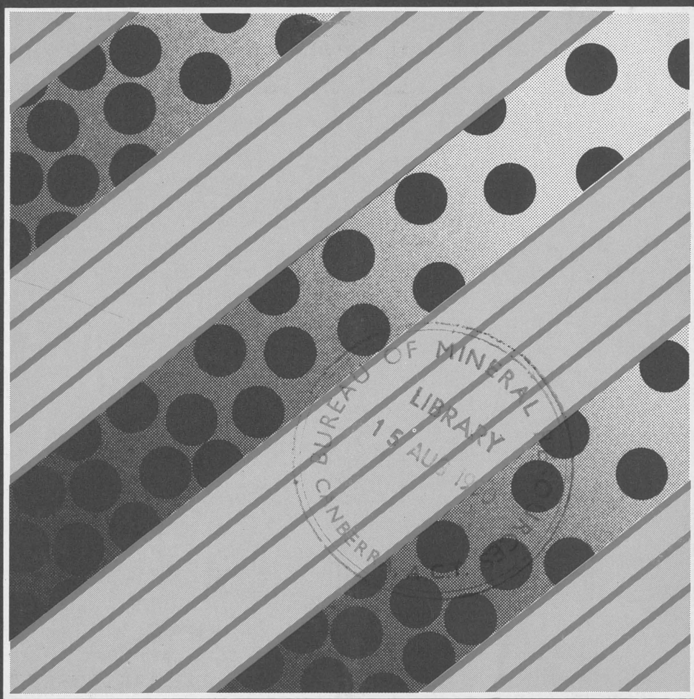
GROUNDWATER 18

SEDIMENTOLOGY AND DIAGENESIS OF THE RENMARK GROUP AQUIFER IN HATFIELD 1, MURRAY BASIN

B. M. RADKE



BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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SEDIMENTOLOGY AND DIAGENESIS OF THE RENMARK GROUP AQUIFER IN HATFIELD 1, MURRAY BASIN

(NSW WATER DEPARTMENT OF WATER RESOURCES BORE No. 36675)
(BMR POONCARIE No. 9)

by

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ABSTRACT

The Renmark Group aquifer lies within the interval 101.5–427 m in the Hatfield-1 bore (BMR Pooncarie No. 9; NSW Water Resources Bore No. 36675). The unit consists predominantly of laminated and cross-stratified, unconsolidated to semi-consolidated sands; laminated and cross-stratified silts; with minor muddy silts, silty peaty muds and very thin traces of lignite.

Accumulation of the Renmark Group was predominantly within fluvial environments (channel, levee, crevasse splay, and floodplain), estuarine, and minor incursions of hyposaline swamp and marginal marine conditions. During deposition, three small transgressive phases imposed the marginal marine and ephemeral marine-related events. Higher precipitation appears to have been related to these phases. Sands of the Renmark Group are ubiquitously quartz-dominant but the stratigraphic pattern of accessory and trace components is suggestive of changing provenance by lateral migration of the fluvial regime and/or tectonics, as well as climate.

Only minor diagenetic modification of the sequence is apparent. Most significant is the post-depositional alteration of detrital feldspar. Pyrite is minor but ubiquitous in all but the lowermost lithofacies, occurring mainly as finely-disseminated framboids but also as mesoscopic replacement of lignite, bioturbation, and laminar porosity. Small pellet-sized pyritic concretions are present in the muddier sediments. Porosity has only been slightly reduced since deposition by burial compaction. Minor, extremely thin horizons have been partly or completely occluded by sideritic cementation.

INTRODUCTION

This report documents a sedimentological and petrographical study of the Upper Eocene – Middle Miocene Renmark Group intersected in Hatfield-1 (BMR Pooncarie No. 9; NSW Water Resources Bore No. 36675), southwestern New South Wales. Detailed logs of lithologies, sedimentary features, sand characteristics, general biota, and diagenesis are presented for the interval 97–427 m. Additionally, interpreted depositional environments, depositional cycles, and diagenetic history of the sequence are discussed.

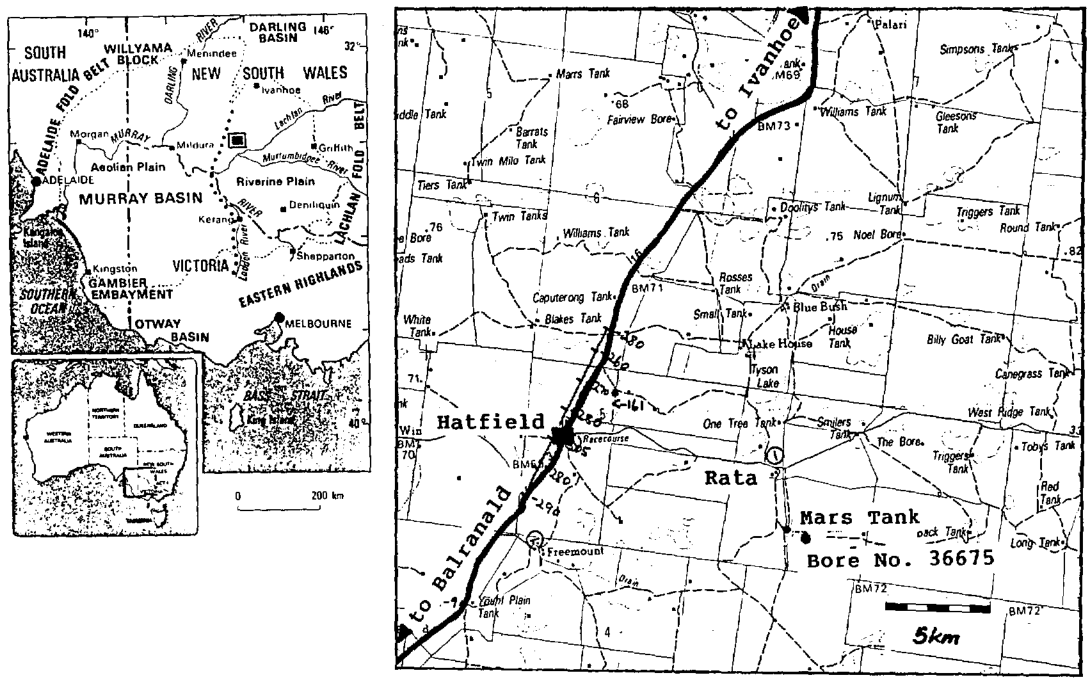
Hatfield-1 is one of a series of regionally-spaced stratigraphic holes in the Balranald area and across the Murray Basin to further knowledge of the Renmark Group aquifer – its geometry, stratigraphy, diagenetic history, and hydrogeological characteristics.

The borehole was sited on an anomalous aeromagnetic low in the Balranald Trough. Basement was predicted to be a granite and this interpretation was confirmed by drilling. The bore was also sited within a low-lying, currently inactive, Pleistocene groundwater discharge complex. The discharge complex is thought to have developed because the underlying thick sediments of the Renmark Group aquifer thin to the west over the Iona Ridge of the Ivanhoe Block, and thin to the southwest where they are stratigraphically replaced by the Geera Clay of the Mid-Tertiary low permeability barrier. Hatfield-1 was sited to test this, and to core the complete sequence to basement. It is to be used as the key lithostratigraphic control for the Renmark Group in the western Riverine Plain. The objective of this study has been to provide detailed lithological, sedimentological and diagenetic descriptions of the Renmark Group and contiguous units. This information is to be integrated with other specialized investigations as part of a program aimed at further understanding groundwater flow in the Renmark Group aquifer.

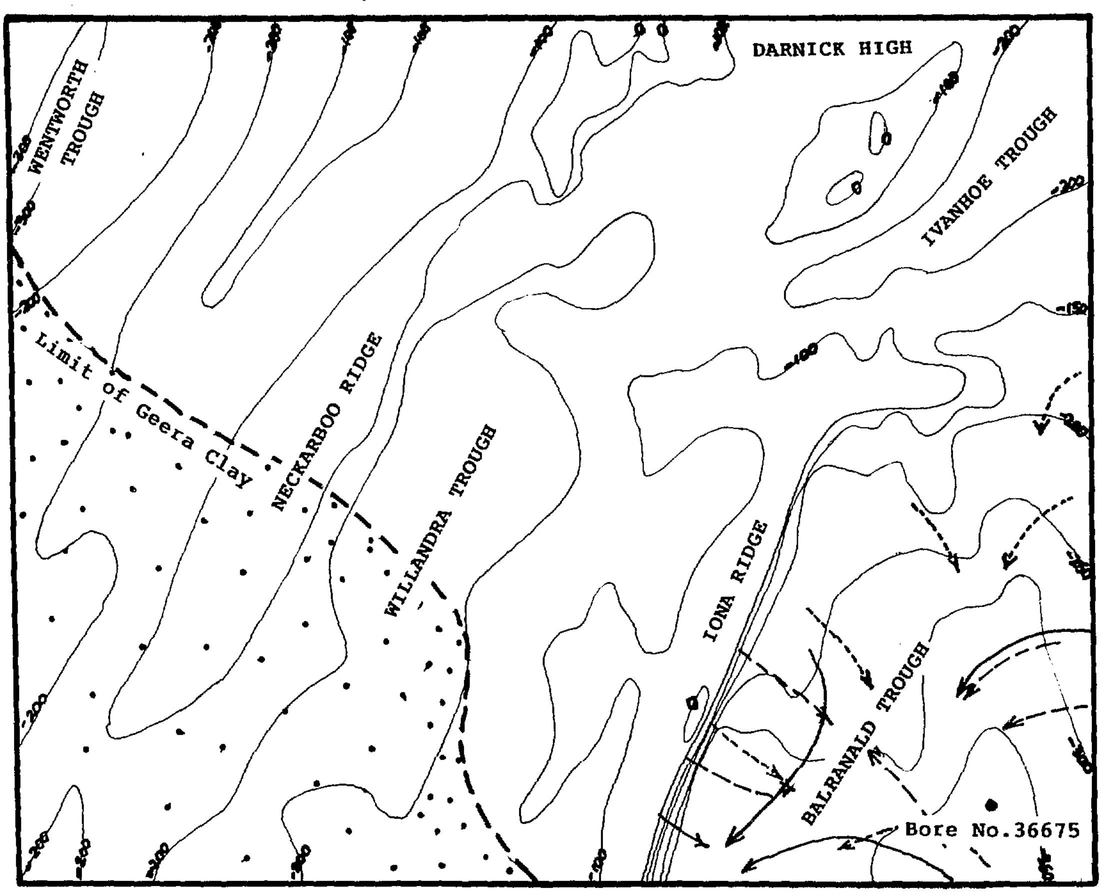
Hatfield-1 is located on the POONCARIE 1:250 000 Sheet at Latitude 33°54'31"S, and Longitude 143°51'34"E, at 71.9 m elevation. The grid reference is E764350 N6255650 on the Hatfield 1:100 000 Sheet (No. 7630). The bore site is adjacent to, and on the north side of, the track 1 km east of "Mars Tank", 3.2 km SSE of "Rata" homestead (Fig. 1).

Core recovery from the drilling was good considering the soft and relatively unconsolidated nature of the sediments. In the interval 97–190 m, recovery was 6%, increasing to 40% from 190 to 304 m. Following no recovery in 304–337 m, 67% recovery was achieved to 400 m, and dropped to 26% down to 427 m. Core material is stored in the BMR Core and Cuttings Repository, Fyshwick, catalogued as BMR Pooncarie No. 9.

Core sampling has previously been conducted for several studies, specifically: pore fluid geochemical, palynological, petrographical, as well as minor mineralogical and palaeontological determinations.



POONCARIE 1:250 000 Sheet, New South Wales



(after J.Kellett, pers.comm.)

Structural contours of Base of Tertiary in metres

Arrows indicate groundwater flow in Renmark Group
Upper Renmark ——>
Middle Renmark – – –>
Lower Renmark ‐‐‐‐>

Fig. 1 Geographical location and geological setting of Hatfield 1 bore (NSW Department of Water Resources Bore 36675; BMR Pooncarie 9).

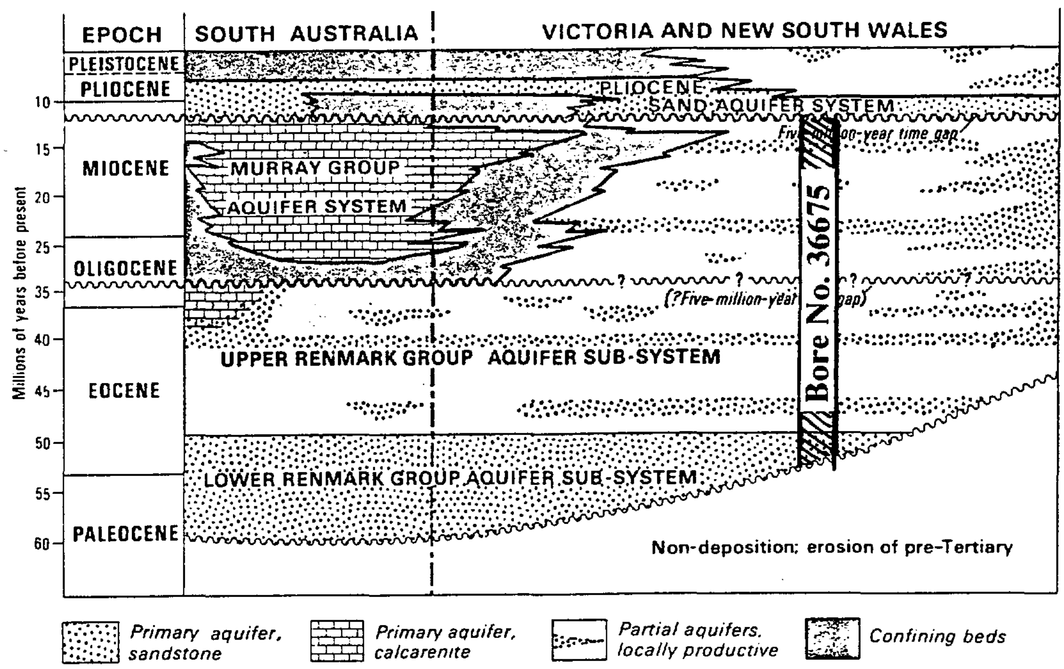


Fig. 2 Cainozoic stratigraphy and regional aquifers of the Murray Basin (after Brown, 1985)

This report utilizes the petrographical, mineralogical, and palaeontological data. Intervals sampled for these studies are listed in Appendix V.

REGIONAL GEOLOGICAL SETTING

In the northeastern part of the Cainozoic Murray Basin, where the basin and adjacent highlands are drained by the Murray, Murrumbidgee, and Lachlan Rivers, Tertiary sediments underlie flat-lying, fluvio-lacustrine sediments of the semi-arid Riverine Plain. Hatfield-1 lies close to the western margin of this topographic feature.

Structural elements beneath the Murray Basin have been defined mainly by regional gravity and aeromagnetic trends which, in combination with limited borehole evidence, suggest that the Cainozoic sequence is locally underlain by poorly defined infrabasins preserved in graben-like troughs and depressions. In the Balranald area, with more detailed seismic and aeromagnetic interpretation, and control provided by a stratigraphic drilling program, the pre-Tertiary basement has been better defined, as shown by the structural contours in Figure 1. The structural trends are northeast-southwest across the Pooncarie Sheet, except for a local added complexity at the northern end of the Iona Ridge. The Iona Ridge, comprising Ordovician metasediments, had a steep downfaulted eastern margin, and was a positive topographic feature for most of the period of deposition of the Renmark Group, until it was finally buried by the upper Renmark Group. Farther to the north and northeast, exposed rocks include Devonian quartzose sandstone of the Cobar Supergroup. Hatfield-1 is centrally sited in the Balranald Trough. Channeling of the Pliocene Calivil Formation into the top of the Renmark Group has incised a deep channel down the axis of the Balranald Trough. Hatfield-1 lies about 2 km east of this channel and has approximately 10 m more section (J. Kellett, pers.comm., 1988).

Throughout the BALRANALD and POONCARIE Sheet areas, the Renmark Group has been subdivided into lower, middle, and upper units by J. Kellett and the lateral variations in thickness of these lithostratigraphic units are documented in Truswell (1987). Kellett notes that there is a general correlation between these units and salinity distribution within the Renmark Group aquifer in this region. The waters in these aquifers are meteoric (not connate), and appear to be discharging upwards through permeable windows in the Renmark units, partly in response to the major permeability barrier posed by the Geera Clay (Fig. 2). Figure 1 shows groundwater flow in the Renmark Group aquifer in the vicinity of Hatfield-1.

The depositional area of the marine to marginal-marine Oligo-Miocene Geera Clay lies to the southwest, and Hatfield-1 is approximately 40 km northeast of this indicator of the marine margin

(Radke,1987). Sea-level fluctuations occurred, but there appeared to be no change to coastal plain gradients and there was probably widespread flooding of the coastal plain at this time. At times of lower sea-level, rivers became entrenched and the flood plains were narrower within steep valleys (J. Kellett, pers.comm., 1988).

LITHOSTRATIGRAPHY

GENERAL STATEMENT

The sequence between 101.5 m and 427 m is recognized as the Renmark Group and will be subdivided and described in this section.

The base of the Renmark Group disconformably overlies a weathered granite, presumed Devonian, at 427 m. The upper boundary of the Group is more conjectural because there was no core recovery at the two horizons of gamma log kicks, 101.5 and 99 m. At approximately 101.5 m, the gamma log went offscale (instrument malfunction?) and there is a distinct change in electric log character which indicates the top sand of the Renmark Group as selected by J. Kellett (pers.comm.).

Lithologies

The interval from 101.5 to 427 m consists predominantly of laminated and cross-stratified unconsolidated to semiconsolidated sand, laminated and cross-stratified silt with minor muddy silt, silty peaty mud, and very thin traces of lignite. The sequence is presented in lithostratigraphic context in Figure 3, and in the detailed lithology in Appendix I. Interpretation of the upper and central-lower sequence is based solely on electric log characteristics because of negligible core recovery.

Biota

The sequence is almost barren of fauna except for very thin, spasmodically-recurring fissile carbonaceous muds and silty muds (Lithofacies C_2) in which a prolific but very low-diversity fauna of agglutinated foraminifera is present (Plate 4a-e). Future biostratigraphic work may gain from a more detailed study of the agglutinated foraminifera. Glaessner (1963) found some Rzehakinids such as *Miliammina* to be useful as index fossils in local and intra-regional correlations.

In one horizon of bioturbated carbonaceous, sulphurous sandy mud and silt (Lithofacies D), a solitary small shark denticle or tooth (Plate 4f,g) occurred with pyritized burrows infilled with pyritic pellets. Although the shark element bears similarity in cusp morphology to those of documented shark teeth, it is much smaller and has a basal root process that would be atypical for a tooth. These differences suggest that it may be either a remnant of a very small shark, or more likely, a denticle from an internal dermal surface such as the bucchal cavity (G. Young, pers.comm.). The element, *gen. et sp. indet.*, may belong to one of three superfamilies and 10 possible genera (N. Kemp, pers,comm.)

Throughout the sequence, lignitic wood fragments and rootlets, leaf fragments, complete leaves, and peaty sediments are variably abundant. The highest concentrations of leaves and lignitic horizons appear to be stratigraphically close to, but not in, the foraminiferal Lithofacies C_2.

The stratigraphic distribution, relative abundance, and differentiation of this biota is presented in Figure 4, and in the detailed lithologs in Appendix I.

The ichnofauna is not prolific, nor is it well preserved. Consequently, specific generic identification has not been attempted and only relative abundance, predominant orientation, and degree of diversity has been documented in Figure 4.

LITHOFACIES

Four lithofacies classes, A, B, C, and D, are differentiated on the basis of the dominant sediment type or intermixture. Within these, subclasses are also differentiated on the basis of characteristic composition, sedimentary structures and/or biota.

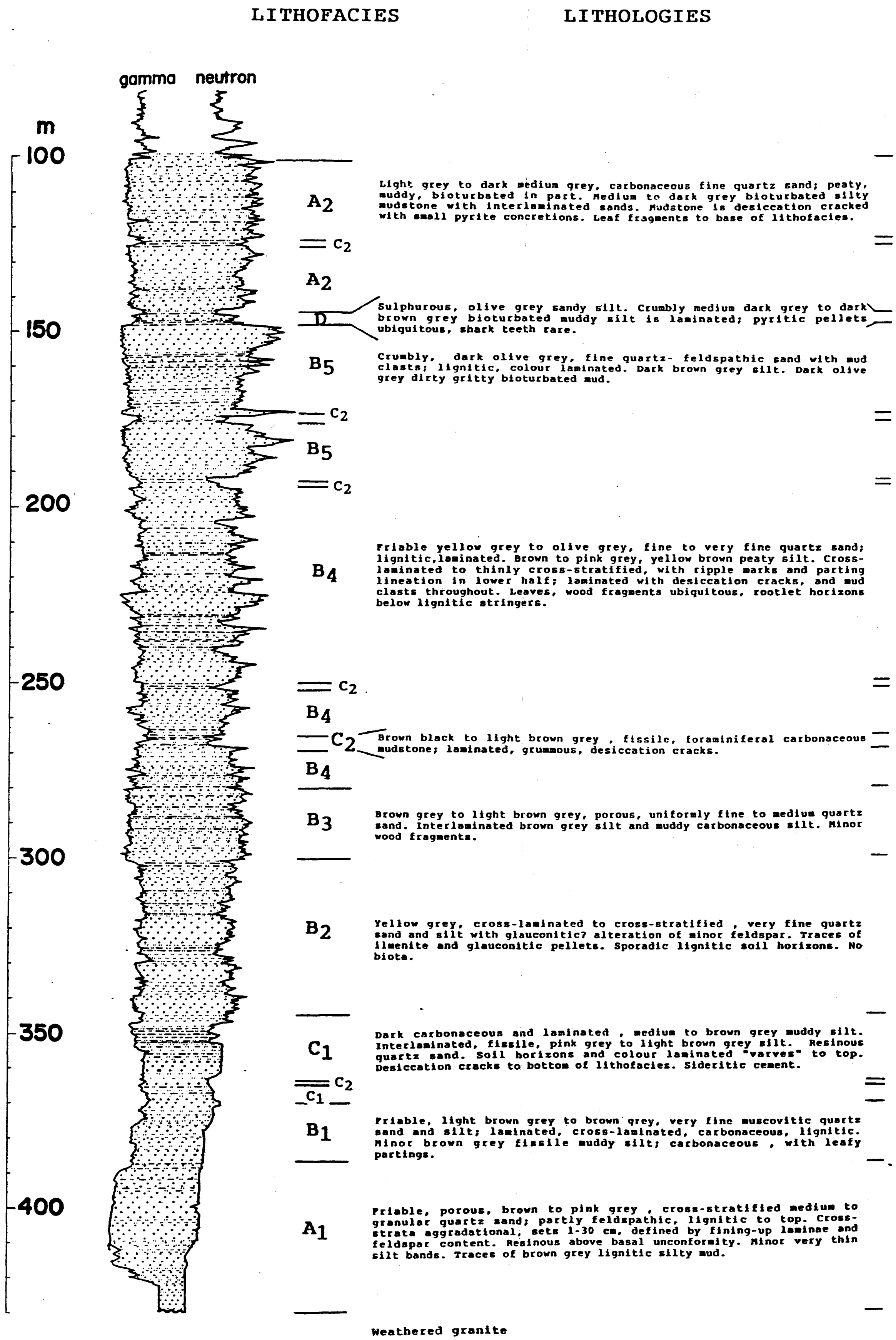


FIGURE 3 Lithostratigraphic Log of Renmark Group, Bore No.36675.

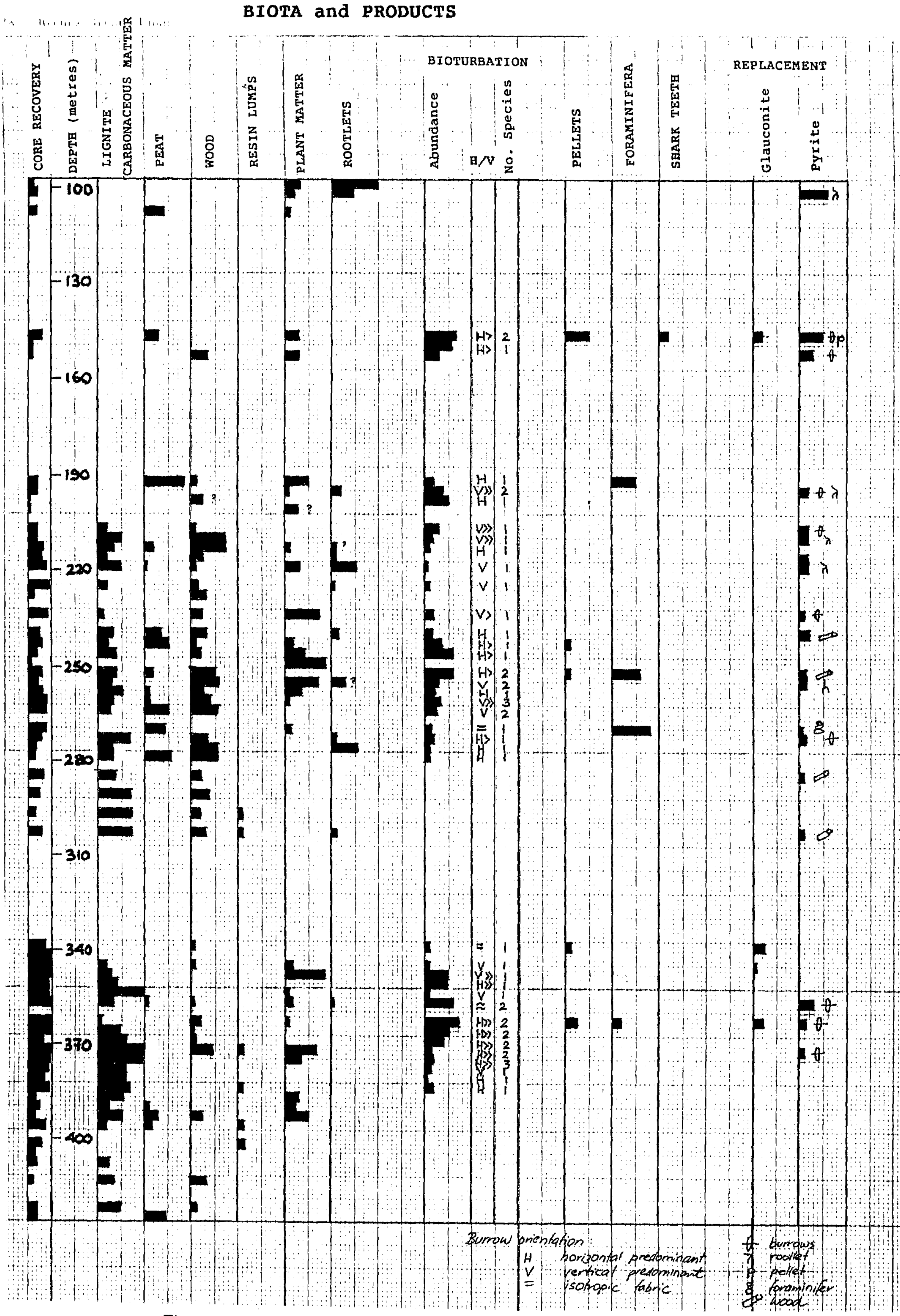


Fig. 4 Biota and biotic products of Renmark Group in bore 36675

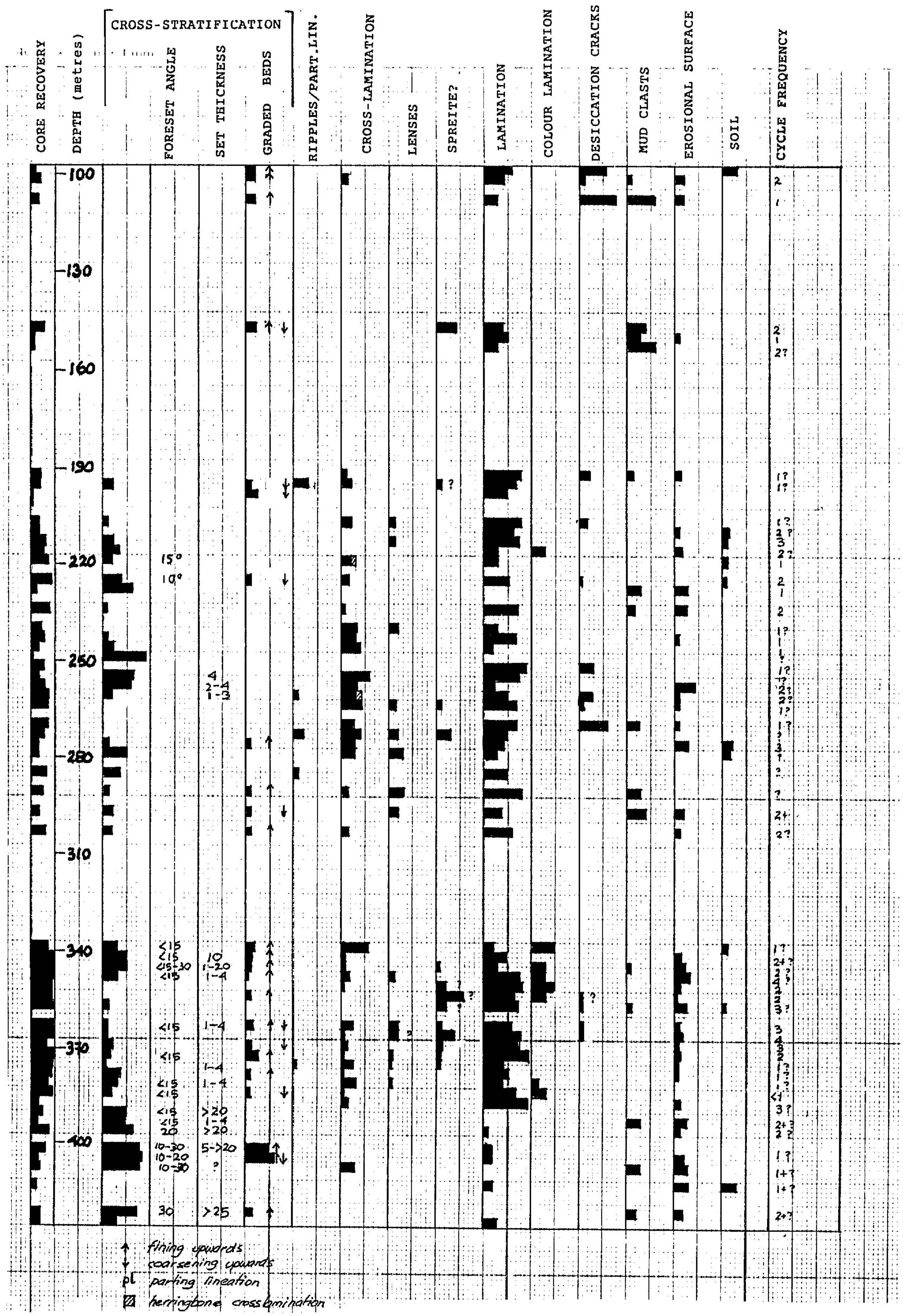


Fig. 5 Sedimentary features of the Renmark Group, bore 36675

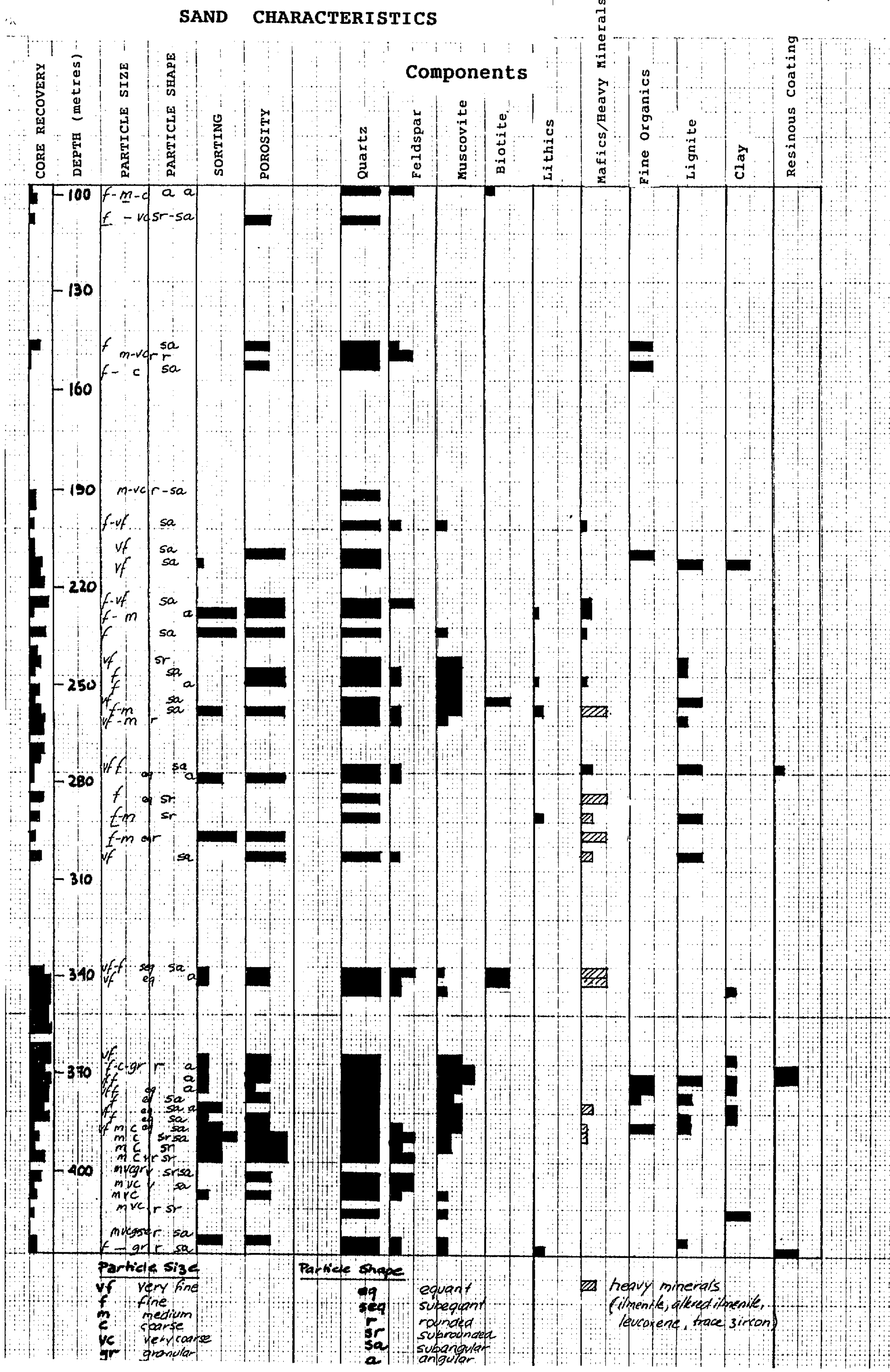


Fig. 6 Sand characteristics in the Renmark Group, bore 36675

LITHOFACIES A – SAND DOMINANT

Lithofacies A_1

Characteristics: Friable and porous cross-stratified medium to granular quartzose sand (Plate 1a).

Lithologies:

72% Brownish-grey to pinkish grey quartzose sand, medium to very coarse to granular, with minor feldspar (now altered) and traces of muscovite, lignite (Plate 1b). Sand particles are subrounded to subangular. Towards the top of the lithofacies, thin lignitic stringers are more abundant and the sand is more yellowish grey. Detrital lumps of resin, small and orange to red, occur as a trace component (Plate 1c) in the sand.
14% Very thin silt bands, clayey, lignitic, muscovitic and fissile, intercalated with 4% brownish-grey lignitic silty mud.

Cross-stratification of the sand is mainly in aggradational sets ranging from 1 to 25 cm, predominantly 20 cm thick. Foreset angles range from 15–30^{o}. The cross-stratification is defined by both fining-upward laminae, and the sometimes increased feldspar content in the top of laminae.

Leaf impressions, leaf fragments, and lignitic stringers are sparingly present in the upper horizons of Lithofacies A_1.

In the basal horizons, the sand has a dark brownish-grey colour from a pervasive resinous/peat coating of particles. Above this, the sands have a relatively uniform appearance.

Cycles: SP logs indicate cycles of increased sorting upwards, and decreasing clay content upwards, with a mean thickness of 7.8 m ($n=5$, $\sigma_n=1.83$). The overall Gamma and Neutron log character of the lithofacies indicates a progressive reduction of clays, increased sorting upwards.

Stratigraphic Distribution: Lithofacies A_1 is 41 m thick, occurring between 386 and 427 m. The sands disconformably overlie a weathered Devonian? granite.

Depositional Environment: The "resinous" horizons are interpreted as residual "A" horizons of a soil profile. The lithofacies is interpreted as a package of channel sands with the sediment source very close by. The persistent, thin sets and coarsening up sequences suggest upper fluvial accumulations in broad shallow channels, probably braided, across a gentle gradient terrain with very low relief.

Lithofacies A_2

Characteristics: Carbonaceous peaty sand, desiccation cracks and mud clasts, repeated micro-erosional surfaces.

Lithologies:

64% Sand, variably coloured from light grey to dark medium grey, fine-grained, quartzose, peaty, muddy and in part (Plate 1d), bioturbated. The quartz particles are subangular to subrounded.

25% Silt

11% Mudstone, mottled light grey, medium grey, to dark medium grey, with interlaminated sand. The mudstone is commonly desiccation-cracked and pyritic.

Burrows are pyritized and pyrite concretions range from small spheres to ellipsoids of a few millimetres diameter.

Mud clasts are common throughout from reworked desiccated erosional surfaces. The base of the lithofacies is a marked brief hiatus and erosional surface with shard-like mudstone clasts over an irregular, bio-eroded, coarsely burrowed and desiccated surface on the top of Lithofacies D.

Some small sandy clay horizons are bioturbated by rootlets? with internal sand and clay fill. The host clays in these horizons are partly restructured as a result of near-surface or groundwater alteration (Plate 1e,f).

Leaves and leaf fragments are common in the lower part of the lithofacies where horizontal bioturbation fabrics predominate.

Cycles: Overall, this lithofacies has an improved sorting and corresponding decreased clay content upwards, as indicated by electric logs. Within this lithofacies, 14 sedimentation cycles are recognized with a mean thickness of 3.0 m (σ_n 0.8), and these also have a predominant but erratically-increased sorting upwards. Some cycles fine upwards or have a more complicated intermixture of trends. Core recovery from this lithofacies was extremely poor but a recovered fining-upward cycle has a basal sand with mud clasts grading up through sand, desiccation-cracked silt to an upper mud.

Stratigraphic Distribution: Lithofacies A_2 is 42.2 m thick, between 101.5–124 m and 126–145.7 m at the top of the Renmark Group. Owing to poor core recovery, interpretation of this lithofacies is based mainly on electric logs.

Depositional Environment: The unit has a noteworthy sulphurous odour at its base where it fills and covers a bio-eroded hardened mudstone (inter-supratidal Lithofacies D). Reworking of reworked clasts is common. Deposition of Lithofacies A_2 was probably in a fluvial channel sand or crevasse splay, spilling out over an emergent Lithofacies D after a slight drop in sea level. The sulphurous odour probably results from marine sulphate-rich waters from below, interacting with post-depositional reducing conditions in the sand.

LITHOFACIES B – SAND & SILT INTERCALATIONS

Lithofacies B_1

Characteristics: Friable, laminated, carbonaceous and lignitic, muscovitic sand and silt; red resin lumps.

Lithologies:

48% Sand; fine, muscovitic and lignitic, quartzose (Plate 2d); porous lignitic coarse and angular quartz sand (Plate 2e).

49% Silt, light brown grey, brown grey; silty, very fine to fine sand; quartzose, muscovitic, lignitic; interlaminated with pinkish white silty, very fine to fine sand; sand particles equant, subangular to angular.

3% Muddy silt, brownish grey, fissile, muscovitic, carbonaceous with leaf partings (Plate 2a,b), lignitic in part; spreiten sporadically present towards the top of the lithofacies.

The sand is commonly cross-laminated and rippled, grading to cross-stratification with set sizes of 1–4 cm thickness, and foreset angles of less than 15^{o} (Plate 2d). Cross-stratification is more abundant in the lower part of the lithofacies. From 370–383 m the sequence has a consistent 5^{o} slope to its lamination. Bioturbation, including some spreiten, increases to the top of the unit with horizontal fabrics predominant and usually comprising 2 ichnospecies.

Leaf fragments are most common in the central part of the unit with more complete leaves towards the top where minor wood fragments occur in the upper 6 m (Plate 2c).

The lithofacies is well laminated and has a very high lignitic, wood, leaf debris and fine carbonaceous content.

Cycles: Five cycles are recognized with a mean thickness of 3.5 m (σ_n 0.77). These have coarsening-up, reduced clay trends. Overall, the lithofacies has an opposite, reduced sorting, fining upward trend from basal nonfossiliferous sands upward to leafy muddy silt.

Stratigraphic Distribution: This lithofacies is 16.8 m thick and lies in the interval 369.1–386 m.

Depositional Environment: The relatively high frequency/abundance of plant material in this lithofacies indicates a possible high rainfall and consequent raised water table. The interval of uniformly sloped sediments is probably a levee deposit with related crevasse splay and/or channel sands.

Lithofacies B_2

Characteristics: Yellowish grey glauconitic sand, cross-laminated, cross-stratified, ilmenite in sand, minor lignitic soil.

Lithologies:

55% Sand

38% Silt; yellowish grey, silty, very-fine to fine, quartz dominant with subdominant weathered greenish feldspar, and accessory muscovite and ilmenite; traces of glauconitic pellets; small cross-strata and laminae (Plate 2f).

6% Muddy silt; brownish grey, with lignitic fragments, rootlets and resin lumps (soils).

1% silty lignite interbanded with friable silt (Plate 2c).

Cross-stratification is predominantly in 10 cm sets with low foreset angles ($< 15^{o}$) and fining-upward lamination. Cross-lamination is abundant. Lamination is recognized from alternating silt and sand.

This lithofacies is virtually barren of biota except for sporadic lignitic soil horizons towards the top of the lithofacies. These lignitic bands typically have underlying bleached sediment which is cracked and filled by lignite.

Cycles: Eight cycles, with general but erratically increased sorting upwards, have a mean thickness of 4.8 m (σ_n 1.3).

PLATE 1

Sedimentary features of Lithofacies A

Lithofacies A_1

a Very friable, porous, bimodal medium-granular quartz sand with faint size-graded laminae. Bar scale in centimetres; from 421.3-.4metres.

b Porous bimodal quartz sand with rounded, equant to subequant granules, and more angular shard-like fine to medium sand. The dark lignitic fragment is cracked by desiccation and compaction. Photomicrograph, partly crossed polars; field of view 8 mm wide; from 412.5 metres.

c Conchoidal fracture on detrital resin lumps which are usually translucent orange to red. Resin lumps are a trace component in bimodal quartz sands at 394.9 metres. Field of view 5 mm wide.

Lithofacies A_2

d Laminated fine quartz sand with variable mud matrix. Mica flakes sub-horizontal and crenulated by compaction. Opaque black fragments are lignite and the central component is a tabular mud flake. Photomicrograph, plane-polarized light; field of view 6.5 mm wide; from 145.5 metres.

e Bioturbated sandy clay. Fine sand and silt fill rootlet casts in a weathered clay horizon within an ancient soil profile. Photomicrograph; plane-polarized light; field of view 6 mm high; from 106.8 metres.

f As for e). Note pervasive extinction pattern in the clay matrix indicating a recrystallized, restructured clay. Photomicrograph, crossed polars; field of view 8 mm high; from 106.8 metres.

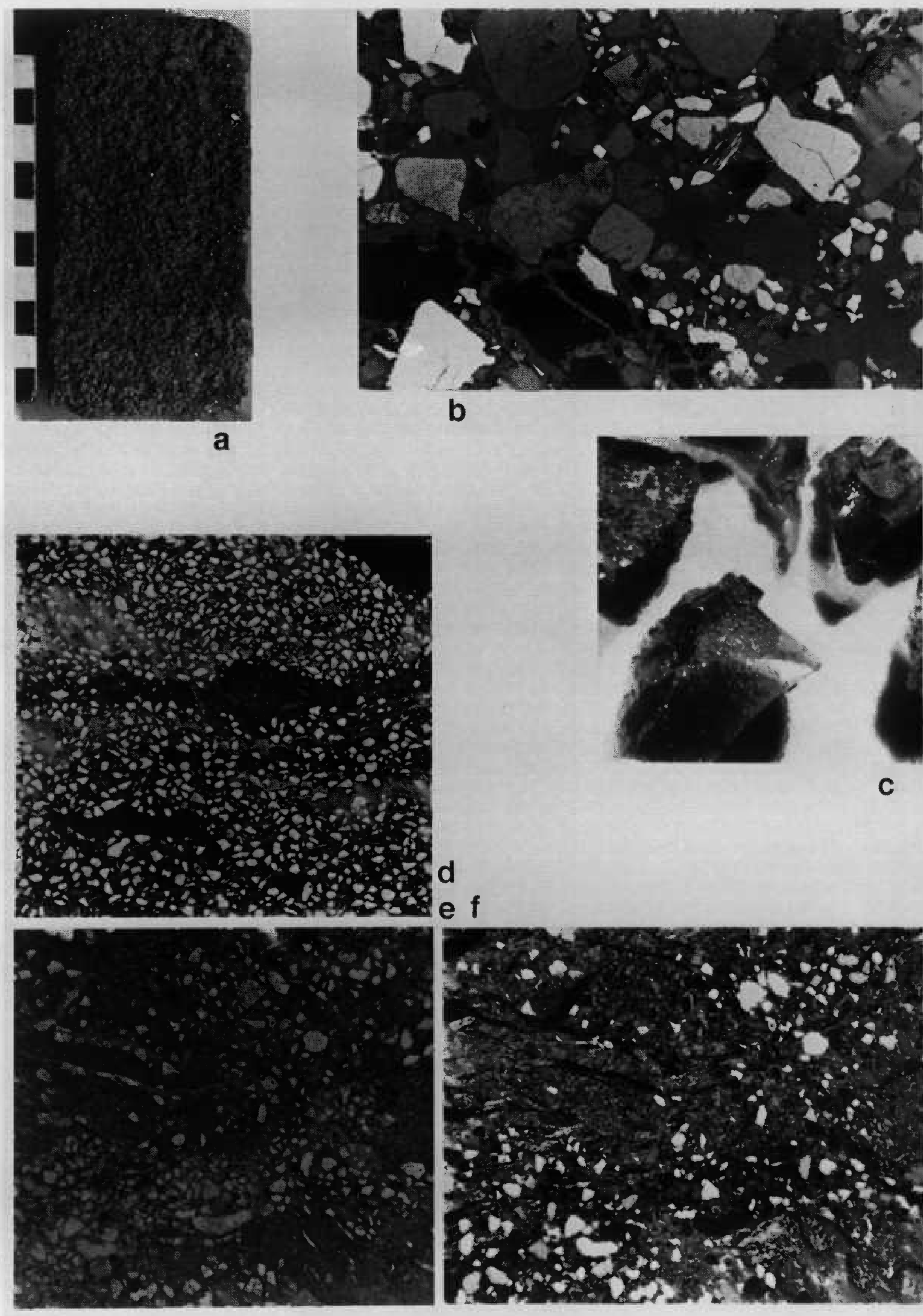

a
b
c
d
e
f

PLATE 2

Lithofacies B

Lithofacies B_1

a Dark carbonaceous laminated muddy silt with minor vertical burrows and more abundant, compacted, subhorizontal spreiten? and burrows. From 365.7-.81 metres.

b Light-coloured muddy silt over a darker friable very fine muscovitic quartz sand with lignitic fragments that are commonly pyritized. From 371.15-.31 metres.

c Muddy silt with lignitic stringers and subhorizontal carbonized wood twigs. From 372.5-.59 metres.

d Small cross-sets in a fine muscovitic and lignitic quartz sand. Muddy silt is interlaminated. From 378.14-.23 metres.

e Porous, angular coarse quartz sand with numerous, very fine, compacted lignitic flakes.Photomicrograph, plane-polarized light; field of view 7 mm wide; from 369.24 metres.

Lithofacies B_2

f Small festoon-type cross-sets in a well-sorted very fine quartz sand, with minor green, altered feldspar (glauconitized?). From 343.27 metres.

g Silty lignite; core is shrunken and cracked from desiccation. From 301.1 metres.

Lithofacies B_4

h Cross-stratified very fine muscovitic quartz sand delineated by very thin silt partings. Faint vertical escape burrows occur in the upper, more uniform sand. From 253.5-.6 metres.

i Sand, as in h), but laminae are partly destroyed by more intensive burrowing. From 253.65-.72 metres.

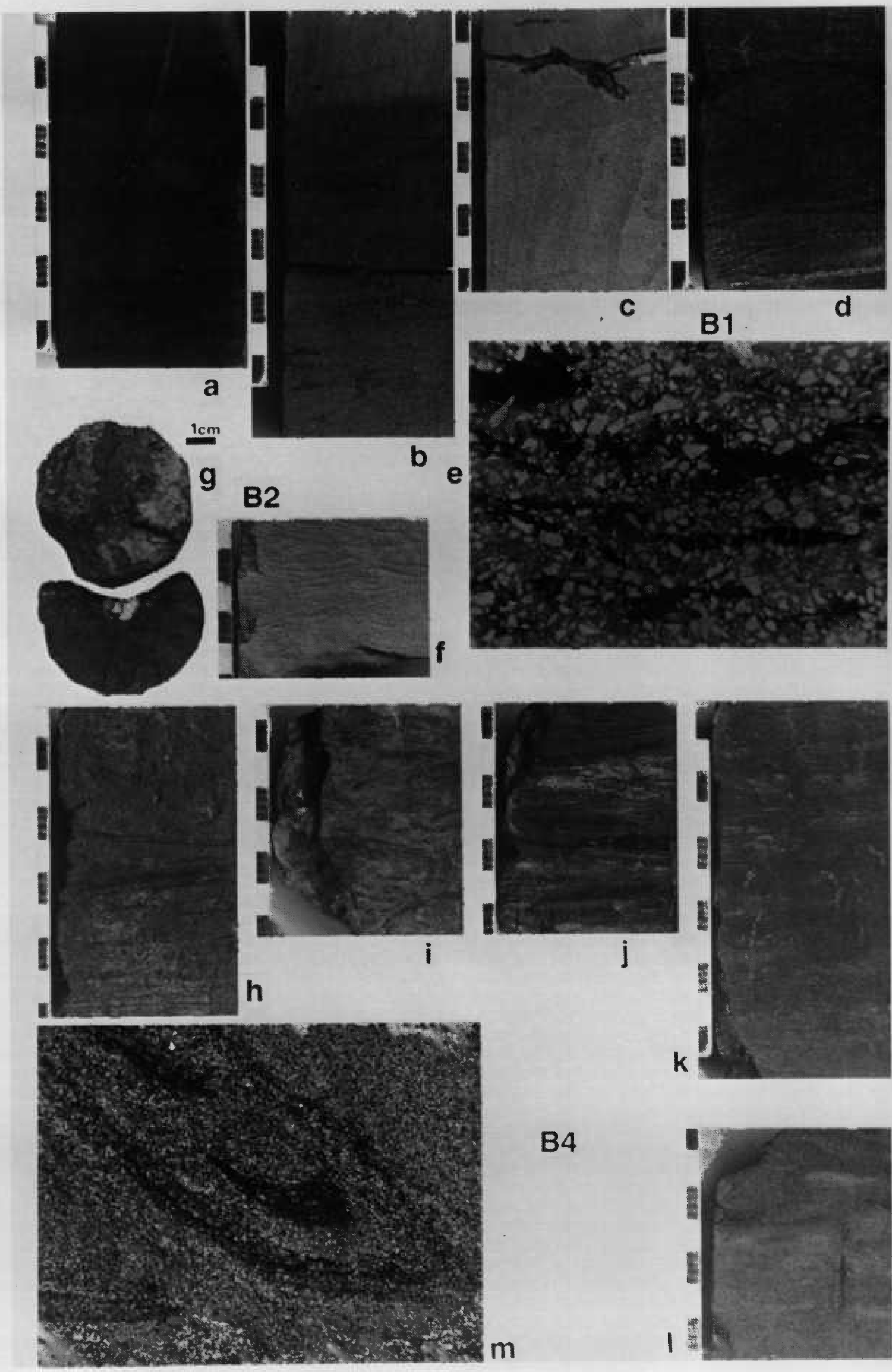
j Cross-laminated coarse quartz silt, interlaminated with very fine peaty silt which has desiccation cracks. From 260.4-.47 metres.

k Friable feldspathic quartz silt with discontinuous laminae defined by lignitic fragments. Thin vertical burrows uncommon. From 262.16-.28 metres.

l Very fine to fine quartz sand with vertical root casts, lignite-stained edges, and filled with sand. From 274.37-.44 metres.

m Burrow? with concentric layers of silt and carbonaceous silt. Photomicrograph, plane-polarized light; field of view 7.2 mm; from 205.7 metres.

(Striped bar scales are in centimetre increments)


a
b
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B1
1cm
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k
B4
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l

Stratigraphic Distribution: This Lithofacies B_2 is 44.8 m thick in the interval 300–344.8 m. There was little core recovery and most lithologies have been projected from lower cores. Small sideritic concretions are present in the sands.

Lithofacies B_2 has a sharp erosional? contact over Lithofacies C_1 and is gradational up into Lithofacies C_2.

Depositional Environment: This lithofacies is interpreted as a sublabile channel sand which has, in part, had estuarine conditions allowing development of some glauconite. The bedload of the channel was significant and considerably diluted the marine alteration products.

Lithofacies B_3

Characteristics: Sand-silt and sand-laminated mud alternations, carbonaceous and lignitic, minor wood.

Lithologies:

46% Sand; fine to medium, quartz dominant, feldspar and ilmenite accessory; brownish grey to light brownish grey; uniform appearance; sorted and very porous. Sand particles are equant, subrounded to subangular.

44% Silt.

10% Muddy silt; brownish grey, fissile, lignitic.

Cross-stratification, which is more abundant towards the top, contains fining-upward strata. Silts and sands are faintly laminated with lignitic debris. Silts are also laminated with muddy silt. Minor mud clasts and wood fragments also occur.

Cycles: Alternating sorting and clay trends indicate 6 cycles with a mean thickness of 3.5 m (σ_n 1.9).

Stratigraphic Distribution: Lithofacies B_3 is 20 m thick over the interval 280–300 m, and is lignitic at the base.

Depositional Environment: The unit is predominantly sand with variable core recovery. The increased cross-stratification upwards, ubiquitous lamination, frequent lignite occurrences but with a paucity of leaves, rootlets and bioturbation, as well as traces of heavy minerals in the sand may indicate channel sands of marginal-marine to estuarine nature during a drier climatic period.

Lithofacies B_4

Characteristics: Laminated and cross-laminated, wood fragment abundance highest in the whole sequence. Leaves and bioturbation peak in abundance within Lithofacies B_4 at 250 m.

Lithologies:

45% Sand; friable, yellow-grey to olive-grey, fine to very fine-grained, quartzose. The sand is dominantly subangular to angular quartz, lignitic, with accessory feldspar and lithic particles. Sand is also ilmenitic in the lower half of the lithofacies and changes to muscovitic in the centre of the unit (Plate 2h).

42% Silt; friable, brownish to pinkish grey, yellowish brown, peaty.

13% Mud, muddy silt, conchoidal, leaf impressions and fragments.

Cross-lamination and minor herringbone cross-lamination with associated ripples and parting lineation is abundant in the lower half of the unit. Cross-stratification with 1–4 cm sets and $10-15^{\circ}$ foresets is more common in the central and lower part of the unit. The sequence is laminated throughout with associated minor desiccation cracks, micro-erosional surfaces, and mud clasts (Plate 2h,i,j,k,m).

Bioturbation is variable throughout, generally low in abundance but increases slowly upwards from the base of the lithofacies to Lithofacies C_2 at 252–250 m, and then decreases to low abundance in the overlying 10 m. This peak is coincident with a higher frequency of plant material and cross-stratification. A second peak in bioturbation frequency/abundance occurs at 199–200 m with a gentle upward increase then sudden decrease to an overlying Lithofacies C_2 at 193–192 m (Figs. 4,5). Burrows are predominantly vertical escape-forms but there appears to be a recurring transition from horizontal-dominant to vertical-dominant in small cycles of <1 m.

Leaf and wood fragments are abundant throughout but leaf abundance peaks in the centre of the unit. Rootlet horizons (Plate 2l) usually underlie peat/lignitic stringers. In some horizons, these features are preserved as charcoal.

Cycles: This lithofacies has varying cycles, of both increased and decreased sorting-upwards. These generally thin towards the top of the unit, but of 14 recognized cycles, mean thickness is 5.2 m (σ_n 2.07). In some cycles, the culmination is a soil horizon with underlying lignitic rootlets.

Stratigraphic Distribution: Lithofacies B_4 occurs in three intervals, 270.2–280, 252–265, and 193–250 m. These alternate with very thin sequences of Lithofacies C_2. Lithofacies B_4 is centrally positioned in the Renmark Group.

Depositional Environment: The coincident frequency/abundance peaks of cross-strata, plant material, and bioturbation below and above C_2 Lithofacies indicates an influence of sea-level rise with associated increased precipitation and or/water table rise. This initiated avulsion of channels. The cycles in rootlet occurrence and bioturbation type suggests levee deposits and crevasse splays alternating with laminated floodplain lignitic silts.

Lithofacies B_5

Characteristics: Sand with mud clasts, crumbly sand, conchoidal dirty gritty bioturbated mud.

Lithologies:

58% Sand, dark olive grey, fine, quartzose, feldspathic, mud clasts, lignitic, colour laminated. Some horizons are bimodal with additional medium and very coarse quartz sand.

40% Silt, dark brown, grey.

2% Mud, dark olive grey, bioturbated, interlaminated with silt, erosional surfaces.

Bioturbation is commonly partly pyritized or contains disseminated pyrite. Burrow abundance increases upwards near the top of the unit in correspondence with increased sorting. Leaf and wood fragments are minor in this lithofacies.

Cycles: Cycles show a general fining-upwards at the base, and increased sorting upwards in the upper unit. Collectively, 8 cycles are recognized with an average thickness of 4.8 m (σ_n 3.6).

Stratigraphic Distribution: This lithofacies occurs in two upper intervals of the Renmark Group, 176–192 m, and 148.2–174 m, separated by a thin interval of Lithofacies C_2. Core recovery was minimal.

Depositional Environment: Interpretation is highly speculative with minimal core recovery. This lithofacies is sandier than B_4 and has more mud clasts indicating interspersed coherent fine sediment. The unit probably resulted from intercalations of crevasse splay and floodplain environments with an increasing proximity to marginal marine upwards towards Lithofacies D. The lithofacies has a distinctive sulphurous odour at the upper contact with Lithofacies D, indicating the effect of marine flooding over it, with downward invasion by sulphate-rich marine waters.

LITHOFACIES C – SILTS DOMINANT

Lithofacies C_1

Characteristics: Laminated, carbonaceous, generally uniform dark colour, very regular colour lamination, spreiten, sideritic cement induration.

Lithologies:

18% Sand, resin coated, quartzose towards base of unit.

37% Silt; fissile light brown grey, light olive grey sandy silt, muscovitic, well-sorted; desiccation cracks, burrows (Plate 3a,b).

40% Muddy silt; fissile medium light grey to brown grey muddy silt, muscovitic, carbonaceous; interlaminated pinkish grey silt and sand partings (Plate 3e).

5% Mudstone, 'varved' colour interlaminations of olive grey and yellow grey, with no biota, structures, or textural variations (Plate 3c).

Colour lamination is predominant in the upper part of the unit. Seat earths containing lignitic rootlets have a bleached colour. Cross-stratification is mainly in aggradational sets 1–4 cm thick, increasing to 1–20 cm with fining-upward laminae at the top of unit, foreset angles $<15^{\circ}$. Desiccation cracks are present in the lower unit adjacent to Lithofacies C_2 contact.

Leaves occur sporadically throughout the lithofacies but are most abundant near the top of the unit (Plate 3f). Burrows are ubiquitous and variable (Plate 3a,b,d,e,g,h). Bioturbation abundance increases consistently towards a peak just below and just above the intercalating Lithofacies C_2 (Fig. 4).

Cycles: No distinctive pattern is apparent in the electric logs but repetitive, sedimentation units of variable thickness and character are recognized in drill core.

Stratigraphic Distribution: Lithofacies C_1 is recognized in the intervals 344.8–363.4 m and 364–369.1 m, enclosing a thin interval of Lithofacies C_2. The overall character is not distinctive as there are no rapid alternations in sorting or lithology.

PLATE 3

Lithofacies C_1

a Burrow structures and desiccation cracks in a firm laminated very fine quartz sand and silt. Laminae are defined by variable lignitic and leaf content. From 345.57-.71 metres.

b Interlaminated silty mud and silt. Mud bands have subhorizontal burrows. From 348.1-.17 metres.

c "Varves"; colour-laminated muddy siltstone with uniform particle-size. From 352.72-.78 metres.

d Uniform burrowed silt with a lignite-rich erosional surface overlain by a burrowed silt. From 356.41-.54 metres.

e Laminated and faintly bioturbated quartz silt. Burrows concentrated in darker carbonaceous bands. Thin partings formed by light-coloured friable silt. From 357.2-.33 metres.

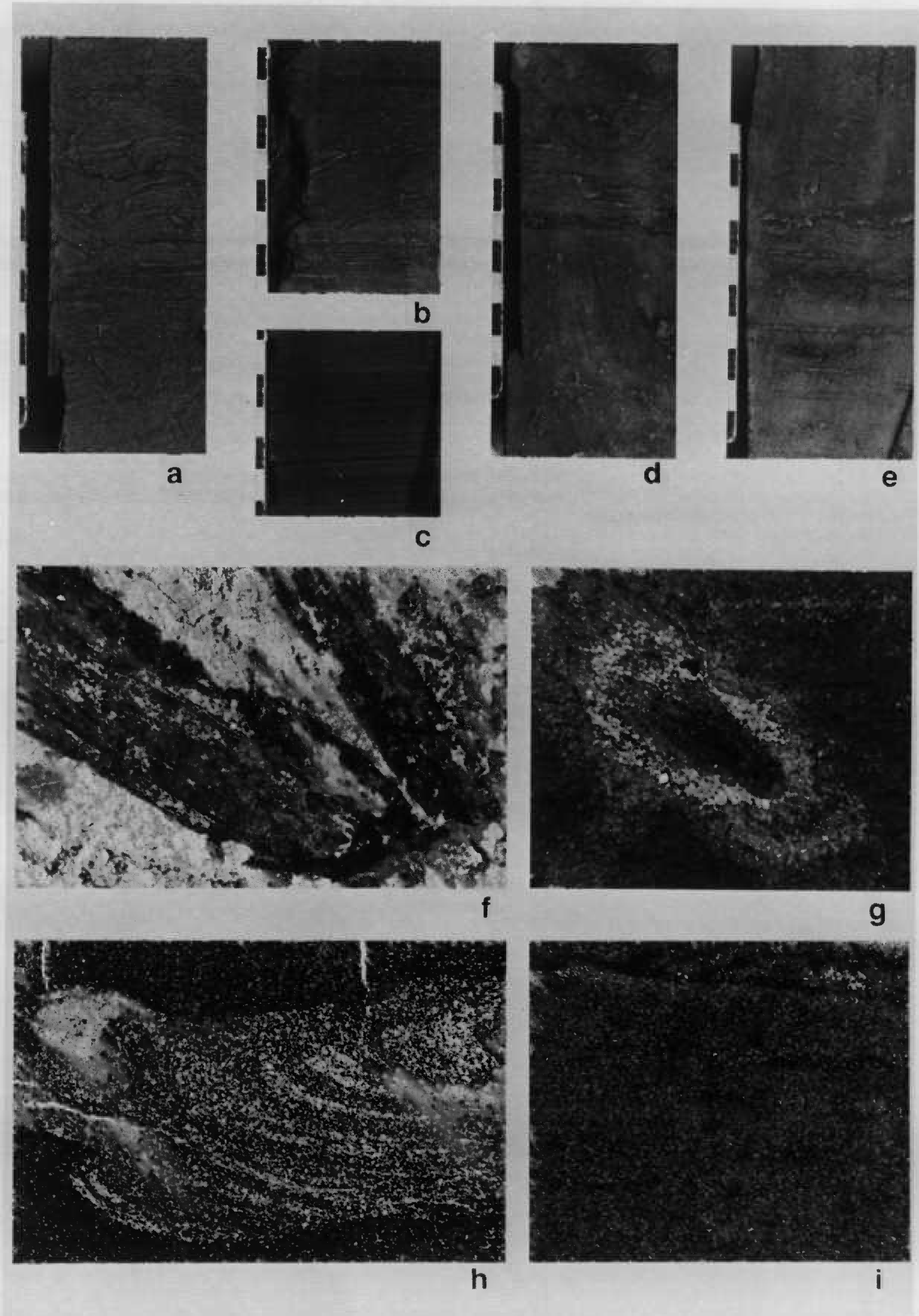
f Plant stem fragments in a friable fine quartz sand. From 347.2 metres. Field of view 8.2 mm wide.

g Burrow, silt-infilled, in a carbonaceous silt host with numerous small plant fragments. Photomicrograph, plane-polarized light; field of view 6.5 mm; from 347.2 metres.

h Spreite produced by lateral burrowing of bivalve (part of bivalve cross-section seen on far right of field of view) within a dark carbonaceous silt. Photomicrograph; plane-polarized light; field of view 8 mm wide; from 351.7 metres.

i Graded laminae in silt, fining upwards from basal carbonaceous coarse silt. Micro-erosional surface in upper field of view. Photomicrograph, plane-polarized light; from 347.2 metres.

(Striped bar scales are in centimetre increments)


a
b
c
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e
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PLATE 4

Lithofacies C_2 and D

Lithofacies C_2

a Peaty mud with grummous texture after compacted faecal? pellets. Microerosional surface is overlain by friable silt. Photomicrograph, plane-polarized light, field of view 6 mm wide; from 250.8 metres.

b Agglutinated foraminifera (white), probably Rzehakinids, associated with burrowed remains of a flat-bladed grass. Field of view 7 mm wide; from 268.1 metres.

c Low-diversity foraminiferal fauna clustered around a site of former swamp grass. It is uncertain if this is an epiphytic association, or if the foraminifera are infauna feeding on bacteria within decaying plant debris. Field of view 6.5 mm wide, from 268.1 metres.

d Dark peaty mud, compacted, with relict porosity after small foraminifera. Photomicrograph, plane-polarized light; field of view 3.2 mm wide; from 269.8 metres.

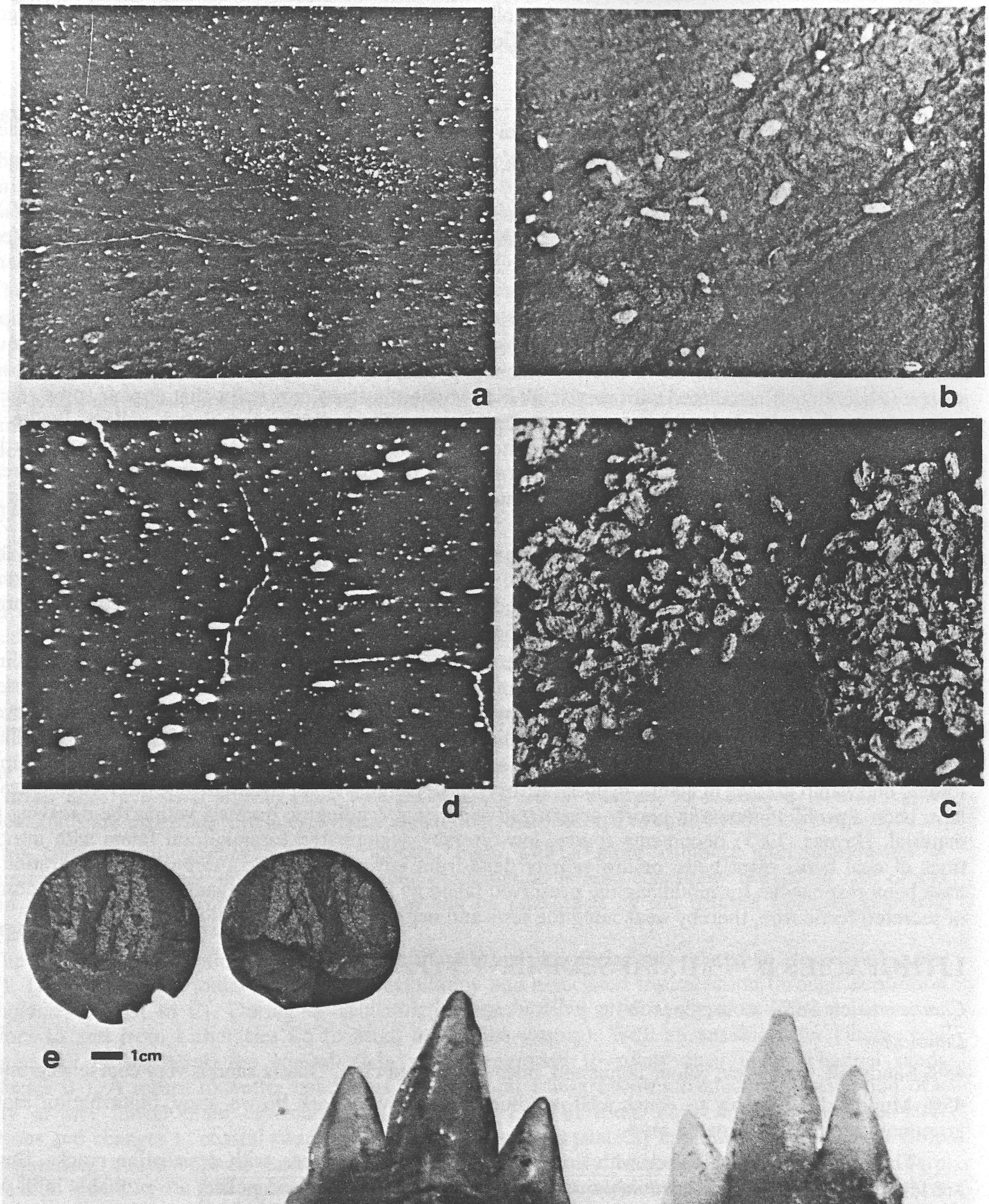
e Arenaceous foraminifera associated with flat-bladed grasses in a fissile carbonaceous silt.
Bar scale 1 cm.

Lithofacies D

f Tricuspate shark denticle or small tooth showing prominent root process?, apatitic; inner concave view 2.5 mm wide at base; from 146,2 metres.

g Outer convex view of shark denticle/tooth (f).

(Striped bar scales are in centimetre increments)


a
b
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1cm
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g

Depositional Environment: This unit has abundant spreiten (Plate 3h shows a spreite complete with infaunal bivalve) in very peaty carbonaceous, laminated silt which was deposited in brackish conditions, possibly an interdistributary bay environment with locally more acidic lacustrine tracts in which varves accumulated. The diversity of organic material implies hyposaline to paralic conditions as a result of gentle sea-level rise and consequent flooding of fluvial floodplain areas.

Lithofacies C_2

Characteristics: White agglutinated foraminifera in very dark fissile carbonaceous mud, desiccation cracks.

Lithologies: Brown black, dark grey to grey black, and dark brown grey to light brown grey compacted fissile mudstone, often grummous, with friable silty interlaminations. Silt is either interlaminated with mud-clasted sand, or can be ubiquitous in some intervals of this lithofacies. Silt is dark brown grey, interlaminated with brown grey or light brown grey silt, and often micaceous, peaty, and lignitic. Carbonaceous mud approaches oil shale character in the interval 192–193 m where on drying, the core is considerably shrunken and lighter than normal muds.

Agglutinated foraminifera, probably *Miliammina* (Family Rzehakinidae), are distinctive as elliptical white specks in a dark sediment. The foraminifera are commonly just blebs of pure white friable quartz silt, sometimes with a pyrite fill in internal chambers. These frequently are clustered in tabular rows or groups (Plate 4b,c,e) associated with very small bioturbation in stratiform strips that appear to be remnant impressions of flat-bladed seagrasses or swamp grasses (Plate 4b,e). Associated pellets, lignite, and partings are pyritized. The lithologies are ubiquitously laminated with cross-lamination, fining-upward and coarsening-upward type laminae. Desiccation cracks are present. Burrows are generally large, if present, with diameters of 1–2 mm up to 6 mm. Bioturbation, when present, is higher in this lithofacies than adjoining ones.

Stratigraphic Distribution: Lithofacies C_2 is recognized at 6 intervals in the sequence, 363.4–364 m, 265–270.2 m, 250–252 m, 192 -193 m, 174–176 m, and 124–126 m. These intervals are distinctive on the electric logs, seen as thin zones of increased shale content and corresponding reduced porosity. Lithofacies C_2 has close visual similarity to the Geera Clay Lithofacies A (Radke, 1987).

Depositional Environment: This lithofacies is seen as the result of small sea-level rises causing flooding of saline waters into the low-gradient fluvial systems, creating hyposaline swamps (brackish, <30 parts per thousand salinity) in the former interdistributary floodplains. Conditions were acidic, negating development of a more prolific fauna but allowing agglutinated foraminifera and swamp grasses to survive. The associated presence of Rzehakinid foraminifera and traces of flat plant material may indicate epiphytic forams on swamp grasses in acidic, hyposaline, oxygen-depleted waters. Alternatively, the foraminifera may have been a prolific infauna in poorly oxygenated sediments, feeding on bacteria within the decaying plant material. Haynes (1981) documents sparse, low-diversity agglutinated foraminiferal fauna with intercalations of coal beds, plant beds, or low salinity delta-front environments. Post-depositional alteration may have been responsible for modifying the preserved fauna by leaching out of organic cements and reduction of secreted ferric iron, thereby weakening the tests and negating their preservation.

LITHOFACIES D – MIXED SEDIMENT TYPES

Characteristics: Sulphurous, glauconitic, pelleted, sparsely fossiliferous.

Lithologies:

48% Sandy silt; olive grey, colour laminated, micaceous, mud clast. Quartz sand is very coarse to granular.

45% Muddy silt: crumbly to conchoidal, medium dark grey to dark brown, grey, bioturbation mottled, grummous with interlaminated mud.

The lithofacies is laminated, with fining-upward laminae in places, with desiccation cracks. Burrows are few but large, of *Callianassid* subhorizontal type. Pockets of pyritized pellets are probably infill of this type of burrow. One small shark tooth (Plate 4f,g) was found associated with these pyritic pellets.

Stratigraphic Distribution: This lithofacies lies between 145.7 and 148.2 m, with a gradational lower contact and a sharp erosional upper contact against the overlying Lithofacies A_1.

Depositional Environment: Lithofacies D is considered estuarine, the interval with the strongest marine influence in the whole Renmark Group. Because of the paucity of fauna, the depositional environment did not, perhaps, reach marginal-marine conditions, but more probably hyposaline salinities. The associated sulphurous odour in these sediments and in the underlying lithofacies reflects the influence of saline waters on early diagenetic products.

The presence of shark material implies only an open connection with marine waters. However, the presence of *Callianassa?*, agglutinated foraminifera, and the pyritization of burrow pellets further suggests hyposaline to marine conditions in a relatively protected area such as a bay or muddy estuary. The desiccated, spalled upper surface of the lithofacies suggests subsequent emergence due to a falling sea level prior to burial by fluvial sands.

DEPOSITIONAL ENVIRONMENT MODELS

Sea-level Fluctuations

Figure 7 shows projected sea-level fluctuations over the period of accumulation of the Renmark Group in Hatfield-1. No time control is yet available and it is speculative as to how this curve relates to that of Vail *et al.*(1977). However, a gross correlation would place the sequence from about 40 Ma (Late Eocene) to 11 Ma (top of Middle Miocene), giving an averaged accumulation rate of 1.1 cm per thousand years.

The rises of sea-level, as reflected in Lithofacies C_2 and D are brief and easily identified. However, the broader cyclicity is more difficult to ascertain and in this study has been based on the megacyclic trends in the electric logs (Fig. 7). These are interpreted as a response to sediment sorting and clay content in sands, both of which are probably indicative of drainage gradient in a fluvial system.

Sea-level fluctuations are influential on sedimentation where fluvial systems are of very low gradients and sedimentation therefore becomes a very sensitive indicator of small changes of sea level in such conditions.

General Model

One rationalization of proposed depositional environments for each of the lithofacies is presented in Figure 8.

In this diagrammatic two-dimensional model, climate and precipitation change from dry on the left hand side, through to wet on the right hand side. Increases in precipitation are seen to be reflected in raised water table on the coastal floodplain, with resultant increases in coastal flooding, abundance of plant material and infaunal bioturbation. Both Brown (1980) and Harris (1980) relate enhanced accumulation of vegetative matter and consequent brown coal development to periods of relative sea-level rise in the Murray, St.Vincent and Eucla Basins.

In the vertical axis, the transitions relate to shoreline and river gradients, from a variable alluvial slope, down onto a coastal alluvial plain with meandering fluvial systems, to a flooded coastal regime where channels are estuarine with lateral transitions to interdistributary bays and hyposaline swamps.

This configuration implies a broader coastal plain with a more complex inter-relationship of environments during higher precipitation. Higher precipitation is also commonly related to rise of sea level, in which case the breadth of coastal plain will be controlled by the balance between sediment discharge, rate of sea level rise and subsidence.

The designated depositional environments of individual lithofacies are related to a sea-level curve (Fig. 7). This indicates an initial increase of precipitation and associated transgression through deposition of Lithofacies A_1, B_1 to C_1. During C_1 accumulation, there were small sea-level oscillations to create transitions to and from Lithofacies C_2 (coastal, hyposaline swamp). With an ensuing drier climate and associated fall in sea level, the coastal plain again prograded to reintroduce upper channel sands (Lithofacies B_3). A return to wetter conditions, with a slight transgression introduced accumulation of a diversity of wet fluvial plain environments (Lithofacies B_4). In these environments, slight sea-level oscillations and changes to coastal swamp (Lithofacies C_2) were repeatedly apparent. With a general drop in precipitation, coastal fluvial environments changed slightly to Lithofacies B_5. A sudden sharp transgression introduced a thin interval of marginal-marine muddy estuarine conditions (Lithofacies D). A subsequent increase in sediment accumulation in channel and crevasse splay environments created a gradual progradation of the shoreline.

Mologa Surface

Evidence exists above the top Renmark sand for two distinctly different periods of soil profile development.

West of Hatfield-1, the Mologa Surface has been recognized on ridges and highs where an extended period of erosion and weathering has increased rare earth concentrations to anomalous levels that can be identified on gamma logs (C.Brown and J. Kellett, pers.comm.).

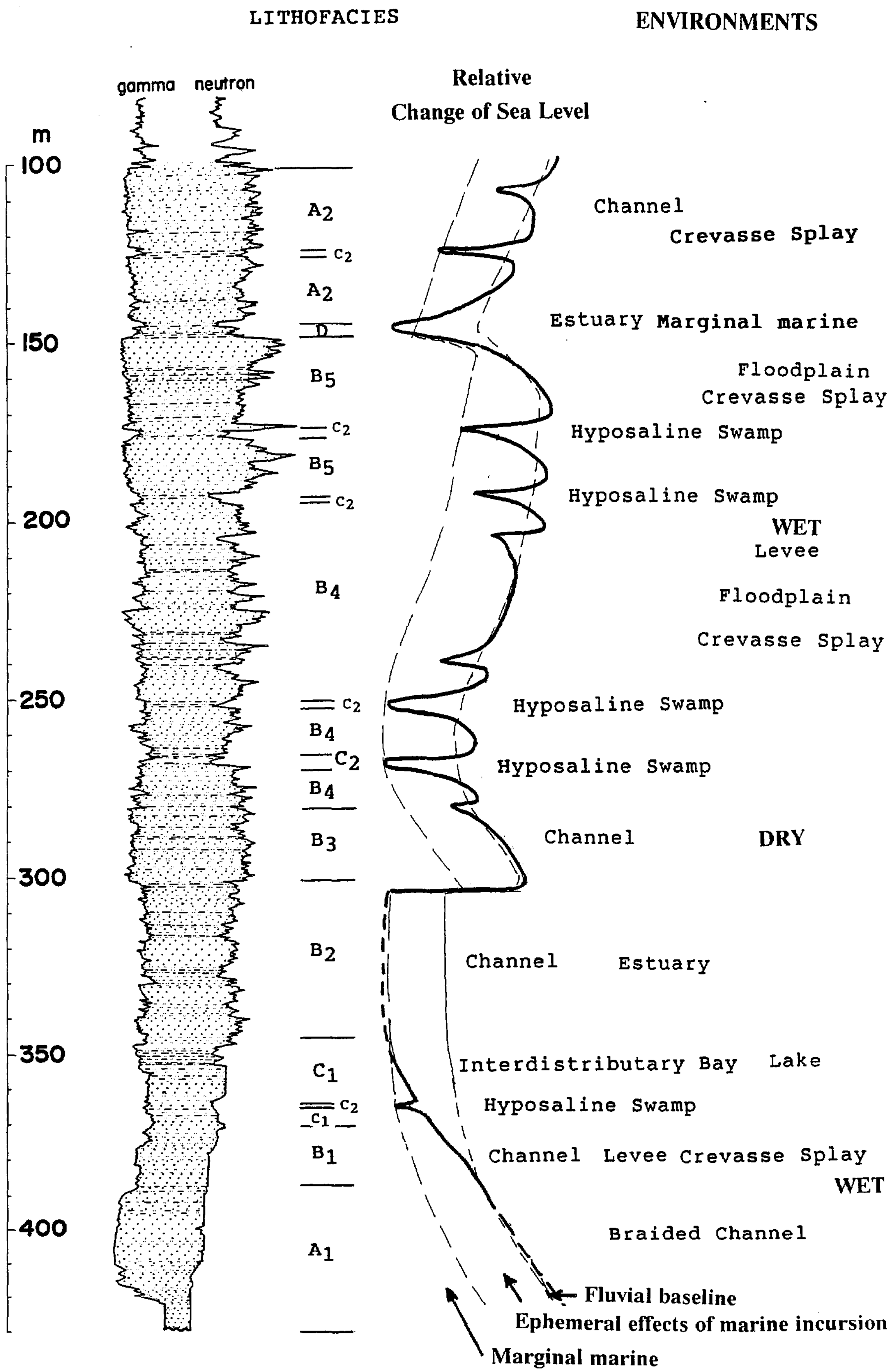


Fig. 7 Interpreted sea level fluctuations and depositional environments of the Renmark Group, bore 36675

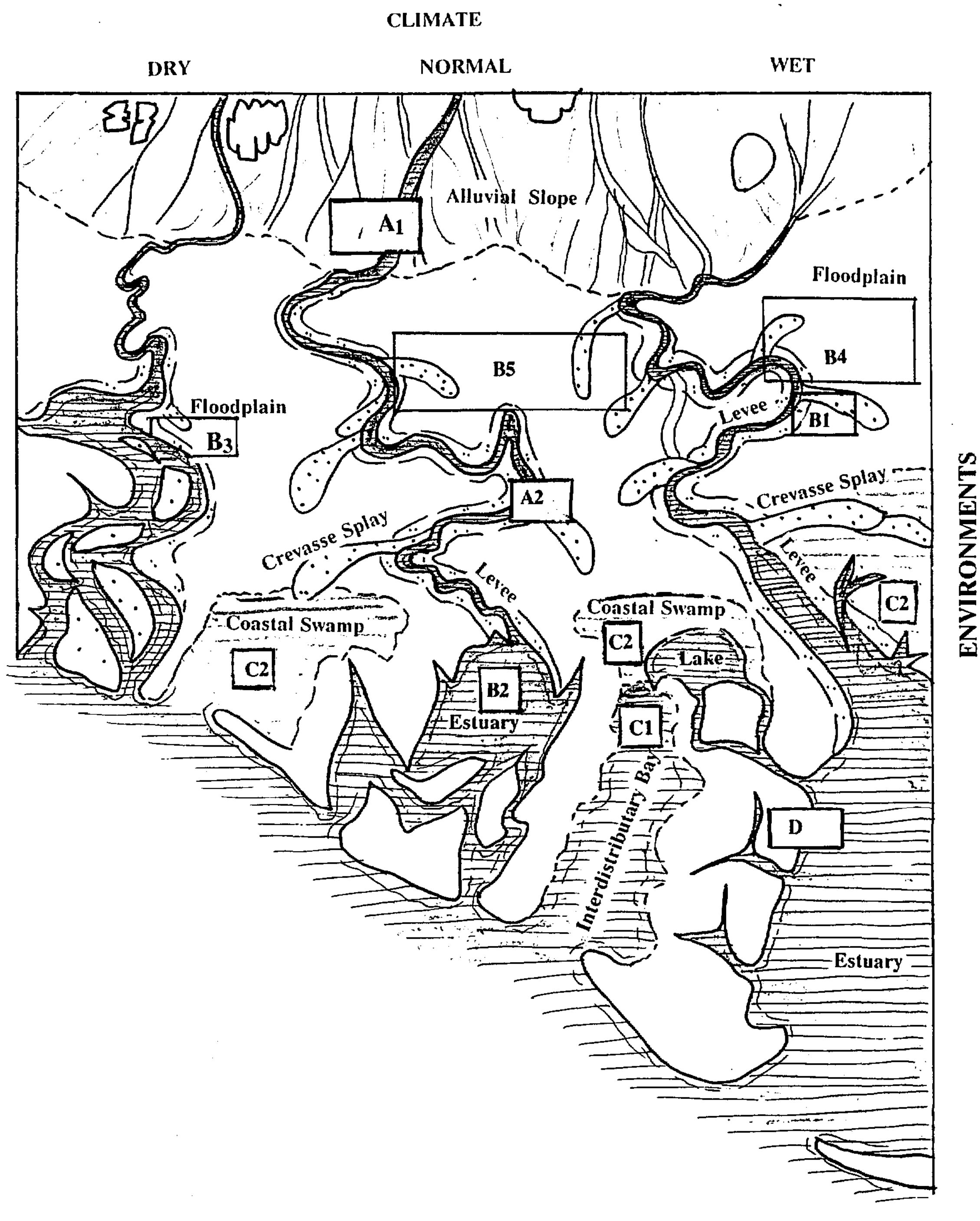


Fig. 8 Interpreted spatial arrangement of environments of deposition of the Renmark Group, bore 36675.

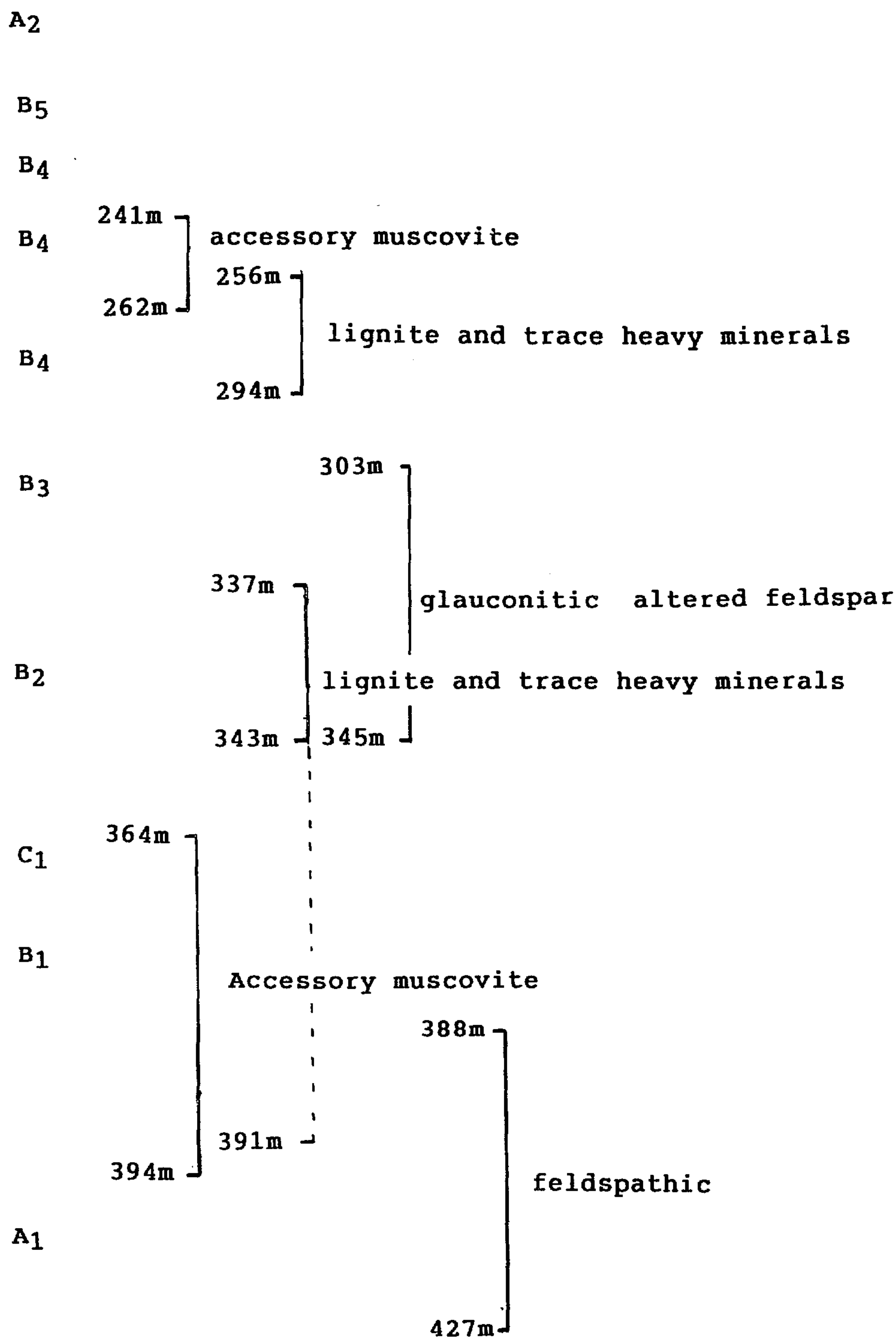


Table 1 Changes in sand character in the Renmark Group, bore 36675

In Hatfield-1, at depths 99 m and 101.5 m, there are distinctive gamma kicks and at 101.5 m on one run, the instrument went offscale. It is uncertain if this was a formation signature, instrument error or processing error. Both horizons also have corresponding drops in resistivity.

Between 97 and 101.5 m, the sequence is predominantly desiccated silt and interlaminated sand, crumbly to slickensided, and contains rootlets of two generations. One that is pervasive into all sediment types and is generally black and lignitic, comparable with those much lower in the Renmark Group. The other consists of brown flexible, papery, well-preserved forms that are confined to fractures and slickensides in the clayey silt. These are much younger and are post weathering of the clayey silt and indicate a probable deep weathering profile that developed on these silts. This study has taken 101.5 m as the top sand of the Renmark Group even though the overlying silts have some similarity to the underlying sands.

Sediment Provenance

Throughout the Renmark Group in Hatfield-1, the sands are monotonously quartzose and only in Lithofacies A_1 and B_2 are they slightly feldspathic. However, there are significant variations in size and shape of quartz particles, and recognized accessory and trace minerals. General patterns of variations in these parameters would indicate changes of provenance, distance of transport, and climate.

Changes in sand characteristics are documented in Figure 6. The significant variations recognized are outlined in Table 1 and show a repeat-reversed pattern with its horizontal axis of bilateral symmetry in Lithofacies B_3.

There are several possibilities to explain this pattern; lateral migration of river channels changing provenance, tectonic, long-term sea-level changes, and climatic changes affecting survival of accessory minerals. The climatic and the river channel migration models, or a combination of both appears most likely.

With climatic changes, at lower temperatures the silicate minerals, aside from quartz, would have reduced chemical weathering and therefore survived considerable transportation proportional with their mechanical properties. Under such conditions, feldspars and micas could survive. With increased temperature, feldspars would be expected to alter first and hence not survive transportation. However, with this model, one would expect both muscovite and feldspar to be present together in some sediments and this is not a consistent feature. Consequently provenance appears to be more significant.

Hatfield-1 is sited near the central axis of the Balranald Trough. Structural contours of basement (J. Kellett, pers.comm.) suggest a confluence of tributaries to the north of the site, with one tributary coming from the northwest off the Iona Ridge and Darnick High, the other coming due south from perhaps the Ivanhoe Trough to the north, or from farther east. With sedimentation, this confluence or others, may migrate down gradient, to the south and over the location of Hatfield-1. If these tributaries meander over this site in time, then individual tributaries may have sole influence on sedimentation at the Hatfield-1 site, and considerable provenance variations of sediment source could be preserved. Tectonism that would affect river patterns, or relief of provenance areas would additionally complicate this model.

DIAGENESIS

GENERAL STATEMENT

Diagenesis is discussed under diagenetic product categories, and paragenesis. Diagenetic events and products are summarized in a lithostratigraphic context in Figure 9.

Clays

Only a cursory sample of intervals was analysed for mineralogic components (Fig. 9).

The clays and clay fraction of muds and weathered sands in the sequence are dominated by smectites and kaolinite, with minor proportions of mica/illite and a trace in one horizon of gibbsite.

Whole sediment samples were separated into the coarse and clay fraction (<2 microns) and Figure 9 shows variations of mineralogy of sediments downhole. Appendix III outlines preparation and analytical procedure used by AMDEL for the Xray diffraction determinations.

Discussion: The trace presence of gibbsite, $Al(OH)_3$, at 353.89 m (Lithofacies C_1), is possibly indicative of high permeability within an open system where fresh silica-free water was supplied fast enough for a continued dissolution of detrital feldspars in the silts (Wollast, 1967; Berner, 1971). At this horizon, the

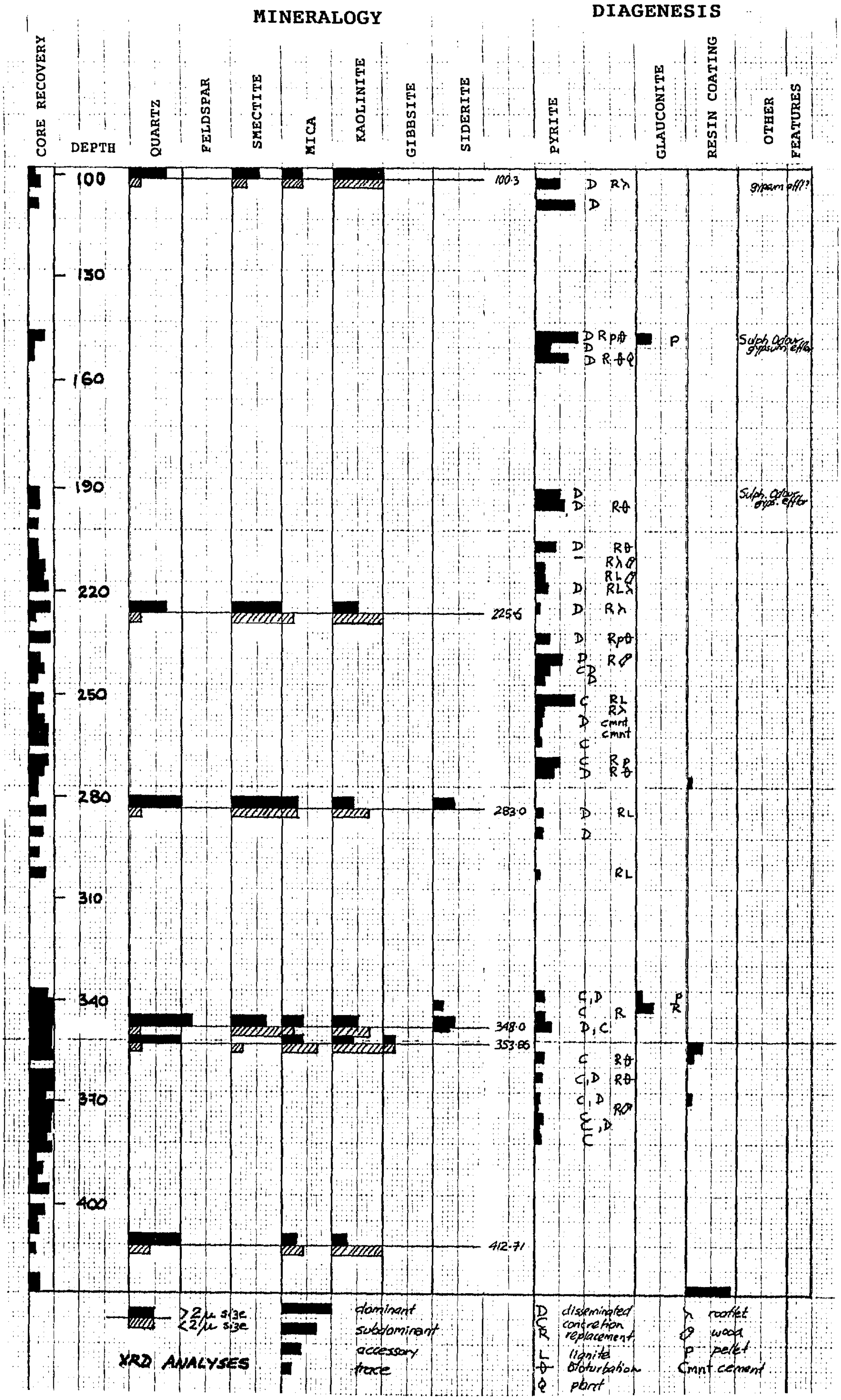


Fig. 9 Mineralogy and diagenesis of the Renmark Group, bore 36675

dominance of kaolinite and virtual absence of smectites would be in keeping with such a model. Very fine carbonaceous matter, present in significant amounts may also account for part, at least, of cation absorption and relative unavailability for clay mineral reactions.

The dominating presence of smectites at horizons 225.6 m (Lithofacies B4), 283.0 m (Lithofacies B_3), and 348.0 m (uppermost Lithofacies C_1), usually in association with co-dominant to subdominant kaolinite may indicate a changing hydrological regime in which diagenetic waters of higher salinity than that at deposition are now causing alteration of kaolinite to smectites. Presently, Total Dissolved Salts at intervals 290–302 m and 384–402 m are 6030 and 4800 ppm respectively in which calcium, magnesium, and sodium are each well in excess of four times the potassium levels of 38 and 29 ppm respectively (J. Kellett, pers.comm.).

Glauconite

Glauconite is a predepositional phase in eogenesis. Its main occurrence is as a replacement of faecal pellets in Lithofacies D, B_2, and C_1. Additionally in Lithofacies B_2 the sands are a yellow grey because of alteration of detrital feldspar to ?glauconite.

Discussion: Mildly reducing conditions (Eh 0 to -150 mV, pH 7–8) are required for glauconite formation. the commonly associated burrowing and presence of clayey-organic faecal matter would have produced the required surfaces of changing Eh conditions necessary to facilitate its precipitation. Such conditions have been documented from marine environments, and consequently the glauconitic horizons within this predominantly fluvial sequence are interpreted as brief marine or estuarine events, perhaps caused by slight sea-level rises and resultant backflooding of the river systems on a very low-gradient coastal-fluvial plain.

Siderite

Siderite is recognized at 283 m (Lithofacies B_3) and in the interval 340–348 m (Lithofacies B_2 and C_1).

It occurs in two forms: predominantly as a poikilotopic cement within interparticle porosity to form either small (millimetre-sized) rose concretions or complete occlusion and induration of bands within sands; and also as small spherical pellet-sized concretions comprising radial-crystalline needle growths on small nuclei within a clay matrix (Plate 5b,c,d). The latter form laminae with a gritty clotted appearance within muddy sediments.

Discussion: Siderite formation requires low Eh and high P_{CO2}, with iron concentrations exceeding 5% that of calcium. Such conditions are most common in fresh waters low in dissolved sulphate where the anaerobic decay of organic matter can produce the requisite reducing conditions without the formation of appreciable H_2S (Berner, 1971). The observed siderite occurs both within mud and clay, but more abundantly within porous, sometimes lignitic, silts and sands interbedded with muds.

Lithofacies B_2 is interpreted as estuarine in part and the presence of siderite probably indicates later diagenetic flushing by fresh groundwaters.

Sulphates

Sulphates are virtually non-existent within the sequence. Rozenite ($FeSO_4.4H2O$) was detected in trace amounts within pyrite replacement of bioturbation at 146.2 m (Appendix III), within Lithofacies D which is interpreted as a marine incursion.

Throughout the sequence, there are small efflorescences of a soft translucent mineral insoluble in dilute and concentrated hydrochloric acid. This is believed to be gypsum, and by its presence on drillcore surfaces, precipitated after drilling, probably from porefluids.

Discussion: Rozenite is considered a late alteration of pyrite, related to the efflorescences of gypsum within the sequence. Collectively, these probably reflect a high sulphate content of present groundwaters in these intervals from 101.5 down to 193 m.

Pyrite

Pyrite is ubiquitous as an eogenetic (early diagenetic) and a possible mesogenetic (late diagenetic) phase within the sequence, and is most abundant down the sequence to 274 m and present down to 382 m. This means a virtual absence in Lithofacies A_1, and only a trace presence in Lithofacies B_1, B_2, B_3, and C_1.

PLATE 5

Diagenesis

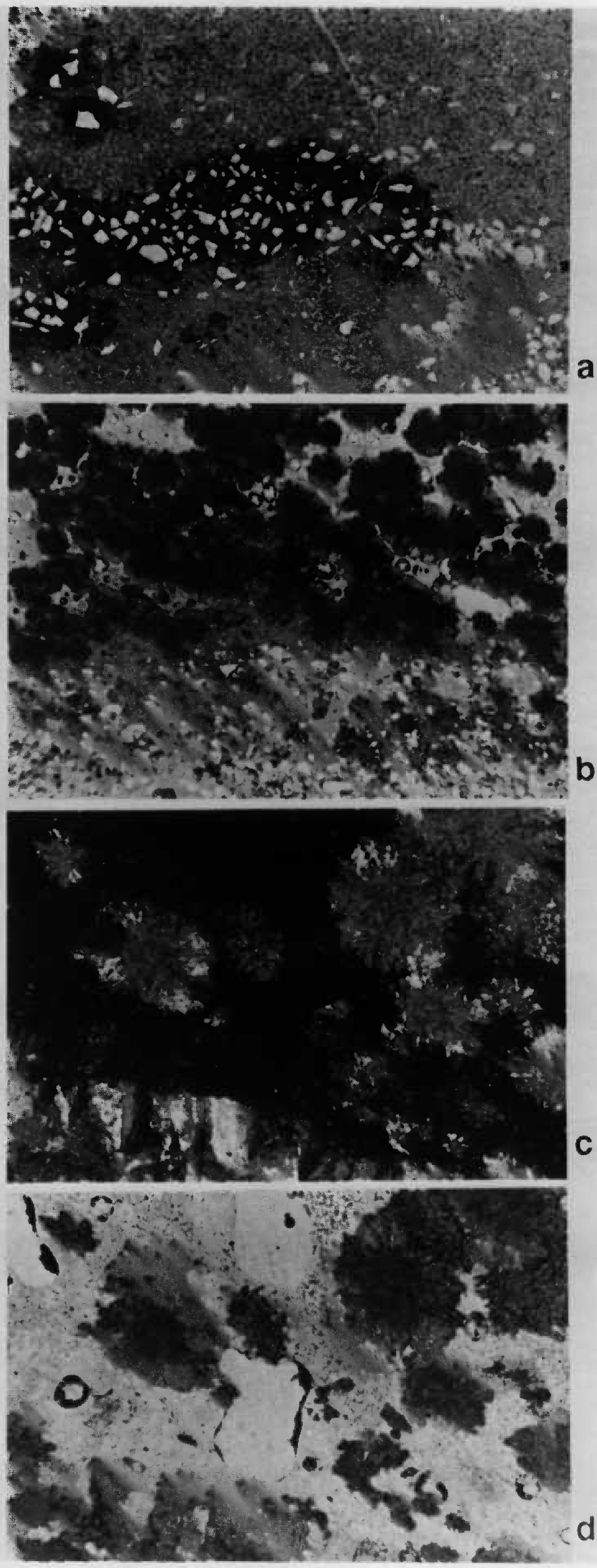
a Framboidal pyrite showing selective replacement in silt along sandier laminae. There is minor replacement of sand particles. Photomicrograph, plane-polarized light; field of view 8 mm wide; from 257.1 metres, Lithofacies B_4.

b Sideritic replacement as micro-rosettes within a clay lamina in a quartz sand. Photomicrograph, plane-polarized light, field of view 7.5 mm wide; from 341.28 metres, Lithofacies B_2.

c Enlarged view of (b) showing dusty nucleation sites and more limpid radial fibrous textures in rosettes. Photomicrograph, crossed polars; field of view 2.3 mm wide; from 341.28 metres.

d View of (c) in plane-polarized light.

DIAGENESIS



Eogenetic pyrite occurs as framboidal precipitation in and replacement of burrows, rootlets and rootlet traces, lignitic matter, leaves, wood, and foraminifera. Very fine disseminated occurrences are also probably eogenetic.

Small millimetre-sized to centimetre-sized spheroidal and ellipsoidal concretions occur between 241 and 382 m in compacted mud and muddy silt. These are distributed seemingly randomly within the compacted laminae with no observed obvious nuclei. Other concretions are more irregular and appear related to porosity variations within laminae (Plate 5a).

Discussion: The replacement of various biotic structures and remains indicates suitable anaerobic conditions in these micro-environments where detrital iron-bearing minerals were able to be solubilized by bacterial and inorganic processes.

That some pyrite concretions are spheroidal while others are ellipsoidal or even hemispherical with the vertical dimension the shorter, suggests that concretion growth occurred prior to and during sediment compaction under suitable reducing conditions.

Resinous Organic Material

Varying detrital carbonaceous biotic remains and accumulations are abundant within the sequence. In specific horizons, especially in porous sands, sand particles may be partly or completely coated in thin amber to thicker black resinous material. Often this is very thin but may be thicker and black at points of interparticle contact.

Resinous coatings are distinctively present in Lithofacies A_1 just above the basal unconformity, as well as in uppermost Lithofacies B_1 and lowermost Lithofacies C_1, within basal sands of sedimentation units which fine up to carbonaceous silty muds.

Discussion: These resinous coatings are usually associated with lignitic fragments or carbonaceous matter within the same sediment and it is considered that the resins have been mobilized only locally over a few centimetres. In the case of basal sands in Lithofacies A_1, it is probable that the stained sands indicate the remnants of or local mobilization from a former humic-rich soil horizon over the weathered granite.

Porosity

The sequence is predominantly very porous within the silt and sand and has remained very close to original interparticle porosity except where humic accumulations or muddier sediments have been compacted with burial. Cement occlusion of interparticle porosity is rare, occurring only in the sideritic intervals discussed under **Siderite**. Throughout many of the sands, thin cutans of varying thickness have been observed, usually where there is a transition into a muddier sediment.

Discussion: Because of the high porosity and permeability of most of the sand and silt in the sequence, invasion of the core by drilling mud may have produced these cutans as a drilling artifact. Where very porous sands were recovered, they were sometimes of a sugary texture because many of the finer particles were flushed out during drilling.

Paragenesis

The paragenesis of the sequence is relatively simple, with early pyrite precipitation and replacement in suitable micro-environments, followed by compaction and continuing pyrite replacement and precipitation. Local precipitation of siderite was limited to few environments. Apart from alteration of detrital feldspar to clays, and their possible modification with groundwaters, compaction, and minor, localized resin mobilization, there has been no other recognized diagenetic modification of the sequence.

CONCLUSIONS

1. The Renmark Aquifer is recognized in Hatfield-1 in the interval 101.5–427 m. The unit comprises laminated and cross-stratified unconsolidated to semi-consolidated sand; laminated and cross-stratified silt with minor muddy silt; silty peaty mud, and very thin traces of lignite.

2. Four lithofacies are distinguished; Lithofacies A – sand dominant; Lithofacies B – sand and silt intercalations; Lithofacies C – silt dominant; and Lithofacies D – mixed sediment types. Ten sub-lithofacies are differentiated on the basis of sediment and sedimentary feature differences.

3. Deposition of the Renmark Group was predominantly within fluvial environments, but with marginal marine, estuarine, and hyposaline swamp incursions. During the period of its accumulation, three small transgressive phases (as indicated by features in the sequence) imposed marginal-marine and ephemeral marine-related events. Periods of higher precipitation appear related to these transgressive events. Additionally, six brief ephemeral marine incursions have been recognized.

Specific environments interpreted are braided channels within alluvial slopes (Lithofacies A_1), coastal plain channels (Lithofacies B_1, B_2, B_3, and A2), levees (Lithofacies B_1, B_4,), crevasse splays (Lithofacies B_1, B_4, B_5, A_2), hyposaline swamps (Lithofacies C_2), interdistributary bay and lake (Lithofacies C_1), and estuary (Lithofacies B_2 and D).

4. Sand characteristics within the Renmark Group are ubiquitously quartzose, but significant patterns of accessory and trace components are suggestive of changing provenance/tectonics,and possibly climate. The pattern indicates a reverse-repeat sequence of conditions within the unit.

5. There has been only minor diagenetic modification of the sequence. Volumetrically, the most significant appears to be post-depositional alteration of detrital feldspathic components. Pyrite is a minor component but ubiquitous down to 382 m, occurring mainly as finely-disseminated framboids, but also as a mesoscopic replacement of lignite, bioturbation, and laminar porosity, and as small ellipsoidal concretions in the muddier sediments. Partial and complete induration is almost non-existent except for a few thin horizons of sideritic cementation.

6. Porosity has varied little since deposition. The finer sediments have noticeable but minimal compaction. Consequently porosity has been reduced moderately, in the order of 15% in the sand and silt, and possibly up to 30% reduction in muddy silt and mud. Only Lithofacies C_2 has marked fissility and significant compaction.

7. The sequence is believed to represent accumulation through the period from 40 Ma to 11 Ma, with a net sedimentation rate of 1.1 cm per thousand years.

ACKNOWLEDGEMENTS

Greg Sparksman provided core preparation and slabbing, as well as generously offering logistical support during study of the core. The discussions with Rob Langford over general trends and features of the core sequence were very helpful and much appreciated. Especial thanks are due to Jim Kellett and Campbell Brown for their overviews of the project and logistical assistance in the study. The author thanks Peter Ryan and Ken Heighway for their assistance in logistical matters. Arthur Wilson kindly provided assistance with preparation of the photographic plates. The text was edited by John Perry and Campbell Brown.

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APPENDIX I

DETAILED LITHOLOG OF BORE No.36675

EXPLANATION AND LEGEND

Format

The stratigraphic log is arranged in 9 columns, being from left to right:

1. Depth below surface in metres
2. Sampled intervals
3. Graphic litholog
4. Sedimentary structures
5. Macrofauna
6. Colour
7. Degree of induration
8. Lithological description
9. Diagenetic features

Scale

The scale on the left hand side indicates depth below surface in metres. Sample intervals are of 4 types:

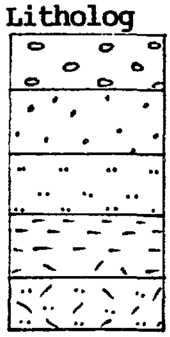
P Petrographic

X Mineralogic

MP/M Macropalaeontologic

uP/μ Palynologic

Graphic Litholog



conglomerate

sand

silt

clay

mud

weathered granite

calcareous

concretion

lignitic band

mud flake/clast

Gradational changes between lithologies have no line separating symbols as used for abrupt changes. Where the contrast is apparent but not abrupt, a dashed line is used for separation. Non-planar contacts are designated with relief and cross section comparable to their form.

Sedimentary Structure Log

Sedimentary structures are designated in graphic form in their relative orientation and abundance observed.

cross-stratification

lamination

cross-lamination

lamination with fining upwards of particle size

lamination with coarsening upwards of particle size

disturbed bedding

erosional surface

flaser structures

desiccation crack

slickensided cellular texture

parting lineation

erosional relief

ripple marks

herringbone cross-lamination

small lens

Bioturbation

variably-oriented small tubules ≲ 0.5 mm diameter

variably-oriented medium tubules and complex burrows, 1-2 mmD

large tubes ≥ 4 mm D

medium or large burrow with central mud trace

very large burrow, spreite, infilled by geopetal sediment

rootlets

Biota

Foraminifera, agglutinated

Shark teeth/denticles

Pellet

Plant material

compl complete leaf

Wood fragment

General subscripts

fr	fragment
gl	glauconitic

Colour

The colour of dry core is determined by visual comparison with the Geological Society of America Rock-Colour Chart, documented by both an abbreviated descriptive term and the numerical designation in square parentheses. Where the rock is variegated owing to bioturbation, lamination or speckled by coloured particles, the colour variations are qualified accordingly.

lt	light
dk	dark
m	medium
olv	olive
gy	grey
blk	black
grn	green
brn	brown
yel	yellow
red	red/reddish
pnk	pink
p	pale
mtl	mottled
intlmntd	interlaminated

Degree of Induration, Coherency

Eleven categories or combinations thereof are used to indicate the mechanical and textural properties of the dry core.

indrtd	indurated
frbl	friable
cmpct	compact
fiss	fissile
uncons	unconsolidated
crmbl	crumbly
slick	slickensided
waxy	waxy
plstc	plastic
cnchdl	conchoidal fracturing
sucrosic	sucrosic gritty appearance along broken surface

Lithological Description

The lithology is qualified by descriptive adjectives, indicating component particles, sedimentary structures, and their relative abundance (underlining - greater abundance, parenthesis - reduced abundance). Additional qualification of any component or structure is given in square brackets immediately following the feature to be qualified.

Most of the abbreviations used are standard BMR abbreviations. As a general rule of thumb, the abbreviation is derived by removing vowels. Abbreviated nouns are indicated by upper case and abbreviated adjectives by lower case.

Particle sizes are documented in accordance with the classification of Wentworth (1922).

```
mm
  256 -----------
                    cbl    cobble
  64 ------------
                    pbl    pebble
  4 ------------
                    g      granule
  2 ------------
                    vc     very coarse sand
  1 ------------
                    c      coarse sand
  0.5-----------
                    m      medium sand
  0.25----------
                    f      fine sand
  0.125---------
                    vf     very fine sand
  0.0625--------
                    slt    silt
  0.004----------
                    c      clay
```

Abbreviations for Lithological Description

ang	angular
biot	biotitic
Biotrbn	bioturbation
Bitmn	bitumen
calc	calcareous
Concrtn	concretion
Clay	clay
Cmnt	cement
cmpctd	compacted
desiccn	desiccation
discont	discontinuous
dissem	disseminated
dolmt	dolomitic
frctd	fractured
facetd	faceted
feldsp	feldspathic
Frgmnt	fragment
frmbdl	framboidal
glauc	glauconitic
horizntl	horizontal
incrsng	increasing
intbdd	interbedded
Intrclst	intraclast
intlmntd	interlaminated
lmntd	laminated
Lmntn	Lamination
lrg	large
Lignt	lignite
ligntc	lignitic
Mud	mud
musc	muscovitic
Mtx	matrix
Mdst	mudstone
mic	micaceous
mtl	mottled
Nodl	nodule
Nucl	nucleus
Orgncs	organic material
Oxdzn	oxidation
oxdzd	oxidized
Ptchs	patches
pel	pelletal
pol	polished
por	porous
pyrt	pyritic
Pyrt	pyrite
pebbl	pebbly

qtz	quartzose
Qtz	Quartz
rndd	rounded
repl	replacing
Replmnt	replacement
Snd	sand
slt	silt
subang	subangular
subsph	subspherical
srt	sorted
spckld	speckled
slick	slickensided
tn	thin
Text	texture
unif	uniform
vari	variably
Xlmntn	crosslamination

Diagenetic Features

These are generally recorded in the last column but, where necessary, follow the lithological description separated by colon or full stop.

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
97			≋ ʎ(≜)		yel gy [5Y7/1]	fiss crmbl	Snd, qtz [m-(c), ang-subang], feldsp, (biot), srt, cellular struct, root traces; intlamnd Slt + f Snd, alternations	
			≋ V ʎ	Q	yel gy [5Y7/1]	fiss	Slt, qtz [ang-rndd], crazed by rootlet penetration + m Snd infil	
			V ʎ brn		lt gy [N7]	cnchdl	Slt-Snd, f, qtz [ang]; alternating Slt, fiss, crazed	
					yel gy [5Y7/1]	fiss	Slt, slick; infill of cracks by m Snd; rootlets follow Snd	
100			(ʎ)		yel gy [5Y7/1]	crmbl cnchdl	Slt, qtz, unif; tn snd Ptchs, Snd, vc, qtz [milky, rndd], cL [pel]	
						(fiss)	Slt; Lmntn of Snd, vc [qtz, milky, rndd]; slick	Pyrt, frmbdl, ptchy in roots
	X ▶		(≡) (ʎ)brn	(Q)	pnk gy [5YR8/1]	(fiss)	Slt, qtz, srt, por	Pyrt
			V	Q	dk pnk gy [5YR7/1]	cnchdl	Slt, qtz, srt, por; (Snd [vc, qtz, milky]); cL Stringers; f Snd in cracks	
			(≡)		lt yel gy [5Y9/1]	(fiss)	Slt, qtz, (cL), (srt); (Qtz [c, rndd, milky])	
			(≜) (ʎ)			crmbl	Slt, qtz, (Snd [c, qtz]), (lmntd)	pyrt Rootlets
			≡ (ʎ)	(Q)	lt yel gy [5Y 7/1]	(fiss)	Slt, (intlmntd) Snd, vf, qtz, por	frmbdl Pyrt in Rootlets
101			ʎ brn		lt pnk gy [5YR9/1]	crmbl	Slt, qtz [m], unif	
			≡ ≜		dk yel gy [5Y7/1]	(fiss)	Slt, vf, unif; intlmntd Snd, qtz [vf]	Pyrt, frmbdl, in por Snd
			(≡)		lt yel gy [5Y9/1]	slick	Slt, qtz, srt, por	Gypsum? on partings
			≡ ≜		dk pnk gy [5YR7/1]	fiss	Slt, vf-c, lmntd c̄ tn light-coloured c Slt	
106			(≡) V ≜	(Q)	lt gy [N7], intlmntd dk pnk gy [5YR7/1]	(fiss)	Slt, unif; v tn intlmntd + craze-infill Snd, m, qtz [subang], slt, (srt)	
					dk m gy [N4] intlmntd	(fiss)	Slt, unif; v tn Lmntn of Snd, qtz [m, subang], peaty, (srt), fining upwards	pyrt Traces
					dk brn gy [5YR3/1]	hrdntd	Snd, vc, qtz [rndd-subang], peaty, cL, Slt, unif	
			V		lt yel brn [10YR 6/2]	(crmbl)	Snd, f, qtz [subrndd], (Slt), por, crazed; infill Snd, qtz, por, m-c	(pyrt Ptchs) in Snd
	P ▶				dk yel gy [5Y6/2]		Snd, f, qtz [subang-subrndd], (cl), srt, por. mud flakes and partings, + c Qtz incrsng downwards	dissem Pyrt
			≡ V V?		m gy [N5]	slick	Mud, mtl + intlmntd (Snd), f, tn stringers; slick, frctd; craze pattern infilled by Snd, f, qtz	(dissem Pyrt)
107								

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
145			2-3mm	Q incl	m gy [N5], mtl c lt gy [N7], p yel brn [10YR 6/2]	(frbl)	Snd, f, qtz [subang], (feldsp), por, vari labile, clasts overfilling crazed brn Mud, pyrtic, vari snd; infill of Biotrbn in Snd + Mud by snd, clean	frmbdl Pyrt in clay flakes
				Q			Snd, f, qtz, (feldsp), vari slt, pyrt, por; colour due to Biotrbn?	
				Q	gy blk, mdk gy, m lt gy [N 2,4,6]	frbl	Snd, f, qtz, (feldsp), vari por; discont Lmntn of Mud + peat; mud Clast v dk, odour	
	P					crmbl	Snd, f, qtz (feldsp), vari por, peat, mud; mtl by Biotrbn, infill Snd, srt, f, por intbndd Mud, Pyrt	(Pyrt); sulph odour
				P			Snd, f, qtz, (feldsp), vari por, peat, mud; mtl cl Clasts, zones of Biotrbn	pyrt Balls in mud; salt efflorescence pyrt Biotrbn; pyrt Pel; Gluc?
				P	m dk gy - m gy [N4,5]	(fiss) cnchdl	Mud, mtl, biotrbtd, vari slt infill; (intlmntd Snd), vf-slt; discont, cpctd	pyrt Biotrbn; oxdn halo in mud
				P	dk brn gy [5YR3/1]	fiss cnchdl		pyrt Pel + Biotrbn; oxdn halo along Biotrbn
146				P	dk brn gy [5YR3/1]	(fiss) cnchdl	Mud, biotrbtd, Ptchs pel, pyrt; tn intlmntd Slt - Snd, vf; lrg Biotrbn	pyrt Biotrbn; por by Pel
	M		P	α	mtl olv gy [5Y5/1]			gypsum? efflorescence on slick. pyrt Pel
					olv gy [5Y4/2] dk brn gy [5YR6/1]	crmbl	Slt, cl, snd [qtz, mdd, gran-vc, clear], mic, clast [slt, platy]	
			(0)	α sp?			intlmntd Slt, Snd, CL; Snd, f, qtz, por, srt; Snd, f, qtz, slt, (por)	pyrt Biotrbn [pentagonal c.s.]
148					dk brn gy [5YR3/1] m gy [N5]	cnchdl frbl	Slt, Snd [f, qtz, feldsp], colour lmntd; lrg Biotrbn infill by Snd, f, por	(Pyrt) in Snd
							Mud, Snd intlmntd; biotrbtd; erosional surfaces on mud	
					dk olv gy [5Y3/1] mtl		Snd; Mud; Slt; Snd, f, vari srt + por	
						crmbl	Snd, qtz [m, rndd], feldsp, slt, pyrt, unif; grading up to mud Bands.	
							Snd, qtz [m + vc, rndd, polished], bimodal, clast [angular, Mud]	(pyrt)
151					dk olv gy [5Y3/1] mtl m dk gy [N4]	crmbl cnchdl	Snd, qtz [f, subang + vc, rndd, pol], slt, peat; ligneous; mud Clasts.	dissem pyrt Ptchs.
				Q?	dk olv gy [5Y3/1]	cnchdl	Mud (snd), spckld ((snd)); oxdn halo around Pyrt	(pyrt Biotrbn/Biota)
					dk olv gy [5Y3/1]	crmbl	Snd, qtz [f, subang + vc, rndd], (slt), por; mud flakes	dissem Pyrt Cmnt

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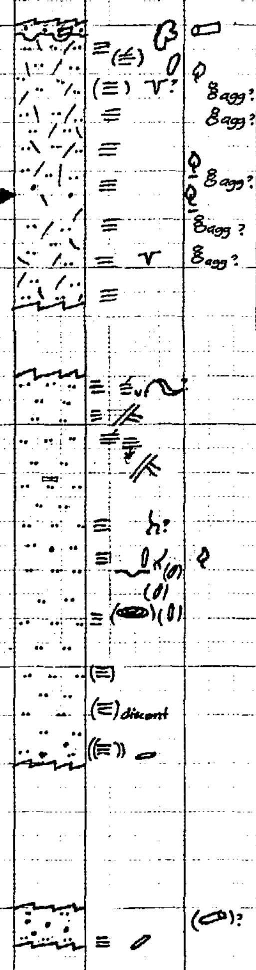

DEPTH metres	SAMPLE	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
190		brn gy [5YR4/1] intlmntd m dk gy [N4]	crmbl cnchdl	Snd; qtz [m; subang + vc, rndd, pol], (clast) [mud]; peaty Mdst ?, unif, faint Lmntn; v tn slt Lines define Xlmntn, Lmntn; peaty	pyrt-coated Clast; sulph odour; pyrt along Joints; oxdn Halos sulphate efflorescence ?
		↓ dk gy [N3]	↓ fiss	Mdst; slt Lmntn produce fissility; peaty	pyrt, dissem
					frbl Pyrt on parting Lmntn
	M ▶	gy blk [N2]		Mdst; vf Lmntn; v tn partings by frbl Slt; peaty	
		gy blk [N2]	(fiss)	Mdst; (Lmntn) by tn slt Partings; peaty	vf Plchs pyrt; white efflorescence
			fiss		
191		dk brn gy [5YR3/1]	fiss	Mdst, ~~vf Lmntn; v tn slt Partings~~; peaty	frmbdl pyrt Balls in Mud por pyrt Replmnt on Slt
193		dk brn gy [5YR3/1] c partings pnk gy [5YR8/1] brn gy [5YR5/1]	(fiss) cmpct	Sltst, qtz [veadish, ang], lmntd; xlmntd bands of lt coloured por Slt [flasered?] becoming more uniform, por, with parting lineation with depth	pyrt Balls [·1-·5mmD] on partings and in Mdst
		↓	cnchdl	Sltst, qtz, (mic), unif; parting lineation	
					pyrt Balls
			cnchdl	↓ some vc, qtz, rndd in Sltst	frmbdl Pyrt in 0·1mm vert tubes
		v faint mtl		alternating biotrbn Mtl + Lmntn	
		pnk gy [5YR7/1] (mtl) v lt gy [N8]	cnchdl	Slt, qtz, (musc); (vari) in Lmntn	frmbdl Pyrt in Balls
194					
				Slt, qtz [ang]; biot, (musc)	
			cnchdl		
			cnchdl	Slt, (vf Snd), qtz, mic, por	frmbdl Pyrt repl Biotrbn
196		dk yel gy [5Y7/1]	cnchdl	Slt, qtz [ang clear], snd [vf], grading down to Snd, vf, slt, (srt), por	
			fiss	Slt, qtz, por, c partings; Biotrbn infilled by vf Snd	

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
199			=	(Q)?	dk yel gy [5Y7/1]	crmbl	Snd, vf [qtz[subang, clear], (feldsp), (mafic), por; intbndd Slt, qtz, mic	
							Snd, f, qtz [subang], (mafic), por; intbndd Slt, qtz, feldsp, mic, mud	
205			(≡) (/)		olv gy [5Y5/1]; sl van toning m dk gy [N4]	cnchdl (fiss)	Snd, vf-slt, qtz, mafic, mic; intlmntd Slt, qtz, mafic + Biotrbn infill Slt, qtz; v tn discont partings; (Biotrbn) infill Snd, m, por, carbonaceous	(pyrt) Biotrbn
			(≡)		dk olv gy [5Y3/1]	slick cmpct	Slt, qtz; v tn fiss partings wavy + discont	Pyrt disem
			≡		dk yel brn [10YR3/2]	(fiss)	as above	
	P		≡	(Qpyrt)	yel brn [10YR5/2]	cnchdl (fiss)	Slt, qtz, (mic), (por); discont, v tn fissile partings	disem Pyrt in vf spheres pyrt replmnt of biota, oxdn Halo
206			≡ (≡)		lt olv gy [5Y6/1]	cnchdl crmbl	as above, (ligneous Lmntn)	(pyrt Replmnt) of Lmntn
208			≡		mtl lt gy [N6, N7] intlmntd gy blk [N2]	frbl	Slt, qtz [vf] mic, charcoal, uncons, por intlmntd charcoal cellular, brittle, crmbl Ptchs	
					brn gy [5YR5/1]	frbl	Slt, qtz [vf, reddish], (mic); por; grades down to v lt slt	
			((≡))		dk yel brn [10YR3/2]	frbl	Snd, vf [qtz][subang, reddish], unif, por, peaty	
			≡		gy blk	crmbl	Lignite Lmntn; intbndd ≡ Snd, qtz [subang, reddish]	
			((≡)) (≡)		p yel brn [10YR6/2]	powdery frbl	Slt, vf, qtz [ang], por, frbl, flaky; below ligneous bands incr. earthy, cellular disturbed structure	
209			= =		↓	frbl		

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
211					pnk gy [5YR7/1]	frbl	Snd, vf, slt [qtz, subang, clear], (srt); alternating c Snd or Slt, (lignitic)	
							Slt, qtz, unif, frbl; cL (Clast), lignitic Frgmnt	
					yel gy [5Y7/1]	frbl	Slt, qtz [subrndd]; tn discont Lens, Lmntn of vf Snd; cf cryptalgalaminite; (waxy peat? Flakes)	(pyrt Replmnt)
					yel gy [5Y7/1]	frbl	Snd f qtz, srt, loadcasted over CL/Mud	
					dk brn gy [5YR3/1]	fiss	lignitc Lmntn in Mud	
					flecked blk, yel gy [5Y7/1]	frbl	Slt, vf, faint Lmntn discont c wisps Peat; regular tn mud Lmntn	
					dusky brn [5YR2/2]		Snd, f, (vc), qtz, over eroded soil? surface	
					mntd p yel brn [10YR6/2]	cmpct	Int lmnd Mud [soil?], lmntd lignitc Frgmnts; tn lenses of frbl por Slt	
212			faint?		v p yel brn [10YR7/1]	frbl	Slt, qtz [equant, subang, clean], mic, flaky peat	(pyrt Rootlet?)
					v lt gy [N8]	frbl	Slt, qtz	
					v lt gy [N8]	frbl	Slt, qtz [vf, ang, clean], mic, (mafic), srt	
			?					
					pnk gy [5YR7/1]	frbl	Slt, qtz [vf], biot, musc, lignt	(pyrt Replmnt wood Frgmnts)
								(Pyrt) c oxdn halo
214			discont		pnk gy [5YR7/1]	frbl	Slt, qtz [vf, clean, subang, equant], (mafic); unif; subvert lignt (Roots)	pyrt Replmnt of wood
			aggrad				faint mtl Fabric [: Biotbn? or discont Lmntn]	
								efflorescence - gypsum? on outer core surface
							Slt, as above	
						cnchdl		
215						cnchdl	Slt, qtz [vf, clean, equant, subrndd], ((CL)), (lignitc Frgmnts)	(pyrt Replmnt small lignitc Frgmnts
					lt gy [N7]		Slt, qtz, musc; Lmntn from colour, not particle size changes	

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR		INDURATION	DESCRIPTION	DIAGENESIS
217			≡ (||)		olv gy faint Varn	[5Y5/1]	(fiss)	Slt, q13, (snd [f]), (Lignt), mic; intlmntd Snd, f-vf, [q13]; (por)	(dissem Pyrt)
					lt gy	[N7]	frbl	Slt, q13, uni, srt, por, 6	
			15° <<<		lt gy	[N7]		lignt Fragmnts define discont Lmntn + lens	
					yel gy	[5Y7/1]			pyrt Lignt
			discont					Slt, unif, lignt frgmnts, wax flakes aligned on Lmntn; cf cryptalgalaminite	
			(≡) clotted		pnk gy	[5YR7/1]		increasing Lignt with depth up to 2%	pyrt Replmnt Plant, Lignt
218			≡						
			≈		pnk gy	[5YR7/1]		Slt, as above; clotted, faint mtl Fabric ē disrupted Lmntn	pyrt Replmnt rootlet Margins
			vert				↓		
219									

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
223					yel gy [5Y7/1]	(fiss)	Slt, qtz [vf, subequant], (mafics), (musc); frbl, por; intlmntd Slt, Md	(pyrt Rootlets)
						cnchdl	desicn. Cracks infilled by Snd, Slt, and sst Pbbl	
							Snd, vf, qtz, feldsp tr intercalations c̄ Slt. thick earthc̄ lignite Matrix	
						cmpct frbl	Snd, f, qtz, grading down to Snd; vf, qtz [subang], feldsp, (mafic), por	
					yel gy [5Y7/1]	v frbl	Snd, vf, qtz, (mafic), por	
224								
							Snd, vf, qtz [subang], -slt, por ; vari sized Slt to f Snd in individual Lmntn. Occas md Snd [rndd]	((pyrt)) dissem
							(lignite Fragments)	
225					yel gy [5Y7/1]	frbl	Slt, qtz, mafic, (srt), snd ; intlmntd Snd, qtz, vf, (lithic), (mafic), srt	
					dk brn gy [5YR3/1]	cnchdl	Mud, slick, lignite Inclusions; vari qtz snd Ptch; slick	
226					lt brn gy [5YR6/1]	frbl	Snd, m, qtz [ang], (mafic), ((lithic)), srt, por	
						cmpct	intlmntd Snd [as above], Md Clasts over Mud	

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DEPTH metres	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
232	brn gy [5YR5/1]	frbl	intlmntd Slt, Snd, vf, qtz[subang], (mafic), (musc), lignte frgmnt, clast[slt]	
		cmpct	Slt, (snd), lmntd; (Snd), f, qtz intlmntd	
	yel gy [5Y7/1]	frbl	Snd, f, qtz [subang], (mic), (mafic); srt, por; (biotrbtd), infill by same snd minor mud flakes [horizntl, crazed] increasing	Ptchs dissem Pyrt
	olv gy [5Y5/1]		distinct intlmntn Mud, Snd, f, qtz	dissem pyrt in Snd
			Slt, qtz, (mafics), (snd), unif; faint lmntn, (disturbed)	
		cnchdl		
233	lt olv gy [5Y6/1]	cnchdl	Slt, qtz[vf], (cl); colour lmntn	dissem Pyrt pel Pyrt infill vert Biotrbn [1½mm D]
		cnchdl	Slt, cl, qtz[vf]	
		cnchdl	Mud; oxd3d leaf + plant impressions horizntl aligned	
234				
238	yel gy [5Y7/1]	cmpct (fiss)	Slt, qtz[subequant], mafics; scattered sm lignte Frgmnts downward incrsng size + abundance of lignte Frgmnts	(dissem Pyrt)
		cmpct	((qtz[m; rndd, pol]	(pyrt Replmnt) wood; oxdn Hdo
	yel gy [5Y7/1]	cmpct frbl	Slt, qtz[subequant]; Snd[qtz, f-m, ang - rndd]; intlmntd Snd, vf, qtz, por	
	m dk gy [N4] intlmntd olv gy [5Y5/1]	(fiss)	Slt, qtz, mic, ((cl)), peat?; intlmntd + lenses of Slt-Snd, vf intlmntd Snd, vf-m, (srt), frbl	Ptchs pyrt Replmnt
				frmbdl pyrt Spheres
239	dk brn gy [5YR3/1] intlmntd pnk gy [5YR8/1]	(fiss)	Slt, qtz, mic, cmpctd; vf intlmntd Slt, frbl, vf.	

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
241			(≡) ≡		brn gy [5YR4/1] tn intlmntd pnk gy [5YR 8/1]	fiss	Slt, qtz [vf], mic, (cl), peat?; intlmntd Slt, qtz, srt, por, frbl as v tn partings, lenses	(sm pyrt Spheres) ↓
			≡			fiss		
			≡ (≡)		dk brn gy [5YR3/1] intlmntd lt brn gy [5YR 6/1]	fiss ↓	Slt, as above, cl; intlmntd Slt, qtz, mic, frbl, por	frmbdl pyrt Spheres ↓
							minor (carbonaceous partings)	tabloid, ellipsoid pyrt Concrtn [pelleted]
242			(≡) disc ≡ disc		brn gy [5YR4/1] c pnk gy [5YR 8/1]	crmbl	Slt, qtz [vf], mic, frbl; colour lmntd Partings	(sph pyrt concrtn)
			≡		brn gy [5YR4/1] pnk gy [5YR8/1]	fiss frbl	Lmntn disturbed; Biotrbn?; humic content [peat]?	
					pnk gy [5YR 7/1]	(frbl)	Snd, qtz [vf, subrndd] – Slt, mic, (lignite fragments)	
			≡ ≡				Lmntn incrsng downwards	
244			(≡)	decr	v lt olv gy [5Y7/1]	frbl ↓	Slt, vc, qtz [subeq, subrndd – subang], (mafic), (mic); Snd, vf, lignite	
			(≡)				decreasing plant fragments ↓	
							Slt, unif	
			≡					
			≡		grn gy [5Y6/1]	fiss/ frbl	Snd, f, qtz [subang], (feldsp), ((mic)) por	dissem Pyrt in por
247					grn gy [5Y6/1]	frbl	Snd, f, qtz [ang, clean], (feldsp), (lithic) ((mafic)), mic, por	

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
250					dkbrngy[5YR3/1]mtl lt brngy[5YR8/1]	fiss	Mud(st), slt, qtz[vf], mafics, mic, humus?; (f lmntd); Biotrbn [1-2mmD, subhoriz, infill by Snd, vf, qtz[clean], frbl; increasing Mic+ lignt Frgmnts[rndd] on partings; blk Mud infill desiccn Cracks	pyrt spher Concrtns in Mud; pyrt Spheres
						fiss	Mdst, vf lmntd, sm Biotrbn restricted to few partings where prolific ± lignt + Mic restricted to specific partings	(Pyrt)
								pyrt Replmnt of lignt Frgmnts
	P					fiss	Mdst, grummous horizons; prolific vf lignt Frgmnts; Forams in Mud	pyrt Concrtns[spher]
251						fiss slick	Mdst, cl, vf slt, mic; fewer slt Partings; reduced lignt Frgmnt	
						fiss		
					dk brngy [5YR3/1] vtn plchs lt brngy[5YR6/1]		Mdst, cl, vf slt, mic., foram; increasing slt size in partings	
253					m lt gy [N6]	frbl	Snd, vf, qtz[subang, clean], slt, mic, (feldsp), lignt; lrg vert Rootlet; incrsng lignt + leaf Frgmnts	pyrt Replmnt of Rootlets
					dk pnk gy [5YR7/1] lignt band m lt gy [N6]		Snd, vf, qtz [clean, subang], lignt [sm], biot, musc; Lmntn defined by lignt Frgmnts	
					dk pnk gy [5YR7/1] lmntd m gy [N5]		Snd, vf, qtz, lignt[v-sm], musc; Lmntn discont, disturbed by drilling; fn Xstratifn – thck Xlmntn; v fn slt bands between sets	
254								

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
256			2-3mm		dk pnk gy [5YR7/1]	cmpct	Slt, vf, qtz, biot, musc, lignte [v sm]; tn Xsets – Xlmntn [convex Strahfen]. Biotbn [horiz 2-3mmD] confined to specific Lmn	
			2cm					
					dk pnk gy [5YR7/1]			
257					dk pnk gy [5YR7/1]			
	P;X						Slt; (m qtz); lens in Snd + heavy minerals	pyrt Cmnt in Snd stringers
			4cm set steep		speckled lt gy [N7]	frbl	Snd, f-m, qtz [subang], (feldsp), mic, heavy minrl, (lithic), srt; por;	dissem pyrt Cmnt
			faint		olv gy [5Y5/1]	frbl	Snd, c̄ peat-rich Partings; Lmntn of peat/snd	
259					dk yel gy [5Y7/1]	cmbl	Snd, vf, qtz, (feldsp), (mic), (lignte), lignte rich Lmntn	(pyrt Cmnt)
			1-3cm sets				Slt (lignte) Lmntn	
							Snd, vf lignte Fragmnts [v sm, rndd]	
					olv gy [5Y6/1]		Slt, vf Lmntd; (biotrbtd)	
						(fiss)		
					lt brn gy [5YR6/1]		Slt, vf, qtz, (musc), (biot); Lmntn discont – biotrbtn? thixotropic disruption	
260								
				sm	pnk gy [5YR7/1]	hard	Snd, m, qtz [rndd, pol]; tn stringer	pyrt Cmnt contact
					lmntd brn gy [5YR4/1]	frbl	Slt, c, qtz [rdd], musc, lignte, peat?; desictd Peat infill by vf Slt	
				sm			lignte/peaty colour Lmntn	
			2mm	v.sm			Biotbn [2-3mmD], infill clean Slt]	
			4mm		pnk gy [5YR7/1]			
			4mm		pnk gy [5YR7/1] intlmntd brn gy [5YR4/1]		Slt, qtz, mic, lignte [f]; lignte Lmntn; infill of Biotbn + Desicn by clean Slt	
261								

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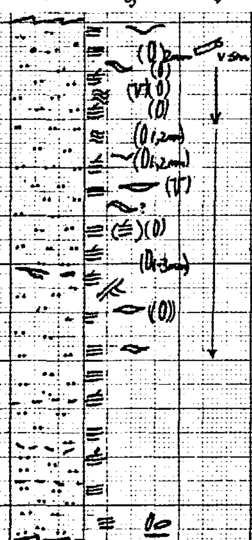

DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
262					lt gy [N7], intlmntd brn gy [SYR5/1]	frbl	Slt, qtz, feldsp, mic [musc], lignte [v sm frgmnts], mafic, snd [Vf]; lmntd by lignte Varns; Biotrbn infil Slt, qtz, srt	
					brn gy [SYR5/1] intlmntd pnk gy [SYR7/1]	(fiss) frbl	Slt, qtz, feldsp?, mic, peat?, lignte [slt - f Snd sized]; distinct lens + Lmntn; lt coloured Slt, fri partings	
							Slt; lmntd, flaser?; continuous dk Lmntn cnpctd; lt Lmntn discontinuous or Vari sized	
					dk brn gy [SYR3/1] intlmntd pnk gy [SYR7/1]	fiss		
263						frbl-Cmpct	Md, qtz, mic, peat, (lignte) cmpctd, dk Lmntd; intlmntd Slt, qtz, lignte, mic, por, frbl; Lenses, LMntn vari geometry + thickness	
						fiss, frbl		
								((pyrt frmbdl Carctns))
264							Slt, unif, qtz, mic; no Lignt.	

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
268	μ ▷		(≡)	8agg Q: 8 agg	dsky brn [5YR2/2]	fiss/ hard	Slt st, gl3, musc; (cl), (peat?) [lmntd), Forams clustered c̄ leaf traces rndd wh slt Clast; resin Ptch	Pyrt Concrtns [ellipsoidal]
			≡ V V			fiss	decreasing Musc. increasing Musc in partings	
			≡				spher Clusters Forams Sltst Clasts in frbl slt Partings	frmbdl Pyrt Pellets
			≡ V	Q 8 8	dk brn gy [5YR3/1] intlmntd olv gy [5Y5/1]		Slt, frbl partings	pyrt Concrtns [sph, hemisph]
269			≡					pyrt Concrtns + partings
			≡ 0	(8) O̸ fr?	olv gy [5Y5/1]; partings pnk gy [5YR7/1] dsky blk [5YR2/1]	cmpct slick	Slt, gl3 (musc), (cl); tn frbl slt Partings Breccia of slt Mdst [lmntd]; blk greasy slick surfaces	As? pyrt Ptchs in breccia
			≡ V V	8 (8)	brn blk [5YR2/1] lt brn gy [5YR6/1] partings	(fiss)	Slt, gl3, (musc), (cl), peaty; frbl slt Partings; crazed Lmntns, infill by blk Mud	(pyrt)
			≡ (V)	8		fiss	Sltst, gl3, (cl); peat?; foram-rich Partings, minor slt cmpctd	
	▶▶		≡ (V)	8		fiss		pyrt Concrtns c̄ Forams in partings
270			≡ V	↓		fiss	mud infill of desiccn Cracks; layers of Clasts [frbl slt]	
			≡ V	8		fiss	basal Snd, f, pyrt stringers, (srt), por; intlmntd Slt [as above]	pyrt Concrtns in Snd
			≡		dk brn gy 5YR3/1		Slt, gl3, (mic), cl, peat?; partings frbl slt, snd	
271			≡	(⊘)	brn gy [5YR4/1]; parting olv gy [5Y5/1]	cmpct	Slt, gl3, lignt, musc, (cl); fnt lmntd; tn partings Snd, gl3 (feldsp), musc, lignt, (srt); incrsng slt heavy mineral Ptchs	
	X ▷		≡ (⊘)			fiss		pyrt frmbdl dissem in por
			≡				Snd, gl3, musc, tn bed; parting lineation	
			≡	(⊘) (⊘)	brn gy [5YR5/1] intlmntd pnk gy [5YR7/1]	(fiss) frbl	Slt, gl3, musc, (lignt); lmntd partings Snd, vf, gl3, musc, lignt Snd, gl3, mafic, (musc), srt, por; intlmntd Slt increasing snd lenses	(frmbdl Pyrt in Biotrbn)
			≤ lignt					Ptch (dissem pyrt)
272			≤		brn gy [5YR4/1]; slt intlmntd olv gy [5Y4/1]	cmpct	Snd, gl3 [as above], lignt, frbl, parting lineation; Lmntn grdtnl to slt	dissem Pyrt in Snd in Biotrbn
			≡					
			≤ (⊘)					

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
274					lt olv gy [5Y5/1] mtl	frbl	Snd, vf-f, (srt), qtz [subang, equant], (feldsp), (mafic), lignt	
							— lrg lignt Root and Frgmnts; vari resinous colour to sand	
							— fn slt intLmntn	
							— lenses snd, slt, flasered?; Snd infill rootlet Casts	
					colour Lmntn		Snd, vari vf-f, (graded), lignt [lrg flakes]; snd infill root casts	
							Snd, slt Snd intbndd, intlmntd	
							Slt – vf Snd, lmntd under erosional surface	
					lt olv gy [5Y6/1] v faint mtl		Snd (srt); slt, Clast [lignt	
275							Lmntn defined by f lignt concentrations	
277				vf	dk brn gy [5YR3/1] c partings pnk gy [5YR7/1]	crmbl / fiss	Slt, qtz, mic [vf], peat?; Lmntd; intlmntd	
							Slt, qtz, mic, lignt, xlmntd; intbdd Snd, vf, qtz, por, lignt	
			faint		olv gy [5Y5/1]	frbl	Snd, qtz [equant, ang, 'rusty'], (feldsp), (mafic), srt, por, unif	
					dk brn gy [5YR3/1]		Slt, unif	
					olv gy [5Y5/1]		Snd, as above, c fn lignt Lmntn	
					dk brn gy [5YR3/1] c pnk gy [5YR7/1]	fiss	Slt, qtz, mic, peat?; vari vf snd content; intlmntd Slt/Snd	
							Slt, as above; vari biotrbtd	
278								
283	X				brn gy [5YR5/1] c partings v lt gy [N8]	cnchdl / frbl	Mud, slt [qtz], cl, musc; lignt	
							Slt, qtz, musc	dissem Pyrt in frbl Slt
							Snd, f, qtz [equant, clean], musc, lignt partings; intlmntd Mud	lignt Lmntn pyritized
					brn gy [5YR5/1]		Snd, f, qtz [equant, subrndd]; mafic [heavy mineral] rich Lmntn	
			faint					
					brn gy, v lt gy partings	fiss	Mud, slt partings; Snd, qtz, lignt intlmntd	
					lt brn gy [5YR6/1]	frbl	Snd, vf-f, qtz [equant subang], (feldsp), (mafic), srt, por	
284						fiss / frbl	Mud, lignt; Slt, frbl; Snd, f-vf, (lignt) intlmntd	
						fiss		
					brn gy, lt gy, lt brn gy	frbl / fiss	intbndd Snd; vf-f, qtz, (mafic); srt; and intlmntd Mud; Slt, lignt Snd	

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289					olv gy [5Y4/1] intlmntd pnk gy [5YR7/1]	fiss- cnchd	Mud, Slt, frbl ; Snd [frbl] lenses + intlmntd. Musc ; lignte Frgmnt [sm, fresh] in Snd	dissem pyrt Ptchs in Snd
					lt brn gy [5YR6/1] c brn gy [5YR5/1]	frbl	Snd, f, qtz [subrndd], (lithic), (mafic) [heavy mineral]; lignte Lmntn vari lignte - slt Clasts ; (fn mud Lmntn)	
							Snd, f-m, qtz, lignte, clast [flat, mud]; (Lmntn c mud Clast)	
290							Mud, slt	
295					lt brn gy [5YR5/1] brn gy [5YR4/1]	frbl	Snd, f, qtz, heavyminerals, srt, por; lensed, intlmntd Slt, (cl), lignte. Slt, Mud, lignte, intlmntd. Snd, f-m, qtz, slt Clast ; bleached Ptchs ; intlmntd lignte Slt	
					lt olv gy [5Y6/1] Ptchs pnk gy [5YR8/1]	frbl	Snd, f, qtz [rndd, subsph], (heavy mafics); srt; bleached Ptchs ; intlmntd Slt clast [lignte slt] (fn slt Lmntn)	
301					brn gy [5YR5/1] brn blk [5YR2/1]	cnchdl	Slt, qtz, mic, lignte [v.sm], cmpctd, unif. Slt, v. lignte, resin ptchs ; v. bleached rndd cl Clasts ; grading down to intlmntd slt - Snd c	pyrt Replmnt of Lignt
			cracked		pnk gy [5YR7/1]		Slt, Mud, lmntd ; intlmntd Slt Ptchs ; cracks Lignt Infilled Lmntn of slt Clasts, lignte Frgmnts ; lignte Rootlets	
					pnk gy [5YR7/1]	frbl	Snd, vf, qtz [subang], (feldsp), (mafic) [heavy], lignte, por	
302							increasing slt Intlmntn	

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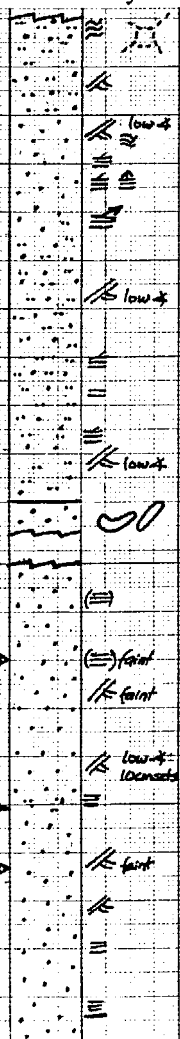

DEPTH metres	SAMPLE	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
337		dk yel gy [5Y7/1] brn gy [5YR5/1]	cmpct	Slt (c Snd) [pol rndd qtz], lignte, (musc) ; scattered f Snd, carb	
		yel gy [5Y8/1]	(fiss) (frbl) (fiss)	Snd, vf, qtz [subang], pel [glauc], (feldsp), xlmntd (graded Lmntn) [basal f Snd to Slt [qtz, glauc] at top	glauc Pel ; (dissem Pyrt)
					(f–m sized pyrt Concrtn)
338				intlmntd vf Snd + Slt 'varves'	
				Slt, vf, ((cl))	
					pyrt Concrtn
339		yel gy [5Y8/1]	frbl	Snd, f, qtz [ang-submdd, clean], (feldsp), (glauc), (mafic), Slt ; lrg Biohbn sl colour mtl	
340		yel gy [5Y8/1] (speckled)	frbl	Snd, f, (Slt), qtz [subang, subsph], (feldsp) [grn, wthrd], ((musc)), (srt), (por) (mafics) [v frsh],	feldsp : altered to glauc ?
	X ▷			[Stratifcn defined by conc. of heavy Minerals]	
		yel gy [5Y8/1] (speckled)		Snd , ncrsd feldsp content ; Lmntn defined by incr Slt, colour	Ptchy poikilotopic Cmnt Ptch up to 5mm. siderite
341	X ▷				
	P ▷				Lmntn of siderite (yel).
		yel gy [5Y7/1]		Snd, f, (srt), qtz [ang, clear], feldsp [grnsh], biot, por	
		p grn yel [10Y7/2]		Snd, f, srt, qtz, feldsp, biot, heavy minerals [~0.5%] por	
				grn colour Lmntn	
342					

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
342					yel gy [5Y8/1]	cmpct (frbl)	Snd, vf, qtz [subang - subrndd], mafic [1%, heavy minrl conc. in Lmntn], feld, por	
			faint			frbl		
			faint				– (fn slt Snd Intlmntn)	
							– phlogopite ?	
343					yel gy [5Y8/1]		Snd, vf, qtz [equant], (feldsp) [wh, grn], mafic, phlog, (srt), por	
			sm festoon					
			lrg med					
			mod					
							– Xstratifn by varntn in phlog + yel feldsp	
344								
	X						– heavy mineral Concntrn in base of sets	
			strat					pyrt Sph Concrtn
								(frmbdl pyrt Concrtn in Slt)
345			aggrad		ltolv gy [5Y7/1]	cmpct	Snd, vf, ± Slt intlmntn; lignt Lmnts, aggrad Xstratifcn	((pyrt Concrtn))
							intlmntd Slt – vf Snd, qtz, (feldsp), (musc), lignt; tn Xsets	
			low					(pyrt Replmnt in Ptchs)
			varve-like					
						(frbl)	– biotrbtd Lmntn	
			steep					(frmbdl pyrt Replmnt in Ptchs, bases of Xstratifn)
346							– lignt + charcoal Frgmnts	

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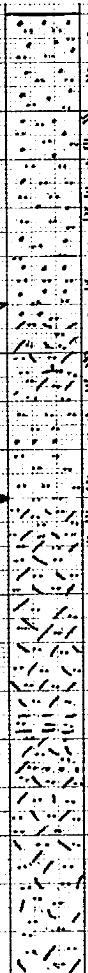

DEPTH metres	SAMPLE	SED. STRUCTURES	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
346			lt bl gy [5B8/1]	cmpct	Snd, vf, qtz, (feldsp), (musc), intlmntd Slt, (cl), musc	scattered vf pyrt Concrtns
		(0?)				(dissem Pyrt in Por)
		fn lowd (0)			– leaf Frgmnts aligned c Lmntn	
				(fiss)		
		(0) (0)	lt olv gy [5Y7/1]	indrtd	Snd, xlmntd, lignte, gradtnt upto cl Slt; biotrbtd erosional Bases of Sets	cmntn by siderite dissem Pyrt
347	MiPD					Cmnt [siderite]
		0		cmpct	– intlmntd Mud, carb, cmpctd, (biotrbtd)	
				Indrtd	Slt, qtz, (musc)	dissem pyrt, dol? Cmnt?
			pnk gy [5YR7/1]	cmpct	Slt, qtz, (musc)(lignte), (cL)	
					– fn intlmntd Snd, f, qtz, (feldsp), (musc), slt, (sdt)	
348	X	(0)		cnchdl		
			lt olv gy [5Y6/1] intlmntd yel gy [5Y8/1]		Mudst, slt, cl, Lmntd; fn Lenses, Partings pyrt Slt [Frbl]. – varve-like colour alternation	dissem pyrt in Lmntd Slt oxn. Halo
		unif	m lt gy [N6]		Mudst, unif, cl partings	
349			olv gy [5Y5/1] intlmntd yel gy [5Y8/1]		Mdst, lmntd; intlmntd Snd, f, qtz, (feldsp), (mafic), Frbl, por, yel gy	
			lt olv gy [5Y6/1] intlmntd yel gy [5Y8/1]	slick cnchdl	Mdst, vf, lmntd [colour], slt, cl, mic, (mafic)	
350						

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
350			colour		lt ol gy [5Y6/1] intlmntd dk gy [5Y5/1]	cnchdl	Mdst, unif, colour Lmntd	
						(fiss)	– tn slt Partings, (frbl)	
					brn gy [5YR5/1] (intlmntd) pnk gy [5YR8/1]	cmpct	Sltst, (cl), qtz, (musc), lignite [v sm Frgmnts]; tn frbl Slt Lenses, biotrbtd	
351							– increasingly carbonaceous	
	μP ▶		disc		brn gy [5YR4/1]	cmpct	Slt; v. tn flasers? [differentiated by vari cl/carb content]	
	P ▶				lt brn gy [5YR5/1] brn gy [5YR4/1]		– intbndd, lt coloured, biotrbtd, Slt ± dk carb Slt; flasers?	
352			faint		m lt gy [N6]	fiss. cnchdl ((fiss))	Mdst, unif, colour Lmntd. Sltst, cl, qtz, musc, carb?; por	
							– vari cl content; sl colour Lmntn	
						(fiss)	– v. regular colour Lmntn; flasers? [wispy colour Lmntn]; por	
					lt gy – m lt gy [N7, N6] colour Lmntn			
353							– fining-up cycles of basal frbl musc Slt, to mud Slt, to Mdst	
					m lt gy – lt gy [N6, N7] colour Lmntn		Sltst, cl, qtz, musc	
							– Increasing tn Partings, Lens of frbl por Slt	
					brn gy [5YR5/1]		Sltst; (cl), qtz, por; discont wavy Lmntn	
	X ▶							
354								

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
354					brn gy [5YR5/1]	cmpct (fiss)	Slts t, gl3, musc, (cL), carb?, vtn discont Lmntn [Flasers?].	
					brn gy [5YR4/1] intbdd lt brn gy [5YR5/1]		– discont Lmntn [Flaser?], sm, vtn	black scummy residue on wet core – carbon / hydrocarbon / resin?
355					brn gy [5YR4/1]	cmdtd	Sltst, c, gl3, musc, (cL), rusty? [carb?]	resin residue?
							– sloping erosional surfaces + reworked plastic slt Clasts less carbonaceous bands	
						fiss		
							– v tn slt, gl3, frbl, por, partings, discont, wispy	resin? residue
356						(fiss)	– spreite biotrbtn [possibly not flasers!]	pyrt Replmnt in Biotrbn
							– increasing slt Partings, [frbl], gl3, c, pnk gy	
					pnk gy [5YR8/1] intlmntd dk pnk gy [5YR7/1]	crmbl	Slt, c, gl3, musc, por, vari coloured; intlmntd; spreite Biotrbn – (intlmntd) lignite-rich Slt + peaty flakes	
					lt gy [N7] mtl [biotrbn]	frbl	Slt, c, gl3, musc, por, unif, (cL), skt	((pyrt Concrtns))
357					gy brn [5YR5/1]	Cmpct	Slt, c, gl3, musc, por, biotrbtd	
							– well defined Lmntn + Biotrbn.	
						crmbl		pyrt Replmnt of Biotrbn.
						(frbl)		
	μ				gy brn [5YR5/1] pnk gy [5YR8/1]	mdrtd ↓ crmbl frbl	Slt, f, gl3, (cL), (musc), unif – lignite rootlets in situ, bleached like a seat earth.	
358								

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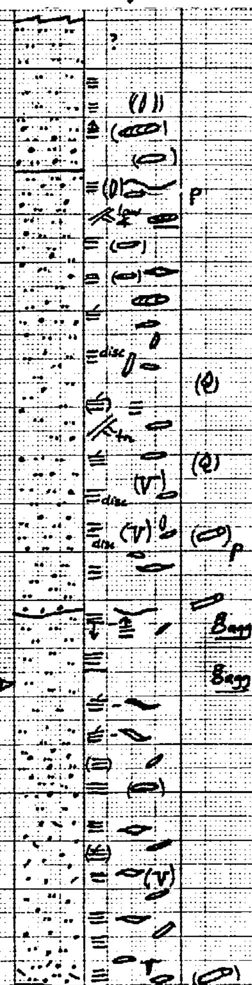

DEPTH metres	SAMPLE	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
361		pnk wh [5YR9/1]	frbl-uncons	Slt, (cL), qtz[vf], musc; por	
				-(v tn lenses of vf-f qtz Snd intlmntd)	
				grading in Lmntn from basal vf qtz Snd upto vf Slt	
				-increasing Snd Lenses	
		lt brn gy [5YR6/1] intlmntd pnk gy [5YR7/1]	cmpct	Slt, qtz, pel[oxdzd Glauc], musc, (cl), lignt, por; biotrbn Infill + Intlmntn of Slt - vf Snd, qtz	dissem Pyrt; pyrt Biotrbn
				- Biotrbn decreasing	
362					pyrt Replmnt of Biotrbn
				-(vf Snd + Slt partings (intlmntn); biotrbn infill)	
				- Infill of desiccn Cracks by vf wh Slt	
363				- Snd lens; pockets of glauc Pel in Biotrbn	
		brn gy [5YR3/1] intlmntd lt brn gy [5YR6/1]	(fiss)	Slt, qtz, musc, ((cL)), humic?; v tn intlmntn by slt Partings gives varved appearance	
	μP		cmpct	gradational	pyrt frmbdl Concrtn [spher, 4mm]
		brn gy [5YR4/1]		Slt, qtz, musc, (cL), (carb?), (srt); tn lenses, flasers? of Slt, srt, frbl	
364		brn gy [5YR5/1]; partings pnk gy [5YR7/1]		Snd, vf, qtz, musc, (cL), slt, (srt), por; tn partings of Slt, vf Snd, por	
				- Biotrbn & geopetal infill	
			(fiss)		
365					

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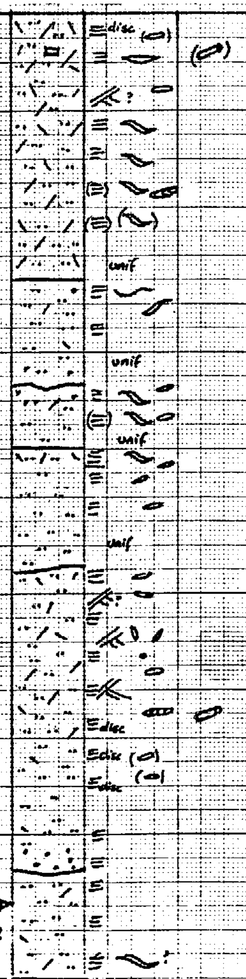

DEPTH metres	SAMPLE	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
365		brn gy [5YR5/1]	(fiss) cmpct	Mud, cl, slt [qtz], musc, carb; ((v.tn lnt/lamtn)) of Slt, fdbl, c.qtz, por	
				Slt, cl; z intlmntd Slt, qtz, musc, fdbl, por as flasers?	
		brngy [5YR5/1] intlmntd pnk gy [5YR8/1]			
366		brngy [5YR5/1] intlmntd pnk wh [5YR9/1]	cmpct	Slt, c, snd [vf], qtz, musc, lignite, (cl), (carb)	
				– cycles from upper lmntd, flasered Slt down to unif mic Slt	
367		olv gy [5Y5/1] intlmntd pnk gy [5YR8/1]		Slt, c, (snd) [vf], qtz, musc [lrg flakes], (cl), (carb)?; v.tn slt Partings	
		brn gy [5YR5/1]			
				– (lignite Frgmnts)	
368			(fiss)	– vari Slt in tn Lmntn [discont] – sm lenses	dissem Pyrt in Ptchs
			cmpct	Snd, vf, qtz [subang, subsph, resin-coated], (musc), srt, to cl Slt Lmntn vari	
	μP EMT 368.2	brn gy [5YR5/1]	(fiss)	Slt as above	
369					

61

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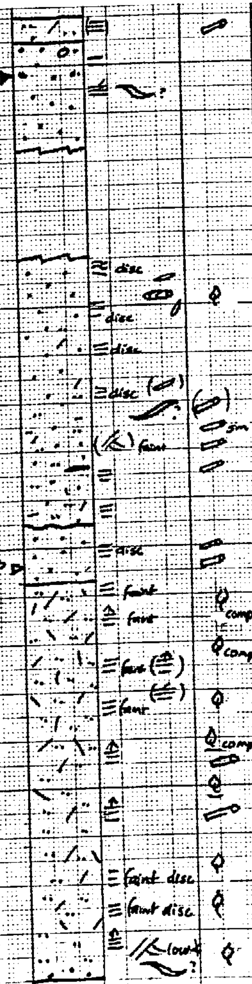

DEPTH metres	SAMPLE	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
369		brn gy [5YR5/1]	(fiss) cmpct	Snd, f-cr-gr, q/3 [rndd-ang], musc, slt, resin coated?, (srt), por;	
	P	lt brn gy [5YR6/1]	(frbl)	? general fining downwards	
			↓	Snd, f-m	(pyrt Concrtn) [lrg]
370		dk gy [5Y5/1]	cmpct	Snd, vf-f, q/3 [ang, resin-coated], musc, slt, (cl), carb?, lignt; por Biotrbn infill by Snd, srt — increasing lignt Frgmnts; less Biotrbn — (red Resin lumps)	
			frbl cmpct	Snd, f-vf, slt, q/3 [ang], musc [lrg flakes], (cl), carb, lignt, por; lignt Partings c̄ vc musc Slt, ~~cl~~ ~~vf Snd~~, frbl snd Partings ~~between Lmntn~~	
371	MP	dk gy [5Y5/1] c̄ lens brn gy [5YR4/1]	cmpct / (frbl)	Snd, vf, q/3 [subang], musc, lignt, ((cl)); abundant fn lenses, lignt, por	pyrt Replmnt of Wood
		brn gy [5YR5/1]	(fiss)	Slt, q/3, cl, lignt, Lmntn regular, faint, (fining upwards) ↓	
372					
		brn gy [5YR5/1]	↓	Slt, q/3, cl, musc, (lignt), carb?; Partings, mic c̄ leaves — increasing Snd, vf, q/3, lignt, musc, alternating fn lenses c̄ Slt	
373					

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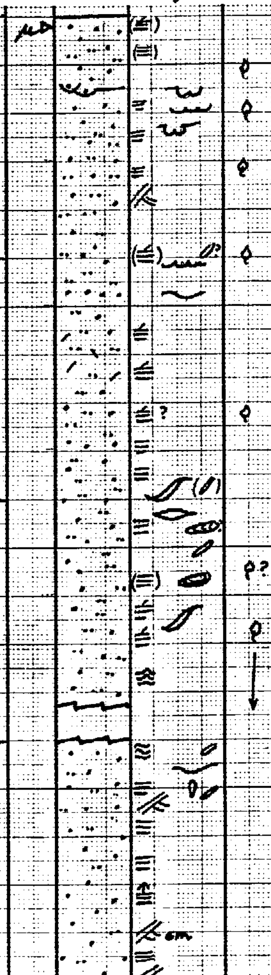

DEPTH metres	SAMPLE	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
373			brn gy [5YR5/1]	fiss	Snd, vf, slt, (cl), qtz [ang, eq], musc, lignte, carb ? [srt], (por); vari cl in Lmntn	pyrt Concrtn [discoid <5mm]
				cmpct		dissem Pyrt in clean snd Lens
					– frbl snd Partings [snd, clean, por]	
					– decreasing cl; mud Lmntn + snd Partings	
						pyrt Concrtn [lamd. sph]
			brn gy [5YR5/1] intlmntd pnk wh [5YR9/1]			
374					– wh frbl snd Partings	
					– v.th alternations of mud slt Snd, clean Snd	
				(fiss) cmpct		
					lignte Frgmnts	
375				frbl	sm lignte Frgmnts	
					Snd, f, qtz, musc, lignte, ((cl)); lens, Lmntn of mic wh frbl Snd Lmntn delineated by lignte Partings	
				frbl		
376			brn gy [5YR5/1] intlmntd pnk wh [5YR9/1] vf colour Lmntn	frbl	Snd, f, qtz [eq, subang], musc, lignte [lrg Frgmnts], ((fldsp), (cl)), por, srt Slt, (cl); lignte defines Lmntn	
						(dissem pyrt Ptchs)
377						

63

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
377			tn; (∅)		lt brn gy [5YR6/1] intlmntd pnk gy [5YR8/1]	(frbl) (cmpd) → frbl	Snd, f, qtz [eq, subang], (musc) [lrg], slt, por; tn partings lignt musc Slt.	pyrt Concrtn [sph, lcnd, zoned]
378	μP		sm; sm		lt brn gy [5YR6/1] intlmntd pnk wh [5YR9/1]		Snd, f, qtz [eq, ang-subang], musc, carb?, (lignt), por; intlmntd vtn Slt, Snd, (cl), musc, lignt	
379			sm		lt brn gy [5YR6/1] intlmntd pnk wh [5YR9/1]	frbl	Snd, vf, qtz [eq, ang-subang], slt, cl or carb, musc; tn partings of a) Snd, vf, qtz [eq, ang, clean], (mafic) [heavy mineral], frbl, srt b) dom Slt-Snd, vf, qtz, (cl), musc [f-lrg], lignt, carb; rich lignt Fragmnts [v sm]	
380			vsm				almost varve-like appearance	pyrt Concrtn [sph]
381			lowd					

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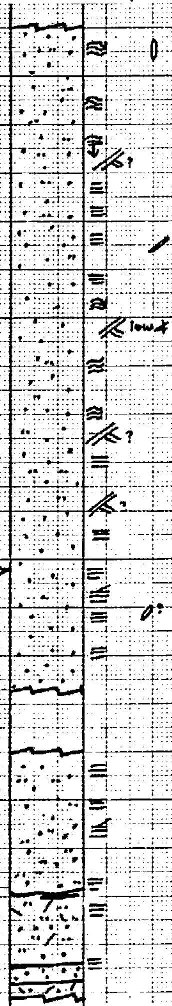

DEPTH metres	SAMPLE	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
382			brn gy [5YR 4/1] intlmntd pnk gy [5YR8/1]	(frbl)	Snd, f-slt, gl3 [eq,subang], musc, ((lignte)), (cl), (srt), por; tn Partings, lenses Lmntn of both dk Snd, and vf gl3 clear frbl, por Snd	
					– partings rich in lignte Frgmnts [v.sm]	
					– red resin Frgmnts	
383					– varying distortion by drilling process	
				frbl		
			brn gy [5YR 5/1] intlmntd pnk gy [5YR8/1]		Snd, f-slt, gl3 [ang, eq], (musc), lignte, (cl), vari cl, srt, por;	
384					– varve-like Lmntn distinctive, sharp changes – frbl to cmpct, colour, and lignte content.	
	μP			frbl (fiss)		
385			lt brn gy [5YR6/1] intlmntd pnk gy [5YR8/1]	frbl	Snd, vf, slt, gl3 [eq, subang], (felsp), musc, (lignte), carb?; lt Partings of Snd, f, gl3 [ang], musc, lignte	
		Q compl	lt brn gy [5YR6/1] partings pnk gy [5YR8/1]	cmpct (fiss)	Slt, gl3, (musc), (cl), lignte; Partings of Snd, m, gl3, musc [v.lrg], lignte por, frbl	
386		Q	pnk gy [5YR7/1]	frbl	Snd, m-c, gl3 [sobrndd], (musc), ((mafic)); heavy mineral, srt, por, frbL; Slt, intlmntd Snd	

DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
388			low ∠ >20cm sets		pnk gy [5YR8/1]	frbl	Snd, m-c, qtz [fab, subang - submdd], (musc), ((mafic)), srt, por; particle-size Stratifn; aggrad Xstratifn [20cm sets, lignite in base]	
			str					
	PLD						- lignite / peaty Partings	
							Snd as above, + feldsp [wthrd, frbl]	
			as above					
389						frbl		
			str					
391					brn gy [5YR5/1]	fiss	Mud, slt, cl, musc, carb; lignite peaty Lmntns, Partings	
			v sm sets		pnk gy [5YR7/1]	frbl	Snd, m-c, qtz [vari, submdd], (mic). (feldsp) [wthrd]; frbl, por, srt; Stratifn by increased wthrd feldsp	
			low ∠				- particle size Varns	
	P				brn gy/pnk wh		fn Mud; lignite, fn intlmntn Snd, m, qtz, feldsp, musc.	
392								
394					brn gy [5YR5/1] intlmntd	cmpct	Mud, slt, cl, lignite; Partings, Intlmntn of Snd, f, qtz, (musc), feldsp [wthrd]	
			sets >20cm		pnk gy [5YR8/1] / v lt gy [N8]	frbl	Snd, m-c, qtz [vari, mdd-subang, sph-nonsph]; feldsp, (slt), frbl, por, srt; Xstratifn defined by particle size, feldsp Content	
			eros					
			sets >20cm				Xstratifn; sets 20° angle, >20cm th; aggradational	
						flaky	intlmntd Lignit + Peat?, Resin [yel, 1cm lumps]	
395					v lt gy [N8]	frbl	Snd, m, qtz, musc, slt	

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DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
395					lt gy [N7]	frbl	Snd; m, qtz [subang, subeq], (feldsp) [wthrd], (slt), por, srt Xstratificn defined by wthrd feldsp concntrn	
						frbl		
							Snd- m-c — lignt wood fragmnts	
396								
400			sets >15cm 30°		pnk gy [5YR 7/1]	frbl	Snd; m-vc; qtz [vari subeq, subang-subrndd]; feldsp [wthrd], slt Mx, (srt), por ; graded Lmntn	
			sets >20cm 25°		yel gy [5Y 7/1]		Snd, m-vc - gran	
			25°				Snd, m-vc - gran, graded Lmntn ; (resin Lump))	
			25°					
401			10°					
			25°					
			sm sets 10°					
403					yel gy [5Y 7/1]	frbl	Snd, m-vc, qtz [vari, subang-subrndd] feldsp [wthrd], (slt), Stratificn defined by particle-size Grading	
			10°					
			20°					
			10°				- lag surfaces	
404			10°					

DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
406			Vari		pnk gy [5YR7/1]	frbl	Snd, m-c, vc, qtz [rndd - subang], (feldsp), slt, (musc), (srt); por	
			?					
			10°					
					brn gy [5YR5/1]	cmpct	Slt, cl, qtz, lignte, (musc)	
					pnk gy [5YR7/1]	frbl	Snd, m-c, as above	
412					pnk gy [5YR7/1]	frbl	Snd, m-c, qtz [rndd - subang], (slt Mtx), (musc)	
	P		(≡)		brn gy [5YR4/1] pnk gy	cmpct	Mud; cl, slt, (snd); frn partings of pnk wh Snd	
	X				m lt gy [N6] intlmntd pnk gy [5YR8/1]		Slt, cl, lignte [frgmnts f-vc Snd], musc; intlmntd vf Snd; seatearth?	
421					pnk gy [5YR7/1]	(frbl)	Snd, (gran)-vc-m, qtz [lrg, rndd, subsph + sm subrndd - subang], (lignte); (musc), (feldsp) [wthrd]; srt, por	
			?					
							– slt Clasts rndd, up to 1.5mm)	
						frbl	lignte vc Snd	
						cmpct	Slt, cl, qtz, musc, lignte	
					lt olv gy [5Y6/1]	frbl	Snd, m-vc-gran, qtz [rndd - subang] (feldsp) [wthrd], slt; Stratificn by particle-size Varns	
422			30° >25cm sets					

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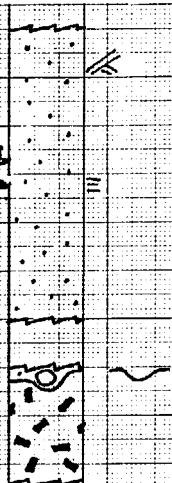


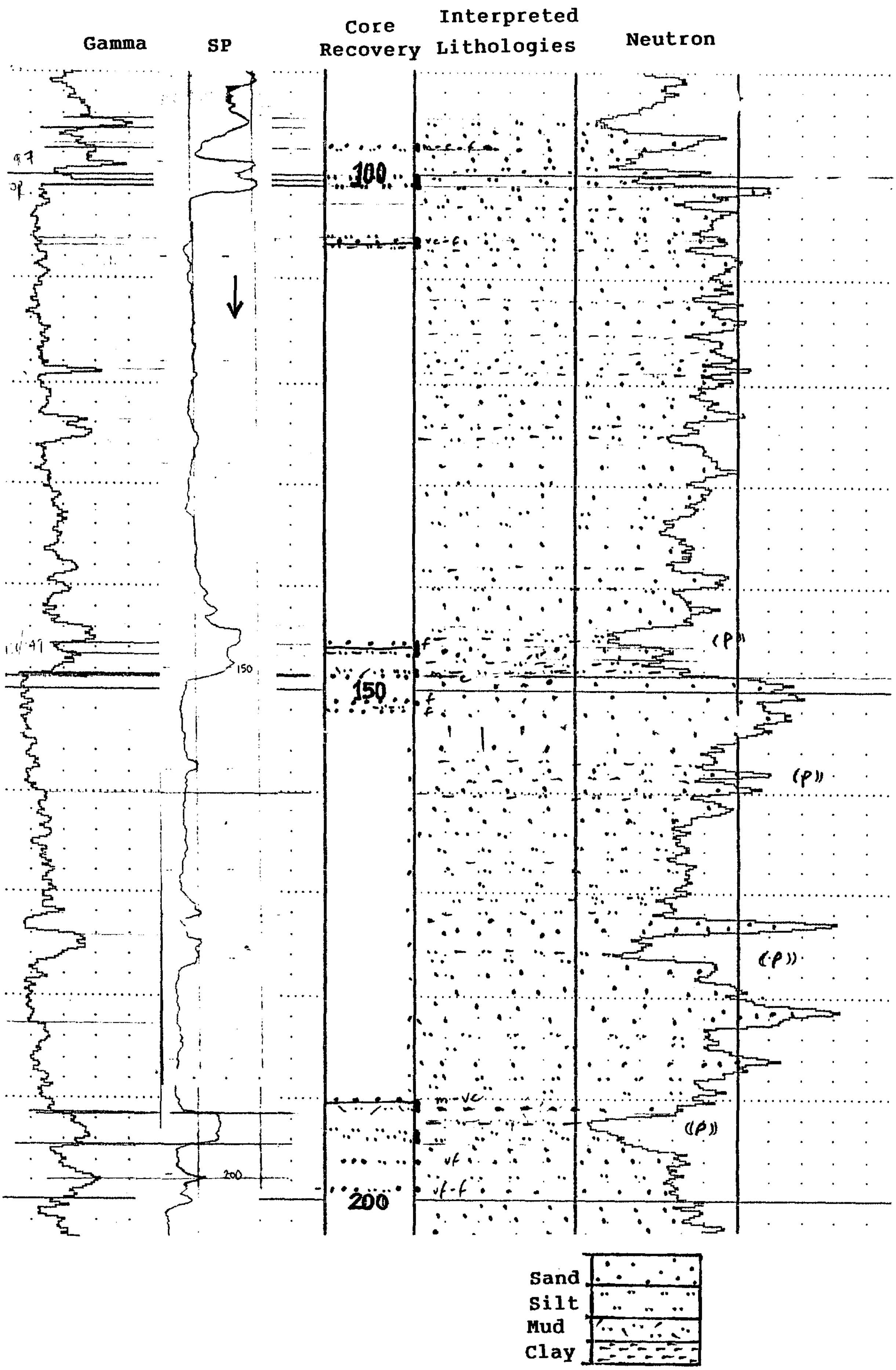
DEPTH metres	SAMPLE	LITHOLOGY	SED. STRUCTURES	BIOTA	COLOUR	INDURATION	DESCRIPTION	DIAGENESIS
424	EMT 424.22 P				brn gy [5YR4/1]	(frbl) (cmpct)	Snd; f-gran, qtz [rndd-subang, coated ē resin/humic residue], (lithic), (feldsp), (musc), slt Mtx, Stratifcn by particle-size varn. – pervasive humic/hydrocarbon Staining	felds
425							Snd, m, qtz [rndd-subang], (musc), (feldsp) [wthrd] ↓ increasing variation of particle-size.	
427					pnk wh [5YR9/1]	crmbl	Granite, wthrd, qtz, kaolinite, matrix, (musc) – pebble mould in upper surface deformity compressed lignite peat + clay	

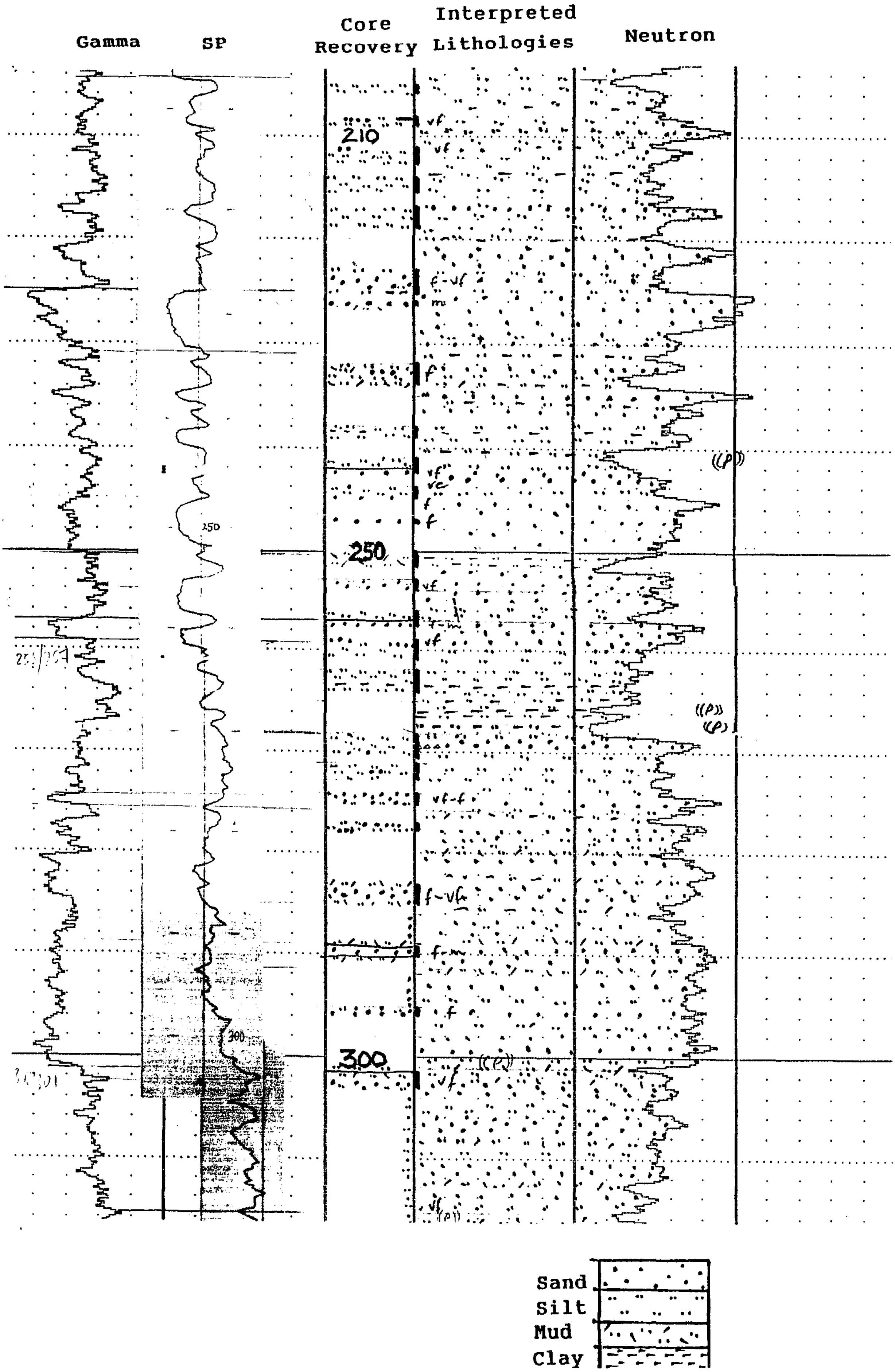
APPENDIX II

ELECTRIC LOG INTERPRETATION

Bore No.36675 (Hatfield 1)

(Interval 97-427 metres)


Gamma
SP
Core Recovery
Interpreted Lithologies
Neutron
100
150
200
Sand
Silt
Mud
Clay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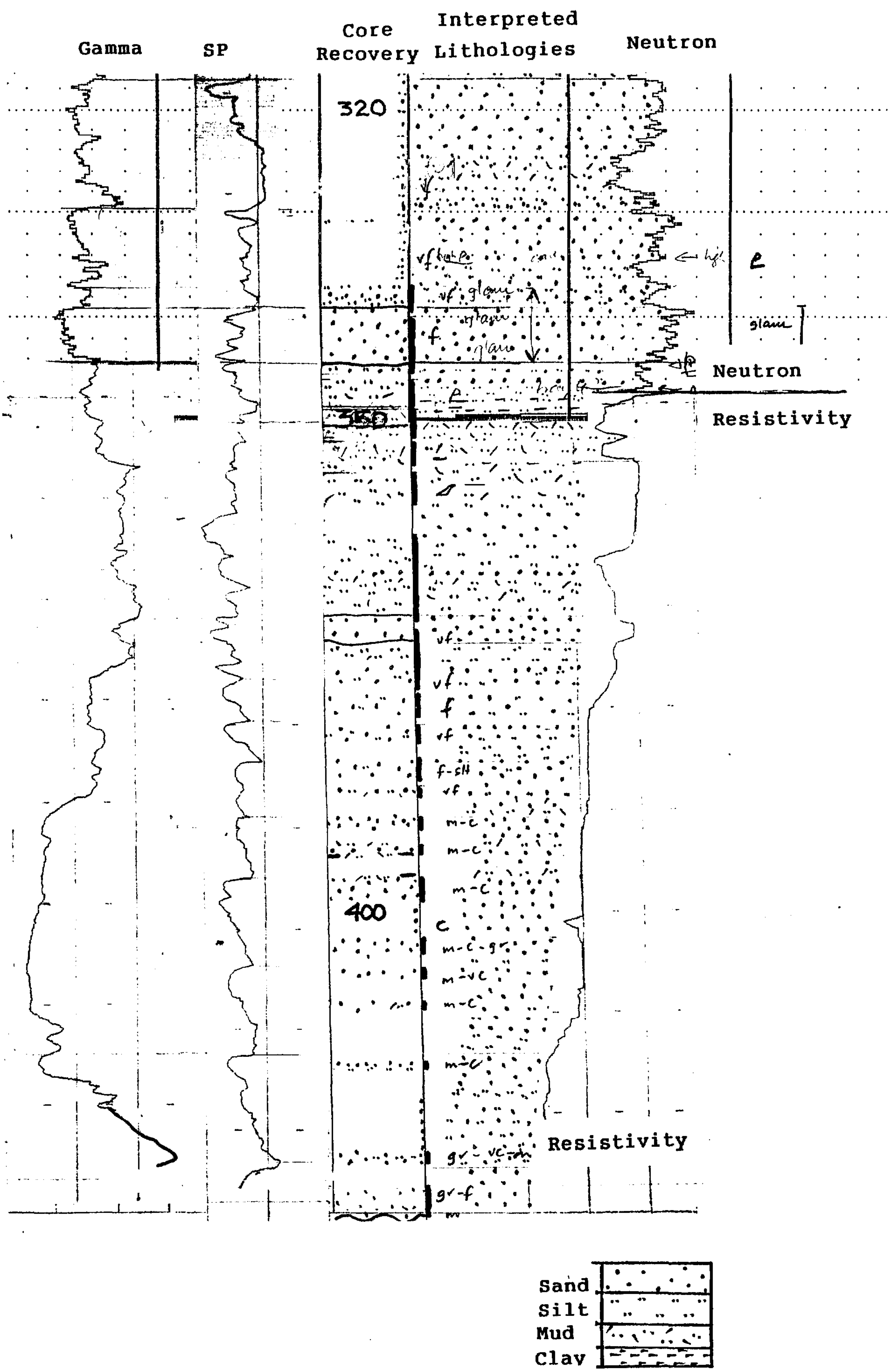
Sand
Silt
Mud
Clay


Gamma
SP
Core
Recovery
Interpreted
Lithologies
Neutron
320
350
400
Neutron
Resistivity
Resistivity
Sand
Silt
Mud
Clay

APPENDIX III

MINERALOGIC DETERMINATIONS BY AMDEL

amdel

MINERALOGY OF TEN SAMPLES FROM POONCARIE BMR9

1. INTRODUCTION

Ten samples received from the Bureau of Mineral Resources were to be examined either for sulphide or heavy mineral mineralogy or for clay mineralogy (Code MC2). The represented material from various depths of Pooncarie BMR9 (Hatfield).

Note that sample 269.2 was not received, but two similarly-numbered samples were received, 283.27 for heavy mineral identification and 283.0 for clay mineralogy.

2. PROCEDURE

The sulphide sample (146.2) was examined in bulk by X-ray diffractometry. The three heavy mineral samples were examined in loose grain mounts and the two samples 271.2 and 283.27 were examined - in addition in polished section (PS47177).

Portion of each clay sample was powdered finely and used to prepare an X-ray diffractometer trace which was interpreted by standard procedures.

Further, weighed, lightly pre-ground subsamples were taken and dispersed in water with the aid of deflocculants and an electric blender, and allowed to sediment to produce -2 μm e.s.d. size fractions by the pipette method. The resulting dispersions were examined by plummet balance to determine their solids contents, and were then used to produce oriented clay preparations on ceramic plates. Two plates were prepared per sample, both being saturated with Mg^{++} ions, and one in addition being treated with glycerol. When air-dry, these were examined in the X-ray diffractometer. Additional diagnostic examinations, carried out as required, consisted of examination of a glycerol-treated plate and examination of the glycerol-free plate after heating for one hour at 550°C.

3. RESULTS

3.1 Heavy Mineral Examinations

146.2

The sample consisted overwhelmingly of pyrite. Quartz was present as an accessory. A trace of a third component was probably rozenite ($FeSO_4.4H_2O$) but this is somewhat uncertain.

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257.1

This was found to be largely quartz. Minor dark flaky opaques appeared to be iron oxide scale (corrosion product). No heavy minerals as such were seen.

271.2

The sample was approximately 95% quartz. About 5% was ilmenite or altered ilmenite. Pyrite and leucoxene were present in trace amounts.

283.27

Approximately 90% was quartz, with about 10% ilmenite or altered ilmenite. Traces of leucoxene, pyrite and zircon were seen.

3.2 Clay Work

The results are given in Table 1, which lists the following:

(a) The mineralogy of the total sample, as derived from examination of the bulk material, with supporting evidence as available. The minerals found are listed in approximate order of decreasing abundance, using the semiquantitative abbreviations given. Coverage of clays may be incomplete, and for full clay mineralogy Section (c) should be consulted. This section (a) is for information on non-clay minerals and to give a general idea of the makeup and proportion.

(b) The proportion of the sample found to separate into the -2 μm size fraction, as determined by the plummet balance. The figure obtained applies only to the pre-treatment and dispersions conditions used.

(c) The mineralogy of the -2 μm fraction, given as in Section (a).

4. REMARKS

The following observations were made relating to evidence for interstratification of the smectite component.

100.3

Apparently not interstratified, but the evidence was poor because of the low level present.

225.6

Certainly the material is largely smectite, but poor peaks and response to tests suggest possibly a complex interstratification rather than simple smectite-illite.

TABLE 1: BULK AND CLAY FRACTION MINERALOGY OF SIX SAMPLES
(POONCARIE BMR9)

Sample:	100.3		225.6		283.0		348.0		353.86		412.71	
Bulk Mineralogy:	K	D	Sm	D	Q	CD	Q	D	Q	D	Q	D
	Q	SD	Q	SD	Sm	CD	Sm	SD	K	A	M	Tr-A
	Sm	A-SD	K	A-SD	Sid	A	K	A-SD	M	A	K	Tr-A
	M	A			K	A	M	A	Gi	Tr		
					M	Tr-A	Sid	A				
							F?	Tr				
-2 µm fraction %:	41		16		15		40		15		6	
Mineralogy:	K	D	K	CD	Sm	D	Sm	D	K	D	K	D
	M	A	Sm	CD	K	SD	K	SD	M	SD	M	A
	Sm	Tr-A	Q	Tr	M	Tr-A	Q	Tr	Q	Tr	Q	A
	Q	Tr	M	Tr	Q	Tr	M	Tr	Gi	Tr	Q	A
									Sm	Tr		

Mineral Key

F	K Feldspar
Gi	Gibbsite
K	Kaolinite
M	Mica/illite
Q	Quartz
Sid	Siderite
Sm	Smectite (see text for comments on interstratification)

SEMIQUANTITATIVE ABBREVIATIONS:

D = Dominant. Used for the component apparently most abundant, regardless of its probable percentage level.

CD = Co-dominant. Used for two (or more) predominating components, both or all of which are judged to be present in roughly equal amounts.

SD = Sub-dominant. The next most abundant component(s) providing its percentage level is judged above about 20.

A = Accessory. Components judged to be present between the levels of roughly 5 and 20%.

Tr = Trace. Components judged to be below about 5%.

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283.0

Non-interstratified.

348.0

Non-interstratified.

353.86

Too little present for assessment. No evidence seen for interstratification.

412.71

Non-interstratified.

APPENDIX IV

PETROGRAPHIC DESCRIPTIONS OF 12 HORIZONS IN BORE No. 36675

PETROGRAPHIC SAMPLE at 106.5 metres depth (thin section)

Description: Bioturbated sandy clay with clotted texture and earthy fabric, weathered.

Particulate components: . . . .**Abundance %**

Quartz, silt-sized, rounded to solution pitted, both scattered and concentrated in root casts 15

Tourmaline? (green pleochroic, cleaved), rounded 1

Cement/Matrix: Clay throughout, with blocky clotted texture;cutans on quartz in root casts; anisotropic fabric indicates clay is product of pervasive alteration 79

Diagenesis: Clay and clay clasts have in situ alteration,recrystallization giving almost mica-like kinked extinction fabric. Pyrite is very finely disseminated and lines segments of cracks in the clay,

Porosity: Original and present bioturbation and crack (fracture) porosity 5

Paragenesis: Rootlet growth within clayey soil, with later oxidation, silt infill, and weathering of profile, desiccation, burial, groundwater migration pyrite precipitation in porosity and throughout clay.

Interpretation: Part of weathering profile related to the Mologa Surface at 97 metres.

. . . .

PETROGRAPHIC SAMPLE at 145.5 metres depth (thin section)

Description: Sparsely burrowed, laminated fine quartzose sand with mud clasts. Compacted.

Particulate Components: . . . .**Abundance %**

Quartz, fine-grained, shardlike, subrounded 37

Feldspar, labradorite? and altered (sericitized) 5

Mud clasts, silt-laminated, burrowed, high organic content 20

Pellets, pyritic 1

Tourmaline? (green pleochroic, high birefringence) . . . .< 1

Ilmenite, rounded, subspherical 1

Cement/Matrix: Variable within laminae ranging from mud matrix to cutans, to no matrix .10

Diagenesis: pyrite is a patchy occluding cement in burrows, is disseminated in mud flakes and the more porous sand laminae 1

Porosity: Original interparticle porosity 30

Present interparticle porosity 25

Paragenesis: Following sedimentation,clay infiltered more porous laminaeto form cutans. Minor pyrite precipitation followed by compaction.

. . . .

PETROGRAPHIC SAMPLE at 205.7 metres depth (thin section)

Description: Laminated, bioturbated muddy quartzose silt. Horizontal and subvertical rootlet casts contain traces of lignite and have colour-zoned concentric infill of clayey silt. Micro-erosional surfaces throughout.

Particulate Components: . . . .**Abundance %**

Quartz silt 49

Lignitic fragments, silt-sized 15

. . . . **Abundance %**
Cement/Matrix: Clay 30
Diagenesis: Pyrite replacement along root traces and of lignitic flakes. Oxidation zones around roots 1
Porosity: Original interparticle porosity . . . . 20?
present interparticle porosity 5
Paragenesis: Rootlet development in clayey silt followed by decay of roots and clayey-silt and silt infill. Minor pyrite precipitation before and during compaction.
Interpretation: Levee deposit?

. . . .

PETROGRAPHIC SAMPLE at 250.8 metres depth (thin section)
Description: Desiccated grummous (pelletal) carbonaceous mud with very thin silt lenses and interlamination. Small erosional surfaces.
Particulate Components: . . . . **Abundance %**
Quartz silt 5
Pellets of compacted carbonaceous mud, 0.6x0.18mm 59
Fish fragment, apatitic, 1 mm long . . . . <1
Foraminifera, arenaceous, 1-.1mm long 1
Lignitic fragments 10
Cement/Matrix: carbonaceous mud 20
Diagenesis: Pyrite, disseminated, and very fine replacement in some lignite particles 2
Porosity: Original interparticle porosity 25
Present 2
Paragenesis: Pyrite precipitation is post-compaction

. . . .

PETROGRAPHIC SAMPLE at 257.1 metres depth (thin section)
Description: Sparsely burrowed silt with erosional surfaces delineated by ilmenitic medium quartz sand. Sand infills burrows.
Particulate Components: . . . . **Abundance %**
Quartz, medium sand, angular to subangular 10
Silt 32
Feldspar, medium sand 2
Lignitic flakes, fine sand 10
Ilmenite, leucoxene, trace zircon 1
Muscovite, very small, thin books 10
Cement / Matrix: Clay ,granular texture (altered feldspathic silt) 25
Diagenesis: Pyrite replacement in burrow centres, of matrix in sandy laminae, lenses with some replacement of periphery of quartz particles, and minor occlusion of porosity . 5
Porosity: Original interparticle porosity . . . . 25?
Present interparticle porosity 5
Paragenesis: Pyrite replacement was precompaction.
Interpretation: Lag deposit from reworking of sandy silt

. . . .

PETROGRAPHIC SAMPLE from 269.8 metres depth (thin section)
Description: Compacted, fissile, opaque foraminiferal peaty mud.
Particulate Components: . . . . **Abundance %**
Quartz silt 15
Foraminifera, arenaceous, 2mm diameter 0.1-0.6mm diameter (plucked) 3

. . . . .Abundance

Cement/Matrix: Peat? . . . . .37?

Clay . . . . .37?

Diagenesis: Pyrite spheres and ellipsoids up to 0.35mm diameter, small framboids 3

Porosity: Original inter and intraparticle in peat . . . . .20?

Present porosity 5

Paragenesis: Pyrite precipitation/replacement prior to and during compaction.

Interpretation: Paralic peat swamp environment.

. . . .

PETROGRAPHIC SAMPLE from 341.28 metres depth (thin section)

Description: Fine-grained quartzo-feldspathic sand with sideritic concretions and cement.

Particulate Components: . . . . .Abundance %

Quartz, fine sand, sunangular 34

Feldspar, fine sand, altered (sericitized) 10

Lithic, quartzite, subrounded 10

Mafic grains, ilmenite? 2

Cement/Matrix: Siderite cement 18

Diagenesis: In one clay lamina, siderite nucleation is around scattered particles? with micro-concretion growth as radial-crystalline needles. The outer growth band is possibly ferroan dolomite. In the sand, scattered siderite poikilotopes partly occlude porosity. Opaque resin fills some interstices in the sand; this is very late occlusion. . .1

Porosity: Original interparticle porosity 33

Present interparticle porosity 15

(reduced by siderite and resin)

Paragenesis: Feldspar alters after sedimentation. Siderite replacement commences in clay. With compaction of clay, microstylolites develop between impinging siderite micro-concretions. Siderite precipitation continues with additional development of poikilotopic cement in sand. With continued compaction of sideritic clay, cracking fracture porosity develops and this occluded by resin.

Interpretation: Sublabile channel sand? altered by interaction with groundwater from peat swamp.

. . . .

PETROGRAPHIC SAMPLE from 347.2 metres depth (thin section)

Description: Sparsely burrowed, laminated sideritic muddy silt. Laminae generally fine upwards, some have grummous texture. Subvertical burrows have concentric silt-infill fabric.

Particulate Components: . . . . .Abundance %

Quartz, silt-sized 30

Lignite and leaf fragments, 0.5-1mm wide, flat 3

Pellets (grummous mud) 19

Resin lumps, very small . . . .< 1

Cement/Matrix: Siderite cement 27

Mud 20

Diagenesis: Pervasive siderite cement – poikilotopic? 27

Pyrite, disseminated framboids (0.1mm D) concretions (1mm D) 1

Porosity: Original interparticle porosity 27

Present 0

Paragenesis: Compaction and pyrite precipitation/replacement began followed by siderite

cementation which totally indurated the silt.
Interpretation: Levee or interfluvial floodplain silt?

. . . .

PETROGRAPHIC SAMPLE from 351.7 metres depth (thin section)
Description: Prolifically burrowed carbonaceous (peaty) silt.Burrow types are diverse, ranging from subhorizontal tubes, to horizontal tubes like *Terebellina*, to horizontal spreite probably produced by chitinous pelecypods or *Teichichnus*.
Particulate Components: . . . . **Abundance %**
Quartz, shard-like silt 58
Muscovite flakes 5
Resin balls (.05mm D) 2
Cement/Matrix: Peat? (very fine carbonaceous matter) 25
Porosity: original interparticle porosity and peat.
intraparticle porosity . . . . 30?
Present interparticle porosity 10
Paragenesis: Compaction followed intense burrowing of sediment.
Interpretation: Peaty silts of paralic lake or interdistributary bay.

. . . .

PETROGRAPHIC SAMPLE from 369.24 metres depth (thin section)
Description: Fine quartz sand with peat and mud lumps, coarsening upwards to coarse quartz sand. Very thin lignitic bands have patches of resin-coated sand immediately above.
Particulate Components: . . . . **Abundance %**
Quartz, coarse sand, subrounded, tabular to equant, fine sand, angular, tabular to shard-like 44
Feldspar, fine sand, sericitized (lt green alteration) 10
Muscovite, books fine-medium sand-sized 3
Resin lumps 1
Tourmaline? (green pleochroic) . . . . <1
Lignite, continuous stringers - fragments? 3
Mud clasts, tabular up to 10 mm D 10
Cement/Matrix: Resin, locally migrated from lignite? 5
Clay cutans, very thin, pervasive 4
Porosity: Original interparticle porosity 35
Present interparticle porosity 21
Paragenesis: During compaction, resins were forced out of lignite and up into overlying sand.
Interpretation: Reworked sand during reduced bedload from local immature source. Channel sand.

. . . .

PETROGRAPHIC SAMPLE from 391.72 metres depth (thin section)
Description: Burrowed carbonaceous very fine quartzose sand with graded (fining-upwards) laminae. Burrows are 5 to 10 mm diameter with laminated sand infill.
Particulate Components: . . . . **Abundance %**
Quartz, very fine sand, subangular-angular 47
Feldspar, sericitized 10
Muscovite, thin books 5
Lignitic fragments, resin lumps 2

. . . . .Abundance

Cement/Matrix: peaty mud 15

Diagenesis: Pyrite,disseminated in some laminae, very small framboids precipitated as pore occlusion; selective replacement of wood 1

Porosity: original interparticle porosity 25
reduced by compaction to 20

Interpretation: Crevasse splay or levee sand.

. . . .

PETROGRAPHIC SAMPLE from 424.65 metres depth (thin section)

Description: Lignitic bimodal quartz sand. Laminae are bimodal at base and fine upwards.

Particulate Components: . . . . .Abundance %

Quartz, – very coarse sand, rounded, subequant, strained, inclusions of muscovite . .20
mediun sand, subangular-angular, shard-equant 30
Lithic, quartzite, v.c., rounded-angular, strained 6
Lignite 2
Muscovite, very thin books 1
Mud clasts/ silt clasts, tabular, compacted 10
Ilmenite, leucoxene? . . . .< 1

Cement/Matrix: few laminae with very thin cutans

Porosity: Original and present interparticle porosity 30

Paragenesis: Very minor compaction

Interpretation: Fluvial channel sand from near source.

. . . .

APPENDIX V
DRILLCORE SAMPLES

PETROGRAPHIC SAMPLES (thin sections)

Depth in hole (metres)

106.5
145.5
205.7
250.8
257.1
269.8
341.28
347.2
351.7
369.24
391.72
424.65

MINERALOGIC DETERMINATIONS

Heavy mineral examination

Depth in hole metres

257.1
271.2
283.27

Xray Diffraction

Depth in hole metres

100.3
146.2
225.6
283.0
348.0
353.86
412.71

PALYNOLOGY SAMPLES

Depth in hole metres

31.0
58.82
67.18
81.96
106.1
108.98
145.7
148.15
153.98
190.1
192.98
195.47
205.28
205.83
208.46
211.58
217.07
225.97
232.2
239.06
243.7
251.8
252.98
259.5
263.26
268.67
269.7
277.02
285.03
301.02

349.4
351.35
355.5
357.7
363.74
368.65 (marked as EMT 369.2m)
372.63 leaf
373.05
377.98
384.24
388.6
424.5
426.23 (marked as EMT 426.23)

MACROPALAEONTOLOGY SAMPLE

146.2 metres