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PERMIAN DEPOSITIONAL HISTORY OF THE NOONKANBAH 1:250 000 SHEET AREA, W.A.

by

R.W.A. Crowe (Geological Survey of Western Australia)
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SUMMARY

The Permian strata of the Noonkanbah 1:250 000 Sheet area are described and their origins interpreted.

The Grant Formation was laid down under glacio-lacustrine and marine conditions. Uplift and erosion preceded a further marine transgression which deposited a thin clastic sequence (Nura Nura Member) in the western part of the area. Slow uneven subsidence continued, and the Poole Sandstone was laid down under shallow-water (possibly lagoonal) conditions. After an episode of fluviatile deposition in the east, the sea transgressed the entire area, depositing the Noonkanbah Formation. During the remainder of the Permian, the environment was marine to deltaic (Liveringa Group).

It is concluded that the only substantiated period of uplift that occurred during the Permian in the area was between deposition of the Grant Formation and that of the Poole Sandstone. All other Permian stratigraphic relationships can be explained by inferring gradual subsidence of the area.

INTRODUCTION

The purpose of this report is to make available rapidly the large amount of detailed stratigraphic information that was collected in 1974 during the Second Edition mapping of the Noonkanbah 1:250 000 Sheet area*. A full stratigraphic table, a bibliography, and sections on such topics as physiography and structure will be included in the Second Edition of the NOONKANBAH Explanatory Notes (Crowe & Towner, in prep.).

The re-mapping of NOONKANBAH has enabled a more detailed study to be made of the Poole Sandstone and Grant Formation which crop out extensively on this Sheet area and until now have received relatively little attention. The main method of study used was the measuring of detailed sections in the St George and Poole Ranges, from which an assessment of the environments of deposition of these units was made.

The logs of numerous bores put down for coal exploration in the area have been examined and correlated with the stratigraphy as established on the surface. This study has also made possible an interpretation of the environment of deposition of the Liveringa Group. The results of these studies form the basis of this report.

In many cases there is insufficient evidence to determine a particular depositional environment, but a suggestion is put forward and it is made clear that further work is needed before the suggestion can be accepted.

The rocks are described according to the classification of Gilbert (in Williams et al., 1958). Grainsize is classified on the Wentworth scale and the terms used for bedding thickness are those of Ingram (1954). The classification of cross-bedding follows McKee & Weir (1953) and that of flaser and lenticular bedding follows Reineck & Wunderlich (1968). Other terms used are referenced in the text.

The subdivisions of the Grant Formation and Poole Sandstone have been defined elsewhere (Crowe & Towner, 1976) and the relationships of these units are shown in Figure 1. Yeates et al. (1975a) have defined and revised the nomenclature of other Permian units (relationships shown as Fig. 9).

Although due regard has been paid to all palynological determinations that have been made, in many cases, all that is presently available is a palynological zone number which has not yet been defined in any publication. In such cases it has been decided not to mention these determinations.

* 1:250 000 Sheet area names are typed in capitals, (i.e. MOUNT RAMSAY) to distinguish them from place names.

The Liveringa Group is known to contain coal (Woodward, 1915; Guppy et al., 1958), and exploration has been carried out in the area by Premier Mining Co. Pty Ltd (1965-66; Baarda, 1967), Australian Inland Exploration (1970-72), Esso Exploration and Production Australia Inc. (1973-74; Galloway & Howell, 1975), Dampier Mining Co. Ltd (1973-75).

The positions of exploration holes drilled by these companies will be published on the forthcoming geological map (Crowe & Towner, in prep.) and available relevant information is included in this Record. Reports by Australian Inland Exploration and Dampier Mining Co. are not yet available to the public and have therefore not been referred to, although A.I.E. have granted permission for some of their information to be incorporated in this Record.

GRANT FORMATION

On NOONKANBAH, from subsurface information, three subdivisions of the Grant Formation (Guppy et al., 1952) have been recognized. WAPET (1973) recognize a basal sandstone unit, a middle shale unit and a top sandstone unit in Mount Hardman No. 1 well and a similar sequence was encountered in St George Range No. 1 (Continental Oil Company of Australia Ltd, 1966). These three units have also been recognized in many other petroleum exploration wells in the basin but they have not yet been formally named. The lower two units have been correlated with Permian units that crop out in the southern part of the basin (Koop, 1966) but because these correlations are in doubt (Playford et al., 1975) the names are not used here. Instead, the three subdivisions are referred to as the 'Lower Sandstone Unit', the 'Middle Shale Unit' and the 'Upper Sandstone Unit'. As far as is known, only the 'Upper Sandstone Unit' is exposed on NOONKANBAH.

As a result of the 1974 mapping, Crowe & Tower (1976) have defined part of the exposed section of the Upper Sandstone Unit as the Wye Worry Member and the Millajiddee Member of the Grant Formation. It is hoped that eventually the units recognized in the subsurface can be formally defined as formations and that the Grant Formation can then be upgraded to group status.

LOWER SANDSTONE UNIT

Distribution

The unit occurs only in the subsurface and was identified in Mount Hardman No. 1 well (WAPET, 1973). Esso No. 27 bore bottomed in it (Galloway & Howell, 1975) and St George

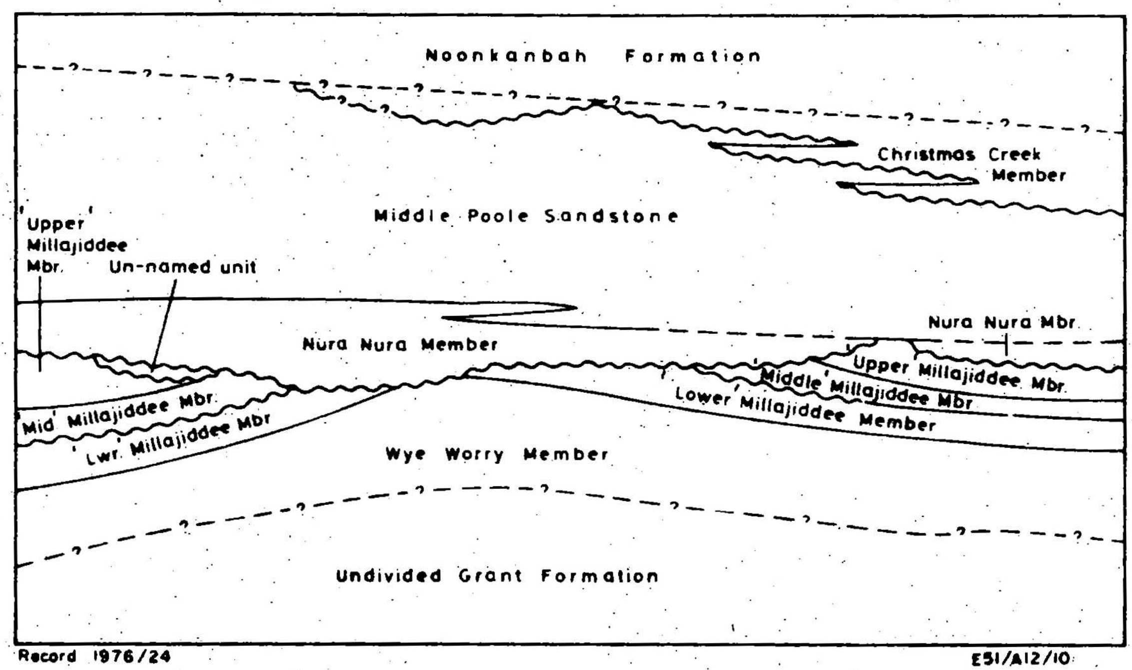

Fig.1. Diagrammatic relationships of units in the Poole Sandstone and the Grant Formation. Solid line is conformable boundary; dashed is disconformable and wavy is erosional

Range No. 1 penetrated it (Continental Oil Company of Australia Ltd, 1966). Other wells on NOONKANBAH may have penetrated this unit but positive identification is not possible. The unit has been recognized in many wells throughout the Canning Basin.

Relationships

The unit rests unconformably on Carboniferous rocks and probably on Devonian rocks and is overlain, apparently conformably, by the 'Middle Shale Unit'.

Lithology

The unit is composed mainly of fine to coarse-grained sandstone and minor silt and clay. Poorly sorted lithicwacke conglomerate and scattered lithic fragments near the base were penetrated in Mount Hardman No. 1. In St George Range No. 1 the lower half is calcareous. The unit contains carbonaceous siltstone and rare coal.

Thickness

The unit is 381 m thick in Mount Hardman No. 1 and 652 m in St George Range No. 1. These figures indicate thickening of the unit into the centre of the Fitzroy Trough. To the southeast, in the Gregory Sub-basin, the unit is 406 m thick in Lake Betty No. 1 (WAPET, 1972a). Only 10 m of the unit is present in Barbwire No. 1, but it thickens again farther to the south (WAPET, 1972b).

Age

Probably Late Carboniferous, based on palynological evidence from Mount Hardman No. 1 well (Dolby, in WAPET, 1973).

Environment of deposition

Microfossils from Mount Hardman No. 1 and Lake Betty No. 1 indicate 'no evidence of a marine environment' (Dolby, in WAPET, 1973). The carbonaceous siltstone and coal recorded in St George Range No. 1 well suggest a continental or transitional environment. The lithic conglomerate in Mount Hardman No. 1 was interpreted by WAPET (1973) as tillite, but we regard the interpretation as tentative. Consequently a possibly cold, continental environment of deposition is indicated.

MIDDLE SHALE UNIT

Distribution

The unit occurs only in the subsurface and was identified in Mount Hardman No. 1, Esso No. 27 bore and St George Range No. 1. Other wells on NOONKANBAH may have intersected this unit, but positive identification is not possible. The unit has been identified in many wells elsewhere in the Canning Basin.

Relationships

The Middle Shale Unit appears to overlie the Lower Sandstone Unit conformably.

The upper boundary is gradational.

Lithology

In St George Range No. 1 the unit consists of calcareous and carbonaceous siltstone and shale, and minor sandstone. The siltstone and shale contain minor pyrite. In Mount Hardman No. 1 and Esso No. 27 bore the unit consists of non-calcareous argillaceous sandstone, and minor siltstone and shale.

Thickness

The unit is 57 m thick in Mount Hardman No. 1 well, 40 m in Esso No. 27 bore, and 225 m in St George Range No. 1.

These figures show that this unit thickens towards the middle of the Fitzroy Trough. In Barbwire No. 1 the unit is thinner again (64 m), and like the Lower Sandstone Unit it thickens southwards into the Kidson Sub-basin (WAPET, 1972b).

Age

Sakmarian (sensu lato), based on palynological evidence. The lower part may range into the Late Carboniferous (Dolby, *in* WAPET, 1973).

Environment of deposition

Microfossils indicate 'no strong evidence of a marine influence' (Dolby, *in* WAPET, 1973). The substantial thickness of shale in St George Range No. 1 indicates quiet water deposition, so that, if the microfossil evidence is correct, the unit may have been deposited under freshwater conditions. The coarser nature of the sediment in Mount Hardman No. 1 may reflect proximity to a source area.

UPPER SANDSTONE UNIT

Crowe & Towner (1976) have defined parts of the exposed section of the Upper Sandstone Unit as the Millajiddee Member and the underlying Wye Worry Member. Rocks below the

Wye Worry Member have been mapped as undivided Grant Formation (Crowe & Towner, in prep.).

As far as is known, all the exposed rocks of the Grant Formation belong to the Upper Sandstone Unit.

Distribution

The major part of this unit is not exposed. North of the Fitzroy River and east of Christmas Creek the unit is exposed in scattered hills and ridges. Identification of members in these exposures is more tentative than to the south of the Fitzroy River and west of Christmas Creek, where the unit is well exposed in the St George and Poole Ranges. The lower part of the unit is known from bores in the Poole Range and near Prices Creek. St George Range No. 1 spudded in the unit just below the Wye Worry Member and Mount Hardman No. 1 and Esso No. 27 also penetrated the unit.

Just east of the Sheet area the unit is well exposed and one locality on Mount Ramsay is described in this report, as it has a bearing on the geology of NOONKANBAH.

Each subdivision of the unit is now dealt with in turn.

Sandstone below the Wye Worry Member (including unexposed part)

Relationships

A sandstone sub-unit below the Wye Worry Member, lies, apparently conformably, on the 'Middle Shale Unit', but as overlying beds overlap onto Carboniferous and Devonian units this part of the formation may do so also. The sandstone sub-unit is overlain, apparently conformably, by the Wye Worry Member.

Lithology

In the subsurface, the sub-unit is composed of interbedded clean and argillaceous, fine to coarse-grained sandstone and minor siltstone. The sorting varies from poor to excellent. It is calcareous in parts, and conglomerate occurs throughout. Many of the well-rounded grains are frosted. On the surface the sub-unit is composed of medium to coarse-grained quartz wacke, feldspathic wacke and minor quartz arenite. It is moderately sorted, and forms cliffs because of its poorly-bedded nature (Plate 1). Many of the exposures are weathered in a polygonal pattern which apparently bears no relation to tectonic or sedimentary structures (Plate 2). The upper part of the sub-unit is better bedded, fine-grained, well-sorted, and bioturbated (see Section No. 12). In the Poole Range the sub-unit contains fossil wood fragments and trace fossils.

At the western end of the St George Range, near Mount Tuckfield, the sub-unit forms rugged hills (Plate 3) and is composed of a series of fining-up cross-bedded cycles which are interpreted as point-bar deposits (Section 13a). Normally, the bedding is too indistinct and obscured by weathering to enable the sedimentary structures to be identified.

Thickness

St George Range No. 1 well was spudded just below the base of the Wye Worry Member and intersected 652 m of the Upper Sandstone Unit. The Upper Sandstone Unit as a whole thins northwards towards the basin margin, as only 217 m was intersected in Mount Hardman No. 1 (WAPET, 1973). The Upper Sandstone Unit most probably also thins to the south onto the Barbwire Terrace, because farther south it wedges out completely. To the northwest and southeast of the area it is present in the Fitzroy Trough and Gregory Sub-basin respectively.

Age

Sakmarian (sensu lato), based on palynology (Dolby, in WAPET, 1973).

Environment of deposition

Palynological results indicate 'no evidence of a marine influence' (Dolby, in WAPET, 1973); however the homogeneity of the sub-unit is not typical of a continental sequence. On the other hand the interpretation of point-bar deposits near Mount Tuckfield suggests a fluviatile or deltaic environment. Reports of well-rounded frosted quartz grains from the sub-surface (WAPET, 1973) suggest that parts of the sequence may have been derived from an aeolian source (see Pettijohn, 1957, p. 70).

Present knowledge does not allow interpretation of any specific environment.

Wye Worry Member

Relationships

The base of the Wye Worry Member (Crowe & Towner, 1976) is exposed in the centre and western end of the St

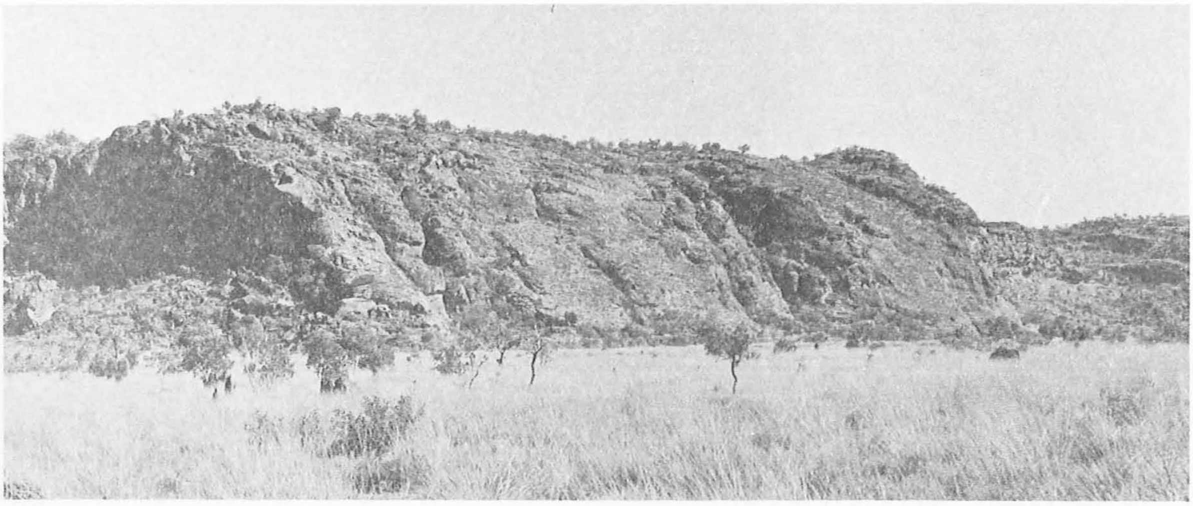

Plate 1 Typical exposure of the Grant Formation in the eastern St George Range. The steep cliffs are a result of the poorly bedded nature of the formation. Lat. 18°49'12"S, long. 125°30'30"E

Plate 2 Polygonal weathering pattern on the surface of an exposure of the Grant Formation. This pattern is apparently unrelated to tectonic or sedimentary structures.

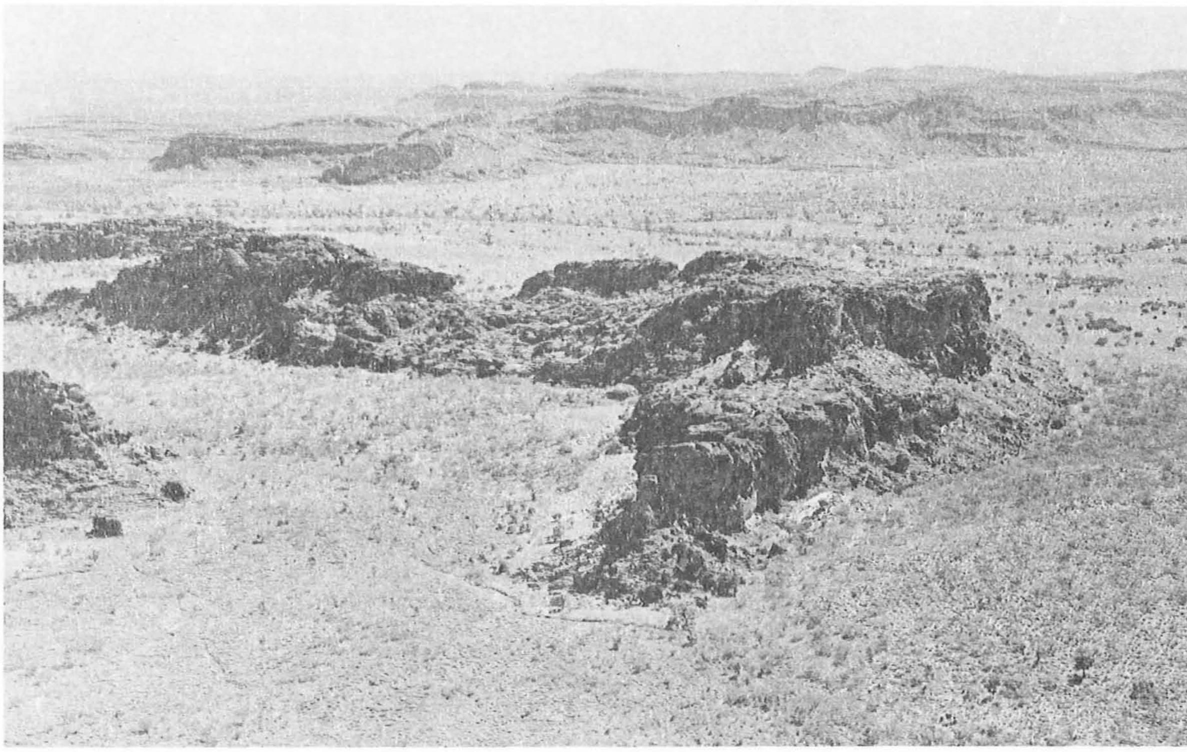

Plate 3 Looking northeast from the top of Mount Tuckfield across the Carolyn Valley. The sandstone below the Wye Worry Member is exposed in the rugged hills in the foreground.

George Range (Sections 12 and 17) and in the centre of the Poole Range. It is marked by a change from non-calcareous well-sorted sandstone to calcareous, poorly sorted sandstone containing dropstones. Exposures are not good enough to enable one to tell whether the relationship is conformable or disconformable.

The member is overlain by the Millajiddee Member. In the Poole Range and St George Range the upper contact is conformable, but on MOUNT RAMSAY and in the Lauris Range it is a disconformity.

Lithology

The Wye Worry Member varies both laterally and vertically (Enclosure 1). In the eastern St George Range it is repetitively exposed in a series of north-trending fault blocks. Section 9 (Location sketch, Enclosure 1) has been designated the type section by Crowe & Towner (1976). The base of the member is not exposed in Section 9; the lowest part of the sequence consists of calcareous and silicified, grey, laminated and thinly bedded very fine-grained quartz wacke, siltstone and claystone. The individual laminae average 5 mm thick and the silt and clay in each lamina are sharply separated into layers (Fig. 2 and Plate 4). The beds are laterally continuous, and contain minor, small-scale, slump-and-flowage structures, together with some burrows and a few dropstones of igneous and metamorphic rocks. In places about 50 percent of these dropstones have well faceted and striated faces (Plates 5 & 6). Many of the boulders and cobbles are well rounded also. Some of the dropstones are of boulder size (Plate 7) but the majority are cobbles or smaller. The large variety of lithologies present, the faceted and striated faces of the boulders, and the fact that they occur in very fine-grained sediment indicate that these dropstones were released by floating ice, so that the deposits may be classed as tillite.

The graded silt and clay laminae are interpreted as glacial varves. According to the classification in Duff et al. p. 51 (1967) most of these varves are diatactic, that is, the silt and clay are separated. Some of the varves are also composite, that is, there are several silt-clay alternations within a particular varve (Fig. 2).

Above the graded laminae sequence the Wye Worry Member consists of unsorted silty claystone and clayey siltstone containing an increasing abundance of dropstones. Conglomerate lenses occur, consisting in places of faceted and striated clasts in a granule and pebble matrix. Farther up the sequence the silt and clay become increasingly calcareous, and calcareous concretions are common (Plate 8). Scattered well-rounded quartz grains are present throughout the sequence and have frosted surfaces. Towards the top of the member, plant fragments occur in siltstone and very fine-grained sandstone. However, in places there is some graded bedding associated with small slump-and-flowage structures. Because of these features, the beds could be interpreted as turbidites. However, typical sequence of turbidite internal structures (Bouma, 1962, p. 49) could not be found.

To the west of the type section, in the central St George Range, the Wye Worry Member becomes thinner and more difficult to recognize. The lithology is similar. However, the graded laminae are not present and, instead, the base of the unit consists of very poorly sorted conglomerate, which is crudely bedded and cross-bedded. The middle part of the member is generally more sandy than at the eastern end of the St George Range (Section 12).

In the western St George Range the member is more sandy than in the centre (Section 17), and contains a well-defined wedge-shaped sandstone sub-unit in the middle. This sandstone is mainly medium-grained and cross-bedded, but it becomes finer grained where it lenses out towards the east (Plate 9).

In the eastern part of the area, in the Poole Range, the Wye Worry Member is coarser grained than in the eastern St George Range. However, in the Poole Range rheotropic structures (both hydroplastic and quasi-solid; Conybeare & Crook, 1968 pp. 36-43) make recognition of the members very difficult. In some parts of this area (e.g. Mount Thorlan, Section 3) the lithology is very similar to that in the St George Range, however elsewhere the lithologies are difficult to map as a result of slumping. It has not been possible to differentiate the two members everywhere in the Poole Range area at 1:250 000 scale on the geological map (Crowe & Towner, in prep.).

The general lithology of the member in the Poole Range is sandy siltstone and silty sandstone. In cliff exposures the member is non-calcareous, but in exposures near plain level the rock is commonly grey and calcareous, suggesting that the higher exposures were calcareous before being de-calcified by weathering. On the south side of the Poole Range a relatively undeformed section was measured in detail (Section 4a), and shows regular alternations of sandstone and siltstone, which are possibly symmict varves (i.e. no separation of silt and clay). However, the absence of well-defined grading makes this identification tentative.

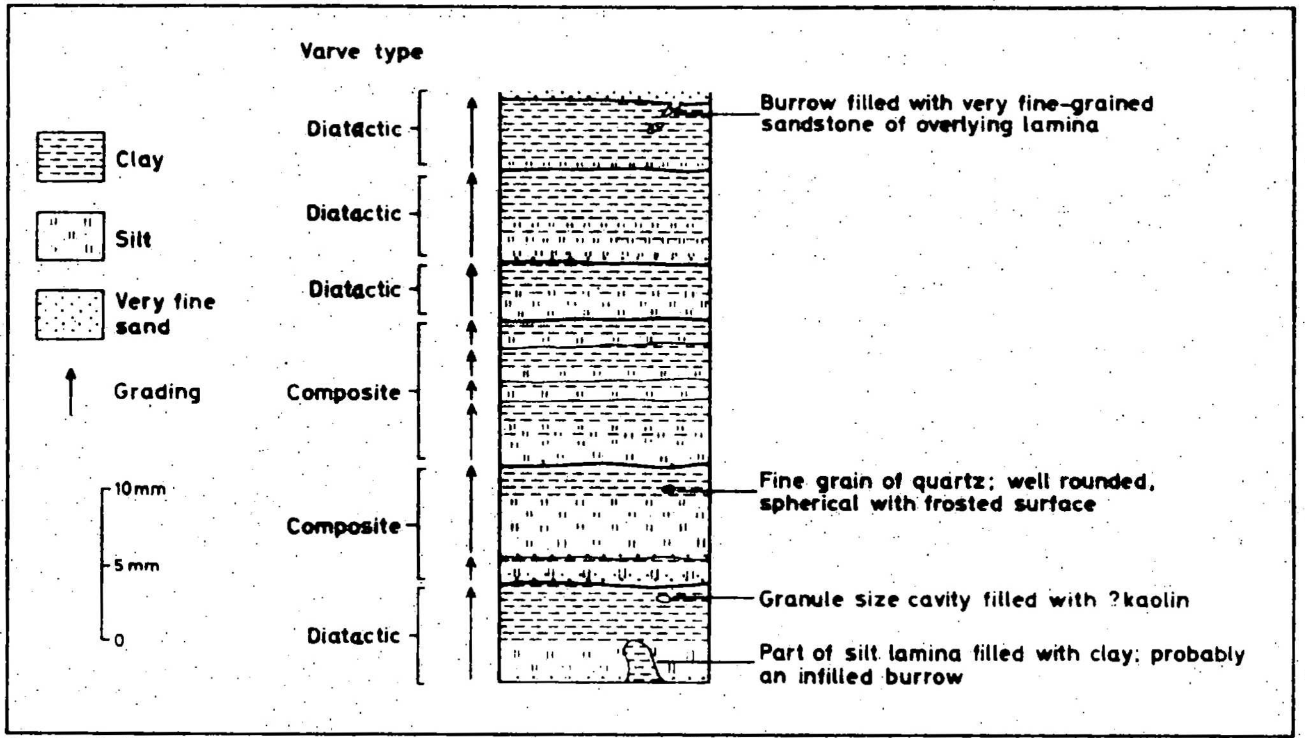

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Fig. 2. Wye Worry Member: detailed section of graded beds interpreted as varves from microscopic examination of slabbed sample. Lat. 18°45'30"S, long. 125°18'50"E

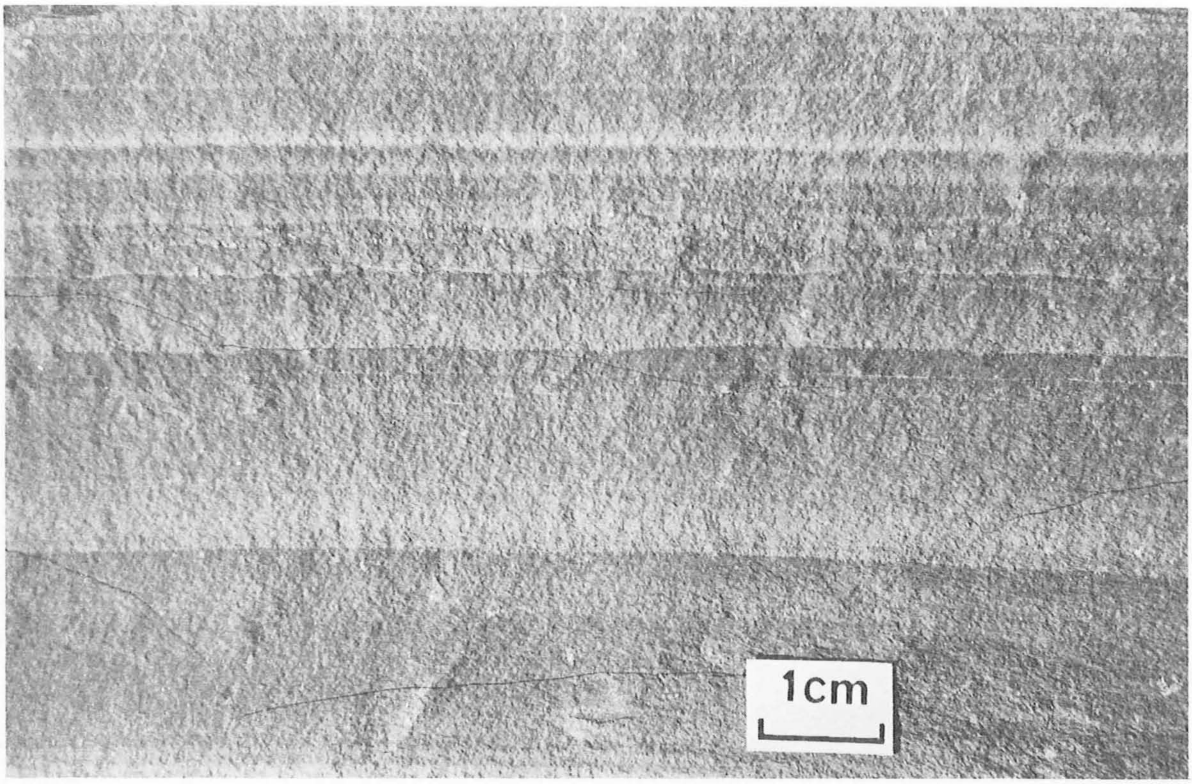

Plate 4 Wye Worry Member, Grant Formation. Laminated graded siltstone and claystone interpreted as varves. The claystone is darker than the siltstone. Lat. 18°46'30"S, long 125°18'50"E

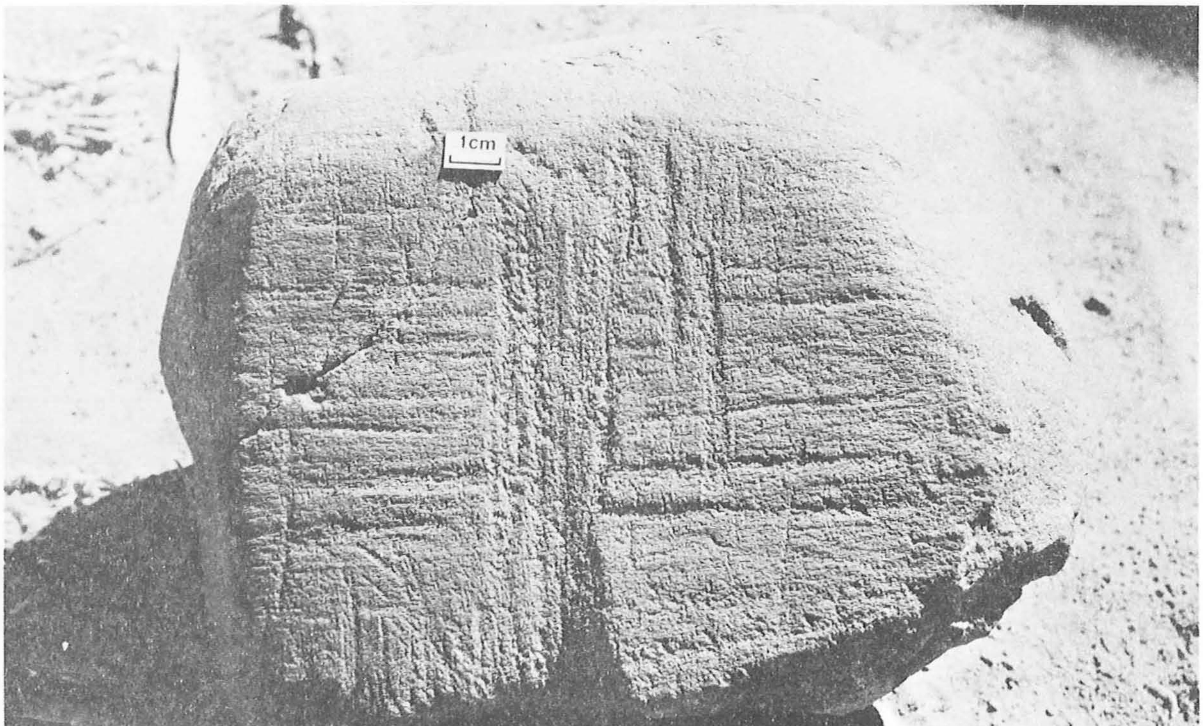

Plate 5 Faceted dropstone, striated in two directions. Wye Worry Member, Grant Formation. Lat. 18°46'30"S, long. 125°18'50"E.

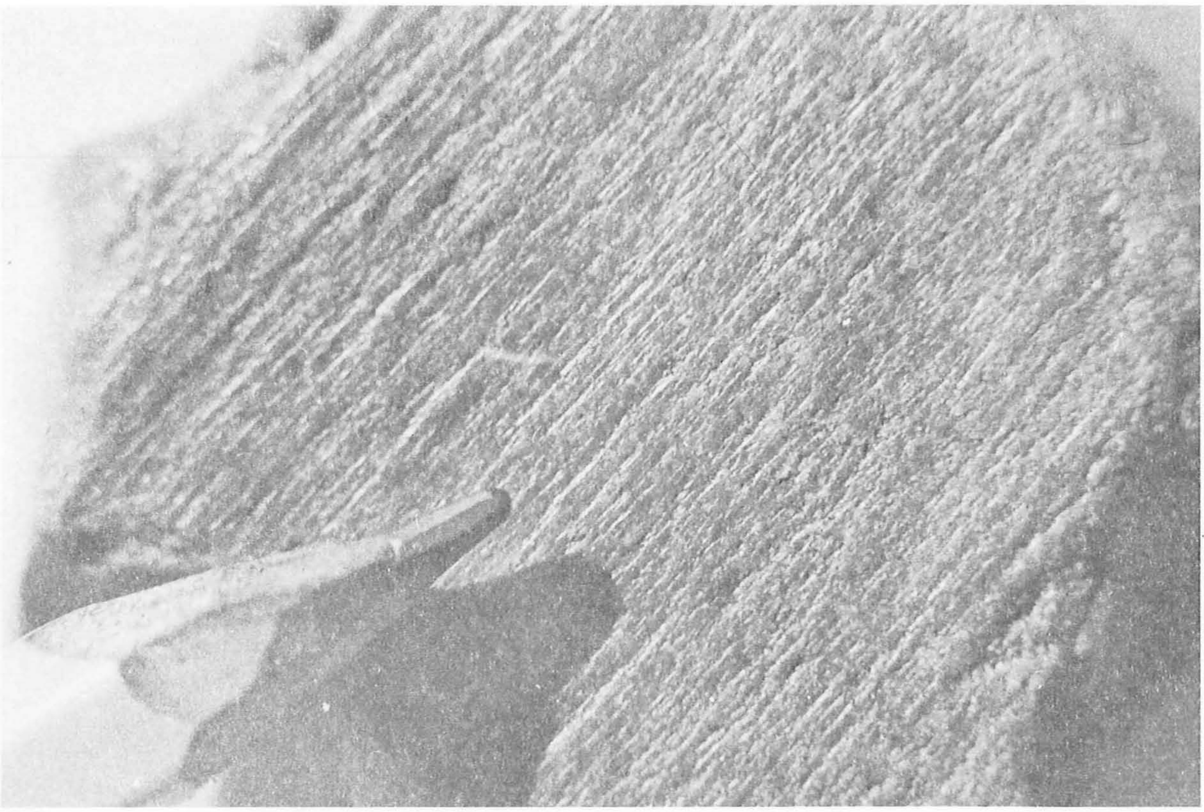

Plate 6 Close-up of striated surface of dropstone, Wye Worry Member.

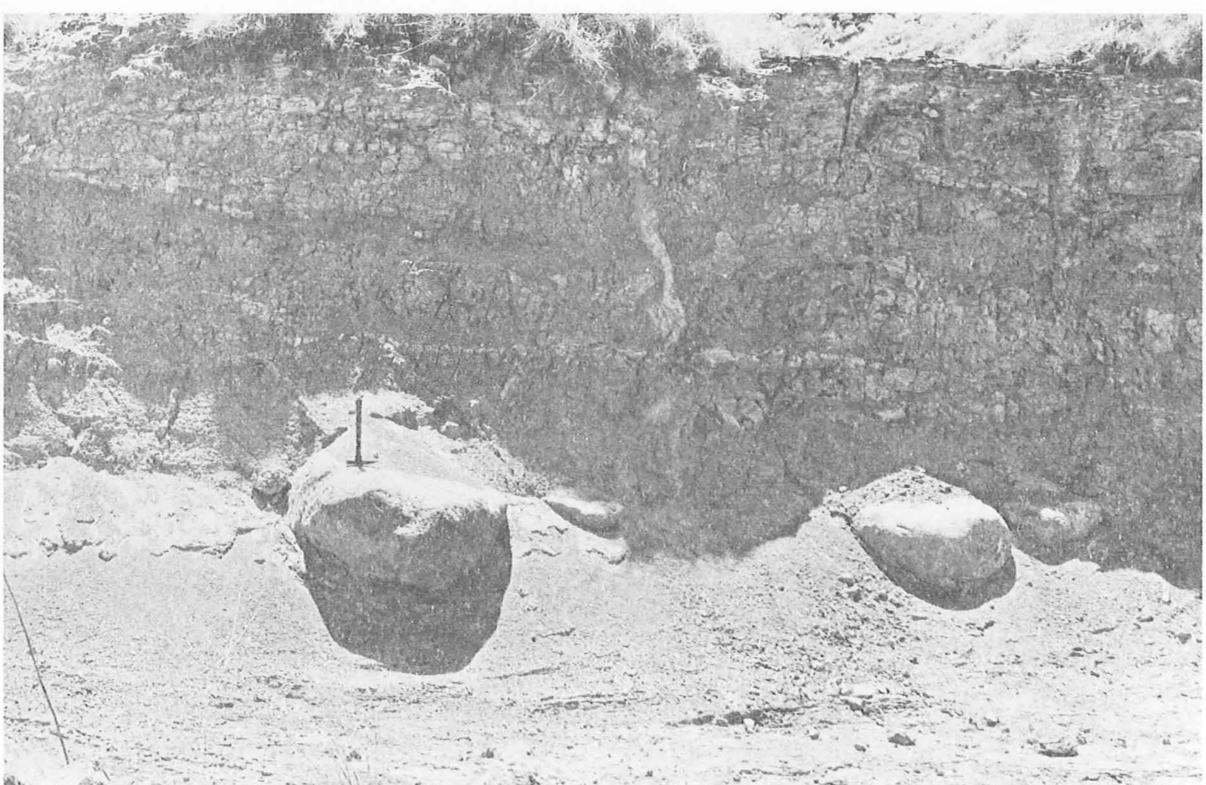

Plate 7 Large dropstones in siltstone, near type section of the Wye Worry Member.
Lat. 18°47'00"S, long. 125°18'36"E

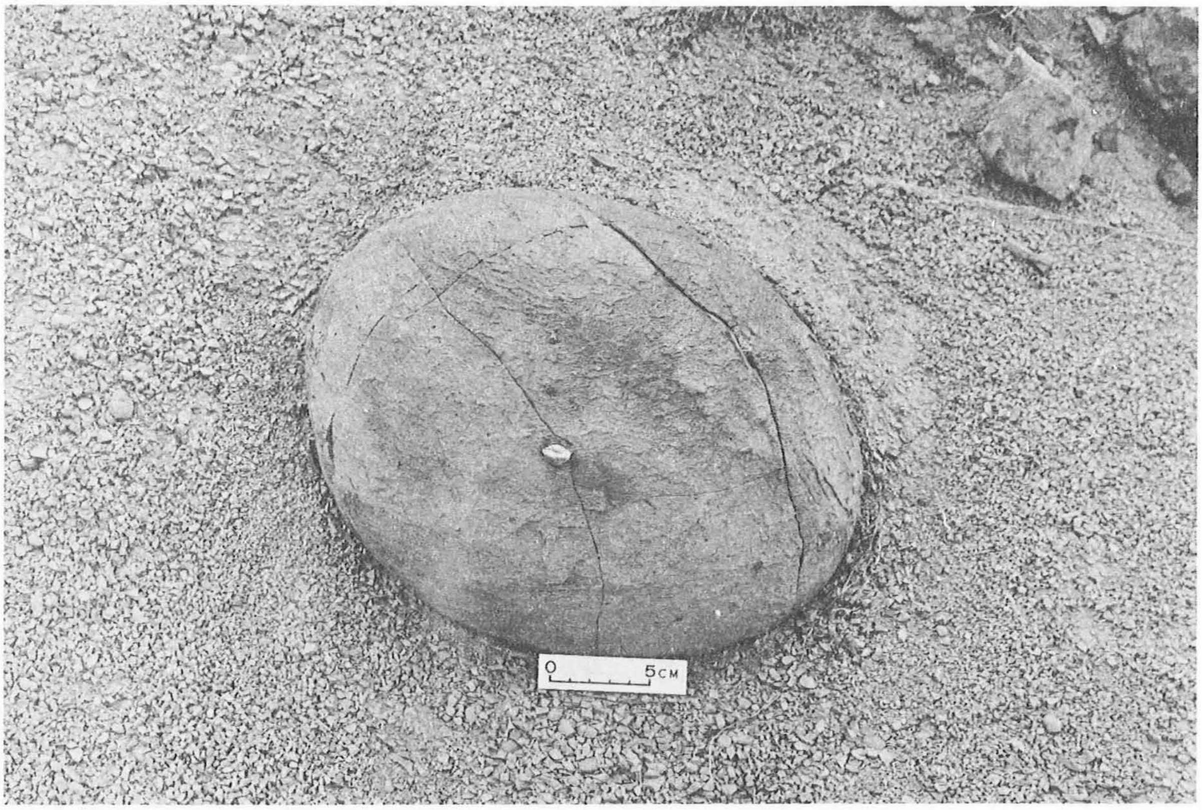

Plate 8 Calcareous concretion from the middle of the Wye Worry Member, at the type section. Note small dropstone pebble near centre of concretion.
Lat. 18°46'30"S, long. 125°18'50"E

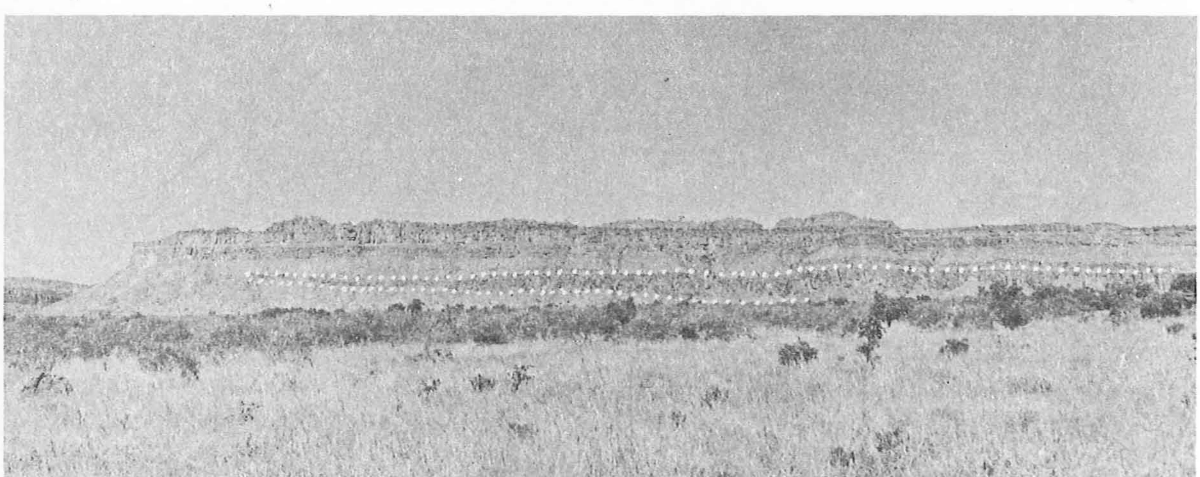

Plate 9 Sandstone lens in Wye Worry Member, southern side of Carolyn Valley.

The Wye Worry Member also crops out on MOUNT RAMSAY at latitude 18°50'30"S, longitude 126°07'00"E, where it is very similar to exposures in the east St George Range. At this locality, in a very weathered outcrop, the siltstone is cut by several clastic dykes which contain pebbles; some of the pebbles are faceted and striated. The dykes widen upwards their relationships are shown in Figure 3. These dykes are interpreted as fossil ice wedges, as they are similar to Pleistocene ice-wedge casts described by Dionne (1975) (see Millajiddee Member, environmental interpretation).

To the north of the Fitzroy River, in the Lauris Range, the Wye Worry Member is similar to sections of the member in the east St George Range. As in the Poole Range, there is much rheotropic deformation. In the Lauris Range area the surfaces of the dropstones bear crescentic impact marks (Plate 1D), as well as later facets and striations. Similar boulders occur in exposures of the Grant Formation around Fitzroy Crossing, and on this basis such exposures are identified as Wye Worry Member.

Thickness

Poole Range	45 m +	(Section 3)
East St George Range	95 m +	(estimated)
Mid St George Range (variable)	25 m	(Section 12)
West St George Range	65 m	(Section 17)

In most areas the member is probably about 50 m thick; it is thinnest (25 m) in the central St George Range and thickest in the east St George Range (95 m +). The Member is tentatively identified in Esso No. 27 bore where it appears to be about 30 m thick.

Age

The following marine macrofossils were found at latitude 18°39'36"S, longitude 124°58'36"E;

Pelecypods:

Eurydesma? sp. ind
Deltopecten lyonsensis Dickins 1957
Etheripecten cf. *tenuicollis* (Dana) 1847
Streblopteria sp.

Gastropods:

Keenia? sp. ind.

Brachiopods:

Unidentifiable dielasmatids and spiriferids

Bryozoans:

Fenestella sp.

Crinoids:

Calceolispongidae sp. nov.

According to Dickins et al. (in press) these species indicate a Late Sakmarian age. Accurate vertical positioning of these fossils was not possible, but they were found in the middle part of the member. Indeterminate wood fragments and plant stem fossils were also found, but are not age-diagnostic.

Environment of deposition

The base of the member, where exposed, consists of lenses of cross-bedded conglomerate containing faceted and striated clasts interpreted as glacial in origin. The cross-bedding indicates these deposits were laid down by currents. Similar lenses occur in the lower part of the type section in the eastern St George Range.

In the type section of the member interpreted diatactic varves occur near the base of the unit. Kuenen (1951 pp. 75) has reviewed the literature which shows that separation between silt and clay is not possible in waters whose salinity is more than 1/50th of that of normal sea water. When the salinity rises above that value, the silt and clay settle simultaneously. Thus the water in which the varves were deposited was probably fresh, and had little or no connection to the open sea. Moreover, the laterally persistent bedding and grading, which are characteristic of varves, indicates that the mudstones were deposited in a quiet, standing body of water. The presence of glacial dropstones throughout the sequence indicates that icebergs or ice sheets periodically floated over the area.

Above the varved part of the sequence there is no grading of silt and clay, which would indicate that the salinity of the waterbody was high enough to cause simultaneous settling. The presence of marine fossils in this part of the sequence supports this hypothesis. Dropstones are also present in this part of the sequence, so that the area was still under the influence of a glacial climate; moreover, the fossils are thick-shelled varieties and are indicative of a cold-water

Plate 10 Well-rounded dropstone in Wye Worry Member in Lauris Range, showing crescentic impact marks. These boulders also have faceted and striated faces. Lat. 18°10'20"S, long 125°25'30"E

environment (Dickins et al., in press). Where dropstones are concentrated inlenses in a conglomerate matrix the lens is interpreted as the load of a single iceberg, dropped when the iceberg melted.

Frosted, well-rounded sand grains are distributed throughout the freshwater and marine parts of the sequence. Frosting of the surface of sand grains is normally indicative of an aeolian environment so that these grains are interpreted as having been transported into the environment by wind.

In the western St George Range there is no separation of silt and clay within the Wye Worry Member, and the sequence is generally more sandy. This may mean that the water body was always too saline or that conditions were not quiet enough for the suspended load to settle out.

In the Poole Range area also, the member is more sandy than in the eastern St George Range. At one locality symmict varves have been tentatively interpreted (Section 4a), so that deposition from a standing body of water is suggested. However, the presence of laterally persistent conglomerate indicates that parts of the sequence were also deposited by currents.

Farther east, on MOUNT RAMSAY, the member is similar to sections in the east St George Range. In the Lauris Range the section is also similar and contains dropstones that are well rounded and have crescentic impact marks, as well as facets and striations. According to Conybeare & Crook (1968, p. 18) such impact marks indicate high-velocity water flow. So the clasts were originally derived from a high-energy fluviatile environment in an area of Precambrian outcrop. They were then transported by glaciers to a large standing body of water where icebergs were formed, and which later melted and dropped their loads.

Millajiddee Member

Relationships

The Millajiddee Member (Crowe & Towner, 1976) overlies the Wye Worry Member everywhere except at Mt Thorlan and in the southwest of the St George Range, where it is cut by the unconformity at the base of the Nura Nura Member of the Poole Sandstone (Fig. 1). The lower contact is conformable in the St George Range, and probably also in the Poole Range. On MOUNT RAMSAY and in the Lauris Range it is a disconformity.

Subdivision

The member is a sandstone unit which generally has three recognizable subdivisions; a lower fine-grained part ('lower' Millajiddee Member), a middle medium and coarse-grained part ('middle' Millajiddee Member), and a fine-grained upper part ('upper' Millajiddee Member), which is characteristically slumped, and commonly cut out by the unconformity at the base of the Nura Nura Member.

Complete sections of the Millajiddee Member were only seen in the southeastern and west central parts of the St George Range. The St George Range section (No. 15) has been designated the type section by Crowe & Towner (1976).

Lithology

'Lower' Millajiddee Member: The 'lower' Millajiddee Member is well exposed in the western St George Range (Section 15). It consists of thinly bedded siltstone and fine-grained quartz wacke and contains climbing ripples, wavy bedding, assymmetrical ripple marks, and minor trough cross-bedding. In section 15 this part of the member is disconformably overlain by the 'middle' Millajiddee Member.

In the central St George Range (Section 10) the 'lower' Millajiddee Member is coarser grained, consisting of medium-grained quartz arenite which grades upwards into fine-grained quartz arenite and quartz wacke. It contains abundant ripple cross-stratification and interference ripple marks; it also contains abundant load casts and is extensively bioturbated near the base (Plates 11 & 12). Fossils found include wood fragments and plant impressions.

In the eastern St George Range the lithology is similar, consisting of medium and fine-grained, massive, poorly-bedded, quartz arenite and quartz wacke. The unit crops out as straight-sided cliffs in many of the hills in this area and lacks any well-defined internal structure.

In the Poole Range the lithology is similar but the unit occurs as slide and slump blocks within the underlying Wye Worry Member, so that on the geological map (Crowe & Towner, in prep.) the two units are locally undivided.

On MOUNT RAMSAY and in the Lauris Range the 'lower' Millajiddee Member is missing. However, on MOUNT RAMSAY, this part of the member is represented by the material filling clastic dykes in the Wye Worry Member (Fig. 3). Overlying this material is a thin siltstone unit with erosional upper and lower contacts. A similar siltstone is present at the same level in the Lauris Range.

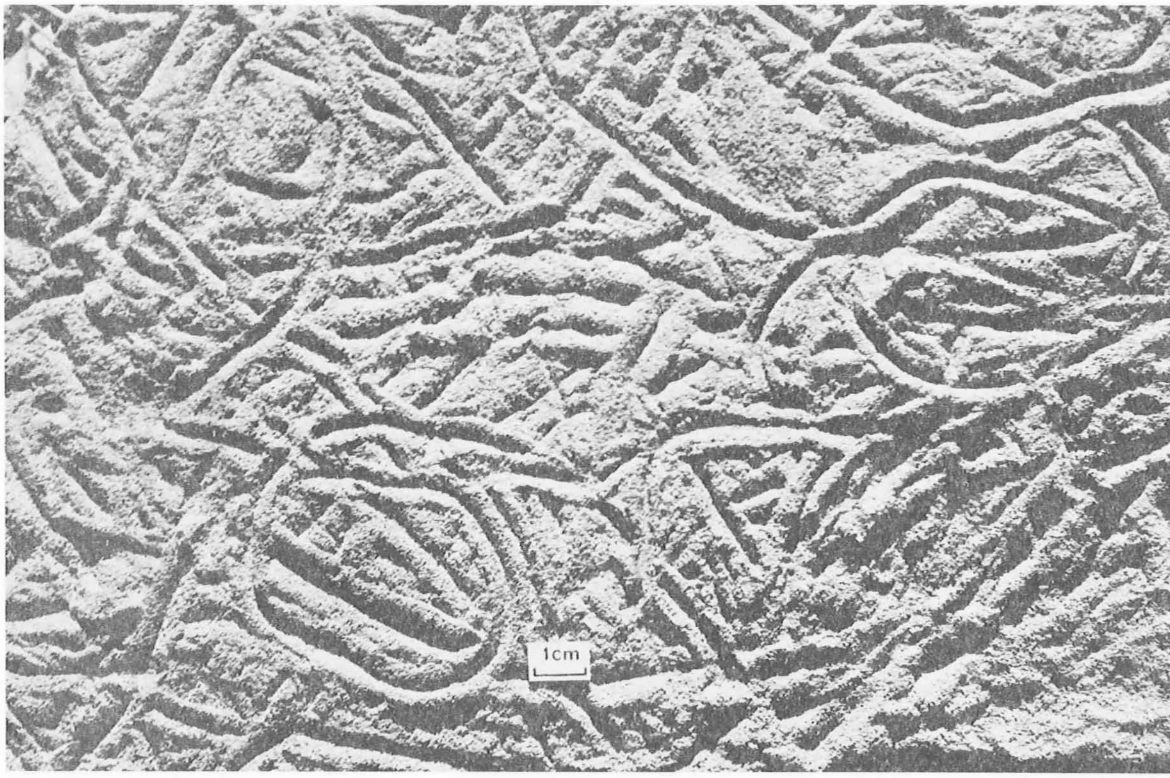

Plate 11 Bioturbated bedding surface, 'lower' Millajiddee Member, central St George Range. Lat. 18°43'52"S, long. 125°07'52"E

Plate 12 Load casts on the underside of a bed, 'lower' Millajiddee Member, central St George Range. Lat. 18°43'52"S, long. 125°07'52"E

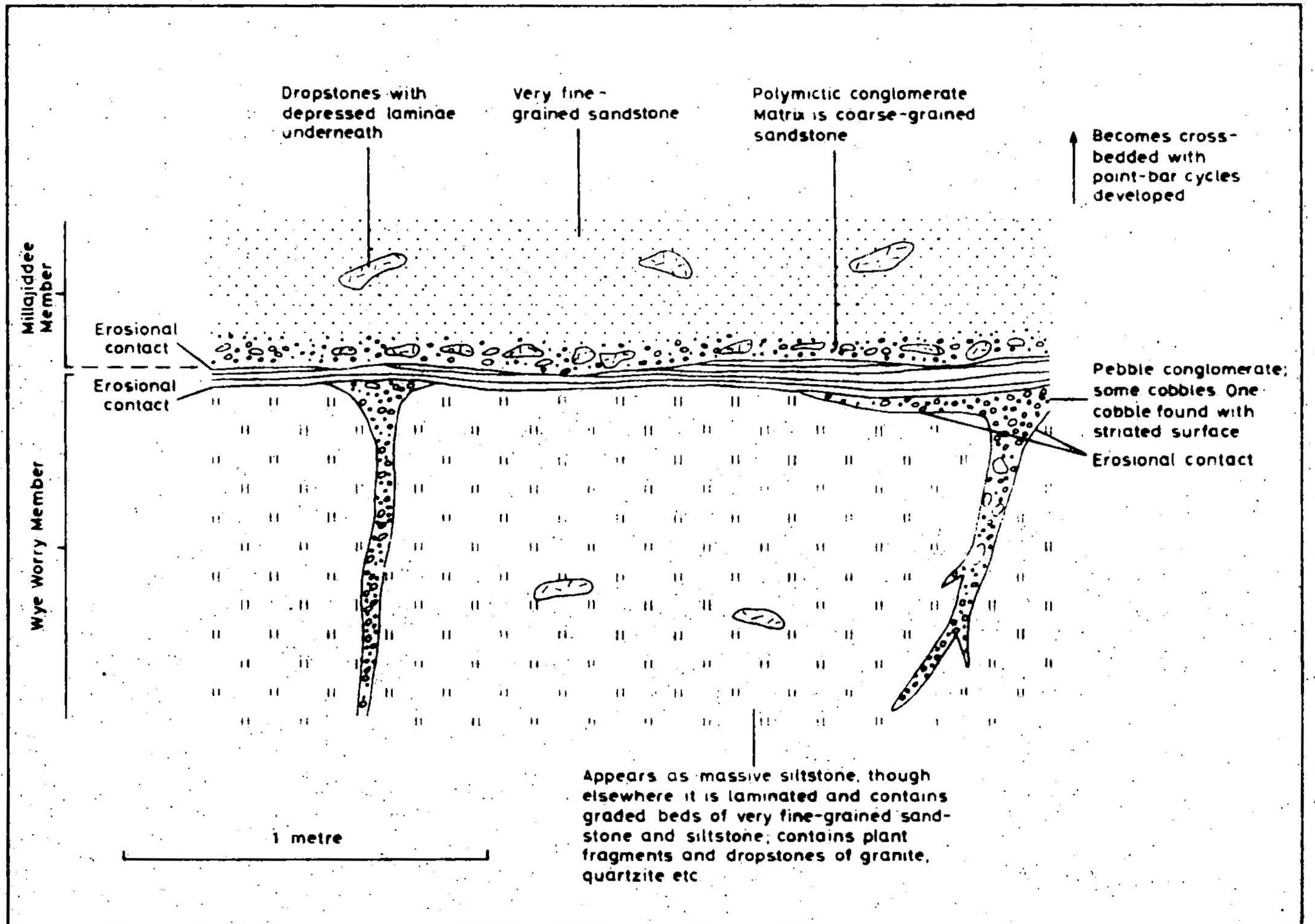

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Fig. 3. Clastic dykes of pebble conglomerate (Millajiddee Member) cutting siltstone of the Wye Worry Member. The dykes are interpreted as infilled ice-wedges. Lat. 18°50'30" S; long. 126°07'00" E (Mount Ramsay)

<u>'Middle' Millajiddee Member</u>: In the western point of the St George Range (Section 15) the 'middle' Millajiddee Member unconformably overlies the finer-grained 'lower' Millajiddee Member, and consists of medium to fine-grained quartz wacke with minor quartz arenite at the base. It contains pebble conglomerate, many erosional contacts, and trough cross-bedded fining-upwards and coarsening-upwards sequences. The fining-upwards sequences are topped by thin-bedded units containing asymmetrical ripple marks and are interpreted as point-bar deposits. Elsewhere in the western St George Range, planar cross-bedding is abundant (Plate 13).

In the centre of the St George Range (Section 10) the 'middle' Millajiddee Member consists of medium and fine-grained quartz wacke with minor lithic wacke. It contains both planar and trough large-scale cross-bedding and has some fining-upwards sequences characterized by basal quartzite-pebble and clay-pellet channel lag deposits.

Towards the southeastern part of the range the 'middle' Millajiddee Member thickens (Section 8) and consists of moderately to poorly sorted feldspathic wacke and quartz wacke. Much of the cross-bedding around Section 8 is of the festoon type (planar) and in places well-developed point-bar sequences occur (Fig. 4).

In the Lauris Range this part of the member is only a few metres thick and is lithologically similar to the sections in the St George Range; on MOUNT RAMSAY, however, the unit contains dropstones at the base. (Fig. 3).

<u>'Upper' Millajiddee Member</u>: The 'upper' Millajiddee Member is everywhere characterized by more or less extensive large-scale slump structures, which commonly obscure the smaller sedimentary structures.

In the western part of the St George Range this part of the member consists of very fine-grained quartz wacke inter-bedded with siltstone. Planar cross-bedding was recognized, but slump structures predominate. At the top of the unit climbing ripples-in-drift (McKee, 1965) were identified.

In the central St George Range the 'upper' Millajiddee Member is absent and is thought to have been eroded before deposition of the Nura Nura Member, but in the eastern part of the range the lithology is similar to that in the west except that parts of the unit are coarse-grained.

The 'upper' Millajiddee Member was identified at Mount Amy and Mount Hutton (Section 5), where large-scale slump structures are well exposed (Plate 14). The beds involved in the slumped masses show a post-deformational horizontal lamination which indicates that further compaction of the sediment took place after the slumping (Plate 15).

In the Poole Range many of the slump and slide blocks of sandstone in the Wye Worry Member appear to have been derived from this part of the member, but as already stated it was not possible to map the members in this area.

In the Lauris Range (Section 18) the sediments are locally undeformed and consist of thin planar-bedded siltstone and very fine-grained quartz wacke and quartz arenite. Large-scale planar cross-sets occur in the upper part of the section and contain intraformational breccia blocks up to a metre in diameter. Above this the rock is interpreted as a mudflow deposit; it is a mass of slumped and brecciated blocks with intervening beds of siltstone and intraformational conglomerate.

Age

The Wye Worry Member is dated as Late Sakmarian (Dickins et al., in press). The overlying Nura Nura Member has been dated as Sakmarian (Glenister & Furnish, 1961); therefore, by inference, the Millajiddee Member is of Late Sakmarian age.

Thickness

'lower' Millajiddee Member

Western St George Range	15 m	(Section 15)
Central St George Range	25 m	(Section 10)
Southeast St George Range	20 m	(Section 8)
Poole Range		probably present

'middle' Millajiddee Member

Western St George Range	30 m	(Section 15)
Central St George Range	40 m	(Section 10)
East St George Range	30 m	(Section 7)
Southeast St George Range	60 m +	(Section 8)
Poole Range		probably present
Lauris Range	5 m	(Section 18)

'upper' Millajiddee Member

Western St George Range	25 m	(Section 15)
Eastern St George Range	25 m	(Section 7)
Mt Hutton	15 m +	(Section 5)
Poole Range		probably present
Lauris Range	25 m +	(Section 18)

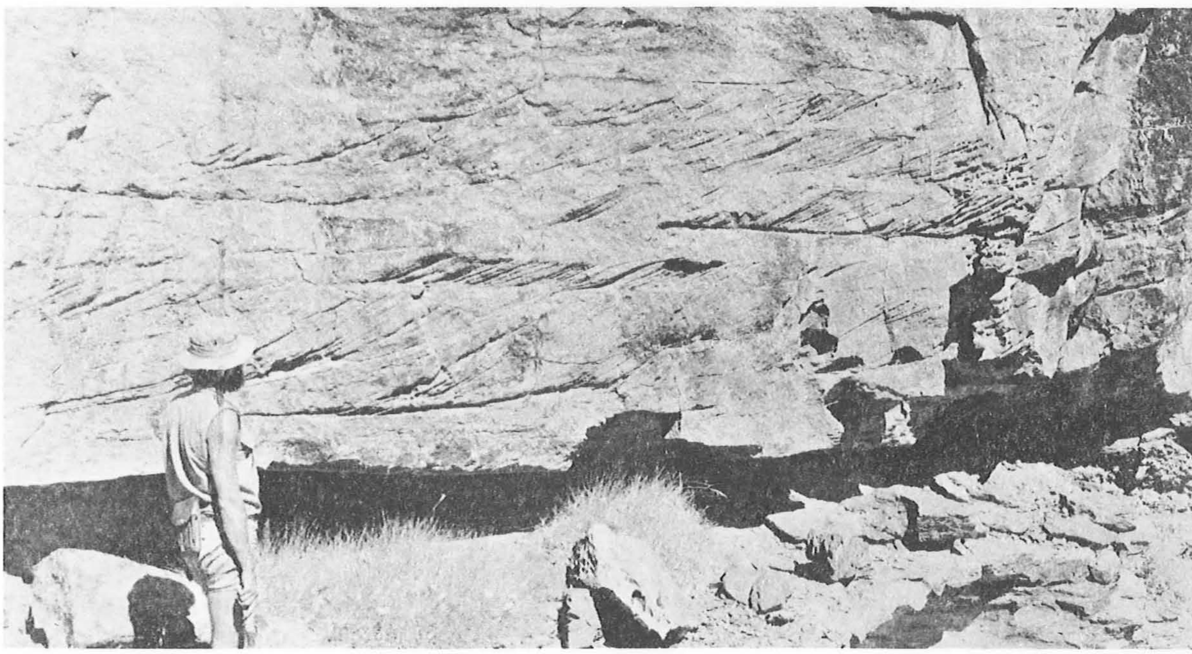

Plate 13 Large-scale planar cross-bedding in the 'middle' Millajiddee Member at the type section. Western part of St George Range. Lat. 18°44'20"S, long. 124°55'52"E

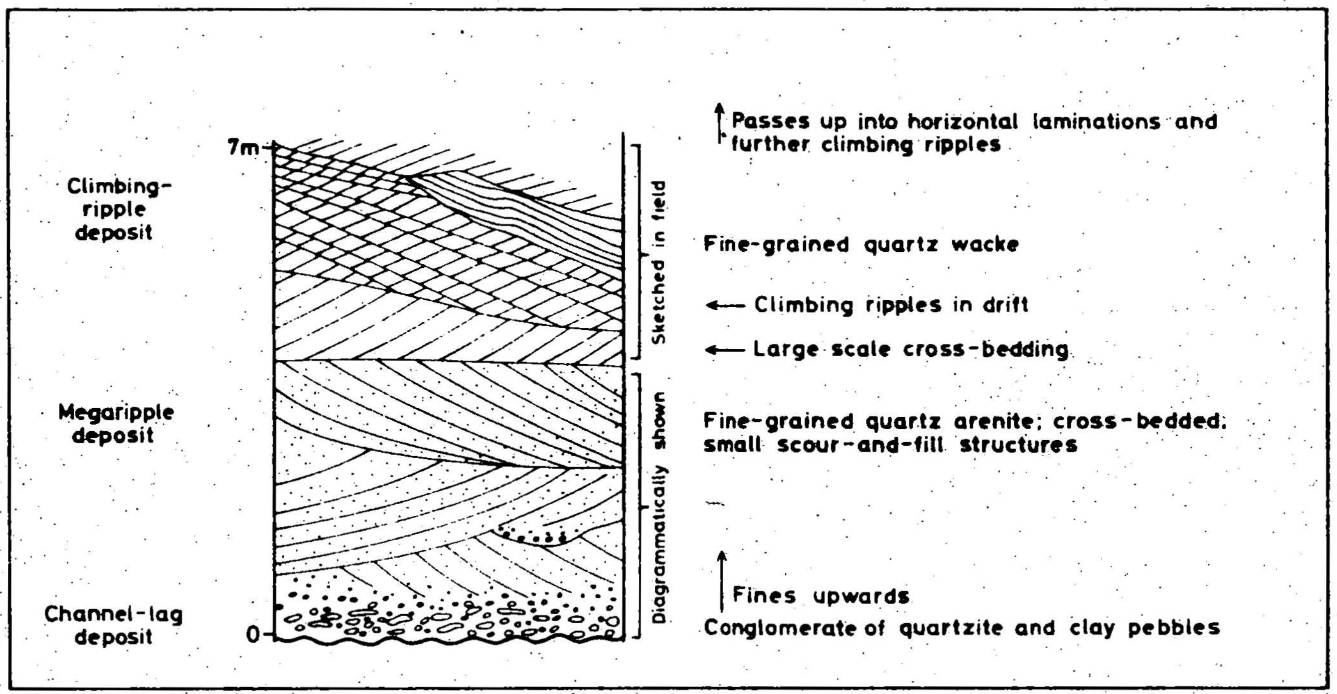

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Fig. 4. Section of point-bar sequence in 'middle' Millajiddee Member in south eastern part of St George Range; lat. 18° 50' 37" S. long. 125° 18' 40" E

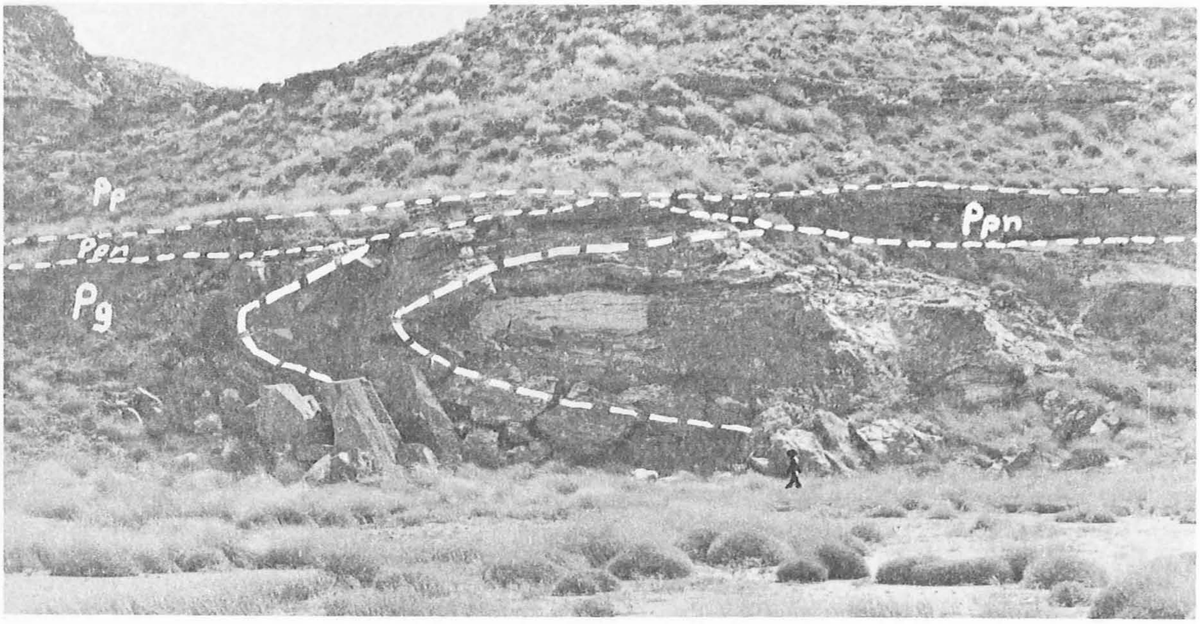

Plate 14 Grant Formation (Pg), Nura Nura Member (Ppn) and 'middle' Poole Sandstone (Pp), at base of Mount Amy. A large slump structure in the Grant Formation is outlined. Plate 17 is a close-up of the middle, light-coloured part of this slump. Inked-in Figure at base of cliff indicates scale.

Mt Hutton - Between St George & Poole Ranges.

Plate 15 Close-up of slump structure in Plate 16, showing overturned beds. The horizontal foliation was caused by compaction of the sediment after it had slumped.

The 'lower' Millajiddee Member is not present in the Lauris Range, nor on MOUNT RAMSAY. The middle part is very thin in the Lauris Range; it is of a fairly uniform thickness over the rest of the area, but thickens to the south in the eastern St George Range to at least 60 m and probably to about 100 m. The Millajiddee Member is also tentatively identified in Esso No. 27 bore where it is possibly 15 m thick.

Environment of deposition

If the Millajiddee Member is considered together with the underlying Wye Worry Member (the boundary is gradational) it can be seen that the lithology passes from siltstone and shale (Wye Worry Member) through interbedded siltstone and sandstone (lower part of Millajiddee Member) into cross-bedded sandstone (middle part of the Millajiddee Member). The sequence shows an overall upward increase in grainsize and sorting, which suggests that it represents a regression (Visher, 1965). To determine whether the regressive shoreline represented by the sequence was linear or deltaic, it is necessary to examine the crossbedded sandstone in more detail. According to Selley (1970, p. 107), the main difference between the two types of regressive sequence is that the lower contact of the cross-bedded sandstone unit is an abrupt erosional one in deltaic sequences and in linear shoreline sequences it is more or less gradational. Moreover in deltaic sequences the cross bedded unit contains fining-upwards point-bar deposits.

Thus in the western St George Range (Section 15) a deltaic interpretation is most appropriate. Similarily in the southeastern part of the range (Section 8) the point-bar deposits could belong in the upper part of a deltaic sequence. On the other hand, in the eastern St George Range (Section 7), a linear shoreline sequence is indicated by the gradational change and the absence of any channel deposits.

Detailed observations help to bear out the interpretation of a regression. The interbedded siltstone and sandstone of the 'lower' Millajiddee Member corresponds well with descriptions of prodelta deposits (Selley, 1970, p.81). For instance, extensively bioturbated zones (~~Plate 12~~) are common in this part of the sequence and the presence of glauconite (noted in thin section) indicates that this part is marine in origin. Plate 11

In the eastern part of the St George Range (Sections 7 and 9), the sequence is somewhat different. The upper part of the Wye Worry Member is similar and agrees well with a prodelta or shelf interpretation. This sequence passes gradationally up into ripple-marked, bioturbated, 'lower'

Millajiddee Member and then, also gradationally, into planar-cross-bedded, fine and medium-grained quartz wacke and quartz arenite of the 'middle' Millajiddee Member. The gradational nature of the boundaries, the better sorting and the absence of point-bar deposits indicate a linear-shoreline (barrier-beach) sequence (Selley, 1970, p. 107).

On MOUNT RAMSAY the 'lower' Millajiddee Member is represented by the clastic dykes, which are interpreted as infilled ice wedges, and the overlying siltstone unit. The ice-wedge interpretation implies that, while pro-delta deposits were being laid down in the west, the extreme eastern part of the area (MOUNT RAMSAY) was above sea level and was being subjected to a periglacial climate.

The 'upper' Millajiddee Member also fits the interpretation of a regression. The topmost part of a deltaic or shoreline sequence normally consists of lagoonal and delta-plain subaerial deposits (Selley, 1970, p. 108). Such deposits are characterized by their fine grainsize, among other features. On NOONKANBAH the environment of the 'upper' Millajiddee Member is hard to interpret, due to hydroplastic deformation but the fine grainsize throughout suggests that low-energy conditions prevailed. Consequently the delta-plain environment seems a possible interpretation.

Esso hole No. 27 intersected small coal seams which are further evidence for a delta-plain origin.

SUMMARY OF DEPOSITIONAL HISTORY

The rocks below the Wye Worry Member were probably deposited in both marine and non-marine environments but there is insufficient evidence collected to differentiate them.

The Wye Worry Member was laid down in a glacial environment. Where it is thickest, its basal part shows evidence of deposition in a freshwater lake but elsewhere basal freshwater indicators are lacking. The lake then became connected with the sea and the rest of the Wye Worry Member was deposited under marine conditions. In Millajiddee Member times, the eastern and northern parts of the area became emergent and permafrost conditions prevailed, while in the south and west the coastline regressed farther, leaving deltaic and shoreline deposits of the 'lower' and 'middle' Millajiddee Member. The area by now had become entirely non-marine, and possible low-energy fluviatile delta-plain deposits were laid down in the south and west.

EVIDENCE OF UPLIFT AND EROSION BETWEEN DEPOSITION OF GRANT FORMATION AND POOLE SANDSTONE

Guppy et al. (1958) described the 'distinct unconformity' between the Grant Formation and the Poole Sandstone, but later Veevers & Wells (1961) claimed the boundary was, at best, a disconformity and that Guppy et al. may have been misled by slumping at the top of the Grant Formation. The slumped beds at the top of the Grant Formation are clearly unconformably overlain by what we now identify as the Nura Nura Member of the Poole Sandstone. Thus it would seem that, at least on NOONKANBAH, Guppy et al. were correct.

From measuring detailed sections, particularly in the St George Range, we are now able to demonstrate that this contact is regionally an angular unconformity and that in at least two places (Sections 3 and 16) the whole of the Millajiddee Member is cut out (Fig. 1; Encl. No. 1), indicating that uplift and erosion occurred prior to deposition of the Nura Nura Member.

In the western St George Range there is an un-named unit which lies unconformably on the Millajiddee Member and unconformably below the Nura Nura Member. This unit is tentatively interpreted as the remnant of an alluvial-fan deposit, which would indicate a period of erosion between the overlying and underlying members, thus supporting the suggestion of an erosional break at the end of Grant Formation deposition.

The unnamed unit consists of a lens (lat. 18°44'20"S, long. 124°55'52"EE) about 20 m long and 1 metre thick containing crudely crossbedded breccia interbedded with sandstone (Plate 16). The breccia blocks consist of angular intraformational clasts and reworked tillitic boulders. The tillitic beds (Wye Worry Member) occur about 100 m below (in the same section), so that the reworked boulders must have been derived from areas where the overlying Millajiddee Member had been stripped off (e.g. near Millajiddee homestead, about 35 km to the east). Moreover the marked angularity of the intraformational blocks indicates very little transportation. The interlayering of such beds with relatively well-sorted current deposits is a characteristic of alluvial fans (Blissenbach, 1954). This deposit may correlate with similar deposits identified in the Lauris Range, although the beds in the Lauris Range have been included in the Millajiddee Member because there is no break in the sequence in that area.

The uplift needed to expose the underlying tillitic beds and to form these deposits could well also have been responsible for the large amount of rheotropic deformation that took place prior to deposition of the Poole Sandstone.

POOLE SANDSTONE

Guppy et al. (1958) described a basal marine member in the Poole Sandstone (Guppy et al., 1952) in the south-western St George Range. They correlated this member with the Nura Nura Member, which occurs on adjoining MOUNT ANDERSON. We have carried the correlation further and have everywhere identified a basal member of the Poole Sandstone which we have called the Nura Nura Member.

The main part of the Poole Sandstone, herein referred to as the 'middle' Poole Sandstone, has not been subdivided.

The top part of the Poole Sandstone, which crops out best in the Poole Range, was previously described as part of the Noonkanbah Formation, (Guppy et al., 1958), but Crowe & Towner (1976) have named it the Christmas Creek Member; as it has an interfingering boundary with the underlying 'middle' Poole Sandstone and appears to have a planar contact with the overlying Noonkanbah Formation.

NURA NURA MEMBER

Section 14 (lat. 18°47'45"S, long. 124°57'33"E.) is proposed as a reference section for the Nura Nura Member (Guppy et al., 1952). However, the lithology of the member varies markedly from place to place, and the other measured sections of the unit should also be taken into account (see particularly Sections 7 and 5, and Figures 5 and 6).

Distribution

The member occurs throughout the St George and Poole Ranges and between these areas it is poorly exposed on the plains. Some outcrops north of the Fitzroy River have been tentatively assigned to this unit. The member has been recognized in the subsurface in Mount Hardman No. 1 well (WAPET, 1973) and in Esso No. 27 bore, where it is fossiliferous.

Relationships

The lower boundary with the Grant Formation is an angular unconformity, although the angular relationship is not always apparent. The upper boundary with the 'middle' Poole Sandstone is conformable in the western part of the area and disconformable in the east. In the eastern part of the St George Range the member interfings with the 'middle' Poole Sandstone.

Plate 16 View of un-named unit between Grant Formation (Pg) and Poole Sandstone (Pp). The unit consists of a breccia overlain by sandstone. Western part of St George Range, lat. 18°44'20"S, long. 124°55'52"E

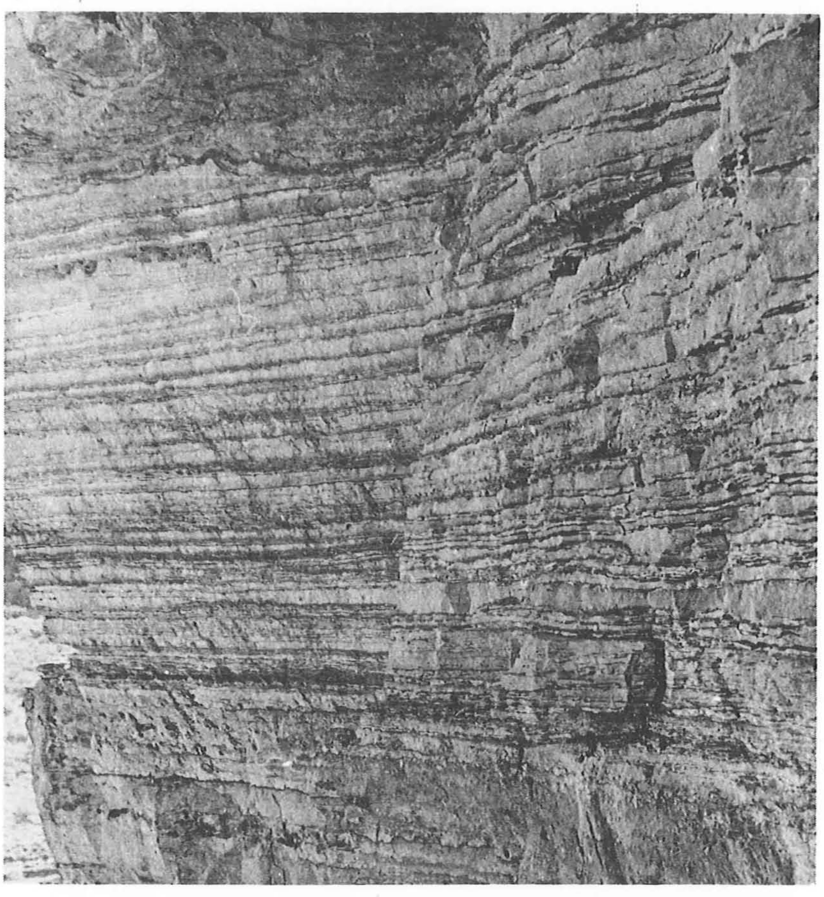

Plate 17 Part of reference section of Nura Nura Member showing wavy bedding with flasers. The photograph covers approximately 5 m of the section. Lat. 18°47'45"S, long. 124°57'33"E.

Lithology

In the west of the St George Range the Nura Nura Member consists mainly of fine-grained quartz wacke and siltstone. Parts of the sequence are calcareous and contain marine fossils. The base of the member is generally marked by a fossiliferous conglomerate which contains boulders of granite, quartzite, etc. derived from the Wye Worry Member of the underlying Grant Formation. Further up the sequence the member contains abundant ripple cross-laminations, wavy bedding, flaser bedding, and minor lenticular bedding (Plate 17). Erosional contacts are common, together with scour-and-fill structures which in places have shell debris constituting the fill. Graded bedding was also noted (Section 14), and bioturbation and vertical burrows are common throughout. In places large-scale cross-bedding is developed, and at one locality near Mount Tuckfield climbing ripples occur near the base. The top 10 m of the member in the reference section consists of massive fine and very fine-grained, well-sorted quartz wacke which contains some faint large-scale festoon cross-bedding.

In the central St George Range the Nura Nura Member is not easily distinguished from the rest of the Poole Sandstone. It appears on the aerial photographs as a darker band overlying the Grant Formation, and this reflects the ferruginization that is present in outcrop. The basal part consists of cross-bedded conglomerate which fines upward into poorly bedded silty sandstone and sandy siltstone. Fossils were found in the member near Tullock Peak on the south side of the range but none were found farther to the north or east. From studies of the aerial photographs in conjunction with the contoured topographic maps (1: 100 000 scale) it is evident that the member thickens abruptly in certain parts of the range. For instance, at a cliff 2.5 km east of Dukes Dome the member thickens from 10 m to 40 m within a distance of about 1 km.

In the eastern part of the St George Range the member is coarser grained than in the west of the range, and consists of a basal sequence of fine to medium-grained quartz wacke which contains numerous vertical burrows, similar to those seen in the member in the western end of the range. This lower part contains small-scale cross-bedding with flasers and lenses of intraformational conglomerate. This passes up into medium-bedded, medium-grained, well-sorted, quartz wacke in which the grains are well-rounded. Above this there is a sequence of fining-upwards cycles consisting of trough cross-bedded coarse to medium-grained quartz wacke and quartz arenite; channel-lag conglomerate occurs at the base of each cycle. The cycles are topped by asymmetrical ripple marks, on some of which trace fossils are preserved. Wood fragments are common in the cross-bedded parts of the sequence.

The Nura Nura Member is well exposed at Mount Hutton, between the St George Range and the Poole Range. At this locality it consists mainly of a fossil root bed which unconformably overlies the slumped Grant Formation (Fig. 5; Plate 15). In detail the Nura Nura Member sequence consists of cross-bedded, fine-grained, quartz-wacke containing some root impressions. This is overlain by a poorly sorted, medium-grained, massive bed, containing very abundant fossil roots, which interfingers laterally with shaly mudstone containing fossil leaf fragments and scattered coarse-grains of sand. This bed is commonly about 2 m thick but it is laterally discontinuous; it is overlain by a completely silicified white quartz arenite bed. Above the silicified white quartz arenite bed. Above the silicified bed are rocks of the 'middle' Poole Sandstone which also contain root impressions. The relationships of these beds are shown in Figure 5.

Farther east, in the Poole Range, the Nura Nura Member consists of various lithologies. At one locality (lat. 18° 47'30"S, long. 125°47'30"E) overturned foresets were observed. At another locality near Poole Range Bore (lat. 18°52'33"S, long. 125°47'53"E) there is a fining-upwards sequence of cross-bedded quartz wacke (Fig. 6). At Mount Thorlan, just to the north of the Poole Range, the Nura Nura Member consists of root beds, silicified quartz arenite and minor conglomerate (Section 5).

The lithology of the Nura Nura Member to the north of the Fitzroy River and the east of Christmas Creek is not known in any detail, as exposures are poor and identification of the member in these areas is either not possible or, at best, tentative. However Mount Hardman No. 1 well intersected the member and showed that it consists mainly of siltstone in that area (WAPET, 1973).

Thickness

Western St George Range	30 m	(Section 14)
Middle St George Range	?12-40 m	(Section 10 and estimation)
Eastern St George Range	27 m	(Section 7)
Mt Hutton	0-12 m	(Section 5)
Poole Range	5-15 m	(Section 3 and others)
Esso No. 27 bore	15 m	

An overall thickening to the west is indicated but local variations occur in the middle of the St George Range area.

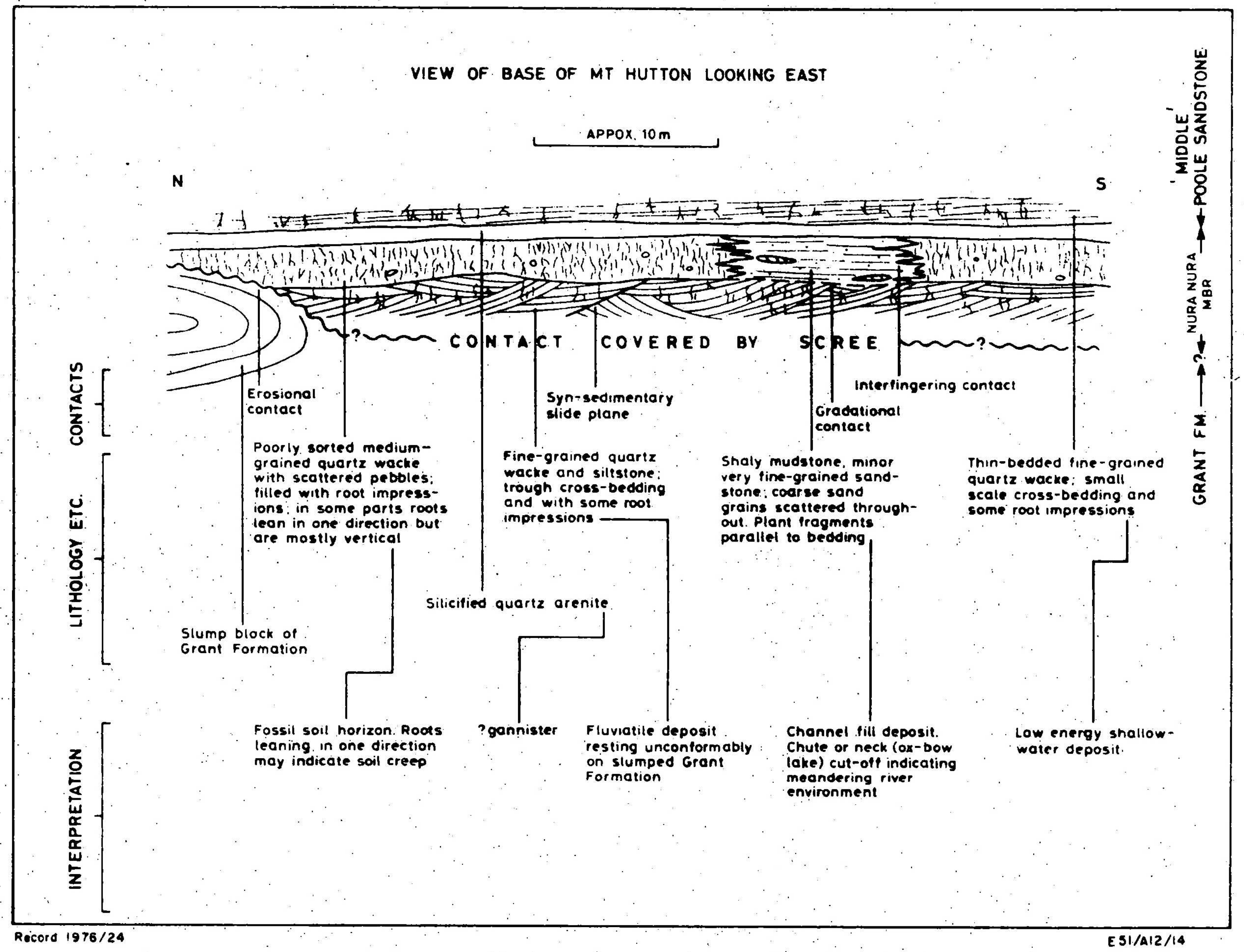

Fig. 5. Diagrammatic field sketch showing relationships, lithology and environmental interpretation of Nura Nura Member at Mount Hutton

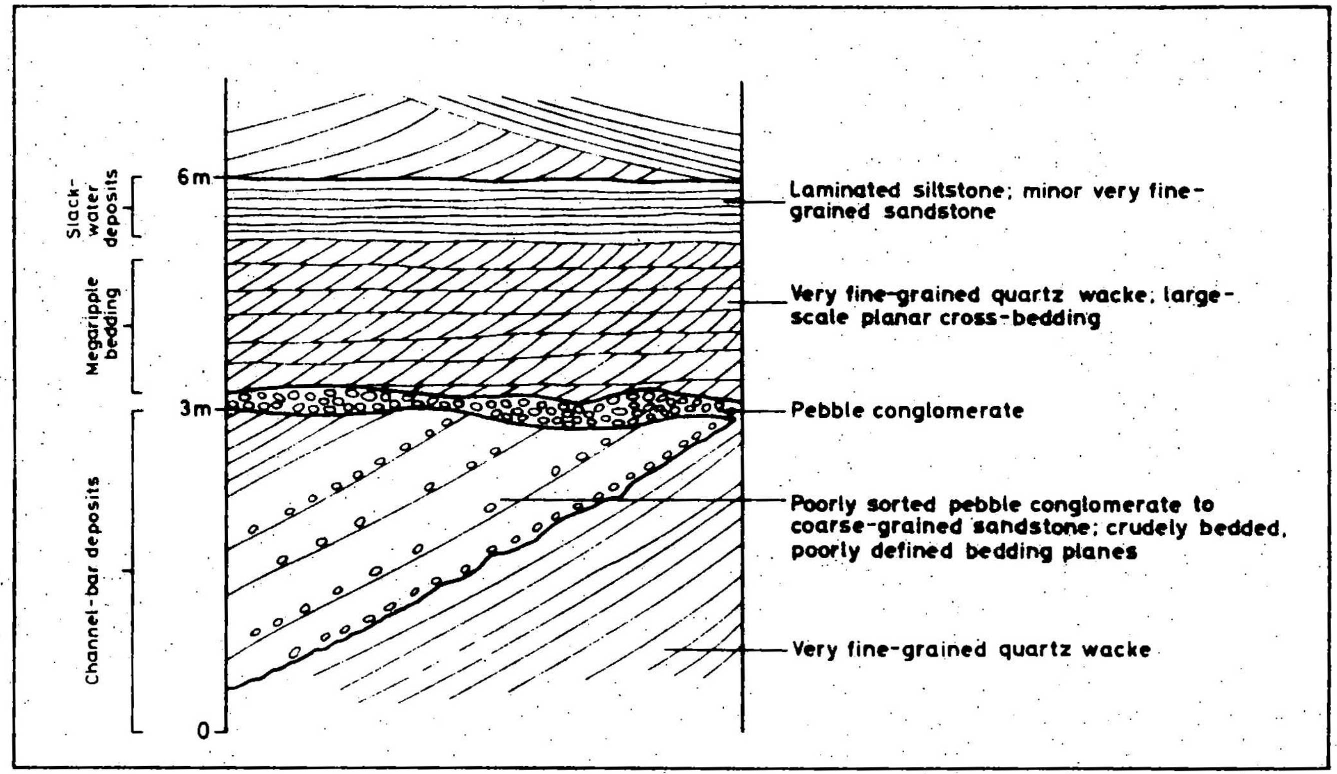

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Fig. 6. Diagrammatic section of Nura Nura Member exposed near Poole Range Bore; lat. 18° 52' 33" S long. 125° 47' 53" E

Age

Guppy et al. (1958) provide faunal lists for the Nura Nura Member and give the age as Early Artinskian. However, this has been amended to Late Sakmarian (sensu lato) by Glenister & Furnish (1961). J.M. Dickins has assigned a Late Sakmarian (sensu lato) age to fossils he collected from near Section 14.

Environment of deposition

In the west of the St George Range the fossils in the member indicate a marine environment of deposition. The basal fossiliferous conglomerate containing clasts derived from underlying units indicates reworking by marine processes as the sea transgressed the area. Further up the sequence the abundant flaser and lenticular bedding is characteristic of shallow-water deposition and the abundance of vertical burrows tends to confirm this interpretation. The beds containing scour-and-fill structures, large-scale cross-bedding and climbing ripples are interpreted as tidal channel deposits. The presence of graded bedding (Section 14) is difficult to explain in shallow-water marine sediments but may be due to deposited suspension loads of either density currents or storm-disturbed water. The relatively clean, fine-grained, well sorted and poorly bedded nature of the massive sandstone at the top of the Nura Nura Member in Section 14 indicates conditions in which the sediment was highly winnowed. Such winnowing is normally attributed to wave action in shallow-marine sediments, and consequently this deposit is interpreted as a beach or sand-bar deposit. The position of this deposit in the vertical sequence (see Visher, 1965) suggests that it may have been a barrier bar.

In the central St George Range little detail is available. The sediments may have been laid down in lagoons, as they are similar to the overlying 'middle' Poole Sandstone.

At the eastern end of the St George Range the overall coarsening-upwards of the sequence indicates regressive marine conditions. The lower part of this section is similar to the sequence at the western end of the range and the abundant burrows and lenticular thin bedding indicate a shallow-marine environment. This part of the section is overlain, with an erosional contact by fining-up cycles interpreted as point-bar deposits. According to Selley (1970, p. 77) such a section is typical of a regressive deltaic sequence and this is the interpretation placed on the member in the eastern St George Range.

At Mount Hutton, the lower part of the sequence is composed of fine-grained cross-bedded sandstone containing root impressions. The fossil roots indicate a continental environment and the cross-bedding suggests fluviatle deposition. Above these deposits is a root-filled bed which is interpreted as a fossil soil horizon. Figure 5 shows how the fossil soil interfingers laterally with undisturbed shaly mudstone. Because this mudstone interfingers with the soil, it must have been deposited at the same time as the soil was supporting vegetation. The absence of current structures in the mudstone indicates that it was deposited from suspension in a standing body of water. The coarse grains of sand distributed throughout the mudstone were probably carried into the water body by wind or on vegetation rafts. Because this mudstone deposit is of limited lateral extent (less than 10 m) it is interpreted as a channel-fill (ox-box lake) deposit similar to those described by Reineck & Singh (1973, p. 245). Thus the Nura Nura Member at Mount Hutton is interpreted as representing meandering river deposition in a vegetated area. Further work in the area may show that other types of meandering river deposit are also present at this level.

In the Poole Range area several environments may be represented. For instance, the essentially plane-bedded part of the sequence at Mount Thorlan consists of graded sandstone and siltstone containing fossil root beds (Section 3). Such deposits were probably deposited on a flood plain, although the high degree of disruption of bedding due to root growth makes this identification tentative. Elsewhere in the Poole Range the available evidence suggests deposition by currents. The overturned foresets indicate high-energy currents and the fining upwards sequence near Poole Range Bore suggests a fluviatile environment. This sequence (see Fig. 6) bears a close resemblance to the typical braided-river sequence shown by Reineck & Singh (1973, p. 241). Features to note in this sequence are the wide range of grain size, the unidirectional current readings and the inclined conglomeratic foresets. Thus in the Poole Range area the environment of deposition is interpreted as a fast-flowing braided river together with its flood plain.

It can be seen, then, that the Nura Nura Member represents a transition from high-energy fluvial conditions in the east through to a shallow-water marine environment in the west (Fig. 7), and therefore that the palaeogradient probably sloped towards the west. Nothing, however, is known about the Nura Nura Member to the north or south of the belt of outcrop, so the environmental interpretation is tentative.

'MIDDLE' POOLE SANDSTONE

Distribution

The 'middle' Poole Sandstone forms rounded hills which flank the St George Range, and comprises the upper part

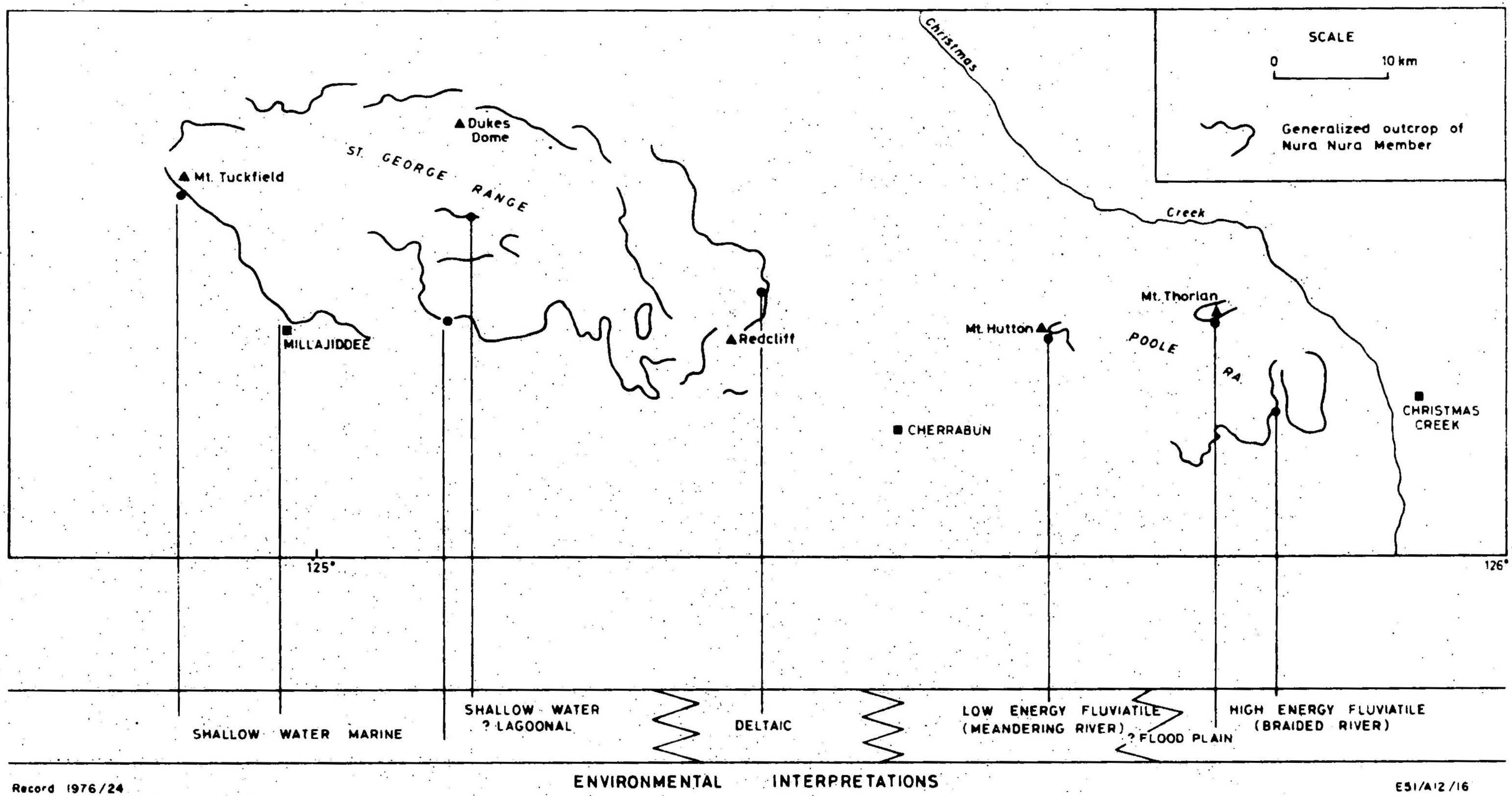

Fig. 7. Distribution and enviromental interpretation of Nura Nura Member. The black dots mark localities where enviromental interpretation have been made

of the sequence at Mount Amy, Mount Hutton and in the Poole Range. Smaller exposures are found in other parts of NOONKANBAH and the unit crops out in gravel plains between such exposures.

Relationships

The 'middle' Poole Sandstone lies conformably or, in places, slightly disconformably on the Nura Nura Member. In the northern part of NOONKANBAH this boundary was not seen, although it was intersected in Mount Hardman No. 1 well (WAPET, 1973).

The upper boundary with the Christmas Creek Member, in the eastern part of the Sheet area, is an interfingering relationship (Encl. 2) which appears erosional in places (Sections 2 and 3). To the west the Christmas Creek Member pinches out and the overlying Noonkanbah Formation rests directly on the 'middle' Poole Sandstone.

Lithology

Unlike the previously described unit, this part of the sequence does not vary much laterally.

The 'middle' Poole Sandstone consists mainly of very fine and fine-grained, quartz wacke and quartz arenite with a varied mica content. It is almost always thin-bedded and fissile. Large scale cross-bedding is rare, but as exposures are commonly covered by scree the sedimentary structures are often obscured. Large-scale planar cross-bedding was noted in the Poole Range in fine-grained, well-sorted, quartz arenite.

The most common sedimentary structure, which occurs throughout the sequence, is small scale cross-bedding, which can generally be found to be cross-sections of symmetrical ripple marks (Plate 18). As other sedimentary structures are rare in the unit some time was spent in studying symmetrical ripple marks. Measurements of their width, wavelength and amplitude were made and the ripple index and ripple symmetry index computed. The resulting figures were then plotted graphically following the method of Tanner (1967). According to Tanner it should be possible to differentiate between ripple marks of different origins on such a graph. All the ripple mark plots obtained fall within the wave-formed bracket (Fig. 8) and although there are insufficient readings to enable positive identification, this strongly suggests that the majority of the ripple marks in the 'middle' Poole Sandstone were formed by waves.

Marine fossils have not been found in this part of the Poole Sandstone, but plant fragments are common. The majority of these are pieces of transported fossil wood, but in the eastern part of the area root beds occur throughout the sequence (~~Plate 20~~); fossil leaves commonly occur in adjacent beds. In the western part of the area bedding - surface trace fossils and bioturbated beds appear to be more common than in the east (Section 13). Lenticular intraformational conglomerate is also more common in the west and may indicate stronger currents in that area.

Plate 19

Thickness

Mount Tuckfield, Western St George Range	245 m +	(Section 13)
Central St George Range	140 m	(estimated)
Eastern St George Range	105 m +	(Section 6)
Mount Hutton	70 m +	(Section 5)
Mount Thorlan	20 m	(Section 3)*
Northern Poole Range	45 m	(Section 2)*

*interfingering upper boundary

Centre Poole Range	65 m	(Section 1)
Southern Poole Range	25 m	(Section 4)

Two trends are obvious from these figures (Encl. No. 2): there is an overall thickening from about 35 m in the east to about 250 m or more in the west (Mount Tuckfield, Plate 20); and in the Poole Range the unit is thicker in the centre of the anticline than on its northern and southern flanks. This latter trend probably continues to the west in the St George Range anticline as the two structures are continuous.

Age

Microfossils from the Poole Sandstone, elsewhere in the basin, indicate an early to late Artinskian age (Yeates et al., 1975b). Plant fossils in the unit in the eastern part of the Sheet area are not age-diagnostic. No marine fossils were found.

Environment of deposition

The thin, laterally continuous bedding containing abundant wave-formed ripple marks indicates a shallow-water environment. The fine grainsize and good sorting throughout the unit are consistent with this interpretation, as wave action causes much winnowing and reworking in such an environment. The frequent presence of root horizons in the eastern part of the area suggests periodic emergence.

The absence of marine fossils in the unit is peculiar, as shallow-water marine sediments normally contain a rich fauna. This suggests that the water may have been either too fresh or too saline to support a normal marine fauna.

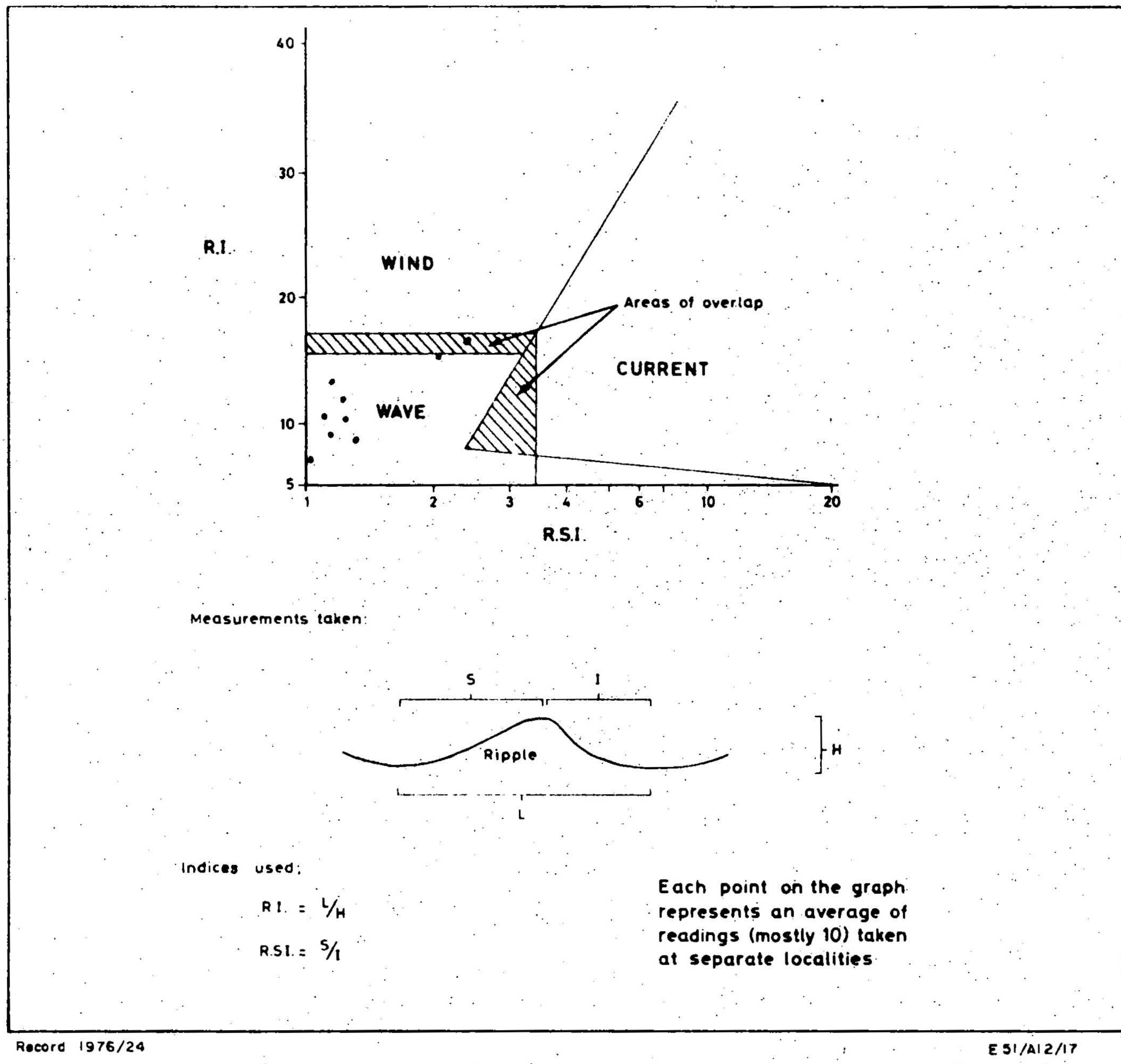

Fig. 8. Plot of ripple index (R.I.) against ripple symmetry index (R.S.I.) from measurements of ripple marks in 'middle' Poole Sandstone

Plate 18 Symmetrical ripple marks in the 'middle' Poole Sandstone, near the top of Mount Tuckfield.

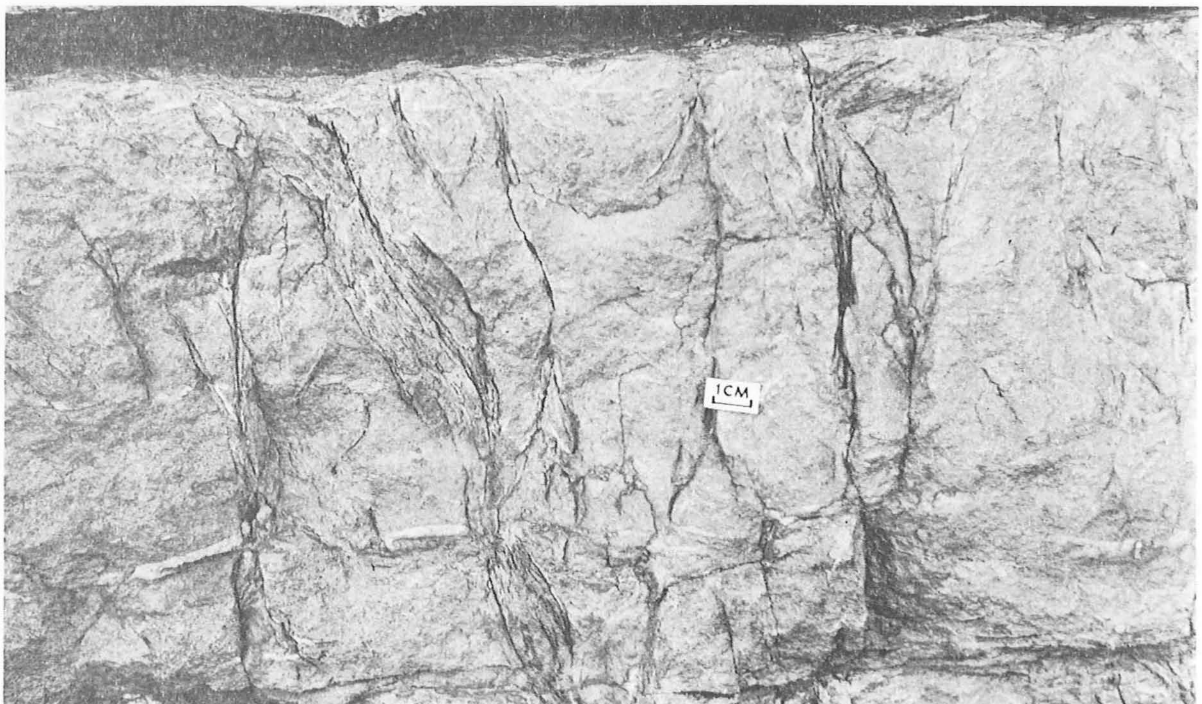

Plate 19 Root bed in the 'middle' Poole Sandstone in the eastern St George Range. Lat 18°50'36"S, long. 125°18'06"E

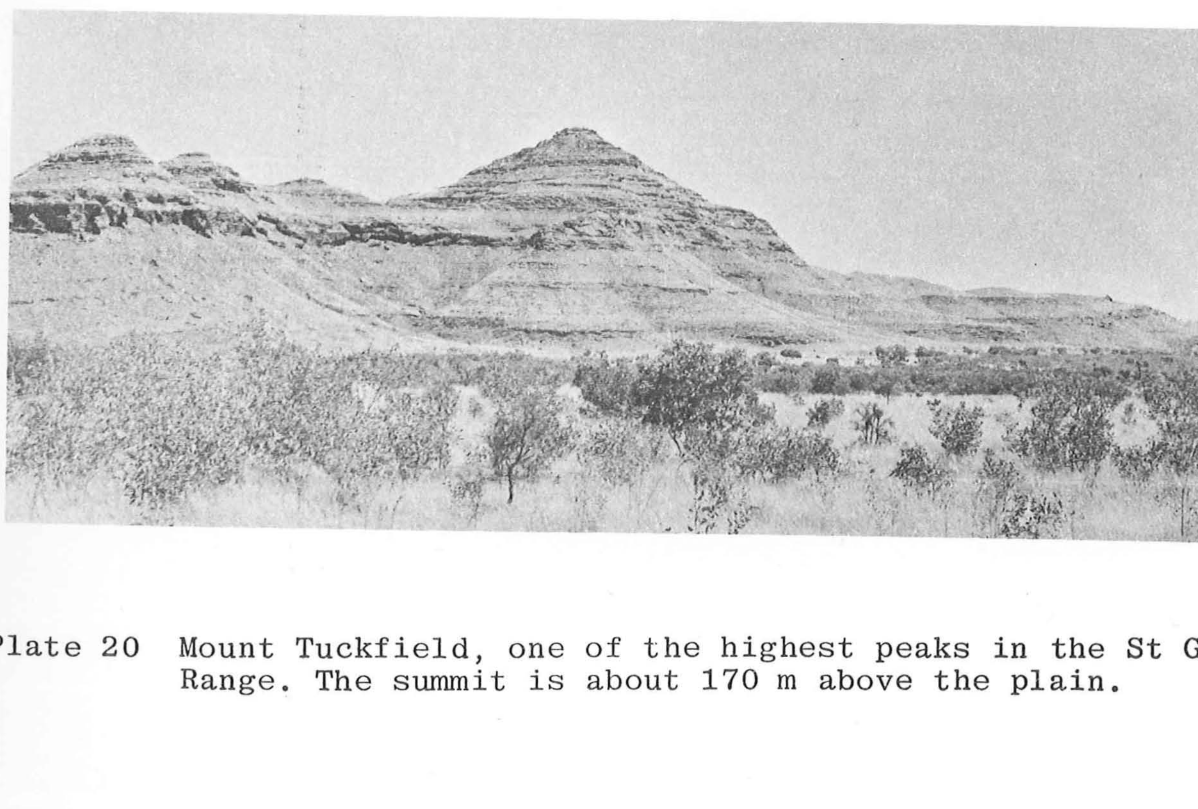

Plate 20 Mount Tuckfield, one of the highest peaks in the St George Range. The summit is about 170 m above the plain.

The interpretation of a barrier-bar or beach deposit at the top of the Nura Nura Member (see above) supports this hypothesis, as this bar may have restricted circulation with the open sea. More detailed work is needed in the eastern St George Range to map the boundaries of the possible barrier-bar deposit; however, if the above theory is correct that the 'middle' Poole Sandstone may have been laid down in a lagoonal environment.

The uniformity of the 'middle' Poole Sandstone from bottom to top indicates that subsidence of the area was occurring contemporaneously with sedimentation, allowing the sediments to be preserved. In the Poole Range (and probably along the axis of the St George Range Anticline) the greater thickness of the unit along the axis of the anticline compared with the flanks, indicates that subsidence was greater in the area now, occupied by the axis. Moreover, the overall thickening to the west suggests a greater amount of subsidence in that direction.

CHRISTMAS CREEK MEMBER

Distribution

The Christmas Creek Member (Crowe & Towner, 1976) is well exposed in the Poole Range and along the northern flank of the St George Range. Smaller exposures occur on the plains to the east of the St George Range and to the northeast and west of Mount Hutton. The member is not present in the western and southern St George Range.

Relationships

The member rests on the underlying 'middle' Poole Sandstone and the contact is interfingering, although in places it is erosional. The Christmas Creek Member is overlain by the Noonkanbah Formation and although the contact is poorly exposed it appears planar and is evidently either conformable or disconformable.

Lithology

The member consists of large-scale trough cross-bedded, poorly sorted, granule conglomerate and fine to coarse-grained, lithic wacke and quartz wacke. The textural maturity is low, as the grains are mostly angular (Plate 21). The bedding is medium to thin and in places it is graded. Fining-upward cycles capped by asymmetrical ripple marks occur (Section 1) and are interpreted as point-bar deposits.

Thickness

No complete sections of the member were measured. The greatest thickness encountered in the Poole Range was 15 m and from photo-interpretation the actual thickness is not thought to exceed 25 m anywhere. However the member varies greatly in thickness and is only a few metres thick to the west of Mount Hutton.

Age

Early Artinskian, because the overlying and underlying units are so dated.

Environment of deposition

The probable point-bar sequences, together with the immaturity of the rock, suggest a fluviatile origin.

SUMMARY OF DEPOSITIONAL HISTORY

After the continental deposits of the Millajiddee Member were laid down the area was uplifted. Some areas appear to have been raised higher than others and in these places the Millajiddee Member was eroded allowing the tillite in the Wye Worry Member to be reworked in a high-energy continental environment. This uplift was probably also responsible for much of the rheotropic deformation of the sediments in the Millajiddee Member.

A shallow sea then transgressed over the area now occupied by the St George Range. Farther to the east a river system existed which appears to have flowed from the east and to have discharged into the sea in the eastern St George Range area, where it formed a delta (Nura Nura Member).

The whole area apparently then became part of a shallow-water (possibly lagoonal) environment, where deposition kept pace with the subsidence. Certain parts subsided at a greater rate than others. The eastern part of the area supported vegetation and was eventually covered by coarser-grained fluviatile material. The sea then transgressed the entire area, and the Noonkanbah Formation was laid down.

Plate 21 Close-up of coarse sandstone of the Christmas Creek Member showing textural immaturity.

NOONKANBAH FORMATION

Distribution

The Noonkanbah Formation (Guppy et al., 1952) is not well exposed; it underlies many of the blacksoil plains around the St George and Poole Ranges and Cherrabun and Noonkanbah Homesteads. Limestone and sandstone beds within the unit crop out in ledges on these plains and other exposures are present in the creeks and gullies around Noonkanbah Homestead and on the northern side of the St George Range.

The formation has been intersected in a number of bores within the Sheet area including Mount Hardman No. 1, Paradise No. 6, and many Esso boreholes north and south of the Fitzroy River.

Relationships

No clear exposure of the lower contact was seen. From bore information in the western and northern parts of the Sheet area, laminated siltstone of the Noonkanbah Formation overlies well-sorted, fine-grained quartz wacke of the Poole Sandstone (e.g. Mount Hardman No. 1, WAPET, 1973). In the southeastern part of the area the change is more pronounced with the Noonkanbah Formation siltstone overlying coarse-grained cross-bedded sandstone of the Christmas Creek Member. As there is a marked change in lithology across this boundary it may be a disconformity.

The contact with the overlying Lightjack Formation is conformable and gradational; the boundary is placed at the top of the uppermost bed of limestone in the sequence.

Lithology

In the subsurface, the formation consists of thinly interbedded shale, siltstone, sandstone and minor limestone. The shale and siltstone are black to dark grey, micaceous, and slightly calcareous. The sandstone is usually light grey to white, very fine-grained, silty, micaceous and calcareous. The thin beds of limestone are grey and finely crystalline. Fossil fragments are abundant in places in the sandstone and limestone beds, but are less common in the siltstone and shale.

Sedimentary structures seen in cores include small-scale cross-bedding and slumps; graded bedding is present locally, and burrowed intervals are common.

Similar lithologies appear on the surface, although the siltstone and shale intervals are rarely preserved. Where preserved from erosion the siltstone is seen to be grey, micaceous, slightly calcareous, laminated to thin-bedded, and contains small-scale ripple cross-lamination. In very weathered exposures the siltstone is commonly ferruginized in a boxwork pattern (Plate 22).

Sandstones and limestones are better exposed, although only minor constituents of the formation. The sandstone is composed of very fine to medium-grained quartz wacke containing scattered coarse grains and granules of quartz, which are subrounded to rounded. It is light grey or brown, moderately to poorly sorted, thin-bedded and has a calcareous matrix. Lenses of very coarse-grained sandstone and granule conglomerate are commonly present in these beds, and contain dispersed shell fragments. Some low-angle ripple cross-lamination is also present.

The limestones are commonly argillaceous or arenaceous, thin to medium-bedded, and micaceous. They generally contain concentrations of well preserved marine macrofossils.

Intraformational small-pebble conglomerate forms lenses in some areas; e.g. on the plains to the north of Cherrabun Homestead. The clasts are subrounded, up to 3 cm in diameter, and consist of mudstone and very fine-grained sandstone, commonly red or purple. Other constituents are quartz granules and shell fragments.

Guppy et al. (1958, p. 100) give a description of the formation at Brutens Yard (lat. 18°44'S, long. 125°38'E). This is one of the best sections of the unit in the Sheet area, but the amount of effective exposure depends on the vegetation cover, which during 1974 was quite dense.

Lateral variations of lithology in the Noonkanbah Formation are not obvious from a study of outcrops. Similarly, drilling by Esso (Galloway & Howell, 1975) indicates that there is little variation in the subsurface to the north of the Fitzroy River. However, in exposures adjacent to the Fenton Fault, just to the east of Mount Fenton, there is a higher percentage of sandstone in the upper part of the formation than was seen elsewhere. Sandstone is also common in the lowest part of the formation where it is exposed on the northwest flank of the St George Range. This lower sandstone part may not continue to the northern edge of the Sheet area as it does not appear in the logs of Mount Hardman No. 1. (WAPET, 1973).

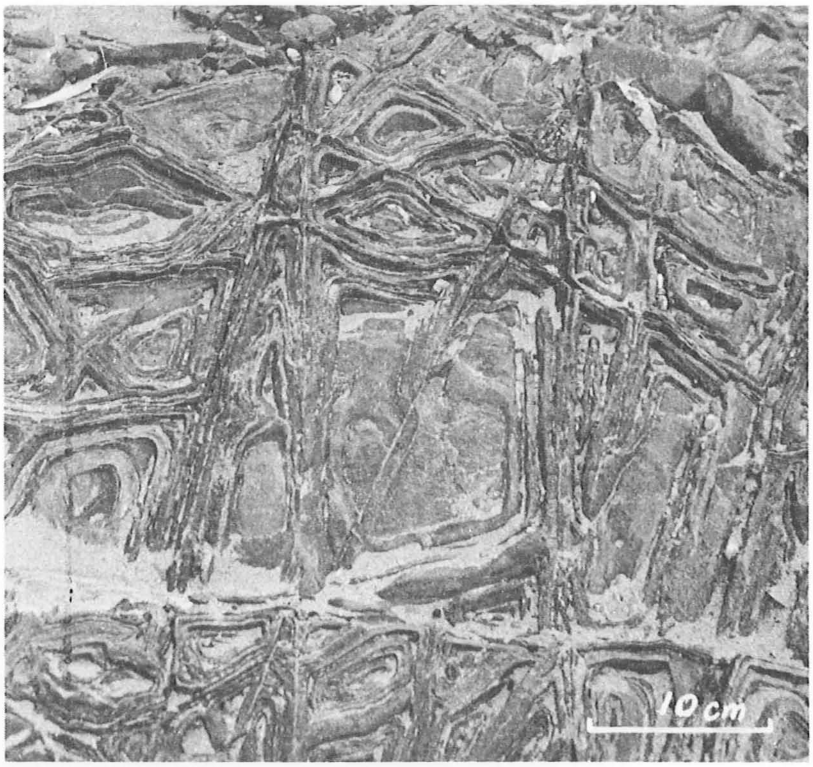

Plate 22 Boxwork pattern in the Noonkanbah Formation caused by intense ferruginization.

Thickness

Surface:	Bruten Yard Section	405.7 m
Subsurface:	Mount Hardman No. 1	311 m
	Paradise No. 6	243.8 m (incomplete)

Age

The formation contains a rich faunal assemblage which is listed by Guppy et al. (1958). They consider the age to be Artinskian.

Further collections of fossils were made during this survey by J.M. Dickins but identifications are not yet available.

Environment of deposition

Marine fossils occur throughout the formation. The lenses of intraformational granule conglomerate and ripple cross bedding indicate that parts of the sequence were deposited from bedload by currents. However most of the formation consists of thinly bedded and laminated mudstone which was deposited from suspension. The inter-laminated silt and shale of the middle parts of the unit suggest deposition below wave base or very quiet conditions in shallow water. The unit contains mainly a 'brachiopodal' assemblage which indicates a water depth of 33-55 m (Thomas, 1958).

The presence of sandstone with some cross-bedding near the base of the unit indicates that this part was deposited in shallower water.

LIVERINGA GROUP

The Liveringa Group (Guppy et al., 1952 & 1958), as redefined by Yeates et al. (1975a), consists of three formations: the Lightjack Formation at the base, the Condren Sandstone and the Hardman Formation. The Hardman Formation is subdivided into three members. All these units were recognized on NOONKANBAH but the Condren Sandstone is not present in the northwestern part of the area. The relationships of the units that comprise the group are shown in Figure 9.

LIGHTJACK FORMATION

Distribution

On NOONKANBAH the Lightjack Formation (Guppy et al., 1958; Yeates et al., 1975a) is exposed over a greater area than the other formations of the Liveringa Group. Where the tops of the hills are composed of sandstone the unit forms ranges (e.g. the Shore Range). Elsewhere the formation is exposed in buttes such as Lightjack Hill and Bucknalls Pinnacle and low rounded hills and ridges (e.g. McLarty Syncline area).

In the subsurface the formation has been intersected in Mount Hardman No. 1, and Paradise Nos. 1 and 2 wells on NOONKANBAH, and Myroodah No. 1 just to the west of the Sheet area. Many of the Esso boreholes (Galloway & Howell, 1975) penetrated the Lightjack Formation although the Esso geologists did not use the name. Esso's Unit A1 and the lower half of Unit A2 are equivalent to the Lightjack Formation.

Relationships

The Lightjack Formation conformably overlies the Noonkanbah Formation with a gradational contact. In the Balgo area to the southeast (LUCAS) this contact is marked by a ferruginized clay-pellet conglomerate (Yeates et al., 1975b), but as this conglomerate is not well developed on NOONKANBAH the boundary is placed above the uppermost limestone bed in the sequence.

The contact between the Lightjack Formation and the overlying Condren Sandstone was not observed. South of the area, in the Millyit Range (CROSSLAND), this contact is conformable and it is probably similar in the McLarty Syncline area. However, farther north the Condren Sandstone wedges out (Galloway & Howell, 1975) and the Lightjack Formation is overlain by the Hardman Formation.

Lithology

In the subsurface, the Lightjack Formation in Mount Hardman No. 1 consists of yellow-brown, very fine-grained, silty sandstone which is slightly calcareous and contains a few medium-sized grains of quartz. In the Paradise and Esso boreholes, the formation consists of interbedded siltstone and fine-grained sandstone containing common fining-upwards cycles each of which has current-rippled sandstone at the base; bidirectional flaser bedding is present; bioturbation is common throughout and shelly fossils occur locally. The wireline logs show an overall gradation in grainsize from siltstone at the base to medium-grained sandstone at the top of the middle sandstone unit (see below).

On the surface the formation is seen to consist of a distinctive sequence of (from bottom to top) fossiferous shale and siltstone, followed by fine-grained, cross-bedded quartz arenite and quartz wacke, overlain by siltstone again.

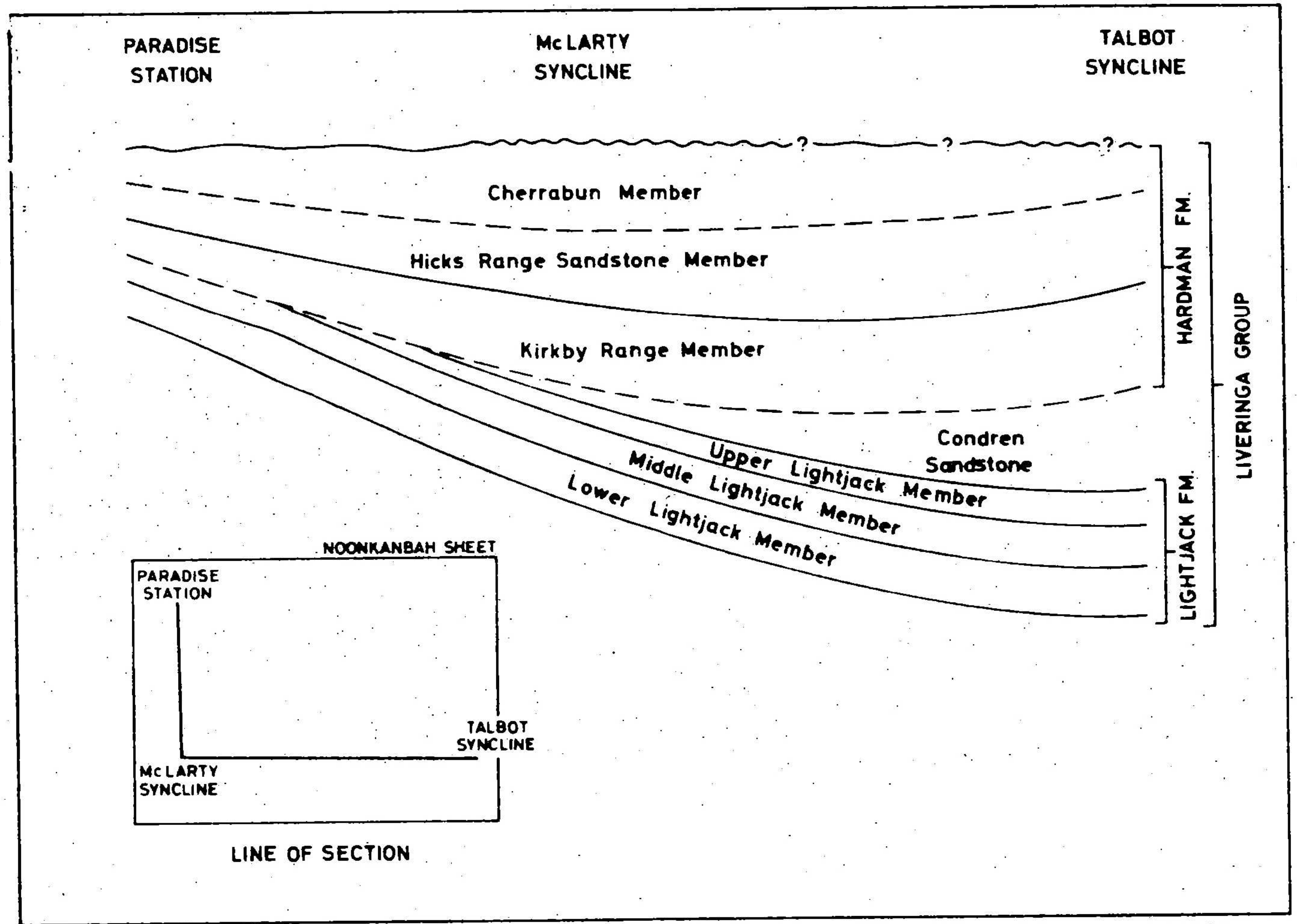

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Fig. 9. Diagrammatic section showing relationships of units within the Liveringa Group; symbols as for Fig. 1

In the Shore Range and at Lightjack Hill (Sections 21 and 22) the base of the formation consists of alternating calcareous sandy siltstone and silty claystone together with fossiliferous grey and brown, very fine-grained quartz wacke and minor limestone. These beds are overlain by micaceous, grey, laminated to thinly bedded lithic-wacke and siltstone together with lenses of richly fossiliferous intraformational pebble conglomerate containing some angular granules of quartz. Near the base of the Lightjack Formation, in the Christmas Creek area, a thin bed of fine to medium-grained sandstone containing ooliths is present. The ooliths are composed of 50% Fe_2O_3 (see Edwards, 1953).

The fine-grained basal part of the formation is conformably overlain by a middle sandstone unit (Section 22) which ranges up to 25 m thick and commonly forms a prominent bench. It is composed of yellow-brown, slightly micaceous, fine-grained quartz arenite and quartz wacke which is well sorted, laminated to thin-bedded, and in which the clasts are sub-rounded to rounded. The unit contains abundant large-scale, low-angle planar cross-bedding (type of Allen, 1963) and ripple cross-lamination. Exposures of this part of the formation on the southwestern flank of the St George Range contain abundant fossil root horizons together with some highly silicified beds. These beds are probably the weathered equivalents of coal seams which were intersected down-dip in Esso No. 41 bore (Galloway & Howell, 1975). The coal-bearing beds reach a thickness of 2.5 m. The coal is of poor quality and has not so far been found to be economic.

Overlying the middle sandstone unit is a sequence of interbedded siltstone and fine-grained quartz wacke which ranges up to 45 m thick. The sequence is laminated to thin-bedded, micaceous, ferruginized and contains abundant interference wave-ripple marks, trace fossils and concretions. Thin lenses of medium to coarse, well-sorted, quartz arenite with rounded clasts are present within this part of the section.

In low rounded hills and on the plains the original lithology is commonly masked due to intense ferruginization. However some sedimentary structures, such as ripple marks, are often well preserved, as are fossiliferous clay-pellet conglomerate beds.

Thickness

On the surface the Lightjack Formation is 97 m + thick at Lightjack Hill (Section 22) and 120 m + in the Shore Range (Section 21). Both these sections are almost complete. In the subsurface, we have interpreted it to be 80 m thick in A.I.E. Paradise Nos 1 and 2, and 135 m in the Esso holes in the McLarty Syncline.

The formation thins to the north. This is confirmed by the fact that according to the logs of the Esso boreholes the siltstone at the top is missing to the north of the Fitzroy River.

Age

Guppy et al. (1958) list the rich fauna. The assemblage is predominantly a molluscan assemblage in the Lightjack Hill area and a brachiopodal assemblage in parts of the Shore Range (Thomas, 1958). The fossils are found below the middle sandstone unit. The formation is considered to be late Artinskian to Kungurian in age (J.M. Dickins, pers. comm.).

Environment of deposition

The increase in grain size and sorting from poorly sorted sandy siltstone at the base to well-sorted, medium-grained quartz arenite at the top of the middle sandstone unit (Sections 21 and 22) indicates a regressive marine sequence (Visher, 1965). The fossiliferous intraformational conglomerate lenses below the base of the middle sandstone unit are identified as channel deposits, possibly of tidal origin. The contact between the middle sandstone unit and the underlying siltstone-sandstone sequence is gradational in the Shore Range and at Lightjack Hill, and the sequence is therefore interpreted as a linear shoreline regressive sequence (Selley, 1970, p. 95) in which the middle sandstone unit represents barrier-bar or beach deposits.

In the west, near Millajiddee Homestead, the sandstone unit contains root horizons which are interpreted as fossil soils; in the subsurface, the root horizons contain interbeds of coal.

The siltstone and sandstone sequence above the middle sandstone member is interpreted as lagoonal because of the abundance of wave-formed ripple marks and its stratigraphic position above the interpreted barrier-bar deposits (see Visher, 1965). The lenses of coarse-grained sediment in this part of the sequence are interpreted as channel deposits.

According to Thomas (1958) the predominantly molluscan assemblage of the Lightjack Hill area suggests a shallow-water environment in which the water depth was between 18 and 33 m (above wave base), whereas the brachiopodal assemblage of parts of the sequence in the Shore Range indicates water between 33 and 55 m deep. However this information is of limited use, as the precise stratigraphical positions of these fossil assemblages are not known.

The contact between the Lightjack Formation and the Hardman Formation to the north of the Fitzroy River was not seen in outcrop. However, where the contact was seen in the subsurface (Esso bore logs) the upper part of the Lightjack Formation is missing. It is not known if this is due to erosion or non-deposition.

In conclusion, the Lightjack Formation is interpreted as representing a change from open-marine conditions (Noonkanbah and lower Lightjack Formations) to a lagoonal environment (upper Lightjack Formation). It is thought that this change was caused by a prograding beach or barrier-bar. As the sequence is regressive it must also be diachronous.

CONDREN SANDSTONE

Distribution

The Condren Sandstone (Casey & Wells, 1964; Yeates et al., 1975a) is represented in only one outcrop in the Sheet area, situated on the northern flank of the McLarty Syncline at lat. 18°49'00"S, long. 124°48'15"E. The formation probably also occurs in the Talbot Syncline on NOONKANBAH, as it crops out in this syncline on MOUNT RAMSAY. The unit occurs to the south on CROSSLAND and to the southeast on MOUNT BANNERMAN (Yeates et al., 1975b).

In the subsurface, the formation was intersected in Esso boreholes in the McLarty Syncline, and north of the Fitzroy River in the Quanbun Homestead area. It wedges out towards the northwest, and is absent in the Paradise boreholes, and in many of the Esso boreholes north of the Fitzroy River.

Relationships

The Condren Sandstone conformably overlies the Lightjack Formation on CROSSLAND (Yeates et al., 1975b) and a similar relationship probably exists on NOONKANBAH, although the boundary was not observed. The boundary with the overlying Kirkby Range Member of the Hardman Formation is described as conformable and gradational on CROSSLAND (Yeates et al., 1975b). On NOONKANBAH, however, logs of the Esso boreholes (Encl. 3) indicate an abrupt change from coarse sandstone upwards into interbedded sandstone and siltstone (Galloway & Howell, 1975). On this evidence and the environmental interpretations it is suggested that the boundary on NOONKANBAH is disconformable.

Lithology

The exposure at lat. 18°49'00"S, long. 124°48'15"E represents the basal part of the formation and consists of coarse to medium-grained quartz arenite and quartz wacke which are crows-bedded and moderately to poorly sorted; the grains are angular and the strata contain possible fossil roots. Pebbles of quartzite on the surrounding plain indicate that the formation is partly conglomeratic.

In the subsurface the unit is described as mainly coarse-grained with little vertical variation (Galloway & Howell, 1975). In BMR Mount Bannerman No. 2 bore coal was recorded in the formation (Yeates et al., 1975b).

Thickness

According to our interpretation of the Esso bore data the formation is about 50 m thick in the McLarty Syncline and Quanbun Homestead areas. However, the unit thins to extinction in the direction of the Paradise bores (Galloway & Howell, 1975) and thickens to the south and southeast on CROSSLAND and MOUNT BANNERMAN (see Yeates et al., 1975b).

Age

No fossils were found in the formation on NOONKANBAH but it contains a rich fossil flora in exposures elsewhere (White, in Veevers & Wells, 1961; White & Yeates, in prep.). The age of this flora is Permian.

Environment of deposition

The relative textural immaturity of the sediment and its cross-bedded, conglomeratic nature indicate deposition by currents, possibly under fluviatile conditions. The tentative identification of fossil roots would, if confirmed, support a continental interpretation, especially in view of the rich flora found in neighbouring areas. When considered in relation to the sequence as a whole, the fluviatile interpretation fits in well, as the Condren Sandstone conformably overlies the regressive sequence of the Lightjack Formation.

HARDMAN FORMATION

The Hardman Formation (Guppy et al., 1958) as redefined by Yeates et al. (1975a) consists of three members; the Kirkby Range Member at the base, the Hicks Range Sandstone Member and the Cherrabun Member at the top. All three units are recognized on NOONKANBAH.

Kirkby Range Member

Distribution

The Kirkby Range Member (Yeates et al., 1975a) crops out poorly in the Sheet area, where it forms low discontinuous strike ridges composed of the more resistant parts of the sequence. The exposures are confined to the southern side of the McLarty Syncline and to the area between the Fitzroy River and Shedforth Bore. An exposure on the southern flank of Warrimbah Hill is also tentatively assigned to this member.

In the subsurface the unit was intersected in many of the Esso boreholes both north and south of the Fitzroy River. The member was also intersected in Paradise coreholes Nos. 1 2 and 3.

Relationships

The contacts of the member were not seen. It is thought that the lower boundary is a disconformity. The upper boundary is conformable to the south on CROSSLAND (Yeates et al., 1975b) and logs of the Esso bores (Encl. 3) indicate a gradational change in lithology.

Lithology

From subsurface information the member is seen to consist predominantly of interbedded siltstone and fine-grained sandstone, the sandstone predominating towards the top. The sequence is red bioturbated throughout, and fossil shells are common in the upper part. Wavy and lenticular bedding are abundant, and mud cracks are present in the basal part of the sequence. The sandstone beds near the top contain both large and small-scale cross-bedding.

Exposures are preferentially weathered, so that the unit appears coarser grained than in the subsurface. The exposed rocks consist of calcareous fine-grained sandstone, limestone (biosparudite), and micaceous siltstone. Ferruginous concretions are common in extensively weathered exposures. The bedding is thin or laminated; other sedimentary structures are rarely seen.

Thickness

No surface sections were measured, but Esso drilling results (Galloway & Howell, 1975) show that in the area north of the Fitzroy River the member thickens southwards from about 75 m along the northern margin of the Sheet area to over 300 m to the south of Mount Hardman. In the McLarty Syncline the member thickens southeast from about 190 m near the western edge of the Sheet area to 250 m just south of Millajiddee Homestead.

Age

The rich marine fauna has not yet been fully studied, but it indicates a Late Permian age (J.M. Dickins, pers. comm.).

Environment of deposition

The unit is marine, and the presence of cross-bedded sandstone, particularly near the top, suggests deposition by currents. Mudcracks occur near the base and suggest intermittent intertidal conditions for that part of the unit. The gradation to sandstone in the upper part of the sequence may indicate the start of a regression (see below).

Hicks Range Sandstone Member

Distribution

The Hicks Range Sandstone Member (Yeates et al., 1975a) crops out in the western portion of the Sheet area in the vicinity of Mount Hardman and in the McLarty Syncline. Outcrops are limited and occur as low strike ridges (e.g. at Mount Abbot), isolated hills (e.g. Mount Noreen) or as low, undulating, rubble-covered hills.

Relationships

The lower contact was not seen on the surface, but electric logs of the Esso drill holes (see Encl 3) indicate the boundary is gradational. Likewise, the upper contact is not exposed; from subsurface data it is thought to be a disconformity (see below).

Lithology

The following account of the vertical sequence is taken mainly from borehole descriptions (Galloway & Howell, 1975). The lower three-quarters of the member is composed mainly of interbedded shale and siltstone, and sporadic beds of sandstone. This part of the sequence contains flaser bedding and wavy bedding, thin coal loads and mudcracks. Surface observation shows that these beds are generally thin-bedded, and contain wave-formed ripple marks and some large-scale planar cross-bedding. Bioturbation and trace fossils are abundant.

The upper quarter of the member is mainly quartz wacke and quartz arenite, with minor interbeds of siltstone. Subsurface data show that fining-upwards cycles are common in this part, although many of the cycles are truncated. The sandstone is moderately to well sorted, and contains scattered lithic pebbles.

Thickness

An incomplete section of the member at Mount Noreen is about 30 m thick. Esso bore logs show that the unit thickens from about 100 m near the northern boundary of the Sheet area to over 325 m near Warrimbah and Millajiddee Homesteads.

Age

No macrofossils have been found in this unit. The faunas in the Kirkby Range Member and the Cherrabun Member indicate that the Hicks Range Sandstone Member is Late Permian in age, possibly lower-most Tatarian.

Environment of deposition

Galloway & Howell (1975) interpret the overall upward increase in grainsize within this member as a regressive marine sequence from shallow-water marine sediments at the base up to deltaic or tidal channel deposits at the top. In our opinion however, the sequence is better interpreted as the top part of a regressive sequence (Visher, 1965) which starts in the underlying Kirkby Range Member. Thus we interpret the basal Hicks Range Sandstone Member as being deposited in lagoonal conditions and the top part in a fluvial (flood plain) environment. The basis for our interpretation is that the lower boundary of the member is apparently conformable and the basal part of the unit contains mudcracks, wave ripple marks and thin coal horizons. Although marine macrofossils are apparently absent, yet spinose acritarchs are recorded, suggesting some connection with the sea. Such features are more typical of lagoonal conditions than an open-marine environment. The upper part of the member also fits this interpretation, as the repeated fining-upwards cycles within it are best interpreted as channel point-bar deposits (Galloway & Howell, 1975).

Thus the Kirkby Range Member and Hicks Range Sandstone Member together are interpreted as representing the typical regressive sequence described by Visher (1965).

Cherrabun Member

Distribution

The Cherrabun Member (Yeates et al., 1975a) is better exposed on NOONKANBAH than the other members of the Hardman Formation. South of the Fitzroy River it crops out around Davies Bore, between Rodneys and Andys Bore and in small scattered outcrops 15 km south of Gum Hole Billabong. It is also exposed as low strike ridges along the edge of the Sheet area to the southwest of Kalyeeda Hills. North of the Fitzroy River the unit crops out at and around Mount Hardman, at a small hill near Mount Cedric, at Howes Hill and as long strike ridges around Sears Bore.

The member was intersected in many of the Esso bore holes and was penetrated in AIE Paradise No. 4.

Relationships

The lower contact was not observed on the surface. In the subsurface it is distinguished by a sudden reduction in grainsize which stands out well on the electric logs (Encl. 3); the contact is therefore thought to be a disconformity.

In the McLarty Syncline on the western edge of the Sheet area the Cherrabun Member is overlain by pebble conglomerate, thin-bedded, ripple-marked, fine-grained quartz wacke and siltstone with some trace fossils (Section 19), although exposure is incomplete. The contact is interpreted as an angular unconformity since there is an obvious divergence of the strike ridges on the aerial photographs. The conglomerate, quartz wacke, and siltstone are tentatively correlated with the Triassic Millyit Sandstone which overlies the Cherrabun Member in the Millyit Syncline on CROSSLAND (Yeates et al., 1975b).

North of the Fitzroy River the Cherrabun Member is to be overlain by the Blina Shale (Esso boreholes). Again the contact is not exposed at the surface. However, palynological information from the Esso boreholes suggests that there is a time gap between the two units (Galloway & Howell, 1975), and as the basal Triassic Millyit Sandstone is missing, it is thought that the contact is a disconformity which may be slightly discordant in places.

In conclusion, the Liveringa Group on NOONKANBAH is overlain by the Triassic Millyit Sandstone and Blina Shale. Previously there had been some doubt about the nature of the Permian-Triassic boundary in the Fitzroy Trough (see Veevers & Wells, 1961, p. 109). It has now been established that the contact is, in at least one place, an angular unconformity but in other areas may be merely disconformable.

Lithology

Subsurface information shows that the member grades from mudstone in the lower part, to sandstone at the top, and that thin coal horizons occur in the upper part of the unit (Galloway & Howell, 1975).

On the surface the best exposure of the member is the type section of the Hardman Formation at Mount Hardman (Section 20). The Esso drilling results indicate that this section represents only the top part of the member. In this section the lower part of the member is sandy mudstone with thin beds of bioclastic limestone. The sequence is shaly in parts and contains some thin beds of bioturbated fine-grained feldspathic wacke. This passes gradationally up into interbedded and bioturbated siltstone and fine-grained quartz wacke which is well sorted and contains well-rounded grains. Some arenites containing symmetrical ripple marks occur in this part of the sequence. The upper part of the member is a fining-upwards sequence of coarse to fine-grained quartz wacke which contains asymmetrical ripple marks at the top, and this is overlain, with a sharp contact, by fine and medium-grained, well-sorted quartz wacke which contains intra-formational conglomerate and large-scale planar cross-bedding. To the north of Mount Hardman, near Sears Bore, plant fossils and wood fragments were found in the uppermost part of the member.

From scattered outcrop data in the area south of the Fitzroy River, the lower and middle parts of the sequence are known to be mainly mudstone but they also contain poorly sorted sandstone beds and minor granule conglomerate. Marine fossils are abundant in these outcrops.

Thickness

The section at Mount Hardman (Section 20) is 50 m thick, but it is incomplete. In AIE Paradise No. 4 the member is approximately 100 m thick, but it appears thicker to the south in the McLarty Syncline (field evidence and Galloway & Howell, 1975).

Age

The Cherrabun Member contains a rich fauna which is listed by Guppy et al. (1958). Another extensive collection was made by J.M. Dickins during 1974 and is currently being studied. The fauna is of Late Permian (possibly Tatarian) age (Thomas, 1954; Coleman, 1957; Dickins, 1963).

The plant fossil Glossopteris occurs in the uppermost part of the unit.

Environment of deposition

Most of the Cherrabun Member is composed of fossiliferous mudstone with thin sandy interbeds which indicate marine probably shallow-water, conditions. The gradation upwards into ripple-marked interbedded sandstone and siltstone is interpreted as being due to a shallowing of water, and the fining-upwards sequence near the top of the member at Mount Hardman is interpreted as a tidal channel-fill deposit. This part of the sequence passes up into planar cross-bedded, well-sorted sandstone which is tentatively identified as a beach deposit because of its position in the vertical sequence and its well sorted nature.

Thus the Cherrabun Member is interpreted as another regressive cycle. This interpretation is supported by the overall upward increase in grainsize and degree of sorting (Visher, 1965), and the change from a marine fauna in the middle and lower parts of the unit to a flora with minor coal near the top of the sequence.

SUMMARY OF DEPOSITIONAL HISTORY

Taken as a whole, the depositional history of the Liveringa Group is interpreted as a series of three regressions separated by two transgressions. This may have been due to cyclic tectonic or eustatic changes. Alternatively, the cyclicity can be explained by a process of imbricate deltaic deposition into a continually subsiding area similar to the process described by Scruton (1960) to explain the Mississippi delta deposits. The theory explains how a delta lobe builds out into the sea and deposits a regressive sequence until it is abandoned due to lateral migration of the river. When this happens, a new delta lobe is built elsewhere; the old one becomes compacted and may be partly reworked and/or buried, before another change in river course deposits a further regressive sequence above the first one. In this way a cyclic vertical sequence is built up.

In our opinion this latter theory is the simplest explanation of the cyclicity in the Liveringa Group and there is no need to invoke tectonic or eustatic changes. Thus the deposits of the Liveringa Group are interpreted as deposits of a large delta system.

CONCLUSIONS

Although only minor changes have been made in the outcrop and structure patterns of the formations for the new NOONKANBAH map, most of the formations have now been subdivided.

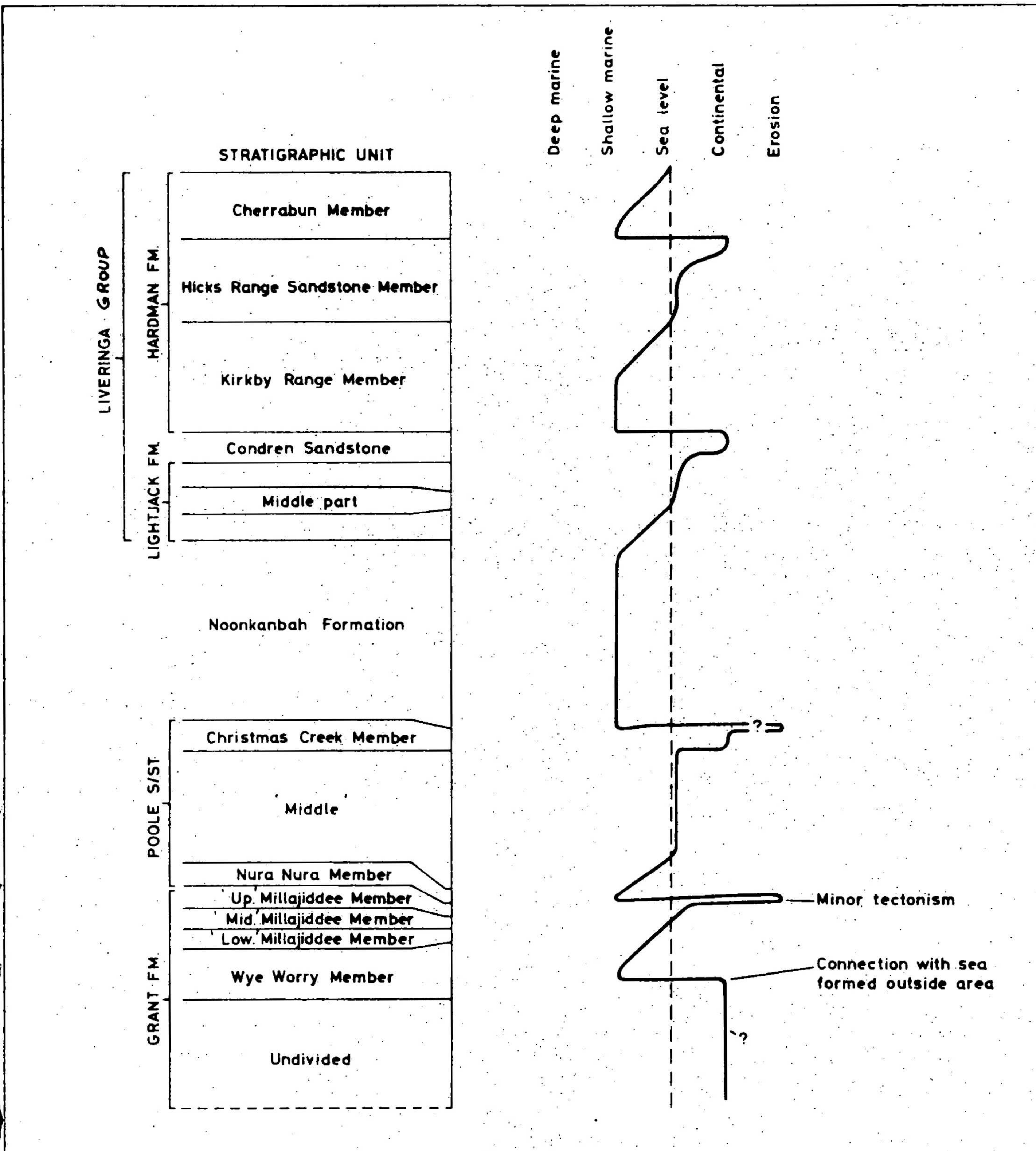

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Fig. 10. Schematic representation of Permian sedimentation in St George Range — McLarty Syncline area

In subdividing the units on NOONKANBAH we have purposely not named every facies within formations and members as this is impractical at 1:250 000 scale mapping and we believe it is often more confusing than useful to name every facies variation. By collating these detailed facies variations in the measured sections it has been possible to arrive at a better understanding of the environments of deposition of the succession (although, because of the reconnaissance nature of the mapping, many of these interpretations are tentative). Fig. 10 shows the history of sedimentation schematically, but it should be realized that the sea in which the Noonkanbah Formation was deposited probably remained either in the area or just outside it until the end of the Permian. The regressions and transgressions of the Liveringa Group were probably the result of changes of the shoreline due to the influx of sediment (in a deltaic environment) rather than changes in sea level and/or land level. Thus the history of subsidence in the area is probably simpler than was indicated by previous reports, but the history of regression and transgression is more complicated (cf. Veevers & Wells, 1961, p. 104). The only substantiated period of uplift that occurred during the Permian on NOONKANBAH was between deposition of the Grant Formation and that of the Poole Sandstone. All other Permian relationships can be explained by inferring gradual subsidence of the area.

The most significant contributions made to geological knowledge of the area during the 1974 field season were the following:

1. Discovery of marine macrofossils in the Grant Formation in the Fitzroy Trough.

2. Interpretation of the uppermost part of the Grant Formation as a regressive sequence which contains evidence suggesting permafrost conditions prevailed.

3. Mapping of an eastward extension of the Nura Nura Member of the Poole Sandstone.

4. Identification and mapping of the Christmas Creek Member at the top of the Poole Sandstone.

5. Mapping of the subdivisions of the Liveringa Group and correlation of these divisions with subsurface sections.

6. Interpretation of the Liveringa Group as a series of regressive cycles probably laid down in a deltaic environment.

SUGGESTIONS FOR FURTHER WORK

1. To study in detail the marked facies variations that occur within the Wye Worry and the Millajiddee Members of the Grant Formation particularly between the northern and southern flanks of the St George Range.
2. To further determine the environment of deposition of the Poole Sandstone with particular study of its contact with the Grant Formation.
3. To gather more information on the environments of deposition of the Liveringa Group and the relationships between the units within it, paying particular attention to diachronous relationships.
4. To study the relationship between tectonsim and sedimentation with particular reference to changing rates of subsidence in certain areas (i.e. Poole Sandstone in Poole Range Anticline and Grant Formation in St George Range Anticline).

Any work in the St George Range will be hampered by poor access. The only practicable method of mapping in the range is by traversing on foot, as the area is a maze of canyons which are mostly inaccessible to vehicles. At least the range is no longer as difficult as it used to be when, in the words of Woolnough (1933): "it had been less fully explored than have most of the other mountains. This is due partly to its comparative inaccessibility and partly to the fact that it has long been the refuge of the more truculent and treacherous of the aboriginals remaining in the district".

ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the many helpful field discussions that took place with geologists from Esso Exploration and Production Aust. Inc., without which many of the correlations between surface and subsurface sections would not have been possible. We would like to thank Australian Inland Exploration for permission to incorporate information from exploration that they undertook in the area. Last but not least we thank the many station managers throughout the area who gave valuable guidance on the positions and condition of the tracks and bores on their properties.

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CAPTIONS FOR PLATES

1 Typical exposure of the Grant Formation in the eastern St George Range. The steep cliffs are a result of the poorly bedded nature of the formation. Lat. 18°49'12"S, long. 125°30'30"E

2 Polygonal weathering pattern on the surface of an exposure of the Grant Formation. This pattern is apparently unrelated to tectonic or sedimentary structures.

3 Looking northeast from the top of Mount Tuckfield across the Carolyn Valley. The sandstone below the Wye Worry Member is exposed in the rugged hills in the foreground.

4 Wye Worry Member, Grant Formation. Laminated graded siltstone and claystone interpreted as varves. The claystone is darker than the siltstone. Lat. 18°46'30"S, long. 125°18'50"E

5 Faceted dropstone, striated in two directions. Wye Worry Member, Grant Formation. Lat. 18°46'30"S, long. 125°18'50"E.

6 Close-up of striated surface of dropstone, Wye Worry Member.

7 Large dropstones in siltstone, near type section of the Wye Worry Member.
Lat. 18°47'00"S, long. 125°18'36"E

8 Calcareous concretion from the middle of the Wye Worry Member, at the type section. Note small dropstone pebble near centre of concretion.
Lat. 18°46'30"S, long. 125°18'50"E

9 Sandstone lens in Wye Worry Member, southern side of Carolyn Valley.

10 Well-rounded dropstone in Wye Worry Member in Lauris Range, showing crescentic impact marks. These boulders also have faceted and striated faces. Lat. 18°10'20"S, long 125°25'30"E

11 Bioturbated bedding surface, 'lower' Millajiddee Member, central St George Range. Lat. 18°43'52"S, long. 125°07'52"E

12 Load casts on the underside of a bed, 'lower' Millajiddee Member, central St George Range. Lat. 18°43'52"S, long. 125°07'52"E

13 Large-scale planar cross-bedding in the 'middle' Millajiddee Member at the type section. Western part of St George Range. Lat. 18°44'20"S, long. 124°55'52"E

14 Grant Formation (Pg), Nura Nura Member (Ppn) and 'middle' Poole Sandstone (Pp), at base of Mount Amy. A large slump structure in the Grant Formation is outlined. Plate 17 is a close-up of the middle, light-coloured part of this slump. Inked-in Figure at base of cliff indicates scale.

15 Close-up of slump structure in Plate 16, showing overturned beds. The horizontal foliation was caused by compaction of the sediment after it had slumped.

16 View of un-named unit between Grant Formation (Pg) and Poole Sandstone (Pp). The unit consists of a breccia overlain by sandstone. Western part of St George Range, lat. 18°44'20"S, long. 124°55'52"E

17 Part of reference section of Nura Nura Member showing wavy bedding with flasers. The photograph covers approximately 5 m of the section. Lat. 18°47'45"S, long. 124°57'33"E.

18 Symmetrical ripple marks in the 'middle' Poole Sandstone, near the top of Mount Tuckfield.

19 Root bed in the 'middle' Poole Sandstone in the eastern St George Range. Lat 18°50'36"S, long. 125°18'06"E

20 Mount Tuckfield, one of the highest peaks in the St George Range. The summit is about 170 m above the plain.

21 Close-up of coarse sandstone of the Christmas Creek Member showing textural immaturity.

22 Boxwork pattern in the Noonkanbah Formation caused by intense ferruginization.

APPENDIX - MEASURED SECTIONS

Figure 11 shows the locations of the sections. The sections are shown as either 'measured' or 'estimated'. 'Measured' means that they were accurately measured on the ground using either the 'height to eyes' technique for predominantly vertical sections or the tape and compass method for horizontal ones. 'Estimated' means that the sections were compiled using a combination of outcrop information, 1:100 000 topographic maps for contour data, and aerial photographs for horizontal control. In most cases the 'estimated' sections were compiled to bring out a particular point that would not otherwise be obvious. Most of the sections are shown at the same scale to make correlation easier, although some additional more detailed sections are included.

LIST OF SECTIONS

Reference No.	Location	Status
1	Mount Piper - Poole Range	Measured
2	Poole Range	Measured
3	Mount Thorlan (part is large scale)	Estimated & Measured
4	Southern Poole Range	Estimated
4a	Southern Poole Range (large Scale)	Measured
5	Mount Hutton	Measured
6	Eastern St George Range	Measured
7	Eastern St George Range	Measured
8	Southeastern St George Range	Estimated
9	Eastern St George Range (type section, Wye Worry Member)	Measured
10	Central St George Range	Measured
11	Tullock Peak	Estimated
12	Central St George Range	Estimated & measured
13	Mount Tuckfield	Measured
13a	Carolyn Valley (large scale)	Measured
14	Millajiddee - Southwestern St George Range (reference section, Nura Nura)	Measured

Reference No.	Location	Status
15	Western St George Range (type section, Millajiddee Member)	Measured
16	Northwestern St George Range	Estimated
17	Western St George Range	Estimated
18	Lauris Range	Measured
19	McLarty Syncline	Measured
20	Mount Hardman	Measured
21	Shore Range	Measured
22	Lightjack Hill	Measured

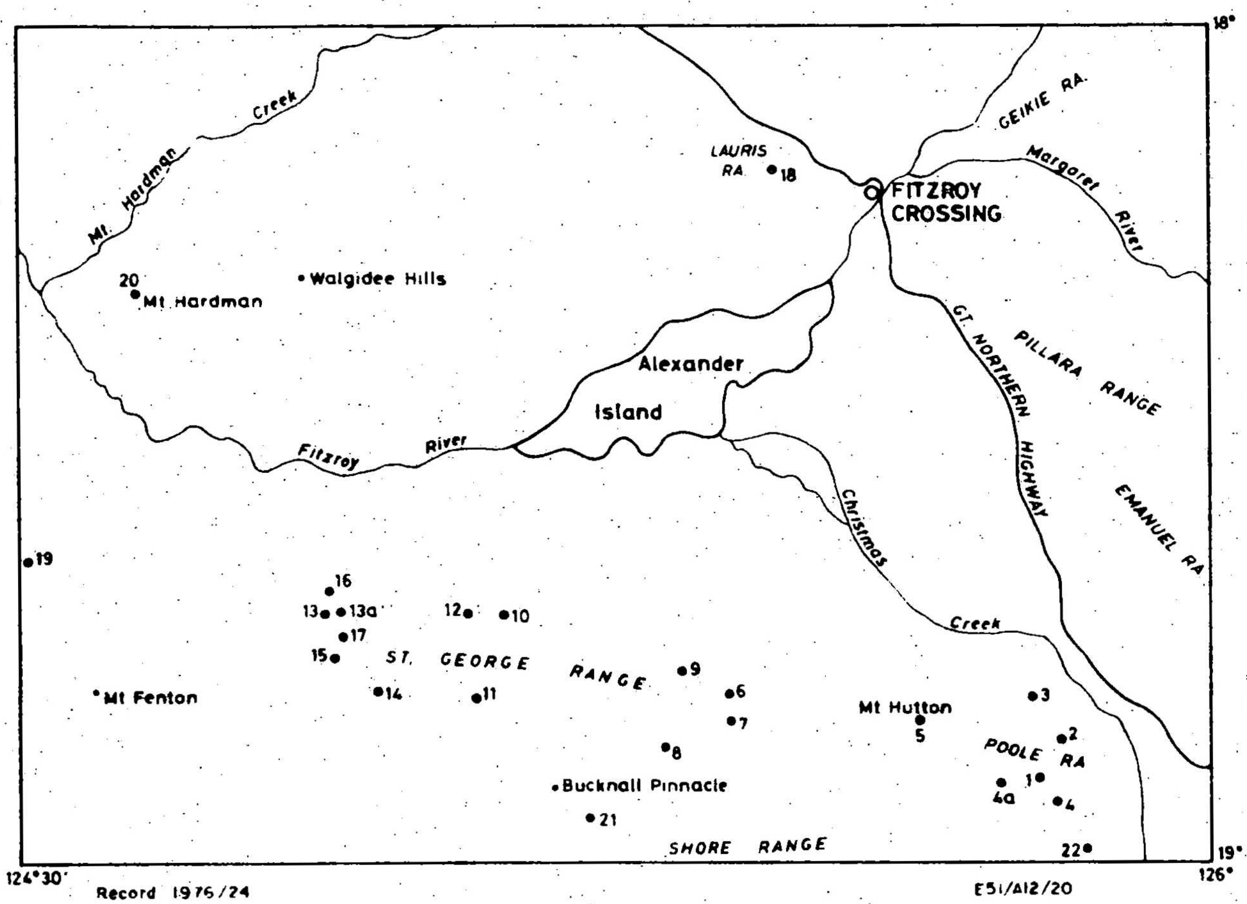
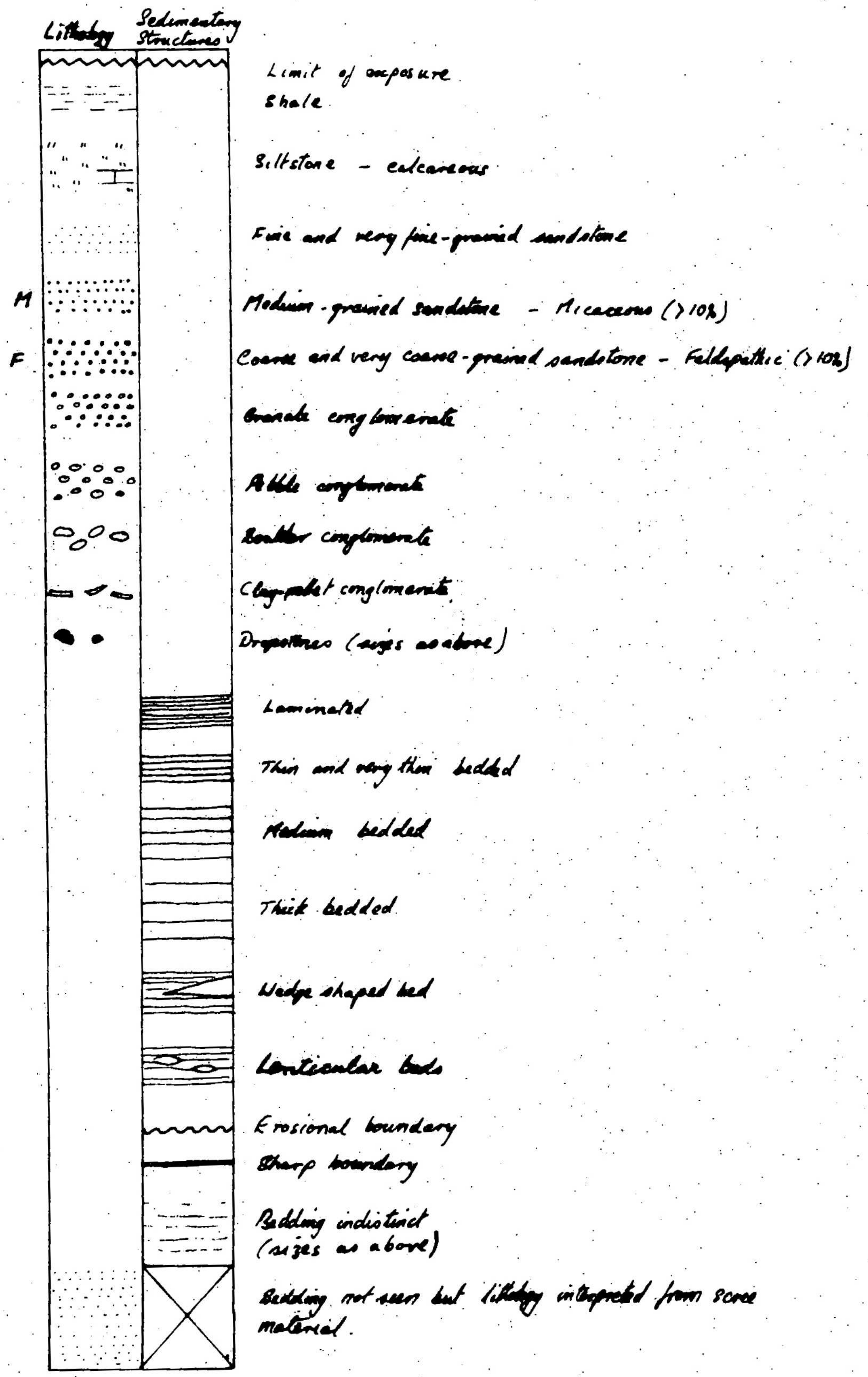


Fig. 11. Noonkanbah Sheet area, showing location of sections described in Appendix. Scale; 1:1 000 000

SYMBOLS USED IN SECTIONS.



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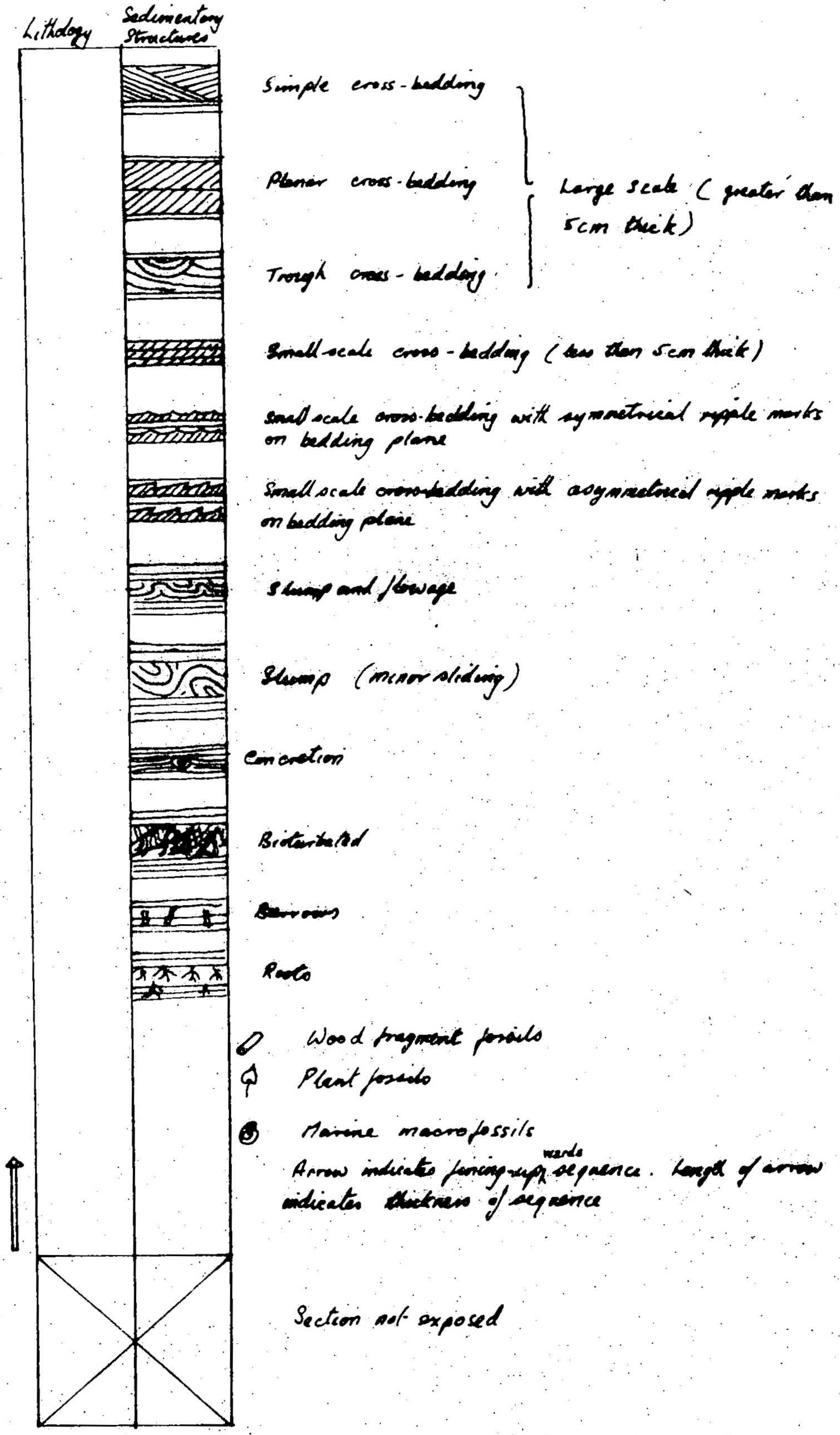
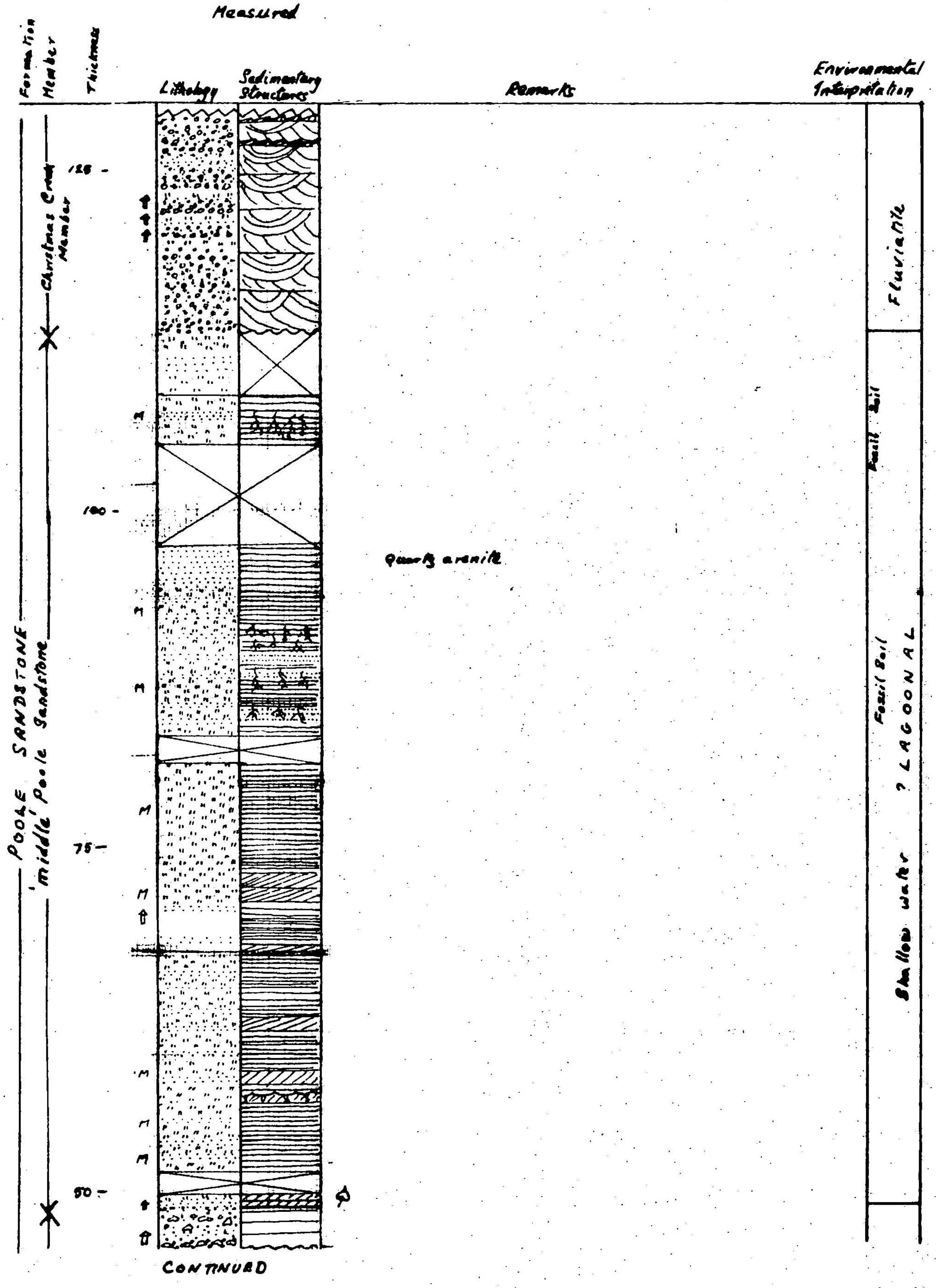

Lithology
Sedimentary Structures
Simple cross-bedding
Planar cross-bedding
Trough cross-bedding
Large scale (greater than 5cm thick)
Small-scale cross-bedding (less than 5cm thick)
Small scale cross-bedding with symmetrical ripple marks on bedding plane
Small scale cross-bedding with asymmetrical ripple marks on bedding plane
Slump and flowage
Slump (minor sliding)
Concretion
Bioturbated
Burrows
Roots
Wood fragment fossils
Plant fossils
Marine macrofossils
Arrow indicates fining-upwards sequence. Length of arrow indicates thickness of sequence
Section not exposed

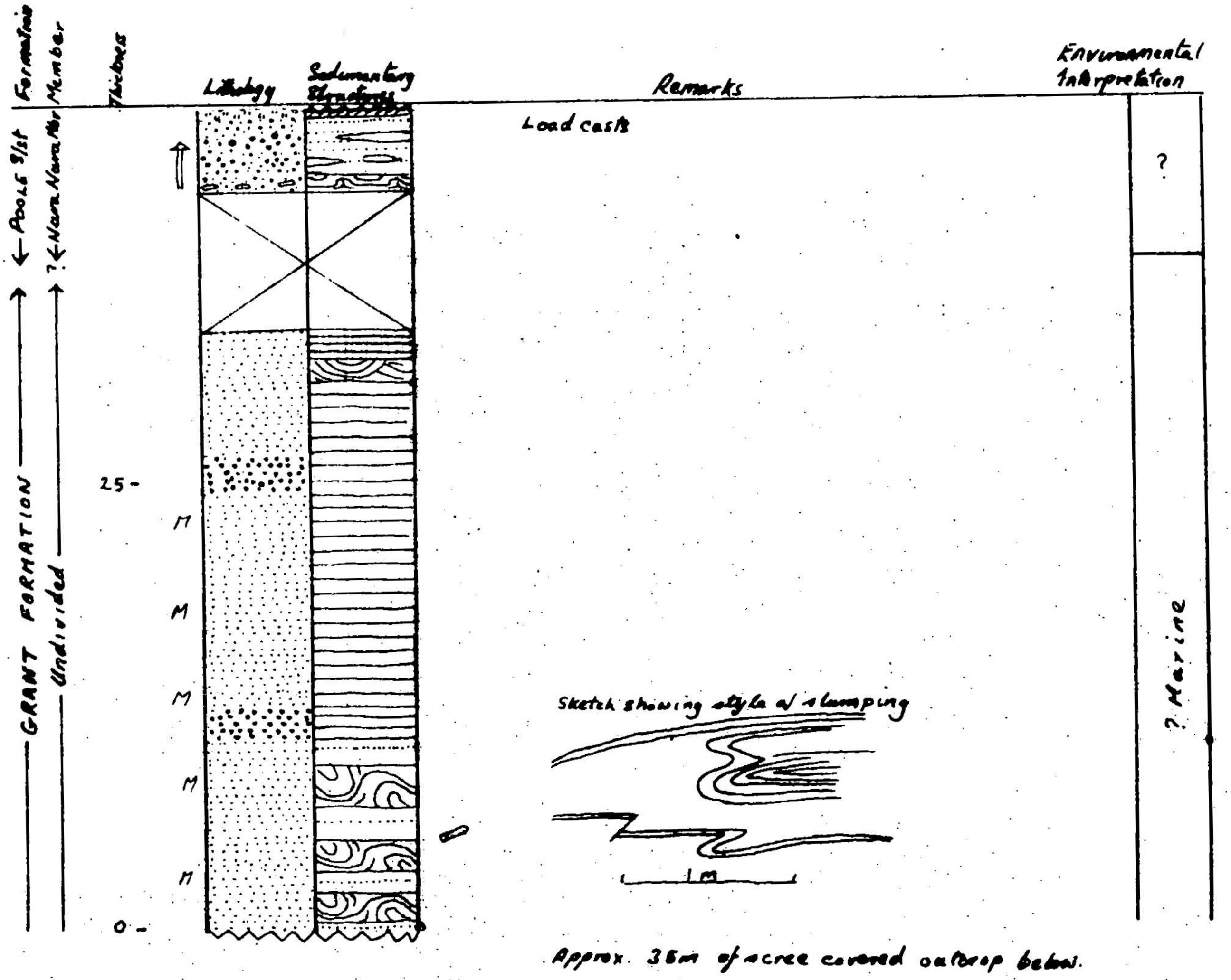
SECTION No. 1

MOUNT PIPER - POOLE RANGE

18° 53' 38" S. 125° 47' 25" E.

Measured



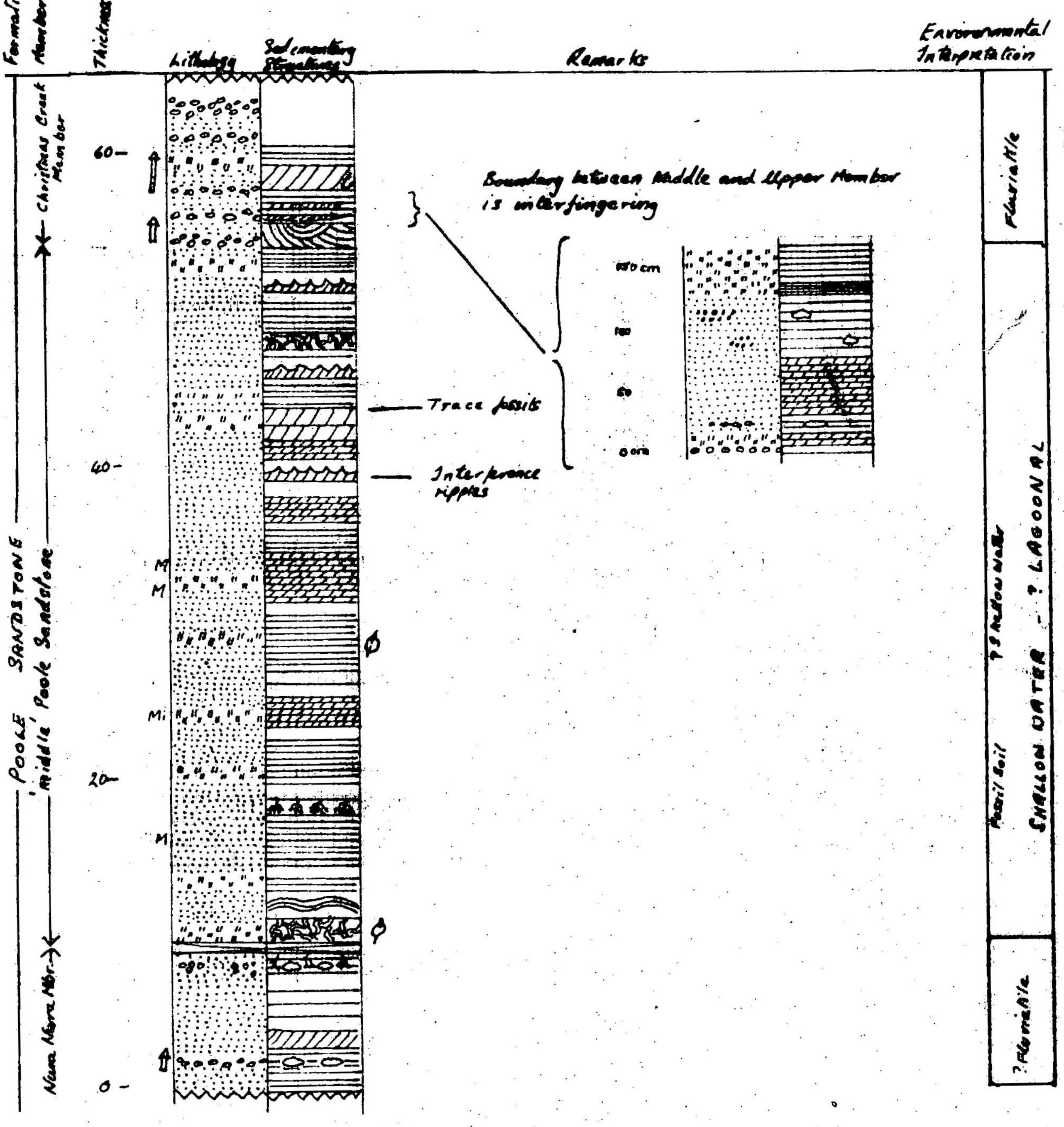

Formation
Member
Thickness
Lithology
Sedimentary Structures
Remarks
Environmental Interpretation
Load casts
?
GRANT FORMATION
Undivided
Pools S/st
Nura Nura Mbr
25 -
0 -
M
M
M
M
M
Sketch showing style of slumping
1M
? Marine
Approx. 35m of scree covered outcrop below.

SECTION No. 2

POOLE RANGE

18° 52' 08"S. 125° 48' 25"E.

Measured

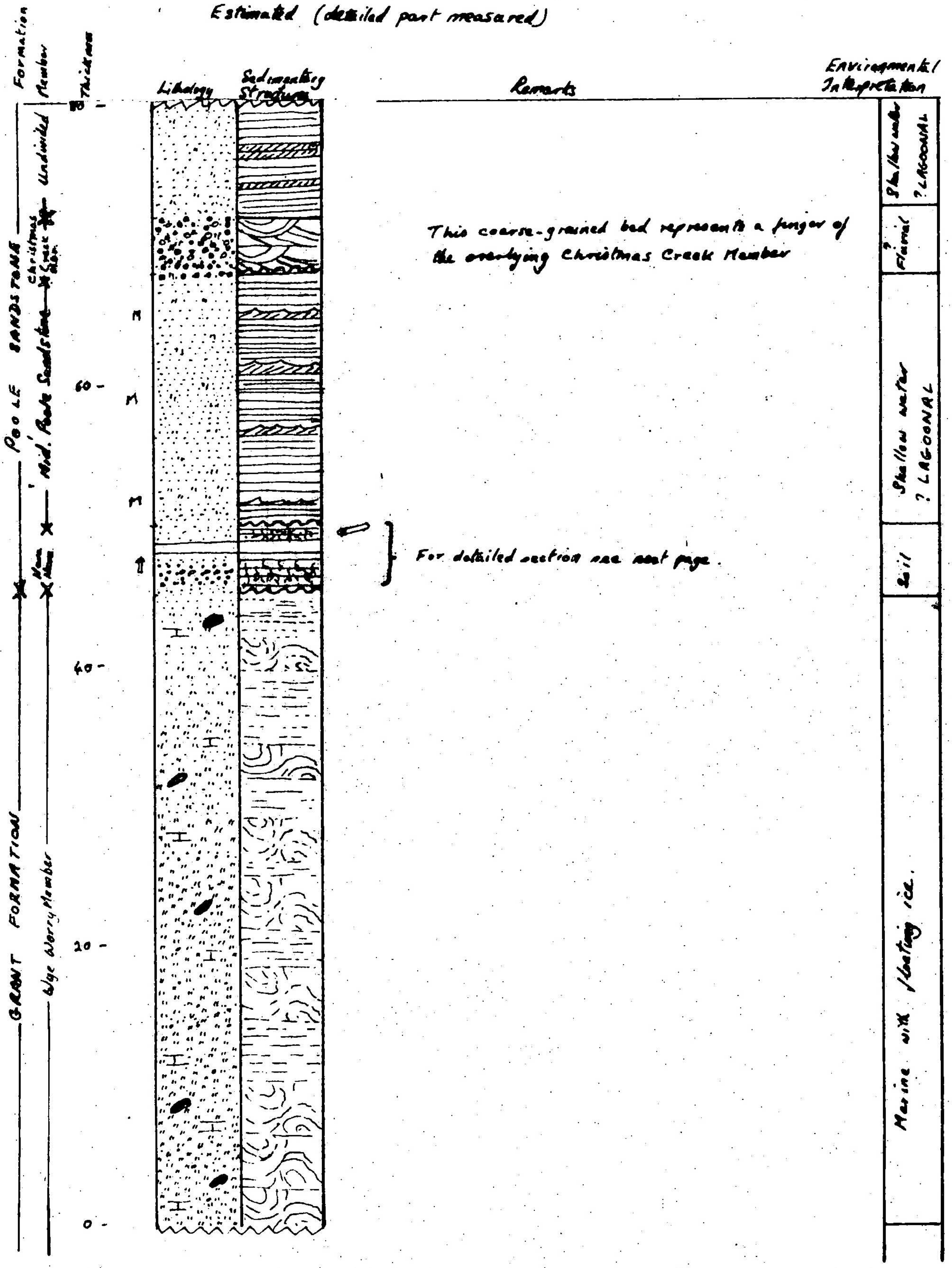


SECTION No. 3

MOUNT THORLAN

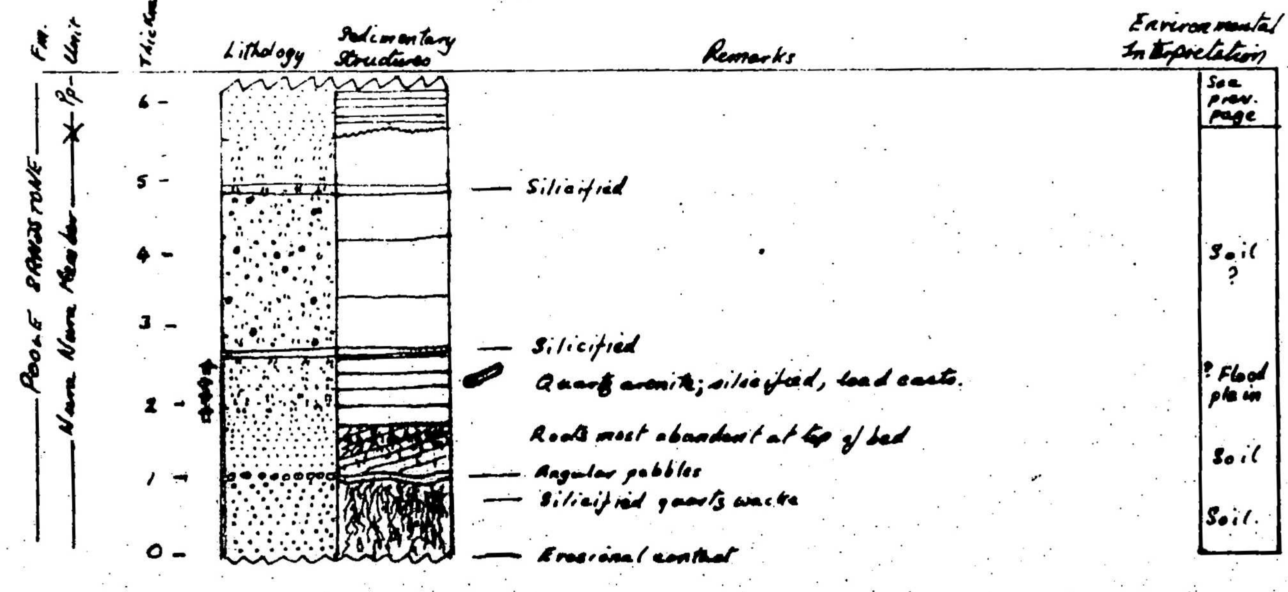
18°47'45"S. 125°46'35"E.

Estimated (detailed part measured)



SECTION No. 3 (cont.)

LARGE SCALE

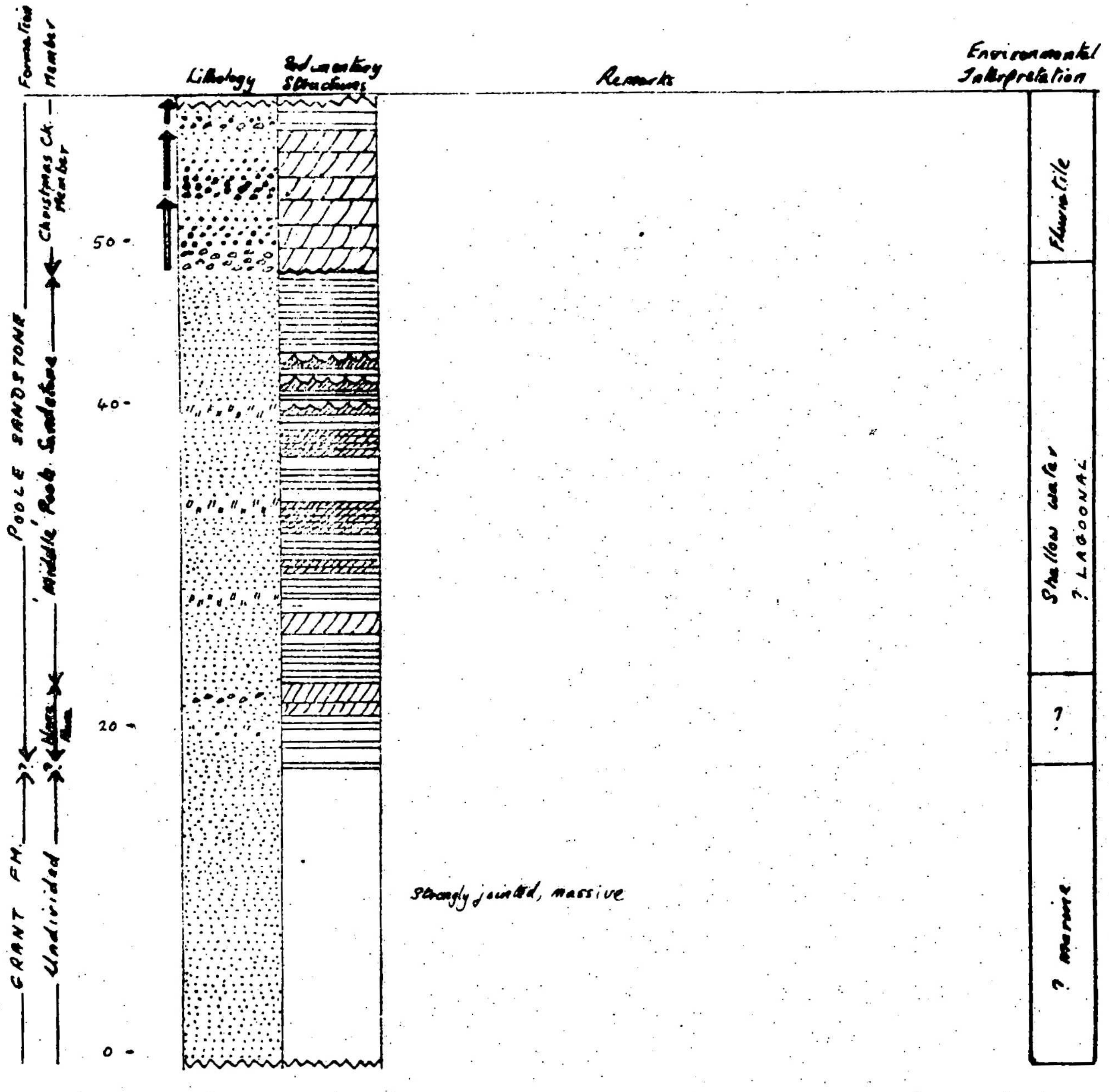


SECTION No. 4 [redacted]

SOUTHERN POOLE RANGE

18°54'28"S. 125°46'30"E.

Estimated



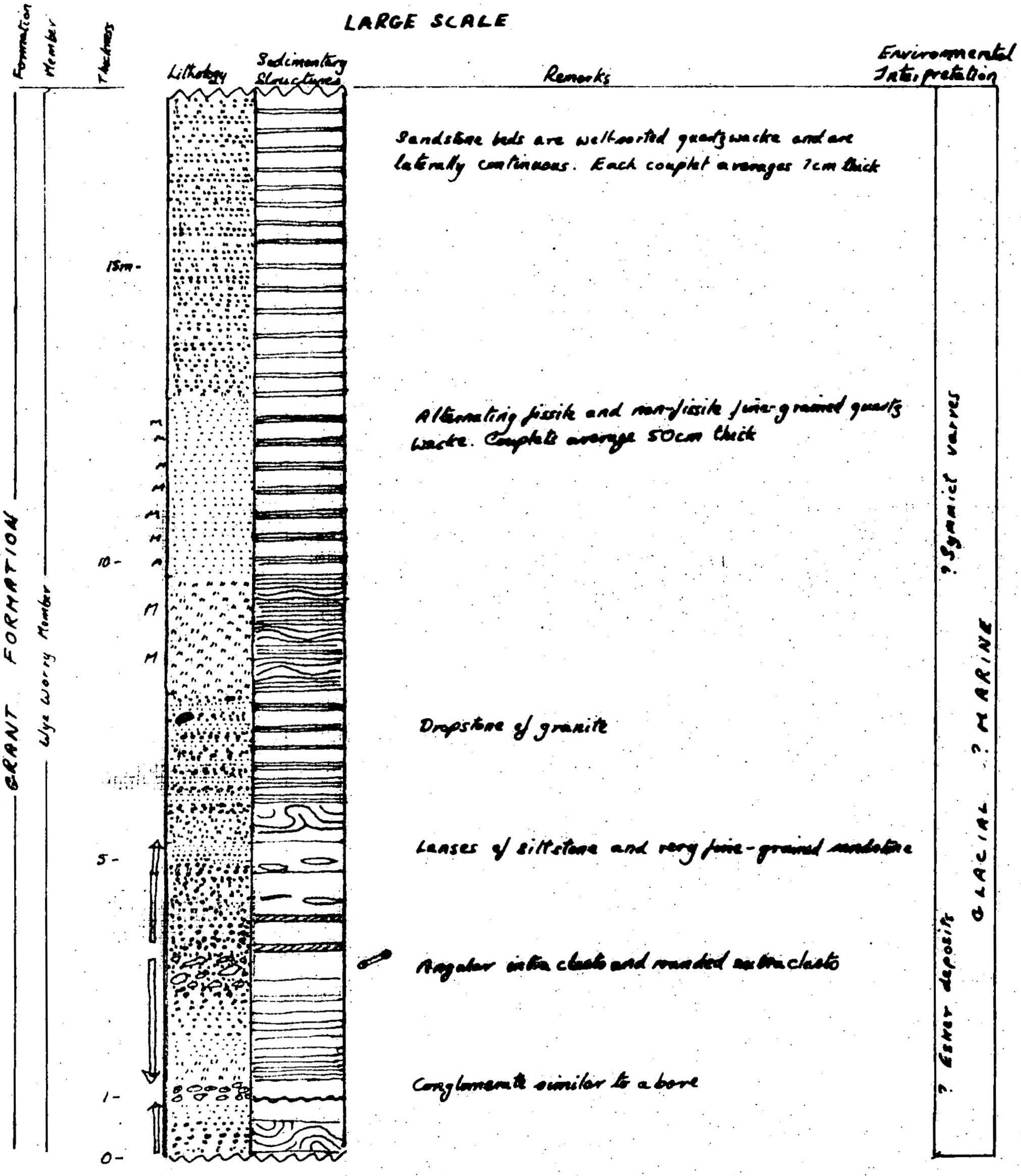
SECTION No 4a

SOUTHERN POOLE RANGE

18°53'37"S. 125°44'30"E.

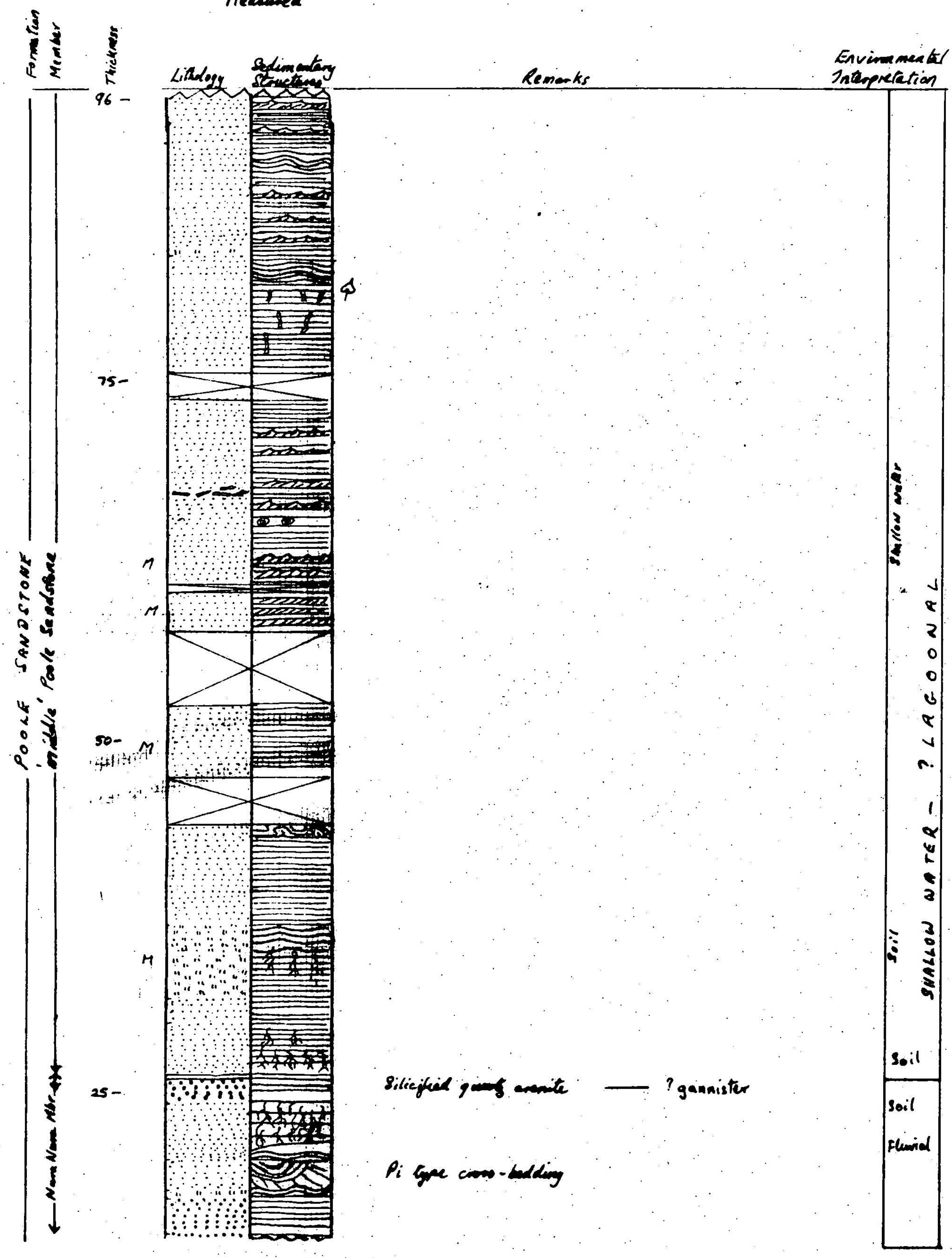
Measured

LARGE SCALE

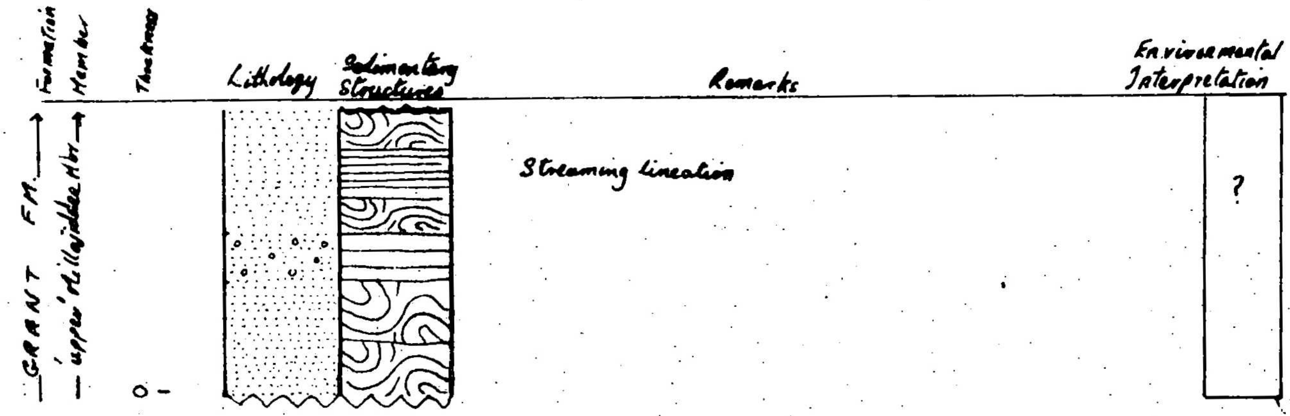


SECTION No. 5

MOUNT HUTTON
18°49'33"S. 125°37'45"E.
Measured



CONTINUED



Record 1976/24

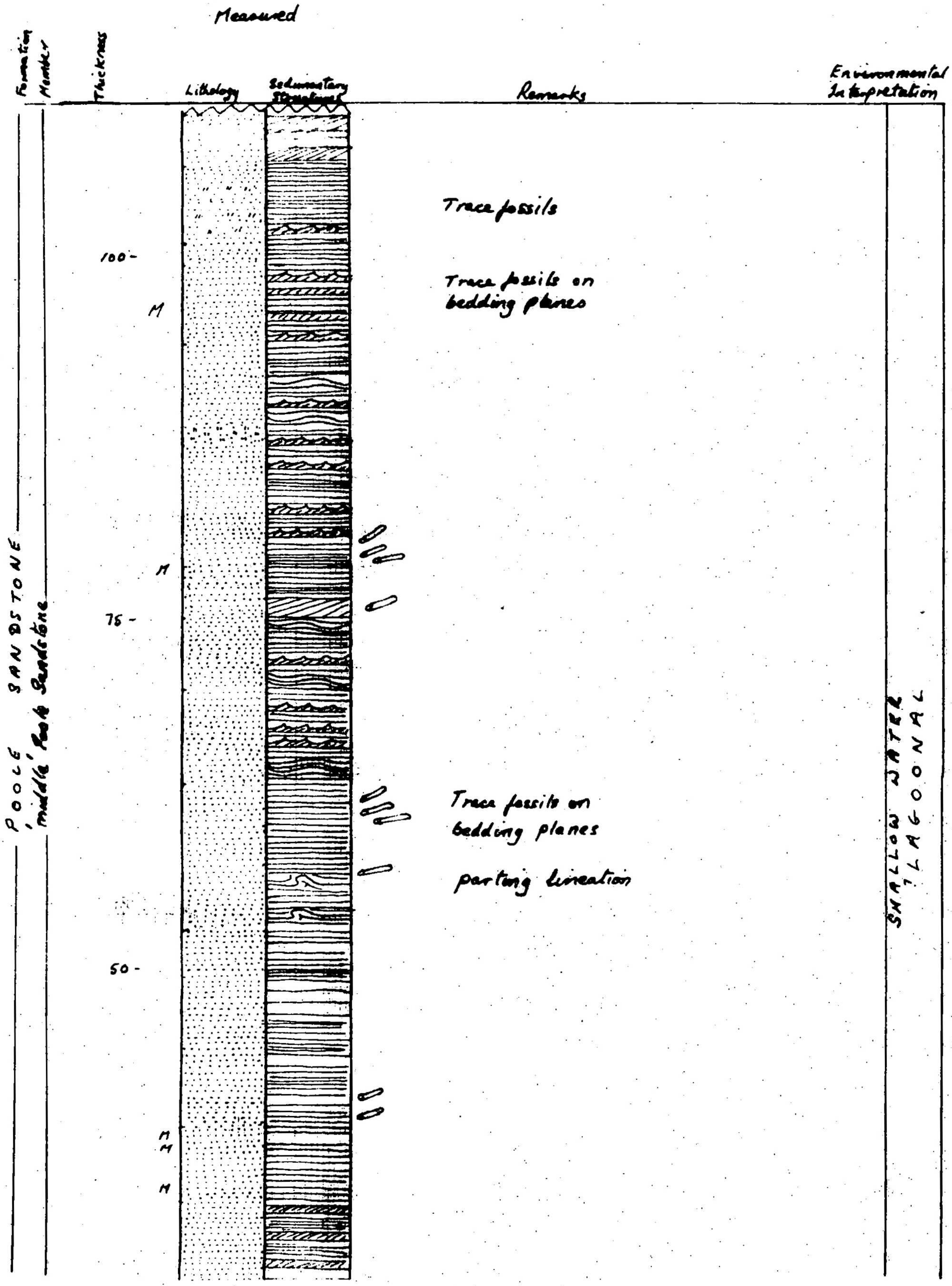
E51/A12/27

SECTION No. 6

EASTERN ST GEORGE RANGE

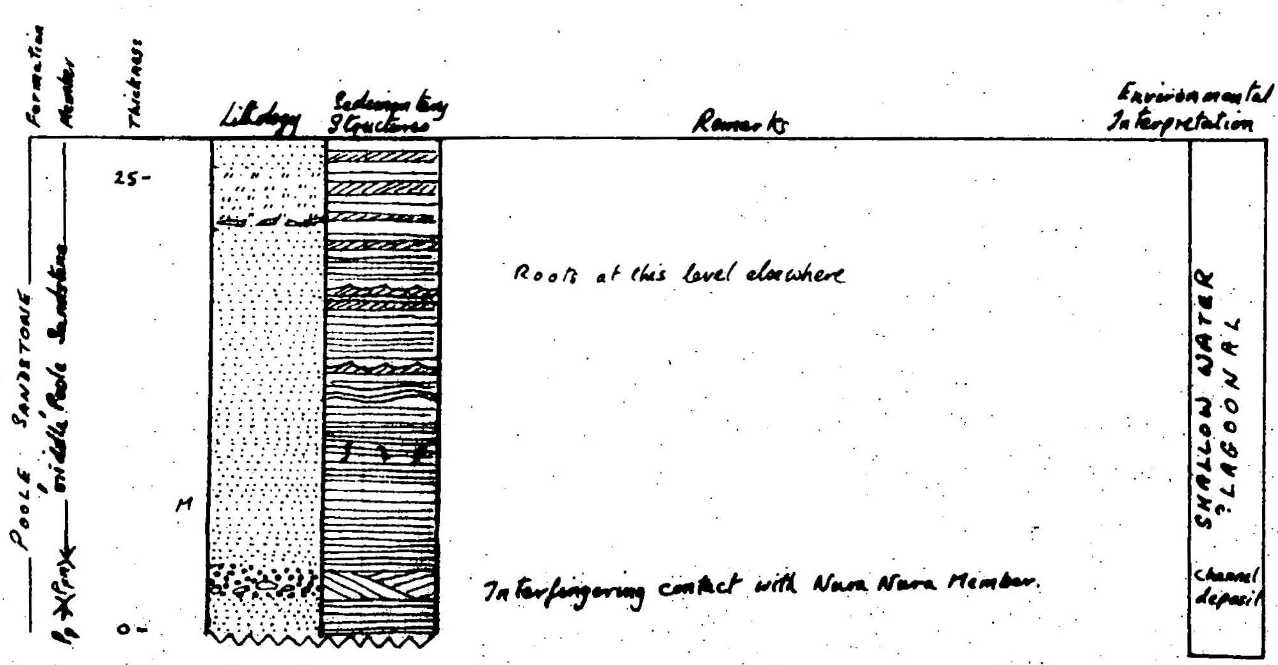
18° 48' 00" S. 125° 23' 25" E.

Measured



CONTINUED

SECTION No. 6 (cont.)



Record 1976/24

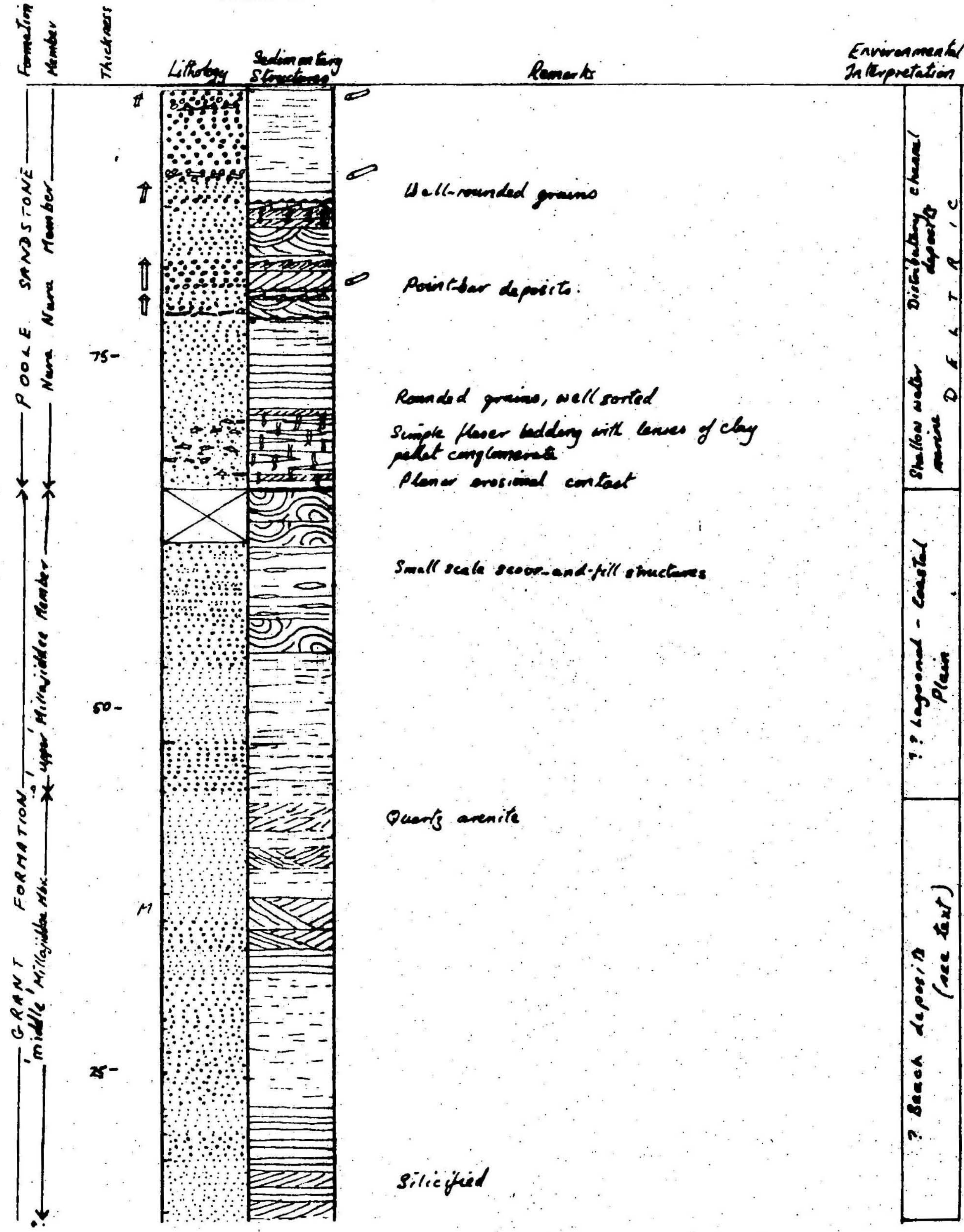
E51/A12/28

SECTION No. 7

EASTERN ST GEORGE RANGE

18° 48' 45" S. 125° 23' 40" E.

Measured



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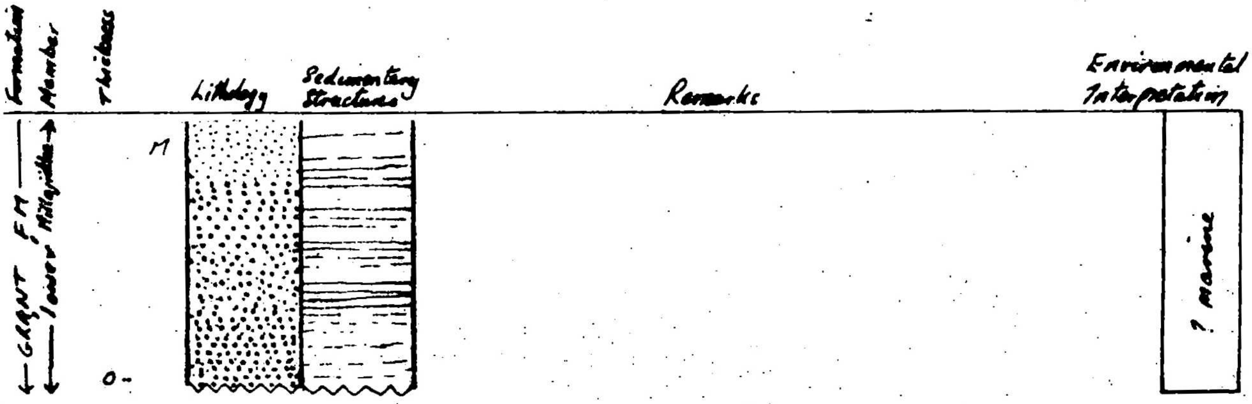
SECTION No. 7 (cont.)

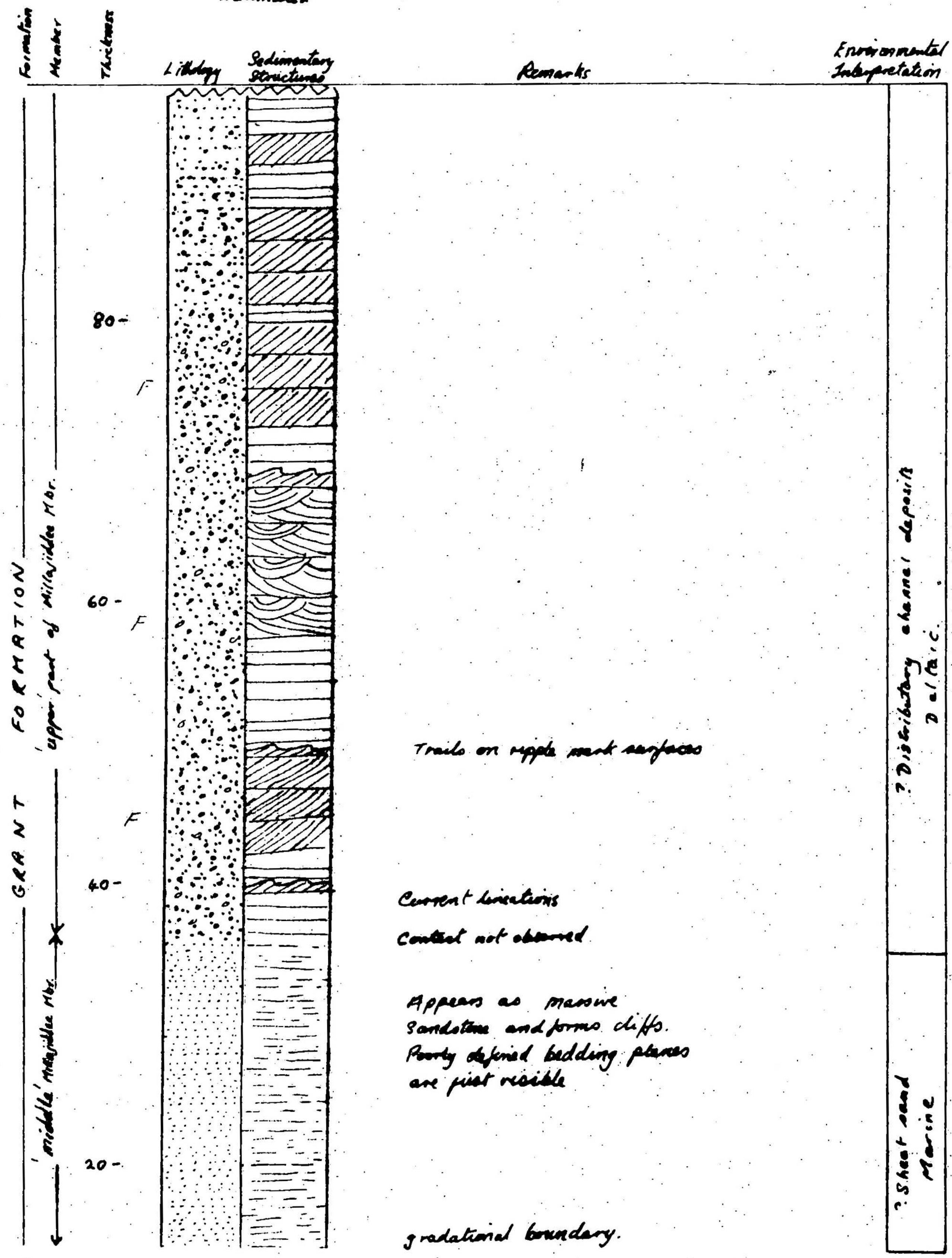


SECTION No. 8

SOUTHEASTERN ST GEORGE RANGE

18° 49' 37" S. 125° 18' 30" E.

Estimated



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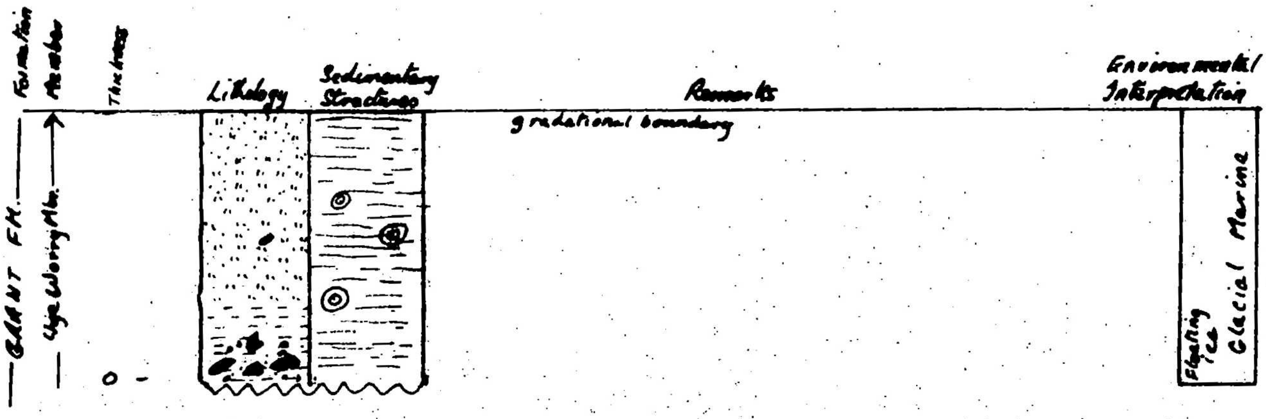
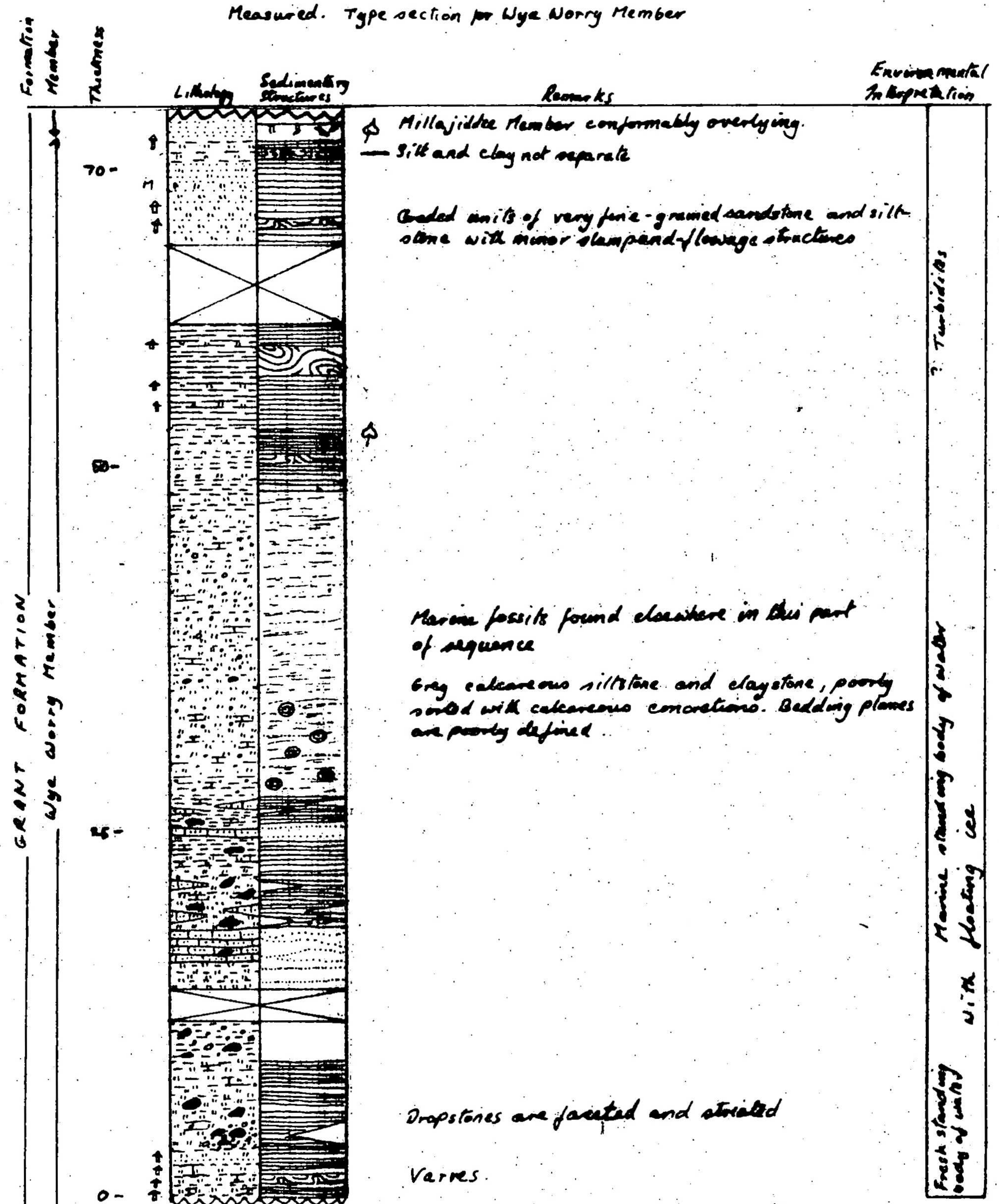

Formation
Member
Thickness
Lithology
Sedimentary Structures
Remarks
Environmental Interpretation
gradational boundary
GRANT FM.
Floating Ice
Glacial Marine
0

SECTION No. 9

EASTERN ST GEORGE RANGE

18° 46'30"S. 125°18'50"E

Measured. Type section for Wye Worry Member

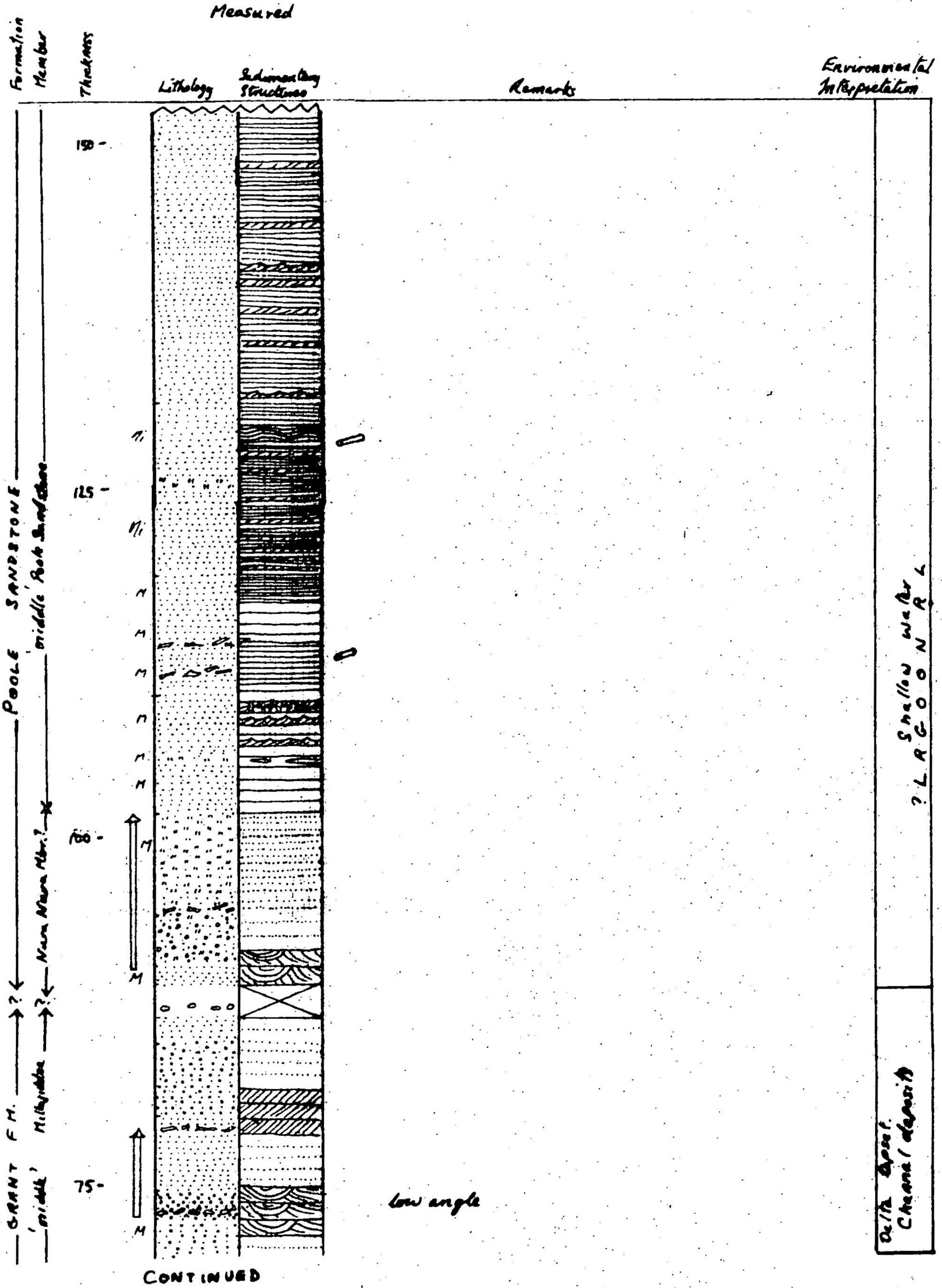


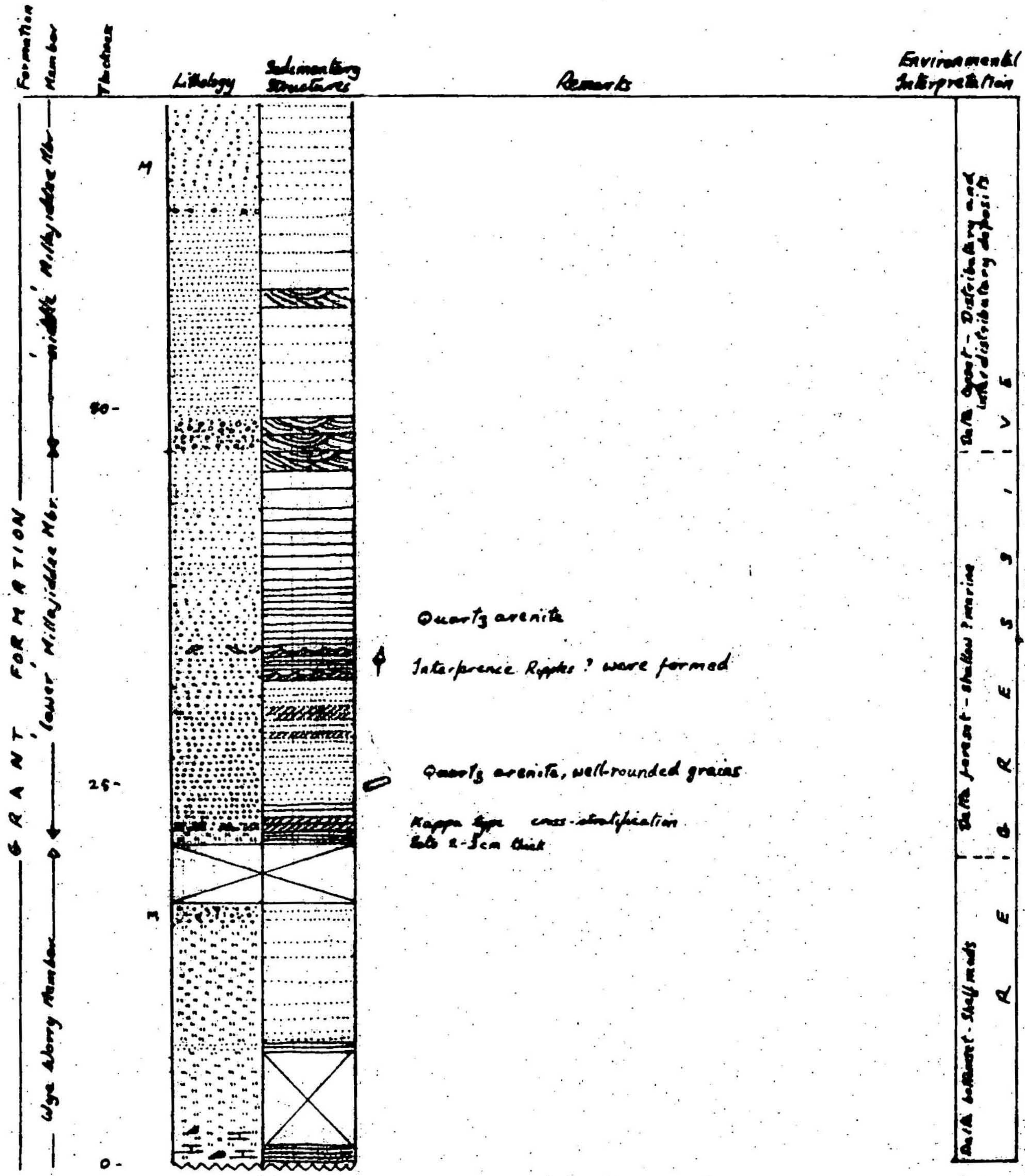
SECTION No. 10

CENTRAL ST GEORGE RANGE

18° 43' 52" S. 125° 07' 52" E

Measured



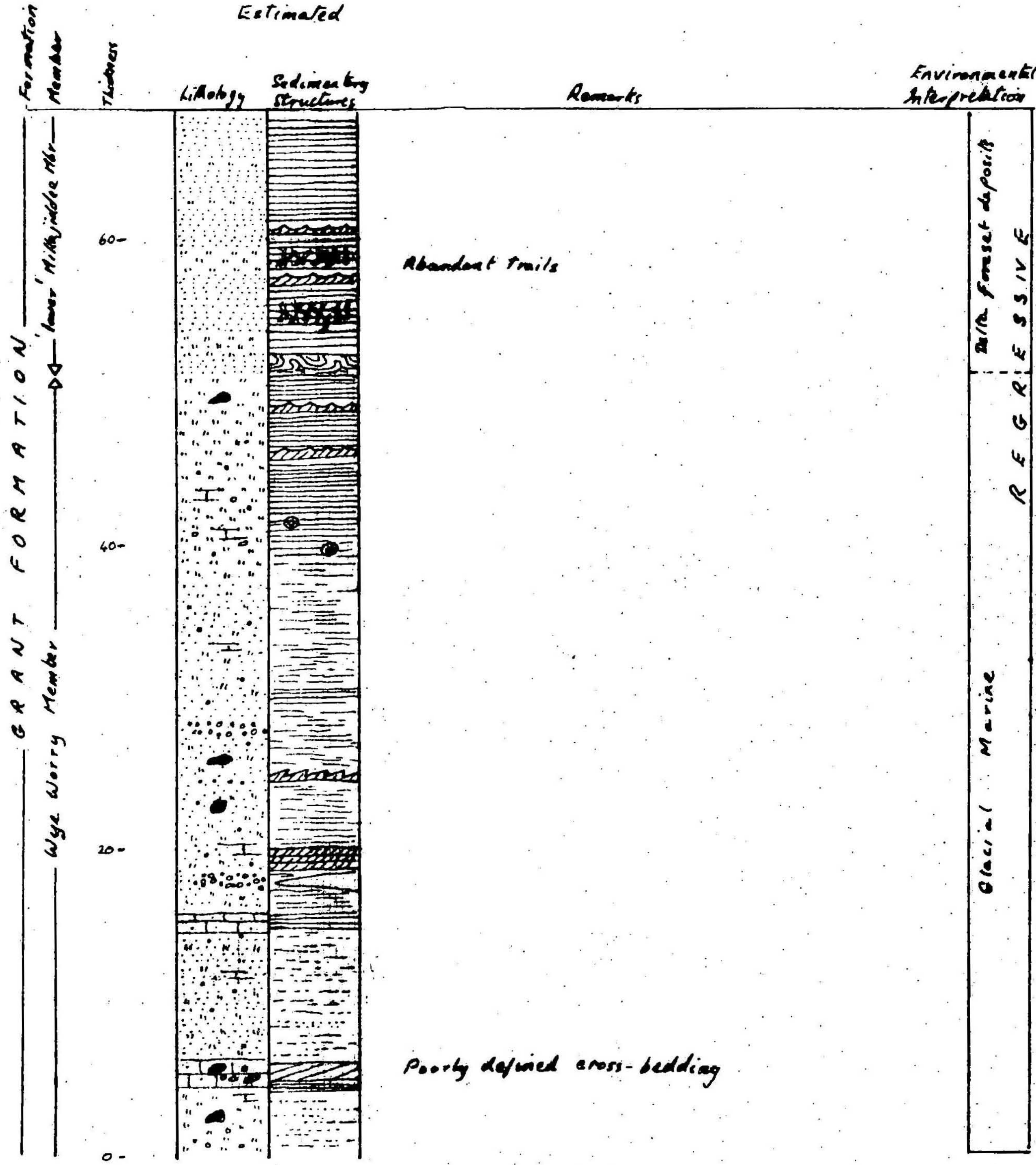

Formation
Member
Thickness
Lithology
Sedimentary Structures
Remarks
Environmental Interpretation
GRANT FORMATION
'middle' Millajiddee Mbr
'lower' Millajiddee Mbr.
Wye Worry Member
30-
25-
0-
Quartz arenite
Interference Ripples ? wave formed
Quartz arenite, well-rounded grains
Kappa type cross-stratification
Sets 2-3cm thick
REGRESSIVE
Delta front - Distributary and interdistributary deposits
Delta foreset - shallow ? marine
Delta bottomset - Shelf muds

SECTION No. 11

TULLOCK PEAK

18° 48' 00" S. 125° 07' 12" E.

Estimated

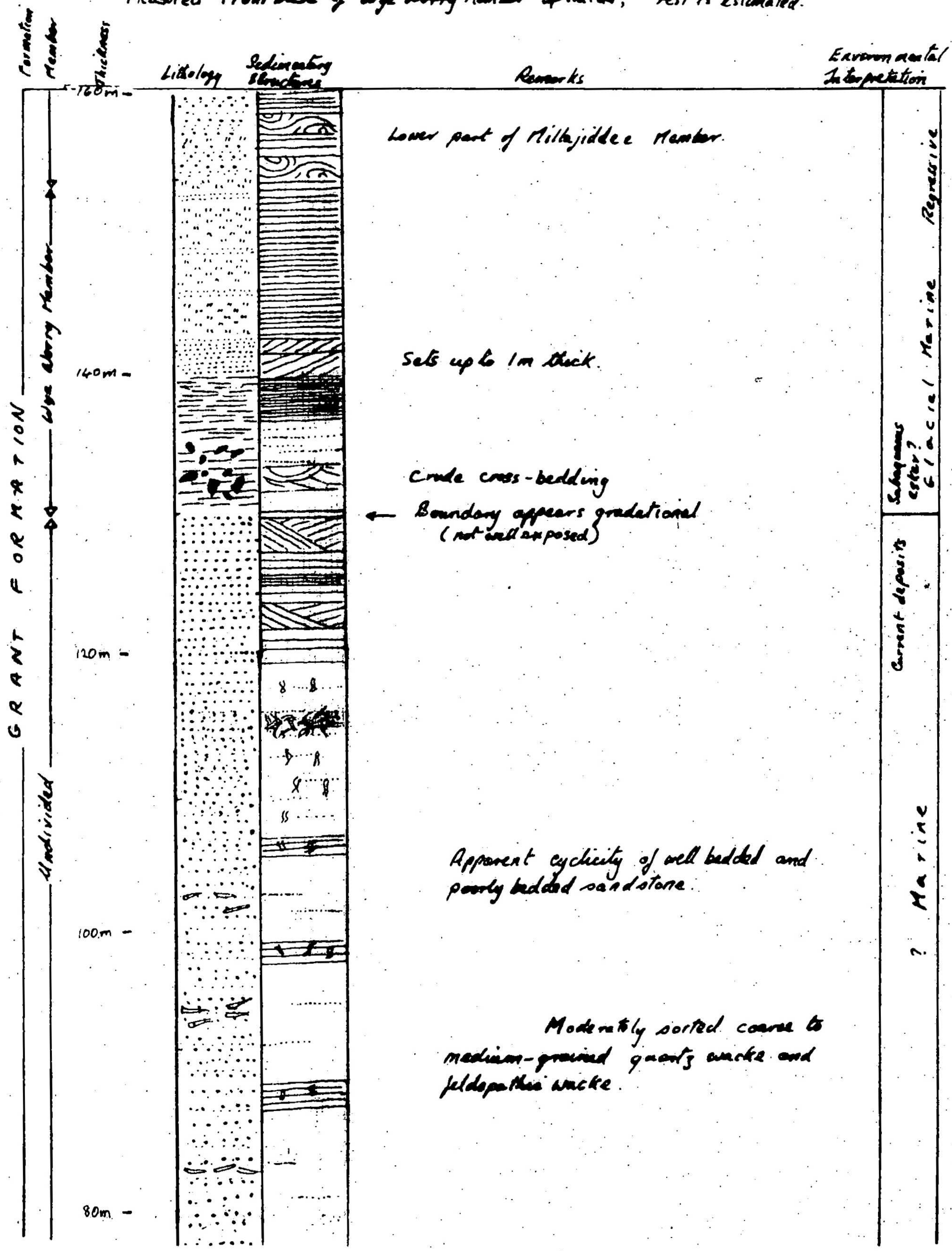


SECTION No. 12

CENTRAL GEORGE RANGE

18°43'25"S 125°07'12"E

Measured from base of Wye Worry Member upwards; rest is estimated.



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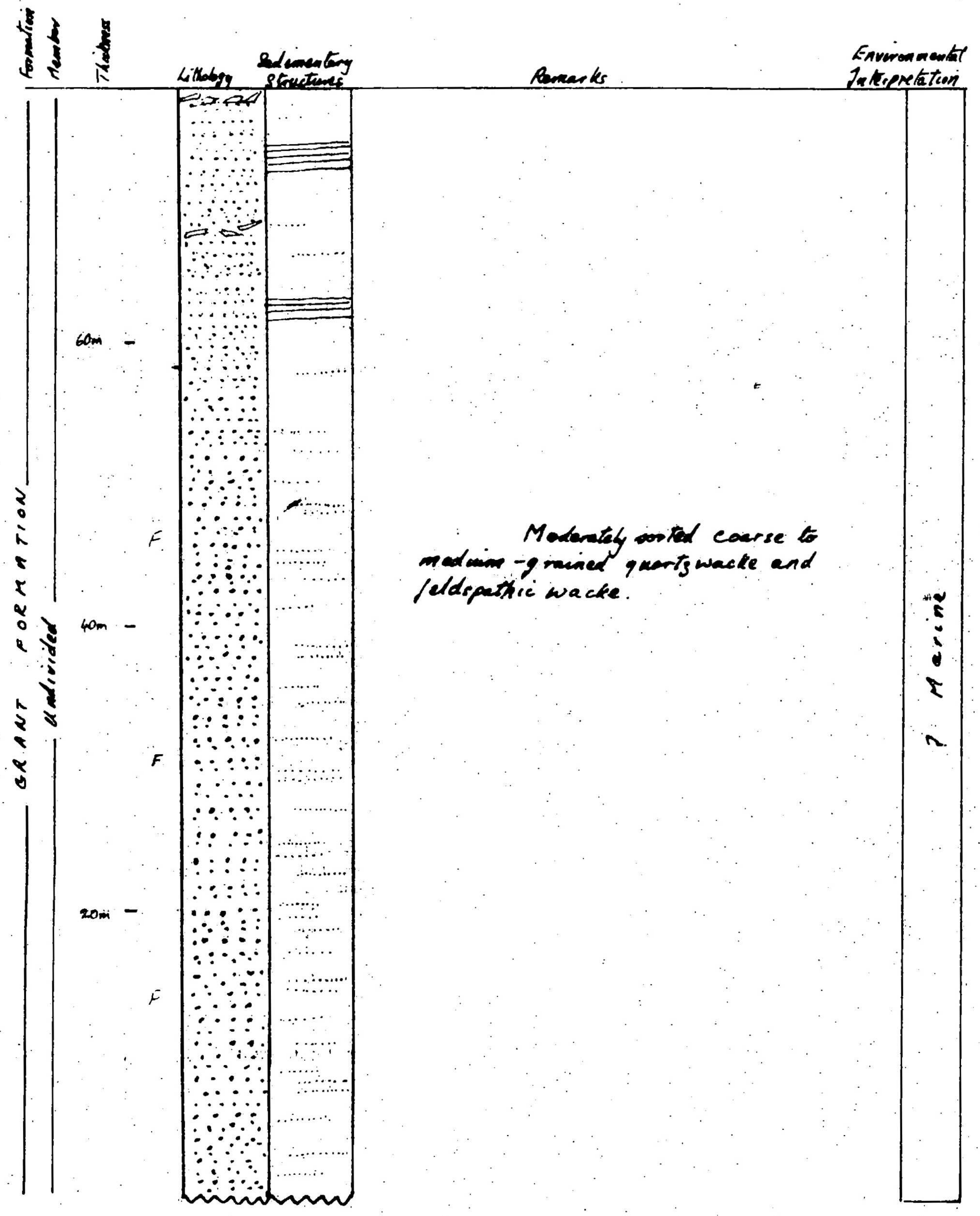
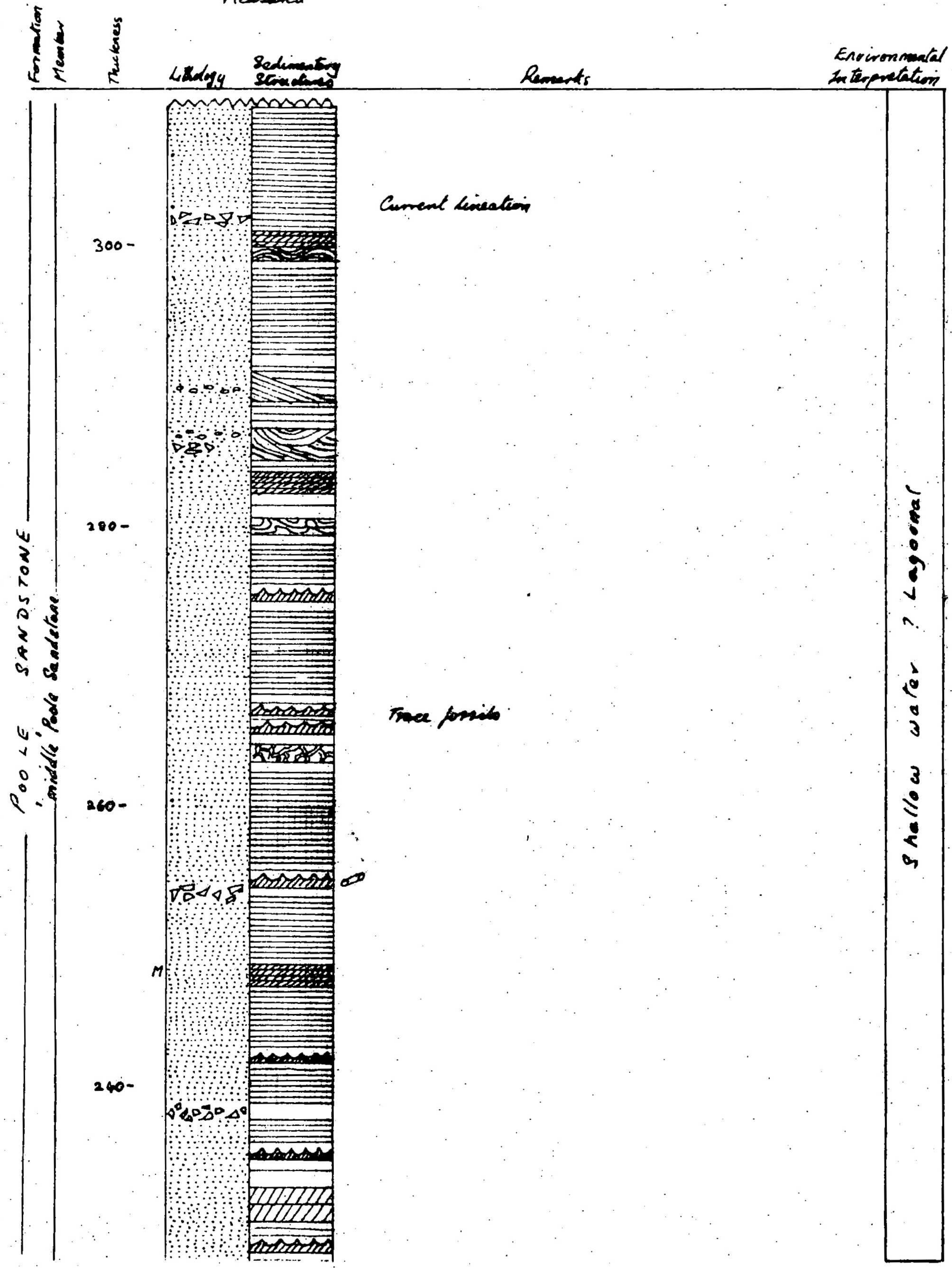

Formation
Member
Thickness
Lithology
Sedimentary Structures
Remarks
Environmental Interpretation
GRANT FORMATION
Undivided
60m
40m
20m
F
F
F
Moderately sorted coarse to medium-grained quartzwacke and feldspathic wacke.
? Marine

SECTION No. 13

MOUNT TUCKFIELD

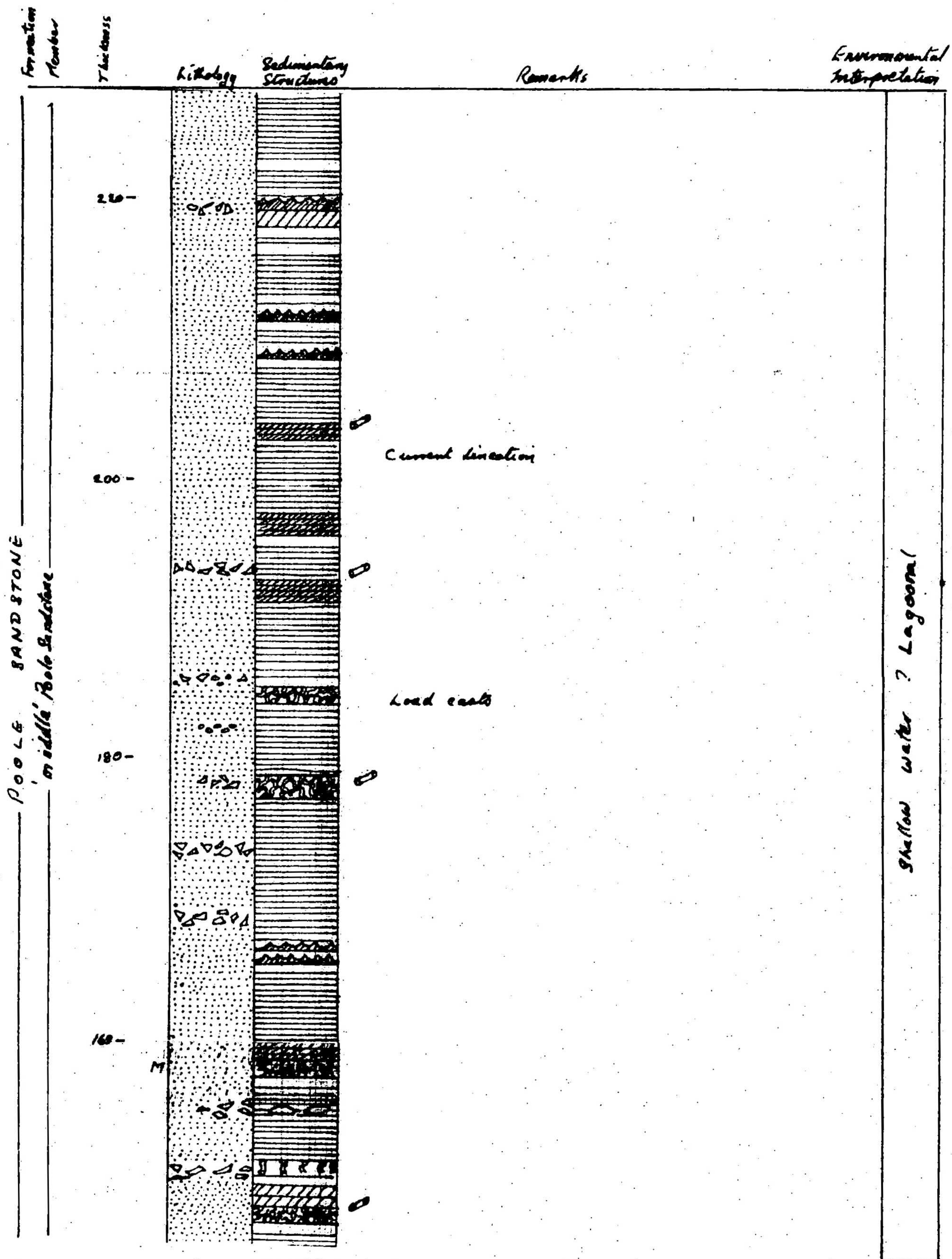
18° 42' 15" S. 124° 53' 35" E.

Measured



Continued

SECTION NO. 13 (cont.)

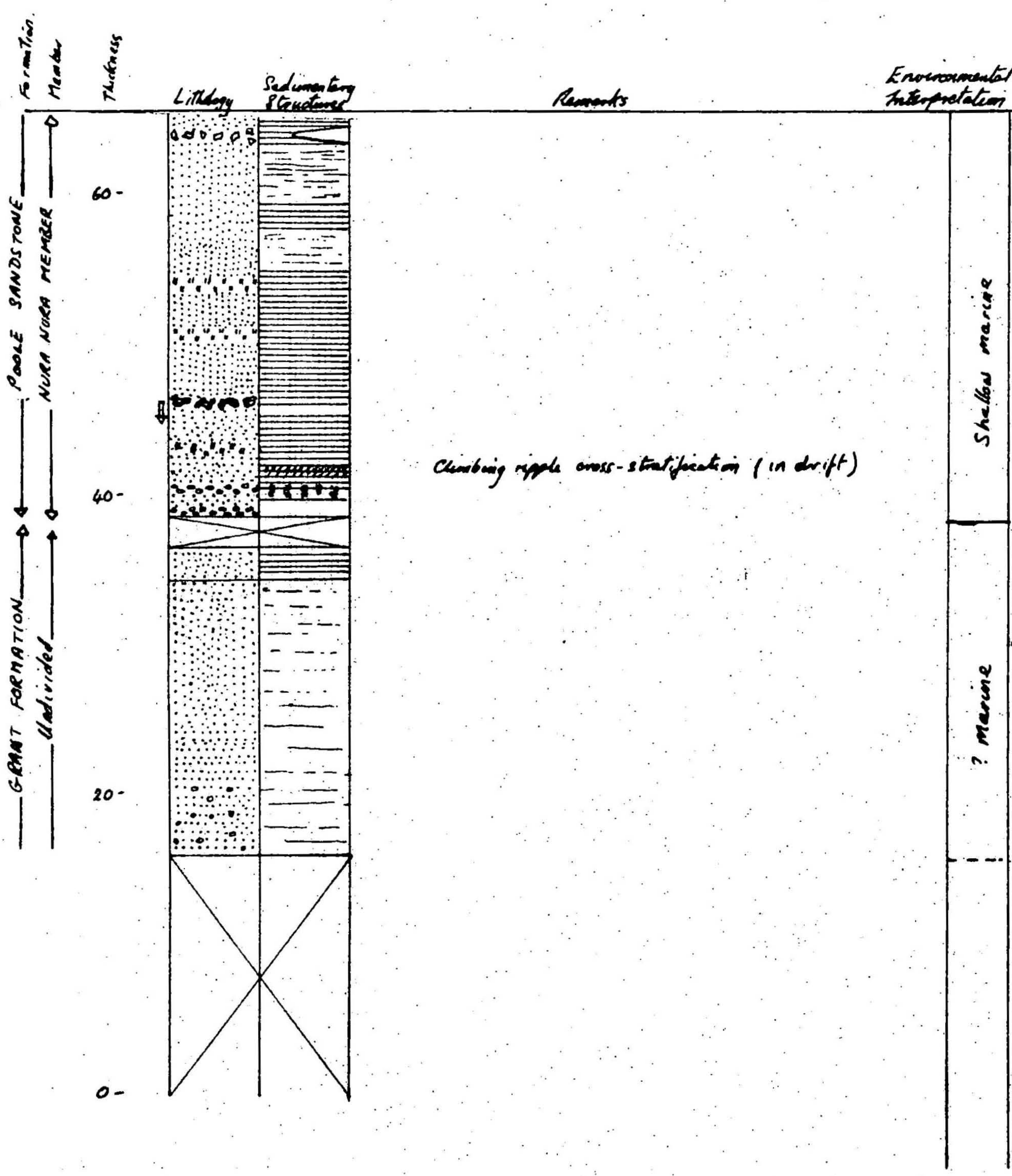


CONTINUED

SECTION No. 13 (cont.)

CONTINUED

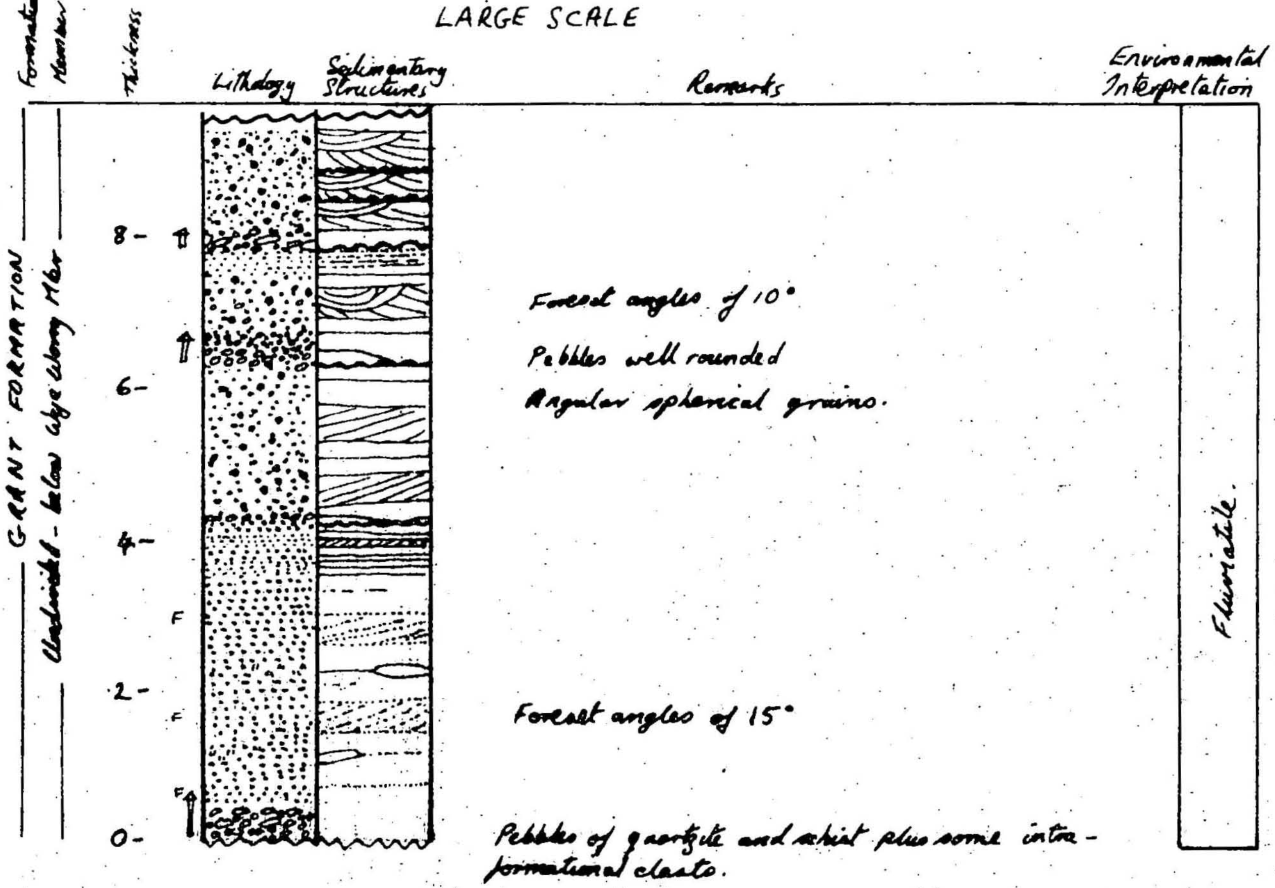
SECTION No. 13 (cont.)



SECTION No. 13a

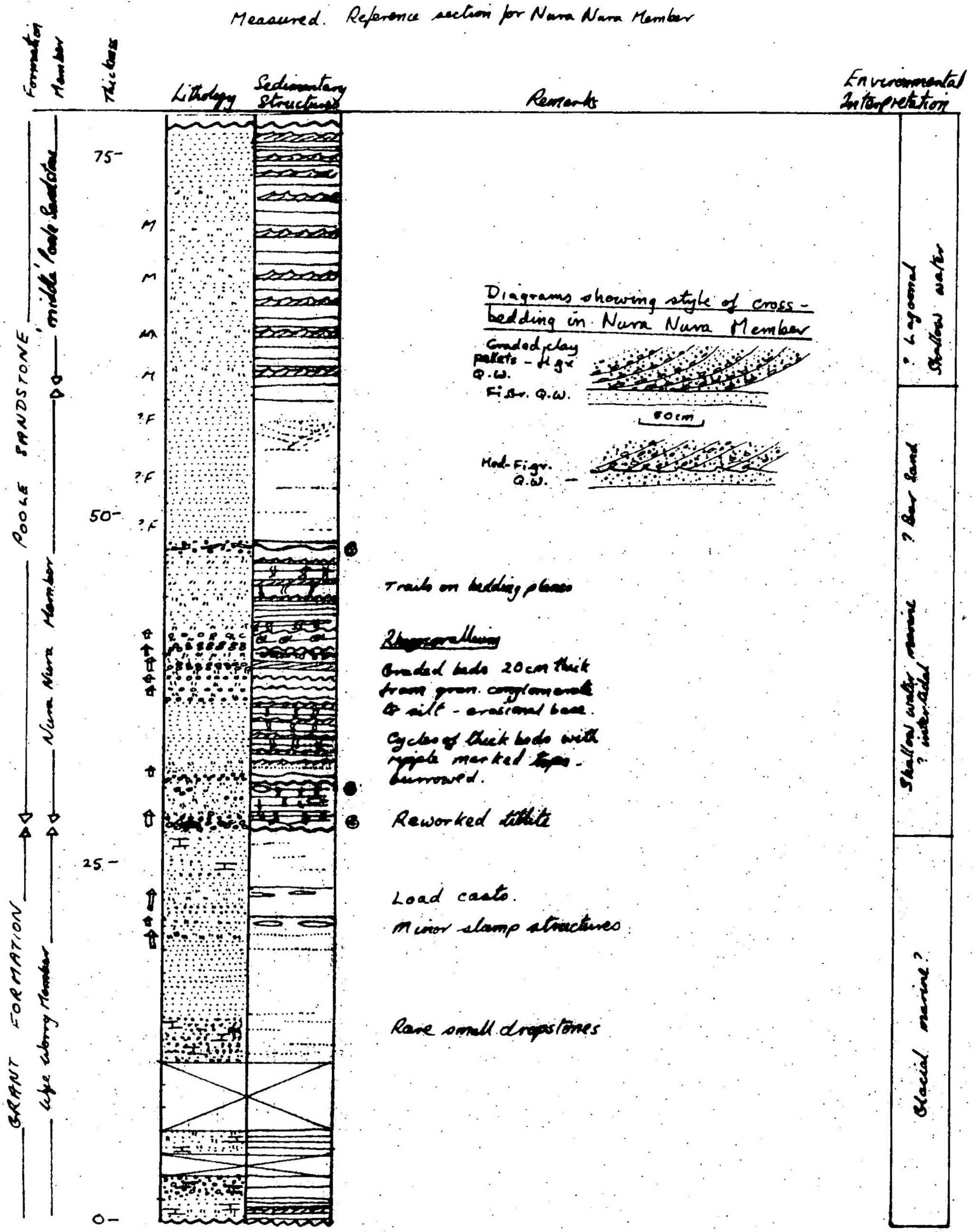
CAROLYN VALLEY
18° 43' 52" S. 124° 53' 45" E.
Measured

LARGE SCALE



SECTION No. 14

MILLAJIDDEE. S.W. ST GEORGE RA.
18°47'45"S. 124°57'33"E.
Measured. Reference section for Nura Nura Member

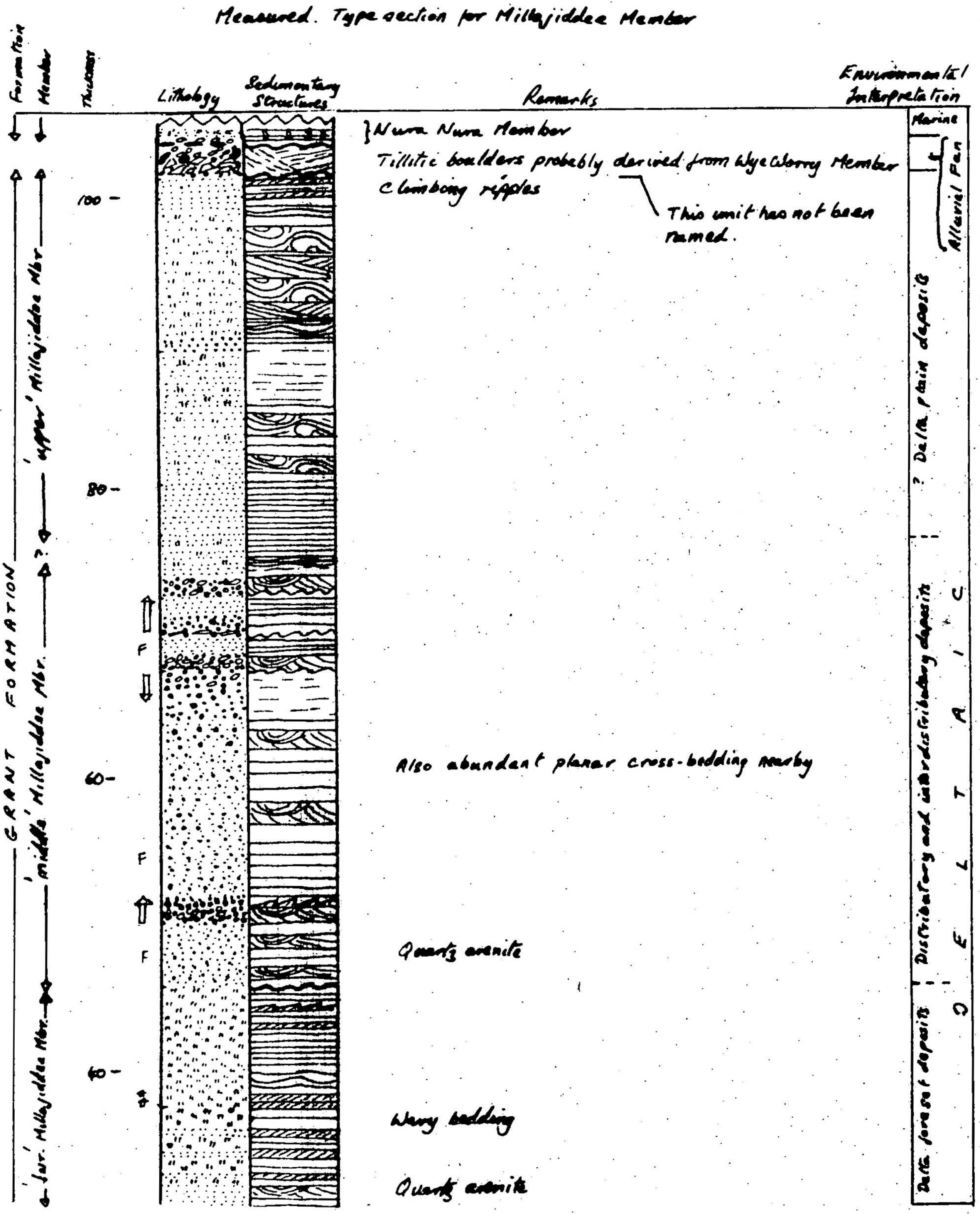


SECTION No. 15

WESTERN ST GEORGE RANGE

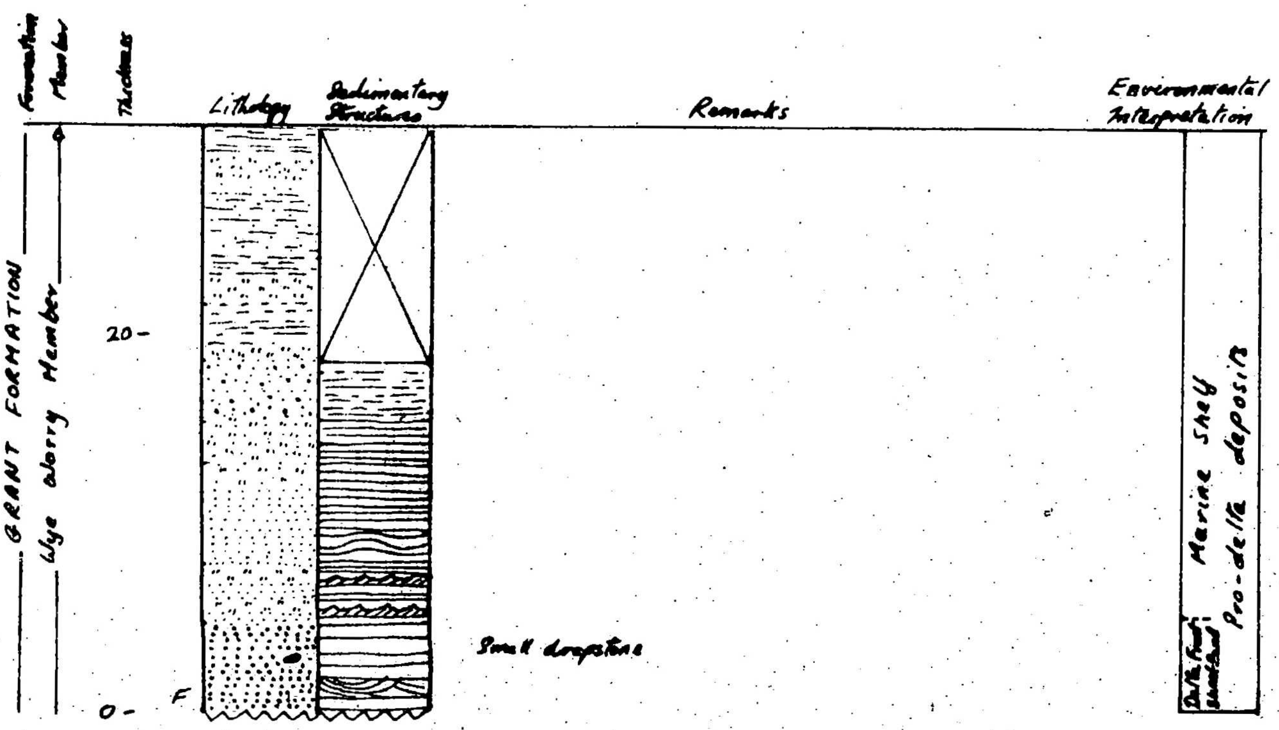
18°44'20"S. 124°55'52"E.

Measured. Type section for Millajiddee Member



CONTINUED

SECTION No. 15 (cont)

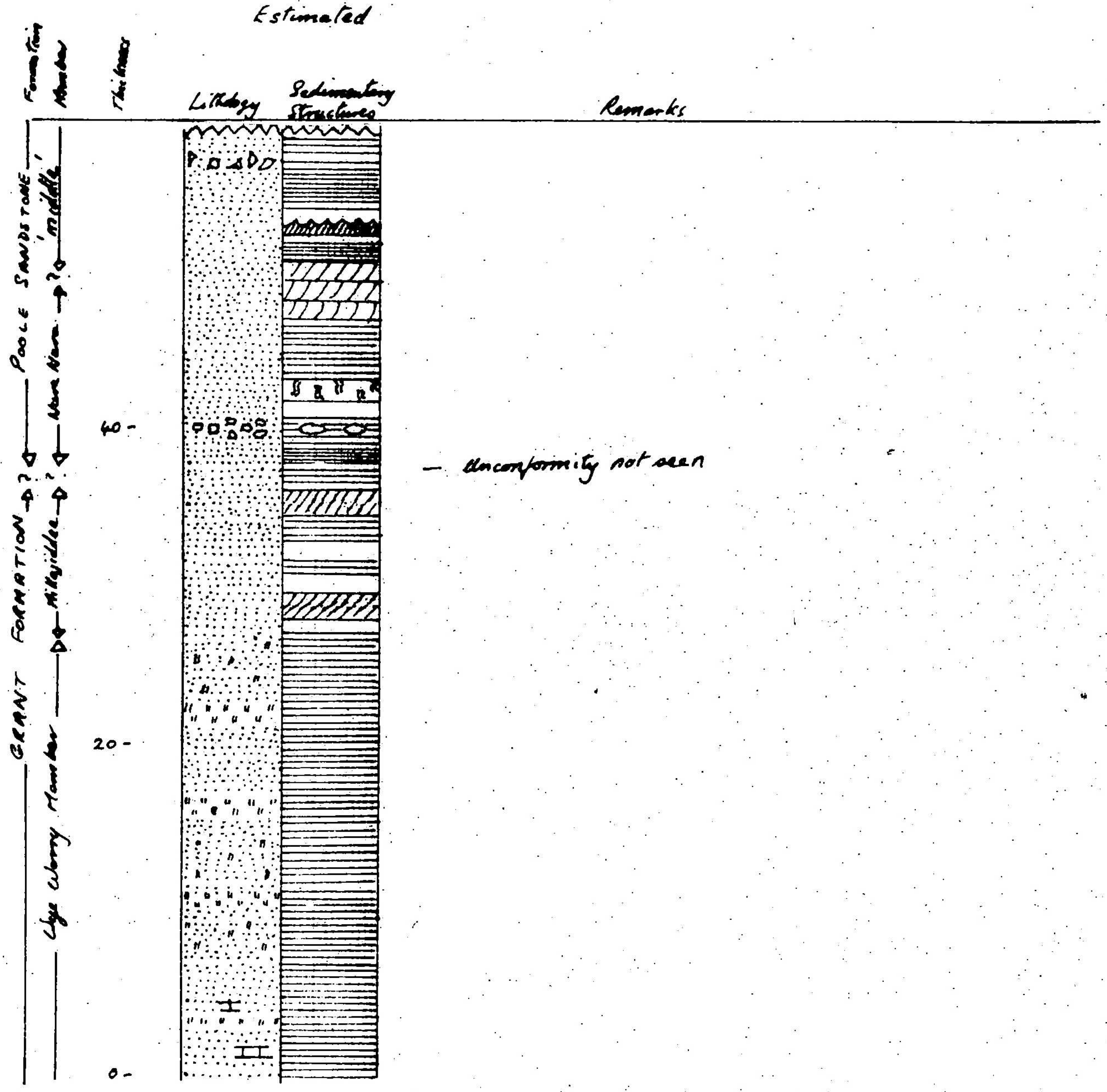


SECTION No. 16

NORTHWESTERN ST GEORGE RANGE

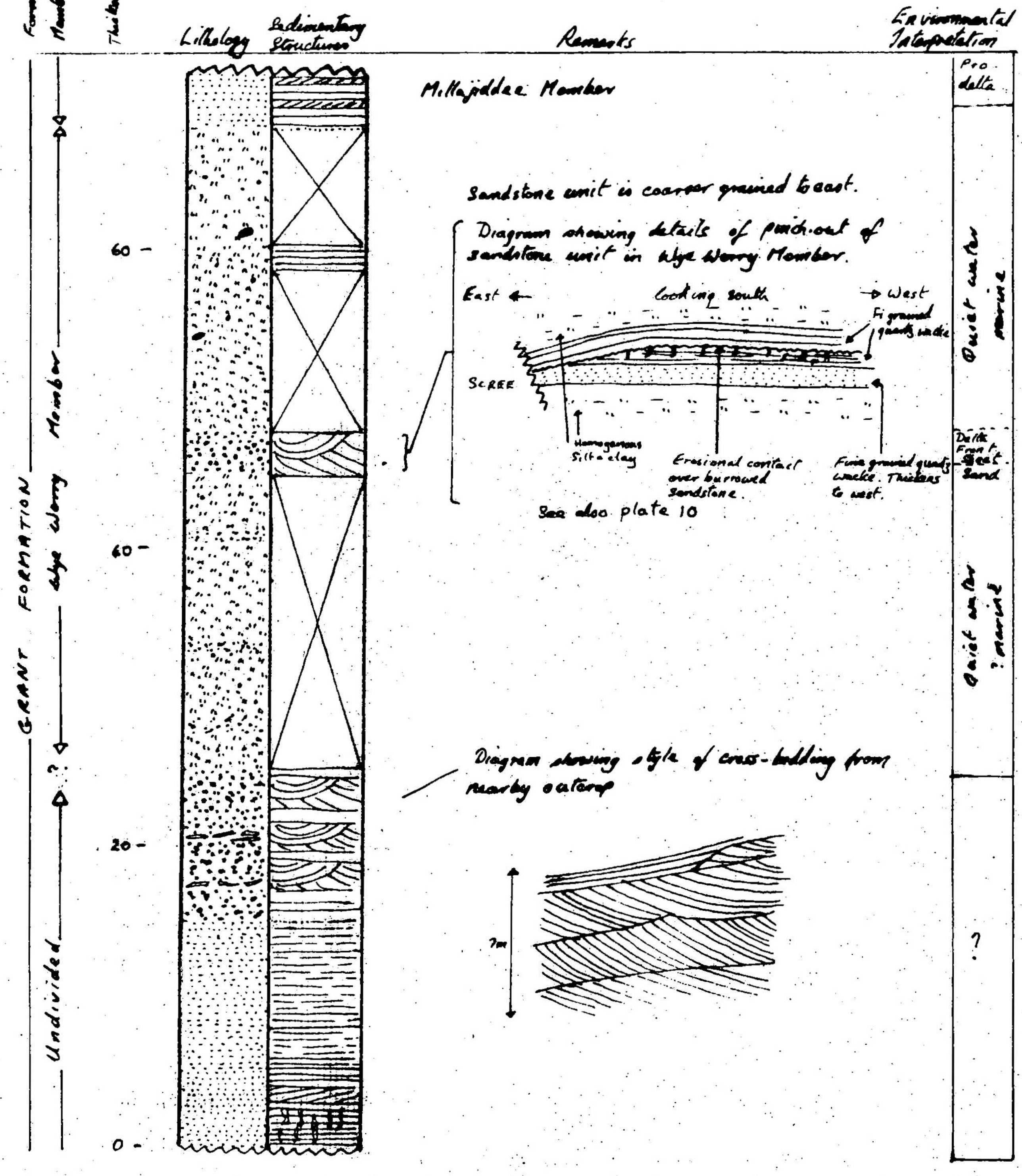
18°40'23"S. 124°52'50"E.

Estimated



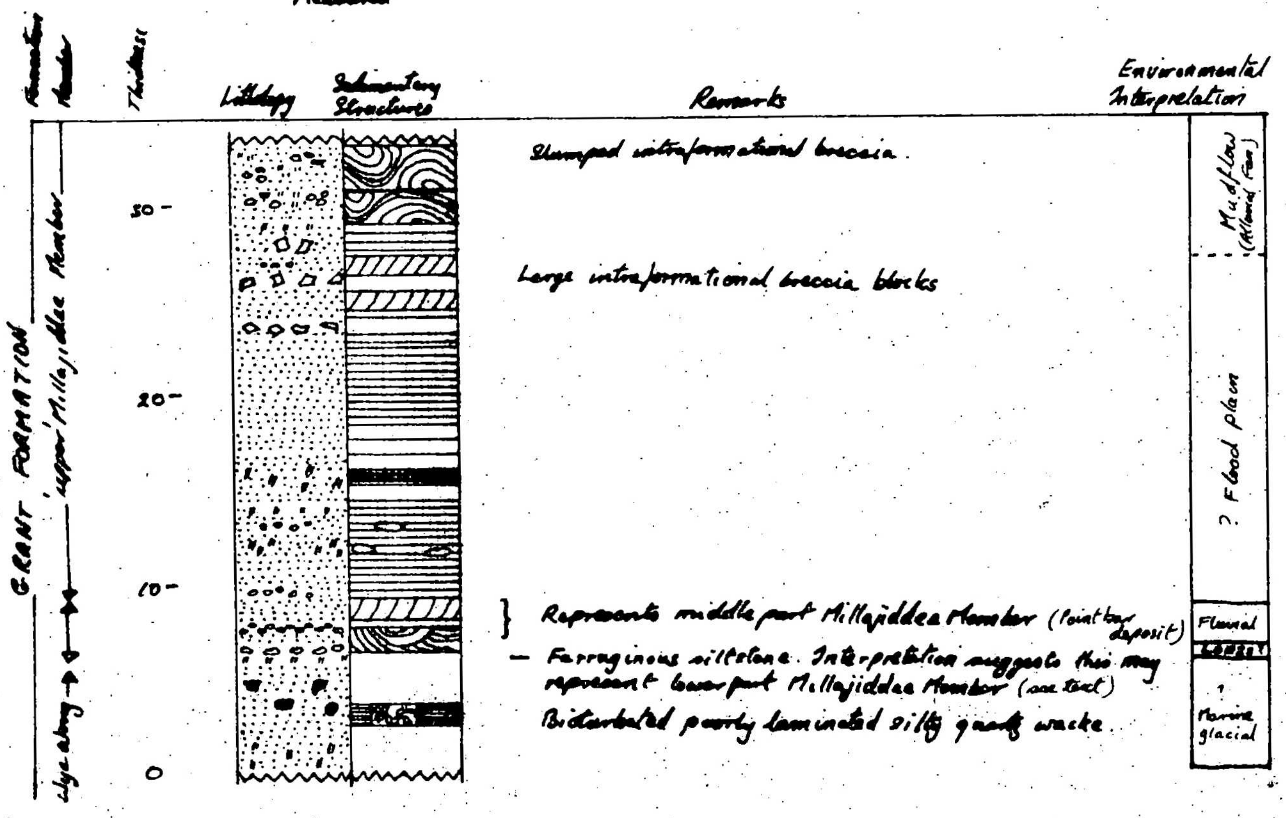
SECTION No. 17

WESTERN ST GEORGE RANGE
18°41'53" S. 124°54'30"E
Estimated



SECTION No 18

LAURIS RANGE
18°10'20"S. 125°25'30"E.
Measured

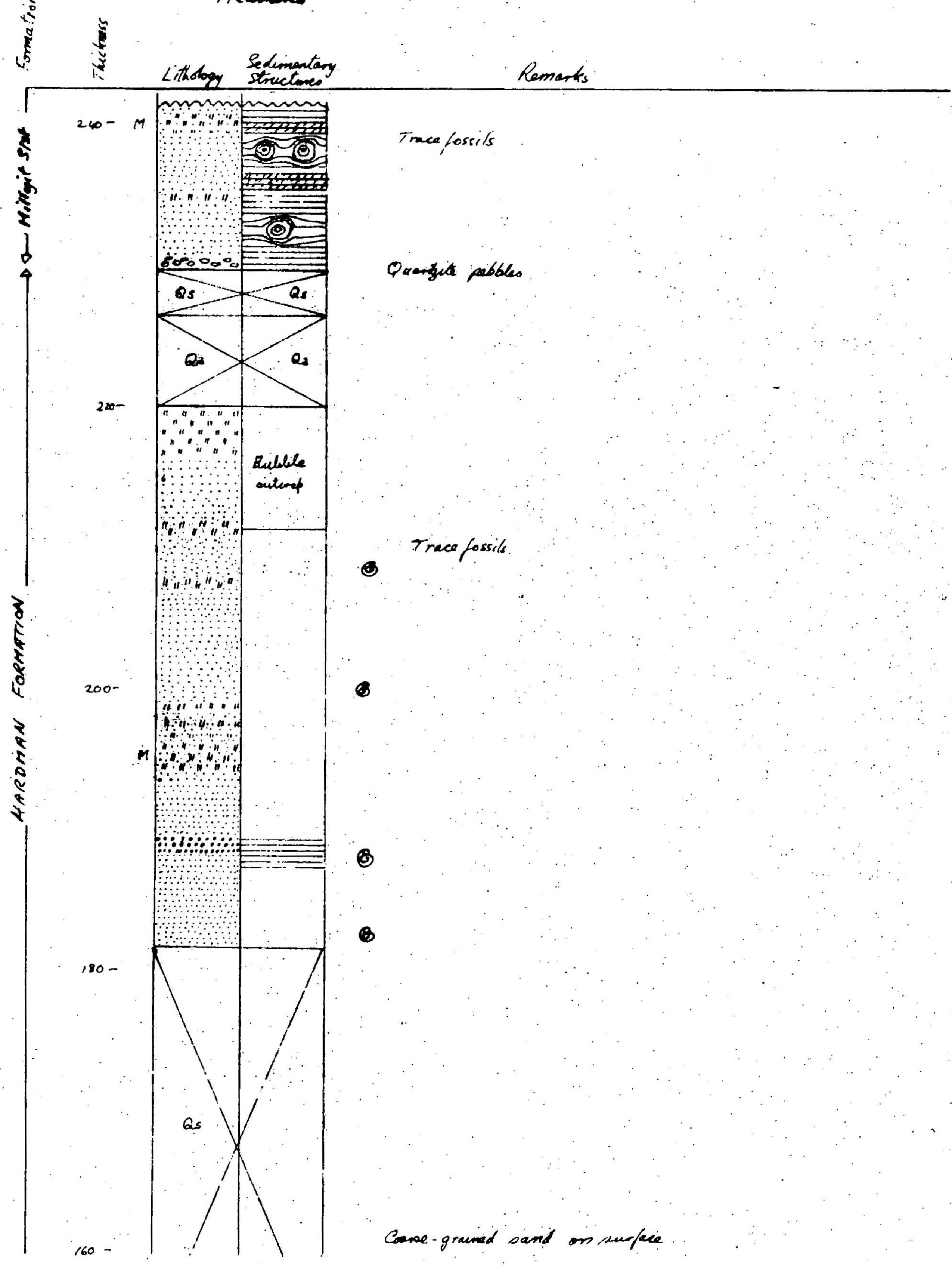


SECTION No. 19

McLARTY SYNCLINE

18°39'00"S. 124°30'05"E.

Measured



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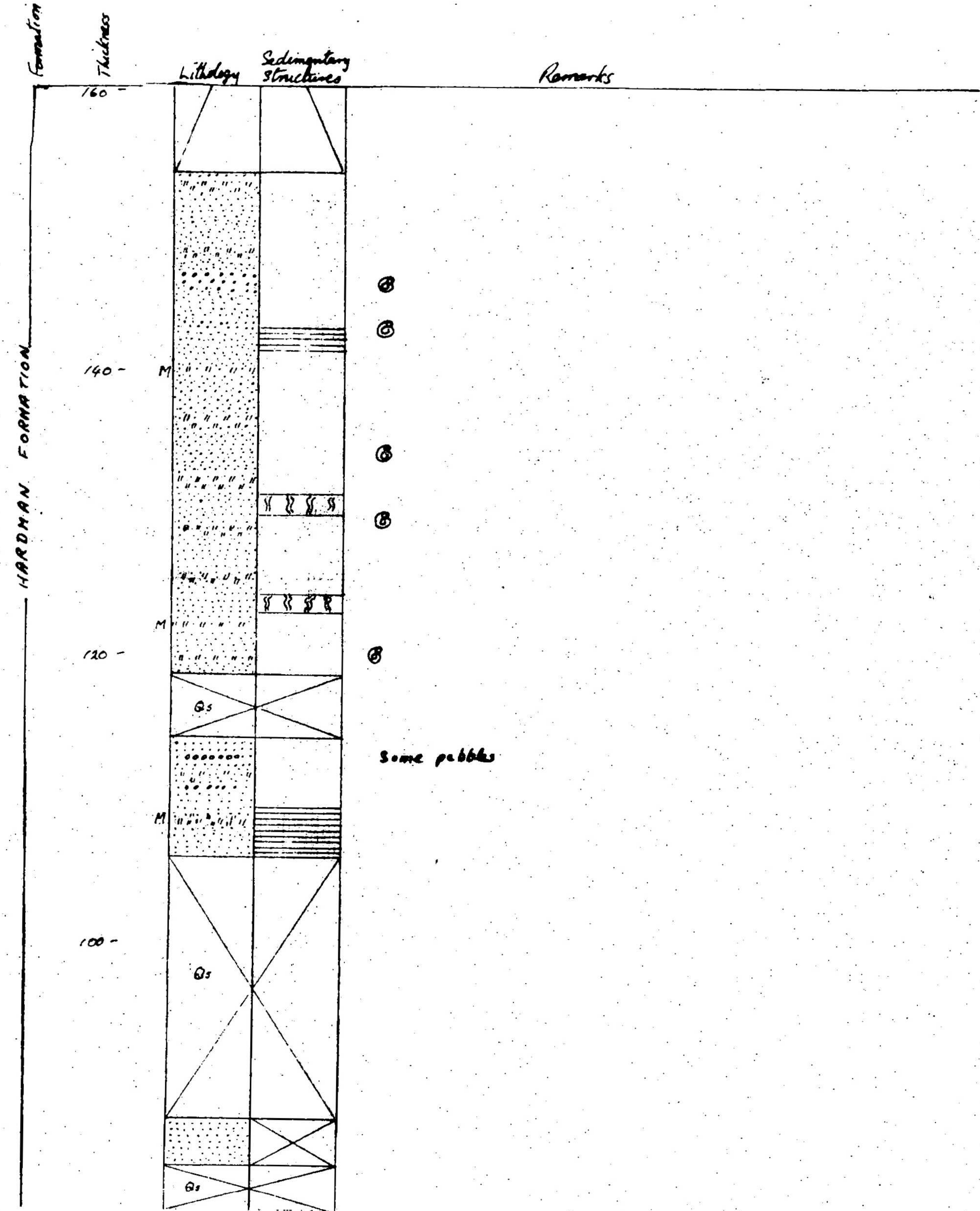
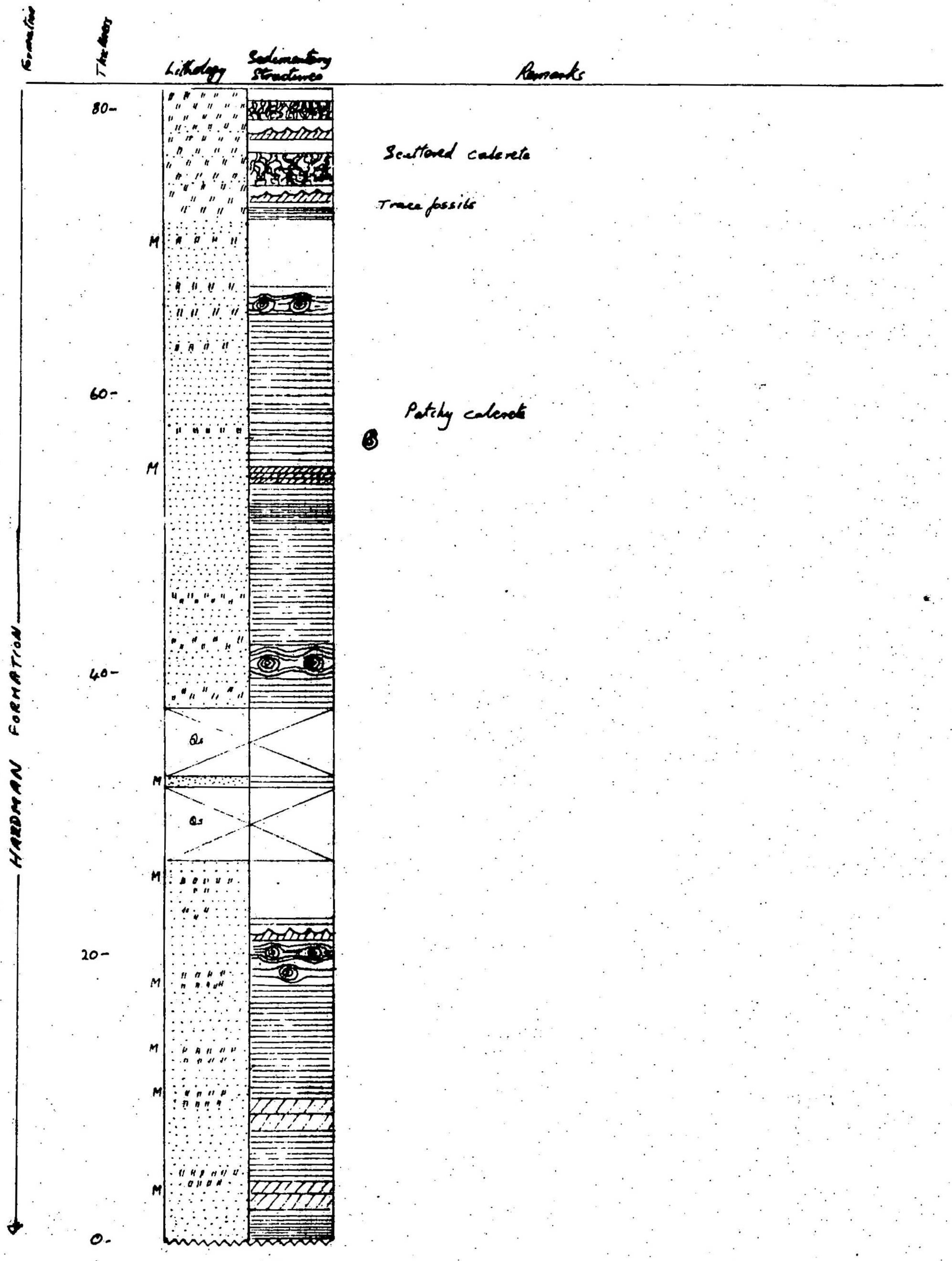

Formation
Thickness
Lithology
Sedimentary structures
Remarks
160 -
140 -
120 -
100 -
HARDMAN FORMATION
M
M
M
Qs
Qs
Qs
Some pebbles

CONTINUED

SECTION No. 19 (cont.)

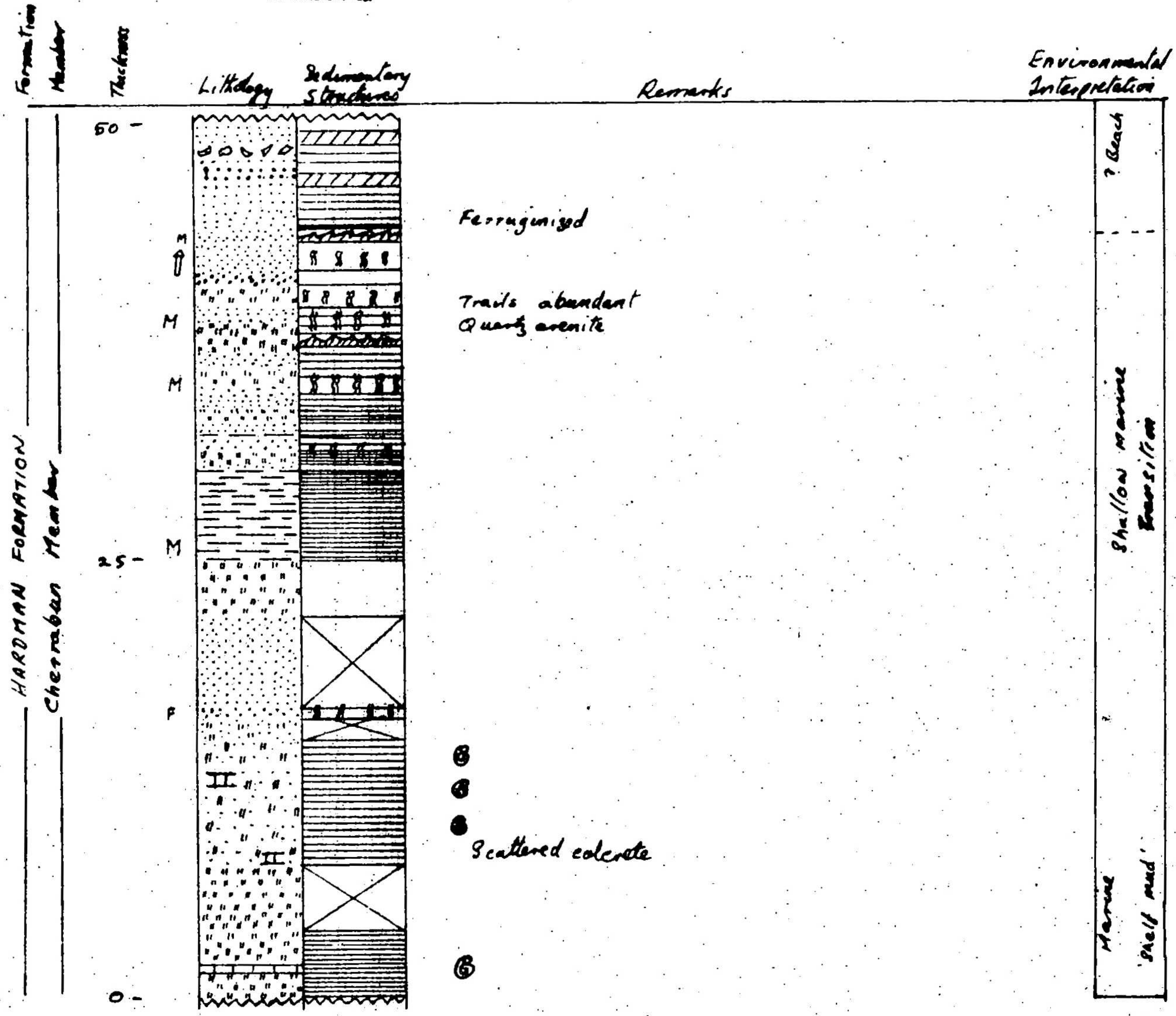


SECTION No. 20

MOUNT HARDMAN

18° 18' 45"S. 124°38'52" E.

Measured

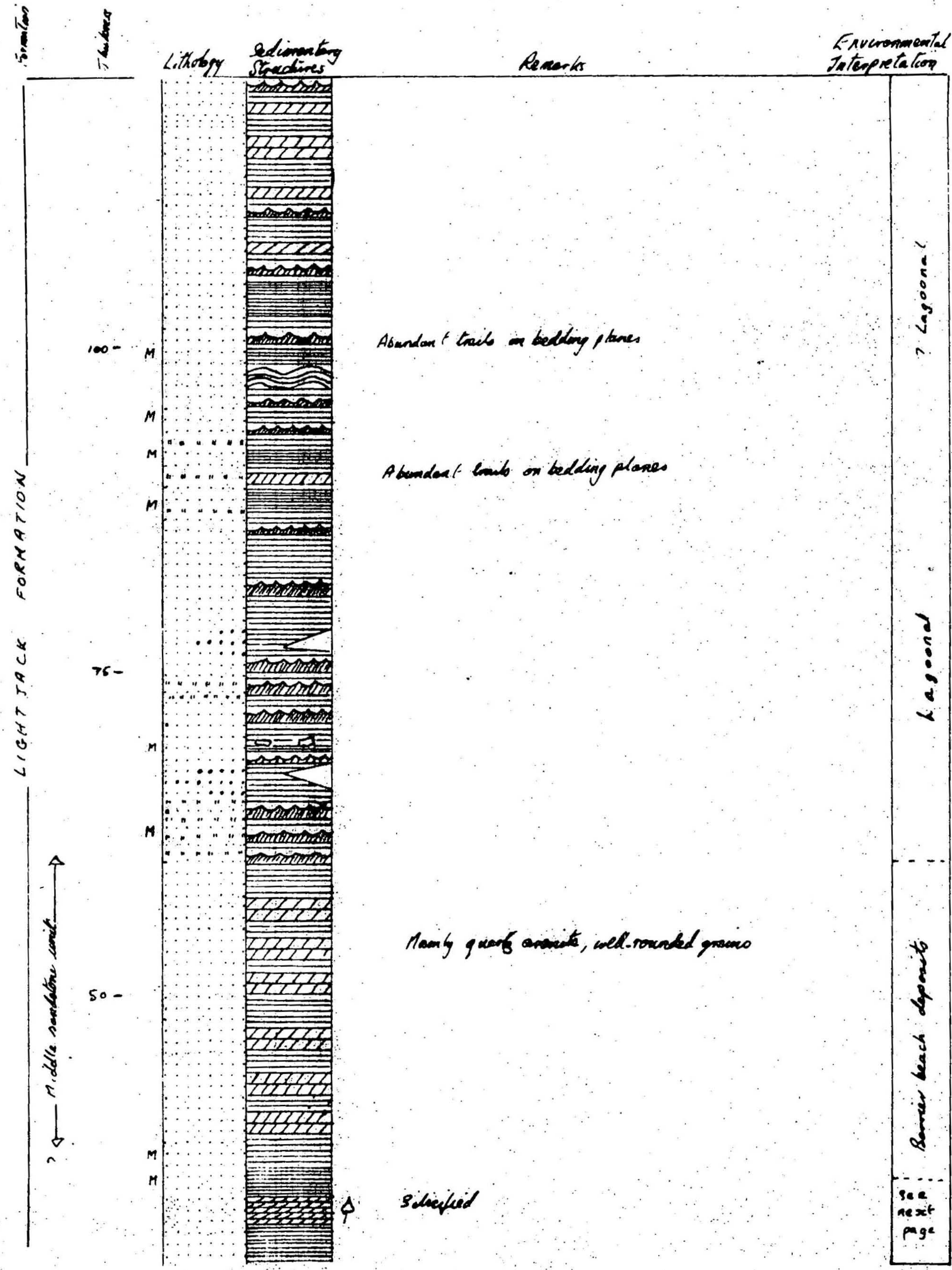


SECTION No 21

SHORE RANGE

18°57'20" S. 125°01'07"

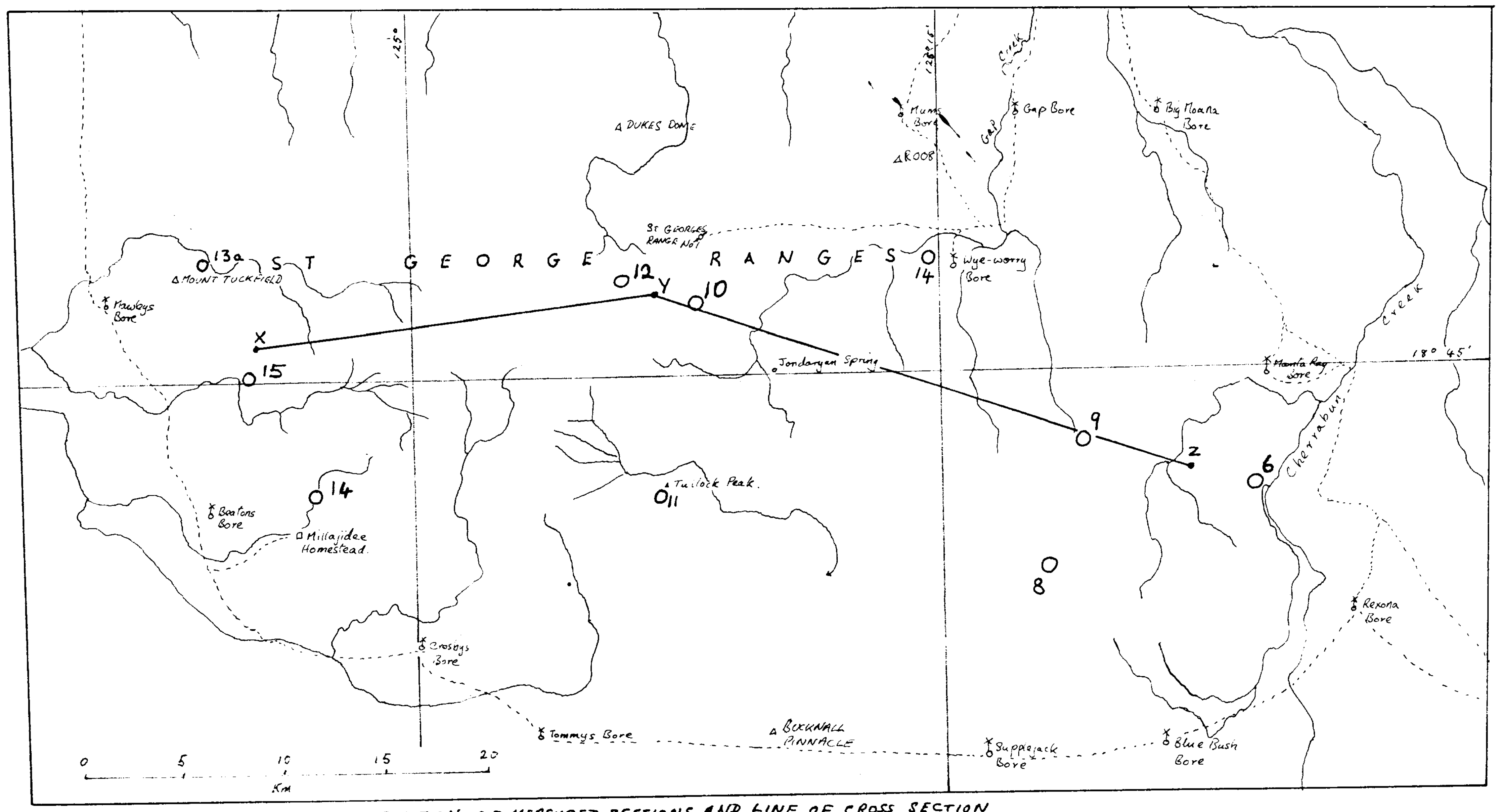
Measured



CONTINUED

CORRELATION SECTION OF THE GRANT FORMATION

ENCLOSURE NO. 1



LOCATION SKETCH SHOWING POSITION OF MEASURED SECTIONS AND LINE OF CROSS SECTION

REFERENCE

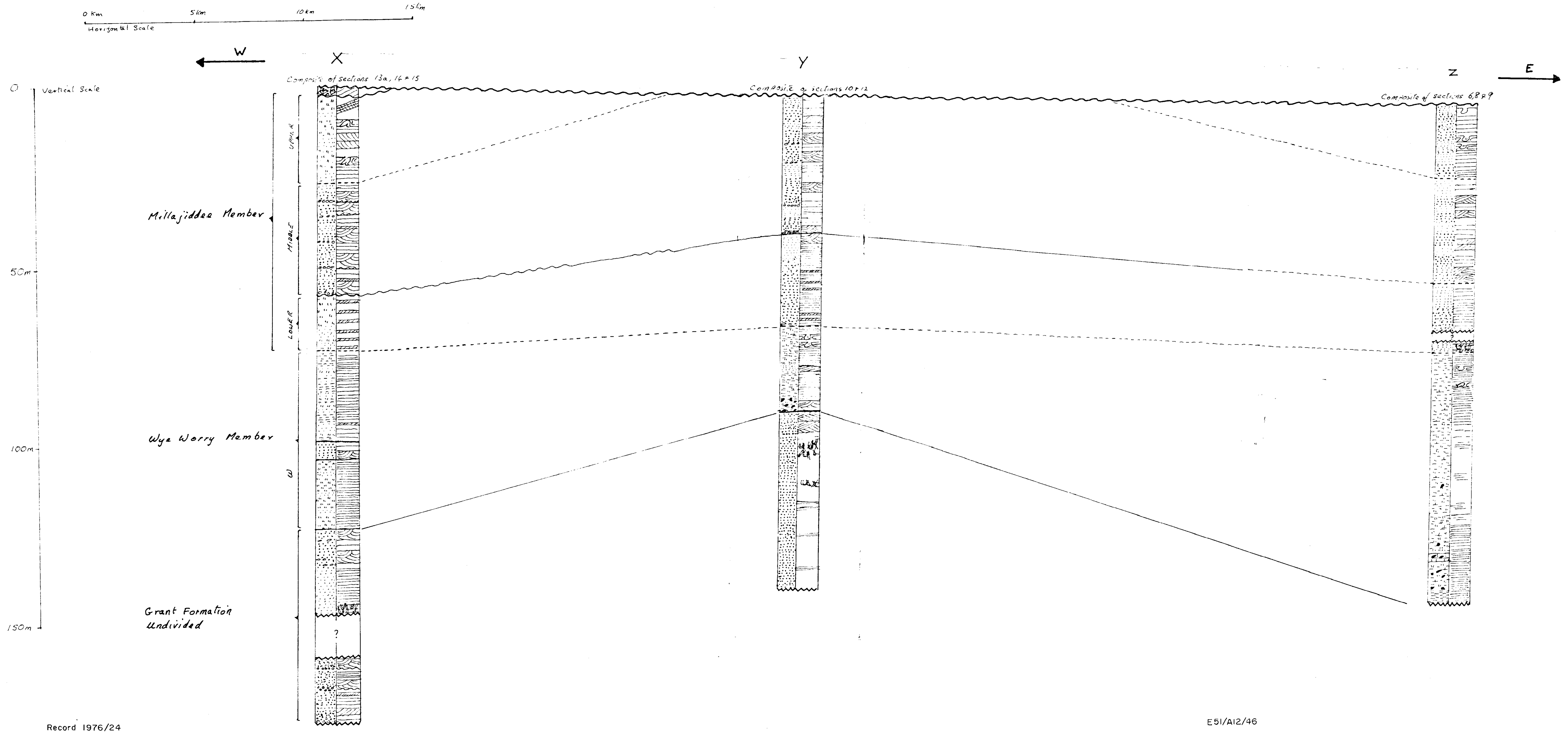
The left hand columns of the sections show lithology and the right hand columns show sedimentary structures.

Lithology

- Clay or shale
- Silt
- Very fine or fine-grained sandstone
- Medium or coarse-grained sandstone
- Conglomerate: extraformational
- Conglomerate: intraformational
- Glacial dropstones

Sedimentary structures

- Laminated or thin-bedded
- Medium or thick-bedded
- Slumped
- Trough cross-bedding (large scale)
- Planar cross bedding (large scale)
- Ripple marks: symmetrical
- Ripple marks: asymmetrical
- Small scale cross-bedding
- Erosional contact
- Fossil roots
- Bioturbated
- Base or top of section



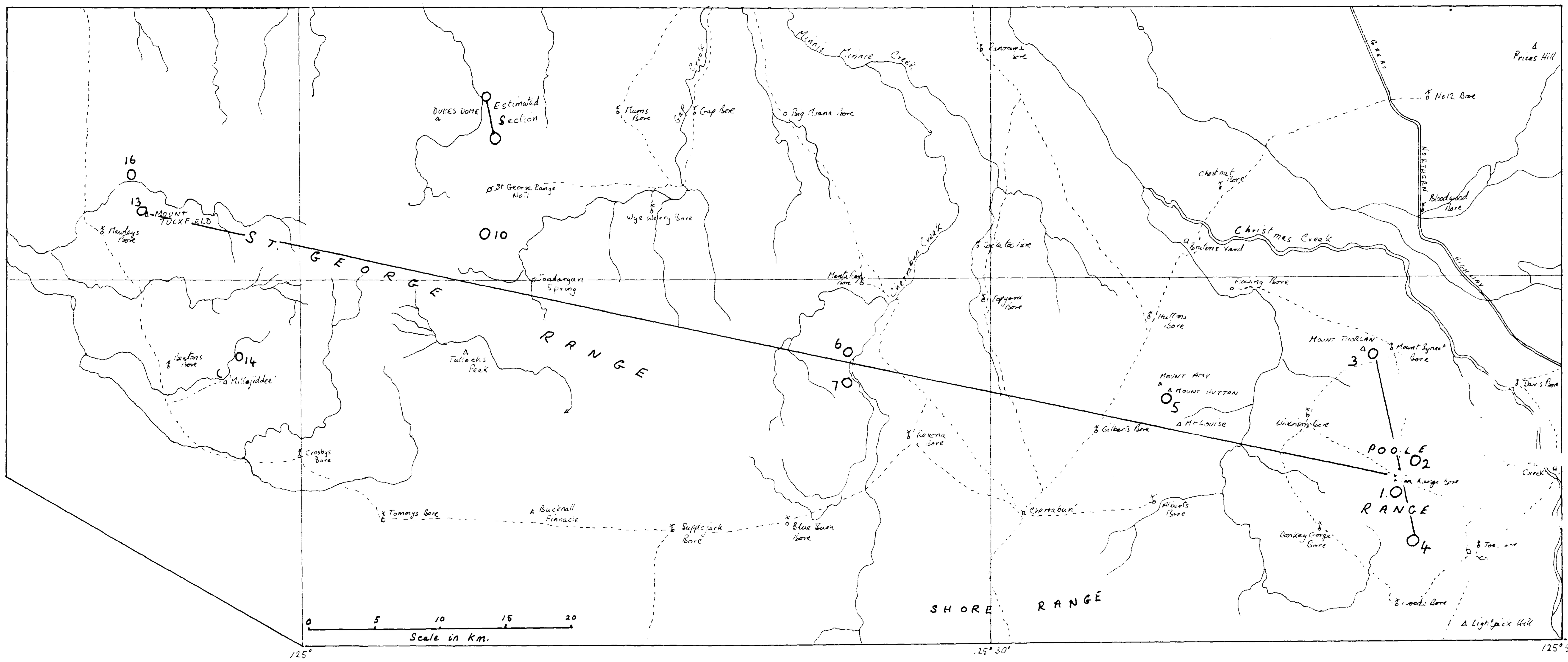
Record 1976/24

E51/A12/46

ENCLOSURE NO. 2

CORRELATION SECTIONS OF THE POOLE SANDSTONE

Reference as for Enclosure No.



LOCATION SKETCH: showing positions of measured sections of Poole Sandstone and lines of cross-sections

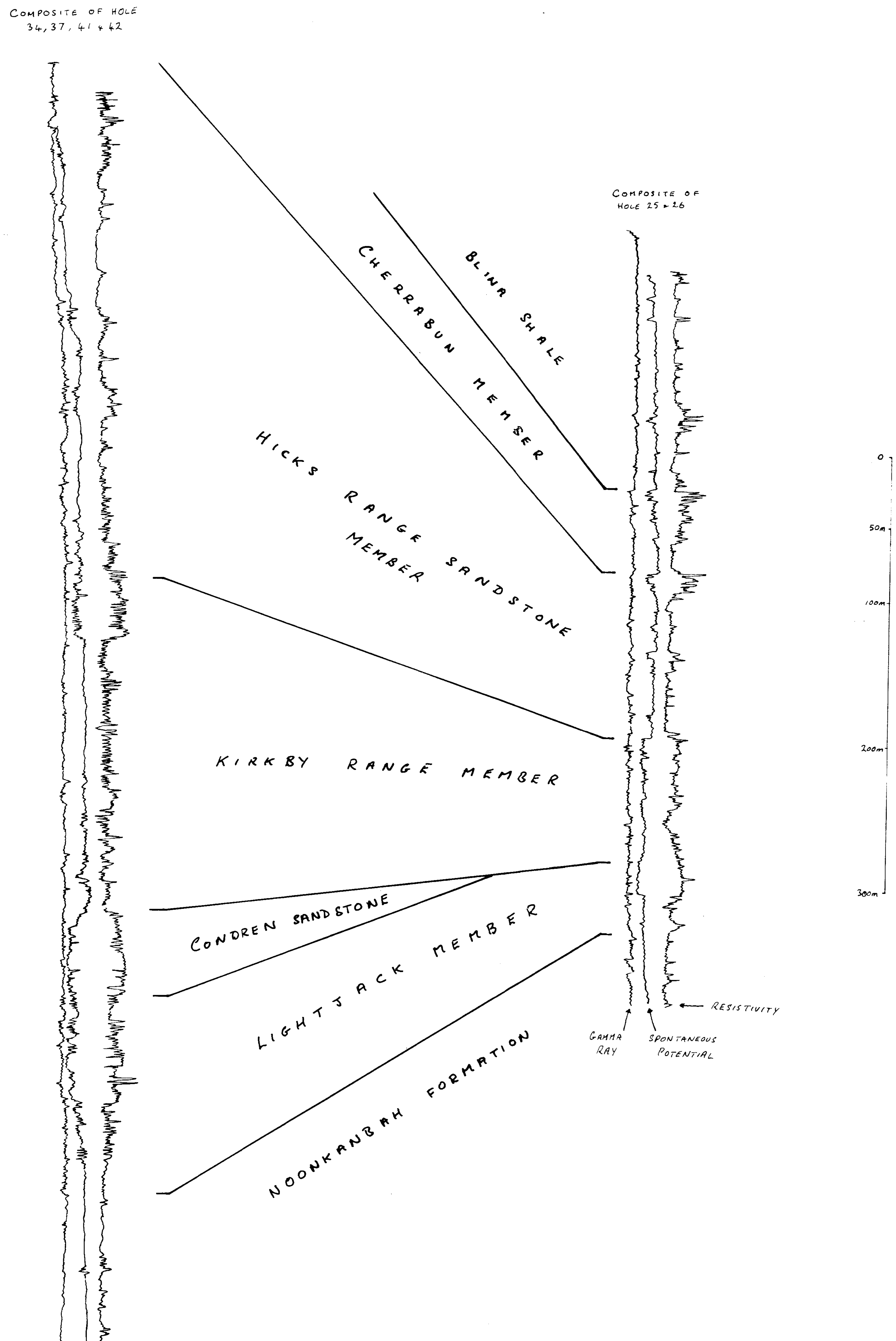
E 51/A12/48

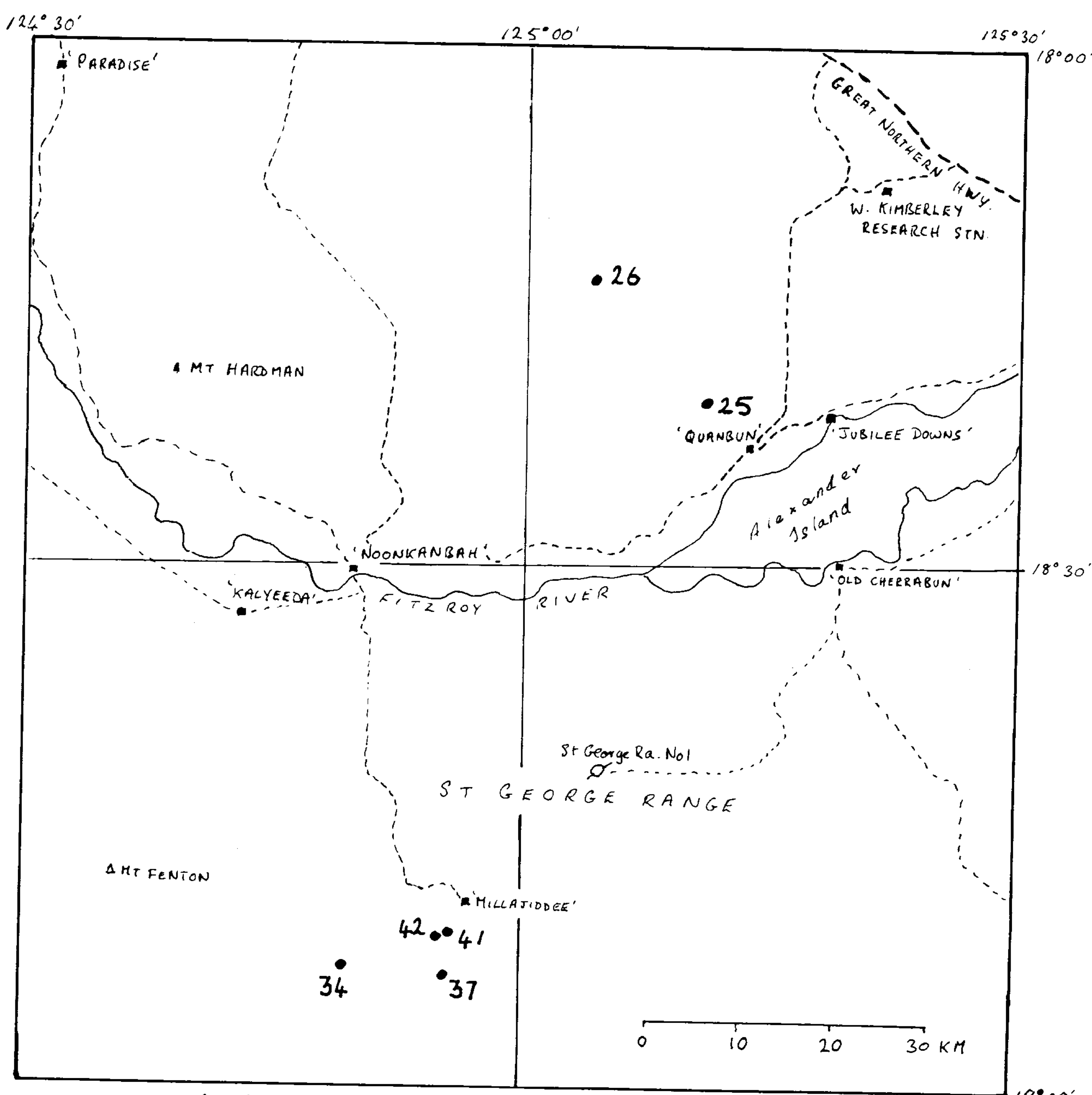
Record 1976/24

ENCLOSURE NO. 3

ELECTRIC LOGS OF THE LIVERINGA GROUP

ADAPTED FROM GALLOWAY & HOWELL (1975)





Location sketch showing Esso bore holes from which logs were compiled.

Record 1976/24

E51/A12/47