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Progress Report on the Moolayember Formation, Bowen Basin, Queensland

by

P.J. Alcock

PROGRESS REPORT ON THE MOOLAYEMBER FORMATION,

BOWEN BASIN, QUEENSLAND

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Records 1969/43

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ABSTRACT

This report covers the initial phase of a study of the Moolayember Formation, which is the topmost unit of the Triassic Mimosa Group in the Bowen Basin. The study involves the erection of a stratigraphic framework for the Formation coupled with a detailed investigation of its sedimentology, eventually leading to an analysis of its geological history and economic prospects.

Areas of better outcrop were selected for initial study and sections were measured where practicable. Three main areas of study were the Northern area (Teviot Formation) where up to 600 feet of section remains, the Dawson Range area where there is over 5,500 feet of section and the Carnarvon Range area, where 1600 feet is exposed.

Mudstone and sandstone are the dominant rock types with conglomerate occurring in the lower part of the Dawson Range section. Tentative unit subdivisions have been made, but basin-wide correlation is not yet possible.

Observations of sedimentary structures suggest the Moolayember Formation and its equivalent the Teviot Formation were deposited largely by rivers which flowed towards the central south of the Bowen Basin and drained areas to the north and northeast where volcanic and sedimentary rocks were being eroded.

Microfossil evidence suggests intermittent marine conditions at least in the west and southwestern areas. Deposition here could have taken place in an estuarine or delta top environment.

INTRODUCTION

General

The Moolayember Formation is a Middle to Upper Triassic unit of the Bowen and Galilee Basins in central and southern Queensland. It is the upper unit of the Mimosa Group (Fig. 1) and its distribution in relation to physiographic features is shown in Plate 1. The Teviot Formation is accepted as being equivalent to the Moolayember Formation but as it occurs about 100 miles from the nearest Moolayember outcrop, it is felt that retention of the name Teviot serves a useful purpose.

Aims and Scope of the Investigation

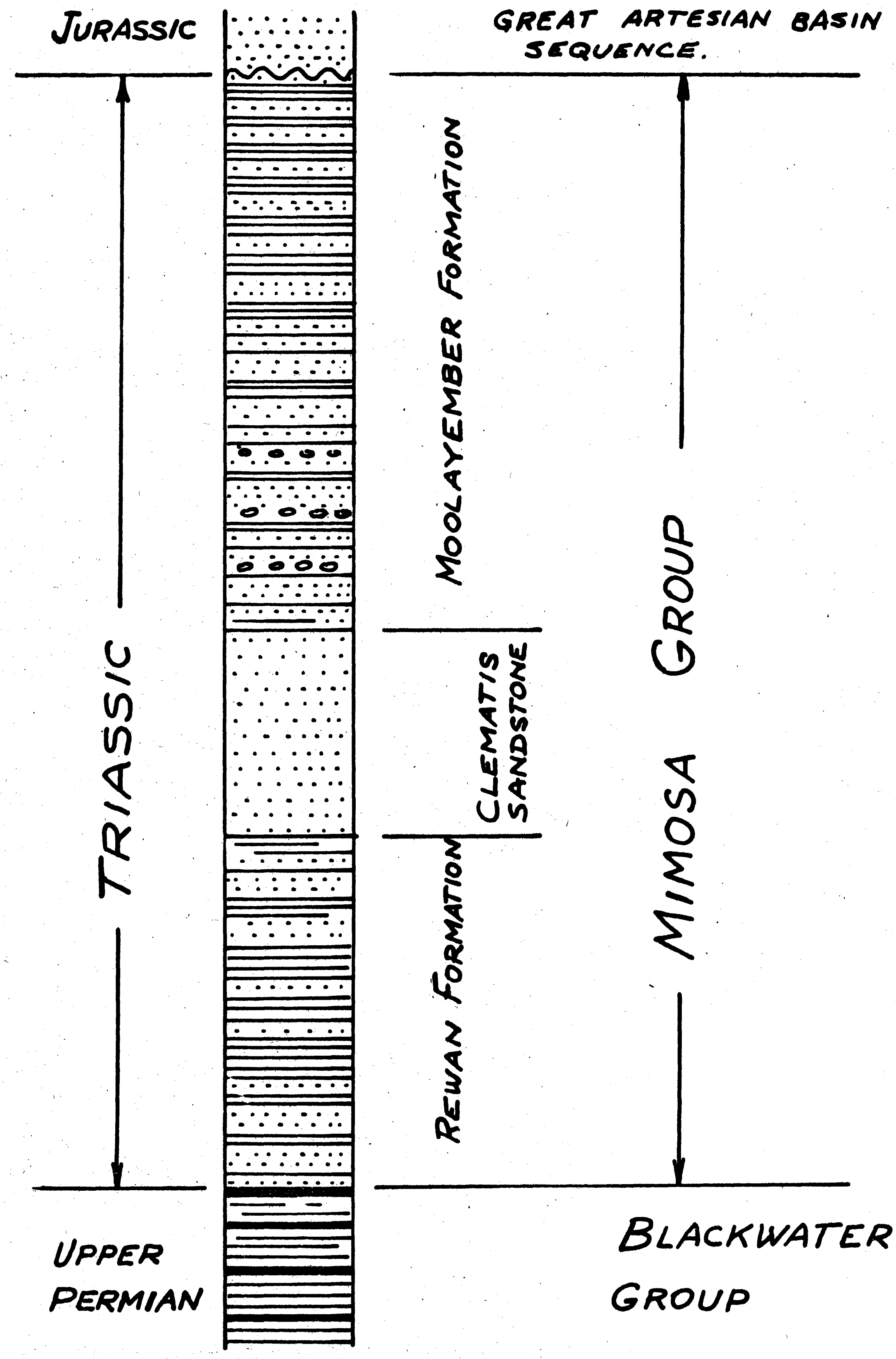
This investigation forms part of a project of detailed study to follow up regional mapping; its aim is to deduce as fully as possible the geological history of the Moolayember Formation. To do this it is necessary to establish a stratigraphic framework upon which detailed studies of the Formation can be based. The first phase of the investigation required measurement of the thickness of the Formation at several places and the recognition of any subdivisions on the basis of lithology. The second phase involves detailed study of the sedimentology, petrology, palynology and palaeobotany of the rocks. During the 1968 field season attention was directed towards stratigraphic subdivision but further work is required to confirm or reject the findings. Some sedimentological and petrological data was also collected. Areas studied or visited are shown in Figure 2.

Methods

Section-measuring with tape and compass was the main technique employed in the field. A Jacob Staff was used for measuring sections in steep country.

STRATIGRAPHIC COLUMN

MIMOSA GROUP



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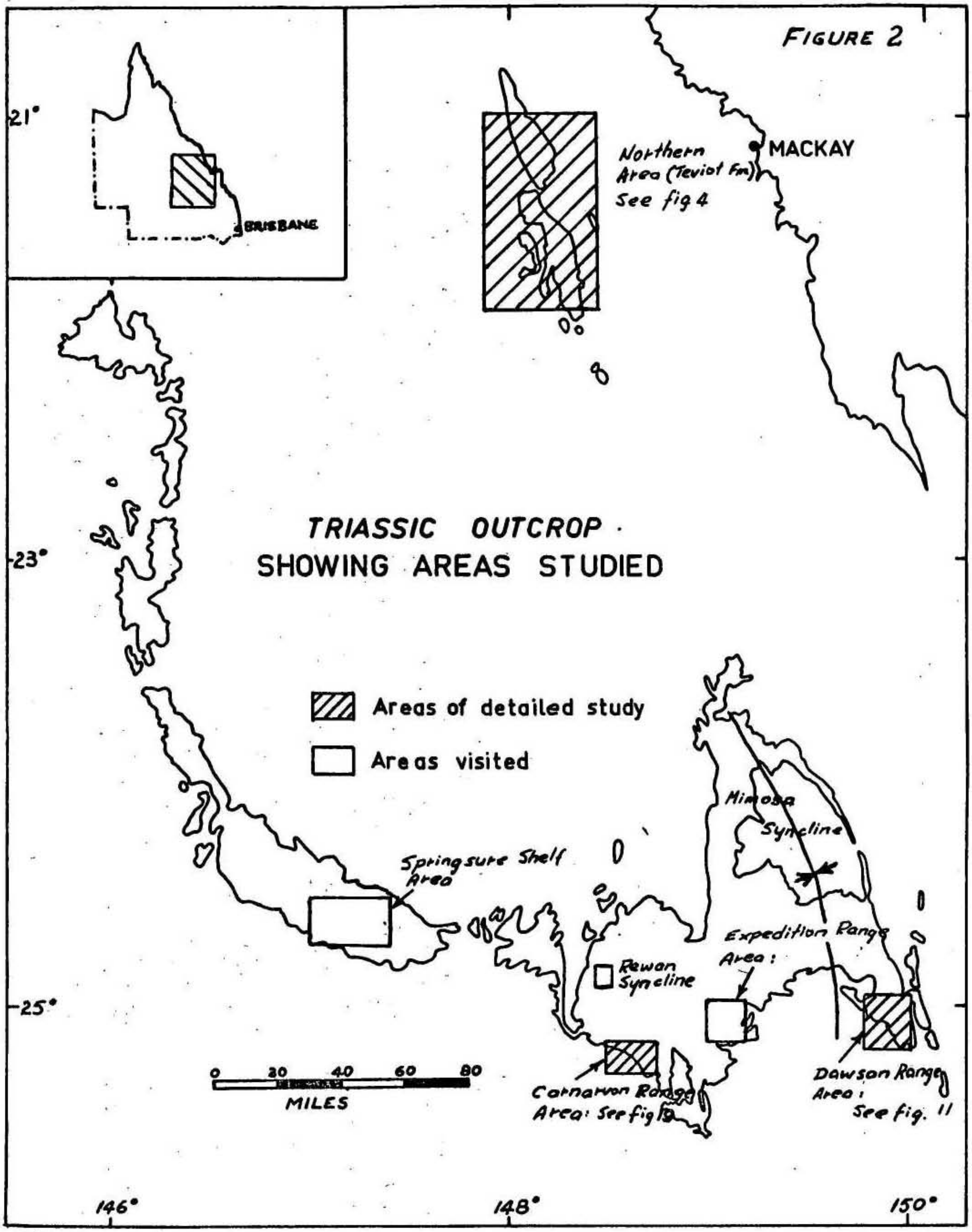

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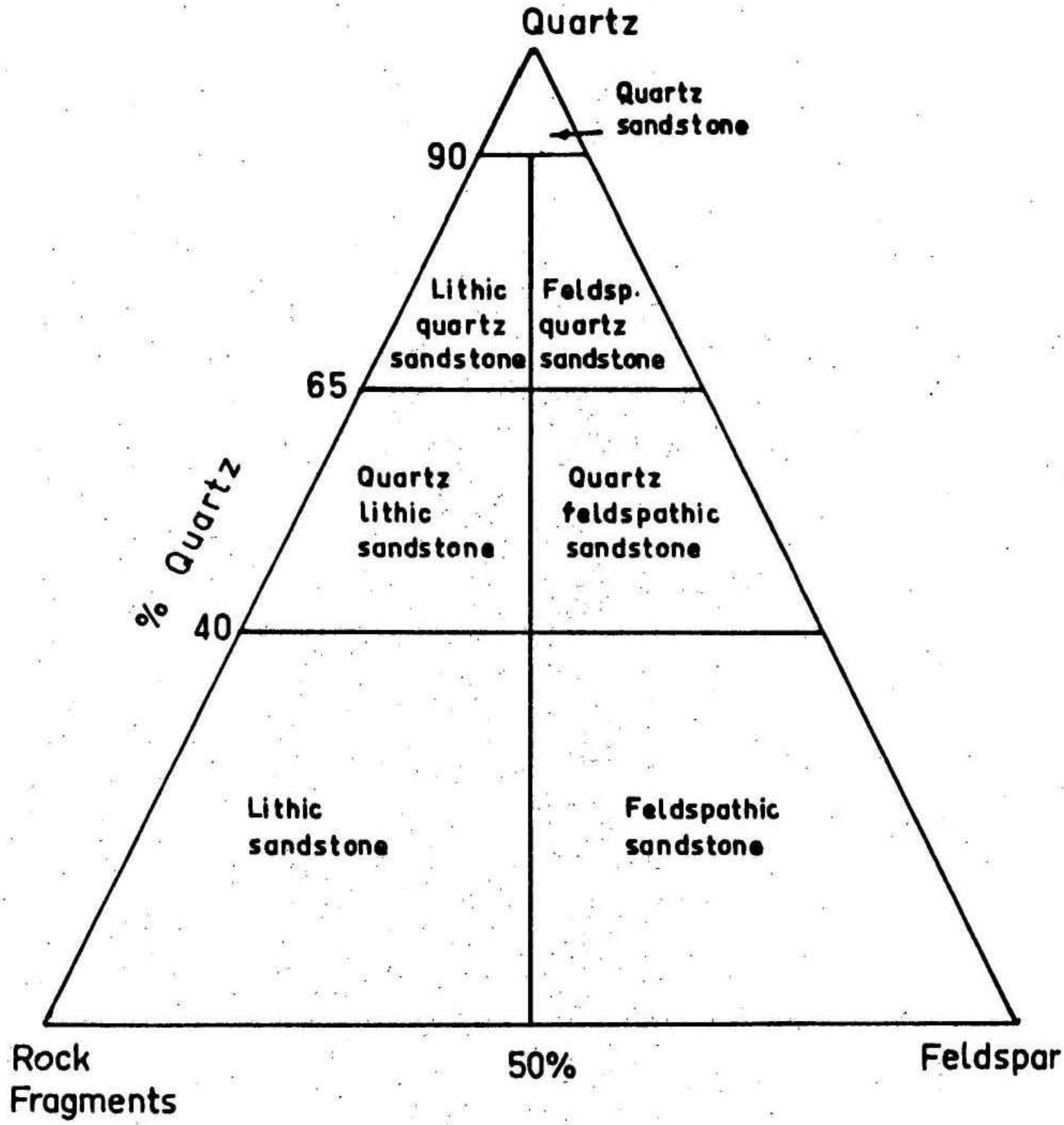
Figure 3

SANDSTONE NOMENCLATURE



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Where there was insufficient outcrop to warrant detailed section-measuring, traverses were undertaken to measure regional dips and make notes on the rocks. In flat or gently undulating country the dips were used in conjunction with distances taken from air photos to determine stratigraphic thickness. In more rugged terrain height differences were measured with an aneroid barometer, a correction being applied for uniform change in air pressure by taking readings at the base of each section before and after section measuring.

Specimens were collected along measured sections with a view to determining the change in percentage composition of quartz, rock fragments and feldspar. Other specimens were collected for palynological and palaeobotanical study.

Sedimentary structures were noted and where possible measured. 250 cross-bedding readings were taken. In some conglomerate beds pebble orientations were measured in an attempt to determine current direction. Other current direction indicators were used wherever possible.

Nomenclature

In this report sandstones have been named according to their content of quartz, rock fragments and feldspar on a matrix and cement-free basis. The concept is best explained by means of the Q.R.F. (quartz rock fragments and feldspar) triangular diagram (Fig. 3). The arbitrary subdivisions based on quartz content are useful for these sediments as they often contain a high proportion of feldspar and rock fragments. The rock names have the advantage of being self-explanatory and are usable in both field and laboratory work.

Modifiers such as "silty", "calcareous" and "ferruginous" have been used where appropriate.

Less than sand-size rocks include those sediments with a mean grain size less than 1/16 mm and are named according to Twenhofel (1937).

Nomenclature for cross-stratification as outlined by McKee and Weir (1953) has been used as far as possible; however, its usage is limited where exposure is poor.

For stratification thickness reference is made to Ingram (1954) for descriptive terms. Otherwise actual figures are quoted in feet and inches.

PREVIOUS INVESTIGATIONS

Regional Geology

The earliest record of the rocks now known as the Moolayember Formation was that of Jensen (1921, 1926). During a very general reconnaissance of the area between Roma, Springsure, Tambo and Taroom, Jensen (1926) noted a sequence of rocks which he referred to as the "Ipswich Series" on the basis of plant fossils.

Reid (1930) described buff-coloured sandstones and shales containing "Thinnfeldia" and Equisetales from the upper parts of Peawaddy and Rocky Creeks in the Carnarvon Range area. Like Jensen (1926) he included these rocks (the basal part of the Moolayember Formation) with the overlying (Precipice) sandstone as the Triassic basal beds of the Great Artesian Basin.

Woolley (1943), in an unpublished report for Shell (Queensland) Development Pty Ltd, referred to the "Moolayember Series" and noted an angular unconformity between it and the overlying (Precipice) sandstone. A maximum thickness of 1400 feet was recorded from Consuelo Gorge. Deposition was thought to have taken place in a series of small isolated basins (Woolley, 1943).

The unit was named Moolayember Shale by Reeves (1947) but no type section or area was given. However Whitehouse (1954) stated that the type section for the Moolayember Shales" ... may be taken as the series of cuttings where the main road north from Injune descends to Moolayember Creek".

The formation name was changed from the Moolayember Shale (Reeves, 1947) to Moolayember Formation by Phillips in Hill and Denmead (1960, p. 281). Discussing its boundary with the underlying Clematis Sandstone Phillips states that "the basal member of the (Moolayember) Formation is a fine-grained, carbonaceous, feldspathic sandstone which in places forms the upper parts of cliffs of Clematis Sandstone" and that "while the Clematis sediments are essentially quartzose in origin, the basal Moolayember is clearly of andesitic provenance with much feldspar and biotite and very little quartz. The presence of conglomerate was recorded by Phillips (op. cit.) from the eastern limb of the Syncline.

The Teviot Formation (Moolayember equivalent in northern part of basin) was first named and defined by Malone et al. (1961, p.45.). The name was derived from Teviot Creek which rises in the Formation between the Carborough and Kerlong Ranges on the Mount Coolon 1:250,000 Sheet area. The type area was given as along the Ellensfield to Kemmis Creek track between the Kerlong and Carborough Ranges. The Formation was also encountered on the Redcliffe Tableland to the north. The Teviot Formation was considered to overlie conformably the Carborough Sandstone, a transition zone 10 feet thick separating the formations. The top of the Formation has been removed by erosion but on the Redcliffe Tableland it is partly covered by Tertiary sediment and basalt (Malone et al. 1961). No sections were measured in the Formation but a thickness of 400 feet for the type area and up to 200 feet on the Redcliffe Tableland was estimated.

Regional mapping of the Springsure, Taroom and Baralaba 1:250,000 Sheet areas by B.M.R. and the Queensland Geological Survey has provided the most recent data on the regional geology of the Moolayember Formation. From the Springsure Sheet, Mollan et al. (1964) recorded the presence of ripple marks, worm tracks and sandstone containing mud clasts. These workers chose the conformable boundary with the underlying Clematis at the highest cross-bedded quartz sandstone. During regional mapping of the Taroom Sheet area Jensen et al.(1964) estimated a thickness of at least 4500 feet for the Moolayember Formation in the Dawson Range area and about 2000 feet in the Carnarvon Range area. A fluvial environment was suggested, with some deposition in land-locked lakes and some contemporaneous vulcanism.

On the Baralaba Sheet area Olgers et al. (1964) reported conglomerate beds up to 200 feet thick. These workers attributed the thinning of the Formation westward partly to pre-Jurassic erosion but mostly to downwarping in the east during sedimentation.

The boundary with the underlying Clematis was placed where the massive quartz sandstone (Clematis Sandstone) gives way to isolated outcrops of feldspathic quartz sandstone.

A Triassic surface of erosion and weathering was recognized on the Springsure, Taroom and Baralaba Sheet areas. It was considered that the Moolayember and older formations were eroded and weathered before deposition of the Jurassic Precipice Sandstone. Evidence for this Triassic regolith was originally recognized on the Mundubbera Sheet area (Mollan et al.in prep.)

Mollan et al. (in prep.) measured a section in the Moolayember Formation in the type area - near the Carnarvon Ranges - and have designated this the type section of the Moolayember Formation.

Subsurface geology

A summary of drilling activity in the Bowen-Surat Basin for oil and gas for the period 1900 to 1946 was published by Reeves (1947). A number of wells in the Roma district encountered probable Moolayember equivalents lying on basement.

A summary of deep wells drilled up to 1964 on the Taroom Sheet area is given by Jensen et al. (1964). Data on later deep wells is at present being collated.

Proline drilling by the Queensland Geological Survey (Gray 1967a) was carried out to obtain fresh material for palynological and lithological studies in the Permian and Lower Mesozoic of the Bowen-Surat Basin. This work was later continued with a stratigraphic continuous coring rig, with which several holes have been drilled in the Triassic sequence (Gray 1967b).

Geophysical Surveys

A reflection seismic survey in the Bauhinia Downs area indicated a probable maximum thickness for the Moolayember Formation in that area of 5500 feet (Marathon 1963).

Other geophysical surveys have been carried out in the area but have had little direct bearing on the Moolayember Formation.

Palaeobotany

Plant fossils were recorded in the Moolayember Formation when the rocks were first discovered by Jensen (1921, 1926) who recognized the following forms:

Thinnfeldia sp.

T. odontopteroides

Equisitites

Schizoneura

Neocalamites carrerii

N. horensis

The presence of these plants strongly favoured a Triassic age and the unit was equated with the "Ipswich series".

A collection by Shell (Queensland) Development Pty Ltd (Woolley 1943) includes:

Thinnfeldia feistmanteli Johnston

T. lancifolia Morris

T. acuta Walkom

?Phoenicopsis

equisetaceous stems and cycadian fronds

Whitehouse (1954) listed the following Moolayember plant fossils in addition to those listed by Woolley (op. cit.):

Thinnfeldia odontopteroides

Neocalamites

Schizoneura

Taeniopteris

Spheriopteris superba Shirly

Thinnfeldia cf. talbragarensis Walkom

Nilssonia sp.

Ginkgoites cf. magnifolia Fontaine

White (1961) identified Dicroidium (Thinnfeldia) feistmanteli (Johns) Gothan and D. odontopteroides (Morris) Gothan from the Teviot Formation, thus providing a basis for correlating the Teviot and Moolayember Formations.

From two samples collected in the Dawson Range area White (1964) identified Dicroidium odontopteroides (Morris) Gothan, D. lancifolia type (Townrow 1957) and equisetalean stems.

A sample from the Expédition Range area (White 1964) revealed the presence of Thinnfeldia acuta Walkom together with the familiar Dicroidium odontopteroides (Morris) Gothan and equisetalean stems.

The macrofossil evidence indicates a Triassic or Lower Jurassic age for the Moolayember Formation according to White (1964).

Comprehensive descriptions of the Moolayember Formation macroflora have not yet been undertaken.

Palynology

Evans (1964) identified microflora from seismic holes in the Bauhinia Downs area, from Baralaba (BMR) No. 19, Carnarvon Highway and Hungry Creek (Arcadia Anticline). All these samples were from the Moolayember Formation but stratigraphic control was poor. On the basis of these studies Evans gave a Middle to Upper Triassic age for the Moolayember Formation. He noted a marked microfloral break at the top of the formation coinciding with the unconformity preceding Jurassic sedimentation. No significant break was detected at the base of the formation by Evans (1964).

De Jersey and Hamilton (1967) described microflora from the proline and stratigraphic core drilling recently undertaken by the Geological Survey of Queensland. They suggest a Middle Triassic age for the Moolayember Formation on the basis of sixty microfloral species. De Jersey and Hamilton's (1967) distribution chart suggests a two-fold division of the Formation and includes marine microfossils. The samples were from a series of drill holes across the northwestern flank of the Mimosa Syncline (Bauhinia Downs area). Outcrop is very poor in this area and so correlation with other parts of the Moolayember Formation may be difficult.

GEOLOGY

GENERAL

Stratigraphic Position

The Moolayember Formation lies at the top of the Permo-Triassic succession in the Bowen Basin (Fig. 1). Over large areas the Formation is being denuded; e.g., the Carborough Syncline, the nose of the Mimosa Syncline and the Rewan Syncline. Elsewhere it is directly overlain unconformably by younger sediments including the Jurassic Precipice Sandstone, Tertiary sandstone and basalt.

Structural Setting

As the Moolayember Formation makes up the top of the succession in the Bowen Basin its presence in outcrop is dictated by the presence of structural lows. Only in synclinal areas has there been insufficient erosion to remove the unit. The Carborough Syncline and the shallow syncline of the Redcliffe Tableland have preserved the only remnants of the Formation in the northern part of the Bowen Basin. Towards the south the unit is folded into the broad Mimosa Syncline and smaller synclines further west with north-south axes. Regional dips do not exceed 15°.

NORTHERN AREA (TEVIOT FORMATION)

Distribution and Type Area

The Teviot Formation - the name retained for the Moolayember Formation in the far north of the basin - occurs over a small area between the Carborough and Kerlong Ranges and on part of the Redcliffe Tableland on the Mount Coolon 1:250,000 Sheet area (Fig. 4). Its type area has been designated as along the track from Ellensfield to Kemmis Creek (Malone et al. 1961). This is the only readily accessible area within the Carborough Syncline but the track is no longer used and is very difficult to follow. Outcrop is fair.

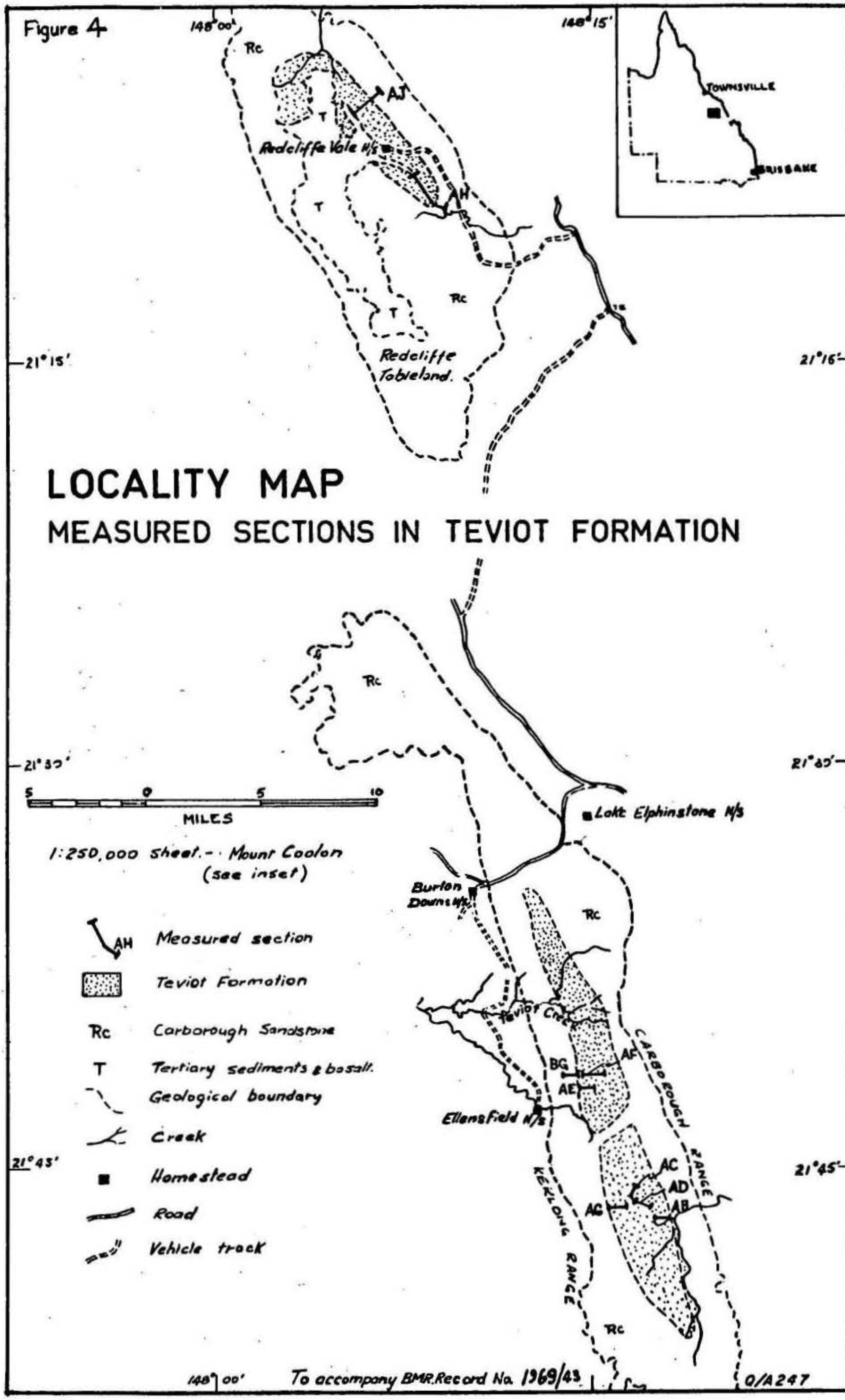

Figure 4
148°00'
148°15'
Rc
T
AJ
AH
Redcliffe Vale H/S
Redcliffe Tableland.
21°15'
21°16'
TOWNSVILLE
BRISBANE
LOCALITY MAP
MEASURED SECTIONS IN TEVIOT FORMATION
21°30'
5 0 5 10
MILES
1:250,000 Sheet.- Mount Coolon
(see inset)
Lake Elphinstone H/S
Burton Downs H/S
Measured section
Teviot Formation
Carborough Sandstone
Tertiary sediments & basalt.
Geological boundary
Creek
Homestead
Road
Vehicle track
Teviot Creek
AF
BG
AE
Ellensfield H/S
CARBOROUGH RANGE
KEMLONG RANGE
AC
AD
AB
AG
21°43'
21°45'
148°00'
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TEVIOT FORMATION - MEASURED SECTIONS: FIGURE 5

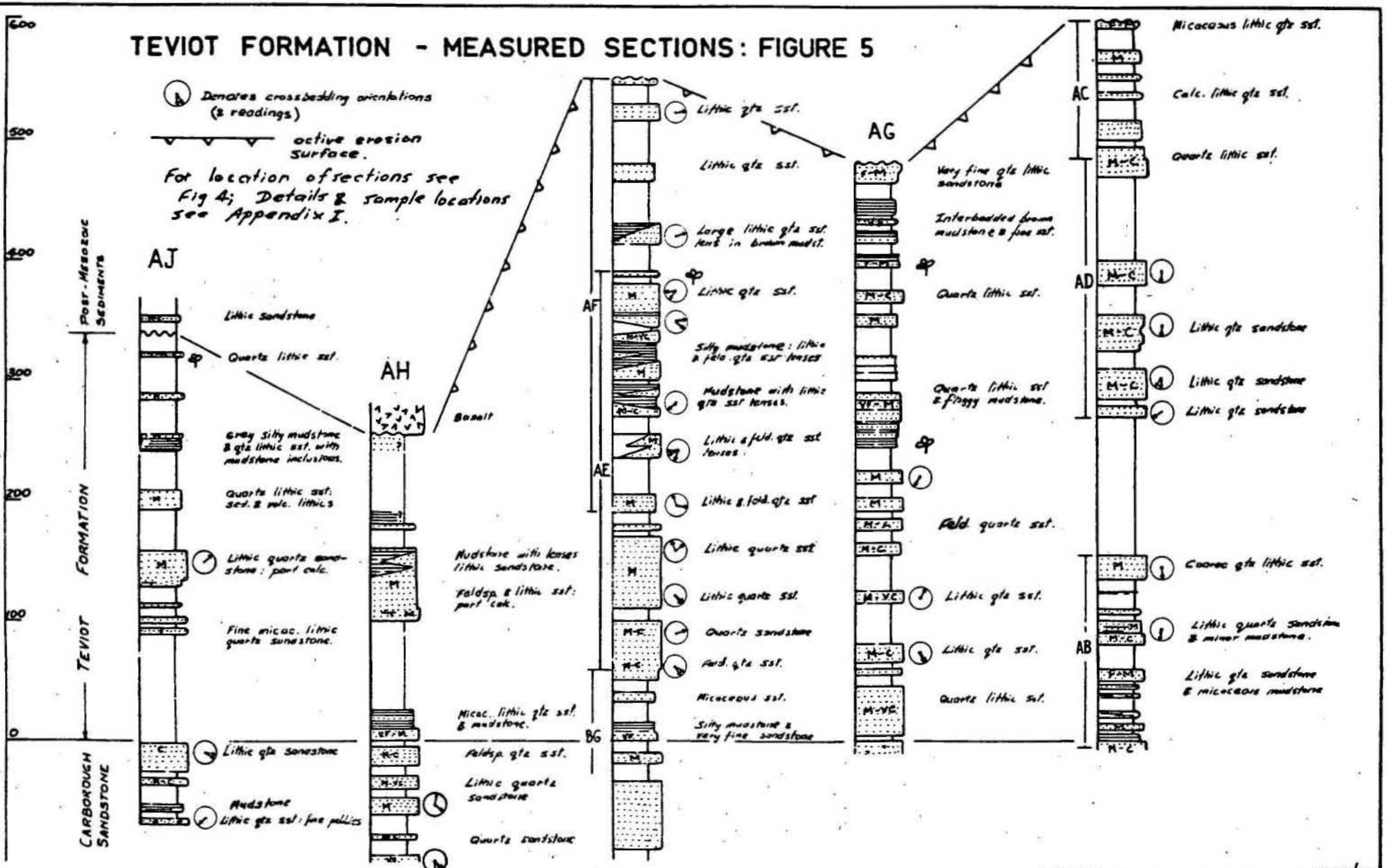

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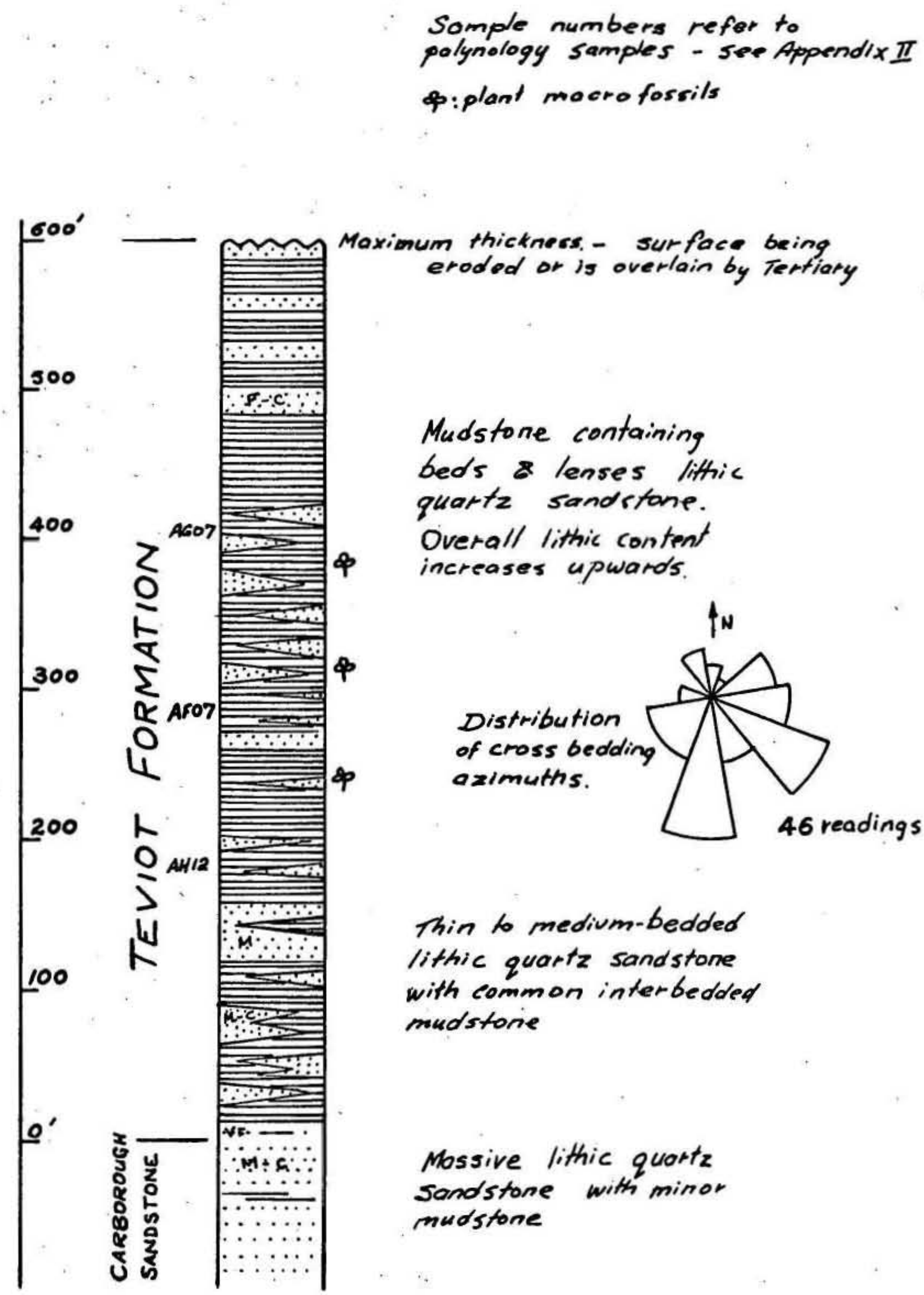
Figure 6

DIAGRAMMATIC COMPOSITE SECTION

TEVIOT FORMATION

NORTHERN BOWEN BASIN



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Stratigraphic Thickness

Eight sections were measured at five localities in the Teviot Formation and plotted together at 1" = 100' (Figs. 4 & 5). Individual sections were originally plotted at 1" = 25' (Appendix I).

This section measuring has shown that the Teviot Formation attains its maximum preserved thickness of 600 feet in the Carborough Syncline and that it is up to 300 feet thick on the Redcliffe Tableland.

The northward thinning of the Formation may be partly depositional thinning, but pre-Tertiary erosion has taken place, as the Formation is unconformably overlain in the northernmost parts by Tertiary sandstone and basalt. Furthermore, the only remnants of the Teviot Formation are in structural lows where it has been protected from erosion.

No unit subdivisions were recognized in the Formation, and correlation between sections proved difficult. However a generalized composite section was compiled (Fig. 6).

Rock Types

The Teviot Formation broadly consists of interbedded sandstone and grey-brown mudstone.

(a) Sandstone

The sandstone is either medium to coarse-grained and cross-bedded, or fine-grained, silty, micaceous and flaggy.

The rocks contain both sedimentary and volcanic rock fragments and range in composition from quartz lithic sandstone to quartz sandstone with minor feldspathic quartz sandstone.

Q-R-F ratios of sandstones on 56 thin sections from measured sections in the Teviot Formation were determined by visual estimation (Fig. 7). Quartz content in these rocks ranges from 40% to 95%, with a mean of 73%. Sedimentary and volcanic rock fragments range from 0% to 45%, with a mean of 19%, whereas feldspar ranges from 0% to 25%,with a mean of 8%.

The sand grains are subangular to angular, and sorting is generally moderate to good. Secondary calcite is common in the sandstone; it replaces rock fragments and feldspar as well as filling voids. Calcareous sandstone has almost no porosity, unlike the noncalcareous, medium to coarse grained variety which has moderate porosity (12-20% approximately).

Fine grained silty sandstone is less common than the coarser grained, cross-bedded type. It is generally micaceous and contains impressions of plant fragments in places.

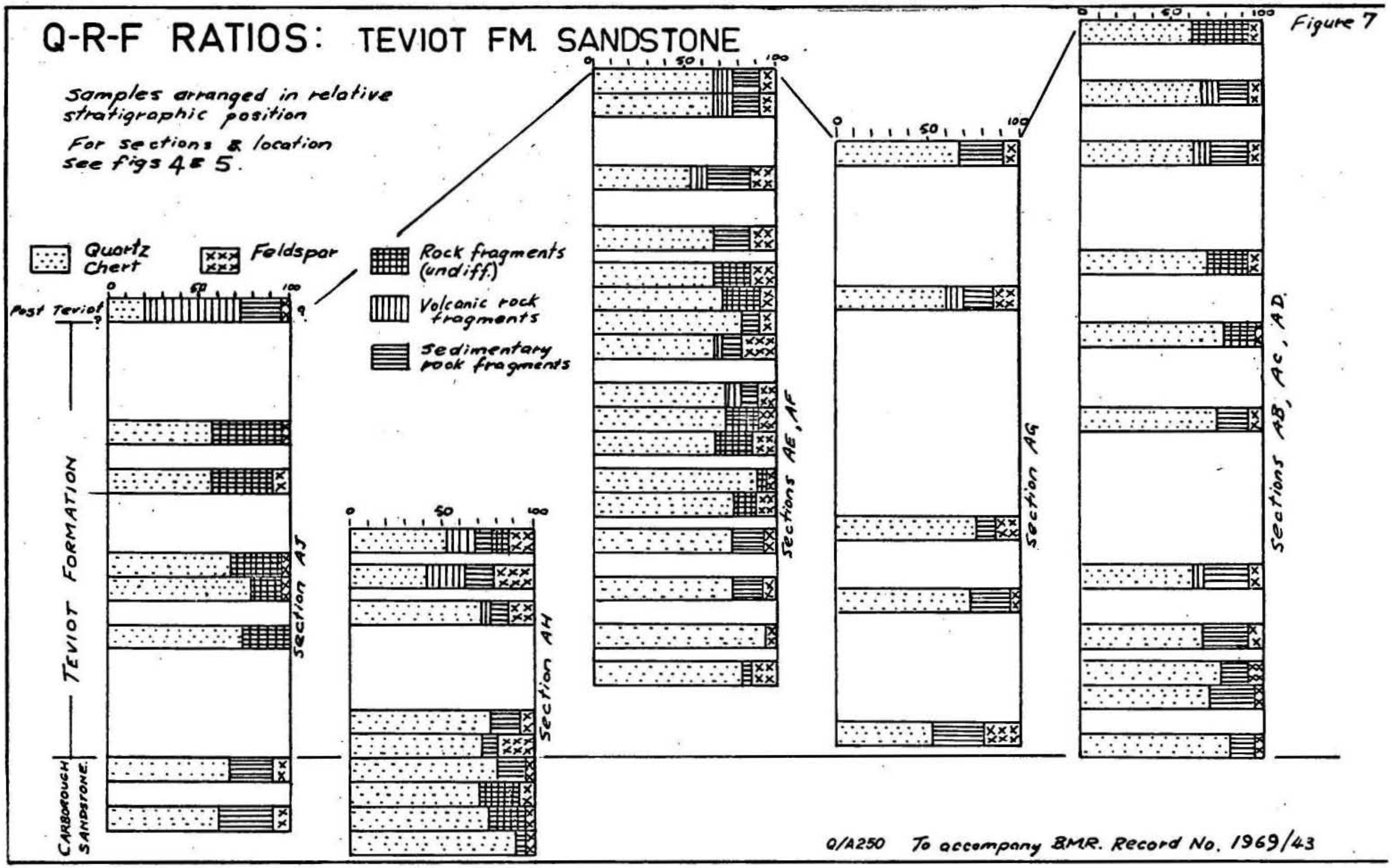
(b) Mudstone

Mudstone is far less conspicuous than the sandstone as outcrop is generally poor, but it probably makes up a larger proportion of the Teviot Formation. Generally the mudstone is grey-brown; rarely dark grey and carbonaceous. Plant impressions are common and rarely well preserved fronds and stems are to be found.

Bedding Characteristics

Bedding in the sandstone is generally 6" to 2' with a few more thickly bedded horizons. Fine micaceous sandstone is usually thinly parted and bedding from ½" to 4" is the rule, while mudstone is well bedded and commonly thinly laminated.

The sandstone beds are discontinuous and often cannot be traced laterally for more than a few yards. Lenticular and wedge-shaped sand bodies from 3'-200' long and 6"-20' thick were observed but larger bodies probably occur.


Q-R-F RATIOS: TEVIOT FM. SANDSTONE
Figure 7
Samples arranged in relative stratigraphic position
For sections & location see figs 4 & 5.
Quartz Chert
Feldspar
Rock fragments (undiff.)
Volcanic rock fragments
Sedimentary rock fragments
Post Teviot
TEVIOT FORMATION
CARBOROUGH SANDSTONE
Section AJ
Section AH
Sections AE, AF
Section AG
Sections AB, AC, AD
0
50
100
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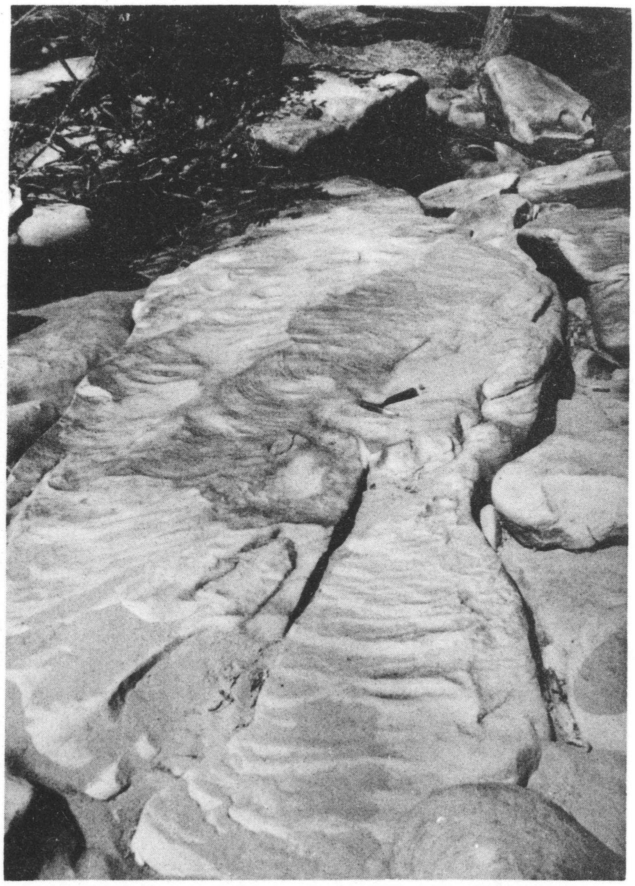


Figure 8: Medium scale trough cross-stratification sets in Teviot Formation sandstone. The sets have gently plunging axes and are symmetric; cross strata are concave and low angle. BMR Neg. No.GA/1336.

Figure 9

HISTOGRAM OF CROSS-BEDDING INCLINATIONS TEVIOT FORMATION

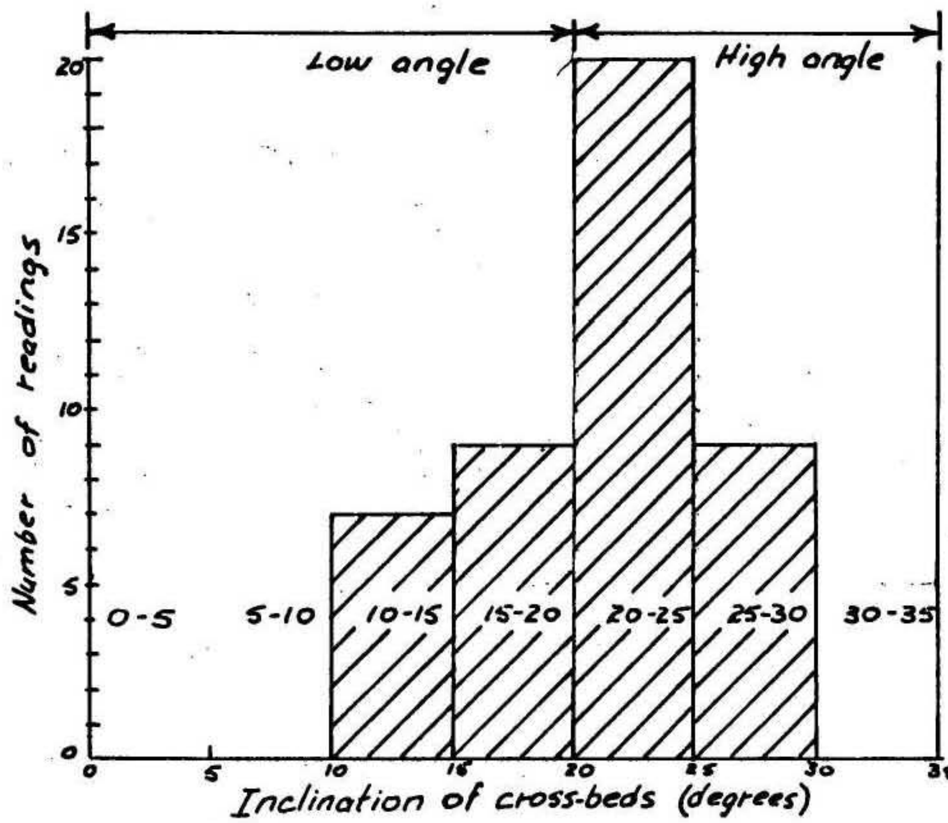
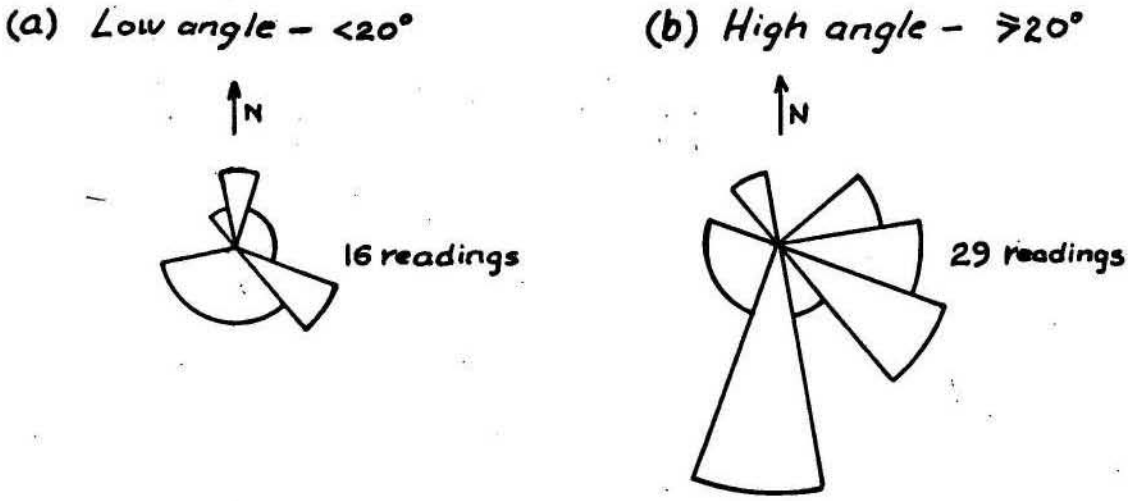


Figure 10

AZIMUTHS OF LOW & HIGH ANGLE CROSS-BEDS IN TEVIOT FORMATION



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Another feature commonly seen is a lateral lithological change from medium-grained sandstone to very thinly bedded silty mudstone.

Cross-stratification

Most of the sandstone in the Teviot Formation is cross-stratified. From 52 measurements in the Teviot Formation sandstone, an overall direction for water movement towards the south and southwest is indicated (Plate 2). However the readings are not well polarized, and even allowing for the small number of readings, it is suggested that the transporting medium followed tortuous paths. Even at the same stratigraphic level widely differing orientations prevail.

Planar and trough (Fig. 8) sets of cross strata were observed in the Formation. These include lenticular, tabular and wedge-shaped sets. Both medium and small scale cross-strata are present. Cross-bedding is confined to medium and coarse-grained sandstone, whereas cross-lamination occurs in sediments ranging from siltstone to fine sandstone.

Inclinations of cross-strata average 20° but range from 10° to 28°. Distribution of these measurements is shown in Figure 9, while the azimuths of high and low angle cross-beds have been plotted in Figure 10.

Other sedimentary structures

Irregular ripple markings occur on the surface of some fine sandstone beds. Some of the ripples are tongue-shaped but others are quite irregular. Similar ripples have been described and named linguoid ripples by Bucher (1919). Their mode of formation is not well understood.

Sandstones containing mudclasts provide evidence of local erosion and redeposition.

Palaeobotany

Samples collected for their plant fossil content have been identified by M. White (in prep.).

Palynology

Surface samples examined by E. Kemp (Appendix II) were barren. No subsurface material is available.

Lower Boundary

Definition of a precise position for the Carborough-Teviot boundary is hindered by lensing and interfingering relationships and lack of continuity of the beds. The base of the Teviot has been chosen at the first appearance of mudstone, fine silty micaceous sandstone or extensive lack of outcrop above the thick-bedded quartz sandstone sequence of the Carborough Sandstone.

DAWSON RANGE AREA

Area Studied

The Dawson Range area of outcrop of the Moolayember Formation lies between the Dawson Range on the east (west-dipping Clematis Sandstone) and the white, cliff-forming Precipice Sandstone on the west (Fig. 11).

The rocks were examined from the most southerly exposure northwards to the Bauhinia Downs Road. The area consists of undulating brigalow and ironbark country with strike ridges and low normal-to-strike ridges. It occupies the eastern part of the Taroom and Baralaba 1:250,000 Sheet areas.

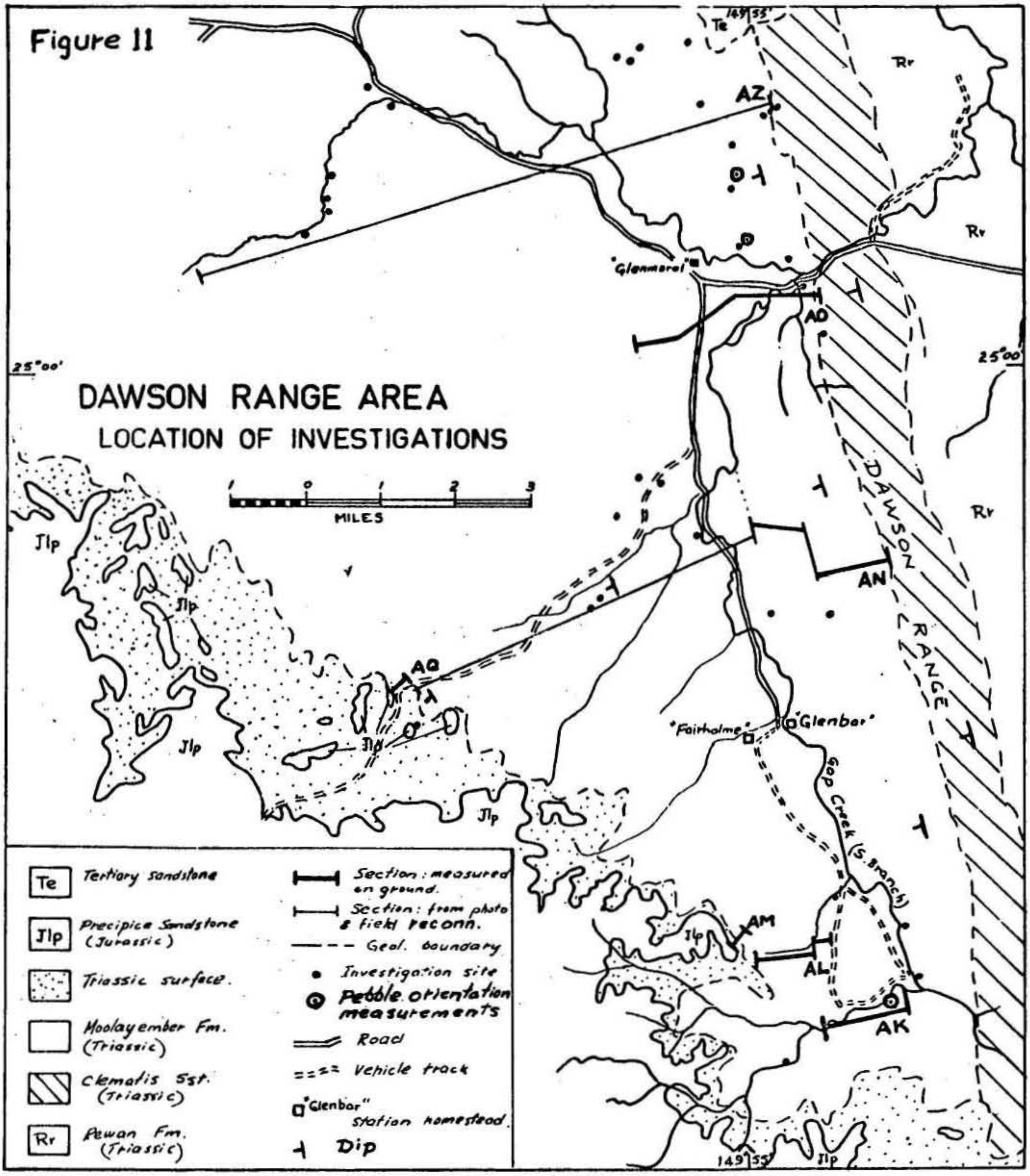
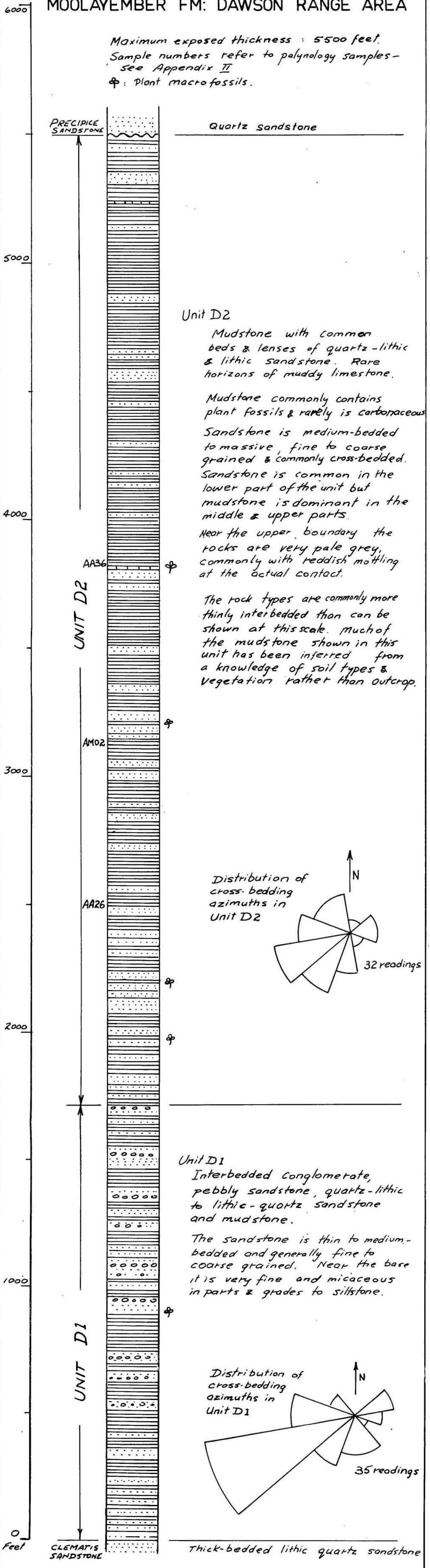


Figure 11
DAWSON RANGE AREA
LOCATION OF INVESTIGATIONS
MILES
Te
Tertiary sandstone
Jlp
Precipice Sandstone (Jurassic)
Triassic surface.
Moolayember Fm. (Triassic)
Clematis Sst. (Triassic)
Rr
Rewan Fm. (Triassic)
Section: measured on ground.
Section: from photo & field reconn.
Geol. boundary
Investigation site
Pebble orientation measurements
Road
Vehicle track
"Glenbar" station homestead
Dip
AZ
AO
AN
AQ
AM
AL
AK
"Glenmorel"
"Fairholme"
"Glenbar"
Gap Creek (S. Branch)
DAWSON RANGE
25°00'
149°55'

Q/A252

Figure 12

DIAGRAMMATIC COMPOSITE SECTION
MOOLAYEMBER FM: DAWSON RANGE AREA



Q/A253

To accompany BMR Record 1969/43

Outcrop is best in the vicinity and south of Glenmoral Gap which is west of Theodore.

Stratigraphic thickness

Six sections were measured in the Moolayember Formation immediately west of the Dawson Range (Plate 3). Where outcrop was insufficient to warrant section measuring, other sections were traversed but not measured thus providing regional dip data so that stratigraphic thickness could be computed using distances taken from air photos. For details of measured sections see Appendix I.

The Formation dips west at a moderate angle and is overlain unconformably by the Precipice Sandstone which successively overlaps older formations to the south. A greater thickness of the Moolayember Formation therefore is exposed as one proceeds northward. However this is accompanied by much poorer outcrop, partial cover by Tertiary sediments and basalt, and more difficult access. The thicknesses measured are necessarily minimum thicknesses.

5500 feet was the maximum thickness in the Dawson Range area, in the vicinity of Glenmoral Gap. South of Fairholme homestead the thickness is 3300 feet (Plate 3).

Units recognized

Section measuring in the Dawson Range area has led to a tentative sub-division of the Formation into two units - D1 and D2. The lower unit (D1) is characterized by the presence of conglomerate beds in a sandstone-mudstone sequence while D2 contains only very rare pebbly horizons (Fig. 12).

Rock Types

Three major rock types occur in this area of the Moolayember Formation. They are sandstone, mudstone and conglomerate. Gradations occur within these types and between them.

(a) Sandstone (Both D1 and D2)

The sandstone is generally buff-coloured, greenish brown or grey in outcrop; it is commonly friable but tough and calcareous in places. Diagenetic calcite occurs in nodules and zones apparently unrelated to bedding. In places soft white calcium carbonate occurs in joints between beds. A sparkling effect in some of the more quartz rich sandstones is caused by secondary overgrowths on quartz grains. Grain size ranges from very fine to coarse but most sandstones are either medium to coarse grained or silty, micaceous and very fine grained. The sandstones are mostly quartz-lithic and lithic-quartz varieties. Many of the medium to coarse grained sandstones contain common angular mudstone clasts - providing evidence of contemporaneous erosion of consolidated sediment. Rarely this rock type grades to an intraformational breccia. Plant impressions on bedding planes are common at some localities.

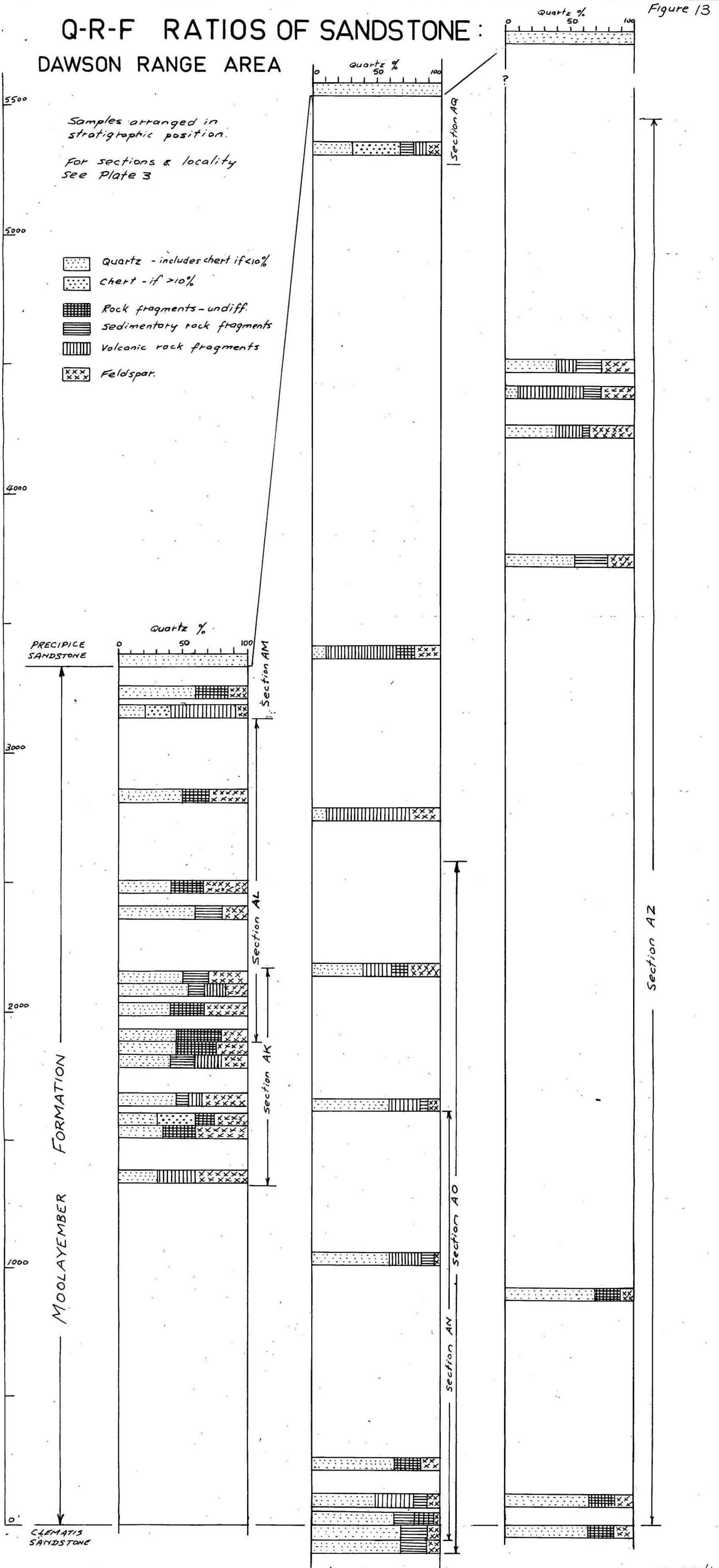
Results of visual estimation of the percentages of quartz, rock fragments and feldspar (Q.R.F.) on 45 thin sections of sandstones are shown in Figure 13. The average quartz content of these rocks is 50%; rock fragments average 31% and feldspar 19%.

The centre and right hand columns of Figure 13 suggest a gradual decrease in quartz content up the Moolayember section. However this is not confirmed by the left hand column and so could be misleading. The topmost quartz sandstone in each case represents the basal beds of the overlying Precipice Sandstone.

(b) Mudstone (both D1 and D2)

Although mudstone is not as common in outcrop as the more resistant interbedded sandstone, it apparently makes up the bulk of Moolayember sediments in this area.

Figure 13



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To accompany BMR. Record. No. 1969/43

Figure 14: Bedding surface of conglomerate in Unit D1. Consists almost entirely of sub-rounded and rounded volcanic pebbles in coarse lithic sandstone matrix. BMR Neg.No.M830/6A.

Figure 15: Unconformity between Moolayember Formation and overlying Precipice Sandstone. Hammer point lies on contact between ferruginous mudstone band and basal quartz pebble conglomerate bed of Precipice Sandstone. BMR Neg. No.M830/10A.

The mudstone seen in outcrop is grey-brown, yellow-brown or rarely dark grey and carbonaceous; it is commonly silty, grading to siltstone and very fine sandstone. Thin bedding is usually well developed and lamination and cross-lamination are not uncommon. Abundant, well preserved plant impressions are to be found in restricted areas while fragmentary impressions and carbonaceous material are scattered throughout.

Minor beds of highly calcareous mudstone grading to buff-coloured, muddy limestone with cone-in-cone structure were seen towards the top of the Formation. One such horizon contains abundant well preserved plant fossils.

Near the unconformity surfaces of the Moolayember Formation some tough, partly silicified mudstone occurs. A similar rock was described by Jensen et al (1964) who tentatively called it tuff. However, it is considered here to be a mudstone which was subject to silicification probably during formation of a Triassic surface of erosion.

(c) <u>Conglomerate</u> (Unit D1). Beds of conglomerate up to 10 feet thick and pebbly sandstone beds are common in the lower part of the Moolayember Formation in the Dawson Range area. Conglomerate beds up to 200 feet thick noted by Olgers et al (1964) were not found during the current survey.

Well-rounded cobbles and pebbles of volcanic origin, are set in a coarse quartz-lithic sandstone matrix which is almost devoid of a fine detrital fraction (Fig. 14).

The pebbles and cobbles average 3" maximum diameter and range up to 8", they are made up of tuffs, intermediate lavas, volcanic lithic sandstone, quartzite and striated lapilli(?) consisting of spherulitic chalcedony.

Bedding characteristics

The medium to coarse-grained sandstones are generally thick-bedded (1-3 feet) but the fine grained micaceous types have thin bedding (1-4 inches).

Mudstones are very thin bedded (0.4-1 inch) and often exhibit thin laminations (less than 0.1 inch) superimposed on the bedding.

Conglomerate beds range from one pebble in thickness up to five feet and interfinger with adjacent sandstone beds. The strata can rarely be traced for more than a few yards and therefore relationships between them are not often clear. This is partly because of poor outcrop but it also reflects the lack of continuity of most beds. Wedging out and lensing of sandstone bodies is commonly seen where the outcrop permits, and gradational lateral changes from sandstone to silty mudstone are not uncommon.

Sandstone bodies exhibit undulating bedding surfaces with variable initial dips but the mudstones which contain them have uniform, planar bedding.

Cross-stratification

(a) Orientation. A number of readings were made on the orientation and inclination of cross-strata in sandstone beds. Only some sandstones are cross-bedded and outcrop is generally poor, so coverage of the Formation was not complete.

A plot of 72 readings for the whole Formation gives an overall southwesterly current direction for this area of the Moolayember Formation (Plate 2).

Plotting separate diagrams for D1 and D2 suggests that little or no change in current directions occurred during deposition of the Formation in this part of the basin (Fig. 12).

Figure 16

HISTOGRAMS OF CROSS-BEDDING INCLINATIONS UNITS D1 & D2

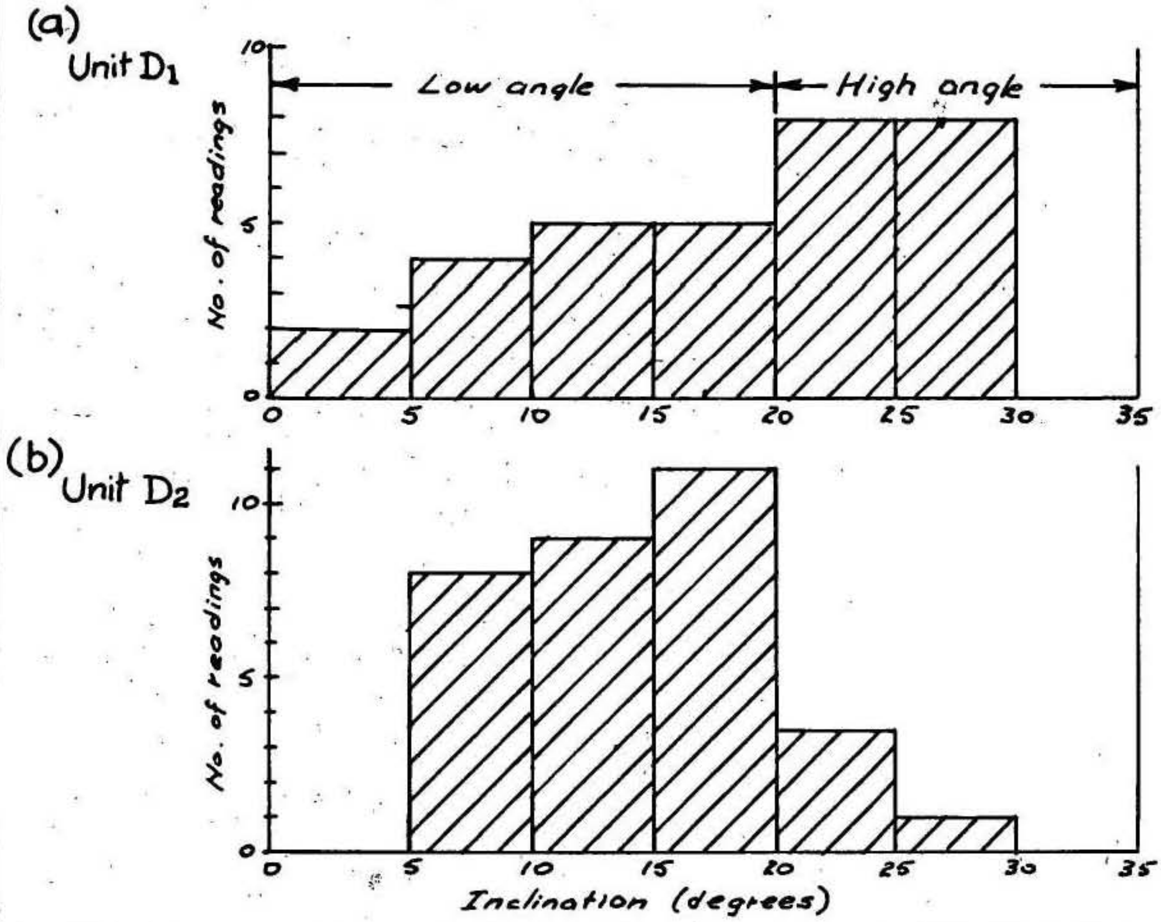
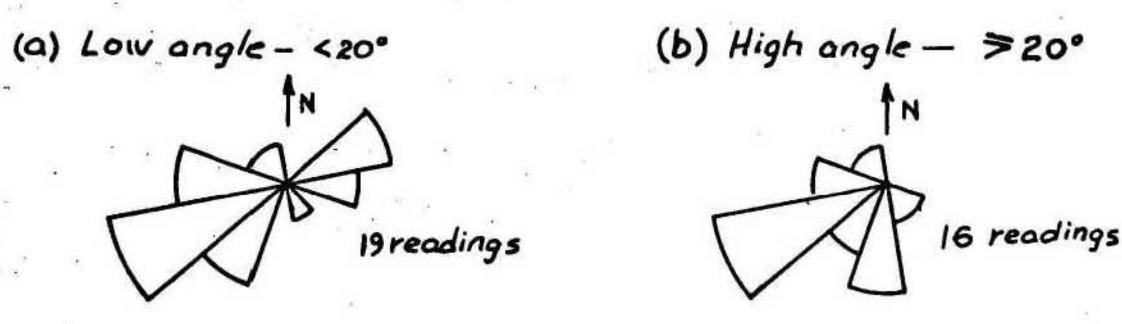


Figure 17

AZIMUTHS OF LOW & HIGH ANGLE CROSS-BEDS IN UNIT D1



Q/A255

(b) <u>Types</u>. Strict adherence to published terminology by McKee and Weir (1953) was hindered by lack of exposure; however the following types and scales of cross-stratification have been recognized:

A. Cross-bedding

(i) Planar tabular and planar wedge-shaped: medium scale, high angle, low angle.

(ii) trough: medium scale, low angle; small scale, low angle.

B. Cross-lamination

(i) Trough (often a "rib and furrow" structure)

(ii) Undifferentiated types seen in single vertical section only.

Plotting the distribution of cross-bedding inclinations for units D1 and D2 (Fig. 16 a & b) shows that high and low angle readings are common in D1 but in D2 the readings are dominantly low angle. This result is in keeping with the overall coarser grain size of D1 sediments. Coarse sediments have a higher angle of rest than do finer grained sediments and require stronger currents to transport them. Plotting azimuths of high and low angle readings in D1 (Fig. 17) shows reversals are common among low angle readings.

<u>Other Sedimentary Structures</u>

Contorted and overturned bedding in sandstone at the base of D1 may have been due to slumping of unconsolidated beds. These structures are associated with high-angle, tabular cross bedding.

Small, sand-filled channels occur in conglomerate beds.

Another feature is the occurrence of conglomerate patches within sandstone containing rare pebbles. This appears to represent filling of scours or depressions with gravel.

Pebble orientation

A. Orientation of long axes

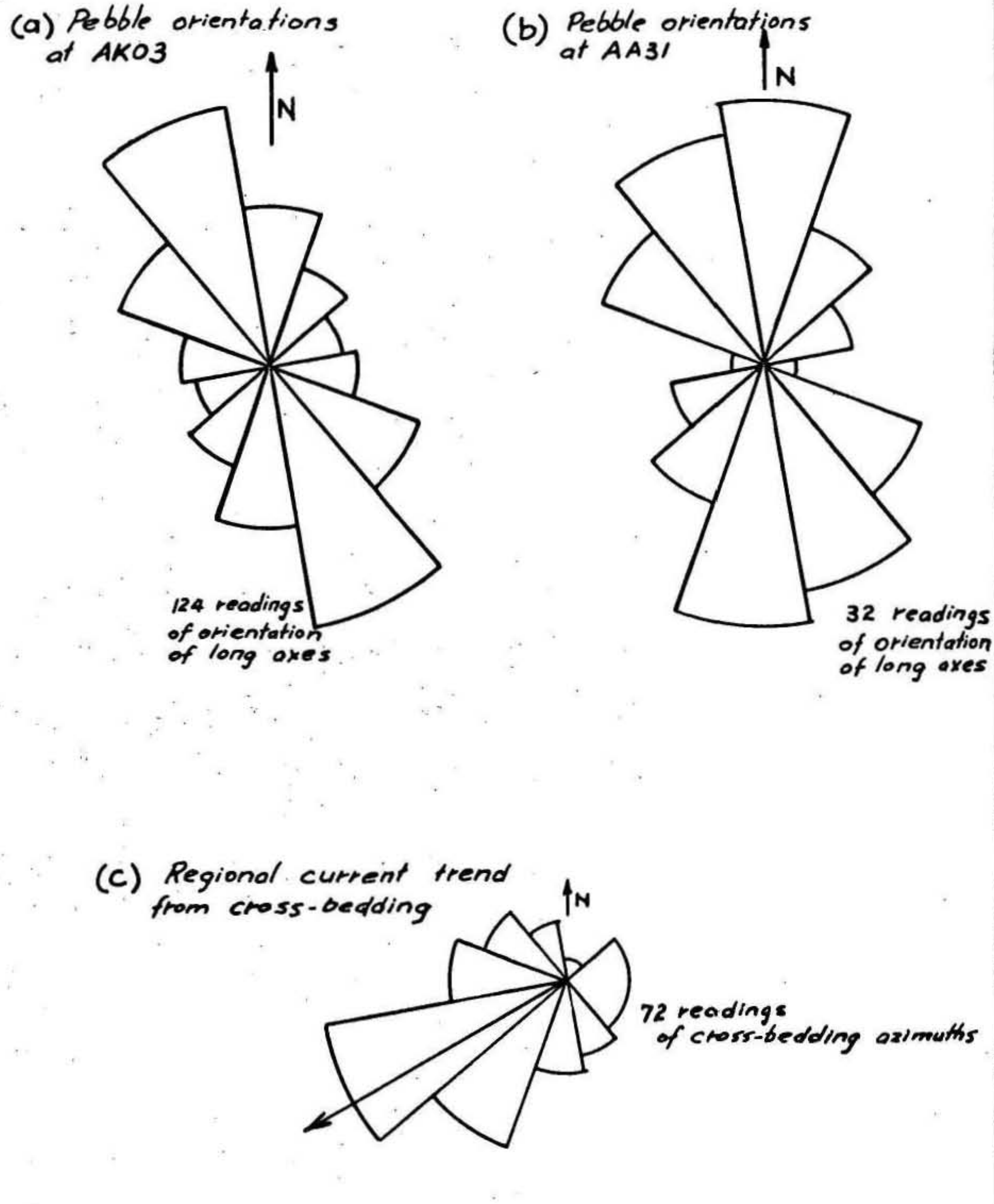
At localities where bedding surfaces of conglomerates were well exposed (Fig. 11) orientations of the long axes of pebbles were measured. Only protruding pebbles were considered so as to reduce errors incurred by concealed parts of the pebbles. Readings were made with a Brunton compass after marking the longest axis on each pebble with marking ink. The pebbles were marked off as the readings were taken so that measurements were not repeated.

The results (Fig. 18) show a distinct polarization of the axes measured, which indicates alignment at right angles to regional current direction. Interpretation of the results however is by no means clear as there is no universal agreement in the literature as to the meaning of oriented pebbles in a conglomerate. Some workers, e.g. Krumbein (1939) and Johnston (1922) have regarded the long axes of pebbles as being aligned with current direction. Schlee (1957) proposed that pebble orientation depended upon pebble shape. Other workers such as Pettijohn (1957) and Wright (1959) judged the concensus of opinion to favour parallelism between long axes and current direction, even though Fraser (1935) and Twenhofel (1932) stated that the long axes of pebbles tend to be at right angles to the current direction. Doeglas (1962) during studies of a modern river found that, in general, pebbles aligned themselves at right angles to the current but occasionally, near river banks, alignment parallel with the current is dominant. Potter and Pettijohn (1963) p. 36 summarized work carried out in this field and recognized the need for further work.

Figure 18

COMPARISON OF PEBBLE ORIENTATIONS (LONGEST AXIS) WITH REGIONAL CURRENT TREND

For location of pebble measurements see Fig. 11



Sengupta (1966) has provided good evidence for a relationship between pebble orientation and initial slope. Elongate pebbles tend to be arranged transversely to current direction on bottomset and topset units and longitudinally in foreset units (Sengupta, 1966).

In the present study the preferred NW-SE alignment of pebbles, together with a regional current movement towards the SW (from cross-bedding) implies a transverse arrangement of pebbles with respect to current direction. In terms of Sengupta's (1966) observations this may mean that depositional slope was very low.

B. Pebble imbrication

It is accepted that discoid pebbles come to rest in a stream with their upstream edge dipping into the stream bed; literature on this topic has been summarized by Potter and Pettijohn (1963).

Measurement of the inclinations of flat pebbles in conglomerates of the Moolayember Formation have shown that for very restricted localities a preferred inclination (imbrication) does exist. However results from localities only a few yards apart are not consistent.

Selection of unit boundaries

(a) Moolayember lower Boundary. The precise position of the Moolayember Formation lower boundary is difficult to define. For regional mapping it was found adequate to place the boundary at the change from strongly outcropping Clematis Sandstone - which forms a steep strike - ridge to the undulating country representing the Moolayember Formation.

Closer study has shown that lensing and interfingering relationships occur so that the base of the ridge is not always the same stratigraphic level. Also there is no sharp change in composition of the sandstones in going from one formation to the other. Lenses of cross-stratified, thick-bedded sandstone have therefore been included in the basal part of the Moolayember Formation; the base being taken at the top of the stratigraphically highest, laterally continuous, thick-bedded sandstone of the Clematis Sandstone.

(b) D1-D2 boundary. The top of unit D1 is taken as the top significant conglomerate or pebbly sandstone horizon. This represents the top of a 1700' sequence containing common conglomerate beds and pebbly sandstones. Little change in the sandstone and mudstone can be detected in going from one unit to the next but overall composition seems to change. There appears to be a decrease in quartz content and a corresponding increase in lithic content up the section - see earlier sub-section on rock types.

(c) Upper boundary. The upper boundary of the Moolayember Formation is represented by a regional unconformity. In the Dawson Range Area the Formation has a remarkably uniform surface and is overlain with slight angular discordance by the Jurassic Precipice Sandstone.

Below the contact, Moolayember sediments take on a pale grey, 'leached' appearance and the contact itself is commonly marked by a red-brown coloration of sediments immediately overlain by a thin quartz pebble conglomerate (Fig. 15). The conglomerate is regarded as the base of the Precipice Sandstone (Jurassic).

The pale grey and mottled red colour of the uppermost sediments is seen to represent part of the weathering profile during a major erosive cycle before the beginning of Precipice sedimentation. However no fossil soil has been seen. A Triassic surface of weathering has been recognized in adjacent areas by Olgers et al. (1964) and Jensen et al. (1964)

EXPEDITION RANGE AREA

Area visited

Outcrop of the Moolayember Formation was examined on the western limb of the Mimosa Syncline in the vicinity of Bedourie and Mopala homesteads on the northwest part of the Taroom 1:250,000 Sheet area. See Plate 1 and Figure 2.

Stratigraphic thickness

The Formation here is folded into a series of shallow synclines and anticlines but exhibits an overall gentle dip eastward. Consequently no determinations of stratigraphic thickness could be made in this area and no units were recognized. However from its structure and width of outcrop it is obvious that a much thinner sequence exists here than in the Dawson Range area - probably less than 2000 feet.

Rock types

In the Expedition Range area sandstone and mudstone are the dominant rock types; secondary muddy limestone is less common. Here sandstone units of the order of 100 feet thick are separated by mudstone units about 30 feet thick. This is in contrast to the Dawson Range area where such alternations occur over intervals of 5-10 feet.

(a) Sandstone

Greenish-brown, buff-coloured and grey, fine to coarse grained sandstones occur. They are lithic to lithic-quartz sandstones which are thin to thick-bedded and commonly cross-bedded. Coalified plant material and coaly laminae were seen.

Large mudstone clasts up to 1 foot across - imbedded in medium grained lithic sandstone provide evidence of contemporaneous erosion and redeposition of consolidated sediment.

Only 7 thin sections of sandstones were examined from this area; lithic sandstones contain abundant volcanic lithic clasts along with some sedimentary grains and minor feldspar.

(b) Mudstone

Mudstone crops out in units up to 30 feet thick; probably much thicker units exist. The mudstone is very thin-bedded and laminated; it contains rare thin beds and laminae of siltstone and very fine sandstone. Plant impressions are common.

(c) Muddy Limestone

Secondary limestones appear more common here than elsewhere. Cropping out in 1-2' beds these rocks are made up of secondary carbonate with abundant silt and clay. They are buff-coloured, tough and massive; some exhibit cone-in-cone structures and in a few places they contain perfectly preserved plant impressions in random orientation.

Some boulders of a sandy limestone with muddy limestone clasts and wood fragments were encountered but none was seen in outcrop.

Bedding characteristics

Sandstones are very thin to thick-bedded (1"-3') and commonly lenticular or wedge-shaped. A gradual lateral change from medium-bedded to very thin-bedded sandstone and thence to silty mudstone is conspicuous at one locality. The sandstone is cross-bedded, medium to coarse grained, containing abundant mudclasts and plant debris. The outcrop is thought to represent a cross section of a point bar deposit in a former river channel.

The mudstone exhibits well developed very thin bedding in places superimposed with thin laminations.

Cross-Stratification

A plot of 33 readings of cross-bedding azimuths in this area is shown on Plate 2; a general southerly orientation with wide variation suggests that sediment was transported from the north.

Cross-stratification ranges from cross-lamination in the finer sediments - sometimes seen as rib-and-furrow structures - to medium scale cross-bedding. Both trough and tabular forms were observed.

Other Sedimentary Structures

Small asymmetrical ripple marks with wave length 3"-5" were seen on surfaces of large blocks of fine to medium sandstone.

Intraformational breccias contain tabular blocks and fragments arranged en echelon, thus providing a key to current direction during deposition of the deposit; the tabular fragments dip upstream.

Local, gentle undulations of sandstone beds may reflect varying initial slopes of deposition or may have been caused by tectonic flexuring. The structures are mostly 10 to 100 feet across and dips vary by as much as 10°.

Lower Boundary

In the Expedition Range area the lower boundary of the Moolayember Formation is not well exposed. However, there is a much higher quartz content in the underlying Clematis Sandstone here than in the Dawson Range area. Thus there is a distinct change from quartz-rich to more labile sandstone as well as an increase in mudstone up the section. This change is reflected very well in the vegetation cover; the Clematis Sandstone supports grasses and ironbark on sandy soil, whereas the Moolayember Formation produces a grey-brown loamy soil supporting dense brigalow scrub and bottle trees.

Upper Boundary

As in the Dawson Range area the upper boundary of the Moolayember Formation is represented by a low angle unconformity overlain by Jurassic Precipice Sandstone. On a regional scale the boundary is easily recognized by the cliff-forming nature of the Precipice.

Closer study shows that there is always a red-brown ferruginous horizon at the top of the Moolayember Formation. This ferruginous layer contains sandstone and mudstone - commonly with Moolayember-type plant fossils.

This is overlain by a bench-forming, white silty fine sandstone about 20 feet thick which is in turn overlain by the cliff-forming cross-bedded quartz sandstone. Both latter units apparently belong to the Precipice Sandstone. On the east limb of the Mimosa Syncline a more extensive bench at the base of the Precipice Sandstone represents the weathered Triassic surface.

CARNARVON RANGE AREA

Area Studied

This area lies on the northwest part of the Taroom 1:250,000 Sheet area, the northeast part of Eddystone and southeast part of Springsure Sheets.

Outcrop is moderate and in some places very good (for the Moolayember Formation). The structural setting closely resembles that for the Dawson Range area; the formation dips 13° to 4° west with dips diminishing westward, and is overlain with slight angular unconformity by the Precipice Sandstone which overlaps it southward.

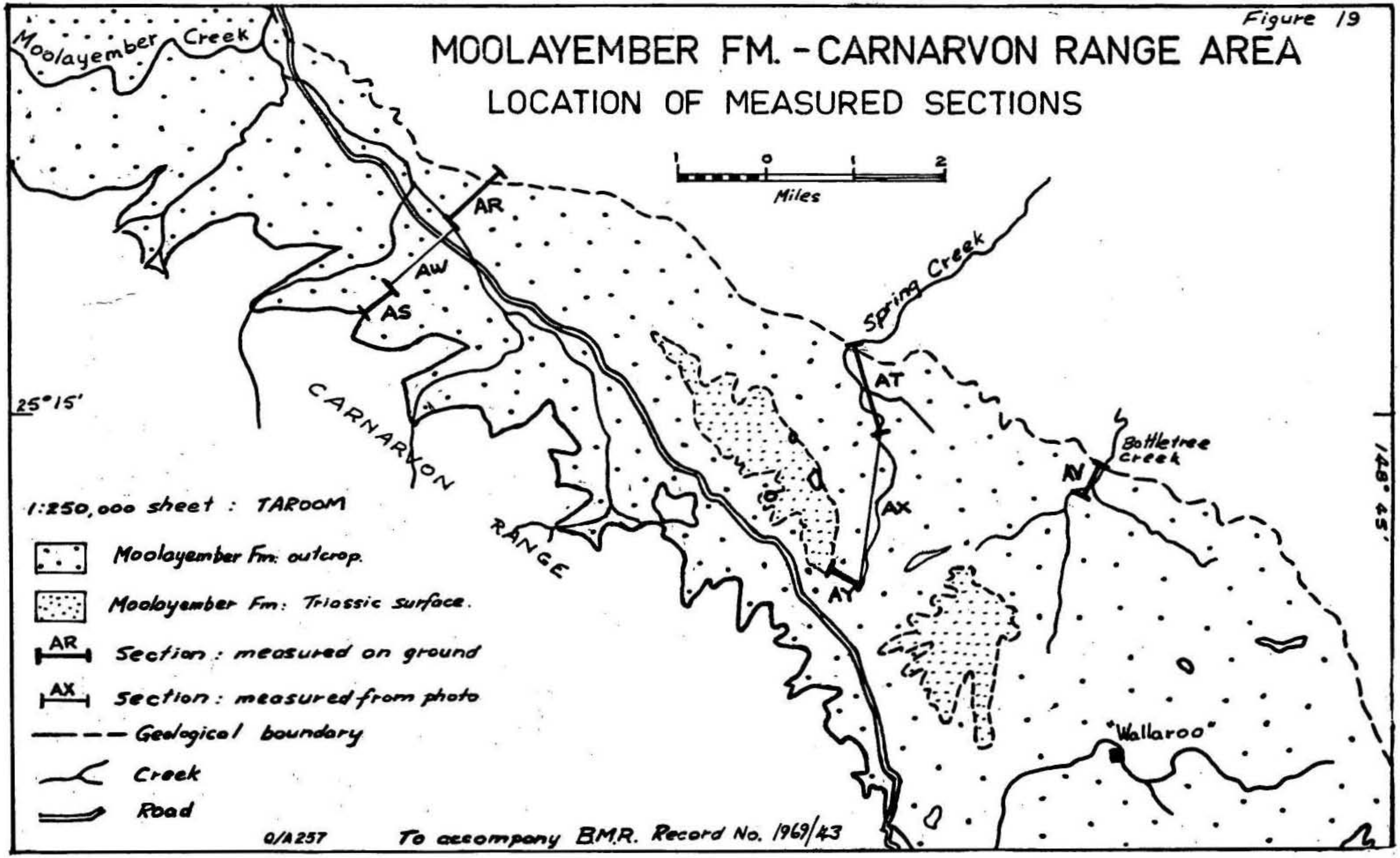
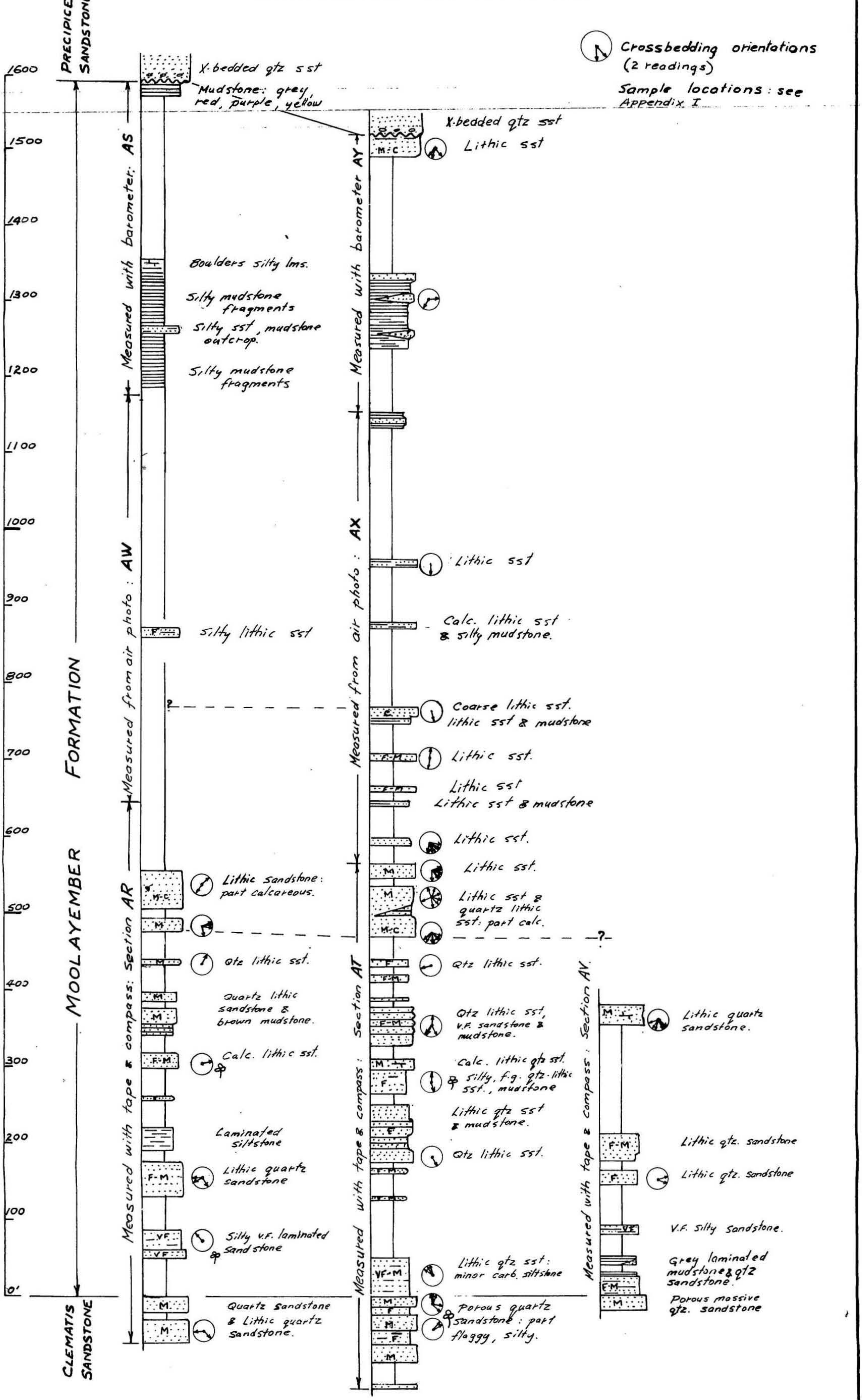


Figure 19
MOOLAYEMBER FM. - CARNARVON RANGE AREA
LOCATION OF MEASURED SECTIONS
1 0 1 2
Miles
Moolayember Creek
Spring Creek
Bottletree Creek
CARNARVON RANGE
AR
AW
AS
AT
AX
AY
AV
"Wallaroo"
25°15'
148°45'
1:250,000 sheet : TAROOM
Moolayember Fm: outcrop.
Moolayember Fm: Triassic surface.
AR Section : measured on ground
AX Section : measured from photo
Geological boundary
Creek
Road
Q/A257
To accompany B.M.R. Record No. 1969/43

Figure 20

MEASURED SECTIONS IN MOOLAYEMBER FORMATION
CARNARVON RANGE AREA



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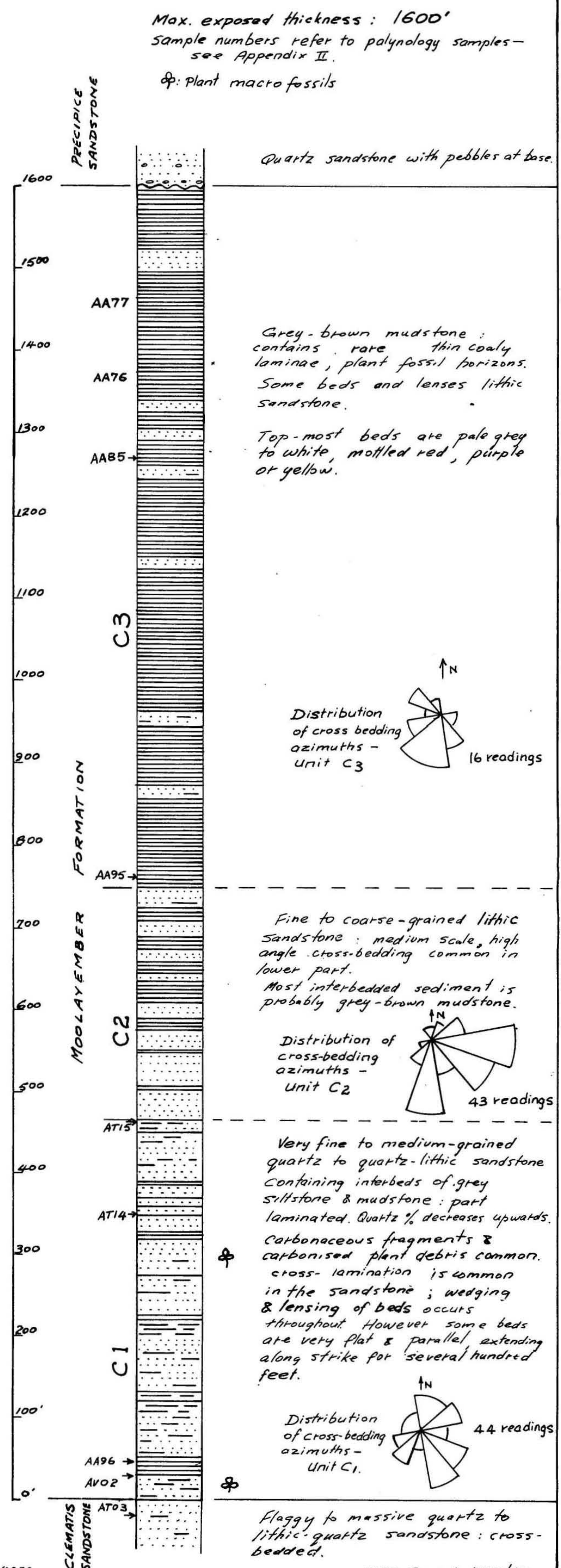
To accompany B.M.R. Record No. 1969/43

Figure 21

DIAGRAMMATIC COMPOSITE SECTION

MOOLAYEMBER FORMATION

CARNARVON RANGE AREA



Q/A259

BMR Record 1969/43

The rocks were examined at some length in several of the east-flowing creeks east of the Carnarvon Range and briefly in the Rewan Syncline.

Stratigraphic Thickness

Five sections were measured on the ground and two others were compiled from air photos in conjunction with dip measurements on the ground. From these data separate determinations of thickness of 1520 feet and 1600 feet were made for the Moolayember Formation in this area (Figs. 19, 20). Again the figures represent minimum thicknesses as the top of the Formation is not exposed.

Units Recognized

The Formation has been divided into 3 units in this area on the basis of lithology. The units have been designated C1, C2 and C3 (Fig. 21).

Unit C1 is a predominantly sandy unit consisting of well-bedded, quartz-lithic and lithic-quartz sandstone along with siltstone and fine silty sandstone.

Unit C2 contains thick-bedded, cross-bedded lithic sandstone, thin to medium-bedded quartz-lithic sandstone and mudstone.

Unit C3 consists largely of mudstone with rare lithic sandstone beds and lenses.

Rock Types

(a) Sandstone. In Unit C1 sandstone is pale grey to pale brown; it is mostly fine to medium grained and well-bedded with cross-lamination and small scale cross-bedding. At the base of C1 there are micaceous, fissile, laminated sandstones containing plant fragments and carbonaceous laminae and possessing broadly undulose bedding (e.g. Spring Creek).

Further south, between Basin Creek and Bottletree Creek the lower part of C1 contains abundant coarse grained, ferruginous quartz sandstone lenses and ripple-marked beds in a mudstone sequence. This implies depositional conditions different from those along strike at Spring Creek, and gives an insight into the local variation in environments during Moolayember deposition.

The composition of the sandstone of C1 ranges from quartz sandstone near the base to quartz-lithic sandstone at the top, but most are of the lithic-quartz type.

Ratios of quartz, rock fragments and feldspar were estimated from 49 thin sections of sandstones. 23 of these have been plotted in their relative stratigraphic position (Fig. 22). In unit C1 quartz averages 69%, rock fragments (volcanic and sedimentary) average 28%, and feldspar 3%.

In C2 the sandstones are greenish-brown, or brown, much more lithic, generally coarser grained and commonly calcareous. Cross-stratification is on a larger scale and generally steeper. The sandstones commonly contain mudclasts, plant fragments and carbonaceous grains.

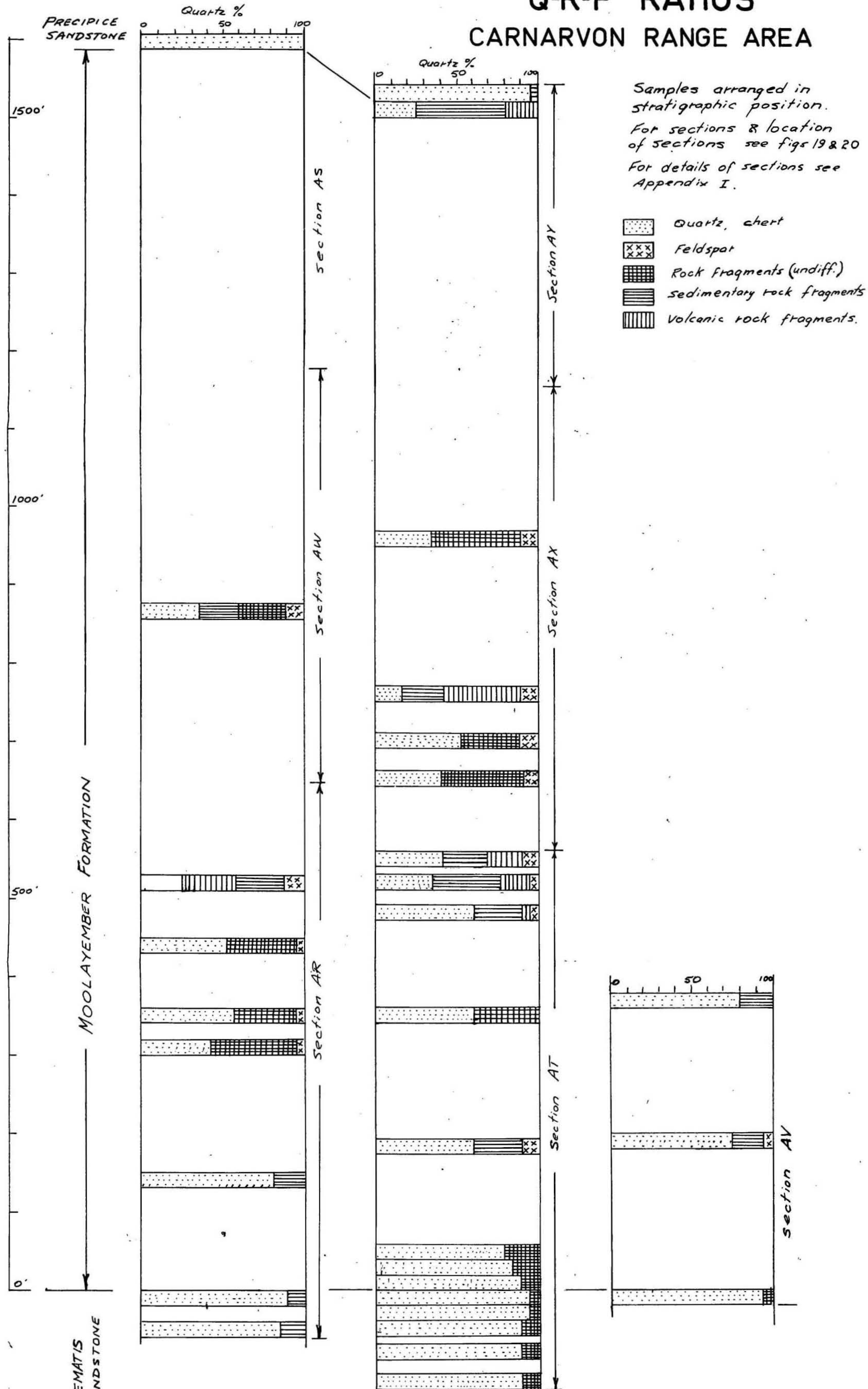
Some well-bedded C1-type sandstones persist in this unit and several contain sub-vertical tubes, at least some of which are root casts.

Q-R-F ratios in sandstones of C2 9Fig. 22) show an average quartz content of 35%, rock fragments 56% and feldspar 9%.

Sandstone in C3 is very minor but those samples examined were found to contain an extremely high lithic content. For these rocks quartz averages only 25%, rock fragments 67% and feldspar 8%.

Figure 22

Q-R-F RATIOS
CARNARVON RANGE AREA



To accompany B.M.R. Record No. 1969/43

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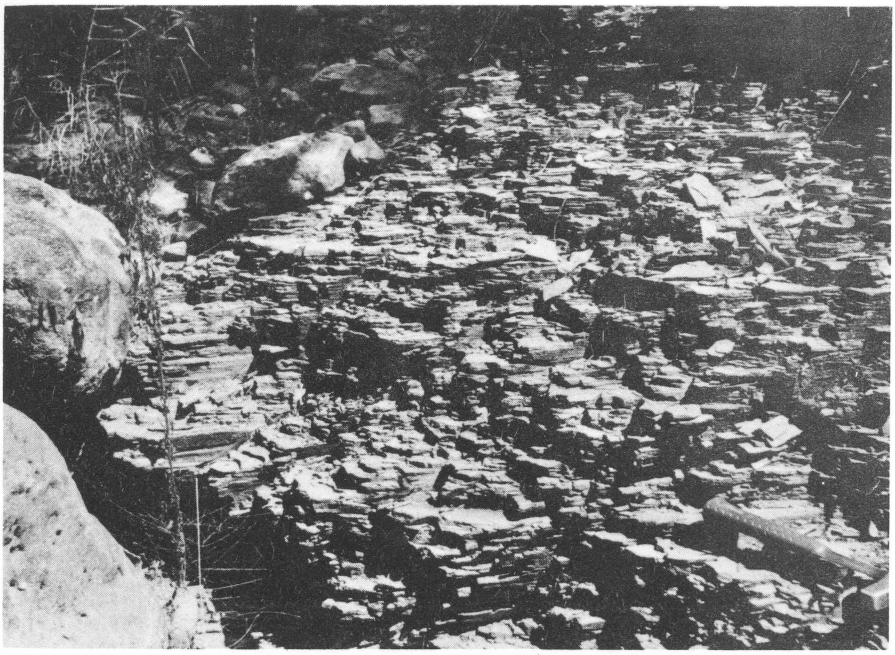


Figure 23: Thinly laminated, very thinly parted, silty mudstone which forms bulk of sediments at Basin Creek, Carnarvon Ranges, and which contain rippled sandstone beds. BMR NEG.No.M830/21A.

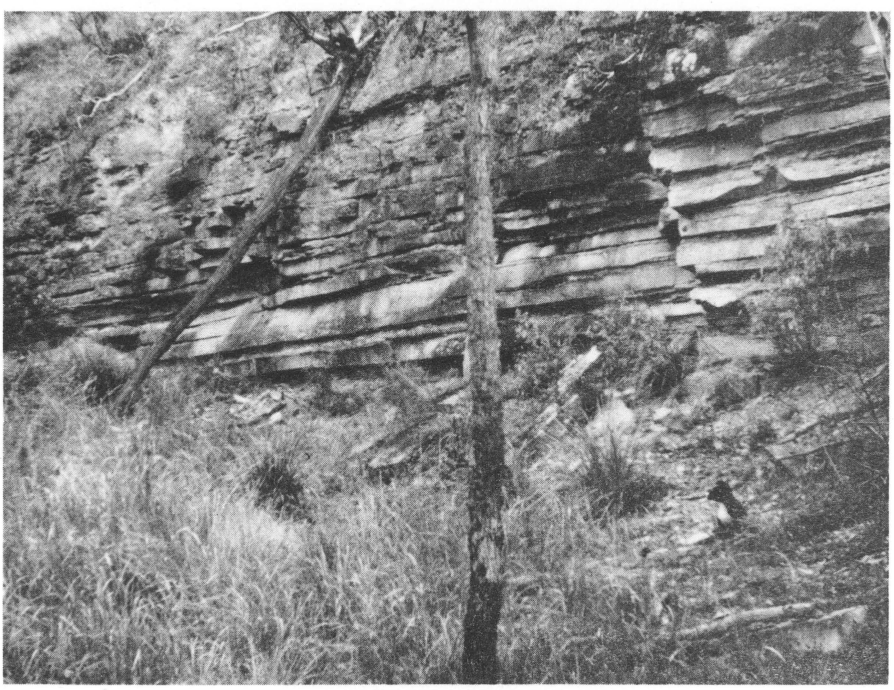


Figure 24: Well bedded sandstone in Unit C1 Spring Creek, Carnarvon Ranges, Less resistant interbeds composed of cross-laminated siltstone. BMR NEG. No.GA/1388.

Siltstone

A common rock type in C1 is grey and grey-brown siltstone which grades to silty, very fine sandstone. This type makes up the less resistant interbeds between the well-bedded sandstones. Near the base of C1 siltstone is micaceous, thinly laminated and carbonaceous. Higher up it becomes more common and is usually cross-laminated. Many exposures show ripple-drifted cross laminae and complex undulose laminae.

Mudstone

Increasing in abundance up the section, mudstone varies between grey to dark grey, grey brown and light brown. It is generally well-bedded and in places laminated. Near the base of C1 in the southern part of the area the mudstone is laminated, dark grey, or mottled grey (Fig. 23).

In C2 grey-brown mudstone becomes common as interbeds between sandstone bodies. In C3 it is apparently the dominant lithology as sandstone beds crop out only rarely. Fresh scours expose great thicknesses of very thinly bedded mudstone, and the soil has a high clay content supporting a very dense vegetation. In places the mudstone is carbonaceous and commonly contains plant fossils.

Bedding Characteristics

In Unit C1 the sediments are characterized by very uniform, planar and well developed bedding which can be traced for several hundred feet in some places (Fig. 24). The bedding is medium scale in the sandstones with some thin-bedded and laminated sediments between. Below the chosen lower boundary of C1 the sandstones are mostly medium to thick-bedded and have undulose bedding surfaces.

South of Spring Creek, in C1, lenticular sand bodies are common. They range in length from a few inches (Fig. 25) to several hundred feet.

As in other areas, lateral changes from sandstone to silty mudstone were observed. Sandstone bedding in unit C2 and C3 is usually medium to thick and can rarely be traced for more than a few yards. The sand bodies are mostly wedge-shaped, lenticular or channel-shaped, although well-bedded, fine grained sandstone like that of C1 does occur.

The finer grained sediments (very fine sandstone, siltstone and mudstone) are mostly well-stratified, ranging from thinly-bedded to very thinly-laminated (Fig. 26). In C3 however, some of the mudstone is massive, containing plant fossils which are twisted and randomly disposed.

Cross-Stratification

108 readings of cross-stratification azimuths for the Carnarvon Range area were plotted (Plate 2) and show an overall inferred current direction towards the southeast.

Both cross-bedded and cross-laminated sediments are common in the Moolayember Formation but inferred palaeocurrent directions were based largely on cross-bedding, except where cross-lamination has produced rib-and-furrow structures on bedding surfaces. In such cases the azimuth of plunge of the furrow axes was recorded.

Cross-stratification types were found to be very difficult to identify in most cases, as outcrop is generally inadequate.

Plotting the results separately for each unit shows an interesting trend (Fig. 21). The inference is that palaeocurrent direction and hence palaeoslope was poorly defined during C1 time but was biased towards the east. During C2 current direction was better defined and towards the south-east quadrant. Later, during C3 the inferred dominant current direction was southwesterly.

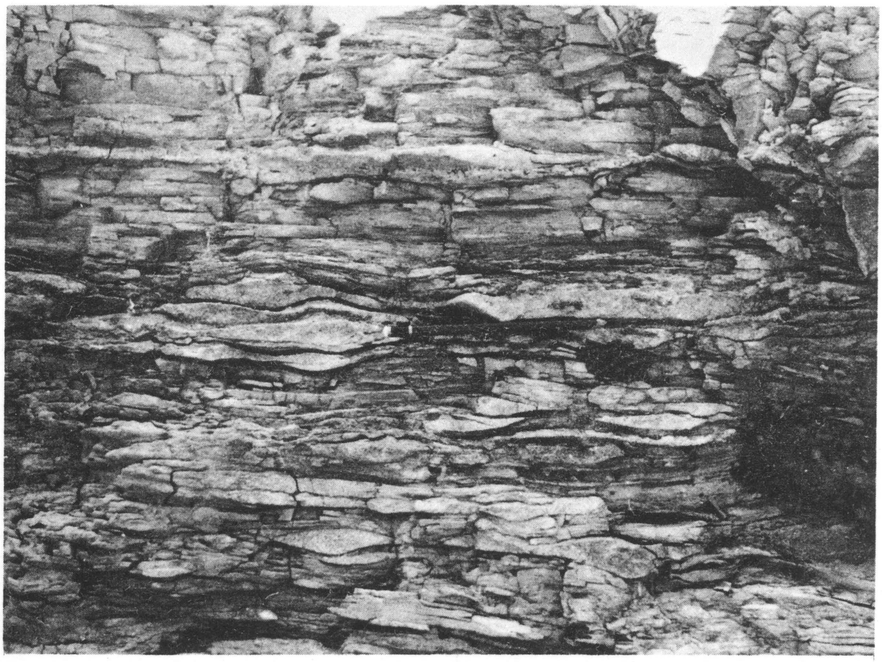


Figure 25: Small sandstone ripples and lenses in laminated mudstone sequence at Basin Creek, Carnarvon Ranges. BMR Neg. No.M830/22A.

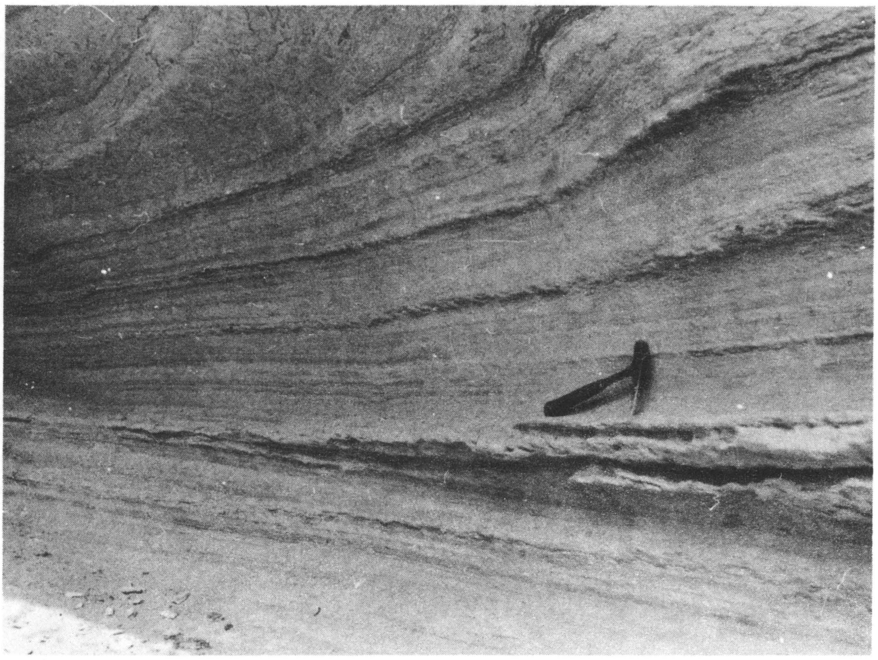
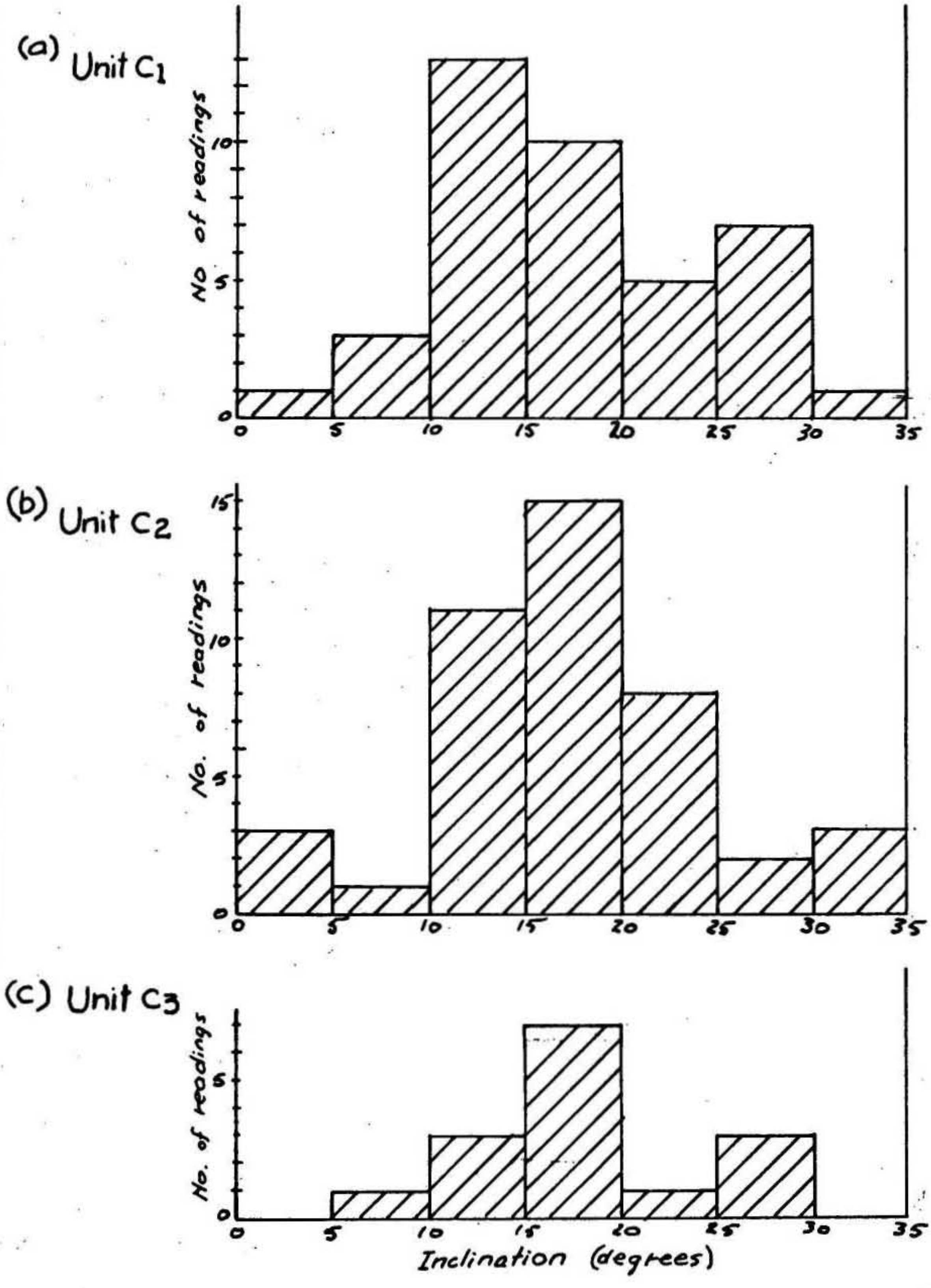


Figure 26: Laminated and cross-laminated sediment grading from fine sandstone to silty mudstone; Bottletree Creek, Carnarvon Ranges. BMR Neg.No.M830/34A.

Figure 27

HISTOGRAMS OF CROSS-BEDDING INCLINATIONS UNITS C1, C2 & C3



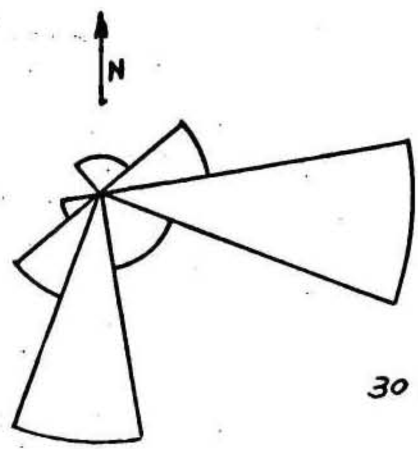
Q/A261

To accompany BMR Record 1969/43

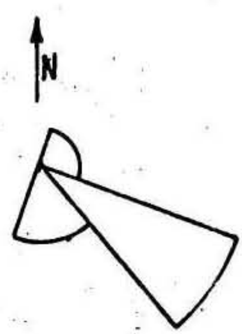
AZIMUTHS OF LOW & HIGH ANGLE CROSS-BEDS IN UNIT C2

CARNARVON RANGE AREA

(a) *Low angle:* <20°



(b) *High angle:* ⩾20°



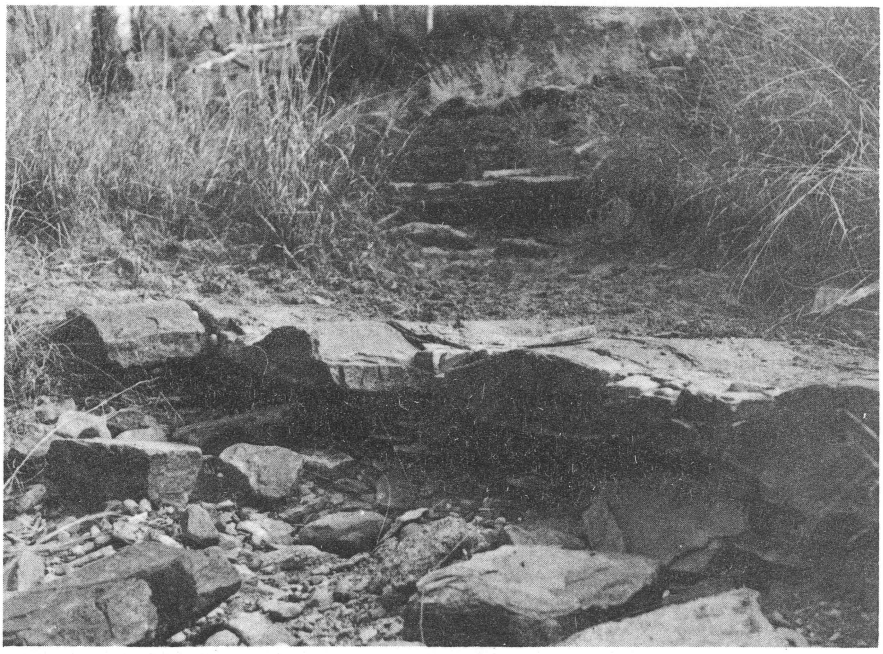


Figure 29: Megaripples in very coarse grained ferruginous quartz sandstone, having wavelength of 3 feet. Troughs contain siltstone. Hammer head on crest of second ripple from right.
BMR NEG. No.M830/27A.

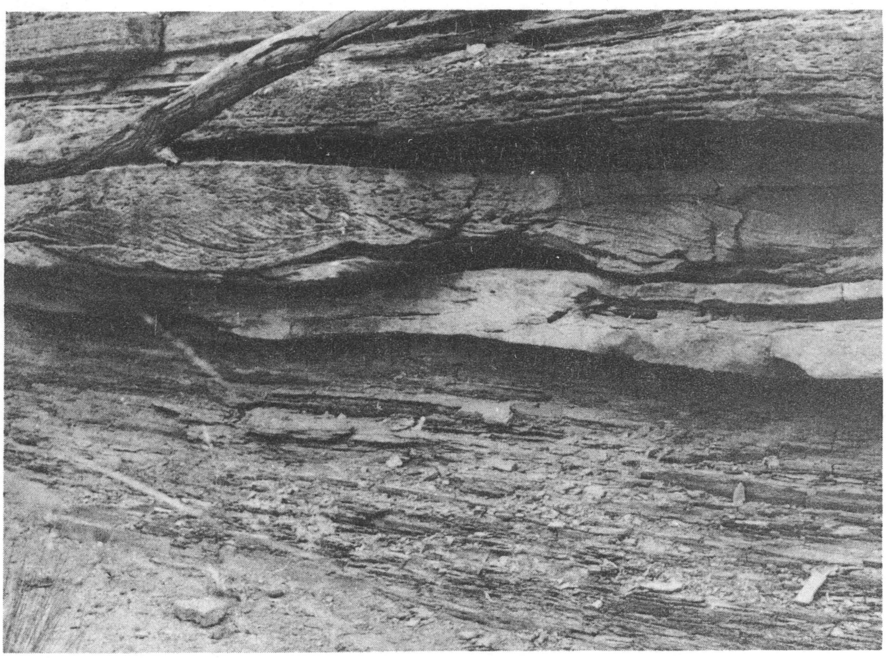


Figure 30: Broad current laminated ripples in sandstone overlying laminated silty mudstone and overlain by thinly-bedded sandstone. Hammer at right of centre. Exposure in creek at "The Basin", Carnarvon Ranges.
BMR Neg. No. M830/31A.

Another feature of the results - probably connected with the above observations - is the distribution of high angle readings (Fig. 27). In C2, where high and low angle readings are both common they have been plotted separately. The high angle readings are well polarized in one direction but low angle ones are spread over a much wider arc and have two main trends (Fig. 28).

Many more readings are required with a more regional distribution before a proper analysis of palaeocurrent trends can be attempted.

Other Sedimentary Structures

Besides cross-stratification, other sedimentary structures include ripple marks, mud clast imbrications, channel erosion structures, sub-vertical root casts and other tubes of uncertain origin.

(a) Ripple marks. Some small, irregular ripple marks with wavelengths from 2"-3" were encountered but not well exposed on bedding surfaces. In Basin Creek and Bottletree Creek, vertical sections of small irregular, sandstone ripples and lenses in mudstone are exposed (Fig. 25). Good exposures of larger transverse ripple marks (megaripples) occur in this area (Fig. 29). These structures are regular, parallel and almost symmetrical ripple marks with wavelength 3 feet and amplitude 6 inches. They are made up of coarse to very coarse-grained ferruginous quartz sandstone and occur, along with the smaller regular and irregular types in a sequence of laminated to very thin-bedded silty mudstone.

No definite current lamination is recognizable in the megaripples but their smaller counterparts do show current markings. Some specimens exhibit current laminations which indicate two currents in opposite directions. Other broad ripples clearly show lamination in one direction (Fig. 30).

(b) Mud clast imbrication. At several localities in units C2 and C3 mudclasts are present in the sandstone. The mudclasts are generally tabular, subrounded to subangular and range up to about 6 inches maximum diameter. Because of their tabular habit they are subject to imbrication during deposition and hence provide a means of assessing palaeocurrent direction. The tabular fragments dip upstream. No systematic measurements of orientations were made because the fragments, unlike the pebbles and cobbles in the Dawson Range conglomerates, do not project from the outcrop and so only 2 dimensional views of these are presented. Nevertheless, a good impression of approximate current direction can be gained as the imbrication of the mudclasts is commonly more pronounced than in the pebbles and cobbles. At one locality in C3 a southerly direction of water movement was inferred from imbrication of mudclasts.

(c) Channel erosion structures. Local erosion and redeposition is apparently common in units C2 and C3. Evidence for this, besides the common occurrence of mudclasts, is seen in local unconformity structures (Fig. 31). Here a stream channel has apparently eroded consolidated, very thinly bedded mudstone and sandstone and redeposited it as cross-bedded sandstone containing mudclasts.

(d) Root casts and other tubes. Well-bedded, fine grained sandstones in units C1 and C2 commonly exhibit sub-vertical tubes from 0.1 to 0.3 inches in diameter and up to 10 inches long. Some of them are branched, taper downwards and contain carbonaceous linings. The structures can be attributed to root casts. Other tubes occurring in association with the root casts do not contain carbonaceous linings. In other respects they are similar although many do not branch and others do not taper downwards. Their association and general similarity however would suggest that most if not all these tubes are root casts. The sandstone containing the tubes is commonly cross-laminated indicating that the plants responsible for them grew in gently moving water where sand-sized sediment was being deposited.

Figure 31: Local unconformity in Spring Creek, Carnarvon Ranges. Erosion of consolidated, thinly bedded sandstone and mudstone formed a ridge. Later deposition of coarse grained, cross-bedded, thickly-bedded sandstone has produced drape and abutment relationships with the eroded surface. BMR Neg. No.GA/1390.

Selection of unit boundaries

(a) Moolayember Formation lower boundary. The boundary between the Moolayember Formation and the underlying Clematis Sandstone is gradational here as in other areas studied. There is an overall change from thick-bedded quartz sandstone and lithic quartz sandstone (Clematis) to finer grained, thin to medium-bedded sandstone and siltstone. During section measuring the boundary was taken at the topmost thick-bedded sandstone forming the dip slope of the Clematis Sandstone range. At Bottletree Creek, Spring Creek and north of Spring Creek, the top thick-bedded sandstone is overlain directly by thin-bedded, well-bedded sandstone with interbedded laminated siltstone. At Basin Creek the thick-bedded sandstone of the Clematis Sandstone is overlain by an area of no outcrop followed by mudstone containing sandstone lenses and beds.

(b) C1-C2 Boundary. The first appearance of sandstone with a high lithic content was taken as the base of unit C2. Below this horizon the sandstone is pale brown to grey, mostly lithic-quartz composition and is generally thin-bedded and fine grained. The typical C2 sandstone on the other hand contains less than 65% quartz, is greenish brown, calcareous in parts, medium to coarse grained, medium to thick-bedded and cross-bedded. It is typically associated with channel erosion structures and contains common mudclasts.

(c) C2-C3 Boundary. The change from unit C2 to C3 is more subtle. It was chosen where the interbedded sandstone-mudstone sequence gives way to mudstone containing only rare sandstone horizons.

(d) Moolayember Formation Upper Boundary. The regional unconformity at the top of the Moolayember Formation exhibits almost identical form with that seen in the more easterly areas of outcrop.

The upper sediments have a 'leached' pale grey appearance and become mottled pink, red-brown and mauve in parts. At the contact a thin, heavily ferruginized layer is overlain by a band of fine quartz pebble conglomerate and then white cross-bedded quartz sandstone. The pebble band is taken as the base of the Jurassic Precipice Sandstone. Angular discordance between the Moolayember and Precipice is very slight in most areas.

OTHER AREAS

Rewan Syncline (see Fig. 2)

A veneer of Moolayember Formation (probably less than 300 feet) occupies the central portion of the Rewan Syncline. No detailed work was done here as the section is so thin. The sediments are mostly very well-bedded sandstone and silty mudstone typical of C1 sediments in the Spring Creek area.

Plant fossil fragments are common in the finer grained sediments and probable root casts were seen at two localities.

Springsure Shelf (See Fig. 2 and Plate 1)

Several localities were visited in the Springsure Shelf where Moolayember Formation is present. Outcrop is very poor and regional dips very low; no sections were measured. Near the base of the Formation on the Claude River the sandstone is well-bedded, fine grained, cross-laminated and cross-bedded. Some bedding surfaces show small, irregular ripple marks. The basal sediments resemble unit C1 rocks of the Carnarvon Range area.

Higher in the section (further south) the sandstones are thicker bedded and more lithic but intervening sediments are rarely exposed.

Red-brown, purplish and grey-green mudstone was observed on the Nogoa River near "Cungelella" homestead. These red beds contain equisetalian stems; associated sandstones are cross-bedded and highly lithic. At one exposure, red and green mudstones are directly overlain by strongly cross-bedded sandstone which shows small slump structures at the top. These in turn are overlain by thin-bedded, finer grained sandstone. The cross-bedded sandstone changes laterally into brown silty mudstone. These relationships are typical of many point bar deposits.

Further east on Wharton Creek near "Yandaburra" the sandstone of the Moolayember Formation is lithic and partly calcareous but again the intervening sediments are not exposed.

Several springs mark the ferruginous top of the Formation which provides an impermeable horizon for groundwater in the Precipice Sandstone.

Bauhinia Downs Area (Mimosa Syncline)

No field work was possible in this area because of the lack of outcrop; however stratigraphic drilling by the Queensland Mines Department (Gray 1967b) has provided good core material from regular intervals within the Formation. The drilling has revealed the presence of coal seams - mostly in the upper part of the section - and has shown that the leached and ferruginized top of the Formation is present in subsurface. The main lithologies are sandstone and mudstone or shale as in outcrop but the fresh rock is generally grey compared with the brown colours seen in outcrop.

De Jersey and Hamilton (1967) recorded acritarchs (microplankton) from some samples in the middle of the Formation. As acritarchs have also been recorded from the Carnarvon Range area (see Appendix II), this suggests that marine water may have covered a wide area at different times. Furthermore no material has been examined for microfossils from the Formation in the eastern and northern areas. Hence marine conditions may have been even more widespread.

REGIONAL ASPECTS

(a) Basin-wide correlation

Correlation between the three main areas studied is difficult for several reasons:

(1) The areas are separated by great distances and outcrop is limited.

(2) There are no obvious marker horizons that can be used throughout the basin.

(3) Overall homogeneity of the sequence allows only very broad unit subdivisions which further hinders regional correlation.

As a result of poor correlation the cause of gross thickness variations cannot be determined with any certainty. It is probably a combination of depositional thickening in the south-east caused by subsidence, and denudation in the north and west. The relative importance of the two factors is difficult to assess. However palynological work suggests that the Carnarvon Range section may correlate with the lower half of the Mimosa Syncline section (see Appendix II). This would imply removal of the top of the section in the west.

Thickness varies from at least 5500 feet in the Dawson Range area to less than 500 feet in the northern part of the basin. 1600 feet were measured in the Carnarvon Range area and thinner sections have been estimated further west.

(b) Lower Boundary

Study of the boundary between the Moolayember Formation and the underlying Clematis Sandstone indicates that no single criterion can be used for a basin-wide definition of the boundary. Distinct changes which can commonly be observed in going from the older formation to the younger are as follows:

(i) a general decrease in grain size of the sediments and a marked increase in the proportion of mudstone and siltstone in the section;

(ii) a gradual increase in lithic content of the sandstone; and

(iii) a change from thick-bedded and massive sediments to thin and medium bedding.

Generally these changes are reflected in a sharp topographic break from prominent strike ridges (Clematis Sandstone) to the subdued, undulating country of the Moolayember Formation. In the Expedition Range, however, the break is clearly marked by a sharp change in the vegetation cover.

Any of the variables enumerated may be used singly or in combination to pick the boundary.

Lithologic comparisons

Rock types remain essentially similar throughout the Moolayember Formation but their relationships and relative abundance vary from one place to the next.

A major exception is the presence of conglomerate in the lower part of the section in the Dawson Range area.

In the sandstone, besides local variation in types which have been described earlier, some regional variations and similarities are apparent. The higher average quartz content in samples from the Northern Area favours correlation with the lower units (C1 in particular) in the southern part of the basin. In each of the areas a gradual increase in lithic content up the section is apparent. It is possible that fining upwards is present throughout the Formation.

In the Carnarvon Range area there is an increase in mudstone and a decrease in sandstone up the section. In the Dawson Range area, conglomerate grading to pebbly sandstone occurs in D1 while the overlying unit D2 contains sandstone and mudstone. Furthermore the mudstone content increases upwards.

The thin sandy sequence in the northern area may represent the basal coarser grained unit (or part of it) which has been left after erosion of overlying finer grained sediment.

Studies of heavy mineral assemblages are currently being undertaken.

POSSIBLE INTERPRETATION OF DEPOSITIONAL ENVIRONMENTS

Results of the study so far allow some tentative conclusions to be drawn concerning the depositional environments of parts of the Moolayember Formation and more tentatively for the Formation as a whole.

Field observations favour a continental environment for most of the Moolayember Formation with some marine influence. Several sub-environments can be postulated which suggest diverse conditions of sedimentation. Such variation is common in continental sediments.

Indicators which support continental, fresh water deposition are:

(1) Lack of marine macrofossils;
(2) Presence of coal;
(3) Presence of common plant fossil horizons and abundant fragmented plant fossils;
(4) Lack of continuity of beds - wedging, lensing, lateral change in lithology;

(5) Evidence of local erosion and redeposition of sediment together with abundance of sandstone containing mudclasts;
(6) Alternation of mudstone, cross-bedded sandstone and conglomerate over a small stratigraphic interval;
(7) Red beds;
(8) Similarities with well documented fluvial sediments in other areas.

Considered together these features lend strong support to the view that the Moolayember Formation sediments were deposited mostly if not entirely in non-marine water. However localized occurrence of acritarchs (microplankton) lends support to brief, local marine incursions. Furthermore some sedimentary structures can be attributed to tidal deposition.

Within this general concept several different sub-environments can be recognized.

In the northern area (Teviot Formation) the Formation was probably deposited over a much larger area than it now occupies for reasons outlined in the section dealing with that region (p. 11).

The sandstone bodies change in grain size both laterally and vertically and are imbedded in mudstone. Relationships such as these are compatible with the formation and migration of point bars which were later buried by flood plain and overbank deposits as the river channel migrated within its meander belt.

Burial and preservation of plant material possibly took place during floods on the flood plain or in swampy areas. Preservation of carbonaceous mudstones suggests the former presence of some small lakes, swamps or swales where water circulation was very restricted.

The presence of shale clasts in sandstone indicates local erosion and redeposition of consolidated sediment, which is likely when a migrating river channel crosses back over sediment deposited in an earlier cycle or a new stream channel is formed. Cross-bedding azimuths are biased towards the south and east but are not well polarised - possibly because they were formed by meandering streams. Sedimentary and volcanic lithics give an indication of some of the source rocks.

In summary, the sediments of the northern area have probably been deposited in meander belts draining a source area to the north and west where sedimentary and volcanic rocks were being denuded. Within the meander belt coarser sediments were deposited as point bars while muds accumulated on flood plains, swampy areas and swales.

In the Dawson Range area the main current direction is towards the southwest, indicating a source northeast of the deposition site. The prevalence of volcanic conglomerate beds in D1 testifies to the availability and proximity of volcanic rocks and also suggests that an area of high relief existed to the northeast. This would provide streams with the capability of moving large quantities of pebbles and cobbles.

The conglomerate is regarded as a fluvial rather than a shore line gravel because:

(i) Orientations of pebbles appear to be related to cross-bedding azimuths in adjacent sandstone.

(ii) It contains abundant sandstone matrix and the sorting is not as good as to be expected on a shore line.

(iii) Shoreline conglomerate of this grainsize implies the presence of very large bodies of water. However associated sediments exhibit the properties of river sediments and not lake deposits.

(iv) Sand-filled channels occur in the conglomerate and pebble-filled scours or depressions were observed in pebbly sandstone.

(v) Pebbles are commonly imbricated locally but the direction varies over a strike distance of a few yards. If the pebbles were imbricated by wave action on a shoreline, more uniformity of orientation could be expected.

The other rocks - sandstone, mudstone, carbonaceous mudstone and muddy limestone - show properties and relationships already described in the northern area. The sandstone bodies can rarely be traced along strike for more than a few yards before they lens out or change to mudstone; mudclasts in sandstone indicate local erosion and redeposition and carbonaceous mudstone and rich fossil plant horizons suggest accumulation in static water for some parts.

The intermittent abundance of moderately fresh volcanic grains and feldspar along with volcanic pebbles and cobbles suggests that not only was the volcanic source close at hand but it may have been active during deposition of the Moolayember Formation. No tuffs have been identified to give positive support to this idea.

A much greater thickness of sediment in the Dawson Range area compared with other parts of the basin would suggest that subsidence here was more rapid or it took place over a longer period.

In the Expedition Range area a thinner section is present but the sedimentary units are thicker. This may indicate that larger rivers were present. Again cross-bedding azimuths are spread over a wide arc but the general direction was from north to south. Good exposures of channel erosion and redeposition, and probable point bar deposits, favour the "meander belt" model for deposition of these sediments. Regular small scale ripple marks associated with sandstone beds, which are generally more uniform and more extensive then further east, suggest that larger bodies of water were involved.

Further west in the Carnarvon Range area the lower sediments of the Formation (Unit C1) are very well bedded and uniformly cross-laminated near Spring Creek, suggesting deposition in a large body of water where uniform, gentle currents were operating. South of Spring Creek, at the same stratigraphic level, a thick laminated mudstone sequence containing beds of coarse-grained sandstone with megaripples may reflect an estuarine or tidal channel environment. Ripple cross sections showing current lamination in opposite directions support this contention. Root casts in water-laid sediment are an indicator of very shallow,fresh or brackish water deposition.

In the upper parts of the section there is a need for reconciliation between two lines of evidence. On the one hand many of the sediments show features of continental sedimentation-channel erosion and redeposition of consolidated sediment; wedging out of sand bodies and lateral lithology changes over very short distances; coal horizons; plant and root beds. On the other hand acritarchs (marine or brackish water microfossils) have been recorded from the upper sediments (see Appendix II).

To accommodate this evidence a suitable depositional setting would have been shallow water near a coastline where relief was low and sediment transport and deposition was, at least partly, by channels.

A delta top or an estuary are the proposed alternatives for the latter part of Moolayember sedimentation in the Carnarvon Range area. Probable palaeocurrent directions determined from the various indicators have been described in an earlier section. They imply east-flowing water during the early part which gradually swung towards the southwest in the upper part of the Formation. In terms of palaeoslope this suggests westward tilting of the area during deposition. This change in palaeocurrent direction corresponds with a change in composition from sandstones dominated by quartz in the lower part to sediments rich in volcanic and sedimentary lithic grains in the middle and upper parts.

Red beds on the Springsure Shelf area are overlain in places by exposures suggestive of point bar deposits. Hence a continental fluvial environment is tentatively proposed for at least some of the rocks of that area.

Although literature on well documented river deposits in the geologic record appears sparse, those which have been satisfactorily established (e.g. Potter and Glass 1958, Stewart 1961) have a number of features in common with Moolayember sediments. This applies also to examples of modern river sediments which have been studied (e.g. Frazier and Osanik 1961, Harms et al. 1963, Wolman and Leopold 1957).

Features common to most river deposits are:

(i) tabular and trough cross-stratification;
(ii) abundance of sand and mud, commonly with gravel;
(iii) ripple marks;
(iv) erosion structures;
(v) limited lateral extent of beds; and
(vi) lamination of some sediments.

These features characterize much of the Moolayember Formation, and although any one of them is not indicative of river sediment, their association lends strong support to the idea that much of the Formation was laid down in a fluvial environment.

LATER EVENTS

Gentle folding of the Moolayember Formation into a series of broad structures trending approximately north-south apparently took place during and after its deposition.

A period of erosion followed during which much of the sediments - particularly in anticlinal areas - was removed.

The resulting late Triassic peneplain cut across the whole of the Moolayember Formation as well as exposed parts of older formations. It is probable that desert conditions prevailed,as no dissection of the Triassic topography was observed and very little weathering of the top beds has occurred apart from colour changes which vary between white, pale grey, yellow, red-brown and mauve. The original rock is recognizable to within an inch or two of the surface and nowhere has any sign of a soil profile been observed.

SUMMARY OF POSSIBLE GEOLOGIC HISTORY

It is suggested that at the beginning of Moolayember deposition rivers carrying sediment from the north and east of the present Bowen Basin deposited their load as point bars and overbank deposits which were derived from sedimentary and volcanic source areas. Volcanic rocks were possibly being extruded at this time as their derivatives are not common in the underlying Clematis Sandstone. Volcanic activity was probably most marked east of the present Dawson Range, providing coarse clastic material for the formation of conglomerate and an abundance of other sediment which was poured into a subsiding depositional basin. In the west of the basin at about this time subsidence was slower and sediments accumulated as river and lake deposits and possibly in estuaries. Water movement was dominantly towards the southeast.

As deposition continued it is likely that the depositional area filled, hinterland topography became subdued and the resulting sediments became finer grained. Under these conditions intermittent incursions from the ocean probably took place - at least in the western part of the basin - and burial of swamps gave rise to coal formation.

Direction of movement of the depositing currents was towards the south and east in the western parts of the basin but as deposition progressed there was a swing towards the southwest near the present Carnarvon Ranges. This was possibly a result of westerly tilting of the area during deposition.

During and after gentle folding along north-south axes, much of the now consolidated sediment was removed by erosion and the whole region reduced to a peneplain, possibly under arid conditions.

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APPENDIX I.

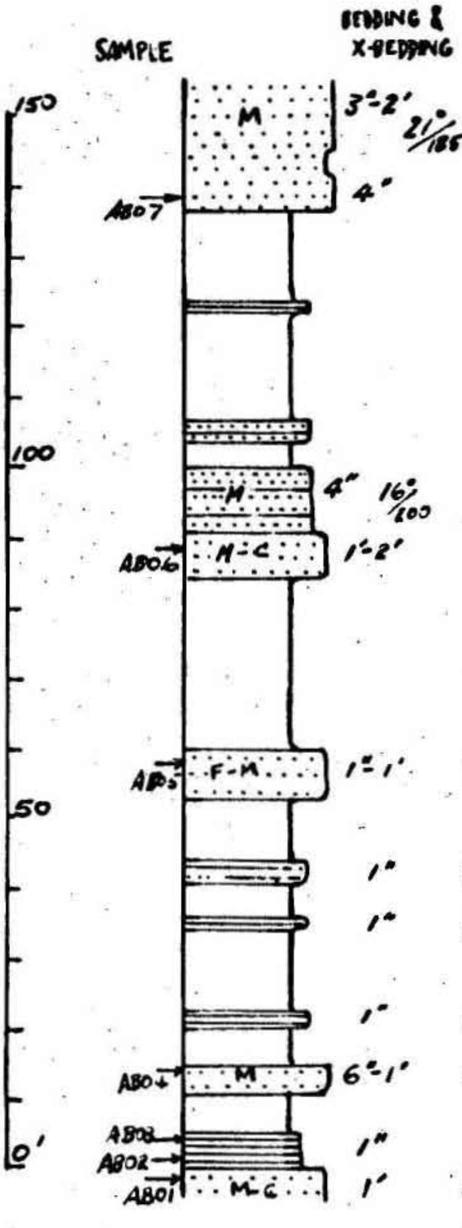
MEASURED SECTIONS

(Includes detail not shown in text).

SECTION AB

- TEVIOT FORMATION.

1:250,000 Sheet. Mt. Coolon
Grid Reference of start.- 66002783
Photo: 45, Run 7, CAB 271.
Scale.- 1" = 25'
Method.- Tape and compass.

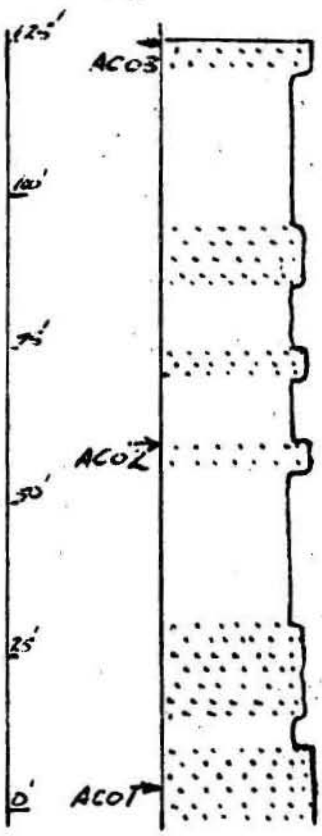


THICKNESS	DESCRIPTION
19'	Sandstone: thin to medium bedded part micaceous. Exhibits rectangular jointing; planar tabular & trough X-bedding.
1'	Grey-brown mudstone: high clay fract?
3'	Sandstone: as for AB06. interbedded with soft brown micaceous mudstone.
10'	Sandstone: as for AB06 but more flaggy, contains thin mudstone beds.
7'	Quartz lithic sst: grains range to fine pebble size; low angle x-bedding has variable orientation; white clay matrix.
7'	Brown sandstone: micaceous, grey-weathering cross-bedded. Contains calc infilling of joints, partings.
3'	Micaceous mudstone: grades to very fine sst.
2'	Greenish brown mudstone
2'	Brown micaceous mudstone
4'	Brown lithic sandstone: contains biotite and specks red iron oxide.
5'	Brown, micaceous mudstone; calc. veins.
	Base of section: Grey-brown quartz-lithic sandstone; med.-coarse, friable, X-bedded.

TEVIOT FORMATION . SECTION AC

1:250,000 Sheet : Mt Coolon
Grid Reference : 658280
Photo : Mt Coolon Run 7, photo 45
Scale : ¾" = 25'
Method : Jacob staff

SAMPLE



BEDDING	THICKNESS	DESCRIPTION
Thin	5'	Sandstone : grey-brown, fine to medium grained, part micaceous. Forms highest stratigraphic point for Teviot Fm. in this area.
		Rubble slope
Medium	10'	Sandstone : poor outcrop
		Rubble slope
Thick	5'	Sandstone : poor outcrop
		Rubble slope
Medium	5'	Sandstone . cross bedded.
		Rubble slope.
Medium	15'	Sandstone : poor outcrop ; part ferruginous.
Thick	10'+	Sandstone : crossbedded, forms top of scarp.

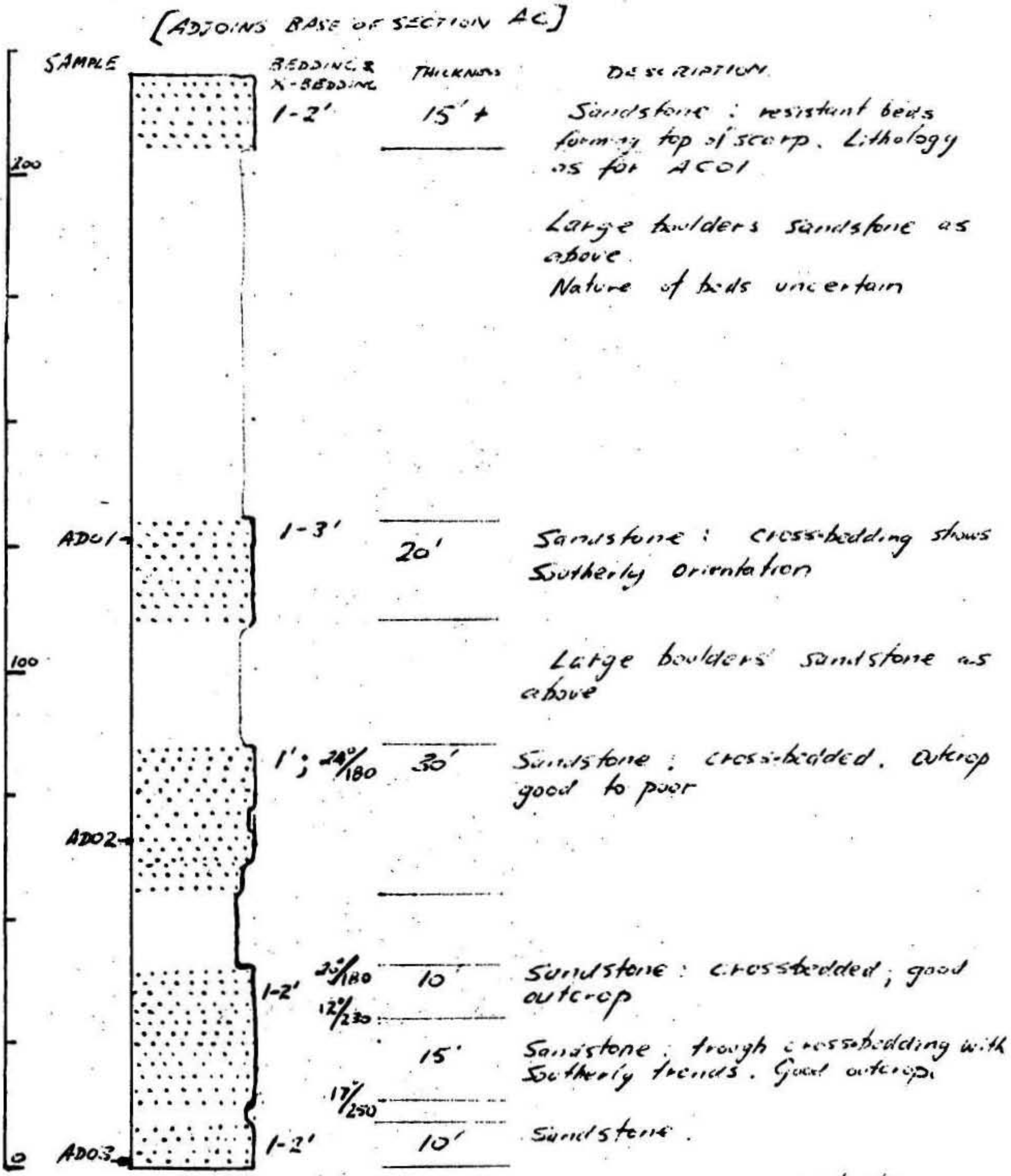
ADJOINS TOP OF SECTION AD.

To accompany BMR Record 1969/43

F55/A7/10

TEVIOT FORMATION - SECTION AD

1:250,000 Sheet: Mt Coolon
Grid Reference: 658280
Photo : Mt Coolon Run 7, photo 45
Scale : ¾" = 25'
Method. : Jacob staff.

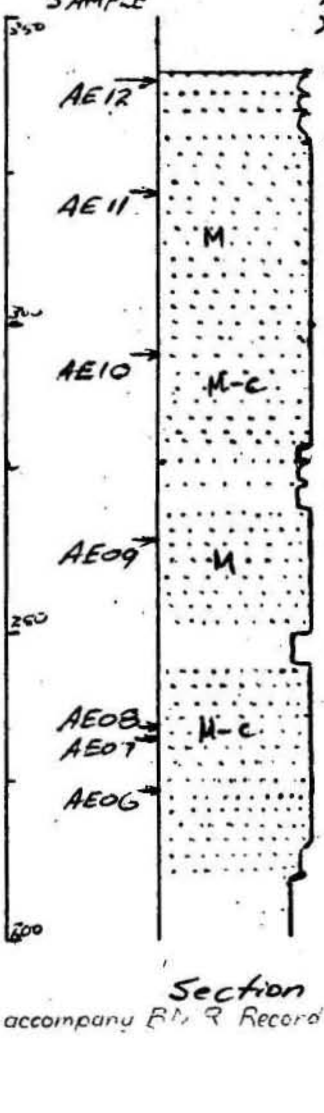


To accompany BMR Record 1969/43

F55/A7/11

TEVIOT FORMATION - SECTION AE

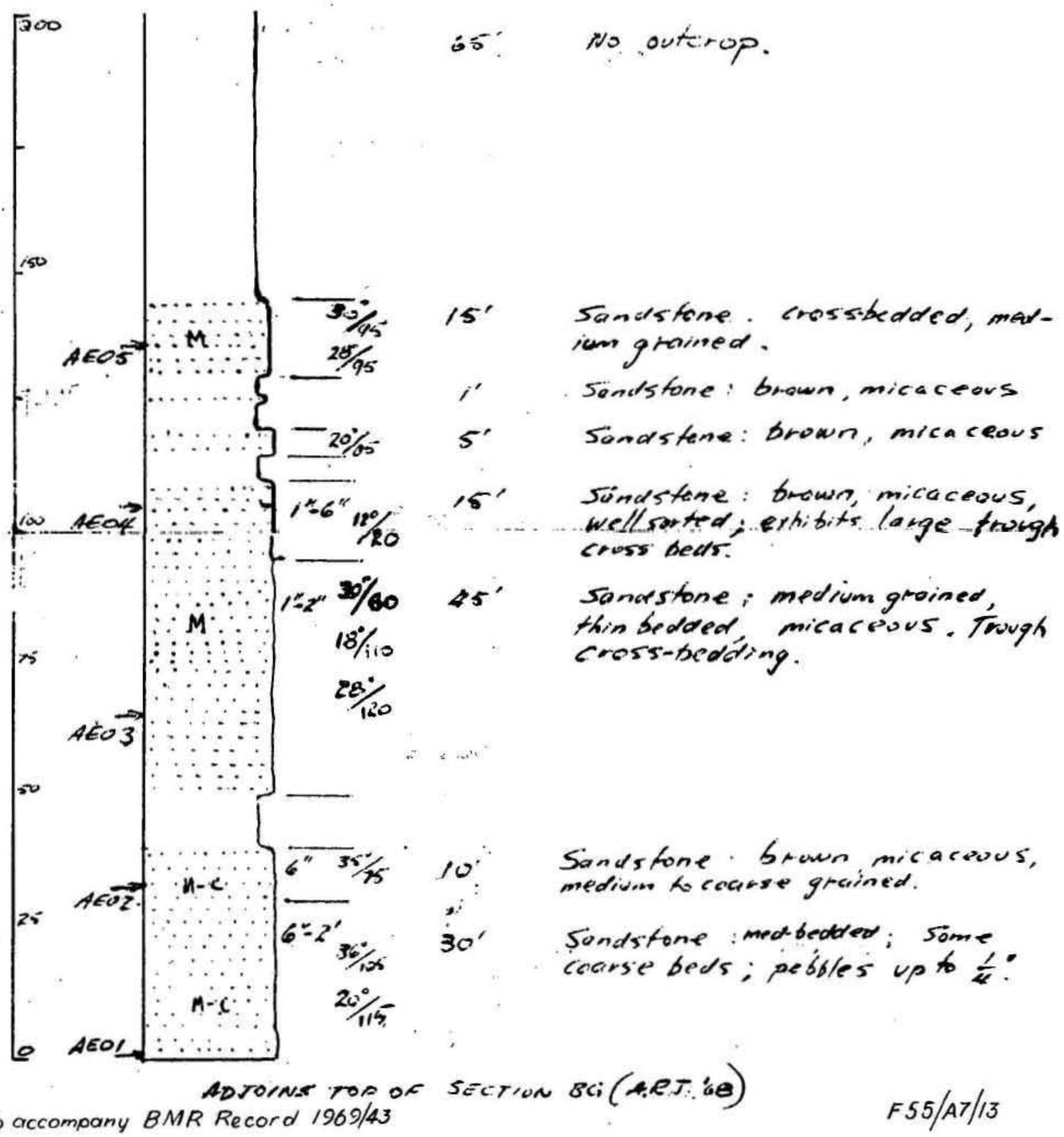
1:250,000 sheet : Mount Coolon
Grid Reference : 654289
Photo : Mount Coolon Run 6, photo 78
Scale 3/4" = 25'
Method: Jacob staff



SAMPLE	BEDDING & X-BEDDING	THICKNESS	DESCRIPTION
AE12	2"-6"	12'	Thin beds sandstone in soil
AE11	2"	30'	Sandstone: brown, thin bedded, part micaceous, medium grained.
AE10	1'-2'; 28/85, 30/116	20'	Sandstone: medium to coarse grained, good outcrop; trough cross bedding
	2"-4"	10'	Thin beds sandstone in soil
AE09	4"-2'	20'	Sandstone: brown, medium grained.
		5'	No outcrop
AE08, AE07, AE06	<2'	30'	Sandstone: medium to coarse; contains dark specks, pebbles up to 1/4" Exhibits ?mud clast impressions on some bedding surfaces.
		5'	Sandstone: poor outcrop.

Section AE continued over page

Section AE continued.



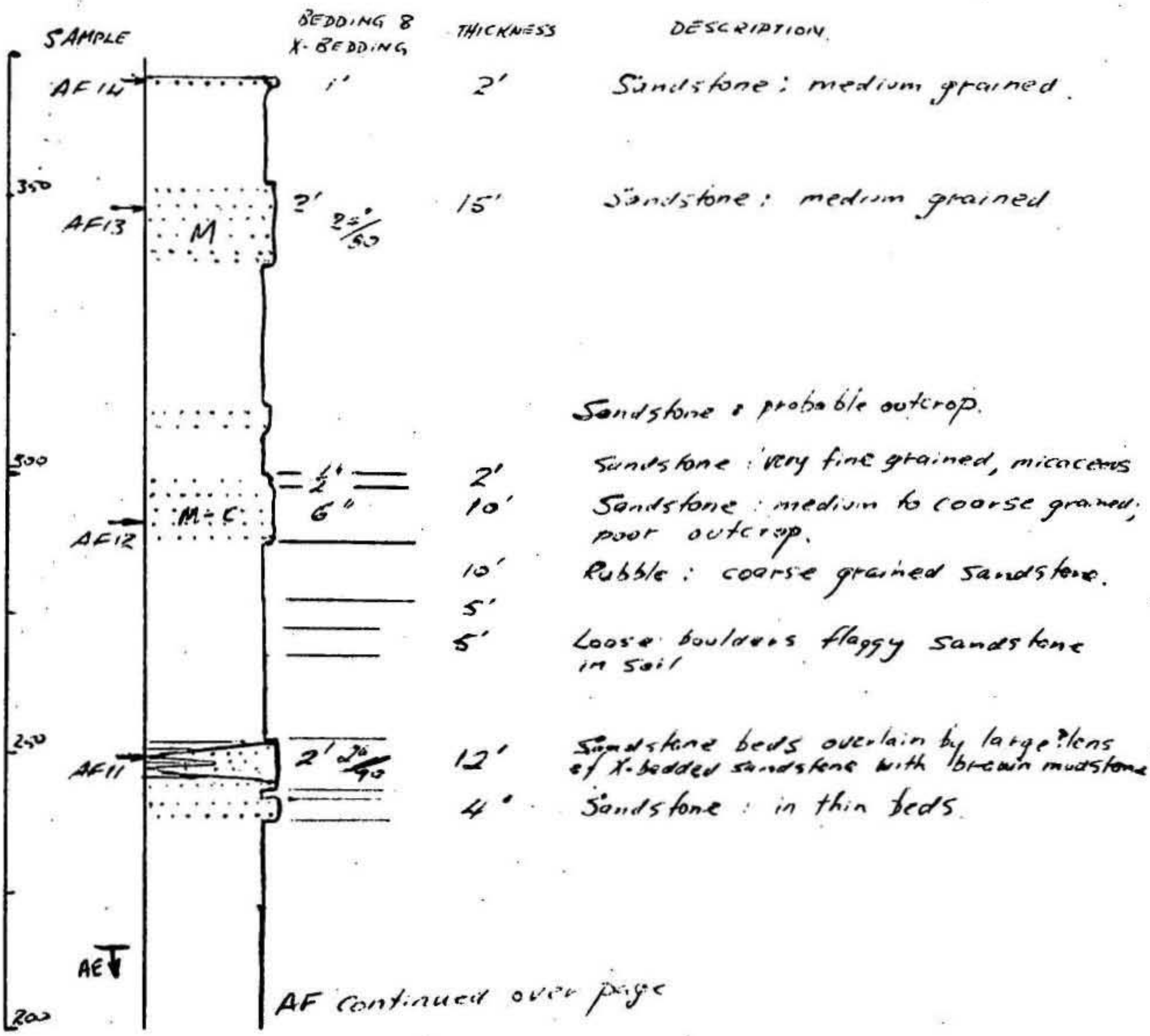
ADJOINS TOP OF SECTION BG (A.R.J. '68)

To accompany BMR Record 1969/43

F55/A7/13

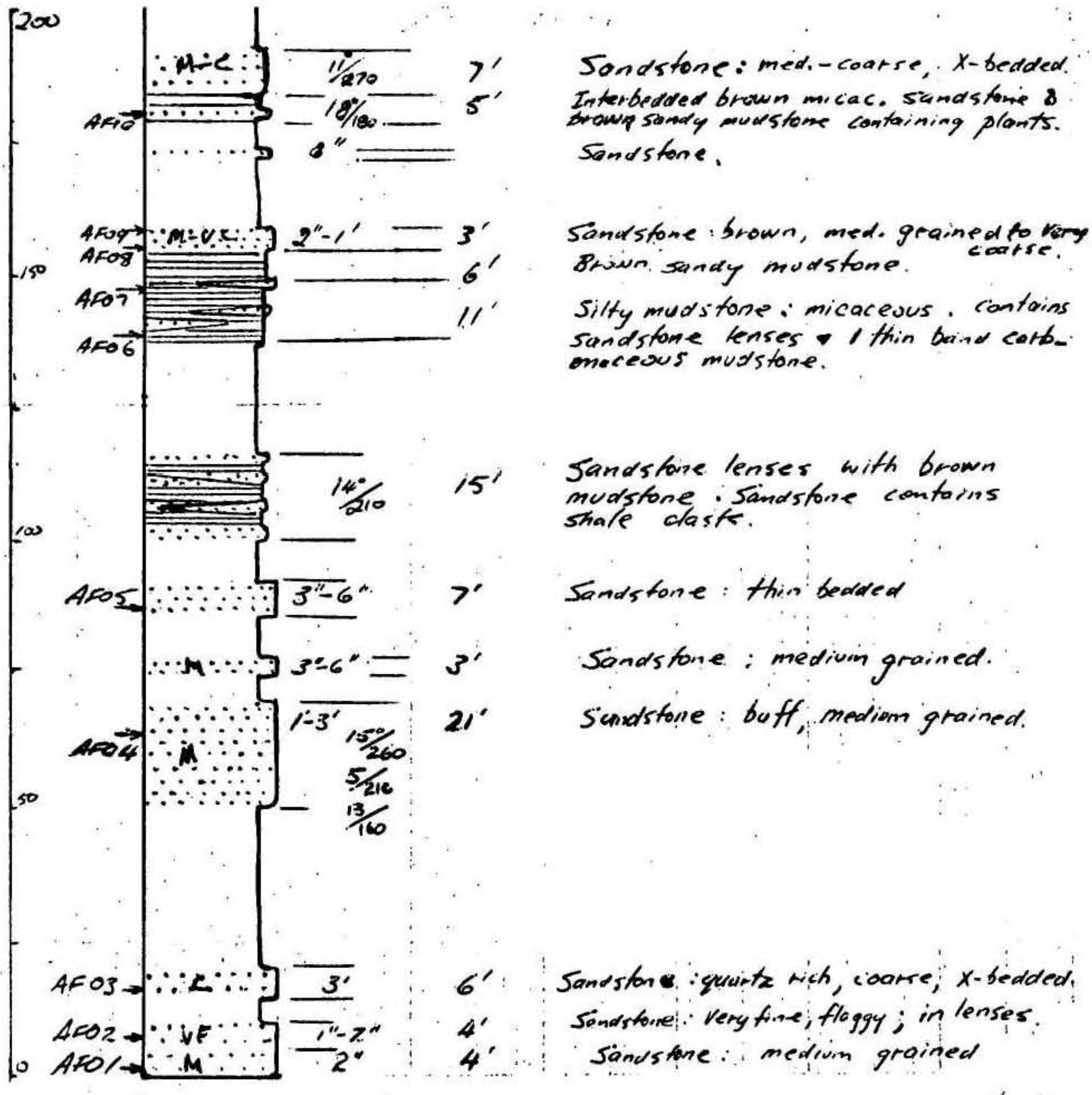
TEVIOT FORMATION - SECTION AF

1:250,000 sheet : Mount Coolon
Grid Reference : 654290
Photo : Mount Coolon Run 6, photo 78
Scale : ¾" = 25'
Method: Compass & tape, Jacob staff.



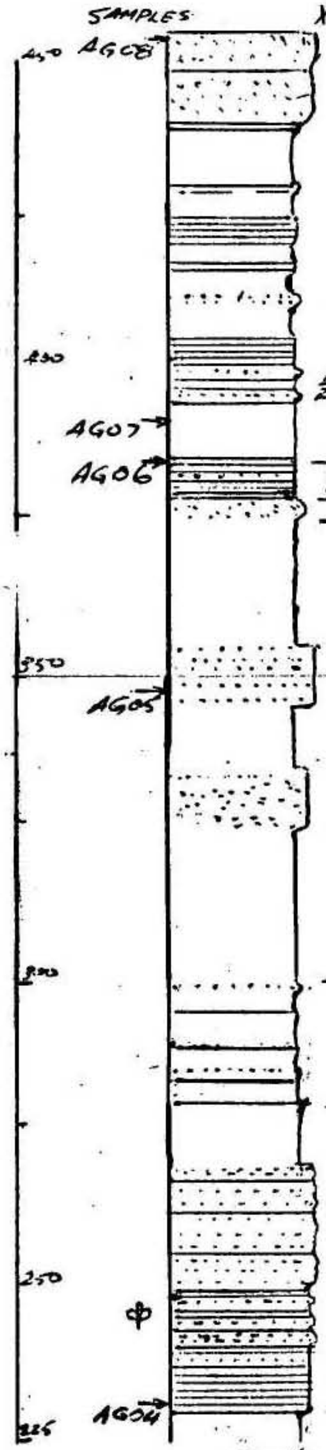
AF continued over page

Section AF continued.



TEVIOT FORMATION SECTION AG.

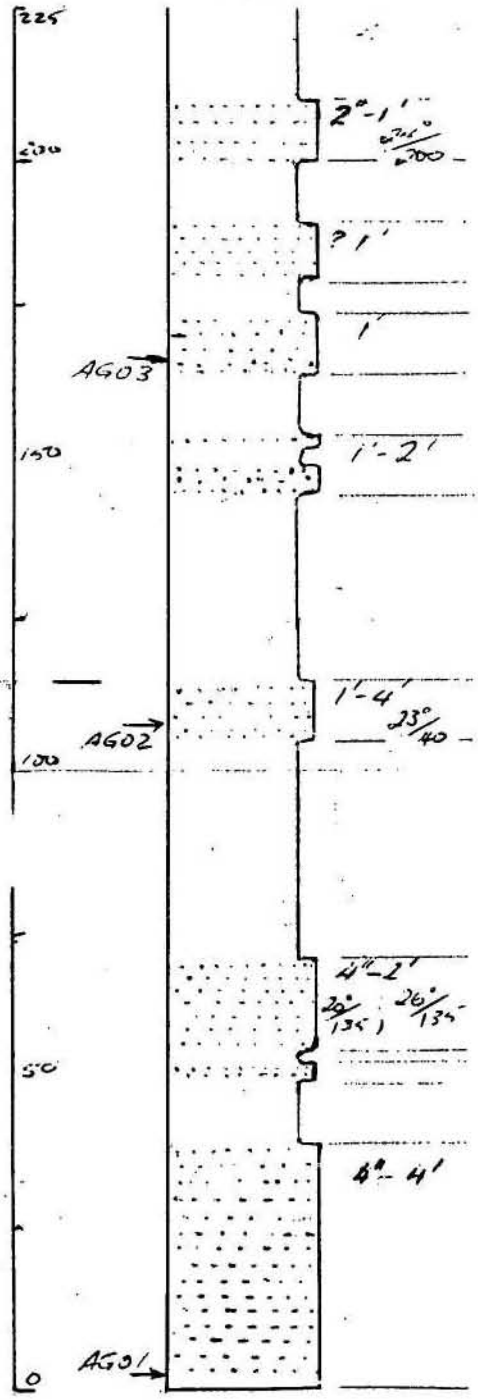
1:250,000 Sheet: Mount Coolon
Grid Reference: 656280
Photo: Mount Coolon, Run 7, photo 45
Scale: ¾" = 25'
Method: Jacob staff.



Samples	Bedding & X-Bedding	Thickness	Description
AG08	2"	15'	Sandstone: fine to medium, flaggy, micaceous. Minor beds mudstone.
		2'	Brown mudstone
		2'	Mudstone: grades to siltstone.
		5'	Grey-brown mudstone.
			Grey-brown mudstone
	2"	2'	Sandstone: very fine, silty.
		5'	Brown mudstone: part micaceous
	½"-4"	5'	Interbedded sandstone & brown mudstone.
AG07		10'	Brown & grey mudstone & claystone
AG06	½"-2"	8'	Brown mudstone grading to claystone. Minor plant fragments. Interbeds grey-brown mudstone, grey carbonaceous mudstone & fine to med. sandstone.
	2'	3'	
AG05	1'-3'	10'	Sandstone: pinkish brown, medium to coarse grained.
		10'	Sandstone: med grained; poor outcrop.
		20'	Some thin beds mudstone & med. grained sandstone.
	½"-1'	20'	Interbedded medium sandstone, micaceous very fine sandstone & minor flaggy mudstone.
⊕	1"-6"	12'	Interbedded sandstone & flaggy mudstone. Some mudstone contains well-preserved plants.
AG04	1"	8'	Mudstone: flaggy, micaceous, contains plant fragments

Section AG continued over page

Section AG continued

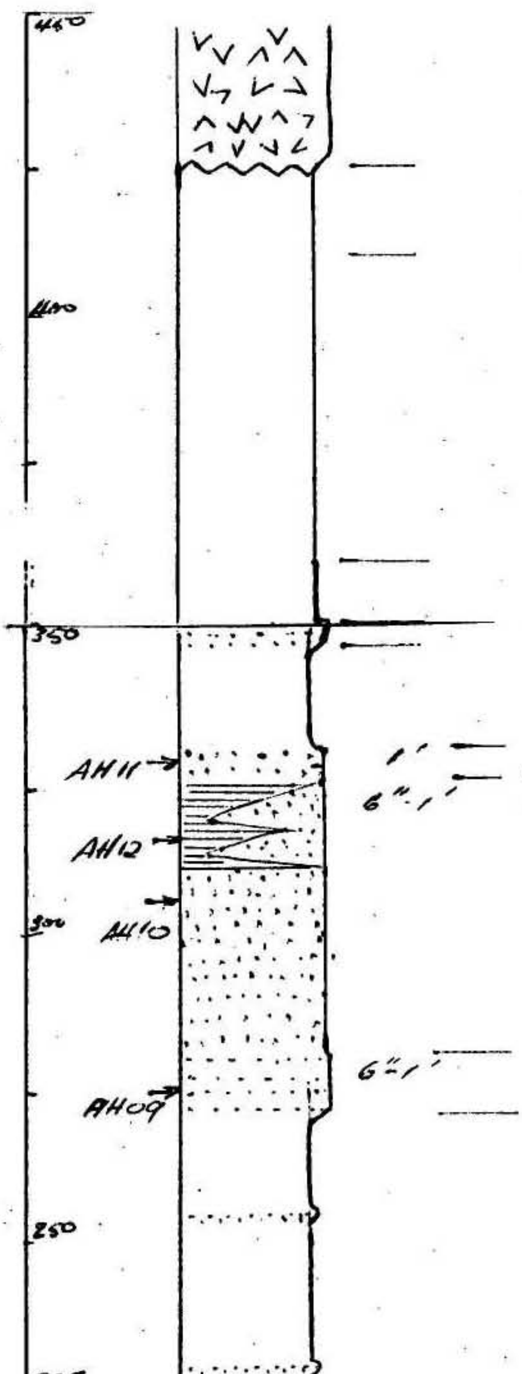


Bedding	Thickness	Description
2"-1' (25°/200)	10'	Sandstone.
?1'	10'	Sandstone: med. grained; poor outcrop.
1'	10'	Sandstone: med. bedded, med.-coarse, part micaceous, X-bedded.
1'-2'	10	Sandstone & minor no outcrop. Med. to coarse grained, cross-bedded.
	15'	No outcrop but fragments brown micaceous mudstone with plants appears in place.
1'-4' (23°/40)	10'	Sandstone: med. to very coarse.
4"-2' (20°/135, 26°/135)	15'	Sandstone: med. bedded, med. to coarse grained.
	3'	Sandstone: med. to coarse.
4"-4'	40'	Sandstone med-thick bedded, cliff-forming, medium to coarse grained, becoming very coarse & friable at top. Cross bedded.

CARBOROUGH SANDSTONE & TEVIOT FORMATION

- SECTION AH -

1:250,000 Sheet Mount Coolon
Grid Reference : 844 354
Photo Mount Coolon, Run 2, photo 66
Scale : 3/8" = 25'
Method Jacob Staff



Tertiary basalt.

15'+ No outcrop but extensive rubble med. sandstone & floggy micaceous mudstone.

50' No outcrop

10' No outcrop but brown mudstone in soil.

3' Sandstone

5' Grey sandstone : medium grained.

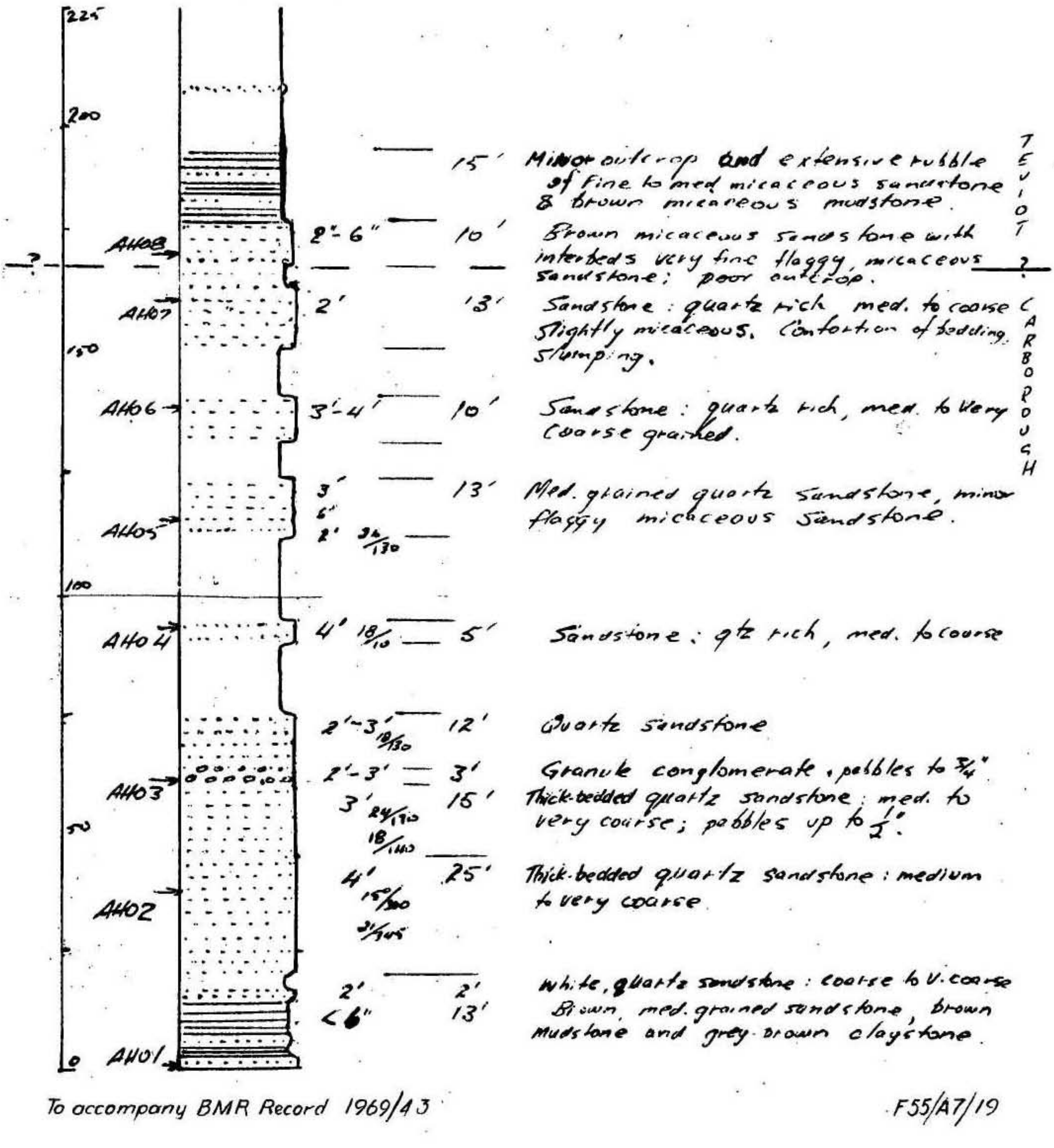
45' Sandstone : argillaceous with some mudstone pellets. Micaceous & calcareous in part; medium grained. Upper 15' apparently a sandstone lens in brown mudstone.

10' Grey calcareous sandstone : medium grained, lustre mottling.

75' Mostly no outcrop but occasional 1' sandstone beds.

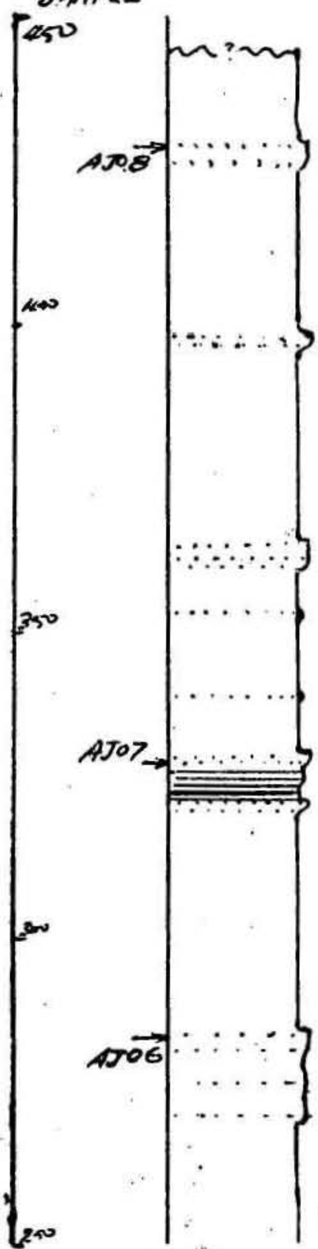
Section AH continued over page

Section AH continued.



CARBOROUGH SANDSTONE & TEVIOT FORMATION
SECTION AJ

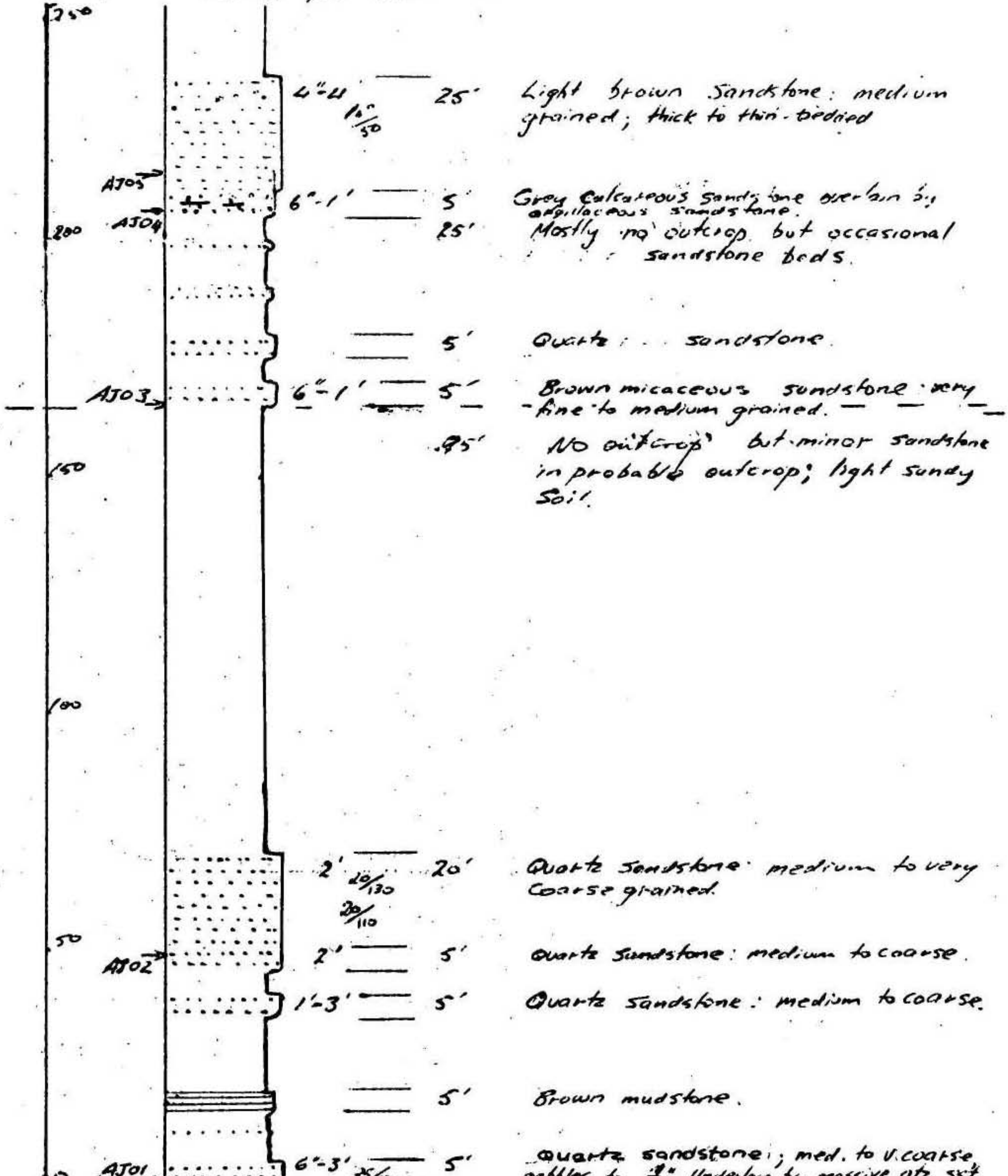
1:250,000 Sheet : Mount Coolon
Grid Reference : 640364
Photo : Mount Coolon, Run 2, Photo 66
Scale ¾" = 25'
Method. Jacob Staff



SAMPLE	BEDDING & X-BEDDING	THICKNESS	DESCRIPTION
			Siliceous sandstone : Tertiary.
		15'	No outcrop: Teviot type sandstone rubble & abund. billy scree.
AJ08	1'	5'	Probable outcrop med. to coarse, buff coloured sandstone.
	2"-1'	3'	Brown micaceous sandstone. fine - med.
		30'	No outcrop : some flaggy mudstone fragments in soil.
	4"-1'	5'	Brown sandstone : med. grained, micaceous.
		30'	No outcrop except occasional beds fine grained micaceous sandstone.
AJ07	4"-1'	10'	Brown, med. grained sandstone with shale clasts & minor plant fragments;
	6"-1'		grey silty mudstone.
AJ06	1'-4"	15'	Brown quartz lithic sandstone; medium grained, poor outcrop.
		35'	No outcrop. light brown sandy soil.

Section AJ continued over page.

Section AJ continued

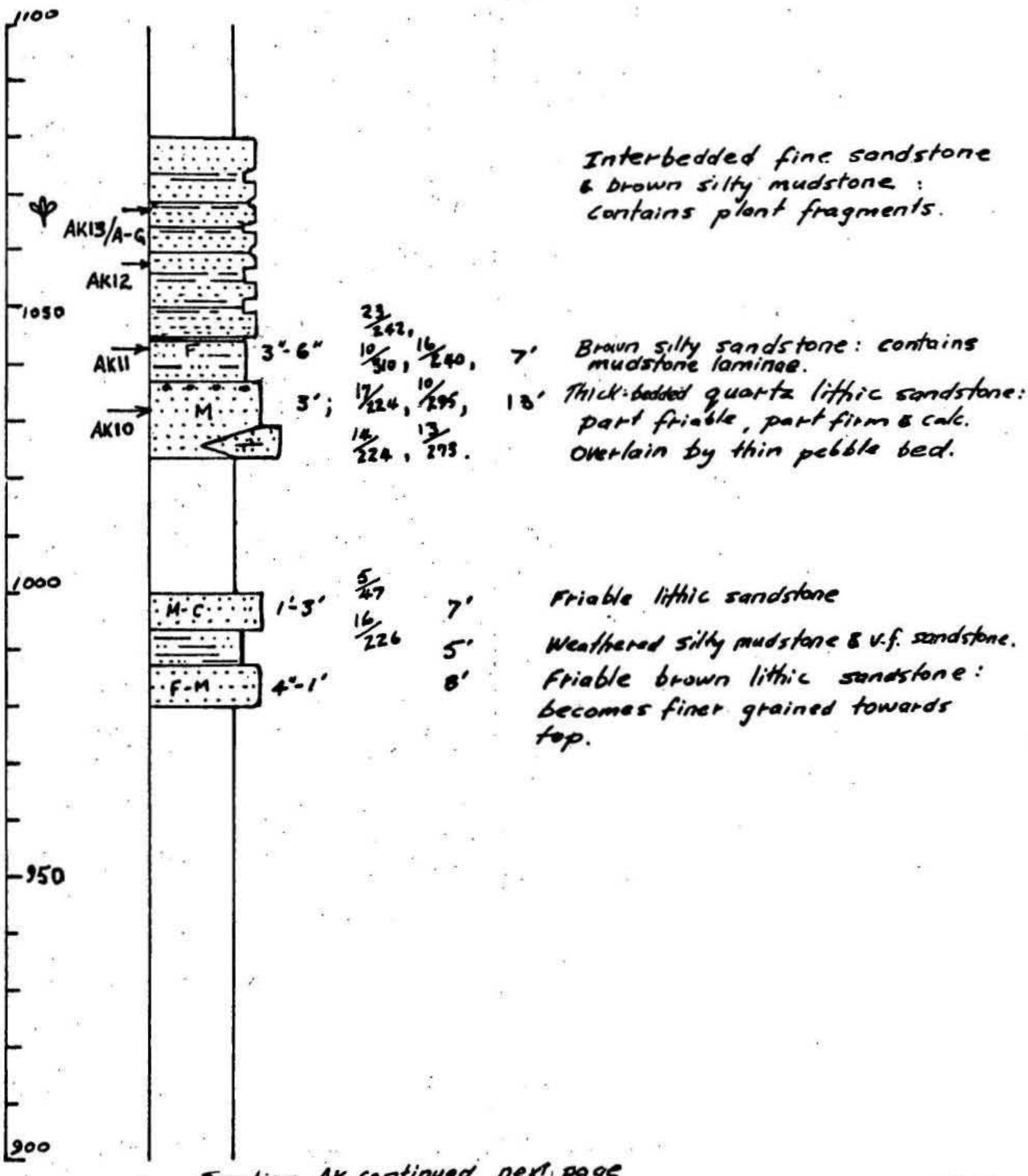


To accompany BMR Record 1969/43

F55 A7/21

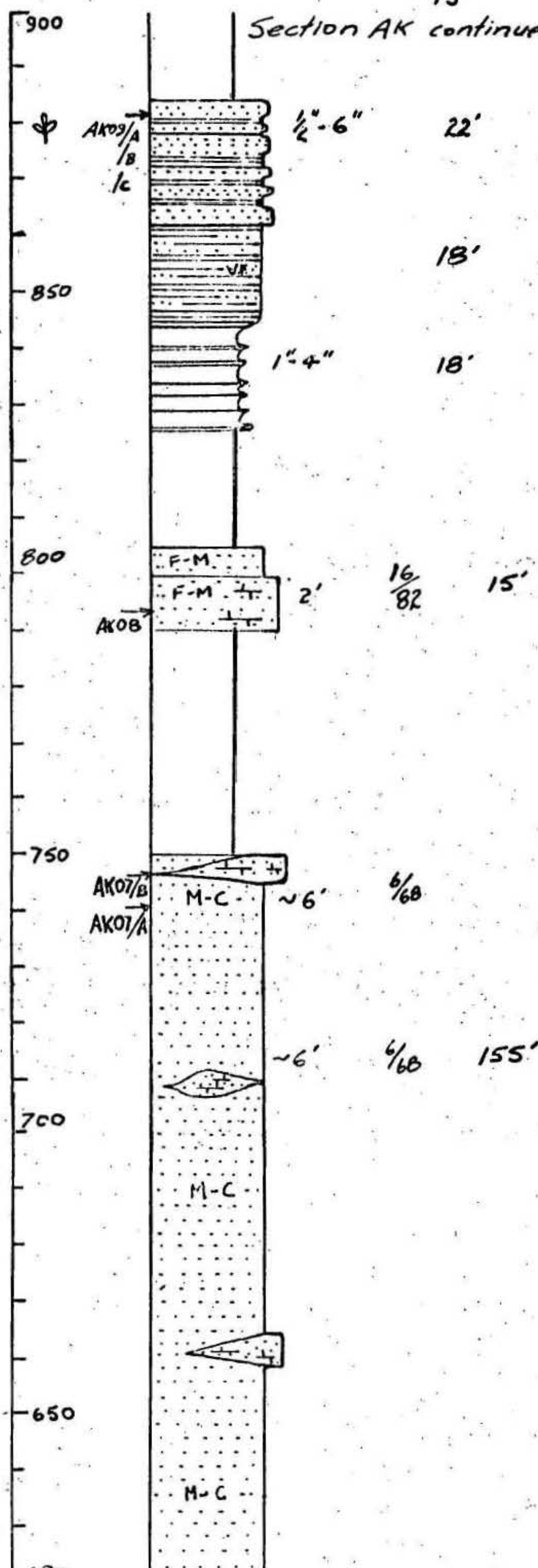
SECTION AK - MOOLAYEMBER FORMATION.

1:250,000 Sheet .- TAROOM
Grid Reference of start.- 28478770
Photo .- 5058, Run1, CAB 210
Scale.- 1" = 25'
Method.- Tape & compass.



Section AK continued next page

Section AK continued



Interbedded quartz lithic sandstone & grey-brown mudstone: contains plant fossils

Brown mudstone, dk. grey mudstone: grades to silty very fine sandstone.

Thin beds brown mudstone

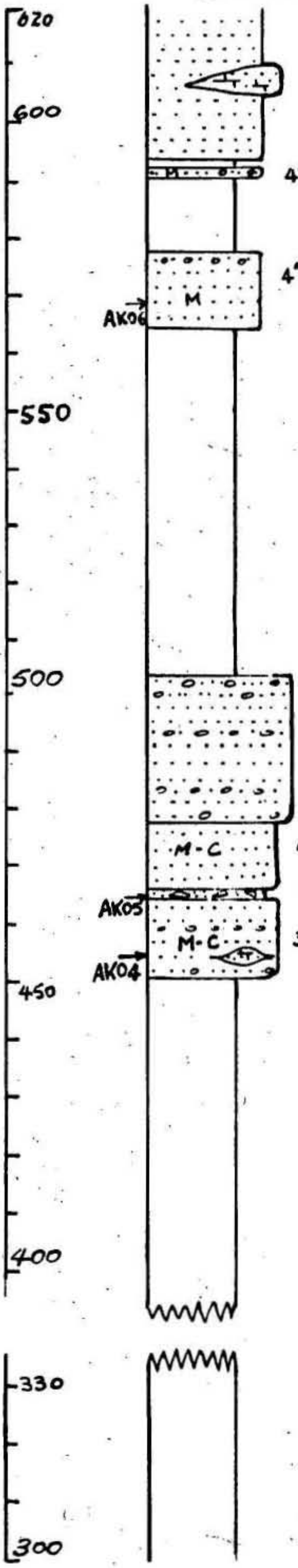
Grey calcareous quartz lithic sandstone; overlain by brown weathered sandstone.

Thick-bedded quartz lithic sandstone: mostly friable and weathered but some resistant nodules and lenses cemented with calcite

Bedding is undulose but thick; no flat regional bedding planes.

Section AK continued on next page

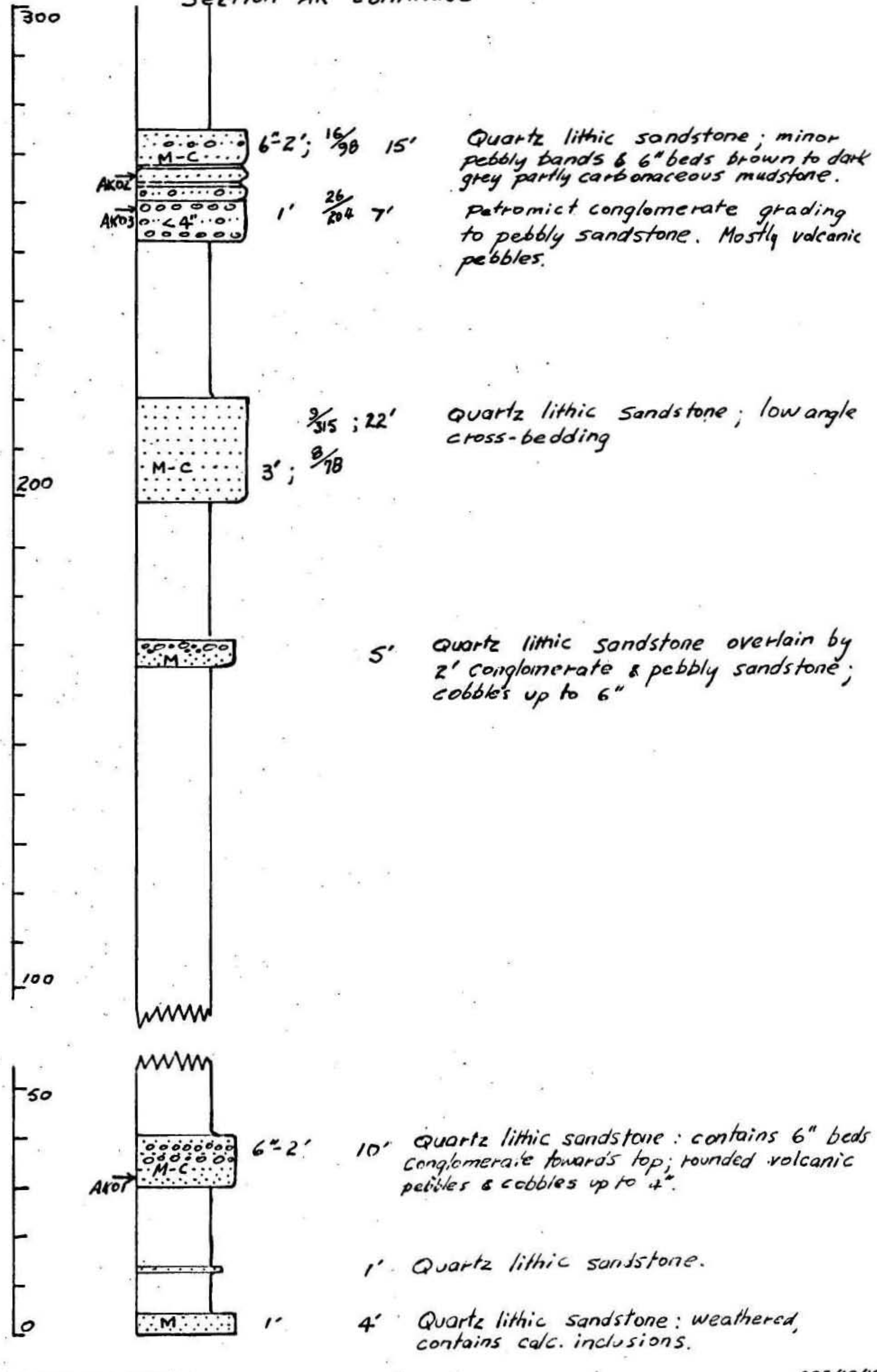
Section AK continued



4"	12/102	2'	Friable lithic quartz sandstone with pebble bed
4"-2'	13/273 13/256	14'	Lithic quartz sandstone: well-sorted, friable; dark minerals produce lamination & define X-beds. Extensive calc. veining. Minor pebbles towards top.
1'-5'		26'	Strongly outcropping, thick-bedded quartz lithic sandstone: Pebbly bands, calc. bands. X-beds poorly defined, low angle. Some horizons with mud clasts.
1'-4'	14/241	11'	Med-thick bedded qtz lithic sandstone.
		1½'	Lithic sandstone with abund. mud clasts
3'-6'	9/60	13'	Thick bedded quartz lithic sandstone with pebble beds, calc. nodules.

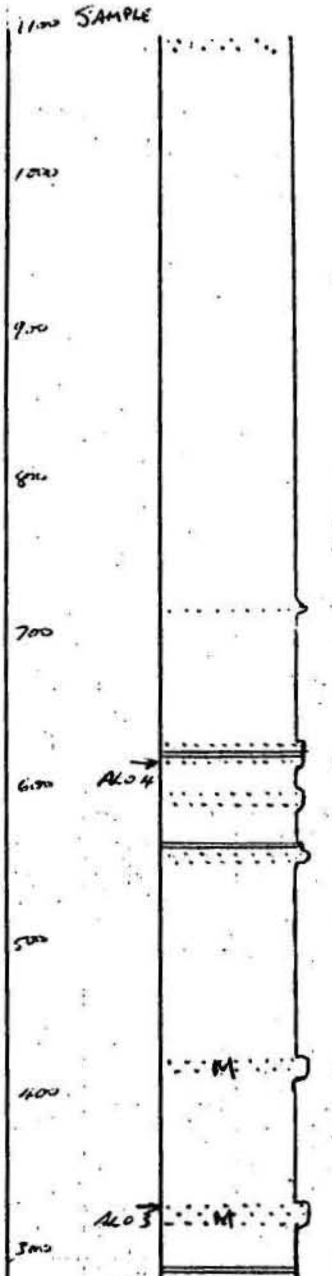
Section AK continued on next page

Section AK continued



SECTION AL MOOLAYEMBER FORMATION

1:250,000 sheet TAROOM
Grid Reference of start 2833 8783
Photo TAROOM, Run 1 CAB 210 - 5058
Scale 3/4" = 100'



Section ends at base of steep slope and along strike from base of section AM. ? o/c of weathered sandstone.

No outcrop Fine sandy & silty soil.

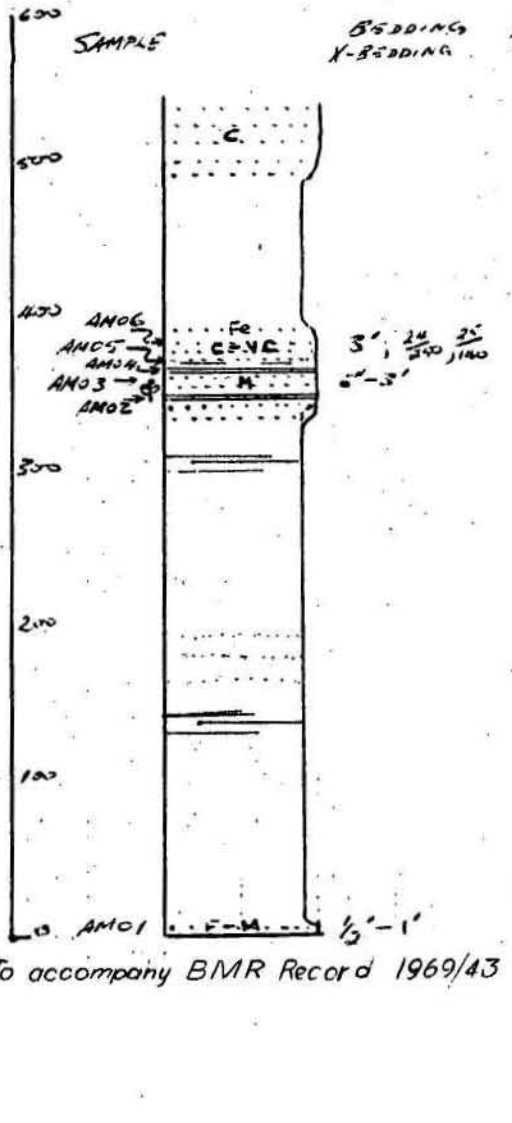
BEDDING & X-BEDDING	THICKNESS	DESCRIPTION
	2'	Brown lithic sandstone
		No outcrop: Mostly sandy soil.
1-2'	15'	Fine silty sandstone; Brown mudstone; Med-bedded, light brown lithic sandstone
	12'	Brown, highly weathered, silty sandstone
	2'	Thin bedded lithic sandstone
		No outcrop: Brown mudstone frags. in soil.
1-2'	10'	Med.-bedding, med.-grained lithic sandstone
		No outcrop: Brown mudstone in soil with minor sandstone rubble.
	13'	Med. grained calcareous lithic sandstone
		Minor brown mudstone beds in soil
1-2'; 15/355; 14/305, 23/300, 23/30	9'	Calcareous lithic sandstone with low angle cross bedding
	5'	Brown massive mudstone
1-2'	2'	Thick-bedded, med. grained, calcareous lithic sandstone - poor outcrop

No outcrop: Brown loam becoming sandy upwards. / Grey-brown loamy soil

Commence on dip slope of sandy soil with rounded volc. pebbles

SECTION AM MOOLAYEMBER FORMATION

1:250,000 Sheet: TAROOM
Grid Reference of start 281 878
Photo: TAROOM Run 1 CAB210 - 5058
Scale. $\frac{3}{4}$" = 100'
Method. Jacob Staff



DESCRIPTION

Massive, cross-bedded coarse quartz sandstone: Precipice Sandstone.

60'
- Ferruginized quartz-lithic sandstone
- Thick-bdd, coarse grained, quartz lithic sandstone
- 2' Beds pale grey, hard mudstone with plants: ?tuff.
- Thick-bdd. pinkish brown lithic sandstone

Mudstone fragments common in soil

?outcrop of lithic sandstone beds.

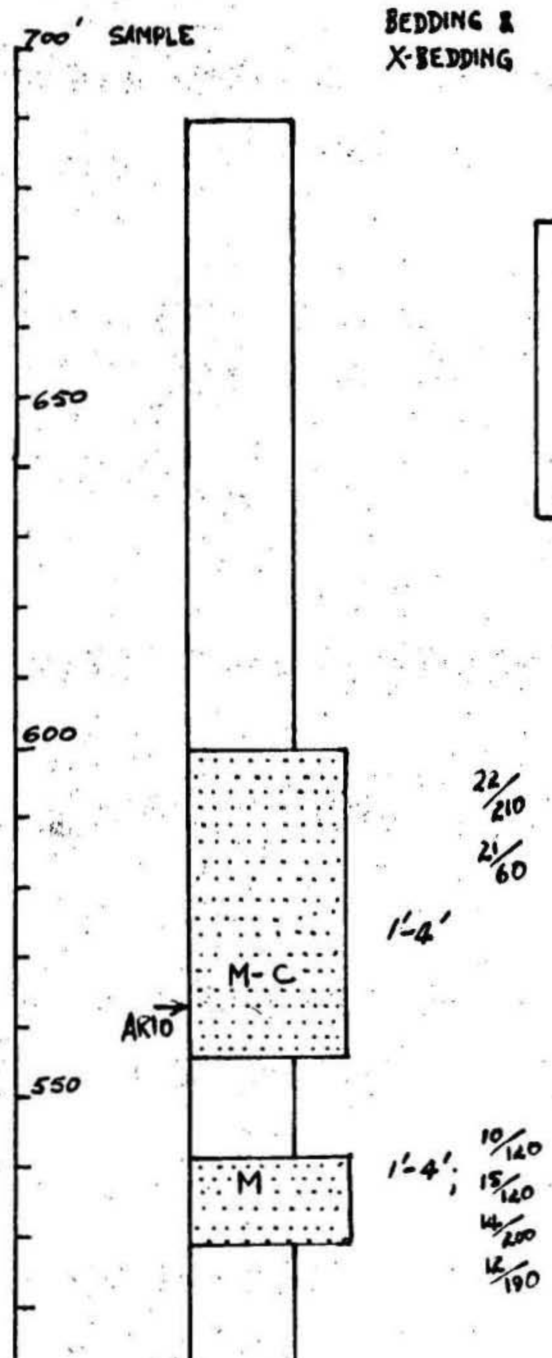
Mudstone fragments common in soil

5' Fine to med. grained lithic sandstone

To accompany BMR Record 1969/43

G55/A8/20

SECTION AR - MOOLAYEMBER FORMATION

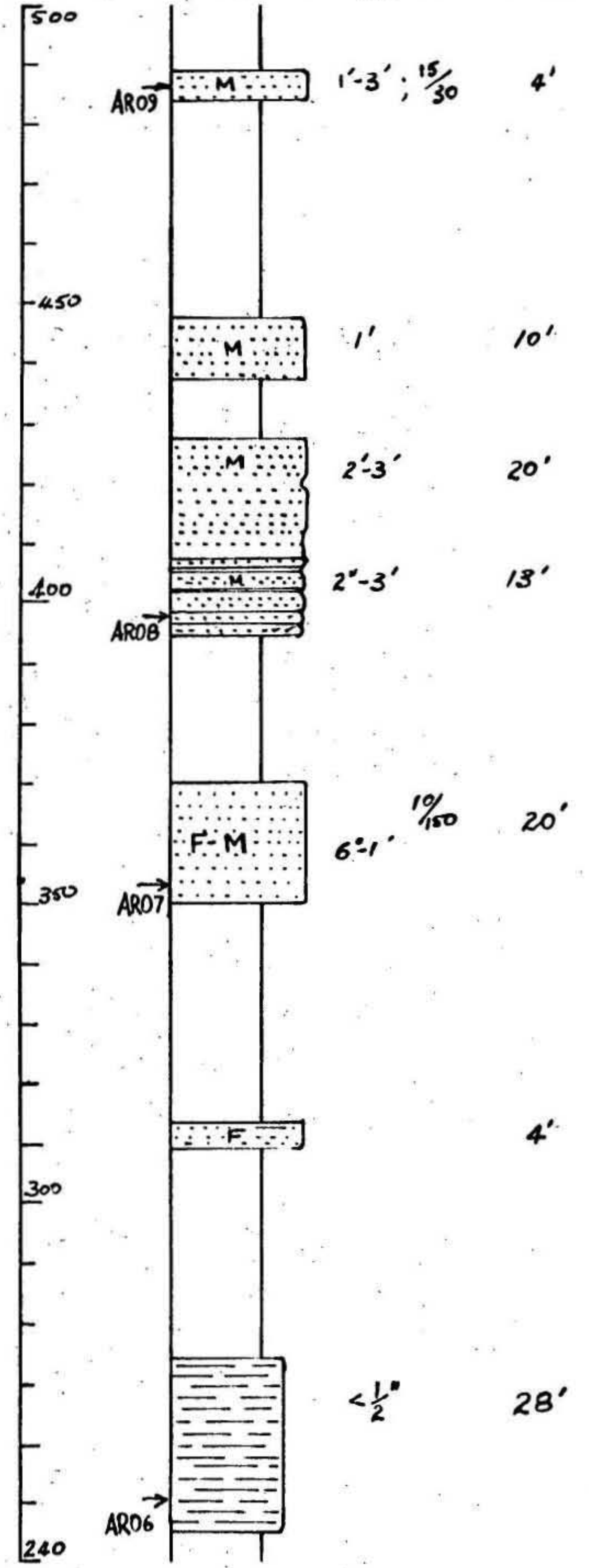


1:250,000 Sheet :- TAROOM
Grid Reference of Start.- 1361B634
Photo.- 5043, Run 2, CAB 209
Scale.- 1"=25'
Method.- tape & compass.

THICKNESS	DESCRIPTION
47'	Lithic sandstone : pale green-grey, part calcareous; medium- to thick-bedded. Appears slumped in parts.
15'	Lithic sandstone : medium to thick-bedded.

Section AR continued on next page

Section AR continued



Lithic sandstone: medium to thick - bedded.

Lithic sandstone: med.- bedded, Small scale x-bedding; rib & furrow structures indicate current direction towards 180°

Discontinuous outcrop of lithic sandstone : medium to thick - bedded.

Firm, brown, lithic sandstone interbedded with grey-brown mudstone. Very well bedded; no x-bedding.

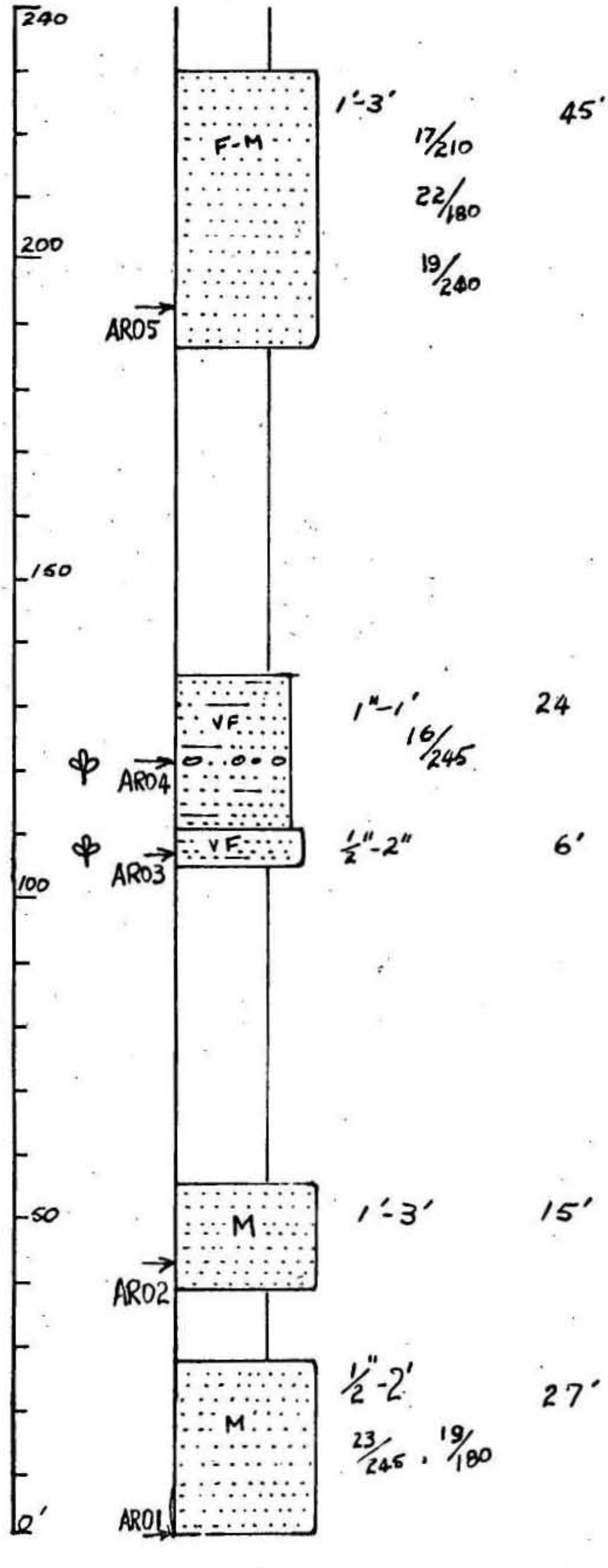
Brown, lithic sandstone : calcareous in part. Contains minor plant fossils, carbonaceous fragments. Becomes flaggy towards top.

Flaggy fine-grained sandstone

Laminated siltstone : cross - laminated

Section AR continued on next page

Section AR continued



Lithic quartz sandstone: pale yellow-brown, med. to thick bedded; flaggy towards top.

Silty, very fine sandstone: laminated; contains 3" band ferrug. conglomerate with coalified plants.

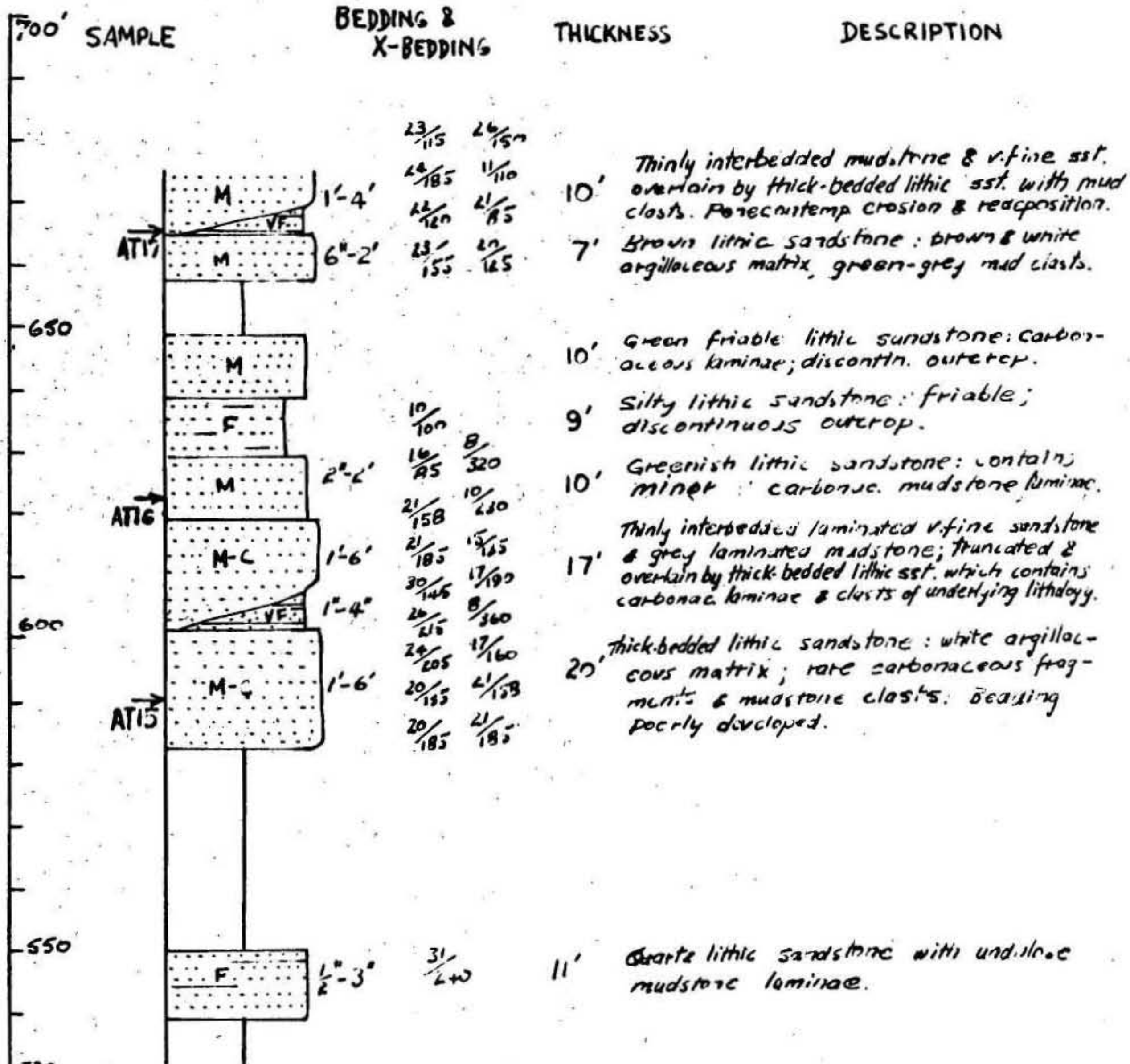
Silty, very fine sandstone: Contains plant fossils.

Porous, lithic quartz sandstone: micac. carbonac. laminae in parts. generally medium to thick - bedded.

Micaceous lithic quartz sandstone: flaggy & laminated to med. bedded; contains mud clasts & carbonaceous laminae in parts.

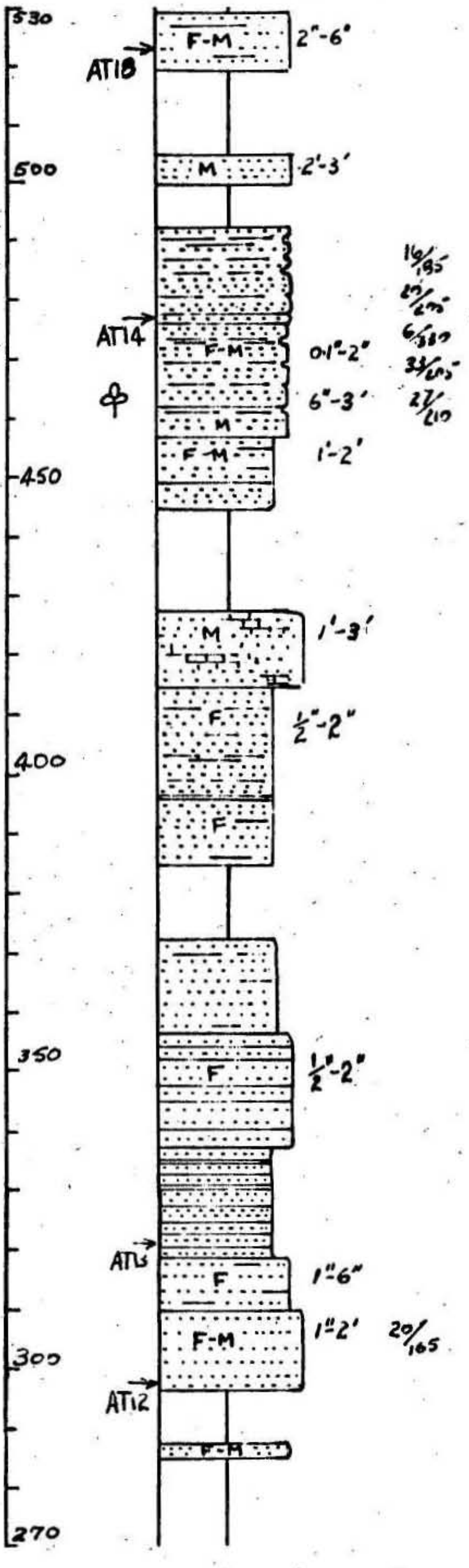
SECTION AT - MOOLAYEMBER FORMATION

1:250,000 Sheet.- TAROOM
Grid Reference of start.- 14228603
Photo.- 5055, Run3, CAB 209.
Scale.- 1"=25'
Method.- tape & compass.



Section AT continued on next page

Section AT continued



8' Lithic quartz sandstone: undulose, carbonaceous, micaceous mudstone laminae; Root casts & tubes of unknown origin are common.

5' med. bedded lithic sandstone.

35' Interbedded lithologies: (1) Medium bedded quartz lithic sandstone with micaceous, carbonaceous mudstone laminae; part calcareous, cross-laminated (2) 1"-1' beds of less resistant, finely laminated grey-brown mudstone & very fine sandstone; contain undulose laminae, plant fragments.

13' Quartz lithic sandstone: contains plant fossils, mudstone laminae. Higher lithic content than underlying sandstones.

12' Calcareous lithic quartz sandstone: exhibits lustre mottling.

30' Silty, fine grained quartz lithic sandstone: contains mudstone laminae; interbedded with silty mudstone containing plant impressions & carbonaceous fragments. Broad, low angle trough X-beds in flaggy sandstone.

16' Quartz lithic sandstone: grades to siltstone & contains brown mudstone laminae.

13' Quartz lithic sandstone with undulose mudstone laminae.

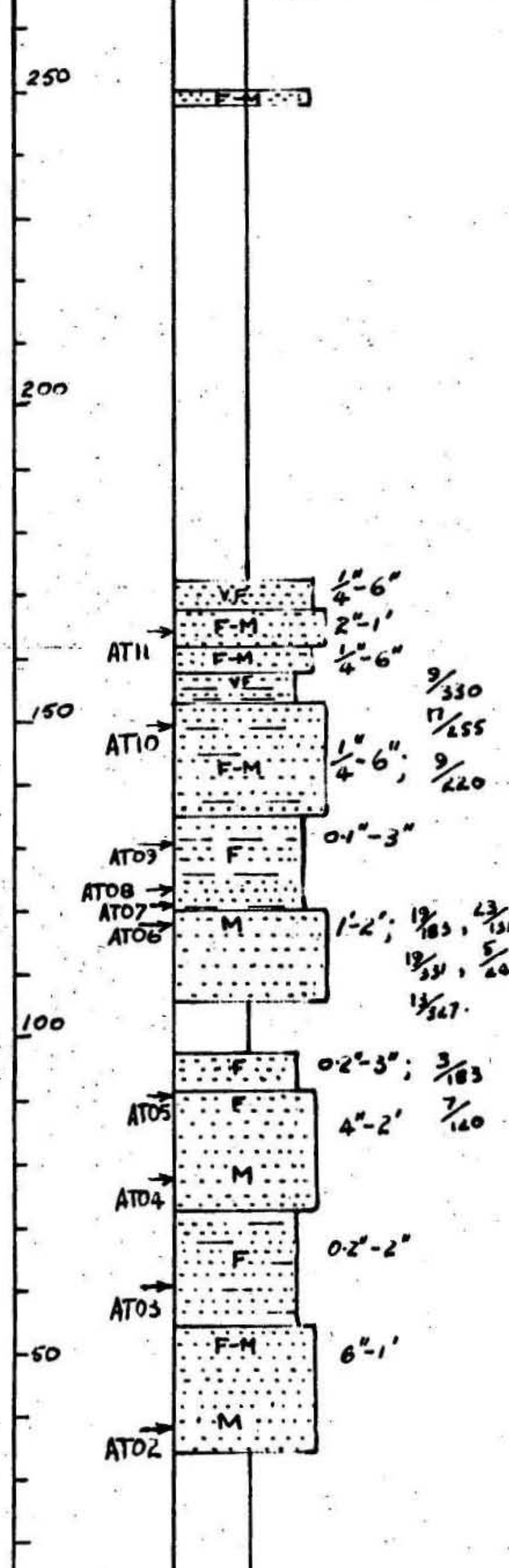
18' Interlaminated fine lithic qtz sandstone & brown mudstone. Mudstone occurs as undulose laminations; it becomes more abundant & more carbonaceous upwards.

8' Silty lithic qtz sandstone: dark carbonaceous laminae, minor mudstone laminae.

13' Pale brown qtz lithic sandstone: cross lamination well developed in 1" sets. Rib & furrows developed on surfaces - random orientation.

2' Pale yellow-brown lithic quartz sandstone: low angle X-bedding.

Section AT continued



2' Buff-coloured quartz lithic sandstone: contains dark carbonaceous, micaceous laminae. X-bedding orientations variable.

4' V.F. Flaggy qtz. sandstone: some carb. laminae

6' White qtz sandstone: grey mudstone blebs

4' Pinkish brown quartz sandstone.

5' Interlaminated v.fine sst. & siltstone: cross-lamination towards arc 340°-360°

18' Lithic qtz. sandstone: contains carbonac. laminae, minor laminated siltstone. Becomes more lithic upwards.

13' Micaceous lithic qtz. sandstone; flaggy; Rib & furrow structures toward 220°. Interbedded grey siltstone with carb. laminae.

13' Porous qtz sandstone: med. undulose bedding. Some ripple marks; variable X-bedding directions.

7' Fine qtz. sandstone: flaggy, laminated but undulose bedding.

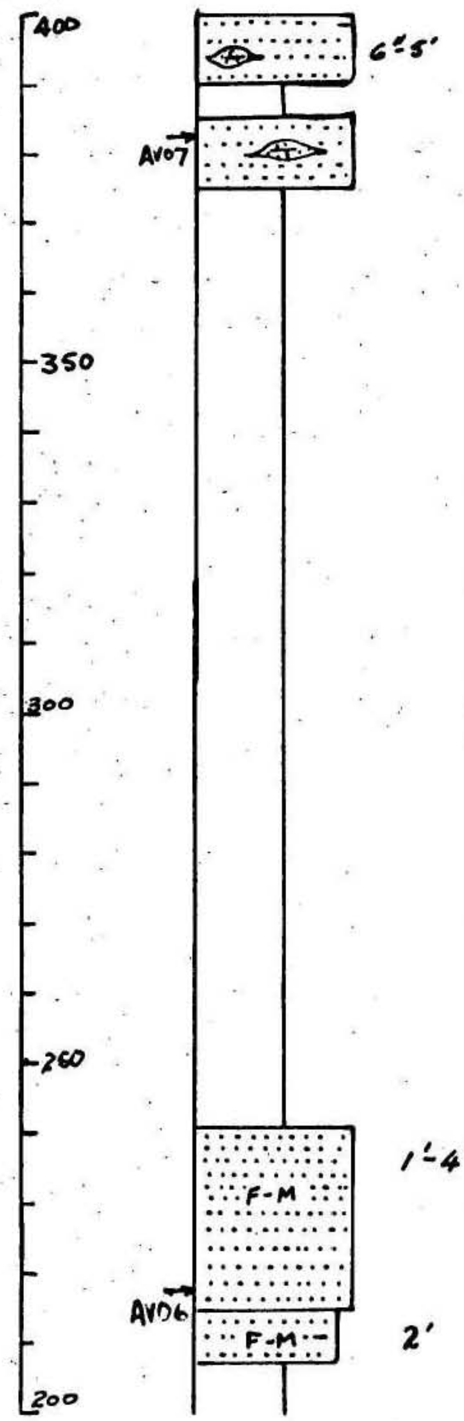
18' Pale brown qtz sandstone overlain by white fine qtz sandstone containing grey mudclasts; broad undulations on bedding surface.

20' Silty qtz sandstone: flaggy, laminated, contains dark carbonac. material & plant fragments on bedding laminae.

20' Porous quartz sandstone: X-bedded; becoming finer grained towards top.

3' Massive quartz sandstone

SECTION AV - MOOLAYEMBER FORMATION

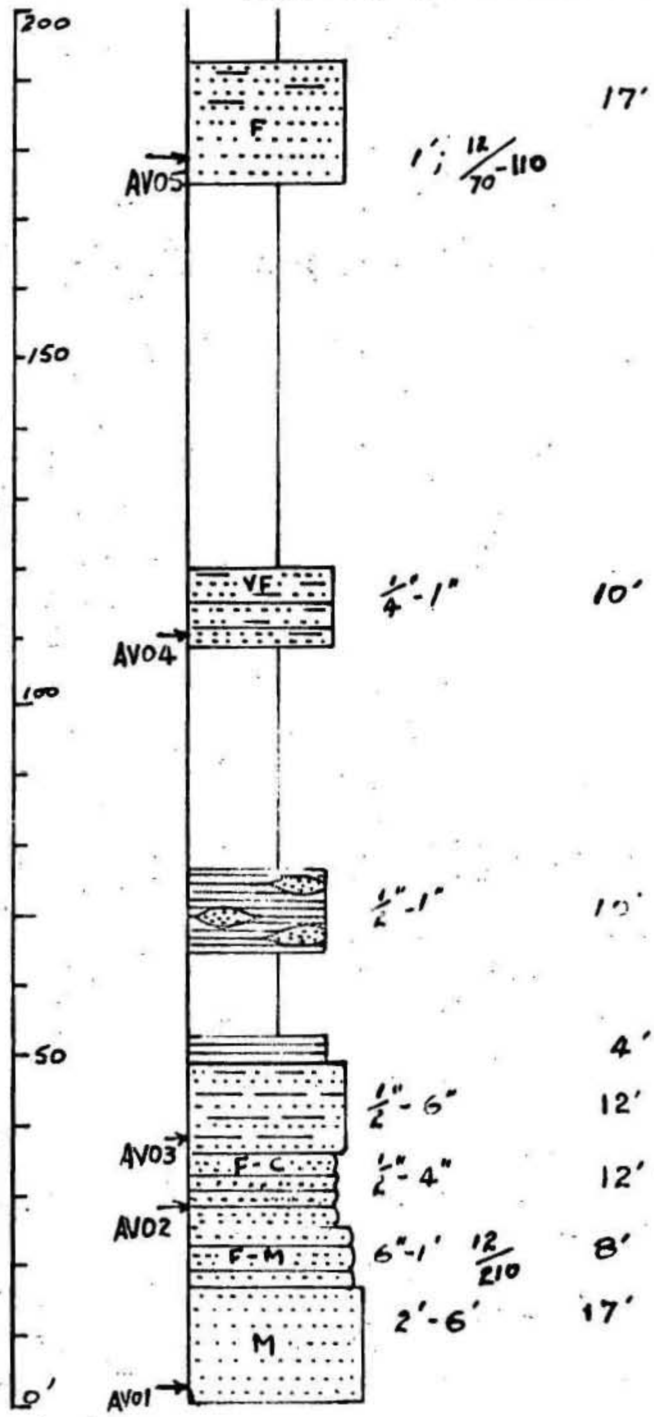


Bedding & X-Bedding	Thickness	Description
26/210, 30/200, 25/160, 24/170, 30/150, 30/195	25'	Lithic sandstone: thin to thick-bedded, cross-bedded, contains calcareous nodules and lenses.
	24'	Lithic sandstone: cross-laminated cliff-forming unit. Bedding becomes thinner along strike, mudstone laminae become common
	7'	Lithic sandstone: consists of 2' beds made up of cross-laminated sets 1"-2" thick.

1:250,000 Sheet - TAROOM
Grid Reference of start. -
Photo. - 5056, Run3, CAB 209.
Scale. - 1" = 25'
Method. - Tape & compass.

Section AV continued on next page

Section AV continued



Quartz lithic sandstone: cross-laminated in 1" thick sets. Inferred current direction towards arc 70°-110°. Some dark micaceous laminae; thin silty horizons towards top.

Very fine silty sandstone: contains mudstone laminae; part carbonaceous.

Mottled grey laminated mudstone: contains common undulose beds and ripples of med. to v. coarse ferrug. qtz sandstone. Ripple x-sections show current lamination.

Laminated, mottled, dk. grey mudstone.

Interbedded quartz sandstone and firm grey siltstone.

Thinly interbedded quartz sandstone and grey laminated mudstone.

Quartz sandstone: med. bedded; contains mudstone laminae.

Quartz sandstone: thick-bedded, x-bedded. This is stratigraphically highest thick-bedded quartz sandstone

APPENDIX II

PALYNOLOGICAL STUDY OF SURFACE SAMPLES

by

E.M. Kemp

PALYNOLOGICAL STUDY OF SURFACE SAMPLES

A palynological study of surface samples collected during the 1968 field season from the Moolayember Formation and uppermost Clematis Sandstone has been undertaken. The data collected may contribute towards establishment of a finer zonation within the Triassic sequence, and also assists in the understanding of depositional environments.

The localities of the samples collected are shown on the sketch map, Text-figure 1. On this map the position of samples collected by the Geological Survey of Queensland, by Mines Administration Pty.Ltd., and by P.R. Evans are also shown. One sample collected from the upper Clematis in the Rewan Syncline by the 1964 Springsure party has also been included.

Some of the horizons sampled in the present study almost duplicate those reported by Evans (1964) as T227 and T232, under the heading of 'Carnarvon Highway'. In this group Evans described another sample collected by Mines Administration from the Moolayember Formation below the waterfall on Hungry Creek in the southwest of the Mimosa Syncline (T286). This sample has been re-examined in the present study, and the species list updated in the light of post-1964 publications.

PREVIOUS INVESTIGATIONS

A taxonomic and stratigraphic study of the palynology of the Moolayember Formation was published by de Jersey and Hamilton (1967). This was based chiefly on material derived from stratigraphic drilling in the Mimosa Syncline area and from proline drilling in the general area of the Carnarvon Ranges. This work also took into account material from the BMR borehole Baralaba 19, and cores from Marathon Glenhaughton No. 1. These authors commented on the lack of satisfactory material from augered holes in the Carnarvon Range area owing to deep weathering of the formation in that region. While such weathering may render spores and pollen too corroded for taxonomic work, the present study demonstrates that assemblages recovered from surface samples are sufficiently well preserved and diverse to find useful stratigraphic application.

De Jersey (1968) described the spores and pollen grains from the Clematis Sandstone in the Mimosa Syncline and discussed the relationship of assemblages from that unit to those of the overlying Moolayember Formation. Evans (1966) subdivided Middle - Upper Triassic microfloras into four units, but later recombined Units Tr3c and 3d on the basis of the co-existence of species of Aratrisporites with Duplexisporites gyratus (Evans, 1966b). De Jersey and Hamilton (1967) recognized a basic subdivision of the Moolayember Formation into two palynological units, but did not give them formal designation. No use of formal units has been made in the present study.

STUDY METHODS

Chemical treatment of samples was kept at a minimum in the extraction of spores from these surface samples. No oxidation procedures were used, as spores in surface samples have usually been partly destroyed by weathering, and oxidation in the laboratory could result in their complete destruction. After solution of the silicates in hydrofluoric acid the organic residues, chiefly spores, pollen and cuticle fragments, were concentrated by mechanical flotation in bromoform. Where preservation was good enough, counts of the relative frequencies of spore species have been made, based on 200 grains per sample. A check list of the distribution of species in the samples studied is shown in Table 1.

MICROFLORAL LISTS

1. Rewan Syncline

Sample MFP 4841 - upper part of Clematis Sandstone. 7 miles S. of Consuelo Homestead. Locality SP508 (Mollan, Exon & Kirkegaard, BMR Rec. 1964/27). Plant fossils described by M.E. White, Appendix 2 of record.

Lithology: Medium grey micaceous siltstone with plant fragments, including two large fronds Dicroidium odontopteroides. The plant fragments were reported by M.E. White as being carbonised, but maceration reveals that carbonisation has not proceeded to a marked degree, and only the soft inner leaf mesophyll appears to have been affected in this way, the cuticle remaining well preserved. Spores show excellent preservation.

Microfloral list	% age composition (x indicates present in sample but not in count)
Osmundacidites wellmanni	15
Dictyophyllidites mortoni	4-5
Falcisporites australis	67
Puncatatisporites spp.	5-6
Tuberculatosporites cf. aberdarensis	2
Aratrisporites spp. indet.	3
Apiculatisporites sp. A (de Jersey 1967)	x
Cycadopites nitidus	1-2
Reticulatisporites distinctus (informal)	1-2
Cardargasporites cf. senectus	x
Krauselisporites sp. indet.	1-2
Tigrisporites playfordi	1
Ephedripites sp.	x
Verrucosisporites cf. carnarvonensis	x
Leiotriletes cf. directus	x
cf. Concavisporites juriensis	x
Punctatisporites sp. A	x
Stereisporites sp.	x
Banksisporites spp. (megaspores)	x

Remarks: Sporomorphs are generally well preserved, although thin-walled forms, such as Aratrisporites spp. are too corroded for specific identifications to be made. A notable feature is the relatively high frequency of thick-walled reticulate forms, referred to Reticulatisporites. Megaspores are common - all are provisionally referred to Banksisporites. The assemblage is basically similar to those from the upper Clematis Sandstone and basal Moolayember Formation outcropping south of Moolayember Creek.

2. Carnarvon Ranges, S. of Moolayember Creek.

Sample AT03 - MFP 4793 - upper Clematis Sandstone

Lithology: Medium grey micaceous siltstone with abundant plant fragments. When peeled from bedding planes these appear brown and translucent.

Microfloral list	%age composition
Osmundacidites wellmanni	3-4%
Dictyophyllidites mortoni	1
Falcisporites australis	78
Punctatisporites spp.	3
Tuberculatosporites aberdarensis	1
Aratrisporites cf. rotundus	2-3
A. sp. indet.	1
Cycadopites nitidus	4
Neoraistrickia taylori	1
Cardargasporites sp.	x
Krauselisporites sp. indet.	x
Tigrisporites playfordi	1
Striate saccate indet.	x
Retusotriletes sp.	x
Ephedripites sp.	x
Verrucosisporites cf. carnarvonensis	x
Leiotriletes sp.	1
MEGASPORES	
Nathorstisporites pulcherrima	x
Banksisporites spp.	x
Reticulate megaspore n. gen. (sp. 931)	x

Remarks: Assemblage is dominated by Falcisporites. Preservation variable, some of the bisaccates are corroded, others well preserved, with the exine pattern distinct and the corpus clearly present. Megaspores, particularly Nathorstisporites pulcherrima, which has delicate spines, show excellent preservation, indicative of a short transport distance before deposition.

Sample AT07 - MFP 4794 - Basal Moolayember Formation.

Lithology: Medium grey micaceous siltstone with abundant plant fragments; these are black or dark brown on bedding planes, but translucent brown when peeled from these surfaces.

Microfloral list

Osmundacidites wellmanni
Dictyophyllidites mortoni
Falcisporites australis
Cycadopites sp.
Punctatosporites walkomi
Taeniasporites sp.
cf. Convolutispora sp.

Remarks: Preservation of spores was too poor for counts to be made. Much fine woody debris was present, obscuring spores. Falcisporites australis was the most abundant form.

Sample AV02 - MFP 4807 - Basal Moolayember Formation.

Lithology: Grey micaceous siltstone with abundant plant fragments, very similar to AT03.

Microfloral list	%age composition
Osmundacidites wellmanni (frequently in tetrads)	6
Dictyophyllidites mortoni	1
Falcisporites australis	64
Punctatisporites spp.	12
Tuberculatosporites cf. aberdarensis	2
Aratrisporites cf. rotundus	3
A. sp. indet.	x
Apiculatisporis sp.	x
Sulcosaccispora sp.	x
Cycadopites nitidus	1
Clavatriletes cf. hammeni	x

Platysaccus queenslandi	x
Reticulatisporites distinctus	x
Convolutispora sp. indet.	x
Leiotriletes directus	2
MEGASPORES	
Nathorstisporites pulcherrima	1
Banksisporites spp.	x
Megaspores indet.	x

Remarks: Spores and pollen are relatively well preserved. The assemblage is not very diverse, being dominated by Falcisporites australis. Megaspores and well preserved cuticular material, chiefly of the Dicroidium type, are frequent.

Sample AA96A - MFP 4811 - Basal Moolayember Formation.

Lithology: Dark grey mudstone.

Comment: After processing, the sample yielded much fine vitrinite, some amber coloured material, probably plant tissue from which most traces of structure have vanished. No spores were present.

Sample AA96H - MFP 4812 - Basal Moolayember Formation.

Lithology: Dark grey, mottled, silty mudstone.

Comment: Barren of spores. Much fine, very dark vitrinite present.

Sample AT14 - MFP 4795 - Moolayember Formation, about 350 feet above base.

Lithology: Dark grey micaceous siltstone, with darkened plant fragments. Sample is massive, nodule-like structure taken from sequence of laminated silty mudstones and fine sandstones.

Microfloral list	%age composition
Osmundacidites wellmanni	12
Falcisporites australis	62
Punctatisporites spp.	2

Tuberculatosporites cf. aberdarensis	1
Aratrisporites cf. rotundus	2
Aratrisporites coryliseminus	x
Apiculatisporis sp.	x
Sulcosaccispora sp.	1
Cycadopites nitidus	10
Clavatriletes sp.	x
Neoraistrickia taylori	1
Krauselisporites sp. indet.	1
?Hamiapollenites sp.	3
Rugulatisporites cf. stonecrofti	x
Lophotriletes bauhiniae	x
Leiotriletes cf. directus	4
MEGASPORES	
Nathorstisporites pulcherrima	x
Megaspore indet. (sp. 931)	x
MICROPLANKTON	
cf. Michrystridium sp.	x

Remarks: Spores and pollen abundant, but their preservation is generally only fair, and corrosion due probably to surface weathering is evident in most grains. Falcisporites australis is the dominant species. The megaspore recorded here as sp. 931 (indeterminate) is a form which is also known to occur in lower Moolayember Formation sediments in BMR Springsure No. 4 on the Springsure Shelf, and from 1266 feet in Maranda No. 1 well.

Sample AT15 - MFP 4866 - Moolayember Formation approximately 500 feet above base.

Lithology: Light grey, flaggy, very micaceous siltstone with fine plant fragments.

Microfloral list	%age composition
Osmundacidites wellmanni	2
Dictyophyllidites mortoni	3
Falcisporites australis	64

Punctatisporites spp.	4
Tuberculatisporites cf. aberdarensis	1
Aratrisporites sp. indet.	5
Cycadopites nitidus	4
Clavatriletes cf. hammeni	2
Platysaccus cf. queenslandi	1
Retusotriletes junior	x
Neoraistrickia taylori	4
?Hamiapollenites sp.	2
Leiotriletes directus	1
Concavisporites sp.	1
Punctatosporites walkomi	2
Nevesisporites limatulus	x
Vitreisporites pallidus	1

MEGASPORES

? Nathorstisporites pulcherrima (spines only)	x

Remarks: Preservation generally poor. Falcisporites australis grains, however, frequently showed excellent preservation, out of keeping with the rest of the assemblage.

Sample AA95 - MFP 4810 - Moolayember Formation approximately 900 feet above base.

Lithology: Pale grey soft clay, iron stained in patches and generally weathered looking.

Microflora

Punctatisporites sp.
Leiotriletes sp.

Remarks: Two specimens listed above were all that were observed. Small fragments of darkly staining cuticle and vascular tissue were present, but spores appear to have been largely destroyed by weathering. Cell masses (probably algal) and fungal hyphae were present, and are probably of recent origin, deriving from the soil cover.

Sample AA85 - MFP 4802 - Moolayember Formation, approximately 1250 feet above base.

Lithology: Dark grey mudstone, some iron staining.

Microfloral list	%age composition
Osmundacidites wellmanni	23
Dictyophyllidites mortoni	3
Falcisporites australis	10
Punctatisporites sp. A (de Jersey & Hamilton 1967)	33
Tuberculatosporites cf. aberdarensis	1
Aratrisporites sp. indet.	x
Cycadopites nitidus	15
Retusotriletes cf. junior	x
Leiotriletes directus	1
Punctatosporites walkomi	8
Rugulatisporites sp.	x
Foveosporites mimosae	4
Cycadopites grandis	x
Polypodiisporites ipsviciensis	x
Lycopodiumsporites sp. indet.	x

Comment: Preservation of spores generally good. The assemblage is an unusual one, in that Punctatisporites sp. A (of de Jersey & Hamilton 1967) is the most abundant form. Foveosporites mimosae is also relatively common. Falcisporites australis, dominant in all other assemblages in this section, is here subordinate and generally less well preserved. The predominance of heavy, thick-walled trilete forms suggests deposition occurred close to the growth site of the parent plants of these forms, so that they are locally over-represented in the sample.

Sample AA76(D) - MFP 4797 - Moolayember Formation, about 1350 feet above base.

Lithology: Fine grained green lithic sandstone.

Microfloral list

Falcisporites australis
Granulatisporites sp.
Aratrisporites cf. *rotundus*
Neoraistrickia taylori
Saccate striate form
Leiotriletes sp.
Punctatosporites walkomi
Lophotrioletes bauhiniae
Polypodiisporites ipsviciensis
Trisaccate
Monosaccate indet.

MICROPLANKTON

Michrystridium sp.

Remarks: Spores and pollen generally well preserved, although not abundant. *Falcisporites australis* dominant, although there is an unusually high frequency of small monolete grains assigned to *Polypodiisporites* and *Punctatosporites*. Spores were too rare for counts to be made.

Sample AA76 (G) - MFP 4800 - roughly the same horizon as AA76 (F)

Lithology: Medium grained green lithic sandstone.

Microfloral list

Falcisporites australis
Osmundacidites sp.
Cycadopites sp.
Sulcosaccispora sp.
Leiotriletes sp.
Punctatisporites walkomi

Remarks: Assemblage generally undiversified, preservation only fair, grains corroded. Much darkened fine woody material present. No microplankton were observed, but their absence may be due to preservation factors.

Sample AA76(E) - MFP 4798 - Moolayember Formation only about 4 feet above AA76 (D).

Lithology: Pale green, finely laminated mudstone, some iron staining. Minute brown plant fragments on bedding planes.

Microfloral list	%age composition
Osmundacidites wellmanni	9
Dictyophyllidites mortoni	1
Falcisporites australis	41
Tuberculatosporites cf. *aberdarensis*	6
Cycadopites nitidus	13
Clavatriletes sp.	x
Neoraistrickia taylori	2
Tigrisporites cf. *playfordi*	x
Leiotriletes directus	10
Punctatosporites walkomi	2%
Lophotriletes bauhiniae	1-2
Polypodiisporites ipsviciensis	2
?*Hamiapollenites* sp.	1
Nevesisporites limatulus	x
Vitreisporites pallidus	x
MICROPLANKTON	5
Michrystridium (2 species)	
Veryhachium sp.	

Remarks: Although spores were abundant in the residue, preservation was generally poor; bisaccates seem to have suffered most in this respect, although they are still identifiable. Monolete spores, which are unusually abundant, show better preservation, due either to their relatively greater exine thickness compared to spore size, or to their having suffered less prolonged transport. Acritarchs are unusually common, totalling 5% of the assemblage.

Sample AA76 (F) - MFP 4799 - 2 feet above AA76 (E).

Lithology: Yellowish green medium grained lithic sandstone with pale green pellets mudstone, equisitalean stem impressions, and small lenses coal.

Microfloral list

Osmundacidites sp.
Dictyophyllidites mortoni
Falcisporites australis
Punctatisporites sp. A
Tuberculatosporites cf. *aberdarensis*
Sulcosaccispora cf. *lata*
Cycadopites nitidus
Leiotriletes directus
cf. *Taeniasporites* sp.
Foveosporites mimosae
?*Hamiapollenites* sp.
Vitreisporites pallidus
Krauselisporites cf. *verrucifer*

MICROPLANKTON
Michrystridium sp.
Veryhachium cf. *reductum*

Remarks: The assemblage is similar to that of AA76(E), although spores were too sparse for counts to be made. Spores are generally corroded. Microplankton are again relatively common.

Sample AA77 - MFP 4801 - Moolayember Formation, approximately 1400 feet above base.

Lithology: Pale green mudstone, some iron staining. Abundant equisitalean stems.

Microfloral list:

- Osmundacidites wellmanni
- Falcisporites sp.
- Leiotriletes sp.
- Cycadopites sp.
- Punctatisporites sp. A

Remarks: Spores were too sparse to count, and were generally much thinned by corrosion. Much darkened, fusinised woody matter was present.

3. Mimosa Syncline samples

A sample from the southern part of the western limb of the Mimosa Syncline was examined by Evans (1964, Sample T286) and an abbreviated microfloral list given. This sample was re-examined in the present study, and its microfloral content is listed below. Several taxonomic papers have been published on Australian Triassic microfloras since 1964, providing new information which has enabled more species names to be given than was previously possible. Additionally, two samples from a section of the Moolayember Formation exposed in Gap Creek, on the eastern limb of the Mimosa Syncline were collected by P.J. Alcock. Results of their palynologic examination are given below.

Sample T286 - MFP 1265 - Moolayember, below waterfall on Hungry Creek (see Evans, loc. cit., p.10)

Microfloral list

- Osmundacidites cf. wellmanni
- Osmundacidites spp.
- Dictyophyllidites mortoni
- Falcisporites australis = Alisporites sp.
- Aratrisporites cf. paenulatus
- Aratrisporites sp. indet.
- Leiotriletes sp.
- Tuberculatosporites aberdarensis = Thymospora sp.?

Tigrisporites cf. playfordi = Zebrasporites sp. ?
Lophotriletes bauhiniae
Neoraistrickia taylori
Taeniasporites sp. indet.
Polycingulatisporites cf. densatus
Platysaccus queenslandi
Podocarpidites sp.
? Quadrisporites sp. (corroded)

MICROPLANKTON
Veryhachium sp.
Micrhystridium sp.

Remarks: Falcisporites australis is the most abundant form, although Aratrisporites spp. are common. The presence of Tigrisporites cf. playfordi and of the acritarchs Veryhachium sp. and Micrhystridium sp. is noteworthy.

Sample AA26 (B) - MFP 4813 - Moolayember Formation, eastern limb of Mimosa Syncline, Gap Creek, south branch 4½ miles S. of Fairholme Homestead.

Lithology: Carbonaceous, laminated silty mudstone.

Microfloral list

Falcisporites australis
Tuberculatosporites aberdarensis
Calamospora sp.
Punctatisporites spp.
?Convolutispora sp.
Cavate spore indet.

Remarks: In the assemblage recovered, Tuberculatosporites aberdarensis was the commonest and best preserved form. This species, according to de Jersey & Hamilton, is typically most abundant in the lower part of the Lower Moolayember, and does not extend into the upper part of the Formation. Other species recovered were very corroded. Some cuticular material, from which most traces of structure had disappeared, was also present.

Sample AA26 (C) - MFP 4814 - Same locality as AA26 (B).

Lithology: Carbonaceous, laminated silty mudstone.

Microflora list

Tuberculatosporites sp.
Falcisporites sp.
Leiotriletes sp.

Remarks: Spores are extremely rare and corroded; the few forms present are long-ranging. There was an abundance of finely divided, fusinised wood in the residue.

4. Samples from Mount Coolon Sheet Area

Two samples from the Triassic sequence on this Sheet area were processed and examined, but both proved barren. Details of localities and lithologies are as follows:

Sample AH12 - MFP 4816 - Measured section, Mount Coolon, Run 2, photo 66. Grid Reference 644354.

Lithology: Brown massive mudstone with reddish specks.

Remarks: No spores were present, only a few corroded cuticle fragments and abundant fusinised wood particles.

Sample AF07 - MFP 4815 - Measured section, Mount Coolon Sheet, Run 7, photo 45, Grid Reference 656280.

Lithology: Pale grey, micaceous, carbonaceous siltstone.
Remarks: Barren of spores, few wood fragments only.

DISCUSSION

a. Carnarvon Range and Rewan Syncline sequence

Sampling gaps due to exposure deficiencies make delineation of palynologic units within the sequence very tentative. In particular, the middle part of the section in the area south of Moolayember Creek is very poorly exposed and consequently is unsampled.

Samples from the basal part of this section (corresponding roughly with Alcock's lithologic unit C1) and from the upper part of the Clematis Sandstone can be grouped within one informal palynological unit. Assemblages recovered from samples AT03 to AT14, and from sample MFP4841 (upper Clematis SS., S. of Consuelo Homestead) are included within this unit. They are characterised by a high frequency of Falcisporites australis, by the presence of thick-walled reticulate forms (referred to as Reticulatisporites distinctus, BMR species No. 943 - although more than one species may be included) and by a relatively high megaspore component. Among the last group are Nathorstisporites pulcherrima, Banksisporites spp., and less frequently, a reticulate megaspore which probably constitutes a new genus.

De Jersey (1968) remarked on a similar lack of ready differentiation, on a palynological basis, between the upper Clematis Sandstone and the lower Moolayember Formation in the Mimosa Syncline. However, the sequences which he studied in that area lacked some of the elements which distinguish the palynologic unit described above from the Carnarvon Range area - viz. the megaspore component and the content of Reticulatisporites. This suggests that this type of assemblage is at least partly controlled by geography and by local depositional environment. The samples from the base of the Moolayember Formation are characterised by large plant fragments (chiefly Dicroidium), a feature which, together with the presence of well preserved megaspores, indicates that deposition occurred at a site not far from the growth site of the parent plants. No acritarchs have been observed in this interval.

The vertical range of this type of association in the Clematis - Moolayember sequence is not known. It occurs in sediments mapped as lower Moolayember in BMR Springsure No. 4 borehole, on the Springsure Shelf, and in what is regarded as the equivalent of the lower Moolayember in Maranda No. 1 well in the Galilee Basin.

The samples from the upper part of the Carnarvon Range sequence, particularly the suite of samples AA76 and AA77, are suggestive of a different depositional environment. Spores recovered from these are in general smaller; no megaspores have been found, and cuticle fragments are rare. The samples contain the highest relative abundance of acritarchs - up to 5%. This combination of features suggests that deposition of spores and pollen occurred at a site more remote from their source. The high acritarch count may indicate that conditions were at least brackish.

Palynofacies changes occur rapidly within the Moolayember Formation, as witnessed by the difference in composition between samples AA85 and AA76, which are less than 100 feet apart. In AA85 the species Punctatisporites sp. A (de Jersey & Hamilton 1967) and Foveotriletes mimosae are dominant, probably due to local over-representation. These localised environmental concentrations of species apparently recur throughout the sequence, since de Jersey and Hamilton record an unusual abundance of F. mimosae in the upper Moolayember of the Mimosa Syncline.

b. Correlation of the Carnarvon Range and Mimosa Syncline sequences

De Jersey and Hamilton (1967) recognized a twofold subdivision of the Moolayember Formation in the Mimosa Syncline. They listed four species as having ranges restricted to the lower part of the formation in that area; Lophotriletes bauhiniae, Aratrisporites cf. rotundus, Tigrisporites playfordi and Rugulatisporites trisinus. On the basis of the occurrence of Tigrisporites playfordi and Aratrisporites rotundus in the Carnarvon Range proline samples, these authors suggested that the sequence there was the correlative of the basal 2000 feet of the Mimosa Syncline sequence.

The present study offers additional evidence in support of this suggestion. The index species Aratrisporites cf. rotundus, Tigrisporites playfordi and Lophotriletes bauhiniae all occur in samples AA76, only 250 feet from the top of the sequence. Additionally, the species Nevesisporites limatulus is present in these samples. This species is shown in the range chart of de Jersey and Hamilton as being restricted to the lower Moolayember unit. It has a restricted range in the Triassic of Western Australia, in both the Perth and Carnarvon Basins, where it is confined to the Woodada Formation and Locker Shale respectively.

Closer correlation between the two areas is not possible with present sampling; indeed, the apparent persistence of most species over relatively long time intervals may preclude detailed correlations based on the ranges of individual species. Correlation by relative abundances is rendered difficult by rapid facies fluctuations.

De Jersey and Hamilton suggested that abundances of Aratrisporites spp. might provide further means of correlation between the two areas. Such correlations should be made with caution, as the form is subject to environmental control in high degree. Also perhaps because of its relatively thin walls, it seems to corrode readily and be under-represented in surface samples. With these qualifications in mind, it may be noted that the greatest concentrations of the species (although only 3-5% of the total spore spectrum) occur in samples AT14 and AT15 of the Carnarvon Range sequence, i.e. about 300 - 500 feet above what has been drawn as the base of the Moolayember Formation. In the Mimosa Syncline sequence present sampling shows the highest concentrations beginning about 250 feet above the base, so there may be some parallel between the two areas in this respect. Sample T286 of Evans possibly occurs in this zone of high Aratrisporites concentration.

The yield from the samples from the eastern limb of the Mimosa Syncline was too poor for them to be used in detailed correlation. It is noteworthy, however, that a relatively high frequency of Tuberculatosporites aberdarensis, as was observed in sample AA26(B), is regarded by de Jersey & Hamilton as being typical of the lower part of the Moolayember, so that this sample, on palynological grounds, derives from probably near the base.

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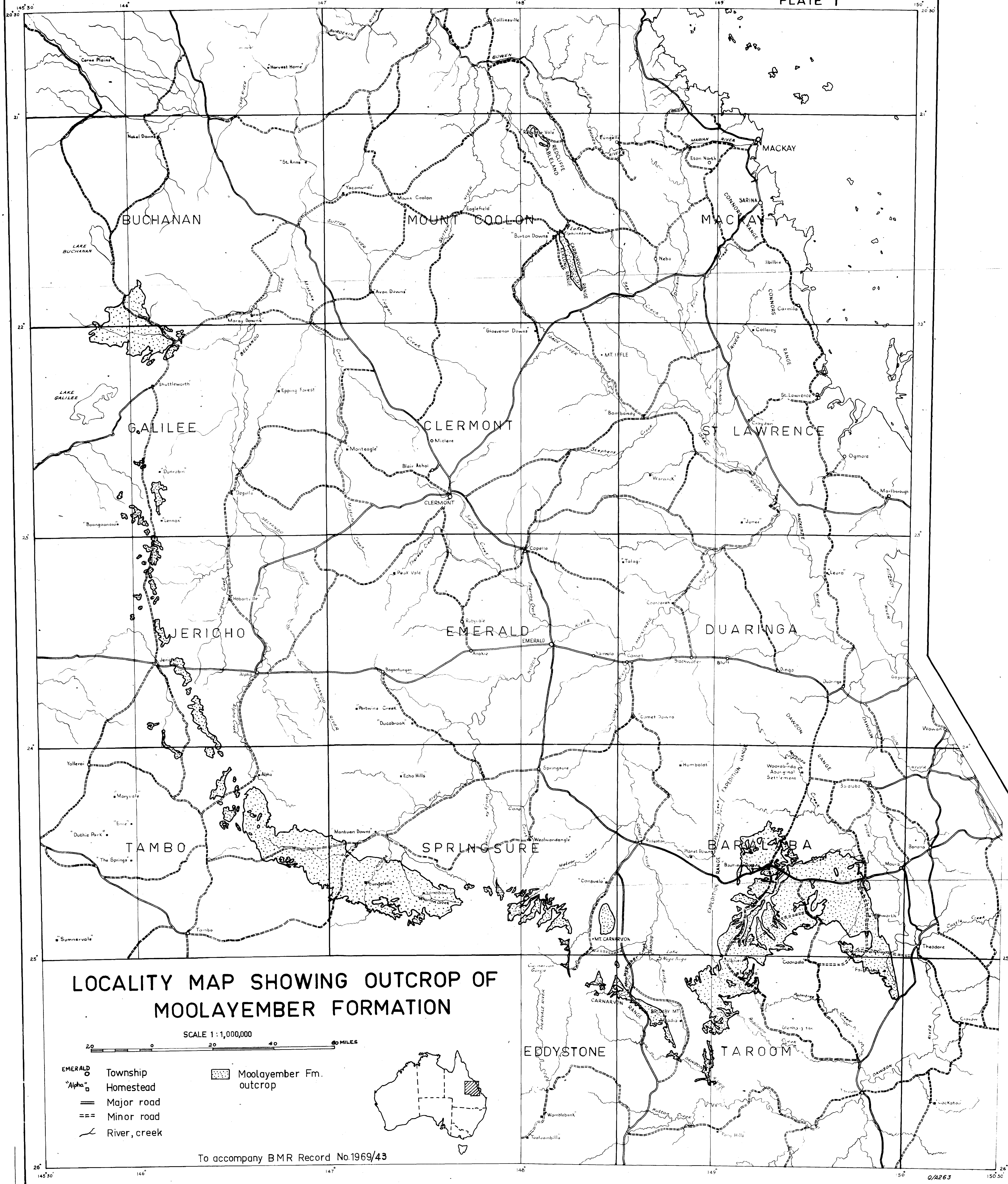
PLATE 1



LOCALITY MAP SHOWING OUTCROP OF MOOLAYEMBER FORMATION

To accompany BMR Record No. 1969/43

Q/A263

PLATE 2

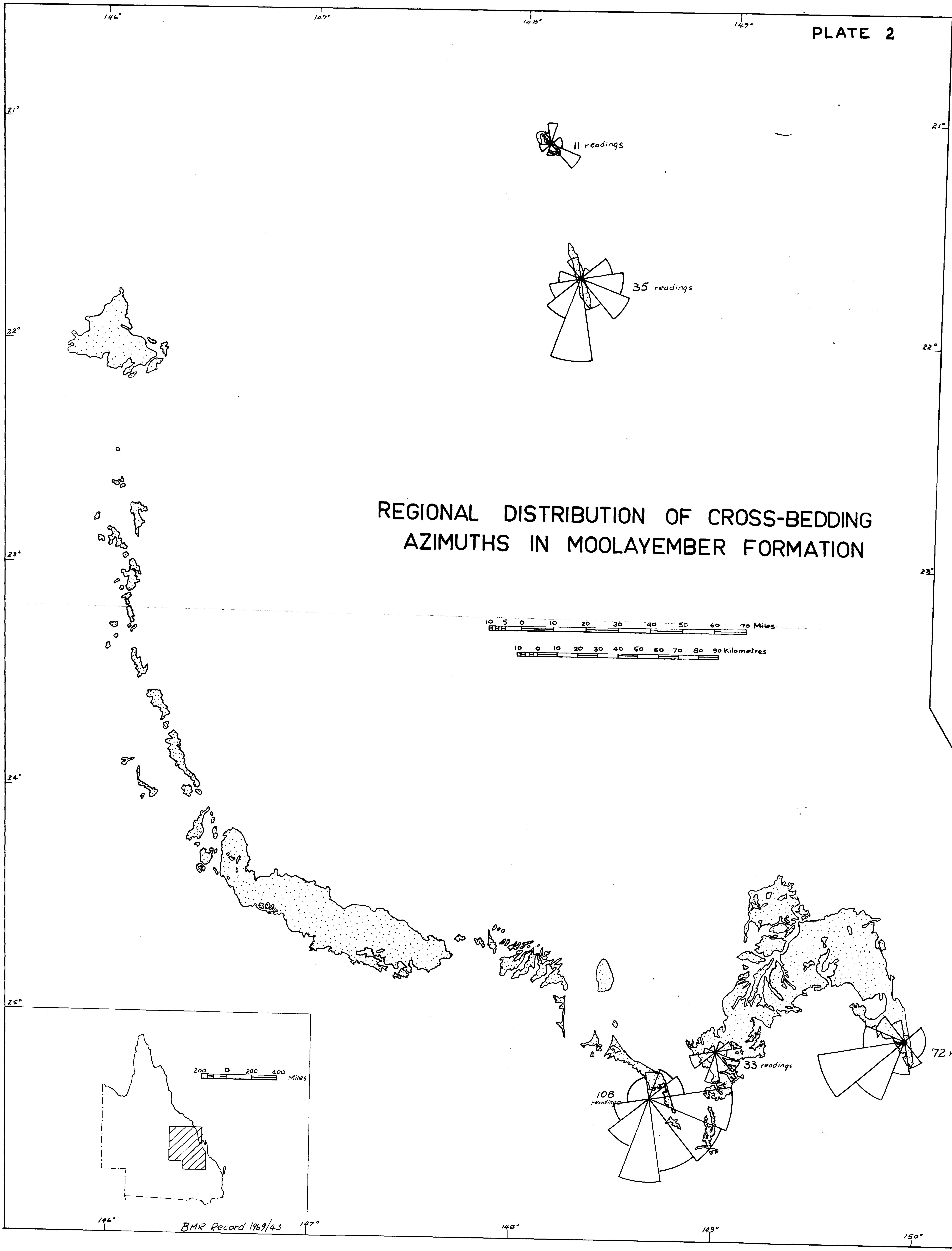
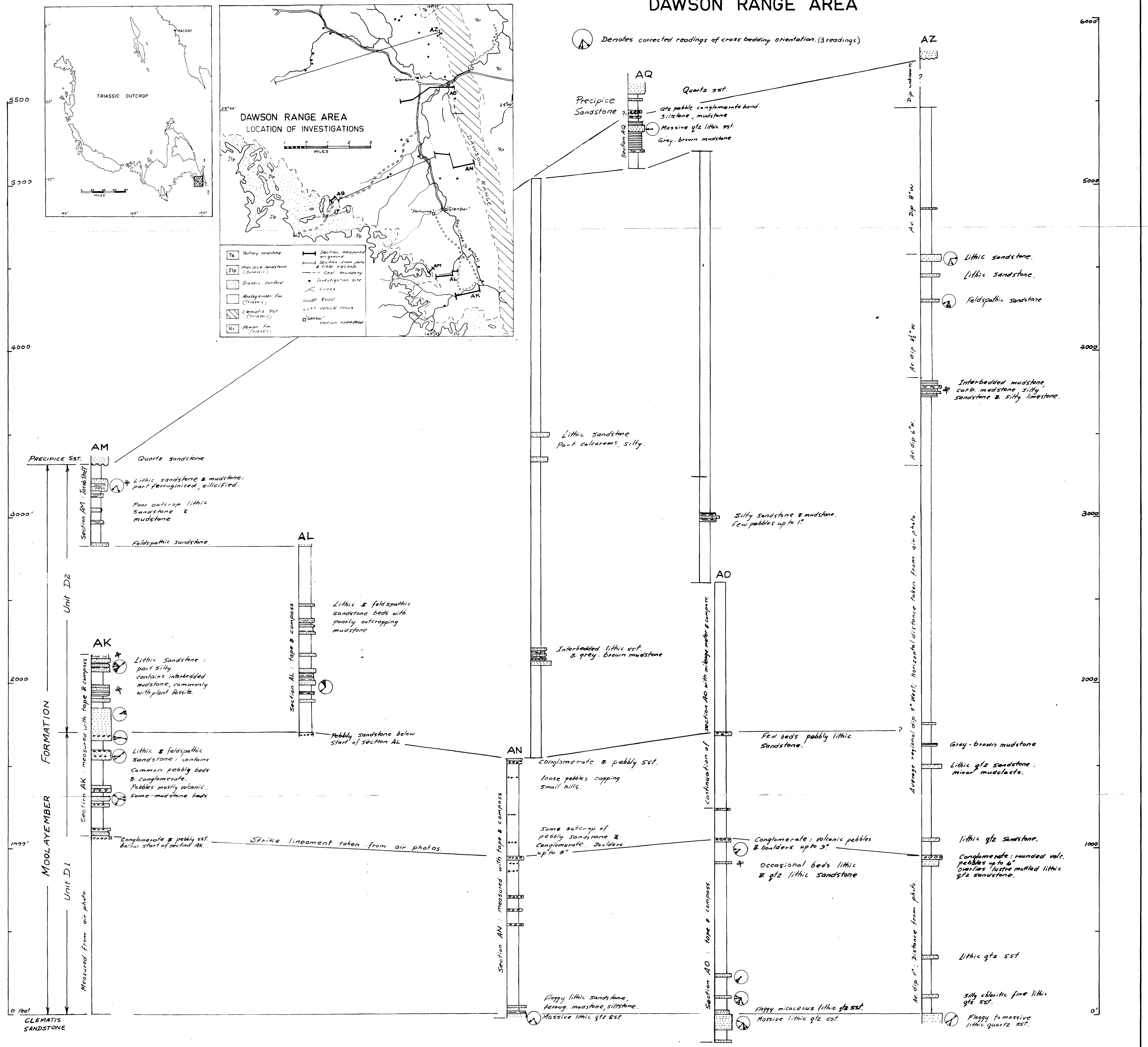

146°
147°
148°
149°
150°
21°
22°
23°
24°
25°
11 readings
35 readings
33 readings
72 readings
108 readings
REGIONAL DISTRIBUTION OF CROSS-BEDDING AZIMUTHS IN MOOLAYEMBER FORMATION
10 5 0 10 20 30 40 50 60 70 Miles
10 0 10 20 30 40 50 60 70 80 90 Kilometres
200 0 200 400 Miles
BMR Record 1969/43
Q/A264

Plate 3

MEASURED SECTIONS IN MOOLAYEMBER FORMATION
DAWSON RANGE AREA



Q/A265

To accompany BMR Record No 1969/43