 3417). GSP BM 2543–4.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Green and Nodular Shales, sample no. 3407.

DESCRIPTION. Sexual dimorphism distinct ; the males are more elongate than the females. *Carapace* subrectangular in side view. Anterior margin broadly rounded, posterior subtriangular. Dorsal margin straight but appears slightly convex in lateral view due to the over-reaching of the dorsal ridge, ventral margin slightly concave in front of the middle. Anterior cardinal angle distinct with a concavity behind in lateral view. Left valve slightly over-reaches right valve at anterior cardinal angle and posterodorsal slope. In dorsal view the greatest width lies in the anterior two-fifths. *Subcentral-tubercle* well developed. *Eye-tubercle* distinct. Surface strongly reticulate with three longitudinal ridges ; the dorsal ridge is curved convexly upwards ; the median ridge is more or less ill-defined in many specimens ; the third or ventral ridge is curved convexly downward anteriorly. Anterior and posterior marginal rims present but not high. Both anterior and posterior margins are denticulate. *Duplicature* of medium width. *Selvage* distinct and at some distance from the outer margin in right valve. Anterior and ventral *flange grooves* well-developed in right valve. *Radial pore canals* not clearly seen due to mineralization. *Hinge* as for the genus.

DIMENSIONS (mm).

		L	H	W
Io. 4334	Carapace male (holotype)	0·68	0·37	0·34
Io. 4281	Carapace female	0·67	0·42	0·37

COMPARISON. This species is smaller than *Gyrocythere grandilaevis* sp. nov. Although the longitudinal ridges are no better developed than *G. grandilaevis* the eye-tubercle and subcentral-tubercle are more prominent, the reticulation is deeper and wider in proportion.

Gyrocythere grandilaevis sp. nov.

(Plate 20, figs. 9–11, 13 ; Plate 21, figs. 1–4)

DERIVATION OF NAME. Latin *grandis*, large + *laevis*, smooth ; with reference to the carapace.

DIAGNOSIS. A species of *Gyrocythere* with large, reticulate, smooth carapace. Three longitudinal ridges, including median ridge which is not well-developed. Anterior and posterior marginal rims distinct.

HOLOTYPE. Io. 4332, a female carapace (Pl. 20, figs. 11, 13 ; Pl. 21, figs. 3, 4).

PARATYPE. Io. 4282.

MATERIAL. 16 specimens from the locality below from four horizons (sample nos. 3463 to 3466). Two specimens from the Shpalai Khwara section from one horizon (sample no. 24692). GSP BM 2545–6.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Shales with Alabaster, sample no. 3463.

DESCRIPTION. Sexual dimorphism moderate ; the males are proportionally longer than the females. *Carapace* subrectangular in lateral outline. Anterior margin broadly rounded, posterior margin almost rounded in left valve but with a slight concavity in the posterodorsal slope of the right valve. Dorsal margin almost straight but appears slightly convex in lateral view due to the dorsal ridge, which slightly over-reaches it ; ventral margin slightly concave in front of the middle. Valves almost equal. *Subcentral-tubercle* and *eye-tubercle* present but not pronounced. Surface reticulate ; the reticulae concentrically arranged around the subcentral-tubercle. There are three longitudinal ridges, a dorsal ridge curved convexly upward, a median or second less well-developed ridge and a ventral or third ridge which runs obliquely from above the anteroventral corner towards the posterior and is curved convexly downward in its anterior portion. Anterior and posterior marginal rims distinct. Anterior and posterior margins denticulate. Internal features not seen.

DIMENSIONS (mm).

		L	H	W
Io. 4332	Carapace male (holotype)	0·85	0·46	0·44
Io. 4282	Carapace female	0·83	0·46	0·46

COMPARISON. This species resembles *Gyrocythere parvicarinata* sp. nov. but differs from it in being larger. Moreover, the posterior in *G. parvicarinata* is subacuminate. *G. grandilaevis* is perhaps ancestral to *Gyrocythere perfecta* sp. nov. which is smaller and has stronger ornamentation.

Gyrocythere mitigata sp. nov.

(Plate 21, figs. 5–11)

DERIVATION OF NAME. Latin *mitigatus*, mellowed ; with reference to the ornamentation, less emphatic than in the typical species of *G. exaggerata.*

DIAGNOSIS. A large, strongly reticulate species of the genus *Gyrocythere* with three longitudinal ridges, the median ridge almost ill-defined.

HOLOTYPE. Io. 4333, a male carapace (P. 21, figs. 5–8).

PARATYPES. Io. 4283 + Io. 3119.

MATERIAL. 9 specimens from the locality below from two horizons (sample nos. 24131 and 24132). Io. 4283. GSP BM 2547–8.

TYPE LOCALITY. Zao River section.

TYPE HORIZON. Lower Chocolate Clays, sample no. 24131.

DESCRIPTION. Sexually dimorphic ; the males are longer than the females. *Carapace* subrectangular in lateral view. Anterior margin broadly and evenly rounded, dorsal margin almost straight in reality but appears slightly convex in lateral view because of the over-reaching of the dorsal ridge ; posterodorsal slope very slightly concave particularly in the right valve, posterior extremity rounded, posteroventral margin curved, ventral margin almost straight. Greatest height in the anterior quarter, greatest length almost in the middle. Anterior and posterior cardinal angles well-marked, particularly in left valve. Left valve slightly overreaches the right valve in the anterodorsal corner and at the posterodorsal slope. Greatest width in dorsal or ventral view lies in the posterior third. *Subcentral-tubercle* prominent, *eye-tubercle* rounded and distinct. Surface strongly reticulate with three longitudinal ridges : the dorsal ridge is curved convexly upwards in the middle and starts anteriorly below the eye-tubercle ; the median ridge is less well-developed, almost ill-defined in most specimens ; it runs posteriorly from the subcentral-tubercle and is curved convexly upwards. The ventral ridge commences anteriorly above the anteroventral corner and runs obliquely upwards towards the posterior and culminates in the posterior third. Marginal rim is distinct at the anterior and posterior but less distinct along the venter. Anterior margin denticulate, posterior extremity and posteroventral margin ornamented with about six short spines or papillae. *Duplicature* of moderate width. *Selvage* well-developed, subperipheral in the left valve but situated at some distance from the outer margin in the right valve. The right valve has a fairly deep *flange groove* along the venter and around the anterior margin. *Hinge* as for the genus.

DIMENSIONS (mm).

		L	H	W
Io. 4333	Carapace male (holotype)	0·88	0·49	0·49
Io. 4283	Carapace female	0·83	0·49	—
Io. 3119	Left valve female	0·80	0·47	—

COMPARISON. *Gyrocythere grandilaevis* sp. nov. is somewhat similar to the present species and might even be ancestral although *G. grandilaevis* is smaller and has a less well-developed subcentral-tubercle. The dorsal and ventral ridges in *G. grandilaevis* are also less well-marked. *G. mitigata* differs from *Gyrocythere exaggerata* sp. nov. in being larger, having a different lateral outline and less emphatic ornamentation. Further, *G. mitigata* has three, rather than four longitudinal ridges and lacks a bilobate subcentral-tubercle.

REMARKS. *G. mitigata* has so far only been found in the Zao River section, where it occurs at two horizons.

Gyrocythere perfecta sp. nov.

(Plate 22, figs. 1–10)

DERIVATION OF NAME. Latin *perfectus*, perfect ; with reference to the beauty of the material.

DIAGNOSIS. *Gyrocythere* with strongly reticulate, concentrically arranged ornamentation. Eye-tubercle, subcentral-tubercle and longitudinal ridges distinct.

HOLOTYPE. Io. 4335, a female carapace (Pl 22, figs. 3, 4, 7, 8).

PARATYPES. Io. 4284 + Io. 3120–1.

MATERIAL. 20 specimens from the locality below from two horizons (sample nos. 3498 and 3499). GSP BM 2548–50.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Lower Chocolate Clays, sample no. 3499.

DESCRIPTION. *Carapace* subrectangular in lateral view, arrow-shaped in ventral view. Sexual dimorphism rather pronounced ; the females are higher and wider than the males. Anterior margin broadly rounded, posterior slightly subangular, particularly in the right valve. Dorsal margin straight but appears to be convex due to the over-reaching of the dorsal ridge ; ventral margin slightly concave anterior to the middle. Anterior cardinal angle distinct and rounded. Valves almost equal. *Eye-tubercle* distinct but not high. *Subcentral-tubercle* distinct, slightly lobate. Surface strongly and deeply reticulate, the reticulation being concentric around the subcentral-tubercle. Four longitudinal ridges occur : the dorsal ridge is convex upwards ; it commences below the eye-tubercle and culminates in the posterodorsal region ; the median or second ridge is also convex upwards ; it runs from the subcentral-tubercle towards the posterior but its continuation anterior to the subcentral-tubercle is not distinct ; the third ridge is convex downwards in its anterior half and slopes obliquely upwards towards the posterior ; the ventral ridge is better seen in ventral view ; it is confined in the posterior three-quarters. Anterior margin denticulate. There is a short posteroventral spine present in most specimens. *Radial pore canals* simple, more or less straight, irregularly spaced, few seem to bifurcate, about 25–28 in the anterior. *Inner margin* and *line of concrescence* coincide throughout. *Duplicature* moderately wide with a distinct *selvage.* In the right valve the selvage lies at some distance from the outer margin and the anterior and ventral flange grooves are distinct. *Adductor scars* in a vertical column of four and with a U-shaped frontal scar. *Hinge* holamphidont.

DIMENSIONS (mm).

		L	H	W
Io. 4281	Carapace male	0·71	0·39	0·38
Io. 4335	Carapace female (holotype)	0·71	0·42	0·42
Io. 3121	Right valve male	0·76	0·42	0·42
Io. 3121	Right valve female	0·76	0·42	—
Io. 3120	Right valve female	0·76	0·44	—

COMPARISON. The present species is similar in all characters to *Gyrocythere exaggerata* sp. nov. but is smaller and with a less well-marked ornamentation. On the other hand, the ornamentation is stronger than in *Gyrocythere grandilaevis* sp. nov. In both the morphological development and stratigraphical position, *G. perfecta* falls between *G. grandilaevis* and *G. exaggerata.*

REMARKS. *G. perfecta* has so far only been found in the type locality.

Genus ***HERMANITES*** Puri 1955

TYPE SPECIES. *Hermania reticulata* Puri 1954.

Hermanites cracens sp. nov.

(Plate 22, figs. 11 ; Plate 23, figs. 1–3)

DERIVATION OF NAME. Latin *cracens*, graceful ; with reference to the pleasing curve of the ridges.

DIAGNOSIS. A large *Hermanites* with well-developed slightly curved dorsal and ventral ridges. Subcentral-tubercle prominent with three small curved longitudinal ridges behind.

HOLOTYPE. Io. 4336, a carapace.

MATERIAL. Only one specimen from the locality and horizon below.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Gorge Beds, sample no. 3111.

DESCRIPTION. *Carapace* large, massive, subrectangular in lateral view. Greatest length through the mid-point, greatest height through the anterior cardinal angle and greatest width in the posterior third. Dorsal and ventral margins almost straight, anterior broadly and evenly rounded, posterodorsal margin very slightly concave, posteroventral margin and posterior extremity rounded. Anterior cardinal angle well-developed particularly in the left valve. Left valve slightly over-reaches the right at the anterior cardinal angle and posterodorsal slope. *Subcentral tubercle* prominent. *Eye-tubercle* rounded and distinct and with a rounded groove in front, particularly in the left valve. Marginal rim high in the anterior but somewhat less high in the posterior and venter. Surface coarsely reticulate with well-marked, dorsal and ventral ridges ; the dorsal ridge commences above the subcentral-tubercle and is slightly curved convexly upwards ; the ventral ridge slopes obliquely upward towards posterior and then curves sharply round towards posteroventral margin in posterior quarter. There are three short curved longitudinal ridges behind the subcentral-tubercle, the bottom one being the shortest. Anterior and posterior margins spinose—anterior with numerous small spines but posterior with few larger spines.

DIMENSIONS (mm).

		L	H	W
Io. 4336	Carapace	0·95	0·51	0·51

COMPARISON. *Hermanites palmatus* sp. nov. is much smaller, has the dorsal and ventral ridges joined posteriorly by a transverse ridge and the ridges in front of the subcentral-tubercle have a palmate appearance.

REMARKS. So far only one specimen of this species has been recovered from the Gorge Beds of the Rakhi Nala section, where it occurs in association with *Alocopocythere rupina* sp. nov. and *Buntonia devexa* sp. nov.

Hermanites scopus sp. nov.

(Plate 23, figs. 4–10)

DERIVATION OF NAME. Latin *scopus*, target ; in allusion to the fancied resemblance of the ornamentation to a bull's-eye.

DIAGNOSIS. A species of the genus *Hermanites* in which ventral ridge curves downward in the middle and is joined by a short vertical ridge at its posterior end ; surface coarsely reticulate with prominent subcentral-tubercle from which a ridge runs towards anterior margin.

HOLOTYPE. Io. 4338, a male carapace (Pl. 23, figs. 4–7).

PARATYPE. Io. 4285.

MATERIAL. 13 specimens from the Rakhi Nala section from six horizons (sample nos. 3499, 3610, 3613 to 3615 and 3618). Two specimens (including holotype) from the Zao River section from two horizons (sample nos. 24148 and 24150). GSP BM 2552–3.

TYPE LOCALITY. Zao River section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 24148.

DESCRIPTION. Sexual dimorphy observed ; the males are longer in proportion than the females. *Carapace* thick-shelled, sub-rectangular in lateral view. Anterior margin broadly and evenly rounded, posterior slightly subtriangular. Dorsal and ventral margins almost straight. Valves more or less equal. Anterior cardinal angle well-developed. In dorsal view, greatest width lies in the posterior third. *Eye-tubercle* rounded and prominent with rounded deep groove in front (better seen in dorsal view). *Subcentral-tubercle* prominent with a ridge running towards the anterior margin. Surface strongly reticulate (occasionally with superimposed rounded spines particularly at the junction where two reticulae meet). Dorsal and ventral ridges well-developed : the dorsal ridge is almost straight while the ventral ridge is curved convexly downward in the middle culminating in a short vertical ridge in the posterior third. Anterior and posterior marginal rims elevated, ventral marginal rim somewhat less elevated. Anterior and posterior margins ornamented with double row of spines (not preserved in all specimens)—one row of spines lies on the anterior and posterior marginal rims and the second row below these rims. *Duplicature* of moderate width with subperipheral selvage. *Radial pore canals* and *muscle scars* not known. *Hinge* holamphidont : left valve hinge consists of two terminal sockets, median element subdivided into anteromedian subconical projecting tooth and denticulate bar ; right valve hinge (seen only in a broken valve) consists of a stirpate, projecting anterior tooth, deep anteromedian socket, locellate posteromedian groove and posterior tooth (broken).

DIMENSIONS (mm).

		L	H	W
Io. 4338	Carapace male (holotype)	0·78	0·44	0·44
Io. 4285	Carapace female	0·81	0·46	0·49

COMPARISON. This species shows some resemblance to *Hermanites cracens* sp. nov. but is smaller, has a more curved ventral ridge culminating in a short vertical ridge in the posterior third and lacks the three small, curved longitudinal ridges behind the subcentral-tubercle.

REMARKS. *Hermanites scopus* rarely occurs in the Lower and Upper Chocolate Clays of the Rakhi Nala and Zao River sections and can easily be recognized by its characteristic ventral ridge.

Hermanites palmatus sp. nov.

(Plate 24, figs. 1–9, 11, 12)

DERIVATION OF NAME. Latin *palmatus*, palmate ; with reference to the palmate appearance of the ridges in front of the subcentral-tubercle.

DIAGNOSIS. *Hermanites* in which dorsal and ventral ridges are alate and joined posteriorly by a transverse ridge which is slightly concave towards posterior. Subcentral-tubercle prominent with palmate appearance of ridges in front.

HOLOTYPE. Io. 4337, a female left valve (Pl. 24, figs. 6, 8, 9, 11).

PARATYPES. Io. 4286 + Io. 3117–8.

MATERIAL. 9 specimens from the Rakhi Nala section from five horizons (sample nos. 3613 to 3615, 3617 and 3618). 17 specimens from the Zao River section from four horizons (sample nos. 24131, 24150, 24152 and 24156). GSP BM 2554–5.

TYPE LOCALITY. Zao River section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 24152.

DESCRIPTION. Sexual dimorphism apparent ; the females being shorter than the males. *Carapace* subrectangular in lateral outline with greatest height in the region of the anterior cardinal angle. Dorsal and ventral margins almost straight, anterior margin broadly rounded, posterodorsal corner very slightly concave, posterior extremity and posteroventral margin rounded. Valves almost equal. *Subcentral-tubercle* prominent. *Eye-tubercle* rounded and distinct. Surface recticulate with alate dorsal and ventral ridges which are joined posteriorly by a transverse ridge which is slightly concave towards the posterior. Anterior and posterior marginal platforms compressed. Anterior and posterior marginal rims distinct. Anterior margin ornamented with 20–25 small spines, posterior with 6–8 larger spines. *Duplicature* of moderate width, 0·050 mm. anteriorly. Both valves have a distinct *selvage*. *Hinge* holamphidont : left valve hinge with fairly deep anterior socket, anteromedian tooth rounded, subconical (slightly projecting towards the anterior in dorsal view), posteromedian ridge denticulate and deep, slightly elongate posterior socket ; right valve hinge with anterior subconical, projecting tooth followed by deep postjacent socket, posteromedian shallow groove and an almost rounded, posterior tooth.

DIMENSIONS (mm).

		L	H	W
Io. 4286	Carapace male	0·69	0·37	0·37
Io. 3117	Carapace female	0·63	0·37	0·37
Io. 4337	Left valve female (holotype)	0·73	0·40	—
Io. 3118	Left valve female	0·73	0·44	—

COMPARISON. *Hermanites scopus* sp. nov. is larger, has a curved ventral ridge and subtriangular posterior margin. *Hermanites indicus* Tewari and Tandon (1960) has a subtriangular posterior end and lacks the transverse ridge which posteriorly joins the dorsal and ventral ridges. The Miocene species *Hermanites purii* Tewari and Tandon (1960) has somewhat similar lateral outline, but lacks both the transverse ridge which posteriorly joins the dorsal and ventral ridges and the palmate appearance of ridges in front of the subcentral-tubercle. Moreover, the greatest width in *Hermanites palmatus* is in the posterior third, but in *Hermanites purii* it is a little to the anterior of the middle (see Tewari and Tandon, p. 158).

REMARKS. The true relationship of the present species with *Hermanites indicus* and *Hermanites purii* cannot be determined until topotype material from Kutch is available for comparison.

Genus ***OCCULTOCYTHEREIS*** Howe 1951

TYPE SPECIES. *Occultocythereis delumbata* Howe 1951.

Occultocythereis interrupta sp. nov.

(Plate 24, figs. 10, 13–18)

DERIVATION OF NAME. Latin *interruptus*, broken apart ; with reference to the break in the dorsal ridge.

DIAGNOSIS. A small *Occultocythereis* with well-marked subangular posterodorsal process which is confluent with four ridges including an oblique ridge running towards posteroventral region and then extending towards anteroventral corner as an oblique ventral ridge.

HOLOTYPE. Io 4339, a female carapace (Pl. 24, figs. 14, 17, 18).

PARATYPE. Io. 4287.

MATERIAL. 28 specimens from the locality below from three horizons (sample nos. 460-f, 460-i and 460-j). GSP BM 2556–7.

TYPE LOCALITY. Sor Range section.

TYPE HORIZON. Upper Palaeocene, sample no. 460-i.

DESCRIPTION. Sexual dimorphism marked ; the females are shorter and wider than the males. *Carapace* subrectangular in side view, tapering towards the posterior. Dorsal and ventral margins almost straight ; the dorsal margin appears slightly irregular in lateral outline because of the over-reaching of the dorsal ridge ; anterior margin broadly and obliquely rounded, posterior narrow, slightly concave in posterodorsal slope but more or less rounded in posteroventral margin. Greatest length lies through the mid-point and greatest height at the anterior cardinal angle. Anterior and posterior cardinal angles well-marked particularly in the right valve. Valves almost equal. *Eye-tubercle* distinct, situated on the anterior marginal rim. Shell surface undulating with compressed anterior and posterior platforms. A well-marked, subangular posterodorsal process is confluent with four ridges : (1) a short ridge extends vertically towards the posterodorsal corner ; (2) a dorsal ridge runs towards the anterior, culminating in the anterior third of the dorsal margin—it is slightly convex upwards ; (3) a short ridge extends vertically below, terminating before reaching the mid-line, whilst the fourth ridge runs obliquely towards the posteroventral region where it is joined by an oblique ventral ridge running towards the anteroventral corner. Anteromedian swelling well-developed. A marginal rim extends around the anterior, ventral and posterior margins, elevated on the anterior margin but less elevated around the venter and posterior. Small ridges run between the anterior marginal rim and the anterior margin (these are better seen in ventral view). Four to five short spines ornament the posteroventral margin. Internal details not known.

DIMENSIONS (mm.)

	L	H	W
Io. 4287 Carapace male	0·39	0·18	0·11
Io. 4339 Carapace female (holotype)	0·38	0·20	0·13

COMPARISON. *Occultocythereis indistincta* sp. nov. is much larger, has a continuous rather than a broken dorsal ridge and lacks the oblique posterior ridge which joins the posterodorsal process and the ventral ridge.

REMARKS. *O. interrupta* is so far only known from the Upper Palaeocene of the Sor Range section.

Occultocythereis Sp.A

(Plate 25, figs. 1, 2, 5, 12)

FIGURED SPECIMEN. Io. 3136.

MATERIAL. Only one specimen from the locality and horizon below.

LOCALITY. Rakhi Nala section.

HORIZON. Lower Rakhi Gaj Shales, sample no. 3672.

DESCRIPTION. *Carapace* subrectangular with ventral inflation. Dorsal and ventral margins almost straight, tapering towards the posterior ; anterior margin broadly and obliquely rounded, posterior narrowly rounded with a slight concavity in the posterodorsal corner. Greatest length runs through the middle, greatest height in the anterior two-fifths and greatest width in the posterior third. Anterior and posterior cardinal angles rounded. Valves almost equal. *Eye-tubercle* distinct but low. *Subcentral-tubercle* weak. Surface reticulate. Posterodorsal process consists of a more or less rounded tubercle which extends anteriorly in a weak dorsal ridge. Anterior marginal rim well-marked, ventral and posterior marginal rims less elevated. Posterior ornamented with 4–5 short spines.

DIMENSIONS (mm).

		L	H	W
Io. 3136	Carapace	0·42	0·22	0·17

REMARKS. This species differs from other known species of the genus *Occultocythereis* in its obliquely rounded anterior margin.

Occultocythereis spilota sp. nov.

(Plate 25, figs. 3, 4, 6–11)

DERIVATION OF NAME. Greek *spilotos*, spotted ; with reference to the largish puncta.

DIAGNOSIS. A species of *Occultocythereis* in which surface is ornamented with largish puncta. Posteroventral margin rounded, posteroventral process a short slightly oblique ridge well-developed in female, ill-defined in male, anteroventral swelling small.

HOLOTYPE. Io. 4342, a female carapace (Pl. 25, figs. 6, 7, 10, 11).

PARATYPE. Io. 4288.

MATERIAL. Four specimens from the locality below from three horizons (sample nos. 3173, 3174 and 3177). GSP BM 2558–9.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Green and Nodular Shales, sample no. 3177.

DESCRIPTION. Dimorphic ; the females are higher and wider than the males. *Carapace* subrectangular in lateral view with greatest length in the middle and greatest height in the anterior third. Anterior margin broadly rounded, posterodorsal slope very slightly concave, posteroventral margin rounded, dorsal and ventral margins almost straight, very slightly converging towards the posterior. Anterior cardinal angle rounded, posterior cardinal angle distinct about 110°. Valves almost equal. In dorsal view the greatest width lies in the posterior third. *Eye-tubercle* more or less distinct. *Subcentral-tubercle* present but not pronounced with a small swelling below and slightly anterior to it. Surface ornamented by large puncta. The posterodorsal process is a short projecting ridge extending vertically towards the mid-line but not reaching it. It extends anteriorly in a short dorsal ridge terminating in the anterior third of the dorsal margin. The posteroventral process is a short slightly oblique ridge lying in the posteroventral swelling. In the male dimorph the posteroventral swelling is less well-developed and the posteroventral ridge ill-defined. Anterior marginal rim prominent, ventral and posterior marginal rims less prominent. Anterior marginal area ornamented by numerous, short ridges lying between the rim and the margin. Posteroventral margin decorated by four to five short spines.

DIMENSIONS (mm).

		L	H	W
Io. 4288	Carapace male	0·38	0·21	0·13
Io. 4342	Carapace female (holotype)	0·38	0·22	0·16

COMPARISON. *Occultocythereis peristicta* sp. nov. Morphotype C is larger, has a vertical rather than an oblique posteroventral ridge joining the second posterior tubercle and the ventral ridge. Further, it lacks the dorsal ridge and the short ridges between the anterior rim and the anterior margin.

Occultocythereis peristicta sp. nov.

(Plate 25, figs. 13–17 ; Plate 26 ; Plate 27, figs. 1–2)

DERIVATION OF NAME. Greek *peristiktos*, punctate or dappled.

DIAGNOSIS. A punctate group of morphotypes of the genus *Occultocythereis* without a dorsal ridge, ventral ridge well-marked, anteromedian swelling distinct, posterodorsal tubercle present.

HOLOTYPE. Io. 4341, a female carapace (Pl. 25, figs. 15) ; (Pl. 26, figs. 2, 3).

PARATYPES. Io. 4289–93 + Io. 3137–40.

MATERIAL. Approximately 800 specimens from the Rakhi Nala section from 42 horizons (sample nos, 3160, 3163, 3167, 3170, 3171, 3173, 3174, 3177, 3179, 3180, 3186–3194, 3197 to 3200, 3401 to 3405, 3407, 3409, 3410, 3415, 3418 to 3423, 3428, 3432, 3434 and 3435). GSP BM 2560–65.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Upper Rakhi Gaj Shales, sample no. 3167.

DESCRIPTION. Sexual dimorphism rather pronounced, the males are longer in proportion than the females. *Carapace* subrectangular or wedge-shaped in lateral outline. Dorsal and ventral margins almost straight, tapering towards the posterior, anterior margin broadly and evenly rounded, posterior narrow, slightly subangular in the middle or almost rounded. Greatest length passes through the middle, greatest height lies at the anterior cardinal angle which is fairly well-developed. Left valve slightly over-reaches the right valve at the anterior cardinal angle and in the region of the posterodorsal slope. *Eye-tubercle* rounded and distinct, lying on the anterior marginal rim. Subcentral or anteromedian swelling distinct, either elongate or almost rounded (elongate in most morphotypes). There is no dorsal ridge. Ventral ridge fairly well-developed, short in most morphotypes, either almost straight or runs slightly obliquely towards the posterior end where it may be connected to the second posterior tubercle or to the posterodorsal tubercle by means of a short vertical ridge. A dorsal ridge runs between the second posterior tubercle and the anteromedian swelling in some morphotypes. Anterior marginal rim high, ventral marginal rim less distinct, posterior marginal rim distinct. Short spines decorate the anterior and posterior margins.

Trends of variants :—

1. Become sparsely punctate.
2. Gain second posterior tubercle, which may join either the posterodorsal tubercle or the ventral ridge.
3. Become wedge-shaped.

REMARKS. *O. peristicta* commonly occurs in the Upper Rakhi Gaj Shales, Green and Nodular Shales and Rubbly Limestones of the Rakhi Nala section.

This species may be divided into the following morphotypes :

MORPHOTYPE A

(Pl. 25, figs. 13–17 ; Pl. 25, figs. 1–3).

This has a well-delimited vertical posterodorsal tubercle. There is no second posterior tubercle. The anteromedian swelling is less well-developed. The ventral ridge is almost straight, short, confined in the mid-ventral region. The surface is densely punctate.

DIMENSIONS (mm).

		L	H	W
Io. 4292	Carapace male	0·43	0·22	0·11
Io. 4341	Carapace female (holotype)	0·42	0·23	0·16

MORPHOTYPE B

(Pl. 26, figs. 4–9)

This is close to Morphotype A but has a more sparsely punctate surface and a second posterior tubercle. In addition, the present morphotype has a well-developed, somewhat elongate anteromedian swelling.

DIMENSIONS (mm).

		L	H	W
Io. 4293	Carapace male	0·44	0·22	0·15
Io. 4291	Carapace female	0·40	0·22	0·16

MORPHOTYPE C

(Pl. 26, figs. 10–15)

This has a higher carapace than the other morphotypes. The ventral ridge runs slightly obliquely towards the posterior. It is joined posteriorly to the second posterior tubercle by a short vertical ridge. The anteromedian swelling and the second posterior tubercle form a broken diagonal ridge.

DIMENSIONS (mm).

		L	H	W
Io. 4289	Carapace male	0·45	0·26	0·17
Io. 4290	Carapace female	0·44	0·25	0·18

MORPHOTYPE D

(Pl. 27, figs. 1–6)

The carapace is much more elongate than Morphotype A, B, C and E. The dorsal and ventral margins taper very slightly towards the posterior. An oblique posterior ridge joins the posterodorsal tubercle, the second posterior tubercle and the posterior end of the ventral ridge. The ventral ridge commences above the anteroventral corner, slopes obliquely upwards towards the posterior and meets the oblique posterior ridge in the posterior quarter. A diagonal ridge which may or may not be continuous passes through the second posterior tubercle and the anteromedian swelling.

DIMENSIONS (mm).

		L	H	W
Io. 3146	Carapace male	0·51	0·24	0·16
Io. 3139	Carapace female	0·51	0·24	0·17

MORPHOTYPE E

(Pl. 27, figs. 7–12)

This is very similar to Morphotype B, but has a wedge-shaped carapace.

DIMENSIONS (mm).

		L	H	W
Io. 3137	Carapace male	0·39	0·20	0·13
Io. 3138	Carapace female	0·37	0·20	0·13

Occultocythereis indistincta sp. nov.

(Plate 27, figs. 13–15 ; Plate 28, figs. 1–4)

DERIVATION OF NAME. Latin *indistinctus*, dim or obscure ; named from the absence of well-marked diagnostic characters.

DIAGNOSIS. A species of the genus *Occultocythereis* with a well-developed dorsal ridge ending posteriorly in a large subangular posterodorsal process, ventral ridge oblique running from anteroventral corner towards posterior, surface ornamentation consists of indistinct puncta.

HOLOTYPE. Io. 4340, a female carapace (Pl. 27, figs. 15 ; Pl. 28, figs. 1, 3, 4).

PARATYPES. Io. 4294 + Io. 3135.

MATERIAL. 44 specimens from the locality below from seven horizons (sample nos. 3499, 3614, 3615, 3621, 3625, 3648 and 3649). GSP BM 2566–7.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Lower Chocolate Clays, sample no. 3499.

DESCRIPTION. Sexual dimorphism apparent ; the males are more elongate, less high and less wide than the females. *Carapace* subrectangular, slightly tapering towards the posterior. Dorsal margin straight but irregular in side view due to the over-reaching of the dorsal ridge, ventral margin almost straight, anterior margin broadly and evenly rounded, posterior narrow, subangular in the middle with slightly concave posterodorsal slope. Greatest length lies in the middle, greatest height in the anterior third. Anterior cardinal angle well-developed particularly in left valve, posterior cardinal angle rounded in the right valve but pointed in left valve. Left valve over-reaches right valve in the region of anterior cardinal angle and posterodorsal slope. *Eye-tubercle* distinct. Surface ornamented with small, indistinct puncta. Anteromedian swelling (which perhaps represents a subcentral-tubercle) distinct. A well-marked dorsal ridge commences behind the eye-tubercle and is slightly convex upward in the middle terminating in a large subangular posterodorsal process. In most specimens it is ornamented with three small tubercles which lie at some distance from one another. Ventral ridge runs obliquely from the anteroventral corner towards the posterior, culminating in the posterior third. (In some specimens it is not well-developed). A small tubercle is present in the posteromedian part of the carapace (halfway between the dorsal and ventral ridges) in a few specimens. A high marginal rim runs round the anterior extending along the venter and posterior as a less high rim. Anterior and posterior margins ornamented with short spines. *Duplicature* wide in anterior and posteroventral regions. *Selvage* distinct and lies at some distance from the outer margin. *Radial pore-canals* and *muscle scars* not determinable. *Hinge* as for the genus.

COMPARISON. *Occultocythereis mutabilis abducta* Triebel (1961) is very similar, but is larger, has a different posterior end, less well-developed subcentral-swelling and posterodorsal tubercle. *Occultocythereis mutabilis mutabilis* Tiebel (1961) has a vertical posteroventral ridge in the right valve of the male and in both valves of the females.

DIMENSIONS (mm).

		L	H	W
Io. 4294	Right valve male	0·47	0·24	—
Io. 3135	Carapace male	0·43	0·22	0·13
Io. 4340	Carapace female (holotype)	0·43	0·24	0·16

REMARKS. *O. indistincta* has so far been found in the Lower and Upper Chocolate Clays of the Rakhi Nala section.

Genus ***PATAGONACYTHERE*** Hartmann 1962

TYPE SPECIES. *Patagonacythere tricostata* Hartmann 1962.

REMARKS. The species here assigned with query to *Patagonacythere* differs in details of muscle scar pattern both from the type species described by Hartmann and from the two species described by Benson (1964) from the Antarctic. In common with the described species it shows the three longitudinal ridges in which a characteristic posterodorsal loop joins the upper two.

Patagonacythere ? nidulus sp. nov.

(Plate 28, figs. 5–12 ; Plate 29, figs. 1–4)

DERIVATION OF NAME. Latin *nidulus*, small bird's nest ; with reference to the reticulate complex of the subcentral node.

DIAGNOSIS. Carapace highly reticulate in which ventral ridge culminates abruptly in posterior third, subcentral-tubercle prominent.

HOLOTYPE. Io. 4349, a female carapace (Pl. 28, figs. 9–12).

PARATYPES. Io. 4295 + Io. 3096–8.

MATERIAL. Over 400 specimens from the Zao River section from 16 horizons (sample nos. 24155 to 24157, 24159, 24166, 24170, 24173, 24175 to 24178, 24180, 24183, 24185, 24187 and 24193). Approximately 60 specimens from the Rakhi Nala section from 13 horizons (sample nos. 3624, 3625, 3628, 3631, 3634, 3640 to 3642, 3645, 3646, 3649, 3658 and 3662). GSP BM 2568–9.

Type locality. Zao River section.

Type horizon. Upper Chocolate Clays, sample no. 24173.

Description. *Carapace* subrectangular in side view with dorsal and ventral margins almost straight, subparallel ; anterior broadly rounded, posterodorsal margin very slightly concave (particularly in the right valve), posterior extremity and posteroventral margin rounded. Anterior cardinal angle well-developed in both valves ; posterior cardinal angle in the left valve obtuse and well-marked but in the right valve it is not very well developed. Left valve over-reaches the right valve slightly at the anterior cardinal angle and at the posterodorsal slope, otherwise the two valves are equal in size. In the dorsal view the greatest width passes either through the subcentral-tubercle or through the posterior third with a sulcus in between. *Eye-tubercle* rounded, polished and distinct ; *subcentral-tubercle* prominent, composed of reticulate complex. Shell surface strongly reticulate with three longitudinal ridges : the ventral ridge slopes obliquely upward towards the posterior, ending abruptly just before reaching the compressed posterior platform; the median ridge springs from the subcentral node, stretching backward to join the ventral ridge and forms a posterodorsal loop. (In some specimens at certain horizons longitudinal ridges are not well-developed.) A marginal rim runs round the anterior, ventral and posterior margins—it is upraised around the anterior margin. Anterior margin ornamented with approximately 20 small spines, posterior margin with 6–8 spines. *Normal pore canals* fairly numerous (these become exaggerated in specimens cleaned in ultrasonic vibrator). *Radial pore canals* simple, nearly straight, irregularly spaced ; few cross one another. There are approximately 40 anterior radial pore canals and about 20 posterior canals. *Inner margin* and *line of concrescence* coincide. *Duplicature* of moderate width (0·073 mm. at anterior, 0·06 mm. at posterior extremity). *Selvage* prominent, submarginal in left valve, at some distance from the margin in the right valve. *Flange groove* well-developed (particularly in the right valve) on the venter and around the anterior margin. *Adductor muscle scars* are in a vertical column of four elongate scars, the second from the top being longest and the bottom one the shortest. There are two frontal scars, the top one is smaller and almost rounded, but the bottom one is ovate. *Hinge* holamphidont :

Element	Left valve	Right valve
Anterior	Deep socket bounded on venter, confluent with ocular sinus.	Strongly projecting slightly stirpate tooth with a concavity on anterior in dorsal view. Ocular sinus opens below and slightly anterior to it.
Anteromedian	Conical tooth with straight anterior and convex posterior in dorsal outline.	Deep rounded socket.

Element	Left valve	Right valve
Posteromedian	Denticulate bar.	Locellate groove.
Posterior	Deep socket bounded on venter.	Tooth which in dorsal view appears pessular but in reality is semicircular or slightly trilobate. In oblique view it can be seen that the line of concrescence deviates in the neighbourhood of the posterior tooth so that only the outside of the semi-circular tooth is bilamellar thus enclosing a monolamellar core formed by the invagination of the line of concrescence.

DIMENSIONS (mm).

		L	H	W
Io. 3096	Carapace male	0·80	0·44	0·41
Io. 4349	Carapace female (holotype)	0·74	0·44	0·39
Io. 3097	Left valve female	0·75	0·45	—
Io. 3098	Right valve female	0·76	0·44	—
Io. 4295	Right valve male	0·80	0·45	—

COMPARISON. The presence of a reduced ventral ridge, which does not reach the posterior marginal rim, separates this species from *Patagonacythere tricostata* Hartmann, *Patagonacythere devexa* (Müller) and *Patagonacythere longiducta antarctica* Benson. *Patagonacythere tricostata* Hartmann (1962) has a smaller and more elongate carapace and three rather than two frontal scars. *Patagonacythere devexa* (Müller) Benson (1964) is larger, has narrow anterior and posterior vestibules, split adductor scars and ill-defined median and dorsal ridges including the posterodorsal loop. (Comparative material of this species from the British Antarctic region was obtained through the courtesy of Dr. R. C. Whately of Aberystwyth.) *Patagonacythere longiducta antarctica* Benson (1964) is about the same size, has a more concave posterodorsal slope and the two median adductor scars are split.

REMARKS. The present species commonly occurs in the Zao River and Rakhi Nala sections, where it has a short vertical range. It is thus a very useful species for correlation in this region. *Patagonacythere* has so far only been described from cold water regions, but *P* ? *indulus* occurs here in a warm water environment. A new generic assignment will therefore probably be necessary at a later time.

Genus ***PHALCOCYTHERE*** nov.

DERIVATION OF NAME. Greek *phalkes*, beam or rib of a ship ; with reference to the ventral ridge + *cythere*.

DIAGNOSIS. Reticulate Trachyleberididae with a ventral ridge ; with or without spines or papillae ; mostly with pronounced posterodorsal process.

TYPE SPECIES. *Cythere horrescens* Bosquet 1852.

DESCRIPTION. Sexual dimorphism present in most of the species. Carapace subrectangular to subquadrate in lateral outline. Anterior margin broadly rounded, posterodorsal margin very slightly concave, posterodorsal margin either curved or almost straight, dorsal margin almost straight or slightly convex (but appears irregular in lateral outline in many species due to surface ornamentation), ventral margin slightly concave in front of the middle or nearly straight (over-reached by a ventral ridge in lateral view in some species). Valves almost equal in size although the right valve over-reaches the left at the anterior margin. Subcentral-tubercle more or less well-developed. Eye-tubercle distinct. Surface reticulate with or without superimposed papillae or spines. A posterodorsal process is generally present. A ventral ridge more or less prominent is always present ; it is either straight or slightly curved convexly downward in the middle culminating in the posterior fourth usually in a spine or an ala. Anterior and posterior marginal rims always present, more or less distinct. Radial pore canals simple, almost straight, irregularly spaced, sometimes crossing one another, fairly numerous (approximately 30 anteriorly in the type species). Line of concrescence and inner margin coincide. Duplicature fairly wide. Selvage more or less pronounced, submarginal in left valve but at some distance in the right valve. Right valve with a deep and well-developed anterior and ventral flange groove. Adductor scars in a vertical column of four elongate scars with two almost rounded frontal scars (see description of *P. horrescens*). Hinge holamphidont.

COMPARISON. *Hirsutocythere* Howe 1951 has a wider duplicature and lacks a ventral ridge. *Australicythere* Benson 1964 is a much larger genus in which fine pittings occur within the reticulae. The two median adductor scars are also divided into two. Moreover, *Australicythere* has a posterior vertical ridge and a less prominent ventral ridge not ending in a spine posteriorly. *Bradleya* Hornibrook 1952 has both dorsal and ventral ridges, in this respect it differs from *Phalcocythere* which has only a ventral ridge.

REMARKS. This genus is so far known from the Eocene of the Paris Basin, West Pakistan, Tanzania and an undescribed species from the Aquitaine Basin.

Phalcocythere horrescens (Bosquet)

(Plate 29, fig. 5 ; Plate 30, figs. 1–6 ; Plate 33, figs. 12, 13)

1852 *Cythere horrescens* Bosquet, p. 119, pl. 6, fig. 5.
1852 *Cythere thierensiana* Bosquet (pars), p. 98.
1852 *Cythere nebulosa* Bosquet, p. 105, pl. 5. fig. 8.
1955 *Trachyleberis horrescens* (Bosquet), Apostolescu, p. 272, pl. 8, figs.125–126.
1957 *Hirsutocythere horrescens* (Bosquet), Keij, p. 101, pl. 15, fig. 4 ; pl. 17, figs.6–7.

DIAGNOSIS. *Phalcocythere* in which posteroventral margin is straight in left valve but curved in the right with five or six large spines, shell surface ornamented by well-developed spines superimposed on reticulations ; ventral ridge and posterodorsal process well-marked.

FIGURED SPECIMENS. Io. 4253–7.

MATERIAL. 8 specimens from Grignon, Paris Basin, from the Lutetian IV (sample no. CAB 1002, Keij 1957, p. 19). 5 specimens from Villiers-St.-Frederic, Paris Basin, from the same horizon.

TYPE LOCALITY. Grignon, Paris Basin.

TYPE HORIZON. Lutetian.

DIMENSIONS (mm).

		L	H
Io. 4253	Left valve	0·60	0·33
Io. 4257	Left valve	0·59	0·33
Io. 4254	Left valve	0·72	0·37
Io. 4255	Right valve	0·59	0·33
Io. 4256	Right valve	0·63	0·37

COMPARISON. This species shows some affinity to *Phalcocythere retispinata* sp. nov. but has a more spinose surface, less tapering carapace and a better developed subcentral-tubercle. Further, *P. horrescens* has straight posteroventral margin in the right valve, different posterodorsal process and less prominent eye-tubercle which lies below and slightly posterior to the anterior cardinal angle.

REMARKS. The present species has been redescribed by Keij (1957) in detail, where, although he ascribed it to the genus *Hirsutocythere*, he noted that it lacked the very wide duplicature of that genus.

Adult specimens vary in size. According to Apostolescu (1955, p. 272), they range from 0·52 mm. to 0·70 mm. in length.

Phalcocythere improcera sp. nov.

(Plate 30, figs. 7–12 ; Plate 31, figs. 1–4)

DERIVATION OF NAME. Latin, *improcerus*, short ; with reference to the carapace.

DIAGNOSIS. A small *Phalcocythere* in which the prominent ventral ridge possesses an alar expansion ; posteroventral margin slightly protracted towards the venter, subcentral-tubercle prominent.

HOLOTYPE. Io. 4344, a male carapace (Pl. 31, figs. 1, 2 ; Pl. 30, figs. 8, 9).

PARATYPES. Io. 4296 + Io. 4258–9.

MATERIAL. 68 specimens from the Sor Range section from four horizons (sample nos. 460-i, 460-j, 460-l and 460-n). GSP BM 2570–1.

TYPE LOCALITY. Sor Range section.

TYPE HORIZON. Upper Palaeocene, sample no. 460-i.

DESCRIPTION. *Carapace* subrectangular in the male dimorph and sub-quadrate in the female. Sexual dimorphy is rather marked ; the males are longer in proportion than the females. Anterior margin broadly rounded, posterodorsal margin very slightly concave, posteroventral margin rounded and slightly protracted towards the venter. Dorsal margin straight but appears irregular in lateral view because of the surface ornamentation ; ventral margin nearly straight (concealed in side view by the ventral ridge). Anterior and posterior cardinal angles well-developed in the right valve but more or less rounded in the left valve. Right valve slightly over-reaches the left at the anterior margin but the left valve over-reaches the right in the region of the posterodorsal slope. *Subcentral-tubercle* prominent. *Eye-tubercle* distinct, rounded and glassy. Shell surface deeply reticulate with superimposed papillae or spines, the ornamentation extending onto the prominent ventral ridge (over-reaching the ventral margin in lateral view) which also develops an alar expansion. The posterodorsal process is developed as a short curved horn-like ridge in specimens with papillose ornamentation but is a projecting, blade-like process in specimens having a spinose surface. Anterior and posterior marginal rims distinct. Anterior margin finely denticulate with 20–22 denticles, posteroventral margin with 7–8 short spines. *Normal pore canals* fairly numerous, one to each reticule. (These become exaggerated in specimens cleaned in the ultrasonic vibrator). *Radial pore canals* not very well preserved but appear to be simple, more or less straight, irregularly spaced, some crossing one another, approximately 35 anteriorly. *Line of concrescence* and *inner margin* coincide. *Duplicature* moderately wide. *Selvage* prominent—submarginal in the left valve but situated in the outer two-fifths of the duplicature in right valve which also has a deep and well marked anterior and ventral *flange groove.* *Hinge* not clearly seen but appears to be holamphidont.

DIMENSIONS (mm).

		L	H	W
Io. 4344	Carapace male (holotype)	0·49	0·29	0·27
Io. 4258	Carapace female	0·49	0·30	0·29
Io. 4295	Left valve female	0·46	0·28	—
Io. 4296	Right valve female	0·46	0·27	—

COMPARISON. Distinguished from the other known species of the genus *Phalcocythere* by its small size and the posteroventral margin slightly drawn out towards the venter particularly in the right valve.

REMARKS. The surface ornamentation is variable. Most of the specimens examined have a combination of reticulations and papillae but in a few specimens spines are superimposed on reticulations.

Phalcocythere rete sp. nov.

(Plate 31, figs. 5–12)

DERIVATION OF NAME. Latin *rete*, net ; with reference to the surface ornamentation.

DIAGNOSIS. Reticulate *Phalcocythere* in which eye-tubercle is prominent, ventral ridge present but not prominent, dorsal margin slightly convex particularly in female.

HOLOTYPE. Io. 4348, a female right valve (Pl. 31, figs. 11).

PARATYPES. Io. 4297 + Io. 3099 + Io. 3141.

MATERIAL. 14 specimens including the holotype from the Sor Range section from one horizon (sample no. 460-i). GSP BM 2572–3.

TYPE LOCALITY. Sor Range section.

TYPE HORIZON. Upper Palaeocene, sample no. 460-i.

DESCRIPTION. Sexual dimorphy rather strong ; the males are longer, less high and less wide than the females. *Carapace* subrectangular to subquadrate in lateral view with a slight taper towards the posterior. Dorsal margin slightly convex particularly in the female, ventral margin almost straight, anterior broadly and evenly rounded, posterodorsal slope very slightly concave, posteroventral margin rounded. Left valve slightly over-reaches the right at the anterior margin. *Subcentral-tubercle* distinct, *eye-tubercle* prominent, rounded and polished. Shell surface reticulate, the reticulae are slightly papillose. The ventral ridge is present but not prominent, sloping obliquely upward towards the posterior and culminating in the posterior third. Marginal rim distinct. Anterior and posterior margins denticulate. *Radial pore canals* simple, straight, slightly thicker on the proximal end, irregularly spaced, about 30 anteriorly. *Inner margin* and *line of concresence* coincide. *Duplicature* fairly wide, 0·060 mm. anteroventrally. *Selvage* well-developed—submarginal in left valve but almost in the middle in the right valve. There is a deep anterior and ventral *flange* groove in the right valve. *Hinge* not clearly distinguished due to mineralization but presumably holamphidont.

DIMENSIONS (mm).

		L	H	W
Io. 3099	Carapace male	0·65	0·35	0·24
Io. 4297	Carapace female	0·47	0·35	0·27
Io. 3141	Left valve female	0·46	0·35	—
Io. 4348	Right valve female (holotype)	0·46	0·35	—

COMPARISON. *Phalcocythere retispinata* sp. nov. is a closely related species but has a reticulate and spinose surface, a more elevated ventral ridge and a well-developed posterodorsal process.

Phalcocythere retispinata sp. nov.

(Plate 31, figs. 13–17 ; Plate 32, figs. 1–3)

DERIVATION OF NAME. Latin *rete*, net + *spinatus*, spined ; with reference to the surface ornamentation.

DIAGNOSIS. *Phalcocythere* with a prominent ventral ridge with alar expansion, surface ornamentation a combination of reticulations and spines, subcentral-tubercle present but not pronounced, eye-tubercle prominent, posterodorsal process well-marked.

HOLOTYPE. Io. 4345, a female carapace (Pl. 31, figs. 15, 16 ; Pl. 32, figs. 2, 3).

PARATYPE. Io. 3165.

MATERIAL. Six specimens from the below locality from three horizons (sample nos. 460-i, 460-j and 460-o). GSP BM 2574.

TYPE LOCALITY. Sor Range section.

TYPE HORIZON. Upper Palaeocene, sample no. 460-i.

DESCRIPTION. Sexual dimorphism rather pronounced ; the females are higher and wider than the males. *Carapace* tapering towards the posterior, subrectangular in side view. Dorsal margin nearly straight in the male dimorph but very slightly convex in the female (appears to be irregular in dorsal view due to ornamentation) ; ventral margin almost straight but concealed by the ventral ridge in side view ; anterior broadly rounded, posterodorsal margin very slightly concave ; posteroventral margin rounded. Greatest length lies below mid-point, greatest height in the anterior third. Anterior and posterior cardinal angles well-developed. Right valve very slightly over-reaches the left at the anterior margin. *Subcentral-tubercle* present but not pronounced. *Eye-tubercle* prominent, rounded and polished. Ornamentation consists of reticulations and spines. The spines are of variable size. A posterodorsal process consists usually of a large spine, which stands out in lateral view. The ventral ridge is high and with an alar expansion, slightly concave in the middle culminating in the posterior third with a pointed end. Anterior and posterior marginal rims more or less distinct and decorated with a row of spines. Anterior and posterior margins denticulate. Internal characters not seen.

DIMENSIONS (mm).

		L	H	W
Io. 3165	Carapace male	0·64	0·37	0·27
Io. 4345	Carapace female (holotype)	0·64	0·39	0·32

COMPARISON. *Phalcocythere improcera* sp. nov. is much smaller, has deeper reticulations and a posteroventral margin slightly drawn out towards the venter.

Phalcocythere sentosa sp. nov.

(Plate 32, figs. 4–10)

DERIVATION OF NAME. Latin *sentosus*, rough ; with reference to the surface ornamentation.

DIAGNOSIS. A species of the genus *Phalcocythere* in which ventral ridge is present but not high ; surface ornamentation consists of combination of reticulations and papillae ; posterodorsal process a small tubercle or short spine. Subcentral-tubercle distinct, eye-tubercle prominent.

HOLOTYPE. Io. 4346, a male carapace (Pl. 32, figs. 4, 5, 8, 10).

PARATYPE. Io. 4298.

MATERIAL. 67 specimens from the Rakhi Nala section from 11 horizons (sample nos. 3153, 3165, 3167, 3169, 3170, 3173 to 3177 and 3180). GSP BM 2575–6.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Upper Rakhi Gaj Shales, sample no. 3167.

DESCRIPTION. Strongly dimorphic, the females are less elongate than the males. *Carapace* subrectangular in lateral view. Anterior broadly rounded, posterodorsal slope very slightly concave, posteroventral margin rounded, dorsal margin almost straight, appearing irregular in lateral view, ventral margin slightly concave anterior to the middle. Right valve slightly over-reaches left valve at the anterior margin but is over-reached by the latter in the region of the posterodorsal slope. Anterior and posterior cardinal angles well-developed, particularly in the right valve. *Eye-tubercle* rounded and prominent, projecting out from the eye-socket. *Subcentral-tubercle* distinct. Surface reticulate with superimposed papillae, posterodorsal process either a small more or less rounded tubercle or a cluster of short spines ; ventral ridge present but not elevated. Anterior and posterior marginal rims distinct. Anterior margin denticulate, posteroventral margin papillose. Internal details not observed.

DIMENSIONS (mm).

		L	H	W
Io. 4346	Carapace male (holotype)	0·56	0·32	0·25
Io. 4298	Carapace female	0·55	0·32	0·29

COMPARISON. *Phalcocythere rete* sp. nov. is larger than the present species, has a less papillose surface and slightly convex dorsal margin in the female.

REMARKS. So far only known from the Rakhi Nala section. The posterodorsal process varies; in some specimens it is almost a rounded tubercle but in others it is a short spine.

Phalcocythere dissenta sp. nov.

(Plate 32, figs. 11–18)

DERIVATION OF NAME. Latin *dis*, not + *sentus*, spiny.

DIAGNOSIS. A reticulate species of the genus *Phalcocythere* with dorsal and ventral margins sub-parallel, anterior rim ornamented like a scallop or flute, subcentral-tubercle prominent, eye-tubercle and ventral ridge distinct.

HOLOTYPE. Io. 4343, a male carapace (Pl. 32, figs. 11, 14, 18).

PARATYPE. Io. 4299.

MATERIAL. Approximately 400 specimens from the locality above from six horizons (sample nos. 3454, 3456, 3460 to 3462 and 3464) and 6 specimens from the Zao River section from one horizon (sample no. 24107). GSP BM 2577–8.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Shales with Alabaster, sample no. 3456.

DESCRIPTION. Sexual dimorphism marked, the presumed males are more elongate, less high and less wide than the females. *Carapace* sub-rectangular in lateral outline with sub-parallel dorsal and ventral margins. Anterior margin broadly rounded ; posterodorsal slope more or less straight ; posteroventral margin rounded ; dorsal margin slightly convex particularly in the female ; ventral margin almost straight, although partly hidden by the ventral ridge in lateral view. Greatest length passes through mid-point, greatest height in the anterior third and greatest width in the anterior two-fifths. Anterior and posterior cardinal angles protruding. Valves almost equal. *Subcentral-tubercle* prominent, *eye-tubercle* distinct and situated below the cardinal angle. Anterior marginal rim distinct, and ornamented with seven very short ridges with small depressions in between (like flutes or scallops), posterior rim more or less distinct. Surface reticulate with a distinct ventral ridge which slopes obliquely upwards posteriorly ending in the posterior third. In many specimens the posterior ending is pointed or spinose. Internal details not determinable, all specimens being complete carapaces.

DIMENSIONS (mm).

		L	H	W
Io. 4343	Carapace male (holotype)	0·60	0·44	0·32
Io. 4299	Carapace female	0·56	0·44	0·44

COMPARISON. This species shows some resemblance to *Phalcocythere rete* sp. nov. but is smaller and has subparallel rather than tapering dorsal and ventral margins. It differs from *Phalcocythere improcera* sp. nov. and *Phalcocythere sentosa* sp. nov. in shape and surface ornamentation.

REMARKS. *P. dissenta* seems to be restricted to the Shales with Alabaster only and has been found in the Rakhi Nala and Zao River sections. It is abundant in the Rakhi Nala section but rare in the Zao River area.

Phalcocythere spinosa sp. nov.

(Plate 33, figs. 1, 2, 7, 8)

DERIVATION OF NAME. Latin *spinosus*, spiny.

DIAGNOSIS. A species belonging to the genus *Phalcocythere* with short spines and/or papillae superimposed on reticulations ; ventral ridge distinct and terminating in a spine in posterior third ; posterodorsal process well-marked and blade-like.

HOLOTYPE. Io. 4347, a carapace.

MATERIAL. 16 specimens from the Zao River section from one horizon (sample no. 24161). GSP BM 2579.

TYPE LOCALITY. Zao River section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 24161.

DESCRIPTION. *Carapace* subrectangular in side view. Dorsal margin almost straight, appearing to be irregular in lateral view due to ornamentation ; ventral margin more or less straight but hidden by the ventral ridge in side view ; anterior margin broadly rounded ; posterodorsal margin slightly concave ; posteroventral margin rounded. Greatest length passes through the mid-point and greatest height passes through the anterior cardinal angle. Valves nearly equal. *Subcentral-tubercle* well-developed, *eye-tubercle* rounded, distinct and lies below the anterior cardinal angle. Surface ornamentation consists of short spines and/or papillae superimposed on reticulations. A distinct ventral ridge, diagnostic of the genus, over-reaches the ventral margin in lateral view and is spinose posteriorly. It extends from the anteroventral corner to the posterior third. The posterodorsal process is projecting and blade-like (present in most specimens). Anterior and posterior marginal rims distinct. Anterior margin finely denticulate, posteroventral margin ornamented with 6–7 short spines or papillae. Internal features not seen.

DIMENSIONS (mm).

		L	H	W
Io. 4347	Carapace (holotype)	0·54	0·33	0·44

COMPARISON. *Phalcocythere sentosa* sp. nov. is similar and perhaps ancestral to the present species. These two, however, can be separated easily due to the fact that *P. sentosa* is strongly dimorphic and has a less well-developed ventral ridge and a posterodorsal process.

REMARKS. This species has so far only been recorded from one horizon of the Upper Chocolate Clays of the Zao River section. Sexual dimorphism has not been observed in this species.

Phalcocythere **sp., cf.** ***P. spinosa***

(Plate 33, figs. 3–6, 9–11)

FIGURED SPECIMENS. Io. 4230—Io. 4232.

MATERIAL. Five specimens from the locality and horizon below (other specimens in the collections of the British Petroleum Co. Ltd., under registration no. FCRM 1648). GSP BM 2580.

LOCALITY. Lindi survey, 10–50 ft. above shore at Kitunga, Tanzania.

HORIZON. Upper Eocene.

DESCRIPTION. Sexual dimorphism rather marked ; the females are higher and wider than the males. *Carapace* subrectangular to subquadrate in lateral outline. Dorsal margin irregular in lateral view due to ornamentation ; ventral margin almost straight ; anterior margin broadly rounded ; posterodorsal margin very slightly concave ; posterior extremity rounded. Right valve over-reaches the left slightly at the anterior margin. Anterior and posterior cardinal angles well-developed particularly in right valve. Greatest length below mid-point, greatest height at anterior cardinal angle and greatest width in the posterior third. *Subcentral-tubercle* distinct. *Eye-tubercle* rounded and prominent. Anterior and posterior marginal rims distinct. Surface ornamentation consists of reticulations with superimposed spines ; ventral ridge prominent, posteriorly alate, ending abruptly in the posterior third ; posterodorsal process prominent and blade-like, standing out in lateral and dorsal views. Anterior margin ornamented with numerous very short spines ; posterior with six larger spines. *Radial pore canals* not discernible. *Duplicature* moderately wide. *Selvage* strong—marginal in left valve but in right valve it is in the outer third. Right valve with a deep *flange groove. Muscle scars* are in a vertical row of four adductors, and frontal scars not seen. *Hinge* holamphidont with the details of each element as follows:

Element	Left valve	Right valve
Anterior	Deep rounded socket.	Projecting conical tooth. Eye-socket opens below and slightly anterior to this tooth.
Anteromedian	Conical projecting tooth.	Socket opening into groove.
Posteromedian	Denticulate bar.	Shallow locellate groove narrowing towards posterior.
Posterior	Elongate groove, presumably deep (filled in with matrix).	Subpessular tooth, higher on the posterior side.

Dimensions (mm).

		L	H	W
Io. 4230	Carapace male	0·55	0·32	0·30
Io. 4231	Carapace female	0·56	0·34	0·34
Io. 4232	Right valve female (broken)—½w, 0·17			

Comparison. *Phalcocythere spinosa* sp. nov. closely approaches the present form but is smaller, has a less reticulate and spinose surface and a more concave posterodorsal slope. *Phalcocythere retispinata* sp. nov. is much larger, has a slightly convex dorsal margin particularly in the female dimorph, and the carapace tapers towards the posterior.

Remarks. The specimens studied were made available through the kindness of Dr. F. E. Eames, lately Chief Palaeontologist of the British Petroleum Co. Ltd. These specimens may represent a distinct sub-species of *P. spinosa.*

Genus ***QUADRACYTHERE*** Hornibrook 1952

Type species. *Cythere truncula* Brady 1898.

Subgenus ***HORNIBROOKELLA*** Moos 1965

Type species. *Cythere anna* Lienenklaus 1894.

Quadracythere (Hornibrookella) platybomus sp. nov.

(Plate 33, figs. 14, 15, 18, 19).

Derivation of name. Greek *platys,* broad + *bomos,* bottom ; with reference to the expanded venter.

Diagnosis. Carapace with expanded venter, subrectangular to subquadrate in lateral outline.

Holotype. Io. 4351, a male carapace (Pl. 33, figs. 14, 18).

Paratype. Io. 4300.

Material. Nine specimens from the locality below from two horizons (sample nos. 460-i and 460-o). GSP BM 2581–2.

Type locality. Sor Range section.

Type horizon. Upper Palaeocene, sample no. 460-i.

Description. *Carapace* subrectangular in the male dimorph and subquadrate in the female. Sexual dimorphism rather apparent ; the females are higher and wider than the males. Carapace compressed in the posterior region. Anterior margin broadly rounded, posterodorsal slope very slightly curved, posterior almost rounded, posteroventral margin slightly curved. The ornamentation over-reaches the dorsal margin giving a jagged appearance, ventral margin almost straight in the male but slightly curved in the female. Left valve very slightly over-reaches the right at the posterodorsal slope and at the anterior cardinal angle. In dorsal view the greatest width is situated anterior to the middle. *Subcentral-tubercle* prominent, *eye-tubercle* distinct. A marginal rim runs around the anterior, ventral and posterior margins. It is upraised around the anterior but less elevated along the venter and around the posterior end. Surface reticulate with a well-marked ventral ridge giving rise to an expanded venter. At the posterodorsal corner a small horn-like projecting ridge is present. Anterior margin ornamented by small, numerous denticles (20–25 in number) but the posterior has only a few denticles.

Dimensions (mm).

		L	H	W
Io. 4351	Carapace male (holotype)	0·57	0·32	0·24
Io. 4300	Carapace female	0·57	0·34	0·29

Comparison. *Quadracythere* (*Hornibrookella*) *directa* sp. nov. is larger, has a less well-developed subcentral-tubercle and lacks an expanded venter.

Remarks. The preservation of the material prevents a description of the internal characters. So far this species is only known from the Upper Palaeocene of the Sor Range section.

Quadracythere (Hornibrookella) directa sp. nov.

(Plate 33, figs. 16, 17 ; Plate 34, figs. 1, 2)

Derivation of name. Latin *directus*, rectangular ; with reference to the outline in lateral view.

Diagnosis. In lateral view carapace subrectangular with protruding anterior and posterior cardinal angles. Surface ornamentation consists of reticulation with an oblique ventral ridge sloping upward towards posterior and a short horn-like ridge at posterodorsal corner. Sexual dimorphism pronounced.

Holotype. Io. 4350, a female carapace (Pl. 33, figs. 17 ; Pl. 34, fig.2).

Paratype. Io. 4301.

Material. 96 specimens from the type locality from four horizons (sample nos. 3184, 3192, 3402 and 3403). GSP BM 2583–4.

Type locality. Rakhi Nala section.

Type horizon. Green and Nodular Shales, sample no. 3403.

DESCRIPTION. Sexual dimorphy rather apparent ; the females are shorter, higher and wider than the males. *Carapace* subrectangular in side view with the greatest height at the anterior cardinal angle and the greatest length below the middle. Anterior margin broadly and evenly rounded, posterodorsal slope very slightly concave, posterior extremity subtriangular, posteroventral margin almost straight. Dorsal margin very slightly undulating, venter slightly incurved in front of the middle. Posterior portion of carapace compressed. Anterior marginal rim high continuing along the venter and around the posterior end as a somewhat less elevated rim. Anterior margin set with numerous small and delicate denticles, posterior with a few denticles. Anterior and posterior cardinal angles protruding. Left valve overreaches the right valve slightly at the anterior cardinal angle and posterodorsal slope. In dorsal view the greatest width is situated almost in the middle of the carapace. *Eye-tubercle* distinct. *Subcentral-tubercle* more or less distinct. Surface reticulate with a ventral ridge, which slopes slightly upwards towards the posterior. A short curved, hornlike ridge at the posterodorsal corner is present (better seen in dorsal view). Internal details not known.

DIMENSIONS (mm).

		L	H	W
Io. 4301	Carapace male	0·68	0·35	0·27
Io. 4350	Carapace female (holotype)	0·63	0·37	0·29

COMPARISON. *Quadracythere* (*Hornibrookella*) *subquadra* sp. nov. is subquadrate in lateral outline, has deeper reticulations and a better developed subcentral-tubercle.

Quadracythere (Hornibrookella) arcana (Lubimova and Guha)

(Plate 34, figs. 3–5)

1960 *Cythereis arcanus* (sic., recte *Cythereis arcana*) Lubimova and Guha, p. 33, pl. 3, fig. 1a–b.

DIAGNOSIS. Carapace with distinct caudal process. Surface coarsely reticulate with superimposed longitudinal lineations in posterior half of carapace.

FIGURED SPECIMEN. Io. 3142.

MATERIAL. Two specimens from the locality and horizon below.

LOCALITY. Rakhi Nala section.

HORIZON. Lower Chocolate Clays, sample no. 3499.

DESCRIPTION. *Carapace* thick-shelled, subquadrate in lateral view. Anterior margin broadly rounded, posterior with a pronounced caudal process. Dorsal margin slightly concave behind the round and protruding anterior cardinal angle, particularly in the right valve. Ventral margin almost straight. Greatest height at the anterior cardinal angle and greatest length below the middle. Left valve slightly overreaches the right in the region of the anterior cardinal angle and posterodorsal slope. *Eye-tubercle* rounded and distinct, *subcentral-tubercle* well-developed. Surface ornamentation consists of coarse reticulations with superimposed longitudinal lineations in the posterior half of the carapace. The ventral ridge is slightly concave downwards culminating in an ala posteriorly. A short ridge at the posterodorsal corner meets the dorsal margin at an angle (better seen in dorsal view) and ends as an ala at the posterior. A marginal rim runs round the anterior, along the venter and round the posterior margin.

DIMENSIONS (mm).

		L	H	W
Io. 3142	Carapace	0·54	0·32	0·32

REMARKS. Topotype material was not available for study, and it is, therefore, difficult to determine whether or not the Rakhi Nala specimens are conspecific with those from the type locality in Kutch.

Quadracythere (Hornibrookella) subquadra sp. nov.

(Plate 34, figs. 6–11)

DERIVATION OF NAME. Latin *subquadrus*, almost square ; with reference to the outline in lateral view.

DIAGNOSIS. Carapace subquadrate with dorsal and ventral margins almost straight and subparallel. Surface strongly and coarsely reticulate. Sexual dimorphy moderate.

HOLOTYPE. Io. 4352, a female carapace (Pl. 34, figs, 7, 10, 11).

PARATYPE. Io. 4302.

MATERIAL. 41 specimens from the locality below from one horizon (sample no. 24161). GSP BM 2585–6.

TYPE LOCALITY. Zao River section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 24161.

DESCRIPTION. *Carapace* subquadrate in lateral outline with a short caudal process. Anterior margin broadly rounded, posterodorsal slope slightly concave, posterior extremity almost straight, posteroventral margin curved. Dorsal and ventral margins nearly straight and sub-parallel. Greatest height at the anterior cardinal angle, greatest length below the mid-point. In dorsal view the greatest width is situated in front of the middle. Anterior cardinal angle rounded, posterior cardinal angle well-developed. Left valve over-reaches the right valve slightly in the region of the posterodorsal slope and the anterior cardinal angle. *Subcentral-tubercle* prominent, *eye-tubercle* rounded and distinct. Surface coarsely and deeply reticulate. There is a distinct ventral ridge at some distance from the venter and a short curved hornlike ridge at the posterodorsal corner. Anterior marginal rim prominent continuing along the venter and around the posterior margin as a less prominent rim. Anterior margin ornamented with numerous denticles.

Sexual dimorphism moderate ; the presumed females are wider than the males.

DIMENSIONS (mm).

		L	H	W
Io. 4302	Carapace male	0·66	0·40	0·32
Io. 4352	Carapace female (holotype)	0·67	0·42	0·34

COMPARISON. *Quadracythere* (*Hornibrookella*) *arcana* (1960) is smaller, has a well-developed caudal process, superimposed longitudinal lineations and a ventral ridge slightly curved downward. *Quadracythere* (*Hornibrookella*) *platybomus* sp. nov. is also smaller, has a different lateral outline, less deep reticulations and an expanded venter.

REMARKS. *Quadracythere* (*Hornibrookella*) *subquadra* sp. nov. commonly occurs at one horizon (sample no. 24161) of the Upper Chocolate Clays in the Zao River section associated with *Echinocythereis multibullata* sp. nov. and *Phalcocythere spinosa* sp. nov.

Quadracythere (Hornibrookella) sp.A

(Plate 34, figs. 12–14)

FIGURED SPECIMEN. Io. 3143.

MATERIAL. Only one specimen from the locality and horizon below.

LOCALITY. Zao River section.

HORIZON. Upper Chocolate Clays, sample no. 24148.

DESCRIPTION. *Carapace* subquadrate in side view. Dorsal and ventral margins almost straight, anterior margin broadly and obliquely rounded, posterodorsal margin slightly concave, posteroventral margin rounded. Greatest length lies below the middle, greatest height at the anterior cardinal angle. In dorsal view the greatest width lies anterior to the middle. Valves almost equal. *Eye-tubercle* distinct, rounded. *Subcentral-tubercle* distinct. Surface coarsely and deeply reticulate. Reticulae are somewhat concentrically arranged around the subcentral-tubercle. Dorsal ridge present but not well-defined, ventral ridge more or less distinct. A low marginal rim runs around the anterior and posterior margins. Anterior and posteroventral margins denticulate. Internal characters not observed.

DIMENSIONS (mm).

		L	H	W
Io. 3143	Carapace	0·93	0·54	0·56

COMPARISON. This is similar to *Quadracythere* (*Hornibrookella*) *subquadra* sp. nov. but is much larger, has coarser and deeper reticulations more or less arranged in a concentric pattern around the subcentral-tubercle. In addition, these two species differ markedly in their posterior outline.

Genus ***STIGMATOCYTHERE*** nov.

DERIVATION OF NAME. Greek *stigma*, mark ; with reference to the ornamentation +*cythere*.

DIAGNOSIS. Highly ornamented Trachyleberididae in which two ridges spring from the eye-tubercle, one to form a high anterior marginal rim, the other curving sharply round to join the subcentral-tubercle.

TYPE SPECIES. *Stigmatocythere obliqua* sp. nov.

DESCRIPTION. Carapace subrectangular in lateral outline. Sexual dimorphy apparent ; the males are longer, less high and less wide than the females. Left valve slightly over-reaches the right in the region of the anterior cardinal angle and at the posterodorsal slope. Subcentral node and eye-tubercle distinct. Surface reticulate, spiny, or a combination of reticulations and spines or with only one to three longitudinal ridges or lines of ornamentation. The dorsal ridge or line when developed may be straight or arched convexly upwards. A strongly curved ridge, diagnostic of the genus, runs from the eye-tubercle to the anterodorsal corner of the subcentral complex and this may be continued posteriorly either as a ridge or a line of tubercles. The anterior marginal rim also springs from the eye-tubercle and is more or less elevated in the anterior region, continuing as a less elevated rim round the venter and posterior margins. A ventral ridge or line of tubercles diverges posteriorly from the ventral marginal rim. Anterior and posterior margins spinose. Normal pore canals simple, medium, some 60 in the female left valve. Radial pore canals simple, straight, irregularly spaced, some crossing one another, 24–26 anteriorly. Inner margin and line of concrescence coincide. Anterior duplicature moderately wide. Selvage well-marked in both valves, submarginal in the left valve but almost in the outer third of the duplicature in right valve. In right valve a well-developed flange groove is present along the ventral margin and around the anterior margin. Muscle scars consist of four adductor scars in an almost vertical column with an oval frontal scar. Hinge holamphidont ; right valve hinge with a strongly projecting anterior tooth followed by anteromedian socket, posteromedian locellate groove present or reduced to a narrow shelf, a posterior tooth, projecting reniform or pessular. Left valve hinge with anterior and posterior sockets, a conical anteromedian tooth and a posteromedian denticulate or almost smooth bar.

COMPARISON. *Stigmatocythere* differs from the genus *Gyrocythere* in the arrangement of the longitudinal ridges and by having a strongly curved ridge connecting the eye-tubercle and the subcentral-tubercle. The anterior marginal rim is less evident in *Gyrocythere* while it is well developed in *Stigmatocythere*. *Costa* has three or four continuous longitudinal ridges, the median or second of which has a characteristic posterior termination absent in *Stigmatocythere* and lacks the anterior connection to the eye-tubercle present in *Stigmatocythere*. *Bradleya* has only dorsal and ventral ridges. *Carinocythereis* Ruggieri 1956 has a V-shaped frontal scar and small vestibules, characters not found in *Stigmatocythere*.

REMARKS. *Stigmatocythere* is so far only known from the Middle and Upper Eocene of the Sulaiman Range.

Stigmatocythere obliqua sp. nov.

(Plate 35, figs. 1–10 ; Plate 36, figs. 1–2)

DERIVATION OF NAME. Latin *obliqua*, oblique ; with reference to the ventral ridge.

DIAGNOSIS. A strongly reticulate species of *Stigmatocythere* with three well-developed longitudinal ridges including an oblique ventral ridge.

HOLOTYPE. Io. 4355, a female carapace (Plate 35, figs. 2, 5, 6 ; Plate 36, fig. 2).

PARATYPES. Io. 4303 + Io. 3147 + Io. 3148 + Io. 3149.

MATERIAL. Over 1400 specimens from the Rakhi Nala section from 17 horizons (sample nos. 3448, 3451 to 3454, 3456, 3457, 3460 to 3467, 3470 and 3473). 470 specimens from the Zao River section from two horizons (sample nos. 24107 and 24110). Approximately 600 specimens from the Shpalai Khwara section from three horizons (sample nos. 24681, 24683 and 24686). GSP BM 2587–8.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Shales with Alabaster, sample no. 24173.

DESCRIPTION. *Carapace* subrectangular in lateral view. Sexual dimorphism rather pronounced ; the females are shorter, higher and wider than the males. Anterior margin broadly and obliquely rounded, posterior nearly straight. Dorsal margin almost intricate because of the over-reaching of the dorsal ridge, venter slightly incurved in front of the middle. Valves almost equal except that the left valve over-reaches the right in the region of the anterior cardinal angle and along the posterodorsal corner. *Eye-tubercle* and *subcentral-tubercle* distinct. Shell surface strongly reticulate. Three longitudinal ridges present ; the dorsal ridge starts almost above the subcentral node and is arched convexly upwards ; the median ridge commences from the eye-tubercle, curves sharply round to join anterodorsal corner of the subcentral complex and continues posteriorly ; the ventral ridge slopes obliquely upwards towards the posterior. The reticulations in the mid-posterior region of the carapace show a concentric pattern, although it is not always present. A high anterior marginal rim commences from the eye-tubercle continuing as a less high rim round the venter and posterior. Anterior and posterior short marginal spines present, 18–20 anteriorly. *Normal pore canals* simple, some 60 in the female left valve. 24–25 anterior *radial pore canals*, simple straight, irregularly spaced, few crossing one another, mostly terminating in marginal spines. *Inner-margin* and *line of concrescence* coincide. Anterior *duplicature* 0·050 mm. wide in the female left valve. *Selvage* strong in both valves, subperipheral in left valve but in right valve it lies in the outer third of the duplicature. Right valve with deep anterior and ventral *flange grooves*. *Muscle scar* pattern consists of four adductor scars in a vertical row with an oval frontal scar. *Hinge* holamphidont, the details are as follows :

Element	Left valve	Right valve
Anterior	Socket confluent with ocular sinus.	Strongly projecting subconical or subpessular tooth with a tendency for the anterior profile in dorsal view to appear concave. The ocular sinus lies distally beyond this and opens to the interior below and in front of it.

Anteromedian	Conical tooth with straight anterior in dorsal view.	Deep socket.
Posteromedian	Denticulate bar.	Locellate shelf, only detectable in best preserved specimens.
Posterior	Deep socket, slightly elongate, open in centre.	Pessular tooth, tending towards reniform in some specimens.

DIMENSIONS (mm).

		L	H	W
Io. 4303	Carapace male	0·61	0·30	0·29
Io. 4355	Carapace female (holotype)	0·54	0·33	0·29
Io. 3149	Left valve female	0·52	0·34	—
Io. 3148	Right valve female	0·54	0·32	—
Io. 3149	Left valve female	0·54	0·34	—
Io. 3146	Right valve female	0·51	0·29	—

COMPARISON. This species is perhaps ancestral to *Stigmatocythere portentum* sp. nov. which it resembles very closely, but differs in being smaller, having deeper reticulations and less prominent subcentral-tubercle.

REMARKS. The present species occurs abundantly in the Shales with Alabaster of the Rakhi Nala, Zao River and Shpalai Khwara sections and seems to be restricted to this formation. It is very likely that this species will prove to be a valuable horizon marker in the region.

The longitudinal ridges in some of the specimens from the upper few horizons of the Rakhi Nala section are exaggerated and in some the dorsal and ventral ridges posteriorly terminate in spines. This is regarded here as specific variation.

Stigmatocythere portentum sp. nov.

(Plate 36, figs. 3–6, 10)

DERIVATION OF NAME. Latin *portentum*, omen or sign ; with reference to the diagnostic ornamentation.

DIAGNOSIS. A large, reticulate species of the genus *Stigmatocythere* with three distinct longitudinal ridges, prominent subcentral-tubercle.

HOLOTYPE. Io. 4357, a male carapace (Pl. 36, figs. 3–6).

PARATYPES. Io. 3144 + Io. 3145.

MATERIAL. Eight specimens from the locality below from two horizons (sample nos. 3498 and 3499). GSP BM 2551.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Lower Chocolate Clays, sample no. 3498.

DESCRIPTION. *Carapace* subrectangular in side view with the greatest height at the anterior cardinal angle and the greatest length above mid-point. Anterior margin broadly rounded, posterior truncated. Dorsal margin straight, but looks irregular in lateral view because of over-reaching of the dorsal ridge ; ventral margin almost straight. Anterior and posterior cardinal angles well-developed particularly in the left valve. Left valve slightly over-reaches the right at the anterior cardinal angle and along the posterodorsal slope. *Eye-tubercle* distinct and rounded. *Subcentral-tubercle* prominent. Surface reticulate with three longitudinal ridges. Dorsal ridge wavy and convex upwards, it begins above the subcentral-tubercle and in the posterodorsal region, curves sharply down to meet the median ridge. A strongly curved ridge runs from the eye-tubercle to the subcentral-tubercle, continuing posteriorly as a median ridge. Ventral ridge commences above the anteroventral corner and is slightly convex downwards. There is a short, curved ridge on the ventral side of the subcentral-tubercle running towards the anterior end. A marginal rim runs along the anterior, ventral and posterior margins. It is high on the anterior but less high along the venter and posterior. Anterior ornamented with short, numerous spines. There is a large posteroventral spine. *Radial pore canals* simple. more or less straight, some crossing one another, few seem to bifurcate, some 25 anteriorly. *Inner margin* and *line of concrescence* coincide ; no *vestibule*. *Duplicature* of moderate width with a well-marked selvage. *Hinge* holamphidont with a projecting conical anterior tooth in the right valve.

DIMENSIONS (mm).

		L	H	W
Io. 4357	Carapace male (holotype)	0·71	0·37	0·32
Io. 3144	Right valve (broken)	—	0·37	—
Io. 3145	Carapace (juvenile)	0·59	0·35	0·29

COMPARISON. This species has already been compared with *Stigmatocythere obliqua* sp. nov.

REMARKS. *S. portentum* is a very rare ostracod and has so far only been found in the uppermost beds of the Lower Chocolate Clays of the Rakhi Nala section.

Stigmatocythere calia sp. nov.

(Plate 36, figs. 7–9 ; Plate 37, figs. 1, 3)

DERIVATION OF NAME. Greek, *kalia*, bird's nest ; from a fancied appearance of the ornamentation in lateral view.

DIAGNOSIS. A non-reticulate *Stigmatocythere* with straight posterior, high anterior marginal rim, prominent and projecting subcentral-tubercle, dorsal and ventral lines of ornamentation, posteroventral ridge, almost straight.

HOLOTYPE. Io. 4353, a female carapace (Pl. 36, figs, 8, 9 ; Pl. 37, figs. 1, 3).

PARATYPE. Io. 4304.

MATERIAL. 15 specimens from the locality below from five horizons (sample nos. 24148, 24150 to 24153). GSP. BM. 2589.

TYPE LOCALITY. Zao River section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 24151.

Description. Sexual dimorphism distinct ; the males are more elongate than the females. *Carapace* subrectangular in lateral outline. Dorsal margin almost straight but appears undulating in side view due to the over-reaching of the dorsal line of ornamentation, ventral margin nearly straight. Anterior margin broadly and evenly rounded, posterior straight, posterodorsal slope almost straight. Left valve slightly over-reaches the right valve in the anterodorsal and posterodorsal corners ; otherwise the two valves are equal. *Eye-tubercle* distinct, rounded and polished. *Subcentral-tubercle* prominent and projecting particularly in dorsal and ventral views. Dorsal line of ornamentation consists of three nodes including a large subangular posterodorsal node which extends vertically down for a short distance. Ventral line of ornamentation consists of two nodes but in some specimens it is just a short ridge. A projecting, almost vertical posteroventral ridge runs from behind the ventral line of ornamentation to a point which is slightly above the mid-line. A curved ridge diagnostic of the genus runs from the eye-tubercle to the subcentral-tubercle ; it is not well-marked. The subcentral-tubercle has two faint, short, curved ridges on its ventral side, one to the anterior and one to the posterior. Anterior marginal rim high, extending along the ventral and posterior margins as a less high rim. Anterior margin set with numerous short spines, concealed in lateral view by the elevated anterior marginal rim. There is one short posterodorsal marginal spine and one short posteroventral marginal spine. Internal details not determinable.

Dimensions (mm).

		L	H	W
Io. 4304	Right valve male	0·61	0·34	—
Io. 4353	Carapace female (holotype)	0·56	0·36	0·32

Stigmatocythere delineata sp. nov.

(Plate 37, figs. 2, 4–10)

Derivation of name. Latin *delineata*, outlined ; from the resemblance of the ornamentation to sketch map.

Diagnosis. A species of the genus *Stigmatocythere* with a large hexagon formed of ridges in the posteromedian region, dorsal ridge broken in the middle and extending vertically below in the posterodorsal region.

Holotype. Io. 4356, a female carapace (Pl. 37, figs. 7–10).

Paratype. Io. 4305.

Material. Six specimens from the type locality from two horizons (sample nos. 24154 and 24155). GSP BM 2590–91.

Type locality. Zao River section.

Type horizon. Upper Chocolate Clays, sample no. 24154.

Description. Sexual dimorphism apparent ; the males are proportionally longer than the females. *Carapace* subrectangular in side view. Dorsal margin slightly concave, ventral margin almost straight, anterior margin broadly and evenly rounded, posterodorsal slope and posteroventral margin nearly straight. Greatest height lies at the anterior cardinal angle, greatest length above the mid-point and greatest width in the posterior third. Anterior and posterior cardinal angles projecting particularly in the left valve. Left valve slightly over-reaches the right valve in the region of the anterodorsal corner and posterodorsal slope. *Subcentral-tubercle* and *eye-tubercle* distinct. The most prominent part of the ornamentation is a large slightly irregular hexagon formed of ridges just to the posterior of centre. Other short ridges, mostly running outwards, join this hexagon at its corners. A sharply curved ridge characteristic of the genus connects the eye-tubercle and the subcentral tubercle. Dorsal ridge is broken in the middle and in the posterodorsal region it extends vertically below to a point slightly above mid-line. The ventral ridge runs at a slightly oblique angle towards the posterior end, its posterior portion forming the ventral part of the hexagon. A high marginal rim runs on around the anterior margin and continues along the ventral and posterior margins as a less high rim. Anterior margin denticulate, posteroventral corner ornamented with a short spine. *Duplicature* of moderate width with a strong *selvage*. *Hinge* holamphidont.

DIMENSIONS (mm).

		L	H	W
Io. 4305	Carapace male	0·61	0·34	0·29
Io. 4356	Carapace female (holotype)	0·56	0·34	0·29

COMPARISON. It is easy to separate *S. delineata* from other described species of the genus *Stigmatocythere* due to its characteristic surface ornamentation particularly the large hexagon formed of ridges just to the posterior of centre.

Stigmatocythere lumaria sp. nov.

(Plate 37, figs. 11 ; Plate 38, figs. 1–10 ; Plate 39, figs. 1–8, 11)

DERIVATION OF NAME. Latin *lumarius*, thorny.

DIAGNOSIS. A species of *Stigmatocythere* with a prominent and bilobate subcentral-tubercle. Surface tuberculate or combination of reticulations and tubercles. Three large, projecting tubercles in the mid-dorsal region.

HOLOTYPE. Io. 4354, a male carapace (Pl. 38, figs. 1, 5, 8).

PARATYPES. Io. 4306–7 + Io. 3150–4.

MATERIAL. Approximately 340 specimens from the Rakhi Nala section from 21 horizons (sample nos. 3621, 3624 to 3628, 3630, 3640 to 3642, 3645 to 3652, 3658, 3662 and 3663). 86 specimens from the Zao River section from 11 horizons (sample nos. 24156, 24157, 24159, 24170, 24173 to 24176, 24180, 24187 and 24193). GSP BM 2592–94.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 3642.

DESCRIPTION. Sexual dimorphism rather pronounced ; the females are shorter and higher than the males. *Carapace* subrectangular in lateral view. Anterior margin broadly rounded, posteroventral margin and posterior extremity more or less rounded, posterodorsal slope very slightly concave. Dorsal margin straight but appears intricate due to surface ornamentation ; ventral margin slightly concave in front of the middle, particularly in right valve. Greatest height lies in the anterior third, greatest length passes above mid-line. Anterior and posterior cardinal angles well-marked. Valves almost equal. *Eye-tubercle* distinct and rounded. *Subcentral-tubercle* prominent and bilobate. Surface ornamentation consists of either tubercles or a combination of reticulations and tubercles. In some cases tubercles become almost spinose. There are three tubercles in the mid-dorsal region and in most specimens these project beyond the dorsal margin in lateral outline. The eye-tubercle is joined to the subcentral-tubercle, by a sharply curved ridge, diagnostic of the genus. The ventral side of the subcentral-tubercle has two weak, short, curved ridges ; one extends towards the anterior and the other towards the posterior end. Anterior marginal rim well-marked, ventral and posterior marginal rims less well-marked. Anterior and posterior margins decorated by short, numerous spines. Posterior has several short spines and two large, somewhat blunt spines, one in the posteroventral corner and the other in the posterodorsal corner. *Radial pore canals*, simple, almost straight, irregularly spaced, some crossing one another, 25–26 anteriorly. *Line of concrescence* and *inner margin* coincide. Anterior *duplicature* moderately wide, one-twelfth of the entire length of the valve. *Selvage* pronounced, in right valve it lies in the outer third of the duplicature but in left valve it is submarginal. Right valve with deep ventral and anterior *flange grooves*. *Adductor scars* in a vertical column of four. *Frontal scar* not clearly seen but appears to be oval in shape. *Hinge* holamphidont with the following details :

Element	Left valve	Right valve
Anterior	Socket bounded on all sides, ocular sinus opening into it.	Strongly projecting conical tooth. Ocular sinus lies below and slightly anterior to it.
Anteromedian	Subconical tooth with straight anterior and convex posterior in dorsal view.	Deep socket bounded on venter and opening into posteromedian groove.
Posteromedian	Denticulate bar.	Locellate groove.
Posterior	Deep socket open in venter.	Tooth more or less rounded in lateral view but pessular in dorsal view.

COMPARISON. *Stigmatocythere portentum* sp. nov. is larger, than the present species, has three distinct longitudinal ridges, lacks a tuberculate surface and bilobate subcentral-tubercle. *Stigmatocythere calia* sp. nov. is probably ancestral to *S. lumaria* but has a vertical posteroventral ridge and more elevated anterior marginal rim. Further, it lacks a tuberculate surface and bilobate subcentral-tubercle.

This species can be separated into two morphotypes, although it is rather difficult to maintain a distinction between them because of many intermediate forms :

MORPHOTYPE A

(Plate 37, figs. 11 ; Plate 38, figs. 1–10 ; Plate 39, fig. 11)

This has a tuberculate surface. Tubercles vary in size and number. Some have few large tubercles with a tendency to become spinose and in others tubercles are small and rounded.

DIMENSIONS (mm).

		L	H	W
Io. 4354	Carapace male (holotype)	0·67	0·37	0·34
Io. 4307	Right valve female	0·63	0·37	—
Io. 4306	Left valve male (juvenile)	0·59	0·32	—
Io. 3151	Right valve male	0·68	0·37	—
Io. 3152	Left valve female	0·59	0·40	—
Io. 3154	Right valve female	0·60	0·37	—

MORPHOTYPE B

(Plate 39, figs. 1–8)

This is very similar to Morphotype A, but has a surface ornamentation which is a combination of reticulations and tubercles.

DIMENSIONS (mm).

		L	H	W
Io. 3150	Carapace male	0·66	0·37	0·32
Io. 3153	Carapace female	0·62	0·37	0·31

REMARKS. This species has been described as Genus and sp. indet.G. by I. G. Sohn in his paper on Lower Tertiary ostracods from Western Pakistan, still in press.

Genus ***TRACHYLEBERIS*** Brady 1898

TYPE SPECIES. *Cythere scabrocuneata* Brady 1880.

Subgenus ***TRACHYLEBERIS*** sensu stricto

Trachyleberis (Trachyleberis) lobuculus sp. nov.

(Plate 39, figs. 9, 10 ; Plate 40, figs. 1, 3)

DERIVATION OF NAME. Latin *lobus*, lobe + *oculus*, eye ; with reference to the lobate eye-tubercle.

DIAGNOSIS. A species of the subgenus *Trachyleberis* in which eye-tubercle is lobate, surface ornamented with tubercles, posterior cardinal angle well-marked in left valve.

HOLOTYPE. Io. 4364, a female carapace (Pl. 40, figs. 1, 3).

PARATYPE. Io. 4308.

MATERIAL. 287 specimens from the locality below from 49 horizons (sample nos. 3147, 3160, 3162, 3163, 3166, 3167, 3169 to 3171, 3173 to 3175, 3177 to 3180, 3183 to 3193, 3197 to 3200, 3401 to 3404, 3407, 3409, 3410, 3415, 3417 to 3422, 3428, 3429, 3434 and 3435). GSP BM 2595–6.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Upper Rakhi Gaj Shales, sample no. 3166.

DESCRIPTION. *Carapace* subrectangular in the male dimorph and sub-quadrate in the female. Sexual dimorphy apparent, the males being larger in proportion to the females. Dorsal and ventral margins subparallel (undulating in lateral view because of surface ornamentation). Anterior margin broadly rounded, posterodorsal margin almost straight, posterior extremity somewhat rounded, posterodorsal margin curved. Greatest height at anterior cardinal angle and greatest length in the middle. Valves more or less equal. *Eye-tubercle* lobate and prominent situated just below a well-developed anterior cardinal angle. Posterior cardinal angle well-marked in the left valve, armed with a node or short spine pointing upwards. *Subcentral-tubercle* distinct. Both anterior and posterior margins ornamented with a double row of tubercles or very short spines. Surface tuberculate or nodose (occasionally tubercles or nodes develop into spines). Anterior and posterior marginal rim more or less distinct. *Hinge* holamphidont : left valve with terminal sockets, postjacent conical tooth and median denticulate bar ; right valve hinge complimentary (anterior tooth being conical). *Duplicature* of moderate width with a submarginal *selvage*. Other internal details not determinable.

DIMENSIONS (mm).

		L	H	W
Io. 4308	Carapace male	0·61	0·34	0·24
Io. 4364	Carapace female (holotype)	0·59	0·35	0·28

COMPARISON. *T. lobuculus* is probably related to *Cythereis spinellosa* Lubimova and Guha (1960) but differs in having a lobate eye-tubercle and a different lateral outline and surface ornamentation.

REMARKS. Specimens of *Cythereis spinellosa* Lubimova and Guha were not available for comparison, but from the description and figure given by these authors it appears that the eye-tubercle in that particular species is not lobate.

Trachyleberis (Trachyleberis) bimammillata sp. nov.

(Plate 40, figs. 2, 4–11)

DERIVATION OF NAME. Latin *bimammillata*, two-breasted ; with reference to the split subcentral-tubercle.

DIAGNOSIS. A small species of the subgenus *Trachyleberis* in which subcentral-tubercle is divided into two horizontally disposed nodes and posterodorsal process consisting of two vertically arranged nodes.

HOLOTYPE. Io. 4363, a male carapace (Pl. 40, figs. 2, 8, 10).

PARATYPES. Io. 3155–9.

MATERIAL. 42 specimens from the Rakhi Nala section from 5 horizons (sample nos. 3610, 3613 to 3615 and 3617). 7 specimens from the Zao River section from two horizons (sample nos. 24150 and 24152). GSP BM 2597.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 3613.

DESCRIPTION. *Carapace* subrectangular to subquadrate in lateral outline. Sexual dimorphism moderate ; the presumed males are longer and less high than the females. Dorsal and ventral margins straight and tapering towards the posterior. Anterior margin broadly rounded, posterodorsal slope very slightly concave, posterior extremity rounded, posterodorsal margin somewhat rounded. Anterior, posterior and ventral margins decorated with a double row of short spines, but dorsal margin with only one row of very short spines (these in some specimens almost look like pustules). Greatest height at the anterior cardinal angle (which is obtuse and angular) and greatest length through the mid-point. In dorsal view the greatest width lies at the anterior node of the subcentral-tubercle. Valves almost equal. *Eye-tubercle* rounded and distinct. *Subcentral-tubercle* divided into two nodes, horizontally arranged, the anterior one being larger (spinose in some specimens). The posterodorsal process consists of two nodes (spines in some specimens), which are vertically disposed. In a few specimens a posteroventral node is also present. Surface ornamented with scattered tubercles and spines. *Duplicature* fairly wide. The *selvage* is subperipheral and well-developed in both valves. *Radial pore canals* not seen because of mineralization. The *adductor muscle scars* are in an oblique row of four at the posterior margin of the subcentral pit. The *frontal scar* is large and U-shaped and opens towards the anterodorsal corner. *Hinge* holamphidont with the following details :—

Element	Left valve	Right valve
Anterior	Socket.	Projecting subconical tooth.
Anteromedian	Subconical tooth.	Socket.
Posteromedian	Denticulate ridge.	Locellate groove.
Posterior	Fairly deep socket.	Tooth, subpessular in dorsal view.

DIMENSIONS (mm).

		L	H	W
Io. 4363	Carapace male (holotype)	0·52	0·29	0·22
Io. 3159	Carapace female	0·50	0·29	0·24
Io. 3158	Left valve male (broken)	—	0·29	—
Io. 3156	Left valve female	0·50	0·29	—
Io. 3155	Right valve female	0·49	0·29	—
Io. 3160	Carapace male	0·54	0·29	0·22
Io. 3157	Carapace female	0·49	0·29	0·24

COMPARISON. This species can easily be distinguished from *Trachyleberis* (*Trachyleberis*) *lobuculus* sp. nov. by its smaller size, slightly concave posterodorsal margin and split subcentral-tubercle. Further, *Trachyleberis* (*Trachyleberis*) *bimammillata* has a posterodorsal process consisting of two nodes in a vertical row and lacks a lobate eye-tubercle.

Subgenus *ACANTHOCYTHEREIS* Howe 1963

TYPE SPECIES. *Acanthocythereis araneosa* Howe 1963.

Trachyleberis (Acanthocythereis) procapsus sp. nov.

(Plate 40, figs. 12, 13 ; Plate 41, figs. 1, 3, 4)

DERIVATION OF NAME. Latin *procapsus*, anterior cage ; with reference to the smooth walled area enclosed behind the anterior marginal rim.

DIAGNOSIS. *Acanthocytheris* in which a smooth walled area lies behind the anterior marginal rim, anterior and posterior platforms compressed.

HOLOTYPE. Io. 4360, a male carapace (Pl. 40, fig. 12 ; Pl. 41, figs. 1, 3).

PARATYPE. Io. 3164.

MATERIAL. Six specimens from the locality below from two horizons (sample nos. 460-j and 460-i). GSP BM 2598.

TYPE LOCALITY. Sor Range section.

TYPE HORIZON. Upper Palaeocene, sample no. 460-j.

DESCRIPTION. Sexual dimorphism apparent ; the males are longer in proportion to the females. *Carapace* elongate, subrectangular in lateral outline with dorsal and ventral margins almost straight, tapering towards the posterior. Anterior margin broadly rounded, posterior subtriangular. Anterior cardinal angle rounded. Left valve over-reaches the right very slightly at the posterodorsal margin. Greatest height through the anterior cardinal angle and greatest length through the mid-point. In dorsal view the greatest width is situated at the anterior third. *Subcentral-tubercle* distinct. *Eye-tubercle* rounded and distinct and lies at the anterior cardinal angle. Surface reticulate (reticulae joined by walls or pustules or papillae). Posterodorsal process consists of small more or less rounded protuberances. Anterior and posterior margins ornamented by a double row of short spines. Anterior and posterior marginal rims high with a smooth walled area behind. Internal details not known.

DIMENSIONS (mm).

		L	H	W
Io. 4360	Carapace male (holotype)	0·68	0·32	0·20
Io. 3164	Carapace female	0·59	0·30	0·20

COMPARISON. This species is distinguishable from *Trachyleberis* (*Acanthocythereis*) *usitata* sp. nov. by its deeper reticulation, more elevated marginal rims and spinose anterior and posterior margins.

The present species has already been compared with *Trachyleberis* (*Acanthocythereis*) *postcornis* sp. nov. and *Trachyleberis* (*Acanthocythereis*) *decoris* sp. nov.

REMARKS. *T.* (*A.*) *procapsus* has so far only been recovered from the Upper Palaeocene of the Sor Range section.

Trachyleberis (Acanthocythereis) usitata sp. nov.

(Plate 41, figs. 2, 5, 7)

DERIVATION OF NAME. Latin *usitatus*, usual.

DIAGNOSIS. Carapace tapering towards posterior. Subcentral-tubercle distinct. Surface reticulate with superimposed pustules and a posterodorsal process.

HOLOTYPE. Io. 4362, a male carapace (Pl. 41, fig. 2).

PARATYPE. Io. 3161.

MATERIAL. Five specimens from the Rakhi Nala section from four horizons (sample nos. 3111, 3130, 3132 and 3133). GSP BM 2599.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Gorge Beds, sample no. 3111.

DESCRIPTION. Sexual dimorphy present ; the males are longer in proportion to the females. *Carapace* elongate, subrectangular, tapering towards the posterior. Anterior margin broadly rounded, posterior narrowly rounded. Dorsal and ventral margins almost straight. Greatest height at the anterior cardinal angle which is well-developed in the left valve. Greatest length passes through mid-point. Valves almost equal. In dorsal view greatest width lies in the anterior third (in the region of the subcentral-tubercle). *Eye-tubercle* rounded and distinct. *Subcentral-tubercle* fairly distinct. Anterior and posterior marginal rims sharply defined. Surface reticulate with pustules at reticulae intersections. A posterodorsal process in the form of more or less rounded tubercle of medium size present. A double row of pustules decorates anterior and posterior margins. Internal characters not known.

DIMENSIONS (mm).

		L	H	W
Io. 4362	Carapace male (holotype)	0·63	0·32	—
Io. 3161	Carapace female	0·59	0·32	0·22

COMPARISON. This species shows some resemblance to *Trachyleberis* (*Acanthocythereis*) *decoris* sp. nov. but is smaller, has marginal pustules rather than spines and carapace more tapering towards the posterior. *Trachyleberis* (*Acanthocythereis*) *postcornis* has a characteristic posterodorsal process, more high marginal rims and spinose anterior and posterior margins.

REMARKS. In some specimens the posterodorsal process is not well-developed.

Trachyleberis (Acanthocythereis) pedigaster sp. nov.

(Plate 41, figs. 6, 8)

DERIVATION OF NAME. Greek *pedigaster*, flat belly ; with reference to the ventral inflation.

DIAGNOSIS. A large species of the subgenus with ventral inflation. Carapace tapering towards posterior. Posterior margin subtriangular.

HOLOTYPE. Io. 4358, a carapace.

MATERIAL. Only one specimen from the locality and horizon below.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Lower Rakhi Gaj Shales, sample no. 3671.

DESCRIPTION. *Carapace* large, elongate, tapering towards posterior and with ventral inflation. Anterior and posterior marginal platforms compressed. Dorsal and ventral margins almost straight, anterior margin broadly rounded, posterior subtriangular. Anterior and posterior cardinal angles well-developed particularly in the left valve. Left valve slightly larger than the right, which it over-reaches in the region of the anterodorsal corner and posterodorsal slope. *Eye-tubercle* rounded and distinct and lies just below the anterior cardinal angle. *Subcentral-tubercle* more or less distinct. Greatest height through the anterior cardinal angle, greatest length below mid-point and greatest width a little posterior to the middle. Surface ornamentation consists of reticulations with superimposed papillae. The posterodorsal process consists of two almost rounded small tubercles (or papillae) joined together in the left valve and one small rounded tubercle in the right. Anterior and posterior marginal rims fairly distinct. Anterior and posterior margins ornamented with a double row of papillae. Internal details unknown.

DIMENSIONS (mm).

		L	H	W
Io. 4358	Carapace (holotype)	1·02	0·51	—

COMPARISON. There is no difficulty in separating *T.* (*A.*) *pedigaster* sp. nov. from other described species of the subgenus *Acanthocythereis* by its large carapace and subtriangular posterior.

Trachyleberis (Acanthocythereis) postcornis sp. nov.

(Plate 41, figs. 9, 10; Pl. 42, figs. 1, 2, 7, 10)

DERIVATION OF NAME. Latin *post*, posterior + *cornis*, horned ; with reference to the posterodorsal process.

DIAGNOSIS. A species of the subgenus *Acanthocythereis* with distinct subcentral-tubercle and eye-tubercle. Surface reticulate with small superimposed spines. Posterodorsal process divided into two spines.

HOLOTYPE. Io. 4361, a male carapace (Pl. 42, figs. 1, 2, 7, 10).

PARATYPES. Io. 4309+3162–4.

MATERIAL. 45 specimens from the locality below from two horizons (sample nos. 3498 and 3499) and 3 specimens from the Zao River section from two horizons (sample nos. 24131 and 24148). GSP BM 2600.

TYPE LOCALITY. Rakhi Nala section.

TYPE HORIZON. Lower Chocolate Clays, sample no. 3499.

DESCRIPTION. *Carapace* elongate, subrectangular in lateral outline with dorsal and ventral margins straight, tapering towards the posterior. Anterior margin broadly and evenly rounded, posterior slightly sub-triangular in right valve but almost rounded in the left, posterodorsal margin very slightly concave. Anterior and posterior cardinal angles well-developed. Sexual dimorphism rather strong ; the presumed males are longer, less high and less wide than the females. Valves almost equal. In dorsal view greatest width lies at the anterior third (in the region of the subcentral-tubercle). *Eye-tubercle* rounded, polished and prominent (standing out from the carapace). *Subcentral-tubercle* distinct. Surface ornamentation consists of combination of reticulations and small spines. The posterodorsal process is divided into two spines (although in some specimens this division is not detectable). In a few specimens a posteromedian process is also developed. The anterior and posterior margins are decorated with a double row of spines ; the second row lies on high anterior and posterior marginal rims. The posterior marginal spines are larger and less in number. *Duplicature* fairly wide. *Selvage* prominent and submarginal. *Radial pore canals* not clearly displayed because of mineralization, but appear to be simple, more or less straight with median swellings, 30–35 anteriorly. *Hinge* holamphidont :

Element	Left valve	Right valve
Anterior	Socket.	Stirpate tooth.
Anteromedian	Subconical tooth.	Deep socket.
Posteromedian	Locellate shallow groove.	Denticulate bar.
Posterior	Deep socket.	Tooth, almost rounded in lateral view.

DIMENSIONS (mm).

		L	H	W
Io. 4361	Carapace male (holotype)	0·62	0·30	0·22
Io. 3162	Carapace female	0·52	0·29	0·21
Io. 3164	Right valve male	0·61	0·29	—
Io. 3163	Right valve female	0·50	0·28	—

COMPARISON. The present species shows some affinity to *Trachyleberis* (*Acanthocythereis*) *decoris* sp. nov. but is shorter, less high and less wide. These two species also differ in surface ornamentation. *T.* (*A.*) *postcornis* has a combination of reticulations and small spines, while *T.* (*A.*) *decoris* is reticulate with superimposed pustules. Further, *T.* (*A.*) *postcornis* has a well-developed posterodorsal process divided into two spines and a distinct subcentral-tubercle. This species may also be distinguished from *T.* (*A.*) *procapsus* sp. nov. in being smaller and lacking a smooth walled area behind the anterior marginal rim. These two species also differ in dorsal outline.

Trachyleberis (Acanthocythereis) decoris sp. nov.

(Plate 42, figs. 3–6, 8, 9)

DERIVATION OF NAME. Latin *decoris*, beautiful, adorned ; with reference to the bejewelled appearance of the pustules and reticulae.

DIAGNOSIS. *Acanthocythereis* in which surface ornamentation consists of reticulations with superimposed pustules. Carapace subrectangular with dorsal and ventral margins almost straight and subparallel.

HOLOTYPE. Io. 4359, a male carapace (Pl. 42, figs. 3, 4, 5).

PARATYPE. Io. 4310.

MATERIAL. Over 250 specimens from the type locality from 18 horizons (sample nos. 3604, 3607, 3610, 3613 to 3615, 3629, 3640, 3642, 3645, 3648 to 3650, 3661 to 3664). 7 specimens from the Zao River section from 3 horizons (sample nos. 24154, 24173 and 24193). GSP BM 2601–2.

TYPE SECTION. Rakhi Nala section.

TYPE HORIZON. Upper Chocolate Clays, sample no. 3640.

DESCRIPTION. Sexual dimorphism rather marked ; the males are longer in proportion than the females. *Carapace* subrectangular in lateral view with dorsal and ventral margins almost straight and subparallel. Anterior margin broadly and evenly rounded, posterior slightly subtriangular. Both anterior and posterior margins ornamented by a double row of short spines, the posterior ones being larger. Anterior cardinal angle rounded, posterior cardinal angle well-marked. Greatest height at the anterior cardinal angle and greatest length in the middle. In dorsal view greatest width lies in the anterior third. Valves almost equal. Surface reticulate with superimposed pustules. *Eye-tubercle* rounded and distinct. *Subcentral-tubercle* more or less distinct (better seen in slightly worn specimens). A large number of specimens (particularly the females) show development of posteroventral prominence. In a few specimens a small posterodorsal process also develops, but these characters here are regarded as variations within the species. *Duplicature* fairly wide with a submarginal *selvage*. *Radial pore canals* not seen. *Muscle scar* pattern consists of four adductors in a vertical superposition at the posterior margin of the muscle scar pit with a U-shaped frontal scar opening towards the anterodorsal corner. *Hinge* holamphidont :

Element	Left valve	Right valve
Anterior	Socket.	Slightly stirpate tooth.
Anteromedian	Subconical tooth.	Denticulate ridge.
Posterior	Deep socket.	Somewhat rounded tooth in lateral view.

DIMENSIONS (mm).

		L	H	W
Io. 4359	Carapace male (holotype)	0·67	0·32	0·24
Io. 4310	Carapace female	0·59	0·32	0·23

COMPARISON. In some respects this species resembles *Trachyleberis* (*Acanthocythereis*) *procapsus* sp. nov., but differs in lacking the smooth walled area enclosed by the anterior marginal rim and compressed anterior and posterior marginal platforms. These two species also differ in size, *T.* (*A.*) *decoris* being smaller, higher and wider in proportion than *T.* (*A.*) *procapsus*.

REMARKS. This species commonly occurs in the Upper Chocolate Clays of the Rakhi Nala section but it is very rare in the Zao River section.

V. OSTRACODA AND EARLY TERTIARY CORRELATION IN THE SULAIMAN RANGE

(a) Biostratigraphic Units

Throughout the succession the ostracods have revealed a fairly shallow-water marine environment. Although Eames (1952a) has recorded small freshwater gastropods in the lower part of the Lower Chocolate Clays (in his local zones 8 & 9) of the Rakhi Nala section, he believes they were carried down from a closely neighbouring source and deposited under estuarine conditions. No freshwater ostracods have been found, however, and the presence of *Neocyprideis* sp. in the Shales with Alabaster could represent either estuarine or super saline conditions.

Except for a few gaps, ostracods occur throughout almost the whole succession. At many horizons, particularly in the Eocene, samples are completely crowded with ostracods. The diversity of the fauna being suggestive of ideal conditions. They usually occur in association with larger and smaller benthonic Foraminifera, but are very rare or almost absent in samples with rich pelagic Foraminifera. The most conspicuous gap in the Eocene succession of the Rakhi Nala and Zao River sections which has not yielded any ostracods is the Platy Limestone and the lower part of the Lower Chocolate Clays. In the Zao River section the top 600 ft. of the Upper Chocolate Clays are devoid of any recognizable ostracods, although at a few horizons some *Nummulites* have been found.

Rakhi Nala Section

The following ostracod biostratigraphic units in the Rakhi Nala section have been recognized (see Table 4). Each unit is identified by a distinct ostracod fauna, a change of faunal suite marking the base.

Ostracod Biostratigraphic Unit I, Palaeocene (lower part)

The first Tertiary ostracod assemblage is encountered in the lower part of the Gorge Beds (samples from the *Venericardia* Shales were not available for study). Seven out of the eight species recorded are restricted to the unit. The species which ranges up into Unit II is *Trachyleberis* (*Acanthocythereis*) *usitata* sp. nov. *Alocopocythere rupina* sp. nov., *Neocyprideis* ? sp.A and *Bairdia* sp.A are abundant and make up over 80% of the ostracod fauna.

Ostracod Biostratigraphic Unit II, Palaeocene (upper part)

This Unit contains the Lower Rakhi Gaj Shales. Ostracods are very rare and have only been found in the upper part which is very rich in pelagic Foraminifera. The ostracods, although very rare, are easily distinguishable from the assemblages below and above. Of the eight species found, all are restricted to the present Unit, with the exception of *Trachyleberis* (*Acanthocythereis*) *usitata* sp. nov. which is also present in the underlying Unit.

Ostracod Biostratigraphic Unit III, Lower Eocene (lower part)

This includes the Upper Rakhi Gaj Shales, Green and Nodular Shales and Rubbly Limestones. Eames' local zones 3, 4, 5 and 6 lie in this Unit.

This is the first Eocene ostracod assemblage. It is fairly rich and at several horizons the ostracods are very abundant. None of the Palaeocene species survive and a completely new fauna evolves. The ostracod fauna is of changing suite ; species appear and disappear in the unit, but there seems to be no major break of any kind in the fauna. *Trachyleberis* (*Trachyleberis*) *lobuculus* sp. nov., *Gyrocythere parvicarinata* sp. nov., *Occultocythereis peristicta* sp. nov. (with five morphotypes), *Schizocythere* sp.A and *Pontocythere* sp.A are the most important members restricted to the unit. Approximately 50% of the species range up into the overlying Unit IV.

Ostracod Biostratigraphic Unit IV, Lower Eocene (*upper part*)

This consists of the Shales with Alabaster and includes Eames' local zone 7. It has a very rich ostracod faunal assemblage. Most of the samples studied were extremely rich in ostracods, which are mostly complete carapaces. The most typical species confined to the unit are *Stigmatocythere obliqua* sp. nov., *Phalcocythere dissenta* sp. nov. Genus C sp. 1 and Genus C sp. 2. More than 50% of the species are restricted to the unit, although approximately 44% are common to Unit III, and only one species ranges up into Unit V.

Ostracod Biostratigraphic Unit V, Middle—Upper Eocene

This comprises the Platy Limestone, Lower Chocolate Clays, Upper Chocolate Clays and *Pellatispira* Beds. Eames' local zones 8 to 15 and Latif's top six pelagic foraminiferal zones occur in this unit. The lowest 730 ft., which form the Platy Limestone and most of the Lower Chocolate Clays, excluding the top 30 ft., are devoid of any recognizable ostracods and are provisionally included in the unit. There are 200 ft. of covered sediments in the Lower Chocolate Clays below sample 3494.

The Unit is very rich in very well-preserved ostracods. It differs markedly from the underlying Unit. All the species except *Alocopocythere transcendens* sp. nov., which survives from the Unit below, appear for the first time, although a few have their ancestors in the Unit IV. The first appearance of ostracods in the Unit is in the uppermost part of the Lower Chocolate Clays (sample nos. 3498 and 3499), which lies at the base of the *Globigerina yeguaensis* zone of Latif. The ostracod fauna is varied and of changing suite. 12% of the species are restricted to the Lower Chocolate Clays (topmost portion) ; 25% are confined to the Upper Chocolate Clays (lower part) ; and only 8% have been recorded from the *Pellatispira* Beds. 33% of the species are shared between the Lower Chocolate Clays (topmost portion) and Upper Chocolate Clays (lower part) ; 17% range from the Lower Chocolate Clays (uppermost part) to the Upper Chocolate Clays (upper part) ; 37% are shared between the Upper Chocolate Clays (lower part) and Upper Chocolate Clays (upper part) ; 8% range from the Upper Chocolate Clays (lower part) to the *Pellatispira* Beds ; and 12% are found in both the Upper Chocolate Clays (upper part) and *Pellatispira* Beds. (The percentages are approximate and are based on the entire ostracod fauna of the Unit).

The genus *Alocopocythere* nov. occurs abundantly almost throughout the Unit.

Alocopocythere transcendens sp. nov., which ranges up from the underlying Units III and IV, is replaced by *A. transversa* sp. nov. just above the middle of the lower part of the Upper Chocolate Clays. This last species has several morphotypes ; in the upper part of the Upper Chocolate Clays the papillose form becomes more common and in the *Pellatispira* Beds this is the only morphotype present. *Stigmatocythere obliqua* sp. nov., which was very abundant in the underlying biostratigraphic Unit IV, is replaced by the larger *Stigmatocythere portentum* sp. nov., which has only been found in the uppermost part of the Lower Chocolate Clays. Higher up in the succession, i.e. in the lower part of the Upper Chocolate Clays the place of *S. portentum* is taken by *Stigmatocythere lumaria* sp. nov. which ranges up into the *Pellatispira* Beds. The genera *Cytherella, Cytherelloidea, Krithe,* and *Paijenborchella* are represented by several species. The genus *Gyrocythere* nov. has two species in the Unit. *Gyrocythere perfecta* sp. nov. occurs in the uppermost part of the Lower Chocolate Clays but in the lower part of the Upper Chocolate Clays it is replaced by the larger *Gyrocythere exaggerata* sp. nov. The subgenera *Scelidocythereis* nov. and *Paracosta* nov. are represented by two and three species respectively. *Paracosta* is known so far only from this Unit. The following are some of the most important species of the Unit : *Bairdoppilata* sp.A, *Cytherelloidea* cf. *C. costatruncata* Lubimova and Mohan, *Cytheromorpha* sp.A, *Cytheropteron* sp.D, *Alocopocythere transversa* sp. nov. (with six morphotypes), *Patagonacythere* ? *nidulus* sp. nov., *Stigmatocythere lumaria* sp. nov. (with two morphotypes) and *Trachyleberis* (*Acanthocythereis*) *decoris* sp. nov.

Zao River Section

The two biostratigraphic Units IV and V of the Rakhi Nala section are found in the Zao River section (see Table 5).

Ostracod Biostratigraphic Unit IV, Lower Eocene (upper part)

This is very similar to biostratigraphic Unit IV of the Rakhi Nala section. The base of the Unit has been taken arbitrarily at the base of the four foot limestone, which lies 332 ft. below the base of the Platy Limestone. The actual base of the Unit, or the Shales with Alabaster, probably lies much lower in the succession, but sediments below the 4 ft. limestone have not been analysed. These have been recorded as the undifferentiated Ghazij by the collectors. No megafossils have so far been recorded from these sediments and it is unlikely that these would yield any smaller foraminifera or ostracods because of their lithology—mostly silty shales.

Ostracods have been found in the upper part of the Unit at two horizons (samples 24107 and 24110). They are extremely abundant in 24107. Approximately half of the Rakhi Nala species of the Unit are found in the Zao River section. None of the species range up into Unit V. *Stigmatocythere obliqua* sp. nov. is the most dominant species and makes about one-third of the ostracod fauna. *Neocyprideis* ? sp.B, *Neocyprideis* sp.C, *Pontocyprella* sp.B, *Pontocyprella* sp.C, *Xestoleberis* sp.C, *Xestoleberis* sp.D, *Xestoleberis* sp.E, Genus C sp.1 and Genus C. sp.2 are some other important species.

Ostracod Biostratigraphic Unit V, Middle-Upper Eocene

The biostratigraphic Unit V of the Rakhi Nala section occurs in the Zao River and is 3743 ft. thick. The Unit includes the Platy Limestone, Lower Chocolate Clays and both lower and upper parts of the Upper Chocolate Clays. The *Pellatispira* Beds have not been recorded in the Zao River section. The bottom 460 ft. of the Unit comprising the Platy Limestone and the lower part of the Lower Chococlate Clays and the top 600 ft. of the upper part of the Upper Chocolate Clays have not yielded any ostracods and are only provisionally included in the Unit.

The Unit is very rich in well-preserved ostracods. The ostracod fauna is completely new since none of the species from the Unit below survive. There are 7% of the species which are restricted to the upper part of the Lower Chocolate Clays ; 26% have only been found in the lower part of the Upper Chocolate Clays ; and 17% have been recorded from the upper part of the Upper Chocolate Clays only. 24% of the species occur in the upper part of the Lower Chocolate Clays and the lower part of the Upper Chocolate Clays ; 13% range from the upper part of the Lower Chocolate Clays to the upper part of the Upper Chocolate Clays and 41% are shared between the lower and upper parts of the Upper Chocolate Clays.

The ostracod fauna of the Unit in the Zao River section is very similar to that of the Rakhi Nala section. It has about 74% of its species in common with the Rakhi Nala. These are shown in Appendix 2. As in the Rakhi Nala, *Alocopocythere* is one of the commonest genera and it occurs in great abundance at several horizons. It is represented by three related species ; *A. transcendens* sp. nov., *A. transversa* sp. nov. (with six morphotypes), and *A. radiata* sp. nov. *Stigamatocythere* is another common genus and has three species in the Unit : *S. calia* sp. nov., *S. delineata* sp. nov. and *S. lumaria* sp. nov. (with two morphotypes). Among these, *S. lumaria* is the commonest, occurring in the lower and upper parts of the Upper Chocolate Clays. *S. calia* and *S. delineata* have so far not been found in the Rakhi Nala section. *Bairdoppilata* sp.A, *Pterygocythereis* (*Pterygocythere*) sp.A are more common in the Zao River section. *Trachyleberis* (*Acanthocythereis*) *decoris* sp. nov. and *Cytheromorpha* sp.A, which were very common in the Rakhi Nala are rare in the Zao River. The subgenus *Paracosta* nov. which is represented by three species in the Rakhi Nala has not so far been recorded from the Zoa River. *Phalcocythere spinosa* sp. nov. and *Quadracythere* (*Hornibrookella*) *subquadra* sp. nov. have only been found in sample 24161 of the Zao River section, where they occur in association with the larger foraminifera *Pellatispira orbitoidea*. Some of the more important members of the unit are : *Alocopocythere transcendens* sp. nov., *Alocopocythere transversa* sp. nov., *Bairdoppilata* sp.A, *Cytherelloidea* cf. *C. costatruncata* Lubimova and Mohan, *Patagonacythere* ? *nidulus*, sp. nov. and *Stimatocythere lumaria* sp. nov.

SHPALAI KHWARA SECTION

The ostracod biostratigraphic Unit IV of the Rakhi Nala and Zao River sections is also represented in the Shpalai Khwara section.

Ostracod Biostratigraphic Unit IV, Lower Eocene (upper part)

Like the Zao River section, the base of the Unit is taken arbitrarily at the base of the 4 ft. limestone, which is 320 ft. below the base of the Platy Limestone. The Platy Limestone is only 40 ft. thick in this section. The 12,450 ft. thick sediments below the 4 ft. limestone are barren except for a few horizons which contain poorly preserved pelagic Foraminifera. These probably represent the following lithological units in ascending order : Upper Rakhi Gaj Shales, Green and Nodular Shales, Rubbly Limestones and lower part of the Shales with Alabaster.

Only the upper part of the Unit has yielded ostracods and the fauna is similar to that of the Zao River and Rakhi Nala sections. About 70% of its species are in common with the Zao River section. Over 40% of the species of the Unit in the Rakhi Nala have been recorded from the Shpalai Khwara section. *Stigmatocythere obliqua* sp. nov. is very abundant, particularly in sample 24686, which is absolutely crowded with this species. Some other common species are : *Neocyprideis* ? sp. B, *Pontocyprella* sp.B, *Cytherella* sp.B, *Cytherella* sp. and Genus C sp.2.

(b) STATISTICAL CORRELATION OF RANGES OF OSTRACOD SPECIES COMMON TO THE RAKHI NALA AND ZAO RIVER SECTIONS.

The tops and bases of ostracod species common to the Rakhi Nala and Zao River sections have been plotted on a graph (Fig. 6). These fall into two rectilinear patterns, one in biostratigraphic Unit IV and the other in biostratigraphic Unit V.

The tops and bases of ostracod species in biostratigraphic Unit IV (i.e in the Shales with Alabaster) lie almost in a straight line on the graph ; this, however, is because ostracods have only been found at two horizons in the Zao River section. The Equations of Correlation for the array of biostratigraphic Unit V (i.e. above the Platy Limestone) can be computed from the data given in Appendix 2. This method has been discussed in detail by A. B. Shaw in his book 'Time in Stratigraphy', published in 1964. The points marked '+' in Appendix 2 have been omitted because they fall outside the main array. Eighty-one points have been considered. The Equations of Correlation between the Rakhi Nala and Zao River sections can be calculated as follows :

$$R\hat{N} = R\bar{N} + \frac{\Sigma(RN—R\bar{N})\ (ZR—Z\bar{R})}{\Sigma(ZR—Z\bar{R})^2}\ (ZR—Z\bar{R}), \text{ where } RN = \text{Rakhi Nala and}$$

$$ZR = \text{Zao River.}$$

$$= 6638 + \frac{21{,}675228}{48{,}697965}\ (ZR—2253)$$

$$= 0{\cdot}4451\ ZR + 5635\cdot 2 \qquad (1)$$

and

$$Z\hat{R} = Z\bar{R} + \frac{\Sigma(RN—R\bar{N})\ (ZR—Z\bar{R})}{\Sigma(RN—RN)^2}\ (RN—R\bar{N})$$

$$= 2253 + \frac{21{,}675228}{11{,}153941}(\text{RN}—6638)$$

$$= 1{\cdot}9433\ \text{RN}—10646 \cdot 5 \qquad (2)$$

Any point in the Zao River section in biostratigraphic Unit V can be correlated with the corresponding point in the Rakhi Nala section by means of Equation (1). Similarly any point in the Rakhi Nala section can be correlated with the corresponding point in the Zao River section by using Equation (2).

The Coefficient of Correlation is expressed by the formula :

$$r = \sqrt{b_1 \times b_2}$$

By substituting the values b_1 and b_2, we get

$$r = \sqrt{0{\cdot}4451 \times 1{\cdot}9433}$$
$$= \sqrt{0{\cdot}8649}$$
$$= 0{\cdot}930$$

This high value of r is above the 99% confidence level.

The standard error of estimate for $\hat{\text{RN}}$ ($S_{\hat{\text{RN}}}$)

$$= \sqrt{\frac{\Sigma(\text{RN}—\hat{\text{RN}})^2}{N}}$$

where RN—$\hat{\text{RN}}$ is the difference between each observed point and its computed equivalent and N is the number of entries.

Hence, $$S_{\hat{\text{RN}}} = \sqrt{\frac{1484288{\cdot}91}{81}}$$
$$= \sqrt{18324{\cdot}554}$$
$$= 135{\cdot}4 \text{ ft.}$$

The standard error of estimate for $\hat{\text{ZR}}$ ($S_{\hat{\text{ZR}}}$)

$$= \sqrt{\frac{(\text{ZR}—\hat{\text{ZR}})^2}{N}}$$
$$= \sqrt{\frac{6464244{\cdot}61}{81}}$$
$$= \sqrt{79805{\cdot}489}$$
$$= 282{\cdot}5 \text{ ft.}$$

When the two straight lines given by Equations (1) and (2) are drawn on a graph, they intersect one another at an angle of 3°. Since the Rakhi Nala section has been regarded as the standard section, therefore, for practical purposes only one straight

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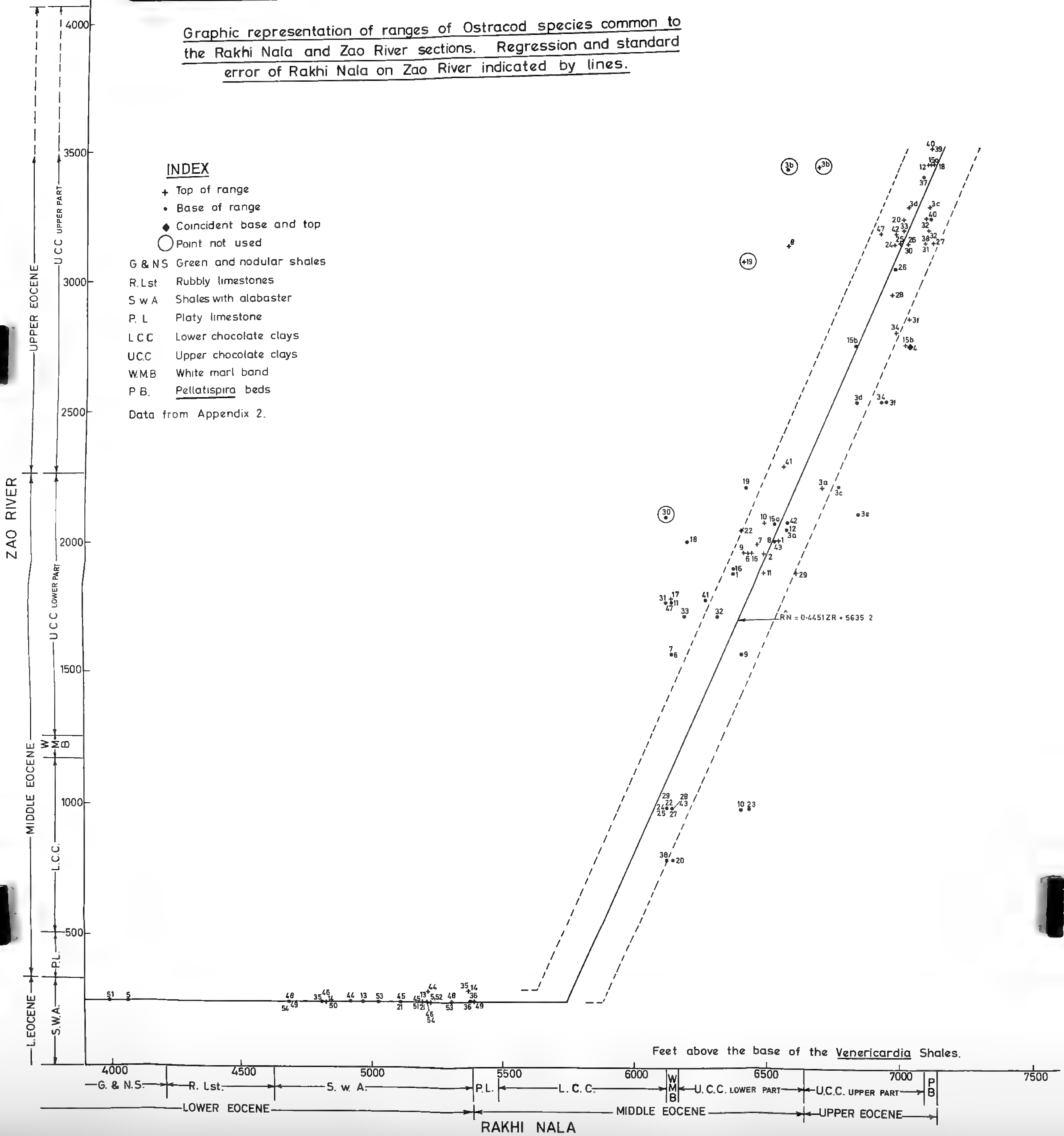

Graphic representation of ranges of Ostracod species common to the Rakhi Nala and Zao River sections. Regression and standard error of Rakhi Nala on Zao River indicated by lines.

FIG. 7

line (i.e. $\widehat{RN} = 0{\cdot}4451ZR + 5635{\cdot}2$) has been drawn on the graph. This is the Correlation or Regression Line of the Rakhi Nala on the Zao River with parallel dotted lines showing the standard error of estimate.

(c) CONCLUSIONS

The Palaeocene and Eocene of the Rakhi Nala section can be divided into five distinct biostratigraphic units on the basis of Ostracoda. Two of these Units, I and II, occur in the Palaeocene and three, III, IV and V, in the Eocene. Biostratigraphic Unit IV of the Rakhi Nala section is represented in the Zao River section by at least 332 ft., and Unit V by 3743 ft. The Units in the two sections have almost identical ostracod faunas. Biostratigraphic Unit IV of the Rakhi Nala is also represented in the Shpalai Khwara section by at least 320 ft.

The Equations of Correlation of biostratigraphic Unit V between the Rakhi Nala and Zao River sections have been calculated by means of ostracod species common to the two sections. From these two equations any point in one section can easily be correlated with the corresponding point in the other section or vice versa. (see Fig. 6). The standard error of estimate for the two equations has also been calculated. Since only the upper part of biostratigraphic Unit IV in the Zao River section has yielded ostracods, only this part of the unit can be correlated with any certainty.

Eames' lithological units for the southern Sulaiman Range (Rakhi Nala and Zinda Pir) extend into the northern part of the Sulaiman Range (Zao River and Shpalai Khwara). This is particularly true for sediments from the Shales with Alabaster (upper Lower Eocene) to the upper part of the Upper Chocolate Clays (upper Eocene). Sediments below the upper part of the Shales with Alabaster of the Shpalai Khwara section are unfossiliferous except for a few horizons containing poorly preserved pelagic foraminifera. These are 12,450 ft. thick and are probably equivalent to Eames' Upper Rakhi Gaj Shales, Green and Nodular Shales, Rubbly Limestones and lower part of the Shales with Alabaster. In the Zao River section sediments below the upper part of the Shales with Alabaster are undifferentiated and are probably unfossiliferous. This suggests that environmental conditions in the northern Sulaiman Range during most of the Early Eocene were not suitable for abundant marine life.

The faunal breaks in the sections studied do not always coincide with Eames' lithological subdivisions. For example, the Upper Rakhi Gaj Shales, Green and Nodular Shales and Rubbly Limestones have a similar ostracod fauna and are regarded as one ostracod biostratigraphic unit. Another example is in the Kirthar Formation where a new fauna appears before a change in lithology. This occurs in the uppermost part of the Lower Chocolate Clays (i.e. just below the White Marl Band). Most of the species range from the uppermost part of the Lower Chocolate Clays to the lower part of the Upper Chocolate Clays, although the White Marl Band lies in between.

The Palaeocene/Lower Eocene boundary in the Rakhi Nala section has been drawn at the base of the *Nummulites irregularis* Limestone of Eames and Nagappa.

(Bayliss, however, identified this as *Nummulites crasseornata* (Henrici) form B.) This is in agreement with Eames, Bayliss and Latif. The ostracod faunal assemblages below and above the *irregularis* Limestone are completely different and have no species in common. These assemblages have been included in ostracod biostratigraphic Units II and III respectively. The Palaeocene and Lower Eocene boundary in fact has been placed between these two biostratigraphic units. The ranges of ostracod species found in the two biostratigraphic units are shown in Appendix 2.

The Shales below the *irregularis* Limestone have a very rich assemblage of pelagic Foraminifera and have been assigned to the *Globrotalia rex* Zone by Latif. Dr. Banner, lately of the British Petroleum Co. Ltd., who very kindly examined these samples, considers them to be of the high *Globorotalia rex* Zone with derived Lower/ Middle Palaeocene pelagic Foraminifera.

The Lower/Middle Eocene boundary in the Rakhi Nala, Zao River and Shpalai Khwara sections has been placed at the base of the Platy Limestone. This is in conformity with Eames, who examined the Rakhi Nala and Zinda Pir sections of the Sulaiman Range. Bayliss and Latif, who worked on the Rakhi Nala section, however, have drawn the boundary in the uppermost part of the Lower Chocolate Clays (i.e. below sample 3498). The Platy Limestone serves as an important horizon marker in the region. The Lower/Middle Eocene boundary lies between ostracod biostratigraphic Units IV and V, which have very different ostracod assemblages. Except for *Alocopocythere transcendens* sp. nov., none of the Lower Eocene ostracod species survive into the Middle Eocene.

The Middle/Upper Eocene boundary in the Rakhi Nala and Zao River sections has been placed between the lower and upper parts of the Upper Chocolate Clays. The upper part of the Upper Chocolate Clays contains the genus *Pellatispira,* which is of Upper Eocene age. In the Rakhi Nala section the boundary is taken arbitrarily between samples 3627 and 3628. This is approximately the same level as drawn by Eames (1952), who recorded the first appearance of *Pellatispira* just above this horizon in the section. Bayliss, however, recorded *Pellatispira* only from one horizon (sample 3657) in the *Pellatispira* Beds. Latif has placed the boundary in the middle of his *Chiloguembelina* aff. *martini* Zone (i.e. above sample 3618). In the Zao River section sample 24161 contains specimens of *Pellatispira* in abundance. These have been assigned to *Pellatispira orbitoidea* (Povale) *sensu* Rao 1941 by Dr. C. G. Adams of the British Museum (personal communication), who very kindly examined these specimens. According to Dr. Adams these fall midway between *P. orbitoidea* and *P. madaraszi* var. *indica.* The Middle/Upper Eocene boundary in the Zao River section can, therefore, safely be placed below sample 24161.

The Middle and Upper Eocene ostracod fauna of the Rakhi Nala and Zao River sections is of changing suite and has been included in ostracod biostratigraphic Unit V. It does not show any sharp break between the Middle and the Upper Eocene. Some species are restricted to the Middle Eocene, but others range from the Middle to the Upper Eocene. Some of the important species restricted to the Middle Eocene are : *Actinocythereis* ? *quasibathonica* sp. nov., " *Anommatocythere* " *confirmata* sp. nov., *Echinocythereis* (*Scelidocythereis*) *rasilis* sp. nov., *Cytheropteron* sp.C, *Gyrocythere exaggerata* sp. nov., *Trachyleberis* (*Trachyleberis*) *bimammillata* sp. nov. Some of the common species which range from the Middle to the Upper Eocene are : *Alocopocythere transversa* sp. nov., *Bairdoppilata* sp.A, *Cytherelloidea* cf. *C. costatruncata* Lubimova and Mohan, *Cytheromorpha* sp.A, *Cytheropteron* sp.D, *Paijenborchella* sp.C, *Patagonacythere* ? *nidulus* sp. nov., *Pterygocythereis* (*Pterygocythere*) sp.A and *Stigmatocythere lumaria* sp. nov. (A complete list of these species is given in Tables 4 & 5).

VI. APPENDICES

APPENDIX I

SOR RANGE LEASE 58, MEASURED SECTION AT LOCALITY 460.
SECTION MEASURED BY J. A. REINEMUND.

Thickness (feet)	Description of Unit	Sample No.
10+	Claystone, grey	
42	Conglomerate containing limestone and chert pebbles, cobbles, boulders as much as 8 in. across ; matrix of medium grained, yellowish brown sandstone forms about 20% of rock.	
42	Concealed by talus	
18	Claystone, medium grey, not fissile, semiplastic, containing scattered fossils. Calcareous nodules at top ; silty and carbonaceous in lower part.	460a (near top)
2–3	Sandstone, very fine grained to silty brownish-grey, imperfect and irregular bedding, contains carbonized plant fragments and vertical root moulds.	
24	Claystone, dark olive grey, not fissile, silty in upper few feet and lower few feet ; contains irregular coal layers as much as 4 in. thick in lower 2 ft.	460b (6–8 above bottom) 460c (3–4 feet above bottom)
7½	Sandstone, fine to very fine grained, light brownish grey, mostly even beds 2–8 in. thick, locally cross-bedded.	460d
2	Siltstone, poorly bedded, carbonaceous, containing very carbonaceous layers as much as ⅛ in. thick in top 2 in.	
1½	Claystone, silty, olive grey, not fissile, containing carbonised plant chips.	
5	Siltstone, brownish grey, imperfect beds, cross laminated.	
45	Claystone, silty at top, olive grey not fissile.	460e (5–6 feet above bottom) 460f (1–2 feet above bottom)

Thickness (feet)	Description of Unit	Sample No.
8	Claystone, containing profuse white calcareous concretions.	
2	Claystone, olive grey, fissile, grading down into siltstone, yellowish-brown, hard, fossiliferous.	460g (Channel sample)
50+	Claystone, slightly fissile, olive grey.	460h–o

APPENDIX 2

LIST OF OSTRACOD SPECIES COMMON TO THE RAKHI NALA AND ZAO RIVER SECTIONS

No.	Species	Rakhi Nala		Zao River	
		Base	Top	Base	Top
5	*"Anommatocythere" laqueta* sp. nov.	4045	5223	252	
13	*Phalcocythere dissenta* sp. nov.	4968	5195	252	
14	*Stigmatocythere obliqua* sp. nov.	4815	5373	252	294
21	*Cytherella* sp.C	5112	5195	252	
35	*Neocyprideis* ? sp.G	4815	5373	252	294
36	*Neocyprideis* sp.C	5373		252	294
44	*Xestoleberis* sp.C	4919	5208	252	294
45	*Xestoleberis* sp.D	5112	5195	252	
46	*Xestoleberis* sp.E	4815	5208	252	
48	*Genus C* sp.1	4687	5304	252	
49	*Genus C* sp.2	4687	5373	252	
50	*Bairdia* sp.C	3682+	4815	252	
51	*Bairdia* sp.D	3995	5195	252	
52	*Cytherella* sp.B	2687+	5223	252	
53	*Pontocyprella* sp.B	5023	5304	252	
54	*Pontocyprella* sp.C	4687	5208	252	
1	*Actinocythereis ? quasibathonica* sp. nov.	6369	6524	1872	1994
2	*Alocopocythere transcendens* sp. nov.	3215+	6488	650+	1948
3a	*A. transversa* sp. nov. Morphotype A	6575	6706	2032	2190
3b	*A. transversa* sp. nov. Morphotype B	6589+	6690	3384+	
3c	*A. transversa* sp. nov. Morphotype C	6764	7014	2190	3230
3d	*A. transversa* sp. nov. Morphotype D	6839	7–37	2504	3230
3e	*A. transversa* sp. nov. Morphotype E	6839	7107	2086	3186
3f	*A. transversa* sp. nov. Morphotype F	6943	7037	2504	2808
4	*A. radiata* sp. nov.	7029		2712	
6	*"Anommatocythere" confirmata* sp. nov.	6138	6424	1570	1948
7	*Echinocythereis (Scelidocythereis) rasilis* sp. nov.	6138	6463	1570	1986
8	*E. (S.) multibullata* sp. nov.	6531	6589+	1994	3095
9	*Gyrocythere exaggerata* sp. nov.	6401	6515	1570	1948
10	*Hermanites palmatus* sp. nov.	6401	6488	994	2060

No.	Species	Rakhi Nala		Zao River	
		Base	Top	Base	Top
11	*Hermanites scopus* sp. nov.	6138	6488	1766	1872
12	*Patagonacythere ? nidulus* sp. nov.	6575	7118	2032	3384
15a	*Stigmatocythere lumaria* sp. nov. Morphotype A	6531	7121	2060	3384
15b	*S. lumaria* sp. nov. Morphotype B	6839	7029	2712	
16	*Trachyleberis (Trachyleberis) bimammillata* sp. nov.	6369	6463	1872	1948
17	*T. (Acanthocythereis) postcornis* sp. nov.	6121	6138	994	1766
18	*T. (Acanthocythereis) decoris* sp. nov.	6200	7124	1994	3384
19	*Aglaiocypris* sp.B	6415		2190	3040+
20	*Bairdoppilata* sp.A	6138	7014	794	3186
22	*Cytherella* sp.E	6121	6401	994	2032
23	*Cytherella* sp.F	6424	6985	994	3040
24	*Cytherella* sp.G	6121	6985	994	3095
25	*Cytherelloidea* cf. C. *costatruncata* Lubimova and Mohan	6121	7001	994	3095
26	*Cytherelloidea* sp.E	6985	7029	3000	3095
27	*Cytherelloidea* sp.F	6121	7124	994	3095
28	*Cytheromorpha* sp.A	6138	6974	994	2904
29	*Cytheropteron* sp.C	6121	6606	994	1872
30	*Cytheropteron* sp.D	6121+	7029	2086+	3095
31	*Krithe* sp.C	6121	7096	1766	3095
32	*Krithe* sp.D	6311	7107	1710	3140
33	*Krithe* sp.E	6138	7014	1710	3140
34	*Krithe* sp.F	6931	6985	2504	2760
37	*Neocyprideis* ? sp.D	7096	7124	3344	3450
38	*Paijenborchella* sp.C	6121	7096	794	3095
39	*Paijenborchella* sp.E	6311	7096	1900	2712
40	*Paijenborchella* sp.F	7114	7124	3186	3450
41	*Propontocypris* sp.A	6266	6564	1766	2266
42	*Pterygocythereis (Pterygocythere)* sp.A	6575	6985	2060	3130
43	*Schizocythere* sp.B	6138	6524	994	1994
47	*Xestoleberis* sp.G	6138	6931	1766	3130

+ Points omitted from computation.

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PLATE 1

Actinocythereis ? quasibathonica sp. nov.

FIGS. 1, 10. Dorsal and right views, carapace male, × 70. Paratype, Io. 4260. Upper Chocolate Clays (lower part), sample 3613, Rakhi Nala.

FIGS. 2, 3, 11, 12. Dorsal, ventral, left and right views, carapace female, × 70. Holotype, Io. 4311. Upper Chocolate Clays (lower part), sample 3611, Rakhi Nala.

FIG. 6. Dorsal view of hinge, left valve male, × 230. Paratype, Io. 3101. Upper Chocolate Clays (lower part), sample 3613, Rakhi Nala.

FIGS. 7, 13. 7, dorsal view of hinge × 230 ; 13, anterior radial pore canals × 230. Right valve male. Paratype, Io. 3100. Upper Chocolate Clays, sample 3611, Rakhi Nala.

Alocopocythere transcendens gen. et sp. nov.

FIGS. 4, 5, 8, 9. Dorsal, ventral, right and left views, carapace male, × 90. Paratype, Io. 3104. Upper Chocolate Clays (lower part), sample 3607, Rakhi Nala.


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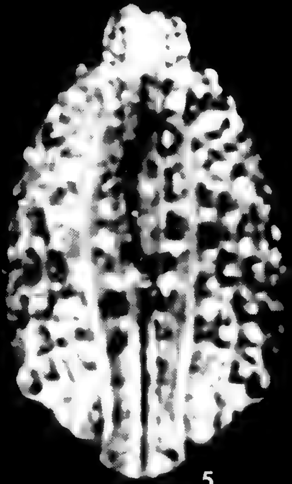
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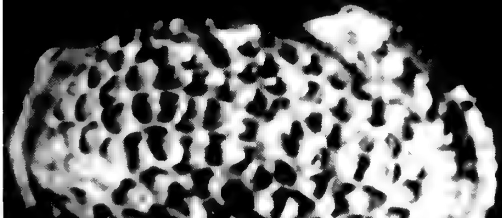
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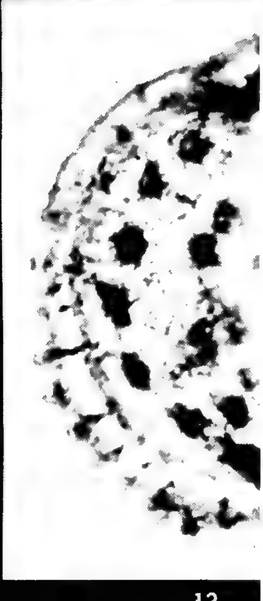
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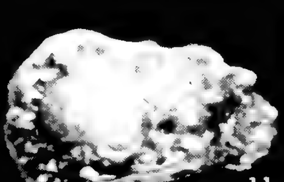
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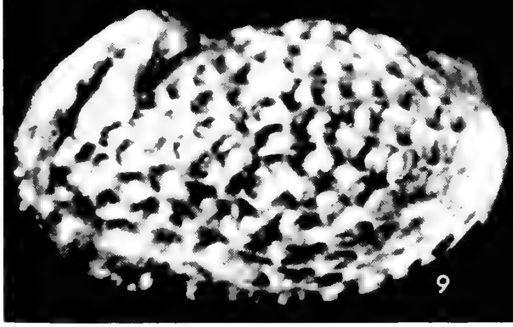
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PLATE 2

Alocopocythere transcendens gen. et sp. nov.

FIGS. 1, 6. External and dorsal views, left valve female, × 90. Holotype, Io. 4315. Upper Chocolate Clays (lower part), sample 24148, Zao River.

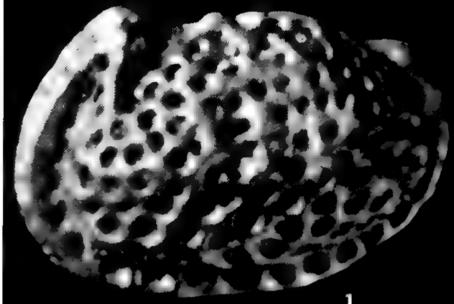
FIG. 2. Muscle scars (× 200) showing four adductors and an oval frontal scar. Right valve male (broken), × 90. Paratype, Io. 3106. Upper Chocolate Clays, sample 24151, Zao River.

FIG. 3. Anterior radial pore canals × 128. Left valve female. Paratype, Io. 4261. Upper Chocolate Clays (lower part), sample 24148, Zao River.

FIGS. 4, 7. External and dorsal views, right valve female, × 90. Paratype, Io. 3105. Upper Chocolate Clays (lower part), sample 24148, Zao River.

Alocopocythere rupina sp. nov.

FIGS. 5, 8–10. Right, left, dorsal and ventral views, carapace male × 90. Holotype, Io. 4314. Gorge Beds, sample 3111, Rakhi Nala.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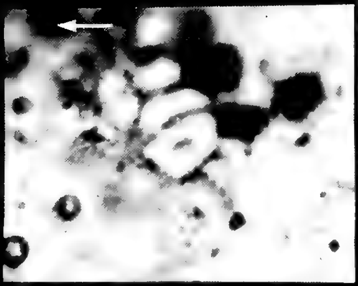
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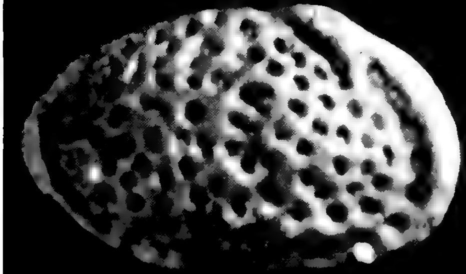
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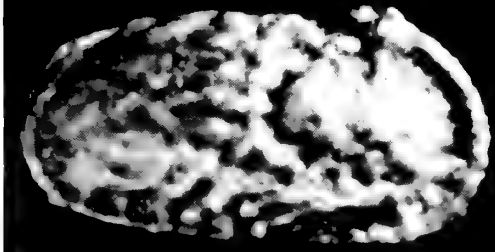
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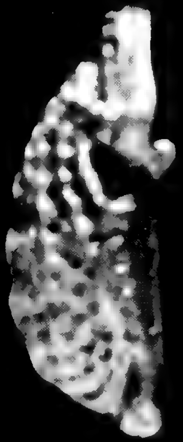
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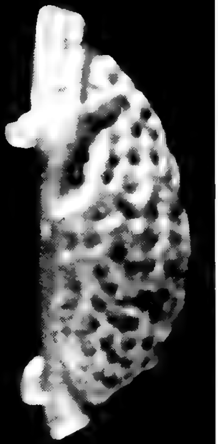
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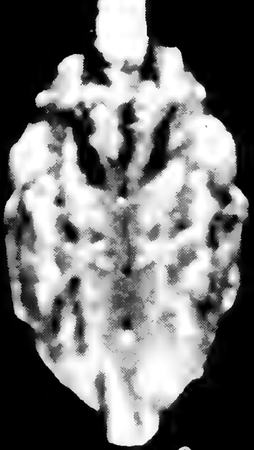
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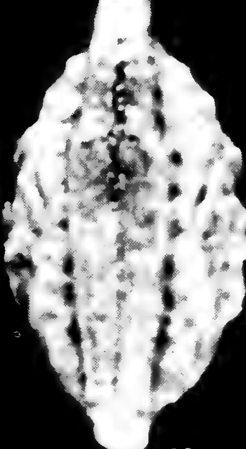
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PLATE 3

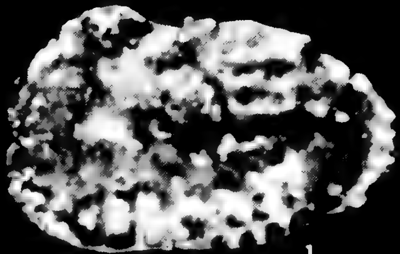
Alocopocythere rupina sp. nov.

FIGS. 1–4. Left, right, dorsal and ventral views, carapace female, × 90. Paratype, Io. 4262. Gorge Beds, sample 3111, Rakhi Nala.

Alocopocythere abstracta sp. nov.

FIGS. 5–8. Left, dorsal, ventral and right views, carapace male, × 90. Paratype, Io. 4263. Upper Rakhi Gaj Shales, sample 3163, Rakhi Nala.

FIGS. 9–11. Right, dorsal and ventral views, carapace female × 90. Holotype, Io. 4312. Upper Rakhi Gaj Shales, sample 3163, Rakhi Nala.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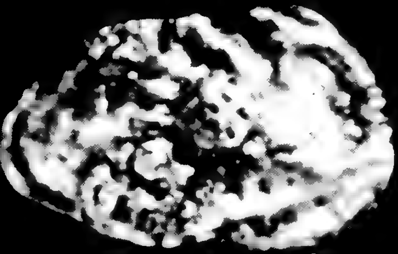
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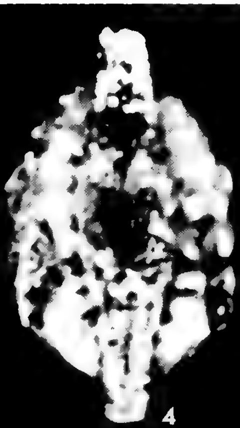
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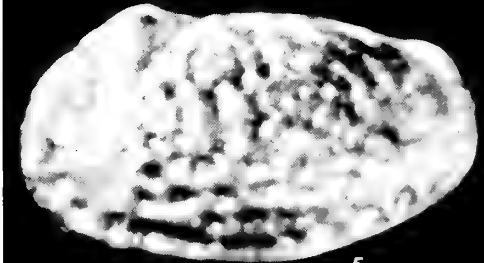
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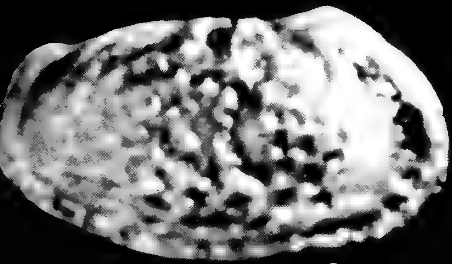
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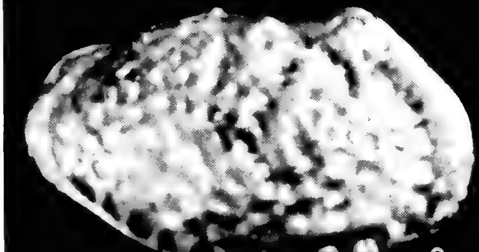
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PLATE 4

Alocopocythere abstracta sp. nov.

FIG. 1. Left view, carapace female, × 90. Holotype, Io. 4312. Upper Rakhi Gaj Shales, sample 3163, Rakhi Nala.

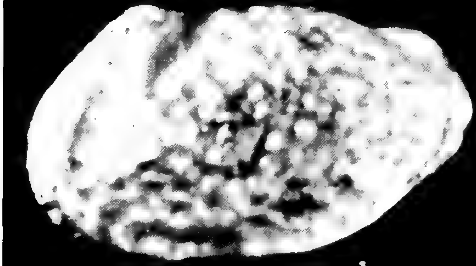
Alocopocythere coarctata sp. nov.

FIGS. 2–5. Dorsal, ventral, left and right views, carapace male, × 90. Paratype, Io. 4264. Shales with Alabaster, sample 3448, Rakhi Nala.

FIGS. 6–9. Dorsal, ventral, left and right views, carapace female, × 90. Holotype, Io. 4313. Shales with Alabaster, sample 3458, Rakhi Nala.

Alocopocythere longilinea sp. nov.

FIGS. 10–13. Dorsal, right, ventral and left views, carapace male, × 90. Holotype, Io. 4318 Shales with Alabaster, sample 3443, Rakhi Nala.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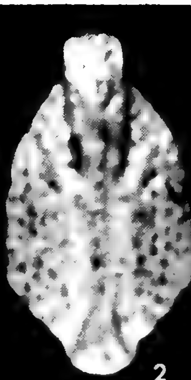
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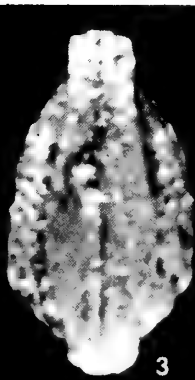
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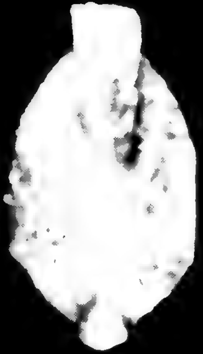
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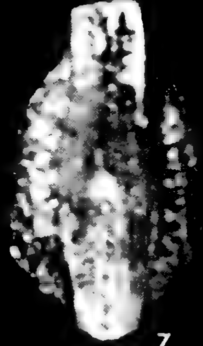
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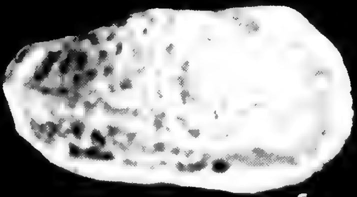
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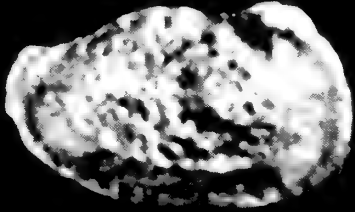
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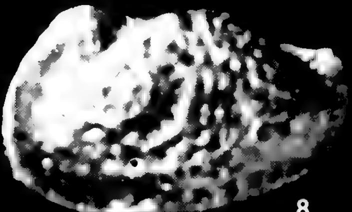
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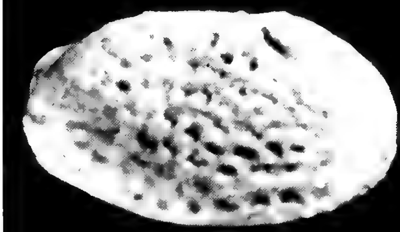
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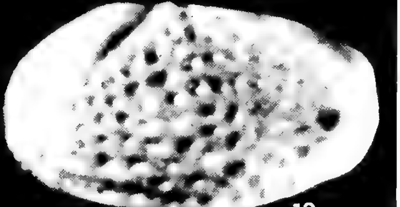
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PLATE 5

Alocopocythere longilinea sp. nov.

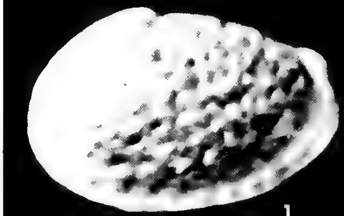
FIGS. 1–3, 6. Left, right, dorsal and ventral views, carapace female, × 90. Paratype, Io. 4265. Shales with Alabaster, samples 3443, Rakhi Nala.

Alocopocythere transversa sp. nov.

Morphotype A

FIGS. 4, 5, 7, 9. Dorsal, ventral, left and right views, carapace male, × 90. Paratype, Io. 4266. Upper Chocolate Clays (lower part), sample 24155, Zao River.

FIGS. 8, 10. Left and right views, carapace female, × 90. Holotype, Io.4316. Upper Chocolate Clays (lower part), sample 24155, Zao River.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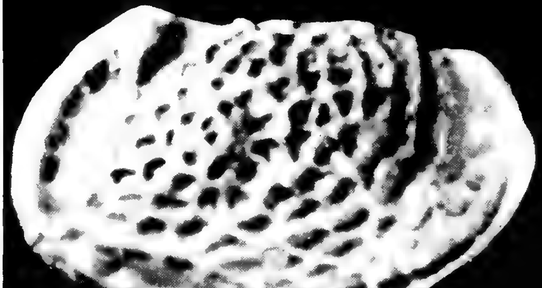
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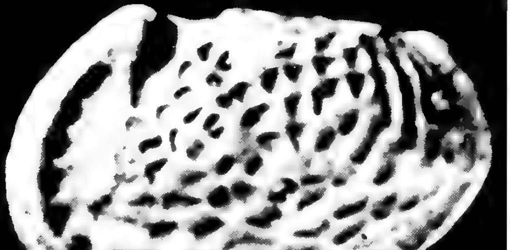
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PLATE 6

Alocopocythere transversa sp. nov.

Morphotype A

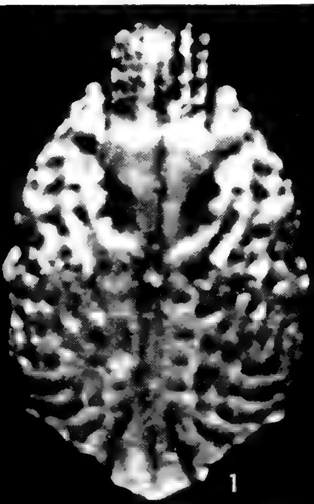
FIGS. 1, 2. Dorsal and ventral views, carapace female, × 90. Holotype, Io. 4316. Upper Chocolate Clays (lower part), sample 24155, Zao River.

FIGS. 3, 4. Dorsal and internal views, right valve male, × 90. Paratype Io. 3107. Upper Chocolate Clays (lower part), sample 3625, Rakhi Nala.

Morphotype C

FIGS. 5, 7. Left and right views, carapace male, × 90. Paratype, Io. 4267. Upper Chocolate Clays (upper part), sample 24183, Zao River.

FIGS. 6, 8. Left and right views, carapace female, × 90. Paratype, Io. 4268. Upper Chocolate Clays (upper part), sample 24183, Zao River.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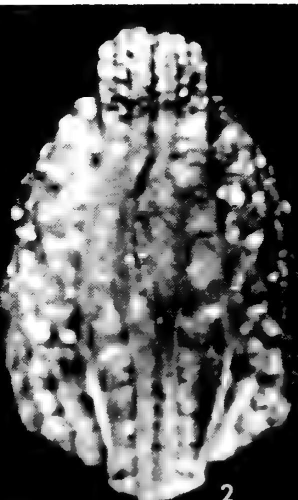
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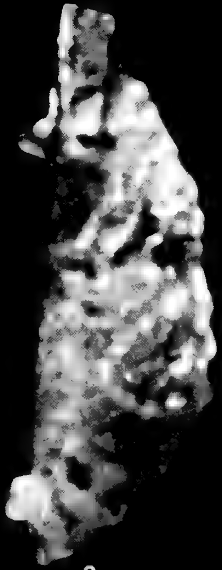
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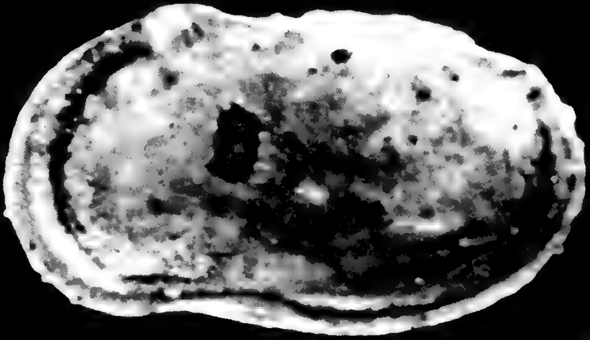
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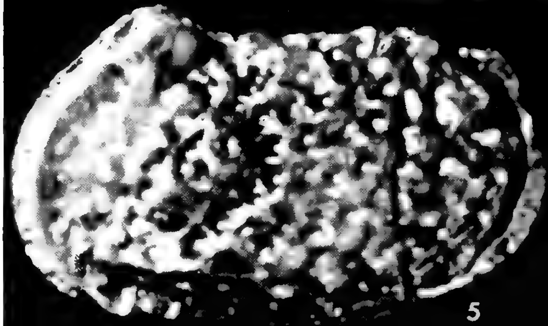
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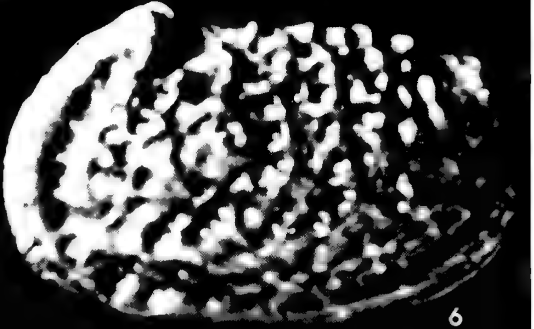
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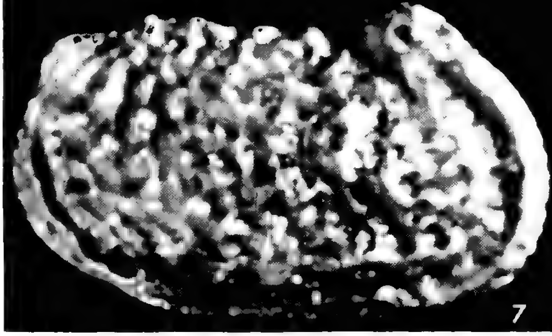
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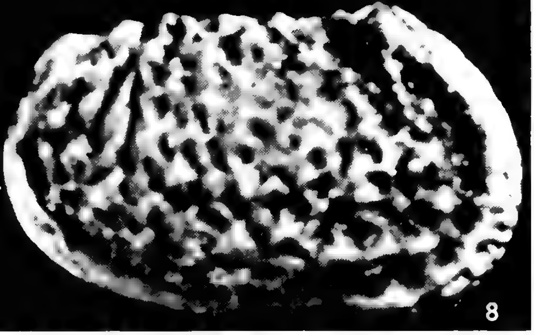
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PLATE 7

Alocopocythere transversa sp. nov.

Morphotype C

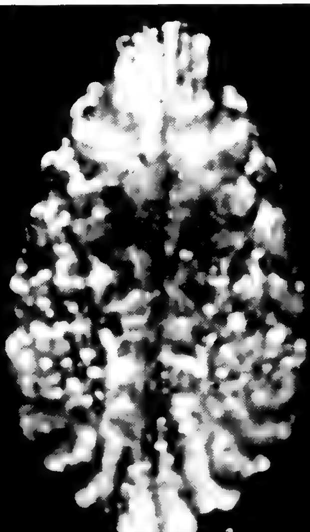
FIGS. 1, 2. Dorsal and ventral views, carapace male, × 90. Paratype, Io. 4267. Upper Chocolate Clays (upper part), sample 24183, Zao River.

FIGS. 3, 4. Dorsal and ventral views, carapace female, × 90. Paratype, Io. 4268. Upper Chocolate Clays (upper part), sample 24183, Zao River.

Morphotype E

FIGS. 5–7. Dorsal, ventral and left views, carapace male, × 90. Paratype, Io. 3110. Upper Chocolate Clays (upper part), sample 24175, Zao River.

FIG. 8. Left view, carapace female, × 90. Paratype, Io. 3111. Upper Chocolate Clays (upper part), sample 24175, Zao River.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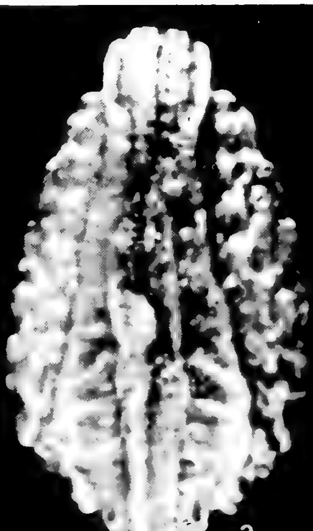
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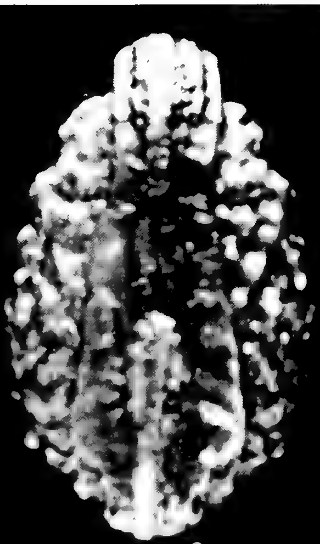
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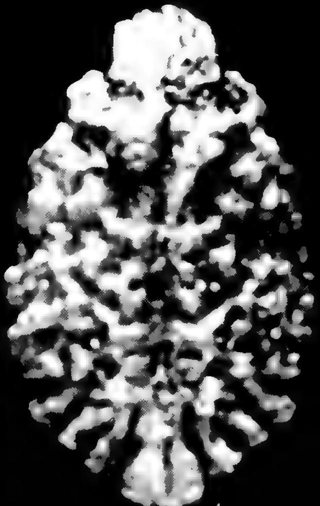
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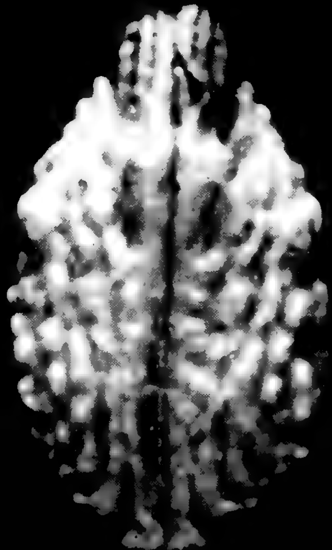
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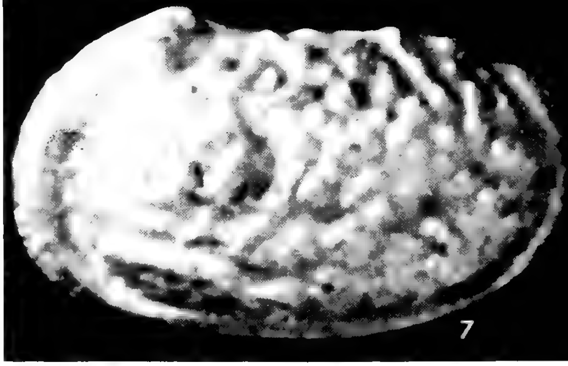
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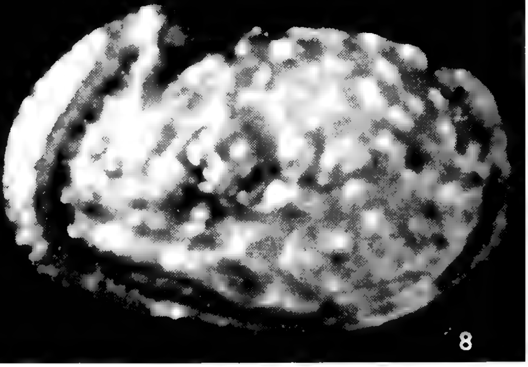
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PLATE 8

Alocopocythere transversa sp. nov.

Morphotype E

FIG. 1. Right view, carapace male, × 90. Paratype, Io. 3110. Upper Chocolate Clays (Upper part), sample 24175. Zao River.

FIGS. 2, 3, 5. Right, dorsal and ventral views, carapace female, × 90. Paratype, Io. 3111 Upper Chocolate Clays (upper part), sample 24175, Zao River.

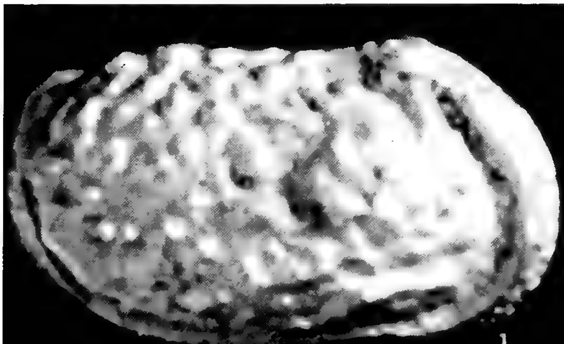
Morphotype C

FIG. 4. Muscle scars (× 200) showing four adductor, an oval frontal and two mandibular scars. Right valve male (broken). Paratype, Io. 4269. Upper Chocolate Clays (upper part), sample 24174, Zao River.

Morphotype F

FIGS. 6, 8. Left and right views, carapace male, × 90. Paratype, Io. 3109. Upper Chocolate Clays (upper part), sample 3652, Rakhi Nala.

FIGS. 7, 9. Left and right views, carapace female, × 90. Paratype, Io. 3108. Upper Chocolate Clays (upper part), sample 3652, Rakhi Nala.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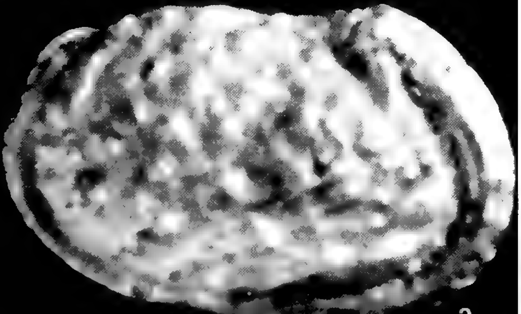
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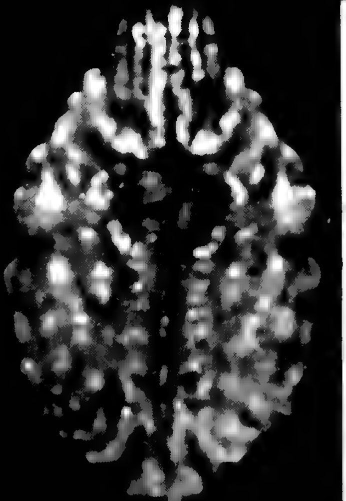
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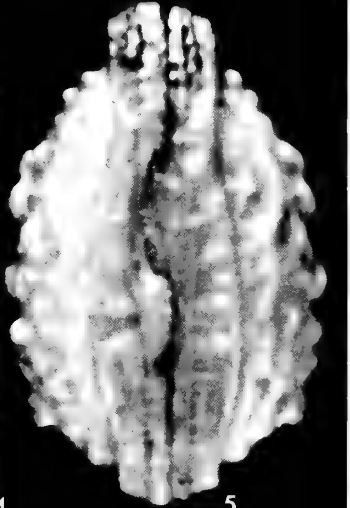
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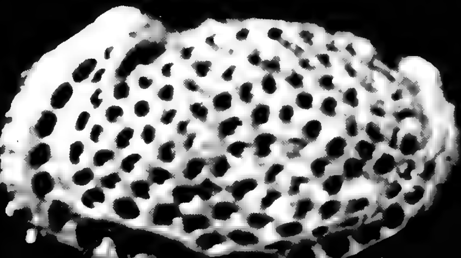
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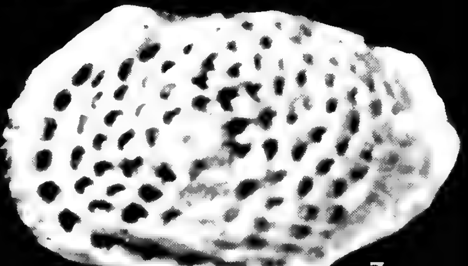
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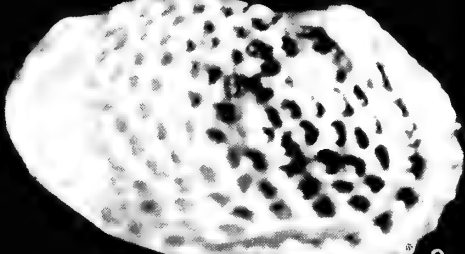
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PLATE 9

Alocopocythere transversa sp. nov.

Morphotype F

FIGS. 1, 2. Dorsal and ventral views, carapace male, × 90. Paratype, Io. 3109. Upper Chocolate Clays (upper part), sample 3652, Rakhi Nala.

FIGS. 3, 5. Dorsal and ventral views, carapace female, × 90. Paratype, Io. 3108. Upper Chocolate Clays (upper part), sample 3652, Rakhi Nala.

FIG. 4. Internal view to show radial pore canals, right valve female, × 108. Paratype, Io. 3112. Upper Chocolate Clays (upper part), sample 24174, Zao River.

Alocopocythere radiata sp. nov.

FIGS. 6, 8. Left and right views, carapace male, × 90. Holotype, Io. 4317. Upper Chocolate Clays (upper part), sample 3652, Rakhi Nala.

FIGS. 7, 9. Left and right views, carapace female, × 90. Paratype, Io. 4270. Upper Chocolate Clays (upper part), sample 3652, Rakhi Nala.


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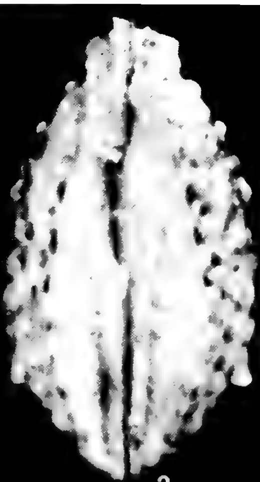
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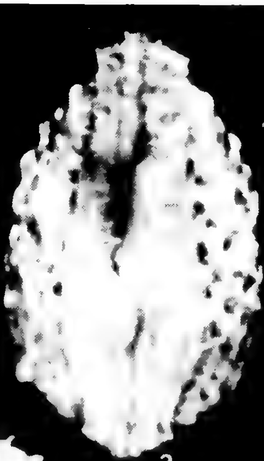
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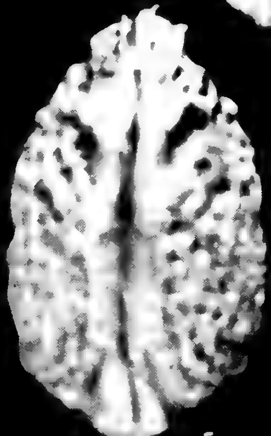
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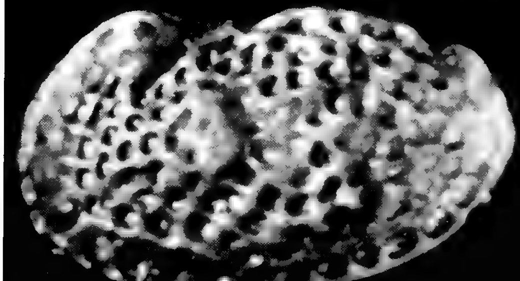
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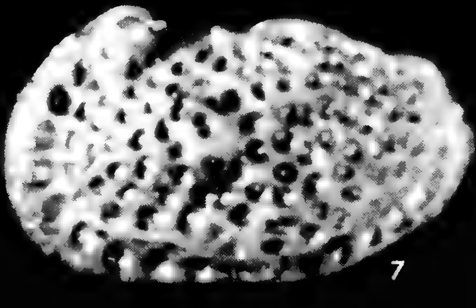
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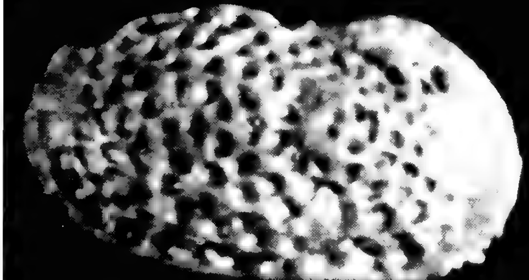
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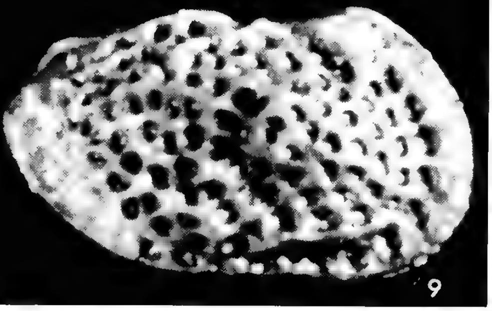
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PLATE 10

Alocopocythere radiata sp. nov.

FIGS. 1, 2. Dorsal and ventral views, carapace male, × 90. Holotype, Io. 4317. Upper Chocolate Clays (upper part), sample 3652, Rakhi Nala.

FIGS. 3, 4. Ventral and dorsal views, carapace female, × 90. Paratype, Io. 4270. Upper Chocolate Clays (upper part), sample 3652, Rakhi Nala.

" *Anommatocythere* " *laqueta* sp. nov.

FIGS. 5–7. Right, left and dorsal views, carapace male, × 70. Paratype, Io. 4271. Green and Nodular Shales, sample 3403, Rakhi Nala.

FIGS. 8–10. Left, right and dorsal views, carapace female, × 70. Holotype, Io. 4320. Green and Nodular Shales, sample 3403, Rakhi Nala.

" *Anommatocythere* " *confirmata* sp. nov.

FIGS. 11, 12. Right and left views, carapace male, × 70. Holotype, Io. 4319. Upper Chocolate Clays (lower part), sample 3611, Rakhi Nala.


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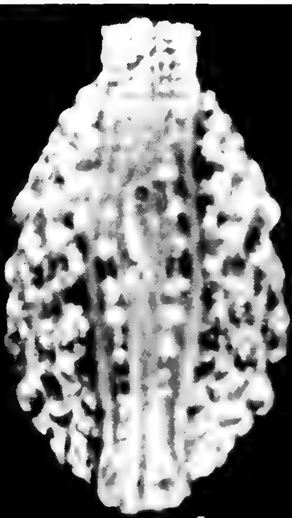
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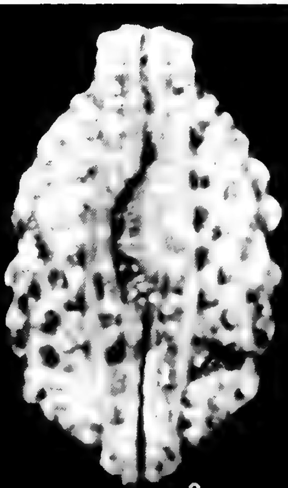
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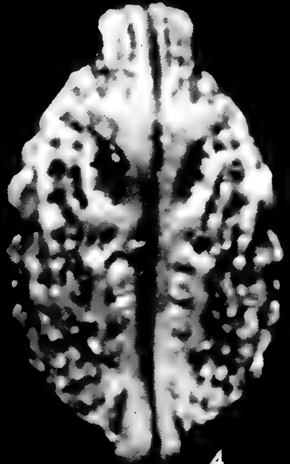
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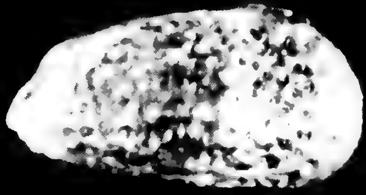
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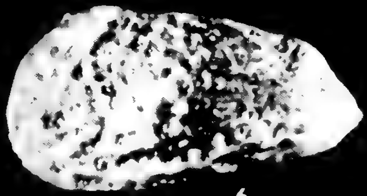
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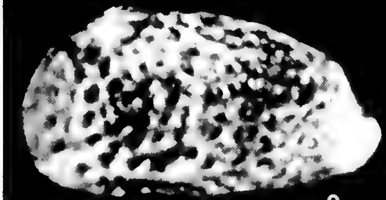
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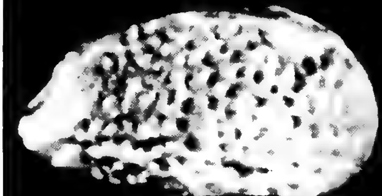
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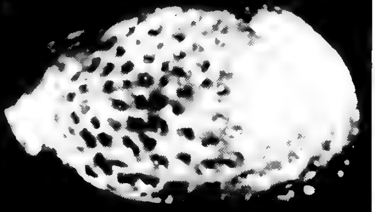
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PLATE 11

" *Anommatocythere* " *confirmata* sp. nov.

Figs. 1, 2. Dorsal and ventral views, carapace male, × 70. Holotype, Io. 4319 Upper Chocolate Clays (lower part), sample 3611, Rakhi Nala.

Fig. 3. Anterior radial pore canals × 232, left valve male. Paratype, Io. 3102. Upper Chocolate Clays (lower part), sample 24151, Zao River.

Figs. 4, 5, 8, 9. Dorsal, ventral, right and left views, carapace female, × 70. Paratype, Io. 4272. Upper Chocolate Clays (lower part), sample 24148, Zao River.

Figs. 6, 7. Anterior and posterior radial pore canals × 232, right valve male. Paratype, Io. 3103. Upper Chocolate Clays (lower part), sample 24151, Zao River.


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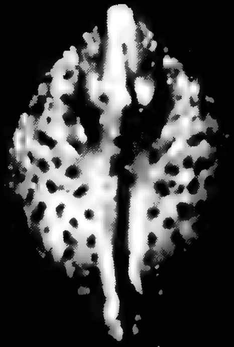
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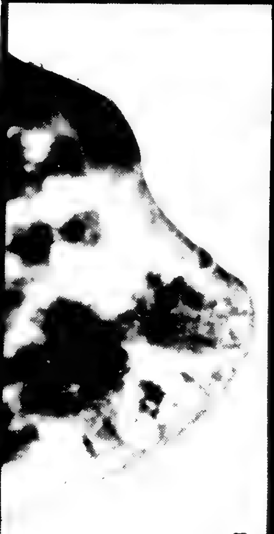
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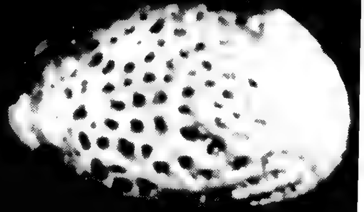
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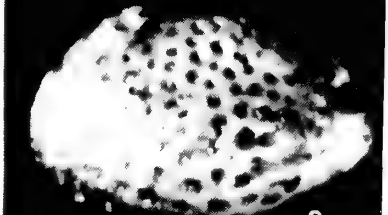
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PLATE 12

" Anommatocythere " confirmata sp. nov.

FIG. 1. Dorsal view of hinge × 183, left valve male. Paratype, Io. 3102. Upper Chocolate Clays (lower part), sample 24151, Zao River.

FIG. 2. Dorsal view of hinge × 183, right valve male. Paratype, Io. 3103. Upper Chocolate Clays (lower part), sample 24151, Zao River.

Bradleya ? voraginosa sp. nov.

FIGS. 3, 5, 7, 8. Dorsal left, right and ventral views, carapace male, × 70. Holotype, Io. 4321. Upper Chocolate Clays (upper part), sample 24161, Zao River.

FIGS. 4, 6. 9. Dorsal, right and left views, carapace female, × 70. Paratype, Io. 3115. Upper Chocolate Clays (upper part), sample 24161, Zao River.


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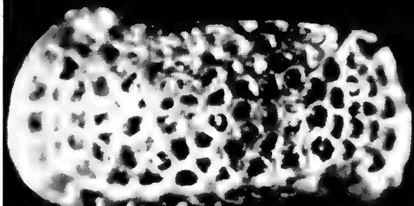
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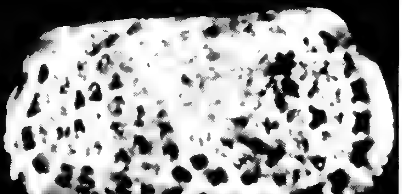
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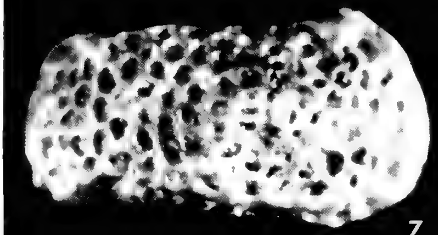
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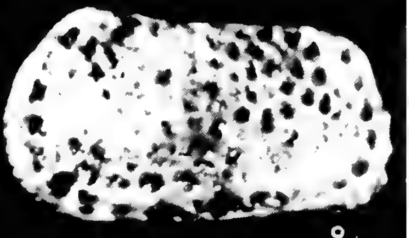
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PLATE 13

Buntonia devexa sp. nov.

FIGS. 1, 3. Left and right views, carapace male, × 70. Paratype, Io. 3113. Gorge Beds, sample 3111, Rakhi Nala.

FIGS. 2, 4, 5. Left, dorsal and right views, carapace female, × 70. Holotype, Io. 4322. Gorge Beds, sample 3111, Rakhi Nala.

Buntonia sp.A

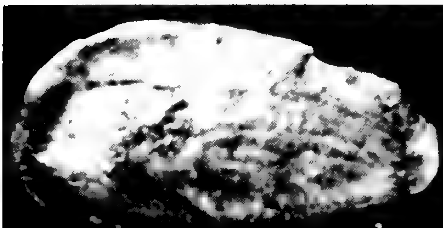
FIGS. 6, 7, 9. Left, right and dorsal views, carapace, × 70. Paratype, Io. 3114. Lower Rakhi Gaj Shales, sample 3133, Rakhi Nala.

Costa (Paracosta) declivis subgen. et sp. nov.

FIGS. 8, 10–12. Left, right, dorsal and ventral views, carapace male, × 68. Holotype, Io. 4325. *Pellatispira* Beds, sample 3662, Rakhi Nala.

FIG. 13. Right view, carapace female, × 68. Paratype, Io. 4273. *Pellatispira* Beds, sample 3662, Rakhi Nala.

FIG. 14. Left view, carapace female, × 68. Paratype, Io. 3116. *Pellatispira* Beds, sample 3662, Rakhi Nala.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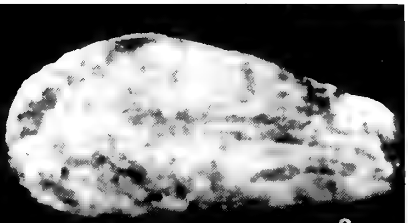
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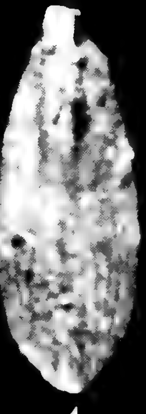
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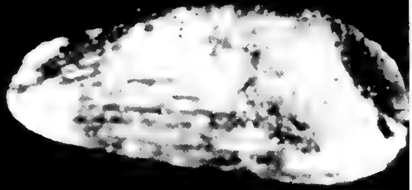
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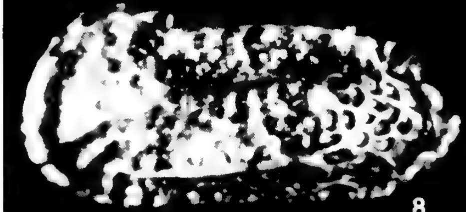
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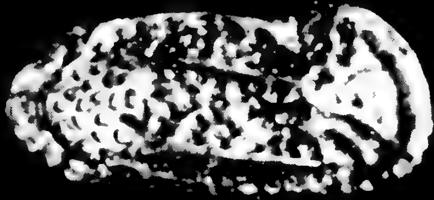
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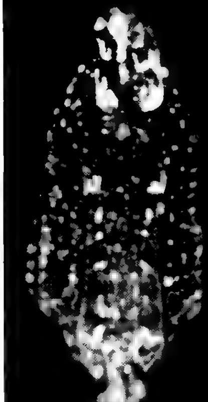
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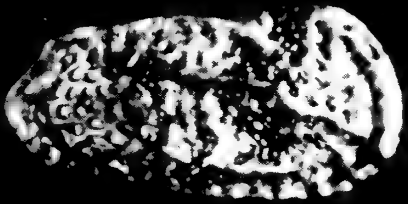
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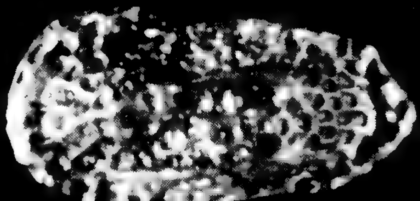
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PLATE 14

Costa (Paracosta) declivis subgen. et sp. nov.

FIG. 1. Dorsal view, carapace female, × 68. Paratype, Io. 4273. *Pellatispira* Beds, sample 3662, Rakhi Nala.

FIG. 2. Ventral view, carapace female, × 68. Paratype, Io. 3116. *Pellatispira* Beds, sample 3662, Rakhi Nala.

Costa (Paracosta) compitalis sp. nov.

FIGS. 3, 4, 7, 8. Dorsal, ventral, right and left views, carapace male, × 68. Paratype, Io. 4274. Upper Chocolate Clays (lower part), sample 3604, Rakhi Nala.

FIGS. 5, 6, 9, 10. Dorsal, ventral, right and left views, carapace female, × 68. Holotype, Io. 4323. Upper Chocolate Clays (lower part), sample 3604, Rakhi Nala.

Costa (Paracosta) disintegrata sp. nov.

FIG. 11. Left view, carapace male, × 68. Paratype, Io. 4275. Upper Chocolate Clays (lower part), sample 3622, Rakhi Nala.


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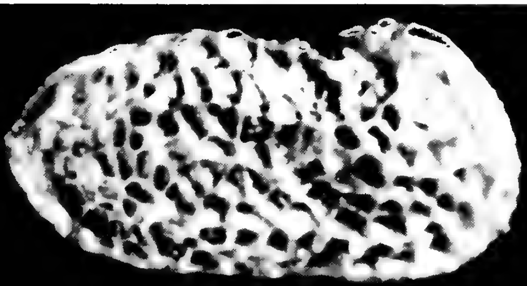
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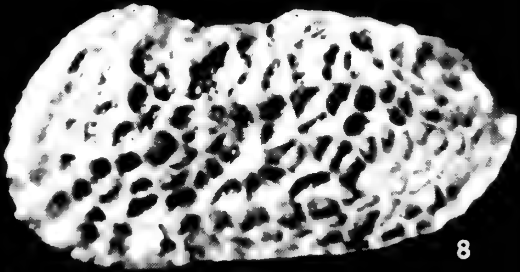
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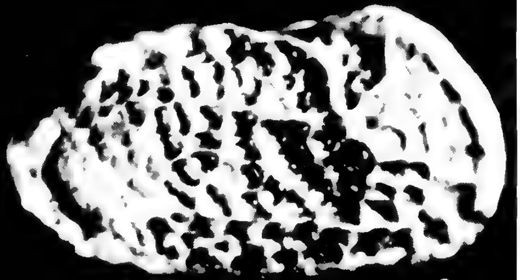
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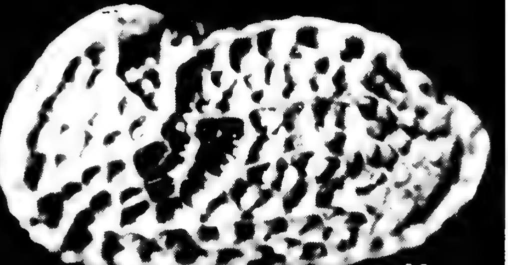
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PLATE 15

Costa (Paracosta) disintegrata sp. nov.

FIGS. 1, 2, 5, 6. Left, right, dorsal and ventral views, carapace female, × 68. Holotype, Io. 4324. Upper Chocolate Clays (lower part), sample 3621, Rakhi Nala.

FIGS. 3, 4. Dorsal and ventral views, carapace male, × 68. Paratype, Io. 4275. Upper Chocolate Clays (lower part), sample 3622, Rakhi Nala.

Echinocythereis (Echinocythereis) contexta sp. nov.

FIGS. 7, 10. Left and dorsal views, carapace male, × 68. Paratype, Io. 4276. Upper Palaeocene, sample 460-j, Sor Range, 8 miles east of Quetta.

FIGS. 8, 13. Left and dorsal views, carapace female, × 68. Holotype, Io. 4326. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

Echinocythereis (Echinocythereis) elongata sp. nov.

FIGS. 9, 11. Left and right views, carapace male, × 68. Paratype, Io. 3130. Rubbly Limestones, sample 3416, Rakhi Nala.

FIGS. 12, 14. Left and right views, carapace female, × 68. Holotype, Io. 4327. Rubbly Limestones, sample 3416, Rakhi Nala.


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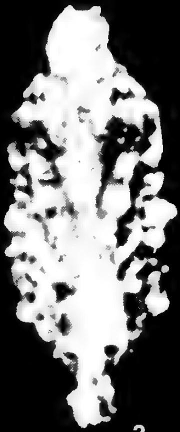
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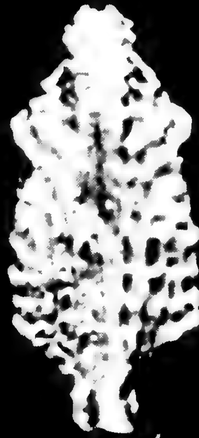
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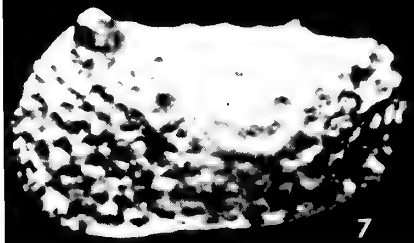
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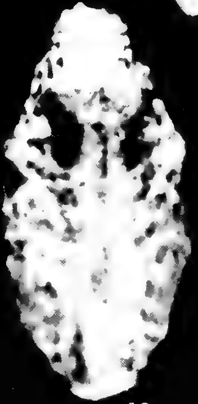
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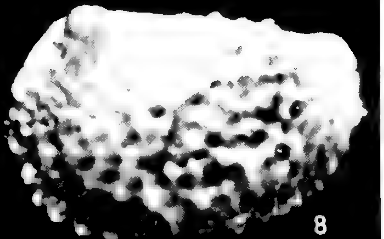
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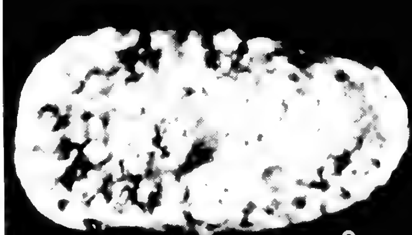
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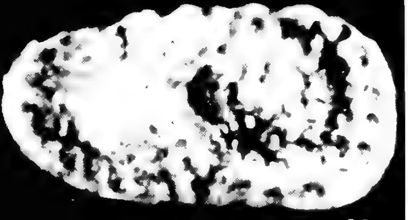
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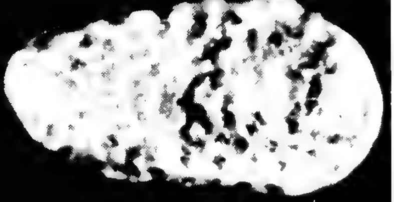
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PLATE 16

Echinocythereis (Echinocythereis) elongata sp. nov.

FIG. 1. Dorsal view, carapace female, × 68. Holotype, Io. 4327. Rubbly Limestones, sample 3416, Rakhi Nala.

FIG. 2. Dorsal view, carapace male, × 68. Paratype, Io. 3130. Rubbly Limestones, sample 3416, Rakhi Nala.

Echinocythereis (Scelidocythereis) multibullata subgen. et sp. nov.

FIGS. 3, 5, 6. Dorsal, left and right views, carapace male, × 68. Holotype, Io. 4328. Upper Chocolate Clays (upper part), sample 24161, Zao River.

FIGS. 4, 7, 8. Dorsal, right and left views, carapace female, × 68. Paratype, Io. 3134. Upper Chocolate Clays (upper part), sample 24161, Zao River.

FIG. 9. Internal view to show radial pore canals, right valve female, × 132. Paratype, Io. 4277. Upper Chocolate Clays (lower part), sample 24159, Zao River.


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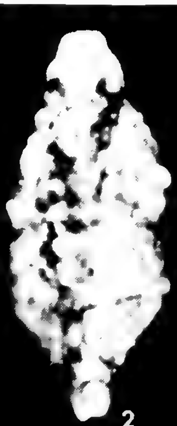
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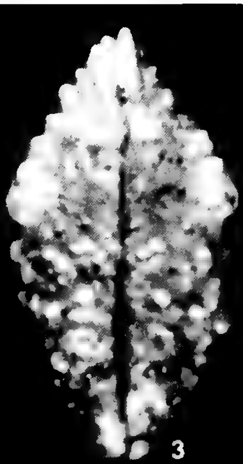
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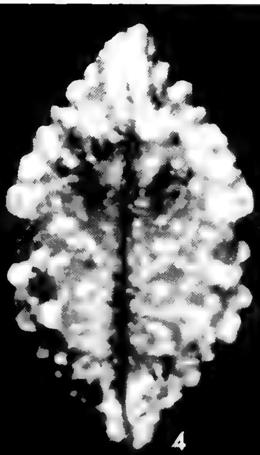
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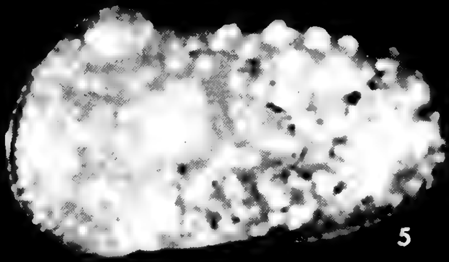
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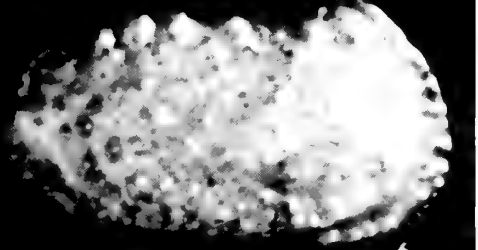
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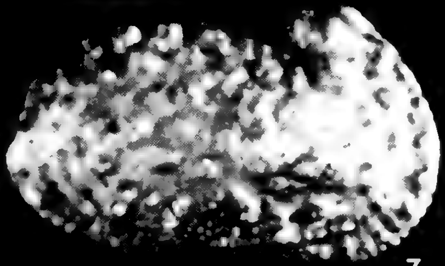
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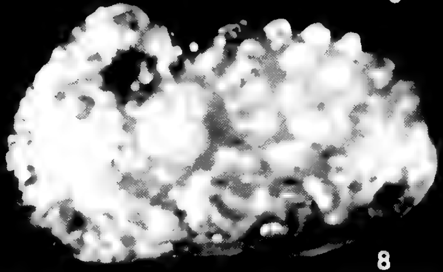
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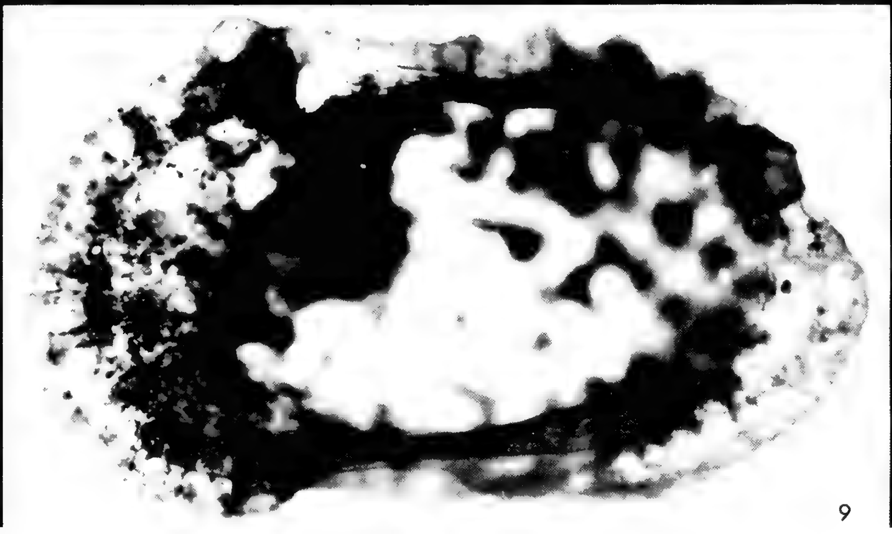
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PLATE 17

Echinocythereis (Scelidocythereis) multibullata sp. nov.

FIG. 1. Dorsal view of hinge, left valve female, × 146. Holotype, Io. 4327. Upper Chocolate Clays (lower part), sample 24159, Zao River.

FIG. 2. Dorsal view of hinge, right valve female, × 146. Paratype, Io. 4277. Upper Chocolate Clays (lower part), sample 24159, Zao River.

FIG. 7. Ventral view, carapace male, × 68. Paratype, Io. 3133. Upper Chocolate Clays (upper part), sample 24161, Zao River.

Echinocythereis (Scelidocythereis) sp.A

FIGS. 3, 4, 8, 9. Left, right, dorsal and ventral views, carapace, × 68. Io. 3129. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

Echinocythereis (Scelidocythereis) rasilis sp. nov.

FIGS. 5, 10. Left and ventral views, carapace male, × 68. Paratype, Io. 4278. Lower Chocolate Clays, sample 3499, Rakhi Nala.

FIG. 6. Left view, carapace female, × 68. Holotype, Io. 4329. Lower Chocolate Clays, sample 3499, Rakhi Nala.


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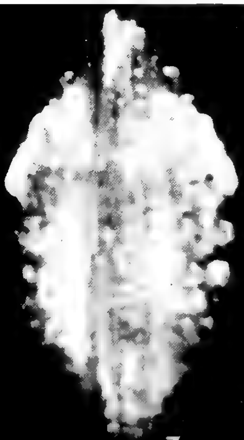
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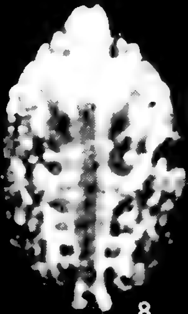
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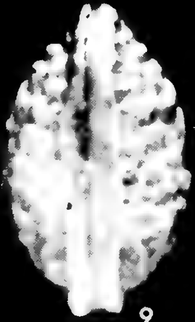
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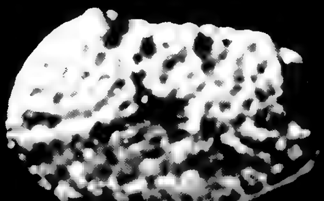
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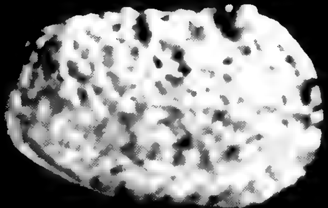
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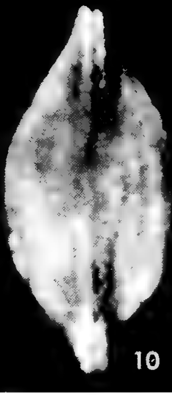
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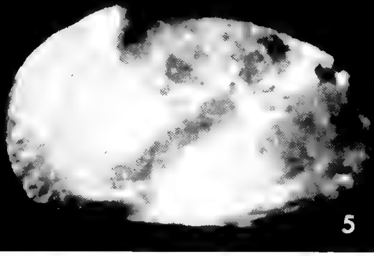
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PLATE 18

Echinocythereis (Scelidocythereis) rasilis sp. nov.

FIG. 1. Dorsal view, carapace male, × 68. Paratype, Io. 4278. Lower Chocolate Clays, sample 3499, Rakhi Nala.

FIGS. 2, 3. Dorsal and ventral views, carapace female, × 68. Holotype, Io. 4329. Lower Chocolate Clays, sample 3499, Rakhi Nala.

FIG. 5. Right view, carapace male, × 68. Paratype, Io. 3131. Upper Chocolate Clays (lower part), sample 24157, Zao River.

FIG. 7. Right view, carapace female, × 68. Paratype, Io. 3132. Upper Chocolate Clays (lower part), sample 24145, Zao River.

Echinocythereis (Scelidocythereis) sparsa sp. nov.

FIGS. 4, 6. Dorsal and left views, carapace male, × 68. Paratype, Io. 4279. Upper Chocolate Clays (lower part), sample 24159, Zao River.

FIGS. 8, 9. Dorsal and left views, carapace female, × 68. Holotype, Io. 4330. Upper Chocolate Clays (lower part), sample 24159, Zao River.

Gyrocythere exaggerata gen. et sp. nov.

FIGS. 10, 12. External and internal views, left valve male, × 68. Paratype, Io. 3125. Upper Chocolate Clays (lower part), sample 24151, Zao River.

FIGS. 11, 14. External and internal views, right valve male, × 68. Paratype, Io. 3127. Upper Chocolate Clays (lower part), sample 24151, Zao River.

FIG. 13. Dorsal view, carapace male (specimen now split giving separate valves Io. 3125 + Io. 3127 above).


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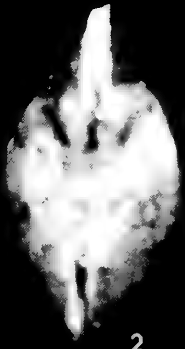
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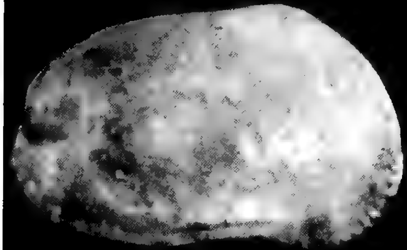
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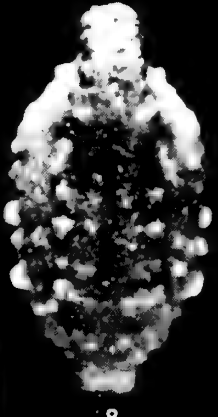
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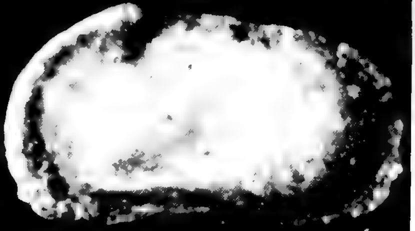
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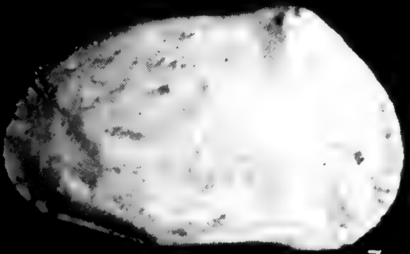
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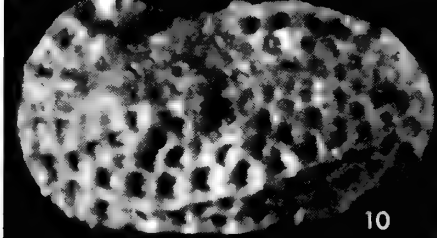
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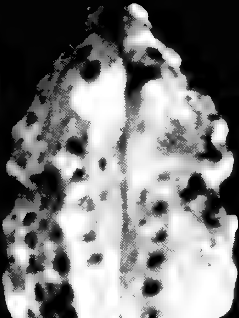
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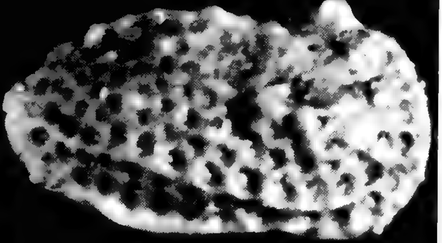
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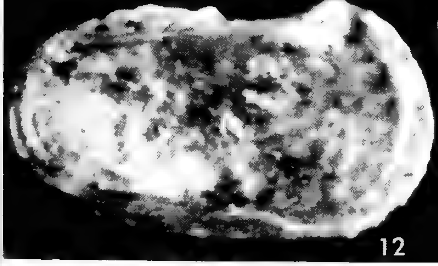
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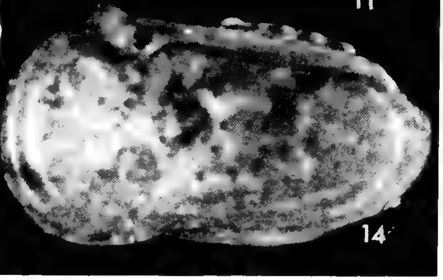
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PLATE 19

Gyrocythere exaggerata gen. et sp. nov.

FIGS. 1–4. Left, right, dorsal and ventral views, carapace female, × 68. Holotype, Io. 4331. Upper Chocolate Clays (lower part), sample 24151, Zao River.

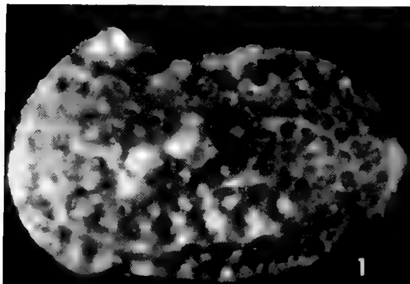
FIG. 5. Muscle scars × 120 showing four adductors and a U-shaped frontal scar, right valve female. Paratype, Io. 4280. Upper Chocolate Clays (lower part), sample 24148, Zao River.

FIG. 6. Internal view to show radial pore canals, left valve male, × 134. Paratype, Io. 3126. Upper Chocolate Clays (lower part), sample 24151, Zao River.

FIG. 7. Internal view to show radial pore canals, right valve female, × 134. Paratype, Io. 3124. Upper Chocolate Clays (lower part), sample 24148, Zao River.

FIG. 8. Dorsal view of hinge × 145, left valve male. Paratype, Io. 3120. Upper Chocolate Clays (lower part), sample 24151, Zao River.

FIG. 9. Dorsal view of hinge × 145, right valve male. Paratype, Io. 3122. Upper Chocolate Clays (lower part), sample 24151, Zao River.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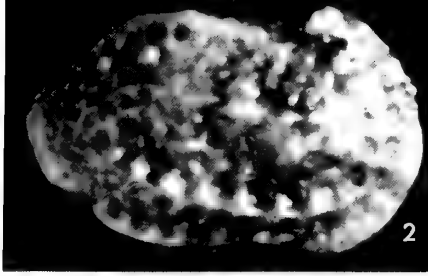
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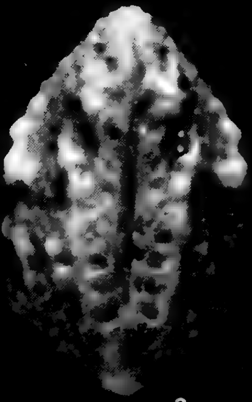
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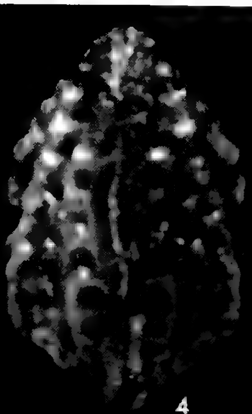
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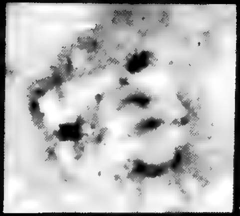
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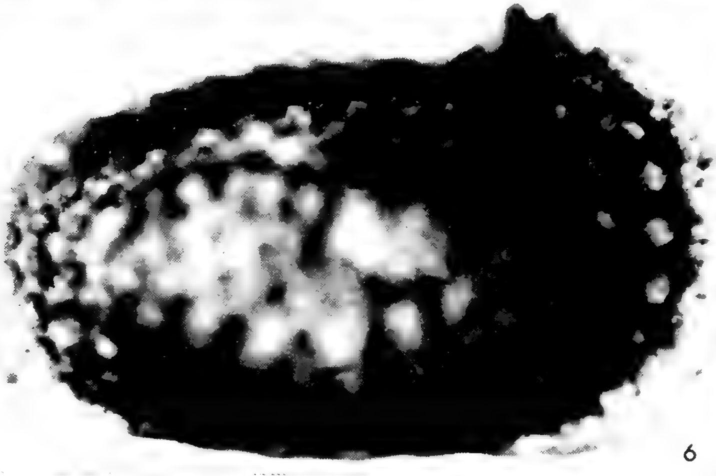
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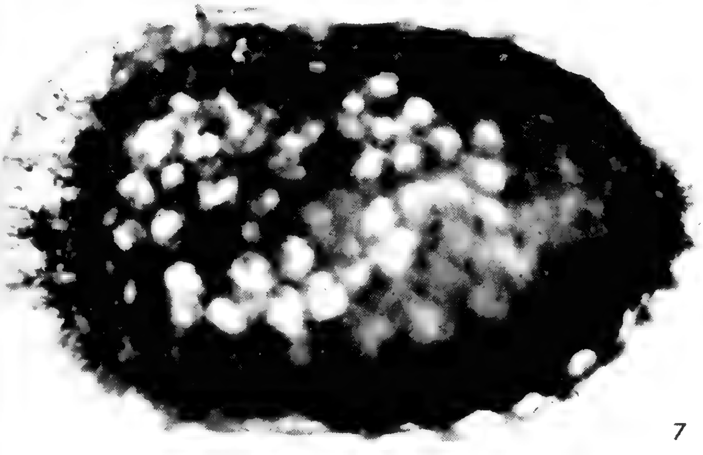
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PLATE 20

Gyrocythere exaggerata gen. et sp. nov.

FIG. 5. Dorsal view of hinge, right valve female, × 150. Paratype, Io. 3128. Upper Chocolate Clays (lower part), sample 24148, Zao River.

Gyrocythere parvicarinata sp. nov.

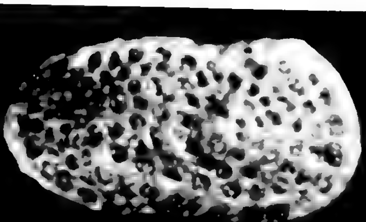
FIGS. 1, 2, 6, 7. Right, left, dorsal and ventral views, carapace male, × 68. Holotype, Io. 4334. Green and Nodular Shales, sample 3407, Rakhi Nala.

FIGS. 3, 4, 8, 12. Right, left, dorsal and ventral views, carapace female, × 68. Paratype, Io. 4281. Green and Nodular Shales, sample 3407, Rakhi Nala.

Gyrocythere grandilaevis sp. nov.

FIGS. 9, 10. Left and right views, carapace male, × 68. Holotype, Io. 4332. Shales with Alabaster, sample 3463, Rakhi Nala.

FIGS. 11, 12. Left and right views, carapace female, × 68. Paratype, Io. 4282. Shales with Alabaster, sample 3463, Rakhi Nala.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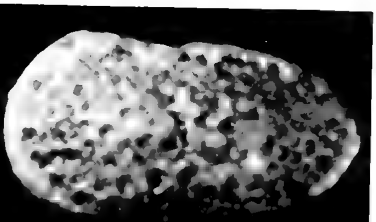
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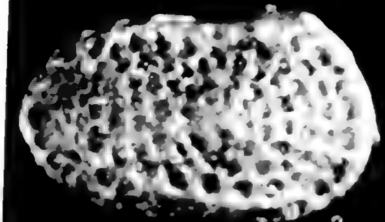
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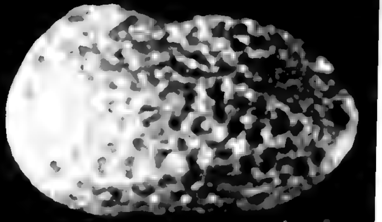
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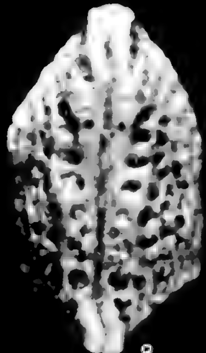
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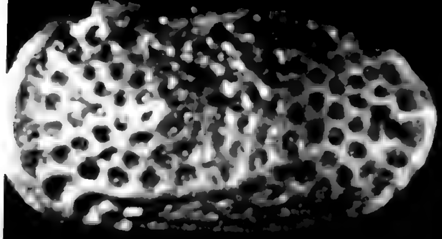
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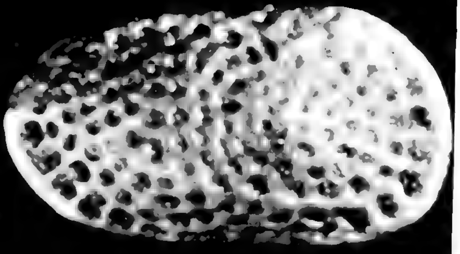
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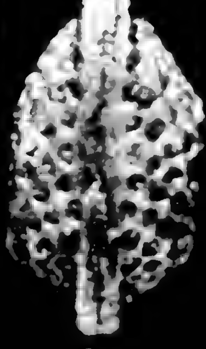
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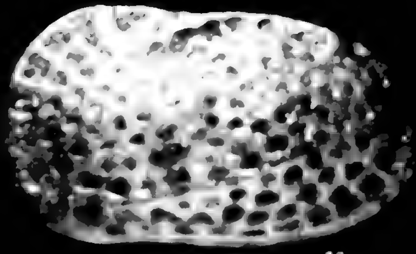
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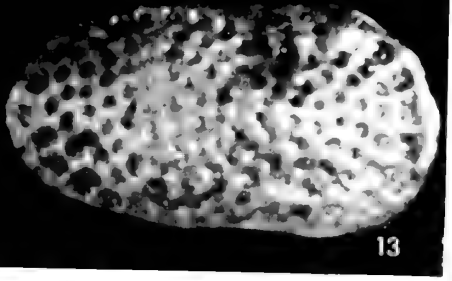
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PLATE 21

Gyrocythere grandilaevis sp. nov.

FIGS. 1, 2. Dorsal and ventral views, carapace male, × 68. Holotype, Io. 4332. Shales with Alabaster, sample 3463, Rakhi Nala.

FIGS. 3, 4. Dorsal and ventral views, carapace female, × 68. Paratype, Io. 4282. Shales with Alabaster, sample 3463, Rakhi Nala.

Gyrocythere mitigata sp. nov.

FIGS. 5–8. Left, right, dorsal and ventral views, carapace male, × 70. Holotype, Io. 4333. Lower Chocolate Clays, sample 24131, Zao River.

FIGS. 9, 11. Dorsal and external views, left valve female, × 70. Paratype, Io. 3119. Lower Chocolate Clays, sample 24131, Zao River.

FIG. 10. Right view, carapace female, × 70. Paratype, Io. 4283. Lower Chocolate Clays, sample 34131, Zao River.


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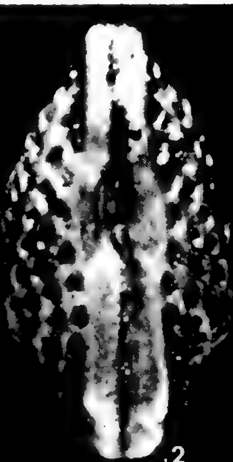
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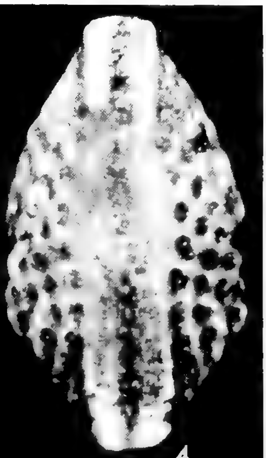
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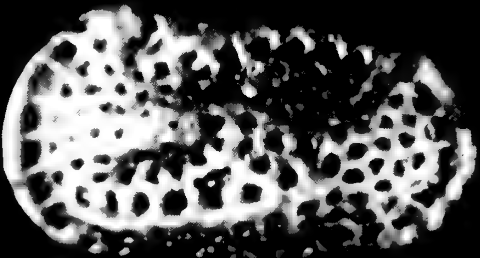
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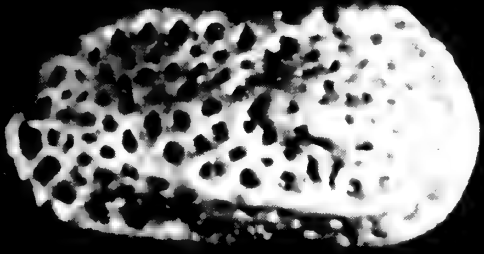
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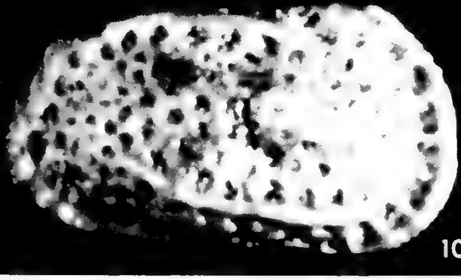
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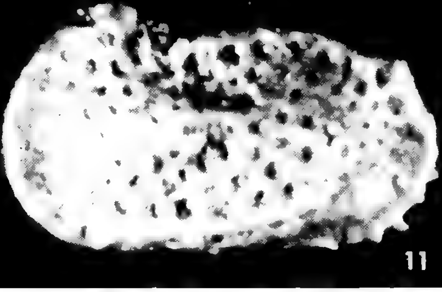
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PLATE 22

Gyrocythere perfecta sp. nov.

FIGS. 1, 2, 5, 9. Left, right, dorsal and ventral views, carapace male, × 68. Paratype, Io. 4281. Lower Chocolate Clays, sample 3499, Rakhi Nala.

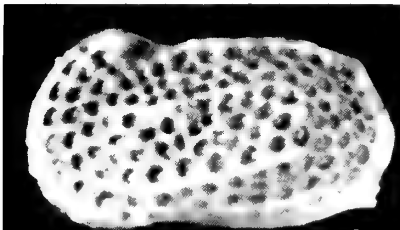
FIGS. 3, 4, 7, 8. Left, right, dorsal and ventral views, carapace female, × 68. Holotype, Io. 4335. Lower Chocolate Clays, sample 3499, Rakhi Nala.

FIG. 6. Muscle scars × 140, right valve male. Paratype, Io. 3121. Lower Chocolate Clays, sample 3499, Rakhi Nala.

FIG. 10. Internal view to show radial pore canals, right valve female, × 134. Paratype, Io. 3120. Lower Chocolate Clays, sample 3498, Rakhi Nala.

Hermanites cracens sp. nov.

FIG. 11. Ventral view, carapace, × 70. Holotype, Io. 4336. Gorge Beds, sample 3111, Rakhi Nala.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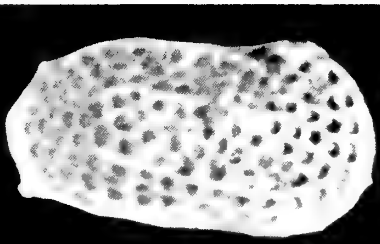
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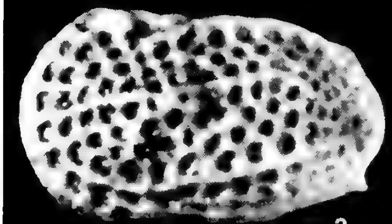
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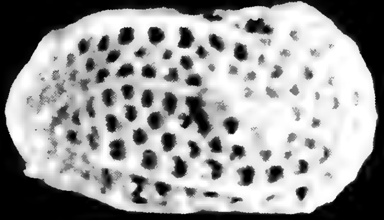
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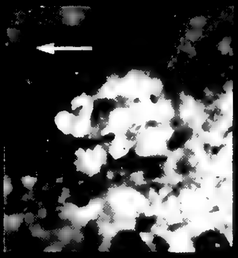
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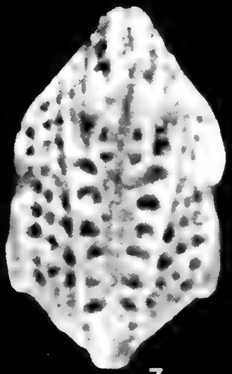
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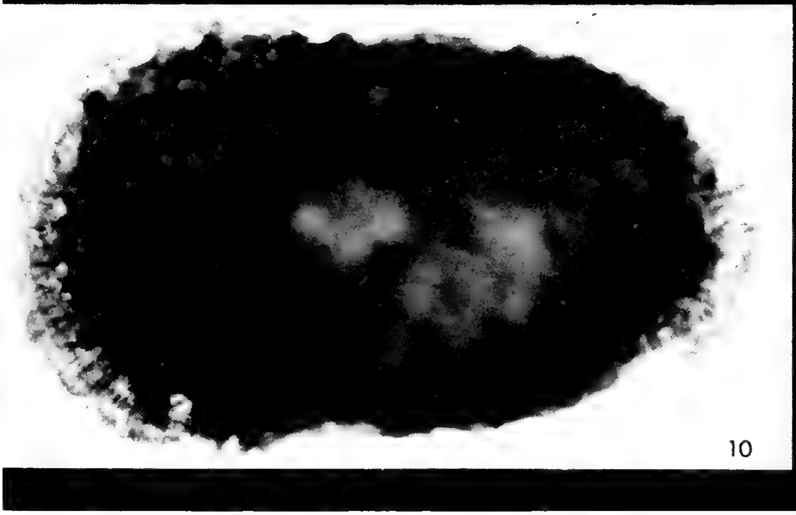
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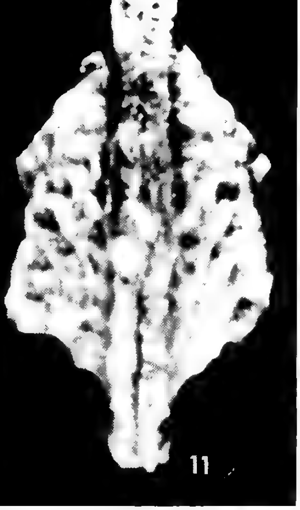
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PLATE 23

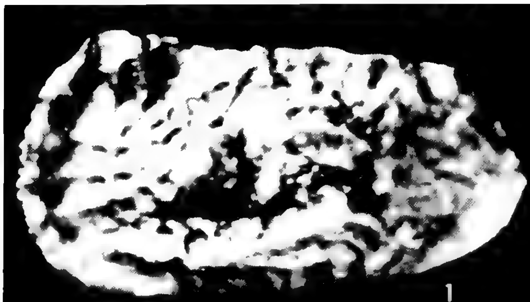
Hermanites cracens sp. nov.

Figs. 1–3. Left, right and dorsal views, carapace, × 70. Holotype, Io. 4336. Gorge Beds, sample 3111, Rakhi Nala.

Hermanites scopus sp. nov.

Figs. 4–7. Left, dorsal, ventral and right views, carapace male, × 70. Holotype, Io. 4338. Upper Chocolate Clays (lower part), sample 24148, Zao River.

Figs. 8–10. Right, dorsal and ventral views, carapace female, × 70. Paratype, Io. 4285. Lower Chocolate Clays, sample 3499, Rakhi Nala.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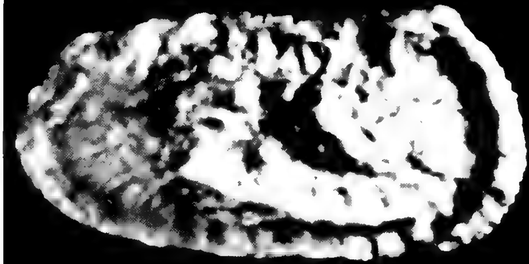
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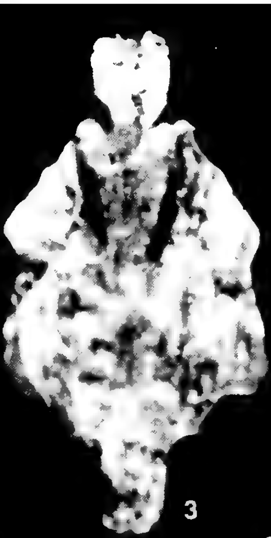
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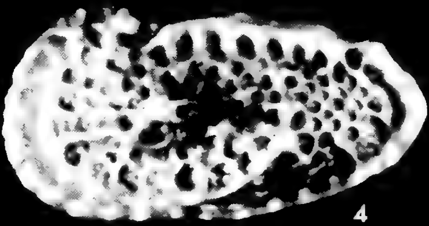
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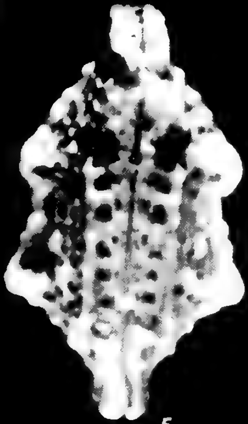
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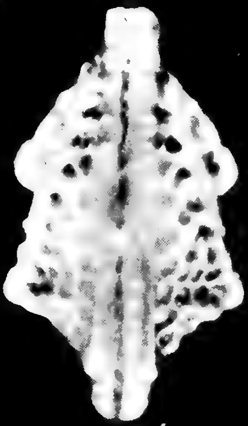
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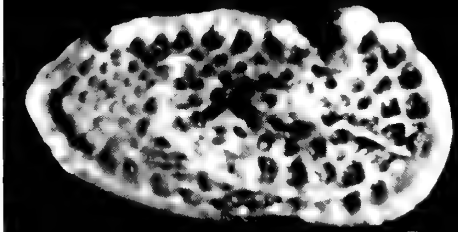
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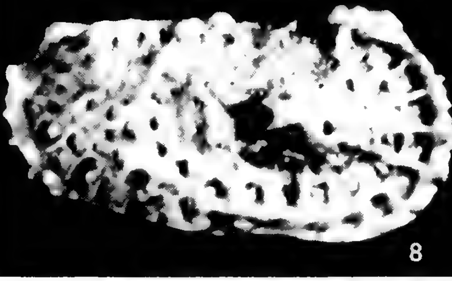
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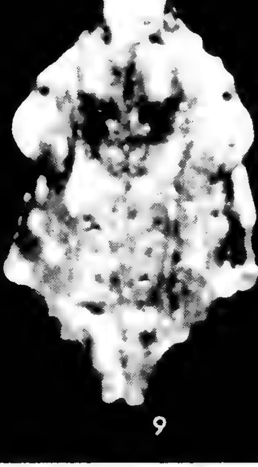
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PLATE 24

Hermanites palmatus sp. nov.

FIGS. 1, 2, 5. Dorsal, ventral and left views, carapace male, × 70. Paratype, Io. 4286. Upper Chocolate Clays (lower part), sample 24156, Zao River.

FIGS. 3, 4, 7. Dorsal, ventral and right views, carapace female, × 70. Paratype, Io. 3117. Upper Chocolate Clays (lower part), sample 24156, Zao River.

FIGS. 6, 8, 9, 11. Dorsal, external, internal and ventral views, left valve female, × 70. Holotype, Io. 4337. Upper Chocolate Clays (lower part), sample 24152, Zao River.

FIG. 12. External view, left valve female, × 70. Paratype, Io. 3118. Upper Chocolate Clays (lower part), sample 3613, Rakhi Nala.

Occultocythereis interrupta sp. nov.

FIGS. 10, 13, 15, 16. Left, right, dorsal and ventral views, carapace male, × 116. Paratype, Io. 4287. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIGS. 14, 17, 18. Right, dorsal and ventral views, carapace female, × 116. Holotype, Io. 4339. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

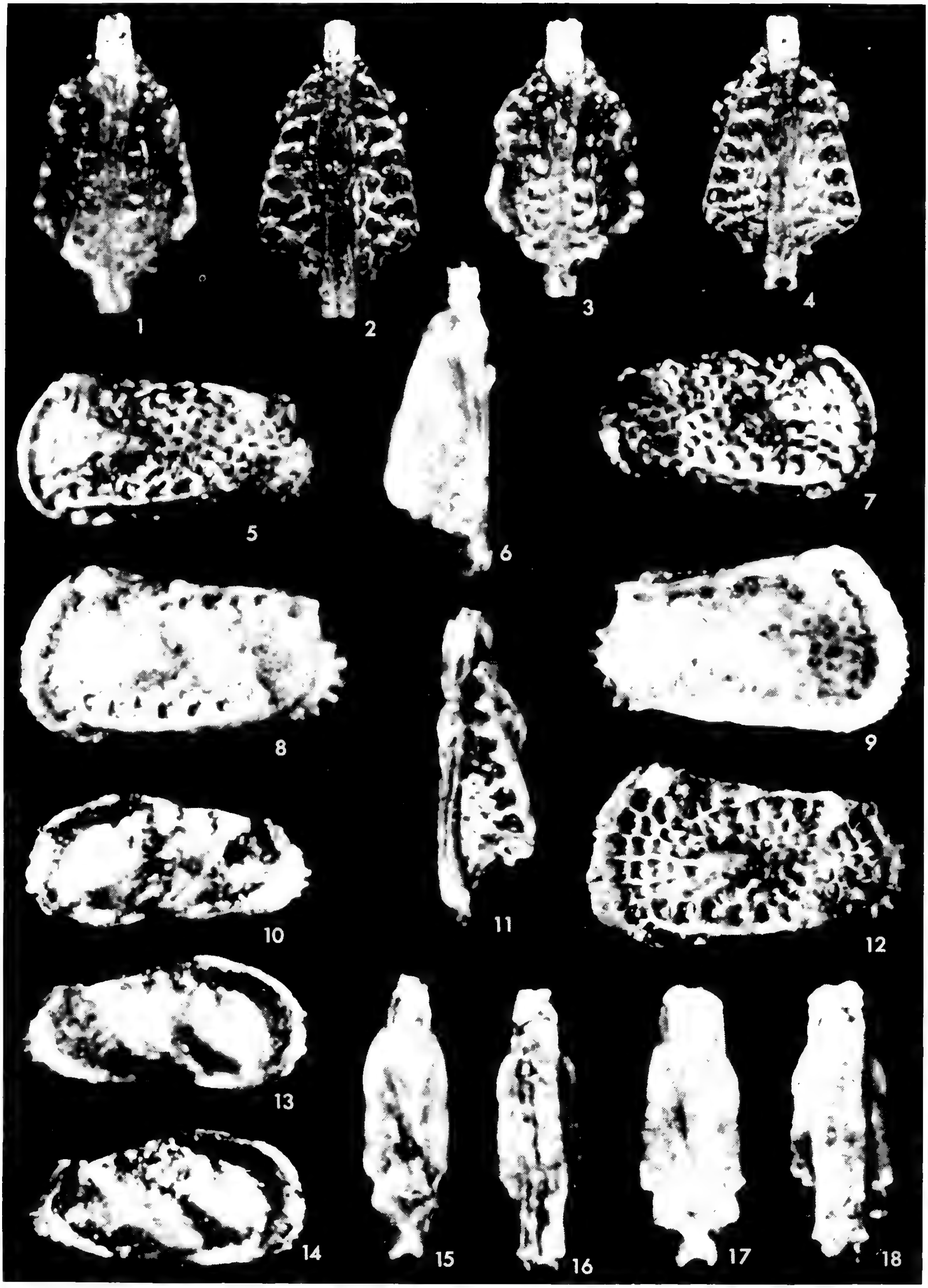
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PLATE 25

Occultocythereis sp.A

FIGS. 1, 2, 5. Left, right and ventral views, carapace, × 116. Io. 3136. Lower Rakhi Gaj Shales, sample 3672, Rakhi Nala.

Occultocythereis spilota sp. nov.

FIGS. 3, 4, 8, 9. Left, right, dorsal and ventral views, carapace male, × 120. Paratype, Io. 4288. Green and Nodular Shales, sample 3177, Rakhi Nala.

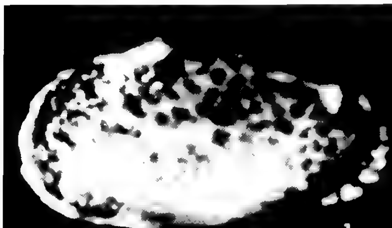
FIGS. 6, 7, 10, 11. Left, right, dorsal and ventral views, carapace female, × 120. Holotype, Io. 4342. Green and Nodular Shales, sample 3177, Rakhi Nala.

Occultocythereis peristicta sp. nov.

Morphotype A

FIGS. 13, 14, 17. Left, right and ventral views, carapace male, × 118. Paratype, Io. 4292. Upper Rakhi Gaj Shales, sample 3167, Rakhi Nala.

FIGS. 15, 16. Left and right views, carapace female, × 118. Holotype, Io. 4341. Upper Rakhi Gaj Shales, sample 3167, Rakhi Nala.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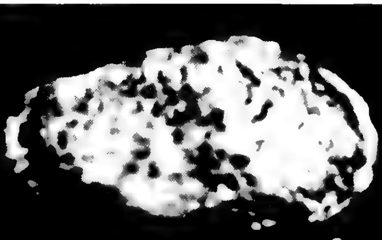
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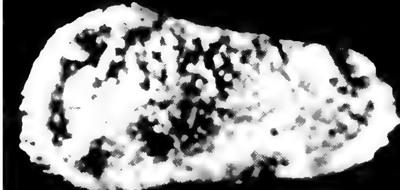
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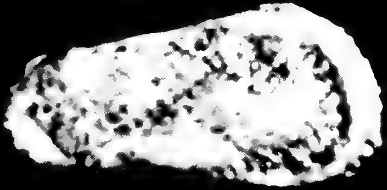
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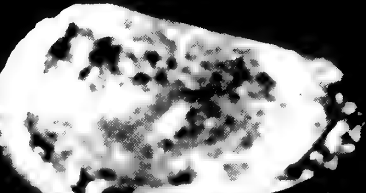
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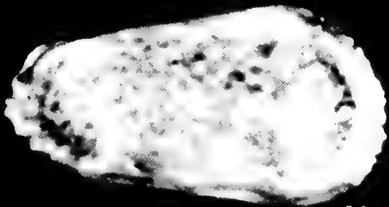
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PLATE 26

Occultocythereis peristicta sp. nov.

Morphotype A

FIG. 1. Dorsal view, carapace male, × 118. Paratype, Io. 4292. Upper Rakhi Gaj Shales, sample 3167, Rakhi Nala.

FIGS. 2, 3. Dorsal and ventral views, carapace female, × 118. Holotype, Io. 4341. Upper Rakhi Gaj Shales, sample 3167, Rakhi Nala.

Morphotype B

FIGS. 4, 6, 7. Ventral, left and right views, carapace male, × 118. Paratype, Io. 4293. Green and Nodular Shales, sample 3193, Rakhi Nala.

FIGS. 5, 8, 9. Ventral, left and right views, carapace female, × 118. Paratype, Io. 4291. Green and Nodular Shales, sample 3193, Rakhi Nala.

Morphotype C

FIGS. 10–12. Ventral, left and right views, carapace male, × 118. Paratype, Io. 4289. Green and Nodular Shales, sample 3191, Rakhi Nala.

FIGS. 13–15. Left, right and ventral views, carapace female, × 118. Paratype, Io. 4290. Green and Nodular Shales, sample 3191, Rakhi Nala.

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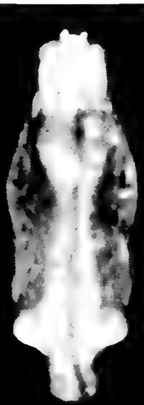

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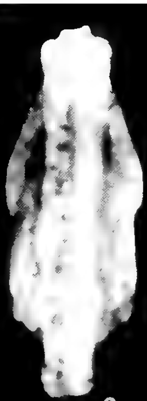

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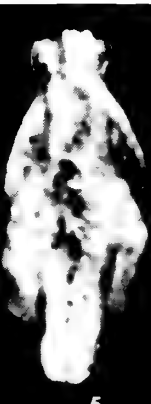

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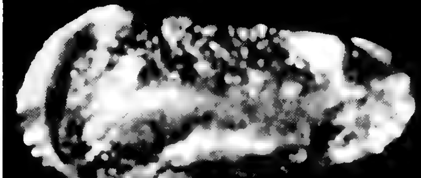

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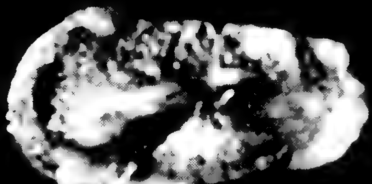

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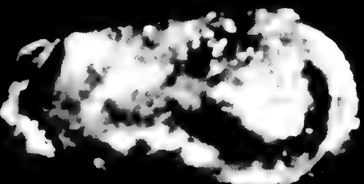

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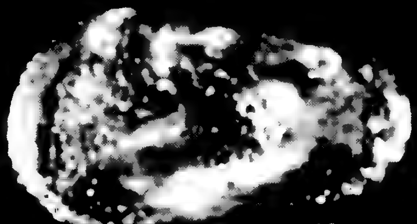

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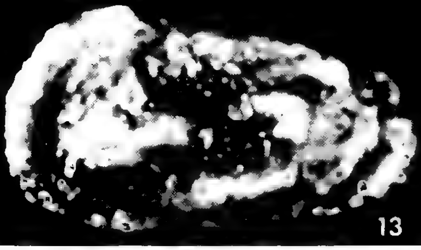

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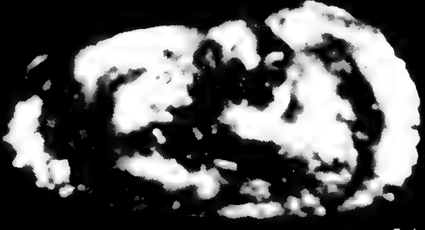

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PLATE 27

Occultocythereis peristicta sp. nov.

Morphotype D

FIGS. 1, 2, 5. Left, right and ventral views, carapace male, × 118. Paratype, Io. 3146. Green and Nodular Shales, sample 3191, Rakhi Nala.

FIGS. 3, 4, 6. Left, right and ventral views, carapace female, × 118. Paratype, Io. 3139. Green and Nodular Shales, sample 3191, Rakhi Nala.

Morphotype E

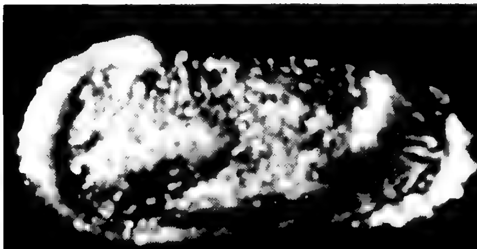
FIGS. 7, 9, 10. Ventral, right and left views, carapace male, × 118. Paratype, Io. 3137. Rubbly Limestones, sample 3418, Rakhi Nala.

FIGS. 8, 11, 12. Ventral, left and right views, carapace female, × 118. Paratype, Io. 3138. Rubbly Limestones, sample 3418, Rakhi Nala.

Occultocythereis indistincta sp. nov.

FIGS. 13, 14. Ventral and right views, carapace male, × 120. Paratype, Io. 3135. Lower Chocolate Clays, sample 3499, Rakhi Nala.

FIG. 15. Right view, carapace female, × 120. Holotype, Io. 4340. Lower Chocolate Clays, sample 3499, Rakhi Nala.



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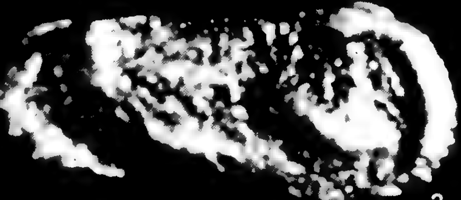

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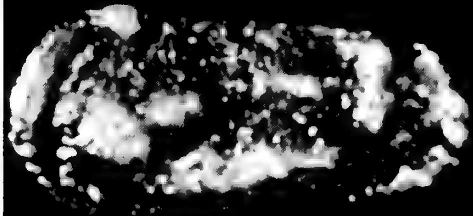

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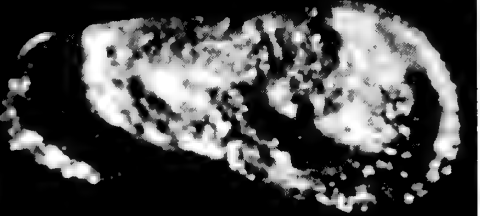

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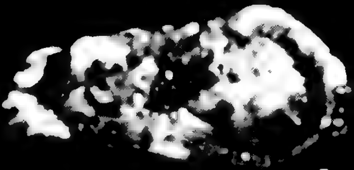

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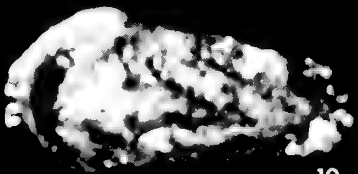

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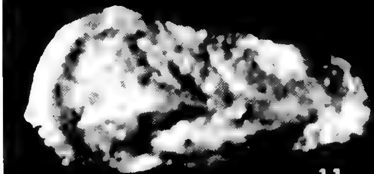

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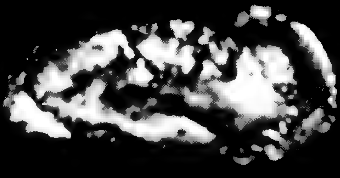

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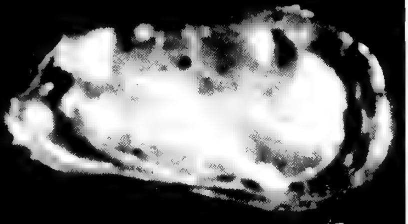

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PLATE 28

Occultocythereis indistincta sp. nov.

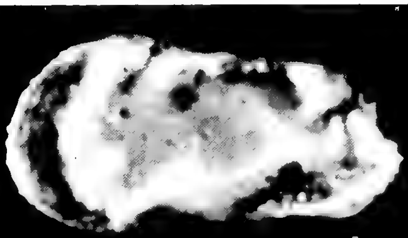
FIGS. 1, 3, 4. Left, dorsal and ventral views, carapace female, × 120. Holotype, Io. 4340. Lower Chocolate Clays, sample 3499, Rakhi Nala.

FIG. 2. Dorsal view, carapace male, × 120. Paratype, Io. 3135. Lower Chocolate Clays, sample 3499, Rakhi Nala.

Patagonacythere ? nidulus sp. nov.

FIGS. 5–8. Left, right, dorsal and ventral views, carapace male, × 70. Paratype, Io. 3096. Upper Chocolate Clays (upper part), sample 24173, Zao River.

FIGS. 9–12. Left, right, dorsal and ventral views, carapace female, × 70. Holotype, Io. 4349 Upper Chocolate Clays (lower part), sample 24173, Zao River.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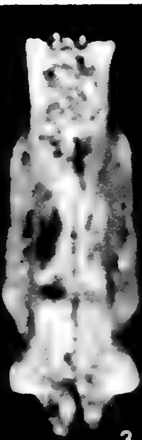
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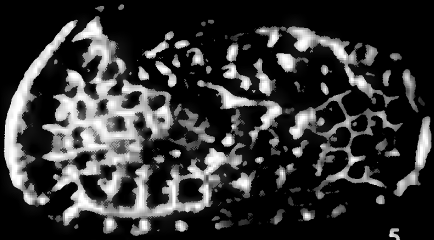
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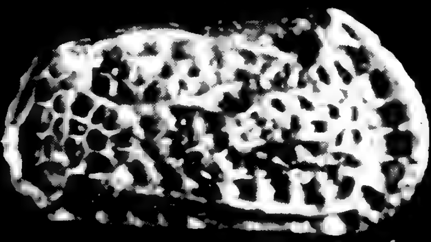
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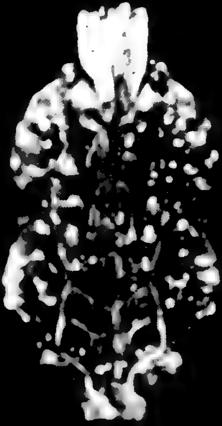
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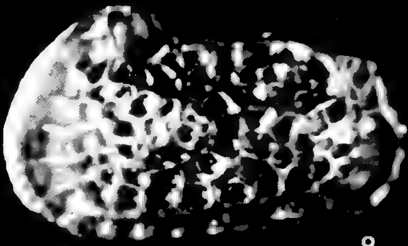
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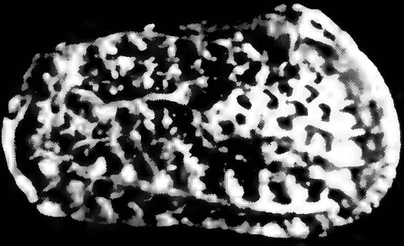
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PLATE 29

Patagonacythere ? nidulus sp. nov.

Specimens showing exaggerated normal pores after being cleaned in the ultrasonic vibrator.

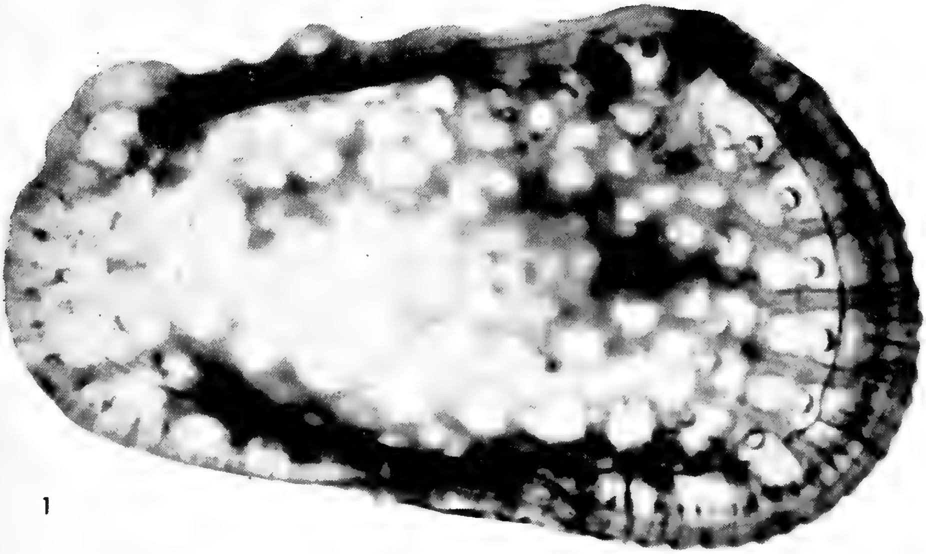
FIGS. 1, 2. 1, Internal view to show radial pore canals, × 160 ; 2, Dorsal view of hinge, × 150. Left valve female. Paratypes, Io. 3097. Upper Chocolate Clays (upper part), sample 24170, Zao River.

FIG. 3. Dorsal view of hinge, right valve female, × 150. Paratype, Io. 3098. Upper Chocolate Clays (upper part), sample 24170, Zao River.

FIG. 4. Muscle scars × 260. Right valve male. Paratype, Io. 4295. Upper Chocolate Clays (upper part), sample 34170, Zao River.

Phalcocythere horrescens (Bosquet) gen. nov.

FIG. 5. Anterior radial pore canals, × 212. Left valve. Io. 4257. Lutetian IV (sample CAB 1002, Keij 1957, p. 19), Grignon, Paris Basin.



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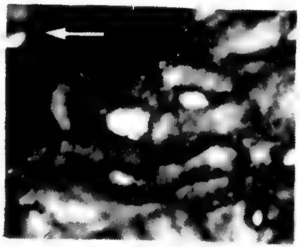

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PLATE 30

Phalcocythere horrescens (Bosquet) gen. nov.

FIGS. 1, 2. External and internal views, left valve, × 68. Io. 4254. Lutetian IV (sample CAB 1002, Keij 1957, p. 19), Grignon, Paris Basin.

FIGS. 3, 4. Dorsal and external views, left valve, × 68. Io. 4253. Lutetian IV (sample CAB 1002, Keij 1957, p. 19), Grignon, Paris Basin.

FIG. 5. Muscle scars × 195. Right valve. Io. 4255. Lutetian IV (sample CAB 1002, Keij 1957, p. 19), Grignon, Paris Basin.

FIG. 6. Internal view, right valve, × 132. Io. 4256. Lutetian, Villiers-St.-Frederic, Paris Basin.

Phalcocythere improcera sp. nov.

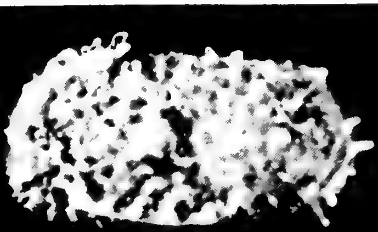
(See Pl. 33, figs. 12, 13 for hinge).

FIG. 7. Anterior radial pore canals × 224. Left valve female. Paratype, Io. 4295. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIGS. 8, 9. Left and right views, carapace male, × 68. Holotype, Io. 4344. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIGS. 10, 11. Left and right views, carapace female, × 68. Paratype, Io. 4258. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIG. 12. Anterior radial pore canals × 224. Right valve female. Paratype, Io. 4296. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.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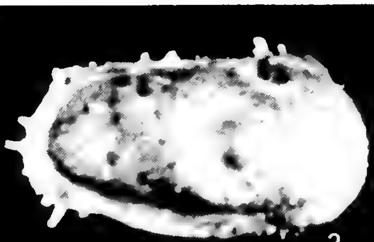
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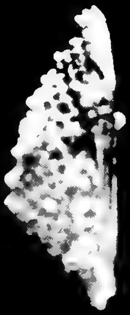
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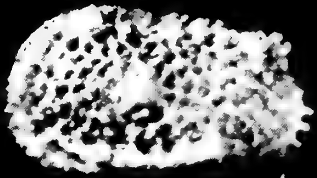
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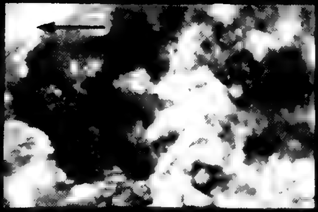
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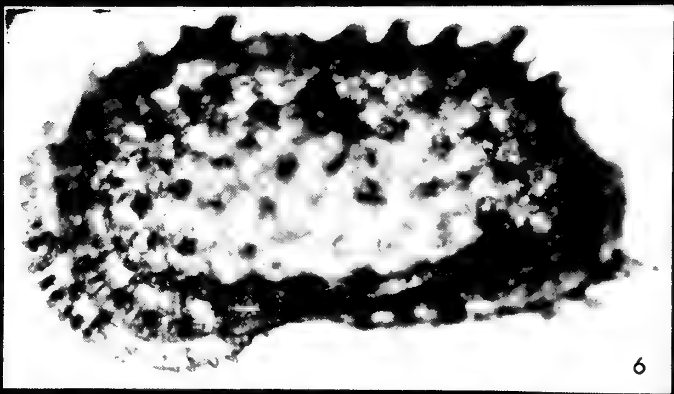
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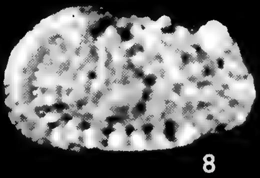
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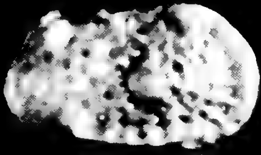
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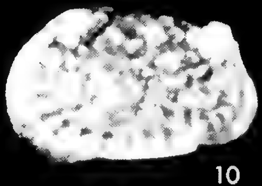
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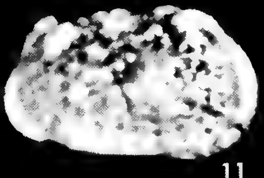
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PLATE 31

Phalcocythere improcera sp. nov.

FIGS. 1, 2. Dorsal and ventral views, carapace male, × 68. Holotype, Io. 4344. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIGS. 3, 4. Dorsal and ventral views, carapace female, × 68. Paratype, Io. 4258. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

Phalcocythere rete sp. nov.

FIGS. 5–8. Left, right, dorsal and ventral views, carapace male, × 68. Paratype, Io. 3099. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIGS. 9–10. Dorsal and left views, carapace female, × 68. Paratype, Io. 4297. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

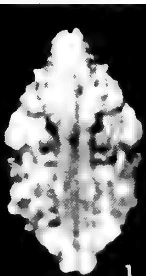
FIG. 11. External view, right valve female, × 68. Holotype, Io. 4348. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIG. 12. External view of valve female, × 68. Paratype, Io. 3141. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

Phalcocythere retispinata sp. nov.

FIGS. 13, 14, 17. Left, right and dorsal views, carapace male, × 68. Paratype, Io. 3165. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIGS. 15, 16. Left and right views, carapace female, × 68. Holotype, Io. 4345. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.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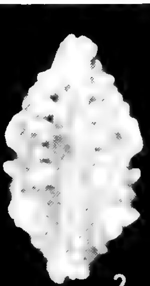
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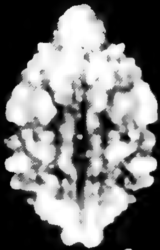
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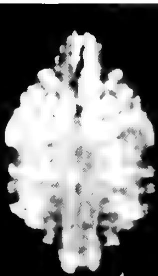
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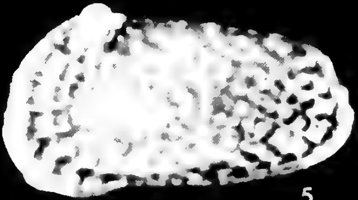
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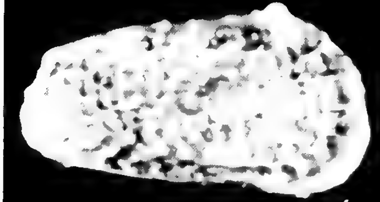
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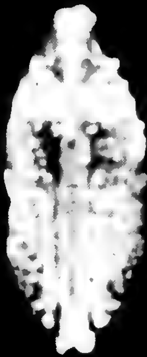
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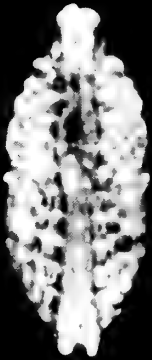
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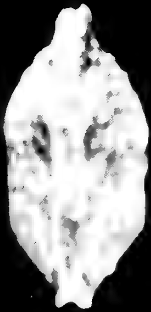
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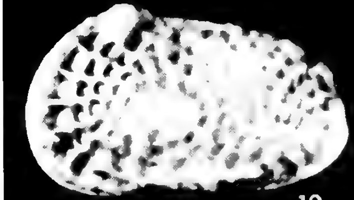
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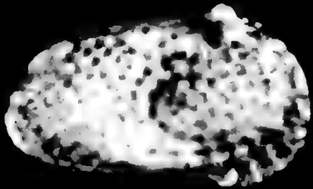
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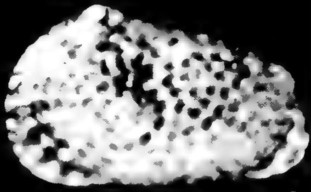
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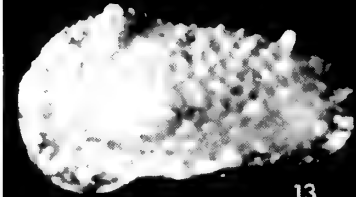
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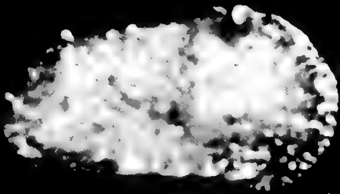
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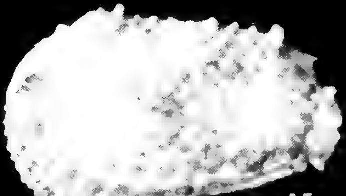
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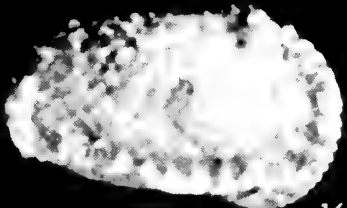
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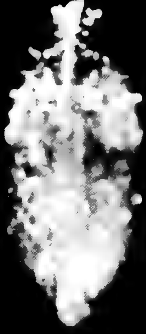
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PLATE 32

Phalcocythere retispinata sp. nov.

FIG. 1. Ventral view, carapace male, × 68. Paratype, Io. 3165. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIGS. 2, 3. Ventral and dorsal views, carapace female, × 68. Holotype, Io. 4345. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

Phalcocythere sentosa sp. nov.

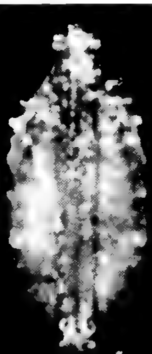
FIGS. 4, 5, 8, 10. Dorsal, left, right and ventral views, carapace male, × 68. Holotype, Io. 4346. Upper Rakhi Gaj Shales, sample 3167, Rakhi Nala.

FIGS. 6, 7, 9. Left, dorsal and right views, carapace female, × 68. Paratype, Io. 4298. Upper Rakhi Gaj Shales, sample 3167, Rakhi Nala.

Phalcocythere dissenta sp. nov.

FIGS. 11, 13, 14, 18. Left, right, dorsal and ventral views, carapace male, × 68. Holotype, Io. 4343. Shales with Alabaster, sample 3456, Rakhi Nala.

FIGS. 12, 15–17. Left, right, dorsal and ventral views, carapace female, × 68. Paratype, Io. 4299. Shales with Alabaster, sample 3456, Rakhi Nala.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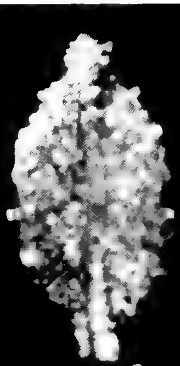
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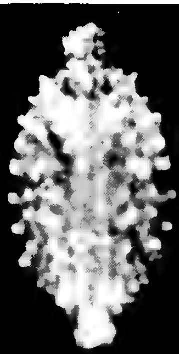
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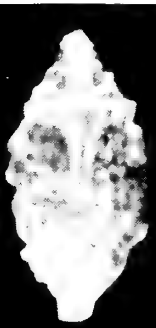
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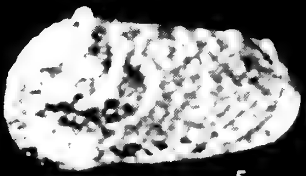
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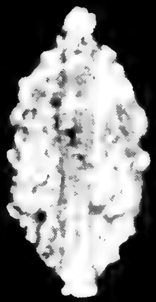
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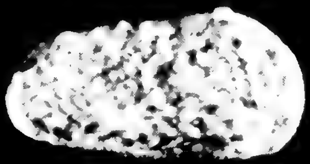
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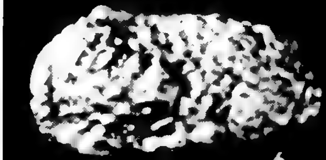
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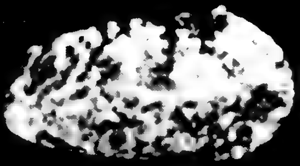
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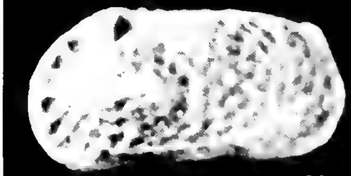
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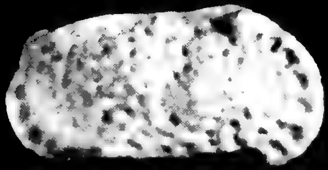
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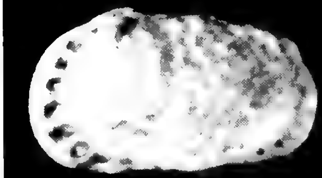
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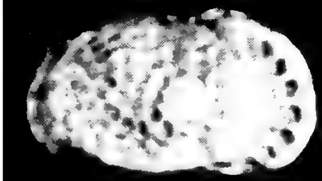
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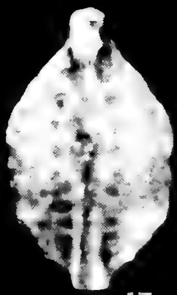
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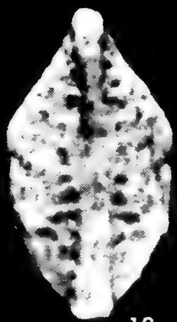
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PLATE 33

Phalcocythere spinosa sp. nov.

FIGS. 1, 2, 7, 8. Left, right, dorsal and ventral views, carapace, × 68. Holotype, Io. 4347. Upper Chocolate Clays (upper part), sample 24161, Zao River.

Phalcocythere sp., cf. ***P. spinosa***

FIGS. 3, 4, 9. Left, right and ventral views, carapace male, × 68. Io. 4230. Upper Eocene, Lindi survey, 10–50 ft. above shore at Kitunga, Tanzania.

FIGS. 5, 6, 10. Left, right and dorsal views, carapace female, × 68. Io. 4231. Upper Eocene, Lindi survey, 10–50 ft. above shore at Kitunga, Tanzania.

FIG. 11. Muscle scars × 210, fragment of right valve female. Io. 4232. Upper Eocene, Lindi survey, 10–50 ft. above shore at Kitunga, Tanzania.

Phalcocythere horrescens (Bosquet) gen. nov.

FIG. 12. Dorsal view of hinge × 183, left valve. Io. 4257. Lutetian IV (sample CAB 1002, Keij 1957, p. 19), Grignon, Paris Basin.

FIG. 13. Dorsal view of hinge × 183, right valve. Io. 4255. Lutetian IV (sample CAB 1002, Keij 1957, p. 19), Grignon, Paris Basin.

Quadracythere (Hornibrookella) platybomus sp. nov.

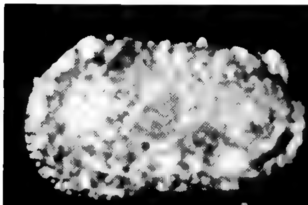
FIGS. 14, 18. Right and dorsal view, carapace male, × 70. Holotype, Io. 4351. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIGS. 15, 19. Right and dorsal views, carapace female, × 70. Paratype, Io. 4300. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

Quadracythere (Hornibrookella) directa sp. nov.

FIG. 16. Left view, carapace male, × 70. Io. 4301. Green and Nodular Shales, sample 3403, Rakhi Nala.

FIG. 17. Left view, carapace female, × 70. Holotype, Io. 4350. Green and Nodular Shales, sample 3403, Rakhi Nala.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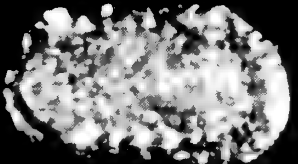
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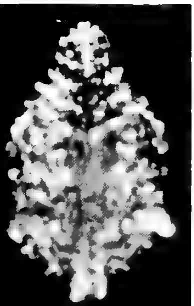
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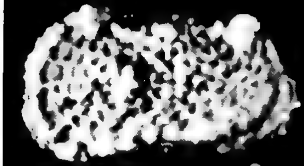
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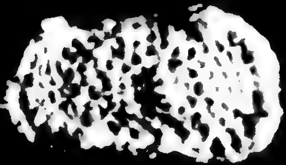
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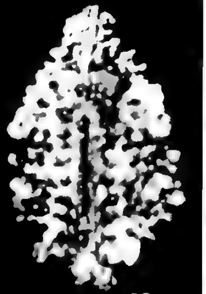
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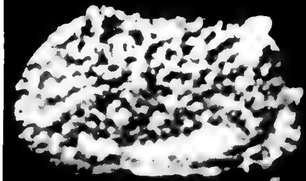
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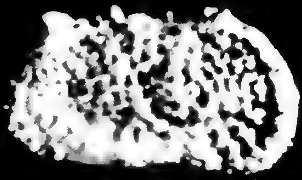
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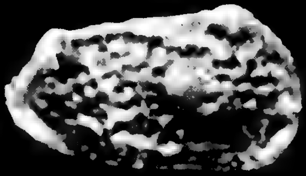
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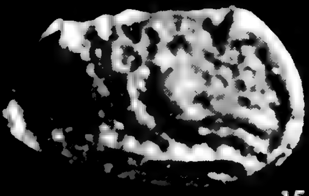
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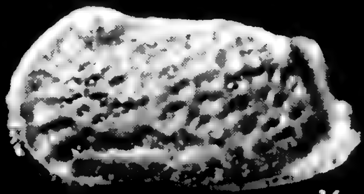
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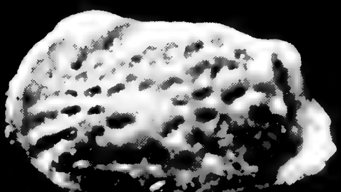
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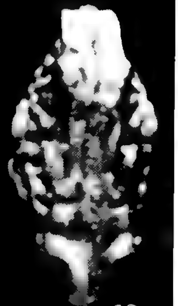
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PLATE 34

Quadracythere (Hornibrookella) directa sp. nov.

FIG. 1. Dorsal view, carapace male, × 70. Paratype, Io. 4301. Green and Nodular Shales, sample 3403, Rakhi Nala.

FIG. 2. Dorsal view, carapace female, × 70. Holotype, Io. 4350. Green and Nodular Shales, sample 3403, Rakhi Nala.

Quadracythere (Hornibrookella) arcana (Lubimova and Guha)

FIGS. 3–5. Right, left and dorsal views, carapace, × 70. Io. 3142. Lower Chocolate Clays, sample 3499, Rakhi Nala.

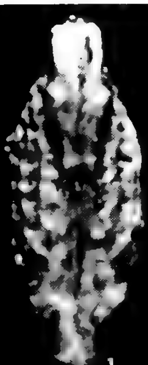
Quadracythere (Hornibrookella) subquadra sp. nov.

FIGS. 6, 8, 9. Left, dorsal and ventral views, carapace male, × 70. Paratype, Io. 4302. Upper Chocolate Clays (upper part), sample 24161, Zao River.

FIGS. 7, 10, 11. Left, right and dorsal views, carapace female, × 70. Holotype, Io. 4352. Upper Chocolate Clays (upper part), sample 24161, Zao River.

Quadracythere (Hornibrookella) sp.A

FIGS. 12–14. Left, right and dorsal views, carapace, × 70. Io. 3143. Upper Chocolate Clays (lower part), sample 24148, Zao River.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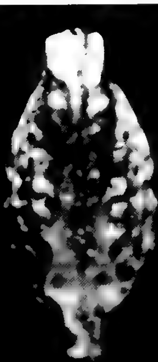
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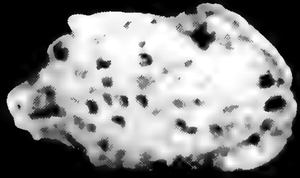
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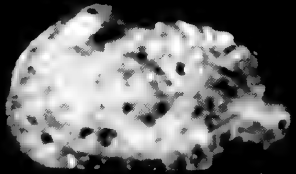
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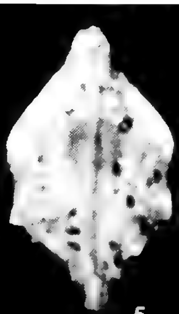
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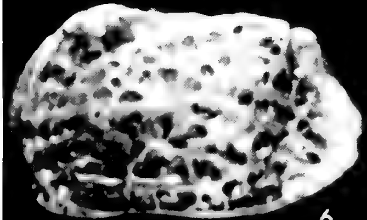
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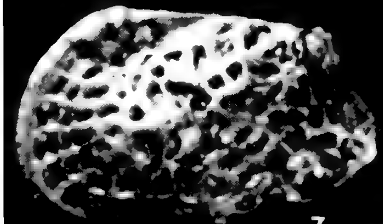
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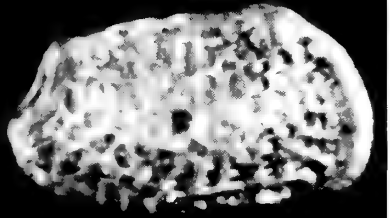
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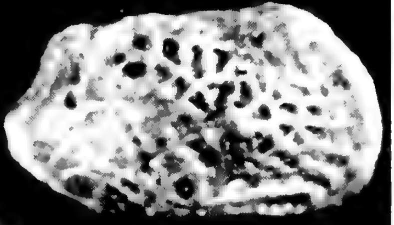
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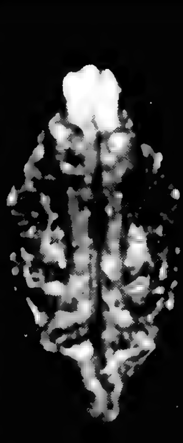
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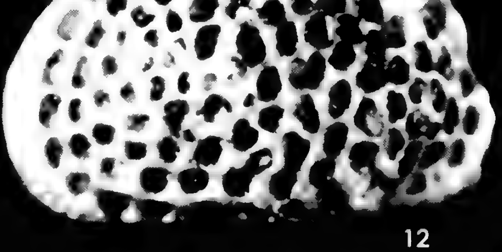
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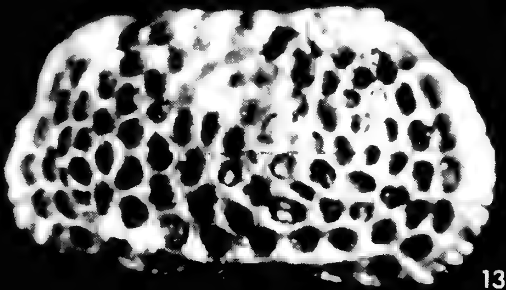
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PLATE 35

Stigmatocythere obliqua gen. et sp. nov.

FIG. 1. Dorsal view, carapace male, × 92. Specimen lost. Shales with Alabaster, sample 24173, Rakhi Nala.

FIGS. 3, 4. Left and right views, carapace male, × 92. Paratype, Io. 4303. Shales with Alabaster, sample 24173, Rakhi Nala.

FIGS. 2, 5, 6. Dorsal, left and right views, carapace female, × 92. Holotype, Io. 4355. Shales with Alabaster, sample 24173, Rakhi Nala.

FIG. 7. Dorsal view, left valve female, × 92. Paratype, Io. 3147. Shales with Alabaster, sample 24173, Rakhi Nala.

FIG. 8. Dorsal view, right valve female, × 92. Paratype, Io. 3148. Shales with Alabaster, sample 24173, Rakhi Nala.

FIG. 9. Internal view to show radial pore canals, right valve female, × 160. Paratype, Io. 3146. Shales with Alabaster, sample 24173, Rakhi Nala.

FIG. 10. Internal view to show radial pore canals, left valve female, × 160. Paratype, Io. 3149. Shales with Alabaster, sample 24173, Rakhi Nala.


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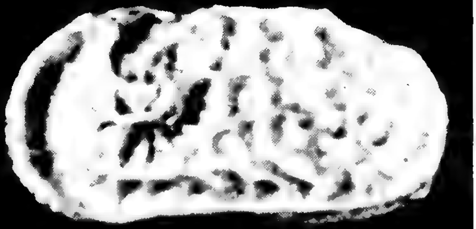
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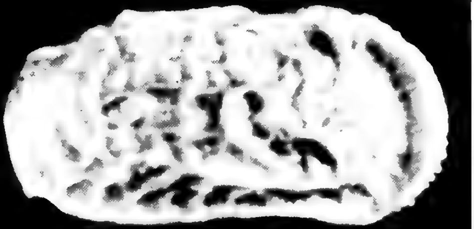
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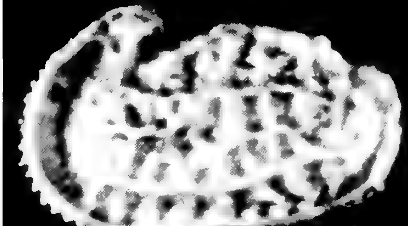
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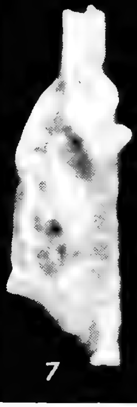
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PLATE 36

Stigmatocythere obliqua gen. et sp. nov.

FIG. 1. Ventral view, carapace male, × 92. Paratype, Io. 4303. Shales with Alabaster, sample 24173, Rakhi Nala.

FIG. 2. Ventral view, carapace male, × 92. Holotype, Io. 4355. Shales with Alabaster, sample 24173, Rakhi Nala.

Stigmatocythere portentum sp. nov.

FIGS. 3–6. Dorsal, ventral, left and right views, carapace male, × 92. Holotype, Io. 4357. Lower Chocolate Clays, sample 3499, Rakhi Nala.

FIG. 10. Anterior radial pore canals × 216, fragment of right valve. Paratype, Io. 3144.

Stigmatocythere calia sp. nov.

FIG. 7. External view, right valve male, × 92. Paratype, Io. 3404. Upper Chocolate Clays (lower part), sample 24152, Zao River.

FIGS. 8, 9. Right and dorsal views, carapace female, × 92. Holotype, Io. 4353. Upper Chocolate Clays (lower part), sample 24151, Zao River.

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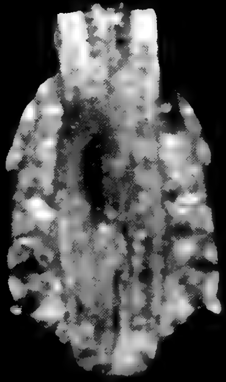

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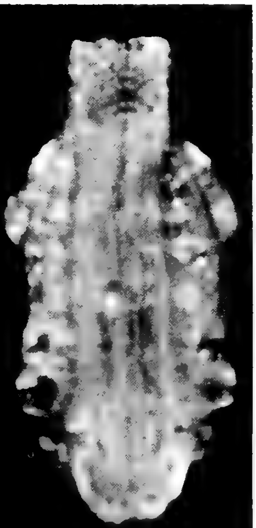

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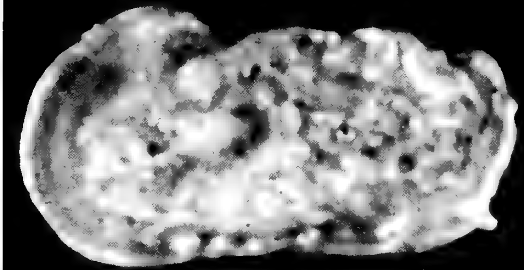

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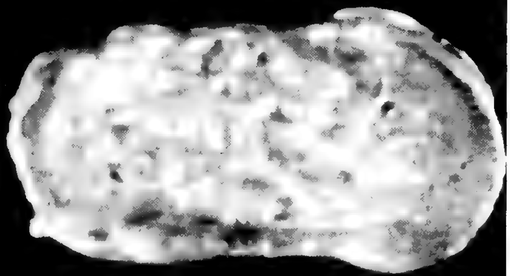

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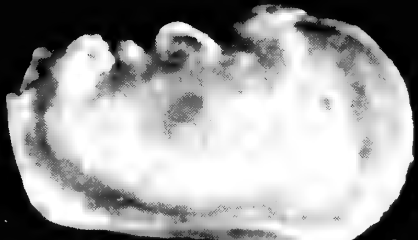

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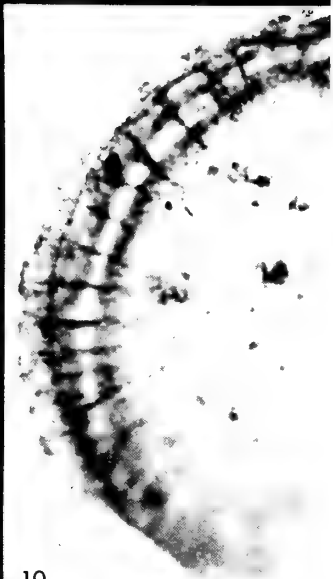

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PLATE 37

Stigmatocythere calia sp. nov.

FIGS. 1, 3. Left and ventral views, carapace female, × 92. Holotype, Io. 4353. Upper Chocolate Clays (lower part), sample 24151, Zao River.

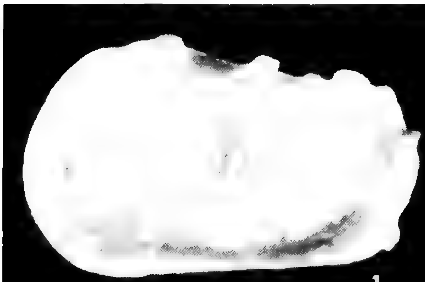
Stigmatocythere delineata sp. nov.

FIGS. 2, 4, 5, 6. Left dorsal, right and ventral views, carapace male, × 92. Paratype, Io. 4305. Upper Chocolate Clays (lower part), sample 24154, Zao River.

FIGS. 7–10. Dorsal, left, right and ventral views, carapace female, × 92. Holotype, Io. 4356. Upper Chocolate Clays (lower part), sample 24154, Zao River.

Stigmatocythere lumaria sp. nov.

FIG. 11. Anterior radial pore canals × 150, right valve female. Paratype, Io. 3154. Upper Chocolate Clays (upper part), sample 24174, Zao River.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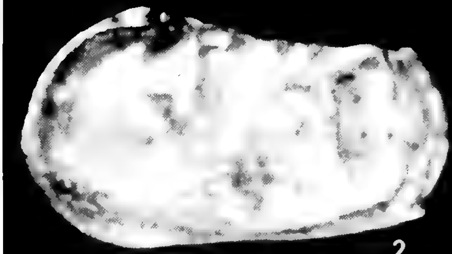
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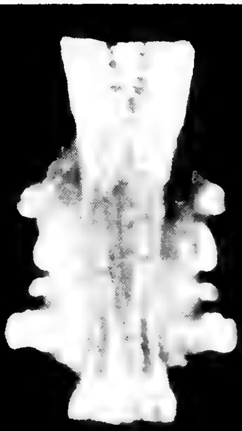
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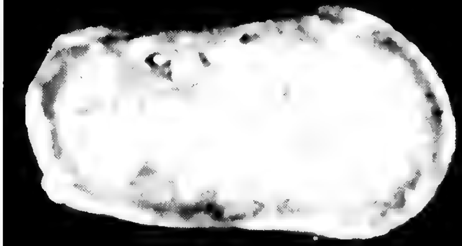
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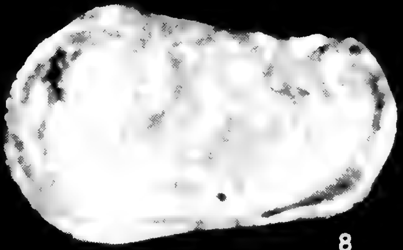
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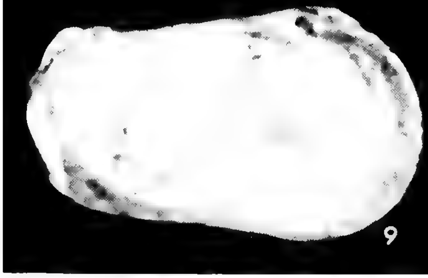
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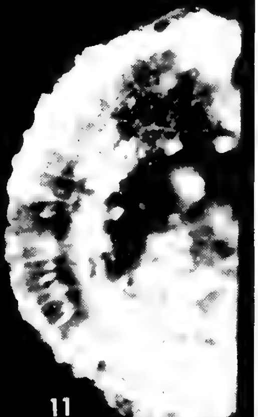
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PLATE 38

Stigmatocythere lumaria sp. nov.

Morphotype A

FIGS. 1, 5, 6. Left, dorsal and ventral views, carapace male, × 92. Holotype, Io. 4354. Upper Chocolate Clays (upper part), sample 3642, Rakhi Nala.

FIGS. 2, 4, 7. External, internal and dorsal views, right valve male, × 92. Paratype, Io. 3151. Upper Chocolate Clays (upper part), sample 3630, Rakhi Nala.

FIGS. 3, 8. External and dorsal views, right valve female, × 92. Paratype, Io. 4307. Upper Chocolate Clays (upper part), sample 3630, Rakhi Nala.

FIG. 9. Dorsal view of hinge × 240, left valve female. Paratype, Io. 3152. Upper Chocolate Clays (upper part), sample 24174, Zao River.

FIG. 10. Dorsal view of hinge × 240, right valve female. Paratype, Io. 3154. Upper Chocolate Clays (upper part), sample 24174, Zao River.


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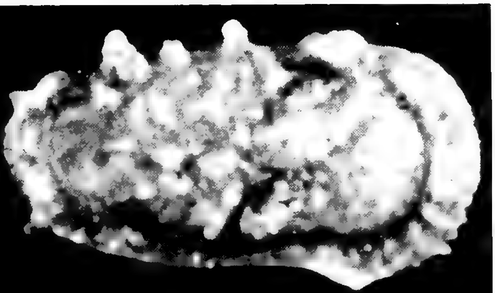
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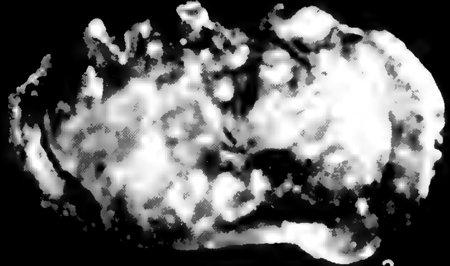
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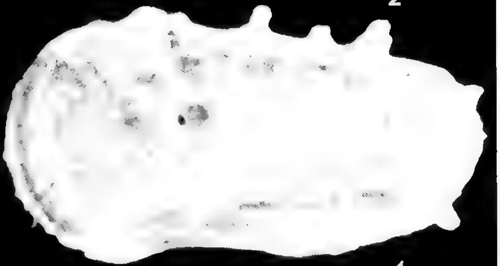
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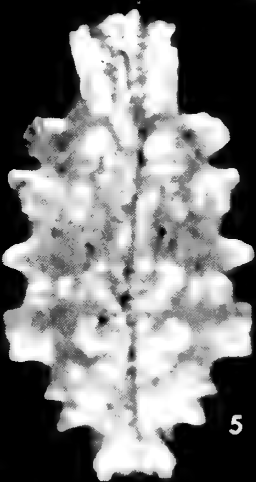
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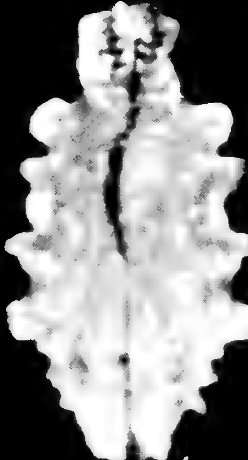
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9&10

PLATE 39

Stigmatocythere lumaria sp. nov.

Morphotype B

FIGS. 1–4. Left, right, dorsal and ventral views, carapace male, × 92. Paratype, Io. 3150. Upper Chocolate Clays (upper part), sample 3649, Rakhi Nala.

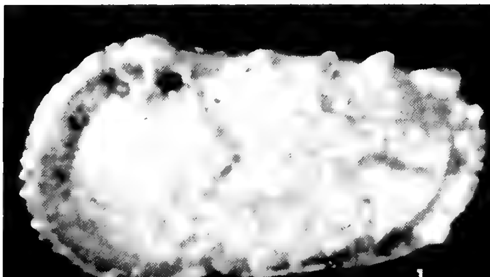
FIGS. 5–8. Left, dorsal, ventral and right views, carapace female, × 92. Paratype, Io. 3153. Upper Chocolate Clays (upper part), sample 3649, Rakhi Nala.

Morphotype A

FIG. 11. Anterior radial pore canals × 232, left valve male (juv.). Paratype, Io. 4306. Upper Chocolate Clays (upper part), sample 24174, Zao River.

Trachyleberis (Trachyleberis) lobuculus sp. nov.

FIGS. 9, 10. Left and dorsal views, carapace male, × 94. Paratype, Io. 4308. Upper Rakhi Gaj Shales, sample 3163, Rakhi Nala.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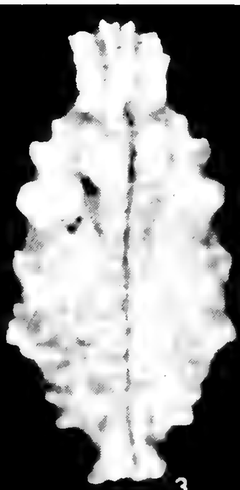
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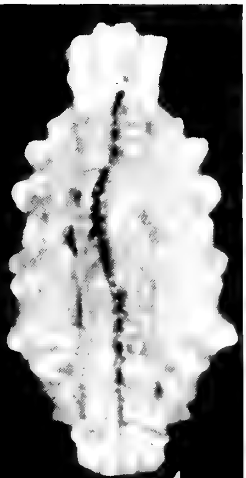
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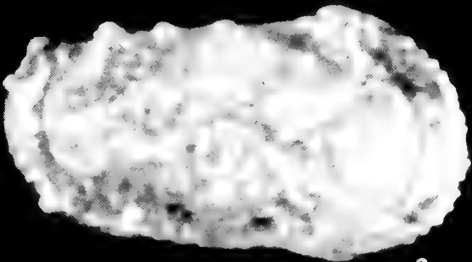
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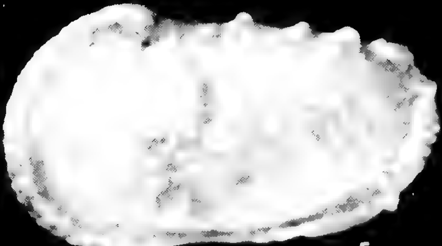
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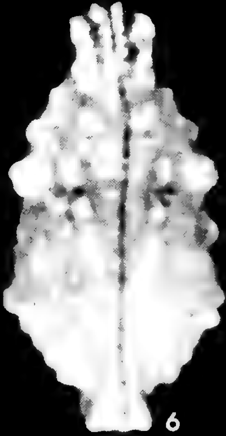
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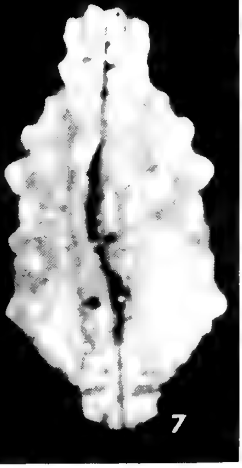
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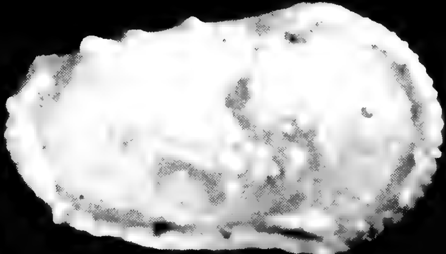
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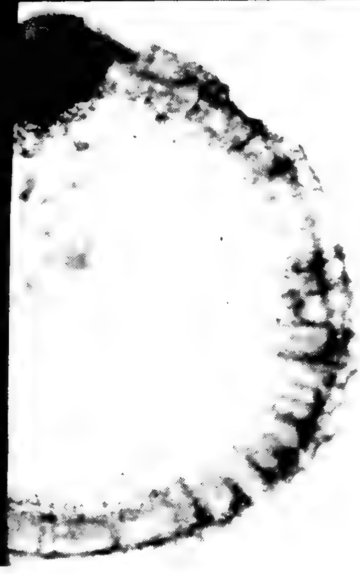
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PLATE 40

Trachyleberis (Trachyleberis) lobuculus sp. nov.

FIGS. 1, 3. Left and dorsal views, carapace female, × 93. Holotype, Io. 4364. Upper Rakhi Gaj Shales, sample 3166, Rakhi Nala.

Trachyleberis (Trachyleberis) bimammillata sp. nov.

FIGS. 2, 8, 10. Left, right and dorsal views, carapace male, × 94. Holotype, Io. 4363. Upper Chocolate Clays (lower part), sample 3613, Rakhi Nala.

FIG. 4. Dorsal view, left valve female, × 94. Paratype, Io. 3156. Upper Chocolate Clays (lower part), sample 3611, Rakhi Nala.

FIG. 5. Dorsal view, right valve female, × 94. Paratype, Io. 3155. Upper Chocolate Clays (lower part), sample 3614, Rakhi Nala.

FIG. 6. Dorsal view, carapace male, × 94. Paratype, Io. 3160. Upper Chocolate Clays (lower part), sample 3613, Rakhi Nala.

FIG. 7. Dorsal view, carapace female, × 94. Paratype, Io. 3157. Upper Chocolate Clays (lower part), sample 3613, Rakhi Nala.

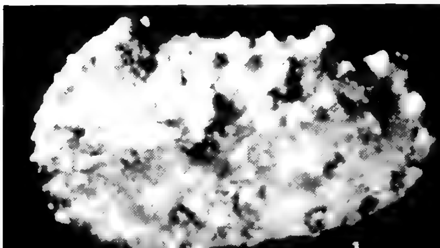
FIG. 9. Left view, carapace female, × 94. Paratype, Io. 3159. Upper Chocolate Clays (lower part) sample 3613, Rakhi Nala.

FIG. 11. Muscle scars × 172, fragment of left valve male. Paratype, Io. 3158. Upper Chocolate Clays (lower part), sample 3613, Rakhi Nala.

Trachyleberis (Acanthocythereis) procapsus sp. nov.

FIG. 12. Left view, carapace male, × 94. Holotype, Io. 4360. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIG. 13. Left view, carapace female, × 94. Paratype, Io. 3164. Upper Palaeocene, sample 460-j, Sor Range, 8 miles east of Quetta.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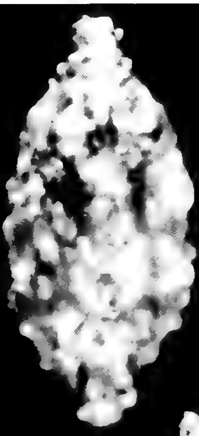
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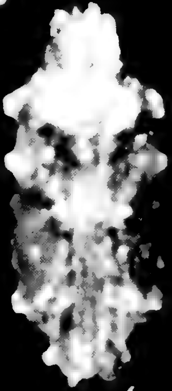
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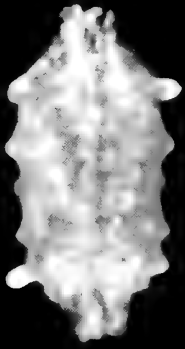
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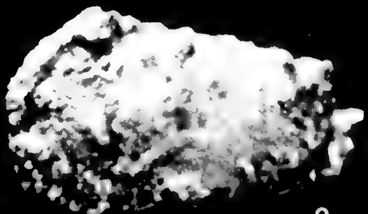
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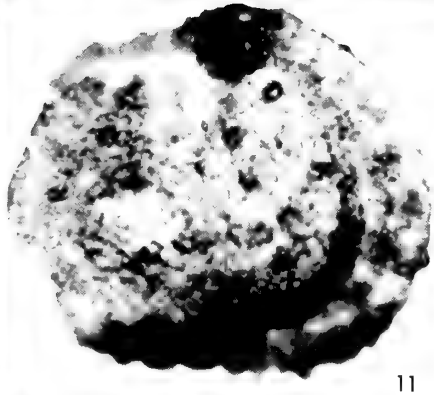
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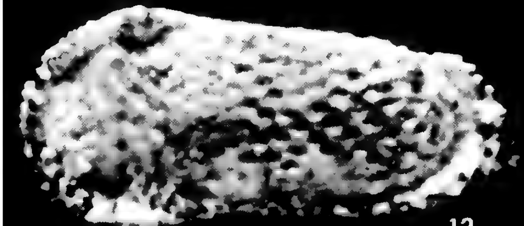
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PLATE 41

Trachyleberis (Acanthocythereis) procapsus sp. nov.

FIGS. 1, 3. Right and dorsal views, carapace male, × 94. Holotype, Io. 4360. Upper Palaeocene, sample 460-i, Sor Range, 8 miles east of Quetta.

FIG. 4. Dorsal view, carapace female, × 94. Paratype, Io. 3164. Upper Palaeocene, sample 460-j, Sor Range, 8 miles east of Quetta.

Trachyleberis (Acanthocythereis) usitata sp. nov.

FIG. 2. Right view, carapace male, × 94. Holotype, Io. 4362. Gorge Beds, sample 3111, Rakhi Nala.

FIGS. 5, 7. Left and right views, carapace female, × 94. Paratype, Io. 3161. Gorge Beds, sample 3111, Rakhi Nala.

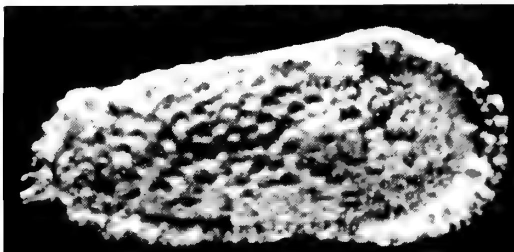
Trachyleberis (Acanthocythereis) pedigaster sp. nov.

FIGS. 6, 8. Right and left views, carapace, × 70. Holotype, Io. 4358. Lower Rakhi Gaj Shales, sample 3671, Rakhi Nala.

Trachyleberis (Acanthocythereis) postcornis sp. nov.

FIG. 9. Left view, carapace male, × 94. Holotype, Io. 4361. Lower Chocolate Clays, sample 3499, Rakhi Nala.

FIG. 10. Left view, carapace female, × 94. Paratype, Io. 3162. Lower Chocolate Clays, sample 3499, Rakhi Nala.



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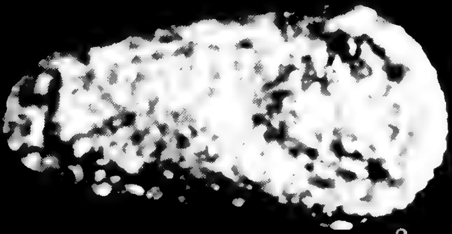

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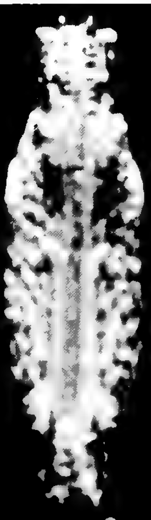

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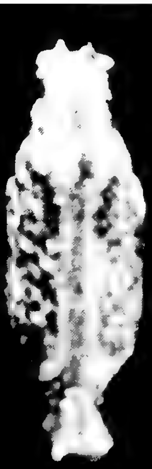

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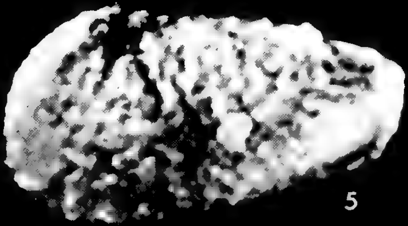

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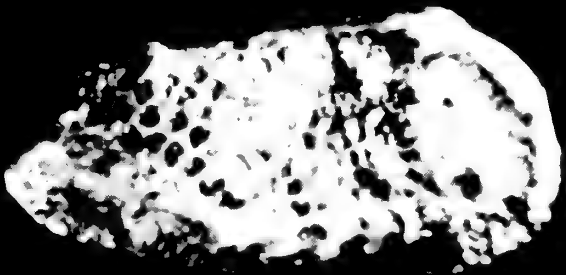

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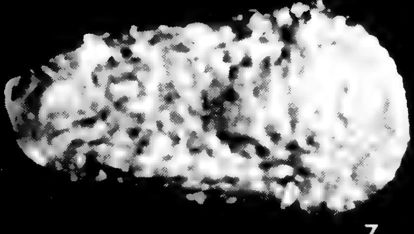

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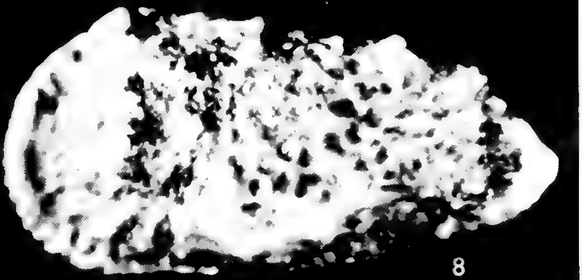

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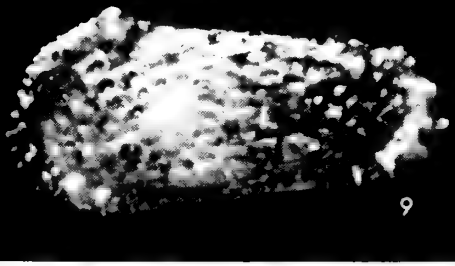

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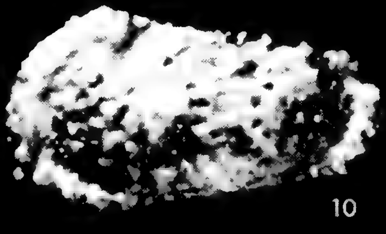

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PLATE 42

Trachyleberis (Acanthocythereis) postcornis sp. nov.

FIG. 1. Dorsal view, carapace male, × 94. Holotype, Io. 4361. Lower Chocolate Clays, sample 3499, Rakhi Nala.

FIG. 2. Dorsal view, carapace female, × 94. Paratype, Io. 3162. Lower Chocolate Clays, sample 3499, Rakhi Nala.

FIGS. 7, 10. 7, Dorsal view of hinge, × 232. 10, Internal view to show radial pore canals, × 178. Right valve female. Paratype, Io. 3163. Lower Chocolate Clays, sample 3498, Rakhi Nala.

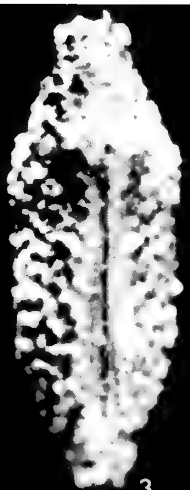
Trachyleberis (Acanthocythereis) decoris sp. nov.

FIGS. 3–5. Dorsal, left and right views, carapace male, × 94. Holotype, Io. 4359. Upper Chocolate Clays (upper part), sample 3640, Rakhi Nala.

FIGS. 6, 8, 9. Dorsal, left and right views, carapace female, × 94. Paratype, Io. 4310. Upper Chocolate Clays (upper part), sample 3640, Rakhi Nala.


1


2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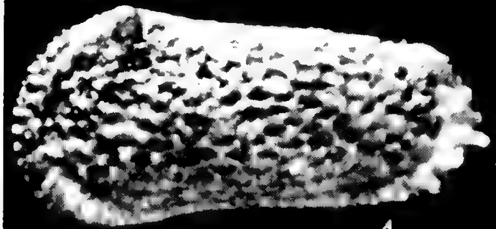
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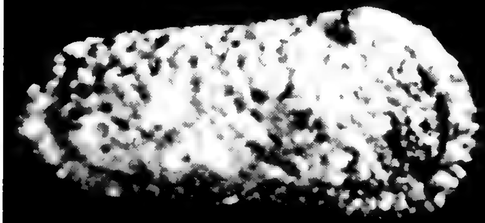
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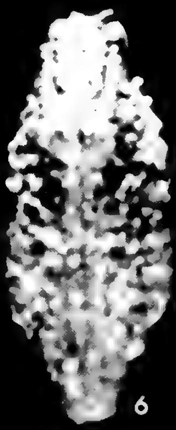
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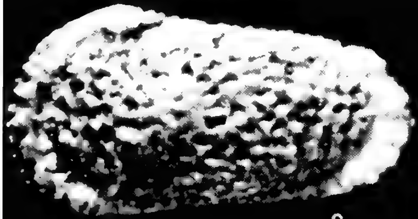
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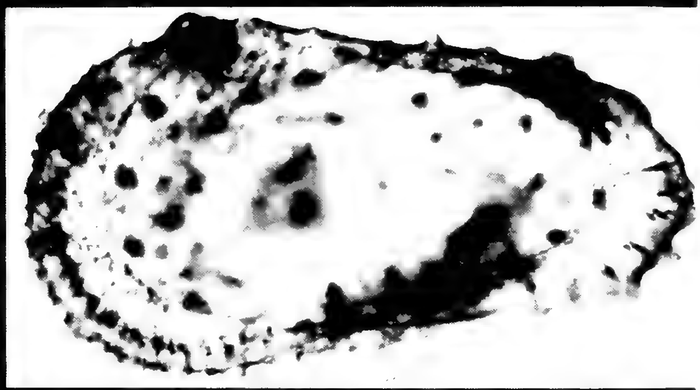
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Table 1. Stratigraphic frequency of the ostracod family Trachyleberididae in the Palaeocene and Lower Eocene of the Rakhi Nala.

Samples with total no. of ostracods Species	3111	3130	3132	3133	3672	3671	3147	3152	3153	3157	3158	3159	3160	3161	3162	3163	3164	3165	3166	3167	3168	3169	3170	3171	3172	3173	3174	3175	3176
1 Alocopocythere rupina sp nov	41																												
2 Buntonia devexa sp nov	8																												
3 Hermanites cracens sp nov	1																												
4 Trachyleberis (Acanthocythereis) usitata sp nov	2	1	1	1																									
5 Buntonia sp A			2																										
6 Occultocythereis sp A					1																								
7 Trachyleberis (Acanthocythereis) pedigaster sp. nov						1																							
8 Alocopocythere abstracta sp nov							10	3	20	1	11	9	1	2	6	13	20	25	18	37	6	17	20	10	2	1	1	30	20
9 Trachyleberis (Trachyleberis) lobuculus sp. nov							1	-	-	-	-	-	1	-	4	6	-	-	4	2	-	2	3	2	-	1	1	5	-
10 Gyrocythere parvicarinata sp. nov									2	-	-	-	-	-	-	-	-	-	-	-	1	4	4	1	1	-	-	-	-
11 Phalcocythere sentosa sp nov									1	-	-	-	-	-	-	-	-	2	-	8	-	3	16	-	-	14	7	2	11
12 Occultocythereis peristicta sp. nov. morphotype A													2	-	-	1	-	-	-	38	-	-	26	14	-	1	3	-	-
13 Alocopocythere transcendens sp nov																								1	-	-	-	-	-
14 Occultocythereis spilota sp. nov																										1	1	-	-
15 Occultocythereis peristicta sp nov morphotype B																													
16 Quadracythere (Hornibrookella) directa sp nov																													
17 Occultocythereis peristicta sp nov morphotype C																													
18 Occultocythereis peristicta sp nov. morphotype D																													
19 Occultocythereis peristicta sp. nov. morphotype E																													
20 Anommatocythere laqueta sp nov																													
21 Echinocythereis (Echinocythereis) elongata sp. nov																													
22 Alocopocythere coarctata sp nov																													
23 Alocopocythere longilinea sp. nov																													
24 Stigmatocythere obliqua sp. nov																													
25 Gyrocythere grandilaevis sp nov																													
26 Phalcocythere dissenta sp. nov																													

Samples with total no. of ostracods Species	3177	3178	3179	3180	3182	3183	3184	3185	3186	3187	3188	3189	3190	3191	3192	3193	3194	3195	3197	3198	3199	3200
1 Alocopocythere rupina sp nov																						
2 Buntonia devexa sp nov																						
3 Hermanites cracens sp nov																						
4 Trachyleberis (Acanthocythereis) usitata sp nov																						
5 Buntonia sp A																						
6 Occultocythereis sp A																						
7 Trachyleberis (Acanthocythereis) pedigaster sp. nov																						
8 Alocopocythere abstracta sp nov	42	2	16	18	7	7	5	-	50	10	45	70	70	85	-	220	250	40	55	30	55	100
9 Trachyleberis (Trachyleberis) lobuculus sp. nov	19	1	14	1	-	2	3	1	14	5	2	18	15	15	9	33	-	-	8	2	6	11
10 Gyrocythere parvicarinata sp. nov	-	-	5	6	-	-	-	1	-	-	-	-	-	-	2	3	-	-	-	-	5	11
11 Phalcocythere sentosa sp nov	1	-	-	2																		
12 Occultocythereis peristicta sp. nov. morphotype A	22	-	1																			
13 Alocopocythere transcendens sp nov	-	-	-	1	-	-	-	-	-	-	-	3	2	10	-	4	13	-	20	7	6	10
14 Occultocythereis spilota sp. nov	2																					
15 Occultocythereis peristicta sp nov morphotype B				10	-	-	-	-	21	1	1	38	18	19	2	91	42	-	8	3	3	33
16 Quadracythere (Hornibrookella) directa sp nov							1	-	-	-	-	-	-	-	57	-	-	-	-	-	-	-
17 Occultocythereis peristicta sp nov morphotype C									9	-	-	31	15	41	2	1	-	-	-	-	-	-
18 Occultocythereis peristicta sp nov. morphotype D									2	2	-	11	1	21	-	-	1	-	-	-	-	-
19 Occultocythereis peristicta sp. nov. morphotype E																3	11	-	5	1	1	17
20 Anommatocythere laqueta sp nov																						
21 Echinocythereis (Echinocythereis) elongata sp. nov																						
22 Alocopocythere coarctata sp nov																						
23 Alocopocythere longilinea sp. nov																						
24 Stigmatocythere obliqua sp. nov																						
25 Gyrocythere grandilaevis sp nov																						
26 Phalcocythere dissenta sp. nov																						

Samples with total no. of ostracods Species	3401	3402	3403	3404	3405	3407	3409	3410	3415	3416	3417	3418	3419	3420	3421	3422	3423	3424	3426	3428	3429	3432	3434	3435
1 Alocopocythere rupina sp nov																								
2 Buntonia devexa sp nov																								
3 Hermanites cracens sp nov																								
4 Trachyleberis (Acanthocythereis) usitata sp nov																								
5 Buntonia sp A																								
6 Occultocythereis sp A																								
7 Trachyleberis (Acanthocythereis) pedigaster sp. nov																								
8 Alocopocythere abstracta sp nov	35	32	38	30	18	190	22	42	5	3	33	55	40	10	170	68	55	30	75	205	55	45	40	90
9 Trachyleberis (Trachyleberis) lobuculus sp. nov	7	2	7	5	-	2	2	7	2	-	2	2	11	3	2	7	-	-	-	1	1	-	11	1
10 Gyrocythere parvicarinata sp. nov	3	5	5	14	7	20	15	3	3	-	1													
11 Phalcocythere sentosa sp nov																								
12 Occultocythereis peristicta sp. nov. morphotype A																								
13 Alocopocythere transcendens sp nov	4	3	4	4	5	26	3	4	-	-	-	8	8	3	14	7	10	1	23	2	13	9	10	29
14 Occultocythereis spilota sp. nov																								
15 Occultocythereis peristicta sp nov morphotype B	11	12	14	4	3	1	-	10	1	-	-	22	11	1	23	12	14	-	-	3	-		12	7
16 Quadracythere (Hornibrookella) directa sp nov	-	7	31																					
17 Occultocythereis peristicta sp nov morphotype C	-	5	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	5
18 Occultocythereis peristicta sp nov. morphotype D	-	4	5	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	5
19 Occultocythereis peristicta sp. nov. morphotype E	2	3	2	1	3	-	-	10	1	-	-	4	13	-	5	4	-	-	-	-	-	1	4	3
20 Anommatocythere laqueta sp nov			4	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-
21 Echinocythereis (Echinocythereis) elongata sp. nov				5	-	-	1	-	-	3														
22 Alocopocythere coarctata sp nov																						4	1	6
23 Alocopocythere longilinea sp. nov																								
24 Stigmatocythere obliqua sp. nov																								
25 Gyrocythere grandilaevis sp nov																								
26 Phalcocythere dissenta sp. nov																								

Samples with total no. of ostracods Species	3438	3440	3443	3444	3445	3446	3447	3448	3450	3451	3452	3453	3454	3456	3457	3458	3459	3460	3461	3462	3463	3464	3465	3466	3467	3470	3473
1 Alocopocythere rupina sp nov																											
2 Buntonia devexa sp nov																											
3 Hermanites cracens sp nov																											
4 Trachyleberis (Acanthocythereis) usitata sp nov																											
5 Buntonia sp A																											
6 Occultocythereis sp A																											
7 Trachyleberis (Acanthocythereis) pedigaster sp. nov																											
8 Alocopocythere abstracta sp nov	175	-	19	-	7																						
9 Trachyleberis (Trachyleberis) lobuculus sp. nov																											
10 Gyrocythere parvicarinata sp. nov																											
11 Phalcocythere sentosa sp nov																											
12 Occultocythereis peristicta sp. nov. morphotype A																											
13 Alocopocythere transcendens sp nov	6	-	-	-	-	-	-	-	-	-	-	-	-	-	100	131	1	-	-	-	-	-	-	-	-	-	-
14 Occultocythereis spilota sp. nov																											
15 Occultocythereis peristicta sp nov morphotype B																											
16 Quadracythere (Hornibrookella) directa sp nov																											
17 Occultocythereis peristicta sp nov morphotype C																											
18 Occultocythereis peristicta sp nov. morphotype D																											
19 Occultocythereis peristicta sp. nov. morphotype E																											
20 Anommatocythere laqueta sp nov	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	26			
21 Echinocythereis (Echinocythereis) elongata sp. nov																											
22 Alocopocythere coarctata sp nov	-	-	-		-	-	-	-	-	-	-	-	-	-	-	39	1										
23 Alocopocythere longilinea sp. nov	9	60	75	105	10	-	-	80	80	1	-	-	-	-	18	300											
24 Stigmatocythere obliqua sp. nov								23	-	3	2	1	25	145	22	-	-	35	48	35	24	170	230	80	30	1	480
25 Gyrocythere grandilaevis sp nov																					10	4	1	1			
26 Phalcocythere dissenta sp. nov													1	30	-	-	-	210	135	50	-	70					

NO OSTRACODS

NO OSTRACODS

GB | LRGS | Upper Rakhi Gaj Shales | Green and Nodular Shales | Rubbly Limestones | Shales with Alabaster

RA. | G H A Z I J

PAL. | LOWER EOCENE

LRGS = Lower Rakhi Gaj Shales
GB = Gorge Beds
RA = Ranikot
PAL = Palaeocene

Table 2. Stratigraphic frequency of the ostracod family Trachyleberididae in the Middle and Upper Eocene of the Rakhi Nala.

	Samples with total no. of ostracods Species		3498	3499		3604	3607	3608	3609	3610	3611	3613	3614	3615	3617	3618	3620	3621	3622	3623	3624	3625	3626	3627	3628	3629	3630	3631	3634	3640	3641	3642	3645	3646	3647	3648	3649	3650	3651	3652	3653	3658	3660	3661	3662	3663	3664
1	Alocopocythere transcendens sp. nov.		58	19		-	2	1	-	1	-	-	2	2	7	3																															
2	Gyrocythere perfecta sp. nov.		5	15																																											
3	Stigmatocythere portentum sp. nov.		1	7																																											
4	Trachyleberis (Acanthocythereis) postcornis sp. nov.		12	33																																											
5	Anommatocythere confirmata sp. nov.			12		-	-	-	-	-	3	6	17	32																																	
6	Echinocythereis (Scelidocythereis) rasilis sp. nov.			12		-	-	-	-	-	-	-	3	-	2																																
7	Hermanites scopus sp. nov.			1		-	-	-	-	4	-	4	1	1	-	2																															
8	Occultocythereis indistincta sp. nov.			2		-	-	-	-	-	-	-	1	1	-	-	-	1	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	1	31										
9	Quadracythere (Hornibrookella) arcana (Lubimova & Guha)			2																																											
10	Costa (Paracosta) compitalis sp. nov.				NO OSTRACODS	14																																									
11	Trachyleberis (Acanthocythereis) decoris sp. nov.	NO OSTRACODS				3	2	-	8	2	2	10	6	5	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	6	-	6	5	-	-	6	38	2	-	-	-	-	-	51	6	9	10
12	Actinocythereis? quasibathonica sp. nov.									1	13	5	2	2	2	3	1																														
13	Trachyleberis (Trachyleberis) bimammillata sp. nov.									4		25	2	6	5																																
14	Gyrocythere exaggerata sp. nov.											7	1																																		
15	Hermanites palmatus sp. nov.											3	3	1	1	1																															
16	Echinocythereis (Scelidocythereis) multibullata sp. nov.																	14	-	-	13	1																									
17	Stigmatocythere lumaria sp. nov. morphotype A.																	2	-	-	2	2	8	1	6	-	5	-	-	6	5	1	13	6	1	23	42	38	6	-	-	1	-	-	5	34	
18	Costa (Paracosta) disintegrata sp. nov.																	2	2																												
19	Patagonacythere? nidulus sp. nov.																				14	5	-	-	5	-	-	3	1	3	3	5	8	1	-	-	8	-	-	-	-	5	-	-	2		
20	Alocopocythere transversa sp. nov. morphotype A																				3	5	8	-	2	-	12	2																			
21	Alocopocythere transversa sp. nov. morphotype B																					3	5	-	-	-	3																				
22	Alocopocythere transversa sp. nov. morphotype C																												2	4	1	-	4	-	-	1	2	2	1								
23	Alocopocythere transversa sp. nov. morphotype D																													7	1	-	-	-	-	2	2	18	3	14	3						
24	Alocopocythere transversa sp. nov. morphotype E																													1	-	2	5	-	-	1	11		1	20		21	63				
25	Stigmatocythere lumaria sp. nov. morphotype B																													1	-	-	6	2	-	14	12	46	1	47							
26	Alocopocythere transversa sp. nov morphotype F																																	1	-	-	8	30	-	35	2						
27	Alocopocythere radiata sp. nov.																																							14							
28	Costa (Paracosta) declivis sp. nov.																																											7	19	6	2

P.L. | L.C.C. | W.M.B | Upper Chocolate Clays Lower part | Upper Chocolate Clays Upper part | *Pellatispira* Beds

LOWER KIRTHAR (= Kirthar sensu stricto of Eames.) | UPPER KIRTHAR (=Tapti of Eames.)

MIDDLE EOCENE | UPPER EOCENE

W.M B = White Marl Band

L.C.C. = Lower Chocolate Clays

P.L. = Platy Limestone

Table 3. Stratigraphic frequency of the ostracod family Trachyleberididae in the Eocene of the Zao River.

	Samples with total no. of ostracods Species	24107	24110	24123	24127	24131	24132	24145	24147	24148	24150	24151	24152	24153	24154	24155	24156	24157	24159	24161	24166	24170	24173	24174	24175	24176	24177	24178	24180	24181	24183	24184	24185	24186	24187	24188	24191	24193	24195
1	Anommatocythere laqueta sp. nov.	2																																					
2	Phalcocythere dissenta sp. nov.	6																																					
3	Stigmatocythere obliqua sp. nov.	440	30																																				
4	Alocopocythere transcendens sp. nov.			14	20	50	35	1	9	30	35	30	39																										
5	Gyrocythere mitigata sp. nov.					8	1																																
6	Hermanites palmatus sp. nov.					2	–	–	–	–	2	–	4	–	–	–	9																						
7	Trachyleberis (Acanthocythereis) postcornis sp. nov					1	–	–	–	2																													
8	Anommatocythere confirmata sp. nov.							3	1	16	24	3	6																										
9	Echinocythereis (Scelidocythereis) rasilis sp. nov.							6	4	11	3	–	5	2	–	–	–	10																					
10	Gyrocythere exaggerata sp. nov.							1	3	15	8	11	1																										
11	Hermanites scopus sp. nov.									1	1																												
12	Quadracythere (Hornibrookella) sp. A.									1																													
13	Stigmatocythere calia sp. nov.									3	2	1	8	1																									
14	Actinocythereis ? quasibathonica sp. nov.										9	–	–	–	1																								
15	Trachyleberis (Trachyleberis) bimammillata sp. nov.										3	–	4																										
16	Patagonacythere ? nidulus sp. nov.										2	–	–	–	–	5	6	24	17	–	1	14	112	–	56	1	7	4	100	–	64	–	1	–	1	–	–	4	
17	Echinocythereis (Scelidocythereis) multibullata sp. nov.														12	–	3	–	8	51	–	–	–	–	–	–	–	–	–	–	2								
18	Stigmatocythere delineata sp. nov.														3	3																							
19	Trachyleberis (Acanthocythereis) decoris sp. nov.														1	–	–	–	–	–	–	–	6																
20	Alocopocythere transversa sp. nov. morphotype A.															15	–	–	1																				
21	Alocopocythere transversa sp. nov. morphotype B.															3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	
22	Stigmatocythere lumaria sp. nov. morphotype A																4	12	4	–	–	16	19	6	6	1	–	–	1	–	–	2	–	–	7	–	–	1	
23	Alocopocythere transversa sp. nov. morphotype E																	2	–	–	–	8	96	4	15	2	15	18	84	5	29	168	3	33	20				
24	Alocopocythere transversa sp. nov. morphotype C.																		1	–	–	1	1	–	5	10	1	–	64	13	10	–	5	–	–	6			
25	Bradleya ? voraginosa sp. nov.																		3	7																			
26	Echinocythereis (Scelidocythereis) sparsa sp. nov.																		16	–	–	–	–	–	–	–	–	–	–	14	13								
27	Phalcocythere spinosa sp. nov.																			16																			
28	Quadracythere (Hornibrookella) subquadra sp. nov.																			41																			
29	Alocopocythere transversa sp. nov. morphotype D.																					12	18	11	16	–	–	–	–	–	–	–	–	–	–	10			
30	Alocopocythere transversa sp. nov. morphotype F																					5	49	15	23	10													
31	Alocopocythere radiata sp. nov.																						8																

NO OSTRACODS

NO OSTRACODS

S.W.A. | P.L. | L.C.C. | W.M.B. | Upper Chocolate Clays. Lower part | Upper Chocolate Clays Upper part

GHAZIJ | LOWER KIRTHAR (= Kirthar s.s. of Eames) | UPPER KIRTHAR (= Tapti of Eames)

Lr. EOC. | MIDDLE EOCENE | UPPER EOCENE

W. M. B. = White Marl Band
L. C. C. = Lower Chocolate Clays
P. L. = Platy Limestone
S. W. A. = Shales with Alabaster

TABLE 4 DISTRIBUTION CHART OF OSTRACODA IN THE PALAEOCENE AND EOCENE OF THE RAKHI NALA

OSTRACOD SPECIES	GORGE BEDS	LOWER RAKHI NALA SHALES	UPPER RAKHI GAJ SHALES	GREEN & NODULAR SHALES	RUBBLY LIMESTONES	SHALES WITH ALABASTER	LOWER CHOCOLATE CLAYS	UPPER CHOCOLATE CLAYS (lower part)	UPPER CHOCOLATE CLAYS (upper part)	PELLATISPIRA BEDS
	PALAEOCENE		LOWER EOCENE				MID EOCENE		UP EOCENE	
*	I	II	III			IV	V			
Alocopocythere rupina	●									
Bairdia sp A	●									
Buntonia devexa	●									
Cytherella sp A	●									
Hermanites cracens	●									
Neocyprideis ? sp A	●									
Genus A sp 1	●									
T(Acanthocythereis) usitata	●	●								
Brachycythere sp A		●								
Buntonia sp A		●								
Bythocypris sp A		●								
Krithe sp A		●								
Occultocythereis sp A		●								
T(Acanthocythereis) pedigaster		●								
Genus A sp 2		●								
Cytheropteron sp B			●	●						
Occultocythereis peristicta A			●	●						
Phalocythere sentosa			●	●						
Pontocyprella sp A			●	●						
Gyrocythere parvicarinata			●	●	●					
Krithe sp B			●	●	●					
Pontocythere sp A			●	●	●					
T(Trachyleberis) lobuculus			●	●	●					
Alocopocythere abstracta			●	●	●	●				
Genus B sp 1			●	●	●	●				
Cytherella sp B			●	●	●	●				
Paijenborchellina sp A			●	●	●	●				
Paracypris sp A			●	●	●	●				
Xestoleberis sp A			●	●	●	●				
Occultocythereis spilota				●						
Q(Hornibrookella) directa				●						
Cytherella sp A				●	●					
Cytherelloidea sp A				○	●					
Occultocythereis peristicta B				●	●					
Occultocythereis peristicta C				●	●					
Occultocythereis peristicta D				●	●					
Occultocythereis peristicta E				●	●					
Paracypris sp B				●	●					
Schizocythere sp A				●	●					
Anommatocythere laqueta				●		●				
Bairdia sp B				●		●				
Bairdia sp C				●		●				
Uroleberis sp A				●		●				
Xestoleberis sp B				●		●				
Alocopocythere transcendens				●	●	●	●	●		
Cytherelloidea sp B					●					
E(Echinocythereis) elongata					●					
Alocopocythere longilinea					●	●				
Alocopocythere coarctata					●	●				
Cytheropteron sp A					●	●				
Paijenborchella sp A					●	●				
Aglaiocypris sp A						●				
Bairdia sp C						●				
Bythocypris sp A						●				
Cytherella sp C						●				
Cytherella sp D						●				
Eucytherura sp B						●				
Gyrocythere granditaevis						●				
Neocyprideis ? sp B						●				
Neocyprideis sp C						●				
Phalocythere dissenta						●				
Pontocyprella sp B						●				
Pontocyprella sp C						●				
Stigmatocythere obliqua						●				
Uroleberis sp B						●				
Xestoleberis sp C						●				
Xestoleberis sp D						●				
Xestoleberis sp E						●				
Xestoleberis sp F						●				
Genus C sp 1						●				
Genus C sp 2						●				
Cytherelloidea sp C							●			
Gyrocythere perfecta							●			
Paijenborchella sp B							●			
Q(Hornibrookella) arcana							●			
Stigmatocythere portentum							●			
T(Acanthocythereis) postcornis							●			
Paracypris sp C							●			
Anommatocythere confirmata							●	●		
Genus B sp 2							●	●		
Cytherella sp E							●	●		
Cytherelloidea sp D							●	●		
Cytheropteron sp C							●	●		
F (Scelidocythereis) rasilis							●	●		
Hermanites scopus							●	●		
Krithe sp C							●	●		
Schizocythere sp B							●	●		
Bairdia sp A							●	●	●	
Cytherella sp G							●	●	●	
Cytherelloidea cf C costatruncata							●	●	●	
Cytheromorpha sp A							●	●	●	
Cytheropteron sp D							●	●	●	
Krithe sp E							●	●	●	
Occultocythereis indistincta							●	●	●	
Xestoleberis sp G							●	●	●	
Cytherelloidea sp F							●	●	●	○
Paijenborchella sp C							●	●	●	
Actinocythereis ? quasibathonica								●		
Aglaiocypris sp C								●		
Bythoceratina sp A								●		
C (Paracosta) compitalis								●		
C(Paracosta) disintegerata								●		
E (Scelidocythereis) multibullata								●		
Gyrocythere exaggerata								●		
Hermanites palmatus								●		
Propontocypris sp A								●		
T (Trachyleberis) bimammillata								●		
Uroleberis sp C								●		
Uroleberis sp D								●		
Alocopocythere transversa A								●	●	
Alocopocythere transversa B								●	●	
Cytherella sp F								●	●	
Paracypris sp D								●	●	
Paracypris sp E								●	●	
Polycope sp A								●	●	
P(Pterygocythere) sp A								●	●	
Krithe sp D								●	●	●
Paijenborchella sp D								●	●	○
Paijenborchella sp E								●	●	●
Patagonacythere ? nidulus								●	●	●
Stigmatocythere lumaria A								●	●	●
T(Acanthocythereis) decoris								●	●	●
Alocopocythere transversa C									●	
Alocopocythere transversa D									●	
Alocopocythere transversa F									●	
Alocopocythere radiata									●	
Stigmatocythere lumaria B									●	
Cytherelloidea sp E									●	●
Cytherelloidea sp G									●	●
Alocopocythere transversa E									●	●
C.(Paracosta) declivis										●
Krithe sp G										●
Neocyprideis ? sp D										●
Paijenborchella sp F										●
Pontocythere sp B										●

*Ostracod Biostratigraphic Units (I-V)

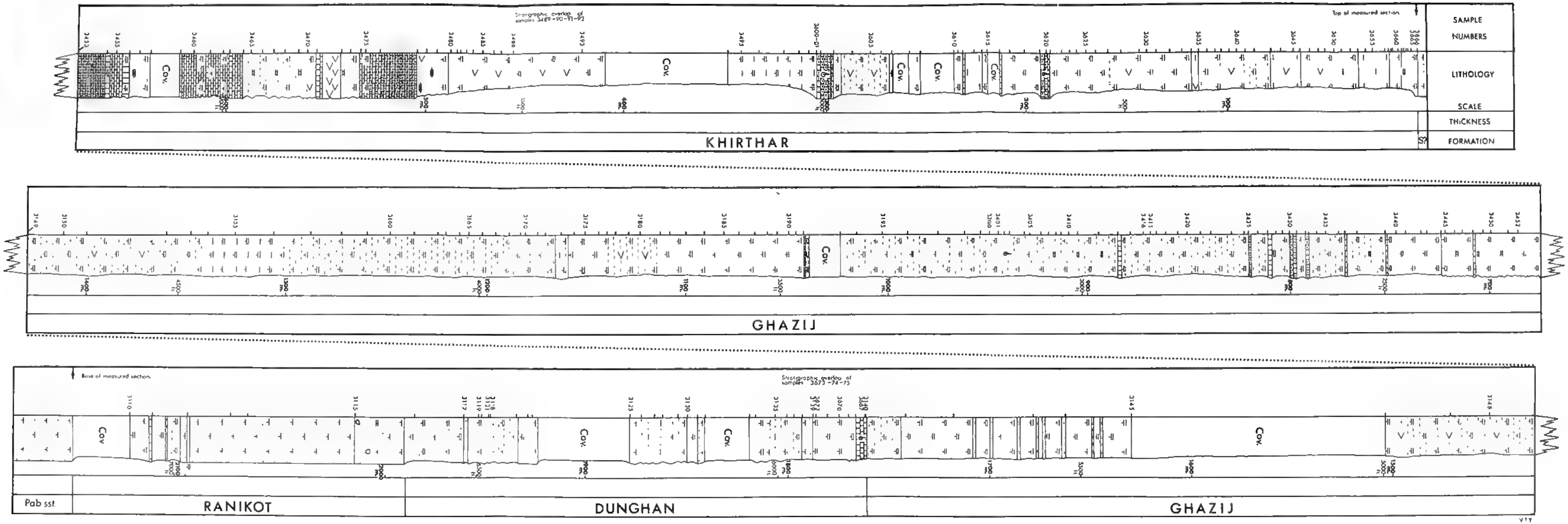
○ doubtful

TABLE 5 DISTRIBUTION CHART OF OSTRACODA IN THE EOCENE OF THE ZAO RIVER

OSTRACOD SPECIES	SHALES WITH ALABASTER LR EOCENE IV	LOWER CHOCOLATE CLAYS MIDDLE EOCENE	UPPER CHOCOLATE CLAYS (lower part) MIDDLE EOCENE V	UPPER CHOCOLATE CLAYS (upper part) UP EOCENE
Anommatocythere laqueta	●			
Bairdia sp C	●			
Bairdia sp. D	●			
Cytherella sp B	●			
Cytherella sp C	●			
Neocyprideis sp B	●			
Neocyprideis sp C	●			
Paracypris sp	●			
Phalcocythere dissenta	●			
Pontocyprella sp B	●			
Pontocyprella sp C	●			
Stigmatocythere obliqua	●			
Xestoleberis sp. C	●			
Xestoleberis sp D	●			
Xestoleberis sp E	●			
Genus C sp 1	●			
Genus C sp. 2	●			
Gyrocythere mitigata		●		
Paijenborchella sp C		●		
Pontocyprella sp. D		●		
Xestoleberis sp H		●		
Alocopocythere transcendens		●	●	
Cytherella sp. E		●	●	
Cytheropteron sp C		●	●	
Hermanites palmatus		●	●	
Schizocythere sp. B		●	●	
T. (Acathocythereis) postcornis		●	●	
Bairdoppilata sp. A		●	●	●
Cytherella sp. F		●	●	●
Cytherella sp G		●	●	●
Cytherelloidea cf C costatruncata		●	●	●
Cytherelloidea sp. F		●	●	●
Cytheromorpha sp. A		●	●	●
Paijenborchella sp C		●	●	●
Actinocythereis ? quasibathonica			●	
Alocopocythere transversa A			●	
Anommatocythere confirmata			●	
Genus B sp. 2			●	
Cytherelloidea cf Cytherelloidea sp C			●	
E. (Scelidocythereis) rasilis			●	
Gyrocythere exaggerata			●	
Hermanites scopus			●	
Paracypris sp G			●	
Pontocythere sp G			●	
Q. (Hornibrookella) sp A			●	
Stigmatocythere calia			●	
Stigmatocythere delineata			●	
T. (Trachyleberis) bimammillata			●	
Aglaiocypris sp B			●	●
Alocopocythere transversa C			●	●
Alocopocythere transversa D			●	●
Alocopocythere transversa E			●	●
Bairdia sp D			●	●
Bradleya ? voraginosa			●	●
Cytheropteron sp D			●	●
E. (Scelidocythereis) sparsa			●	●
E. (Scelidocythereis) multibullata			●	●
Krithe sp D			●	●
Krithe sp E			●	●
Paijenborchella sp E			●	●
Patagonacythere ? nidulus			●	●
P. (Pterygocythere) sp A			●	●
Stigmatocythe lumaria A			●	●
T. (Acanthocythereis) decoris			●	●
Xestoleberis sp G			●	●
Alocopocythere transversa E				●
Alocopocythere transversa F				●
Alocopocythere radiata				●
Cytherelloidea sp E				●
Krithe F				●
Neocyprideis ? sp D				●
Neocyprideis ? sp E				●
Paijenborchella sp F				●
Paracypris sp F				●
Phalcocythere spinosa				●
Q (Hornibrookella) subquadra				●
Stigmatocythere lumaria				●

* Ostracod Biostratigraphic Units (IV–V)

Rakhi Nala Stratigraphic Section, measured by S.L.Rieb and sampled by D.D.Bayliss. 1957.



LEGEND

⬚	Sand	⬚	Siltstone	⬚	Argillaceous formation	▦	Coquina or fossiliferous limestone
⬚	Sandstone	⬚	Siltstreaks	⬚	Shale or clay lenses	▩	Argillaceous limestone
⬚	Conglomeratic sandstone	⬚	Mudstone	⬚	Marl	⬚	Calcareous streaks or lenses
⬚	Silt	⬚	Shale	▦	Limestone	⬚	Gypsum

ABBREVIATIONS

Cov.	Covered
S?	Siwalik
Pab sst.	Pab Sandstone

SCALE: Feet and Metres.
0.5 inches = 100 feet
4.2 cms. = 100 metres.

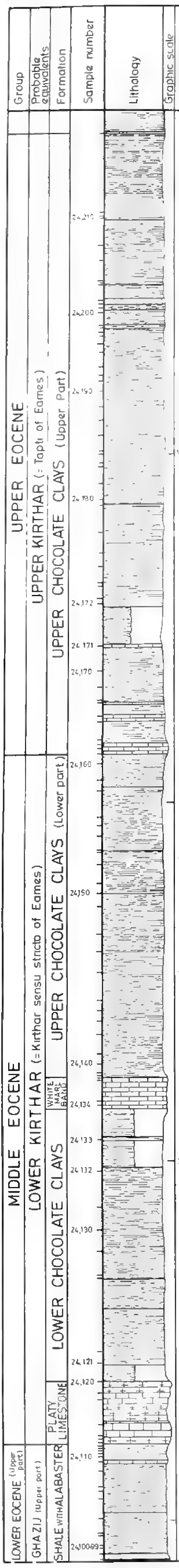
N.B. Sample numbers for every fifth sample unless otherwise indicated.

ZAO RIVER SECTION

Measured by

S.M. Ahmed & W.A. Zuberi.

Scale 0 200 Feet
0 20 40 Metres



LITHOLOGICAL DESCRIPTION

1 Shale, brown variegated, blocky, silty, with argillaceous pebble of limestone and sandstone.

2 Shale with sandstone and grit; shale, yellowish brown weathered brown, silty-calcareous blocky sandstone, brown, weathered brown, medium hard, friable, calcareous, coarse grained, thick bedded, cross bedded, grit brown, friable, calcareous, very coarse grained, massive, poorly consolidated

3 Shale, green below brown above, silty calcareous, plant remains below, 12' sandstone below grey, weathered brown coarse gritty, calcareous.

4 Shale, chocolate brown, clay, silty, with mudstone, white massive, weathered brown, yellowish brown shale at top 12' yellowish brown mudstone at top

5 Shale with mudstone, shale, like unit 6 irregular alternate of green and brown shale grading to mudstone and claystone, few Foram marl and limestone band near top

6 Shale, greenish grey to chocolate brown, weathered green to brown, clay, soft; occasional thin limestone or marl band

7 Covered

8 Shale with limestone, siltstone, shale, grey-brown, silty sandstone, grey, weathered brown, flaggy, medium grained, siltstone, grey, soft, 10' limestone at top, light grey light brown, weathered yellowish brown, argillaceous, silty, Forams and Molluscs

9 Shale with limestone and sandstone, shale like unit 14, limestone, like unit 10, sandstone, greenish grey, very argillaceous, blocky

10 Limestone, grey, weathered brown, very argillaceous, thin-very thin bedded, blocky nodular, Forams few shale banded

11 Shale, like 12 with occasional fossiliferous marl

12 Shale with marl, shale grey, weathered green, blocky, soft, calcareous clay, marl, like limestone in 13 Forams

13 Shale with limestone, shale, like unit 14; limestone grey, weathered brown, silty, argillaceous, marly, abundant Forams, Molluscs and echinoids

14 Shale, grey-brown below grey-chocolate brown above, soft clay fissile laminated, gypsum

15 Limestone light brown-white, weathered brown, argillaceous, marly, medium hard (white marl band).

16 Covered with occasional outcrop of shale like unit 18

17 Shale, like unit 18, thin Foram, silty argillaceous limestone and marl band

18 Shale, grey, weathered green, soft, gypsum, silty, papery, thin streak of silty argillaceous limestone

19 Shale with limestone, shale, greyish green, soft, clay, limestone, grey, argillaceous

20 Covered

21 Limestone with shale, limestone, grey, weathered tan, flaggy-platy, very argillaceous hard, shale, grey, calcareous, limestone and shale interbedded

22 Limestone, light grey - light brown, weathered brown, very massive, hard, argillaceous, grading down to very argillaceous below, fossils abundant Assilina and Nummulites

23 Shale with marl and limestone, shale, like unit 24, marl, grey, weathered brown, coquinoidal with Assilina and Nummulites, limestone, argillaceous, grey, Foram.

24 Shale with marl and limestone, shale, grey, weathered green clay, marl, like unit 25 Forams and Molluscs, limestone, argillaceous, grey, bed of white gypsum

25 Shale with marl and limestone, shale, marly-variegated, like unit 26; marl, platy nodular, hard, argillaceous; 4' limestone at base, light brown argillaceous

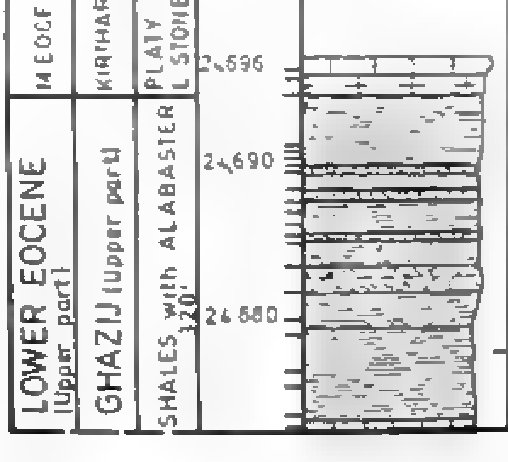
SHPALAI KHWARA SECTION.

(Uppermost part)

Measured by

S.M. Ahmed & W.A. Zuberi.

Scale 0 200 Feet
0 20 40 Metres



LITHOLOGICAL DESCRIPTION

1 Limestone, very light grey, weathered brown, hard, massive, very fossiliferous with large Nummulites and Assilina

2 Limestone, grey, weathered brown, coquinoidal with Assilina, grading up to hard limestone.

3 Shale with marl and limestone, shale, grey, weathered green clay fissile, soft, marl, grey, medium hard-soft, argillaceous coquinoidal with Forams, limestone like unit 5

4 Shale with limestone and gypsum; shale, like unit 5; limestone, light grey, weathered tan, very argillaceous, Forams and abundant Molluscs; gypsum, like unit 5

5 Shale with gypsum and claystone, shale, grey, weathered green, silty, calcareous, gypsum, bedded, white. claystone, grey, 1' thick limestone at top, chocolate brown, ves. ves. filled with gyp.

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