D52308´84

PALYNOSTRATIGRAPHY OF UPPERMOST ALBIAN TO BASAL CONIACIAN

(CRETACEOUS) SEDIMENTS OF THE WESTERN ANGLO-PARIS BASIN

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Thesis submitted to the Council for National
Academic Awards in partial fulfilment for the
requirements of the Degree of Doctor of
Philosophy

JUNE, 1984

Palynostratigraphy Of Uppermost Albian To Basal Coniacian (Cretaceous) Sediments From The Western Anglo-Paris Basin

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Abstract

The distribution of dinoflagellate cysts in sediments of the mid Cretaceous from the western Anglo-Paris Basin are examined. Samples were collected from a range of facies types (i.e. basin margin-central basin) but particular emphasis was placed on those which represented deposition around the basin margins.

Seventeen sites were sampled in southern England and N.W. France, and included a section from the Turonian stratotype in Touraine, and the type localities of the Craie de Villedieu (Villedieu-le-Chateau), the Beer Head Limestone and the Seaton Chalk (S.E. Devon). The existing lithostratigraphic schemes for the various formations examined were reviewed and correlated to allow good control on sampling.

Two hundred and forty samples were processed from which 144 species of dinoflagellate cysts were recorded. These included 5 new species, Achomosphaera simplex, Epelidosphaeridia tuberculata, Litosphaeridium medius, L. urna and Pyxidinopsis parvum, and 2 new subspecies, Achomosphaera sagena brevispinus and Cleistosphaeridium armatum brevispinosum. In addition, 16 species were recorded for the first time in sediments from the Anglo-Paris Basin. Dinoflagellate cyst distribution charts were constructed for each productive locality and a summary "range" chart produced. Disagreements between ranges recorded here, and published ranges from elsewhere in the basin indicate that the cyst distribution in marginal environments is primarily the result of local facies variation and not evolution.

Lithological/palynological relationships were assessed to provide data on possible palaeoenvironmental indicators, in particular relative water depth, and transgressive-regressive phases of the Chalk Sea. Increases in cyst abundance are thought to be related to periodic influxes of nutrient-rich currents. Significant increases in abundance and diversity are related to major eustatic transgressive episodes.

Acknowledgements

List of contents

Index of figures

CHAPTER 1

INTRODUCTION

1.1 Aims and scope

The present study has 2 main aims:-

A) To examine the biostratigraphic distribution of dinoflagellate cysts
in mid Cretaceous sediments from a range of facies in the Anglo-Paris Basin
(i.e. basin margin-central basin), but with particular emphasis on those
which were deposited near the basin margins. The results will be compared
with previous work on the Anglo-Paris Basin which, until now, has been con-
centrated mainly on material deposited in the deeper water, more central
parts of the basin.

B) To make a detailed comparison between dinoflagellate cyst
abundance/diversity and lithology in order to determine whether particular
cysts, or cyst associations can be used as indicators of specific deposition-
al environments (e.g. neritic, inner shelf, outer shelf), and also of
changing palaeoenvironmental conditions (e.g. transgressive/regressive
phases, nutrient input, current activity). Post-depositional effects on the
cyst distribution will also be analysed.

1.1.1 Fieldwork area

The major fieldwork area is shown on Fig. 1 and covers approximately
50,000 sq. kms. Studies were concentrated on coastal exposures from south-
ern England, and inland exposures in NW France (Fig. 1). The French sites
were intended to include the Cenomanian and Turonian stratotype sections and

the type sections for the Craie de Villedieu (Jarvis et al., 1983). However, it was found that due to poor exposure, and unsuitability of material for palynological processing, the Cenomanian stratotype sections around Le Mans (NW France) could not be examined further and, therefore, similar aged material was collected from elsewhere in NW France. In SW England samples were collected from the type localities of the Beer Head Limestone and the Seaton Chalk (Jarvis & Tocher, 1983; Jarvis & Woodroof, 1984). Samples ranging in age from late Albian (Stoliczkaia dispar Zone) to early Coniacian (Micraster cortestudinarium Zone) were collected from 17 sites.

1.1.2 Fieldwork method

Detailed measured sections were regarded as an essential prerequisite for the collection and evaluation of the samples. Both published sections and data collected during the present study were used (Chapter 2). Sample collection was based on the desire to examine the cyst content from a wide variety of lithologies rather than just concentrating on the normally organic-rich argillaceous horizons. In order to achieve this, sample spacing was not taken at any set interval (since many lithologies would have been omitted) but rather was dependant on the degree of lithological variation present at each particular locality.

Fig. 1   Location Map Of Sample Localities In The Western Anglo-Paris Basin

ENGLAND

DEVON

SUSSEX

●Arlam

St. Juan●

●Beachy Head

Blane Nez

ENGLISH CHANNEL

Cap Antifer

Ville-sur-mer

PAYS DE CAUX

PAYS DE BRAY

○Rouen

St. Sylvestre-de-Cormeilles

Femichon

Cordebeale

PAYS D'AUGE

PAYS D'OUCHE

●Le Mans

PERCHE

○Nogent-le-Rotrou

Bonnétable

MAMERS

Offranc-Evron

Maret

la Chartre-●

sur-le-Loir

la Cahogere

ANGLO-PARIS BASIN

●St. Colais

●villedieu-la-Chatee

TOURAINE

OTours

○Loches

ANJOU

le Flechno

●Fontevraud

●Paris

FRANCE

50Km

Sample Localities

○ Other Localities Mentioned in Text

Extent Of Cretaceous Outcrop

1.1.3 Laboratory work

Preparation of material:- The methods used to isolate the organic residues were mainly developed by Aberdeen University Geology Department, although a number of minor modifications were found to be necessary after experimentation to accomodate the particular problems of extracting palynomorphs from the carbonate-rich (chalks), and silica-rich (flints) samples.

Cleaning the sample:- Each sample was scrubbed thoroughly under running water with a hard brush to remove any surface contamination. This, of course, was not possible for the sand samples. Strongly indurated sediments such as hardgrounds were also scraped with a scalpel. The sample was then placed in a clean polythene bag and crushed with a hammer.

Weighing the sample:- I decided to use a standard sample weight for all lithologies examined (i.e. 40 grams) in order to facilitate correlations based on the abundance and diversity of the palynomorph assemblages recovered. Each sample was placed in a disposable weighing boat and measured on a Stanton Unimatic CL41 Balance. It was then placed in a labelled, 250ml polypropylene beaker ready for the next stage.

Removal of the carbonates:- Sufficient 10% HCl was poured into each beaker to cover the sample and the reaction noted. The beaker was then covered. When the reaction had ceased and the sediment settled, the liquid was decanted and fresh 10% HCl added. This process was repeated until no further reaction took place (i.e. all the carbonate material had been removed in solution. The beaker was then filled with distilled water. When the sediment had completely settled the liquid was decanted and fresh distilled water added. This process was repeated until the sample was neutral when tested with litmus paper. The same process was carried out on the flint

samples in order to remove any of the adhering chalk material. In these cases, however, all the liquid was decanted after every acid addition. The sample was then thoroughly washed with distilled water.

Removal of the silicates:- The excess water in each beaker was decanted and the sample placed in the fume cupboard. A small amount (~5-10ml) of conc. HCl was then added and the sample stirred slowly with a polypropylene rod to check that no carbonate material remained. The beaker was then carefully topped up with 200ml of Hydrofluoric Acid (HF 23N) and placed in a preheated water bath. The instrument used was a Grant JB polypropylene-lined bath with a 6x250ml beaker capacity. Each sample batch was heated for 3 hours, stirring carefully every 30 minutes. After 3 hours the beakers were removed and the stirring rods placed in a beaker containing a neutralising solution (NaCO3). The samples were allowed to settle for at least 1 hour before the HF was decanted into a large polypropylene container for neutralisation and disposal. The beakers were then filled with distilled water and left until the sediment had settled. The liquid was then decanted and fresh distilled water added. This process was repeated at least 6 times until the sample was neutral when tested with litmus paper, and could then be removed from the fume cupboard.

Sintering procedure:- For this, a "sintaglass funnel" (porosity 2) was used in conjunction with a pyrex Buchner flask (1 litre capacity) and a hand bellows. The sample was washed into the funnel using distilled water, and first agitated then drained using the bellows. This was repeated several times, while adding fresh distilled water, until most of the finer material was removed. To check whether any further treatment was necessary, the residue was collected in a pasteur pipette and a small amount placed on a glass slide for examination under the microscope.

Ultrasonic treatment:- If large concentrations of amorphous organic material were present the sample residue was placed in a labelled 50ml polypropylene beaker and placed in an ultrasonic tank. Treatment times varied from 1-4 minutes. In most cases during the present study, this was sufficient to remove all the unwanted material.

Oxidation:- When the organic residue was too dark for examination under the microscope oxidation using fuming Nitric Acid was tried. For this, the "sintaglass"/buchner flask/bellows set-up was placed in the fume cupboard and a few mls. of acid added. The sample was then agitated for a maximum of 2 minutes, then drained and washed through with distilled water until neutral. This treatment was rarely necessary.

Other treatment:- A few of the coarse sand samples had concentrations of insoluble detritus which none of the above procedures could remove. This problem was overcome by placing the residue in a large watch-glass and swirling it round until the heavier material was concentrated in the centre. The rest of the sample could then be removed by pipette and sintered normally.

Slide preparation:- When the aforementioned treatments were completed, the organic residues were collected in pipettes prior to slide-making. Prior to immediate use, the glass slides (76x26mm) were numbered with a diamond pencil and placed in a beaker containing methylated spirits. The glass coverslips (40x22mm) were similarly stored in a seperate beaker. Each slide was then carefully wiped and placed on a low temperature hot-plate. Using a pipette, a few drops of the mounting medium (heated glycerin jelly) were placed on the slide. A corresponding amount of residue was added and the two thoroughly mixed using a glass rod. The slide was then replaced on the hot-plate to remove some of the excess water. After a few minutes the slide was removed from the hot-plate and the coverslip applied. When the jelly was

completely set, the excess material was removed from the edges of the cover-slip, and the slide sealed by applying clear varnish. The slide was then labelled and set aside for examination.

Storing of residue:- Any remaining residue was placed in a small, labelled glass bottle and allowed to settle. The excess water was then removed and a few drops of Phenol added. The bottle was then topped up with glycerol and stored.

Examination of material:- All of the slides were given an initial examination and a small number which contained particularly rich palynomorph assemblages were selected as the basis for a taxonomic study. All of the specimens recorded in these samples were identified, where possible, by comparison with previously published data, and used to compile a checklist of dinoflagellate cyst taxa. This checklist was accompanied by a photographic file in which all the recorded forms were illustrated. All the slides were then examined and the numbers of each species recorded on the checklist. When samples were particularly rich (e.g. Beachy Head and Asham) the first 500 specimens only were noted, and each species was recorded as a percentage of the overall assemblage. In all other cases, the total microplankton content for each sample was recorded. Finally, any new species or subspecies were described.

CHAPTER 2

LITHOSTRATIGRAPHY

Introduction

This chapter examines the detailed lithostratigraphy of the various geological formations present in the western Anglo-Paris Basin (sections 2.1 & 2.3), and the individual exposures from which samples were collected (sections 2.2 & 2.4). All localities mentioned in the text can be found on Fig. 1, and lithostratigraphic correlations are provided on Fig. 2.

2.1 Lithostratigraphy of formations examined in western France.

2.1.1 Glauconie de base (ALBIAN-LOWER CENOMANIAN)

The term Glauconie de base was first introduced by Juignet (1974) who defined it as the glauconite-rich beds that rest unconformably on the Sables ferrugineux (Aptian) east of a line between Villers-sur-mer and Gacé, and on Oxfordian strata west of this line. The formation ranges in thickness from 4-6m and extends westwards between Cormeilles and Bernay up to the edge of the Normandy Basin. It is overlain everywhere by the Craie de Rouen. Juignet (1974, 1980) divides the Glauconie de base into two units. The lower unit consists of lenticular sequences of glauconitic sand containing phosphatic nodules, and is regarded as the lateral equivalent of the Poudingue ferrugineux and Gault of the Pays de Caux. The upper unit is more carbonate-rich and is correlated with the Gaize and the Craie glauconieuse.

2.1.2 Craie glauconieuse (LOWER CENOMANIAN)

This formation as defined by Passy (1832), includes the entire Cenomanian Stage in Normandy. Bizet (1881, 1882, 1885) however, working in the Pays d'Auge and the Perche restricted the Craie glauconieuse to Lower Cenomanian strata. More recently, Juignet (1974) defined it as a widespread formation

resting on the Gaize in Normandy, the Glauconie de base in the Pays d'Auge, and the Glauconie à Ostrea vesiculosa in the Perche and North Sarthe. The base of the formation in Normandy is marked by the "Octeville" erosion surface (Juignet, 1974) and the top taken at the surface of "Rouen No.1" Hardground (Juignet, 1974), a regional marker bed. The thickness of the formation ranges from 30m in the Pays d'Auge and Perche, to less than 3m in the Pays de Bray. In expanded successions the Craie glauconieuse can be subdivided into six sequences separated by moderately to well-developed hardgrounds. Each of these sequences is further divisible into three parts; the lowest is characterised by a glauconitic, bioclastic marl containing phosphatic nodules and fauna; the middle by grey, or light-brown chalks with flint bands; the upper by heavily-burrowed nodular chalks. Towards the edge of the Normandy Basin, the bioclastic chalks become sandy locally.

2.1.3 Craie de Rouen (MIDDLE-UPPER CENOMANIAN)

The Craie (glauconieuse) de Rouen was originally introduced by Hebert (1857) to include all the strata in the Normandy region which overlay the Gault and was overlain by the "Craie Marneuse" (sensu Passy, 1832). This interpretation was later revised by Lapparent (1879) who restricted the use of this term to the upper part of Heberts' original _formation. Juignet (1974) described the Craie de Rouen as overlying the Craie glauconieuse, underlying the Craie à Actinocamax plenus, and extending from the Pays de Bray to the Perche. The base of the formation rests on the surface of the "Rouen No.1" Hardground (Juignet, 1974) and the top is defined by "Antifer No.1" Hardground (Juignet, 1974). The average thickness is 15-20m, although there are considerable local variations (e.g. from 2m at Rouen up to 30m in the Pays de Bray). The basal bed of the Craie de Rouen is a classic fossil horizon ("l'horizon fossilifère de Rouen") which contains an abundant, and diverse fauna. The remainder of the succession consists mainly of white chalks and numerous flint bands, with occasional nodular units and associated

glauconite-rich horizons.

2.1.4 Sables du Perche (MIDDLE-UPPER CENOMANIAN)

Sables du Perche was first utilised as a Cretaceous formation by Guillier (1880) while mapping the area around Nogent-le-Rotrou, although the term had been used previously by Desnoyers (1856) to describe Tertiary sands in the same area. More recently, Juignet (1974) has described this formation in : the area around Le Mans. Here the Sables du Perche rest on the Sables et Gres à _Catopygus obtusus_, the junction being marked by the "Jalais" Hardground (Juignet, 1974). To the north and north-east, the Sables du Perche overlie successively the Marnes de Nogent-le-Bernard, Craie de Theligny and the Craie de Rouen, and is overlain by the Marnes à _Ostrea biauriculata_. In the Perche, however, the formation rests on the Craie de Rouen and is overlain by the Craie à _Terebratella carantonensis._ Thicknesses range from 15m around Le Mans, to more than 40m in eastern Perche. The sediments comprise 0.1-1m thick sequences of fine sands, or coarse sands and gravels, with varying amounts of glauconite. Cross-bedding and thin argillaceous horizons are common.

2.1.5 Marnes à _Ostrea biauriculata_ (UPPER CENOMANIAN)

Guillier (1886) gave the first precise definition of this formation, which extends over the major part of Southern Maine and also into Touraine and Anjou, from several quarry exposures around Yvres-l'Eveque. His work was used by Grossouvre (1900) and Delauney (1934), and later by Hancock (1959) who produced a detailed ammonite biostratigraphy for the region. The Marnes à _O. biauriculata_ lie between the Sables du Perche and the Sables et Gres à _Catopygus obtusus_ with an average thickness of ˜5m, although there are considerable local variations. Throughout its regional extent, the Marnes à _O. biauriculata_ consists of alternations of marls and marly chalks. The con-

trast of facies with the Sables du Perche is less marked to the south of Le Mans where more argillaceous sedimentation continued. North of Le Mans, however, the boundary between the two formations is sharp and is marked locally by either the "Fayeau" or "Duneau" Hardground (Juignet, 1974).

2.1.6 Sables et Gres à _Catopygus obtusus_ (UPPER CENOMANIAN)

This sequence of beds was first distinguished (but not named) in a number of exposures in the area around Le Mans. They were later grouped under the name Craie à _Terebratella pectita_ by Triger (1858) and assigned a basal Turonian age. Guillier (1886) subdivided it into the Sables à _C. obtusus_ and the overlying Craie à _Terebratella carantonensis_ but still retained both formations in the Turonian. Later work by Grossouvre (1900) suggested that the Craie à _C. obtusus_ was in fact late Cenomanian in age and this was confirmed later by the detailed ammonite studies of Juignet et al. (1973). In the most recent revision of this formation, Juignet (1974) described the Sables et Gres à _C. obtusus_ as having a similar geographic extent to that of the underlying Marnes à _O. biauriculata_ ; i.e. from around Bonnetable in the north, eastwards to Connerré, and southwards to the Loir Valley. The sequence varies in thickness from 2m at Le Mans up to 15m around Mayet and La Flèche. In the latter area the facies is much sandier and is known locally as the Sables de Bousse. The Sables et Gres à _C. obtusus_ are regarded as the lateral equivalent of the Marnes à _Actinocamax plenus_ (Jefferies, 1962, 1963) and the sequence typically consists of grey, shelly limestones associated with sandy marls or fine sands. A hardground often occurs, in conjunction with a grey nodular unit, in the lower or middle part of the formation.

2.1.7 Craie à _Terebratella carantonensis_ (UPPER CENOMANIAN)

Triger (1858), in his stratigraphic scheme for Upper Cretaceous sedi-

ments in the Sarthe Region, placed the Craie à _Terebratella pectica_ at the base of the Turonian. Grossouvre (1900) disputed this interpretation and maintained that the Craie à _Terebratella carantonensis_ was topmost Cenomanian in age and that the overlying Craie à _Inoceramus labiatus_ represented the base of the Turonian. Juignet et al. (1973) concurred with this view but emphasized the difficulty of dating this particular formation because of the scarcity of ammonite data. They suggested that this level be known as Horizon A, although this term has since been abandoned (Wright & Kennedy, 1981). Juignet (1974) redescribed the type succession of the Craie à _I. carantonensis_ around Le Mans where the formation overlies the Sables et Gres à _C. obtusus_. In the Perche, however, it overlies the Sables du Perche. The base of the formation is clearly marked in the type area by the "Mezieres" Hardground (Juignet, 1974) and in the Pays de Bray by the "Savigny" Hardground (Juignet, 1974). The average thickness is about 2m and the sediments consist of sandy chalks, occasionally coarse grained and commonly very glauconitic. They also contain phosphatic nodules and shell debris. The basal hardgrounds are often strongly bioturbated and contain fragments of the underlying formations.

2.1.8 Craie à _Actinocamax plenus_ (UPPER CENOMANIAN)

In 1832, Passy termed the middle part of the Upper Cretaceous succession in Normandy the "Craie Marneuse". Later, Hebert (1863, 1866) subdivided Passy's 'formation' into three units: Craie de Touraine, Craie à _Micraster cortestudinarium_ and Craie à _Micraster coranguinum_, and restricted the "Craie Marneuse" to the basal beds of the Craie de Touraine. Subsequently the "Craie marneuse" was subdivided into 4 zones, the lowest of which Hebert named the Zone à _Belemnites verus_ (=_A. plenus_) and assigned it to the base of the Turonian. Jefferies (1962, 1963) accepted Hebert's definition and used it in his correlation of the "Zone of _A. plenus_" throughout the Anglo-Paris Basin. Juignet (1970, 1974), however, using Antifer as the type

section, interpreted the Craie à A. plenus as Upper Cenomanian. He described the formation as overlying the Craie de Rouen and underlying the "Craie Marneuse" (sensu Passy, 1832; Hebert, 1863, 1866). The base is marked by "Antifer No.1" Hardground (Juignet, 1974) and the top by "Antifer No.3" Hardground (Juignet, 1974) and thicknesess ranges from 0.5-3m. The sediments consist of a sequence of argillaceous chalks and marls passing up into grey-white nodular chalks, and typically, can be sudivided into 8 units seperated by erosion surfaces and hardgrounds which are often glauconitised.

2.1.9 Craie noduleuse (UPPER CENOMANIAN-MID TURONIAN)

The term Craie noduleuse was first used by Chelloneix (1872) in a study of the chalk cliff exposures at Blanc-Nez, Pas-de-Calais. He divided the Turonian strata into three zones which were adopted by several later workers (e.g. Barrois, 1878; Gosselet, 1891; Pruvost & Pringle, 1924). More recent work (Amedro et al., 1976a) on sections at Blanc-Nez has resulted in a detailed lithostratigraphic scheme in which the succession is subdivided into 7 units (=UNITS J-O). The Craie noduleuse (=UNIT L) overlies the Craie à A. plenus (=UNIT K). Unit L is divided into three beds (a-c). The lowest, Bed a, is described as 1.5m of nodular chalk containing abundant (>1cm) nodules of hard, compact, yellow chalk. These nodules, which are sometimes iron-stained, are distributed in bands and separated by marly chalks. This level is regarded as topmost Cenomanian in age. Bed b is more nodular in overall appearance, while Bed c consists of massive white chalk with only occasional nodular units. The Craie noduleuse ranges from 12-20m in thickness and is the lateral equivalent of the Melbourn Rock in southern England (2.4.2).

2.1.10 Craie à Inoceramus labiatus (LOW TURONIAN)

The Craie à I. labiatus is used here in the sense proposed by Alcayde

(1980) from sections sampled in Touraine and Maine. Further north in the Pays de Caux, Pays d'Auge and Pays d'Ouche the Craie à _L. labiatus_ is regarded as being synonomous with Beds b-c of the Craie noduleuse and the Craie marneuse (sensu Amedro et al., 1976a).

Triger (1858), in his Sarthe Memoir, subdivided the Cretaceous succession into a number of groups and described "Groupe VII" as representing the Craie à _Inoceramus problematicus_ (=_L. labiatus_). Later Guillier (1886) and Cayeux (1897) described exposures of this formation in Maine and Touraine. In both cases they noted the prescence of a thin bed of marly chalk underlying the Craie à _L. labiatus_ which they called the Craie à _I. carantonensis_ and assigned an early Turonian age to the succession. Grossouvre (1900) however, placed the Craie à _L. labiatus_ at the base of the Turonian. Alcayde (1980) described the formation as outcropping in numerous valleys in Touraine, north Berry, and Anjou where it overlies conformably the Craie à _I. carantonensis_ and underlies the Craie micacée. The average thickness is ⁻20m and the sediments consist of 1-5m thick sequences of soft chalks interbedded with thin grey marl seams.

2.1.11 Craie marneuse (TURONIAN)

The term Craie marneuse is used here in the lithostratigraphic sense as proposed by Amedro et al. (1976), and should not be confused with the "Craie Marneuse" first introduced by Passy (1832) which is regarded by Alcayde (1980) as being synonymous with the Craie à _L. labiatus_.

This formation was described from the cliff section at Blanc-Nez where it overlies the Craie noduleuse and is overlain by the Craie à silex rares (Amedro et al., 1976). The sediments consist of a monotonous sequence of granular, grey-white chalks with marl seams, flaser chalks (sensu Garrison & Kennedy, 1977), and occasional nodular bands. The chalk becomes marlier in the upper part of the succession.

2.1.12 Craie micacée (MID TURONIAN)

The term Craie micacée was first used by Dujardin (1837). Grossouvre (1898), in his subdivision of the Turonian stage, described the Craie micacée (=Tuffeau de Bourre, Tuffeau de Ponce, Tuffeau de Saumur, and Tuffeau de Loches) as overlying the "Craie Marneuse" (sensu Passy, 1832) and underlying an unnamed sequence of yellow coloured sandy chalks and marls (Tuffeau Jaune). More recently Alcayde (1980) has described the Craie micacée as ranging from 15-40m in thickness and consisting of 1-4m beds of sandy micaceous chalk interbedded with bands of massive, soft white chalk. Flint nodules occur occasionally, particularly in the upper part of the sequence. This formation is exposed in most of the valleys in Touraine.

2.1.13 Tuffeau jaune (HIGH TURONIAN)

The Tuffeau Jaune was first distinguished by Rolland et al. (1890) Lecointre (1947, 1960) described the formation as a chalk sequence with a high detrital quartz content, numerous hardgrounds, and occasional cross-bedded sandy horizons. It outcrops extensively in Touraine and local facies variations have resulted in a variety of different terms (e.g. Pierre de Clion, Pierre d'Écorcheveau, Falun de Continvoir, etc.). In central Touraine the sequence is 30-35m thick and consists of 1-3m beds of homogeneous sandy chalks containing burrow, and semi-tabular flints (Alcayde, 1980; Robaszynski et al., 1982a).

2.1.14 Craie de Villedieu (CONIACIAN-SANTONIAN)

The first details of sections in the type area of the Craie de Villedieu (Villedieu-le-Château) are given by Bourgeois (1862), and Cotteau & Triger (1855-1869) who distinguished a "zone à _Spondylus_ _truncatus_" (=Craie de Villedieu). The term Craie de Villedieu was first applied by Coquand (1856) and later (e.g. Dormoy, 1869; Guillier, 1886) this, with a more rigorous appli-

cation of stratigraphic terminology, gradually replaced the "zone à _S._ _truncatus_" as a lithostratigraphic unit, the lower boundary being taken universally at the base of the Calcaire dûr de la Ribochere. In the most recent revision of the Craie de Villedieu (Jarvis et al., 1982; Jarvis & Gale, 1984) the formation is divided into three members. The lowest of these, the Calcaire dûr de la Ribochere, overlies the Tuffeau jaune and is the only member sampled in the present study. The base of this member consists of a 60cm thick hardground, penetrated by numerous _Thalassinoides_ burrows ¡ (Langeais Thalassinoides Hardground) which is overlain by a sequence of indurated biomicrites and calcarenites with two prominent levels of syn-sedimentary lithification (Cangey Massive Hardground, and Franceuil Planar Hardground).

Fig. 2 Correlation Chart Of Geological Formations In The Anglo-Paris Basin

STAGE	TRADITIONAL ZONE	AMMONITE ZONE	DEVON	SUSSEX	LIEUVIN Pays de CAUX et de BRAY	Pays d'OUCHE et d'AUGE	PERCHE	MAINE	TOURAINE ANJOU
CONIACIAN	M. cortestudinarium		Seaton Chalk	Upper Chalk	Craie à silex abondante	Craie à silex abondante		Craie de Villedieu	Craie de Villedieu
	H. planus	S. neptuni			Craie à silex rare	Craie à silex rare		Tuffeau jaune	Tuffeau jaune
TURONIAN	T. lata	C. woollgari			Craie marneuse	Craie marneuse		Craie micacée	Craie micacée
	I. labiatus	M. nodosoides		Middle Chalk MR	Craie noduleuse	Craie noduleuse	Craie à I. labiatus	Craie à I. labiatus	Craie à I. labiatus
		W. coloradoense					Craie à T. carantonensis	Craie à T. carantonensis	Craie à T. carantonensis
	S. gracile	N. juddii	Beer Head Limestone	Lower Chalk PM	Craie à A. planus	Craie à A. planus	Sables du Perche	Sables à C. obtusus	Sables à C. obtusus
CENOMANIAN	C. naviculare	M. geslinianum			Craie de Rouen	Craie de Rouen	Craie de Rouen	Marnes à O. biauriculata	Marnes à O. biauriculata
	A. rhotomagense			GM	Craie glauconieuse	Craie glauconieuse	Craie glauconieuse	Sables du Perche	Sables du Perche
	M. mantelli					Glauconie de base	Glauconie à O. vesiculosa		
ALBIAN	S. dispar		Upper Greensand	Upper Greensand	Gaize				

MR Melbourn Rock

PM Plenus Marls

GM Glauconitic Marl

1 Marnes de Nogent-le-Bernard

2 Craie de Théligny

3 Sables et Grès du Mans

4 Sables et Grès du Maine

5 Sables et Grès de la Trugalle et Lamnay

6 Craie glauconieuse

7 Marnes de Ballon

8 Argile glauconieuse à mineral de fer

9 Glauconie à O. vesiculosa

2.2 Lithostratigraphy of sections sampled in western France

2.2.1 Livet Quarry, Cordebugle (Figs. 3, 4)
Co-ords.   x=455,40 y=157,80

The sequence in this large working quarry was described in detail by Juignet (1974). Above thick Aptian sands it is possible to examine the Glauconie de base and the overlying Craie glauconieuse. The Glauconie de base comprises almost 7m of extremely glauconitic sands, with coarse-grained lenses, interbedded with more argillaceous horizons, and often containing an abundant fauna. The sediments are heavily bioturbated at several levels. Juignet (1974) places the Albian-Cenomanian boundary at an inconspicuous erosion surface which is difficult to locate due to the friable nature of the sediment. The base of the Craie glauconieuse, however, is marked by a prominent omission surface. The Craie glauconieuse is accessible for approximately 6m and comprises green, and dark maroon, glauconitic sediments at the base passing up into marlier sediments above. Irregular flint nodules start to appear halfway up the sequence, just below the omission surface termed "Livet" by Juignet (1974). Above this surface there is a distinct change in lithology from glauconitic sands to creamy-brown marls with numerous bands of large, distorted grey flints.

Fig. 3   Location Of Livet Quarry, Cordebugle, France
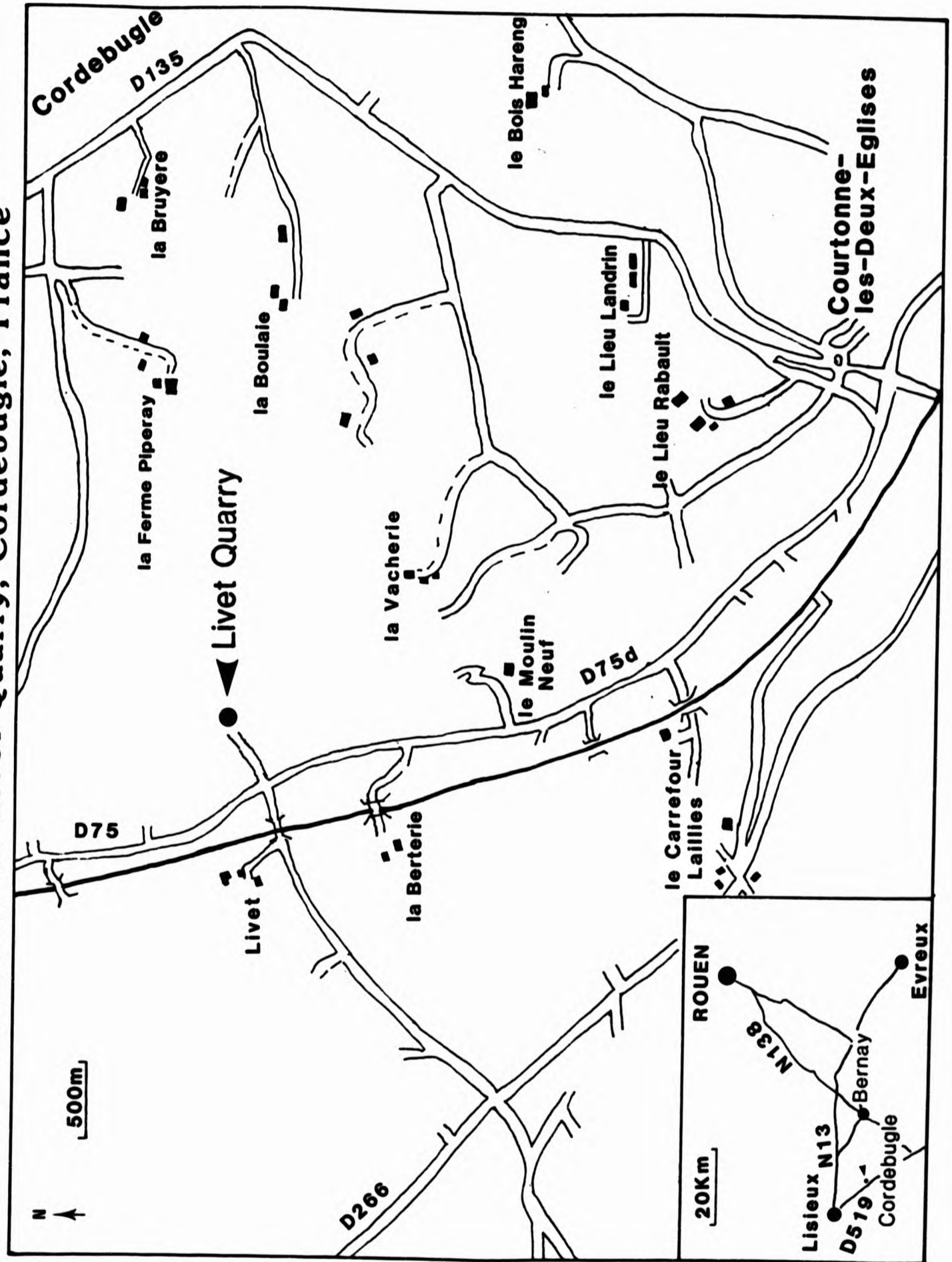
Fig. 4 Lithostratigraphy Of Livet Quarry, Cordebugle, France
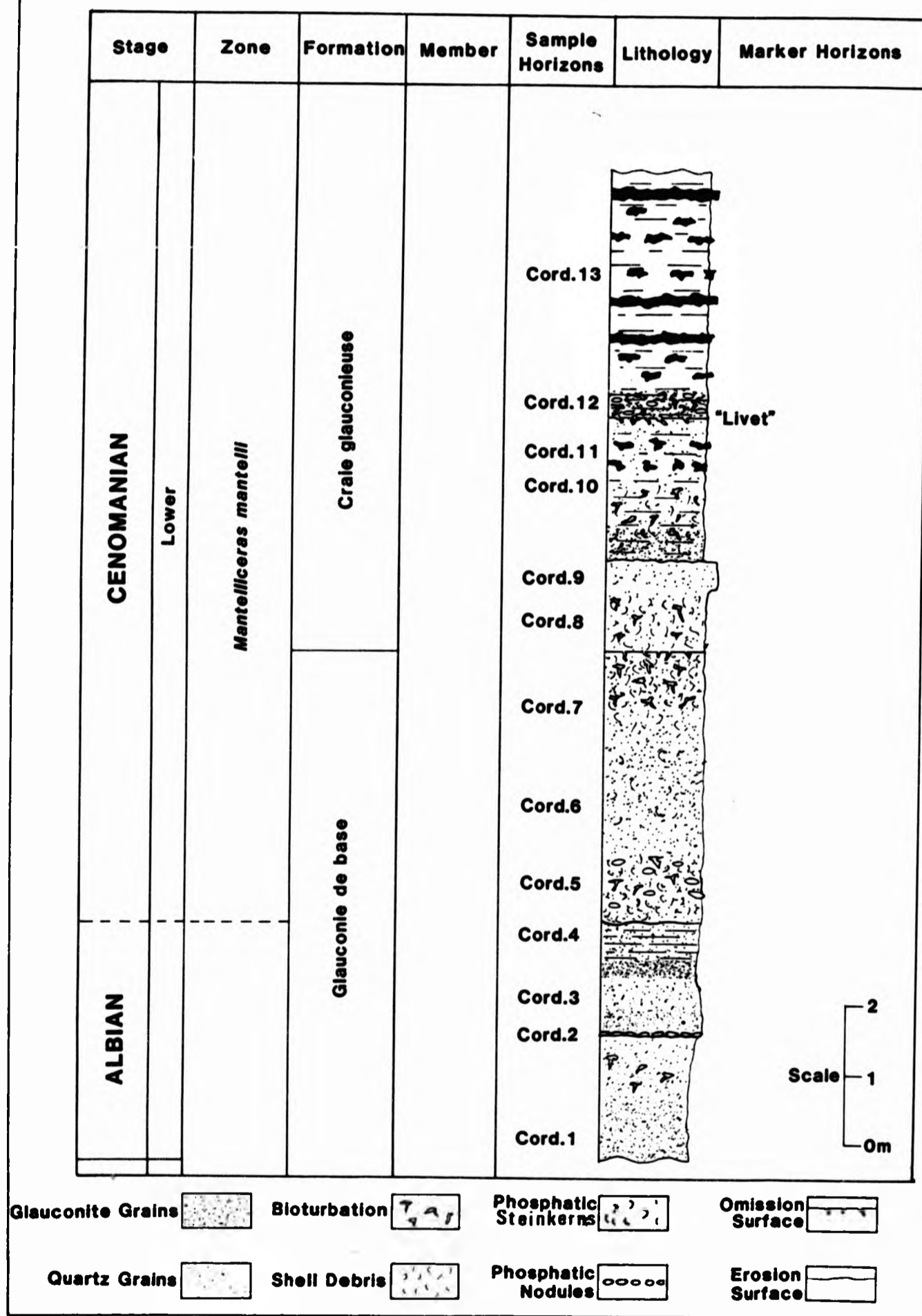
After Juignet,1974

2.2.2   Hameau-Frédet Quarry, Fumichon (Figs. 5, 6)

Co-ords.   x=456,75 y=163,80

This is an abandoned quarry situated behind the Chapel of Canteloup on the right bank of the Paquine River.   Juignet (1974) records that this is one of the few exposures in the Lisieux area which shows the upper part of the Craie glauconieuse and its contact with the Craie de Rouen.   The lower part of the sequence consists of glauconitic chalks, containing occasional nodules and small grey flints, passing up into less glauconitic chalk with nodular and semi-tabular flints.   A number of nodular, burrowed hardgrounds are present which Juignet (1974) correlates with "Bruneval Nos. 1, 2 & 3" Hardgrounds from the type section of the Craie glauconieuse at St.   Jouin. The top of this formation is taken at the surface of a regionally-developed hardground termed "Rouen No. 1" by Juignet (1974).   In this locality the overlying Craie de Rouen consists of glauconite-rich, marly chalks containing an abundant phosphatic fauna and numerous bivalve fragments.   Two prominent omission surfaces are present which Juignet (1974) correlates with "Rouen Nos. 2 & 3" Hardgrounds from the type section of the Craie de Rouen at St. Jouin.

Fig. 5 Location Of Hameau-Frédet & Canteloup Quarries, Fumichon, France
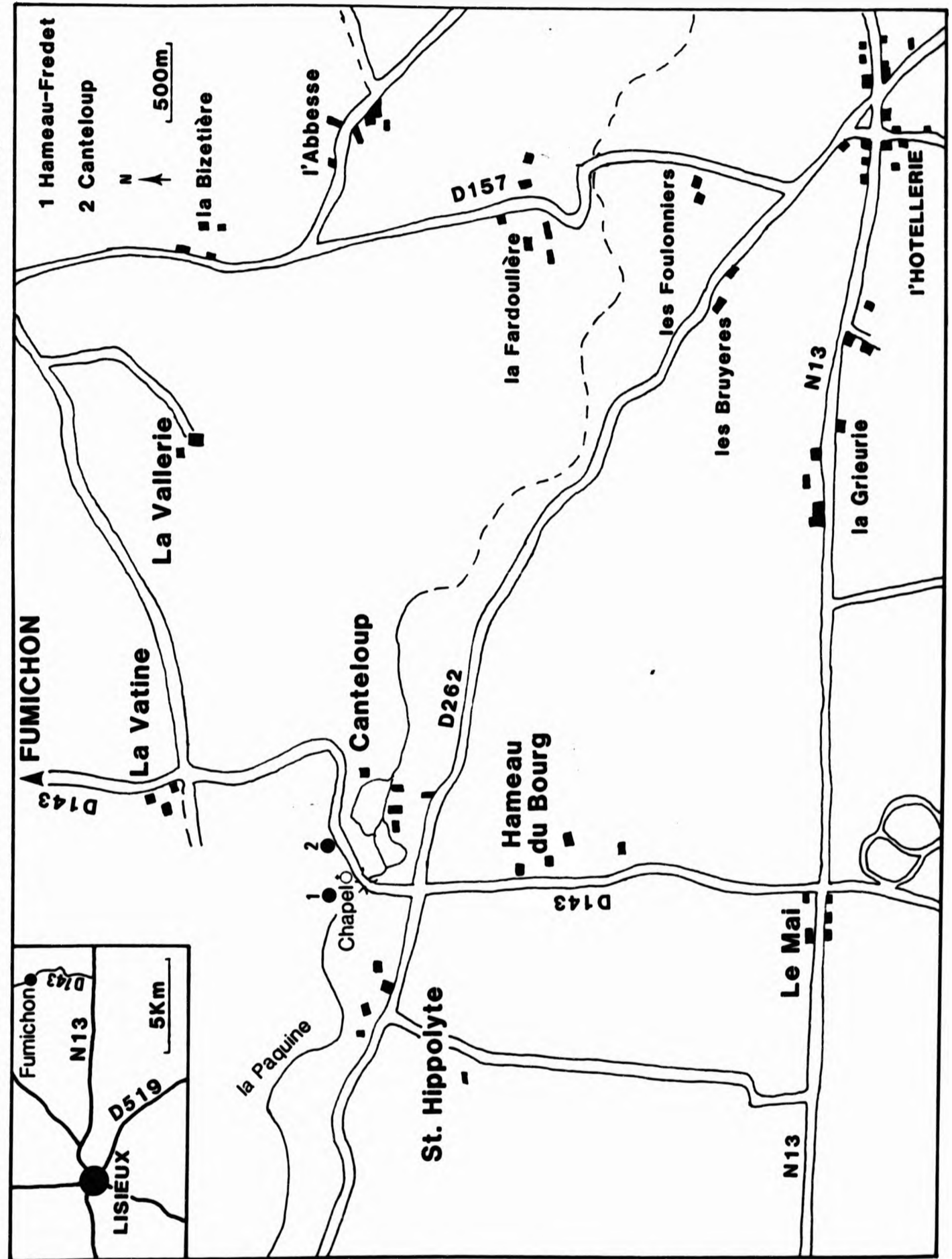
Fig. 6 Lithostratigraphy Of Hameau-Frédet Quarry, Fumichon, France
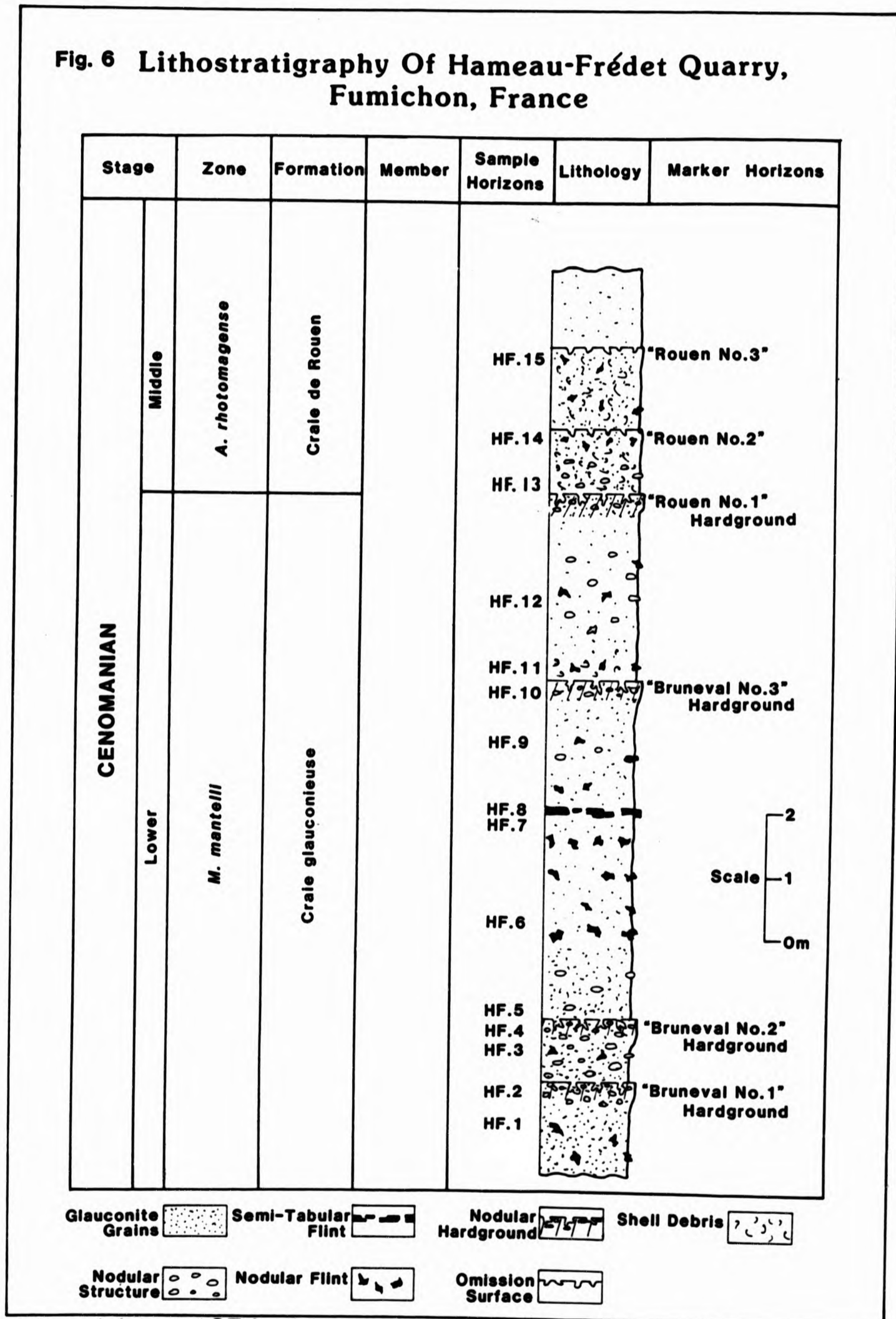
After Juignet, 1974

2.2.3 Canteloup Quarry, Fumichon (Figs. 5, 7)

Co-ords. x=456,80 y=163,80

This abandoned quarry can be found by the side of the D143 in the vicin-
ity of the Chapel of Canteloup. The succession exposes the top 0.5m of the
Craie glauconieuse overlain by almost 14m of the Craie de Rouen. The top of
the Craie glauconieuse consists of a nodular, indurated limestone with a net-
work of glauconitised burrows.   This unit has been correlated with the
regionally-developed "Rouen No. 1" Hardground by Juignet (1974). Above this
the lower part of the Craie de Rouen consists of glauconitic, marly chalks
containing phosphatic nodules, reworked yellow chalk intraclasts, and scat-
tered calcareous nodules. There are also two prominent omission surfaces
which Juignet (1974) correlates with "Rouen Nos. 2 & 3" Hardgrounds from the
type-section of this formation at St. Jouin. The upper part of the succes-
sion is characterised by a reduction in the amount of glauconite and the
appearance of white chalks containing numerous bands of grey semi-tabular,
and nodular flints.

Fig. 7

Lithostratigraphy Of Canteloup Quarry, Fumichon, France
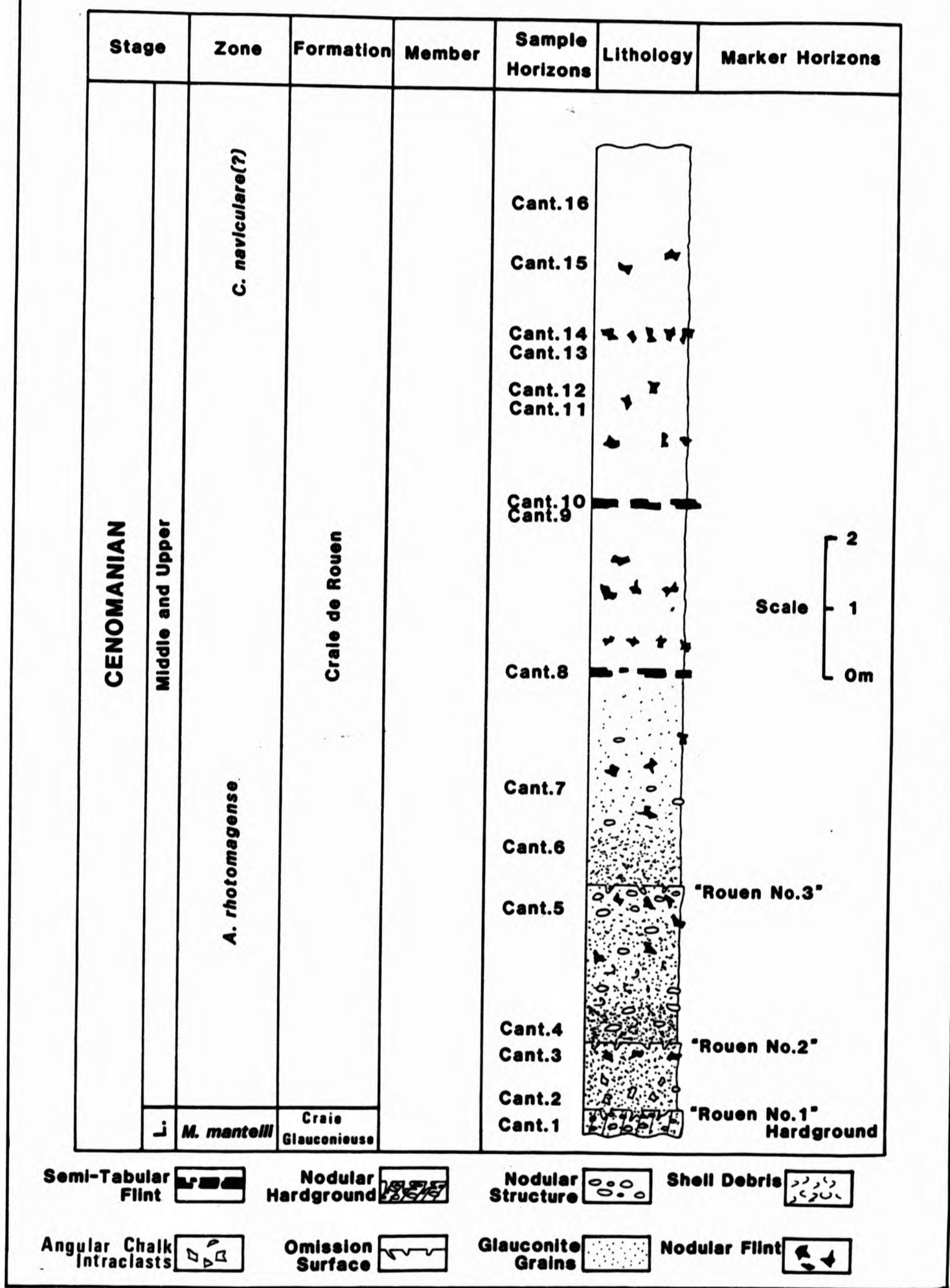
After Juignet, 1974

2.2.4 Les Fosses Blanches Quarry, La Caluyere (Figs. 8, 9)

Co-ords. x=464,10 y=341,65

The section shown on Fig. 9 is a composite of a small working quarry and an adjacent disused sand-pit. The latter exposure shows the upper part of the Sables du Perche which here consist of yellow, medium-grained, glauconitic sands containing large calcareous nodules which give the sediment a distinctive blocky appearance. The top of this formation is taken at the surface of a blocky hardground which also marks the top of the sand-pit, and which Juignet (1974) has correlated with the "Duneau No. 1" Hardground from the type-section near Duneau. At the base of the working quarry, the succession consists of a thin sequence of glauconite-rich and quartz-rich, marly chalks which represent the Marnes à Q. biauriculata. The contact with the overlying Sables à C. obtusus is sharp. The latter formation is represented here by a 30cm thick, grey, nodular indurated limestone which Juignet (1974) has correlated with the "Bousse" Hardground from the type section near Duneau. The overlying Craie à I. carantonensis consists of glauconitic, marly chalks with associated quartz gravel and an abundant fauna. This formation passes upward without visible break into the monotonous grey, marly chalks of the Craie à I. labiatus. Rare calcareous nodules and small flints are present in the upper part of the succession.

Fig. 8   Location Of Les Fosses Blanche Quarry, La Caluyere, France
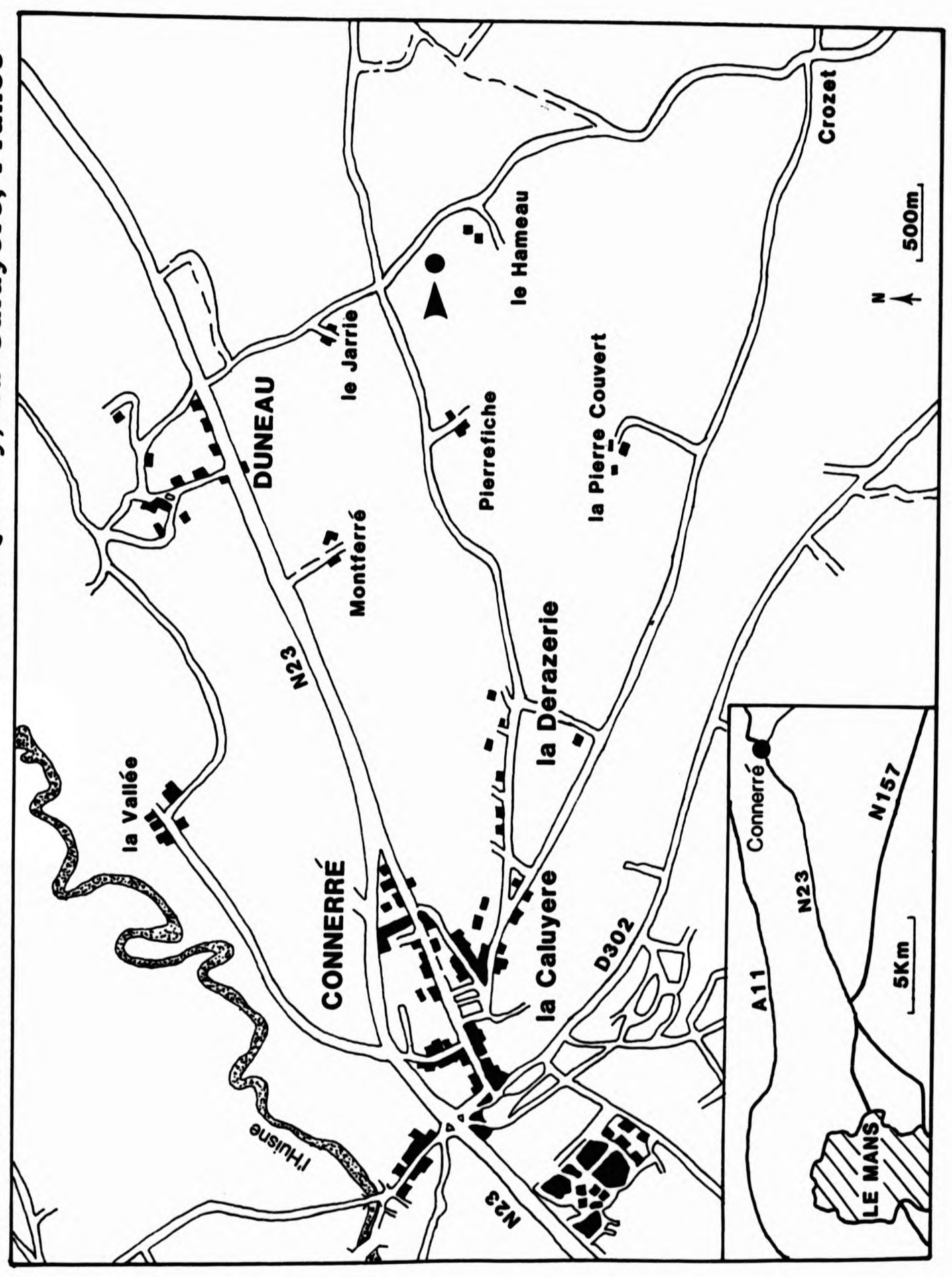
Fig. 9 Lithostratigraphy Of Les Fosses Blanches Quarry, La Caluyere, France

Stage	Zone	Formation	Member	Sample Horizons	Lithology	Marker Horizons
TURONIAN	W. coloradoense	Craie à I. labiatus		Cal.9 Cal.7		
				Cal.8		
				Cal.6		Scale 2 / 1 / 0m
				Cal.5		
				Cal.4		
	N. juddii	1		Cal.3		
CENOMANIAN	A	2		Cal.2		"Bousse" Hardground
	B	3		Cal.1		
	A. rhotomagense	Sables du Perche		Cal.12		"Duneau No.2" Hardground
				Cal.11		
				Cal.10		

Blocky Structure — Nodular Flint — Nodular Structure — Glauconite Grains

Marly Chalk — Shell Debris — Blocky Hardground — Quartz Grains

1 – Craie à *T. carantonensis*   2 – Sables à *C. obtusus*   3 – Marnes a *O. biauriculata*
A – *M. geslinianum*   B – *C. naviculare*

Modified from Juignet,1974

2.2.5 Moulin Ars Quarry, St. Calais (Figs. 10, 11)

Co-ords. x=481,45 y=326,90

This is a large disused quarry, just off the D1 to the north of St. Calais which exposes a thick succession of the Sables du Perche, overlain by a thin development of the Craie à I. carantonensis and the Craie à I. labiatus. Due to the dangerous state of the quarry face it was only possible to sample the lower two formations.

The basal part of the Sables du Perche consists of yellow and white quartz sands, occasionally cross-bedded, and containing abundant shell debris. Further up the succession the presence of large calcareous nodules give the sediment a distinctive blocky appearance. The top of this formation is taken at the surface of a well-defined blocky hardground (Savigny No. 2; Juignet, 1974). The overlying Craie à I. carantonensis consists of glauconitic chalks with occasional phosphatic nodules.

Fig. 10   Location Of Moulin Ars Quarry, St. Calais, France
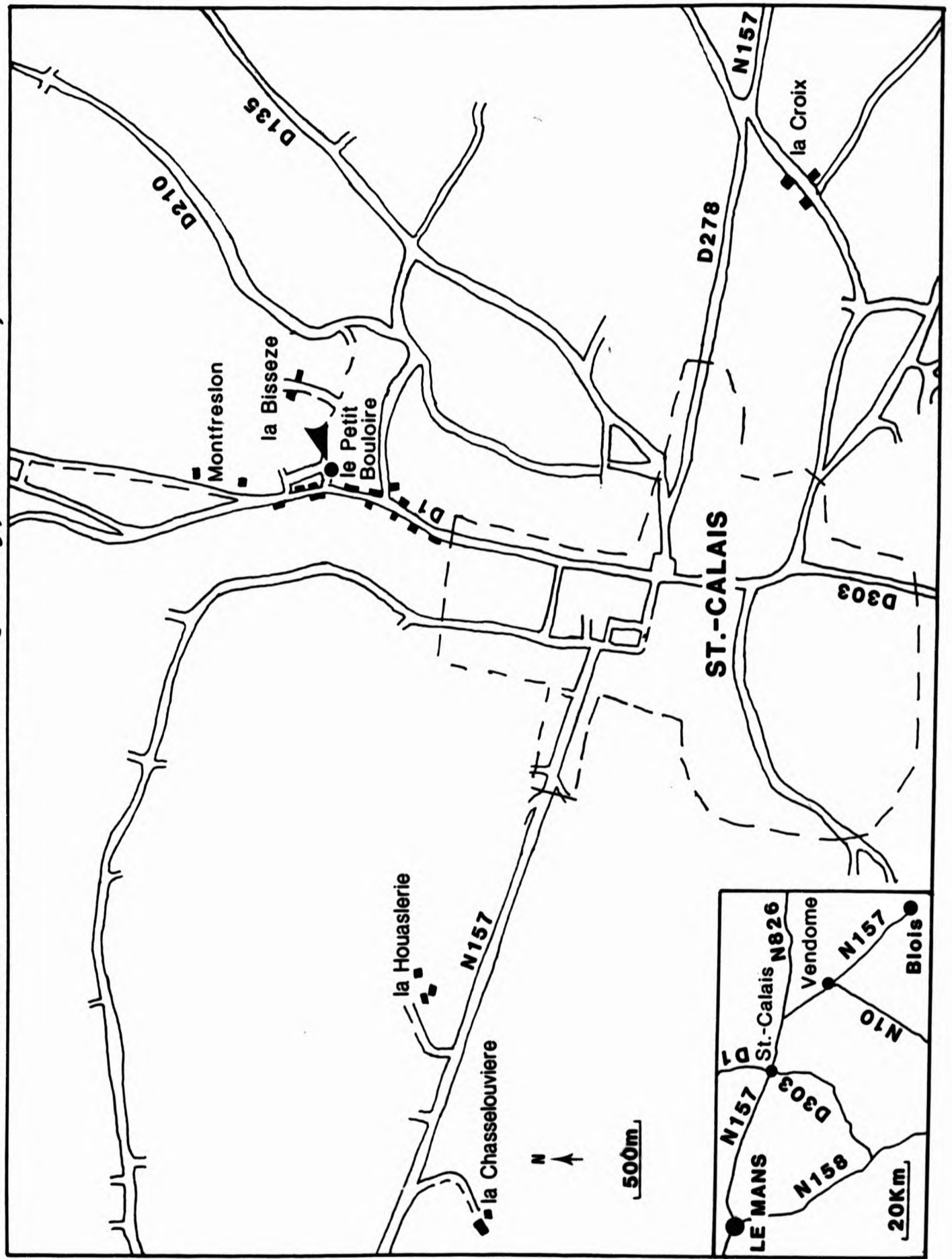
Fig. 11

Lithostratigraphy Of Moulin Ars Quarry, St. Calais, France
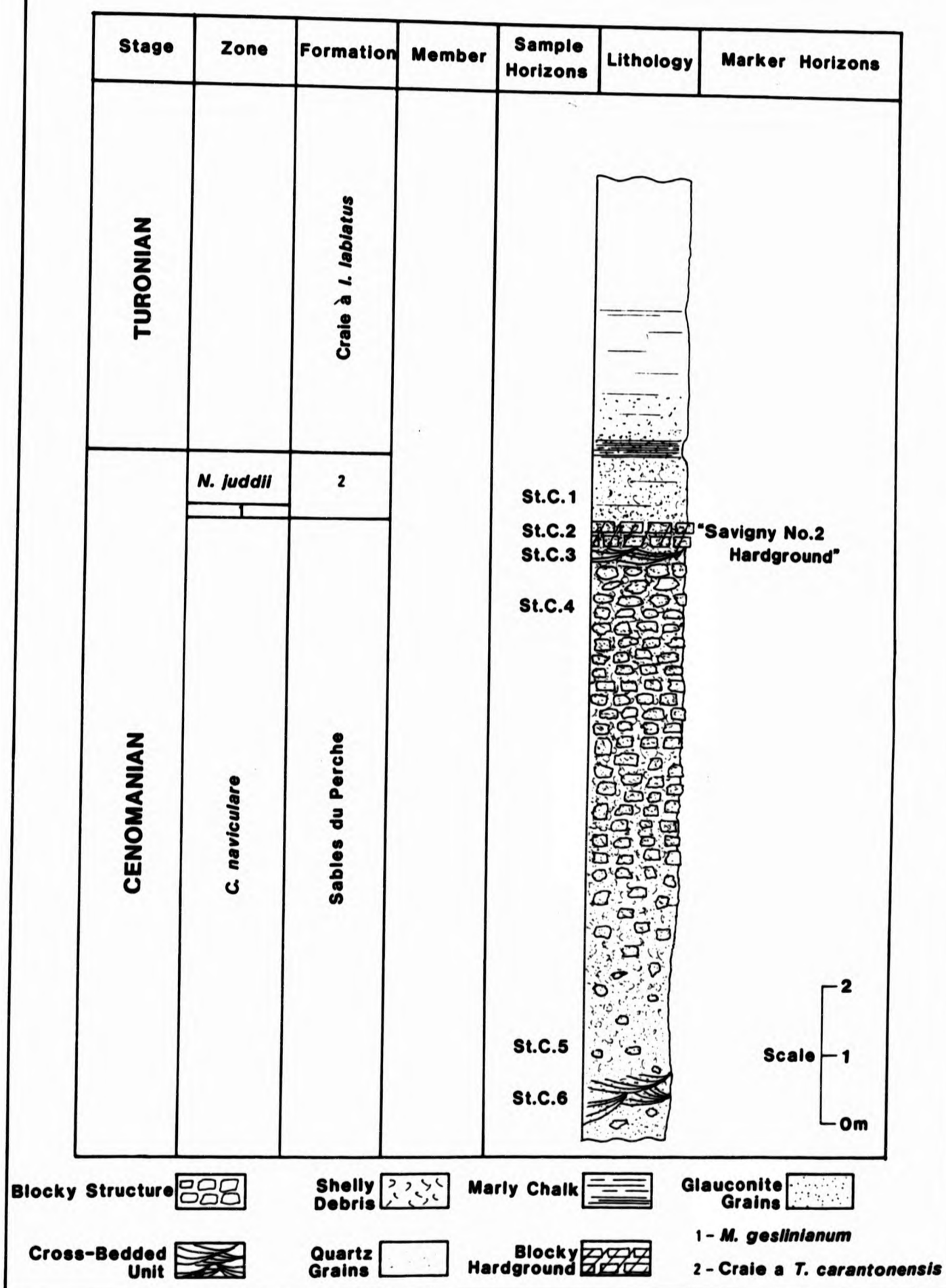
After Juignet, 1974

2.2.6 Bois du Galet Marl Pit, St. Sylvestre-de-Cormeilles (Figs. 12, 13)

Co-ords. x=460,60 y=173,05

This large disused marl pit exposes the Craie à A. plenus, Craie noduleuse, and Craie marneuse (sensu Amedro et al., 1976a). The Craie à A. plenus is characterised here by light grey marly chalks seperated by two massive-topped nodular hardgrounds, with glauconitised surfaces which are penetrated by numerous Thalassinoides burrows. The lower hardground is correlated with "Antifer No. 2" Hardground which Juignet (1974) described from the type section at Antifer, and the upper hardground is correlated with "Antifer No. 3". Resting on the surface of the latter, the sediments consist of light-grey chalks with prominent bands of calcareous nodules. Juignet (1974) correlated these nodular chalks with the now defunct unit "Horizon A" (Juignet et al., 1973) and the basal part of the Craie à I. labiatus. I have followed the more recent lithostratigraphic scheme introduced by Amedro et al. (1978) and correlated the nodular chalks with the Craie noduleuse from the Pas-de-Calais region. Above this the rest of the sequence consists of creamy-white marly chalks with occasional bands of grey nodular flints and is correlated here with the Craie marneuse (2.1.11).

Fig. 12 Location Of Bois du Galet Marl Pit, St. Sylvestre-de-Cormeilles, France
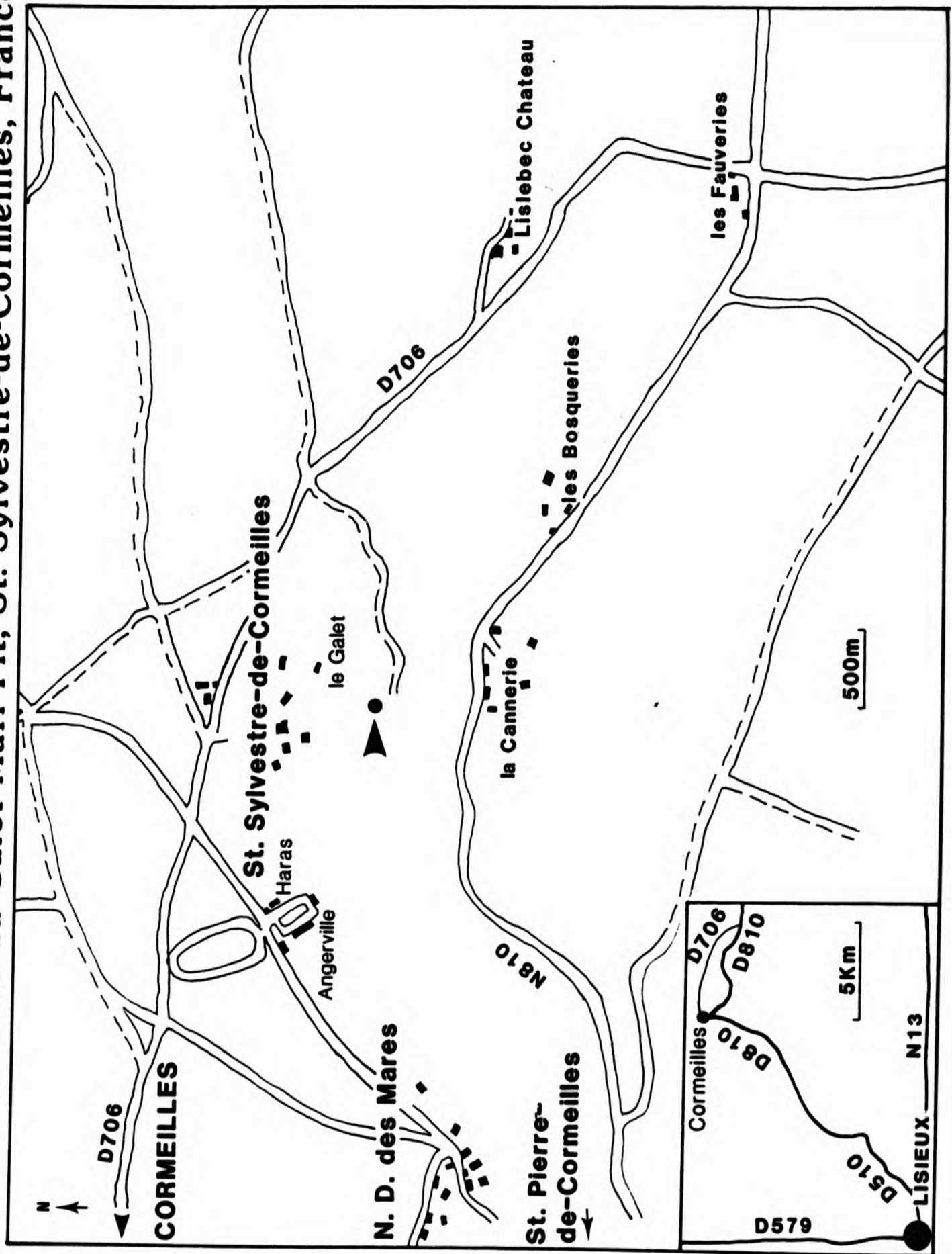
Fig. 13 Lithostratigraphy Of Bois du Gallet Marl Pit, St. Sylvestre-de-Cormeilles, France
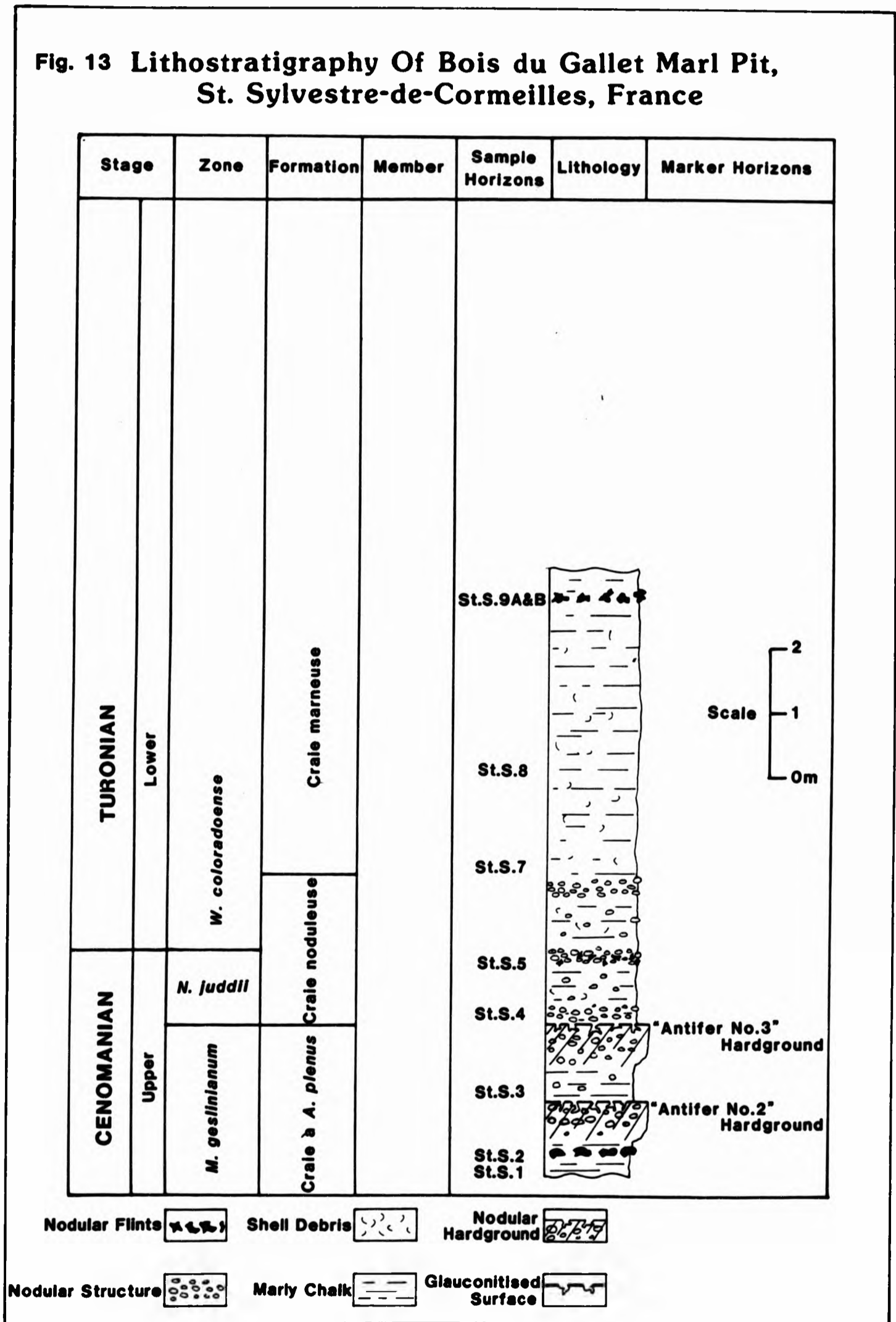
2.2.7 Roadside Exposure At Ports (Figs. 14, 15)

Co-ords.   x=464,00 y=226,25

A number of samples were collected from the steep chalk cliffs on the east bank of the River Vienne to the north of Ports. The exposure comprises about 21m of 1-2m thick hard white chalks interbedded with thin light-grey marl seams representing the Craie à *L. labiatus*. Near the top of the cliff the chalk becomes slightly micaceous, which may indicate the prescence of the Craie micacée. However, the intermittent nature of the exposure makes this very difficult to establish. Small amounts of shell debris are present throughout the succession.

Fig. 14   Location Of Roadside Cliff Section At Ports, France
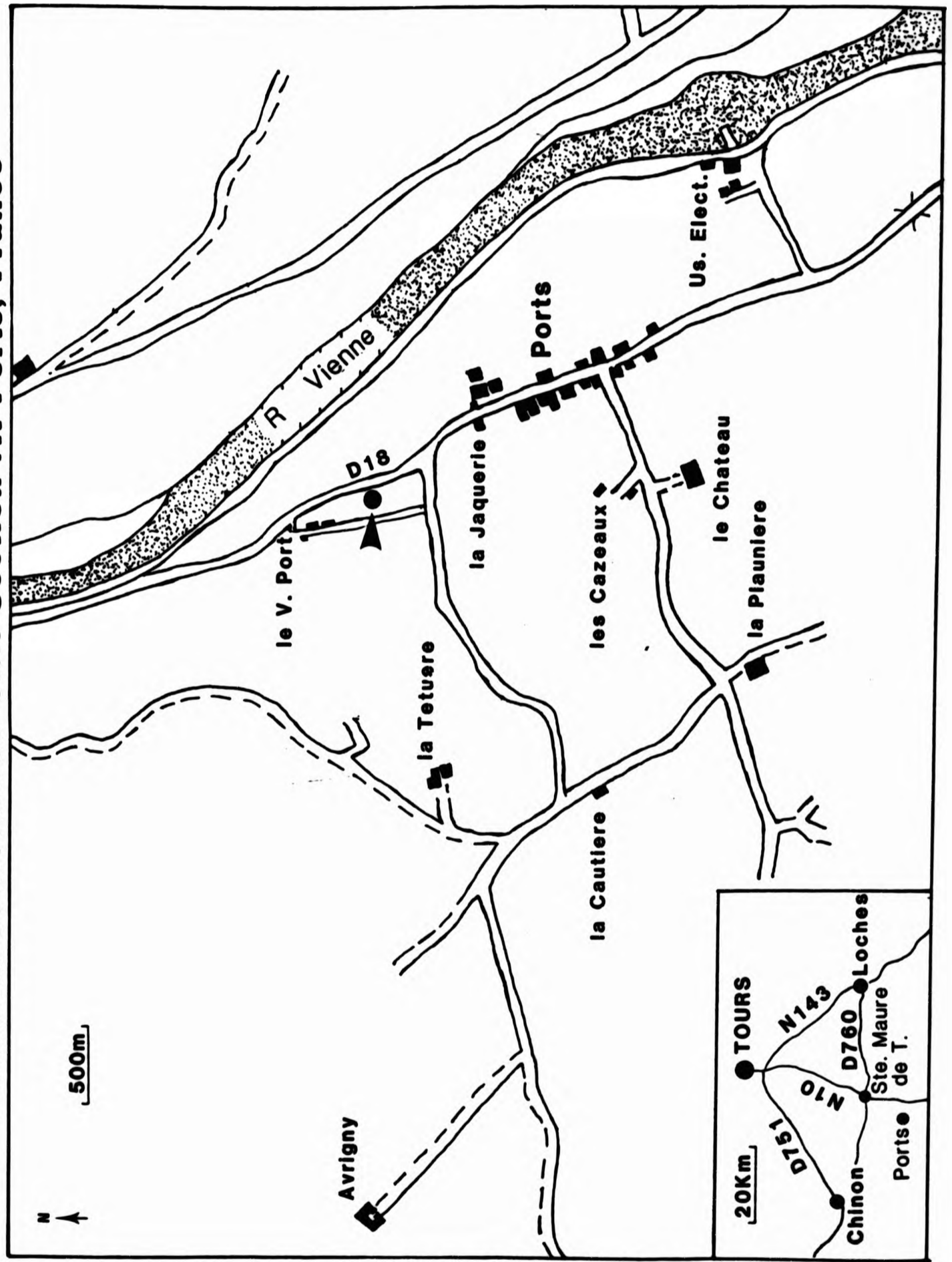
Fig. 15

Lithostratigraphy Of Roadside Section, Ports, France

Stage	Zone	Formation	Member	Sample Horizons	Lithology	Marker Horizons
TURONIAN	W. coloradoense	Craie à I. labiatus		Po.1		
				Po.2		
				Po.3		
				Po.4		
				Po.5		
				Po.6		
				Po.7		
				Po.8		
				Po.9		
				Po.10		
				Po.11		
				Po.12		Scale 2 — 1 — 0m
				Po.13		

Shell Debris ▨   Marly Chalk ▤   White Chalk ☐

Mica ▨   Marl Seam ▬
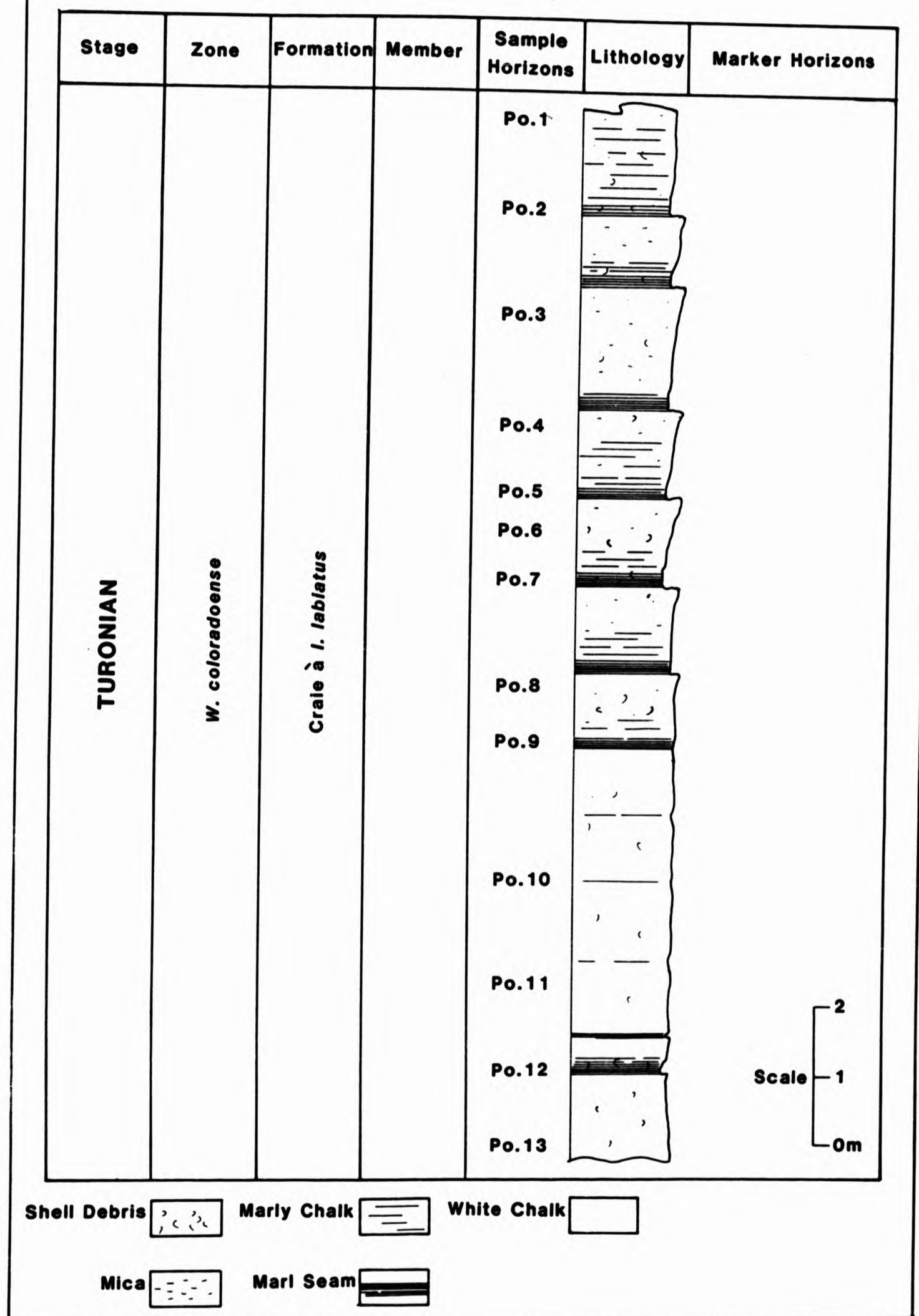
2.2.8   Fontevraud Quarry (Figs. 16, 17)

Co-ords.   x=426,70 y=243,40

The section shown on Fig. 17 is a composite of two adjacent disused quarries, just off the main road south of Fontevraud, and exposes the Craie à _I._ _labiatus_ and the overlying Craie micacée. The former consists of a mono-tonous sequence of massive, white, slightly micaceous chalks interbedded with thin light-grey marl seams. Rare small grey sponge flints occur at the base of the section and minor amounts of shell debris are present throughout. The Craie micacée is much richer in mica and occasionally contains an abundant ammonite and inoceramid fauna (Woodroof, 1981). The junction between the two formations is taken here at the break between the two quarries.

Fig. 16 Location Of Fontevraud Quarry, France
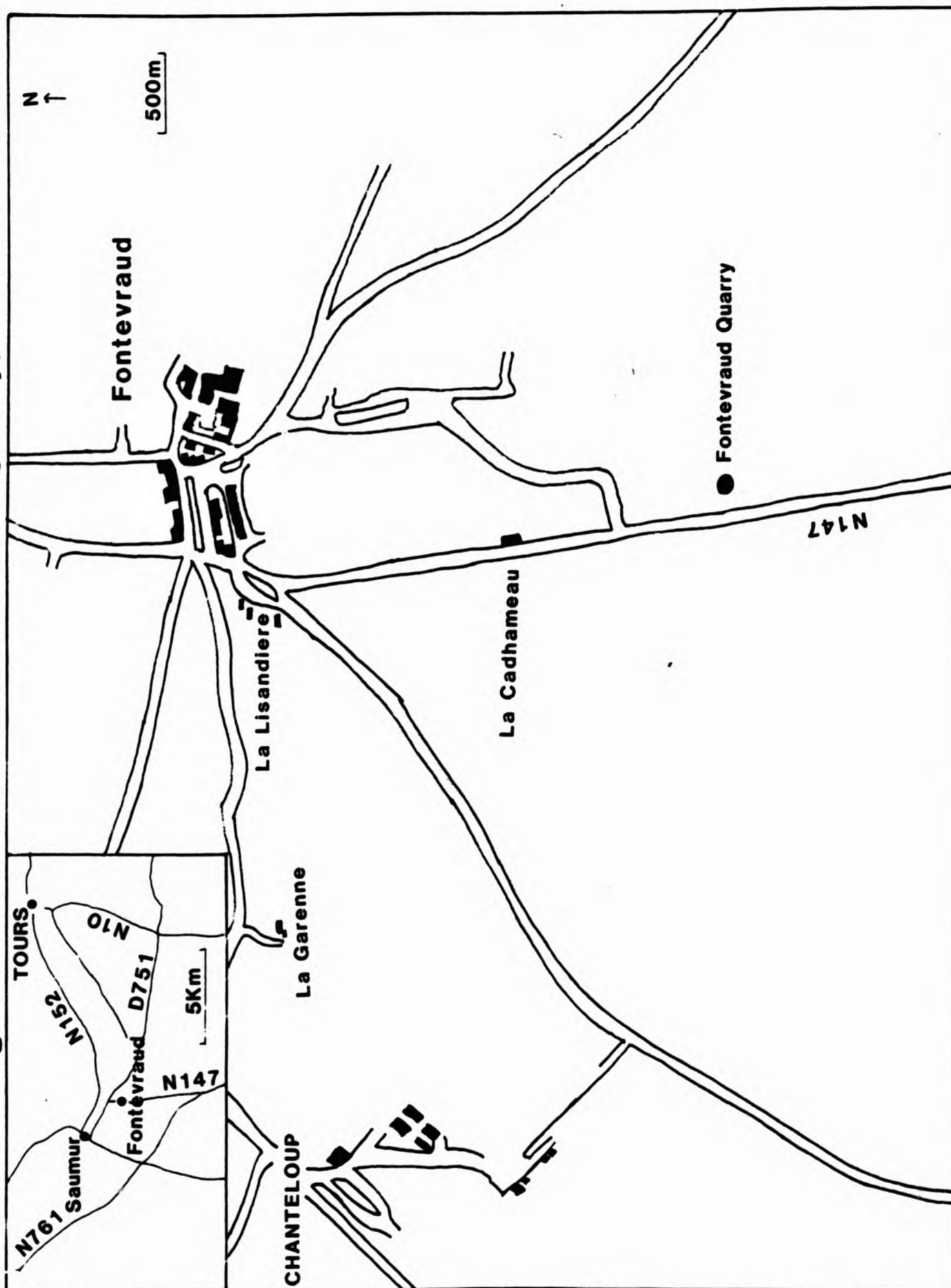
Fig. 17 Lithostratigraphy Of Fontevraud Quarry, France

Stage	Zone	Formation	Member	Sample Horizons	Lithology	Marker	Horizons
TURONIAN	M. nodosoides	Craie micacée		Fo.13 Fo.10 Fo.11 Fo.1			
	W. coloradoense	Craie à I. labiatus		Fo.12 Fo.2 Fo.3 Fo.4 Fo.5 Fo.6 Fo.7 Fo.9 Fo.8		Scale	2 1 0m

Mica · Shell Debris · Marl Seam

Nodular Flint · Marly Chalk
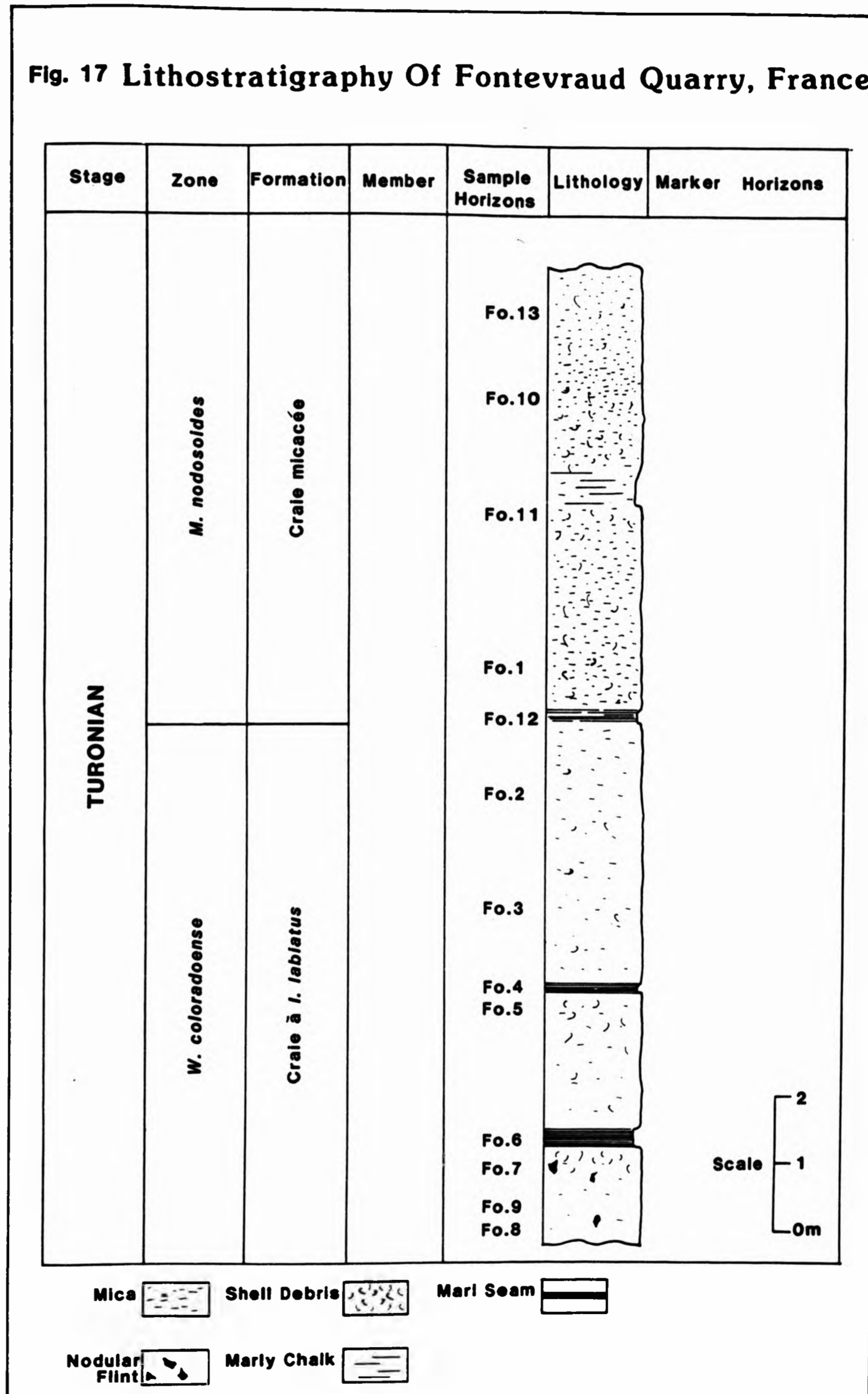
After Woodroof, 1981

2.2.9 "Mushroom Farm Section" At La Chartre-sur-le-Loir (Figs. 18, 19)

Co-ords. x=465,10 y=304,90

This section, which exposes the junction between the Craie micacée and the Tuffeau jaune, can be examined beside the track which leads up to a mushroom farm east of La Chartre. The lower part of the succession consists of micaceous sands, with some glauconite, shell debris, and calcareous nodules. The top of the Craie micacée is taken at the surface of a prominent burrowed hardground surface. Above this the Tuffeau Jaune becomes steadily less micaceous and nodular and semi-tabular flints start to appear. Near the top of this exposure the sediments change from sandy chalks to white marly chalks containing small flints, occasional calcareous nodules and shell debris.

Fig. 18

Location Of "Mushroom Farm Section", la Chartre-sur-le-Loir, France
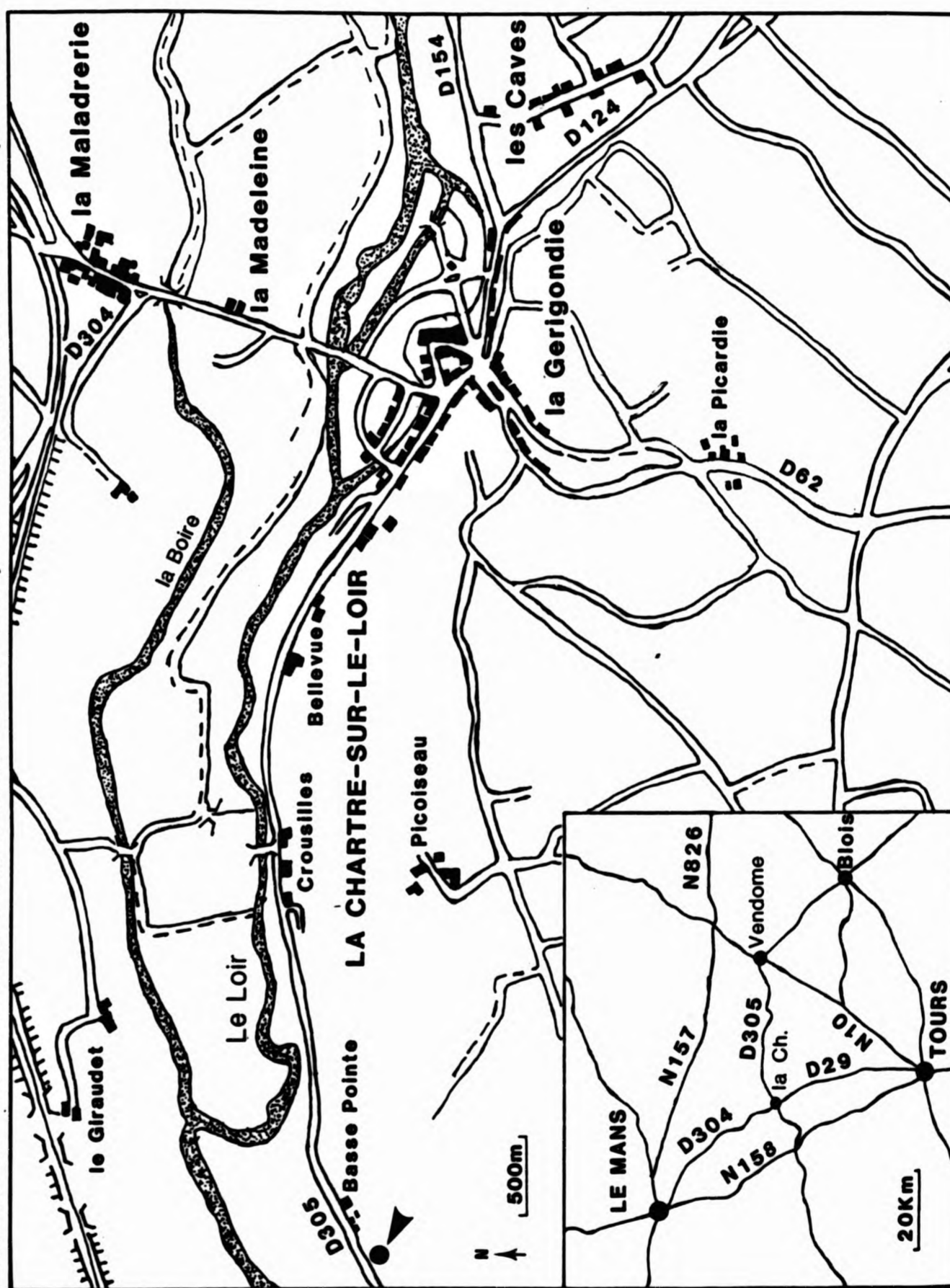
Fig. 19 Lithostratigraphy Of "Mushroom Farm Section",
La Chartre-sur-le-Loir, France

Stage	Zone	Formation	Member	Sample Horizons	Lithology	Marker Horizons
TURONIAN	S. neptuni	Tuffeau Jaune		La Ch.19		
				La Ch.18		
				La Ch.17		
				La Ch.16		
				La Ch.15		
				La Ch.14		
				La Ch.13		
				La Ch.12		
				La Ch.11		
				La Ch.10		
				La Ch.9		
				La Ch.8		
				La Ch.7		
				La Ch.6		
	C. woolgari	Craie Micacée		La Ch.5		
				La Ch.4		
				La Ch.3		
				La Ch.2		
				La Ch.1		

Scale: 2 — 1 — 0m

Quartz Grains		Nodular Structure		Nodular Hardground		Shell Debris	
Glauconite Grains		Semi-tabular Flint		Nodular Flints		Marly Chalk	

2.2.10 Roadside Section At Villedieu-le-Château (Figs. 20, 21)

Co-ords. x=472,45 y=304,09

This section exposes the junction between the Tuffeau Jaune de Touraine and the Craie de Villedieu. Only the top few metres of the former and the basal member (Calcaire dûr de la Ribochère) of the latter were sampled. This section has recently been described in detail by Jarvis et al. (1982). The topmost beds of the Tuffeau Jaune consist here of greenish-yellow, weakly indurated glauconitic calcarenites with scattered calcareous nodules. The top of the formation is marked by a strongly indurated hardground penetrated by numerous Thalassinoides. Above this the basal bed of the Calcaire dûr de la Ribochère Member is composed of strongly lithified, cream-coloured, medium to coarse sands, bryozoan calcarenites and biomicrites. This is separated from the coarser-grained material above by an omission surface. The top of the coarse-grained bed is marked by a massive planar hardground and this is in turn overlain by a succession of moderately indurated bryozoan sands, gravels and biomicrites containing numerous oysters and other bivalves. This passes up into the strongly indurated, flat topped Franceuil   Planar Hardground (Jarvis et al., 1982).

Fig. 20   Location Of Roadside Section At Villedieu-le-Chateau, France
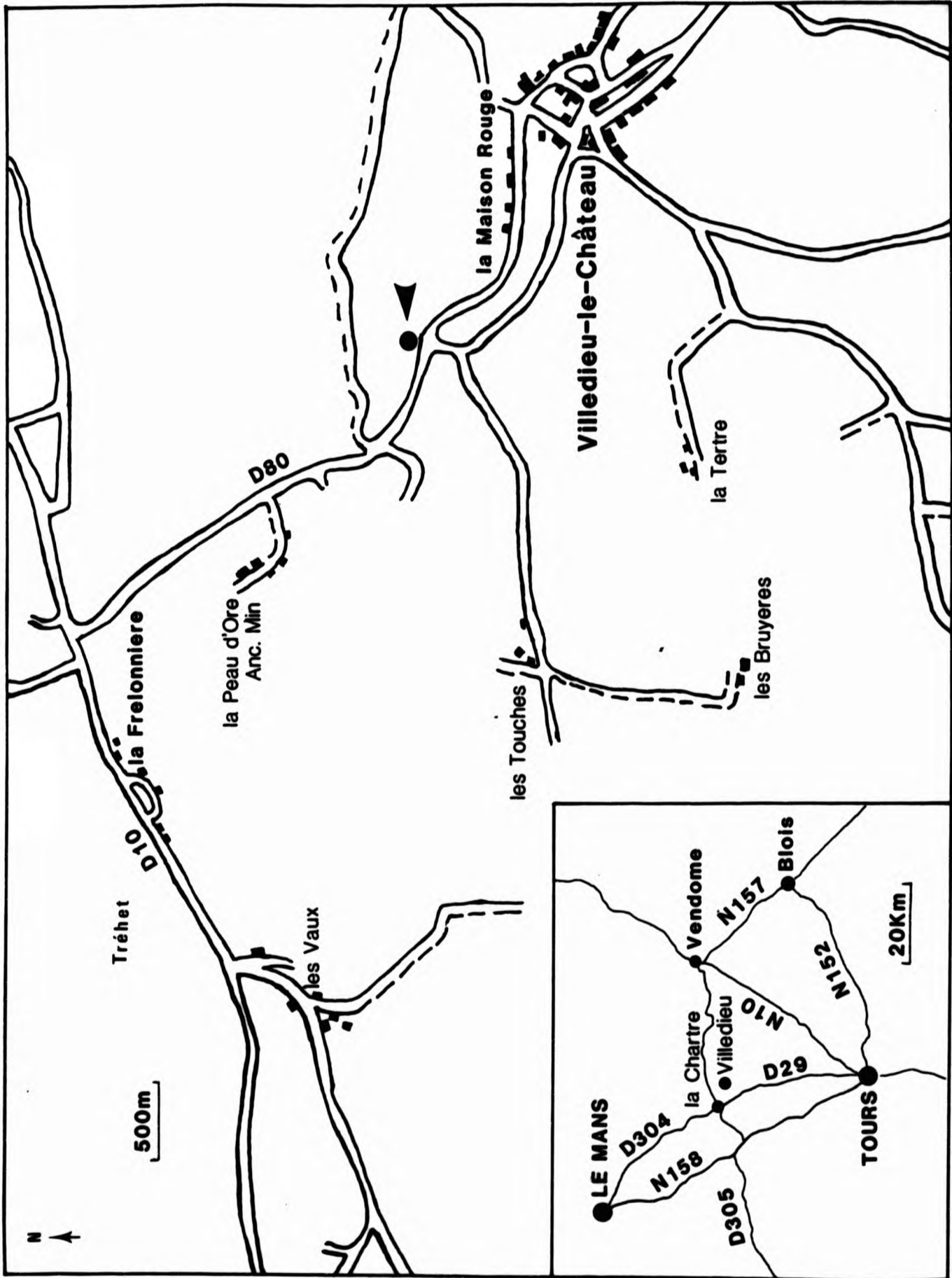
Fig. 21

Lithostratigraphy Of Section At Villedieu-le-Chateau, France

Stage	Zone	Formation	Member	Sample Horizons	Lithology	Marker Horizons

Scale: — 2 — 1 — 0m

				VIII.7		PLANAR HARDGROUND
CONIACIAN		Craie de Villedieu	Calcaire dur de la Ribochere	VIII.6		MASSIVE HARDGROUND
				VIII.5		
				VIII.4		THALASSINOIDES HARDGROUND
TURONIAN		Tuffeau Jaune		VIII.3		
				VIII.2		
				VIII.1		

Planar Massive Hardground	▨	Glauconite Grains	▦	Nodular Structure	▨
Convolute Massive Hardground	▨	Omission Surface	∿	Calcarenite	▨
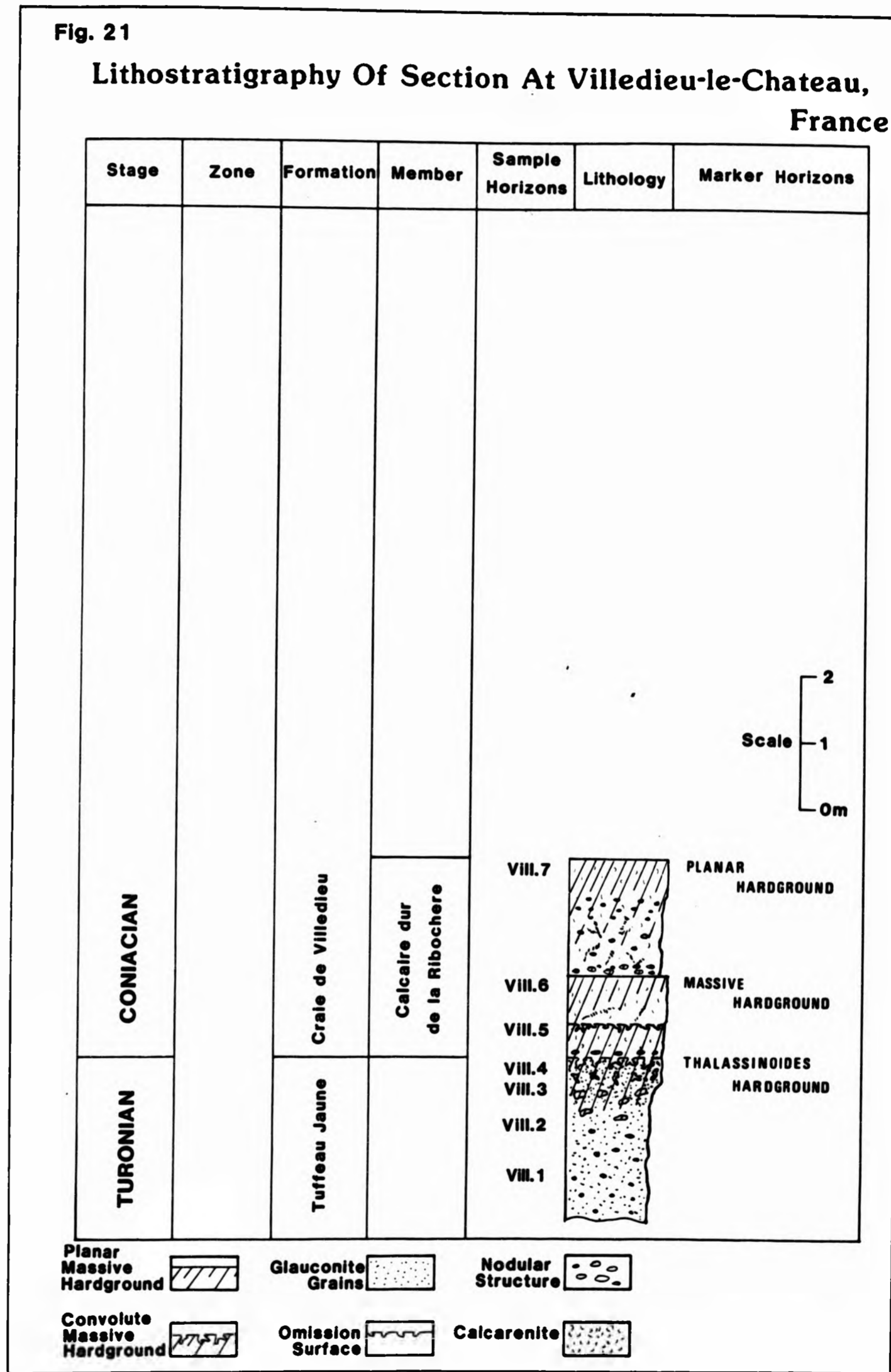
2.3 Lithostratigraphy of formations examined in southern England

Since no generally accepted lithostratigraphic scheme exists for SE England despite extensive previous work (see Wright & Kennedy, 1981 for a recent review), this section examines only those geological formations present in SW England.

2.3.1 Beer Head Limestone (CENOMANIAN)

The Beer Head Limestone consists of a succession of sandy biomicritic limestones which may be subdivided into four members (Jarvis & Woodroof, 1984) : Pounds Pool Sandy Limestone (base), Hooken Nodular Limestone, Little Beach Bioclastic Limestone, and Pinnacles Glauconitic Limestone (top). The base of each member is defined by a laterally extensive level of synsedimentary lithification i.e. a hardground surface. The Beer Head Limestone rests on the indurated summit of the Upper Greensand (?Albian), the Small Cove Hardground. The thickest sections of the formation are in Hooken Cliffs (e.g. Beer Stone Adit, Fig. 25) where the succession is most complete, attaining a thickness of 12.4m. Here the hardgrounds are moderately lithified nodular units up to 60cm thick, separated by less indurated nodular limestones and sands containing prominent _Thalassinoides_ burrows. In more attenuated sections, the formation consists of a massively indurated complex of superimposed hardgrounds, locally having a total thickness of ‾60cm. Even in the thinnest sections, however, it is generally only the basal (Pounds Pool) member that is absent (Jarvis & Tocher, 1982; Jarvis & Woodroof, 1984).

2.3.2 Seaton Chalk (TURONIAN-CONIACIAN)

The Seaton Chalk consists of a succession of nodular, marly, and flinty chalks, and is also divided into four members (Jarvis & Tocher, 1982, 1983;

Jarvis & Woodroof, 1984) : Connett's Hole Nodular Chalk (base), Beer Roads
Flinty Chalk, Pinhay Nodular Chalk, and Clevelands Flinty Chalk (summit).
Only the lower 3 members were sampled during the present study. The base of
the formation is taken at the surface of the Haven Cliff Neocardioceras
Hardground (= Neocardioceras Pebble Bed of previous authors), which is
present throughout the area. Like the Beer Head Limestone, the Seaton Chalk
displays considerable variation in thickness and lithology. In general the
members thicken towards Hooken Cliffs (Fig. 25) but probably thinned consid-
erably west of Branscombe, where most of the succession has now been removed
by erosion. This trend of thickening to the west is broken at the base of
the Beer Roads Member in the Hooken Cliffs, where the surface of the Bran-
scombe Hardground represents a significant disconformity. The Branscombe
Hardground passes laterally into 8 separate hardgrounds (upper part of the
Connett's Hole Member, ~9m of sediment) at White Cliff, which in turn pass
laterally into an even thicker succession of nodular chalks and weak
hardgrounds further east (Jarvis & Tocher, 1982, 1983; Jarvis & Woodroof,
1984).

2.4 Lithostratigraphy of sections sampled in southern England

2.4.1 Asham Pit, Beddingham (Figs. 22, 23)

Co-ords. 440073-440062

This large disused quarry (now infilled) was previously examined by Gaster (1929), and Kennedy (1969). The quarry consisted of 3 large pits which, combined, exposed strata ranging from Gault (Albian) to Middle Chalk. Figure 23 shows a composite of part of the succession exposed in Pits 1 and 2. The base of Pit 1 consists of ~1m of blue-grey silty clay which passes up into 3m of light brown silty clay representing the Upper Greensand. The silt content rises towards the top of the succession and occasional thin laminated units are present. The top of the Upper Greensand is defined by an omission surface which is penetrated by numerous Thalassinoides burrows. The sediment within these burrows is identical to the overlying basal bed of the Lower Chalk (the Glauconitic Marl) which is represented here by a light brown, glauconitic, sandy marl which is intensely bioturbated and penetrated by numerous Thalassinoides. Small, 1-3cm, phosphatic nodules and bivalve fragments are common. The glauconite content decreases upwards and virtually disappears at the summit of the marl. Above this is a thin exposure of interbedded hard white chalks and medium-light grey marls. Pit 2 exposed approximately 25m of interbedded white chalks and medium-light grey marl seams. About halfway up the exposure, the appearance of numerous O. mantelliana indicates the presence of the mid-Cenomanian O. mantelliana Band (Kennedy, 1969).

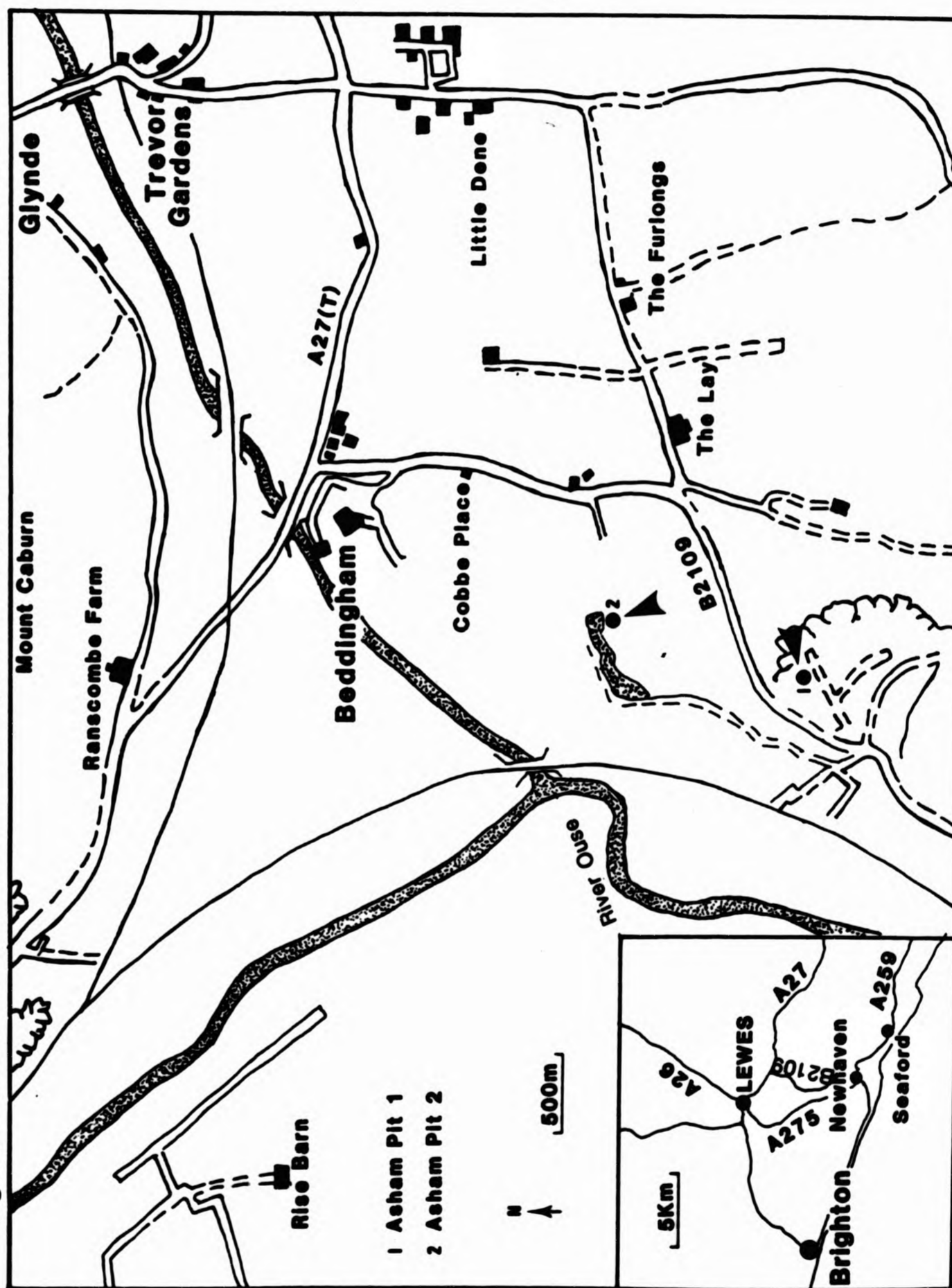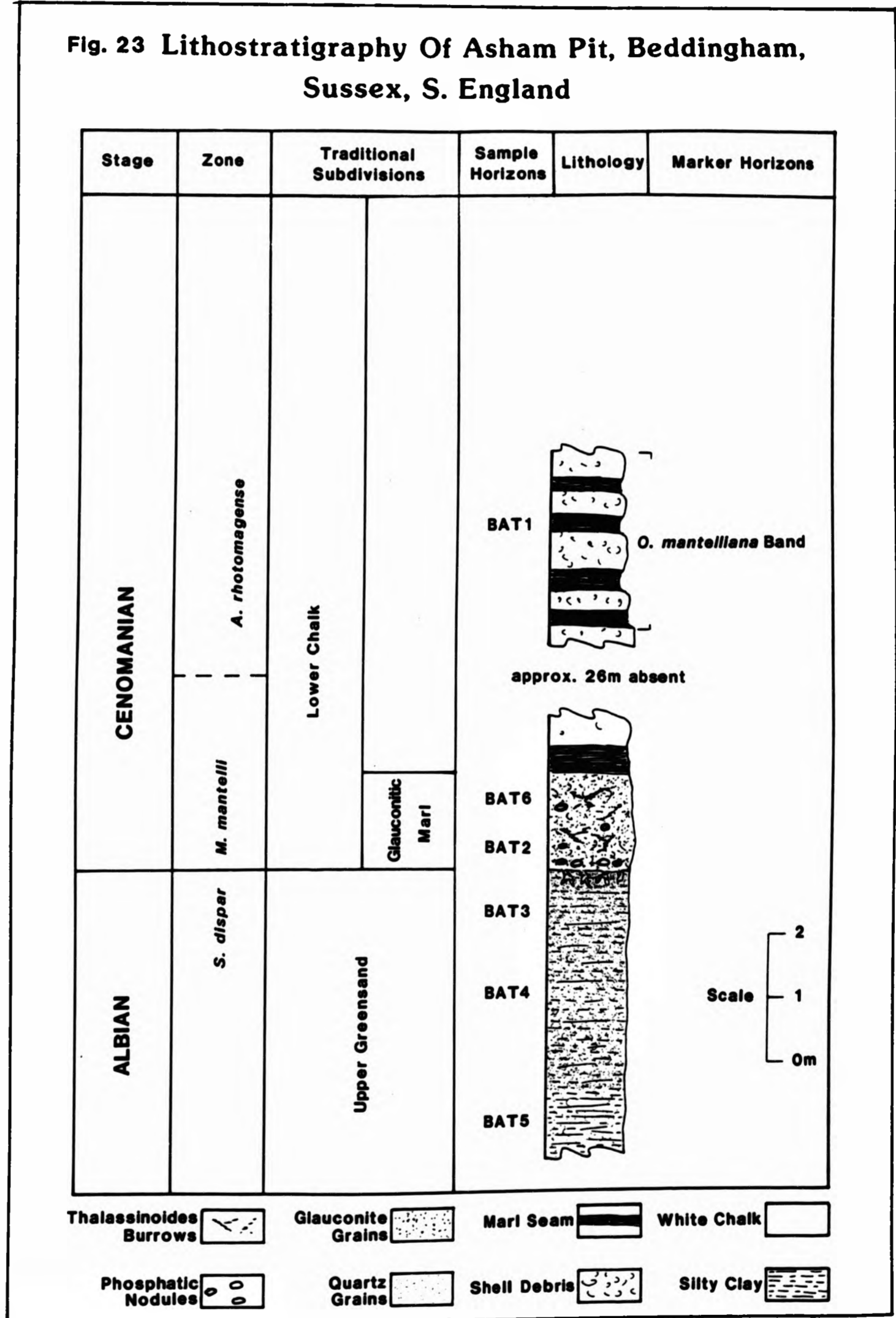Fig. 22 Location Of Asham Pit, Beddingham, Sussex, S. England

Fig. 23 Lithostratigraphy Of Asham Pit, Beddingham, Sussex, S. England

After Kennedy, 1969

2.4.2 Beachy Head, Eastbourne (Figs. 24, 25a-d)

Co-ords. 595958-585952

This coastal exposure, which has been described by a number of previous authors (e.g. Barrois, 1876; Reid, 1898; Jukes-Browne & Hill, 1903; Bull & Milner, 1925; Jefferies, 1962, 1963; Kennedy, 1969, and Woodroof, 1981), exposes Upper Albian-High Turonian strata. The sequence is complicated by numerous landslips which obscure parts of the succession. The topmost bed of the Upper Greensand (Albian) is an intensely bioturbated, fine glauconitic sand. The junction with the basal bed of the Lower Chalk, the Glauconitic Marl, is sharply defined and marked by numerous Thalassinoides burrows which are infilled with material originating from the overlying horizon. The Glauconitic Marl is light-brown, sandy and glauconite rich. It contains numerous 1-3cm phosphatic nodules, particularly at the base and is penetrated by prominent Thalassinoides burrows. Shell debris is common throughout. The glauconite content decreases towards the top of the marl and disappears at the sharp, burrowed contact with overlying sequence of interbedded marls and blue-grey chalk units. Near the top of the Lower Chalk, a conglomererate of green-coated pebbles and phosphatic nodules marks the base of the Plenus Marls (Jefferies, 1962, 1963). These are a sequence of 8 beds consisting primarily of marls and marly chalks separated by prominent omission surfaces and hardgrounds. An abundant fauna is often present. The transition from marly chalks to nodular chalks at the top of the Plenus Marls marks the junction between the Lower and Middle Chalk. The nodular chalks (Melbourn Rock) are approximately 8m thick at this locality and the Cenomanian-Turonian boundary is at present taken ~1.5-2m above the base of this unit. The remainder of the Middle Chalk is represented here by a thick monotonous sequence of white chalks interbedded with thin medium-dark grey marl seams, with occasional nodular units and weak hardgrounds near the summit. The junction of the Middle Chalk and Upper Chalk is taken at a thin dark grey marl seam, above which there is a series of weak nodular hardgrounds and the first

flints appear.

Fig. 24 Location Of Coastal Section At Beachy Head, Eastbourne, S. England

Fig. 25a Lithostratigraphy Of Beachy Head,
Eastbourne, S. England

Stage	Zone	Traditional Subdivisions	Sample Horizons	Lithology	Marker Horizons

CENOMANIAN

A. rhotomagense

M. mantelli

Grey Chalk

Lower Chalk

Chalk Marl

G. M.

BH7
BH6

BH5

BH4

BH3

BH2

BH1

O. mantelliana Band

Scale 2 — 0m

| ALB. | *S dispar* | Upper Greensand | BH1 | | |

| Glauconite Grains | Nodular Structures | Bioturbation | Shell Debris |
| Phosphatic Nodules | Marl Seam | Marly Chalk | G.M.- Glauconitic Marl |
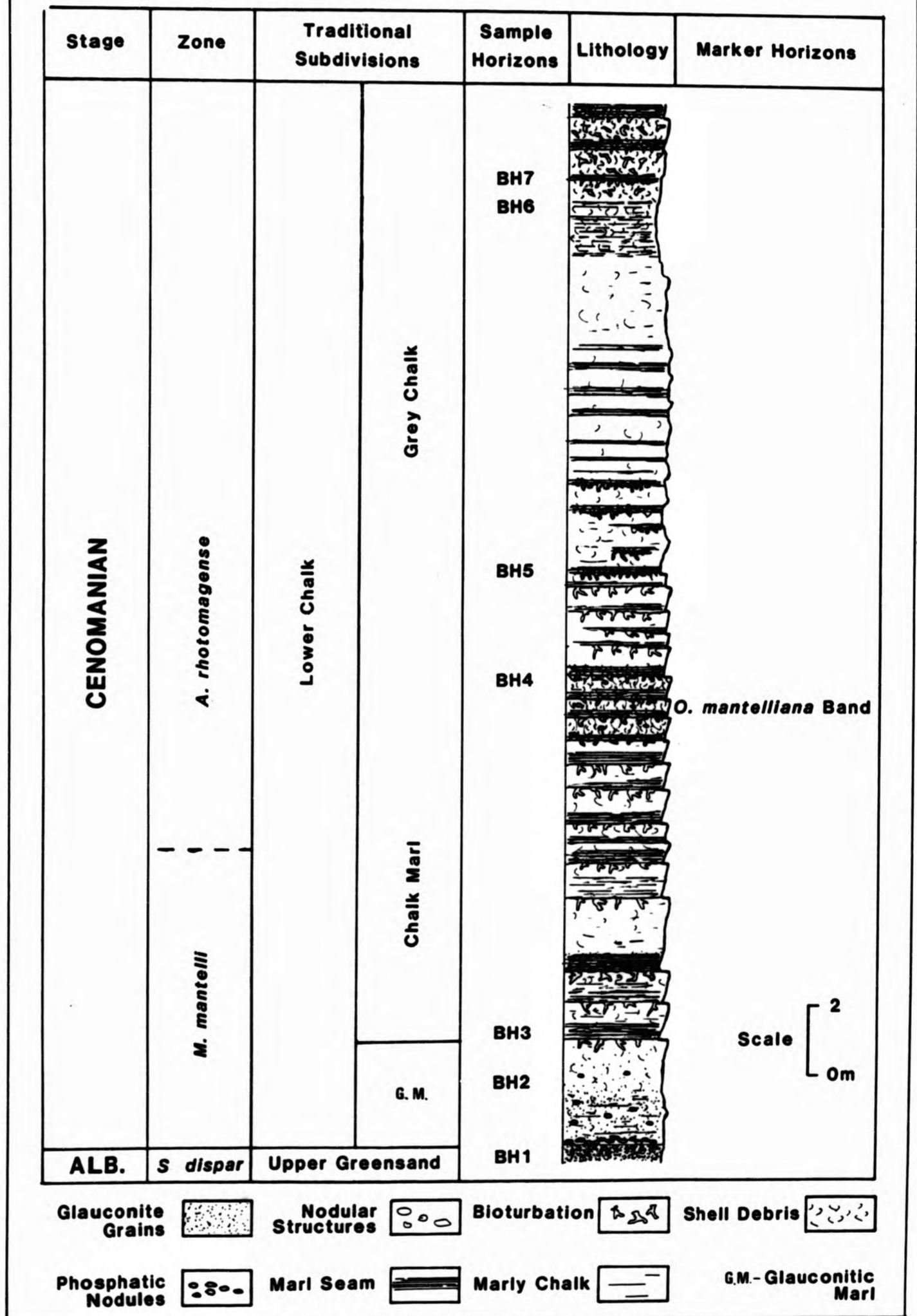
After Kennedy, 1969

Fig. 25b Lithostratigraphy Of Beachy Head, Eastbourne, S. England

Stage	Zone	Traditional Subdivisions		Sample Horizons	Lithology	
CENOMANIAN	S. gracile	Middle Chalk	Melbourn Rock	BH12		
				BAT16		
		Lower Chalk	Plenus Maris	BH13		
				BH11		
				BH10		
				BH9		
	C. naviculare		Grey Chalk	BH8		

Scale: 2 — 0m

Thalassinoides Burrows		Omission Surface		Bioturbation		Marl Seam	
Phosphatic Nodules		Nodular Structure		Marly Chalk		Shell Debris	
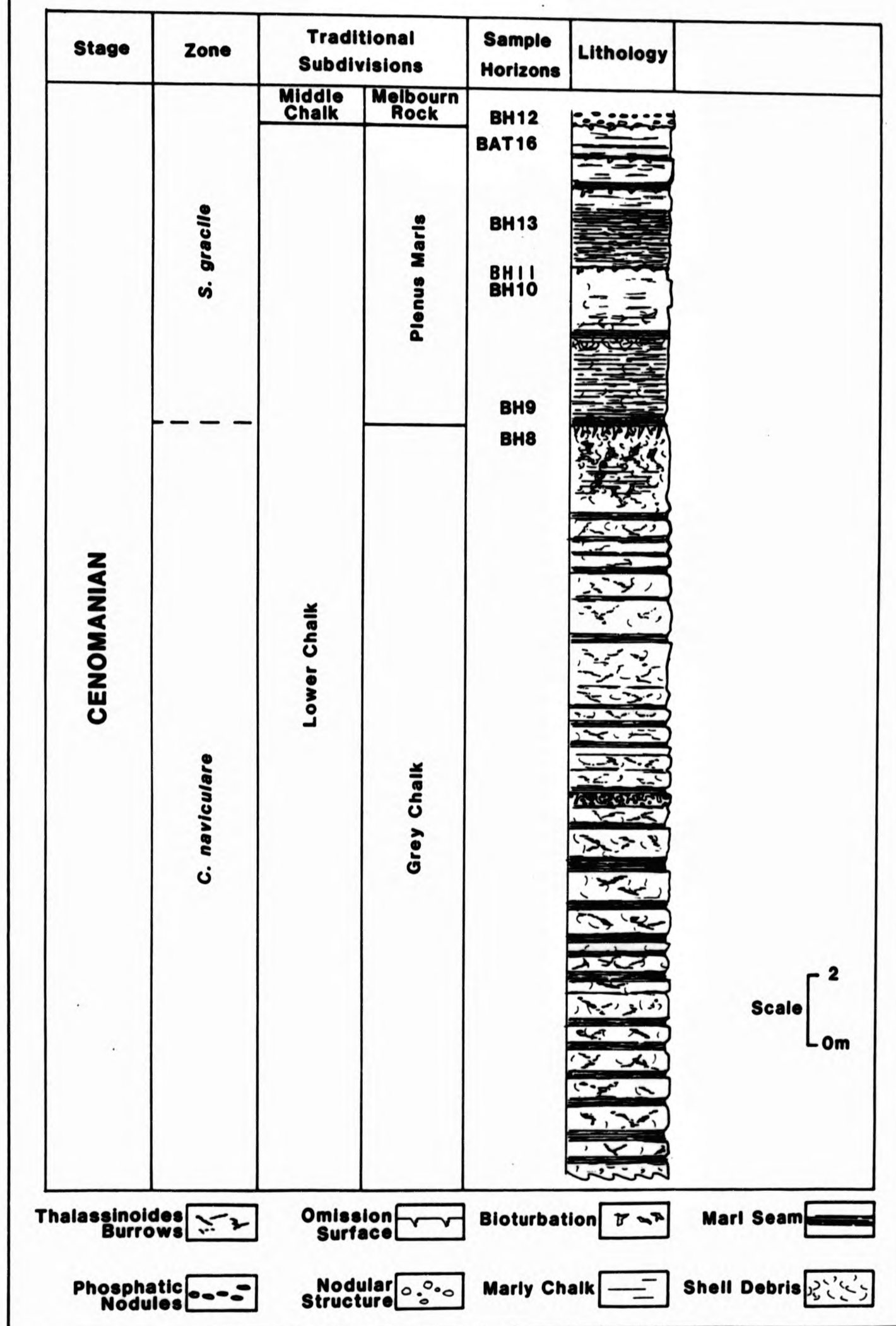
After Jefferies,1962,1963:Kennedy,1969

Fig. 25c   Lithostratigraphy Of Beachy Head, Eastbourne, S. England

Stage	Zone	Traditional Subdivisions		Sample Horizons	Lithology	
TURONIAN	T. lata	Middle Chalk				
	I. labiatus		Melbourn Rock	BH15		Scale ⌐ 2 └ 0m
				BH 14		
				BAT17		~20m absent
						~5m absent

Nodular Hardground   **Marly Chalk**   **Shell Debris**   **Nodular Structures**
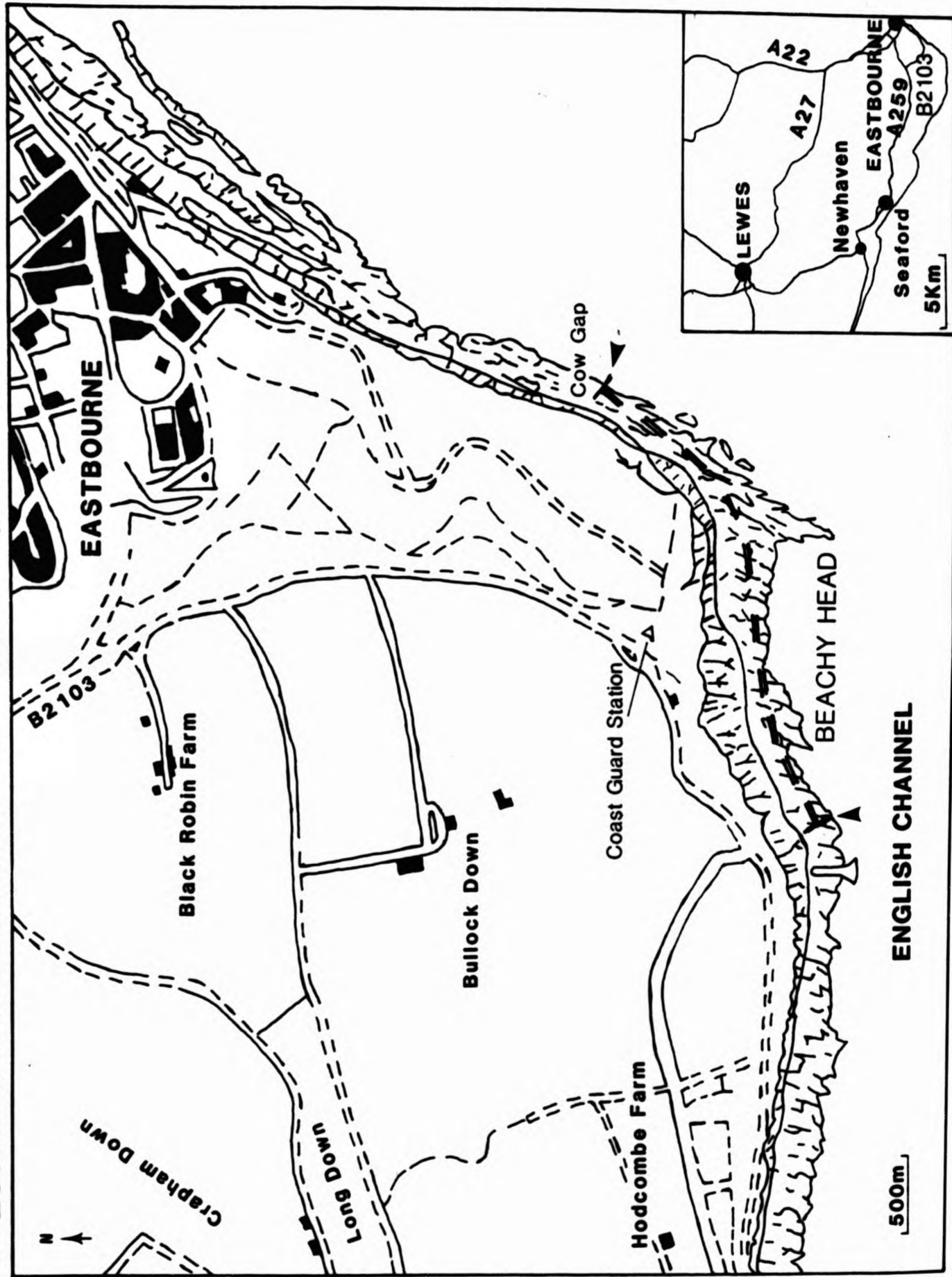
Marl Seam

After Woodroof, 1981
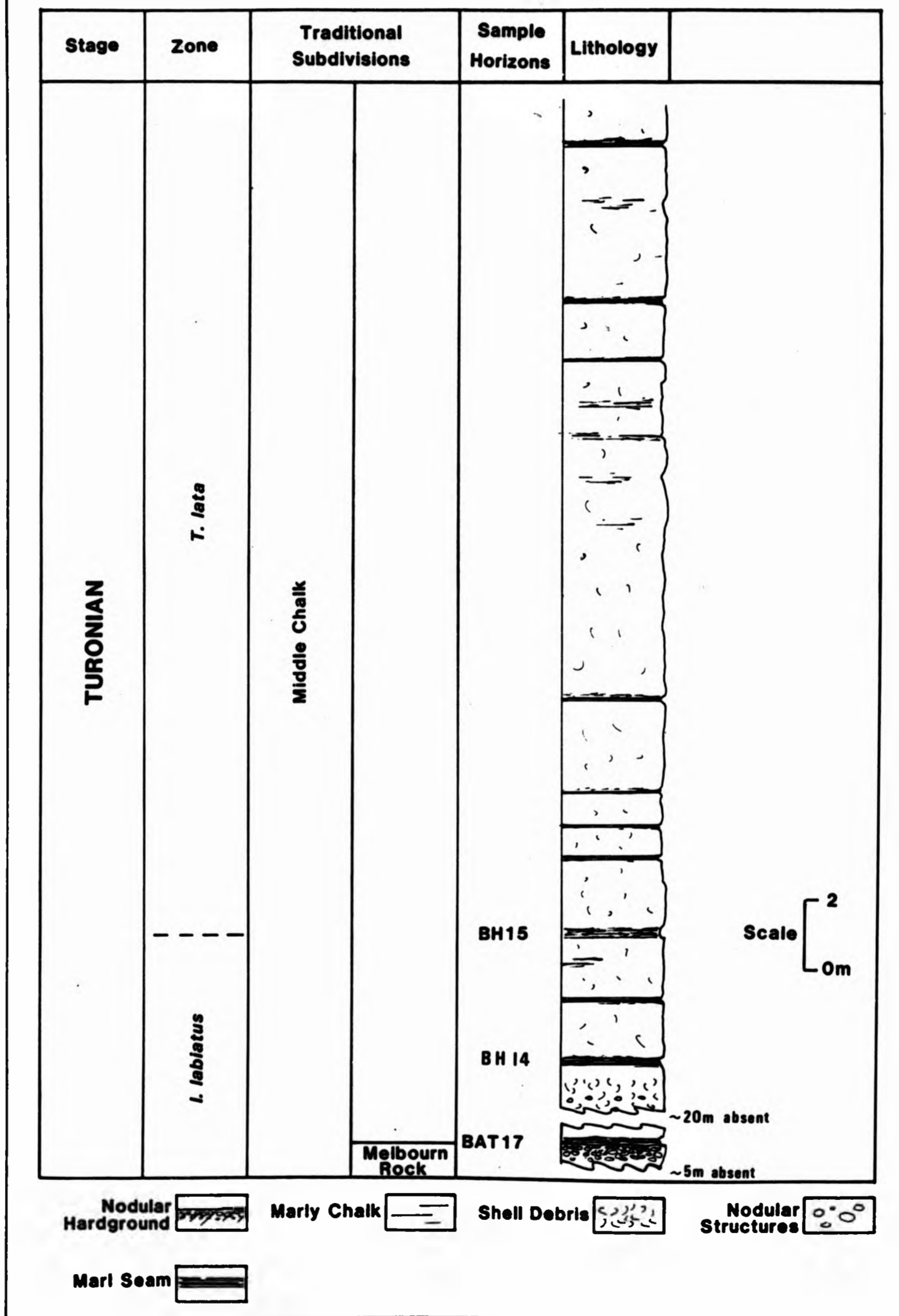
Fig. 25d   Lithostratigraphy Of Beachy Head, Eastbourne, S. England
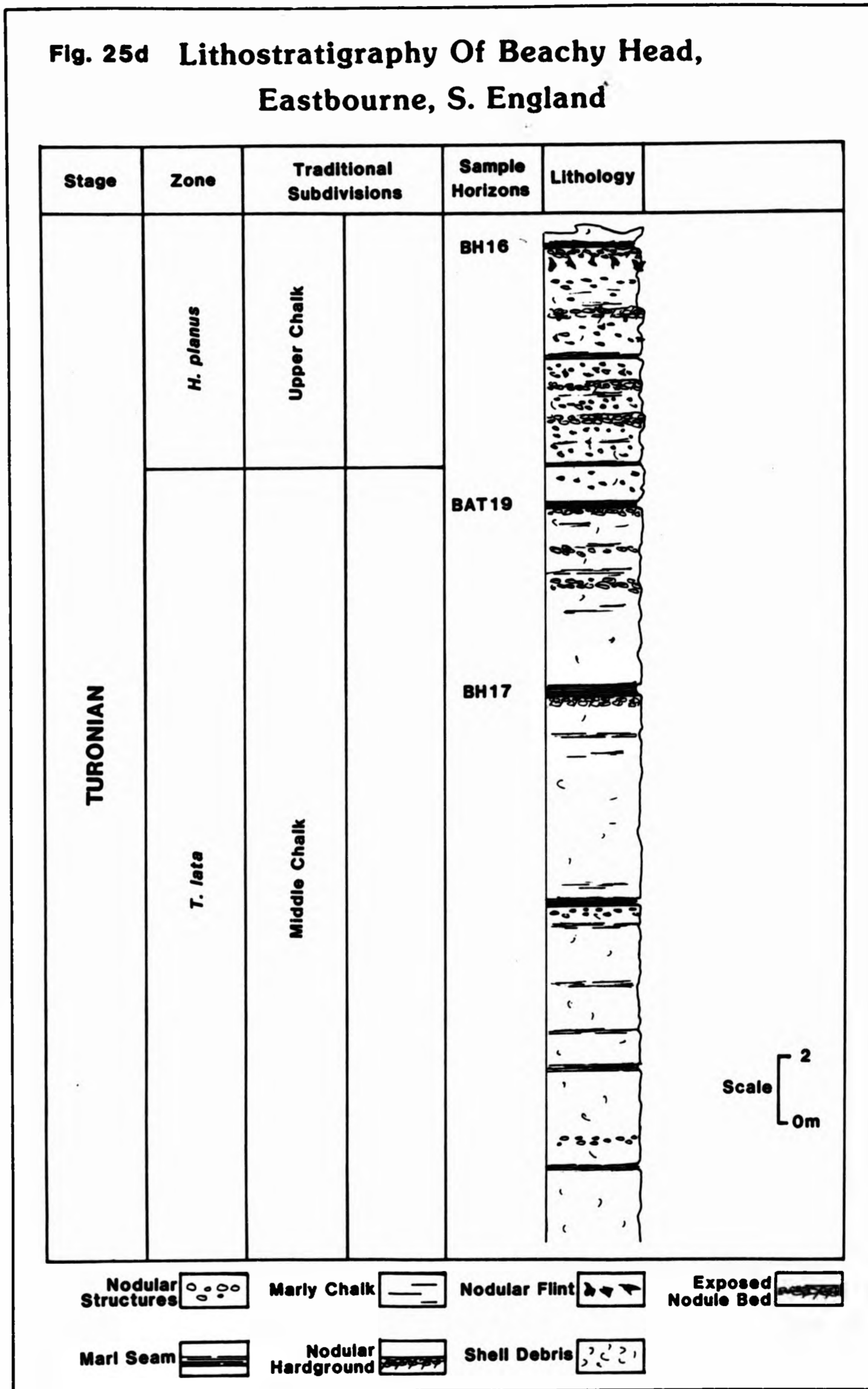
After Woodroof,1981

2.4.3 Beer Head, Beer (Figs. 26, 27a-b)

Co-ords. 227879

This section exposes the Upper Greensand, Beer Head Limestone, and part
of the Seaton Chalk.   The Upper Greensand at this locality consists of a
thick succession of coarse calcarenites rich in detrital quartz and contain-
ing several thin tabular chert bands. In the sequence measured there were
two nodular hardgrounds and the top was marked by a complex level of synsedi-
mentary lithification, the Small Cove Hardground (Jarvis & Woodroof, 1984).
This hardground consists of a 1-1.5m thick bed of strongly indurated
cross-bedded calcarenites penetrated by numerous _Thalassinoides_ burrows which
have isolated 5-30cm irregular masses of sediment; these burrows allied with
synsedimentary fracturing have resulted in a blocky morphology (Jarvis & Woo-
droof, 1984). The Beer Head Limestone rests on the surface of the Small Cove
Hardground.   The basal Pounds Pool Member is ~3.5m thick at this locality.
The lower part of the member consists of yellowish-brown, limonite-stained,
very coarse calcareous sandstones which are commonly decalcified and weather
out to form a notch in the cliff. Large _Ceriopora_ _ramulosa_ Michelin are com-
mon.   The upper part of the member is composed of pale brown strongly
indurated sandy bioclastic limestones. _C._ _ramulosa_ remains common but glau-
conitised intraclasts are rare and large (1-5cm) fragments of bivalve shells
are more abundant. The Pounds Pool Member is generally structureless but
towards the top becomes more shelly and weakly nodular. The top is a hum-
mocky, weakly glauconitised and limonite stained surface which produces a
slight parting in most exposures. The Hooken Nodular Limestone Member is
very thin at Beer Head (~90cm compared with 5m at the Beer Stone Adit) and
consists of a medium to light grey shelly detrital limestone which has a
characteristically rubbly appearance. In the thin development at Beer Head
almost all the nodules have been reworked, weakly glauconitised and/or limon-
ite stained. The top of this member is defined at the surface of a heavily
mineralised hardground, the King's Hole Hardground. Overlying this the basal

Little Beach Member consists of a hardground and a bed of white nodules. The hardground in this exposure has a strongly mineralised and highly convolute surface. A bed of 2-5cm white nodules, surrounded by a light grey glauconitic and sandy matrix, overlies the cavernous hardground. Above the nodule bed there is a moderately indurated unit of light grey calcisphere biomicrites penetrated by prominent idiomorphic <u>Thalassinoides</u>. These burrows are filled with medium to coarse quartz sand and fine sand sized glauconite bearing biomicrites and originates from the prominent hardground which forms the top of the Little Beach Member, the Humble Point Hardground. The darker, more friable burrow infill is identical to that immediately overlying this hardground and clearly originates from the Pinnacles Member. This member has a very thin development (~20cm) at Beer Head and consists of a massively indurated hardground, the surface of which marks the base of the Seaton Chalk Formation. Only the lower part of the Connett's Hole Member was sampled at this locality.

The foundered bluffs at the top of Beer Head expose ~17m of the Pinhay Nodular Chalk Member and Clevelands Flinty Chalk Member of the Seaton Chalk (Jarvis & Tocher, 1983). Only the former was sampled during the present study.   The Pinhay Member consists mainly of nodular chalks and hardgrounds with numerous nodular flints and one prominent semi-tabular flint, Annis' Knob Flint.

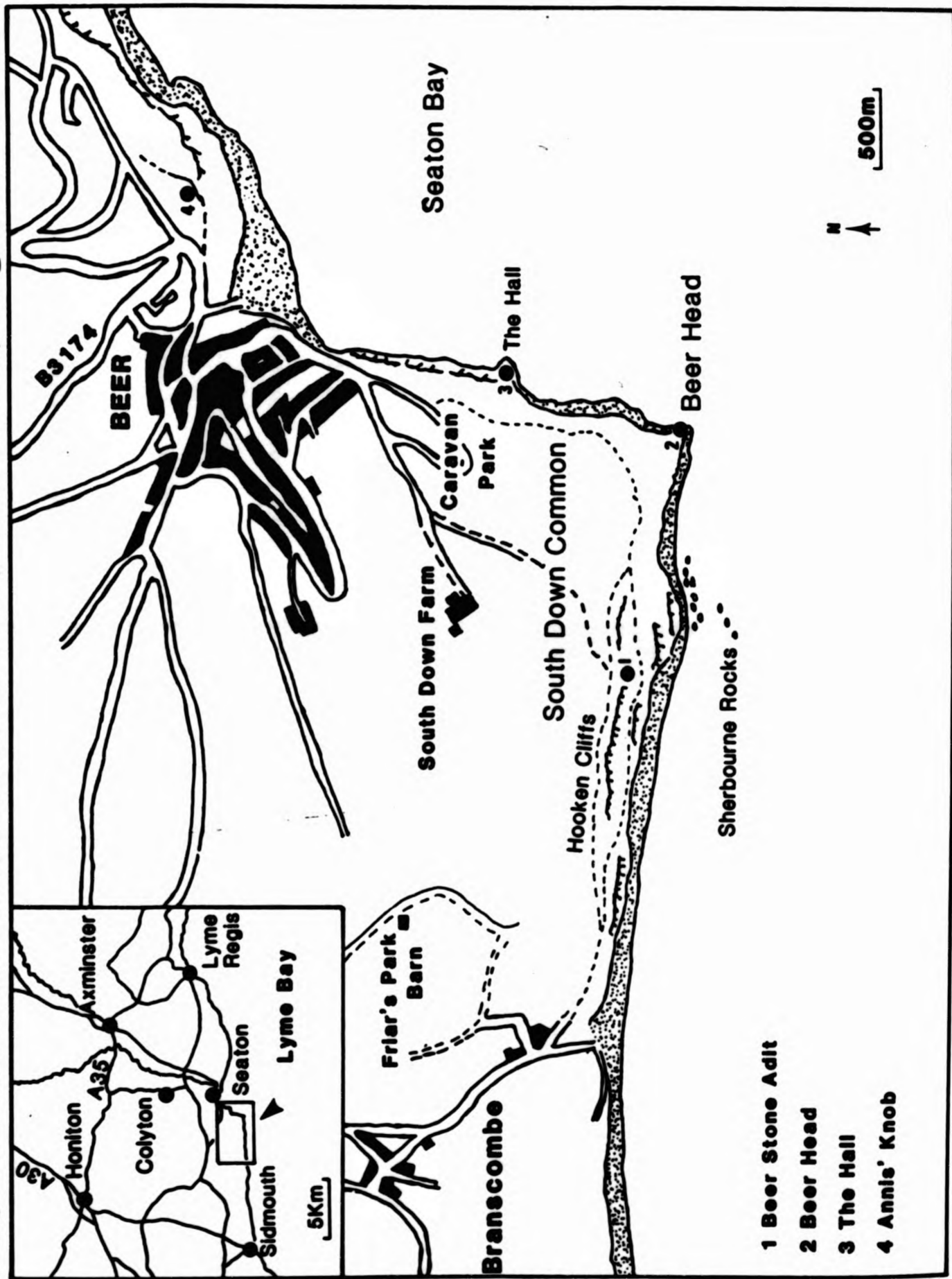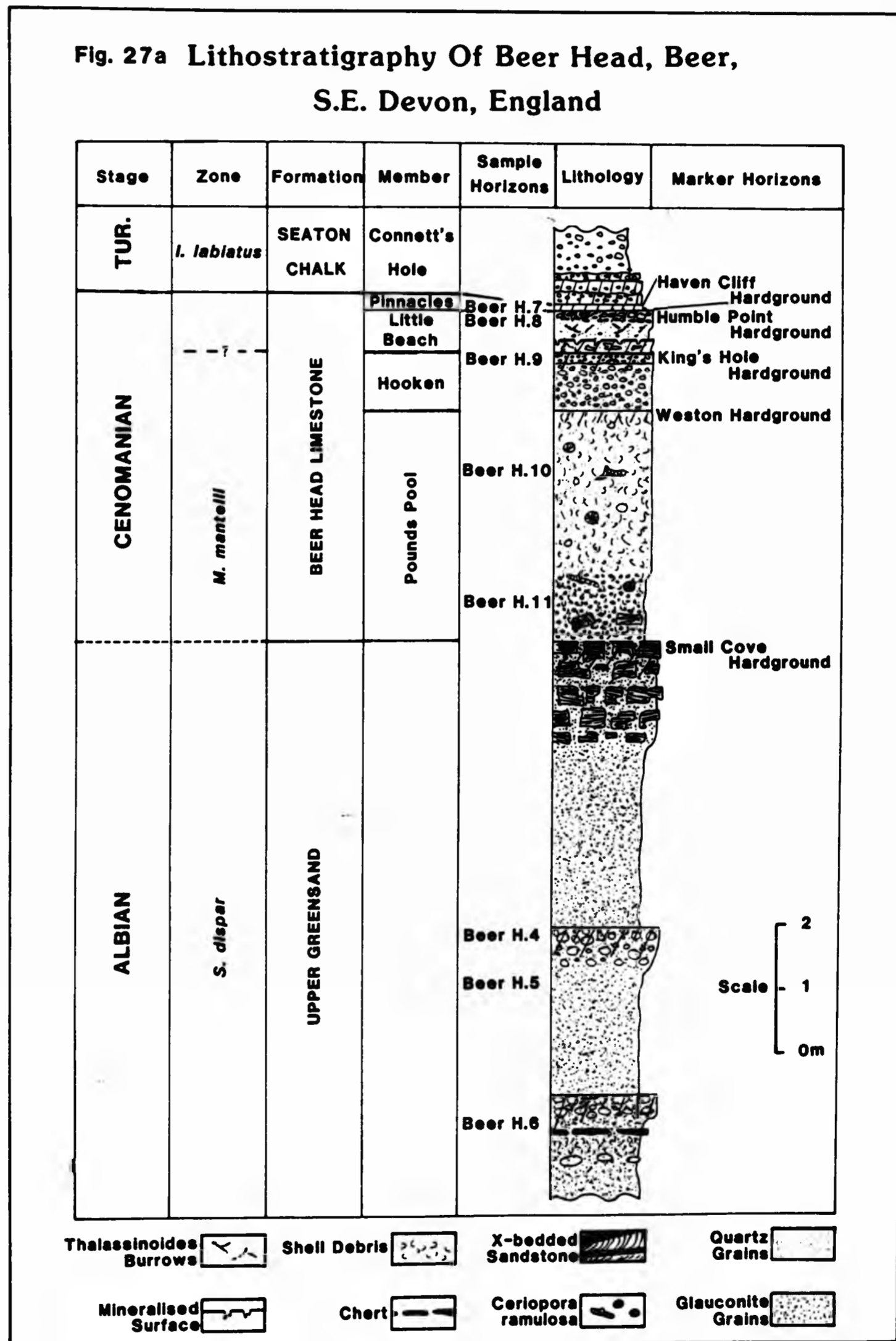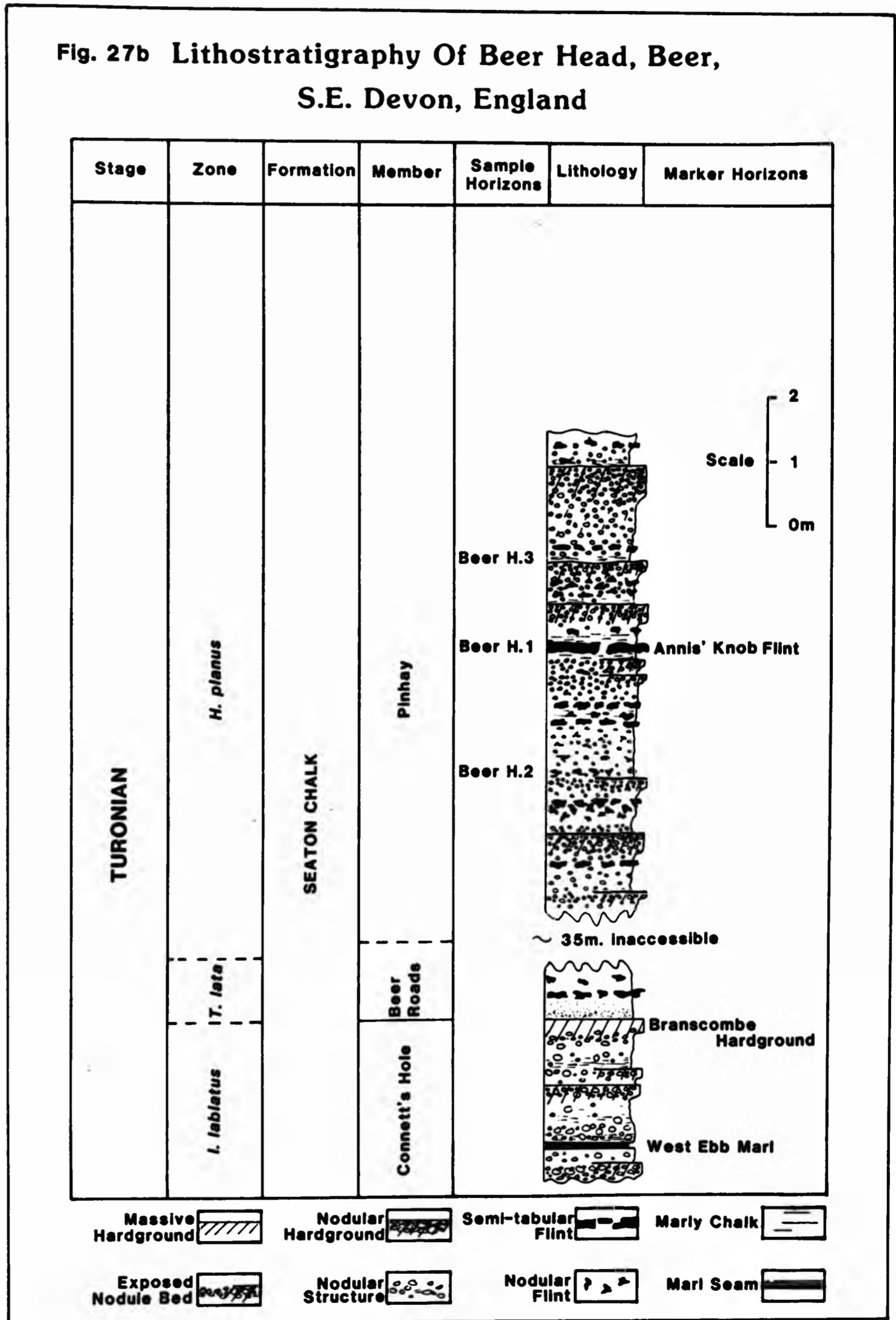Fig. 26 Location Of Sections At Beer, S.E. Devon, England

1 Beer Stone Adit
2 Beer Head
3 The Hall
4 Annie' Knob

Fig. 27a Lithostratigraphy Of Beer Head, Beer, S.E. Devon, England

Stage	Zone	Formation	Member	Sample Horizons	Lithology	Marker Horizons
TUR.	I. labiatus	SEATON CHALK	Connett's Hole			Haven Cliff Hardground
CENOMANIAN	M. mantelli	BEER HEAD LIMESTONE	Pinnacles Little Beach	Beer H.7 Beer H.8		Humble Point Hardground
			Hooken	Beer H.9		King's Hole Hardground
						Weston Hardground
			Pounds Pool	Beer H.10		
				Beer H.11		
						Small Cove Hardground
ALBIAN	S. dispar	UPPER GREENSAND		Beer H.4 Beer H.5		
				Beer H.6		

Scale — 2 — 1 — 0m

Thalassinoides Burrows		Shell Debris		X-bedded Sandstone		Quartz Grains
Mineralised Surface		Chert		Ceriopora ramulosa		Glauconite Grains

After Jarvis & Woodroof, 1984

Fig. 27b Lithostratigraphy Of Beer Head, Beer, S.E. Devon, England
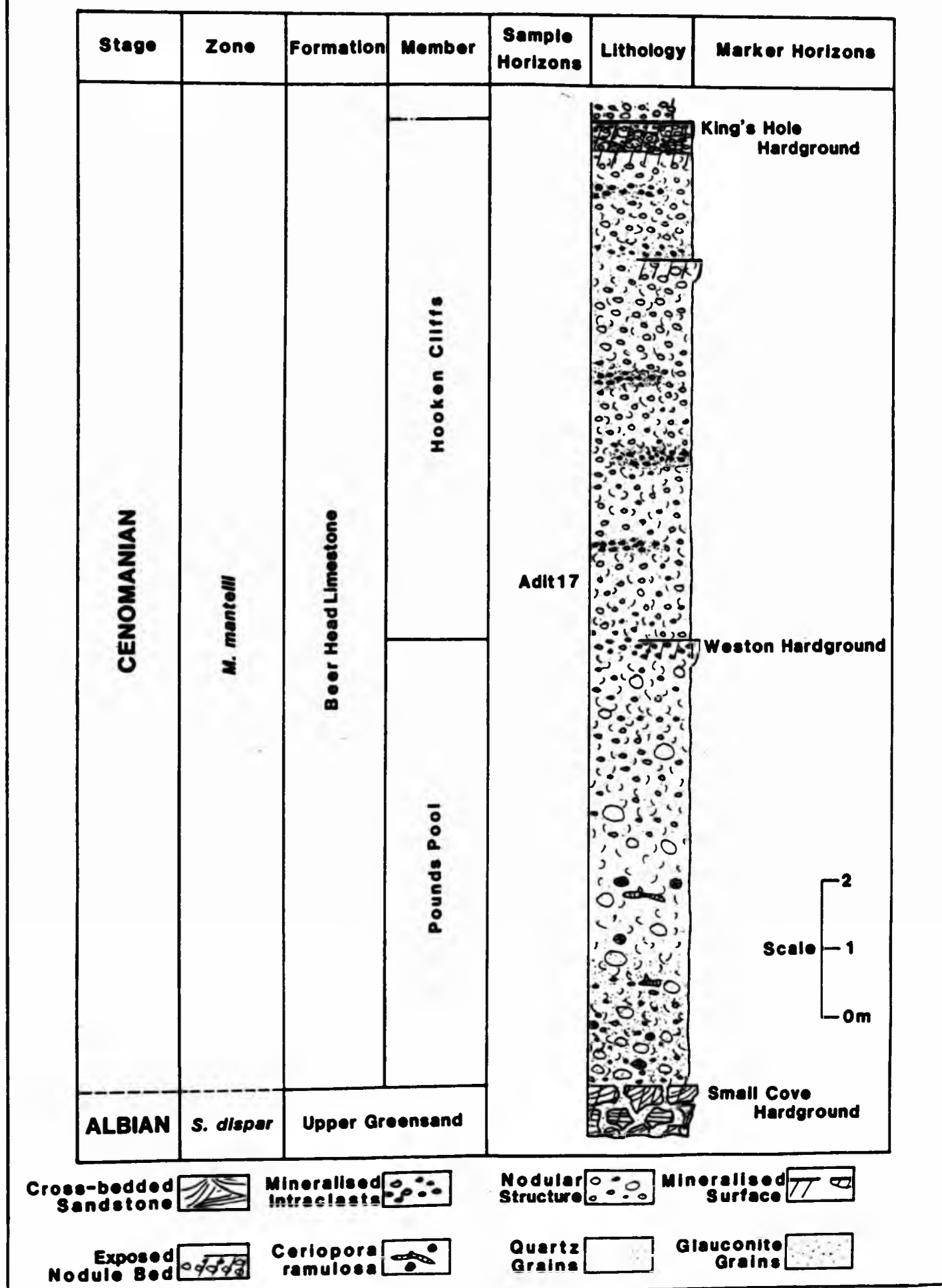
After Jarvis & Woodroof,1984; Jarvis & Tocher in prep.

2.4.4 Beer Stone Adit, Beer (Figs. 26, 28a-d)

Co-ords. 219879

This section exposes the top of the Upper Greensand here represented by
the Small Cove Hardground, the Beer Head Limestone and part of the Seaton
Chalk. The basal metre of the Pounds Pool Member, which rests on the surface
of the Small Cove Hardground, consists of yellowish-brown coarse calcareous
sandstones containing large pieces of _Ceriopora ramulosa_. Fragments of the
underlying Small Cove Hardground indicate a degree of lateral reworking. The
upper part of the member is here composed of pale-brown, strongly indurated,
sandy bioclastic limestones and the top is marked by a weakly nodular unit,
the Weston Hardground (Jarvis & Woodroof, 1984). The overlying Hooken Cliffs
Member attains a maximum thickness (~5m) at the Beer Stone Adit. It is com-
posed of medium to light grey shelly detrital limestones with a
characteristically rubbly appearance. Many large (>1cm) partly silicified
fragments of inoceramids, oysters and other bivalves are common. The top of
the member is defined by the heavily mineralised King's Hole Hardground
(Jarvis & Woodroof, 1984). The basal part of the Little Beach Member con-
sists of a bed of white nodules (2-5cm) surrounded by a light grey
glauconitic and sandy matrix. Above this is a moderately indurated unit of
light grey calcisphere biomicrites penetrated by prominent _Thalassinoides_.
The burrows are infilled with material which originated from the overlying
Pinnacles Member. The top of the Little Beach Member is defined by the Hum-
ble Point Hardground, which is is the most indurated and highly mineralised
hardground in the Beer Head Limestone. The Pinnacles Member is 2.3m thick at
this locality (compared with 20cm at Beer Head). The basal bed is a friable
glauconitic sandy limestone containing two sets of white 2-5cm nodules and
scattered phosphorite clasts. These are overlain by a bed of pale yellow
indurated sediment with a phosphatised top. Towards the top of the member
the sediment becomes lighter in colour and develops a nodular structure.
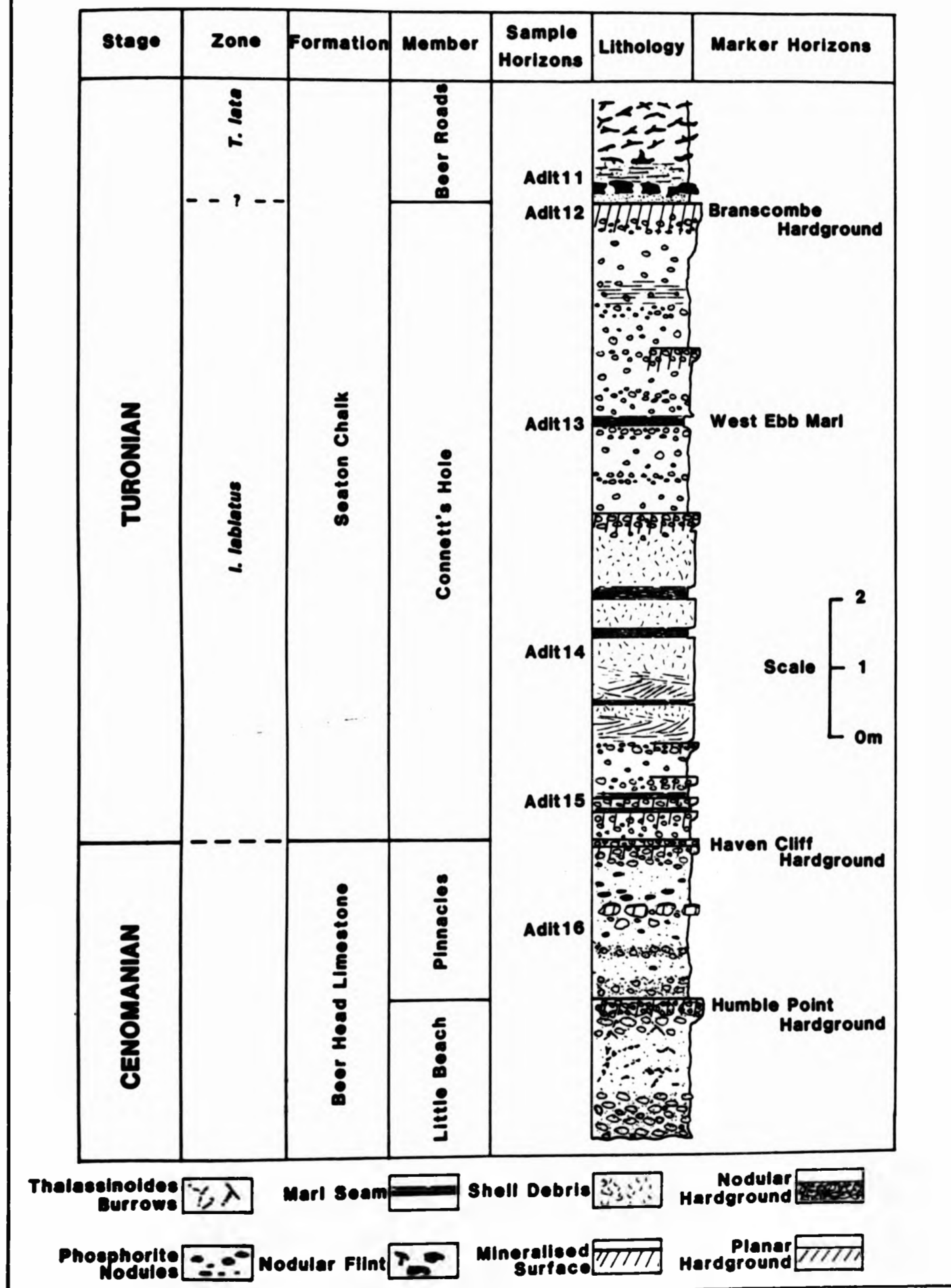This is the base of a glauconitised and limonite stained hardground, the

Haven Cliff Neocardioceras Hardground (Jarvis & Woodroof, 1984), the surface
of which defines the base of the Seaton Chalk Formation. The basal member of
this formation, the Connett's Hole Member is 9m thick at this locality and
contains 2 well developed nodular hardgrounds overlain by 2 higher beds of
limonite stained nodules. Above this there is a 3m development of the Beer
Stone which is a succession of weakly cross-laminated echinoderm biomicrites.
The top of these beds is marked by a weakly developed nodular hardground
overlain by a series of nodular chalks containing abundant inoceramid deris.
The summit of these beds is taken at a prominent marl containing abundant
Mytiloides. the West Ebb Marl (Jarvis & Woodroof, 1984). Above the West Ebb
Marl are ~2.5m of flaser, nodular and hardground chalks at the top of which
is a prominent, massively-indurated hardground with a planar surface, the
Branscombe Hardground. This hardground marks the top of the Connett's Hole
Member. The overlying Beer Roads Flinty Chalk Member consists of soft white
chalks with numerous semi-tabular and thalassinoid burrow flints, and occa-
sional prominent marl seams (e.g. Two Foot Band and Four Foot Band (Jarvis &
Tocher, in prep.).

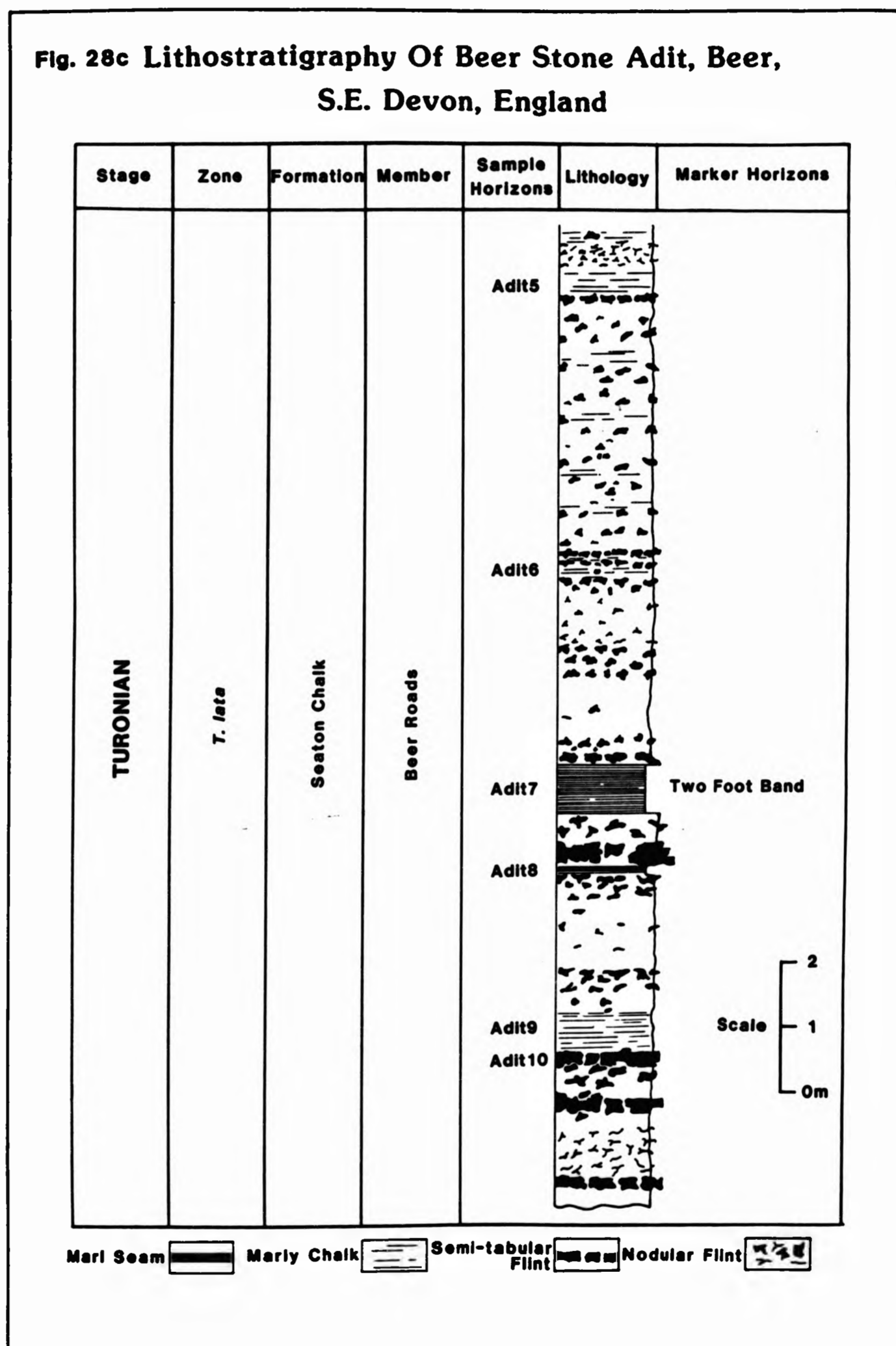# Fig. 28a Lithostratigraphy Of Beer Stone Adit, Beer, S.E. Devon, England

Stage	Zone	Formation	Member	Sample Horizons	Lithology	Marker Horizons
CENOMANIAN	M. mantelli	Beer Head Limestone	Hooken Cliffs			King's Hole Hardground
				Adit17		
						Weston Hardground
			Pounds Pool			
ALBIAN	S. dispar	Upper Greensand				Small Cove Hardground

Scale: 2 — 1 — 0m

Cross-bedded Sandstone	Mineralised Intraclasts	Nodular Structure	Mineralised Surface
Exposed Nodule Bed	Ceriopora ramulosa	Quartz Grains	Glauconite Grains

After Jarvis & Woodroof, 1984

Fig. 28b Lithostratigraphy Of Beer Stone Adit, Beer, S.E. Devon, England

Stage	Zone	Formation	Member	Sample Horizons	Lithology	Marker Horizons
TURONIAN	T. lata	Seaton Chalk	Beer Roads	Adit11		
	?			Adit12		Branscombe Hardground
	I. lablatus		Connett's Hole	Adit13		West Ebb Marl
						Scale 2 — 1 — 0m
				Adit14		
				Adit15		Haven Cliff Hardground
CENOMANIAN		Beer Head Limestone	Pinnacles	Adit16		
			Little Beach			Humble Point Hardground

Thalassinoides Burrows | Marl Seam | Shell Debris | Nodular Hardground

Phosphorite Nodules | Nodular Flint | Mineralised Surface | Planar Hardground

After Jarvis & Woodroof,1984

Fig. 28c Lithostratigraphy Of Beer Stone Adit, Beer, S.E. Devon, England

Stage	Zone	Formation	Member	Sample Horizons	Lithology	Marker Horizons
TURONIAN	*T. lata*	Seaton Chalk	Beer Roads	Adit5		
				Adit6		
				Adit7		Two Foot Band
				Adit8		
				Adit9		
				Adit10		

Scale: 2 — 1 — 0m

Marl Seam █████ Marly Chalk ▭ Semi-tabular Flint ▬▬ Nodular Flint ▨

After Jarvis & Woodroof, 1984; Jarvis & Tocher in prep.

Fig. 28d Lithostratigraphy Of Beer Stone Adit, Beer, S.E. Devon, England
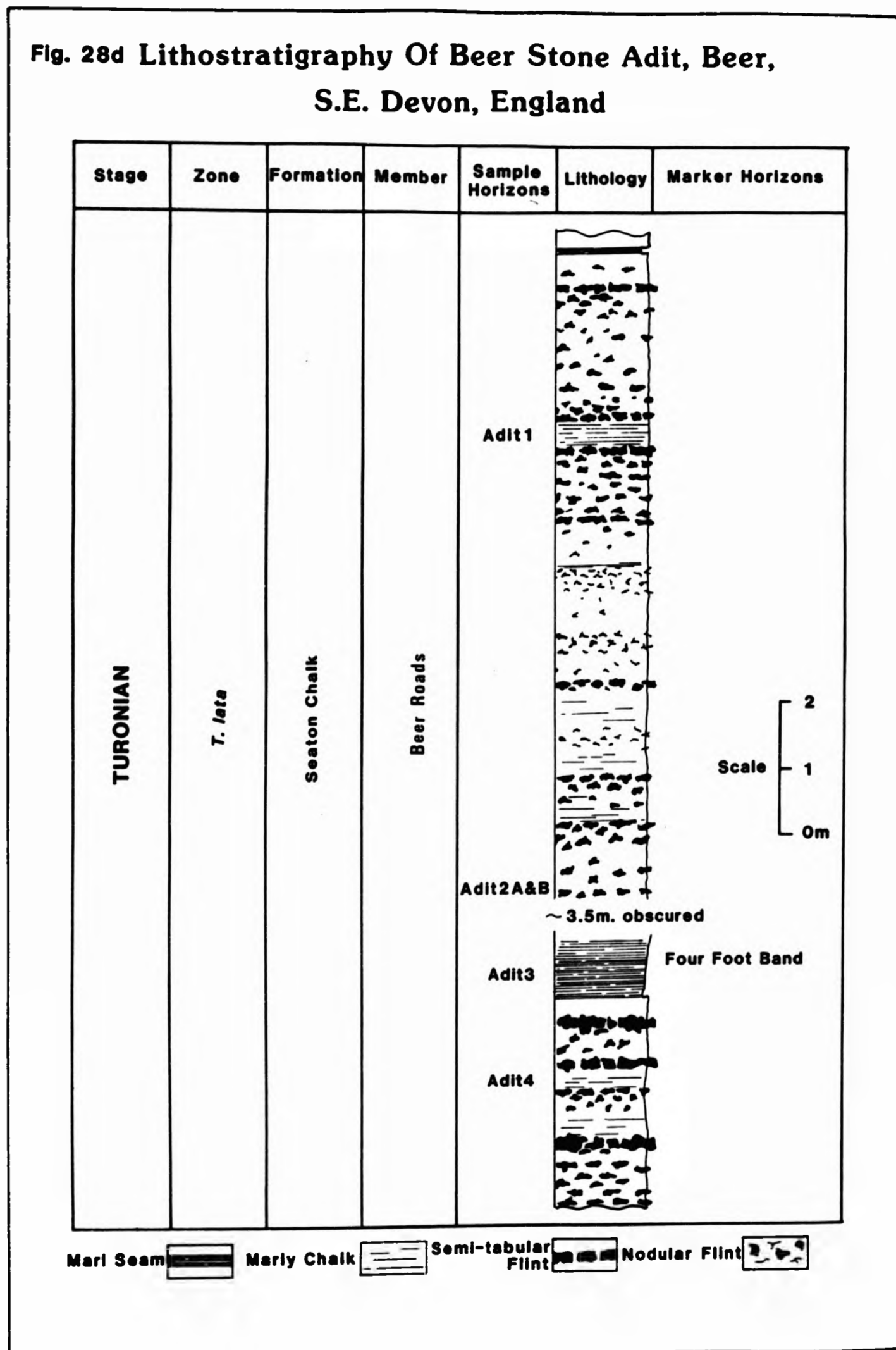
After Jarvis & Tocher in prep.

2.4.5 Annis' Knob, Beer (Fig. 26, 29)

Co-ords. 232892

This section exposes ~12m of the Pinhay Flinty Chalk Member of the Seaton Chalk (Jarvis & Tocher, 1983). The succession consists dominantly of nodular chalks and hardgrounds with numerous semi-tabular and thalassinoid burrow flints. The Turonian-Coniacian boundary is taken here at a prominent semi-tabular flint line (Rock Orchard Flint).

Fig. 29 Lithostratigraphy Of Annis' Knob, Beer,
S E. Devon, England

Stage	Zone	Formation	Member	Sample Horizons	Lithology	Marker Horizons
CONIACIAN	*M. cortestudinarium*					South Down Marl
				AK1		Rock Orchard Flint
TURONIAN	*H. planus*	Seaton Chalk	Pinhay	AK2		
				AK3 AK4		Annis' Knob Flint
				AK5		
				AK6		

Scale: 2 — 1 — 0m

Nodular Hardground	Marly Chalk	Marl Seam	Semi-tabular Flint
Exposed Nodule Bed	White Chalk	Nodular Structure	Nodular Flint
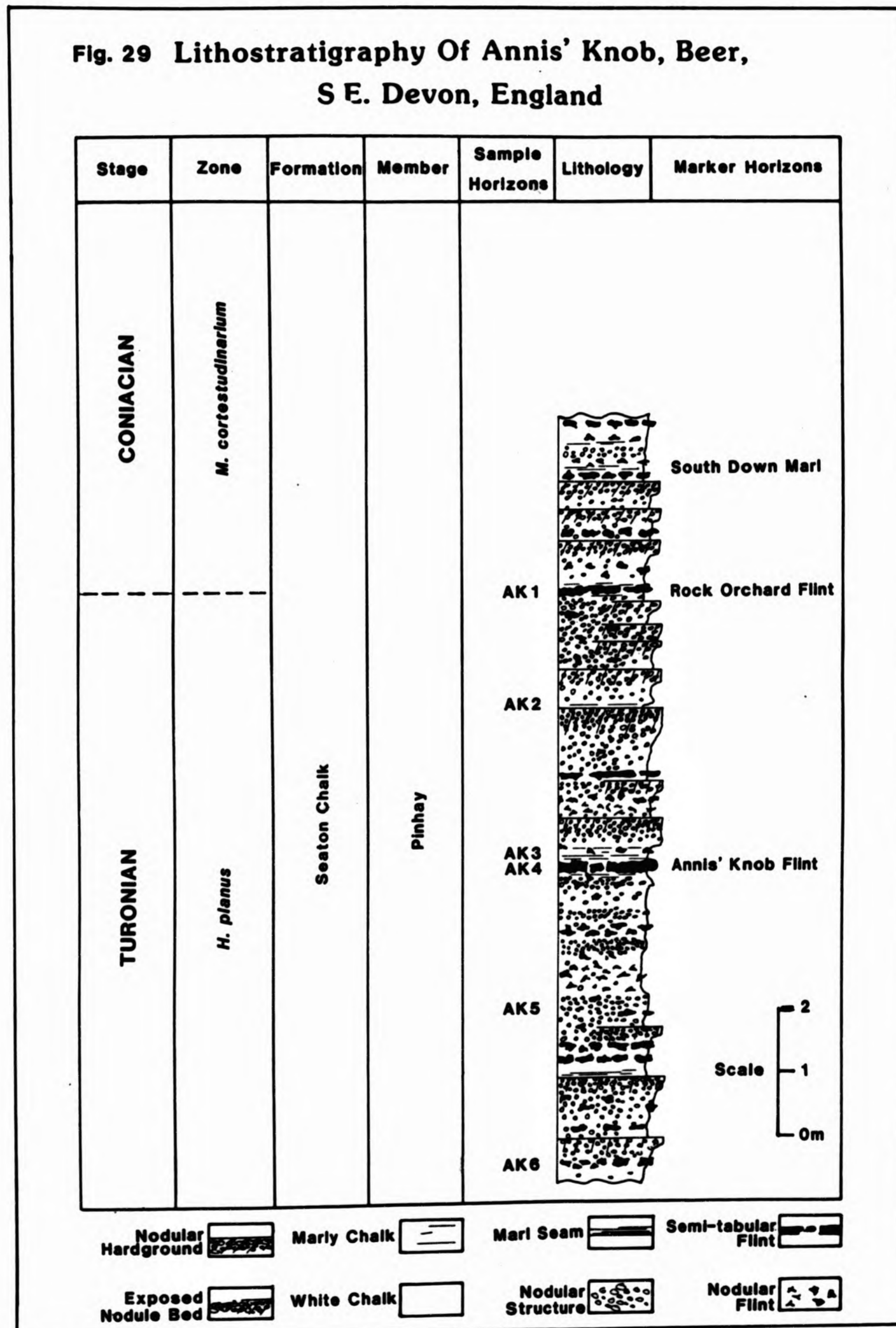
After Jarvis & Tocher in prep.

CHAPTER 3

TAXONOMY

Introduction

This chapter is divided into 2 parts. The first lists, in alphabetical order, all the microplancton taxa encountered during the present study, and indicates the plates on which they are figured. The second part deals with new species and subspecies, or forms for which some amplifying remarks are thought necessary. Provisionally accepted species are preceded by a question mark (?). Forms which show only minor differences from published species are preceded by cf.

List Of Taxa

Achomosphaera crassipellis (Deflandre & Cookson, 1955) Stover & Evitt, 1978

[pl.1,fig.1]

A. ? neptunii (Eisenack, 1958) Davey & Williams, 1966a [pl.1,fig.2]

A. ramulifera (Deflandre, 1937b) Evitt, 1963 [pl.1,fig.3]

A. regiensis Corradini, 1973 [pl.1,fig.4]

A. sagena (Davey & Williams, 1966a) subsp. brevispinus subsp. nov.
[pl.1,fig.5]

A. sagena subsp. sagena Davey & Williams, 1966a [pl.1,fig.6]

A. simplex sp. nov. [pl.1,fig.7-8]

A. verdieri Below, 1982 [pl.1,fig.9]

Aldorfia deflandrei (Clarke & Verdier, 1967) Stover & Evitt, 1978
[pl.1,fig.10]

Apteodinium maculatum Eisenack & Cookson, 1960 [pl.1,fig.11]

A. reticulatum Singh, 1971 [pl.1,fig.12]

A. sp.A [pl.2,fig.1]

A. sp.B [pl.2,fig.2]

Ascodinium acrophorum Cookson & Eisenack, 1960a [pl.2,fig.3]

Bacchidinium polypes (Cookson & Eisenack, 1962b) subsp. clavulum (Davey,

1969a) Lentin & Williams, 1981 [pl.2,fig.4]

B. *polypes* subsp. *polypes* (Cookson & Eisenack, 1962b) Davey, 1979b
[pl.2,fig.5]

Batiacasphaera eutiches (Davey, 1969a) Davey, 1979d [pl.2,fig.6]

Callaiosphaeridium asymmetricum (Deflandre & Courteville, 1939) Davey &
Williams, 1966b [pl.2,fig.7]

Canningia attadalica (Cookson & Eisenack, 1962b) Stover & Evitt, 1978
[pl.2,fig.8]

C. *colliveri* Cookson & Eisenack, 1960b [pl.2,fig.9]

C. *reticulata* Cookson & Eisenack, 1960b [pl.2,fig.10]

Cassiculosphaeridia reticulata Davey, 1969a [pl.2,fig.11]

Chytroeisphaeridia chytroeides (Sarjeant, 1962a) Downie & Sarjeant, 1965;
emend. Davey, 1979d [pl.2,fig.12]

Cleistosphaeridium ancoriferum (Cookson & Eisenack, 1960a) Davey et al.,
1966; emend. Cookson & Eisenack, 1968 [pl.3,fig.1]

C. *armatum* subsp. *armatum* (Deflandre, 1937b) Davey, 1969a
[pl.3,fig.2]

C. *armatum* (Deflandre, 1937b) subsp. *brevispinosum* subsp. nov.
[pl.3,fig.3]

Codoniella campanulata (Cookson & Eisenack, 1960a) Downie & Sarjeant, 1965;
emend. Davey, 1979b [pl.3,fig.4]

Cometodinium ? *whitei* (Deflandre & Courteville, 1939) Stover & Evitt, 1978
[pl.3,fig.5]

Coronifera oceanica Cookson & Eisenack, 1958; emend. May, 1980
[pl.3,fig.6]

Craspedodinium indistinctum Cookson & Eisenack, 1974 [pl.3,fig.7]

Cribroperidinium cf. *cooksonae* Norvick, 1976 [pl.3,fig.8-9]

C. *edwardsii* (Cookson & Eisenack, 1958) Davey, 1969a [pl.3,fig.10]

C. *exilicristatum* (Davey, 1969a) Stover & Evitt, 1978 [pl.3,fig.11]

Cyclonephelium clathromarginatum Cookson & Eisenack, 1962b [pl.4, fig.1]

C. compactum Deflandre & Cookson, 1955 [pl4,fig.2]

C. distinctum Deflandre & Cookson, 1955 [pl.4,fig.3-4]

C. eisenackii Davey, 1969a [pl.4,fig.5]

C. hughesii Clarke & Verdier, 1967 [pl.4,fig.6]

C. membraniphorum Cookson & Eisenack, 1962b [pl.4,fig.7-8]

Dapsilidinium conispinum (Davey & Verdier, 1973) Lentin & Williams, 1981

[pl.4,fig.9]

D. laminaspinosum (Davey & Williams, 1966b) Lentin & Williams, 1981

[pl.4,fig.10]

D. multispinosum (Davey, 1974) Bujak et al., 1980 [pl.4,fig.11]

Dinopterygium cladoides Deflandre, 1935 [pl.4,fig.12]

D. medusoides (Cookson & Eisenack, 1960a) Stover & Evitt, 1978 [pl.5,fig.1]

Disphaeria macropyla Cookson & Eisenack, 1960a [pl.5,fig.2]

D. munda (Davey & Verdier, 1973) Norvick, 1976 [pl.5,fig.3]

Ellipsodinium rugulosum Clarke & Verdier, 1967 [pl.5,fig.4]

Ellipsoidictyum circulatum (Clarke & Verdier, 1967) Lentin & Williams, 1977b

[pl.5,fig.5]

Endoceratium dettmannae (Cookson & Hughes, 1964) Stover & Evitt, 1978

[pl.5,fig.6]

Endoscrinium campanulum (Gocht, 1959) Vozzhenikova, 1967 [pl.5,fig.7]

Epelidosphaeridia spinosa (Cookson & Hughes, 1964) Davey, 1969a [pl.5,fig.8]

E. tuberculata sp. nov. [pl.5,fig.9-10]

Exochosphaeridium arnace Davey & Verdier, 1973 [pl.5,fig.11]

E. phragmites Davey et al., 1966 [pl.5,fig.12]

Florentinia buspina (Davey & Verdier, 1976) Duxbury, 1980 [pl.6,fig.1]

F. deanei (Davey & Williams, 1966b) Davey & Verdier, 1973 [pl.6,fig.2-3]

F. ferox (Deflandre, 1937b) Duxbury, 1980 [pl.6,fig.4]

F. cf. ferox Davey & Verdier, 1976 [pl.6,fig.5]

F. laciniata Davey & Verdier, 1973 [pl.6,fig.6]

F. mantellii (Davey & Williams, 1966b) Davey & Verdier, 1973 [pl.6,fig.7]

_F_. _radiculata_ (Davey & Williams, 1966b) Davey & Verdier, 1973; emend. Davey & Verdier, 1976 [pl.6,fig.8]

_F_. _resex_ Davey & Verdier, 1976 [pl.6,fig.9]

_F_. ? _torulosa_ (Davey & Verdier, 1976) Lentin & Williams, 1981 [pl.6,fig.10-11]

_F_. _tridactylites_ (Valensi, 1955a) Duxbury, 1980 [pl.6,fig.12]

Fromea _amphora_ Cookson & Eisenack, 1958 [pl.8,fig.3]

Gonyaulacysta _cassidata_ (Eisenack & Cookson, 1960) Sarjeant, 1966b [pl.7,fig.1]

_G_. _polythyris_ Davey, 1979b [pl.7,fig.2]

Hapsocysta _dictyota_ Davey, 1979b [pl.7,fig.3]

Heterosphaeridium ? _heteracanthum_ (Deflandre & Cookson, 1955) Eisenack & Kjellstrom, 1971a [pl.7,fig.4]

Hystrichodinium _pulchrum_ Deflandre, 1935 [pl.7,fig.5]

Hystrichosphaeridium _bowerbankii_ Davey & Williams, 1966b [pl.7,fig.6]

_H_. _difficile_ Manum & Cookson, 1964 [pl.7,fig.7]

_H_. _tubiferum_ (Ehrenberg, 1838) subsp. _brevispinum_ (Davey & Williams, 1966b) Lentin & Williams, 1973 [pl.7,fig.8]

_H_. _tubiferum_ subsp. _tubiferum_ (Ehrenberg, 1838) Deflandre, 1937b; emend. Davey & Williams, 1966b [pl.7,fig.9]

Hystrichostrogylon _membraniphorum_ Agelopoulos, 1964 [pl.7,fig.10]

Isabelidinium _acuminatum_ (Cookson & Eisenack, 1958) Stover & Evitt, 1978 [pl.7,fig.11]

Kleithriasphaeridium _readei_ (Davey & Williams, 1966b) Davey & Verdier, 1976 [pl.7,fig.12]

Leberidocysta _chlamydata_ (Cookson & Eisenack, 1962b) Stover & Evitt, 1978 [pl.8,fig.1]

_L_. _defloccata_ (Davey & Verdier, 1973) Stover & Evitt, 1978 [pl.8,fig.2]

Litosphaeridium _arundum_ (Eisenack & Cookson, 1960) Davey, 1979b [pl.8,fig.4]

_L_. _medius_ sp. nov. [pl.8,fig.5-6]

<u>L</u>. <u>siphoniphorum</u> (Cookson & Eisenack, 1968) Davey & Williams, 1966b

[pl.8,fig.7]

<u>L</u>. <u>urna</u> sp. nov. [pl.8,fig.8-9]

<u>Microdinium</u> ? <u>crinitum</u> Davey, 1969a [pl.8,fig.10]

<u>M</u>. <u>distinctum</u> Davey, 1969a [pl.8,fig.11]

<u>M</u>. <u>ornatum</u> Cookson & Eisenack, 1960a [pl.8,fig.12]

<u>M</u>. <u>setosum</u> Sarjeant, 1966b [pl.9,fig.1]

<u>M</u>. <u>veligerum</u> (Deflandre, 1937b) Davey, 1969a [pl.9,fig.2]

<u>Nematosphaeropsis</u> <u>densiradiata</u> Cookson & Eisenack, 1962b [pl.9,fig.3]

<u>Odontochitina</u> <u>costata</u> Alberti, 1961; emend. Clarke & Verdier, 1967

[pl.9,fig.4]

<u>O</u>. <u>cribropoda</u> Deflandre & Cookson, 1955 [pl.9,fig.5]

<u>O</u>. <u>operculata</u> (O. Wetzel, 1933a) Deflandre & Cookson, 1955 [pl.9,fig.6]

<u>Oligosphaeridium</u> <u>anthophorum</u> (Cookson & Eisenack, 1958) Davey, 1969a

[pl.9,fig.7]

<u>O</u>. <u>complex</u> (White, 1842) Davey & Williams, 1966b [pl.9,fig.8]

<u>O</u>. <u>poculum</u> Jain, 1977 [pl.9.fig.9]

<u>O</u>. <u>prolixispinosum</u> Davey & Williams, 1966b [pl.9,fig.10]

<u>O</u>. <u>reticulatum</u> Davey & Williams, 1966b [pl.9,fig.11]

<u>Operculodinium</u> sp.A [pl.9,fig.12]

<u>Ovoidinium</u> <u>scabrosum</u> (Cookson & Hughes, 1964) Davey, 1970 [pl.10.fig.1]

<u>O</u>. <u>verrucosum</u> (Cookson & Hughes, 1964) subsp. <u>ostium</u> (Davey, 1970)

Lentin & Williams, 1975 [pl.10,fig.2]

<u>O</u>. <u>verrucosum</u> subsp. <u>verrucosum</u> (Cookson & Hughes, 1964) Davey, 1970

[pl.10,fig.3]

<u>O</u>. sp.A [pl.10,fig.4]

<u>Palaeohystrichophora</u> <u>infusorioides</u> Deflandre, 1935 [pl.10,fig.6]

<u>P</u>. <u>paucisetosa</u> Deflandre, 1943 [pl.10,fig.7]

<u>Palaeoperidinium</u> <u>cretaceum</u> Pocock, 1962; emend. Davey, 1970a

[pl.10,fig.8]

Palaeostomocystis reticulata Deflandre, 1937b [pl.10,fig.9]

Pervosphaeridium bifidum (Clarke & Verdier, 1967) comb. nov.

[pl.10,fig.10]

P. cenomaniense (Norvick, 1976) Below, 1982 [pl.10,fig.11]

P. pseudohystrichodinium (Deflandre, 1937) Yun, 1981 [pl.10,fig.12]

P. truncatum (Davey, 1969a) Below, 1982 [pl.11,fig,1]

Prolixosphaeridium conulum Davey, 1969a [pl.11,fig.2]

Protoellipsodinium spinocristatum Davey & Verdier, 1971 [pl.11,fig.3]

Psaligonyaulax deflandrei Sarjeant, 1966b [pl.10,fig.5]

Pterodinium cingulatum subsp. cingulatum (O. Wetzel, 1933b) Below, 1981

[pl.11,fig.4]

P. cingulatum (O. Wetzel, 1933b) subsp. granulatum (Clarke & Verdier,

1967) Lentin & Williams, 1981 [pl.11,fig.5]

P. cingulatum (O. Wetzel, 1933b) subsp. reticulatum (Davey & Williams,

1966a) Lentin & Williams, 1981 [pl.11,fig.6]

P. cornutum Cookson & Eisenack, 1962b [pl.11,fig.7]

Pyxidinopsis parvum sp. nov. [pl.11,fig.8-9]

Raphidodinium fucatum Deflandre, 1936b [pl.11,fig.10]

Rhombodella paucispina (Alberti, 1961) Duxbury, 1980 [pl.11,fig.11]

Senoniasphaera rotundata Clarke & Verdier, 1967 [pl.11,fig.12]

Sentusidinium sp.A [pl.12,fig.1]

S. sp.B [pl.12,fig.2]

S. sp.C [pl.12,fig.3]

Spiniferites ? dentatus (Gocht, 1959) Lentin & Williams, 1973; emend.

Duxbury, 1977 [pl.12,fig.4]

S. ramosus (Ehrenberg, 1838) subsp. gracilis (Davey & Williams, 1966a)

Lentin & Williams, 1973 [pl.12,fig.5]

S. ramosus (Ehrenberg, 1838) subsp. multibrevis (Davey & Williams, 1966a)

Lentin & Williams, 1973 [pl.12,fig.6]

S. _ramosus_ subsp. _ramosus_ (Ehrenberg, 1838) Loeblich & Loeblich, 1966
[pl.12,fig.7]

S. _ramosus_ (Ehrenberg, 1838) subsp. _reticulatus_ (Davey & Williams, 1966a)
Lentin & Williams, 1973 [pl.12,fig.8]

Stephodinium _coronatum_ Deflandre, 1936a [pl.12,fig.9]

Subtilisphaera _pontis-mariae_ (Deflandre, 1936b) Lentin & Williams, 1976
[pl.12,fig.10]

S. sp.A [pl.12,fig.11]

S. sp.B [pl.12,fig.12]

Surculosphaeridium _longifurcatum_ (Firtion, 1952) Davey et al., 1966
[pl.13,fig.1]

Tanyosphaeridium _salpinx_ Norvick, 1976 [pl.13,fig 2]

T. _variecalamum_ Davey & Williams, 1966b [pl.13,fig.3]

T. sp.A [pl.13,fig.4]

Trichodinium _castaneum_ (Deflandre, 1935) Clarke & Verdier, 1967
[pl.13,fig.5]

Valensiella _ovula_ (Deflandre, 1947c) Eisenack, 1963a [pl.13,fig.6]

Wallodinium _anglicum_ (Cookson & Hughes, 1964) Lentin & Williams, 1973
[pl.13,fig.7]

Xenascus _ceratioides_ (Deflandre, 1937b) Lentin & Williams, 1973
[pl.13,fig.8]

X. _plotei_ Below, 1981 [pl.13,fig.9]

X. sp.A [pl.13,fig.10-11]

Xiphophoridium _alatum_ (Cookson & Eisenack, 1962b) Sarjeant, 1966b
[pl.13,fig.12]

Systematic descriptions and discussions

Class DINOPHYCEAE Fritsch, 1929

Order PERIDINIALES Haeckel, 1894

Genus ACHOMOSPHAERA Evitt, 1963

Achomosphaera crassipellis (Deflandre & Cookson, 1955) Stover &
Evitt, 1978

[pl.1,fig.1]

Remarks: The thick coarsely reticulate, subspherical central body of
this species serves to distinguish it from most other forms of this genus.
The most similar species, A. sagena, differs by not possessing faint parasu-
tural markings.

A. ? neptunii (Deflandre, 1937) Evitt, 1963

[pl.1,fig.2]

Description: This is a subspherical, skolochorate cyst with a finely
reticulate periphragm. The processes are hollow, occasionally faintly stri-
ate, trifurcate and typically closed distally. The cingular processes are
linked by low membranes.

Remarks: While corresponding closely to the forms described by Davey &
Williams (1966a), the figured specimen is only provisionally retained in this
genus due to the presence of an intratabular process on the opercular para-
plate.

A. ramulifera (Deflandre, 1937) Evitt, 1963

[pl.1,fig.3]

Remarks: A. ramulifera is characterised by the considerable variations
in its process morphology. The apical, antapical and in particular, the
pre-, and postcingular processes are commonly fused together, usually trifur-

cate, with bifurcate terminations, although they can be more complex distally. The combination of the smooth walled, roughly polygonal, central body and prominent fused processes serve to distinguish this species from all others in this genus.

A. regiensis Corradini, 1973
[pl.1,fig.4]

Remarks: This species is similar to A. ramulifera and A. simplex. It differs from the former by possessing more numerous processes, which are often medially bifurcate, and which are not fused together by prominent membranes, and from the latter by its much larger size.

A. sagena Davey & Williams, 1966a

brevispinus subsp. nov.

1966a; Achomosphaera sagena : Davey & Williams, p. 31, pl. 2, figs. 1,2.

[pl.1,fig.5]

Diagnosis: A subspecies of A. sagena which posesses characteristically short, poorly developed gonal and intergonal processes.

Holotype: Slide MCP/1307; Sample BAT 19(1), Middle Chalk (Turonian); Beachy Head, Eastbourne, Sussex.

Dimensions: Holotype-Length of central body 53 μm, Width 49 μm, Length of processes 7-9 μm.

Range-Length of central body 45-60 μm, Width 35-49 μm, Length of processes 6-11 μm.

A. sagena sagena Davey & Williams, 1966a
[pl.1,fig.6]

Remarks: The most similar species to A. sagena sagena is A. crassipellis which also possesses a thick-walled, densely reticulate central

body, and distally trifurcate processes. However, the former differs by lacking parasutural features between the process bases, and also by having processes which are only reticulate proximally and not along their entire length. Some examples of A. sagena sagena have a large circular perforation approximately halfway along the processes. This feature, however, can also occur on transitional forms between A. sagena sagena and A. crassipellis, thus making consistent identification difficult.

A. simplex sp. nov.
[pl.1,fig.7-8]

Derivation of name: Latin, simplex, simple-with reference to the simple nature of the processes.

Diagnosis: A small, smooth-walled, subspherical species of Achomosphaera which posesses a moderate number of simple, slightly fibrous, gonal and intergonal processes.

Holotype: Slide WHP/355; Sample BH 3, Lower Chalk, Cenomanian; Beachy Head, Eastbourne, Sussex.

Dimensions: Holotype-Overall length 36.5 μm, Overall width 35 μm, Length of processes 10-15 μm.

Range-Overall length 30-37.5 μm, Overall width 25-35 μm, Length of processes 10-15 μm.

Description: The cyst wall is thin and frequently distorted. There are approximately 30 slightly fibrous processes which are distally trifurcate, with bifurcate terminations. The processes widen proximally and adjacent ones are occasionally linked by a low membrane (particularly in the cingular region). The archeopyle is formed by the loss of a single precingular para-plate.

Remarks: A. simplex sp.nov. is distinguished from A. ramulifera by its smaller size, and absence of prominent membranes linking adjacent processes. A. regiensis is larger and has medially bifurcating processes.

Genus ALDORFIA Stover & Evitt, 1978

Aldorfia deflandrei (Clarke & Verdier, 1967) Stover & Evitt, 1978

[pl.1,fig.10]

Remarks: The subspherical central body, short apical projection, and seperated wall structure (seen particularly well in the apical region) make this a relatively easy species to identify. Clarke & Verdier (1967) mentioned the presence of paracingular features on some of their specimens but this feature was not observed during the present study.

Genus APTEODINIUM Eisenack, 1958

Apteodinium maculatum Eisenack & Cookson, 1960

[pl.1,fig.11]

Remarks: This species is usually easy to recognise although there is some variability in the development of parasutural features. In some specimens the paracingulum is clearly defined, albeit faintly, whereas in others it is absent. Eisenack & Cookson (1960) also remarked on the presence of small circular areas of thickening which were particularly well developed on the operculum. This feature was only noticeable on a few of the specimens examined. The most similar species, Apteodinium grande Cookson & Hughes differs by being much larger.

Apteodinium sp.A

[pl.2,fig.1]

Description: This is a large species of Apteodinium having a subspherical central body and short apical projection. The cyst wall is finely reticulate with an ornament of low tubercles which show a distinct alignment in the cingular region. A large hoof-shaped archeopyle, formed by the loss

of a single precingular paraplate, is developed. Only one specimen of A. sp.A was recorded during the present study.

A. sp.B
[pl.2,fig.1]

Description: This form has a finely reticulate, subspherical central body with a short apical horn. The paracingulum is distinct and formed by two low ridges. The archeopyle is formed by the loss of a single precingular paraplate. No other indications of paratabulation are present.

Genus BACCHIDINIUM Davey, 1979

Bacchidinium polypes polypes (Cookson & Eisenack, 1962b) Davey, 1979b

[pl.2,fig.5]

Remarks: B. polypes polypes differs from B. polypes clavulum by possessing spinose, rather than capitate, process terminations.

Genus CALLAIOSPHAERIDIUM Davey & Williams, 1966b; emend. Below, 1981.

Callaiosphaeridium asymmetricum (Deflandre & Courteville, 1939) Davey & Williams, 1966b.

[pl.2,fig.7]

Remarks: The presence of 6 large, tubular intratabular processes make this an easy species to identify.

Genus <u>CANNINGIA</u> Cookson & Eisenack, 1960b;

emend.   Below, 1981.

<u>Canningia colliveri</u> Cookson & Eisenack, 1960b

[pl.2,fig.9]

<u>Remarks</u>: This species differs from other forms in this genus by pos-
sessing a thin, finely granular autophragm. The type material illustrated by
Cookson & Eisenack (1960b) shows prominent antapical lobes, while the speci-
mens figured by Clarke & Verdier (1967) from the Anglo-Paris Basin have a
rounded antapical region. The material examined during the present study
more closely resembled the latter.

Genus <u>CASSICULOSPHAERIDIA</u> Davey, 1969a

<u>Cassiculosphaeridia reticulata</u> Davey, 1969a

[pl.2,fig.11]

<u>Remarks</u>: This species is similar to <u>Ellipsoidictyum circulatum</u> Clarke &
Verdier in that both possess a reticulate autophragm and an apical archeo-
pyle. However <u>C</u>. <u>reticulata</u> has no other indications of paratabulation
other than the archeopyle whereas <u>E</u>. <u>circulatum</u> possesses a well-defined
paracingulum.

Genus CLEISTOSPHAERIDIUM Davey et al., 1966

Cleistosphaeridium armatum (Deflandre, 1937b) Davey, 1969a
brevispinosum subsp. nov.

1969a; Cleistosphaeridium armatum : Davey, p. 153, pl. 8, figs.
1,2,12.

[pl.3,fig.3]

Diagnosis: A small subspecies of C. armatum which possesses character-
istically short acuminate processes.

Holotype: Slide WHP/58; Sample Hall 1, Seaton Chalk, Turonian; Beer,
S.E. Devon.

Dimensions: Holotype—Overall length 28 ⋏m, Overall width 25 ⋏m, Length
of processes 4-5 ⋏m.

Range—Overall length 28-30 ⋏m, Overall width 25-26 ⋏m,
Length of processes 4-5 ⋏m.

Description: This subspecies of C. armatum has a subspherical central
body with a large number of short acuminate processes. The autophragm has a
dense covering of elongated granules which give the cyst a distinctly hairy
appearance

Remarks: This subspecies differs from C. armatum armatum by having
consistently shorter processes.

Genus CODONIELLA Cookson & Eisenack, 1961a; emend. Davey, 1979

Codoniella campanulata (Cookson & Eisenack, 1961a) Downie &
Sarjeant, 1965; emend. Davey, 1979b

[pl.3,fig.4]

Remarks: The figured specimen clearly illustrates the high, funnel-
shaped, membranous structures which extend apically and antapically from the

spherical central body. Also visible are the longitudinal process thicken-
ings (Davey, 1979b) which support these structures.

Genus CRIBROPERIDINIUM Neale & Sarjeant, 1962; emend. Davey, 1969a

Cribroperidinium cf. cooksonae Norvick,1976
[pl.3,fig.8-9]

Remarks: While resembling the type material described by Norvick (1976)
in general morphology, the figured specimen differs by not possessing para-
cingular plates.

C. edwardsii (Cookson & Eisenack, 1958) Davey , 1969a
[pl.3,fig.10]

Remarks: This is a large species of Cribroperidinium, which differs
from other forms of this genus by possessing a thick, granular autophragm and
prominent parasutural ridges from which a number of short, blunt spines
arise. The intratabular ridges characteristic of this genus are discontinu-
ous and formed by either rows of short, blunt projections or low crests of
variable length.

C. exilicristatum (Davey, 1969a) Stover & Evitt, 1978
[pl.3,fig.11]

Remarks: This species is distinguished by its thin, finely granular
wall, and large number of accessory, intratabular ridges.

Genus CYCLONEPHELIUM Deflandre & Cookson, 1958; emend. Stover & Evitt,
1978

<u>Cyclonephelium distinctum</u> Deflandre & Cookson, 1955

[pl.4,fig.3-4]

Remarks: <u>C</u>. <u>distinctum</u> encompasses a wide range of morphological vari-
ations. A number of authors have attempted to subdivide this species into
subspecies on the basis of process size, density and distribution, but the
results have not proved satisfactory thus far. During the present study I
have examined large numbers of this species and found that many of the pro-
posed subspeciess show complete intergradation within the same assemblage.
At present, therefore, I prefer to treat <u>C</u>. <u>distinctum</u> as a morphological
group (sensu Norvick, 1976; p.70).

<u>C</u>. <u>eisenackii</u> Davey, 1969a

[pl.4,fig.5]

Remarks: <u>C</u>. <u>eisenackii</u> is distinguished by the complex nature of its
surface ornament which consists of an irregular network of low crests and
short, capitate processes.

<u>C</u>. <u>membraniphorum</u> Cookson & Eisenack, 1962b

[pl.4,fig.7-8]

Remarks: <u>C</u>. <u>membraniphorum</u> includes a wide range of forms in which the
middorsal and midventral areas of process reduction may be large or almost
non-existent. The ornamentation varies from high curved crests to wide tubu-
lar projections which are connected distally. The crests are supported by
localised thickening of the periphragm.

Genus <u>DAPSILIDINIUM</u> Bujak et al., 1980

<u>Dapsilidinium multispinosum</u> (Davey, 1974) Bujak et al., 1980

[pl.4,fig.11]

Remarks: This species differs from D. laminaspinosum by possessing a moderately thick, scabrate autophragm. and having thinner, and more numerous, tubular processes.

Genus DISPHAERIA Cookson & Eisenack, 1960a; emend. Norvick, 1973.

Disphaeria macropyla Cookson & Eisenack, 1960a; emend. Norvick, 1973.

[pl.5,fig.2]

Remarks: D. macropyla differs from D. munda by not possessing intratabular processes.

Genus ELLIPSODINIUM Clarke & Verdier, 1967

Ellipsodinium rugulosum Clarke & Verdier, 1967

[pl.5,fig.4]

Remarks: This is a very distinctive species due to the parallel alignement of longitudinal ridges on the central body. The cyst also has a well defined paracingulum and a reduced precingular archeopyle (type P, 3" only). E. rugulosum differs from Protoellipsodinium spinocristatum by not having short spines emanating from the longitudinal ridges.

Genus EPELIDOSPHAERIDIA Davey, 1969a

Epelidosphaeridia tuberculata sp. nov.

[pl.5,fig.9-10]

Derivation of name: Latin, tuberculum, small rounded projections-with reference to the surface ornament of this species.

Diagnosis: Large species of Epelidosphaeridia which possesses a granulate/tuberculate surface ornament. Paracingulum defined by 2 parallel rows of tubercles; parasulcus indicated by smooth-indented area. Archeopyle apical.

Holotype: Slide WHP/355; Sample BH 3, Lower Chalk, Cenomanian; Beachy Head, Eastbourne, Sussex.

Dimensions: Holotype-Overall length (incl. operculum) 62.5 µm, Overall width 52.5 µm.

Range-Overall length (incl. operculum) 62.5-65 µm, Overall width 52.5-60 µm.

Description: Cyst proximate, smooth-walled, compressed peridinioid. The autophragm is ornamented with large granules or tuberculae. The paracingulum is clearly defined by 2 parallel rows of tubercles. The parasulcus can usually be distinguished as an indented area with reduced ornamentation. An apical archeopyle is present but there are no parasutural features to indicate the type.

Remarks: This species is easily distinguished from E. spinosa by its larger size, and by possessing a tuberculate, rather than spinose ornament.

Genus EXOCHOSPHAERIDIUM Davey et al., 1966

Exochosphaeridium arnace Davey & Verdier, 1973
[pl.5,fig.11]

Remarks: This is an easily recognised species due to its intricately linked, fibrous processes which give the cyst a distinctly "hairy" appearance. It also possess a prominent apical process, and a precingular archeopyle formed by the loss of a single paraplate (3" only). The most similar species are Cometodinium obscurum, which differs by not possessing aa apical process, and having a well-defined paracingulum, and C. ? whitei

which is much larger.

E. phragmites Davey et al., 1966

[pl.5,fig.12]

Remarks: The distinctive foliate apical process, precingular archeopyle formed by the loss of a single paraplate, and long acuminate processes, distinguish this species from other members of this genus. Taxa belonging to the genus _Pervosphaeridium_ Yun, 1981 differ by having a 2P, rather than a type P (3" only), archeopyle.

Genus _FLORENTINIA_ Davey & Verdier, 1973; emend. Duxbury, 1980

Florentinia buspina (Davey & Verdier, 1973) Duxbury, 1980

[pl.6,fig.1]

Remarks: _F. buspina_ is distinguished by the presence of large complex processes, particularly in the postcingular region (usually 3 in number), and a densely granular cyst wall.

F. deanei (Davey & Williams, 1966b) Davey & Verdier, 1973

[pl.6,fig.2-3]

Remarks: This species is easily distinguished from other forms of the genus _Florentinia_ by its simple tubular processes, one per paraplate, and its large lagenate antapical process.

F. ferox (Deflandre, 1937b) Duxbury, 1980

[pl.6,fig.4]

Remarks: This species is characterised by having a granular wall, and a moderate number of simple, medially trifurcating, and medially bifurcating processes which are thin walled and distally truncated. The absence of large, complex processes distinguish this species from _F. buspina_.

_F_. cf. _ferox_ Davey & Verdler, 1973

[pl.6,flg.5]

Remarks: This form is similar in most respects to _F_. _ferox_ except for having a large, distally closed, antapical process, and occasionally extra processes in the pre-, and postcingular areas.

_F_. _laciniata_ Davey & Verdler, 1973

[pl.6,flg.6]

Remarks: This is a very distinctive species which differs from other forms of _Florentinia_ by possessing several large complex processes, and a large tubular antapical process which is open distally and has a crenulated margin.

_F_. _mantellii_ (Davey & Williams, 1966b) Davey & Verdler, 1973

[pl.6,flg.7]

Remarks: _F_. _mantellii_ most closely resembles _F_. _deanei_ but differs by having a granular cyst wall, and processes which are faintly striate and branch distally. Also the antapical process on _F_. _deanei_ tends to be larger and more obviously lagenate.

_F_. _radiculata_ (Davey & Williams, 1966b) Davey & Verdler, 1973; emend. Davey & Verdler, 1976

[pl.6,flg.8]

Remarks: _F_. _radiculata_ is distinguished by its slender, tubular processes which are often divided medially or proximally, giving the appearance of more processes than are actually present. The processes and cyst wall are faintly striate.

F. resex Davey & Verdier, 1976

[pl.6,fig.9]

Remarks: F. resex is distinguished by its numerous simple processes (more than 2 per paraplate) which are typically wide-based, distally tapering, and have a truncated margin. The antapical process is distinctively large, tubular, and closed distally.

F. ? torulosa (Davey & Verdier, 1976) Lentin & Williams, 1981

[pl.6,fig.10-11]

Remarks: F. ? torulosa is easily distinguished by its thick granular wall, and large distally rounded processes.

F. tridactylites (Valensi, 1955a) Duxbury, 1980

[pl.6,fig.12]

Remarks: F. tridactylites is characterised by possessing long, thin processes which are medially bifurcate or trifurcate in the pre- and postcingular regions. The most similar species, F. ferox, differs by having a granular cyst wall.

Genus GONYAULACYSTA Deflandre, 1934; emend. Stover & Evitt, 1978

Gonyaulacysta polythyris Davey, 1979b

[pl.7,fig.2]

Remarks: This species is distinguished by possessing perforate parasutural crests and an intratabular ornament of short solid spines.

Genus HAPSOCYSTA Davey, 1979b

Discussion : In his original description of this genus, Davey (1979b; p.56), regarded the presence of a net-like periphragm as the most distinctive and unique feature. However Cookson & Eisenack (1958; p.58-59, pl.12, figs. 1,2) described the genus Cyclodictyon, which also possesses a net-like periphragm and subspherical endocyst. The latter authors did not specify the archeopyle type, but Stover & Evitt (1978) diagnosed it as apical, although whether this was based on re-examination of the type specimens or on new material is not clear. Their are several other points of similarity between Cyclodictyon and Hapsocysta. In particular, the lines of parasutural thickening which Davey (1979b) describes on Hapsocysta dictyota, can also be seen on the specimens of Cyclodictyon paradoxum illustrated by Morgan (1980). Whether or not there is a relationship between the two forms is impossible to tell at the moment as it would require an examination of the type material from Australia in order to confirm the archeopyle type. Since the specimens found during the present study all possessed precingular archeopyles, I have retained them in the genus Hapsocysta for the present.

Genus HYSTRICHOSPHAERIDIUM Deflandre, 1937b; emend. Davey & Williams, 1966b

Hystrichosphaeridium bowerbankii Davey & Williams, 1966b
[pl.7,fig.6]

Remarks: This is a distinctive species which is characterised by having a small elongate central body, with a moderate number of thin, tubular processes. The processes show prominant circular, basal wrinkles, and terminate with a number of short spines. H. bowerbankii is similar to Oligosphaeridium prolixispinosum but differs by having a greater number of processes, and also by not having processes which terminate with long, fili-

form spines.

<div align="center">

H. <u>difficile</u> Manum & Cookson, 1964

[pl.7,fig.7]

</div>

Remarks: This species is easily distinguished from other forms of this genus by its large size, finely reticulate periphragm, and the variable nature of its fibrous processes. <u>Cordosphaeridium inodes</u> has similar processes but differs by having a precingular, rather than apical archeopyle.

Genus <u>KLEITHRIASPHAERIDIUM</u> (Davey & Williams, 1966b) Davey & Verdier, 1976

<div align="center">

<u>Kleithriasphaeridium</u> <u>readei</u> (Davey & Williams, 1966b) Davey &

</div>

Verdier, 1976

<div align="center">

[pl.7,fig.12]

</div>

Remarks: This species has distinctive ribs running lengthwise along its processes, and which continue onto the central body of the cyst, linking adjacent processes.

Genus <u>LITOSPHAERIDIUM</u> Davey & Williams, 1966b; emend. Davey & Verdier, 1973

<div align="center">

<u>Litosphaeridium</u> <u>medius</u> sp. nov.

[pl.8,fig.5-6]

</div>

Derivation of name: Latin, <u>medius</u>, intermediate-with reference to the intermediate morphology of this cyst between <u>L</u>. <u>siphoniphorum</u> and <u>L</u>. <u>urna</u> sp. nov.

Diagnosis: A species of <u>Litosphaeridium</u> which has a reticulate, subs-

pherical central body and a moderate number (17) of open lagenate and closed conical intratabular processes. Archeopyle apical, type tA.

Holotype: Slide WHP/360; Sample BH 8, Lower Chalk, Cenomanian; Beachy Head, Eastbourne, Sussex.

Dimensions: Holotype-Overall length 42.5 μm, Overall width 37.5 μm, Length of processes 15-17.5 μm.

Range-Overall length 40-42.5 μm, Overall width 36-37.5 μm, Length of processes 14-17 μm.

Description: Central body subspherical with a distinctly reticulate surface ornament. The holotype has 13 processes (excluding those on the operculum) which are lagenate, of similar size, and normally open distally with a denticulate margin. The parasulcal processes differ by being conical and often closed distally.

Remarks: This species differs from L. siphoniphorum by possessing lagenate, rather than conical or subconical, tubular processes; L. urna has a smooth, or microreticulate wall, and more consistently developed lagenate processes.

L. urna sp. nov.
[pl.8,fig.8-9]

Derivation of name: Latin, urna, urn-with reference to the urn-like (lagenate) shape of the processes.

Diagnosis: A species of Litosphaeridium which is characterised by having a smooth or microreticulate cyst wall and a moderate number (usually 17) of open lagenate processes.

Holotype: Slide MCP/1304; Sample BAT 16, Plenus Marls, Upper Cenomanian; Beachy Head, Eastbourne, Sussex.

Dimensions: Holotype-Overall length 37.5 μm, Overall width 35 μm, Length of processes 17.5-20 μm.

Range-Overall length 35-42.5 μm, Overall width 33-37 μm,

Length of processes 12.5-20 μm.

Description: Cyst subspherical with smooth or microreticulate wall. Processes typically open lagenate, of similar size, and with a denticulate margin.

Remarks: This species differs from L. medius by possessing a smooth, or microreticulate wall rather than being distinctly reticulate. Also the processes tend to be more consistently lagenate on the former.

Genus MICRODINIUM Cookson & Eisenack, 1960a; emend. Sarjeant, 1966b; emend. Stover & Evitt, 1978

Microdinium ? crinitum Davey, 1969a
[pl.8,fig.10]

Remarks: The typically thick covering of long, hair-like spines on this species make determination of the paratabulation impossible, and therefore it is only provisionally accepted in this genus.

M. distinctum Davey, 1969a
[pl.8,fig.11]

Remarks: This species is easily recognised by its thick, smooth periphragm and lack of cingular paraplates.

M. ornatum Cookson & Eisenack, 1960a
[pl.8,fig.12]

Remarks: Sarjeant (1966b) described a number of specimens from the English Cenomanian which differed from the Australian type material by lacking one of the sulcal paraplates. However, this feature was observed only in some cases, and not in others during the present study, and therefore, probably falls within an acceptable species variation.

M. <u>setosum</u> Sarjeant, 1966b

[pl.9,fig.1]

Remarks: The characteristic spinose crests which define the paratabulation of this species make it easy to identify, and distinguish it from all other forms of this genus.

M. <u>veligerum</u> (Deflandre, 1937b) Davey, 1969a

[pl.9,fig.2]

Remarks: M. <u>veligerum</u> differs from other forms of this genus by possessing high, smooth crests formed by two membranes which are fused distally to form a "tent-shaped" cavity. The membranes are often perforated and divided by thickened septa. The surface of the cyst is densely granular.

Genus <u>OLIGOSPHAERIDIUM</u> Davey & Williams, 1966b

<u>Oligosphaeridium poculum</u> Jain, 1977

[pl.9,fig.9]

Remarks: This species is characterised by its distinct short, widely-flaring processes. A prominent circular wrinkle is present at the base of each process marking the seperation of endophragm and periphragm. The processes are flared distally and have an uneven, but entire margin.

Genus <u>OPERCULODINIUM</u> Wall, 1967

<u>Operculodinium</u> sp.A

[pl.9,fig.12]

Remarks: Small subspherical form of <u>Operculodinium</u> with a finely reticulate surface ornament, and numerous short capitate spines of equal length.

The archeopyle is precingular and formed by the loss of a single precingular paraplate.

Genus OVOIDINIUM Davey, 1970; emend. Lentin & Williams, 1976

Ovoidinium sp.A

[pl.10,fig.4]

Remarks: Smooth-walled, bicavate form of Ovoidinium. Paracingulum clearly defined by 2 parallel rows of small granules. Archeopyle apical, margins angular. Operculum often remains attached.

Genus PALAEOHYSTRICHOPHORA Deflandre, 1935

Palaeohystrichophora paucisetosa Deflandre, 1945

[pl.10,fig.7]

Remarks: P. paucisetosa differs from P. infusorioides by having a distinctly sparser covering of hair-like appendages. Stover & Evitt (1978) suggested that P. paucisetosa might fall within the morphological range of P. infusorioides, but I feel that they are sufficiently distinct to warrant continued separation.

Genus PALAEOPERIDINIUM Deflandre, 1935; emend. Lentin & Williams, 1976

Palaeoperidinium cretaceum Pocock, 1962; emend. Davey, 1970

[pl.10,fig.8]

Remarks: This species differs from other forms of the genus by possess-

ing a very thin cyst wall which is often irregularly wrinkled. Parasutural features are confined to the paracingulum only.

Genus PERVOSPHAERIDIUM Yun, 1981

Pervosphaeridium bifidum (Clarke & Verdier, 1967) comb. nov.

1968; Exochosphaeridium bifidum : Clarke et al., p.182.

[pl.10,fig.10]

Remarks: This species is transferred to the genus Pervosphaeridium due to the presence of a type 2P, rather than type P (3" only) archeopyle.

Genus PYXIDINOPSIS Habib, 1976

Pyxidinopsis parvum sp. nov.

[pl.11,fig.8-9]

Derivation of name: Latin, parvum, small-with reference to the small size of this species.

Diagnosis: Small subspherical species of Pyxidinopsis; cyst wall irregularly reticulate; archeopyle precingular, formed by the loss of a single paraplate.

Holotype: Slide WHP/365; Sample BH 13, Plenus Marls, Upper Cenomanian; Beachy Head, Eastbourne, Sussex.

Dimensions: Holotype-Overall length 39 μm, Overall width 29 μm.

Description: The cyst is subspherical, smooth-walled or micro-granular, and has a dense, but irregular reticulation. The muri are relatively thick (1-1.5 m) and distinctive. Parasutural features are absent. Paratabulation is indicated by the archeopyle only which is reduced precingular, formed by the loss of a single paraplate.

Remarks: This species differs from other forms of the genus by its smaller size and prominent muri.

Genus SENTUSIDINIUM Sarjeant & Stover, 1978

Sentusidinium sp.A

[pl.12,fig.1]

Description: This form has a subspherical central body and an evenly distributed surface ornament of low granules.

S. sp.B

[pl.12,fig.2]

Description: S. sp.B differs from S. sp.A by having a surface ornament of elongate granules, some of which are connected by low ridges which, when well developed, can give the impression of an imperfect reticulum. The archeopyle is apical and has an angular margin.

S. sp.C

[pl.12,fig.3]

Description: This form is characterised by having a dense, even cover of short spines. The archeopyle is apical and has a distinctly angular margin.

Remarks: All of the above-mentioned forms encountered during the present study were thin-walled and often considerably distorted. They have been placed in the genus Sentusidinium on the basis of their subspherical central body, apical archeopyle, and even cover of low, non-tabular ornament.

Genus <u>SPINIFERITES</u> Mantell, 1850; emend. Sarjeant, 1970

<u>Spiniferites</u> ? <u>dentatus</u> (Gocht, 1959) Lentin & Williams, 1973;
emend. Duxbury, 1977

[pl.12,fig.4]

<u>Remarks</u>: <u>S</u>.? <u>dentatus</u> includes a variety of forms with high parasutural crests which give the cyst outline a scalloped appearance. The gonal processes are trifurcate. The parasutural membranes have a variable number of peaks, which bifurcate distally.

<u>S</u>. <u>ramosus</u> <u>ramosus</u> (Ehrenberg, 1838) Loeblich & Loeblich, 1966

[pl.12,fig.7]

<u>Remarks</u>: This subspecies is distinguished by having an unornamented, subspherical central body, relatively long, slender, gonal processes (and occasionally intergonal processes) which are typically trifurcate with distal bifurcations. <u>S</u>. <u>ramosus</u> <u>multibrevis</u> differs by possessing much shorter processes, while <u>S</u>. <u>ramosus</u> <u>gracilis</u> has thinner, more slender processes which are distally more complex.

Genus <u>SUBTILISPHAERA</u> Jain & Millepied, 1973; emend. Lentin & Williams, 1976

<u>Subtilisphaera</u> sp.A

[pl.12,fig.11]

<u>Remarks</u>: This is a small form of <u>Subtilisphaera</u> possessing a smooth central body and a well-defined paracingulum. There are no other indications of paratabulation present.

<u>S</u>. sp.B

[pl.12,fig.12]

<u>Remarks</u>: This form differs from <u>s</u>. sp.A by having a finely granular periphragm.

Genus <u>TANYOSPHAERIDIUM</u> Davey & Williams, 1966b

<u>Tanyosphaeridium</u> sp.A

[pl.13,fig,4]

<u>Remarks</u>: This form differs from other species of this genus by possessing processes which have a distinctly recurved distal termination.

Genus <u>XENASCUS</u> Cookson & Eisenack, 1969

<u>Xenascus</u> sp.A

[pl.13,fig.10-11]

<u>Remarks</u>: This form shows a well-developed, perforate antapical horn. Subsidiary processes normally present on species of this genus are absent.

CHAPTER 4

BIOSTRATIGRAPHY

Introduction

This chapter is divided into 2 main parts. The first is a synthesis of the cyst distribution from all the sites examined during this study (summarised in 4.2; Fig. 30). Comments on cysts which may be stratigraphically significant (4.1) are based on the present study and a comparison of all relevant published work on the Anglo-Paris Basin,

The second main part deals with the detailed biostratigraphy of each site examined (4.3 & 4.4) and includes details of both the macrofauna and the microfauna. The sections at St. Calais (Figs. 10, 11), La Chartre-sur-le-Loir (Figs. 18, 19) and Villedieu-le-Château (Figs. 20, 21) were barren of palynomorphs and are not discussed in this chapter (see Chapter 5).

4.1 Stratigraphically significant dinoflagellate cysts

4.1.1 Upper Albian (Stolicskia dispar Zone)

1) Achomosphaera regiensis Corradini. Corradini (1973) originally described this species from the Senonian of the northern Appennines in Italy. Its appearance in the Upper Greensand at Beachy Head (Fig. 39; BH 1) marks not only the earliest stratigraphic record of this form, but also its first record in the Anglo-Paris Basin.

2) Achomosphaera simplex sp. nov. This species first appears in the Upper Greensand (S. dispar Zone) at Asham Pit (Fig. 38; BAT 4) and may be a useful indicator of the S. dispar Zone.

3) Apteodinium reticulatum Singh. This species has only previously been

recorded from the late Albian of Canada (Singh, 1971). Its sole occurrence in the present study was in the U. Greensand at Asham (Fig. 38; BAT 3).

4) *Cribroperidinium* cf. *cooksonae* Norvick. This form was only recorded from the base of the section at Livet Quarry (Fig. 31; Cord 1). *C. cooksonae* has been recorded from the Cenomanian of Australia (Norvick, 1976).

5) *Cribroperidinium exilicristatum* (Davey) Stover & Evitt. The first appearance of *C. exilicristatum* is regarded by Davey & Verdier (1973) and Verdier (1975) as indicative of sediments of topmost Albian age (*S. dispar* Zone). Its appearance in the basal sample (BAT 5) at Asham (Fig. 38) therefore, suggests an age no older than the *S. dispar* Zone for the Upper Greensand at this locality.

6) *Disphaeria macropyla* Cookson & Eisenack. This species was originally described from the Turonian of Australia by Norvick (1976), although Morgan (1980) later reported *D. macropyla* from the *S. dispar* Zone in the same area. In the present study, it first appears in the U. Greensand at Asham (Fig. 38; BAT 4). This is the first known record of this species in sediments from the Anglo-Paris Basin.

7) *Endoceratium dettmannae* (Cookson & Hughes) Stover & Evitt. This a relatively rare but persistent species which first appears in the Glauconie de base at Livet Quarry (Fig. 31; Cord 3) and the Upper Greensand at Beachy Head (Fig. 39; BH 1). Davey & Verdier (1973) regard the first appearance of this form as indicative of the *S. dispar* Zone.

8) *Florentinia buspina* (Davey & Verdier) Duxbury. This species has not previously been recorded from pre-Turonian sediments in the Anglo-Paris Basin (Davey & Verdier, 1976). Its appearance in the Upper Greensand at both Asham (Fig. 38; BAT 5) and Beachy Head (Fig. 39; BH 1), therefore, marks a significant extension of the previously published range.

9) *Florentinia deanei* (Davey & Williams) Davey & Verdier. This species first appears in the *S. dispar* Zone in France (Verdier, 1975; Davey & Verdier, 1973; Fauconnier, 1979). Its occurrence in the Glauconie de base at

Livet Quarry (Fig. 31; Cord 3) suggests a similar age for the lower part of this formation.

10) *Heterosphaeridium* ? *heteracanthum* (Deflandre & Cookson) Eisenack & Kjellstrom. The incoming of this species is regarded as characteristic of the *S. dispar* Zone by Davey & Verdier (1973). It was not found at Livet Quarry (France), but appears in the Upper Greensand at Asham Pit (Figs. 22, 23 & 31; BAT 4), and at Beachy Head (Figs. 24, 25 & 32; BH 1).

11) *Hystrichosphaeridium bowerbankii* Davey & Williams. *H. bowerbankii* has been recorded from sediments of *S. dispar* Zone age in the Anglo-Paris Basin by a number of authors (e.g. Davey & Verdier, 1973; Verdier, 1975). It first appears in the Upper Greensand at Beachy Head (Fig. 39; BH 1) but not until the basal Glauconitic Marl (?Cenomanian) at Asham Pit (Fig. 38; BAT 2).

12) *Nematosphaeropsis densiradiata* Cookson & Eisenack. The appearance of this species in the U. Greensand at Asham (Fig. 38; BAT 4) is the first record of this form from the Anglo-Paris Basin. Its only previous record is from the *Mortoniceras inflatum* Zone (Upper Albian) in Australia (Morgan, 1980).

13) *Odontochitina costata* Alberti; emend. Clarke & Verdier. This species is recorded as first appearing in the *S. dispar* Zone at Col de Palleul, SE France, by Davey & Verdier (1973). Its occurrence in the Upper Greensand at Asham (Fig. 38; BAT 3) suggests a similar age for this formation.

14) *Odontochitina cribropoda* Deflandre & Cookson. This species, originally described from the Senonian of Australia (Deflandre & Cookson, 1955), is recorded for the first time in sediments from the Anglo-Paris Basin. A very rare species, it first occurs in the U. Greensand at Asham (Fig. 38; BAT 4).

15) *Oligosphaeridium reticulatum* Davey & Williams. This species has not previously been recorded from pre-Cenomanian sediments in the Anglo-Paris Basin (Davey & Williams, 1966b; Davey, 1969; Foucher, 1979). Its appear-

ance in the U. Greensand at both Asham (Fig. 38; BAT 5) and Beachy Head (Fig. 39; BH 1) therefore, indicates an extension of the published range.

16) _Ovoidinium_ _verrucosum_ (Cookson & Hughes) _ostium_ (Davey) Lentin & Williams. This subspecies has not previously been reported from the Anglo-Paris Basin. It first appears in the U. Greensand at Beachy Head (Fig. 39; BH 1).

17) _Ovoidinium_ _verrucosum_ _verrucosum_ (Cookson & Hughes) Davey. This species is recorded from sediments belonging to the _S._ _dispar_ Zone by Fauconnier (1979), Verdier (1975), and Davey & Verdier (1973). Its first appearance in the Glauconie de base at Livet Quarry (Fig. 31; Cord 2) is taken to suggest a similar age for the lower part of this formation.

18) _Palaeohystrichophora_ _infusorioides_ Deflandre. The first appearance of _P._ _infusorioides_ is regarded by Davey & Verdier (1973), Verdier (1975), and Fauconnier (1979) as being characteristic of the _S._ _dispar_ Zone in France. Its earliest occurrence in the present study occurs in the U. Greensand at Asham (Fig. 38; BAT 4).

19) _Pervosphaeridium_ _bifidum_ (Clarke & Verdier) comb. nov. This species has an earliest recorded occurrence in the _S._ _dispar_ Zone in N.W. France (Fauconnier, 1979). Its first appearance in the present study is in the U. Greensand at Asham (Fig. 38; BAT 5).

20) _Pervosphaeridium_ _cenomaniense_ (Norvick) Below. This species has only previously been found in Albian-Cenomanian sediments from Australia (e.g. Norvick, 1976). Its appearance in the U. Greensand at Asham (Fig. 38; BAT 4) is the first reported occurrence in the Anglo-Paris Basin.

21) _Pervosphaeridium_ _pseudohystrichodinium_ (Deflandre) Yun. The first appearance of _P._ _pseudohystrichodinium_ is regarded as indicative of the _S._ _dispar_ Zone (topmost Albian) in the Anglo-Paris Basin by Davey & Verdier (1973). Its appearance therefore, at the base of the Asham Pit section (Fig. 38; BAT 5) suggests an age no older than topmost Albian for the Upper Greensand at this locality.

22) _Prolixosphaeridium_ _conulum_ Davey. The first appearance of this species in the Anglo-Paris Basin is taken to indicate sediments belonging to the _S._ _dispar_ Zone (Davey & Verdier, 1971; Verdier, 1975). Its earliest appearance in the present study comes in the Glauconie de base at Livet Quarry (Fig. 31; Cord 3).

23) _Tanyosphaeridium_ _salpinx_ Norvick. _T._ _salpinx_ has previously only been recorded from Aptian-Cenomanian strata in Australia (e.g. Norvick, 1976; Morgan, 1980). Its appearance in the U. Greensand at Beachy Head (Fig. 39; BH 1) is the first reported occurrence in sediments from the Anglo-Paris Basin.

24) _Raphidodinium_ _fucatum_ Deflandre. The appearance of this species in the U. Greensand at Asham (Fig. 38; BAT 5) is the oldest known record of _R._ _fucatum_. Its only previous record is from from late Turonian-Senonian sediments (Foucher, 1979).

4.1.2 Lower Cenomanian (_Mantelliceras_ _mantelli_ Zone)

25) _Cleistosphaeridium_ _armatum_ Deflandre _brevispinosum_ subsp. nov. This subspecies first appears near the Albian-Cenomanian boundary at Livet Quarry (Fig. 31; Cord 4), Beachy Head (Fig. 39; BH 2) and Asham Pit (Fig. 38; BAT 6).

26) _Cyclonephelium_ _clathromarginatum_ Cookson & Eisenack. This species has been described from the late Albian-Cenomanian of Australia (Cookson & Eisenack, 1962; Morgan, 1980) but has not previously been recorded from the Anglo-Paris Basin. It is a very rare species which first appears in the upper part of the _M._ _mantelli_ Zone (_M._ _dixoni_ subzone) at Hameau-Frédet Quarry (Fig. 32; HF 9).

27) _Cyclonephelium_ _eisenackii_ Davey. The highest occurrence of this species is in the Craie glauconieuse at Livet Quarry (Fig. 31; Cord 12) and the Glauconitic Marl at Asham (Fig. 38; BAT 6). Its previous highest recorded occurrence in the Anglo-Paris Basin was from the Upper Albian,

Mortoniceras inflatum Zone (Davey & Verdier, 1971).

28) Florentinia ferox (Deflandre) Duxbury. This species was originally described from the Turonian of the Anglo-Paris Basin by Davey & Verdier (1976), although more recently, Foucher (1980, 1981) has recorded F. ferox from sediments of Upper Cenomanian (C. naviculare Zone) age. Its occurrence in the Glauconitic Marl (L. Cenomanian) at Beachy Head (Fig. 39; BH 2) is the earliest known record of this species.

29) Gonyaulacysta polythyris Davey. This species was recently described from sediments of S. dispar Zone age from the northern Bay of Biscay (Davey, 1979d). Its solitary occurrence in the Lower Chalk at Beachy Head (Fig. 39; BH 3) is the first record of this species in the Anglo-Paris Basin.

30) Oligosphaeridium poculum Jain. O. poculum was first described from Albian age sediments from India (Jain, 1977). Its occurrence in the Lower Chalk at Beachy Head (Fig. 39; BH 3) is the only known record of this species from sediments in the Anglo-Paris Basin.

31) Ovoidinium verrucosum (Cookson & Hughes) ostium (Davey) Lentin & Williams. This subspecies has its last appearance in the H. carcitanensis subzone (basal M. mantelli Zone) at Livet Quarry (Fig. 31; Cord 9).

32) Ovoidinium verrucosum verrucosum (Cookson & Hughes) Davey. The last appearance of this subspecies is taken here to coincide with the basal part of the M. mantelli Zone, of Lower Cenomanian age.

33) Palaeoperidinium cretaceum Pocock; emend. Davey. This species has a last recorded appearance in the lower M. mantelli Zone in France (Fauconnier, 1979; Foucher, 1981). During the present study, P. cretaceum was not found in sediments higher than the Glauconitic Marl.

34) Protoellipsodinium spinocristatum Davey & Verdier. This species is generally regarded as having a top occurrence in the late Albian (S. dispar Zone) in the Anglo-Paris Basin (e.g. Fauconnier, 1979). Its presence in the basal Glauconitic Marl (?Lower Cenomanian) at Asham (Fig. 38; BAT 2) may be due to reworking (4.4.1).

35) _Rhombodella paucispina_ (Albertl) Duxbury. This rare species has its
last appearance in the Lower Chalk at Beachy Head (Fig. 39; BH 3).
Previous authors (e.g. Fauconnier, 1979; Verdier, 1975) regarded the last
occurrence of this species as indicating the top of the Albian. Its appear-
ance at Beachy Head may be due to reworking (4.4.1).

36) _Xenascus plotei_ Below. This species occurred as a solitary specimen
near the base of the Lower Chalk at Beachy Head (Fig. 39; BH 3), and is the
only known record of _X. plotei_ from the Anglo-Paris Basin. It was original-
ly described from Aptian-Cenomanian sediments from Morocco (Below, 1981).

4.1.3 Middle Cenomanian (_Acanthoceras rhotomagense_ Zone)

37) _Codoniella campanulata_ (Cookson & Eisenack) Downie & Sarjeant;
emend. Davey. Foucher (1980) regarded the first appearance of this species
as indicative of the middle Cenomanian of the Anglo-Paris Basin. Its occur-
rence in the _A. rhotomagense_ Zone at Beachy Head (Fig. 39; BH 5) appears
to confirm this interpretation.

38) _Cribroperidinium exilicristatum_ (Davey) Stover & Evitt. _C.
exilicristatum_ has a top occurrence in the _A. rhotomagense_ Zone at Asham
(Fig. 38; BAT 1), and Beachy Head (Fig. 39; BH 6). Davey (1969), also
shows this species disappearing at this level. Foucher (1980) reported a
solitary occurrence from the Upper Cenomanian in France, but this is probably
due to reworking.

39) _Dapsilidinium conispinum_ (Davey & Verdier) Lentin & Williams. This
is another species which has its last appearance in the mid Cenomanian at
Asham (Fig. 38; BAT 1), although its previous recorded top occurrence was
from the Lower Cenomanian of Wissant, N.W. France (Fauconnier, 1979). The
poorly preserved state of the specimen at Asham suggests reworking.

40) _Endoceratium dettmannae_ (Cookson & Hughes) Stover & Evitt. This
species has a highest recorded occurrence in the mid Cenomanian of the
Anglo-Paris Basin (Clarke & Verdier, 1967) although many subsequent records

have placed the top occurrence in the Lower Cenomanian (Davey, 1970; Fauconnier, 1979 and Foucher, 1981). Its highest recorded appearance during the present study is in the O. mantelliana Band (A. rhotomagense Zone) at Asham Pit (Fig. 38; BAT 1).

41) Epelidosphaeridia tuberculata sp. nov. This species has a top occurrence in the lower A. rhotomagense Zone at both Asham (Fig. 38; BAT 1), and Beachy Head (Fig. 39; BH 5).

42) Litosphaeridium urna sp.nov. The first appearance of this species occurs in the Mid-Cenomanian at Beachy Head (Fig. 39; BH 6), in the upper part of the A. rhotomagense Zone.

43) Microdinium distinctum Davey. This is a very rare species and was originally described as having a first occurrence near the top of the Mid-Cenomanian in S.E. England (Davey, 1969). Its appearance in the rhotomagense Zone at Beachy Head (Fig. 39; BH 5) is only the second record of M. distinctum in the Anglo-Paris Basin.

44) Operculodinium sp. A. This form has a top occurrence in the A. rhotomagense Zone at Hameau-Frédet Quarry (Fig. 32; HF 15A).

45) Palaeostomocystis reticulata Deflandre. The appearance of this species in the Middle Cenomanian at Hameau-Frédet (Figs 32; HF 15) is the earliest record of P. reticulata in the Anglo-Paris Basin. Previously, it was only known from basal Coniacian sediments (Foucher, 1979).

4.1.4 Upper Cenomanian (Calycoceras naviculare Zone)

46) Ascodinium acrophorum Cookson & Eisenack. A. acrophorum last appears at the top of the C. naviculare Zone at Beachy Head (Fig. 39; BH 8).

47) Craspedodinium indistinctum Cookson & Eisenack. This species has not previously been recorded from the Anglo-Paris Basin. Its last appearance in the C. naviculare Zone at Les Fosses Blanche Quarry (Fig. 34; Cal 1) is the highest recorded stratigraphic occurrence of this species. It was origi-

nally described from Aptian/Albian strata in Australia (Cookson & Eisenack, 1974).

48) _Litosphaeridium_ _medius_ sp. nov.. The first appearance of this species at Beachy Head (Fig. 39; BH 8) is taken here to indicate the upper part of the C. _naviculare_ Zone.

49) _Litosphaeridium_ _siphoniphorum_ (Cookson & Eisenack) Davey & Williams. This species has a top occurrence in the C. _naviculare_ Zone at Beachy Head (Fig. 39; BH 8). Although Foucher (1982), has recorded this form from the Turonian in the Civray Borehole (N.W. France), I suspect that the latter occurrence may be due to reworking or contamination.

4.1.5 Upper Cenomanian (_Metoicoceras_ _geslinianum_ Zone)

50) _Achomosphaera_ ? _neptunii_ (Eisenack) Davey & Williams. This species has its last appearance at the base of the Plenus Marls (M. _geslinianum_ Zone) at Beachy Head (Fig. 39; BH 9).

51) _Apteodinium_ _maculatum_ Eisenack & Cookson. This species is recorded here for the first time from the Anglo-Paris Basin. It has a top occurrence in the M. _geslinianum_ Zone at Beachy Head (Fig. 39; BH 10).

52) _Dinopterygium_ _medusoides_ (Cookson & Eisenack) Stover & Evitt. D. _medusoides_ is also recorded here for the first time in sediments from the Anglo-Paris Basin. A solitary specimen appears in the Plenus Marls (M. _geslinianum_ Zone) at Beachy Head (Fig. 39; BAT 16).

53) _Isabelidinium_ _acuminatum_ (Cookson & Eisenack) Stover & Evitt. The only previous record of this species from sediments in the Anglo-Paris Basin is from the Santonian of the Isle of Wight (Clarke & Verdier, 1967), although it has been found in Cenomanian-early Turonian strata in Australia (Cookson & Eisenack, 1962). In the present study, it first appears near the top of the Plenus Marls at Beachy Head (Fig. 39; BAT 16).

54) _Litosphaeridium_ _medius_. sp. nov.. The top occurrence of this species, in the upper part of the Plenus Marls at Beachy Head (Fig. 39; BAT

16), is taken here as evidence of the M. geslinianum Zone.

55) Litosphaeridium urna sp. nov.. This species also has a top occurrence near the top of the Plenus Marls at Beachy Head (Fig. 39; BAT 16)

56) Nematosphaeropsis densiradiata Cookson & Eisenack. This species, which has not previously been recorded from the Anglo-Paris Basin, has a top occurrence in the Plenus Marls at Beachy Head (Fig. 39; BH 13).

57) Pyxidinopsis parvum sp. nov.. This is a very rare species which has only been found in a single sample from the Plenus Marls at Beachy Head (Fig. 39; BH 13).

4.1.6 Upper Cenomanian (Neocardioceras juddii Zone)

No appearances or disappearances of cyst taxa were recorded from this zone during the present study.

4.1.7 Low Turonian (Mytiloides labiatus Zone)

58) Achomosphaera simplex sp. nov. This species has its highest occurrence in the M. labiatus Zone at Beachy Head (Fig. 39; BH 15).

59) Achomosphaera verdieri Below. This species has not previously been recorded from the Anglo-Paris Basin. It first appears in the M. labiatus Zone at Beachy Head (Fig. 32; BH 14), although it was originally described from Aptian/Albian sediments from Morocco (Below, 1981).

60) Disphaeria munda (Davey & Verdier) Norvick. The previously recorded top occurrence of this species in the Anglo-Paris Basin was in the Lower Cenomanian (Davey & Verdier, 1973; Foucher, 1981). Its last appearance in the M. mantelli Zone at Beachy Head (Fig. 32; BH 4) and at Asham (Fig. 38; BAT 6) would appear to confirm this. The solitary species recorded from the M. labiatus Zone at Beer Roads in Devon (Fig. 40; BR 3) is probably reworked.

61) Hystrichosphaeridium tubiferum brevispinum (Davey & Williams) Lentin

& Williams. This species has only previously been found in Eocene sediments from the Anglo-Paris Basin. Its appearance, therefore, in the Craie à _l._ _labiatus_ at Ports (Fig. 36; Po 11), and the Seaton Chalk in Devon (Fig. 40; BR 3) suggest a more extensive range than previously realised.

62) _Hystrichosphaeridium difficile_ Manum & Cookson. Although Davey (1969), recorded this species from the Cenomanian at Fetcham Mill, Surrey, during the present study, _H. difficile_ was not found in sediments older than Turonian. This latter occurrence agrees with Foucher (1981), who records the first appearance of this species at the base of the _C. woollgari_ Zone (= topmost _Mytiloides labiatus_ Zone) in N.W. France.

63) _Microdinium setosum_ Sarjeant. The last appearance of this species is normally associated with the top of the Cenomanian (Clarke & Verdier, 1967; Davey, 1969; Foucher, 1980). Its occurrence in the Craie à _l._ _labiatus_ at Ports (Fig. 36; Po 11) indicates a more extensive range than previously realised.

64) _Oligosphaeridium anthophorum_ (Cookson & Eisenack) Lentin & Williams. The appearance of this species in the Craie à _l._ _labiatus_ (early Turonian) at Ports (Fig. 36; Po 2) is the youngest known record in the Anglo-Paris Basin. However, the poor preservation, and general scarcity of material suggest that the specimens may be reworked.

65) _Senoniasphaera rotundata_ Clarke & Verdier. Foucher (1981) records the first appearance of this species at the base of the _C. woollgari_ Zone (topmost _M. labiatus_ Zone), in N.W. France. It appears somewhat earlier, in the _M. labiatus_ Zone, at Ports (Fig. 36; Po 3).

66) _Subtilisphaera pontis-mariae_ (Deflandre) Lentin & Williams. This species first appears in the Middle Chalk at Beachy Head (Fig. 39; BH 14) Its previous earliest record in the Anglo-Paris Basin was from the late Turonian (Foucher, 1979).

67) _Wallodinium anglicum_ (Cookson & Hughes) Lentin & Williams. The disappearance of this species at the top of the _M. labiatus_ Zone at Beachy

Head (Fig. 39; BH 15) corresponds with the previously accepted range for this species in the Anglo-Paris Basin (Foucher, 1982).

4.1.8 Middle Turonian (<u>Terebratulina lata</u> Zone)

68) <u>Achomosphaera sagena brevisinus</u> subsp. nov.. This rare subspecies first appears in the <u>T. lata</u> Zone at Beachy Head (Fig. 39; BH 17).

69) <u>Cyclonephelium clathromarginatum</u> Cookson & Eisenack. The last appearance of this species occurs in the <u>T. lata</u> Zone at the Beer Stone Adit (Fig. 40; Adit 1). It has not previously been recorded from the Anglo-Paris Basin.

70) <u>Florentinia mantelli</u> (Davey & Williams) Davey & Verdier. This species disappears at the base of the <u>T. lata</u> Zone in S.E. Devon (Fig. 40; Hall 1). It has also been recorded from the low Turonian in France (Davey & Verdier, 1976; Foucher, 1982).

71) <u>Florentinia resex</u> Davey & Verdier. The last appearance of <u>F. resex</u>, at the top of the <u>T. lata</u> Zone at Beachy Head (Fig. 39; BH 17), corresponds with previous stratigraphic records from the Anglo-Paris Basin.

72) <u>Leberidocysta defloccata</u> (Davey & Verdier) Stover & Evitt. The last appearance of <u>L. defloccata</u> at the top of the <u>T. lata</u> Zone at Beachy Head (Fig. 39, BAT 19), is the highest recorded occurrence of this species in the Anglo-Paris Basin.

73) <u>Palaeohystrichophora paucisetosa</u> Deflandre. This species first appears at the top of the <u>T. lata</u> Zone at Beachy Head (Fig. 39; BAT 19). The only previous record of this species is from the ?Senonian of N.W. France, by Deflandre (1943).

74) <u>Spiniferites</u> ? <u>dentatus</u> (Gocht) Lentin & Williams; emend. Duxbury. The last appearance of this species at the top of the <u>T. lata</u> Zone at Beachy Head (Fig. 39; BAT 19) marks the highest recorded occurrence of this form in the Anglo-Paris Basin.

75) <u>Tanyosphaeridium salpinx</u> Norvick. This species has its last occur-

rence at the top of the I. lata Zone at Beachy Head (Fig. 39; BH 17).

4.1.9 High Turonian (Holaster planus Zone)

76) Bacchidinium polypes clavulum (Davey) Lentin & Williams. The
previously recorded top occurrence of this species was from the Cenomanian of
S.E. England (Davey, 1969). Its appearance in the H. planus Zone at Beachy
Head (Fig. 39; BH 16), therefore, marks a significant extension of the
known range.

77) Cleistosphaeridium armatum brevispinosum subsp. nov.. This subspe-
cies has its last recorded occurrence in the Seaton Chalk (Pinhay Member) at
Annis' Knob in S.E. Devon (Fig. 40; AK 2).

78) Dapsilidinium laminaspinosum (Davey & Williams) Lentin & Williams.
Foucher (1982) recorded the previous highest occurrence of this species from
low Turonian sediments in the Civray Borehole (W. France). Its last appear-
ance in the present study is from the H. planus Zone at Annis' Knob (Fig.
40; AK 5).

79) Hapsocysta dictyota Davey. The last appearance of this species
occurs in the H. planus Zone at Beachy Head (Fig. 39; BH 16).

80) Hystrichosphaeridium bowerbankii Davey & Williams. This species has
only previously been recorded from the Albian-low Cenomanian in the
Anglo-Paris Basin (Davey & Williams, 1966b). Its last appearance in the H.
planus Zone at Beachy Head (Fig. 39; BH 16), therefore, marks a significant
extension of the known range.

81) Pterodinium cornutum Cookson & Eisenack. The last appearance of
this species in the H. planus Zone at Beachy Head (Fig. 39; BH 16) is the
highest known stratigraphic record of this form in the Anglo-Paris Basin.

4.2   Summary of microplankton biostratigraphy

4.2.1 Upper Albian (<u>Stoliczkaia</u> <u>dispar</u> Zone).

First appearances :- <u>Achomosphaera</u> <u>simplex</u>, <u>Apteodinium</u> <u>reticulatum</u>, <u>Cribroperidinium</u> <u>exilicristatum</u>, <u>Endoceratium</u> <u>dettmanniae</u>, <u>Florentinia</u> <u>deanei</u>, <u>Heterosphaeridium</u> ? <u>heteracanthum</u>, <u>Hystrichosphaeridium</u> <u>bowerbankii</u>, <u>Odontochitina</u> <u>costata</u>, <u>Oligosphaeridium</u> <u>reticulatum</u>, <u>Ovoidinium</u> <u>verrucosum</u> <u>ostium</u>, <u>O.</u> <u>verrucosum</u> <u>verrucosum</u>, <u>Palaeohystrichophora</u> <u>infusorioides</u>, <u>Pervosphaeridium</u> <u>bifidum</u>, <u>P.</u> <u>cenomaniense</u>, <u>P.</u> <u>pseudohystrichodinium</u>, <u>Prolixosphaeridium</u> <u>conulum</u> and <u>Tanyosphaeridium</u> <u>salpinx</u>. Of these, only <u>Apteodinium</u> <u>reticulatum</u> does not occur in post-Albian sediments.

4.2.2 Lower Cenomanian (<u>Mantelliceras</u> <u>mantelli</u> Zone)

First appearances :- <u>Cleistosphaeridium</u> <u>armatum</u> <u>brevispinosum</u>, <u>Epelidosphaeridia</u> <u>tuberculata</u>, <u>Florentinia</u> <u>ferox</u> and <u>Cyclonephelium</u> <u>clathromarginatum</u>.

Last appearances :- <u>Cyclonephelium</u> <u>eisenackii</u>, <u>Ovoidinium</u> <u>verrucosum</u> <u>ostium</u>, <u>Ovoidinium</u> <u>verrucosum</u> <u>verrucosum</u>, <u>Palaeoperidinium</u> <u>cretaceum</u>, <u>Protoellipsodinium</u> <u>spinocristatum</u> and <u>Rhombodella</u> <u>paucispina</u>.

4.2.3 Middle Cenomanian (<u>Acanthoceras</u> <u>rhotomagense</u> Zone)

First appearances :- <u>Codoniella</u> <u>campanulata</u>, <u>Litosphaeridium</u> <u>urna</u>, <u>Microdinium</u> <u>distinctum</u>, and <u>Palaeostomocystis</u> <u>reticulata</u>.

Last appearances :- <u>Cribroperidinium</u> <u>exilicristatum</u>, <u>Endoceratium</u> <u>dettmanniae</u>, <u>Epelidosphaeridia</u> <u>spinosa</u>, and <u>E.</u> <u>tuberculata</u>.

4.2.4 Upper Cenomanian (<u>Calycoceras</u> <u>naviculare</u> Zone)

First appearances :- <u>Cyclonephelium</u> <u>compactum</u>, <u>Litosphaeridium</u> <u>medius</u>.

Last appearances :- <u>Ascodinium acrophorum</u>, <u>Craspedodinium indistinctum</u>, <u>Litosphaeridium siphoniphorum</u>.

4.2.5 Upper Cenomanian (<u>Metolcoceras geslinianum</u> Zone)

First appearances :- <u>Isabelidinium acuminatum</u>, <u>Dinopterygium medusoides</u> and <u>Pyxidinopsis parvum</u>.

Last appearances :- <u>Apteodinium maculatum</u>, <u>Litosphaeridium medius</u>, <u>L.</u> <u>urna</u> and <u>Nematosphaeropsis densiradiata</u> disappear.

4.2.6 Upper Cenomanian (<u>Neocardioceras juddii</u> Zone)

No appearances or disappearances of cyst taxa were recorded from this zone during the present study.

4.2.7 Low Turonian (<u>Mytiloides labiatus</u> Zone)

First appearances :- <u>Achomosphaera verdieri</u>, <u>Hystrichosphaeridium tubiferum brevispinum</u>, <u>H. difficile</u>, <u>Senoniasphaera rotundata</u>, <u>Subtilisphaera pontis-mariae</u>.

Last appearances :- <u>Achomosphaera simplex</u>, <u>Microdinium setosum</u>, <u>Wallodinium anglicum</u>.

4.2.8 Mid Turonian (<u>Terebratulina lata</u> Zone)

First appearances :- <u>Achomosphaera sagena brevispinus</u>, <u>Palaeohystrichophora paucisetosa</u>.

Last appearances :- <u>Cyclonephelium clathromarginatum</u>, <u>Florentinia mantellii</u>, <u>F. resex</u>, <u>Leberidocysta defloccata</u>, <u>Spiniferites</u> ? <u>dentatus</u>, <u>Tanyosphaeridium salpinx</u>.

4.2.9 High Turonian (<u>Holaster planus</u> Zone)

First appearances :- None.

Last appearances :- <u>Bacchidinium polypes clavulum</u>, <u>Cleistosphaeridium armatum brevispinosum</u>, <u>Dapsilidium laminaspinosum</u>, <u>Hapsocysta dictyota</u>, <u>Hystrichosphaeridium bowerbankii</u>, <u>Pterodinium cornutum</u>.

Fig. 30   Microplankton Distribution Chart

From

The Mid-Cretaceous

Of

The Western Anglo-Paris Basin

4.3 Biostratigraphy of sections sampled in western France.

4.3.1 Livet Quarry, Cordebugle (Figs. 3, 4 & 31)

4.3.1.1 - Glauconie de base

Macrofauna

No macrofaunal data is available for the lowest 3.5m of the Glauconie de base at this locality. Bigot (1895), however, recorded an ammonite fauna from the lower part of this Formation at Villers-sur-mer (Fig. 1) which indicated an Albian age for at least part of the succession. At Livet Quarry, Juignet (1974) recorded an abundant fauna from just above an omission surface, 3.5m above the base of the section (Fig. 4), which included specimens of Sharpeiceras laticlavium (Sharpe) as well as Cyclothyris sp. and Spondylus striatus (J. Sowerby). This assemblage is indicative of the Neostlingoceras carcitanensis Zone (basal subzone of the broad Mantelliceras mantelli Zone) of lowest Cenomanian age (Kennedy, 1969).

Microplankton

There are no dinoflagellate cysts diagnostic of the S. dispar Zone, present in the basal sample from this quarry (Fig. 31; Cord 1), although the presence of Cyclonephelium eisenackii and Ellipsodinium rugulosum indicate that the sediments are no older than the Upper Albian, Mortoniceras inflatum ammonite zone (Davey & Verdier, 1971). Samples Cord 2 and Cord 3, which were collected from above a poorly-defined omission surface (Fig. 4), contain a number of stratigraphically significant taxa. The first appearances of Endoceratium dettmannae, Florentinia deanei, Ovoidinium verrucosum verrucosum, Pervosphaeridium bifidum and Prolixosphaeridium conulum indicate

strata of latest Albian age (_Stoliczkaia dispar_ Zone)(see 4.2.1). Definite
Lower Cenomanian indicators are rare, but the first appearance of
Cleistosphaeridium armatum brevispinosum (Fig. 31; Cord 4) and
Epelidosphaeridia tuberculata (Fig. 31; Cord 6) is taken to indicate that
the upper part of the Glauconie de base belongs to the _Neostlingoceras
carcitanensis_ Zone (basal subzone of the _M. mantelli_ Zone) of earliest Ceno-
manian age. Based purely on the cyst distribution, the age of the lower part
of this formation appears to be topmost Albian, while the upper part is basal
Cenomanian.

It is interesting to note that the cyst distribution in Samples Cord 2,
and Cord 3, is very similar to that present in the lower part of the Glaucon-
itic Marl at Asham Pit (Fig. 38). The presence of an omission surface, with
phosphatized pebbles, just below Cord 2 (Fig. 31), overlain by marly glau-
conitic chalks leads one to suspect that this part of the succession may be
laterally equivalent to the Glauconitic Marl (see 4.4.1).

4.3.1.2 - Craie glauconieuse

Macrofauna

Juignet (1974) recorded numerous examples of _Schloenbachia subvarians_
Spath, _Neostlingoceras carcitanensis_ (Matheron), _Anisoceras jacobi_ Breis-
troffer, _Hypophlites falcatus falcatus_ (Mantell), _H. arausionensis_ (Hebert &
Munier-Chalmas) and _Mantelliceras cantium_ Spath from the Craie glauconieuse
at this locality. This assemblage indicates that the sediments belong to the
Neostlingoceras carcitanensis Zone (basal _Mantelliceras mantelli_ Zone) and
are lowest Cenomanian in age.

Microplankton

The last appearances of _Cyclonephelium eisenackii_ (Fig. 31; Cord 12), _Ovoidinium verrucosum ostium_ (Fig. 31; Cord 10) and _Ovoidinium verrucosum verrucosum_ (Fig. 31; Cord 10) are taken to indicate that the Craie glauconieuse exposed here is earliest Cenomanian (_Neostlingoceras carcitanensis_ Zone) in age. It is important to note, however, that the majority of the microplankton species present have more extensive ranges than is apparent here (Fig. 30), a feature which becomes increasingly marked as one moves up section from sandy, glauconitic chalks, into creamy-brown, marly chalks with large, irregular flint bands. This indicates that the distinct levels of cyst appearances, and disappearances (e.g. Fig. 31; Cord 10 & 12), are probably more the result of local facies control, than evolution (see Chapter 5).
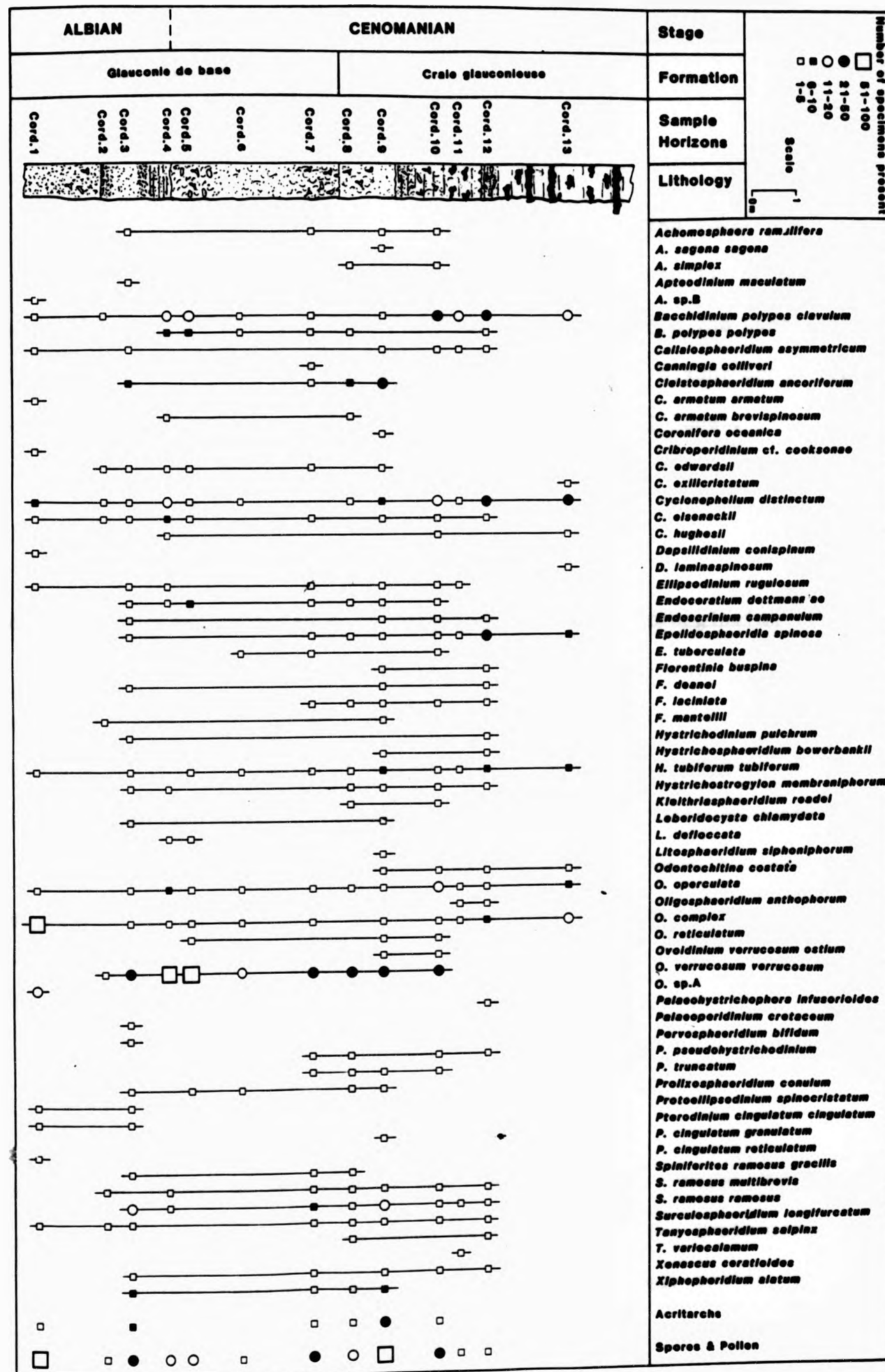
Fig.31 Distribution Chart Of Palynomorphs From The Mid-Cretaceous Of Livet Quarry, Cordebugle, France

4.3.2 Hameau-Fredét Quarry, Fumichon (Figs. 5, 6 & 32)

4.3.2.1 – Craie glauconieuse

Macrofauna

Very little macrofaunal data is available for most of the lower part of
this exposure. Juignet (1974), has correlated it with faunally richer suc-
cessions in the Pays d'Ouche and Lieuvin (Fig. 1) and regards the upper part
of the Craie glauconieuse as belonging to the Mantelliceras dixoni Zone (top-
most subzone of the Lower Cenomanian, Mantelliceras mantelli Zone).

Microplankton

The first recorded appearance of Cyclonephelium clathromarginatum (Fig.
32;   HF 9A) is taken here to indicate the Mantelliceras dixoni Zone, of the
uppermost Lower Cenomanian. Operculodinium sp.A, which is only recorded from
this exposure, also has its first appearance in this zone. However, all of
the remaining dinoflagellate cysts recorded from the Craie glauconieuse, at
this locality, have more extensive ranges than is apparent here, suggesting a
strong degree of facies control affecting their distribution.

4.3.2.2 – Craie de Rouen

Macrofauna

The Craie de Rouen, which rests on the surface of the "Rouen No.   1"
Hardground (Fig. 6), contains more fauna than the underlying Craie glaucon-
ieuse. Juignet (1974), recorded numerous specimens of Aequipecten aspera
(Lamark), Lima sp., Neithea aequicostata d'Orbigny and Exogyra obliquata
(Pulteney) from the basal bed of the former which he correlates with the

well-known "horizon de Rouen à Turrilites costatus" (= "l'horizon fossilifère
de Rouen"). This indicates that the lower part of the Craie de Rouen belongs
to the Turrilites costatus Zone of Kennedy (1969) (i.e. basal subzone of the
Middle Cenomanian, Acanthoceras rhotomagense Zone). Specimens of Inoceramus
cripposi Mantell, recorded from just below the "Rouen No. 3" ommission sur-
face (Juignet, 1974), confirm a mid-Cenomanian age for this part of the
succession.

Microplankton

As in the Craie glauconieuse, the cyst distribution at this locality is
thought to be predominantly facies controlled (see Chapter 5). However,
biostratigraphically significant occurrences include the first appearance of
Palaeostomocystis reticulata (Fig. 32; HF 15B) which has not been recorded
below the Turrilites costatus Zone (basal subzone of the Middle Cenomanian,
A. rhotomagense Zone) at any of the other sites examined. Also the occur-
rence of Cleistosphaeridium armatum brevispinosum indicates that the
sediments are definitely post-Albian, while the presence of Cyclonephelium
clathromarginatum is an indication that the Craie de Rouen is no lower than
topmost Lower Cenomanian (section 4.2.2). The continued presence of
Cribroperidinium exilicristatum, and Epelidosphaeridia spinosa in the topmost
sample at Hameau-Frédet (Fig. 32; HF 15), suggests that the succession is
no younger than mid-Cenomanian in age (section 4.2.3). Therefore the palyno-
logical evidence appears to corroborate the macrofaunal data in assigning the
Craie de Rouen to the lowest Middle Cenomanian at this locality.

Fig. 32 Distribution Chart Of Palynomorphs From The Mid-Cretaceous Of Hameau-Frédet Quarry, Fumichon, France
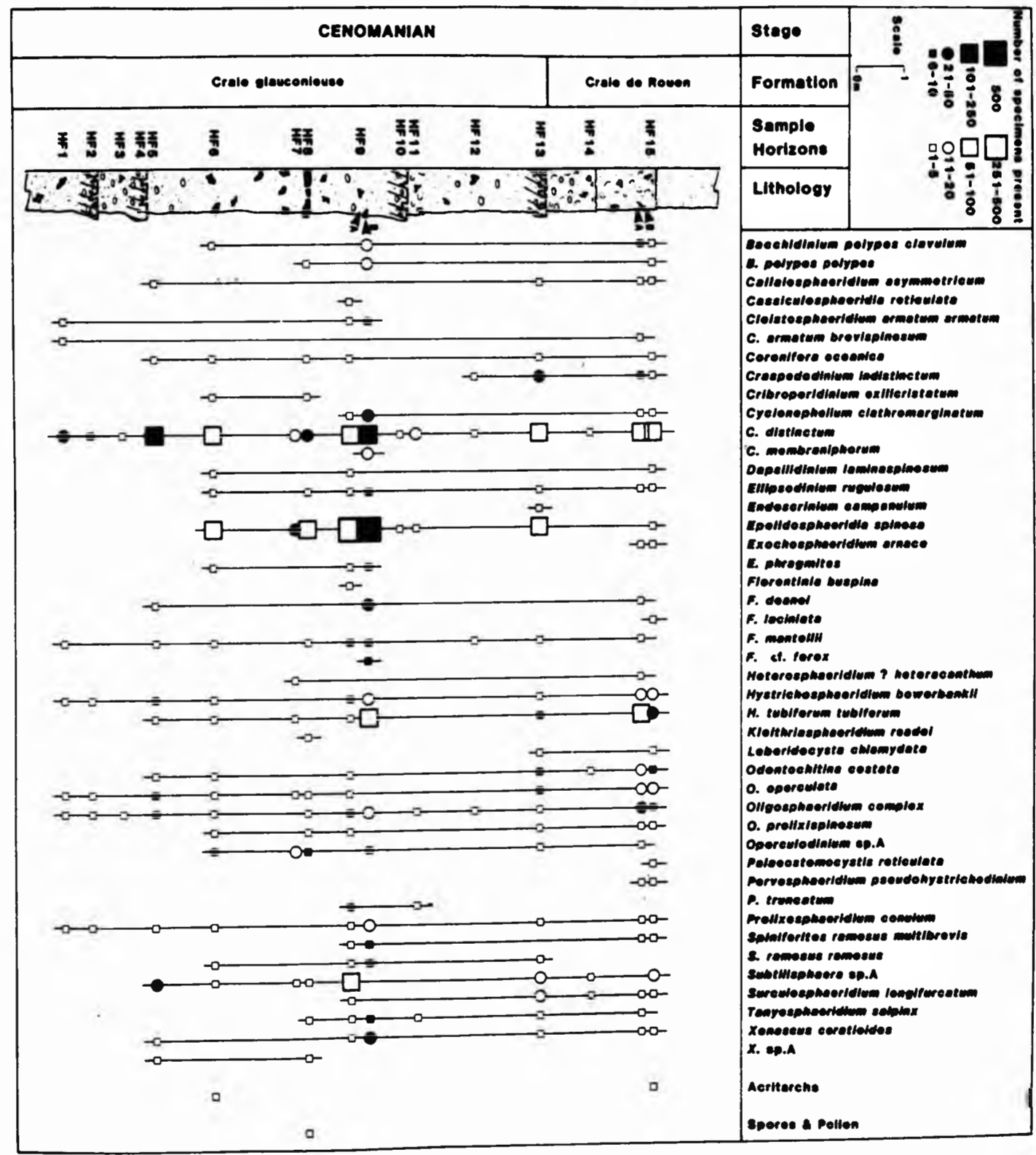
4.3.3 Canteloup Quarry, Fumichon (Figs. 5, 7 & 33)

4.3.3.1   – Craie de Rouen

Macrofauna

The lateral equivalent of the "horizon de Rouen à _Turrilites_ _costatus_" can be found resting on the surface of the "Rouen No. 1" Hardground at the base of this quarry (Figs. 5,7). Juignet (1974) recorded numerous examples of _Turrilites_ _acutus_ Passy, _T._ _costatus_ Lamark, _Aequipecten_ _aspera_, _Inoceramus_ sp., and _Avellana_ _cassis_ d'Orbigny which suggest that this part of the succession belongs to the _Turrilites_ _costatus_ Zone (basal subzone of the Middle Cenomanian, _Acanthoceras_ _rhotomagense_ Zone). Juignet (1974) also recorded a single specimen of _Holaster_ _subglobosus_ Leske from just above "Rouen No. 3" omission Surface (Fig. 7), which is taken to indicate the _Turrilites_ _costatus_ Zone. There are no macrofaunal records for the upper part of the succession at Canteloup (Fig. 7).

Microplankton

The most biostratigraphically significant cyst appearances and disappearances are the top occurrence of _Epelidosphaeridia_ _spinosa_ (Fig. 33; Cant 8), which has previously not been recorded from sediments lower than the Middle Cenomanian (section 4.2.3), and the first appearance of _Cyclonephelium_ _compactum_ (Fig. 33; Cant 13)(section 4.2.4). The latter species is regarded herein as indicative of the _Calycoceras_ _naviculare_ Zone, which suggests that the upper part of the sequence exposed at Canteloup (at least above sample Cant 13; Fig. 7 & 33), is of earliest, late Cenomanian age. None of the other Middle Cenomanian, and lower Upper Cenomanian index species (sections 4.2.3 & 4.2.4) were found at this locality. Again, as at Hameau-Frédet (Fig. 32), the most important control on the cyst distribution appears to be

local facies variations, and not evolution.

Fig. 33 Distribution Chart Of Palynomorphs From The Mid-Cretaceous Of Canteloup Quarry, Fumichon, France
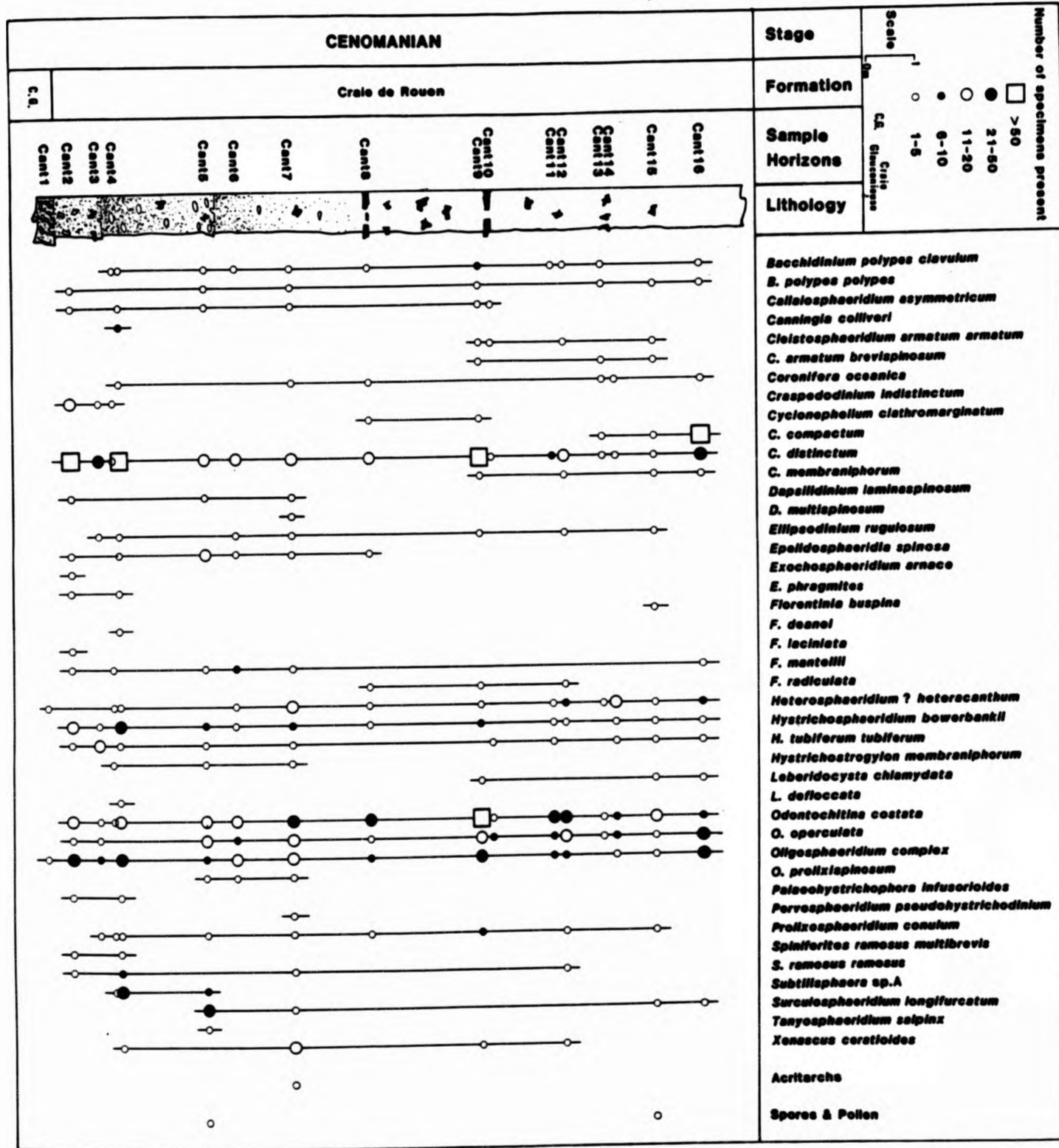
4.3.4   Les Fosses Blanches Quarry, La Caluyere (Figs. 8, 9 & 34)

4.3.4.1   - Sables du Perche

Macrofauna

No macrofauna has been collected from the Sables du Perche at this quarry, but a specimen of the brachiopod, _Gemmarcula menardi_ (Lamark) was recorded from the top of this Formation in a nearby exposure (i.e. Grand Crozet à Duneau) which is associated with the _Calycoceras naviculare_ Zone (Juignet, 1974).

Microplankton

The 3 samples collected from this formation were found to be palynologically barren.

4.3.4.2   - Marnes à _Ostrea biauriculata_

Macrofauna

Abundant specimens of _Pycnodonte biauriculata_ (Lamark) were found in the soft, glauconitic chalks which overlie the Sables du Perche at this locality (Fig. 9). The presence of large numbers of this bivalve is indicative of the Upper Cenomanian, _C. naviculare_ Zone (Juignet, 1974).

Microplankton

One sample was processed (Fig. 34; Cal 1) which contained a moderate dinoflagellate cyst assemblage. Almost all of the species found have more extensive ranges than is evident here, but the last recorded appearance of _Craspedodinium indistinctum_ is worthy of note. The distinctive cyst distribution pattern shown on Fig. 34 gives an indication of how important it is

to examine closely the relationships between lithology, sedimentary environ-
ment, and cyst preservation (see Chapter 5).

4.3.4.3   – Sables à _Catopygus obtusus_

Macrofauna

At this locality, the Sables à _C. obtusus_ are represented by a thin
indurated limestone, the "Bousse" Hardground (Juignet, 1974). There are no
macrofaunal records for this level at Les Fosses Blanches, but Juignet (1974)
recorded a relatively rich assemblage from its lateral equivalent exposed at
Grand Crozet à Duneau (Juignet, 1974). This included fragments of
Metoicoceras geslinianum (d'Orbigny) and _Sciponoceras gracile_ (Shumard) as
well as specimens of _Catopygus obtusus_ Desor, Cotteau & Triger, _Nucleolites
parallelus_ (Dixon), _Exogyra columba gigas_ (Deshayes) and _E. columba media_
(Deshayes) which are typical of the Upper Cenomanian, _Metoicoceras
geslinianum_ Zone (Wright & Kennedy, 1981).

Microplankton

Only 5 species of dinoflagellate cyst were recorded from this formation,
none of which are biostratigraphically significant at this locality.
However, the nature of the cyst assemblage, i.e. dominated by specimens of
Cyclonephelium distinctum, _Hystrichosphaeridium bowerbankii_, _Odontochitina
costata_, and _Oligosphaeridium complex_, is a recurrent feature at several
localities (e.g. Fig. 40; AK 2), and its significance will be discussed
later (Chapter 5).

4.3.4.4   – Craie à _Terebratella carantonensis_

Macrofauna

Very little macrofauna has been recorded from this formation at this quarry although several rolled and phosphatized specimens of Metoicoceras cf. geslinianum (d'Orbigny) and Sciponoceras gracile (Shumard) have been found at its base (Juignet, 1974). Wright & Kennedy (1981) state that the only indigenous ammonite found in this formation so far, is a single specimen of Neocardioceras juddii juddii (Barrois & Guerne) (see Woodroof, 1981) from Le Moulin Ars Quarry, St. Calais (Figs. 10 & 11), which indicates the presence of the topmost Cenomanian, N. juddii Zone.

Microplankton

Only 5 cyst species were found in the sample from this formation (Fig. 34; Cal 3) none of which are stratigraphically significant at this locality.

4.3.4.5 - Craie à Inoceramus labiatus
Macrofauna

Juignet (1974) recorded numerous specimens of M. labiatus (Schlotheim) and Orbirhynchia cuvieri (d'Orbigny) from the marly chalks overlying the Craie à I. carantonensis, indicating an early Turonian age for the Craie à I. labiatus. Woodroof (1981) placed the lower part of the latter formation in his Mytiloides cf. opalensis Zone, while the top of the section (including samples Cal 7 & 9; Fig. 34) lie within his Mytiloides mytiloides Zone.

Microplankton

Dinoflagellate cysts are very rare in the Craie à I. labiatus at this locality, and those which are present are not biostratigraphically significant.

Fig. 34 Distribution Chart Of Palynomorphs From The Mid-
Cretaceous Of Les Fosses Blanche Quarry, Caluyere, France

4.3.5 Bois du Galet Marl Pit, St. Sylvestre-de-Cormeilles (Figs. 12, 13 & 35)

4.3.5.1   - Craie à _Actinocamax plenus_

Macrofauna

No diagnostic macrofauna were found in the formation at this locality.
However, by correlating it with faunally richer successions in the Lieuvin
and the Pays de Caux (Figs. 1 & 2), Juignet (1974), assigned the Craie à _A._
plenus to the _Metoicoceras geslinianum_ Zone (Upper Cenomanian).

Microplankton

The three samples which were processed from this formation (Figs.   35;
St.S.   1, 2 & 3) contained moderately rich dinoflagellate cyst assemblages.
The presence of _Cyclonephelium compactum_ (Fig. 35; St.   S.   3) indicates
that the Craie à _A._ _plenus_ is at least late Cenomanian (_C._ _naviculare_ Zone)
in age.   Unfortunately, however, none of the cyst species regarded as indica-
tive of the _M._ _geslinianum_ Zone (section 4.2.5) were found at this locality.

4.3.5.2   - Craie noduleuse

Macrofauna

Specimens of _Inoceramus pictus_ (Sowerby) were recorded from the lower
part of this formation which indicate a topmost Cenomanian age. Due to the
lack of ammonite data, Juignet (1974) denoted the level between the top of
"Antifer No. 3" Hardground and the incoming of _Mytiloides labiatus_, Horizon
A (Juignet et al., 1973). This term is no longer used and the topmost Ceno-
manian is regarded here (Chapter 2; section 2.6) as belonging to the _N._
Juddii Zone (Wright & Kennedy, 1981).

Microplankton

Two samples were processed for palynomorphs but they contained poor assemblages of little biostratigraphic value, although, as discussed above, the presence of _Cyclonephelium compactum_, indicates that the sediments are no older than late Cenomanian (_C. naviculare_ Zone) in age. The poor recovery of cysts in nodular chalks seen here is a persistent feature throughout the exposures examined during the present study (see Chapter 5).

4.3.5.3   - Craie marneuse

Macrofauna

The only macrofauna found in this formation at St. Sylvestre were occasional specimens of _M. labiatus_.

Microplankton

Four samples were processed for palynomorphs all of which produced relatively poor dinoflagellate cyst assemblages. None of the forms present are biostratigraphically significant.

Fig. 35 Distribution Chart Of Palynomorphs From The Mid-Cretaceous Of St. Sylvestre, France
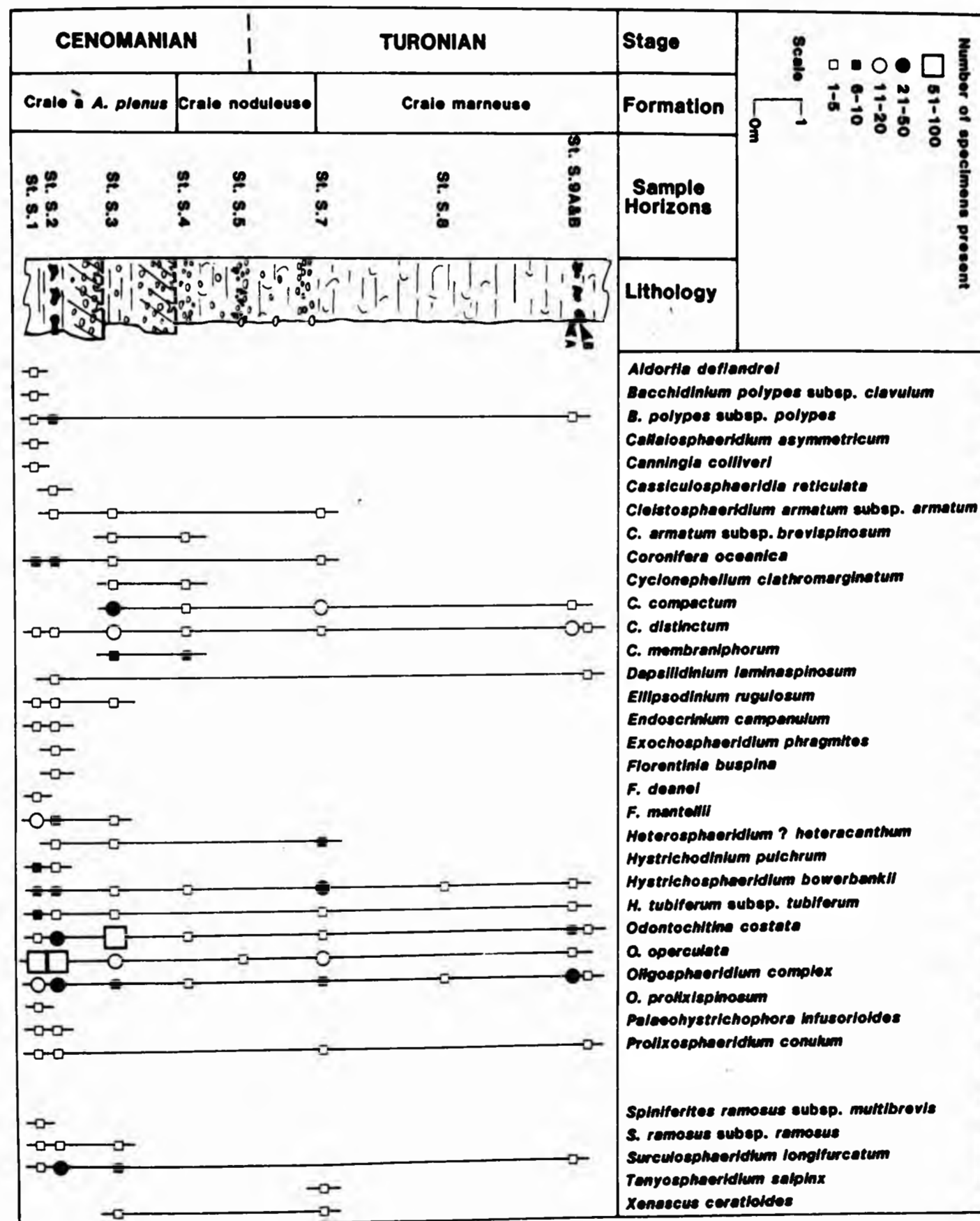
4.3.6 Ports (Figs. 14, 15 & 36)

4.3.6.1   - Craie à _Inoceramus labiatus_

Macrofauna

Macrofaunal records are very scarce in this formation which is regarded as belonging to the low Turonian, _I. labiatus_ Zone (Lecointre, 1947). Recently, however, Woodroof (1981) subdivided this exposure using a zonation based on the incoming of certain key inoceramid species. In this scheme, the lower part of the section (i.e. Fig. 36; Po 9-13) lies within a Zone of _Mytiloides_ cf. _opalensis_, while the overlying sediments belong to a Zone of _Mytiloides mytiloides_ (Woodroof, 1981: see section 4.4.2.3 for full inoceramid zonation).

Microplankton

Rich and diverse dinoflagellate cyst assemblages were recorded from several of the samples collected at this locality, particularly in the lower part of the section (Fig. 36; Po 9-13). It is interesting to note here that the richest assemblages correspond precisely with the _Mytiloides_ cf. _opalensis_ Zone of Woodroof (1981), indicating the possible importance of both fossil groups as palaeoenvironmental, as well as biostratigraphic indicators. The first appearances of _Hystrichosphaeridium tubiferum brevispinosum_, _H. difficile_ and _Senoniasphaera rotundata_, and last appearance of _Microdinium setosum_ are taken here to confirm an early Turonian (_M. labiatus_ Zone) age for the Craie à _I. labiatus_ exposed here. Also, the continued presence of species such as _Florentinia mantellii_ and _Leberidocysta defloccata_ (which have a top occurrence in the _I. lata_ Zone; section 4.2.8) at the top of the section at Ports, is regarded here as further evidence of an early Turonian age for this formation.
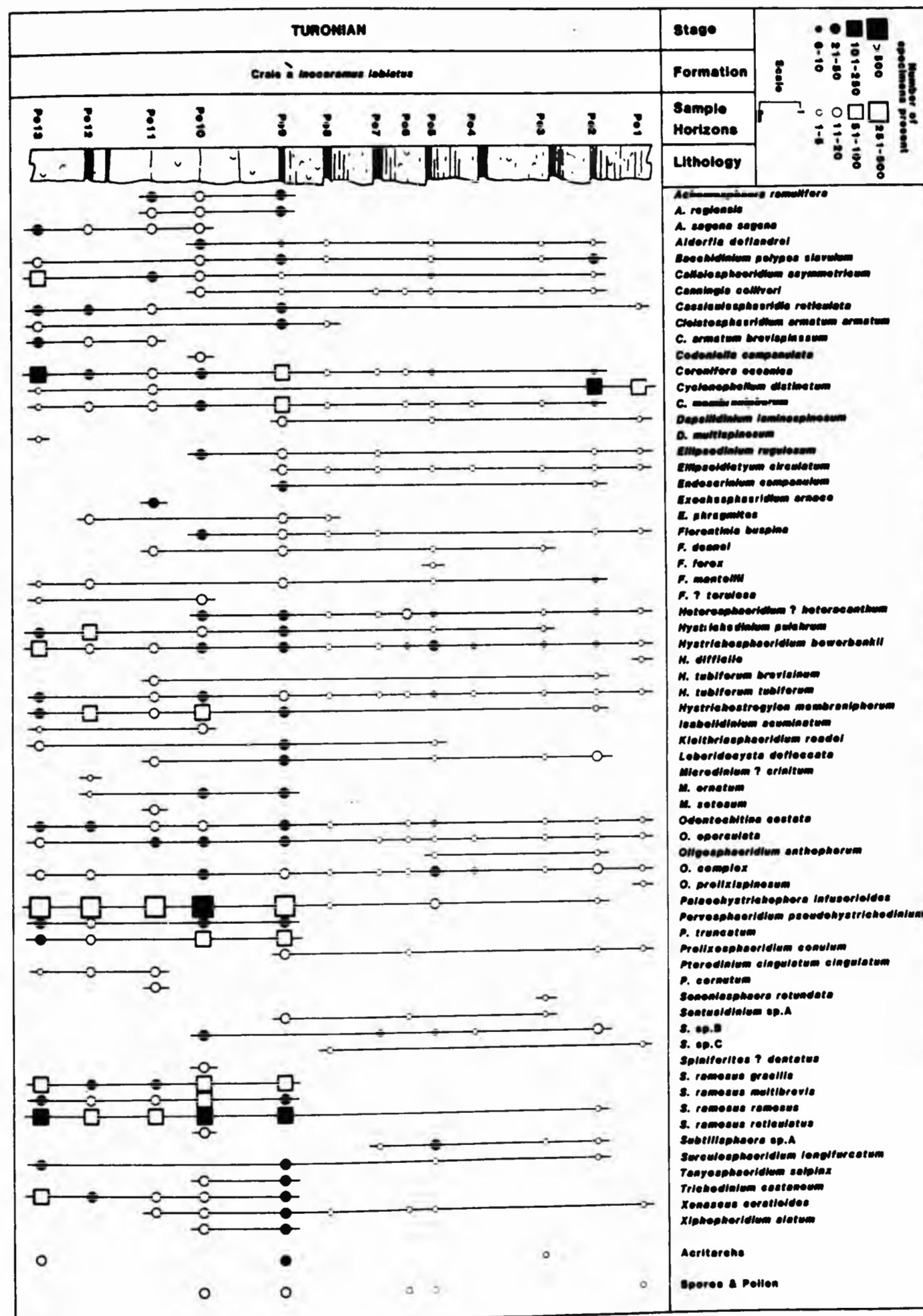
Fig. 36 Distribution Chart Of Palynomorphs From The Mid-Cretaceous Of Ports, France

4.3.7 Fontevraud Quarry (Figs. 16, 17 & 37)

4.3.7.1 – Craie à _Inoceramus_ _labiatus_

Macrofauna

Woodroof (1981) originally placed the lower part of this quarry in his basal Turonian, _Mytiloides_ cf. _opalensis_ Zone. However, the section has since been partially obscured, and the lowest Zone now exposed is that of _Mytiloides_ _mytiloides_ (Woodroof, 1981). The upper part of the Craie à _I._ _labiatus_ lies within Woodroofs' Zone of _Mytiloides_ cf. _labiatus_ (Woodroof, 1981), and the junction between the two zones is taken at a prominent marl seam (Fig. 36; Fo 6), approximately 1m above the base of the quarry.

Microplankton

There is a lack of biostratigraphically significant dinoflagellate cysts in the Craie à _I._ _labiatus_ at this locality, although the presence of _Senoniasphaera_ _rotundata_ (Fig. 38; Fo 5) at least indicates a post-Cenomanian age. However it is interesting to note that , as at Ports, there appears to be a distinct relationship between the dinoflagellate cyst distribution and the inoceramids (see Chapter 5).

4.3.7.2 – Craie micacée

Macrofauna

This formation lies within the Zone of _Mytiloides_ cf. _labiatus_ as proposed by Woodroof (1981). Near the top of the Craie micacée, Woodroof (1981) also recorded specimens of _Kamerunoceras_ _salmuriense_ (Courtiller), _Lecointriceras_ _fleuriasianum_ (d'Orbigny) and _Eutrephoceras_ sp. which indi-

cate the <u>Collignonoceras</u> <u>woollgari</u> Zone (Fig. 2).

Microplankton

The cyst assemblages recovered here are not particularly significant biostratigraphically, although the presence of <u>Senoniasphaera</u> <u>rotundata</u> together with <u>Cyclonephelium</u> <u>clathromarginatum</u>, <u>Florentinia</u> <u>mantellii</u>, and <u>Tanyosphaeridium</u> <u>salpinx</u> is considered to be definite evidence of the <u>M</u>. <u>labiatus</u> Zone.

Fig. 37 **Distribution Chart Of Palynomorphs From The Mid-Cretaceous Of Fontevraud, France**
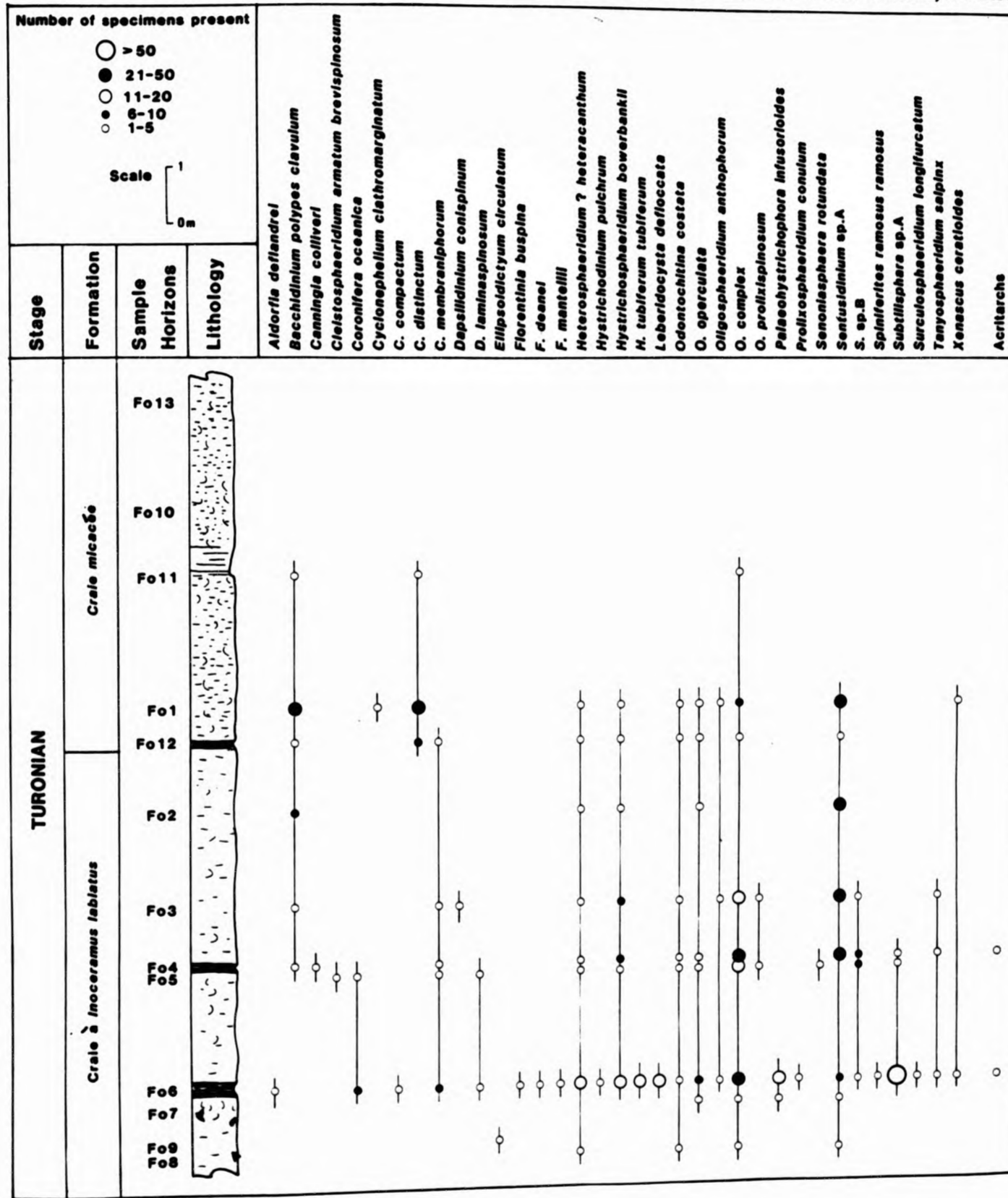
4.4 Biostratigraphy of sections sampled in southern England

4.4.1 Asham Pit, Beddingham (Figs. 22, 23 & 38)

4.4.1.1 — Upper Greensand

Macrofauna

No macrofaunal data are available for the age of the buff silty clays underlying the Glauconitic Marl at this locality (Fig. 23), although they are generally regarded as belonging to the topmost Albian, Stoliczkaia dispar Zone (Kennedy, 1969; Owen, 1975).

Microplankton

The presence of Cribroperidinium exilicristatum, Oligosphaeridium reticulatum, Pervosphaeridium bifidum, P. pseudohystrichodinium and Psaligonyaulax deflandrei in the basal sample at Asham (Fig. 38; BAT 5) indicate an age no older than the latest Albian, Stoliczkaia dispar Zone (section 4.2.1). Furthermore, the first appearances of Achomosphaera simplex, Apteodinium reticulatum, Disphaeria macropyla, Heterosphaeridium ? heteracanthum, Nematosphaeropsis densiradiata, Odontochitina costata, Palaeohystrichophora infusorioides and Palaeoperidinium cretaceum in samples BAT 4 and BAT 3 (Fig. 38) are considered to definitely indicate a late Albian (Stoliczkaia dispar Zone) age for the Upper Greensand in this area. However, the occurrence of a number of S. dispar Zone index species in the overlying Glauconitic Marl (see below) suggests that part of the topmost Albian may be absent at this locality, and that the latter material has been reworked. This would agree with the foraminifera evidence (Carter & Hart, 1977) which suggests that most, if not all, of the S. dispar Zone is missing

at Asham.

4.4.1.2 - Lower Chalk

<u>Macrofauna</u>

The Glauconitic Marl is generally regarded as the basal unit of the Lower Chalk and, therefore, of the Cenomanian Stage, in Sussex. No diagnostic macrofauna have been recorded from the lower part of this bed at Asham, but Kennedy (1969) found rare examples of <u>Hypoturrilites</u> sp., <u>Idiohamites alternatus</u> (Mantell), <u>I. ellipticus</u> (Mantell) and <u>Schloenbachia subvarians</u> Spath from the nodular limestone at its summit. This assemblage is regarded as indicative of the <u>Neostlingoceras carcitanensis</u> subzone (lowest zone of the broad <u>Mantelliceras mantelli</u> Zone) of basal Cenomanian age.

Approximately 27m above the Glauconitic Marl, another sample was collected from a marl seam (Fig. 38; BAT 1) which contained numerous examples of the brachiopod, <u>Orbirhynchia mantelliana</u> (J. Sowerby). This O. mantelliana Band is placed between the <u>Turrilites costatus</u> Zone (lowest subzone of the Middle Cenomanian, <u>Acanthoceras rhotomagense</u> Zone) and the <u>Turrilites acutus</u> Zone (middle subzone of the <u>A. rhotomagense</u> Zone) by Kennedy (1969).

<u>Microplankton</u>

A number of dinoflagellate cyst species appear for the first time in the lower part of the Glauconitic Marl (Fig. 38; BAT 2) which are regarded as indicative of the topmost Albian (<u>S. dispar</u> Zone). These include <u>Endoceratium dettmannae</u>, <u>Florentinia deanei</u>, <u>Hystrichosphaeridium bowerbankii</u>, <u>Ovoidinium verrucosum ostium</u>, <u>Ovoidinium verrucosum verrucosum</u> and <u>Tanyosphaeridium salpinx</u>. Their occurence here suggests that, either the

lower part of the Glauconitic Marl is not earliest Cenomanian, but latest Albian in age, or that the Albian forms are reworked. The marked change in lithology from the buff silty clays representing the Upper Greensand, to the sandy glauconitic marls at the base of the Lower Chalk suggest the latter explanation is more likely. However, definite Cenomanian indicators are extremely rare and it may be that the lower part of the Glauconitic Marl represents a condensed topmost Albian sequence. The presence of Cleistosphaeridium armatum brevispinosum at the top of this bed (Fig. 38; BAT 6) is taken here to indicate definite Cenomanian age sediments and therefore this level at least agrees with both the macrofaunal and foraminiferal data. As discussed in section 4.3.1.1, the assemblage present in the lower part of the Glauconitic Marl (Fig. 39; BAT 2) at Asham, is very similar to that found in the Glauconie de base at Livet Quarry (Figs. 3, 4 & 31; Cord 2 & 3), and these levels may be laterally equivalent.

The presence of both Cribroperidinium exilicristatum and Endoceratium dettmanniae as well as the absence of Codoniella campanulata and Microdinium distinctum in Sample BAT 1 (Fig. 39), indicates an early mid Cenomanian age for the O. mantelliana Band at Asham. This is in agreement with both the macrofaunal data of Kennedy (1969), and the foraminiferal evidence of Carter & Hart (1977).

Fig. 38 Distribution Chart Of Palynomorphs From The Mid-Cretaceous Of Asham Pit, Sussex, England
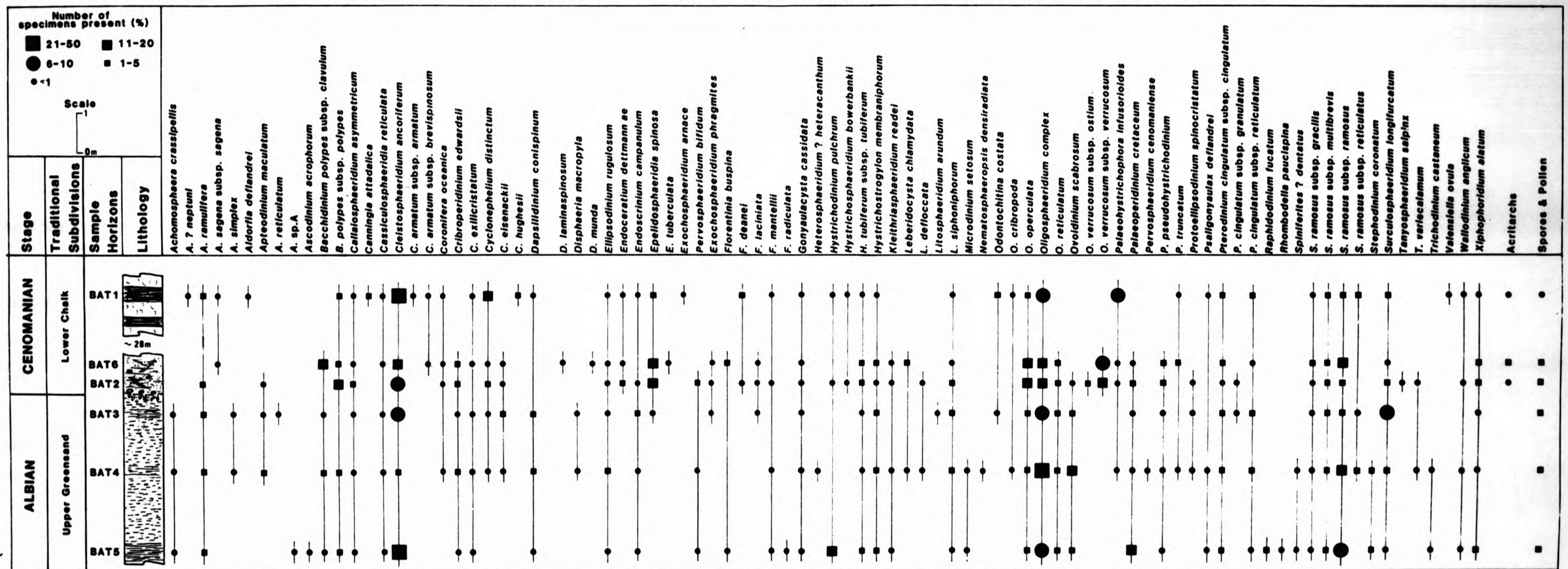
4.4.2 Beachy Head, Eastbourne (Figs. 24, 25 & 39)

4.4.2.1 Upper Greensand –

Macrofauna

As at Asham, there are no diagnostic macrofauna recorded from the Upper
Greensand (Kennedy, 1969;   Owen, 1975) although the succession is widely
regarded as belonging to the topmost Albian, $S.$ dispar Zone.

Microplankton

Since only the very top of the Upper Greensand was sampled during the
present study,   It is not possible to give a definite age for this formation
because the lower extent of the microplankton ranges is not seen.   However,
the presence of Endoceratium dettmannae, Heterosphaeridium ? heteracanthum,
Hystrichosphaeridium bowerbankii, Oligosphaeridium reticulatum, Ovoidinium
verrucosum ostium, O. verrucosum verrucosum, Palaeohystrichophora
Infusorioides, Pervosphaeridium bifidum and Tanyosphaeridium salpinx (Fig.
39; BH 1) at least indicates an age no older than the latest Albian ($S.$
dispar Zone)(section 4.2.1).

4.4.2.2   – Lower Chalk

Macrofauna

Kennedy (1969) recorded a rich phosphatized fauna in the Glauconitic
Marl which was dominated by hexactinellid sponges and fragments of
Schloenbachia which he regarded as belonging to the Neostlingoceras
carcitanensis subzone (lowest subzone of the Mantelliceras mantelli Zone) of
basal Cenomanian age. He also found unphosphatised specimens of

Mantelliceras and Mariella, particularly in the upper part of this bed. The sediments from immediately above the Glauconitic Marl, are also regarded as lying within the N. carcitanensis Zone (Kennedy, 1969). The top of the M. mantelli Zone (i.e. the top of the Lower Cenomanian) is taken approximately half-way between samples BH 3 and BH 4 (Fig. 25a). The latter sample contains numerous small brachiopods referable to Orbirhynchia mantelliana. Kennedy (1969) also recorded specimens of Sciponoceras, Scaphites, and Turrilites, and rare examples of Acanthoceras, Calycoceras and Anisoceras, from this level, which he regards as indicative of the Turrilites costatus zone (lower subzone of the Middle Cenomanian, Acanthoceras rhotomagense Zone). Above the O. mantelliana Band, Kennedy (1969) recorded a fauna which included occasional large Acanthoceras, Scaphites equalis (J. Sowerby), Turrilites acutus and also aequipecten beaveri (J. Sowerby) and Onchotrochus serpenticus Duncan. This assemblage is characteristic of the Turrilites acutus zone (middle subzone of the A. rhotomagense Zone). Samples BH 6 and BH 7 were collected from Band 14 of Kennedy (1969) from which he recorded specimens of Holaster trecensis Leym and Pycnodonte vesicularis (Lamark). A single specimen of Calycoceras cf. boulei Collignon was found which was taken to mark the top of the Middle Cenomanian. Sample BH 8 was collected from the chalk just below the Plenus Marls (i.e. from Bed 18 of Kennedy, 1969) which is considered to be from the topmost Calycoceras naviculare Zone.

The biostratigraphy of the Plenus Marls was examined in detail by Jefferies (1962, 1963) who divided the sequence into a lower Zone of Metoicoceras geslinianum, and an upper Zone of M. gourdoni. Recently, however, Wright & Kennedy (1981), revised the ammonite taxonomy, and demonstrated that M. gourdoni is synonymous with M. geslinianum. The latter authors recorded numerous specimens of M. geslinianum, Eumphaloceras septemseriatum (Cragin) and Sciponoceras gracile, as well as occasional Pseudocalycoceras dentorense (Moreman) and Tarantoceras cautisalbae Wright &

Kennedy, which they use to define a Zone of _Metolcoceras geslinianum_ (Upper Cenomanian). This Zone is equivalent to the lower part of the _Sclponoceras gracile_ Zone as used by Kennedy & Hancock (1978) and Rawson et al. (1978).

Microplankton

As at Asham Pit (Fig. 38) a number of dinoflagellate cysts which are normally associated with the topmost Albian, _S. dispar_ Zone, have their first appearance in the Glauconitic Marl, at the base of the Lower Chalk. These include _Florentinia deanei, F. ferox_ and _Psaligonyaulax deflandrei_. Their occurrence can probably be explained by reworking of the topmost Albian. The first appearance of _Cleistosphaeridium armatum brevispinosum_ (Fig. 39; BH 2) is taken here to indicate definite Lower Cenomanian, _Neostlingoceras carcitanensis_ zone (lowest subzone of the _M. mantelli_ Zone) sediments. The mid-Cenomanian, _Turrilites costatus_ Zone is not characterised by any significant cyst appearances or disappearances, but the _T. acutus_ Zone is marked by the first appearances of _Codoniella campanulata_ and _Microdinium distinctum_ (Fig. 39; BH 5), and the last occurrence of _Epelidosphaeridia spinosa_. The top of the Middle Cenomanian (_Acanthoceras jukes-brownei_ Zone) at Beachy Head, sees the first appearance of _Litosphaeridium urna_, and last occurrences of _Cribroperidinium exilicristatum_ and _Epelidosphaeridia tuberculata_ (Fig. 39; BH 6). The late Cenomanian, _C. naviculare_ Zone is characterised by the first appearance of _Litosphaeridium medius_, and the last appearance of _Litosphaeridium siphoniphorum_. Finally, the _M. geslinianum_ Zone is indicated by the first appearance of _Isabelidinium acuminatum_. _Dinopterygium medusoides_ and _Pyxidinopsis parvum_ also occur in this Zone at Beachy Head (Fig. 39; BAT 16), but do not appear at any other locality examined during this study.

4.4.2.3   - Middle Chalk

Macrofauna

The biostratigraphy of the Middle Chalk is less well-defined than that
of the Lower Chalk in this area ,largely due to the lack of ammonite data.
The standard zonation of Rawson et al.   (1978) is basically still that of
Rowe (1900) with later modifications by Jukes-Browne & Hill (1903, 1904) and
White (1924, 1926).   Zonal indices, from summit to base, are :-

Terebratulina lata

Inoceramus labiatus

Sciponoceras gracile (top part only)

Wright & Kennedy (1981) recorded Sciponoceras bohemicus anterius (Wright
& Kennedy) from the base of the Middle Chalk at Beachy Head, which they
regard as indicating the Neocardioceras juddii Zone (topmost Cenomanian).
This Zone is equivalent to the upper part of the Sciponoceras gracile Zone as
used by Kennedy & Hancock (1978) and Rawson et al.   (1978).   However, the
lack of ammonite data in the upper part of the succession makes precise bios-
tratigraphic zonation very difficult. Woodroof (1981;   Jarvis & Woodroof,
1984) has recently developed a zonal scheme based on the inoceramid data. He
divides the Middle Chalk into 5 Zones which are defined rigidly on the   lower
limit of the following index species :-

Inoceramus securiformis (top)

Inoceramus cf. cuvieri

Mytiloides cf. labiatus

Mytiloides mytiloides

Mytiloides cf. opalensis (base)

Microplankton

Three dinoflagellate cyst species, Achomosphaera verdieri, Hystrichosphaeridium difficile and Subtilisphaera pontis-mariae, have their first appearance, and two, Achomosphaera simplex and Wallodinium anglicum, their last appearance in the M. labiatus Zone at Beachy Head (Fig. 39; BH 14, 15). Both samples BH 14 & BH 15, fall within the M. cf. labiatus Zone of Woodroof (1981). Achomosphaera sagena brevispinus (Fig. 39; BH 17) and Palaeohystrichophora paucisetosa (Fig. 39; BAT 19) first appear in the I. lata Zone, while Florentinia resex, Leberidocysta defloccata, Spiniferites ? dentatus (Fig. 39; BAT 19) and Tanyosphaeridium salpinx (Fig. 39; BH 17) have their last appearance at this level. Both Samples BAT 19, and BH 17 (Fig. 39), fall within the Inoceramus securiformis Zone of Woodroof (1981).

Although the relationship between the dinoflagellate cyst distribution and the inoceramid zones of Woodroof (1981) are not as marked at Beachy Head as at Ports or Fontevraud, for example, there does appear to be some correlation (see Chapter 5).

4.4.2.4 - Upper Chalk

Macrofauna

The lowest Zone in the Upper Chalk is that of Holaster planus (Fig. 2). Only one sample was collected from this part of the succession at Beachy Head (Fig. 39; BH 16). It also falls within the M. ex gr. dresdenensis Zone of Woodroof (1981).

Microplankton

The cyst species Hapsocysta dictyota, Hystrichosphaeridium bowerbankii

and *Pterodinium* *cornutum* have their last appearance in the H. planus Zone at Beachy Head (Fig. 39; BH 16). A number of species, which were relatively common a few metres below do not appear in this sample. This coincides both with a change in the inoceramid fauna and also with the incoming of nodular chalks, the significance of which will be discussed in the following chapter (Chapter 5).

Fig. 39 Distribution Chart Of Palynomorphs From The Mid-Cretaceous Of Beachy Head, Sussex, England
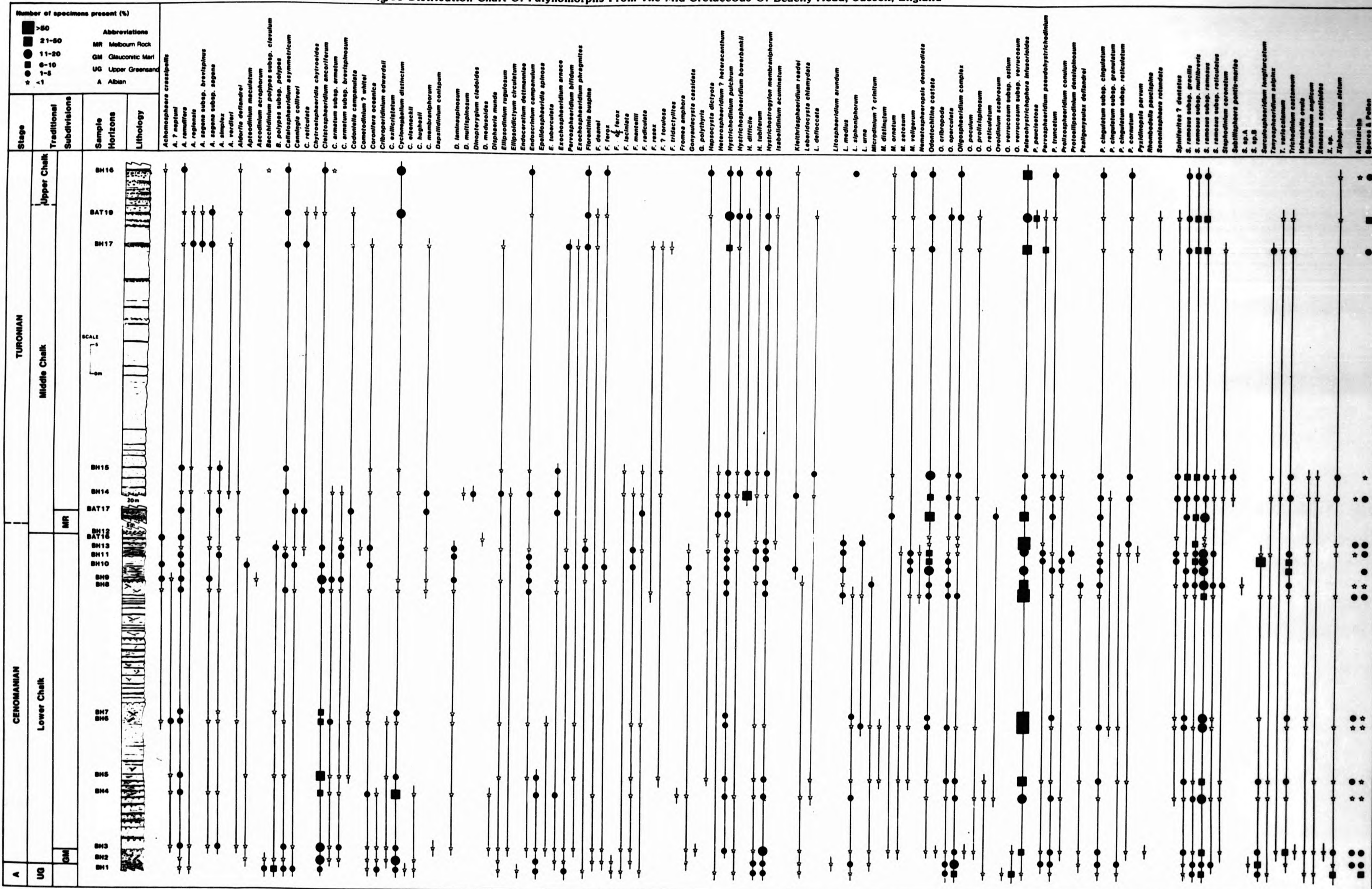
4.4.3   Beer Head, Beer, S.E. Devon (Figs. 26, 27, & 40)

4.4.3.1   - Upper Greensand

No dinoflagellate cysts were recovered from samples of the Upper Green-
sand during this study.

4.4.3.2   - Beer Head Limestone

The samples from this formation at Beer Head were palynologically barren
and, therefore, will not be discussed further in this section.

4.4.3.3   - Seaton Chalk

Macrofauna

Only the topmost bluffs at Beer Head were examined (Fig.   27b).   Here,
the Pinhay Member (Chapter 2; 2.4.3) of the Seaton Chalk (Jarvis & Tocher,
1983; Fig.   27b)) falls within Rowe's Zone of Holaster planus.   Woodroof
(1981) placed the sediments below the prominent hardground, shown just above
Annis' Knob Flint (Fig.   27b), in his Zone of Mytiloides gr.   dresdensis.

Microplankton

Only 3 samples were collected from this exposure, all of which contained
very poor dinoflagellate cyst assemblages.   None of the forms present have
any particular biostratigraphic significance at this level, apart from the
presence of Senoniasphaera rotundata (section 4.2.7).

4.4.4 Beer Stone Adlt, Beer, S.E. Devon (Figs. 26, 28 & 40)

4.4.4.1 Upper Greensand -

All of the samples from this formation proved to be palynologically barren.

4.4.4.2 Beer Head Limestone -

Only the Pinnacles Member (topmost part of the Beer Head Limestone) will be discussed in this section due to the absence of palynomorphs in the underlying sediments.

The ammonite fauna of the Pinnacles Member has been revised recently by Wright & Kennedy (1981). These authors demonstrate that although phosphatized steinkerns of basal Upper Cenomanian, _Eucalycoceras pentagonum_ Zone (Kennedy & Hancock, 1976; Juignet & Kennedy, 1976) ammonites locally overlie the Humble Point Hardground (Jarvis & Woodroof, 1984), the bulk of the indigenous and reworked ammonites in the Pinnacles Member are referable to the overlying _Metoicoceras geslinianum_ Zone. In addition, the upper part of the Pinnacles Member (between the Limonitic Nodule and Haven Cliff Hardgrounds; Jarvis & Woodroof, 1984) in Hooken Cliffs yields occasional _Actinocamax plenus_, a belemnite which is restricted to the _Metoicoceras geslinianum_ Zone (Kennedy & Hancock, 1976; Wright & Kennedy, 1981). Ammonites recovered from the Haven Cliff Neocardioceras Hardground (Jarvis & Woodroof, 1984), however, include common _Sciponoceras gracile_ and _Neocardioceras juddii_ in pebble preservation, while burrow fills within the hardground and the immediately overlying chalks contain a fauna of species of _Watinoceras_. Wright & Kennedy (1981) have suggested therefore, that the summit of the Pinnacles Member

(Haven Cliff Neocardioceras Hardground of Jarvis & Woodroof, 1984) should be placed in a Zone of <u>Neocardioceras juddii</u> and that the base of the Seaton Chalk (Jarvis & Woodroof, 1984) should be refered to the <u>Watinoceras coloradoense</u> Zone.

Microplankton

The dinoflagellate cysts which appear in the Pinnacles Member, at the Beer Stone Adit (Fig. 40; Adit 16), are all relatively long-ranging forms, and therefore of little biostratigraphic significance. However, their sudden occurrence at this particular level indicates an important environmental change which will be discussed in Chapter 5.

4.4.4.3   - Seaton Chalk

Macrofauna

The current zonal scheme for the Turonian of Southern England (Rawson et al., 1978) is basically that of Rowe (1900, 1902, 1903, 1904, 1908) and Jukes-Browne & Hill (1903) and this does not supply sufficient resolution to distinguish individual horizons with the same precision as the new lithostra-tigraphy proposed by Jarvis & Woodroof (1984). Furthermore, the <u>M</u>. <u>labiatus</u> and <u>I</u>. <u>lata</u> Zones are poorly defined and have no precise boundaries. A potentially more useful zonal scneme is that found in Woodroof (1981) and Jarvis & Woodroof (1984) which uses the first appearances of key inoceramid taxa. Jarvis & Woodroof (1984) recorded <u>M</u>. cf. <u>opalensis</u> from the surface of the Haven Cliff Neocardioceras Hardground (Jarvis & Woodroof, 1984) which they took to confirm a basal Turonian age for the Seaton Chalk. The next zonal index, <u>M</u>. <u>mytiloides</u> first appears in the nodular chalks between the West Ebb Marl and the limonitic nodular hardground (Fig. 28b), in the upper part of the Connett's Hole Member. This marks the base of the second Turoni-

an Inoceramid Zone, the M. mytiloides Zone, and demonstrates that the M. cf. opalensis Zone is equivalent to the W. coloradoense and M. nodosoides Zones of the ammonite zonation.

Jarvis & Woodroof (1984), report the first appearance of their next zonal inoceramid, i.e. M. cf. labiatus, between the Branscombe Hardground and Flinty Hardground 1 at White Cliff (Jarvis & Woodroof, 1984). However, at the Beer Stone Adit (Fig. 28b) small examples of I. cf. cuvieri appear directly above the Branscombe Hardground (which is here in the M. mytiloides Zone, there being no representation of the M. cf. labiatus Zone). Thus, where the post-Branscombe Hardground beds are absent, so is the M. cf. labiatus Zone.

Jarvis & Woodroof (1984) recorded I. cf. cuvieri from Rowe's two foot band (Fig. 28c), but there is no published inoceramid data from above this level. Woodroof (1981) suggested that the boundary between the Zones of I. cuvieri and I. securiformis, lies near the top of the section exposed at the Beer Stone Adit (Fig. 28d).

Microplankton

The majority of species present in the middle part of the Connett's Hole Member (Fig. 40; Adit 13) are relatively long-ranging, but the appearance of Hystrichosphaeridium difficile is significant as it is the earliest record of this form found during the present study. Sample Adit 11, also contains a rich and diverse assemblage, although there are no biostratigraphically significant forms present. The sudden increase of cyst abundance and diversity at this point coincides with the base of Woodroof's (1981) Zone of I. cf. cuvieri (and locally the base of the Beer Roads Member of Jarvis & Woodroof, 1984). Other significant cyst occurrences are the first appearance of

Sanoniasphaera _rotundata_ (Fig. 40; Adit 9), which is a definite Turonian indicator, and the last appearance of _Leberidocysta_ _defloccata_ (Fig. 40; Adit 9) which also disappears in the _I._ _lata_ Zone at Beachy Head (Fig. 39). Also the highest recorded occurrence of _Cyclonephelium_ _clathromarginatum._ is from the _I._ _lata_ Zone, near the top of the Beer Roads Member (Fig. 40; Adit 1).

Above Adit 11 (Fig. 40), there is a steady decline in cyst numbers and diversity. This feature of the late Turonian is apparent in other localities examined (e.g. Fontevraud; Fig. 37) and appears to be a basin-wide phenomenon (see Chapter 5).

4.4.5 Annis' Knob, Beer, S.E. Devon (Figs. 26, 29 & 40)

4.4.5.1 Seaton Chalk –

Macrofauna

This section is part of the Pinhay Member of the Seaton Chalk (Jarvis & Tocher in prep.; Fig. 29). Biostratigraphically it lies within the top part of Rowe's (1900) Zone of *Holaster planus*, and the lower part of the Zone of *Micraster cortestudinarium* (basal Coniacian), the boundary between the two being taken at the Rock Orchard Flint (Jarvis & Tocher in prep.). Woodroof (1981) placed the basal part of this exposure (i.e. below the hardground, midway between AK 5 and AK 4; Fig. 29) in his Zone of *I. costellatus*. Above this hardground, and up to just above Annis' Knob Flint, Woodroof (1981) found *M*. gr. *dresdenensis*. No inoceramid data are available for above this level.

Microplankton

The samples from this exposure were all either palynologically barren, or contained very poor cyst assemblages which were comprised of long-ranging forms of little biostratigraphic value.

Bailey (1975), described a distinctive change in the planktonic foraminifera approximately 1m above the Annis' Knob Flint (Fig. 29). This consisted of an increase in the total number of planktonic forms, and the replacement of *Globotruncana pseudolinneiana*, by *G. bulloides*, which he takes to indicate the base of the Coniacian Stage. However, this is not confirmed until the appearance of *Globotruncana renzi*, ~ 3m above the Annis' Knob Flint.

4.4.6 Beer Roads, Beer (Fig. 40)

4.4.6.1 Seaton Chalk –

Macrofauna

Two samples were collected from the hardground beds above the Branscombe Hardground (Jarvis & Woodroof, 1984) to examine the cyst assemblages from sediments which had been pinched out further west at the Beer Stone Adit. These sediments fall within Woodroof's (1981) Zone of _l_. cf. _lablatus_.

Microplankton

Both samples processed (Fig. 40; BR 2, 3) contained rich and abundant dinoflagellate cyst assemblages. The first appearance of _Hystrichosphaeridium tubiferum brevispinum_ (Fig. 40; BR 3), however, is the only biostratigraphically significant form present.

4.4.7 The Hall

4.4.7.1 Seaton Chalk -

<u>Macrofauna</u>

A single flint sample was collected from this locality to compare it with the base of Woodroof's (1981) Zone of <u>I</u>. cf. <u>cuvieri</u> at the Beer Stone Adit.

<u>Microplankton</u>

The sample contained a rich and diverse cyst assemblage but the forms present are relatively long-ranging and are not biostratigraphically significant.

Distribution Chart Of Palynomorphs From The Mid-Cretaceous Of S.E. Devon, England
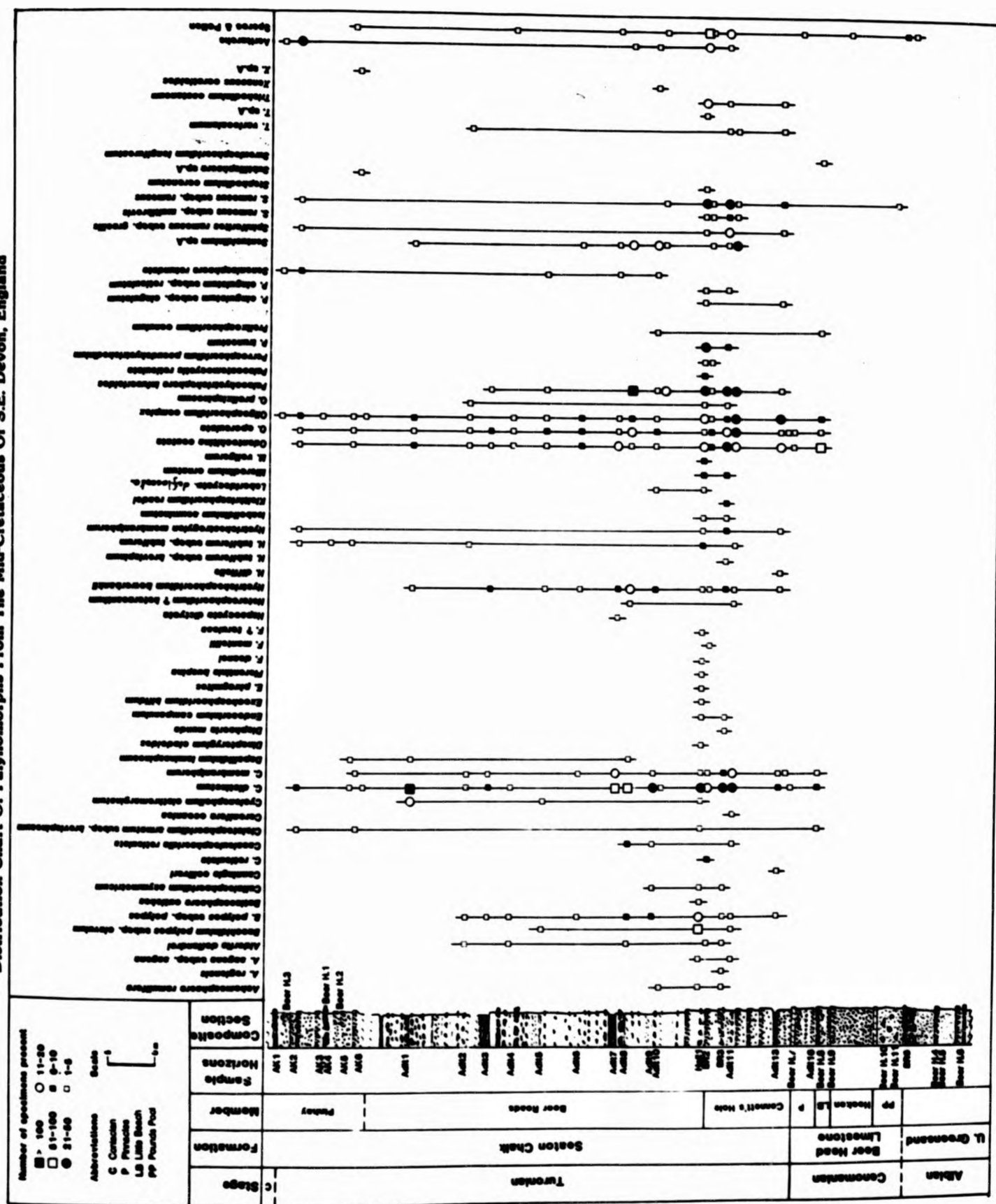
CHAPTER 5

PALAEOENVIRONMENT

Introduction

The following chapter is divided into five parts. Section 5.1 examines those environmental parameters (water depth, water temperature, salinity, nutrient supply) which are thought to be the dominant influences on dinoflagellate cyst distribution, while Section 5.2 looks at the cyst distribution in certain specific lithologies. The importance of dinoflagellate cysts as palaeoenvironmental indicators is assessed in Section 5.3, and this is used in conjunction with other data to suggest depositional environments for each locality examined (5.4, 5.5).

5.1 Palaeoenvironmental parameters

5.1.1 Water depth

Published studies of estimated water depths fall into two categories, actual and relative. Actual estimates for the depth of the Chalk Sea have been based on lithological, faunal and floral characteristics (Hakansson et al., 1974; Scholle, 1974; Kennedy & Garrison, 1975b; Hancock, 1975a; Jarvis, 1980). The fine-grained nature of white chalks indicate deposition below wave base (~20m) while the general absence of bioherms and algal borings is taken to indicate that the sea floor was aphotic (>150m). Quantitative studies of hexactinellid sponge faunas by Reid (1962a, 1962b, 1968, 1973) have shown that the depth of the Chalk Sea is unlikely to have been in excess of 200-300m. This sort of figure is in agreement with studies of eustatic sea level rises for this period (Hayes & Pitman, 1973). Estimates of minimum water depths have been based on the presence in certain

horizons (hardgrounds) of borings of enterolithic algae and possible algal crusts (Kennedy & Garrison, 1975b; Jarvis, 1980). These indicate deposition within the photic zone (<150m). In fact, some workers (Gebelein, 1969; Logan, Rezak & Ginsberg, 1964; Walter, 1972; Kennedy & Garison, 1975b) believe that algal crusts indicate depths of the order of 60m or less. Kennedy & Garrison (1975b) have also suggested that obvious shallow water horizons in the Anglo-Paris Basin (e.g. Glauconitic Marl, Chalk Marl : see Asham Pit, Fig. 23 and Beachy Head, Fig. 25) were deposited in depths of ⁻50m.

Relative estimates of water depth have been based on facies analysis (Hancock, 1975a; Hancock & Kauffman, 1979), and on studies of benthic/planktonic foraminifera (Barr, 1962; Jefferies, 1962; Burnaby, 1962; Hart, 1970; Carter & Hart, 1977; Hart & Bailey, 1979). The water depth curves produced have been used to indicate regressive and transgressive phases of the Chalk Sea.

Water depth studies based on dinoflagellate cyst distributions are rare, particularly with respect to the mid Cretaceous of the Anglo-Paris Basin. Certain microplankton associations have been used to indicate regressive and transgressive periods (Downie et al., 1971; Schumacker-Lambry, 1978; May, 1980), while it is generally recognised that cysts with elaborate ornamentation (i.e. processes, horns, prominent membranes etc.) are indicative of open marine (i.e. relatively deep water) conditions (Davey & Rogers, 1975; Williams, 1977; Tappan, 1980). Thick-walled species which lack prominent ornamentation are thought to indicate nearshore environments (Vozzhennikova, 1967; Williams, 1977). Also Davey (1970a), suggested that the relative abundances of marine microplankton and terrestrially derived miospores could be used as a rough guide to distance from a landmass. However, this simplified relationship would also be affected by other factors such as changes in

terrestrial vegetation and the direction of prevailing winds and currents (Davey, 1969a,1970a). It has also been suggested (Gruas-Cavagnetto, 1965) that increased abundance and diversity of cyst species is an indication of deeper water conditions. Wall et al. (1977) noted that cyst diversity showed an inshore-offshore trend which increased seawards. As part of the present study, diagrams showing the relationship between dinoflagellate cyst abundance/diversity and lithology were constructed for each locality (Figs. 41-50). From these it is postulated that cyst diversity can be used as a guide to relative water depth, and thereby indicate major changes in eustatic sea level (5.3.1, 5.3.2).

5.1.2 Salinity

In general, the abundance and diversity of stenohaline organisms (e.g. echinoderms, brachiopods) indicate deposition under normal salinities of ¯36ppt (Kennedy & Garrison, 1975b). Near the basin margins, however, salinities must have fluctuated in response to changes in sea level and variations in terrigenous runoff and climate. Previous dinoflagellate cyst studies (e.g. May, 1980) have noted that assemblages commonly show rapid changes in character which may reflect changing salinities. However, this is very difficult to evaluate quantitatively due to possible reworking and current transport of material from other parts of the basin. Harland (1973) suggested that the ratio of peridiniacean/gonyaulacacean cysts could be used as an indication of changing salinity (and water depth) since the former seem to prefer reduced-salinity, nearshore conditions. However, his study was carried out on sediments which were deposited in cooler water conditions than those which existed in the Anglo-Paris Basin during the Upper Cretaceous (5.1.3). In the sub-tropical/tropical environment of the Chalk Sea (5.1.3) the microplankton assemblages were totally dominated by cysts with gonyaulacacean affinities, making construction of the "Gonyaulacacean Ratio"

(Harland, 1973) impractical and misleading. Other palynomorph associations associated with changing salinities include assemblages dominated by acritarchs which are regarded as indicating nearshore, reduced salinity environments (Downie et al., 1971; May, 1980).

5.1.3 Water temperature

As with water depth and salinity, previous studies are based on actual, and relative, estimates. Palaeomagnetic work places southern Britain at approximately 32-35 N during the Upper Cretaceous (Smith & Briden, 1977). This corresponds to the present subtropical belt. However, during this period it has been suggested (Jarvis, 1980) that because of the lower climatic, and annual and diurnal temperature ranges, the climate was probably more tropical in aspect. Oxygen isotope based palaeotemperatures have been obtained from a number of Chalk fossil groups (Urey et al., 1951; Lowenstam & Epstein, 1954; Bowen, 1966) and have resulted in a temperature scatter of 13.5-25.8 C. These results have been questioned, however, on the basis of poor stratigraphic control, possible isotope fractionation by the organisms concerned, doubts over original mineralogy and diagenetic recrystallisation (Kennedy & Garrison, 1975b).

Relative temperature estimates have been based on the appearances of "warm water" groups such as hermatypic corals, rudistid bivalves, larger foraminifera (Carter & Hart, 1977), and dinoflagellate cyst assemblages dominated by spiniferate or chorate species (Davey & Rogers, 1975).

5.1.4 Nutrients

It is now generally accepted that phytoplankton productivity is directly

related to nutrient input (Tappan, 1968). The major nutrients in the ocean are oxygen (O_2), carbon dioxide (CO_2), nitrogen (N), phosphate (PO_4), and silicon (Si) (Williams, 1971a; Lentin & Williams, 1980). Since O_2 and CO_2 are always present in sufficient amounts, and Si has no effect on dinoflagellate productivity, the limiting factors appear to be N and PO_4. Lentin & Williams (1980) suggested that N is removed from the photic zone when phytoplankton sink in deeper waters and, therefore, agencies which recirculate this "lost" N (e.g. upwelling currents) constitute an important influence on productivity. Although this appears to be an acceptable mechanism to account for increases in cyst abundance (see also 5.2.4), it does not explain major increases in cyst diversity. Piper & Codispoti (1975) have suggested that an increase in the areal extent of the O_2 minimum layer might alter the nutrient cycles in the ocean by enhancing the precipitation of phosphorous from its surface layers. The most obvious way of doing this would be to envisage a widespread sea-level rise. Associated current activity would circulate N-rich and PO_4-rich waters, thereby increasing the nutrient levels in the oceans, while the creation of new habitats and environmental niches would result in increased cyst diversification. Therefore, while increases in dinoflagellate cyst abundance may be explained by recirculation of nutrient-rich currents, major increases in diversity are thought to indicate periods of rising sea levels (5.3.3).

5.2 Lithological/palynological relationships

5.2.1 Omission surfaces

Omission surfaces were defined by Bromley (1975a) as "discontinuity sur-
faces of the most minor nature, which mark temporary halts in deposition but
involve little, or no, erosion". These surfaces occur at most, if not all of
the localities examined during this study. They can often be recognised by
changes in sediment type or, in some cases, mineralisation of the omission
surface itself. In less obvious cases, Bromley (1975a) has shown that it is
possible to distinguish these surfaces on the basis of changes in the ichno-
logical record. In most cases, palynomorph assemblages recovered from these
levels were either poor or absent (e.g. Livet Quarry, Fig. 30; Cord 2:
Hameau-Fredet Quarry, Fig. 31; HF 14). It is thought that the omission
surfaces formed during periods of increased current activity, thus reducing
deposition of the finer sedimentary fraction. The sediments are also subject
to increased oxidation due to the flushing action of the currents (5.2.2) and
bioturbation.

5.2.2 Nodular chalks and hardgrounds

The generally acepted model of hardground formation (Bromley, 1975a;
Kennedy & Garrison, 1975b) involves an initial stage of early diagenesis
associated with a pause in sedimentation causing the growth of calcareous
nodules below the sediment/water interface (nodular chalks). Further pro-
longed diagenesis may lead to the coalescing of individual nodules to produce
a continuously lithified subsurface layer (incipient hardground). If subse-
quent erosion of the overlying soft sediment exposes this layer at the
seafloor, a true hardground will develop.

A number of samples were collected from these sedimentary units, all of which were either palynologically barren or, at best, contained poor dinoflagellate cyst assemblages. The reasons for this are thought to be the result of the environmental conditions present during deposition of the sediment and/or the post-depositional diagenetic formation of the unit itself. Hardgrounds form in relatively shallow water, probably during period of increased current velocity and low sedimentation rates (5.3.3; E). Organic content would normally have been correspondingly low, although the occurrence of pyrite in some of these units indicates an organic-rich source on a local scale at least. In addition to this, the process of lithification of the unit may have involved the flushing action of low-energy currents, which removed the finer sedimentary particles from, and continuously oxygenated, the top few cms of the seafloor, thus resulting in the removal and degradation of much of the contained organic matter. In fact the total absence of organic matter was a feature of several hardgrounds examined, particularly those with a long history of formation (e.g. Branscombe Hardground at the Beer Stone Adit, Fig. 40; Adit 12). However, not all hardground samples processed were barren. Poor cyst assemblages were obtained from units which were penetrated by prominent burrow systems (particularly <u>Thalassinoides</u>) which were open at the time of lithification, and subsequently filled with sediment which was originally deposited on the hardground surface (e.g. Hameau-Fredet Quarry, Fig. 31; HF 2). It is almost certain that the poor cyst assemblages recorded from such hardground units were contained within the burrow fill. More work needs to be done, in which the burrow sediment is processed separately from the lithified hardground. Some of these burrow systems are very extensive. Jarvis (1980) has recorded <u>Thalassinoides</u> systems as much as 5m below hardground surfaces. Also, in areas such as SE Devon, whole thicknesses of sediment have been eroded off hardground surfaces, and often the only remnants of these units is the unlithified burrow fill.

5.2.3 Flints

It is generally accepted that most flints typically replace burrow
infillings, particularly Thalassinoides (Bromley, 1965, 1967a; Kennedy &
Garrison, 1975b; Hakansson et al., 1974; Jarvis, 1980; Clayton, 1982).
These accentuate otherwise indistinct omission and erosion surfaces. With
further silicification, these flints may extend beyond the original burrows
to form semi-continuous bands. Separate samples taken from flints and the
surrounding sediment usually contained different cyst assemblages (e.g.
Hameau-Fredet Quarry, Fig. 31; HF 9). This is partly because the material
within the burrow represents a higher stratigraphic level than the surround-
ing sediment. If the difference between the two samples is great this may
indicate an extensive period of non-deposition, or perhaps a significant
change in environmental conditions (5.2.4). If there is little difference it
may reflect a very minor period of omission, or perhaps result from the flint
sample being a siliceous overgrowth (see above) and not part of the original
burrow.

5.2.4 Marl seams

Numerous clay-rich horizons (marl seams) were sampled during the present
study. In many cases they contain abundant and diverse dinoflagellate cyst
assemblages. The precise origin of these units has been the matter of some
debate. Early work by Troelson (1955) and Jefferies (1963) suggested that
the marl seams resulted from a sudden influx of fine terrigenous material
during periods of regression. More recent hypotheses, however, suggest that
these units were formed by the selective dissolution of $CaCO_3$ during sedimen-
tation (Worsley, 1971; Ernst, 1978, 1982; Ekdale & Bromley, 1982), or that
they result from ashfalls (Jeans, 1968; Jeans et al., 1982; Pacey, 1984).
A mechanism for the former has been suggested by Ernst (1982) which involves

the decomposition of organic-rich layers on the seafloor. The CO produced results in a rise in the solution rate of $CaCO$. The occurrence of organic-rich layers is related to increased nutrient input (5.1.4). All of the marls examined rested either on omission surfaces, erosion surfaces or hardgrounds, the presence of which indicates a period of increased current activity prior to the deposition of the organic-rich layer. This appears to agree with the evidence for increased phytoplankton productivity which is thought to result either from influxes of nutrient-rich currents, or periods of rising sea level (5.1.4). Many of the marl seams have a cyclical distribution (e.g. the Lower Chalk at Beachy Head, Fig. 25a) which is thought to be the result of periodic climatic changes caused by the Earths' orbital perturbations (Schwarzacher & Fischer, 1982). Others, however, are related to major transgressive episodes (e.g. Beachy Head, Fig. 49; BH 3), and are thought to be eustatic in origin (5.1.4, 5.3.3).

5.3 Palaeoenvironmental significance of dinoflagellate cyst distribution

5.3.1 Species diversity as an indicator of relative water depth

Comparisons were made between dinoflagellate cyst diversity in sediments from the central parts of the Anglo-Paris Basin (e.g. Beachy Head), with those deposited nearer the basin margins (e.g. Livet Quarry). Lower Cenomanian material from Livet Quarry (Fig. 41) showed a maximum cyst diversity of 36 compared with 69 from the corresponding level at Beachy Head (Fig. 49). An examination of the sediments indicated that the depositional environment at the former locality was shallow water, neritic (5.4.1), while that at Beachy Head was relatively deep water, open shelf (5.5.2).

The second stratigraphic level examined was the low Turonian (M. labiatus Zone) at Ports (Fig. 46), Beachy Head (Fig. 49) and Beer (Fig. 50). Maximum cyst diversities ranged from 30 at Beer (Fig. 50; BR 3), to 42 at Ports (Fig. 46; Po 9) and 55 at Beachy Head (Fig. 49; BH 14). The sediments at Beer were dominantly nodular chalks with numerous hardgrounds, while those at the other two localities consisted mainly of thick chalk units interbedded with thin marl seams.

In both of the above cases, samples from the more central parts of the basin contained more diverse cyst assemblages than those from the basin margins. If one assumes that the sediments in the central basin were deposited in deeper water (shown by thicker, more complete successions), the results indicate that species diversity may be a useful guide to relative water depth. However, it must be remembered that this criterion can only be applied when comparing sediments from corresponding stratigraphic levels, since absolute cyst diversity can be affected by other variables such as salinity (5.1.3) and nutrient input (5.1.4).

5.3.2 Palaeoenvironmentally significant dinoflagellate cyst associations

An analysis of overall cyst abundances, diversity and morphology, and comparisons with lithology has shown that it is possible to delimit the following palaeoenvironmentally useful associations.

GROUP 1 :- _Ovoidinium verrucosum verrucosum_ and _O. verrucosum ostium_ are regarded here as indicators of shallow water deposition. The former was the dominant form in microplankton assemblages recovered from the Glauconie de base and the lower part of the Craie glauconieuse at Livet Quarry (Fig. 31). These sediments are regarded as having been deposited in a nearshore, neritic environment (5.4.1). _Ovoidinium verrucosum verrucosum_ was also an important constituent of the assemblages recovered from the Glauconitic Marl at Asham Pit (Fig. 38), and this unit is also interpreted as a relatively shallow-water deposit (5.3.3, 5.5.1). Neither of the above cysts were recorded in sediments younger than the early Cenomanian (_N. carcitanensis_ Subzone) and their disappearance may be related to the basin-wide increase in water depth (5.3.3) associated with the onset of carbonate sedimentation.

GROUP 2 :- _Bacchidinium polypes clavulum_, _Cyclonephelium distinctum_, _Epelidosphaeridia spinosa_, _Heterosphaeridium ? heteracanthum_, _Subtilisphaera_ sp.A and _Surculosphaeridium longifurcatum_ are taken to indicate relatively deeper water depositional conditions than for Group 1. Group 2 cysts tend to be most abundant in sediments representing marginal chalk facies, in particular, the upper part of the Craie glauconieuse at Livet Quarry (Fig. 31) and Hameau-Fredet Quarry (Fig. 32), and the Craie de Rouen at Hameau-Fredet and Canteloup (Fig. 33). Most of these forms were also encountered in the Craie micacee at Fontevraud (Fig. 37), and in the upper part of the Seaton Chalk at Beer (Fig. 40).

Group 3 :- Most species of _Achomosphaera_, _Exochosphaeridium_, _Florentinia_, _Pervosphaeridium_, _Spiniferites_, _Microdinium_, _Litosphaeridium_ and

also _Palaeohystrichophora_ _infusorioides_, _Xenascus_ _ceratioides_ and _Xiphophoridium_ _alatum_ are regarded here as indicative of relatively deep water ('outer shelf') depositional environments. These cysts, particularly P. _infusorioides_, were the most common forms in assemblages recovered from Beachy Head, (Fig. 39) and Ports (Fig. 36). Many of these have an ornate morphology, a feature which is generally regarded as a flotational aid typical of deep water cysts (5.1.1). The appearance of Group 3 cysts in more marginal environments can, in some cases (e.g. Beer, 5.3.3), be related to transgressive episodes.

Group 4 :- _Codoniella_ _campanulata_, _Disphaeria_ _macropyla_, _D._ _munda_, _Hapsocysta_ _dictyota_ and _Nematosphaeropsis_ _densiradiata_ are regarded here as deep water ('oceanic') species because of their ornate morphology and comparitive rarity. Their distribution is almost invariably restricted to samples from the central basin (e.g. Beachy Head, Fig. 39) but the occurrences were too sporadic to be able to relate them to specific events (5.3.3).

Group 5 :- _Hystrichosphaeridium_ _bowerbankii_, _H._ _tubiferum_ _tubiferum_, _Odontochitina_ _costata_, _O._ _operculata_ and _O._ _complex_ were found occurring in most samples processed and are regarded here as tolerant cosmopolitan forms. This group was particularly evident in sediments deposited during periods of regression (e.g. Beer, Fig. 40: 5.3.3; G).

5.3.3 Transgressive-regressive phases

This section examines the transgressive and regressive phases of the Chalk Sea during the mid Cretaceous in the Anglo-Paris Basin. Evidence for these events is based on facies analysis, palynomorph distribution (5.3.1, 5.3.2), and on comparisons with published water depth studies (Hancock, 1975a; Hancock & Kauffman, 1979; Cooper, 1977; Hart & Bailey, 1979).

A) Early late Albian transgression :- Cooper (1977), and Hancock & Kauffman (1979) recorded an early late Albian transgressive episode in the

Anglo-Paris Basin. The latter authors were of the opinion that this event carried Cretaceous seas onto many ancient massifs for the first time during the Mesozoic. Evidence for this event can be observed at Livet Quarry (2.1.1) where shallow-water, glauconitic sediments of late Albian (S. dispar Zone) age (4.3.1) rest unconformably on Aptian sands. The transgression reached a peak in the late Albian and was followed by a period of shallowing at the Albian-Cenomanian boundary (Cooper, 1977), although it is uncertain whether this shallowing was eustatic in origin, or was caused by local tectonic uplift. Palynological evidence for a rise in sea level during this period can be found at both Livet Quarry and Asham Pit. At the former there is a distinct increase in the proportion of bisaccate pollen (Fig. 31; Cord 3) which is taken to indicate increased representation of the hinterland flora (sensu Batten, 1974) during a period of transgression. The cyst diversity also shows an increase at this level which is associated with the increased representation of cyst Groups 2 & 3 (5.3.2), again indicating a transgressive phase. At Asham Pit (Fig. 38) there is a cyst diversity peak in the Upper Greensand (Fig. 48; BAT 4) which can probably be correlated with that at Livet Quarry (Fig. 41; Cord 3).

B) Albian-Cenomanian boundary regression :- A regressive phase is indicated at the level of the Albian-Cenomanian boundary in the Anglo-Paris Basin (Kennedy & Juignet, 1975; Cooper, 1977). Samples were collected from supposed Albian-Cenomanian sediments at Livet Quarry (4.3.1), Asham Pit (4.4.1) and Beachy Head (4.4.2). The stage boundary at all three localities is marked by an omission, or erosion, surface. Dinoflagellate cyst diversities at Livet Quarry (Figs. 31, 41) and Asham Pit (Figs. 38, 48) are lower at this level than those described in the previous section (A). At Livet, Group 1 cysts show an increased abundance, while Group 3 forms are virtually absent. At Asham Pit (Fig. 38), a number of Group 2 cysts become more important (particularly Surculosphaeridium longifurcatum) near the top of the Upper Greensand. The cyst distribution at both localities, therefore,

appears to indicate a period of shallowing prior to the erosion of the topmost Albian sediments (5.3.3; C).

C) Early Cenomanian transgression :- A major transgressive episode in the early Cenomanian has been recorded in many parts of the world (Cooper, 1977; Hancock & Kauffman, 1979) and has been dated as N. carcitanensis Zone at its base in southern England (Kennedy, 1971; Kennedy & Garrison, 1975b). The basal unit of the Lower Chalk in this area, the Glauconitic Marl, is thought to represent a basement transition facies (Kennedy & Garrison, 1975b) and, as indicated in the previous section (5.3.3; B), rests on a prominent omission surface at both Asham Pit (2.4.1) and Beachy Head (2.4.2). The Glauconitic Marl contains a large proportion of reworked Albian material and in some areas (e.g. Beachy Head) is markedly condensed. The sediments are intensely bioturbated and penetrated by prominent burrow systems (2.4.2). The dinoflagellate cyst distribution almost certainly represents a mixed Albian-Cenomanian assemblage (4.4.1, 4.4.2) and, therefore, the species diversity plots at Asham Pit (Fig. 48) and Beachy Head (Fig. 49) are probably artificially high. The presence of cyst Groups 1 & 2 in this unit would normally be taken as evidence of relatively shallow-water depositional conditions. However, the sedimentological evidence points to repeated current and biogenic reworking on the seafloor and, therefore, the possibility of much of this material having been transported in from the basin margins cannot be discounted. A sample collected from a thin marl seam overlying the Glauconitic Marl at Beachy Head (Figs. 39, 49; BH 3) contained the most abundant and diverse cyst assemblage recorded during this study. Hart & Bailey (1979) also recorded a significant expansion of the planktonic foraminifera at the same level which they interpreted as indicating a major rise in sea level. At Livet Quarry (Figs. 31, 41; Cord 9) dinoflagellate cyst diversity also reaches a peak in the N. carcitanensis Zone. The cyst assemblages are characterised by the increased numbers of cyst Groups 2 & 3 (5.3.2, 5.4.1), and also of bisaccate pollen, all of which is taken to indicate a period of

transgression. In the upper part of the section at Livet Quarry there is a distinct change from shallow-water glauconitic facies to fine-grained carbonate facies (2.2.1). Cyst assemblages from the latter are characterised by the increasing dominance of Group 2 forms, with a corresponding decrease, and eventual disappearance of cyst Group 1. Terrigenous input also shows a marked decrease over this interval (5.4.1). Palynological and sedimentological evidence from the three sites studied (Asham Pit, Beachy Head and Livet Quarry) indicates a transgressive episode during the early Cenomanian (N. carcitanensis Zone). The occurrence of Group 2 cysts (5.3.2) in the upper part of the section at Livet Quarry, after the main diversity peak (Fig. 41; Cord 9), indicates that sea level continued to rise (e.g. Hancock & Kauffman, 1979), rather than follow a rapid transgressive-regressive pattern (e.g. Cooper, 1977).

D) Late Cenomanian transgression :- A minor transgression during the late Cenomanian (C. naviculare Zone) is indicated by the onlap of a thin development of the Marnes à O. biauriculata (2.1.5) over the Sables du Perche (2.1.4) in the area around Le Mans (Les Fosses Blanches Quarry, Figs. 8, 9). A sample from the former formation contained a poor cyst assemblage, consisting mainly of Groups 2 & 5, with a few Group 3 forms (5.3.2), which suggests a fairly shallow-water depositional environment. Species diversity is low (as is abundance) indicating low nutrient levels (5.1.4). This transgressive phase was not recorded at any other locality studied and is thought here to be the result of local tectonic downwarp rather than a significant rise in sea level.

E) Earliest Turonian stillstand :- The basal Turonian is marked by nodular chalks and hardgrounds (5.1.2) over most of the Anglo-Paris Basin. Samples analysed from this level at Bois du Galet Marl Pit (5.4.5), Beachy Head (5.5.2) and Beer (5.5.3), invariably contained poor cyst assemblages, or were barren. Despite this, there is no definite evidence of shallowing (sensu Cooper, 1977) and it is thought likely that the cyst distribution is

the result of increased current activity and low nutrient levels during a period of stillstand in sea-level rise (sensu Hancock & Kauffman, 1979).

F) Early Turonian transgression :- A major early Turonian transgressive phase has been recorded world-wide (Cooper, 1977; Matsumoto, 1977; Jeletsky, 1977; Reyment & Morner, 1977; Hancock & Kauffman, 1979; Hart & Bailey, 1979). However, interpretations differ as to whether this represents a fresh transgressive pulse, or whether it represents the maximum extent of an earlier phase (see discussion below). Samples from the low Turonian (M. labiatus Zone) were collected from a number of localities (Les Fosses Blanches Quarry, Bois du Galet Marl Pit, Ports, Beachy Head and Beer). At Les Fosses Blanches Quarry (5.4.3) and Bois du Galet Marl Pit (5.4.5) the marly chalks contained poor cyst assemblages consisting mainly of Groups 2 & 5, and are thought to indicate low nutrient levels. At Beer (5.5.3), cyst abundance and diversity increase throughout the Connett's Hole Member of the Seaton Chalk. This is characterised by an increased representation of Group 3 cysts over Groups 2 & 5, and is taken to indicate increasing water depth and nutrient levels. A similar pattern can also be seen at Ports (5.4.6) and to a lesser extent at Beachy Head (5.5.2). Diversity peaks recorded at these localities were the second highest recorded during this study.

G) Mid-late Turonian regression :- A middle to late Turonian regressive phase has been suggested by a number of authors (Hancock, 1975a; Cooper, 1977; Hancock & Kauffman, 1979; Hart & Bailey, 1979; Jarvis & Gale in press). Samples from this stratigraphic level were collected from Ports (5.4.6), Fontevraud (5.4.7), La Chartre-sur-le-Loir (5.4.8), Villedieu-le-Château (5.4.9), Beachy Head (5.5.2) and Beer (5.5.3). Where preserved, cyst assemblages showed a significant decrease in abundance and diversity associated with increased representation of cyst Groups 2 & 5. In addition to the palynological evidence, the sediments show evidence of increased current activity (probably associated with shallowing; 5.2.1) in the central parts of the basin (Beachy Head; 5.5.2), while in the more mar-

ginal areas there is evidence of increased terrigenous runoff from emergent massifs (Fontevraud; 5.4.7: La Chartre-sur-le-Loir; 5.4.8).

Discussion :- The transgressive-regressive phases outlined above (5.3.3; A-G) were defined on the basis of changes in the dinoflagellate cyst distribution (5.3), lithology (5.2) and comparisons with published data. However, the question of what causes these events is the matter of some debate. On the one hand, Cooper (1977) is of the opinion that most of these phases were discrete, essentially synchronous events resulting from fluctuations of eustatic sea level, whereas Hancock & Kauffman (1979) regard eustatic transgressions and regressions as occurring over long periods of geological time. They suggest that many of Coopers' episodes are in fact diachronous or can be explained by local tectonic downwarping, or stillstands in sea level rise.

Both Hancock (1975a) and Cooper (1977) recognise major eustatic pulses in the early Cenomanian (N. carcitanensis Zone) and the early Turonian (M. labiatus Zone), and these coincide with significant increases in dinoflagellate cyst diversity. It has long been recognised that phytoplankton abundance is related to nutrient levels (5.1.4); however, increased diversity results from the creation of new habitats and ecological niches (Cooper, 1977). Therefore, an increase in both abundance and diversity requires nutrient enrichment and the creation of new habitats. The most obvious mechanism to explain this would be a widespread sea-level rise (5.1.4). From the evidence, therefore, it seems likely that those events associated with increased phytoplankton abundance and diversity (5.3.3; C, F) are eustatic in origin.

5.4 Palaeoenvironment of sections sampled in western France

5.4.1 Livet Quarry, Cordebugle (Fig. 41)

5.4.1.1 Glauconie de base - The presence of highly glauconitic sands, with occasional coarse lenses, phosphatic nodules and abundant shell debris suggests that the Glauconie de base was deposited in a shallow-water, nearshore (probably neritic) environment. Terrigenous input was high, as indicated by hte large numbers of miospores recorded (Fig. 31). Periods of increased current activity are indicated by the presence of erosion, or omission, surfaces. Dinoflagellate cyst assemblages recovered from these sediments were generally dominated by Group 1 cysts (5.3.2), with more minor amounts of Groups 2 & 3. A late Albian transgressive episode (5.3.3; A) is indicated by the occurrence of this formation resting unconformably on Aptian sands (2.2.1). This transgression reached a peak in the _S. dispar_ Zone, and is associated with the appearance of deeper-water Group 3 cysts, and a reduction in numbers of Group 1. The proportion of miospores (particularly bisaccate pollen) increased at this level, and is taken to indicate increased representation of the hinterland flora (sensu Batten, 1974) during a period of rising sea level.

5.4.1.2 Craie glauconieuse -

The Craie glauconieuse exposed at Livet Quarry consists of fine glauconitic sands at its base, passing up into marly chalks with flint lines, and is regarded here as having been deposited in fairly shallow, 'inner shelf' conditions. Relatively poor cyst assemblages, dominated by Group 1 forms, were recovered from around the Albian-Cenomanian boundary (Fig. 31; Cord 4, 5) and are associated with a regressive phase in the Anglo-Paris Basin at this

time (5.3.3; B). A peak in cyst diversity in the Lower Cenomanian (Fig. 41; Cord 9) is characterised by an increased abundance of cyst Groups 2 & 3 (5.3.2), and also of bisaccate pollen, indicating a rise in sea level. This peak is correlated with a cyst diversity increase at Beachy Head (Figs. 39, 49; BH 3), and is thought to represent a major world-wide transgressive event (5.3.3; C). Samples from the carbonate-rich sediments near the top of the section contained poor cyst assemblages, consisting mainly of cyst Groups 2 & 5 (Figs. 31, 41), and probably represent low nutrient levels.

Fig. 41 Relationship Between Dinoflagellate Cyst Abundance/Diversity And Lithology At Livet Quarry, Cordebugle, France
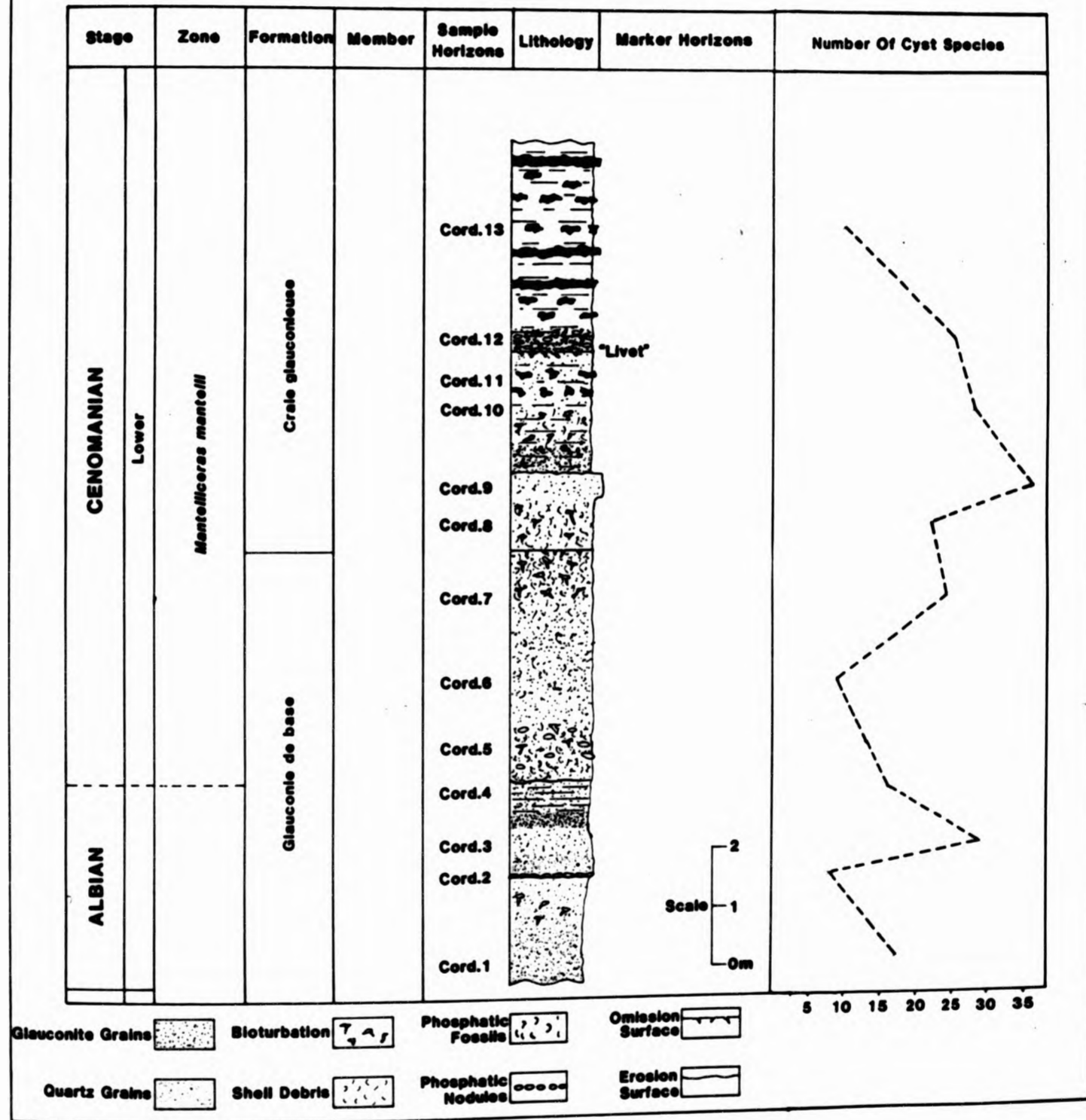
5.4.2 Hameau-Frédet, and Canteloup, Quarries, Fumichon (Fig. 42, 43)

5.4.2.1 Craie glauconieuse -

The Craie glauconieuse exposed in Hameau-Fredet Quarry is Lower Cenomanian (M. dixoni Zone; 4.3.2.1). The sediments consist of glauconitic chalks, with several hardgrounds and flint lines, and are laterally equivalent to the cyclic chalk/marl sequences found in the Lower Chalk in southeast England (e.g. Beachy Head, Fig. 25a). Dinoflagellate cyst assemblages recovered from this formation are dominated by Group 2 forms, indicating fairly shallow-water conditions (5.3.2). Cyst diversity is generally low (never exceeeding 25 species) compared with that found in more central basin sediments (e.g. Beachy Head, Fig. 49; 5.3.1). Fluctuations in cyst diversity are thought to be related to changes in the current regime (assemblages are poorer in sediments deposited during periods of increased current activity and low sedimentation rates; 5.2.1, 5.2.2, 5.2.3), and minor nutrient influxes (5.1.4, 5.2.4).

5.4.2.2 Craie de Rouen -

The lower part of this formation at both Hameau-Frédet, and Canteloup is characterised lithologically by glauconitic chalks containing calcareous nodules, chalk intraclasts and numerous omission surfaces (2.2.2, 2.2.3). As one goes higher up the succession, the amount of glauconite decreases and flint lines become more common (5.2.3). The low overall cyst diversities (and abundances) and the predominance of Group 2 cysts (5.3.2) suggest a similar depositional environment to that of the underlying Craie glauconieuse (5.4.2.1).

Fig. 42 Relationship Between Dinoflagellate Cyst Abundance/Diversity And Lithology At Hameau-Frédet Quarry, Fumichon, France

Stage	Zone	Formation	Member	Sample Horizons	Lithology	Marker Horizone	Number Of Cyst Species
CENOMANIAN							
	Middle	A. rhotomagense	Craie de Rouen		HF.15		"Rouen No.3"	
					HF.14		"Rouen No.2"	
					HF.13		"Rouen No.1" Hardground	
	Lower	M. mantelli	Craie glauconieuse		HF.12			
					HF.11		"Bruneval No.3" Hardground	
					HF.10			
					HF.9			
					HF.8 HF.7			
					HF.6			
					HF.5 HF.4 HF.3		"Bruneval No.2" Hardground	
					HF.2 HF.1		"Bruneval No.1" Hardground	

Scale: 2 — 1 — 0m

Number Of Cyst Species: 5 10 15 20 25

Legend:
Glauconite Graine, Semi-Tabular Flint, Nodular Hardground, Shell Debris
Nodular Structure, Nodular Flint, Omission Surface

Fig. 43 Relationship Between Dinoflagellate Cyst Abundance/Diversity And Lithology At Canteloup Quarry, Fumichon, France
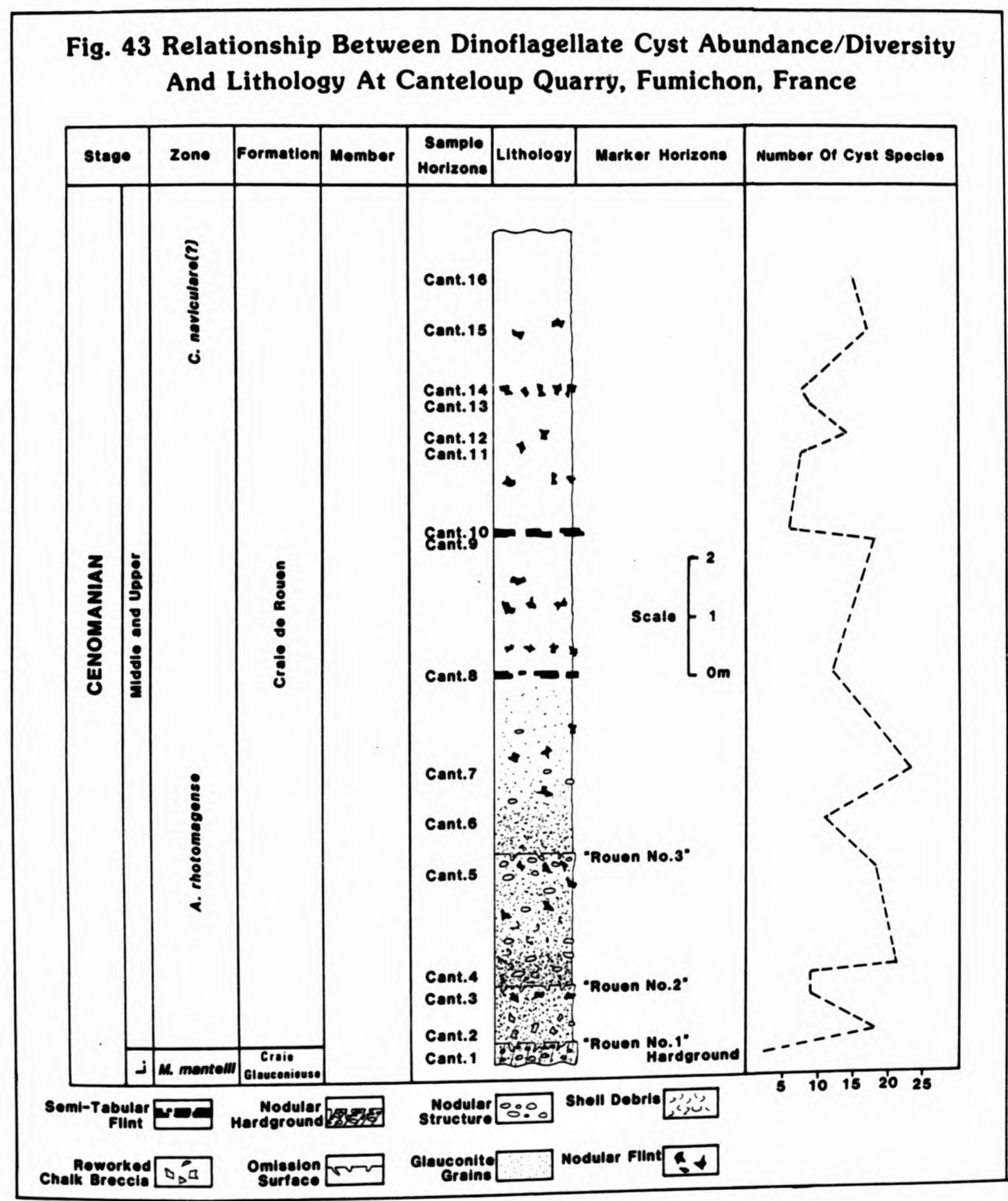
5.4.3 Les Fosses Blanches Quarry, La Caluyere (Fig. 44)

5.4.3.1 Sables du Perche –

The Sables du Perche consist here of highly-oxidised, coarse, glauconitic sands which show evidence (e.g. large scale current bedding) of deposition in a high-energy, nearshore environment. Samples from this formation were palynologically barren.

5.4.3.2 Marnes à O. biauriculata –

The occurrence of these comparatively fine-grained, highly glauconitic sediments (2.2.4) is thought to represent a minor transgression (5.3.3; D) probably caused by local downwarping at the basin margin. The cyst assemblage recovered was poor, and comprised mainly of cyst Groups 2, 3 & 5 and is thought to indicate a fairly shallow-water depositional environment.

5.4.3.3 Sables à C. obtusus –

This formation is represented by a thin hardground unit at this locality (2.2.4). The cyst assemblage recovered was typically poor (5.2.2) and marked a return to higher energy depositional conditions.

5.4.3.4 Craie à I. carantonensis –

Sample Cal 3 (Fig. 44) was collected from the glauconitic chalk at the base of this formation. It contained a poor cyst assemblage consisting mainly of Groups 2 & 5, indicating fairly shallow-water depositional conditions

and low nutrient levels (5.3.2).

5.4.3.5 Craie à _I._ _labiatus_ -

Samples from the Craie à _I._ _labiatus_ also contained very poor cyst
assemblages. This is a feature of samples from basal Turonian sediments
throughout the Anglo-Paris Basin (5.3.3; E) and is thought to be the result
of low nutrient levels during a period of stillstand in sea level rise.

Fig. 44 Relationship Between Dinoflagellate Cyst Abundance/Diversity And Lithology At Les Fosses Blanche Quarry, La Caluyere, France
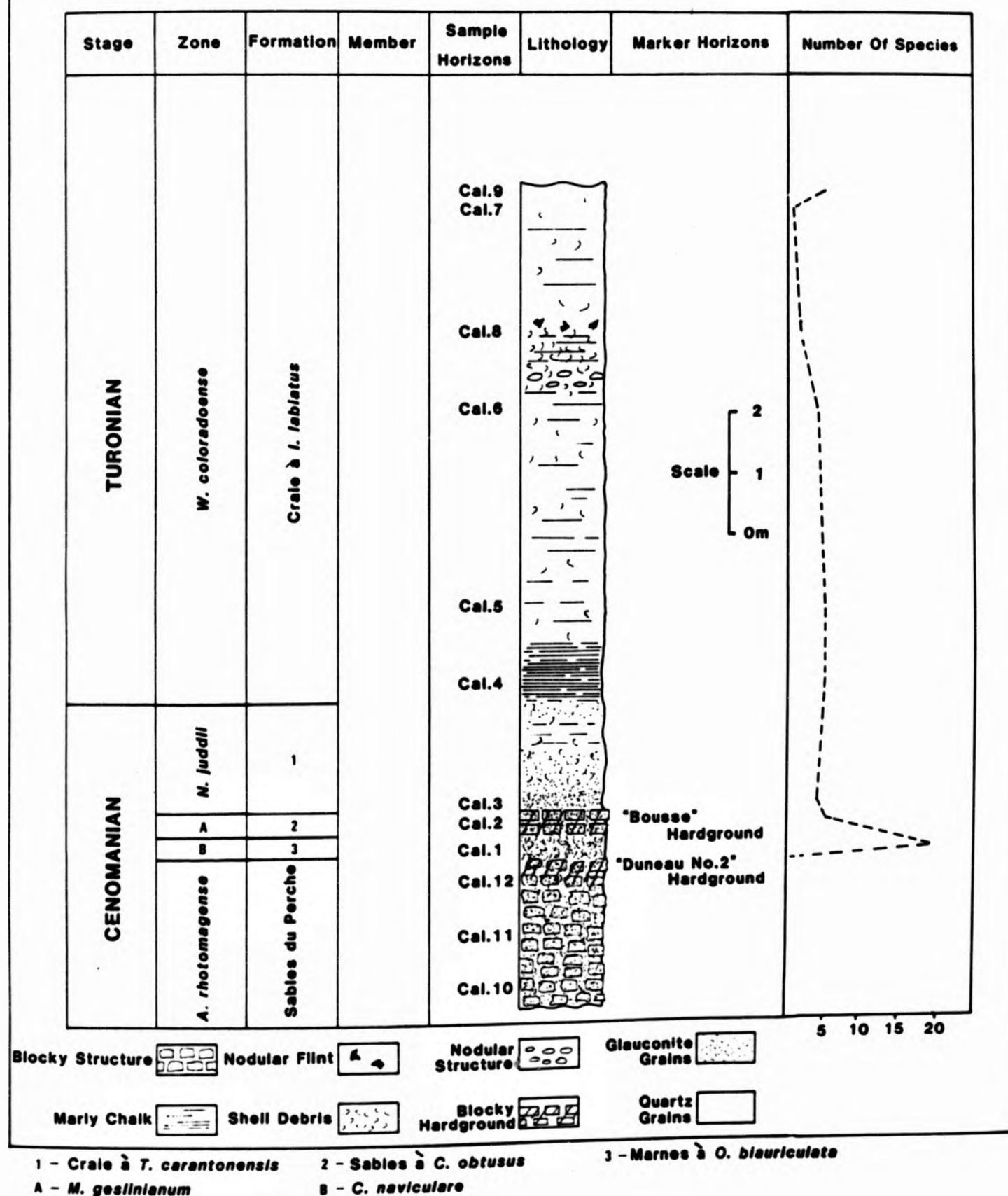
5.4.4 Moulin Ars Quarry, St. Calais (Figs. 10, 11)

5.4.4.1 Sables du Perche -

Samples St. C. 2-6 were barren of palynomorphs (see 5.4.3.1 for depositional environment).

5.4.4.2 Craie à I. _carantonensis_ -

Sample St. C. 1 contained a few poorly preserved specimens of _Cyclonephelium_ _distinctum_ (Group 2). See 5.4.3.4 for depositional environment.

5.4.5 Bois du Galet Marl Pit, St. Sylvestre-de-Cormeilles (Fig. 45)

5.4.5.1 Craie à A. plenus -

This formation is represented here by marly chalks and is laterally equivalent to the Plenus Marls of southeast England (2.4.2). The presence of several nodular hardgrounds, and flint lines indicates periodic increases in current activity (5.1.2, 5.1.3). Samples from the lower part of the exposure contain moderately rich cyst assemblages (Figs. 35, 45; St. S. 1, 2). Cyst Groups 2 & 5 were particularly well-represented, while the occurrence of several Group 3 forms may reflect increased phytoplankton productivity due to nutrient influxes (5.1.4). The average cyst diversity in samples from the Craie à A. plenus was 21, compared with 36 for the Plenus Marls at Beachy Head (Fig. 49), indicating the comparitively shallow depth of deposition of the former (5.3.1).

5.4.5.2 Craie noduleuse -

This formation consists of numerous banks of calcareous nodules which are thought to represent periods of increased current activity and low phytoplankton productivity (5.1.2). Similar sediments were recorded in other parts of the basin at this stratigraphic level (5.3.3; E). Cyst assemblages were very poor (Fig. 45) and comprised mainly of Groups 2 & 5 (5.3.2).

5.4.5.3 Craie marneuse -

The Craie marneuse consists mainly of marly chalks with occasional flint lines (2.2.5). Cyst assemblages recovered were poor, and consist mainly of Groups 2 & 5 (5.3.2). The absence of hardgrounds, and reduced number of

omission surfaces suggests lower current velocities than for the underlying sediments. However, the level of phytoplankton productivity recorded indicates that nutrient levels were still low.

Fig. 45 Relationship Between Dinoflagellate Cyst Abundance/Diversity
And Lithology At Bois du Galet Marl Pit, St. Sylvestre, France

Stage		Zone	Formation	Member	Sample Horizons	Lithology	Marker Horizons	Number Of Species

Nodular Flints Shell Debris Nodular Hardground

Nodular Structure Marly Chalk Glauconitised Surface
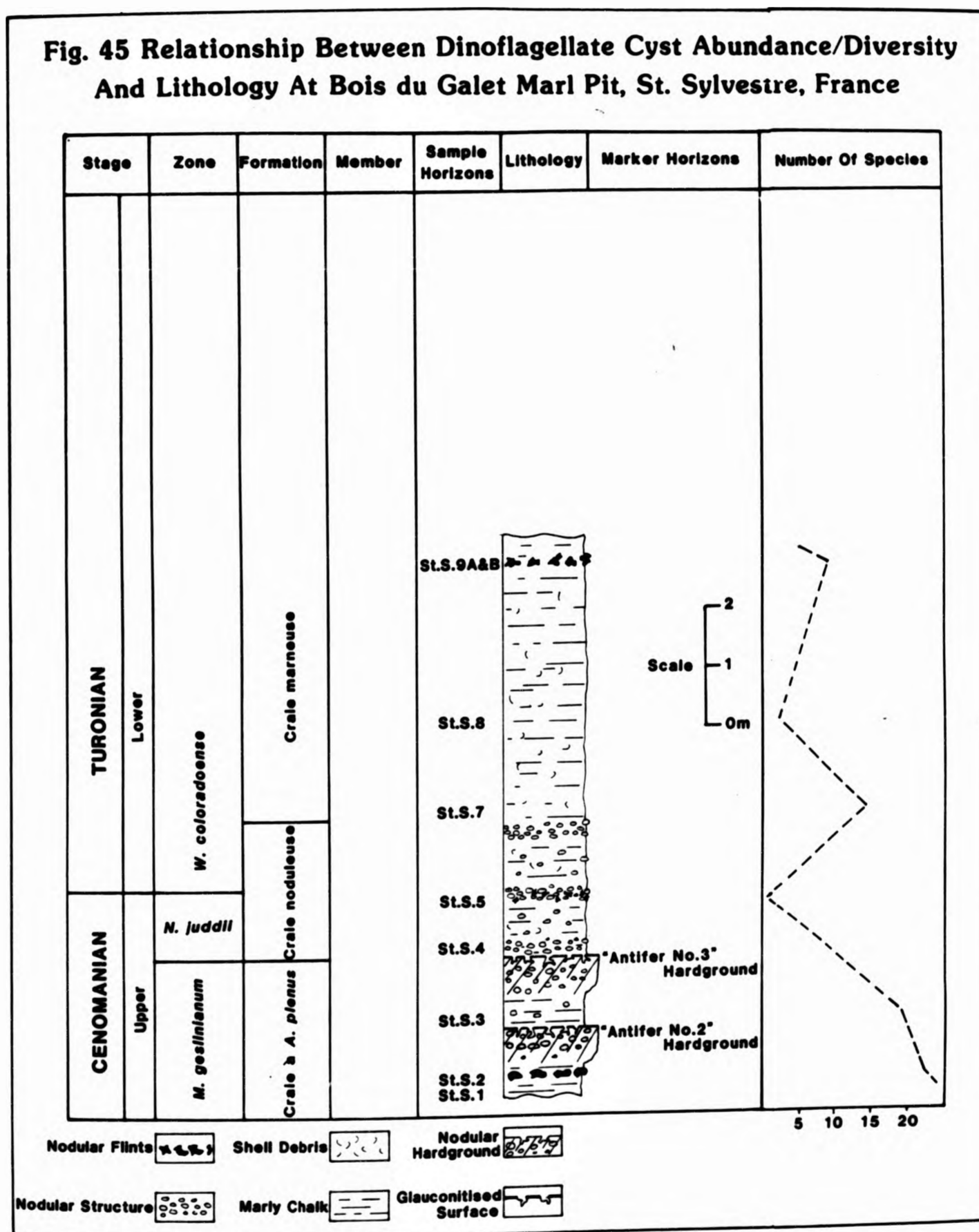
5.4.6 Ports (Fig. 46)

5.4.6.1 Craie à _I. labiatus_ -

The Craie à _I. labiatus_ at Ports consists of a thick sequence of chalk/marl units, which become increasingly micaceous near the top of the exposure (2.2.7). Abundant and diverse dinoflagellate cyst assemblages, dominated by relatively deep-water Group 3 forms, were recovered from the lower part of the succession (Figs. 36, 46; Po 9-13). Cyst diversity reached a peak in Sample Po 9 (Fig. 46), and this is correlated with an early Turonian transgressive episode (5.3.3; F). The sediments in the upper part of the exposure are mica-rich, indicating emergence and erosion of a nearby mica-rich source (i.e. the Armorican Massif). The cyst assemblages recovered from these micaceous chalks were relatively poor compared to those from the lower part of the succession, and Group 3 forms virtually disappear to be replaced by Groups 2 & 5 (Fig. 36). The lithological and palynological evidence points to a regressive phase at this time (5.3.3; G).

It is worthy of note here that the rich cyst assemblages recovered from the lower part of the succession correspond to the Inoceramid zone of _Mytiloides_ cf. _opalensis_ (Woodroof, 1981), while the poor assemblages from the micaceous chalks (above Sample Po 9) fall within the Zone of _Mytiloides mytiloides_ (Woodroof, 1981). This close association between the two fossil groups was noted at other localities (5.4.7, 5.5.3) and indicates their potential value as palaeoenvironmental indicators.

Fig. 46   Relationship Between Dinoflagellate Cyst Abundance/Diversity And Lithology At Ports, France
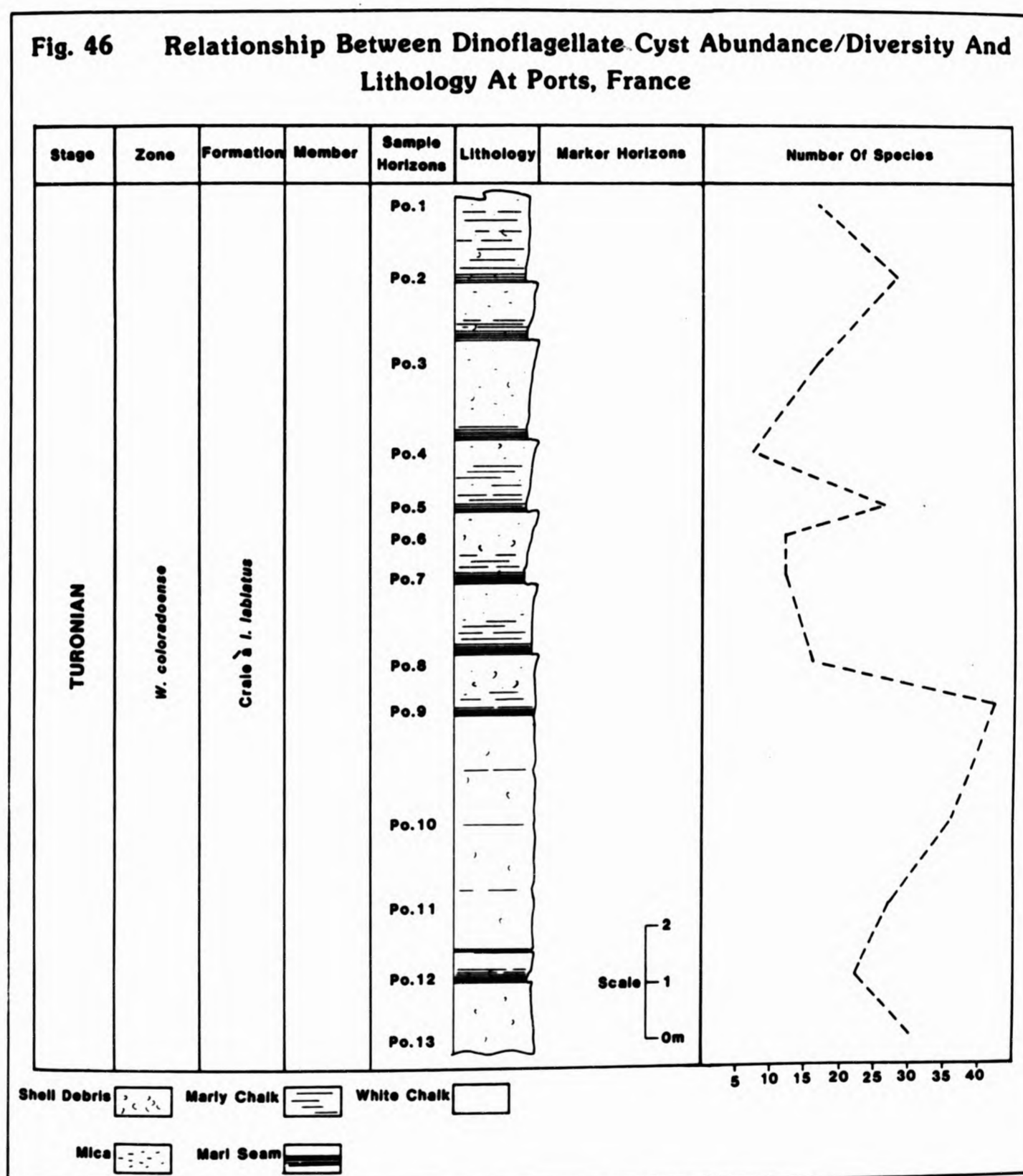
5.4.7 Fontevraud Quarry (Fig. 47)

5.4.7.1 Craie à I. labiatus -

The sediments from this formation at Fontevraud Quarry closely resemble those from the upper part of the section at Ports (5.4.6.1), and contain similar cyst assemblages. See 5.4.6.1 for depositional environment.

5.4.7.2 Craie micacée -

All the samples processed from the Craie micacée contained either poor cyst assemblages or were barren (Figs. 37, 47; Fo 1, 10, 11 & 13). Those that were recorded comprised mainly cyst Groups 2 & 5 and are thought to indicate deposition in a relatively shallow water, 'inner shelf' environment during a period of regression (5.3.3; G).

As at Ports, changes in the dinoflagellate cyst distribution show a close relationship to changes in the Inoceramid fauna. Sample Fo 6 marks the junction between the Zones of Mytiloides mytiloides (lower) and M. cf. labiatus (Woodroof, 1981). AND

Fig. 47 Relationship Between Dinoflagellate Cyst Abundance/Diversity And Lithology At Fontevraud Quarry, France
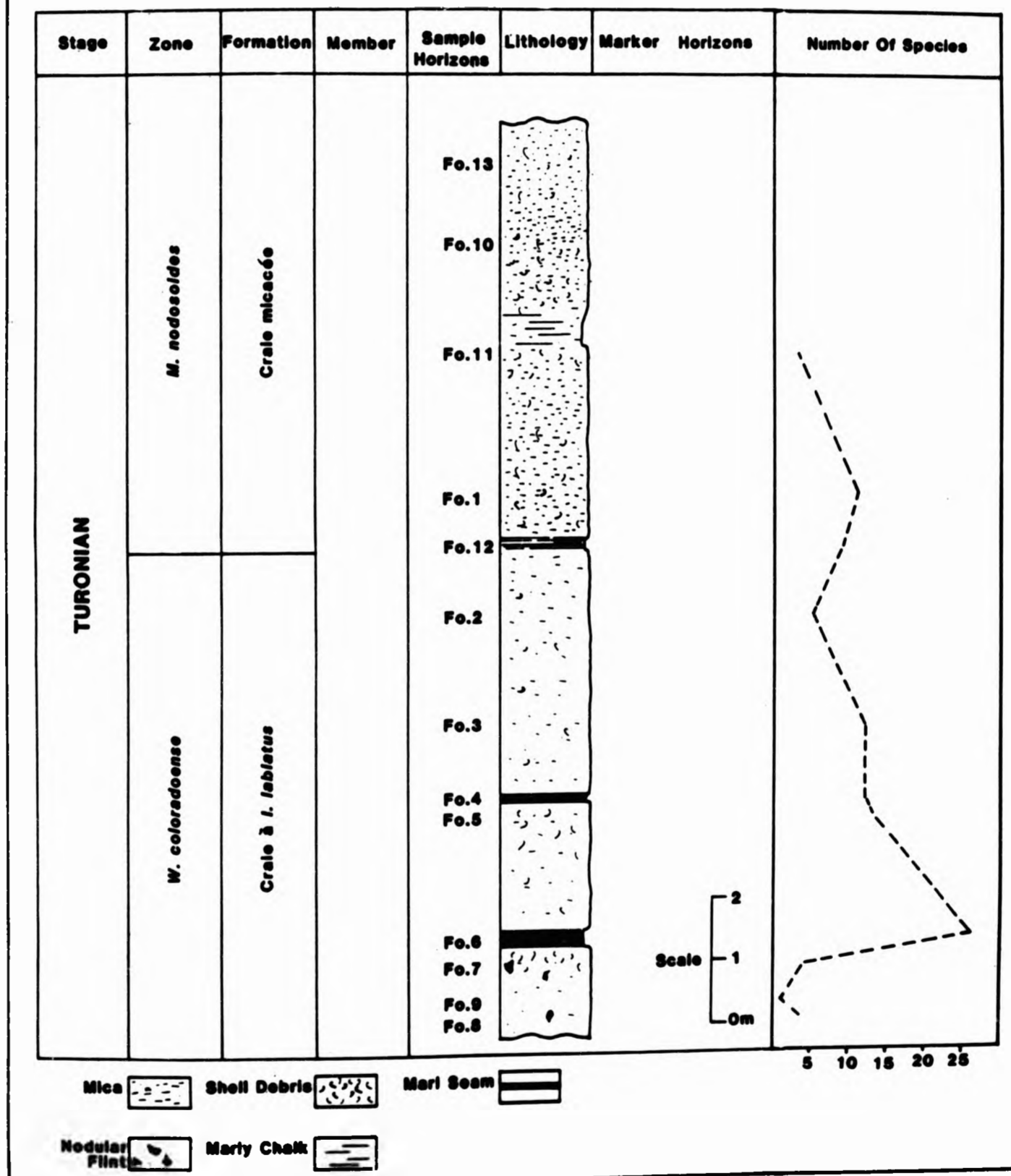
5.4.8 Mushroom farm section, La Chartre-sur-le-Loir (Figs. 18, 19)

A total of 19 samples were collected from the top of the Craie micacée
and the Tuffeau Jaune at this locality, all of which proved to be palynologi-
cally barren. The sandy, detrital and highly oxidised nature of the
sediment, the presence of prominent hardgrounds and nodular units indicate
that the sediments were deposited in a high energy nearshore environment dur-
ing a major regressive (5.3.3; G).

5.4.9 Roadside section, Villedieu-le-Château (Figs. 20, 21)

As at La Chartre (5.4.8), samples from this locality proved to be
palynologically barren indicating a similar depositional environment.

5.5 Palaeoenvironment of sections sampled in southern England

5.5.1 Asham Pit, Beddingham (Fig. 48)

5.5.1.1 Upper Greensand -

The buff, silty clays of the Upper Greensand at Asham Pit (2.4.1) are regarded by several workers (e.g. Kennedy & Garrison, 1975b) as having been deposited in low-energy, shallow-water, open shelf conditions. Despite the abundance of terrigenous clays, the proportion of miospores recovered was low (< 5%), suggesting that the sediments were not nearshore in origin. zthe abundant and diverse dinoflagellate cyst assemblages recovered from this formation were dominated by Group 3 forms (5.3.2). Cyst diversity reached a peak in Sample BAT 4 (Fig. 48), and this is thought to be related to a transgressive episode in the Anglo-Paris Basin at this time (5.3.3; A).

5.5.1.2 Lower Chalk -

The basal unit of the Lower Chalk, the Glauconitic Marl, is regarded as a condensed sequence (5.3.3; B) and contains reworked Albian material (2.4.1, 4.4.1). Samples from this unit contain abundant and diverse cyst assemblages, which is partly due to reworking and mixing of Albian-Cenomanian material. Unlike the Upper Greensand (5.5.1.1), the cyst assemblages contain numerous examples of cyst Groups 1 & 2, as well as Group 3 (5.3.2), possibly indicating a shallower depositional environment (5.3.3; B).

Fig. 48 Relationship Between Dinoflagellate Cyst Abundance/Diversity And Lithology
At Asham Pit,Beddingham, S. England
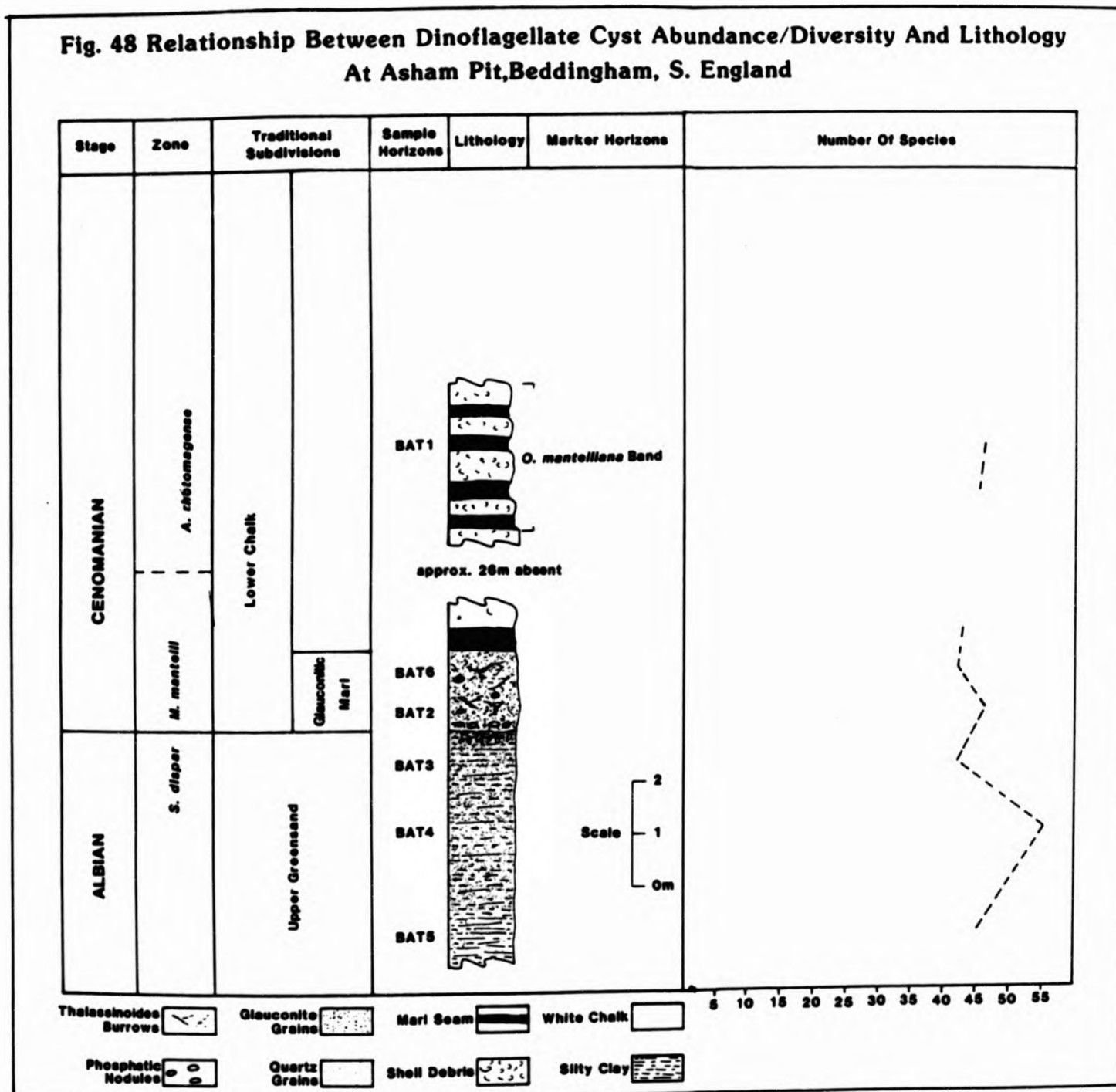
5.5.2 Beachy Head, Eastbourne (Fig. 49)

5.5.2.1 Lower Chalk -

Much of the Lower Chalk at Beachy Head consists of distinctive
chalk/marl sequences (see 5.5.1.2 for depositional environment of the Glau-
conitic Marl). The exact origin of these is not fully understood but recent
work (5.2.4) suggests that they may be related to climatic fluctuations. The
dinoflagellate cyst assemblages recovered from this 'formation' tend to be
more abundant in the clay-rich layers, and it is suggested here that this is
the result of periodic influxes of nutrient-rich currents (5.1.4). There is
a significant diversity peak in the Lower Cenomanian (Fig. 49; BH 3) which
is thought to be due to a major transgressive episode (5.3.3; C). The cyst
assemblages in the Lower Chalk are dominated by Group 3 forms (5.2.3). This,
combined with the greater abundance and diversity of cyst assemblages, and
the fine-grained nature of the sediment compared with material of similar age
from other parts of the basin (e.g. Hameau-Fredet, Canteloup) indicates a
relatively deep water, central basin environment of deposition.

5.5.2.2 Middle Chalk -

The lower part of the Middle Chalk at Beachy head is characterised by
nodular chalks, samples of which yield very poor cyst assemblages (Figs. 39,
49). The former are thought to be formed during periods of relatively high
current activity and low nutrient levels, and can be correlated basin-wide
(5.3.3; E). Samples from higher up in the succession (Figs. 39, 49; BH
14, 15) contain richer cyst assemblages than those from the Melbourn Rock
(2.4.2). Unfortunately, however, that part of the Middle Chalk which immedi-
ately overlies the latter unit was not sampled (2.4.2) and, therefore, it is

not known for certain whether the phytoplankton expansion recorded in low Turonian sediments at Ports (5.4.6) and Beer (5.5.3), also occurs at Beachy Head. However, increased planktonic/benthonic foraminifera ratios recorded from this level by Carter & Hart (1979) suggest that it probably does. Samples from near the top of the Middle Chalk show an increased abundance of some Group 2 forms (particularly Cyclonephelium distinctum), indicating a period of regression (5.3.3; G).

5.5.2.3 Upper Chalk -

The occurrence of nodular chalks and hardgrounds, relatively poor cyst assemblages and the increased importance of cyst Groups 2 & 5 are taken to indicate a mid-late Turonian regressive phase (5.3.3.; G).

Fig. 49 Relationship Between Dinoflagellate Cyst
Abundance/Diversity And Lithology
At Beachy Head, Eastbourne, S. England
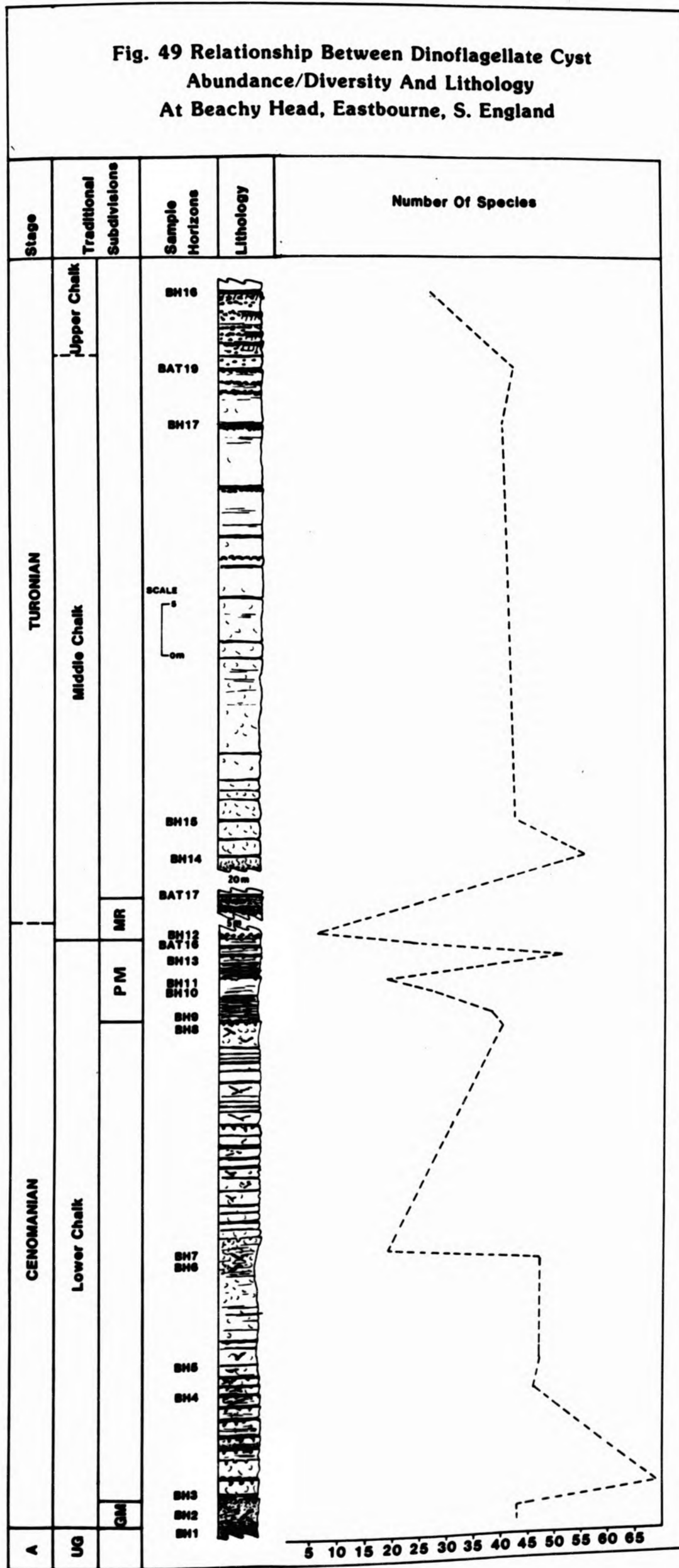
5.5.3 Beer, S.E. Devon (Fig. 50)

5.5.3.1 Upper Greensand -

Samples from this formation (Fig. 40; Beer H. 4-6) were palynologically barren. The sediments, which consisted of coarse, trough cross-bedded calcarenites, with large amounts of detrital quartz, were probably deposited in high-energy, shallow water conditions.

5.5.3.2 Beer Head Limestone -

The sediments which comprise the lower part of this formation (i.e. Pounds Pool, Hooken Cliffs and Little Beach Members) consist of coarse calcareous sandstones, with numerous hardgrounds (2.4.3). These show considerable lateral reworking and were probably deposited in a high-energy, shallow-water environment. Dinoflagellate cyst first appear in the Pinnacles Member (Figs. 40, 50; Adit 16). The reasons for this are unclear but may be due to a continuation of the transgressive episode which was initiated in the Lower Cenomanian (5.3.3; C), or local tectonic downwarping on the basin margin.

5.5.3.3 Seaton Chalk -

Sediments ranging in age from Turonian to basal Coniacian were sampled (2.4.3). The cyst assemblages recovered showed considerable variations in abundance and diversity (Figs. 40, 50). Those from the Connett's Hole Member increased in diversity up-section, reaching a high of 28 species in Sample BR 2 (Fig. 50). This is thought to be related to the early Turonian transgressive episode recorded elsewhere in the Anglo-Paris Basin (5.3.3;

F). Surprisingly, however, a second diversity peak was recorded from the base of the Beer Roads Member (Fig. 50; Hall 1), which is thought to be in the _I. lata_ Zone (4.4.3). Samples collected from this level elsewhere show regressive trends and, therefore, the stratigraphic interpretation of this part of the succession may have to be revised. Dinoflagellate cyst assemblages from the remainder of the succession were poor (average 10 species) and consisted mainly of Groups 2 & 5 (5.3.2). This is correlated with a basin-wide regressive episode during the mid-late Turonian (5.3.3; G).

Fig. 50 Relationship Between Dinoflagellate Cyst
Abundance/Diversity And Lithology
At Beer, S.E. Devon, England
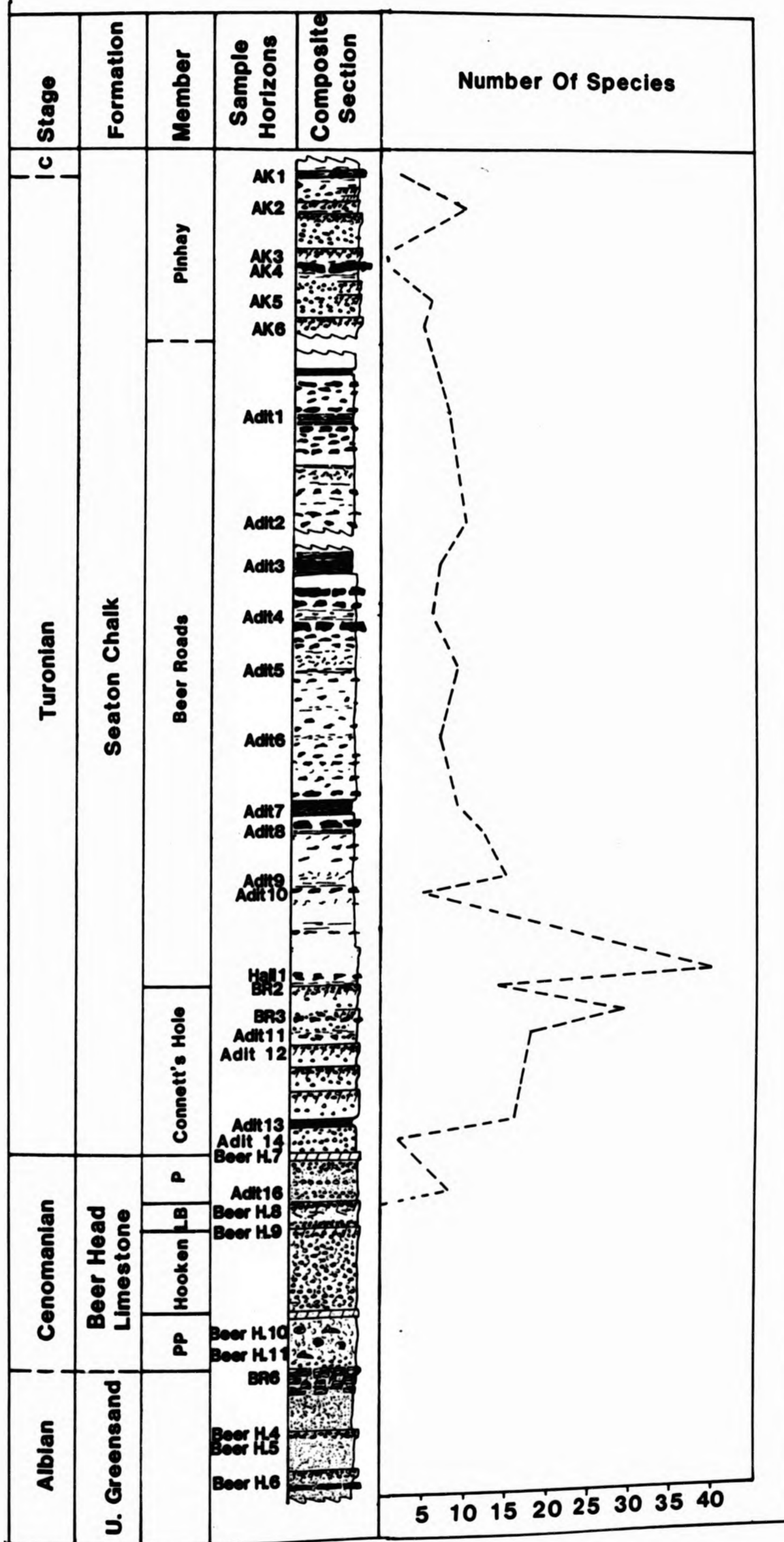
CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 Lithostratigraphy

The existing lithostratigraphic schemes for the various geological for-
mations examined in southern England and N.W. France during this study have
been reviewed, described and correlated (2.1, 2.3). Location diagrams, stra-
tigraphical sections (including details of geological stages, formations,
significant marker horizons, and current macrofaunal zonations) and lithos-
tratigraphic descriptions have also been provided for each sample site; i.e.
Livet Quarry (2.2.1), Hameau-Frédet Quarry (2.2.2), Canteloup Quarry (2.2.3),
Les Fosses Blanches Quarry (2.2.4), Moulin Ars Quarry (2.2.5), Bois du Galet
Marl Pit (2.2.6), Ports (2.2.7), Fontevraud Quarry (2.2.8), La
Chartre-sur-le-Loir (2.2.9), Villedieu-le-Château (2.2.10), Asham Pit
(2.4.1), Beachy Head (2.4.2), Beer Head (2.4.3), Beer Stone Adit 2.4.5), and
Annis' Knob (2.4.5). Sample localities are shown on Fig. 1, and lithostra-
tigraphic correlations are provided on Fig. 2.

6.2 Taxonomy

Two hundred and forty samples were processed, two hundred and nine of
which were productive. One hundred and forty four species and subspecies of
dinoflagellate cysts were recorded (3.1) and photographed. General descrip-
tions and amplifying remarks have been provided where necessary (3.2). Five
new species, Achomosphaera simplex (Pl. 1, figs. 7-8), Epelidosphaeridia
tuberculata (Pl. 5, figs. 9-10), Litosphaeridium medius (Pl. 8, figs.
5-6), L. urna (Pl. 8, figs. 8-9) and Pyxidinopsis parvum (Pl. 11, figs.
8-9), and 2 new subspecies, Achomosphaera sagena brevispinus (Pl. 1, fig.

5) and Cleistosphaeridium armatum brevispinosum (Pl. 3, fig. 3) are des-
cribed and illustrated (3.2).

6.3 Biostratigraphy

Dinoflagellate cyst distribution charts were constructed for all the
sites examined (Figs. 31-40) apart from St. Calais, La Chartre-sur-le-Loir,
and Villedieu-le-Chateau where the sediments were palynologically barren.
The charts were based, where possible, on the percentage distribution of
cysts present (on a spot count of 500 specimens). In those cases where the
cyst abundance was low (i.e. <500 specimens) the absolute number of cysts
was recorded.

Sixteen species were recorded for the first time in mid Cretaceous sedi-
ments from the Anglo-Paris Basin (Achomosphaera regiensis, Apteodinium
reticulatum, Cribroperidinium cf. cooksonae, Disphaeria macropyla,
Nematosphaeropsis densiradiata, Odontochitina cribropoda, Oligosphaeridium
reticulatum, Ovoidinium verrucosum ostium, Pervosphaeridium cenomaniense,
Tanyosphaeridium salpinx, Cyclonephelium clathromarginatum, Gonyaulacysta
polythyris, Oligosphaeridium poculum, Xenascus plotei, Craspedodinium
indistinctum and Achomosphaera verdieri; 4.1).

A summary chart (Fig. 30) was constructed on which all the cyst data
was correlated. The recorded "ranges" differ in many cases from the pub-
lished data (i.e. the former are usually less extensive) indicating that the
dominant control on the cyst distribution in marginal areas is not evolution,
but local facies variations.

6.4 Palaeoenvironment

Diagrams showing the relationship between dinoflagellate cyst abundance/diversity and lithology were constructed for each productive local-ity (Figs. 41-50). The cyst distribution in samples from different lithologies was examined in detail. Poor assemblages were recorded from omission surfaces (5.2.1), nodular chalks and hardgrounds (5.2.2), and some flints (5.2.3). Samples from marl seams on the other hand, commonly con-tained rich and diverse cyst assemblages (5.2.4). These clay-rich units are thought to result from increased deposition of organic-rich material, oxida-tion of which causes local carbonate dissolution (5.2.4). This can be caused by transgressive episodes (5.1.4, 5.3.3), or by the periodic influx of nutrient-rich currents.

Cyst assemblages from the central part of the basin were more abundant and diverse than those recovered from the basin margins. Provided close, independent stratigraphic controls are available, the differences in cyst diversity can be used as a relative guide to water depth (i.e. greater diversity=greater water depth ; 5.3.1).

A number of cyst associations were recognised which appear to character-ise particular depositional environments (5.3.2). These are :-

Group 1 :- <u>Ovoidinium verrucosum verrucosum</u>, <u>O</u>. <u>verrucosum ostium</u>.

Group 2 :- <u>Bacchidinium polypes clavulum</u>, <u>Cyclonephelium distinctum</u>, <u>Epelidosphaeridia spinosa</u>. <u>Heterosphaeridium</u> ? <u>heteracanthum</u>, <u>Subtilisphaera</u> sp.A and <u>Surculosphaeridium longifurcatum</u>.

Group 3 :- most species of <u>Achomosphaera</u>, <u>Exochosphaeridium</u>, <u>Florentinia</u>, <u>Pervosphaeridium</u>, <u>Spiniferites</u>, <u>Litosphaeridium</u>, <u>Microdinium</u>, and also <u>Palaeohystrichophora infusorioides</u>, <u>Xenascus ceratioides</u> and <u>Xiphophoridium alatum</u>.

Group 4 :- Codoniella campanulata, Coronifera oceanica, Disphaeria macropyla, D. munda, Hapsocysta dictyota and Nematosphaeropsis densiradia.

Group 5 :- Hystrichosphaeridium bowerbankii, H. tubiferum tubiferum, Odontochitina costata, O. operculata and Oligosphaeridium complex.

Groups 1 (shallow water) - 4 (deeper water) are essentially indicators of relative water depth within the Anglo-Paris Basin. Group 5 on the other hand consists of tolerant, cosmopolitan species, and can be used to indicate periods of regression (5.3.3) and low nutrient levels.

A number of transgressive-regressive episodes were recognised on the basis of changes in dinoflagellate cyst distribution, lithological variations and comparisons with published data (5.3.3; A-G).

    A) Early late Albian transgression

    B) Albian-Cenomanian boundary regression

    C) Early Cenomanian transgression

    D) Late Cenomanian transgression

    E) Earliest Turonian stillstand

    F) Early Turonian transgression

    G) Mid-late Turonian regression

Those events which are associated with significant increases in dinoflagellate cyst abundance and diversity (5.3.3; C, F) are thought to be eustatic in origin (5.1.4).

Finally, the depositional environments of each productive locality are described and discussed (5.4, 5.5).

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Plate 1

Fig. 1 – Achomosphaera crassipellis (Deflandre & Cookson) Stover & Evitt
(x600), MCP/1284, Sample BAT 6. Antapical view, showing reticulate
periphragm and low parasutural ridges.

Fig. 2 – Achomosphaera ? neptunii (Eisenack) Davey & Williams (x600), WHP/355
Sample BH 3. Dorsal view; arrow indicates distally closed process
terminations.

Fig. 3 – Achomosphaera ramulifera (Deflandre) Evitt (x600), WHP/355, Sample
BH 3. Dorsal view, showing prominent membranes connecting adjacent
cingular processes.

Fig. 4 – Achomosphaera regiensis Corradini (x600), WHP/307, Sample Po 10.
Lateral view; arrow indicates medially bifurcating process.

Fig. 5 – Achomosphaera sagena (Davey & Williams) brevispinus subsp. nov.
(x600), MCP/1307, Sample BAT 19. Dorsal view, showing short, poorly
developed gonal and intergonal processes.

Fig. 6 – Achomosphaera sagena sagena Davey & Williams (x600), MCP/1307,
Sample BAT 19. Dorsal view.

Fig. 7 – Achomosphaera simplex sp. nov. (x600), WHP/355, Sample BH 3.
Holotype; Dorsal view, showing characteristic thin, slightly fibrous
processes.

Fig. 8 – Achomosphaera simplex sp. nov. (x600), WHP/355, Sample BH 3. Dorsal
view.

Fig. 9 – Achomosphaera verdieri Below (x600), MCP/1306, Sample BAT 18.
Dorsal view.

Fig. 10 – Aldorfia deflandrei (Clarke & Verdier) Stover & Evitt (x600),
WHP/366, Sample BH 14. Dorsal view, showing the separated wall
structure.

Fig. 11 – Apteodinium maculatum Eisenack & Cookson (x600), MCP/1291, Sample
BAT 3. Dorsal view, showing large, 'hoof-shaped' precingular
archeopyle.

Fig. 12 – Apteodinium reticulatum Singh (x600), MCP/1291, Sample BAT 3.
Dorsal view, showing reticulate periphragm and type P archeopyle.

PLATE 1
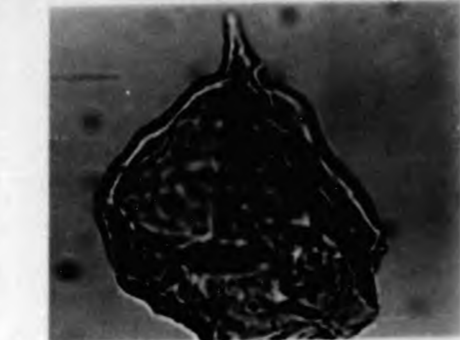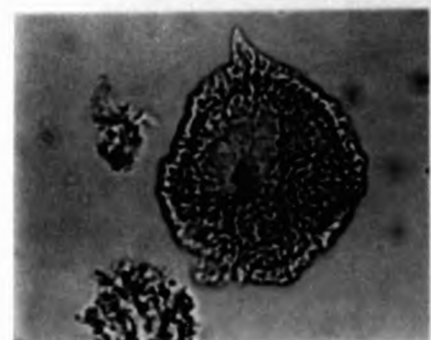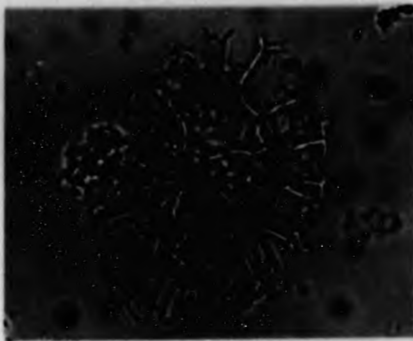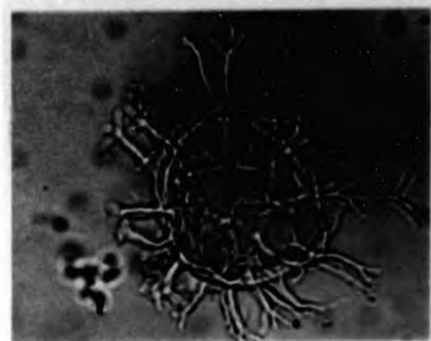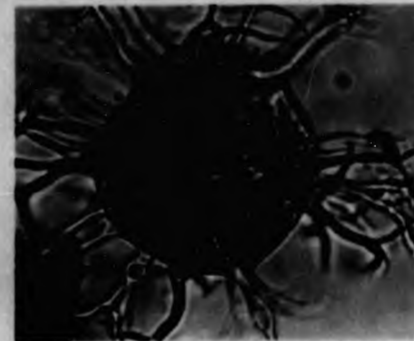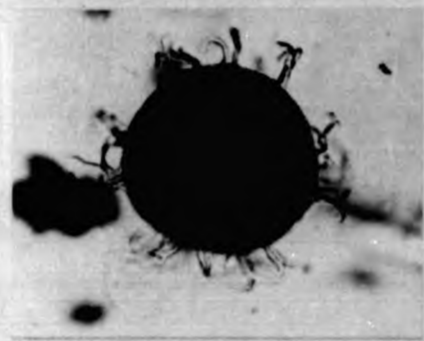
PLATE 1
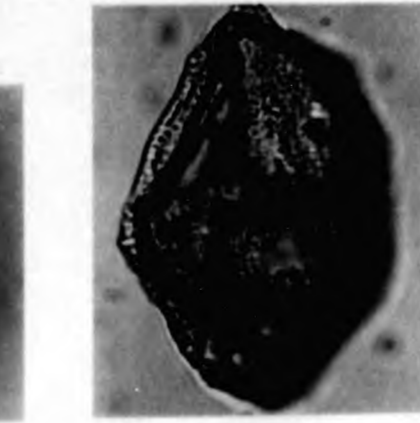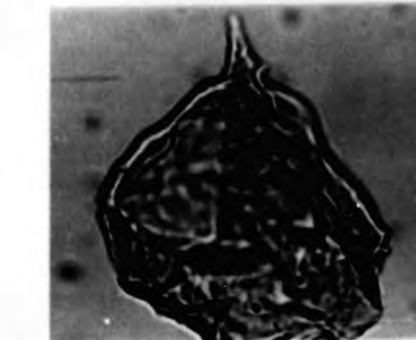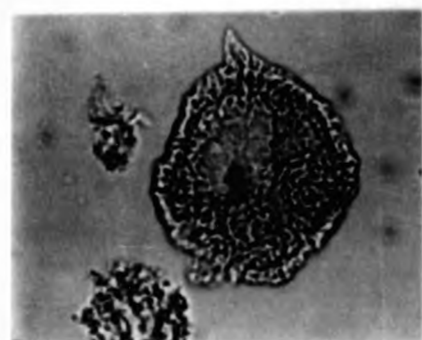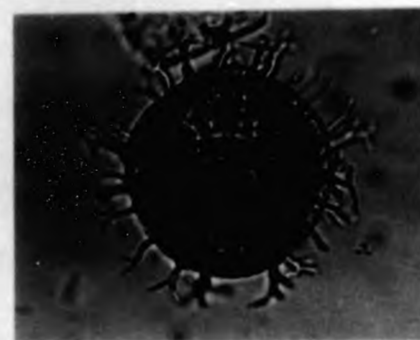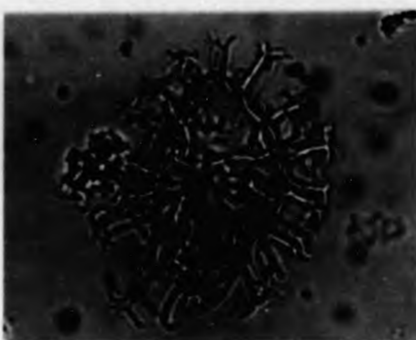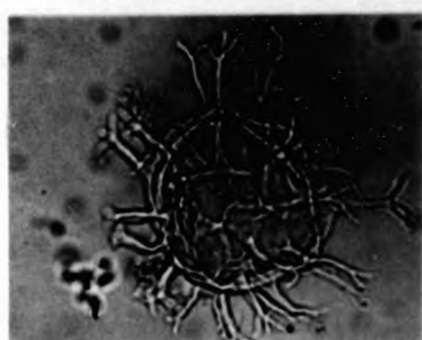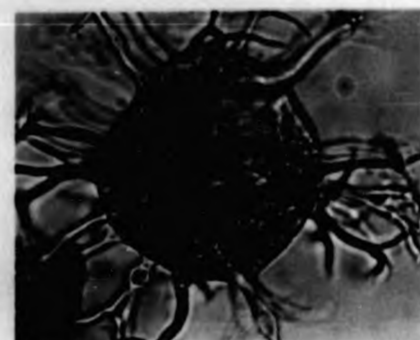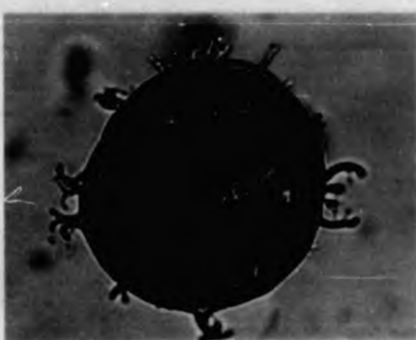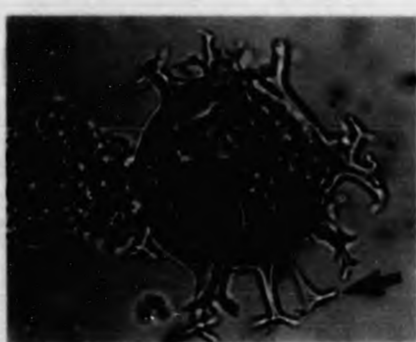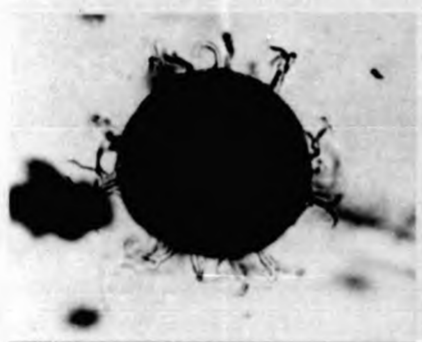
Plate 2

Fig. 1 – <u>Apteodinium</u> sp.A (x600), MCP/1293, Sample BAT 5(1). Lateral view, precingular archeopyle and ornament of low tubercles.

Fig. 2 – <u>Apteodinium</u> sp.B (x600), WHP/311, Sample Cord 1. Dorsal view.

Fig. 3 – <u>Ascodinium acrophorum</u> Cookson & Eisenack (x600), WHP/361, Sample BH 9. Dorsal view.

Fig. 4 – <u>Bacchidinium polypes</u> (Cookson & Eisenack) <u>clavulum</u> (Davey) Lentin & Williams (x600), MCP/1290, Sample BAT 2. Dorsal view, showing precingular archeopyle and capitate process terminations.

Fig. 5 – <u>Bacchidinium polypes polypes</u> (Cookson & Eisenack) Davey (x600), WHP/233, Sample Cant 4B. Lateral view, indicating precingular nature of archeopyle; arrow shows process termination bearing several small spines.

Fig. 6 – <u>Batiacasphaera eutiches</u> (Davey) Davey (x600), WHP/58, Sample Hall 1. Dorsal view, showing thick, sponge-like periphragm.

Fig. 7 – <u>Callaiosphaeridium asymmetricum</u> (Deflandre & Courteville) Davey & Williams (x600), WHP/368, Sample BH 16. Antapical view; arrow indicates parasutural process.

Fig. 8 – <u>Canningia attadalica</u> (Cookson & Eisenack) Stover & Evitt (x600), MCP/1289, Sample BAT 1. Showing typical spinose ornament and prominent antapical lobe.

Fig. 9 – <u>Canningia colliveri</u> Cookson & Eisenack (x600), WHP/360, Sample BH 8. Lateral view.

Fig. 10 – <u>Canningia reticulata</u> Cookson & Eisenack (x600), WHP/53, Sample BR 2.

Fig. 11 – <u>Cassiculosphaeridia reticulata</u> Davey (x600), WHP/356, Sample BH 4. Shows coarsely reticulate periphragm.

Fig. 12 – <u>Chytroeisphaeridia chytroeides</u> (Sarjeant) Downie & Sarjeant (x600), MCP/1307, Sample BAT 19(2). Lateral view, showing precingular archeopyle.
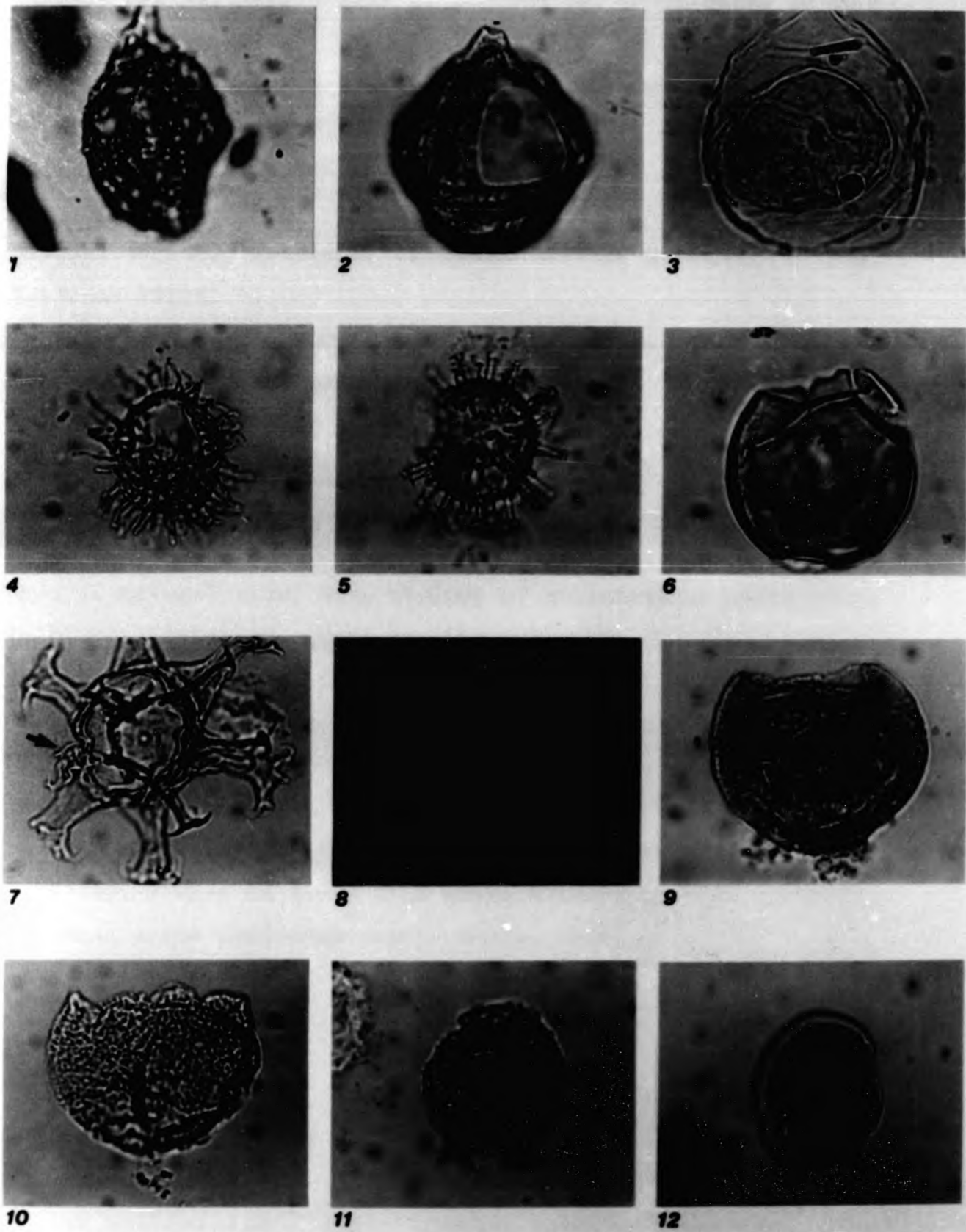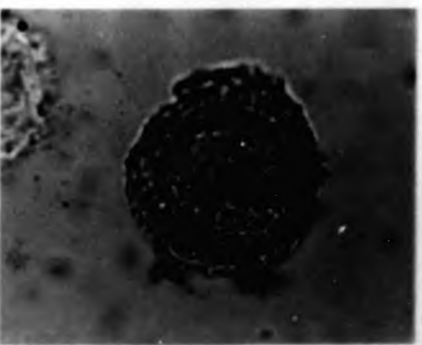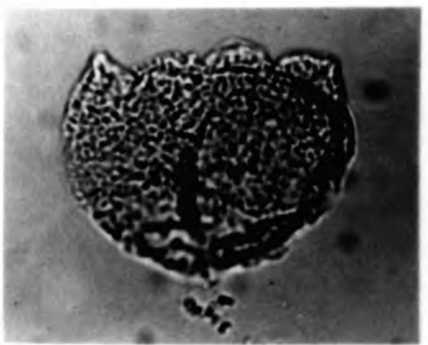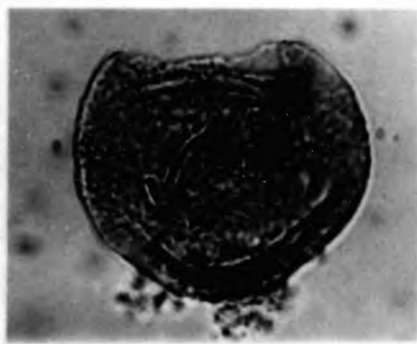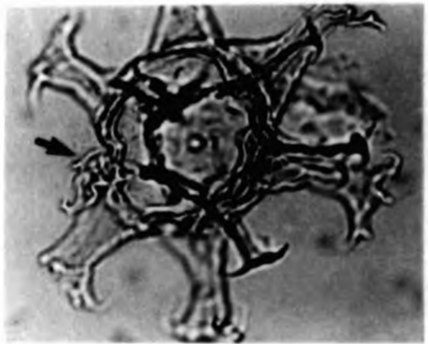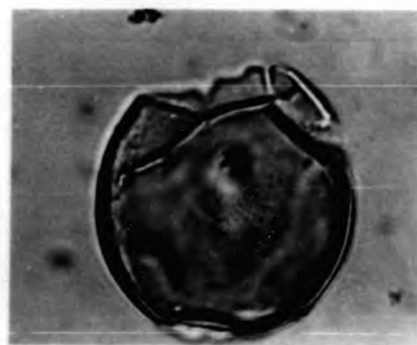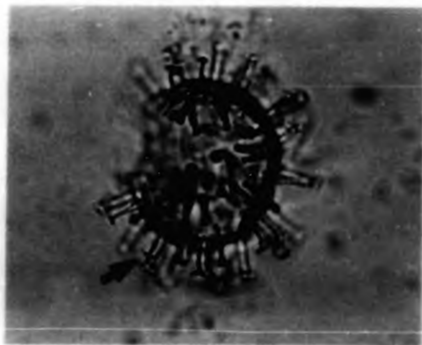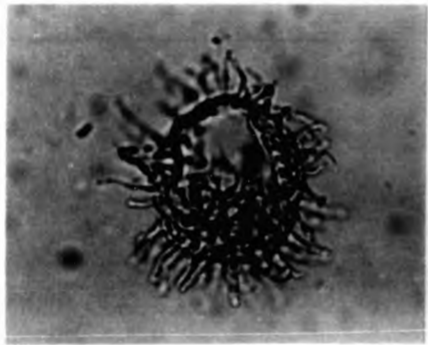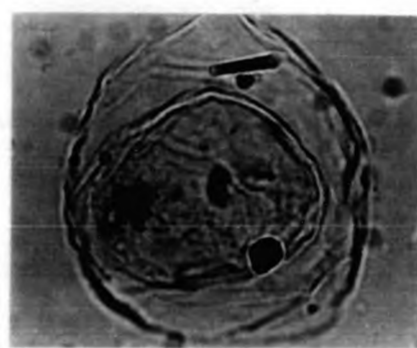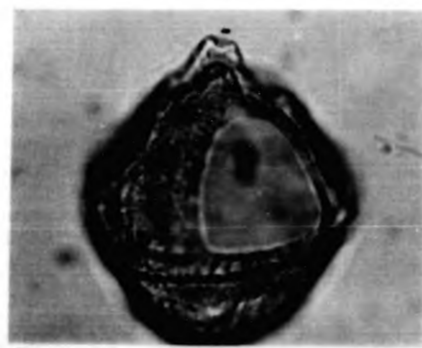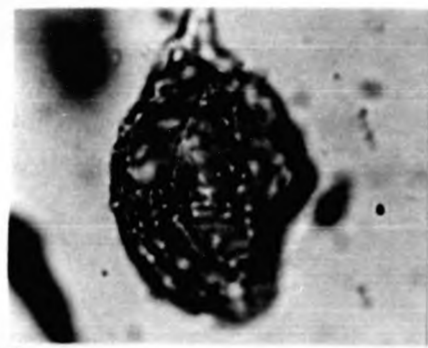
Plate 2

Plate 2

Plate 3

Fig. 1 – <u>Cleistosphaeridium</u> <u>ancoriferum</u> (Cookson & Eisenack) Davey et al.
(x600), MCP/1303, Sample BAT 15.

Fig. 2 – <u>Cleistosphaeridium</u> <u>armatum armatum</u> (Deflandre) Davey (x600), WHP/358,
Sample BH 6. Apical view, showing typical acuminate processes.

Fig. 3 – <u>Cleistosphaeridium</u> <u>armatum</u> (Deflandre) <u>brevispinosum</u> subsp. nov.
(x600), WHP/58, Sample Hall 1. Showing characteristically short,
acuminate processes.

Fig. 4 – <u>Codoniella</u> <u>campanulata</u> (Cookson & Eisenack) Downie & Sarjeant;
emend. Davey (x600), MCP/1305, Sample BAT 17. Arrow indicates
parasutural crest thickening.

Fig. 5 – <u>Cometodinium</u> ? <u>whitei</u> (Deflandre & Courteville) Stover & Evitt
(x600), WHP/365, Sample BH 13. Shows surface ornament of long,
flexuous hairs.

Fig. 6 – <u>Coronifera</u> <u>oceanica</u> Cookson & Eisenack; emend. May (x600), WHP/365,
Sample BH 13. Dorsal view, showing precingular archeopyle; arrow
indicates open tubular antapical process.

Fig. 7 – <u>Craspedodinium</u> <u>indistinctum</u> Cookson & Eisenack (x600), WHP/219,
Sample HF 13.

Fig. 8 – <u>Cribroperidinium</u> cf. <u>cooksonae</u> Norvick (x600), WHP/311, Sample
Cord 1. Lateral view. Note absence of paracingular paraplates.

Fig. 9 – <u>Cribroperidinium</u> cf. <u>cooksonae</u> Norvick (600), WHP/311, Sample
Cord 1. Lateral view.

Fig. 10 – <u>Cribroperidinium</u> <u>edwardsii</u> (Cookson & Eisenack) Davey (x600),
WHP/313, Sample Cord 3. Ventral view, showing characteristic
parasutural crests.

Fig. 11 – <u>Cribroperidinium</u> <u>exilicristatum</u> (Davey) Stover & Evitt (x600),
WHP/358, Sample BH 6. Ventral view, showing typical accesory
crests; arrow indicates short, apical horn.

Plate 3
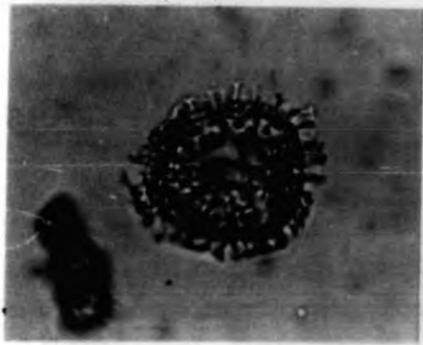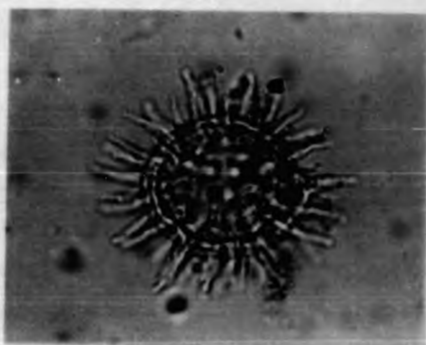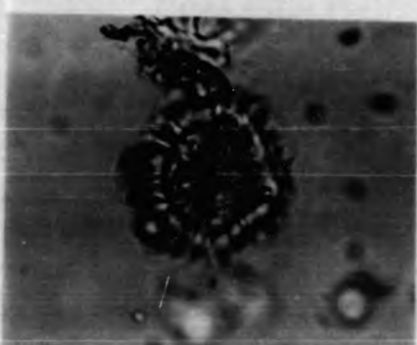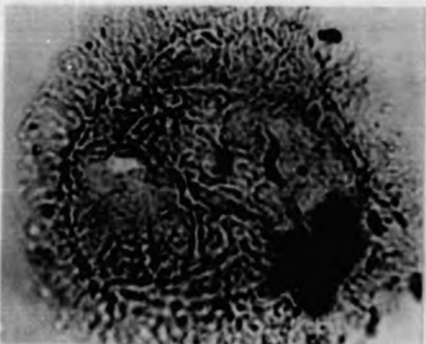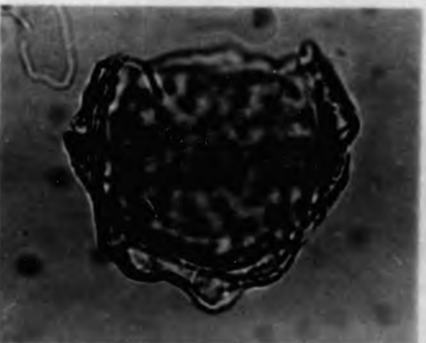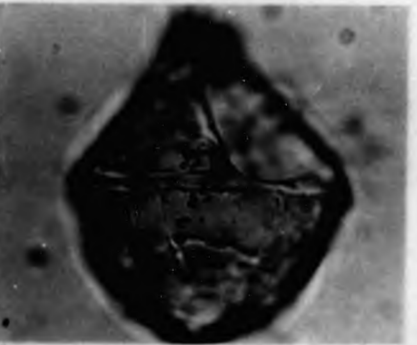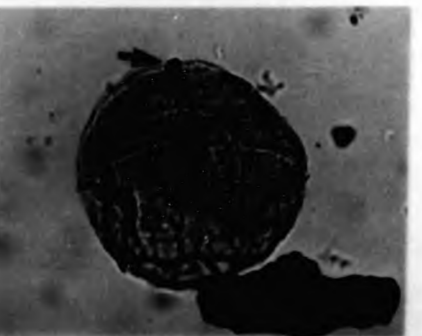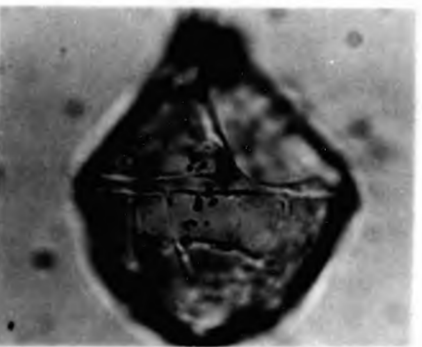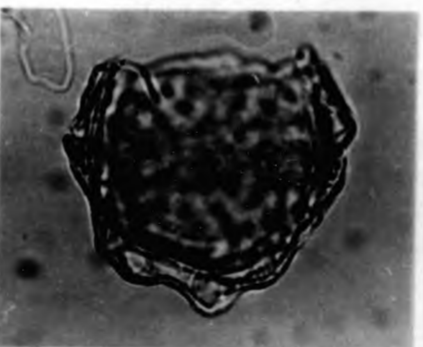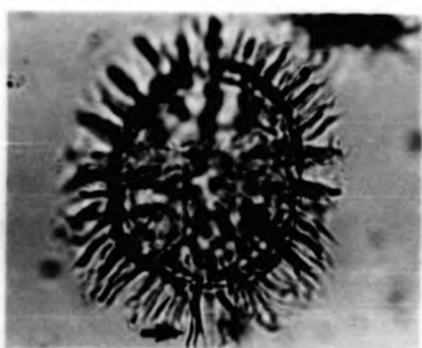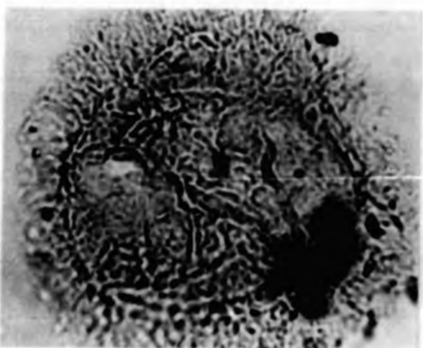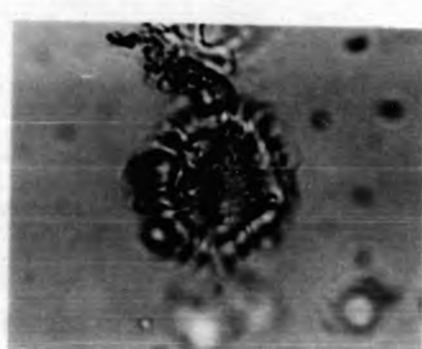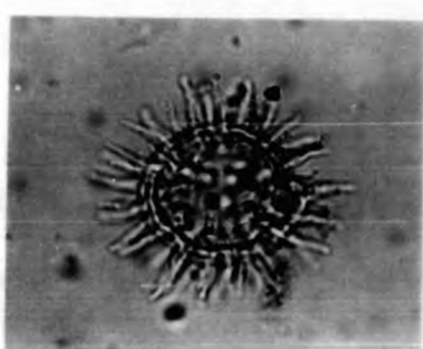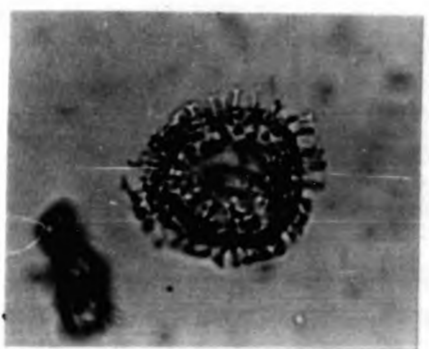
Plate 3

Plate 4

Fig. 1 – <u>Cyclonephelium clathromarginatum</u> Cookson & Eisenack (x600), WHP/58, Sample Hall 1. Ventral view, showing characteristic peripheral crests.

Fig. 2 – <u>Cyclonephelium compactum</u> Deflandre & Cookson (x600), WHP/326, Sample St. S. 3. Dorsal view, showing striate discontinuous crests.

Fig. 3 – <u>Cyclonephelium distinctum</u> Deflandre & Cookson (x600), WHP/342, Sample Adit 1. Ventral view.

Fig. 4 – <u>Cyclonephelium distinctum</u> Deflandre & Cookson (x600), WHP/321, Sample Cord 11.

Fig..5 – <u>Cyclonephelium eisenackii</u> Davey (x600), WHP/319, Sample Cord 9. Dorsal view, showing typical irregular low crests.

Fig. 6 – <u>Cyclonephelium hughesii</u> Clarke & Verdier (x600), WHP/356, Sample BH 4. Ventral view, showing typically short, broad, fibrous processes.

Fig. 7 – <u>Cyclonephelium membraniphorum</u> Cookson & Eisenack (x600), WHP/366, Sample BH 14.

Fig. 8 – <u>Cyclonephelium membraniphorum</u> Cookson & Eisenack (x600), WHP/319, Sample Cord 9. Figures 7 and 8 showing variable development of parasutural crests.

Fig. 9 – <u>Dapsilidinium conispinum</u> (Davey & Verdier) Lentin & Williams (x600), MCP/1291, Sample BAT 3. Ventral view, showing open tubular, and closed conical processes.

Fig. 10 – <u>Dapsilidinium laminaspinosum</u> (Davey & Williams) Lentin & Williams (x600), WHP/355, Sample BH 3. Apical view.

Fig. 11 – <u>Dapsilidinium multispinosum</u> (Davey) Bujak et al. (x600), WHP/356, Sample BH 4.

Fig. 12 – <u>Dinopterygium cladoides</u> Deflandre (x600), WHP/366, Sample BH 14. Apical view.
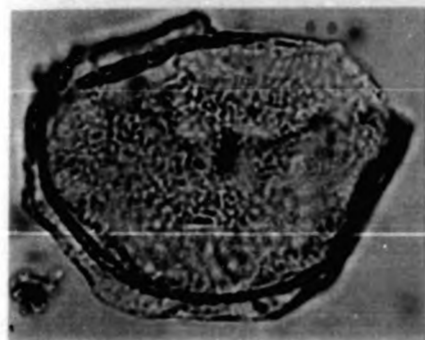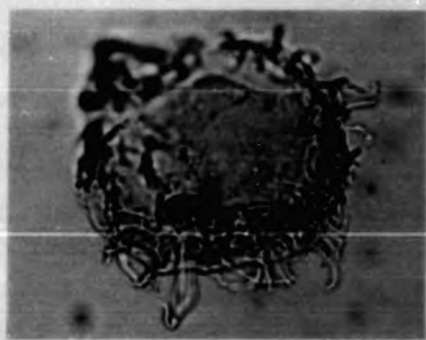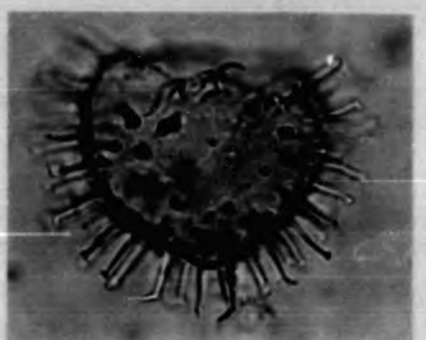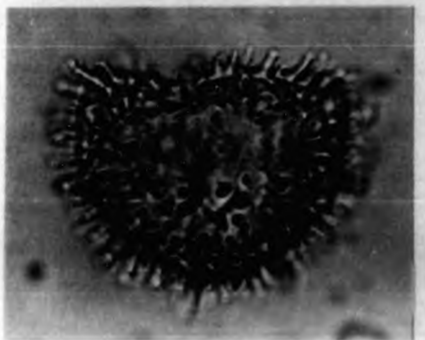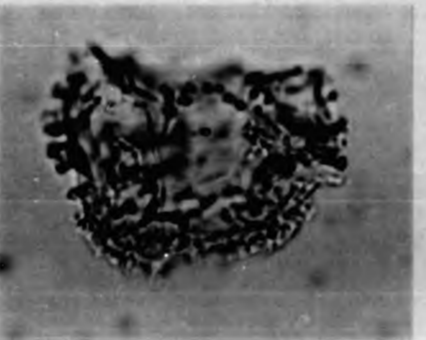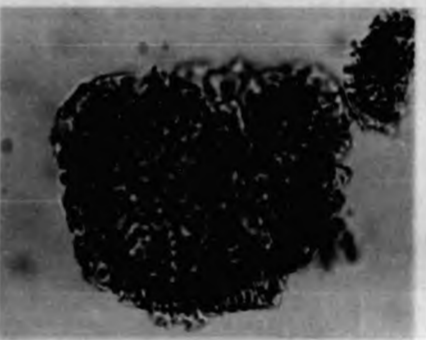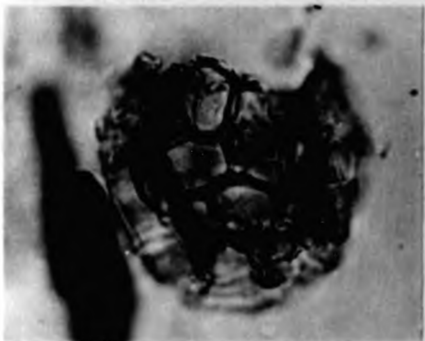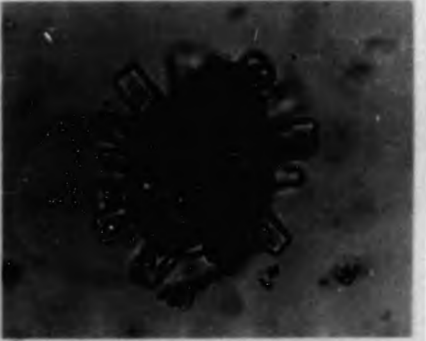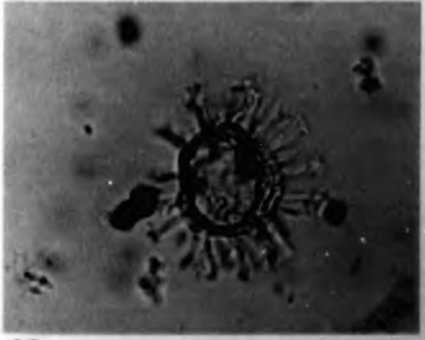
Plate 4

Plate 4

Plate 5

Fig. 1 – <u>Dinopterygium</u> <u>medusoides</u> (Cookson & Eisenack) Stover & Evitt (x600), MCP/1304, Sample BAT 16. Apical view.

Fig. 2 – <u>Disphaeria</u> <u>macropyla</u> Cookson & Eisenack; emend. Norvick (x600), MCP/1291, Sample BAT 3. Dorsal view, showing precingular archeopyle.

Fig. 3 – <u>Disphaeria</u> <u>munda</u> (Davey & Verdier) Norvick (x600), MCP/1294, Sample BAT 6. Lateral view; arrow indicates intratabular process.

Fig. 4 – <u>Ellipsodinium</u> <u>rugulosum</u> Clarke & Verdier (x600), WHP/367, Sample BH 15. Dorsal view, showing reduced precingular archeopyle.

Fig. 5 – <u>Ellipsoidictyum</u> <u>circulatum</u> (Clarke & Verdier) Lentin & Williams (x600), WHP/355, Sample BH 3. Ventral view; arrows indicate position of paracingulum.

Fig. 6 – <u>Endoceratium</u> <u>dettmannae</u> (Cookson & Hughes) Stover & Evitt (x600), WHP/319, Sample Cord 9.

Fig. 7 – <u>Endoscrinium</u> <u>campanulum</u> (Gocht) Vozzhenikova (x600), WHP/362, Sample BH 10. Ventral view.

Fig. 8 – <u>Epelidosphaeridia</u> <u>spinosa</u> (Cookson & Hughes) Davey (x600), MCP/1289, Sample BAT 1. Showing typical spinose ornament.

Fig. 9 – <u>Epelidosphaeridia</u> <u>tuberculata</u> sp. nov. (x600), WHP/356, Sample BH 4,. Holotype; dorsal view, showing characteristic surface ornament, and clearly defined paracingulum.

Fig. 10 – <u>Epelidosphaeridia</u> <u>tuberculata</u> sp. nov. (x600), WHP/356, Sample BH 4. Ventral view, showing indented sulcal area with reduced ornamentation, and rounded archeopyle margin.

Fig. 11 – <u>Exochosphaeridium</u> <u>arnace</u> Davey & Verdier (x600), MCP/1289, Sample BAT 3. Dorsal view, showing precingular archeopyle formed by the loss of a single precingular paraplate.

Fig. 12 – <u>Exochosphaeridium</u> <u>phragmites</u> Davey et al. (x600), WHP/355, Sample BH 3. Ventral view, showing foliate apical process.
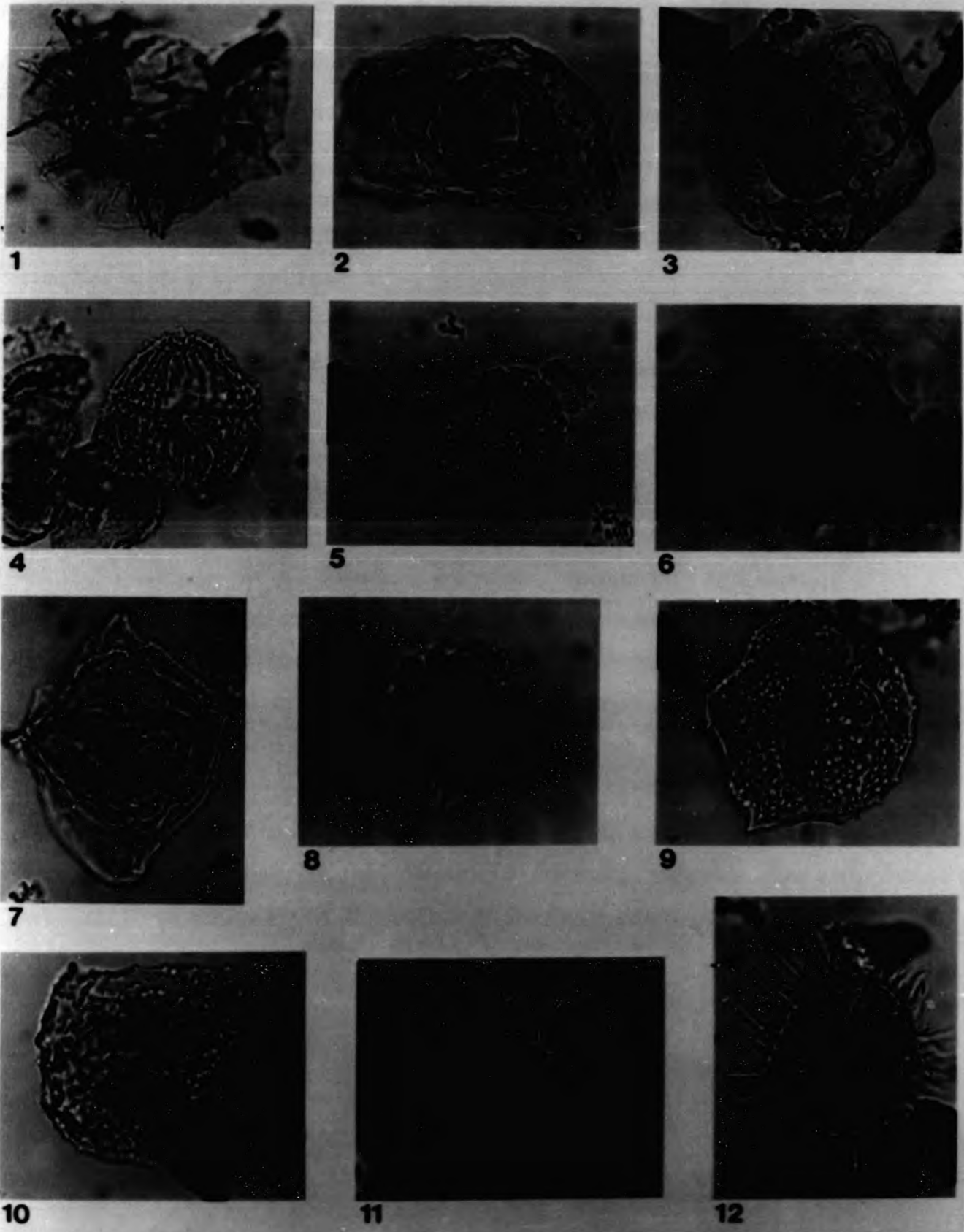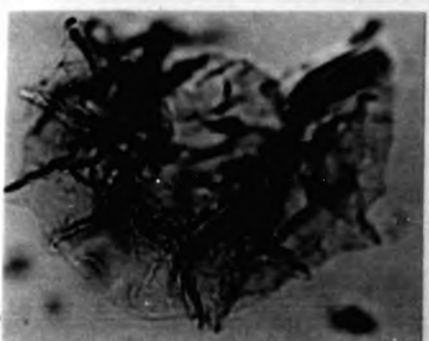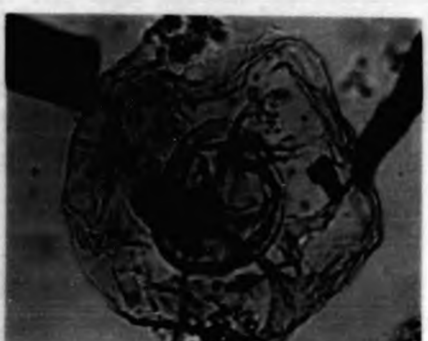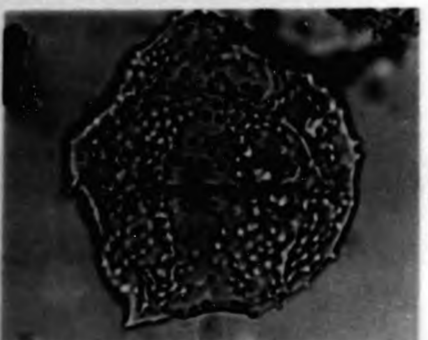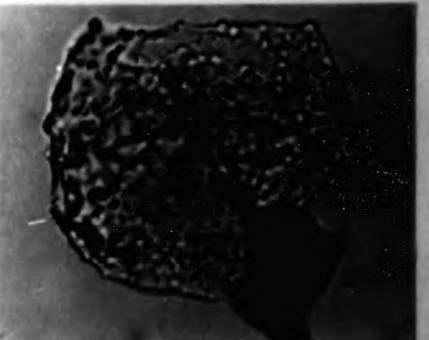
Plate 5

Plate 5

Plate 6

Fig. 1 – <u>Florentinia</u> <u>buspina</u> (Davey & Verdier) Duxbury (x400), MCP/1307,
Sample BAT 19(1). Shows large complex postcingular processes.

Fig. 2 – <u>Florentinia</u> <u>deanei</u> (Davey & Williams) Davey & Verdier (x400),
WHP/355, Sample BH 3. Dorsal view; arrow indicates position of
archeopyle.

Fig. 3 – <u>Florentinia</u> <u>deanei</u> (Davey & Williams) Davey & Verdier (x600),
WHP/355, Sample BH 3.

Fig. 4 – <u>Florentinia</u> <u>ferox</u> (Deflandre) Duxbury (x600), WHP/355, Sample BH 3.
Dorsal view, showing granular cyst wall; arrow indicates medially
trifurcate process.

Fig. 5 – <u>Florentina</u> cf. <u>ferox</u> of Davey & Verdier (1976). (x400), WHP/306,
Sample Po 9. Showing characteristic large antapical process, and
simple, medially trifurcating processes.

Fig. 6 – <u>Florentinia</u> <u>laciniata</u> Davey & Verdier (x400), MCP/1280, Sample
BAT 2. Showing distinctive complex processes.

Fig. 7 – <u>Florentinia</u> <u>mantellii</u> (Davey & Williams) Davey & Verdier (x600),
WHP/233, Sample Cant 4B. Showing typical faintly striate, distally
bifurcate processes.

Fig. 8 – <u>Florentinia</u> <u>radiculata</u> (Davey & Williams) Davey & Verdier (x600),
WHP/358, Sample BH 6. Showing slender, medially bifurcating
processes, and distinctively long, slender antapical process.

Fig. 9 – <u>Florentinia</u> <u>resex</u> Davey & Verdier (x600), WHP/369, Sample BH 17.
Dorsal view, showing characteristically numerous wide-based, simple
processes with a distally truncated margin.

Fig. 10 – <u>Florentinia</u> ? <u>torulosa</u> (Davey & Verdier) Lentin & Williams (x400),
WHP/307, Sample Po 10. Showing distinctive large, rounded processes.

Fig. 11 – <u>Florentinia</u> <u>tridactylites</u> (Valensi) Duxbury (x600), WHP/369, Sample
BH 17. Note medially bifurcate3trifurcate processes.
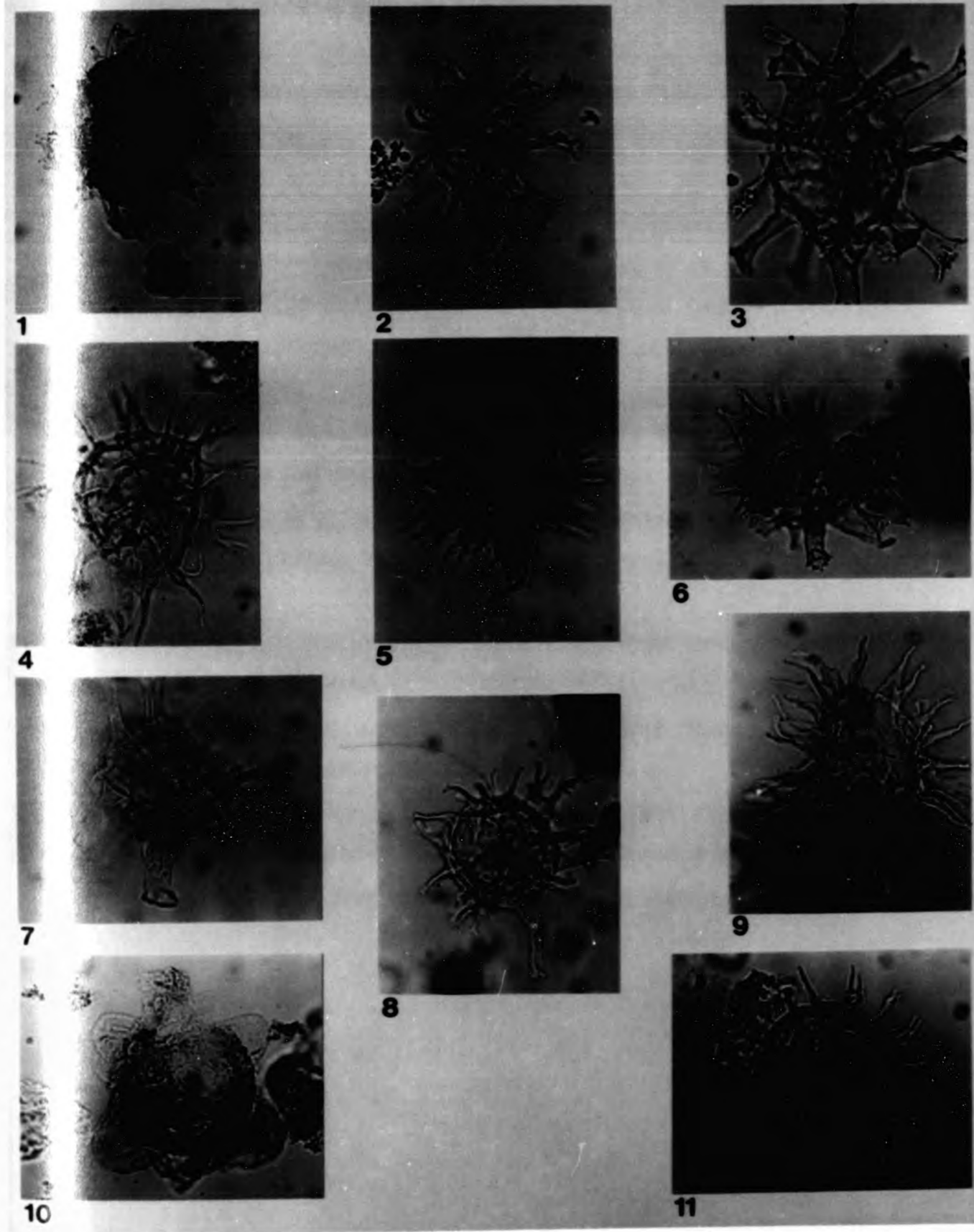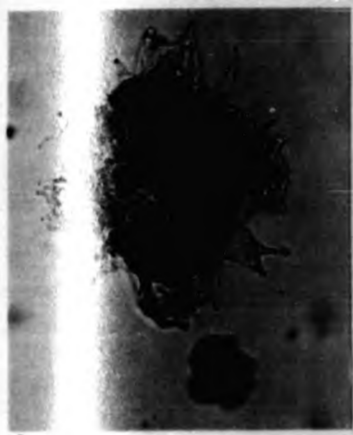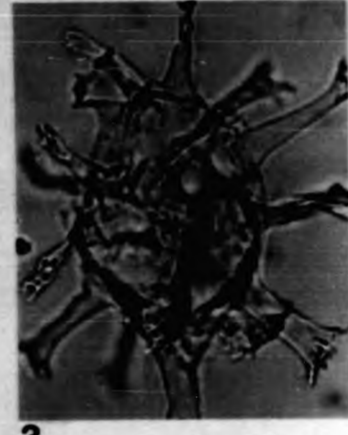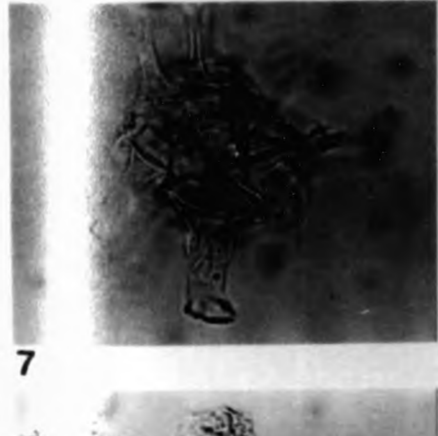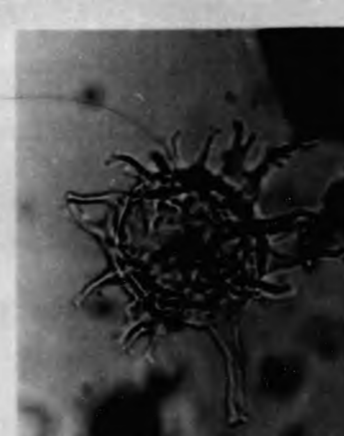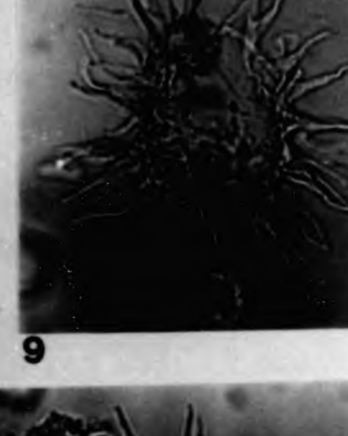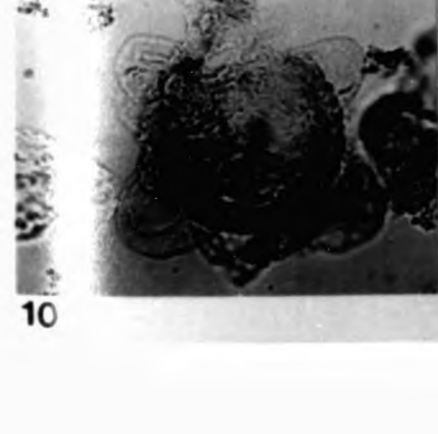
Plate 6

Plate 6

Plate 7

Fig. 1 - <u>Gonyaulacysta</u> <u>cassidata</u> (Eisenack & Cookson) Sarjeant (x600), WHP/355, Sample BH 3. Lateral view, showing prominent apical pericoel, and denticulate parasutural crests.

Fig. 2 - <u>Gonyaulacysta</u> <u>polythyris</u> Davey (x600), WHP/355, Sample BH 3. Arrow indicates characteristic perforate parasutural crests.

Fig. 3 - <u>Hapsocysta</u> <u>dictyota</u> Davey (x600), WHP/365, Sample BH 13. Lateral view, showing net-like periphragm.

Fig. 4 - <u>Heterosphaeridium</u> ? <u>heteracanthum</u> (Deflandre & Cookson) Eisenack & Kjellstrom (x400), WHP/367, Sample BH 15.

Fig. 5 - <u>Hystrichodinium</u> <u>pulchrum</u> Deflandre (x400), WHP/355, Sample BH 3. Dorsal view.

Fig. 6 - <u>Hystrichosphaeridium</u> <u>bowerbankii</u> Davey & Williams (x600), WHP/244, Sample Cant 16. Showing typical circular wrinkles at process bases.

Fig. 7 - <u>Hystrichosphaeridium</u> <u>difficile</u> Manum & Cookson (x600), MCP/1307, Sample BAT 19(2). Showing distinctive fibrous processes.

Fig. 8 - <u>Hystrichosphaeridium</u> <u>tubiferum</u> (Ehrenberg) <u>brevispinum</u> (Davey & Williams) Lentin & Williams (x600), WHP/308, Sample Po 11. Ventral view, showing typically short, tubular processes.

Fig. 9 - <u>Hystrichosphaeridium</u> <u>tubiferum</u> <u>tubiferum</u> (Ehrenberg) Deflandre; emend. Davey & Williams (x600), WHP/307, Sample Po 10. Lateral view.

Fig. 10 - <u>Hystrichostrogylon</u> <u>membraniphorum</u> Agelopoulos (x600), WHP/355, Sample BH 3. Lateral view.

Fig. 11 - <u>Isabelidinium</u> <u>acuminatum</u> (Cookson & Eisenack) Stover & Evitt (x600), MCP/1304, Sample BAT 16. Dorsal view.

Fig. 12 - <u>Kleithriasphaeridium</u> <u>readei</u> (Davey & Williams) Davey & Verdier (x600), WHP/366, Sample BH 14. Shows thickened ribs running lengthwise along the processes and onto the central body.
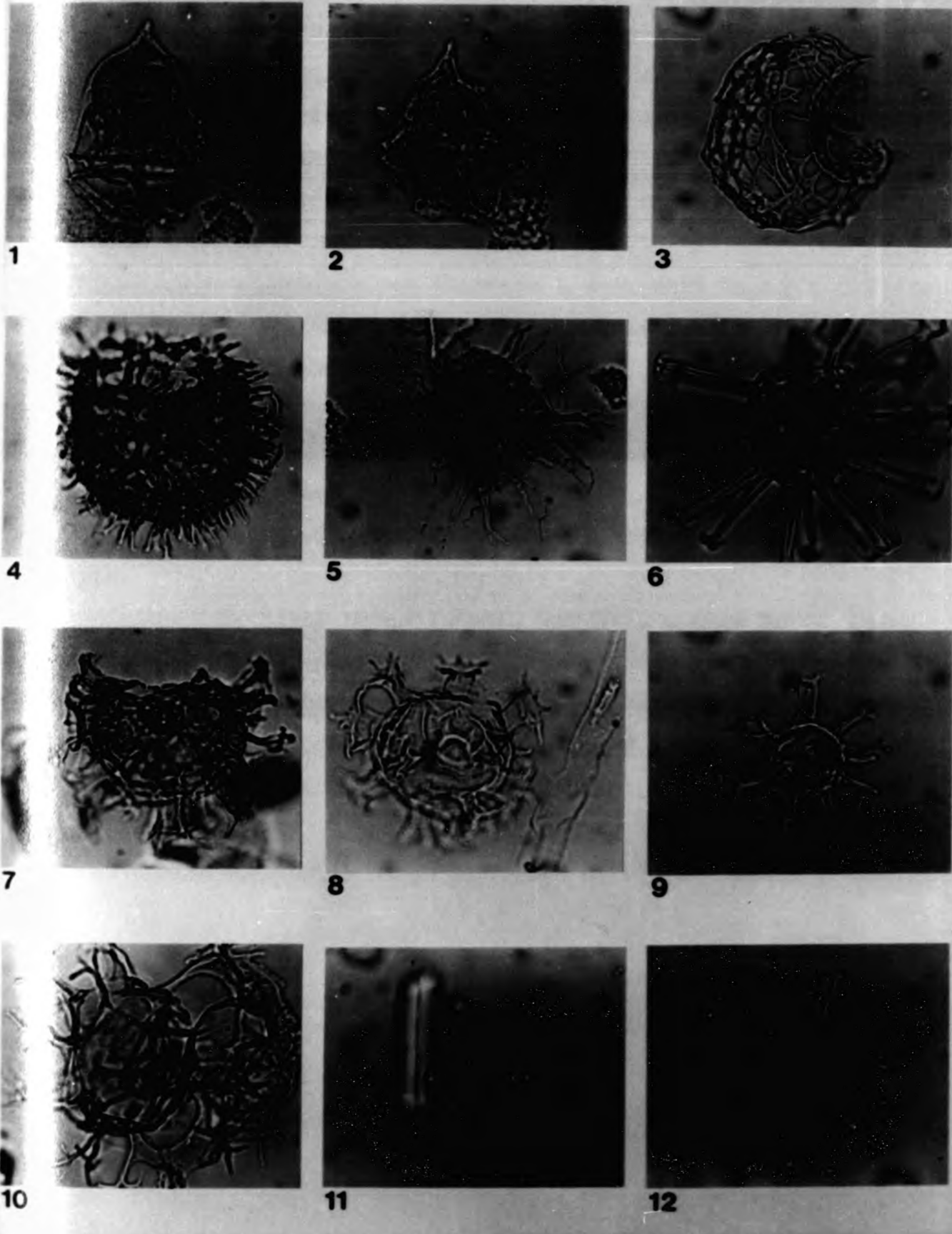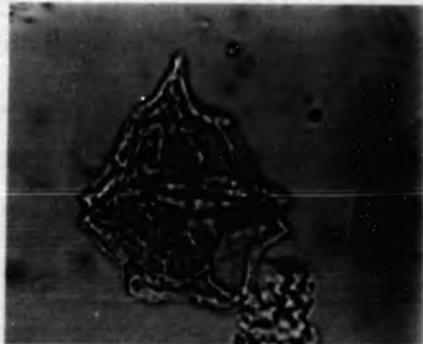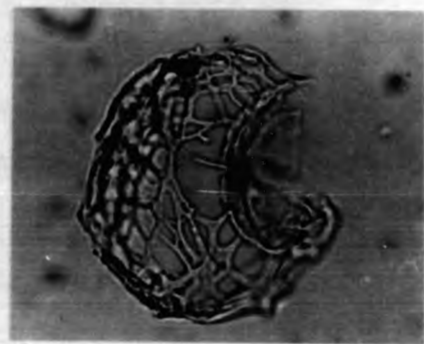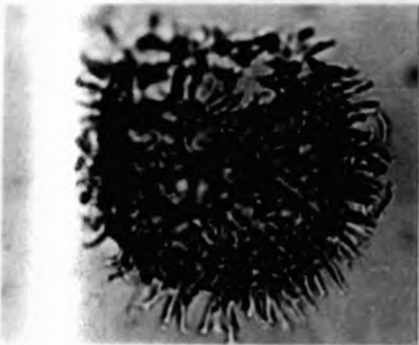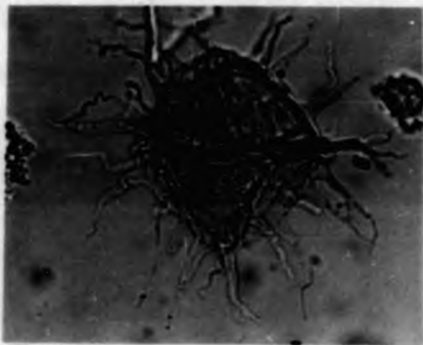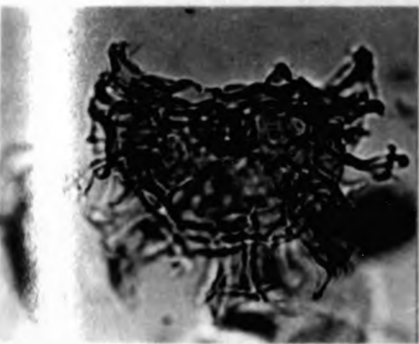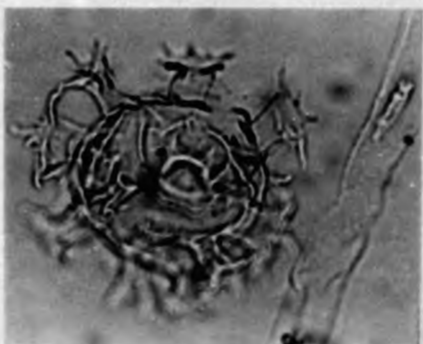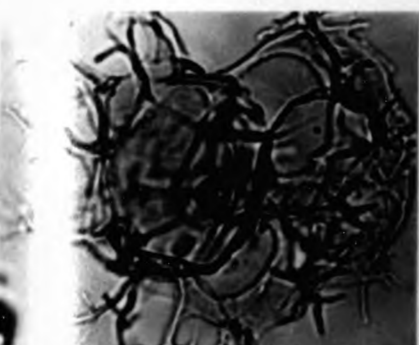
Plate 7

Plate 7

Plate 8

Fig. 1 - <u>Leberidocysta</u> <u>chlamydata</u> (Cookson & Eisenack) Stover & Evitt (x600),
WHP/355, Sample BH 3. Shows characteristic verrucose ornament.

Fig. 2 - <u>Leberidocysta</u> <u>defloccata</u> (Davey & Verdier) Stover & Evitt (x600),
WHP/366, Sample BH 14.

Fig. 3 - <u>Fromea</u> <u>amphora</u> Cookson & Eisenack (x600), WHP/366, Sample BH 14.

Fig. 4 - <u>Litosphaeridium</u> <u>arundum</u> (Eisenack & Cookson) Davey (x600), MCP/1291,
Sample BAT 3. Shows variable width of tubular processes.

Fig. 5 - <u>Litosphaeridium</u> <u>medius</u> sp. nov. (x600), WHP/360, Sample BH 8.
Holotype; shows open lagenate processes with denticulate margins,
and reticulate cyst wall.

Fig. 6 - <u>Litosphaeridium</u> <u>medius</u> sp. nov. (x600), WHP/360, Sample BH 8.
Shows closed conical (sulcal) processes.

Fig. 7 - <u>Litosphaeridium</u> <u>siphoniphorum</u> (Cookson & Eisenack) Davey & Williams
(x600), WHP/356, Sample BH 4. Shows reticulate cyst wall and typical
tapering, tubular processes.

Fig. 8 - <u>Litosphaeridium</u> <u>urna</u> sp. nov. (x600), MCP/1304, Sample BAT 16.
Holotype; dorsal view, showing smooth cyst wall and well-developed
open, lagenate processes.

Fig. 9 - <u>Litosphaeridium</u> <u>urna</u> sp. nov. (x600), MCP/1304, Sample BAT 16.
Holotype.

Fig. 10 - <u>Microdinium</u> ? <u>crinitum</u> Davey (x600), WHP/367, Sample BH 5. Shows
parasutural ridges.

Fig. 11 - <u>Microdinium</u> <u>distinctum</u> Davey (x600), WHP/367, Sample BH 5. Dorsal
view, showing absence of paracingular plates.

Fig. 12 - <u>Microdinium</u> <u>ornatum</u> Cookson & Eisenack (x600), MCP/1305, Sample
BAT 17. Dorsal view.
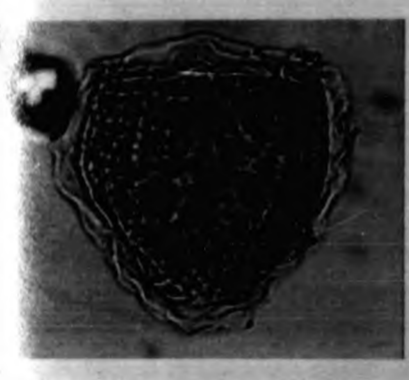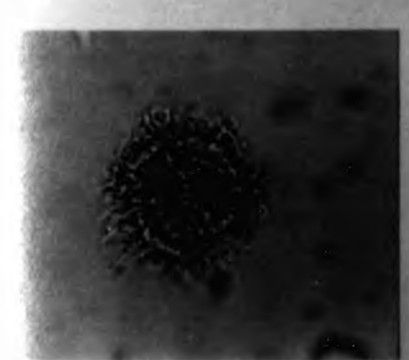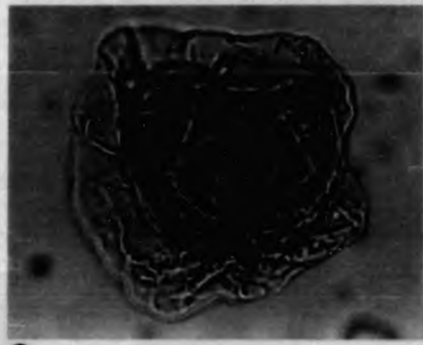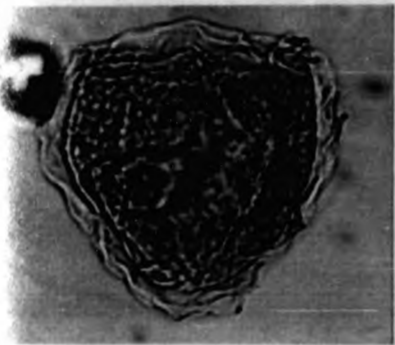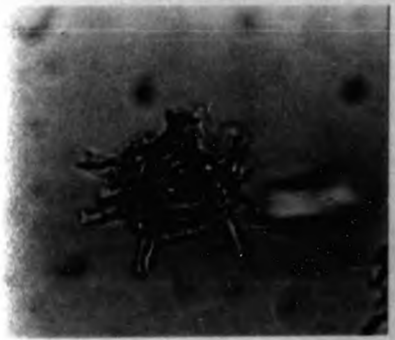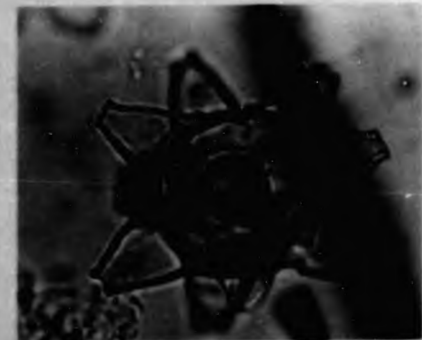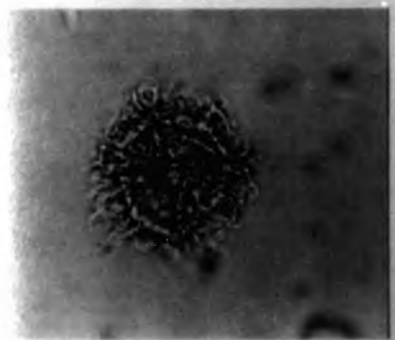
Plate 8

Plate 8

Plate 9

Fig. 1 – <u>Microdinium</u> <u>setosum</u> Sarjeant (x600), WHP/355, Sample BH 3. Showing characteristic spinose parasutural crests.

Fig. 2 – <u>Microdinium</u> <u>veligerum</u> (Deflandre) Davey (x600), MCP/1307, Sample BAT 19(2). Ventral view.

Fig. 3 – <u>Nematosphaeropsis</u> <u>densiradiata</u> (Cookson & Eisenack) Stover & Evitt (x600), WHP/365, Sample BH 13. Shows interconnecting trabeculae between process tips.

Fig. 4 – <u>Odontochitina</u> <u>costata</u> Alberti; emend. Clarke & Verdier (x400), MCP/1305, Sample BAT 17.

Fig. 5 – <u>Odontochitina</u> <u>cribropoda</u> Deflandre & Cookson (x400), WHP/355, Sample BH 3. Shows distally perforate apical, and antapical horns.

Fig. 6 – <u>Odontochitina</u> <u>operculata</u> (O. Wetzel) Deflandre & Cookson (x400), MCP/1303, Sample BAT 15. Showing unornamented antapical region.

Fig. 7 – <u>Oligosphaeridium</u> <u>anthophorum</u> (Cookson & Eisenack) Davey & Williams (x600), WHP/288, Sample Fo 3. Detached operculum showing flared, perforate process terminations.

Fig. 8 – <u>Oligosphaeridium</u> <u>complex</u> (White) Davey & Williams (x600), WHP/306, Sample Po 9.

Fig. 9 – <u>Oligosphaeridium</u> <u>poculum</u> Jain (x600), WHP/355, Sample BH 3. Showing short, distally-flared, intratabular processes.

Fig. 10 – <u>Oligosphaeridium</u> <u>prolixispinosum</u> Davey & Williams (x600), WHP/356, Sample BH 4. Showing elongate central body; arrow indicates typical filiform spines forming the process terminations.

Fig. 11 – <u>Oligosphaeridium</u> <u>reticulatum</u> Davey & Verdier (x600), WHP/315, Sample Cord 5. Showing reticulate periphragm; arrow indicates faint parasutural markings.

Fig. 12 – <u>Operculodinium</u> sp.A (x600), WHP/210, Sample HF 5. Dorsal view, showing type P archeopyle, and even cover of short acuminate spines.

Plate 9
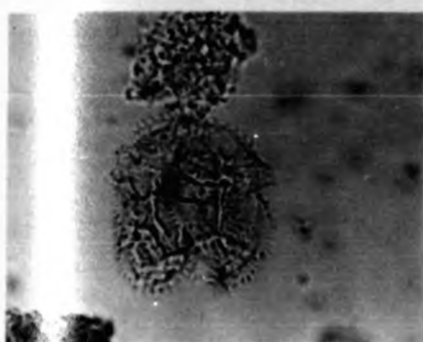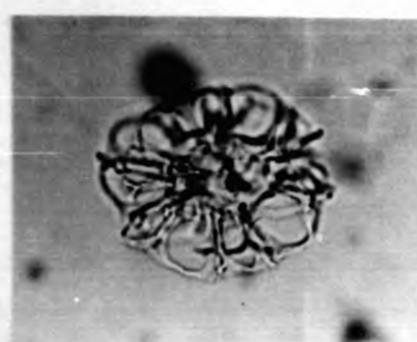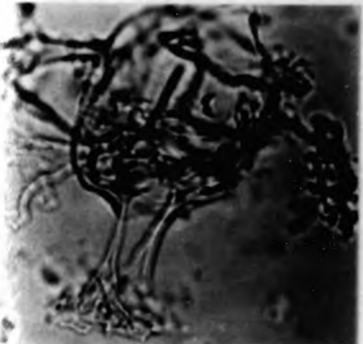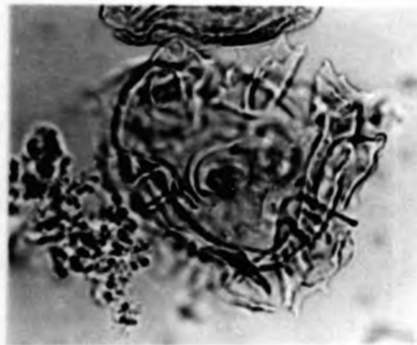
Plate 9

Plate 10

Fig. 1 - <u>Ovoidinium</u> <u>scabrosum</u> (Cookson & Hughes) Davey (x600), MCP/1291, Sample BAT 3. Dorsal view, showing scabrate central body.

Fig. 2 - <u>Ovoidinium</u> <u>verrucosum</u> (Cookson & Hughes) <u>ostium</u> (Davey) Lentin & Williams (x600), MCP/1290, Sample BAT 2. Ventral view, showing characteristic opening in the posterior pericoel.

Fig. 3 - <u>Ovoidinium</u> <u>verrucosum</u> <u>verrucosum</u> (Cookson & Hughes) Davey (x600), WHP/355, Sample BH 3.

Fig. 4 - <u>Ovoidinium</u> sp.A (x600), WHP/311, Sample Cord 1. Complete specimen showing smooth wall, and paracingulum defined by 2 parallel rows of low tubercles.

Fig 5 - <u>Psaligonyaulax</u> <u>deflandrei</u> Sarjeant (x400), WHP/357, Sample BH 5. Ventral view, showing large apical, and antapical pericoels.

Fig. 6 - <u>Palaeohystrichophora</u> <u>infusorioides</u> Deflandre (x600), MCP/1304, Sample BAT 16.

Fig. 7 - <u>Palaeohystrichophora</u> <u>paucisetosa</u> Deflandre (x600), MCP/1309, Sample BAT 19(2). Showing typical sparse covering of short hairs.

Fig. 8 - <u>Palaeoperidinium</u> <u>cretaceum</u> Pocock; emend, Davey (x400), MCP/1293, Sample BAT 5. Dorsal view.

Fig. 9 - <u>Palaeostomocystis</u> <u>reticulata</u> Deflandre (x600), WHP/58, Sample Hall 1.

Fig. 10 - <u>Pervosphaeridium</u> <u>bifidum</u> (Clarke & Verdier) comb. nov. (x600), WHP/353, Sample BH 1.

Fig. 11 - <u>Pervosphaeridium</u> <u>cenomaniense</u> (Norvick) Below (x600), MCP/1292, Sample BAT 4. Ventral view, showing coarsely reticulate periphragm and short, broad-based, striate processes.

Fig. 12 - <u>Pervosphaeridium</u> <u>pseudohystrichodinium</u> (Deflandre) Yun (x600), WHP/368, Sample BH 16. Showing numerous simple, or distally branched acuminate processes.
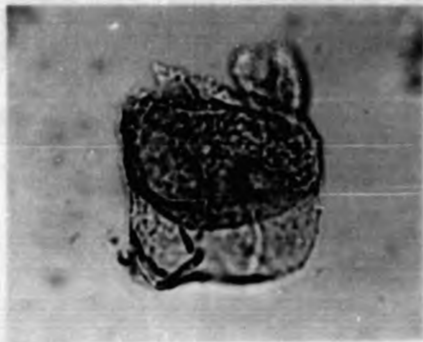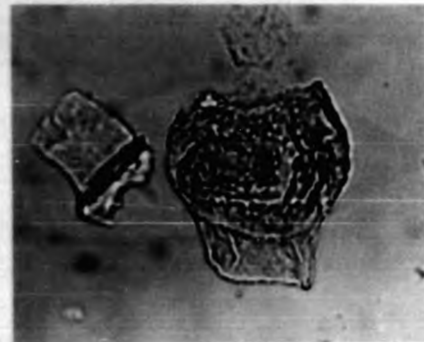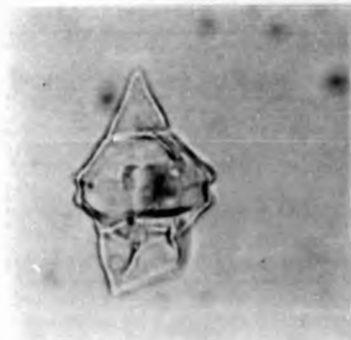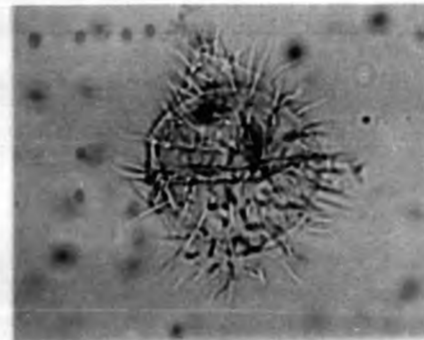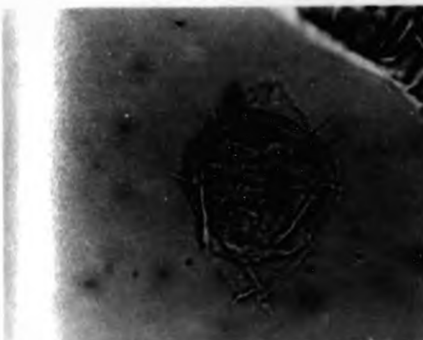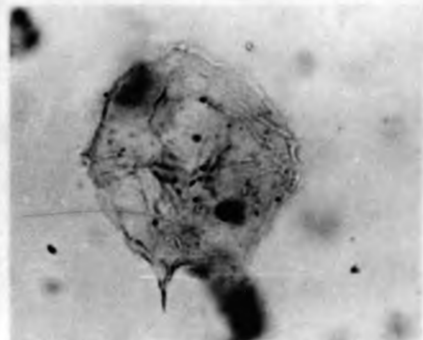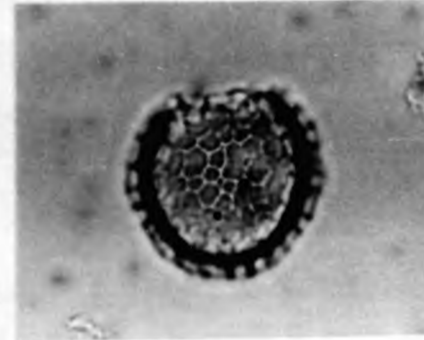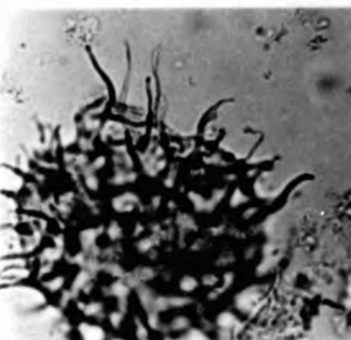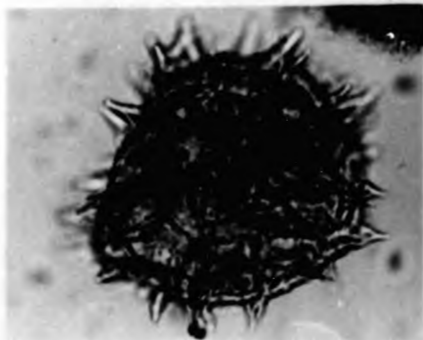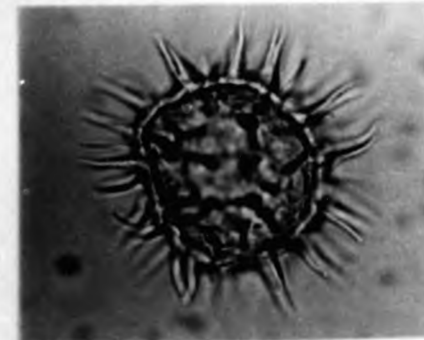
Plate 10

Plate 10

Plate 11

Fig. 1 – <u>Pervosphaeridium</u> <u>truncatum</u> (Davey) Below (x600), WHP/355, Sample
BH 3. Dorsal view, showing Type 2P archeopyle.

Fig. 2 – <u>Prolixosphaeridium</u> <u>conulum</u> Davey (x600), WHP/303, Sample Po 6.
Shows elongate, densely granular central body, and thin, smooth
acuminate processes.

Fig. 3 – <u>Protoellipsodinium</u> <u>spinocristatum</u> Davey & Verdier (x600), MCP/1292,
Sample BAT 4. Dorsal view, showing characteristic longitudinal
crests, and numerous short spines.

Fig. 4 – <u>Pterodinium</u> <u>cingulatum</u> <u>cingulatum</u> (O. Wetzel) Below (x600),
WHP/355, Sample BH 3. Lateral view, showing smooth, unornamented
cyst wall.

Fig. 5 – <u>Pterodinium</u> <u>cingulatum</u> (O. Wetzel) <u>granulatum</u> (Clarke & Verdier)
Lentin & Williams (x600), WHP/366, Sample BH 14. Dorsal view.

Fig. 6 – <u>Pterodinium</u> <u>cingulatum</u> (O. Wetzel) <u>reticulatum</u> (Davey & Williams)
Lentin & Williams (x600), MCP/1291, Sample BAT 4. Dorsal view.

Fig. 7 – <u>Pterodinium</u> <u>cornutum</u> Cookson & Eisenack (x600), WHP/368, Sample
BH 16. Dorsal view, showing distinctive apical protrusion.

Fig. 8 – <u>Pyxidinopsis</u> <u>parvum</u> sp. nov. (x600), WHP/368, Sample BH 13.
Holotype; dorsal view, showing rediced precingular archeopyle.

Fig. 9 – <u>Pyxidinopsis</u> <u>parvum</u> sp. nov. (x600), WHP/368, Sample BH 13
Holotype; ventral view, showing irregular reticulation.

Fig. 10 – <u>Raphidodinium</u> <u>fucatum</u> Deflandre (x600), MCP/1293, Sample BAT 5.

Fig. 11 – <u>Rhombodella</u> <u>paucispina</u> (Alberti) Duxbury (x600), MCP/1293, Sample
BAT 5. Lateral view, showing characteristic short spines restricted
to the cyst "corners".

Fig. 12 – <u>Senoniasphaera</u> <u>rotundata</u> Clarke & Verdier (x600), WHP/345, Sample
Adit 5. Dorsal view, showing distinct paracingulum, and angular
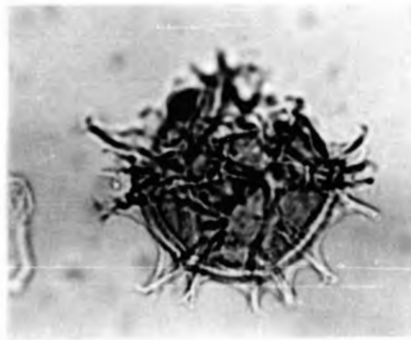archeopyle margin.
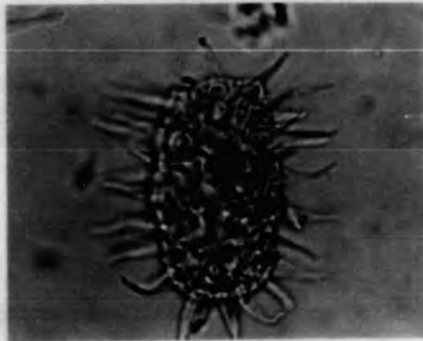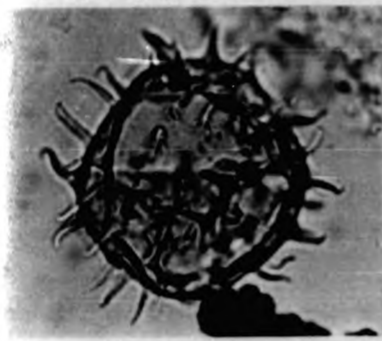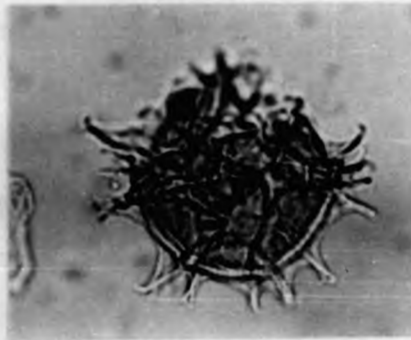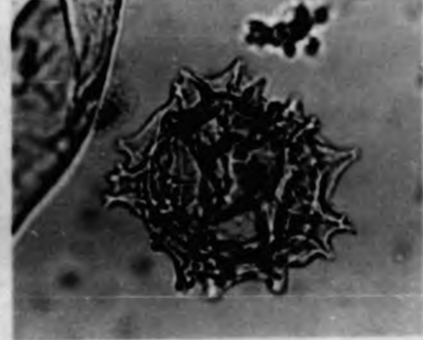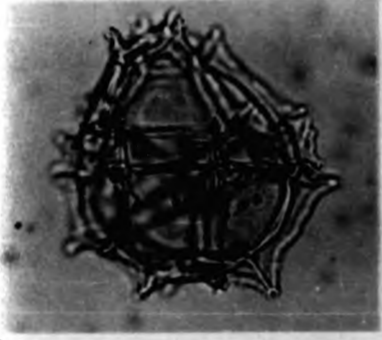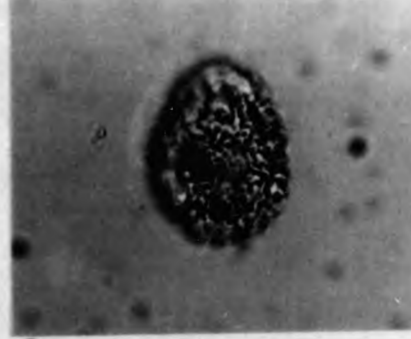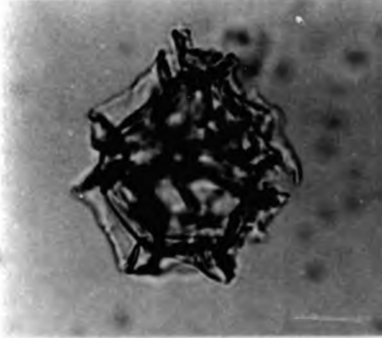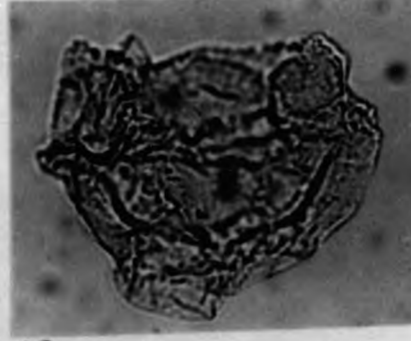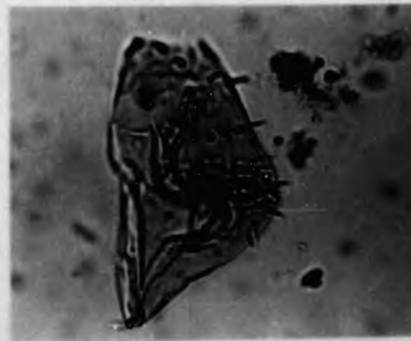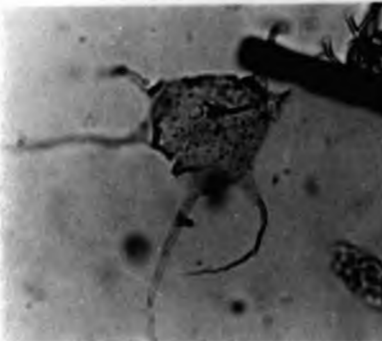
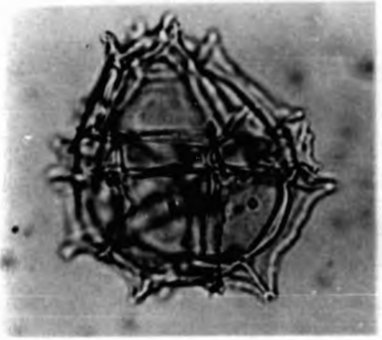**Plate 11**

Plate 11

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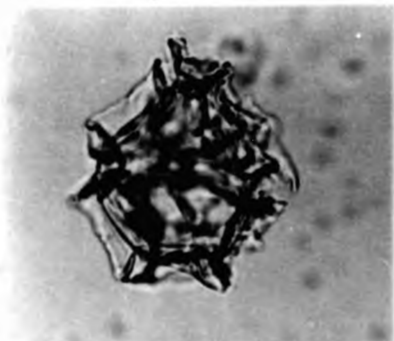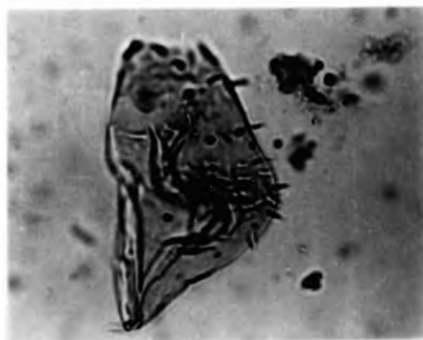
4   5   6

7   8   9

10   11   12

Plate 12

Fig. 1 – <u>Sentusidinium</u> sp.A (x600), WHP/287, Sample Fo 2. Shows surface
ornament of low tubercles.

Fig. 2 – <u>Sentusidinium</u> sp.B (x600), WHP/288, Sample Fo 3. Shows surface
ornament of elongate tubercles and short ridges.

Fig. 3 – <u>Sentusidinium</u> sp.C (x600), WHP/297, Sample Fo 12. Shows dense cover
of short spines.

Fig. 4 – <u>Spiniferites</u> ? <u>dentatus</u> (Gocht) Lentin & Williams; emend. Duxbury
(x600), MCP/1303, Sample BAT 15. Dorsal view.

Fig. 5 – <u>Spiniferites ramosus</u> (Ehrenberg) <u>gracilis</u> (Davey & Williams)
Lentin & Williams (x600), MCP/1307, Sample BAT 19(2). Dorsal view,
showing long slender gonal, and intergonal processes.

Fig. 6 – <u>Spiniferites ramosus</u> (Ehrenberg) <u>multibrevis</u> (Davey & Williams)
Lentin & Williams (x600), MCP/1307, Sample BAT 19(2). Dorsal view,
showing typically short processes.

Fig. 7 – <u>Spiniferites ramosus ramosus</u> (Ehrenberg) Loeblich & Loeblich
(x600), WHP/360, Sample BH 8. Dorsal view.

Fig. 8 – <u>Spiniferites ramosus</u> (Ehrenberg) <u>reticulatus</u> (Davey & Williams)
Lentin & Williams (x600), WHP/360, Sample BH 8. Lateral view.

Fig. 9 – <u>Stephodinium coronatum</u> Deflandre (x400), MCP/1303, Sample BAT 15.
Apical view, showing large precingular archeopyle, and distinctive
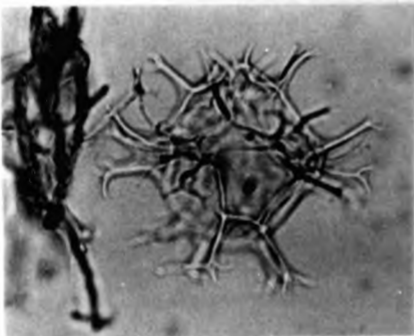seperation of the endophragm and periphragm.

Fig. 10 – <u>Subtilisphaera pontis-mariae</u> (Deflandre) Lentin & Williams (x600),
WHP/366, Sample BH 14.

Fig. 11 – <u>Subtilisphaera</u> sp.A (x600), WHP/299, Sample Po 2.

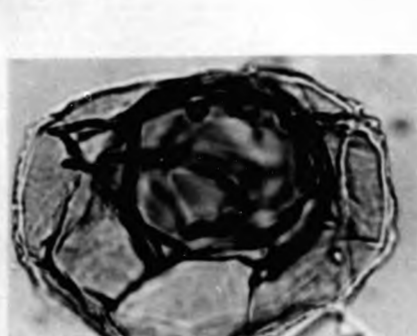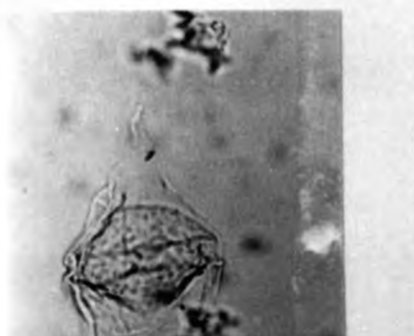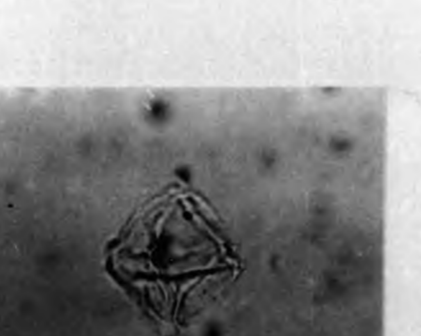Fig. 12 – <u>Subtilisphaera</u> sp.B (x600), WHP/361, Sample BH 9.
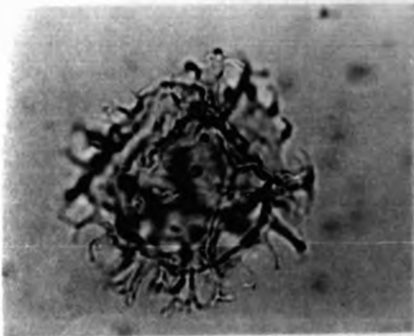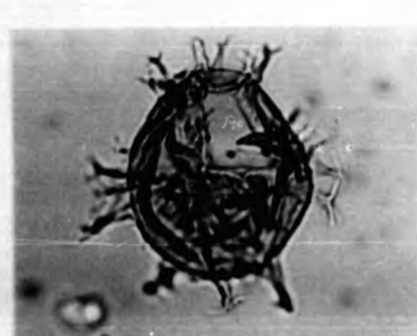
Plate 12

Plate 12

Plate 13

Fig. 1 - _Surculosphaeridium_ _longifurcatum_ (Firtion) Davey et al. (x600), WHP/355, Sample BH 3. Showing variable nature of the process terminations.

Fig. 2 - _Tanyosphaeridium_ _salpinx_ Norvick (x600), MCP/1303, Sample BAT 15. Showing elongate central body; arrow indicates open, trumpet-shaped process termination.

Fig. 3 - _Tanyosphaeridium_ _variecalamum_ Davey & Williams (x600), WHP/366, Sample BH 14. Showing elongate central body, and tapering, open tubular processes.

Fig. 4 - _Tanyosphaeridium_ sp.A (x600), WHP/58, Sample Hall 1. Showing recurved, spinose process terminations.

Fig. 5 - _Trichodinium_ _castaneum_ (Deflandre) Clarke & Verdier (x600), MCP/1303, Sample BAT 15. Lateral view.

Fig. 6 - _Valensiella_ _ovula_ (Deflandre) Eisenack (x600), MCP/1289, Sample BAT 1.

Fig. 7 - _Wallodinium_ _anglicum_ (Cookson & Hughes) Lentin & Williams (x600), WHP/355, Sample BH 3.

Fig. 8 - _Xenascus_ _ceratioides_ (Deflandre) Lentin & Willaims (x600), WHP/355, Sample BH 3. Antapical region.

Fig. 9 - _Xenascus_ _plotei_ Below (x600), WHP/355, Sample BH 3. Antapical region, showing short, rounded antapical horn.

Fig. 10 - _Xenascus_ sp.A (x600), WHP/210, Sample HF 5.

Fig. 11 - _Xenascus_ sp.A (x600), WHP/210, Sample HF 5.

Fig. 12 - _Xiphophoridium_ _alatum_ (Cookson & Eisenack) Sarjeant (x400), MCP/1303, Sample BAT 15.

Plate 13

Plate 13

Plate 14

1

2

Plate 14

1

2

Plate 14

1

2

Plate 15

Fig. 1 - Hameau-Frédet Quarry, Fumichon, NW France. Shows poor exposure
of Craie glauconieuse (L. Cenomanian) and Craie de Rouen (M.
Cenomanian).

Fig. 2 - Moulin Ars Quarry, St. Calais, NW France. Shows thick development
of the Sables du Perche (U. Cenomanian) overlain by the Craie à
Terebratella carantonensis (U. Cenomanian) and the Craie à
Inoceramus labiatus (Turonian).

Plate 15

1

Sables du Perche

2

Plate 15

1

Sables du Perche

2

Plate 15

1

Sables du Perche
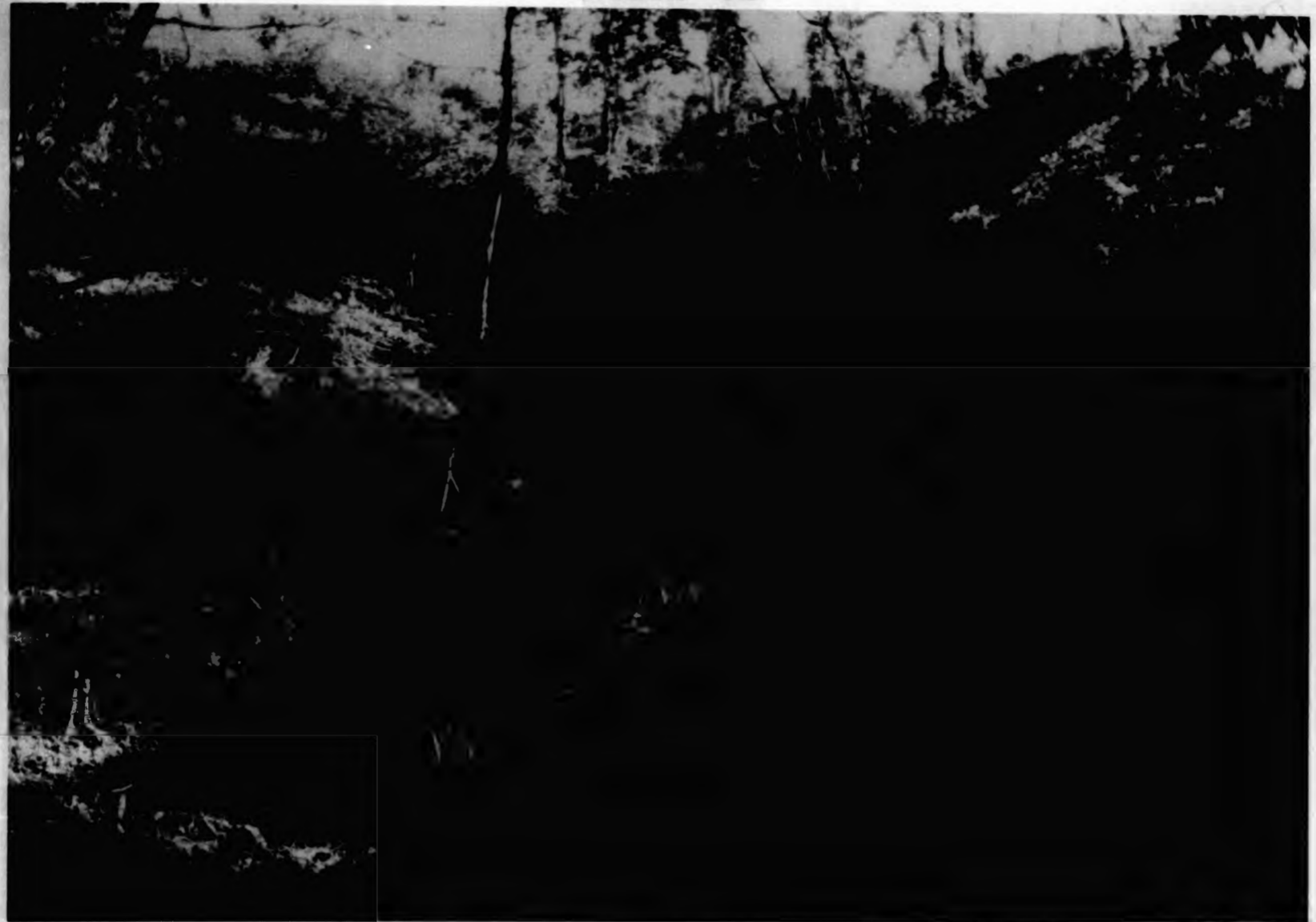
2

Plate 16

Fig. 1 - Beer Head, Beer, SW England. Shows the Upper Greensand (?U.
Albian), Beer Head Limestone (Cenomanian) and Sbaton Chalk
(Turonian).
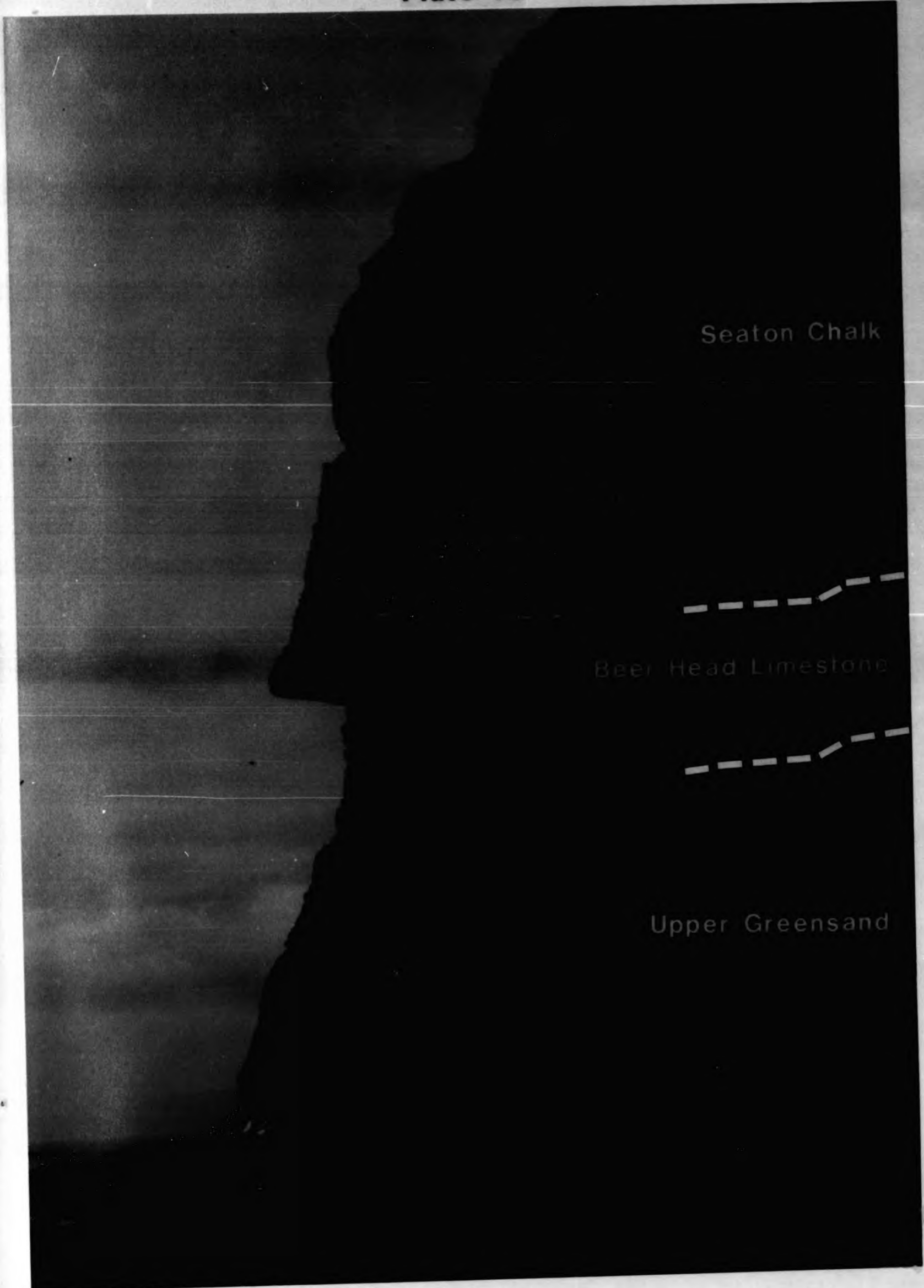
Plate 16

Seaton Chalk

Beer Head Limestone

Upper Greensand

1

Plate 16

Seaton Chalk

Beer Head Limestone

Upper Greensand

1

Plate 16

Seaton Chalk

Beer Head Limestone

Upper Greensand

1
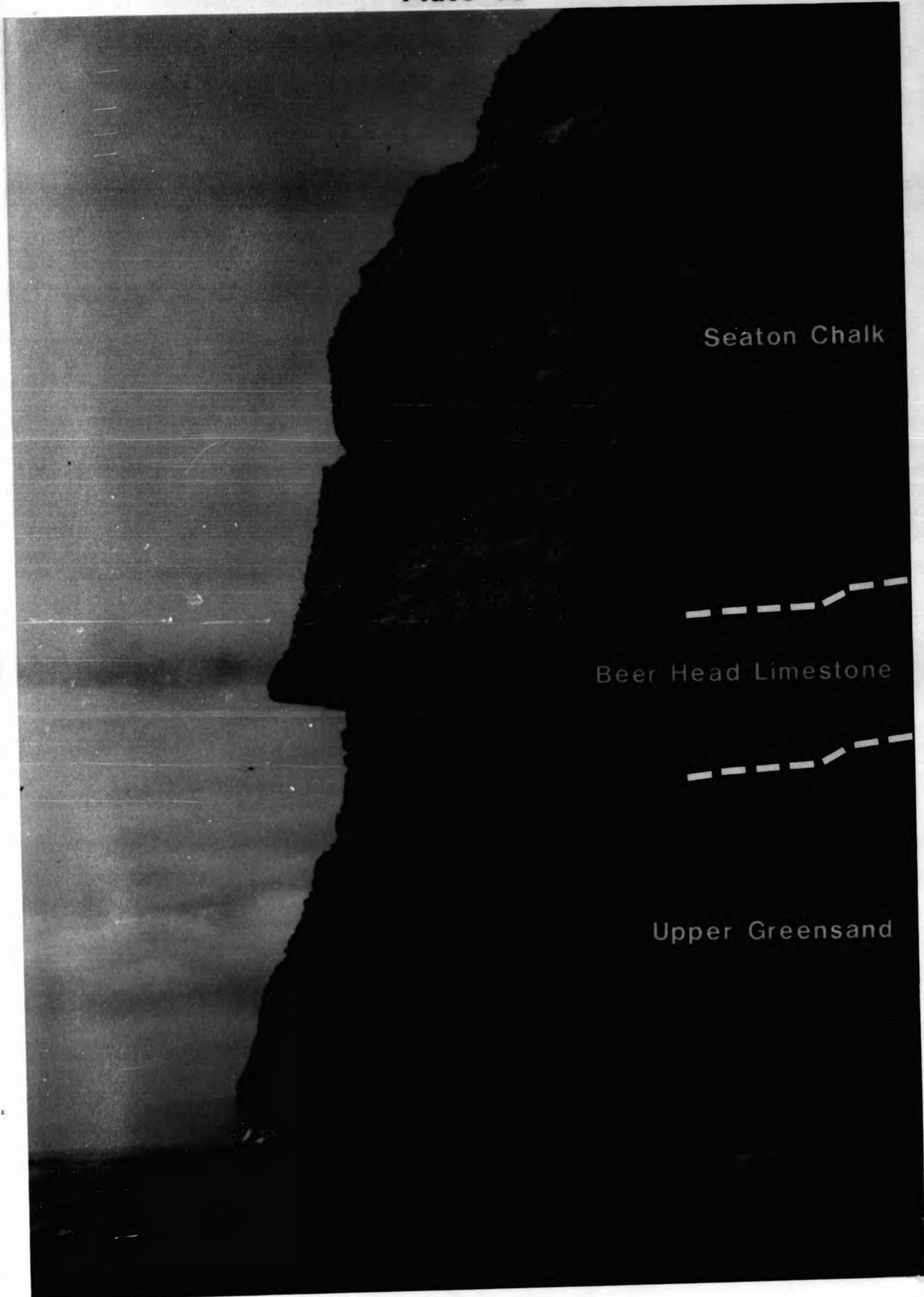
STRATIGRAPHY AND PALYNOLOGY OF THE MID CRETACEOUS (CENOMANIAN - TURONIAN)
OF SOUTH-EASTERN DEVON, ENGLAND

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The coastal sections of mid Cretaceous rocks in SE Devon form the
southern ends of several small (~10km) outliers constituting the western-
most remnants of Cenomanian-Turonian in Britain. In contrast to SE England,
the structure is dominated by NNW-SSE trends. The mid Cretaceous rests
on the calcarenitic sandstones of the Upper Greensand which are of late
Albian (possibly earliest Cenomanian) age. Consisting of sandy limestones
with prominent hardgrounds at the base, the succession passes up through
calcarenitic chalks, nodular chalks and hardgrounds, to soft white chalks
with burrow flints at the summit. Thick marl seams and prominent levels of
bioclastic debris are common within the chalks. The region is characterised
by considerable lateral variations in thickness and lithology which have
resulted in a confused stratigraphy. The purpose of this paper is to erect
a new lithostratigraphical scheme, as a prerequisite to obtaining new data
on the biostratigraphy of the area.

The succession at Beer Head near Seaton was the first to be described
in detail and retains the best exposure in the region. It has been chosen
as the type area for two new formations: the Beer Head Limestone and the
White Cliff Chalk. The Beer Head Formation approximates to the Cenomanian
Limestone of earlier authors, but confusion over the limits, subdivision
and age of the latter, makes it necessary to erect a new lithostratigraph-
ical term. The base of this formation is taken everywhere at the strongly-
developed hardground surface that marks the top of the Upper Greensand. The
base of the White Cliff Formation is also taken at a laterally persistent
hardground surface - the Neocardioceras Hardground; the top of the formation
is not defined. Preliminary work indicates that our lithostratigraphical
scheme may be applied readily throughout SE Devon.

The Beer Head Formation is divided into four members. The Pounds Pool
Member, at the base, consists of brown-grey massive sandy limestones with
abundant *Ceriopora ramulosa* Michelin. Large fragments of bivalve shell and
quartz grains up to pebble-grade are common. The summit becomes nodular
due to the development of the Shelly Hardground. Despite a thickness
variation of 0 - 3½m, the lithology is relatively uniform. The overlying
Hooken Cliffs Member is characterised by dark grey shelly and sandy nodular
limestones. The member passes from 25cm of massively indurated hardground
at White Cliff, to 8m of nodular limestones with soft-sediment filled
Thalassinoides at the Beer Stone adit. The Pebble Hardground at the summit
is a cemented bed of reworked glauconitized and phosphatized 1-5cm intra-
clasts and steinkerns. At some sites the surface is coated with a dark-
brown shiny phosphate skin. Above, the Little Beach Member is only
moderately indurated. It displays less variation in thickness (50-175cm)
than the underlying members, consisting of cream-coloured glauconitic and
sandy limestones penetrated by prominent *Thalassinoides*. Burrows are
picked-out by their dark, glauconite-rich, soft sandy fill. Beds of white,
detritus-free carbonate nodules, and laterally impersistent hardgrounds
occur at the base of the member. The Phosphate Hardground is the final bed
of the Little Beach Member. It is the most complex and highly-mineralized

level of synsedimentary lithification in the succession. Like the Pebble
Hardground below, the Phosphate Hardground consists of recemented pebble
intraclasts and displays a long history of burial, reworking and mineral-
ization. A dark-brown veneer of shiny phosphate is generally present but
is best developed where the overlying Pinnacles Member is thin or absent.
The fill of the *Thalassinoides* burrows which penetrate the hardground and
are conspicuous throughout the member, clearly originate from the Pinnacles
Member. This final member of the Beer Head Formation displays the greatest
lithological variation of any part of the section. At many localities it
is represented only by ~10cm of cream-coloured hardground chalk with
scattered glauconite and quartz grains. The surface of this Neocardioceras
Hardground is characterised by numerous *Sciponoceras gracile* (Shumard),
cidarid spines and occasional *Neocardioceras juddi* (Barrois and Guerne)
and marks the boundary between the Beer Head and White Cliff Formations.
In Hooken Cliffs, however, the Pinnacles Member expands to >2m of soft
glauconitic quartz sands with calcareous and phosphatic nodules. A
phosphatized cobble-hardground overlain by phosphatized steinkerns occurs
in the middle of this expanded sequence. Biostratigraphical analyses by
previous authors has shown that the Pounds Pool Member yields a Lower
Cenomanian *Hypoturrilites carcitanensis* Zone assemblage, and the Hooken
Cliffs Member contains *Mantelliceras saxbii* Zone ammonites. The Little
Beach Member has been assigned to the Lower-Middle Cenomanian *M.* ex gr.
dixoni - Turilites costatus Zones while the Pinnacles Member falls in Upper
Cenomanian *Eucalycoceras pentagonum* and *Sciponoceras gracile* Zones.

The White Cliff Formation also displays considerable variations in
thickness. The basal Sherborne Rocks Member generally has two strongly-
indurated hardgrounds closely welded on the surface of the Neocardioceras
Hardground. Although sandy at the base, detritus decreases upwards through
the member which is composed dominantly of nodular chalks and limonitic
nodular-hardgrounds rich in comminuted inoceramid-shell and other bioclastic
debris. Major thickening from 1½ to 6m in Hooken Cliffs is principally due
to the development of a >3m-thick bioclastic calcarenite lens - the Beer
Stone. The lower boundary of the overlying Connett's Hole Member is taken
at the base of the Mytiloides Marl, a prominent marl seam containing
abundant complete and fragmentary *Mytiloides*. In the White Cliff section
the Connett's Hole Member is 11½m thick but it thins westwards to <2m at
Beer Head. This extreme attenuation results from the erosional convergence
and merger of eight nodular hardgrounds into a single massive unit - the
Planar Hardground. The lowest beds of the Connett's Hole Member consist
everywhere of shelly nodular chalks with iron-stained nodular-hardgrounds
and weak marl seams. In more complete sections the chalks become less
nodular above the Planar Hardground and five nodular hardgrounds associated
with burrow flints occur in the upper half of the succession. Erosional
truncation and thinning of individual beds cause these surfaces to
converge westwards so that by Beer Head they are represented by a single
surface and 80% of the member is absent. Where strongly-developed as in
Hooken Cliffs, the Planar Hardground is massively indurated and calcarenitic
with prominent light-brown iron and phosphate mineralization. The truncation
continues to the west so that at Mitchell's Rock the hardground surface is
the top of the Pounds Pool Member of the Beer Head Formation; the five
intervening members have been removed by erosion. A more complete succession
reappears west of Branscombe. Coarse detritus on the surface of the Planar
Hardground attests to the reworking of the Beer Head Formation or below.
The remainder of the White Cliff Formation as considered here, is the Beer
Roads Member. Consisting of soft white chalks with semi-tabular and burrow
flints, sections measured to the base of the Two Foot Marl indicate that
the basal beds of the member may be absent in Hooken Cliffs.

The surface of the Neocardioceras Hardground is taken as the local base
of the Turonian. The Sherborne Rocks and Connett's Hole Members fall within

the broad *Mytiloides labiatus* Zone and the overlying Beer Roads Member in the *Terebratulina lata* Zone, but a more detailed biostratigraphy may be discerned from the inoceramid succession. The Sherborne Rocks Member and the basal few decimetres of the Connett's Hole Member yield low Turonian *Mytiloides* aff. *opalensis* (Böse). From just above the Mytiloides Marl, *M.* aff. *opalensis* is replaced by *M. mytiloides* (Mantell) which ranges up to the surface of the Planar Hardground (or just above in more complete sections). Above the Planar Hardground the erosional truncation displayed by the lithostratigraphy is confirmed by the biostratigraphy. At White Cliff, in the upper half of the Connett's Hole Member, *M. mytiloides* is replaced by *M.* cf. *labiatus* (Schlotheim). The latter species is absent at Beer Head and further west where the white chalks of the Beer Roads Member, containing mid Turonian *Inoceramus* cf. *cuvieri* Sowerby, rest directly on nodular chalks with *M. mytiloides*. A restricted *M.* cf. *labiatus* Zone is absent. At Mitchell's Rock mid Turonian chalks rests directly on top of probable Lower Cenomanian.

THE CENOMANIAN-TURONIAN BOUNDARY IN SE DEVON, ENGLAND.

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The Cenomanian limestones and basal Turonian chalks of Devon (Fig.1) are lithologically distinct from their lateral correlatives in SE England. Their importance lies in the abundant and diverse ammonite assemblages which span what is generally regarded as the Cenomanian-Turonian boundary in the area. These assemblages have been utilised recently by Wright & Kennedy (1981) to erect a new ammonite zonation for the high Cenomanian-low Turonian of the Anglo-Paris Basin.

The Upper Cretaceous of SE Devon has been divided into 2 formations (Jarvis & Woodroof MS), the Beer Head Limestone (below) and the Seaton Chalk (above). The Beer Head Limestone consists of a succession of sandy biomicritic limestones which may be subdivided into 4 members: Pounds Pool Sandy Limestone (base), Hooken Nodular Limestone, Little Beach Bioclastic Limestone, and Pinnacles Glauconitic Limestone (summit). The base of each member is defined by a laterally extensive level of synsedimentary lithification, i.e. a hardground surface. The Beer Head Limestone rests on the indurated summit of the Upper Greensand (?Albian), the Small Cove Hardground. The thickest sections of the formation are in Hooken Cliffs (Fig.1) where the succession is most complete, attaining a thickness of 12.4m. Here the hardgrounds are moderately lithified nodular units up to 60cm thick, separated by less indurated nodular limestones and sands containing prominent Thalassinoides burrows. In more attenuated sections, the formation consists of a massively indurated complex of superimposed hardgrounds, locally (e.g. Beer Roads, Fig.1) having a total thickness of ¯60cm. Even in the thinnest sections, however, it is generally only the basal (Pounds Pool) member that is absent.
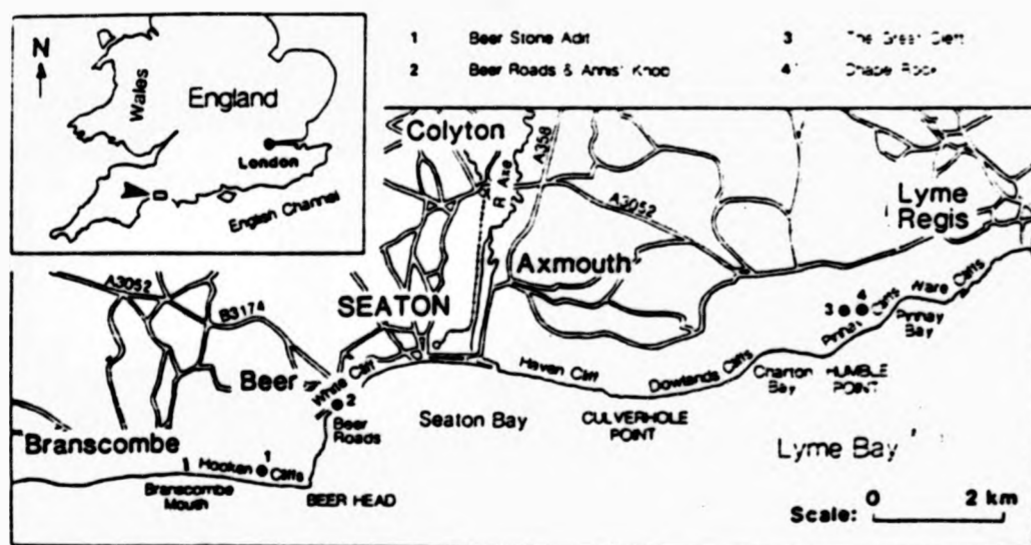
Fig.1 Location of major exposures of Upper Cretaceous in SE Devon.

The Seaton Chalk consists of a succession of nodular, marly and flinty chalks, and is also subdivided into 4 members: Connett's Hole Nodular Chalk (base), Beer Roads Flinty Chalk, Pinhay Nodular Chalk, and Clevelands Flinty Chalk (summit). The base of the formation is taken at the surface of the Haven Cliff Neocardioceras Hardground (=Neocardioceras Pebble Bed of previous authors), which is present throughout the area. Like the Beer Head Limestone, the Seaton Chalk displays considerable variation in thickness and lithology. In general the members thicken towards Hooken Cliffs (Fig.1) but probably thinned considerably west of Branscombe, where most of the succession has now been removed by erosion. This trend of thickening to the west is broken at the base of the Beer Roads Member in Hooken Cliffs, where the surface of the Branscombe Hardground represents a significant disconformity. The Branscombe Hardground passes laterally into 8 separate hardgrounds (upper part of the Connett's Hole Member, ~9m of sediment) at White Cliff, which in turn pass laterally into an even thicker succession of nodular chalks and weak hardgrounds further east (e.g. The Great Cleft, Fig.1). These lateral variations have been ascribed by Jarvis & Woodroof (MS) to differential movement on a series of fault blocks.

The lithostratigraphic complexity of the region has hampered biostratigraphic evaluation of the succession. Wright & Kennedy (1981) have demonstrated that the uppermost Beer Head Limestone (Pinnacles Member) yields a _Metoicoceras geslinianum_ Zone ammonite assemblage but that the Haven Cliff Hardground marks a major change in the fauna. Steinkerns associated with the hardground are dominated by _Neocardioceras_, principally _N. juddii juddii_ (Barrois & Guerne), while immediately above the hardground surface there is an _in situ_ assemblage of _Watinoceras_. Large ammonites, _Mammites nodosoides_ (Schlüter), _Lewesiceras peramplum_ (Mantell) and _Metasigaloceras rusticum_ (J. Sowerby), appear above the thin complex of hardgrounds that immediately overlie the Haven Cliff Hardground, at the base of the Seaton Chalk. Wright & Kennedy (1981) erected _N. juddii_ and _W. coloradoense_ Zones to characterise these faunal changes. Although the _M. geslinianum_ Zone is widely regarded as Upper Cenomanian and the _M. nodosoides_ Zone as basal Turonian, there is no firm evidence from the stage stratotypes to locate the new ammonite zones with respect to the Cenomanian-Turonian boundary. Wright & Kennedy (1981) argued on taxonomic grounds that the junction between the two zones (i.e. the surface of the Haven Cliff Hardground) should be regarded as the stage boundary.

The Upper Cenomanian belemnite _Actinocamax plenus_ (Blainville) occurs frequently in the lower part of the Pinnacles Member but no other belemnites are recorded from around this level.

The major changes in ammonite assemblages associated with the surface of the Haven Cliff Hardground are accompanied by new inoceramid bivalve faunas. The surface of the hardground yields _Inoceramus pictus_ (J. de C. Sowerby) and marks the first appearance of _Mytiloides_ cf. _opalensis_ (_sensu_ Kauffman _non_ Böse=_Inoceramus goppelnensis_ Sornay). _I. pictus_ occurs at other levels in the Beer Head Limestone but does not extend above the Haven Cliff Hardground. _M._ cf. _opalensis_ is unequivocally low Turonian while _I. pictus_ is regarded as a Cenomanian species. Tröger (1981) considered that the base of the Turonian should be marked by the first appearance of _M. submytiloides_ Seitz, which commonly extends below the range of _M._ cf. _opalensis_. In SE Devon _M._ cf. _submytiloides_ has been recovered from the nodular chalks above the basal chalk hardgrounds of the Connett's Hole

Member, and a related form is abundant immediately above this, in the West Ebb Marl (Jarvis & Woodroof MS).

The foraminiferan assemblages have been studied in detail by Hart (1982). Rotalipora cushmani (Morrow), a high Cenomanian species, occurs in the lower part of the Pinnacles Member of the Beer Head Limestone, while Praeglobotruncana helvetica (Bolli), an international basal Turonian index, appears in the nodular chalks above the base of the Connett's Hole Member of the Seaton Chalk. Neither species occurs in the Haven Cliff Hardground or immediately above it, and these beds are assigned (Hart 1982) to a Zone of Whiteinella anrica (Loeblich & Tappan). This is regarded as Cenomanian by Hart (1982) but includes both the N. juddii and W. coloradoense Zones of the ammonite stratigraphy.

We have studied the palynostratigraphy of the type sections of the Beer Head Limestone and Seaton Chalk (Fig.2). Unfortunately, the majority of dinoflagellate taxa present do not help define the Cenomanian-Turonian boundary. However, a small number of forms which first appear during the Turonian do occur in the succession: Hystrichosphaeridium difficile Manum & Cookson first appears above the base of the Connett's Hole Member, while H. tubiferum brevispinum Lentin & Williams occurs at the summit of the same member. Dinopterygium cladoides Deflandre and Senoniasphaera rotundata Clarke & Verdier, which also first appear in the Turonian, occur in the Beer Roads Member.

Where diagnostic data are available, they indicate that the Cenomanian-Turonian boundary approximately coincides with the surface of the Haven Cliff Hardground, the base of the Seaton Chalk. Discrepancies between the zonal schemes may be attributed partly to the condensed nature of the succession across the stage boundary. Reworking associated with the formation of the Haven Cliff Hardground has produced mixed Cenomanian and Turonian assemblages of ammonites and inoceramids, some of which are preserved as pebbles or are preserved in hiatus sediments within burrows. Sedimentologic considerations indicate that the hardground surface marks a disconformity, and that the faunal succession may be incomplete across the stage boundary.

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Fig.2 (caption) Distribution of palynomorphs from the Cenomanian-Coniacian of SE Devon.
The composite section is based on several measured sections: a) Upper Greensand - Beer Head, b) Beer Head Limestone - Beer Stone Adit, c) Connett's Hole Member - Beer Roads, d) Beer Roads Member - Beer Stone Adit, e) Pinhay Member - Annis' Knob.

Albian	Cenomanian	Turonian		C	Stage
U. Greensand	Beer Head Limestone	Seaton Chalk			Formation
	PP	Haoken LB.	P	Cannett's Hole	Beer Roads	Pinhay		Member

Sample Horizons

Composite Section

Achomosphaera ramulifera
A. regosa
A. sagena subsp. sagena
Aldorfia deflandrei
Bacchidinium polypes subsp. clavatum
B. polypes subsp. polypes
Batiacasphaera setilosa
Callaiosphaeridium asymmetricum
Canningia callewi
C. reticulata
Cassiculosphaeridia reticulata
Cleistosphaeridium armatum subsp. brevispinosum
Coronifera oceanica
Cyclonephelium clathromarginatum
C. distinctum
C. membraniphorum
Daprosidinium laminaspinosum
Dinopterygium cladoides
Disphaera munda
Endoceratium compandum
Exochosphaeridium bifidum
E. phragmites
Florentinia buspina
F. deanei
F. mantellii
F. ? torulosa
Hapsocysta dictyota
Heterosphaeridium ? heterocanthum
Hystrichosphaeridium bowerbankii
H. difficile
H. tubiferum subsp. brevispinum
H. tubiferum subsp. tubiferum
Hystrichostrogylon membraniphorum
Isabelidinium acuminatum
Kiokansphaeridium raadei
Lithoridocysta sp.A
Microdinium ornatum
M. veligerum
Odontochitina costata
O. operculata
Oligosphaeridium complex
O. prolixispinosum
Palaeohystrichophora infusorioides
Palaeostomocystis reticulata
Pervosphaeridium pseudohystrichodinium
P. truncatum
Prolixosphaeridium conulum
Pterodinium aliferum
P. cingulatum subsp. cingulatum
P. cingulatum subsp. reticulatum
Senoniasphaera rotundata
S. sp.A
Sentusidinium sp.A
Spiniferites ramosus subsp. gracilis
S. ramosus subsp. multibrevis
S. ramosus subsp. ramosus
Stephodinium coronatum
Surdasphaera sp.A
Surculosphaeridium longifurcatum
Tanyosphaeridium salpinx
T. verrucosum
T. sp.A
Trichodinium castanea
Xenascus coronoides
X. sp.A
Acritarchs
Spores & Pollen

NEOGENE AND QUATERNARY DINOFLAGELLATE BIOSTRATIGRAPHY

OF THE EASTERN EQUATORIAL PACIFIC:

DEEP SEA DRILLING PROJECT LEG 85

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ABSTRACT

Samples from DSDP Leg 85 Sites 572-575 in the central equatorial Pacific were analysed for palynomorph content; only those from Site 572 consistently yielded assemblages of Neogene-Quaternary dinoflagellate cysts. These assemblages are described and compared with coeval material from elsewhere in the world. Several of the 15 species identified are stratigraphically restricted, and comparison with published ranges suggests that they may provide world-wide stratigraphic indices. <u>Nematosphaeropsis labyrinthea</u> (Ostenfeld) Reid and identified species of the genus <u>Impagidinium</u> range from middle Miocene to Quaternary. <u>Palaeocystodinium golzowense</u> Alberti disappears in the middle Miocene and <u>Pyxidiella simplex</u> Harland is restricted to the basal upper Miocene. <u>Operculodinium</u> cf <u>israelianum</u> Wall and <u>Spiniferites</u> <u>bentorii</u> <u>truncatus</u> (Rossignol) Lentin and Williams are Quaternary species. An increased abundance of dinoflagellate cysts in the uppermost Miocene at Site 572 is associated with the common occurence of the diatom genera <u>Thalassionema</u> and <u>Thalassiothrix</u>. which are regarded as indicators of upwelling. The higher concentration of dinoflagellate cysts in this interval is related to the site being located below the equatorial high productivity belt at a time of enhanced local upwelling in the eastern equatorial Pacific.

INTRODUCTION

One of the primary aims of Deep Sea Drilling Project (DSDP) Leg 85, to the central equatorial Pacific, was to recover undisturbed Neogene-Quaternary sediments for detailed biostratigraphic analysis. This was accomplished using the newly developed hydraulic piston corer.

Previous attempts at recovering dinoflagellate cysts from equatorial Pacific sediments have proven unsuccessful (T. Saito, pers. comm., 1982). We have processed 101 samples from Leg 85 Sites 572-575 for biostratigraphic analysis, using standard palynological techniques (Neves and Dale, 1963; Doher, 1980). The majority of samples (92%) from the central equatorial Pacific (Sites 573-575) were barren. However, all five holes drilled at Site 572, located at the eastern edge of the equatorial sediment bulge (Fig.1), yielded assemblages of Neogene-Quaternary dinoflagellate cysts (only 7% barren). Spores and pollen were absent throughout. Biozonal correlations produced by shipboard paleontologists, based on foraminifera, nannofossils, radiolaria and diatoms, have been related (Mayer, Theyer et al., in press) to the established magnetostratigraphy and chronostratigraphy of the central Pacific. This integrated stratigraphic framework was used to provide age assignments for the palynomorph assemblages recovered. Sample locations at Site 572 are plotted stratigraphically in Fig.2 and the positions of productive samples are listed in the Appendices.

BIOSTRATIGRAPHY

Fifteen species of dinoflagellate cyst have been identified in the present study (Fig.2). The main species are figured in Plate 1.

Site 572

Most samples from Site 572 (Fig.2; Appendix 1) contain <u>Impagidinium</u> <u>patulum</u> (Wall) Stover and Evitt , <u>I.</u> <u>sphaericum</u> (Wall) Lentin and Williams and <u>Nematosphaeropsis</u> <u>labyrinthea</u> (Ostenfeld) Reid. Two further species of <u>Impagidinium</u> appear within the succession. <u>I.</u> <u>paradoxum</u> (Wall) Stover and Evitt occurs towards the top of the middle Miocene (318m sub-bottom depth) and ranges into the Pleistocene, while <u>I.</u> <u>aculeatum</u> (Wall) Lentin and Williams occurs only in the upper Pliocene and Pleistocene (above 50m). Other genera have more restricted distributions.

<u>Palaeocystodinium</u> <u>golzowense</u> Alberti and <u>Spiniferites</u> <u>pseudofurcatus</u> (Klumpp) Sarjeant occur only in the middle Miocene (423 and 319m respectively). <u>Pyxidiella</u> <u>simplex</u> Harland is restricted to the base of the upper Miocene (262m), while <u>Operculodinium</u> <u>centrocarpum</u> (Deflandre and Cookson) Wall and <u>Tectatodinium</u> occur in the Miocene and Pliocene. <u>Impagidinium</u> sp. A, <u>Operculodinium</u> cf <u>israelianum</u> (Rossignol) Wall, <u>Spiniferites</u> <u>bentorii</u> <u>truncatus</u> (Rossignol) Lentin and Williams and <u>S.</u> sp. A occur only in Pleistocene samples (above 5m).

Other sites

<u>Impagidinium</u> <u>patulum</u>, <u>I.</u> <u>paradoxum</u> and <u>Nematospaeropsis</u> <u>labyrinthea</u> occur rarely in the upper Miocene and lower Pliocene at Sites 573 and 574 (Appendix 2). A single specimen of <u>Spiniferites</u> <u>pseudofurcatus</u> was recorded from the lower Oligocene at Site 574.

DISCUSSION

The biostratigraphy and geographic range of Neogene and Quaternary dinoflagellate cysts are still poorly known. Pioneering work on Quaternary species by Rossignol (1962, 1964, 1969) in the eastern Mediterranean, and Wall (1967, 1970) in the Caribbean and western Europe, has been augmented by studies on the Neogene and Quaternary palynology of the Black Sea and the North Atlantic, particularly offshore eastern Canada (see Reid and Harland, 1977; Williams and Bujak, 1977; Harland, 1978, for reviews). We know of no comparable data from the equatorial Pacific, although Neogene and Quaternary dinoflagellates have been recorded in DSDP samples from off the coasts of southern California (Ballog and Malloy, 1981), Mexico (Fournier, 1981) and Peru (Wiseman, 1976).

Dinoflagellate ranges and zones

There is no formal dinoflagellate cyst zonation for the Neogene and Quaternary, although Williams (1975, 1978), Williams and Brideaux (1975), Gradstein and Williams (1976) and Williams and Bujak (1977) have developed an informal scheme based primarily on material from offshore eastern Canada. Other informal schemes have been proposed by Manum (1976) for the Tertiary of the Norwegian-Greenland Sea, Harland (1978, 1979) for the Neogene and Quaternary of the Bay of Biscay, Costa and Downie (1979) for the Cenozoic of the Rockall Plateau and Piasecki (1980) for the Miocene of Denmark. Our records correspond most closely to those from the Bay of Biscay (Harland, 1979) but are less diverse.

Palaeocystodinium _golzowense_ was recovered solely from the middle Miocene at Site 572, supporting records (Alberti, 1961; Williams and Bujak, 1977; Williams, 1978; Harland 1979) which suggest that the species became

extinct in the mid Miocene. <u>Pyxidiella</u> <u>simplex</u> occurs only in the basal upper Miocene, confirming data from the Bay of Biscay (Harland, 1979) which indicates that the species is restricted to that stratigraphic level. <u>Operculodinium</u> <u>centrocarpum</u> also only occurs in the Miocene at Site 572, but the species is a common constituent of Quaternary pelagic sediments in many areas (Wall, 1967; Wiseman, 1976; Reid and Harland, 1977) and certainly ranges back to the Eocene (Williams and Bujak, 1977; Williams, 1978). <u>Nematosphaeropsis</u> <u>labyrinthea</u> and three species of <u>Impagidininm</u> (<u>I.</u> <u>paradoxum</u>, <u>I.</u> <u>patulum</u> and <u>I.</u> <u>sphaericum</u>) range from middle Miocene to Quaternary at Site 572, although <u>I.</u> <u>paradoxum</u> appears above the base of the succession. <u>I.</u> <u>aculeatum</u>, on the other hand, occurs only in the upper Pliocene and Quaternary. <u>Nematosphaeropsis</u> <u>labyrinthea</u> and <u>Impagidinium</u> <u>patulum</u> are known to range down into the upper Eocene in the eastern Atlantic (Williams, 1978; Costa and Downie, 1979), but <u>I.</u> <u>paradoxum</u> and <u>I.</u> <u>aculeatum</u> first appear in the middle Miocene (Stover and Evitt, 1978; Williams, 1978; Costa and Downie, 1979; Harland, 1978, 1979). We record <u>Spiniferites</u> <u>pseudofurcatus</u> from the middle Miocene at Site 572 and the lower Oligocene at Site 574 (Appendix 2), but the species is known to extend into the Eocene (Klumpp, 1953; Sarjeant, 1970; Williams and Bujak, 1977; Williams, 1978). <u>Operculodinium</u> cf <u>israelianum</u> and <u>Spiniferites</u> <u>bentorii</u> <u>truncatus</u> occur only in the youngest sediment at Site 572, conforming with a Pleistocene age for these species (Rossignol, 1962, 1964; Wall, 1967; Wiseman, 1976), although a comparable form of <u>O.</u> <u>israelianum</u> is recorded as ranging down into the lower Eocene (Williams and Bujak, 1977; Williams, 1978).

Abundance and diversity

The small number of species recorded here from the Neogene and Quaternary of the eastern equatorial Pacific is similar to the low diversity

displayed by coeval pelagic assemblages from the Atlantic (Williams and Bujak, 1977; Williams, 1978; Harland 1979), and off the Peruvian coast (Wiseman, 1976). The common occurrence of _Impagidinium aculeatum_, _I. paradoxum_, _I. patulum_ and _Nematosphaeropsis labyrinthea_ supports the widely held view (Reid and Harland, 1977; Wall et al., 1977; Harland, 1978, 1979) that these are tropical to temperate deep oceanic species.

Uppermost Miocene sediments (140–170m sub-bottom depth) at Site 572 yielded larger numbers of dinoflagellate cysts than samples from other parts of the succession (Fig.2), but there is no increase in diversity associated with this acme. The latest Miocene falls within a broader period (late Miocene to early Pliocene, 7.8–4.0Ma) characterised at Site 572 by high sedimentation rates and the deposition of sediments with low carbonate contents (Pisias and Prell, this volume). These resulted primarily from high productivity as the site passed under the equator. The deposition of siliceous oozes resulted from the high proportion of siliceous microplankton and the diagenetic dissolution of carbonate, indicated by the poor preservation of foraminifera and calcareous nannofossils. Dissolution was probably a consequence of the enhanced preservation of organic matter which resulted from the increased flux of biogenic debris to the seafloor. An increased input of organic matter is supported by the abundance of dinoflagellates. Subsequent oxidation of organic material during early diagenesis caused the dissolution of carbonate.

The concentration of dinoflagellate cysts in Site 572 sediments cannot be related simply to the equatorial location of the site, since other Leg 85 sites yielded few dinoflagellates. Site 572 is unique amongst the sites examined, however, in having siliceous intervals which are characterised by sediments composed almost entirely of diatom species (particularly species of _Thalassionema_ and _Thalassiothrix_) which are regarded as indicators of

deep-water productivity and upwelling (Hasle, 1960; Hasle and de Mendiola, 1967; Bukry and Foster, 1973; Sancetta, 1982, 1983). Sediments of this type were deposited at Site 572 (Barron, this volume) in the late Miocene-early Pliocene (7.8-4.0Ma) when the site crossed the equator, and in the mid Miocene (13.0-11.8Ma), an equatorial Pacific-wide interval of high biogenic silica accumulation (Leinen, 1979). The occurence of upwelling diatom assemblages has been related (Keller et al., 1982) to periods of expanded Antarctic glaciation causing increased gyral circulation, and increased upwelling throughout the eastern equatorial Pacific. We suggest, therefore, that Site 572 falls geographically in a broad area favourable to dinoflagellate productivity, but that during the latest Miocene (a period of enhanced upwelling) when the site was located immediately below the equatorial high productivity belt, there was a significant increase in the flux of dinoflagellate cysts to the seafloor.

ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

Figure 1. Location map of DSDP Site 572. Positions of other DSDP drill sites in the central Pacific are indicated. Isopachs relate to acoustic sediment-thickness (units are tenths of seconds two-way travel time).

Figure 2. Range chart of dinoflagellate cysts recovered from Site 572. Lithostratigraphic units (left) are those distinguished by Leg 85 sedimentologists - Unit I (0-454.5m): cyclic siliceous calcareous ooze-chalk; Subunit A, gray-brown ooze; Subunit B, varicolored ooze; Subunit C, green-varicolored ooze; Subunit D, yellow chalk. Unit II (464.5-?479.5m): metalliferous chalk. Unit III (479.5-489.0m): basalt. Chronostratigraphic subdivisions (right) are based on age assignments made by shipboard paleontologists using nannofossils, foraminifera, diatoms and radiolaria. The nannofossil zonation is based on Pujos (this volume). Dinoflagellate cyst abundance can be gauged from the graph (right center) showing the number of specimens recovered from each 20g sample of dry sediment.

PLATE CAPTIONS

Plate 1. Dinoflagellate cysts from DSDP Site 572. All figures are magnified x1000 except number 10 which is x400. 1. _Impagidinium aculeatum_ (Wall) Lentin and Williams, sample 572A-3-2(115-135), 21.65-21.85m sub-bottom depth. 2-3. _I. sphaericum_ (Wall) Lentin and Williams, sample 572C-2-2(144-150), 13.04-13.10m. 4. _I. patulum_ (Wall) Stover and Evitt, sample 572-1-3(100-120), 4.00-4.20m. 5-6. _I. paradoxum_ (Wall) Stover and Evitt, sample 572C-3-5(144-150), 27.14-27.10m. 7. _I._ sp. A, sample 572-1-1(115-135), 1.15-1.35m. 8-9. _Operculodinium_ cf _israelianum_ (Rossignol) Wall, sample 572-1-1(115-135), 1.15-1.35m. 10. _Palaeocystodinium golzowense_ Alberti, sample 572D-29-4(140-150), 422.90-423.00m. 11. _Tectatodinium_ sp. B, sample 572D-12-4(144-150), 261.44-261.50m. 12. _Tectatodinium_ sp. A, sample 572A-4-4(95-115), 34.05-34.25m. 13. _Pyxidiella simplex_ Harland, sample 572D-12-4(144-150), 261.44-261.50m. 14. Cyst (?_Protoperidinium_) sp. A, sample 572C-5-5(144-150), 46.34-46.40m. 15. _Spiniferites_ sp. A, sample 572A-1-4(50-70), 5.00-5.20m. 16. _S. bentorii truncatus_ (Rossignol) Wall and Dale, sample 572A-1-4(50-70), 5.00-5.20m.

APPENDIX 1

Samples from Site 572 (27 samples, 2 barren) examined for dinofla-
gellate cysts. Age assignments are based on nannofossil, foraminifera,
radiolaria and diatom determinations made by shipboard paleontologists.
No a priori assumptions were made concerning the stratigraphic ranges of
dinoflagellate cyst species.

Location   Core-section-interval (cm)   Sub-bottom depth (m)   Age

Hole 572

1-1(115-135)	1.15-1.35	(Quaternary)
1-2(100-120)	2.50-2.70	(Quaternary)
1-3(100-120)	4.00-4.20	(Quaternary)

Hole 572A

1-1(0-20)	0.00-0.20	(Quaternary)
1-4(50-70)	5.00-5.20	(Quaternary)
2-1(0-20)*	9.50-9.70	(Quaternary)
3-2(115-135)	21.65-21.85	(Quaternary)
4-4(95-115)	34.05-34.25	(upper Pliocene)
6-3(85-105)	49.75-49.95	(upper Pliocene)
9-3(85-105)*	76.15-76.35	(lower Pliocene)
13-5(85-105)	116.75-116.95	(lower Pliocene)

Hole 572B

2-3(123-143)	163.53-163.73	(upper Miocene)

Hole 572C

2-2(144-150)	13.04-13.10	(Quaternary)
3-5(144-150)	27.14-27.20	(Quaternary)
5-5(144-150)	46.34-46.40	(upper Pliocene)
7-5(144-150)	65.54-65.60	(lower Pliocene)

10-5(144-150)	97.34-97.40	(lower Pliocene)
17-3(144-150)	144.74-144.80	(upper Miocene)

Hole 573D

1-3(144-150)	155.44-155.50	(upper Miocene)
2-5(144-150)	167.94-168.00	(upper Miocene)
7-5(144-150)	215.44-215.50	(upper Miocene)
12-4(144-150)	261.44-261.50	(upper Miocene)
18-4(144-150)	318.44-318.50	(middle Miocene)
21-4(144-150)	345.94-346.00	(middle Miocene)
24-5(144-150)	376.94-377.00	(middle Miocene)
29-4(140-150)	422.90-423.00	(middle Miocene)
32-4(140-150)	453.40-453.50	(middle Miocene)

Species records are given in Fig. 2.   * = barren sample.

APPENDIX 2

Samples from DSDP Sites 573-575 yielding dinoflagellate cysts. Age assignments as in Appendix 1. Samples were identical to those used for pore-water analysis, see Stout (this volume) for further details of barren intervals. Number of specimens recovered are indicated in brackets after each record.

Location   Core-section-interval (cm)   Sub-bottom depth (m) Age Species

SITE 573 (28 samples, 24 barren)

Hole 573

   9-5(140-150)   74.10-74.20   (lower Pliocene)   I. paradoxum (1)

   12-5(140-150) 102.60-102.70 (upper Miocene)   I. paradoxum (1)

                                                 I. patulum (2)

                                                 N. labyrinthea (5)

   16-5(140-150) 137.70-137.80 (upper Miocene)   I. paradoxum (4)

                                                 N. labyrinthea (1)

Hole 573A

   6-4(143-150)   55.13-55.20   (lower Pliocene)   I. paradoxum (1)

                                                 I. patulum (2)

SITE 574 (29 samples processed, 27 barren)

Hole 574A

   7-4(144-150)   51.84-51.90   (upper Miocene)   N. labyrinthea (1)

Hole 574C

   29-1(135-150) 461.85-462.00 (lower Oligocene) S. pseudofurcatus (1)
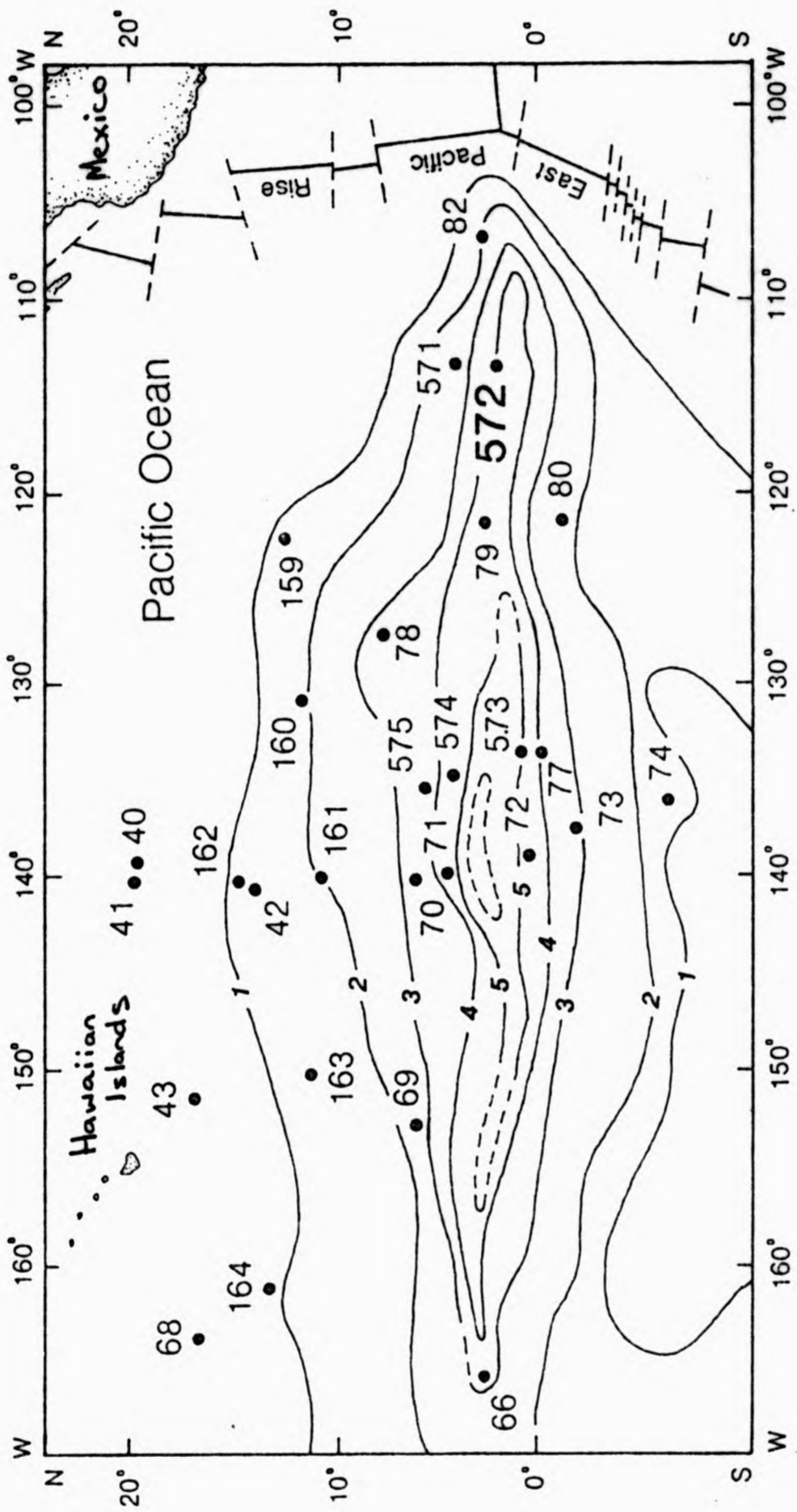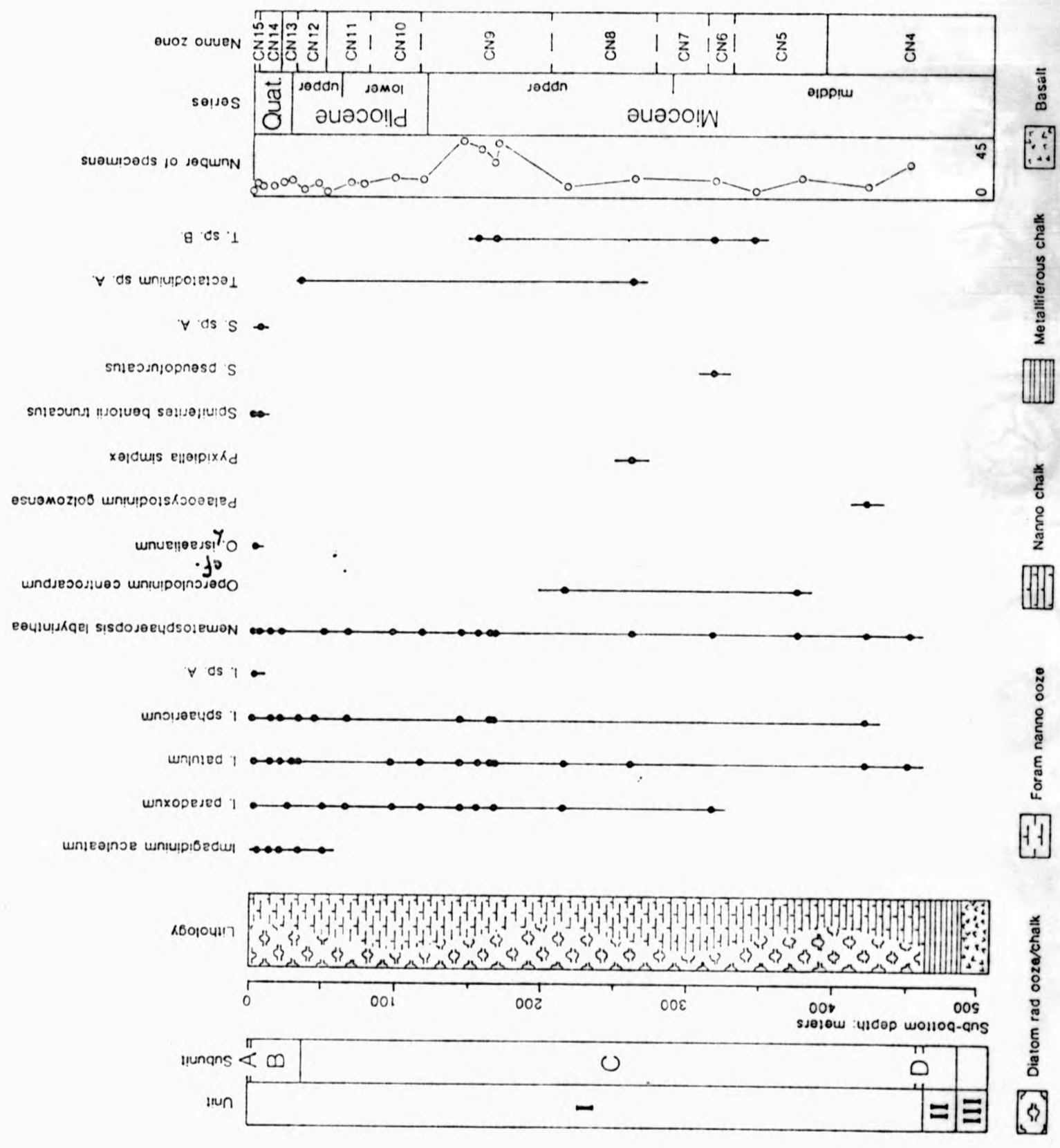
SITE 575 (17 samples processed, all barren)

Fig.1

Fig.2

Plate 1