PROBLEMS OF THE RHAETIC IN THE EAST MIDLANDS

by

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Summary

The paper describes the broad palaeogeographical and structural setting of the Rhaetic formation and its deposition. The East Midland development is then discussed in terms of local stratigraphical and physiographical problems and the scope for further investigation stressed. An Appendix describes U-shaped burrows at the Rhaetic/Lias junction.

1. General

The Rhaetic is now classed as the terminal formation of the Trias, approximately equivalent to the Rhaetian stage (or substage) of the Continent. This grouping is essentially on faunal grounds, being based on the Triassic affinities of the vertebrates and molluscs. The name is an informal one: whether its lower limit corresponds to that of the stage is not known. Formal names for the British lithostratigraphical units have recently been proposed by the Geological Society Stratigraphical Committee, and these are shown in Table 1.

In northwestern Europe the formation marks the beginning of the main marine transgression of the Mesozoic and it was therefore formerly grouped with the Jurassic (Arkell, 1933), but this practice is now generally abandoned. Its special characteristics and interest thus stem from the circumstance that it was deposited at a time of major geographical and faunal change; these are recorded in varying types of rock and in their faunal content.

The preceding Keuper was a period of continental deposition, with red dust deserts, and salt lakes covering much of Northern Europe. In our area the lake included all the English Midlands, probably bounded by subdued highlands in the Western Pennines, low hills of the London/Ardennes island, and on the west by the Welsh mountains (although doubt has lately been thrown on the Mesozoic history of the latter area by the Mochras boring on the coast). Only a few jagged hills such as Charnwood broke the surface of a vast mud-flat. The surface of the sediments in this region of desert lakes was remarkably flat, and some of the few irregularities may have been washed away as the Rhaetic sea arrived. Into this low lying area the sea swiftly flooded, so that almost simultaneously the whole area was occupied by marine waters, with marine life (albeit specialised) in abundance, marine-plants and a reducing instead of an oxidising environment. Under these conditions were deposited the Black Shales, the most characteristic part of the Rhaetic sequence, notable for their extent - from the Alps to the Baltic and westwards into northern Ireland - and for their uniformity of lithology and fauna.

Despite the great lateral extent of the Black Shale facies it was a relatively short-lived interlude. The full marine conditions retreated over most of Britain and a temporary partial reversion to Keuper conditions occurred with deposition of the grey green Cotham Beds, much like Tea Green Marl, which further grade into a brown or red shale and marl facies in Lincolnshire and the North Sea. Later deposits of the formation were again marine - the limestone and shales of the "White Lias" (again presenting a long-standing classification problem, but now formally grouped as pre-Hettangian and hence by definition pre-Liassic) developed mainly in southern England and the South Midlands.

Table 1. Correlation and Subdivision of the Rhaetic

Stage	Informal Divisions	Ostracod Zones (provisional)	Southern England	Midlands	Geological Society Proposals 1969	
Rhaetian	UPPER RHAETIC	Hungarella moorei	Watchet Beds 0 - 2·4 m	Absent?	Lilstock Formation	PENARTH GROUP
			Langport Beds 0 - 7·6 m	White Lias (local) 0 - 3·0 m		
			Cotham Beds 0 - 5·7 m	Cotham Beds 0·9 - 7·6 m		
	LOWER RHAETIC	Hungarella bristolensis	Westbury Beds or Black Shales 0 - 14·3 m	Black Shales 0 - 13·7 m	Westbury Formation	
		Hungarella martini				
		Rhombocythere penarthensis		Absent?		
			Sully Beds 0 - 4·3 m	Absent?		
?	KEUPER		Tea Green Marls	Tea Green Marls		

The Rhaetic of the East Midland province illustrates all these changes and holds an important place in their regional understanding; in the following outline (based mainly on more detailed descriptions published in 1953 and 1968) the local aspects of the formation and its special problems, solved and unsolved, are given particular emphasis.

2. Stratigraphic Features

(a) The Keuper-Rhaetic Junction

Within our region the Keuper-Rhaetic junction is everywhere sharp and is marked by an interruption in deposition. The varying features at the non-sequential contact have been excellently demonstrated by different sections in south Nottinghamshire (Fig. 1).

At Owthorpe the National Coal Board borings (Ivimey-Cooke and Elliott 1969) showed a sharp Black Shale/Tea Green Marl contact, in which the Marl was penetrated by shale-filled borings to a depth of two or three centimetres. At Plumtree (SK 627,323.2) a basal bone bed was exposed in 1940 in a roadside ditch (unpublished record), even though it was absent at Stanton Tunnel 1200 metres to the southeast. At Bunny Hill and also west of Gotham a thin sandstone marks the contact, resting on a polygonally cracked (presumably sun cracked) surface of the yellow marls; at Costock a mile to the south there was a basal bone bed, two centimetres thick, crowded with small *Acrodus* and fewer *Hybodus* teeth, in which flakes of yellow marl indicate breaking up of the Tea Green Marl - perhaps disintegration of sun dried polygons like those of Bunny. At East Leake railway cutting the basal sandstone had itself been broken up and mixed with marl, presumably contemporaneously. Excavation for pylon foundations in 1955 east of Cotgrave (SK 658.8, 351.6) and the recent re-investigation of the railway cutting at Barnstone (Sykes et al., 1970) have confirmed the absence of a basal bone bed at these localities.

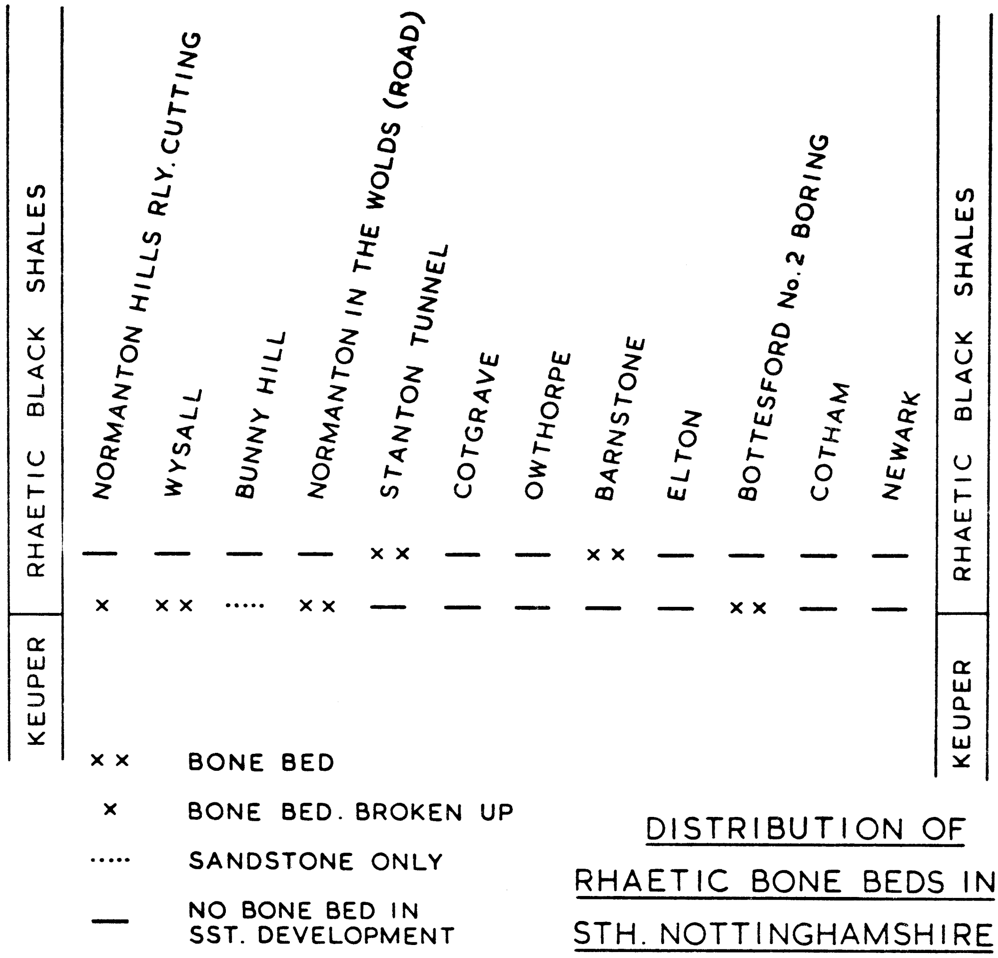
Thus the basal sandstone is discontinuous; and is often but not invariably bone bearing. Whether or not it is present there was a clear break in deposition after formation of the Tea Green marls, with evidence of exposure of these beds to the atmosphere and local boring of their surface by organisms of the Rhaetic Sea.

Whether the Tea Green Marls were originally deposited in that form or whether to any extent they may be altered normal red Keuper; the amount of erosion which may have preceded Rhaetic deposition and the existence of local overlaps are all matters requiring further detailed investigation. Indentification of marker horizons, such as the levels with fish remains found by Harrison at Leicester and by R.E. Elliott in borehole cores near Cotgrave (Ivimey-Cook and Elliott, 1969) would throw much light on these problems.

(b) Lower Rhaetic (Westbury Beds)

The lithological and faunal characteristics of the Black Shales, Bone Beds and the associated *Pecten valoniensis* limestone were reviewed recently by the writer in "Geology of the East Midlands" and it is not necessary to repeat them here. As already stated, a detailed description of the Barnstone section was published in the last issue of this journal (Sykes et al., 1970). The salient feature is the relatively uniform lithology of the shales - predominantly fine-grained, with occasional silty or finely sanded layers, frequently (but not entirely) finely laminated. Bone beds are variable, more numerous in the thicker developments, with the *Ceratodus* bone bed (believed to be a country-wide marker horizon) a short distance above the base at Stanton-on-the-Wolds and Barnstone.

Although there is a broad similarity to deep-water black shales in other formations, it is evident that the Lower Rhaetic deposition began with shallow water or dried-out conditions, that it



Text **Fig.** 1 Distribution of Bone Beds in the Lower Rhaetic in Nottinghamshire.

was interrupted by shallow water bone beds and finally passed up into lacustrine Cotham Beds, so that water depth is unlikely to have been more than a few metres at most. As already commented, the marked local variation in faunal distribution - the characteristic *Rhaetavicula contorta* being sometimes present in enormous numbers, sometimes rare; at some localities quite large, elsewhere very small - points to restricted circulation and strong variations in salinity and oxidation, possibly produced by heavy growth of aquatic weed in a nearly tideless shallow sea. Hallam (1967) has recently postulated somewhat similar conditions for the bituminous paper shales of the basal Upper Lias.

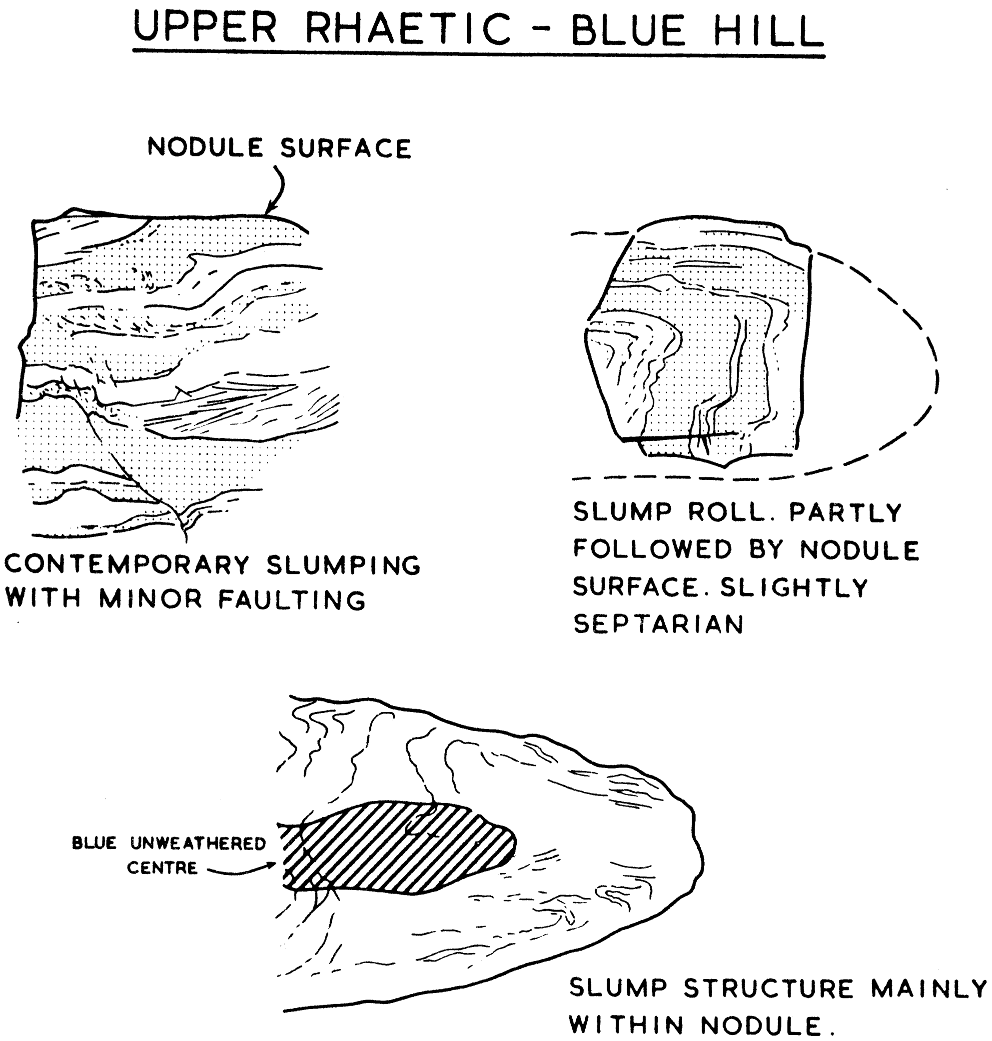
There is scope for further investigation of this problem by comparison of detailed sections to investigate continuity of the shelly layers. The recent Barnstone study has contributed particularly to investigation of the Bone Beds, which require more study in relation to their vertebrate fauna and the circumstances of their deposition. Their multiplication in thick sequences and other features argue against interpretation as condensed units, but they show various features little understood, including the local development of authigenic bi-pyramidal quartz crystals and other minerals.

(c) Upper Rhaetic (Cotham Beds)

The main Upper Rhaetic unit of the Midlands is the grey-green marl, weathering yellowish, correlated with the Cotham Beds of southern England. Large flattened nodules of porcellanous limestone are characteristic, and sandy shales occur locally. The small water-flea *Euestheria minuta* is found throughout the marls is unweathered material, rarely in great abundance, and is soft limestone nodules at outcrop. In the northeast, in Lincolnshire and also in the North Sea, the buff and pale grey-green tones give way to light chocolate brown, red brown and reddish colours : this could be due to a change to oxidising conditions in the area more distant from the contemporary marine connection (believed to be in southwestern England) or alternatively to contemporary erosion of red Keuper Marl over rising salt structures in the North Sea.

The smooth-fracturing porcellanous limestones of the Cotham Beds provide an interesting, previously unrecorded feature. They frequently show sedimentary structures and in the old section at Blue Hill, Owthorpe (now unfortunately overgrown) minor faulting and slump-rolls could be traced in the weathering colour banding, when the nodules were cut with a diamond saw. They are thus classic cases of replacive nodules, in which calcium carbonate lithified the original mud before any major compaction took place, preserving structures which have become obliterated in the surrounding marls (Fig. 2). There is scope for more investigation of this phenomenon. How widespread, for example, were the contemporaneous disturbances of Blue Hill? Were they related to instability on the edge of the Carboniferous Widmerpool Gulf, or are they a general feature?

The absence of marine elements in the fauna, the fine grade and very fine lamination and the pale colours suggest depositional conditions in broad shallow lakes, on which coarser material was dropped by debouching rivers on the distant margins. The most important variation in the East Midlands is in thickness, and an understanding of this might be derived from availability of detailed sections. Present indications are that the only beds of sandstone grade are in the upper part (Bunny Hill) where they could represent a terminal phase of deposition in the local basinal centre. The stratigraphic breaks above and locally also below the Cotham Beds could be related to either overlap and overstep, and the tracing of precise horizons - possibly the limestone nodule bands - would help to define these relationships. One difficulty is that slippage of beds on the scarp face impedes accurate measurement in shallow sections, and close sampling of boreholes is required for the necessary discrimination.



Text Fig. 2 Sedimentary structures in Upper Rhaetic limestone nodules, Blue Hill, Notts.

(d) The Rhaetic - Lias Junction

Over most of the East Midlands area there is an abrupt change from the yellowish weathering grey-green Cotham Beds marls to the thin limestones-and-shales alternation of the Lias Pre-planorbis beds. Locally the latter contain faunal elements suggestive of the Rhaetic - notably an elongate species of *Modiolus*, reminiscent of a small *Modiolus langportensis* instead of the characteristic sub-triangular Liassic *M.minimus*, and (rarely) *Dimyopsis intusstriatus*, suggesting that the renewed marine transgression came before the end of the Rhaetic, and that we may have in south Nottinghamshire a partial representative of the White Lias of the south. However, this element is not lithologically distinctive except in the Cotgrave district, where bored surfaces of thinly bedded limestones - A.E. Trueman's "Sun Bed" - recall White Lias lithology (see Appendix). The basal member of the transgressive Lias marine beds is locally a bituminous fissile shale (as at Blue Hill near Owthorpe), reflecting stagnant anaerobic conditions similar to those discussed above.

A shallow section at Kettlethorpe, west of Lincoln (SK 851.5, 762.6), has recently thrown new light on the problem of the Upper Rhaetic. This is a locality in the main Rhaetic basin of northwest Lincolnshire, close to the thick developments of Thorney and Stow Park. Thinly bedded shelly limestones and shales of the Pre-planorbis beds, with abundant *Ostrea*, rest on yellowish weathering clays of Cotham Beds facies (Fig. 3). At the junction large flat nodules of smooth fracturing pale blue-grey limestone, 1 - 1.5 metres across and 20 cms. thick, yielded in 1968 a rich fauna of characteristic White Lias lamellibranchs. *Dimyopsis intusstriatus* occurs in abundance, together with large *Modiolus langportensis* (s.s.) and other forms (LIST).

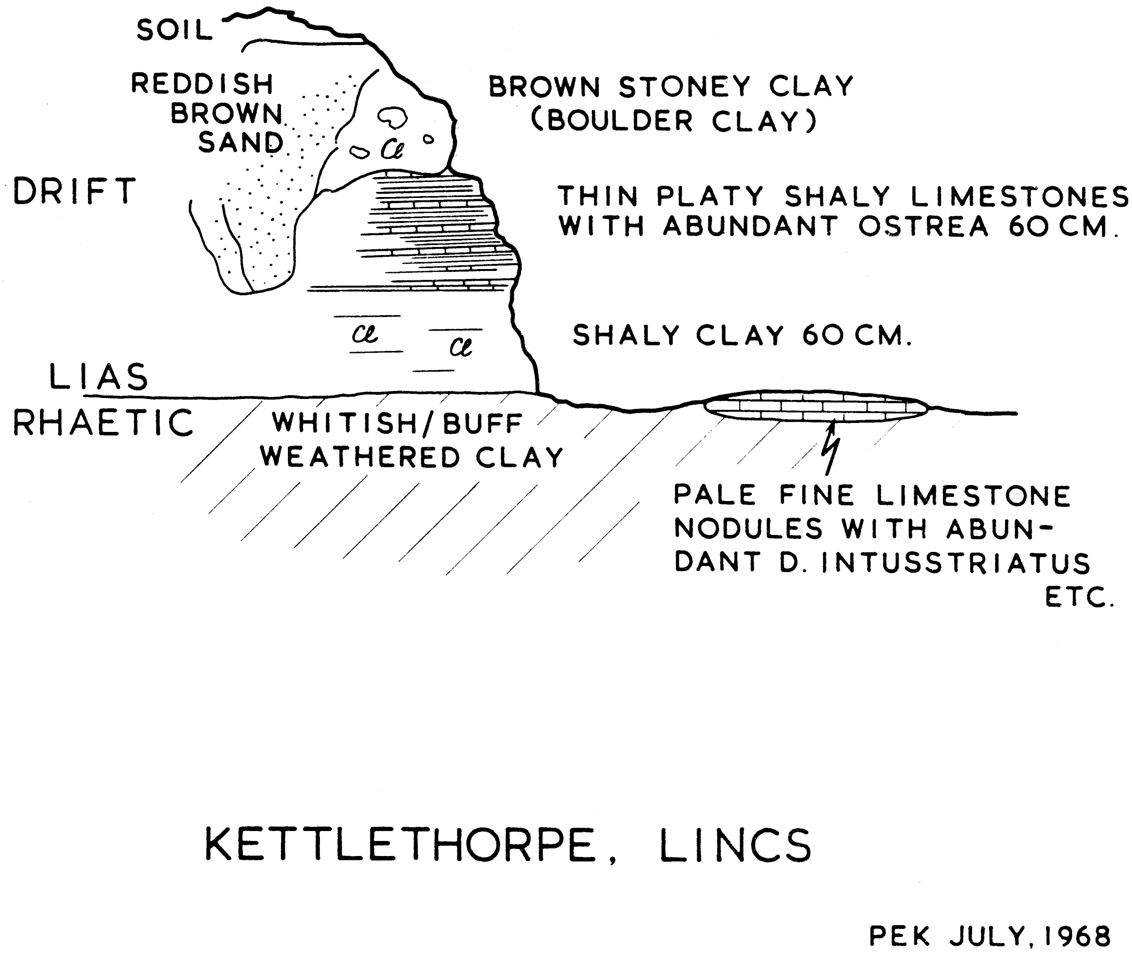
The lithology of the nodules is distinctively Rhaetic; they are embedded in normal "Cotham" type of weathered clay, and there is no reasonable doubt that here a marine fauna of White Lias type is developed beneath the Pre-planorbis Beds - still with an abrupt lithological change at the junction. Apart from questions of correlation, this occurrence raises the query as to whether the normal Cotham nodules may be marine elsewhere.

There is clearly scope for further investigation of the regional relationships of the formations, and searching for a representative of the Kettlethorpe fauna in the basinal developments of the Bunny area as well as further north in Lincolnshire.

3. Structural Relationship

The moderate thickness, clearly defined boundaries and distinctive lithologies have made possible study of thickness variation of the Rhaetic in more detail than that of any other formation in the East Midlands. Surface sections, shallow and deep borehole data have together shown the existence of a thick development in south Nottinghamshire centred on Bunny, and a broader depositional basin in Northwest Lincolnshire (Kent 1953). This general arrangement is well controlled, but more detail would be welcome in the thinner developments, particularly southeast of the outcrop, and in the neighbourhood of the Wreak Valley.

The Rhaetic Bunny basin is located over the Carboniferous Widmerpool Gulf : it represents one phase of an accentuated relative subsidence of this area which characterised the early Mesozoic. The relation of the N.W. Lincolnshire basin is less obvious, for erosion has removed evidence of the shape of the downwarp west of the Lower Trent. It lies however west of the shallower part of the Carboniferous East Midlands shelf and at least in part coincides with the position of the Gainsborough Gulf. The present writer hopes in due course to compile data from other formations bearing on the history of these basinal areas, since the wealth of information from oil exploration



Text Fig. 3 Section of the Rhaetic/Lias junction at Kettlethorpe, Lincs.

borings makes the East Midlands unique for its opportunity of relating fundamental thickness variations in the Carboniferous with those of later rocks.

4. Physiographical Expression of the Rhaetic

The "Rhaetic Scarp" is perhaps the most continuous feature of the drift-free Midland area. Although of minor size - often only 6 to 15 metres above general level - it can be followed across the south Midlands, is interrupted by the Boulder Clay mass of South Leicestershire, appears again from Leicester to the Wreak Valley, and from Barrow-on-Soar almost continuously to the Humber. The Rhaetic beds occupy the face of this scarp, and to its existence we owe all the important surface sections of the formations in our area - the railway cuttings at East Leake, Stanton-on-the-Wolds, Barnstone, Elton, Cotham, Torksey and Lea (Gainsborough) and the road cutting at Bunny. Attempts to work out additional Rhaetic sequences by augering on the scarpface tend to be unsuccessful, for the solid rocks are largely blanketed by thick slip in which the slabs of the overlying Lias limestones are frequent.

As a student at Nottingham in the 1930's the present writer attempted to work out further detail of the Rhaetic variation by examining shallow sections where streams or minor exposures showed the solid rock. The result was the discovery that surprising lengths of the Rhaetic scarp in south Nottinghamshire are truly fault-line scarps, with much of the Rhaetic cut out by normal faults with throws of 6 to 12 metres, so that the Lias is frequently found almost in contact with the Tea Green Marl. In the Cotgrave district study of the faults has been continued and given much greater precision by the National Coal Board (particularly under the President of this Society), but the same fault trends have been traced eastwards to Colston Basset, Cropwell Bishop and Langar, and southwards past Normanton-in-the-Wolds (Fig. 4).

Strictly speaking the "Rhaetic Scarp" is the Hydraulic Limestone scarp, and its continuity primarily reflects the persistence of this hard group at the base of the soft Lias clays. The fault-line scarps show that it is no differently developed where the Hydraulic Limestones abut directly against Keuper.

Nevertheless there are unsolved problems. The scarp-forming Hydraulic Limestones are some 6 to 9 metres thick, but quite frequently only the lowest beds occur in the scarp face and the greater thickness outcrops on the dipslope side of the cuesta sometimes half a mile or more back from the scarp, as at Kettlethorpe and over much of the country between Bottesford and Newark, where the Pre-planorbis beds have a very broad outcrop in relation to their small thickness. The simplest explanation of this truncation of the harder beds is that the scarp summit is relict from an earlier denudation cycle, the Rhaetic face and lower ground of the Upper Keuper being due to a more modern erosional phase. Less probably it could be a function of the glacial scouring effect which affected much of the "Vale" country of the northeast Midlands; the regularity of the feature would be difficult to explain in this case. There is clearly scope for an investigation into the development of the Rhaetic Scarp.

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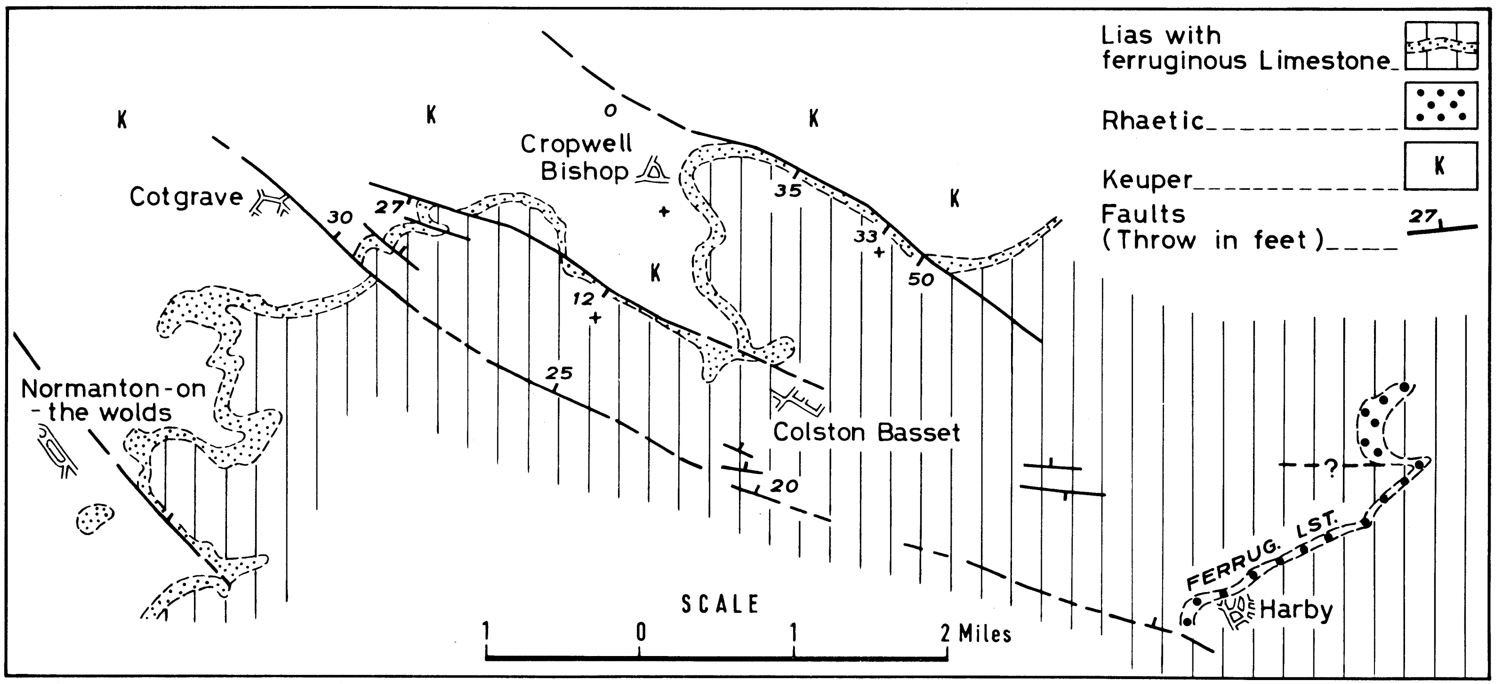

Fig. 4: POST-LIASSIC FAULTS SOUTH-EAST OF NOTTINGHAM

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APPENDIX

U-Shaped Burrows in the Rhaetic of Cotgrave, Nottinghamshire

Summary

A bored limestone at the top of the Rhaetic in Nottinghamshire shows abundant paired borings which prove to be comparable with the U-shaped burrows of a small species similar to *Arenicolites* in type, probably *Diplocraterion*. This indicates estuarine, tidal flat conditions at the time of deposition, with borings made before lithification of the bed.

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In 1918 A.E. Trueman recorded a bored bed at the top of the Rhaetic at Cotgrave Gorse, six miles W.S.W. of Nottingham, and called it the "Sun Bed" by analogy with a bored horizon in the Rhaetic of Warwickshire. It has since been found to extend along the outcrop for about two miles, from Clipston in the west to the line of the Fosse Road in the east, but although the limestone continues, the bored bed is apparently not developed further east or south (Kent 1953 p. 121). In the course of recent mapping the bed has provided a useful marker in a faulted belt, and in examining additional exposures it has been observed that the borings are similar in general structure to those ascribed to *Arenicolites*.

The "Sun Bed" as developed in this area is a pale grey limestone about five centimetres thick, with a finely laminated structure which produces only incipient fissility. In its even thickness it is more like the overlying Liassic Limestones than those of the Rhaetic, contrasting with the faintly purplish cream-weathering large nodules which characterise the Cotham Beds. It differs from the basal Liassic beds however in the laminated structure (like Rhaetic shales) and in showing neither trace of shells nor of the finely crystalline streaks which are frequent in the pre-Planorbis beds of the Lias.

The under surface of the limestone is flat and notably smooth, the last character being presumably due to the exceedingly fine grain of the calcite mud which originally made up the rock. The upper surface is rendered rough by irregular small pits and "rillmarks" - irregular flattish channels one to two centimetres in width and a few centimetres long. This surface shows the very abundant borings described below. Some of the borings are individual and nearly straight with annular constrictions, and a very few of these pass right through the rock bed, but the majority are paired and are seen in section as small U-shaped burrows.

The Polychaet worm which made these burrows was evidently a very much smaller species than the *Arenicolites* described by Bather (1925) from the Yorkshire oolites. The emergent ends of the holes are about 2 mm. in diameter, with centres 5-6 mm. apart. The holes are connected with a surface groove due to collapse of the tunnel after death of the occupant. The clearest section available reaches a depth of 7 mm., as compared with about 250 mm. in the Yorkshire specimens. Nevertheless the overlapping U-structures are clearly marked, and appear beyond much doubt to be due to movement of the bottom of the U to successive different levels and not to sagging of the laminae of the matrix. It is clearly a tunnel due to a different organism from the lower Rhaetic worm from Leicester described as *Archarenicola rhaetica* by Horwood (1912). This is an organism 1 cm. wide and at least 10 cm. long, and is not certainly known to have made deep U-burrows, although the surface groove is developed. From the presence of a funnel in some of the specimens the Cotgrave form is provisionally identified as *Diplocraterion* (Goldring 1962).

A limestone bed is not the environment in which a sand-worm would be expected; these worms were not rock borers. But the frequent surface evidence of collapse of the burrows and their internal structure shows clearly that the material was soft when the animal lived: presumably it was a fine calcite mud. The lithification which cemented the original finely laminated rock into a non-fissile limestone must have been later than the boring operations. The rill-like erosion of the surface seems to have occurred both before and after the borings, for some of the channels are bored like the upstanding areas and others are nearly free from worm holes. The former are smoothed out; the latter are sharper edged and sometimes cut pre-existing U-burrows. Subsequently a little cellular tufa-like material has been deposited in some of the hollows, but (contrary to expectation) there is no indication of a real erosional phase preceding Lias deposition; the surface is that of a mud flat after a very minor and temporary emergence.

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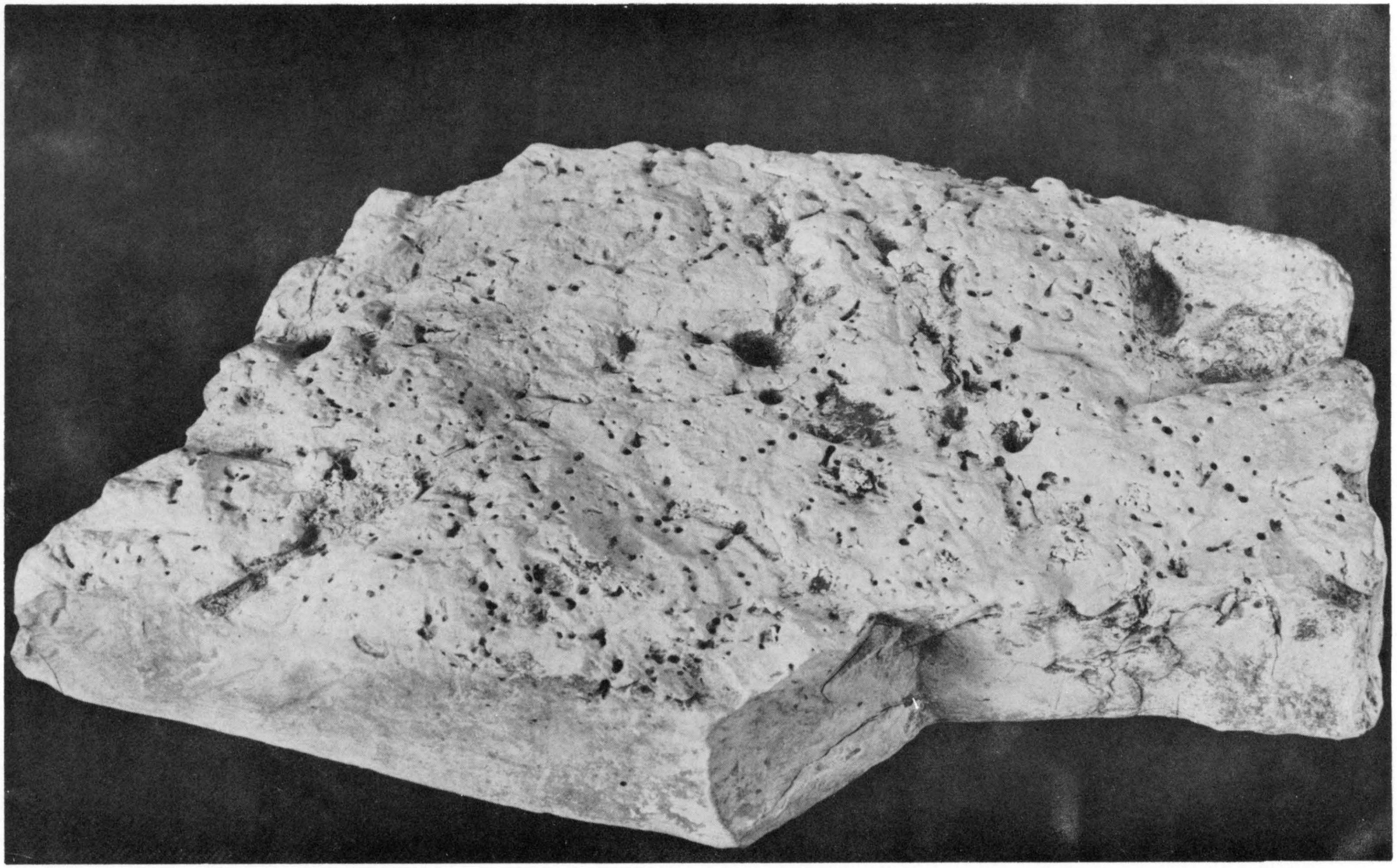

Plate 28. Limestone bed from Rhaetic/Liassic junction at Cotgrave, showing U-shaped borings.

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