Zitteliana	10	27–41	München, 1. Juli 1983	ISSN 0373 – 9627

The stratigraphy and sedimentation of the Turonian-Campanian in the Southern Province of England

By

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With 5 text figures and 2 tables

ABSTRACT

A new lithostratigraphic and revised biostratigraphic scheme for the White Chalk of the Southern Province of England is proposed, introducing a Sussex White Chalk Formation with six Members, the Caburn, Lewes, Seaford, Newhaven, Whitecliff and Portsdown Chalks, based on stratotype sections in East Sussex and the Isle of Wight.

Isopachyte and lithofacies data indicate that the Turonian-Campanian Chalk was deposited in a complex basin with an axial trough surrounded by shelves and containing many local periclinal shaped swells across which condensation occured. Consequently ideal type sections for stratigraphic purposes are limited. As far as possible the thickest and most complete sections have been chosen as stratotypes but many anomalies occur; these are discussed.

KURZFASSUNG

Eine neue lithostratigraphische Gliederung und ein revidiertes biostratigraphisches Schema für den White Chalk der Süd-Provinz Englands wird vorgeschlagen. Es wird eine Sussex White Chalk Formation eingeführt mit 6 Unterteilungen: Caburn, Lewes, Seaford, Newhaven, Whitecliff und Portsdown Chalk Member, deren Stratotyp-Profile in East Sussex und auf der Isle of Wight liegen.

Isopache Rekonstruktionen und lithofazielle Analysen zeigen, daß die Turon-Campan-Kreide in einem differenzierten Becken mit einem axialen Trog abgelagert wurde, umgeben von Schelfgebieten. Dieses Becken enthielt viele lokale kuppige Schwellen, auf denen Kondensation stattfand. Deshalb sind gute komplette Profile für stratigraphische Zonierungen begrenzt. Die komplettesten und mächtigsten Profile wurden als Stratotyp-Profile ausgewählt, obwohl Anomalien auftreten, die hier diskutiert werden.

TABLE OF CONTENTS

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I. INTRODUCTION

Upper Cretaceous stratigraphy in the Southern Province of England (Figure 1) has altered little since publication of the Cretaceous Memoir by JUKES-BROWNE & HILL (1903–4), (Table 1). Elsewhere, FLETCHER (1979; and see also FLETCHER & WOOD in WILSON & MANNING, 1978) and WOOD & SMITH (1978) have introduced new lithostratigraphies for the Upper Cretaceous in Northern Ireland and the Northern Province of England respectively. This paper complements that work with the introduction of a new lithostratigraphy (Table 2) for the Turonian-Campanian of the Southern Province of England. The biostratigraphy remains largely as introduced from France by HÉBERT (1874) and BARROIS (1876) with modifications by BRYDONE (1914) and GASTER (1924). It is suggested that a more refined use can be made of inoceramids, *Micraster* and *Echinocorys*.

The Southern Province (Figure 1) as understood here is both a biogeographic region as defined by STOKES (1975) and a tectofacies region (sensu KRUMBEIN & SLOSS, 1955) which is determined partly from the isopachyte orientations (Figure 3) and on lithostratigraphical evidence. The Northern Province (STOKES 1975; WOOD and SMITH 1978) is clearly defined in Yorkshire, Lincolnshire and northern Norfolk but grades both bio- and lithostratigraphically into a transitional region. This transitional region is not as well researched, and on present evidence provides difficulties in correlation between the Northern and Southern Provinces because both the lithologies and the faunas appear to be transitional. These difference are most apparent in the Coniacian and Santonian.

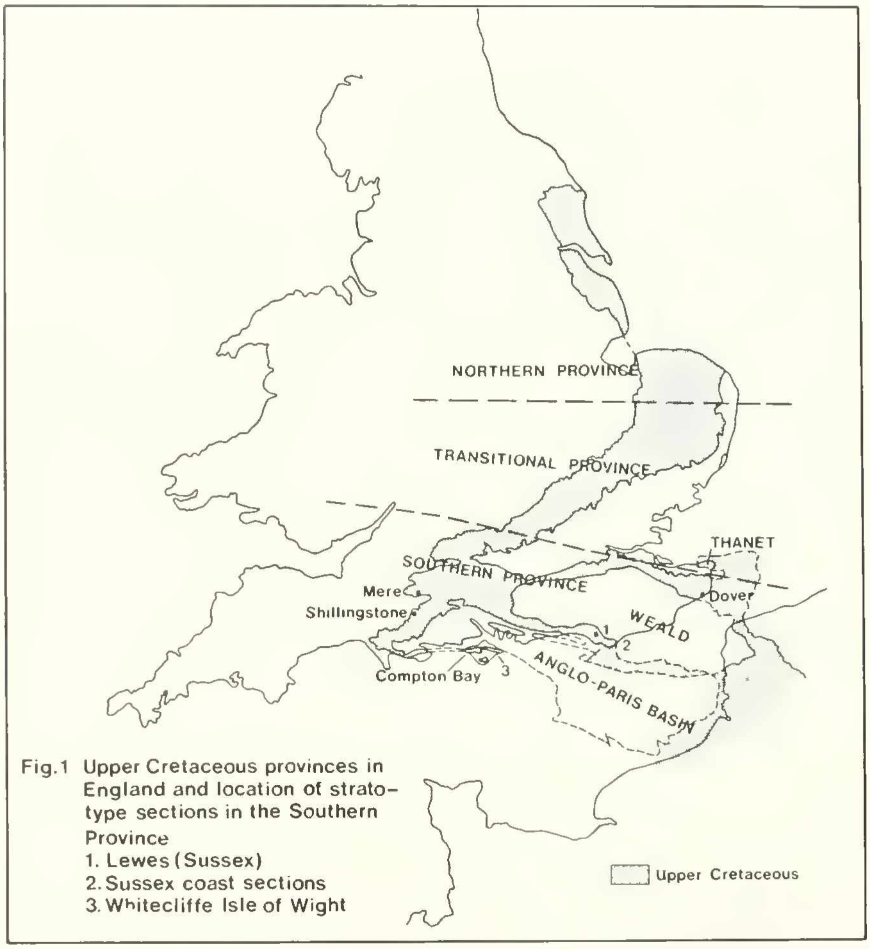

Fig. 1 Upper Cretaceous provinces in England and location of stratotype sections in the Southern Province
1. Lewes (Sussex)
2. Sussex coast sections
3. Whitecliffe Isle of Wight

II. LITHOSTRATIGRAPHY

JUKES-BROWNE & HILL (1903–4) retained two lithostratigraphic sub-divisions for the Turonian-Campanian in England, the Middle and Upper Chalk, although the boundary between these implied formations was taken variously at either the base of the Chalk Rock (Figure 4a) or the first flints, or the base of the *Sternotaxis (Holaster) planus* Zone. Current re-mapping of the Chalk by the Institute of Geological Sciences has shown that, at least in Sussex, the boundary between these two formations is difficult to recognize in the field and therefore, un-mappable. Thus, the Middle and Upper Chalk have been "lumped" into one unit.

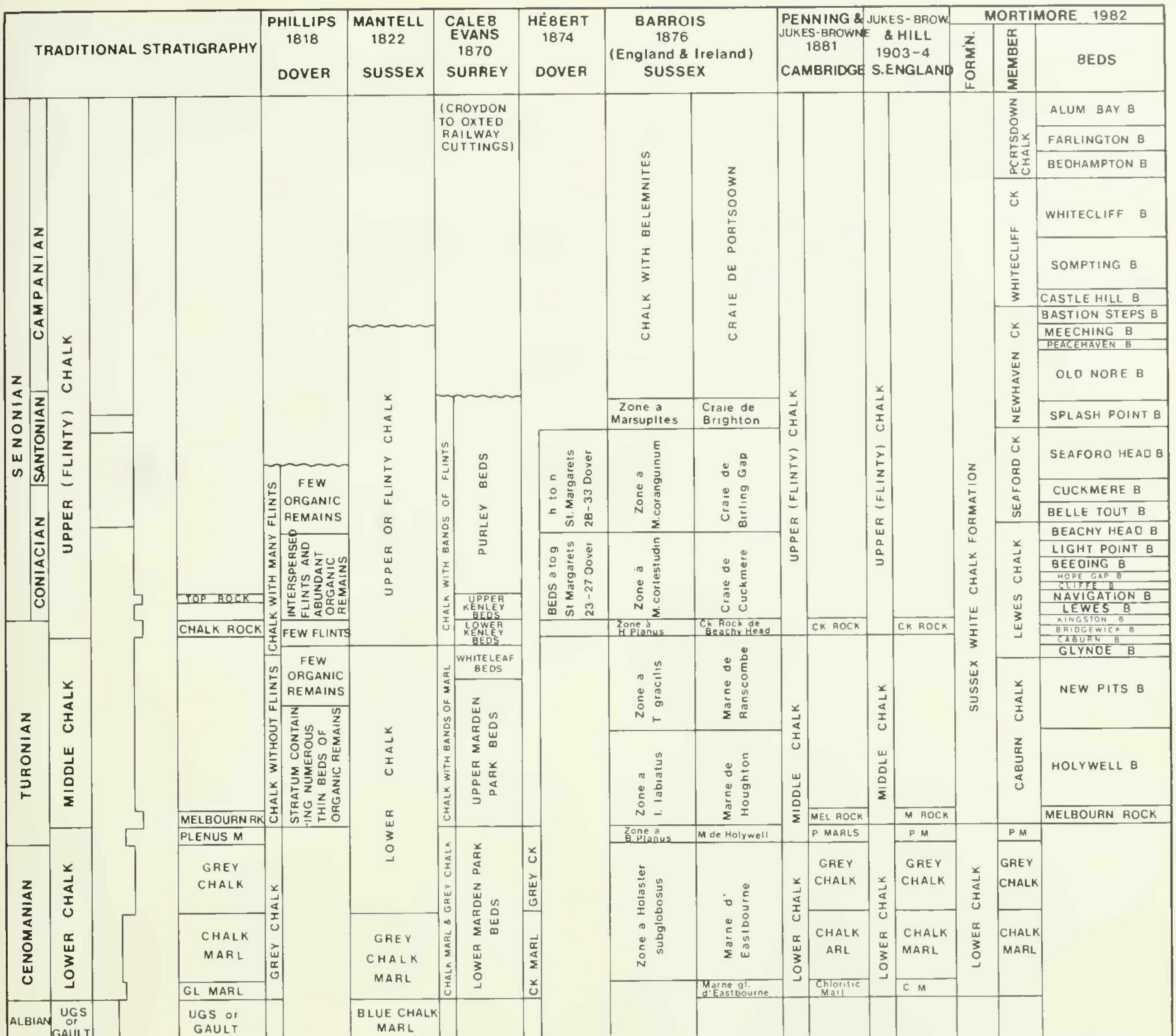

Table 1 EVOLUTION OF LITHOSTRATIGRAPHIC CONCEPTS IN THE CHALK OF SOUTHERN ENGLAND

It is proposed to replace this undifferentiated sequence with a Hedbergian lithostratigraphy, recognizing a Sussex White Chalk Formation with six members which are in turn subdivided into beds (Table 2). The sections around Lewes and on the coast between Eastbourne and Brighton in Sussex and the coast section at Whitecliff, Isle of Wight, are selected as stratotypes.

The Sussex White Chalk Formation is defined as all the chalk above the Plenus Marls i. e. starting at the base of the Middle Chalk sensu JUKES-BROWNE & HILL 1903–4 as preserved in the Southern Province up to the Tertiary erosion surface. This term follows ROWE's concept of the White Chalk in his study of the coast sections (ROWE 1900–1907). The highest preserved chalk in the Province is found on the Isle of Wight and in Dorset and falls within the lower part of the Upper Campanian.

On the basis of major lithological changes which nevertheless do not constitute mappable units, the Sussex White Chalk Formation is divided into six units of member status. These lithologies are sufficiently distinct to be recognized both in the field and in cores and geophysical logs of boreholes. The distinctive lithologies are:

1. Griotte texture (TUCKER 1973) a term derived from the Pyrennean Devonian and Carboniferous griotte formations used to describe the marl plexus beds which contain augens of chalk surrounded by interlacing network of marl often with horsetails.

2. Nodular and hardground chalks which represent a series in sea floor lithification and burrowing (BROMLEY 1975), from indistinct, slightly red iron-stained lumpy chalks with no clear upper surface to well cemented hardgrounds with well defined upper surface which may be mineralised with glauconite and phosphate as well as iron.

3. Soft, featureless chalks, locally laminated, containing very few obvious sedimentary discontinuities but often containing distinctive seams of nodular or semicontinuous (tabu-

lar) flints. The laminae usually contain small lithoclasts derived from the chalk and small-scale slump folds and usually truncate burrow structures indicating a post sedimentary origin.

4. Discrete marls are distinct from either the griotte texture or the marly chalks which contain less than 80% carbonate, primarily on the basis of scale and structure. For example, marly chalks tend to be massive (i. e. 0.5–1.0 m thickness) while griotte marly layers may range from 0.03 m to 0.5 m in thickness but will comprise a heterogeneous plexus. Discrete marls, by contrast, range from 0.03 m to 0.3 m in thickness but on average are between 0.05–0.10 thick. The seam is

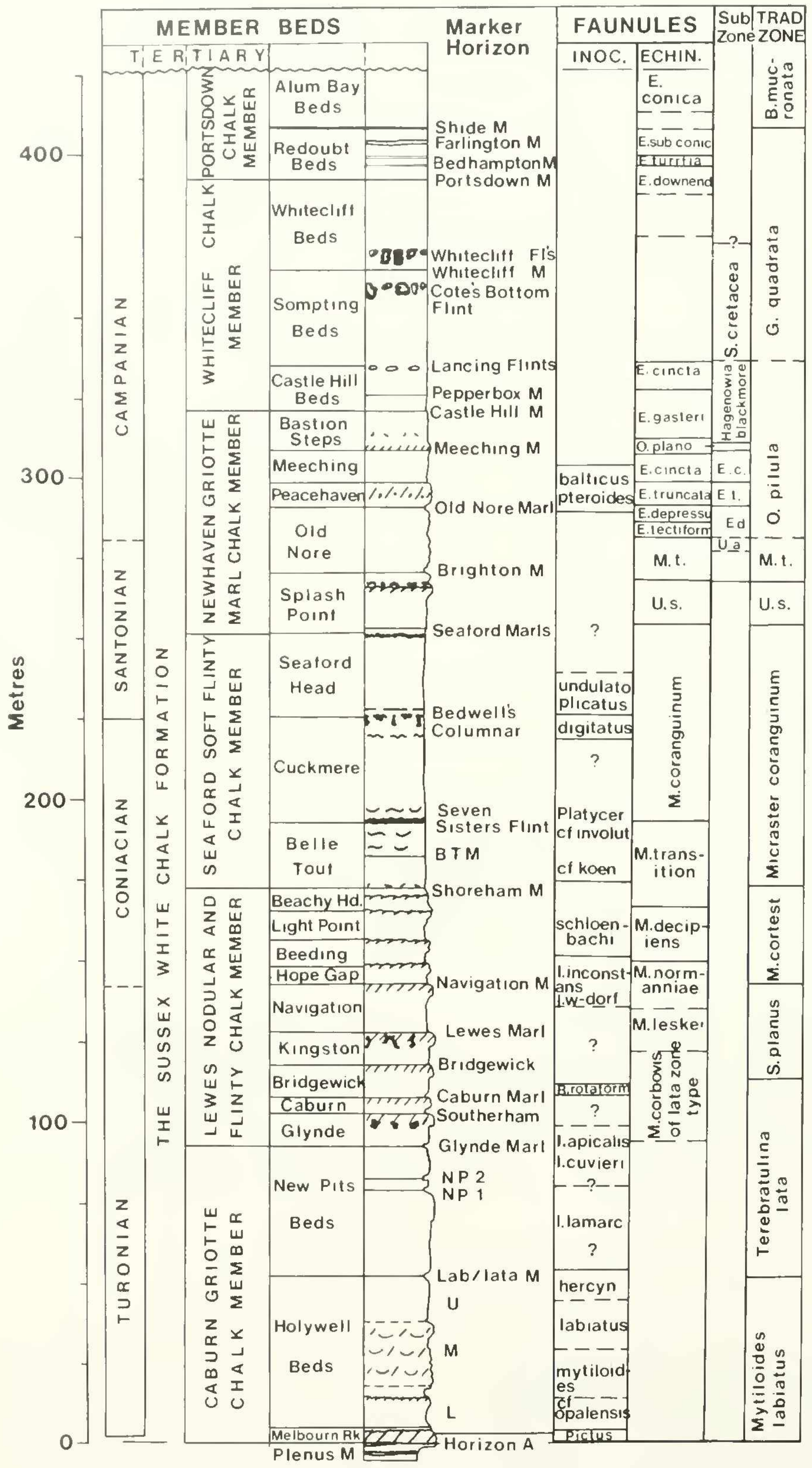

Table 2 Stratigraphy of the Sussex White Chalk Formation: Lewes and Whitecliffe stratotypes

much more homogeneous than the griotte marl, has a distinct base and a dark colour and may posess either a plastic or brittle texture. The homogeneous nature of these marl seams (closed seam of ROWE 1900) is maintained over thousands of square kilometres and provides an unmistakable signature on geophysical borehole logs (particularly electrical resistivity and natural gamma). In consequence these marls provide a convenient series of easily recognizable marker horizons within the succession which are used to delimit the boundaries between many of the members and beds.

Six members are recognized as follows:

1. The Caburn Chalk Member; type locality Mount Caburn, Lewes, Sussex; basal marker, base of the Melbourn Rock (see JEFFERIES 1963 Plate 2 P. 7, Holywell coast section Eastbourne [boundary stratotype]). The whole member comprises predominantly griotte chalks both of a nodular type e. g. Melbourn Rock and Middle Holywell Beds, and a more massive soft chalk type in the remainder of the sequence. Discrete marl seams particularly characterise the upper part of the sequence beginning with the Malling Street Marls at the boundary between the conventional *Mytiloides labiatus* and *Terebratulina lata* Zones and the lower marl which is also the boundary between the Holywell and New Pits Beds.

2. The Lewes Chalk Member; type locality Lewes, Sussex, basal marker the surface beneath the Glynde Marl at Caburn Pit, Lewes (boundary stratotype). Well developed beds of nodular chalk enter above the Glynde Marl and recur in belts separated by softer sometimes griotte chalks. Discrete marls are present in the lower half of the member and the first regular flint seams enter in the Glynde Beds in association with the first nodular chalks.

The boundary between the Caburn and Lewes Chalk so defined does not equate with the boundary between the Middle and Upper Chalk used by the Geological Survey in the south coast counties of England (JUKES-BROWNE & HILL 1903–4) but falls considerably below it (Table 1). Both the Chalk Rock and the Top Rock (Figure 4a and b), however defined stratigraphically, fall within the Lewes Chalk. These two marker units represent varying degrees of condensation resulting in complex amalgamation of nodular chalks to mature hardgrounds. Various horizons have been identified as the Chalk Rock or Top Rock sensu lato (HILL 1886). These various levels are indicated in Figure 4a and b. The Chalk Rock sensu stricto (i. e. WHITAKER 1861; HILL 1886) has been investigated by BROMLEY & GALE (in press). The bed names proposed for the subdivision of the Lewes Chalk are intended to replace the ambiguous terms Chalk Rock and Top Rock particularly in the region of the Chalk Rock sensu lato.

Bänderkreide texture, a term derived from the Maastrichtian Chalk of north-west Germany (VOIGT & HÄNTSCHEL, 1956) to describe discrete millimetre-thick lenses of whispy dark clay and silt grade marl occurs at two distinct levels in the Lewes Member. The lower horizon occurs everywhere between the Lewes Hardground and the Navigation Marl (Figure 4a) and the upper horizon between the various hardgrounds and nodular beds comprising the Beachy Head Beds. This streaky marl structure has been referred to the trace fossil *Zoophycos* and this identification has now been confirmed for the first time in the Sussex White Chalk (R. G. BROMLEY and A. EKDALE, personal communication).

3. The Seaford Chalk Member; type locality Seaford Head, Sussex; basal marker lower Shoreham Marl Seam at Seaford Head (boundary stratotype). Seaford chalk is typical of the featureless lithology but containing numerous laminae at Seaford Head and also containing several prominent flint seams of which the Seven Sisters Flint is the most conspicuous.

4. Newhaven Chalk Member; type localities Seaford Head and Newhaven, Sussex; basal marker the Seaford Marl at Sea-

Table 2: Note that the column showing faunules shows levels of abundance and not total ranges.

Key: Shide M	=	Marl
BTM	=	Belle Tout Marl;
NP 2	=	New Pits Marl No. 2;
Inoceramids:		
hercyn	=	*hercynicus;*
lamarc	=	*lamarcki;*
I. w. dorf	=	*waltersdorfensis;*
cf koen.	=	*koeneni;*
M. transition	=	group of Micrasterids as yet not formally identified transitional between *M. decipiens* and *M. coranquinum* with affinities to *M. intermedius;*
U. s	=	*Uintacrinus socialis;*
M. t	=	*Marsupites testudinarius;*
E. tectiform	=	*Echinocorys scutata* var: *tectiformis;*
E. depressu	=	*Echinocorys scutata* var: *depressula;*
O. plano	=	*Offaster planatus (planoconvexus);*
E. downend	=	*Echinocorys* of particular shape found in the higher Whitecliff Chalk (see also Fig. 4 d E. s. type 6) found at Downend Quarry, Portsdown and not yet formally identified.

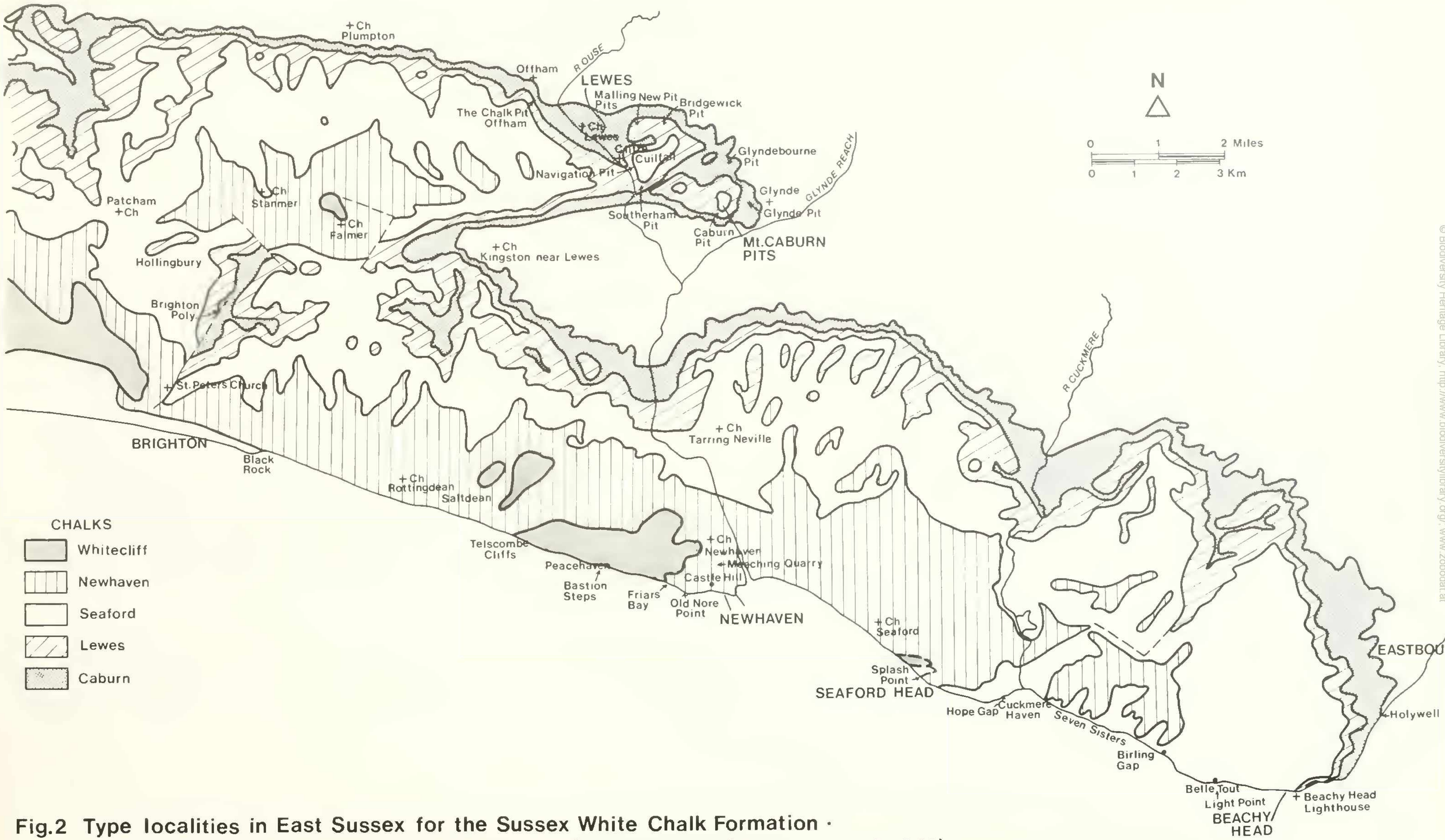

Fig.2 Type localities in East Sussex for the Sussex White Chalk Formation · Outcrop of members is modified from Gaster's zonal maps (Gaster 1939 & 1951)

ford Head (boundary stratotype). The Newhaven Chalk sees the return of griotte marl lithologies but in chalk of greater purity than the Caburn Member and with greater intervals between the griotte marl layers. Of particular interest are some of the discrete marl seams particularly the Brighton Marl in the *Marsupites testudinarius* Zone and the Old Nore Marl (Figure 4c). Marl in this part of the sequence is restricted to Wessex and Sussex and is better developed in the central part of the trough around Salisbury and Winchester, where for example the Pepperbox Marls appear but are absent in East Sussex at Newhaven. Consequently the upper limit of marl in the sequence is stratigraphically variable but within limited bounds.

5. Whitecliff Chalk Member; type locality Whitecliff, Isle of Wight; basal marker the upper Castle Hill Marl; Castle Hill, Newhaven and Whitecliff, Isle of Wight (boundary stratotypes). As stated above the upper limit of marl seams around the junction between the Newhaven and Whitecliff Chalk varies between Sussex and Wessex but the Castle Hill Marls remain, everywhere, a major and easily recognizable marker and are therefore chosen as the boundary between these members. With the exception of the Castle Hill Beds, a distinctive flinty unit at the base of the member, in which marl seams such as the Pepperbox Marls are developed in the western part of the region, the Whitecliff Chalk is devoid of good marl seams. The member contains flint seams throughout but at certain levels columnar or paramoudra potstone flint horizons (sensu BROMLEY et al. 1975) are present and these are laterally persistent (see Figure 4d). Paramoudras in association with levels of pelletal phosphate enrichment are a feature of the higher part of the member.

6. The Portsdown Member; type localities Portsdown (Bedhampton and Farlington) Hants and Whitecliff, Isle of Wight; basal marker, the Portsdown Marl at Whitecliff (boundary stratotype). Griotte marl seams return in the Portsdown Member and as in the Newhaven Chalk many of the seams are paired (e. g. BRYDONE 1914). The upper limit of this member is not defined although in the Scratchells Bay section the return of marl-free chalk can be recognized.

These six members are subdivided into beds (see Table 2) but the delimiting marker horizons for all bed divisions are defined elsewhere (Mortimore in preparation).

III. BIOSTRATIGRAPHY

An internationally agreed scheme for the boundaries and subdivisons of the Coniacian to Campanian is still not resolved. Critical ammonites and belemnites are either absent or not preserved in sufficient numbers in the chalk facies of the Southern Province of England to contribute to such a discussion. However inoceramid, echinoid and brachiopod assemblages are abundant at many levels, and the first two groups potentially allow a more refined subdivision then the traditional zonal scheme suggests (Table 2). Some of the critical taxa also occur in the Paris Basin Chalk associated with ammonites notably in the Craie de Villedieu and, therefore, a preliminary statement or their position in the southern English Chalk is considered to be of value.

Ranges of the key marker species, both macro-fossils and foraminifera are shown in BAILEY et al. 1982 against the lithostratigraphical framework defined here. It is hoped that at a later stage modifications to the zonal structure of the Sussex White Chalk can be made based on *Micraster* (DRUMMOND in preparation). From BAILEY et al. Figures 2 and 3, it will be seen that an inoceramid zonation is implicit in the Coniacian and Santonian. Inoceramids are also of particular use in subdivision of the Turonian (Table 2).

IV. SEDIMENTATION IN THE SUSSEX TROUGH AND IN ITS MARGINS

Isopachyte data (Figures 3a–d) indicates that the Southern Province Upper Cretaceous was deposited in a broad basin which had an axial trough running close to the northern margin of the South Downs of East Sussex and through Winchester and Salisbury to the west. Maximum fluctuation in thickness throughout the Upper Cretaceous is concentrated in East Sussex.

Isopachyte maps (Figure 3) demonstrate that areas of shoaling are present around the western and northern margins of the basin, (Mid-Dorset Swell and the Berkshire-Chilterns Shelf, Figure 3). Local thinning across periclinal-shaped structures is also apparent from the isopachyte data. Many more of these structures probably exist on both the shelves and in the main basin of deposition. The Wessex part of the Lower Chalk isopachytes (Figure 3a) follow those of DRUMMOND (1970) who defined the Wessex Shelf and Mid-Dorset Swell. The Berkshire-Chilterns Shelf is a region of general thinning but also clearly contains swell-like structures (Figure 3c).

Lithofacies variation is clearly controlled by both the gross basin structure of the region (Figure 3a–d) and the local periclinal axes (e. g. Brighton Dome, Figure 5a). Shelves and local swells tend to be the sites of sediment attenuation and the concomittant development of nodular chalks and mature hardgrounds. Some marker beds such as marl and flint seams may have been eroded, or in fact never deposited, across such structures as the Brighton Dome. Coarser, calcarenitic chalks are frequently found in the cuvettes associated with local structures, or as in the case of the Kingston Beds, infill the main axis of the trough (BRYDONE's Twyford Down facies, Figure 3c, GRIFFITHS & BRYDONE, 1911 p. 13–14). This facies is now best seen in the upper Kingston Beds in Bridgewick Quarry near Lewes.

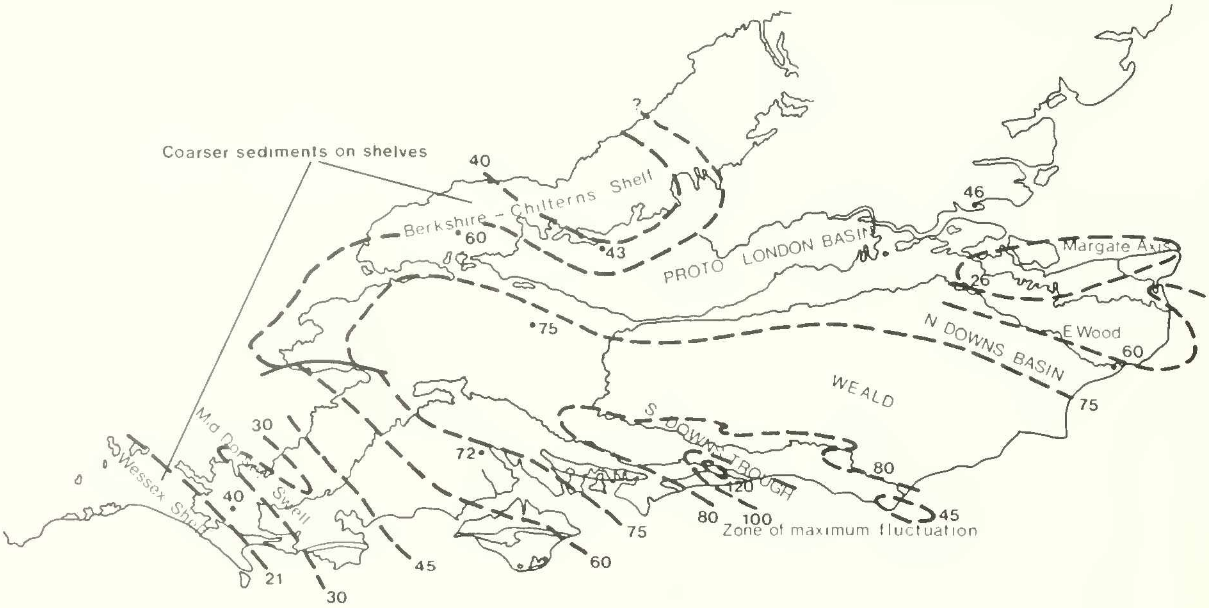

Fig. 3a Lower Chalk Isopachytes (Metres): Wessex data from Drummond 1970

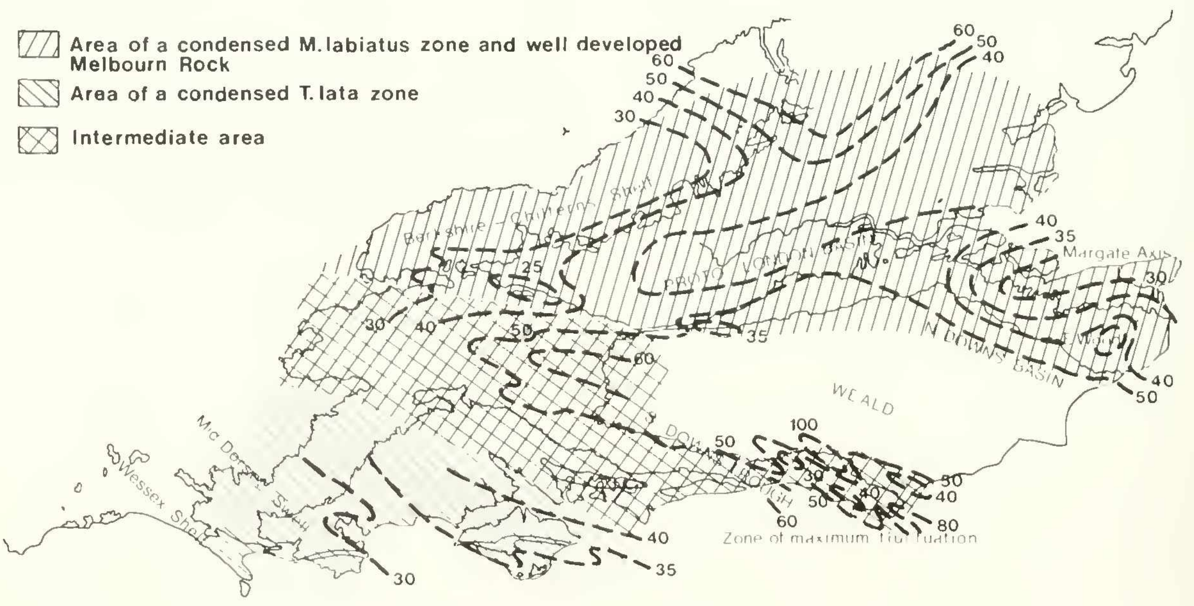

Fig. 3b Caburn Chalk Isopachytes Low and Mid Turonian (Metres)

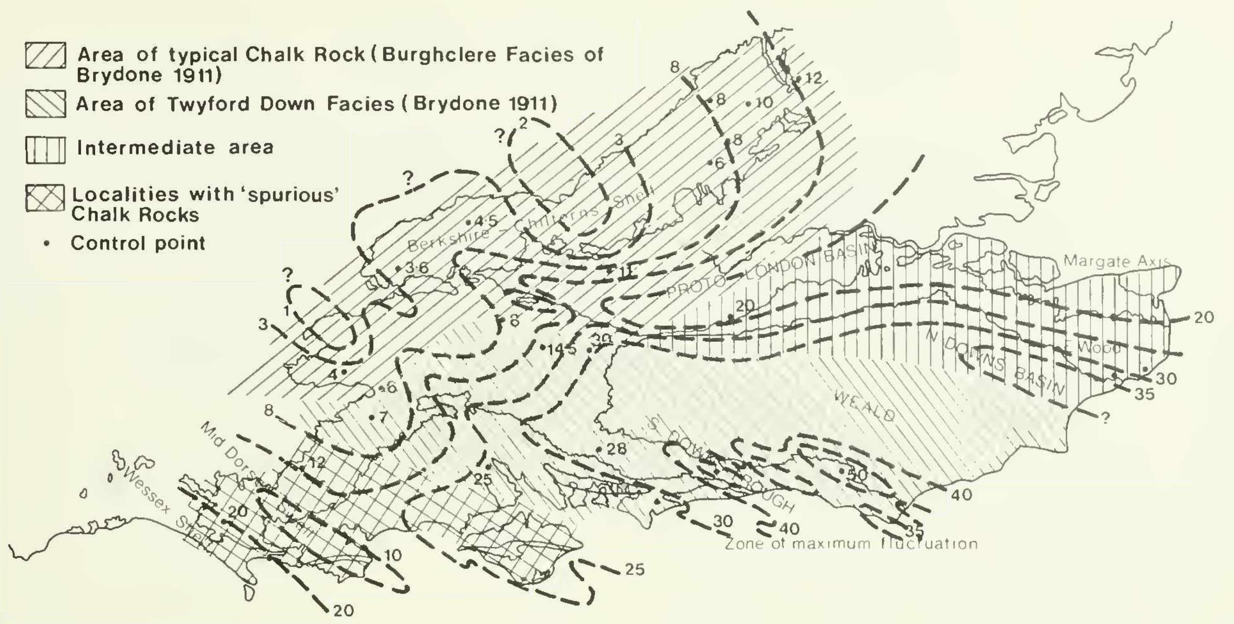

Fig. 3c High Turonian Isopachytes (Metres)

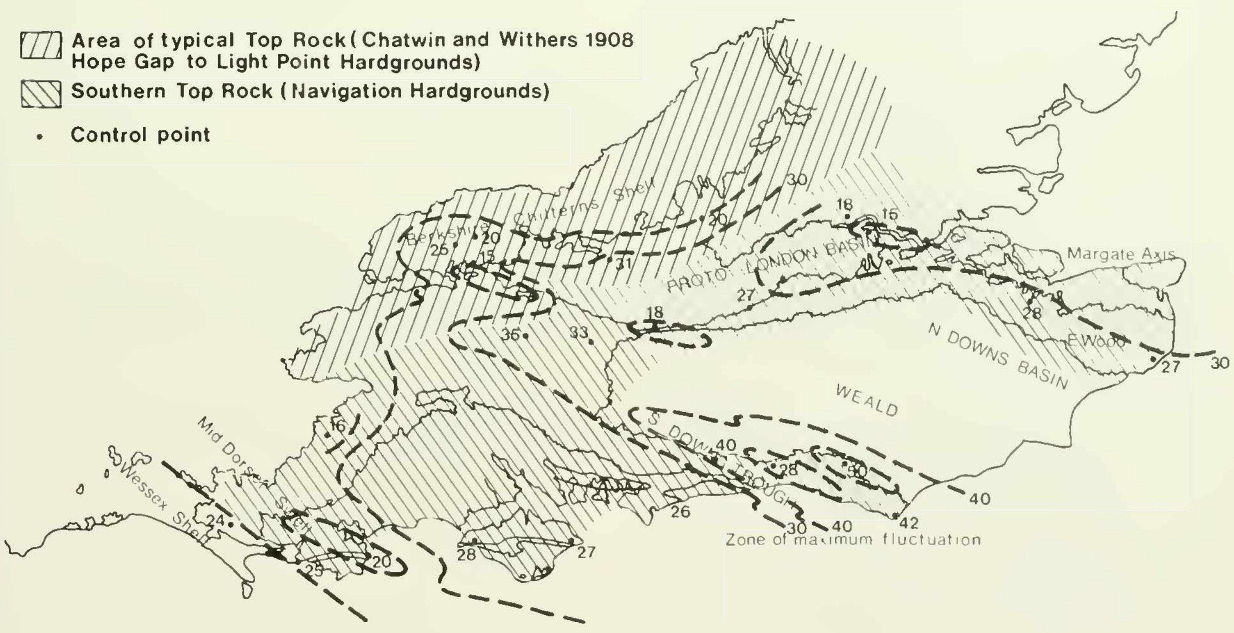

Fig. 3d Upper Lewes Chalk Isopachytes (metres) Low and Mid Cсniacian

V. STRATIGRAPHIC ANOMALIES

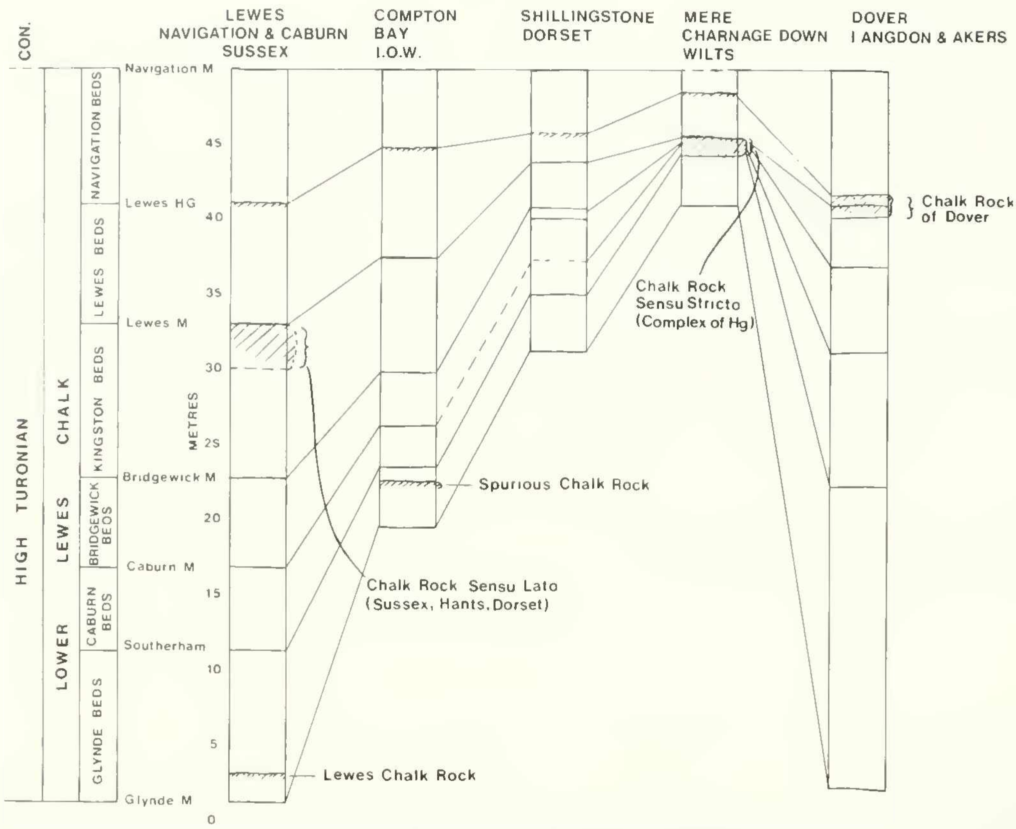

Fig. 4a Variation in the Lower Lewes Chalk in the Southern Province · England
The various horizons of Chalk Rock are only shown on the sections where they were named by previous authors

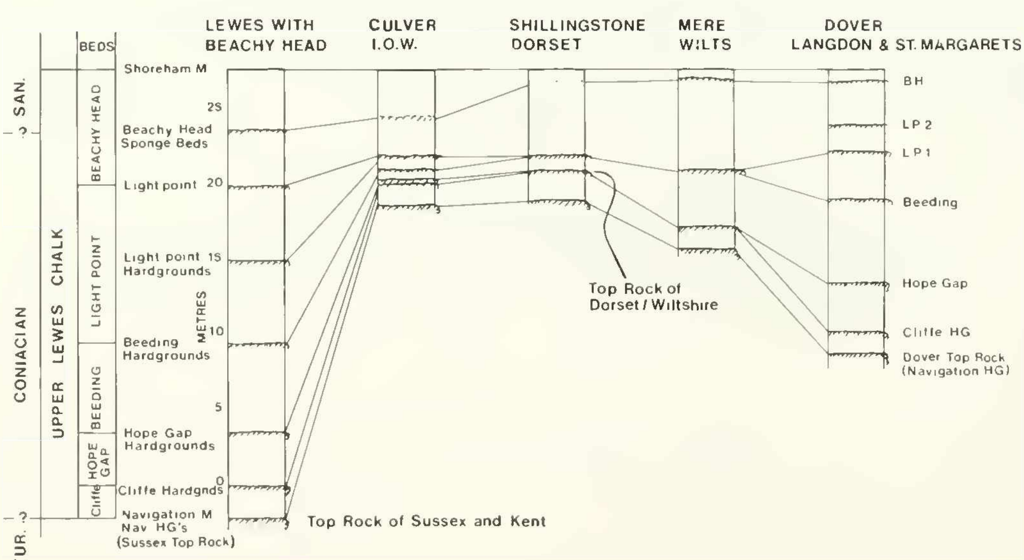

Fig. 4b Variation in the Upper Lewes Chalk in the Southern Province · England, showing the many have been taken as top rock replaced by the bed names proposed here

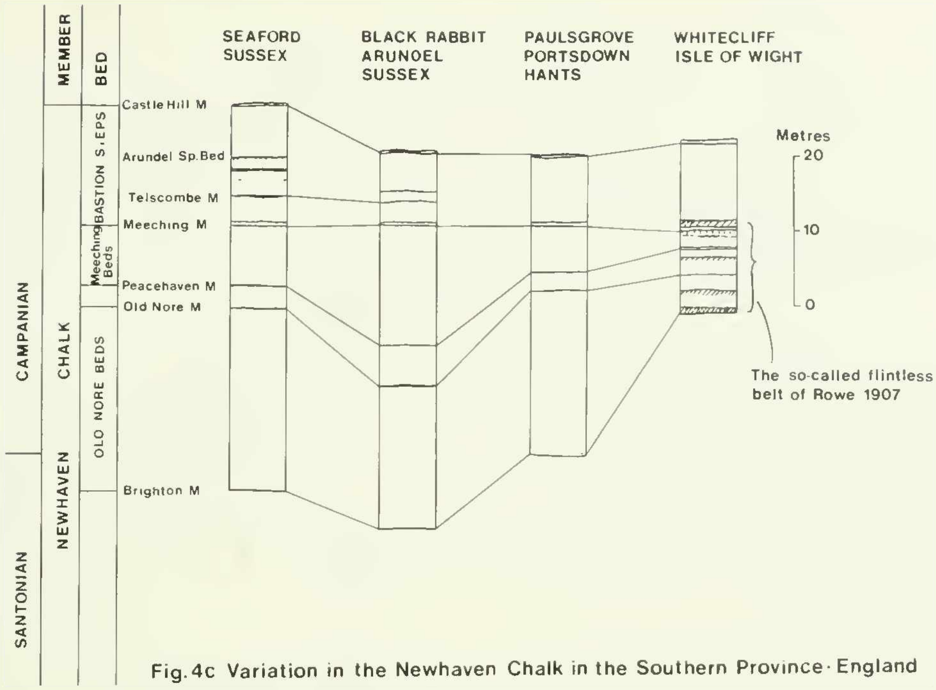

Fig. 4c Variation in the Newhaven Chalk in the Southern Province · England

As a result of the variation in thickness and lithofacies indicated in Figure 3, it might be expected that correlation of litho- and biostratigraphic marker beds would encounter difficulties. It is clear from Figure 4a–d, however, that some marker beds not only cross all the structures of the basin but also occur on an interbasinal scale from southern England to the North Sea and possibly beyond. A good example of a persistent horizon is given by the Glynde Marl (Figure 4a) which survives the attenuation occuring in the high Turonian between Lewes and Mere and through the Chiltern Hills and continues into the Northern Province.

On the other hand, marl seams such as the Southerham, Caburn, Bridgewick and Lewes Marls gradually disappear westwards in the sequences of West Dorset (Shillingstone), Mere and in the Chilterns. These Marls then reappear northwards in thicker sequences in the transitional and Northern Provinces. Even in the more expanded sections such as Dover, the Lewes Marl has been cut out in the development of the "Dover Chalk Rock" (Figure 4a; Hill 1886).[1]) At Lewes the Navigation Marls are cut out at Offham Chalk Pits 1.5 km west of the type locality, whilst southwards the Lewes and Navigation Beds condense from 17 m to 8 m with the resultant loss of most flint seams and many nodular beds. Such a condensed sequence is well exposed in Shoreham Cement Works.

Extreme attenuation has reduced the Lewes Chalk from 80 m at Lewes to 20 m at Mere and in the Chilterns area to some 8–10 m. This process of attenuation was not confined to the Turonian-Coniacian sequence but also affected the Campanian Newhaven and Whitecliff Chalks. Part of the Newhaven Chalk is reduced from 50 m in East Sussex to 20 m at Whitecliff, Isle of Wight while the Whitecliff Chalk is reduced from 115 m at Whitecliff to 35 m at Downend (Portsdown) (Figure 4c and d). Altough not shown on the diagram, (Figure 4d), the Whitecliff Chalk in Sussex must have attained a thickness considerably greater than is found on the Isle of Wight based on the evidence from the scatter of quarries in the Worthing District.

Not only are many anomalies in thickness of preserved sediment evident in the region but in some cases displacement of sediment has occured. On the swell around Brighton, the Brighton Dome, (Figure 5a), synsedimentary sliding of blocks of sediment downslope can be demonstrated. This sliding has produced distinctive sedimentary-tectonic structures, particularly flint shard horizons (the roller beds, Figure 5a). At other localities, such as Downend (Gale 1980) on Portsdown, the condensed sediments are involved in a complex set of structures which are here interpreted as progressively developed downslope slides which ultimately broke away and produced slump folding and displaced bedding (Figure 5b). Both the Brighton and Portsdown structures probably reflect periods of seismic activity which generated sediment instability. These seismic events possible relate to movement in deep-seated horst structures such as those indicated by Lake 1975 linking the Pevensey blocks to the Arlington Axis.

As a result of these sedimentary processes selection of a type section for the stratigraphy of the Province becomes critical. The thickest and most continuously exposed sections around Lewes and the Isle of Wight provide the chance of studying the most complete stratigraphy against which lateral variation can be tested.

As an example, it is clear that around Lewes the critical Turonian-Coniacian boundary sequence is more than twice as thick as anywhere else in the province and contains well pre-

[1]) Note terms such as "Dover Chalk Rock" or "Top Rock" are intended to indicate horizons referred to by previous authors and are in no way intended to be verification of a stratigraphic terminology. It is intended that such terms should be replaced by the lithostratigraphy defined in this paper.

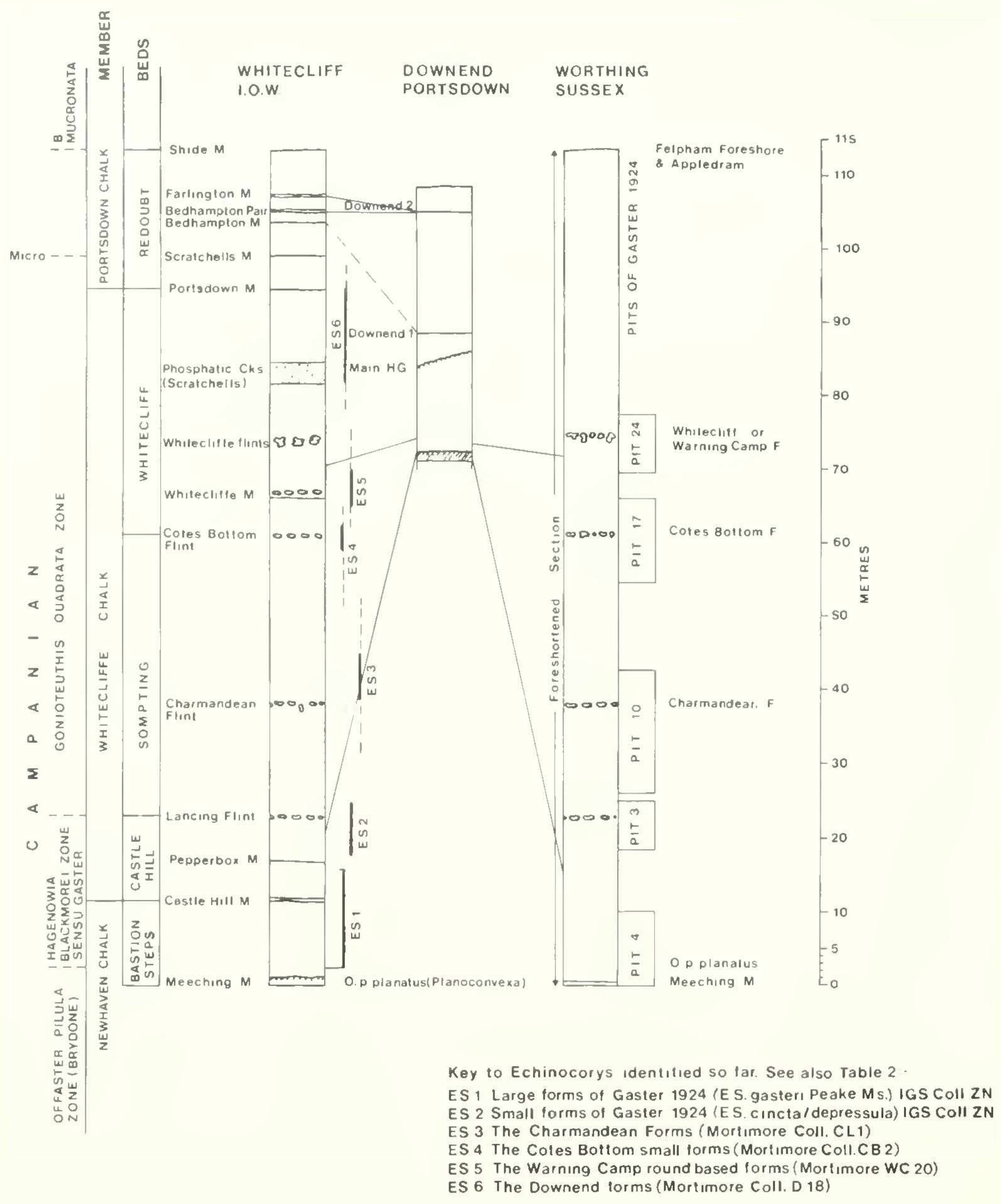

Fig. 4d Variation in the Whitecliff Chalk in the Southern Province England

served echinoid and inoceramid taxa either not preserved or poorly preserved elsewhere in the Province but which are an important part of the stratigraphy in Germany and the Paris Basin. These taxa include *Micraster praecursor* (pars: sensu ROWE 1899) *M. normanniae* (BUCAILLE) and *M. corbovis* (FORBES).

The inoceramids are dominated by *Mytiloides striatoconcentricus* (GÜMBEL) s. l. and mytiloid forms of the *I. waltersdorfensis* ANDERT complex (see also BAILEY et al. 1982).

In highly condensed sequences, for example in parts of Dorset, Berkshire and the Chilterns, critical ammonites and other fossils are found occasionally but it has in the past proved difficult to relate individual horizons such as hardgrounds to other more complete stratigraphic sequences.

Other differences within the region are particularly well illustrated by the Turonian (Figure 3b) showing the *M. labiatus* Zone condensed throughout the North Downs associated with an expanded *T. lata* Zone. A reverse situation is found in Wessex and it is only in the intermediate area where both zones are expanded and of the same order of thickness that a satisfactory study of their stratigraphies can be carried out.

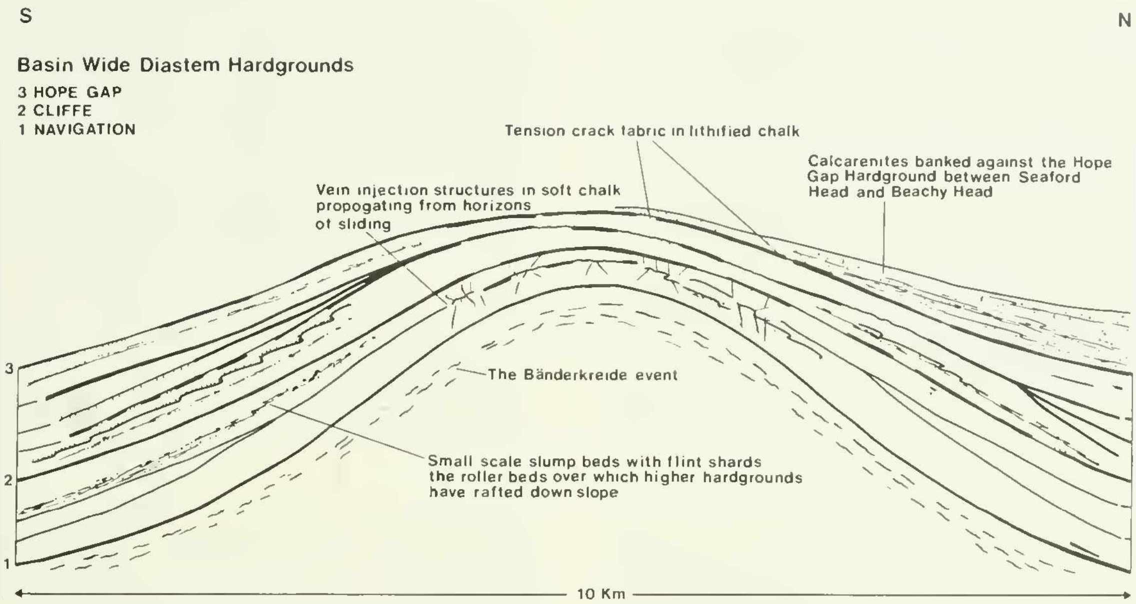

Fig.5a Diagrammatic representation of sedimentary events across the Brighton Dome during Micraster normanniae times (low Coniacian)

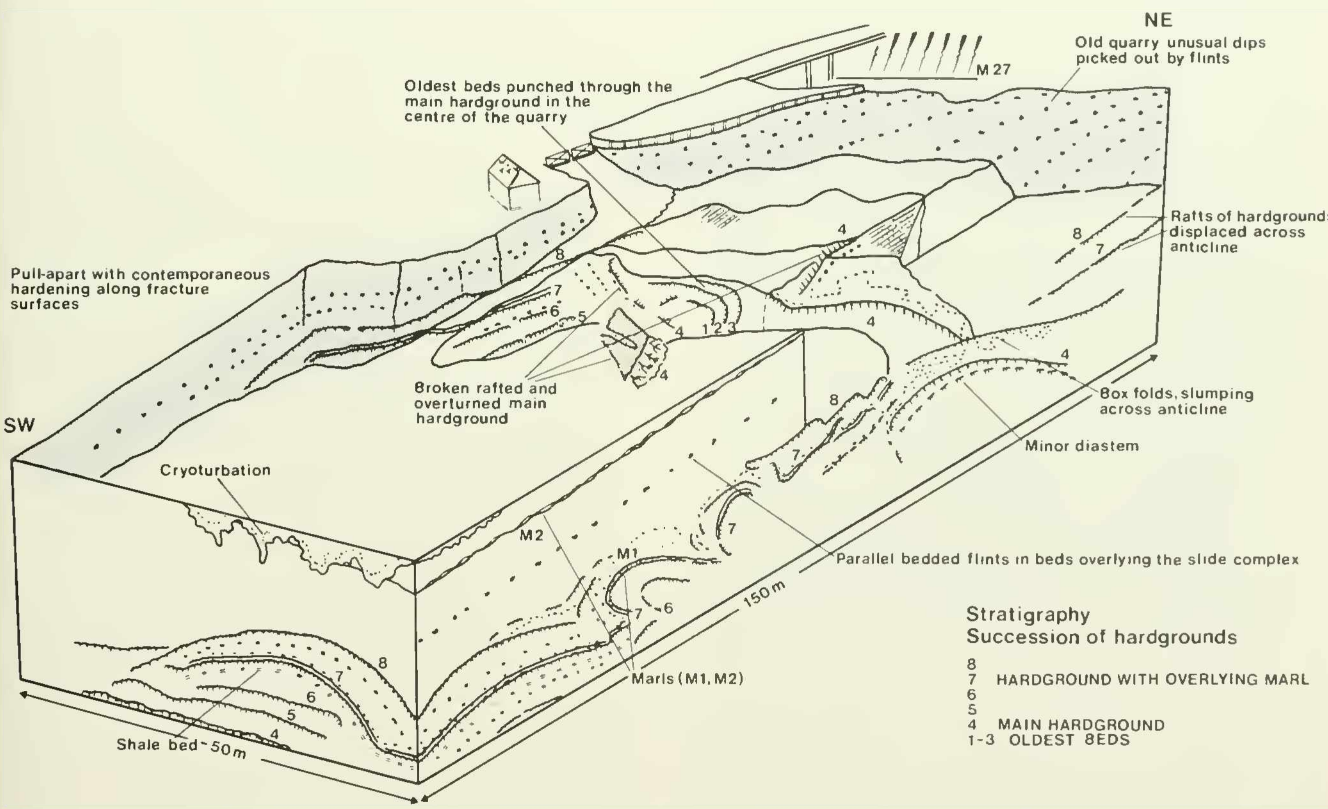

Fig.5b DOWNEND PORTSDOWN – A Sketch Block Diagram illustrating the more important field relations
Complex zone, apparent compression interpreted as slumping resultant upon a much larger scale slide inducing under-tow and local diapirism

VI. CONCLUSIONS

A Sussex trough bordered by areas of general thinning in Dorset and the Berkshire Chilterns region is identified as the major feature of the Upper Cretaceous of the Southern Province of England. Many local anomalies occur, such as projecting swells. As a result, stratigraphic hiati are present and it is only by studying the thickest stratigraphic sequences which occur around Lewes and on the coast of East Sussex, supplemented by the coast sections on the Isle of Wight that a complete stratigraphic picture can emerge.

The South Downs of Sussex are the focus of the maximum fluctuation in thickness in the region. The Wessex Basin of DRUMMOND (1967; 1970) is simply the head of a southeasterly plunging structure which had its main area of deposition in Sussex throughout most of the Upper Cretaceous. This is shown by the parallelism of the isopachyte pattern in the Lower Chalk and the Lewes Chalks (Figure 3).

Altough anomalies are present, nevertheless correlation of many of the major marker horizons and chalk members is possible over very long distances. Where attentuation has resulted in the loss of a marker bed, renewed expansion usually sees the reappearance of that bed. Many different levels have been called "Chalk Rock" or "Top Rock" (Figure 4a, b) as a result of spurious correlations. The new stratigraphy proposed replaces these terms with bed and member divisions.

It can frequently be demonstrated that some bedding planes follow marked erosion surfaces and, in many situations, the debris of mixed fossil assemblages scattered through a bed suggests current reworking, transportation and deposition. This clearly suggests that no one locality will necessarily contain every aspect of the stratigraphy of the region and that a "type section" will necessarily be a composite.

ACKNOWLEDGEMENTS

I am particularly grateful to my colleague Dr. Phillip Drummond for his continuous help and encouragement throughout the development of this research project which was funded by Brighton Polytechnic.

The final form of the stratigraphy proposed owes a great deal to discussions with members of the Institute of Geological Sciences, in particular to Ray Gallois, Bob Lake, Roy Shepard-Thorn, Brian Young and Chris Wood. Chris Wood has also been a continuous source of guidance with Chalk palaeontology. My family, Diana, Jamie, Sally and Tom have also proved invaluable field assistants. Richard Bromley, Chris Wood and Jake Hancock have provided constructive criticisms of drafts to this paper.

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