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PETROLOGY OF SEDIMENTS FROM THE 1962 COLLECTIONS IN THE EROMANGA BASIN

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SUMMARY

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ABSTRACT

A petrographic examination has been carried out on thin sections cut from sediments collected by the Great Artesian Basin field party during 1962. Twenty two rocks are described, and problems relating to genesis and source rocks are discussed.

Sandstones from the White Mountains and the Gilbert River Formation are quartz sandstones containing important but variable proportions of mylonitized quartzose rocks as lithic constituents. They were probably derived from acid metamorphics such as gneisses, to the west of the outcrops studied, and now covered beneath later Cretaceous sediments. Sediments of the Wilgunya Formation, Mackunda Beds and Winton Formation originated from a region dominated by acid volcanics, probably the Urannah Complex and Lower Bowen Volcanics to the east of the outcrops studied.

Glauconite is abundant in the Doncaster Member, and was largely formed from alteration of muscovite, but in higher levels it changes in its internal structure and the bulk of it in the Mackunda Beds and Winton Formation is thought to be detrital celadonite. A reducing environment and restricted circulation is inferred for the period of deposition of the Doncaster Member, but plentiful inorganically precipitated calcium carbonate in rocks throughout the marine Cretaceous sequence suggest that the sea persisted to be at least fairly shallow and rather isolated from main oceanic waters.

INTRODUCTION

A petrographic examination has been carried out on sixty six thin sections, cut from sediments collected by the Great Artesian Basin Party during 1962. They were taken from the following units: unnamed sandstone of the White Mountains, Gilbert River Formation, Wilgunya Formation: Doncaster Member, Jones Valley Member, Toolebuc Member, and Allaru Member; Mackunda Beds, Winton Formation and Glendower Formation.

The full range of lithologies in these units is described in Vine, Bastian, and Casey (1963). The specimens examined do not necessarily represent all the lithologies seen in the field, but are in general typical of the coarser beds in each unit. For this report the author has selected one-third of the descriptions, being those which best illustrate the various lithologies seen in the thin sections.

Specimen numbers are those of the Great Artesian Basin Party's collections. The registered rock numbers of these specimens are given in Appendix A. Localities are quoted by reference to the 1:250,000 Sheet name, aerial photograph run and photo number, and the point number marked on the party's photos when the specimen was collected, followed by a brief descriptive note on the approximate location. Following upon the thin section descriptions for each unit, brief comments are made on the genesis and possible source rocks for the sediments.

The arrangement of descriptions of minerals in the thin sections follows the generally accepted triangular construction upon which the terminology of clastic sediments is based. This arrangement has as its major parameters quartz, feldspars and rock fragments. Minerals are described in this order, chert being included with quartz unless it is related in character to other lithic grains. Micas are described after feldspar, as they are frequently sufficiently abundant to provide important qualifiers to the rock names. Other minerals which are not normally used in naming a rock, and usually present in accessory amounts, are described last. Percentages are visual estimates made on each without recourse to any counting methods, and are not intended to suggest averages for the rock types, as the number of representatives is too small. The percentage estimates are summarized in Table I at the conclusion of this report.

DESCRIPTIONS

White Mountains sandstone

Specimens from the White Mountains are white, medium-grained sandstones belonging to the dominant rock type, and brick-red siltstones, belonging to a minor rock type.

GAB 875. Hughenden 15/5205, pt. 308-309, 8 miles south-east of Lake Moocha.

The rock is an exceptionally white, medium-grained sandstone with a high content of powdery white grains resembling kaolinized feldspars. It is very friable and porous, and weakly bedded, and appears to be poorly sorted.

In thin section it is seen to be made up of a moderately sorted fine - to medium-grained sand, whose grain-size averages about 0.25 mm, and ranges up to about 0.9 mm. There are, besides quartz, abundant lithic grains and it has an unusual type of argillaceous matrix. Quartz (50%) is angular to subangular, and includes some composite grains with quartzitic textures, commonly with trains of inclusions, and a few embayed grains; the composite grains show strong pressure solution. Plagioclase is present but rare, and is strongly sericitized. Illite (5%) occurs in patches of squat "books", of variably low birefringence due to hydration; much of this material shows a further partial conversion to very low birefringent kaolinite, indicative of leaching following hydration. They are identical with clumps of hydrated micas occurring in mylonitized gneisses in nearby localities, and represent individual mica grains which were broken down during mylonitization. Lithic grains (30%) include a wide variety of fine and very fine to microgranular quartzose rocks, commonly with finely divided mica. These are the powdery white grains of the hand-specimen. The majority resemble laminae of mylonitized quartz-rich rocks common in nearby Precambrian gneisses (fig. 1), but some are clearly recognizable as quartz-porphyries identical with specimens GAB 973 and GAB 978. A few have criss-crossing veinlets of quartz, and there are some rare banded chalcedonic grains, rare grains with rosette-like intergrowths of quartz similar to textures seen in rhyolites within the Precambrian gneiss complex, and rare grains with micrographic texture. The matrix (10%) consists of patches of strongly curved aggregates of minute clay flakes, and all patches show curvatures facing the same way; presumably due to reorganization under gravity forces. The clay contains very fine silt and illite, but is mainly of very low birefringence, and has not been identified. Many of the large illite clumps, and also some grains which appear to be composites between these and the mylonitized quartzose rocks, have been partly crushed out to form a matrix for neighbouring grains.

Name : medium-grained lithic quartz sandstone.

GAB 1029. Hughenden 7/5069, pt. 66-67, in Flinders Gorge about two miles east of Clyde Park Homestead.

The rock is a very micaceous deep brick-red sandstone. It has slightly undulating laminae, is tough and impermeable, and before ferruginisation appears to have had a strong bedding plane cleavage.

In thin section it is seen to be made up of silt detritus in abundant ferruginous matrix. The silt consists of moderately sorted angular chips with an average grain-size of about 0.03 mm., and well oriented with long axes roughly parallel to the bedding plane. Quartz (35%) commonly has composite quartzitic textures, also very fine lithic intergrowths as above. Feldspar is rare, and only microcline has been identified. Illite (5%) occurs as long thin flakes of micas which have been hydrated to varying degrees. Their dimensions are suggestive of quiet settling conditions during deposition. The matrix (60%) is composed of hydrated iron oxide, ranging from translucent deep red to opaque dark brown; it has transgressed into many of the illite grains. The absence of biotite may be due to this ferruginisation.

Name : Micaceous ferruginous siltstone.

Discussion:

The wide range of finely sutured quartz and crushed quartz rocks in this unit probably has its source in the metamorphic complex forming basement to the Gilbert River Formation to the north-west of this area. The minor quartz-porphyry type and (?)rhyolitic grains may also have been derived from that area. The mylonitized material is, because of its tendency to crush out between quartz grains, obviously very weak, and probably could not have survived more than very brief transport; hence a nearby source such as this, with distances ranging from about 20 to 70 miles, is virtually essential. The only problems associated with this source are its abundance of micas - notably muscovite - and fairly abundant feldspars. It is likely that the former, with the exception of the large hydrated mica clumps as are seen here, which were probably less buoyant, would have been swept on by vigorous current action. Feldspars could have suffered much chemical change before actual erosion. The rare feldspar seen here is very altered, as is much of the feldspar in specimens collected from the metamorphics. Thus metamorphic alteration, plus weathering, could have largely reduced them to clay before transport began. On the other hand, the mylonitized quartz rocks, although weak under transport, were probably at least intact when actual transport began. The minor rock type probably represents brief pauses in deposition.

<u>Gilbert River Formation</u>

This unit includes several distinctive sandstone types. Vine et al. (1963) recognize five members in sections measured in the northern parts of the Richmond and Hughenden 1:250,000 Sheet areas.

<u>GAB 1037A</u>. Richmond 2/5103, pt. 57, on Cambridge Creek 19 miles east of Stawelton Homestead; measured section X3, at 9'.

The rock is a light brown pebbly coarse sandstone, which is very friable and porous, and has no apparent bedding.

The thin section shows it is made up of a low-maturity, very poorly sorted, sand with an average grain-size of about 1.5 mm.; the coarsest grains measure over 4 mm. Detrital grains are mainly angular to subangular, with a few subrounded, and were probably derived from the nearby metamorphic complex. Quartz (40%) consists mainly of composite grains showing a wide range of fine to coarse, strongly sutured, quartzitic textures. Microcline (15%) is fresh and angular; a few untwinned feldspar grains may be orthoclase. A red-brown phyllosilicate (10%) common in soils or weathered rocks coats many grains, and is probably derived from alteration of an argillaceous matrix. Cavities in the slide (35%), are probably mainly due to grinding.

Name : coarse feldspathic sandstone.

GAB 1037B. Measured section X3, at 92'. Other locality details as for GAB 1037A.

The rock is a cream sandy claystone. It is friable and crumbly with a rough fracture and no apparent bedding.

The thin section shows a very poorly sorted sand in abundant silty clay. Grain sizes range from about 1.5 mm. down to clay size, but there is a coarse mode at about 1.5 mm., grains of about this size occupying about 20% of the rock. The sand grains are angular to subangular. Quartz is the major detrital mineral, and is represented mainly by composite grains as in the previous specimen, commonly with undulose extinction. Muscovite is minor, and flakes are small and partly altered to illite. The argillaceous fraction is a very silty illitic clay with scattered pockets of yellowish silky material filling voids. This material is known by some pedologists as a "clay mineral cutan", and indicates that soil-forming processes have been active.

Name : Sandy claystone.

GAB 1037D. Measured section X3, at 237'. Other details as for GAB 1037A.

The rock is a light to medium brown fine-grained sandstone, grading to hard chocolate claystone on one surface. It is fairly friable and rather porous, and contains many white grains like kaolinized feldspars which give it a speckled appearance.

Thin section examination shows it to be made up of a fine-grained quartz and lithic sand which is moderately well sorted, with an average grain size of 0.2 - 0.25 mm. Originally subangular to subrounded, the grains are largely affected by later authigenic quartz development. Quartz (50%) occurs mainly as composite grains with sutured quartzitic textures, commonly with undulose extinction, and numerous acicular and fluid inclusions; extensive authigenic outgrowth has resulted in partial interlocking of grains. Lithic fragments (30%) are very fine to microcrystalline mylonitized quartzose rocks, individual elements range from silt to clay size and mostly are too small to be identified; some illite is present. These are the white grains of the hand specimen. Tourmaline and (?)staurolite are rare accessories. The matrix (20%) is made up of lithic grains which have been squashed and injected into pore spaces; much of it has suffered ferruginisation.

Name : fine-grained lithic sandstone.

GAB 1037G. Measured section X3, at 368'. Other details as for GAB 1037A.

The rock is a laminated cream to orange and light brown medium to coarse-grained sandstone, with fairly common white powdery grains in some laminae. It is friable and fairly porous.

Thin section examination shows it is made up of a bimodal quartz sandstone, with a coarse mode averaging about 1 mm., and a fine mode, itself fairly well sorted, averaging about 0.2 mm.. Detrital grains have a vague dimensional orientation towards the bedding plane, and were originally subangular to rounded, before later authigenic quartz overgrowths occurred. Quartz (85%) is, as before, mainly composite quartzitic grains with strong suturing, and there are heavy authigenic overgrowths, which have welded many grains together; one grain of chalcedony from a vein-filling is present. Other detrital grains (3%) include rare muscovite, and some mylonitized quartzose rocks as in other specimens. The matrix (12%) is essentially finely broken down detritus from the above material, and ferruginisation has occurred in the matrix, particularly adjacent to detrital grains.

Name : Medium- to coarse-grained quartz sandstone.

GAB 861. Richmond 2/5098, pt. 333, 9 miles north-east of Stawelton Homestead; measured section X2, at 170'.

The rock is a cream very micaceous coarse siltstone, ranging to very fine sandstone in some laminae. It is firm and thin-bedded, with undulating cross-laminae resembling large ripple marks, and a low porosity. There are some pale brown ferruginisation streaks in some laminae.

Thin section examination shows it is made up of a very well sorted quartz silt, with grain-size averaging about 0.04 mm., and a minor size mode in the fine sand range. Most grains are welded together by quartz overgrowths. Quartz (90%) grains are mostly simple individual crystals, but there are some composite grains with quartzitic texture and minor cherty and chalcedonic textures; grains show fairly pronounced dimensional orientation towards the bedding plane. Overgrowths show strong pressure solution, and few original grain outlines are visible. Microcline is a very minor constituent. Muscovite (5%) occurs as long thin flakes bent by compaction of the sediment; some are partly altered to illite. Biotite (2%) is much less common. Accessories are particularly common along some bedding planes, and include tourmaline, zircon, sphene, and rare (?)sillimanite; most grains show some rounding. Hydrated iron oxide occurs as translucent to opaque brown micro-granular coatings on detrital grains, and also in pore spaces along some laminae.

Name : micaceous quartz siltstone.

GAB 1037H. Measured section X3, at 480'. Other details as for GAB 1037A.

The rock is a pale buff fine-grained sandstone. It is very friable and porous, with vague bedding and a slight tendency to part along bedding planes.

Thin section examination shows it is made up of a moderately well sorted lithic and quartz sand with average grain-size of about 0.2 mm.. Grains are mainly angular to subangular, and a few subrounded, and show a vague dimensional orientation towards the bedding plane. Quartz (40%) occurs mainly as composite quartzitic grains, some with authigenic overgrowths. Feldspar (2%) includes fairly fresh orthoclase and microcline. Muscovite is very minor. Lithic fragments (45%) are very fine to microcrystalline mylonitized quartzose rocks, and some show, within the one grain, textures transitional between the fairly coarsely sutured quartzitic grains and finely broken down material. A few grains appear to have the texture of andesite, containing what appear to be oriented small laths. There are rare zircons. The matrix (10%) is mostly lithic grains which have been squashed into neighbouring pores, and these are difficult to distinguish from detrital clay, of which a small amount may be present.

Name : fine-grained lithic sandstone.

GAB 1037L. Measured section X3, at 503'. Other details as for GAB 1037A.

The rock is a cream to light brown, medium-grained sandstone. It is friable and fairly porous, and contains a scattered speckling of white powdery grains; no bedding is visible. The thin section examination shows a fairly well sorted medium- to coarse-grained sand with an average grain-size of about 0.4 mm.. Detrital grains were originally subangular to subrounded but the original porosity (about 15%) has been greatly reduced by quartz overgrowths. Quartz (80%) is represented mainly by composite quartzitic grains as before; overgrowths have developed good crystal faces and a few of the grains have been welded together. Microcline (1%) is fresh. Lithic grains (4%) are mylonitized quartzose rocks with minor illite and kaolinite, as in other specimens, and a few grains have been partly squeezed into neighbouring pores by compaction of the sediment. One grain of unaltered epidote was noted. The matrix (8%) includes a pale brown phyllosilicate, occurring as pockets of curved flakes partly filling pores (a "cutan" indicative of soil forming processes), and illite (3%), occurring as clumps of small flakes in some pores: this is probably of the same origin as the clumps of illite and kaolinite "books" seen in GAB 875. The remainder (7%) is pore space, possibly increased by grinding.

Name : medium-grained quartz sandstone.

Discussion:

Four stages of maturity can be distinguished in these sediments:

i) Very low maturity, poorly sorted, fairly feldspathic sand, derived from acidic crystalline source rocks in the immediate vicinity. e.g. GAB 1037A.

ii) Quartz sandstones containing a high percentage of crushed quartzose rocks derived from mylonitized acid metamorphics, as in the White Mountains sandstone. These occur in all members except Member 4.

iii) Sandstones with a low percentage of mylonitized material. This and the previous type are commonly closely interlaminated, so little difference in transport history can be inferred. Their deposition is characterised by strong currents as micas have been largely winnowed out. High matrix percentages are due to a later squashing of the mylonitized grains as the sediments compacted, and so the sands were probably fairly clean originally.

iv) Very fine micaceous sandstones and siltstones of high maturity. This type occurs only in Member 4 of the unit. Sorting is excellent, and the sediment was deposited with little matrix, as shown by its clean quartz cements. Winnowing of the clays was evidently active, but the abundant mica indicates weaker currents than in the previous types. Furthermore, the high maturity shows it had a much longer transport. e.g. GAB 861.

Quartz dominance in Gilbert River Formation is obviously not due to long transport, but to an abundance of quartz in the source rocks, which were probably acid metamorphics such as gneisses or quartzites. In the case of Member 1, material comes from very close by, and field work shows that the member filled strong relief on the Precambrian basement (Vine et al., 1963). The unit then covered this area of source rocks. For the remainder of the unit, the generally lower content of mylonitized material than is seen in the White Mountains sandstone suggests somewhat greater distances, but still the same type of source rocks are indicated. Appropriate rocks are represented in the Einasleigh Metamorphics of the Clarke River area (White, 1962), but they are not favoured because the Gilbert River Formation appears to have extended completely over their outcrop. Current directions measured in the unit suggest, furthermore, a source to the west or south-west. However, no rocks now exposed in that direction appear able to supply enough of the one type of sediment without also supplying large amounts of other material foreign to the unit. Carter, Brooks and Walker (1961) record too great a variety of rock types in the Precambrian belt of north-west Queensland to commend that area. The Saint Elmo Structure, (Vine and Jauncey, 1962), 120 miles west of the nearest outcrops of the Gilbert River Formation, offers the best possible source. Drillers' logs of water bores over the structure record "granite" basement almost exclusively, which is as close to the required rock-types as can be expected.

In the case of the mature sediments of Member 4, the ubiquity of its quartz, and the lack of any measurements of current directions preclude any firm suggestions as to source.

Doncaster Member

Specimens from the Doncaster Member include glauconitic silty claystones, calcilutites, and strongly brecciated calcilutites.

GAB 1017E. Richmond 7/5063, pt. 74, 2 miles north of Dutton River Homestead.

The rock is a light greenish grey glauconitic claystone, well bedded and fairly firm. The glauconite occurs in irregular patchy streaks, suggesting that discrete laminae of glauconitic sand and clay had been partly intermixed after deposition.

Thin section examination shows the rock is polymodal, being composed of very fine-grained glauconitic sand with coarse silt, set in abundant silty clay. The sand fraction (10%) is itself rather well sorted, with an average grain-size of about 0.09 mm., and grains are angular. The sand includes: quartz (5%), commonly composite types with suturing; plagioclase and other untwinned feldspars; andesite; and mylonitized quartz grains. Glauconite (20%) is khaki green to pale green and occasionally brownish green, and grains range around 0.15 - 0.2 mm. in size; most grains are of lobate form with shallow radial cracks, a few showing shrinkage from the matrix. The clay fraction (70%) is a silty illitic clay, well oriented towards the bedding plane, but with illite flakes bent around the sandy streaks. Very fine silt is common, particularly tiny muscovite flakes, some of which are slightly converted to glauconite.

Name : sandy glauconitic claystone.

Four origins of glauconite can be distinguished in this specimen:

i) from muscovite; all stages of conversion are represented, from slight alteration along mica cleavages (fig. 2), to strongly expanded, concertinaed, and vermicular forms with swollen lobate ends;

ii) from biotite; much less common than (i);

iii) from fine volcanic grains such as andesites; volcanic textures are still clear in partly converted material;

iv) from organic remains such as foraminiferal tests (fig. 3); this origin appears to develop a darker brownish glauconite, representing about 15% of the glauconite here.

GAB 685B. Hughenden 8/5149, pt. 29, 4 miles south of Strath Stewart Homestead.

The rock is an olive grey to brownish silty claystone. It is patchy in colour with pellets of darker grey claystone flattened parallel to the bedding plane, and has an obliquely sloped burrow. It is fairly firm but powders up when broken.

Thin section examination shows the rock is made dominantly of an organic-rich clay, carrying about 45% of glauconitic silt. Silt grains are angular; fairly well sorted, with an average grain-size of about 0.02 mm., and well oriented, with long axes parallel to the bedding plane. The silt (30%) includes quartz, chert, microcline, plagioclase and other untwinned feldspars, muscovite, lesser biotite, and some uncommon andesite. The plagioclase is unaltered. Glauconite (15%) ranges from pale green to deep green, olive green and brownish green, the darkest types lying in patches rich in organic matter. Grains average about 0.07 mm. in size, but a few deep green grains are much larger than the rest, and possibly reflect a different origin. The clay (55%) is colourless to brownish grey and brown, depending upon its organic content, and is illitic, with well oriented illite flakes parallel to the bedding. It contains abundant very fine silt, and some organic-rich parts have clots with dark outer skin-like bands, suggestive of faecal pellets.

Name : silty glauconitic claystone.

GAB 827. Richmond 1/5049, pt. 317, 2 miles north-east of Pialah Homestead.

The rock is a slightly pinkish brown tough limestone, with no visible bedding, a smooth conchoidal fracture, and manganese oxide in dendritic patterns.

Thin section examination shows the bulk of the rock is coarsely crystalline calcite with complexly interlocking grain borders, the grains ranging in size from 0.08 mm. to 0.4 mm.. It has a very dirty brownish appearance and is probably a recrystallized clayey calcilutite. Manganese oxide dendrites occupy about 10% of the rock, and detrital silt less than 1%; the silt grains are transparent, but were not identified.

Name : calcilutite (or "micrite" under classification of Folk (1959)).

GAB 1017C. Richmond 7/5063, pt. 74, 2 miles north of Dutton River Homestead.

Macroscopically the rock is a brecciated calcilutite, consisting of angular fragments of olivey brown calcilutite of various sizes, ramified by veinlets of light grey calcilutite. The fragments are in part granular, elsewhere aphanitic. The rock is tough with a very irregular fracture.

Thin section examination shows the fragments are composed of a pale brown to brown well oriented illitic clay, slightly silty, which has been mostly replaced by layers or rosettes of calcite crystals; a few flakes of partly hydrated muscovite are also present. Crystallization of the calcite has advanced like drusey growths into the clay from the calcilutite veinlets, and the calcite crystals have very irregular edges (fig. 4). Most of the veinlets are composed of very light grey, slightly silty calcilutite which is finely recrystallized, and these have in turn been cut by a later generation of veinlets filled by dense grey calcilutite. There are also several grains of pale yellow-green glauconite and numerous brown clay patches with darker rims, which may be concentrations of insoluble residues following upon carbonate replacement of the clay. It is apparent that the clay offered very weak resistance to the calcite, as if it were a cavity.

Name : calcilutite breccia (or dismicrite under the classification of Folk).

Discussion:

Glauconite ranges from 5% to 35% in the thin sections, and is mostly of the pale yellowish green type derived from muscovite, but deeper green types are present in some specimens. The origin ascribed here has been recorded by Wermund (1961) and Hodgson (1962) and is probably more common than generally supposed. Glauconite is considered to form in marine waters of normal salinity, at shallow depths, most favourably less than 400 fathoms, and under slightly reducing conditions (Cloud, 1955). Such conditions are compatible with the concept of a sudden marine incursion into the Eromanga Basin, resulting in the spread of a broad but shallow sea with poor outlets onto open ocean waters.

The sand or silt components of these sediments are made up dominantly of quartz, with little or no rounding. The quartz is of types similar to those in the Gilbert River Formation and probably likewise derived from acid metamorphics. However plagioclase is common, and andesite fragments appear in some specimens. The plagioclase is much fresher than many of the feldspars from the metamorphic complex which supplied Gilbert River and White Mountains sediments, and present mapping suggests (Vine et al., 1963) that this source had by Doncaster time been covered by sediment over each of its several elevated areas, with the possible exception of the southerly source area postulated for Member 5 of the Gilbert River Formation. Thus much of the detritus evidently came from new sources, probably the same as those which supplied abundant volcanic detritus to succeeding units.

The calcilutites and calcilutite breccias show in their fragments no evidence of transport, such as rounding or size sorting, and probably were precipitated in place with contemporaneous brecciation more or less on the spot, possibly due to wave or current action upon very soft lime muds. Some specimens reveal that peripheral cracking of fragments occurred at various stages of lime accretion, showing that they were simply disturbed and turned about, and in other cases, as in the described specimen, the pieces fit together.

The probable shallowness of the sea favours such precipitation for the following reasons. Inability of water to circulate fully means that greater changes in chemical conditions are possible than in open waters. The reducing conditions indicated by the glauconite, and high organic content of sediment suggest that normally the water was acidic and capable of carrying much lime in solution. Slight shallowing, particularly over banks, accompanied by warming of the waters and consequent loss of CO_2, would thus lead to super-saturation with lime and eventually to a sudden precipitation of lime mud to restore equilibrium.

Alternatively the breccias could be algal: very similar rocks from the Old Red Sandstone have been described by Allen (1962) as algal biolithites. On the other hand similar limestone from the Ogallala Formation in Kansas, long referred to as of algal origin, was recently shown (Swineford, Leonard and Frye, 1958) to be merely a caliche. Furthermore, algae are present in the Doncaster Member (GAB 890) and have a very distinct internal structure; cracks are common but fracturing has not been accompanied by turning of fragments or injection of lime mud into the material. Hence these limestones are not thought to be organic precipitates.

<u>Jones Valley Member</u>

Only one specimen was available for thin section examination. This was collected from thick-bedded calcareous siltstone just below one of several thin limestone beds which are developed in the type area of this member.

<u>GAB 686</u>. Richmond 10/5141, pt. 13, near Back Valley Creek about 2 miles north-east of Alderley Homestead.

The rock is a light to mid brown calcareous siltstone, slightly micaceous. It is tough with a conchoidal fracture, slightly porous, and bedding planes are marked by bands of manganese oxide.

Thin section examination shows it is composed of silt detrital grains in calcite cement. The silt (55%) is very well sorted, with an average grain size of about 0.03 mm. Grains are angular and loosely packed, with a fairly distinct dimensional orientation towards the bedding plane. Detrital minerals include: quartz (20%), plagioclase (about 4% recognisable by twinning), muscovite (2%) in small squat flakes; glauconite (3%), occurring as rounded grains about 0.04 mm. in size, pale yellow green to brownish due to weathering; and a variety of lithic fragments (10%), including chert, unidentified cloudy grains, and grains with volcanic textures. The remainder are unidentified clear detrital grains, amongst which other feldspars may be present. The cement (45%) is crystalline calcite with a brown dirty appearance, made up of coarse crystals generally around 0.5 mm. in size, with vague irregular boundaries and undulose extinction. It is probably a recrystallized clayey lime mud matrix.

Name : calcareous siltstone.

Discussion:

This rock introduces no new features as to genesis other than those detailed for the Doncaster Member. Field work suggests for the member as a whole, a marked increase in clastics, probably due to increased erosion from the source areas. It also has a series of thin beds of silty limestone developed above repeated intervals of siltstone and calcareous siltstone. The shallow and reducing conditions as postulated for the previous unit are compatible with this, for increased clastic sedimentation could have led to filling of the sea temporarily exceeding the rate of sinking of the basin, until a very shallow depth was attained when lime precipitation reached a peak. Slight pauses in sedimentation then could have led to increased depth and the cessation of lime precipitation to begin further cycles.

No specimens were available from the Ranmoor Member.

Toolebuc Member

Only one thin section was available from this member, but as it is very consistent in lithology throughout its known distribution it is likely that the features observed here are typical.

GAB 946. Richmond 9/5117, pt. 731, on the Richmond-Woolgar Road 2 miles west of Silver Hills Homestead.

The rock is a very pale pinkish limestone, tough and impermeable with a smooth conchoidal fracture and lacking visible bedding. A few fragments of Inoceramus are present.

Thin section examination shows the rock is composed of calcilutite pellets in a fine calcite cement. The pellets are moderately sorted, averaging about 0.1 mm. in size, and are generally somewhat ovoid, with a distinct dimensional orientation, presumably arranged with long axes parallel to the bedding plane. They have rather vague boundaries and are microcrystalline but structureless, with component grains around 0.003 mm. in size. Besides those there are numerous spherical bodies. The larger ones are probably solution pockets, and are filled with sparry calcite up to 0.05 mm. or more in grain size. Smaller ones are Globigerina tests (fig. 5). There are scattered bone fragments, occasionally with central cavities filled with chalcedony. The cement ranges around 0.01 mm. in grain size and appears too fine to be sparry cement; it is probably a recrystallized lime mud matrix. It contains some fine opaque matter, and very rare fine silt.

Name : pelmicrite (Folk classification).

Discussion:

This specimen came from a limestone concretion typical of those which characterise the Toolebuc Member in its outcrops. The only change in texture which this secondary development is thought to have created is the completion of filling of pores by calcite cement. The excellent preservation of the Globigerina tests shows that the primary framework was not affected. Similar concretionary bodies exist in the Mackunda Beds.

The texture seen here is what one might expect if a calcareous sand deposit, such as described by Illing (1954) and Newell, Purdy and Imbrie (1960) from the Bahama Banks, were lithified. Illing noted that much of the Bahaman sand does not have an oolitic structure, the most common type being grains formed of cryptocrystalline aragonite. It is suggested that the Toolebuc Member developed in very shallow, warm waters by precipitation of carbonate, but that the precipitation was not heavy enough to spoil living conditions for marine animals. Newell, Purdy and Imbrie consider that the essential cause of Bahaman precipitation is the tidal onrush of cool oceanic water saturated with $CaCO_3$ onto the Banks, which on warming up and consequent loss of CO_2 causes supersaturation, and eventually precipitation of carbonate. Since the variations of internal structure of the sand across the Banks are related to the regional pattern of islands and banks, it is possible that similar variations might appear in a regional study of this unit, which could lead to conclusions as to the location and size of possible outlets to oceanic waters. At this stage it can only be suggested that the origin of Toolebuc Member is probably related to a shallow depth of basin at a time of poor terrigenous sediment supply and restricted access of oceanic waters.

Allaru Member

Specimens from this member are all calcareous coarse siltstones, with calcite cement ranging from 20% to 55%. Lithic fragments are important constituents, and range from about one fifth to nearly half of the detrital grains.

GAB 895. Manuka 3/5103, pt. 374, at Warianna Creek crossing, Hughenden-Winton road, 1 mile south-west of Warianna Siding.

The rock is a light grey calcareous coarse siltstone with a vague bedding lamination. It is non-fissile, firm, and has an irregular fracture.

Thin section examination shows it is made up of well sorted silt in calcite cement. The silt (45%) averages about 0.03 to 0.04 mm. in grain-size, and grains are mainly angular or less commonly subangular, and fairly well oriented with long axes parallel to the bedding plane. Quartz (6%) is of a normal type, and there is plentiful chert (5%). Plagioclase grains (8%) are mostly unweathered but some are sericitized, and they commonly show peripheral replacement by calcite. Other feldspars (12%) are mostly fresh, but some show minor kaolinization. Other minerals include: muscovite (4%) and biotite (minor); glauconite (celadonite?) (5%), mostly brownish to green and of the same size range as other detritus; and minor sericitic cherty or volcanic grains. The cement is calcite recrystallized to about 0.15 mm., occurring as curved crystals with irregular boundaries. Much of it is derived from replacement of detrital grains around edges and cleavages.

Name : calcareous feldspathic siltstone.

Discussion:

Probably only a small amount of the glauconite was derived from alteration of minerals in transport. Some partly converted micas are seen as in the Doncaster Member, but the majority of grains have a coarser flaky texture than is usual in marine glauconite, while some have radial textures or double-layered groupings of fibres suggestive of a drusey habit of growth. It is thought that most of it is detrital celadonite, a type of [illegible] occurring in volcanics and other igneous rocks, as [illegible] product. Other discussion on this member is dealt with in the next section.

Mackunda Beds

Specimens from the Mackunda Beds include calcareous fine and very fine-grained sandstones, calcareous siltstones and silty calcilutites. An example of each is described below.

GAB 806. Manuka 10/5135, pt. 303, ½ mile north of Montone Homestead.

The rock is a light to mid brown fine-grained sandstone, with a strong but rather disturbed lamination. It is calcareous and tough with a low porosity. There is a fossil band with numerous single pelecypod valves and some gastropods, the valves facing mostly concave upwards. In this band also are many thin and slightly rounded pellets of light brown calcilutite.

Thin section examination shows it is made up of a moderately well sorted lithic and feldspathic sand, with average grain size about 0.14 mm., in a ferruginized calcite cement. Grains are angular to subangular, except for rounded glauconites. Detrital grains make up about 65% of the rock; cement 30%; fossils and pellets 5%. Quartz (12%) occurs mainly as angular chips, occasionally showing deep indentations; with lesser numbers of composite quartzitic grains, some showing strain or bubble inclusions; a few grains with graphic texture are present. Plagioclase (25%) occurs as angular to subangular prisms, mostly broken laths, and few show any alteration. Many grains are deeply indented due to their originating from an igneous source. Many are zoned, commonly with strong oscillatory zoning, and the composition ranges up to about An60. Other feldspars are minor (4%) and include some microcline. Andesine (6%) has a wide variety of textures, some with coarse phenocrysts in fine crystalline matrices, others with devitrified glass matrices, transitional towards pure glasses; there is much partial replacement by calcite. Devitrified glass (8%) is mostly cherty and rather sericitic, commonly with flow texture and containing small feldspar laths, or crystals of quartz with reaction rims. Glauconite (3%) is about the same size as other detritus, and is pale brownish yellow to yellow-green, well rounded and commonly ovoid, with shallow radial cracks and slight shrinkage. About half has the fine mesh texture of marine glauconite, but the rest shows various degrees of textural organisation, including many with rather shard-like patterns. Types with internal patterns of some sort are referred to celadonite. Hornblende (2%) is exceptionally common, and occurs as angular prisms of the normal green to brown pleochroic type, considerably replaced by calcite (fig. 6). Muscovite and epidote are rare, and there are some grains of calcite (3%) which may be echinoid fragments. The calcilutite granules are made up of a recrystallized clayey and slightly silty calcilutite, the crystals displaying a rosette habit of growth similar to that seen in GAB 1017D. The cement (30%) is brown calcite crystals, commonly strongly curved, formed from recrystallization of a matrix accompanied by strong replacement of detritus. The calcite has been partly replaced during weathering by hydrated iron oxide along cleavages to produce a peculiar radial spoked pattern (fig. 6).

Name : fine-grained calcareous feldspathic sandstone.

<u>GAB 914</u>. Manuka 5/5185, pt. 622, ½ mile south-west of Windsor Park Homestead.

The rock is a slightly brownish grey calcareous coarse siltstone. It is homogeneous with no apparent bedding, very tough with a conchoidal fracture but a weak tendency to cleave in one direction.

Thin section examination shows it is made up of coarse silt in abundant calcite cement. The detrital grains (45%) are well sorted, with an average grain-size of 0.04 mm., and are angular chips or laths with a fair dimensional orientation towards the bedding plane. Quartz (8%) occurs as angular chips, and grains are simple types. Plagioclase (15%) is mostly fresh but partly replaced by calcite on edges and cleavages; composition in the andesine range. Other feldspars (10%) have not been distinguished optically. Volcanic grains (8%) include andesite and chertified glasses, and are heavily replaced by calcite. Glauconite (4%) is mainly light yellowish-brown, rarely greenish, but the usual rounded form is seen and some grains have shallow radial cracks. Accessories are very common, and include tourmaline, epidote and hornblende, which shows deep intrastratal solution effects. Cement (55%) is made up of coarse curved crystals around 0.5 - 1 mm. in size. Deeply corroded detritals suggest that the bulk of it formed by replacement of them, but there may also have been some calcareous mud in the original pores.

Name : calcareous feldspathic siltstone.

<u>GAB 675C</u>. Manuka 3/5129, pt. 9-10, on Alick Creek 4 miles east of Coleraine Homestead.

The rock is a light khaki-brown to brown silty limestone. It has thin undulating laminae with a small-scale irregular cross-lamination. It is firm with a low porosity, and manganese oxide dendrites are common.

Thin section examination shows it is made up of coarse and fine silt detrital grains in low and widely variable amounts, set within abundant clayey calcilutite. The grains range in size from about 0.05 mm. to 0.01 mm. in different laminae, but are well sorted within any band. They are angular, and chips are common. The calcilutite ranges from about 40% to 90% of the rock, averaging about 65%. Detrital minerals (30%) include: quartz (6%), plagioclase (10%), other unidentified feldspars (8%), muscovite (1%), glauconite (celadonite?) (2%), chertified volcanics (3%), and andesite (rare). Manganese oxide sprays and iron oxides occupy about 5%. The calcilutite is very clayey and pale brown and dirty in appearance, with many slightly darker brown mottles throughout. It is slightly recrystallized in parts, to form a microcrystalline texture with general grain-size about 0.003 mm. Clay forms a matrix amongst these tiny crystals, and the darker mottles are patches richer in calcite crystals. They probably indicate that a slight clotting action took place during precipitation of a lime mud matrix.

Name : silty calcilutite (or silty micrite under the classification of Folk).

Discussion:

The general features which characterise both the Allaru Member and Mackunda Beds lithologies are the abundance of lithic material, almost entirely of volcanic origin, and plagioclase derived from breakdown of this material. The provenance is obviously volcanic, chiefly with an andesitic source. Accessories are much more common than in lower units, the most significant increase being the marked rise of hornblende in a number of specimens. Glauconite shows a gradual change in its internal structure upwards through the sequence, which culminates in a complete change from the normal fine mesh texture in the succeeding unit. Discussion on the full significance of these trends will be dealt with in the next section.

Field work has shown that some extensive calcareous beds in this sequence terminate abruptly, with rounded faces like the surfaces of concretions, against poorly calcareous sandstone or siltstone beds, with which they are laterally continuous. This suggests that the calcareous cements of these rocks originated partly or largely from replacement of non-calcareous matrices, in which case the initial composition of the sediments might feasibly have been that of greywackes or sub-greywackes. However there is in most specimens evidence for considerable replacement of detrital grains by calcite, suggesting that the original matrix proportions would have at least been much less than are now seen, and a primary porosity might reduce such a figure still further. The author believes that these sandstones were in fact deposited with relatively little clay matrix.

It is suggested that calcium carbonate was precipitated with the sediments, in some instances so abundantly as to produce initially a limestone, as in the case of GAB 675C, but generally in smaller proportions. This material then partly redissolved under rising pressures, and migrated within the unconsolidated sediments for short distances, to be deposited in some beds in preference to others. Precipitation may have occurred preferentially in those beds already fairly rich in lime, because of the abundant nuclei available, or perhaps in the more porous sand bodies, because of their lower pore pressures and the resulting drop in CO_2 solubility that would occur in fluids entering them. Thus the abrupt form of the very calcareous sandstone and siltstone beds is thought to be due to an early diagenetic process of redistribution of calcium carbonate. Concretions in the Toolebuc Member of the Wilgunya Formation may also have been developed at an early stage in the compaction and diagenesis of that unit.

Winton Formation

Specimens from this formation are lithic, feldspathic sandstones and calcareous coarse siltstones.

GAB 847. Manuka 11/5103, pt. 317, on Io Creek 3 miles east of Manuka Homestead.

The rock is a light brown, fine to medium-grained sandstone. It is friable and porous, with no bedding traces, but has a poor bedding-plane cleavage. There are many prominent white grains.

Thin section examination shows it is made up of a lithic and feldspathic sand. It is fairly well sorted, with an average grain-size of about 0.15 mm., reaching a maximum of 0.4 mm. Grains are mostly subangular to subrounded, but some are rounded, and they are fairly well oriented with long axes parallel to the bedding plane. There is almost no matrix, but there are thin coatings of hydrated iron oxide around grains. Mineral grains occupy 15%, lithic grains 65%, pores 20%. Mineral grains include: quartz (2%), a few with myrmekitic texture; plagioclase (10%), in the andesine range, some grains zoned, and also a peculiar type carrying many fluid inclusions with bubbles, all distributed and elongated in lines down the 010 twin planes; a few untwinned feldspars, heavily kaolinized (these are the white grains seen in the hand-specimen); muscovite, biotite (1%). Andesite (40%) has a wide variety of textures and compositions, generally showing good flow orientation of feldspars (fig. 7); the composition ranges from dark iron-rich types to plagioclase-rich types. Many grains show irregular patches of celadonite amongst feldspar laths. Celadonite (12%) ranges from pale bluish green to yellow-green and brownish, and grains are mostly of rounded bulbous form, occasionally with shallow radial cracks due to swelling. Nearly all grains have internal patterns of fibres, such as layered banding and shard-like textures. Very few have the fine patternless mesh texture typical of glauconite, so at least the great majority can be referred to celadonite as in other cases; but even those lacking a patterned texture may be, and probably are, celadonite. Chert (8%) is commonly sericitic to varying degrees, with vague relics of altered volcanic textures and probably was derived from tuffs and volcanic glasses. Some grains are still partly vitric. Claystone grains (3%) appear as brown, well oriented clay aggregates, and there are also other dark ferruginized grains, not identified. There are a few hornblendes and rare garnet.

Name : fine-grained lithic sandstone.

GAB 902. Manuka 15/5155, pt. 606, 4 miles south-west of Cooinda Homestead.

The rock is a medium grey calcareous coarse siltstone, weathered to light brown on one surface. It is non-fissile, very even in texture, with no bedding traces, and is firm with a smooth rather conchoidal fracture.

Thin section examination shows it is made up of a sandy silt in abundant calcite cement. It is moderately well sorted, with an average grain size of about 0.06 mm. Grains are angular to subangular (minor), and well oriented towards the bedding plane. General percentages are: mineral grains 30%, lithic fragments 20%, and cement 50%. Quartz (5%) is mainly simple grains but a few show composite textures. Plagioclase (15%) is generally fresh, but there is heavy replacement by calcite. Other feldspars (6%) mostly show no twinning, but a few grains of microcline can be recognised. Biotite (1%) occurs in small flakes not bent by packing. Hornblende is particularly abundant (3%) and is a normal type, occurring as euhedra, but heavily replaced by calcite down cleavages. Andesite (10%) occurs in a wide range of types as before, and is heavily replaced by calcite. Celadonite (7%) occurs as rounded grains with common shallow radial cracks, and rather ferruginized to a light brown colour. Chert (3%) is minor, and sericitic types uncommon. There are also rare muscovite, apatite, and sphene. The cement (50%) is an anhedral mesh of small calcite grains, with average grain-size about 0.15 mm., largely derived from replacement of detrital minerals; many relic grain outlines are still discernible.

Name : very fine-grained calcareous lithic-feldspathic sandstone.

Discussion:

The same volcanics and plagioclase are seen in the Winton Formation as in the Mackunda Beds. This assemblage indicates a source area composed almost exclusively of volcanics, with little or no material from other rock provinces represented. The nearest possible source for this material is the Bowen Basin, and the resemblance is very close to the lithology of a wide area of rocks in that basin.

Three units could have supplied the material. The nearest, the Theresa Creek Volcanics, is described by Veevers, Randal and Mollan (1961) as containing flows which are mainly andesite, and about half is pyroclastics which are mainly andesitic in composition. No rocks stratigraphically overlie the Theresa Creek Volcanics. They are about 250 miles distant from the nearest Winton outcrops, but their present outcrop area is small and nothing is known of their possible extent, so this source is not favoured. The Lower Bowen Volcanics and the Urannah Complex offer the most likely source. Malone, Corbett and Jensen (1961) noted that flows, mainly andesite, make up about one third of the Lower Bowen Volcanics, and pyroclastics, mainly andesitic, comprise about half the unit. In the Bowen South area, Malone, Jensen, Gregory and Forbes (1962) identified diorite, hornblende diorite, hornblendite, microdiorite and andesite as important constituents of the Urannah Complex below the Lower Bowen Volcanics. Thus appropriate sources for the abundant hornblende are also represented. The Lower Bowen Volcanics has a thickness estimated at roughly between 10,000 and 20,000 feet, and with the Urannah Complex suffered severe tectonism which would have exposed these rocks to heavy erosion. The nearest outcrops today are about 300 miles away from the Winton outcrops, a short distance indeed for material to be carried from a high mountain range and still be fairly fresh on arrival. More distant from this area, the Bulgonunna Volcanics east of the Anakie Inlier also present a feasible source, but distance and the presence of intervening rocks not represented in the Mackunda and Winton sediments makes them unlikely as a source.

The difficulty found in recognition of glauconite in the Allaru Member, Mackunda Beds and Winton Formation has already been mentioned. A wide range of colours and internal textures was found, ranging from the usual micro-crystalline texture, to sheaves of fibres with a shard-like appearance, to obvious cavity fillings, such as concentric, curved bands of fibres and double layered groups. Although Wermund (1961) has recognized vermicular and mono-crystalline textures in marine glauconite, these other types of organization have not been recorded. On the other hand, celadonite, which is considered to be mineralogically identical with glauconite (Lazarenko 1956), has been described from a wide variety of sources, including basalts, veins and nests in metamorphic rocks, and also from zones of intense hydrothermal alteration in nepheline syenites (Semenov, 1959). However, with the wide range of textures seen here, it was not possible to put a clear division between grains which could have had such origins and which a marine origin. Perhaps many grains began as celadonite, and continued to swell under water, to produce intermediate textures and lobate forms. In any case, no conclusion can be made for a marine environment for the higher units studied based on the presence of this abnormal type of glauconite, especially in the case of the Winton Formation, for which other evidence points to terrestrial deposition.

Glendower Formation

Specimens from this unit are very poorly sorted sandstones, showing evidence of silcrete development.

GAB 1026D. Hughenden 8/5159, pt. 51-52, from a measured section about 10 miles north-east of Worwombie Homestead.

The rock is a cream, silicified sandstone. It is poorly sorted, hard and impermeable, but has a few isolated cavities lined by white clays.

Thin section examination shows it to consist of a very poorly sorted quartz sand in abundant siliceous matrix. The quartz (40%) is angular to subangular, rarely subrounded. Coarse quartzitic textures are very common, many with undulose extinction, and the grain-size averages about 0.25 mm.. There are rare cherty grains, and also sphene. The cavities are lined by a pale yellow-brown phyllosilicate, a soil "cutan"; it has grown in layers parallel to the cavity walls. The matrix is a fine mesh of cryptocrystalline silica, with numerous shreds of the same cutan giving it an overall pale brownish tint.

Name : medium-grained quartz sandstone.

Discussion:

The poor sorting of Glendower sediment is due to the combined effect of short transport distances plus weak sorting power of streams. This contrasts with the better sorting of the White Mountains sands, which was attained by strong currents even though transport was very short, because the currents were strong enough to lift grains and winnow them. Glendower sand, on the other hand, was probably mostly moved by traction along stream bottoms, and consequently unable to be winnowed. High maturity of the sediment is mainly inherited, due to its derivation from preexisting sandstones such as the Gilbert River Formation and White Mountains sandstone.

CONCLUSION

This study has shown that a marked change in sediment sources took place after deposition of the Gilbert River Formation. That unit and the White Mountains sandstone had their sources in acid metamorphics with abundant mylonitized zones, mainly to the north and west of the present outcrops. Sediments of the Wilgunya Formation, then Mackunda Beds and Winton Formation, came from andesites and related volcanics of the Bowen Basin to east and south-east of the outcrops studied. During this period, glauconite in these units showed two types of internal structure. Initially, in the Doncaster Member, it was formed mainly from muscovite, but material present in higher units is probably mainly detrital celadonite derived from alteration products of the volcanics.

A consistent feature of the marine Cretaceous sequence, although varying in amount in different units, is the precipitation of calcium carbonate that accompanied sediment deposition. This is probably related to shallowness of the sea plus restricted outlets to actively circulating ocean waters. After deposition, calcite appears to have been concentrated in some beds during early diagenesis, to produce the numerous sharply defined thin calcareous sandy or silty beds which characterise the sequence in its outcrops.

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APPENDIX A

LIST OF SPECIMEN FIELD NUMBERS AND REGISTERED ROCK NUMBERS

Specimen Number		Registered Rock Number
GAB	875	13128
	1029	13129
	1037A	12794
	1037B	12796
	1037D	12798
	1037G	12801
	861	13130
	1037H	12802
	1037L	12805
	1017E	13120
	695B	13113
	827	12610
	1017C	13118
	686	12751
	946	13109
	895	13110
	806	13107
	914	13105
	675C	12793
	847	13124
	902	13103
	1026D	13099

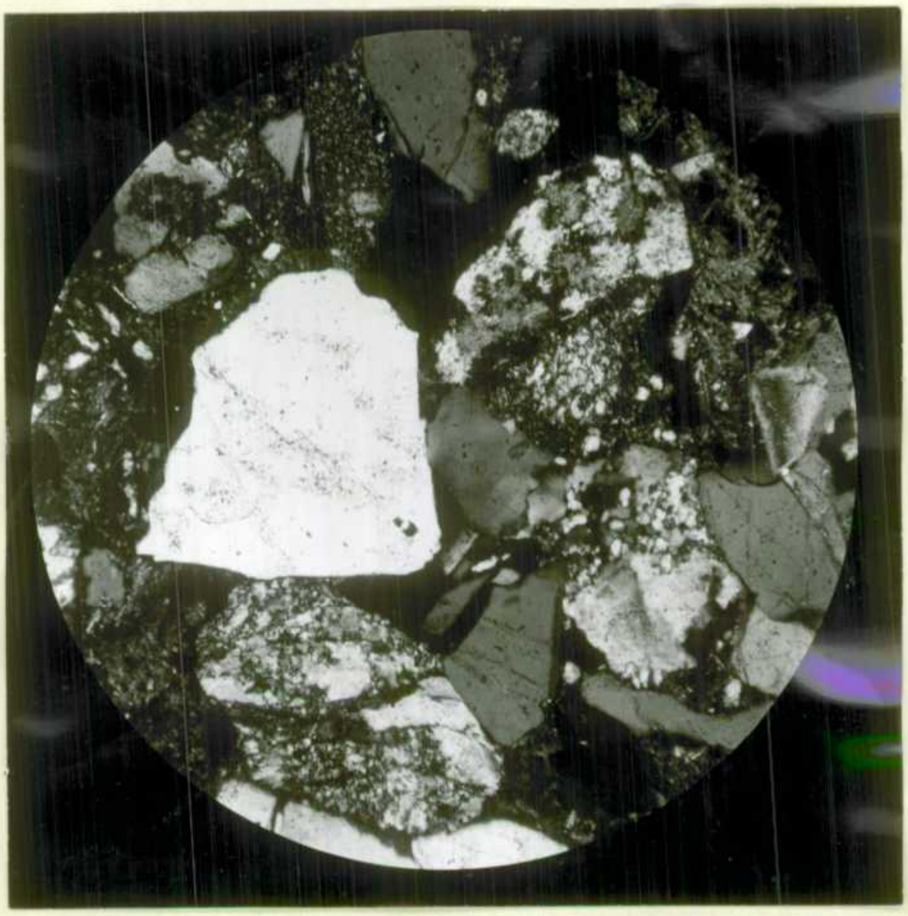

Fig. 1. GAB 875. Lithic quartz sandstone.

Rock fragments include one composed of interlocking quartz grains, with relics of a replaced spherulitic texture, derived from (?)rhyolite (upper right); and one composed of quartz, partly sheared into a fine granular texture, derived from mylonitized rocks (lower left). The large white grain is quartz.

Crossed nicols, X60.

Fig. 2. GAB 1017E. Grains of glauconite in silty clay, with a grain of muscovite expanded slightly by alteration to glauconite along its cleavages.
Ordinary light, X210.

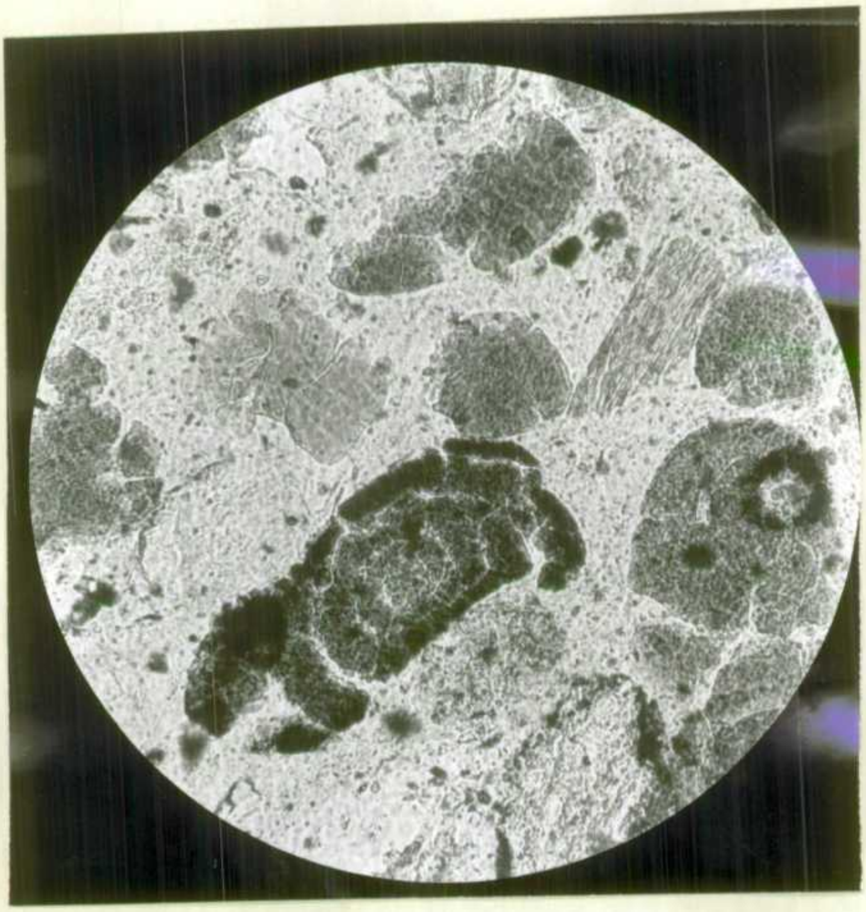

Fig. 3. GAB 1017E. Dark brownish green glauconite formed in chambers of a foram.
Ordinary light, X210.

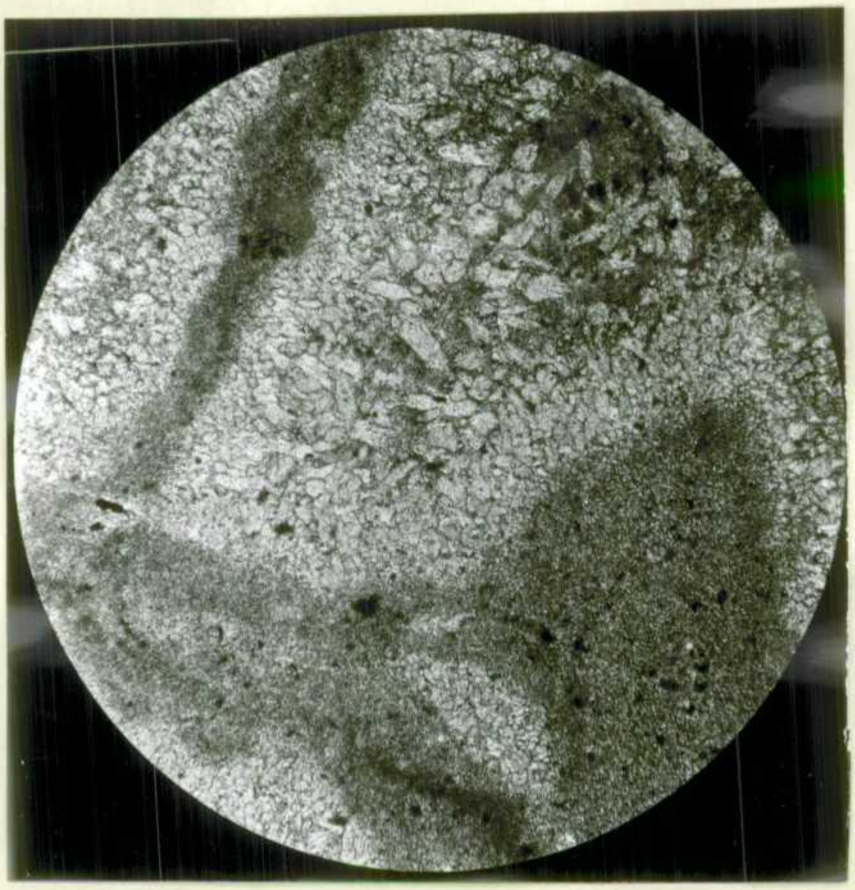

Fig. 4. GAB 1017C. Calcite replacing clay in brecciated limestone. Calcite crystals originate from veinlets of microcrystalline calcite; note radiating crystal growth in upper right.
Ordinary light, X60.

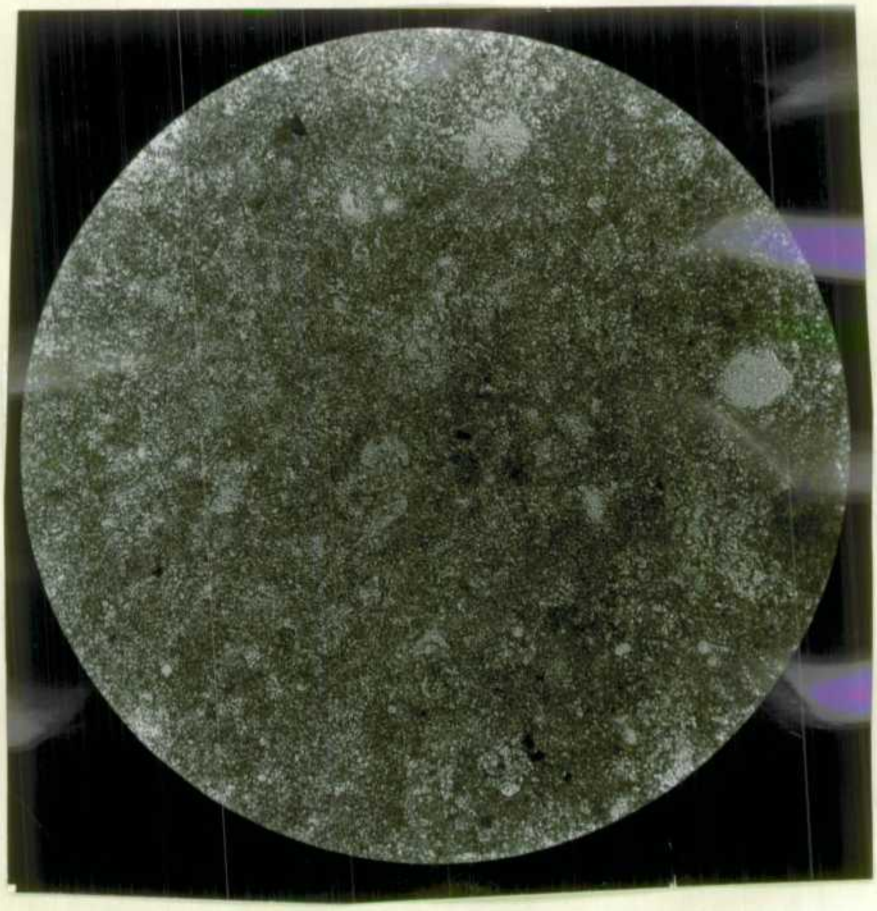

Fig. 5. GAB 946. Grains of microcrystalline calcite in a calcite cement of slightly coarser grain-size. Globigerina just left of centre; other clear patches are calcite-filled spherical cavities.
Ordinary light, X60

Fig. 6. GAB 806. Sandstone with partly ferruginised cement, showing spoke-like arrangement of hydrated iron oxide along cleavages of calcite. Grains include: hornblende, corroded down cleavages (upper right); deeply indented plagioclase lath (left of centre); celadonite with shallow peripheral cracks (right edge); calcite (right of centre). Crossed nicols, X90.

Fig. 7. GAB 847. Lithic-feldspathic sandstone, showing grain of andesite near centre, plagioclase near right edge. Crossed nicols, X140

TABLE 1. PERCENTAGE ESTIMATES

Formation	Spec.No.	Quartz	plagio-clase	other feldspars	mica	lithic grains	glauco-nite	matrix	cement	accessory minerals	others and unidentified	pores
Sandstones of White Mountains	875	50	rare		5) *	30		10				5
	1029	35		rare	5)			60				
Gilbert River Formation	1037A	40		15				10				35
	1037B	important constituent	(no estimates made)					major constituent				
	1037D	50				30		20				
	1037G	85				3		12				
	861	90			7					3		
	1037H	40		2		45		10				3
	1037L	80		1		4		8				7
Wilgunya Formation : Doncaster Member	1017E	5	(- - - 3 - - - -)			2	20	70				
	695B	(- - - - - - - - - - 30 - - - - - - - - - - -)					15	55				
	827		no estimates made									
	1017C		no estimates made									
Jones Valley Member	686	20			2	10	3		45		20	
Toolebuc Member	946		no estimates made									
Allaru Member	895	11	8	12	4		5 }		55		5	
Mackunda Beds	806	12	25	4		14	3 } ƒ		30	4	8 x	
	914	8	15	10		8	4 }		55			
	675C	6	10	8	1	3	2 }		65		5	
Winton Formation	847	2	10	1	1	65) ϕ			20	1		
	902	5	15	6	1	20)			50	3		
Glendower Formation	1026D	40						55				5

* includes illite. x includes 5% fossil fragments. ƒ includes some celadonite, identification uncertain. ϕ includes celadonite.