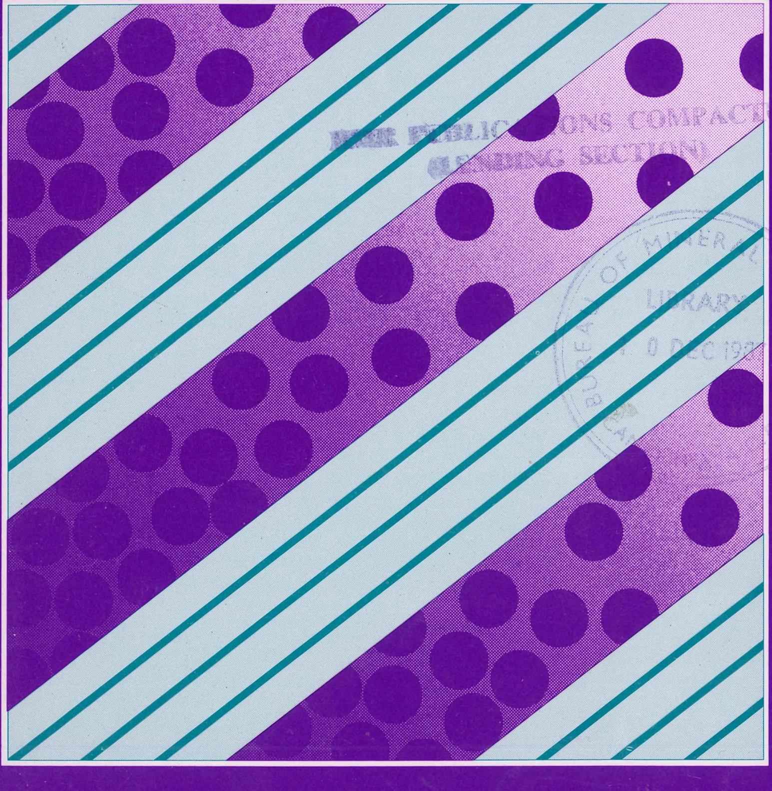
GROUNDWATER 3

Studies in Hydrogeology

SEDIMENTOLOGY AND DIAGENESIS OF SEDIMENTS ENCOUNTERED BY VIC. D.M. PIANGIL WEST 1. SWAN HILL AREA, MURRAY BASIN, SOUTH EASTERN AUSTRALIA

B. M. RADKE



BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

DIVISION OF CONTINENTAL GEOLOGY

RECORD 1987/25

RECORD 1987/25

Division of Continental Geology Groundwater Series No. 3

SEDIMENTOLOGY AND DIAGENESIS OF SEDIMENTS ENCOUNTERED BY VIC. D.M. PIANGIL WEST 1 MURRAY BASIN, SOUTHEASTERN AUSTRALIA

by

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This report is submitted in fulfilment of the requirements of the
Sedimentology of the Geera Aquitard Study
Murray Basin Hydrogeological Project
Division of Continental Geology
Bureau of Mineral Resources

1987

FOREWORD

JOINT COMMONWEALTH - STATES MURRAY BASIN HYDROGEOLOGICAL PROJECT

The Murray Basin Hydrogeological Project is a long-term study which was established to improve the understanding of the groundwater regime of the basin by examining it as a single entity, unencumbered by State boundaries. The project is being undertaken jointly by the South Australian, Victorian and New South Wales geological surveys and water authorities, and by the Division of Continental Geology of the Commonwealth Bureau of Mineral Resources.

The Murray Basin contains some of the most important agricultural land in Australia and currently generates several billion dollars annually in agricultural revenue. Unfortunately, both the clearing of natural vegetation and irrigation have been accompanied by rising groundwater-tables and discharge of saline waters. In order to develop an understanding of the systems in which these salinity problems have developed, it is fundamental that the relationships between aquifer geometry, groundwater flow and distribution of surface discharge be fully understood. It is now believed that several active and fossil groundwater discharge sites are related to flow disruption and upward leakage created at permeability barriers formed where the deeper aquifers are truncated stratigraphically or are significantly thinned by concealed basement barriers.

One of the research objectives for 1986-87 has been to investigate the disruption of groundwater flow in the Renmark Aquifer by marginal-marine fine clastics of the Geera Clay. The Geera Clay is thickest in an arcuate belt extending from southern Victoria, through northwest Victoria into southwestern New South Wales, and into adjacent areas of South Australia. The resultant stratigraphic thinning of the Renmark Aquifer is thought to find surface expression in a broad band of surface groundwater discharge features.

As a contribution to the investigation of the Geera Clay, the BMR Division of Continental Geology has collaborated with the Victorian Department of Industry, Technology and Resources to obtain core samples from the unit. Piangil West 1 was drilled by the Victorian Department of Mines with a financial contribution from BMR. The following report contains descriptive sedimentology and diagenesis prepared as a contribution to the collaborative study. Other reports on the results of the Piangil drilling will be released in the near future.

Peter J. Cook
Chief
Division of Continental Geology

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ABSTRACT

In Piangil West 1, the cored Geera Clay sequence is predominantly dark carbonaceous burrow-mottled silts and muddy silts (65%), with minor unconsolidated sands, mud and clay. Plastic smectite-rich clay comprises only 6% of the sequence.

Deposition of the sequence was by micro-progradational (shoaling-upward) cycles during a rise in relative sea level to produce shallow intertidal flat, estuarine channel, subtidal-intertidal restricted marine and supratidal facies in a convoluted embayed configuration. As the rate of relative sea-level rise diminished, the environments were subjected to more reworking and a simpler, subparallel coastal configuration developed with more open marine, supratidal and paralic conditions established.

Bioturbation enhanced porosity in the fine siliciclastic sediments. Early porosity ranged from 0% in the clays, to about 5-10% in the silts, up to 30% in sands. With early diagenetic cementation by clays, carbonate and pyrite, and subsequent compaction of the sequence, porosity was drastically reduced to a present range of 0-7% as interparticle and burrow interparticle porosity types.

During early diagenesis, low permeability vertically up-sequence was made possible by burrow porosity. Lithofacies D with thick clay beds, was a permeability barrier. Depending on the spatial configuration of Lithofacies B (channel sands), these sands may have been a bypass to the clay barrier until occluded by cement later in diagenesis.

Late diagenetic events (post compaction) include continued calcite and dolomite cementation, and almost total occlusion of larger burrow types by pyrite, traces of arsenopyrite, and resinous organic material.

INTRODUCTION

This report documents a sedimentological and petrographical study of the Late Oligocene - Late Miocene sequence intersected in Piangil West 1 Borehole, SWAN HILL 1:250 000 Sheet, northwestern Victoria. Detailed logs of lithologies, sedimentary structures, depositional events, general macrofauna, general ichnofauna, mineralogy, diagenesis, and paragenesis are presented. Additionally, interpreted depositional environments and diagenetic history of the sequence are discussed.

The objective of the study has been to provide detailed sedimentological and diagenetic descriptions of the Geera Aquitard and contiguous units. This information will then be integrated with other specialized investigations as part of a program aimed at furthering understanding of the role of the Geera Clay in influencing groundwater flow in the Renmark Aquifer (Figure 2), and investigating the relationships between aquifer geometry, groundwater flow, and surface discharge of saline waters.

Piangil West 1 borehole is one of a series of regionally-spaced stratigraphic holes across the Murray Basin to further knowledge of the Geera Aquitard and Renmark Aquifer; of their geometry, stratigraphy, diagenetic history, and hydrogeological characteristics.

Piangil West 1 is located on the SWAN HILL 1:250 000 Sheet at 35° 03' 9.5"S latitude, 143° 13' 07"E longitude. The grid reference is 54YG 015184 on the 7527 NYAH 1:100 000 Sheet. The borehole is sited adjacent to the north side of the road, in the centre of a western embayment of a salina, 8.5 kilometres west of Piangil township (Figure 1).

R.L. 51 m AHD (ground level)

Drill Rig Bourne 1250

Average core diameter 75mm

Total depth at the time of completion of logging, was 185.88 metres (late January, 1987). Drilling has subsequently resumed but new material has not been examined and described in this report because of time limits imposed on this contract.

Core recovery from the drilling was non-existent to 67.3 metres, and less than 30% down to 120 metres. Beyond this depth, core recovery exceeded 80%. Because of the soft and relatively unconsolidated nature of the sediments, no cuttings could be recovered. Core material is stored in BMR core and cutting repository, Fyshwick, catalogued as Swan Hill BMR No.1.

Photographs of representative sections of the core are presented in Appendix V, Plates 7 and 8. Core sampling was conducted for several studies, specifically: petrographical, clay mineralogical, geochemical, pore fluid, geochemical, foraminiferal and palynological determinations.

Intervals sampled for these studies are listed in Appendix VI.

This report utilizes the petrographical, mineralogical, total organic carbon, and geochemical data.

REGIONAL GEOLOGICAL SETTING

The Geera Clay has an arcuate distribution across the Murray Basin (Brown and Stephenson, 1986) extending from the Flinders Ranges in South Australia east-southeastwards and then increasingly southerly to the Grampians in Victoria. Geera Clay reaches thicknesses exceeding 160 metres and Piangil West 1 is sited over the broadest belt of thickest section (Figure 1).

Brown (1985) considered the Geera Clay to have been deposited under shallow and marginal marine, interdistributary bay, lagoonal and tidal flat conditions. These environments formed an arcuate coastal belt bordering fluvial marsh, fluvial-deltaic and fluvio-lacustrine plains (Olney Formation of the Renmark Group), but restricted from open marine conditions by platform carbonate shoals and a restricted platform lagoonal belt (Winnambool Formation; Brown, 1984).

Basement tectonic elements and infrabasins below the Murray Basin also have a basin-wide arcuate trend from the northeast, arcing in a southwesterly, southerly, then southeasterly direction towards the Lachlan Fold Belt.

Piangil West 1 is sited just east of where the Geera Aquitard overlies shallow basement in a region of constriction to the westward groundwater flow in the underlying Renmark Aquifer (Figure 2).

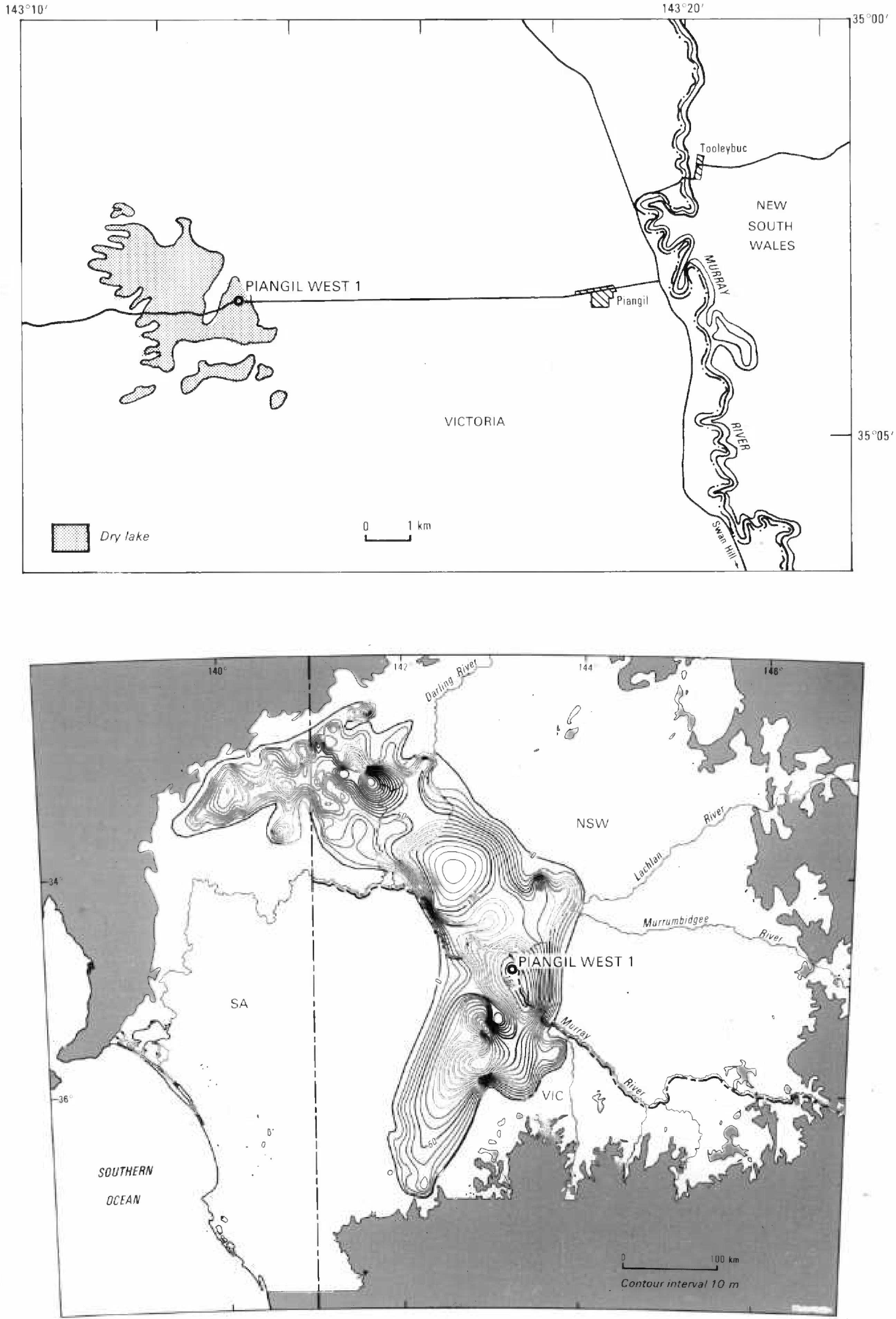

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Fig. 1 Piangil West 1 borehole: geographic location and position on the thickest section of Geera Clay

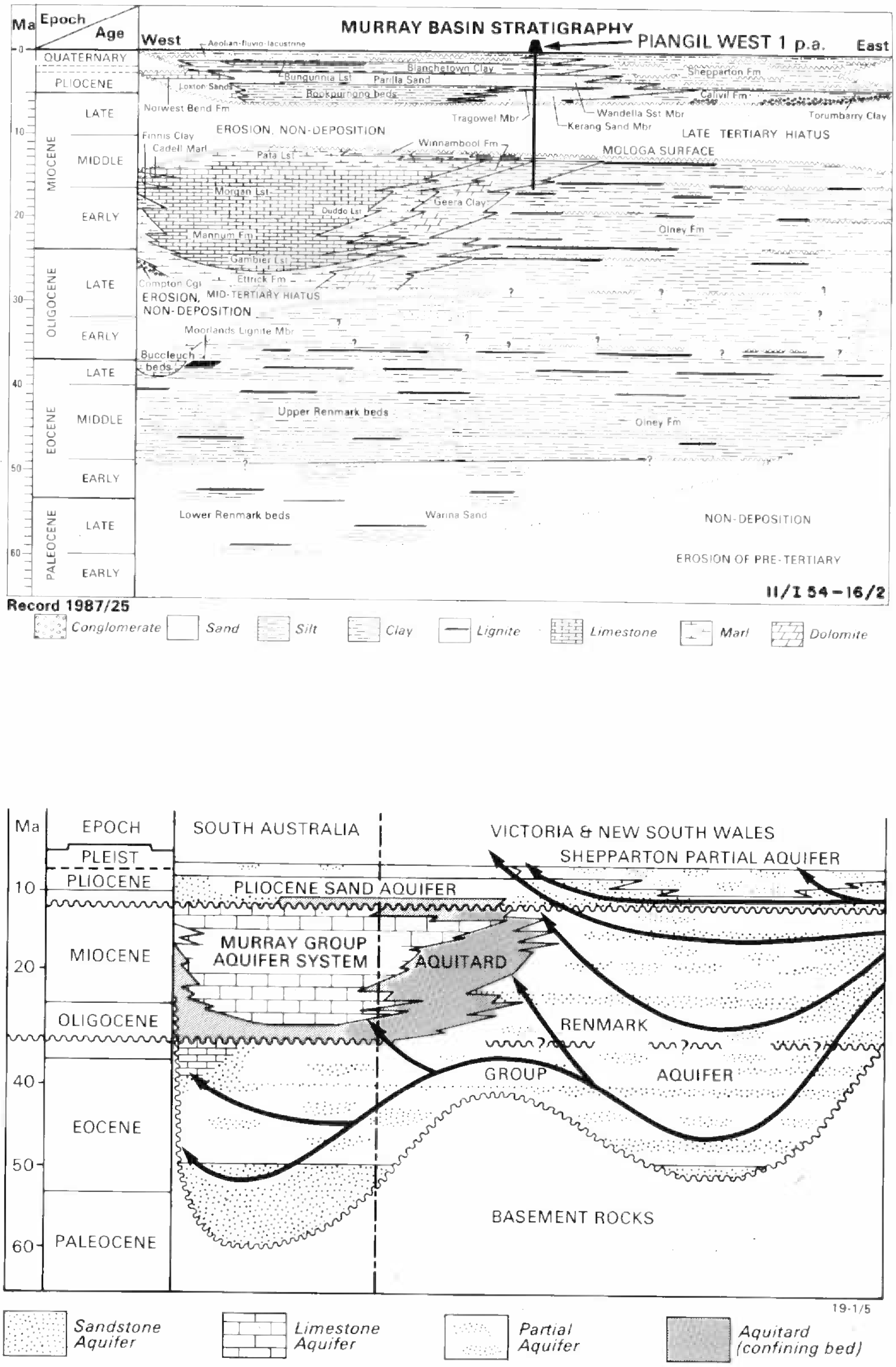
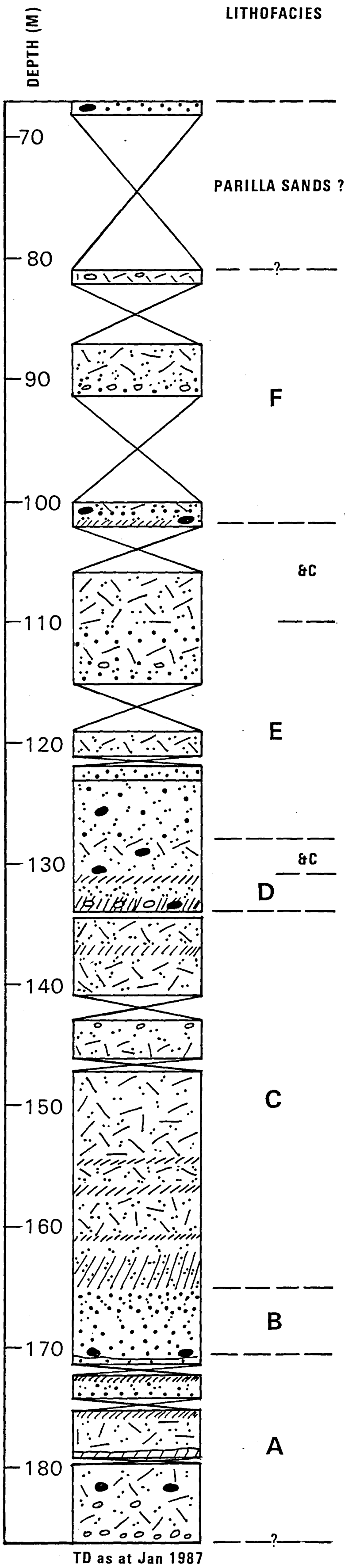


Fig.2. Cainozoic stratigraphy and regional aquifers of the Murray Basin (Based on Brown, 1983)

LITHOSTRATIGRAPHY



LITHOLOGIES

Light to medium olive grey, fine to very fine quartzose sand with minor mica, feldspar, lithics; well sorted; dolomitic concretions; minor pyrite.

Mottled grey and olive black, pebbly sandy clay.

Grey to olive black mud, sandy, pelletal, skeletal and burrowed; pyrite infill foraminifera. Mud grades down to burrow-mottled green-grey silt, Dark olive grey gravelly sand over erosional surfaces.

Rythmic gradational alterations of dark olive grey sand, mud, and sandy silt; burrowed, fossiliferous, pyritic; calcareous concretions.

Olive black clayey silt; burrowed, fossiliferous, pyritic, glauconitic.

Burrow-mottled light and dark olive grey, quartzose, glauconitic sand; pyritic; intergradational with burrowed silt and minor gravelly sand. Faint relict lamination and ? flasers.

Dark brown to olive grey burrow-mottled silt, clayey inpart, fossiliferous, pyritic.

Weathered ? crumbly slickenslided, olive black sandy silt

Dark olive grey - black burrowed silt and sand

Dark olive grey finely burrowed pyritic silt.

Brown black - olive black clayey silt, mud, silt and minor sand interbanded; burrowed, fossiliferous, pyritic and slickenslided; carbonate concretions.

Gradationally interbedded clay predominant; pyritic; cherty dolomitic concretions have fractured and resin coated centres. Minor gravelly clay.

Olive black - dark olive grey clayey silt, minor mud and clay, burrows increasingly smaller down sequence - large burrows are pyrite and resin part-occluded.

Dark olive grey burrowed silt; gradational down to burrowed, faintly laminated mud and clayey silt; pyritic, glauconitic

Dark olive grey-light olive grey burrow mottled clayey silt and minor mud; fossiliferous, faintly laminated, pyritic.

Monotonous gradational alternations of dark olive grey - light olive grey and olive grey - yellow grey burrow-mottled clayey silt, mud, and minor clay; pyritic but with goethitic haloes in places.

Pyritic *Ophiomorpha*-like burrows increasingly abundant down to underlying sands.

Dark olive grey - yellow grey burrow-mottled, fine, sorted quartzose sand, glauconitic, shelly, locally indurated and dolomitic; glauconitic and muddy firmgrounds. Separate sandy muddy silt and flasered silt carbonate concretions.

Dark yellow brown - light olive grey laminated foraminiferal micaceous silt, clayey to top, sandy to base; abundant graded laminae and flasers

Olive grey - yellow grey (laminated) sandy silt, clayey silt; minor micaceous quartzose sand at base, clay at top, flaser structures.

Dark olive grey - yellow grey burrow-mottled and laminated clayey silt, minor mud, clay, and sandy gravelly clay; fossiliferous, pyritic; oxidized firmgrounds.

Yellow orange - yellow brown oxidized cobbly gravel.

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Fig. 3 Lithostratigraphic log of Piangil West 1 borehole.

LITHOSTRATIGRAPHY

GENERAL STATEMENT

The sequence between 81.5 metres and 185.88 metres is discussed in this section. The cored sand above, at 67.0 - 68.3 metres, is assigned to the Parilla Sands (Victorian terminology).

Lithologies

The sequence from 81.5 to TD 185.88 metres is characteristically dark and carbonaceous, olive black to dark olive grey, burrow-mottled with light olive grey or yellow grey colours, and is dominated by firm to semiconsolidated silts and muddy silts (65%), with lesser unconsolidated sands (15%), mud (14%) and plastic clays (6%). These are presented in stratigraphic context in Figure 3, and in the detailed litholog (Appendix I).

Low core recovery in the upper cored sequence severely reduces the confidence of lithostratigraphic classification, especially in the absence of electric logs.

Macrofauna

The fauna is rarely present beyond trace amounts in the sequence but is quite distinctive. Faunal elements, in approximate decreasing abundance are:

pelecypods - articulated, disarticulated, fragmented clams and pectins, fragmented and abraded oysters;

gastropods - complete and fragmented fusiform, turreted, conoidal, small orthostrophic, and pupaeform types;

echinoids - partly intact, disarticulated and fragmented irregular echinoids,cidarid and unspecified spines;

bryozoa discoidal, branching, articulated branching, planar and encrusting forms;

foraminifera - agglutinated, calcareous, and ?chitinous types;

malacostracans - complete, disarticulated and fragmented assemblages of decapod (crab) and unidentified (possibly shrimp) types;

ostracods - complete and disarticulated;

corals - solitary scleractinian forms;

scaphopods - complete and fragmented;

fish or cetacean? - teeth;

brachiopods - terebratulid types.

Preservation of the calcareous fauna is poor because of partial dissolution of the tests. Although mould impressions in the moist core may replicate surfaces in equisite detail, the skeletal material is friable or powdery and deteriorates, like the sediment, very quickly on drying.

Wood fragments are rare but are tabulated with the fauna for convenience.

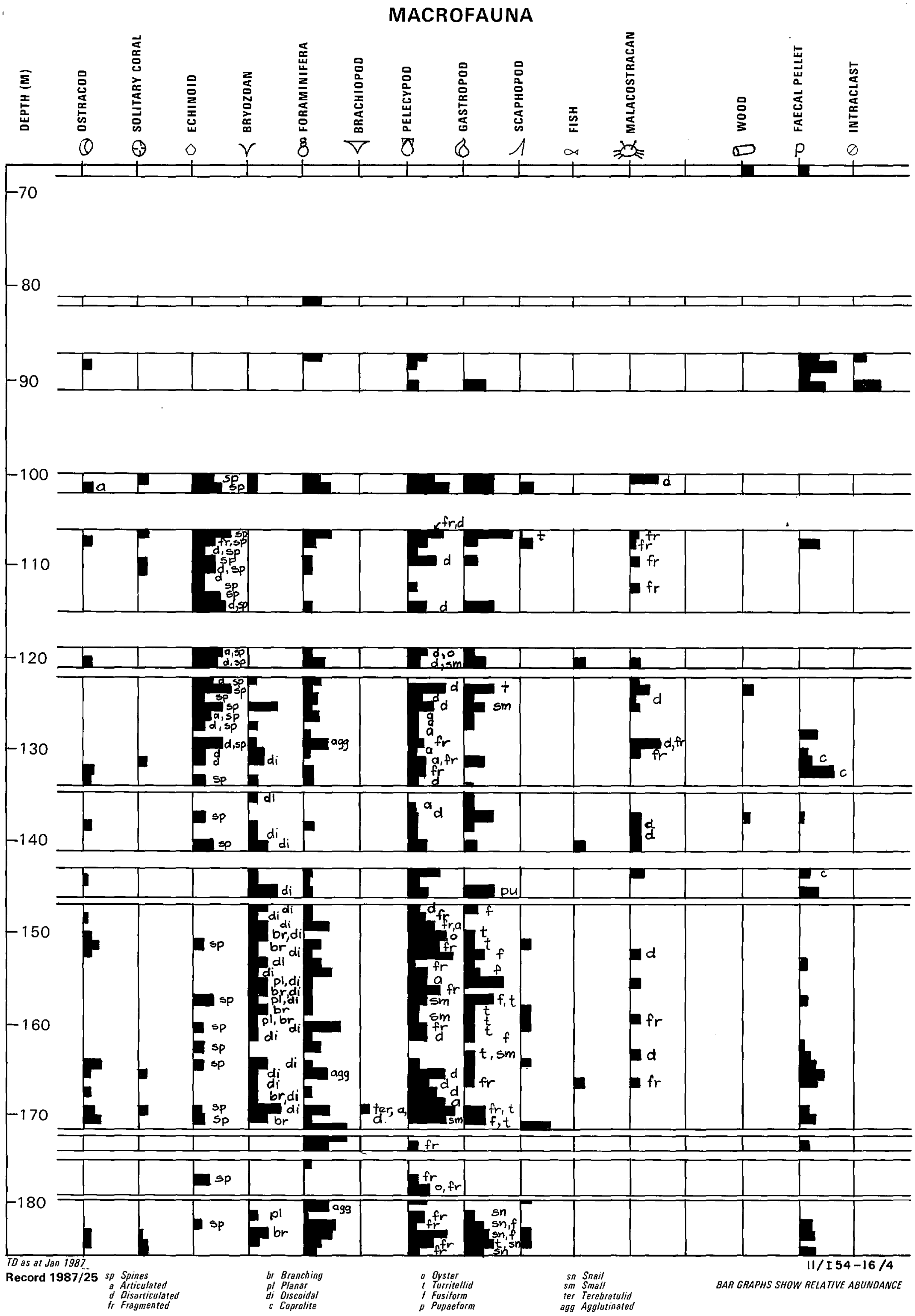


Fig. 4 Macrofaunal log of Piangil West 1 borehole.

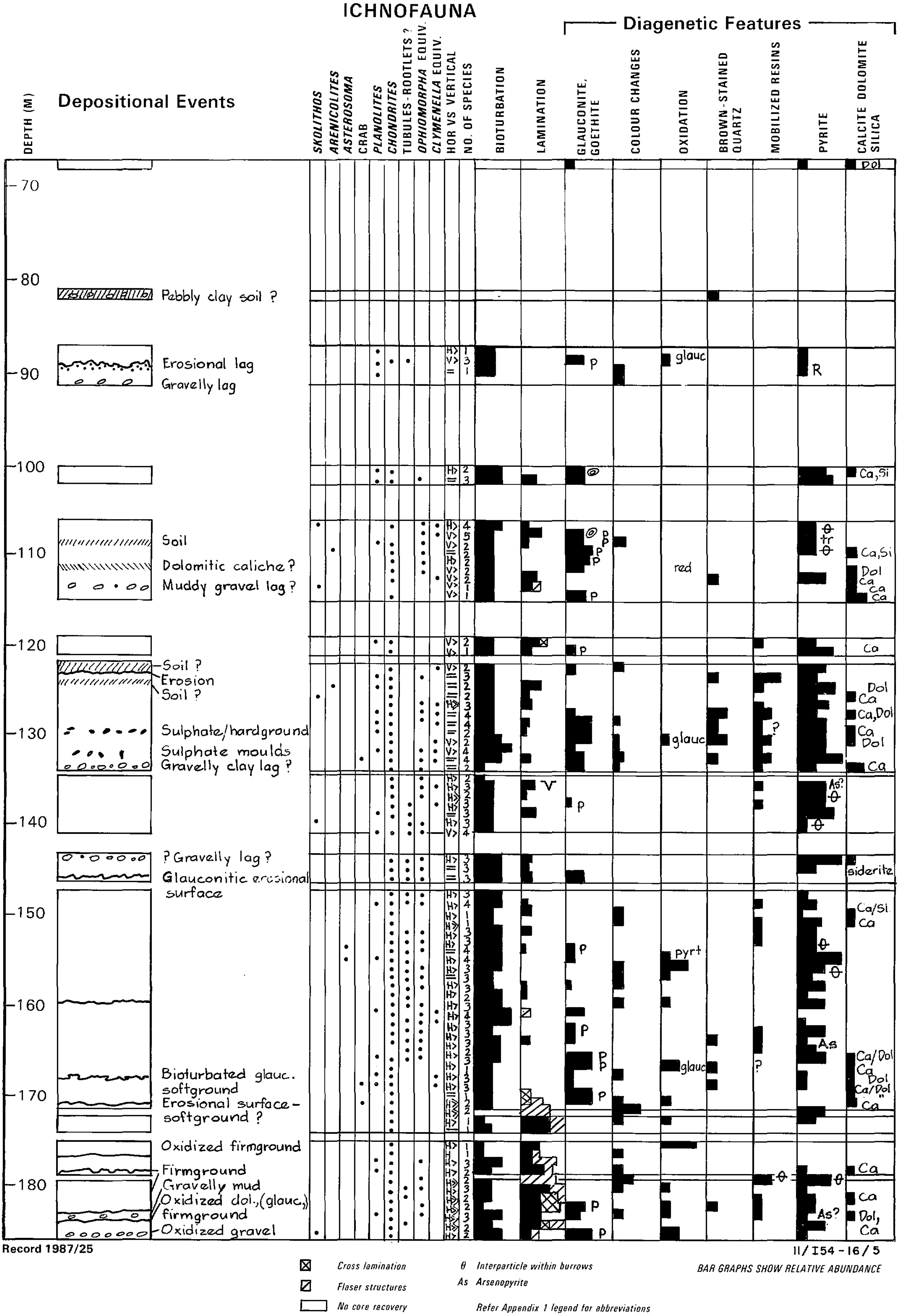


Fig. 5 Log of depositional events, ichnofauna, and macroscopic diagenetic features, Piangil West 1 borehole

The stratigraphic distribution, relative abundance, and morphological types of this fauna are presented in Figure 4 and characteristic elements are illustrated in lithostratigraphic context in Plates 4, 5 and 6 of Appendix II.

Ichnofauna

Bioturbation is prolific and moderately diverse in types within the sequence contributing up to over 30% modification of the sediment. In most lithofacies variation in bioturbation abundance is cyclic and is used as a parameter in lithofacies interpretation. Few ichnofossils have been identified with certainty but most have been categorized into species equivalents (Figure 5) for stratigraphic and environmental consideration.

Chondrites is ubiquitous in varying diameter, orientation and sediment infill types (Plate ld).

Ophiomorpha-like vertical and horizontal burrows are typically pyritized and original porosity is commonly preserved.

Surface morphology of these burrows varies with sediment. In unconsolidated sediment the burrow wall has been pelleted. Smooth burrow walls (Plate la) which are the most common, indicate a firmer substrate.

Very fine tubules approximately 0.1mmD and outlined by pyrite, are bifurcate, anastomosing, arcuate or irregular in trace and either totally confined to parting surfaces, or penetrate through laminae. Their origin is enigmatic, whether a fine animal trace, or plant rootlet, but they are restricted to Lithofacies C and the lower part of Lithofacies A.

Other distinctive but less common ichnofossils have similarities to *Clymenella*, *Planolites*, *Asterosoma*, *Skolithos*, and *Arenicolites*.

The predominant burrow orientation of the ichnofauna changes from horizontal-dominant in Lithofacies A, B and C, to varying vertical-horizontal intermixtures in Lithofacies D and lower E, to vertical-dominant in upper Lithofacies E, and back to vertical-horizontal intermixtures in Lithofacies F (Figure 5). Burrow orientation indicates the relative rates of erosion and deposition against bioturbation. Where horizontal burrows predominate, sedimentation has been at a steady rate and the burrowers have been able to maintain activity in suitable laminae. A predominance of vertical burrows, *Skolithos* ichnofacies, suggests continually changeing sediment surfaces as a result of erosion and rapid deposition which forces the infauna to reposition to their optimum depth below surface. This creates a predominance of vertical escape burrows (Ekdale, & others, 1984).

Some of the diversity of bioturbation types and internal structures is illustrated in Plate 1.

LITHOFACIES

Six lithofacies are recognized, nominally A to F up-sequence. Lithofacies differentiation is based on lithology or cyclical lithological patterns, sedimentary structures, ichnofauna and ichnofaunal cyclicity, and fauna. In shallow near-shore environments, the fauna is less significant than ichnofauna as a key to environments because of the reworking and transport of skeletal material.

In the Piangil West 1 sequence, lithofacies differentiation is relatively subjective because of the subtlety of changes selected as characteristics. Lithofacies A, B and D are the most distinctive of the sequence.

Lithofacies A

Characteristics: Lamination, both fining up and coarsening up, crosslamination, and flaser bedding in brownish black and yellow brown micaceous silts characterize this lithofacies which has abundant agglutinated foraminifera on parting surfaces. Bioturbation is minor, small, and horizontally predominant.

Lithologies: Colour-laminated and occasionally burrow-mottled foraminiferal micaceous silts,clayey silts and very fine sandy silts of dark olive grey, brown black or dark yellow brown interlaminated with lighter pale yellow brown or yellow grey.

Cycles: Fining upwards sequences of 2.4 metres average thickness, are of three types:

1) Over an irregular and prominent erosional surface on hardground or firmground, basal sandy silt grades up to silty clay.
2) unconsolidated very fine micaceous quartzose sand grades up to a clayey silt.
3) a coarse conglomeratic silt grades up to an oxidized and indurated clayey dolomicrite.

Discussion: Lithofacies A is 15.2 metres thick, between 170,7 and 185.88 metres depth. This is a Geera Clay facies and is interpreted as intertidal-high intertidal tidal flat deposits which have had a continued steady sediment supply. During slower influx of sediment and or emergence, firm and hardgrounds developed and exposed silts were resorted into coarsening-upwards laminae. With greater supply of silty sediment, flasers and fining upward laminae predominated.

Lithofacies B

Characteristics: White flecked and shelly dark olive grey fine quartz sands, varying from muddy to silty, are unconsolidated and friable except in thin intervals where indurated by dolomite. There is an absence of malacostracan and scaphopod debris, and *Ophiomorpha.*

Lithologies: Burrow-mottled dark olive grey and yellow grey skeletal fine quartz sand is dominant, with minor muddy silt and sandy muddy silt. The sand particle size increases up from the base, grading from very fine-fine sand to medium-fine sand.

Cycles: Two cycles averaging 2.65 metres thick, overlie irregular erosional surfaces on firm mud (burrowed in places). The basal sediment may be a muddy silt or sand which

PLATE 1

Bioturbation Fabrics

a. Pyritic cast of a dwelling burrow within mud. The burrow was probably created by a malacostracan.

X 0.8; from 163.5 metres

b. Cross-section of back fill in a burrow within a sorted very fine quartzose sand. Dark laminae are now micritic carbonate and indicate concave alternations of sand and mud pushed behind the animal as it moved through the sediment.

field of view is 8 mm wide; from 67.1 metres

c. Varied textures within a burrow-mottled micrite. Quartz sand is unevenly scattered throughout a grumous micrite, indicating an original pelleted texture. Infilled burrows around mollusc fragments are pellet-rich.

Photomicrograph, field of view is 8 mm high; from 101.48 metres

d. Compacted bioturbated silty mud with burrows infilled by silt and muddy silt. Sub-horizontal cracks are a post-drilling desiccation phenomenon.

Photomicrograph, field of view is 8 mm high; from 120.64 metres

e. Dark silty dolomitic micrite containing glauconitic ooids and pellets contrasts a burrow/boring which is silt infilled and cemented by glauconite. The host is interpreted as a dolomitic hardground.

Photomicrograph, field of view is 8 mm high; from 183.8 metres

f. Bioturbated silty-sandy grumous micrite containing burrows with mud centres (*Clymenella*-like). The host sediment was originally pelletal mud prior to compaction.

Photomicrograph, field of view is 8 mm high; from 109.25 metres

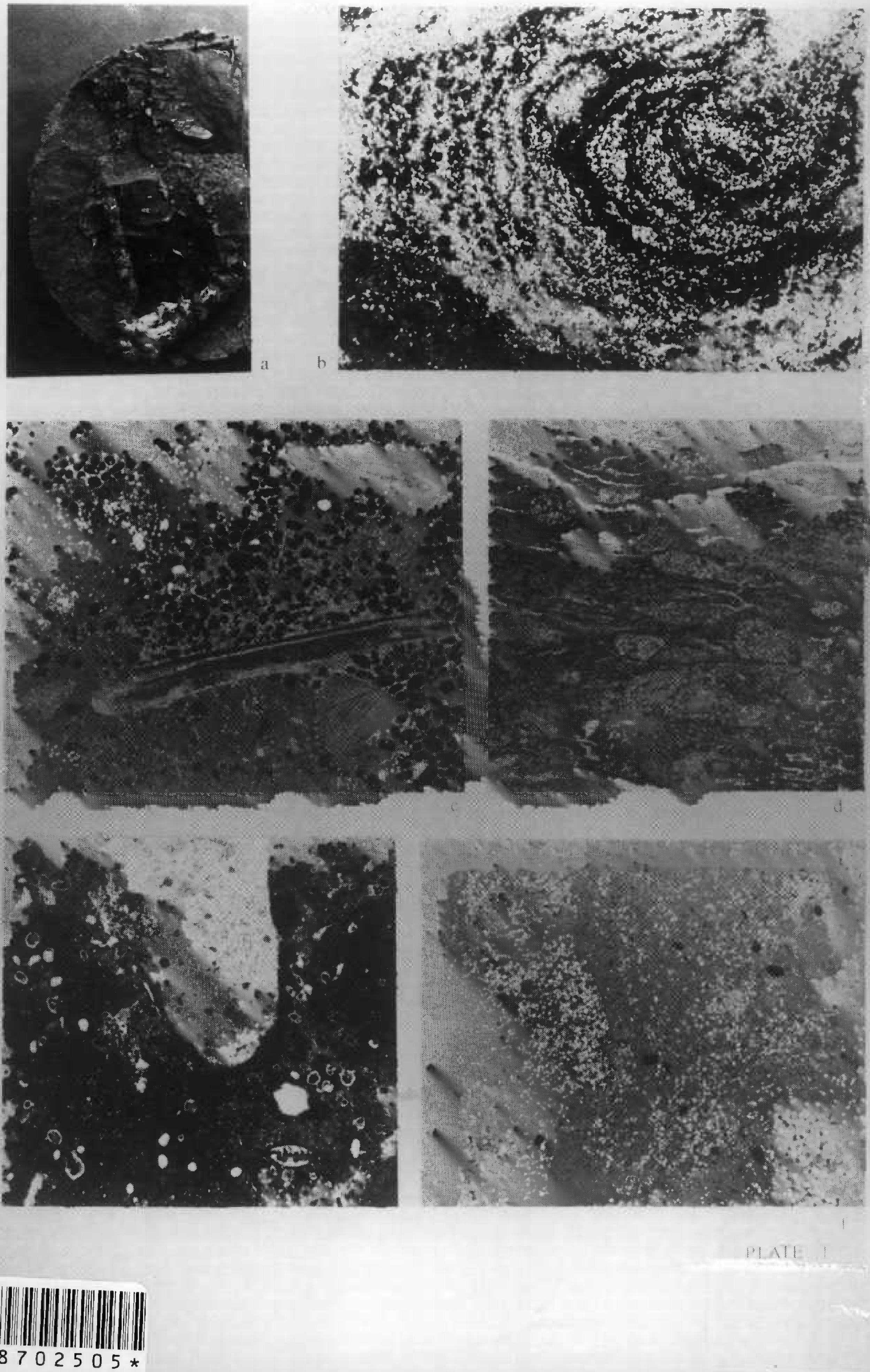


PLATE 1

grades up through cross-stratified fine quartz sand (shelly bands of disarticulated pelecypod valves, bryozoa, and turritellid gastropods are scattered through the sand) to an upper burrowed sandy silt firmground in which the burrows have remained open to the subsequent depositional events.

Discussion: Lithofacies B is 5.4 metres thick, between 170.7 and 165.3 metres depth.

The lack of any thickness of cross-stratified sediment and the preservation of irregular relief in the underlying firmground imply that these are channel sands of low velocity regime, but not deep enough to meet the subtidal niche of scaphopods. These cycles probably reflect broad shallow tidal channels which have subsided through compaction of the underlying muds, resulting in deposition of thicker sands.

Lithofacies C

Characteristics: The monotonous and faintly laminated dark olive grey muds and silts have characteristic vertical fine pyritized tubules throughout a partly laminated sediment. Scattered pyritized *Ophiomorpha* tubes are ubiquitous, with some *Clymenella*-like burrows.

Lithologies: Silts and muds are colour-mottled from burrowing, and are dark olive grey, light olive grey, and olive grey-yellow grey combinations. Silts have slightly more varied bioturbation than very uniform micaceous muds. Minor clay occurs in thin bands. Some silt horizons are indurated.

Cycles: The changes in bioturbation abundance are cyclic. This is not as apparent with lithological changes. The base to cycles is usually lighter coloured mud which grades up to a glauconitic silt with an upper dark erosional surface. Cycles average 2.7 metres thick and are apparent from sharp colour changes across the erosional surfaces.

Discussion: Lithofacies C is 31.3 metres thick between 165.3 and 134 metres depth. Nine cycles are recognized. The general diminution of burrowing activity within the clayier sediments may be due to decreased oxygenation within the sediment, making it inaccessible to most infauna. The very fine pyritized tubules are probably small *Chondrites*, traces of animals which are most tolerant of anaerobic bottom water and sediment environments (Bromley and Ekdale, 1984). *Ophiomorpha* shrimps could burrow beneath an oxygenated surface into reducing environments. Such conditions were probably in a tidal lagoon which had infrequent water exchange.

Lithofacies D

Characteristics: Diversely and prolifically bioturbated glauconitic silts contrast the thick non-bioturbated clay bands. Crumbly gravelly clay bands, sulphate moulds and pseudomorphs, minor desiccation cracks, and dolomite-calcite-chert nodules are characteristic.

Lithologies: Olive black to dark olive grey, brown black carbonaceous clays, both uniform and lightly bioturbated are compact to crumbly and gravelly. The olive black clay is slickensided, especially around concretions. The olive black, brown black muddy silts are prolifically burrow-mottled and colour-mottled in light yellow brown and light olive grey.

Cycles: The cyclic sequence is uncertain because contacts are indistinct. However the olive black clay with fine pyritized tubules appears to be at the base, grading up to muddy silt and glauconitic silt.

Discussion: Lithofacies D is 6 metres thick. The presence of sulphate moulds, desiccation cracks, and very limited bioturbation indicate an upper intertidal evaporative pond which is restricted to normal tidal exchange but is periodically flooded with sands or silts when, with drops in salinity, there is a corresponding boom in infaunal bioturbation.

Lithofacies E

Characteristics: This is a silt-dominated unit with minimal clayey silts and muds. Reddish black, crumbly or clotted horizons with soil or dolomitic caliche fabrics are recurrent. *Malacostracan* debris is most abundant in this lithofacies and bioturbation is prolific (Plate 1d,f). Flaser structures and gravel lags are minor features.

Description: The silts are predominantly dark black to dark olive grey and burrow-mottled with light olive grey tones. The carbonaceous sediments range from:

laminated and micaceous silts, to
sandy silts, and
dolomitic and glauconitic silty fine to very fine sands.

Laminated silts and intensely burrowed clayey silts are more characteristic in the upper part of the lithofacies. Cyclical patterns are not very apparent although repeated fining up from silty sand to silt occurs. Lamination and bioturbation structures alternate in approximately one metre cycles throughout the interval regardless of sediment changes.

Discussion: Lithofacies E is 26 metres thick, between 128 and 102 metres depth. Core recovery was 61% and the type of nonrepresented sediments is significant in the overall character of the unit. The Lithofacies is ascribed to the Geera Clay as a unit of more consistent episodic tidal flat deposition which exceeded bioturbation rates, as indicated by the rhythmic laminated/flasered and burrow-dominant alternations.

Lithofacies F

Description: Thin rhythmic fining upward sequences are characteristic in the dark olive grey to grey black carbonaceous silts, micaceous silts, fine to medium quartz ooid sands, and brown black to grey black clay of this lithofacies. The silts and muds have a distinctive friable gritty peaty appearance. Carbonate nodules occur in the sands.

Cycles: Cycles average 0.55 metre thickness, as fining upward sequences from quartz and quartz ooid sand up to sandy muddy silts and are carbonaceous. Few cycles have a reworked sand above the upper muddy silt.

Discussion: Lithofacies F is 20.5 metres thick between 102 and 81.5 metres depth. Only 27% core recovery is available, making this characterization of the unit tenuous at best.

Seven thin sand to silt cycles are identified and a thicker reverse-graded cycle with an upper gravelly lag clay occurs at the top of the unit.

The thin cycles and gravelly lag in black clay indicate perhaps regressive or progradational conditions with shallow water as would be encountered in sand shoal and landward tidal salt marsh-paralic conditions.

This lithofacies is tentatively assigned to the Bookpurnong beds. The expected disconformable contact with the Geera Clay is thought to lie within a 4 metre core loss between lithofacies E and F.

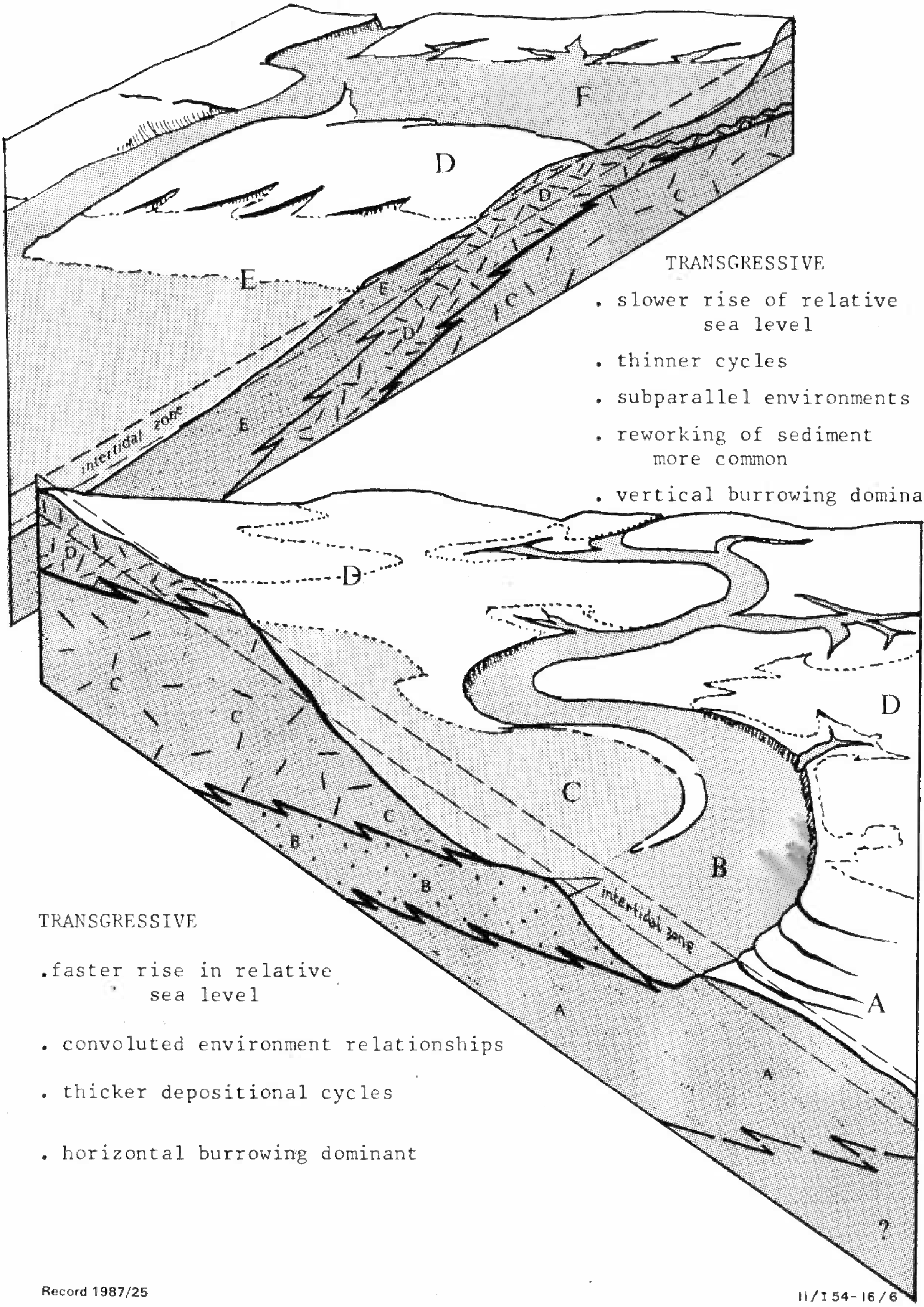
DEPOSITIONAL ENVIRONMENTAL MODEL

The sediment for the Geera Clay is presumed to have originally come from the southeast Australian Highlands but has been considerably modified during transportation across the extensive fluvial-deltaic and fluvial-lacustrine environments of the Olney Formation. Consequently a particle-size range of fine siliciclastics is to be expected. The sequence lacks any autochthonous carbonate contribution from open marine conditions and this is in agreement with the palaeofacies model of Brown (1984, 1985) where platform carbonate shoals isolate a restricted platform lagoon adjoining the tidal flats.

The spatial distribution of macroenvironments within the Geera Clay (Lithofacies A, B, C, D and E) is speculative when based on one hole. There is, however more certainty of juxtaposed microenvironments on the basis of Walther's Law (Walther, 1893/94).

One interpretation is offered in Figure 6. Lithofacies A, B, C and D are transgressive facies deposited during a period of relative sea level rise, with minimal erosion and reworking of sediment within the depositional setting and shoaling-upwards cycles average 2.4 to 2.7 metres thick. Bioturbation is dominantly horizontally oriented. The Geera Clay environment is envisaged as a complex flooded coastline with convoluted broad and shallow estuaries and tidal channels (Lithofacies B) with adjoining small intertidal-subtidal levees. These demark extensive areas of more restricted shallow marine conditions with predominant anaerobic sediment interfaces (Lithofacies C). Such areas shoaled up to high intertidal-supratidal flats which were in part evaporitic. Episodic flooding returned conditions to marine intermittently and sustained a fluctuating ichnofauna (Lithofacies D). Limited sulphate, chert and dolomite precipitation occurred within the sediment.

Elsewhere along the shoreline to the lagoonal Winnambool environment, broad intertidal flats had active sediment movement and winnowing, and also formation, burial and re-emergence of firmgrounds and hardgrounds (Lithofacies A).



TRANSGRESSIVE

- slower rise of relative sea level
- thinner cycles
- subparallel environments
- reworking of sediment more common
- vertical burrowing dominant

TRANSGRESSIVE

- faster rise in relative sea level
- convoluted environment relationships
- thicker depositional cycles
- horizontal burrowing dominant

Figure 6 Interpreted Depositional Environments

The rate of rise in relative sea level is considered to have reduced during deposition of Lithofacies D in the borehole section, and as a result, Lithofacies D and E were still transgressive, but had thinner shoaling-upward cycles (1-0.55m) because of more active redispersal of sediment. As a consequence, environments tended to be of simpler spatial geometry and subparallel. This contributed to a more efficient exchange of the water mass, maintained an oxygenated sediment surface, and stimulated greater infaunal activity. Additionally, most of the glauconitic particles were oxidized. Because of the increased sediment mobility and erosional events, vertical burrows predominated (*Skolithos* facies). Lithofacies E sedimentation ranged from low intertidal to supratidal with periodic development of soil and caliche overprints adjoining Lithofacies D conditions.

Lithofacies F is envisaged as a restricted marine saltmarsh-paralic environment with a high organic matter influx from land sources.

DIAGENESIS

GENERAL STATEMENT

Diagenesis is discussed under diagenetic process and product categories and is then placed in time context in Figure 7, with a following discussion of paragenesis.

Clays

The clays and clay fraction of muds in the sequence are dominantly smectites (and smectites with a minor proportion of interstratified illite), subdominant kaolinite, mica-illite-glauconite, and minor mixed layer smectite-illite.

Whole sediment samples were separated into the clay and clay fraction and Figure 8 shows variations of mineralogy of sediments downhole. Where quartz was not dominant in the non-clay fraction, then clay minerals predominated. Unfortunately analyses are from two sources and there may be slightly differing interpretations on abundance of smectite and mixed-layer smectite-illites.

In Lithofacies A, mixed-layer smectite/illite component and kaolinite are approximately equally proportioned, with accessory mica/illite. (It is uncertain if this difference from Lithofacies C, D, and E is real or one of interpretation differences).

Lithofacies C, D and E (AMDEL analyses) are very similar in clay mineral ratios in having smectites dominant, kaolinite subdominant, and accessory or trace mica/illite/glauconite. Some smectites in upper C and middle of D Lithofacies have a minor proportion of interstratified illite.

Lithofacies F (1 sample) has a clay fraction dominated by equi-proportioned kaolinite and mica/illite.

Discussion: Interpretation of origins of clays of the sequence is difficult because of the multiple overprints of diagenesis, climatic conditions of provenance and the original source of the clay. Glauconite is common in the sequence. This is to be expected when an abundance of detrital mica is available in the sediment. The predominance of smectites may be a diagenetic overprint, reflecting uptake of magnesium from seawater or groundwaters, or indicate a volcanic source. If the smectite is diagenetic, it would indicate Mg-rich connate waters. However, smectite-rich soils are usually indicative of desertic soils (Grim,1968). Additionally, the presence of magnesium and calcium will tend to inhibit kaolinite formation. Perhaps the kaolinite and part of the illite are unchanged transported components of the sediment and may be related to climatic and soil conditions of the adjoining fluvial plains. Kaolinite can form in laterosols, requiring warm, humid, wet conditions. With cooler, moist conditions as in podzols, illite becomes slightly dominant over kaolinite. Truswell & others (1985) come to an interpretation of Geera Clay climate being a drier type of rainforest growing under mildly seasonal moisture regime, a climate in which podzolic to slightly lateritic soils could form.

In Lithofacies F, the application of soil type characteristics would suggest a podzolic source because of the equi-proportioned kaolinite and illite. This would imply cool damp climatic conditions in the Late Miocene and Early Pliocene.

Glauconite

Glauconite is both a predepositional and postdepositional phase in eogenesis. Its most pronounced occurrence is as coatings on sand and silt particles, ooids, and as a replacement of faecal pellets (Plate 1c,d), coprolites (Plate 4a) and grapestones. Much of this early predepositional glauconite is partly or wholly oxidized to goethite in the topmost sand of Lithofacies B, and in almost all occurrences in Lithofacies D, E and F (Figure 7). Glauconite has also precipitated in and replaced bioturbated eroded hardgrounds and firmgrounds. These surfaces may also be dolomitized and or oxidized.

An early very pale green, poorly crystalline clay, presumed glauconite, is an important porefill cement within burrow interparticle porosity, interparticle porosity in sands, and in intraskeletal porosity.

Discussion: Petrographic evidence suggests that oxidation of glauconite to goethite occurred in varying degrees before deposition. Most environments interpreted in the sequence are very shallow marine to intertidal. Mildly reducing conditions (Eh 0 to -150 mV, pH 7-8) are required for glauconite formation. Although the bottom-water environments are more likely oxidizing, the prolific bioturbation and production of mixed organic matter and clays in faecal pellets would have produced numerous surfaces of changeing Eh conditions to facilitate its precipitation. The abundance of early framboidal pyrite is consistent with such microenvironments.

Goethite/Phosphate

Goethite is evident as a product of syndepositional glauconite oxidation, especially in Lithofacies F, E, D and to a lesser degree in B. Phosphate is uncommon but where present is in trace amounts, with manganese?, in goethitic particles (EDAX analysis of pellets at 99.5m). Phosphate is also present as a trace with pyrite and arsenopyrite in burrow geodes (0.2% at 132.77m).

Discussion: The abundance of goethitic coatings on sand and silt, and replacement of pellets (some slightly phosphatic), is indicative of the mobility of these particles within the shallow marine - tidal regime after glauconitization, and the time of exposure to oxidizing conditions prior to burial. EDAX analysis of pellets shows varying degrees of oxidation of glauconite, and of minor phosphate and manganese scavenging by these particles.

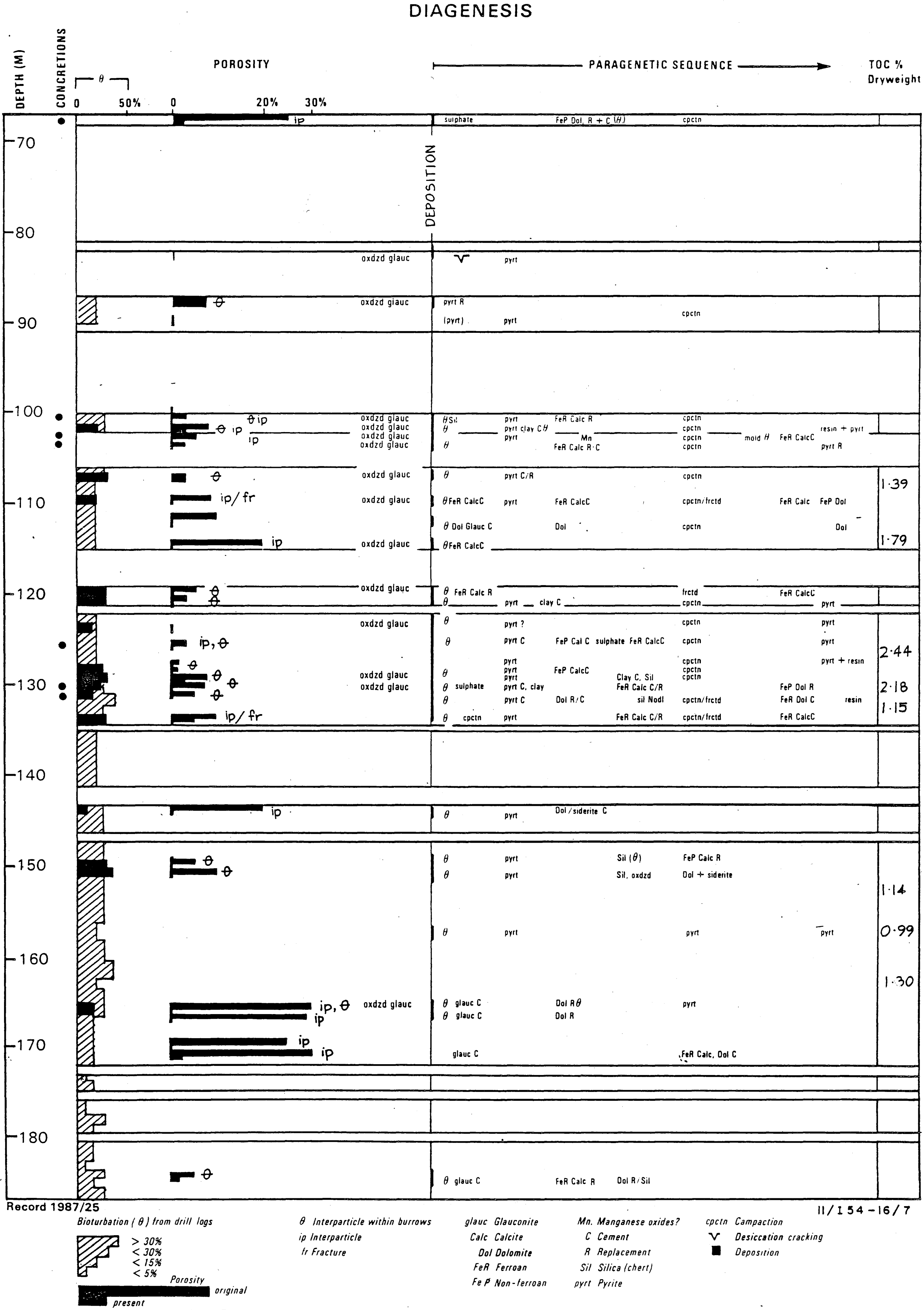


Fig. 7 Log of diagenesis and paragenesis, Piangil West 1 borehole.

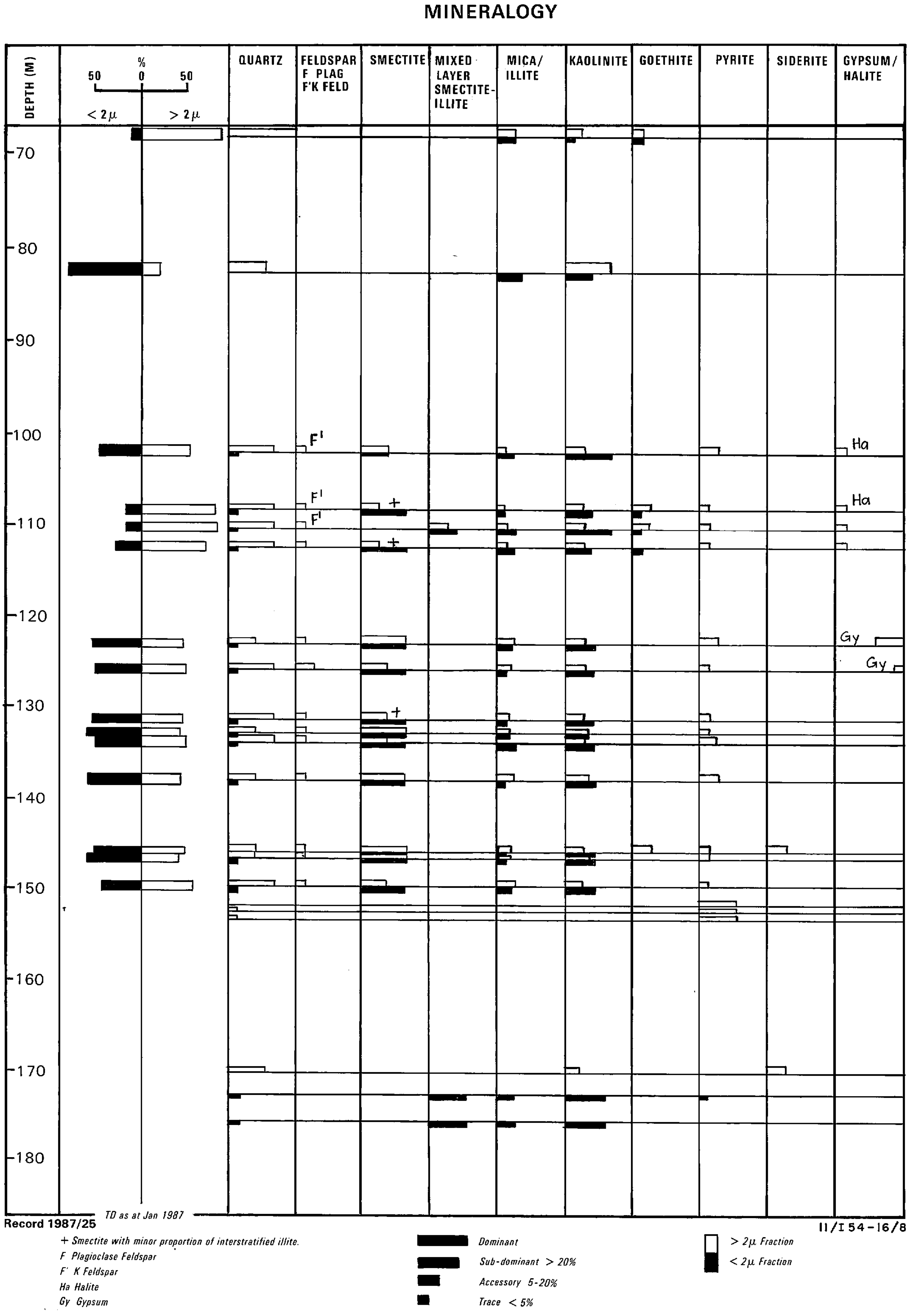


Fig. 8 Mineralogic log of Piangil West 1 borehole.

Carbonates

Concretions and Indurated Horizons: Concretions occur either within homogeneous silts or clays, or close to a porosity transition-usually in the more porous sand or silt adjoining a contact with a less permeable sediment. Nodules are spheroidal to ellipsoidal and commonly range in diameter from 40-100 mm. Very large concretions may be misidentified as indurated beds because of the core provided. Seven petrographic samples above 132 metres are concretions (Figure 7, Appendix IV) and were selected because they preserve pre-compaction textures.

Concretions are usually composed of one phase of carbonate and contain replacement/micrites which may obliterate original textures unless sand or coarse silt-sized siliciclastic particles are the dominant components. Additional replacement phases may be present, such as patchy dolomite in calcitic micrite, or chert replacement in the centre of dolomitic nodules.

Calcite: Calcite is the most common carbonate within the sequence but this is in very small amounts, % of the sequence as scattered nodules and patchy induration of porous sands and silts.

The main carbonate fabric is micrite, with accessory druse cements, and rare radiating needle fabrics.

Micrite forms nodules that replaced the fine siliclastics, forming nodules. This fabric is pervasive, commonly having grumous texture, but it is uncertain if this reflects earlier pelletal muds and silts. Micrite replaces very fine siliclastics but only embays and partly replaces coarse silt and sand.

Druse Cement is the most common porefill cement, competing with clay cements in burrow interparticle porosity and in occluding interparticle porosity of sands and silts. More elongate crystal form drusy cements which heal fracturing in nodules following compaction (Plate 3b).

Radiating needle fabrics are rare but occur in intraskeletal porosity with manganese dioxide? in remnant porosity. These fabrics are probably early high magnesium calcite precipitates (Plate 2f).

The calcite is predominantly ferroan, as expected with abundant iron in the sediment, but this also indicates an absence of, or low, sulphate activity in the precipitating waters, as is usually common in fresh water.

One interval, the zone with known sulphates in Lithofacies D and lower E (Figure 7) has initial nonferroan calcite. When sulphate is present in porefluids, pyrite and nonferroan calcite will precipitate whereas in the absence of sulphate ions, the iron is incorporated into the lattice to form ferroan calcite (Davies, 1971). Ferroan calcite is ubiquitous elsewhere in the section, and implies an absence of sulphate, most probably by reduction prior to pyrite precipitation.

Dolomite: Dolomite is less common than calcite (< 1% of sequence) but has minor distribution in nodules and in indurated bands. Micritic fabrics are dominant as precipitate/replacement in early diagenetic nodules, and in glauconitic burrowed crusts and horizons with clotted textures.

As a cement, it has a sucrosic rhombic fabric, and fills pores and replaces clay cements within burrow interparticle porosity.

In concretions, dolomitic micrite has gradational transitions with the host sediment. The centres of concretions may be chert with gradational change to the outer dolomite (Plate 3e).

At one occurrence at 129.73m, dolomite replaces palimpsest poikilotopic authigenic sulphate forms, 0.5-3mm tabular outlines filled with fine sucrosic dolomite, within a silty clay host.

Discussion: Dolomite is predominantly ferroan poor, and occurs in glauconitic bioturbation horizons which are interpreted as hardgrounds. These have been eroded, and reincorporated in situ, confirming syndepositional development. The nonferroan composition and very fine sucrosic textures indicate early marine precipitation, which is in accord with the early chert precipitated as silicic gels. One horizon, 111.6 metres, has clotted colour and texture and is considered to be caliche after a probable firmground-hardground.

Dolomite replacement and cementation late in diagenesis is post compaction.

Siderite: Traces of siderite were detected with XRD at 145.8m and 170.0m (Figure 7) and are considered an accessory to late-stage dolomitization, probably under high organic freshwater conditions.

Chert

Chert is almost exclusively a replacement phase within the centres of micritic dolomitic concretions. It is microcrystalline and may exhibit several phases of concentric accretion, with corresponding variable preservation of palimpsest textures. The chert was apparently a gel at time of replacement, with resultant shrinkage and synaeresis cracking (Plates 2d,3e). The occurrence in Lithofacies C (Plate 2d) shows chert replacing the glauconitic/goethitic wall of a burrow, with associated iron staining.

Discussion: Chert appears to be a minor replacement phase within the sequence. Because it is almost invariably within dolomitic replacements, estimation of its timing is difficult, but appears by its occurrence to be an early diagenetic replacement within early dolomite in concretions and hardgrounds.

Sulphates

Evidence for precipitated sulphates within the sequence is minimal. As the core material dried out, white efflorescences developed over some finer clastics indicating quite saline porefluids. XRD analyses of muds and clays repeatedly showed traces of halite and gypsum in Lithofacies E. Halite is presumed attributable to these efflorescences and consequently implies very saline pore fluids in Lithofacies E.

Three horizons do have evidence of former sulphate emplacement

67.1m in the Parilla Sands?; see Plate 2b: columnar subhedral crystals of dolomite in a felted fabric within a dolomitic concretion. Although this superficially appears like interparticle cement within a sand, the almost regular crystal orientations and their dual porefill/replacive nature are suggestive of this being a dolomitized anhydrite nodule.

PLATE 2

Diagenetic Features

a. A uniform silty - very fine sand (grainstone texture) comprises angular quartz particles with embayed surfaces. These are suggestive of dissolution and/or calcite replacement.

Photomicrograph, field of view 1.5 mm high; plane-polarized light

from 114.4 metres

b. Columnar subhedral crystals of dolomite (after anhydrite?) generally occlude interparticle porosity as well as penetrating and replacing quartz particles.

Photomicrograph, field of view 0.5 mm high; crossed polars

from 67.1 metres

c. Relict pelleted texture in a carbonate concretion is contrasted by early diagenetic pyrite porefill (black) between the pellets. This cement has prevented obliteration of the texture by subsequent early compaction which occurred elsewhere in the host sediment.

Photomicrograph, field of view 2.0 mm high; crossed polars

from 125.22 metres

d. Burrow with silicified iron-stained walls. Fracturing within the chert is a synaeresis effect.

Photomicrograph, field of view 7.4 mm high; plane-polarized light

from 150.9 metres

e. Framboidal pyrite is a geopetal sediment within zooecia of a bryozoan (intraskeletal porosity). The remaining porosity was subsequently occluded by a ferroan calcite druse cement

Photomicrograph, field of view 580 microns wide; plane-polarized light

from 101.48 metres

f. Remnant intraskeletal porosity within a gastropod chamber, after partial infill by detrital sand and mud, is finally occluded by needle-like calcite crystals (pseudomorphs after aragonite?) and later opaque manganese dioxide.

Photomicrograph, field of view 580 microns wide; plane-polarized light

from 101.48 metres

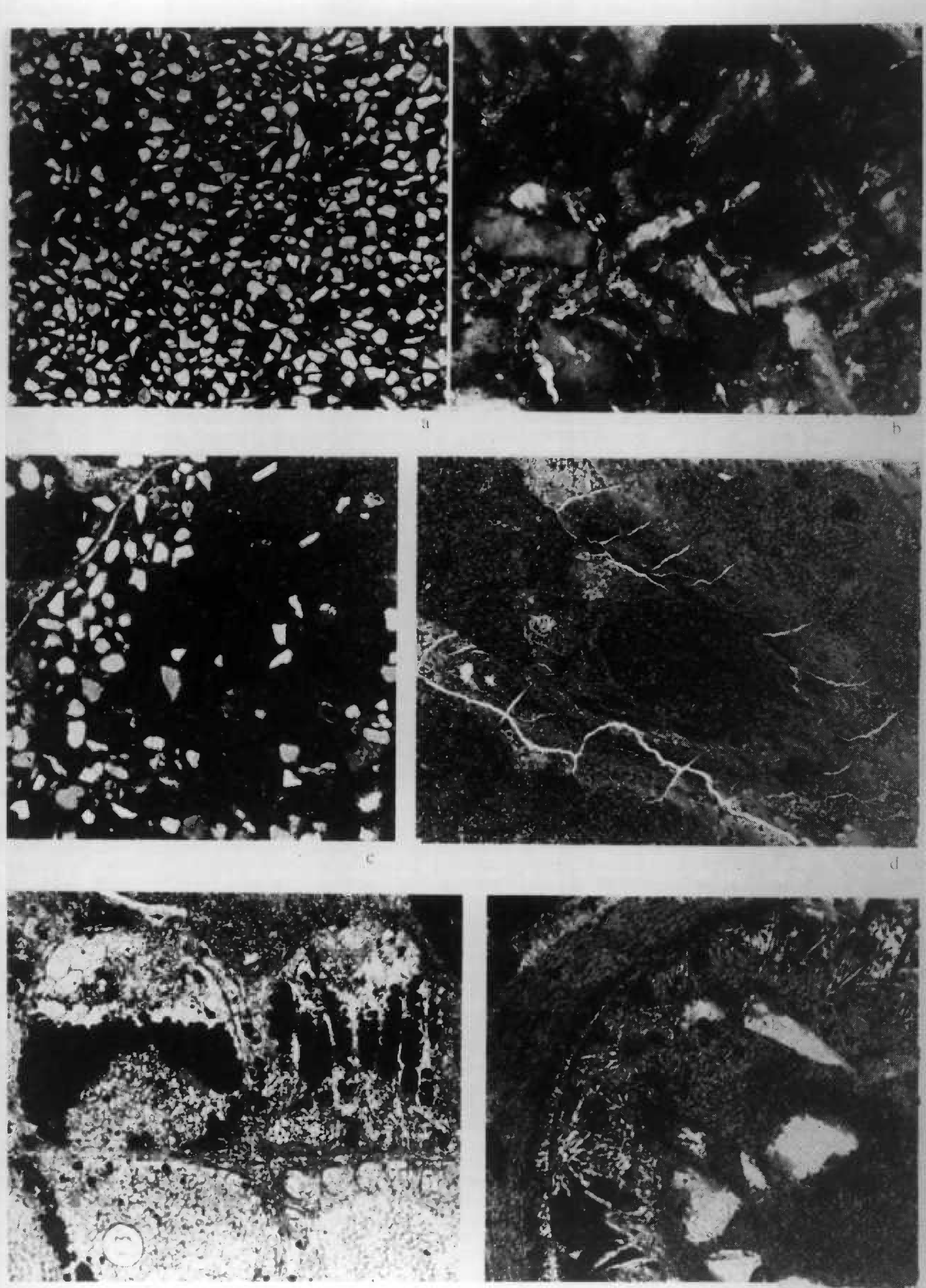


PLATE 2

129.73m in Lithofacies D :Within a carbonate concretion, palimpsest rectangular and composite rectangular forms 0.5-3mm long are preserved by a micritic dolomite within a silty micrite. These structures crosscut sedimentary fabrics, and envelop particles. Tabular shapes appear to be poikilotopic replacements within the sediment with no evidence of displacement of any kind. Consequently this appears to have occurred prior to and perhaps during early carbonate nodule growth.

132.35-.5m in Lithofacies D: a mottled green grey - dark yellow brown muddy silt has mesoscopic tabular to columnar vugs. The oxidized mottled colour and texture are believed indicative of an exposed surface-soil or evaporative pan in which gypsum crystals grew, displacing the host, and were later redissolved. These vugs have no infilling sediment or cement, and it is probable that sulphate dissolution was significantly post-depositional.

Discussion: Lithofacies E has the only occurrences of existing halite and gypsum as indicated by the limited number of XRD determinations. Gypsum is present at horizons 125.8 metres, and above at 122.9 metres where it exceeds 20 % of the sediment. These samples are just above Lithofacies D where there is evidence of former sulphates.

The occurrences in Lithofacies D - E suggest that sulphate-rich connate fluids and groundwaters existed early in diagenesis; this interpretation is supported by the initial absence of non-ferroan carbonates. It remains speculative whether the existing sulphate in Lithofacies E is evaporitic, an early diagenetic groundwater precipitate, or a more recent phase related to the present groundwater system.

Pyrite

Pyrite is ubiquitous as an eogenetic and mesogenetic diagenetic phase in the sequence, and is most abundant in Lithofacies C, D, and E where it is predominantly a porefill cement and a minor replacement phase.

As a porefilling cement, pyrite occurs in framboidal habit (framboids approx. 30 microns diameter) within intraskeletal porosity (Plates 2e,3a,4c,4d), burrow porosity (Plates 1a,3c,3d), burrow interparticle porosity and interparticle porosity. It is most obvious as porefill in large burrows where it most commonly has framboidal habit, often intermixed with resinous organic matter. Some horizontal segments of *Ophiomorpha* burrows are incompletely occluded and contain pyrite and minor arsenopyrite in delicate compound needle-like habit as fringe cements, almost always in association with resinous organics. Such crystalline aggregates are usually very friable inside of the outer replacement shell because the resin interpenetrates most crystal-crystal boundaries.

Pyrite can totally replace skeletal components, pellets or nuclei of glauconitic ooids. One type of bioturbation, very fine bifurcate traces (approx. 0.1mmD), can only be recognized by their preservation as thin pyritic films or tubules. These are of undetermined rootlet or animal origin.

Discussion: Once anaerobic conditions are established within the sediment, detrital iron-bearing minerals are able to be solubilized by bacterial or inorganic processes. With hydrogen sulphide production from either bacterial sulphate reduction or decomposition of organic sulphur compounds from dead organisms, iron sulphides and pyrite will precipitate quickly to form framboids and geopetal framboid cements.

When the core was unwrapped from cold storage and warmed up, the exposed surfaces very quickly changed colour, darker by 1 tonal increment of the Rock colour

TABLE 1 : GEOCHEMICAL ANALYSES FROM PIANGIL WEST 1 BOREHOLE

SAMPLE DEPTH Metres	Cu ppm	Mn ppm	Fe %	As ppm	U ppm	Cr ppm	V ppm	
109.00	13	220	9	255	4	130	370	
132.77*	5	50	20	10000	-	-	10	pyrite crystals
135.80	14	49	2.4	33	4	135	170	
136.52	18	225	13.1	110	4	86	10	
163.5A	4	14	34.7	1950	4	145	170	pyritized burrow
163.5B	18	75	5.25	94	8	135	530	host sediment

Analyses by AMDEL

Bismuth and Gold below detection level Bi (10), Au (0.05 ppm) all samples

*132.77 m Semiquantitative spectrographic analysis
Additional elements Co (20), Ni (80), Pb (30), Sb (30), P (2000), A1 (1500), Mg (200), Si (4000 ppm)

PLATE 3

Diagenetic Features

a. Gastropod within quartzose silt. Intraskeletal porosity is occluded by pyrite (lower, white) and resin (upper, black) which migrated into this porosity. This resin is brittle and crazed, indicating loss of moisture or other volatile components.

Photomicrograph, field of view 1.44 mm high; reflected light

from 100.73 metres

b. Healed fracture within a calcitic concretion (ferroan calcite) is occluded by fibrous ferroan calcite.

Photomicrograph, field of view 2.8 mm high; crossed-polars

from 133.5 metres

c. Cross section of horizontal cylindrical burrow (*Ophiomorpha-* like) occluded by pyrite and resin. Gravity-settled pyritic framboids form a geopetal surface in the lower part of the burrow. The upper area is a spongy intermesh-work of framboidal pyrite, resin and porosity. This overall fabric suggests that the resin was or became immiscible with the groundwater and floated within the porosity.

Photomicrograph, field of view 1.44 mm high; reflected light

from 127.75 metres

d. Detail of upper part of (c) showing discrete and interpenetrating framboids within a resin matrix.

Photomicrograph, field of view 600 microns high; reflected light

from 127.75 metres

e. Dolomitic concretion with nucleus of crazed chert, lies within a muddy silt. Synaeresis cracks are thinly coated with dolomitic druse cement and or a resinous film.

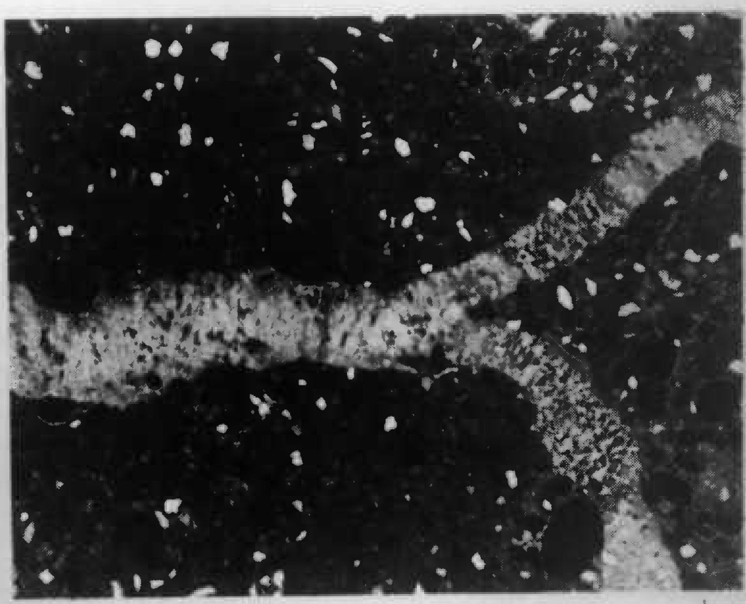
x 0.44; from 130.5 metres

f. Detail of e, showing fracture within chert that is coated with a film or desiccated crust of black resin (diterpenoid compounds). Speckled area is open porosity.

Photomicrograph, field of view 1.76 mm high; reflected light

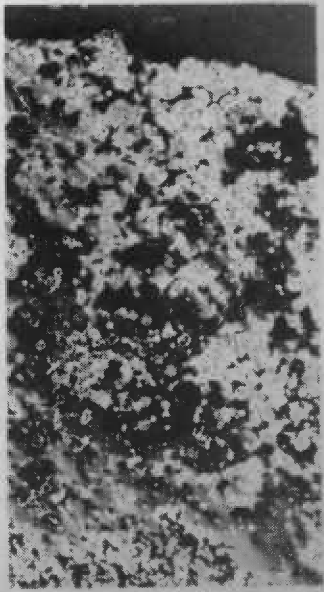
from 130.5 metres

a



b

c



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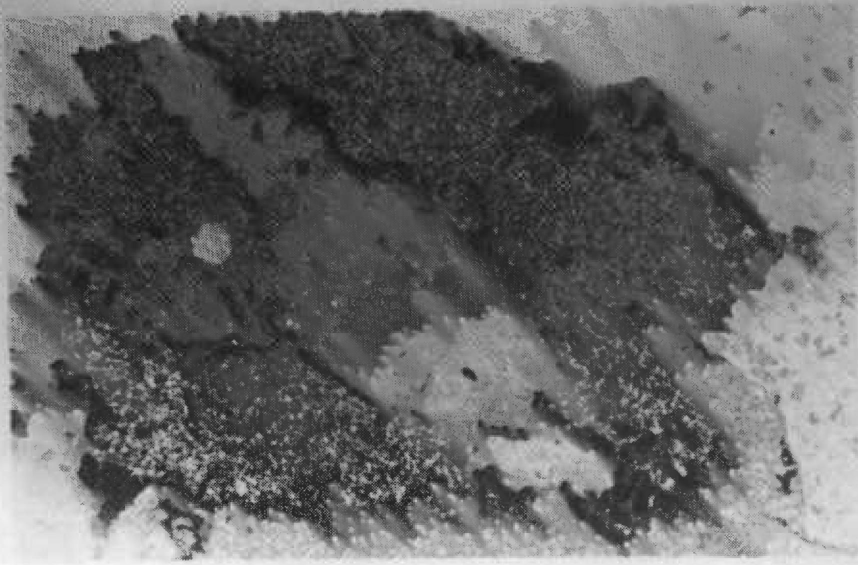

f

PLATE 3

chart, and this slowly penetrated the core over time. During drilling, 'rotten fish' and 'garlic' odours were unavoidably noted by the drillers. It is likely that traces of hydrogen sulphide were being released through the drilling mud. This phenomenon, in conjunction with the core darkening on exposure, suggests precipitation of very fine sulphides during the sudden temperature, pH and Eh change with exposure. The principal phases which may have formed at room temperature and neutral pH by the reaction of H_2S and HS- with fine-grained goethite or dissolved ferrous iron are black mackinawite and greigite (Berner, 1971).

The 'garlic' odour is attributed to arsenopyrite which occurs with pyrite in scattered intervals of Lithofacies D (1% as at 132.77 metres), Lithofacies C (0.2% as at 163.5 metres) and possibly in Lithofacies A (Figure 5, Table 1). The presence of arsenic and mobilized resinous material suggests a later diagenetic phase for arsenopyrite. The source of arsenic remains unresolved.

Resinous organic material

This organic material occurs microscopically as non-fluorescent opaque black blobs with a granular texture, and a dull grey reflectance under incident light (R_0% of 0.3-0.4%). Where visible to the naked eye, the resin has a bright vitreous lustre on conchoidal fractures of its crazed habit. One gas chromatographic analysis of a resinous extract in chloroform indicated a total absence of saturated hydrocarbons but the presence of diterpenoids (C20) and high concentrations of C35 compounds. The resinous material is most readily observed as a late void-occluding phase in intraskeletal porosity (Plate 3a), in synaeresis cracks within dolomite-chert nodules (Plate 3e,f) or in the larger horizontal burrows of *Ophiomorpha* and related malacostracans (Plate 3c,d). In the latter occurrence, framboidal pyrite is commonly associated. In other instances the resin is only a thin desiccated film over needle-like pyrite and arsenopyrite crystals within burrows where the porosity has not yet been totally occluded. The resin is more widespread in occurrence within burrow interparticle porosity in association with disseminated finely crystalline pyrite, and within the finer clastic host sediments. Resinous stains occur below the 120 metre level of the borehole in the lower 10 metres of Lithofacies E, Lithofacies D, scattered throughout Lithofacies C and in the lower part of Lithofacies A (Figure 5). Total organic carbon levels in the sequence are higher, up to 2.5% dry weight, near the Lithofacies D-E boundary (Figure 7). However it is unknown whether this TOC anomaly is a direct indication of the resin or perhaps the source material of the mobilized resin.

The occurrence documented in Plate 3c, above a geopetal accumulation of pyritic framboids and intermixed with pyrite in a spongy texture is strongly indicative of a later (mesogenetic) stage of emplacement as fluid which was both immiscible with and less dense than the groundwater.

Discussion: The origin of the resinous material remains speculative. In composition, the resin is most likely a derivative from wood or tree saps. Its habit and paragenetic associations are both in accordance with its migration up to relatively late stage (mesogenetic of Choquette and Pray, 1970). Possible sources are either the host sediment, or the underlying Renmark Group.

1) **Geera Clay as a source:** Wood fragments were observed only in three horizons, 67, 123, and 137 metres depth and although possible, these meagre occurrences do not seem significant. However, Truswell & others (1985) note that the pines, Araucariaceae, are consistently represented in the microflora and locally reach

frequencies as high as 35% within the Geera Clay in Oakvale 1. The aerial dispersal of such species is believed limited and *Araucaria*, at least, is only well recorded from within *Araucaria*-dominated forests. On this reasoning they inferred transport of pollen material to be entirely by water. In such a situation, it is possible that exuded resins from such forests may have also had similar transportation. This, however does not explain the predominance of later diagenetic occurrences without any associated evidence for pre-existing resin accumulations in the host sediment.

2) The Renmark Group as a source: As fluvial deltaic and fluvio-lacustrine derived sediments, this unit has potential for wood-derived diagenetic products. The Renmark Group interdigitates with and underlies the Geera Clay (Figure 2). If the resins have migrated from here, it may have been lateral migration along aquifers and into the aquitard as well as vertical migration from the underlying aquifer. The resin probably migrated in a low viscosity state, whether emulsified in water or borne by organic solvents, until it was trapped in blind pockets of porosity where it separated out and floated above the groundwater in this porosity or just slowly lost more volatile components leaving it to harden and desiccate in situ.

POROSITY

The sequence has very low porosity which is predominantly interparticle porosity within burrows. Because of the spatial separation between burrows, and their resultant infrequent intersection, this remnant porosity does not contribute much to permeability of the sequence. Most intervals are 0%, less than 1%, and a few reach 7% porosity. This contrasts with original (eogenetic) porosity which was much more variable, from 30% interparticle porosity in sands, down to 5-10% burrow interparticle porosity in muddy silts, and muds.

Reduction of porosity from early diagenesis to present, from 7-30% down to 3-% was mainly by cementation in bioturbation and porous sands, as well as by compaction of soft pellets in the finer host sediment. Cements are predominantly clays and carbonate.

Porosity estimates are qualitative, based on limited petrographic examination (Appendix IV) and summarized in Figure 7. A more consistent documentation (but less accurate) is available in the detailed litholog of Appendix I.

In the lowermost Lithofacies A, primary burrow interparticle porosities (Plate 1e) of about 5% are reduced to approx. 2% by clay (glauconite?) and minor dolomite porefill.

The very fine quartz sands of Lithofacies B had initially high (25-30%) interparticle porosity which has been reduced to 0-3% (1% interparticle and 2% intraskeletal) by precipitation of both clay (glauconite?) and ferroan calcite. The calcite precipitation was relatively late, most probably in groundwaters with low sulphate content. Clay precipitation may have been much earlier, sourced from recrystallization of clays already present in the sediment.

Lithofacies C is now virtually impervious with no apparent porosity except in loose networks of *Ophiomorpha* burrows, pyritized and resin filled, but with relict porosity in some places. Initial burrow interparticle porosity was 5-10% of the sediment.

Present porosity in Lithofacies D ranges from 0 to 3%. Originally burrow interparticle porosity was 5-10%. Clays and minor pyrite now occlude this earlier porosity. Two clay horizons constitute significant vertical permeability barriers. They have minimal bioturbation. An interstratified muddy silt has at present, and possibly back to the eogenetic phase, sulphate mould porosity which does not appear interconnected sufficiently to increase permeability.

Early porosity in Lithofacies E was variable, from 20 to 0%. This was predominantly burrow interparticle porosity, 3.6% (standard deviation 3.2%, n = 7) and minor interparticle porosity of 9.6% (standard deviation 9.6%, n = 3). This has been reduced to 0.15% (0.3% standard deviation, n = 10) with the precipitation of early pyrite, clays and manganese dioxide?, and late ferroan calcite.

Lithofacies F also had variable original porosity of 0-8% (3.3% mean, 3.5% standard deviation, n = 7) as predominantly burrow interparticle porosity with minor intraskeletal porosity. Porosity has remained unvaried or slightly reduced in burrows but lost from former intraskeletal porosity (Plate 2e,f). Present porosity is estimated to be 1.6% (standard deviation 2.8%, n = 7). Reduction of porosity was mainly by calcite and pyritic cements.

PARAGENESIS

The paragenesis of the sequence is summarized in Figure 7. The most dramatic diagenetic changes appear early, with syndepositional glauconitization and subsequent oxidation of sediments and hardgrounds, followed by early post-depositional pyrite precipitation, growth of carbonate nodules, and initiation of cementation in burrow and interparticle porosity by clays and carbonate. After compaction of the sediment, cementation and replacement by clays and carbonate continued at a slower rate, with final pyrite and resin occlusion of remaining porosity.

GENERAL DISCUSSION

Porosity has been consistently reduced with time. During early diagenesis, there was probably vertical permeability, albeit low, up through the sequence, via burrow interparticle porosity in the muddier sediments, to the clay beds of Lithofacies D. These have not been burrowed and consequently remained impermeable. The upper Lithofacies would have been permeable to vertical fluid migration.

Lateral porosity and permeability was initially high in the sands (Lithofacies B, and intervals of C and E) but this would have been strongly influenced by the geometry of the sand bodies, their continuity, and diachroneity within the sequence. Apart from speculation on depositional facies models based on one hole, additional drilling and stratigraphic logging would be necessary to build a more reliable understanding of sediment body geometry.

Lithofacies D and the lower part of E appear to be the most impermeable barrier to upward migration of groundwater during early diagenesis. The presence of halite and gypsum above, but not below Lithofacies D (Figure 8), is congruent with this model.

With a general occlusion of porosity throughout the sequence since early diagenesis, vertical permeability has been greatly reduced, and lateral permeability remains only within specific intervals.

CONCLUSIONS

1. The cored sequence is characterized by dark and carbonaceous semiconsolidated silts and muddy silts (65%), unconsolidated and partly indurated sands (15%), mud (14%), and black plastic clays (6%).

2. Generally the clays and clay fraction of muds comprise dominant smectite, subdominant kaolinite, minor mica-illite-glauconite and mixed layer smectite-illite.

3. Six Lithofacies are recognized in Piangil West 1 borehole. Lithofacies A to E are considered Geera Clay, and Lithofacies F - Bookpurnong beds. This is overlain by the Parilla Sands.

4. Deposition of the sequence wàs by micro-progradational cycles (shoaling-upward cycles) during a rise in relative sea level to produce shallow intertidal flat, shallow estuarine channel, subtidal-intertidal restricted marine and supratidal facies in a convoluted embayed configuration. As the rate of sea-level rise diminished, the transgressive environments were subjected to more reworking and a simpler subparallel coastal configuration developed with more open marine, supratidal and paralic conditions being established.

5. Bioturbation in the fine siliciclastic sediments enhanced the original porosity of the sequence. Early porosity ranged from zero in the clays, to about 5-10% in the silts, and up to 30% in sands. Burrow interparticle porosity predominated, with additional interparticle porosity in sorted coarse silts and sands. The combined effect of early diagenetic cementation by clays, carbonate and pyrite, and subsequent compaction of the sequence reduced porosity to an existing range of 0-7% as interparticle and burrow interparticle porosity types.

6. Clays, glauconite, pyrite, calcite and dolomite precipitated in the sediment at an early stage. Carbonate and minor pyrite precipitation continued as both replacement and porefill during compaction to very late diagenesis when pyrite, resinous organic matter, and traces of arsenopyrite occluded remaining porosity.

7. During early diagenesis, vertical permeability in the sequence was low, created in part by the ubiquitous bioturbation. Lithofacies D, with clay bands up to 1.5 metres thick, would have been a permeability barrier. Depending on spatial configurations of Lithofacies B (shallow channel sands), there may have been bypass permeability to this barrier until later in diagenesis when the sands were totally occluded by cement.

8. The possibility of vertical groundwater flow, at least for the earlier part of diagenesis, is supported by the occurrence of late resinous matter in burrow porosity. The resin material has most probably been derived from woody tissue that is prolific in the underlying Renmark Group.

ACKNOWLEDGEMENTS

Thanks are extended to the Victorian Department of Industry, Technology and Resources which undertook the drilling of Piangil West 1 bore. Thanks are also extendry to Ken Heighway, Arthur Wilson, and Frank Kane of BMR for their cooperation in logistics and technical assistance. Michael Doyle kindly undertook the photography and printing of macrofossil specimens. Isopach and stratigraphic data in Figures 1 and 2 were provided by Campbell Brown and the text was edited by John Perry.

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APPENDIX I

DETAILED LITHOLOG OF PIANGIL WEST 1 BOREHOLE

EXPLANATION AND LEGEND

Format

The stratigraphic log is arranged in 8 columns, being from left to right:

1. Depth below surface in metres and sampled intervals
2. Graphic litholog
3. Sedimentary structures
4. Macrofauna
5. Colour
6. Degree of induration
7. Lithological description
8. 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
G	Geochemical
TOC	Total Organic Carbon

Graphic Litholog

○ ○ ○	conglomerate
⁖	sand
∵	silt
⟍⟋	clay
⁘⟋	mud
⊥	calcareous
―	dolomitic
◎	concretion
✶	synaeresis cracks

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
	slickenslided cellular texture
	skeletal hash
	erosional relief

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 infilled by variety of sediment types ≥ 10 mm
	very fine traces, ubiquitously pyritized, frequently bifurcate, penetrating bedding or being confined to laminar parting surfaces. rootlets? or very fine burrows?
	very large boring/dominichnia with concentrated mud-rich striations around a pyritic centre

≤10%	Approximated % abundance of all bioturbation in the sediment
⬯	pyritized burrow

Macrofauna

Y	Brachiopod
Y	Bryozoan
di	discoidal colony
pl	planar colony
br	branching colony
0	Coprolite
◇	Echinoid
sp	spine
8	Foraminifera
agg	agglutinated
∝	Fish
δ	Gastropod
f	fusiform
t	turreted
pu	pupaeform
sn	snail
✳	Malacostracan
0	Ostracod
Ծ	Pelecypod
o	ostrea
P	Pellet
♀	Plant material
/	Scaphopod
⊕	Scleractinian, solitary coral
▭	Wood fragment

General subscripts

a	articulated
ab	abraded
d	disarticulated

fr	fragment
gl	glauconitic
hs	hash
sm	small

Colour

The colour of wet 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 due 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
ptchy	patchy
mtl	mottled

Degree of Induration, Coherency

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

indrtd	indurated
frbl	friable
cmpct	compact
fiss	fissile
uncons	unconsolidated
crmbl	crumbly
slick	slickenslided
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
2μ -----------		
	c	clay

Abbreviations for Lithological Description

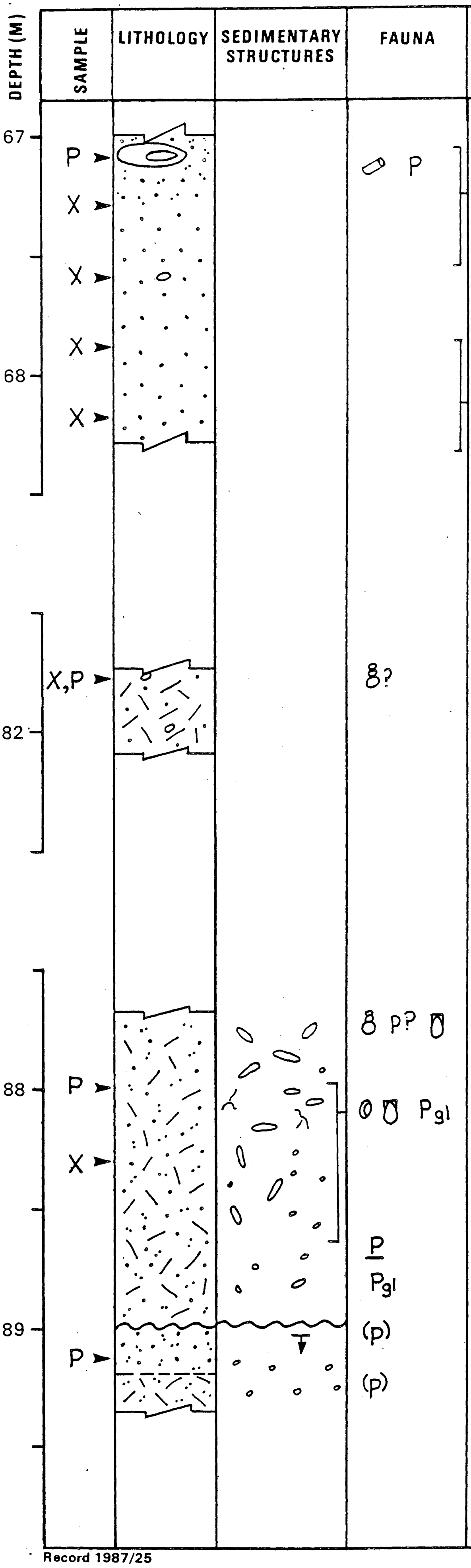
ang	angular	Ptchs	patches
Biotrbn	bioturbation	pel	pelletal
Concrt	concretion	por	porous
Clay	clay	pyrt	pyritic
Cmnt	cement	Pyrt	pyrite
dissem	disseminated	pebbl	pebble
frctd	fractured	rndd	rounded
facetdn	faceted	Replmnt	replacement
frmbdl	framboidal	Snd	sand
glauc	glauconitic	Sndst	sandstone
Gastrp	gastropod	Slt	silt
intbdd	interbedded	Sltst	siltstone
Intrclst	intraclast	subang	subangular
intlmn	interlaminated	subsph	subspheroidal
lmntd	laminated	srt	sorted
Lmntn	Lamination	skltl	skeletal
Xlmntnd	crosslamination	staind	stained
lrg	large	slick	slickenslided
Mud	mud	tublr	tubular
Mdst	mudstone	trace	trace
mtl	mottled	Text	texture
Nodl	nodule		
Nucl	nucleus		
Orgncs	organic material		

Diagenetic Features

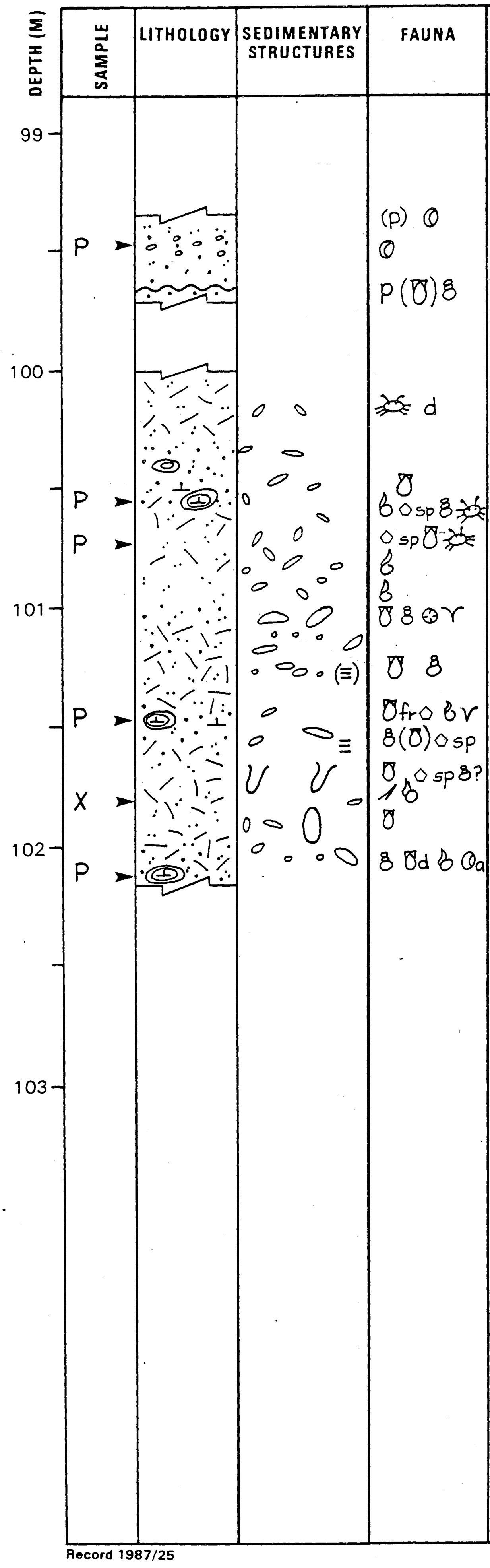
These are generally recorded in the last column but, where necessary, follow the lithological description separated by colon or full stop.

APPENDIX 1

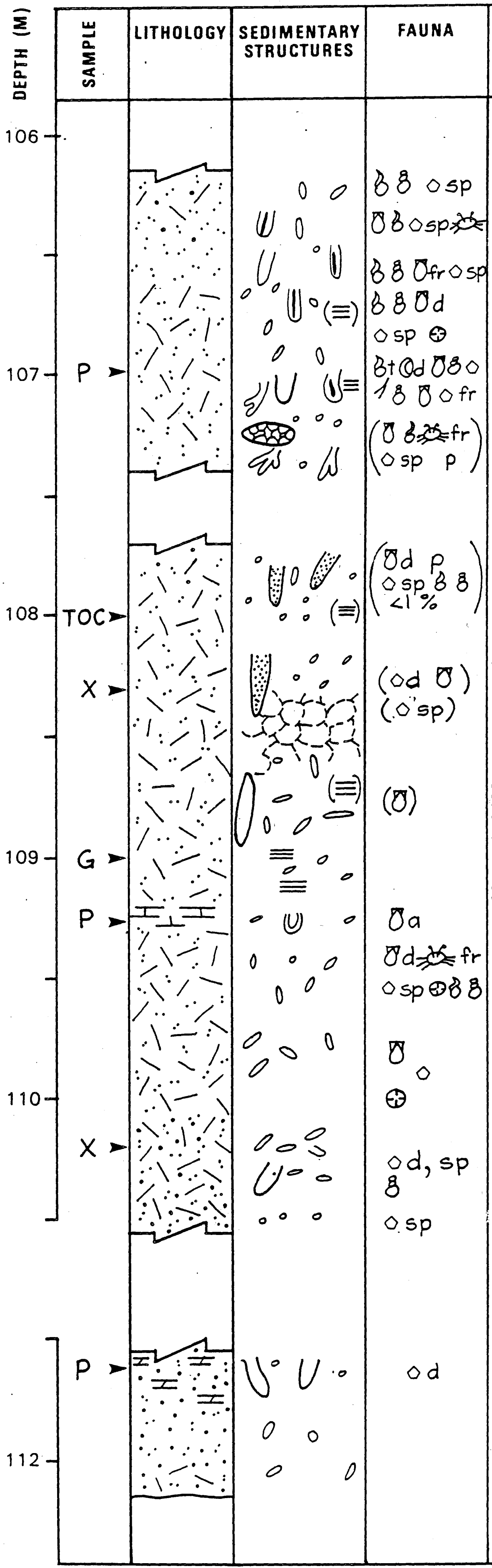
Detailed Litholog of Piangil West 1 Borehole



COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIA-GENESIS
olv blk [5Y2.1] lt olv gy [5Y5.2]	plst/frb concr.	Snd, ((srt)),f, slt, qtz[(mic), unif]. Concrtn, cl Sltst, (qtz); pyrt Cmnt in Nodl	Pyrt
lt olv gy [5Y5/2]	uncons	Snd, vf, slt, qtz [subang], fldsp, mic; unif srt	
	uncons	Snd, vf-f, qtz [submdd], (fldsp), (mic) [glauc], (lith); unif, srt.	
(mtl) m olv gy			
lt olv gy [5Y5/2]		Snd, vf-f, qtz[rndd-subrndd], (fldsp) 5%, (mic) [Biot, Musc.]5%; incr subang particles downsection.	
gy blk [N2] mtl olv blk[5Y2/1]	plstc	Clay; (snd)$_{10}$, pbbl [ang, Sltst, m snd]; qtz [rndd, brn staind surfaces], org -rich;crmbly	
gy blk [N2] olv blk [5Y2/1]	plstc/ crmbl	Mud? snd10% [qtz, m, rndd], foram Biotrbn, 2mmD, Slt [por, srt] infill; mtl.	pyrt Forams
gy blk [N2]	cmpct	Mud? (snd), pel [oxdzd Glauc], skltl; Pyrt repl skltl frags + tubules [frmbdl Text]	Pyrt
grn gy blk[5G1/1]	plstc	Slt, qtz, pel20% [glauc, grn blk], intrclst [mud];	
mtl dk olv gy[5Y2/2]	plstc	biotrbn Mtl of Slt, snd [qtz], mic pel 5-10%	
ptchy dk yel brn olv blk [5Y2/1]	plstc	abrupt colour chnge	
m olv gy [5Y4/2]		Snd, vf-slt, qtz, mic, (cl), pel; (srt), unif	
dk olv gy [5Y3/1] darkening to gy blk [N2]	plstc	mtl Slt, sd [vf qtz], pel.	
		Slt, sd [qtz], (pel), cl	frmbdl Pyrt

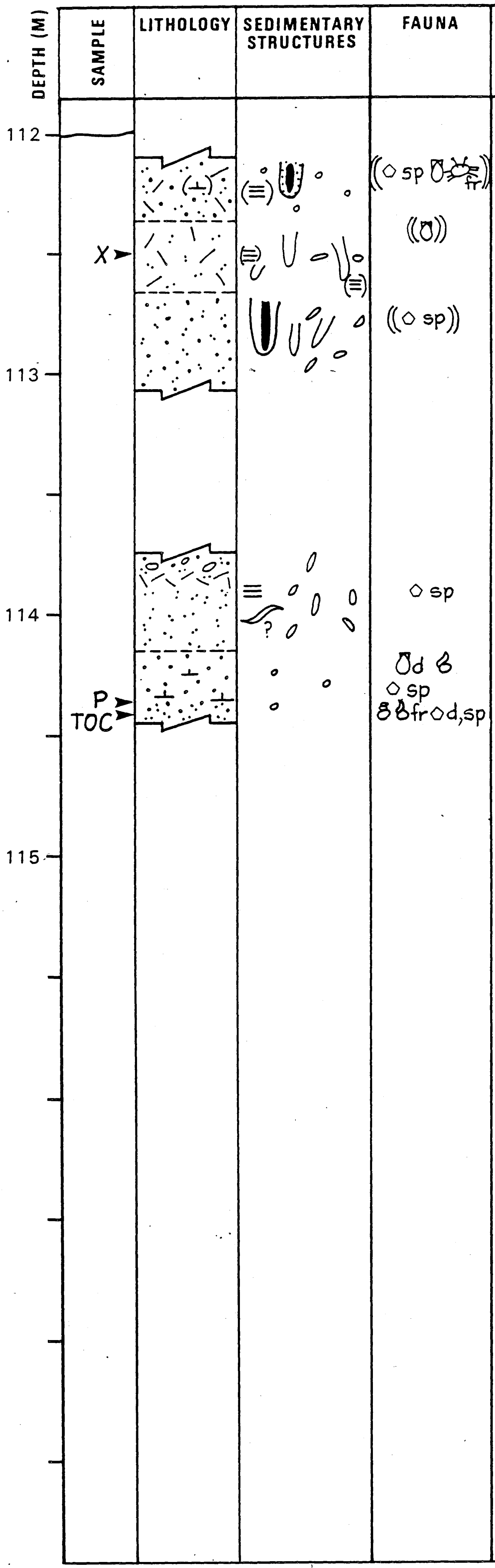


COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIA-GENESIS
dk olv gy [5Y2/2] gy blk [N2] mtl olv gy [5Y3/2]	crmbl	Slt, snd [vf], qtz, pel, intrclst [dk gy mud], cl, mic.	
	frbl	Grvl, snd [vc], gran/pbbl [sil Sltst, rnd, frctd], matrix of vf Snd, cl	
olv gy blk [N2] mtl dk yel brn [10YR2/2]		Snd, vf-slt [qtz, coated grains], biotrbn Mtl	
gy blk [N2] mtl		Slt, cl, (pel), (mic)	frmbdl Pyrt
dk olv gy [5Y2/2]	cons	Snd, f-m, ooid [glauc pyrt Nucl]; calc Cmt	calc/ Concrtn Pyrt
dk olv gy [5Y2/1]	waxy	Slt, cl, (snd) [vf qtz], mic; blk glauc coated grains);	
		Biotrbn, lmmD, subvert/horiz, pyrt or slt + snd infill	frmbdl Pyrt
dk olv gy [5Y2/1]	crmbl waxy	Slt, snd [coated grains]; mtl Biotrbn, irreg, > lcmD, vc snd + skltl infill	
		Mud, mtl [lcmD patches],	frmbdl Pyrt
brn blk [5YR2/1]	crmbl	Mud, snd [coated grains]; Biotrbn, reddish slt + snd infill	pyrt Blebs
dk olv blk[5Y1/1]	crmbl waxy	Snd, cl; snd Clay intlmntd, Clay, + Snd, clay, slt [blk pel] + Slt, cl, (glauc), qtz	calc pyrt Blebs in Biotrbn
brn blk [5YR2/1]	fiss waxy	Clay, slt, (snd), (skltl), (pel), mic	pyrt Concrtn pyrt sm Biotrbn
		Biotrbn, v thin, infill, Slt-Snd vf.	
gy blk [N2]	(fiss) waxy	Concrtn, in snd, slt Mud	Pyrt, Calc

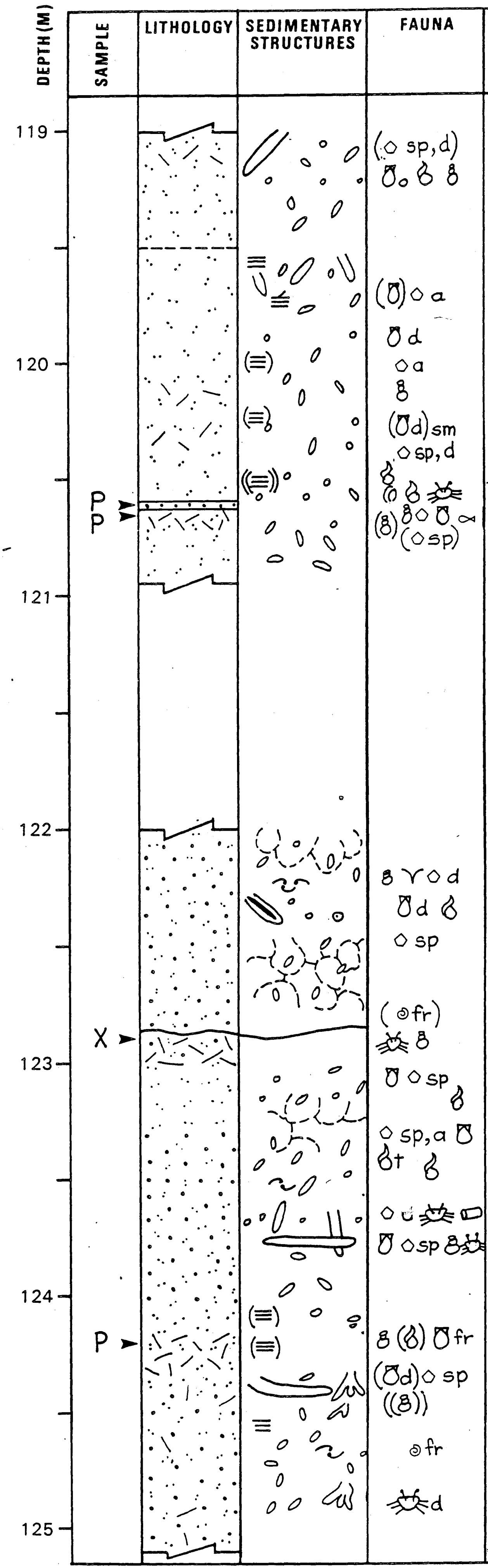


COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIA-GENESIS
olv blk [5Y2/1]	waxy/ cnchdl		
olv blk [5Y2/1] mtl ol gy [5Y3/1]	waxy/ cnchdl	Slt, cl, snd [vf], qtz [ang], pel [blk glauc], mic;Biotrtn 2-4mm D, infill concntrc Slt + clay	frmbdl pyrt [illegible] to Biotrtn
olv blk.[5Y2/1]	waxy	Slt, cl, snd [qtz, vf], pel [glauc] mtl Biotrtn 1-2mm D, 10-15 mm D, concntrc infill] outter pyrt + mud	Pyrt
olv blk [5Y2/1]	waxy	Slt, (srt); Biotrtn 1-2 mmD, infill Slt, srt, skltl	pyrt Biotrtn
dk olv gy [5Y2/2]	waxy	Slt, qtz, [ang.], pel + ooid [glauc]; mtl; Biotrtn, infill Slt, qtz, srt	frmbdl Pyrt in lrg Biotrtn
	plstc?	Clay? (dk clay lines on outside of core below)	
dk olv gy [5Y2/1]	cmpct sucrosic	Slt, cl, vf snd, +slt [qtz, ang] pel [glauc] Biotrtn, vertical, 4mmD, pyrt; horzntl mic srt Slt +(srt). Lmntn of blk peaty cl	complete Replmnt of vertical [illegible] by frmbdl Pyrt
dk olv gy [5Y2/2] vf unif Mtl, lightening with depth	cmpct clotted	Slt, cl, (mic); infill of Biotrtn is Snd [srt, reddish qtz] and gy (srt) Slt Biotrtn infill Slt, snd, srt, brn + Slt, (srt), pel [glauc]	frmbdl pyrtin lrg vertical + (horizntl) Biotrtn
micro Mtl-red/grn meso Mtl-brn/ olv gy[5Y3/2]	clotted	Slt, cl, Snd [vf qtz],pel [glauc] intbdd, intlmnd reddish Clay + vf Biotrtn th/out [1-2 mmD, infill srt slt, (srt)	pyrt lrg vert. Biotrtn
olv gy [5Y4/2]	indrtd	Micrite, slt, qtz [rndd], mic, pel [glauc];frctd	Calc + ? Sil
dk olv gy [5Y2/2] mtl lt olv gy [5Y5/2]	waxy	Slt, cl, snd [qtz, rndd, vf], pel [glauc, red, oxdzd]. m-lrg Biotrtn infill srt brn vf Snd	dissem frmbdl Pyrt
dk olv gy [5Y3/2] biotrtn mtl olv gy	plstc/ sucrosic	Mud, pel [glauc], slt [qtz]; prolific Biotrtn, 1-2 mmD, subhoriz, infill srt Slt Biotrtn increases downsection to homog Text	patches dissem frmbdl Pyrt
		Slt, (vf-f snd), glauc	
		Snd ((srt)), qtz [f-vf, subang, grn pel [glauc]	
dk olv gy [5Y2/2]	plstc	Snd, ((srt)), qtz [f-vf, rndd, mic, pel [glauc]; biotrbd Mud matrix.	
olv gy [5Y3/2] mtl lt olv gy [5Y5/2]	sucrosic	Snd(srt), qtz, mic, pel;Biotrtn,1-4mmD);infill Snd srt,	Dol, reduced
dk olv gy [5Y2/2] darkens to bottom	plstc/ sucrosic	Snd, slt, qtz [f-vf, rndd - subang], mic, pel [glauc], mud matrix Biotrtn subtly apparent. Clayier to base	

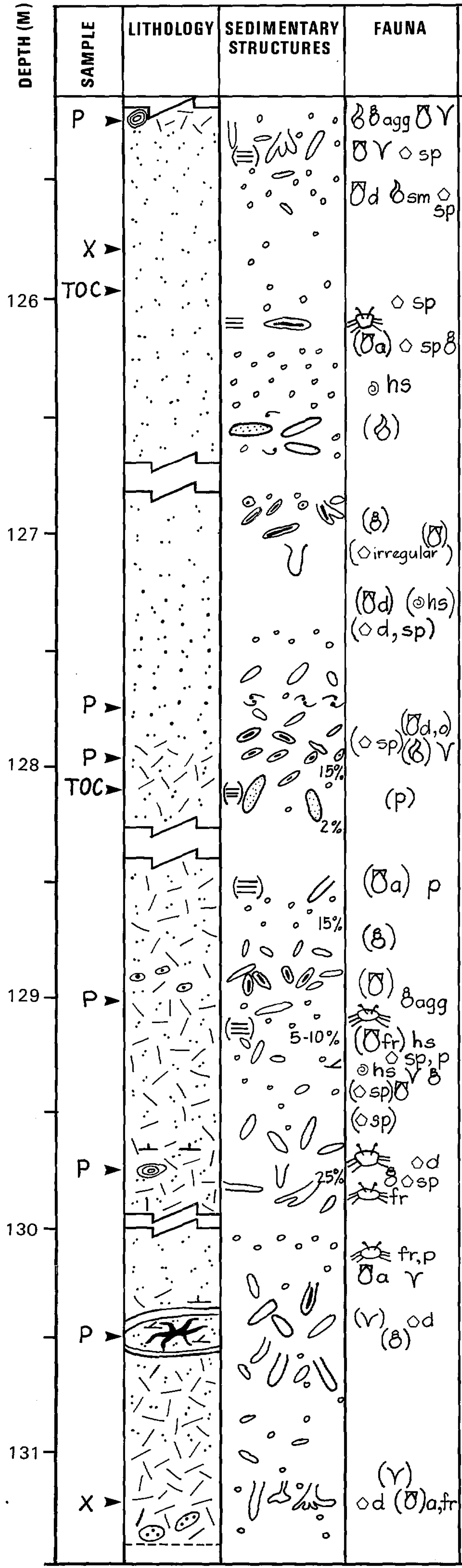
4



COLOUR	DEGREE OF INDUR-ATION	DESCRIPTION	DIA-GENESIS
olv blk [5Y2/1]	cmpct/ plstc	Slt, snd, cl, qtz [vf-slt,rndd-subang],mic, cl matrix; (Calc)	frmdl Pyrt [nodl + dissem]
olv gy [5Y3/2] mtl, lt olv gy	cmpct	intlmntd Md; Slt, Snd [vf-f, subang-rndd]; Biotrtn 3 mmD, infill, Snd, <u>srt</u>, vf qtz, uncons	pyrt tubes 3 encl dissem Pyrt
olv gy [5Y3/2] mtl Biotrtn lt olv gy [5Y5/2]	cmpct/ sucrosic	Mtl Slt, snd, [vf-f qtz, subang, brn + clear], mic, slt/cl matrix; Biotrtn, infill slt, snd [vf-f, srt, uncons]	pyrt core in l Biotrtn + scattered horiz tubes
lt olv gy [5Y3/2]	plstc/	Snd, qtz [f-vf], (srt), mud mtrx, clast?	calc
olv gy [5Y3/2] mtl Biotrtn	cmpct	intlmntd Mud [((sklt))] and Slt; [<u>srt</u>,qtz]	
olv gy [5Y4/2]		lighter coloured, biotrbtd	
olv gy [5Y4/1]	frbl	Snd, vf, <u>srt</u>, qtz [subang-subsph], (pel), [glauc + pyrt], intrclst [mud lumps]; var calc Cmnt in bands	calc Cmnt
olv gy [5Y3/2]	indrtd plstc	Slt, (cl), qtz	moldic + interparticle For
		presumed plstc Mud which is pressed against base of indurated Sndst at 114.35m: Possible also that unconsolidated sand occurs between Sndst and Mud.	



COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIAGENESIS
brn blk [5YR2/1]	waxy cmpct	Slt, cl, mtrx, qtz [subang], mic (srt); Biotrtn v small, infill Slt, [qtz, srt]	dissem frmbil Pyrt in Biotrtn
dk brn gy [5YR3/1] (mtl)	waxy/ cmpct	Slt, (srt), mic, qtz [subang]; small Biotrtn, infill Slt, srt, pyrt; lrg Biotrtn, >2mmD	Pyrt + resin
dk ovl gy [5Y3/1] mtl, olv gy [5Y4/1]	cmpct/ waxy	Slt, (srt), qtz [ang, subsph], ((cl)), mic; Biotrtn 1-1½mm, infill Slt, srt, uncons,	dissem Pyrt
olv blk [5Y2/1] biotrtn Mtl	cmpct/ waxy	Slt, cl, qtz [ang], mic [biotite musc], skltl [hash 5%] mtl 2 tone Slt [srt] in Biotrtn [subhoriz,.5-1.5mmD]	pyrt repl shells, patches
lt olv gy [5Y6/2]			
olv gy [5Y4/1]	indrtd	Sltst, snd, mud lumps, pel [glauc];over biotrbtd	Pyrt; fractured
olv blk [5Y2/1] biotrtn Mtl lt olv gy [5Y5/2]	cmpct/ waxy	Mud, Slt, (srt), qtz, mic [biot + musc, f-m snd] Biotrtn, subhoriz., .5-1mmD, infill, lt, srt, qtz mic	vf. Pyrt, [illegible] Skltl + Biotrtn
	uncons	v. soft	
olv gy [5Y3/2] biotrtn Mtl	crmbl/ slick	Snd, slt, (srt), qtz [ang, subsph], peaty? mic;	frmbdl Pyrt repl Biotrtn
lt olv gy [5Y4/2] homog by Biotrtn	cmpct/ crmbl	Biotrtn infill Snd [vf-f, qtz, ang, subsph] por	(Pyrt) in skltl Hash
		crumbly zones slickensided dk reddish gy + Pyrt; clotted (soil?)	
	crmbl		
olv gy [5Y3/2]		Snd, slt, vf-f qtz, skltl hash, mic	
olv blk [5Y2/1]	plstc	Snd, peaty, cl, (srt); qtz [f], glauc pel	dissem Pyrt
		Slt, (srt), peaty, qtz [ang], mic [biot + musc];	resin? + Pyrt
olv blk [5Y2/1]	cmpct	Biotrtn sm, infill, Slt, srt, qtz	inside Gastrpds
dk olv gy [5Y2/2]	frbl	Snd, vf, (srt), qtz [ang], mic; mtl towards bottom	pyrt + resin
lt olv brn [5Y5/6] biotrtn infill		infill, Snd [vf-f qtz, yel, submndd], por	stains in Gastrpds
dk gy [5Y2/2] mtl	cmpct	Slt, snd, qtz, [ang], mic, (srt),; Biotrtn infill Pyrt or Snd-Slt, srt, qtz, resin	
dk yel brn [10YR3/2]			
	waxy/ cmpct		
olv blk [5Y2/1]			
		Snd [vf-f], Slt, qtz [ang, nonsph], (mic), Cl; Biotrtn `10%, v sm; (Lmntn with subhoriz pyrt debris	Pyrt + resin in Gastrpds; dissem frmbdl Pyrt
dk ovl gy [5Y2/2] biotrtn Mtl	waxy	Slt, cl?, snd [vf], qtz [ang,] mic (srt);	pyrt
lt olv gy [5Y4/2]		Biotrtn, 1-2 mmD,[fodichnia], infill Snd [vf qtz, ang],srt, por, frbl	skltl Hash. lrg Pyrt Biotrtn
	waxy/ cmpct		



COLOUR	DEGREE OF INDUR-ATION	DESCRIPTION	DIA-GENESIS
olv gy [5Y3/2]	indrtd	Pckst, skltl, slt, (mud)	
olv gy [5Y2/2] lt olv gy [5Y5/2]	cmpct	Slt, qtz [ang, clear], mic; Biotrbn small, subhoriz, 1-1}mmD infill Slt srt	vf dissem Pyrt repl Skltl
brn blk [5YR2/1]	waxy		
olv blk [5Y2/1]	waxy	Slt, (srt), qtz [ang], mic [biot + musc] Biotrbn smaller to bottom, subhoriz; infill, Slt, srt, uncons	(pyrt) Replmnt of Biotrbn
dk olv gy [5Y2/2]	cmpct/ waxy	Slt, (srt), qtz [Lang], mic [biot + musc]; Biotrbn v small, infill Slt, qtz, srt	fmbdl pyrt [illegible] in Biotrbn
olv blk [5Y2/1]	waxy	Slt, (srt), qtz [ang], mic [biot + musc]; small subhoriz Biotrbn th/out.	Pyrt Replmnt of lrg Biotrbn
dk olv gy [5Y2/2] mtl Biotrbn lt olv gy [5Y4/4]	waxy/ cmpct	Slt (srt), qtz [ang, clear], mica [m Snd]; Biotrbn, vf dissem pyrt in srt Slt	Pyrt + resin in Ophiomorphia
olv blk [5Y2/1]	waxy/ cmpct	Slt, (srt), qtz [slt-f snd, ang; lrg grains brn staind], mic, skltl	Pyrt + resin in Ophiomorpha
olv blk [5Y2/1] mtl Biotrbn dk yel brn [10YR4/2]	waxy/ cmpct	Slt, (srt), qtz [slt-vf snd, ang], glauc; Pyrt Biotrbn 1-2mmD, infill Slt, qtz, [amber colrd), srt	+ resin in Ophiomorpha
brn blk [5YR2/1]	waxy/ cnchdl	Mud, qtz [ang, Slt-f snd, brown staind], pel [glauc]; Biotrbn subhoriz, sm, pyrt + slt infill	pyrt lrg Biotrbn
olv blk [5Y2/1]	cmpct/ cnchdl	Slt, cl, qtz [ang], pel [glauc], mic	pyrt Skltl + lrg Biotrbn
olv blk [5Y2/1]		Slt, (cl), qtz [slt-vf, ang], pel [glauc], mic; Biotrbn infill snd [(srt), f, glauc]	pyrt Biotrbn
brn blk[5YR2/1]mtl dk yel brn [10YR3/1]	clotted	Mud, homog; Biotrbn infill Snd, (srt), vf-f, qtz, mic [50%], por; resin or Goethite?	dissem pyrt Cmnt in Biotrbn
brn blk[5YR2/1]	cmpct	Mud, (lmntd), qtz [ang], mic	
olv blk [5Y2/1]	cmpct	Slt, cl, qtz [ang], (srt), pel [glauc],mic; Biotrbn infill f-vf Snd, (srt), brn coated qtz,frbl	Pyrt Slick; resin Goethite?
olv blk [5Y2/1] mtl lt olv gy[5Y5/1]		Snd, slt - vf [qtz, ang], pel [m, glauc], mic; Biotrbn, sm; infill Snd, f, qtz [ang], srt, por, vf	pyrt Biotrbn
olv blk [5Y2/1] mtl Biotrbn	gritty	pyrt Cmnt; m, Snd, f, qtz, srt, calc Mud + calc Nodule,; Biotrbn .25% infill Slt, (srt), m snd [glauc].	Slickenslides calc Concrtn
lt olv gy [5Y5/1] concr 5Y6/1 dk yel brn[10YR4/2]	cmpct		
olv blk [5Y2/1] mtl Biotrbn lt yel brn[10YR5/4]	waxy cmpct	Slt, (srt), (cl), qtz [ang, (brown-stained)], pel [m, glauc]; Biotrbn infill Slt, qtz, brown coated, srt, por, frbl	resin in Bryozoa + Biotrbn
olv blk [5Y2/1]+ [10YR7/4],[10YR3/2]	waxy	Slt, cl, qtz; Biotrbn infill Snd, vf-f, qtz,	resin +Pyrt in
lt olv gy [5Y4/2]	brittle	Slt, cl, qtz, pel [glauc] + Nodl [Pckst-Wckst]	Biotrbn
dv blk [5Y2/1] dk yel brn[10YR4/2]	slick	Mud, qtz [ang]; Biotrbn infill Slt, snd qtz, resin, pel [glauc oxdzd]	Calc/Dol Sil Slick Pyrt
olv blk [5Y2/1] lrg biotrbn dk yel brn[10YR4/2]	(fiss)		
		Clay, (slt), (mic); Biotrbn infill Slt - f-Snd, frbl, por	pyrt skltl Hash
olv blk [5Y2/1] mtl dk yel brn[10 YR 4/2]		Clay, as above, with >30% Biotrbn; infill Slt, snd, frbl, srt, por.	

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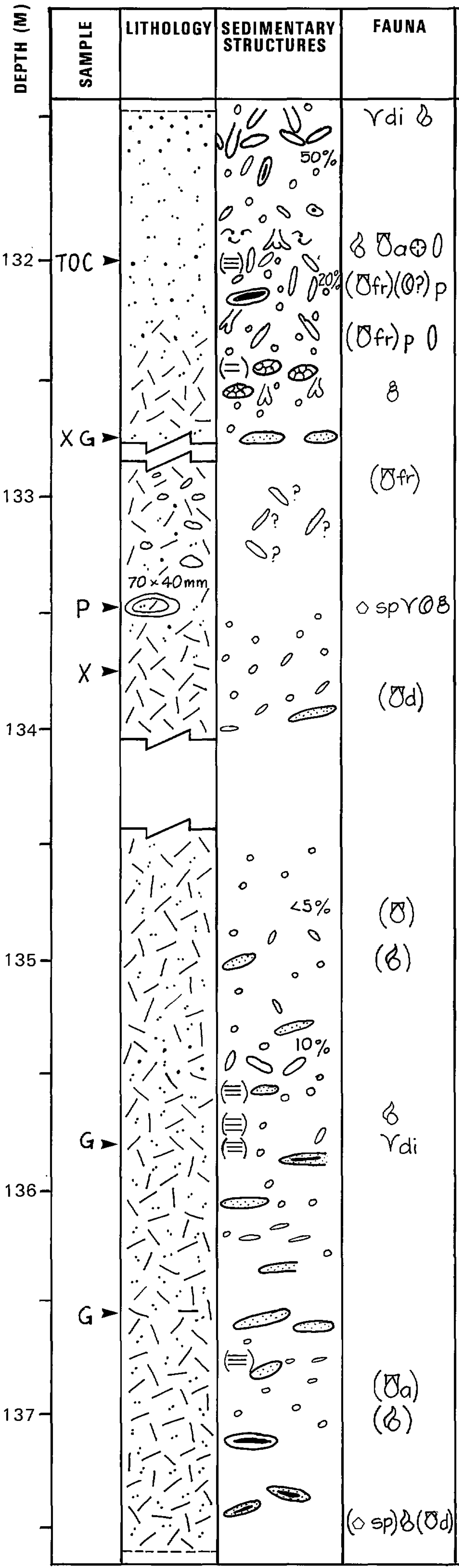

COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIAGENESIS
olv blk [5Y2/1] mtl dk yel brn[10YR4/2]	cmpct crmbl	Slt, (cl), qtz [ang], mic; Biotrbn infill Slt, snd, (cl), (srt) Biotrbn, 2-4 mmD, infill Snd [qtz, subang,vf],por, srt[vari]	
	cmpct/ (fiss)		
olv blk [5Y2/1] mtl Biotrbn dk yel brn [10YR4/2]	cmpct	Slt, qtz [ang, vf snd], glauc (srt) Slt, snd (srt), qtz [ang, brown, to msnd], pel [m, glauc], Biotrbn infill, Snd, vf, srt, por	dissem Pyrt Pyrt + resin in Skltl Pyrt + resin in Biotrbn
grn gy [5GY5/1] mtl Biotrbn dk yel brn[10YR4/2]	cmpct	Slt, cl, snd [f-vf qtz, ang], pel [m snd, glauc]; Biotrbn infill Snd (srt), cl, slt; clay bands around burrows	dissem Pyrt repl (Skltl).
dk olv gy[5Y3/1]	cnchdl/ (fiss)	Clay, (slt), Biotrbn infill, Slt, qtz, srt	pyrt infill Ophiomorpha
dk olv gy[5Y2/1] [5Y3/1]	plstc/ brecc	Clay, mic, (slt), crmbl appearance; clasts [tabular, 1.5 x .5cm; Sltst, dol, pyrt, facetd]	
olv blk [5Y2/1]	plstc/ crmbl	Clay, slt, snd [glauc pel], mic Ptchs; clasts [.5 x 2.5cm, Sltst, calc, facetd + frctd]	
		Clast of Mdst, glauc, skltl, bioturbtd; frctd	dol + calc Cmnt
olv blk[5Y2/1] mtl dk yel brn[10YR4/2]	cmpct/ cnchdl	Clay, (slt), (skltl hash); Biotrbn infill slt [feldsp + qtz], srt, por: py Cmnt; Slick	dissem Pyrt Pyrt + resin in Biotrbn
olv blk [5Y2/1] (mtl)	cmpct/ cnchdl	Slt, (cl), qtz, Biotrbn infill Slt, srt-srt.	
olv blk [5Y2/1] sl mtl lt olv gy [5Y4/2]	cmpct	Slt, (cl), qtz, mic, ((srt)); Biotrbn infill Slt, srt por, frbl	vf pyrt Cmnt, in Biotrbn
dk blk [5Y2/1] (mtl) .10% olv gy [5Y4/2]	cmpct	Slt, cl, qtz [ang], (mic), (srt); possible dession Crack; faint Lmntn; Biotrbn, small, infill by Slt, srt.	Arsenopyrite? resin + pyrt Biotrbn
olv blk [5Y2/1]		Slt, cl, ((srt)), vf 'tracks' along parting surface (˜5% of surface), Biotrbn cmpctd, slt + pyrt infill	
			pyrt lng Biotrb
olv blk [5Y2/1]	cmpct	Clay, slt; pyrt infill in large Biotrbn slt, srt infill in sm Biotrbn	
olv blk [5Y2/1]	cnchdl cmpct	Biotrbn infill by Slt [qtz + feldsp, srt, por] or Pyrt + resin	Pyrt + resin

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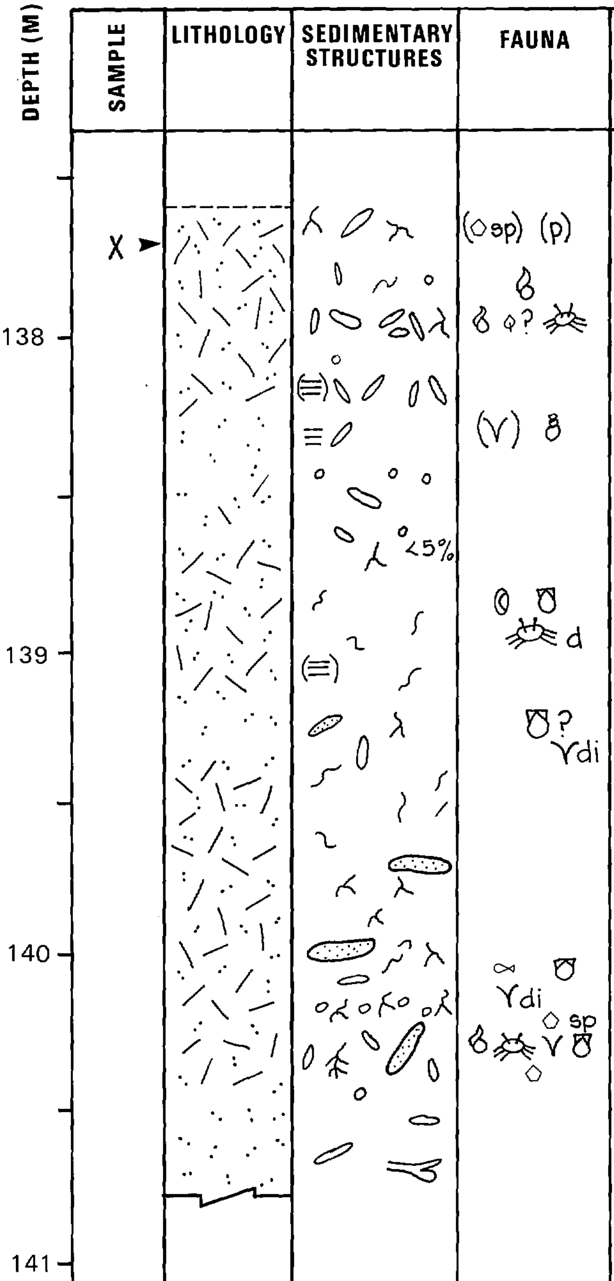
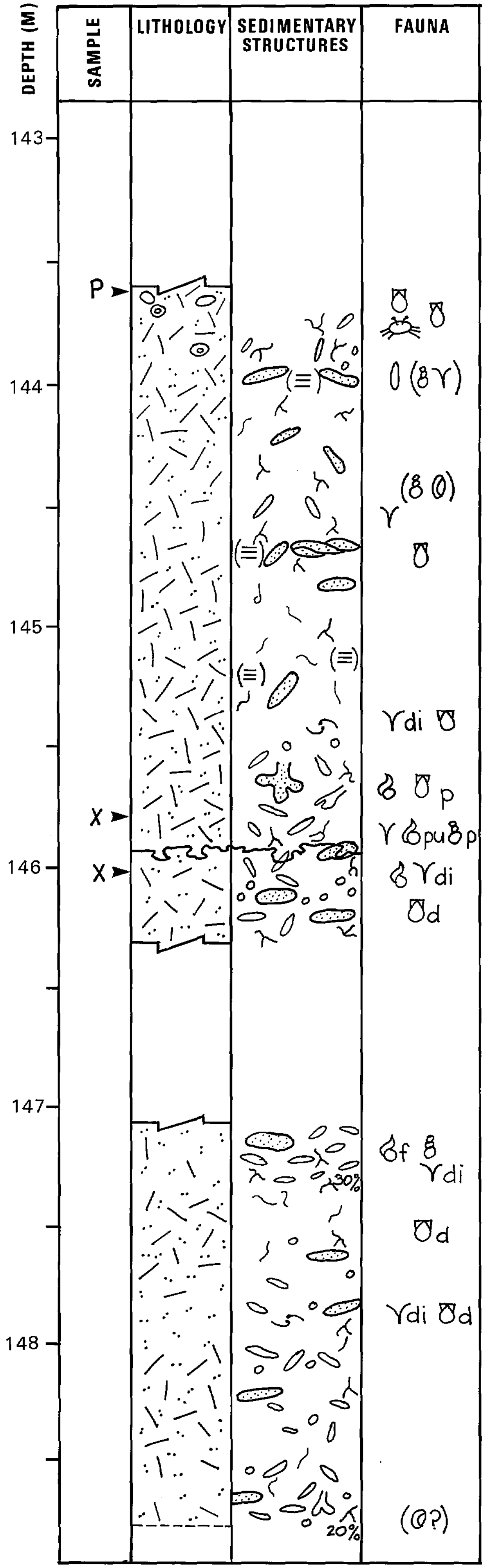
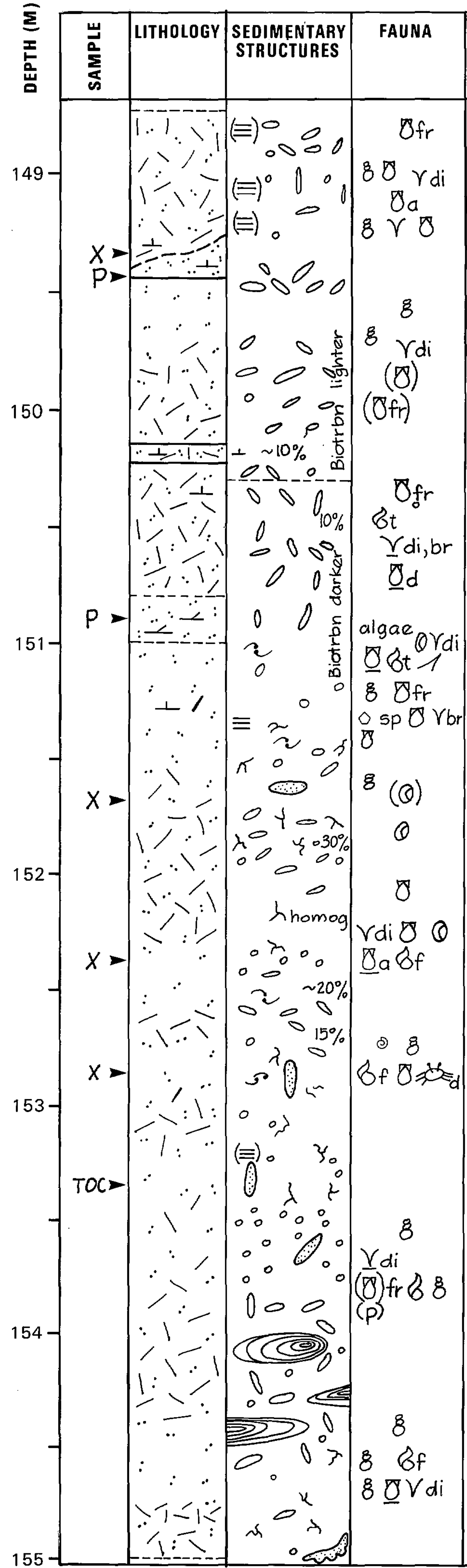


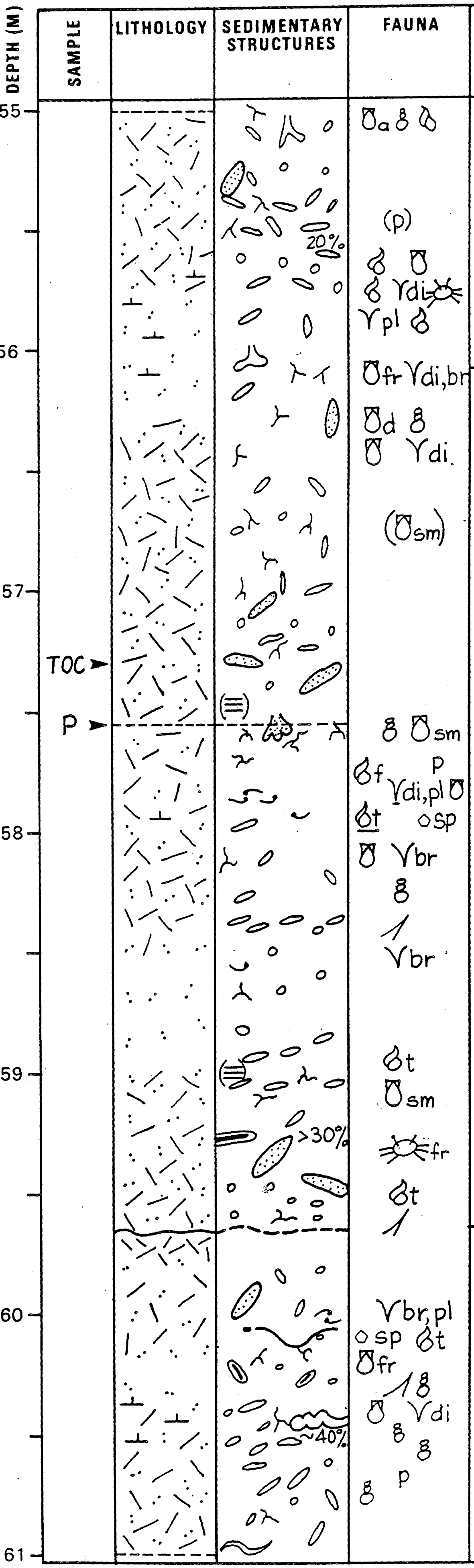
COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIA-GENESIS
dk olv gy [5Y3/1]	plstc/ waxy	Mud, cl, (pel); possible f root traces	Pyrt in traces
olv blk [5Y2/1]	(fiss)/ cmpct	Mud, cl, homog, fiss; slickensides	
dk olv gy [5Y3/1] mtl	cmbl	Slt, (cl), (mic) [blk]; Biotrbn 10%, vari	Pyrt
olv gy [5Y4/2]	cmpct		dissem Pyrt
olv blk [5Y2/1]	cmbl		
			pyrt root traces?
dk olv gy [5Y3/1]	cmpct	Slt, (cl), unif, Ptches pel; (Biotrbn) small, slt infill	(pyrt) Biotrbn
dk olv gy [5Y3/1]	cmpct/ conchdl.	Slt, (cl), qtz [ang, nonsph]; vf root? traces	pyrt traces
dk olv gy [5Y3/1]	conch	Slt, (cl), qtz [rndd, uni] homog	
dk olv gy [5Y3/1]	cmpct	Slt, (cl), qtz, pyr [dissem]; vf tubules	pyrt traces
olv blk [5Y2/1] mtl	(fiss) cmpct		
		Slt, (cl), qtz; Biotrbn more vari but fine tubules/traces predom.	
olv blk [5Y2/1]	cmpct	Slt, qtz, mafic[vf], (srt) - srt	Pyrt in Biotrb.



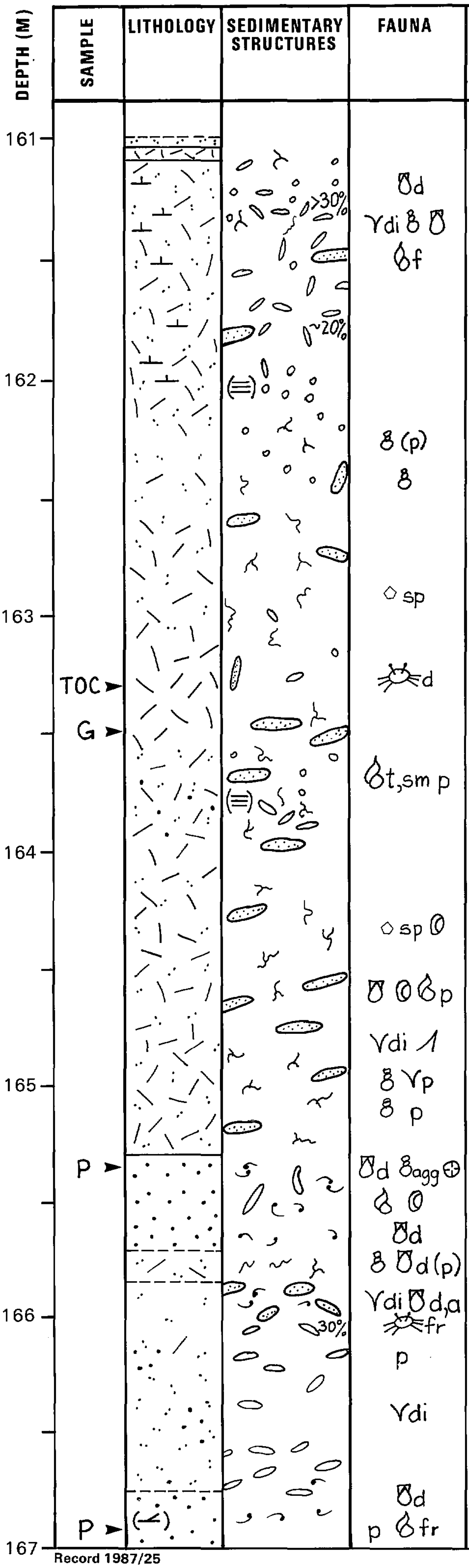
COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIA-GENESIS
		Snd or Slt? possibly related to clast at 143.6m	
dk olv gy [5Y3/1]	plstc	Slt, cl, qtz, clasts; Concrtns 1 cmD, irreg, pyrt + skltl; vf plant rootlets?	Pyrt repl skltl Hash
olv blk [5Y2/1]		Biotrtn, lrg + v sm, repl by Pyrt intermed burrows have pyrt rims, Slt [srt] contr	Pyrt
dk olv gy [5Y3/1] ((mtl)) wh speckled	cmpct/ (fiss)	Slt, (cl), qtz [ang, srt], mic [vf slt, Biot].	
	cmpct		
	cmpct	Slt, (cl), qtz [ang, minor f snd] cmpctd	pyrt concrtn, repl of '[illegible]'
dk olv gy [5Y3/1]	cmpct/ (fiss)		
		Mud, (slt), uni, Biotrbn? wh pyrt traces	
dk olv gy [5Y3/1]			
	cmpct/ fiss	Mud, unif, (mtl), biotrbtd, colour mtl	
olv gy [5Y4/2] biotrtn (Mtl) lt olv gy [5Y5/2]			
	cmpct	Mud, qtz, [ang, slt + vf snd], pel [glauc] glauc Grapestone in ptchs	Glauc
	cmpct	glauc erosional surface	
dk olv gy [5Y3/1] Biotrtn (Mtl)	cmpctd	Slt, cl, qtz [subang], srt, mic [vf]; Biotrtn	frmbdl Pyrt in lrg Biotrtn
dk olv gy [5Y3/1] biotrtn Mtl lt olv gy [5Y5/2]	cmpct	Slt, cl, qtz [ang,] mic, [slt Biot], srt; mtl Biotrtn, infill Slt, srt, qtz + feldsp, por, frbl	
	cmpct/ fiss		
olv blk [5Y2/1]		Mud, cmpctd, homog; vf pyrt tubules	pyrt
dk olv gy [5Y3/1]	cmpct/ fiss		
	cmpct/ cnchdl	Slt, cl, qtz [fv slt]; faint Mtl, biotrtn infill Slt, v wh, srt	
mtl olv gy [5Y4/2]	cmpct/ cnchdl	Slt, cl, qtz [vf slt]; ((mtl)) Biotrtn mostly 0.5mmD tubules; lrg hollow tubes	Pyrt + resin in lrg tubules.
dk olv gy [5Y3/1] mtl			pyrt in horiz Ophiomorpha
olv gy [5Y4/1]	cmpct		
dk olv gy [5Y3/1] lt olv gy [5Y5/1]		Slt, cl, qtz [ang]; mtl from m-lrg Biotrtn; infill Slt, srt, qtz, por, fri, lt olv gy	



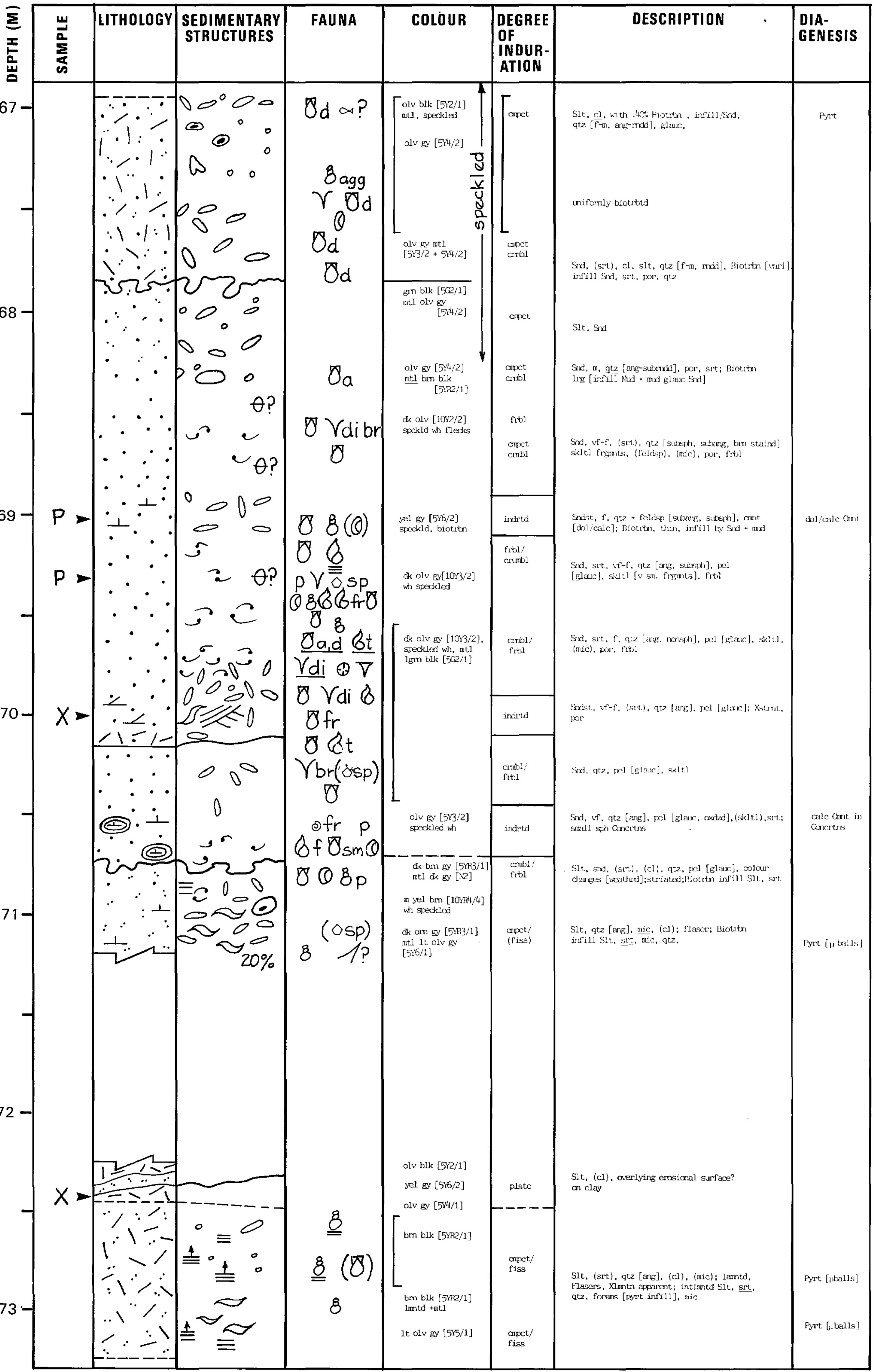
COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIAGENESIS
olv gy [5Y3/2] olv gy [5Y3/1] mtl gy grn [10YR6/4]	cmpct	Slt, qtz [uni, ang], ((cl)), (srt), colour Lmntn distorted by >2 phases m Biotrbn; 2nd phase - more distinctive infill - Slt, qtz, srt, por; (sm Biotrbn) infill Slt, wh, srt	
olv gy [5Y4/2]			
yel gy [5Y6/2] mtl	indrtd	Slt, qtz, (cl), (mic), srt, becoming clayey below indurated zone	Sil
olv gy [5Y3/1]	cnchdl	Slt, qtz [ang], (srt), (cl); (Biotrbn) increasing down section; infill Slt, srt qtz, por; Biotrbn v sm, wh slt infill;	
(mtl) biotrbn gy orn [10YR6/4]			((pyrt)) tubules
olv gy [5Y3/2] lt olv gy [5Y5/2]	cmpct/ cnchdl	Slt, qtz, (srt), (cl); speckld biotrbn Mtl; infill Slt, srt,	(pyrt) horiz Biotrbn)
ol blk [5Y2/1]	plstc	Slt, qtz, (mic), cl; homog colour	(Pyrt + resin) in Biotrbn
m olv gy [5Y4/2] mtl olv gy [5Y3/2]	cmpct/ cnchdl	Slt, qtz, (mic), cl; uni except for Biotrbn [vf pyrt rims]	
lt olv gy [5Y5/2	indrtd	Wckst qtz [vf slt, subang], unif indrtd	calc Cmnt
m olv gy [5Y4/2] dk olv gy [5Y3/1] mtl olv blk [5Y2/1]	cmpct crmbl	Slt; qtz, srt, (cl), (mic)	
olv blk [5Y2/1]	cmpct	Slt, qtz, (srt), ((cl)), (mic) [Biot]; colour Lmntn; - no Biotrbn in dk band	(Calc)
		Slt, qtz, (srt), cl; Biotrbn infill Slt, qtz, srt; vf traces pyrt Replmnt; v sm Biotrbn infill Slt, wh	Pyrt
dk olv gy [5Y3/1]		Slt, qtz, (srt), (cl); Biotrbn (text diffrnce)	
homog, increasingly lighter ↓			
lt olv gy [5Y5/1]		slt, qtz, cl, homog	
olv gy [5Y4/2] (mtl) [5Y5/2]	cnchdl	Slt, qtz, (srt), ((cl)), mic [Biot]; Biotrbn phases, infill Slt, qtz, srt, (mic), por	Pyrt Pelecypods Pyrt + resin
dk olv gy [5Y3/1] mtl olv gy [5Y4/1]	cmpct	Slt, cl, qtz, (srt); Biotrbn 2mmD in subhoriz clusters. Infill Slt, srt; vsm Biotrbn infill Slt, wh, srt, dk centres; Ptches of pel Pyrt	Pyrt
dk olv gy [5Y3/1] (Mtl) by Biotrbn olv blk [5Y2/1]	cmpct/ cnchdl	Slt, (cl), qtz, Pyrt; vari Biotrbn; (Lmntn)	Pyrt in lrg Biotrbn
	cmpct	Slt, (cl), qtz [subsph, ang], mic [musc], mafic; (Biotrbn), v sm infill Slt, wh, srt	Pyrt
dk olv gy [5Y3/1] mtl lt olv gy [5Y5/s]	cmpct/ crmbl	Slt, qtz, cl, (pel) [glauc], (striations); Biotrbn infill Slt, srt	
dk olv gy [5Y3/1] to brn blk [5YR5/1] lrg Mtl lt olv gy [5Y5/2]	cmpct/ slick	Slt,qtz,(cl),(mic),(pel)[glauc];Biotrbn vari;infill Slt, srt, qtz [subsph], por, frbl; to v wh Slt	dissem Pyrt
olv gy [5Y4/1] (mtl) v lt olv gy [5Y6/2]	cmpct	Slt, qtz (cl), (mic); (Biotrbn) infill Slt, qtz, srt	dissem Pyrt in Biotrbn dissem Pyrt
olv gy [5Y4/1] ((mtl))	cmpct/ (fiss)	Slt, qtz, cl, mic [Musc], mafics	stain of oxdzd Pyrt



COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIAGENESIS
	cmpct	Slt, qtz, (cl), (srt); (Biotrtn)	oxdzd stains on pyrt surfaces
olv gy [5Y4/2]	cmpct/ crmbl		
olv gy [5Y4/2] mtl yel gy [5Y6/2]		Slt, qtz, (cl), (srt), pyrt; mtl Biotrtn, infill slt qtz + f, (srt), pel Ptches; v sm Biotrtn infill wh Slt	vf dissm Pyrt
lt olv gy [5Y5/2] mtl lt gy orn [10YR8/4]	cmpct	Slt, qtz, (cl), mic [Biot], mafic; Biotrtn vf infill wh Slt, srt; dk striations	oxdzd Pyrt Fe staind Biotrtn
lt olv gy [5Y5/2] mtl v lt olv[5Y6/2]	cmpct/ cnchdl	Slt, qtz, srt, (mic), pyrt; Biotrtn (colour Mtl)	Pyrt Biotrtn oxdtn staining
		Biotrtn, v sm, wh	
olv gy [5Y4/2] mtl	cnchdl		
olv gy [5Y7/2]		Slt, qtz, (cl), mafic; Biotrtn vf, wh slt infill	oxdzd halo on pyrt traces
olv gy [5Y4/2]	cmpct		
olv gy [5Y3/2]	cnchdl	Mud, qtz, v uniform; ((Biotrtn))	(Pyrt)
dk olv gy [5Y3/1] ((mtl))	cnchdl		
olv blk [5Y2/1]	cnchdl/ fiss	Mud, minor Biotrtn but lrg pyrt Ophiomorpha	Pyrt
dk olv gy [5Y3/1]	cmpct	Slt, cl; qtz [subsph, rndd], (mic), (mafic), pyrt traces; pel Ptches	pyrt Biotrtn
olv gy [5Y4/2] (mtl) yel gy [5Y6/2]		Slt, calc, qtz, (mafic), (cl), skltl; Biotrtn [dk striations]	
olv gy [5Y3/1]	cnchdl	Slt, qtz [subsph], (mafic), (cl)	
olv gy [5Y3/2] mtl yel gy [5Y7/2]		Slt, qtz, cl, (mafic); mtl by distinct bifurcate Biotrtn, horiz, infill Slt, qtz, mic, srt	
olv gy [5Y3/2]			
	cmpct		
olv blk [5Y2/1] mtl yel gy [5Y7/2]			
olv gy [5Y3/2] mtl yel gy [5Y6/2]		Slt, qtz, cl, mic [Biot], striated; Biotrtn, horiz	Pyrt
	cmpct/ crmbl		
olv gy			
		Slt, qtz [subsph], (cl), mic [Biot]	Pyrt
dk olv gy [5Y3/1]			
		Slt, qtz, (mic) [Biot], (cl) Mud, f snd [Qtz, Musc, Phlogpt]	
olv blk [5Y2/1]			
olv gy 5Y3/2	cmpct		
		Slt, qtz, [subsph], (cl), (pel) [glauc]; skltl, ptches	oxdzd rims on Pyrt
olv gy [5Y3/2] mtl lt olv gy [5Y5/2]		Slt, qtz, calc, (mic), skltl; Biotrtn, infill Slt, srt	
olv gy [5Y3/1] mtl yel gy [5Y6/2]		Slt, qtz, (cl); Biotrtn, infill Slt (srt); pel [glauc] ptches	

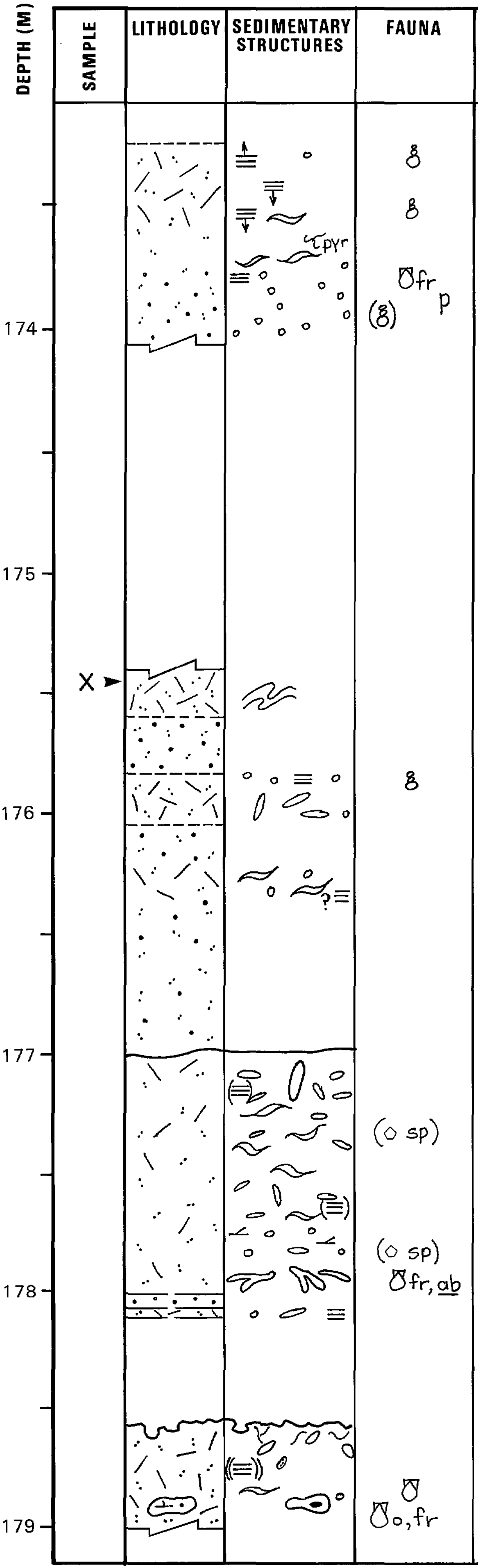


COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIA-GENESIS
dk olv gy [5Y3/1]			
dk olv gy [5Y3/1] mtl lt olv gy [5Y5/2)		Slt, snd [subsph], cl; mtl + biotrbtd	
	cmpct		
		Slt, snd [qtz, subsph], calc, (cl); Biotrbn 3mmD prominent infill Slt, por	Pyrt in horiz Biotrbn
olv blk [5Y2/1] mtl lt olv gy [5Y5/2]		Slt, qtz [subsph], (cl), (mic) [Biot]; pel Ptches	Pyrt + resin in Biotrbn
	cnchdl		
			Pyrt
olv blk [5Y2/1] homog		Mud, slt; Biotrbn [vf traces - 'rootlets?', pyrt], lrg Biotrbn	
	cmpct/ (fiss)	Mud, cl, uniform	
			resin + Pyrt in Biotrbn
olv blk [5Y2/1] red/bluish ptches		Mud, slt, pel [glauc]; Ptches Snd [m, qtz, brown stained]; Biotrbn infill snd Mud	Goethite or Bitumen?
dk olv gy [5Y3/2]			
olv blk [5Y2/2] uniform except for large pyrt + Biotrbn	cnchdl/ cmpctd	Mud, slt [qtz + feld?], cl	Pyrt + resin in lrg Biotrbn
	fiss/ (cmpct)	Slt, qtz [subsph, rndd], cl; numerous vf pyrt traces on bedding partings	Pyrt in lrg Biotrbn
		v sm, Biotrbn, infill wh Slt	
		Mud, cl, qtz, (mic)	
dk olv gy [10Y2/2] speckled wh dk olv gy [10Y2/2] mt olv gy [5Y4/1]	cmpct/ (frbl)	Snd, srt, m-f, qtz, feldsp, pel [glauc], por; Biotrbn; some pyrt areas, ptches of grn clay	Pyrt
olv blk [5Y2/1]	(fiss)	Slt, qtz [vf-m], (cl), pel [glauc], snd to top	pyrt vf Biotrbn (rootlets?)
grn blk [5G2/1] biotrbn Mtl			
lt ol gy [5Y4/2]		Slt, snd, (srt), qtz [m, ang-rndd, honey coloured] (pel) [glauc], mtrx?; Biotrbtd, infill by Snd, pel [oxdzd glauc], qtz, (srt)	
grn blk [5G2/1] Biotrbn Mtl	cmpct		
lt olv gy [5Y5/2]			
olv gy [5Y4/2] speckled	frbl uncons	Snd, qtz [m, ang], pel [glauc], (skltl), mtrx, srt, por.	

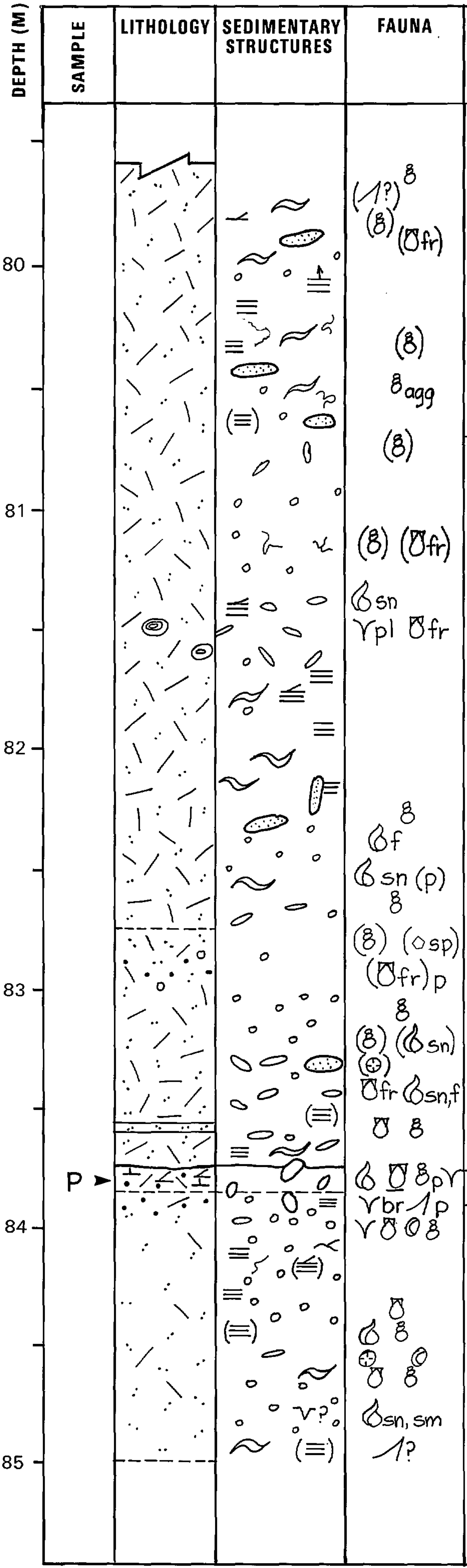


SAMPLE	COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIAGENESIS
	olv blk [5Y2/1] mtl, speckled	cmpct	Slt, cl, with 40% Biotrbn , infill/Snd, qtz [f-m, ang-rndd], glauc,	Pyrt
	olv gy [5Y4/2]			
			uniformly biotrbtd	
	olv gy mtl [5Y3/2 + 5Y4/2]	cmpct crmbl	Snd, (srt), cl, slt, qtz [f-m, rndd], Biotrbn [vari] infill Snd, srt, por, qtz	
	grn blk [5G2/1] mtl olv gy [5Y4/2]	cmpct	Slt, Snd	
	olv gy [5Y4/2] mtl brn blk [5YR2/1]	cmpct crmbl	Snd, m, qtz [ang-subrndd], por, srt; Biotrbn lrg [infill Mud + mud glauc Snd]	
	dk olv [10Y2/2] spckld wh flecks	frbl		
		cmpct crmbl	Snd, vf-f, (srt), qtz [subsph, subang, brn staind] skltl frgmnts, (feldsp), (mic), por, frbl	
P	yel gy [5Y6/2] speckld, biotrbn	indrtd	Sndst, f, qtz + feldsp [subang, subsph], cmnt [dol/calc]; Biotrbn, thin, infill by Snd + mud	dol/calc Cmnt
P	dk olv gy[10Y3/2] wh speckled	frbl/ crumbl	Snd, srt, vf-f, qtz [ang, subsph], pel [glauc], skltl [v sm. frgmnts], frbl	
	dk olv gy [10Y3/2], speckled wh, mtl lgrn blk [5G2/1]	crmbl/ frbl	Snd, srt, f, qtz [ang, nonsph], pel [glauc], skltl, (mic), por, frbl	
X		indrtd	Sndst, vf-f, (srt), qtz [ang], pel [glauc]; Xstrat, por	
		crmbl/ frbl	Snd, qtz, pel [glauc], skltl	
	olv gy [5Y3/2] speckled wh	indrtd	Snd, vf, qtz [ang], pel [glauc, oxdzd],(skltl),srt; small sph Concrtns	calc Cmnt in Concrtns
	dk brn gy [5YR3/1] mtl dk gy [N2]	crmbl/ frbl	Slt, snd, (srt), (cl), qtz, pel [glauc], colour changes [weathrd];striated;Biotrbn infill Slt, srt	
	m yel brn [10YR4/4] wh speckled			
	dk orn gy [5YR3/1] mtl lt olv gy [5Y6/1]	cmpct/ (fiss)	Slt, qtz [ang], mic, (cl); flaser; Biotrbn infill Slt, srt, mic, qtz,	Pyrt [µ balls]
	olv blk [5Y2/1]			
X	yel gy [5Y6/2]	plstc	Slt, (cl), overlying erosional surface? on clay	
	olv gy [5Y4/1]			
	brn blk [5YR2/1]			
		cmpct/ fiss	Slt, (srt), qtz [ang], (cl), (mic); lamntd, Flasers, Xlmntn apparent; intlmntd Slt, srt, qtz, forams [pyrt infill], mic	Pyrt [µballs]
	brn blk [5YR2/1] lmntd +mtl			
	lt olv gy [5Y5/1]	cmpct/ fiss		Pyrt [µballs]

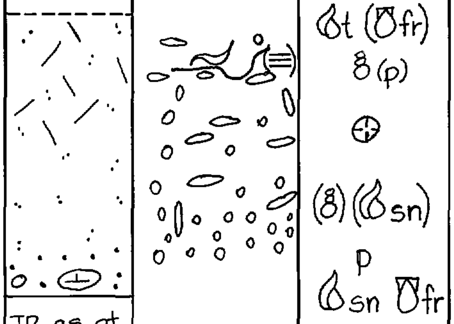
14



COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIA-GENESIS
dk yel brn[10YR2/2] intlmntd lt olv gy [5Y6/1]	cmpct/ (fiss)	Slt, qtz, (cl), mic, (srt); coarsening up or down to Slt, srt, qtz, mic, foram; graded + inverse graded laminae and flasers.	
dk yel brn[10YR2/2] Biotrbn lt olv gy [5Y6/1]	cmpct/ frbl	Slt, snd [vf-m], qtz [ang], pel [glauc], mic, (cl)	
olv gy [5Y4/1] banded yel gy [5Y7/2]	plstc	Clay, (slt), (mic), colour mtl/bndd variegated oxidized surface	
olv gy [5Y4/2]	cmpct/ frbl	Slt, snd [vf], qtz [subang, subsph], mic, mafic Intlmntd Slt (srt) - srt	
olv gy [5Y4/2] mtl	cmpct		
yel gy [5Y8/1] lt ol gy [5Y5/2]	uncons	Slt, snd [vf], qtz [subang, subsph], mic, mafic.	
olv gy [5Y4/2] mtl yel gy[5Y6/2]	cmpct	Slt, qtz, (mic), (cl), (srt); (Biotrbn), lmntn	
lt olv gy [5Y5/2]	uncons	Slt, (snd) [vf], qtz [ang, subsph], mic [Musc], srt	
olv blk [5Y2/2] biotrbn Mtl yel gy [5Y6/2]	cmpct/ crmbl	Slt, qtz, (cl), srt; f lmntd, biotrbtd; flasers?; intlmntd, Slt, srt, qtz, mic	
	crmbl plstc		
		Snd, vf qtz, (mafic), srt	
lt olv gy[5Y5/2]	uncons	Snd, vf, srt, qtz [subang, subsph], mic [Musc], mafic, por	
brn blk [5YR2/1] brn blk [5YR2/1] olv gy [5Y4/1]	cmpct	Slt, cl, qtz, mica [Biot], intlmntd Slt, srt, qtz; biotrbtd	Pyrt in Biotrbt.
dk yel brn [10 YR2/2]; mtl p yel brn [10YR6/2]	cmpct	Slt, cl; biotrbtd, flasers [(srt) slt infill]; lrg Biotrbn infill vf snd, srt	Pyrt + resin in Biotrbn



COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIA-GENESIS
dk yel brn[10YR3/2] p yel brn[10YR6/2]	cmpct	Slt, qtz, mic [Biot + Musc], mafic, ((srt)), cl; structures diffrntd with Slt, (srt)	
			Pyrt in Biotrtn
	cmpct/ fiss		
dk yel brn [10YR2/2] intlmntd		Slt, qtz, (mic), (mafic), cl, (srt)	
gy orn [10YR6/4]	cmpct/ (fiss)		
dk olv gy [5Y3/1]	cmpct		
olv blk [5Y2/1]			
		Slt, (srt), qtz, cl, (mic); minor Mtl, biotrbtn infill Slt [srt]	
			Pyrt + resin in Biotrtn
olv gy [5Y3/2] biotrbn mtl yel gy [5Y6/2]	cmpct	Slt, qtz, [mdd], (cl), (mic) [Biot + Musc], (srt); v thin Lmntn + Xlmntn; (Biotrbn) infill Slt, srt; qtz, (mafic), por.	calc + pyrt veining in Concrtn
olv gy [5Y4/1] yel gy [5Y6/2]	cmpct/ (fiss)	Slt, qtz, (cl), ((mic)), ((srt)), Lmntn Slt, srt, frbl, por, striated	
			(Pyrt + resin) in Biotrbn
dk olv gy [5Y3/1]	cmpct	Slt, qtz [c snd], (pel) [glauc], (mafic), (cl), (srt); Biotrbn .5%, infill Slt, qtz, srt	
olv blk [5Y2/1] mtl one patch yel gy [5Y6/2[	plstc/ crmbl	Mud lumps and mudbands intermixed Slt, qtz [vvf + m snd, brown stained snd], (mafic), cl, pel [oxdzd glauc], few lrg clasts of Sndst	Pyrt
olv blk [5Y2/1]	(fiss)	Slt, (srt), qtz, (p), (cl), (Biotrbn) apparent srt Slt.	
dk olv gy [5Y3/1] biotrbn Mtl lt olv gy [5Y5/2]	cmpct	Slt, (srt), qtz, (mafic), Mtl biotrbn; infill Slt, srt, fri, por	Pyrt(Arsenopy?) in Biotrtn
[5Y6/2-5Y4/2] mtl	frbl cmpct		
[5Y3/1-5Y6/2]mtl			
yel gy [5Y6/2]	indrtd	dol indrtd surface, oxdzd, biotrbtd, lag of Skltl + glauc Pel in dol Mudst. Lag decreases down from surface	Dolomite resin in Skltl
olv blk [5Y2/1] spkld, biotrbd lt olv gy [5Y5/2]	cmpct/ (fiss)	Slt, (srt), qtz, (mafic), (cl); srt slt Lmntn	dissem Pyrt
brn blk [5YR2/1] biotrbtd yel gy [5Y6/2]			
		Slt, (srt), qtz [vvf], (mic), (mafic) (cl); fiss mic partings; Biotrbn + Lmntn have Slt, srt, por, qtz, (mud clast).	pyrt traces in Biotrbn
dk olv gy [4Y3/1] mtl yel gy [5Y6/2]		Slt, (srt), qtz, (mafic), (mic), (cl); Biotrbn infill Slt, srt, por, uncons.	



DEPTH (M)	SAMPLE	LITHOLOGY	SEDIMENTARY STRUCTURES	FAUNA	COLOUR	DEGREE OF INDURATION	DESCRIPTION	DIA-GENESIS
185					dk olv gy [5Y2/2] yel gy [5Y6/2]	cmpct	Slt, (srt), qtz, (mic), (pel) [glauc]; Lmntn + Biotrbn of Slt, srt, por, streaked with clay; small erosional ledge 1 cm deep.	pyrt traces in Biotrbn
						cmpct	Slt, (srt), (snd), qtz [ang, irreg], (mafic), cl, pel [glauc]; Biotrbn infill Slt, srt, por	
					yel gy [5Y6/2] yel orn [10 YR7/6] yel brn [10YR 2/2]	crmbl	Conglom, mtrx Slt ((srt)), snd [qtz, glauc Pel], cobbles [rndd sph, calc Sltst]	oxdzd Glauc
186		TD as at 1 Jan. 87						

APPENDIX II

MACROFAUNA

Some characteristic and more obvious components of the macrofauna of the sequence are documented in plates 4, 5, and 6 under lithofacies categories.

In general, the preservation of the calcareous macrofauna is very poor because of partial dissolution of the carbonate. The elements are friable or powdery and deteriorate quickly on drying.

This documentation is intended to provide some record, albeit incomplete, of the distinctive fauna.

PLATE 4

Microfauna of Lithofacies A, B and D

Lithofacies A

a. Parting in laminated micaceous silt with agglutinated foraminifera.

x 2; from 172.8 metres

b-e. Agglutinated foraminifera with pyritic framboids within tests.

x 2; from 172.8 metres

Lithofacies B

f-i. Terebratulid brachiopod, external views of pedicle valve (f), brachial valve with predatory boring (g), anterior sulcus (h), and lateral views of shell (i).

x 6.7; from 169.7 metres

j. Internal mould of opposite valve, pelecypod

x 6.7; from 167.7 metres

Lithofacies D

k. Glauconitic and phosphatic? coprolites

x 4; from 131.94 metres

l. Fragmented leg segment of a malacostracan

x 4; from 129.05 metres

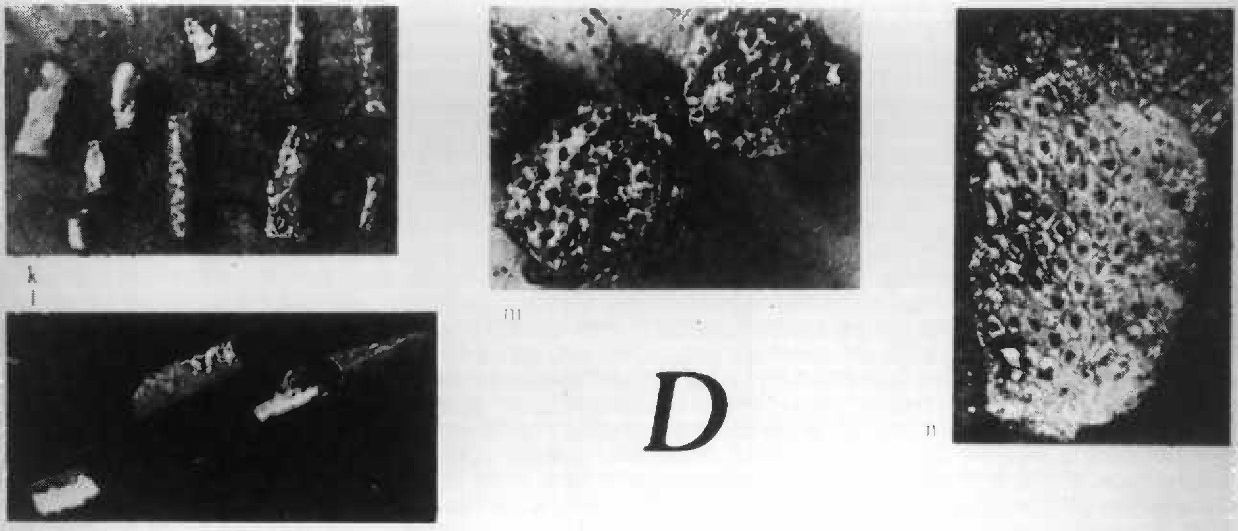
m. Discoid cheilostome bryozoan, obverse side,

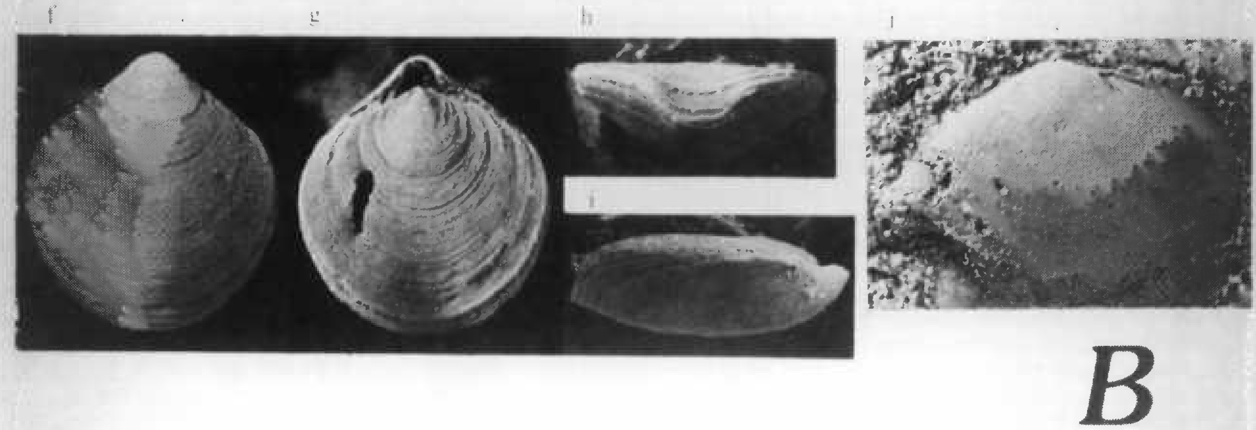
zooecia pyrite-infilled.

x 8; from 129.35 metres

n. Encrusting cheilostome? bryozoan

x 10.7; from 129.35 metres





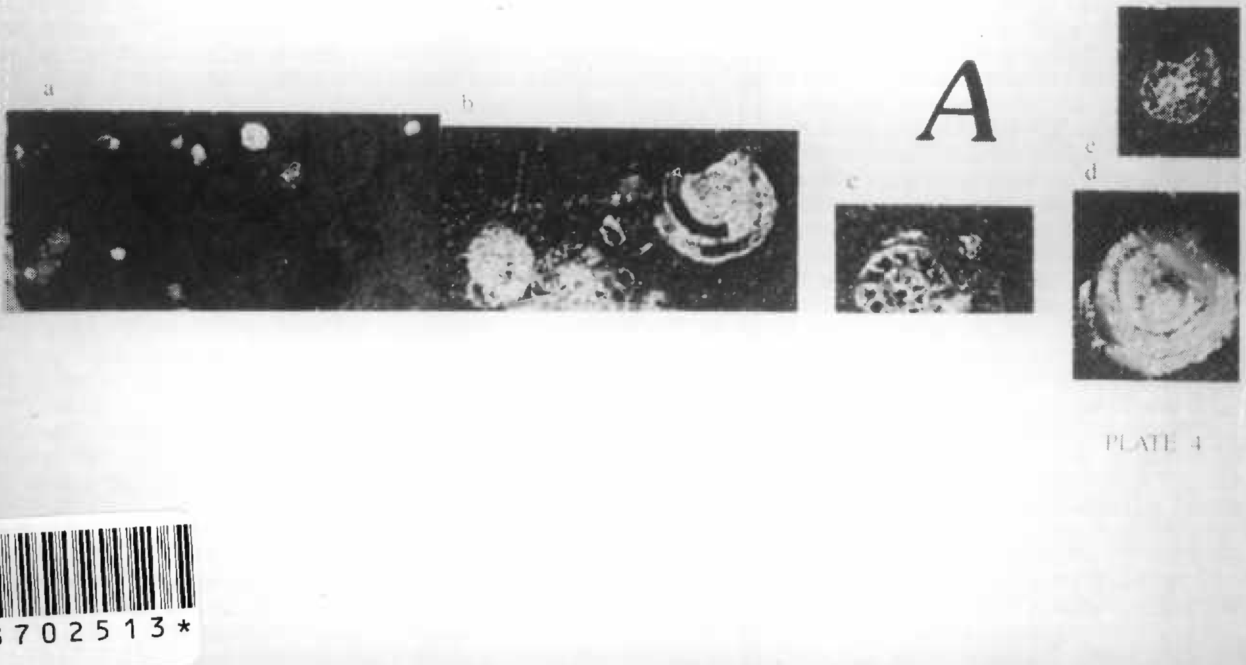


PLATE 4

PLATE 5

Macrofauna of Lithofacies C

a,b Spurred shafts of cidarid (echinoid) spines; x 4.3; from 151.3 metres

c,d Discoid cheilostome bryozoan, obverse, reverse sides; x11.5; from 135.9 metres

e Branched cyclostome? bryozoan; x 11.5; from 157.9 metres

f,g Encrusting cheilostome bryozoan; f. x 8.6; from 157.9 metres

g. x 4.3; from 155.85 metres

h,i Discoid cheilostome bryozoan, obverse and reverse sides

x 11.5; from 147.2 metres

j. Branched and articulated? cheilostome bryozoan; x 11.5; from 151.3 metres

k. Small pelecypod; x 11.5; from 157.9 metres

l,m. Fusiform siphonostomatous gastropod; x 2.9; from 152.37 metres

n. rib and costate ornament detail; x 11.5; from 152.37 metres

o. Apatitic fish or cetacean tooth; x 8.6; from 140.0 metres

p,q,r Malacostracan pincer appendage, mould, part pyritic

x2.2, 4.3, & 8.6; from138.95 metres

s,t Conoidal siphonostomatous gastropod, aperture/adaperture views

x 11.5; from 147.2 metres

u. Turreted gastropod; x 4.3; from 157.9 metres

v,w. Fusiform siphonostomatous gastropod, aperture/adaperture views

x 5.8; from 147.2 metres

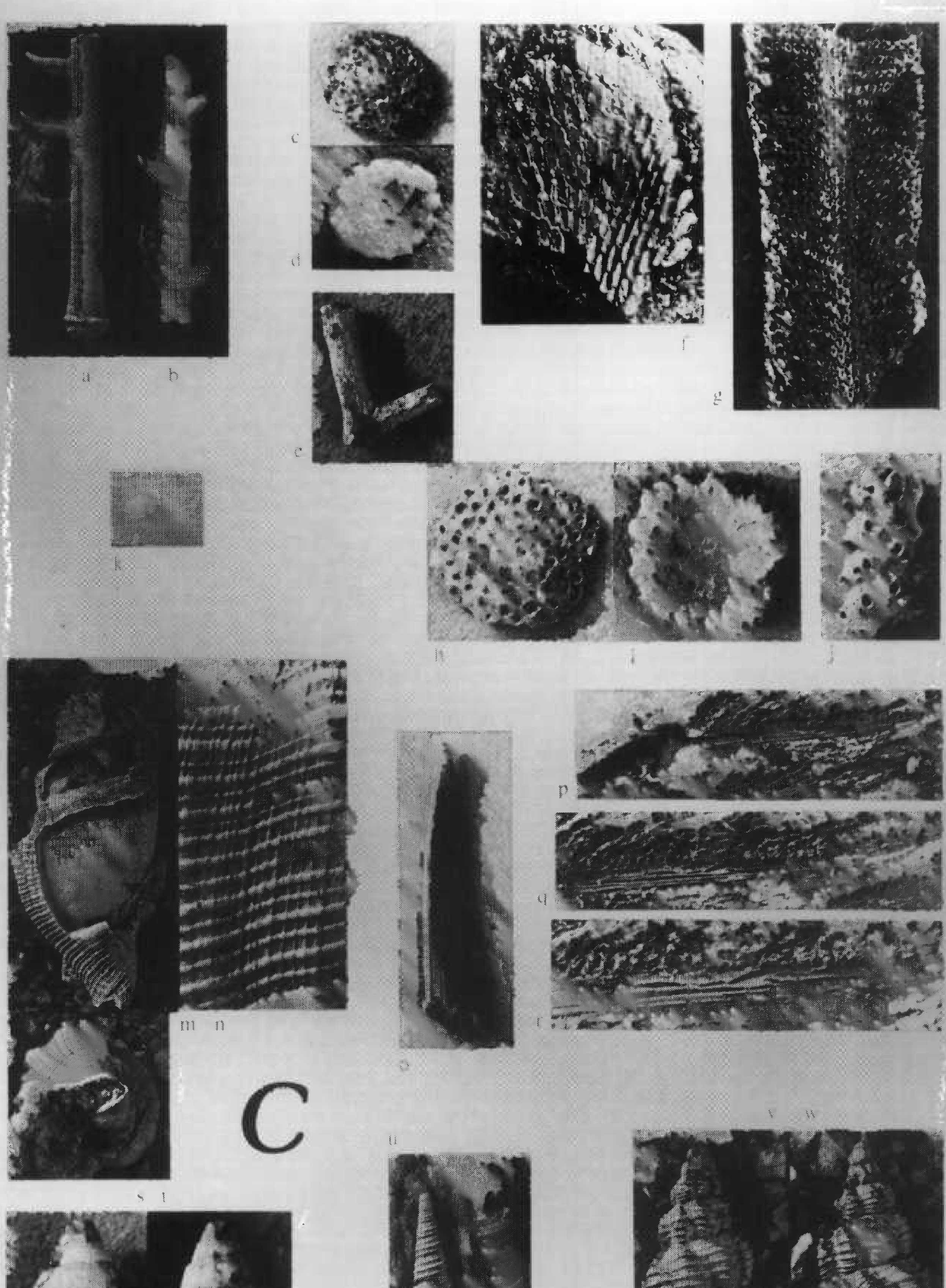


PLATE 5

PLATE 6

Macrofauna of Lithofacies E and F

Lithofacies E

a. Irregular echinoid, external dorsal view of petal; x 2.1; from 119.77 metres

b. Irregular echinoid, view of ventral interior with peristome; x 2.1; from 119.77 metres

c,d Fragmented cheilostome bryozoan, obverse and reverse sides

x 8.5; from 107.0 metres

e,f Turreted gastropod (aperture and adaperture views),

taxodont pelecypod (internal and external opposite views)

x 8.5; from 107.7-108.1 m

g,h Multispiral pupaeform gastropod; x 8.5; from 126.9-127.1 m

i. Pelecypod, opposite side; x 2.8; from 129.1 metres

Lithofacies F

j,k,l Solitary scleractinian coral (end, side and top views); x 4.3; from 101 metres

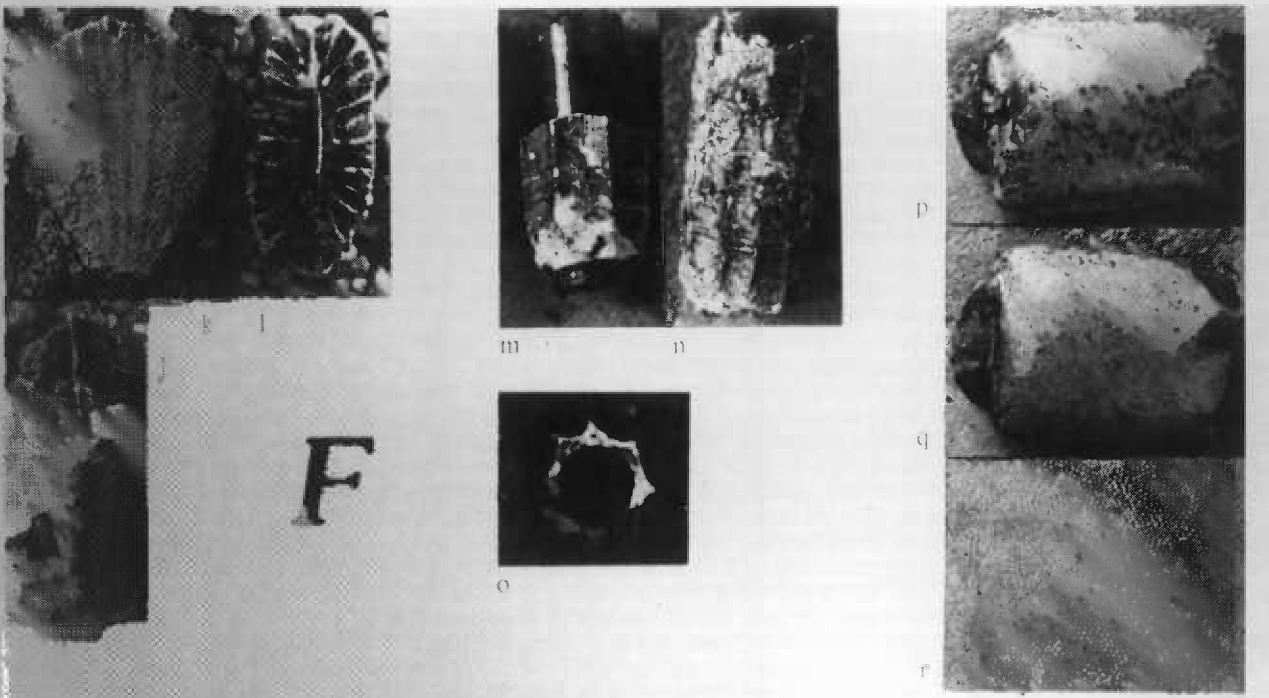
m,n,o Scaphopod, longitudinally costate (side views and cross-section), pyrite infilled

x 11.4; from 100.75metres

p,q Decapod malacostracan, ventral and dorsal views of segment of pincer-bearing assemblage; x 5.7; from 101.15 m

r Ornament of decapod segment (p,q)

x 28.5; from 101.15 m



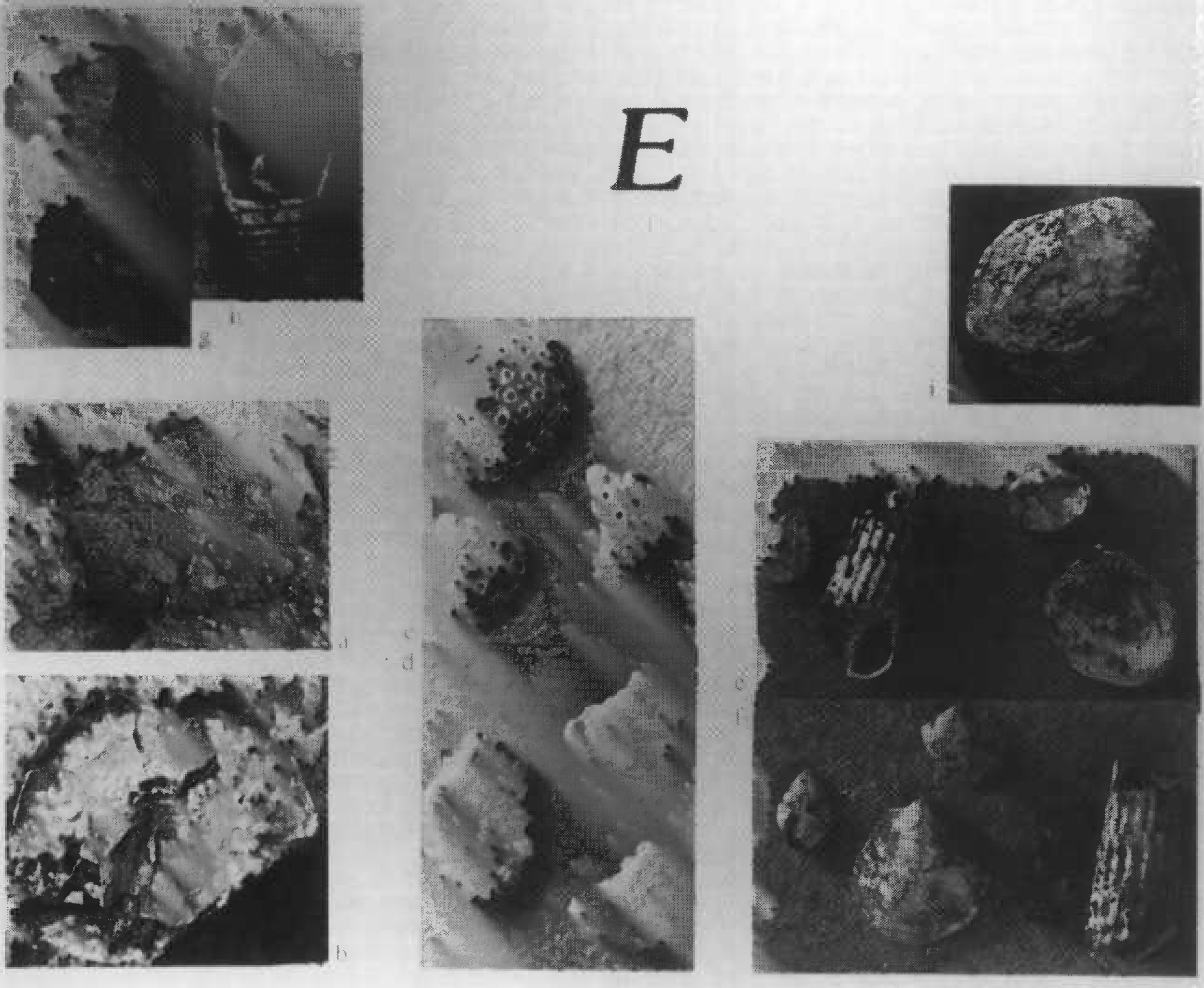


PLATE 6

APPENDIX III

XRD Mineralogic Determinations by AMDEL

MINERALOGY OF 13 CLAY SAMPLES

1. INTRODUCTION

Thirteen samples of dark-coloured clays received from Mr. F.M. Kane of the Bureau of Mineral Resources were to be examined by X-ray diffraction procedures for detailed clay mineralogy (Code MC2).

2. PROCEDURE

The samples were air-dried at room temperature. Portion of each was powdered finely and used to prepare an X-ray diffractometer trace which was interpreted by standard procedures.

Further, weighed 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 were carried out and consisted of examination of the glycerol-free plate after heating for one hour at 550°C.

3. RESULTS

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

Note that there is no sharp distinction between Sm, Sm^+ and ML, which represent successively increasing proportions of illite interstratified with the smectite layers.

Table 2 : BULK AND -2 µm MINERALOGY OF 13 CLAYS

Sample	Piangil 21 101.80m		Piangil 30 108.30m		Piangil 36 110.20m		Piangil 41 112.45m		Piangil 56 122.90m		Piangil 66 125.80m		Piangil 85 131.20m		Piangil 92 132.75m	
Bulk Mineralogy:	Q	D	Q	D	Q	D	Q	D	Sm	D	Q	D	Q	D	Sm	D
	Sm	SD	Sm^+	A	K	A	Sm^+	A	Q	SD	Sm	SD	Sm^+	SD	Q	SD
	K	A	G	A	ML	A	K	A	Gy	SD	K	A	K	A	K	A-SD
	Py	Tr-A	K	A	G	A	M	Tr	K	A	F'	A	M	Tr-A	F'F	Tr-A
	F'	Tr	M	Tr	M	Tr	Py	Tr	M	A	M	Tr-A	F'	Tr	M	Tr-A
	M	Tr	Py	Tr	F'	Tr	F	Tr	Py	A	Py	Tr	Py	Tr	Py	Tr
	Ha	Tr	F'	Tr	Py	Tr	Ha	Tr	F'	Tr	Gy	Tr				
			Ha	Tr	Ha	Tr										
-2 µm fract. %:	46		19		18		29		51		50		52		59	
Mineralogy:	K	D	Sm^+	D	K	D	Sm^+	D	Sm	D	Sm	D	Sm^+	D	Sm	D
	Sm	SD	K	SD	ML	SD	K	SD	K	SD	K	SD	K	SD	K	SD
	M	Tr-A	M	Tr	M	A	M	A	M	Tr-A	M	Tr	M	Tr	M	Tr-A
	Q	Tr	G	Tr	G	Tr	G	Tr	Q	Tr	Q	Tr	Q	Tr	Q	Tr
			Q	Tr	Q	Tr	Q	Tr								

Sample	Piangil 97 133.75m		137.7m		145.8m		146.0m		149.35m	
Bulk Mineralogy:	Q	D	Sm	D	Sm	D	Sm	D	Q	D
	Sm	SD	Q	SD	Q	SD	Q	SD	Sm	SD
	K	A	K	A-SD	K	A	K	A-SD	K	A
	Py	Tr-A	M	A	G?	A	M	Tr-A	M	A
	M	Tr	Py	A	Sid	A	Py	Tr	FF'	Tr-A
	FF'	Tr	F'	Tr	M	Tr-A	F'	Tr	Py	Tr
					Py	Tr				
					F'	Tr				
-2 µm fract. %:	50		59		51		57		45	
Mineralogy:	Sm	D	Sm	D	Sm	D	Sm	D	Sm	D
	K	SD	K	SD	K	SD	K	SD	K	SD
	M	A	M	Tr	M	Tr	M	Tr	M	Tr-A
	Q	Tr	Q	Tr	Q	Tr	Q	Tr	Q	Tr

<u>Mineral Key</u>

F	Plagioclase feldspar (albite or sim.)
F'	K feldspar
G	Goethite
Gy	Gypsum
Ha	Halite
K	Kaolinite
M	Muscovite (mica/illite)
ML	Mixed-layer smectite-illite with approx. equal proportions of the two layer types (see text)
Py	Pyrite
Q	Quartz
Sid	Siderite
Sm	Smectite
Sm^+	Smectite with minor proportion of interstratified illite (see text)

<u>SEMIQUANTITATIVE ABBREVIATIONS:</u>

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

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%.

APPENDIX IV

PETROGRAPHIC DESCRIPTIONS OF 32 HORIZONS IN PIANGIL WEST 1

……

PETROGRAPHIC SAMPLE at 67.1 metres depth Type: stained TS

Description: Bioturbated very fine and sorted quartzose sand with subspherical dolomitic nodules. Burrows are sand-lined, 5mmD, with a periphery 14-30mmD of concentrically striated sandy pelletal dolomitic micrite. Wackestone-Packstone texture?

Particulate Components:	**Abundance %**
Quartz, v fine sand, angular	**70**
Mica, thin books and flakes	**5**
Pellets, v fine sand-sizes, goethitic	**5**
Cement/Matrix: Dolomite cement, idiotopic-subidiotopic	**20**

Diagenesis: Ferroan dolomite, encloses and penetrates into quartz as columnar crystals, 0.25mm long. These generally follow interparticle porosity as well as radiate within the quartz framework.

Porosity: Original interparticle porosity	**25**
Intermediate occlusion by cementation	
Present	**2**

Paragenesis: A relatively late precipitation of fine non ferroan dolomite in sand. Muddy peripheries to burrows were replaced and the original pelletal texture obliterated.

……

PETROGRAPHIC SAMPLE at 81.8 metres depth Type: TS

Description: Very sandy and pebbly clay overlies a sandy and clotted burrowed sandy claystone. The clotted fabric is 1.5-0.15mmD centred.

Particulate Components:	**Abundance %**
Quartz, silt- v fine sand, angular-rounded, spherical; many particles rounded coarse sand, goethitic coatings to form superficial ooids and some grapestones	**21**
Cement/Matrix: Matrix of silty clay: a pelletal to irregular cellular texture is defined by dessication fractures? and or pyritic reaction rims	**79**

Diagenesis: Goethitic (oxidized glauconite) ooid laminae on sand particles

Pyrite,scattered replacement of particles,now oxidized in rims and stains extend into the surrounding clay **<5**

Cellular liesegang rings mimic outlines of clay clots because of concentrations of an unidentified v finely crystalline mineral.

Porosity: Original	**0**
Intermediate	**0**

Present	0

Paragenesis: Glauconite oxidized to goethite prior to precipitation of liesegang ring cements. Pyrite precipitated early, with subsequent oxidation.

Interpretation: Claystone was partly indurated at time of sedimentation. It is indeterminate whether the gravelly clay was deposited over a firmground, or if it was the resultant lag from an erosional event.

……

PETROGRAPHIC SAMPLE at 88.0 metres depth Type: TS

Description Burrowed sandy-silty clay. Burrows are infilled by v. fine to fine pelletal sand. The clay is variably sandy. Patches of low sand content are densely striated with pyritized trace borings/rootlets which tend to be subparallel and subhorizontal.

Particulate Components:	**Abundance %**
Quartz, v fine -fine sand, angular to subangularcoated particles	**20**
Goethitic, fine -medium sand	**5**
Cement/Matrix: silty clay matrix	**75**

Diagenesis: Pyrite replaces pellets;reaction rims in the host clay along the margins of fine burrow? tubules

Porosity: Original burrow interparticle porosity	**7**
Intermediate	**7**
Present	**7**

Paragenesis: Glauconitic pellets oxidized to goethite before deposition. Finely crystalline pyrite was an early replacement phase in the clay and oxidized possibly during early diagenetic exposure.

Interpretation: Soil overprint on a burrowed clay.

……

PETROGRAPHIC SAMPLE at 89.15 metres depth Type: TS

Description: Uniform silty very fine sand (packstone texture).

Particulate Components:	**Abundance %**
Quartz, v fine sand & silt, angular	**55**
Pellets, goethitic, fine-coarse sand, scattered distribution	**5**
Mudlumps,1.1mmD, impregnated with silt	**<5**
Cement/Matrix: silty clay matrix throughout	**35**

Diagenesis: pyrite, minor disseminated v fine crystals

Porosity: Original	**0**
Intermediate	**0**
Present	**0**

Paragenesis: compacted in part (squashed mudlumps)

……

PETROGRAPHIC SAMPLE at 99.5 metres depth Type:TS

Description: Gravel interbanded with v fine quartzose sand (Packstone-Grainstone texture).

Particulate Components:	**Abundance %**

Gravel, granules and minor pebbles	**50**
a) sandy dolmicrite (palimpsest pelletal fabric)	
b) glauconitic pelletal clay with fine pyritic tubules	
c) dolomitic calcrete?	
Quartz, metamorphic?,v coarse rounded subsherical sand	**5**
Quartz, v fine angular	**10**
Pellets,goethitic, v slightly phosphatic	**5**
Cement/Matrix: Clay	**30**
Diagenesis: Pyrite, replacing pellets and some clasts in disseminated form	
Porosity: Original	**0**
Intermediate	**0**
Present	**0**

Paragenesis: No erosional surface was observed, therefore unsure of origin but presume this is a lag deposit concentrated from normal muddy sand deposition.

……

PETROGRAPHIC SAMPLE at 100.52 metres Type: TS

Description: grainstone texture. Some have a compact sand centrefill with a concentric peripheral zone of mud.

Particulate Components:	**Abundance %**
Quartz, silt to v fine sand, angular, with brown surface staining (goethite?)	**20**
Mica flakes and thin books	**<2**
Pellets, goethitic (palimpsest grummous texture to matrix	
Skeletal: gastropods(mud and pellet filled); echinoid spines and plate fragments; foraminifera; malacostracan and pelecypod fragments	
Cement/Matrix: Micrite with grumous texture (unsure if originally pelletal grainstone or mud)	**78**
Diagenesis: Pyrite: lines burrows that are carbonate infilled; scattered framboids in skeletal pores	
Ferroan calcite/dolomite replaces and obliterates original textures	
Porosity: Original :intraskeletal	**<1**
Intermediate	
Present (cement occluded)	**0**

Paragenesis: 1) deposition of oxidized pellets and ooids
2) bioturbation
3)fibrous chalcedony lines gastropod intraskeletal porosity
4) framboidal pyrite precipitated in skeletal pores
5) replacement of host sediment by ferroan calcite
6) calcite druse cement in intraskeletal porosity

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PETROGRAPHIC SAMPLE at 100.73 metres depth Type: TS

Description: Burrow-mottled v fine quartzose silt with v fine sand patches. Burrows, 1mmD, comprise about 20% sediment, and are infilled with sorted v fine to fine sand (grainstone texture).

Particulate Components:	**Abundance %**
Sand-sized components occur both in burrows and scattered irregularly throughout silt.	
Quartz, silt, v fine - fine sand, angular, tabular to subspherical, many goethite-coated	**10**
Pellets, goethite, fine sand sized, ellipsoidal to spheroidal	
Skeletal: gastropods (pyrite-filled); malacostracan pieces	
Cement/Matrix: Clay matrix; pyrite is a minor cement in burrows	

Diagenesis: Resin, inside gastropod porosity as crazed opaque nonfluorescent residue

Pyrite, framboidal in intraskeletal porosity, replacement in matrix, disseminated framboidal cement in burrows,replacement of nuclei in pellets and ooids

Porosity: Original intraskeletal,burrow interparticle	**7**
Intermediate	**?**
Present burrow interparticle	**<4**

Paragenesis: 1) oxidation of glauconite before and during deposition

2)porosity enhanced by burrowing

3) pyrite starts to precipitate in porosity

4) some clay cement in burrows

5) compaction

6) pyrite and resin occlusion of remaining intraskeletal porosity

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PETROGRAPHIC SAMPLE at 101.48 metres depth Type: stained TS

Description: Micrite, burrow mottled with sandy grainstone-packstone textures. Burrows, 0.4mmD, are infilled with quartz-rich grainstone, and 5mmD types infilled by pelletal wackestone. Abraded skeletal fragments are scattered throughout the micrite.

Particulate Components:	**Abundance %**
Quartz, coated grains and ooids, mostly in burrows	**10**
Grapestone, goethitic, 1.2mm, ellipsoidal	**3-20**
Pellets, goethitic, 1.2-0.3mm, ellipsoidal-spheroidal, varied distribution	
Skeletal; pelecypod,echinoid,gastropod, bryozoan fragments	**5**
Cement/Matrix: Micrite, ferroan calcite (originally pelleted)	**65**

Diagenesis: Ferroan calcite, replacing host siliciclastic

Pyrite, porefill cement in patches of micrite, revealing palimpsest pelletal grainstone texture that was probably originally pervasive.

Manganese oxides?, opaque radiating crystals replacing parts of mollusc fragments or porefill in moldic porosity.

Porosity: Original intraskeletal (bryozoa), interparticle in host pelletal sediment	**5**
Intermediate skeletal moldic	**1**
Present , occluded	**0**

Paragenesis: 1) oxidation of glauconitic pellets before and during deposition

2) pyrite commences precipitation as framboids in interparticle and intraskeletal porosity

3) compaction commences

4) moldic porosity from carbonate dissolution

5) manganese dioxide precipitation commences

6) replacement of sediment by ferroan calcite
7) calcite druse cement porefill of remnant porosity

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PETROGRAPHIC SAMPLE at 102.15 metres depth Type: stained TS

Description: Calcitic concretions occur in compacted burrow-mottled silty very fine sandy mud which has faint relict lamination from sandy and clayey alternations. Concretions have sandy packstone texture.

Particulate components in host:	**Abundance %**
Quartz, coarse - v fine sand - silt	**30**
Intraclasts of sandy packstone carbonate, 3.2mmD	
Pellets, goethitic, medium to coarse sand-sized	
Particulate components in concretion:	
Quartz, v fine sand-silt, angular, coated and ooids	**15**
Muscovite flakes	**<1**
Pellets, goethitic, fine sand-sized	**1**
Skeletal; disarticulated thin-shelled pelecypods, gastropod, foraminiferal, and articulated ostracod material	**<1**
Cement/Matrix of concretions: Micrite, ferroan calcite, grumous texture	**85**
Diagenesis: Pyrite, minor replacement of ooid nuclei and framboidal cement in interparticle porosity in burrows; opaque mineral (MnO_2?), porefilling intraskeletal and burrow interparticle porosity; ferroan calcite, micritic texture, replaces host clay and some quartz particles	
Porosity: Original burrow interparticle	**3**
Intermediate	
Present occluded	**0**

Paragenesis: 1) oxidation of glauconitic pellets
2) bioturbation
3) localized calcite replacement in concretions
4) compaction commences
5) pyrite precipitates in porosity (predominant in clay)

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PETROGRAPHIC SAMPLE at 107.0 metres depth Type: TS

Description: Burrowed muddy silt. Burrows are of two types: 0.3 mmD mud-filled, subhorizontal, 20% of sediment 1mmD silt-filled (finer silt than in host sediment), oblique to horizontal, 10% of sediment.

Particulate Components:	**Abundance %**
Quartz, coarse silt - v fine sand, subangular v fine silt	**45**
Muscovite, thin books	
Pellets, goethitic, 0.3mmD, ellips.-spheroidal	**1**
Skeletal; scaphopods, disarticulated echinoids and ostracods	
Cement/Matrix: mud (silt & clay)	**55**
Diagenesis: pyrite: v fine disseminated in mud	**3**

irregular replacement of matrix from initial precipitation in interparticle porosity on margins of burrows; replacement of skeletal fragments

Porosity: Original burrow interparticle **3**

Intermediate **reduced**

Present **reduced** ~2

Paragenesis: early oxidation of glauconitic pellets, burrowing, pyrite cement and replacement, compaction

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PETROGRAPHIC SAMPLE at 109.25 metres depth Type: stained TS

Description: Burrowed silty-sandy micrite. Burrows are: horizontal, 1.3-3mmD, *Clymenella*-like (mud-centred with concentric outer sand-lined grainstone); vertical, *Phycodes*-like burrows 10-20% of sediment, few but large. Original texture of host is presumed grummous.

Particulate Components:	**Abundance %**
Quartz, mixed igneous and met., v fine sand-silt, vari shaped	**20**
Range from uncoated to coated ooids, gradational with	
Pellets, goethitic, medium sand-sized	**1**
Skeletal, pelecypod, complete but small	
Cement/Matrix: micrite	**79**
Diagenesis: pyrite, framboidal cement and replacement in burrow interparticle porosity	**0.5**
Ferroan calcite, micritic replacement or syndepositional precipitate?	**79**
Porosity: Original burrow interparticle porosity	**8**
Intermediate fracture porosity	**~2**
Present occluded	**0**

Paragenesis: 1) Oxidation of pellets

2) calcite cementation in burrows

a) thin layer of druse cement

b) pyrite framboids

c) ferroan calcite cement

3) compaction and fracture

4) calcite cementation healing fractures ferroan followed by nonferroan dolomite

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PETROGRAPHIC SAMPLE at 111.6 metres depth Type: stained TS

Description: Bioturbated dolomitic grainstone-packstone. Burrows are 4mmD, subvertical, wackestone texture around the periphery. Pellet quartz sand infill of burrows is better sorted, with an absence of mudlumps or fewer than the host sediment. Burrow infill is more oxidized.

Particulate Components:	**Abundance %**
Quartz, igneous and met., v fine sand - silt, angular, equant, to shard-like with embayed (corroded) surfaces, coated	**30**
Mudlumps, 0.9mmD, rounded, in host	**60**
Pellets, goethitic, 0.3-0.5mmD, spheroidal, in burrows	**40**

Skeletal, disarticulated echinoid pieces

Cement/Matrix: host has clay/glauconitic matrix with locally compacted mudlumps. Burrows have compacted pellet matrix with some glauconitic cement.

Diagenesis: clay, not apparently crystalline, glauconite? in burrows. Dolomite, nonferroan micrite with clotted appearance

Porosity: Original burrow interparticle porosity	**~10**
Intermediate	**reduced**
Present	**0**

Paragenesis: 1) surface dolomitization to form firmgrounds

2) bioturbation producing dolomitic mudlumps

3) dolomitic micrite precipitation continued in host

4) clay precipitation in burrows

Interpretation: Firmground which was later modified in soil profile to a caliche.

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PETROGRAPHIC SAMPLE at 114.4 metres depth Type: TS

Description: Uniform silty very fine sand of grainstone to packstone texture.

Particulate Components:	**Abundance %**
Quartz & minor feldspar, v coarse silt - v fine sand angular, tabular - equant, corroded surfaces, some mud-coated	**60**
Mudlumps, 1mmD, compacted, distorted	**5**
Mica flakes	**<1**
Pellets, goethitic,0.3-0.5mmD,ellipsoidal to spheroidal	**1**
Skeletal, foraminifera, fragmented gastropods echinoid spines and disarticulated pieces	
Cement/Matrix: Ferroan calcite cement pervasive	**30**

Diagenesis: Ferroan calcite cement, very finely crystalline druse extending from calcareous muddy coatings of particles

Porosity: Original interparticle	**20**
Intermediate	**reduced**
Present occluded	**0**

Paragenesis: Corrosion of quartz particles, mud-coated before deposition, and calcite cementation continued

Interpretation: Probably sediment was exposed to alkaline low-salinity groundwater very early after deposition

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PETROGRAPHIC SAMPLE at 120.6 metres depth Type: stained TS

Description: Burrowed silty micrite. Burrows comprise approximately 30% of sediment, are 1-2mmD, subvertical, subhorizontal, with varying infills: v fine silty pelletal sand, sandy silty pelletal grainstone and micrite

Particulate Components:	**Abundance %**
Quartz and Feldspar, v fine sand to silt:	**20**
rounded, subspheroidal, stained in burrow, subangular, subspheroidal in host	
Pellets, goethitic, medium to v fine sand-sized	**2**
Skeletal, malacostracan fragments	**<1**

Cement/Matrix: Micrite	**78**
Diagenesis: Ferroan calcite, micrite, pervasive cement (v fine druse and fibrous) occluding fractures in host	
Porosity: Original burrow interparticle	**5**
Intermediate fracture	**~1**
Present occluded	**0**

Paragenesis: 1) oxidation of glauconitic pellets
2) carbonate micrite precipitation
3) porefill by v fine ferroan calcite cements
4) fracture of firmgrounds
5) occlusion of fracture porosity by ferroan calcite

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PETROGRAPHIC SAMPLE at 120.64 metres depth Type: TS

Description: Burrowed and compacted silty mud with wackestone texture. Silt particles are aligned. Burrows comprise 30% of sediment,are compacted to elliptical section, 1mmD, horizontal orientation, infilled by: v coarse silt packstone-grainstone, v fine silt and clay packstone-wackestone

Particulate Components:	**Abundance %**
Quartz, v fine silt, angular, tabular	**10**
Coarse silt	**?**
Pellets, 0.2mmD	**minor**
Skeletal,echinoid and fish fragments, foraminifera and small pelecypods	**?**
Cement/Matrix: Clay	**~90**
Glauconite, cement in burrows	**?**
Diagenesis: Pyrite:	**2**
framboids in burrow porosity; replacement within clay host	
Porosity: Original burrow interparticle	**3**
Intermediate	
Present occluded by cement, compaction	**0**

Paragenesis: Pyrite precipitated in burrow porosity; compaction; pyrite precipitation continued as patchy replacement

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PETROGRAPHIC SAMPLE at 124.2 metres depth Type: TS

Description: Bioturbated mud with burrows comprising 15% of sediment, 1mmD, horizontal, infilled by v fine sandy mud (wackestone texture).

Particulate Components:	**Abundance %**
Quartz, v fine sand and silt, angular to subangular, coated grains to ooids	**15**
Mica flakes	**2**
Pellets, goethitic, medium sand-sized	**0.5**
Skeletal, pelecypod fragments, foraminifera	**<1**
Cement/Matrix: Mud throughout(quartz and mica silt, clay)	**80**
Diagenesis: Pyrite, scattered, as well as in centres of burrows	**1**

Dolomite, patchy

Porosity: Original	**0**
Intermediate	**0**
Present	**0**

Paragenesis: Oxidation of pellets, sedimentation, compaction pyrite replacement in burrows

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PETROGRAPHIC SAMPLE at 125.22 metres depth Type: stained TS

Description: Carbonate concretion in a host mud. Concretion is a burrowed sandy skeletal packstone-wackestone. Burrows are sand-lined and infilled with micrite.

Particulate Components:	**Abundance %**
Quartz, v fine sand - silt, angular, irregular shards	**30**
Pellets, mud, fine- medium sand-sized	**0.5**
Skeletal; discoid, planar and branching bryozoa, pelecypod fragments, foraminifera, gastropods, echinoid spicules	**20**
Cement/Matrix: Micrite, pervasive, ferroan calcite	**50**
Fibrous calcite cement in bryozoa	**~1**

Diagenesis: Pyrite: patchy porefill between pellets (burrows? or relicts of original sediment texture?); replacement of bryozoan tests

Resin, in bryozoa as late porefill after calcite

Ferroan calcite; pervasive replacement micrite radiating fibrous crystals in bryozoa

Porosity: Original intraskeletal	**1**
burrow interparticle	**1**
interparticle around pellets	**>1**
Intermediate moldic	**2**
Present solution enhanced moldic	**0.5**

Paragenesis: 1) Bioturbation

2) pyrite precipitation as porefill commences

3) aragonitic cement?

4) ferroan calcite micrite replacement and cement

5) compaction

6) pyrite replacement, further cementation and resin influx

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PETROGRAPHIC SAMPLE at 127.75 metres depth Type: Polished Stub

Description: A horizontal cylindrical burrow of *Ophiomorpha*, infilled with pyrite and resin in a geopetal fabric. The lower third is a dense pyrite sediment with a horizontal upper surface, overlain by a porous intermixture of pyrite framboids in resin. This intermixed texture coarsens to the top and sides of the burrow.

Interpretation: Burrow porosity remained open to fluids well after compaction when resin was mobilized with water movement while pyrite was precipitating. The resin partly separated out and rose to the upper part of the cavity. Pyrite continued precipitating as long as groundwater could permeate through this porosity.

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PETROGRAPHIC SAMPLE at 127.95 metres depth Type: TS

Description: Bioturbated sandy mud, slightly compacted. Burrows comprise about 25% of the sediment, are 2-5mmD, horizontal, with similarities to *Teichicthus*, and are infilled by sandy packstone.

Particulate Components:	**Abundance %**
Quartz: v fine sand - silt, angular, tabular	**20**
fine silt	**?**
Mica flakes throughout	**1**
Pellets, goethitic, 0.15mmD	**1**
Skeletal; oyster fragments	**< 1**
Cement/Matrix: Mud, host sediment and burrow infill	**77**
Calcite cement	**very minor**
Diagenesis: Pyrite: occluding porosity around pellets in burrows, disseminated framboids replacing mud in burrows	
Clay, cement occluding burrow porosity	
Porosity: Original burrow interparticle	**< 0.5**
Intermediate	
Present occluded	**0**

Paragenesis: Pyrite and minor calcite precipitation until compaction

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PETROGRAPHIC SAMPLE at 129.0 metres depth Type: TS

Description: Compacted, bioturbated silty mud (wackestone-mudstone texture). Burrows comprise about 30% of sediment and are variably sized from 0.3-1.5-4mmD, generally horizontal, and infilled by v fine quartzose pelletal sand.

Particulate Components:	**Abundance %**
Quartz and feldspar, silt and v fine sand, angular to subrounded, some have goethitic coatings : v fine sand and coarse silt	**15**
v fine silt	**20**
Mica flakes	**1**
Pellets, goethitic, fine-medium sand-sized, spheroidal, predominant in burrows	**2**
Skeletal, agglutinated foraminifera	**< < 1**
Cement/Matrix: Clay	**60**
Diagenesis: Pyrite; selective as a porefill andreplacement in burrow interparticle porosity	**2**
Clay, light green, also in burrow porosity	
Porosity: Original burrow interparticle	7
Intermediate occlusion by cements	
Present	<3

Paragenesis: 1) oxidation of glauconitic particles

2) deposition, bioturbation

3) framboidal pyrite precipitating in burrows

4) clay and ?silica precipitation

5) compaction

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PETROGRAPHIC SAMPLE at 129.73 metres depth Type: TS

Description: A calcareous concretion of bioturbated sandy micrite occurs within a bioturbated mud. Burrows comprise 25% of the sediment, are subvertical to subhorizontal in orientation, 1.5-3mmD, and some have compacted margins. Infilling is sandy pelletal grainstone.

Particulate Components:	**Abundance %**
Quartz, coarse silt - fine sand, angular nonspheroidal, embayed margins, some with goethitic coatings	**25**
Mica flakes, carbonate-coated	**1**
Pellets, goethitic, fine-medium sand-sized	**1**
Skeletal: echinoid spines, foraminifera	**< 1**
Intraclasts, dolomitic indurated fragments, very large, tabular	**5**

Cement/Matrix: Calcite cement, v fine druse in burrows

Calcite micrite replaces host mud

Diagenesis: Pyrite, framboids in burrow interparticle porosity

Calcite; v fine druse cements, replacement micrite

Sulphates?, crystal moulds 1.5-3mm long, prismatic, in the host silty clay

Porosity: Original burrow interparticle **7**

Intermediate compacted, occluded

Present **0**

Paragenesis: 1) reworking of an earlier ferroan dolomitic crust into intraclasts; oxidation of glauconitic ooids and pellets.

2) bioturbation

3) displacive sulphate growth

4) pyrite precipitation in porosity

5) cementation/replacement by ferroan calcite

6) sulphate replaced by nonferroan dolomite

Interpretation: Dolomitic hardground in salt flat environment

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PETROGRAPHIC SAMPLE at 130.5 metres depth Type: stained TS

Description: Dolomitic chert concretion, synaeresis cracked, within a clayey silt. The dolomitic micrite has approximately 15% burrows, 2.5mmD, subhorizontal, infilled by coarse silt and pelletal dolomitic packstone. There are grumous patches throughout the micritic concretion.

Particulate Components:	**Abundance %**
Quartz, coarse silt, v angular and embayed, shard-like	**10**
Muscovite flakes	**0.5**
Mudlumps, glauconitic	**< 1**
Pellets: carbonate and goethitic, medium sand, ellipsoidal	**< 1**

Cement/Matrix: Mud, now dolomite and chert, palimpsest pellet packstone **88**

Pyrite, porefill in pellet-filled burrows as framboids (20 microns D)

Diagenesis: Pyrite, burrow interparticle porosity porefill, early, precompaction	**0.5**
Chert, pervasive and total replacement, 2-3 phases of accretion	**50**
Dolomite, original precipitate as sediment?, precipitation continued to post-early compaction	**40**
Resin, black, crazed, thin coating and crust on surfaces of synaeresis cracks	**< 1**
Porosity: Original burrow interparticle	**5**
Intermediate	
Present post lithification fractures in concretions	**5**

Paragenesis: 1) pyrite precipitation
2) dolomitization in burrows and host sediment
3) chert replacement in phases of gel precipitation
4) gel shrinkage and fracture
5) dolomite cementation in part in fractures
6) resin migration

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PETROGRAPHIC SAMPLE at 133.5 metres depth Type: stained TS

Description: A calcitic and dolomitic concretion in mud. The concretion is a sandy silty clotted micrite. Burrows comprise 30% of the sediment, average 1.5mmD, are subhorizontal, and infilled by a sorted sandy pelletal grainstone-packstone.

Particulate Components:	**Abundance %**
Quartz, v fine-fine sand, angular, sunrounded, some coated with goethite	**25**
Mudlumps,1-3.5mmD, variably distorted	**?**
Pellets, goethitic, medium sand-sized	**5**
Skeletal; bryozoan and decapod pieces	**< 1**
Cement/Matrix: Micrite (compacted mudlumps?)	**59**
Calcite cement, coarse druse in burrows	**10**

Diagenesis: Pyrite, framboids (10-30 microns) in burrows;
Calcite, coarse drusy cement in burrows; ferroan,vein infill in fractured concretions

Porosity: Original interparticle	**10**
Intermediate fracture	**5**
Present recemented	**0**

Paragenesis: 1) bioturbation and slow compaction
2) pyrite precipitation commences
3) pervasive ferroan calcite cementation and replacement
4) compaction, fracturing of concretions
5) ferroan calcite continued to occlude porosity

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PETROGRAPHIC SAMPLE at 143.6 metres depth Type: stained TS

Description: Clast from a gravelly flasered silt is a laminated sandy micrite with 10% burrows (1.5mmD) and infilled by pelletal mud.

Particulate Components:	**Abundance %**
Quartz and Feldspar, v fine to fine sand, angular	**10**

Pellets?, 20-50 microns D, spherical, recrystallized	**60**
Cement/Matrix: Micrite, replacement of pellets?	
Diagenesis: Pyrite, patchy replacement and porefill along laminae in sandier horizons	
Siderite?, part poikilotopic cement between ?pellets	
Porosity: Original interparticle	**25**
Intermediate	
Present occluded	**0**

Paragenesis: Initially pyrite precipitation and then sideritic cementation as well.

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PETROGRAPHIC SAMPLE at 149.45 metres depth Type: stained TS

Description: Variably bioturbated silty micrite. Burrows comprise 20-30% of the sediment, up to 2.2mmD and horizontal, and 1.4mmD and vertical (*Teichichnus*?).

Particulate Components:	**Abundance %**
Quartz and Feldspar, coarse silt, angular	**15**
Mudlumps, coarse sand-sized	**20**
Pellets	**?**
Cement/Matrix: Calcitic micrite; Calcite cement in burrows	
Diagenesis: Calcite and Chert replacement	**40**
Pyrite, scattered replacement - margins of small burrows	**< 1**
Porosity: Original burrow interparticle	**5**
Intermediate	
Present	**0**

Paragenesis: Deposition, bioturbation, followed by early pyrite precipitation. Silicification then selective of burrow porosity; calcite replacement.

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PETROGRAPHIC SAMPLE at 150.9 metres depth Type: TS

Description: Burrowed silty dolomitic mudstone. Burrows comprising 30-40% of the sediment, are variably sized from 0.15-0.4-3.2mmD. Some burrows are composite, with thinner tubules intertwined within the soft infilling sediment.

Particulate Components:	**Abundance %**
Quartz, silt	**15**
Skeletal: calcareous algal tubules and encrustations	
Cement/Matrix: Micrite in burrows	**5?**
Mud	**80?**
Diagenesis: Dolomite, small rhombs, sucrosic texture, pervasive	
Chert, pervasive in host, especially rimming large burrows, synaeresis cracks, goethitic (and phosphatic?) staining associated.	
Pyrite, early precipitate as scattered framboids in the margins of burrows. Oxidation is apparent as diffused haloes of goethite around framboids.	
Porosity: Original burrow interparticle	**10**
Intermediate	
Present	**0**

Paragenesis: 1) deposition and bioturbation of sediment

2) pyrite commences precipitation

3) silicification and dolomitization extensive, indurating exposed surface. Algal encrustation and boring.

4) oxidation of pyrite

Interpretation: This horizon was a syndepositional hardground with active silicification and dolomitization

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PETROGRAPHIC SAMPLE at 165.35 metres depth Type: TS

Description: Burrowed sandy pelletal packstone. Burrows comprise approximately 15% of sediment. Original sediment texture was grainstone, now compacted to packstone.

Particulate Components:	**Abundance %**
Quartz, v fine to fine sand, angular subrounded	**15**
Pellets, glauconitic and goethitic, medium sand-sized, most have concentr internal reaction rims of undetermined mineralogy	**50**
Skeletal: agglutinated foraminifera, solitary corals, pelecypod fragments	**<2**
Cement/Matrix: Glauconite cement pervasive except in burrows	**30**
Diagenesis: Glauconite, pervasive, two phases; a rim cement on particles, separated from later porefill by a zone of undetermined composition (opaque), identical to the zonation in pellets	**30**
Dolomite, sucrosic with rhombs microns, in burrows as replacement of matrix	
Porosity: Original interparticle, burrow	**30**
Intermediate	
Present occluded	**0**

Paragenesis: 1) some oxidation of glauconitic pellets

2) bioturbation

3) glauconite cementation

4) replacement dolomitization in burrows

5) replacement pyritization

Interpretation: This horizon is a reworked firm or hardground. Old exposed burrows have oxidized margins.

……

PETROGRAPHIC SAMPLE at 166.9metres depth Type: TS

Description: Uniformly burrowed pelletal sand. Burrows are indistinct, approximately 6mmD, and are apparent by a slight concentric pattern in sand orientation within the grainstone texture.

Particulate Components:	**Abundance %**
Quartz and Feldspar, fine - v fine sand, angular-subrounded, pitted surfaces	**40**
Pellets, glauconitic, pyritic, medium sand-sized	**30**
Grapestone, glauconitic and goethitic	**<2**
Skeletal, pelecypod fragments (abraded)	**<1**
Cement/Matrix: Glauconite cement pervasive	**28**

Diagenesis: Glauconite, poorly crystalline cement

Dolomite, small rhombs throughout glauconitic cement

Porosity: Original interparticle **30**

Intermediate

Present cement porefill **0**

Paragenesis: Grainstone, following bioturbation, porosity occluded by early glauconitic cement. Replacement by dolomite as disseminated rhombs throughout the glauconite.

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PETROGRAPHIC SAMPLE at 169.0 metres depth Type: TS

Description: Calcitic fine - v fine quartzose sandstone with grainstone texture.

Particulate Components:	**Abundance %**
Quartz and Feldspar, fine-v fine sand, shards angular -subrounded, equant, coated	**60**
Mica, thin books	**1**
Mudlumps, coarse sand-sized, originally soft	**3**
Skeletal: foraminifera, minor fragments of ostracods	**2**
Cement/Matrix: Ferroan calcite cement	**25**

Diagenesis: Ferroan calcite, very coarse druse cement, invades and replaces margins of quartz sand

Porosity: Original interparticle **25**

Intermediate

Present cement occlusion **0**

Paragenesis: Deposition, compaction, then total induration

……

PETROGRAPHIC SAMPLE at 169.35 metres depth Type: TS

Description: Homogeneous pelletal skeletal quartzose sand with grainstone texture.

Particulate Components:	**Abundance %**
Quartz and Feldspar, fine-v fine sand, angular, tabular to equant	**60**
Pellets: glauconitic, medium to coarse sand	**2**
goethitic, v fine - medium sand-sized	**8**
Skeletal: fragmented/complete gastropods, disarticulated ostracods, variably-sized pelecypod fragments, disarticulated oysters, bryozoa, echinoid spines	**3**
Cement/Matrix: Glauconite cement	**27**

Diagenesis: Glauconite, pervasive as cement/matrix

Dolomite, patchy cement

Porosity: Original interparticle **27**

intraskeletal **4**

Present **3**

Interpretation: Originally a grainstone texture, the sand was almost totally occluded by glauconite.

……

PETROGRAPHIC SAMPLE at 175.55 metres depth Type: polished stub

Description: Pyritized burrow (*Dominichnia*).

Diagenesis: Pyrite present as euhedral tetrahedra grading to subhedral crystals where crystal growth interference has resulted. Only walls of burrow have been replaced.

……

PETROGRAPHIC SAMPLE at 183.8 metres depth Type: TS

Description: Silty dolomitic micrite. Minor burrows are distinct and large (8 by 16 mm), infilled by silty grainstone, and flecked with resin. Texturally, the sediment is a colour-mottled wackestone with patches of mudstone or locally packstone where it is glauconitic.

Particulate Components:	**Abundance %**
Quartz and Feldspar, silt-sized, angular, equant	
in burrows	**70**
in host	**5**
Pellets, glauconitic, medium sand-sized, some with unusual irregular nuclei	**20**
Skeletal, bryozoa	**<1**
Cement/Matrix: Calcite, v finely crystalline throughout	**80**
Dolomite,matrix in discrete patches (large clasts?)	
Clay, (glauconite?) cement in burrows	
Diagenesis: Ferroan calcite, replacement of mud and a cement?	
Dolomite, non-ferroan, micrite	
Clay, porefill in burrows	
Chert, in small patches associated with dolomite	
Porosity: Original burrow interparticle	**5**
Intermediate	
Present	**2**

Paragenesis: There appears to be a repeated sequence of bioturbation, synsedimentary dolomitization, erosion and reworking. Calcite replacement and clay precipitation appears to follow after deposition.

Interpretation: Dolomitized muddy hardground where glauconitic replacement of pellets was incomplete.

……

APPENDIX V

PHOTOGRAPHY OF DRILLCORE

PLATE 7

Representative sections of split core from

67.57 to 154.5 metres depth.

		metres depth
Parilla Sands ?		
	--------------	81.5
Lithofacies F		
	--------------	102
Lithofacies E		
	--------------	128
Lithofacies D		
	--------------	134
Lithofacies C		
	--------------	165.3

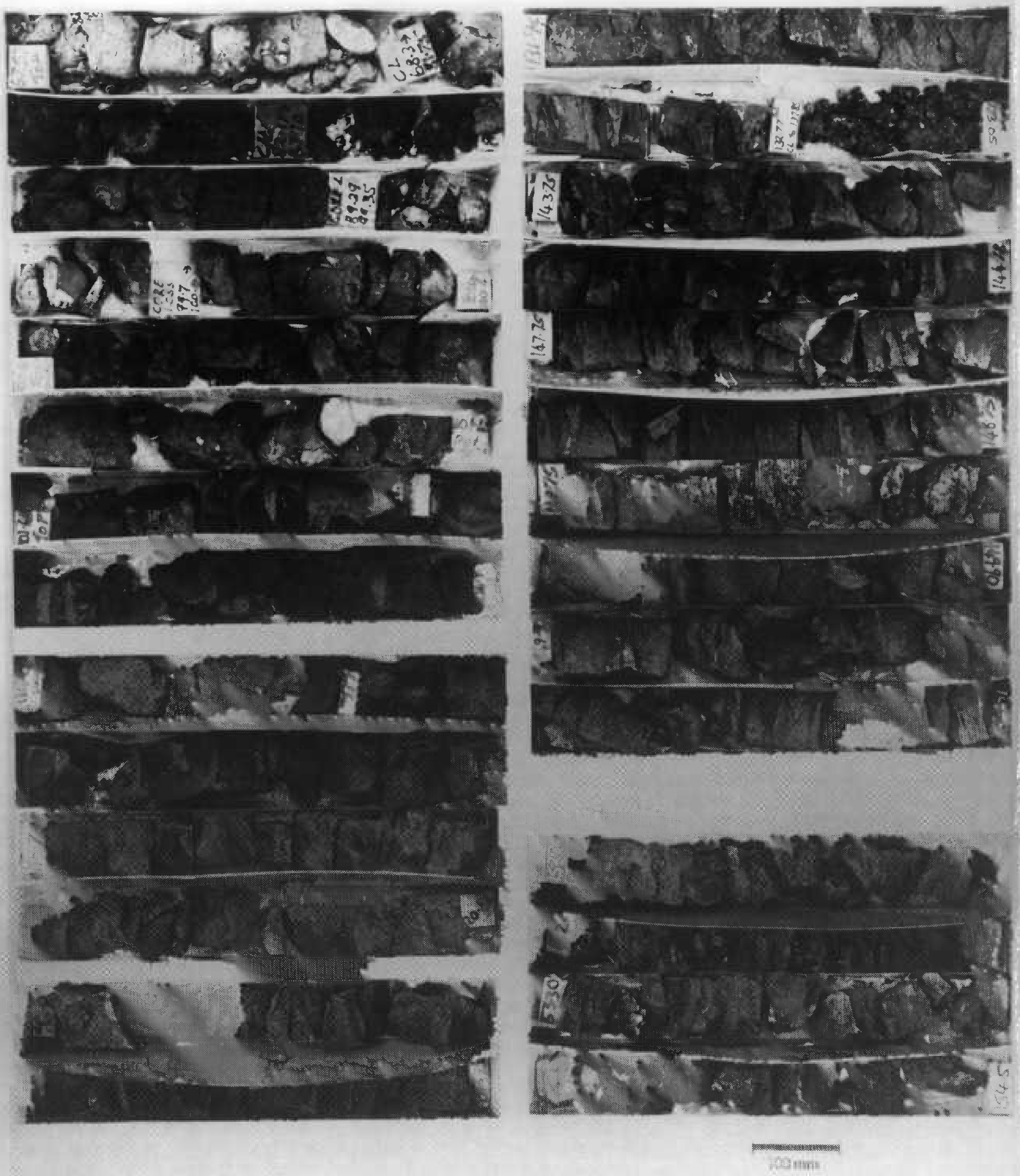

PLATE 2

PLATE 8

Representative sections of split core from

154.5 to 185.88 metres depth

```
                         metres depth

   ---------------      134


Lithofacies C

  ---------------        165.3

Lithofacies B
  ---------------        170.7

Lithofacies A
   ----------T.D. at   185.88
```

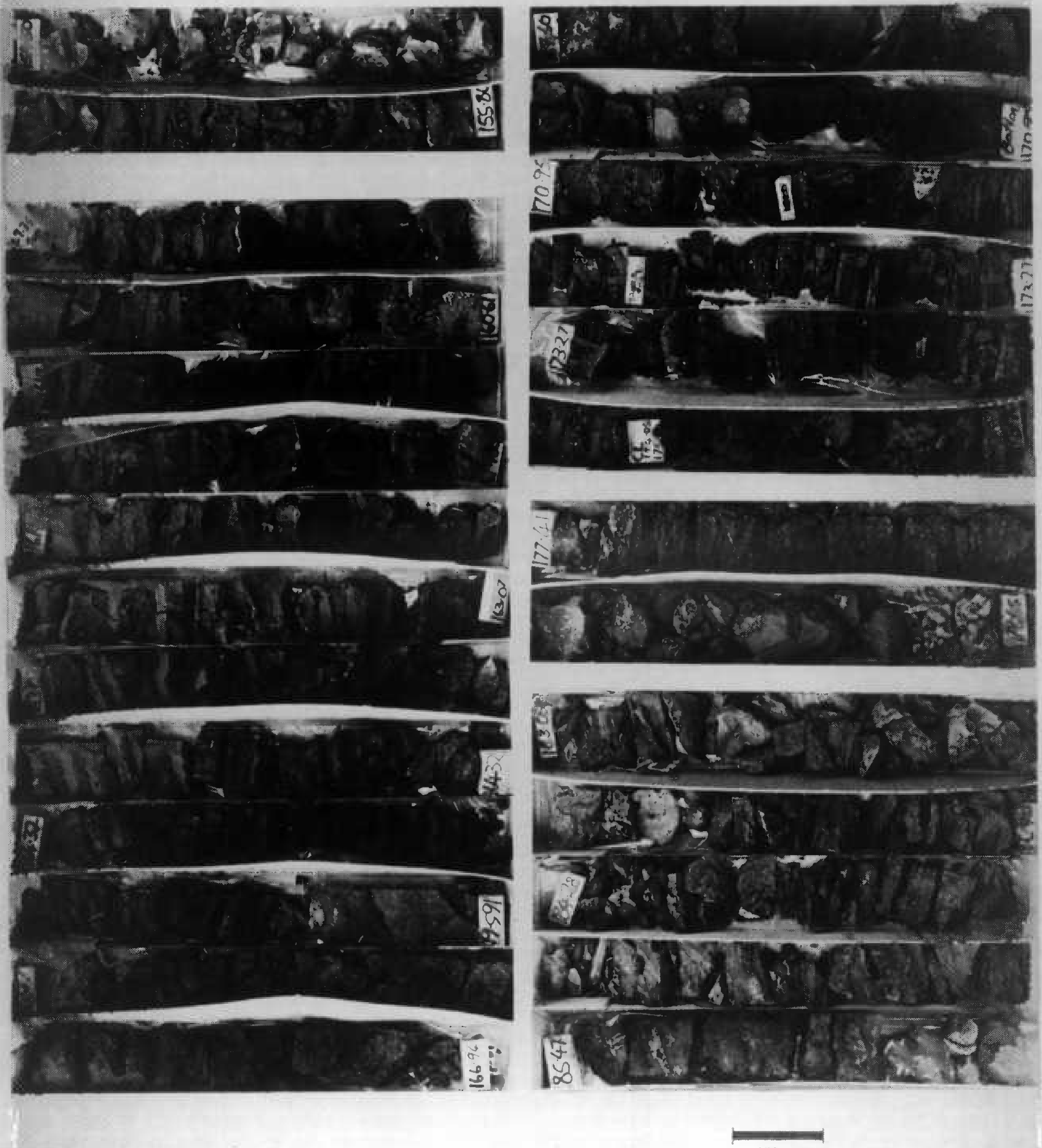

PLATE 8

APPENDIX VI

DRILLCORE SAMPLES

PETROGRAPHIC SAMPLES

Depth in hole m

67.1	Thin Section
81.8	"
88.0	"
89.15	"
99.5	"
100.52	"
100.73	"
101.48	"
102.15	"
107.0	"
109.25	"
111.6	"
114.4	"
120.6	"
120.64	"
124.2	"
125.22	Thin section
127.75	Polished Stub
127.95	Thin section
129.0	"
129.73	"
130.5	"
133.5	"
143.6	"
149.45	"
150.9	"
165.35	"
166.9	"
169.0	"
169.35	"
175.55	Polished stub
183.8	Thin Section

MINERALOGIC DETERMINATIONS (XRD)

BMR

*AMDEL

Depth in hole m

67.3
67.6
67.9
68.2
101.8*
108.3*
110.2*
112.45*
122.90*
128.80*
131.2 *
132.75*
133.75*
137.7 *
145.8 *
146.0 *
149.35*
151.7
152.37
152.87
170.0
172.45
175.43

TOTAL ORGANIC CARBON ANALYSES

Sample Depth (metres)	BMR NO
108.00	3712
114.40	3703
125.95	3704
128.10	3705
132.00	3706
153.35	3707
157.30	3708
163.30	3709

GEOCHEMICAL DETERMINATIONS

Depth (metres)

109.00
132.77
135.8
136.52
163.5A
163.5B

FORAMINIFERA SAMPLES

Interval (metres)

87.7 - .8
101.6 - .7
102.15 - .25
106.25 - .35
107.1 - .15
109.6 - .7
119.25 - .3
120.1 - .15
122.8 - .9
125.2 - .25
126.25 - .35
129.3 - .4
133.5 - .6
138.3 - .4
147.1 - .2
149.0 - .1

Interval (metres)

150.2 - .3
151.6 - .7
153.7 - .8
154.6 - .7
157.6 - .7
160.5 - .6
162.3 - .4
165.0 - .1
169.3 - .4
171.2 - .3
172.5 - .6
172.8 - 173.0
173.3 - .4
175.9 - 176.0
182.3 - .4
183.0 - .1
184.0 - .1
184.5 - .6
185.2 - .3

PALYNOLOGY SAMPLES

Depth. (m)	**Depth (m)**
68.0	113.8
82..0	119.9
89.0	123.4
99.5	127.1
100.0	129.2
100.9	133.0
101.2	138.0
101.5	143.8
101.8	149.0
102.0	154.0
106.2	164.0
106.5	169.4
110.2	174.0
	179.0
	184.0

PORE FLUID GEOCHEMISTRY SAMPLES

Sample No. & Depth in metres

1 67.5
2 67.5
3 67.8
4 68.3
5 81.8
6 82.1
7 87.7
8 88.0
9 88.3
10 88.6
11 88.9
12 89.2
13 99.4
14 99.7
15 100.0
16 100.3
17 100.6
18 100.9
19 101.2
20 101.5
21 101.8
22 102.1
23 106.2
24 106.5

52 123.1
53 123.4
54 123.7
55 124.0
56 124.3
57 124.6
58 124.9
59 125.2
60 125.5
61 125.8
62 126.1
63 126.4
64 126.8
65 127.1
66 127.4
67 127.7
68 128.0
69 128.4
70 128.7
71 129.0
72 129.3
73 129.6
74 129.9
75 130.1

103 139.1
104 139.4
105 139.7
106 140.0
107 140.3
108 140.6
109 143.8
110 143.9
111 144.2
112 144.5
113 144.8
114 145.1
115 145.4
116 145.7
117 146.0
118 146.3
119 147.1
120 147.4
121 147.7
122 148.0
123 148.3
124 148.6
125 148.9
126 149.2

154 157.6
155 157.9
156 158.2
157 158.5
158 158.8
159 159.1
160 159.4
161 159.7
162 160.0
163 160.3
164 160.6
164 160.9
166 161.2
167 161.5
168 161.8
169 162.0
170 162.4
171 162.7
172 163.0
171 63.3
174 163.6
175 163.4
176 164.2
177 164.5

205 175.4
206 175.7
207 176.0
208 176.3
209 176.6
210 176.9
211 177.2
212 188.5
213 177.8
214 178.1
215 178.4
211 78.7
217 179.1
218 180.2
219 180.5
220 180.8
221 181.1
222 181.4
223 181.7
224 182.0
225 182.3
226 182.6
227 182.9
228 183.2

25 106.8
26 107.1
27 107.7
28 108.0
29 108.3
30 108.7
31 109.0
32 109.3
33 109.6
34 109.9
35 110.2
36 110.5
37 111.8
38 112.1
39 112.3
40 112.6
41 112.9
42 113.8
43 114.1
44 119.0
45 119.3
46 119.6
47 119.9
48 120.2
49 120.5
50 120.8
51 122.8

76 130.5
77 130.8
78 131.1
79 131.4
80 131.7
81 132.0
82 132.3
83 132.6
84 132.9
85 133.2
86 133.5
87 133.8
88 134.5
89 134.8
90 135.1
91 135.4
92 135 .7
93 136.0
94 136.3
95 136.7
96 137.0
97 137.3
98 137.6
99 137.9
100 138.2
101 138.5
102 138.8

127 149.5
128 149.8
129 150.1
130 150.4
131 150.7
132 151.05
133 151.3
134 151.6
135 151.9
136 152.2
137 152.5
138 152.8
139 153.1
140 153.4
141 153.7
142 154.0
143 154.3
144 154.6
145 154.9
146 155.2
147 155.5
148 155.8
149 156.1
150 156.4
151 156.7
152 157.0
153 157.3

178 164.8
179 165.1
180 165.7
181 166.0
182 166.3
183 166.6
184 166.9
185 167.2
186 167.5
187 167.8
188 168.1
189 168.4
190 168.7
191 169.0
192 169.3
193 169.6
194 169.9
195 170.2
196 170.5
197 170.8
198 171.1
199 172.3
200 172.6
201 172.9
202 173.2
203 173.5
204 173.8

229 183.5
230 183.8
231 184.2
232 184.5
233 184.8
234 185.1
235 185.4
236 185.7