INSTITUTE OF GEOLOGICAL SCIENCES

Geochemical Division

Radioactive and Metalliferous Minerals Unit

Report No. 316

NEW RADIOACTIVE NODULE AND REDUCTION FEATURE OCCURRENCES IN THE LITTLEHAM - LARKBEARE AREA OF DEVON

by

B.C. Tandy

Gray's Inn Road

January 1974

CONTENTS

ILLUSTRATIONS

(at rear)

SUMMARY

On the evidence of highly anomalous (up to 36 µgU/l) water samples collected from a number of streams draining into the River Clyst and on the eastern side of the Exe estuary in Devon during an earlier geochemical reconnaissance in the Permian of south west England, detailed radiometric traverses were made, mostly in stream sections upstream of anomalous sites, of the area between Littleham Cove and Larkbeare.

The traverses revealed a widespread occurrence of radioactive reduction features including uraniferous nodules of the type previously recorded from only two sites near Littleham, throughout the whole 16 Km length of the area. Radiometric readings (up to 100 µR/h) and uranium values (up to 2,000 ppm) increase with the increasing size of spots and nodules (up to 150 mm diameter) and high values of other metals (V, Cu, Pb, Zn, Ni and Co) have been recorded. A sequence of six separate nodular bands and six reduced zones have been observed in the 160 m thick succession examined and a stratigraphical correlation attempted.

INTRODUCTION

An earlier geochemical reconnaissance in the Permian of south west England[5] revealed a large number of sites with anomalous (up to 36 µg/l) uranium in water in streams draining into the River Clyst and on the eastern side of Exe estuary in Devon, over a N-S length of 16 km (Fig. 1).

Uranium is known to occur in this area in the Littleham nodular horizon and the occurrence of reduction features, with which uranium is sometimes associated, is common. The streams sampled run across the NW-NE strike of the Permian and the distribution of anomalies suggests an extensive strike or strike-fault-controlled uranium source between the sampling sites and the base of the Budleigh Salterton Pebble Beds which form a watershed. Sample sites in streams draining to the east of the watershed have little uranium in water.

To examine the possibility of an extension of the Littleham nodular zone, following the strike, or the occurrence of widespread uraniferous reduced zones in the rocks, a detailed radiometric reconnaissance (the subject of this report) was carried out upstream of the anomalous water sites in the area between Littleham (NGR 30.0295 8125) and Larkbeare (30.0590 9790), covering the whole 16 km N-S length of the geochemically anomalous area.

Indications of widespread reduced zones would suggest a parallel between this area and the uraniferous deposits of the Permian of France (near Nimes), Niger and the Colorado Plateau, and large accumulations of the nodules would represent large tonnage - low grade uranium mineralisation. Reduction spots, nodules and reduced bands owe their origin to the reducing effects of accumulations of vegetation which developed on the flood basin deposits predominating in this area in late Permian times, and uranium and other metals (V, Cu, Pb, Zn, Ni and Co) are fixed in the reduced zones as organometallic complexes, a process which is still continuing.

The survey reported here was carried out in a limited amount of time and covers only radioactive reduction features observed in stream sections and other scattered exposures. A rough stratigraphical correlation has been attempted. An economic appraisal would require detailed mapping and sampling, and drilling on interfluves in favourable areas.

GEOLOGY

Investigation was confined to the formation described by Ussher[6] as the 'Lower Marls and occasional sandstones' but now re-classified as the Exmouth Formation and Littleham Mudstone Formation[2].

The Exmouth Formation is exposed along the coast between Exmouth (30.0100 800) and Littleham Cove (30.0400 8000) and strikes inland generally in a north to north easterly direction. The formation is characterised by thick complex sandstone units and occasional mudstones (originally termed 'Marls') cyclothems, channel structures, reduction spots and many other sedimentological features[2].

The Littleham Mudstone Formation is a generally finer grained sequence of red-brown mudstones with intercalated, persistent, olive-green silty-sand and sandy-silt beds. This formation, having a maximum thickness of about 115 m, is exposed in the coast section between Littleham Cove and Budleigh Salterton (30.0640 8170) although it is somewhat obscured there by cliff falls; and is exposed inland in numerous stream sections. To the east, the formation is overlain by the Budleigh Salterton Pebble Bed forming a marked escarpment. Formational dip is generally

eastwards at about 5^{o}-10^{o}. Pale green (reduction) spots, and pale olive silty sand (reduced) beds and nodules are common.

The depositional environment of the two formations is interpreted by Henson[2] as an alluvial flood plain complex of channels, overbank and transitional deposits. Channel deposits are represented by the thick (> 1.25 m) sandstone units. Fine grain silts and clays (stilled suspension load deposits), intercalated with coarse overbank deposits, green silty sands and sandy silts of levée and crevasse splay deposits, represent overbank floods. Some ripple marking indicates the existence of ephemeral lakes and infilled abandoned channels characterize transitional deposition. Channel deposits predominate in the Exmouth Formation whereas flood basin deposits predominate in the Littleham Formation, with green silt and clay horizons caused probably by the reducing effects of the development of vegetation.

Hematitic staining is responsible for red colouration of much of the succession; and calcite is the intergranular cement. Absence of hematitic staining, due to the presence of organic material, leads to the occurrence of green spots, which also form continuous haloes around nodules - suggesting a genetic relationship between green (reduced) spots and nodules.

REDUCTION FEATURES

Examination of exposures (indicated on Figs 2, 3), mostly in streams, suggests that reduction features fall into three main types, all showing radioactivity to varying degrees:

1. Reduction spots
2. Nodules
3. Reduced bands

Types 1 and 2 are gradational into each other. Reduction spots vary in size from being barely visible up to about 100 mm in diameter, usually flattened out along the general bedding plane. However the spots often have some thickness and many may be described as ellipsoidal. Many reduced 'spots' have black cores, in which radioactivity is highest and this tendency increases with the size and sphericity of the 'spot'. Great variety in size and hardness of the core occurs up to the point where a 'spot' core becomes a hard nodule surrounded by a reduction halo up to a maximum diameter of about 150 mm.

Spots and nodules of varying sizes are randomly distributed at any one locality and in any one horizon. Reduced spots are more common and generally occupy a greater thickness of rock in any one part of the succession than nodules do. In the upper parts of Withycombe Brook, however, smaller nodules, associated with reduced spots, occupy a considerable thickness (up to 30 metres). Both nodules and spots seem to persist over great distances horizontally since equivalent sequences occur in separate stream sections along the strike of the rocks and stratigraphical projection suggests that some occurrences of reduced spots are lateral equivalents of nodular occurrences elsewhere, this being reconcilable with their possible genetic origins.

Altogether, six separate nodular sequences have been found to occur in the Exmouth-Littleham Formations in this study, including the 'original' horizon identified at Littleham Cove and Carter's Brick Pit (30.0230 8200). The

recently discovered nodules observed by the present author seem to match the Littleham nodules, described by previous authors, in every way.

Reduced bands show a great variety in colour, from white to dark green, and vary in size up to an observed maximum of 20 metres length by 1 metre thickness. They are usually lensoid in shape although some appear to be neptunian dykes. A maximum of six separate 'zones' of reduced bands have been observed within the 160 m or so thickness of the succession examined and, like the nodules and reduction spots, can be correlated from one stream section to another. Each individual band is separated from the next by the normal red bed sequence. Nodules are sometimes closely associated with reduced bands and may actually occur within them.

Each of the types of reduced features occurs singly or in varying combinations at each site described below.

DISTRIBUTION

The distribution of observed reduction features is shown in Figs 2, 3 and 4, where a possible stratigraphic correlation across non-exposed areas has been attempted from the juxtaposition of various features observed in exposures and extrapolation along strike. A detailed description of sites with local correlations follows, and these details are used to build up the stratigraphical correlation shown in the figures.

1. Coastal Section

Much of the cliff exposure is obscured by land slip, although between Straight Point (30.0400 8000) and the base of the Budleigh Salterton Pebble Bed, many fragmented green silty sand beds can be seen in a generally red brown mudstone sequence. The green (reduced) beds give radiometric readings of up to 80 μR/h, and analyses of 40 ppm U, 360 ppm Cu, 185 ppm Pb, 180 ppm Zn, 56 ppm Ni, 56 ppm Co and 5% V.

At the southern end of Littleham Cove is the classical nodular horizon[1,3] contained in red-brown mudstones. The nodules give radiometric readings of 80-100 μR/h. Sixty metres north of this well-known occurrence is another horizon of nodules exposed in the inter-tidal wave-cut platform, seen only at low tide and covered towards the cliff by storm beach and cliff slip. The nodules here give values of 40-60 μR/h as does a green siltstone horizon capping the nodular band. Analyses of the most active nodules give 2,010 ppm U, 1,725 ppm Cu, 1,020 ppm Pb, 755 ppm Zn, 3,200 ppm Ni, 1,800 ppm Co and V -13% (whole analysis).

2. Littleham Brook

At about 150 metres and 225 metres upstream of the point at which Littleham Brook passes beneath the road at Littleham Church (30.0295 8125) are exposures of reduced siltstones and clays reading 20 μR/h. The remainder of the brook has a bed of superficial material over which ratemeter readings of 10-12 μR/h are of background level. However 14 μR/h is obtained at points between 200-500 metres upstream of this last exposure, corresponding to the points at which two nodular bands should be present. An exposure of mudstones at Stallard House (30.0385 8170) shows reduction spots reading 20 μR/h.

3. Withycombe Brook

Examination of this stream section commenced at Withycombe Raleigh at

(30.0150.8205). At two hundred metres above this point and at various points to about 500 metres upstream, are a number of persistent reduced bands (green silty sandstones) with a thickness of about 10 cm and giving a maximum reading of 20 μR/h. One band, just south of Withycombe House (30.0210 8230) reaches a thickness of 50 cm with reduction spots occurring nearby. At 100 m upstream of this point, outcropping above more reduced bands, is a three metre-long lens of reduced clay, ranging from 25 μR/h at the ends to 80 μR/h in the centre, where the maximum thickness of 10 cm is reached. Analysis of this clay gives 150 ppm U, 520 ppm Cu, 210 ppm Pb, 310 ppm Zn, 100 ppm Ni, 100 ppm Co and 2.8% V.

At 150 metres upstream are seen the first well-developed reduction spots in the succession, many of which have active black cores (up to 30 μR/h.) The first nodular horizon seen in the succession occurs 75 m above this point, giving a radiometric reading of 100 μR/h and analyses of U -1300 ppm, Pb-830 ppm, Cu-1515 Zn-620 ppm, Ni-2400 ppm, Co-1600 ppm and V-11.2%. The remainder of the succession up the various tributaries of the brook is tabulated below (Table 1, 2) to show correlations.

4. Watton Brook

Exposures in the lower part of this stream are somewhat sparse, but a number of the units seen in the upper parts of Withycombe Brook are encountered. Upstream from Coombe Farm (30.0090 8505) at 200 m, 450 m and 550 metres are exposures of reduced horizons giving radiometric readings of 20 μR/h. These may be the lateral equivalents of units 5 and 7 in Withycombe Brook (Fig. 2 and 4). The second of the three reduced bands is a lens 15 metres long by 30 cm thick.

The occurrences of nodules, marking the bottom and top of the uppermost nodule band as seen in Withycombe Brook (Unit (8)), occur at 700 and 820 metres upstream from Coombe Farm. They give radiometric readings of 40 and 60 μR/h respectively. Immediately above the uppermost nodule occurrence are reduced horizons also giving up to 60 μR/h, equivalent to unit (9) in Withycombe Brook. Analyses of nodules give values of 1200 ppm U, 520 ppm Pb, 450 ppm Zn, 1600 ppm Ni, 1200 ppm Co and 8.7% V, 820 ppm Cu.

5. Woodbury

The two southern branches of the stream upstream of the confluence at (30.0195 8650) were examined (see Fig. 2). At about 450 metres upstream of the confluence, on the more southerly branch is an exposure of reduced lenses reading 30 μR/h. These may be the lateral equivalents of unit (7) as seen on Withycombe Brook and Watton Brook. A little further upstream, reduction spots reading 30 μR/h are exposed and are probably lateral equivalents of the uppermost nodular horizon (unit (8) of Withycombe Brook and Watton Brook). Similar reduction spots are seen in the same stratigraphic position in the easterly branch (Fig. 2). Unit (9) is represented in this section by reduced bands reading 22 μR/h in a roadside ditch at (30.0400 8600).

6. Grindle Brook

Upstream of (30.0500 8975), Grindle Brook is formed by five successive tributaries (Fig. 3) the successions in which are tabulated below (Table 3, 4) from south to north (1 to 5) across the table, and upstream down the table.

TABLE 1

Withycombe Brook

Distance upstream of confluence	E-W (Liverton) branch	N-S (Veiges) branch	Distance upstream of confluence
50m 100m	(1) Thin reduced beds 40 μR/h *Nodule 40 μR/h *U-530, Cu-420, Pb-210, Zn-220 Ni-600, Co-350 (all ppm) V-4%	Reduced 'dyke' and band ($2\frac{1}{2}$ long x 30 cm thick) with nodules. 60 μR/h max	50m
200 m	(2) Well-jointed Mn-stained siltstones - 20 μR/h	-	
250m	(3) Thin reduced silt bands (20 μR/h - 40 μR/h). Numerous nodules (caught up in NW-SE fault 25m long) - 40 μR/h. Localised within reduced band sequences	Thin reduced silt* bands 25 μR/h) Head *U-10, Cu-120, Pb-60, Zn-55, Ni-20, Co-20 (all ppm) V-0.5%	180m
400-550m	(4) Reduction spots up to 26 μR/h	Reduction spots (25 μR/h) some with cores - incipient nodules (30 μR/h). Reduced 'dykes' along E-W joints. Nodules, 'relict' nodules and reduction spots. 30 μR/h	230-400m 400-500m
	(5) Head	Reduced beds, Neptunian dykes? Faulted and Mn stained 50 μR/h	550m
1000m	(6) Head Reduced band - corresponds to uppermost band at Bystock: - (9)	Reduced spots 30 μR/h	600m

Succession in each tributary listed down the table, correlation units ((1)-(6)) across the table.

Table 2

Withycombe Brook

Above Lower Veiges (30.0255 8300), Withycombe Brook is formed of three tributaries, in which the successions are tabulated below and correlated across the table.

Distance upstream	West Tributary	Distance upstream	Mid Tributary	Distance upstream	East Tributary
0-70m	Head				
70-100m	Reduced horizon 20 uR/h - western extension of unit (5) above)				
250-400m	(6) Reduction spots 20 - 30 µR/h	0-70m	Reduction spots 30 µR/n	0-70m	Many small nodules 30 µR/h
	(7) Head	100-300m	Reduced siltstone bands 20 - 30 µR/h	100m	Reduced band 20 µR/n
	(8) Head	350m	Reduced spots and nodules 50 µR/h		Head
	(9) -	500m	Reduced silt bands 20 µR/h (Bystock)		Head

(1) - (9) refers to correlation unit numbers

Table 3

Grindle Brook

1		2		3		4		5	
15-110m	Reduced silt-stones 30 μR/h	250m	Reduced silt-stones (3.5 x 0.5) lenses - 20 μR/h	-		800-900 m	Reduced silt-stones, dykes and lenses 20 μR/h	800m	Head
200m	Nodule horizon 40 μR/h	270m	Nodule horizon 40 μR/h	-		1050m	Reduction spots 20 μR/h		Head
240-500m	Reduced band up to 25 x 0.2m thick 20 μR/h		Head	-		1150m	Reduced horizon 20 μR/h	1200m	Reduced horizon 20 μR/h
	?	500m	Nodules - 40 μR/h					)	
	Head		Head		Head	1400m	Reduction spots 20 μR/h	) ?	Nodule 25 μR/h
	?		Head	900m	Nodules-30 μR/h	1500m	Nodules-40μR/h	)	1220m
700m	Reduced silt-stone 20 μR/h		Head		Head		Head	1240m	Reduced horizon 25 μR/h
800m	Reduced clay and siltstone 80 μR/h	900m	Reduced horizon 25 μR/h	1300m	Reduced horizon 20 μR/h		Head		
	Head		Head		Head	1640m	Reduced* clay bands 30 μR/h		Equivalent to unit further S?

* U-30 ppm, Cu-320, Pb-150, Zn-150, Ni-60, Co-68 (all ppm) V-2%

Table 4

Grindle Brook

1	2	3	4	5
?	Head	1300m *Nodules 50 μR/h *U-720, Cu-510, Pb-310, Zn-250, Ni-1000, Co-600 ppm, V-4%	1640m Nodules 30 μR/h	-
1250m Reduced band 25 x 15m 25 μR/h	Head	?	1660m Reduced clay 20 μR/h	-
?	Head	1850m Reduced band 25 μR/h	-	- (7)
1750m Reduction spots 22 μR/n	Head	1900m Nodules 25 μR/h	-	- (8)
Head	-	2000m Reduced horizons 25 μR/h	-	- (9)

* - metre distances refer to distance upstream from 30.0500 8975

? - laterally equivalent beds not seen

\- - stratigraphic level not covered by section

(8) - correlation unit numbers

7. Aylesbeare

Only a limited section of the succession (Fig 3) is seen in the stream section east of Aylesbeare (30.0385 9185) consisting of a number of reduced horizons reading 30 μR/h which cannot be correlated with any of the succession further south on present evidence.

8. Larkbeare

In the northernmost stream section examined, upstream of (30.0590 7970), is a nodule band (at 30.0630 9790) occurring more than 16 km north of any previously recorded nodule occurrence. Nodules may occur yet further north in stream sections not examined in this project. The nodule occurrence is only moderately radio-active - 18 μR/h (over a background of 12-16 μR/h) and is associated with reduced bands giving 18 μR/h. Its stratigraphical position is difficult to assess due to limited exposure, but close proximity of the Budleigh Salterton Pebble Bed just to the east suggest the horizon is equivalent to the uppermost nodule horizon seen further south. Analysis of a nodule gives 250 ppm U, 180 ppm Cu, 100 ppm Pb, 80 ppm Zn, 340 ppm Ni, 150 ppm Cu and 3.8% V.

CONCLUSIONS

Only a few selected samples of reduction features were collected for analysis, but the values give some idea of metal values to be expected. Uranium values vary greatly from about 10-30 ppm in reduced bands to 2,000 ppm in large nodules (whole analysis). Nodule cores generally have 10 x the uranium value of the reduced halo. Cu values reach a maximum of 1700 ppm, Pb - 1000 ppm, Zn - 800 ppm, Ni - 3200 ppm, Co- 1800 ppm and V - 13% in nodules, the core generally showing 10 x - 2 x the metal value of the halo. Maximum values in reduced bands in ppm are Cu - 520, Pb - 210, Zn - 310, Ni - 100, Co - 100 and V up to 5%. The metal values from these few samples suggest moderate grade mineralisation in nodules over wide areas.

Because of the sparsity of exposure, thick nodular accumulations could only be shown by closely spaced drilling, based on detailed mapping and sampling. However an interesting geochemical and metallogenic occurrence has been discovered over a much wider area than the originally known local occurrence at Littleham, and the use of stream water samples for uranium prospecting in such an environment has been vindicated. Economic prospects for uranium and other metals would favour further detailed work.

REFERENCES

1. Carter, G.E.L. An Occurrence of Vanadiferous Nodules in the Permian beds of South Devon. Mineralogical Mag. 22, 1931.

2. Henson, M.R. Unpublished Ph.D. Thesis, University of Exeter, 1972.

3. Perutz, M. Radioactive Nodules from Devonshire, England. Miner. Petrogr. Mitt. 51, 1940.

4. Ponsford, D.R.A. Radioactivity Studies of Some British Sedimentary Rocks. Bull. Geol. Surv. G.B., No.10, 1955.

5. Tandy, B.C. A Radiometric and Geochemical Reconnaissance of the Permian Outcrop and Adjacent Areas in South-West England. Inst. Geol. Sci. G.B. Geochem. Div., RMMU Report No 315 1973.

6. Ussher, W.A.E. Geology of the Country around Newton Abbot. Geol. Surv. G.B., New Series Sheet Memoir 339, 1913.

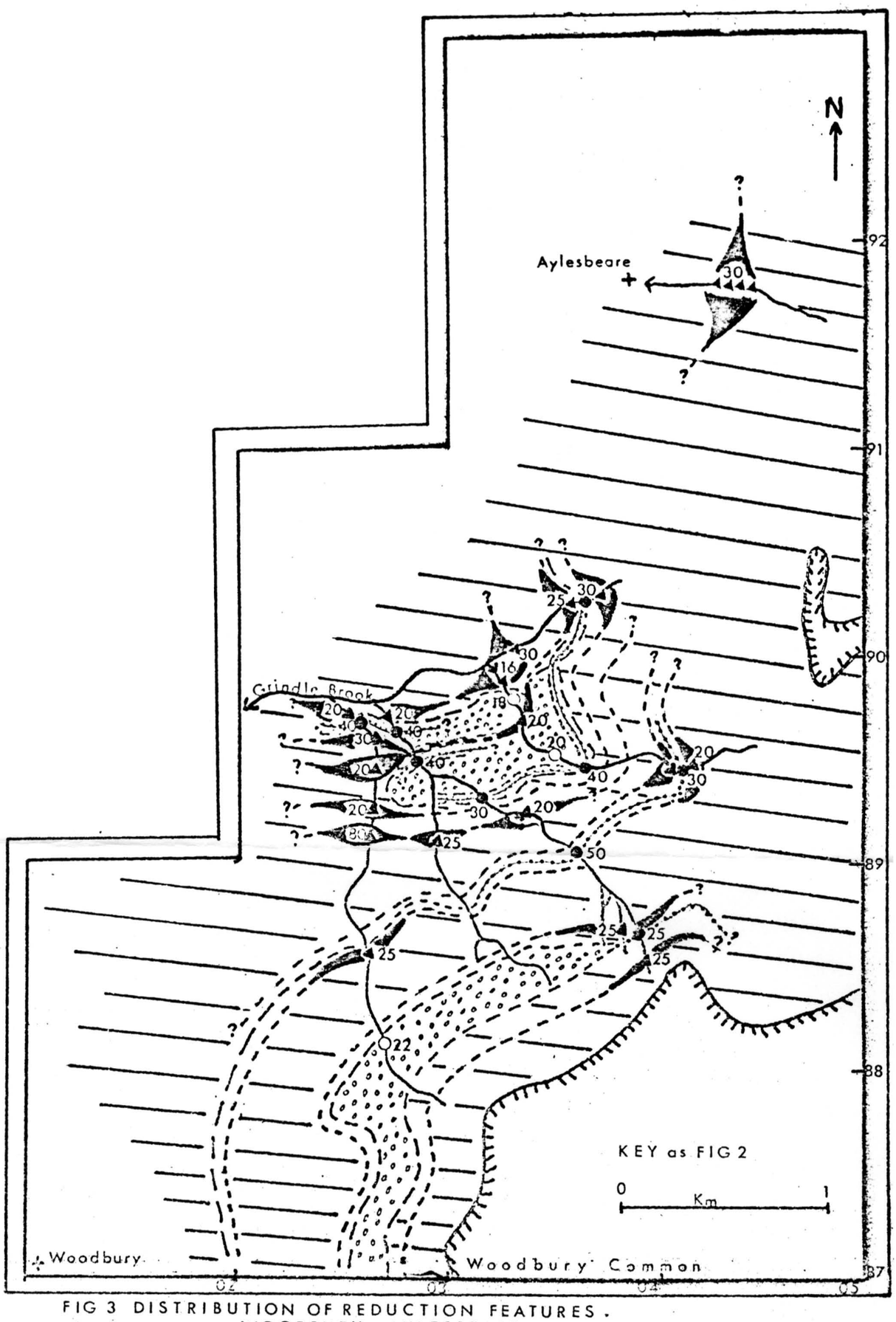

FIG 3 DISTRIBUTION OF REDUCTION FEATURES.
WOODBURY – AYLESBEARE

KO-90246

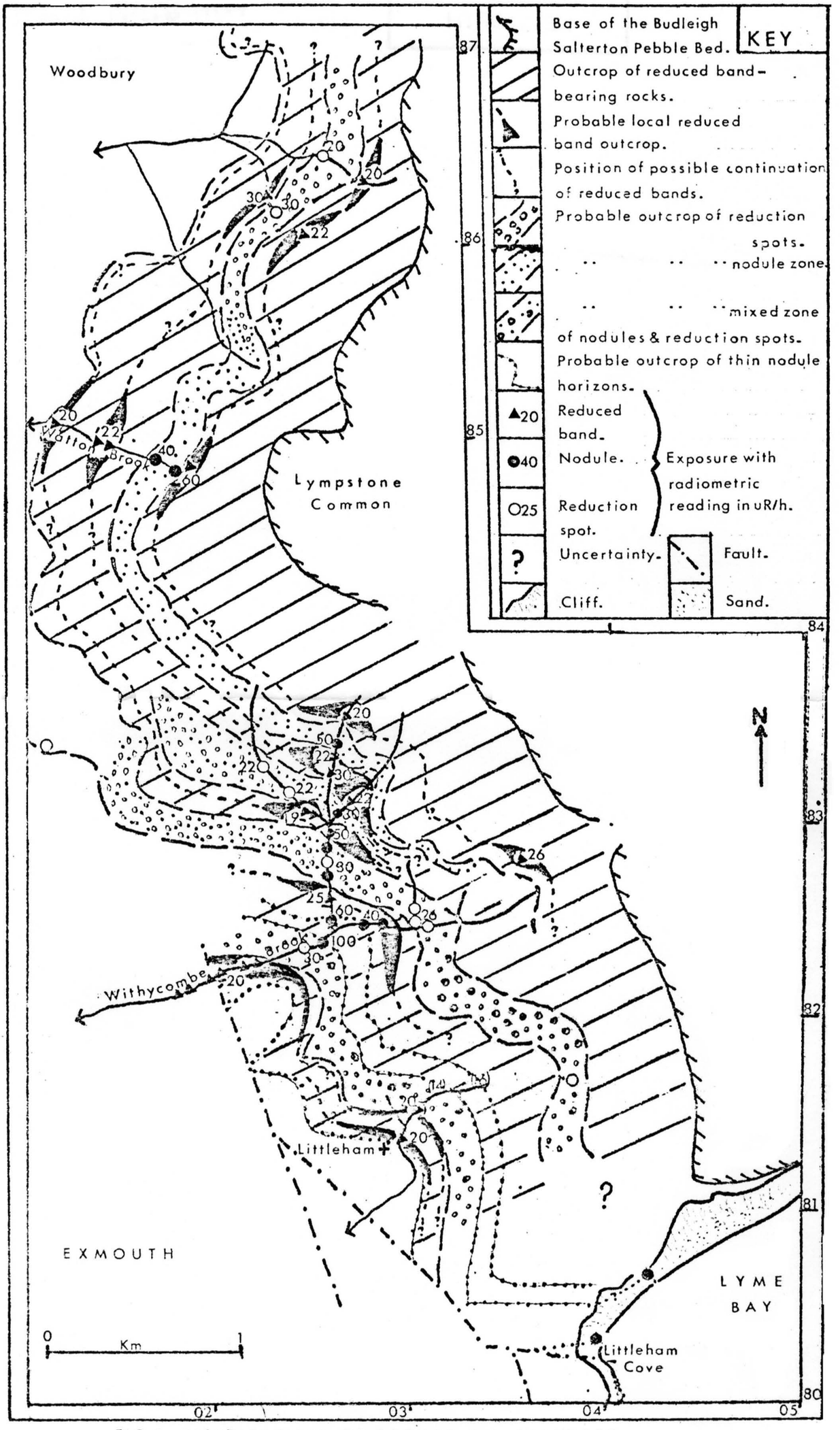

FIG 2 DISTRIBUTION OF REDUCTION FEATURES
LITTLEHAM – WOODBURY

KW-90246

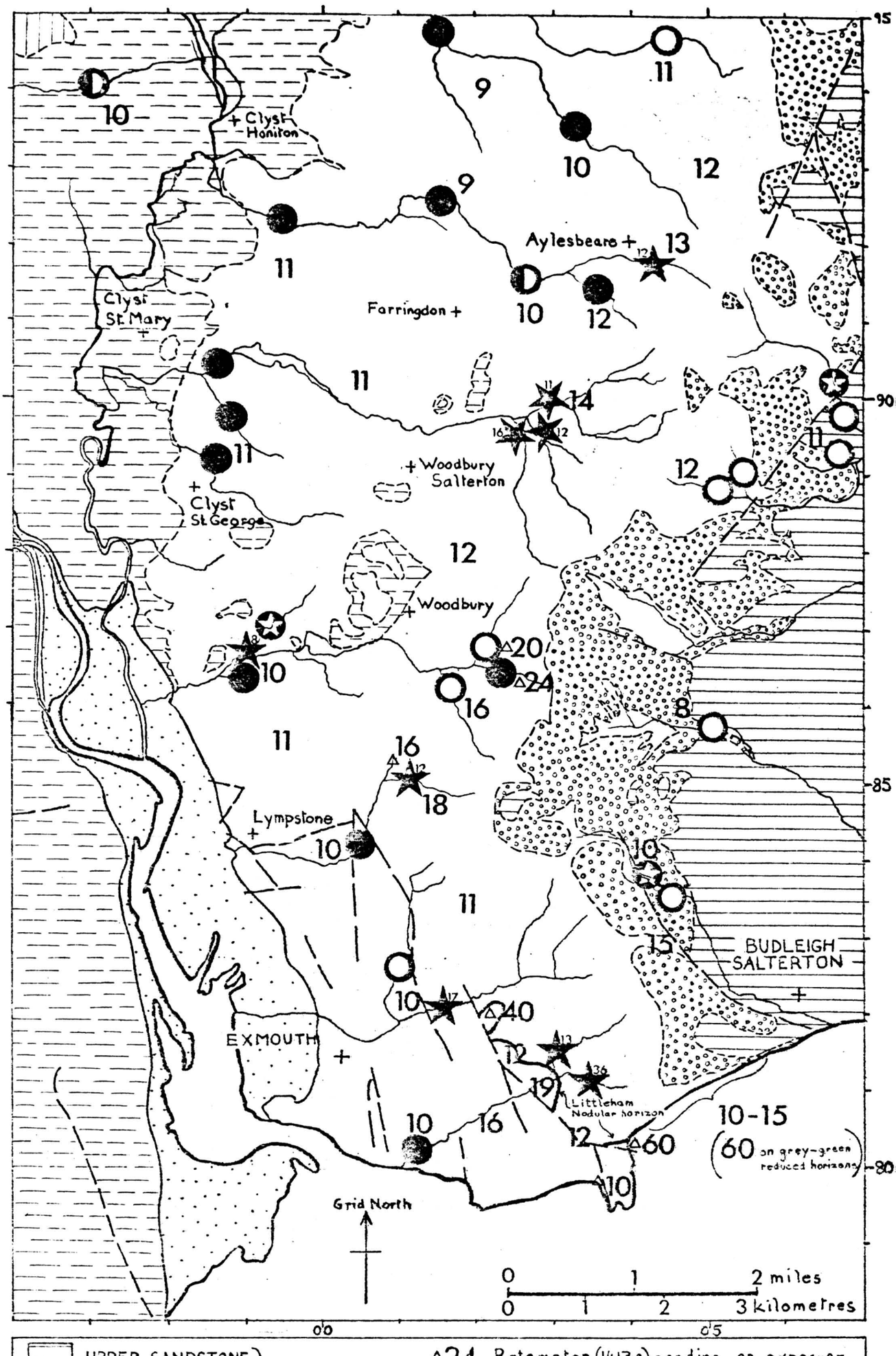

Fig.1 URANIUM ANOMALIES – EXMOUTH AREA.

Ref. 4024 A

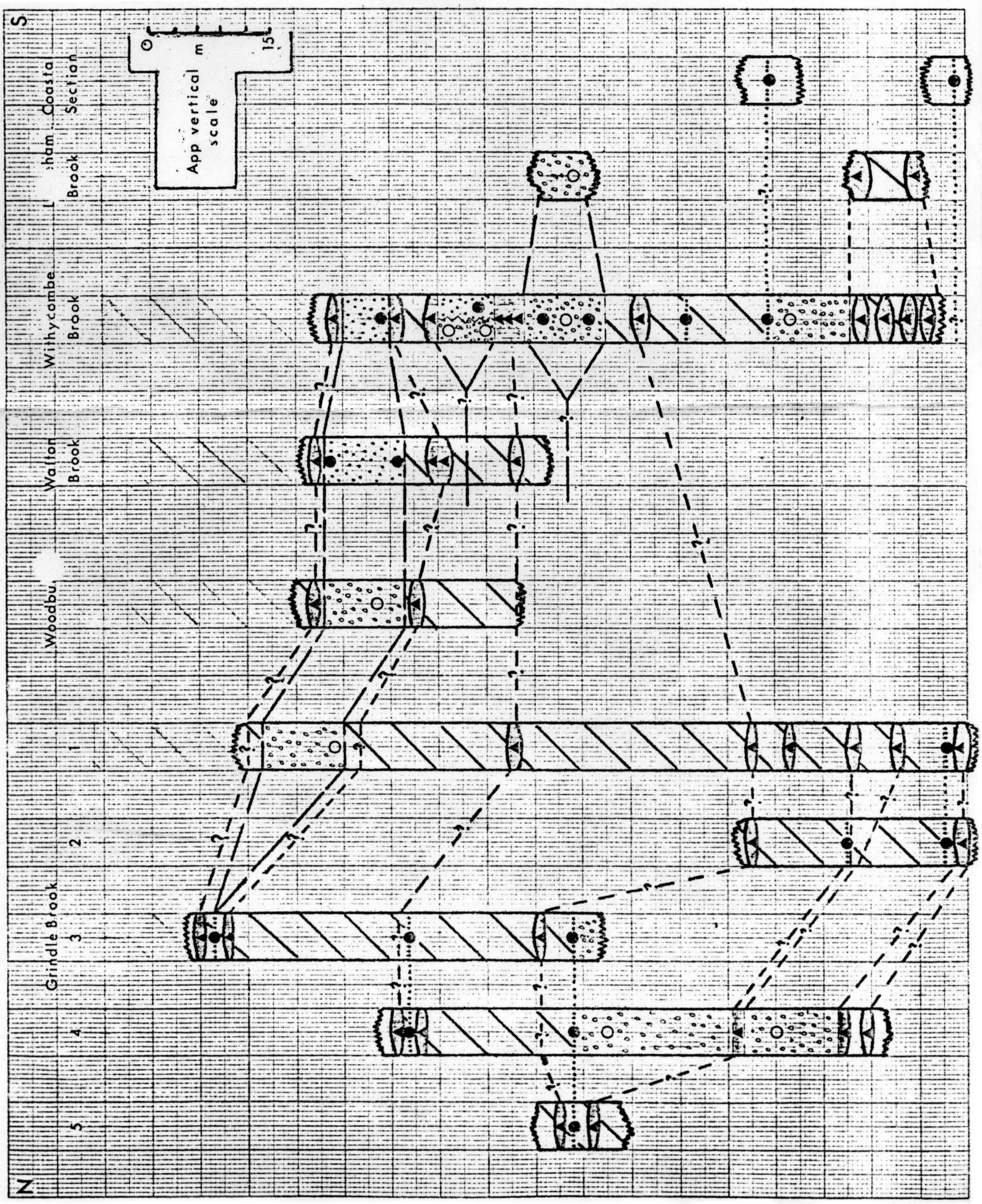

Figure 4: Diagramatic Sections and Correlation: Coast - Grindle Brook