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PETROGRAPHIC NOTES ON THE CLEMATIS SANDSTONE AND MOOLAYEMBER FORMATION, BOWEN BASIN, QUEENSLAND.

by

L.V. Bastian

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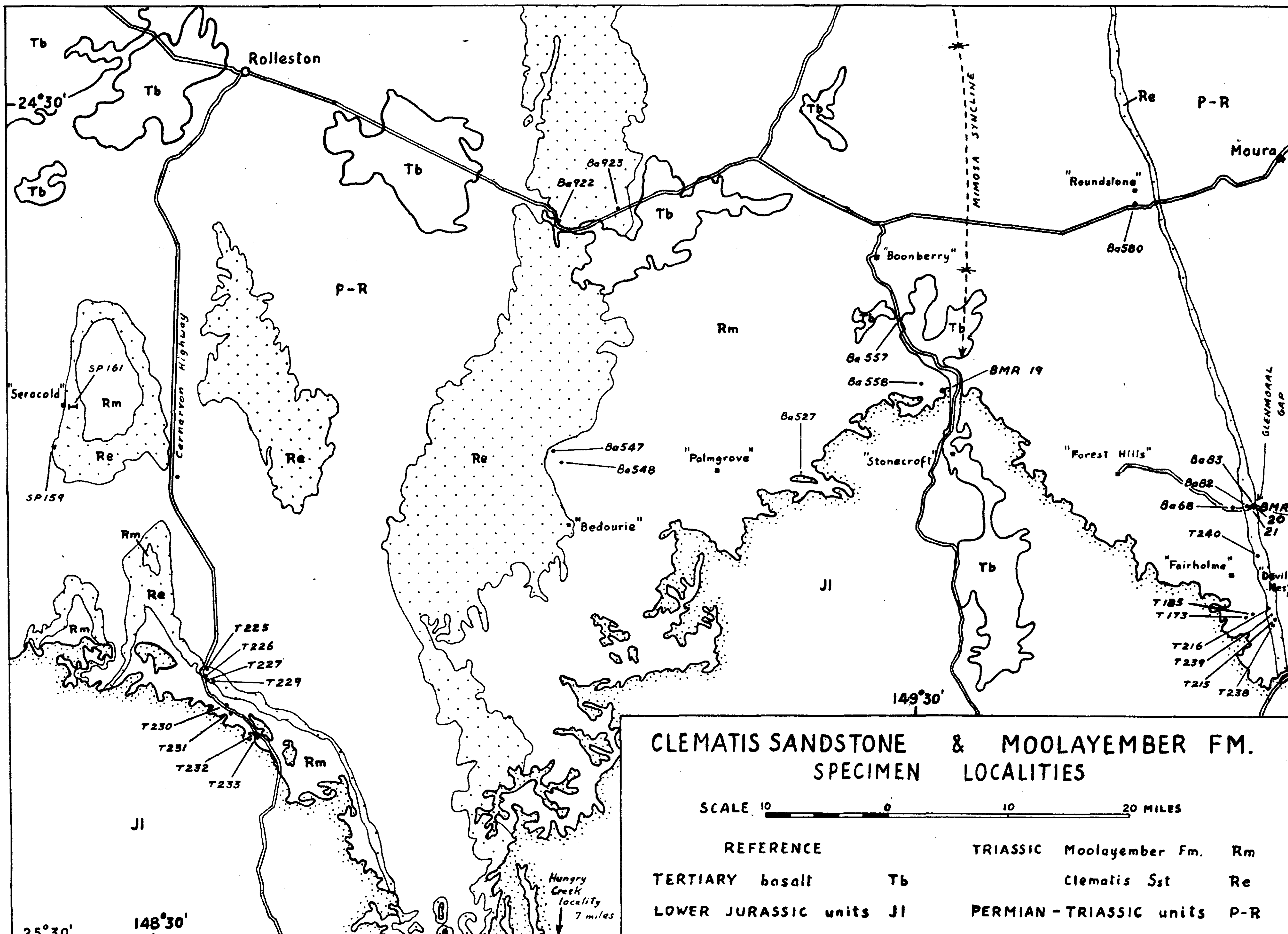
Fig. 1.




Bureau of Mineral Resources, Geology and Geophysics

To accompany Record 1965/240

G55/A3/53

# PETROGRAPHIC NOTES ON THE CLEMATIS SANDSTONE AND MOOLAYEMBER FORMATION, BOWEN BASIN, QUEENSLAND.

## SUMMARY


Sixty specimens from the Clematis Sandstone and Moolayember Formation were studied in thin section. These were collected from outcrops in the Springsure, Taroom and Baralaba 1:250,000 Sheet areas.

The most common arenites in the Clematis Sandstone are protoquartzite and argillaceous sandstone; they are typically polymodal, show poor rounding of grains, and are feldspar-poor. The main source areas for the sediments were probably the Anakie Metamorphics and metamorphic sources to the south-west. Arenites in the Dawson Range have more volcanic detritus and include many beds of volcanic-rich conglomerate; this detritus probably came from areas of volcanics to the east. Deposition of the Clematis Sandstone was fluvial and took place under oxidising conditions.

The most common arenites in the Moolayember Formation are subgreywackes. They are better sorted and finer than those of the Clematis Sandstone, contain feldspars and a wide range of rock fragments, and are commonly calcareous. The quartz percentage is low and decreases upwards. The plentiful greenish-yellow phyllosilicate ("green biotite"), in these sediments is probably an alteration product of biotite formed during sediment transport. The Moolayember Formation was derived from various sources, notably granodiorite and diorite terrains of the Auburn Complex and Urannah Complex to the east. The unit was probably deposited in relatively quiet brackish waters.

The Moolayember Formation contains more quartz and more phyllosilicates, especially biotite, than the Rewan Formation but less lithic detritus, and lacks red beds. The data suggest that the igneous complexes may have been largely covered up to Middle Triassic time, when they were exposed over wide areas.


## INTRODUCTION

Thirty-four specimens of Clematis Sandstone and twenty-six specimens of Moolayember Formation, collected from the Springsure, Taroom and Baralaba* 1:250,000 Sheet areas, are described here. These units, which are of Middle to Upper Triassic age, crop out on the east and west flanks of the Mimosa Syncline, and around the Arcadia Anticline, Rewan Syncline and Reid's Dome. General descriptions of the units in these various localities appear in Jensen, Gregory and Forbes (1964), Mollan, Exon and Kirkegaard (1964), and Olgers, Webb, Smit and Coxhead (1964). Mack (1964) correlated the Moolayember Formation with the Cabawin Formation, and considered that the Clematis Sandstone was stratigraphically equivalent to part of the Cabawin Formation of the eastern flank of the Mimosa Syncline.

Altogether eighty-two thin sections, including those cut from pebble suites, were examined. The essential data are given in Tables I and II and the text of the report comprises discussion and particular observations rather than complete lithological descriptions of the thin sections. Mineral percentages have been estimated in each case. The terminology used follows the classification of Pettijohn (1957), except in the case of "volcanic sandstone", which is after Williams, Turner and Gilbert (1955) - rocks given this name might generally be called "subgreywacke" in the Pettijohn classification. It should be noted that, in applying the Pettijohn classification, only the minerals appearing in Pettijohn's compositional tetrahedron (see p.292) were accounted.

* Subsequent reference to 1:250,000 Sheet areas is signified by the use of capital letters, e.g. SPRINGSURE.

## CLEMATIS SANDSTONE

### PETROGRAPHY

Specimens from the Clematis Sandstone came from several general localities (see Fig. I):

near Mount Carnarvon on SPRINGSURE (8 specimens);

along Carnarvon Highway on TAROOM, about 25 miles south-south-east of Mount Carnarvon (13 specimens);

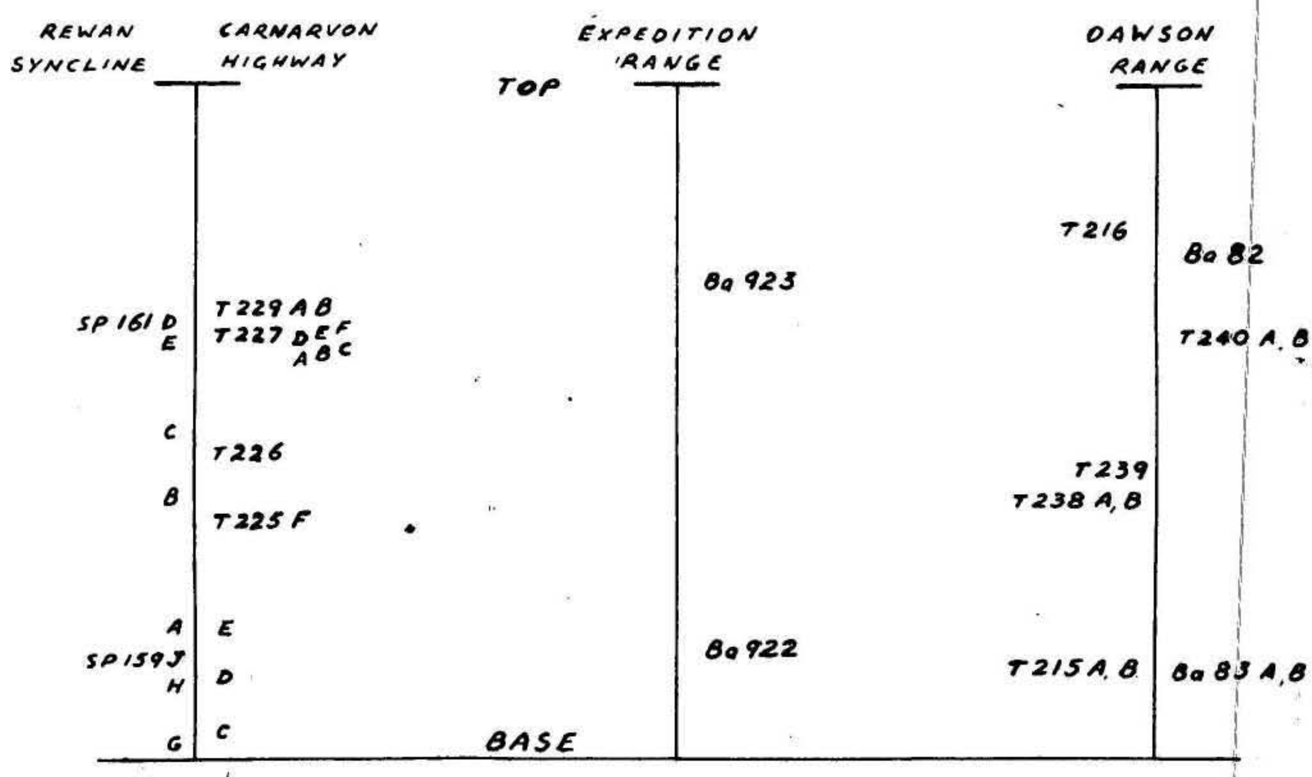
on the eastern flank of the Mimosa Syncline on TAROOM and in the south-eastern corner of BARALABA, about 80 miles east-north-east of the Carnarvon Highway locality (11 specimens);

in the Expedition Range along the Rolleston-Bauhinia Downs road, on BARALABA, about 45 miles east-north-east of Mount Carnarvon (2 specimens).

Estimated stratigraphic positions of these specimens are shown in Fig. 2. Because of the long distances involved, each of these localities is considered separately. Only a few of the specimens were collected from measured sections, and the stratigraphic positioning of most of the specimens is based on field observations and airphoto interpretation.

Fig. 2 CLEMATIS SANDSTONE

ESTIMATED POSITIONS OF SPECIMENS (not to scale)

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Mount Carnarvon locality.

Specimens were collected on measured section S29 of Mollan et al. (1964). The lower part of this section, involving specimens SP159G-J, was measured in a small creek near the base of Mount Carnarvon. The upper part involving specimens SP161A-E, was measured east of Serocold Homestead, i.e. about 3½ miles north-east of the lower part. The positions of these specimens from the base of the unit are: SP159G-7', H-119', J-134'; SP161A-162', B-227', C-290', D-407', E-393'. SPI59G-J was taken from below a prominent cliff-forming part of the Clematis Sandstone; SPI61A and B are typical of this cliff-forming part; and SPI61C to E are from higher parts of the unit.

The three lower specimens are argillaceous sandstones; two have fairly low quartz percentages and plentiful matrix, and one, SP159G, has abundant chert grains. They are very fine-grained, and show poor rounding of grains. SP159J is coarser and more quartzose, but matrix is still plentiful. In the two specimens from the main cliff quartz showing composite quartzitic textures is abundant, the total quartz and quartzite exceeds 90%. Grains are, in general, subangular, medium to coarse, and show a number of size modes. SP161C is fairly typical of the ochrous red siltstones which give staining effects to cliffs of Clematis Sandstone. The colour is due to primary iron oxides, which in thin section appear as fine, slightly translucent, deep red-brown spots about $5/^{u}$ in diameter, distributed fairly evenly through the matrix of the silt. SPI59H has similar iron oxides, but they are more abundant and the spotted texture only shows up well in very thin parts of the slide. This texture, which does not resemble that produced by the dense ferruginous grain coatings seen in weathered rocks, reflects the persistence of the red bed characteristics of the Rewan Formation into the Clematis. SP161D is an impure "orthoquartzite" similar to sandstones of the main cliffs; it may have been an argillaceous sandstone before weathering. SP161E is an unusual type of mudstone containing angular quartz and rather irregularly shaped clay pellets with low birefringence in a groundmass of mainly isotropic clay, which has a mottled texture. (Fig. 3). Small opaque chips, possibly of wood, ranging up to about 0.2 x 0.5mm in size, are common, and many fossil rootlets were seen in the hand-specimen. The lithology is like that of pelletal underclay as described by Carozzi (1960).

In general the sandstones are polymodal, commonly having plentiful matrix, and poorly rounded grains with moderate sphericity. Quartz overgrowths are lacking.

Carnarvon Highway locality.

Specimens were collected from several outcrops in this area. T225C to F were collected about 300 yards south-east of the Clematis-Rewan boundary on the Carnarvon Highway. Their approximate positions from the base of the unit are: T225C-5', D-35', E-60', F-95'; the base of the cliff-forming sandstones being at about 55' above the base of the unit. (T225G, a red ochre which was not thin-sectioned, was taken from about 70' above the base). Of these specimens, T225E is probably in a similar stratigraphic position to SP161A in relation to the cliff-forming sandstone. T226 was taken about ½ mile south of the T225 specimens on the Carnarvon Highway, T227A to F were collected from a road cutting about ½ mile farther south, and T229A and B came from approximately the same stratigraphic position as the T227 specimens, about 1000 yards east-south-east of them.

T225C, stratigraphically below the cliff-forming sandstone, is similar to T225E and F higher in the unit; they are all medium to coarse-grained, in general not well sorted, and show poor rounding of grains, many of which are of low sphericity (Fig. 4); the quartz grains lack overgrowths. The total "quartz + quartzite + chert" content of these rocks ranges from 85% to 95%. T225D is a micaceous siltstone, and has abundant black heavy minerals, some tourmaline and zircon; the mica is muscovite. The specimens T227A to F include three sandstones which are similar to the sandstones of the main cliffs, but are fine and very fine-grained, and have more heavy minerals than the coarser sandstones.

The other specimens from this locality are argillaceous; they include a yellow ochre which contains 25% hydrated iron oxide, and abundant nearly isotropic clay. The iron oxide is light yellow brown in thin section.

T229A is probably typical of much of the sandstone in the upper half of the Clematis Sandstone in this locality. Like the T227 sandstones, it is very fine-grained, and has plentiful micas and a variety of rock fragments. T229B contains very fine, disseminated, opaque black matter which is probably carbonaceous. When fresh this rock is a dark grey, almost black, claystone, but it readily weathers to a buff colour. In the laboratory it was found that the fine black matter washes away very easily with water.

East flank of Mimosa Syncline.

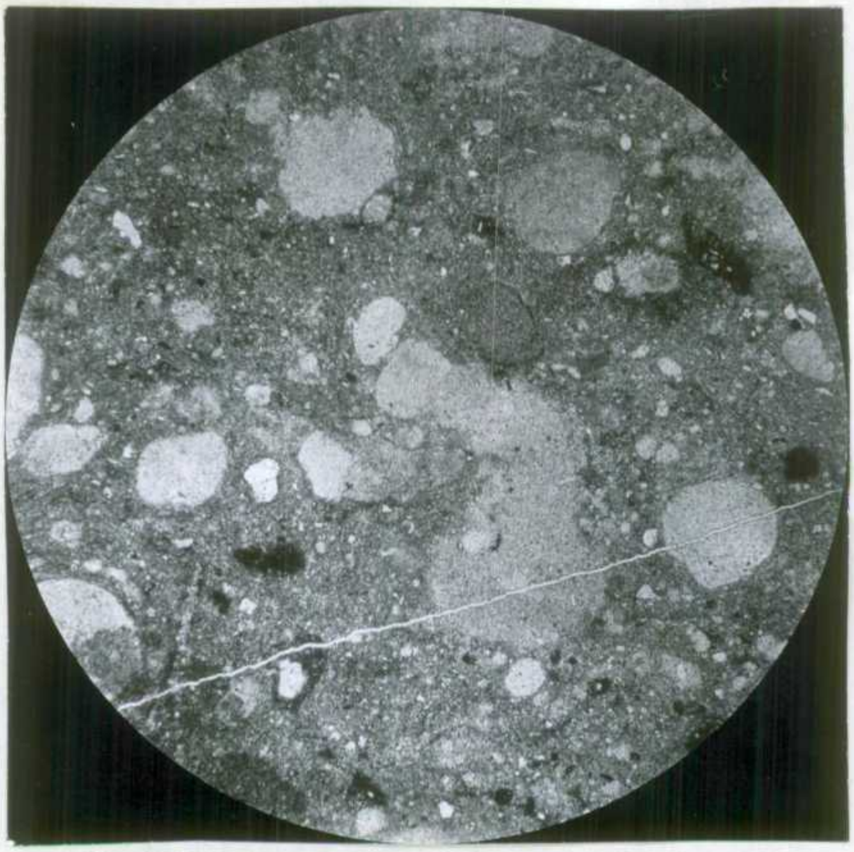
Because of an abrupt lateral facies change at the southern end of the Clematis Sandstone outcrops, the specimens from this locality are dealt with in two portions: (i) the Glenmoral Gap area and (ii) an area about 10 miles south of Glenmoral Gap.

Specimens in the first area include Ba83A and B, which were collected in Glenmoral Gap near the base of the unit; Ba82, from near the west end of Glenmoral Gap; and T240A and B, from about 4½ miles to the south.

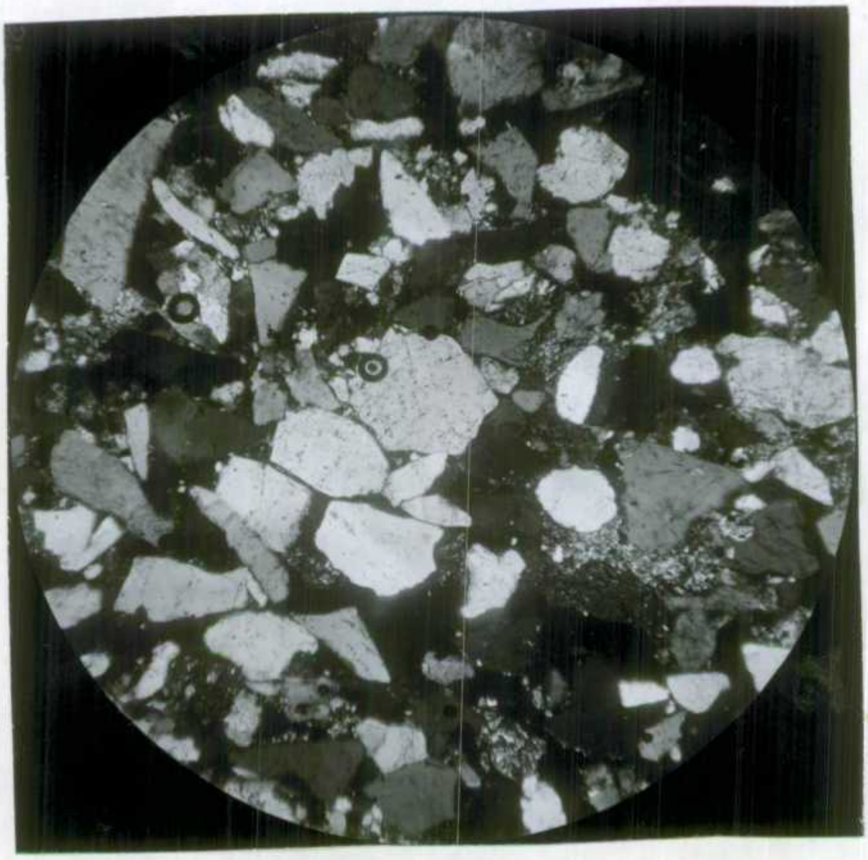
Judging by field appearances, Ba83B would be most typical of the sandstones at this locality. Volcanic detritus is common in Ba83B and abundant in Ba83A, in which there is only 35% quartz. Corroded quartz of volcanic origin has been noted in these specimens, and the K-feldspar, which appears to be all orthoclase, could also have come from a volcanic source. In some respects, however, they are similar to sandstones of the western outcrops, notably in the poor rounding of grains, and bimodal size distribution. Lithologies in B.M.R. Baralaba, No. 20, and the top part of B.M.R. Baralaba, No. 21, which were drilled in Glenmoral Gap, are almost identical with those of Ba83A (Arman, 1965). Ba82 has less volcanic material. T240A and B were collected from an interval of fine and very fine-grained sandstones, to complete the range of rock types at this locality. They appeared in the field to have come from bottomsets, the bulk of the sandstones being foresets. They are more quartz-rich than the Glenmoral Gap specimens, and unlike most Clematis Sandstone specimens have strong overgrowth and fairly strong pressure solution. The finer specimen, T240A, has plentiful illite and fine muscovite - indicating a quieter depositional environment than that of the coarser sandstones. Heavy minerals are common.

Specimens from the second area, south of Glenmoral Gap, include T215A and B, near the base of the unit from 2½ miles south-south-west of Devil's Nest Homestead; T238A and B, from 3 miles south-south-west of Devil's Nest; T239, from about 1 mile north of T238; and T216, from about 2 miles south-west of Devil's Nest.

The rock types here differ from those of the Glenmoral Gap area, mainly by the presence of many beds of conglomerate. Pebbles from conglomerates at the various localities include rhyolite, vitric tuff, crystal-vitric tuff, trachyte, pumice and tuffaceous claystone indicating volcanic sources, and vein quartz, microadamellite, microgranite, and silicified wood from other sources. The volcanic material is far more abundant than non-volcanic material. T215A is typical of the sandstones intercalated with these conglomerates; it is similar to Ba83A, and the total content of volcanic material probably exceeds 30%. The "Chert" in it was probably derived from tuffs or groundmass material of volcanic flow rocks; some of the "chert" grains contain devitrified glass shards. T216, from near the top of the unit, resembles the more quartzose lithologies in the western localities, but on the whole the quartzose sandstones are not conspicuous here. Some volcanic quartz is present, and fluid inclusions in quartz are common; overgrowths are minor.



Field 3.6mm. mag. X32, ordinary light.
Fig. 3. Specimen SP161E; claystone showing clay pellets and quartz in a silty clay groundmass - most of the rounded bodies are pellets. BMR neg. G/8019.



Field 3.5mm. mag. X32, crossed nicols.
Fig. 4. Specimen T225E; poorly sorted quartz sandstone, showing many grains with low sphericity.
BMR neg. F/4566A.

Expedition Range.

The two specimens, Ba922 and Ba923, may not be fully representative of the unit in the Expedition Range, but give some idea of its characteristics. Ba922 was collected from close to the base of the unit, and Ba923 from near the top.

Both specimens are similar to the sandstones of the other western outcrops of Clematis Sandstone. They are only moderately sorted, and Ba923 has a bimodal grain-size distribution. Ba923, however, has minor K-feldspar, and is the only sandstone collected from the western localities which has any feldspar at all.

The sandstones in B.M.R. Baralaba, No. 16, which drilled through the base of the unit near Ba922, have much lower quartz percentages and abundant ferruginous clay matrix; these probably belong to a transitional zone below the main sandstone facies. Apart from the different matrix they are similar to the outcrop specimens; most of the detrital grains being quartz.

SOURCE AREAS

The petrographic data indicate at least two sources for the Clematis Sandstone, in each case consistent with observations of current directions recorded in the Taroom and Baralaba geological reports (Jensen et al., 1964; Olgers et al., 1964). A third source is indicated by the current direction observations, and some support for this is afforded here.

The three nominated source areas are:-

(i) An important source area contributed quartzose sands devoid of feldspar. Fairly low sphericity of quartz, which is considered by Folk (1964) to indicate a metamorphic provenance, characterises these sandstones, and some may have metaquartzite clasts. Accordingly, the source area for these sediments was probably a terrain of metamorphic rocks. Cross-stratification measurements in the western part of TAROOM (Jensen et al., op.cit.) indicate sediment transportation to the north-east, from which it was concluded that the provenance area for the Clematis Sandstone at the Carnarvon Highway locality was to the west. The source area may have been a part of the Nebine Ridge.

(ii) A second source gave acid volcanic detritus, including corroded quartz of volcanic origin. Cross-stratification observations (Jensen et al., op. cit) suggest that this source was to the east of the Mimosa Syncline. The volcanic detritus which mixed with the quartzose sands at the south-east corner of the Mimosa Syncline did not constitute much of the total sand sheet. The presence of conglomerates suggests a fairly close source; probably the Lower Bowen Volcanics supplied the bulk of the material. The Auburn Complex is not favoured as a source, because it is thought that this unit supplied the biotite-rich sands which appear in abundance in the younger Moolayember Formation.

(iii) A third, probably important, source area is indicated by cross-stratification measurements (Olgers et al., 1964) in the Expedition Range. These indicate a north-westerly source, probably the Anakie High. The main rock units in that area are the Retreat Granite and the Anakie Metamorphics, and the data from Ba922 and Ba923 are consistent with these as possible sources. The cross-stratification measurements suggest that sediments from this source area comprise a large part of the Clematis Sandstone.

ENVIRONMENT OF DEPOSITION

Besides the field observations of cross-bedding, there is strong indication of fluvial deposition in the characteristic polymodal nature of these sandstones, which is typical of river deposits. That deposition took place in a terrestrial oxidising environment, is indicated by the thin bands of red and yellow ochre and by a fossil soil horizon (SP161E). The poor rounding of grains suggests rapid transport from the various source areas, and fairly fast accumulation with little reworking. This is supported also by the appreciable amounts of matrix in these sediments. Evidently the thickest sand sheets spread quite rapidly from the source areas, although deposition of the thinner-bedded, finer sands, and the various argillaceous beds was slower and subject to more winnowing.

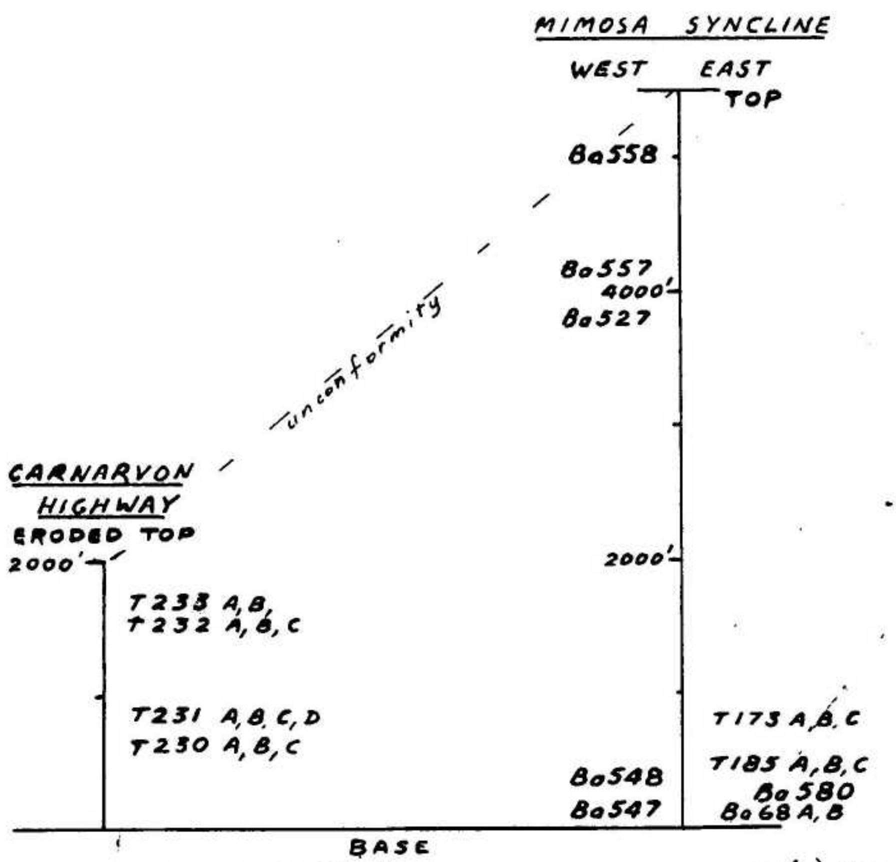
MOOLAYEMBER FORMATION

The localities of specimens collected from this unit are shown in Fig. 1, and their approximate relative stratigraphic positions are shown in Fig. 5. Suites of specimens from each of four areas are discussed separately then compared to determine trends in mineralogy and other features.

Where strong replacement by calcite has occurred, the rock names have been assigned on the assumption that calcite has mostly replaced labile materials such as feldspars and rock fragments. There is usually evidence for this in the form of partially replaced grains, and "ghost" outlines of completely replaced grains. Quartz appears to have been almost unaffected by calcite replacement. Most of the arenites have been named "subgreywacke". Others which have abundant volcanic detritus have been named "volcanic sandstone"; they differ from the subgreywackes, only in that they have more volcanic detritus. In the case of tuffs, some of which appear as pebbles in the conglomerates Ba68 and Ba580, the predominant component is used as the first of the qualifying names in accord with Pettijohn's nomenclature.

Fig.5 MOOLAYEMBER FORMATION

ESTIMATED POSITIONS OF SPECIMENS

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PETROGRAPHY

Specimens from the Mimosa Syncline - (near base of unit).

Most of these specimens were collected on the east limb of the syncline. Specimens T185A-C were collected from Gap Creek in TAROOM about 4 miles south-south-east of "Fairholme", and specimens T173A-C were also collected from Gap Creek, about $\frac{3}{4}$ mile west of T185. The pebble suite Ba580 was collected beside the Bauhinia Downs-Moura road on BARALABA, about 1 mile south of "Roundstone", and the other pebble suite Ba68 was collected about 1 mile west of Glenmoral Gap, close to the Theodore-Forest Hills road. Ba547 and Ba548 came from the west limb of the syncline, about 6 miles north-north-west and 5 miles north, of "Bedourie" respectively.

All except T173 were taken probably within 500' of the base of the unit; T173 is stratigraphically higher, probably between 500' and 1000' above the base.

The sandstones are generally very similar, but some differences were noted between specimens from the east and west limbs of the syncline. Those on the east limb are fine and medium-grained while those on the west limb are very fine-grained. All are fairly well to well sorted, and the grains are poorly rounded. In the western specimens, there is extensive calcite replacement of grains, with a corresponding drop in the amounts of feldspar and rock fragments. The quartz (25%-30%) has low sphericity and includes embayed grains from volcanic sources; primary crystal faces are common. Inclusions are minor and straight extinction is general. Occasional quartz grains are heavily dusted with fine inclusions; these were probably derived from silicified volcanics, in which the quartz had replaced groundmass material. In the eastern specimens, the average feldspar (mainly orthoclase) content exceeds 15% while, in the western specimens, feldspar is minor. Plagioclase is usually subordinate, except in Ba68A, the matrix of a conglomerate, in which weathered plagioclase is common.

Rock fragments in the sediments comprise a wide range of rock types, and the coarser sandstones, T185C and Ba68A, contain considerably more rock fragments than the other specimens. Most of the fragments are volcanics such as devitrified tuffs and rhyolites; two other noteworthy rock types are epidote-rich rocks and micrographic rocks (? granophyre). Epidote is also an abundant accessory mineral, especially in T185B. Biotite (up to 10%) and a hydrated greenish yellow to greenish brown phyllosilicate are abundant. The phyllosilicate is commonly swollen into vermicular forms (Fig. 6), and is clearly an alteration product of biotite.

The two suites of pebbles consist wholly of volcanic rocks. All but one of the Ba68 pebbles are tuffs, while four out of the nine Ba580 pebbles are tuffs, the others are various acid and intermediate volcanics. The collecting was too sparse to propose trends on these different assemblages. Some of the tuffs have flattened shards and streaky texture indicative of welding.

The siltstones, T185A and T173A, are poorly sorted and contain the greenish yellow phyllosilicate and many small pockets of kaolinite formed either from diagenetic reorganization or slight reworking. Their matrices are pale brownish, almost isotropic, clay; the particles lack the aggregate orientation typical of illite and the fine "book" structures typical of kaolinite. However, the very low birefringence and positive relief ($n >$ balsam) suggest that the material is mainly kaolinite.

Two common difficulties in naming sedimentary rocks were met here. Firstly, it is not clear whether the matrix of T185B is primary of diagenetic; at least some reorganization appears to have occurred during diagenesis. If the matrix is primary then the rock may be a feldspathic greywacke, otherwise it would be an arkose. Secondly, the original source of ferruginized material in T173B is not known. If it was derived from labile clasts the rock may be a subgreywacke (counting the green phyllosilicate as labile material); otherwise it may be an arkose.

Specimens from the Carnarvon Highway locality - (near base of unit).

This suite comprises specimens T230A-C and T231A-D. Specimens T230A-C were collected in Bullaroo Creek beside the highway, about 3 miles south-east of the Junction of Moolayember and Bullaroo Creeks. Specimens T231A-D were collected close to Bullaroo Creek about $\frac{3}{4}$ mile south of T230. The stratigraphic positions of T230 and T231 are near the middle of the unit; T230 being slightly higher stratigraphically than T231.

The sandstones from this suite are well sorted, and very fine-grained. The grains are poorly rounded and of moderate to low sphericity. The sphericity is perhaps slightly greater than that of grains in specimens from the eastern flank of the Mimosa Syncline. The quartz content ranges from about 15 to 40%, and only in T231D are there any overgrowths; this specimen also has embayed quartz of volcanic origin. The feldspars are mostly K-feldspar, and range from 5 to 10%; the plagioclase is fairly sodic. Biotite and swollen, occasionally vermicular, hydrated micas are common, and muscovite and chlorite are less common.

The rock fragments include less volcanic detritus than rock fragments in the more eastern specimens; the less stable types, such as volcanic flow rocks, are almost absent, while only siliceous material ("chert"), probably derived from tuff and rhyolite groundmass, is common. Metamorphics, shales and other sediments, are plentiful. Many of the sediment fragments resemble the lithology of T230B, suggesting derivation from penecontemporaneous strata; the softer of these tend to be more rounded than other detritus. Epidote rocks and micrographic grains are absent.

The matrix of T230A has been reorganized to produce patches of well oriented clay. These differ from the swollen micas, which show sharp grain outlines and fairly good cleavage even after strong swelling; the clay "mats" have a poor cleavage and finger into the poorly oriented clay background.

T231D has abundant diagenetic kaolinite. In support of a diagenetic origin for this kaolinite are the following features:-

(i) many swollen, strongly leached, muscovite flakes merge into kaolinite (fig. 7);

(ii) many of the kaolinite flakes are suggestive of feldspar grain shapes; it is noteworthy that feldspar is absent from this specimen.

The kaolinization probably expanded specimen T231D, causing a relative decrease in quartz content. The quartz overgrowths suggest that the sand was cleaner than the other Moolayember sands when deposited.

Calcite, abundant as cement and replacements of grains, attains 50% in T231C, which has a fontainebleau texture.

Fig. 6. Field 1.45mm. mag. X76, ordinary light. Specimen T185C, showing leached, strongly swollen biotite; the swollen grains are part of the sediment framework. BMR neg. F/4560A.

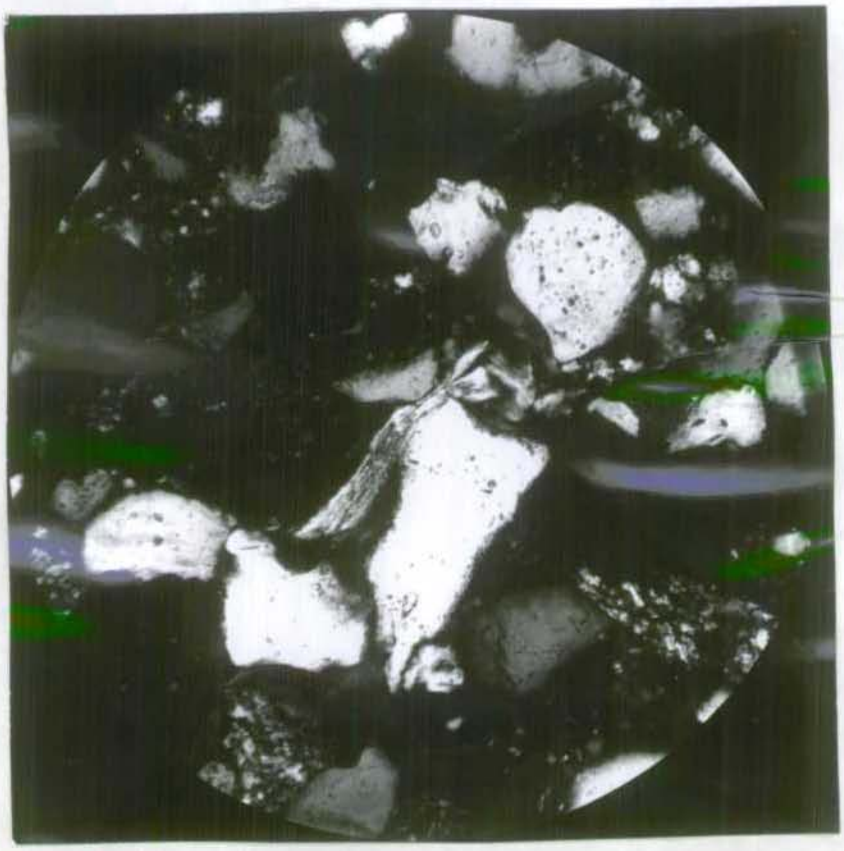

Fig. 7. Field 1.0mm. mag. X110, crossed nicols. Specimen T231D, showing a muscovite flake fanning out into a pore. The flake is leached except where held between grains. BMR neg. G8017.

The silty claystone, T230B, is similar to the siltstones of the eastern limb of the Mimosa Syncline. Most of the clay matrix is poorly oriented but patches have good orientation. The clay appears to have undergone diagenetic reorganization.

Specimens from Carnarvon Highway locality ( near top of unit).

This suite includes specimens T232A-C and T233A and B. Specimens T232A-C were collected in cuttings on the Highway about 2½ miles south-east of T231, and specimens T233A and B were collected about ¼ mile farther south-east.

The sandstones are very fine-grained, and generally well sorted, and, in general the grains are somewhat better rounded than those in the lower sandstones. Quartz is subordinate (5 to 20%) and there are no overgrowths. The feldspar content is about 10% throughout. Yellow-brown phyllosilicates are plentiful. Where there has not been widespread replacement by calcite, such as in T232B, there is an increase in volcanic rock fragments, (including "chert", of probable volcanic origin) which occupy up to 30%. T232B and C contain abundant fragments of chloritized volcanic rocks, including vesicular rocks which have been wholly chloritized; shale and siltstone clasts are also plentiful. The lithic assemblages in T232B and C are distinct from those in other specimens examined. In T233B, many compressed lithic grains resemble matrix, and it was difficult to identify individual grains.

Detrital matrices are in general more abundant than in the Mimosa Syncline specimens, mainly because they are very fine-grained. The matrices consist of kaolinite, illite or yellow and greenish phyllosilicates, and commonly show evidence of reorganization, such as sheaf-like textures. T232C has a chalcedonic cement, which is unusual for sediments of the Moolayember Formation.

Like the other silty claystones in this unit, T233A contains a pale brownish clay, but the patches of oriented clays were not seen.

Specimens from Mimosa Syncline - (near top of unit).

These specimens are stratigraphically much higher than those of the upper part of the Carnarvon Highway section, because of erosion of most of the unit in that locality before deposition of the Precipice Sandstone.

Assuming the 5500' thickness estimate for Moolayember Formation in the Mimosa Syncline, made by Olgers et al. (1964), there is about 2000', representing the middle part of the unit,which was not sampled.

Ba527 was collected 7 miles east of "Palmgrove"; Ba557 was collected in Spottswood Creek beside a homestead about 5½ miles south-south-east of "Boonberry"; and Ba558 was collected about 7 miles north-north-west of "Stonecroft".

These sandstones are moderately sorted and well sorted, fine-grained and very fine-grained; grains are mainly subangular. Quartz is subordinate, and rock fragments are abundant in the two specimens which do not have very much calcite replacement. Rock fragments include andesite, rhyolite and tuffs, with lesser amounts of sedimentary and metamorphic fragments. Ba527 has 20% of fibrous green-brown chlorite as prominent banded linings to the pores (fig.8). This chlorite, is a product of diagenetic alteration of the original matrix and biotite. Ba558 has more calcite than detritus, and evidently came from a calcareous concretion, as there is evidence of much replacement of feldspars and rock fragments by calcite. This specimen has been called a calcareous sub-greywacke rather than sandy limestone in order to emphasize that detrital minerals originally formed a framework for the rock.

Except for epidote and chlorite, accessory minerals are uncommon. This is a consistent feature of the Moolayember Formation. The abundance of epidote and detrital chlorite in some specimens is attributed mainly to a supply of rocks rich in these minerals rather than to concentrative processes.

MINERALOGY TRENDS AND SOURCE AREAS

The main trends from east to west in the lowest 2000' of the unit are:

(i) the grain-size changes from fine and medium-grained in the east to very fine-grained in the west; conglomerates in the east appear to be lacking in the west;

(ii) the content of volcanic rock fragments decreases westwards;

(iii) the content of sedimentary and metamorphic rock fragments increases westwards;

(iv) calcite cement and replacements increase westwards.

The last trend may be only a result of inadequate collecting; Jensen et al. (1964) noted that calcareous concretions are common in the vicinity of the Dawson Range, on the eastern flank of the Mimosa Syncline.

Stratigraphically upwards in the section the quartz content decreases from about 30% in the lower specimen to about 15% in higher specimens. There are insufficient data available to show if this quartz content is consistent in the remainder of the unit.

The yellow-green phyllosilicate, developed from leaching of biotite, is common in all suites. The colour varies somewhat, but this may be partly due to degrees of weathering rather than to colour variations of the mineral. This material may be the same as that called "green biotite" by Folk (1964). The alteration of biotite probably took place during transport rather than during burial. Micas wedged between other grains commonly show swelling into pores but are unaltered in the parts where they are in contact with other grains. This feature is common in the kaolinitic sandstone, T231D (fig. 7), but it does not characterize the swollen phyllosilicates (fig. 6), which were probably expanded when derived into the sediment.

The Moolayember Formation and the Rewan Formation look similar in the field but they may be distinguished by the following petrographic differences:-

(i) the yellow-green phyllosilicate, common in the Moolayember, does not occur in the Rewan;

(ii) more micas especially biotite, in the Moolayember than in the Rewan;

(iii) generally less quartz in the Rewan;

(iv) much more lithic detritus, notably devitrified volcanic glass, in the Rewan;

(v) redbeds occur in the Rewan, but not in the Moolayember; some minor redbeds occur in the Clematis.

The Moolayember sediments were not derived predominantly from volcanic sources as were the Rewan sediments, but instead they originated from many source areas. Volcanic detritus is more prominent in the eastern outcrops of the Moolayember Formation, indicating that the volcanic source was to the east. This is consistent with grainsize and other compositional trends. The abundant biotite and its alteration products point to granodiorite and diorite sources such as occur in the Auburn Complex and Urannah Complex. Jensen et al. (1964, p.89) noted up to 15% biotite in granodiorite of the Auburn Complex, and (p.90) that muscovite appears to be completely lacking from all the rocks examined. Epidote rock and chlorite were probably also derived from this source; Jensen et al. (op.cit. p.90)

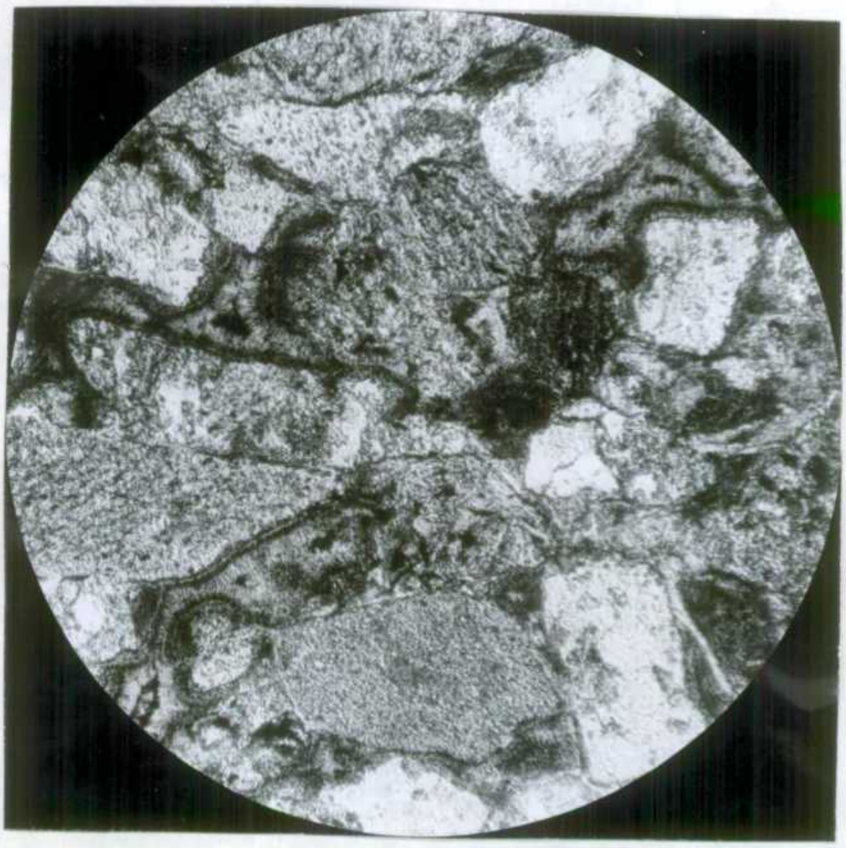

Fig. 8. Field 1.0mm. mag. X110, ordinary light. Specimen Ba527; subgreywacke with fibrous chlorite lining the pores; most of the lithic grains are volcanic rocks.

BMR neg. F/4556A.

noted that much feldspar in the Complex has been altered to epidote. Rocks of the Anakie High, such as the Anakie Metamorphics, were not likely sources, as that area had previously supplied biotite-poor material to Permian units such as the Colinlea Sandstone (Bastian, 1965). Metamorphic detritus, possibly from slates and phyllites, which is present in the unit farther west, may have originated from the Anakie Metamorphics. The source of the mineral assemblage in T232A and B is not known.

The main source areas for the Moolayember Formation were probably to the east. Eastern sources are also inferred for the Rewan Formation (Bastian, in prep.) and for part of the Clematis Sandstone. The incoming of biotite at the top of the Clematis, e.g. in T215B, suggests that the Auburn Complex may have been exhumed at that time by erosion of overlying Permian units and the Rewan Formation.

## ENVIRONMENT OF DEPOSITION

Terrestrial depositional conditions, as for the Clematis Sandstone, cannot be inferred for the Moolayember Formation. Alteration of biotite in the Moolayember Formation during transport suggests a reducing environment in contrast with the inferred oxidizing depositional environment for the Clematis. However, the presence of carbonaceous matter and the lack of marine fossils suggest deposition in a non-marine, possibly brackish, environment. Acritarchs in the Moolayember Formation at Hungry Creek (Evans, 1964) suggest a brackish environment of deposition.

Angular grains generally indicate rapid transport with little recycling, but abrasion of grains would be slower for the fine Moolayember sands than for the coarser Clematis sands. Thus the fine grains in the Moolayember Formation may have been subjected to longer periods of transport than at first implied by their poor rounding. Furthermore, while the poor sorting and polymodal character of the Clematis sands, indicate virtually no reworking, the good sorting of the Moolayember sands suggests that some reworking took place; such reworking was not sufficient to remove labile grains. The Clematis Sandstone and the Moolayember Formation were deposited in different environments; the former was deposited fluvially and the latter was probably laid down under the quiet waters of lakes or estuaries; Olgers _et al_. (1964) have also suggested this.

## REFERENCES


ARMAN, M., 1965 — Petrographic notes on Bowen Basin shallow holes drilled in 1963. Bur.Min.Resour.Aust.Rec. 1965/215 (unpubl.)

BASTIAN, L.V., 1965 — Petrographic notes on Permian Sandstones of the Springsure 1:250,000 Sheet area, Queensland. Ibid. 1965/230 (unpubl.)

BASTIAN, L.V., 1965 — Petrographic notes on the Rewan Formation, southern Bowen Basin, Queensland. Ibid. (in prep.)

CAROZZI, A.V., 1960 — MICROSCOPIC SEDIMENTARY PETROGRAPHY. John Wiley, New York.

EVANS, P.R., 1964 — Some palynological observations on the Mesozoic of the Baralaba, Monto, Taroom and Mundubbera 1:250,000 Sheet areas, Bowen-Surat Basin, Queensland. Bur.Min.Resour.Aust.Rec. 1964/91 (unpubl.)

FOLK, R.L., 1964 — PETROLOGY OF SEDIMENTARY ROCKS. Hemphills, Austin, Texas.

JENSEN, A.R., GREGORY, C.M., & FORBES, V.R., 1964 — The geology of the Taroom 1:250,000 Sheet area and of the western third of the Mundubbera 1:250,000 Sheet area, Queensland. Bur.Min. Resour.Aust.Rec. 1964/61 (unpubl.)

MOLLAN, R.G., EXON, N.F., & KIRKEGAARD, A.G. — The geology of the Springsure 1:250,000 Sheet area, Queensland. Ibid. 1964/27 (unpubl.)

OLGERS, F., WEBB, A.W., SMIT, J.A.J., & COXHEAD, B.A., 1964 — The geology of the Baralaba 1:250,000 Sheet area, Queensland. Ibid. 1964/26 (unpubl.)

PETTIJOHN, F.J., 1957 — SEDIMENTARY ROCKS. Harper, New York.

WILLIAMS, H., TURNER, F.J., & GILBERT, C.M., 1955 — PETROGRAPHY. Freeman, San Francisco.

## APPENDIX A

List of specimen field numbers and registered rock numbers.

| Field No. | Registered No. | Field No. | Registered No. |
|---|---|---|---|
| SP159G | R17124 | T227E | R16361 |
| SP159H | R17125 | T227F | R16362 |
| SP159J | R17126 | T229A | R16363 |
| SP161A | R17127 | T229B | R16364 |
| SP161B | R17128 | Ba83A | R16365 |
| SP161C | R17129 | Ba83B | R16366 |
| SP161D | R17130 | T240A | R16377 |
| SP161E | R17131 | T240B | R16378 |
| T225C | R16351 | Ba82 | R16367 |
| T225D | R16352 | T215A | R16375 |
| T225E | R16353 | T215B | R16376 |
| T225F | R16354 | T238A | R16372 |
| T226 | R16356 | T238B | R16373 |
| T227A | R16357 | T239 | R16374 |
| T227B | R16358 | T216 | R16371 |
| T227C | R16359 | Ba922 | R17105 |
| T227D | R16360 | Ba923 | R16218 |
| T185A | R16368 | T230C | R16381 |
| T185B | R16369 | T231A | R16382 |
| T185C | R16370 | T231B | R16383 |
| T173A | R16393 | T231C | R16384 |
| T173B | R16394 | T231D | R16385 |
| T173C | R16395 | T232A | R16386 |
| Ba68A | R16391 | T232B | R16387 |
| Ba68B | R16392 | T232C | R16388 |
| Ba580 | R16401 | T233A | R16389 |
| Ba547 | R16397 | T233B | R16390 |
| Ba548 | R16398 | Ba527 | R16396 |
| T230A | R16379 | Ba557 | R16399 |
| T230B | R16380 | Ba558 | R16400 |

## APPENDIX B.

List of abbreviations used in Tables.

| | | | |
|---|---|---|---|
| abundant | a | moderate | mod. |
| angular | ang. | muscovite | musc. |
| biotite | biot. | phyllosilicate | phyllo. |
| black | blk | pressure | press. |
| brown | brn | rare | r |
| calcite | calc. | replacement | repl. |
| carbonaceous | C. | rounded | rd |
| cement | cem. | sandstone | sst. |
| claystone | clst. | sedimentary | sed. |
| coarse | crs. | shale | sh. |
| common | c | siltstone | sltst. |
| crystal(s) | Xl(s) | solution | soln. |
| devitrified | devit. | subangular | subang. |
| feldspar | felds. | subrounded | subrd |
| hydrated | hyd. | uncommon | u |
| iron (oxide) | Fe(ox). | unidentified | unident. |
| kaolinite | kaol. | very | v. |
| maximum | max. | volcanic(s) | volc(s). |
| metamorphic | meta. | yellow | yel. |
| microcrystalline | microXline | | |

TABLE A

CLEMATIS SANDSTONE

| Specimen Number and Name | TEXTURE | | | | PERCENTAGE ESTIMATES | | | | | | | | | | ACCESSORIES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | sorting | ~~grain-size~~ mm. | round-ness | sphericity<br>----------<br>orientation | quartz | quartzite | chert | micas | ~~K-felds~~ | plag. | rock frags. | matrix | ~~cement~~ | alter. | tourm. | zircon | garnet | apatite | epidote |
| SP159G argillaceous sandstone | fairly good | max. > .15<br>mode .08 | ang.-subang. | fairly low<br>----------<br>strong | 40 | > 5 | 25 | 2 | | | | 20<br>(illite, kaol.) | | 5<br>(hyd. Fe ox) | c | v.c. | | | |
| SP159H argillaceous sandstone | poor, polymodal | max. > .15<br>modes < .15, .07, & clay | ang.-(subang.) | fairly low<br>----------<br>nil | 35 | | | < 5<br>(musc.) | | | | > 60<br>(primary hyd. Fe ox) | | | | | | | |
| SP159J argillaceous sandstone | good | max .65<br>mode .15<br>crs. mode .35 (minor) | ang.-subang. | mod.<br>----------<br>weak | 70 | 5 | < 5 | 1 | | | | < 20<br>(illite, kaol.) | | | u | u | | | |
| SP 161A orthoquartzite | mod., bimodal | max. > 2<br>crs. mode 1<br>main " .4 | (ang.)-subang. (-subrd.) | mod. - high<br>---------- | 70 | 25 | | r | | | | 5<br>(colloform clay aggregates) | | | | | | | |
| SP161B orthoquartzite | mod., polymodal | max. .75<br>main mode < .3 | ang. - subang. (-subrd.) | mod.<br>----------<br>mod. | 75 | < 20 | | u | | | | > 5<br>(kaol., & some illite) | | | | | | | |
| SP161C ferruginous, micaceous siltstone | fairly good | max. .08<br>mode .03 | ang.-(subang.) | low - mod.<br>----------<br>mod. | 35 | u | 2 | 5 | | | | < 60<br>(10% kaol., 30% Fe ox. in fine spots, remainder illite & fine silt.) | | | r | | | | |
| SP161E underclay, pelletal type | poor | max. > .2<br>no clear mode | ang. | mod.<br>----------<br>weak, | 10<br>plus 30% nodules up to 2.5 mm. (? kaol.), 60% lt. brn clay, mostly isotropic, with C. matter & minute chips (? woody). | | | | | | | | | | | | | | |
| SP161D. orthoquartzite, ferruginized | fairly good, polymodal | max. 1.2<br>modes .6, > .2, < .1 | (ang.) subang. (subrd) | mod. - low<br>----------<br>fairly good | 65 | < 5 | < 10 | r | | | r | 2 | | 20<br>(hyd. Fe ox) | u | c | | | |
| T225C protoquartzite | fairly good | max. 1.2<br>mode < .6 | subang. -subrd. | fairly high<br>----------<br>mod. | < 80 | 10 | > 5 | | | | | > 5<br>(colloform clay aggregates) | | | | | | | |
| T225D micaceous siltstone | good | max. .1<br>mode .05 | ang.-(subang.) | mod.<br>----------<br>mod. | > 50 | | < 5 | 5<br>(musc.) | | | | 40<br>(illite, kaol., & yel.-brn clay) | | | v.c. | v.c. & abundant blk minerals | | | |
| T225E protoquartzite | rather poor | max .7<br>min .05<br>no clear mode | ang.-(subang.) | mod. - low<br>----------<br>rather weak | < 70 | > 5 | < 10 | u | | | 5<br>(sst, sltst) | 10<br>(kaol. "books", less illite) | | | u | | | | |
| T225F protoquartzite | mod. | max. 1.5<br>crs. mode 1<br>main " > .3 | ang.-subang. (-subrd) | mod.<br>----------<br>mod. | < 75 | > 5 | > 5 | u | | | 5<br>(sh, sltst) | 10<br>(kaol., illite, silt) | | | c | | | | |

| Specimen Number and Name | sorting | grain-size mm. | roundness | sphericity orientation | quartz | quartzite | chert | micas | K-felds | plag. | rock frags. | matrix | cement | alter. | tourm. | zircon | garnet | apatite | epidote |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TEXTURE | | | | PERCENTAGE ESTIMATES | | | | | | | | | | ACCESSORIES | | | | |
| T226 orthoquartzite, kaolinitic | mod. | max. >.2<br>mode .07 | ang.-<br>(subang) | low<br>----------<br>poor | <75<br>(mod. press. soln.) | | 2 | 3 | | | | >20<br>(kaol., less illite) | | | a | c | | | |
| T227A micaceous orthoquartzite | v. good | max. >.15<br>mode .08 | ang.-<br>subang. | mod.<br>----------<br>poor | 70<br>(plus - 5% pale yel.-brn. leached micas)<br>(mod. to strong press. soln.) | u | >5 | >5 | | | 3 | 10<br>(kaol., illite & yel. phyllo.) | | | c | u | | | |
| T227B sandy siltstone | poor, polymodal | max. .7<br>modes .35, .1, .04 | ang.-<br>(subang.) | mod - low<br>----------<br>strong | 30<br>(plus - 30% silt, ?quartzose; >30% clay, mainly yellow illite; 2% C. matter - leaves.) | | | 5 | | | | | | | c | c | | | |
| T227C yellow ochre | good | v. fine, silty clay | | | 5% fine silt; 10% illite; 25% hydrated Fe oxides; remainder clay - near isotropic. | | | | | | | | | | | | | | |
| T227D silty shale | good | max. .08<br>mode .02 | ang. | mod. - low<br>----------<br>fairly strong | 30% silt; 60% illite & kaol.; 10% micas (musc., less biot.), & C. matter. | | | | | | | | | | u | | | | |
| T227E protoquartzite | good | max. .25<br>mode <.15 | ang.-<br>subang.<br>(-subrd.) | fairly low<br>----------<br>strong | 75 | 5 | <5 | 1<br>(musc.) | | | 5<br>(shale, meta.) | 10<br>(illite, with Fe alteration) | | | c | | | | |
| T227F lithic greywacke | rather poor | max. .25<br>mode <.1 | ang.-<br>(subang.) | fairly low<br>----------<br>mod.-strong | 40 | 10 | >5 | <5<br>(musc., less biot. & yel.-grn phyllo.) | | | 15<br>(shale, meta.) | 15<br>(silt., illite) | | 10<br>(Fe alteration of matrix) | u | | | | |
| T229A protoquartzite | good | max. <.2<br>mode <.1 | ang. -<br>subang.<br>(-subrd.) | low<br>----------<br>fairly strong | 65 | 5 | <5 | >5<br>(as above) | | | <10<br>(shale, sltst, meta.) | 5 | | >5<br>(kaol., large "books" from leached micas) | u | u | | | |
| T229B carbonaceous, silty claystone | good | max. .05<br>main mode <.01 | ang. | mod. | 30% silt, ? quartzose; >65% clay fraction - includes 15% illite and fine musc., & 50% clay, pale brn, ? kaolinitic; <5% C. matter, v.fine, & leaf shreds. | | | | | | | | | | | | | | |
| Ba83A volcanic sandstone | fairly good | max. 1.0,<br>modes .5<br>& .2 | subang.<br>(-subrd.) | fairly high | 35 | | >15<br>(? volc. source) | u | 15 | | 15<br>(volc.) | >15<br>(kaol., diagenetic; some illite) | | | | | | | |
| Ba83B subarkose | fairly good | max. 1.0<br>modes .5, .25 | (ang.)-<br>subang.<br>(-subrd.) | mod.<br>----------<br>fairly strong | <60<br>(corroded)<br>(strong over-growths) | 5 | 15<br>(volc.) | 1 | <10 | | <5<br>(sltst., sh.) | <10<br>(kaol.) | | | r | | | | |
| T240A argillaceous sandstone | rather poor | max. <.3<br>crs. mode .2<br>mode .07 | ang.-<br>subang.<br>(-subrd.) | fairly low<br>----------<br>fairly strong | 60<br>(strong over-growths)<br>(fairly strong press. soln.) | | 10 | 5<br>(musc.) | | | | 25<br>(illite & kaol). | | | c | c | | | |

| | TEXTURE | | | | PERCENTAGE ESTIMATES | | | | | | | | | | ACCESSORIES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Specimen Number and Name | sorting | grain-size mm. | round-ness | sphericity / orientation | quartz | quartzite | chert | micas | K-felds | plag. | rock frags. | matrix | cement | alter. | tourm. | zircon | garnet | apatite | epidote |
| T240B orthoquartzite | v. good | max. .25<br>mode <.15 | subang.<br>-subrd. | fairly high<br>fairly strong | >70<br>(strong O'growth)<br>(fairly strong press.soln.) | >5 | 5 | u | | | u | >15<br>(kaol.) | | | r | | | | |
| Ba82 subgreywacke | good | max. .4<br>mode .2 | (ang.)-<br>subang.<br>(-subrd.) | mod.<br>mod. | 55<br>(mod. o'growth) | <5 | >5 | u | <10 | | 10<br>(shale, volcs., chloritic & sericitic grains) | 10 | | <5<br>(Fe ox.) | | r | | | |
| T215A volcanic sandstone | mod. | max. .65<br>mode .25 | ang.-<br>subang.<br>(-subrd.) | mod.<br>fairly strong | 30 | 5 | >10 | >5<br>(biot.) | <15 | | 20<br>(volcs., clst., granophyre) | <10<br>(detrital, silt & clay)<br>+ 5% kaol. patches | | | | | | | |
| T215B Pebbles from conglomerate | | | | | Pebbles:- porphyritic rhyolite, tuffaceous claystone, pumice, vitric tuff, vein quartz, trachyte. | | | | | | | | | | | | | | |
| T238A pebble-conglomerate | poor, biomodal | max. >2cm.<br>sand mode 3mm. | subang.<br>-subrd.<br>(-rd.) | mod. | 50 | | 30<br>(data for sand fraction) | u | 10 | | | <10 | | | – & augite (u) | | | | u |
| | | | | | pebbles:- vitric tuff, rhyolite, ? andesite, trachyte, leucocratic microgranite. | | | | | | | | | | | | | | |
| T238B pebbles | | | | | rhyolite (3), & tuffaceous silty claystone. | | | | | | | | | | | | | | |
| T239 pebbles | | | | | vitric crystal tuff, microadamellite, silicified wood. | | | | | | | | | | | | | | |
| T216 subarkose | good | max. .6<br>mode .3 | (subang.)<br>-subrd.<br>-rd. | mod.<br>weak | <70<br>(few o'growths) | >5 | >5 | r | <10 | | u | 10<br>(kaol. & brn clay lining pores) | | | | | | | |
| Ba922 orthoquartzite | mod. | max. .7<br>mode .3 | subang.<br>-subrd. | mod.<br>fairly strong | >80<br>(slight o'growth) | 2 | u | 1 | | | u | <15<br>(brn ferruginous aggregates) | | | | | | | |
| Ba923 protoquartzite | mod., bimodal | max. .6<br>crs.mode .5<br>main " .2 | ang.-<br>subang.<br>(-subrd.) | low<br>fairly strong | >75 | >5 | 2 | 1 | 2 | | <5 | 10<br>(brn clay) | | | r | | | | |

TABLE B MOOLAYEMBER FORMATION

| Specimen Number and Name | TEXTURE: sorting | grain-size mm. | roundness | sphericity / orientation | PERCENTAGE ESTIMATES: quartz | quartzite | chert | micas | K-felds | plag. | rock frags | matrix | cement | alter. | ACCESSORIES: tourm. | zircon | chlorite | apatite | epidote |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T185A sandy siltstone | poor-biomodal | max. .15<br>crs.mode .08<br>fine " clay | ang.-subang. | low / nil | 10 | u | > 5 | < 5 | < 10 | | < 5 | 45<br>(pale brn.,)<br>(microXline,)<br>( ? kaol.) | | | | | u | | 1% |
| | | | | | (plus - 5% green (-yellow) phyllosilicate -15% kaol., small nodules | | | | | | | | | | | | | | |
| T185B feldspathic greywacke | fairly good | max. .25<br>mode .12 | ang.-subang. | low / mod | 30<br>(some embayed) | | 5 | > 5<br>(biot.)<br>& grn. phyllo. | < 20 | 2 | 20<br>(devit. glass)<br>( ? shale)<br>(r. granophyre) | 15<br>kaol., illite | | 1<br>(Fe ox.)<br>(coats.) | | r | r | | 1% |
| T185C volcanic sandstone | mod. | max. .9<br>mode .4 | ang.-subang. | fairly low / poor | 25<br>(some embayed) | | | >5<br>(biot.)<br>& minor grn-brn phyllo. | < 15 | 5 | < 40<br>( 30% devit. glass, tuff, volcs)<br>( 5% granophyre )<br>( 5% sst., meta.) | 10 | | | | | | | |
| T173A sandy siltstone | poor | max. < .15<br>no clear mode | ang. | fairly low / nil | 10 | | < 5 | 5 | 15 | < 5 | | 35<br>(pale brn, )<br>(microXline,)<br>(? kaol., illite) | | | | r | u | | |
| | | | | | & 10% yel (-grn) phyllo., 15% kaol. (illite) small nodules | | | | | | | | | | | | | | |
| T173B subgreywacke (or ? arkose) | fairly good | max. .25<br>mode .12 | ang. (-subrd.) | fairly low / mod. | < 30 | | | 10<br>(biot.) | 15 | < 5 | < 10<br>(devit. glass,) | 15 | | calcite, (u) | | | c | | u |
| | | | | | & 10% grn-brn phyllo., (volcs.) 10% unidentified ferruginised, grains. | | | | | | | | | | | | | | |
| T173C subgreywacke (or ?arkose) | good | max. .4<br>mode < .2<br>& rare crs. grains | ang. (-subang.) | low / fairly strong | < 30 | | | 5<br>(biot.) | 10 | < 5 | 10<br>(volcs.) | < 10 | | 20<br>(calcite, cem)<br>(& repl. ) | | | c | | u |
| | | | | | & 10% grn-brn phyllo., 5% opaque grains, unidentified | | | | | | | | | | | | | | |
| Ba68A matrix of conglomerate | v. good | max .6<br>mode .35 | ang.- (subang.) | mod / poor | < 30 | | | u | | 10 | < 50<br>( 40% devit. glass)<br>( 5% other volcs.)<br>rhyolite, pumice, etc. | | 15<br>(chalcedony) | | | | | | |
| Ba68 B pebbles from conglomerate | | | | | Pebbles - Rhyolite, vitric-crystal tuff, vitric-crystal tuff (? welded), ? vitric-lithic tuff, vitric tuff. | | | | | | | | | | | | | | |
| Ba580 pebbles from conglomerate | | | | | Pebbles - andesite (or ? soda-trachyte), soda-trachyte (or ? vitric-crystal tuff), vitric-crystal-lithic tuff, soda-trachyte, crystal tuff, ? trachyte, soda-rhyolite, crystal-vitric tuff, andesite. | | | | | | | | | | | | | | |
| Ba547 calcareous ? subgreywacke | v. good | max < .2<br>mode .1 | ang.-subang. | fairly low / mod. | 30 | < 5 | > 5 | 3<br>(musc., biot.,)<br>(yel. phyllo.) | 2 | u | < 10<br>(volcs.,)<br>(shale) | < 5<br>(kaol.) | | 40<br>(calc. repl.) | r | | | | |
| Ba548 calcareous ? subgreywacke | v. good | max < .15<br>mode .08 | ang.-subang. (subrd.) | mod. (-high) / fairly good | < 30 | 3 | 2 | 5<br>(as above) | 5 | | 2<br>(strong replacement by calcite) | 15<br>(kaol.) | | 40<br>(calc. cem. & repl.) | u. | u. | | | |

| | TEXTURE | | | | PERCENTAGE ESTIMATES | | | | | | | | | | ACCESSORIES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Specimen Number and Name | sorting | grain-size mm. | roundness | sphericity / orientation | quartz | quartzite | chert | micas | K-felds | plag. | rock frags. | matrix | cement | alter. | tourm. | zircon | chlorite | apatite | epidote |
| T230A lithic greywacke | good-bimodal | max <.15<br>modes .08<br>& clay mode | ang.- subang. (-subrd.) | mod. / mod. | 20 | | < 20 | > 5 | 6 | 4 | 10<br>(acid volcs., meta., sh.) | 35<br>(illite - parts (reorganized)) | | | | r | | | |
| T230B silty claystone | fairly good-bimodal | max. .12<br>main mode clay | ang. | | 20% silt - quartz, quartzizte, ? felds.<br>80% clay - pale brn, kaol. & illite, mostly poor orientation but patches good orientation.<br>1% blk ?wood. | | | | | | | | | | | | | | |
| T230C calcareous subgreywacke | good | max. .3<br>mode .15 | ang.- subang. (-subrd.) | mod. / fairly strong | 15 | 5 | 10<br>& 5% grn. phyllo. aggregates. | 5<br>(biot., swollen) | | > 5 | > 20<br>(clst., acid volc., sltst., meta.) | < 10 | (chlorite grain coats) | 25<br>(calc. repl.) | | | u | | |
| T231A calcareous ? subgreywacke | good | max <.25<br>mode .12 | ang. subang. (-subrd.) | mod. / poor | 30 | u | < 10 | 3 | < 5 | u | > 10<br>(shale) (minor acid volc,) meta. | 5 | | < 40<br>(calc. cem. & repl., Xls .6mm) | r | | | | |
| T231B calcareous ? subgreywacke | good | max .2<br>mode .1 | ang. subang. (-subrd.) | low-mod. / poor | 25 | < 5 | 10 | 5<br>(biot., musc.) | < 5 | 1 | < 15<br>(10% shale, subrd., meta. 5% acid volc.) | | | < 40<br>(calc. cem. & repl.) | u<br>r. garnet | r | c | | c |
| T231C calcareous ?subgreywacke | fairly good | max .15<br>mode < .07 | ang.- (subang) | mod. / nil | > 30 | | < 10 | 5 | 5 | u | | | | 50<br>(calc., fontain-bleow textured, repl.) | c. | c. | | | |
| T231D kaolinitic protoquartzite | polymodal | max 1.2<br>mode .4<br>main mode < .15 | ang.- subang. -subrd. | mod. / v. strong | 40<br>(volc. embayments,) (few o'growths) | 5 | < 10 | < 1<br>(leached) | | | 5 | 40<br>(kaol., patches & vermicular grains) | | | c. | c. | | | |
| T232A sandy siltstone & shale | fairly good-polymodal | max. .15<br>mode .05<br>& clay mode | subang. -subrd. | mod. / mod. | 10 | (streaks of C. matter) | < 30 | < 15 | 5 | r | 10<br>(shale, clay) | 30 | | 5<br>(calc. repl.) | | | | | |
| T232B calcareous ?subgreywacke | fairly good | max. .2<br>mode .08 | (ang)- subang.- subrd. | mod. / mod. | 10<br>(& 1% C. matter, woody). | | | 5<br>(biot., grn. phyllo.) | 5 | | > 20<br>(volcs, devit. glass, meta. chloritized volcs.) | | | > 50<br>calc. strong repl. | | 1% | | | |
| T232C subgreywacke | good | max .25<br>mode .12 | (subang.) -subrd. -rd. | mod - high / strong | > 5<br>& 10% yel-grn phyllo. | 2 | 10 | u | 10 | u | 40<br>(15% shale, sltst, clst. 15% acid volcs, many chloritized) | 5 | 15<br>banded chalcedony | | r | | | | |
| T233A silty claystone | fairly good | max .06 | ang. | --- / nil | 30% silt. - quartz, ? felds, chert, micas, grn(-yel.) phyllo.<br>70% clay - pale brn, microXline, ?kaol.,<br>& 2-3% blk matter, ?woody. | | | | | | | | | | | | | | |

B.3.

| Specimen Number and Name | TEXTURE<br>sorting | grain-size mm. | round-ness | sphericity<br>orientation | PERCENTAGE ESTIMATES<br>quartz | quartzite | chert | micas | K-felds | plag. | rock frags. | matrix | cement | alter. | ACCESSORIES<br>tourm. | zircon | chlorite | apatite | epidote |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T233B subgreywacke | good | max. .15<br>mode .06 | ang.- subang. (-subrd.) | mod<br>fairly strong | <20 | >5% yel-grn. phyllo. | 10 | 5 | 10 | u | 35<br>(devit. glass, shale,)<br>( clst, few meta.) | 15<br>? | | | r | u. | u | | |
| Ba527 subgreywacke | good | max .4<br>mode .2 | subang. -subrd. | fairly high<br>mod. | 5 | 5 | 20 | | <1 | | 35<br>( andesite, acid)<br>(volc, shale, sltst,)<br>( few meta.) | | 20<br>(chlorite,)<br>(druses in pores) | 15<br>calc. | | | | | |
| Ba557 calcareous ?volcanic sandstone | v. good | max .5<br>mode .3 | ang.- subang. -subrd. | mod.<br>poor | <20 | | | 10 | >10 | >5 | 20<br>(acid volcs., andesite,)<br>(basalt, meta.)<br>few sed. rocks | | | <35<br>(calc. cem.)<br>(& repl. ) | | | | | |
| Ba558 calcareous ?subgreywacke | mod. | max. .2<br>mode .07 | ang.- subang. | mod. - low<br>rather poor | 15 | 2 | <5 | <5<br>(musc, biot.)<br>(swollen )<br>& 1% C. matter, leaves etc. | 3 | 5 | <5<br>(as above) | | | >60<br>calc., strong repl. | | r | c | | |