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LITHOSTRATIGRAPHY OF THE NINMAROO FORMATION
(UPPER CAMBRIAN - LOWER ORDOVICIAN),
GEORGINA BASIN, QUEENSLAND AND NORTHERN TERRITORY

by

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ABSTRACT

The Ninmaroo Formation (Upper Cambrian - Lower Ordovician) has a widespread distribution in the southeastern Georgina Basin of Queensland and the Northern Territory, extending from northwest of the Toko Syncline to the east and south over the Smoky Anticline to the Burke River Structural Belt. It overlies Middle and Upper Cambrian units with disconformity and unconformity, except in the Toko Syncline and Southern Burke River Structural Belt, where the sequence is conformable. To the west of the Toko Syncline it interfingers laterally with the Tomahawk Beds. The upper boundary is an erosional surface everywhere except in the central Toko Syncline, where it is apparently conformably overlain by the Kelly Creek Formation. The formation is up to 950 m thick, and comprises bituminous limestone, limestone, sandy limestone, dolostone, calcareous sandstone, siltstone, and minor shale. Lithofacies distribution in the Ninmaroo Formation indicates a sequence that is progradational to the east and southeast. The sequence consists of a basal ooid carbonate lithofacies overlain by peloid carbonate lithofacies, a terrigenous lithofacies in the Toko Syncline, flat-pebble conglomerate lithofacies, mixed carbonate lithofacies in the Toko Syncline, skeletal carbonate and peloid carbonate lithofacies in the Burke River Structural Belt. A crystalline dolostone lithofacies occurs mainly along fault zones. Most of these lithofacies accumulated by cyclic sedimentation, which produced sheet deposits 0.1-4.5 m thick. Three cycles are recognised; cryptalgal carbonate, peloid carbonate, and skeletal-ooid carbonate.

INTRODUCTION

This report documents the lithostratigraphy of the Ninmaroo Formation (Upper Cambrian - Lower Ordovician) in the Georgina Basin. Carbonate rock types are described, sedimentation cycles interpreted, and lithofacies defined.

The study is part of the joint Bureau of Mineral Resources/Geological Survey of Queensland Georgina Basin Project, a multidisciplinary program undertaking research in stratigraphic and structural problems as well as assessment of economic potential of the region.

Acknowledgements

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Fieldwork commenced in 1974 and continued through to 1976 in the BMR Georgina Basin Project. E.C. Druce, J.H. Shergold, J.J. Draper, C.R. Pointon, and J. Kennard provided fruitful discussion and assisted in the fieldwork. K. Heighway provided logistical support throughout the entire project and his efforts with A.T. Wilson to get the most out of the processing for conodont faunas are much appreciated. Faunal determinations were kindly provided by E.C. Druce, J.H. Shergold, and J. Pojeta, Jr.

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Previous Investigations

A thick sequence of limestone exposed at Mount Unbunmaroo, Mount Ninmaroo, and Mount Datson in the Burke River Structural Belt was named the Ninmaroo Limestone and interpreted as having an age of Croixian (Late Cambrian) to Early Ozarkian (Early Ordovician) by Whitehouse (1936). No further work was undertaken until the late 1950s, when the Bureau of Mineral Resources and the Geological Survey of Queensland commenced regional stratigraphic mapping of 1:250 000 Sheet areas in the Georgina Basin.

The Ninmaroo Limestone (Whitehouse, 1936) was later subdivided into two formations, the lower Chatsworth Limestone overlain by the Ninmaroo Formation (Casey, 1959). This subdivision and change in name was based on the prevalence of dolostones and sandstone interbeds in outcrops to the west of the Burke River

Structural Belt.

The fauna of gastropods, nautiloids, ribeirioids, monoplacophorans, brachiopods, trilobites, coralline algae, and echinoderms (Gilbert-Tomlinson, 1959) was noted to differ between the lower and upper parts of the formation (Opik, 1960). An unconformable contact with the overlying Swift Beds was reported by Opik (1960) and Brown (1961).

The extent, stratigraphic relations, and variations of the Ninmaroo Formation were progressively defined by regional mapping on the Urandangi Sheet (Noakes & others, 1959), Boulia Sheet (Casey, 1960), Tobermory Sheet (Smith & Vine, 1960), Duchess Sheet (Carter & Opik, 1963), Hay River Sheet (Smith, 1963), Sandover River Sheet (Nichols, 1964), and Glenormiston and Mount Whelan Sheets (Reynolds & Pritchard, 1964).

In the Urandangi area, bedded dolostones were mapped as the Ninmaroo Formation (Noakes & others, 1959). In the Tobermory area, the formation was described as overlain by the Kelly Creek Formation (Smith & Vine, 1960) and was later shown to interfinger with the terrigenous Tomahawk Beds (Smith, 1967) beneath it.

On the eastern limb of the Toko Syncline (Mount Whelan and Glenormiston Sheet areas), five informal rock units were recognised, containing a fauna of nautiloids and ribeirioids that was comparable to that known from the Boulia area (Pritchard, 1960). A more complete documentation of the fauna by Reynolds (1968) listed algal stromatolites, nautiloids, brachiopods, ribeirioids, gastropods, trilobites, conodonts, and echinoderms. The formation was considered to be disconformable on the Georgina Limestone, and to grade into the overlying Kelly Creek Formation (Reynolds & Pritchard, 1964). This upper contact was later shown to be a disconformity (Reynolds, 1968).

Further to the work of Casey (1960) in the Boulia Sheet area, a more detailed lithostratigraphic and petrographic study was undertaken by Brown (1961), who concluded that the Ninmaroo Formation is the result of carbonate and terrigenous deposition in warm shallow tidal seas with spasmodic and cyclic transgressions as well as the periodic emergence of island chains. Deposition was considered to be in a gulf, a north-south graben that corresponded to the Burke River Structural Belt (Boulia and Duchess Sheet areas). Subsequent detailed biostratigraphic studies established assemblage zones based on conodont faunas (Druce & Jones, 1971) and indicated a general younging of the sequence to the south (Jones & others, 1971). Further mapping at 1:100 000 scale (BMR, 1976) and stratigraphic drilling (Kennard & Draper, 1977) established the spatial distribution of informal members, modified from Brown (1961), within the

Burke River Structural Belt. The overlying Swift Formation was proposed to be, in part, a regolith that accumulated over a weathered surface of the Ninmaroo Formation. Recently, the ribeirioid (rostromer) fauna of the formation has been described and related to the existing biostratigraphic framework (Pojeta & others, 1977).

Reviews of the stratigraphy of the Ninmaroo Formation are given in Smith (1972), Shergold & others (1976), and Radke (1980).

Methods of investigation

Field documentation

The objective of the field work was to acquire a representative sampling of the Ninmaroo Formation over its geographic extent and the spectrum of its tectonic settings. The locations of stratigraphic sections were selected from 1:250 000 BMR Geological Series maps of Boulia, Duchess, Glenormiston, Hay River, Mount Whelan, Sandover River, Tobermory, Urandangi, as well as unpublished maps of Brown (1961) and the 1:100 000 BMR preliminary edition of the Southern Burke River Structural Belt. Section lines were determined from the relevant aerial photographs: 1:80 000 RC9 Series and 1:26 000 colour series. Section locations are given in Appendix III. Each selected locality was mapped at photo-scale. In most areas the sequence is flat to gently dipping (<5 degrees), but steeper dips (up to 60°) occur in narrow fault blocks and in large folds. Sections were measured with Abney level and Jacob's staff. In dissected terrain, sections were measured along spurs of ridges, a compromise between access and minimal scree coverage. Creek sections were generally unsuitable because of masking of outcrop by flood debris and calcrete coatings.

Stratigraphic information was logged at 1:200 scale in the format outlined in Appendix I. These sections were too detailed for general lithofacies trends to be readily apparent and were subsequently reduced to a manageable scale by the procedure described in Appendix II.

Chronostratigraphic correlation

To put Ninmaroo sedimentation in a time context, chronostratigraphic units were superimposed on stratigraphic sections. The chronostratigraphic classification adopted is that of Jones & others (1971), based on faunas of the Ninmaroo Formation in the Burke River Structural Belt. The stages are Payntonian (Late Cambrian), and Datsonian, Warendian, and post-Warendian (Arenigian) of the Early Ordovician. Sub-stages in the Ordovician are numbered

sequentially from 1-3 in the Datsonian, 4-6 in the Warendian, and 7 for the Arenigian.

Samples were collected from the stratigraphic sections for conodonts, trilobites, and ribeirioids. The conodont samples were processed in the BMR Mobile Conodont Laboratory in the field and in the BMR Acid Laboratories, Canberra. Assemblage determinations were made on conodont faunas by E.C. Druce (personal communication, 1974-76), on trilobite faunas by J.H. Shergold (personal communication, 1976), andostroconch (ribeirioid) faunas by Pojeta & others (1977). These determinations supplemented the earlier work of Jones & others (1971).

Conodont assemblages provide the best zonal resolution in the lower Ordovician. However, localities with sufficiently prolific faunas for adequate resolution are restricted to the Burke River Structural Belt and the Toko Syncline. Elsewhere, zonations are based on additional trilobite and ribeirioid determinations. But these do not have the same resolution as conodont assemblage zones and, consequently, the regional correlation is not of a consistent resolution, although it is adequate for the regional synthesis in this study.

Regional synthesis

Maps of outcrop, thickness, and stratigraphic contacts with the Ninmaroo Formation were compiled from 58 stratigraphic sections measured from outcrop, including 17 sections from the Boulia area provided by E.C. Druce and J.J. Draper (personal communication), 1:250 000 BMR Geologic maps, and previous stratigraphic boreholes. These include Beantree No. 1 (Phillips Petroleum, 1963), Boulia No. 8 and Duchess No. 13 (Kennard & Draper, 1977), BMR Cockroach (Smith, 1967), Ethabuka No. 1 (Alliance Oil Development, 1975), Mulga No. 1 (Alliance Petroleum Australia, 1965), Netting Fence No. 1 (Papuan Apinaipi Petroleum Company, 1965), and The Brothers No. 1 (French Petroleum Company, 1965).

In this report, the regional pattern of Ninmaroo lithofacies is based on a representative cross-section of the major structural and depositional regions. Seven stratigraphic sections (Appendices I and II), some of which are composite sections, include two sections from the Toko Syncline in a northwest line, one section from the northern part of the Smoky Anticline, and four sections in a north-south line within the Burke River Structural Belt.

The Cambrian-Ordovician boundary was used as a chronostratigraphic datum. Smaller sections of younger sequences were positioned approximately with respect to this chronostratigraphic datum.

Laboratory methods

The petrographic study of carbonates was based on 280 stained thin sections, 70 polished thin sections, 170 stained acetate peels, and 210 rock slabs.

Terrigenous particle size is described according to the scale of Wentworth (1922). Classification of sedimentary carbonate textures follows that of Dunham (1962) and for crystalline textures and fabrics, the terminology of Friedman (1965) is used.

Mineralogy of the carbonates was ascertained by selective staining for ferroan and non-ferroan calcites (Friedman, 1959; Jackson, 1966) and dolomite (Friedman, 1959). Additionally, stained acetate peels were prepared after the techniques of Davies & Till (1968). Where staining was not effective, growth zonation in crystals, and relict sedimentary textures in recrystallised carbonates were determined by cathodoluminescence (Sippel & Glover, 1965; Meyers, 1974).

Non-carbonate minerals were determined by optical properties and X-ray diffraction. The presence of traces of sulphates in some carbonate rocks was determined by X-ray diffraction of the heavy fraction from insoluble residues. Additional determinations were attempted on a smaller scale using a JSM II scanning electron microscope with an ORTEC energy dispersive X-ray analytical unit.

For X-ray diffraction, the carbonates were ground to approximately 100 mesh with mortar and pestle and digested in cold dilute (1:20) hydrochloric acid. The heavy fraction of the residues was separated in bromoform. Although the fine particle size from grinding inhibited bromoform separation, it was necessary to have adequate mineral purity in the particles to make the bromoform separation effective. Separation was accelerated using an ultrasonic bath. Heavy fraction yields were frequently less than 0.1 gram. For X-ray sample preparation, a petrographic glass slide was smeared with a mixture of powdered heavy mineral extract and spike (fluorite) in a 'Duco' cement-acetone medium and allowed to dry to a smooth surface. Determinations were made using Cu K α X-radiation on a General Electric BR Model Type I Diffractometer.

Geological setting

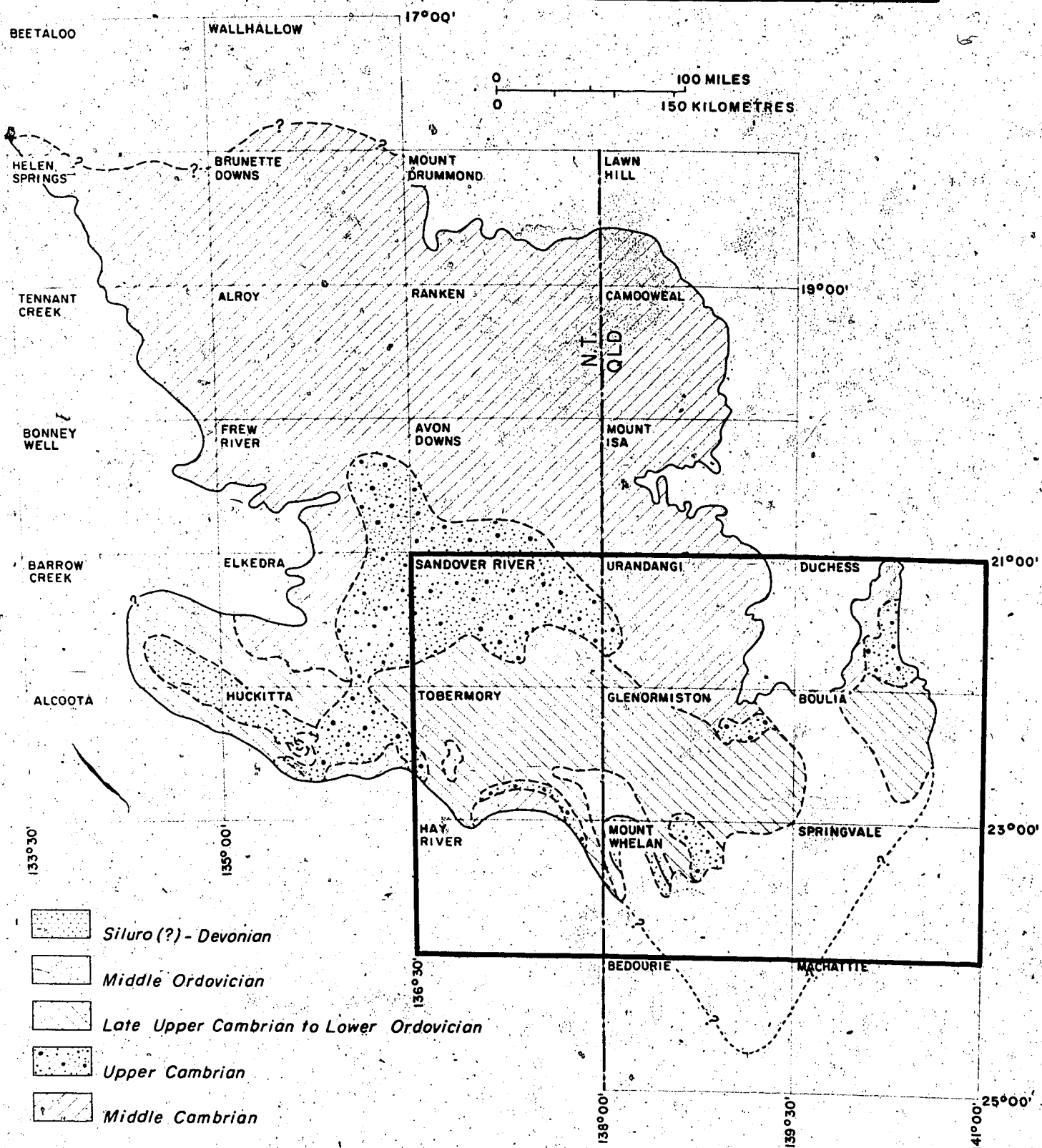
The Georgina Basin covers approximately 325 000 square kilometres in western Queensland and the Northern Territory.

Sedimentation was initiated in the basin in the early Middle Cambrian and continued intermittently through the middle Paleozoic. The sequence consists predominantly of Middle Cambrian to Middle Ordovician shelf sediments, carbonates in the north and east, and mixed carbonate and terrigenous rocks in the west (Figure 1).

Basement under the basin is an irregular surface of granitic ridge and depression topography, subdued by Upper Proterozoic to Lower Cambrian terrigenous sequences. The western limits of the basin are both erosional and tectonic contacts with the Precambrian Arunta Complex. To the east is the Precambrian Cloncurry Complex, and to the north, the Adelaidean South Nicholson Basin (Smith, 1972). Mesozoic basins overlap the Georgina Basin: the Carpentaria Basin to the northeast and the Eromanga Basin to the southeast.

In the southeastern region, the site of Ninmaroo sedimentation, the significant structural elements that influenced deposition and subsequent erosion have north-northwest trends (Figure 2). The easternmost element is the Burke River Structural Belt, a down-faulted block with confining faults that extend north into the Precambrian Cloncurry complex as major features. To the west lies a broad anticlinal swell, the Smoky Anticline, which is also a southern extension of the Mt. Isa orogen. The western side of the swell dips gently below the Toko Syncline (Figure 3), an asymmetric fold with a steep western limb that is in part overthrust from the west by a block of the Precambrian Arunta Complex. This syncline deepens to the south, plunging below the Mesozoic Eromanga Basin.

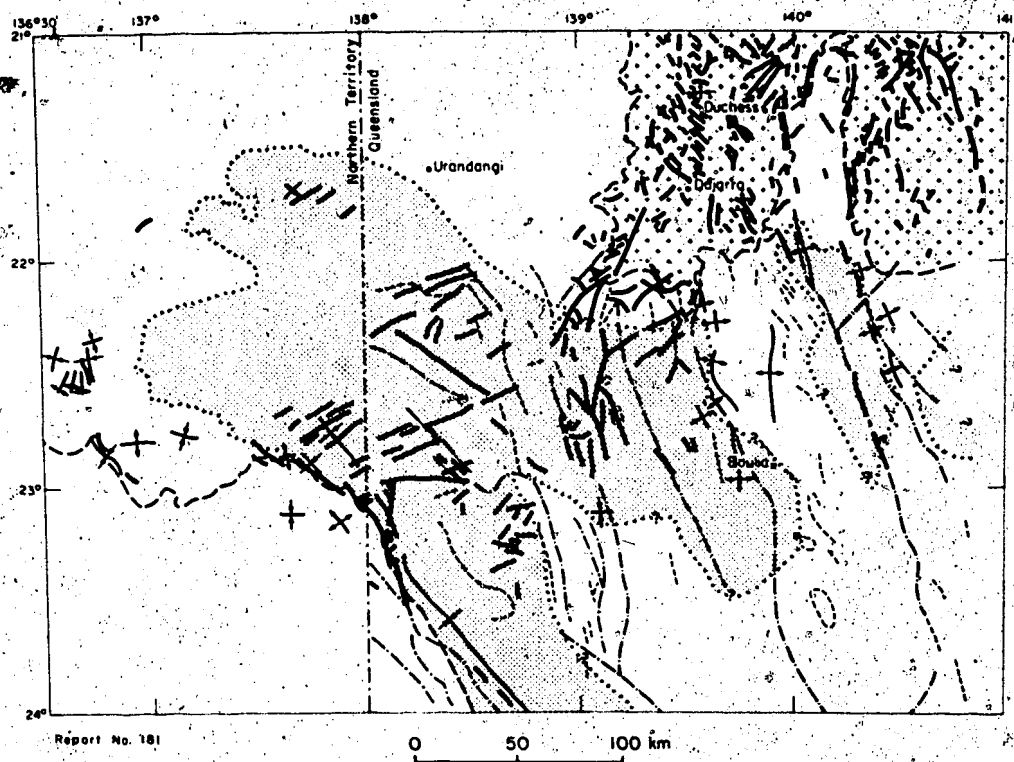
The Upper Cambrian - Lower Ordovician Ninmaroo Formation disconformably overlies in part, Upper Cambrian units, which generally are time transgressive eastwards. These resulted from normal shallow marine carbonate and terrigenous deposition. The Upper Cambrian Arrinthrunga Formation in the west is of comparable facies to the Ninmaroo Formation and it is possible that they are both of the same magnafacies, which has also been time transgressive eastwards. The Ninmaroo Formation was deposited during the Delamerian Orogeny (Webby, 1978) and lies between two unconformities of Late Cambrian and early Arenig age. These unconformities correlate approximately with the two major pulses of the Delamerian Orogenic activity in southern Australia (Webby, 1978).



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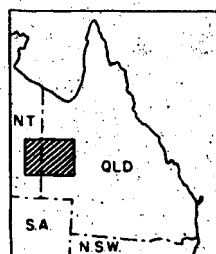
Figure 1 Location and Regional Geology of the Georgina Basin, Australia.

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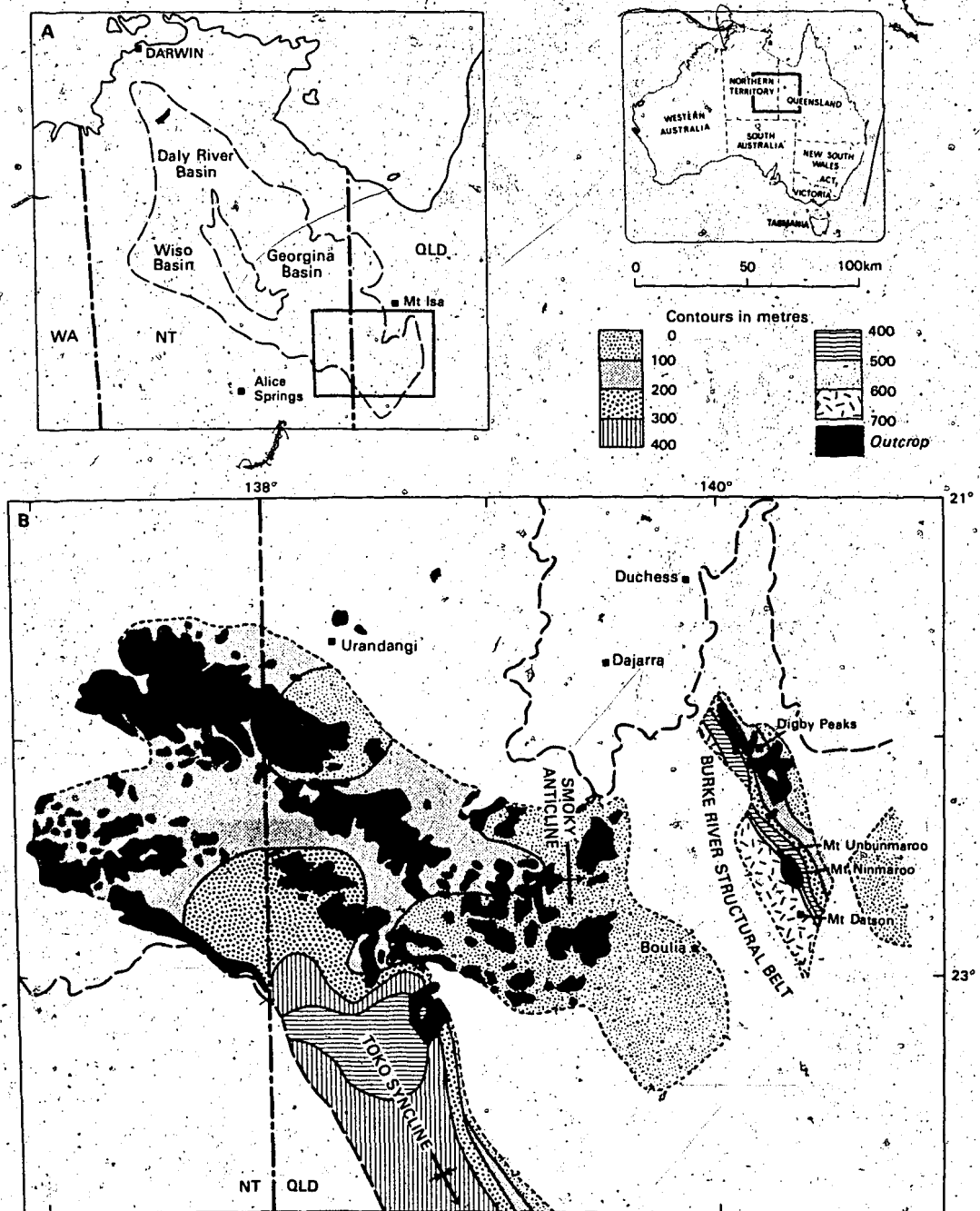
0 50 100 km



- Present extent of Palaeozoic units
- Extent of Ninmaroo Formation
- Surface faults
- Surface structures
- - - Basement faults (magnetic interpretation)
- - - Basement structures (magnetic interpretation)

Fig. 2 Structural trends within the extent of the Ninmaroo Formation

16/F54/2



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Figure 3 Extent, thickness and generalised structural provinces of the Ninmaroo Formation

16/F54/3

STRATIGRAPHY

The Ninmaroo Formation (Whitehouse, 1936; amended by Casey, 1959) consists of well-bedded bituminous limestone, limestone, sandy limestone, dolostone, calcareous sandstone, siltstone, and shale. The dominant carbonate rock types are peloid and ooid grainstone, cryptalgal boundstone and laminites, flat-pebble conglomerate, echinoderm grainstone, peloid and skeletal packstone, wackestone, and lime mudstone. These carbonate types are variably and repeatedly interbedded throughout the sequence.

Distribution

The formation extends over a large area of the eastern Georgina Basin, covering approximately 70 000 square kilometres of western Queensland and the Northern Territory (Figs. 1, 3), and is present on eight 1:250 000 Sheet areas; Boulia, Duchess, Glenormiston, Mount Whelan and Urandangi in Queensland; Hay River, Tobermory and Sandover River in the Northern Territory (Smith, 1972).

The most complete sections in surface exposures occur in the Burke River Structural Belt, where localities, including the type section at Mount Unbunmaroo (Fig. 3, 6a), have up to 950 m of continuous section on the western side of faulted domes. The western margin of this structural belt is down-faulted against a parallel block which separates it from a flat-lying region of dissected dolostones further west in the Smoky Anticline region. From here, the sequence dips gently southwest into the Toko Syncline. Dolostones and terrigenous rocks are dominant on the eastern side of this structure, while, on the western margin, thicker sequences of bituminous limestones, dolostones and terrigenous rocks are present. The subsurface extent of the Ninmaroo Formation remains speculative, because of the sparse drilling and seismic coverage compared to the abundance of basement structural features (Fig. 2) that have been delineated by geological mapping, LANDSAT imagery, and total magnetic intensity patterns. The easterly extent of the formation beyond the Burke River Structural Belt is the least known, as the Palaeozoic sequence plunges below the onlapping Mesozoic rocks of the Eromanga Basin.

Thickness

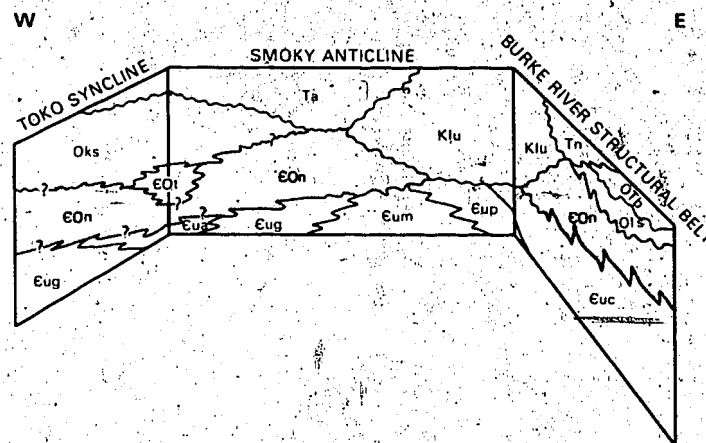
Thickness of the formation ranges from 40 to 1100? m. The two belts of maximum preserved sequence (Fig. 3) are the Burke River Structural Belt and the Toko Syncline. Between these regions the section is thinner, partly because of erosion. It is unlikely that the thickness of the sequence in the central region ever equalled that to the east and west.

Stratigraphic Relations

The Ninmaroo Formation is conformable over Middle and Upper Cambrian units in the western and eastern regions (Figs. 4, 5). In the central Smoky Anticline region, it is unconformable over the Middle and Upper Cambrian units (Reynolds & Pritchard, 1964; Reynolds, 1965; and Opik, 1963, 1967), but is apparently conformable in the Toko Syncline and the northwest, where it interfingers with the terrigenous Tomahawk Beds to the west. In the north of the Burke River Structural Belt, the formation lies disconformably over a karstified Chatsworth Limestone, but farther south this contact is diachronous and conformable. A significant disconformity defines the upper boundary of the Ninmaroo Formation (Fig. 4). In the Burke River Structural Belt the overlying Swift Formation is, in part, a regolith of accumulated chert and siliciclastic detritus (Fig. 6b) from subaerial weathering and karst development on the Ninmaroo Formation. Farther west, the terrigenous rocks of the Kelly Creek Formation overlie a karstified and dolomitised Ninmaroo surface with apparent disconformity. Where the Kelly Creek Formation has been subsequently eroded, Cretaceous, Tertiary, and Quaternary units overlie the formation unconformably (Fig. 7).

Age

The Ninmaroo Formation ranges in age from Payntonian (late Trempealeauan) to post-Warendian (early Canadian) (Jones & others, 1971; Shergold & others, 1976). The regional variations in age of the sequence are summarised in Figure 16.



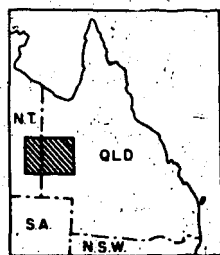
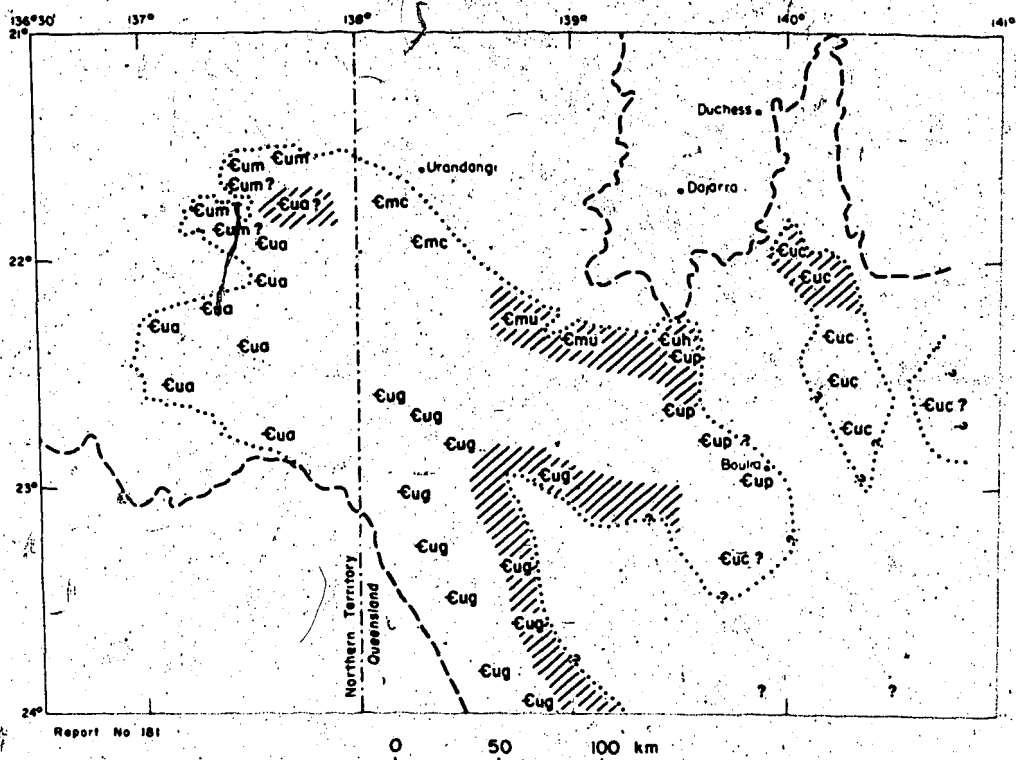
TERTIARY		Ta	Austral Downs Limestone
		Tn	Noranside Limestone
CRETACEOUS	Lower	Klu	Undifferentiated
ORDOVICIAN	? to Lower	Otb	Digby Peaks Breccia
		Ols	Swift Formation
	Lower	Oks	Kelly Creek Formation
CAMBRIAN	Lower O to Upper E	EOn	Ninmaroo Formation
		EOt	Tomahawk Beds
	Upper	Euc	Chatsworth Limestone
		Eup	Pomegranite Limestone
	Upper to Middle	Eua	Arrinthrunga Formation
		Eug	Georgina Limestone
		Eum	Mungerebar Limestone

(After Smith, 1972; Druce, Radke, Draper and Tucker, 1976; and Shergold, Druce, Radke and Draper, 1976)

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Figure 4 Stratigraphic Relationships of the Ninmaroo Formation

16/F54/4

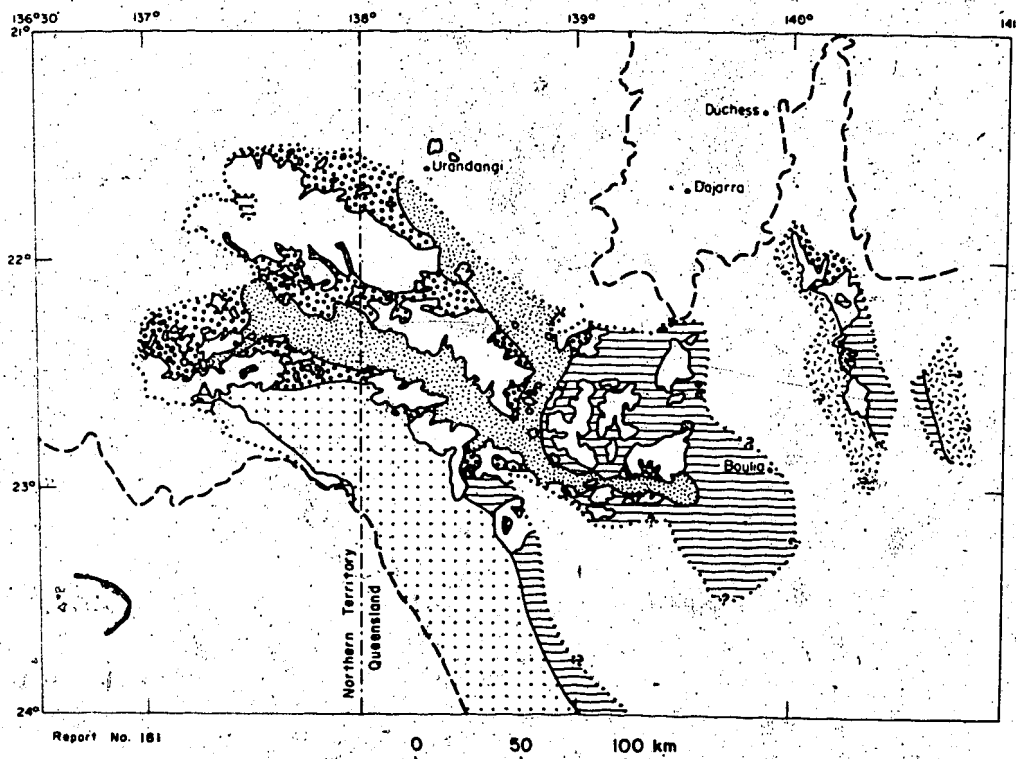


- Present extent of Palaeozoic units
- Extent of Ninmaroo Formation
- Conformable contact
- ▨ Unconformable contact

- €mc Camooweal Dolomite
- €mu Mungerebar Limestone
- €ua Arrinthrunga Formation
- €uc Chatsworth Limestone
- €ug Georgina Limestone
- €uh O'Hara Shale
- €um Meeta Beds
- €up Pomegranate Limestone

Figure 5 Map of the basal contact of the Ninmaroo Formation and the underlying lithostratigraphic units

16/F 54/5

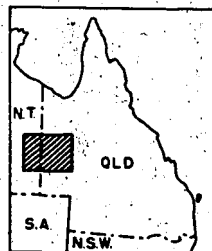


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0 50 100 km

--- Present extent of Palaeozoic units

..... Extent of Ninmaroo Formation



- QUATERNARY
- TERTIARY
- MESOZOIC
- ORDOVICIAN**
 - Swift Formation (regolith in part)
 - Kelly Creek Formation (disconformable in part)

Figure 7 Map of the lithostratigraphic units unconformably overlying the Ninmaroo Formation.

16/F 54/6

LITHOSTRATIGRAPHY

Formation subdivisions

In this report, the lithofacies are described and correlated throughout the extent of the formation. Six lithofacies are recognised, five being comparable to the informal members of earlier stratigraphic work in the Burke River Structural Belt. The remaining crystalline dolostone lithofacies is of diagenetic origin and not exclusively stratigraphically controlled.

In the Burke River Structural Belt, there were several previous schemes for the subdivision of the formation into members. These were proposed by Brown (1961), Casey, (1968), Jones & others (1971), Shergold & others (1976), and BMR (1976). The presently used nomenclature is defined in Appendix IV. Correlation between these previous schemes and the lithofacies subdivision is shown in Table 1.

As the two regions of exposure of the Ninmaroo Formation are separated by both a central area of dolostones and a belt of no exposure (Fig. 3), previous workers were unable to correlate members successfully between the two regions and, consequently, separate subdivisions of the formation were established in the broad western belt. Here, the Ninmaroo Formation was subdivided into four members, based on exposed sequences in the Glenormiston and Mount Whelan Sheet areas (Reynolds & Pritchard, 1964). The members are:

- 1) dolarenite, dolomitic sandstone and sandy dolostone;
- 2) stromatolitic micrite with oolite, grainstone, and breccia beds;
- 3) dolarenite and dolomitic quartz sandstone;
- 4) mottled and sandy micrite; grainstone, calcareous sandstone, stromatolitic beds.

Each of these members was documented from separate localities. The area has underlying basement highs (Wells & others, 1966) that were emergent before and after Ninmaroo deposition. The terrigenous rocks probably reflect only local influences of uplift and erosion of basement. On the western side of the Toko Syncline, the sequence has a greater carbonate component with lithofacies comparable to those in the Burke River Structural Belt. To the northwest, the Ninmaroo Formation has progressively more interbedded terrigenous rocks and an arbitrary boundary (Smith, 1972) separates the contiguous terrigenous Tomahawk Beds to the west.

TABLE I.

Subdivisions of the Ninmaroo Formation,
Burke River Structural Belt

Members				Lithofacies
Brown (1961); Casey (1968)	Jones, <u>et al.</u> (1971)	Shergold, <u>et al.</u> (1976)	Druce, <u>et al.</u> (1976)	(Radke, 1978)
6	Laminated Dolomite Member	5	Datson Member	VI _d II _{ps}
5	Encrinite	4	Corrie Member	Io IV _s IV _{scp}
4	Breccia Member	3	Mort Member	Io III _c
3	Variegated Limestone/ Dolomite Member	2	Jiggamore Member	II _p
2		1	Unbunmaroo Member	VI _d Io
1				

Lithofacies concept

Six lithofacies are recognised in the Ninmaroo Formation, five carbonate and one terrigenous (Figure 8). One carbonate lithofacies, comprising crystalline dolostones, is of diagenetic origin and consequently is not always stratigraphically controlled. This lithofacies consists only of dolostones which have had primary sedimentary textures obliterated. Dolostones with sedimentary textures preserved are classified into the other five lithofacies.

The formation consists of a sequence of monotonously repetitive rock types, but, on a larger scale, lithic associations and generalised trends are evident.

Each lithofacies comprises several rock types, but is characterised by one. The repeated associations of rock types are identified as components of sedimentary cycles. A single lithofacies may contain up to three types of sedimentary cycles (Figure 9).

Rock Types

This section describes, in order of increasing complexity, rock types, sedimentary cycles, and lithofacies. Rock types which may be common to several lithofacies, will be described individually and then related in the description of sedimentary cycles. The larger scale patterns of lithic associations will be discussed in the description of lithofacies.

The spatial distribution of the lithofacies is shown in Figure 8. In the Burke River Structural Belt, it is comparable with the distribution of the mapped informal lithostratigraphic members (BMR, 1976).

Cryptalgal carbonate

Structures resulting from sediment-binding or carbonate-precipitating activities of blue-green algae have been termed cryptalgal (Aitken, 1967), and may be either laminated types termed stromatolites (Kalkowsky, 1908) or non-laminated types termed thrombolites (Aitken, 1967).

Body geometry is used to differentiate cryptalgal bodies. Two categories are used, the bioherm and biostrome as defined by Cummings (1932), and distinguished by an upper limit of the breadth to height ratio of 30:1 for the bioherm (Nelson & others, 1962). Growth structures are classified on morphology to include both stromatolite and thrombolite, regardless of the degree of preservation of internal fabric. During formation, both types may

Biostratigraphic Units

POST WARENDIAN (ARENIGIAN)	07
WARENDIAN (W)	06
WARENDIAN (W)	05
WARENDIAN (W)	04
WARENDIAN (W)	03
WARENDIAN (W)	02
WARENDIAN (W)	01
DATSONIAN (D)	01
PAVTONIAN	LCp
	LC

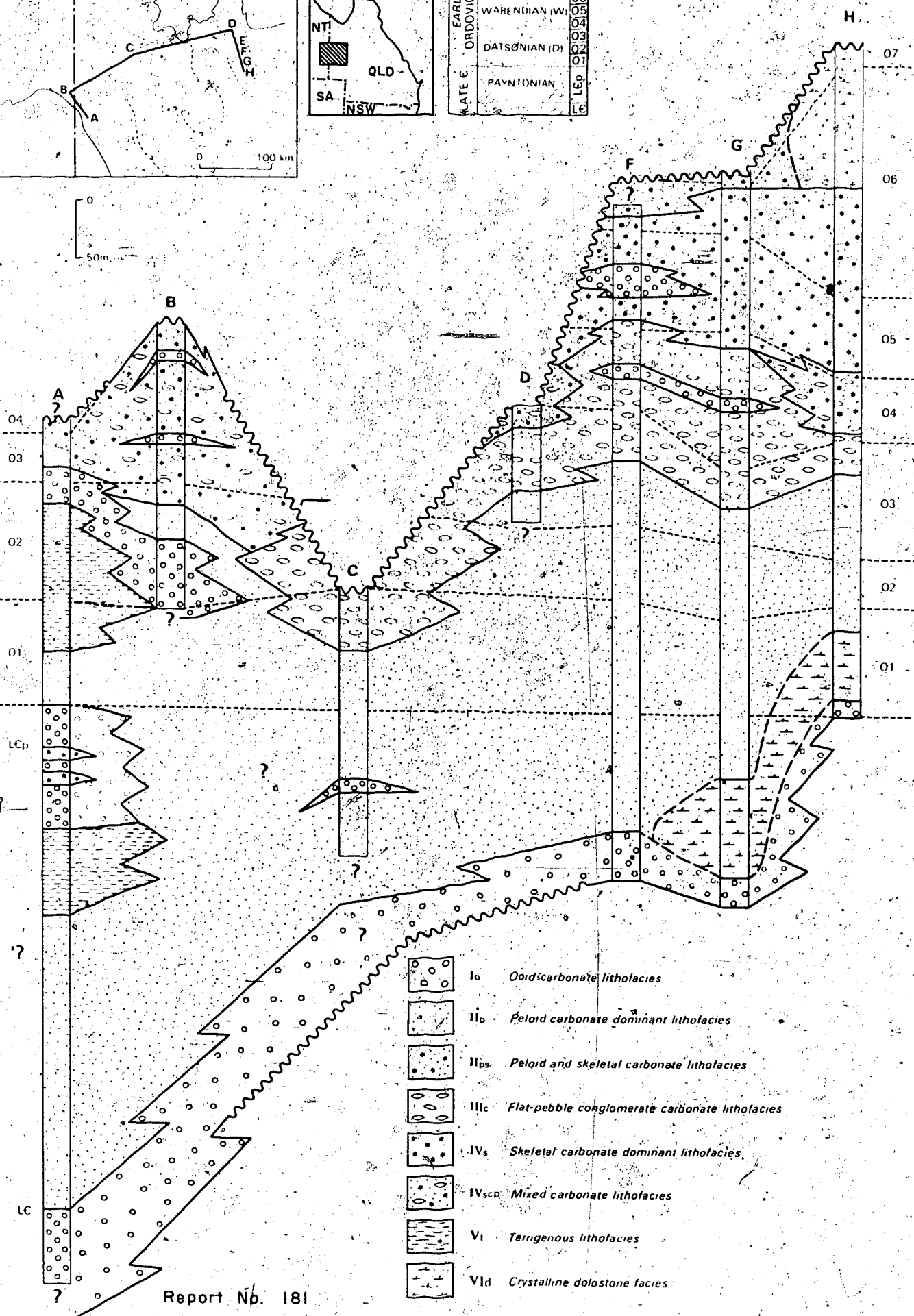
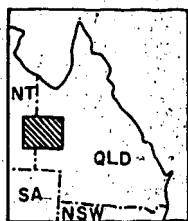
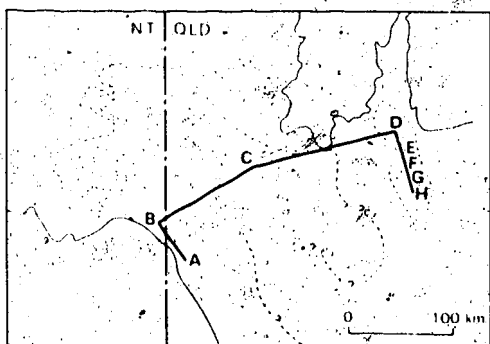
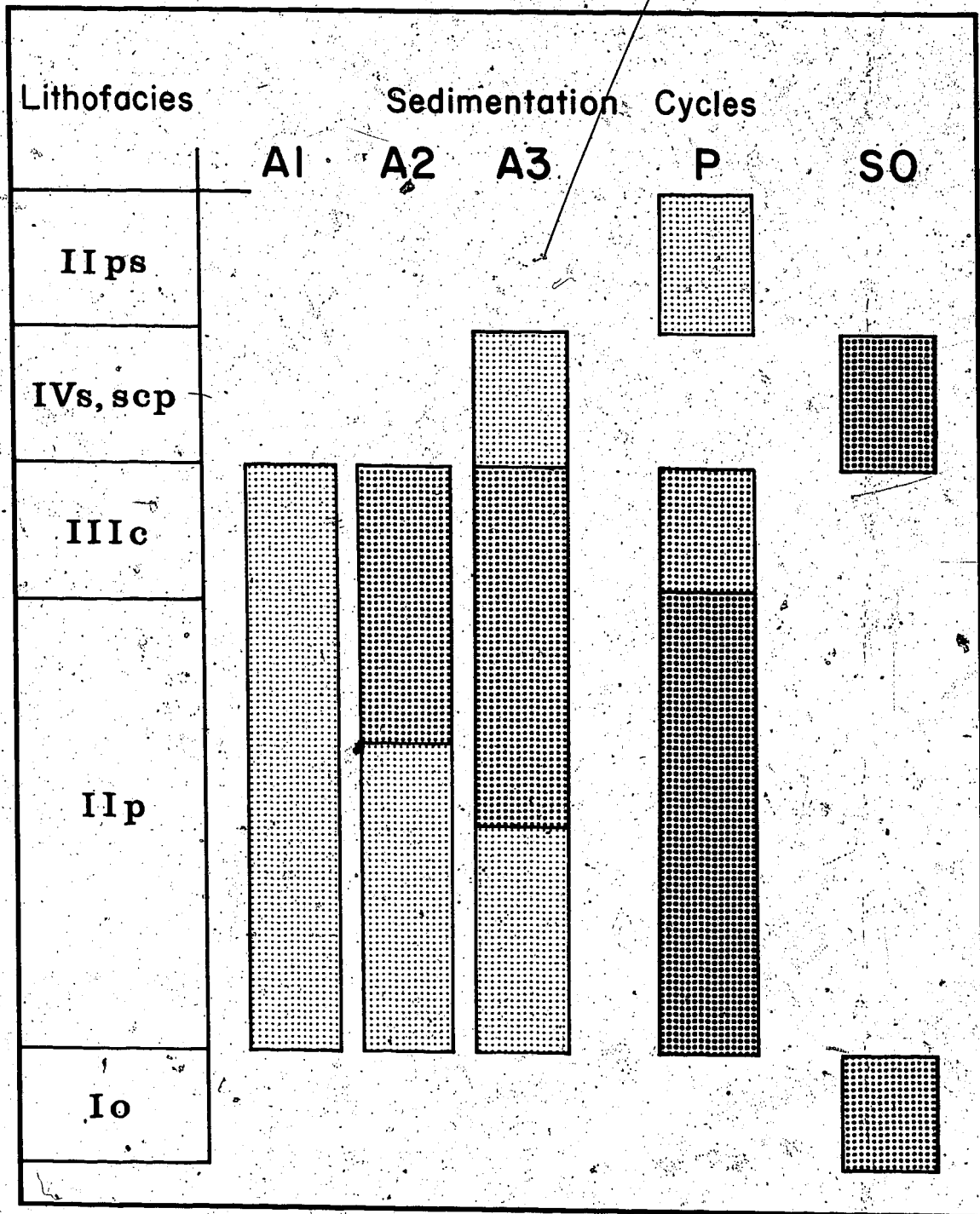


Figure 8 Stratigraphic relationships between the Ninmaroo lithofacies and biostratigraphic units



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Figure 9 Occurrence of sedimentary cycles in the lithofacies of the Ninmaroo Formation, Burke River Structural Belt.

16/F54/8

have been laminated, but such features may have been modified or obliterated by organic or diagenetic processes. Growth forms comprise mound structures, oncolites, and planar layers. Mound types form biostromes where they are closely grouped and extensive laterally. More commonly they occur as bioherms comprising smaller groups or individual mounds.

Fenestrae (Tebbutt & others, 1965) are formed by the interaction of algal mats, the sediment, and diagenetic processes, such as desiccation, oxidation, lithification (Logan & others, 1974) and the displacive growth of evaporite minerals. The descriptive classification used for fenestral fabrics is that of Logan (1974). This distinguishes three fabric patterns: laminoid (Tebbutt & others, 1965), irregular, and tubular, each of which are further subdivided on average void size (Table II).

Cryptalgal bodies are common in the Ninmaroo Formation, especially in the Smoky Anticline region, where they are the most conspicuous if not dominant rock type.

Mounds

Mound structures are of several types and are distinguished by surface relief and morphology. These are columnar, close-crinkled, open-crinkled, or smooth mounds. Stratiform layers have either smooth or crinkled surfaces, but will be discussed collectively as laminites.

Columnar mounds: Columnar mound bioherms are discrete domed bodies up to 2 metres high, within thick beds of cross-stratified peloid-intraclast, or ooid grainstones. The mounds are circular to oblong in plan, 2-3 m wide, 4-6 m long, and have an apparent relief of 1-2 m. They occur singly or in closely-spaced circular groups up to 11 m across. Each mound comprises a group of smooth, circular columns, 0.4-0.8 m diameter, up to 2 m high, and, when closely packed, the columns are polygonal in outline (Figure 6c). Some columns are slightly arcuate in section, curving into the centre of the bioherm at the top. Undercut re-entrant cavities may be present on one side of the bases of some columns (Fig. 6d).

Internally, the columns are zoned, having a peripheral rim of homogeneous to mottled light grey micrite, which grades into a central core of fenestrate boundstone with mudstone and wackestone texture, crudely layered with irregular, pseudocolumnar, gently convex laminae (Figure 6e). Fine to medium laminoid fenestrae enhance lamination, and medium to coarse irregular fenestrae show outlines of gypsum crystal clusters. Intact ribeirioids, straight nautiloids, and fragments of trilobites are incorporated in this boundstone.

TABLE II

Classification of Fenestral Fabrics
(after Logan, 1974, p. 214)

Type	Void Size	Coarse	Medium	Fine
laminoid	av. ht. (mm)	5	1-5	1
	av. length	10-30	10-30	5-30
irregular	av. ht. (mm)	5	1-5	1
	av. length	5-10	1-5	1
tubular	av. diam. (mm)	5	1-5	1

A cryptalgal boundstone fills the intercolumnar spaces in some mounds and encrusts a scalloped to cusped erosional surface on the micrite rims of the columns. This boundstone is darker, bituminous, and mottled with peloid-intraclast grainstone, packstone, and wackestone fabrics, which contain a sparse but distinctive fauna of nautiloids, trilobites, ribeirioids, and brachiopods. Where zonation is absent in the columns, the fabric is mottled and thrombolitic, enhanced by selective dolomitisation of the mottling.

The bioherms overlie an indurated pavement of cross-stratified peloid-intraclast grainstone. Similar cross-stratified coarse grainstone beds abut and drape over the mounds. These beds are moderately bioturbated and dolomitised (Fig. 6c).

Close-crinkled mounds: Close-crinkled mounds are subspherical to domed bioherms, 0.1-1 m high, and from 0.4 m wide and 0.8 m long up to 2 metres diameter. The subspherical forms, which are commonly oblong, are most probably oriented perpendicular to local strandlines. The mounds have an apparent relief of 0.04-1 m, but most commonly about 0.5 m.

The bioherms have a crenulate surface (Fig. 10a) like the Cryptozoon form of Logan (1961), with internal closely-packed branched and unbranched columns that have low to highly convex lamination. This lamination is defined by distinct colour alternations. Fine laminoid fenestrae are uncommon. In the subspherical forms component columns have a radial pattern. In the central zone, columns are erect with symmetrical lamination. Peripherally, columns are inclined with asymmetrical lamination, which indicates geotropism or phototropism (Fig. 10b).

Generally, evidence of bioturbation and of a fauna is absent, except in the oriented mounds, where straight nautiloids and disarticulated plates of chitons may be present.

Substrates are indurated and eroded surfaces on imbricate flat-pebble conglomerate, ooid peloid grainstone, or cryptalgalaminites. Adjacent lithologies are dominantly cross-stratified ooid, peloid, or intraclast grainstone, imbricate conglomerate, peloid wackestone or mudstone. Layers of solution-collapse breccia with distinct but irregular lower contacts commonly occur along the tops of the bioherms where mudstones are overlying. Evaporite nodules, sulphate crystal moulds, and erosional unconformities with cusped or irregular surfaces (Fig. 11d) are common within the bioherms.

Open-crinkled mounds: Open-crinkled surfaces are present on bioherms of domed, subspherical, and bulbous shape, as well as biostromes of slightly domed to tabular form. Bioherms are typically 0.02-0.5 m high, 0.2-2 m in diameter (commonly 0.5 metres), and have a relief of 0.01 to 0.5 m.

The characteristic open-crinkled surface of these bodies results from small columns that are 1-2 cm diameter and spaced one diameter apart (Fig. 10c). The intercolumnar spaces are filled with trapped detrital sediment, bound into flat cryptalgalaminites. Columns are oriented subparallel or radiate with respect to a central growth axis of the body. Individual columns may be branched, anastomosing, or straight with connecting bridges. Where columns are not continuous throughout the extent of the body, they start and terminate within discrete growth horizons that imply periodic fluctuations in the growth environment.

The columns generally have irregular outlines with a discernible peripheral zone, which may be either homogeneous micrite or a skeletal encrustation zone that has variable thickness and density of encrustation. These are thicker on the undersides of irregularities on the surface of the columns. The encrustation comprises small porcellaneous brown pustules (Fig. 10d) that are of probable foraminiferal or algal origin. Column centres consist of either a bioturbated mottled fabric or a poorly laminated fabric with a planar or slightly domed nature. Lamination is indistinct, because of irregular and gradational textural variations, but may be enhanced in patches by the presence of fine laminoid fenestrae.

Most but not all open-crinkled bodies have relatively abundant accumulations of bound or attached faunal elements compared to other cryptalgal types. The fauna comprises ribeirioids, brachiopods, straight nautiloids, disarticulated trilobites, chitons, and ostracodes.

The substrate is commonly indurated, consisting of cross-stratified peloid or intraclast grainstones and, less commonly, mudstone. The adjacent and overlying rocks are dominated by edgewise conglomerate, peloid-intraclast grainstone, or rare breccia in fenestrate mudstone and wackestone. Sulphate crystal moulds, preserved as irregular fenestrae, are ubiquitous. Pseudomorphs of sulphate nodules and collapse breccias may be present.

Repeated erosional surfaces within the mounds are common. Where extreme erosional scour has reduced mounds to a mere indurated rim, calyx structures of Logan & others, (1974), there are modified 'microatoll' forms with a central core of cryptalgalaminites (Fig. 10e).

Smooth mounds: Domed and bulbous bioherms with smooth surfaces may accumulate up to 0.3 m thick, with 0.1 m relief. The relief generally varies with that of the substrate surface. Where the bioherms are closely spaced, they may collectively form biostromes.

The smooth surface results from uniform lamination contouring the shape of the underlying structure in concentric layers. The presence of smooth surfaces on a variety of forms implies underlying templates of differing origin. These templates may be of any other cryptalgal body type, but close-crinkled and open-crinkled forms are the most common substrates. These may have been directly covered in the smooth mat, or may have been initially indurated and/or eroded. Additionally, imbricate and edgewise conglomerates also occur as substrates.

Laminites

Laminites occur as extensive stratiform sheets (Fig. 10f). They have very low relief and biostromes are 0.03-3 m thick.

The basic unit, the lamina, results from the interplay of sedimentation and algal mat activity. At one extreme, its origin may be entirely sedimentary, and at the other, an algal or inorganic precipitate. Between these extremes, a spectrum of combined sedimentation, algal binding, algal textural modification, as well as carbonate precipitation exists. Often the origin of a lamina is conjectural without diagnostic evidence of algae or, in contrast, traction current features.

Laminae range from 1 to 33 mm thick. Thin laminae are usually of one colour and texture, recognisable by distinct textural differences with contiguous sediment. Thicker laminae have discernible zonation with a thicker basal zone above a sharp or indistinct basal contact, gradational with a thin upper micritic rind.

The basal zone is relatively light coloured, comprising fine-grained peloid grainstone, which fines upward to muddier textures. The zone may have either a vermiform fabric of fine tubular fenestrae or of laminoid fenestrae with outlines of single or clustered gypsum crystals (Fig. 11a). The upper rind is darker, finer-grained, commonly bituminous, and is either homogeneous or has alternating dark and light layers of olive grey-green, grey, or grey-brown tones. Individual laminae vary from being planar and of uniform thickness (Fig. 11b) to mildly undulose with uneven thickness when overlying an undulose substrate.

Substrates to the sheets are commonly indurated and vary from coarse pelmatozoan grainstone to bioturbated packstone and mudstone. Shrinkage cracks (Fig. 11c), indurated crusts, and eroded surfaces with overlying flat-pebble and grapestone-lag deposits may be present within the sheets. Tops of sheets are commonly erosional surfaces overlain by coarse skeletal grainstone, ooid, intraclast, and peloid grainstone or peloid packstone.

Oncolites

Oncolites (Pia, 1933; Logan & others, 1964) are asymmetrical subspherical bodies of 3 millimetres to 1 centimetre diameter, light coloured, with large grapestone nuclei and a thin, irregular, outer concentric laminar zone of variable thickness. Individual laminae are indistinctly defined bands of micrite.

They occur in rare stratiform sheets, 0.2 m thick, that have gradational lower contacts with underlying ooid intraclast grainstones.

The biostrome consists of oncolite ooid grainstone and is texturally moderately sorted.

Peloid Carbonate

This rock type is commonly thin to medium-bedded, but can be laminated or thick-bedded. Peloid carbonate is the dominant rock type in the Nimmaroo Formation and characteristically occurs in the upper parts of sedimentary cycles. Grainstone textures (Fig. 11e) are dominant and grade up into less abundant packstone, wackestone, and mudstone. Peloid carbonates with boundstone fabric predominate in cryptalgal structures.

Peloid carbonates comprise peloids, with subsidiary skeletal particles, ooids, intraclasts, and variable amounts of mud. Cross-laminated peloid grainstone commonly contains quartzose and feldspathic sand. Peloids (McKee & Gutschick, 1969) are of three types:

- 1) small rounded lath-shaped particles, 100 μ m diameter and 150 μ m long, probably of faecal origin (Bathurst, 1975; and Friedman & Sanders, 1978);
- 2) rounded micritised particles of skeletal, intraclast, aggregate, or ooid origin (Fig. 11e);
- 3) irregularly shaped micritic particles of 100-800 μ m diameter, with angular indented outlines produced by growth of sulphate crystals.

Skeletal particles comprise sand-sized pieces of echinoderms, ostracodes, and gastropods, as well as minor trilobite, ribeirioid, and brachiopod fragments, and sponge spicules. Ooids and sand-sized aggregate lumps are usually spherical. Intraclasts are rounded sand to granule-sized, spherical to tabular grains of peloid grainstone and packstone, which may have micritised rims and are thus gradational with peloids.

The carbonates are commonly either cross-laminated or laminated with fenestrae, and have shrinkage cracks, bioturbation or overprints of crystal and nodular sulphates.

Laminar, fine-grained peloid carbonates characteristically have thin dolomite or yellow dedolomite laminae, which impart a characteristic striped appearance to the rocks.

Pebble-conglomerate carbonates

Of the intraclast carbonates, pebble conglomerate is distinguished from the finer-grained intraclast carbonate (Fig. 11f). Pebble-conglomerate carbonate occurs in the bases of sedimentary cycles, forming thin beds or constituting the bases of thicker, internally graded beds. Two types of conglomerate carbonate are distinguished, the abundant flat-pebble conglomerate and the less common round-pebble conglomerate.

Flat-pebble conglomerate: This is a grainstone, less commonly a packstone, with pebble-sized, disc-shaped intraclasts as the dominant framework element. Pebbles may form an open framework enclosed by a finer matrix of granule to sand-sized peloids, intraclasts, ooids or skeletal grains. The pebbles are of rounded tabular shapes (Fig. 12a) that may be slightly arcuate or cusped in cross-section, and range from granules to pebbles 60 mm long and 5 mm thick. Larger cobble-sized intraclasts are not as well-rounded or as abundant. Pebble elongation normally parallels the lamination of the host lithology, which is fine-grained peloid grainstone, cross-laminated silty to sandy grainstone, ooid grainstone, or cryptalgalaminites. The conglomerates are predominantly monomictic, with the constituent pebbles being the same as the underlying substrate. Locally, pebbles may have irregular cryptalgal encrustations.

The fabric of the conglomerates is varied, even within a single bed. Low-angle imbrication of the pebbles is common in well-sorted unimodal sediments, and large-scale stratification may be associated with these imbrication fabrics.

Where sand-sized particles are a significant component of the conglomerate, the tabular clasts parallel the bedding lamination. Edgewise fabrics (Fig. 12d) occur where there is relief on the substrate surface resulting from holes or crevices or from cryptalgal mounds. With edgewise fabrics, the clasts are inclined at a steep angle to bedding, and are wedged with a matrix of smaller particles. Edgewise stacking may be extensive vertically (Fig. 12d), although clast orientations vary from horizon to horizon.

Beds of flat-pebble conglomerate range from extensive sheets to small lenses with gradational contacts. These bodies normally overlies planar to irregular erosional surfaces on indurated substrates of fine sandy grainstone,

peloid grainstone and wackestone, ooid and intraclast grainstone, cryptalgal mounds and laminites, and lime mudstone. Eroded surfaces may recur within the conglomerate, but are only obvious at sharp changes of fabric and texture (Fig. 12b).

An almost ubiquitous feature is the presence of mesoscopic solution-modified vugs that either conform to the undersides of horizontal pebbles, or occur within the matrix at points of contact between pebbles. Some vugs have geometrical shapes suggestive of large crystal moulds. These are filled with coarsely crystalline white saddle dolomite, opaque red, orange, or yellow calcite, purple fluorite, or bitumen.

Round-pebble conglomerate: This is a minor constituent compared to flat-pebble conglomerate and is characterised by more spherical and equant pebbles, which may be slightly deformed from depositional compaction. Round pebbles are smaller than flat pebbles, having diameters of 10 mm or less and rarely exceeding 30 mm (Fig. 12c). They are composed of lime mudstone or laminated fine peloid grainstone and packstone, usually the same lithology as the underlying substrate.

Other intraclast carbonates

Of minor, less conspicuous occurrence compared to pebble conglomerate, are intraclast-peloid carbonates, which are medium to thin-bedded or very thick where they abut and drape over cryptalgal mounds. They are commonly stratified or cross-stratified grainstones, that may be gradational with coarse peloid grainstone, minor packstone and wackestone.

Intraclast-peloid grainstone consists of sand to granule-sized intraclasts and peloids with variable amounts of ooids, aggregate lumps, and skeletal particles (Nuia, echinoderm, trilobite, brachiopod, chiton and ostracode fragments, unidentified fragments, and nautiloids).

Intraclasts are equant to lath-shaped fragments of peloid or skeletal grainstone and wackestone, commonly with cryptocrystalline rims of variable thickness. Some intraclasts have cusped or rounded outlines with angular geometric embayments (Fig. 11f) and overall varied complex shapes. These grains are modified and reworked lithologies overprinted with reticulate fabrics of sulphate crystals. Additionally, some intraclast grainstones also have an expanded appearance with large pores, fewer grain-grain contacts, and some flattened grain margins, resulting from displacive inter-particle growth of sulphate crystals.

Ooid carbonate

Ooid carbonates are thin to very thick-bedded, commonly cross-stratified, grainstone composed of ooids, sand to pebble-sized intraclasts, skeletal fragments (echinoderm plates, trilobite and mollusc fragments, and Girvanella clasts), minor peloids, quartzose sand, and aggregate lumps of peloid grainstone.

Ooids are mostly simple, but also superficial or minor compound forms. Simple ooids are spherical to oblong with thick coronas of concentric regular laminae and variably developed radial fabric. Frequently the outer rim is altered to cryptocrystalline calcite (Fig. 12e). Nuclei are small and usually consist of fine sand grains. Superficial ooids have thin coronas of regular concentric laminae or irregular crypto-crystalline coatings over well-rounded intraclasts of fine grainstones. Bulbous to elongate compound ooids incorporate smaller simple or superficial ooids.

Ooid grainstones are commonly cross-stratified (Fig. 12f) or planar-stratified, and are in places associated with cryptalgal mounds or laminites. Depositional fabrics are modified by displacive growth of sulphate crystals.

Oomoldic porosity has two expressions. One is in a variegated dark - light striped or mottled fabric (Rees & others, 1976) that follows lamination and bioturbation (Fig. 13a). The dark patches have traces of bitumen filling moldic or collapsed ooids, and the lighter bands, which are yellowish orange on weathered surfaces, consist of dedolomite after ferroan dolomite that selectively replaced ooids. The second type is in stratiform breccias resulting from collapse of crystal mould and oomoldic porosity.

Ooid carbonates are commonly dolomitised and silicified, the original ooid fabrics being preserved in the chert nodules and laminae.

Skeletal carbonate

Skeletal carbonate is a dominant and conspicuous rock type in the upper part of the formation; elsewhere, it is minor. Skeletal elements include echinoderm, trilobite, brachiopod, ribeirioid, gastropod, nautiloid, chiton, and ostracode fragments, and sponge spicules.

Echinoderm grainstone termed 'encrinite' by previous workers, is thick bedded, cross-stratified to structureless, consisting of sand to granule-sized echinoderm plates and abraded fragments with syntaxial cement overgrowths (Fig. 13c). Broken surfaces of this rock appear coarsely crystalline because fracture occurs along boundaries of the large syntaxial calcite crystals. The grainstone contains varying amounts of trilobite hash, sponge spicule fragments, brachiopods, ribeirioids and nautiloids, as well as peloids, ooids, and flat pebbles.

Spiculite grainstone occurs characteristically in carbonates preserved as thin chert beds, sometimes cross-stratified, and comprising well-sorted siliceous sponge spicules, 0.4 to 1.5 mm long and 50 μ m diameter, with minor amounts of trilobite fragments, echinoderm platelets, and uncommon nautiloids. Spicules are only preserved in layers or nodules of chert.

Mixed skeletal carbonates are thick to thin-bedded grainstone, packstone, and wackestone with varying amounts of trilobite, echinoderm, brachiopod, ribeirioid, gastropod, nautiloid, and chiton fragments, as well as peloids, flat pebbles, intraclasts or ooids. Trilobites are the most conspicuous elements. Mollusc and brachiopod components are commonly broken and abraded.

Ostracodes are commonly the sole skeletal element in many medium to thick-bedded limestones. Ostracode elements may be complete, dis-articulated valves, or hash, commonly occurring in a matrix of mud or pellets.

Lime mudstone

Lime mudstone is abundant only in the lower part of the formation in thin to thick beds. It occurs in the upper parts of sedimentary cycles with gradational lower contacts and eroded upper surfaces. Lime mudstone may contain ostracode fragments, is commonly bioturbated (Fig. 13d) and has variable abundance of shrinkage cracks (Fig. 13e) and pseudomorphs after anhydrite nodules. Evidence for an originally plastic coherent nature is the distorted vertical shrinkage cracks (Fig. 13e) and smooth undulose erosional surfaces.

Pervasive fine-grained dolomitisation is common. Surface exposures may have a yellowish colour from dedolomitisation and oxidation of the ferroan dolomite. This coloration emphasises bioturbation or laminar fabrics and has previously been described as 'two-toned' (Brown, 1961; Casey, 1968; Jones & others, 1971).

Impure carbonates

In outcrop, impure carbonate beds which constitute 35 percent or more of the sequence, form recessive units, 0.3-3 m thick. These limestone and dolostone beds have a terrigenous component of fine sand, silt, or clay, which is commonly less than 30 percent of the rock. Silty carbonates are dominant, with angular quartz and feldspar detrital grains incorporated in fine peloid or flat-pebble limestones.

The contacts between impure and more resistant cleaner carbonates are both gradational and abrupt.

Sandstones

Quartz arenite constitutes a minor component of the sequence, although impure carbonates are very common.

Bimodal sandstone: This forms thin beds defined by a sparse basal lag conglomerate of angular flat intraclasts, that are of the same composition as the substrate. This lag conglomerate grades upward into thin, low-angle, cross-stratified sets of sandstone, 20-60 mm thick, with broad slightly trough-shaped erosional bases. At the top of some beds is a thin set of climbing ripple laminations. These sandstones, which weather dark brown with a friable and porous texture, have bimodal sorting of fine and coarse sand grains of quartz and feldspar. The coarse component is spherical, well-rounded, with frosted surfaces and, in some occurrences, thin ferruginous coatings. There is an absence of bioturbation.

The sandstones overlies indurated and eroded dolostone and chert, that have preserved shrinkage cracks and features of sulphate overprint. Bimodal sandstones are not common and are found only in the central Smoky Anticline region.

Fine-grained sandstone: This sandstone occurs in thin to thick beds with sets of both planar and moderately-angled cross-strata. The sandstone is white, light yellow to dark brown, and commonly friable, with some cementation by calcite, dolomite or silica. It is a well-sorted grainstone, comprising subangular fine and very fine sand grains of quartz and feldspar, as well as peloids, minor flat pebbles and glauconitic peloids. Bioturbation may be present.

Sedimentary cycles

A sedimentary cycle is a sequence of related processes and conditions that produces a sedimentary deposit of various rock types that may occur in a particular order. These cyclic deposits may occur repeatedly in a lithofacies. Such deposits are termed sedimentary cycles. These units are bounded by basal and upper erosional surfaces which separate repeated lithological patterns.

The Ninmaroo Formation contains both carbonate and incompletely exposed terrigenous sedimentary cycles.

Cycles are present throughout most of the formation except the uppermost part, where little can be discerned through dolomitisation and silicification of the section. 38 cycles of sedimentation have been recognised in the type section. There are three types of cyclic deposits, named by the dominant rock type; Type A - cryptalgal carbonate cycles, Type P - peloid carbonate cycles, and Type SO - skeletal-oid carbonate cycles.

Type A - Cryptalgal carbonate cycles

Three sub-types of cryptalgal cycles are distinguished by the presence of different cryptalgal morphologies: Type A1 - cryptalgal domes, Type A2 - cryptalgal domes and laminites, and Type A3 - cryptalgalaminites.

Type A1 cryptalgal carbonate cycle. This cycle (Fig. 14) contains in ascending order:

- 1) imbricated flat-pebble conglomerate with an ooid, peloid, or skeletal matrix;
- 2) bioherms or biostromes of cryptalgal domes with a sparse fauna of nautiloids, trilobites, ribeirioids, and chitons;
- 3) adjacent and overlying edgewise flat-pebble conglomerate, grading up to
- 4) cross-stratified intraclast-peloid grainstone and lightly bioturbated packstone.

This unit forms sheets and probable lenses, 1-3 m thick, bounded between an abrupt erosional surface, which is usually irregular to cusate, developed on basal indurated grainstones and cryptalgal domes. The upper contact is also an irregular erosional surface.

There are variations on this generalised sequence.

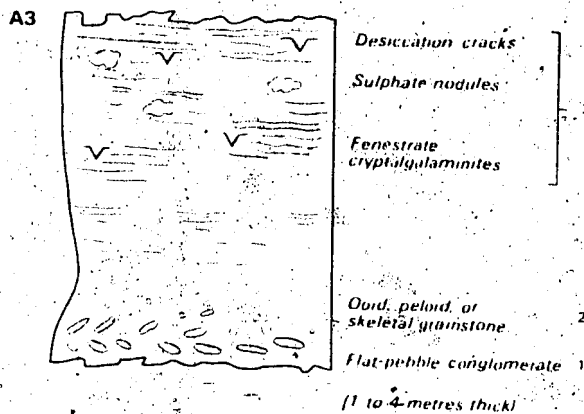
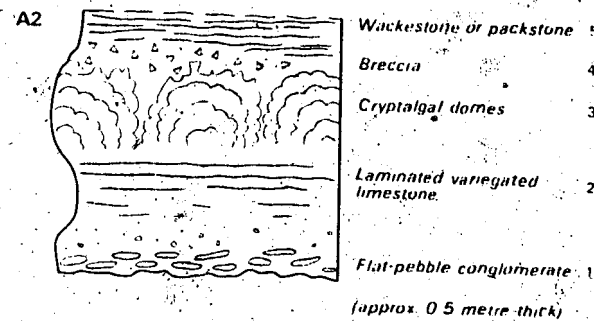
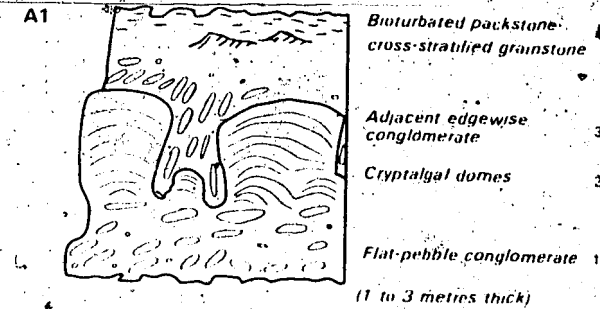
1. The basal contact may have considerable relief from eroded and indurated cryptalgal mounds.
2. Cryptalgal mound development may be directly on the basal indurated surface, and be selective of high areas such as older eroded mounds.
3. Sediments adjacent to the domes may be fine-grained intraclast, peloid, ooid, or skeletal grainstones.
4. Solution-collapse breccias may occur within the cryptalgal lithologies

Type A2 cryptalgal carbonate cycle. This cycle (Fig. 14) contains in ascending order:

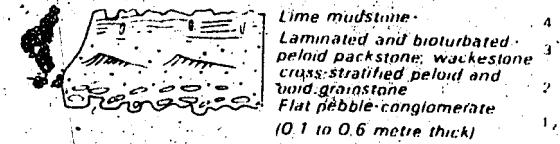
- 1) basal intraclast flat-conglomerate and ooid-intraclast grainstone, grading up to
- 2) laminated muddy wackestone or packstone which may be cryptalgalaminite,
- 3) bioherms or biostromes of cryptalgal domes with adjacent lime mudstone,
- 4) irregular collapse breccia layers on top of the domes,
- 5) homogeneous or laminated lime mudstone.

This cycle forms sheets, 0.5 metres thick, which are defined by a clearly defined erosional base and either an erosional or gradational upper contact.

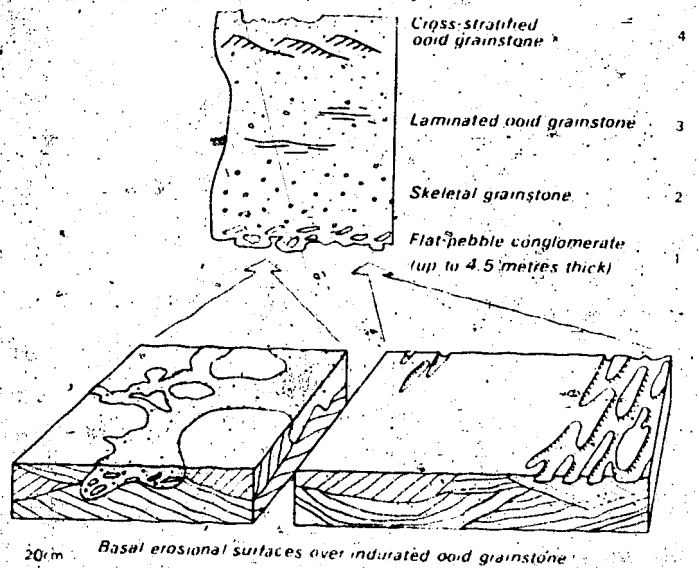
Type A Cryptalgal carbonate cycles



Type P Peloid carbonate cycle



Type SO Skeletal-ooid carbonate cycle



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Figure 14 Type A (cryptalgal), P and SO carbonate cycles.

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Variations within this cycle include the following.

1. The basal grainstone and fining-upwards horizon may be absent, with cryptalgalaminites overlying the basal erosional surface.
2. The collapse breccia is variable in thickness and may be absent.
3. Pseudomorphs after sulphate nodules may occur within the cryptalgal domes.

Type A3 cryptalgal carbonate cycle. This cycle (Fig. 14) contains in ascending order:

- 1) basal flat-pebble conglomerate which is gradational up to
- 2) ooid, peloid, and minor skeletal grainstone;
- 3) cryptalgalaminites comprising peloid limestone with fenestral fabrics, shrinkage cracks, chert nodules, and pseudomorphs after sulphate nodules and crystals.

This cycle forms sheets 1-4 m thick, with gradational or distinct basal erosional contacts that may not always be exposed. The upper contact is distinct basal erosional contacts that may not always be exposed. The upper contact is distinct and planar.

The following are variations within this cyclic unit.

1. The basal conglomerate may be absent.
2. Fenestral and sulphate overprints are variable.
3. Tubular fenestrae are present in some horizons.
4. Indurated and eroded crusts recur in the laminites.
5. There is a cyclicity in the fenestral fabrics.
6. Calcrete cements and replacement zones commonly coincide with the indurated horizons.

Type P - Peloid Carbonate Cycle

Peloid carbonate cycle (Fig. 14) contains in ascending order:

- 1) imbricated pebble conglomerate with intraclast and peloid matrix;
- 2) cross-stratified peloid and ooid grainstone - with thinner sets towards the top and gradational with
- 3) laminated packstone and wackestone;
- 4) lime mudstone with minor bioturbation and a homogeneous upper rind.

This cyclic unit occurs as sheets and lenses, 0.1-0.6 m thick, defined by distinct, irregular erosional surfaces at the base and top. The basal contact may overlie a firm ground, or indurated substrate.

Modifications to this generalised cyclic unit include the following.

1. The lag deposit consists of either a flat-pebble or round-pebble conglomerate.

2. This basal conglomerate may be absent.
3. Fine terrigenous sand may be abundant in the grainstones.
4. The upper packstone, wackestone, and lime mudstone may be absent.

Type SO - Skeletal-oid carbonate cycle

This cycle (Fig. 14) contains in ascending order:

- 1) a skeletal-intraclast grainstone, grading up to
- 2) planar-laminated ooid grainstone;
- 3) cross-stratified ooid grainstone.

This unit forms extensive sheets up to 4.5 m thick, defined by distinct basal contacts that are planar or irregular with relief of up to 0.2 m. Irregular depressions commonly have large blocks of underlying rock types (Fig. 14). Lower relief of about 50 mm may be in the form of unidirectional anastomosing rills (Figs. 14, 15a) with smooth depressions. The upper contact is similar, though not always exposed.

Variations within the unit include:

- 1) an absence of pebbles in the basal skeletal grainstone;
- 2) minor bioturbation in the planar-laminated grainstone;
- 3) a dominance of skeletal grainstone in the thinner units;
- 4) a variable terrigenous sand content of the ooid grainstone;
- 5) dolomitisation of the central and upper zones.

Lithofacies

The lithofacies are:

- | | |
|-------|--|
| Io | Ooid carbonate lithofacies; |
| II | Peloid carbonate lithofacies, consisting of two kinds; |
| IIp | Peloid carbonate dominant lithofacies; |
| IIps | Peloid and skeletal carbonate lithofacies; |
| IIIc | Flat-pebble conglomerate carbonate lithofacies; |
| IV | Skeletal carbonate lithofacies, consisting of two kinds; |
| IVs | Skeletal carbonate dominant lithofacies; |
| IVscp | Mixed carbonate lithofacies; |
| Vt | Terrigenous lithofacies; and |
| VId | Crystalline dolostone lithofacies. |

I. Ooid carbonate lithofacies

Description. This lithofacies consists of cross-stratified ooid grainstone, peloid grainstone, minor flat-pebble conglomerate, echinoderm grainstone, and, locally, large columnar thrombolitic bioherms (Figs. 6c, 6d). Interbedded cross-stratified sandy carbonate and sandstone may be abundant locally. Cross-stratification is common in the facies, with individual sets up to one metre thick, trough-shaped erosional bases, and moderately-angled internal stratification. A thin lag deposit of skeletal detritus may cover the base of the troughs and herringbone cross-lamination may be present. Locally, centimetre-sized vugs with quartzine linings form pseudomorphs after sulphate nodules.

The grainstones vary from ooid to mixed ooid-peloid and peloid grainstone, with a locally variable terrigenous sand content. Skeletal fragment grainstone comprises echinoderm, trilobite, minor brachiopod, ribeirioid, and nautiloid fragments. These may be gradational or are interbedded with the ooid grainstone.

This lithofacies is commonly dolomitised, and is gradational with massive crystalline dolostone (Facies VIId). Quartzine-rich chert is locally associated with this dolostone and dedolomite which have a characteristic yellowish-orange colour.

Stratigraphic distribution and variations. This lithofacies is exposed as massive scarp-forming beds, and forms an extensive unit up to 60 m thick, defining the base of the formation in both the Burke River Structural Belt and the Toko Syncline. In this occurrence it is gradational with the overlying lithofacies IIp, commonly with an increase of skeletal limestone content.

In the Smoky Anticline region, lithofacies I is completely dolomitised, and recognised only by the original fabrics preserved in chert nodules. The stratigraphic position of the lithofacies in this region is not clear. Thinner bodies, from less than 10 m to 40 m thick, recur within lithofacies IIp, and, in the Toko Syncline, these bodies overlie lithofacies Vt, which is also enclosed within lithofacies IIp. Thin stratiform bodies less than 10 m thick, are enclosed in the larger bodies of lithofacies IIIc and IVs, where SO cycles have a dominant sandy ooid grainstone component.

II. Peloid carbonate lithofacies

This lithofacies is subdivided into two groups, a peloid carbonate dominant lithofacies, and a peloid and skeletal carbonate lithofacies. The subdivision is based on the diversity of subordinate carbonate types.

IIp. Peloid carbonate dominant lithofacies

Description. Sedimentary cycles are the basic components of this lithofacies, each consisting of a range of carbonate rock types with interbedded, poorly exposed, impure carbonates and possible sandstone, siltstone and shale. The cycles are of type A1, A2, A3 (each containing cryptalgal carbonates), and type P, cyclic peloid carbonate units described in Figure 14. Type P cycles are dominant and some have channel-shaped basal erosional surfaces (Fig. 13f). Type A2 cycles are unique to this lithofacies.

The carbonates of these cycles are peloid grainstone, packstone, wackestone, flat-pebble and round-pebble conglomerate, intraclast and skeletal carbonates, fenestrate cryptalgalaminite biostromes, domed cryptalgal bioherms, and lime mudstone. The bioherms have open-crinkled, close-crinkled, and, less commonly, smooth surfaces.

Skeletal elements are not commonly a dominant component of the carbonates, although the contributing fauna was diverse. Trilobites, ellesmeroceroid nautiloids, ribeirioids, brachiopods, chitons, and gastropods are commonly associated with cryptalgal bodies. One gastropod, Ceratopea, is unique to this lithofacies. Other fossils include blastoids and undifferentiated echinoderms, ostracodes, ichnofossils, calcareous sponges from the base of the lithofacies, and in places, detritus of calcareous algae such as Nuia.

Pseudomorphs of sulphate nodules and sulphate crystals are ubiquitous, and are associated with minor occurrences of thin stratiform collapse breccias. Striped coloration of the limestones, called 'two-tone', is common in the finer-grained and more bituminous limestones. Lamination, bioturbation, and fracturing are enhanced with secondary pink, yellow, or orange tones produced by selective dolomitisation and dedolomitisation. Some skeletal-rich laminae are partially or totally silicified and chert nodules are common.

Stratigraphic distribution and variations. Lithofacies IIp is dominant in the lower part of the sequence, gradational over the basal ooid lithofacies (Io) and interfingering with contiguous lithofacies. In the Burke River Structural Belt it varies from 30 to 340 m thick, and the upper part has a well-developed 'two-tone' appearance. In the Toko Syncline, the lithofacies may be as thick as 510 m with enclosed bodies of lithofacies Io, IVs, and VIId. In the central Smoky Anticline region, type A1 cycles are common, forming prominent and extensive strata.

IIps. Peloid and skeletal carbonate lithofacies

Description. This facies characteristically comprises thin beds of fine-grained peloid grainstone and packstone interbedded with laminae of coarse skeletal grainstone, minor cryptalgal limestone and siltstone. The skeletal grainstone contains dis-articulated trilobites, siliceous sponge spicules, brachiopods, minor bellerophontid gastropods, hyolithids, and calcareous algae. The base of the lithofacies is delineated in places by a prominent bed of skeletal mudstone with trilobites, echinoderms, nautiloids, bryozoans, sponges, and brachiopods. This bed grades up through packstone into skeletal grainstone with large-scale sets of festoon cross-strata up to one metre thick.

Locally, the lithofacies is completely dolomitised and is gradational with crystalline dolostone (Facies VIId). Skeletal horizons are invariably silicified, and chert laminae commonly preserve bioturbation structures and skeletal outlines, including siliceous sponge spicules. Where the lithofacies is totally dolomitised, sedimentary fabrics may only be discernible within the chert.

Stratigraphic distribution and variations. Lithofacies IIps is known only in the Burke River Structural Belt. Brown (1961) records thickness variations from 21 to 260 m. Locally it intertongues with the underlying lithofacies IVs. A regolith of pre-Cretaceous age, the Swift Formation, overlies the lithofacies with unconformity.

IIIc Flat-pebble conglomerate carbonate lithofacies

Description. This lithofacies consists of carbonate cycles alternating with sandy carbonates and minor fine-grained sandstone.

The carbonate cycles are of type P and A with thin to medium beds dominated by flat-pebble conglomerate, lesser amounts of peloid, ooid, skeletal grainstone/minor packstone, cryptalgal limestone, and lime mudstone. Type P cycles generally vary from the idealised form (Fig. 14) in having thicker layers of basal conglomerate and an absence of the upper muddy carbonates. Instead, tops of cycles are terminated by cross-laminated fine grainstone, bioturbated in places, with overlying planar to irregular erosional surfaces.

The minor skeletal-fragment carbonates contain elements of cystoids and undifferentiated echinoderms, trilobites, ostracodes, brachiopods, and gastropods. Ellesmeroceroid nautiloids, ribeirioids, trilobites, and calcareous algae are associated with cryptalgal mounds, which have either close-crinkled or open-crinkled surfaces.

Flat-pebble conglomerate is generally characterised by conspicuous solution vugs on the undersides of clasts, infilled by saddle dolomite or opaque red to orange calcites, clear calcite, fluorite and bitumen. Thin ooid limestone beds are commonly pervasively dolomitised and dedolomitised.

Stratigraphic distribution and variations. Lithofacies IIIc is recognised only in the Burke River Structural Belt and in the central Smoky Anticline region, where type A1 cycles are abundant. In the Burke River Structural Belt, the lithofacies is lens-shaped in north-south section (Fig. 10), thickest at Mount Unbunmaroo (130 m) and thinning to 40 m at Mount Datson in the south, and 60 m at Digby Peaks in the north. In the Smoky Anticline region, only 50 m is preserved in outcrop at the top of the exposed section.

Lithofacies IIIc overlies and interfingers with lithofacies IIp and grades laterally as well as upwards into lithofacies IVscp with an increasing abundance of skeletal carbonate, or into lithofacies IVs with an additional abrupt decrease of flat-pebble conglomerate.

In the Mount Nimmaroo and Mount Unbunmaroo area, a thin lens of lithofacies Io lies within lithofacies IIIc.

IV. Skeletal carbonate lithofacies

This lithofacies is subdivided into two groups: IVs, a skeletal carbonate dominant lithofacies; and IVscp, a mixed skeletal-pebble conglomerate-peloid carbonate lithofacies.

IVs. Skeletal carbonate dominant lithofacies

Description. Lithofacies IVs comprises structureless skeletal carbonate with lesser amounts of peloid, flat-pebble, cryptalgal, and boid carbonates, and cross-stratified sandy carbonates.

Type S skeletal carbonate cycles and type A3 cryptalgal carbonate cycles are present, the type S containing mainly echinoderm and ooid grainstone. Type A3 cycles, though of minor occurrence, are well-developed and contain conspicuous fenestrate or fenestrate-laminated limestone (Fig. 11a) with repeated indurated and eroded surfaces (Fig. 15d). Type S0 cycles have basal erosional contacts of irregular relief (Figs. 14, 15a).

Skeletal limestones are dominant, forming prominent thick beds of white echinoderm grainstone with a coarsely crystalline appearance and faint cross-stratification. Minor skeletal components, which also form separate, thinner beds, are brachiopod, ostracode, trilobite, ribeirioid, sponge spicule, and rare nautiloid fragments.

Peloid-oid grainstone is commonly sandy and gradational to fine sandy grainstone, with thin cross-sets and herringbone cross-lamination. These limestones are commonly dolomitised, porous, and friable. Echinoderm limestone is locally dolomitised and can be gradational with crystalline dolostone (Facies VI_d). Silicification is both selective of skeletal fragments, and more extensive as laminae or chert nodules within crystalline dolostone.

Stratigraphic distribution and variations. Lithofacies IV_s occurs in the upper part of the formation in the Burke River Structural Belt, being thickest at Mount Datson (170 m) and thinning 90 m at Mount Unbunmaroo.

Lithofacies IV_s interfingers with and overlies lithofacies III_c (flat-pebble conglomerate carbonate) and IV_{scp} (mixed skeletal-pebble conglomerate-peloid carbonate) as well as being laterally gradational with IV_{scp}. The lithofacies grades up into lithofacies II_p. Lithofacies I_o occurs as a 30 m-thick lens within this lithofacies at Mount Unbunmaroo.

At Mount Unbunmaroo, dolomitisation is minimal, but becomes more extensive to the south, where it is gradational with crystalline dolostone (lithofacies VI_d) at Mount Datson. In the Toko Syncline, only thin lenses of lithofacies IV_s, less than 10 m, occur within thick units of lithofacies I_o (Fig. 8).

IV_{scp}. Mixed skeletal-pebble conglomerate-peloid carbonate lithofacies

Description. Lithofacies IV_{scp} consists of carbonates and impure carbonates, the carbonates being skeletal, flat-pebble conglomerate, and peloid grainstones with minor ooid and cryptalgal carbonate. Type A, type P, and type S-O cycles are present.

This lithofacies is associated with lithofacies IV_s (skeletal carbonate dominant) in having a similar dominance of echinoderm elements in the skeletal grainstone, but also has similarities with lithofacies II_p (peloid carbonate dominant) and III_c (flat-pebble conglomerate carbonate).

Lithofacies IV_{scp} is heterogeneous, with horizons that are dominant in one lithologic type, but with gradational variations. It has been impractical to separate these into smaller units of lithofacies II_p, III_c and IV_s.

Additional to the dominant echinoderm grainstone, other skeletal carbonates comprise brachiopod, trilobite, ostracode, ribeirioid and nautiloid elements. Locally the limestone may be dolomitised.

Stratigraphic distribution and variations. Lithofacies IVp occurs in the Burke River Structural Belt at Mount Datson (50 m) and at Digby Peaks (15 m), where it is truncated by an unconformity, the upper boundary of the formation. In the Toko Syncline this lithofacies has an increased proportion of impure carbonates. Here, it reaches 150 m, but is again truncated by the upper unconformity. Lenses of lithofacies Io, of various thickness, are enclosed in this lithofacies (Fig. 8).

Vt. Terrigenous lithofacies

Description. Lithofacies Vt comprises poorly exposed, thin-bedded sandstone interbedded with recessive rock types, which do not crop out, but are assumed to be calcareous siltstone or very fine-grained sandstone. Exposed flaggy sandstone is light coloured with dark reddish-brown weathered surfaces, and well-sorted, and consists of fine to very fine sand-sized quartz, feldspar, and minor glauconite. Planar lamination is common, occurring with cross-lamination.

The sandstone has minor megaquartz cement and variable intergranular porosity, resulting from surface leaching of calcite cement.

Stratigraphic distribution and variations. This lithofacies occurs in the Toko Syncline, with a probable thickness of 130 metres, overlying lithofacies IIp, and overlain by lithofacies Io. In the Smoky Anticline region, this facies is not represented in the figured section (Fig. 8), but significant occurrences have been reported south of this section line (Reynolds & Pritchard, 1964).

VId. Crystalline dolostone lithofacies

Description. This facies incorporates crystalline dolostones lacking relict sedimentary features. Stratification and other large-scale sedimentary structures may be evident from differential weathering or crystal size variations, but, commonly, fracturing and karst morphology obliterate these features. In places, extremely pock-marked vuggy surfaces occur in weathered dolostone.

The dolostone is light coloured, orange, yellow or white, and comprises centrimicron to millimetre-sized subhedral to euhedral crystals of dolomite, minor interstitial subhedral calcite and finely disseminated pyrite. Terrigenous components have a variable abundance. Millimetre-sized dolomite crystals are commonly the saddle dolomite variety.

Where silicified layers are interbedded with the dolostone beds, primary features may be preserved in the chert. Silicification is apparently selective of particular rock types and, therefore, it is improbable that the chert laminae are representative of adjacent interlaminated dolostones.

Stratigraphic distribution and variations. In the Burke Structural Belt, this lithofacies is gradational with other lithofacies and is prevalent at the base of the formation at Mount Ninmaroo and Mount Datson adjacent to faulting, as well as the uppermost 130 m of section at Mount Datson. Many areas have dolomitised beds, but, commonly, sufficient features are preserved for identification of original limestone textures. Fig. 8 shows the extent of lithofacies VI_d and its cross-cutting relationships with other lithofacies.

Regional synthesis

Introduction

With such a diversity of lithofacies, an understanding of spatial relationships between them during sedimentation is important. To illustrate the regional configuration of lithofacies during sedimentation, the formation is considered in a chronostratigraphic framework (Fig. 16). The chronostratigraphic units of Jones & others, (1971) are used. The Late Cambrian Payntonian is informally subdivided to further refine sedimentation patterns during that time.

The crystalline dolostone lithofacies, a post-depositional diagenetic overprint, is removed and pre-existing sedimentary lithofacies are extrapolated into areas of this overprint.

Lithofacies in Time

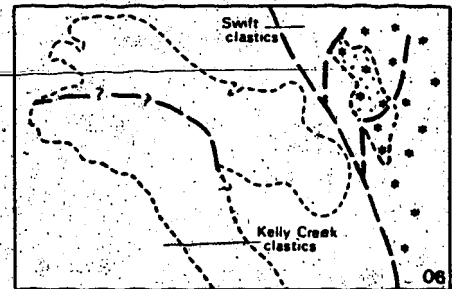
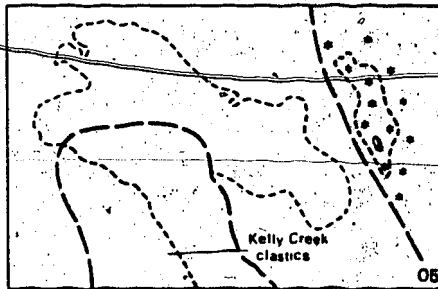
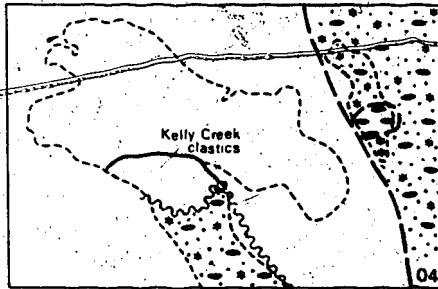
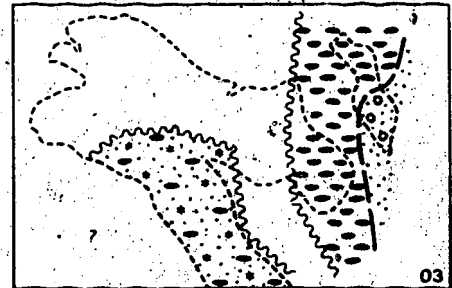
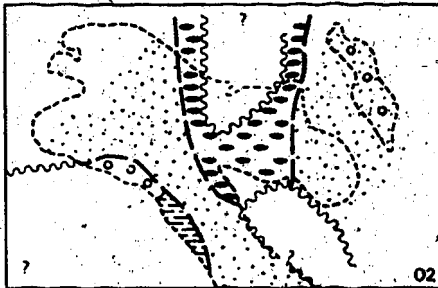
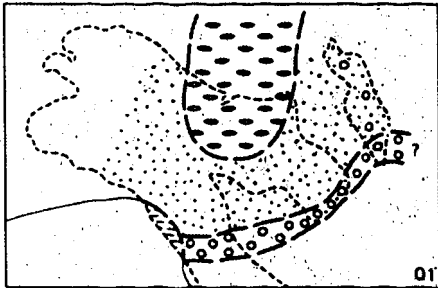
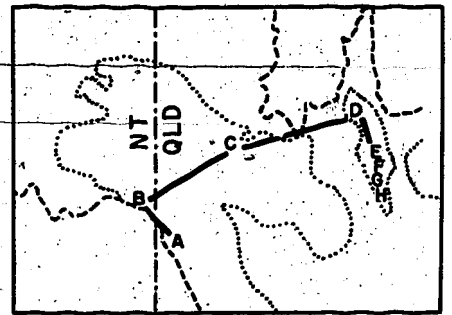
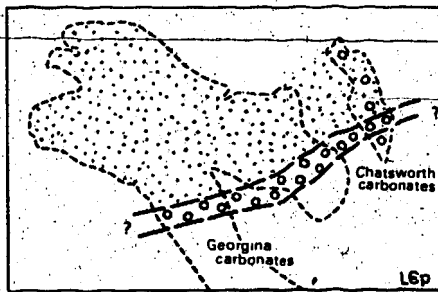
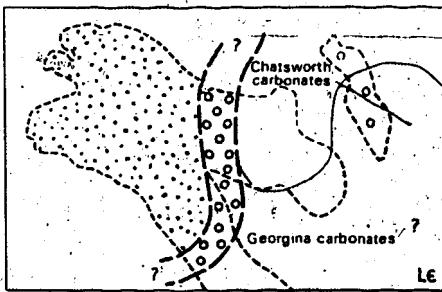
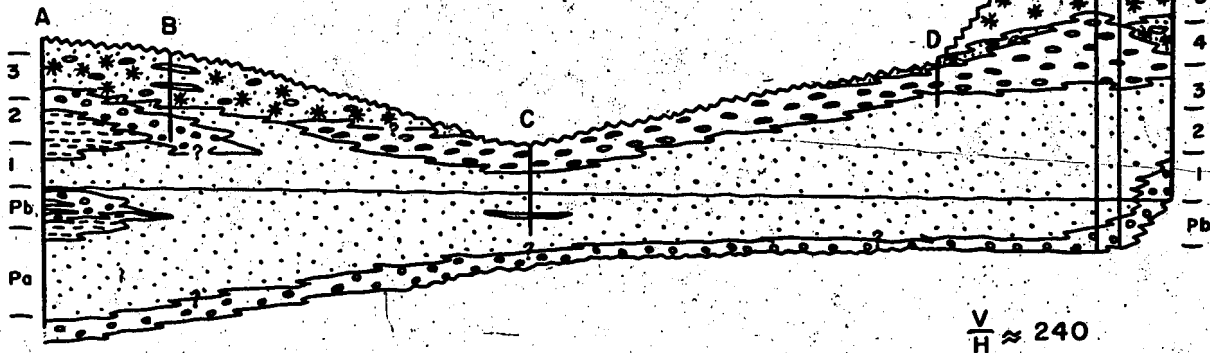
Ninmaroo sedimentation (Fig. 16b) was initiated ~~in the Late Cambrian~~ with a general eastward and southeastward migration of the ooid carbonate lithofacies (I_o) from the northwestern region. This basal lithofacies was conformable on, and interfingered with contiguous rocks of the Georgina Limestone in the Toko Syncline and the Chatsworth Limestone in the Burke River Structural Belt, delineating a progradational offlap in these two areas. It is probable that this lithofacies was also the basal unit of a depositional onlap over the Smoky Anticline region and the northern end of the Burke River Structural Belt (Fig. 5) which were both previously emergent.

WEST

EAST
BURKE RIVER STRUCTURAL BELT

TOKO SYNCLINE

SMOKY ANTICLINE



Biostratigraphic Units

EARLY ORDOVICIAN	POST WARENDIAN (ARENIGIAN)	07
	WARENDIAN (W)	06
		05
	DATSONIAN (D)	04
		03
LATE C	PAYNTONIAN	02
		01
		L6p
		L6



I₀



II_p



II_{ps}



III_c



IV_s



IV_{acp}



V_t



Emergent



Marine to semiemergent



Erosion

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Figure 16 Ninmaroo sedimentation in time

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By Early Datsonian time (01), the ooid carbonate lithofacies (Io) had prograded south, with sedimentation of the peloid-carbonate-dominant lithofacies (IIp) being established over the western region (Fig. 16b). The central Smoky Anticline area that was emergent prior to Ninmaroo sedimentation, again became intermittently emergent with deposition of the flat-pebble conglomerate carbonate lithofacies (IIIc), and totally emergent again by 02 time. As the extent of emergence in the northern Smoky Anticline area increased, lithofacies IIIc extended east into the northern part of the Burke River Structural Belt and west into the Toko Syncline region, where sedimentation of lithofacies Io, IIp, and Vt (terrigenous lithofacies) had prevailed earlier. By 03 time, a transgression in the Toko Syncline enabled deposition of the mixed carbonate lithofacies (IVscp). By 04 time, a response in sedimentation to this now regional transgression also occurred in the Burke River Structural Belt, except in the Mount Ninmaroo-Mount Unbunmaroo area, where lithofacies IIIc deposition continued under intermittent emergence. Ninmaroo sedimentation in the western Toko Syncline region at this time slowly receded south in response to increased terrigenous sedimentation of the Kelly Creek Formation to the north. By 05 time, Ninmaroo sedimentation was only within the Burke River Structural Belt. Deposition of the skeletal carbonate lithofacies (IVs) under these conditions produced a progradational offlap. Deposition of lithofacies IIps began in the north of the Burke River Structural Belt and prograded south over lithofacies IVs. By 06 time, this lithofacies IIps dominated Ninmaroo sedimentation which continued into 07 time.

CONCLUSIONS

1. The Ninmaroo Formation comprises bituminous limestone, limestone, sandy limestone, dolostone, calcareous sandstone, siltstone, and minor shale.

Dominant carbonate types are peloid and ooid grainstone, cryptalgal boundstone and laminites, flat-pebble conglomerate, echinoderm grainstone, peloid and skeletal packstone, wackestone, and lime mudstone.

Dolostone is mostly a secondary rock type after limestone and it commonly lacks pre-existing sedimentary textures.

2. The formation overlies the Upper Cambrian Chatsworth Limestone in the Burke River Structural Belt, conformably in the south, but with unconformity in the north. Over the Smoky Anticline area it unconformably overlies the

Middle Cambrian Camooweal Dolomite and Mungerebar Limestone in the north, while to the south its contact with the Upper Cambrian Georgina Limestone is apparently unconformable. This relationship becomes conformable into the Toko Syncline region. Further west, the contact with the Upper Cambrian Arrinthrunga Formation is complicated by faulting. It is inferred to be an unconformity. In this area, the Ninmaroo Formation interfingers westwards with the Tomahawk Beds.

In the central Toko Syncline area, the formation apparently interfingers with and is overlain by the Kelly Creek Formation. Elsewhere, the upper contact is an erosional surface. The Ninmaroo Formation is exposed west of the Smoky Anticline and north of the Toko Syncline.

In the Burke River Structural Belt, the formation is overlain by the Swift Formation - in part a regolith of pre-Cretaceous age. The Cretaceous Rolling Downs Group overlies the Ninmaroo Formation over part of the Smoky Anticline and further east, where it is not overlain by the Swift Formation.

3. Six lithofacies are recognised in the Ninmaroo Formation:

- Io Ooid carbonate lithofacies;
- II Peloid carbonate lithofacies, consisting of two kinds;
- IIp Peloid carbonate dominant lithofacies;
- IIps Peloid and skeletal carbonate lithofacies;
- IIIc Flat-pebble conglomerate carbonate lithofacies;
- IV Skeletal carbonate lithofacies, consisting of two kinds;
- IVs Skeletal carbonate dominant lithofacies;
- IVscp Mixed carbonate lithofacies;
- Vt Terrigenous lithofacies; and
- VIc Crystalline dolostone lithofacies.

4. These lithofacies contain cyclic deposits which result from sedimentary cycles. Each cycle is a discrete event of related processes and is represented by a set order of associated rock types.

Three carbonate cycles are recognised:

A cryptalgal carbonate cycles, which can be further subdivided into

- A1 cycles with cryptalgal domes,
- A2 cycles with cryptalgal domes and planar cryptalgalaminites,
- A3 cycles with planar cryptalgalaminites;

P peloid carbonate cycles; and

SO skeletal-ooid carbonate cycles.

Each lithofacies may contain one or more cycle types. It is the relative abundance of the cycles present and their rock types that characterise the lithofacies.

5. The Ninmaroo Formation is a diachronous unit that youngs to the east and southeast. Sedimentation continued from the Payntonian (Late Cambrian) to post-Warendian (Early Ordovician).

In this progradational sequence, the basal unit was the ooid carbonate lithofacies (Io), which conformably overlaid or interfingered with the Georgina Limestone in the Toko Syncline and the Chatsworth Limestone in the southern Burke River Structural Belt. In both the Smoky Anticline region and the northern end of the Burke River Structural Belt, this lithofacies overlies Upper Cambrian formations unconformably.

Interfingering with and prograding southeastwards over the basal lithofacies was the peloid-carbonate-dominant lithofacies (IIp). Intermittent sedimentation of the terrigenous lithofacies (VT) occurred in the Toko Syncline.

Deposition of the flat-pebble conglomerate carbonate lithofacies (IIIc) was occurring in the northern Smoky Anticline, but as this area became emergent, lithofacies IIIc prograded south and eastwards into the Burke River Structural Belt and the Toko Syncline area.

Deposition of the mixed carbonate lithofacies (IVscp) ensued in the Toko Syncline, but was terminated with increased terrigenous deposition of the Kelly Creek Formation.

In the Burke River Structural Belt, sedimentation of the skeletal carbonate lithofacies (IVs) resulted in progradational offlap to the south, followed by the peloid-skeletal carbonate deposition (lithofacies IIps).

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FIGURE 6

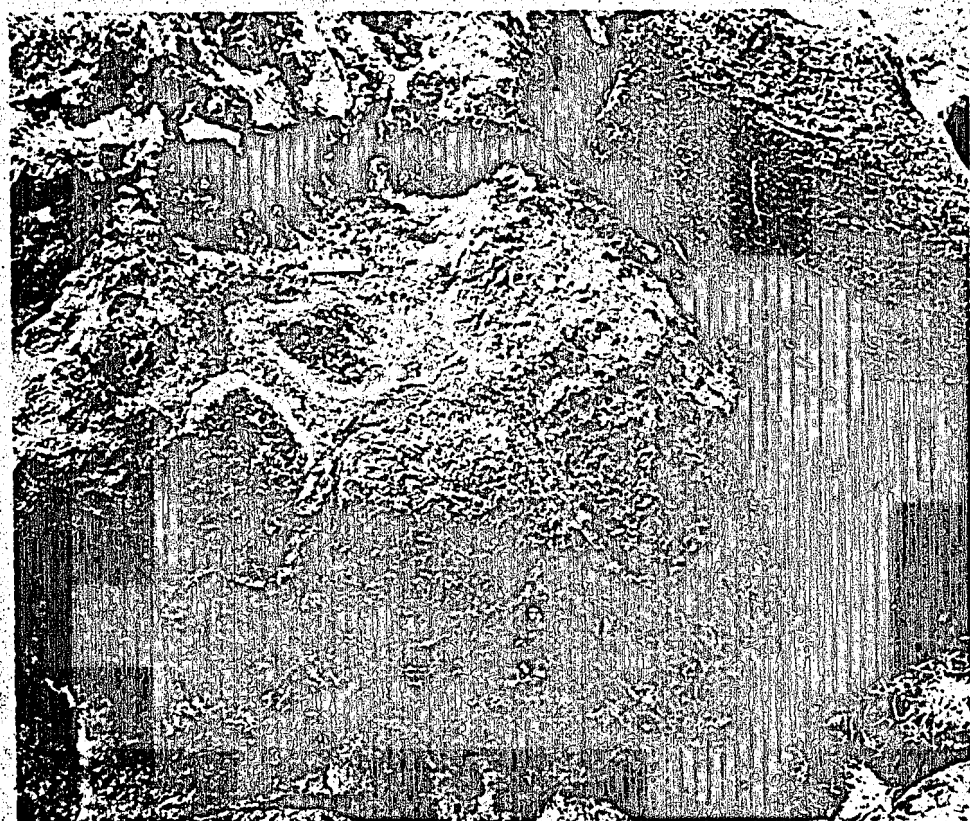
- a. Exposed section of Ninmaroo Formation conformably overlying the Chatsworth Limestone on the limb of a faulted dome, Mount Unbunmaroo, the type area of the Ninmaroo Formation. Bouliia 1:250 000 Sheet area, Queensland.
- b. Swift Formation regolith unconformably overlying silicified echinoderm limestone of Lithofacies IVp, Ninmaroo Formation at Mount Ninmaroo. Scale is 10 cm.
- c. Columnar cryptalgal bioherm draped with bioturbated peloid grainstone. Individual columns are circular to polygonal in cross-section. Bioherms are up to four metres in diameter. Scale is 10 cm.
- d. Reconstruction of the morphology of columnar bioherms within tidal channels of the ooid carbonate lithofacies. Relief was approximately 2 metres. Undercut bases occur on one side and draped sediment on the opposite side.
- e. Cross-section of a column of these bioherms with a central core (a) of crudely laminated boundstone with bioturbation mottling and sulphate moulds, and peripheral rinds of light-coloured micrite (b). Irregular erosional surfaces on (b) are encrusted with bituminous bioturbated boundstone (c). Scale is 10 cm.



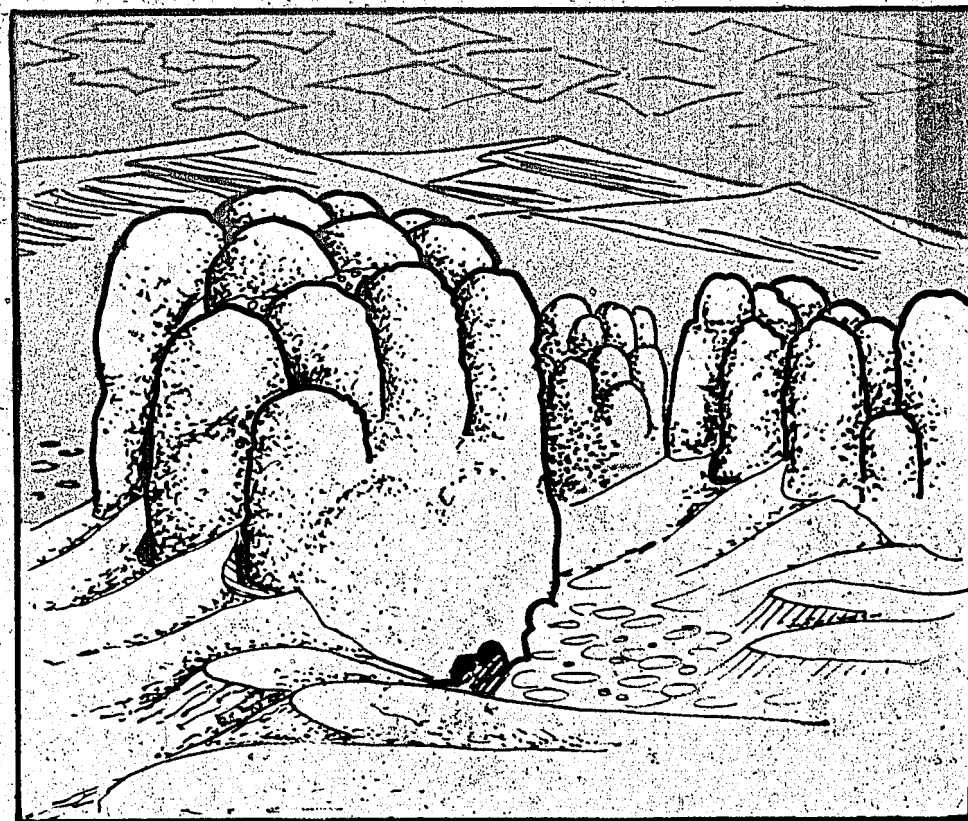
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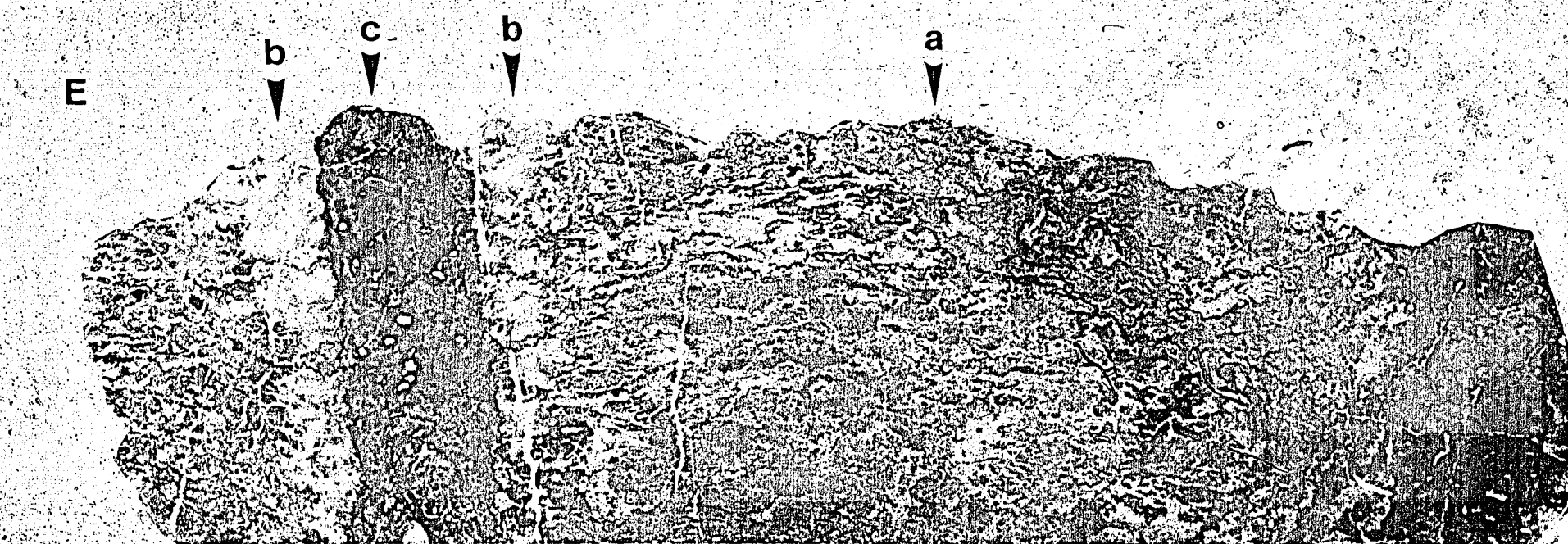


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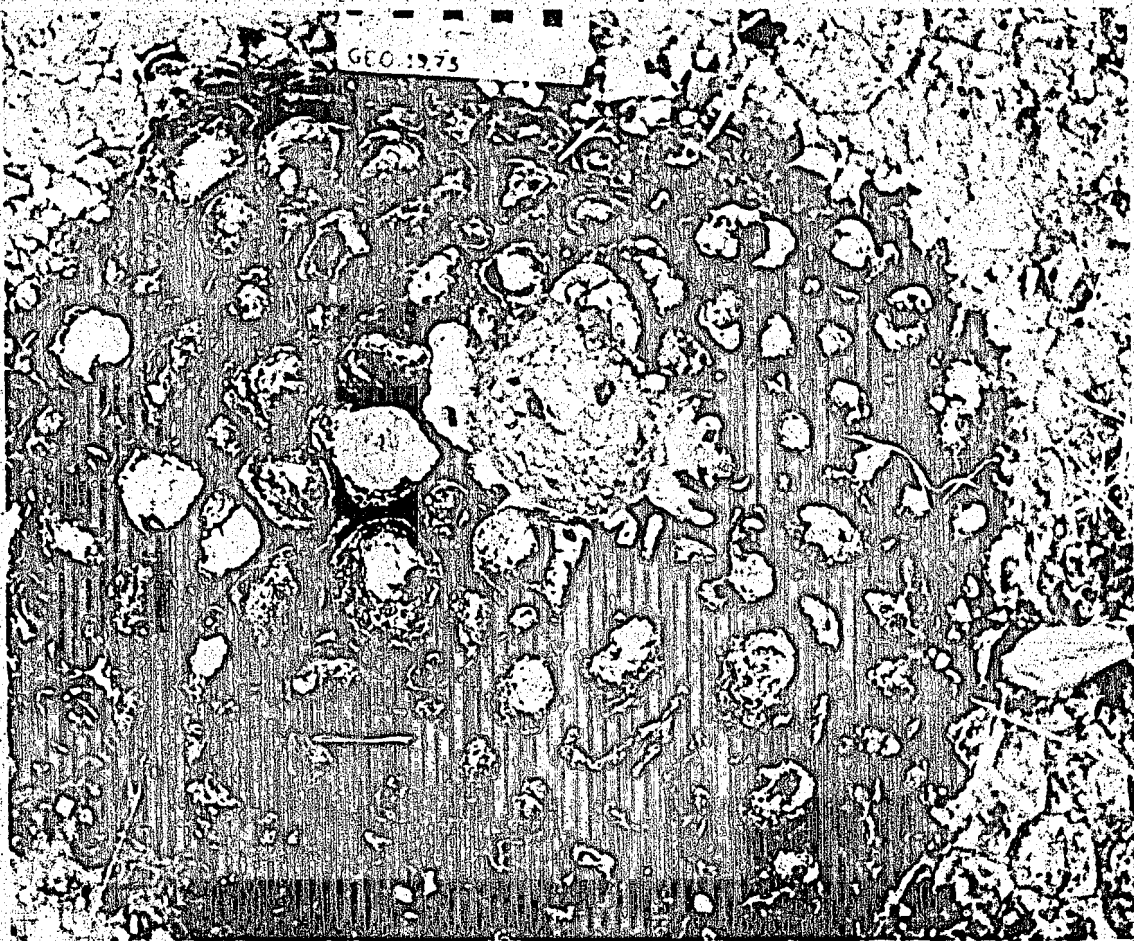
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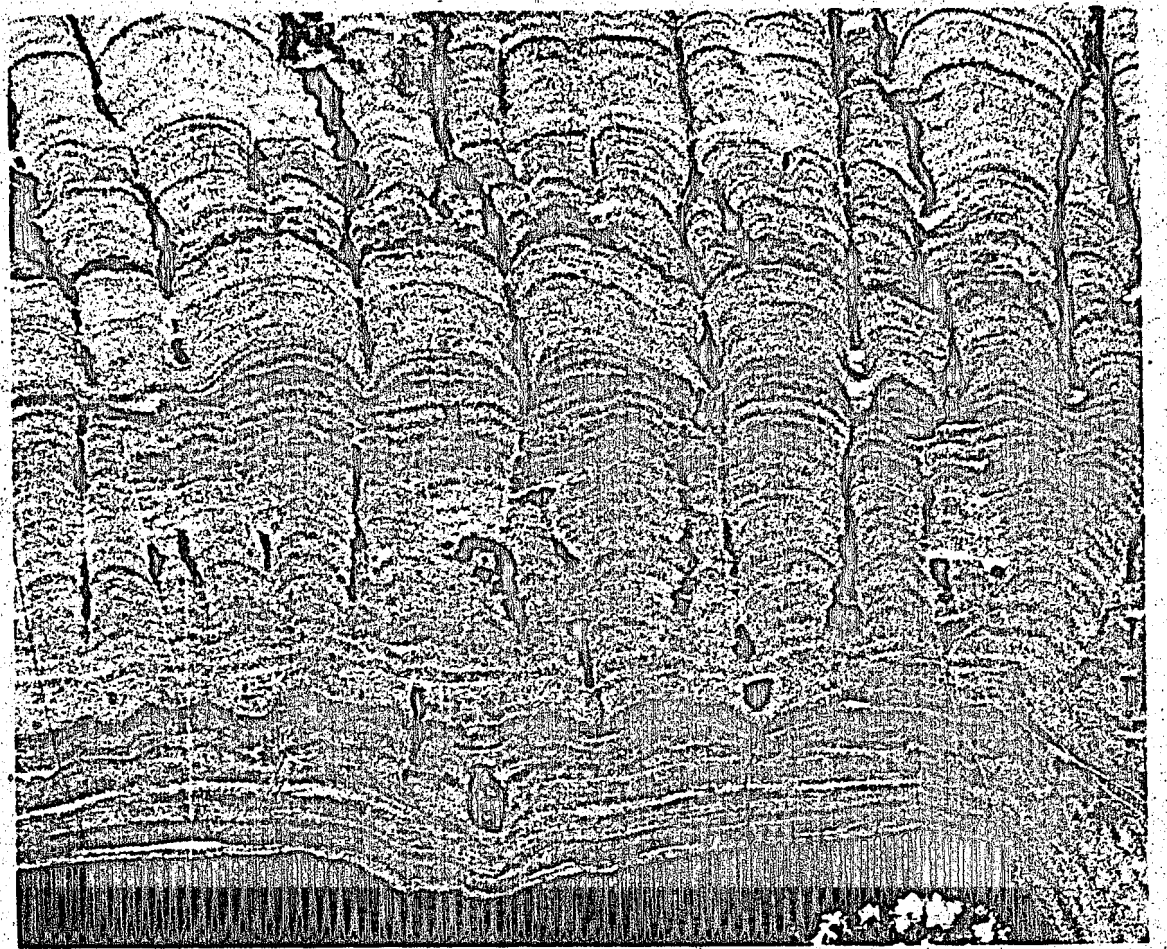
Figure 6

FIGURE 10

- a. Silicified surface of a close-crinkled cryptalgal mound showing the apparent growth morphology. Scale is 10 cm. 74712340.
- b. Cross-section of a close-crinkled cryptalgal mound with branching columns containing regular, gently convex laminae. The substrate of the mound was a tepee structure with an enclosed sulphate nodule. 74712338.
- c. Anastomosing columns with planar, fenestral-enhanced laminae. Sessile ribeirioids (R) are attached to the columns. 74712597.
- d. Unbranched columns with gently convex laminae and dark peripheral encrustations (E) of unidentified calcareous organisms. 74712598.
- e. "Atoll" stromatolite with a peripheral zone of vertical anastomosing columns and a central depression filled with subparallel algal mats. 74712484.
- f. Horizon of planar cryptalgalaminites with marked fissility of the beds. Scale is 10 cms. Lithofacies IIa, GEO 202 section, 126 metres.

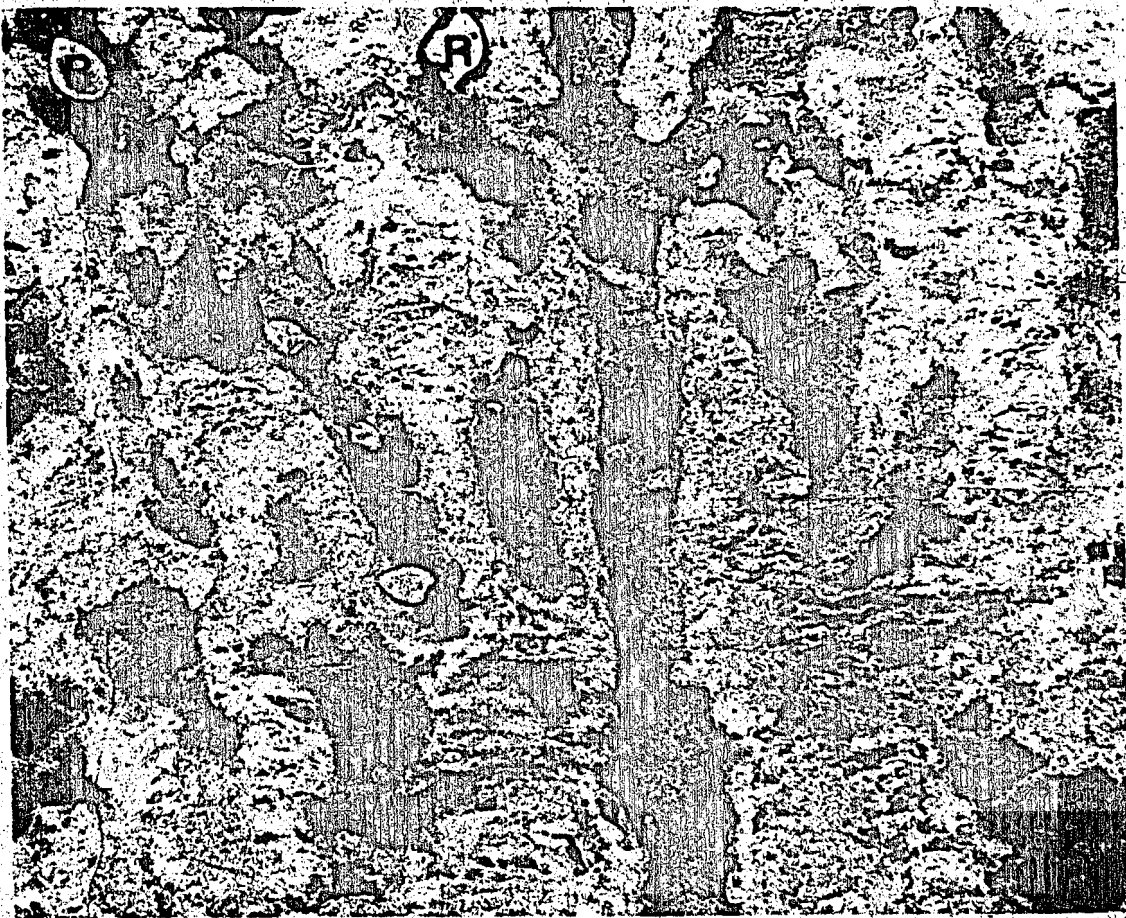


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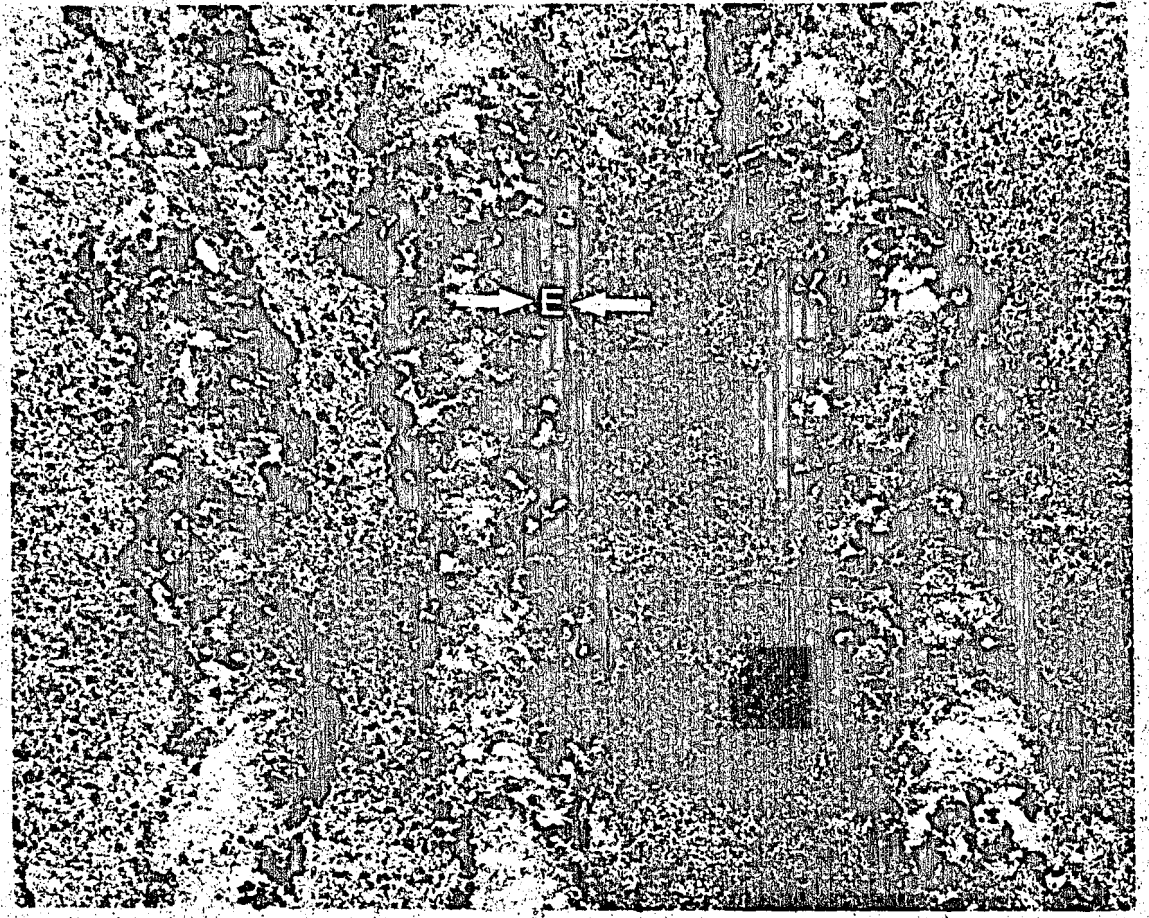
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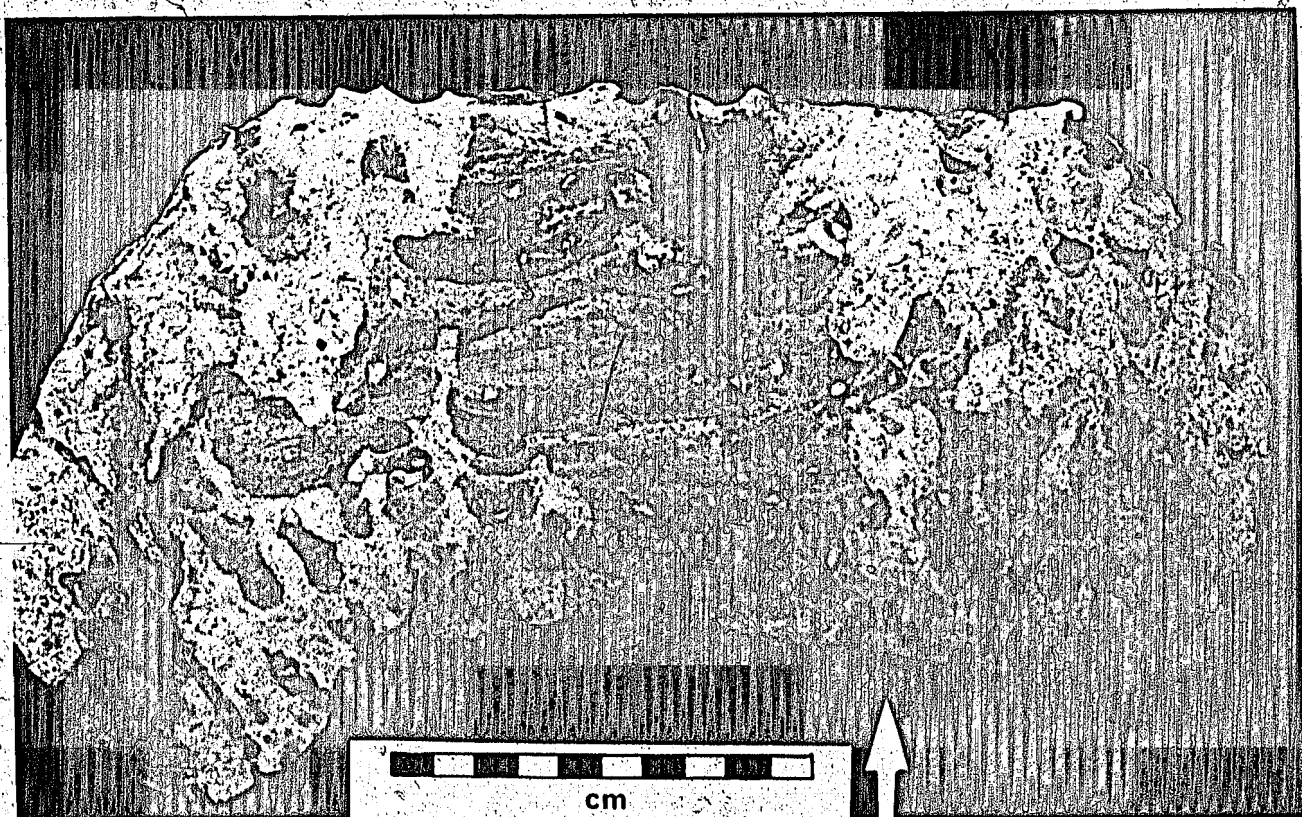
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F

Figure 10

FIGURE 11

- a. Cryptalgalaminite dominated by tubular fenestrae, the dwelling burrows of small suspension feeders. 74712660.
- b. Laminite of possible cryptalgal origin has alternating laminae of fine-grained peloid limestone and light-coloured dedolomites. 74712614.
- c. Cryptalgalaminite with fenestrate laminae and shrinkage cracks (SC). 74712618.
- d. Erosional and recolonisation features within a cryptalgal mound. The cusped erosional surface (E) on a skeletal-rich thrombolitic boundstone is encrusted with irregular dark laminations of Girvanella. Open-crinkled stromatolitic growths have grown over this encrusted surface. 74712645.
- e. Peloid grainstone with peloids of varied shape and size. Peloids are probable micritisation products after ooids, grapestone, and intraclasts. In some peloids, the relict fabric is still evident in central unaltered zones. Photomicrograph, plane-polarised light. 74712390.
- f. Coarse intraclast and skeletal detritus in peloid matrix adjacent to a stromatolite head. The intraclasts of irregular varied shape are products of biologic or diagenetic degradation of the stromatolite. 74712455.

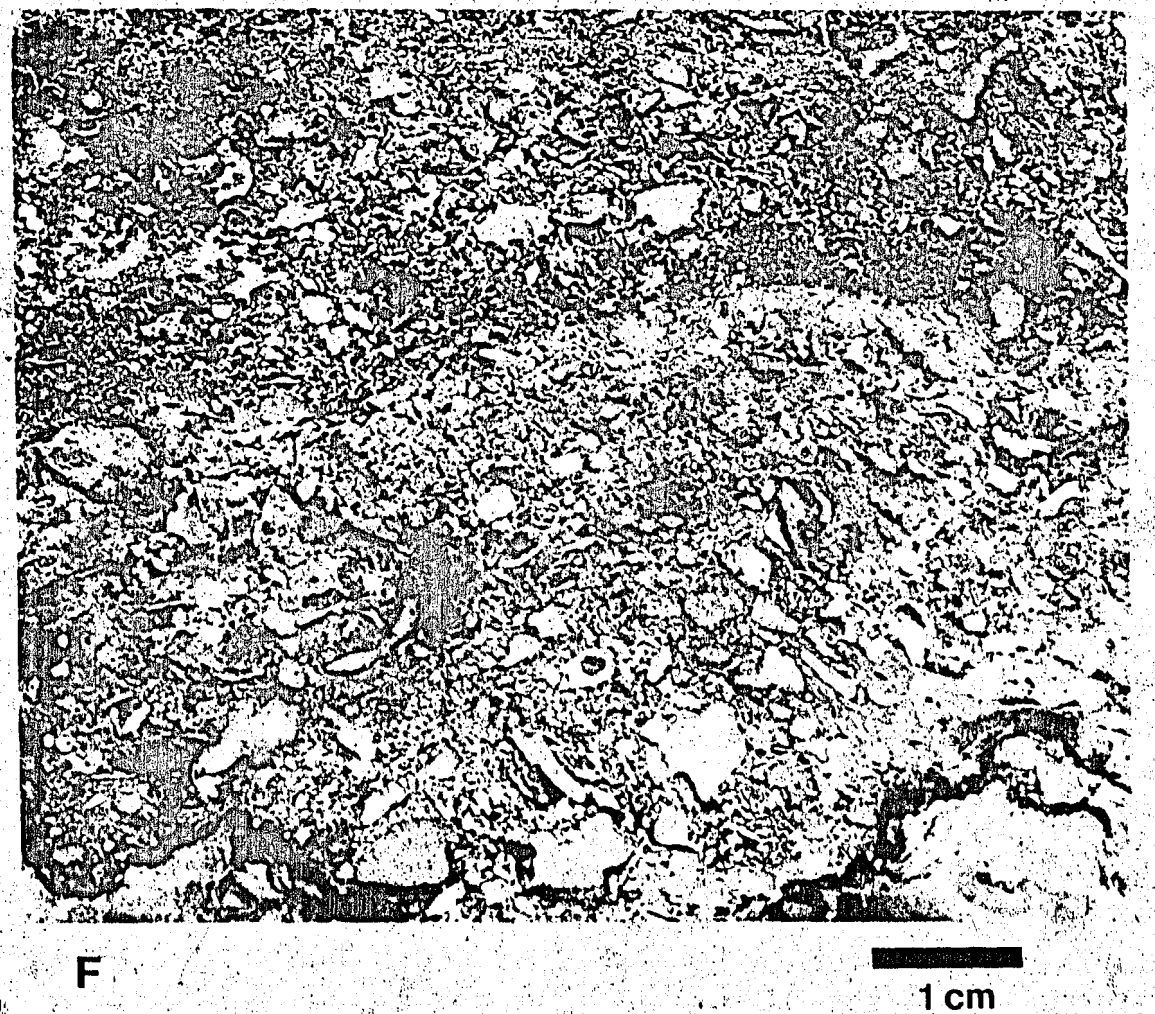
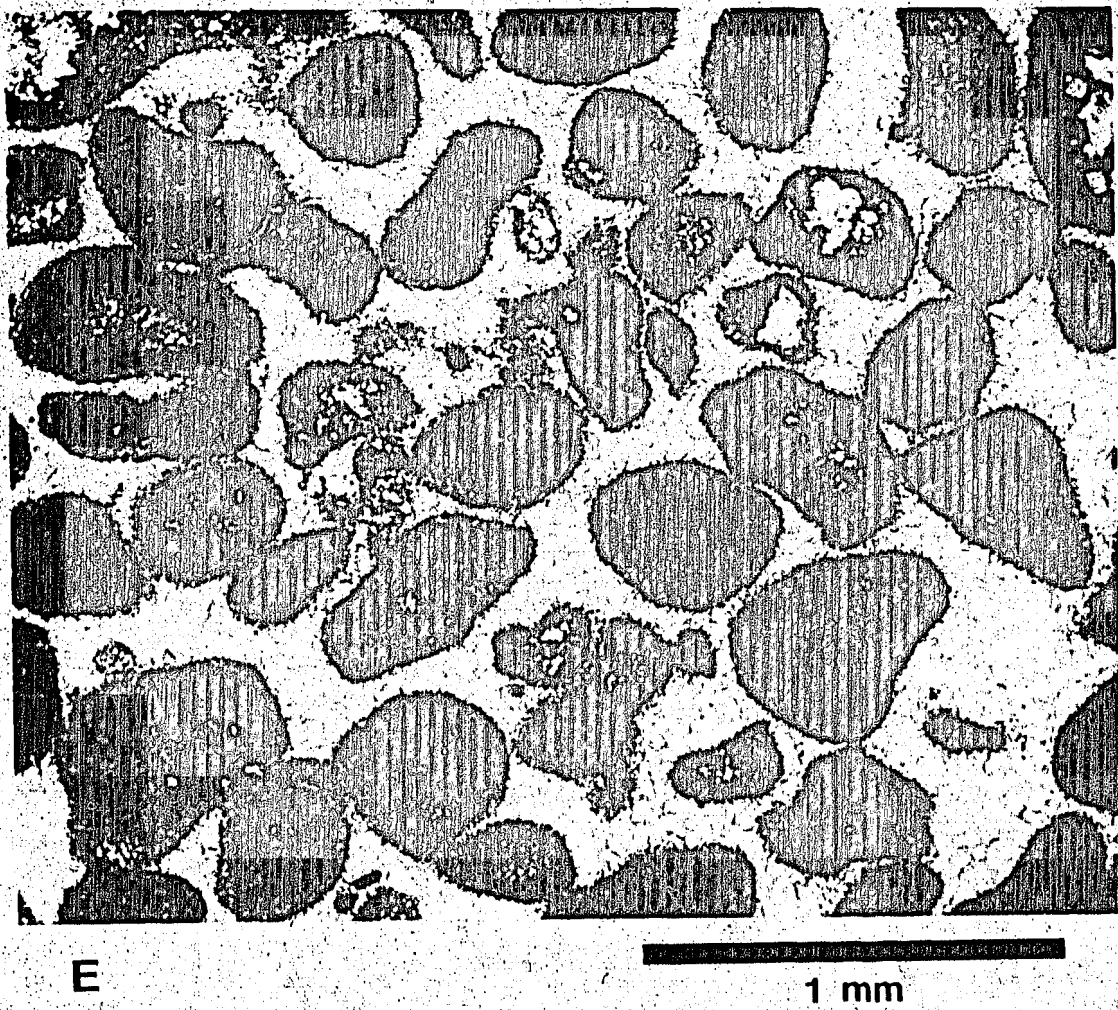
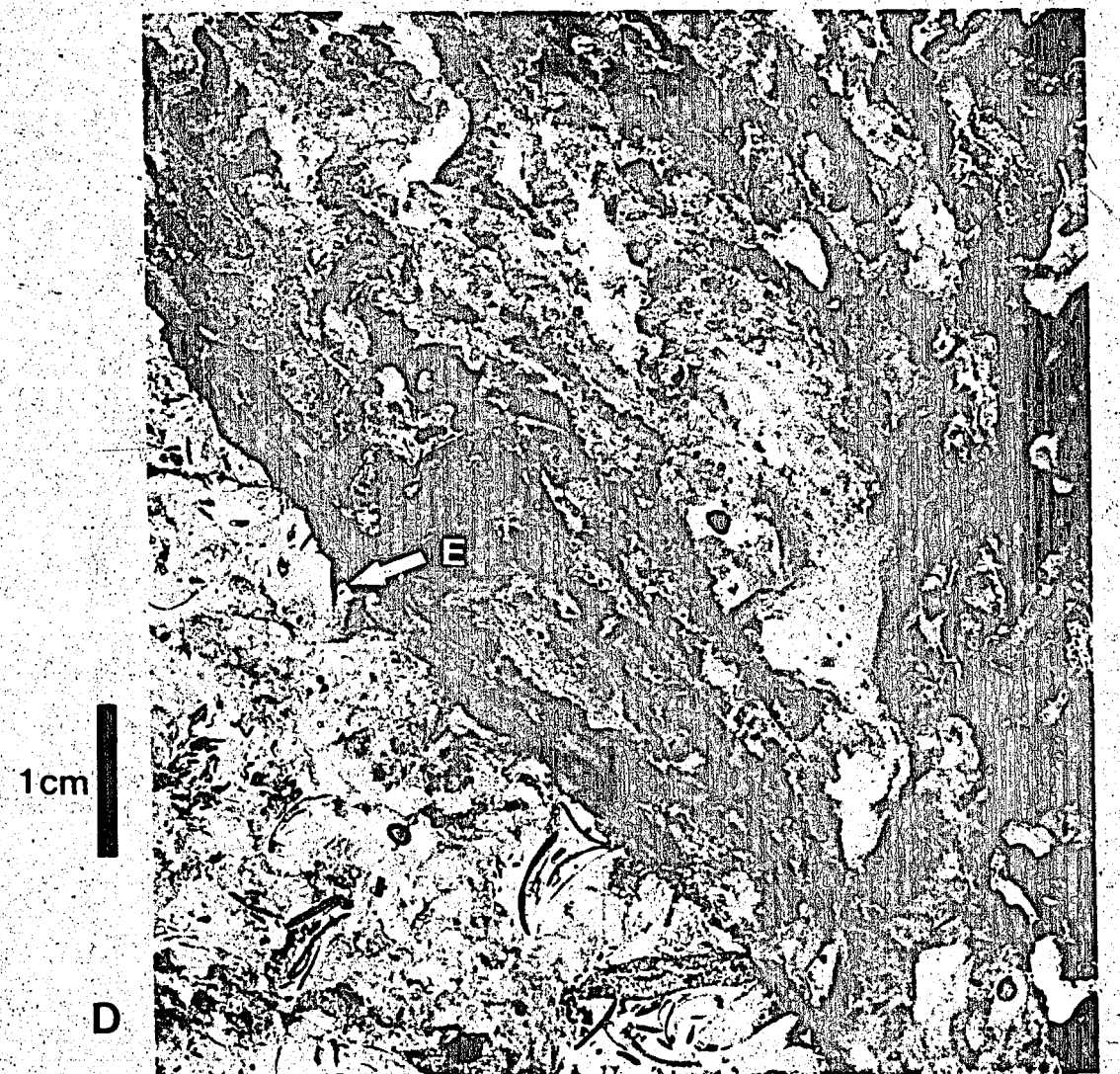
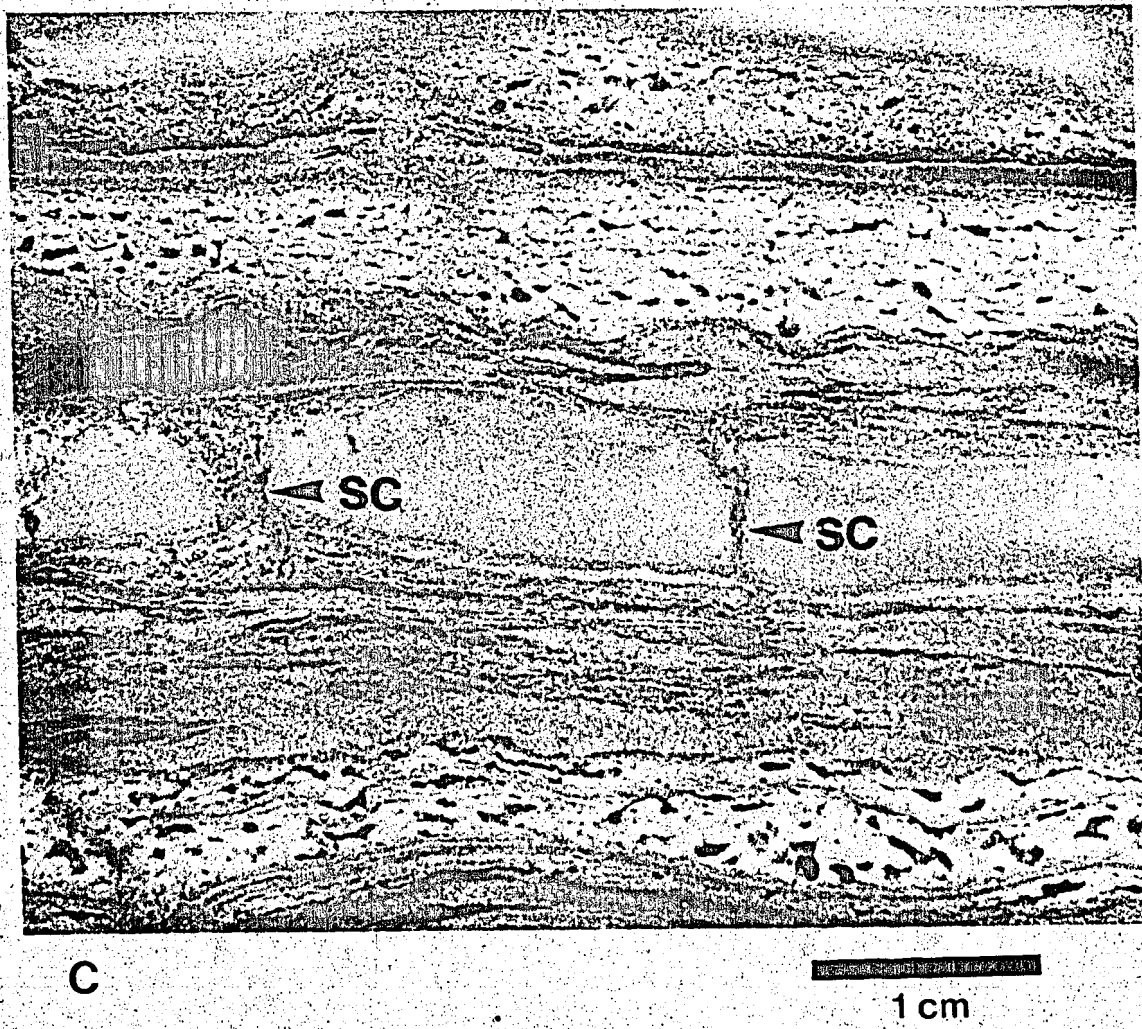
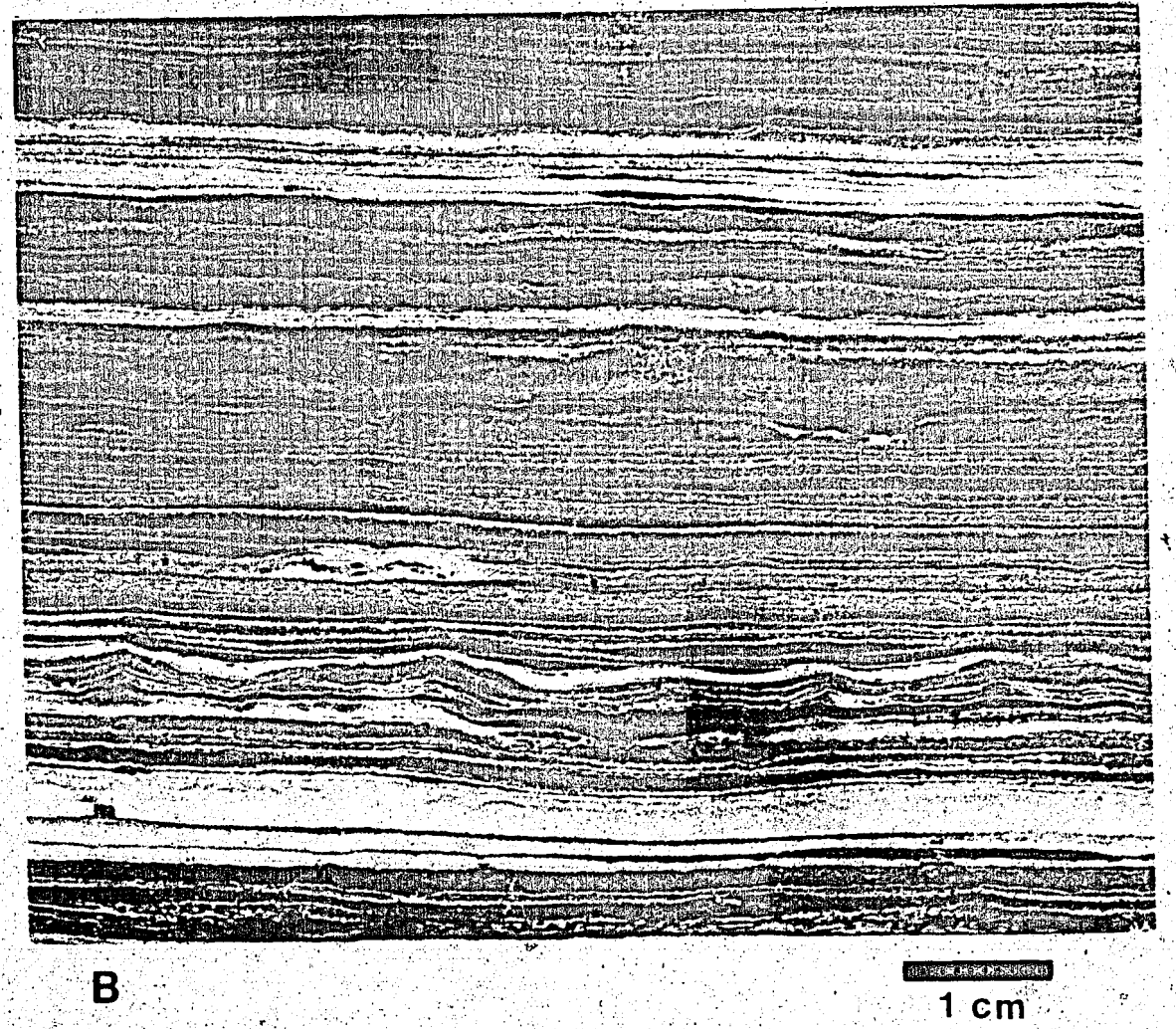


Figure 11

FIGURE 12

- a. Flat-pebble conglomerate consisting of rounded disc-shaped granules and pebbles in imbricated fabric. 74712038.
- b. Recurring eroded indurated surfaces (I) that are overlain by flat-pebble lag deposits. The conglomerates fine upwards to another indurated surface. 74712303.
- c. Round-pebble conglomerate beds form thin lag deposits over laminated peloid packstone and wackestone. Scale is in 1 cm increments. 74712634.
- d. Edgewise conglomerate that is adjacent to a cryptalgal mound. The tabular clasts are subparallel and packed subvertically within discrete bands. 74712398.
- e. Ooid grainstone comprising partially micritised ooids with poorly preserved concentric fabrics. These are present in the cross-stratified grainstones of Figure 14 (f). Photomicrograph, plane-polarised light. 74712658.
- f. Thin sets of cross-strata in sandy ooid grainstones are typical of type C cyclic sedimentation units. GEO 202 section, 504 metres.



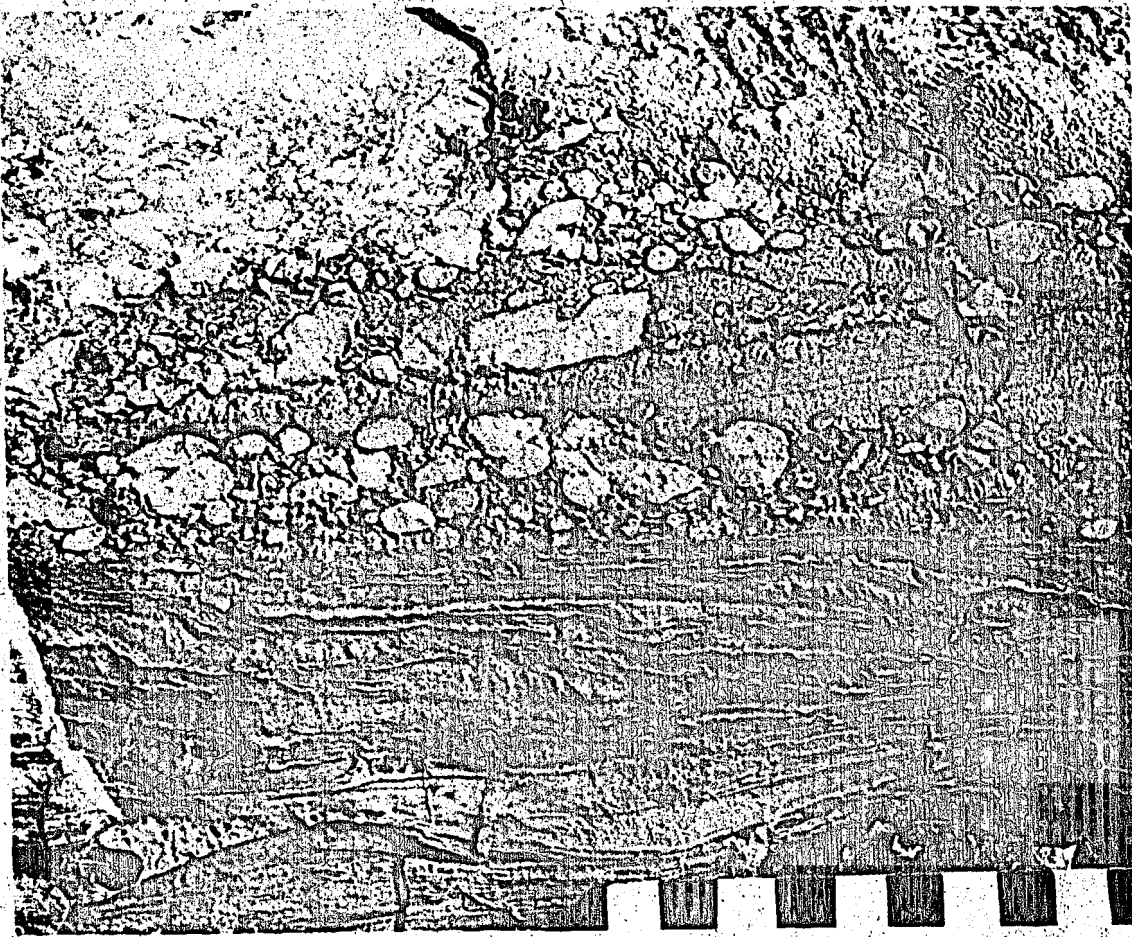
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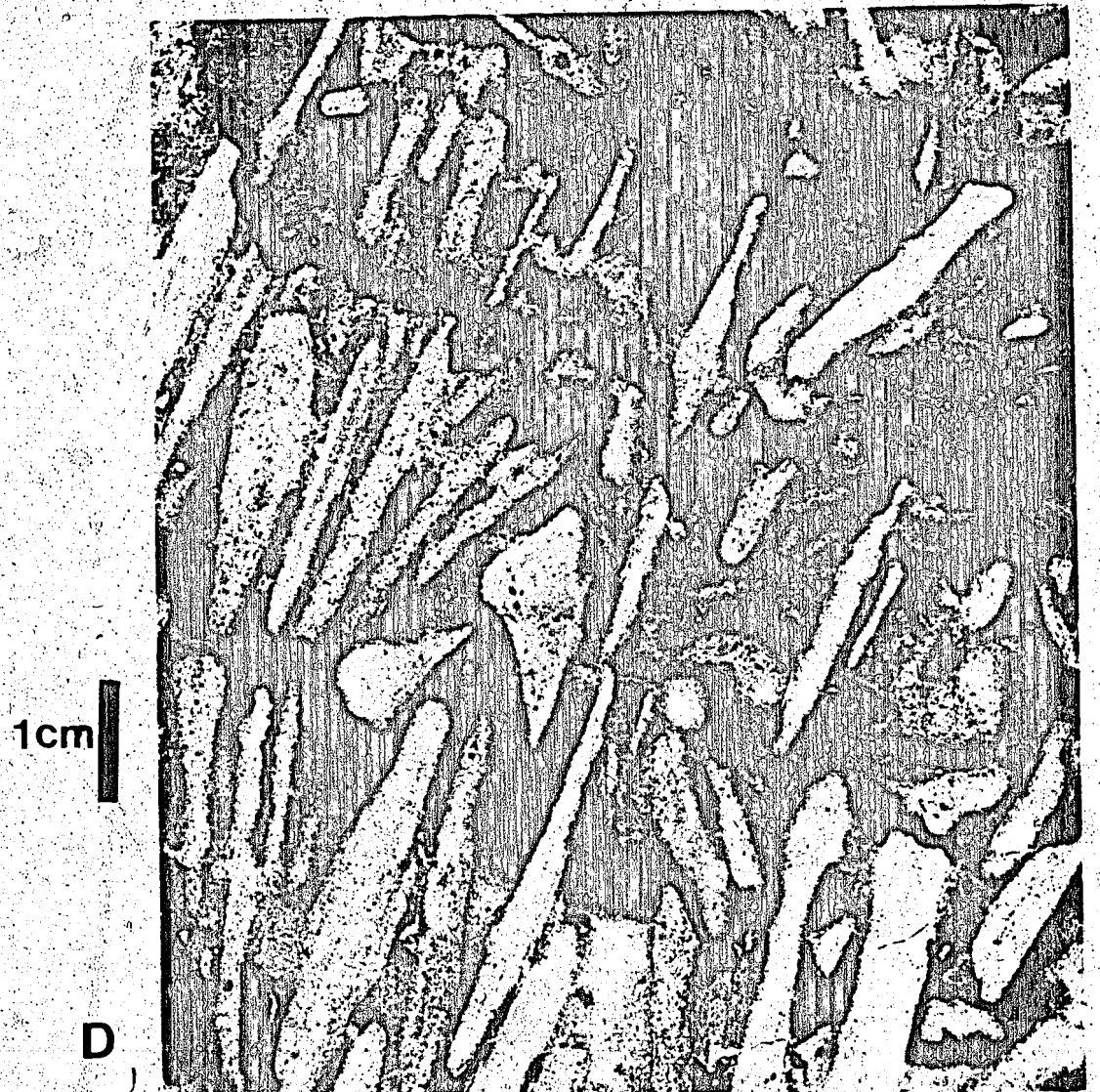


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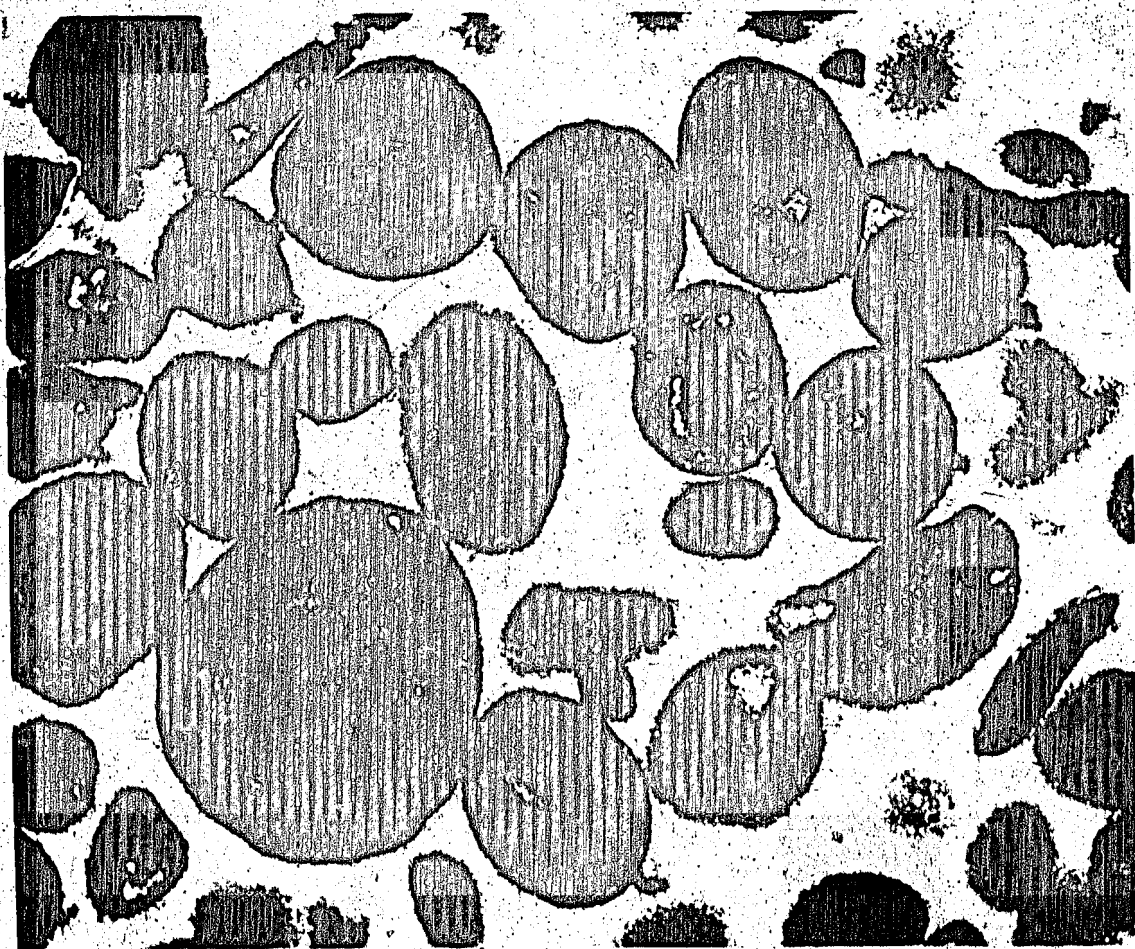


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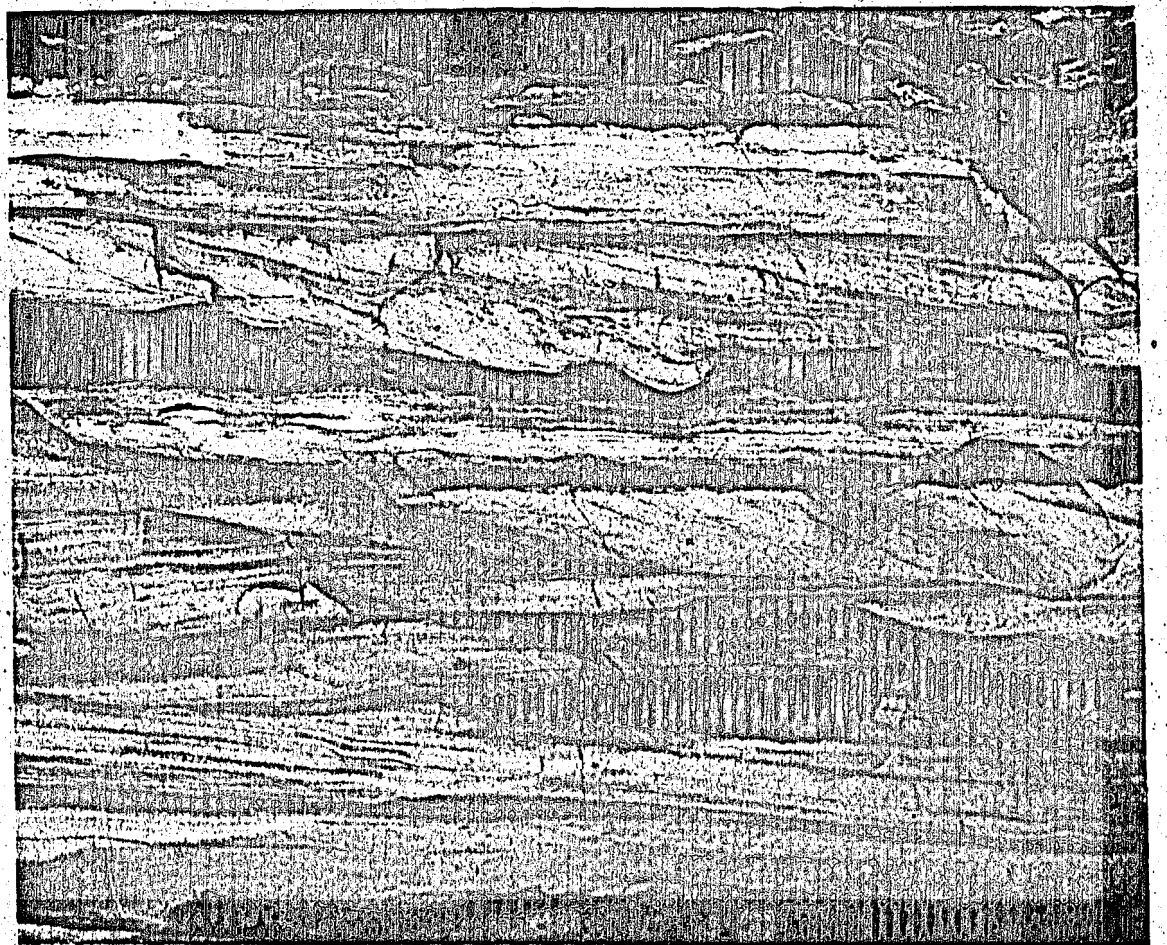
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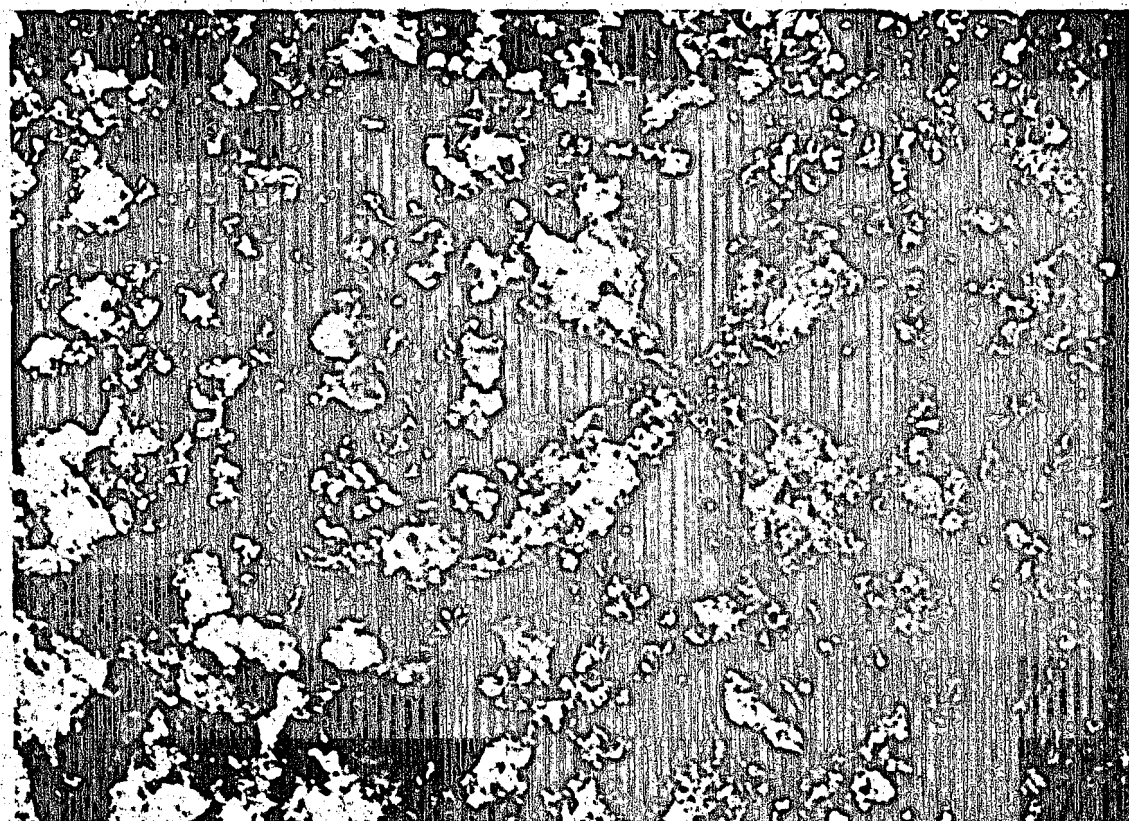
Figure 12

FIGURE 13

- a. Bioturbation-mottled and laminated ooid grainstone with dark patches of bituminous limestone enclosed in a light coloured dedolomitised host. This ooid grainstone is commonly associated with cryptalgal limestone. GEO 263 section, 86 metres. Scale is 10 cm.
- b. Spherulites with dominant radial fabric and very small nuclei are characteristic of mottled ooid limestone (Figure 15a). Photomicrograph, crossed polars. 74712536.
- c. Echinoderm grainstone comprising platelets and columnals with well-developed syntaxial cement rims. Photomicrograph, plane-polarised light. 74712276.
- d. Bioturbated mudstone with both coarse mottling from deposit feeders, and small subvertical burrows from infaunal suspension feeders. These small burrows are now spar-filled. 74712300.
- e. Shrinkage cracks within dedolomitised mudstone are deformed, probably by early compaction. The mudstone was originally micron-sized dolomite but has subsequently been dedolomitised. 74712622.
- f. Channel-scour structure with gently sloping banks cut into underlying sediment. The coarse, well-sorted lag deposit within the channel is now better indurated and more resistant to weathering than the underlying sediment. GEO 202 Section, 177 metres.



A



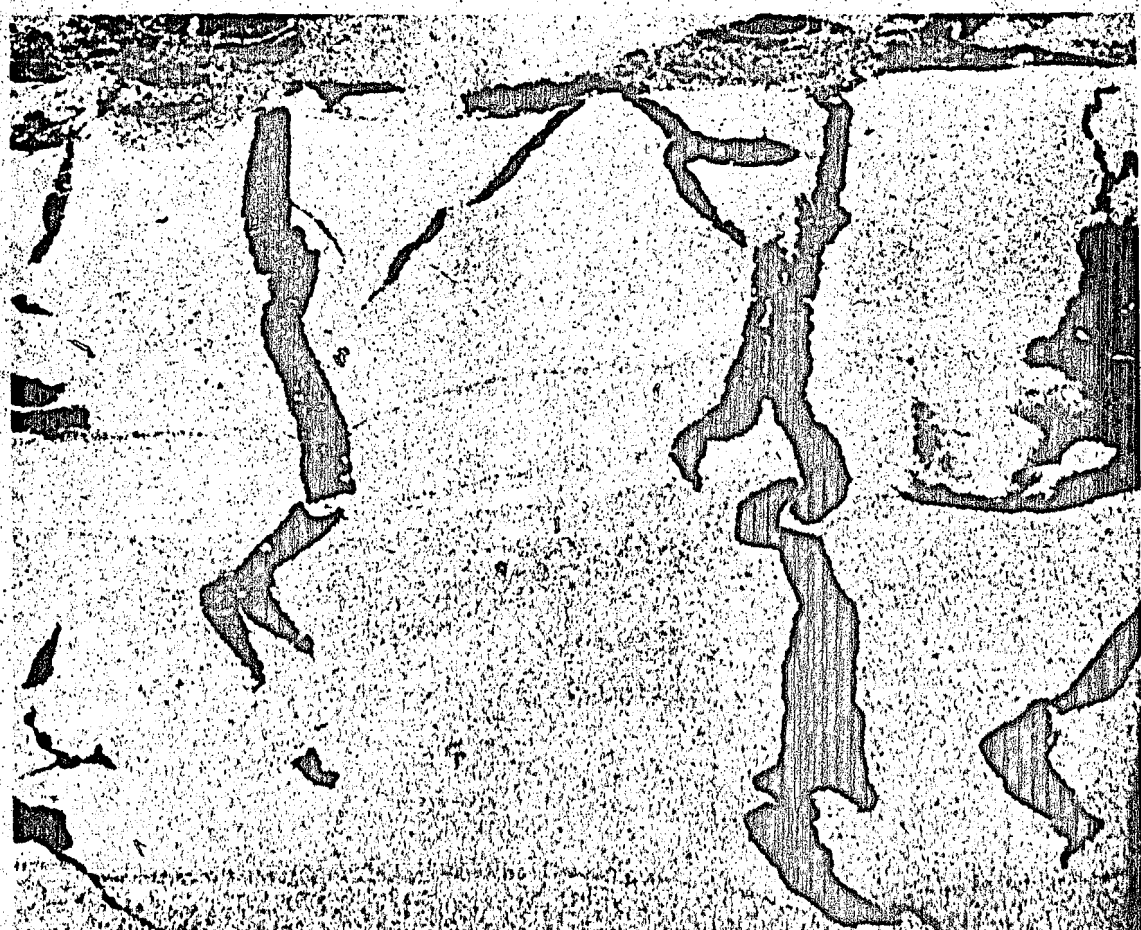
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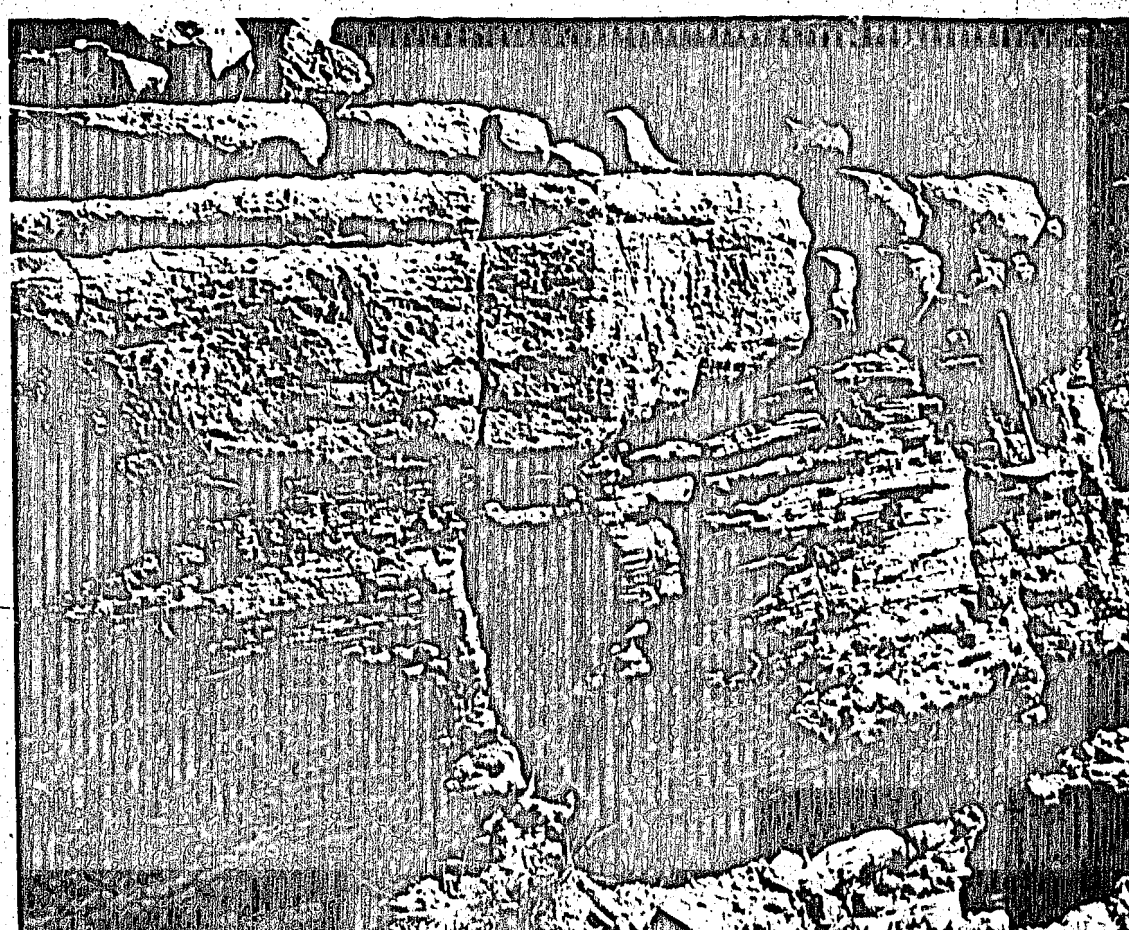
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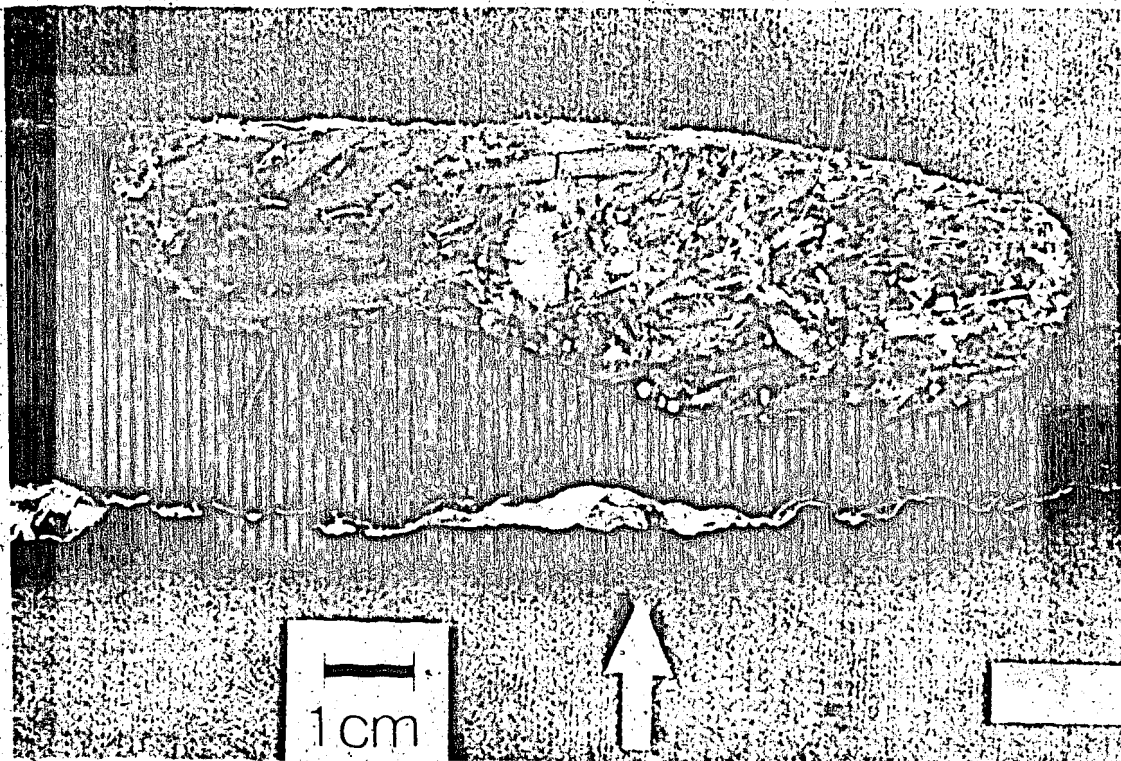


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Figure 13

FIGURE 15

- a. Cross-section of a groove with an abrasion-smoothed and iron-stained lower surface that truncates both cement and grains of the ooid grainstone host. This erosional feature has overhanging walls. An oblique view of this abrasion-modified karst feature is shown as the basal erosional surface of type S0 units (Figure 17). 74712655.
- b. An irregular internal solution cavity within a columnar cryptalgal mound, infilled by stalagmitic cements which have convex lamination (L) and cellular crustal cement fabrics. 74712714.
- c. Cuspate erosional surface (S) within a cryptalgal mound. The cusps are probable bioerosion pockmarks produced by grazers, such as chitons. Chiton and nautiloid (N) fragments are bound into the upper encrusting algal boundstone. GEO 202 section, 433 metres.
- d. Smoothed planar erosional surface over an indurated cryptalgalaminite. Note the solution-enlarged fracture. Calcrete cements encrust and partially occlude fenestrae. 74712328.
- e. Oligomictic collapse breccia with stylolite-enhanced close-fitted fabric in bioturbated mudstone. The matrix is dolomite and iron-stained calcite. 74712617.
- f. Chert nodules within cryptalgalaminite. The nodule shapes conform to the outlines of shrinkage polygons (arrows) in the host sediment. Lithofacies IIp. Scale is 10 cm. 74712623.



A



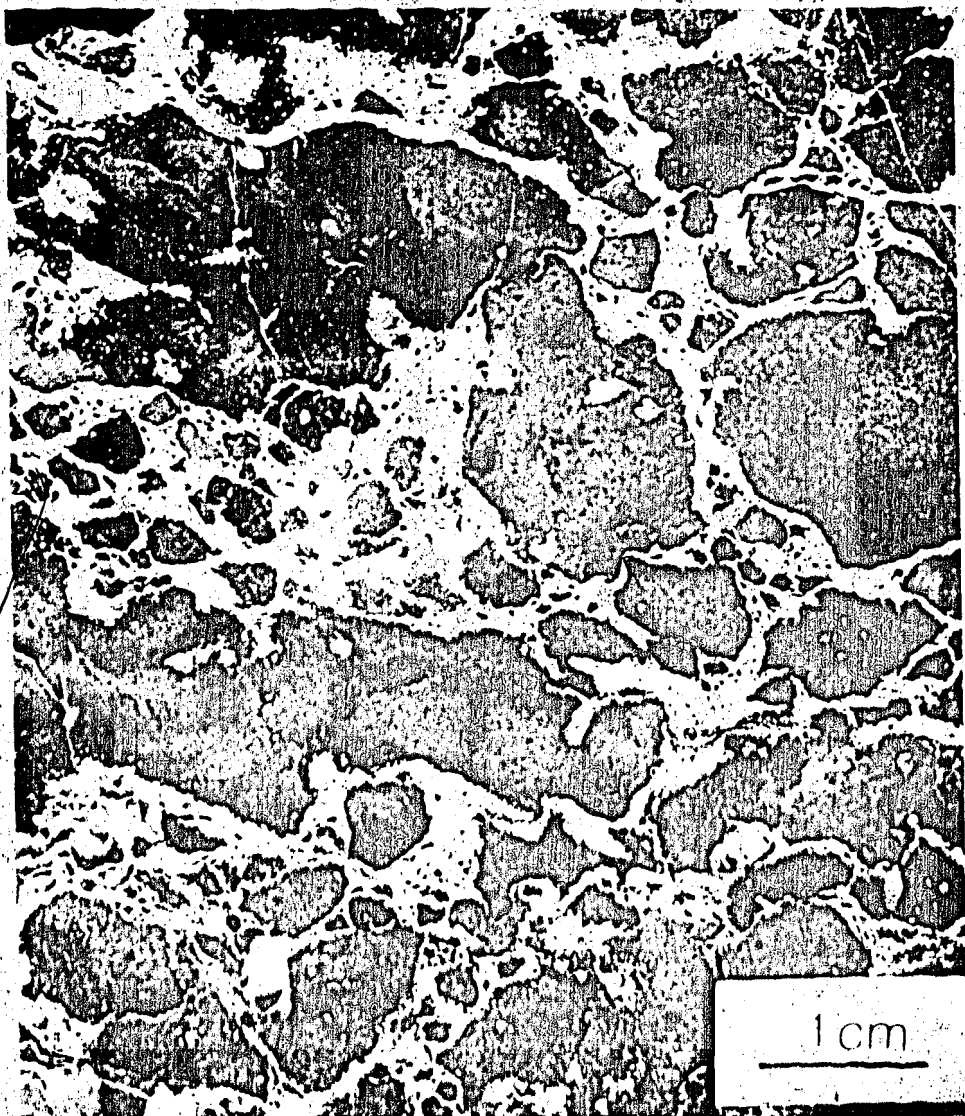
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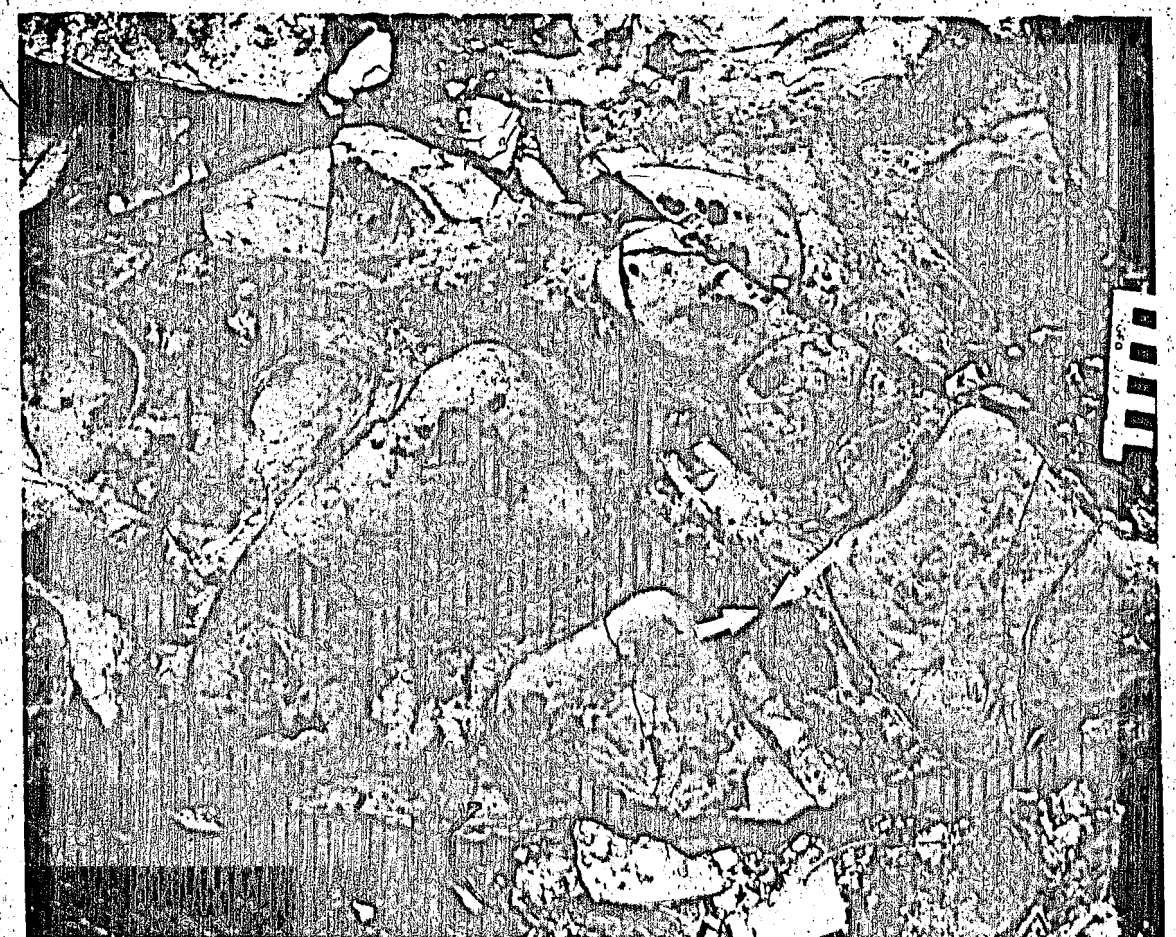
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Figure 15

APPENDIX I

DETAILED STRATIGRAPHIC SECTIONS

Explanation and legend for stratigraphic logs

Layout

Stratigraphic logs are arranged in 8 columns which are, from left to right:

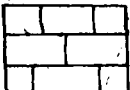
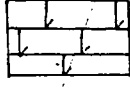
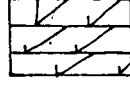
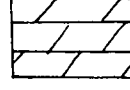
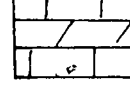
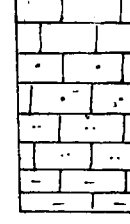
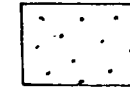
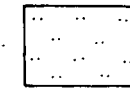
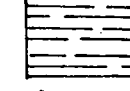
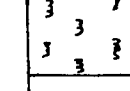
1. Scale
2. Graphic litholog
3. Sample horizons
4. Bedding thickness
5. Sedimentary structures
6. Grain size of terrigenous component in lithologies
7. Abbreviated description
8. Symbol summary of particle types

Scale (Column 1)

The scale on the left hand side of the graphic log indicates the stratigraphic level in metres above the base of the section.

Graphic litholog (Column 2)

The left side of the graphic log is a generalisation of differential weathering characteristics of the sequence. Gradational contacts have no line separating symbols which are consequently merged.

	limestone
	dolomitic limestone
	calcareous dolostone
	dolostone
	interbedded limestone and dolostone
	limestone sandy silty shaly
	sandstone
	siltstone
	shale, mudstone
	chert
	chert nodule, chert stringer
	no exposures

The following symbols may be superimposed on the lithological symbols:

o	conglomeratic
Δ	brecciated
⊥	calcareous
⌊	dolomitic
✱	vuggy

Sample Horizons (Column 3)

Sample horizons are indicated by arrowheads and the accompanying sample number may be followed by sample type:

P - petrographic; G - geochemical; IR - insoluble residue;
C - conodont; M - macrofossil. Sample descriptions are on permanent file, Microfiche CPDMRXWG, Bureau of Mineral Resources, Canberra, Australia.

Bedding Thickness (Column 4)

	very thick	100 cms
	thick	35 - 100 cms
	medium	10 - 35 cms
	thin	1 - 10 cms
	laminated	1 cm

Sedimentary Structures (Column 5)

	lamination	
	cross-stratification	
	cross-lamination	
	ripple marks	
	undulose bedding	
	erosional surface	
	bioturbation	horizontal trails
		burrow
	shrinkage cracks	

Terrigenous Grainsize (Column 6)

vf	very fine sand
f	fine sand
c	coarse sand
vc	very coarse sand
g	granule
cbl	cobble

Abbreviated Description (Column 7)

The ordering of each description is standardised, beginning with

1. colour, the abbreviated description from the G.S.A. rock colour chart.
2. a qualifier, if necessary, of the rock type indicated in the graphic log, e.g., grainstone qualifying limestone.

3. the qualifier is followed by descriptive adjectives, indicating component particles and sedimentary structures, listed in decreasing order of abundance.
4. a colon separates these sedimentary features from diagenetic and weathering features.

Many of the abbreviations used are from the standard Bureau of Mineral Resources abbreviation list. As a general rule of thumb, they are derived by removing vowels. In some cases, consonants from word endings are also removed. Nouns are indicated by uppercase, and adjectives by lower case.

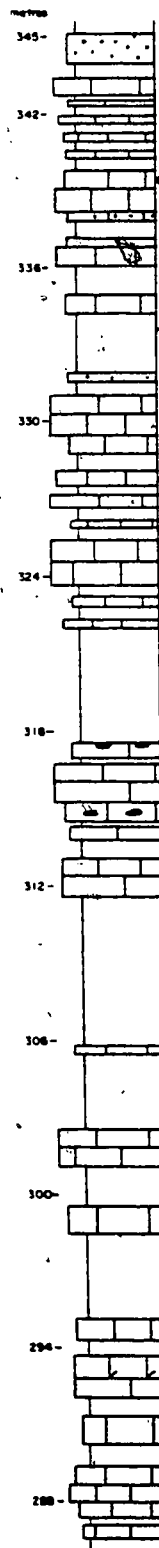
Symbol Summary (Column 8)

This column is repetitive after the abbreviated description in that it summarises the component particle types in decreasing order of abundance. Additionally, emphasis on abundance is made by underlining e.g., p, or on rarity by bracketing, e.g., (p). The particle types are:

p	peloid
o	ooid
⊙	pisolith
⊖	intraclast
⊖	trilobite
∇	brachiopod
⊗	sponge
∧	sponge spicule
◇	echinoderm
⊗	ribeirioid, pelecypod
⊗	gastropod
∇	nautiloid, monoplachophoran
⊖	ostracode
α	fish
⊗	calcareous algae
⊖	cryptalgal dome
⊖	cryptalgal (undifferentiated)
⊖	skeletal (undifferentiated)

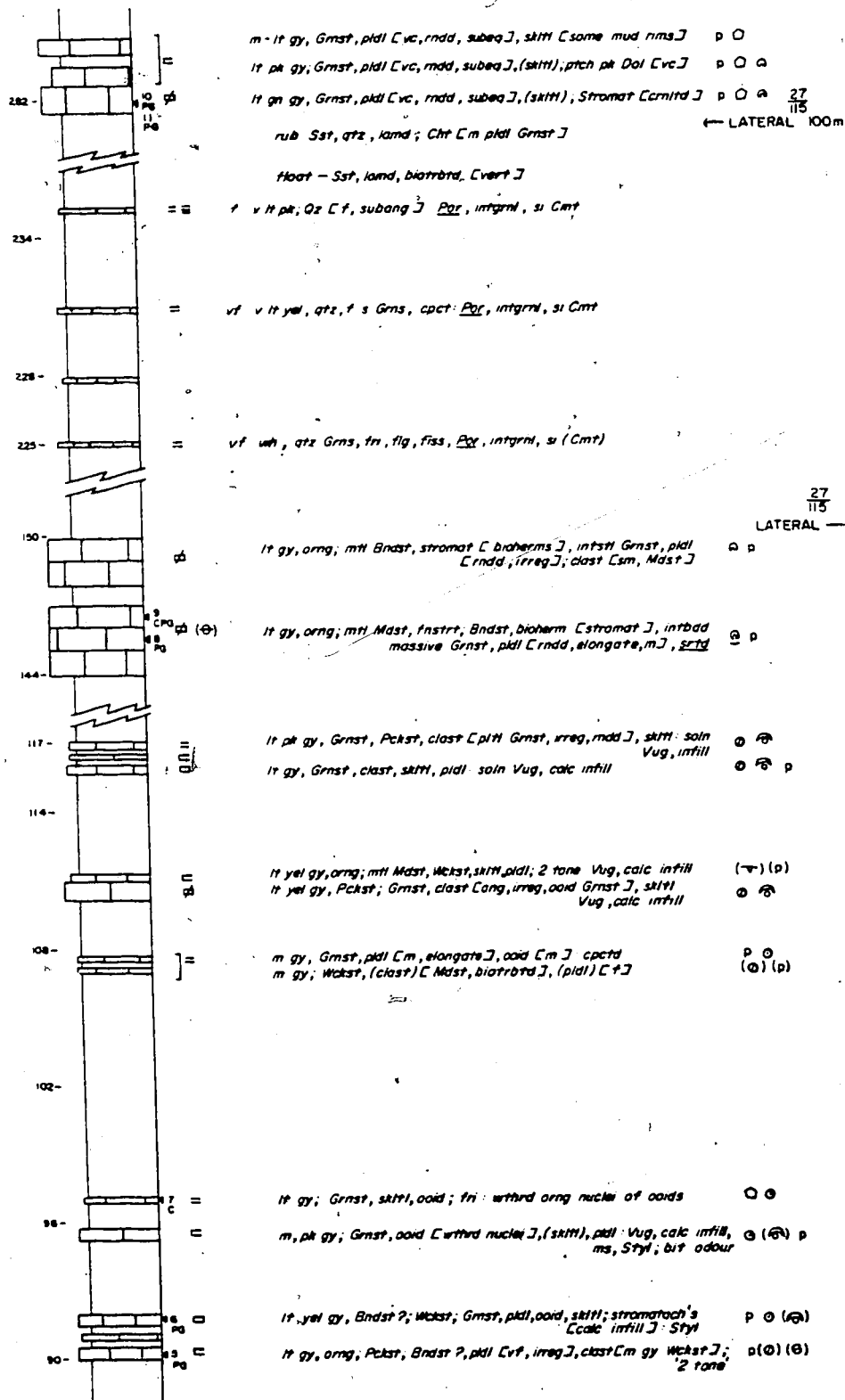
GEO SECTION 263

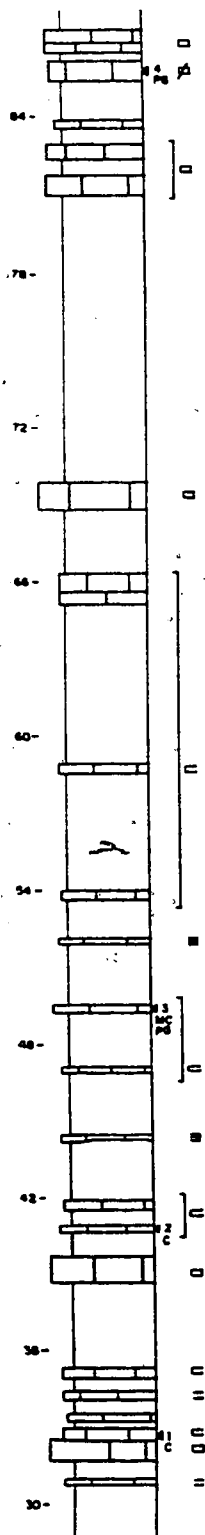
top of A



It gy, Bndst, bioherm C Mdst, fnstst J, Wckst '2 tone', orng xl
 m gy, Pckst Dol? replmt in irreg Pch
 m gy, Grnst, clast C lrg, lath, rndd J, py, F?
 It pk gy, Grnst, clast C lrg, lath, elong, rndd, Pckst, red rims J, orng
 It pk gy, Pckst? pth? py xl Dol replmt nms
 pk gy, gn gy; Mdst C alg J; adj Grnst, pldl?, skth, Stromat C 50cm
 dia heads J orng xl Dol replg grains, si
 It yel gy, Bndst Crnd, F? J; adj Grnst, skth Cc, fragd J, F?
 It gy; Grnst, vt, pth?
 It gy, Mdst, fnstst; Wckst, skth in pch between Stromat py
 It gy, yel, speckled Grnst, skth, pth Grnst, clast sm pth orng Dol
 pk orng, Grnst, skth Cm, fragd J; Xstrat C sets, 10cm; mod angle;
 uni Lam
 vt vlt gy, calc, cpct, lamd, fiss
 It yel gy, m gy, mlt Grnst, skth, ooid Cm, orng; rexld J, dol
 Biotron, Yug, calc infill
 It yel gy, m gy, orng; mlt Grnst?, pldl? Cm, repld by Dol; Fld??
 irreg orng calc
 It gn gy; Grnst, skth Cvc J, cpct cpctd; syntaxial Cmt?; lrg
 Yug Cms, calc infill
 It yel gy; Pckst?; Grnst?, vt pth, lamd cpctd, py cubes
 It gy; Mdst, fnstst; pth Grnst, clast C irreg, sm, Mdst J
 It gy, yel, Bndst Crnd, alg J; assoc Grnst, clast C sm, Mdst, rndd,
 eq to irreg J, skth '2 tone', yel Calc replg Bnds; Styl, Brec
 It gy, yel, mlt Grnst, clast C Mdst, alg J, pldl, skth, adj Bndst
 '2 tone', yel Calc, cpctn
 pk yel, Grnst, ooid Cm, sph, yel, rexld J, (skth)
 It gy, Grnst, skth Cm J, fri Chr C Grnst, pldl, skth J, cpctn
 It gy, Grnst, ooid Cm, sph, m mud rim J, strd
 It yel, Grnst, ooid? Cm-c J, pldl C sph J Styl, sub parallel
 It gy, pk, Wckst, (skth) '2 tone', Brec E pk f calc Cmt, cpctd,
 Styl, Chr C Grnst, ooid, skth J
 It yel, Grnst, skth, ooid, pldl Crndd J
 yel pk, Pckst, pldl Crndd, sph J, skth; md lenses, Grnst, clast
 C sm, rndd J Styl
 It yel gy, Grnst, ooid Cc, sph J pldl C sph J, strd Xstrat C 2-3cm
 sets, planar + trough J
 It gy, orng; mlt Wckst, skth inhamd orng f Calc, '2 tone'
 It pk gy, Grnst, pldl Crndd, sph, c J Styl
 It yel gy, mlt Bndst C skth hash in Mid Mtx J pth yel Calc
 Cvf xl J
 yel; Grnst, ooid? yel, rexld ooids, Mn calc Zones
 It gy yel, Grnst, pldl Cc, rexld, sph, ooid? J, (skth); Xstrat
 C 10cm sets J yel rexld: Calc
 It gy yel; Grnst, skth, clast C sm J; fr: wthrd
 It yel gy, Grnst, skth C fragd J, pldl Cm J
 It gy, orng; Pckst, pth Cvf J inhamd '2 tone', vt rexld orng Calc
 It gy; Grnst, clast Crndd, lath J, skth cpct
 It gy, Grnst, clast Crndd, lath, f rexld J, vt pth soln Yug, py under
 clast

27
 115
 LATERAL 100m →





m yel gy, Grnst, pldl Ec, rndd J, oord (Por), vug Ecald infill J,
bif odour
m gy, lt org, mtl Grnst, oord Cm J, (skth), Stromatolites, Vug,
calc infill, Styl

p o

o (T) o ? *

35
95

lt gy, org, Grnst, oord; mtl: withrd nuclei

o

lt pk gy; Grnst, oord, (skth); cpct: realzd, Vug, calc infill, withrd

o (O)

m yel gy, Grnst, oord, skth; (Stromat), tn mtl clmnr realzd

o (T) (A)

35
95

lt yel gy, Grnst, oord, pldl, (skth) withrd

o p o

lt gy, Grnst, skth Evc-grain J; fri withrd

o (A)

pk gy, Grnst, skth Evc J; fri withrd

o

— FAULT ?

m gy; Pckst; Grnst, pldl Cvf J

p

lt gy, brn, Grnst, skth, clast Crndd, withrd, lorn J Styl

o (A) o ?

lt gy, pk, Grnst, oord Cf-m J, (skth) Por, mtl + Vug, Styl; withrd

o (A)

m gy; Grnst, oord Cf-vf J bif odour

o

m gy, red; Grnst, oord Cf-m, rndd J realzd, mtl, (sl); bif odour

o

— FAULT ?

lt gy, Grnst, skth Evc J; fri (Por), mtl; withrd

o (A)

m gy, org; mtl Grnst, oord Cm, (dol) J: realzd; bif odour

o

repeated ?

— FAULT ?

lt gy; Grnst, skth Evc J; fri

o

lt gy, Grnst, skth Evc J, fri withrd

o (A)

lt gy, Grnst, skth, cpct: syntaxial Cmt; withrd

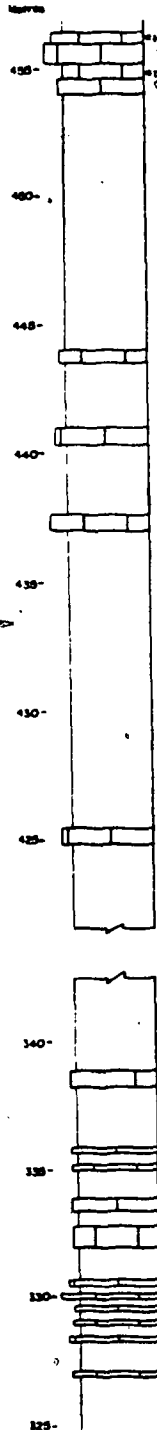
o (A)

org, m gy; mtl Grnst, oord, skth: realzd, frac, mtl withrd, bif odour

o (A)

SECTION GEO 265

base of A



V. lt. gr. mtl Grnst, clast (rhds, latn, Grnst), oad
m. gr. gr, arng. Grnst, oad (m, m, mature), still styl
V. lt. gr. Grnst, still; ft: soln Vug, calc infil, dol grains

○ ○
○ (○)
○

585

m. gr, arng withrd Grnst, oad styl
m. gr, dk red mtl Grnst, oad (mtl, withrd) arng red calc Rhombs, F?
yel ph Grnst, oad (m, mature, srt) yel withrd oads, (Vug), ms, calc
infil, Styl

○
○
○

equiv to base 263 Section ??

m. gr, ph mtl Grnst, oad (m, soln, mature), sd ph atm pth, soln
Vug, crystal silt and calc infil

○

585

Fault

lt. gr. gr Grnst, clast (Pkst, Mdst latn, sm-ling, mdd), pel F?
in sm Vug

○ ○

lt. gr. gr Wickst, vt grains

m. gr. gr. Endst (mtl Wickst, Mdst) still, domed, adj lamd Pkst,
Grnst, pel (m, along, aurdd) dol nap
m. gr, lt. yel Mdst?, apch Lam v m; '2 tone' flaser

○ (○) ▽ ○

lt. gr. gr. Grnst, clast (lrg, mdd, latn, Mdst B Grnst), pth (F) Styl,
soln Vug under clast, F?
m. gr. gr. Grnst, clast (lrg, latn, Pkst?), pth (vt); intbd lamd Pkst,
Grnst (pel)

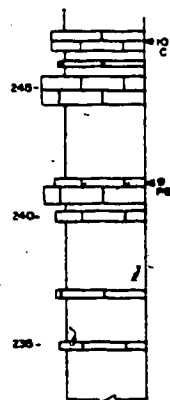
○ ○

○ ○

v. lt. gr. Grnst, pel (q, mdd), sd (qz, sph, mdd): apch

○





If red, if gy on Bndst, domed (alg frstnt Mdst). adj Grst, pel, clast, skilt, styl; red at
 If red, if org Grst? v f part? fig. f x L, fantaine bleu patterns; (Vug)
 If gy, m gy Bndst (frstnt Mud in patches, m. spin Vug, org calc infill)
 ph

Repeated sequence - cycle?, fault?

If red, org Grst, pel (v f), Xstrol (3cm sars) v f x L; at
 If gy on Bndst, domed (pel Grst, frstnt Wkst, mtl); adj Grst, pel (irreg, ang): Styl
 If gy on Mdst, frstnt (horiz, m) inland Wkst, grd mtl contact

If gy Mdst, (frstnt, skilt) calc infill ms Vug

If gy Mdst, un f - (caprd)

Q p Q

p

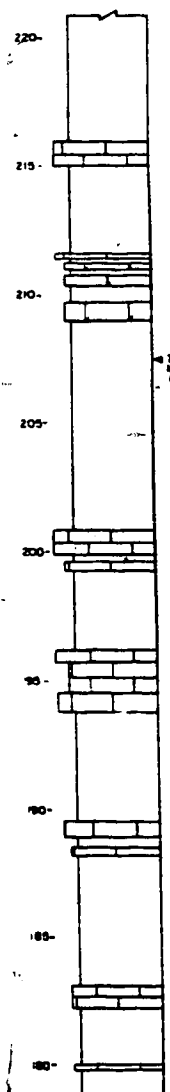
p

p

42

110

(V) (V)



If gy, m gy mtl Bndst (pel frstnt Wkst, Mdst) Vug, ms, calc infill

m gy Grst, pel (m), clast (sm B. ing mdd kth, Wkst) bit Odour

If yel gy, If ph gy Grst, pel (sm, dol), clast; inland Mdst '2 tone'

If gy, If org mtl, wkst, (skilt), (frstnt) org mtl dol Replmt, '2 tone'

Rub (1mm pseudomorphs after sulphides)

If yel gy Grst, clast (Mdst, sm irreg, pel (irreg); Bioherms

If yel gy, yel Mdst?, Lamd, grd mtl colour & caprd Lam: '2 tone'

If gy Grst, pel (c, along to submda) Vug, calc infill

m gy, yel gy mtl Mdst?, '2 tone' v f x L

If gy Grst, pel (f to vc, irreg to eq, subang), srt var

If yel gy Grst, pel (var, submda, f-c) sm irreg Pth, dol repl

If gy Grst, clast (sm, Lamd Grst, Mdst), pel (vc-grm)

Rub (1mm pseudomorphs of sulphides)

If gy, org mtl Grst? pel, Bndst?, domed: reXtld; sm irreg dol Pth

If yel gy Grst, clast, pel caprd; nod Chl

Q p Q?

p

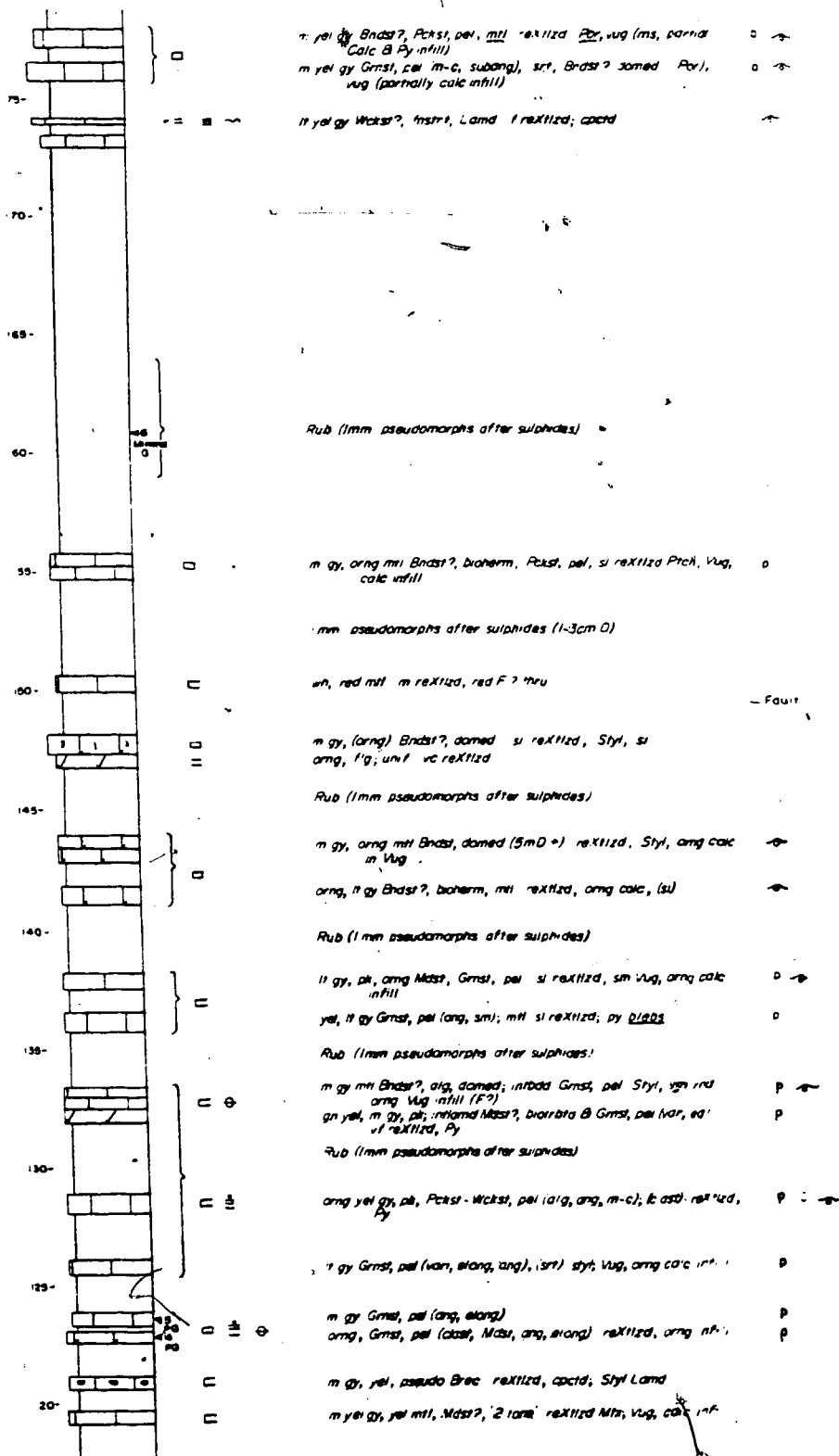
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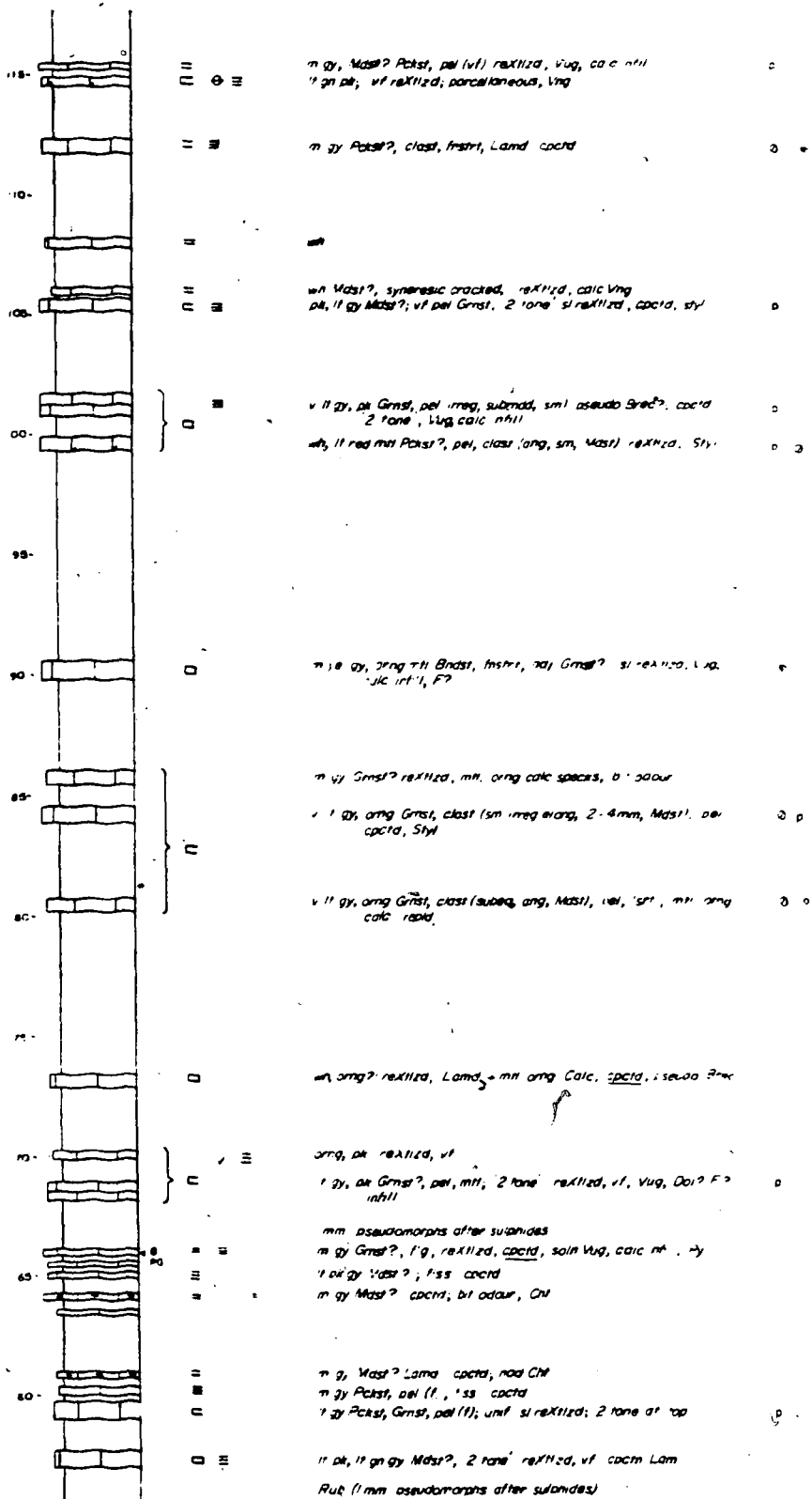
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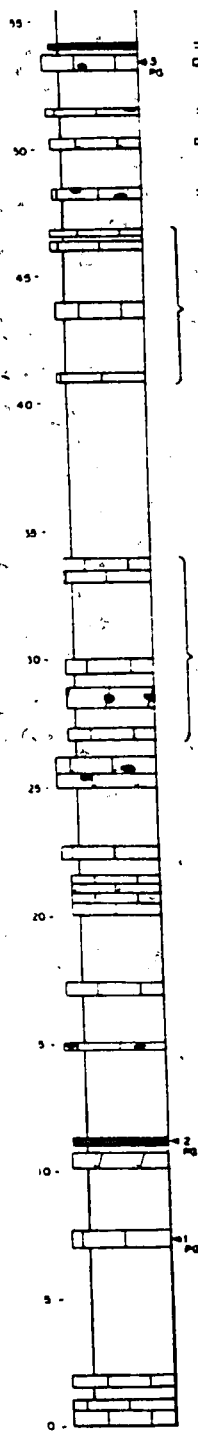
Q p

p

Q p







m gy Vast? Pkist? nLamd. rextid, coctd
 m gy Grst, banded, clast ag. rnas, eicng, oad. fl. chr. ind
 of oads 2 0

1 gy Grst, pel (c, subrad); oad (fl) Pich. rextid; nod Chr 0

m, it pe Mast, instr; Grst, pel, grunous rextid, apct Lam, 0

Rub (imm pseudomorphs after sulphides)
 m gy Mast, instr rextid; nod Chr; bit odour 0

m gy Grst, oad rextid; bit odour 0

1 gy Mast? instr; Lam rextid, Styl 0

11 gy Grst, oad (c, mature), clast (vtn) rextid 0 0

1 gy Grst, pel (ang, irreg), clast (sm, mlatr) rextid 0 0

m, crng mlt rextid, X; P; lvs cubes; m crng Calc

Chr Rub E imm pseudomorphs after sulphides

Chr Rub

1 gy, it pe Mast? rextid, v, styl Spctr

Chr Rub (Grst, oad, m)

m gy, 1 pel gy Fcst? instr, (Lamd) rextid, styl Bnd 0

m m gy Grst, oad (c, mature) vst, chr. nod 0

11 gy, v it pe mlt Pkist? (v), oad ag? Grst rextid, lamd

m pel gy Grst? Pkist? clast, pel, instr rextid, som enhan.
 ced instr, coctm enhanced Lam, 2 tone 0 0

m, 11 gy Mast, Pkist, inhamd, ag? styl apcm 0

1 gy Vast? instr

m gy, 11 gy Mast? Pkist? 2 tone rextid, m Lamd sty apcm 0

Chr Rub (Grst, clast, oad)

1 gy Mast, stromat, and; ad-nLama Mast, Pkist coctd 0

m gy, pel Pkist, instr? rextid, styl Bnd; pel ddi Repl 0

Chr Rub (oad Grst)

m gy Grst, oad (c, mature), clast (rg, dcl, vst 1), pel 2L 0 0

11 pel Mast? Pkist? oad, parcellaneous 0 0

Chr Rub (Grst, oad, clast)

m gy Mast, Pkist, clast (ang), instr b-odour 0

Chr Rub

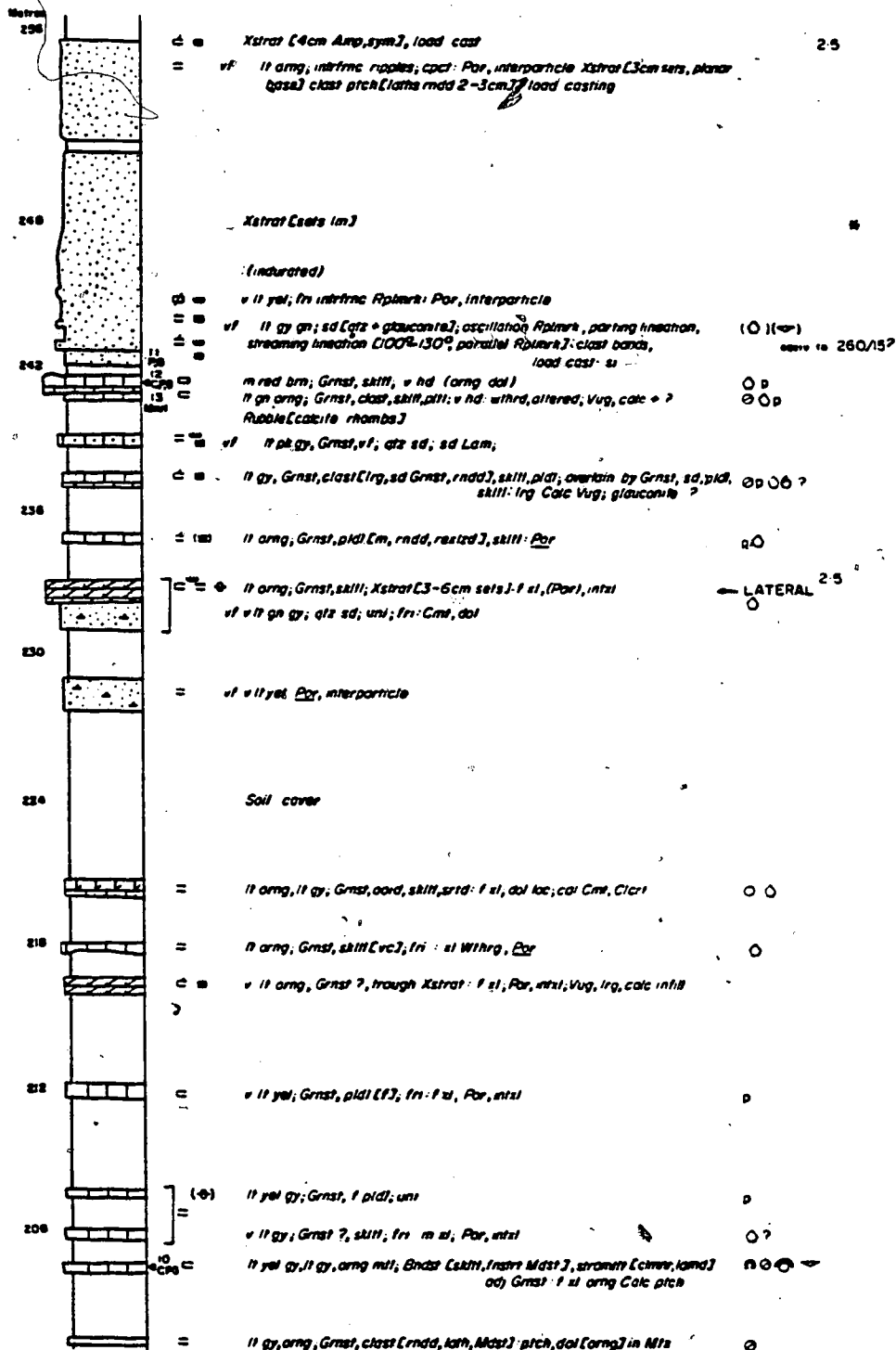
Chr Rub (Grst, oad, (pel, clast)) 0 0

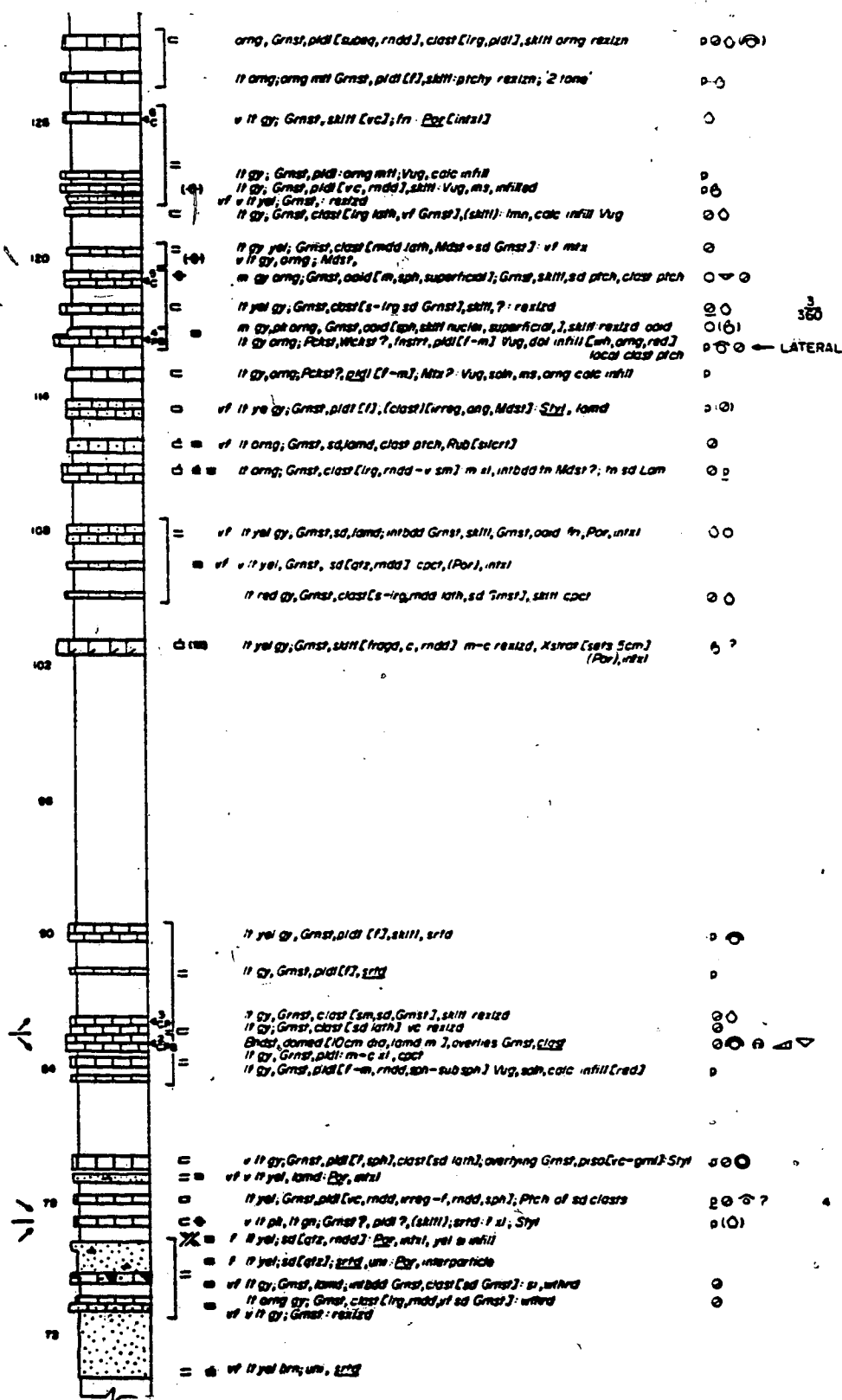
m gy, 1 gy mlt Bndst, ag, stromat Vug, s and F nll, rs; 301
 nll, rghulate Vug pattern 0

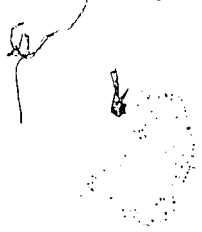
m gy, pel Grst? pel (c, rrad): apctd, Styl 0

SECTION GEO 269

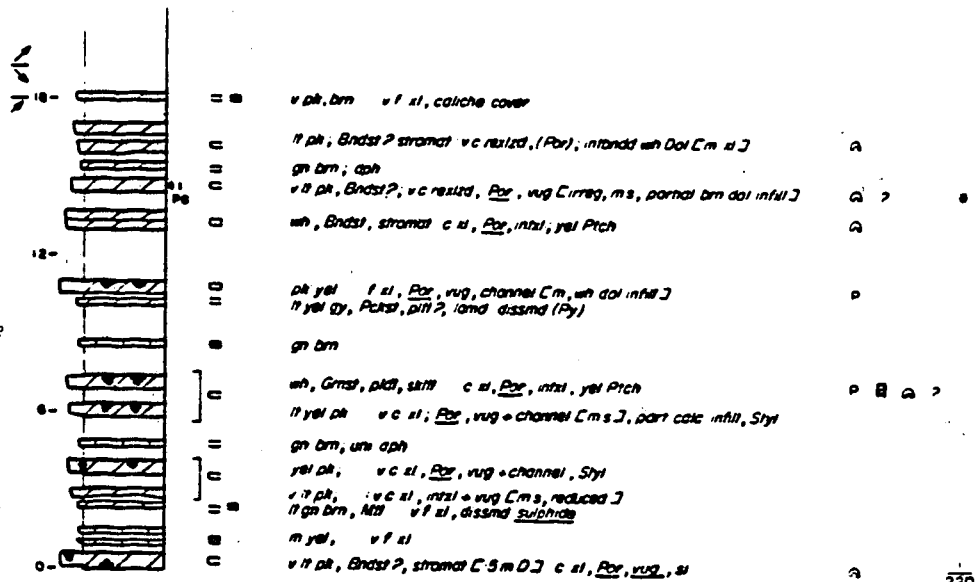
B







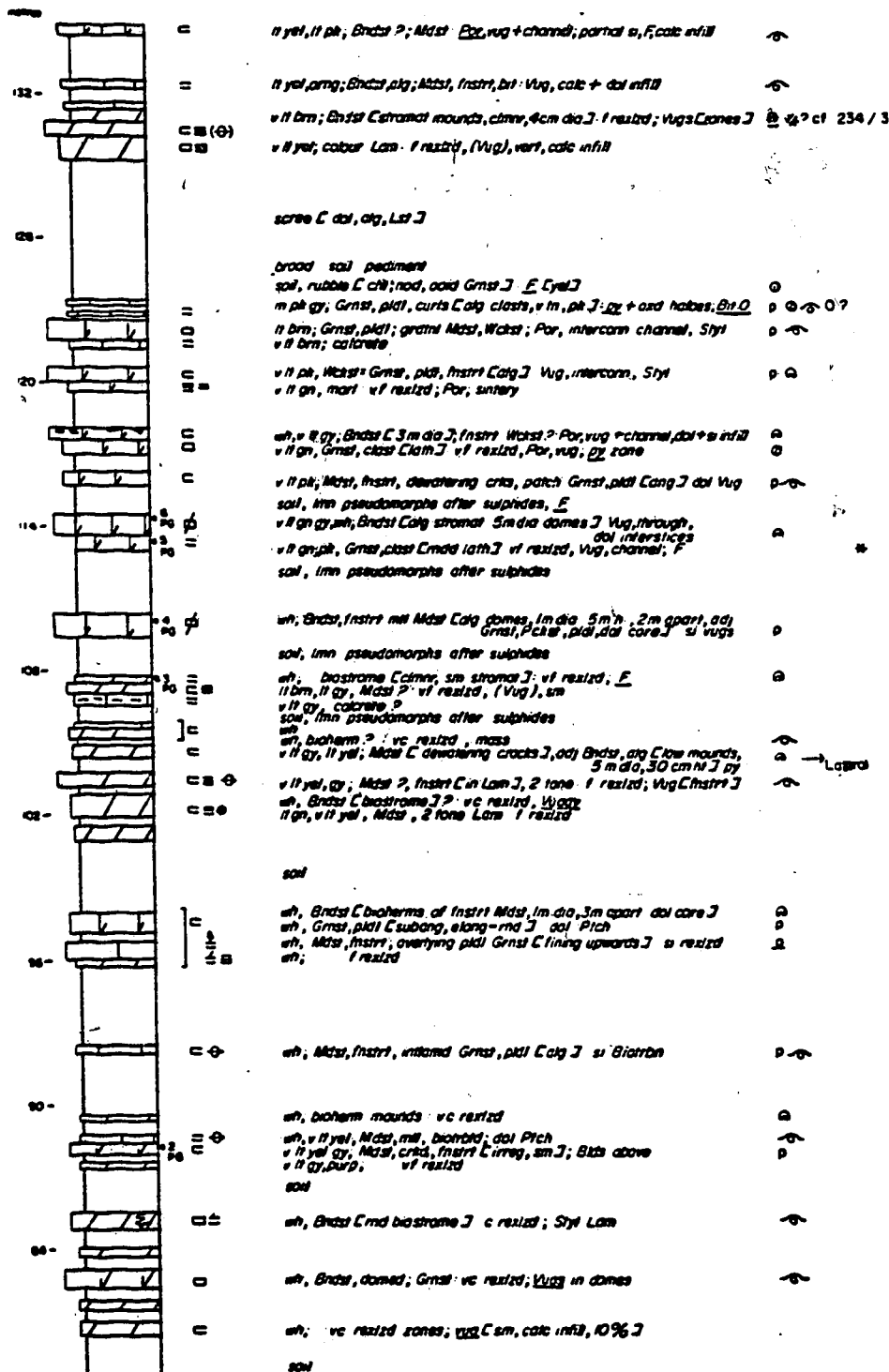
DATE 17-49-9-75
GEOLOGIST B. Radke
MAP SHEET Tobermory
F54/A10/15

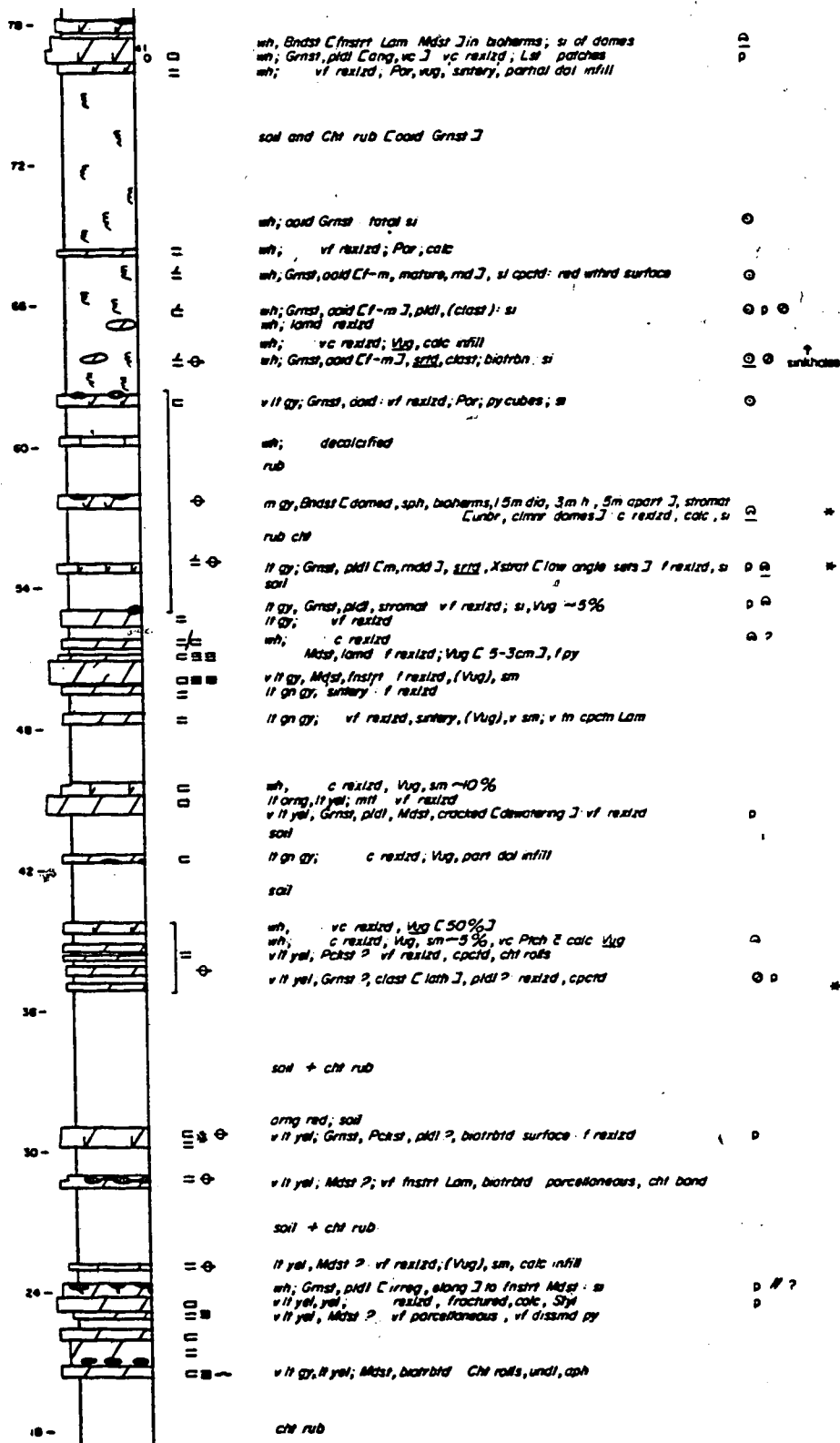


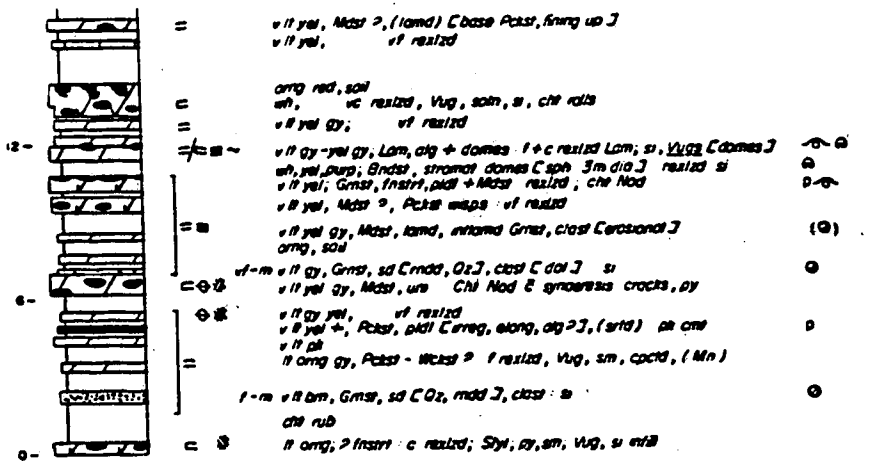
DATE 24, 25-7-75
GEOLOGIST B Rode
MAP SHEET Georgia Basin
F54/A10/125

base of C

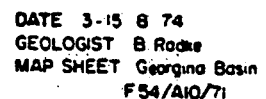
SECTION GEO 236



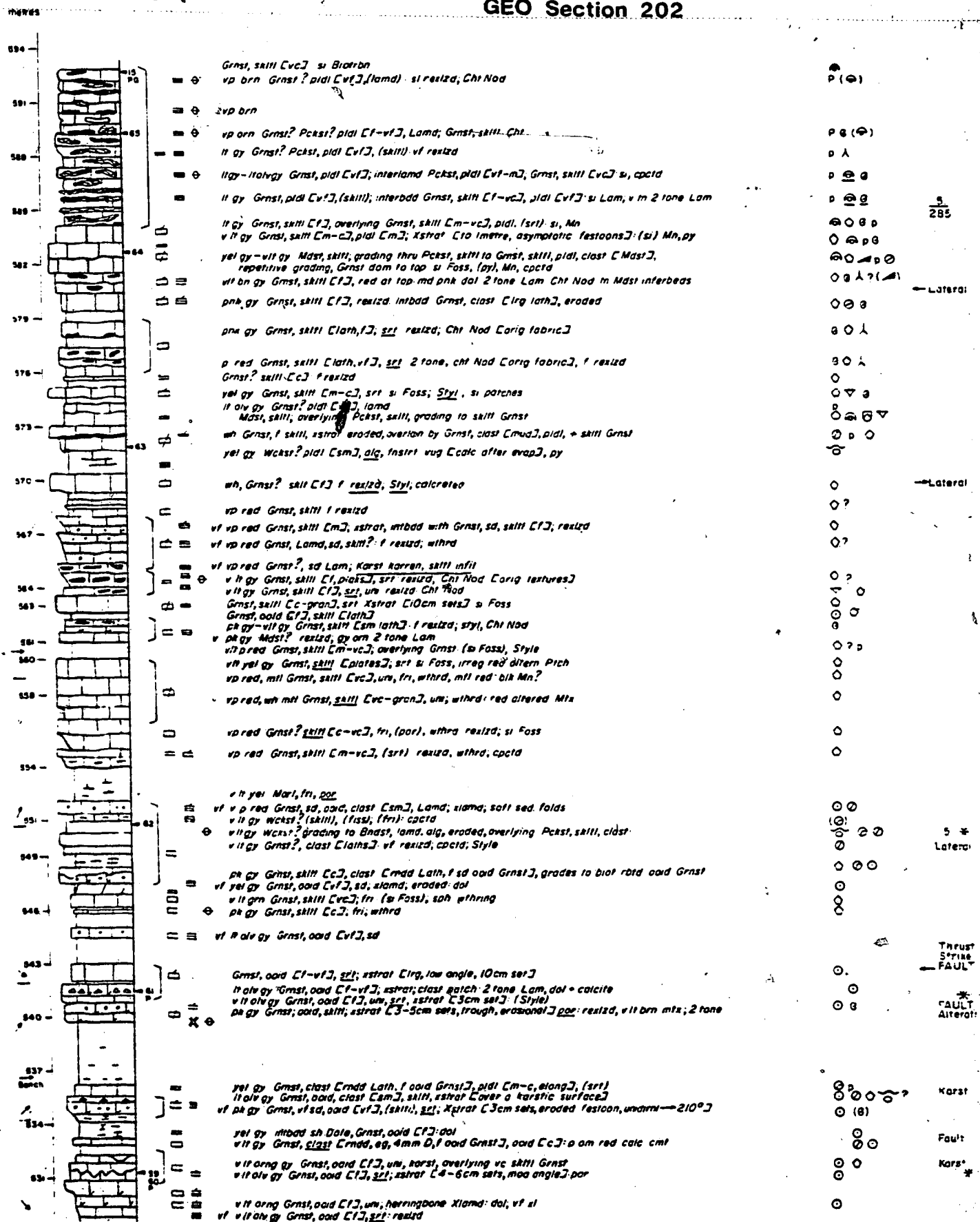


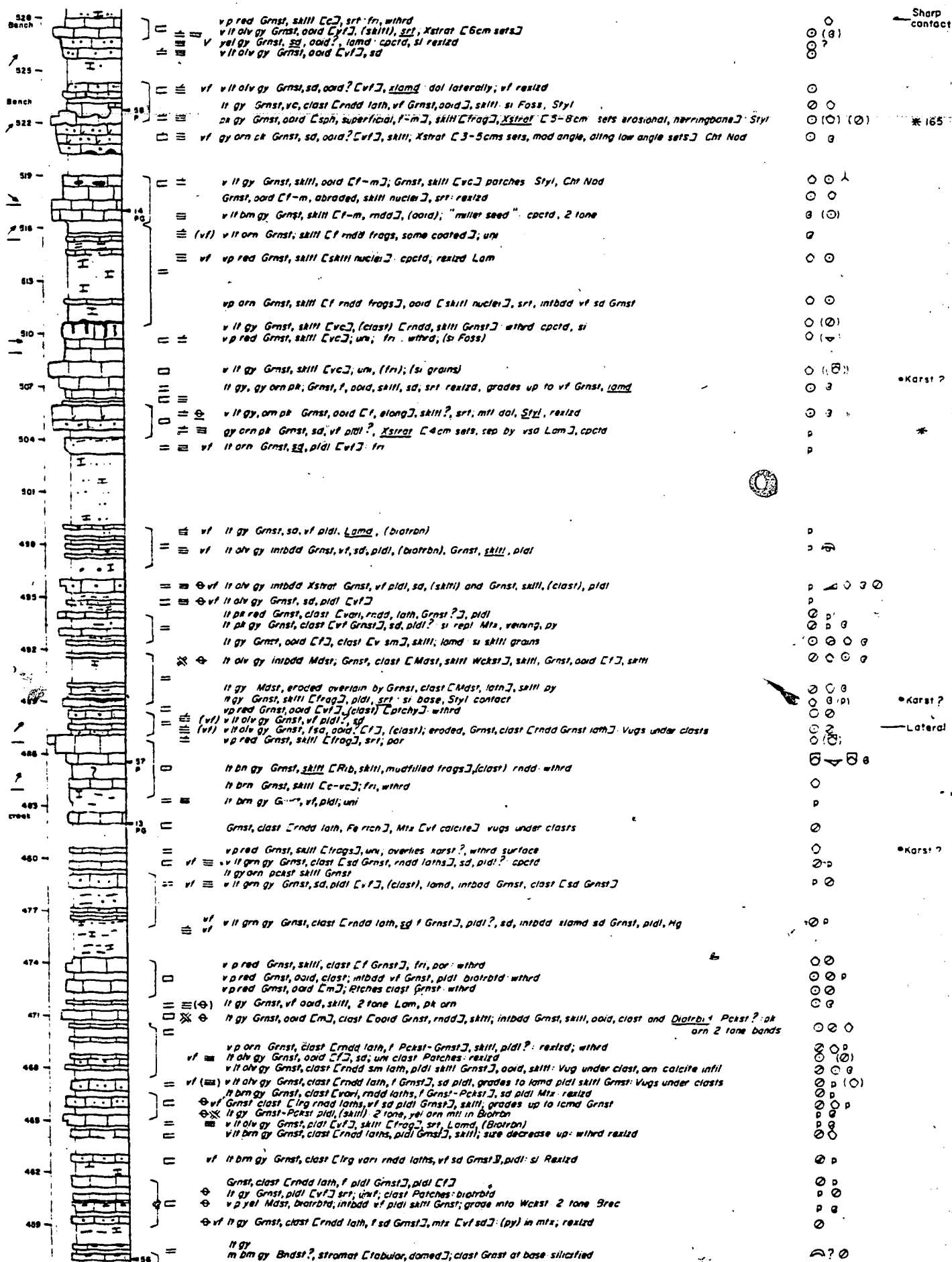


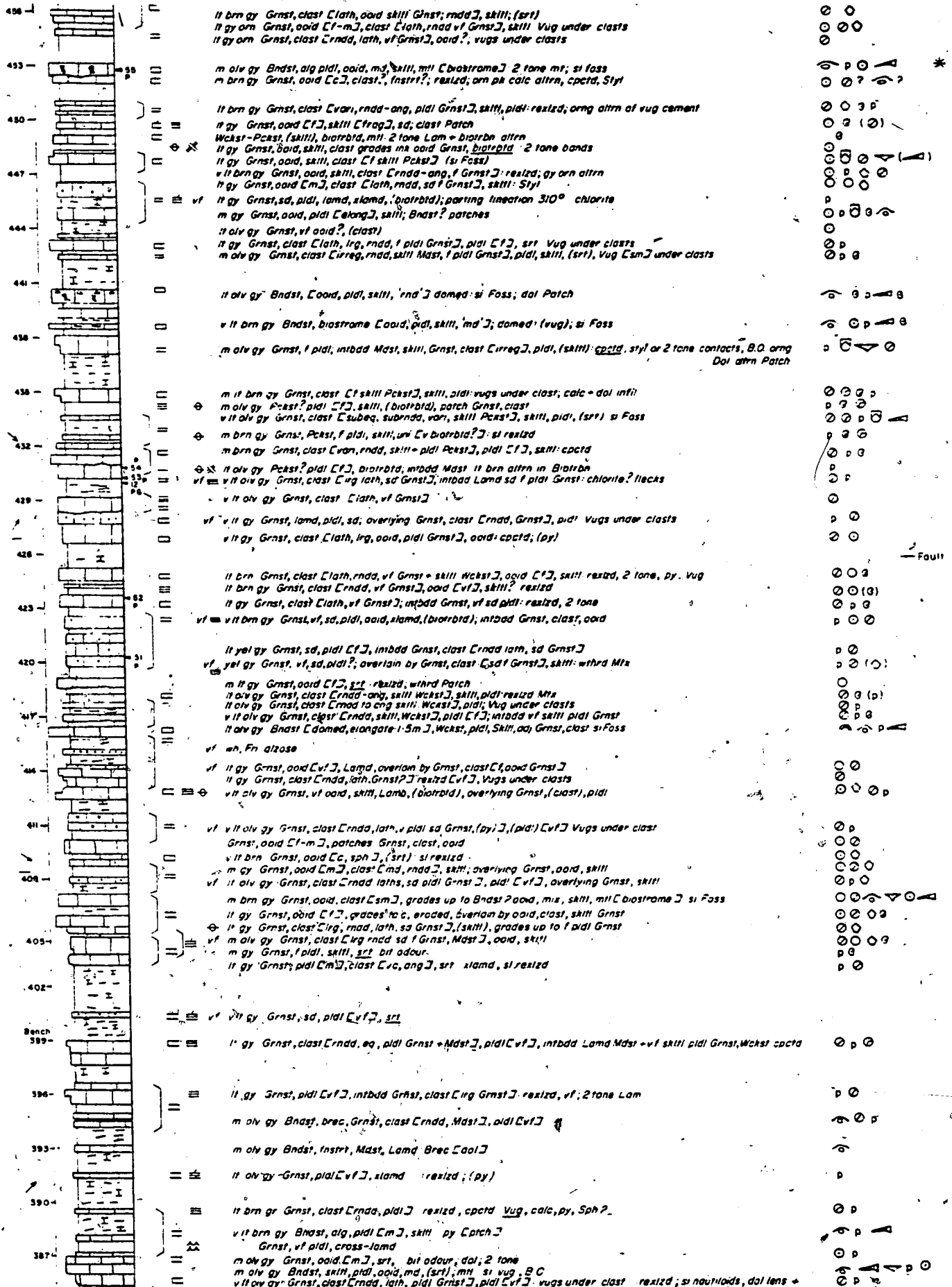
DATE 18-19-6-75
GEOLOGIST: B Radde
MAP SHEET Genarmston
F94/A10/114

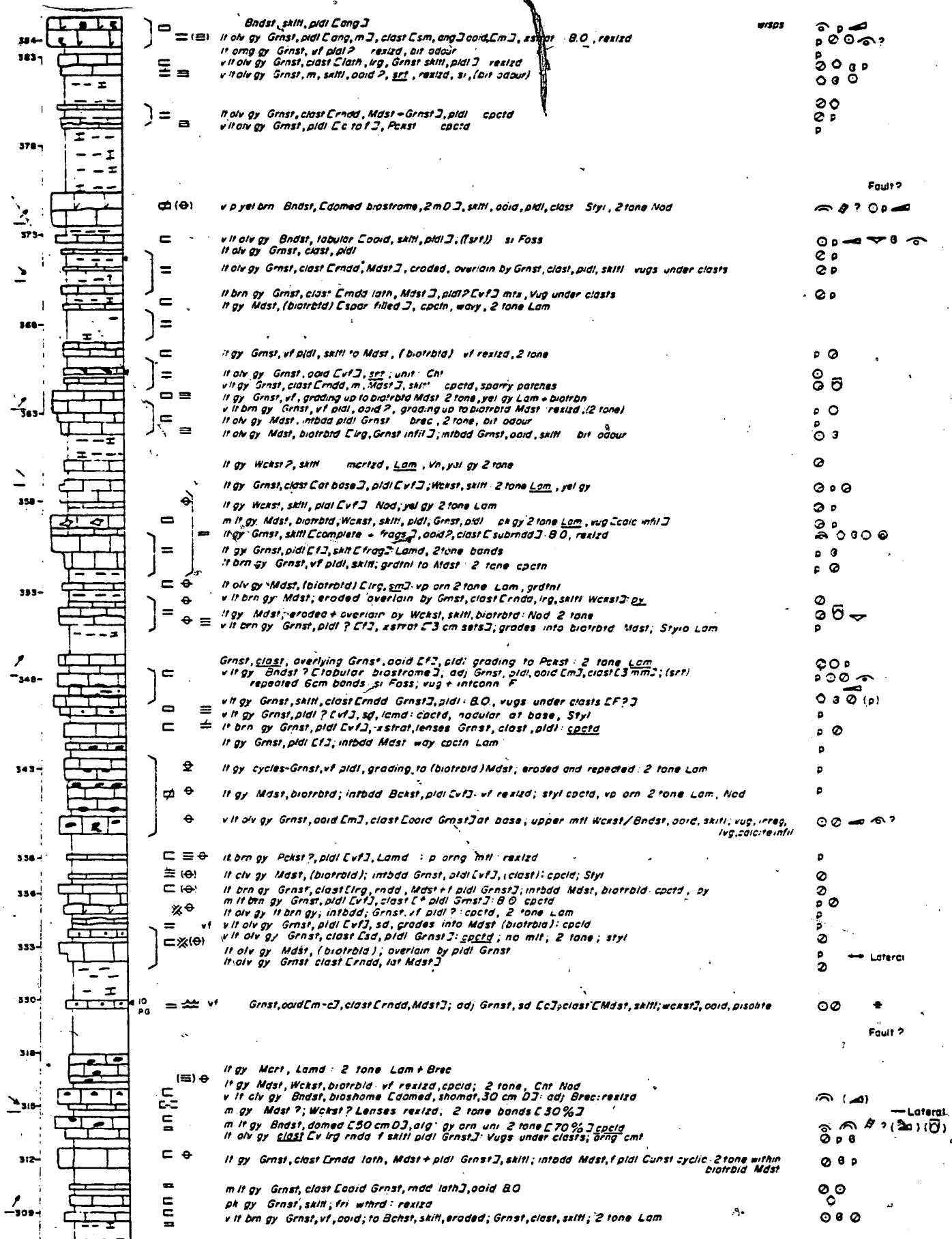
Abstract

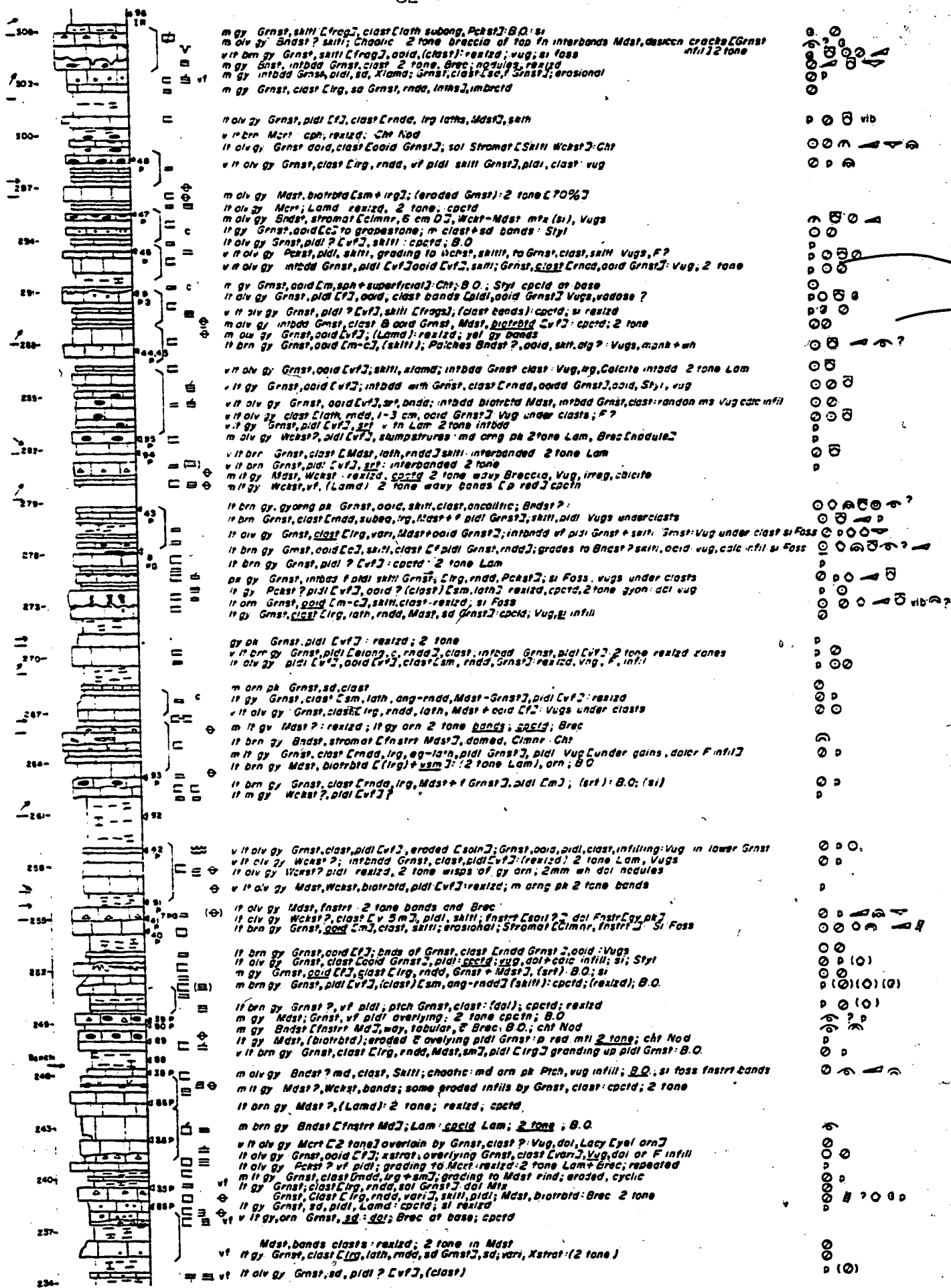
F - Type Section (Mount Unbunmaroo)
GEO Section 202

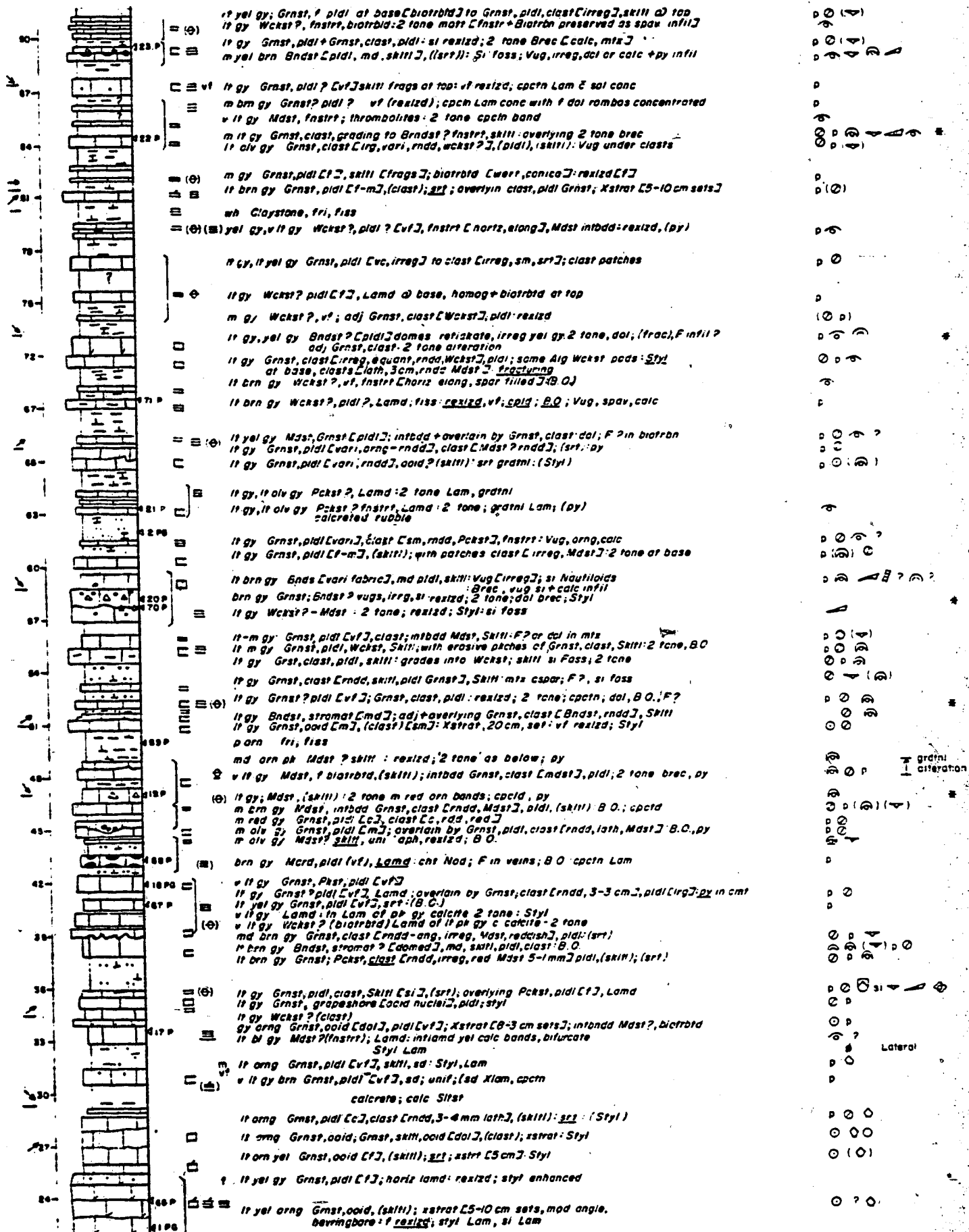


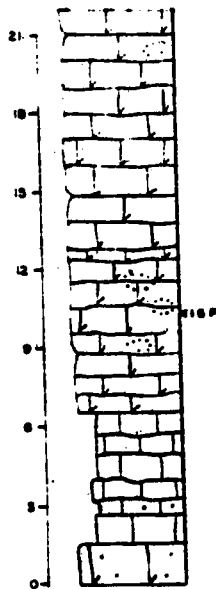










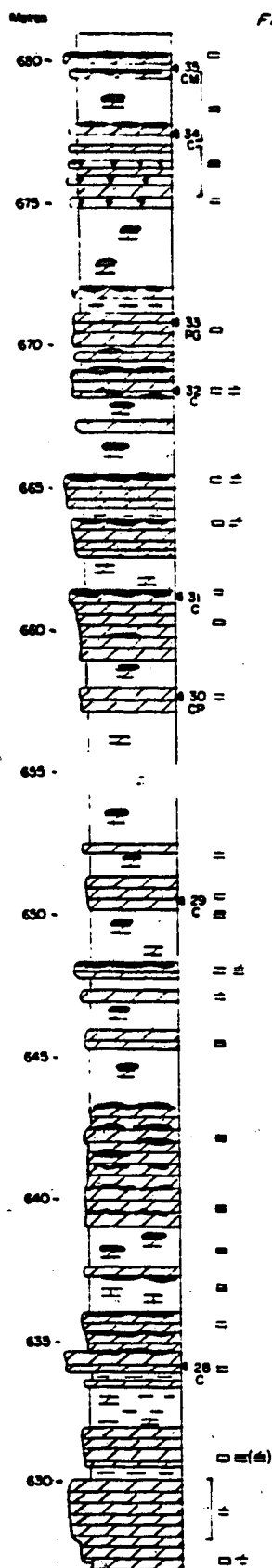


- lt yel brn Grnst, ooid, (skM), Xstrat: dol repl coids; f realzd; (styl)
- lt orng pn Grnst, ooid, skM; Ernd; Xstrat: vari from 40 cm
sets to 15 cm festoons with
erosive tops, skM coids
at base
realzd, m; dol ?; Styl, Lamd; (py)
- dk yel orng Grnst, ooid Cm, sph, dol; si Rings; Vug, calc; (py)
- lt orng Grnst, pldi Cm, skM: orn Dol Crepl grn; (py)
Xstrat: 30cm sets, erosive base, mod angle
- lt yel fri: f realzd; por
- (B) vt lt orng Grnst, p, pldi Cuf, sd; (Lam), sd, w tn: f realzd
- vt md gy+lt orn Grnst, sd, pldi C, uni; el realzd

DATE 1976
GEOLOGIST: B M Radke
SHEET AREA: GEORGINA
BASIN
AUS/1/705

SECTION GEO 228

G



FAULT - UPTHROWN TO N

Wlt yel Grnst ? , sktll , rexizd , si interstices
Wlt yel Grnst , sktll si Foss thru

It yet Grns? skm, plit? si infil interstices
It yet rexizd

It'ye! sponges mxi, intbad ē chi Lam
It'ye! Grnst?; skill (v); dense s; Foss

Rub, s:

Grnst, skltl
wh, vlt yel: rexlzd, vc calc infil Vugs, (sl)

with yet relaxed, VC, Vugs

v't brn Grnst, skill, pill [m] si on surface
nyet, skill. vc rnzld; lrg vugs, calc infil, si Foss
v't yet Grnst, skill [vc-gran]; clast [lath, 2-5 cm]

wh Grnst, sklti [gran] · interstices s.
wh, sklti ? vc, raxizd, vuggy
wh Grnst, sklti [gran]. si Foss o' rod
vlt brn, 'heavy' vc, raxizd, vug

v n yel,wh Grnst,skitl[vc] si surface

wh, l1 brn Grnst, sktl : rexizd, Yug
wh Grnst, sktl [vc] s: Foss
Grnst, sktl rexizd

Rub

Rub, encrinoidal

wh Grnst? , vt skill

u l' yel Grns^t, skilⁿ [vc] Py, u^t dissma

11 orn skiff; scours, 4cm: si Foss
11 orn Grnst, vf

It yet Grnst, f' skill? [f]

morn Grnst, plfl? rexld

m orn spiculite ? Cht Lam-ē pores; Mn

Rub

lt brn; spiculite: sl rexlzd; Cht Lam

It brn Grnst, plll? sl rexld; wh chr Bnds

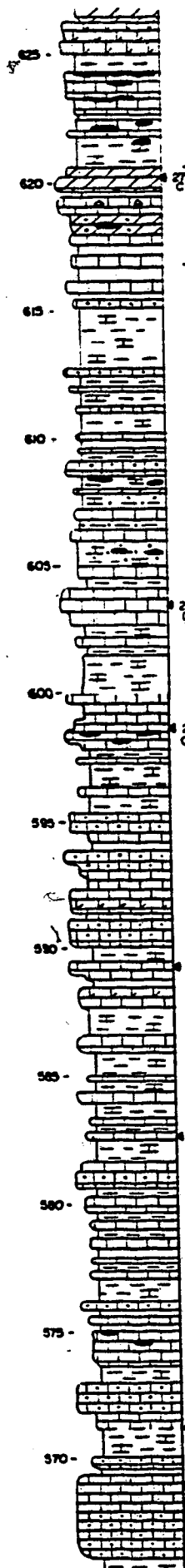
lt brn Grnst ? , sktl . rexlzd ; si of tn zones

vlt brn; (skl?l): rexizd

v lt brn ; Xstrat [10cm seas, mod angle]

vlt buff; sponges; Xstrat [low angle 10cmsets] rexizd

Lateral

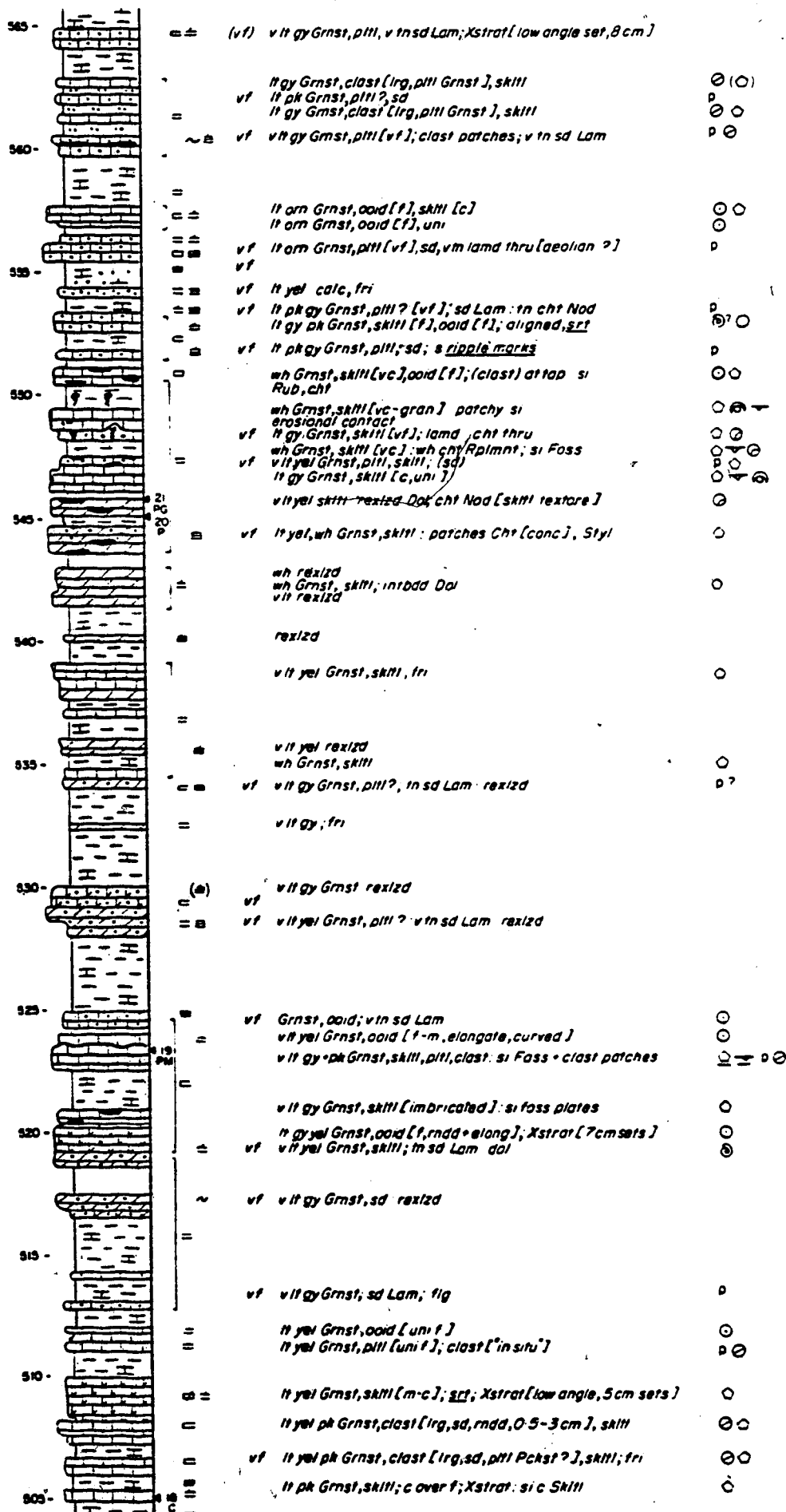


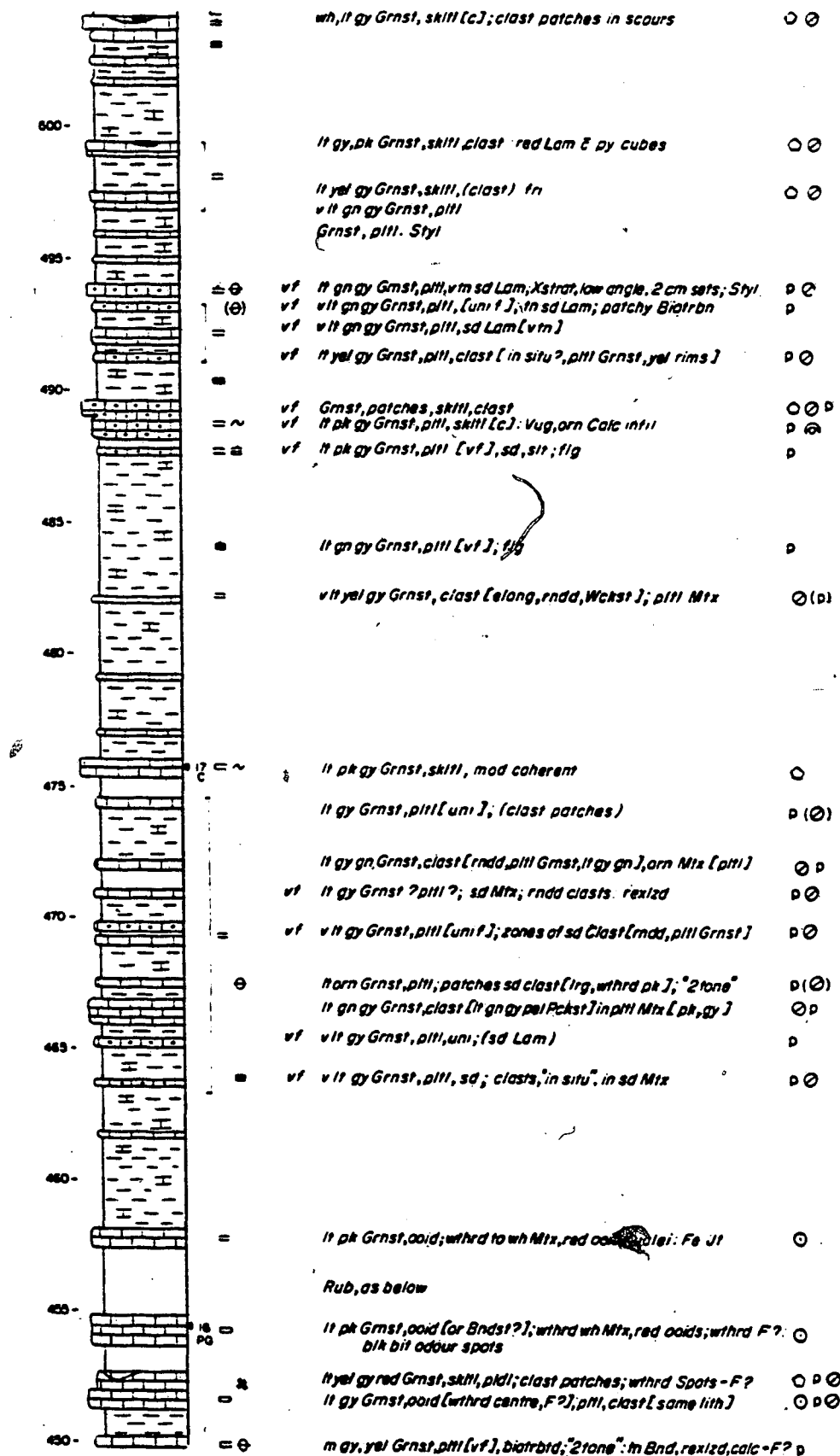
- It yel gy Grnst, f, skll; patches of sponges; Xstrat [set 20 cm] dol thru; Styl
- vt gy Grnst, skll [f-si to c] relaxed
- It pk gy Grnst, pth [f], sd Lam, trails in, sinous
- wh Grnst, skll [vc-m]; (si Foss)
- wh Grnst skll, clast (si), si Foss
- (vf) It yel, spicwlg
vt gy Grnst skll [vc] si of some frags
vt gy Grnst, skll [vc-gran]: si of some Frags
vt gy Grnst, skll [f-c], vc in patches at top; fri. si
vt It pk Grnst, pth
- vt vt gy Grnst, pth; in sd Lam; Xstrat [mod angle, 3 cm sets]
- (E) vt It pk gy Grnst, pth, v in sd Lam
vt gy Grnst, skll, oad, clast [tn lath]
- vt vt gy Grnst, skll [vc] si Foss
- vt It gn gy Bndst, skll, clast: si thru, patchy
vt It gy, orn Grnst, skll, clast: orn Calc Rdmnt
- vt It yel brn Grnst, vc skll si Foss
It gy Bndst [Mdst], skll, pld, si Vugs; Styl
It gy Wkst, Bndst? skll, clast; mud; mll gy Styl
It yel gy Grnst, pth [vt], to clast; Bndst, skll, clast [rdd]: Vug
- crnld; fiss
vt gy Grnst, skll [f]; uni si Nod
vt gy Bndst, lamd, mud, skll, biotrbld: si soln Vug
- It pk Grnst, pth [f]
- (E) vt It pk Grnst, pth [f], Xstrat [v low angle sets 3 cm], X Lam
- vt It pk Grnst, pth [grt], uni; Xstrat [5 cm low angle sets]
- vt gy Grnst, skll [platelets], uni; c sets
vt yel Grnst, skll, uni, grt; Xstrat, 5 cm Styl
vt vt yel Grnst, skll [m]; Xstrat [sets 4 cm], vc si Foss
- wh pk Grnst, skll [c]; uni. withd pk spots
vt yel Grnst, pth, skll, f
It yel Grnst, skll, pld [m], v irreg surface
- It gn gy Grnst, oad, skll, pth?, (vc patches): Styl
It pk Grnst, pth [vt]
- It pk gy Grnst, clast [rdd, sd pth Grnst] to skll: si Foss
- orn brn Grnst, skll [vc]; v fri. si Foss
- Grnst, skll, clast [rdd, 2 cm]; patchy, fri
vt vt gy Grnst, pth [vt]
pk, gn gy Grnst, pth, skll, clast [gran, ang], grt
vt gy Grnst, skll [f-c in patches]: (si Foss)
vt yel Grnst, pth
It pk gy Grnst, pth [f]
- vt It pk gy Grnst, pth [pk, f], clast [mud, gran]
vt yel gy Grnst, skll [c]; fri vc patches
It yel gy Grnst, skll [vt-m], grt: si Nod; si Foss
vt yel Grnst, skll [vt], uni
- (vf) vt gy Grnst, pth [vt], uni; patches skll, clast [rdd]: Styl
vt gy Grnst, pth [vt], uni; in sd Lam; Xstrat [steep 2 cm sets]
It yel gy Bndst, pth [md], pld; Stromat [rdd, domed, separate, 5 cm]
- vt pk gy Grnst, pld [rdd], pth [vt], grt
m gy Grnst, oad [f, md, mature]; Xstrat [low angle]; skll
patches: contact Styl
It yel Grnst, pth [vt]; Xstrat [3 sets, 10 cm coset, opposed]; fri
- (vt) It orn Grnst, pth [vt], in sd Lam; Xstrat [2 cm sets]

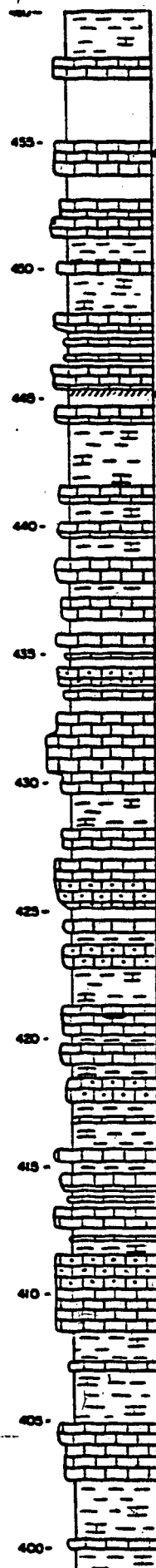
12
36

Lateral 10
315

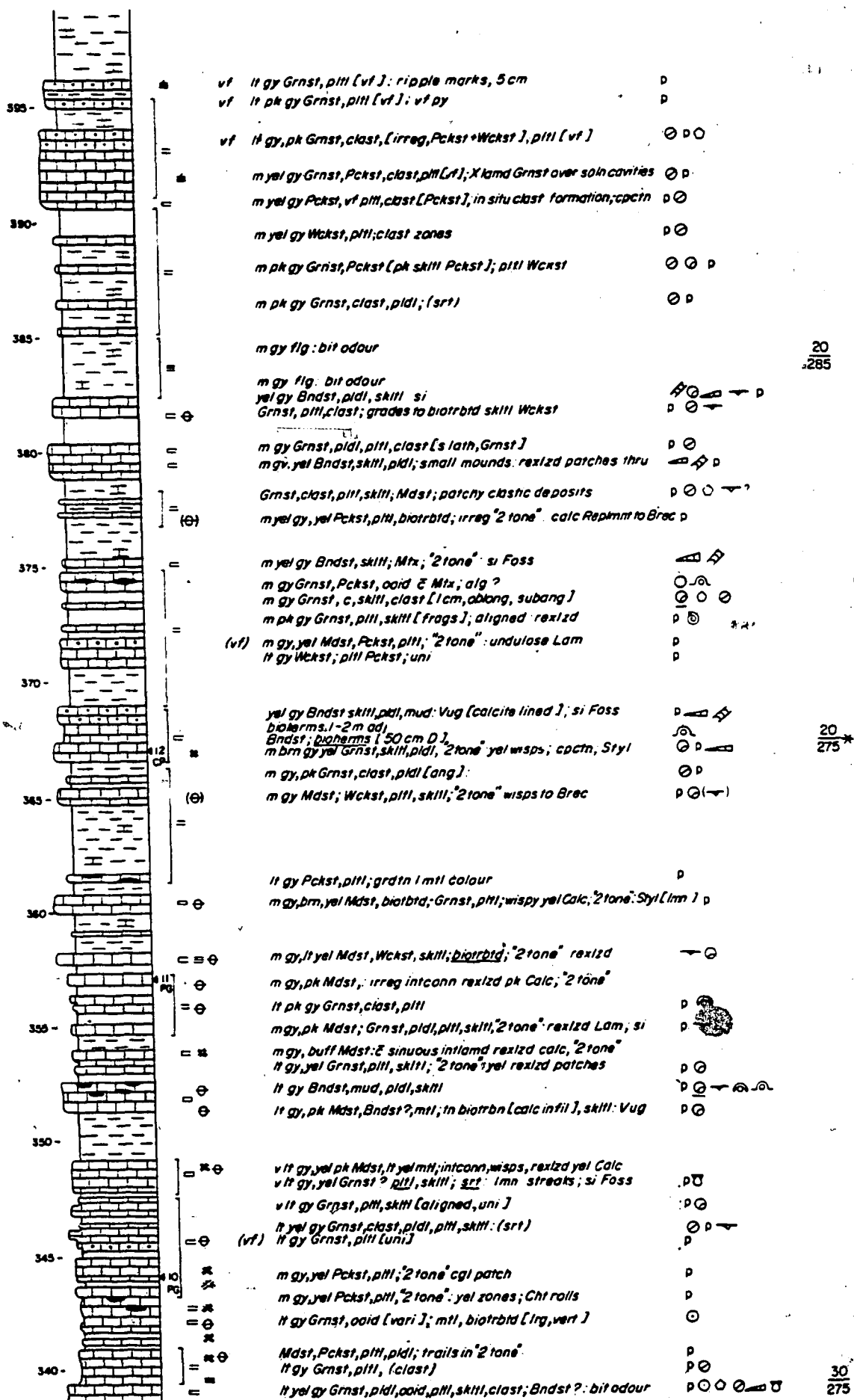
15
296

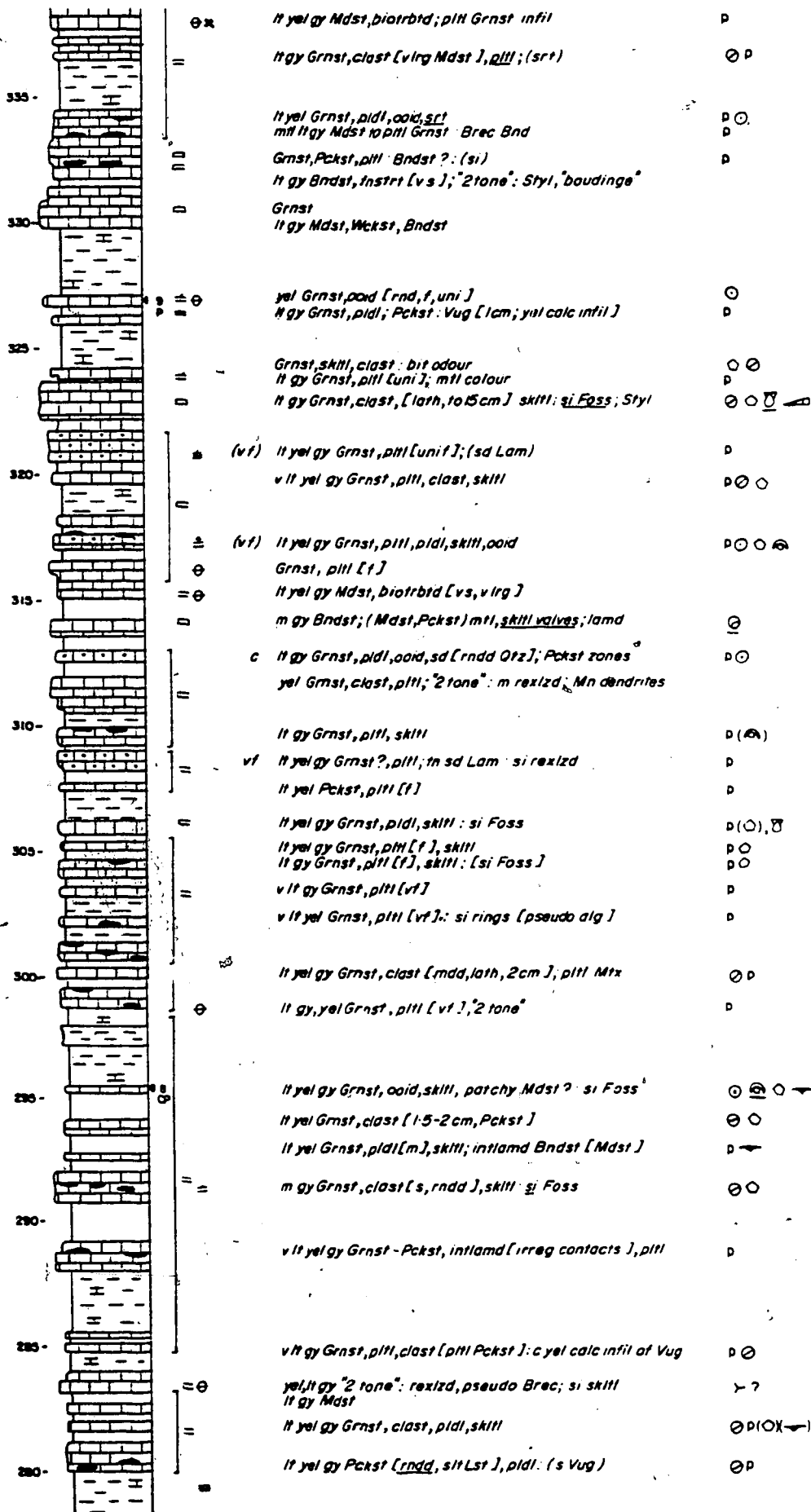


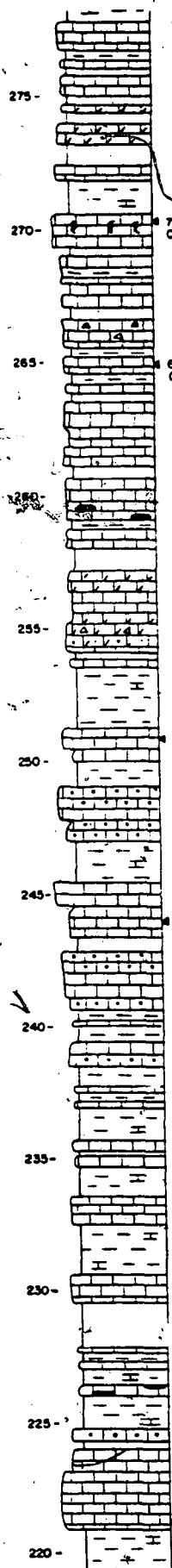




	lt pk Grnst, ooid; withrd to wh Mtx, red ooid nuclei: Fe Jr	⊙	
	Rub, as below		
455-	lt pk Grnst, ooid (or Bndst?), withrd wh Mtx, red ooids; withrd F? blt bit odour spots	⊙	
	lt yel gy red Grnst, skiff, pldi, clast patches; withrd Spots - F?	⊙ ⊙	
	lt gy Grnst, ooid (withrd Centre, F?), pldi, clast (same lith)	⊙ ⊙	
450-	m gy, yel Grnst, pldi (vf), biotrbtd; "2 tone": in Bnd, rexlzd, calc + F?	⊙	
	m gy + red Grnst, pldi, ooid, skiff; Grnst, clast patches	⊙ ⊙ ⊙	20
	m pk gy Grnst, pldi, clast, skiff	⊙ ⊙	305
	m gy Grnst, pldi (m) rexlzd	⊙	
	lt gy Grnst, clast (pld Grnst)	⊙	Lateral
445-	vt gy Grnst, pldi (clast): pk yel withrg; Styl	⊙	
	yel, red Gossan, fn, calc, assoc & fault line	⊙	12
	lt yel Wckst?, pldi?: sl rexlzd	⊙	275
	yel pk Grnst, clast, skiff wh Calc Vng	⊙ ⊙	
440-	lt yel pk Grnst, clast	⊙	
	lt gy yel Bndst, pldi (alg), skiff: si Foss	⊙ ⊙ ⊙	
	lt yel, lt gy Bndst, pldi, skiff, mud; mlt: Fe sulphide in Crk; si Nautiloid	⊙	Fault?
	gy yel Grnst, clast (pld Grnst); Fe trails	⊙	
435-	gy yel Grnst, skiff, pldi	⊙	
	vt m yel gy Grnst, clast (pld Grnst), pldi; sd Lam	⊙	
	lt gy, yel Mdst, Wckst, biotrbtd; "2 tone" Lam	⊙	
	lt gy Bndst, pldi, clast, skiff	⊙ ⊙ ⊙	
	dk yel gy Bndst, ooid, alg, skiff: si Nautiloid	⊙	
430-	Grnst, pldi, clast	⊙	
	Grnst, clast, pldi, pldi	⊙	
	m gy Grnst, clast (pld Grnst); Vug, soln (under clast)	⊙	
	Grnst, clast; "2 tone"	⊙	
	lt gy Grnst, clast, (pld Grnst), pldi	⊙	
425-	lt gy Grnst, pldi; flg: rexlzd, vf py	⊙	
	m m gy Grnst, clast (varying Lith), mdd m Qtz Sd: vf py	⊙	
	vt lt gy Grnst, pldi (uni), clast (insitu, orn rims): Vug, soln prn	⊙	
	dk gy Bndst, pldi, ooid, alg, md: Lm withrg	⊙ ⊙ ⊙	
420-	yel gy Grnst, clast, pldi; "2 tone" intlamd	⊙	
	yel gy Grnst, pldi; clast bands; Crk, vert, orn Calc infil	⊙	
	Mdst	⊙	
	vt yel gy Grnst, pldi, clast (rndd, pld Grnst): orn Vn infil	⊙	
	yel gy Grnst, pldi, clast (rndd pld Grnst); intfrnc ripples: orn Calc	⊙	
415-	dk gy, yel gy Bndst, dk, ooid, alg, md: Lm withrg	⊙ ⊙ ⊙	
	lt yel gy, gy Grnst, clast (lrg, mdd, Grnst), pldi: clasts, yel Calc rims	⊙	
	m gy yel Grnst, pldi, skiff, clast (rndd Pckst, skiff)	⊙ ⊙	
	dk yel gy Bndst, md, alg; mass	⊙	
410-	vt m pk gy Grnst, pldi, sd Lam; Xstrat (low angle, 3 cm set)	⊙	
	m yel gy Grnst, pldi, um, X lamd, intbdd Grnst, clast, pldi		
	m yel gy Grnst, Pckst, pldi, clast (rndd; in situ); intfrn ripples	⊙	12
			275
405-	m gy, yel gy Bndst, md, skiff; 50cm mounds, biotrbtd	⊙ ⊙ ⊙	
400-	m yel gy Grnst, pldi, (skiff), (clast) (insitu formation)	⊙ ⊙ ⊙	







vt yel gy Grnst, clast [biotrbtd Mdst], pldl [m]
 wh: rexizd
 yel, ph: rexizd, Mn stnd
 yel: rexizd, c&vc
 vt gy Mdst, biotrbn [tn, Cmt intil]: Brec; dol replmnt
 th yel gy Grnst, ooid [c, rndd], srt: dol Styl Bnd; bit odour

⊙

⊙

lt gy Wckst, ooid, sklll, pldl, clast: si Foss, clast
 lt yel gy Pckst, pldl, tn Bnds [sklll Grnst]
 lt yel gy Pckst, pldl, sklll, clast [Pckst, pldl]
 (vt) lt gy Grnst, pldl [f], lamd [reg]

⊙ ⊙ ⊙

⊙

⊙

⊙

⊙

⊙

lt yel gy Mdst Brec, cpcl
 m gy Grnst, pldl [vt]: bit odour

⊙

lt gy Grnst, ooid, pldl, clast, sklll [si]

⊙

vt gy Grnst, pldl, sklll [frags]

⊙

lt gy Bndst, irreg fnsrt to pldl

⊙

wh Pckst, pldl tn yel rexizd Lam

⊙

lt yel pk Wckst [wh], "2 tone" Bnds rexizd

⊙

Pckst, pldl [vt], irreg pk Lam, "2 tone"

⊙

lt pk gy Pckst, pldl [vt], pk brec Bnd

⊙

lt yel gy Bndst? (Grnst - Mdst intilamd)

⊙

lt yel gy Grnst, pldl [f - vc laths, irreg], pldl, (srt)

⊙

"2 tone"

(vt) lt gy, yel Grnst, pldl, "2 tone" yel dol, rexizd patches; styl Lam p
 m gy Grnst, pldl

⊙

lt yel gy Grnst, ooid [immature, wthrd], pldl [alg], si Foss
 Grnst, clast, sklll

⊙

⊙

vt lt gy, yel Grnst, pldl, sklll; yel sd Lam: si Foss

⊙

vt lt gy yel Grnst, pldl, clast; (sd Lam)

⊙

tn pk gy Grnst, clast, sklll; clast [Bndst?]

⊙

m gy Grnst, clast, sklll: si surface Foss

⊙

(vt) lt yel gy Grnst, clast [of below lth], pldl, sklll [frags]

⊙

lt gy Grnst, clast, (pld); (srt)

⊙

(vt) lt gy Grnst, pldl, (clast); sd Lam, tn

⊙

Grnst, clast

⊙

(vt) lt gy Grnst, pldl, (clast) [lrg Mdst], tn sd Lam

⊙

lt yel Grnst, clast, pldl: rexizd zones
 vt gy Grnst, clast [elong, rndd, Pckst], pldl py

⊙

⊙

lt may Grnst, mtl, pldl: Styl

⊙

wh, yel Mdst, yel Lam: Styl

⊙

wh Pckst - Grnst, p: (py)

⊙

lt gy Grnst, clast [lath, subang, Pckst], pldl

⊙

lt yel gy Grnst clast [lath, ooid Pckst], pldl

⊙

Grnst, pldl

⊙

lt gy Grnst, clast [ang], Bndst?

⊙

vt, m lt gy Grnst, pldl, sd: sd Lam; clasts [gran, rndd]
 lt gy Mdst, uni; laterally Grnst, pldl [gran]; clast [Grnst]

⊙

⊙

lt gy Grnst, pldl [c], pldl [f]

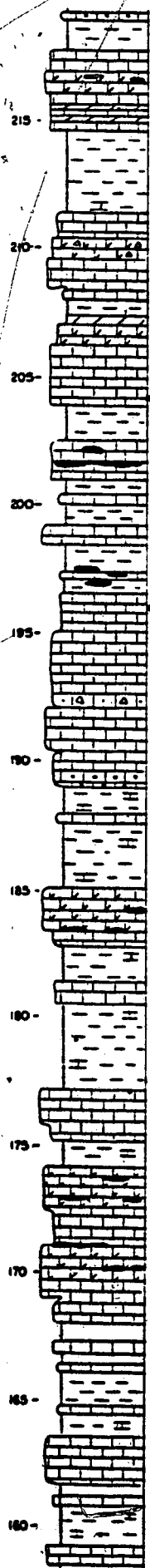
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lt yel gy Grnst, pldl, sklll [single valves], m; fig

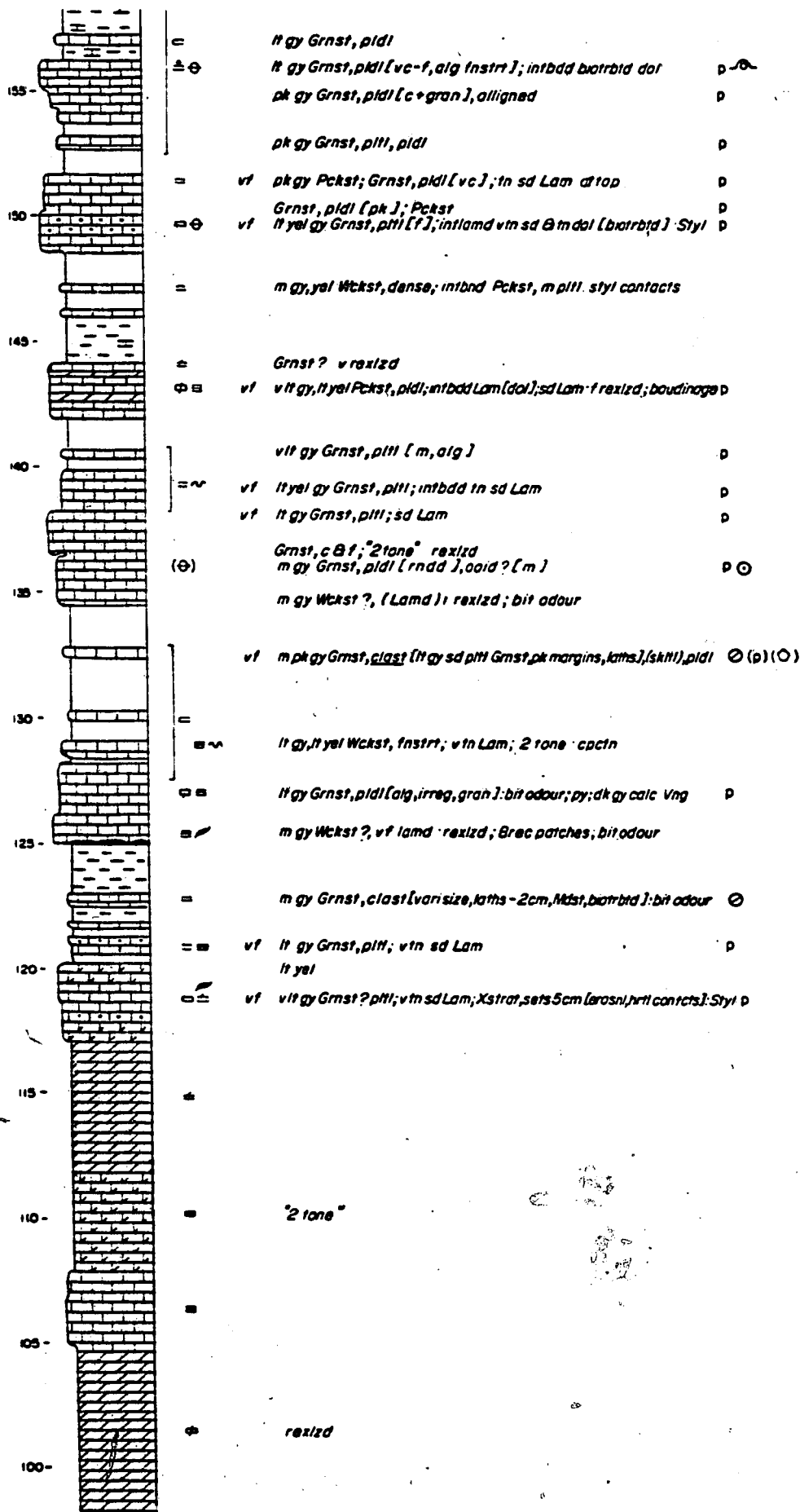
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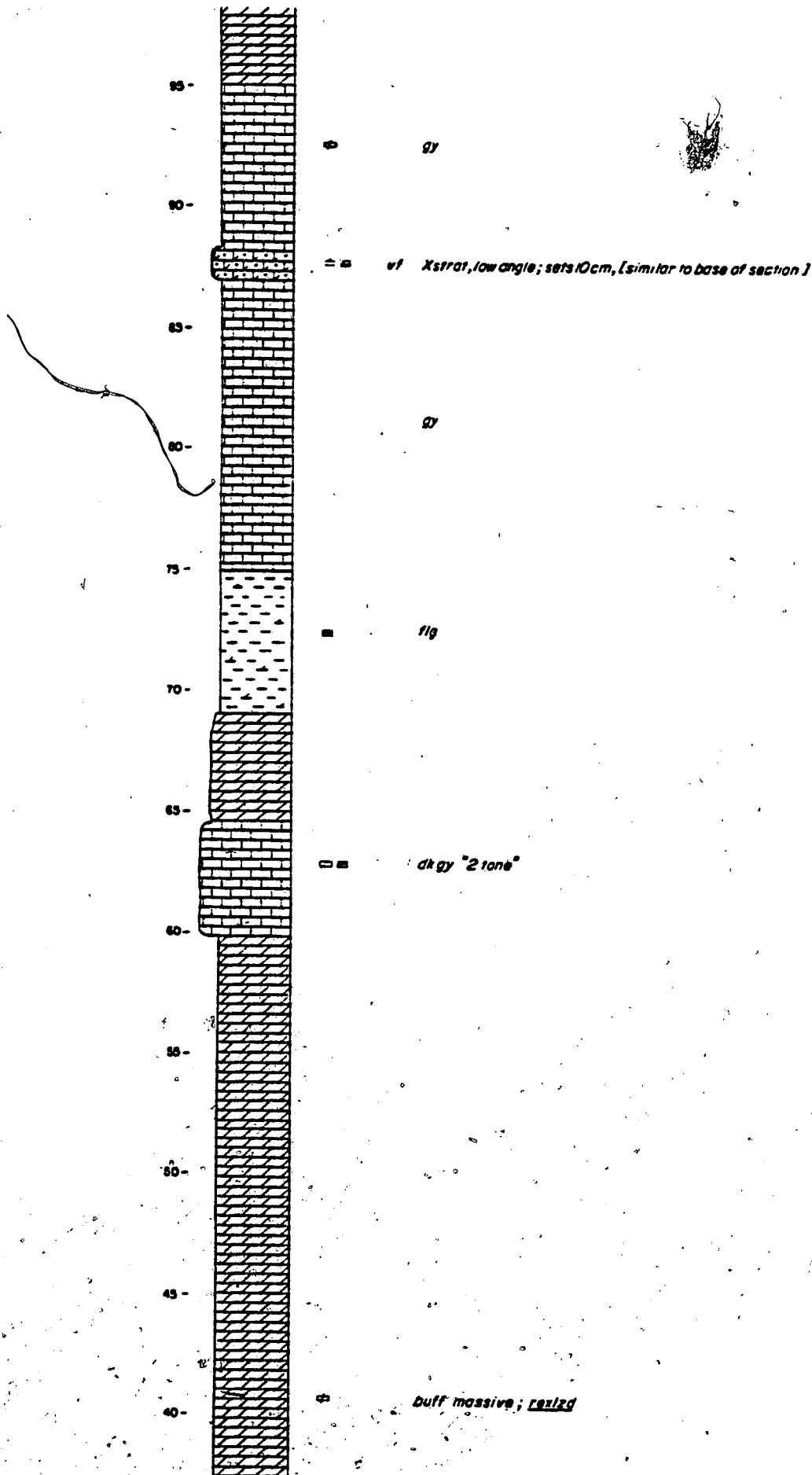
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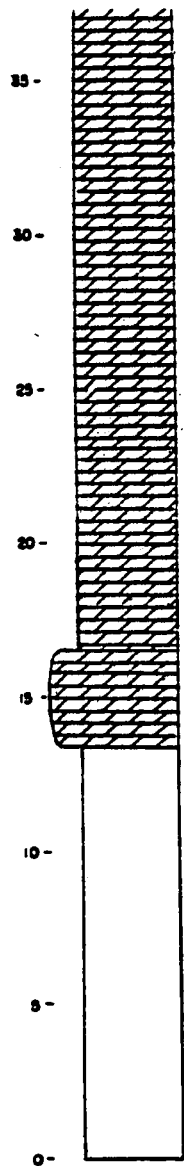
45
275



215	=	vf	lt yel gy Grnst, pili (vf)	D
	=		Mdst	
	=		wh, lt gy Mdst, gradling up to Pckst, pidi	D
	=		yel - rexizd	
	=		m gy, lt yel gy Mdst; intbdd yel dol (biotrbn); contacts sharp - gradn	
210	=		vt gy, wh Bndst, pidi, clast, mud; mtl: Styl	D O
	=		m gy, yel Brec, dol + calc	
	=		m gy, lt yel "2 tone" Brec: intbdd rexizd dol	
	=		lt gy Grnst, pili (vf)	D
205	=		Grnst, Wckst, pili, pidi (alg)	D O
	=		Grnst, pili, pidi	D
	=		Grnst, pili (vf)	
	=		lt yel gy Grnst, pili, pidi (gran Mdst, alg), skill	D O
200	=		lt + m yel gy Mdst & lt erosional surfaces bit adour	
	=		lt yel gy Mdst; few in pockets, Grnst, pili	D
	=		lt gy Grnst, clast (gran, rxdg)	O O
	=		vt gy, m pk gy Bndst, md, mtl Styl	
	=		m yel gy Grnst, pili (vf) bit adour; vt py	D
195	=		Grnst, pidi, skill (vc); intlamd dol	D
	=		gy yel Pckst, pili (vf) Styl	D
	=		gy yel Wckst (Bndst?); intlamd dol	
190	=		vt gy yel Brec: cpcn; Styl	O
	=		lt gy yel Wckst, alg?	O
	=		vt lt yel gy Mdst, dessicc cracks, infit & vt pili Grnst	D
	=		vt lt yel Mtl; intlamd sd Grnst	
	=		lt gy Mdst	
185	=		lt gy Grnst, Bndst; clasts (gran), pidi (alg) Styl	O D
	=		vt lt yel gy Bndst, lamd; small erosional surfaces	
180	=		vt lt gy Grnst, pidi (gran)	D
	=		vt lt gy Grnst, clast; Bndst? si (clast)	O D
175	=		wh, yel Bndst?, intlamd wtn yel dol Bnd	
	=		lt gy Grnst, Bndst? pili: rexizd	D
	=		m gy Grnst, pidi (t); Bndst (Mdst), & clasts	D O
170	=		lt gy, yel Grnst; in Lam, intbds biotrbn dol	D
	=		vt lt gy Grnst, pidi (vc-m, irreg)	D
	=		lt gy Grnst, ooid, pili (m), clast (Grnst) at top	O D O
165	=		lt gy Wckst, Pckst, mtl	
	=		(vf) lt gy Grnst, pili (vf); Xstrat (sets 10cm, eroded base); wtn sd Lam	D
160	=		yel gy Grnst, pidi	
	=		lt pk gy Grnst, pidi (gran lath, aligned); vt py in Cmt	D







— = *red gy; Xstrat, low angle, set's 10cm*

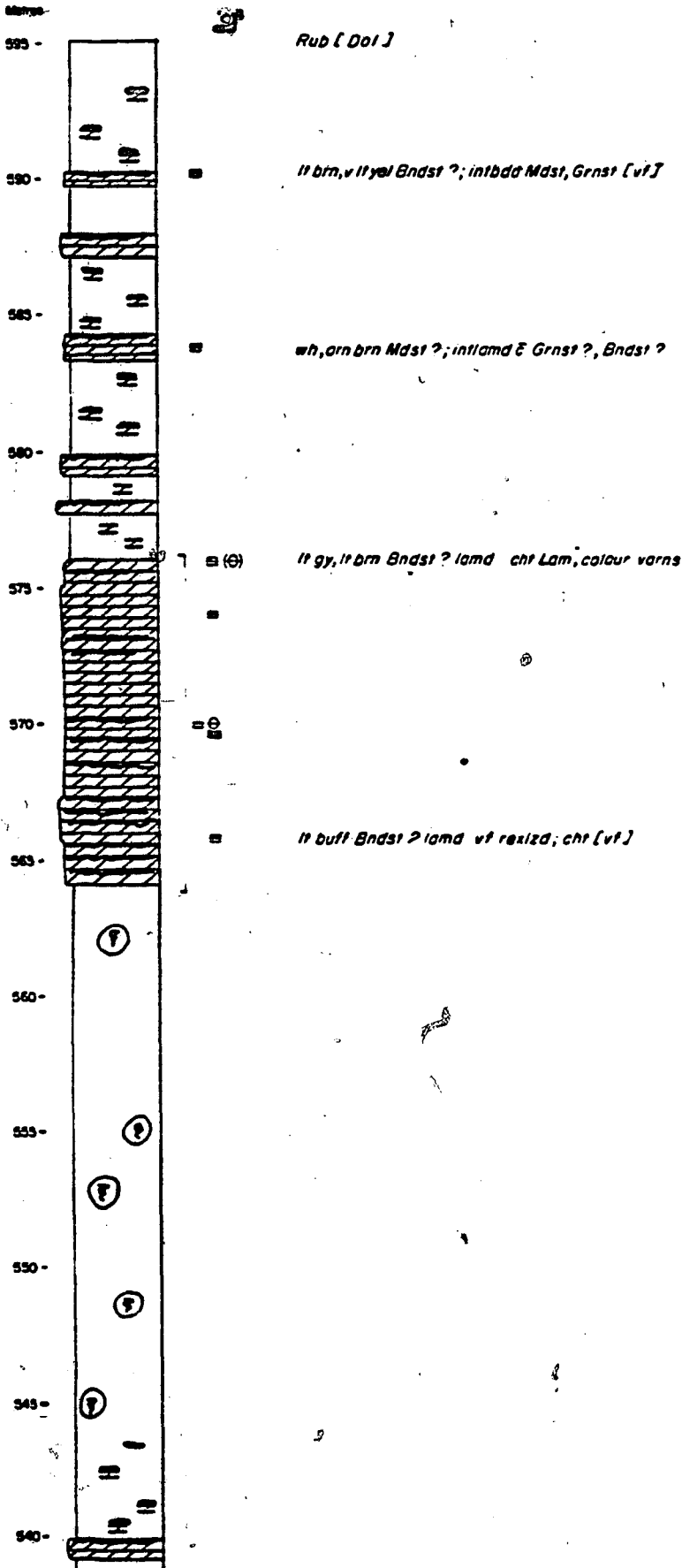
DATE: 3-4-6-75
GEOLOGIST: B. Radke
MAP SHEET: Boulic

F 54/A10/94

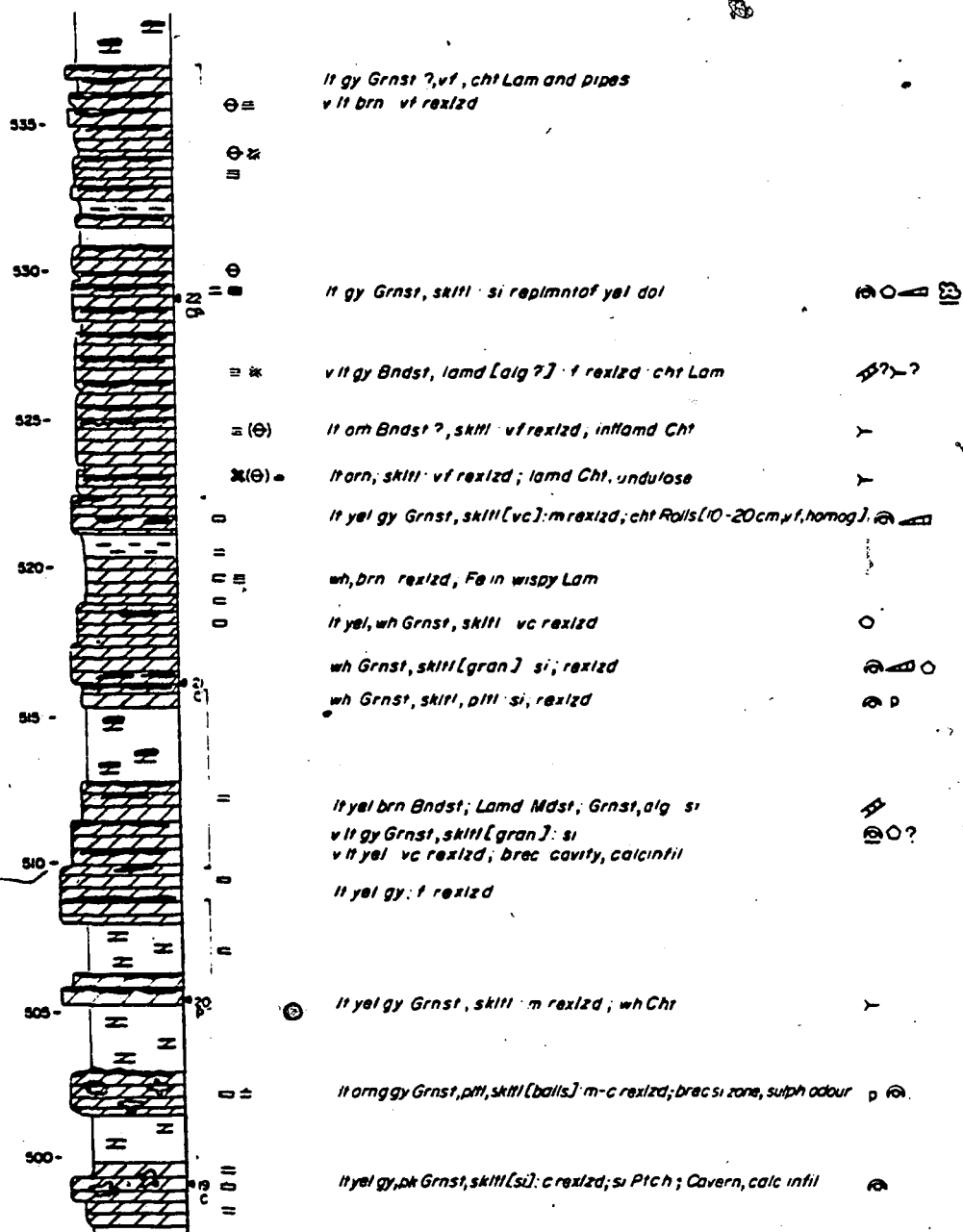
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250

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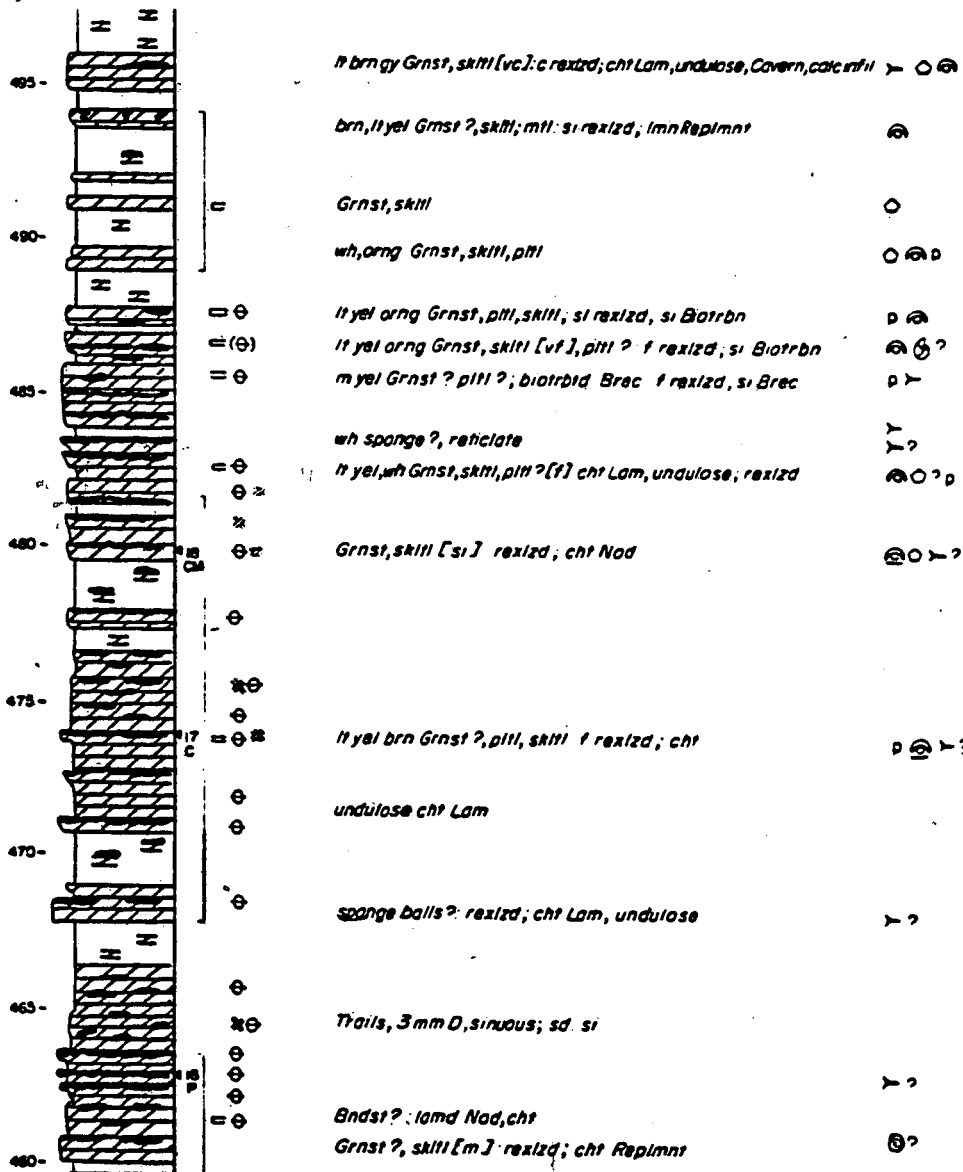
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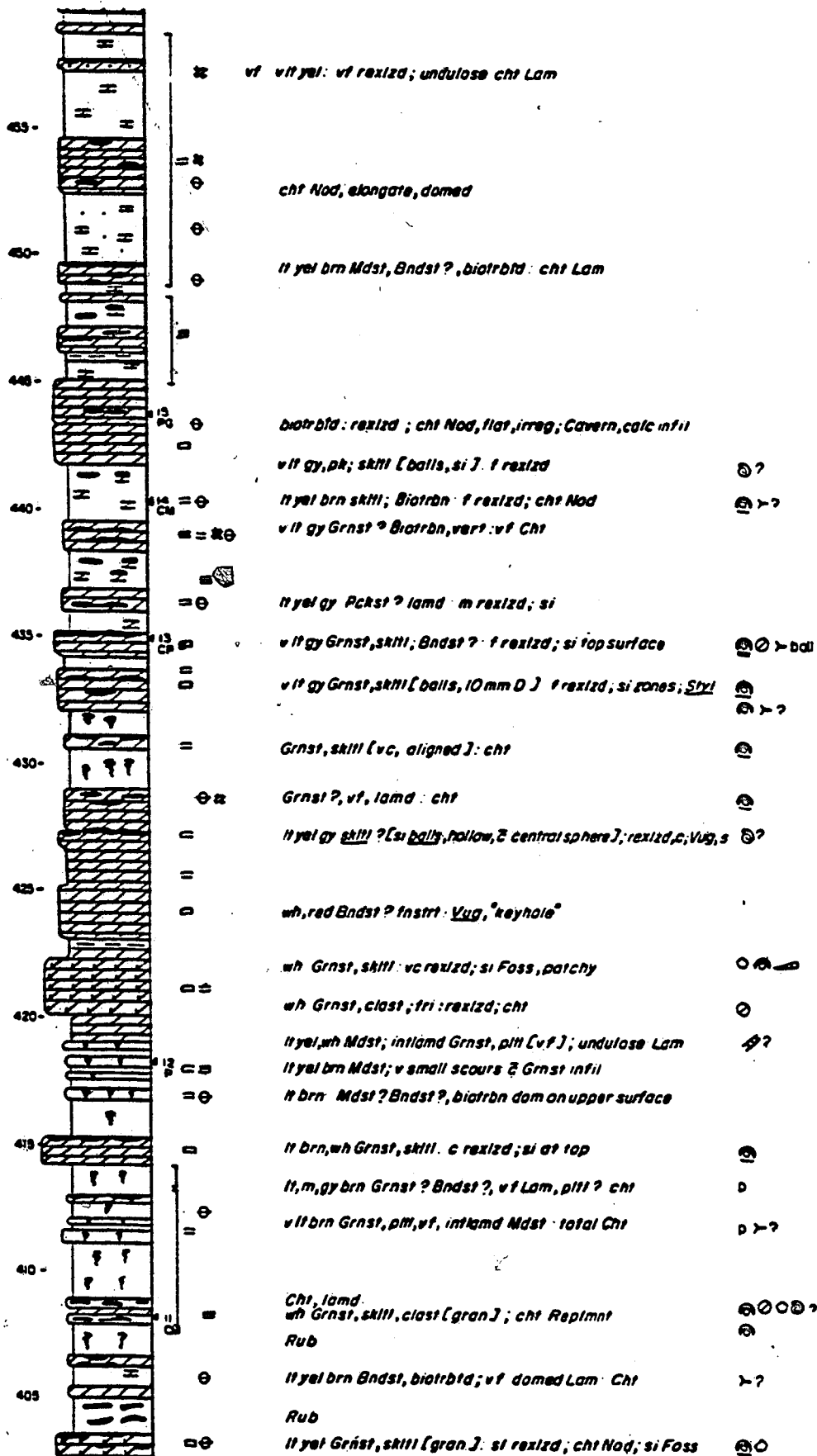


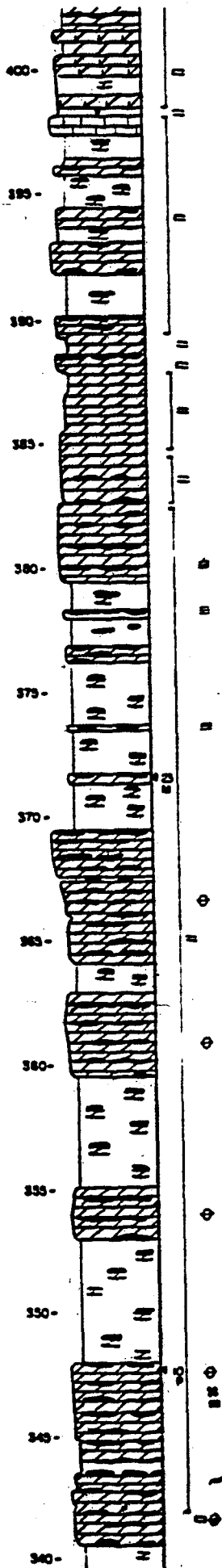
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200



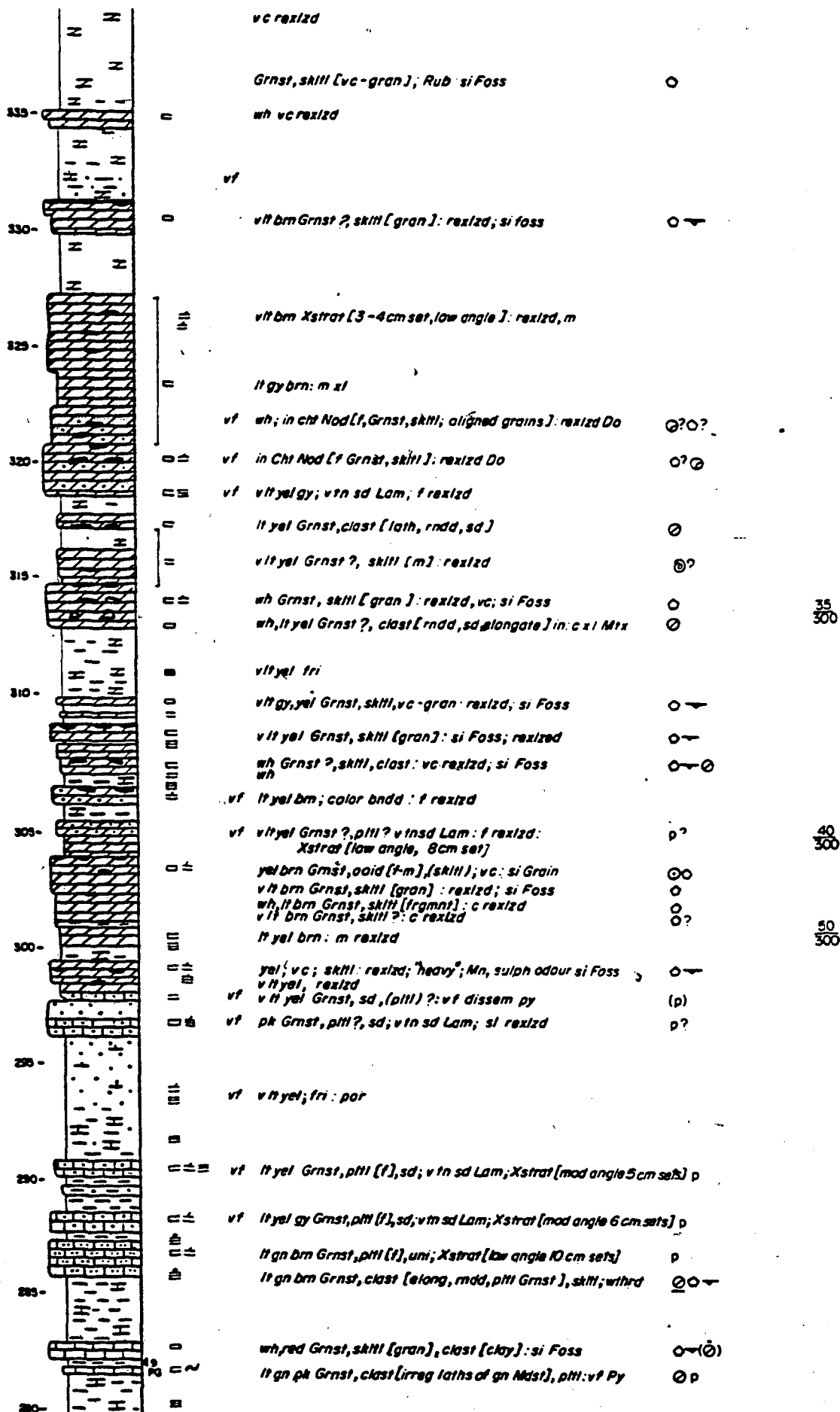
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295

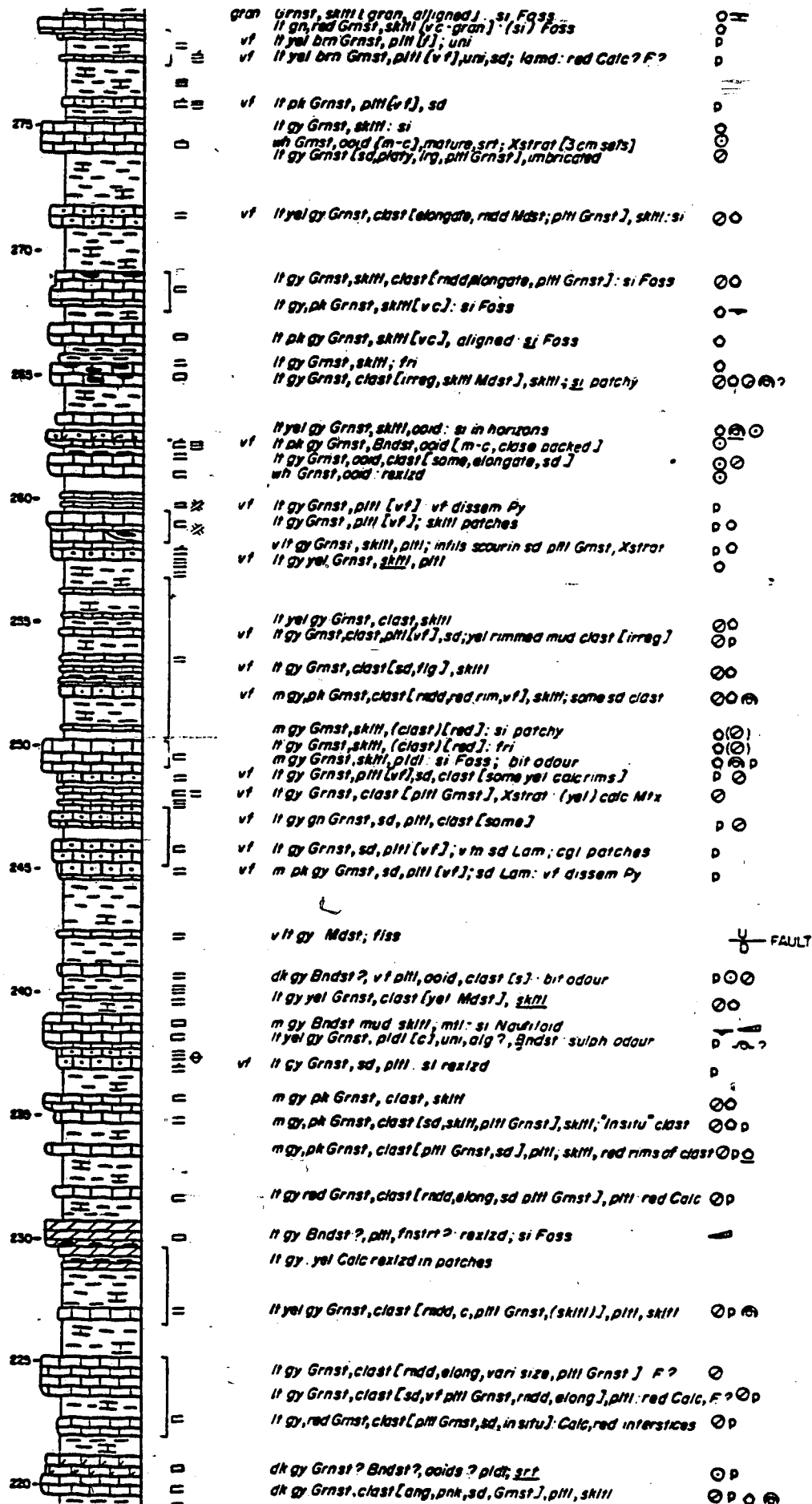


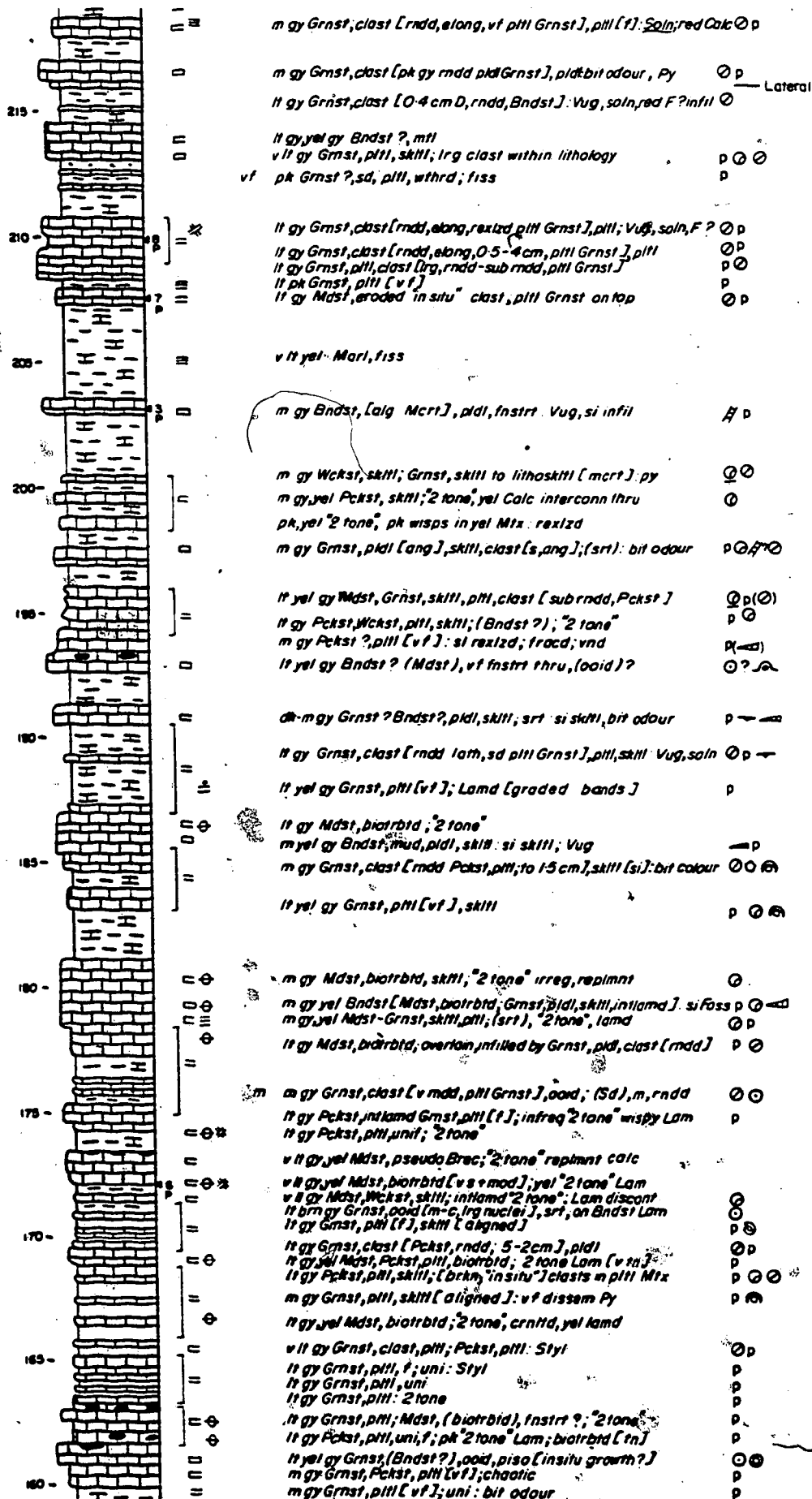


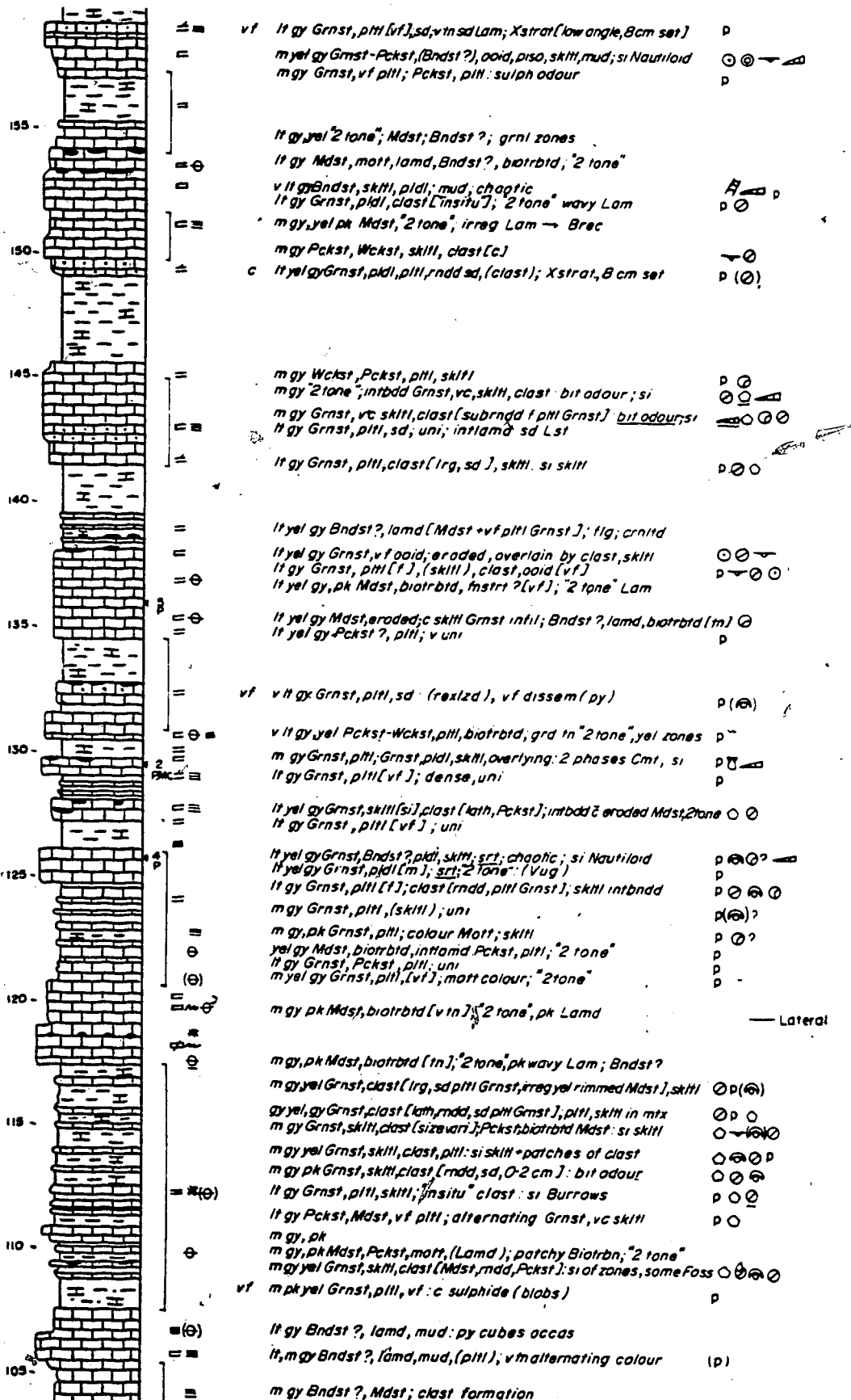


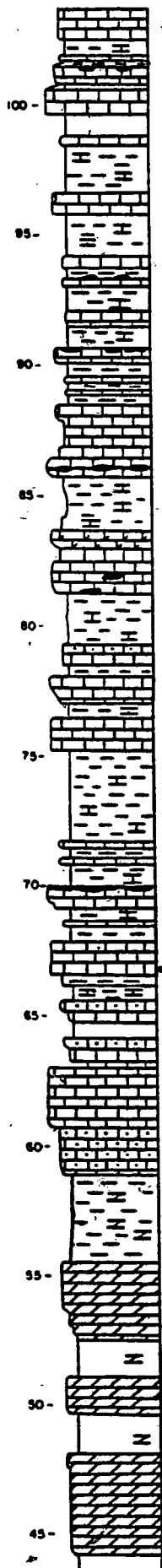
in Chl Lam vlt yel: rexizd, m-c; elongate Vug, calc part infil; si Foss	⊙
wh, lt yel: c rexizd; si Foss	⊙ (⊙)
wh, dk Grnst, skiff [vc]: rexizd; si colour patchy; si Foss	⊙ ⊙
wh Grnst?, skiff, pliff: rexizd; chl; si thru	⊙ ⊙ ⊙
wh, yel; skiff pieces: vc rexizd	⊙
wh Grnst, skiff [vc], pliff: rexizd; chl Patches	⊙ ⊙ ⊙
lt yel Grnst?, skiff: calc Vug; si patches; Frac	⊙ ⊙?
wh Grnst? skiff [vc-gran]: vc rexizd; si surface	⊙ Y?
wh Grnst?, skiff: rexizd, vc; lt yel patches; si Foss	⊙
wh Grnst, skiff [gran] Foss, si; chl Bnd, "heavy"	⊙
vlt brn Grnst?, skiff [aligned] f xl Dol; chl, m, lt gy	Y?
vlt gy Grnst?, skiff? vlt rexizd	Y?
vlt yel Grnst, skiff? [vlt]; lamd	Y? ⊙ ⊙
lt gy Grnst, skiff [spiculate? vc-vlt]: si Grnst	⊙ ⊙ Y
lt gy Grnst, skiff, pliff: rexizd Dol; si Grnst	⊙ ⊙ ⊙
lt brn Grnst, Bndst?; biotrbld surface, rexizd; chl Bd, Mn coated	
wh, lt brn: rexizd Dol; intralmd chl Nod	
wh, lt, brn: rexizd Do; chl Nod	
wh, lt brn Bndst, intralmd Do; biotrbld: si Bndst	Y? Y? ⊙
lt brn, wh Bndst?, lamd, (biotrbld): vlt rexizd; chl Nod	
vlt brn: rexizd; chl Nod, pores, bulbous tops	Y?
lt brn; biotrbld (in, vert): vlt rexizd; chl Nod; chl mlt Bndst	





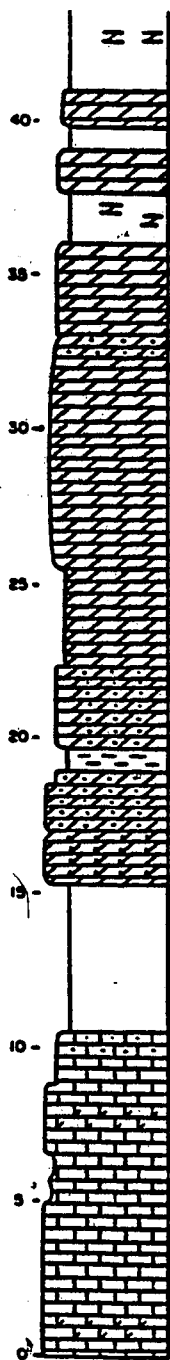






≡	m gy yel Bndst, lamd, pili, mud: flg	p	
	m gy, pk Pckst, pili, lamd; "2 tone" pk rexizd calc Lam	p	
100	lt gy Grnst, pili, clast [subnrd, pili Grnst, Pckst]	p ⊙	
	lt gy Grnst, Pckst, pili; alternating Lam	p	
	lt gy yel Grnst, Pckst, pili [m]	p	
	• vt pk, yel Grnst, vf pili; Lam; rndd clasts of same at top: Styl	p(⊙)	
95	≡		
	m gy Mdst, lamd; (patches), pidi Grnst: Styl		
	lt m yel gy Grnst, pili; colour Lam; tn Lam rexizd Calc	p	
	lt gy Grnst, pili, (skili)	p ⊙	
90	lt gy yel Grnst, pili [f]; uni; patches clast, skili [si]	p ⊙ ⊙	
	lt gy Grnst, skili [m Platelets, elongate, mcrst envelopes]: si	⊙?	33
	lt gy yel Mdst, uni		275
	lt gy Mdst, unif; Biotrbn, tn vert tubes		
85	≡		
	m gy, pk Grnst, pili [vf]; "2 tone" pk Lam rexizd	p	
	wh Pckst, clast [insitu, Mdst?]: Styl	⊙	
	wh Grnst, pili [vf]: do		
	tn vert Biotrbn: py cubes		
	wh Grnst, pili [vf]; vtn Lam, yel do	p	
80	≡		
	(vf) lt gy Grnst, pili [vf]; vtn Lam, (sd)	p	
	m yel gy Grnst?, pidi [elongate, uni, f], (clast) [alg?]	p ⊙ ⊙	33
	m yel gy Grnst, vf pili, skili, clast [rndd, "in situ"]	p ⊙ ⊙ ⊙	375
	m gy Grnst, clast [laths, subnrd, fnstr, Pckst], skili [si]	⊙ ⊙ ⊙	
75	≡		
	lt gy yel Grnst?, pili [vf], ooid, clast: Styl	p ⊙ ⊙	
	m gy yel Grnst, skili, clast [Mdst, skili]	⊙ ⊙ ⊙	
	m gy Grnst, pili [vf]; patches Grnst, skili, clast	p ⊙ ⊙	
70	≡		
	vt yel gy Grnst? Bndst?, pidi [c]; uni f	p	
	vt yel gy Grnst, pidi, clast [gran lath, Mdst], aligned	p ⊙	
	lt gy Grnst, pili [vf]; (fnstr)	⊙	
	vt gy Pckst, Wckst, alg: Styl		
	vt gy yel Grnst, Pckst, pidi [ang, c, alg]	p ⊙	
	lt gy yel Bndst; fnstr Lam; Stromat, domed, pseudocolumnar	⊙	*
65	≡		
	vt m gy Grnst, pili	p	
	m gy Grnst, pidi [f]; (horiz Fnstr)	p ⊙	
	vt m gy Grnst, pili; sd Lam	p	
	m gy Grnst, pili	p	
	vt yel gy Grnst, pidi, clast [Mdst laths, 0.3-1.5 cm]; (umbication)	p ⊙	35
60	≡		
	vt lt gy Grnst?, pidi [vf]; tn sd Lam; Xstrat, mod angle, 10 cm sets	p	20
	Rub		375
55	≡		
	vt lt gy brn; Xstrat, low angle, ~15 cm set: m-c rexizd; jtd		
	Rub		
50	≡		
	lt brn gy: m rexizd; fracc		
	wh; c rexizd; jtd		
45	≡		
	wh; f rexizd; jtd		

FAULT



Rub

wh: f rexizd; fracd

wh; mass: c rexizd

Rub

wh; mass: m rexizd

fracd

vf It gy Lam, sd: rexizd; fracd; vf dissem Py

It gy, mass: vf rexizd; fracd; Py (c cubes)

It gy, mass: m rexizd

It gy, mass: vf rexizd; fracd

It gy, mass: vf rexizd; fracd

vf It yel: f rexizd; fracd

It yel: rexizd

vf v It yel, It gy Grnst?, Lamd (almt sd, non sd)

vf It gy, It yel Grnst?, pili; Lamd (sd + non sd)

vf v It gy Grnst, pili (vf); (Bndst) rexizd

vf vlt gy brn Grnst?, pili?; Xstrat, low angle, 20 cm sets

It gy, It yel mott Grnst?, pidi, clast rexizd

Rub, do (sd, vf pili: fracd)

vf It gy, yel Grnst, pili (vf): fig; fracd, do

It yel gy Grnst, pili (vf): (rexizd) Pich

m gy Grnst, pili (vf): (rexizd); Sty

m gy, It yel gy Bndst, pidi, ooid, skili: (rexizd)

It yel gy Bndst?, Wckst, ooid, pidi: yel Wmrg; (rexizd); Sty

It gy, yel Grnst, Bndst?, ooid, pili; Wckst

It yel gy Grnst, pili (vf), clast (subang, 1 cm D; in situ); Xstrat, sets (5-10 cm, low angle)

DATE: 10-11-6-75

GEOLOGIST: B. Radke

MAP SHEET: Bouha

F 54/A10/95

15
275

10
275

APPENDIX II

GENERALISED STRATIGRAPHIC SECTIONS

Generalised stratigraphic sections

The stratigraphic sections that are referred to in the text are based on generalised sections. As listed in Figures 8 and 17, the sections are annotated A, B, C, D, E, F, G, and H. Section E (Fig. 17) has been taken from Jones & others (1971).

Five sections correspond directly with detailed stratigraphic sections. These are:

- B - Section GEO 269 from the north-western Toko Syncline (Fig. 20)
- D - Section GEO 214 from Digby Peaks, Burke River Structural Belt (BRSB) (Fig. 22)
- F - Section GEO 202 from Mount Unbunmaroo (BRSB) (Fig. 23)
- G - Section GEO 228 from Mount Ninmaroo (BRSB) (Fig. 23)
- H - Section GEO 230 from Mount Datson (BRSB) (Fig. 24)

Sections that are composites of two locally related stratigraphic sections are:

- A - Section GEO 265 (as base) and Section GEO 263 (as top) from the western side of the Toko Syncline (Fig. 19),
- C - Section GEO 236 (as base) and Section GEO 253 (as top) from the Smoky Anticline (Fig. 21)

Reduction procedure

Approach

For interpretation of the stratigraphic information, the logs of detailed stratigraphic sections were reduced to comprehensible generalisations. In this section, the manipulations applied for this reduction are discussed.

Reordering. At the detailed scale, information from the stratigraphic logs was transposed to columnar format under which features were separated and categorised. In addition, interpretations of tidal, elevated salinity, evaporitic and emergent conditions based on this information were plotted.

Reduction of stratigraphic data. The reduction is performed by making 10 metres of section the basic increment. Normalisation of information contained in that increment is based on:

$$\frac{\text{number of occurrences of the feature in 10m}}{\text{number of data horizons in the 10m interval}}$$

The basic assumption for this procedure is that each observation is of equal significance within a 10 metre interval.

Information reliability. The estimated percentage of outcrop is presented in histogram form. Many recessive rock types are of indeterminate original composition, owing to subsequent surface weathering, and the confidence of interpretation of the sequence has been reduced by this lack of knowledge. An insoluble residue study indicated that these recessive beds are carbonates with higher terrigenous content than the prominent rock type in the section. One small section of the Ninmaroo Formation has been cored in a region of total dolomitisation. In this section, dolostone was dominant throughout, but with numerous terrigenous-rich horizons that would, on weathering, result in recessive layers. An extrapolation of carbonate dominance in this one section implies that the Ninmaroo sequence is dominantly carbonate.

Carbonate textures

The six textural categories of Dunham (1962) are plotted as normalised abundance in histogram format.

Carbonate particle types

In the detailed stratigraphic sections, particle types were recorded numerically in decreasing order of abundance from 1 to 4. To generalise both this weighting and occurrence from each horizon, a crude parameter is calculated from:

$$\frac{(\text{number of occurrences})^2}{\text{total numerical score of weightings} \times \text{number of sample horizons in 10 metres}}$$

This calculation ranks the most abundant and/or recurring particle type with the highest value, to an approximate percentage of abundance. This parameter is valid for comparison of vertical variations of abundance of one particle type.

Skeletal particle types

Where skeletal components are present, they are listed in decreasing order of abundance in the symbol form outlined in Appendix I.

Occurrence of algae

Domed and stratiform cryptalgal body types are differentiated in a histogram of normalised abundance of algal horizons.

Environmental parameters

Crude parameters of the environment are approximated to outline the physical limits of the depositional environment.

Minimum relief of the sediment surface. The minimum relief of the depositional surface is averaged from both set thickness of cross-strata and the relief of cryptalgal bodies. These values define the minimum water depth of the environment.

Tidal character. The presence of herringbone cross-lamination or tidal scour channels is used to categorise the 10 m increment as tidal.

Salinity. Increased salinities are inferred from four features; the presence of ooids or grapestones, cryptalgal features, absence of bioturbation, reduced faunal diversity quantified as the number of phyla recognised. Where three of the four features occur together, the horizon is considered to have been deposited under higher salinities. The histogram records the normalised number of horizons of increased salinity.

Evaporites. This histogram represents the normalised abundance of horizons with one or more evaporitic features; pseudomorphs of sulphate nodules and crystals, equant vugs after sulphate nodules, and solution-collapse breccias.

Induration and erosion. The recognition of horizons with eroded surfaces of indurated sediments is based on the presence of weathered profiles, surfaces truncating underlying fabric (not stylolites), and distinct upper contacts with overlying lag deposits of the same lithology.

Emergence. Horizons of emergence are recognised by shrinkage cracks, karst surfaces, cavern porosity, and tepee structures. The emergence parameter indicates the normalised ratio of horizons bearing features of emergence.

Dolostone. Dolostone occurrences have been recorded only as total or partial dolomitisation. Thus for each 10-m increment, the abundance of dolomitised horizons is calculated from:

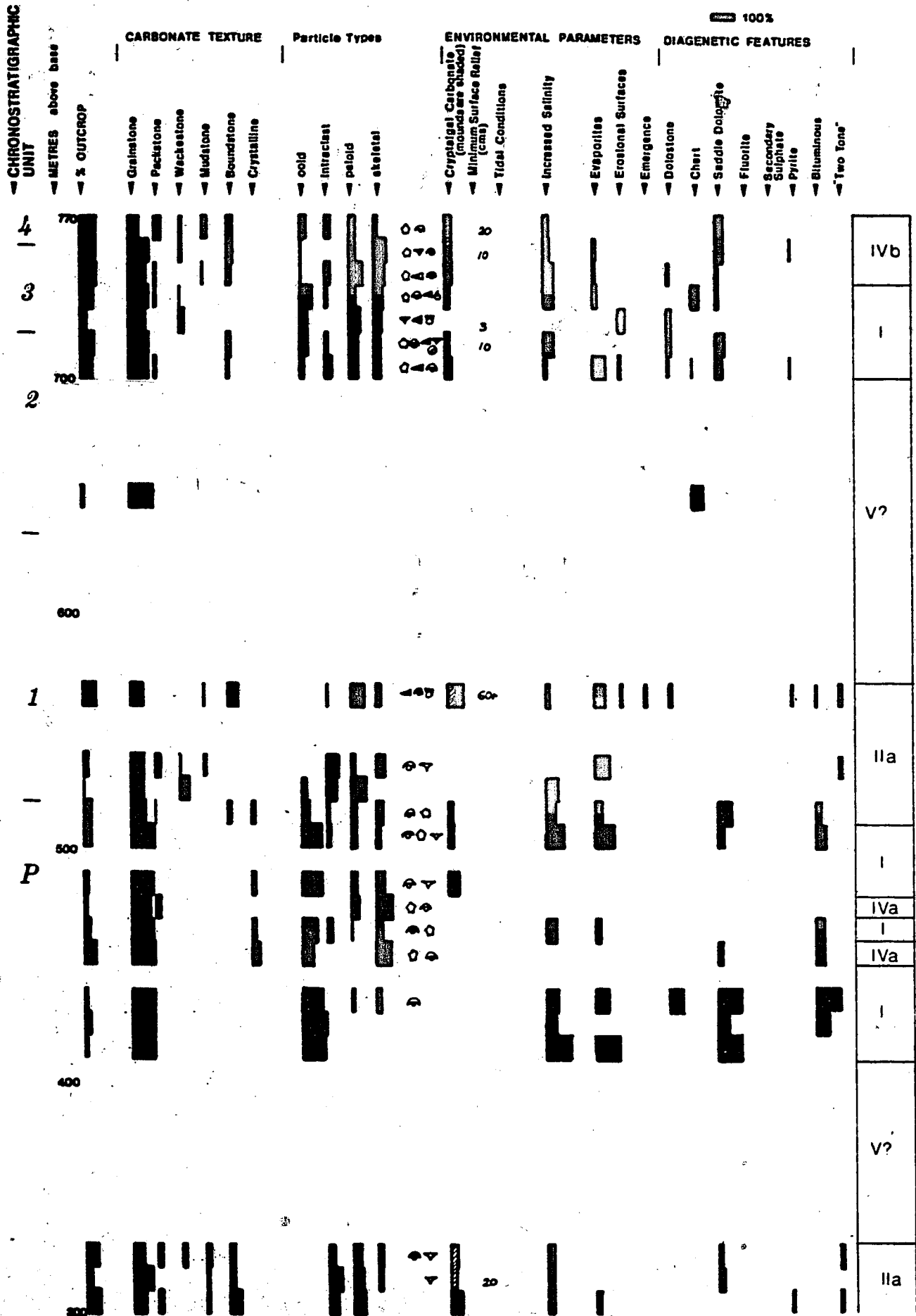
$$\frac{\text{Number of totally dolomitised beds}}{\text{Number of beds}} + \frac{\text{Number of partially dolomitised beds}}{3 (\text{Number of beds})}$$

Chert. The abundance of chert horizons in each increment is calculated similarly to that of dolostone.

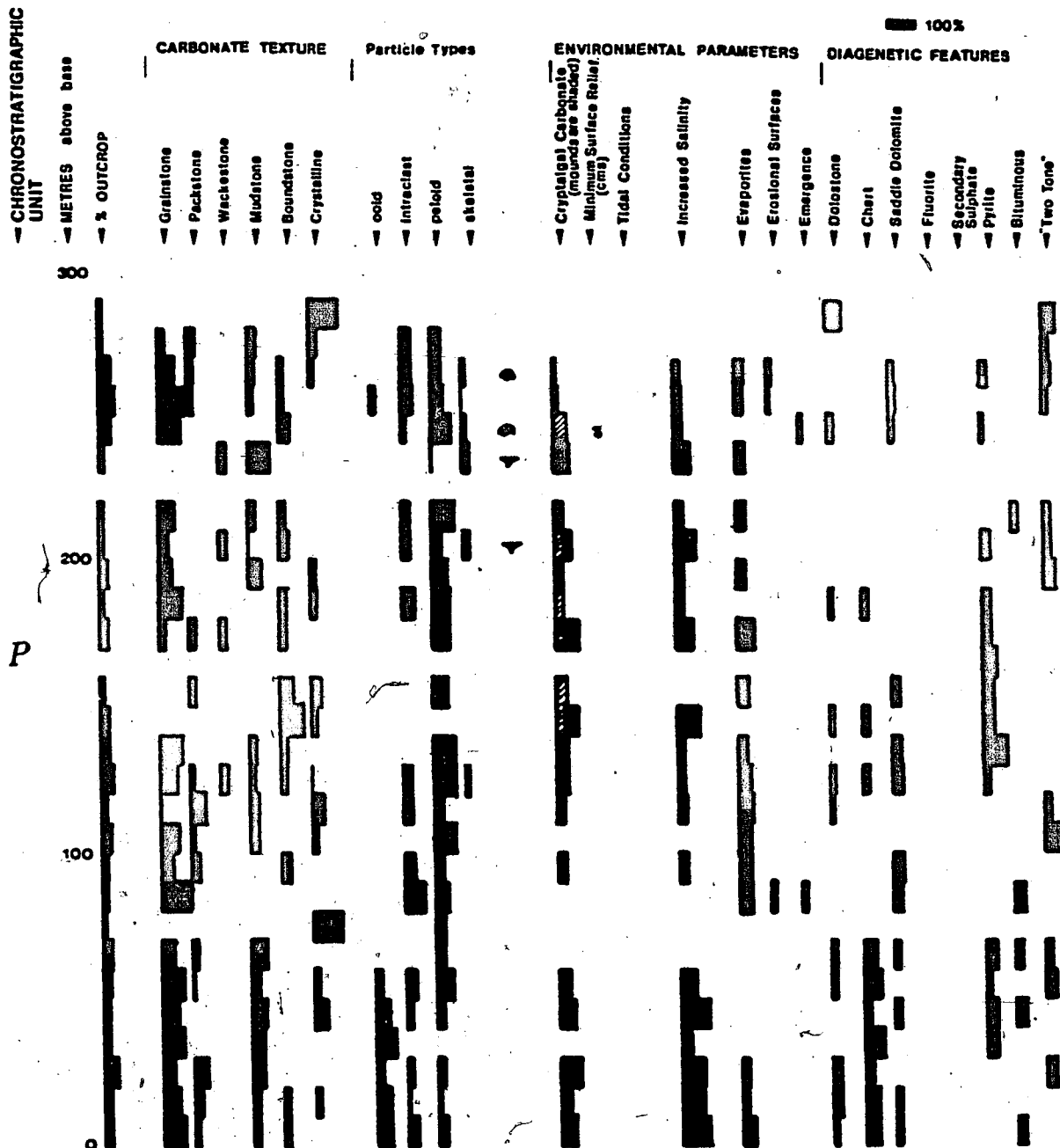
Other diagenetic features. Saddle dolomite, fluorite, secondary sulphates, pyrite, bituminous zones, and 'two-tone' are also normalised as percentage of horizons with the specified feature.

A -GEO Sections 265 & 263

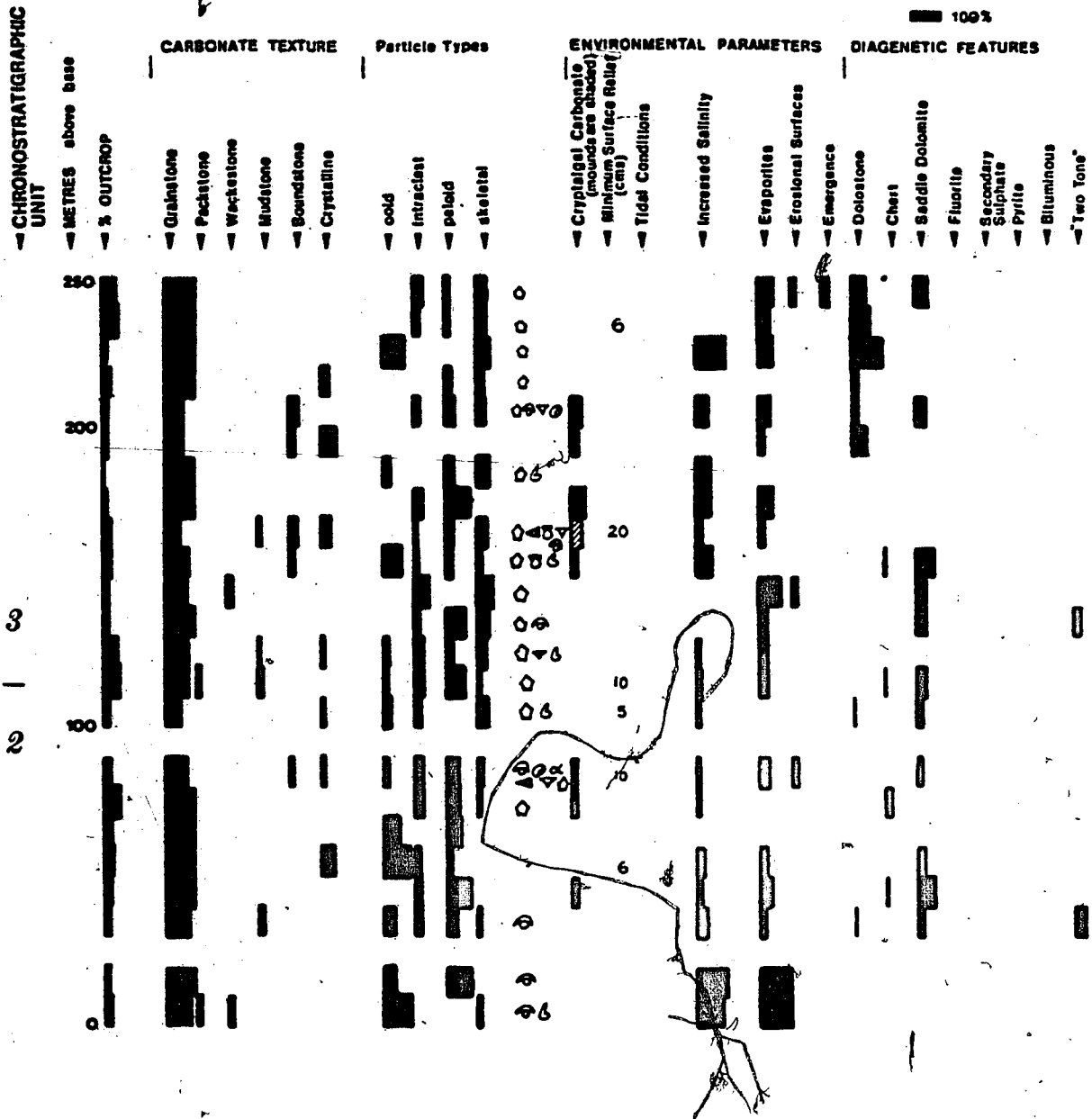
100%

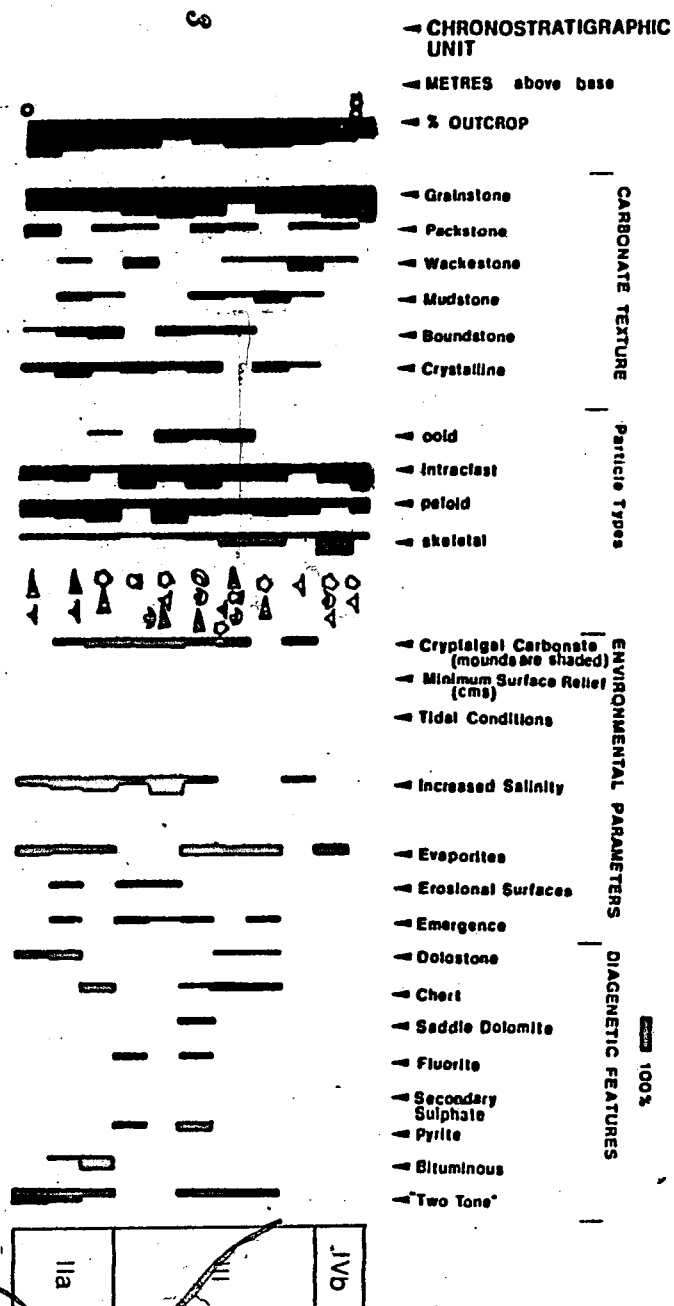
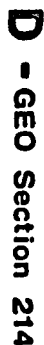


A (continued) -GEO Sections 265 & 263

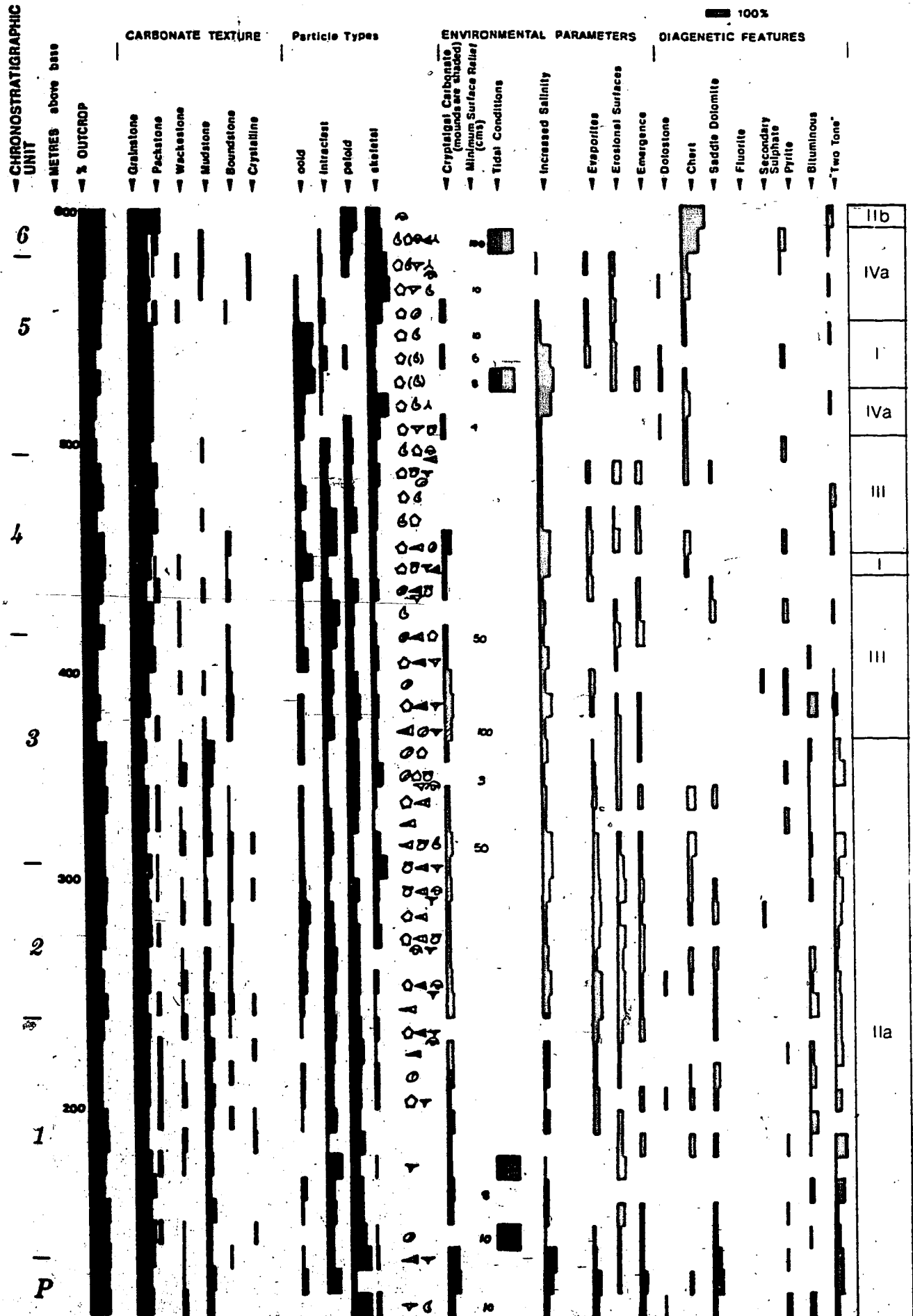


B - GEO Section 269

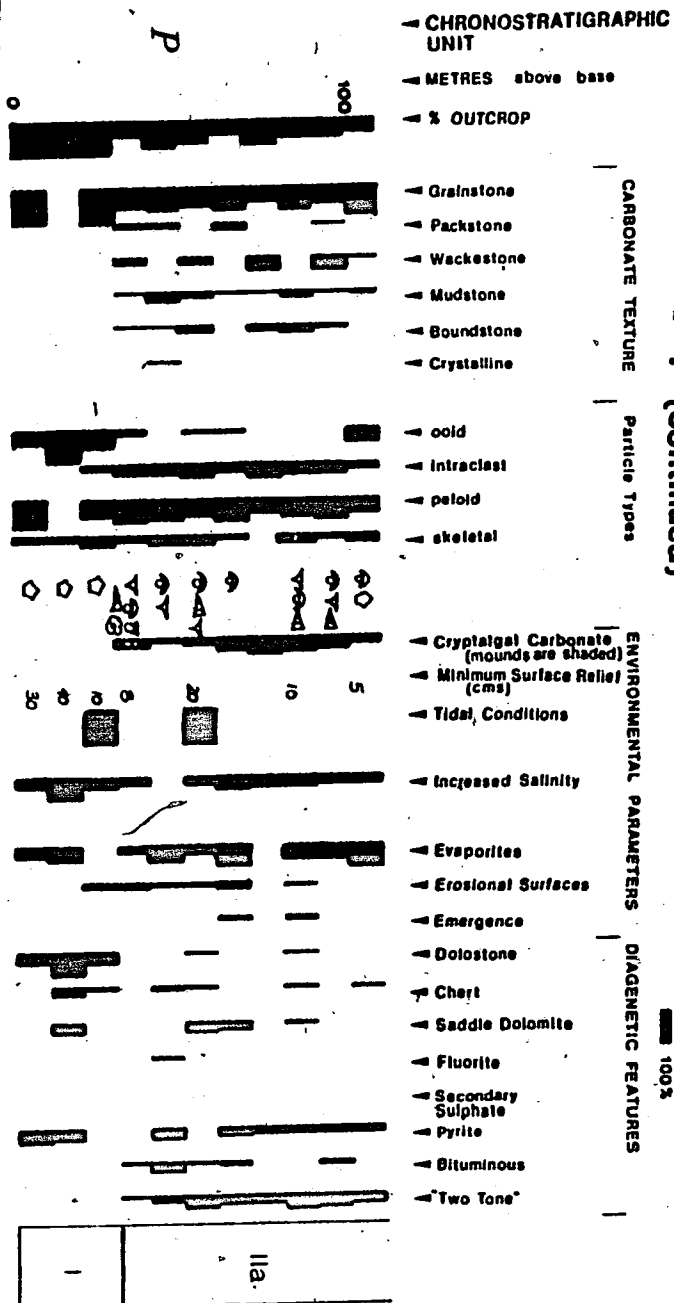




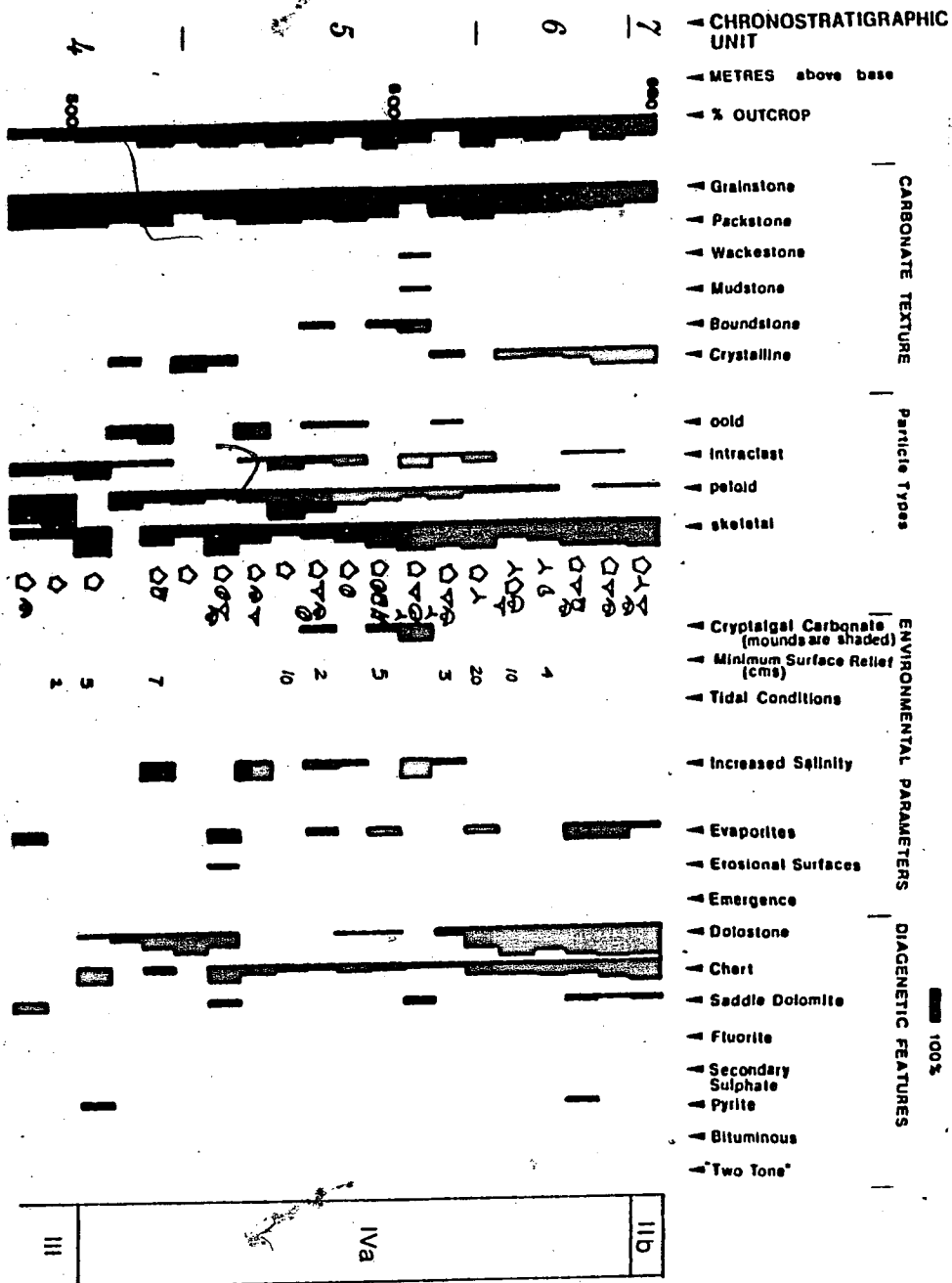
F - GEO Section 202



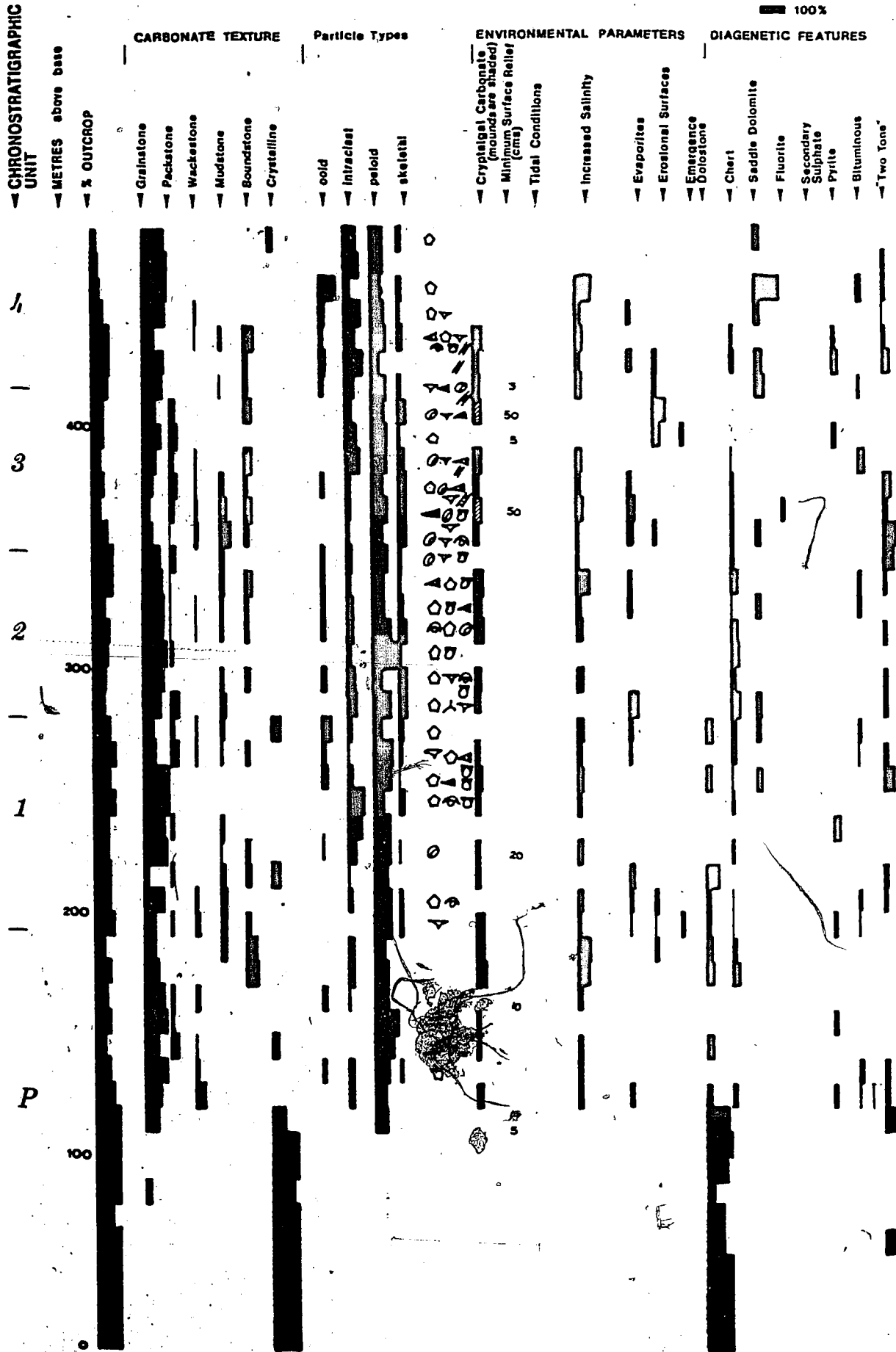
F (continued)



G-GEO Section 228



G (continued) - GEO Section 228



III

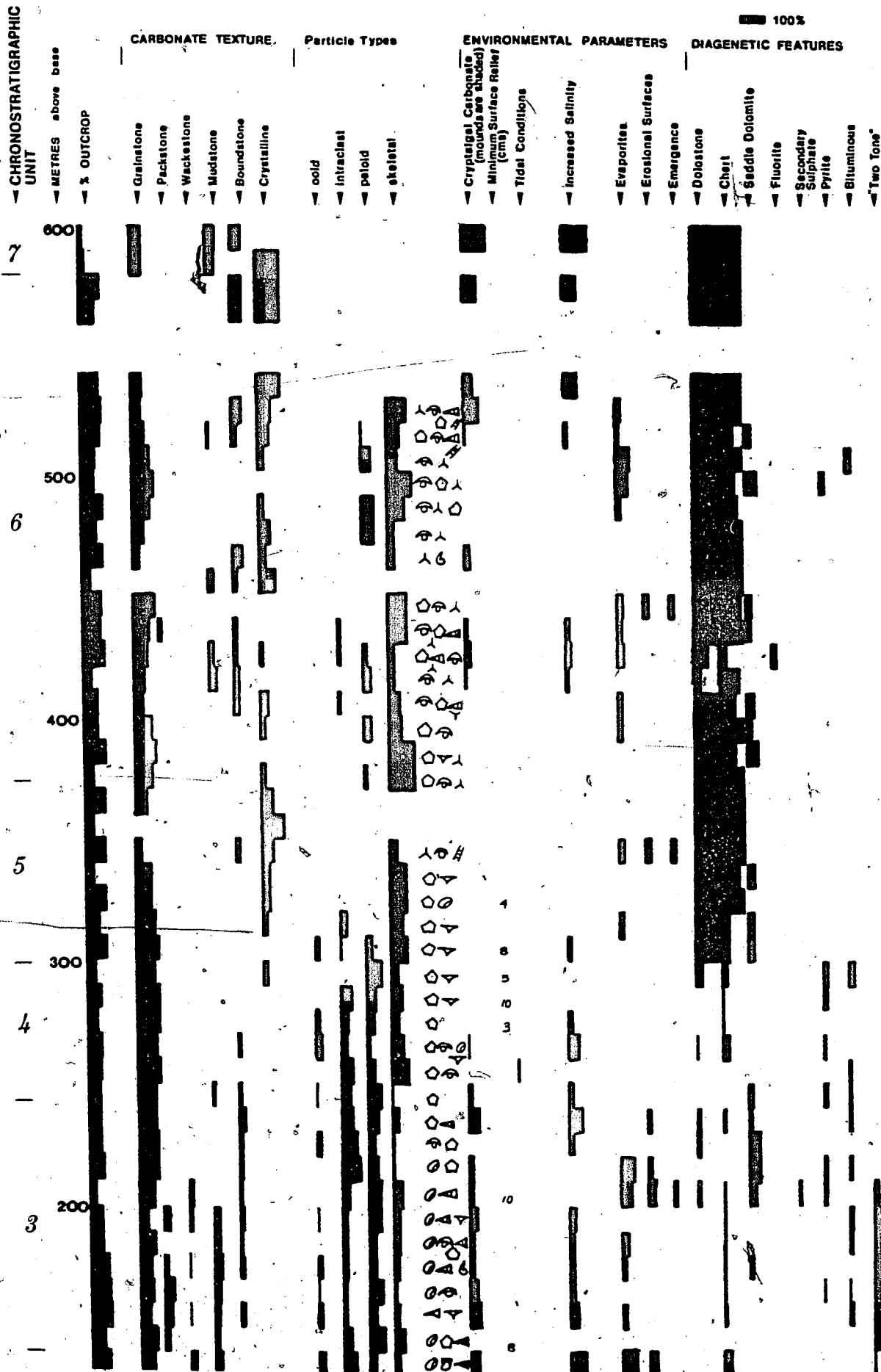
III

IIa

VI

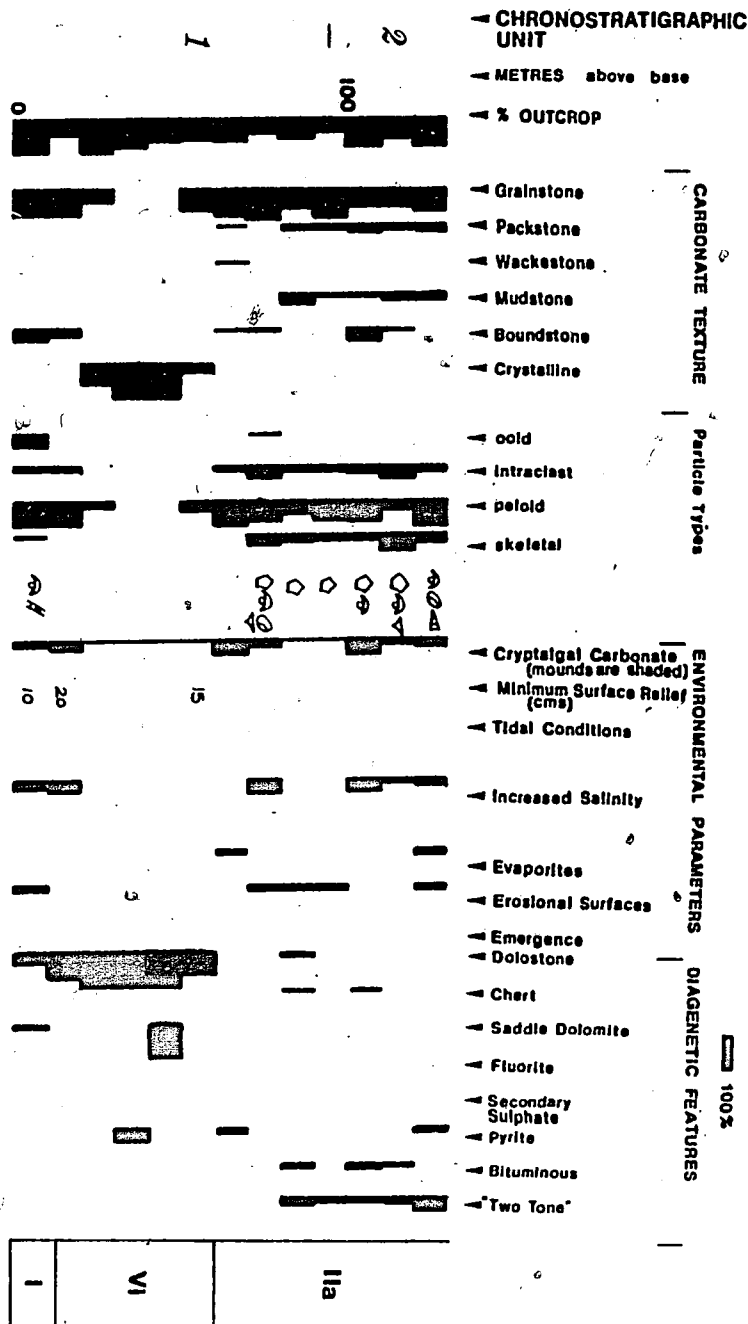
1?

H -GEO Section 230



IVa
IVb
III
IIa

H (continued)—GEO Section 230



APPENDIX III

GEOGRAPHIC LOCATIONS AND GEOLOGICAL
SETTINGS OF STRATIGRAPHIC SECTIONS

Table III Locations of stratigraphic sections

Section	Field section no.	Map sheet	Coordinates	Description	Photo Reference	Reference Figure
base A	GEO 265	Mt Whelan 1:250 000	138°04'05" 23°15'08"	3 km west of Eurithethera Soak	Abudda Lakes	19
top A	GEO 263	Mt Whelan 1:250 000	138°04'35" 23°17'48"	3 km northeast of Cravens Peak	Abudda Lakes Run 8-0060	19
B	GEO 269	Tobermory 1:250 000	137°49'10" 22°58'25"	5 km WSW of Burnt Well	Toko Run 13-0018 Run 12-0012	20
base C	GEO 236	Glenormiston 1:250 000	138°35'0" 22°12'24"	5 km WNW of Bullock Paddock No. 2 Bore Linda Downs	Lake Katherine	21
top C	GEO 253	Glenormiston 1:250 000	138°39'48" 22°23'36"	14 km west of Lake Katherine	Lake Katherine Run 11-0479	21
D	GEO 214	Southern Burke River Structural Belt. Special 1:100 000	408975566	2 km NW of Digby Peaks	Digby Peaks Run 3-0070	22

Table III Locations of stratigraphic sections (cont)

Section	Field section no.	Map sheet	Coordinates	Description	Photo Reference	Reference Figure
E	see Jones & others, 1971	Southern Burke River Structural Belt. Special 1:100 000	418675271	5 km east of Robinson Bore, Corrie Downs.	Digby Peaks Run 10-0113	-
F	GEO 202	Southern Burke River Structural Belt. Special 1:100 000	426375083	Just below trig point, Mt Unbunmaroo	Boulia RC9 Run 5-0076	23
G	GEO 228	Southern Burke River Structural Belt. Special 1:100 000	428974992	0.8 km NNE of Mt Ninmaroo	Boulia RC9 Run 5-0076	23
H	GEO 230	Southern Burke River Structural Belt. Special 1:100 000	436974811	Eastern slope of Mt Datson	Boulia RC9 Run 7-0234	24

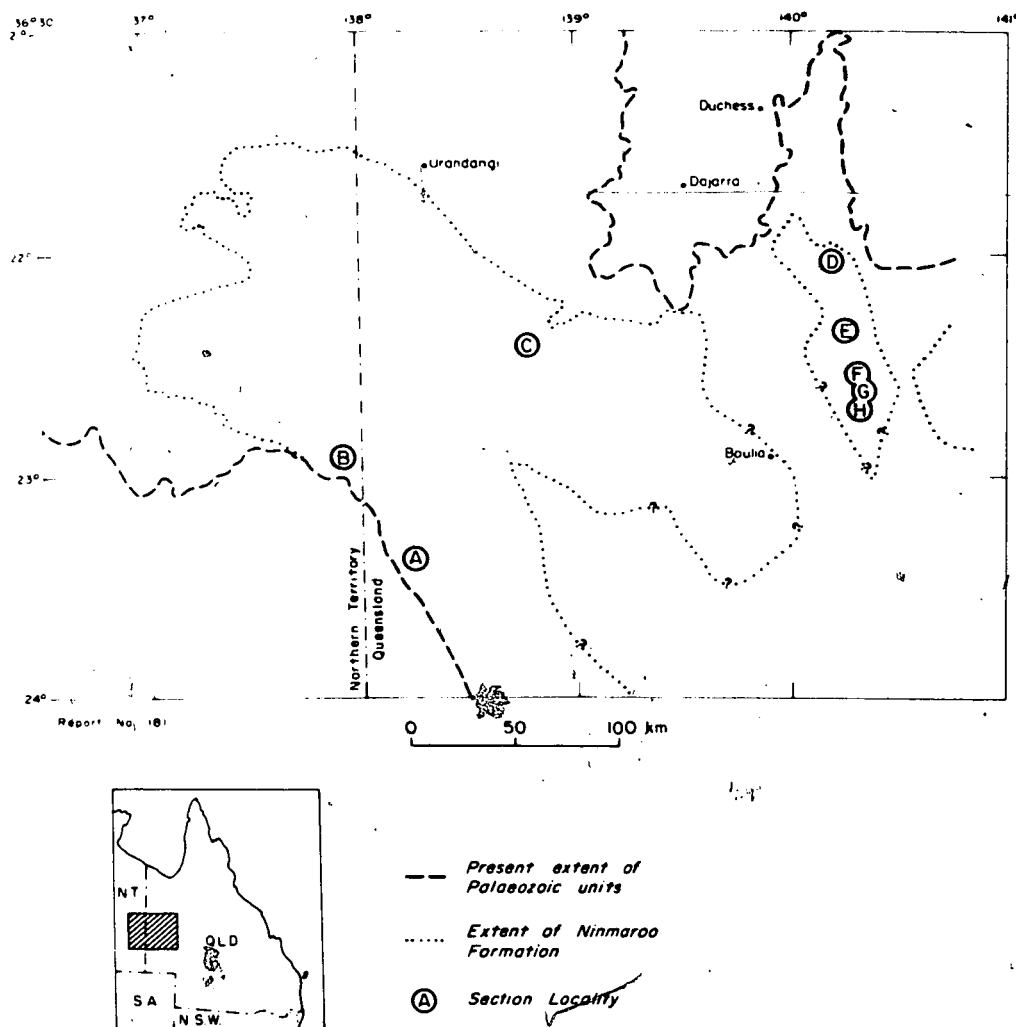


Figure 17 Regional location of stratigraphic sections

16/F54/11

CAINOZOIC	Cz, Q	Undifferentiated
TERTIARY	Tb	Beattie Creek Conglomerate
	Ta	Austral Downs Limestone
	Tn	Noranside Limestone
ORDOVICIAN-TERTIARY	OTb	Digby Peaks Breccia
MESOZOIC	JKh, K	Hooray Sandstone
ORDOVICIAN	Omm	Mithaka Formation
	Omc	Carlo Sandstone
	Omn	Nora Formation
	Olc	Coolibah Limestone
	[Olk	Kelly Creek Formation
	[Olw	Withilidarmna Dolostone Member
	Ols	Swift Formation
CAMBRO-ORDOVICIAN	EOn	Ninmaroo Formation undifferentd.
	EOn _d	dolomitized
	EOn _d	Datson Member
	EOn _c	Corrie Member
	EOn _m	Mort Member
	EOn _j	Jiggamore Member
	EOn _u	Unbunmaroo Member
CAMBRIAN	[Euc	Chatsworth Limestone
	[Eucl	Lily Creek Member
	Eua	Arrinthrunga Formation
PROTEROZOIC	Euu	Undifferentiated
	Pb	Black Stump Arkose
	Pt	Yardida Tillite

Table 4

Legend to stratigraphic units in the locality maps

- Geological boundary
- Anticline showing plunge
- Syncline showing plunge
- Fault (D, U indicates relative movement down, up where known)
- Normal fault, triangle indicates direction of dip
- Fault (showing relative horizontal movement where known)

Where location of boundaries, folds and faults is approximate, line is broken, where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes

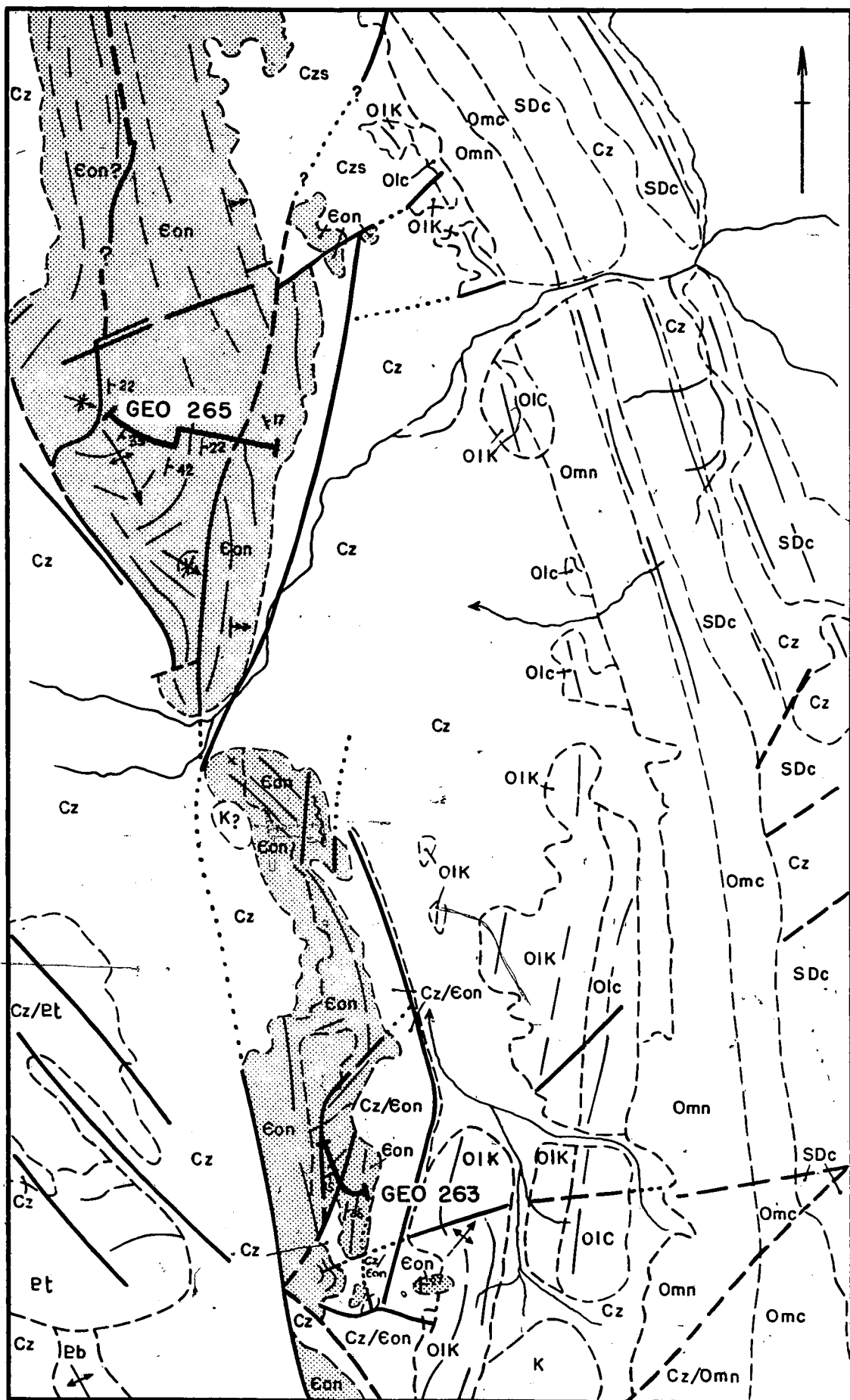
- < 20 Strike and dip of strata, facing known or inferred
 - < Strike and dip of strata, facing known or inferred, dip unmeasured
 - < Strike and dip of strata, facing not known, dip unmeasured
 - + Horizontal strata
 - < Dip < 5°
 - < Dip 5-15°
 - < Dip 15-45°
 - Trend line
 - Joint pattern
 - Lineament
- } airphoto interpretation

- Measured section
- ✕ Abandoned mine
- Pb Lead
- ⊗ St Stratigraphic hole

- Bore
- ⊗ Bore with windpump
- ◇ Bore - abandoned
- ! Windpump
- ^E Earth tank or dam
- ^T Metal tank
- Dam on stream
- Waterhole

- Road
- Vehicle track
- Digby Peaks
- Homestead
- Building
- ^d Yard
- Fence
- Telephone line
- △ Trigonometrical station
- abd Abandoned

Figure 18 . Legend to locality maps



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Ninmaroo Formation

Approx. 1 km

Figure 19 Geologic setting of section A (Geo 263, 265)



Figure 20 Geologic setting of section B (GEO 269)

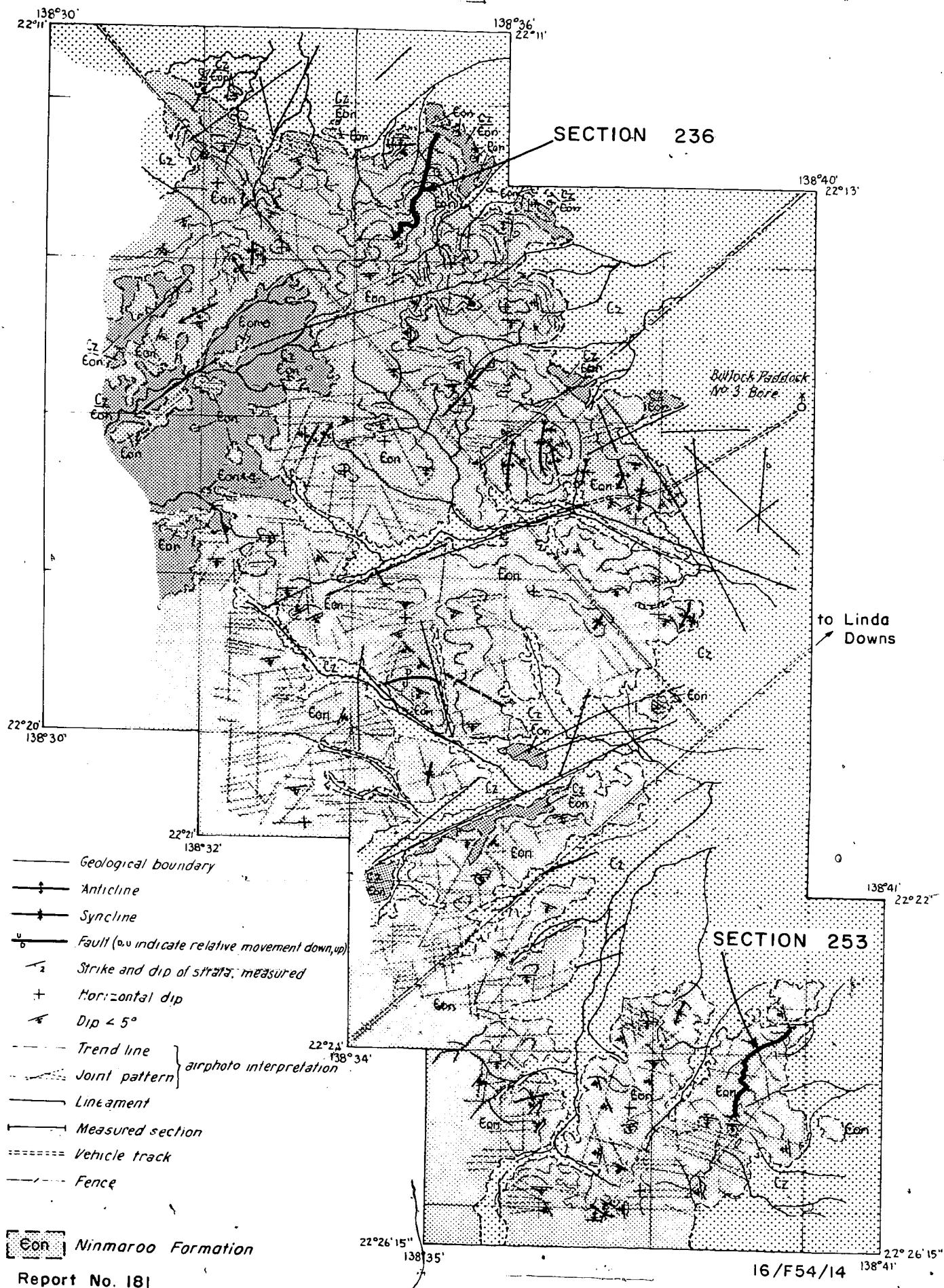


Figure 21 Geologic setting of section C (Geo 236 and 253)

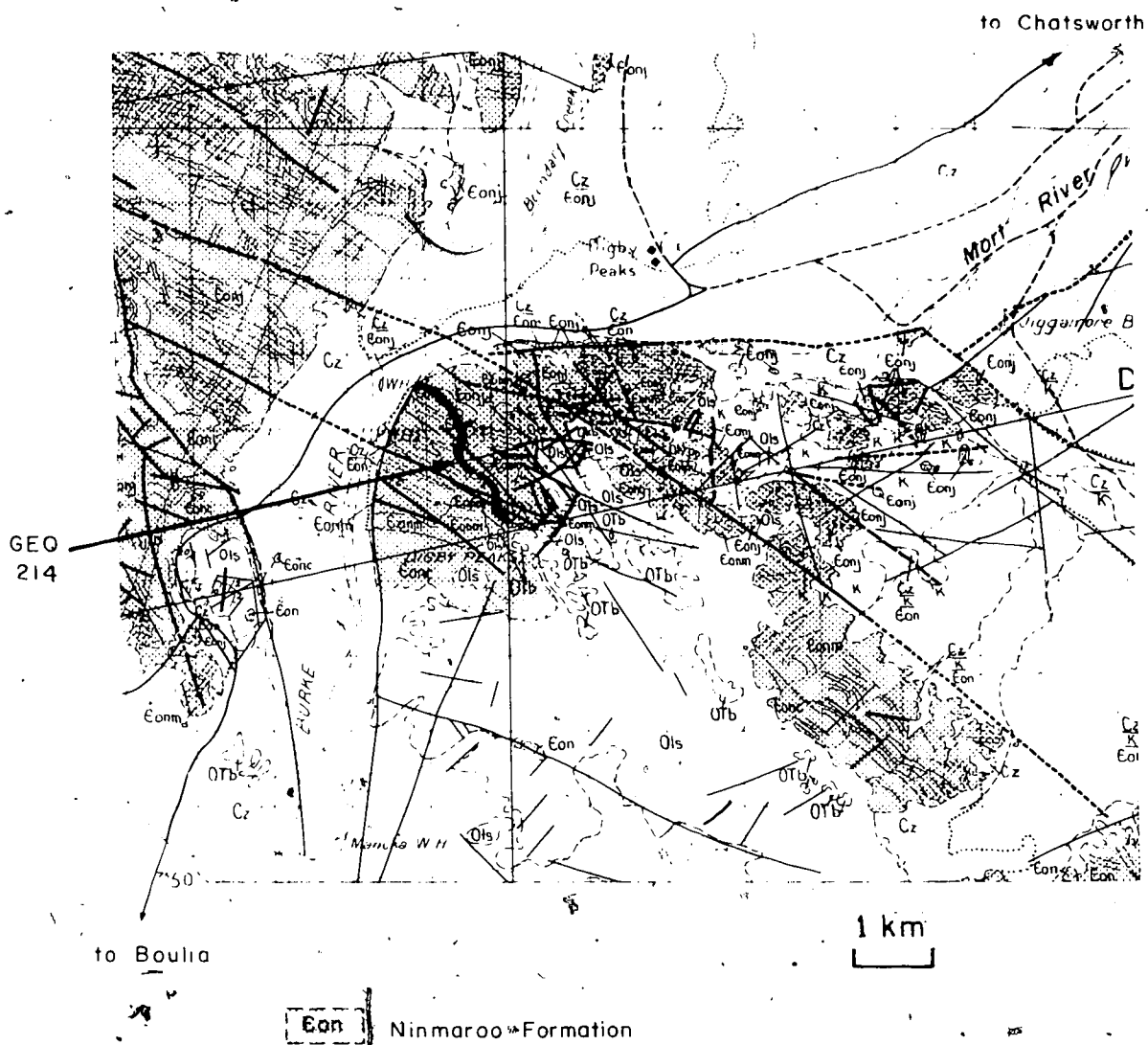


Figure 22 Geologic setting of section D (GEO 214)
(after Druce et al., 1976)

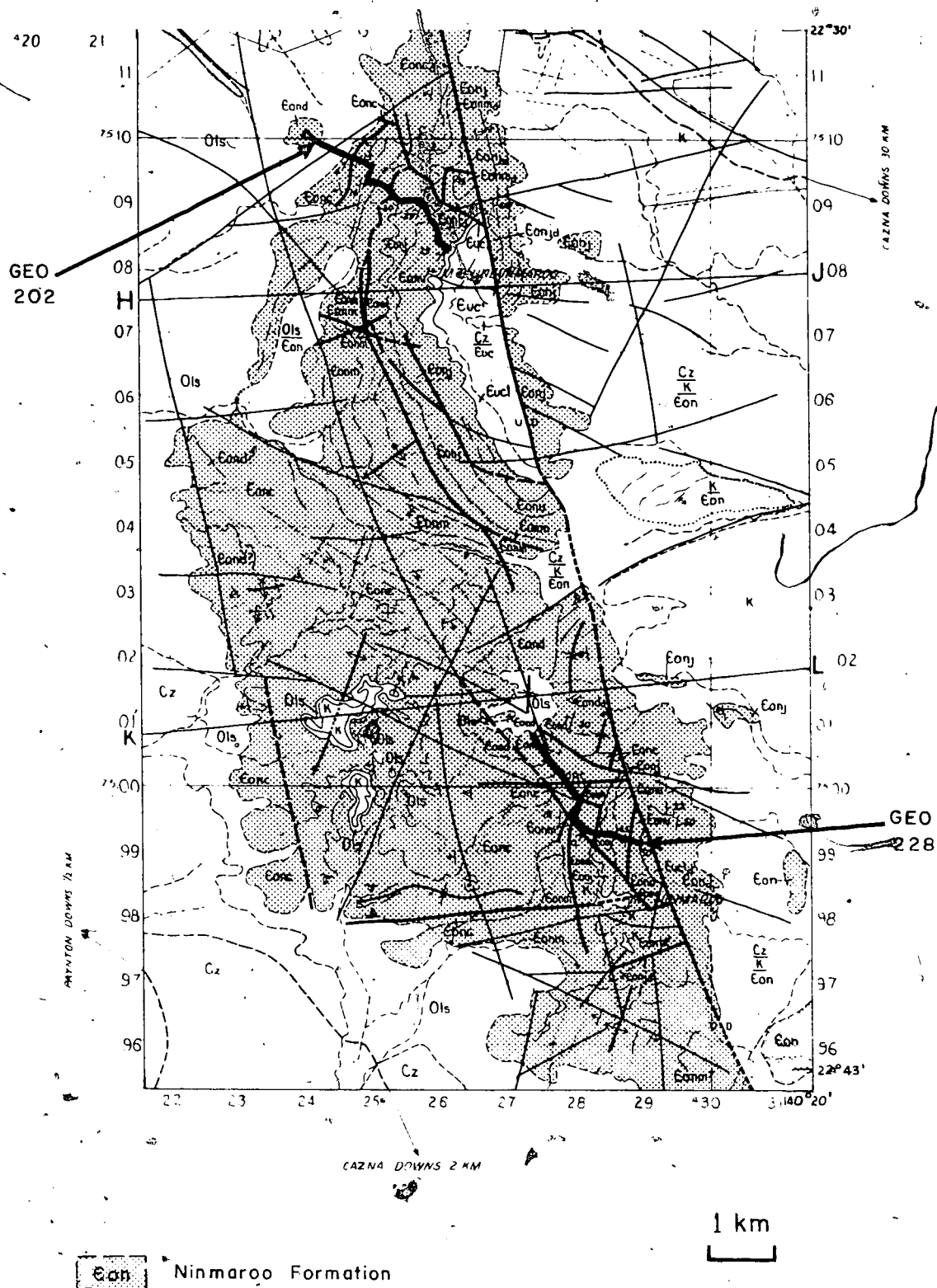


Figure 23 Geologic setting of sections F (GEO 202) and G (GEO 228)
(after Druce et al., 1976)

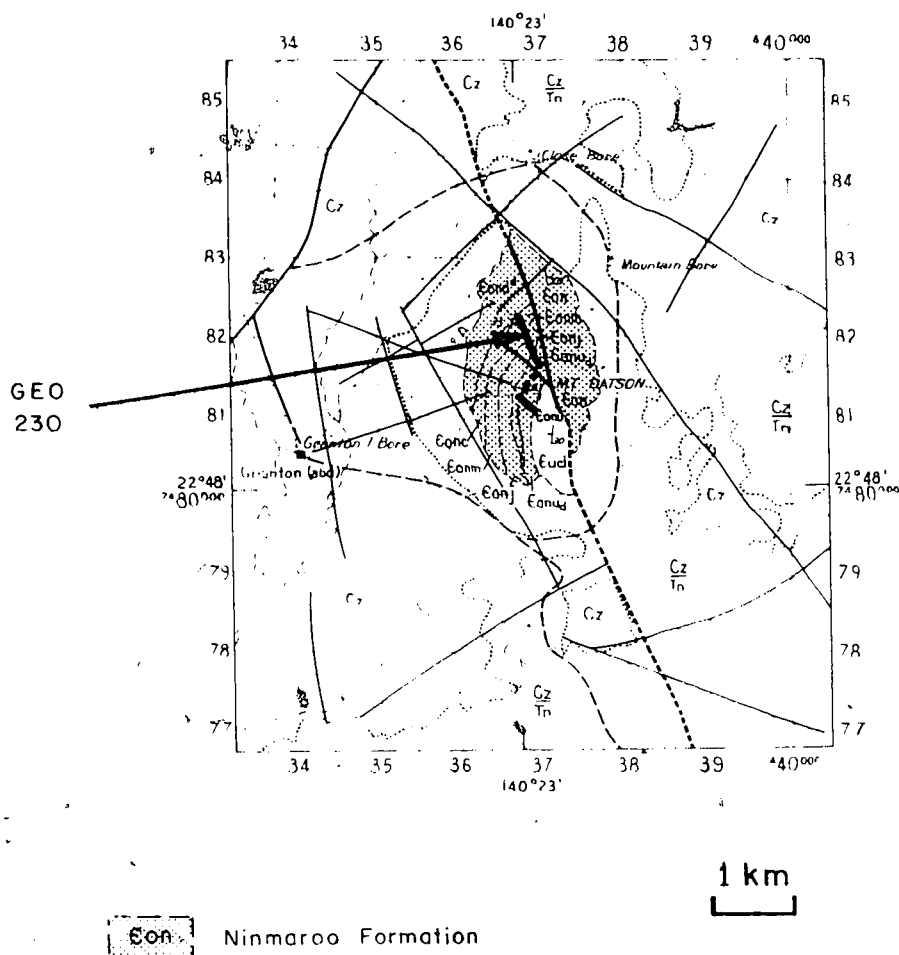


Figure 24 Geologic setting of section H(GEO 230)
(after Druce et al., 1976)

APPENDIX IV

Proposed stratigraphic members of the
Chatsworth Limestone and Ninmaroo Formation

Georgina Basin

by

E.C. Druce, B.M. Radke, & J.H. Shergold

As a result of the lithostratigraphic study of the Ninmaroo Formation and 1:100 000 mapping in the Southern Burke River Structural Belt (BMR, 1976), the following distinction of members in the Chatsworth Limestone and the Ninmaroo Formation is proposed and defined.

CHATSWORTH LIMESTONE

Lily Creek Sandstone Member

The Lily Creek Sandstone Member is named after Lily Creek (140°17'30"E, 22°00'S), a tributary of the Mort River. The type section is the upper 12 m of the Chatsworth Limestone type section at Lily Creek, within the interval 288-300 m (Shergold & others, 1976, figs. 5,6).

The member comprises white to light red, very fine calcareous cross-stratified sandstone with foresets at an angle of 5°-15°. Thin beds of intraclastic limestone with abundant fine sand and some skeletal fragments, and calcareous siltstone are also present. Peloidal grainstones of the typical Chatsworth Limestone underlie the Lily Creek Sandstone Member. No contact with overlying strata is seen at the type section, but to the south the member is conformably overlain by the Unbunmaroo Member of the Ninmaroo Formation. In this area it is thicker (40 m at Black Mountain) and is less sandy and more calcareous, consisting of sandy cross-stratified limestones with interbedded friable sandstone, light grey and brown siltstone, and intraclastic limestone with some horizons of skeletal hash limestone.

The Lily Creek Sandstone Member is strongly diachronous. At Lily Creek it lies within the Hapsidocare lilyensis Assemblage-Zone (Shergold, 1980), which is thought to equate with the Rhaptagnostus bifax/Neoagnostus denticulatus A.-Z. at Black Mountain. At the latter site, the Member occurs in the Neoagnostus quasibilobus/Tsinania nomas A.-Z. This infers a southerly regression during the latest Cambrian which took the time equivalents of the Rhaptagnostus clarki maximus/R. papilio and Sinosaukia impages Assemblage-Zones to migrate the 54 km from Lily Creek to Black Mountain. At Dribbling Bore, the most southerly locality at which Chatsworth Limestone is exposed, dolomitised sediments thought to represent the Lily Creek Sandstone Member, lie at the base of the Cordylodus proavus Assemblage-Zone, illustrating the continuation of the regression into younger biochronological horizons yet.

NINMAROO FORMATION

The Ninmaroo Formation (Whitehouse, 1936 amend. Casey, 1959) extends as a thick sheet of carbonate rocks over much of the southern and southeastern region of the Georgina Basin. The type section is at Black Mountain (Mount Unbunmaroo) where five members are recognised: the Unbunmaroo, Jiggamore, Mort, Corrie and Datson Members (Fig. 23). Detailed mapping has demonstrated that a consistent lithofacies pattern can be recognised throughout the Burke River area, and that these lithofacies approximate closely to the recognised members (Table 1). The three upper members are essentially the same as those of previous workers (Jones & others, 1971; Smith, 1972). The lower two members are equivalent to the variegated limestone/dolomite member of Jones & others (1971). The Unbunmaroo Member is equivalent to units 1 and 2 of Casey (1968) and members 1 and 2 of Smith (1972).

Unbunmaroo Member

Unbunmaroo is the aboriginal name for Black Mountain (140°17'E, 22°32'S) on the Boullia 1:250 000 Geological Series Sheet. The Unbunmaroo Member is exposed in a narrow 90 km long belt which extends from the Swift Hills in the north to Dribbling Bore in the south. Its type section lies within that of the Ninmaroo Formation at Black Mountain. The thickness of the Unbunmaroo Member varies: it is 165 m at Black Mountain, 250 m at Mount Ninmaroo, and 120 m at Mount Datson. At Dribbling Bore, 69 m of dolomitised sediment referable to the Lily Creek Sandstone Member of the Chatsworth Limestone or the Unbunmaroo Member of the Ninmaroo Formation, or both, is exposed, but the top is eroded. Similarly, to the north, at Lily Creek, only 40 m of poorly exposed sequence are referable to this Member.

The Unbunmaroo Member comprises medium to thick bedded limestone, peloidal clast, and peloidal grainstone, micrite (probably thrombolitic), and sandy peloidal grainstone. Pseudomorphs after gypsum crystals and anhydrite nodules are relatively common in the limestones and chert nodules. A massive cross-stratified peloid and ooid grainstone, sandy in places and commonly dolomitised, occurs at the base: within this bed are biohermal mounds of stromatolitic boundstone.

The Unbunmaroo Member conformably overlies the Lily Creek Sandstone Member of the Chatsworth Limestone at Black Mountain, Mount Ninmaroo, Mount Datson and possibly at Dribbling Bore. In the Lily Creek area, however, detailed mapping has revealed a probable unconformity, and this is supported by

~~the intersection of a karst surface in drill-holes. The base of the Unbunmaroo Member lies within the late Payntonian at Black Mountain and Mount Ninmaroo, in the latest Payntonian at Mount Datson, and in the earliest Datsonian at Dribbling Bore.~~

Jiggamore Member

The Jiggamore Member is named after Jiggamore Bore (140°11'15"E, 22°05'S) on the Mort River. It is exposed in a 120 km long belt from Mount Merlin (Duchess sheet area) southward to Mount Datson. The type section is within the type section of the Ninmaroo Formation at Black Mountain where it is 206 m thick. At Mount Ninmaroo it attains 130 m, and at Mount Datson 92 m. The Jiggamore Member is characterised by 'two-tone' limestone, and comprises thin to thick bedded limestones (micrite, frequently bioturbated, clast peloidal and peloidal grainstone, and ooid grainstone), dolostone, and dolomitic breccia. Diagnostic 'two-tone' patterns in the carbonates are a conspicuous diagenetic overprint which has gradational limits. The lower boundary of the member is drawn at the first occurrence of 'two-tone' limestone pressaging its dominance of the sequence. The upper boundary is drawn at the change to predominantly flat-pebble conglomerate limestone. The Jiggamore Member is regionally stratiform, but the boundaries may be discordant on a small scale.

Mort Member

The Mort Member is named after the Mort River (140°10'E, 22°05'S) on the Boulija 1:250 000 sheet area. It is exposed in a 95 km belt from the Swift Hills in the north to Mount Datson in the south, and its type section is also within that of the Ninmaroo Formation at Black Mountain where it is 129 m thick. Some 104+ m has been measured in the Swift Hills, 120 m at Mount Ninmaroo, and 40 m at Mount Datson. The Mort Member conformably overlies the Jiggamore Member, and is conformably overlain by the Corrie Member.

The Mort Member is dominated by thin bedded flat-pebble conglomerate limestone and intraformational breccia, together with peloidal ooid and peloidal clast grainstone. Stromatolitic and thrombolitic biostromes have also been observed in the Mort Member. Flat-pebble conglomerate is formed by the exfoliation of algal mounds and the break-up of hardgrounds during periods of high energy conditions.

Corrie Member

This member is named after Corrie Downs pastoral property (140°06'E, 22°18'S) on the Boulia 1:250 000 sheet area, where it outcrops parallel to the Mort Member in a 95 km belt between the Swift Hills and Mount Datson. The type section is within that of the Ninmaroo Formation at Black Mountain where it is 90 m thick. In the Swift Hills it is 186+ m thick, 170 m at Mount Ninmaroo, and 200 m at Mount Datson.

The member comprises medium to thick bedded echinoderm limestone (skeletal grainstone) together with ooid and peloidal grainstone, skeletal peloidal clast grainstone, and cross-stratified dolomitic sandstone. The white to pale yellow echinoderm limestone, which weathers spheroidally and has a uniform crystalline appearance, is the characteristic rock type. The lower boundary is marked by the change from the dominance of flat-pebble conglomerate to echinoderm grainstone, and the upper boundary by a change to thin bedded peloidal skeletal limestone (Datson Member) which is commonly dolomitised and silicified.

The Corrie Member has in places been deeply weathered resulting in silicification of the skeletal grainstones and the development of chert lenses. The regolith developed over this unit has been mapped separately as the Swift Formation (see also Datson Member).

Datson Member

The Datson Member is named from Mount Datson (140°23'E, 22°47'S) on the Boulia sheet area. It also extends like the underlying Members, from the Swift Hills to Mount Datson, and its type section is also within that of the Ninmaroo Formation at Black Mountain where it is probably 215 m thick. At Mount Ninmaroo it is 62+ m thick, at Mount Datson 295 m, and in the Swift Hills is preserved only in scattered remnants.

The member comprises thin to thick bedded limestone or dolostone (skeletal grainstone, boundstone, peloidal grainstone, clast grainstone, lime mudstone), and chert. The unit is characterised by dolomitisation and silicification.

The Datson Member conformably overlies the Corrie Member, and is gradational laterally and vertically into the siltstones and mudstones of the Swift Formation. Additional to this gradational boundary with the Swift Formation, a regolith composed of chert fragments derived from the Corrie and Datson Members and which has been mapped as Swift Formation, overlies the Datson Member unconformably.

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