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The Scalby Formation (Middle Jurassic, Ravenscar Group) of Yorkshire: reassessment of age and depositional environment

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SUMMARY: Re-examination of the Scalby Formation of the Middle Jurassic Ravenscar Group in Yorkshire, using integrated sedimentology and palynofacies techniques, has led to a re-interpretation of the depositional environments. Overlying the marine Scarborough Formation, the Moor Grit Member appears to represent a deltaic distributary system. Where overbank deposits are preserved, they are found to reflect saline interdistributary bay environments. Similar saline-influenced delta plain deposition persisted throughout sedimentation of the overlying Long Nab member, interrupted by smaller distributary channels of varying sinuosity, some of which may have been partly tidal.

Palynological evidence indicates that at least part of the Long Nab Member is no younger than late Bajocian in age.

Depositional models for the Scalby Formation have been discussed by Leeder and Nami (1979). These authors conclude that the most acceptable model is of an alluvial plain traversed by a major braided river channel system, represented by the Moor Grit Member, which was succeeded by backswamp and floodplain environments traversed by meandering and low-sinuosity streams, represented by the Long Nab Member. Implicit in their preferred model is the acceptance of a major hiatus between the *humphriesianum* and *aspidoides* zones at the base of the Scalby Formation. Subsequently Livera and Leeder (1981) have adopted a less positive stance.

Hancock and Fisher (1981) report marine microplankton from the Long Nab Member exposed south of Cloughton Wyke. These occurrences are inconsistent with the backswamp/floodplain environments proposed by Leeder and Nami and have stimulated a reassessment of depositional models for the Scalby Formation.

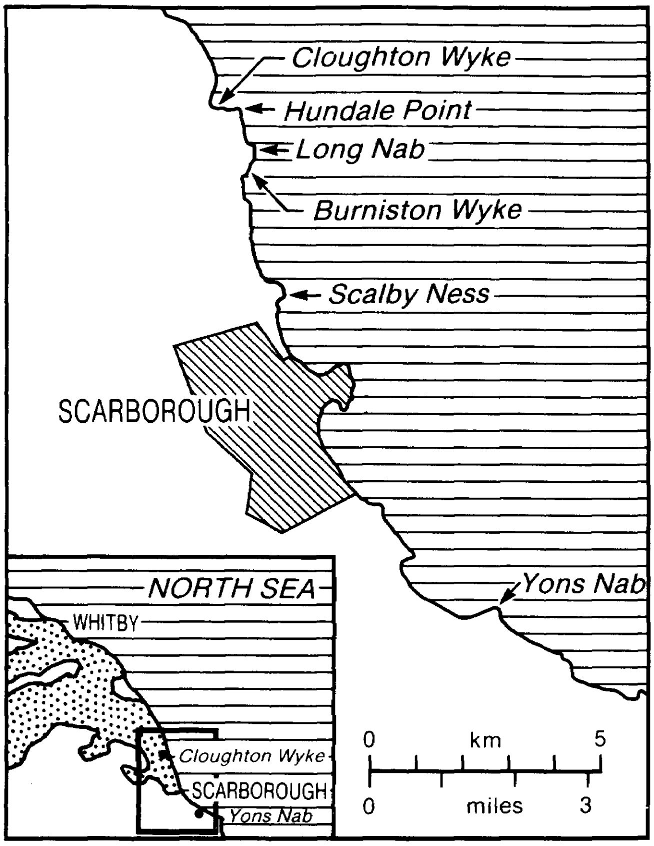

Fig. 1. Map of north-east Yorkshire showing coastal outcrops of Middle Jurassic (stippled in inset) and localities discussed in the text.

1. DEPOSITIONAL ENVIRONMENTS

The sections examined for this study are located between Cloughton Wyke and Yons Nab and form part of the classic coastal outcrops (Fig. 1). Sedimentary structures, lithologies and palynofacies are illustrated in Figures 2 to 5.

1.1. Moor Grit Member

The lithological characteristics of the Moor Grit Member north of Long Nab are largely consistent with its interpretation as a channel complex. Above an erosive contact with the underlying Scarborough Formation, cross-bedded sandstones, approximately 8 m thick, often richly carbonaceous and with major reactivation surfaces, are succeeded by 3 m of rippled sandstone with mudflake conglomerate (samples 51-56; Fig. 2). The palynofacies of these samples is typical of high energy fluvial channels with a dominance of unstructured inertinite (Fisher 1980). Thirty metres to the south, the rippled sandstone is cut by a small channel with similar palynofacies (sample 57). A further 50 m to the south, this horizon is represented by a grey sandy shale (sample 58). This local development of overbank

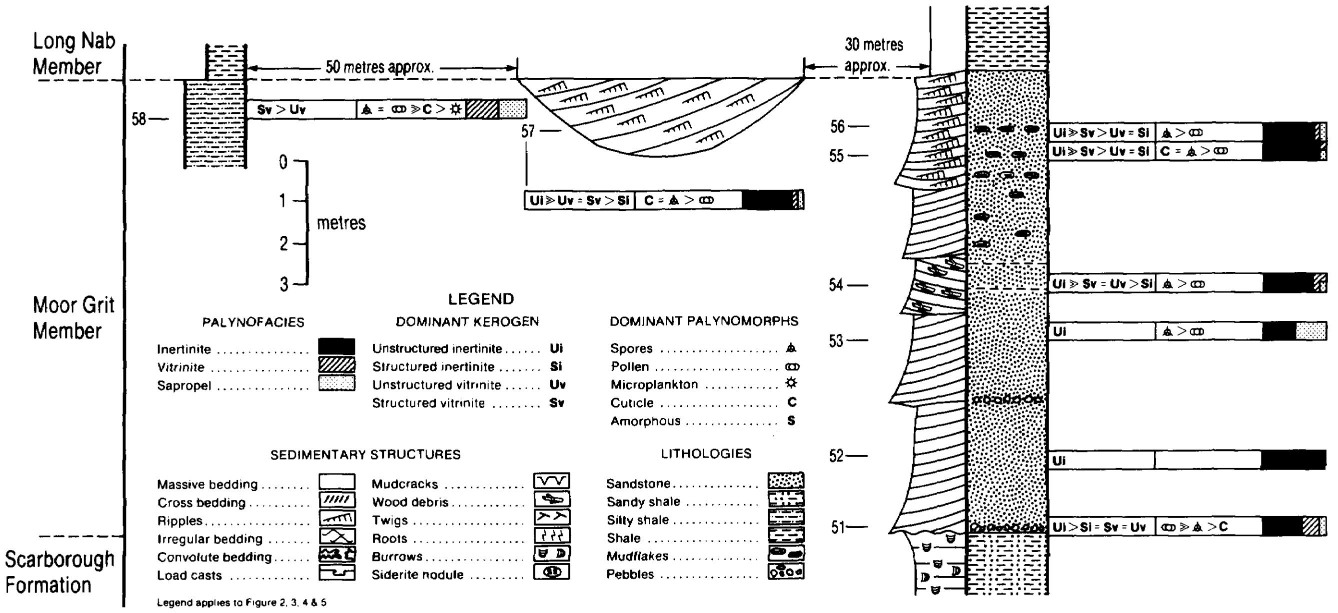

Fig. 2. Section at Long Nab (north) through the Moor Grit Member, showing lateral facies changes with indications of saline environments to the south (sample 58). Numbers on figures 2-5 refer to palynofacies samples: the legend refers to abbreviations of Figures 2-5.

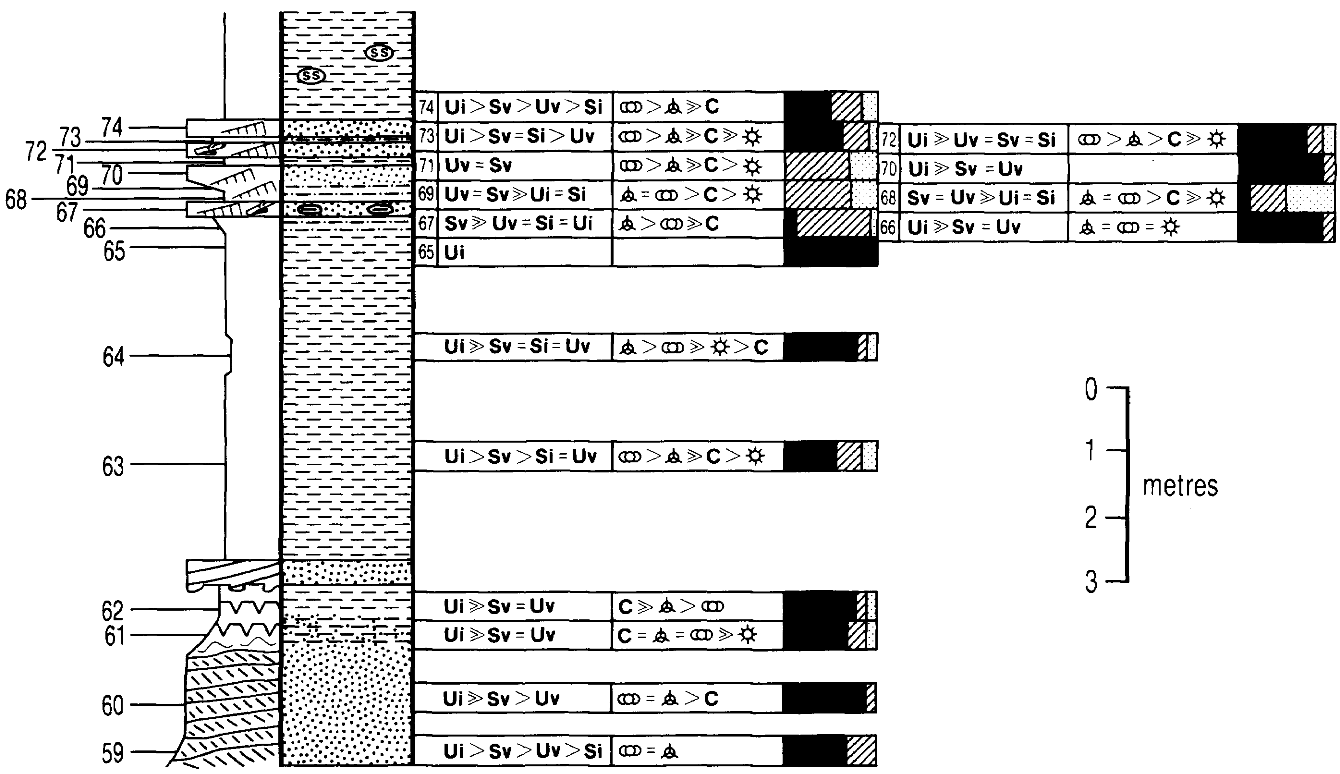

Fig. 3. Section between Long Nab and Scalby Ness through the meander-belt sand (basal 2 m) and delta-plain shales of the Long Nab Member. See Figure 2 for legend.

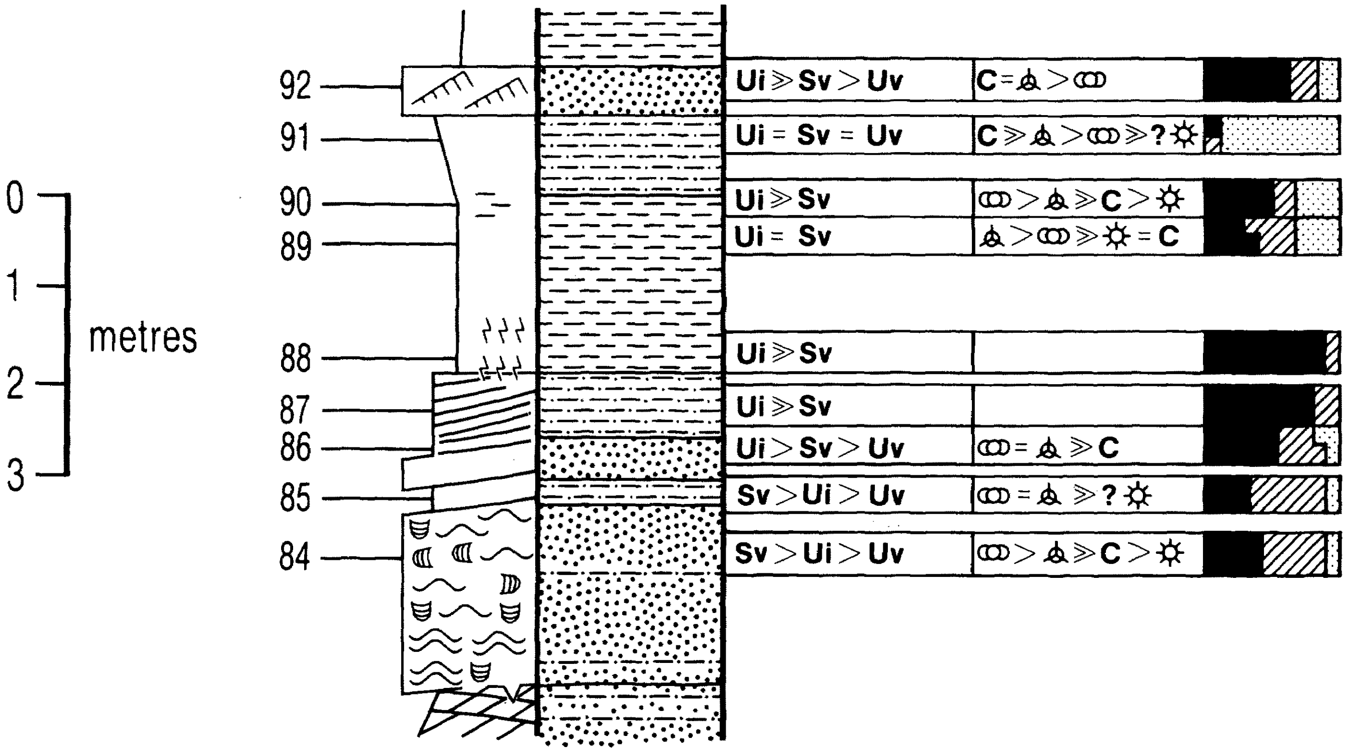

Fig. 4. Section at Burniston Wyke through the meander-belt sand (basal 0.5 m) and delta-plain shales of the Long Nab Member. See Figure 2 for legend.

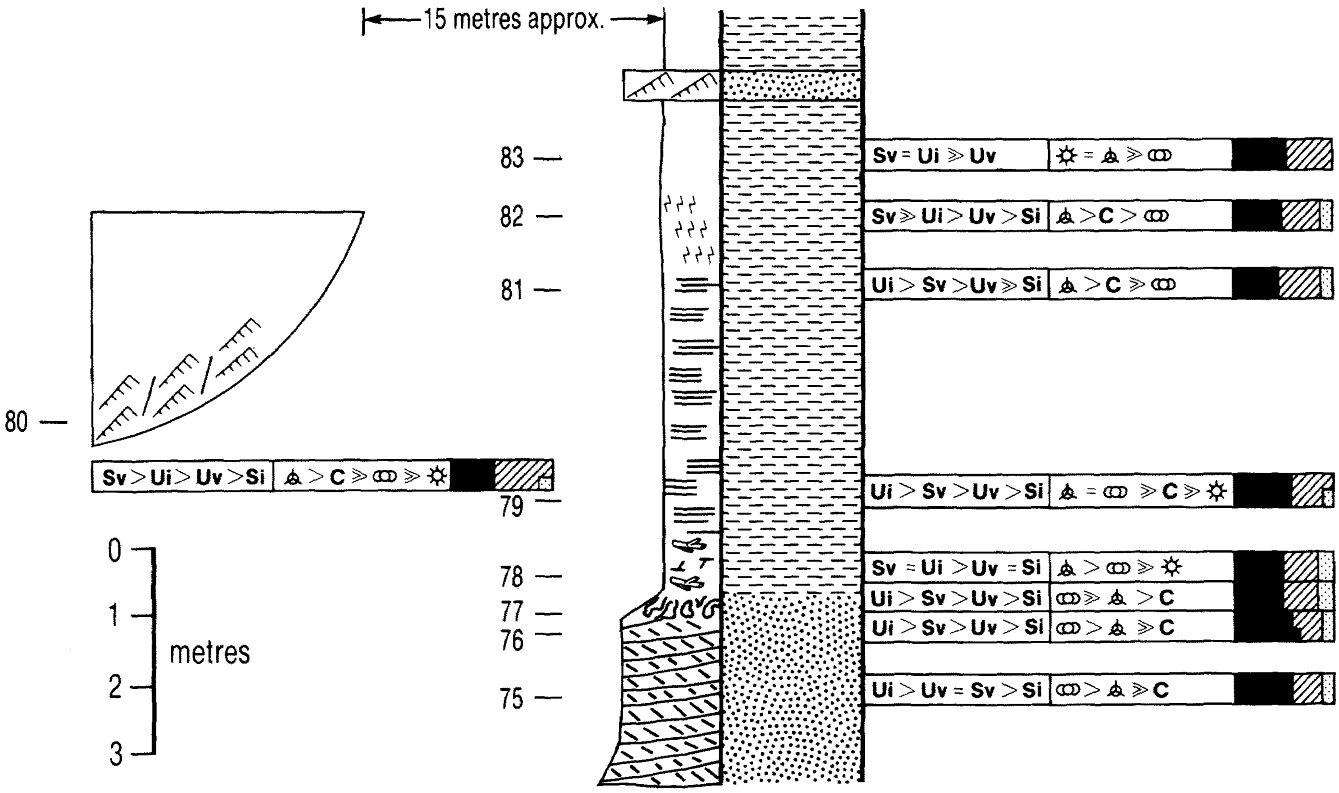

Fig. 5. Section south of Long Nab through the delta-plain shales of the Long Nab Member, with small argillaceous sand-filled channel cutting through interdistributary bay shales. See Figure 2 for legend.

shale contains acanthomorph acritarchs indicative of saline environments. Thus, although the major part of the Moor Grit Member appears to reflect large-scale channel deposition, saline waters penetrated between the active channels in the high part of the member.

1.2. Long Nab Member

1.2.1. Meander-belt sand

Overlying the Moor Grit Member, Nami (1976) has described a 3 to 4 m thick exhumed meander belt exposed between Long Nab and Scalby Ness (Fig. 3). The epsilon cross-bedded sandstones of the point bars yield well sorted inertinite-dominated palynofacies (samples 59 and 60). However, the immediately overlying mud-cracked sandy shales of the channel levees contain rare ancanthomorph acritarchs, indicating saline influence (sample 61). Both of the samples from the levee (samples 61 and 62) exhibit the common cuticle component deposited from the flotation load which is characteristic of levees.

1.2.2. Delta-plain shales

Above the meander-belt sand, a 41 m succession of the Long Nab Member has been examined, comprising shales with thin crevasse-splay sands. These are cut by isolated ribbon sand bodies representing channels of varying sinuosity (Nami & Leeder 1978).

The 10 m of shales and thin crevasse-splay sands immediately above the meander-belt sand (samples 63-74; Fig. 3) yield acanthomorph acritarchs indicating brackish to saline conditions and occasionally (sample 69) the dinocyst *Nannoceratopsis gracilis* indicative of more normal marine salinity. This succession is repeated at Burniston Wyke (samples 84-92; Fig. 4), where the laterally equivalent beds comprise bioturbated argillaceous sands overlain by shales which are locally rooted. Five of the samples have yielded acanthomorph acritarchs.

A point-bar sand showing limited lateral accretion crops out south of Long Nab at a level stratigraphically younger than the meander-belt sand (Fig. 5). The samples (75-77) have typical well sorted point-bar palynofacies, and exhibit a clear 'fining upward' sequence with decreasing inertinite and increasing vitrinite and cuticle. The overlying 10 m of shales yield palynofacies typical of low-energy interdistributary bays (samples 78, 79, 81-83). Three out of five of the samples contain marine microplankton (acanthomorph acritarchs and leiospheres), confirming that the bays were at least intermittently saline.

Argillaceous sand at the base of a small channel cutting through these shales has yielded the marine dinocyst *Dichadogonyaulax* sp. (sample 80). Swamp influence is seen in samples 81 and 82, associated with a rootlet bed, and fungal debris in sample 81 suggests the development of a soil at this level.

High in the cliff section some 400 m south of Hundale Point, bioturbated sandstones and shales with desiccation cracks include the Burniston Footprint Bed some 6 m above the base of the Long Nab Member. Palynofacies yield marine microplankton including the dinocyst *N. gracilis* (Hancock & Fisher 1981).

2. BIOSTRATIGRAPHY

Leeder and Nami (1979) postulate a major hiatus comprising the *subfurcatum* to ?*retrocostatum* zones, following the deposition of the Scarborough Formation and prior to the deposition of the Scalby Formation. This hypothesis would place the Scalby Formation in the late Bathonian, although Livera and Leeder (1981, p. 246) now admit that the evidence is 'suggestive rather than compelling'.

The association of common and well preserved *N. gracilis* with *Dichadogonyaulax* sp. in the Long Nab Member restricts the age to the two ammonite zones *garantiana* and *parkinsoni* (latest Bajocian) (Fenton & Fisher 1978). This age is based on concurrent ranges; as *Dichadogonyaulax* sp. is not recorded in sediments of pre-*garantiana* age, its presence precludes any possibility that the dinocyst assemblages result from reworking of older sediments. Moreover the palynological data provide conclusive evidence of marine influence within Leeder and Nami's (1979) postulated *subfurcatum* to ?*retrocostatum* zones hiatus. Further palynological evidence provided by Woollam and Riding (1983) confirms a ?*subfurcatum* to *parkinsoni* age for the Scalby Formation.

Regionally there is little biostratigraphical support for a major *subfurcatum*/*retrocostatum* hiatus. South of the Market Weighton axis, where palynological assemblages are more age-diagnostic, all the available evidence supports a more complete record of sedimentation throughout this interval with a number of relatively minor breaks, for example in the *subfurcatum* and *garantiana* zones (Fenton 1980). In the context of the deposition of the Scalby Formation, it does therefore appear more likely that the time interval from the *humphriesianum* Zone (Scarborough Formation) to the *macrocephalus* Zone (Cornbrash) accommodated a number of relatively small hiatuses. This could also include a hiatus immediately prior to deposition of the Cornbrash.

3. CONCLUSIONS

The sedimentological and palynofacies characteristics of the large-scale cross-bedded Moor Grit Member are consistent with their interpretation as deposits of a channel complex (Nami & Leeder 1978). Thereafter our evidence deviates from the interpretation preferred by Leeder and Nami (1979). The epsilon cross-bedded sandstones of the lower part of the Long Nab Member are interpreted as meandering distributary channel deposits (Nami 1976). The associated shales and argillaceous sandstones which contain burrows, marine or saline microplankton, plant debris and in situ roots are interpreted as saline swamp and interdistributary bay deposits with variable salinities occasionally achieving fully marine salinity. The distributary channels that traversed this delta plain may have been partly tidal (see sample 80) and there is even evidence of marine incursions occurring towards the end of the Moor Grit deposition.

In studying paralic sequences such as the Scalby Formation, it is important to use as many lines of evidence as possible. Although conventional sedimentology allows the recognition of sand environments, only palynofacies studies have demonstrated the true nature of the intervening shales, while also adding an extra dimension to the interpretation of the sands. It is now clear that the Scalby Formation was deposited in an overall delta-plain setting with saline interdistributary environments, and the prior interpretation of the Formation as an uplifted fluvial sequence (Leeder & Nami 1979) cannot be supported.

This interpretation, by obviating the need to postulate a major late Bajocian to late Bathonian hiatus is also more consistent with the available biostratigraphical evidence.

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DISCUSSION

DR M. R. LEEDER and MS J. ALEXANDER write:

We would like to thank Fisher and Hancock for making available a preprint of their paper so that we can briefly respond to their work.

Although Nami and Leeder (1978) and Leeder and Nami (1979) ascribed the Scalby Formation to a purely alluvial environment, Livera and Leeder (1981) pointed out that these interpretations must be tempered by the frequent occurrence of bioturbation and the muddiness of certain meandering channel lateral-accretion deposits. These features led Livera and Leeder (op. cit. pp. 246, 249) to suspect the spectre of marine influence, perhaps due to tidal-prism backup.

Confirmation of marine influence at certain stratigraphic levels now comes from the palynofacies work of Fisher and Hancock (see above) following on from the first reports by Hancock and Fisher (1981). We welcome their paper and congratulate the authors on a substantial contribution to knowledge of the depositional environments of the Scalby Formation. It certainly seems that the Scalby alluvial plains were occasionally marine influenced and that a strong case can be made for placing the alluvial plains closer to the coastline than hitherto stressed. However we suggest that the term *coastal plain alluvium* still best fits the current data since Fisher and Hancocks frequent use of the term interdistributary bay implies a *predominantly* delta front environment for which there is little sedimentary evidence. Although temporary saline bays seem to have developed it seems probable that tidal-prism back up effects (as seen in many modern tidal estuaries) provided only temporary marine-influenced floods in otherwise alluvial levees, backswamps and lake environments. Similar temporary marine events may also be triggered by seismic seiches over low-lying coastal plains. Work in progress by one of us (JA) indicates considerable tectonic effects during sedimentation. Very detailed analysis of the fine-grained Scalby facies is in progress (JA) and we hope that ultimately the results of this work can be married to the palynofacies work to solve the very real problem of the degree and magnitude of marine influence in such coastal plain environments. At the moment we feel that no convincing evidence of truly delta-front coastal lithofacies exists in the Scalby Formation, the palynofacies simply suggest marine influence of a temporary kind.

In this connection we point out to Fisher and Hancock that saline palynomorphs may be carried far upstream in estuarine or tidally-influenced channels and hence deposited in backswamp environments when high river discharge coincides with spring tides, causing extensive crevasse or over-bank flooding to occur. For example, marine ostracods from the outer Thames Estuary are found up to 20 km upstream in the river from their life habitats and show decreasing mean grain size upstream (Prentice *et al.* 1968). Palynomorphs, being even more susceptible to post-mortem transport, are expected to show similar distributions and thus cannot be considered *a priori* indicators of marine dominance.

It now seems certain that the suggestion by Leeder and Nami (1979) of a tectonically-activated hiatus at the base of the Scalby Formation is wrong, as proven by biostratigraphic testing (Woollam & Riding 1983). There seems to be no very large hiatus recorded at the erosive base to the Moor Grit Member. However, the time problem discussed by Leeder and Nami is still acute. Maybe Fisher and Hancock are correct in thinking that many small hiatuses are present in the Scalby succession, or maybe Rawson was right (1979) in pointing out that a substantial hiatus could exist at the Cornbrash/Scalby contact.

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