DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

Rept.Bk.No. 84/30

PETROGRAPHY OF THIRTEEN SPECIMENS FROM STRATIGRAPHIC DRILL HOLE LAKE MAURICE EAST

GEOLOGICAL SURVEY

by

M. FARRAND

REGIONAL GEOLOGY SECTION

APRIL 1984

D.M.E. No. 454/82

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DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SADME Pet. Rep. 3/84
1:100 000 Sheet 5138

Rept. Bk. No. 84/30
D.M.E. No. 454/82
Disk. No. 83

PETROGRAPHY OF THIRTEEN SPECIMENS FROM STRATIGRAPHIC DRILL HOLE LAKE MAURICE EAST

ABSTRACT

The stratigraphic drill hole has intersected high grade gneisses of the Precambrian basement below a sequence of unmetamorphosed, dominantly arenaceous and rudaceous sediments, known as the Murnaroo sandstone of probable Cambrian age. Evidence from the clasts in conglomerates of the latter succession suggests that the drill was sited on a basement high which had been stripped of at least two sequences, one volcanic and one of quartzofeldspathic sediments, before the deposition of the Murnaroo sandstones. These sequences outcropped in Murnaroo times close enough to the drill site to provide a source of detritus for sediments deposited at that point. Conglomerate clasts also indicate that much of the Murnaroo sedimentation was of colloidal silica at localities close enough to the drill site for partially lithified intraclasts to be incorporated in the conglomerates. A desert environment with intermittent drainage is suggested for the deposition of the Murnaroo sediments.

INTRODUCTION

Thirteen thin sections of nine samples of core from stratigraphic drill hole Lake Maurice East were received for petrographic examination from R.B. Major of the Mineral Resources Branch. The majority of the samples were from the earliest Cambrian formation in the area, the Murnaroo sandstone, and the four lowest samples from the Precambrian gneiss below an unconformable contact at 691.33 metres. It was requested that particular attention should be paid to the nature and origin of pebbles in conglomerates at 585.2 m and 583.46 m, iron staining in the intersection of Murnaroo sandstone between 590.2 and 687.7 m, the nature and possible mylonitic origin of basement gneisses and the diagenetic history of the sediments.

PETROGRAPHY

5138 RS 21, 738.9 m, TS C41542

Rock name: Sericitised pyroxene-garnet gneiss.

Hand specimen:

The rock is a banded gneiss in which the plane of foliation contains the long axis of the drill core. Black and white bands and planes rich in mica run along the length of the specimen of core. Large, pinkish brown porphyroblasts of garnet are distributed patchily, mainly along the foliation planes but overlapping these discordantly in places.

Thin section:

In brief, the rock consists of fractured and fragmented quartz, garnet, pyroxene, feldspar, biotite and opaque minerals in a fine, felted mass of sericite.

The quartz occurs in thin, long but discontinuous, slightly sinuous lenses in which individual crystals are up to 2 mm long. The lenses are concentrated into bands and surrounded by the mass of sericite. Individually they are irregular and corroded along the edges and are branched in places and broken almost everywhere.

Garnet occurs in broken masses without crystal outlines and several millimetres long which are mainly concentrated in bands but sometimes make up isolated lenticular masses. Much of the garnet contains dense arrays of opaque inclusions, often in an oriented pattern resembling myrmekite. Larger masses of opaque material are intergrown closely with the grains of garnet.

The pyroxene is probably a diopside but is almost straight extinguishing and with a faint pink to green pleochroism. It is not a true hypersthene, however, since it is optically positive. It forms long prismatic crystals aligned along the bands in which it is concentrated. The crystals are broken, corroded and fragmental and include irregular forms. Sericitic replacement has taken place along fractures and grain margins.

Feldspar only remains as ragged and irregular fragments surrounded by the sericitic felt. Most of the fragments are recognisable as microcline but some are untwinned and may be a species of potash feldspar or of plagioclase. The alteration of feldspar is either total replacement by sericite or absent. Relict fragments are unaltered.

Biotite may have originated as an alteration product of ferromagnesian minerals, in this specimen probably pyroxene. It is concentrated in bands containing pyroxene but is not seen in a replacement relationship to that mineral. It also forms a few independent flakes in leucocratic bands from which pyroxene is absent. It is certainly not part of the process of potash metasomatism which produced the sericite felt. In places the biotite itself is corroded by the sericite or has been altered to chloritic patches within the replacement felt.

The opaque material is concentrated within, but not restricted to, bands containing pyroxene, garnet and biotite. It forms elongated to irregular masses up to 3 mm long as well as the oriented inclusions in garnet already described.

Fine grained zircon is widespread and probably abundant enough for age determination by the uranium-lead method if the required 30 kg of core is available.

A few rectangular grains are present of a mineral with low refractive index, low birefringence, positive optic sign and a very small optic axial angle. It is probably a zeolite such as chabazite.

Comment:

Where the pyroxene and garnet are seen to be in contact, textural relationships suggest an equilibrium assemblage. This evidence suggests that the gneiss was originally of granulite facies. Crystallisation of biotite probably occurred at a lower temperature but before the metasomatic episode in which sericite replaced most of the feldspar and some of the quartz, pyroxene and biotite. It is the corrosion, replacement and fracturing forming part of this episode which has fragmented many of the minerals, particularly the feldspar, but there is no evidence of the kind of tectonic cataclasis which would justify the term 'mylonite'.

5138 RS 20, 737.05 m, TS C41541

Rock name: Retrograde gneiss

Hand specimen:

A gneissic banding is still identifiable but is far less sharply defined than in the specimen from 738.9 m. A coarse grained band runs down the centre of the core but most of the specimen consists of a fine grained mass of grey-green minerals in which both mica and chlorite are present. The plane of what foliation remains is at a slight angle to the length of the core.

Thin section:

The section consists partly of the coarse grained band, which is similar to the specimen examined from 738.9 m but more strongly altered, and partly of the fine grained mass of alteration products, in which biotite is included, which makes up most of the core.

Quartz in the coarse grained facies is almost identical to that described in specimen RS 21. It is slightly less abundant and more corroded in this specimen. In the fine grained facies quartz only occurs as a few scattered relict grains and as a thin vein filled with relatively fine quartz grains closely interlocked along complex intergranular sutures.

Garnet is less susceptible to alteration than any of the other minerals of the paragenesis. It is almost identical in specimens RS 20 and RS 21. The only significant difference is that in RS 20 there are fewer opaque inclusions in the garnet. There is no garnet in the fine grained facies.

Pyroxene, in contrast, shows clearly a greater degree of corrosion and replacement in specimen RS 20. Pyroxene is not abundant and consists of relict fragments surrounded by fine grained alteration. There is no pyroxene in the fine grained facies.

There is no feldspar in either facies.

Biotite is more abundant in this specimen than in RS 21. It is somewhat more abundant in the coarse grained facies than in similar material in specimen RS 21. It forms masses of fine flakes, particularly in the vicinity of garnet grains. In the fine grained facies of RS 20 it is considerably more abundant than in RS 21 and forms bands and patches of fine flakes with a strictly consistent preferred orientation.

Opaque material occurs in irregular masses with garnet in the coarse grained facies and in oriented lenticular to elongated masses in both coarse and fine facies.

The mass of felted alteration products consists mainly of sericite in the coarse facies and mainly of chlorite, biotite and clay minerals in the fine grained facies. The orientation of some of the biotite is at an angle to the main foliation of the gneiss.

Comment:

The division between coarse and fine grained facies is approximately conformable to the foliation but in thin section is not clearly defined, with a transitional boundary. The change from one to the other may mark the limits of a particular type of alteration rather than an original compositional difference. However, minerals such as garnet and opaque minerals, which are apparently not subject to hydrous alteration, do vary in abundance between one facies and the other and the evidence for variation in original composition is strong. Possibly the presence of sericite in one part and chlorite and clay in the other is also the result of variations in the original composition. It is not possible to determine on petrographic evidence whether the compositional variation is the result of metamorphic differentiation or of pre-metamorphic lithology.

There is no evidence of tectonic granulation and the term 'mylonite' does not appear to be applicable to this specimen.

5138 RS 19, 734.05 m, TS C41540

Rock name: Quartz, microcline, garnet gneiss.

Hand specimen:

The metamorphic differentitation is well marked with pink and grey bands running almost parallel with the length of the core. The bands are slightly sinuous and on the sawn surface of the specimen, cut perpendicular to the length of the core, the dark bands are seen to be lenticular in section. The fabric appears to be partly a lineation and partly a foliation.

Thin section:

The gneiss is composed essentially of quartz and potash feldspar. Garnet and opaque material are relativey minor constituents. Sericitic alteration is widespread but is not as complete as in the specimen from 738.9 m. A green chlorite is a minor alteration product.

Quartz occurs as long, thin bands which are more continuous than in specimen RS 21 and which are more sinuous than is apparent in hand specimen. Individual quartz crystals within the bands are as much as 4 mm in length but as little as 0.3 mm wide. Many quartz bands are disposed en echelon and separated only by a thin layer of sericite. The bands only rarely merge into each other.

The feldspar is a microcline with rather irregular twinning and strong strain polarisation. It is cleaved and fractured, with sericitic alteration along the cleavages and fractures. Alteration also occurs from the edges of the crystals inwards. The alteration has not replaced more than about 15% of some grains although wide areas of sericite may mark the complete replacement of other grains.

Garnet occurs as lenticular patches of fine, fractured grains. The patches are partly within individual bands of the gneiss but extend beyond the bands and into adjacent bands as broad, lenticular masses.

Opaque material occurs as long, irregular grains in restricted bands but is most abundant in the bands containing garnet where large, elongated, irregular patches form nuclei for garnet masses.

Sericitic alteration occurs in large, elongated areas between quartz bands, and may have replaced completely a feldspar band in these areas. It also occurs in much less abundance and less continuously as a marginal replacement and as a replacement along cleavages of feldspar grains which still remain substantially unaltered. Intermediate stages in which the microcline is almost completely replaced are common.

Chlorite is a minor replacement product and occurs in substantial proportions only at one point where a large mass, some 3 mm long, of fine grained green chlorite may have replaced a ferromagnesian mineral. The iron content of the presumed ferromagnesian mineral remains as inclusions of opaque oxide in the chlorite.

A few fine grains of zircon are present.

Comment:

The abundance of microcline, the relative rarity of garnet and the apparent absence of pyroxene and biotite in this specimen suggests that variation in composition of the gneiss observed in the specimens examined reflects an original variation and is not a difference imposed by metamorphic or metasomatic processes. The amount of fragmentation observed in the specimen is insufficient to justify classification of the rock as a mylonite.

5138 RS 18, 726.95 m, TS C41539

Rock name: Quartz, garnet, mica gneiss

Hand specimen:

The most striking difference between this and the other gneiss specimens in hand specimen is that the garnet here is a strong pinkish red instead of a faintly pink brown. A wide garnet band runs down the centre of the core specimen with minor garnet bands each side of it. The banding is again close in direction to the length of the core. The major part of the rock is grey.

Thin section:

There are many features displayed by this specimen that are common to all the gneisses examined. One feature that distinguishes it from the other specimens in thin section is the coarse grain of micaceous alteration products. A feature of structural significance is the superimposition of a foliation marked by oriented biotite and alteration products on the regular gneissic foliation.

The quartz forms thin bands which are virtually identical to those of specimen RS 19. The bands are more complete than in the other specimens described and are grouped together to form wider quartz-rich bands. Many of the quartz grains are fractured and a slight sericitic alteration has penetrated the fractures in some places. Little or no marginal corrosion has affected the quartz. Some quartz is almost without strain polarisation.

Garnet is less prominent in thin section than it appears in hand specimen because the colour is not obvious. The mineral is concentrated in bands and occurs both as the aggregates of fine grains which are familiar from other specimens and as large, separate, fractured and fragmental grains distributed along a few bands of the foliation. The coarse garnet is clear of opaque inclusions and is unaltered except along the fractures.

Only a few ragged and fragmental relics of feldspar remain in the micaceous alteration products. Most of the fragments are recognisable as microcline but the smaller ones tend to be somewhat altered as well as replaced round the margins.

Biotite is present as small flakes in two types of occurrence. Clusters of flakes occur around garnet and iron oxide in the garnet-rich bands and, in the other mode of occurrence, concentrations of fine flakes form a discontinuous foliation at about 30° to the main gneissic foliation. The bands of flakes in the second mode of occurrence often originate in the vicinity of the garnet-opaque oxide patches but extend into the light bands of the gneiss.

The opaque material forms irregular patches closely intergrown with garnet and elongated patches which are consistent with the foliation planes. The oriented patches of opaques occur both in the light bands of the gneiss and with biotite in the dark bands. In the association with biotite, opaque material occurs in both the regular gneissic foliation and in the biotitic foliation at 30° to the main fabric.

The mass of felted sericitic alteration products differs from that encountered in the basement gneisses described above in that it includes frequent flakes of muscovite up to 1 mm across. The mica is mottled in appearance with almost uniaxial optics. Both of these properties are evidence of an imperfect crystal structure and it is suggested that the coarse mica flakes grew by the amalgamation of fine sericite. Most of the flakes are elongated along the direction of the foliation planes but with the second diameter of the flakes perpendicular to that plane.

A few fine grains of zircon are present.

Comment:

Indications of a second biotite foliation were also encountered in specimen RS 20 from 737.05 m and the evidence apparently implies a second period of stress at the time biotite was developing by alteration of the ferromagnesian minerals. A third period of stress is perhaps indicated by the orientation of muscovite flakes in specimen RS 18. Since the main foliation is parallel to the length of the core, which may be assumed to be close to vertical, the development of coarse grained muscovite must have occurred under a lateral stress, whether it took place with the gneiss in its present attitude or in an attitude with the foliation close to horizontal.

5138 RS 17, 687.7 m B, TS C41538

Rock name: Coarse sandstone with ferruginous bands

Hand specimen:

The sandstone consists of coarse, well-rounded clasts, mainly of quartz, in a matrix which varies from a pinkish brown clay to a dark red-brown ferruginous material. The sharp alternations of these colours produce an attractively banded rock but the bands are not entirely coincident with the bedding although both bands and bedding are perpendicular to the length of the core. Red brown bands stop short across the width of the core without any obvious explanation in sedimentary features.

Thin section:

The rock is more feldspathic than appeared in hand specimen, largely because the microcline is almost completely unaltered and appears vitreous. Quartz is the most abundant framework mineral but microcline is not much less frequent. Minor plagioclase and lithic fragments also form clasts. The matrix is composed of fine, angular quartz fragments and either fine grained sericitic muscovite or red-brown iron oxide.

The coarse quartz grains of the framework are rounded to sub-rounded and are well sorted at about 1 mm average grain size. Grain size varies between beds, with a maximum of about 2 mm and a minimum about 0.5 mm. even close quartz grains are rarely in contact and the sediment is essentially matrix-supported. When originally deposited the sediment was probably, at least in part, framework supported and the present matrix has been partly introduced by replacing clasts along grain boundaries. This is illustrated in places by adjacent grains exhibiting pressure solution effects although currently separated by a thin layer of sericite.

Quartz also occurs as a matrix constituent. Much of the matrix consists of angular to sub-angular quartz grains of fine sand grade. Grain shapes are strongly modified by corrosion in the brown ferruginous matrix but appear little altered in the sericitic matrix. Quartz grain sizes in the sediment as a whole are bimodal but not as sharply as might have been the case without corrosive modification of grain sizes.

Microcline is virtually the only feldspar present and occurs in grain sizes similar to those of the quartz, both as framework clasts and in the matrix. The shape of the microcline grains is similar to that of the quartz except for a tendency towards rectangular, cleavage-controlled fragments with well-rounded corners and edges. The shape of some clasts is modified by corrosion.

Plagioclase clasts are very rare.

Lithic clasts are not abundant but include polygranular quartz, quartz and microcline, and rare quartz and mica fragments. These are almost certainly derived from the underlying basement.

The arenaceous part of the matrix is common to both light sericitic and dark brown ferruginous bands. The shape of the fine quartz and feldspar clasts is strongly modified by corrosion in the dark bands. The margins of the grains are embayed in regular and irregular shapes and many grains are reduced to thin, angular and fragile relics.

It is the nature of the finest part of the matrix, or cement, which determines the strikingly banded appearance of the sediment in band specimen. The pale coloured bands are cemented by fine, sericitic mica. The original matrix may have been argillaceous and the Cambrian may have been as much affected by sericitisation as the underlying basement. The dark brown cement is an amorphous haematite. The relationship between the two types of cement is not entirely clear but the balance of evidence suggests that the iron compounds are replacing the sericite.

This explains why the banding stops short in some beds. Other beds may have provided more open and continuous channels for the transport of what must have been highly corrosive solutions.

Fine grained zircon and a green to yellow tourmaline are trace minerals.

Comment:

The basal Cambrian sandstone consists essentially of coarse, well-rounded quartz and microcline deposited in an energetic environment and lithified before alteration of the feldspars could occur. The sediment may have been a desert arkose carried by wind or by sudden floods in a wadi or piedmont environment.

It has been suggested that the sericite matrix may not have been original but the result of the same sericitic alteration that affected the underlying basement gneisses. The rock is a light pinkish brown where the cement is sericitic. The amorphous haematite which gives the dark red-brown bands a distinctive colour appears to have been introduced along certain bedding planes in a strongly corrosive solution. The solution has dissolved the sericite and corroded both quartz and feldspar clasts of coarse and fine grain sizes. Iron oxide has been precipitated where sericite and clastic material were removed. The abrupt end of some colour bands at various points in various beds may be attributed either to the blockage of moving solutions by a discontinuity of porosity or to the exhaustion of the reacting solvent in the corrosive solutions carrying the haematite.

5138 RS 16, 687.7 m A, TS C41537

Rock name: Coarse, banded, ferruginous sandstone

Thin section:

The second section of the specimen differs from the first only in the greater extent of the ferruginous beds compared with the sericitic beds. There is some indication that the beds which are penetrated by the iron-bearing solutions are finer in grain size than those in which the sericitic matrix is preserved. Because of the severe corrosion of both clasts and matrix by the iron-bearing solutions, the evidence on grain size is not entirely reliable.

Comment:

Examination of a second thin section of the specimen RS 16 reinforces the suggestion that the colour variation is due to iron oxide deposited from a corrosive solution introduced after the deposition, diagenesis and lithification of the sediment.

5138 RS 15, 597.9 m B, TS C41536

Rock name: Ferruginous and dolomitic sandstone.

Hand specimen:

The sediment is a fine to medium grained, quartz-microcline sandstone in which colour variation includes the red-brown bands noted in the coarser sandstone below but also includes a greenish facies which occurs in both regular and irregular bands and patches only partially controlled by bedding directions. A variety of shades of both brown and green are evident. The boundary between the red-brown and greenish facies is rippled in places. Bedding is disrupted, probably by soft sediment structures.

Thin section:

One thin section cut from this specimen consists of a fine grained, sandy sediment with an irregular, patchy colour variation in shades of light pinkish brown, grey and green. Heavy impregnation with oxidised iron compounds is absent from this part of the specimen. In thin section the rock is seen to differ from the sandstone at 687.7 m in its finer grain size, high proportion of matrix and, despite the absence of oxidised iron, its wide variety of matrix material. Three kinds of fine grained matrix minerals are present, the sericite encountered in specimens RS 16 and 17, a dolomitic carbonate and a combination of sericite and clays of moderate to low birefringence which in hand specimen are coloured in various shades of green. A very weak bedding is expressed in alignment of elongated quartz and in sericite of the matrix.

The quartz clasts which make up the main framework of the sediment are rounded to angular and are much more varied in grain size than in the other specimen of sandstone already described. Sorting is generally poorer than in the coarser facies and there is no systematic variation between one bed and another. The bimodal distribution of grain size is not apparent and clast size varies continuously between about 0.02 mm and 0.8 mm. There is little evidence of corrosion of clasts and a few quartz grains show a rim of authigenic silica grown over the detrital nucleus.

Grains of feldspar exhibit the same range of shapes and a somewhat lower size range than the quartz. Microcline is again the major species but the proportion of plagioclase is slightly higher than in RS 16 and 17.

Lithic fragments are mainly quartz sediments but vary in grain size between a fine, devitrified chert and a coarse quartzite. A few lithic clasts are feldspathic but it is not clear whether they are derived direct from basement gneiss or from the recycling of the sediment lower in the succession.

Trace minerals consist of well-rounded grains of opaque material and very rare zircon and yellow tourmaline.

The sericitic matrix consists of a fine grained felt of mica with a rather weak preferred orientation. Occasional coarser flakes of muscovite may be original detrital clasts but are not conclusively distinguishable from a possible coarse recrystallisation of part of the matrix. Clay minerals are also included with the sericite.

The carbonate matrix is distributed in large patches which are unrelated to the bedding of the sediment. It appears to be derived from post-diagenetic replacement of the sericitic matrix but may have been controlled by porosity variations in discordant soft-sediment structures such as load casts. The carbonate does not stain with the dye alizarin red which is used by Amdel to identify calcite. One of the refractive indices of the mineral is almost exactly that of the epoxy resin used in thin section making and the other is considerably higher than that of the resin. The carbonate is almost certainly dolomitic but the exact composition could be obtained by X-ray or chemical analysis.

The third type of matrix material is distributed in lenticular masses and discontinuous bands which in places conform to an irregular bedding and in places appear to be completely discordant. This, however, is in places where the bedding has been completely disrupted by probable soft-sediment structures. The material is lithic in the sense that it resembles a sedimentary silty shale but has been included among matrix materials rather than detrital clasts because it is intraformational and tends to grade into the sericitic matrix of the sandstone. Some fragments have a zonal structure in which the outer zones are dominantly sericitic and the inner parts grade from moderately birefringent clays to a central zone of kaolinitic clays. The material is probably derived from a thin layer of mud which was partially lithified, possibly by drying out, in stagment conditions with very little sediment supply, to be broken up and reincorporated in a coarser sediment when current activity was resumed.

Comment:

The sediment exhibits the features of intermittent, rapid erosion, transportation and deposition. These are poor sorting, weak bedding, fresh feldspar and angular fragments. The inclusion of many well-rounded clasts probably implies a contribution of aeolian sand or the destruction and reworking of slightly earlier sediments. The presence of disrupted mud flakes demonstrates the latter on a minor scale.

The suggestion of a desert environment which was made on the evidence of the first basal Cambrian sandstone examined, is reinforced by the evidence observed in this specimen. The processes of sedimentation certainly appear to be intermittent, possibly comprising the cycle of flood and drought which prevails in parts of inland South Australia today. The complement of well-rounded quartz and fresh feldspar was probably derived, or at least augmented, from desert sand dunes. A turbulent flood dumped sediment in a sand bank or as sheet wash and later the drying water deposited thin mud over the sand. The next flood broke up the surface of the sediment and incorporated it in the next bed of sediment. Dewatering and load casting produced the soft sediment structures.

Introduction of a dolomitic cement by replacement of silicate matrix minerals was a post-diagenetic process.

5138 RS 14, 597.9 m A, TS C41535

Rock name: Ferruginous, dolomitic sandstone.

Hand specimen:

This part of the specimen includes the red-brown iron oxide cement which was absent from the other thin section cut from the specimen. The pink and the greenish grey facies are also present and display a fine bedding with ripple markings. Undulations in the surface of the iron-stained part of the specimen appear to be influenced by, but do not coincide with, the sedimentary ripples. A good display of graded bedding is observable with a hand lens and indicates that the sediment is not inverted.

Thin section:

The overall range of grain size is similar to that of specimen B from 597.9 m but sorting is much better in that size variation is small in individual beds. The bedding is more regular and more continuous than in specimen B and some of even the fine, muddy beds reach across the width of the thin section. Other muddy bands are discontinuous, either tapering off or ending quite abruptly. The same zoning between sericite and clay of low birefringence as was observed in the disrupted bedding of specimen B is evident in the more continuous beds of specimen A.

As in specimen B, the detrital clasts include quartz, microcline, lithic fragments, largely of closely interlocked quartz, very minor plagioclase and trace zircon and tourmaline.

Interstitial crystals of dolomite are widespread as a matrix in the sandstones but do not appear to have penetrated the shaly bands. The concentration of dolomite is slightly patchy and is not rigidly controlled by sedimentary features. There is possibly a weak correlation between a medium grained facies and a more abundant concentration of dolomite but the effect is not prominent. The material most easily replaced is the sericitic matrix and it is possible that a little clastic material is corroded at the margins. It is not clear why the sericite of the shale bands is not replaced.

The iron oxide replacement of matrix and clast margins is similar to that described in other specimens. Corrosion and deposition of iron oxide is consistent in that the fine grained shaley material is replaced in shaley bands as well as in the matrix of the sandy facies. Replacement of shaley bands is so complete that they are prominent as dark red brown bands in a paler red brown of the altered sandstone. Examination of the thin section reveals that the physical penetration of the shaley bands is slower than that of the sandstones so that, although the shaley bands are marked by strong dark red colouration, they are not altered as far along strike as the limit of alteration in the sandstones. This line is seen clearly in thin section and underlines the nature of the iron oxide replacement. Although the penetration of the rock fabric is influenced by the lithology, the iron oxide is precipitated from post-diagenetic solutions and is not a sedimentary material.

Comment:

To sum up the information obtained from the examination of thin sections C41535 to C41538; the Murnaroo sandstone was deposited on a desert terrain by intermittent drainage as fluvial sands or sheetwash. The sequence is the right way up. The colours displayed depend on the matrix of the sediments. Greenish grey is the colour of sandstone with a sericite-clay matrix. This becomes a stronger green where the proportion of sericite to quartz is high in fine grained shaley beds. Dolomitic replacement or a weak development of iron oxide gives a pinkish brown colour. Replacement of the matrix and marginally of the clasts by amorphous, haematitic iron oxide produces a deep red-brown colour. This process was accomplished by the permeation of the sediment after diagenesis by corrosive solutions which deposited the oxide in the space provided by the dissolution of both matrix and clasts.

5138 RS 13, 590.2 m, TS C41534

Rock name: Dolomitic and ferruginous sandstone

Hand specimen:

Four shades of colour between pale pink and deep red brown are displayed by a sandstone in which medium grain size and a massive non-bedded texture is contrasted with bands and patches of fine, finely bedded red shale which are highly contorted.

Thin section:

The fabric of the sandstone is massive and quite uniform with well-sorted clasts between about 0.2 mm and 0.7 mm in a dolomitic matrix. The colour banding is due to the abundance of haematitic oxide superimposed on the dolomite. The fine grained material is distributed within the sandstone as small dispersed, discontinuous patches and bands of iron oxide.

The quartz grains are strongly rounded with a high degree of sphericity. The detrital material has been well worked in this specimen although final deposition has been rapid and continuous on the evidence of the absence of bedding planes.

The feldspathic component consists largely of microcline with a minor proportion of plagioclase.

Lithic fragments are moderately abundant and a high proportion of them are fine grained siliceous rocks which are probably recrystallised cherts.

The iron oxide has almost certainly replaced fine grained shaley material which was probably incorporated in the sandstone as mud flakes. The original material has been completely replaced. The thin section does not include the well-bedded fine sediment visible in the hand specimen. Dispersed iron oxide has tinted one end of the section a light red-brown.

Dolomite forms an interstitial, crystalline matrix throughout the whole sandstone apart from the fragments of shaley material. Many of the dolomite crystals are as coarse as the framework clasts suggesting either that there was originally a substantial shaley matrix on that some enlargement of interstitial spaces had been effected by corrosion before deposition of the dolomite.

The iron oxide which has tinted part of the sandstone has penetrated the fabric along grain boundaries and fractures, leaving thin layers of stain coating the clasts and even some crystals of dolomite.

Comment:

On the assumption that the interclastic spaces were originally filled by a shaley matrix, this sandstone also is the product of rapid dumping of material. The clastic fraction was relatively well sorted but was dumped with a much finer muddy fraction. Possibly the material is fluvial and the clasts originated in a well sorted sand bank which was later disrupted by storm water and redeposited by a muddy torrent.

5138 RS 12, 585.2 m, TS C41533

Rock name: Conglomerate pebble. Rhyolite or rhyodacite

Hand specimen:

The section of core consists of a rounded pebble from a conglomerate in the Murnaroo sandstone sequence. The pebble is a purplish grey colour and contains patches with a pink colour. The fabric is patchy and poorly defined with gradational boundaries. Some patches are spherulitic and some appear to be zoned.

Thin section:

The specimen has a fine grained and poorly crystalline ground mass with quartz and plagioclase phenocrysts. Patches of finely granular material alternate in the groundmass with spherulites, radiating fibres and flame structures with a fibrous texture. No evidence of primary groundmass textures such as glass shards or flow structures remains but a somewhat irregular, sub-parallel fracturing may have originated in either pyroclastic bedding or magmatic flow banding. Some of the phenocrysts are unbroken but others are fractured. Since the broken fragments tend to remain close together, the balance of evidence possibly indicates that the rock was a glassy lava rather than a tuff when erupted but the identificaion is not conclusive. The rock is certainly of volcanic origin. Without chemical analysis the composition of the rock can only be estimated from the phenocrysts.

Quartz occurs in resorbed phenocrysts up to 4.5 mm across. The resorbtion has rounded the outer shape of the grains and deeply embayed the margins in forms typical of volcanic rocks.

The only feldspars which occur as phenocrysts are plagioclases. As far as may be determined on the limited number of phenocrysts, the maximum symmetrical extinction angle is 18°. The refractive index of the plagioclase is lower than that of the epoxy resin mounting medium and the optic sign is positive. On this evidence the plagioclase is close to pure albite in composition.

A critical factor in identification of the composition is the content of potassium feldspar. There is no direct evidence of this since potash feldspar does not form phenocrysts and no feldspars can be identified optically in the groundmass. Fine grained micaceous alteration is widespread in the groundmass, however, and it appears a reasonable assumption that potassium feldspar is present. The relative concentration can not be quantitatively assessed.

The tentative identification of rhyodacite accompanying the specimen is entirely reasonable on the rather limited evidence available but a chemical analysis of the groundmass is necessary for conclusive definition.

A little biotite and opaque material are also present in the specimen.

Comment:

Six thin sections of Gawler Range Volcanics were examined to determine whether any correlations could be made. All were identified as rhyodacite by chemical analysis. Most of the quartz must have been in the groundmass as very few quartz phenocrysts were seen. Some contained phenocrysts of potassium feldspar and none were devitrified in the same fibrous form as the Lake Maurice East specimen. It is possible that the latter specimen is a rhyolite rather than a rhyodacite since it contains quite abundant quartz phenocrysts. It appears unlikely that it is a member of the Gawler Range Volcanic sequence on textural evidence but chemical data are necessary for a more conclusive definition of both rock type and genetic affinity.

5138 RS 11, 583.46 m, TS C41532

Rock name: Conglomerate

Hand specimen:

The rock is mainly a clast-supported orthoconglomerate with a wide variety of clasts. In some fragments of the core a large proportion of the rock is made up of a fine grained green shale similar to that seen in, for example, RS 15 from 597.9 m. This appears to be not so much a matrix as a soft-sediment intraclast incorporated with lithified clasts and squeezed round them to some extent, giving the appearance of a paraconglomeratic matrix. The true matrix of the conglomerate is a coarse sand composed of highly rounded grains. An iron oxide cement and a dolomitic carbonate are present as interstitial cements which have partially replaced the detrital component of the matrix.

Thin section:

The sediment is composed of four types of material : (a) fully lithified detrital clasts, (b) partially lithified intraclasts, (c) sandy interstitial matrix and (d) cement.

(a) The lithified clasts consist of well rounded to sub-angular fragments of a wide variety of lithologies. Grain sizes of 10-20 mm are common. Some of the grains are derived from the basement and some from earlier sediments. The most abundant lithology is a fine grained to cryptocrystalline siliceous rock, probably a chert.

Distinctive lithologies include the following:

1. Graphic granite. This is a very distinctive lithology not intersected by the drill hole. It is probably derived from the basement and is part of a granite in which the pegmatitic fraction has been contained within the main mass so that a low temperature eutectic of quartz and feldspar crystallises in a closely interlocked and interpenetrant mass. It is probably a deep-seated pluton.
2. Quartzite. This rock consists of strongly oriented, highly recrystallised and closely interlocked quartz with a high degree of strain exhibited by undulose extinction. It is also probably from basement exposed at the time the conglomerate was deposited.
3. Strongly recrystallised rocks, of uncertain provenance. These rocks are distinguished by the kind of flame and rosette textures seen in the pebble of volcanic rock obtained from 585.2 m. It must be emphasised that this is the only characteristic linking the two lithologies. No phenocrysts are identifiable. The devitrification of a glass of volcanic origin is a similar process to the dehydration and crystallisation of a colloidal silica gel and it is possible that the pebbles are in fact original cherts. The textures are distinct from those of other, less strongly recrystallised cherts in the conglomerate. The provenance of these clasts remains uncertain.

4. Recrystallised feldspathic sediments. These rocks are not as highly metamorphosed as those of the basement intersected in the drill hole but are substantially recrystallised in comparison with the sediments of the Murnaroo sandstone. It appears likely that a sequence of rocks was exposed in the terrain from which the clasts of the conglomerate originated which has not been intersected by the drill hole and which is intermediate in degree of alteration, and hence probably in age, between the high grade Precambrian gneisses of the basement and the unmetamorphosed sediments of the presumed Cambrian Murnaroo sandstone sequence.

5. Siliceous oolites. These sediments are composed of spherical to slightly flattened ooliths about 1 mm in diameter with a concentrically banded structure. The ooliths are composed of extremely fine grained silica except for the outermost shell which is fibrous in form and stained with iron oxide. Rosettes of fibrous silica extend into interstitial spaces where they merge with more coarsely granular matrix quartz. In one such oolite fragment dolomite rather than iron oxide is part of the matrix. It is not evident whether the ooliths were originally carbonate, now silicified, or whether the sediment was formed from colloidal silica from the outset. The latter is likely in view of the high percentage of chert clast.

6. Chert. The largest category of clasts in the conglomerate consists of cherts. These vary in texture from massive and extremely fine grained to strongly recrystallised, forming both granular patches of irregular shape and regular rosettes. One chert is bedded. The recrystallisation is of a much finer grain size than that of the specimens described in category 3. Chert fragments tend to be elongated, sub angular and sometimes indented by adjacent matrix fragments. They are probably paenecontemporaneous with the conglomerate and may not have been completely lithified when incorporated in the coarse sediment. Both the siliceous oolites and the cherts are probably part of

the Murnaroo sandstone sequence. These clasts are transitional to the category of intraclasts, category (b).

(b) One end of the hand specimen of core is composed of a fine grained shaley lithology and fragments of this material are incorporated in the conglomerate. Like several other specimens of Murnaroo sandstone, the conglomerates contain undoubted intraclasts of muddy sediment. The cherts may be intraclasts, the shaley sediments certainly are. In thin section C41532 only one small, highly ferruginous clast represents this category.

(c) The detrital matrix of the conglomerate consists of sand-size quartz, microcline and siliceous lithic fragments. Many of the grains are very strongly rounded but some of the polycrystalline material is present in angular grains. Some lithic clasts are partly replaced by iron oxide and may be derived from earlier Murnaroo sandstone sediments.

(d) The syngenetic cement of the conglomerate is colloidal silica, often in rosettes. Two forms of cement have been introduced, as they have been in the other specimens of Murnaroo sandstone examined. These are iron oxide and dolomite. Iron oxide has penetrated the matrix which it has replaced in patches and has also penetrated some of the framework clasts. It is a dark red-brown amorphous material. The dolomite is coarsely crystalline and has replaced patches of matrix up to 2 mm in length.

Comment:

Examination of the clasts of this conglomerate has provided evidence of the rocks being eroded at the time the sediment was deposited and expands the direct evidence obtained from the drilled intersections. Three main categories of rocks not intersected were exposed. The first is a graphic granite which is a post-tectonic deep intrusion of the basement. The second is a sequence of quartz and feldspar-bearing sediments of presumed post-gneiss, pre-Murnaroo sandstone age with a moderately recrystallised fabric. The third is a sequence of sediments composed of colloidal silica, massive, bedded and oolitic in texture. These are recrystallised but not metamorphosed and are possibly lateral equivalents of earlier sediments of the Murnaroo succession. The affinity of rocks with very strongly recrystallised textures is not known but may possibly be volcanic.

5138 RS 10, 583.46 m, TS C41531

Rock name: Conglomerate

Hand specimen:

The part of the specimen represented by this thin section contains a few additions to the rock types described above. Another difference is the greater extent of dolomitic replacement of both matrix and parts of some clasts in this specimen as compared with RS 11.

Lithological features additional to those seen in RS 11 are as follows:

(a) Clasts

1. A clast of gneissic basement contains strongly oriented quartz and feldspar with a little fine grained biotite.
2. A clast of undoubted volcanic rock contains phenocrysts of plagioclase and possibly of orthoclase in a strongly flow-banded groundmass. Heavy haematitic impregnation conceals any evidence of genetic relationships which there may have been in original textural features. It is not possible to determine on the available evidence whether the rock is a lava flow or a welded tuff or ignimbrite. No quartz phenocrysts are present and the rock may be andesitic, dacite or trachytic in composition.
3. A second clast of probable volcanic origin consists of a fine grained mass of lath-like crystals which may have been feldspar. Most of the rock is now replaced by amorphous haematite. The specimen may have been andesitic but any attempt to assign it to a related series such as the Gawler Range Volcanics would not be supported by the evidence.

4. Several finer grained fragments may be devitrified glassy volcanic rocks but the textures are so poorly defined that the indications are not conclusive.
5. A finely granular quartz rock contains scattered coarse grains of deformed quartz. This is probably not of the same origin as the abundant clasts of recrystallised chert but is more likely a basement quartzite which has been almost completely granulated by intense local strain. This is the only lithology encountered in this series of specimens for which the term 'mylonite' would be justified.

(c) One matrix characteristic not observed in RS 11 is the presence of a bundle of muscovite flakes abut 4.5 mm long in the interstitial space between chert fragments. Since it is shaped to fit the space without deformation it is taken to be a matrix component rather than a detrital clast. The mica is probably the product of a highly potassic pore solution, possibly the same as carried the iron oxide since the mica impregnated with opaque material. It may be of syngenetic or epigenetic origin.

Comment:

The only petrographic features described here are those which add to the understanding of the geology of the source terrain which has been gained directly from intersection in the drill hole or indirectly from the clasts examined in RS 11. Much of the evidence observed is common to the two thin sections cut from the one specimen of core from 583.46 m. The main additional information is that a sequence of volcanic rocks not intersected in the drill hole was exposed at the time the conglomerate was being deposited. The information lacks precision because the volcanic lithologies are quite strongly altered but the variety of lithologies encountered, whatever their precise compositions, indicates the presence of a sequence substantial enough to have given rise to differentiation. The few examples examined, both of volcanic rocks from the Lake Maurice East drill hole and from the Gawler Ranges, does not support a genetic correlation between the two sequences but a good deal more investigation is required before any definitive conclusion may be reached.

Other additional information is of a possible shear zone in the basement and of a micaceous component in the matrix material.

5138 RS 9, 583.46 m, TS C41530

Rock name: Conglomerate and dolomitised silt.

Thin section:

This thin section, cut from near the end of the core, is composed of a fine grained lithology. Examination of the section shows that at this point it is a silty facies which has been strongly dolomitised.

Additional information gained from examination of the clasts is as follows:

1. Microcline granite. A clast composed largely of coarse grained microcline crystals adds to the available data on the intrusive in the basement which was recognised from evidence in specimen RS 11, the other end of the core sample. It is a highly potassic granite with a pegmatitic facies consisting of coarse microcline with minor quartz and biotite as well as a graphic intergrowth of quartz and microcline.
2. A large quartzite clast consists of closely interlocked quartz grains of coarser grain size than in the quartzite encountered in the other conglomerate specimens. The quartz grains are strained but without a strongly marked preferred orientation. A second quartzite fragment has a very prominent oriented fabric.
3. A relatively small clast has been extensively replaced by dolomite and is somewhat altered but, from the evidence of grain shape rather than optical properties, it appears to be composed of medium grained, interlocking, decussate plagioclase laths. On this evidence it may be an andesite which was originally part of either a thick, slow-cooling lava flow or possibly a minor intrusive such as a dyke or sill.

Comment:

The additional evidence gained from this thin section extends the known range of lithologies in degree rather than in kind. No new rock type is revealed but more information is available on the granitic, quartzitic and volcanic lithologies already known from clasts in the conglomerate.

DISCUSSION

Petrological information on the nature of the basement has been obtained both directly from rocks intersected in the drill hole and indirectly from clasts in the Murnaroo conglomerates. Volcanic and sedimentary units corresponding to many of the clasts in the conglomerates are not represented in the drillhole intersections sampled. Since the intersection from which no samples have been examined is less than forty metres, it seems likely that the volcanic and sedimentary sequences are not just unsampled but are really missing and that the drill has penetrated an older gneissic basement high from which considerable thickness of rock had been stripped prior to the deposition of the Murnaroo sandstone. The sequences missing from the drill core must be present within a relatively short distance of the drill site since the pebbles had probably not travelled very far from the point of exposure.

Basement rocks intersected in the drillhole along with gneissic clasts in the conglomerates suggest that the basement consists of an older sequence of high grade gneisses which includes probable granulite facies pyroxene-garnet gneiss and more granitic quartz-microcline gneiss with at least two retrograde facies marked respectively by biotite and by a very low grade sericitic alteration. Two episodes of minor deformation possibly correlate with the two retrograde metamorphic episodes. It is possible that age determinations might be carried out on zircons in the gneisses.

Using the evidence of clasts in the conglomerates the highly deformed basement also includes quartzites, one sample of which was granulated by shear. Some quartzites are much less deformed than others and may have annealed during episodes of minor recrystallisation which may have been local only in effect. Shearing has produced mylonitic fabrics only in restricted localities.

A younger sequence of basement rocks represented by clasts within the conglomerates has been recrystallised but not deformed. Rocks represented include quartzo-feldspathic sediments in which the shape of the clasts is determined by authigenic growth but in which no metamorphic preferred orientation is evident. Other rocks represented include a variety of volcanic rocks with fabrics of flow orientation but not of metamorphic foliation. There is no positive evidence of any genetic affinity to the Gawler Range Volcanic sequence but rather, where a distinctive fabric is present, it is not diagnostic of volcanics of the Gawler Ranges. Considerably more investigation is necessary before any definitive conclusions would be justified however. The range of composition indicates a magma source substantial enough to have differentiated.

Another rock represented in conglomerate clasts is a post-tectonic, potash-rich granite which is pegmatitic in texture. Both a coarse microcline facies with minor quartz and biotite and a graphic granite are represented in the clasts. There is no evidence of deformation.

The post-basement sedimentary sequence of the Murnaroo Sandstone is dominated by quartz arenites and rudites in the borehole intersections and by colloidal silica sediments, both cherts and oolites, in the conglomerate clasts. The environment of deposition appears to have been arid and much of the clastic material was possibly dune sand. Intermittent floods in wadi-like water courses and as sheet wash produced the rudaceous and arenacous sediments while temporary lakes precipitated cherts and siliceous muds which were deposited in oolitic forms when the waters were shallow during droughts. Argillaceous silts and muds were also deposited as the supply of coarse terrigenious detritus diminished. Occasional cloud bursts remobilised the mud in some places and these are represented by partially lithified flakes incorporated in overlying coarser sediments. It is probably an environment not very different from arid areas of intermittent drainage in Australia today.

One lithology not assigned to a specific category consists of crystalline material which was produced either by the advanced dehydration and crystallisation of a hydrated colloidal silica gel or by devitrification of a volcanic glass (a similarly amorphous material). Less advanced crystallisation processes are observed in the cherts and in one of the volcanic clasts investigated here. Neither of these processes duplicates the textures of the enigmatic rocks but either might eventually do so if the processes were intensified. On balance the textures appear more closely similar to those in the volcanic rock but origin as a chert cannot be entirely ruled out.

Three different materials, a carbonate, an oxide and a mica have replaced some of the matrix of the Murnaroo Sandstone sediments and, to a minor extent, some of the clasts. The basement gneisses are rich in opaque material which is probably at least in part an iron oxide, and the feldspar of the gneisses is strongly affected by a micaceous alteration. It is possible that iron oxide weathered out of the basement has been redeposited in a more highly oxidised form as a cement in the overlying sandstones. It is also possible that sericitisation affected both basement and sandstones and that relatively coarse grained muscovite was deposited from the same solutions in the intergranular spaces of the conglomerate. Both these possibilities lack proof and further investigation is necessary.

MF:DP DR. M.G. FARRAND