CHAPTER 5

# THE PORTLAND GROUP IN THE VALE OF WARDOUR, WILTSHIRE,

## with a short summary of the Portland Group of the Vale of Pewsey



Vol II

"The Vale of Wardour is rich in geological interest, and in associations with one of the earliest of scientific lady workers, Etheldred Benett, whose home was at Pyt House, to the west of Tisbury. The name is perpetuated in the "Benett Arms", which affords a welcome to the weary geologist."

H.B. Woodward in
Monkton & Herres 1910

## 1. Introduction

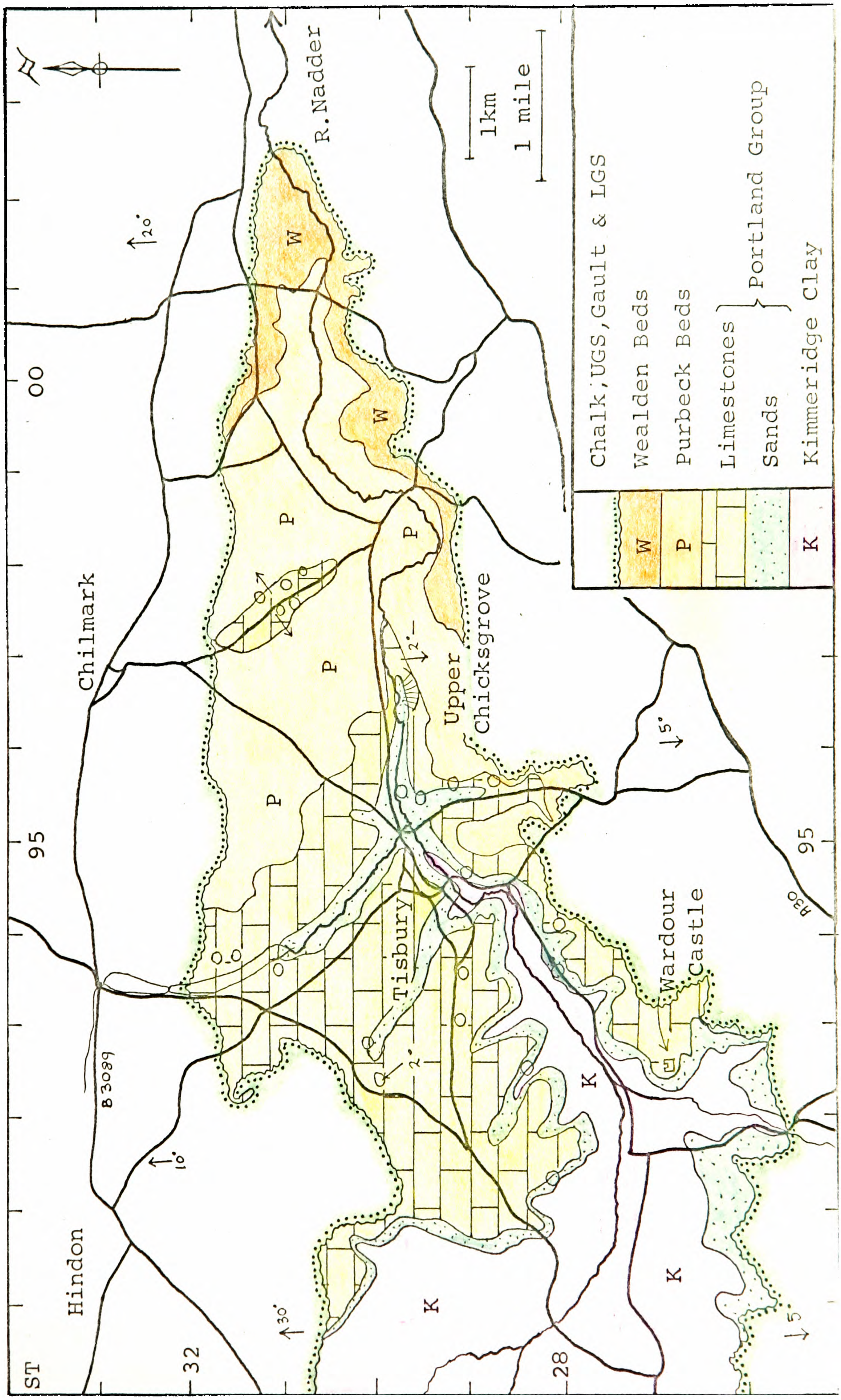
The Vale of Wardour is a triangular indentation in the west margin of the Chalk uplands of Wiltshire, about 20-25km west of the City of Salisbury. Upper Jurassic strata are exposed in the core of an anticline which strikes east-west, parallel to both the Weymouth-Purbeck Anticline 50km to the south, and to the Vale of Pewsey Anticline 25km to the north (Fig. 1 ).

Before the deposition of Upper Cretaceous strata the Upper Jurassic and Wealden beds were tilted to the south-east at a general angle of 2°. As a result, the Upper Cretaceous rocks successively overlie, from east to west, Wealden Beds, Purbeck Beds, Portland Group and Kimmeridge Clay (Fig.87 ). During the Tertiary period, the strata were folded into an asymmetrical anticline with the steep dip of 15-20° to the north and a gentle slope of about 5° to the south. The axis lies a little to the north of the course of the River Nadder.

The rocks of the Portland Group are 30-40m thick and cover an area of approximately 18sq.km, dipping away from the axis of the fold usually at a low angle. There are some local minor undulations of the strata, such as that south of Chilmark Village where the Portland Group reappears below the Purbeck Beds. This inlier is deeply incised by a small stream forming what is known as the Chilmark Ravine (ST 9731).

The Portland Group has been known for a long time in the area; certain horizons were quarried during the Roman occupation and the stone was renowned for its quality long before beds of about the same age were exploited in Dorset. For example, Corfe Castle (11th Century) in the Isle of Purbeck is constructed of stone from the Vale of Wardour although it is only about 4km away from the outcrop of the later quarried Freestone Beds of the Portland Limestone Formation. Geologically, the area has been a place of interest since the early 18th Century (Woodward 1729). The first detailed account of the Portland Group was given by a local resident, Miss Etheldred Benett (in Sowerby 1816) and since then the following have contributed noteworthy information: Fitton (1836), Blake (1880), Andrews (1881, 1882), Phillips (1881), Hudleston (1881a,b,c), Andrews & Jukes-Browne (1894), Woodward (1895),

GEOLOGICAL MAP OF THE VALE OF WARDOUR, WILTSHIRE, ENGLAND. (From Geological Survey Sheets 282,297. FIG 87



Clement Reid (1903), Jukes-Browne (1903), Andrews (1903), Arkell (1933), House (1958).

This chapter on the Portland Group of the Vale of Wardour is not intended to be a comprehensive summary of all the previous work but a study of the present exposures with special emphasis on that part which has not been studied in detail before - the sediments themselves. In the course of this work 34 exposures were examined and 15 sections measured; 122 rock specimens and several fossils were collected and 105 thin sections have been studied.

## 2. Stratigraphical Nomenclature

The terms used to describe divisions of the Portland Group have varied in the past. Those of Arkell (1933) have been used up to now but they are not particularly useful because they do not supply much geological information. Thus it has been felt justifiable to adapt the names so that they are more enlightening. This policy has been applied in this work for the Portland Group elsewhere, although an exception was made for the Freestone Beds of Dorset which are so well known but so variable in composition that the general name is retained.

Arkell (1933) gives the succession for the Vale of Wardour as follows:-

THE PURBECK BEDS

| | |
|---|---|
| PORTLAND STONE | Upper Building Stones<br>Chalky or Cherty Series<br>Ragstone Beds |
| PORTLAND SAND | Main Building Stones<br>Basement Beds with Upper Lydite Bed |

THE KIMERIDGE CLAY

The overall two-fold division of the Portland Group is here retained but re-named as the Wardour Limestone Formation and the

BED NOMENCLATURE OF THE PORTLAND GROUP IN THE VALE OF WARDOUR, WILTSHIRE. FIG 88

| ARKELL 1933 | | TOWNSON 1971 | |
|---|---|---|---|
| LOWER PURBECK BEDS | | | |
| PORTLAND STONE 9.7-15.3m | Upper Building Stones 0-5m | The Chilmark Oolite Beds 5.4m | WARDOUR LIMESTONE FORMATION up to 21.2m |
| | Chalky or Cherty Series 7.3m | The White Micrite Beds 4.5-7.8 m | |
| | Ragstone Beds 2.4-3.0m | The Main Limestone Beds up to 8m | |
| PORTLAND SAND 14.4-17.4m | Main Building Stones 5.4m | The Sandy Limestone Beds c7.4m | WARDOUR SAND FORMATION (including U.Sandy Kimm Beds?) c18m? |
| | Basement Beds with Upper Lydite Bed 9-12m | The Wardour Exogyra Beds c3.8m | |
| | | The Basal Sand Beds (including or equiv. to the Upper Sandy Kimmeridge Beds?) c7m? | |
| KIMERIDGE CLAY | | KIMMERIDGE CLAY | |

Wardour Sand Formation. As is the case in Dorset, the proportion of quartz sand in the lower unit never reaches 50% but below the level of the junction taken it becomes an increasingly significant constituent of the sediment. The position of the junction between the two Formations is not put at the level indicated by Arkell (1933) but at a level which may correlate better in time with that between the two Formations in Dorset. That is, not at the top of the "Main Building Stone" but part way down. (Fig. 83).

The "Upper Building Stones" are dominantly composed of ooid sand and apparently confined to the Chilmark inlier in the east of the area. They are thus re-named The Chilmark Oolite Beds. This will usually be contracted for convenience to the Chilmark Oolites.

The "Chalky or Cherty Series" consist of soft white micrite with chert in the upper part of the outcrop in the Chilmark inlier. Elsewhere there is very little chert and thus these beds are re-named The White Micrite Beds.

The "Ragstone Beds" are shell-rich horizons, below the White Micrite Beds, considered here to be laterally equivalent to the upper part of the "Main Building Stones". The name is not used in this thesis.

The "Main Building Stones" are composed essentially of biochem and quartz sand with a variable amount of glauconite and sometimes with a matrix of clay or lime mud. The base is not recorded as having ever been exposed when most of the quarries were worked, and the "Basement Beds with Upper Lydite Bed" have been previously examined only in small isolated exposures. In the last few years the beds have been better exposed and a four-fold sub-division is now used.

The upper part, that is the beds exposed in most of the old quarries, is named The Main Limestone Beds or the Main Limestones. The "Ragstone Beds" are local shelly horizons included in this. The base of the Main Limestones is taken as the base of the Wardour Limestone Formation.

Below, and only partly exposed in the deeper old quarries, is The Sandy Limestone Beds or the Sandy Limestones. The "Upper

Lydite Bed" is a micrite which contains very few "lydites" (black pebbles of derived chert, probably mostly Carboniferous in age. See the section in the chapter on the South Midlands.), but Exogyra nana is very common in many exposures. Thus it is termed here The Wardour Exogyra Beds and abbreviated to the Exogyra Beds when in the context of the Vale of Wardour.

The sediments below are called The Basal Sand Beds or the Basal Sands and may be equivalent, in part at least, to the Sandy Upper Kimmeridge Beds.

3. Lithofacies of the Portland Group in the Vale of Wardour

The facies designated are based mainly on a study of 105 stained thin-sections. As is seen in Fig. 89 the classification used to describe the Portland Limestone Formation of Dorset can be applied with only a few modifications. For this reason the descriptions given here are more concise.

A. Components of the facies

(i) Grains:

(a) Mollusc fragments

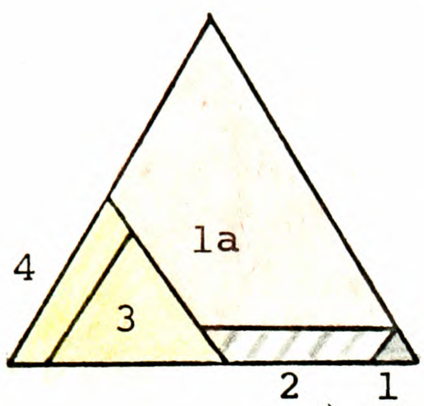
These consist of bivalve and gastropod material varying in size from whole skeletons and valves down to very fine sand grade. The most common bivalves in the Portland Group with shells of calcite ± aragonite, are pectinids, isognomonids, limids and ostreids. The skeletons of these are often micritised by algal and/or fungal borings, especially the finer grain sizes. Common aragonitic bivalves include trigoniids, pleuromyoids and cardiids which, together with gastropods, are preserved as casts by having a micrite envelope filled with sparry calcite (Plate 79); sometimes they remain as empty moulds.

(b) Echinoderm fragments

These sometimes occur as an accessory constituent with molluscan sand and are generally recognised as being parts of echinoid tests or spines. Syntaxial overgrowths on echinoid debris is a common feature, especially when the matrix is lime mud.

FACIES OF THE PORTLAND GROUP IN THE VALE OF WARDOUR
COMPARED WITH THOSE OF THE PORTLAND LIMESTONE FORMATION
OF DORSET

FIG 89




Facies in Dorset (See Figs 38, 39)

1 = Lime Mud. Dunham Mudstone.

1a= Sponge Spicule Lime Mud. Wackestone.

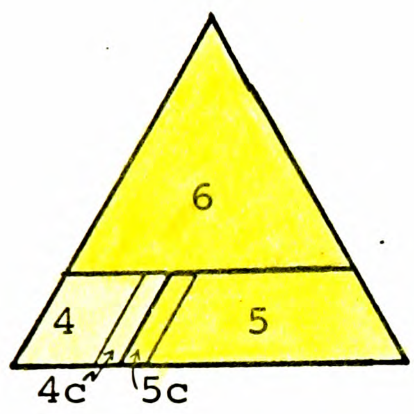
2 = Sandy (biochem) Lime Mud. { Packstone. / Wackestone.

3 = Muddy Fine Biochem Sand. Packstone.

4 = Biochem Sand. Grainstone.

4c= Ooid Biochem Sand. Grainstone.

4M= Biomicrite. Packstone.




5 = Ooid Sand. Grainstone.

5c= Biochem Ooid Sand. Grainstone.

5M= Oomicrite. Packstone.

6 = Intraclast Sand. Grainstone.

Facies in the Vale of Wardour (See Figs 90, 91

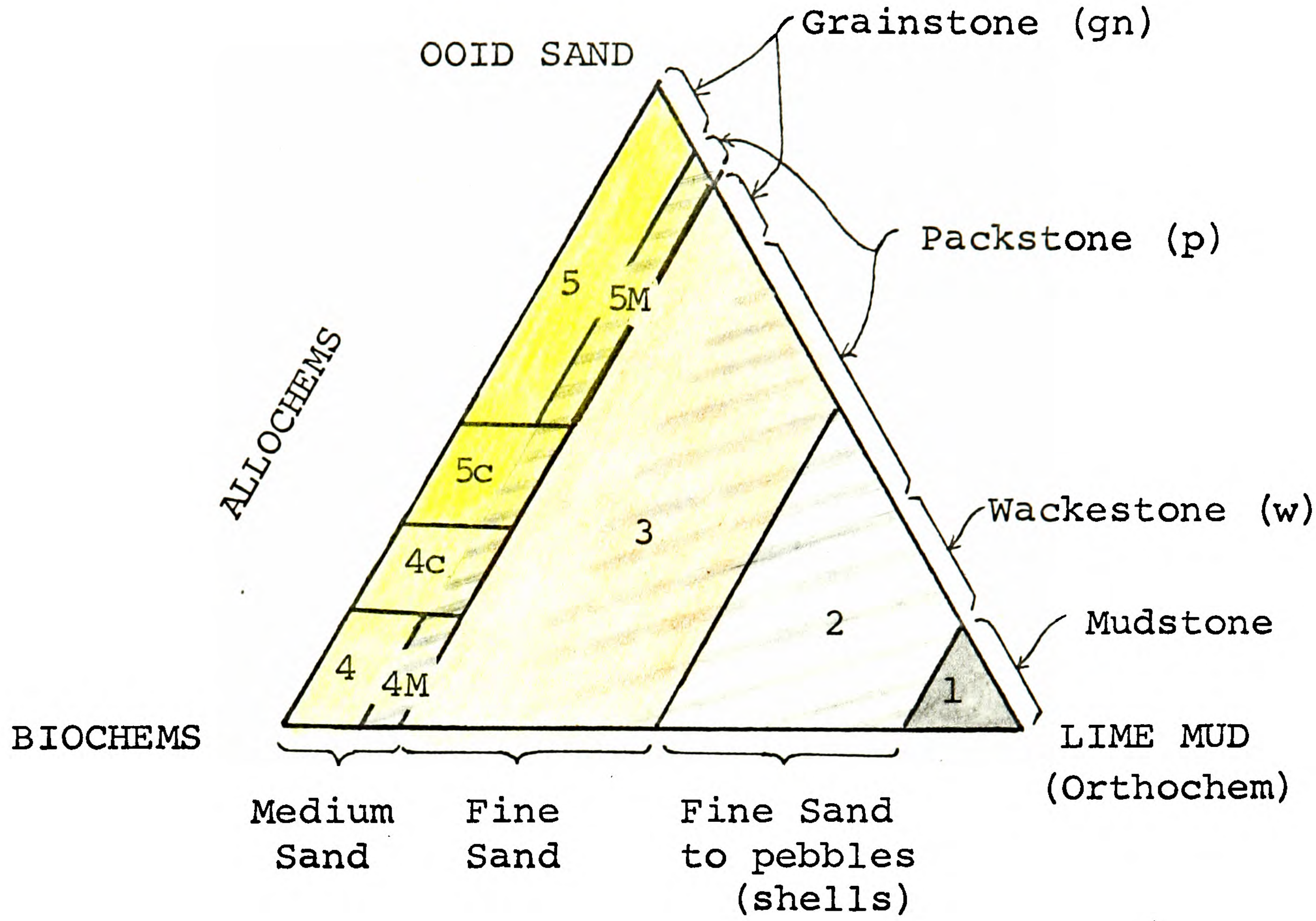
The only major difference is the presence of glauconite with terrigenous quartz and clay. Also, in contrast to the Portland Sand Formation of Dorset, there is no significant dolomite.

All the above Facies are used except number 6. Facies 1a is not found but is postulated for the unexposed chert-rich part of the White Micrite Beds.

| | | | | | | |
|---|---|---|---|---|---|---|
| When quartz sand | = 1-5% | the prefix | q | is added | } | See Fig 91 |
| " " " | = 5-25% | " " | Q | " " | | |
| " " " | > 25% | " suffix | Q | " " | | |
| When glauconite | = 1-5% | the suffix | gl | is added | | |
| " " | = 5-10% | " " | Gl | " " | | |

Other slight differences in the definition of the Facies are described in the text, especially for 3 and 4.

FIG 90




1 : LIME MUD. Sediment with < 10% allochems. Lime Mudstone. Matrix to Facies 2, 3, 4M & 5M.

2 : SANDY (biochem) LIME MUD. Matrix of lime mud. Allochems poorly sorted, fine sand to coarse pebble grade. Packstone and Wackestone.

3 : MUDDY FINE BIOCHEM SAND. Well-sorted very fine to fine sand. Grain supported with lime mud matrix ± clay. Usually quartzose and glauconitic. Generally Packstone (add suffix p); sometimes Grainstone (add suffix gn).

4 : BIOCHEM SAND. Medium sand. Grainstone. 4M = same but with mud matrix. Packstone.

5 : OOID SAND. Medium sand. Grainstone. 5M = same but with mud matrix. Packstone.

(c) Sponge fragments

In the Portland Group of Dorset spicules of the sponge *Rhaxella* are an essential component of one of the facies (1a) and an accessory in others. In the Vale of Wardour only rare casts of these have been detected; for example, in the topmost bed of the Main Limestones of the Chilmark inlier, and the topmost beds of the Basal Sands near Tisbury Station. It is suggested that they may be common in the now unexposed, cherty, upper part of the White Micrite Beds at Chilmark.

Spicules of *Pachastrella* are common as original silica and as ferroan calcite casts, especially in the chert-rich medium and fine biochem sand facies of the Main and Sandy Limestones. The cherts are particularly rich in spicules and represent current concentrations of nearby disintegrated sponges.

(d) Pellets

These include both fine faecal pellets and micritised biochems. In the fine biochem sands with a lime mud matrix it is not always easy to distinguish between them (Plate 73). This is fully discussed for the Portland Limestone Formation of Dorset.

(e) Ooids

These occur in the Chilmark Oolite Beds, also rarely in the Main Limestones. The size is generally medium sand and they vary from having well-preserved concentric lamellae to being almost completely micritised. The nucleus is usually a grain of biochem sand or, less commonly, fine quartz sand. Occasionally composite grains occur with lamellae enclosing two ooids; these are not regarded as being intraclasts.

(f) Intraclasts

These are not common and nowhere does Facies 6 of Dorset occur (Fig. 39). Sometimes grains of biomicrite are seen up to 2mm across with the boundary of the grain cutting the internal structure which must indicate erosion from a partly consolidated sea bed (Plate 79).

(g) Minor organic components

These include serpulid fragments, calcareous forams and ostracods but none are common, except the latter just below the Purbeck Beds. Corals occur at one horizon but fragments have not been recognised. Algae are not known but some of the fine micritised biochem sand could be algal in origin.

(h) Quartz sand and accessories

This never reaches 50% of the sediment in the Wardour Sand Formation and is rare in the Wardour Limestone Formation. The grain size varies from very fine to medium sand. The finer grade is well sorted and moderately well rounded, in contrast to the coarser grade which is less well sorted but more rounded.

Feldspars have been recognised but are a very minor component, as are the heavy minerals described by Neaverson (1925).

(i) Glauconite

This reaches 10% in the Wardour Sand Formation but is rare in the overlying rocks. The grains vary in size from fine to medium sand, are light green in colour and fresh in appearance. Occasionally, diffuse glauconite can be seen penetrating bivalve sand grains and the pores of echinoid fragments, which presumably indicates the site of formation of an appreciable amount of this mineral.

(ii) Matrix

(a) Lime mud

This is generally not recrystallised and remains as soft white chalky micrite with crystals of about 1μ or less, which, on staining, prove to be iron-free. It is an essential component of Facies 1 and 2 and is a common matrix to Facies 3, often with a proportion of clay.

(b) Clay

This often occurs as matrix to the fine grained sand facies and is common in the lower part of the Wardour Sand Formation. Clay horizons also occur in the basal part of the Purbeck Beds.

(c) Dolomite

This was not detected in the Portland Group but may occur in the Basal Sands which were not studied in detail.

(iii) Cement

In the mud-supported facies the intergranular spaces are usually filled with lime mud which is only rarely recrystallised to microsparite (Plate 73). In the grain supported sediments lime mud is more commonly recrystallised but the grains are usually cemented by low-iron calcite or sometimes there is an original porosity remaining (Plate 74).

Ferroan calcite often occurs as a later-stage cement filling secondary pores formed by solution of sponge spicules and micrite-enveloped shell fragments, as well as vertical veins in the limestones. This stage must be post consolidation and probably mostly formed after the first phase of uplift and folding.

B. Facies of the Portland Group

Facies 1: Lime Mud.

This consists of micrite with <10% allochems, other than micropellets which are sometimes visible in parts which have escaped compaction. Occasional bivalve and gastropod fragments exist, and ostracods are common when this facies occurs just below the Purbeck Beds. Quartz sand is rare and always <1% of the sediment. By Dunham's classification this is a lime mudstone.
Occurrence: White Micrite Beds and parts of the basal Purbeck Beds.

Facies 1a: Sponge Spicule Lime Mud.

This is a mud-supported sediment with >10% allochems, of which >50% are sponge spicules. These are Pachastrella and possible Rhaxella but the latter have not been recorded. The texture of this facies in Dorset is generally a wackestone.
Occurrence: Postulated for the upper part of the White Micrite Beds of the Chilmark inlier.

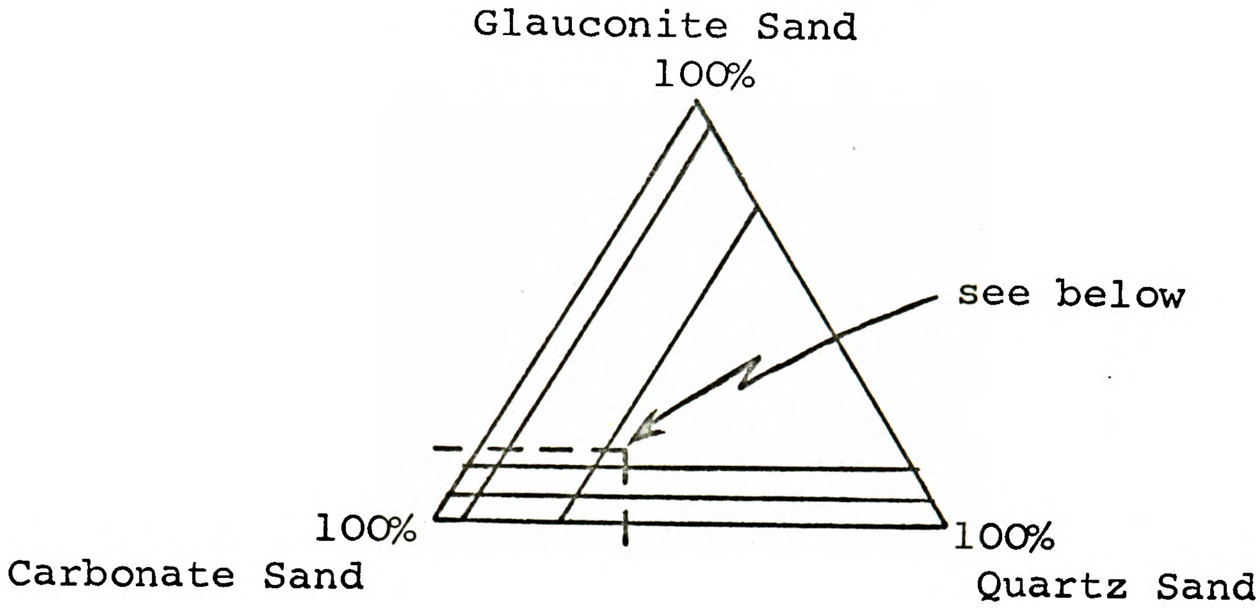
Facies 2: Sandy (biochem) Lime Mud.

This is a shell-rich variation of Facies 1 and is characterised by having poorly-sorted, coarse-grained skeletal material in a lime mud matrix. The texture is usually a wackestone but if the shells are very concentrated it becomes a packstone; e.g. parts of the "lamellosus bed", White Micrite Beds.
Occurrence: Exogyra Beds and parts of the Main Limestones and

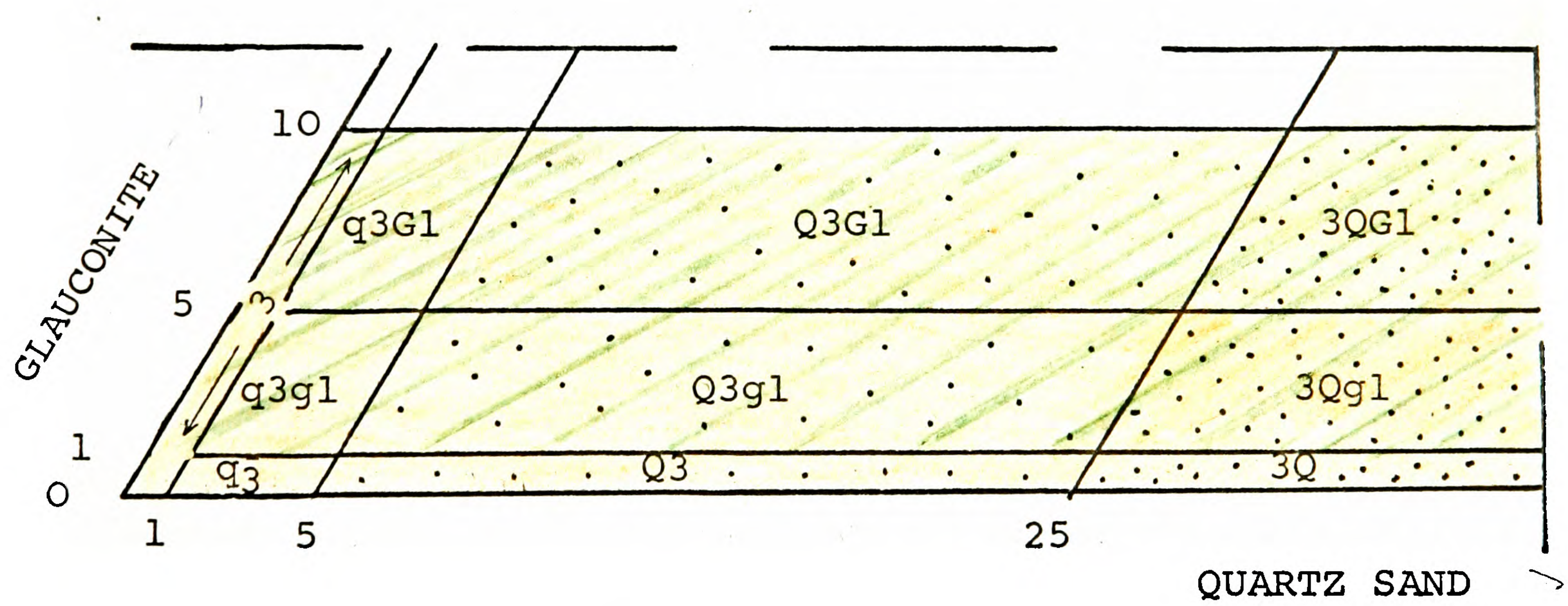
FACIES OF THE PORTLAND GROUP OF THE VALE OF WARDOUR

Showing modification due to the presence of quartz sand and glauconite

FIG 91




USING FACIES 3 AS AN EXAMPLE:-



Facies 3: Fine biochem Sand.

As indicated in Fig. 90 this can have a packstone texture with a matrix of lime mud, sometimes argillaceous, or it can be a mud-free grainstone cemented by fine grained sparite. This differs slightly from Facies 3 of the Portland Limestone Formation of Dorset in that the latter is defined as having a mud matrix. The texture is indicated by the suffixes (p) and (w) as shown in Fig. 90 and appropriately shaded in Figs 92,93. Common accessory components also include quartz sand and glauconite, the proportions of which are indicated in Fig. 91 by suitable addition to the Facies number. (Plate 73)

Occurrence: Sandy Limestone Beds and parts of the Main Limestones.

Facies 4: Medium Biochem Sand. (Plate 74)

This is usually grain supported with well rounded and well sorted particles. Quartz is rare but may reach 1.5% (Facies q4) and if there is a mud matrix then the facies becomes a packstone, Facies 4M.

Occurrence: Almost exclusively in the Main Limestone Beds but may occur in exposed parts of the Chilmark Oolites as the ooid-containing variety, Facies 4c.

Facies 5: Ooid Sand.

This is grain supported with or without a lime mud matrix (Fig. 90 ) and quartz <1%. The variety 5c is formed as indicated in Fig. 90

Occurrence: Chilmark Oolites and is rare in the Main Limestones.

## 4. The Wardour Sand Formation

The following is a general account from a study of the Beds at several localities. Details are given in the Figures and in a separate section at the end of the chapter.

### A. The Basal Sand Beds (7m?) and their relationship to the Kimmeridge Clay

The underlying Kimmeridge Clay is very poorly known in the Vale of Wardour and such exposures in the past that have been recorded were in the lower part of the succession. The vertical section on the Geological Survey map (Wincanton sheet 297. 1969) gives a thickness of 35-40m.

The Basal Sands consist of dark sandy clays and silts which appear to grade into the typical black mudstones of the Kimmeridge Clay. There is no record of a section which has exposed this junction, which forms a springline. A well dug in the floor of Teffont Quarry, Chilmark (ST 975313) went through 15m of "clays and calcareous sandy beds to very black clay (Kimeridge Clay)" (Woodward 1895). This thickness has been quoted by later authors (e.g. Arkell 1933) as the true thickness of the Basal Sands but Clement Reid (1903) comments "It is not quite clear whether this may not have been a clay-bed in the Portland Sands; for the foreman told me that the well was still in sand at the bottom, and that the solid clay had not been touched. At any rate, the Kimeridge Clay cannot be far below the stream-bed at this point." The upper 8-9m probably included the Sandy Limestones and Exogyra Bed, making the Lower Sands at least 6-7m thick.

A recent section on the south side of Tisbury Railway Station (ST 947291) shows 5-6m of clay and silty clay with harder beds of fossiliferous limestone in the top 1.3m. The original sediment of the latter was lime mud with about 1% of very fine quartz sand and 1% Rhaxella sponge spicules. (Fig. 92 ). Other sections have been recorded by Blake (1880), Hudleston (1882) and Woodward (1895) see end of chapter. One can conclude that the thickness of the Basal Sands appears to be approximately 7m.

Until a good exposure is available from which a biostratigraphically useful fauna can be obtained it is not known whether these sediments belong wholly or in part to the lowest beds of the Portland Group or to the highest Kimmeridge Clay - the Sandy Upper Kimmeridge Beds.

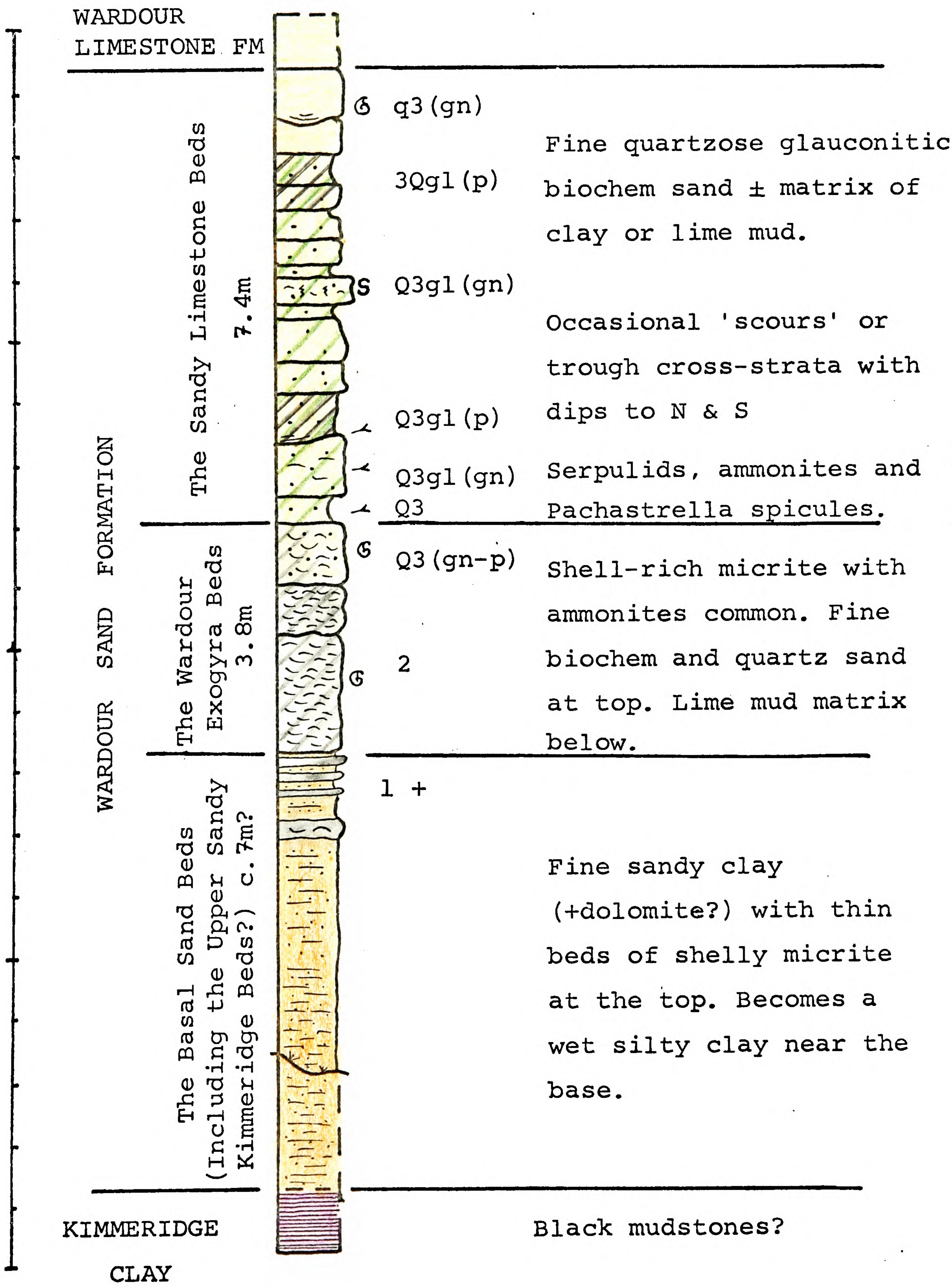
B. The Wardour Exogyra Beds (c.3.8m)

These Beds were exposed when Upper Chicksgrove Quarry (ST 961296-964296) was deepened in 1970. They consist of approximately 3.8m of very shelly limestone, the matrix of which, at the time of deposition, was lime mud with some very fine sand-

THE WARDOUR SAND FORMATION, PORTLAND GROUP.

VALE OF WARDOUR, WILTSHIRE FIG 92

Upper Chicksgrove Quarry (ST 9629)
Tisbury Station (ST 946291)




(For symbols and colours see Figs)

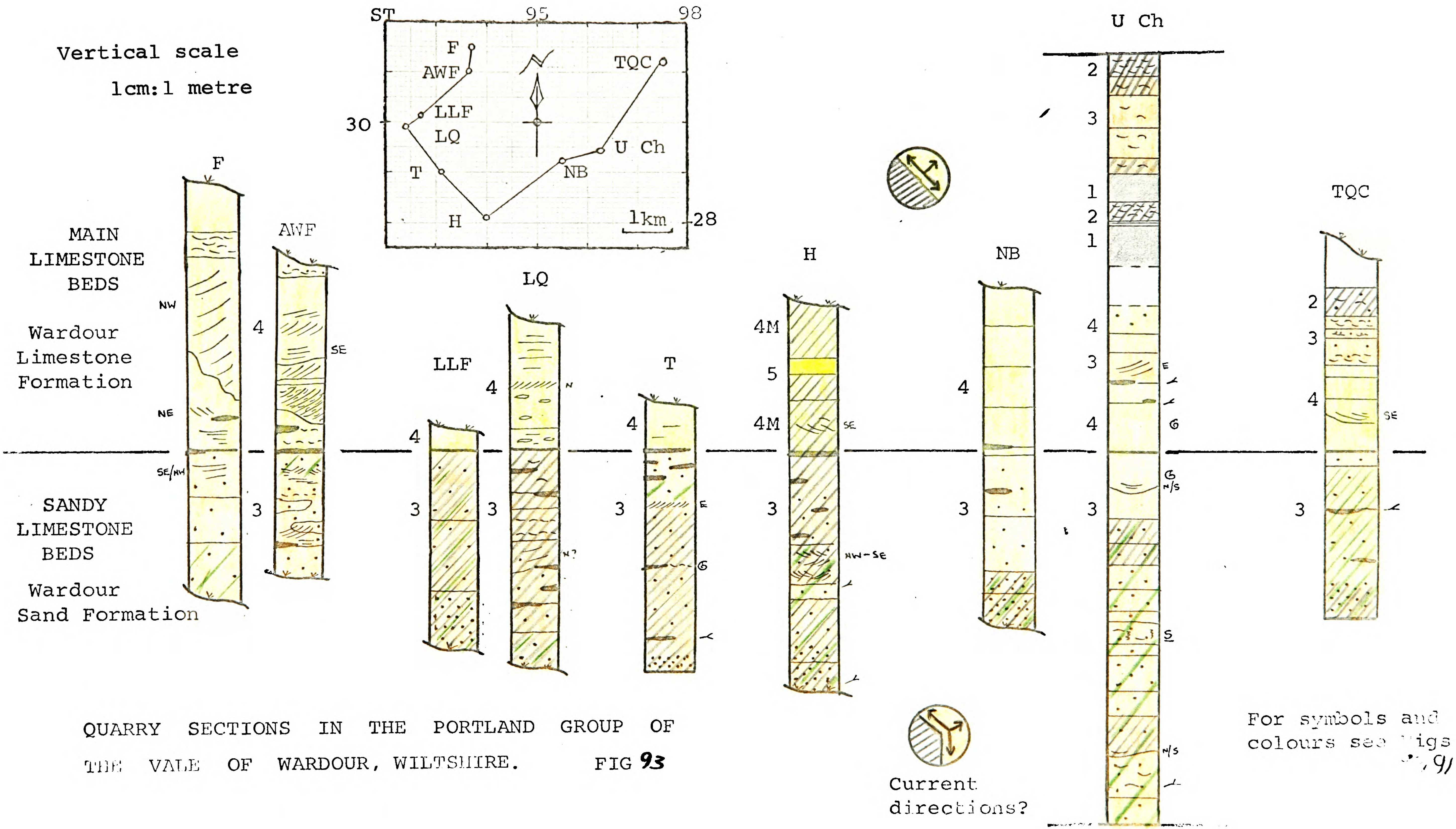
grade shell fragments, about 1% quartz sand and <1% glauconite. The upper 1.0m contains 20% v.f. quartz sand in a matrix of v.f. biochem sand. Common fossils include Exogyra, Ostrea, Glomerula, Isognomon, Laevitrigonia, Falcimytilus and medium and large sized ammonites (Glaucolithites?).

These beds have been described in the past at only a few isolated exposures and never in context of a complete sequence. At other less well-exposed localities the Beds seem to consist almost entirely of Exogyra nana shells. No lydite pebbles were found in any of the numerous blocks of Exogyra Beds in Chicksgrove Quarry and from six other localities only one specimen was detected. Previous workers have described their distribution as "scattered" and the point must be made that they are not nearly so common as in the South Midlands outcrop.

C. The Sandy Limestone Beds (c.7.5m)

These have not been completely exposed in the past because only the upper part is sufficiently well cemented to have been worth quarrying. The lower part has been described by previous authors (e.g. Arkell 1933) only as "loose sands". The recent downward extension of Upper Chicksgrove Quarry has revealed the whole succession which consists of thirteen beds of quartzose glauconitic limestones (Facies 3), variable in hardness and totalling 7.4m thick (Plate 76). The original sediment was essentially v.f.-f. biochem sand with up to 30% v.f. quartz sand, 1-5% glauconite and sometimes with a matrix of clay or lime mud (Plate 75).

The lowest three beds contain casts of Pachastrella sponge spicules (usually ferroan calcite), and scattered trigoniid moulds; the cement is sometimes silicified. The seventh bed up from the base contains common large Serpula (but is not the "Pinney Bed" of previous authors). Other fossils and sedimentary structures are poorly preserved in these generally soft porous sediments. Large ammonites with an epifauna of serpulids and oysters are common when the beds are worked (Plate 77,78). Vague scours or possible trough cross-strata are sometimes discernible, trending north-south.




QUARRY SECTIONS IN THE PORTLAND GROUP OF THE VALE OF WARDOUR, WILTSHIRE. FIG 93

The other sections are shown in Fig. 93 and details given at the end of the chapter. General points are that the glauconite content seems to increase to the ENE whereas the mud matrix decreases in the same general direction. The quartz sand content, however, remains about the same everywhere. Information on current directions from depositional structures is far from adequate but directions to the NW, N, NE, E, SE and S have been observed. Cross sets were not seen in the section in the Chilmark inlier, only horizontal and ripple lamination.

D. Fauna recorded from the Wardour Sand Formation

Basal Bands (low preservation potential)

Fauna found by present author, near the top only:

Thracia depressa Sowerby
Musculus autissiodorensis Cotteau
Exogyra sp.
Protocardia sp.
Eocallista sp.?
Echinoid spine
Small serpulid (Glomerula sp.?)
Discinid brachiopod?
Fish tooth

Exogyra Beds (high preservation potential)

Fauna found by present author plus previous records:

Common:
Laevitrigonia gibbosa Sowerby
Exogyra nana Sowerby (E. bruntrutana Thurmann)
Camptonectes lammellosus Sowerby
Protocardia dissimilis Sowerby
Isognomon bouchardi Oppel (I. listeri)
Falcimytilus suprajurensis Cox
Glomerula gordialis Schlotheim
Glaucolithites sp.

Less Common:
"Trigonia" Pellati Munier-Chalmas
"Trigonia" concentrica Agassiz
Pteria chilmarkensis Cox
"Natica" elegans Sowerby

Sandy Limestone Beds (low preservation potential)

Fauna found by present author:

*Laevitrigonia* sp.
*Glaucolithites* sp.
*Serpula* sp.
"*Pachastrella*" spicules
Echinoid spines

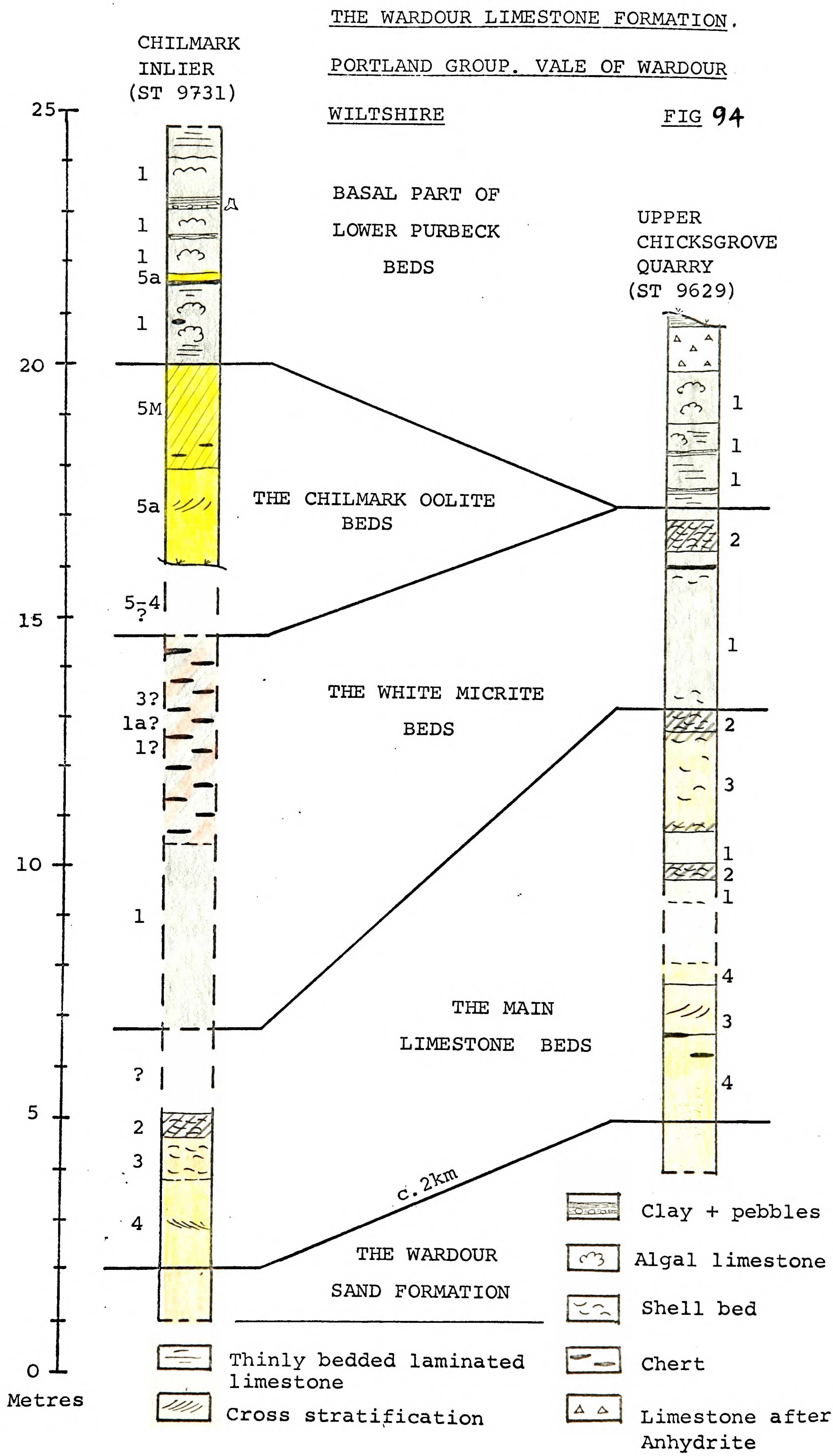
5. The Wardour Limestone Formation

The following account of the Main Limestones is made from a study of the beds at several localities. Details are given in the Figs 93,94 and in a separate section at the end of the chapter. The overlying succession in the Chilmark inlier differs from that at Chicksgrove but the complete section is not exposed. Reference to previous accounts is made to fill this gap.

A. The Main Limestone Beds (up to 8m)

The top of these beds is defined by the base of the White Micrite Beds. This junction was probably once exposed in the highest parts of a number of the building-stone quarries but the only locality where it can now be seen is at Upper Chicksgrove. Here the Beds are approximately 8m thick and can be divided into three parts (Figs 94,93).

The lower part consists of approximately 3m of cherty quartzose limestone composed of fine to medium biochem sand, 1-10% quartz sand, <1% glauconite and without mud matrix (Plate 74). Ammonites and occasional casts of *Laevitrigonia* occur and sets of cross-strata, less than 0.5m thick, dip to the east. The middle part consists of approximately 2.5m of micrite with a shell bed containing bivalves and gastropods. The upper part is approximately 2.5m thick and composed of fine biochem sand with <2% quartz sand, scattered bivalves and occasional ammonites. The topmost 0.5m of this is a shell bed with a matrix of lime mud. This latter part and the succession above is best exposed in a disused part of the quarry at the east end of the present worked face (described in Benett 1831).



THE WARDOUR LIMESTONE FORMATION.
PORTLAND GROUP. VALE OF WARDOUR
WILTSHIRE
FIG 94
CHILMARK INLIER (ST 9731)
UPPER CHICKSGROVE QUARRY (ST 9629)
BASAL PART OF LOWER PURBECK BEDS
THE CHILMARK OOLITE BEDS
THE WHITE MICRITE BEDS
THE MAIN LIMESTONE BEDS
THE WARDOUR SAND FORMATION
c. 2km
25
20
15
10
5
0
Metres
1
1
1
5a
1
5M
5a
5-4 ?
3?
1a?
1?
1
?
2
3
4
1
1
1
2
1
2
3
1
2
1
4
3
4
Thinly bedded laminated limestone
Cross stratification
Clay + pebbles
Algal limestone
Shell bed
Chert
Limestone after Anhydrite

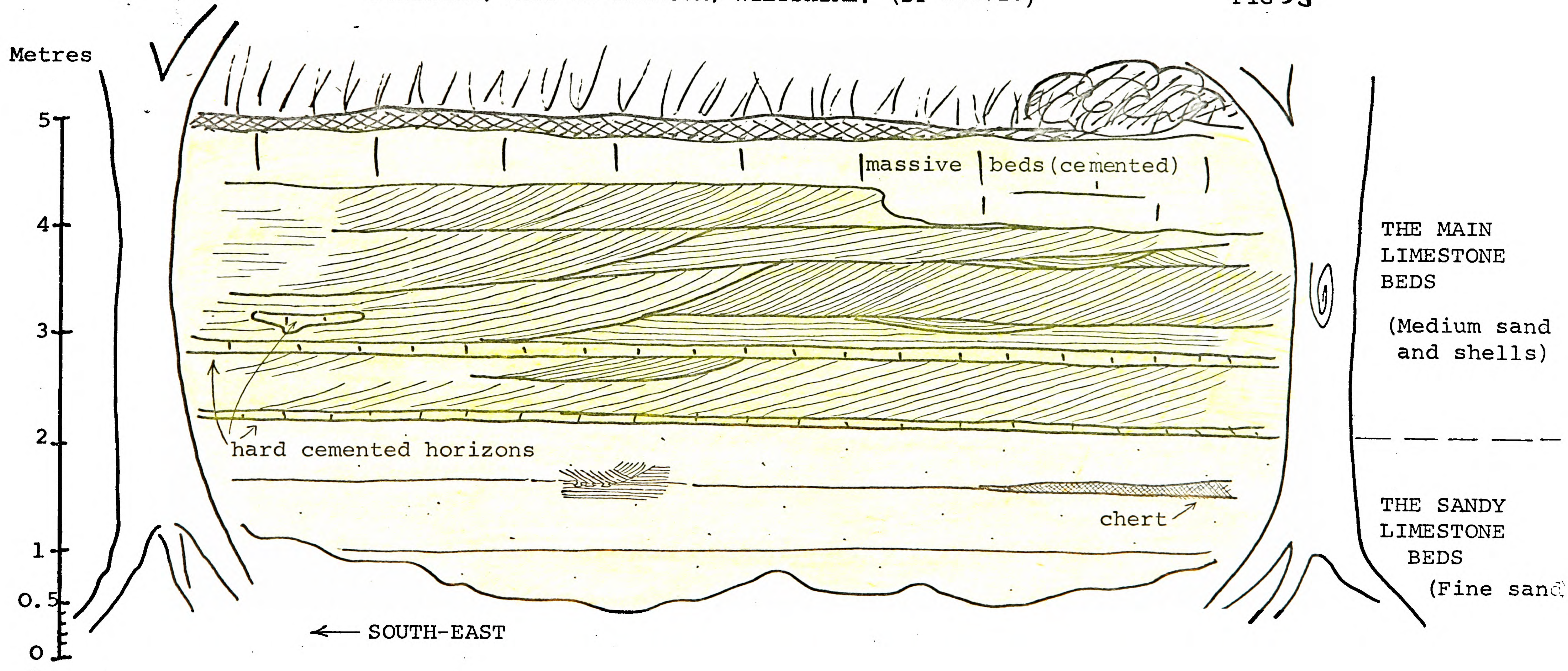
The sections at the other localities are shown in Fig. 93 and details are given at the end of the chapter. Only the lower part and perhaps some of the middle part is now exposed but the following general points can be made:- Massive cross-stratified shelly medium and coarse biochem sand is prevalent in a belt running NW/SE (Plate 79); the biochem sand becomes finer grained and lime mud more common to the NE; medium biochem sand with a mud matrix occurs to the SW where ooid grains make their only appearance (Plate 75).

The coarse cross-stratified shelly facies, constituting what was previously known as the "Ragstone Beds" or "Lower Cyrena Beds" (Hudleston 1881a), is now visible only at the disused quarries in Quarry Wood and Ashleywood Farm, Fonthill (ST 937315), 936310). It has been suggested that there is a break at the base of these beds (Hudleston 1881a & b), but although it is seen to undulate in places this is considered to be merely the result of contemporary erosion of the sea-bed, probably due to the action of migrating submarine sand dunes. At the exposure in Quarry Wood the base of the massive cross-stratified shell-fragment limestone has cut into the bedsbelow up to a depth of 0.4m. The cross-sets above dip to the north-west and the massive bed thickens to the north from 1.8m to 2.9m, over a distance of about 20m. At the exposure at Ashleywood Farm the depositional structures are well displayed and are depicted in Fig. 95. The sets are planar, erosive, up to 0.5m thick and generally seem to be trough cross-strata with foresets dipping to the south-east. The sediment consists of shells and fragments of bivalves and gastropods from 2-20mm across, in the lower part (average 4mm) and 2-3mm in the upper part, in a matrix of medium biochem sand (Plate 79). Finer grained beds have been selectively cemented into structureless thin horizons and nodules in the lower part and massive beds at the top.

This shelly facies contains a fauna which is in some respects atypical. In the past a "fluvio-marine" origin was postulated (Hudleston 1881b) but later work has indicated a shallow marine environment, probably neritic, but with a generallydecreased salinity (Casey 1955). This will be further discussed elsewhere

CROSS STRATIFICATION IN THE LOWER PART OF THE MAIN LIMESTONE BEDS, WARDOUR LIMESTONE FORMATION. DISUSED QUARRY AT ASHLEYWOOD FARM, FONTHILL, VALE OF WARDOUR, WILTSHIRE. (ST 936310)

FIG 95



but the faunal list is given on page 198, and modes of life of the animals is given in the chapter on Palaeoecology. The apparent absence of ammonites is not surprising as they are rare in shallow water high-energy environments. Those in the much thicker Freestone Beds of the Portland Limestone Formation of Dorset occur at levels which are considered to represent phases of quiet water. The cross-stratified beds of the Wardour Limestone Formation are not more than 3m thick and probably accumulated over a much shorter period of time. They are virtually unbioturbated and consist of coarse shell fragments in contrast to the ooid sands of Dorset. The coral Isastrea occurs at the base of the medium carbonate sand facies in the Vale of Wardour (see discussion at the end of this chapter).

B. The White Micrite Beds (4.5-7.8m)

These were, in the past, three sections which showed the complete succession from the Main Limestones to the Lower Purbeck Beds but of those only that at Upper Chicksgrove Quarry remains. The very top of the White Micrite Beds is still visible at Wockley Quarry (ST 955286) but the beds in the Chilmark inlier are concealed. At the two western localities the Purbeck Beds rest directly on 4-5m of White Micrite Beds which have a prominent shell-rich horizon at the top. In the inlier, about 2km to the north-east of Upper Chicksgrove, the Purbeck Beds rest on the Chilmark Oolite Beds (5m thick) which overlie about 7.8m of White Micrite Beds.

(i) The Chilmark inlier

One can only generalise from previous accounts which are not very informative. The thickness is given as either 7.8m with black chert horizons (horizontal and vertical) in the upper 4.2m (Blake 1880), or as 7.3m with chert in the upper 3.8m (Hudleston 1881a). The latter thickness has been quoted by Andrews (1882), Woodward (1895) and Arkell (1933) but the more detailed measurements by Blake are used here (Fig. 94). The rock has been described as fossiliferous "white chalk" and has been compared with the Cherty Micrite Beds of the West Mainland Area, Dorset. At the base in places a shell-bed dominantly composed of trigoniids is recorded. This compares with the topmost bed of the Main Limestones of Upper Chicksgrove and is thus not included with the White Micrite Beds.

J.K. Phillips (in Hudleston 1881c) examined thin sections of chert from these beds and found spicules of Pachastrella and shell fragments in a fine grained matrix. It is probable that these cherty beds are of the same facies as the top part of the Upper Cherty Beds on the Isle of Portland, Dorset - that is, sponge spicule lime mud (Facies 1a) with Pachastrella, but possibly also Rhaxella as an essential constituent. The Cherty Micrite Beds of the West Mainland Area, Dorset, consist of alternations of Facies 1a and 1 (lime mud) and this is probably the case here, with Facies 1 comprising all the lower half of the sequence. All accounts agree in the abundance of bivalves and ammonites and it is likely that Facies 2 and possibly Facies 3 are also present at some levels.

(ii) Upper Chicksgrove Quarry

A disused part of the original quarry shows the thinner complete section which compares best with the lower part at Chilmark. The beds are 4.5m thick and the original sediment was lime mud throughout (Facies 1) (Fig. 94). The basal 0.5m, which contains scattered bivalves and biochem sand, is a continuation of the shell bed at the top of the Main Limestones. The overlying 2.75m consists of homogeneous soft white micrite with scattered Camptonectes in the upper 0.4m. A bed of black chert, 10-20mm wide, separates the lower part from the upper 1.15m.

This upper part contains innumerable large Camptonectes and large Ostrea in a matrix of micropelletal lime mud with 1% v.f. quartz sand. This is informally known as the "lamellosus bed". It is 0.70-0.75m thick with shell-free Facies 1 below and above, the latter rich in ostracods. This forms a transition into laminated ostracod-rich lime mud which constitutes the base of the Purbeck Beds (Fig. 96). The bed contains articulated and disarticulated whole valves of large bivalves, the latter being mostly convex-up. The presence of closed valves of mobile and sessile epifauna in a mud matrix suggests rapid burial, before decay of the soft parts could take place. The presence of convex-up valves suggests that current action was involved. It is possible that the "lamellosus bed" represents a strand-line concentration bordering a usually low-energy lime mud environment. The upper half of the "lamellosus bed" is highly consolidated and, together with the uppermost shell-free part, forms a projecting ledge upon which rests the Purbeck Beds. Contrary to the opinion of Hudleston (1881a) and in accordance with Andrews and Jukes-Browne (1894), there does not seem to be a break between the White Micrite Beds and the Lower Purbeck at this junction. (This is discussed later).

(iii) Wockley Quarry

Only the uppermost part is still exposed but previous accounts describe "chalky limestones" and give thicknesses from 3-4.5m (Woodward 1895) to 4.9m (Andrews and Jukes-Browne 1894). The beds were described as "uniform, soft, very white limestone" by Fitton (1836). The top part has been described by Woodward as a "Bed of Roach with lenticular mass of black flints at the top", 0.7m thick.

All that is now visible is approximately 0.6m of hard white micrite, with the "lamellosus bed" in the lower half, overlain by about 2m of basal Purbeck Beds (Fig. 96).

C. The Chilmark Oolite Beds

Upper Quarry (ST 975313), on the east side of Chilmark Ravine, exposes about 2.5m of the basal Purbeck Beds overlying approximately 4m of oolitic limestones (Fig. 94). The following total thicknesses have been recorded by previous workers:

| | | |
|---|---|---|
| Hudleston (1881a) and Andrews (1882 & 1903) | : | 5.4m |
| Blake (1880) | : | 5.3m |
| Andrews & Jukes-Browne (1894), Woodward (1895) | : | >4.8m |
| Jukes-Browne (1903) and Arkell (1933) | : | 4. 8m |

The thickness of 5.4m is taken here, leaving approximately 1.4m unexposed. The beds are described by Woodward as being "in places rather sandy limestones" and as containing chert in the lower part. The latter is probably less oolitic than above, possibly Facies 4, 4c or 5c with sponge spicules and quartz sand >1%.

A small exposure 350m to the south-east (ST 977311), probably at a horizon slightly lower than at Upper Quarry, shows chert lenses and the sediment proved to be Facies 5c, but with <1% quartz. At Upper Quarry, the sediment of the lowest exposed 2m is porous, well compacted and sorted micritised medium ooid sand, with 1% quartz and some shell fragments. Cross-stratification can be dimly discerned in the walls of an underground gallery, with foresets dipping to the NW-WNW.

The sediment of the overlying 2.2m is a mixture of ooids and pelletal lime mud (Facies 5M) with <1% quartz sand. Chert occurs 0.5m from the base of this upper part and micrite bivalves and gastropods, as well as Camptonectes, are preserved. The overlying 0.6m is hard with some chert, and the topmost 1.1m consists of soft, porous unfossiliferous oomicrite. Common fossils recorded in the top few metres of the Chilmark Oolite Beds include Aptyxiella, Eomiodon, Laevitrigonia and Camptonectes.

The Chilmark Oolites are known only in the Chilmark inlier and exposed now only on the east side. Andrews (1903) says "Although it is a thick bed here on the eastern side of Chilmark Valley, it is but slightly represented on the western side, and is absent in the old quarries of Chicksgrove and of Wockley." Thus, this oolitic facies thins rapidly to the west, the opposite side of Chilmark Valley being only 300m away and Chicksgrove 2.1km. Jukes-Browne (1903) suggests that the top part of the "lamellosus bed" at Wockley is a reduced representative of this, if it is represented at all.

D. Fauna recorded from the Wardour Limestone Formation

Main Limestone Beds (preservation potential moderate to good)

Fauna found by present author plus previous records.

Common: Myophorella incurva Benett

Laevitrigonia radiata Benett

<u>Laevitrigonia gibbosa</u> Sowerby

<u>Eomiodon cuneatus</u> Cox

<u>Corbicellopsis uniodes</u> de Loriol

<u>Corbicellopsis moreanssa</u> Buvignier

<u>Protocardia dissimilis</u> Sowerby

<u>Eocallista pulchella</u> de Loriol

<u>Corbula saltans</u> Blake

<u>Corbula chilmarkensis</u> Cox

<u>Isognomon bouchardi</u> Oppel

<u>Camptonectes lamallosus</u> Sowerby

<u>Lucina portlandica</u> Sowerby

<u>Neritoma sinuosa</u> Sowerby

"<u>Chemnitzia</u>" <u>teres</u> Hudleston

<u>Actaeonina signum</u> Hudleston

<u>Natica incisa</u> Blake

Less Common: <u>Pteria chilmarkensis</u> Cox

<u>Plagiostoma rustica</u> Sowerby

<u>Pholodomya rustica</u> Phillips

<u>Tancredia Chicksgrovensis</u> Cox

<u>Pronoella nuculaeformis</u> Roemer

<u>Falcimytilus suprajurensis</u> Cox

<u>Pleuromya</u> sp.

<u>Neritoma transversa</u> Von Seebach

"<u>Chemnitzia</u>" <u>teres</u>. Hudleston } <u>Zygopleura</u> or

"<u>Chemnitzia</u>" <u>naticoides</u> Hudleston } <u>Katosira</u> ?

<u>Pseudomelania? percincta</u> Hudleston

<u>Isastrea oblonga</u> Edwards & Haime

Echinoid spines

<u>White Micrite Beds</u> (Good preservation potential)

Fauna found by present author plus previous record.

Common: <u>Ostrea expansa</u> Sowerby

<u>Camptonectes lamellosus</u> Sowerby

<u>Protocardia calcarea</u> Blake

<u>Protocardia dissimilis</u> Sowerby

<u>Laevitrigonia gibbosa</u> Sowerby

| | |
|---|---|
| | Lucina portlandica Sowerby |
| | Pleuromya sp. |
| | "Behemoth" |
| | "Pachastrella" spicules (+ Rhaxella?) |
| | Crustacean fragments |
| Less Common: | Ostrea Chicksgrovensis Cox |
| | Thracia incerta? Thurmann |
| | Buchia sp.? |
| | Actaeonina sp. |

Chilmark Oolite Beds (Moderate preservation potential)

Fauna found by present author plus previous records.

| | |
|---|---|
| Common: | Laevitrigonia gibbosa Sowerby |
| | Isognomon bouchardi Oppel |
| | Camptonectes lamellosus |
| | Eodonax dukei Morris & Lycett |
| | Lucina portlandica Sowerby |
| | Eomiodon cuneatus Cox |
| | Aptyxiella portlandica Sowerby |
| | Ampullina ceres de Loriol |
| Less Common: | Neritoma sinuosa Sowerby |
| | "Chemnitzia" sp. |

## 6. The Relationships between the Lower Purbeck Beds and the Wardour Limestone Formation

### A. The Basal part of the Lower Purbeck Beds

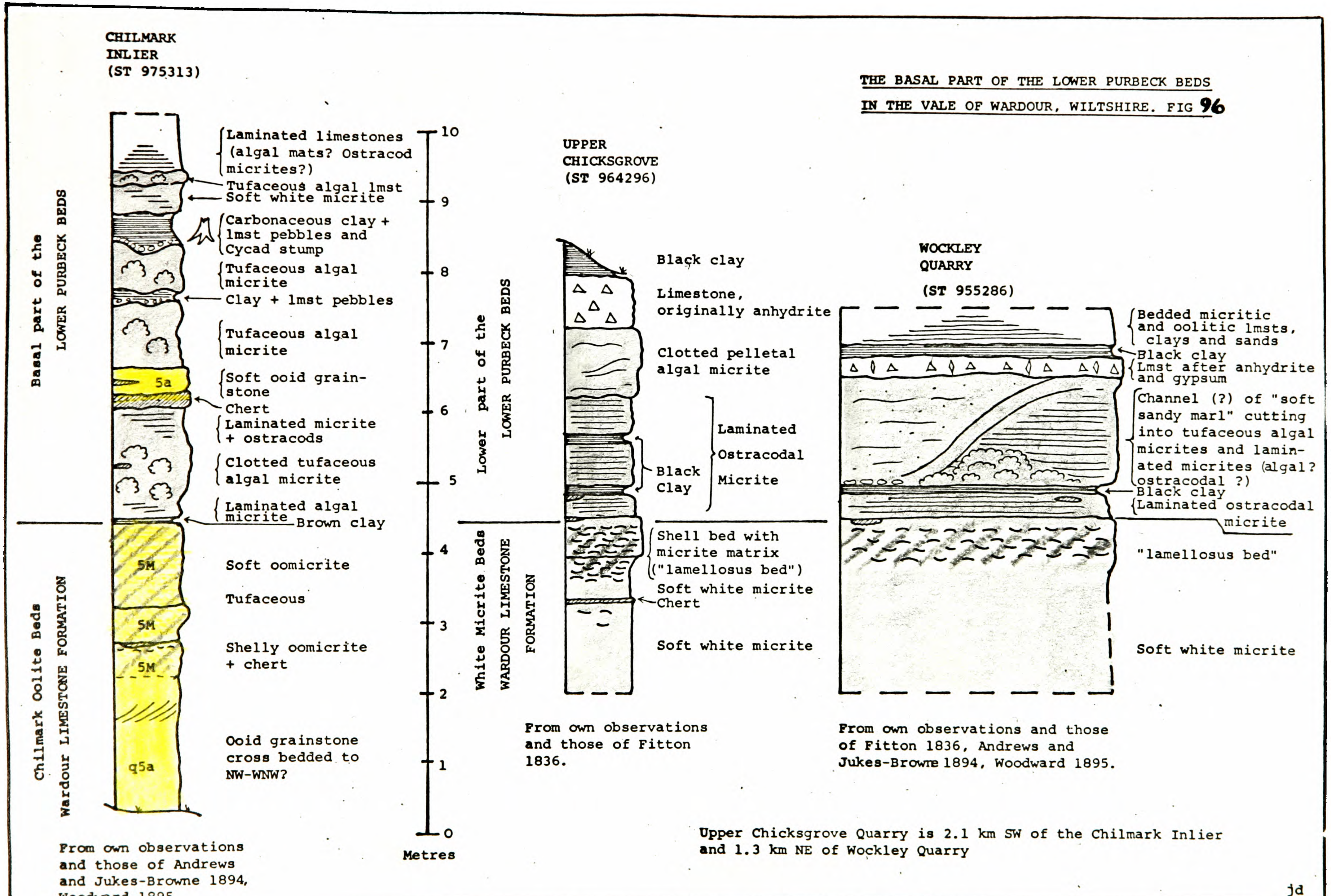
#### (i) Chilmark inlier (Fig. 37 )

Two metres of Lower Purbeck Beds are exposed above the Chilmark Oolites, the junction being taken at a thin seam of brown clay at the top of Facies 5M. The overlying 1.55m is hard grey micrite consisting of partly laminated lime mud at the base and top, with a tufaceous "clotted" micropelletal lime mud between. The whole bed is undoubtedly algal in origin. Small black chert nodules occur in the middle portion. At one is approximately 0.3m of chert consisting of silicified lime mud with micrite clasts in the lower part, and silicified oolite in the upper part. It is overlain by porous well-sorted medium sand-grade ooid grainstone.

Andrews and Jukes-Browne (1894) give a more complete section, included in Fig. 96 . The oolite is 0.4m thick and contains chert. This is overlain by 1.5-1.95m of "Tufaceous marly limestone, very soft in places and irregularly bedded". The top of this is uneven and covered by 0.3-0.5m of "stiff grey clay, containing pebbles of whitish limestone and many pieces of wood. ... An upright and rooted stump of a tree was found in it, the stem standing about (2m) high." This is undoubtedly the same phenomenon as the "dirt beds" of the Dorset basal Purbeck Beds and the clay with pebbles represents a weathered surface of algal limestone upon which Cycads grew. Above is about 0.3m of "soft, white chalky limestone" 0.2m of "yellow tufaceous limestone" and 0.6m of "shaley marl, with lenticular beds of soft limestone, bedding wavy" (Andrews & Jukes-Browne 1894).

#### (ii) Upper Chicksgrove (Fig. 96 )

An obscured section above the top of the Wardour Limestone Formation was dug clear by the author in the summer of 1970 exposing 3.5-4m of the basal Purbeck Beds. Immediately above the "lamellosus bed" of the White Micrite Beds is 1.7m of laminated ostracodal micrite with two beds of black clay, each 0.1m thick. This is overlain by approximately 1.7m of limestone which is algal




THE BASAL PART OF THE LOWER PURBECK BEDS IN THE VALE OF WARDOUR, WILTSHIRE. FIG 96 in the lower part and a replacement after anhydrite in the upper part. This is overlain by black clay and topsoil.

(iii) Wockley Quarry (Fig. 96)

The exposures here are very poor now and the details are synthesised from the accounts of several authors (including Jukes-Browne 1903, not given on Fig. 96). Some horizons are still exposed, enabling petrographic study. The sequence is essentially the same as at Upper Chicksgrove but there appears to have been a channel exposed, cutting through laminated ostracodal micrites and stromatolitic mounds. The evaporite horizon of Upper Chicksgrove was detected and here calcite replaces small gypsum crystals as well as anhydrite (Plate 80).

B. <u>The environment of deposition of the basal Purbeck Beds</u>

The facies at the above three localities are the same as comprise the basal part of the Lower Purbeck Beds in Dorset. Massive stromatolitic algal limestones with tree-bearing clays are typical in the Central and West Areas of Dorset where it is seen, in the excellent cliff exposures, that ostracod limestones occur between algal mounds and sometimes fill shallow channels. Cycad and Araucarian trees grew on the weathered surfaces of the algal mounds with their roots either in or just above water level. It is thought that the algal mounds acted as a barrier to free circulation of marine water. Behind this was a shallow hypersaline intertidal and supratidal environment where laminated lime muds were deposited, sometimes as desiccated algal mats, and ostracods occasionally flourished (Brown 1961, 1963, 1964, Pugh 1968). On the subaerially exposed margins evaporation resulted in the precipitation of calcium sulphate.

This model can also be applied for these beds in the Vale of Wardour and it seems probable that the facies in the east were formed at the same time as those further west, and that the litho-stratigraphical base of the Purbeck Beds, over the short distance of 2km, approximates to a time plane. If this is so, then the thicker algal barrier sediments were to the east and the shoreline with evaporites lay to the west. It would appear from the presence of the intercalated oolite in the east that seaward of the algal barrier was an area of ooid formation.

## C. The "Missing beds" of the Wardour Limestone Formation: Discussion

Approximately 9.5m of the upper part of the Wardour Limestone Formation is absent in the west of the Vale of Wardour. This fact puzzled geologists in the late nineteenth century but it has not been discussed in detail since. (Arkell 1933) commented that it was due to "attenuation or unconformable overlap of the Purbeck Beds". Hudleston (1881a) thought that the latter was the case but Andrews (1903) could find no sign of erosion and decided that the absence of the upper part of the White Micrite Beds and all of the Chilmark Oolites was due to gradual thinning to the west.

There are three possibilities to explain the phenomenon (Fig.97)

Possibility 1 (Fig.97.1) The upper part of the Wardour Limestone in the east is the same age as the lower part of the Purbeck Beds in the west.

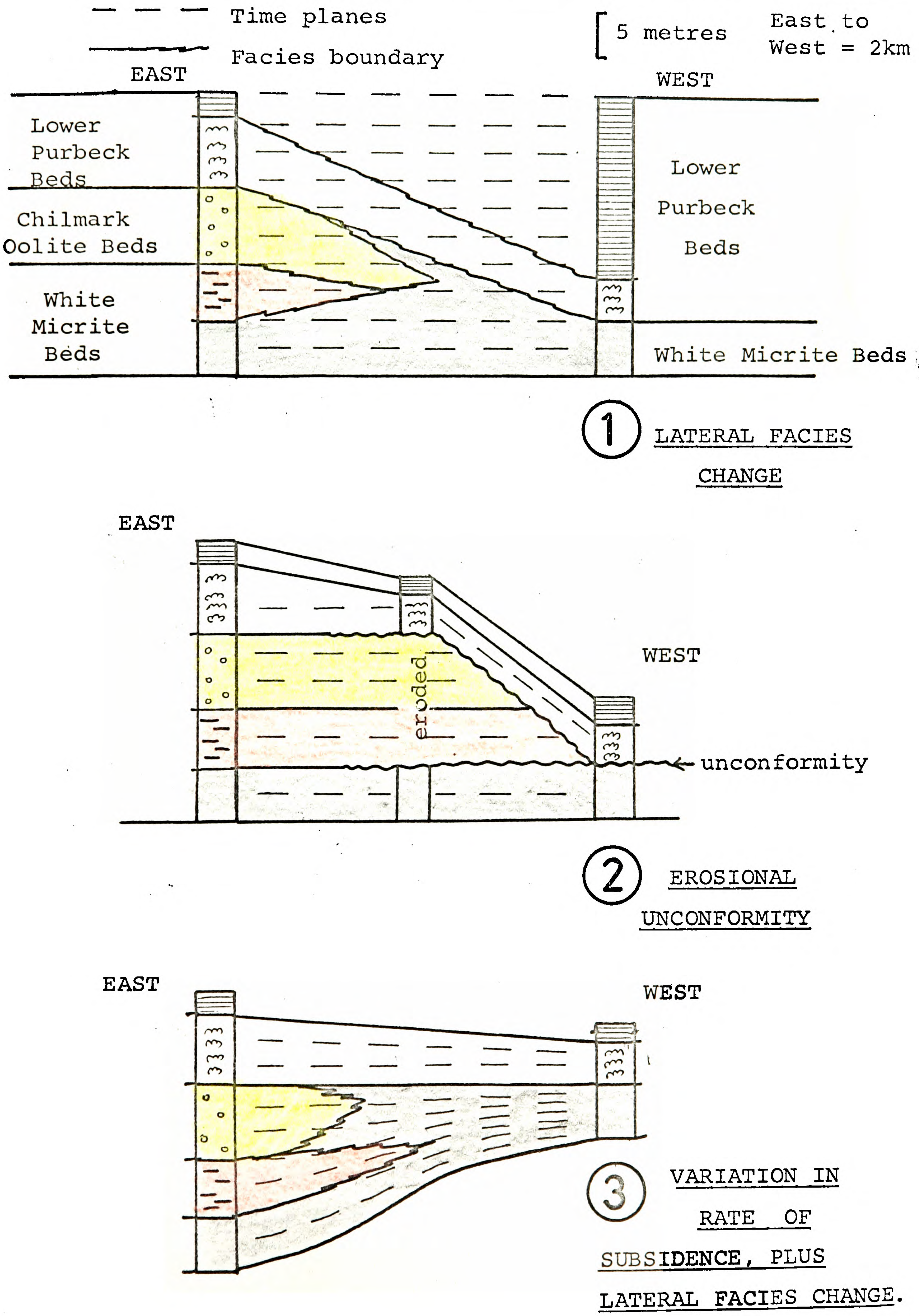
The difficulty in accepting this explanation is that there would have to be over a long period of time a barrier between the marine Wardour Limestone facies and the non-marine Lower Purbeck facies, in the distance of 2km between the two areas. Also, the rates of subsidence in the two areas would have to be assumed to be approximately the same. On its own, this seems improbable and in the light of the evidence below it is regarded as untenable.

Possibility 2 (Fig.97.2) The upper part of the Wardour Limestone was deposited over the whole area but removed in the west before synchronous deposition of the Purbeck Beds.

It is reasonable to have had, in the west, erosion of widely deposited beds due to rapid uplift, or a lower rate of subsidence combined with a fall in sea-level. However, there is no sign of a lithological break at the top of the "lamellosus bed" and, according to Andrews (1903), the ostracods show a transition of environment into the basal Purbeck Beds. No break was found by the present author at this level or at any level below the shell

POSSIBLE EXPLANATIONS FOR THE ABSENCE OF THE UPPER PART OF THE WHITE MICRITE BEDS AND THE CHILMARK OOLITE BEDS OVER A DISTANCE OF 2km. WARDOUR LIMESTONE FORMATION, PORTLAND GROUP, VALE OF WARDOUR, WILTSHIRE.

FIG 97



bed, thus the hypothesis of Hudleston (1881a) is unacceptable. It is suggested that the shell bed is a strand-line deposit which accumulated slowly in a generally low-energy environment.

Possibility 3 (Fig. 97.3) There was more rapid subsidence in the east and the Lower Purbeck Beds succeeded conformably at approximately the same time over the whole area.

There is no detectable erosional break in sedimentation between the Portland Group and the Purbeck Beds. There is, however, evidence that throughout the deposition of the Portland Group the margin of the basin was to the west and more rapid subsidence took place in the east. Assuming that the deposits of each of the major Beds were laid down approximately synchronously over the short distance involved, it is suggested that the sediments in the east were formed in deeper water than those to the west, for the following reasons:-

(i) The "lydite" pebbles in the Wardour Exogyra Beds are not found to the east of Tisbury which suggests a land source and shallower water to the west.

(ii) The glauconite content of the Sandy Limestones increases to the east which suggests a lower rate of accumulation of sediment and deeper water in that area. (Glauconite forms in depths >50m) (Ehlmann 1964).

(iii) During the deposition of the Main Limestones there was a NW/SE belt of medium sand across the centre of the area with a decrease of grain size and increase in lime mud content to the east. To the west of themaximum concentration of cross-stratified shelly sand, a lime mud matrix reappears and rare ooids occur. This suggests that carbonate banks formed on a break of slope, with ooid formation and lime mud accumulation behind and fine grained sediment on the slope and in deeper water to the east.

From this model of a basin with a shallow margin in the west and a break of slope and deeper water to the east; more rapid subsidence to the east, and an overall lowering of sea-level, the following could be suggested:-

(i) The sponge mud facies of the White Micrite Beds was deposited only in the deeper water to the east.

(ii) The Chilmark Oolite Beds occur only in the east and rapidly thin westwards because they formed an ooid bank on the break of slope, whilst lime mud was slowly deposited in shallower, lower energy water westwards.

(iii) The maximum development, in the Lower Purbeck Beds, of algae in the east and ostracod limestones with evaporites in the west was due to deposition in an intertidal environment in the east and a supratidal environment in the west, during a phase of maximum regression of the sea.

In conclusion, it seems that the non-existence of the Chilmark Oolites and the upper part of the White Micrite Beds in the west of the Vale of Wardour is not due to erosion of about 1m of beds per 200m but to the sediments being deposited in the east about eight times faster than in the west, resulting in shallowing of water round the basin margin at the same time as the sea level fell.

## 7. Supplementary Details

### A. The Isastrea horizon

The coral Isastrea oblonga (Edwards & Haime) has long been known from the Portland Group of the Vale of Wardour but its exact position in the sequence has not been satisfactorily agreed upon. J. Woodward (1729) described it as "Starr'd Agate" occuring in chert beds overlying "strata of sand stone". H.B. Woodward (1895) says that this position agrees with that assigned to it by Andrews "who has found the fossil above the Ragstones" west of Tisbury; and that this is the horizon described by Benett north of Tisbury (1831).. Arkell (1933) quotes J. Woodward but has followed H.B. Woodward by stating that it comes from the base of "Chalky or Cherty Series".

Hudleston (1881a), however, places Benett's horizon at the junction between the "Ragstones" and the "main building stone" and

Andrews (1882) agrees with this lower position. Fitton (1836) described the coral from a chert bed in a quarry north-west of Tisbury and Clement Reid (1903) records it in "chalky limestone at the junction with the hard cherty limestone" which was worked in a quarry also north-west of Tisbury.

Unfortunately Isastrea was not found during this work but it seems that the horizon lies at the base of the Main Limestones, around or just above the junction with the Sandy Limestones; that is, at the base of the Wardour Limestone Formation. It seems likely that this is the only position and that the records of J. Woodward and Benett were misinterpreted by H.B. Woodward and Arkell.

According to H.B. Woodward (1895) it has also been found in the Chilmark inlier, but Hudleston (1881c) says that it has never been detected in the east and again H.B. Woodward's record is probably suspect. This coral has also been noted in the Isle of Portland and the Boulonnais and was collected from these localities during the course of this present study. It is considered to be a facies fauna of no biostratigraphical significance (see chapter on Palaeoecology).

B. Exposures in the Portland Group. See Fig. 87 (Map)

(i) Basal Sands

(a) Blake 1880: Area west of Tisbury. "Yellow grey uncompacted calcareous stone" with no fossils and a spring line 6m below its top.

(b) Hudleston 1881a: Roadside between Tisbury and Wardour (near Hazeldon) (ST 9327-8) 6.3m "Loamy sands and clays".

(c) Woodward 1895: Railway cutting between Upper Chicksgrove and Tisbury (ST 9529) up to 6m "Brown and greenish-brown sand with clay seams and bands of indurated sand. Casts of shells here and there, thin beds of stone near top".

(ii) Exogyra Beds

(a) Road cutting near Hazeldon Farm (ST 934280). Approx. 1.0m of fossiliferous micrite with about 1% v.f. quartz sand and 0.5% glauconite. Blake (1880) described 2.1m and recorded lydites but only a few quartz grains 1-2mm across were found. Hudleston (1882) described 0.9m of fossiliferous limestone with occasional lydite pebbles in this vicinity.

(b) Road cutting in East Hatch village (ST 926284). c.0.5m of fossiliferous limestone exposed with abundant E. nana. One small lydite pebble found.

(c) Road cutting near Pyt House Farm (ST 912281). c.0.8m exposed. Very fossiliferous but no lydites.

(d) Track to New Barn (ST 954295). Small exposure of shelly micrite with <1% quartz sand. Abundant Exogyra. No lydites found.

(e) Railway Cutting (ST 954296). Loose block of Exogyra-rich limestone. No lydites. Woodward (1895) described c.3.9m of fossiliferous limestone at about this locality but does not mention lydites. His section matches that for the recent exposure at Upper Chicksgrove Quarry.

(f) Tisbury Station, cutting behind Forge (ST 946291). Approx 3m of fossiliferous limestone (including ammonites - Glaucolithites?) but no lydites found.

(iii) Sandy Limestones (SL) and Main Limestones (ML)

(a) Disused underground quarry. South side of Quarry Wood. Fonthill (ST 937315) Fig.93F.

SL: 3m Q3. Depositional structures NW/SE.

ML: 3-3.5m Facies 4. Lowest 1m cherty cross strata to NE; overlain by massive cross strata 2-3m thick, dipping to NW; coarse shell fragments. Shell bed above. Laevitrigonia, Neomiodon etc.

(b) Disused quarry. North side of Quarry Wood. Fonthill (ST 936316)

ML: over SL; overgrown. 5-10m

(c) Disused quarry. Ashleywood Farm. Fonthill (ST 936310) Fig.93AWF & Fig.95

SL: c.2m Q3. Cross strata dip NW/SE

ML: c.2.5m Facies 4 Cross strata up to 0.5m thick, dipping to NW; shells and fragments. Chert in lowest 0.5m.

(d) Disused quarry. Lower Lawn Farm. Fonthill (ST 927301) Fig.93 LLF. SL: c.4m. Lower part 3Q, upper part Q3. Ammonite at top. ML: 0.5m q4.

(e) Disused quarry. Lawn Quarry. West Tisbury (ST 924299) Fig.93LQ SL: c.3.5m Lower 1.5m Q3. Upper part q3. Shells and chert common in top one metre.
ML: c.2.75m. Lower 0.5m q4, upper part 4. Depositional sturctures dip to north and east? Gastropods in top 1m

(f) Working Quarry. Tisbury Quarry, West Tisbury (ST931290) Fig.93T SL: c.4.5m Lower 0.5m 3Q. Ammonites and silicified minute bivalves and gastropods 1.5m up from base. Depositional structures are dipping to the east. Upper part Q3; top 1.0m cherty and upper 0.5m Q3.
ML: c.1m Facies 4.

(g) Working quarry. Tuckingmill Quarry. West Tisbury (ST 934291) Fig 87 . Permission for entry refused. Probably similar to (f).

(h) Disused quarry between Wallmead, Haygrove and Hazeldon Farms. West Tisbury (ST 940281) Fig.93 H.
SL: 5m. Lowest 1m Q3 and 3Q. Pachastrella spicules common. Upper part q3 and top one metre Facies 3. Depositional structures in middle part in all directions. Cherts in top 2m.
ML: 3m. Lowest 1m facies 4, structures dip to SE? 1m above facies 4M, 4cM and 5c. Top 1m facies 4M.

(i) Disused quarry south of New Barn, Tisbury. (ST 955292) Fig.93 NB Measured but no thin sections cut.
SL: 4m. Lower part Q3? Upper part q3? Chert in top 1m.
ML: 3.5m Facies 4?;

(j) Working quarry. Upper Chicksgrove, Tisbury (ST 961296-964296) See Fig.93 UCh & Fig. 94

(k) Disused underground quarry. Teffont Quarry. Chilmark Ravine (ST 975312) RAF Bomb store. Fig.93 TQC.
SL: c.4m. Lowest 3m Q3 with chert. Top 0.75m q3.
ML: C.3.5m. Lowest 1.75m q4. 1.0m above is Q3 with bivalves and gastropods abundant. 0.5m above is fossiliferous Q2

(l) Disused underground quarry. Chilmark Quarries. Chilmark Ravine (ST 973311) RAF bomb store. Area c. 0.04 sq.km.
SL: Roof shows laminated Facies Q3 with silicified lenses containing shell debris, scattered <u>Laevitrigonia</u>, <u>Camptonectes</u> and ammonites (<u>Glaucolithites</u>?) & fossil wood. Sediment finely laminated, only rare vertical or high angle burrows c.10mm diameter. Symmetrical ripples, wave-length 20-30mm trending N/S. No cross strata, only low angle laminations.

(m) Disused open and underground quarries. Chilmark Quarries. Chilmark Ravine (ST 973313) RAF bomb store and abandoned galleries. No entry. Same as (l).

(iv) White Micrite Beds (WMB), Chilmark Oolites (CO) and basal Purbeck Beds

(a) Disused part of Upper Chicksgrove Quarry, Tisbury (ST 964296) See Figs. 94, 96.

(b) Disused quarry. Wockley Quarry. (or Shaver's Bridge Quarry) (ST 955286) Basal Purbeck c.2m. WMB 0.6m. Facies 1 & 2.

(c) Disused quarry. Upper Quarry, Chilmark (ST 975313) RAF property, unsafe. Basal Purbeck c.2m CO c.4m Facies 5M & 5a.

(d) Disused underground quarry. Old Level, Chilmark (ST 977311) CO c.3m. Facies 5.

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"The party moved briskly on until arrested by an opening in the Purbeck Beds, where Mr. Meyer found a nice little fish about the size of a sardine, and everyone was emmensely puzzled by a curious structure which nobody could explain."

From field report of an excursion to the Vale of Wardour.

Hudleston 1881c

## 8. Synthesis and Interpretations

The Portland Group in the Vale of Wardour was formed during three regressive phases of deposition in a progressively shallowing sea. These three main phases are regarded as being approximately synchronous with those represented in Dorset, 50km to the south.

Throughout the deposition of the beds the land was to the west, the basin margin trended NW-SE or N-S and deeper water lay to the east; reasons for these conclusions are given on page 204. The area of outcrop is too limited for a detailed environmental model to be suggested but the sediments can be interpreted by reference to their position on the basin margin, the depth of water and the varying influence of terrigenous material.

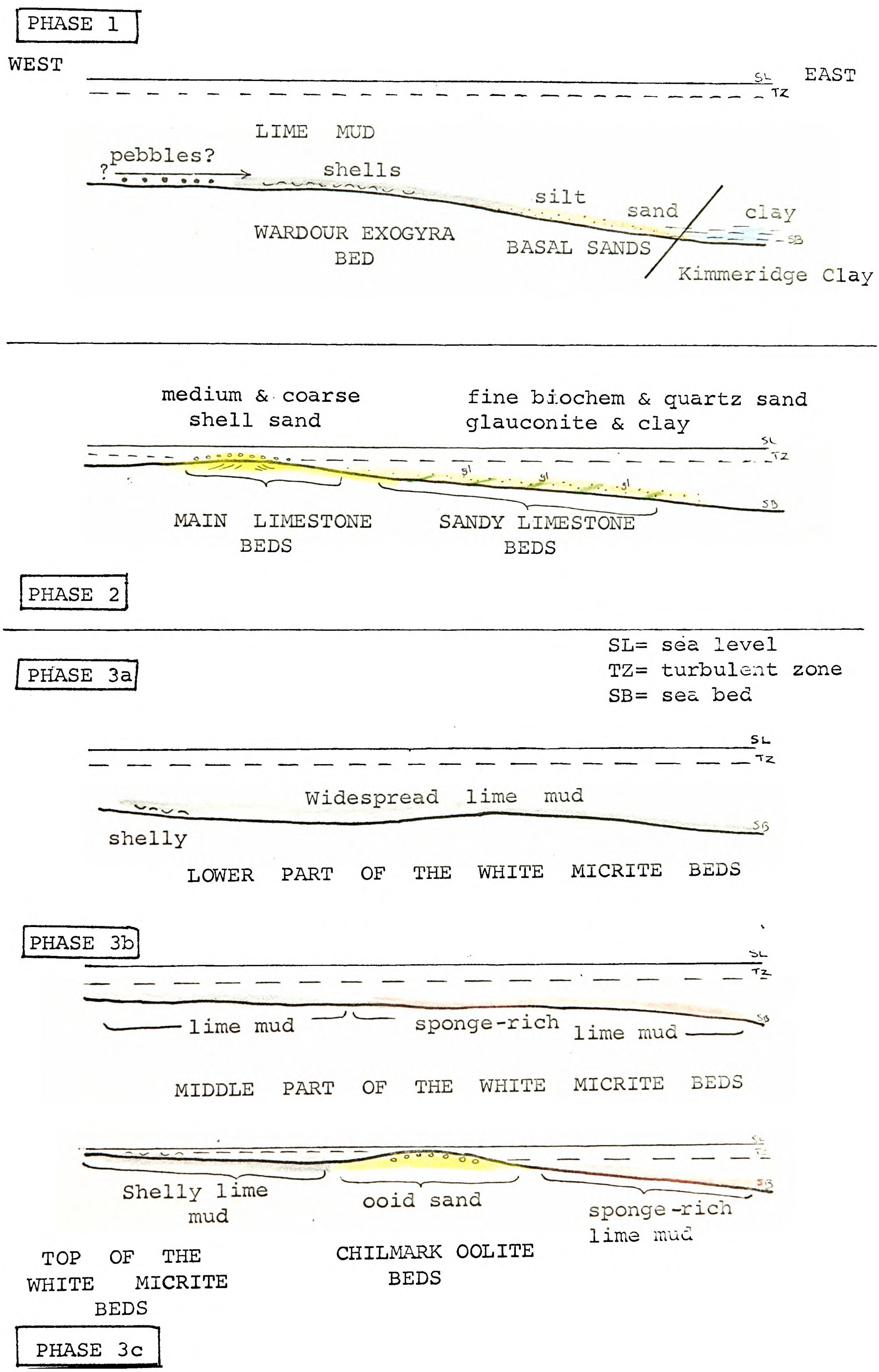
The first phase started within the Kimmeridge Clay and includes the Basal Sands and the Wardour Exogyra Beds. There is an upward decrease in clay content and an increase in the proportion of calcium carbonate. Fine quartz is present in the Basal Sands but the amount decreases to 1% in the Exogyra Beds. The latter contain an abundant bivalve fauna and a few derived Palaeozoic pebbles. These cherts are common at the base of the Portland Group in the South Midlands and mark an unconformity, but it is not known whether beds present in Dorset are also unrepresented in the Vale of Wardour.

This poorly-known part of the succession is considered to have been laid down in relatively deep, quiet water further from the land than were the higher beds. The clay, silt and sand were deposited in the basin to the east and shelly lime mud on the margin but the sedimentology of the derived pebbles is not claimed to be understood (Fig. 98 ).

The second phase was a transition period from terrigenous influenced deposition in the basin to almost pure carbonate shelf deposition. The water depth was initially slightly deeper than that during the deposition of the Wardour Exogyra Beds and the Sandy Limestone Beds contain sponge spicules, clay, c.25% fine quartz sand and up to 5% glauconite which indicates slow accumulation. The proportion of glauconite increases away from the basin margin and current directions have been observed

SUGGESTED ENVIRONMENTAL PICTURES FOR DEPOSITION OF THE PORTLAND GROUP IN THE VALE OF WARDOUR

FIG 98



parallel to and away from the shoreline. The beds contain the same ammonites as the Black Dolomite Beds of Dorset (Glauco-lithites) and are thus correlated, which fits with the "event" stratigraphy. The presence of terrigenous material at this level in the Vale of Wardour indicates that the site of accumulation was nearer to the point where rivers entered the sea, which may be a function of distance from the land.

The main Limestone Beds were formed in shallower water indicated by an absence of clay, a decrease in the quartz sand and glauconite content and an increase in the proportion and grain size of the biochem sand component. The sea level was lowered to such an extent that submarine sand dunes developed in a belt parallel to the shore and currents flowed along this and into deeper water. From this time on, terrigenous material was excluded from the area and carbonate shelf deposits were laid down similar to those of the Portland Limestone Formation of Dorset.

The Dorset model can be employed in the Vale of Wardour to a certain extent and it is suggested that the high energy sands developed on the break of slope between the shelf and the basin - a common setting for marine sand belts according to Ball (1967). Fine biochem sand and lime mud was deposited in quiet deeper water offshore but lime mud also settled in quiet shallow water between the sand body and the shoreline (Fig. 98).

These beds correlate approximately with the Lower Cherty Bed of Dorset; thus the junction between the Wardour Sand Formation and the Wardour Limestone Formation corresponds with that between the Portland Sand Formation and the Portland Limestone Formation in Dorset. The water was shallower in the Vale of Wardour at the end of this second phase which may indicate deposition nearer land. The presence of Eomiodon in the cross-stratified shell sand is thought by Casey (1955) to indicate a slight decrease in salinity. This may have been the case due to the influence of freshwater from the land, but any river-borne sediments must have bypassed this high energy zone.

The third phase was one of virtually pure carbonate deposition. The White Micrite Beds and Chilmark Oolite Beds are similar deposits to the Cherty Micrite Beds and Freestone Beds in the West Area of Dorset. In the Vale of Wardour, lime mud was widespread over the shell-sands of the Main Limestone Beds indicating a change from high to low energy conditions due to a temporary rise in sea-level. The water resumed shallowing and sponges flourished in the deeper water to the east. The decrease in water depth again produced high energy conditions on the break in slope and lime mud accumulated in the sheltered zone behind. This facies change from ooid sand at Chilmark to lime mud at Upper Chicksgrove 2km away is the same as that seen in Dorset over a similar distance between Ringstead Bay and Poxwell. The development of algal limestones and evaporite horizons in the Lower Purbeck Beds above is discussed in part 6 of this chapter but the evidence again indicates land in the west.

The third phase in Dorset includes a minor period of deep water which has not been detected in the Vale of Wardour. It is possible that the third phase here represents only the lower part of that in Dorset and non-marine Purbeck facies spread over the area before they did in Dorset. Bearing in mind that at the top of the second phase in the Vale of Wardour the beds were deposited nearer to the land than those in Dorset, it is probable that after the lower part of the third phase in Dorset, intertidal and supratidal deposits were laid down in the Vale of Wardour. However, it is also possible that the minor deepening within the Dorset third phase is only detectable when facies belts are narrow and in the Vale of Wardour any minor fluctuations in water depth went unrecorded because the facies belts were not crossed. On general consideration it is highly improbable that the change from marine Portland Group facies to non-marine Purbeck facies took place simultaneously at widely separated localities unless they both just happened to be in the same environment at the same time.

## 9. The Portland Group in the Vale of Pewsey, Wiltshire

### A. Introduction

The Vale of Pewsey runs east-west between the chalk uplands of Salisbury Plain and the Marlborough Downs, forming the catchment area for the southward-flowing Wiltshire and Hampshire River Avon. The valley lies along the core of the asymmetrical Tertiary Vale of Pewsey Anticline, at the west end of which Upper Jurassic strata appear beneath unconformable Upper Cretaceous rocks, 4km south of Devizes. This area is the source of the westward-flowing Somerset River Avon.

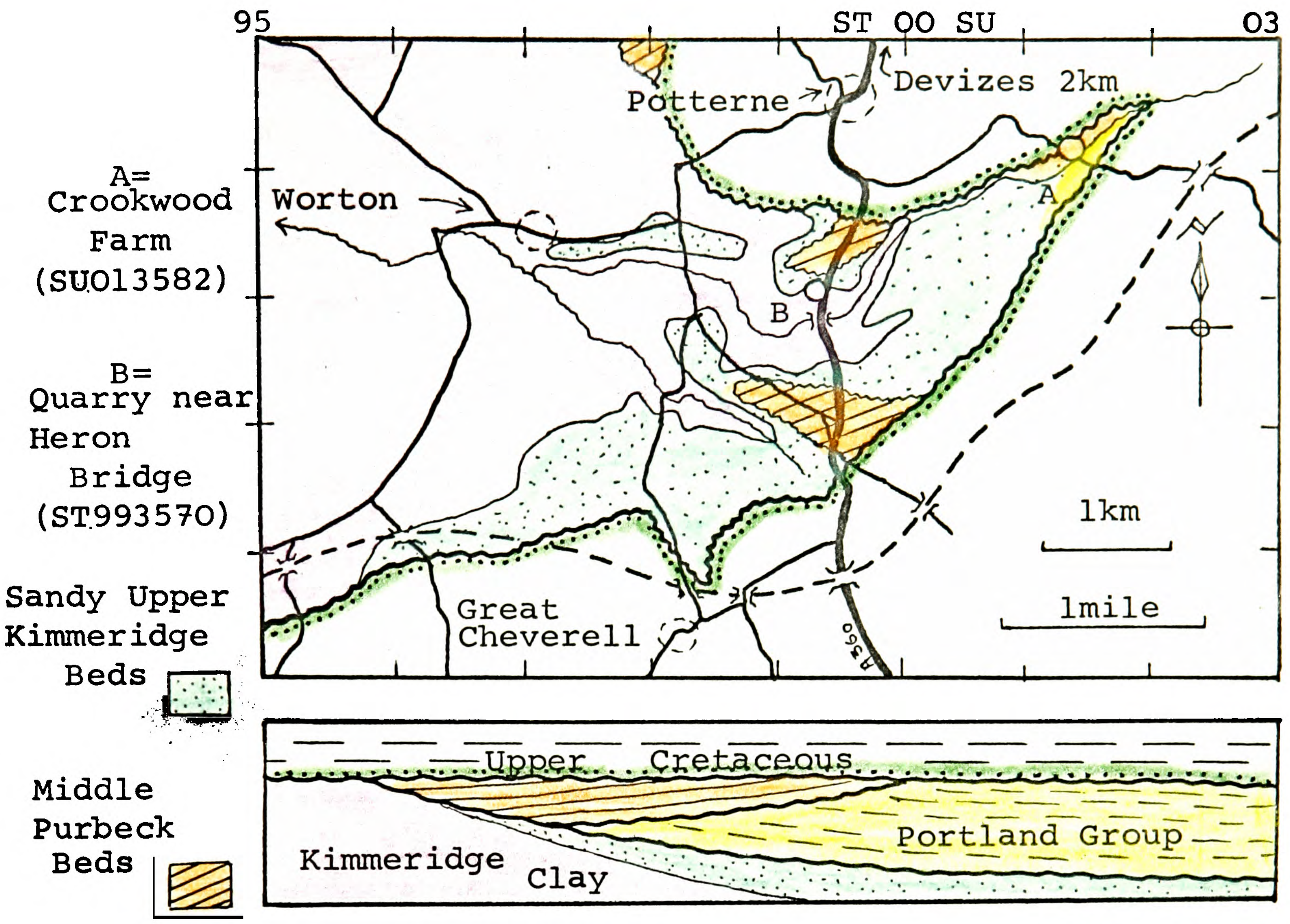
The Gault and Upper Greensand rest on Kimmeridge Clay and on an overlying series of sandy beds which were referred to as Lower Greensand for many years. Fitton (1836) states that the Portland and Wealden strata have not been observed and that the Lower Greensand is "perfectly distinguishable". The first Geological Survey Map of the district was by W.T. Aveline and the results were published in 1857 (old series 1" sheet 14). It was remapped by F.J. Bennett and A.J. Jukes-Browne and the present available edition is a reprint of their map of 1899 (new series 1" sheet 282). This map shows "Portland Beds" outcropping over an area of about 5sq km and overlain in places by "Lower Greensand" which is shown to overstep onto Kimmeridge Clay. Most of this "Portland Beds" outcrop was referred to as the "Portland Sands" but it was long known that there is a sandy development at the top of the Kimmeridge Clay (Blake 1880, Woodward 1895) upon which the Portland Group rests non-sequentially with a basal pebble bed.

In the next chapter it is seen that the Sandy Upper Kimmeridge Beds and basal Portland conglomerate occurs in all the outcrops in the South Midlands, and the Vale of Pewsey succession is probably similar to that at Swindon 30km to the north-north-east. The evidence for the break is summarised by Arkell (1933). A section in the Sandy Upper Kimmeridge Beds near Heron Bridge, about 1km south of Potterne, is summarised in Fig. 99, from the accounts by Woodward (1895) and Jukes-Browne (1905).

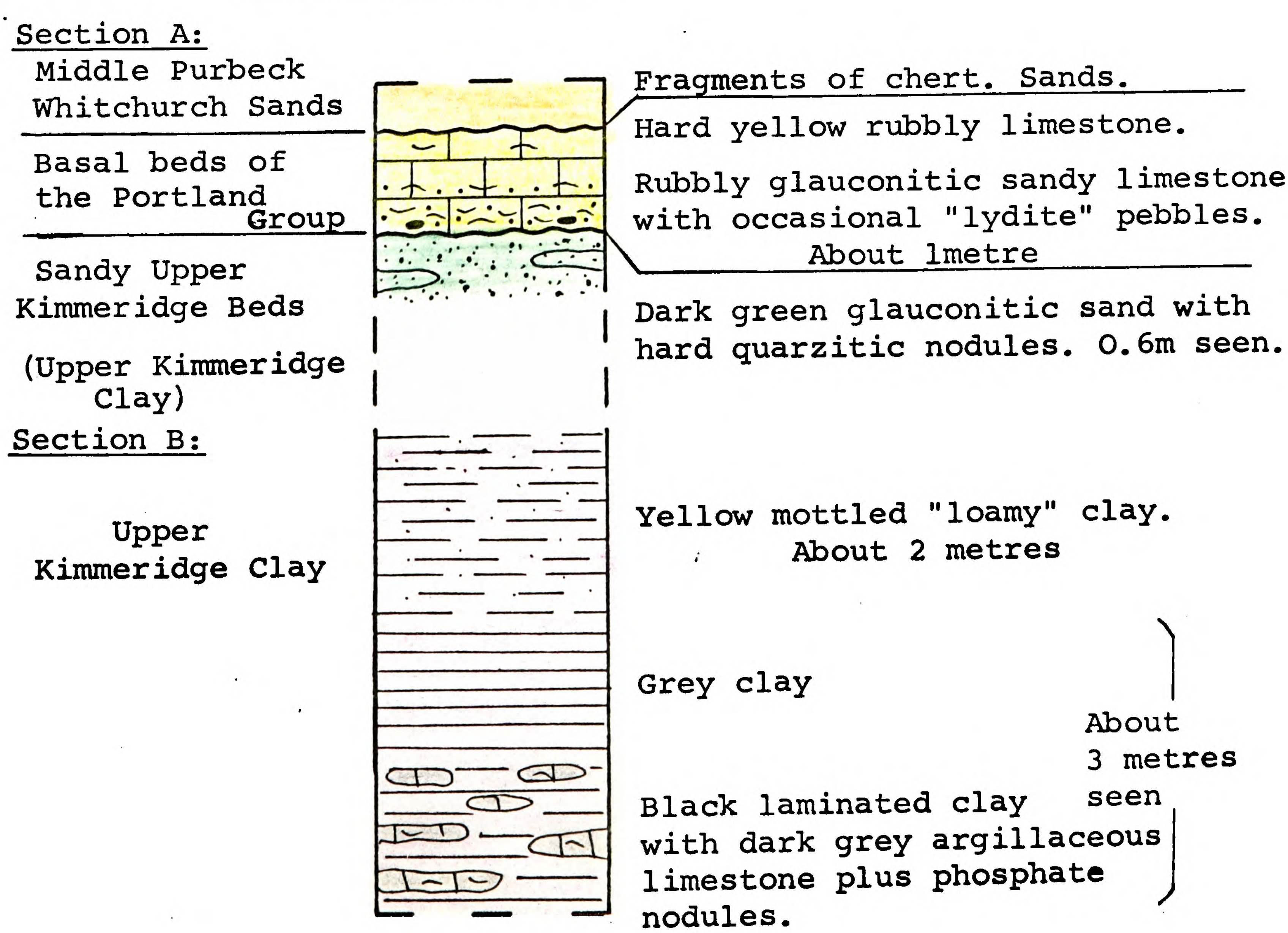
The only section which is undoubtedly in the Portland Group

THE PORTLAND GROUP IN THE VALE OF PEWSEY, WILTSHIRE.

SUMMARY OF KNOWN DETAILS. FIG 99




GEOLOGICAL MAP based on Survey Sheet 282 and Casey & Bristow 1964.



is at Crookwood Farm (Fig 99). This small exposure of glauconitic sandy limestone was considered by Blake (1880), Bell and Bennett (1892), Woodward (1895) and Jukes-Browne (1905) to be "Portland Stone" but Casey and Bristow (1964) have shown that it is the same as the basal part of the Portland Group at Swindon and therefore on the horizon of the upper part of the Portland Sand Formation of Dorset. Thus, only the lowest part of the Portland Group is preserved at this far easterly locality which suggests that the outcrop of the Portland Group in the Vale of Pewsey is extremely limited and scarcely mappable.

Casey and Bristow (1964) have also shown to their satisfaction that the "Lower Greensand" in the area is a south-westerly continuation of the Middle Purbeck Whitchurch Sands of Buckinghamshire.

In summary, the various strata in the Vale of Pewsey are now referred to as follows:-

The "Lower Greensand" equals the Middle Purbeck Whitchurch Sands

The "Portland Stone" is equivalent to part of the Portland Sand Formation of Dorset

The "Portland Sand" is equal to the Sandy Upper Kimmeridge Beds

Each division is separated by an unconformity as depicted in Fig. 99

B. <u>The Portland Group</u>

The outcrop of the "Portland Beds" shown on the Geological Survey map was visited during the summer of 1970 but the only exposure found was that at Crookwood Farm. At this locality only a single specimen of iron-stained glauconitic quartzose micrite was collected. A summary of previous accounts is given in Fig 99 and a faunal list is as follows:-

<u>Camptonectes lamellosus</u> Sowerby
<u>Protocardia dissimilis</u> Sowerby
<u>Laevitrigonia gibbosa</u> Sowerby
<u>Modiolus</u> sp.
<u>Eocallista</u> sp.

*Pleuromya* sp.

*Ostrea* sp.

*Myophorella* sp.

*Serpula* sp.

Rolled Pavlovid fragments

The fauna of the Whitchurch Sand consists of minute gastropods and *Serpula coacervata*.

The fauna of the Upper Kimmeridge Clay nodules is recorded as being

"*Trigonia*"sp.

*Exogyra* sp.

*Thracia* sp.

"*Perna*" sp.

# CHAPTER 6

## THE PORTLAND GROUP IN THE SOUTH MIDLANDS

Swindon: "It is famous for the Quarrie, which is neer the Towne, of the excellent paveing stone, which is not inferior to the Purbec Grubbes, but whiter, and will take a little polish; they send for it to London; it is a white stone; it was not discovered till about thirty yeares agon: and I am now writing in 1672: yet it lies not above 4 or 5 foot deep."

J. Aubrey 1659-91

## 1. Introduction and Nomenclature

The South Midlands Area stretches from Swindon (North Wiltshire) in the south-west, to Wing 80km to the north-east (South-east Buckinghamshire) (Fig. 1 ). For convenience it is divided into the Swindon, Oxford and South Bucks Districts. These widely separated outcrops are grouped together because the successions can be referred to in terms of a single general sequence. The existing bed-nomenclature is varied (over 80 papers have been written in the last 130 years) and in this work local bed names have been rationally adjusted so as to be applicable throughout the Area. The terms are given in Fig. 100.

The "Upper Lydite Bed" of previous authors rests non-sequentially on various facies of the Upper Kimmeridgian strata and has appropriately been called the "basal conglomerate of the Portlands" (Hudleston 1880) (Fig. 101 ). The "Lower Lydite Bed" is a similar horizon which locally occurs some metres below, at the top of the pectinatus Sands (Fig. 101 ). Other such "lyditic" levels exist in the Corallian Beds in the Area (Arkell 1927) and in the Wealden Beds of south-east England (Allen 1960, 1961, 1967). To avoid any confusion with these other horizons and to emphasise the break beneath, the "Upper Lydite Bed" is here referred to as the Basal Pebble Bed of the Portland Group in the South Midland Area.

The term Lower Sandy Beds is used here for the sediments immediately overlying the Basal Pebble Bed because although they are often very glauconitic, some of the higher beds also contain glauconite. The "Cockly Bed" (Arkell 1933) and the "Aylesbury Limestone" (Farey 1815) are local names for what will be called the Lower Limestone Beds. In places a distinct limestone does not exist at this level and the Lower Limestone and Sandy Beds are grouped together.

The "Swindon Sand and Stone" is the same as the "Crendon Sands" (Buckman 1926) and are here called the Upper Sandy Beds. The Upper Limestone Beds refer to the "Creamy Limestones" of Blake (1880), the "Freestones" of the Oxford District, and part of the "Swindon Series" (Keeping 1883), the lower beds of which

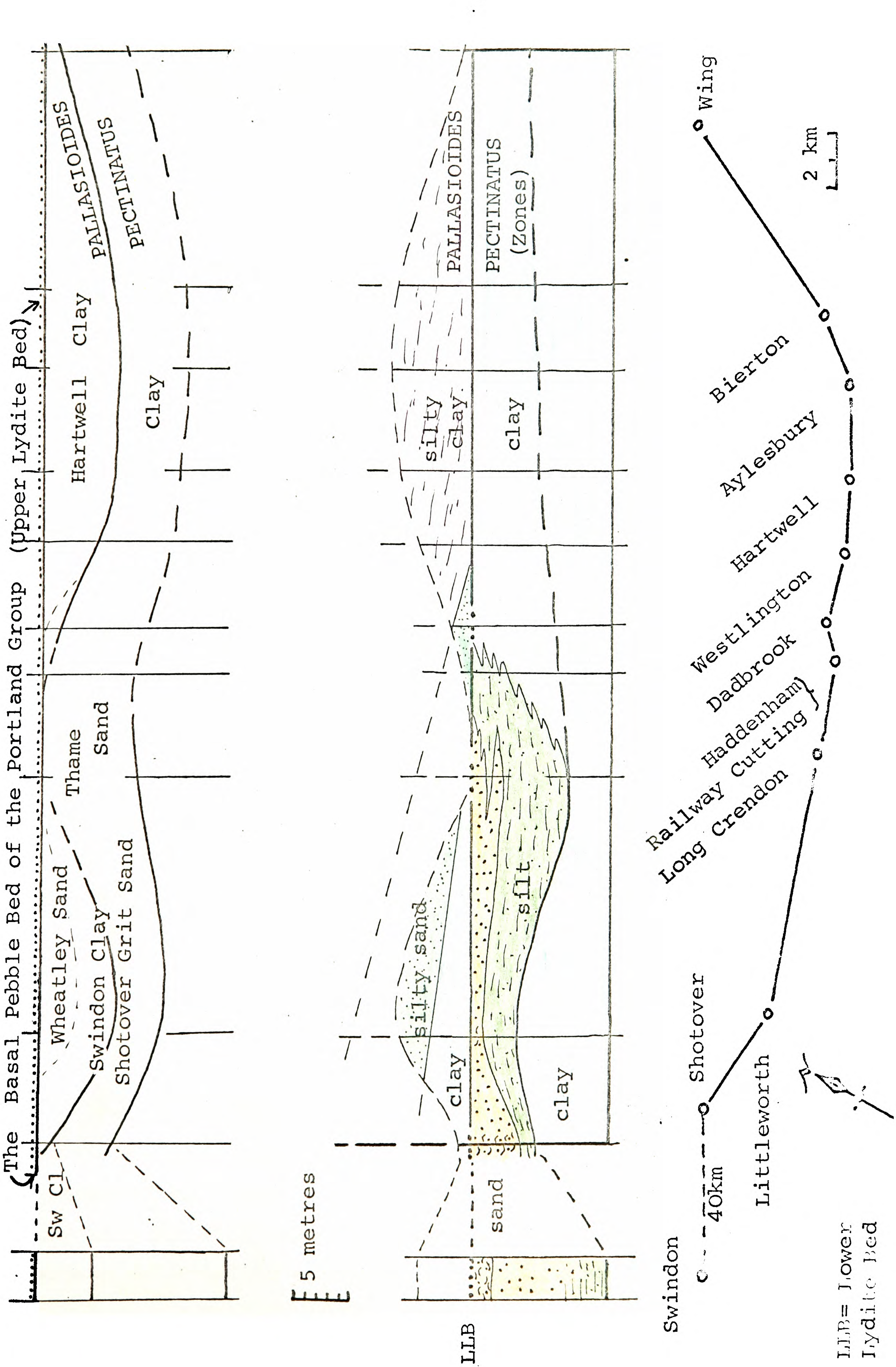
BED NOMENCLATURE OF THE PORTLAND GROUP IN THE SOUTH MIDLANDS AREA

FIG 100

| | Townson 1971 | Summarised in Arkell 1947 | | |
|---|---|---|---|---|
| | SOUTH MIDLANDS AREA | SWINDON DISTRICT | OXFORD DISTRICT | SOUTH BUCKS DISTRICT |
| PORTLAND GROUP | Upper Limestone Beds | Creamy Limestones (Bourton) L. part of Swindon Series (Swindon) | Creamy Limestones (Freestone) | Creamy Limestones |
| PORTLAND GROUP | Upper Sandy Beds | Swindon Sands and Stone | Crendon Sand | Crendon Sand |
| PORTLAND GROUP | Lower Limestone Beds | Cockly Bed | Rubbly Beds | Aylesbury Limestone |
| PORTLAND GROUP | Lower Sandy Beds | Glauconitic Bed | Rubbly Beds | Glauconitic Beds |
| PORTLAND GROUP | Basal Pebble Bed | Upper Lydite Bed | Upper Lydite Bed | Upper Lydite Bed |
| SANDY UPPER KIMMERIDGE BEDS | | | | |

THE UPPER KIMMERIDGE CLAY IN THE SOUTH MIDLANDS AREA
SHOWING THE FACIES OF THE SANDY UPPER KIMMERIDGE BEDS
AND THE FOLDING BEFORE DEPOSITION OF THE PORTLAND GROUP

FIG 101



are included in the Portland Group in this work (see later).

## 2. The Relationship of the Basal Pebble Bed to the Underlying Kimmeridgian Strata

Soon after the South Midlands Area was found to be geologically interesting, controversy and confusion arose concerning the relationships between the sands, silts and clays of the Sandy Upper Kimmeridge Beds (Arkell 1942) at different localities, and the correlation with the thicker successions in Dorset and the Vale of Wardour. For details, the reader is referred to the accounts by Arkell (1933, 1947b). To summarise, it was not at first realised that the Basal Pebble Bed is the unconformable base of the Portland Group and thus the Sandy Upper Kimmeridge in places was called the "Portland Sand". Also, the ammonite sequence was not clearly understood, with the result that the Kimmeridgian *Pavlovia pallasioides* Zone was defined in Buckinghamshire, whereas the other zones were designated in Dorset. The Basal Pebble Bed rests on different facies of different ages in different places making correlation difficult, especially before it was shown that the ammonite zones were in the wrong order (Casey 1967, Cope in Torrens 1969).

The suggested relationships are shown in Fig. 101, where it is seen that *Pectinatus* Zone silts and sands die out to the north-east where they are represented by clays; the Wheatley Sand and Swindon Clay are lateral facies equivalents of the Hartwell Clay; the Kimmeridgian strata were folded prior to the deposition of the Portland Group. (Data for the construction of Fig. 101 was taken from many publications, thirty of which are listed as a separate table on page 226).

## 3. Lithofacies in the South Midlands Area

Due to the poor exposure of the Group throughout the Area the erection of an elaborate quantitative facies classification would not only be difficult but would serve little purpose. The main purpose of detailed schemes, as used in Dorset and the Vale of Wardour, is for detecting slight changes in rock type over closely controlled distances, horizontal or vertical. As the study of the South Midland Area is necessarily a study of widely separated, isolated outcrops in which only part of the sequence can be examined at one time, it is better to use generally qualitative descriptions. In some cases, the rock types have been studied in detail and a facies designation, as used in Dorset and the Vale of Wardour, is also given.

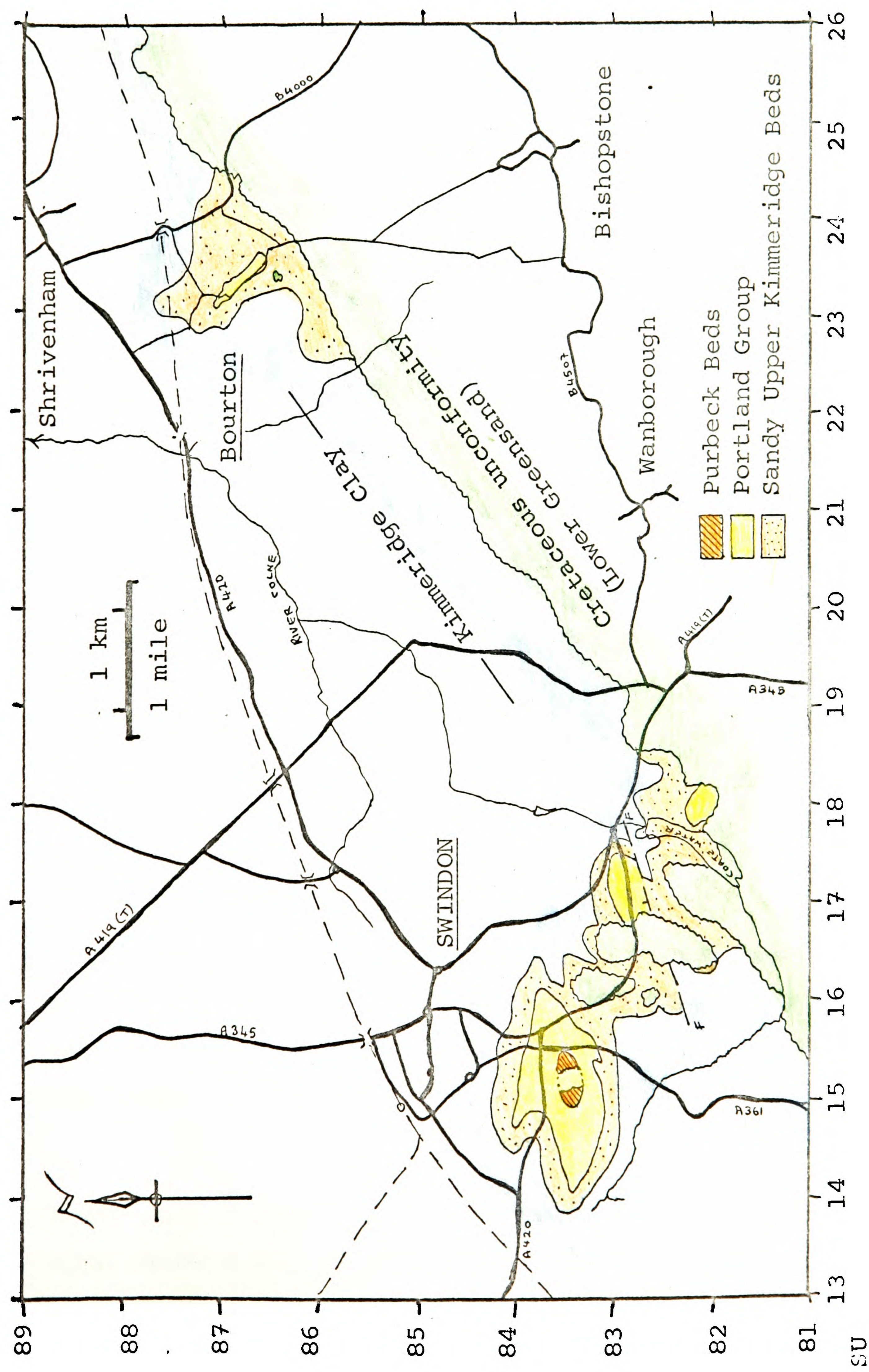
4. <u>The Swindon District</u> (30km N.E. of the Vale of Pewsey)

A. <u>Introduction</u>

The Portland Group is preserved as three small outliers and in one tiny patch which emerges below the overstepping Cretaceous rocks (Fig. 102). The beds have been quarried in the district from about 1640 up to recently; firstly the Purbeck Beds ("Swindon Flags") for roofing and paving, and soon after, limestones and sandstones of the Portland Group for building ("Swindon Stone"). The Geological Survey Map (Old Series 34. Hull 1857) shows the distribution of the beds fairly accurately but the 1932 Revised quarter-inch map inexplicably omits the Portland Group and depicts Purbeck Beds resting directly on the Kimmeridge Clay of Swindon Hill.

The largest outcrop is that forming the hilltop upon which the older parts of Swindon Town were built (SU 1483/1583). The structure was proved to be synclinal when railway cuttings were made (Woodward 1895) and a map by Hall (1911) shows the details as well as the approximate position of the minor outcrops to the south-east. One underlies Coate Road and the other is on the east bank of Coate Water (both in SU 1782). The exact outcrops were mapped by Arkell (1948) who also mapped the fourth outcrop at Bourton, (SU 2386), 8km to the WNW of Swindon (Arkell 1941b). The total area of the Portland Group outcrop in the Swindon District is less than 1.5km and the maximum thickness preserved is approximately 13m. The Kimmeridge Clay is about 150m thick which includes 18m of Sandy Upper Kimmeridge Beds (Fig. 101).

GEOLOGICAL MAP OF THE SWINDON DISTRICT, SOUTH MIDLANDS AREA. Kimmeridge Clay to Cretaceous. From Arkell 1941b & 1948. FIG 102



B. Description of the Beds Figs 103, 104

(i) The Basal Pebble Bed: This is no longer exposed but blocks are common around the village at Bourton. The bed is 0.1-0.2m thick and contains numerous lydite pebbles up to 20mm across, as well as up to 20% coarse lydite and white "vein" quartz sand and granules (Glauconite content is less than 1%). The rock at Bourton has a micrite matrix (Wackestone) and rests on sands of the Sandy Upper Kimmeridge Beds, but at Okus Quarry (SU 145835) it is recorded as having a clay matrix and rests on the Swindon Clay. The composition of lydites varies and they are dealt with in a separate section at the end of this Chapter.

(ii) The Lower Sandy Beds: These beds are not exposed but have been described as sandy limestone about 1m thick with scattered pebbles. The rock is probably micrite with about 25% medium quartz sand. Hall (1911) remarks that the bottom layer is thin bedded and often ripple-marked.

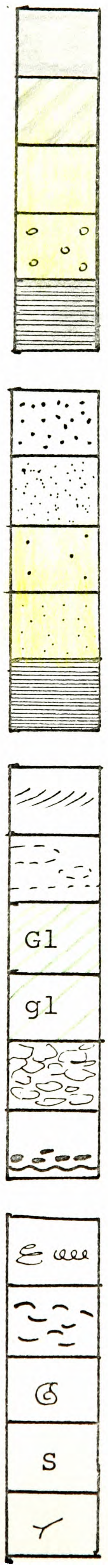
(iii) The Lower Limestone Beds: These are no longer exposed but slabs rich in bivalves and ammonites are to be found in many collections. Hall (1911) describes 1.5m of hard "marly" fossiliferous limestone with abundant ammonites in the lower part and a maximum concentration of bivalves in the middle part. A large slab in the University Museum, Oxford, shows abundant whole valves of Myophorella, Laevitrigonia, Protocardium, Isognomon, Camptonectes, Pleuromya and several Glaucolithites. The sediment is composed of medium-coarse biochem sand, 5-10% quartz sand with virtually no glauconite, all in a lime mud matrix (packstone).

At Bourton, Austen (1850) records 3.5m of limestones with numerous bivalves and with common ammonites and gastropods in the upper part. (Arkell omitted Austen's bed 5 "thick bedded fossiliferous band, 3 feet" when quoting the section in 1933 and 1947.)

(iv) The Upper Sandy Beds: These are best exposed in the north-west corner of Town Gardens Quarry (SU 151835) where approximately 7m

KEY TO SYMBOLS USED ON THE FIGURES OF THE PORTLAND GROUP IN THE SOUTH MIDLANDS AREA. i.e. Figs 104, 108, 109, 110, 111

FIG 103

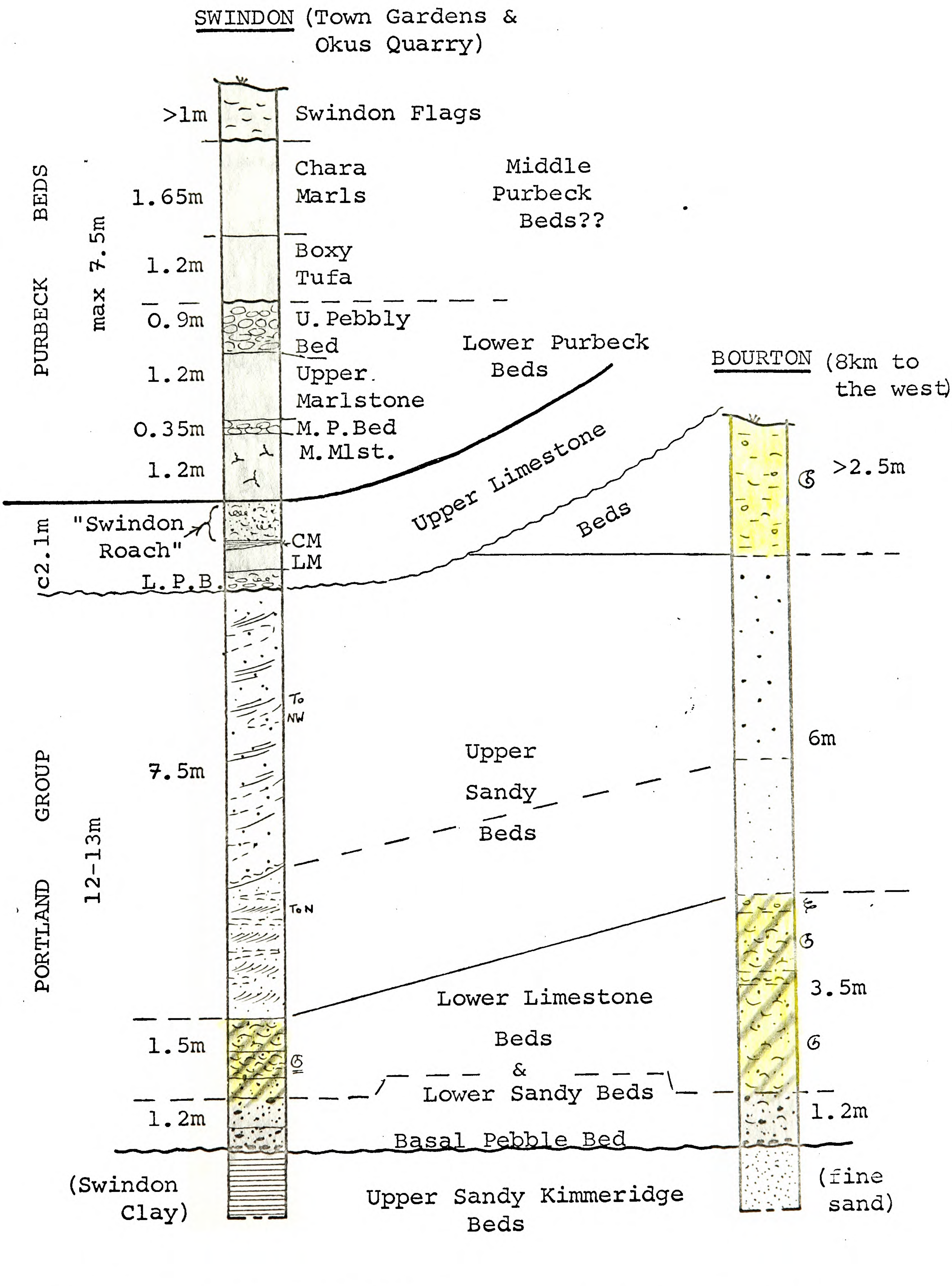



| | |
|---|---|
| LIMESTONES | Lime mudstone and wackestone |
| | Carbonate sand and mud. Packstone |
| | Carbonate sand (biochem). Grainstone |
| | Ooids |
| | Thinly bedded |
| QUARTZ SANDS | Medium to coarse |
| | Very fine to fine |
| SANDY LIMESTONES | 1-10% quartz sand |
| | 10-50% quartz sand |
| | Clay |
| STRUCTURES | Cross stratification |
| | Concretions and cemented horizons |
| GLAUCONITE | Very glauconitic >5% |
| | Glauconitic 1-5% |
| PEBBLE BEDS | Pebble and boulder bed |
| | "Lydite" pebbles Unconformable base |
| FOSSILS | Gastropods (low & high spired) |
| | Bivalves |
| | Ammonite |
| | Serpulids abundant |
| | *Pachastrella* sponge spicules common |

< High energy

THE PORTLAND GROUP IN THE SWINDON DISTRICT, SOUTH MIDLANDS AREA. Data from personal observations and those of authors listed below. FIG 104

For key to symbols see Fig 103




Also From: Austen 1850, Hall 1911, Chatwin & Pringle 1922, Sylvester-Bradley 1940.

Also From: Austen 1850, Ramsey *et al* 1858, Blake 1880.

of the maximum 7.5m is still exposed (Plate 81 ). The Beds can be divided into a lower 2.0-2.5m of well-sorted fine-medium quartz sand with c.10% micritised biochem sand and virtually no glauconite; the upper remainder is composed of well-sorted medium quartz sand with 10-20% biochem sand. Cemented horizons and nodules have a cement of ferroan microspar calcite but the softer beds between have a certain amount of clay matrix. The lower part has horizontally continuous beds with tabular cross-stratification. The beds are on average 0.3m thick and the foresets dip to the north.

The upper part of the Upper Sandy Beds has thicker lenticular beds with scoured bases and foresets dipping to the north-west. At the erosive base of the upper part is a shell bed containing Laevitrigonia valves and fragments (preserved as limonite-stained decomposing aragonite). The bed is approximately 0.1m thick and contains 5% fine quartz sand, 60% medium biochem sand with a clay matrix. The shell fragments fine upwards and at least three successive fining-upward units 0.1m thick are visible. An obvious feature of the Upper Sands is the lack of bioturbation, except for possible vertical tubes in the topmost part. This suggests that the sediment was often mobile and ripped up and dumped by intermittant current action. Apart from the shell bed, fossils are rare and ammonites not recorded.

In a protected remnant of Okus Quarry the lower part is visible and at Coate Water (SU 176822) 2-3m of well-sorted fine quartz sand is seen with cross strata dipping northwards.

The Bourton succession has been described by Austen (1850) and Ramsey (1858) where apparently the Upper Sandy Beds are 6m thick including a lower 2.5m of sandy limestone ("oolitic sands" composed of 5-10% fine quartz, 30% biochems and micrite matrix) and an upper part similar to that at Swindon.

(v) The Upper Limestone Beds: Overlying an erosion surface at the top of the Upper Sandy Beds in Swindon is a succession of limestones which has been the subject for controversy and speculation. Keeping, in the Sedgwick Prize Essay for 1879, called the beds the "Swindon Series" (Keeping 1883).

(vi) **The Swindon Series:** At least twenty-five papers have been written about or mentioning these much disputed rocks. Sylvester-Bradley (1940) gives a bibliography and summary of the previous literature, as well as his own conclusions. Arkell (1940) and Anderson (1940) report their palaeontological findings and the whole subject was then jointly discussed by Arkell and Sylvester-Bradley (1941) but little has been published since. In spite of the numerous papers, the Swindon Series can be described, with reference to the works of only Blake (1880) and Sylvester-Bradley (1940), and discussed with reference to only these plus Keeping (1883), Arkell (1940), Anderson (1940), Arkell and Sylvester-Bradley (1941), West (1961) and Casey and Bristow (1964).

Approximately 9m of limestones, with subordinate argillaceous and arenaceous horizons, unconformably succeed the Upper Sandy Beds but their relationships with the Portland Group and with the Purbeck Beds are not exactly known. Arkell (in Arkell and Sylvester-Bradley 1941) considered the beds to be Middle Purbeck in age, whereas Sylvester-Bradley (same paper) thought they were Lower Purbeck. West (1961) supports the latter after comparison with similar beds in Dorset, and Casey and Bristow (1964) propose that the "Wealden", (Jones 1948, Arkell 1948) above the Swindon Series, is Middle Purbeck in age.

The locality which has been the source of the discussion is Town Gardens Quarry in Swindon (now a park). The sections illustrated by Blake (1880), copied by Sylvester-Bradley (1940) and Arkell (1947), are in a poor condition. Consequently, Blake's original observations of lateral variation have to be relied upon, although a small section in the lower part is still visible in the north-east corner. Arkell (1940) commented that "The interpretation of the data, however, is legitimate sport for all."

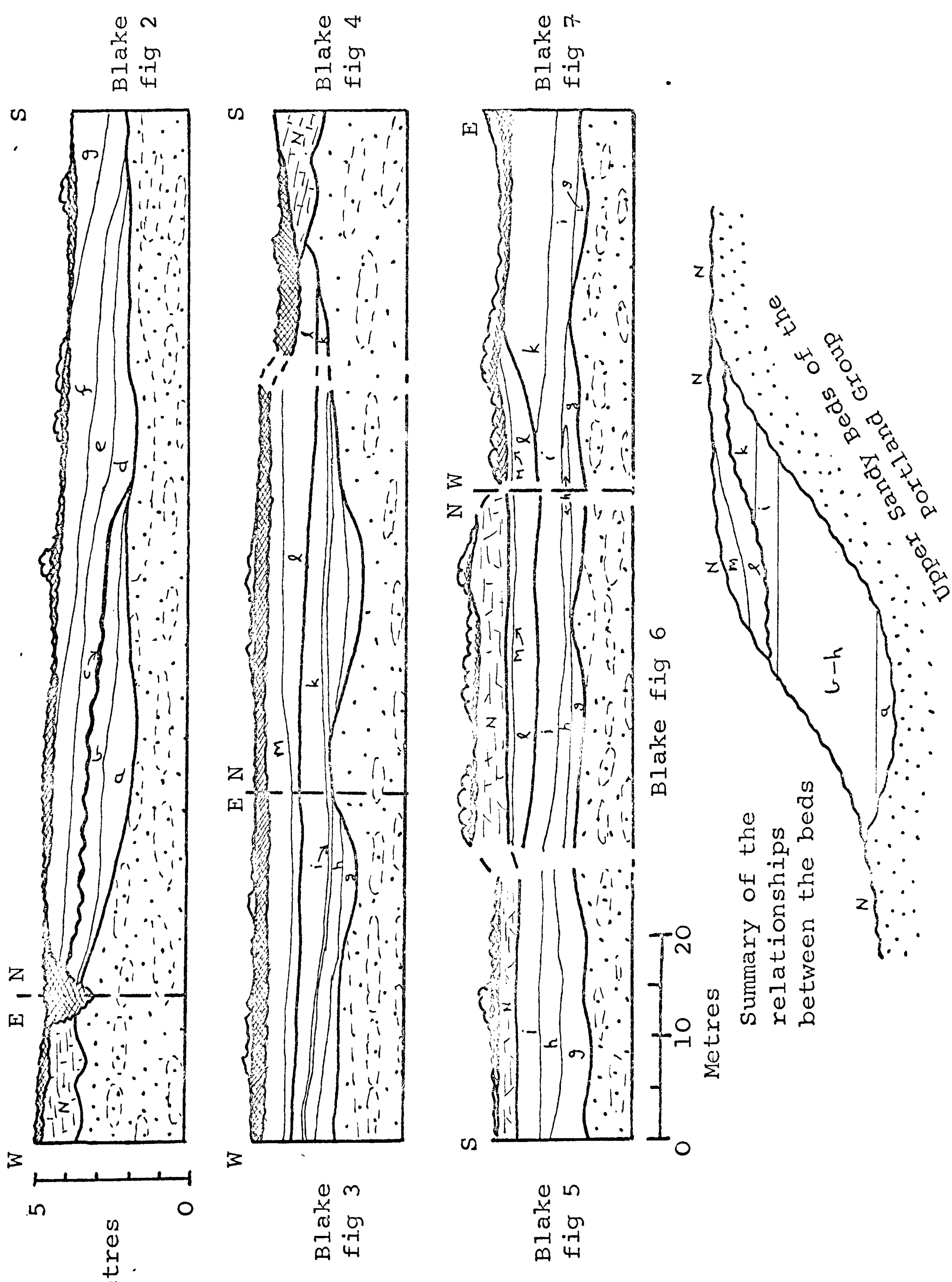
A copy of Blake's original sections is given in Fig.105. In the later copies by Sylvester-Bradley and Arkell figs 4 and 5 were inexplicably omitted. Blake's beds a-N have been named by Sylvester-Bradley and are given in Fig.106 with maximum thicknesses, descriptions from various papers and personal observations.

THE "SWINDON SERIES" AT TOWN GARDENS QUARRY, SWINDON, FROM BLAKE (1880). Purbeck Beds and upper part of the Portland Group. Swindon District, South Midlands Area.

FIG 105

figs 2-4 = Eastern face

figs 5-7 = Western face



NOMENCLATURE OF THE "SWINDON SERIES". TOWN GARDENS QUARRY, SWINDON. With descriptions from own observations and those of various authors (see text).

FIG 106

| Blake's Letters | S-Bradley's Names | Max M thick | Descriptions from various authors, and own observations | |
|---|---|---|---|---|
| N | Swindon Flags | >1 | Laminated calcareous sandstones with marine bivalves | ?Middle Purbeck? |
| M | Chara Marls | 1.65 | "Soft brown, earthy marls. Abundant ostracods and charophytes" | |
| l | Boxy Tufa | 1.2 | Ferrugineous sandy limestones | |
| k / i | Upper Pebbly Beds | 0.9 | "Sand or marl, with small limestone pebbles and freshwater fossils". In places ostracod rich | Lower Purbeck Beds |
| h | Upper Marlstones | 1.2 | "Hard white marlstones or calcareous mudstone with casts of small freshwater gastropods | |
| g | Middle Pebbly Beds | 0.35 | "Sandy marl" with "abundant freshwater fossils" | |
| f / e | Middle Marlstones | 1.2 | Blotchy micrite with shrinkage cracks. Occasional bivalve fragments. No quartz. No obvious ostracods | |
| d | SWINDON ROACH | 0.9 | Quartzose shell lime mud (30% f-m Qtz). Moulds of whole and fragmented aragonitic bivalves. Occasional ostracod valves | Upper Limestone Beds. Portland Gp. |
| c | Cythere Marl | 0.15 | Thin irregular bed of soft calcareous clay with abundant ostracods | |
| b | Lower Marlstones | 0.6 | Lime mud (<1% m Qtz). Scattered moulds of bivalve fragments. Occasional ostracods and gastropods | |
| a | Lower Pebbly Bed | 0.45 | Carbonaceous clayey sand with pebbles fron beds below. Mixture of marine and non-marine fossils | |

Examination of Blake's sections shows the presence of unconformities and overlaps within the Series but the significance of this was not discussed by Sylvester-Bradley. It is apparent from Blake's sections and personal observations that the beds a-k were laid down unconformably on an eroded, undulating, channel-like surface, each bed overlapping the one below and some being discontinuously preserved in pockets at the junction into the Upper Sandy Beds (Fig. 105 figs 2, 3 & 4). Bed l is unconformable on the beds below (figs 6 & 7) and so is Bed N (figs 2, 4, 5 & 6). These facts are schematically summarised in Fig. 105.

Interpretation of this sequence is best understood by reference to the outcrops in the Oxford and Bucks Districts, where the Upper Sandy Beds pass up conformably into the Upper Limestone Beds. These contain an abundant marine molluscan fauna, typical of the higher beds of the Portland Limestone Formation in Dorset; and are overlain conformably by laminated ostracodal limestones which contain a bed of shelly limestone very similar to the "Swindon Roach". In places lenses of shelly limestone occur just above, within laminated ostracodal limestones. It seems very probable that these beds of "Portland Facies" intercalated in "Purbeck Facies" represent marine strandline storm-deposits in an intertidal or supratidal non-marine (hypersaline?) environment in which the ostracodal limestones formed. It seems reasonable to draw the upward boundary of the Portland Group at the top of the highest "Portland Facies limestone", as did Blake (1880) and Keeping (1883), and to relegate the Cythere Marl, Lower Marlstones and Lower Pebbly Bed at Swindon to the Portland Group, instead of being Lower Purbeck Beds as suggested by Sylvester-Bradley (in Arkell & Sylvester-Bradley 1941).

The succession at Bourton, only 8km to the ENE, consists of at least 2.5m of Upper Limestones with ammonites and bivalves conformably overlying the Upper Sandy Beds (Fig. 104). It is suggested that these may also have been deposited at Swindon and subsequently eroded, perhaps by an intertidal channel. The Lower Pebbly Bed (Blake a) represents the net result of erosion and subsequent deposition. The gastropod Aptxyiella portlandica, which typifies postulated strandline deposits in Dorset, occurs in the topmost shell bed in the Oxford and Bucks Districts and in the Lower Pebbly Bed at Swindon. The fauna is described by Arkell (1940) who found only marine bivalves and many gastropods, of which 75% were marine. He concluded that the bed contained no autochthonous fossils and may have formed in "a clear shallow sea near land and not far from the mouth of a stream draining out of marshes". The Lower Marlstones and Cythere Marls represent a quiet-water deposit in a non-marine environment and the Swindon Roach represents a final accumulation of marine fauna (including Aptyxiella), perhaps due to slight subsidence which let normal-marine water into the channel, or due to a gentle rise in sea-level following the erosion.

The succeeding beds e-k are conformable but contain a non-marine fauna and shrinkage cracks indicative of a supratidal environment. The pebble horizons are related to the overstep onto the Upper Sandy Beds as the erosion surface was filled. These beds are referred to here as being Lower Purbeck in age.

The comments of the nineteenth century workers summarise the origin of the Swindon Series in a satisfactorily succinct fashion as follows:

Hudleston (1876) " 'Purbeck' and 'Portland' conditions inosculated at this spot."

Keeping (1883) "What we have here is the record of the gradually diminishing but oscillating stages of the latest Jurassic sea."

The exact time correlation of this marginal deposition with the sequence in Dorset will be discussed in the overall synthesis in Chapter 9 .

Speculation: Although not part of this study, it is suggested that beds l-n may represent the Middle Purbeck Beds. The facies is similar to that in the Vale of Wardour (Andrews and Jukes-Browne 1894) and in the Bucks District (Casey and Bristow 1964). The latter authors suggest that the "Wealden" which overlies the Swindon Flags is the same as the Whitchurch Sands-Cinder Bed horizon.

C. Macro-faunas recorded from the Swindon District:

Note: It is not always known whether recorded species are common when the bed is no longer exposed.

Upper Limestone Beds (Swindon)

Swindon Roach: *Laevitrigonia gibbosa* Sowerby
*Protocardium dissimile* Sowerby
*Pleuromya uniformis* Sowerby
*Eomiodon cuneatus* Sowerby
*Corbula saltens* Blake
*Lucina* sp.
*Eocallista* sp.?
*Aptxyiella portlandica* Sowerby
*Ampullospira ceres* de Loriel
*Ampullospira incisa* Blake
+ other small gastropods

Cythere Marl: Ostracods, foraminifera, fish.

Lower Marlstone: *Valvata* sp.
*Viviparis* sp.

Lower Pebbly Bed:

Common: *Coelodiscus swindonensis* Brösolmlen
*Neritoma sinuosa* Sowerby
*Valvata sabandiensis* Maillord
*Aptyxiella portlandica* Sowerby

*Acteonina hypermeces* Cossmann
*Ceritella lorteti* de Loriol
*Nucula lorioli* Cox
*Lucina portlandica* Cox
*Eocallista pulchella* de Loriol

Less Common:
*Delphinula portlandensis* Cox
*Delphinula boloniensis* Arkell
*Delphinula aff. vivauxea* Buvignier
*Neridomus minimus* Credner
*Viviparis* sp.
*Valvata helicoides* de Loriol

Hydrobia chopardiana de Loriol
Ampullospira ceres de Loriol
Procerithium leblanchi de Loriol
Procerithium bradleyi Arkell
Nerineopsis pseudoexcavata de Loriol
Physa bristovii Phillips

Upper Limestone Beds (Bourton)

"Trigonia" Various ammonites

Upper Sandy Beds

Pleuromya sp. Agassiz
Protocardium dissimile Sowerby
Laevitrigonia gibbosa Sowerby
"Mytilus" pallidus Sowerby
Ostrea sp.

Lower Limestone Beds

Common:

Laevitrigonia gibbosa Sowerby
Myophorella incurva Bennett
Protocardium dissimile Sowerby
Pleuromya tellina Voltz
Isognomon bouchardi Oppal
Camptonectes lamellosus Sowerby

Less Common:

Plegiostoma ornata Buvignier
Plagiostoma rustica Sowerby
Falcimytilus suprajurensis Cox
"Mytilus" boloniensis de Loriol
Quenstedia portlandica Cox
Pseudotrapezium Swindonense Cox
Barbatia Cavata de Loriol
Ostrea "blakei" Cox
Nucleolites sp.
Corbicellopsis uniodes de Loriol
Corbula dammariensis Buvignier
Cyprina elongata Blake
Cypricordia costifera Blake

Eocallista pulchella de Loriol

Pleurotomaria rugata Bennett

Natica elegans Sowerby

~~Echinobrissus brodei Wright~~

Various ammonites including Glaucolithites sp.

Lower Sandy Beds and Basal Pebble Bed

Only "Mytilus" boloniensis de Loriol recorded

Papers Used in Preparation of FiG. 101

Phillips 1860

Hudleston 1880, 1892

Blake 1893

Woodward 1895

Davies 1899, 1904, 1934

Healey 1904

Douglas, in Monkton & Herres 1910

Hall 1911

Salfeld 1913

Neaverson 1921, 1924, 1925

Sherlock, in Chatwin & Pringle 1922

Buckman 1922, 1926

Pringle 1926a, 1926b

Kitchin 1926

Spath 1931

Arkell 1933, 1942, 1947b

Ballance 1960, 1963

Bristow 1963

Casey 1967

Cope, in Torrens 1969

5. The Oxford District (c.40km NE of the Swindon District)

A. Introduction Fig. 1, 107

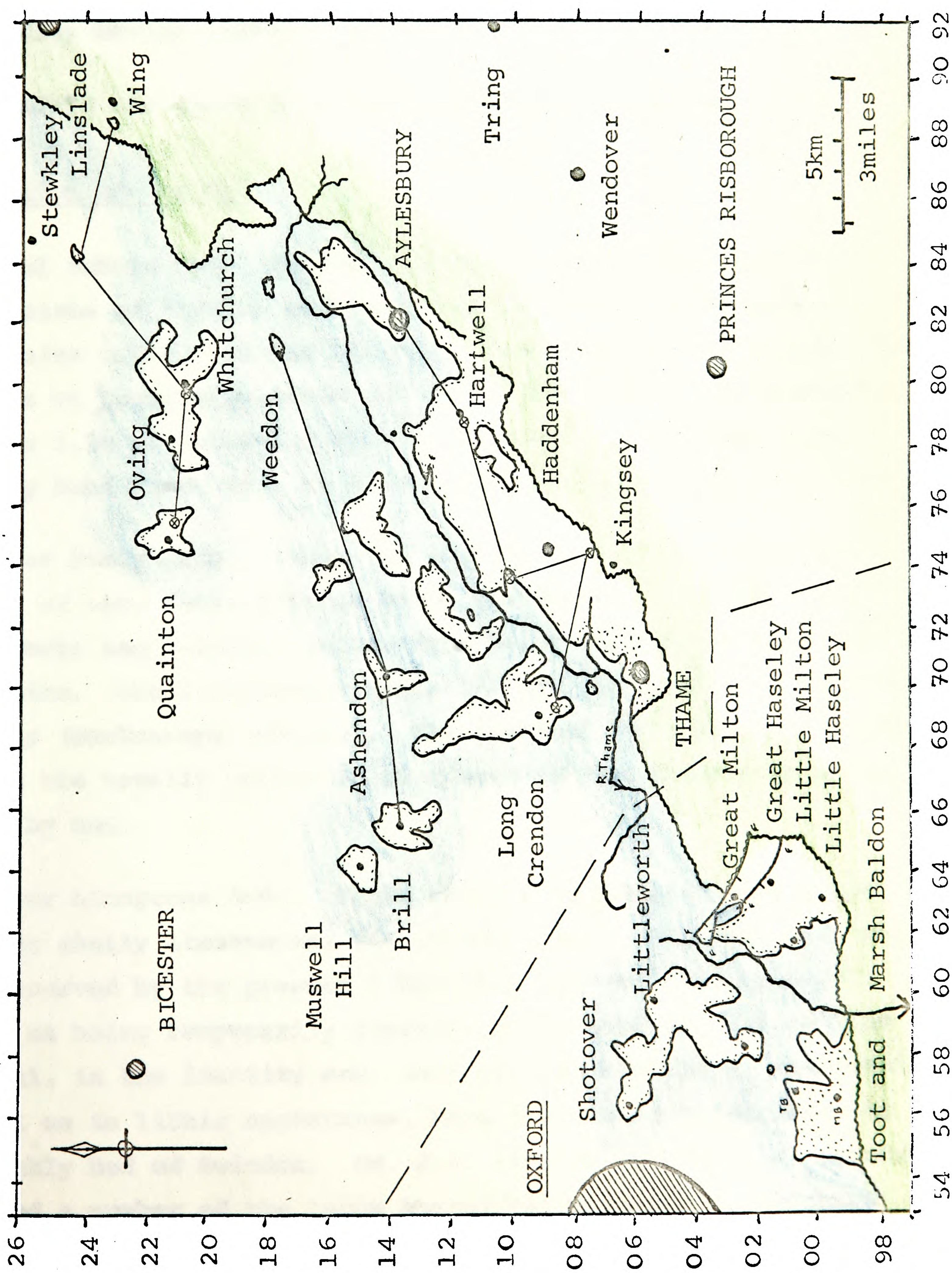
Rocks of the Portland Group exist in at least two outliers in the Oxford District. The region was first mapped by Hull (Hull & Whitaker 1861) although descriptions of several exposures had already been published by Fitton (1836) and Phillips (1860). The main outliers from Shotover to Garsington (SP 5606–SP 5802) and in the area of Great and Little Milton and Haseley (SP 6203-SP 6400) were remapped by Arkell (1942, 1944). The previous map showed Upper Kimmeridgian Sands as "Portland Sand" and it is in this district that Arkell first used the term Sandy Upper Kimmeridge for all the beds from the pectinatus-Zone upwards to the Basal Pebble Bed of the Portland Group - a thickness of approximately 12m, of the total 30m for the Kimmeridge Clay.

Some maps show "Portland Sand" in the area between Nuneham Courtenay and Marsh Baldon (SU 5599–SU 5799). As the area has not been remapped it is not known whether any Portland Group overlies the Sandy Upper Kimmeridge Beds in this third possible outlier but Phillips (1860) records lydite pebbles and ammonites which suggest that at least the Basal Pebble Bed is present.

The complete sequence of the Portland Group in the Oxford District is 12-13m thick but it is preserved only in the Milton-Haseley outlier. To the north, the upper part of the succession was eroded and unconformably overlain by the "Shotover Ironsands" which have been called "Wealden" but as suggested by Casey & Bristow (1964) they may be, in part, of Middle Purbeck age. Some authors have called the topmost part of the Upper Limestone Beds, Lower Purbeck, but it is considered here to be all Portland Group.

The only permanent exposure of the Portland Group is at Littleworth Brickpit, Wheatley (SP 596055) where the Basal Pebble Bed and parts of the Lower and Upper Sands are visible above the Sandy Upper Kimmeridge Beds (Fig. 108, Plate 82). Temporary exposures have been examined by the author at many localities enabling most of the succession to be sampled. A general section

GEOLOGICAL MAP OF THE OXFORD DISTRICT AND THE SOUTH BUCKINGHAMSHIRE DISTRICT, SOUTH MIDLANDS AREA. Sandy Upper Kimmeridge Beds to the Cretaceous unconformity (indicated by the base of the Upper Greensand and Gault Clay.) FIG 107



for the Oxford District is given in Fig.108, synthesised from the accounts of several people, plus personal observations. Works referred to are:

| | |
|---|---|
| Fitton 1836 | Pocock 1908 |
| Phillips 1860 | Pringle 1926a & b |
| Hull & Whitaker 1861 | Sollas 1926 |
| Blake 1880 | Arkell 1933, 1942, 1944, 1947 |
| Woodward 1895 | McKerrow 1958 |
| Morley Davies 1899 | |

Faunal lists are given in a table after the following.

B. Description of the Beds

(i) The Basal Pebble Bed: This varies in thickness from 0.05-0.15m and consists of "lydite pebbles" inaa calcareous clay matrix (glauconite c.5%). In the Haseley-Milton outlier and at Garsington it rests on pectinatus-sands but to the north-west at Shotover it rests on 1.2m of Swindon Clay. At Littleworth it overlies 3.6m of Wheatley Sand which rest on 3.6m of Swindon Clay (Fig.101, Plate 82).

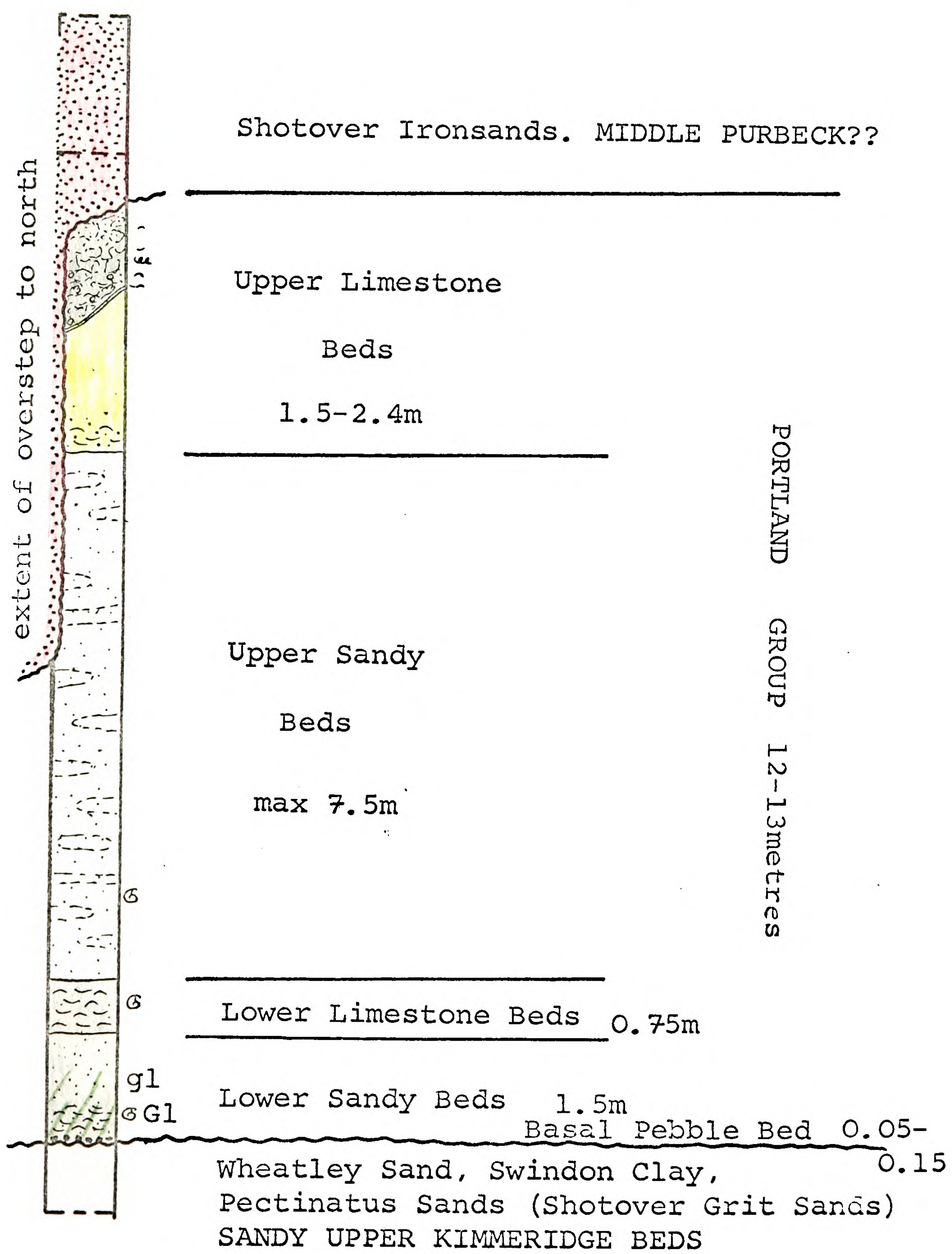
(ii) The Lower Sandy Beds: These are approximately 1.5m thick and consist of very fossiliferous sandy glauconitic micrite. The v.f. quartz sand content varies from 5-20% with about 1% f.-m. glauconite. Shell fragments reach 10% and the matrix is lime mud and clay (wackestone texture). The infaunal and epifaunal molluscan fossils are usually preserved as closed valves suggesting rapid burial by mud.

(iii) The Lower Limestone Beds: These are partly argillaceous white micritic shelly limestones, only 0.75m thick. The beds have not been observed by the present author but are recorded by Arkell (1933) as being temporarily exposed on Shotover Hill where "The material, in the identity and state of preservation of the fossils as well as in lithic appearance, bore a striking resemblance to the Cockly Bed of Swindon. Dr. J.A. Douglas and Mr. C.J. Bayzand obtained a number of the large ammonites comparable with those from the Cockly Bed, and it is hoped that a publication will soon

GENERALISED SECTION IN THE PORTLAND GROUP OF THE OXFORD DISTRICT FROM PERSONAL OBSERVATIONS AND THOSE OF AUTHORS LISTED IN THE TEXT

FIG 108

For key to symbols see Fig 103



appear on the subject." It never did.

(iv) The Upper Sandy Beds: A maximum of 7.5m has been recorded in the Milton-Haseley outlier (Arkell 1944) but due to the "Wealden" overstep only 4.5m are now preserved at Shotover. The Beds consist of soft, yellow, calcareous, argillaceous glauconitic fine quartz sand, with hard calcite-cemented concretionary nodules and continuous bands. The latter consist of grain-supported v.f. well-sorted angular quartz sand with about 1% v.f. glauconite and a cement of ferroan calcite microspar. Occasionally v.f.-f. sand grade calcitic bivalve fragments occur. A temporary exposure near Little Milton (SP 623005) showed 5-6m of these Beds but the only sedimentary structures visible were one or two lenses, about 1m across, of shell fragments less than 10mm in size.

The Upper Sandy Beds in the Oxford District are essentially the same facies as they are at Swindon but slightly finer grained, less calcareous and more argillaceous. Faunal preservation potential is low but the Beds are by no means unfossiliferous. Bivalves were found at the above temporary exposure and ammonites have been recorded and personally found at Littleworth, albeit in a poor state.

(v) The Upper Limestone Beds: Unfortunately these are no longer permanently exposed, but some specimens have been obtained from small temporary exposures in the Milton-Haseley outlier and as loose blocks in overgrown quarries.

From the literature (see previous list) it would appear that there is a lower 1.5-2.4m of sandy shelly limestone which passes down into glauconitic sandy "oolitic" limestone with a basal shell bed. The variation in thickness seems to be due to erosion of the top part, for overlying this is 0.15m of clay with shell fragments and then a thinly-bedded, hard, cemented conglomeratic bed 1.2-1.5m thick. The latter contains, from the bottom upwards, tufaceous, ostracodal, oolitic algal micrite clasts in a matrix of fine "oolite" with "lyditic grit" containing gastropods, _Aptxyiella_, "_Mytilus_" and _Modiolus_; this is followed by clasts of oolitic gastropod-rich limestone with "_Mytilus_"; overlain by clasts of argillaceous micrite and silicified wood with non-marine gastropods; capped by clasts of cherty glauconitic sandy limestone with Ostrea and Isognomon. The top of the bed is an erosion surface upon which the Shotover Ironsands rest.

A study of 8 thin-sections from different levels and localities in the Upper limestones revealed the following rock types (Folk classification):-

(a) Moderately well-sorted, medium - coarse sand grade quartzose (30%) biointrasparite, <1% glauconite. Lowest part of the Beds?

(b) Medium - coarse oobiosparite with Pachastrella spicules in places, <1% quartz, <1% glauconite. Higher part?

(c) Poorly sorted medium - coarse intrasparite with <1-2% quartz sand and intraclasts of micrite, biomicrite and quartzose micrite.

(d) Moderately well-sorted very fine to fine sand grade biointra-sparite with c.1% v.f.-f. quartz.

Thus, although the exact location of these rock-types in the succession is unknown, it is seen that the sediments were laid down under higher energy conditions than those below or the same horizon in the S. Bucks District (based on the mud-free grain-supported texture, and the presence of intraclasts and ooids). The presence of clasts of gastropod and ostracod bearing algal micrite and silicified wood, with Aptxiella in the matrix, suggests erosion of the facies found at the junction between the Portland Group and the Basal Purbeck Beds elsewhere. It seems likely that similar conditions to those at Swindon also existed in the Oxford District towards the end of deposition of the Portland Group.

C. Macrofauna recorded from the Oxford District

Upper Limestone Beds

Laevitrigonia gibbosa Sowerby
Protocardium dissimile Sowerby
Camptonectes lamellosus Sowerby
Plagiostoma rustica Sowerby
Ostrea expansa Sowerby
Lucina portlandica Cox

Aptyxiella sp.

Natica elegans Sowerby

Ampullospira ceres de Loriol

Isognomon sp.

Pleuromya sp.

Modiolus sp.

"Mytilus" sp.

Non-marine gastropods.

Ostracods

Upper Sandy Beds

Laevitrigonia gibbosa Sowerby

Protocardium dissimile Sowerby

Falcimytilus suprajurensis Cox

Isognomon bouchardi Oppel

Lucina portlandica Cox

Ampullospira ceres de Loriol

Serpula sp.

Glaucolithites sp.?

Lower Limestone Beds

Not known but according to Arkell (1933), it is the same as at Swindon (see page 225).

Lower Sandy Beds

Plagiostoma rustica Sowerby

Ostrea expansa Sowerby

Camptonectes lamellosus Sowerby

Isognomon bouchardi Oppel

Protocardium dissimile Sowerby

Falcimytilus suprajurensis Cox

Pholadomya sp.

Pleuromya sp.

Pleurotomaria rugata Bennett

Glaucolithites gorei

Basal Pebble Bed

This very thin horizon is intimately associated with the above and no separate list is given.

## 6. The South Buckinghamshire District (Fig. 107)

### A. Introduction

The Portland Group emerges from under the Cretaceous unconformity in a belt from Thame (SP 7005), just in Oxfordshire, to Bierton (SP 8417) near Aylesbury - a distance of 20km. There are also several outliers to the north and west of the main outcrop, extending the District as far as from Muswell Hill (SP 6415) to Stewkley (SP 8524), 23km to the ENE. (Fig. 107). Sections of the beds are given along the main outcrop and across the outliers from Brill (SP 6514) to Weedon (SP 8118), and from Quainton (SP 7521) to Wing (SP 8722), giving for the first time in this study a picture of the Portland Group in more than two dimensions, over a wide region. Although the area of the Portland Group outcrop is greater than elsewhere in England (approximately 50sq. km) the beds are at their thinnest. The successions can all be referred to in terms of a standard sequence composed of alternations of sandy beds and limestones, with local variations in thickness. The total thickness is found to be approximately proportional to the amount of quartz sand. Thus, thinner successions have a higher limestone to quartz sand ratio than thicker ones. This suggests that the areas with the lower total thicknesses did not receive so much terrigenous sediment, perhaps because they were further from the source, or, more likely, they were in an area of slower rate of subsidence (a "bypass area").

The Southern Belt. Long Crendon to Aylesbury (SP 6908-SP 8213):

Numerous small sections have been described over the years from 1836 (Fitton) to 1966 (Barker), of these, however, only three reliably complete successions have been recorded, and only two partial sections exposed more than half the beds. Previous figures showing sections from south-west to north-east have been given by Davies (1899) and Ballance (1963). The former gives sections at Long Crendon and Haddenham (SP7310) which he synthesised from various exposures and a section at Stone and Hartwell (SP 7912) from Woodward (1895). Ballance gives a section at Long Crendon based on that by Fitton (1836) and one for Haddenham Railway Cutting as described by Davies (1904) (SP 7308). This section was never well exposed and in view of thicker successions to the NE and SE it is thought that the thicknesses given are too little. Ballance gives a section at Hartwell (Bugle Pit), from Hudleston (1880, 1887) and criticised Davies (1899) for giving Woodward's "general section at Aylesbury" for this locality. Ballance mapped the area (1960, 1963) and found that the total thickness of the Portland Group at Hartwell is less than given by Woodward. He then gives Woodward's section as being representative of Aylesbury, 1-2km to the NE, where the lower part of the succession is undoubtedly thicker. However, it is obvious that the upper part of Woodward's "general section" describes the Bugle Pit and should not have been duplicated by Ballance as representing a complete succession at Aylesbury.

The sections given in this work (Fig. 109) are at:

(a) Long Crendon. Fitton (1836), Woodward (1895), Davies (1899) and own observations.

(b) North of Haddenham. Davies (1899).

(c) Haddenham and Kingsey Sewage Works (SP 7407). Temporary exposure in 1968-9. Own observations.

(d) Hartwell: Hudleston (1880, 1887) Woodward (1895), Ballance (1963) Barker (1966).

(e) Aylesbury. Woodward (1895), Pringle & Chatwin (in Sherlock 1922).

The outliers: Although the main outcrop was recently remapped by Ballance, published maps of the outliers show Sandy Upper Kimmeridge Beds as "Portland Sand". Numerous small exposures have been recorded but no complete successions were seen in the course of this study (1968-1971). Samples from isolated exposures, combined with previous descriptions have had to suffice; nevertheless a tolerably complete idea of the composition of the Portland Group in this District, its far north-eastern appearance in this country, has resulted.

The sections given in Fig. 110 are at:

(a) Brill. Mitchell (1834), Fitton (1836), Woodward (1895)

(b) Ashendon (SP 7014). Whitaker (in Green 1864).

(c) Weedon. (SP 8118). Bristow (1963).

The sections given in Fig. 111 are at:

(a) Quainton. Mitchell (1834), Fitton (1836), Davies (1899), Bristow (1963).

(b) Oving-Whitchurch (SP 8021). Bristow & Kirkaldy (1962), Bristow (1963), Barker (1966).

(c) Stewkley (Warren Farm). Fitton (1836), Davies (1915), Woodland (1943), Bristow (1963), Barker (1966).

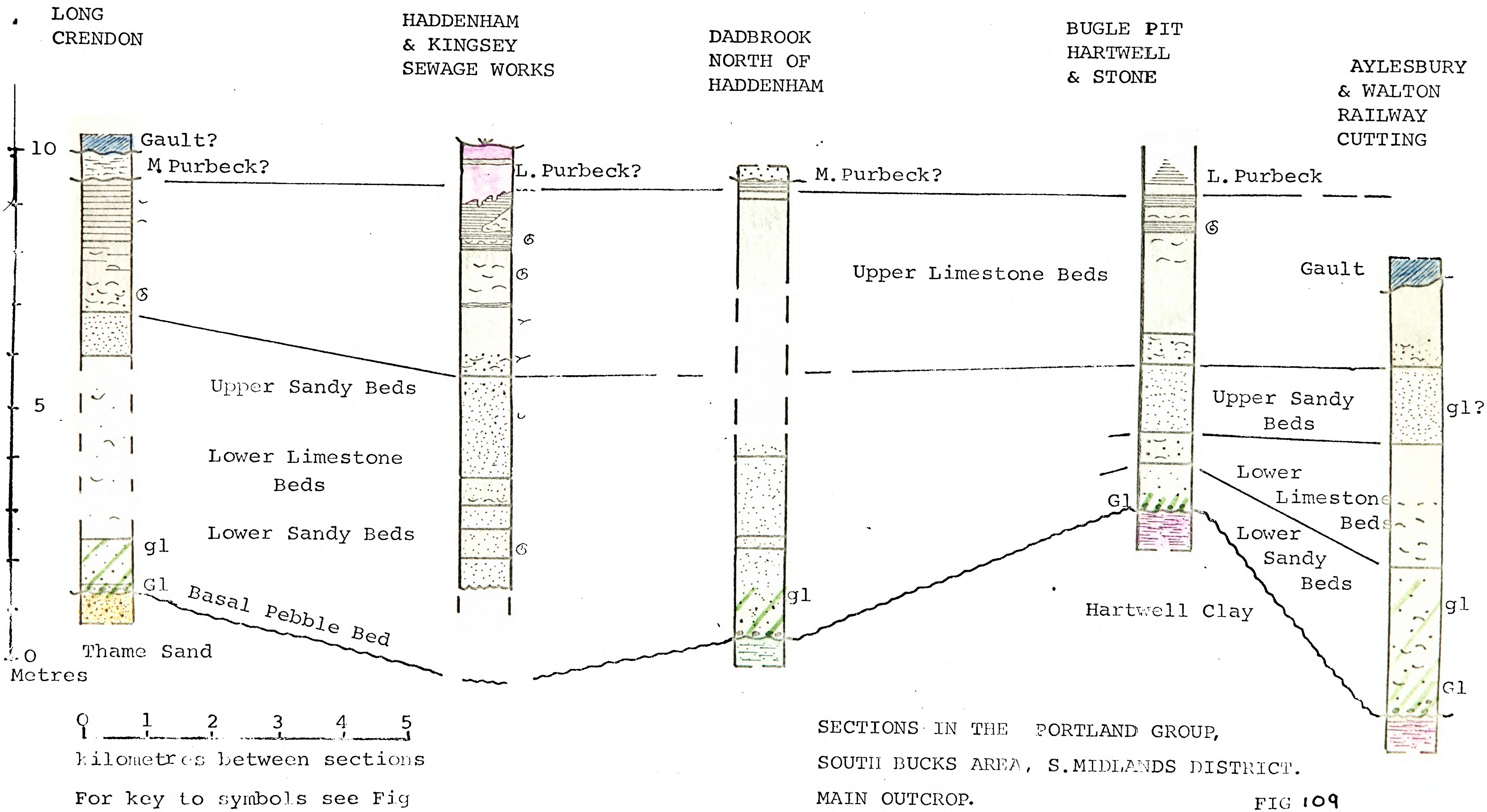
(d) Wing. Bristow (1963).

B. Description of the Beds

(i) Basal Pebble Bed: This is exposed in many small scrapings throughout the area and forms a useful mapping horizon. The bed varies from 0.1-0.3m thick consisting of "lydite" pebbles in a matrix of calcareous glauconitic sand or soft sandy glauconitic limestone. The best expesure is in the railway cutting near Chearsley (SP 713103) where phosphatised pavlovid fragments are common. (See section on the Basal Pebble Bed and "Lydites" at the end of this chapter).

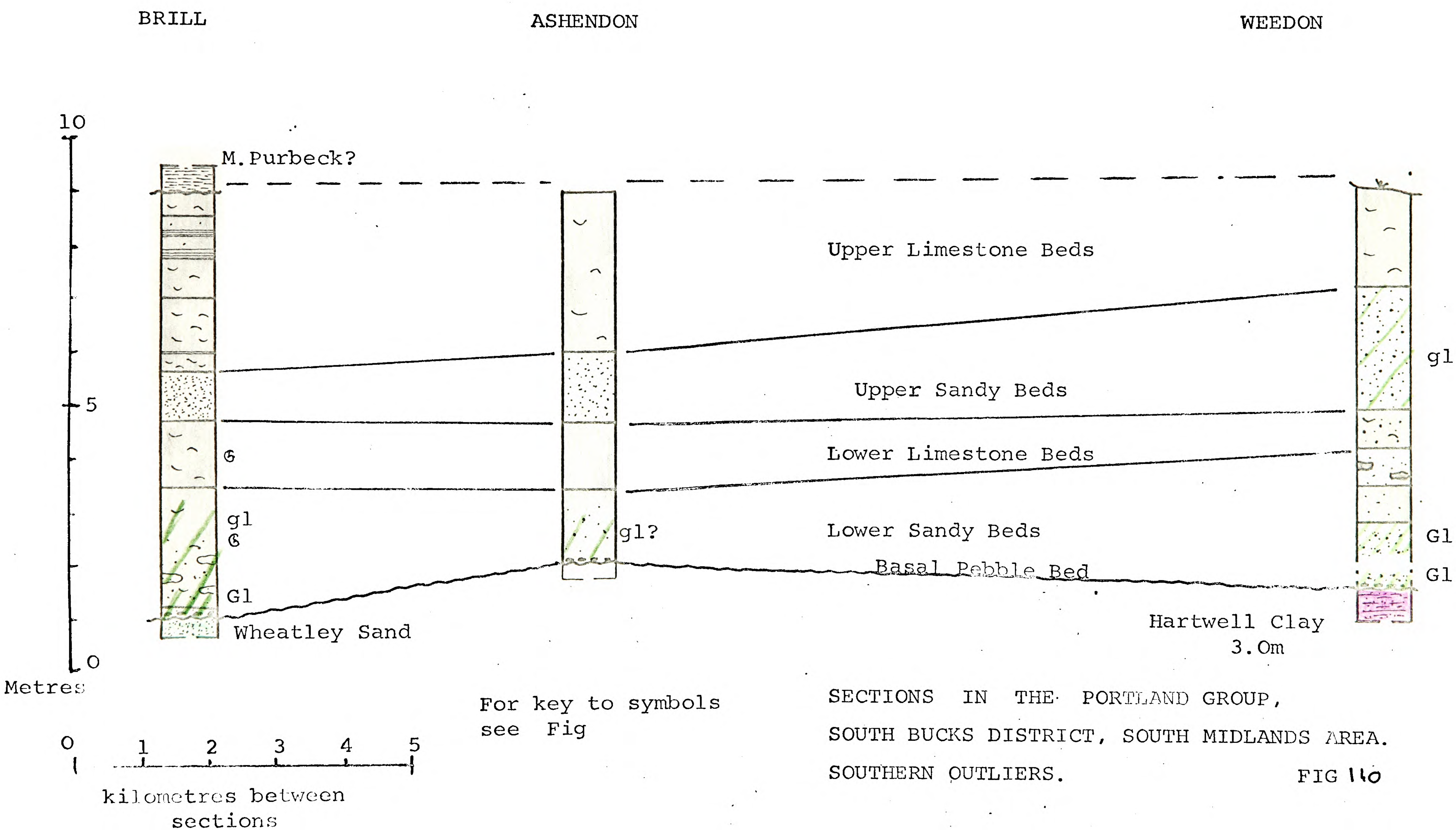
(ii) The Lower Sandy Beds: The variation in thickness of these beds is considerable and accounts for most of the variation in total thickness of the Portland Group. The Lower Sandy Beds, including the Basal Pebble Bed, are 2.4m to c.2.55m thick from Brill to Weedon but thicker to the north and south, being 3.6-5.4m at Long Crendon and 3.0m at Aylesbury, and 6.45m at Quainton and 4.3m at Oving-Whitchurch.

The composition of the beds is apparently much the same over the whole area, being a mixture of glauconite, fine to medium quartz sand, shell fragments, lime mud and clay in various proportions. In general, the lowest parts are very glauconitic (up to 25%) and the proportion decreases upwards (1-5%). In thin sections from Weedon, Oving, Quainton and Wing the fine, angular quartz sand content was <10%. The carbonate proportion varies but the rocks are mostly sandy limestones and some horizons are very fossiliferous. The thicker successions consist of alternations of calcareous sands and concretionary sandy limestone nodules and continuous



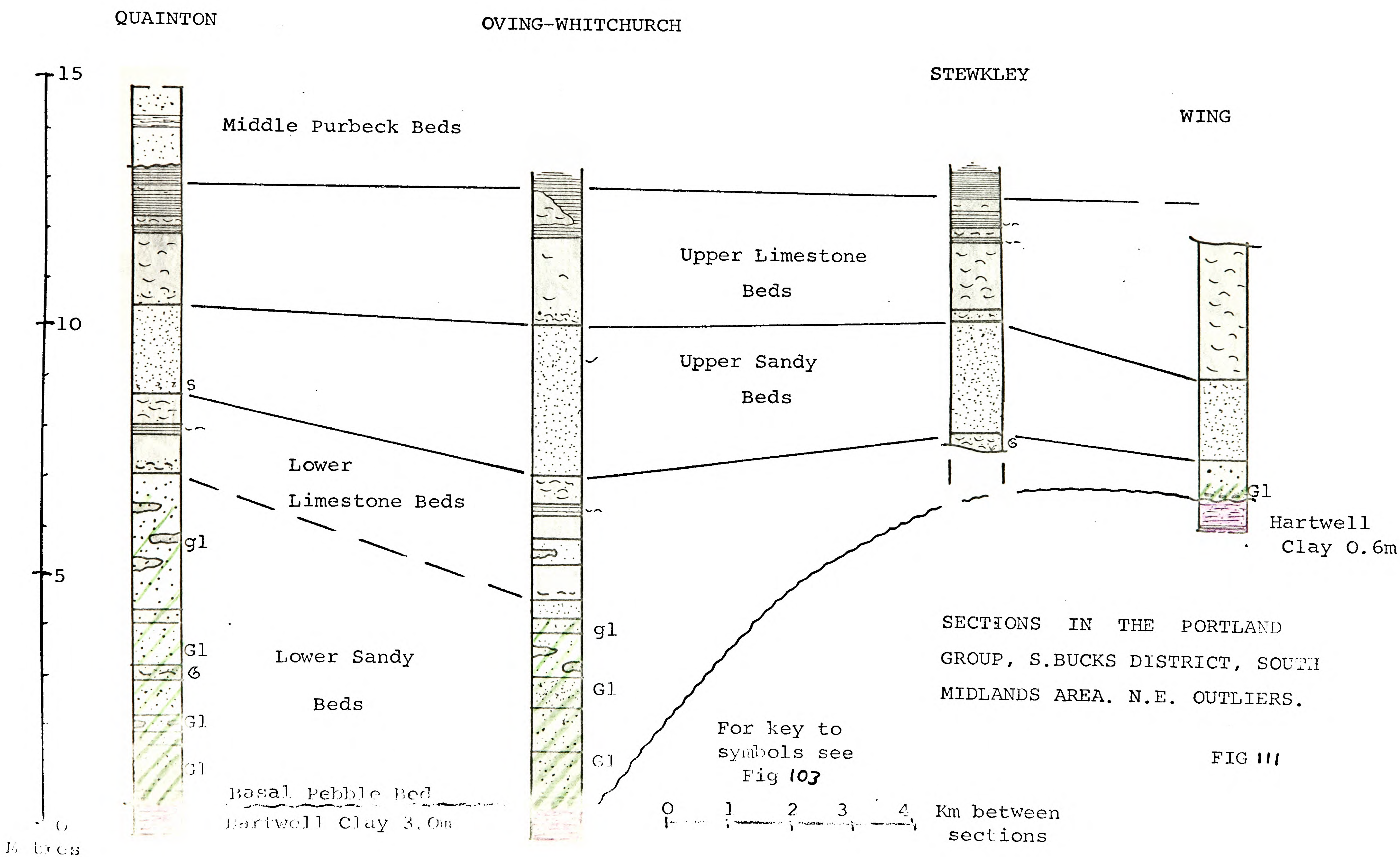

SECTIONS IN THE PORTLAND GROUP,
SOUTH BUCKS AREA, S.MIDLANDS DISTRICT.
MAIN OUTCROP.

FIG 109




SECTIONS IN THE PORTLAND GROUP,
SOUTH BUCKS DISTRICT, SOUTH MIDLANDS AREA.
SOUTHERN OUTLIERS.

FIG 11c




SECTIONS IN THE PORTLAND GROUP, S.BUCKS DISTRICT, SOUTH MIDLANDS AREA. N.E. OUTLIERS.

FIG 111

beds. The approximate proportions of quartz and glauconite sand are indicated in the sections (Figs 109-111).

(iii) The Lower Limestone Beds: These vary in thickness and in a few cases cannot be satisfactorily separated from the Beds above and below. At Hartwell the Lower Limestone Beds are 0.6m thick, but they thicken to 2.4m in 1-2km eastwards, where they have been known as the "Aylesbury Limestone". From Brill to Weedon they vary from 1.3-0.6m thick, and from Quainton to Oving-Whitchurch they are 1.6-2.2m thick.

The beds differ from below in being very low in glauconite (<1%) and having a higher medium quartz sand content, probably indicative of a more rapid rate of deposition in shallower water. The matrix is lime mud with up to 40% medium sand-grade shell fragments of echinoids and of both aragonitic and calcitic bivalves, often very micritised. The "Aylesbury Limestone" is exceptional in that quartz is virtually absent and no glauconite has been found. The Lower Limestones are normally fairly fossiliferous but were not sufficiently well exposed during the course of the study for collections to be made.

(iv) The Upper Sandy Beds: These are thinner than in the Oxford and Swindon Districts, varying from 0.8m (+?) at Long Crendon to 3.0m at Oving-Whitchurch. The sediment is soft yellow to grey very fine quartz sand with up to 10% fine to medium carbonate sand, 10-15% clay and silt, and glauconite % ≃2 or <1. Sieve analysis of samples collected from Haddenham and Kingsey sewage works showed that the very fine quartz sand was completely sorted (sorting coefficient <1-see appendix). The only sign of sedimentary structures were horizontal bedding and possible low angle cross-stratification to the north; the beds seem to be bioturbated throughout but details of the burrows were not visible except for a large <u>Rhizocorallium</u> from a cemented level (Plate 83 ). Nodules and continuous horizons of cemented sand sometimes occur and these have a higher shell fragment content than usual and 20-60% very fine quartz sand. In unweathered dark grey to black specimens the colour is due to pyritisation of the shells. At Quainton Blake (1880) records a basal serpulite.

(v) The Upper Limestone Beds: These are more constant in thickness than the beds below but, as in the other Districts of the South Midlands Area, the exact position of the junction with the Purbeck Beds is disputed. The thickness varies from 2.25-3.5m and details have been personally examined at Haddenham & Kingsey Sewage Works and Long Crendon; and were recently recorded by Barker (1966) at Hartwell, Whitchurch and Stewkley; and by Bristow & Kirkaldy (1962) and Bristow (1963) at Whitchurch.

The basal 0.5m of the Upper Limestone Beds forms a transition with the Upper Sandy Beds. At Long Crendon and the Haddenham & Kingsey Sewage Works the top of the Sandy Beds contains 30% medium quartz sand and the junction is marked by a few mm of laminated lime mud and quartz sand. The basal 0.5m of the bed above contains 40-60% poorly sorted v.f.-c. quartz sand with occasional m.-c. bivalve fragments and common *Pachastrella* spicules preserved as ferroan calcite casts. Above, the quartz sand content drops to <1% and it is very fine grained. This basal quartzose bed sometimes contains "lydite grit" and is fossiliferous. The overlying beds, except for about the topmost metre are thick bedded pale brown to white shelly micrites with a v.f. quartz sand content of either c. or <1%. The matrix is lime mud with scattered f.-m. bivalve fragments comprising up to 25%; *Pachastrella* spicules are common in places (Plate 84) (c.f. Facies 1a of Dorset). The texture is either that of a lime mudstone or wackestone. At no locality has a texture been detected or recorded which would suggest deposition in a high energy environment, a contrast to the Oxford District. For the faunal list, including ammonites, see page 239.

(vi) The nature of the boundary with the Purbeck Beds: It is apparent from the description of the nineteenth and early twentieth century workers in the District that they had difficulty in deciding which bed marked this junction. From the more recent descriptions in the 1960's and from personal observations of the temporary exposures at the Haddenham & Kingsey Sewage Works, it is obvious that there is an alternation of what has been called "Purbeck Facies" with "Portland Facies" at the top of the massive micritic Upper Limestone Beds.

The succession at the Sewage Works was exposed in several trenches and large pits over an area of a few hundred square metres. Above the main, very shelly, micrite is a thin bed of calcareous clay with an oyster bed at its base (not an encrusted surface), passing up into at least 1.2m of soft, thinly-bedded argillaceous ostracodal limestone which is cemented in places (once used for roofing: "Pendle"). These cemented levels are ostracod-rich shell-fragment biosparites with a packstone-grainstone texture and ferroan calcite cement. In most of the exposures at this locality there is a hard bed of shelly limestone, 0.2m thick, consisting of moulds of trigoniids and gastropods, including Aptyxiella, set in a micrite matrix. Above this in places, separated by 0.15m of clay, is a much more lenticular bed of trigoniids, Protocardium and gastropods. The matrix is lime mud with shell fragments and intraclasts up to 4mm across of micrite with sponge spicules (Pachastrella, and Rhaxella?), ostracodal micrite and bivalve biomicrite. The rock is a biointraclastic medium carbonate sand with a packstone texture. The lens was seen to reach 1.0m thick and die away to nothing in a distance of 10 metres (Plate 86). Its upper surface is iron-stained and the surrounding sediment is composed of lime mud with some bivalve fragments (mudstone-wackestone texture).

It seems, that these beds with a molluscan macrofauna are storm accumulations, probably on intertidal mudflats. The work of Barker (1966) shows that the ostracods of the lowest beds at other localities are marine forms. Above the laminated limestones is up to 1.0m of black clay with trigoniid fragments at its base, resting on an undulating "piped" surface suggestive of solution. (Plate 85). This clay contains a thin micritic layer near its top and its microflora indicates that it is "Pre-Cretaceous" (M. Muir pers. comm.).

This sequence above the main shelly limestones is essentially the same at Hartwell where a bed, 0.3m thick, of micrite with trigonids is intercalated between 0.2m of "marly shale" below and above with large oysters and other bivalve casts. The ostracods of these are marine, as below, according to Barker (1966), but above there is only "euryhaline forms" (hypersaline?) which pass up into "freshwater to oligohaline" forms in 1.5m. Wilson (in Davies & Wilson 1949) noted the presence of a stromatolitic band in this sequence.

At Whitchurch, above the main shelly micritic limestone, is 0.2m of "marl with oysters" followed by 0.75m of shelly limestone with trigonids which rapidly passes laterally into fissile limestone and sandy clay. These contain marine ostracods but clays, sands and limestones above contain euryhaline forms. Essentially the same picture is recorded for Stewkley and, on interpretation of previous accounts, applies to the outcrops at Brill, Quainton, Long Crendon and probably the whole District. On Muswell Hill, a small exposure in the Basal Purbeck Beds revealed dessicated lime mud overlain by rippled coarse quartzose shell sand, indicative of sub-aerial exposure probably in a supratidal environment.

(vii) The Purbeck Beds; Although not strictly part of this work it is worth noting that far more of the Lower Purbeck Beds are preserved in this District than in the Oxford District. Up to 5m are recorded at Hartwell and 7-8m at Whitchurch. The Middle Purbeck "Whitchurch Sands" at Whitchurch (Casey & Bristow 1964) unconformably overstep the Lower Purbeck Beds and rest on the Portland Group as far down as the Lower Sandy Beds. Details are summarised by Bristow (in Sylvester-Bradley & Ford (1968)). (Note: He also gives an incorrect interpretation of the succession at Quainton (fig. 46) and a Correlation Chart (Table 17) with at least four mistakes.)

## C. Macrofauna recorded from the South Buckinghamshire District

### Upper Limestone Beds

**Common:**

*Laevitrigonia gibbosa* Sowerby
*Isognomon Bouchardi* Oppel
*Camptonectes lamellosus* Sowerby
*Camptonectes suprajurensis* Buvignier
*Ostrea expansa* Sowerby
*Ostrea bononiae* De Loriol
*Ampullospira ceres* de Loriol
"Ammonites Boloniensis" de Loriol
Various large ammonites (see Buckman 1922)

**Less Common:**

*Alaria Beaugrandi* de Loriol
*Natica elegans* Sowerby
*Natica incisa* Blake
*Aptyxiella portlandica* Sowerby
*"Cerithium" Hudlestoni* Blake
*Orthostoma acuticarena* Blake
*Pleurotomaria rugata* Bennett
*Pleuromya tellina* Agassiz
*Corbula damariensis* Buvignier
*Lithophaga* sp.
*Eomiodon cuneatus* Cox
*Eocallista implicata* de Loriol
*Pseudotrapezium(?) costiferum* Blake
*Lucina portlandica* Sowerby
*Protocardia dissimilis* Sowerby
*Protocardia calcarea* Blake
*Myophorella incurva* Bennett
*Trigonia pellati* de Loriol
*Arca beaugrandi* de Loriol
*Nucula lorioli* Blake
*Plagiostoma rustica* Sowerby
*Exogyra nana* Thurmann
*Plicatula boisdini* de Loriol
*Serpula quinquangularis* Goldfuss

Nuculana damariensis Buvignier

Thracia incerta Thurmann

Isocyprina pringlei Cox

Isocyprina elongata Cox

Anisocardia Buckmani Cox

Corbicellopsis Loreoli Cox

Eocallista pulchella de Loriol

Quenstedia portlandica Cox

Barbatia cavata de Loriol

Parallelodon dorsetensis Cox

Plagiostoma boloniensis de Loriol

Modiolus pallidus Sowerby

Modiolus Hudlestoni Cox

Corbula saltans Blake

Corbula mosensis Buvignier

Purpuroidea portlandica Hudleston

Blake 1880: The topmost beds have abundant trigoniids and small Lithophaga, also Mytilus pallidus. Characteristic of the main beds is Ampullospira ceres. Aptyxiella portlandica is common only in one place in the higher beds. Lucina portlandica and Eomiodon are rare. Large oysters are abundant. Plicatula is "not rare". Serpula sp. are common. At Quainton the gastropod Neritoma sinuosa "occurs, but is rare".

Upper Sandy Beds (Lower preservation potential)

Serpula quinquangularis Goldfuss

Camptonectes lamellosus Sowerby

Protocardia dissimilis Sowerby

Exogyra nana Thurmann

Rhizocorallium and various crustacean remains

Lower Limestone Beds

Common: Pleuromya tellina Agassiz

Myoconcha portlandica Blake

"Trigonia" pellati de Loriol

**Less Common:** Musculus autissiodoriensis Cotteau

Eodonax pellati Cox

Mactromya verioti Buvignier

Protocardia dissimilis Sowerby

Pleurotomaria rugata Bennett

Natica turbiniformias Romer

[illegible]ia depressa Sowerby

Sowerbya longior Blake

Eocallista implicata de Loriol

Unicardium circulare D'Orbigny

Falcimytilus suprajurensis Cox

Mytilus boloniensis de Loriol

Laevitrigonia gibbosa Sowerby

Myophorella incurva Bennett

"Trigonia" Voltzeii Agassiz

"Trigonia" Muricata Goldfuss

"Trigonia" Manseli Lycett

"Trigonia" Micheloti de Loriol

Isognomon Bouchardi Oppel

Plagistoma rustica Sowerby

"Lima (Mantellum)" cf. ornata Buvignier

Plagiostoma bifurcata Blake

Camptonectes lamellosus Sowerby

Ostrea soletaria Sowerby

Plicatula boidini De Loriol

Serpula quinquangularis Gol̃dfuss

Barbatia cavata de Loriol

Plagiostoma Blakei Cox

Crustacean remains are recorded ("Glyphea sp.") and several ammonites are known including Glaucolithites.

Lower Sandy Beds and Basal Pebble Bed

Many of the above common bivalves, also Modiolus boloniensis de Loriol, occur and ammonites are common, especially Glaucolithites. Casey (1967) says that the albani fauna has been identified from the Basal Pebble Bed.

## 7. The Significance of the Basal Pebble Bed and "lydite pebbles"

Neaverson (1925) describes and discusses the origin of the pebbles in the Basal Pebble Bed of the Portland Group and suggests that they are part of one phase of sedimentation which began in late Callovian times and ceased at the close of the Aptian stage. Arkell (1927) discusses similar pebbles in the Corallian strata of Oxford and agrees that the source during this phase was the same but disagrees on its location.

The pebbles, up to 20mm in diameter, are described by Neaverson under two headings:-

(i) Authigenous

These are dull black pebbles, variable in shape and often irregular. They consist largely of very fine sand to silt grade quartz set in a brown phosphatic matrix, in which shell fragments can sometimes be discerned (personal observations). Neaverson quotes an analysis of one pebble which contained 56% calcium phosphate, the remainder being $CaCO_3$, $Fe_2O_3$, MgO and insoluble residue. Phosphatic casts of bivalves and Pavlovid ammonites are found at most localities in the South Midlands Area; they also occur in Dorset and the Boulonnais.

(ii) Derived pebbles

The following have been recorded:-

(a) Very Common: well rounded and polished dark brown or black chert (the original "lydian stones").

(b) Common: white vein-quartz.

(c) Moderately common: speckled silicified oolite.

(d) Rare (<1%): brown spicular cherts with a rough surface. They consist entirely of siliceous sponges resembling *Hyalostelia* of Lower Carboniferous age.

(e) Rare: spherulitic felsite (Davies 1899) (=silicified oolite?).

### The significance of the phosphatic content

The youngest Kimmeridgian strata upon which the Basal Pebble Bed rests in the South Midlands belongs to the *Pallasioides* Zone and Casey (1963, 1967) suggests that the phosphatised Pavlovid ammonites are the sole representatives of deposition in Dorset of the beds from the Zone of Pavlovia rotunda to the base of the Portland Group. It should be noted that the much-maligned Buckman correlated the Basal Pebble Bed with the rotunda- nodules of Dorset and noted that there was a sedimentary break in the succession (1926). The rotunda-nodule bed of Dorset is described by Casey as the only sign of a slight pause in deposition in the centre of the basin. At Chapman's Pool (Isle of Purbeck) the nodules are calcareous and only slightly phosphatic but at Ringstead Bay, (West Area) where the beds from above this horizon to the Exogyra Beds of the Portland Group are nearly half the thickness of those 20km to the east, the rotunda-nodule bed contains phosphatic nodules, and phosphatised bivalves and Pavlovids (Arkell 1947a). Thus, slow rate of deposition is conducive to phosphatisation.

In the South Midlands the Basal Pebble Bed contains an indigenous fauna of the Progalbanites albani-Zone, the basal time-division of the Portland Group. Casey says the break in sedimentation increases in magnitude from the South Midlands east and westwards. In S.E. Lincolnshire it is represented by the gap between the Basal Spilsby Nodule Bed and the Kimmeridge Clay. The basal beds of the Sandringham Sands and the Spilsby Sandstone contains Paracraspedites which occurs in the topmost beds of the Portland Limestone Formation in East Dorset. Casey also suggests that the break is included in the gap in Yorkshire between the Kimmeridge Clay and the Lower Cretaceous Speeton Clay, marked by the "Coprolite Bed". The Basal Pebble Bed is described, therefore, as one of the most important stratigraphical planes in the British Mesozoic (Casey 1967).

## The significance of the derived pebbles

Davies (1899) suggested that some lydites are derived from Palaeozoic cherts, and Kendall (1905) compared them with cherts of the Belgium Carboniferous. Neaverson (1925) says that the black cherts are similar to those of the Carboniferous Limestone of Derbyshire; Hyalostelia is known from the Lower Carboniferous of Scotland, Yorkshire, North Wales and Ireland; and that silicified oolite is known from the Cambrian of the N.W. Highlands of Scotland and the Carboniferous of S. Wales. He concludes that the pebbles came from the north and, in part, Scotland.

Arkell (1927) considers that a northern origin is unlikely and suggests that they were brought in from the south-east; this is supported by Allen (summarised in 1967) who postulates that there was a Basal Pebble Bed of Portland Group age spread over the London Platform which was then dominantly composed of Lower Carboniferous rocks. Arkell (in Allen 1960) concludes that the phosphatised ammonites in the Wealden of S.E. England could have been derived from the Basal Pebble Bed in the South Midlands and the rotunda-nodule bed in Dorset (Ringstead), but not from the phosphatic beds in the Boulonnais.

This point may preclude the suggestion by Allen (1967) that his palaeogeology of S.E. England during upper Hastings Times could be rotated through $180^{\circ}$.

## 8. Synthesis and Interpretation

The three main phases of progressively shallowing sedimentation which are well represented in Dorset can be recognised in the South Midlands but the succession is much thinner. The sediments from the rotunda-nodule bed to the Exogyra Bed are not represented due to slight folding in the area and non-deposition at the end of Upper Kimmeridge Clay times. The only record of the lowest phase is phosphatised ammonites, derived Palaeozoic pebbles and the indigenous albani-fauna reported by Casey (1967) from the Basal Pebble Bed.

Following this remanié deposit the second phase is represented by the Lower Sandy Beds and the Lower Limestone Beds which contain common Glaucolithites, as do the sediments of the second phase in Dorset and the Vale of Wardour. Rates of subsidence and shallowing were slow, indicated by the beds being thin, fossiliferous and glauconitic with an upward decrease in quartz sand and glauconite content and an increase in sand grain size and micrite content.

The model of deposition suggested for the Vale of Wardour can be applied although terrigenous material continued to enter the basin even during the latest phase, indicating a nearer source of supply than in the Vale of Wardour and in Dorset. The margin of the basin lay to the north-west and Swindon was nearer to land than Oxford. Glauconite formed on the mid-shelf in moderately deep water when the deposition rate was slow; lime mud was deposited in slightly shallower, but quiet water nearer the shore.

The rate of subsidence increased during the third and final phase and quartz sand was deposited on the shelf. In the Swindon district cross-stratification in the fine to medium quartz sand shows that currents moved onshore and shallowing is indicated by an upward increase in grain size and carbonate sand content as well as a change from tabular to lenticular bedding. In the Oxford district the Upper Sandy Beds are the same thickness but they are finer, better sorted and more argillaceous, indicating deposition further from the source of supply, either along or away from the shoreline. To the north-east, in the Buckinghamshire district, the lithology is the same but the sands are thinner.

The shallowing continued and upwards the sand content decreases, becomes coarser and more lime mud and shell sand appear. These sediments were deposited on the shallow carbonate shelf and in the Oxford district high energy biochem, intraclast and ooid sands developed. To the north-east, behind this high energy zone, shelly lime mud was deposited, probably in sheltered shallow water. The micrites pass up transitionally into hypersaline ostracod-rich thin-bedded limestones of the Purbeck Beds. These contain clay brought in from the land and the freshwater entering the sea was evidently sufficient to prevent the precipitation of evaporites. In the Oxford and Swindon districts the Upper Limestone Beds were eroded, probably by intertidal channels. Occasional high energy events and/or slight fluctuations in sea level, resulted in the accumulation of lenticular shell beds in the intertidal zone where lime mud was being deposited.

As in the Vale of Wardour, it is not known whether the transition from the Portland Group to the Purbeck Beds took place at the end of the third phase in Dorset or at the minor phase of shallowing halfway through. The proximity of the South Midlands Area to the land, indicated by the high proportion of terrigenous deposits, suggests that the change probably took place earlier than in Dorset. The heavy mineral assemblages (Neaverson 1925) are the same as those in Dorset which presents the problem of deriving metamorphic minerals from land to the north, unless one advocates rivers draining the Scottish Highlands as did Neaverson. Despite the freshness of the grains it is possible that they were derived from earlier Jurassic littoral sands.

# CHAPTER 7

## THE PORTLAND GROUP IN THE BAS BOULONNAIS, NORTH-EAST FRANCE

### with a short summary of the Portland Group of the Pays de Bray

## 1. Introduction

The Upper Kimmeridge Beds and Portland Group are brought to the surface in the anticlines of the Bas Boulonnais and Pays de Bray and in a small faulted inlier at Rouen (Fig. 1 ), but apart from these places they are not exposed until as far south-east as the valley of the Meuse (Bar le Duc, Savonnières) and as far south-west as Aquitaine (Cognac). In the north-west, near the mouth of the Seine, the Cretaceous strata overstep the Upper Jurassic and the youngest beds preserved are of Lower Kimmeridge age.

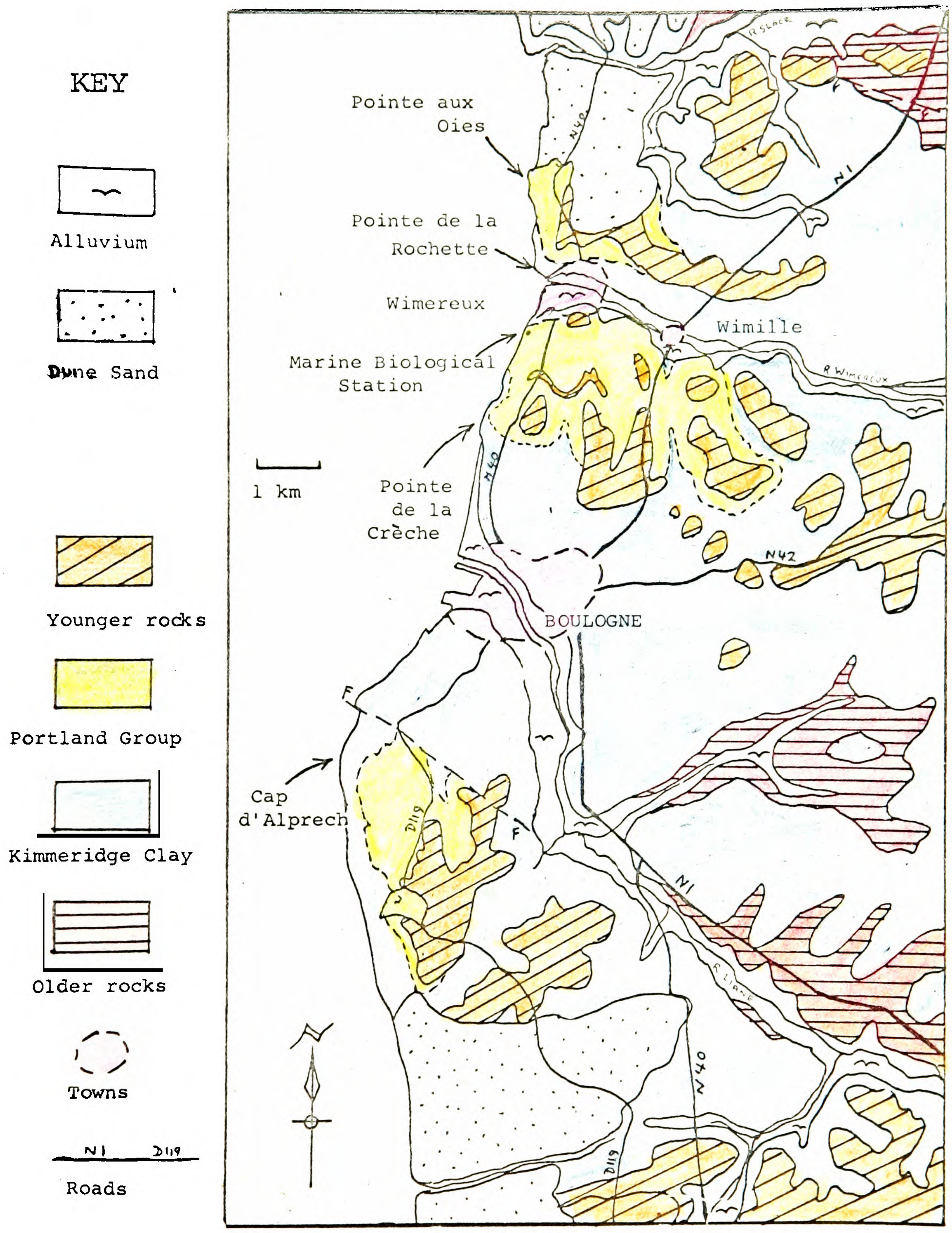
The Bas Boulonnais and the Pays de Bray were visited in the course of this study and the Portland Group was found to be well displayed between Boulogne and Wimereux (Fig. 112) but very poorly exposed in the Pays de Bray. Thus, most details are given for the former district and only a brief summary of the literature for the latter. No information was found about the beds at Rouen and the area was not visited.

The outcrop in the Bas Boulonnais is a natural south-eastern continuation of the Wealden anticlinarium and the succession is similar in many respects to those already described in England. The area has been studied for many years and since the pioneer work of Fitton (1826) and d'Orbigny (1842-51, 1849-52, 1850-52) at least thirty papers have been written about these rocks. The fauna and sediments have been repeatedly described and various interpretations made, some more bizarre than others. The ammonite succession has not been satisfactorily detailed but there is enough evidence to make an approximate time correlation with the sections in England.

The English use of the terms Kimmeridgian and Portlandian is different from that on the Continent. The Portlandien of d'Orbigny (1850-52) includes the Upper Kimmeridge Clay and Portland Group of England (*elegans* to *Titanites* - Zones) and the Portlandian of the English refers to only the Portland Group (*albani* to *Titanites* - Zones) (Fig. 113 ) For further details see Arkell (1946) and Michailov (1962). For this present work adjectives denoting time are avoided and the rock terms Portland Group and Upper Kimmeridge Beds are used throughout in the English sense.

GEOLOGICAL MAP SHOWING THE DISTRIBUTION OF THE PORTLAND GROUP (Assises de Croi & Grès des Oies) IN THE BAS BOULONNAIS, FRANCE. Adapted from the French Geological Survey map 3:Boulogne.

FIG 112



NOMENCLATURE OF THE PORTLAND GROUP IN THE BAS BOULONNAIS, FRANCE.

FIG 113

| | | FRENCH TERMINOLOGY<br>Rigeaux 1865, 1892<br>Pellat 1878 | Pruvost 1921, 1925<br>Lemoine 1911 | Ager & Wallace<br>1966a & b, 1970 | TOWNSON 1971<br>(This thesis) | |
|---|---|---|---|---|---|---|
| Lower and Middle Purbeck | Purbeckien & Wealdien | Calcaire lacustre à Anisocardia socialis | | Calcaire des Oies | | ZONES |
| PORTLAND GROUP — Upper | Portlandien Supérieur | GRÈS À TRIGONIA GIBBOSA | et à Cardium dissimilis | GRÈS DES OIES | Upper | Titanites ? |
| | | | et à Ampullina ceres | | Middle | ? G.gorei |
| | | | et à Cardium Pellati | | Lower | G.gorei |
| PORTLAND GROUP — Lower | Portlandien Moyen | MARNE À PERNA BOUCHARDI | Couches à Astarte saemanni | ASSISES DE CROI | Upper | G.gorei |
| | | | P4 Argiles à Ostrea expansa et Perna Bouchardi | | Middle | P. albani |
| | | | | | Lower | P. albani ? |
| | | P3 Tour de Croi Nodule Bed | | Rotunda Nodule Bed | | Rotunda & Pallasioides |
| UPPER KIMM CLAY | | Argiles a Exogyra dubiensis | | Argiles de Wimereux | | Pectinatus |

The only locality where a complete section through the Portland Group was measured is just South of the town of Wimereux (Fig. 112), in the cliffs between the Marine Biological Station and Pointe de la Crèche. The upper part was examined again nearer to the Biological Station. Just north of Wimereux, six sections in the upper part were studied in the cliffs between Pointe aux Oies and Pointe de la Rochette. On the south side of Boulogne, 8km from Wimereux, the upper part of the succession is exposed at the top of Cap d'Alprech and a section was measured there.

The Portland Group outcrop in the Bas Boulonnais covers an area of about 20sq.km and the maximum thickness is approximately 20m, less than in the Vale of Wardour and greater than that of the South Midlands.

## 2. Nomenclature

The beds which are recognised as being equivalent to the Portland Group have long been divided into the lower "Marne (or Argiles) à Perna bouchardi et Ostrea expansa" and an upper "Grès (or Couches) à Trigonia gibbosa". These have been renamed by Ager & Wallace (1966a) as the Assises de Croi overlain by the Gres des Oies.

The base of the succession is marked by a condensed horizon, the Tour de Croi nodule bed, which is equivalent to the rotunda-nodule bed of Dorset and the Basal Pebble Bed of the South Midlands. This rests on what was known as the "Argiles à Exogyra dubiensis" until Ager & Wallace (1966a) changed the name to Argiles de Wimereux. The Lower and Upper divisions of the Portland Group are here each sub-divided into Lower, Middle and Upper parts, some of which correspond approximately to previous French divisions (Fig. 113)

From the interpretation of the work of several authors it appears that the ammonite Progalbanites albani occurs in the Middle and Lower Assises de Croi and Glaucolithites gorei ranges from the Upper Assises de Croi to the Lower, and possibly Middle, Grès des Oies. The latter part also contains Titanites. No ammonites have been recorded from the Upper Grès des Oies and none were found by the present author in summer 1970. The above ammonite distribution differs slightly from that given by Arkell (1935) who regarded the gorei-zone as being limited to the Lower and Middle Assises de Croi. (Data for the present conclusions was taken from the following papers: Rigeaux 1865, 1892; Pellat 1878; Pruvost 1921, 1925; Pruvost & Pringle 1924; Dutertre 1925, 1925-6, 1926, 1927a & b, 1933; Arkell 1935, 1956).

The Grès des Oies is overlain by a thin bed of algal limestone which has been called "Purbeckien" and named the Calcaire des Oies by Ager & Wallace (1966a). Above this are non-marine clays and sands known as the "Wealdien".

## 3. The relationship of the Portland Group with the Kimmeridge Clay Beds

The Tour de Croi nodule bed is one of four phosphatic horizons in this part of the sequence, named P1-4 by Pruvost (1921). P1, La Rochette nodule bed, separates the Argiles de Wimereux (Pectinatus-Zone) from the underlying Argiles de la Creche (Hudlestoni-Zone?) and P2 lies just above, within the Argiles de Wimereux. P3, the Tour de Croi nodule bed, contains rolled and phosphatised Pavlovia rotunda and P. pallasioides which are otherwise not known in the succession. The Middle and Lower Assises de Croi contains Progalbanites albani and related forms, therefore P3 represents a gap from the Pectinatus-Zone to the albani-zone, whereas the Basal Pebble Bed of the South Midlands represents a gap from the Pallasioides-zone to the gorei-zone, the albani-zone being represented only by the thin pebble bed itself (Fig. 101). The term Sandy Upper Kimmeridge Beds cannot be applied here as only the lowest Upper Kimmeridge Clay is arenaceous (Grès de la Crèche).

## 4. Lithofacies of the Portland Group of the Bas Boulonnais

The remarks made about facies in the South Midlands apply here because there are not enough exposures to justify a detailed quantitative classification such as was used in Dorset to detect subtle vertical and lateral environmental changes. There is only one complete accessible section through the Portland Group and eight in the upper half of the succession. The rocks are mixtures of clay, very fine to coarse quartz sand, glauconite and calcium carbonate. The succession is dominated by terrigenous sediment and at one horizon Palaeozoic pebbles form a conglomerate. Limestones occur only as thin nodular horizons of micrite interbedded with sandy clays. Forty hand-specimens were collected and studied in the laboratory and 23 of these were made into stained thin-sections. Qualitative descriptions are generally given but in some cases a facies designation, as used in Dorset or the Vale of Wardour, is added for comparison.

5. The Lower Portland Group. Section south of Wimereux

A. The Tour de Croi Nodule Bed: 0.55m. Fig. 114

This is exposed at the foot of the cliff just north of Pointe de la Crèche. At the base there is a concentration, 0.15m thick, of phosphatised vertebrate fragments, bivalves, ammonites gastropods, brachiopods, echinoids, belemnites and indeterminate phosphatic pebbles up to 20mm across. The clay matrix contains lignite, an indigenous bivalve fauna and granules of quartz, quartzite and chert (lydite). (See faunal list later). Above this is 0.2m of slightly calcareous and glauconitic clay, in which was found a rhynchonellid brachipod (R. subvariablis pers. comm. A. Childs); the upper part contains lenses of Exogyra. The top of the Tour de Croi nodule bed is a nodular limestone 0.15-0.20m thick composed of microsparite with <1% quartz and glauconite, but with occasional lydite grains (Facies A" of the Dorset Portland Sand Formation).

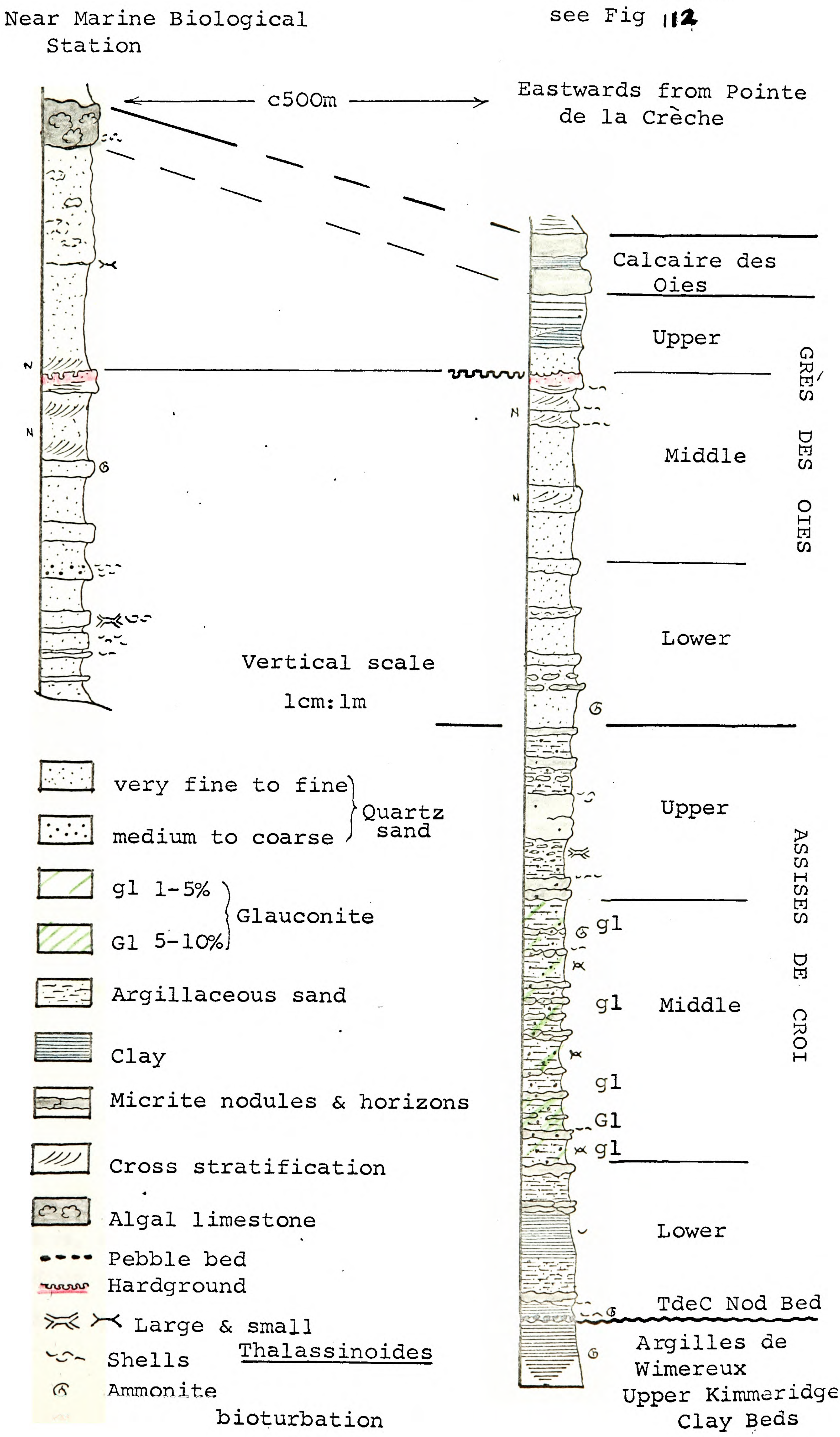
This sequence 0.55m thick is similar to a single cycle of the Exogyra and Upper Black Nore Beds of Dorset. The phosphatic bed is the result of non-deposition and sedimentation recommenced with a shallowing cycle.

B. Lower Assises de Croi 2.25-2.3m Fig. 114

The lowest 0.7m consist of laminated calcareous silty sandy clay (v.f.-f. quartz) and contains poorly preserved ammonites. The overlying 0.7m is sand-free clay but very large Myophorella (up to 0.15m long) occur. This is followed by two nodular beds

SECTIONS IN THE PORTLAND GROUP OF THE BAS BOULONNAIS, SOUTH OF WIMEREUX. FIG 114

For localities see Fig 112



of fine grained limestone 0.2-0.25m thick (<1% quartz and glauconite. Facies A"), separated by 0.4m of silty sandy clay, as below, but with 1-2% medium quartz sand and containing common large Isognomon. These beds are not particularly bioturbated and contrast with the overlying sediment. They are considered to have been laid down in quiet, relatively deep water.

C. Middle Assises de Croi 4.6-4.7m. Fig. 114

These beds are characterised by containing a significant proportion of glauconite and medium to coarse quartz sand. The sequence includes ten beds of nodular fine-grained limestones (originally lime mud), 0.1-0.15m thick, which contain up to 20% v.f. to medium quartz sand, and glauconite (c.5% of the quartz proportion). The limestones are separated by beds, 0.2-0.5m thick, which are composed of v.f. quartz sand, silt and clay with up to 50% well rounded medium to coarse quartz sand and some granules of lydite (chert?), and up to 10% fresh, medium sand-grade glauconite. Sand-sized shell fragments and a few calcareous foraminifera occur.

The sediment is very bioturbated (Rhizocorallium?) but in places is seen to have been laid down as laminations of clay and sand. Large oysters are sometimes common at the top of the limestones and some of these may be encrusted surfaces (Ager & Wallace 1970). The presence of glauconite and coarse terrigenous material in a "background" of bioturbated clay, silt and very fine quartz sand suggests that the Middle Assises de Croi was deposited slowly and in slightly shallower water than the Lower part.

D. Upper Assises de Croi. 3.0-3.1m Fig. 114

These again consist of alternations of fine-grained nodular limestones with argillaceous silts and fine sands. There is a basal limestone 0.45m thick, with Camptonectes and oysters on its upper surface, which is succeeded by 0.7m of calcareous clay with fine to medium quartz sand, <1% glauconite, common Exogyra, Astarte and echinoids, plus limestone nodules which appear to be altered large *Thalassinoides*. (Plate 87) Above is 0.8-0.9m of hard nodular limestone with scattered bivalve fragments and <1% f.-m. quartz and <1% glauconite. The overlying 1.5m consists of three thin nodular limestones similar to that below, separated by calcareous silty clay with some f.-m. quartz and <1% glauconite.

These are thought to have been deposited in slightly shallower water than the Middle part and probably more rapidly, based on the low proportion of glauconite and coarse terrigenous sediment.

6. *The Upper Portland Group, "Purbeck" and "Wealden" Beds*. North and South of Wimereux, Cap d'Alprech.

A. *Lower Grès des Oies*. Up to 2.85m (FIG 114)

The separation of these beds from the Middle Grès des Oies is arbitrary and done in order to correspond with the French division between lower beds with common "*Cardium pellati*" (*Protocardium dissimilis*) and higher beds with common *Ampullospira ceres*; the sediment, however, is essentially the same throughout. The beds are 2.5-2.85m thick and consist of soft, v.f.-f. quartz sands, <5% clay and carbonate, and <1% glauconite. Thin cemented horizons occur, 0.1-0.3m thick, composed of c.80% v.f. quartz sand with shells and fragments of bivalves and gastropods (glauconite <1%) in a microsparite cement. The lower 0.7m in places is a mixture of loose sand with sandstone nodules throughout, the result of diagenetic modification of large *Thalassinoides*.

B. *Middle Grès des Oies*. 0-3.1m (FIG 114)

The variation in thickness, and in places absence, of these beds is due to down-cutting of the Upper Grès des Oies. When preserved, the beds consist of up to 80% well-sorted v.f. quartz sand with only a small amount of clay, <1% glauconite, micrite pellets up to 1mm long, shells and fragments of bivalves and gastropods. A shelly cemented bed 0.3m thick occurs in the middle and is composed of microsparite with a variable amount of v.f. quartz sand and no glauconite. The soft sands have been bioturbated but at three localities cross-stratification can be discerned, with fore-sets dipping northwards.

The Lower and Middle Grès des Oies were deposited in shallower water than the Assises de Croi, indicated by the decrease in clay and presence of cross-strata instead of horizontally laminated sediments. The low proportion of glauconite indicates that the rate of deposition was not unusually slow.

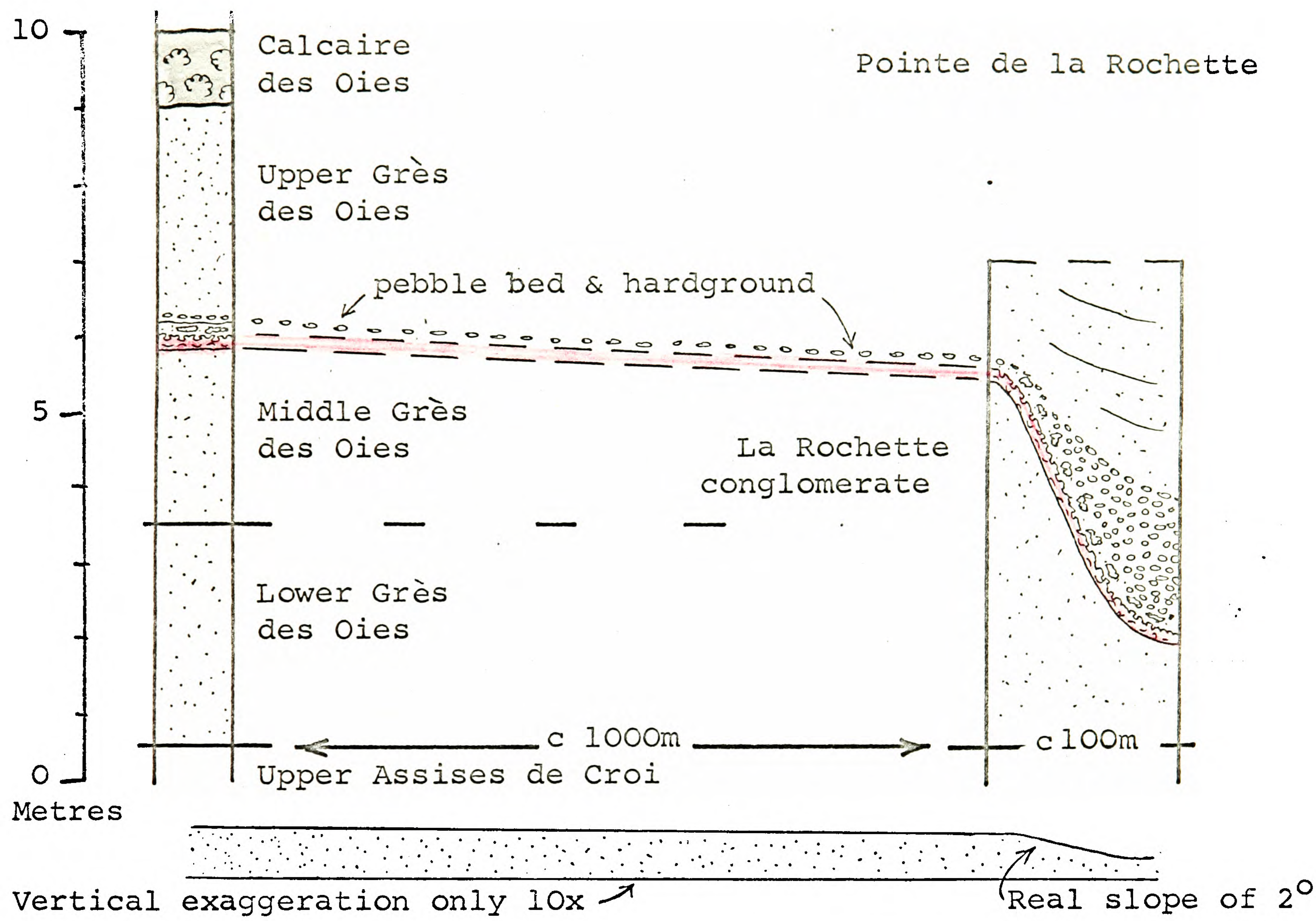
C. Upper Grès des Oies. 2.5->5m? (FIG 114, 117)

The base of these beds is a hard shelly sandstone 0.1-0.2m thick composed almost entirely of v.f. quartz sand with a ferroan microspar cement. The bed is a "hard-ground" with its upper surface bored by Lithophaga and encrusted with serpulids and oysters. This horizon is first exposed north of Wimereux, at Pointe aux Oies, where it rests on 2.2m of Middle Grès des Oies. It can be traced southwards towards Pointe de la Rochette maintaining approximately the same level for about 1km. However, within 100m at Pointe de la Rochette it cuts down through the Middle Grès des Oies to rest on the basal 1.5m of the lower Grès des Oies. This bored horizon also occurs at the next locality, about 1km south of Wimereux, resting on 3.5m of Middle Grès des Oies. Thus the downcutting at Pointe de la Rochette is a local phenomenon. (Fig. 115)

This hard-ground must represent a significant break in time; because not only was the bed lithified, encrusted and bored but aragonitic skeletons were dissolved before the deposition of the overlying sediment. At Pointe aux Oies the bored surface is covered with a layer, 0.05-0.10m thick, of Laevitrigonia, shell fragments, pebbles and blocks up to 0.4 x 0.1m eroded from the hard-ground. This is covered by a fine quartz sandstone and the whole bed (0.25m) has been burrowed by small Thalassinoides. Above is 0.25m of very fine quartz sand (originally almost 100% quartz) which is horizontally laminated with primary current lineation and has been burrowed in places by Thalassinoides (Plate 88). In places, fallen blocks show the bored horizon covered directly by this sand and in these cases the sediment fills borings and empty moulds of aragonitic bivalves (Plate 93).

The solution and cementation of this bed may indicate emergence

THE ROCHETTE CONGLOMERATE AND EROSION OF THE MIDDLE GRÈS DES OIES. BAS BOULONNAIS. FRANCE. FIG 115



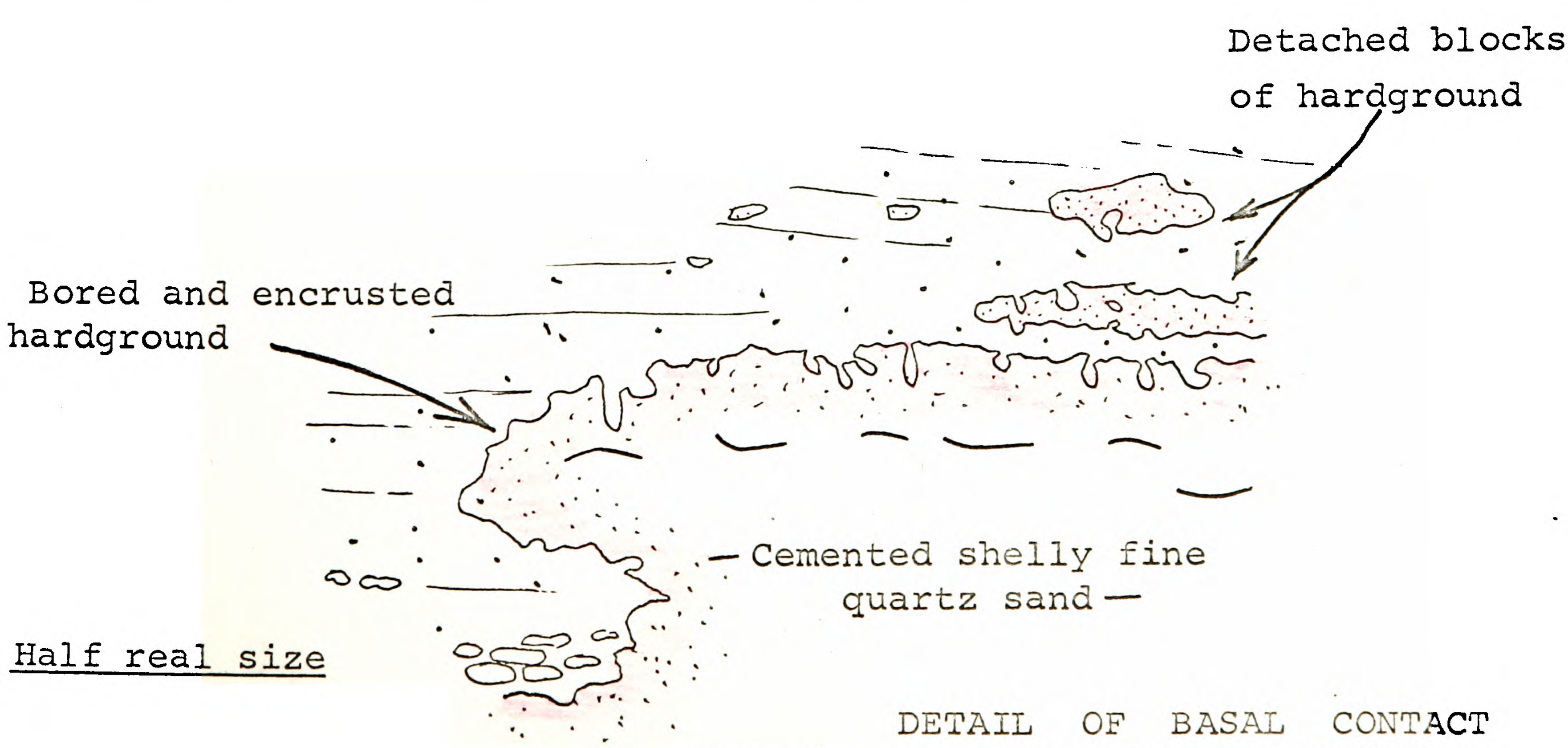




FIG 116 DETAIL OF BASAL CONTACT OF ROCHETTE CONGLOMERATE FROM A FIELD SKETCH.

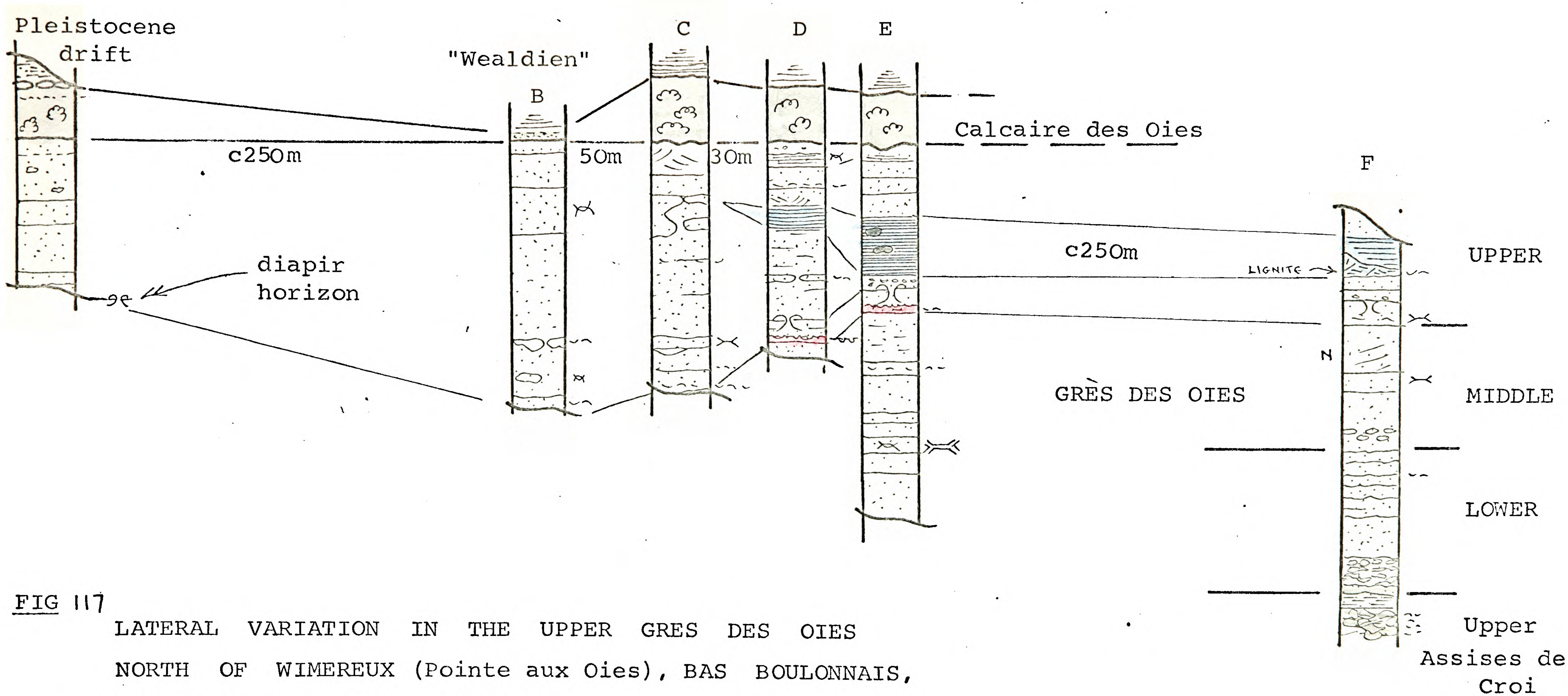



FIG 117
LATERAL VARIATION IN THE UPPER GRES DES OIES NORTH OF WIMEREUX (Pointe aux Oies), BAS BOULONNAIS, FRANCE. Vertical Scale 1cm:1m. (For symbols see) (Fig 114)

above sea level to account for the lack of sediment in the empty moulds and the presence of ferroan calcite cement, but it seems unlikely that even the floor of the erosional structure at Pointe de la Rochette was also subaerially exposed. The ferroan calcite cement suggests precipitation below a water table in reducing conditions (Evamy 1969). It is possible that cementation took place in an intertidal or supratidal environment and then the bed was submerged, bored, encrusted, covered by sand and burrowed by bivalves and crustaceans. Similar horizons in the Middle Jurassic of the Paris Basin are considered by Pursar (1969a & b) to have been subtidally cemented.

At Pointe aux Oies the next event was diapiric intrusion and "fissure eruption" of the bioturbated shelly sand from below, through the fine sand and pebble bed. Similar structures have been described from alluvial deposits in the Torridonian by Selley <u>et al</u> (1963). These structures in the Grès des Oies have been interpreted by Ager & Wallace (1966a & b, 1970) as being due to water saturation, loading and possible sudden shock in an intertidal environment. The diapirs are thought by them to have been burrowed afterwards and the organisms "congregated at the sandstone pipes because of the rising water". Field observations, and their own diagrams, show in fact that the burrowing took place before upward movement of the sediment (Plate 91,92). Saturation of the sediment was obviously due to the impervious hardground below preventing downward flow of water, and loading was due to the bed of sand above, the fine grained nature of which hindered a diffuse general upward flow of trapped water.

Above the diapir horizon is a thin layer of pebbles of vein quartz, chert, jasper, Carboniferous Limestone and Jurassic rocks. The coral <u>Isastrea oblonga</u> was found amongst these but it was not possible to prove that it was in position of growth, as has been recorded in the past. The matrix of the pebble bed is a mixture of clay, silt and v.f. sand (10-25%) with well-rounded coarse sand and granules of quartz and chert. This pebbly, gritty mixture forms a bed 0.4-0.5m thick and is overlain by 1.0m of grey silty clay with medium to coarse sand in places and with "planks" of lignite at the base and micrite nodules up to 1m across near the top. The latter are regarded as algal by Ager & Wallace (1970) but a thin section of one revealed vertical and radiating lozenge-shaped moulds up to 1mm long, identical to gypsum-crystals; these are characteristic of intertidal zones bordering sabhkas according to Shearman (1966). No shell fragments were found except for a few ostracod valves, a foram and possible Rhaxella spicule casts. This clay is overlain by 0.45-0.50m of soft wet fine quartz sand capped by 0.25m of limestone composed of desiccated laminations of micrite with scattered v.f. quartz sand (Fig.117E). This obviously represents the development of an algal mat at this level but a further 0.6m of laminated f.-m. soft sand overlies this below the base of the main algal limestone, the Calcaire des Oies.

The lignitic clay in the Upper Grès des Oies becomes sandier to the north and dies out within 50m of the section just described, to be replaced by soft v.f. sand with c.1% glauconite, containing oysters, Exogyra and Camptonectes. The topmost 0.55m below the Calcaires des Oies consists of 60% fine quartz sand, 20-30% fragments of bivalves, gastropods, serpulids and echinoids up to 2mm long and 10-20% intraclasts up to 3mm long (quartzose micrite and micrite-coated rounded bivalves and gastropods). The sandy facies is known to continue northwards for at least 400m where it reappears in a small inlier surrounded by recent sand-dunes. To the south, about 200m from the above described section with clay, the basal part contains "planks" of lignite 0.2-0.3m long in a lenticular bed of clay which passes up into clayey sand.

South of Wimereux near the Marine Biological Station, the Upper Grès des Oies consists of 4m of soft sand with cross-stratification to the north visible at the base, and with concretions in the upper half. At Cap d'Alprech, south of Boulogne, these beds are again sands and sandstones with cross-strata dipping to the north.

At Pointe de la Rochette, where the channel-like erosion surface exists, there is a conglomerate up to 2m thick resting on the hardground and containing great eroded and bored blocks up

to 1.5m across from the cemented bed (Plate 69/90 & Fig. 115, 119).
The conglomerate is also composed of pebbles of earlier Jurassic rocks (including Kimmeridge Clay) and Palaeozoic rocks such as red, white and pink quartz, Lower Carboniferous limestone and chert, Devonian psammites, Silurian slates and Cambrian quartzites. There are also rolled Portland Group bivalves and gastropods, reptile bones and Isastrea, apparently in position of growth. Above the conglomerate is at least 3m of inaccessible cross-stratified sands and sandstones.

The "Rochette conglomerate" is recorded in a quarry about 1km south-east of Wimille (Fig. 112) where it is 2m thick with the Lower Grès des Oies exposed below and sands above (Rigeaux 1892). It was also seen by the present author in a road-cutting on the N1 about 1km south of Wimille where 1.5-1.6m of pebbles was exposed, with current-deposited trigoniids in the upper part. The conglomerate rests on 1.5+m of hard shelly sandy limestone with ammonites. The top of the conglomerate was covered irregularly by red clay with ironstone known as "Wealdien". The conglomerate is not recorded in other sections at this level elsewhere in the region.

The Rochette conglomerate must be contemporary with the diapiric sediments at Point aux Oies to the north and probably represents a sub-tidal deposit filling a local line or depression on the sea bed parallel to the shoreline. This bed, the overlying cross-stratified sands and the lignitic clays have been in the past interpreted as estuarine and fluvial deposits of distributaries of a river flowing from Belgium and entering the sea at Pointe aux Oies and La Rochette (theories summarised by Lemoine 1911 & Dutertre 1925). But, as Pruvost (1921) and Dutertre (1925) conclude, the Rochette conglomerate is littoral marine because it contains trigonids and corals- the lignitic clays also contain trigoniids.

The pebbles were studied by Barrois (1902) who could find no evidence of a source in the Ardennes or Brabant and concluded that they were locally derived from the Palaeozoic rocks in the neighbourhood of the Pas-de-Calais. Thus the Upper Grès des Oies is a very shallow marine deposit probably with intertidal sands and clays in the north and subtidal (also possibly intertidal) sand-dunes to the south with current direction onshore, northwards. A subtidal slope with a maximum angle of 2° bordered the intertidal zone and was the site of deposition of redistributed land-derived pebbles, together with boulders eroded from the cemented sea-bed. This was then buried by shoreward migration of submarine sand dunes. It is only at the topmost level that non-marine beds occur, although small patches of evaporite-bearing limestone formed just below the top, probably in hypersaline pools above high-water level.

D. The Calcaire des Oies. 0.2-1.3m (Figs. 114, 117)

The Grès des Oies is capped by algal limestones but in places there are beds with ostracods and beds composed almost entirely of the tiny bivalve Eocallista socialis, which is also common at the junction of the Freestone Beds and the basalPurbeck Beds in Dorset.

In the northern part of the outcrop, around Pointe aux Oies, the algal limestone is 0.9-1.3m thick, resting on laminated or bioturbated calcareous sands of the Grès des Oies, although at one point (Fig. 117 B) it thins to only 0.2m. The limestone is tufaceous, consisting of large circular concretionary masses identical to those of the basal Purbeck Beds in Dorset. Pugh (in Ager & Wallace 1966a) identified the bulk of the Calcaire des Oies as being formed by the blue-green alga "Spongiostromata". They form laterally-linked hemispheres (LLH) and concentric stacked hemispheres (SH-C) of Logan et al (1964), as described by Pugh (1968) in the Dorset Lower Purbeck Beds where they are considered to have formed in an intertidal environment about midway between the landward margin and low water mark. The top 0.1-0.15m of the Calcaire des Oies often contains minute bivalves and pisolitic algal debris which rapidly grades up into grey and red clays of the "Wealdien".

South of Wimereux, near to the Marine Biological Station, is 0.5-1.0m of similar algal limestone but partly composed of nothing but whole internal casts of Eocallista forming a bivalve granule conglomeratic limestone. A little further south towards Pointe de la Creche, above the Grès des Oies, there is 1.1m of micrite containing minute bivalves, with 0.2m of clay in the middle part. The limestone contains c.1% v.f. quartz, bivalve fragments and vague indeterminate biochems, occasional superficial ooids and possible shrinkage cracks. This suggests an intertidal environment and the lime mud component probably formed in the presence of algae.

Above Pointe de la Crèche, at this horizon, is recorded 1.8m of limestone, "concretionary" in the lower part, rich in Eocallista in the middle and fine grained above (Rigeaux 1865). The only other locality is just south of Capd'Alprech where there is recorded 1.4m of fine grained concretionary limestone with the base full of ostracods and the top becoming laminated (Rigeaux 1865).

Assuming that the Calcaire des Oies was formed more or less at the same time along this north-south outcrop, the facies variation suggests that the shoreline lay to the north with the greatest development of algal limestones in shallower, intertidal water, and the ostracod and bivalve concentrations forming rapidly in periods of suitable salinity. The numerous small articulated Eocallista suggest rapid burial of a live population, possibly stunted by living in the stress conditions imposed by rapidly fluctuating salinity.

The presence of gypsum pseudomorphs in the Upper Gres des Oies and the hypersaline association of the comparable limestones in Dorset suggest that the Calcaire des Oies formed in non-marine conditions of increased salinity. The absence of ammonites in the Upper Grès des Oies may support this but in view of the presence of trigoniids and Protocardia it is more likely that the shallowness of the sea and turbulent water (cross-stratified sands) were unpleasant for ammonites to live in. They are found in the high-energy carbonate sands of Dorset only at horizons formed in periods of untroubled water.

E. "<u>Wealdien</u>" (?20-30m Arkell 1956)

Grey and red clays rest on the Calcaire des Oies, with an apparently transitional base. There is no marked break at this level despite the strange record of Bonte & Broquet (1962) of "Wealdien" with a basal conglomerate containing green Albian sandstone, Chalk and Chalk flints. (At Le Fart the "Wealdien" of Bonte & Broquet (1962) does contain Chalk pebbles according to Ager and Wallace 1966b).

The clays immediately succeeding the Calcaire des Oies do not contain ostracods according to Arkell (1956) but have a mixture of continental and marine macrofossils according to Dutertre (1925), who recorded <u>Ostrea</u>, "<u>Mytilus</u>", <u>Corbula</u>, <u>Cyrena</u>, <u>Unio</u>, <u>Viviparis</u>, fish and reptile bones. "Wealdien" yellow sands with ironstone layers lie above and cut through these clays as far down as the Grès des Oies at Point aux Oies and near Cap d'Alprech, and as far as the Rochette conglomerate near Wimille.

Allen (1959) found that the "Wealdien" of the Bas Boulonnais was anomalous when compared with the Wealden of England, and Casey & Bristow (1964) propose it is of Middle Purbeck age. It is reasonable to suggest that the Calcaire des Oies may be equivalent to the Upper Part of the Portland Group or Basal Purbeck Beds, and the "Wealdien" clays are a natural continuation of the Lower Purbeck Beds formed in a terrigenous-dominated environment. It is likely that the discordant ferruginous sands are Middle Purbeck in age and represent the Whitchurch Sands - Cinder Bed "event" in England.

The stratigraphic confusion is the inevitable result of fossiliferous marine beds being called Portlandian, non-marine limestones Purbeckian and continental terrigenous deposits Wealden, each with a facies-controlled fauna. The above correlation with Purbeck Beds elsewhere supports the suggestion of Allen (1959) that the Wealden of the Bas Boulonnais is separated in time from that of Southern England.

7. Fauna recorded from the Portland Group of the Bas Boulonnais

Calcaires des Oies ("Purbeckien")

*Eocallista socialis* d'Orbigny
? *Eocallista intermedia* de Loriol
Various ostracods

Grès des Oies

Common: *Laevitrigonia gibbosa* Sowerby (and other species?)
*Myophorella* sp.
*Protocardia dissimilis* Sowerby
*Plagiostoma rustica* Sowerby
*Camptonectes lamellosus* Sowerby

Less common: *Eomiodon cuneatus* Sowerby
*Ostrea blakei* Cox
*Camptonectes suprajurensis* Buvignier
*Corbula autissiodorensis* Cotteau
*Isocardia lettesoni* de Loriol
*Anomia suprajurensis* Buvignier
*Eodonax pellati* de Loriol
*Corbicella unionides* de Loriol
*Eocallista pulchella* de Loriol
*Cyrena pellati* de Loriol
*Mactromya verioti* Buvignier
*Musculus autissiodorensis* Cotteau

*Nucleolites* sp.
*Pseudodiadema Thirriai* Etallon
*Cidaris florigemma* Phillips
*Isastrea* (oblonga? Edwards & Haime)

*Chenopus Beaugrandi* de Loriol
*Procerithium Leblanchi* de Loriol
*Procerithium Manseli* de Loriol
*Procerithium pseudoexcavata* de Loriol
*Ampullospira ceres* de Loriol

*Natica elegans* Sowerby
*Natica pellati* de Loriol
*Nerita Davidsoni* de Loriol
*Nerita sinuosa* Morris
*Nododelphinula vivauxea* Buvignier
*Trochus Morierei* de Loriol
*Littorina bononiensis* de Loriol
*Dentalium pellati* de Loriol

No ammonites in the Upper Grès des Oies

*Titanites giganteus* Buckman
*Glaucolithites gorei* Salfeld
*"Behemoth"* sp.

Also various reptiles and fish remains

Assises de Croi

Common:

*Myophorella* sp.
*Laevitrigonia* sp.
*Isognomon Bouchardi* Oppel
*Ostrea expansa* Sowerby
*Ostrea dubiensis* Contejeau
*Camptonectes lamellosus* Sowerby
*Plagiostoma rustica* Sowerby
*Pleuromya tellina* Agassiz
*Musculus autissiodorensis* Cottean
*Glomerula gordialis* Schlotheim

Less common:

*Thracia* sp.
*Oxytoma octavia* d'Orbigny
*Buchia mosquensis* Buch
*Protocardium morinicum* de Loriol
*Plicatula boisdini* de Loriol
*Pinna constantini* de Loriol
*Barbatia cavata* de Loriol
*Pholadomya rustica* Phillips
*Anomia suprajurensis* Buvignier
*Astarte saemanni* de Loriol
*Eocallista implicata* de Loriol

Mactromya verioti Buvignier
Corbula bayani de Loriol
Natica athleta d'Orbigny
Pleurotomaria sp.

Rhynchonella subvariabilis Davidson
"Terebratula" bononiensis Sauvage & Rigeaux
(="Zeilleria", ?= T. ovoides Sowerby?, = Rouilleria Makridin?)
Discina latissima Sowerby
Lingula ovalis Sowerby

Nucleolites sp.
Pseudodiadema sp.
Cyphosoma sp.
Hemipedina Bouchardi Wright
Hemicidaris sp.
Cidaris Legayi Sauvage
Acrosaline Koenigii Wright

Glaucolithites gorei Salfeld
Progalbanites albani Arkell
and others not satisfactorily known

Tour de Croi Nodule Bed Dutertre 1927

Phosphatised: Pavlovia rotunda
"Pavlovia" pallasioides
and various other perisphinctids with assorted names

Dicroloma sp.
Ampullospira atheta d'Orbigny
Pleurotomaria sp.
"Macrodon"
Various trigoniids
Protocardium morinicum de Loriol
"Goniomya" sp.
"Cyprina portlandica" (=Eocallista sp?)

*Anisocardia* sp.

*Corbicella* sp.

*Lithophaga* sp.

*Lucina* sp.

*Pleuromya tellina* Agassiz

*Pleuromya sinuosa* Roemer

*Corbula* sp.

*Rhynchonella* sp.

"*Terebratula*" sp. ("Zeilleria")

Not Phosphatised: *Exogyra nana* Sowerby

*Plagiostoma boloniensis* de Loriol

"*Chlamys*" sp.

*Oxytoma octavia* d'Orbigny

*Laevitrigonia* sp.

"*Belemnites*" sp.

*Protocardium morinicum* de Loriol

*Ampullospira athleta* d'Orbigny

Also various reptiles and fish bones, Crustacean remains, Cycads, "*Sequoia*", *Pinites*, *Pinus*

## 8. The Portland Group of the Pays de Bray

The Pays de Bray lies between the Bas Boulonnais and Paris, about 100km south of Boulogne (Fig. 1 ). Upper Jurassic strata are brought to the surface in an elongated asymmetrical anticline which runs NW-SE and is partly faulted along the steeply-dipping NE margin. The Portland Group is poorly exposed but has been mapped, in outliers and along the margins of the fold, for about 50km SE from Neufchâtel to Beauvais.

The following description is assimilated from the works of Lemoine (1911, 1912), Thomas (1912-14), Dollfus & Fortin (1928-30), Laffite (1939) and Arkell (1956). The Upper Kimmeridge Beds appear to consist of 40-50m of clays, marls, limestones and calcareous sandstones. The Portland Group consists of 8-10m of yellowish-green fine quartz sands, with lenses of calcareous sandstone up to 2m across and 0.5m thick, possibly with a basal lydite bed (Thomas 1912-14). The sands contain common *Myophorella incurva*, *Laevitrigonia gibbosa*, *Protocardium dissimilis*, *Astarte* sp., *Corbula* sp., *Perna* sp., *Ostrea* sp., *Ampullospira ceres*, *Glaucolithites gorei*, "*Behemoth*", echinoids and silicified wood. This assemblage suggests a correlation with the Lower and Middle Grès des Oies of the Boulonnais.

Discordantly overlying the Portland Group are several metres of supposedly fluviatile coarse ferruginous sands known as Wealden. These have a basal pebble bed which is said to be Purbeckian. A section in the Wealden about 5km SE of Neufchatel, seen in the summer of 1970, showed c.10m of cross-stratified white and yellow lignitic coarse sand with various structures suggestive of a deltaic origin.

The Wealden may be Middle Purbeck in age but the data is so poor that no more can be said except that the sand of the Portland Group and overlying beds indicates that these are marginal deposits.

## 9. Synthesis and Interpretation

Three main phases of shallowing are recognised in the Bas Boulonnais but the correlation of these with those represented in the thicker Dorset successions is uncertain because the ammonite ranges are not precisely known and the sediments do not indicate differences in depth so clearly. However, an attempt at correlation is made which is thought to be more plausible than those of previous authors.

The break at the base of the Portland Group extends further into the Kimmeridge Clay than it does in the South Midlands but more of the albani-zone is preserved, indicating that uplift and non-deposition during Upper Kimmeridge Clay times started earlier on the eastern margin but deposition began again earlier - when the Upper Black Nore Beds were being laid down in Dorset.

Following the phosphatic Tour de Croi nodule bed, the first phase of shallowing is represented by the Assises de Croi. The quartz-sand content and grain size increases from the Lower to the Middle division, which becomes very glauconitic and then passes up into less glauconitic but more calcareous sediments of the Upper division. This is accompanied by an increase in the bivalve content and a change in burrow-type from Rhizocorallium to large Thalassinoides which, according to Ager & Wallace (1970) indicates a rise in environmental energy.

The model of deposition suggested for the Vale of Wardour and the South Midlands can be applied, although terrigenous material entered the basin throughout the deposition of the Portland Group, indicating the proximity of land. The margin of the basin lay to the north-east and the site of the Boulonnais outcrops was nearer to the land than any of the English localities were. Glauconite formed on the mid-shelf in moderately deep water when the deposition rate was slow; lime mud was deposited in slightly shallower, but quiet water nearer the shore.

The second phase started with the influx of fine quartz sand forming the Lower and Middle Grès des Oies. The water shallowed during this phase as indicated by cross-stratification in the Middle division with foresets dipping onshore, and by the presence of large Thalassinoides. The culmination of this phase was the formation of a "hard-ground" probably in the intertidal zone. This phase is correlated with the second phase in England on the presence of Glaucolithites but this does not imply that the start and end were synchronous throughout the Portland Group Basin.

The onset of the third phase is marked by a basal accumulation of pebbles resting on the "hard-ground" and derived from it and from the nearby land. The water was shallow during this phase and sand with small Thalassinoides, ligniticclay and algal limestones developed, the latter indicating intertidal and probably supratidal deposition. As in the South Midlands, the run-off from the land counteracted evaporation and beds of evaporites were not formed.

It is not known whether the change from marine to non-marine sediments took place at the end of the third phase in Dorset or after the minor shallowing half-way through. Considering the proximity of the land it is likely that the change took place earlier than in Dorset which was further from the basin margin, but it is doubtful whether this can ever be fitted precisely into the English successions. The heavy mineral assemblage is meagre and was derived from the Devonian rocks of the nearby land (Neaverson 1925).

The thin succession in the Pays de Bray is poorly known but the overall regression is indicated by sands resting on finer grained sediments and there is probably a break corresponding to the Tour de Croi nodule bed. These rocks were also laid down close to the margin of the Portland Basin, probably on the south-west side (see Chapter 9).

# CHAPTER 8

# THE PORTLAND GROUP
# IN SOUTH-EAST ENGLAND

## 1. Introduction

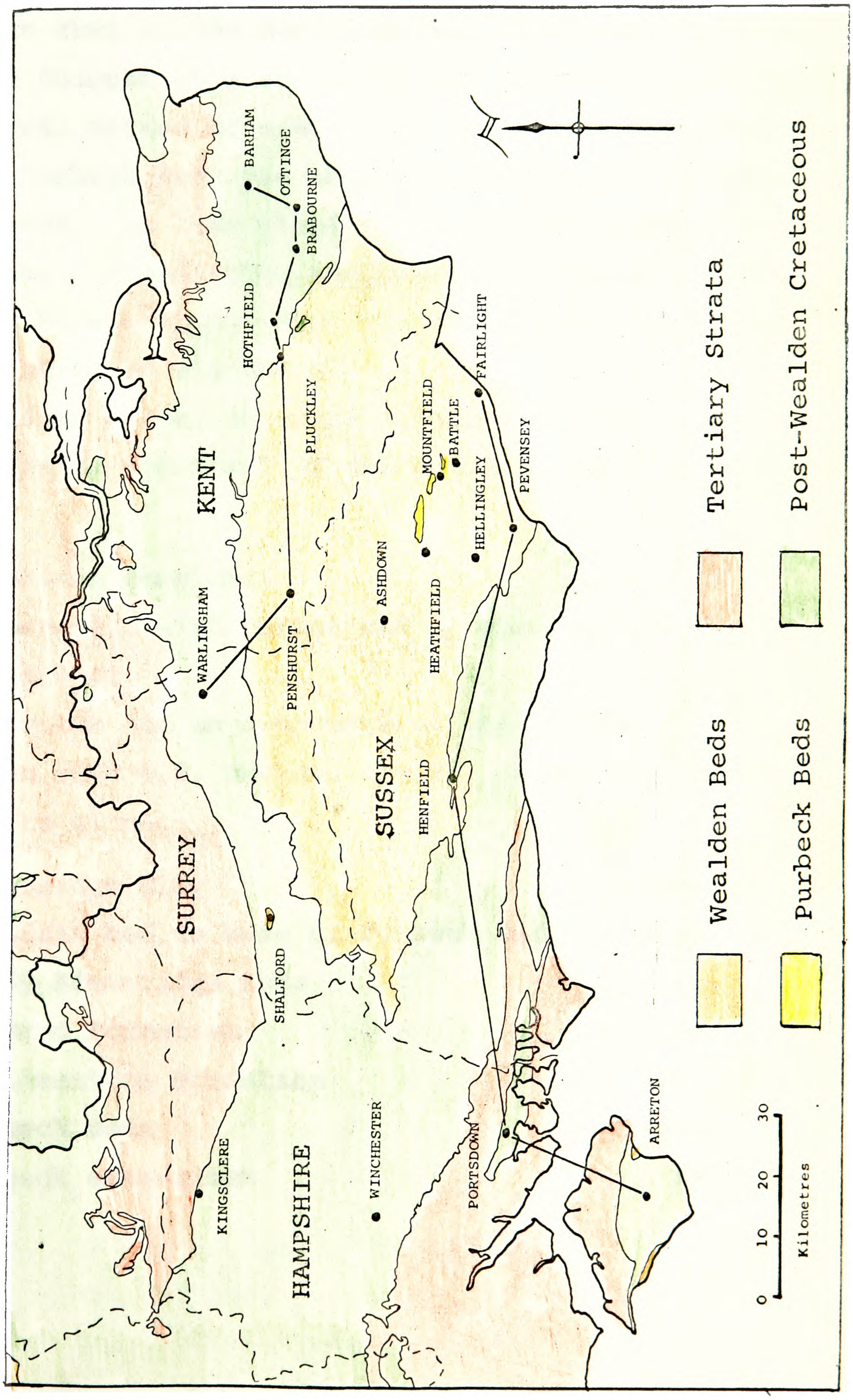
The Portland Group does not reach the surface in South-east England but there are published records of at least two dozen boreholes which penetrated Upper Jurassic strata in Hampshire, Surrey, Sussex and Kent. Most of these were drilled for economic reasons, those in Kent in search of Coal Measures and the others for oil and gas. Three boreholes were put down mainly for scientific reasons.

The amount of information which can be obtained about the subsurface Upper Jurassic varies considerably. Details of the published logs and the amount or rock-samples preserved are often insufficient for satisfactory conclusions to be drawn. However, a large number of specimens from a total of eight widely spaced boreholes were examined and forty-one thin sections made. This has enabled a general, if somewhat hazy, picture to be drawn. It is clear that the Kimmeridge Beds, Portland Group and Purbeck Beds are present but the published time correlations of the junctions between these and within the Portland Group appears often to be arbitrary.

An example of this is the succession in one of the north Kent boreholes (Penshurst, Fig. 118); Lamplugh, Kitchin & Pringle (1923) assign the 50m of sediment between the Kimmeridge Clay and Purbeck Beds to the "Portland Stone Series" and suggest that the "Portland Sands" are missing in South-east England. Taitt & Kent (1958), however, say the 50m is "Portland Sand" and that there is a break at the top throughout the region. The main reasons for these conflicting correlations and the general vagueness about the subsurface Portland Group are firstly that the facies does not vary much vertically or laterally, and secondly that the ammonites are not well enough known. The cores are 0.15-0.025m wide, whereas the ammonites reach 1.0m across with the result that different names and ages are given to different parts of the same fossil.

GENERALISED GEOLOGICAL MAP OF SOUTH-EAST ENGLAND SHOWING LOCALITIES OF BOREHOLES WHICH PENETRATED THE PORTLAND GROUP, AND LINES OF SECTIONS OF FIGS 119, 120, 121

FIG 118



The nature of the data happily forbids the use of elaborate facies classifications; in fact, the whole aspect of this chapter is on a different scale from those concerned with outcrops.

Throughout the region, except for the far eastern part, there is a transition from Kimmeridge Clay mudstones through Sandy Upper Kimmeridge argillaceous silts and sands to the Portland Group of a facies similar to that of the Portland Sand Formation of Dorset. These beds are all thinner than in Dorset and in most places they are capped by several metres of evaporites (anhydrite and gypsum) recorded as Lower Purbeck Beds and succeeded by M. & U. Purbeck Beds and Wealden Beds. In this chapter the Portland Group is not formally divided and the overlying anhydrite and gypsum deposits are called Purbeck Beds although they may be in part equivalent to some of the Portland Group elsewhere.

Several questions arise, to which possible answers are suggested after a brief appraisal of the borehole data. The most important are:-

1. Are the successions complete?
2. How do they correlate with Dorset and by what means, if any, is correlation possible?
3. What were the rates and environments of deposition?

For comparison with S.E. England the following maximum thicknesses in Dorset are given:-

| | | |
|---|---|---|
| Total Kimmeridge Clay | c.480m | |
| <u>rotunda</u> nodule bed to base of Purbeck Beds | c.140m | |
| Upper Sandy Kimmeridge Beds | c. 34m | |
| Portland Sand Formation | c. 40m | c. 78m |
| Portland Limestone Formation | c. 38m | |
| Total Purbeck Beds | c.120m | |
| Lower Purbeck evaporites | c. 9m | |

## 2. Sections

The region is divided into:-

(a) Northern Area

North Hampshire, Surrey and Kent

| | | |
|---|---|---|
| Kingsclere | Penshurst | Ottinge |
| Shalford | Hothfield | Barham |
| Warlingham | Brabourne | |

(b) Southern Area

South Hampshire and Sussex

| | | |
|---|---|---|
| Winchester | Ashdown | Battle |
| Arreton | Hellingley | Pevensey |
| Portsdown | Heathfield | Fairlight |
| Henfield | Mountfield | |

(a) Northern Area

(i) Kingsclere. (Lees & Taitt 1945, IGS core store, Oxford Univ. Museum).

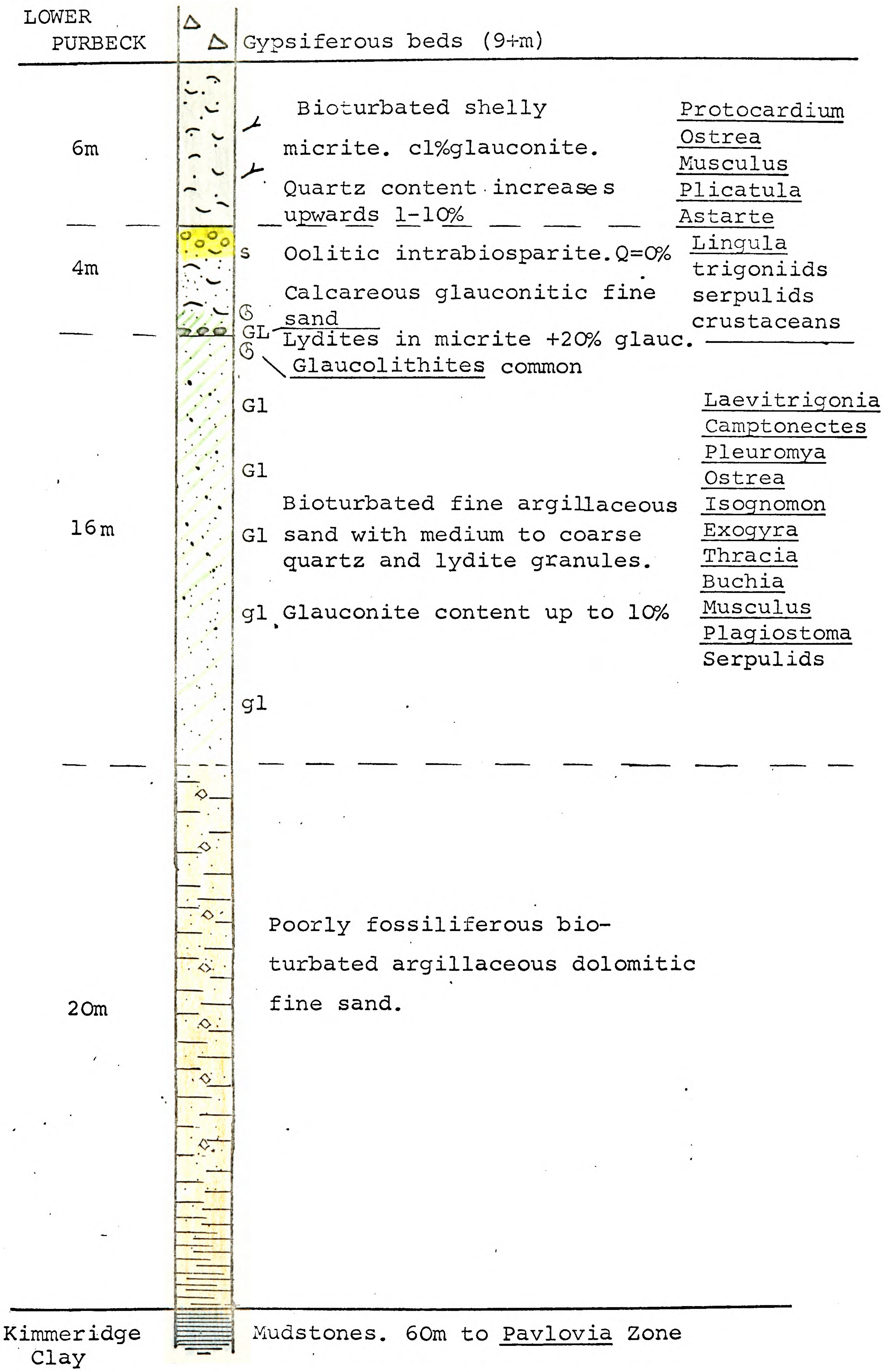
The Kimmeridge Clay is c.280m thick, the Upper Sandy Kimmeridge Beds plus Portland Group totals c.33m and the Purbeck Beds are c.162m thick. The succession from the rotunda-zone of the Kimmeridge Clay to the Purbeck evaporites is c.136m and comprises three phases of sedimentation (Fig. 119).

There was a gradual filling and shallowing of the basin due to a decrease in rate of subsidence; the mudstones above the rotunda-zone pass up into argillaceous dolomitic fine sands and glauconitic argillaceous sand with quartz and lydite granules (Plate 95 ). This was followed by an influx of lydite pebbles and deposition of micritic glauconitic fine sand with a shallow water deposit of intrabiosparite at the top. The final phase started in slightly deeper water and comprises shelly micrite followed by evaporites which may have formed supratidally.

(ii) Shalford. (Falcon & Kent 1960, IGS core store).

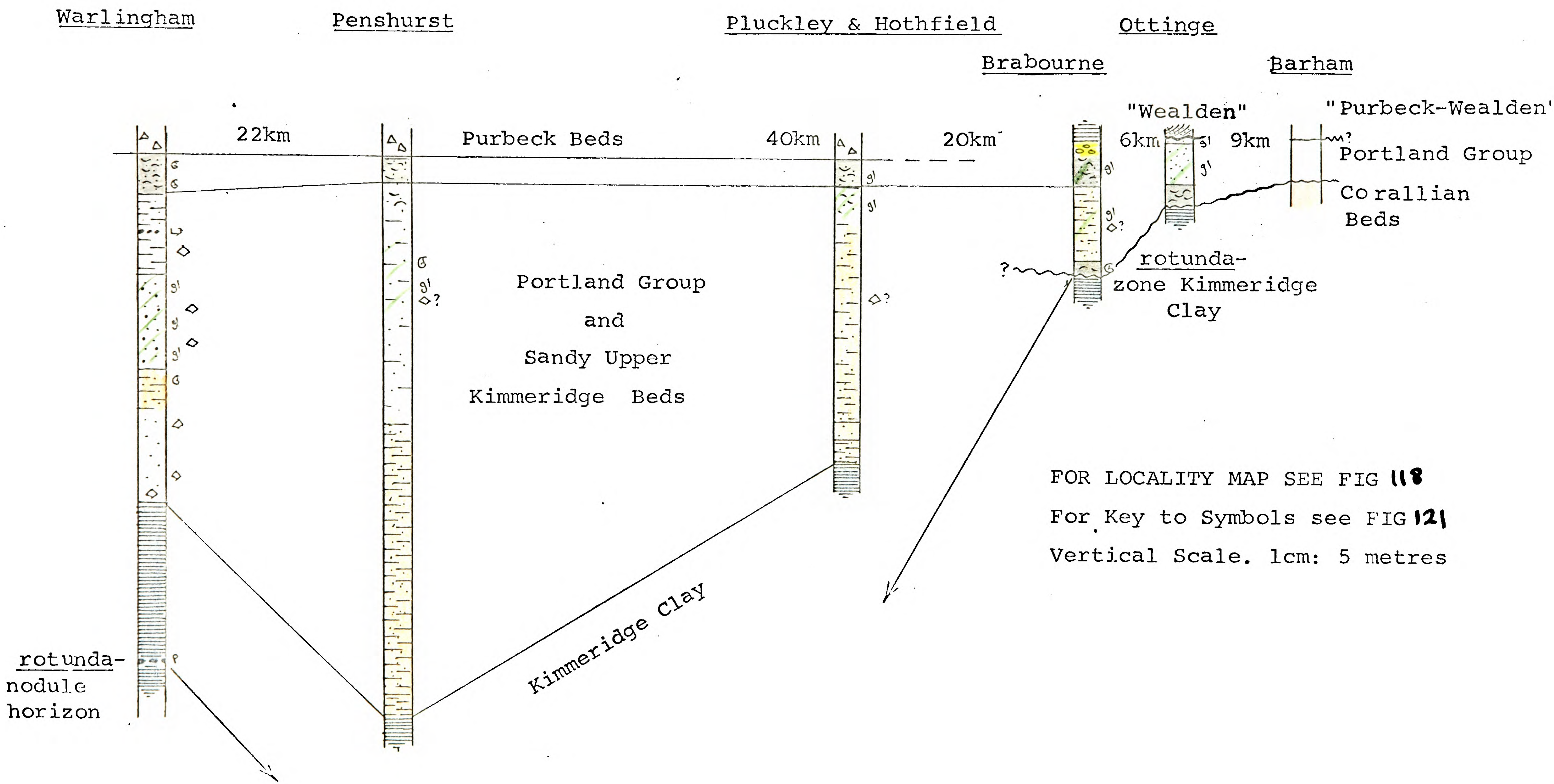
Data is poor but it is known that the total Kimmeridge Clay is c.380m thick, the Sandy Upper Kimmeridge Beds plus Portland Group comprises c. 48m of glauconitic argillaceous sands and there

THE UPPER SANDY KIMMERIDGE BEDS AND PORTLAND GROUP OF THE KINGSCLERE BOREHOLE, HAMPSHIRE. FIG 119



SECTIONS IN THE SANDY UPPER KIMMERIDGE BEDS AND THE PORTLAND GROUP ALONG THE NORTHERN SIDE OF THE WEALD BASIN, SOUTHERN ENGLAND.

FIG 120




FOR LOCALITY MAP SEE FIG 118

For Key to Symbols see FIG 121

Vertical Scale. 1cm: 5 metres

is c.10m of Purbeck evaporites. The junction with the latter consists of shelly calcareous silty sand overlain by laminated limestone and nodular anhydrite.

(iii) Warlingham. (Holmes 1958, IGS core store).

The core from here is well preserved and a detailed study was made. The total thickness of the Kimmeridge Clay is 210m and from the rotunda nodule horizon to the Purbeck evaporites is c.50m, including a lower 12m of mudstones. The beds become dolomitic, sandy and glauconitic upwards and increase in grain size (Fig 120). This again represents a phase of filling and shallowing of the basin. A few metres of finer sediment follows which may be a second phase of deposition. The final sequence starts with a micritic sand with lydite pebbles passing up, with a decrease in sand content, into shelly micrite overlain by beds of nodular anhydrite and gypsum.

(iv) Penshurst, Pluckley and Hothfield. (Lamplugh & Kitchin 1911, Lamplugh, Kitchin & Pringle 1923).

The Portland Group and Sandy Upper Kimmeridge Beds thicken southwards from the London Platform towards the centre of the Weald Basin and thin again to the east where the London Platform passes beneath east Kent. Details of these boreholes are poor but there is a general upward increase in the content of silt, sand, glauconite and probably dolomite. The topmost 2m is shelly quartzose micrite overlain by evaporites (Fig. 120).

(v) Brabourne, Ottinge and Barnham (Ropersole) (Whitaker 1908, Lamplugh & Kitchin 1911).

The Portland Group is thin and has an unconformable base, a situation similar to the South Midlands Area on the northwest side of the London Platform. A Conglomeratic shelly limestone rests on rotunda-zone Kimmeridge Clay at Brabourne and Ottinge; and the beds rest on Corallian strata at Barham (Fig.120). Above the basal shell bed are a few metres of glauconitic argillaceous sands (dolomitic?) followed by quartzose shelly micrite, the top of which at Brabourne is said to be oolitic, followed by Purbeck limestones and "shales" but no evaporites. At Ottinge cross-stratified Wealden sands rest on the Portland Group and at Barham the overlying beds are termed "Purbeck-Wealden".

(b) Southern Area

(i) Winchester. (Wilson 1965).

Details are scanty but c.78m of sands and sandy limestones are recorded above Kimmeridge Clay mudstones. About 12.5m from the Purbeck Beds is a layer of lydite pebbles and fine grained dolomites with empty moulds occur near the top. The latter facies is similar to the Black Dolomite Beds of Dorset (Facies B).

(ii) Arreton. (Wilson 1965, Falcon & Kent 1960).

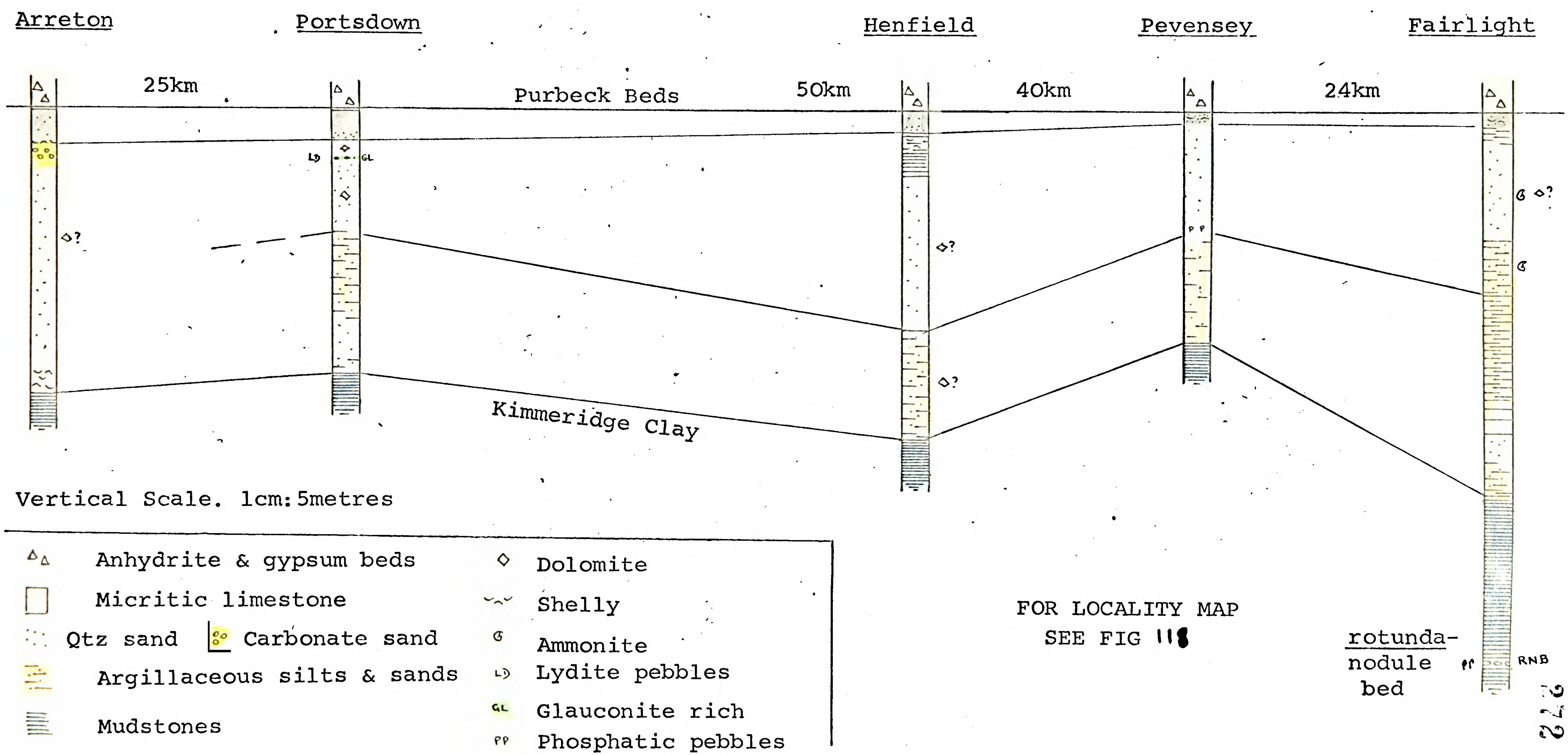
The total Kimmeridge Clay is 332m thick and is overlain by c.26m of beds before a Purbeck evaporite sequence (Fig. 121). The base of the Portland Group is shelly and passes up into very fine glauconitic calcareous sands (+ dolomite?) capped by a bed of superficial oosparite and oomicrite with nuclei of quartz and glauconite. This represents a sequence which was formed in water which progressively shallowed until an agitated zone was reached. Between this and Purbeck anhydrite is a few metres of fine micritic sandy limestone with the sand content decreasing upwards, containing scattered Rhaxella casts throughout and many serpulids at the top. This second sequence represents another shallowing phase.

(iii) Portsdown. (Taitt & Kent 1958, IGS core store).

The thickness from the Saccocoma-horizon in the Upper Kimmeridge Clay (Wheatleyensis zone) to the Purbeck evaporites is about half that in Dorset and the Sandy Upper Kimmeridge Beds plus Portland Group is c.24m thick. There is one main phase of shallowing from Kimmeridge Clay mudstones upwards shown by an increase in silt and sand content. These are followed by argillaceous dolomite with occasional Rhaxella moulds passing up into argillaceous calcareous dolomite with some medium quartz sand (Plate 96). The next few metres before the evaporites has a basal glauconitic lydite bed with coarse quartz grains passing up into dolomite with 1-5% quartz. This is succeeded by shelly micrite

SECTIONS IN THE SANDY UPPER KIMMERIDGE BEDS AND THE PORTLAND GROUP ALONG THE SOUTH SIDE OF THE WEALD BASIN, SOUTHERN ENGLAND.

FIG 121



with a decrease in quartz content upwards from 10% and with scatteredlydites at its base.

(iv) Henfield. (Taitt & Kent 1958, IGS core store).

The total thickness from the rotunda nodule horizon to the Purbeck Beds is c.50m and the Sandy Upper Kimmeridge Beds plus Portland Group is c.29m thick. The usual shallowing phase takes up most of the thickness and consists of mudstones passing up into argillaceous silts, calcareous argillaceous sands (+ dolomite?) and calcareous mudstones with thin limestone beds. The second phase consists of a couple of metres of shelly micrite with 40% quartz sand at the base and is overlain by several metres of anhydrite.

(v) Ashdown. (Falcon & Kent 1960).

The total Kimmeridge Clay is c.500m (a little more than in Dorset), the Sandy Upper Kimmeridge Beds plus Portland Group is c.21m (?) and the Purbeck Beds total c.160m (c.130% that in Dorset). From the Purbeck Beds to the Pavlovia-zone is c.50m.

(vi) Hellingley (Grove Hill) and Heathfield. (Wilson 1965)

No details are known other than the Sandy Upper Kimmeridge Beds plus Portland Group are c.24m thick at Hellingley and c.28m at Heathfield.

(vii) Mountfield. (Woodward 1895, Whitaker & Reid 1899, Falcon & Kent 1960, Wilson 1965).

At least four boreholes have been drilled in this area and these show that the Kimmeridge Clay totals c.387m thick, the Sandy Upper Kimmeridge Beds plus Portland Group is 31-33m and the Purbeck Beds are c.116m thick. Details are poor and the descriptions by Whitaker & Reid of two adjacent boreholes show few features in common, and the account by Woodward of one of these differs from that of the same core by Whitaker & Reid.

There is the usual shallowing, coarsening-upwards sequence from Kimmeridge Clay mudstones into silty clays and sands. One log records "much chert" (lydite?) in sandy clay c.6m above the Kimmeridge Clay and more in a calcareous sand c.11m above.

Overlying this is c.10m of sandy clay which may represent the start of a second depositional phase. It passes up into c.6m of argillaceous glauconitic sand with lydites, overlain by c.15m of gypsum beds with a thin bituminous clay at the base.

(viii) Battle (Lamplugh 1917).

This was about 5km ESE of the Mountfield borehole just described. The Kimmeridge Clay is c.335m thick, the Sandy Upper Kimmeridge Beds plus Portland Group is c.42m (or less?) and the Purbeck Beds are c.116m with c.14m of gypsum beds at the base. The usual shallowing sequence occurs with sands in the upper part.

(ix) Pevensey (Hankham) (Lees & Kent 1945, IGS core store).

This reached only the top of the Kimmeridge Clay but the Sandy Upper Kimmeridge Beds plus Portland Group are c.21m thick and the Purbeck Beds are c.70m with a basal c.14m of evaporites (Fig. 121). Details are poor but the succession becomes silty and sandy upward and there is a layer of "phosphatic pebbles" 10.8m below the Purbeck Beds. The topmost metre is shelly quartzose micrite with 40-50% quartz sand.

(x) Fairlight (IGS core store).

This borehole was completed in 1970 and details are not published. Examination of the core shows that the thickness from the phosphatic rotunda nodule bed (no lydites) to the basal Purbeck evaporites is c.50m. The Sandy Upper Kimmeridge Beds plus Portland Group is c.36m thick and is overlain by c.150m of Purbeck Beds. There are possibly two phases of deposition, the lower one consisting of mudstones passing up into sandy mud and fine sand with a couple of metres of nodular micrite at the top. The upper phase comprises mudstones and silty mudstones with numerous thin limestone beds and nodules passing up into silty mudstones and bioturbated laminated silts. The upper 2-3m consists of muddy silts with a topmost bed of hard shelly calcareous sandstone. A possible thin algal mat limestone occurs between this and the Purbeck nodular anhydrite and gypsum. All the muddy silts and sands resemble those which proved to contain dolomite in other boreholes.

3. Summary of the Data

Isopachyte maps of the total thickness of the Jurassic strata show that maximum subsidence in Southern England was in two regions; (a) between Dorset and the Isle of Wight; (b) in northern East Sussex (King 1954, Howitt 1964, Terris & Bullerwell 1965). This is also true for the Kimmeridge Clay which is at its thickest at Ashdown. The thickness from the *rotunda*-horizon to the Purbeck Beds is approximately constant from north to south across the Weald but increases towards Dorset. The *rotunda*-horizon marks a very widespread decrease in the rate of deposition and occurs in the Bas Boulonnais, the Weald, Dorset, beneath the English Channel south of the Isle of Purbeck (Larsonneur & Rioult 1969) and in the South Midlands. Deposition ceased in the marginal areas but continued in the Dorset and Weald Basins. In the latter region the Sandy Upper Kimmeridge Beds plus Portland Group thicken towards the centre and thin less rapidly southwards than in the north, assuming the extreme thinning and breaks in deposition seen at the margin of the basin in east Kent continue westwards round the London Platform.

There is a transition upwards from mudstones to argillaceous silts and sands everywhere in the basin except on the east Kent margin. This main phase of coarsening upwards accounts for most of the thickness of the beds referred to as Sandy Upper Kimmeridge plus Portland Group. These beds are similar to those in Dorset in consisting of alternations of relatively hard and soft horizons, the bioturbated sediment being originally a laminated mixture of clay, dolomite, calcite and v.f.-m. quartz sand, at times with glauconite. The fauna is usually poorly preserved and similar to that of the Portland Sand Formation of Dorset although no fossils are particularly diagnostic of age. The following are known from the major shallowing phase:-
*Thracia*, *Myophorella*, *Laevitrigonia*, *Ostrea*, *Exogyra*, *Musculus*, *Camptonectes*, *Isognomon*, *Plagiostoma*, *Buchia*, *Rhynchonella*, inarticulate brachiopods, *Glomerula*, *Glaucolithites*, virgatotome and pavlovid ammonites.

This depositional sequence is considered to have been laid down in Southeast England at the same time as the beds up to and including the Exogyra Beds of the Portland Sand Formation in Dorset. This correlation conveniently brings the lydite horizons at Portsdown, Kingsclere and possibly Warlingham into line with the Basal Pebble Bed of the South Midlands. The oolitic limestone at Arreton on the eastern margin of the Dorset Basin may represent an even shallower deposit than the carbonate facies of the Exogyra Beds in the West, Mainland, Dorset Area .

After the main shallowing period, one or two minor phases follow before evaporite deposition. These may be correlated in time with the deposits which succeed the Exogyra Beds in Dorset and which are considered to have been laid down in two stages of decreasing water depth. These are:

1. Cast Beds, Black Dolomite Beds, Lower Cherty Beds.
2. Upper Cherty Beds, Freestone Beds.

The only place where two minor phases of shallowing occur in S.E. England is at Kingsclere towards the western margin of deposition, mid-way between the Vale of Wardour and the Oxford District. The latter two regions also comprise two shallowing stages following a lydite pebble bed which is correlated with the Exogyra Beds of Dorset.

The other basinal subsurface successions have one thin shallowing sequence of sandy micrite followed by calcium sulphate deposits. The marginal successions in east Kent also comprise one shallowing sequence but whether the basal break represents only the Exogyra Beds and below, or also includes the next phase is not known.

The fauna of these thinner, upper beds are again diagnostic of facies rather than age. The following are often recorded:- Thracia, Myophorella, Laevitrigonia, Pleuromya, Protocardium, Astarte, Ostrea, Exogyra, Plicatula, Musculus, Falcymytilus, Isognomon, Camptonectes, Rhynchonellids, Glomerula, Glaucolithites, "Behemoth" (=Glaucolithites?), echinoid debris and crustacean fragments.

To suggest possible answers to the questions put at the start of this chapter one has to descend to the level of hopefully intelligent guesses with the aid of intuition but often "geology has to choose between the rashness of using imperfect evidence or the sterility of uncorrelated, unexplained facts" (Gregory). With borehole data even the use of the word "fact" may be dubious.

With the exception of the extreme east of Kent there is no evidence of an erosional break in the succession. Although the concentration of glauconite and lydite pebbles indicates slow deposition there are no really condensed phosphatic beds analogous to that of the rotunda-zone of the Kimmeridge Clay. The junction with the Purbeck Beds appears concordant and the evaporites are part of the final shallowing phase, although the absence of intermediate beds of high-energy carbonate sands and relatively thick algal limestones are a contrast with the Dorset Area. Thus in answer to the first question, the successions are probably complete, albeit slowly deposited.

Correlation with Dorset by means of ammonites is only broadly possible in that faunas of the Upper Kimmeridge Clay, Upper Sandy Kimmeridge Beds plus Portland Group have been recognised, but refined correlation within the upper part of the subsurface sequences is not satisfactory because the relationship of Glaucolithites to ammonites of higher beds is not known and this genus may range even to the base of the Purbeck Beds. It is felt that the only way possible to suggest any form of correlation is to use "events" which are sufficiently widespread in effect to be recognisable from one basin to the next. The general phases of deepening and shallowing are regarded here as such events, although it is readily accepted that boundaries between them may be slightly diachronous. Using this method the following correlations with Dorset are suggested:

1. The culmination of the main phase of shallowing equates with the Exogyra Beds.
2. The second, minor, phase correlates with the Cast Beds, Black Dolomite Beds and Lower Cherty Beds.
3. Part of the "Purbeck" evaporites, and the third phase at Kingsclere, correlates with the Upper Cherty Beds and Freestone Beds of Dorset.

These statements are thought to approximate to the truth for the following reasons:-

a) There is no visible discontinuity between the Purbeck Beds and Portland Group.

b) The evaporites fit in as part of a shallowing phase.

c) The number of shallowing phases below the Purbeck Beds and the Kimmeridge Clay is less than in Dorset.

d) The Kimmeridge Clay, Sandy Upper Kimmeridge Beds plus Portland Group are generally all thinner than in Dorset whereas the Purbeck Beds are often thicker.

The first part of the final question has already been partially answered. To summarise: subsidence rate decreased at the end of Upper Kimmeridge Clay times causing the Weald Basin to slowly fill and the water to become shallower. The rate of subsidence remained slow, water depth fluctuated a little and finally calcareous sediments and evaporites were deposited. The latter are moderately thick and widely distributed suggesting that the rates of subsidence and deposition were approximately the same.

It is difficult not to be vague about the environments of deposition of the beds dealt with in this chapter. The dolomitic argillaceous sands are considered in Dorset to have been laid down in relatively deep water away from the basin margin and the same picture applies in the Weald. The glauconitic sands probably formed on the middle of the shelf shoreward of the argillaceous silts. The lydite beds represent phases of influx of multicycled Palaeozoic material derived from earlier Jurassic strata eroded during uplift of the basin margins.

The shelly sandy limestones formed in shallower water which was sufficiently protected from high energy events for lime mud to be deposited. The situation in the far easterly part of Kent was similar to that in the South Midlands with an unconformable base, no evaporites and erosive younger beds above. The "Wealden" of Ottinge (Whitaker 1908) may be the same as the Middle Purbeck Whitchurch Sands, a shallow water deposit equivalent to the Cinder Bed of Dorset, also represented in the Weald Basin.

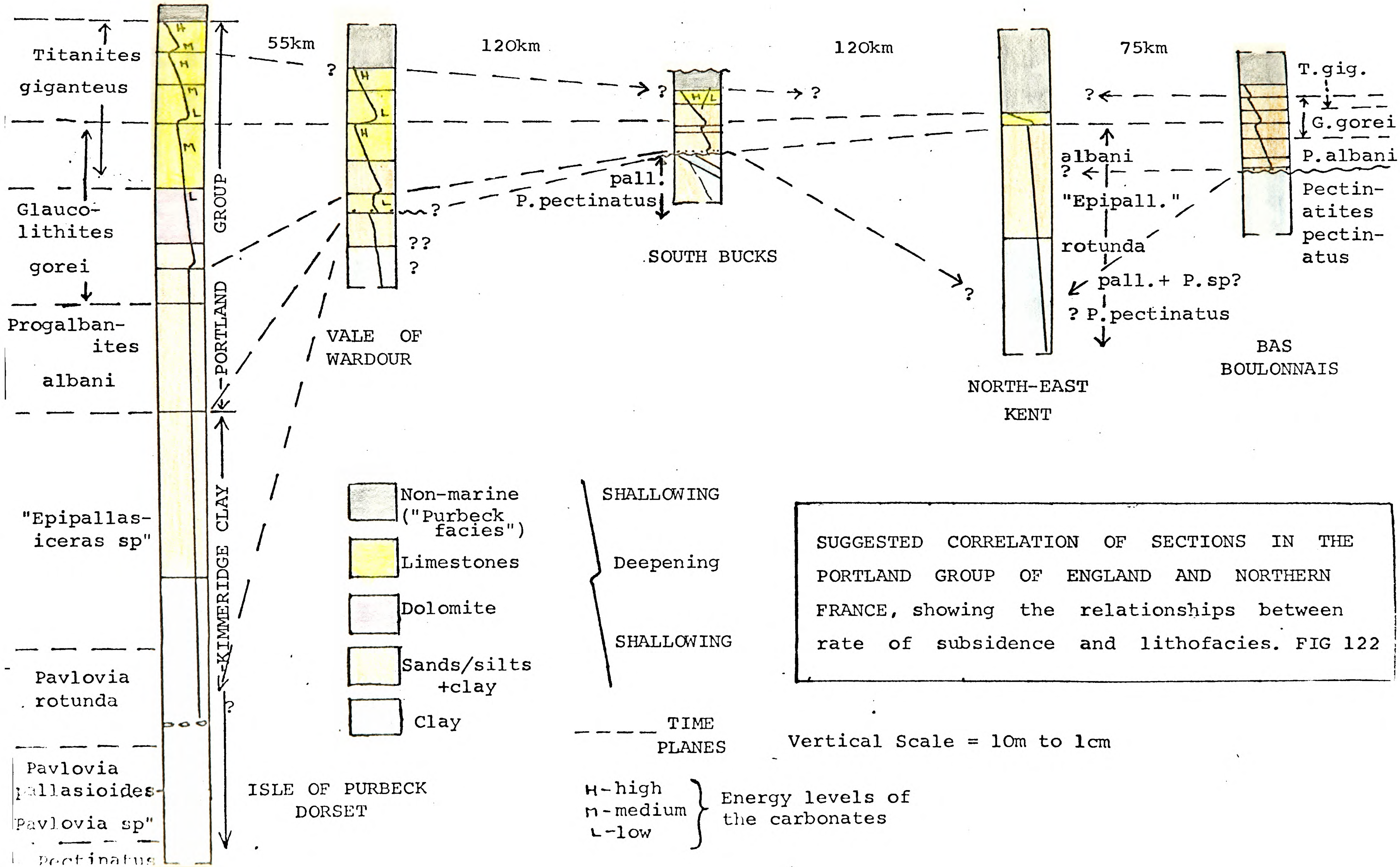
Nodular anhydrite deposits are popularly regarded as supratidal in origin and those of the Warlingham borehole have been compared with sabhka sediments by Shearman (1966). The Lower Purbeck evaporites in Dorset do not have all the features of recent supratidal evaporites and there is only one convincing sabhka horizon above the basal algal limestones. One significant difference is the absence of dolomite (West 1964, 1965). Few people would agree that anhydrite-gypsum deposits are all undoubtedly supratidal in origin and it is felt that the Lower Purbeck evaporites of Dorset and the Weald merit further investigation to ascertain their environment of deposition.

# CHAPTER 9

# OVERALL CONCLUSIONS

Most of the detailed interpretations are given within the previous chapters and this is only a short summary bringing the conclusions together. After several attempts had been made at drawing conservative and liberal palaeogeographical maps for various periods of time it was found that the degree of subjectivity required removed the results from the confines of science to the realms of fantasy. It is not clear, for example, whether Brittany, South-east England, Wales, the Pennines, Scotland and Ireland were land or sea during the deposition of the Portland Group, nor is it known whether the successions truncated by unconformable younger strata were ever once complete. Biostratigraphical correlation over an area as large as Northern Europe is unsatisfactory because the ammonites are parochial in distribution and poorly documented which has rendered the literature a confusing mass of misconception. Until a detailed system of correlation with the rest of Europe is established it is safest to restrict discussion to the Basin in which the Portland Group is known to have been deposited. A broad time correlation is made using postulated widespread changes in sea level, supported by ammonite distribution wherever possible. (Fig 122)

The geological history of North-west Europe during the uppermost stages of the Jurassic is one of overall fall in sea level. The succession from the Kimmeridge Clay to the base of the Cretaceous contains progressively shallower water deposits culminating in continental strata and non-deposition in many regions. Superimposed on this is the effect of varying regional and local rates of subsidence producing major and minor basins and swells which resulted in variation in thickness and facies across the the area of deposition. More rapid facies variation is due to the influence of terrigenous material and freshwater entering the marginal areas. The distribution of the fauna and flora is controlled by all the above factors superimposed on the overall regression which produced land barriers in the later stages of emergence. Despite this, the differences between the bivalve faunas of the Volgian, Portlandian and Tithonian "provinces" are less pronounced than generally believed (See Appendix).




SUGGESTED CORRELATION OF SECTIONS IN THE PORTLAND GROUP OF ENGLAND AND NORTHERN FRANCE, showing the relationships between rate of subsidence and lithofacies. FIG 122

During the lower part of Upper Kimmeridge times the sea was widespread and clay was deposited in relatively deep water in Southern and Eastern England. Interfingering littoral sands occur in the South Midlands and the Bas Boulonnais which indicates proximity of land. As the regression continued, the area of the basin decreased and the margins were uplifted resulting in a break in the South Midlands, east Kent and the Bas Boulonnais before deposition of the Portland Group. In the parts of the basin which continued to subside, silt and sand were deposited and the Sandy Upper Kimmeridge Beds were laid down in Dorset and the Weald. This phase of shallowing sedimentation took place between the zones of Pavlovia rotunda and Progalbanites albani and set the scene for the deposition of limestones and sands during the succeeding zones of Glaucolithites gorei and Titanites giganteus.

The albani-zone defines the base of the Portland Group (see Chapter 1) and the ammonite ranges up to the base of the Exogyra Beds in Dorset. Thus the lowest beds of the Portland Group are the highest part of a major shallowing phase which began in the Upper Kimmeridge Clay. This first phase includes the lower part of the gorei-zone and culminates in the deposition of the Exogyra Beds in Dorset and the Vale of Wardour, the Basal Pebble Bed of the South Midlands, the Tour de Croi Nodule Bed and the Assises de Croi in the Boulonnais. During the albani-zone, glauconitic quartz sand was deposited on the marginal mid-shelf areas (west Dorset, Boulonnais) and calcareous silty clay accumulated in the basins (east Dorset, Weald). The lime mud in the basins was dolomitised, probably by the action of magnesium-enriched sea water within an anaerobic sea bed. The high Mg/Ca ratio is thought to have resulted from evaporation in very shallow water bordering the land, where beds of a "Lower Purbeck facies" were deposited but are no longer preserved.

During the final part of this first shallowing phase (in the lower part of the gorei-zone), quartzose lime mud was deposited on the shelf away from the influence of rivers (West Dorset, Vale of Wardour) and a diverse fauna of bivalves and sometimes sponges developed. Where the water was shallow, superficial ooids formed on quartz grains (Arreton, Isle of Wight). In the South Midlands and parts of South-East England, where deposition was slow and the sediment is glauconitic, Palaeozoic pebbles were added by rivers presumably draining the north Midlands and the London Platform which was probably land with the coast-line just touching east Kent and the Thames estuary. In East Dorset, where the basin subsided at approximately the same rate as the sea level fell, fluctuations about the "critical level" of dolomitisation resulted in repeated deposition of Exogyra beds. In the Boulonnais lime mud, clay and quartz sand were deposited on the shelf near to a supply of terrigenous sediment.

After a slight deepening of the water throughout the Portland Group Basin, the second major phase of shallowing began. Its end appears to coincide with the top of the gorei-zone but it is likely that the range of this ammonite and that of Titanites giganteus overlap; the junction between the two zones has not been precisely defined at any locality. Dorset was further from land than other Areas and, as the water shallowed, the influence of terrigenous sediment decreased; only clay and lime mud was deposited in the basin and the calcium carbonate was dolomitised. The swell area, which had previously controlled only the thickness of the accumulated sediments, began to influence the facies. As the sea level dropped, the ratio of the water depth over the swell to that over the basins increased and the swell area became colonised by bivalves and sponges before the more rapidly subsiding basins. In the regions nearer to land (Wardour, South Midlands and Boulonnais) glauconitic quartz sands were deposited which became coarser and more calcareous upwards. In South-east England thin beds of shelly quartzose lime mud were laid down and these pass up into evaporite deposits.

At the shallowest point of this phase, fine shell sand and lime mud were deposited in the East Basin of Dorset and high energy medium to coarse shell sand formed submarine dunes in the Vale of Wardour. An intraclastic shell sand appears in North-west Hampshire (Kingsclere) and an oolite is recorded in North-east Kent (Barham). In the Boulonnais, shelly fine to medium quartz sand was laid down indicating proximity to land and during the shallowest period the sea bed was eroded and lithified.

Deposition was slow in the South Midlands and shelly lime mud was deposited with a variable amount of fine to medium quartz sand, as in South-east England.

Following this second phase the sea once more deepened slightly before continuing its overall shallowing. From this time on (the period of the Titanites-zone) the sea became very shallow and as a result, the facies changed rapidly in space and time. Within this third phase, correlation by "events" becomes more difficult. It appears that over most of South-east England, the second phase ended with supratidal (?) deposition of evaporites. This interpretation of the borehole sequences accounts for the absence of the Titanites-zone and eliminates the "widespread break" suggested by Taitt and Kent (1958); the basal Purbeck Beds of the Weald were deposited at the same time as the Upper Cherty Beds and Freestone Beds in Dorset.

The third and final phase in Dorset and the Vale of Wardour commenced with deposition of lime mud in quiet, relatively deep, water on the shelf. As the depth decreased, turbulence increased with the result that biochem and ooid sand-bodies developed on the edge of the shallow carbonate shelf in the Vale of Wardour and on the swell in Dorset. In the South Midlands, quartz sand was laid down and this coarsens upwards and passes into shell sand and lime mud. In the Boulonnais locally derived pebbles and boulders, quartz sand, lignitic clay and algal limestones were deposited littorally and are overlain by non-marine clay.

It is probable that the end of marine deposition in the Vale of Wardour, the South Midlands and the Boulonnais occurred following the deposition of the Lower Freestone Beds of East Dorset. The latter area was always the site of maximum subsidence and was further from the land, therefore it is likely that marine conditions persisted in Dorset longer than in the marginal areas. The facies sequence from the Upper Cherty Beds to the Lower Freestone Beds is repeated in Upper Freestone Beds which finally pass up into non-marine basal Purbeck Beds. It is suggested that the third major phase of shallowing took place in two stages and it was only in Dorset that marine sedimentation persisted throughout.

The most interesting aspect of this work has been the description and interpretation of the swell in Dorset. This ridge of minimal subsidence played an important part in the development of the Portland Limestone Formation. By a combination of chance preservation and exposure of the succession in Dorset these beds have come to be regarded as typical deposits with which those of the Portland Group elsewhere are to be compared. It is, however, mainly due to the swell that the economic carbonate grainstones developed and thus they are the exception rather than the rule. In a simplified fashion, it has been possible to erect microfacies and to give these a hydrodynamic interpretation. The sediments are directly comparable with those of the carbonate environments in the Bahamas, Florida and the Persian Gulf (Kendall & Skipwith 1969).

It may be significant that the swell lies in the region of the Weymouth-Purbeck Anticline. It has been suggested by Lees & Cox (1937) that the underlying cause of the folds in Dorset is the presence of salt domes derived from Triassic or Permian beds. If the monoclinal folding in Dorset is due to draping of the Mesozoic rocks over a fault in the basement, as might be the case in the Isle of Wight (White 1948), then halokinetic movement could have taken place along the line of disturbance. It is possible, therefore, that the swell in the Dorset Basin is due to domes or a ridge of salt which controlled sedimentation during the uppermost Jurassic times.

# APPENDIX

## 1. Measurements of fossils

(a) Study of a bedding plane in the Exogyra Beds at Gad Cliff West.

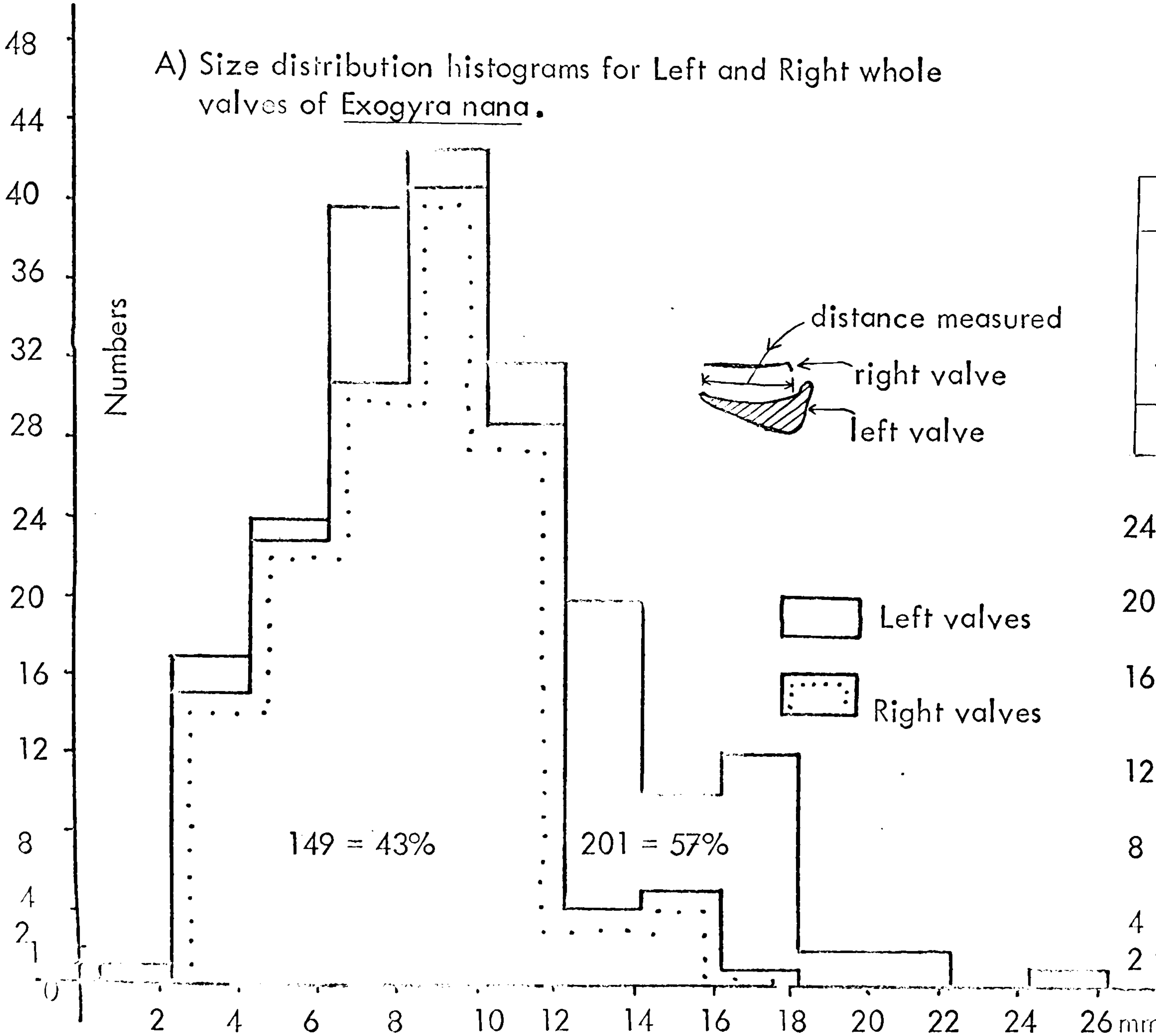
Exogyra Bed J was examined in detail on a clean bedding plane at the far western end of Gad Cliff and a size-frequency study was made of the *Exogyra* shells on an area of one square metre. The shells were nearly always disarticulated but the right and left valves were not moved far and could often be found a few centimetres apart and matched. There were a few "nests" with *Exogyra* from 4-20mm long cemented together in life position and with more than one generation preserved. It is normal for valves to separate after death due to decay of the muscles and ligaments, and a high proportion of shells with valves closed would indicate that they were suddenly buried alive. This obviously is not the case here as only 1-2% had their valves together (Fig. 123). With the asymmetrical shell of *Exogyra* the thin right "lid" valve would be more easily moved than the thick, left "basal" valve which was half sunk into, or cemented to, the substrate.

If currents had selectively transported one of the valves then the size-frequency histograms for each valve would not coincide. The close similarity of the histograms here suggests that this is not the case, in spite of the lower number of right valves, especially in the 12-26mm range (Fig. 123A). This lower value is due to two reasons: one is an operator sampling deficiency which accounts for there being only 149 right valves instead of 201 (a difference of 26%). This is due to the thin flat right valves having a lower chance of being exposed on a two-dimensional surface than the thick angular bulky left valves. The second reason, which probably accounts for there being only 10 right valves in the 12-26mm range instead of 47 (a difference of 79%), is that the larger right valves were easier to fragment than the smaller ones because they have a higher surface to thickness ratio.

PORTLAND SAND FORMATION. EAST AREA DORSET. ISLE OF PURBECK, WEST. GAD CLIFF.

EXOGYRA BED No. J. Biometric study of 1sq.m. of bedding plane.

FIG. 123




Whole valves = 360. Articulated specimens = 1-2%.

Fragmented valves = c.400. Disarticulated specimens = 98-99%.

| Orientation | Left valve | Right valve | Total % |
|---|---|---|---|
| Right way up | 28 | 17 | 45 |
| Upside down | 16 } 28 | 14 } 27 | 30 } 55 |
| Vertical | 12 | 13 | 25 |
| Total % | 56 | 44 | 100 |

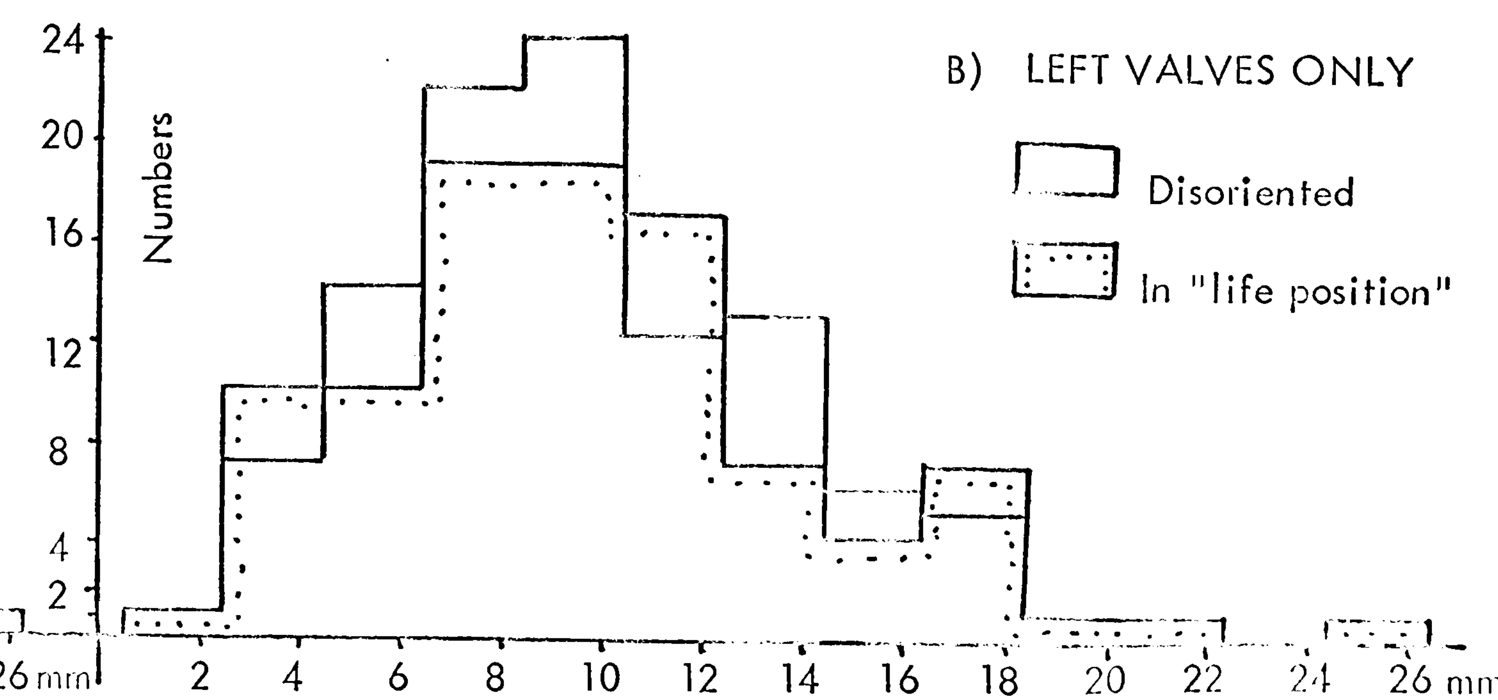
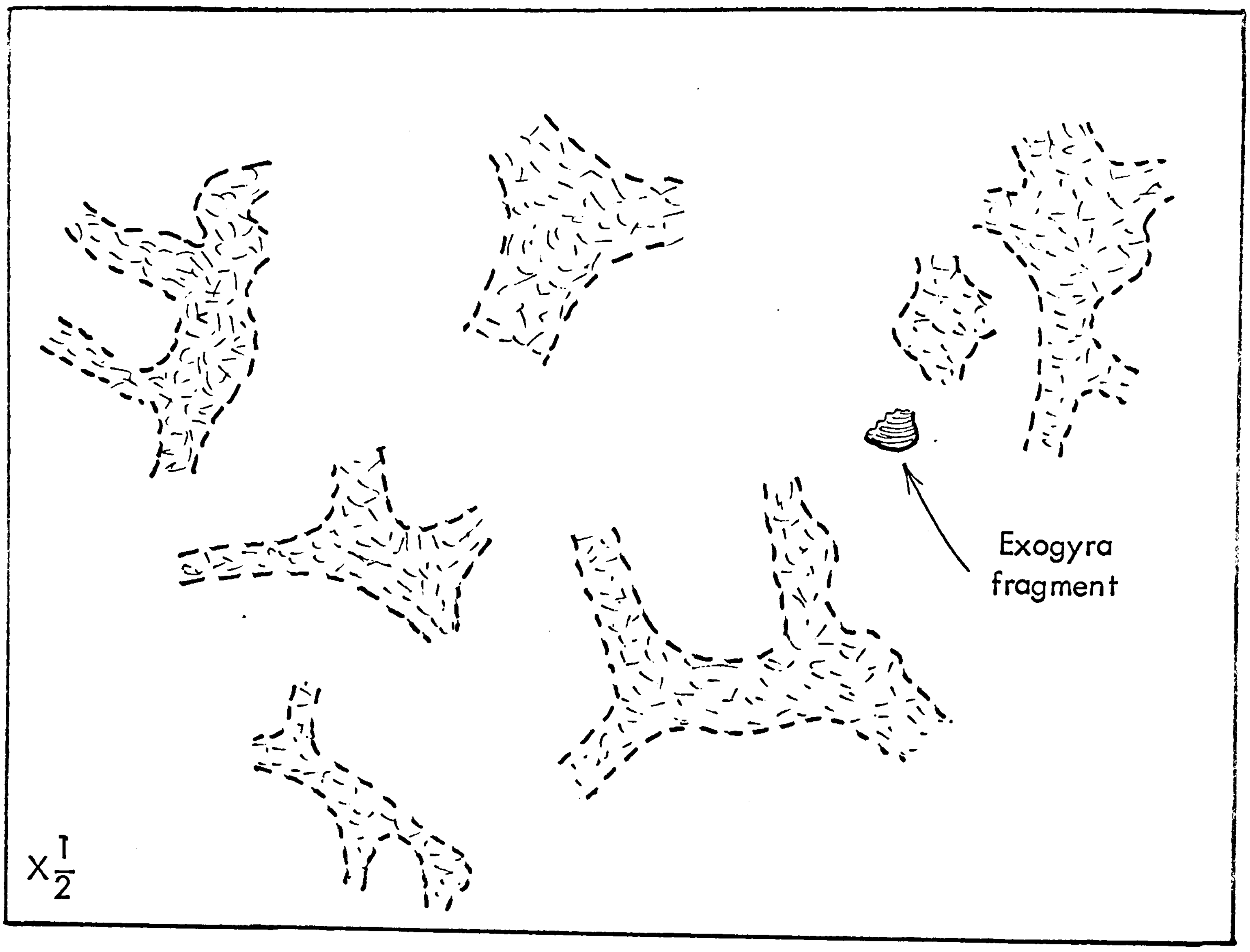


FIG. 124




BEDDING PLANE, EXOGYRA BED J. GAD CLIFF. PURBECK WEST.

Thalassinoides? Burrows filled with Exogyra fragments.

Valve orientation is often considered to be significant in deciding if an accumulation of shells is current deposited. A high proportion of valves concave downwards indicates current action which placed them in a stable position, and a closely packed, random orientation is typical of shell beds deposited by storm action. The latter case does not apply here because the Exogyra valves were not closely packed, there being only 350 on one square metre of bedding plane. The orientation of the flat right valve is not significant due to its shape but the left valves are sufficiently concave-convex to have stable and unstable positions. Fifty per cent of these were concave up (life position) and of the disoriented valves, only 57% were concave down, the rest being vertical. Thirteen per cent of all the right valves were also in a vertical position (Fig. 123).

If disorientation of the left valves was due to current action and some had been transported away from the sample area, it might be expected that the size frequency histogram for the disoriented ones would not coincide with that for those in "life position". However, this is not the case here, as not only is the number of concave-up left valves the same as the disoriented ones, but also the histograms do approximately coincide (Fig. 123B). Thus, from a study of 350 whole valves there is no evidence that Exogyra Bed J was current-deposited. About 400 fragments wee also counted in the one square metre which indicates that any currents present were not strong enough even to remove the finer grade material.

Disorientation of the valves was due to bioturbation. Evidence of this is seen in the light and dark grey mottled matrix of the bed, and in the presence of discrete shell-fragment filled burrows which resemble _Thalassinoides_ (Fig. 124). This accounts for the fact that a quarter of all the valves were vertical.

In summary, the combination of a wide range of valve size, absence of evidence of current action and signs of burrow indicates that Exogyra Bed J contains a bioturbated _in situ_ life assemblage. It is interesting to note that the histograms for this undisturbed assemblage show a positive skew. According to Hallam (1967a) this indicates a condition of declining mortality rate with age, based on a study of Recent and Pleistocene bivalve assemblages. These _Exogyra_ from the Portland Sand Formation probably provide the first Mesozoic example.

1. (b) Ammonite sizes on Bed J' in the east of the Isle of Purbeck.

A total of 68 "Behemoth" (Titanites?) were measured as indicated in Fig. 125. The data seems to indicate that the ammonites all have the same degree of whorl coiling and thus probably belong to the same Family. It also shows that over 80% are 0.3–0.6m in diameter and this suggests that the collection is not a mass mortality assemblage in which one would expect to find a higher proportion of smaller forms, but probably a "cemetary" assemblage which accumulated slowly. The high faunal density at this horizon is interpreted as being due to condensation.

1. (c) Trigoniids on a bedding plane in the Freestone Beds in the west of the Isle of Purbeck.

The bivalves were measured as indicated in Fig. 126. The histograms and the plot of length to width ratios shows a clear distinction between the two genera Myophorella and Laevitrigonia.

2. Laboratory Procedures

(a) The determination of the calcium carbonate content of a rock.

The titration method described by Grimaldi, Shapiro and Schnepfe (1966) was usdd without modification.

2. (b) Test for aragonite.

Meigen's reaction was used. When boiled for a few minutes in a solution of cobalt nitrate a violet stain results.

2. (c) Test for phosphate.

The addition of nitric acid and ammonium molybdate produces a yellow precipitate.

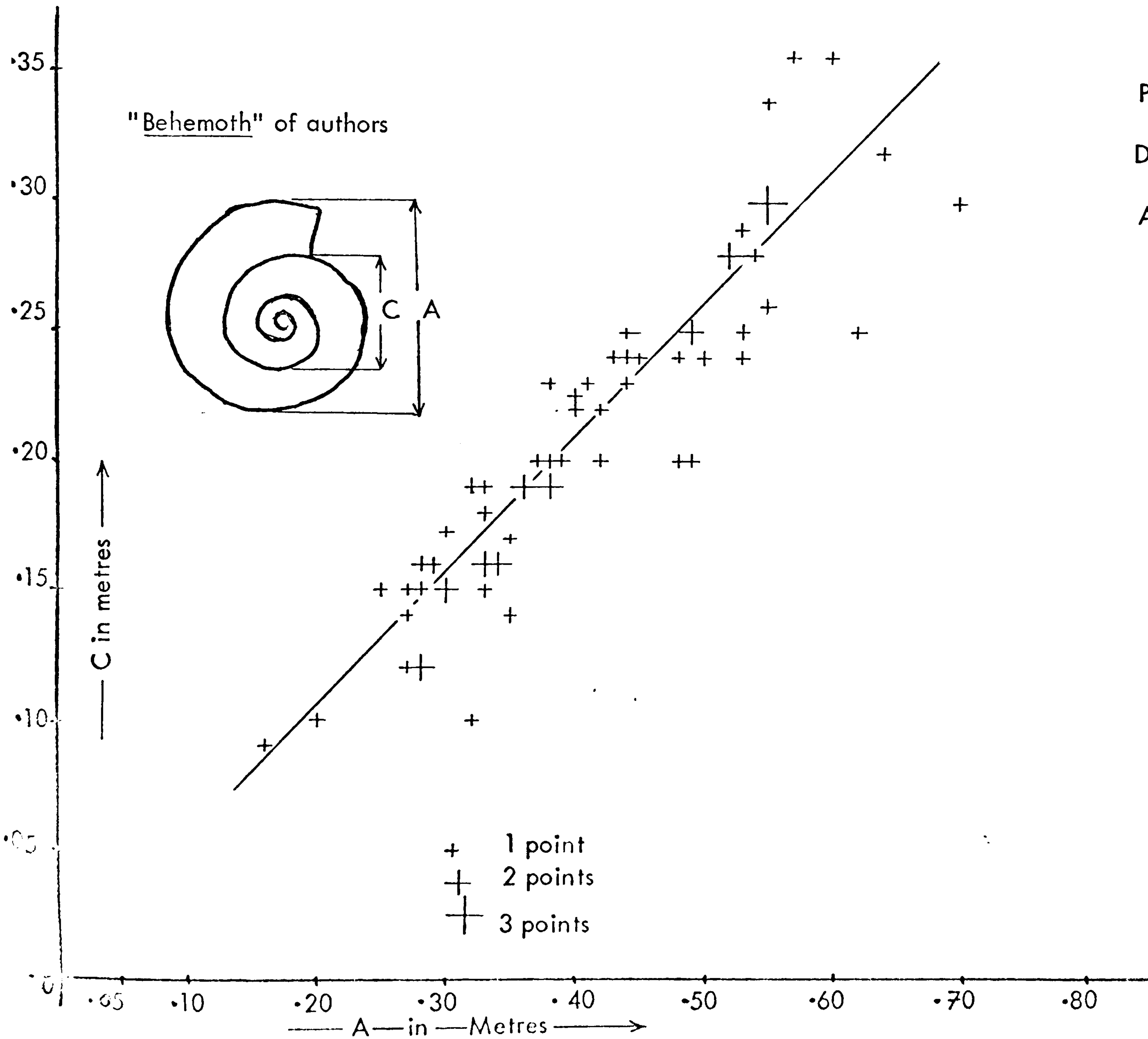
2. (d) Sieve analysis of Upper Sandy Beds, South Midland Area.

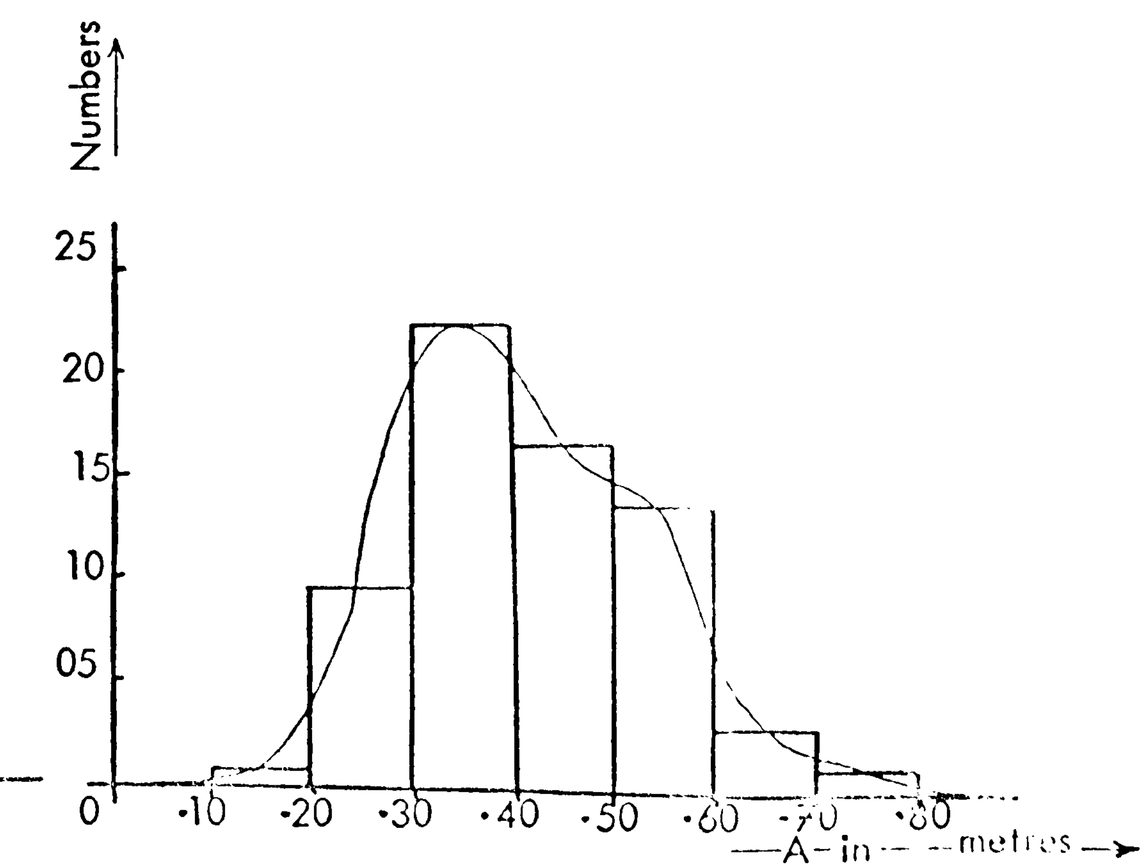
Four samples were taken at different levels in the Upper Sandy Beds temporarily exposed at the Haddenham & Kingsey Sewage Works near Thame. Each bulk sample was split into four

PORTLAND LIMESTONE FORMATION. EAST AREA,
DORSET. Isle of Purbeck East. Top of Lower Cherty Beds.
Arkell's Bed J'. Ammonite size distribution plots.

Total measured = 68

FIG 125



PORTLAND LIMESTONE FORMATION. FREESTONE BEDS. EAST AREA DORSET.

ISLE OF PURBECK WEST. Warbarrow Tout. Base of Top Grey Micrite (Fig )

FIG 126

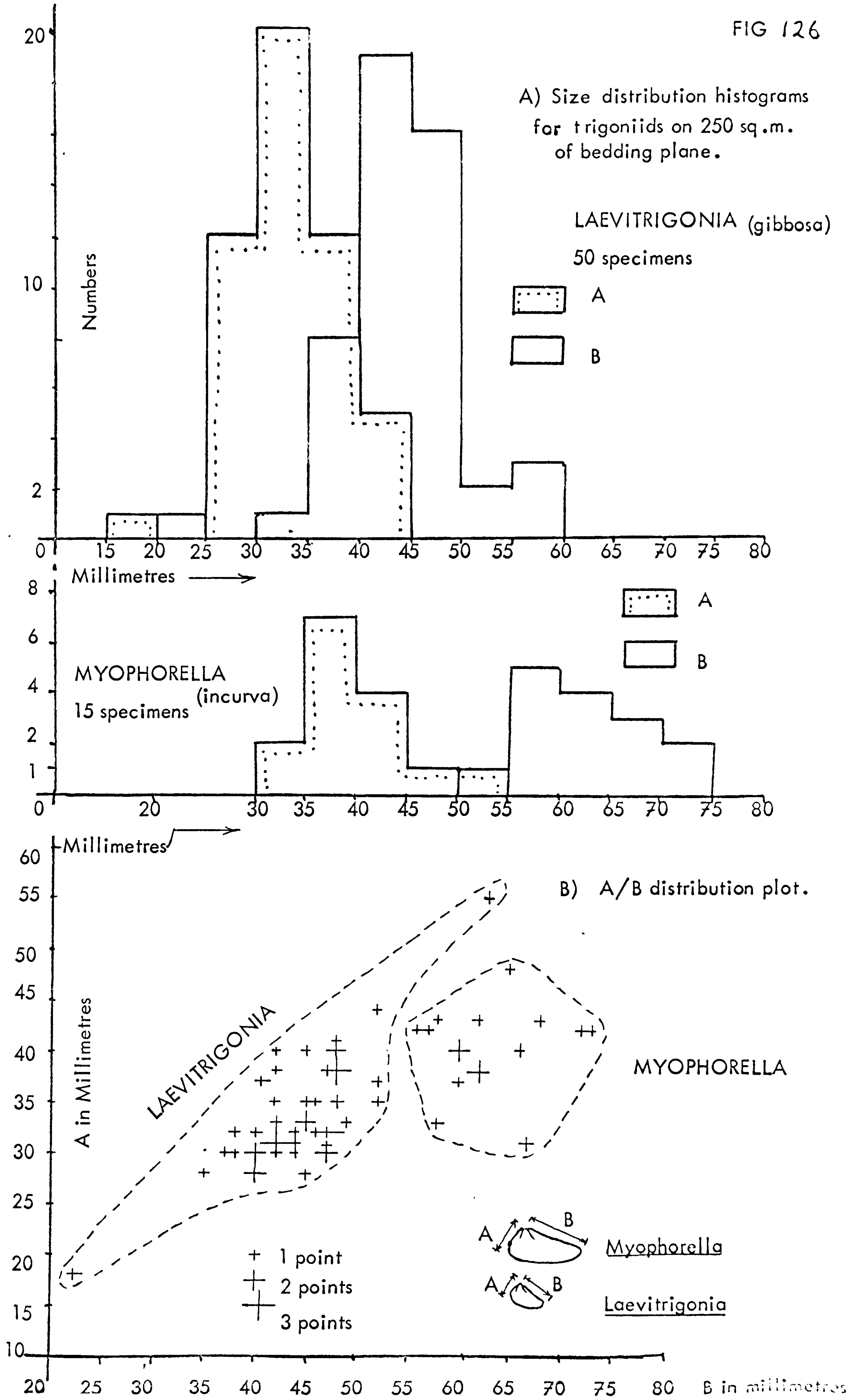
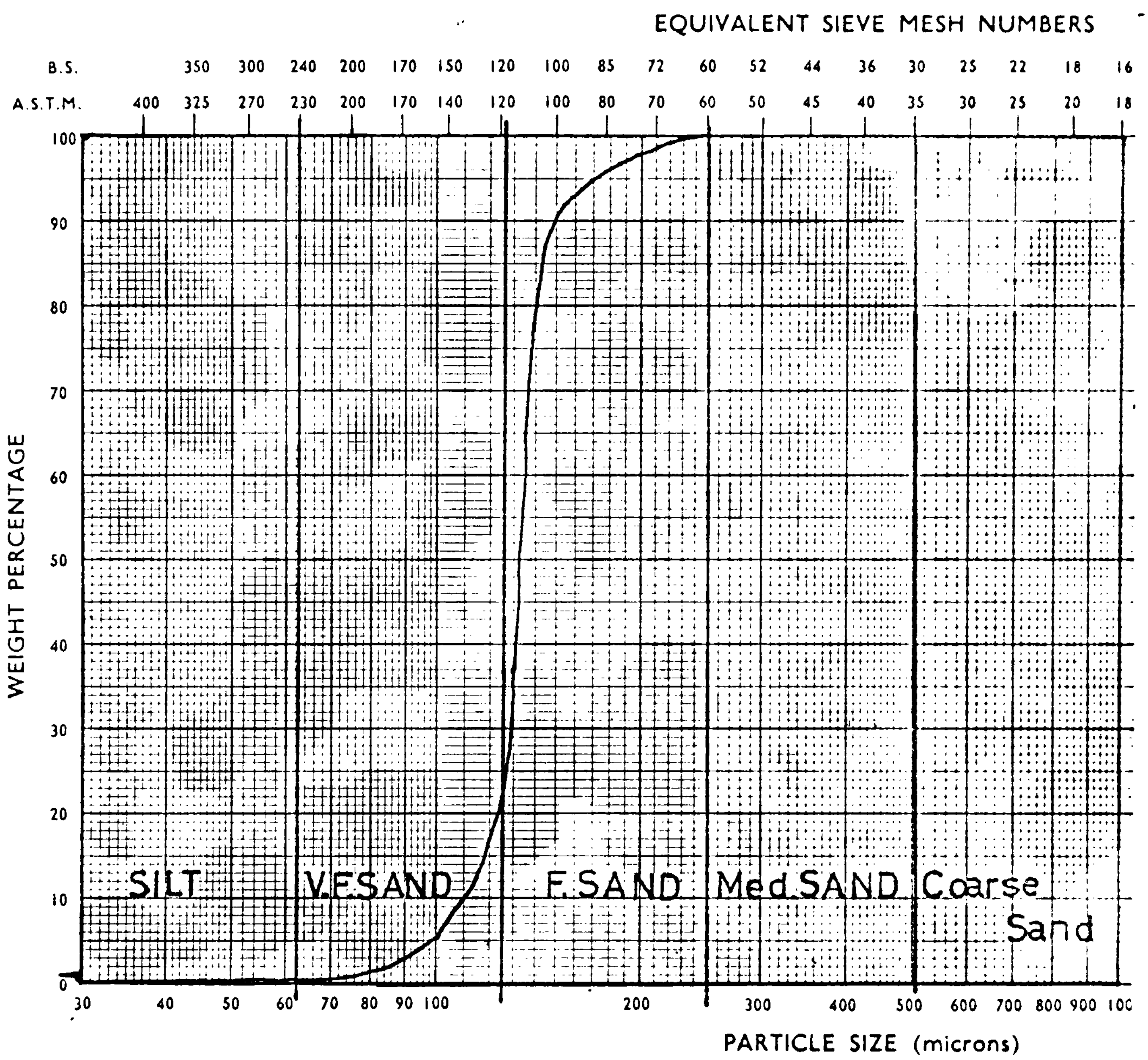


FIG 127

CUMULATIVE CURVE FROM SIEVE ANALYSIS OF THE UPPER SANDY BEDS, PORTLAND GROUP, SOUTH MIDLANDS.



50gm quantities. From each level, two were treated with acid to remove the carbonate and then one was sieved wet and the other dry. The other two samples from the same level were untreated and one sieved wet and the other dry. The results were consistent for the four levels sampled and a representative cumulative curve is given in Fig. 127. The sediment is 80-85% very well sorted very fine to fine quartz sand with <5% silt and clay and 5-10% fine to medium carbonate sand.

3. Dedolomitisation in the Portland Sand Formation and the occurrence of celestite

Nodules of poikilitic calcite occur in the Black Dolomite Beds of Dorset at several localities. The calcite crystals are several millimetres across and enclose large areas of fine-grained dolomite mosaic (Plate 6 ), an obvious indication of dedolomitisation.

This process is brought about by solutions with a high Ca/Mg ratio reacting with dolomite to form calcium carbonate, as fundamentally indicated by Von Morlot as long ago as 1848. Various resulting textures have been described by Shearman et al (1961) and Evamy (1967). Experimental dedolomitisation was effected by de Groot (1967) and his results show that as well as a high rate of water flow and high Ca/Mg ratio, a partial pressure of $CO_2$ lower than 0.5 atmospheres and a temperature of <50°C is necessary. This means that the process must be a Recent subsurface phenomenon, of if found at depth, indicates former emergence.

The poikilitic calcite in the Black Dolomite Beds is not a surface effect like the crusts on Carboniferous dolomites of the Russian Platform (Tatarskiy 1949) but occurs as lines of nodules some way below the top of the beds. If they are a superficial effect this could have taken place by downwards percolation of calcium-rich solutions from the Portland Limestone Formation above, either in Recent or Pleistocene times or conceivably during the Pre-Albian earth-movements when the Portland Group was uplifted and eroded in parts of Dorset.

Celestite, strontium sulphate, was identified chemically and optically but its exact composition was not determined. It occurs in the Black Dolomite Beds at Dungy Head (Fig. 18 ) as nodules in the same way as does the dedolomite, although not poikilitic. The proportion of strontium in the lattice of carbonate minerals decreases drastically from a maximum of 8000 ppm in aragonite, 700 ppm in calcite to 200 ppm in dolomite. In dedolomite it is very low, reaching only 30 ppm (lecture by R.C.L. Wilson). If the original lime mud of these beds was organic in origin then the strontium content would have been high and when dolomitisation took place strontium ions would have been released. The origin of the sulphate ions, however, is unknown. The similarity of the occurrence of this mineral with that of the dedolomite suggests a common origin but it must be confessed that this is not understood. It may be significant that this unique record is from a locality on the swell.

Celestite ($SrSO_4$)

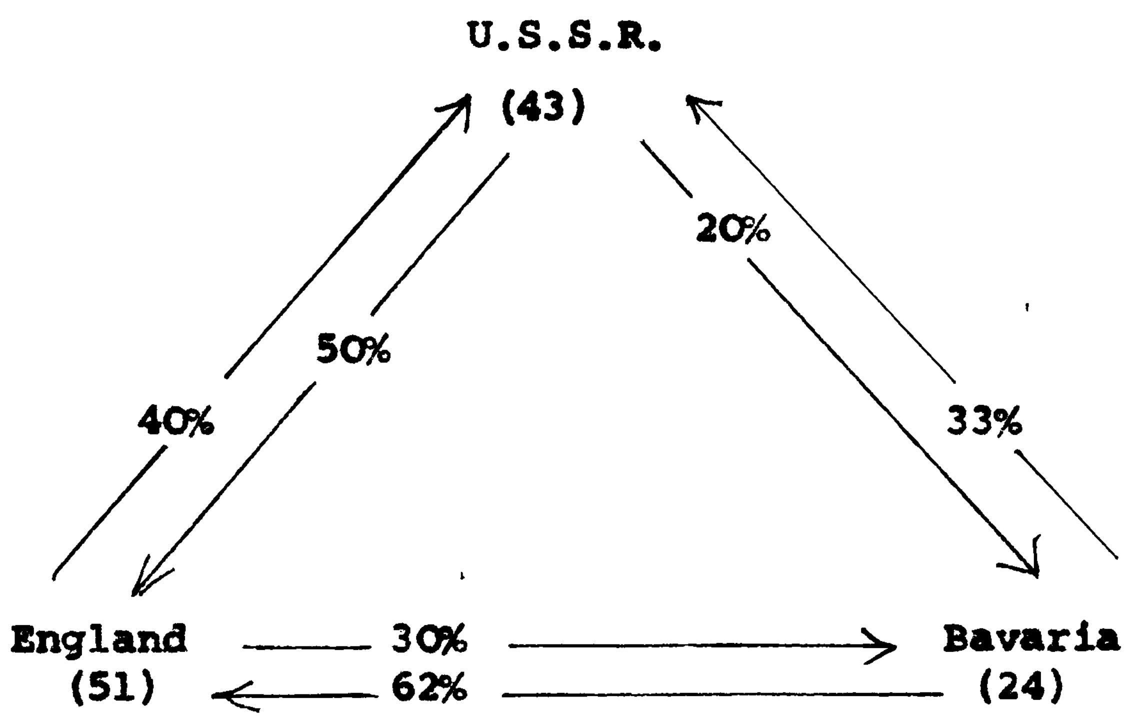
This mineral was identified chemically and optically but its exact composition was not determined although the 2v is exactly that for pure celestite (50°). It occurs in the Black Dolomite Beds at Dungy Head as nodules in the same way as the dedolomite does. (Fig 18)

The proportion of strontium in the lattice of carbonate minerals decreases drastically from a maximum of 8000 ppm in aragonite, 700 ppm in calcite to 200 ppm in dolomite; in dedolomite it is very low, reaching only 30 ppm (lecture by R.C.L. Wilson). If the original lime mud of these beds was organic in origin then the strontium content would have been high and when dedolomitised, strontium ions would have been released. However, the origin of the sulphate ions remains unknown. The similarity of the occurrence of this mineral with that of the dedolomite suggests a common origin but it must be confessed that this is not understood. It may be significant that the unique occurrence is at a locality on the swell area.

4. <u>A comparison of the bivalves genera of Russia, England, and Bavaria</u>

The bivalves of the Portland Group of England have been monographed by Cox (1928) and the fauna of the Middle and Upper Tithonian Neuburg Formation of Bavaria is described by Barthel (1969). Information about the bivalves of the U.S.S.R. (Mid-Russian Plain and North Siberia) has been obtained from Zakharov (1966, 1970 and pers. comm 1970).

The proportion of genera which occur in the three areas is as follows:




If these comparisons are at all significant then the Portland Group fauna appears to bridge the two areas in that it has much in common with both as well as having its own fauna. Further conclusions cannot be made without more detailed information on generic and specific abundance, which would first require an assessment of the validity of many of the "local" names.

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# PLATES

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74 Medium biochem sand, Main Limestone Beds, Wardour Limestone Formation.

75 Medium biochem sand with intraclasts, ooids and quartz, plus micrite in the matrix. Main Limestone Beds.

76 Upper Chicksgrove Quarry, Vale of Wardour.

77 Serpulid encrusted ammonite, Sandy Limestone Beds.

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84 Sponge spicule-rich Upper Limestone Beds at the locality of Plate 83.

85 The topmost part of the Upper Limestone Beds at Haddenham & Kingsey Sewage Works.;

86 Lens of shells with a micrite matrix in the topmost part of the Upper Limestone Beds at the locality of Plate 85.

87 Large Thalassinoides from the Upper Assises de Croi, Bas Boulonnais, France.

88 Small Thalassinoides in the Upper Gres des Oies, Boulonnais.

89 Pointe de La Rochette, Bas Boulonnais, showing the down-cutting Upper Gres des Oies.

90 Fallen block of the Rochette conglomerate.

91 Diapir in the Upper Gres des Oies, Boulonnais.

92 Vertical view of a diapir showing the upturned rim.

93 Bored hard-ground at the top of the Middle Gres des Oies.

94 Fallen mass of algal limestone from the Calcaire des Oies.

95 Thin section of glauconitic, quartzose micrite from the Portland Group, 480m below Kingsclere, Hampshire.

96 Thin section of dolomite from the Portland Group, 748m below Portsdown, Hampshire.

Plate 1 Hounstout and Chapman's Pool. East Isle of Purbeck (SY 9577), Dorset. Arrow indicates position of rotunda nodule bed in the Upper Kimmeridge Clay, 1. The Sandy Upper Kimmeridge Beds are numbered 2 and the Portland Sand Formation is 3, overlain by part of the Portland Limestone Formation, 4. Hounstout is 150m above sea level.

Plate 2 St. Alban's Head, east Isle of Purbeck (SY 9575), Dorset. The sheer cliff is 40m high and consists of the Portland Limestone Formation, A on top of the Black Dolomite Beds of the Portland Sand Formation, B.1. The softer rocks below are the St. Alban's Head Beds, B.2, underlain by the Emmit Hill Beds, B.3.

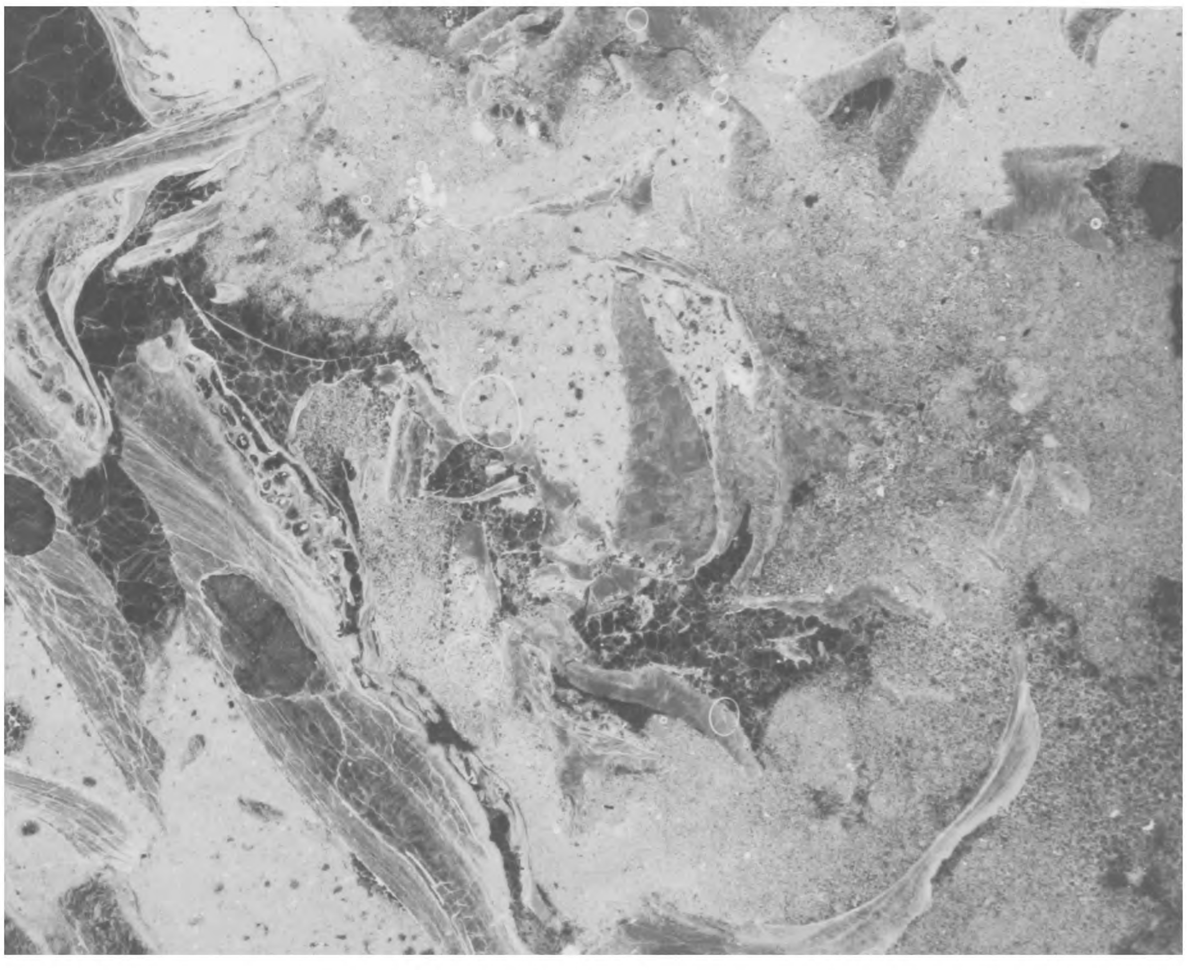

4
3
2
1


A
B'
B²
B³

Plate 3 Thin section of Black Dolomite Beds, St. Alban's Head showing original laminations partly ~~described~~ disturbed by a burrow (negative print).

Plate 4 Thin section of partially silicified Exogyra encrusted by bryozoa and fractured. Sparry calcite fills the cavities and the micrite matrix grades into microsparite from the centre to the lower right margin. (Negative print) Exogyra Beds, Plaisters Lane, West Mainland Area (SY 698844), Dorset.

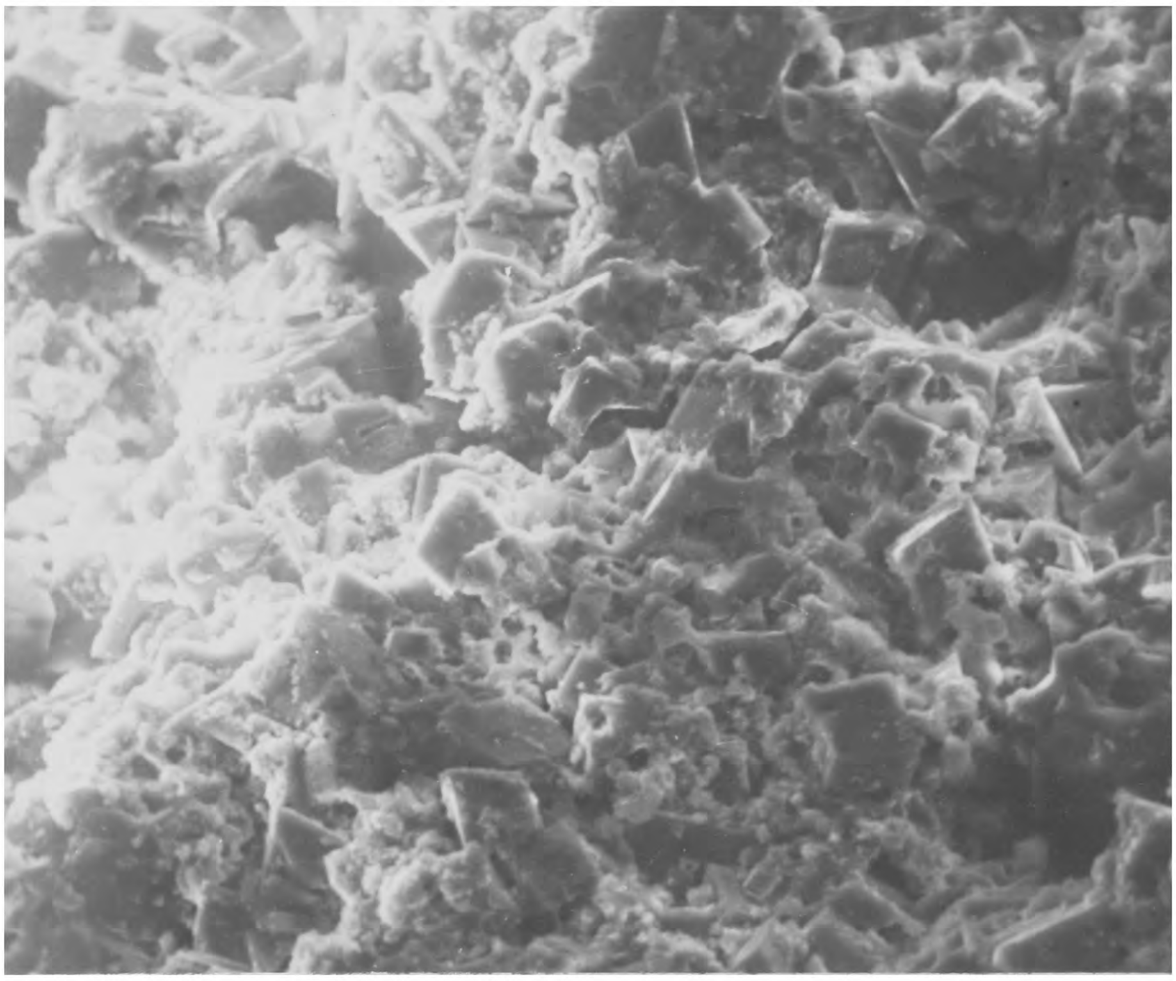
250μ



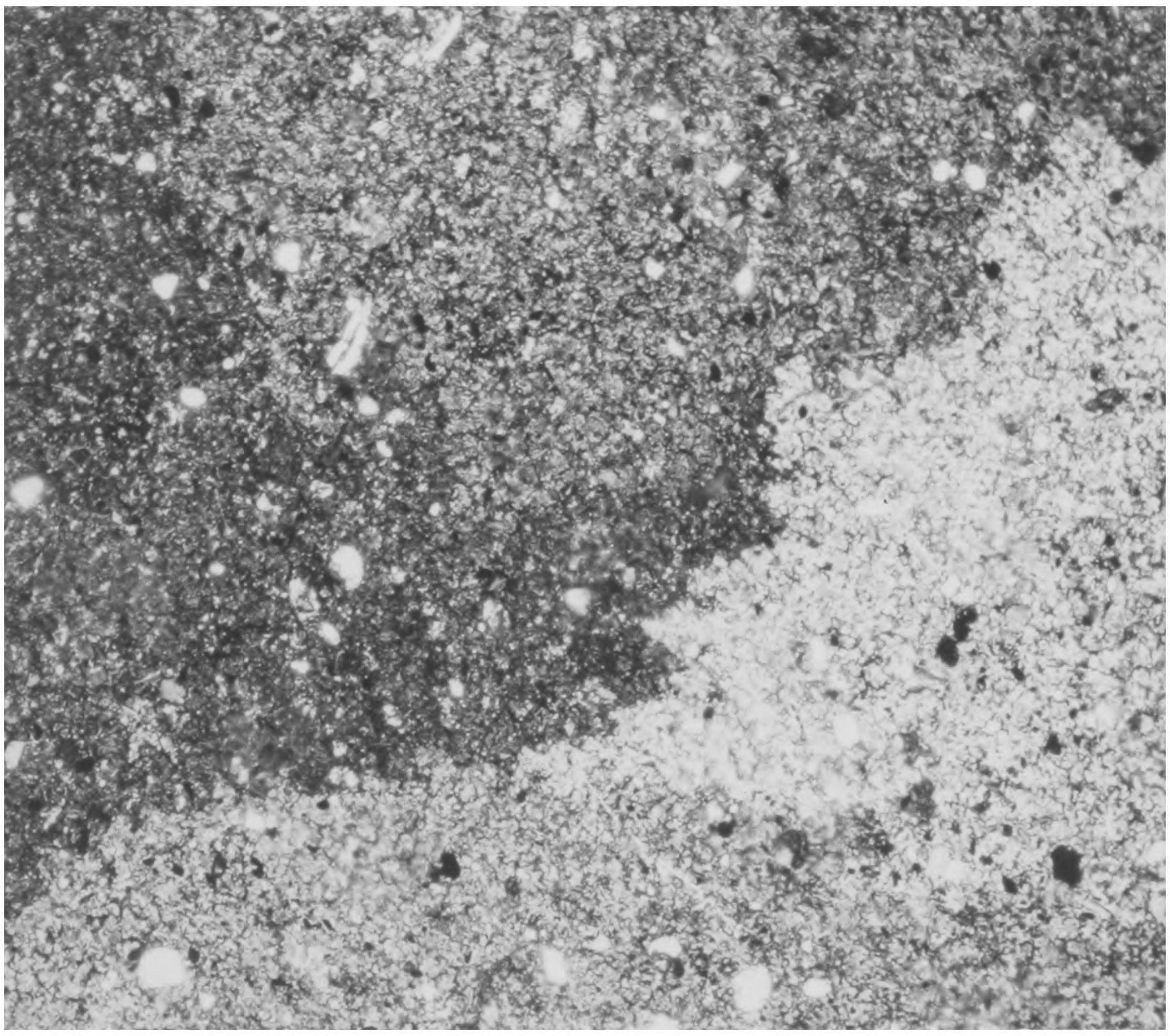
2·5 mm

Plate 5 Scanning electron photomicrograph of the Black Dolomite Beds at the west end of Gad Cliff (west Isle of Purbeck Dorset) showing dolomite rhombohedra.

Plate 6 Thin section of a dedolomitised nodule in the Black Dolomite Beds at the west end of Gad Cliff. Four calcite crystal boundaries are seen in crossed polarised light and the fine grained texture of the dolomite is still preserved.



100μ



100μ

Plate 7 Thin section of the *Exogyra* Beds at West Wear Cliffs on the Isle of Portland (West Area) showing selective dolomitisation of the micrite matrix (the circles are air bubbles). The *Exogyra* fragments remain as calcite.

Plate 8 Long *Rhizocorallium* burrows on a bedding plane in the Black Dolomite Beds, exposed on a fallen block below St. Alban's Head (SY 960755) "Spreite" are visible a little way above and to the left of the hammer head.

250 µ

0·5m

Plate 9 The Black Dolomite Beds overlain by the Lower Cherty Beds at St. Alban's Head (SY 960755). The arrow shows the junction between the Portland Limestone Formation and the Portland Sand Formation. The Black Dolomite Beds show a "honey-comb" weathering due to calcite veining and Rhizocorallium bioturbation. The lower part of the Lower Cherty Beds is very cherty and has many horizons of pressure solution.

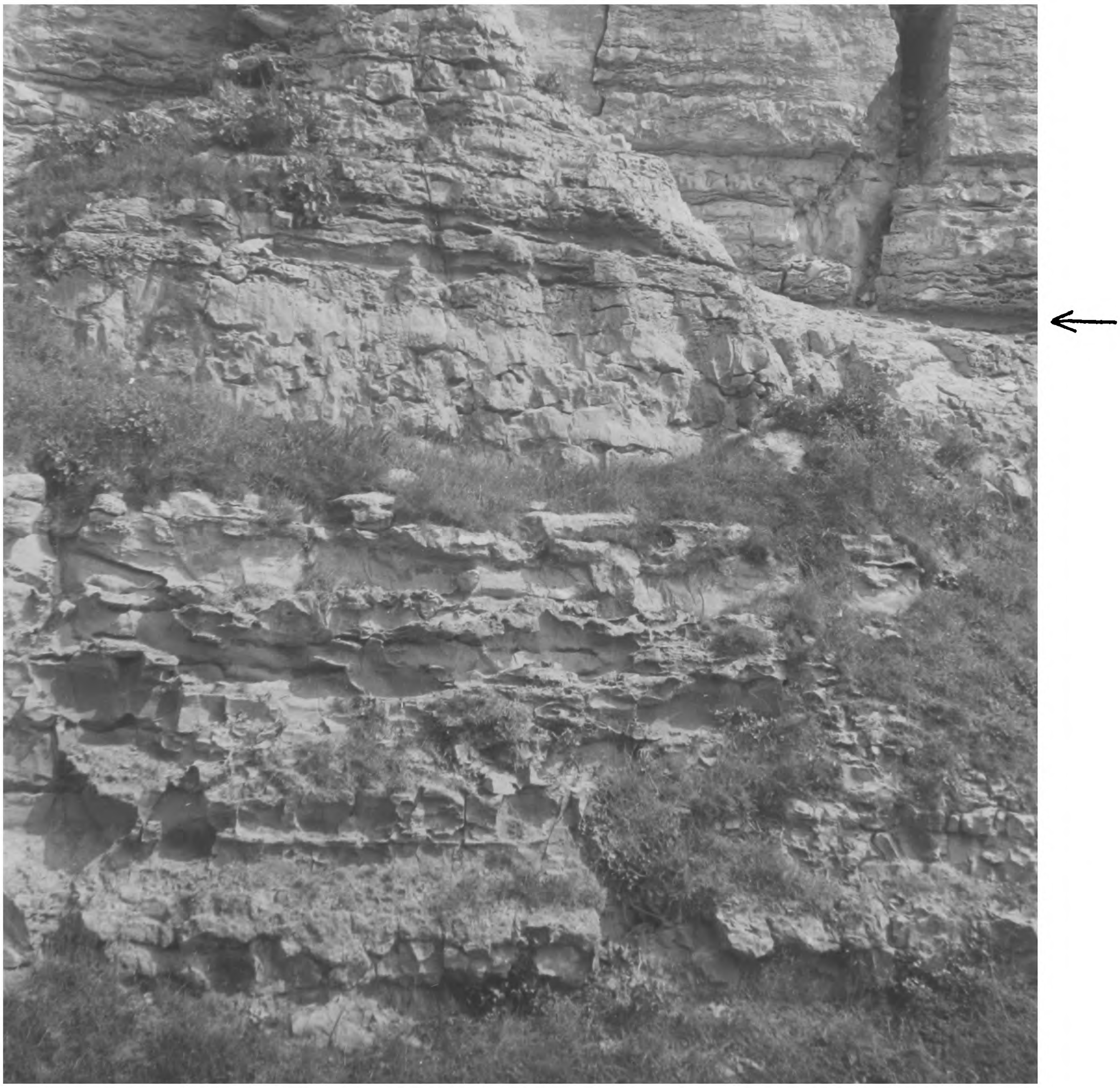


Plate 10 View of Gad Cliff from Brandy Bay (west Isle of Purbeck) (SY 893790). Mudstones of the Kimmeridge Clay are seen in the foreground and in the middle distance these pass up into the Sandy Upper Kimmeridge Beds. The Portland Sand Formation lies below the sheer cliff in the distance a and is overlain by the Portland Limestone Formation and the Lower Purbeck Beds. The limestone cliffs of the Central Area are seen in the far distance.

Plate 11 A view of the central part of Gad Cliff taken from sea level (SY 887795). A coccolith limestone in the Upper Kimmeridge Clay is visible in the foreground; the junction between the Sandy Upper Kimmeridge Beds and the Portland Sand Formation is shown by a dashed line. The major overhang is at the base of the Portland Limestone Formation (X). The top of the cliff is c.140m above sea level.

Plate 12 The section in the Portland Sand Formation at the far west end of Gad Cliff. A hammer is circled for scale. The "cycles" of limestone and facies A are seen in the Exogyra Beds overlain by the soft Cast Beds and the rough-weathering Black Dolomite Beds.

Black
Dolomite Beds

Cast Beds

Exogyra
Beds - horizons
F-J

Plate 14 *Rhizocorallium* with well preserved "spreite", seen on a fallen block of Upper Black Nore Beds at the east end of Gad Cliff, Isle of Purbeck

Plate 13 Bioturbation by *Rhizocorallium* well displayed on a wave washed fallen block of Black Dolomite Beds below Gad Cliff, west Isle of Purbeck. "Spreite" and faecal pellets are visible.

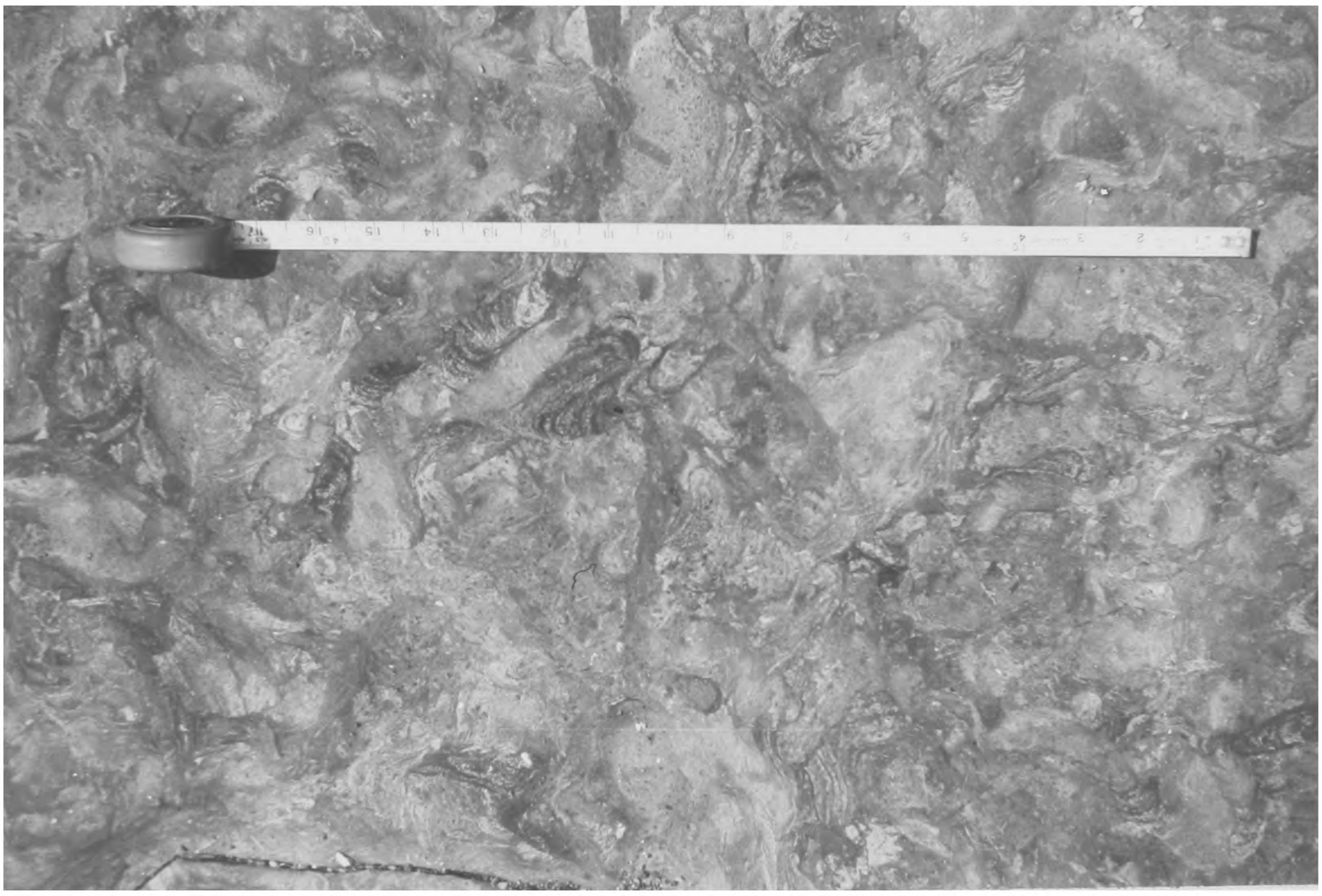
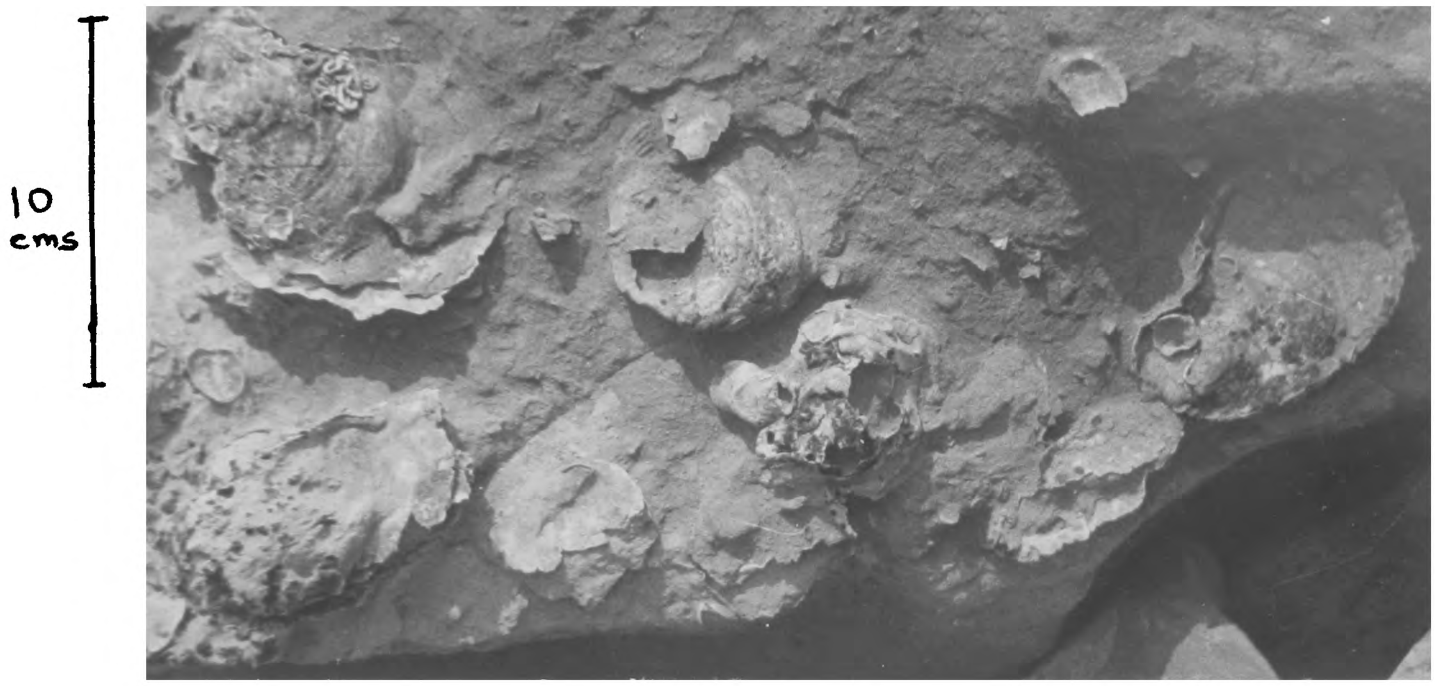
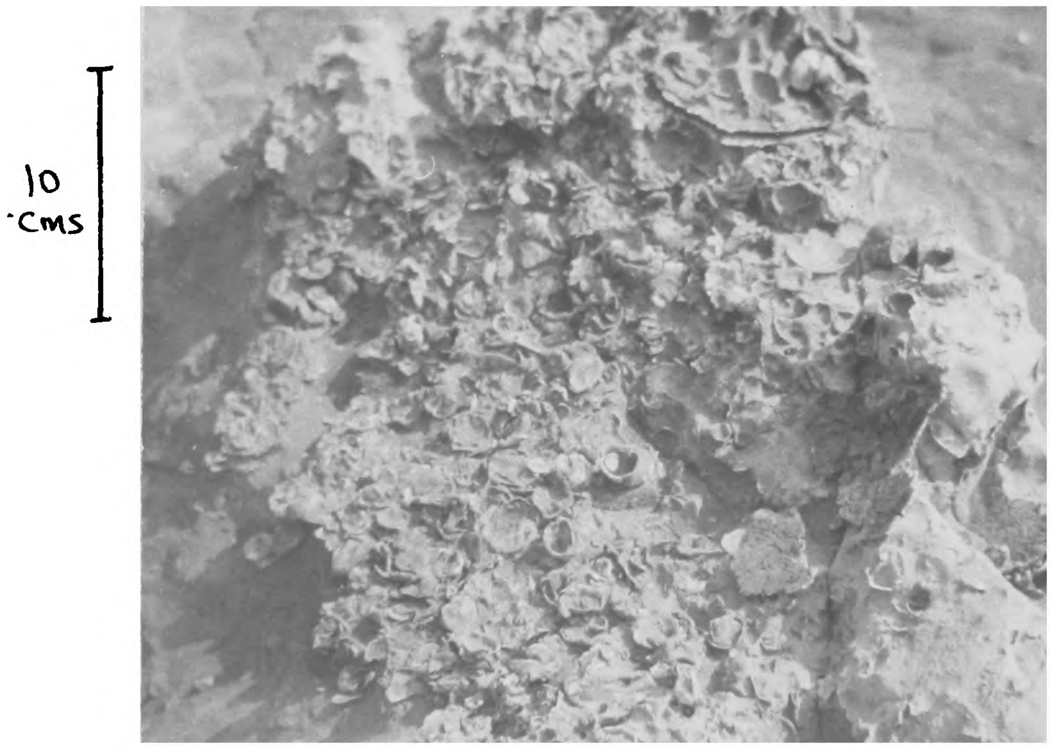


Plate 15 Ostrea expansa and Ostrea bononiensis encrusted by Glomerula gordialis and Exogyra nana, seen on a bedding plane in the Exogyra Beds at the far west end of Gad Cliff, west Isle of Purbeck.

Plate 16 "Nests" of Exogyra nana in life position and an encrusted articulated Ostrea expansa seen on a bedding plane in the Exogyra Beds at the far west end of Gad Cliff.

Plate 17 Large Glaucolithites gorei (not encrusted) in the Black Dolomite Beds. Also shown is a dedolomitisation nodule of poikilitic black calcite crystals. Fallen blocks below the far west end of Gad Cliff.


10
cms


10
cms


0·2m

Plate 18 The Black Dolomite Beds at Gad Cliff, showing *Rhizocorallium* burrows in vertical section. The disturbances produced by upward movement of the animals sometimes superficially resembles depositional structures.

Plate 19 View westwards from the seaward side of Stair Hole, near Lulworth Cove in the Central Area of Dorset. Cherty beds in the foreground are part of the Portland Limestone Formation, overlain by the Lower Purbeck Beds in the middle distance. The arrow shows Dungy Head (SY 816779) where the Portland Sand Formation forms the vegetated area below. The local *Exogyra* horizon in the Black Dolomite Beds is at position X.

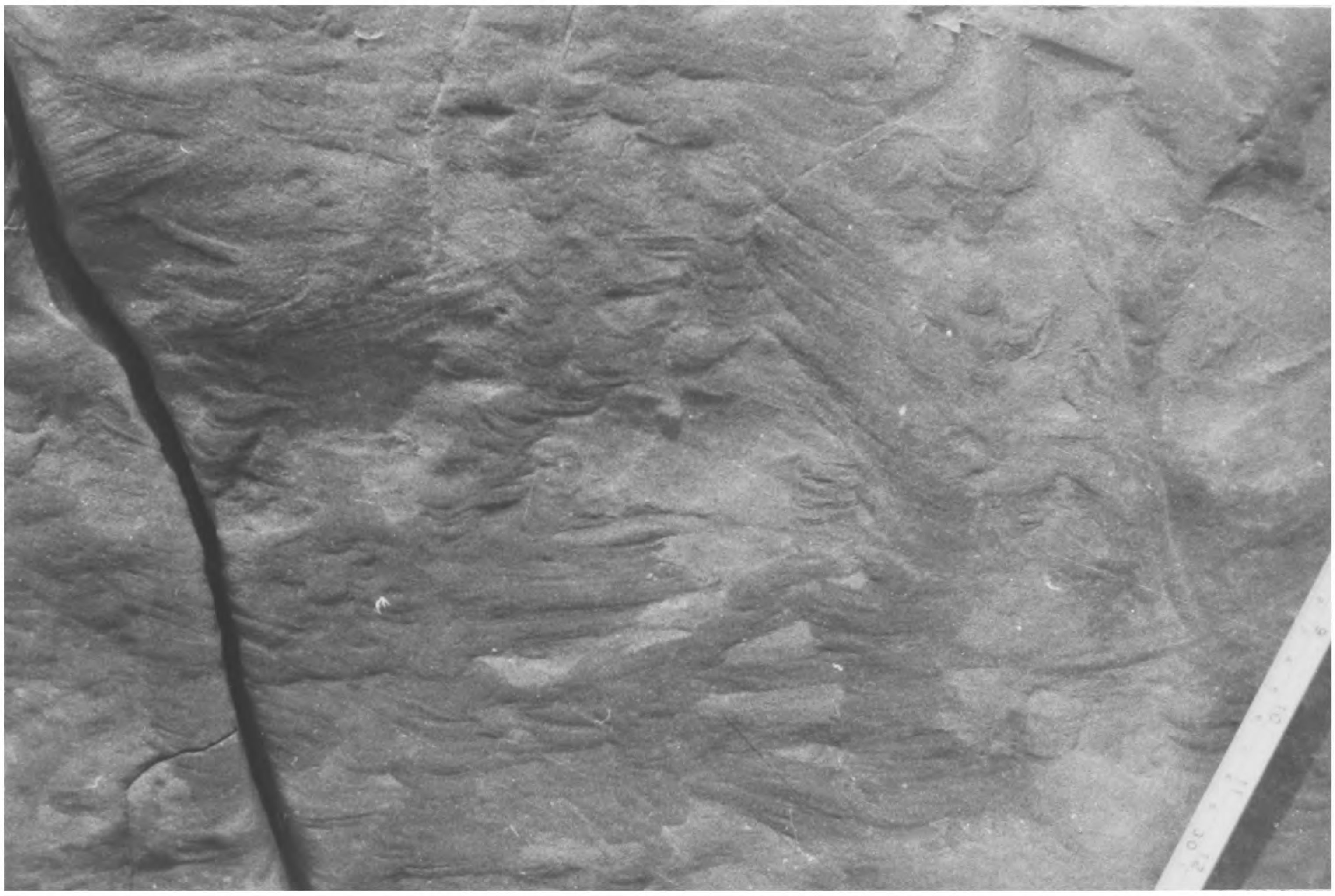


Plate 21 Partially dolomitised micrite at the horizon of the Black Dolomite Beds near Holworth House, Ringstead Bay (West, Mainland Area, Dorset) (SY 763816). The dark patches are dolomite. (Rucksack in foreground for scale.)

Plate 20 The local development of _Exogyra_-rich limestone in the Black Dolomite Beds at Stair Hole West in the Central Area of Dorset. (see plate 19). The lower part is very nodular and _Glaucolithites_ is common. The beds above the man's head are packed with _Exogyra nana_. The lighter-colour beds above are the chert-rich lowest horizons of the Portland Limestone Formation.

Plate 22 The Portland Group at West Weare Cliffs, Isle of Portland, Dorset.

| | | | |
|---|---|---|---|
| Portland Limestone Formation | Freestone Beds (part) | D | |
| | Upper Cherty Beds | C | |
| | Basal Shell Bed | B | Lower Cherty Beds |
| | Portland Clay | A | |
| Portland Sand Formation | Black Dolomite Beds | 5 | |
| | East Beds | 4 | |
| | Exogyra Beds | 3 | |
| | Upper Black Nore Beds | 2 | |
| | Upper Sandy Kimmeridge Beds | 1 | |

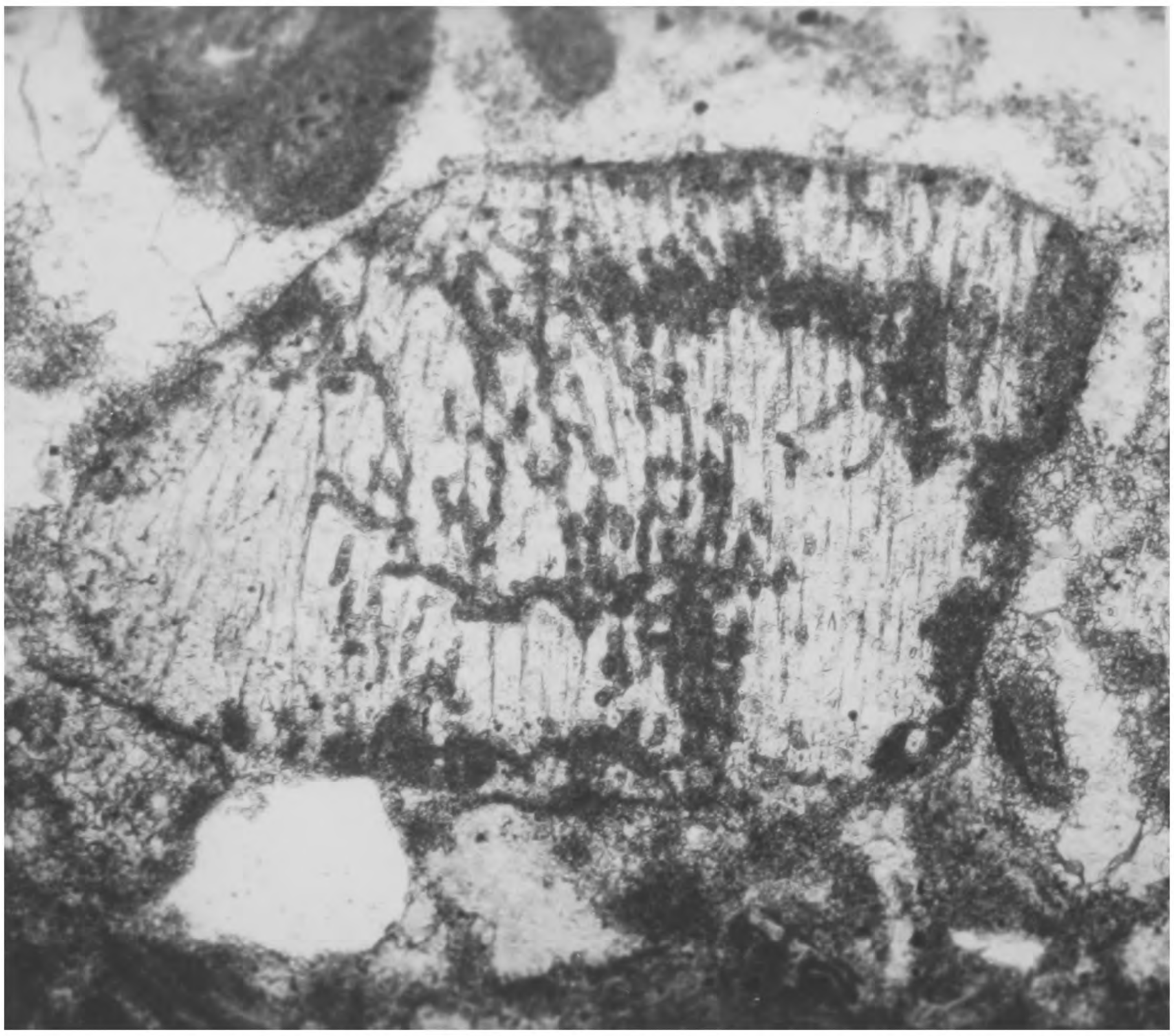
Plate 23 Block of the Exogyra Beds from the Isle of Portland showing current deposited encrusted valves and fragments of *Exogyra nana*. Some valves are bored.


D
C
B
A
5
4
3
2
1

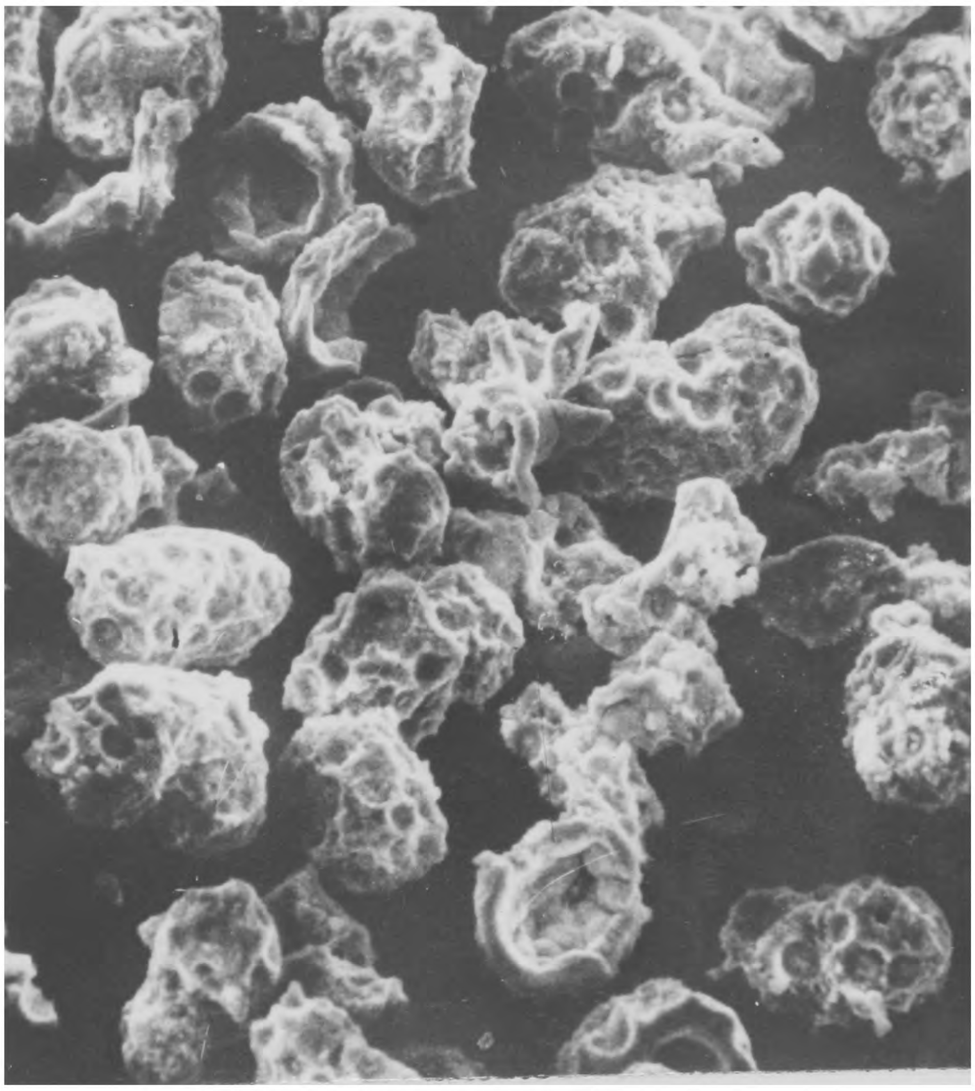

CMS

Plate 24 Algal borings in sand-sized fragment of a calcitic bivalve, from the biochem sand facies of the Upper Freestone Beds in the east part of the Isle of Purbeck, Dorset.

Plate 25 Scanning electron photo-micrograph of silica Rhaxella spicules, prepared by acid treatment of a specimen of the Lower Cherty Beds from the Central Area of Dorset. The spicules (sterrasters) are hollow, kidney shaped bodies with a pocked surface ornament. They are more often represented by calcite casts (see Plate 30).



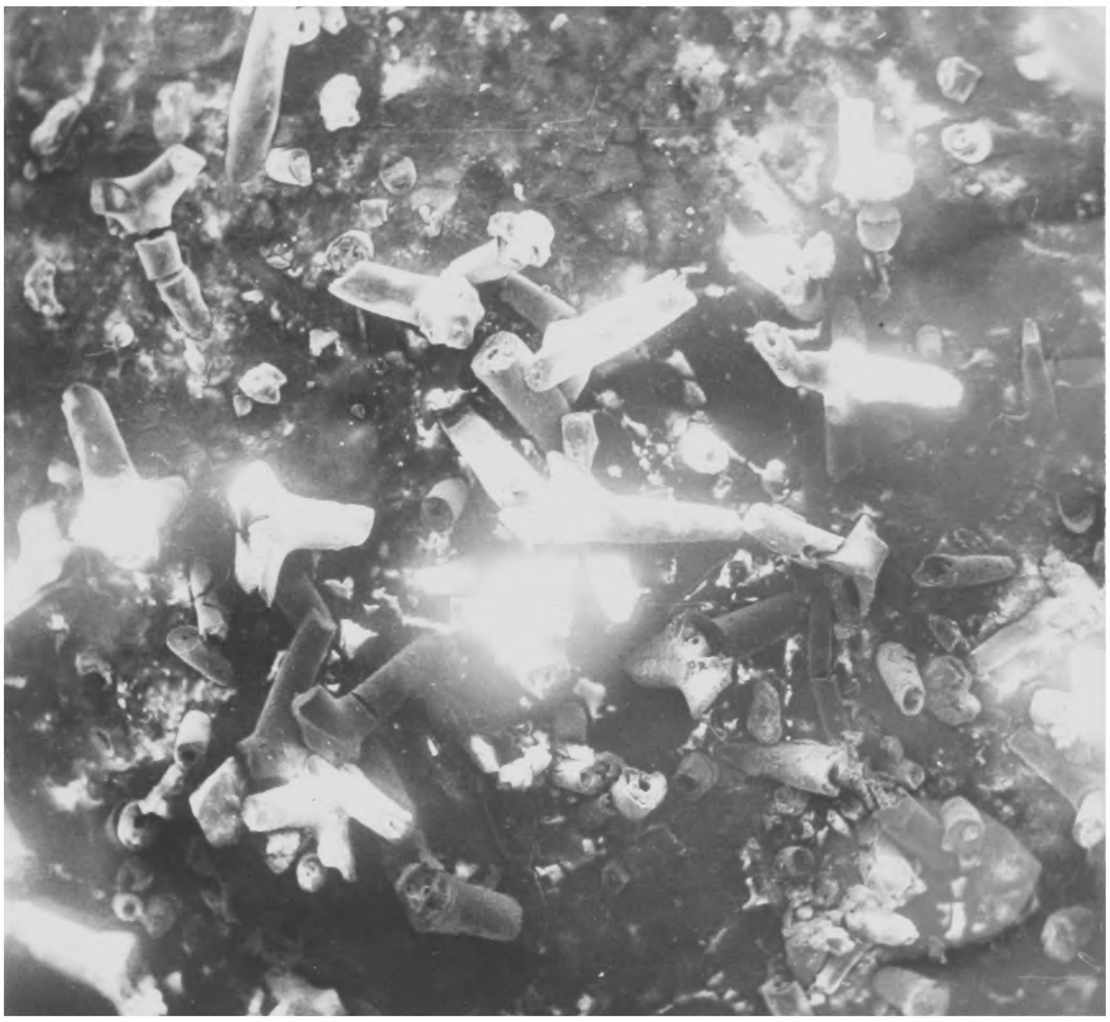
250μ



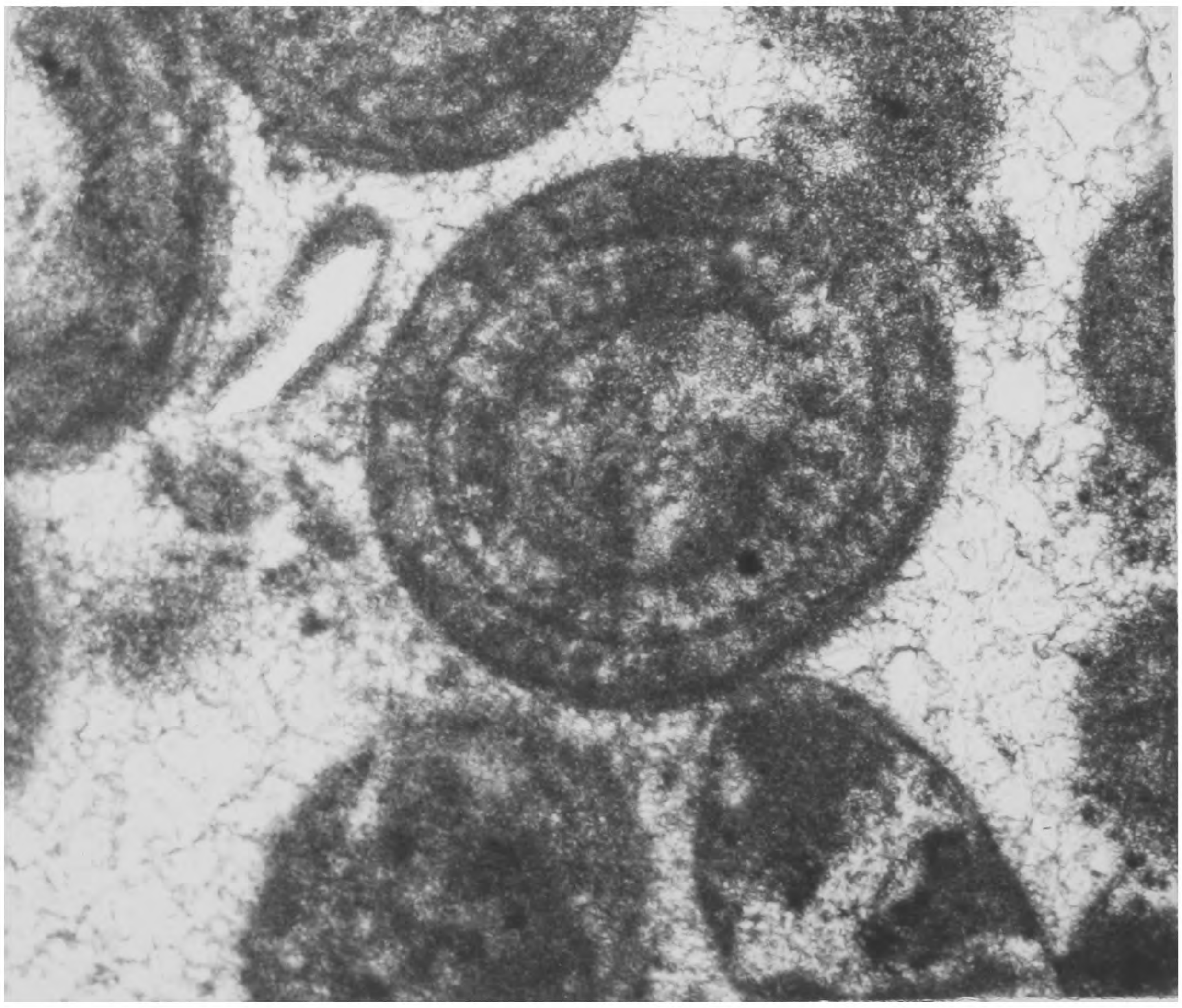
100μ

Plate 26 Scanning electron photomicrograph of siliceous Pachastrella spicules prepared by acid treatment of a specimen of the Upper Cherty Beds from the east Isle of Purbeck. The spicules are hollow tetraxons which sometimes are preserved as calcite casts (see Plates 30 and 84).

Plate 27 Thin section of a pelintraoosparite from the Freestone Beds in the Central Area of Dorset showing an ooid with the structure moderately well preserved. An intraclast of biomicrite lies to its lower right and an unidentifiable micritised grain to its lower left. The grains are set in a sparite cement.



1mm



250 μ

Plate 28 Scanning electron photomicrograph of an etched ooid from the Freestone Beds of the Central Area of Dorset showing the formation of a micritised rim probably due to the action of boring algae.

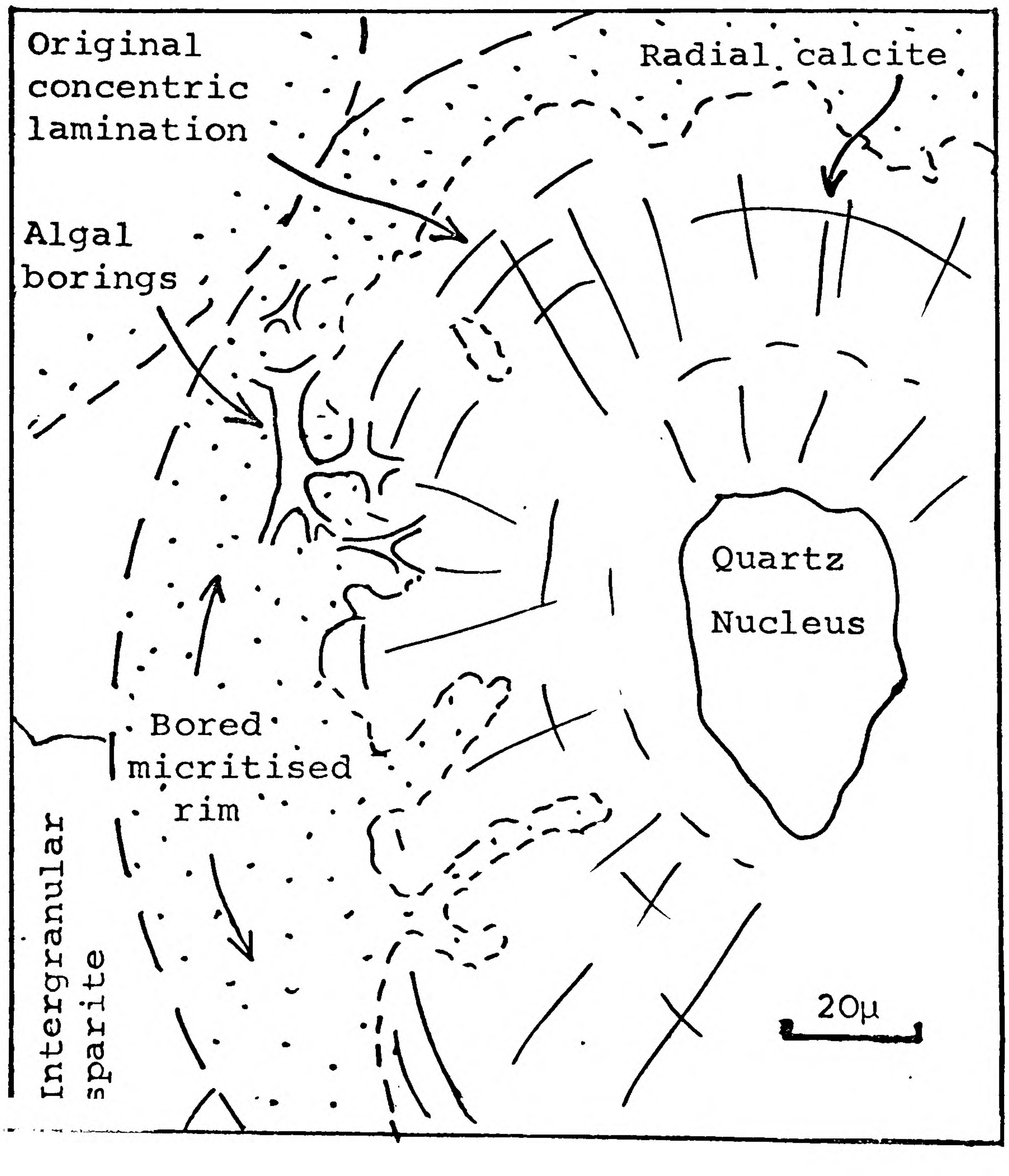
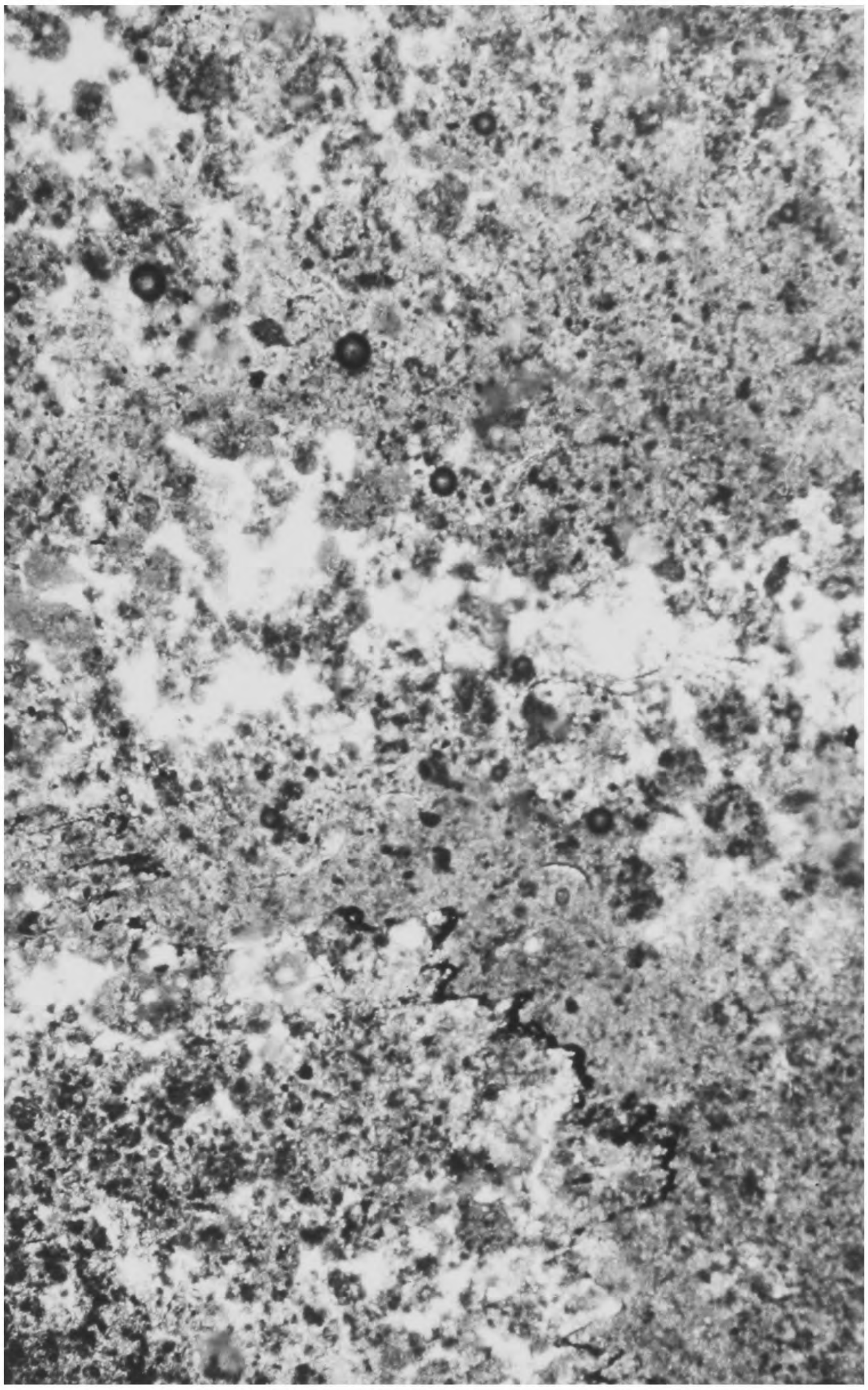
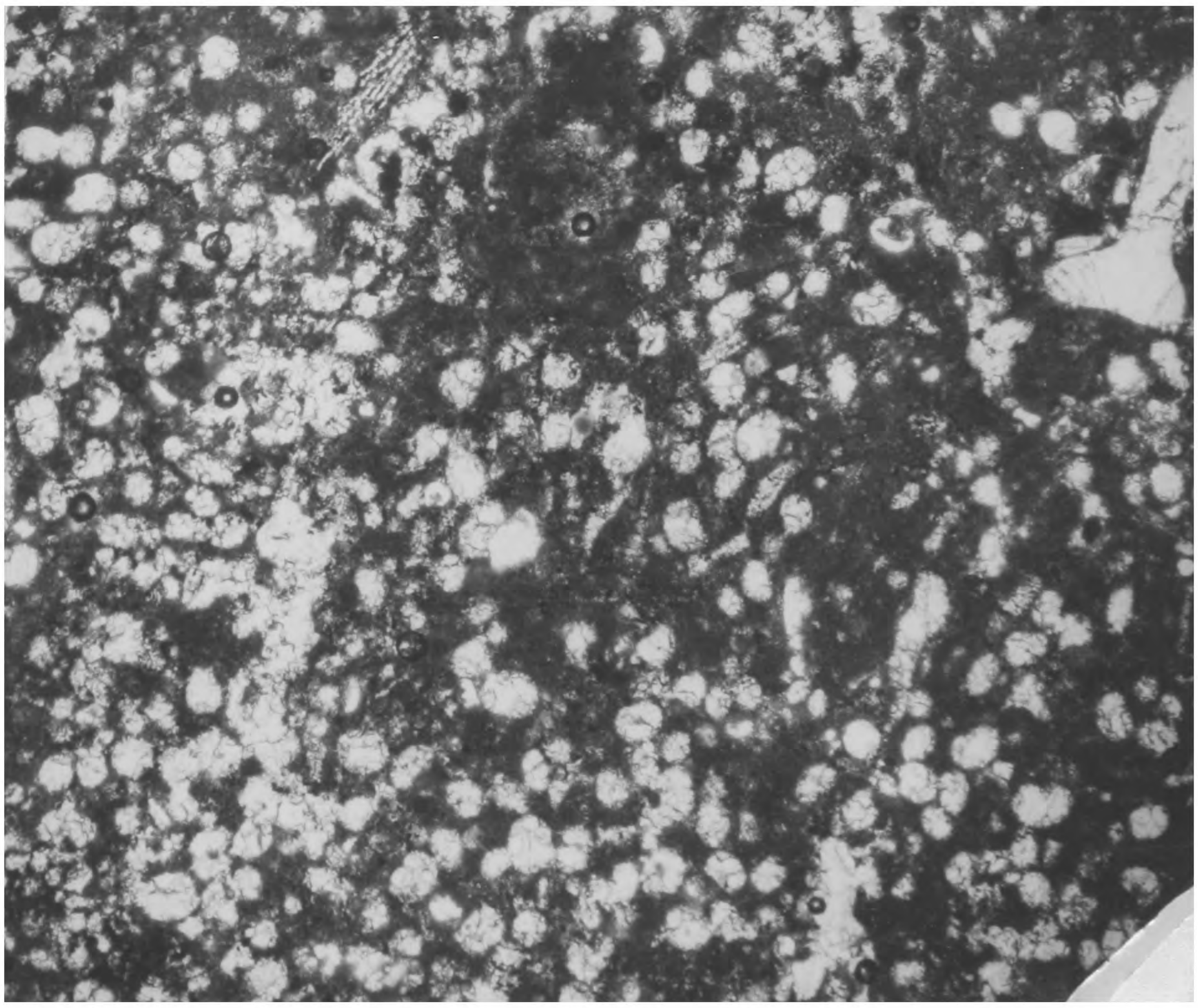

Original
concentric
lamination
Radial calcite
Algal
borings
Quartz
Nucleus
Bored
micritised
rim
Intergranular
sparite
20μ

Plate 29 Thin section of laminated pelmicrite (algal mats?) at the junction of the Freestone Beds and the Lower Purbeck Beds in the east of the Isle of Purbeck, Dorset. These laminations consist of alternations of compacted lime mud pellets with sparite-cemented pellets. A stylolite cuts across the lower half of the picture. (Viewed through normal light.)

Plate 30 Thin section of the Upper Cherty Beds on the Isle of Portland, Dorset, showing abundant calcite casts of Rhaxella spicules and a few Pachastrella spicules, set in a micrite matrix. (Viewed through normal light.)



250 µ



500µ

Plate 31 Thin section of a biomicrudite in the topmost part of the Freestone Beds near Durlston Head in the east Isle of Purbeck, Dorset (SZ 035771). The rock consists of whole and fragmented calcitic (A) and aragonitic bivalves (B), gastropods (C), and solenoporacean algae (D) in a micrite matrix. The grains are sand to pebble grade and very loosely packed; sparry calcite was precipitated in the cavities which were not filled by lime mud. Aragonitic bivalves are preserved as sparry calcite casts with a micrite envelope. (Viewed under ordinary light.)

Plate 32 Thin section of biosparite (biochem sand, facies 4) from the Lower Freestone Beds, east Isle of Purbeck, Dorset. Most of the grains are micritised shell fragments, some are micrite-coated, others are probably very micritised ooids and there is an intraclast of biomicrite at the bottom of the picture. (Viewed through ordinary light.)


D
B
A
C
500 μ

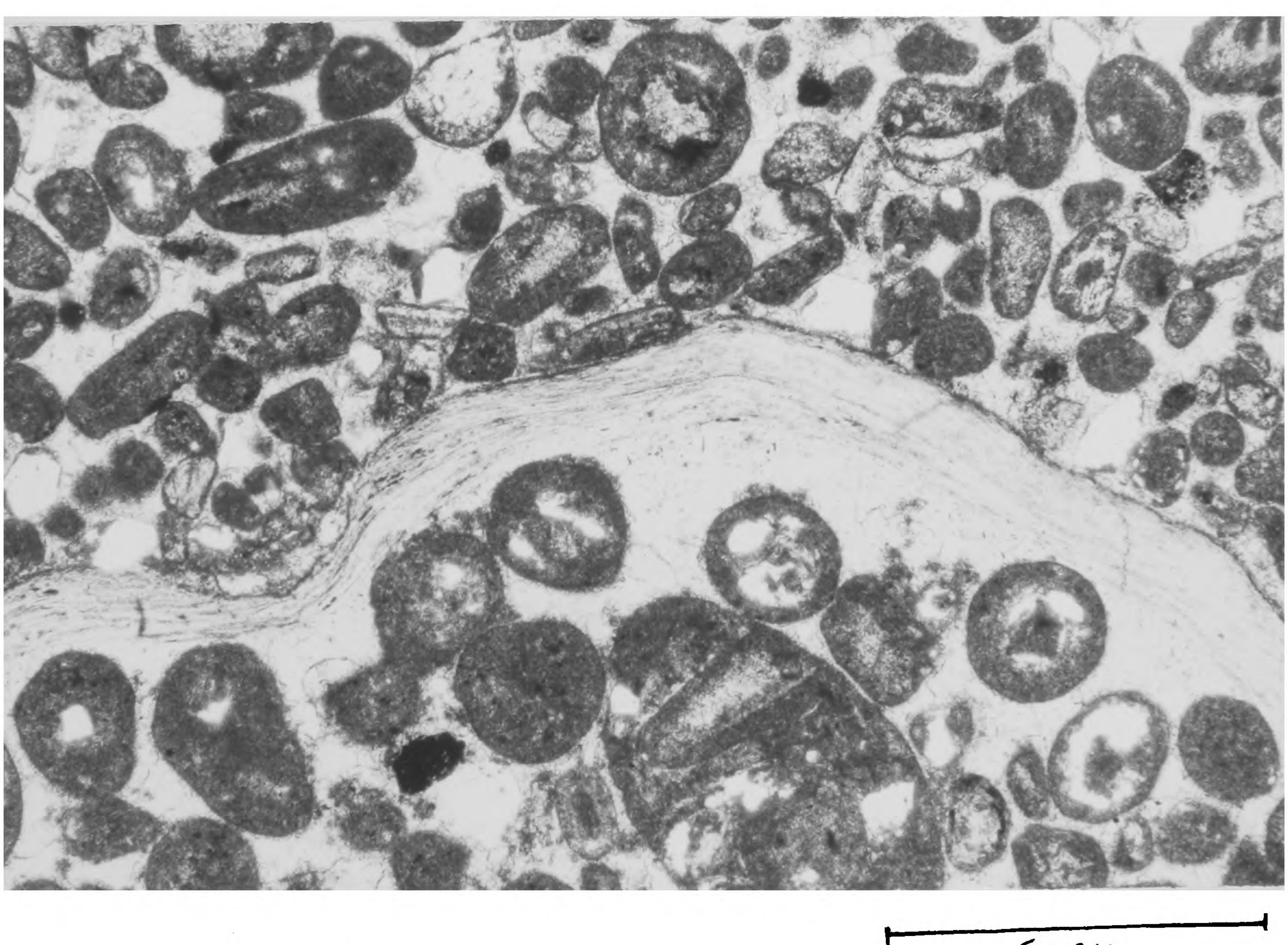

500 μ

Plate 33 Thin section of biointrasparite (Facies 6c) from the Freestone Beds of the Central Area, Dorset. The sediment is composed of intraclasts of oomicrite and biomicrite with micrite pellets and is cemented by spary calcite. (View through ordinary light.

250µ

Plate 34 View from St. Alban's Head eastwards along the cliff sections of the Portland Limestone Formation in the east Isle of Purbeck, Dorset. The junction of the Lower and Upper Cherty Beds is seen in the foreground marked by Arkell's Bed J'. Cliff-top quarries in the Freestone Beds can be seen in the middle distance. Fourteen vertical sections were measured along this outcrop.

Durlston Head

- St. Alban's Head

Plate 35 The Portland Limestone Formation in the east Isle of Purbeck, Dorset. The prominent thin bed half way up marks the top of the Lower Cherty Beds (Bed J'). The Upper Cherty Beds and Freestone Beds form the top half of the cliff which is approximately 30m high.

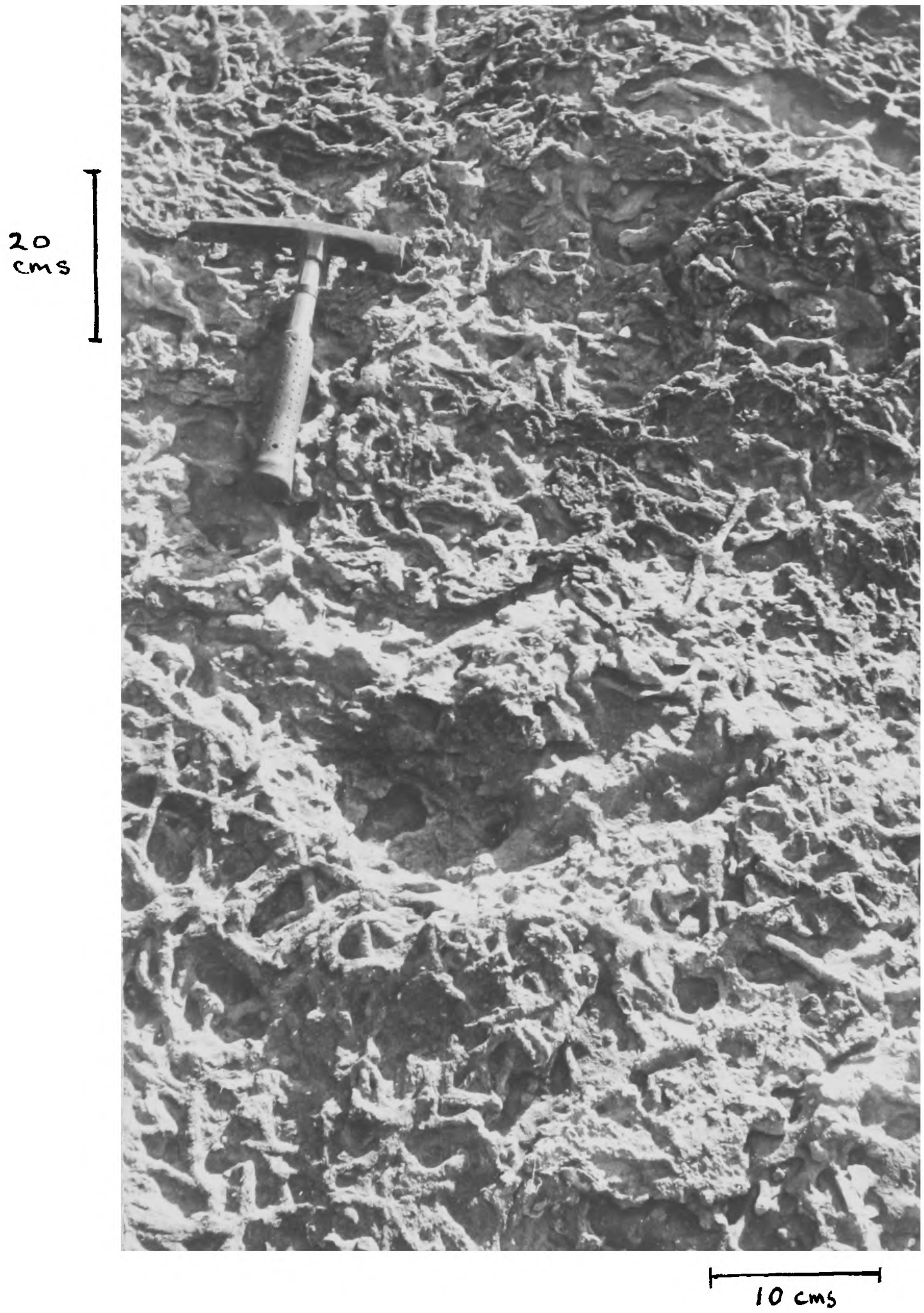
Plate 36 A bioturbated horizon in the upper part of the Lower Cherty Beds in the east Isle of Purbeck (see Plate 35). *Thalassinoides* burrows are compacted and distorted by pressure solution which has concentrated dark insoluble residues and shell fragments.


J'


0.2m

Plate 37 *Thalassinoides* on a bedding plane surface at the top of Lower Cherty Beds (Bed J') seen on a fallen block below St. Alban's Head, east Isle of Purbeck, Dorset.

Plate 38 Ammonite on surface of Bed J', top of the Lower Cherty Beds, Dancing Ledge, east Isle of Purbeck, Dorset. The ammonite is encrusted with *Exogyra* and serpulids. The dark areas on the bed are due to pressure solution.


20
cms
10 cms

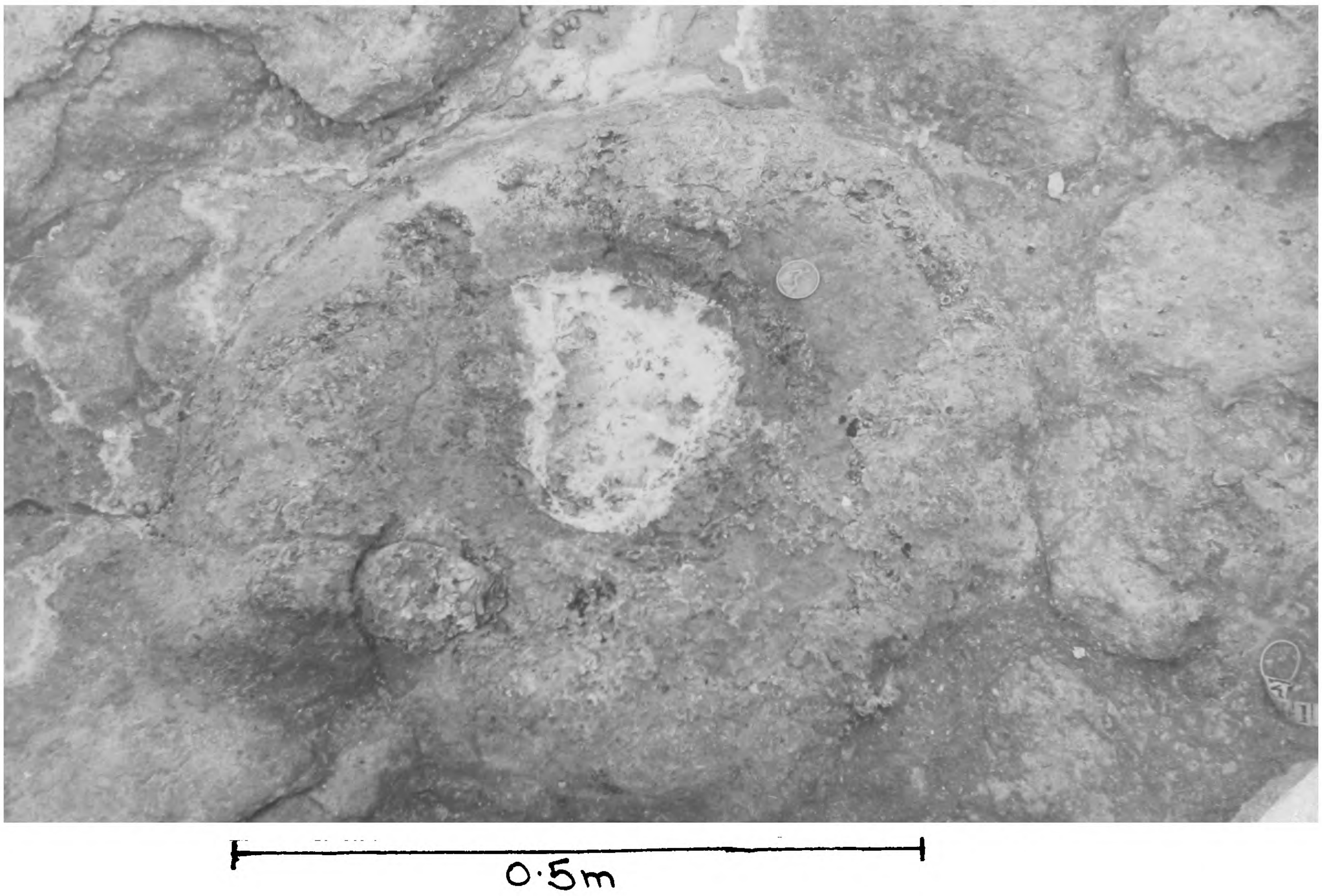

0·5m

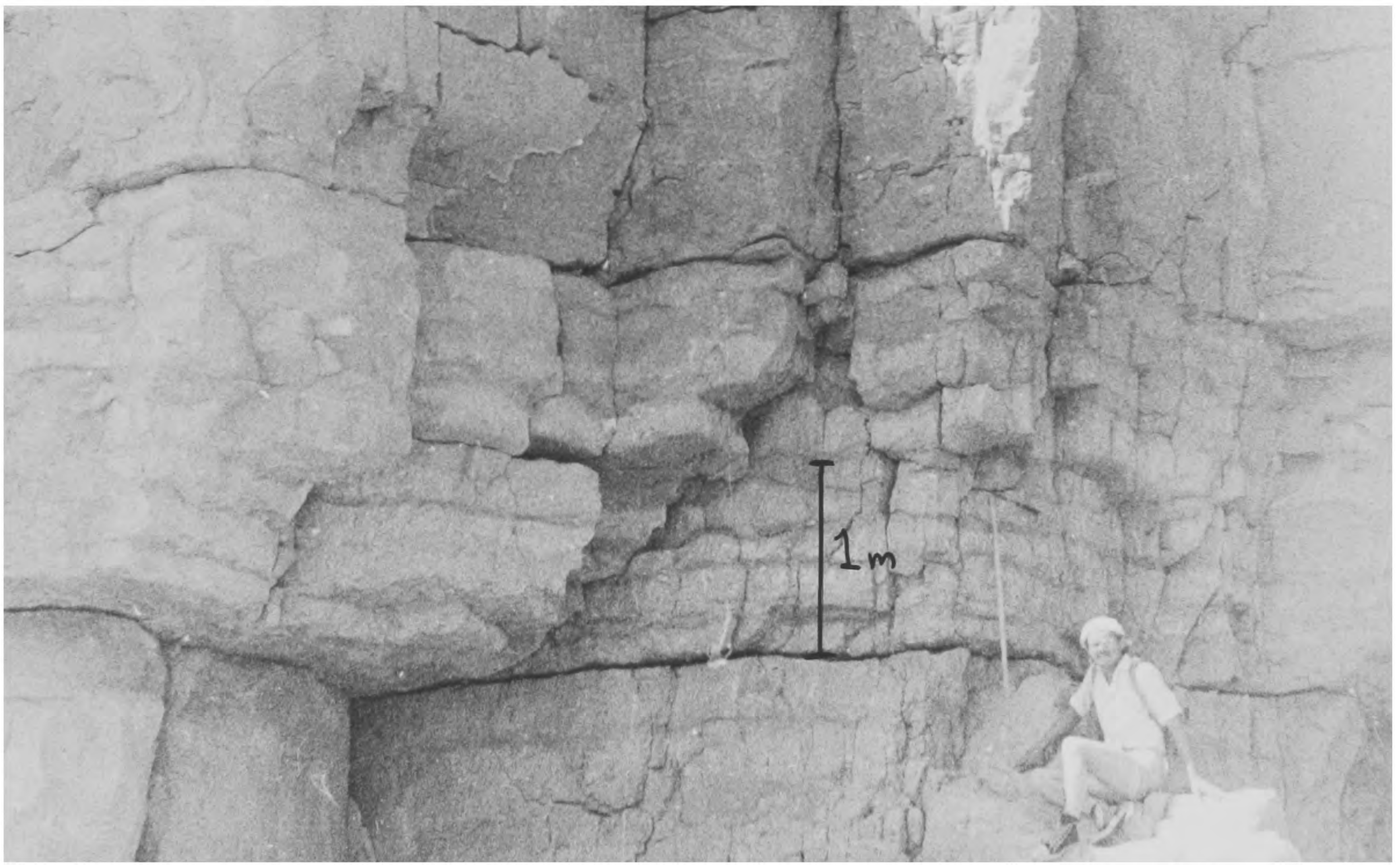
Plate 39 Thin section through a pressure solution horizon at the base of the Upper Cherty Beds in the east Isle of Purbeck. The sediment consists of biochems and scattered fine quartz sand in a micrite matrix with partially silicified (s) serpulids which are crushed and dissolved (see arrow).

Plate 40 A massive chert nodule in the Upper Cherty Beds in the east Isle of Purbeck (Dancing Ledge), showing zones of varying degrees of silicification.


S
500µ

Plate 41 Pressure solution horizons in the Lower Freestone Beds, east Isle of Purbeck, Dorset (biochem sand facies).

Plate 42 Detail of slumped avalanche foresets in the Freestone Beds of the east Isle of Purbeck.


1m


0.1m

Plate 43 The Freestone Beds at Dancing Ledge, east Isle of Purbeck (SY 998769). The junction of the Top Grey Micrite (TGM) with the Purbeck Beds is indicated by an arrow.

Plate 44 The Portland Limestone Formation at the east end of Gad Cliff, west Isle of Purbeck, Dorset. The Lower Cherty Beds are indicated as 1, overlain by the Upper Cherty Beds and Freestone Beds, 2, and the Lower Purbeck Beds, 3.


TGM

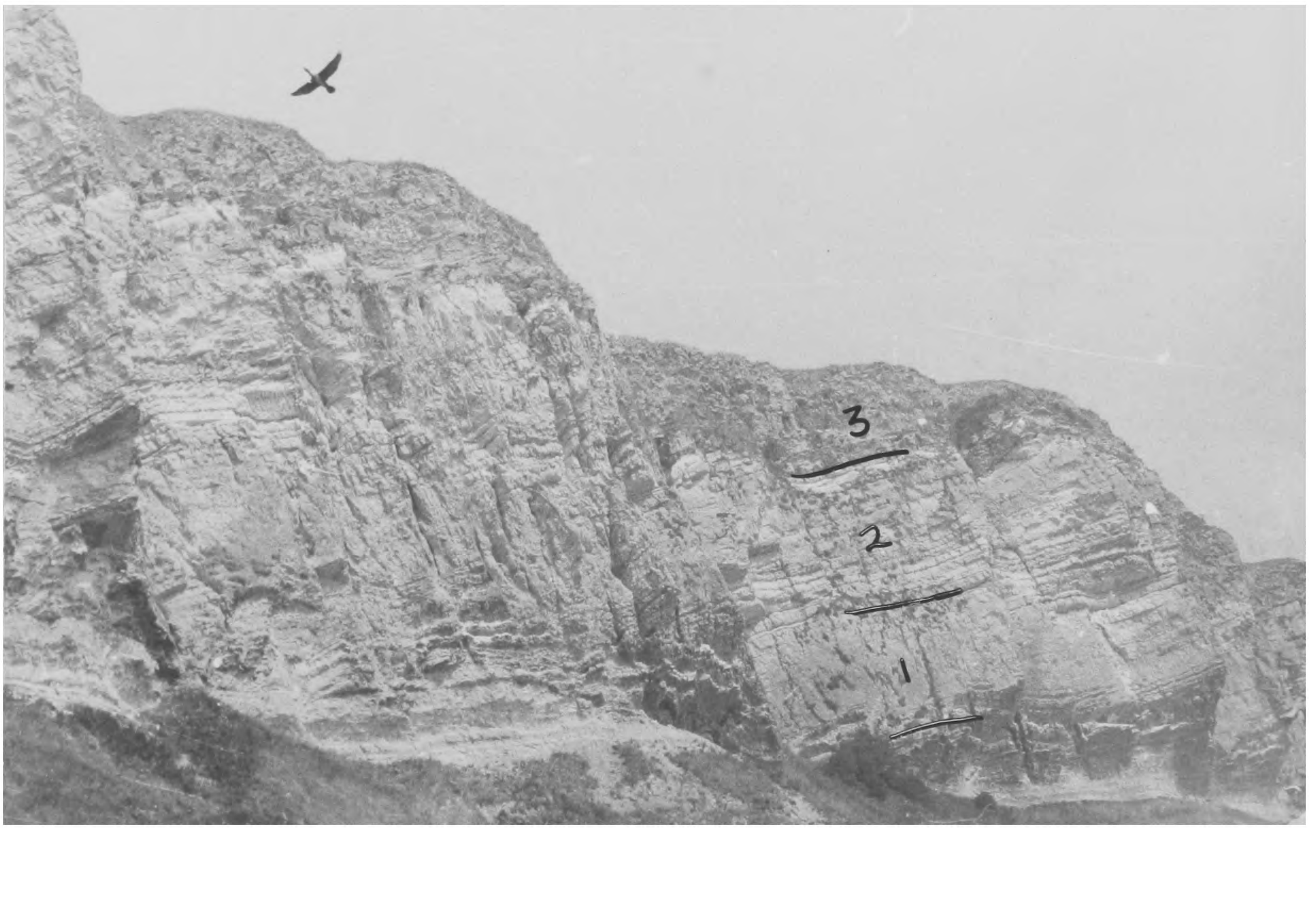

3
2
1

Plate 45 Huge fallen block of the Lower Cherty Beds on the beach below the central part of Gad Cliff, showing the intense silicification and numerous pressure solution horizons. Hammer and knapsack encircled for scale.

Plate 46 Concentration of Glomerula gordialis in the Lower Cherty Beds of Gad Cliff.

Plate 47 "*Teichichnus?*" on a bedding plane in the Lower Cherty Beds of Gad Cliff.

Plate 48 View of Gad Cliff from Warbarrow Tout, west Isle of Purbeck. In the foreground are the Lower Cherty Beds (the man is standing on the top of Arkell's Bed J'), succeeded by the Upper Cherty Bed with thin inclined chert veins in the lower part. The beds can be traced to Gad Cliff where the Portland Sand Formation, 1, is overlain by the Lower Cherty Beds, 2, the Upper Cherty Beds and Freestone Beds, 3, and the Lower Purbeck Beds, 4. The vertical dashed line shows where a section was measured.

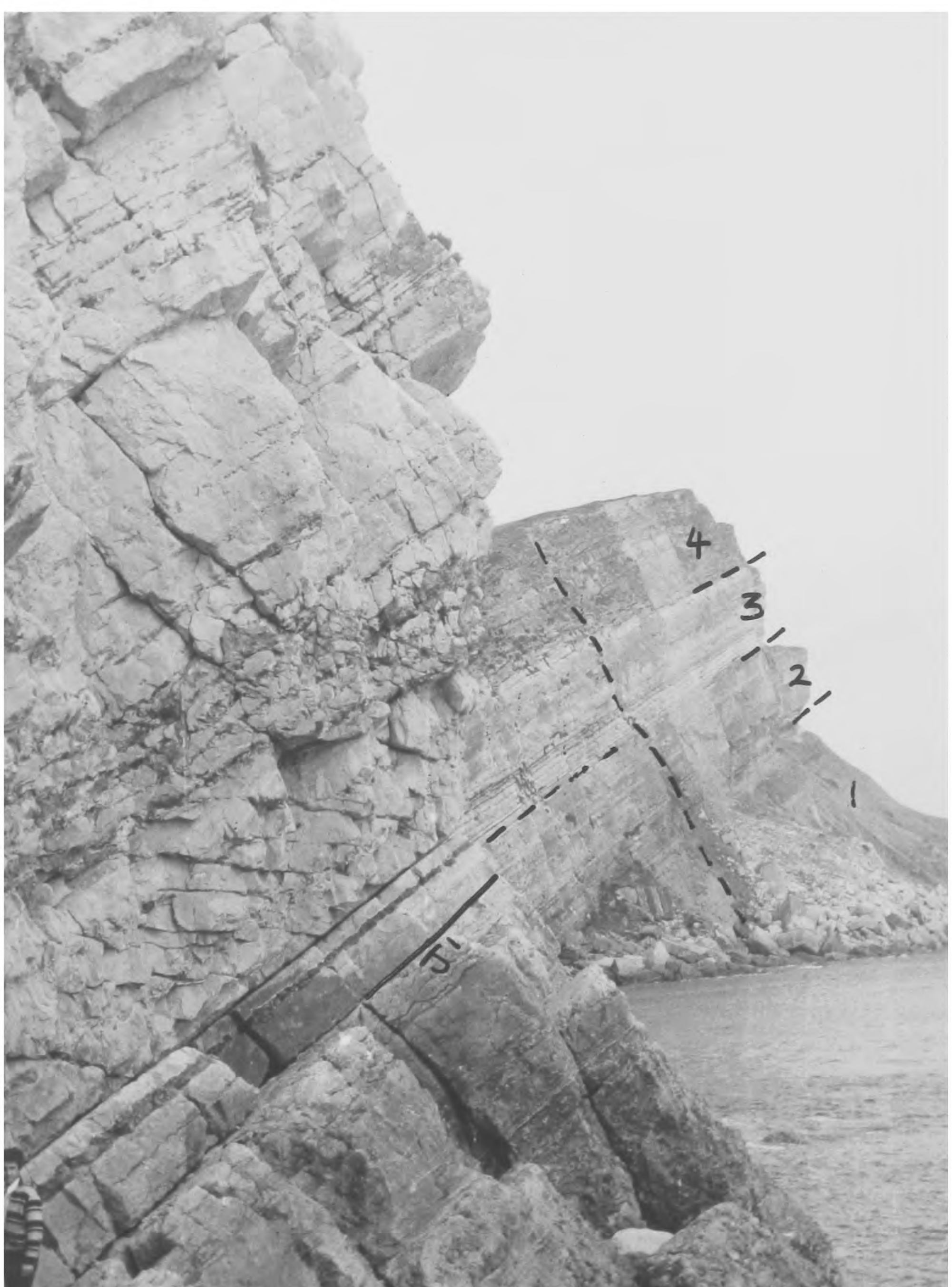
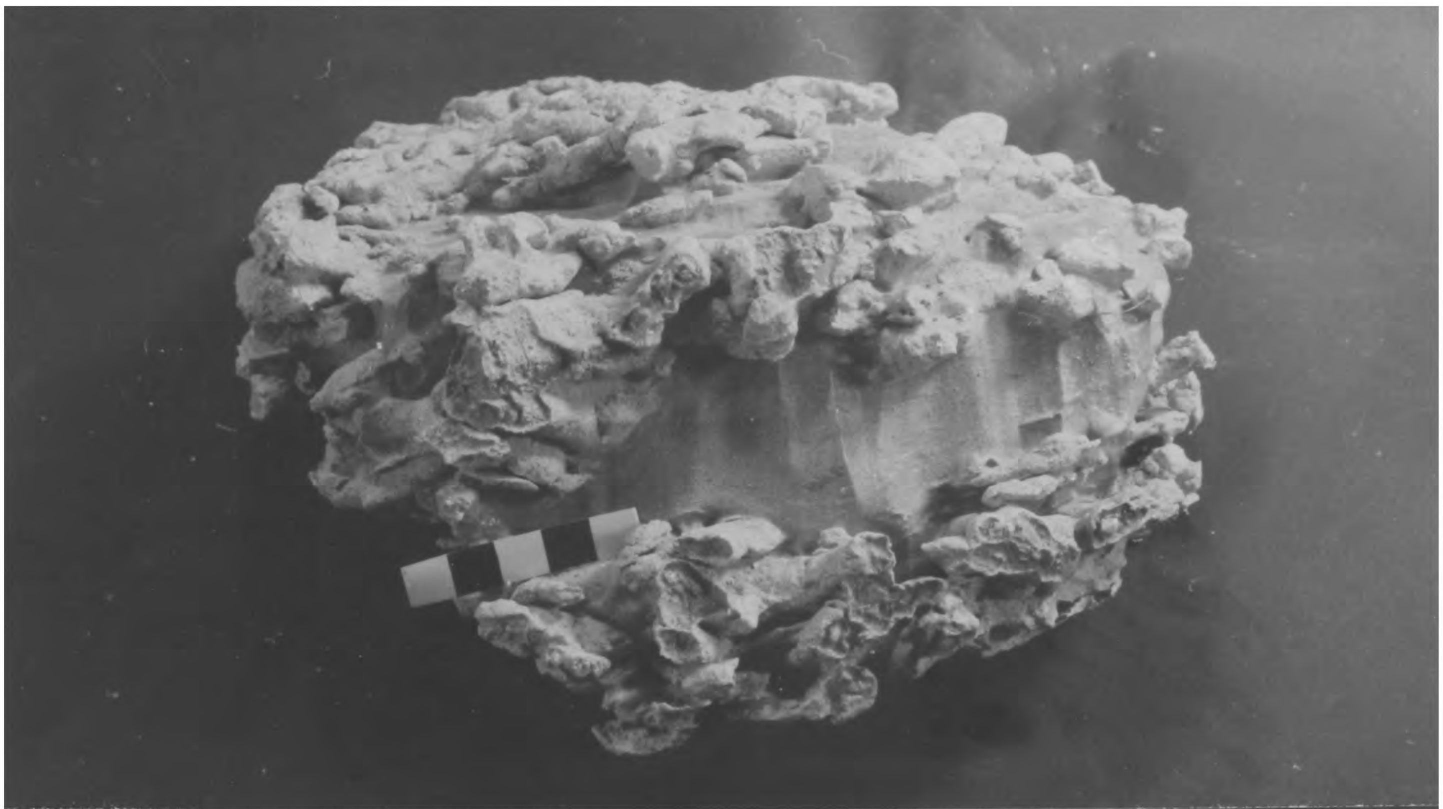

4
3
2
1
5

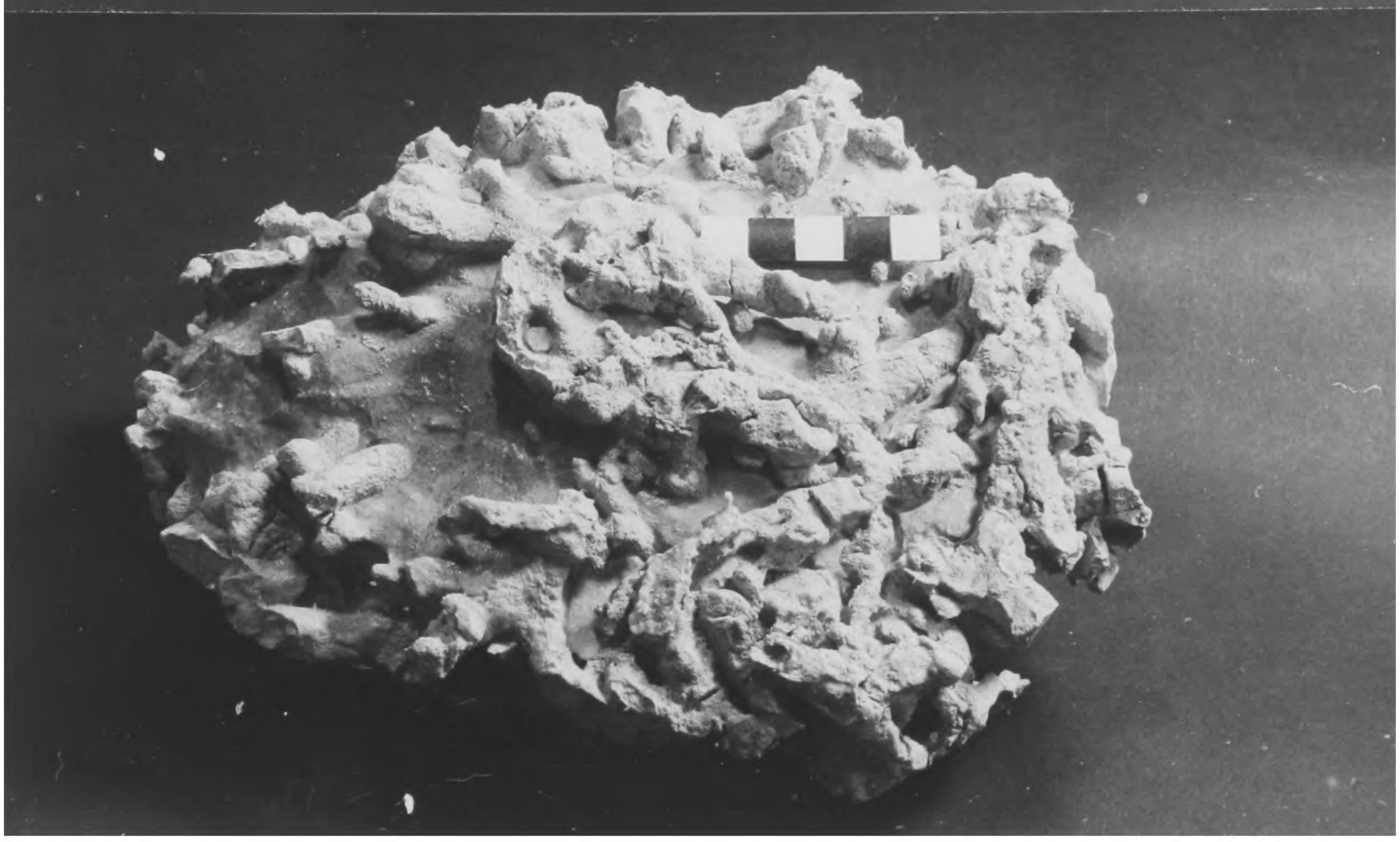
Plate 49 The Upper Cherty Beds and Freestone Beds between Stair Hole and Lulworth Cove in the Central Area, Dorset. Cross-stratification is visible above the silicified horizons of the Upper Cherty Beds. The Purbeck Beds from the grassy cliff top.

Plate 50 Chert burrows with Cherty Beds, west of Stair Hole, Central Area, Dorset. Rhaxella spicules were concentrated by bioturbation and the tubes selectively silicified.

Plate 51 Silicified trace fossils revealed after acid treatment. Scale in cms. See Plate 50.

Plate 52 Planar cross-stratification shown by the concentration of shell fragments on foresets. Fallen block (upside down) of Freestone Beds, west Stair Hole, Central Area, Dorset. Silicified foresets are seen above.






0·5m

Plate 53 The condensed succession of the Portland Limestone Formation at Dungy Head in the Central Area, Dorset. The Black Dolomite Beds of the Portland Sand Formation are seen in the middle distance (BDB) overlain by the Lower Cherty Beds capped by Bed J'. The chert-rich lower part of the Lower Cherty Beds and relatively chert-rich upper part shows clearly and Bed J' is still recognisable (compare with Plate 35). Massive black chert associated with faulting is seen in the Upper Cherty Beds. The dip is 40$^{\circ}$ to the north, on the north limb of the Weymouth-Purbeck Anticline.

Plate 54 The Upper Cherty Beds and Freestone Beds at Mutton Cove on the west Coast of the Isle of Portland. Thin bedded chert-rich Facies 1a forms the lower part of the cliff and massive cross-stratified shell beds occur in the upper half. The cliff top is at the junction of the Portland Limestone Formation with the Purbeck Beds.

c6m
J1
BDB


Plate 55 The Freestone Beds on the south-west coast of the Isle of Portland, Dorset with cross-stratified oolite in the lower part.

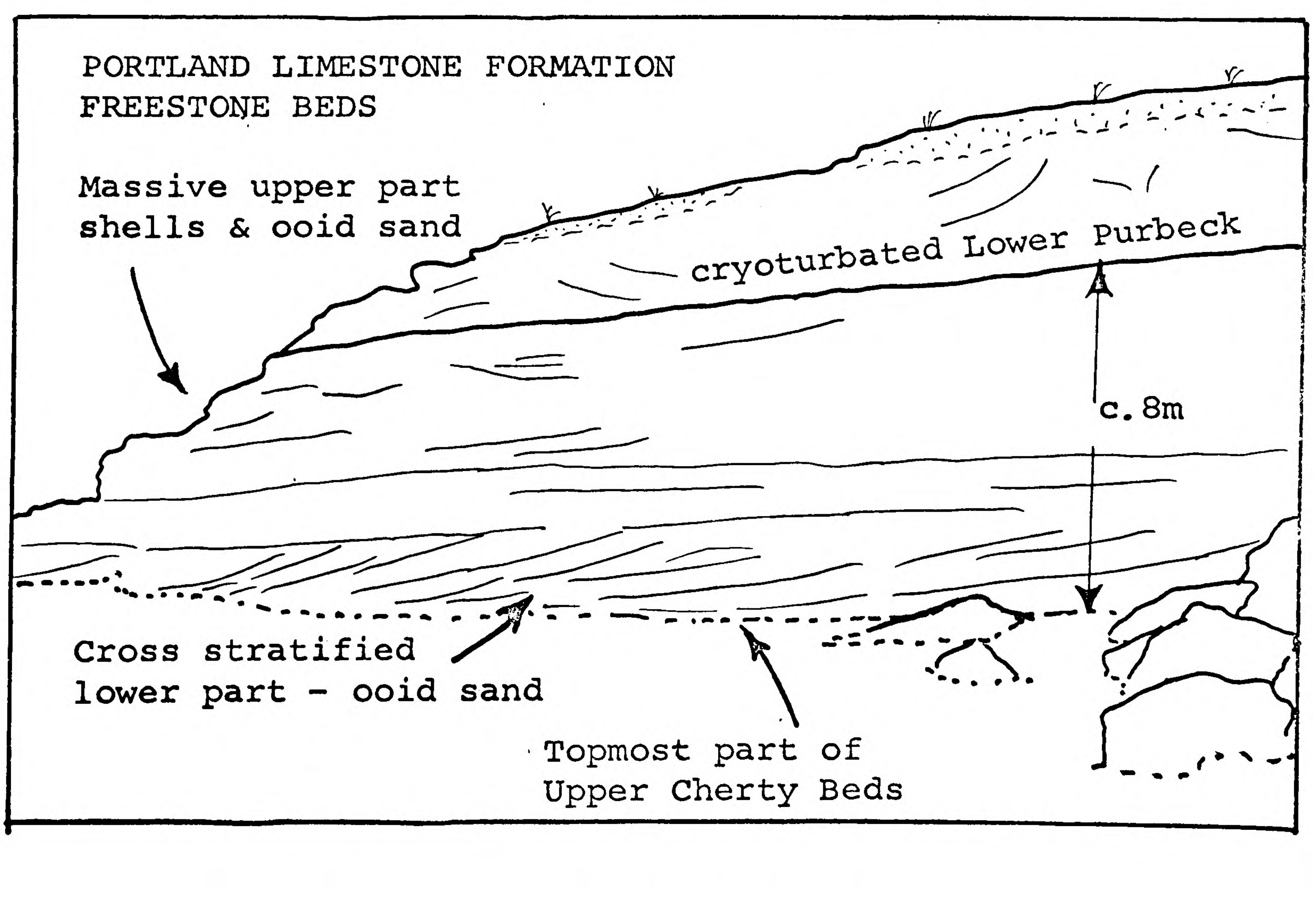
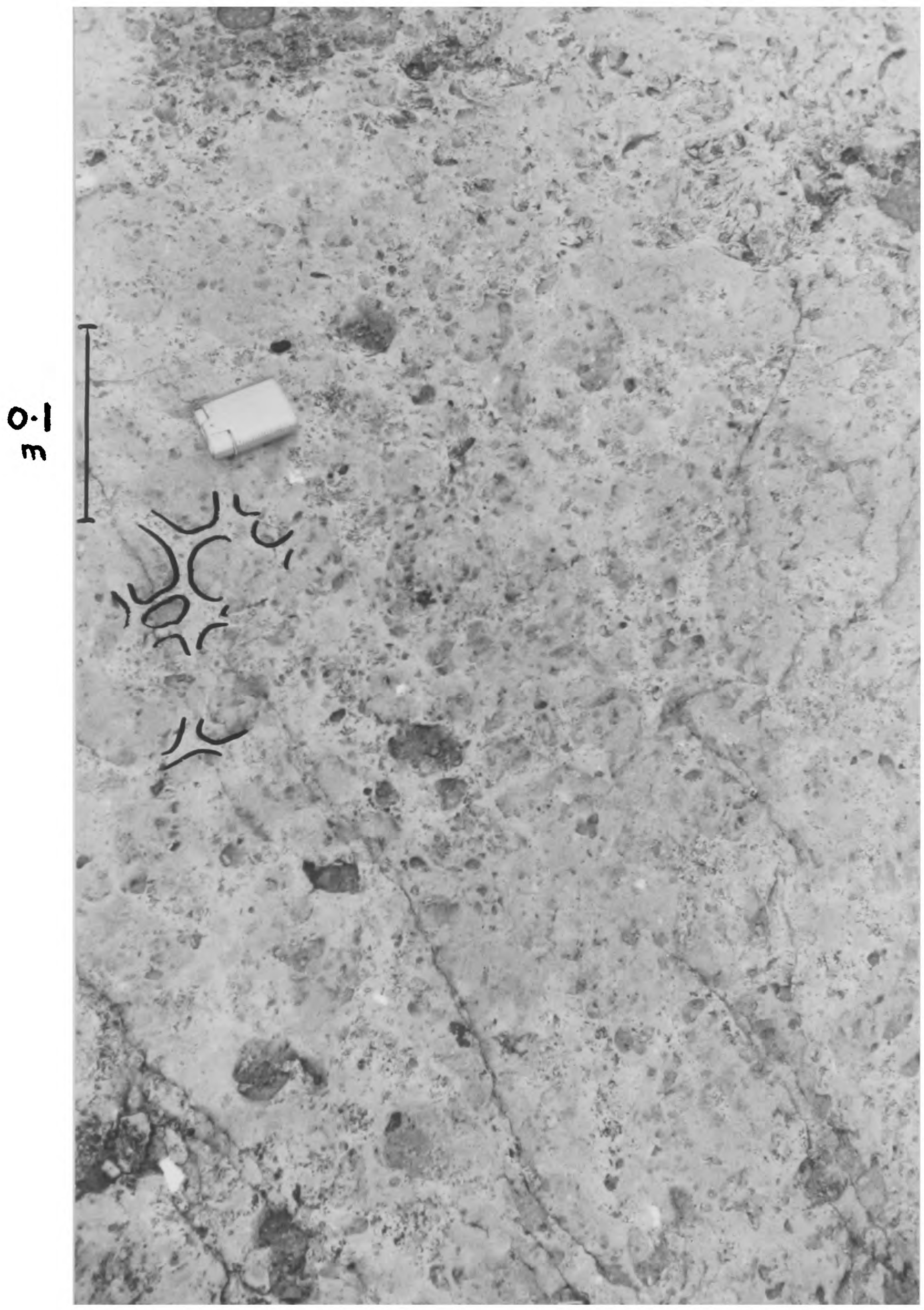

PORTLAND LIMESTONE FORMATION
FREESTONE BEDS
Massive upper part
shells & ooid sand
cryoturbated Lower Purbeck
c. 8m
Cross stratified
lower part - ooid sand
Topmost part of
Upper Cherty Beds

Plate 56 *Thalassinoides* on a bedding plane in the Freestone Beds on the south-west coast of the Isle of Portland, showing the polygonal branching pattern of the burrows over the whole field of view.

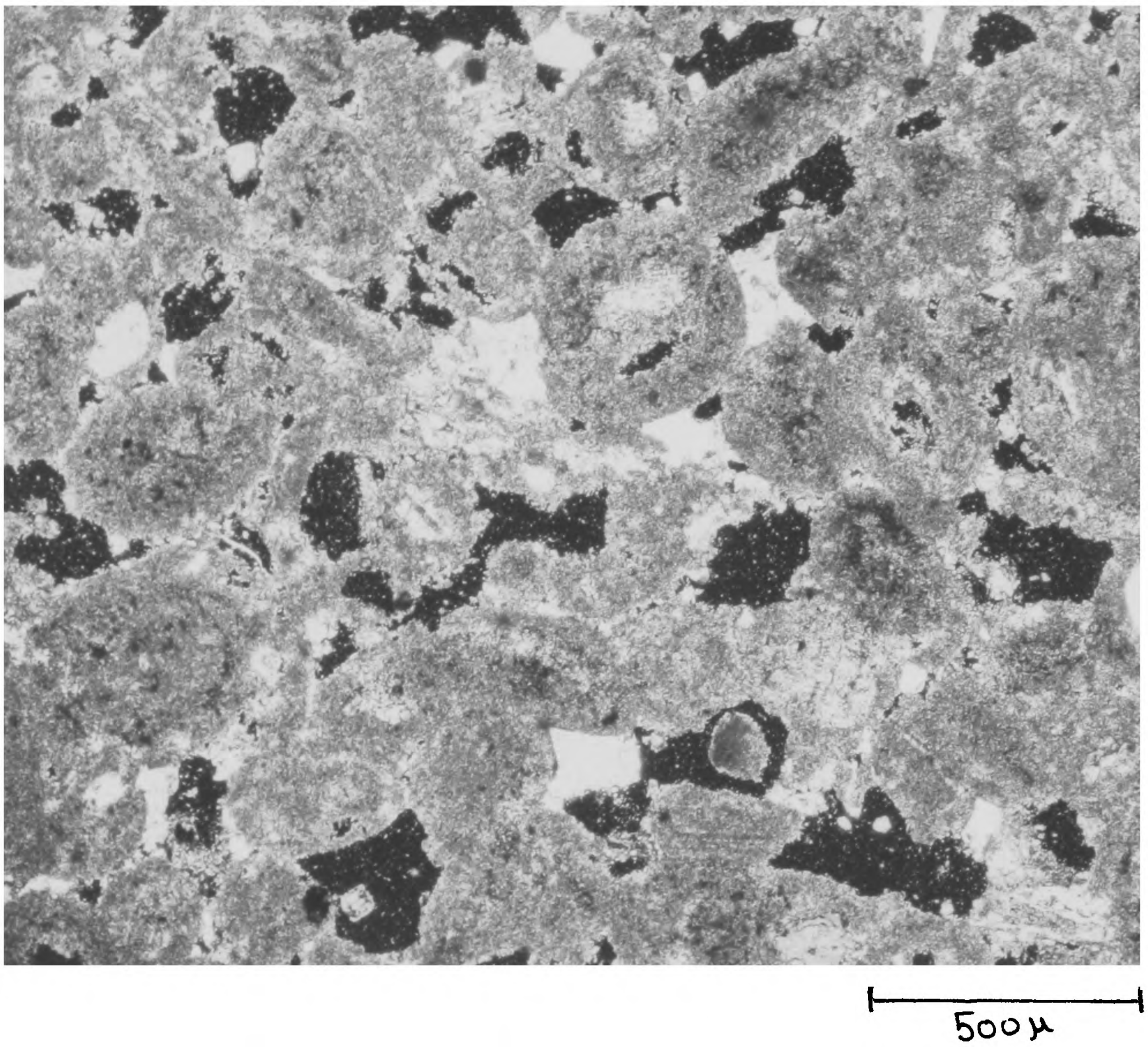
Plate 57 Bioturbated top of an ooid sand body overlain by laminated micrite, seen in an old quarry in the Freestone Beds on theIsle of Portland, Dorset. The dashed line shows the junction of the shelly oolite with the micrite and the arrow indicates the base of the Purbeck Beds.


0·1
m


1m

Plate 58 Thin section of a very micritised, very porous oolite. This is a typical sample from the Freestone Beds of the Isle of Portland. (Viewed through crossed polarised light.)

Plate 59 Blocks of oyster patch reef and shell debris in the ooid-sand facies of the Upper part of the Freestone Beds in the north of the Isle of Portland.


500µ

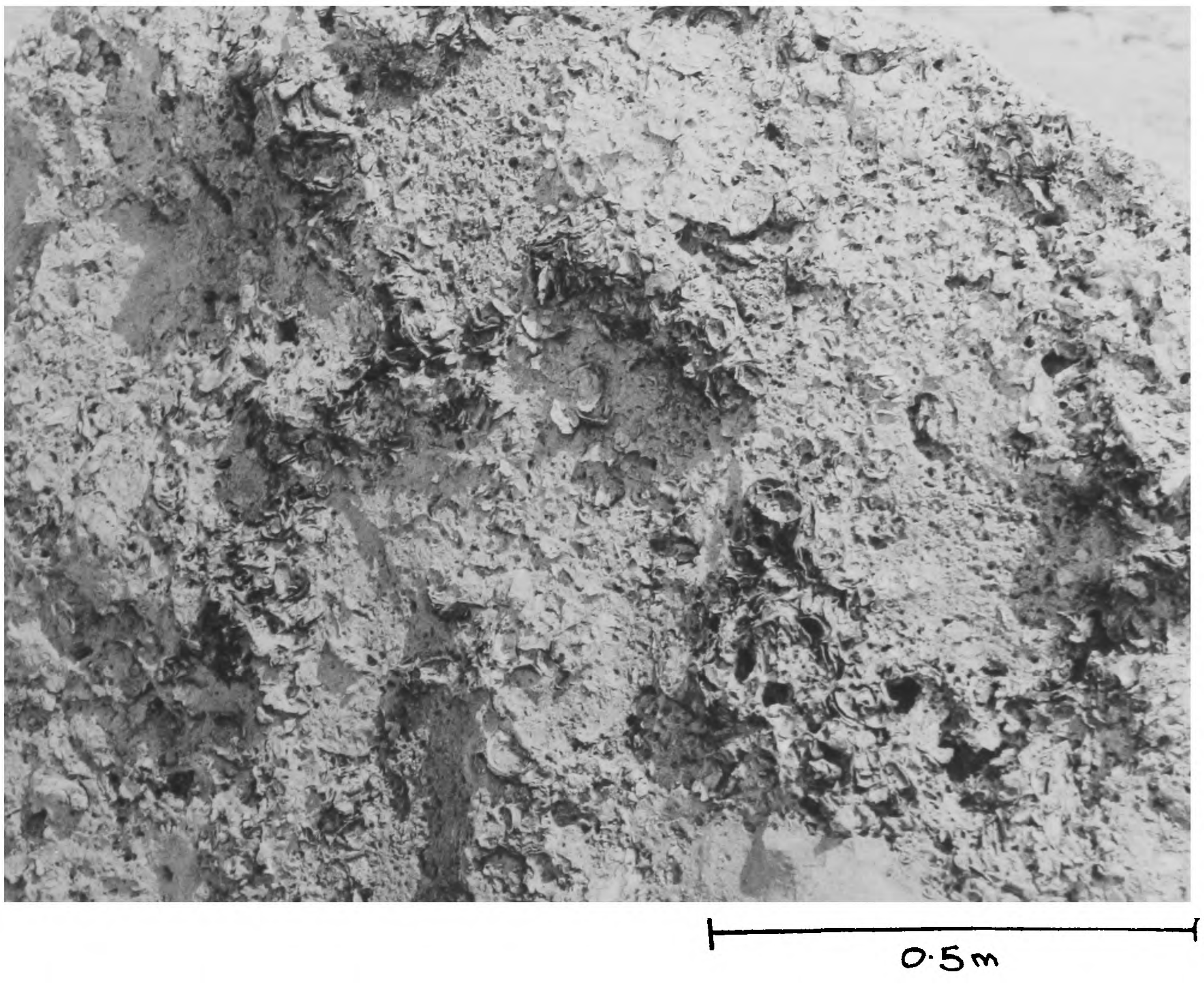

0·5m

Plate 60 Negative print of a thin section cut vertically through a lithified carbonate sand composed of whole and fragmented aragonitic and calcitic bivalves, bryozoa (bottom left), gastropods (centre) and intraclasts. The main cement is sparry calcite but there is also a microstalactitic fringe on the underside of the grains which was probably an early subaerial precipitate of aragonite. This cement formed before the aragonitic bivalves were dissolved, indicated by the fracture of the fringe and the micrite envelope in places (e.g. bottom left). This is considered to be a Portlandian beach-rock. Upper part of the Freestone Beds, south-west coast of the Isle of Portland.

1 cm

Plate 61 Polished slab cut vertically through an algal-oyster-bryozoan "patch-reef" in the upper part of the Freestone Beds of the Isle of Portland. The top left corner is shelly ooid sand with fragments of algae, the remainder of the field of view consists of a solid framework of the red algae, Solenopora, encrusted by Ostrea, Plicatula and bryzoa and bored by Lithophaga, annelids and sponges. The latter are best seen along the contact with the carbonate sand, riddling the oyster shells and truncating the structure of the "reef".

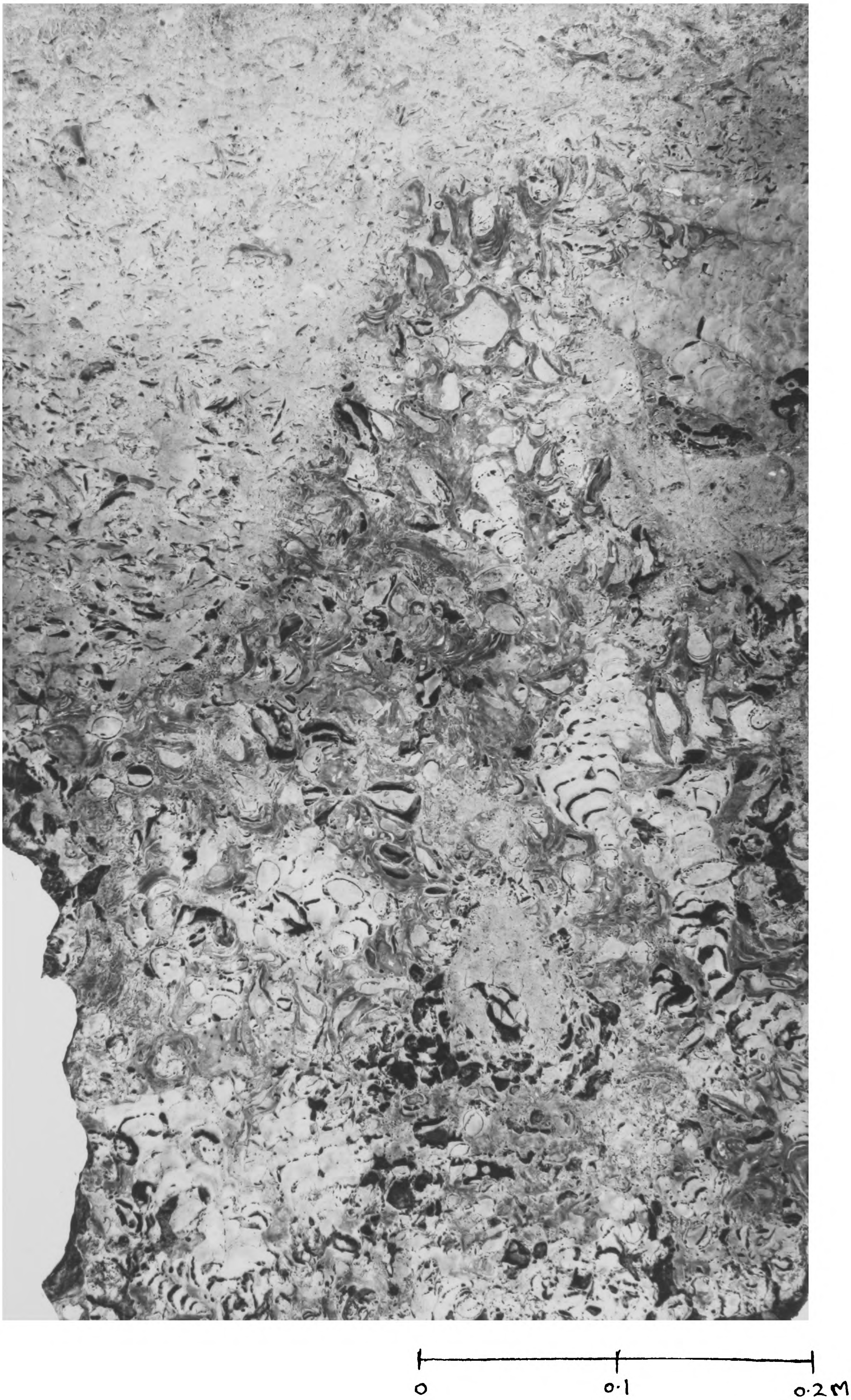

0
0·1
0·2M

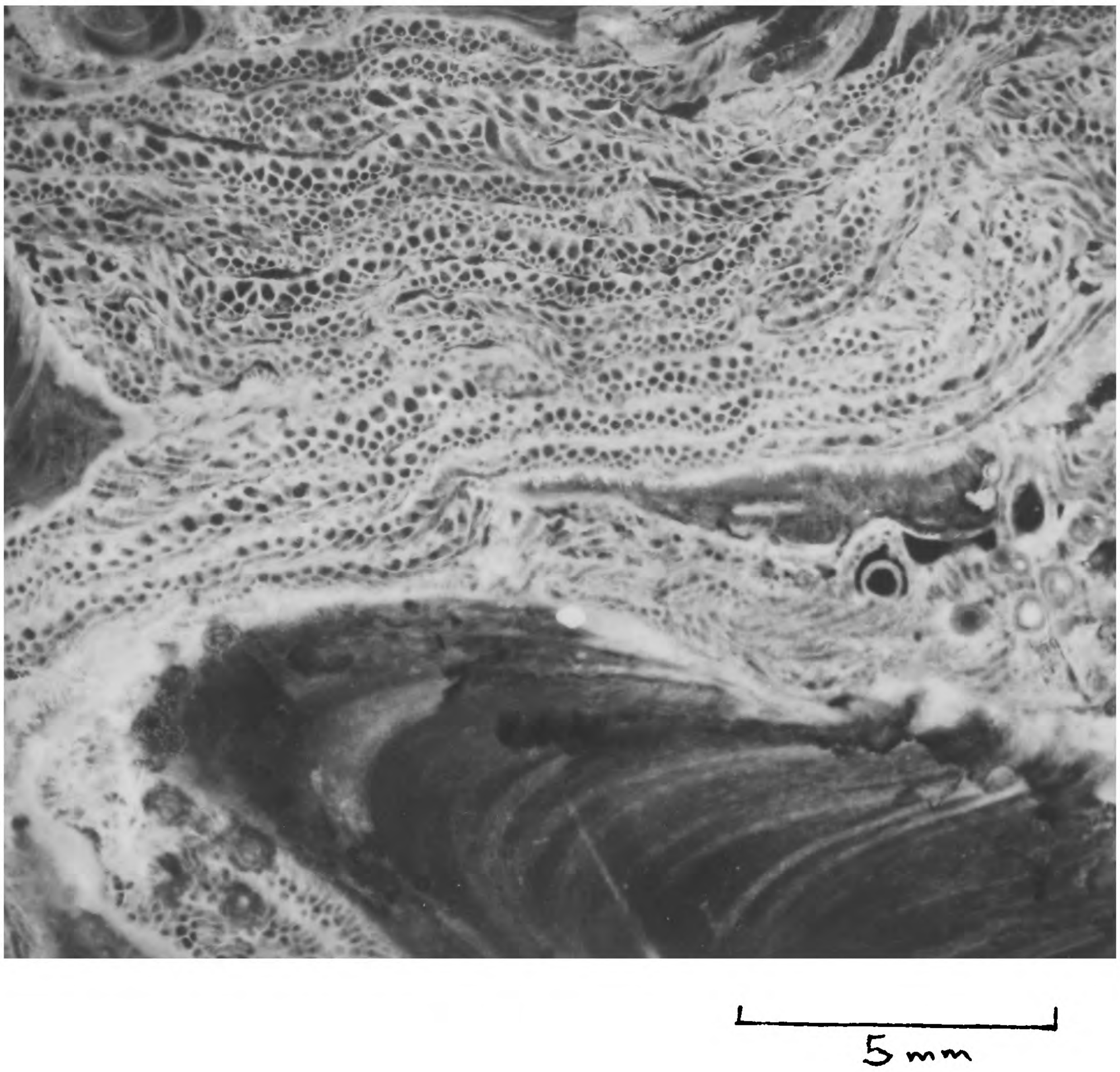
Plate 62 "Patch-reef" of oysters and algae in the Freestone Beds exposed on the south-west coast of the Isle of Portland. The surrounding sediment was originally shelly ooid sand. The structure of the "reef" was truncated by penecontemporaneous erosion (the pen is 0.15m long).

Plate 63 Vertical section in the upper part of the Freestone Beds in a quarry on the south-west coast of the Isle of Portland showing rolled and fragmented Solenopora colonies in a matrix of shelly oolite.


1m

Plate 64 Negative print of a thin section through part of a "patch reef" in the upper part of the Freestone Beds on the Isle of Portland. A partially silicified oyster shell is encrusted by lamellar bryozoa growing from the bottom to the top of the picture. Algal borings are visible in the oyster fragments left and right of the centre and enclosed serpulids are seen on the right.

Plate 65 Thin section of bryozoan-encrusted Solenopora. The Algal structure is seen in transverse section at the bottom of the picture and longitudinally showing septae, in the top left. The sediment above the bryozoa is pelletal lime mud plus ooids. (Viewed through ordinary light.)



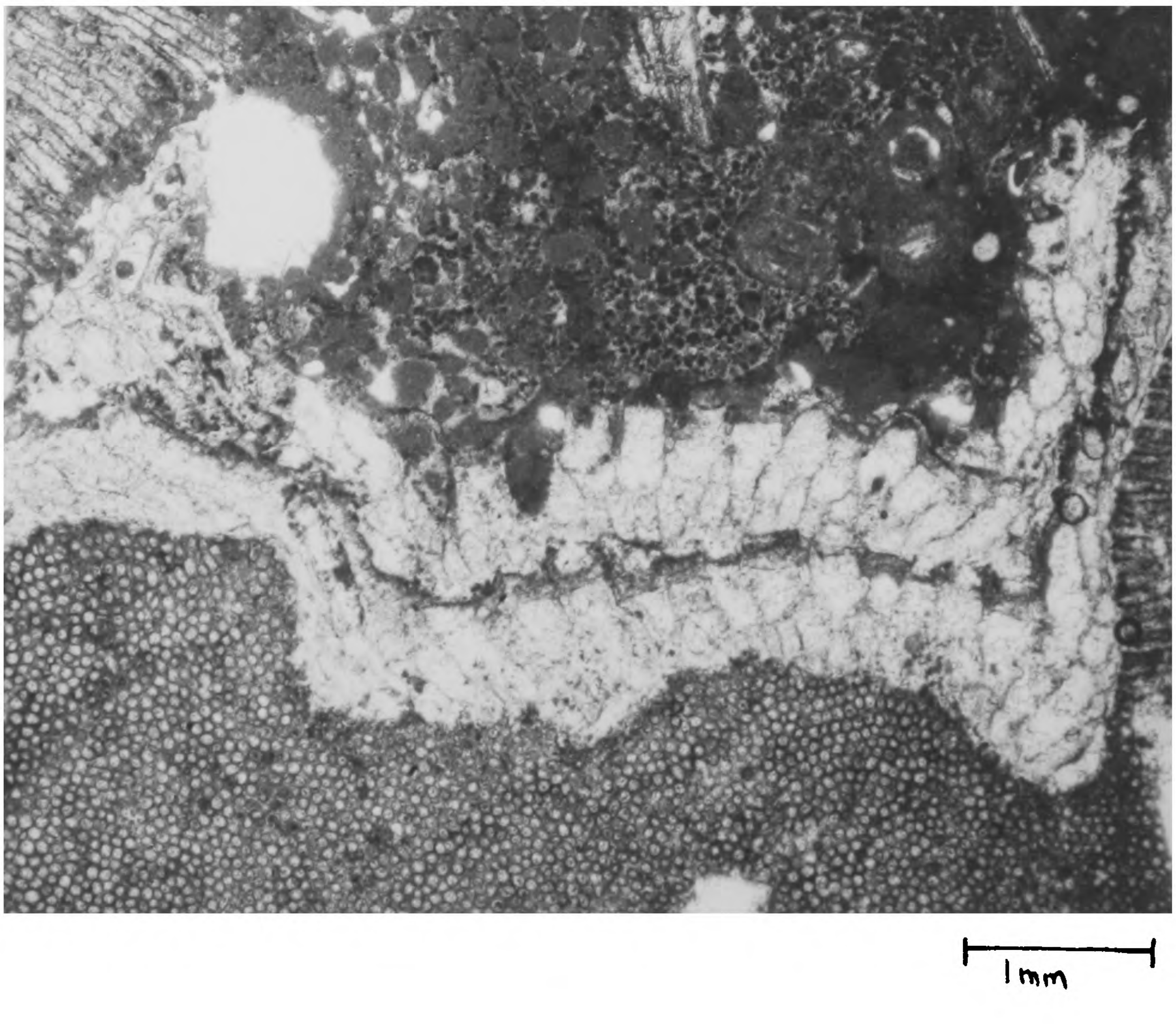


Plate 66 Negative print of thin section through a banded _Solenopora_ colony from the Freestone Beds of Portland, showing the varying degree of calcification. The cavities are filled by sparry calcite; a boring in the bottom left of the picture contains ooids and biochem sand.

Plate 67 Thin section of "pseudoboring" in _Solenopora_ showing how the algae spread over and encapsulated a serpulid which encrusted the surface. (Viewed through ordinary light.)


5mm

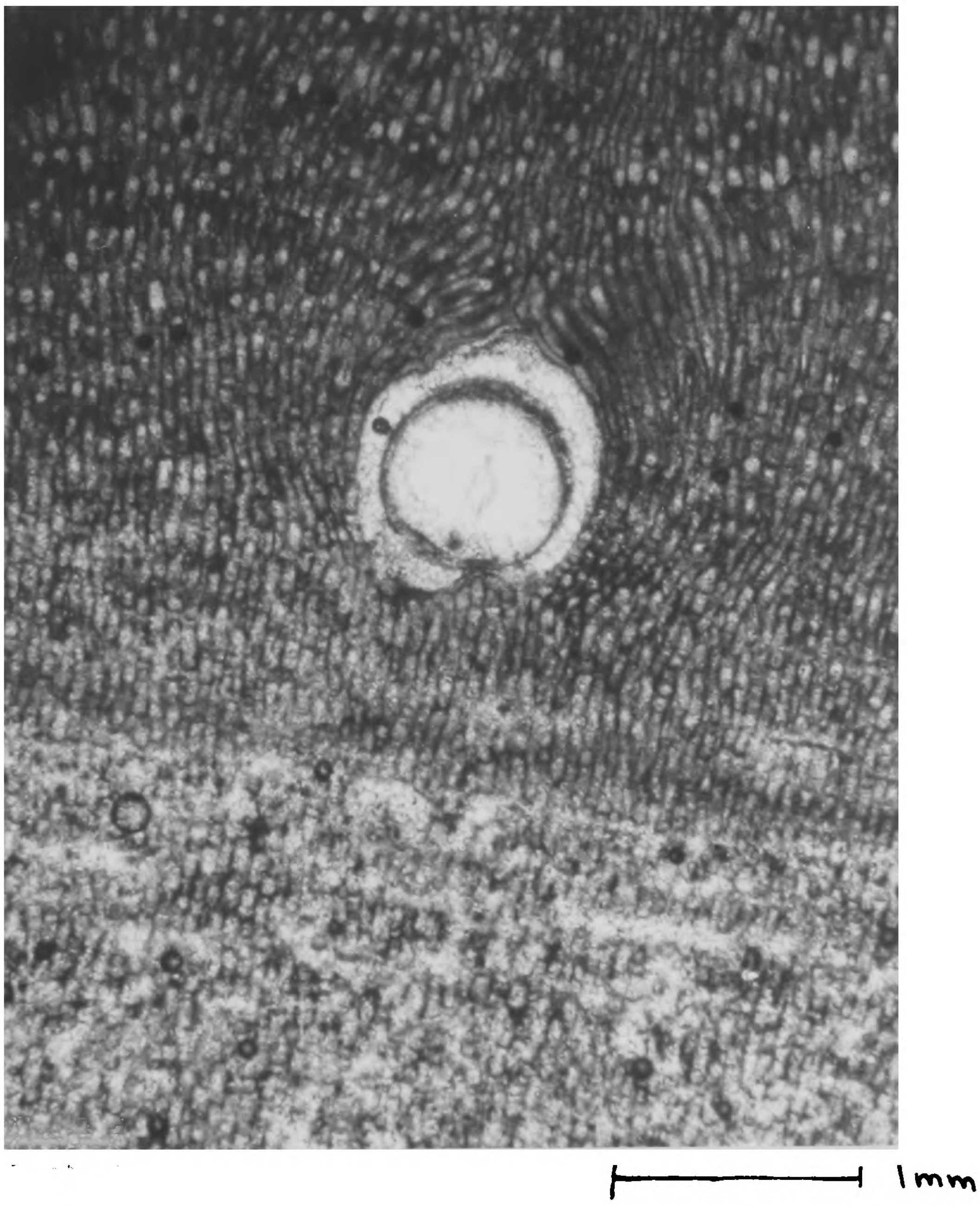
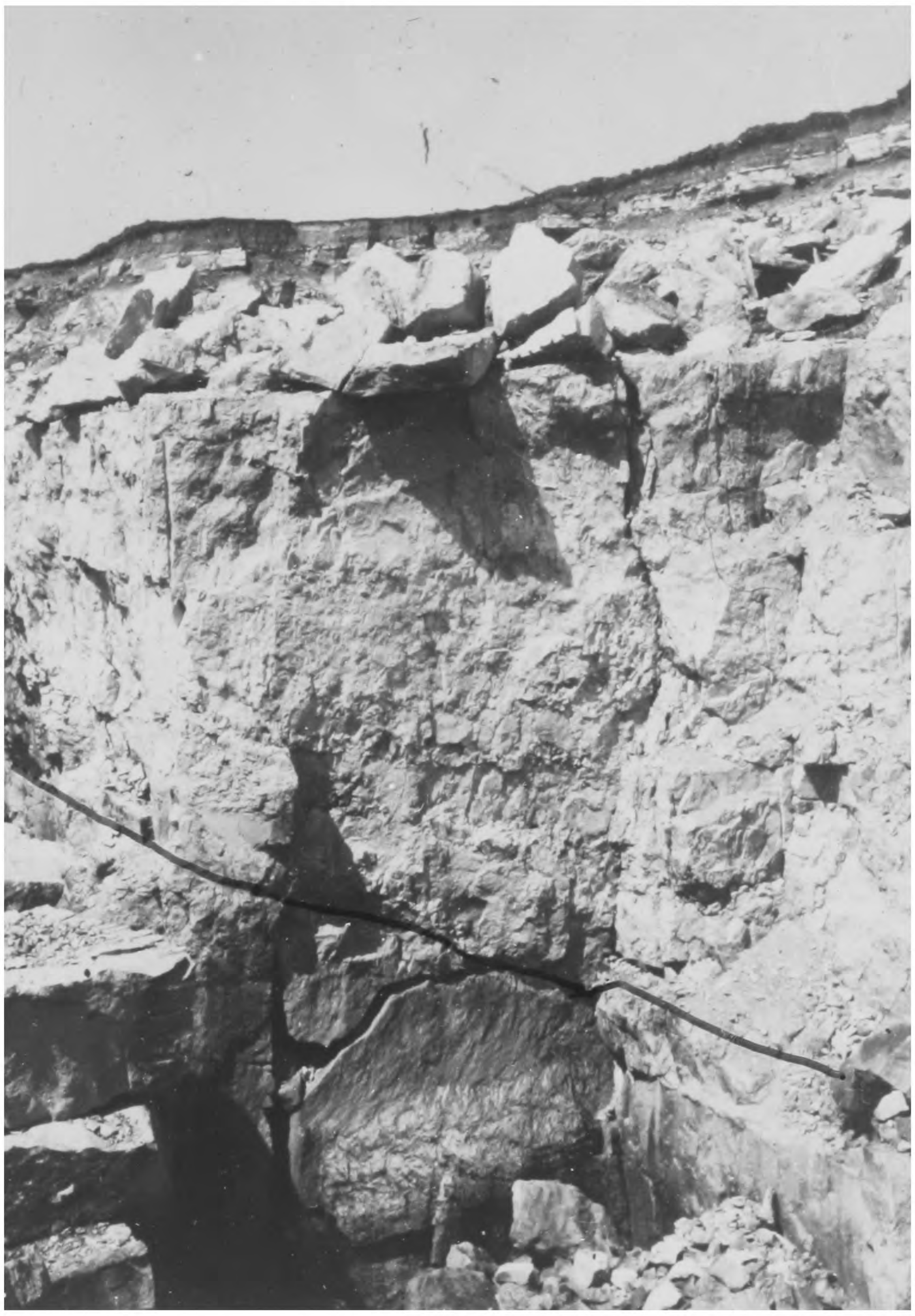

1mm

Plate 68 Photograph of shelly sponge spicule-rich micrite filling an erosion surface in the oolitic Freestone Beds seen in the north face of Broadcroft Quarry on the Isle of Portland, Dorset. The top of the section is the base of the Purbeck Beds which have been stripped off.

Plate 69 Thin section of micrite seen in Plate 68, showing calcite casts of *Rhaxella* spicules, micritised biochem sand, intraclasts and *Pachastrella*.



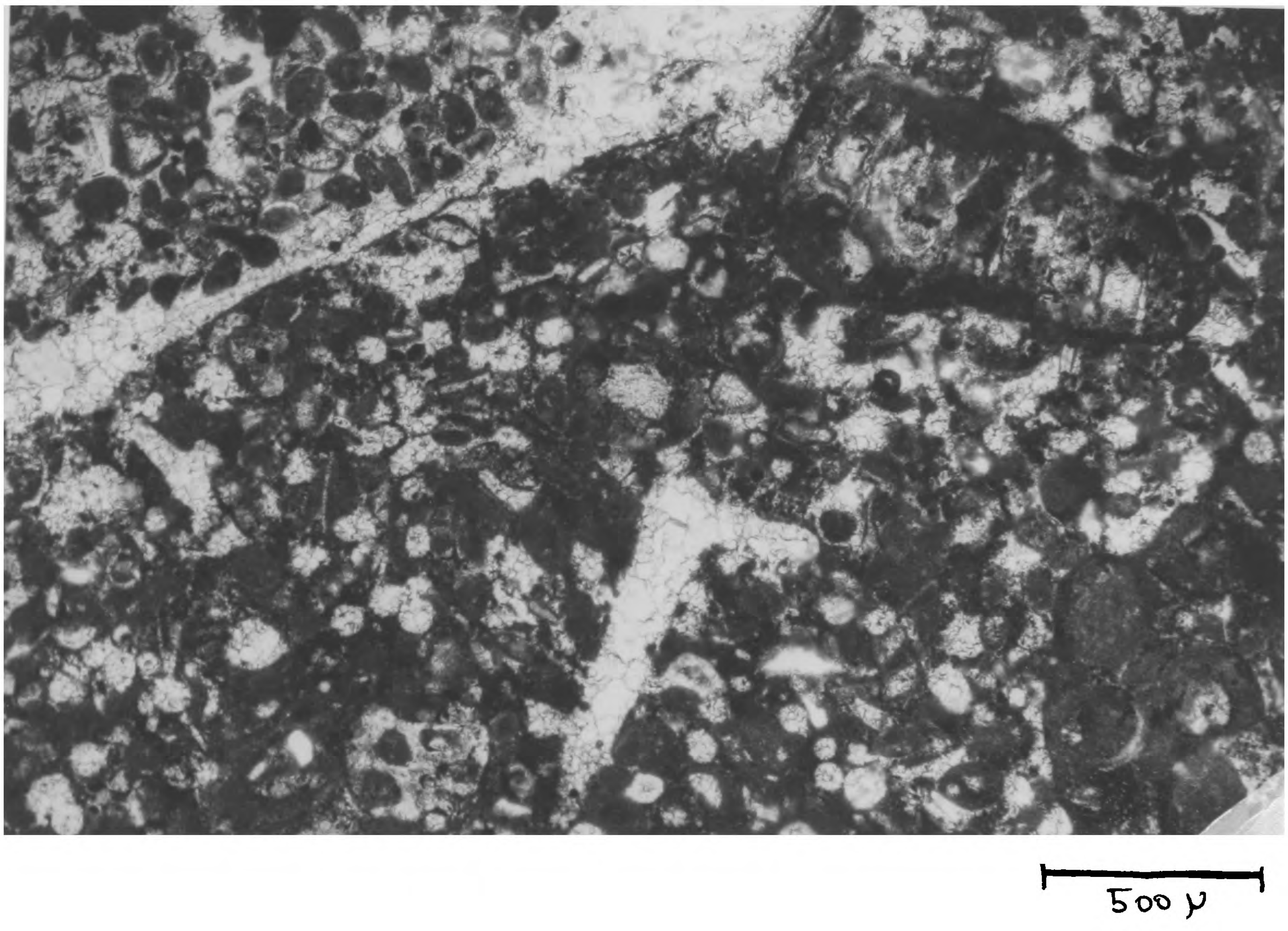

500 μ

Plate 70 An oyster "patch-reef" in micrite overlying an oolite sand body. Exposed at the north-east corner of Broadcroft Quarry in the Upper Part of the Freestone Beds on Portland.

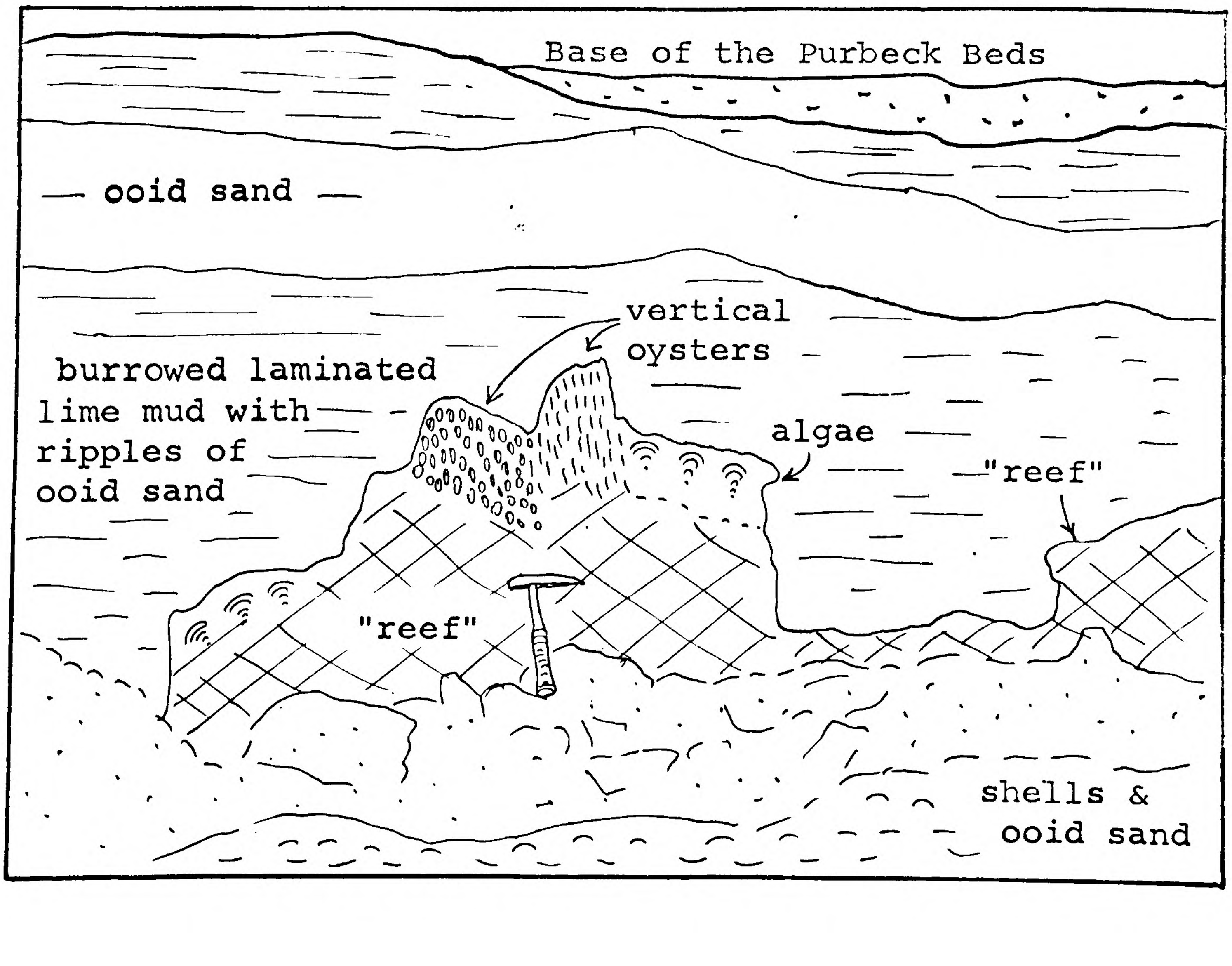
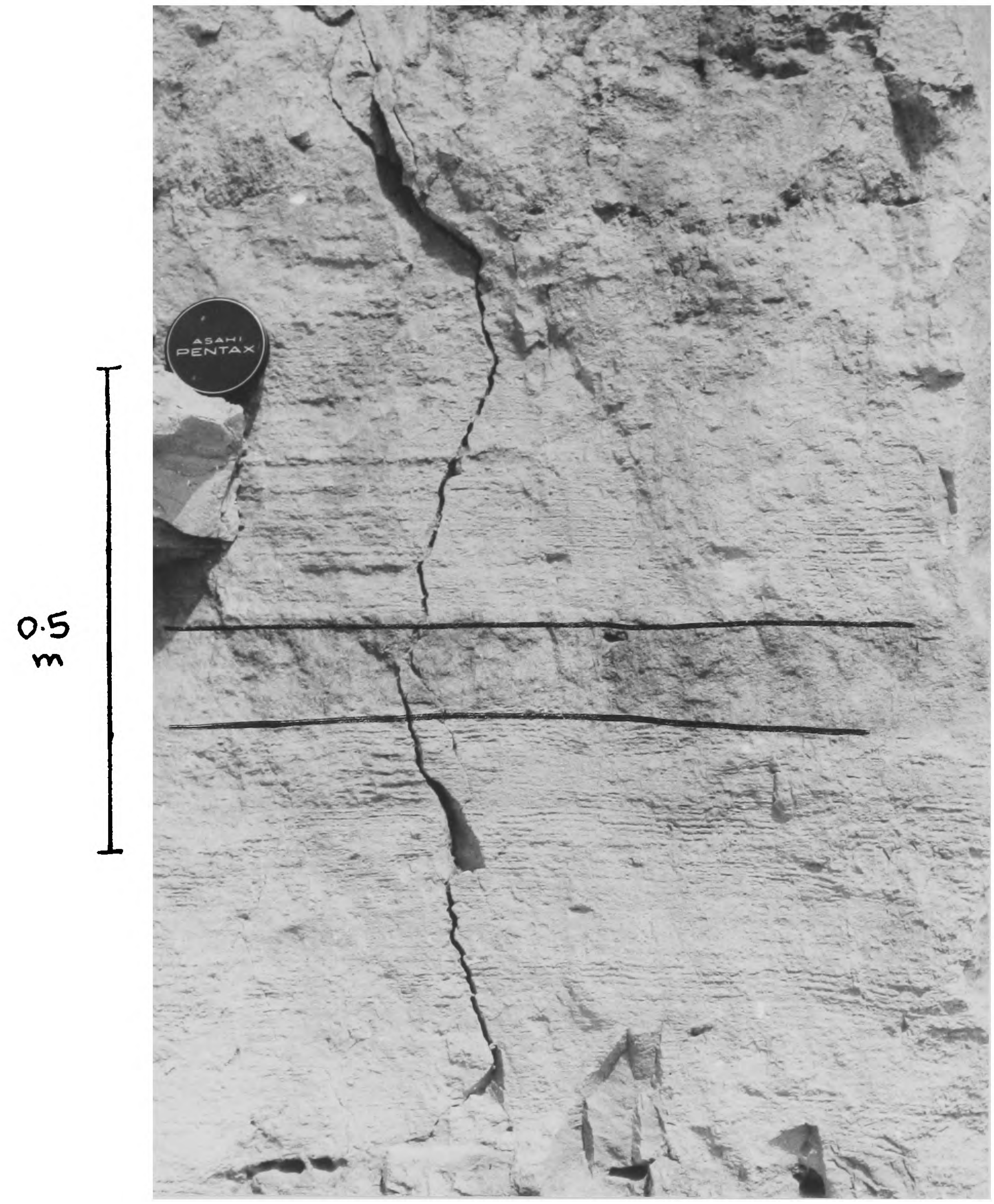
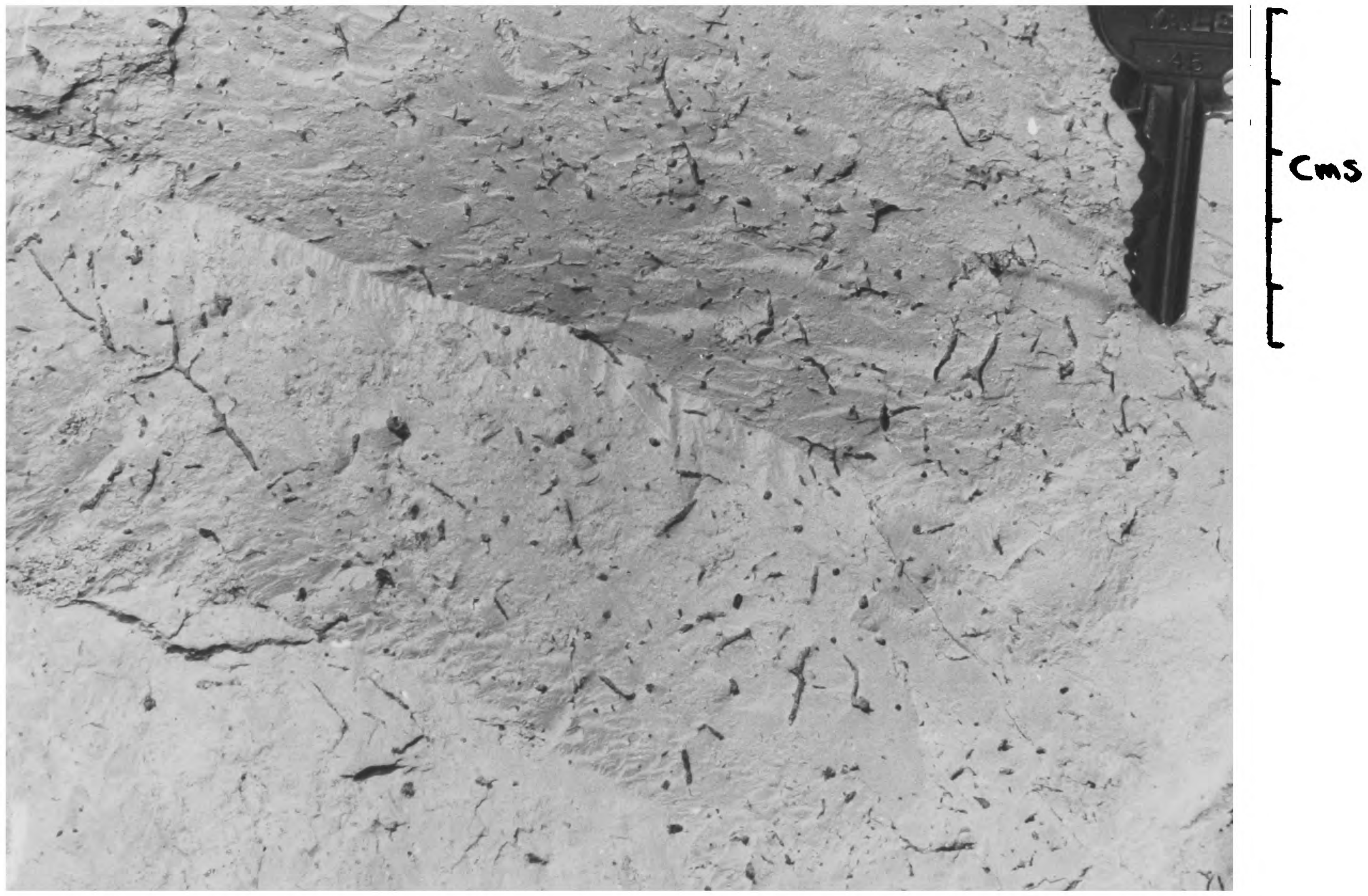

Base of the Purbeck Beds
ooid sand
vertical
oysters
burrowed laminated
lime mud with
ripples of
ooid sand
algae
"reef"
"reef"
shells &
ooid sand

Plate 71 Laminated micrite with a bed of oolite in the middle of the picture. This fills an erosion surface in the oolite sand bodies of the Upper Part of the Freestone Beds on Portland, seen in Broadcroft Quarry. The micrite is probably algal deposited intertidally and the ooid sand was a small dune which migrated over the surface (see also Plates 68 and 70).

Plate 72 Detail of burrowed micrite in the Upper Part of the Freestone Beds in Broadcroft Quarry (see Plate 71). The twig-shaped tubes are empty burrows in stiff mud, not shrinkage cracks.



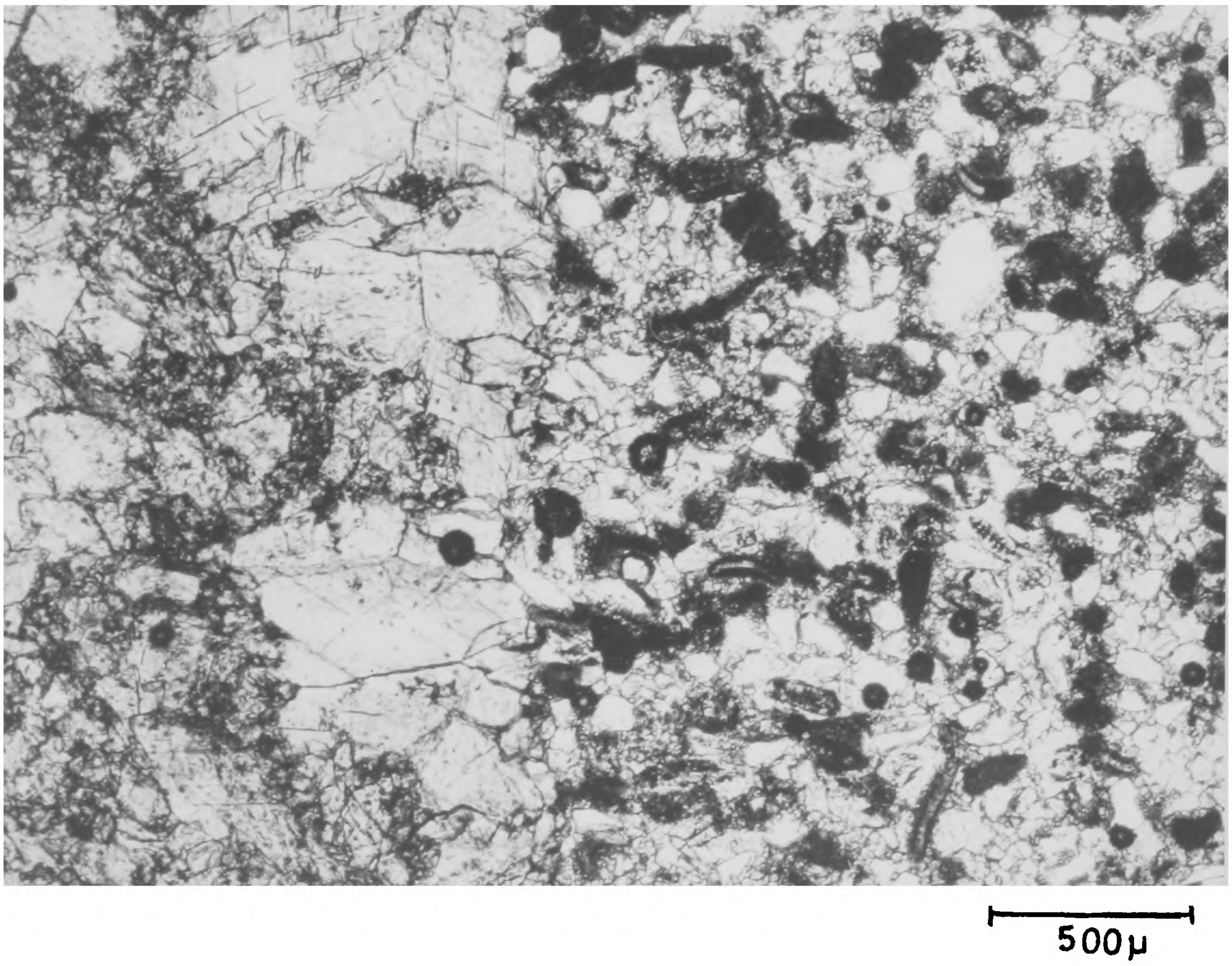
0.5 m
ASAHI PENTAX

Cms

Plate 73 Thin section of fine-grained biochem sand with a microsparite matrix due to recrystallisation of lime mud. There are scattered fine quartz grains and the rock is cut by veins of ferroan calcite partly shown in the left half of the picture. Sandy Limestone Beds, Wardour Sand Formation, Wiltshire. (Viewed through ordinary light.)

Plate 74 Thin section of medium biochem sand with sparite matrix and some empty pore spaces. Some very micritised grains are present as well as micrite-enveloped fragments of calcitic bivalves, echinoid fragments and a few quartz grains. Main Limestone Beds, Wardour Limestone Formation, Wiltshire. (Viewed through crossed polarised light.)


500µ

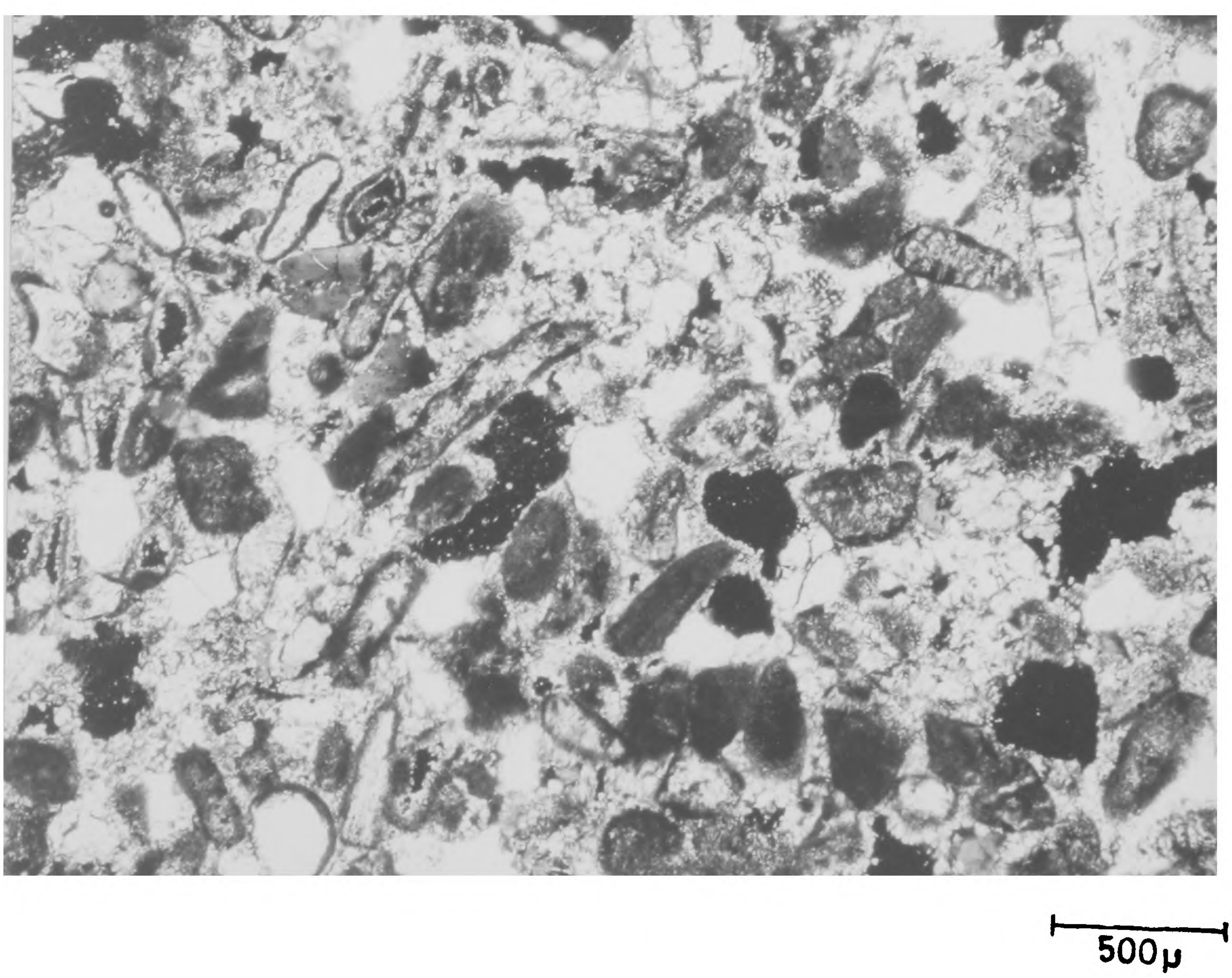
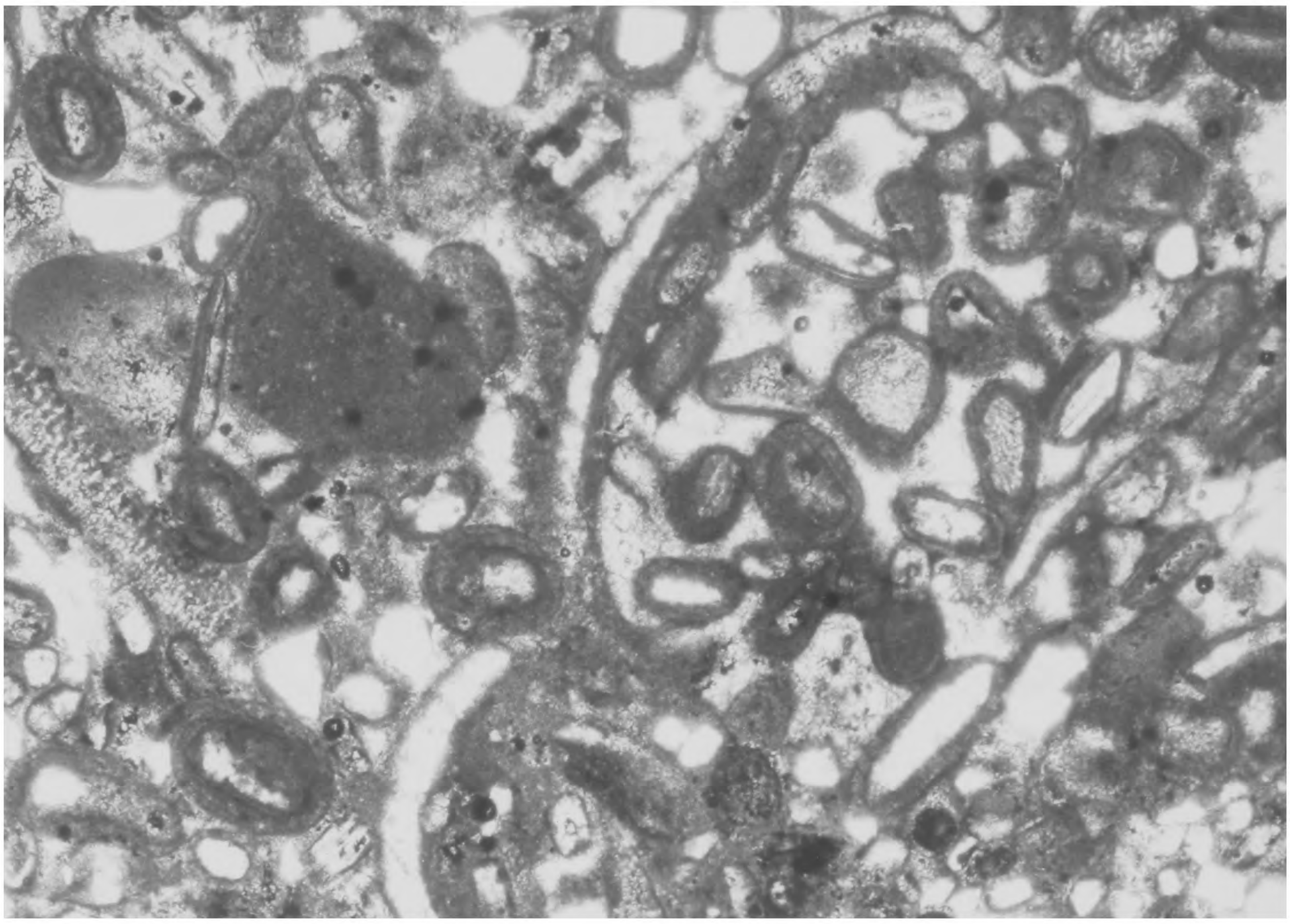

500µ

Plate 75 Thin section of medium biochem sand composed of part-coated and part-micritised bivalve fragments, intraclasts, superficial ooids and scattered quartz with a considerably amount of micrite in the matrix. Main Limestone Beds, Vale of Wardour, Wiltshire.

Plate 76 Upper Chicksgrove Quarry, Vale of Wardour showing the Sandy Limestone Beds of the Wardour Sand Formation overlain by the Main Limestone Beds of the Wardour Limestone Formation (the dashed line marks the junction).



500µ

Plate 77 *Glaucolithites* from the Sandy Limestone Beds of the Vale of Wardour showing encrustation by *Glomerula* near the aperture. Both serpulid and ammonite were probably living at the same time.

Plate 78 The above ammonite showing attachment areas of encrusting oyster, which probably settled after the death of the ammonite.

Scale in centimetres

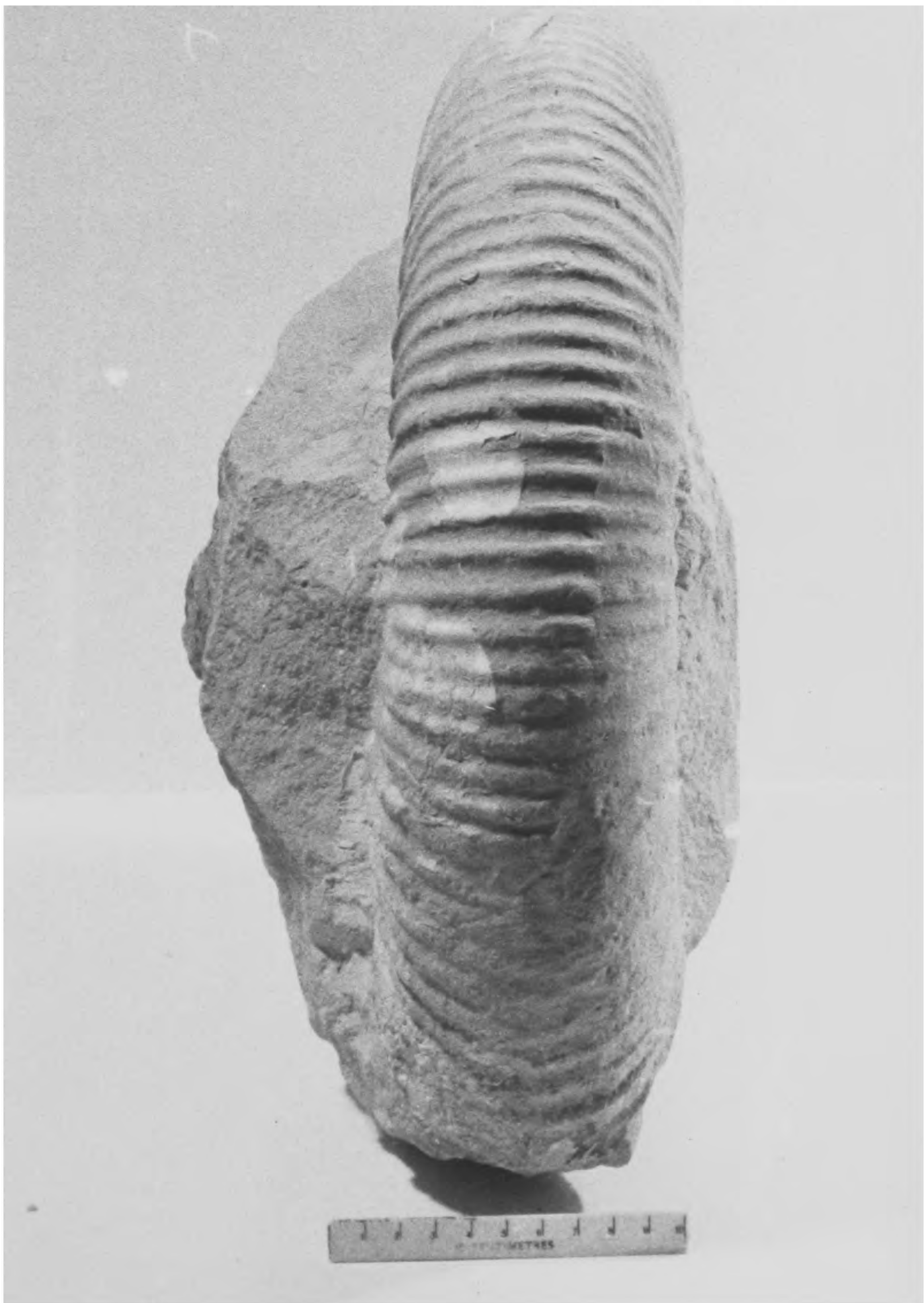
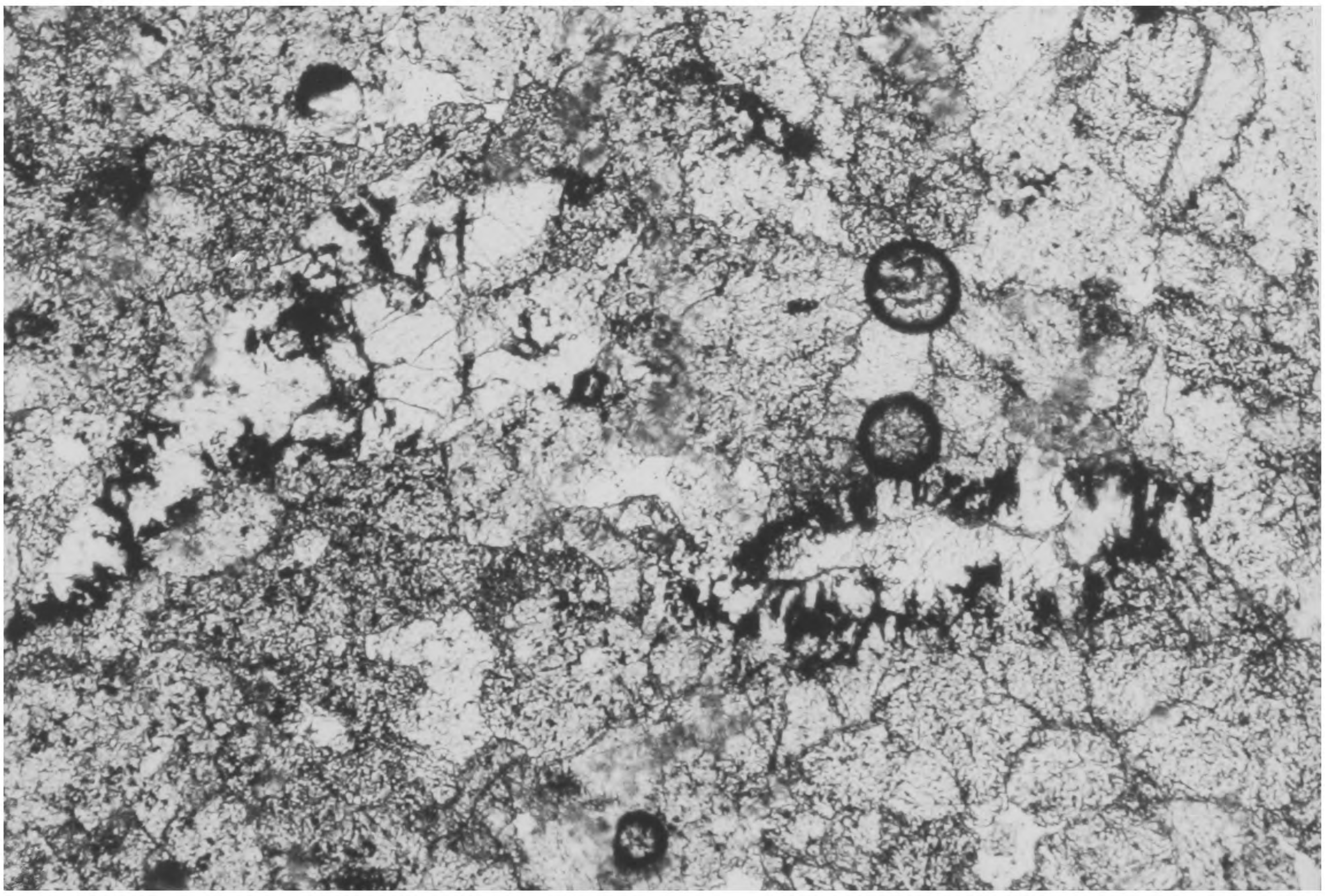


Plate 79 Thin section of medium to coarse biosparite, Main Limestone Beds of the Vale of Wardour. The grains are mostly micrite-enveloped fragments of aragonitic bivalves but there is also some intraclasts and quartz. (Viewed under ordinary light.)

Plate 80 Thin section of calcite which replaced micro-mesh anhydrite with gypsum crystals. The dark margin to the gypsum pseudomorphs is oxidised pyrite and the black circles are air bubbles. Lower Purbeck Beds, Wockley Quarry, Vale of Wardour. (Viewed under ordinary light)

1000µ



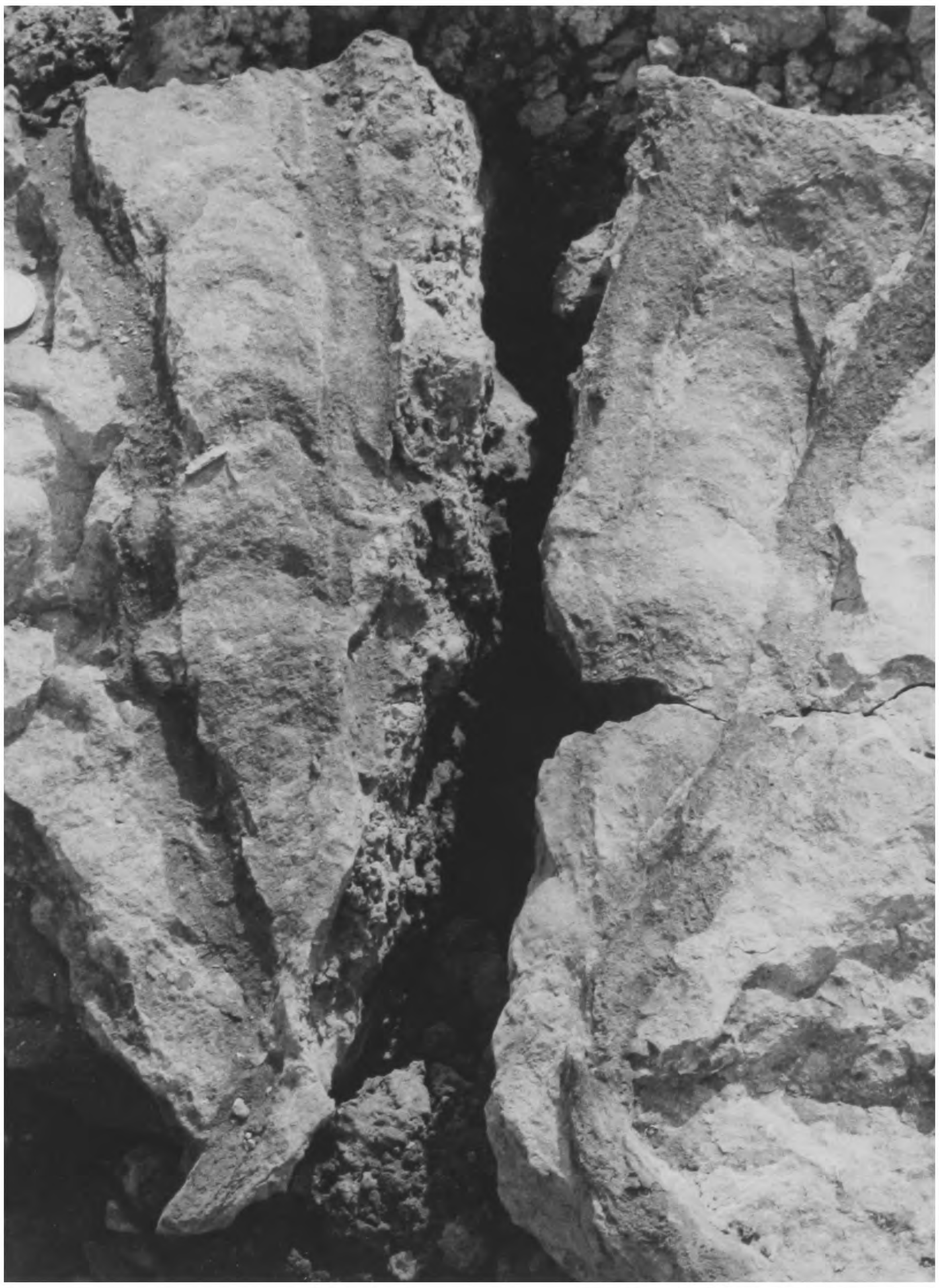
250µ

Plate 81 The Upper Sandy Beds of the Portland Group in the South Midlands. Town Gardens Quarry, Swindon. The lower part is flat-bedded fine to medium quartz sand and the upper part is lenticular bedded scoured medium quartz sand. The camera was facing NNE; A. Hallam for scale.

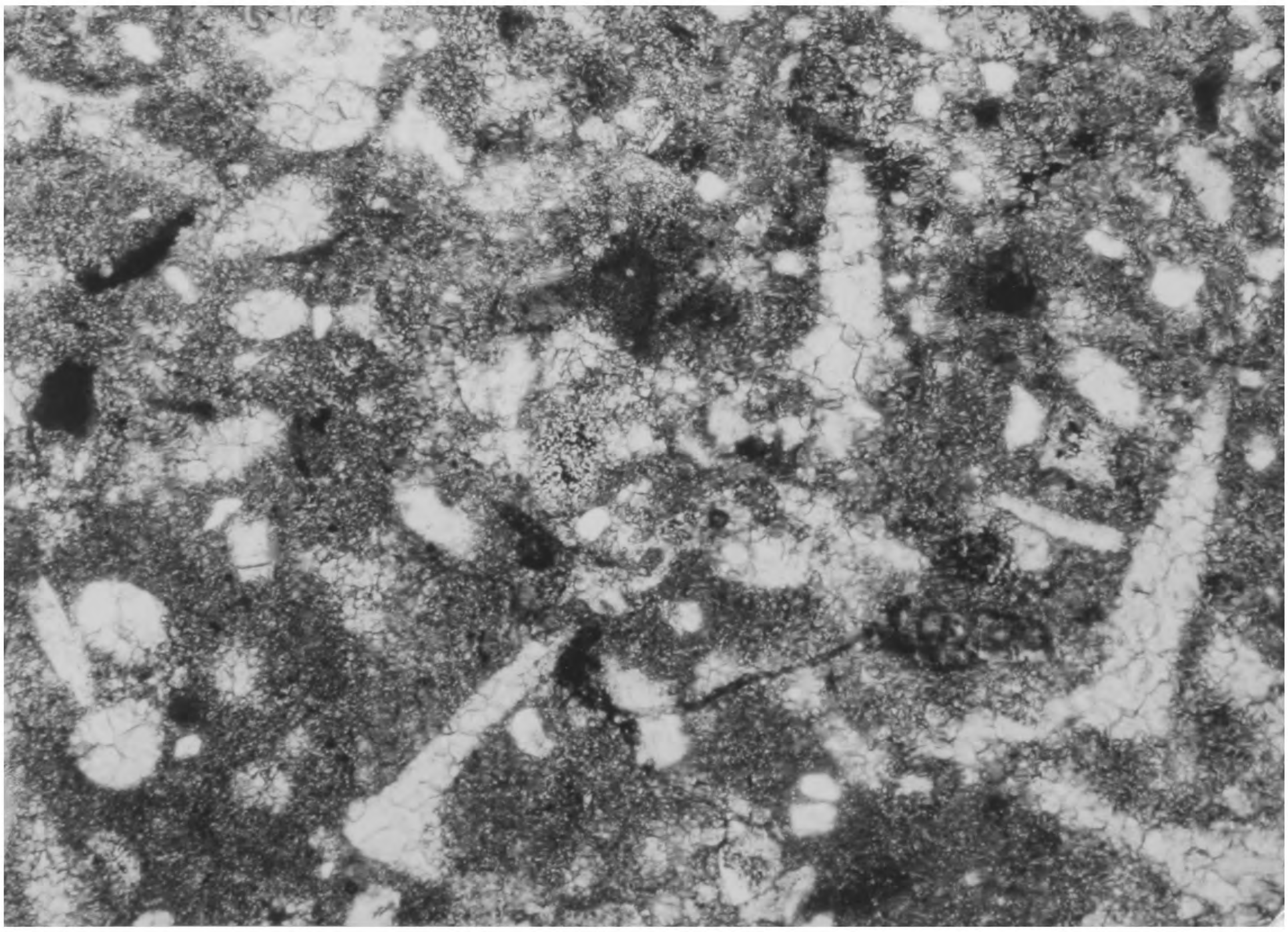
Plate 82 The Portland Group resting non-sequentially on the Sandy Upper Kimmeridge Beds in the South Midlands. Littleworth Brickpit, Oxford District. The arrow shows the Basal Pebble Bed which is overlain by the Lower Sandy Beds. S. Baker for scale.

Plate 83 *Rhizocorallium* from a nodule in the Upper Sandy Beds in the South Midlands. Haddenham & Kingsey Sewage Works, South Bucks District. The "spreite" ase clearly shown; the rock contains abundant crustacean fragments.

Plate 84 Thin section of *Pachastrella*-rich Upper Limestone Beds at the above locality. The spicules are preserved as sparry calcite casts and are set in a microsparite matrix. (View through ordinary light.)



5 cms



500μ

Plate 85 Section through the topmost part of the Upper Limestone Beds at Haddenham and Kingsey Sewage Works showing black clay piped into laminated ostracod limestones which overly thicker bedded white micrite.

Plate 86 Lens of shells with a micrite matrix in the topmost part of the Upper Limestone Beds at the above locality.


1m


1m

Plate 87 Large *Thalassinoides* from the Upper Assises de Croi, Bas Boulonnais. The tube is 2.5-3.5cms across.

Plate 88 Small *Thalassinoides* exposed on a bedding plane in the Upper Grès des Oies, Bas Boulonnais, showing the central point on the right. The tubes are 1cm across.

5Cms

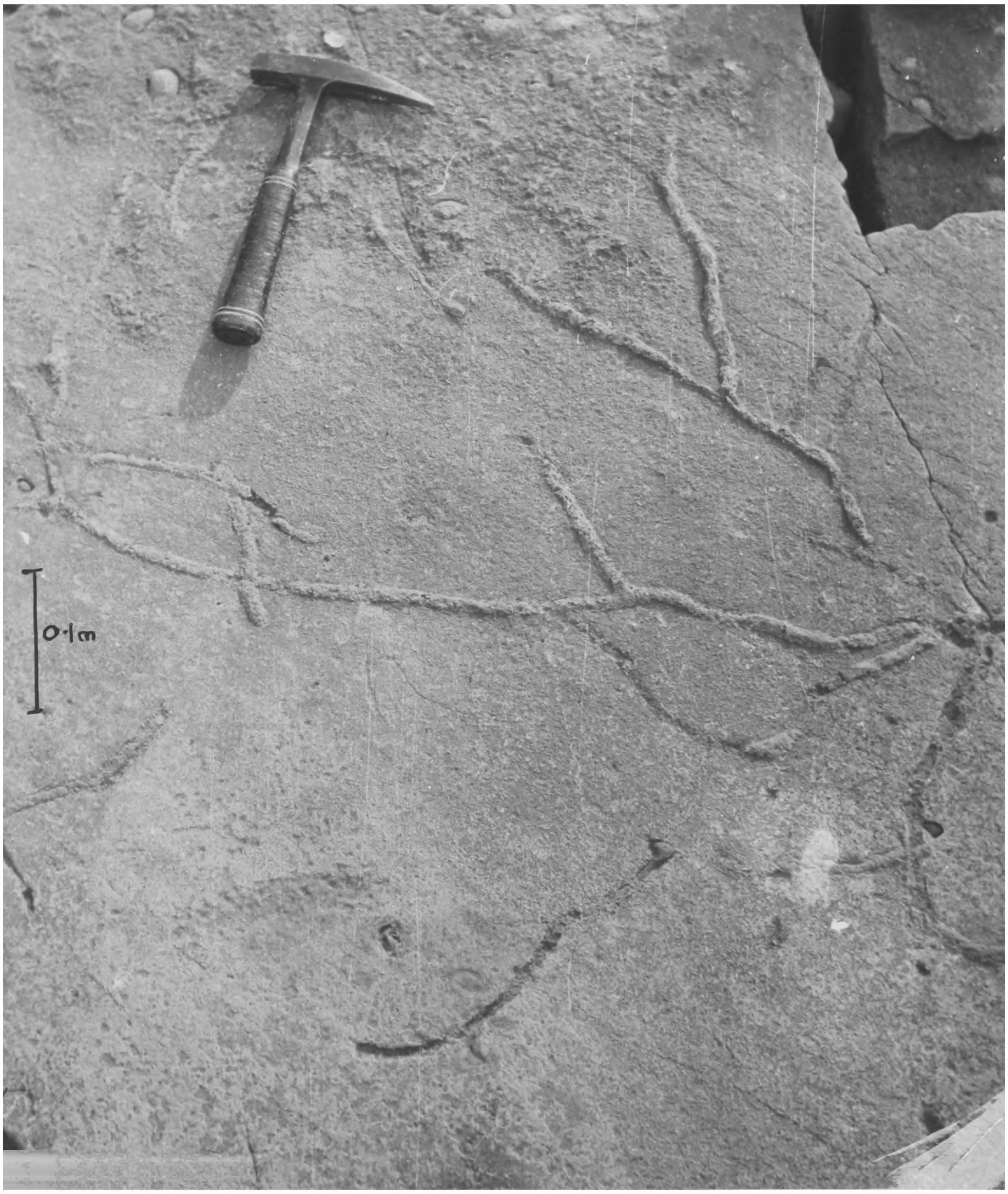
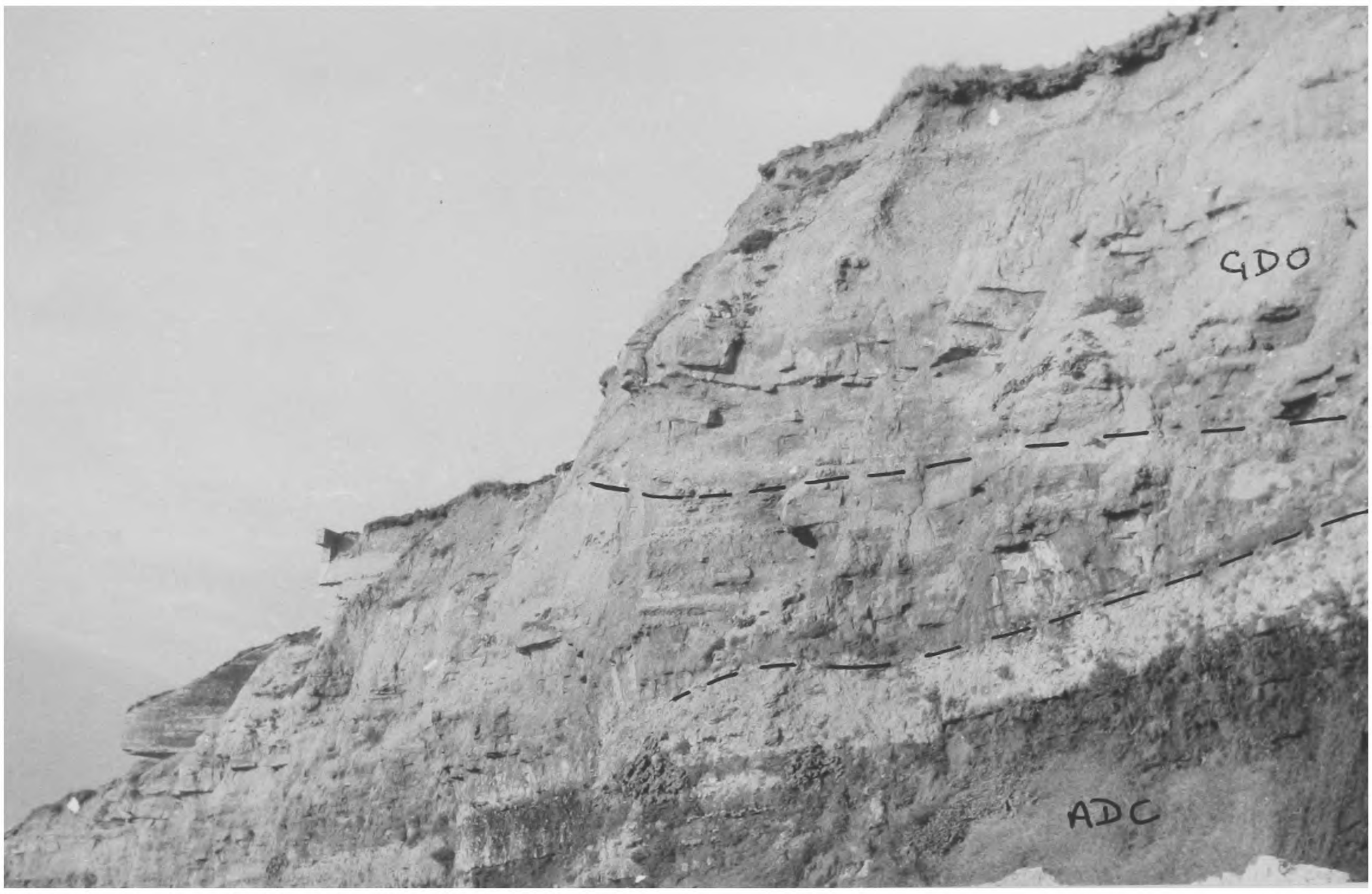


Plate 89 View of Pointe de La Rochette, Bas Boulonnais showing the down-cutting Upper Grès des Oies sands (GDO) and the argillaceous sediments of the Assises de Croi (ADC).

Plate 90 Fallen block of the Rochette conglomerate composed of Palaeozoic pebbles and blocks derived from the hardground upon which it rests (X). (The photograph is upside-down)


GDO
ADC


0·5
m

Plate 91 Diapir in the Upper Grès des Oies showing the upturning of the adjacent sediment, the hard-ground at the base (X) and burrows within the diapir.

Plate 92 Vertical view of erupted diapir showing upturned rim and burrows in the surrounding sediment (foreground).


X
0·5
m

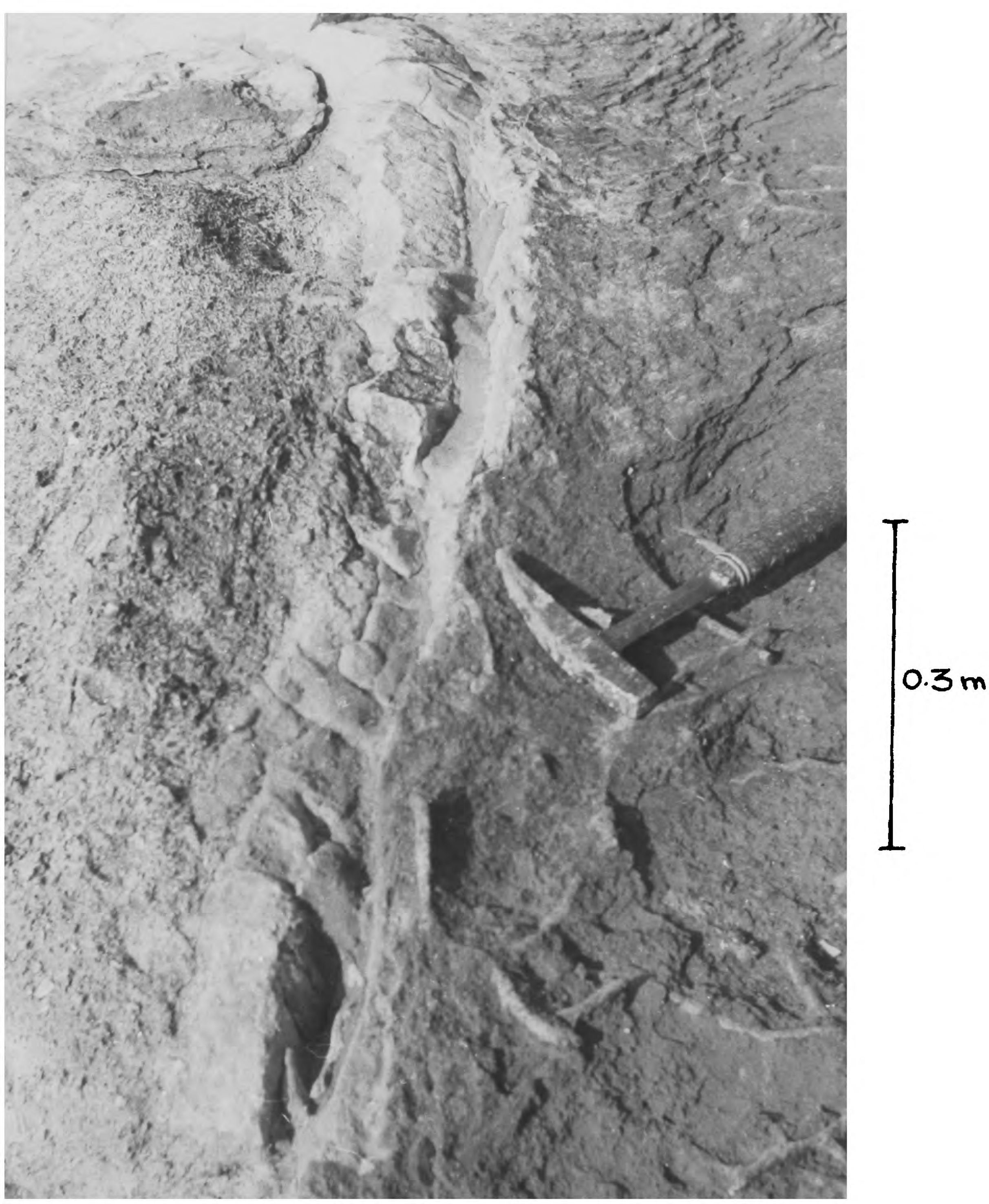
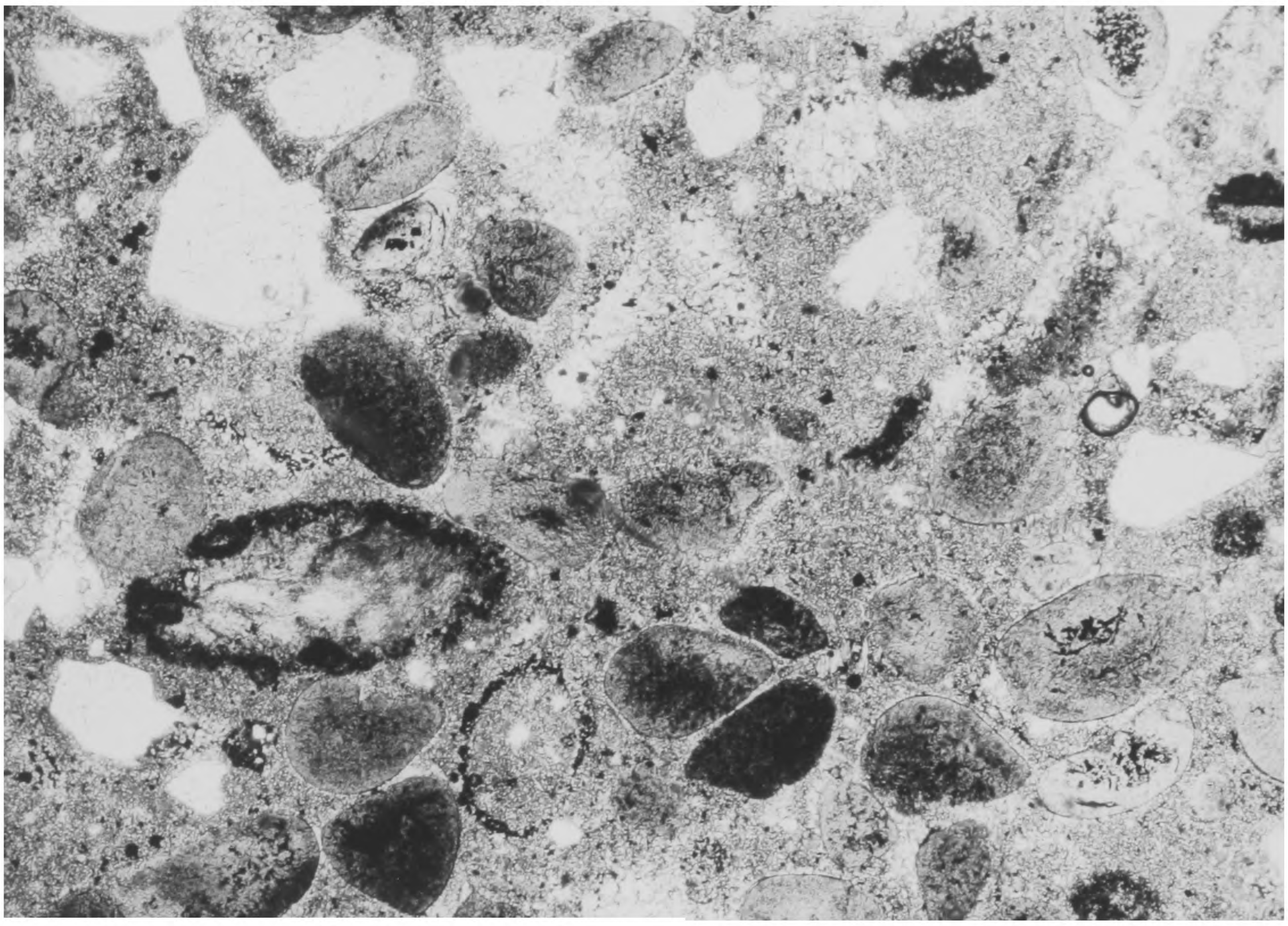

0.3 m

Plate 93 Hard-ground at the top of the Middle Grès des Oies showing sediment-filled moulds of Lithophaga borings and aragonitic bivalves (from a colour slide).

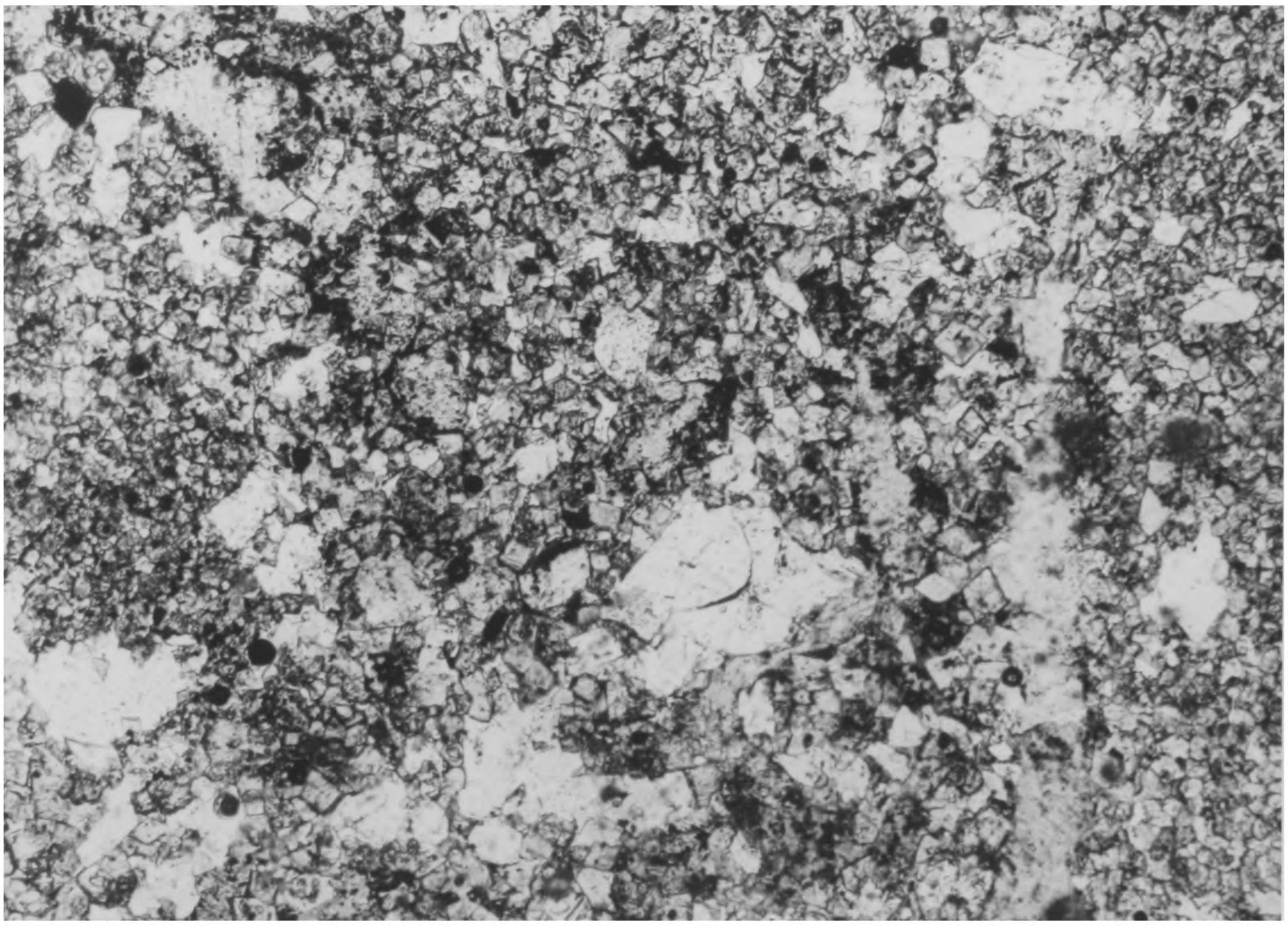
Plate 94 Fallen mass of algal limestone from the Calcaire des Oies, "Purbeckien", Boulonnais (From a colour slide).

Plate 95 Thin section of glauconitic, quartzose micrite from the Portland Group, 480m below Kingsclere, Hampshire. (Viewed through ordinary light)

Plate 96 Thin section of dolomite from the Portland Group, 748m below Portsdown, Hampshire. (Viewed through ordinary light)



500µ



200µ