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FACIES RELATIONSHIPS IN A TIDALLY INFLUENCED ENVIRONMENT:
A study from the Eocene of the London Basin

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SUMMARY

The sedimentology and burrow associations of a lower Tertiary (Lutetian and Cuisian) section in south-east England are described and compared with bedding types described from the Wadden Sea and Rhine estuary. In the lower part two facies are distinguished representing channel and bank deposits. Their relationship, bed forms, fauna and general lack of bioturbation suggest deposition in an inshore tidally influenced region. The sequence is truncated by bioturbated glauconitic sediments of the transgressive Bracklesham Beds.

INTRODUCTION

A temporary exposure in the lower Tertiary sediments of the London Basin has furnished a section in sediments which are similar to recent estuarine and lower tidal flat channel deposits. They are described here as they add information on the relationships of facies, many of which have been described from the Holocene of The Netherlands and Germany, in particular in the Haringvliet (Oomkens and Terwindt, 1960; Terwindt, 1971). The continuous exposure has made it possible to trace lateral and vertical relationships of these deposits which was not possible in the Haringvliet excavations or in boreholes across the estuary.

Bramshill sand pit (Osborne White, 1909) (British National Grid SU 76 758610), northern Hampshire, England, displays a 300 m long face of Lower Bagshot Beds (Cuisian) and a veneer of overlying Bracklesham Beds (Lutetian). No detailed sedimentological studies have been published on the Lower Bagshot Beds of the London Basin but Curry (1965), used foraminifera to correlate the Lower Bagshot Beds with the marine lowest Bracklesham Beds (Lutetian) of the type area of the Hampshire Basin.

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GENERAL DESCRIPTION AND DISTRIBUTION OF FACIES

The ribbon diagram (fig. 1) shows the distribution and relations of the facies. Facies 1 (cf. Small Scale heterolithic group of de Raaf and Boersma, 1971; Lithofacies II and III of Terwindt, 1971) occurs as sheetlike units of silts and cross-laminated fine sands measuring 0.5 to 1.5 m in thickness and dipping 10 to 20° to the south-west. Facies 2 (cf. Large Scale group of de Raaf and Boersma, 1971; Lithofacies I, Terwindt 1971) is the product of higher flow velocities and displays strongly discordant channel like scours with a north-south orientation. The scours are filled vertically with mud-flake conglomerates and plane and cross-bedded medium sands.

The Bracklesham Beds (fig. 1 and 4) transgress both facies with a sub-horizontal erosion surface and a basal deposit of well rounded pebble and cobble sized patinated flints. These flints are set in a glauconitic matrix of bioturbated silts and sands which also form the overlying beds. Bedforms are only occasionally visible; they are a cross-lamination with silty drapes and some interlaminated silt and fine sand.

Ophiomorpha nodosa Lundgren is common in the Bracklesham Beds. Infilled burrows may penetrate as much as 1 m down into the underlying Bagshot Beds (fig. 4A). The burrow is in all respects similar to that described by many authors including Weimer and Hoyt (1964) and Kennedy and Sellwood (1970). At Bramshill *O. nodosa* is commonly found in association with fine, cylindrical (2-3 mm diam) burrow infills (fig. 4F and G) which form a sinuous, irregularly branching, burrow system. There is no pattern to the burrows but they tend to aggregate around and within *O. nodosa* (fig. 4F) as described by Kennedy and Sellwood (op. cit., p. 108). The association with *O. nodosa* suggests that the organism responsible was a burrowing scavenger which found greater concentrations of food and oxygenated sediment around the larger callianassid burrow.

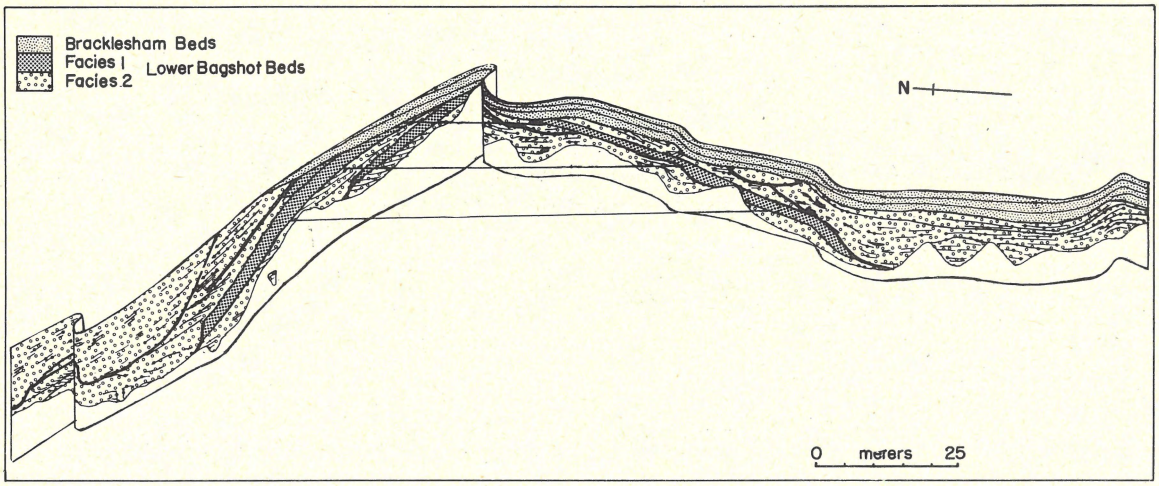


Fig. 1
Ribbon diagram showing relations of the facies (vertical scale equals horizontal scale).

DETAILS OF FACIES ONE AND TWO

There are three units of Facies 1, each having a discordant erosion surface at its base dipping to the south-west, and so outcropping on both faces of the pit (fig. 1). Above the base are small-scale rippled fine sands, or silt lamina and then rippled sands (fig. 2A). The layers of the basal sands vary from 20 to 40 cm in thickness and contain climbing foresets, symmetrical wave ripples (fig. 2A and B) and occasionally regressive backflow ripples (J o p l i n g, 1961). Areas of ripples have been excavated which show an asymmetrical linguoid ripple pattern. Current directions are locally bimodal (north-south) parallel with the strike of the depositional slope. Frequently the ripples possess silt drapes which may be complete, or eroded, to give rise to simple, wavey and then bifurcated flaser bedding (fig. 2B) (R e i n e c k and W u n d e r l i c h, 1968). Upwards, sands diminish giving way to lenticular bedding (fig. 2C) and then interlaminated silt and sand (fig. 2D) (R e i n e c k, 1963). This sequence always coarsens upwards into lenticular, flaser and then cross-laminated sand from the interlaminated portion resulting in a symmetrical sedimentary cycle. In an adjacent pit 200 m to the north-east similar units of this facies show this same sequence but on a smaller scale. The cause of these symmetrical cycles is not understood. (See below).

Facies 2 displays large channel-like scours with sands and intraformational conglomerates. The complete sequence fines upwards from pebble-grade conglomerates into fine sands (fig. 3). The base is always erosive and strongly concave upwards in cross section. The initial fill is an intraformational conglomerate with rectangular blocks of silty beds up to 50 cm in length set in a matrix of medium grained sand (fig. 3C). The clasts are often contorted. This is thought to have occurred when they lodge against existing flakes of the substrate (fig. 3C and D). The texture and lithology of the mud flakes indicate their derivation from Facies 1, and by their mainly angular nature they could not have travelled far (fig. 3). The basal conglomerate is interbedded upwards and laterally with plane bedded and planar cross-bedded medium sands which may be conglomeratic. Some of the foresets are covered with a silt drape (fig. 3A). Facies 2 may contain small scale current rippled fine sands near the top of this fining upwards sequence (fig. 3B). The individual vertical fills show a undirectional current direction (cross-bedding and cross-lamination) parallel to the sides of the channels. The overall section however, shows a bimodal current direction, the northern part of the section having current directions to the south and the southern part to the north.

No micro- or macro-body fossils have been found in either of the two facies but trace fossils are locally abundant below erosion surfaces. They are generally restricted to one type, especially in the exposure 200 m to the north-east, and five burrow types are present.

1) *Ophiomorpha nodosa* Lundgren occurs in one bed of Facies 1 but it is of a smaller size (diam. 0.6-1.0 cm) and a different burrow pattern with more frequent branchings than the large burrows in the Bracklesham Beds (above).

2) In another unit of Facies 1 (fig. 4H) apparently J-shaped burrows (diam. 1 cm) with walls 1 mm thick occur in silty substrates to a depth of up to 20 cm. The steeply inclined shaft turns into a horizontal, lateral and vertical retrusive section. In spite of careful excavations it has not been possible to show whether this is J or U shaped.

3) Burrows or borings without walls (fig. 4) in silty substrates having single branches and an L-shaped system. Two size populations are found: 1 cm (diam.) burrows and smaller burrows of 3-4 mm diam..

4) In one section in the fine sands of Facies 1 infilled burrows (1 mm diam.) (fig. 4D and E) are found beneath a minor erosion surface displaying rosettes of burrows proba-

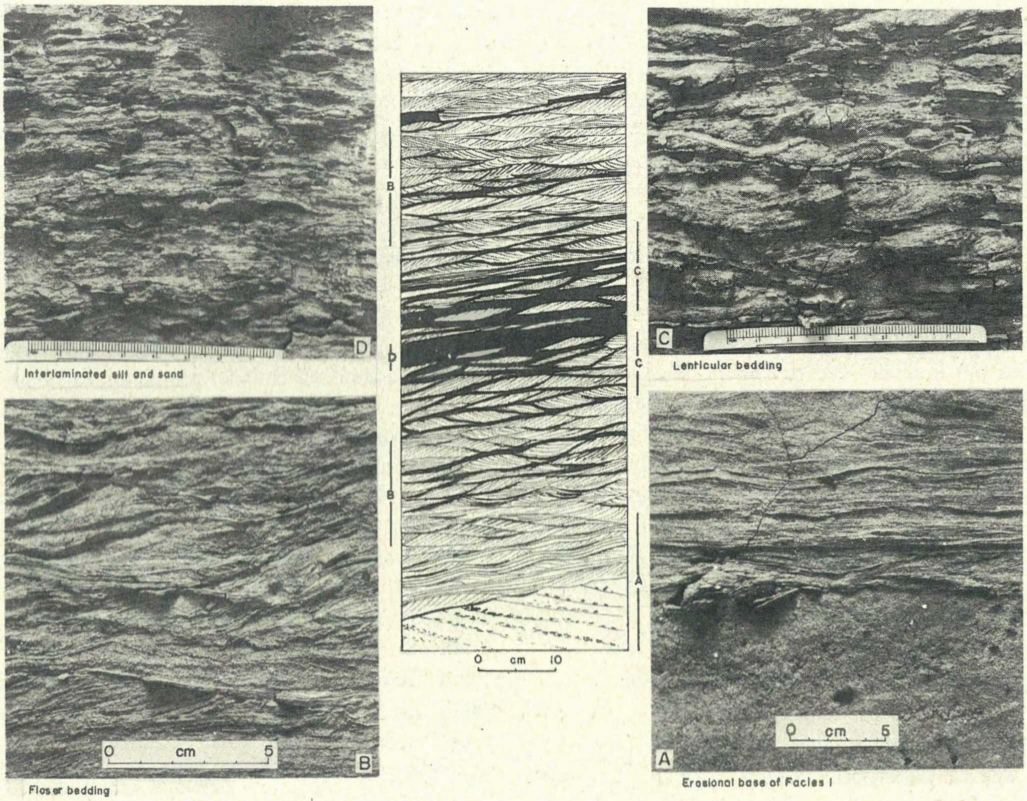
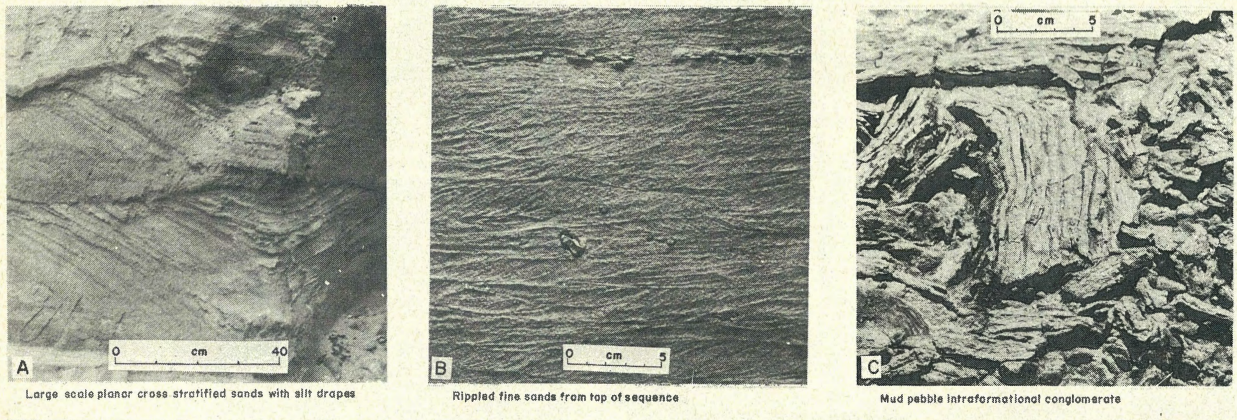
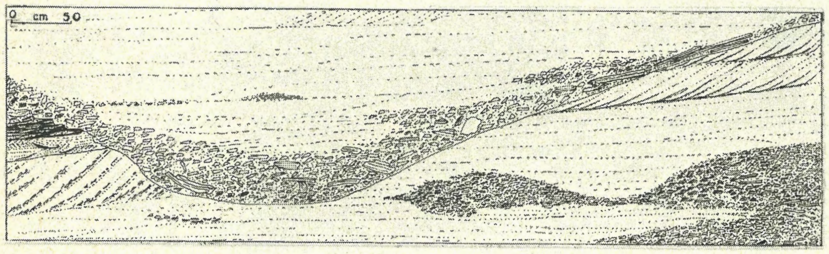


Fig. 2
Facies 1. A typical sequence showing detail of bed forms. Original photographs of B and D from acetate peels.





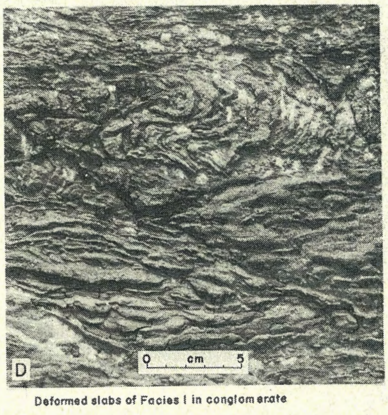


Fig. 3
Facies 2. A typical sequence showing details of beds. Original photographs taken from acetate peels from northwestern face of pit.

bly occurring at concentrations of food.

5) The only trace fossils in Facies 2 are essentially vertical tubes (diam. 3-5 mm) with a well defined wall of cemented sand grains a few grains thick. The tubes may penetrate clasts of silt in conglomeratic beds where they tend to be deeper and straighter, probably representing escape burrows from rapid sedimentation (Goldring, 1964, fig. 1 (2)). The normal shape is sinuous and branched (fig. 4I). Occasional silty beds in Facies 2 may be completely bioturbated by these burrows.

O. nodosa is generally held to be an indicator of inshore marine sediments, but the environmental significance of the other traces is not understood. In general facies 1 and 2 contrast with the Bracklesham Beds in that they are not bioturbated. However, where found, each ichnotype is concentrated in a particular bed, where the burrows are of a similar size (fig. 4) and originate from one substrate surface, suggesting a single colonization. This can be explained by a rapid sedimentation rate, interrupted by periods of erosion, which either prevented colonization or eroded existing burrows (van Straaten, 1954).

INTERPRETATION AND CONCLUSIONS

Facies 1 and 2 have recent analogues from the Haringvliet estuary (Oomkens and Terwindt, 1971), the Jade estuary (Reineck and Singh, 1966), from lower parts of tidal flat areas of the Wadden Sea (van Straaten, 1954 p. 89, 1959, 1961; Reineck, 1967; Reineck and Wunderlich, 1967) and from the tidal channel floor environment of the Wadden Sea (van Straaten, 1954 p. 88, 1959, 1960, 1961; Reineck, 1963).

Facies 1 is the result of lateral accretion of fine sand and silt along a palaeoslope, which, with the described bed forms and vectorial bimodality, suggest deposition on the inside banks of a tidal channel (Oomkens and Terwindt, 1960; Land and Hoyt, 1966). Facies 2 is thought to have been deposited in large scale scours cutting into the floor of this or an associated channel producing smaller local channels or scours (cf. van Straaten, 1960). These scours were filled vertically contrasting with the laterally migrating pattern of tidal flat channels (van Straaten 1954, 1961. Evans, 1965). The alternation and repetition of these two facies (fig. 1) shows that channel and bank were frequently reworked leading to the complex, but invariably discordant, relationships between the two facies. No instance of lateral facies change has been observed. This juxtaposition of units produced from contrasting flow velocities is accepted as characteristic of tidal deposits (de Raaf and Boersma, 1971). Great variation in bed forms and facies alternations is recorded from recent tidal sediments of the Haringvliet estuary in which it is the direct result of fluctuating bottom

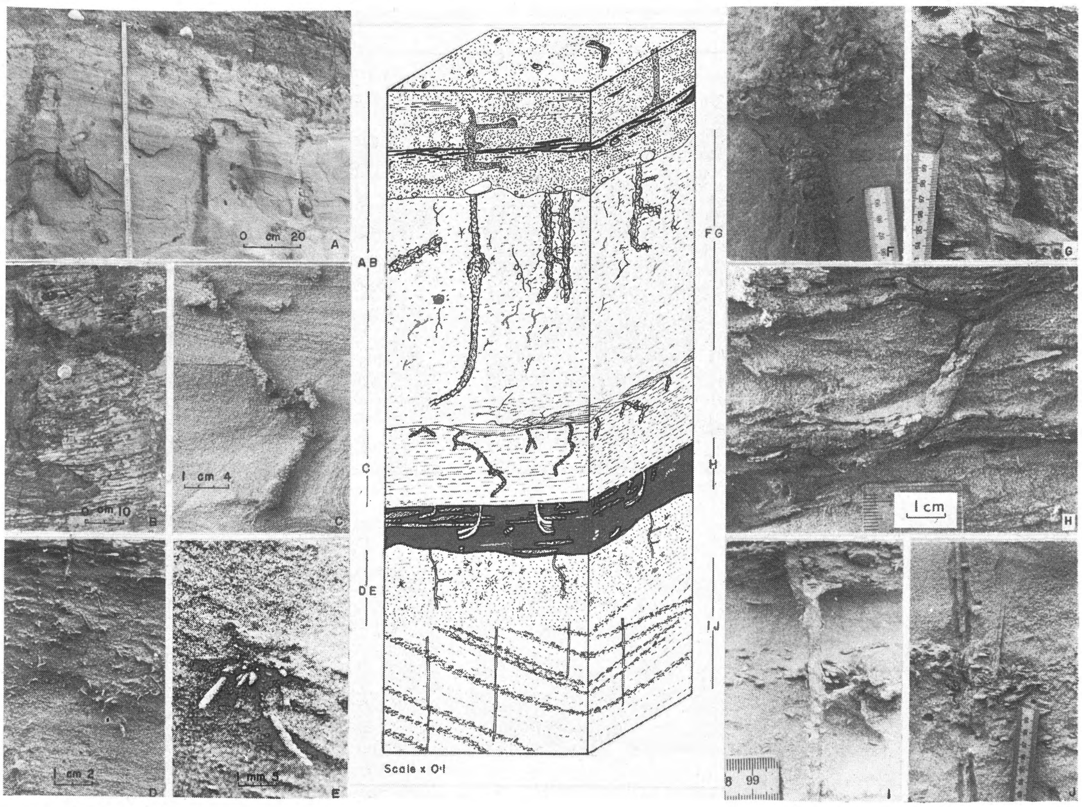


Fig. 4
A schematic sequence illustrating the burrow morphology and variations.

currents in the tidal environment (T e r w i n d t, 1971).

These fluctuations can have a semidiurnal/diurnal, two weekly or six monthly tidal periodicity or an irregular fluctuation from storms. At Bramshill three repeated hierarchical sedimentary sequences are found; (A) the small scale alternation of silt and sand of Facies 1, (B) the sequences of bed forms in Facies 1 and 2, and (C) the large scale alternation of Facies 1 and 2. It has been demonstrated by R e i n e c k and W u n d e r l i c h (1967) that (A) can be the result of semidiurnal tidal current fluctuations in inshore areas. The effects of two weekly and six monthly fluctuations have not yet, to my knowledge, been published but the existence of alternations (B) and (C) may be of interest to other workers.

The southwestern part of the pit shows an increase of channel deposits over bank deposits which outcrop to the north-east. This suggests that the outside bank of a major channel lay to the south-west whilst to the north-east sediments were being deposited from the relatively quieter water towards the inside bank of this major channel. Variations in channel width and scours in the meander bank are thought to cause the repeated original erosive and depositional slopes to the south-west.

The absence of bioturbation is probably due to two factors; principally to the high sedimentation rate but also perhaps to reduced salinity. However, a marine influence at times allowed colonization by callianassids. The area of depositional environment may thus be delimited within the tidally influenced environment. Tidal flats and offshore areas are strongly bioturbated and it is therefore suggested that Facies 1 and 2 were deposited in an estuarine environment or as channel floor deposit in the lower flat environment.

With the evidence from this exposure, and the lack of adjacent exposures to place this succession in its environmental context, it is not possible to define the environment of deposition to any greater extent.

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