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THE GEOLOGY OF THE EUDUNDA-HANSBOROUGH AREA OF SOUTH AUSTRALIA WITH EMPHASIS ON THE PEPUARTA TILLITE FORMATION OF UPPER PRECAMBRIAN AGE.

by

L. J. Morris, B.Sc. 1972.

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This thesis is submitted as partial fulfilment of the course requirements of the Honours Degree of Bachelor of Science in Geology at the University of Adelaide, 1972.

ERRATUM.

Appendix I. p. A I4:

38I-I59 wrongly included in the Pepuarta Tillite section, should be in the Eudunda Arkose section of p. A 5.

Contents

Abstract

The sediments described herein represent a total of some 6,300 m thickness, and are of the Umberatana Group which includes the Sturtian glacial period, the interglacial period of the Sturtian and Marinoan ages, and the Marinoan glacial period.

Emphasis has been laid on the upper glacial sequence which is over 1,800 m thick at the location of the measured stratigraphic section. This sequence, known as the Pepuarta Tillite (Formation), has been divided into 9 members which are probably not sufficiently continuous to be mappable units over very great distances. These members are described and the indicated depositional environment is discussed in some detail.

The calcareous nature of the interglacial and upper glacial rocks has been noted, though further work is needed before an adequate interpretation can be given to these data, esepcially in the upper glacial beds.

Introduction

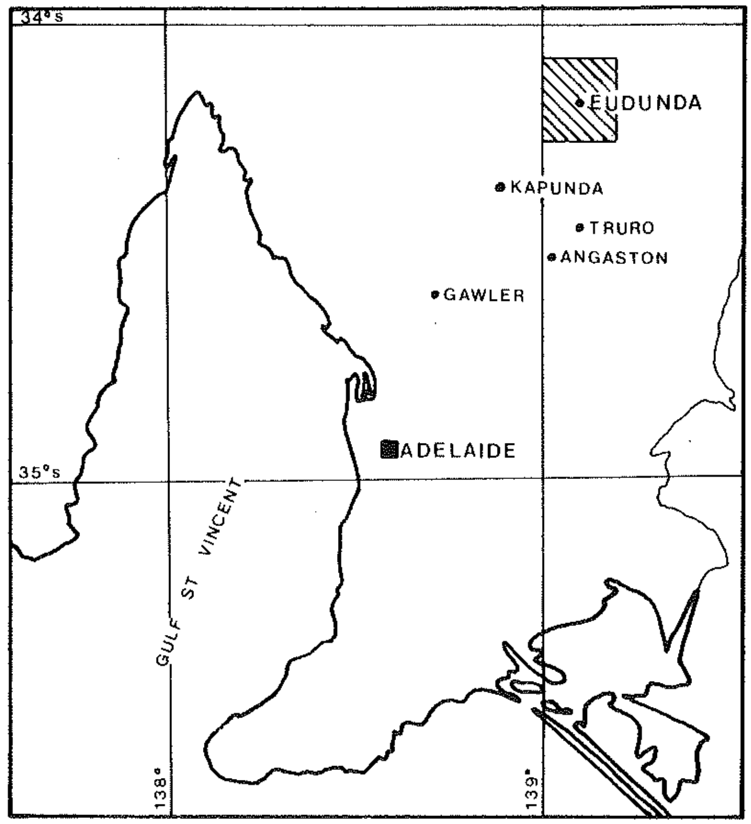
The mapped area lies immediately south of Eudunda and extends southward to include Hansborough in the south west corner, and is approximately 8 km by 6 km. The area examined is somewhat larger, including extensions to Hampden in the north and some 2 km further west than the map boundary and some area to the south west. A locality sketch is submitted with this report.

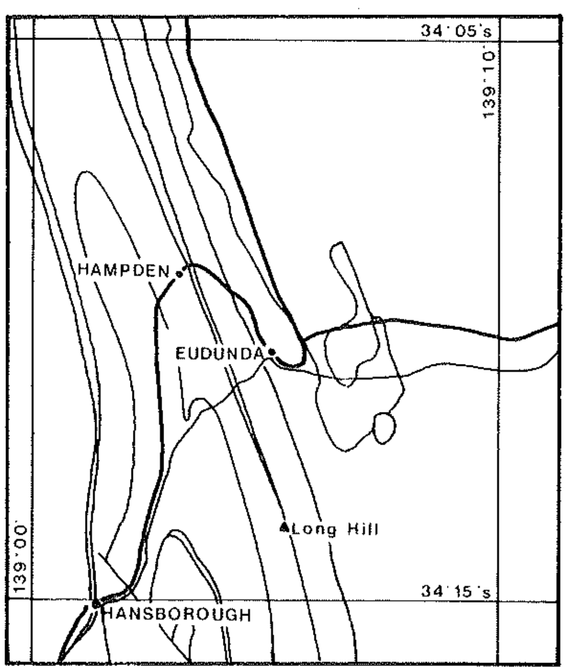
Outcrop is generally adequate for reliable mapping and those boundaries marked as observed are placed with a high degree of confidence.

Topography is varied but is dominated by a strong north-south trending ridge marking the position of the Eudunda Arkose Member which stands some 100 m above alluvium covered plains to east and west, and by a discontinuous series of ridges where quartzites of the Gilbert Range Quartzite (west) and Pepuarta Tillite (east) crop out. Most significant creeks in the area drain east or west away from the central ridge and dissect the above mentioned quartzites. This drainage pattern probably reflects east-west faulting. Good exposure of most units is seen in the creek beds, though the rocks are quite deeply weathered.

Fieldwork occupied some 10 weeks and mapping was carried out on an overlay on an approximately 10,000-scale enlargement of a Lands Department aerial photograph. W.B. Robinson of the S.A. Department of Mines has previously mapped the area and his work has been published in the Eudunda 1-mile and Adelaide 4-mile sheets.

Laboratory work included cutting and describing about 60 thin sections and full hand specimen description of these and some 30 other rocks considered important to interpretation of the interglacial and upper glacial periods. Emphasis has been laid on the upper glacial (Marinoan) rocks.





LOCALITY SKETCH

EUDUNDA — HANSBOROUGH AREA

SOUTH AUSTRALIA

L J M 1972

Stratigraphy

Sediments in the area mapped are of Upper Proterozoic age and have been assigned to the Sturtian and Marinoan epochs. They comprise the Umberatana and Wilpena Groups. The formations occurring in this area have been named by W.B. Robinson of the South Australian Department of Mines as follows:

Ulupa Siltstone Equivalent
Nuccaleena Formation Equivalent?
Pepuarta Tillite
Tarcowie Siltstone Equivalent
Tapley Hill Formation with:
1. Eudunda Arkose Member
2. Siltstone Member
3. Tindelpina Shale Member
Appila Tillite (Sturt Tillite Equivalent?)
Gilbert Range Quartzite
Hansborough Tillite.

It is proposed that these names be retained for this thesis, though R.P. Coats of the Mines Dept. (personal communication, 1972) has raised doubts about some correlations, and it will be suggested in this report that the Sturtian glacial interval is wrongly named.

No previous reports exist which deal with sediments in the Eudunda district, and no report accompanies the Eudunda 1-mile or Adelaide 4-mile sheets.

Descriptive Stratigraphy

A Sturtian

1. Yudnamutana Sub-group.

(a) Hansborough Tillite Formation.

This unit is approximately 1000 m thick south-east of Eudunda and it is generally very poorly exposed owing to its poor resistance to weathering and erosion. This is due to the weakly indurated nature of the tillite in this region. The only good exposure is in a road cutting on the Eudunda-Truru road.(1a,b) The lithology here is monotonous light to mid grey, weakly indurated, massive, very poorly sorted, very sandy, coarse siltstone to very silty, gritty sandstone with abundant clasts. Clasts are rounded to well rounded meta-quartzites, coarse acid igneous (granitic and porphyritic), acid gneisses, carbonate (white or cream dolomite), black shales and schist fragments. Of these the metaquartzites and acid igneous rocks were numerically dominant and comprsied the larger clasts - up to about 25 cm diameter. None was seen to be clearly facetted and no striae were observed on any clast. Most clast lithologies have resisted deformation during the metamorphism which has imparted a well-developed cleavage to the pelitic rocks of the region, (1a) and they can be seen to be rounded to well-rounded with high sphericity. Clear pressure shadows can be seen around many clasts. The dolomite and shale fragments have been considerably deformed however.

No exposure of the base of the Hansborough Tillite was seen, and its relationship to the underlying Saddleworth Formation is not known in this area. K. Hamdorf (pers. comm.) believes than an unconformity exists in an area mapped by him near Point Pass, north of Eudunda. He has also observed lens-shaped sandstone bodies near the base of the tillite and although they were not observed in the area mapped by this author, they may be present but not exposed.

(b) Gilbert Range Quartzite.

This lithology varies in thickness from about 500 m to about 650 m in about 4 km strike length to the south of Eudunda. This is considerably less than the variation shown on the Eudunda 1-mile sheet, however, and appears to be due to an increased percentage of siltstone to sandstone towards the south. The sandstone beds appear to be of approximately uniform thickness over considerable strike lengths, even though most are only a few metres thick, and it is the siltstones which thicken, perhaps in response to a local topographic variation in the underlying Hansborough Tillite. Lithologies were of three types.

(1) White, yellow or red weathering, indurated cross bedded, moderately to poorly sorted medium to coarse sandstones with clasts either rare or fairly common.

PLATE 1

a & b

The Hansborough Tillite, exposed by earthmoving, is well cleaved - b shows a cleavage face - with pressure shadows formed around the larger, more resistent clasts in places. Clasts are generally well-rounded. Boulders of up to 25 cm were observed.

Road works 3Km. south from Eudunda on the Truro Rd.

c

A single calcite lens was seen in the Tapley Hill Shale Member. It is conformable to bedding and was probably deposited contemporaneously with the surrounding siltstone, indicating a shallow water environment. The shale member is apparently equally calcareous throughout its 1000 m in this region.

Southern side of Adelaide Rd. 34° 10·80'S 139° 4·92'E.

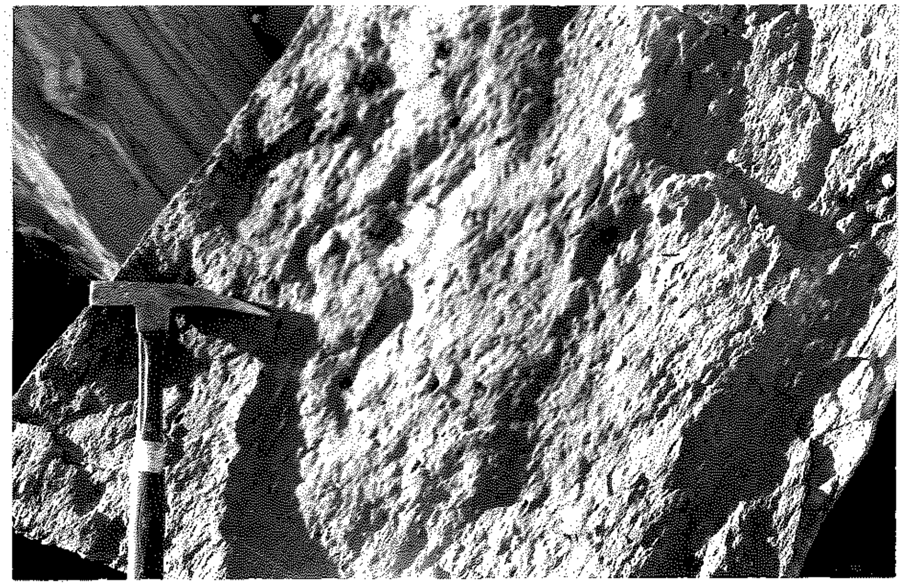


PLATE 1

a

b

c

(2) White, yellow or red weathering, indurated, cross bedded, moderately sorted medium to coarse sandstones with no clasts.

(3) Greenish or grey, weakly indurated, laminated and cross laminated, moderately sorted, sandy siltstones. No clasts were found in these despite examination of numerous exposures.

Current directions in the Gilbert Range Quartzite have been summarized in Fig. 1 and are uniformly from slightly west of north. Readings were obtained largely from tabular cross bedding in both sandstones and siltstones and from some trough cross bedding in the sandstones.

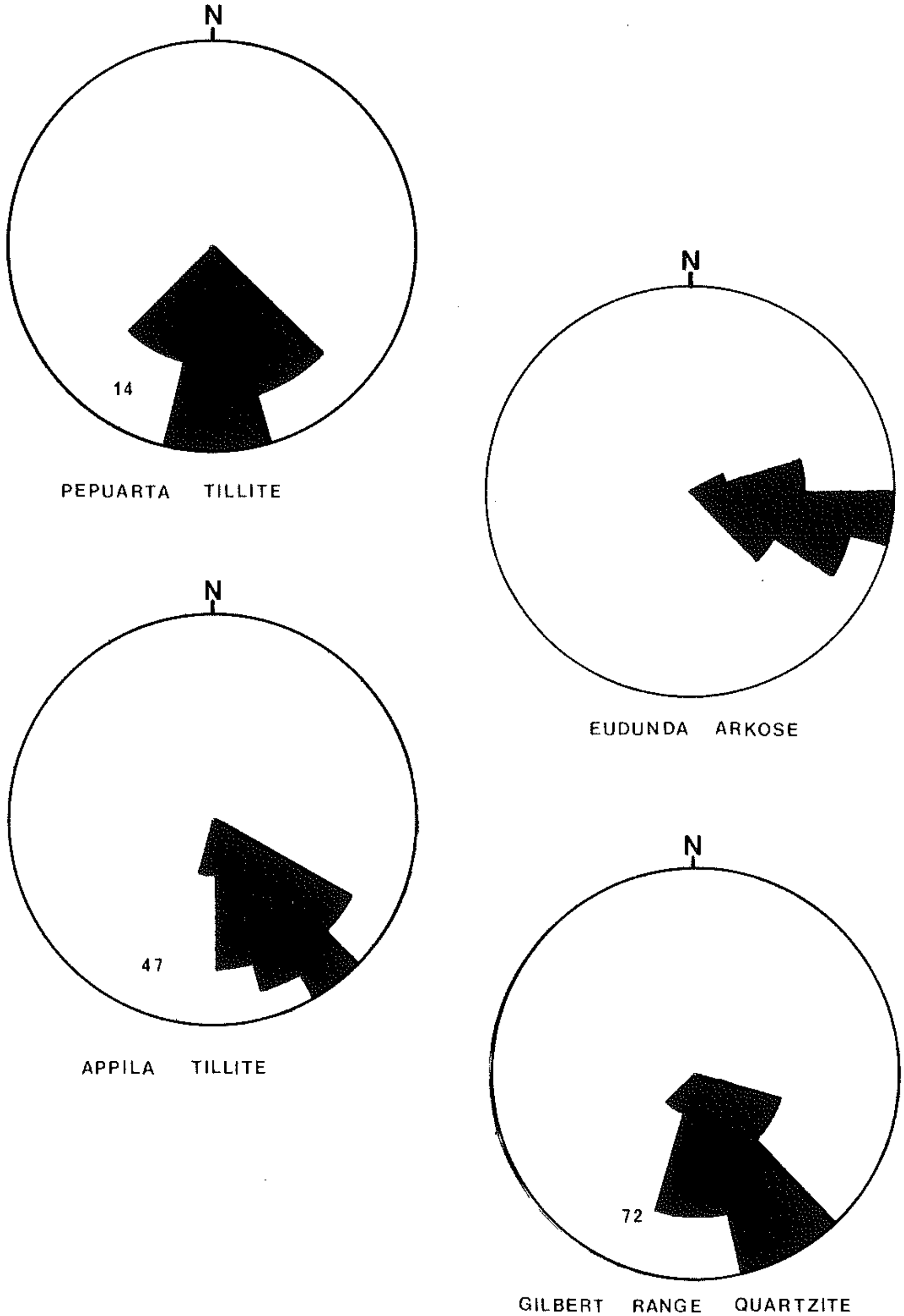
(c) Appila Tillite.

The basal beds of this member are poorly exposed in direct contrast to the Gilbert Range Quartzite and those beds higher up in this member. They consist of green and grey, grey weathering, weakly indurated, laminated, generally well sorted, slightly sandy, coarse and medium siltstones with rare mixtite lenses with up to cobble sized clasts. This lithology persists for about 200 m and it is overlain by a 10 cm thick band of white, well indurated, tabular cross bedded, well sorted, very coarse sandstone with a finer laminated coarse sandstone 3 m thick in turn overlying this. Alternating beds of slightly sandy medium and coarse siltstone with occasional gritty bands with up to granule or pebble sized material and various sandstones, ranging from white to red and from very fine to very coarse grained overly these beds. The sandstones are generally thin - less than 10 m - and most are cross bedded. Current directions obtained are represented in Fig. 1 and indicate a consistent source just west of north.

This lithology persists for approximately a further 300 m making the Appila Tillite about 500 m thick. The upper limit of the unit is a band of pink fine sandstone about 1 m thick, continuous throughout the area examined - about 6 km strike length - immediately underlying a persistent black dolomite band, the base of the Tindelpina Shale of the Tapley Hill Formation. This marks the close of the Yudnamutana Sub-group, the lower glacial sediments.

FIG 1

CURRENT DIRECTION DIAGRAMS



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Depositional Environment

The tillite of the basal unit of the Sturt glacials, the Hansborough Tillite, lacks stratification throughout its entire thickness. This indicates deposition of the material directly from a dry-based continental ice sheet as a lodgement till. The sandstone lenses reported near the base of the tillite may be similar in origin to those described by Lindsay (1970, p. 1155) in his description of the tillites of the Transantarctic Mountains. Lindsay's sandstone lenses were, however, thinner and less extensive laterally. That author considers that these features indicate deposition from "actively deforming temperate ice".

There followed a period during which the ice sheet retreated and interbeds of laminated, clast-free siltstones - possibly varved - and clast-bearing or clast-free cross bedded sandstones were deposited as the beds of the Gilbert Range Quartzite. It is considered that these sediments reflect outwash and shallow ?freshwater lakes into which deltas of outwash were built for considerable distances by rapidly deposited sandy sediments. The depth of water in the lakes was probably shallow as the ?varved siltstones are free of clasts, implying no rafting of glacier ice. The sandstones are thin - generally only a few metres - further implying shallow lakes if some of these sediments are indeed deltaic. It is probable that the sandstones are a combination of outwash and deltaic deposits, but there appears no way of deciding which environment applies to which sandstone or to which part of a given body. The bases and upper limits are very sharp with no visible grading observed in several hundred exposures examined. The clasts in the sandstones probably represent those frozen to the base of winter ice and rafted by small ice floes which broke free in spring thaws. These features have been described by Flint (1970) in Pleistocene outwash deposits. As expected these clasts are small and well rounded. The alternating lake and outwash deposits imply some instability of the ice sheet terminus, which probably lay somewhere to the north or north north west, as well as instability of the lake shoreline.

A further retreat of the ice is considered probable at the close of deposition of the Gilbert Range Quartzite when laminated siltstones were deposited with only occasional lenses of till-like material, mainly near the base. These lenses are seen as deposits from overturned icebergs floating on a deep, extensive lake or the sea. The sediments may contain individual clasts dropped from icebergs but none were seen and this is probably a reflection of the very poor exposure of the lower beds of the Appila Tillite. Interbedded cross bedded coarse to fine sandstones and siltstones with occasional gritty bands overly the poorly exposed siltstones near the base of this unit and these probably represent a shallowing or perhaps fluctuating water depth, or merely a variable source. The gritty bands, which are of up to small pebble sized material, all well rounded, have been deposited into the siltstones with no interruption of the deposition of the siltstones, which have laminations of 2 to about 6 mm thickness. These grits possibly represent rafted material frozen to the base of ice formed along well washed beaches at the shore of lake or sea, which would break up and drift away during spring. Palaeocurrents show a northerly source but winds may have affected this with respect to floating ice. The material of the grits is entirely quartz or quartzite and this indicates vigorous mechanical reworking has eliminated the less resistent material which was probably present at the source ?beach.

2. Tapley Hill Formation and Tarcowie Siltstone Equivalent - The Interglacial Period of Sturtian and Marinoan age.

   (a) Tapley Hill Formation

   (1) Tindelpina Shale Member*

   This is a persistent marker bed throughout the whole Adelaide Geosyncline (Thompson in Parkin (ed.), 1969, p. 66) and is seen in the Eudunda - Hansborough area as a thin - approximately 60 to 80 m - black, extremely finely laminated, extremely fine grained shale with pyrite and thin but persistent bands of sharply defined, massive, black dolomite of up to about 10 cm thick, concentrated mainly in the basal 20 m of the member. The pyrite which appears to be disseminated with only occasional cubes - now limonite - also appears to be concentrated within this interval. The upper

* Note that the basal conglomerate (Serle Member) as described by Coats (1964 p. 11) is absent also from this area. This author cannot agree with Coats' correlation of the Eudunda Arkose Member with the Willigan Member of the Tapley Hill Formation and the existence of two members - non-calcareous and calcareous - is not true of this area.

boundary of the Tindelpina Shale is gradational from black into dark and mid grey with a corresponding increase in grainsize and lamination thickness over at least 20 m. The boundary has been arbitrarily taken as the lowermost occurrence of a clear change in these three characters. The shale does not appear to be calcareous as is the overlying Tapley Hill Shale Member. The dolomites appear to be primary and closely follow the bedding planes of the enclosing shale. The origin of the black colour of both is possibly due to organic carbon.

(2) Tapley Hill Shale Member.

In the mapped area the shale member is between 1000 and 1100 m thick, though according to Robinson (1966) it thins to the north and where the Eudunda Arkose Member reaches a thickness of over 600 m. Except in creeks downcutting at rightangles to strike, outcrop is limited, though this lithology, the Eudunda Arkose and to a somewhat lesser extent the Tarcowie Siltstone form a topographic high as a north-south trending ridge. Relief is of the order of 100 m. Lithologically the shale is a mid to dark grey occasionally light grey, grey weathering, indurated, evenly laminated, generally well sorted, medium to coarse siltstone: calcareous quartz lutite, with occasional thin - up to about 2 m - bands of grey, grey or brown weathering, indurated, generally massive, poorly sorted, gritty fine sandstone. Some of these contain a high percentage of fresh feldspar (381-214) while others contain very little (381-215). All samples of the Tapley Hill Shale Member examined had significant calcite. It is felt that the reported increase in calcite in the upper part of the shale (Mawson and Sprigg, 1950) does not apply in this region at least, and that the formation is equally calcareous throughout. A single band of white medium to coarse grained sandstone (quartzite) was observed near the top of the member and was continuous for some 400 m where outcrop vanished and any float was removed by the pastoralists. Despite quite exhaustive search and adequate outcrop in creeks only a single carbonate lens approximately 6 cm thick and 40 cm long was seen. (1c) This was of buff to white pure limestone.

Petrological examination of five specimens of the "typical" shale lithology (381-212, -213, -216, -217 & -218) yielded one slide showing clearly graded bedding in a very fine grained rock (381-217).

The only trend discerned was an increase in the massive sandy beds towards the top of the member. This may be related to the Eudunda Arkose Member which overlies the Shale Member. No sedimentary structures other than lamination, microcross lamination (381-216), the ?soft sediment slide structures (two only) (2a) and the calcite lens were seen in the Shale Member.

(3) Eudunda Arkose Member.

Robinson (1966) describes this lithology as a "Flaggy and massive cross-bedded blue-grey arkose" but quite extensive examination of it in outcrop in the Eudunda - Hansborough area, and in six other areas including the type area (the Kapunda rubbish dump - a disused quarry) have shown it to be variable in feldspar content and not more feldspathic than a subfeldsarenite of Folk, Andrews and Lewis (1970). Five thin sections were cut from the freshest material available from the type section, 381-210-A and -210-B, and from two rocks collected from near Julia about 12 km north west of Eudunda, 381-209-A and -209-B and from Long Hill, 381-159. The highest feldspar content observed was 12% from the rocks collected near Julia. No exposure appeared to have obviously high Feldspar content.

The "arkose" is cross bedded pink white and grey fine sandstones and interbedded blue-grey siltstones in the Eudunda-Hampden area, south of which, in the mapped area, exposure is very poor. Abundant fresh coarse pyrite cubes with pressure shadows (2b,c) are present in the sandstones in the Eudunda-Hampden area and this feature appears to persist to the most southerly exposure of this limb of the Eudunda Arkose. Examination of some chemical analyses done for pastoralist J. Nichols of "Kingscourt" near Long Hill show high iron values exist in the soil along the ridge, in the projected position of the "arkose" for some 2 km at least beyond the most southerly outcrop at Long Hill. The "arkose" can thus be

PLATE 2

a

Possible soft sediment slide structures in the Tapley Hill Shale Member, near the top. The clear banding, made by differential erosion, is due to bedding, with cleavage poorly developed. (Not seen in the photograph.) Two of these structures were seen within 20 m, but they were not in the same bedding plane.

Southern side of stock track running East off St. Kitts Rd. 34° 12·20'S 139° 05·08'E.

b

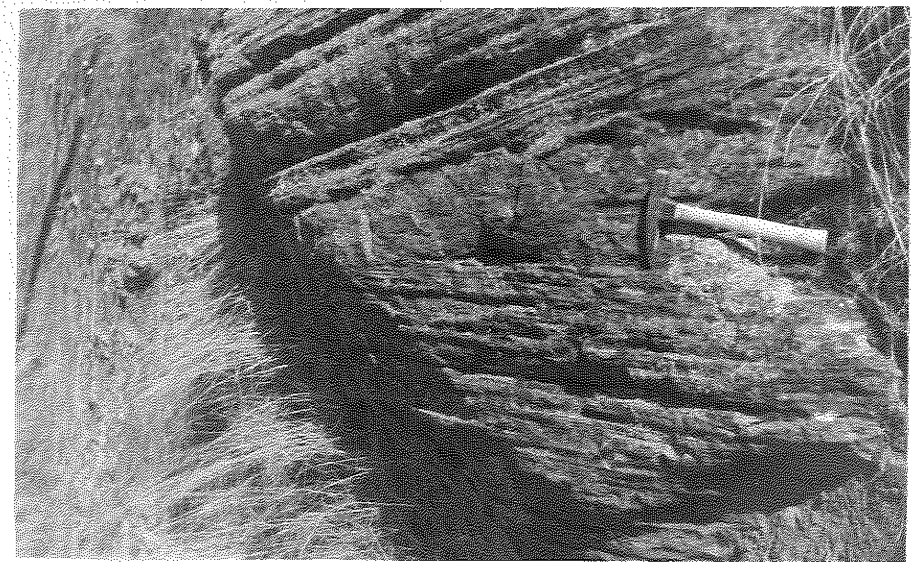
Pyrite cubes in a very fine sandstone bed of the Eudunda Arkose Member. The pyrite cubes are of up to 8 mm along edges in some beds, and are usually fresh, though the outer surface is tarnished. Most of the sandstones are cross bedded and indicate a western source.

Southern side of Railway Cutting East of Hamden 34° 08·90'S. 139° 03·40'E.

c

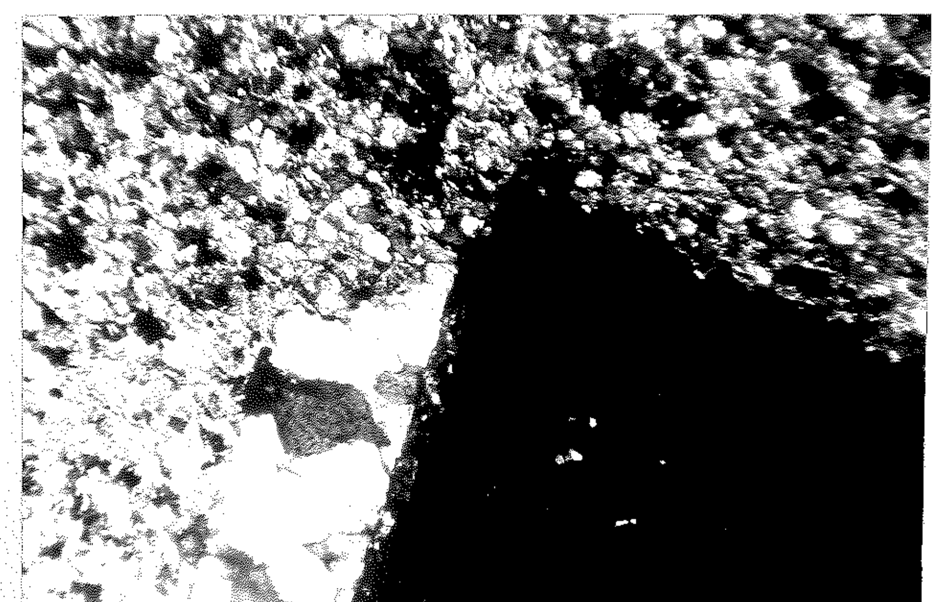
Photomicrograph (100X) of a coarse limonite pseudomorph of pyrite with a clearly developed pressure shadow. The cleavage direction is from top left to bottom right. Crossed nicols.

PLATE 2



a

b



c

extended at least 8 km south of the southern extent shown by Robinson (1966).

It is suggested that "arkose" be dropped from the name Eudunda Arkose Member if further work confirms the conclusions herein.

B Marinoan

(b) Tarcowie Siltstone Equivalent?

In the mapped area there appears to be no difference between the Tapley Hill Shale Member and the lower Tarcowie Siltstone Equivalent and their separation by the Eudunda Arkose Member appears to be the only reason for separating these lithologies. Thomson (in Parkin (ed.) 1969, p. 69) says: "In places (the Tarcowie Siltstone and its equivalents) closely resemble the Tapley Hill Formation, although overall the Tarcowie Siltstone has a higher proportion of coarser clastics ...". The coarser clastics are absent from the siltstone in the Eudunda-Hansborough area.

Generally the lithology is mid to light grey, grey weathering, indurated, evenly laminated generally well sorted, medium to coarse siltstone: calcareous quartz lutite. It lacks the sandy bands seen in the Tapley Hill Formation though a band approximately 80 m thick of visually identical but much more boldly outcropping siltstone runs parallel to bedding about 400 m above the Eudunda Arkose. There is a narrow band - about 8 m wide - of more calcareous shale along the upper boundary of this band. The better indurated material, however, does not appear to be more or less calcareous than the bulk of the siltstone. Some slumping has occurred affecting about 8 m of beds near the base of the formation in places.

The upper boundary is arbitrarily taken as the first occurrence of very thin sandy laminae which are continuous laterally. The transition from the siltstone to the overlying Marinoan glacials is very gradual going from siltstone to siltstone with very fine sandstone laminae, the sandstone thickening and increasing in number per metre of sediment and in grainsize until coarse gritty sandstone layers become predominant. Within this interval occasional small clasts are found with disrupted bedding indicating rafting. The interval is 357 m thick in the stratigraphic section presented with this report - member 1 of 9 members. Coats (1964, p. 12) states that a "satisfactory mappable boundary can be based on the first appearance of sandstones" when writing of the Yerelina Formation, the equivalent of the upper (Marinoan) glacials in the Flinders Ranges.

The Sturtian - Marinoan boundary is placed near the base of the Tarcowie Siltstone Equivalent. (Thomson in Parkin (ed.) 1969, P.69).

Depositional Environment

The interglacial sediments in the Eudunda-Hansborough-Hampden area appear to be completely void of any evidence of a direct glacial contribution. An extensive search in all creeks in the area, where exposure is good has failed to find any evidence of such a contribution.

Sedimentation of the Tindelpina Shale occurred when bottom conditions were stagnant and strongly reducing. The laminae are then due to variation of either grainsize or composition due to variable ?seasonal contributions. The cold conditions prevailing during the preceeding sedimentary cycle may well have continued such that meltwater influxes into a shallow but stagnant epicontinental sea produced varves It is felt that these laminae must be seasonal as production of laminations by agitation would destroy the stagnant conditions which must have prevailed. Deposition occurred over a very large area and the formation of dolomites is believed to imply very shallow conditions. To maintain reducing conditions throughout such an area in shallow water seems an impossibility unless oxygen consuming organisms were present in vast numbers. The answer to the problems of the deposition of the Tindelpina shale remains speculative.

The Tapley Hill Shale (siltstone) may also be in part varved. A single thin section (381-217) demonstrates graded bedding which may be evidence of the presence of varves in the formation. The alternative hypothesis - turbidity deposition - is considered unlikely because the laminae are very even and no proximal turbidity current deposits are known within the formation. The poorly sorted, sometimes feldspathic sandstones have been described elsewhere as greywackes (Coats, 1964, p. 11). This lithology is also extremely wide-spread, but again deposition is believed to be in shallow waters. R. Love (personal communication, 1972) considers it possible that the salinity of waters during the deposition of the Tapley Hill Shale Member may have varied erratically, which may indicate vast influxes of meltwaters into a shallow epicontinental sea. The coarser sediments seen in the Eudunda region may imply proximity to a source of the silts, but only regional consideration of grainsize distribution would indicate whether or not this was a probability.

The Eudunda Arkose is not widespread, and being of coarser sediment, must have had a nearby source. The abundant cross bedding indicates the source was in the west. This information is summarized in the rose diagram of Fig. 1. Cross bedding implies shallow moving water. This, being a member of the Tapley Hill Formation deposited contemporaneously with the shale, supports the concept that the shale member was deposited in shallow water, as no break in sedimentation has occurred in the interglacial interval. The outcrop pattern of the Eudunda Arkose, which appears to interfinger with the Tapley Hill siltstone in the mapped area further supports the view that the source was in the west.

The Tarcowie Siltstone Equivalent, which as stated above, resembles strongly in lithology the Tapley Hill siltstones, was probably deposited under very similar conditions. Late in the depositional history of this unit the transition to glacial conditions began.

3. Pepuarta Tillite (Formation)

Introduction

This formation is the upper glacial unit of Marinoan age. It is the uppermost unit of the Umberatana Group of sediments (Robinson, 1966). The sediments are extremely varied throughout its approximately 1800 m thickness, the depositional environment exhibiting similarly wide variation from probable subaereal to subaqueous and subglacial. It is for this reason that the stratigraphic section has been divided into 9 parts; to facilitate description and interpretation. This author does not propose that these 9 members are continuous, mappable units over great distances, though close examination of three sections through the formation indicates a broad uniformity over some 3 km strike length. Outcrop is inadequate to trace these subdivisions further north and time limitations prevented close examination of the interval much to the south of the mapped area. Outcrop is again inadequate on the western limb of the syncline, though the subdued topography indicates that many of the quartzites at least are not present in this region, as dips are similar, though in the opposite sense, to those of the east limb.

Perhaps the strangest feature of these sediments is their very general lack of structures which could indicate a specific environment for each of the sediment types. This factor itself may indicate something about the environment.

It is intended to describe each member separately in some detail and to follow each description with an interpretation of the environment of deposition. A summary stratigraphic column has been prepared and is presented in Fig. 2. A general discussion of

(1) Carbonate Contents of the Sediments,

and (2) Glacial Origin for the Mixtites

follows this descriptive section. Some references to these factors here is unavoidable, however, and is presented without evidence in this part of the text.

Description and Interpretation

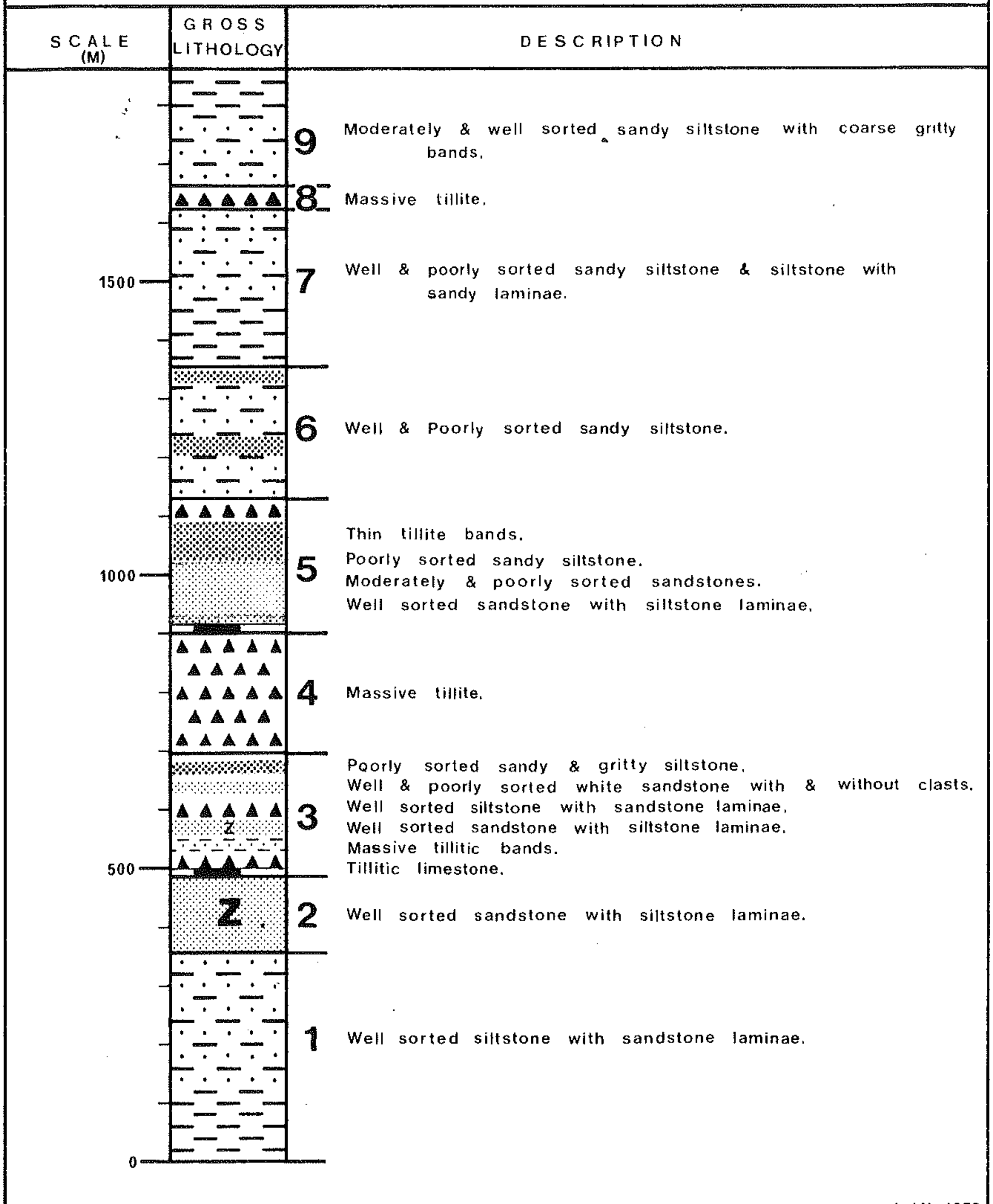
Member 1.

As previously stated, the basal member is a transition zone of some 357 m thickness, the lower boundary being placed at the first appearance of thin, laterally continuous, sandstone laminae in the siltstone lithology of the Tarcowie Siltstone. Initially the sandy layers in the well-sorted, laminated siltstone occur at 1 to 2 m spacing, but increase in regularity and number per meter approximately uniformly throughout the member. Grain-size of both silt and sand components remain fairly constant upwards from the base - medium to coarse silt and fine to very fine sand, except near the top where sand grainsize increases and sorting of the sandy layers worsens. The thickness of laminae in the siltstone is constant, but the sandy layers gradually increase in thickness from about 0.3 mm to 5 mm.

FIG 2

SUMMARY STRATIGRAPHIC SECTION

PEPUARTA TILLITE (Schematic)



Cleavage has dissected the sandstone laminae in places to produce semi-continuous augen-shaped lenses about 5 to 25 mm long. Near the top of this member an occasional small clast can be seen to have disrupted the bedding beneath it. (3a) This member is closed at the appearance of a 2 cm thick band of coarse sand. Specimen numbers 381-128 and -129 are from near the top of this member. (See detailed section for location.) The sediments contain abundant calcite.

Depositional Environment

The resurgence of glacial activity in Marinoan times must have been very gradual, and it was not until about 330 m of sediments had been deposited that signs of rafted clasts appear (in several creek exposures). These are rare and although they are probably ice rafted material, the possibility of Precambrian seaweed rafting cannot be discounted here. (Refer to Spencer, 1971, p. 34). Deposition, then, probably occurred in the relatively shallow but extensive sea or lake which existed in the preceeding interglacial period. Encroachment of an ice sheet into the water provided some icebergs late in the depositional history of this member, and the absence of grit bands probably implies remoteness from any shore-line pack ice which may have formed.

Member 2.

Sample and thin section 381-130 shows the first coarse sandstone band, poorly sorted and with little feldspar. Following this, the lithology is generally similar to that of member 1 except that the sandstone laminae are here predominent. (See detailed section.) The grainsize shown for this lithology represents an attempt to show major variations of sandstone-siltstone ratios. A single band of ripple marks occurs at 368 m, and an unsorted, sandy siltstone, very similar to tillite matrix can be seen at 371 m. (381-131) In the bed overlying this a large ?scour and fill channel has cut down through about 2 m of sediment into the unsorted siltstone. The structure is only partially exposed but is at least 2 m deep and 6 m wide. It is filled with laminated siltstones and coarse or gritty sand-stones, but their distribution is difficult to explain, with fine sediments in the base of the channel and a gritty lithology on the upper part of the

PLATE 3

a

A small quartzite clast dropped into the siltstone with sandstone laminae of Member 1 of the Pepuarta Tillite (Formation). This photograph shows the deformation of the bedding beneath the clast. This was the lowest observed occurrence of a clast in Member 1.

Southern bank of creek 34° 14·35'S. 139° 04·90'E

b & c

The ?scour and fill structure near the base of Member 2 of the Pepuarta Tillite (Formation) showing the relationship of the surrounding bedding (B) and the cleavage (Cl) to the infill sediments. Note the near right angle relationship of bedding in the right hand corner of b.

The infill sediments near the base of the channel are laminated siltstones (c) while those on the channel ?wall are gritty coarse sands. A 25 cm thick sandstone (S) overlies the siltstone (Z) and this can be seen in c. The sandstone thins towards the edges of the channel.

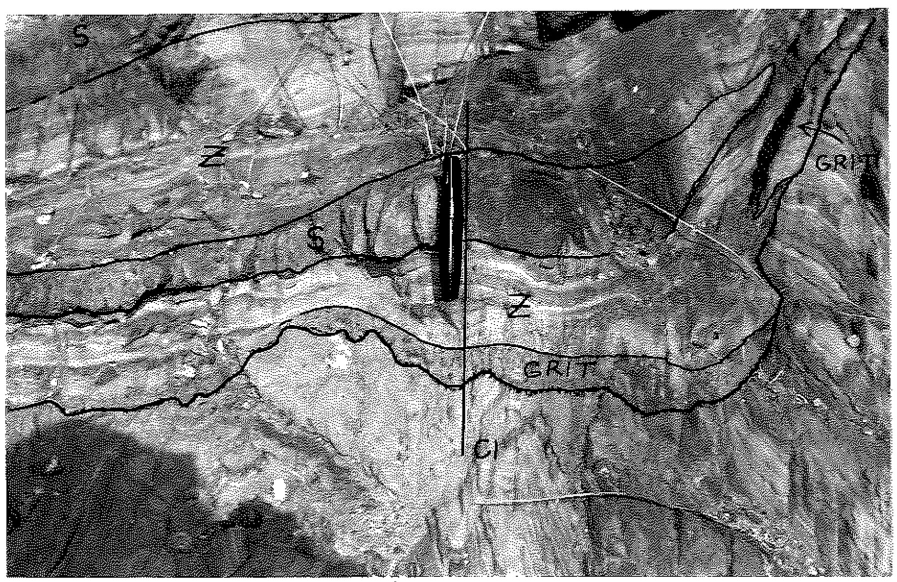
The distribution of the infill lithologies is unexplained.

Southern bank of creek 34° 14·35'S. 139° 04·85'E

PLATE 3

a

b



c

channel wall and also overlying the fine sediment. It may be that this is an ice scour structure filled by sediments from a western source which would explain the problems posed by the channel fill. This explanation, however, is in disagreement with the palaeocurrent evidence which is summarized in Fig. 1, and shows a consistent northern source. V. Gostin (personal communication, 1972) pointed out that fine material filling channels is not unusual. The distribution of the fill is, however, difficult to explain. See pl. 3a,b). At 386 m the sandstone content increases to over 95% and the resulting band of sediment stands out in moderate relief and is seen also in creek exposures about 1 km to north and south. Although it cannot be traced further north than that (poor exposure) it may well be able to be traced southwards beyond the mapped area. Again the sediments are calcareous and they are represented by specimens 381-130, -131, -132, -133.

Depositional Environment

The average feldspar content of the four sections examined is about 8% with a range of 2 to 14% . It seems likely that most if not all of these sediments are first cycle (Pittman, 1970, p. 591, Kuenen, 1959, p. 31, Folk, 1959, p. 149). Cameron and Blatt (1971, p. 575) state that felsic fragments reach a rounded state fairly quickly, at least under some conditions, as a result of weathering and abrasion. The thin sections were examined to find the roundness of the constituent grains, but suturing and welding of contacts has generally masked this throughout the formation. Such particles are, however, durable, and their presence indicates little about the source distance. The feldspars are fresh and this may indicate a cold climate during deposition of this member. The water body in which the sediments were deposited was at least at times quite shallow, with ripple marks and scour and fill features. The degree of sorting of sandstone and siltstone layers can be seen in 381-132 (4a). The calcite present in the rock is approximately the same percentage in both coarse and fine fractions, and no ?seasonal variation in calcite precipitation can be discerned.

Member 3.

From 485 m to 697 m (212 m) the lithology is extremely variable. Beds include:

PLATE 4

a

A photomicrograph (100X) showing a typical portion of the laminated sandstone-siltstone lithology of member 2 of the Pepuarta Tillite (Formation). Specimen and thin section number 381-132. Crossed nicols.

b

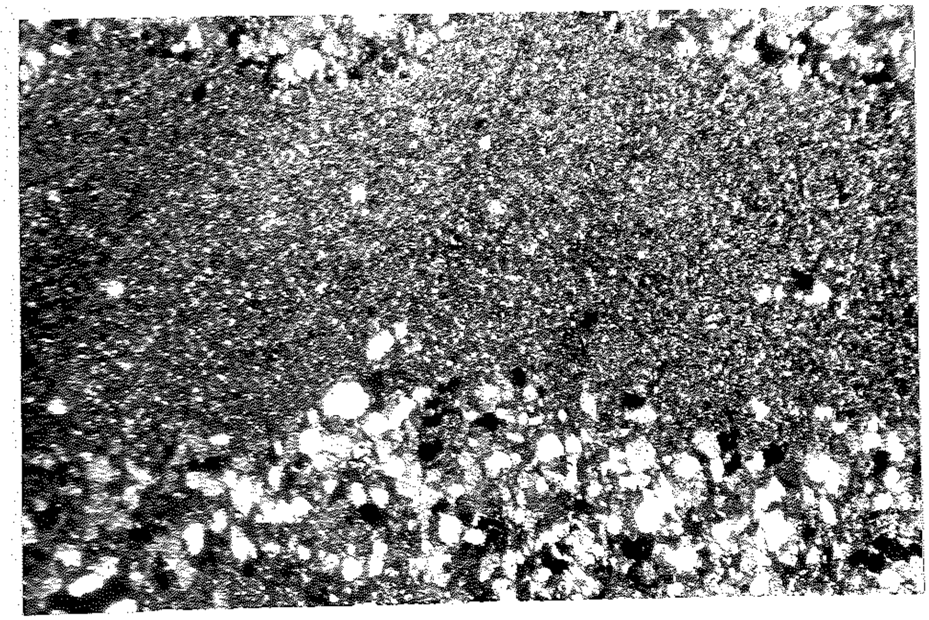
A photomicrograph (100X) showing the grading of clastics in 381-175. The matrix is carbonate, presumably dolomite, and it was deposited contemporaneously with the clastics. Up to 60% carbonate is present in the finer fraction. Crossed nicols.

c

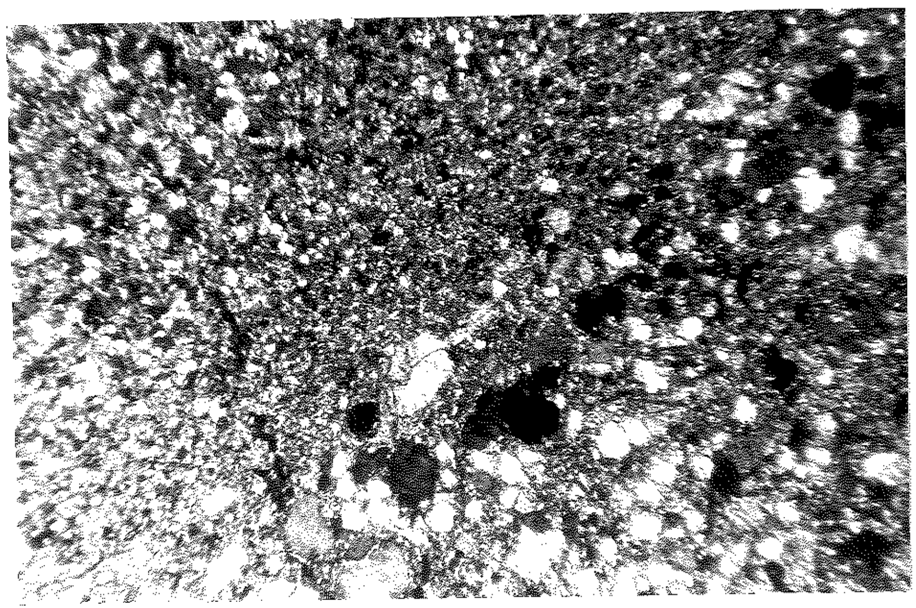
Cross lamination in a generally massive siltstone. Note the complete sets, without eroded tops. This is interpreted as evidence of very rapid deposition.

Creek bed. 34° 14·25'S. 139° 03·70'E.

PLATE 4



a



b

c

(1) Massive tillite bands (381-134, -155),

(2) Well sorted sandstones with siltstone laminae and siltstones with sandstone laminae (381-139, -141, -144, -166. These resemble the lithologies of members 2 and 1 respectively),

(3) Poorly sorted gritty or sandy siltstones, apparently without clasts, but probably tillitic (381-137-A, -142, -147, -150, -151, -161),

(4) Well and poorly sorted white sandstones which have sharp base and top, are generally massive, and are with and apparently without clasts. (381-137, -145, -152, -153, -155, -157, -163, -167),

(5) Laminated siltstones,

(6) Poorly sorted silty sand (381-165), and

(7) White limestone with abundant small clasts with fines removed by running water (381-135).

With few exceptions the boundaries are very sharp between lithologies and little grading was observed within each lithology. Notable were the gradational boundaries of an unsorted sandy siltstone at about 500 m. Both upper and lower boundaries were gradational over about 20 cm. The sandstones initially appear similar to those of the Gilbert Range Quartzite, but generally lack the lamination and cross bedding of the Sturtian sediments. Most beds are thin - apparently tabular and some lensoidal sandstones were as thin as 4 cm - and the siltstones, and the well sorted siltstones with sandstone laminae and sandstones with siltstone laminae are generally much thicker, but still less than 10 m.

Depositional Environment

No clear cyclic changes can be discerned from the lithological pattern. It seems likely that subaqueous, glaciofluvial and subglacial deposition has occurred, the former in shallow, tranquil lakes into which discharged the melt water from the nearby ice sheet. The sediments may be varved, but no clear evidence of this was seen. Certainly the sandstone-siltstone layers may represent seasonal variation in source, with the sands coming into the lake with spring and summer meltwaters. The well sorted nature of this material would imply a quite remote source. The gradational variation in percentages of sandstone and siltstone present in these sediments may be a function of the distance from the discharge point(s) into the lake with more sand (thicker sandstone layers and consequently a smaller percentage of siltstone) being deposited near the discharging stream mouth. This could be explained if the level of the lake varied slowly with time. The very even grainsizes of both sand and silt fractions of this lithology is remarkable. It may indicate that only those grainsizes were derived from the source areas, or that the ?seasonal flows were very regular in their transporting power. The former is unlikely, and is certainly incompatible with a glacial origin for the sediment. In the latter event, presumably extensive deposits of coarser material must have developed somewhere.

The sandstone beds appear to possess no obvious trends. It was generally the coarser bodies in which clasts were found, but neither coarse nor fine, thick nor thin sandstones are consistently massive or laminated. In this member the sandstones appear to be tabular with only one exception, and they have extremely sharp boundaries at both base and top of each bed. The structureless nature of many would indicate extremely rapid, single cycle deposition of up to 12 m of sand. Two origins can be proposed for such deposits in the context of the other sediments present, assuming rapid deposition:

1. Sand was transported by irregularly flooding high volume meltwater streams and discharged rapidly into a shallow lake (or sea).
2. Outwash sand in very large quantities was dumped into a lake (or sea) by irregular and violent wind storms. Such deposits of traction load material would be dumped near to the shoreline and would thin rapidly away from the shore. This feature was not observed, but it should be pointed out that the outcrop pattern in this area is such that thinning to east or west is unlikely to be observed. Horwitz (1962, p. 365 in Coats and Blissett, 1971, p. 85) assigned an eastern provenance to the Yerelina Sub-group, but Coats (p. 85) considers that the source was a western one, and the glacials include fragments of the Pandurra Formation. The outcrop in the Eudunda area strikes north-south and it is unlikely that east-west variations would be seen under these conditions. The eastern source, however, conflicts with the regular pattern of the rose diagram (Fig. 1) with currents from the north. Similarly in disagreement with both of these is the fact that of all beds examined, five were seen to lens out towards the north, and none towards the south. The sample

numbers for the observations in the Eudunda area are small, however. The remaining sands are poorly sorted, often with rare well rounded clasts, and are generally laminated, though no cross bedding was observed in sandstones of this member. The poor sorting, it is felt, reflects a fairly local origin, the distance of transport being insufficient to allow much sorting. It is proposed that these sediments may represent outwash, with the grainsize and sorting indicating the distance from the terminus of the ice sheet. Flint (1970, p. 186) states that outwash sediments are well sorted in contradiction of the above statement of this author that the sediments are generally poorly sorted. It seems likely that Flint means to imply only that some sorting into, say, sand size occurs and not sorting into individual sand grainsize groups. The presence of clasts in outwash sediments cannot be taken as being indicative of the proximity of an ice sheet as Flint (1970, p. 187) cites an example of winter-formed river ice transporting clasts up to 300 km. The high feldspar content of many of the beds, both coarse and fine, structured or not, implies that they are both first cycle sediments, and that they were produced and transported in times of cold climate. (Pittman, 1970, p. 591, Kuenen, 1959, p. 31, Folk, 1959, p. 81; and Flint, 1970, p. 149, respectively.)

Against an outwash origin for some of these sandstones are the absence of some structures seen by Flint as common in such deposits. These are that the sediments are "... commonly stratified in thin courses of fore-set layers ...", and that "variations in grainsize are numerous ... vertically". (Flint, 1970, p. 186) What few grainsize variations which are present within the sandstones do not appear to conform to those considered by Selley (1970, p. 24-25) to be typical of braided streams.

It is intended to treat both the sandy siltstones and massive tillites together here as it is considered probable that they are all tillitic. Three types of deposit exist within this group in member 3.

(1) Massive, clast-bearing tillite with sharp boundaries,

(2) Massive unsorted sandy siltstones, apparently without clasts and with sharp boundaries, and

(3) A single bed of the same lithology as (2) above but with gradational boundaries top and bottom.

Spender (1971, p. 11-12) describes some mixtites in Scotland as having sharp, conformable boundaries and as having (usually) undisturbed sediments underlying them. He proposes that such mixtites are lodgement-type tillites from an over-riding ice sheet. This proposition applies equally well to the first group of mixtites described here, and it is probable that the second group, without clasts, were deposited in a similar fashion. Spencer indicates that there are differences between individual mixtites in Scotland as there are at Eudunda (p. 5), and Flint, (1970, p. 156) speaks of distinction between tills on the basis of grainsize differences, and it is this factor alone which divides these two classes ((1) and (2) above). The third type, with gradational boundaries and no clasts, was probably deposited from floating ice of the wet-based glacier type of Carey and Ahmad (1960, p. 871). The bedding is presumably absent because the floating ice sheet prevented sorting by wave action of these deposits.

The sixth group above - poorly sorted gritty sand - probably represents another cycle of subaqueous sedimentation, as its grainsize range is not large enough to indicate a directly glacial origin.

Lastly, the clast-bearing limestone of 7 above, is probably a subglacial limestone deposit as described by Page (1970). The restricted range of grainsizes of clasts indicates sorting by running water.

Member 4.

From 697 m to 901 m (204m), despite poor outcrop in part, has been considered as a single unit. The lithology is massive boulder tillite. The only discernable difference within the member is the change from rounded to a mixture of rounded and subrounded clasts from base to top. The base is not exposed but cannot be gradational over more than the 1 m of missing outcrop below it. The member is structureless except for a siltstone bed and a few sandstone lenses of less than 10 cm thickness at about 865 m. These are not completely exposed and their lateral extent could not be determined, but was probably not great. The lenses are considered to be similar to those described by Lindsay (1970, p. 1155) and to reflect a similar depositional environment - one of deposition of a lodgement till at the base of a continental ice sheet with some basal meltwater present at times. The single siltstone band of about 2 m thickness may or may not be similar to those described by Spencer (1971, p. 12 & p. 14) who considers them to be strong evidence for the presence of confined meltwater streams at the base of a grounded ice sheet. This author feels, however, that lenses of clast free, well sorted and laminated lithologies such as siltstones should not be taken as unassailable evidence of such environments, though the unbedded sandstone lenses surrounded by homogeneous tillite are convincing.

Member 5.

From 901 m to about 1130 m (approximately 229 m) a further series of complex lithological changes exists. The member is composed of 6 different types of beds.

(1) Limestone precipitate with abundant, graded, clastic material, and with a scour and fill channel. The lower boundary is gradational from a tillite. (381-175)

(2) Laminated and occasionally cross bedded or massive sandstones, rarely with clasts. (381-176, -177, -178, -181)

(3) Massive unsorted sandy siltstones. (381-180, -182)

(4) Laminated siltstones and sandy siltstones. (381-179)

(5) Sandstone with siltstone laminae.

(6) Massive tillite. (381-183)

Depositional Environment

The limestone is a chemical precipitate into which ?seasonally variable clastic material was dumped. The grading can be seen clearly in the photomicrograph of plate 4b. The clastic grains are frequently not in contact, with calcite separating them. The deposit is not of turbidity current origin as the carbonate deposition was contemporaneous with clastic deposition.

The sandstones of this member are as difficult to explain as those of member 3. The unstructured nature of some seems to imply continuous, single cycle deposition and this is possible as the clast-bearing layer at 948 m is at the extreme top of the sandstone bed. Although deposition appears continuous, this uppermost band may have received some ice-rafted clasts. The cross bedded and laminated sandstone at 910 m probably represents outwash material as it has the features listed by Flint, (1970, p. 186) except for vertical grainsize variation.

Exposure of the unsorted sandy siltstones was intermittent, but sufficient to be confident that they are generally clast-free, except for a band of tillite about 1 m thick at 1117 m. It is difficult to see how clast-free tillite can be in contact with clast-bearing tillite with apparently sharp boundaries, as it requires a sudden change of source materials. Nonetheless, the clast free material appears identical to the matrix of the clast-bearing tillite, although subtle differences of, say, chemistry may be present.

The lithologies of (4) and (5) above have previously been discussed and considered to be of shallow lacustrine or possibly shallow marine origin (see discussion of members 1 and 2).

Member 6.

224 m from 1130 to 1354 m consists of:

(1) Laminated and unlaminated siltstones. (381-184, -185, -186, -189, -191, -192, -193)
(2) Sandstone with siltstone laminae, and
(3) Unsorted sandy siltstones.

Depositional Environment

Lithology (1) above is seen as normal deep lake or moderately shallow sea deposits. Some beds contain a little sand, but they are generally well sorted. They show no sign of grading.

The unsorted sandy siltstones (3) resemble those described before (Member 5) except that here, at 1250 m, two lenses of pure white and grey limestone, free of clastic material, occur within the apparently continuous matrix. These could represent subglacial limestones within a lodgement type of (clast-free) till, but the base of this particular unit is gradational over about 2 m, and this feature contradicts an over-riding ice sheet origin as proposed by Spencer (1971, p. 11-12), and as mentioned above (Member 3). The origin of these lenses, which are parallel to the bedding of the nearby lithologies, is sedimentary, and they do not represent stretched limestone clasts, but further refinement of origin is not considered possible.*

The remaining lithology (2) has already been discussed (Member 2).

Member 7.

This member of 267 m thickness consists of:

(1) Laminated and unlaminated siltstones with minor micro cross lamination. (381-194, -195, -196, -197 & 381-083)

(2) Silty sandstone (381-204)

(3) Graded bedded sandy siltstone (381-200), and

(4) Tillite

Depositional Environment

A thin layer of tillite at 1543 m in this member is the only clear evidence of the presence of glacial conditions at the time of deposition of these sediments. The generally well sorted siltstones, mostly unlaminated, appear to be of deeper water origin than the previously described sediments. The grading in 381-200 is poorly developed, but clearly present over some 14 m. This, it is felt, represents a seasonal source. Sedimentation was rapid, with probably insufficient time for sorting to occur between sediment influxes. A layer of complete cross beds was seen near the top of the member at 1565 m and is indicative of rapid sedimentation. (See plate 4c.) The rapid deposition and not deep water may be responsible for the predominantly unlaminated lithology.

Member 8.

40 m of massive boulder tillite occurs from 1621 to 1661 m (201 m from the top of the sequence).

Depositional Environment

The base appears to be sharp, but no other evidence of the method of deposition was noted. It is probable, if the underlying sediments represent

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* It should be pointed out that stoss and lee structures are absent from these continuously deposited sediments and hence the mechanism of deposition mentioned by Page (1970) is inadequate in the Pepuarta Tillite Deposits. Other mechanisms may exist.

a deeper water environment, that at least some of this material was rafted, in contradiction of the sharp base of the lithology. No evidence of a shallowing environment was seen in the underlying sediments.

Member 9.

Apart from occasional gritty bands, generally only a few centimetres thick, the lithology of this member is laminated siltstone, some showing small-scale cross lamination. The grits appear to be deposited over a period with normal sedimentation continuing uninterrupted. The siltstones are moderately to well sorted fine, medium and coarse grained rocks with no calcite detected in any outcrop or specimen (381-080, -081, -082), though dolomite may be present. (No test for dolomite was attempted)

Depositional Environment

Similar conditions to those prevailing before deposition of the tillite of member 8 are indicated except that the laminations and cross laminations indicate a shallow water body. The Nuccaleena dolomite must have been deposited under shallow water conditions and that unit directly overlies this member. The complete lack of carbonate in these sediments is their most notable feature, as calcite is abundant in almost all other sediments of the formation. (See "Calcium Carbonate in the Pepuarta Tillite (Formation)", Appendix II).

The Pepuarta Tillite Formation - Summary

A gradational base and top of the formation is indicated, although the mapped top is taken as the distinctive Nuccaleena Dolomite Equivalent. Glacial advances and retreats appear to have been numerous throughout deposition of the formation, with predominantly shallow water sedimentation and grounded continental ice sheets depositing lodgement tills and various outwash sediments according to the position of the ice sheet terminus. Rapid sedimentation is indicated in many places by the lack of sedimentary structures. It is probable that both wet- and dry-based glaciers contributed to deposition in this area.

It seems, from the above discussion and from mapping, that the members described are not likely to be traceable over great distances, and there appears to be a significant change in lithology across the syncline in the mapped area. Further, Robinson (1966) shows that the formation thins greatly elsewhere within the area of the Eudunda 1 mile sheet. Various authors have described the upper glacial sequence and have commented similarly on its discontinuous nature (e.g. Coats, 1971, p. 86, Dalgarno & Johnson, 1964b, p. 3, Coats, 1964, p. 12). This fact appears to be in disagreement with the concept of a continental ice sheet having provided the source material of the formation.

The problem of defining the direction of movement of the ice cannot be solved in this area, and the data of palaeocurrent directions (14) and thinning of sandstones (5) conflict not only with each other, but with ice movement directions determined elsewhere.

The total thickness of the Pepuarta Tillite Formation in this area is 1862 m.

Conclusions

1. The Eudunda 1-mile sheet is a generally adequate representation of the sedimentological boundaries in the examined area.

2. The Eudunda Arkose Member of the Tapley Hill Formation is not truly an arkose.

3. The so-called interglacial period is free of any evidence of glacial activity.

4. The Tapley Hill Shale in this region is not more calcareous towards the top as it reportedly is elsewhere in the Adelaide Geosyncline.

5. The return of glacial conditions during the Marinoan epoch was gradual as was the return to non-glacial conditions at the close of sedimentation of the Pepuarta Tillite (Formation).

6. The individual beds of the Pepuarta Tillite (Formation) are generally highly calcareous. The deposition of this material (micrite) was probably contemporaneous with sedimentation though a mechanism cannot be proposed. (See Appendix II).

7. One major deformation has affected the area, the metamorphism being of low biotite grade. A second, minor, deformation may have occurred and produced a second, very weak, cleavage.

8. The nomenclature of the lower glacial beds suggested by Robinson (1966) is unsatisfactory. It is considered that these rocks should be given a formation name with the individual units, the Hansborough Tillite, Gilbert Range Quartzite, and Appila Tillite becoming members.

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APPENDIX I

Rock and Thin Section Descriptions

Explanations

1. Detrital rock names conform to the scheme proposed by Folk, Andrews and Lewis, 1970.

2. Clastic constituent percentages are not expected to be precisely reproducible. They represent the number of grains in a counted 100 which were of each of the mineral types listed. The 100 grains counted represented approximately proportionally the full range of grainsizes of the identifiable clastics - those of coarse silt size or larger. Matrix to clastic ratios and mineral percentages within the matrix were estimated.

3. The grainsize analyses were obtained in the same way, and the figures quoted are for the coarse silt and larger grains only. That fraction of the slide of finer material, finer silt and orthogenic minerals, was ignored.

4. Control on grainsize grouping was maintained by using a card of standard grainsizes, which was viewed through the microscope before each slide was examined for grainsize.

Tapley Hill Formation

381-212

Grey, greeny-brown weathering, indurated, laminated, well-sorted, medium siltstone: calc-cemented quartz lutite.

Micro:

1. Constituents:

Quartz	40%
Feldspar	18%
Zircon	Trace
Muscovite	1%
Biotite	9%
Opaques	1%
Calcite	42%

2. Fabric:

Biotite is aligned parallel to cleavage. The calcite is strongly deformed.

381-213

Grey, green-weathering, indurated, thinly laminated, very well sorted, very fine siltstone: lutite.

Micro:

Platey minerals, ?biotite, are aligned parallel to cleavage. A slight compositional grading of slightly more siliceous, coarser grained bands and finer grained, more ?biotite-rich bands is present in this section. This banding coincides with bedding and also cleavage, which are approximately coincident in this rock.

381-214

Grey, brown-weathering, well indurated, massive, poorly sorted gritty fine sandstone: calc-cemented feldsarenite.

Micro:

1. Constituents:

Quartz	40%
Feldspar (Orthoclase 60%, Plagioclase 35%, Microcline 5%)	36%
Biotite	17%
Sericite (Alteration product of feldspar)	$<1\%$
Calcite	6%

2. Fabric:

Quartz grains are sutured and show some welding of contacts. Biotite is aligned parallel to cleavage.

Tapley Hill Formation

381-212

Grey, greeny-brown weathering, indurated, laminated, well-sorted, medium siltstone: calc-cemented quartz lutite.

Micro:

1. Constituents:

Quartz	40%
Feldspar	18%
Zircon	Trace
Muscovite	1%
Biotite	9%
Opaques	1%
Calcite	42%

2. Fabric:

Biotite is aligned parallel to cleavage. The calcite is strongly deformed.

381-213

Grey, green-weathering indurated, thinly laminated, very well sorted, very fine siltstone: lutite.

Micro:

Platey minerals, ?biotite, are aligned parallel to cleavage. A slight compositional grading of slightly more siliceous, coarser grained bands and finer grained, more ?biotite-rich bands is present in this section. This banding coincides with bedding and also cleavage, which are approximately coincident in this rock.

381-214

Grey, brown-weathering, well indurated, massive, poorly sorted gritty fine sandstone: calc-cemented feldsarenite.

Micro:

1. Constituents:

Quartz	40%
Feldspar (Orthoclase 60%, Plagioclase 35%, Microcline 5%)	36%
Biotite	17%
Sericite (Alteration product of feldspar)	1%
Calcite	6%

2. Fabric:

Quartz grains are sutured and show some welding of contacts. Biotite is aligned parallel to cleavage.

381-218

Grey, greeny-brown weathering, indurated, laminated, very well sorted, medium to fine siltstone: Calcareous lutite.

Micro:

Biotite and chlorite are recognizable in the fine grained groundmass. The clastics have not been identified. Platey minerals are parallel to cleavage.

Eudunda Arkose Member

381-209-A

Grey, dark brown-weathering, indurated, laminated, moderately sorted, silty fine to very fine sandstone: subfelds-arenite.

Micro:

1. Constituents:

Quartz		47%
Feldspar	(Orthoclase 80%) (Plagioclase 20%)	12%
Opaques		<1%
Biotite	(± chlorite)	40%

2. Fabric:

   Biotite is aligned parallel to cleavage. Quartz and feldspar grains are only slightly sutured.

3. Grain Size:

Quartz & Feldspar	FS	5%
	VFS	16%
	CZ	79%

381-209-B

Similar in all respects except that a higher proportion of the feldspar present is plagioclase.

381-210-A

Grey, indurated, laminated moderately sorted fine sandstone: quartz arenite.

Micro:

1. Constituents:

Quartz	92%
Muscovite	5%
Feldspar (Plagioclase & Microcline)	3%

2. Fabric:

   Homogeneous. Micas not aligned (detrital). Quartz grains are welded at points of contact and show some suturing.

3. Grainsize:

Quartz	FS	10%	Feldspar	VFS ~ 70%
	VFS	37%		CZ ~ 30%
	CZ	53%		

381-210-B

Is identical in all respects to 210-A.

Pepuarta Tillite Formation

381-128

Grey, grey-weathering, indurated, well-sorted, finely laminated, medium siltstone: calc-cemented lutite with poorly-sorted coarse to very fine sand in thin bands, and clast(s) up to 3 cm. diameter.

381-129

Grey, grey-weathering, indurated, well-sorted, finely laminated, medium siltstone: slightly-calcareous lutite with poorly-sorted coarse to very fine sand in thin bands.

381-130

Laminated siltstone with sandy layers. Siltstone: Grey, light brown-weathering, laminated, moderately sorted, sandy siltstone: calc-cemented lutite. Sandstone: White, grey-weathering, indurated, poorly-sorted, silty coarse sandstone: calc-cemented quartz arenite.

Micro:

1. Constituents:

(a) Siltstone:	Quartz	34%
	Opaques	1%
	Matrix (with abundant calcite)	63%
(b) Sandstone:	Quartz	48%
	Feldspars (Orthoclase)	4%
	Opaques	1%
	Calcite	25%
	Matrix	12%

2. Fabric:

Coarser quartz grains show some suturing and no welding is evident, presumably because grains are surrounded by calcite and matrix particles.

3. Grainsize:

(a) Siltstone:	FS	10%
	VFS	15%
	CZ	75%
(b) Sandstone:	CS	38%
	MS	25%
	FS	7%
	VFS	10%
	CZ	20%

381-131

Grey, grey-weathering indurated massive very poorly sorted gritty siltstone: calcareous quartz lutite.

Micro:

1. Constituents:

Quartz	26%
Feldspar (Orthoclase)	14%
Calcite	12%
Mica (Biotite)	48%

381-131 (contd.)

2. Fabric:

Quartz grains show very little suturing and are angular. The mica is aligned parallel to cleavage. Homogenous.

3. Grainsize:

Quartz and feldspar grains average about the same size. Size analysis of the ≥ coarse silt is as follows:

CS	6%
MS	14%
FS	21%
VFS	24%
CZ	35%

381-132

Grey, light brown-weathering indurated interbedded moderately sorted sandy coarse siltstone: quartz lutite and moderately sorted silty medium sandstone: calc-cemented quartz arenite.

Micro:

1. Constituents:

Sandstone:	Quartz	59%
	Feldspar (Orthoclase & Plagioclase)	10%
	Opaques	<1%
	Biotite	7%
	Muscovite	~1%
	Calcite	22%

Siltstone: Sand sized grains appear to be mainly quartz with minor feldspar.

2. Fabric:

Quartz and feldspar grains are sutured with welded contacts. Biotite is parallel to cleavage.

381-133

White, brown-weathering, well-indurated, massive, moderately sorted medium sandstone: calc-cemented quartz arenite.

Micro:

1. Constituents:

Quartz	72%
Feldspar (Plagioclase)	2%
Opaques	<1%
Calcite	21%
Limonite (after Pyrite?)	~2%
Muscovite	2%

381-133 (contd.)

2. Fabric:

Homogeneous. Quartz grains show some suturing and they are welded at points of contact. There is no apparent orientation of the minerals.

3. Grainsize:

Quartz:	MS	12%
	FS	48%
	VFS	40%

381-134-B

Grey, grey-green-weathering, weakly indurated, very poorly sorted, sandy coarse siltstone: calc-cemented quartz lutite.

Micro:

1. Constituents:

Quartz	50%
Feldspar	20%
Opaques	< 1%
Calcite	18%
Biotite	11%

2. Fabric:

Few grains are in contact and no welding has occurred although grains are sutured. Biotite parallels the dominant cleavage, though a second much less well-defined alignment is visible at an angle to it. A few? micas parallel this ?second cleavage.

381-135

White, yellow-weathering, indurated, massive, very poorly sorted intraclast-bearing micrite.

Micro:

1. Constituents:

Quartz	19%
Feldspar	10%
Rock fragments	10%
Calcite	60%
Sericite	~ 1%

2. Fabric:

Groundmass of calcite contains isolated, poorly-sorted, well-rounded grains of Q, R & F. The calcite matrix is streaked out parallel to cleavage.

3. Grainsize:

Granular & Clasts	5%
VCS	20%
CS	45%
MS	20%
FS	10%

381-136

White microcrystalline calcite with a few quartz sandgrains.

Micro:

Constituents:

Calcite (some recrystallized)	98%
Quartz	2%

381-137

White, brown weathering, massive, very well sorted, medium- to fine-grained sandstone: calc-cemented quartz arenite.

381-138-A

Greeny-grey, brown-weathering, indurated, laminated, very poorly sorted, gritty coarse siltstone: calc-cemented quartz lutite.

Micro:

Quartz and feldspar grains are sutured. Biotite in the matrix is aligned parallel to cleavage.

381-139

Yellow-brown weathering, moderately indurated, laminated, cross-laminated, moderately sorted fine sandstone: ?calc-cemented, subfeldsarenite.

381-140-A

Grey, grey-weathering, massive, poorly sorted, slightly sandy coarse siltstone: calc-cemented lutite.

381-140-B

White, brown-weathering, indurated, massive, well-sorted, fine sandstone: calc-cemented subfeldsarenite.

381-141-A

Grey, white-weathering, massive, poorly sorted, silty, very fine sandstone: calc-cemented, ?subfeldsarenite.

381-142

Grey, grey-green weathering, indurated, massive, poorly sorted, sandy coarse siltstone: calc-cemented quartz lutite.

Micro:

1. Constituents:

Quartz $\pm$ Feldspar	30%
Opaques	$<$ 1%
Biotite	23%
Calcite	40%
Chlorite	$\sim$ 6%

381-142 (contd.)

2. Fabric:

Quartz grains are sutured and mica is aligned parallel to cleavage.

381-144

Grey, white-weathering, weakly indurated, moderately sorted, sandy coarse siltstone: Calc-cemented quartz-lutite.

381-145

Grey, grey-weathering, indurated, massive very poorly sorted, dirty fine sandstone: calc-cemented subfeldsarenite.

Micro:

1. Constituents:

Quartz	31%
Feldspar (Plagioclase 20% Orthoclase 80%)	17%
Carbonate clasts (dirty calcite)	8%
Muscovite	30%
Calcite	14%

2. Fabric:

Quartz and feldspar grains are sutured and muscovite is parallel to cleavage. The carbonate clasts are elongated parallel to cleavage.

3. Grainsize:

VCS	2%
CS	2%
MS	45%
FS	45%
VFS	3%
CZ	3%

This sediment appears to be bimodal with medium and fine sand being dominant among the identifiable clastics.

381-146

White, brown-weathering, well-indurated, massive, very well sorted medium sandstone: calc-cemented feldsarenite.

Micro:

1. Constituents:

Quartz	10%
Feldspar (Orthoclase 75% Plagioclase 23% Microcline 2%)	62%
Opaques	1%
Chlorite	2%
Muscovite (Sericite as alteration of feldspars)	2%
Calcite	23%

381-146 (contd.)

2. Fabric:

Muscovite is parallel to the boundaries of the grains of quartz and feldspar and is not parallel to cleavage as in other rocks. The quartz and feldspars show suturing and welding of contacts.

381-147

Grey, grey-green-weathering, weakly laminated, poorly sorted, silty fine sandstone: ?quartzarenite.

381-148

Grey, brown-weathering, indurated, massive, very poorly sorted, silty very coarse sandstone: calc-cemented subfeldsarenite with clasts.

Micro:

1. Constituents:

Quartz	40%
Feldspar (Orthoclase 68% Microcline 32%)	11%
Opaques	< 1%
Biotite	9%
Chlorite	~2%
Calcite	37%

2. Fabric:

Quartz grains are slightly sutured and some contact points are welded. Biotite alignment is parallel to cleavage and the calcitepore filling is streaked out parallel to this direction also.

3. Grainsize:

Quartz and feldspar grains average about the same size.

VCS	12%
CS	21%
MS	32%
FS	22%
VFS	6%
CZ	7%

381-149

White, indurated, massive, very poorly sorted intraclast-bearing partially recrystallized micrite.

381-150

Pinkish-white, indurated, massive, poorly sorted, coarse sandstone: calc-cemented feldsarenite.

381-150 (contd.)

Micro:

1. Constituents:

Quartz	39%
Feldspar (Orthoclase 82%, Plagioclase 18%)	32%
Opaques	$<$1%
Muscovite	4%
Chlorite	2%
Biotite	$<$1%
Calcite	21%

2. Fabric:

Muscovite and chlorite are aligned parallel to cleavage. Quartz and feldspar grains are sutured and welded at points of contact. Some feldspar grains show a degree of alteration to sericite.

3. Grainsize:

Quartz	CS	7%	Feldspar	CS	18%
	MS	34%		MS	38%
	FS	29%		FS	34%
	VFS	27%		VFS	10%
	CZ	3%			

381-151

White, weakly indurated, massive, poorly sorted gritty sandstone: calcareous ?subfeldsarenite.

381-152

White, brown-pink-weathering, well indurated, massive, moderately sorted medium to fine sandstone: calc-cemented ?subfeldsarenite.

381-153

White, white-weathering, very well indurated, massive, moderately- to well-sorted medium sandstone: slightly calcareous quartzarenite.

381-154

Greyish white, grey-weathering, well indurated, massive moderately- to well-sorted medium sandstone: slightly calcareous ?subfeldsarenite with rare quartzite clasts up to 5 cm. diameter.

Micro:

1. Constituents:

Quartz	51%
Feldspar (Orthoclase)	28%
Calcite	20%
Muscovite	$<$1%

381-154 (contd.)

2. Fabric:

Quartz and feldspar grains are sutured and welded at points of contact.

3. Grainsize:

VCS	3%
CS	37%
MS	30%
FS	20%
VFS	9%
CZ	1%

381-155

White, grey weathering, massive, moderately sorted, gritty coarse sandstone: calc-cemented subfeldsarenite.

Micro:

1. Constituents:

Quartz	62%
Feldspar	12%
Opaques	Trace
Carbonate clasts (?Calcite)	6%
Calcite	18%
Sericite (Alteration of feldspars)	2%

2. Fabric:

The carbonate clasts are brown stained while other calcite is colourless. The clear calcite separates the quartz and feldspar grains. Quartz and feldspar grains are sutured and some welding of points of contact has occurred. Some of the matrix calcite has recrystallized.

3. Grainsize:

Quartz	CS	27%	Feldspar	MS	54%
	MS	34%		FS	26%
	FS	15%		VFS	10%
	VFS	14%		CZ	10%
	CZ	10%			

381-156

Grey, grey-green weathering, massive, very well sorted, medium siltstone: micaceous, pyritic, lutite as a clast 13 cm. diameter.

381-157

White, pink weathering, well indurated, massive, moderately sorted coarse sandstone: calc-cemented feldsarenite.

381-157 (contd.)

Micro:

1. Constituents:

Quartz	41%
Feldspar (Plagioclase 37% Microcline 5% Orthoclase 58%)	21%
Opaques	1%
Calcite	30%
Sericite (Alteration of feldspar)	7%

2. Fabric:

Quartz and feldspar grains are sutured and welded at contacts.

381-159

Light grey, brown-weathering, indurated, laminated, moderately sorted, fine sandstone: micaceous subfeldsarenite.

Micro:

1. Constituents:

Quartz	65%
Feldspar (Plagioclase ± Orthoclase)	~6%
Muscovite (Detrital ~5% Orthogenic ~95%)	19%
Opaques	< 1%
Limonite (Pseudomorphing Pyrite)	4%
Biotite	5%

2. Fabric:

The rock is homogeneous with respect to quartz feldspar and biotite but the muscovite, which is aligned parallel to cleavage is variable, being much more abundant in some areas of this slide than in others. Some limonite staining near pyrite pseudomorphs is evident. Clear pressure shadows have formed around the limonite cubes. Quartz and feldspar grains are sutured and welding at points of contact has occurred.

3. Grainsize:

Quartz Fine and very fine sand.
Feldspar Very fine sand and coarse silt.

381-161

White, well indurated, massive, very poorly sorted, sandstone: calc-cemented subfeldsarenite with clasts.

381-161 (contd.)

Micro:

1. Constituents:

Quartz		60%
Feldspar	(Plagioclase 70%	
	Orthoclase 30%)	12%
Opaques		<1%
Calcite		26%
Limonite	(Pseudomorphing pyrite)	<1%

2. Fabric:

Quartz and feldspar grains are only slightly sutured in this rock and the grains were originally rounded to subangular with high sphericity.

381-162

Grey, white-weathering, indurated, laminated, moderately sorted fine sandstone: calc-cemented quartz arenite with siltstone layers.

Micro:

1. Constituents:

Quartz		67%
Feldspar	(Plagioclase 63%	
	Orthoclase 33%	
	Microcline 2%)	12%
Zircon		Trace
Opaques		Trace
Calcite		14%
Biotite		6%
Chlorite		1%

2. Fabric:

Quartz and feldspar grains are sutured and welded at contacts. Biotite and chlorite are aligned parallel to the cleavage direction.

3. Grainsize:

Quartz	FS	26%
	VFS	48%
	CZ	26%

Feldspars are somewhat smaller, mostly very fine sand.

381-163

White, well-indurated, laminated, moderately sorted, medium sandstone: calc-cemented, pyritic subfeldsarenite.

381–163 (contd.)

Micro:

1. Constituents:

Quartz	67%
Feldspar (Orthoclase)	12%
Opaques	Trace
Pyrite	2%
Calcite	18%
Biotite	<1%

2. Fabric:

Quartz and feldspar grains are sutured, but biotite is not aligned in this section.

3. Grainsize:

Quartz and feldspar grains are approximately similar in size distribution.

CS	3%
MS	34%
FS	37%
VFS	14%
CZ	12%

381–164

Greenish-grey-weathering, moderately indurated, laminated poorly sorted very sandy coarse siltstone: calc-cemented lutite with slightly more sandy layers containing less carbonate and being slightly more resistant to weathering.

381–165

Grey, grey-weathering, moderately indurated, weakly laminated, moderately sorted sandy coarse siltstone: calc-cemented lutite.

381–166

White, grey-weathering, indurated, laminated, well-sorted fine sandstone: calc-cemented ?subfeldsarenite with siltstone bands.

381–167

Grey, white-weathering, well indurated, weakly laminated, moderately sorted, medium sandstone: calc-cemented subfeldsarenite.

Micro:

1. Constituents:

Quartz	50%
Feldspar (Plagioclase 65% Orthoclase 35%)	20%
Opaques (Magnetite)	1%
Calcite	28%
Biotite	<1%
Chlorite	Trace

381-167 (contd.)

2. Fabric:

Quartz and feldspar grains are sutured with contacts welded. Biotite has formed at the expense of magnetite. Chlorite, where it occurs, appears to be a weathering product of biotite. The calcite matrix has been partially recrystallized.

3. Grainsize:

Quartz	MS	30%	Feldspar	MS (Mainly Orthoclase)	60%
	FS	40%		FS (Mainly Plagioclase)	40%
	VFS	30%			

381-168

Grey, green-weathering, indurated, massive, poorly sorted sandy siltstone: calc-cemented quartz lutite.

Micro:

1. Constituents:

Quartz	35%
Feldspar	5%
Calcite	4%
Biotite	54%
Opaques	~ 2%

2. Fabric:

Biotite in the matrix is aligned parallel to cleavage. Quartz grains are slightly sutured.

3. Grainsize:

Quartz	MS	5%
	FS	6%
	VFS	30%
	CZ	59%

381-169

White, very well indurated, banded, very well sorted, fine quartzite: quartzarenite, metamorphosed such that the quartz grains have recrystallized and carbonete has been introduced along fractures at some time since the quartzite became brittle. The carbonate is probably dolomite, as no reaction with weak acid has been observed.

381-170

Coarse grained quartz-feldspar-biotite igneous rock - granitic.

381-170 (contd.)

Micro:

1. Constituents:

Quartz	15%
Feldspar (Orthoclase)	39%
Biotite	2%
Magnetite	< 1%
Haematite	Trace
Sericite (Weathering product of Feldspar)	41%
Zircon	Trace
Pyrite	1%
Sphene	Trace
Ilmenite	Trace

381-171

Grey, indurated, massive, very poorly sorted sandy siltstone: calc-cemented quartz lutite with clasts.

Micro:

1. Constituents

(a)	Clast:	Quartz	46%
		Feldspar (Orthoclase 70% Microcline 30%)	5%
		Biotite	14%
		Sericite (Alteration product of feldspars)	33%
		Opaques (?Magnetite)	2%
(b)	Matrix:	Quartz	44%
		Rock fragments (Carbonate and some acid igneous)	6%
		Biotite	21%
		Calcite	24%

2. Fabric:

(a) Clast: Biotite is aligned parallel to a former cleavage. The regional cleavage has not affected the orientation of micas in the clast.

(b) Matrix: Biotite is aligned parallel to the cleavage direction, and there appears to be a weak alignment of micas at 70° to the dominant cleavage direction.

3. Grainsize: (of matrix)

Quartz	CS	4%
	MS	2%
	FS	4%
	VFS	17%
	CZ	73%

381-173

Coarse grained quartz-feldspar acid igneous rock. Granite.

Micro:

1. Constituents:

Quartz	22%
Feldspar (Orthoclase 70% Microcline 30%)	73%
Opaques	5%

381-174

Grey, grey weathering indurated massive slightly sandy poorly sorted coarse siltstone: calc-cemented lutite.

381-175

Light grey, light brown weathering indurated graded bedded moderately sorted silty fine sandstone: calc-cemented quartz arenite.

Micro:

1. Constituents:

(a) Coarser fraction of each lamination:

Quartz	50%
Feldspar	~ 2%
Muscovite	~ 1%
Opaques (Pyrite)	< 1%
Limonite	< 1%
Biotite	7-10%
Carbonate (?Dolomite)	37%

(b) Finer fraction of each lamination:

Detrital	40-50%
Carbonate (?Dolomite)	60-50%

2. Fabric:

Laminated with respect to composition (detrital/chemical) and grainsize. Quartz grains are welded and sutured. Biotite is prominent in the coarser fraction. The finer fraction is largely carbonate with finer and occasionally coarser clastics, largely quartz.

3. Grainsize:

Clastics range from fine sand to coarse silt, graded within the laminations. Finer material is not identified. Feldspars are smaller than the coarser quartz grains.

4. Grainshape:

All detritals are angular with high sphericity.

381-176

White, pinky-grey weathering, well indurated, laminated, poorly sorted coarse sandstone: very slightly carbonate-bearing feldsarenite.

Micro:

1. Constituents:

Quartz	50%
Feldspar (Orthoclase)	43%
Opaques	Trace
Carbonate (?Dolomite)	6%
Limonite	< 1%
Muscovite	Trace

2. Fabric:

Quartz and feldspar grains are sutured and points of contact between grains are welded.

3. Grainsize:

Quartz and feldspar grains are approximately of the same grainsize distribution.

CS	5%
MS	5%
FS	50%
VFS	25%
CZ	15%

381-177

Greenish white, light brown weathering, well indurated, massive, moderately sorted, coarse sandstone: subfeldsarenite.

Micro:

1. Constituents:

Quartz	53%
Feldspar	8%
Zircon	< 1%
Biotite	11%
Muscovite	21%
Chlorite	4%
Sericite	~ 2%

2. Fabric:

Quartz grains are sutured and show welding of points of contact. Micas are aligned with a trend parallel to cleavage, but are refracted around the grains.

3. Grainsize:

Quartz	VCS	4%	Feldspar	CS	60%
	CS	31%		MS	30%
	MS	23%		FS	10%
	FS	20%			
	VFS	10%			
	CZ	2%			

381-178

White, dark-brown weathering well indurated massive, very poorly sorted gritty sandstone: calc-cemented feldsarenite with rare clasts.

Micro:

1. Constituents:

Quartz	45%
Feldspar	10%
Rock fragments	5%
Opaques	Trace
Calcite	30%
Chlorite	8%
?Biotite	1%

2. Fabric:

Micas parallel the cleavage direction. The calcite is deformed to reflect this orientation. The quartz shows little suturing and no welding of contacts.

3. Grainsize:

All sizes from granular to coarse silt are present. Material finer than this has been largely removed.

381-179

Grey, green weathering, indurated, laminated moderately sorted sandy siltstone: pyritic quartz lutite.

Micro:

1. Constituents:

Quartz	27%
Biotite	60%
Chlorite	8%
Pyrite	5%

2. Fabric:

Layered with indistinct grading of the finer fraction of the clastics, but with coarser grains randomly distributed. Biotite tending to be aligned parallel to the cleavage direction.

3. Grainsize:

Quartz	MS	3%
	FS	4%
	VFS	6%
	CZ	87%

381-180

Grey, grey-brown-weathering, indurated, massive, poorly sorted, sandy, medium siltstone: quartz lutite.

381-180 (contd.)

Micro:

1. Constituents:

Quartz	16%
Feldspar (Orthoclase)	4%
Biotite	35%
Muscovite	35%
Chlorite	5%
Carbonate	2%
Pyrite	3%

2. Fabric:

Quartz grains are deeply sutured. Biotite tends to be aligned parallel to cleavage.

3. Grainsize:

Quartz and feldspar grainsizes are approximately similarly distributed.

VCS	1%
CS	2%
MS	4%
FS	4%
VFS	12%
CZ	77%

381-181

White, grey-weathering, indurated, weakly laminated, moderately sorted, silty medium sandstone: slightly calcareous, ?subfeldsarenite.

381-182

Grey-green, grey-weathering, indurated, moderately to poorly sorted, slightly sandy coarse siltstone: slightly calcareous lutite.

381-183

Mixtite with quartzite clasts up to 6 cm. diameter in a matrix of grey, indurated, massive, moderately sorted sandy siltstone: calc-cemented quartz lutite.

Micro:

1. Constituents:

(a) Clasts:	Quartz	97%
	Calcite	2%
	Opaques	<1%
(b) Matrix:	Quartz	65%
	Opaques	<1%
	Muscovite	15%
	Calcite	19%

2. Fabric:

Homogeneous with mica aligned parallel to the cleavage direction. There is a suggestion of a second weak orientation direction of muscovite.

381-183 (contd.)

3. Grainsize: (Matrix only)

Quartz	MS	8%
	FS	20%
	VFS	34%
	CZ	38%

381-184

Grey-green, grey-weathering, indurated, weakly laminated, well sorted medium to coarse siltstone: lutite.

381-185

Grey, grey-weathering, indurated, massive, well sorted, coarse siltstone: lutite with manganese dendrites on cleavage planes.

Micro:

1. Constituents:

Quartz	50%
Feldspar (Plagioclase)	< 1%
Mica (Detrital Muscovite)	~ 1%
Opaques (Pyrite)	3%
Biotite	12%
Chlorite	23%
Calcite	10%

2. Fabric:

Quartz grains are sutured. Biotite and chlorite are aligned parallel to cleavage and the calcite pore filling reflects this alignment.

3. Grainsize:

Quartz	FS	12%
	VFS	16%
	CZ	72%

381-186

Green, grey-weathering, indurated, laminated, well-sorted, slightly sandy coarse siltstone: calc-cemented lutite.

381-189

Grey, green-weathering, indurated, massive well sorted medium to coarse siltstone: calc-cemented quartz lutite.

Micro:

1. Constituents:

Quartz and Feldspar (Indistinguishable)	~ 40%
Opaques (? and Pyrite)	~ 5%
Biotite	~ 23%
Calcite	~ 25%
Chlorite	~ 7%

381-189 (contd.)

2. Fabric:

Biotite and chlorite parallel cleavage. The coarser grains can be seen to be sutured slightly.

3. Grainsize:

Some coarse silt, but mainly finer.

381-190

Cream and grey laminated fine grained limestone as lenses within a tillite band.

381-191

Grey, brownish-grey -weathering, indurated, laminated, well sorted fine to medium siltstone: quartz lutite.

Micro:

1. Constituents:

Quartz and feldspar	25%
Biotite	~ 70%
Carbonate	~ 3%
Opaques (Pyrite)	2%

2. Fabric:

Quartz grains are sutured and biotite is aligned parallel to cleavage.

381-192

Grey, light-grey weathering, indurated, massive, well sorted, slightly sandy siltstone: ?quartz lutite.

381-193

Grey, brownish-grey weathering, indurated weakly laminated, moderately sorted slightly sandy coarse siltstone: quartz lutite.

Micro:

1. Constituents:

Quartz	54%
Feldspar (Orthoclase)	~ 1%
Opaques	<1%
Muscovite	20%
Biotite	13%
Chlorite	7%
Calcite	3%
Pyrite	1%

381-193 (contd.)

2. Fabric:

Quartz grains are sutured and show some welding of contact points between grains. Micas are mostly aligned parallel to the dominant cleavage direction, although a second alignment is evident with chiefly chlorite with some ?muscovite defining it. Some chlorite appears to be replacing biotite in places.

381-194

Green, brownish-grey weathering, indurated, laminated, very well-sorted medium siltstone: slightly calcareous lutite.

381-195

Grey, grey weathering, moderately indurated, massive, well sorted, coarse siltstone: calc-cemented quartz lutite.

Micro:

1. Constituents:

Quartz and feldspar	55%
Opaques (? and Pyrite)	5%
Biotite	~ 5%
Chlorite	5%
Calcite	~ 30%

2. Fabric:

Biotite is aligned parallel to the cleavage direction and the calcite pore filling reflects this. Quartz grains are sutured.

381-196

Grey, dark-grey-weathering, well indurated, massive, moderately to poorly sorted sandy coarse siltstone: quartz lutite.

381-197

Dark-grey, greeny grey-weathering, well indurated, massive, poorly sorted sandy siltstone: quartz lutite.

Micro:

1. Constituents:

Quartz	40%
Biotite	57%
Opaques (Pyrite cubes)	3%

2. Fabric:

Quartz grains are sutured and biotite is aligned parallel to cleavage.

<u>381-197</u> (contd.)

3. Grainsize:

Quartz	MS	6%
	FS	14%
	VFS	30%
	CZ	50%

<u>381-200</u>

Greenish-grey, grey-weathering, indurated, graded, bedded, poorly sorted sandy coarse and fine siltstone: calc-cemented quartz lutite.

The grading is irregular from $<$1 mm. to $>$1 cm. There is a slight compositional change with calcite being more abundant in the coarse fraction than in the finer layers.

<u>381-204</u>

Grey, grey weathering, indurated, massive, moderately sorted very silty very fine sandstone.

<u>381-082</u>

Grey, grey-brown-weathering, indurated, laminated and cross laminated, moderately sorted, slightly sandy, fine siltstone: lutite.

<u>381-081</u>

Greenish grey, grey-weathering, indurated, laminated, moderately sorted, slightly sandy, fine siltstone: lutite.

<u>381-080-</u>

Grey, light brown-weathering, indurated, laminated, well sorted, fine siltstone: lutite.

Igneous Rocks

381-197-A

Biotite-feldspar rich coarse grained igneous rock.

Micro:

1. Constituents:

Biotite	30%
Orthoclase	55%
Microcline	4%
Plagioclase	2%
Chlorite	$<$ 1%
Calcite	~ 3%
Quartz	~ 2%
Magnetite	2%
Sericite	2%

2. Fabric:

Homogeneous holocrystalline rock with biotite replacing magnetite. Some calcite, presumably an alteration product of plagioclase, is present. Sericite represents the alteration of feldspars. Some chlorite is present, and probably represents the weathering of biotite.

381-199-A

This is an intrusion breccia with fragments of siltstone and fine sandstone cemented by a very fine grained, biotite-rich magma.

381-199-B

This shows the contact between the igneous matrix and a sandy fine siltstone fragment in the breccia. Iron-rich solution staining can be seen in the siltstone near the contact.

381-202

Fine grained melanocratic igneous intrusion with chilled margins intruded along a ?fault plane. Biotite is the only recognizable mineral, and it is coarser near the centre of the vein.

APPENDIX II

Calcium Carbonate in the Pepuarta Tillite (Formation)

The percentages of calcite, mostly micrite, present in each thin section was estimated, and the results for the slides of the Pepuarta Tillite rocks are shown in Fig. 3. No pattern is discernable, at least with this number of samples (36). The average value is 20% leaving out the non-calcareous sediments of Member 9. The average for the matrix of the tillites is somewhat higher at 26%.

Carey & Ahmed (1960, p. 871) consider that dry-based glaciers lead to sediments associated with calcite, but the evidence that both wet- and dry-based glaciers were present is considered reasonable though probably dry-based glaciers predominated.

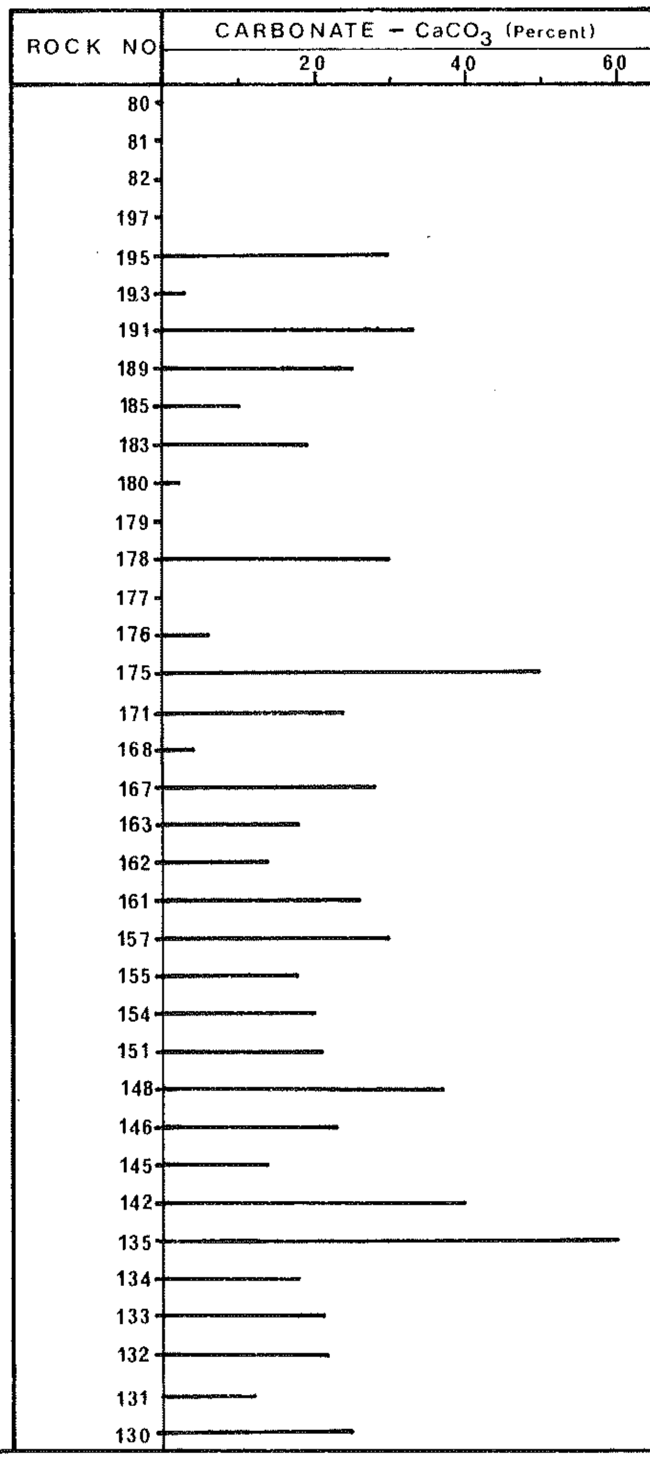
Kirkland and Anderson (1969, p. 19) have shown that varved sediments have a higher calcite content in the light coloured laminae (up to 60%), but this feature has not been identified here. The sediments examined may not, therefore, be varves.

From consideration of the thin sections, it seems likely that the calcite of at least the siltstones is a direct chemical precipitate as permeability of these beds is too low to allow diagenetic deposition of calcite from circulating conate waters. The same argument cannot be advanced for the high calcite sandstones, but it is felt that at least the subaqueous sediments must have obtained their calcite from contemporaneous precipitation.

The source of the calcite may have been the glacial sediments themselves as some calcite clasts are present in the tillites, but whether supply of such vast quantities of calcite by such means is possible is not known. It is possible that what has been interpreted as lacustrine environments were shallow marine environments, and that the calcite was derived from the sea. Palaeosalinity work may help to resolve the calcite supply difficulty.

FIG 3

CARBONATE IN SEDIMENTS OF THE PEPUARTA TILLITE.



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APPENDIX III

The Origin of the Mixtites of the Pepuarta Tillite Formation

Abundant works exist which indicate differences between tillites and mixtites of other origins. (Flint, 1970, p. 152-153 & p. 156-158, Harland, et. al., 1966, p. 251, and Spencer, 1971, p. 63-65, to mention a few.) Spencer sets out a table of criteria which is presented (modified) here as Table 1, which is largely self-explanatory.

To summarize, however, 8 criteria are present in the area examined which indicate the tillitic nature of the Pepuarta Tillite sediments. Of these, no. 7 (see Table 1) is considered concrete evidence by Harland, et. al. It should be pointed out however, that dropped clasts are confined to member 1, and that they are not frequently seen. Similarly the laminated deposits are quite possibly varved, at least in places, but definite identification of varves has not been possible. It is felt, however, that these deposits are seasonal. Further petrological examination of a large number of samples of laminated siltstones and siltstone-sandstone beds may indicate seasonal deposition of calcite as described by Kirkland and Anderson (1969) when speaking of varves. Lastly, while facetted clasts were not definitely seen, many generally rounded stones possessed one or more flattened surfaces which may or may not be facets. The lithologies of such clasts were largely metaquartzite and acid igneous with no cleavage or obvious planar features present.

Of those criteria absent, the most damaging to the case for a glacial origin for the mixtites is the complete lack of structures made by moving ice and of ice-contact features (5 in Table 1). The proposed series of ice advances and retreats, it is felt, should have left some of these features preserved in the sediments. If the source was an eastern or western one (for which no evidence exists in the examined area) these features may be present but concealed by the nature of the outcrop which strikes north-south.

Table 1. Criteria for Identifying Glacial & Cold Climate Deposits applied to the Pepuarta Tillite.

Criteria	Evaluation of Criteria	Present (P) Absent (A) Comments
A. Evidence of Glaciation:		
1. Basement Pavements	2	Not expected - no unconformity
2. Streamline Topographic Forms		Unlikely in this deposit
3. Tillite:		
(a) Large range of grainsizes		P
(b) Unsorted deposits		P
(c) Shaped stones	2	?
(d) Striated stones	2	A
(e) Till Fabric	2	Obliterated if present
(f) Erratic Clasts & Fresh Minerals		P
(g) Boulder Pavements		A
(h) Great Thickness & Lateral Extent	1	P
(i) Moraine Deposits		A
4. Stratified Drift:		
(a) Outwash Sediments		P
(b) Varved Deposits		? P
5. Structures made by Moving Ice:		A
B. Non-glacial Evidence of Cold Climates:		
6. Features made by Freeze & Thaw: (Solifluction, Involution, Ice-wedge Pseudomorphs)		A
7. Rafted Clasts in Laminated Sediments	3	P
8. Presence of Rock Flour	2	No attempt to identify it
9. Large Blocks of Extra-basinal Material widely distributed	2	P

Harland et al. (1966, P.251) noted: 3 - this is "one criterion for glacial origin which can be used alone & considered decisive"; 2 - these "can be explained in more than one way. However, in sufficient quantity or quality, these factors may justify a claim for glacial origin"; 1 - the results of the very extensive areas over which tills may be present. This factor "may be overwhelmingly convincing but is not in itself decisive".

This table is modified after one by Spencer (1971, P.64).

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APPENDIX IV

Structure

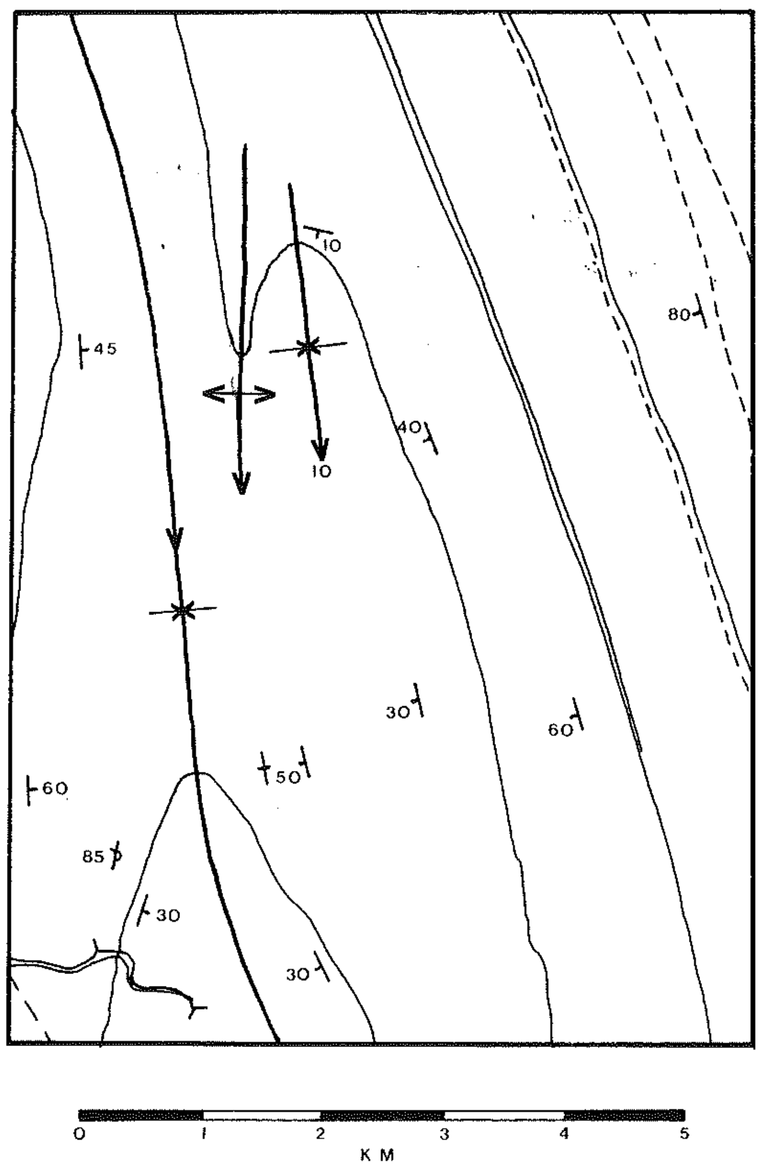
Structurally the area is simple with a major north-south trending syncline with steeply dipping limbs, and a minor anticline and syncline parasitic on the larger structure which die out towards the south. It is these structures which produce variations in dip from steeply west to horizontal across the western limb of the major syncline which are seen on the map. Additionally, numerous small parasitic folds (1-5 m across) can be seen in the western limb. These probably exist also in the eastern limb, although exposure is limited in that position. All measured structures plunge at about 10^o towards the south. A strong axial plane cleavage has developed in the siltstones. A simplified tectonic sketch is presented in Fig. 4. The probable time of deformation was Early Palaeozoic.

Outcrop in the examined area reveals only evidence of a single deformation, but some thin sections appear to show some evidence of a second, subsequent event. (381-134-B, -171, -183, -193) The grade of metamorphism is lower biotite grade, and this is in agreement with Offler & Fleming (1967). The minerals defining the ?second cleavage, which is extremely poorly developed, appear to be chlorite and possibly muscovite. These are shown best in 381-193.

The drainage pattern consists of minor north-south trending creeks feeding major east-west creeks. The former is considered a consequence of differential weathering properties of the lithologies, but the latter creeks have cut down through thick, very resistent quartzites in places. It is probable that a series of minor east-west faults or joints has made this possible, and in places the creeks can be seen to follow closely, widely spaced joints which are, at one location, intruded by a dark igneous rock.

FIG 4

SIMPLIFIED TECTONIC SKETCH



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APPENDIX V

Photographs not Specifically Referred to in the Text

PLATE 5

a

Slumped beds near the top of the Tarcowie Siltstone. About 8 m of beds are affected.

Creek bed 34° 14·70'S. 139° 05·50'E.

b

Typical of the siltstone with sandstone laminae about half way up Member 1 of the Pepuarta Tillite (Formation). Cleavage has broken the sandstone laminae into augen-shaped pieces in places. The length of the bar perpendicular to bedding is 45 cm. The individual sandstone laminae are marked with a black stroke. Note that the siltstone between sands is still laminated, indicating the intermittent supply of the (here) very fine sand.

In creek near track between St. Kitts Rd. & Adelaide Rd. 34° 13·65'S 139° 04·60'E.

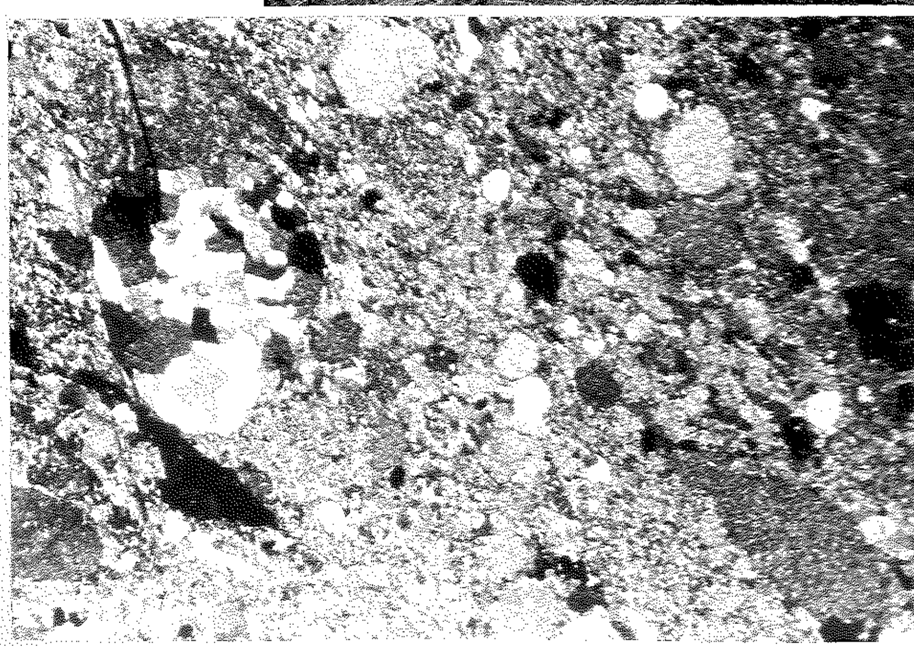
c

A photomicrograph (100X) of 381-135. The matrix is calcite (micrite) and flowing water has removed the fines, leaving only coarser sand and small clasts. This is probably a subglacial limestone. Crossed nicols.

PLATE 5

a

b



c

<u>PLATE 6</u>

a

The largest clast seen in the Pepuarta Tillite (Formation). This is a broken round of about 1 m long axis. The clast is of vein-type quartz and is enclosed in a poorly sorted gritty coarse sandstone about 3 m thick with a few other, much smaller, clasts.

In Quartzite outcrop near top of hill 34° 13·30'S. 139° 04·40'E.

b

A band or lens of pebbles and cobbles seen in a massive coarse siltstone. The clasts are frequently in contact and the matrix resembles the surrounding siltstone. No grading is visible. The material may have been dumped from an overturned iceberg but no other clasts were seen in the enclosing lithology. Note the clast below the band of cobbles. The card is standard size.

Creek bed 34° 14·35'S 139° 04·25'E.

c

A grit band now deformed, in the laminated siltstones of member 9 of the Pepuarta Tillite (Formation). Siltstone deposition appears to have been uninterrupted and vague bedding occurs within the grit band itself.

34° 15·00'S. 139° 04·10'E.

PLATE 6

a

b

c

PLATE 7

a

A small plug of coarse grained biotite- and Feldspar-rich igneous rock. Several larger plugs occurred nearby, with the nearby siltstones showing an aureole in which some epidote was seen on joints. Similar, though finer grained material intruded east-west ?fault planes and the creek had followed the joints.

Creek bed 34° 14·35'S. 139° 04·07'E.

b

An intrusion breccia showing angular fragments of siltstone in a matrix of the above biotite-rich material and crushed siltstone. The coarse grained nature of the igneous rock and the presence of the intrusion breccia are conflicting evidence of emplacement depth, but it is considered that the intrusions were emplaced at very shallow depths.

Creek bed 34° 14·35'S. 139° 04·07'E.

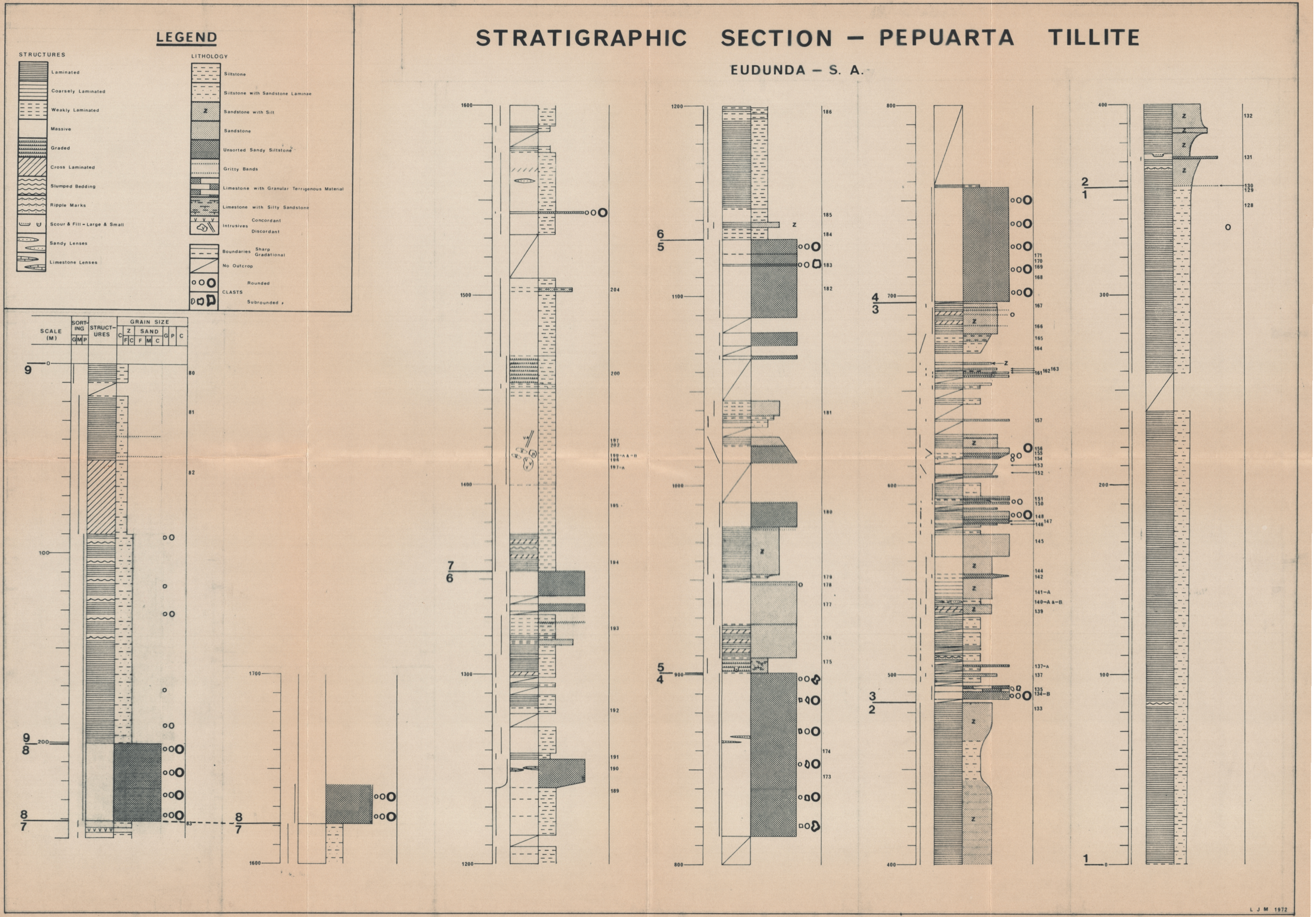
PLATE 7

a

b

STRATIGRAPHIC SECTION – PEPUARTA TILLITE

EUDUNDA – S. A.



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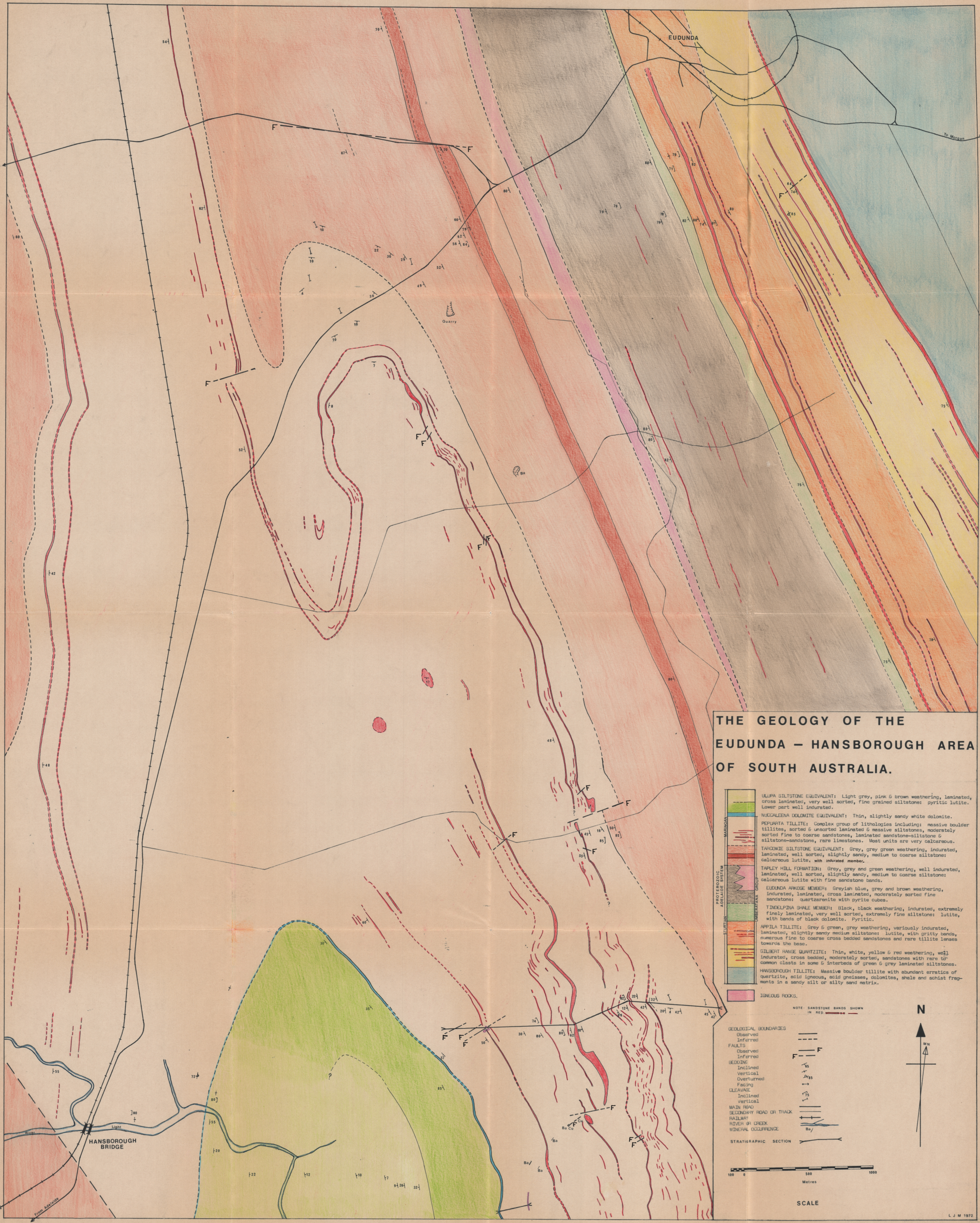
THE GEOLOGY OF THE
EUDUNDA – HANSBOROUGH AREA
OF SOUTH AUSTRALIA.
EUDUNDA
To Morgan
HANSBOROUGH BRIDGE
River Light
From Adelaide
Quarry
PROTEROZOIC
ADELAIDE SYSTEM
MARINOAN
STURTIAN
UMBERATANA GROUP
ULUPA SILTSTONE EQUIVALENT: Light grey, pink & brown weathering, laminated, cross laminated, very well sorted, fine grained siltstone: pyritic lutite. Lower part well indurated.
NUCCALEENA DOLOMITE EQUIVALENT: Thin, slightly sandy white dolomite.
PEPUARTA TILLITE: Complex group of lithologies including: massive boulder tillites, sorted & unsorted laminated & massive siltstones, moderately sorted fine to coarse sandstones, laminated sandstone-siltstone & siltstone-sandstone, rare limestones. Most units are very calcareous.
TARCOWIE SILTSTONE EQUIVALENT: Grey, grey green weathering, indurated, laminated, well sorted, slightly sandy, medium to coarse siltstone: calcareous lutite, with indurated member.
TAPLEY HILL FORMATION: Grey, grey and green weathering, well indurated, laminated, well sorted, slightly sandy, medium to coarse siltstone: calcareous lutite with fine sandstone bands.
EUDUNDA ARKOSE MEMBER: Greyish blue, grey and brown weathering, indurated, laminated, cross laminated, moderately sorted fine sandstone: quartzarenite with pyrite cubes.
TINDELPINA SHALE MEMBER: Black, black weathering, indurated, extremely finely laminated, very well sorted, extremely fine siltstone: lutite, with bands of black dolomite. Pyritic.
APPILA TILLITE: Grey & green, grey weathering, variously indurated, laminated, slightly sandy medium siltstone: lutite, with gritty bands, numerous fine to coarse cross bedded sandstones and rare tillite lenses towards the base.
GILBERT RANGE QUARTZITE: Thin, white, yellow & red weathering, well indurated, cross bedded, moderately sorted, sandstones with rare to common clasts in some & interbeds of green & grey laminated siltstones.
HANSBOROUGH TILLITE: Massive boulder tillite with abundant erratics of quartzite, acid igneous, acid gneisses, dolomites, shale and schist fragments in a sandy silt or silty sand matrix.
IGNEOUS ROCKS.
NOTE: SANDSTONE BANDS SHOWN IN RED.
GEOLOGICAL BOUNDARIES
Observed
Inferred
FAULTS
Observed
Inferred
BEDDING
Inclined
Vertical
Overturned
Facing
CLEAVAGE
Inclined
Vertical
MAIN ROAD
SECONDARY ROAD OR TRACK
RAILWAY
RIVER OR CREEK
MINERAL OCCURRENCE
STRATIGRAPHIC SECTION
N
MN
100 0 500 1000
Metres
SCALE
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