DEPARTMENT OF MINES AND ENERY
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PETROGRAPHY OF CORE SAMPLES FROM DDH KONGOLIA S1 DRILLED BY NORTH BROKEN HILL LTD NEAR SEDAN, S.A.

GEOLOGICAL SURVEY

by

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BIOSTRATIGRAPHY

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ABSTRACT

Specimens from DDH Kongolia S1, drilled by North Broken Hill Ltd near Sedan, include metasediments which may be equivalent to Kanmantoo Group mature and immature sediments. Regional foliation from the Delamerian Orogeny has been overprinted by thermal recrystallisation associated with massive plutonic intrusion. Metasomatic activity is of greisenising type but may include the introduction of porphyroblastic feldspar. An enigmatic 'rhyolite' appears to be a metasomatised metasediment. Amphibolites are pyroclastic in origin and may be related to seafloor volcanics to the southeast. Minor intrusives are probably hybridised extensions from the irregular margins of mafic plutons.

INTRODUCTION

A programme of drilling was carried out near Sedan in the eastern foothills of the Mount Lofty Ranges by North Broken Hill Ltd between 1975 and 1977 (DME Envelope 2631 Vols I-VIII). The main purpose was evaluation of the Black Hill Norite and other targets of anomalous gravity and magnetic intensity but a secondary aim was a search for stratabound copper in metasediments. Drill hole S1, cored in the pre-Tertiary basement, intersected altered sediments with, according to a petrological consultant, a rhyolitic member of the succession. The possibility of using the volcanic unit for purposes of age dating is of considerable interest but a primary consideration is the affinity of the sedimentary succession itself. It is possible, but by no means certain, that Kanmantoo sediments may extend eastwards from outcrop in the Mount Lofty Ranges beneath a cover of Tertiary sediments. An alternative possibility is that the sediments in DDH S1 may be equivalent to the Early Cambrian

succession of the Hawker Group and Normanville Group outcropping near Truro and Carrickalinga respectively.

PETROGRAPHY

Specimen 6728 RS 154, TS C50387, 729'-730' (c222.5 m)

Rock name Quartzite.

Hand specimen

The rock is fine grained except at the extreme end of the core specimen. It is grey in colour with a weak directional fabric and a closely interlocked texture. The dip of the foliation is at a low angle to the length of the core.

Thin section

Quartz is by far the most abundant constituent with minor amounts of opaque minerals, biotite, chlorite and epidote and traces of muscovite, sphene, apatite, zircon, garnet, dolomite and tourmaline.

Quartz grains are recrystallised and tend to be elongated with a preferential orientation. Mosaic patches are common with simple grain boundaries meeting at 120° triple junctions. Grain size varies between about 0.01 mm and 4 mm in the small patch of coarse grains at one end of the section. Most grains are about 0.2 mm across.

Opaque minerals occur mainly as fine grains, sometimes with a square outline, which tend to be associated with epidote in interstitial spaces. Occasional coarse grains and patches tend to be elongated and associated with a linear fabric. This is not always the same as the main fabric of the rock and in places appears to be controlled by radiating fractures. One such fracture contains a filling of opaque material.

Epidote occurs as fine grains and irregular patches in spaces between quartz grains but on a wide scale forms subparallel bands. The fabric produced by bands in which epidote concentration as an interstitial phase is high do not conform in orientation with the directional fabric of quartz grains. Some control is exerted by the same radiating fractures as influence the distribution of opaque minerals. In the coarse grained part of the specimen epidote grains are coarse.

Biotite is frequent as small flakes widely distributed in interstitial positions. It is concentrated in the radiating fractures, particularly at the centre of radiation where opaque material forms a short vein.

Muscovite is much less abundant than biotite. It occurs as a few, widely scattered fine flakes but is concentrated at the centre of radiating fractures. A few large muscovite flakes are present in the coarse grained part of the specimen.

Chlorite is widely distributed, partly as patches of alteration in biotite, partly as independent flakes. Even in the latter form, the distribution of chlorite is closely similar to that of biotite.

Sphene is present in small quantities both as independent grains and as an alteration product of opaque grains, presumably ilmenite.

The rare occurrence of apatite may also be related to a calcium metasomatic process.

Trace constituents such as zircon, tourmaline and garnet were probably part of the original sediment.

Occasional patches of dolomite are probably introduced.

Comment

The rock is of sedimentary origin but has been altered by at least two episodes of metamorphism, the later of which may have involved some metasomatic activity. The original composition of the sediment was extremely siliceous. Whether the original quartz sandstone contained any matrix is uncertain and depends on the extent of subsequent metasomatic introduction of epigenetic material.

Dynamic metamorphism, probably related to the Delamerian Orogeny, imposed a directional fabric marked by elongation of quartz grains. If there were a muddy matrix originally, it was probably altered to chlorite and micas of the greenschist facies. Some epidote may have originated at that stage if the matrix was in any way calcareous.

Subsequent alteration imposed a fracture system, redistribution of epidote, opaques and platy minerals and recrystallisation of the quartz. The imposed fabric was discordant to the Delamerian foliation. At least some of the redistributed material may have been introduced epigenetically. This episode may have been the result of plutonic intrusion and of the heat flow and hydrothermal activity related to high temperature magma. Epidote, sphene and apatite, may have developed from calcium in the hydrothermal solutions.

Specimen 6728 RS 155, TS C50388, 731'-731'3" (c222.8 m)

Rock name Quartz - biotite schist.

Hand specimen

The section of core contains a contact between a fine grained grey rock and a fine grained black rock. Schistosity is not developed enough to produce a parting or cleavage.

Thin section

Dark and light rocks are differentiated by grain size and by the relative proportions of quartz, biotite and opaque minerals. These three constituents form the major part of both rock types. There is a close association between biotite and opaque minerals but an inverse relationship between them and quartz. Minor and trace constituents include feldspar, chlorite, epidote, zircon, tourmaline and garnet.

The light coloured rock consists largely of quartz. Much of this occurs in ovoid patches up to 2 mm long with a strong preferred orientation. Each patch may originally have been a single grain but now consists of many grains about 0.2 mm across in a mosaic intergrowth. Outside the oval areas quartz grains may be individual or in small, irregular patches.

Between quartz grains and patches a close intergrowth of opaque material and biotite is as closely aligned with the quartz fabric as an interstitial position permits.

Minor constituents include occasional coarse grains of altered feldspar. Remnants of polysynthetic twinning identify a few of these as plagioclase but most are too altered for twinning to be visible. Potash feldspar may be present.

Patchy chlorite is relatively common. It is associated with biotite and may be derived from it. Epidote is less common.

Zircons are common trace constituents and include grains up to about 0.2 mm across. Tourmaline is less common and garnet is very rare.

The dark coloured rock is finer grained, averaging about 0.05 mm, and consists mainly of oriented biotite and opaque grains with interstitial quartz. Chlorite, tourmaline and zircon are rare accessories.

The contact between dark and light lithologies is at about 45° to the length of the core. The foliation is at about 60° to the length of the core.

Comment

Contact between lithologies is almost certainly sedimentary and represents a bedding plane. The directional fabric is a metamorphic foliation which is schistose but relates to a relatively low grade of metamorphism (greenschist facies). It is not pronounced enough to form a marked cleavage.

Although only one metre from specimen RS 154, the rock has avoided hydrothermal alteration which must be retrogressive in effect. This alteration is apparently controlled closely by the presence of fractures.

Specimen 6728 RS 156, TS C 50389 731'9" - 732'3" (c223.1 m)

Rock name Quartz-biotite schist

Hand specimen

A thin (7mm) band of very fine grained dark grey rock cuts a fine grained light grey rock.

Thin section

The main constituents of both the light grey rock and the darker band are quartz, opaque minerals and biotite but there are minor differences between this specimen and RS 155. Quartz is more abundant in both fine and coarse grained sediments in comparison with equivalents in RS 155. Feldspar is fresh enough for plagioclase and microcline to be identified as minor components of the light coloured lithology.

Trace minerals include zircon, tourmaline, epidote, garnet, apatite and chlorite.

Biotite exhibits a strong preferred orientation but quartz is less preferentially oriented than in RS 155.

Comment

The rock is a moderately metamorphosed sandstone with a siltstone band. An original clay content is now oriented biotite. Trace minerals have been little affected.

Specimen 6728 RS 157, TS C 50390, 763'4" - 763'7" (c233.8 m)

Rock name Amphibolite.

Hand specimen

The rock is fine grained, dense, coherent and varies in colour between green and grey. The colours are transitional rather than sharply bounded but one end of the specimen is green and the other grey. As well as a gradual change in the dominant colour, lenticular patches of green occur in grey areas and grey in green areas. These patches impact a directional fabric to the rock through preferential orientation of long axes.

Thin section

The section consists mainly of green rock. The most abundant constituent is hornblende. A pale, weakly pleochroic biotite is also common and opaque minerals are abundant. Minor and trace constituents include epidote, chlorite, sericitic muscovite, dolomite, apatite, sphene and a feldspar which is probably anorthoclase.

Hornblende occurs as irregular, often ragged grains in closely-interlocked clusters. It is strongly pleochroic from blueish green to pale yellowish brown. Individual crystals are not strictly oriented but in aggregate the hornblende forms bands.

Biotite is generally interstitial to hornblende, forming a close mass without consistent orientation.

Opaque minerals are closely associated with hornblende as fine grains and irregular patches. Occasionally clusters of opaque grains make up lenticular patches up to 5 mm long. A banded disposition is pronounced in aggregate distribution.

Light coloured patches, usually bands and lenses, consist largely of platy minerals. The most abundant of these is a fine grained, irregularly crystalline, colourless mica which is probably a sericitic muscovite. In places a pale green, pleochroic chlorite is associated with the mica. Relict crystals of a biaxial negative feldspar with a 2V of about 45° are probably anorthoclase. It is possible that the abundant sericite was derived from original feldspar.

Calcium-bearing phases such as epidote, apatite and sphene, as well as dolomitic carbonate are in close or approximate association with the light coloured patches. Epidote is moderately abundant in some areas but the other three minerals occur as scattered grains.

A few thin, discordant veins contain chlorite, epidote, plagioclase and dolomite.

Comment

The original characteristics of the rock have been modified by regional metamorphism of a moderate severity extensive enough to introduce uncertainty as to the origin of the rock. Mineralogical evidence suggests an igneous rather than sedimentary origin but chemical analysis would assist in the diagnosis. The mineralogy indicates high calcium with moderately high magnesium and iron, suggesting an andesitic basalt or basaltic andesite in the igneous field. Strong metamorphism of a siliceous and magnesian limestone might produce a similar assemblage but no carbonate remains. Since the latter origin

implies a relatively strong alteration, it is possible that contact metamorphism occurred and may have involved metasomatic action.

Specimen 6728 RS 158, TS C 50391, 796'7"-796'10" (c242.9 m)

Rock name Amphibolite.

Hand specimen

The specimen contains a contact between fine grained, dark green rock and light grey rock. The contact is at about 45° to the length of the core. A fracture with light coloured wall rock is parallel to the contact within the green lithology. The wall rock contains brown minerals. Between this and the grey rock a greenish grey transition zone is offset by microfaults. Thin, pale, veinlets run parallel to subparallel to the length of the core. Fine grains of pyrite are distributed through both green and grey lithologies.

Thin section

The section does not include the grey lithology but part of the transitional zone shows an increase in plagioclase relative to hornblende. Grain size variation produces a fabric of parallel laminations on a scale of about 1 mm. Strongly preferential orientation of hornblende grains produces a marked foliation throughout the whole rock, including coarser and finer grained bands.

The mineralogy of the rock is essentially the same as that of RS 157 but proportions of individual phases differ. Hornblende is more abundant in RS 158 and the constituents of the grey lithology much less abundant than in RS 157. Opaque grains are very frequent and include pyrite, as seen in hand specimen.

Hornblende is generally finer in grain size than in RS 157 but somewhat coarser grains occur in veins occupying both conformable and discordant fratures. The grains are of prismatic dimensions but of poor shape and form closely packed bands, often with little interstitial material. The mineral is moderately well crystallised and shows the same pleochroic scheme, blue green, green and yellow brown, as in RS 157.

Pale biotite is present interstitially to hornblende in some bands.

In lighter coloured bands feldspar is a major constituent but in most of the rock it is rare. Occasionally polysynthetic twinning indicates that the feldspar is plagioclase but most grains are untwinned.

Epidote, sericitic mica and dolomite are rare except in veins.

Opaque grains are abundant and consist mainly of very fine, elongated grains with a strong preferential orientation and distribution. Coarser grains with a random orientation and generally irregular shape are less abundant but widely distributed. These are probably sulphide.

Comment

The composition of the rock is of igneous rather than sedimentary type but the laminated texture is more akin to sediments than magmatic rocks. A pyroclastic origin would reconcile the apparent conflict of evidence. The rock may originally have been an ash fall tuff of relatively distal deposition. The composition is that of an andesitic basalt.

Specimen 6728 RS 159, TS C 50392, 807' - 807'3" (c246 m)

Rock name Quartz-biotite schist.

Hand specimen

The section of core includes a contact, dipping at about 45° to the length of the core, between an altered finely laminated silty and shaley rock and a darker, finer grained and more uniform altered shaley lithology.

Thin section

The thin section does not include the shaley lithology but consists of laminated metasediment with grain sizes between 0.5 mm and 0.01 mm and knots about 0.5 mm across. The constituents are biotite, quartz, opaque minerals and muscovite.

Biotite is the most abundant component overall but quartz is dominant in the coarser grained laminations. The biotite is pale brown and weakly pleochroic. Most flakes are 0.1 mm to 0.2 mm long with a strong preferred orientation.

Quartz grains are irregular to elongated in shape and also tend to be preferentially oriented.

Opaque grains are fine, elongated and preferentially oriented.

Muscovite occurs as scattered flakes between those of the oriented biotite but is more concentrated in the knots. These consist of fine grained biotite, muscovite and opaque minerals closely interlocked in random orientation. The oriented minerals of the main fabric sweep around the knots, indicating that the latter predate the metamorphism.

Comment

The minerals present are of normal detrital origin with metamorphic recystallisation. No material of volcanic origin is identifiable. The specimen is of similar lithology to RS 156.

Specimen 6728 RS 160, TS C 50393, 838'-838'3" (c255.4 m)

Rock name Schistose quartzite.

Hand specimen

The core contains a contact between a pinkish brown rock with poorly defined pink spots and oriented linear patches and a dark grey, finer grained rock with a different foliation. The contact dips at 45° to the core barrel. A few grains of pyrite are present.

Thin section

The section contains a very small area of the dark grey rock but it is enough to identify a biotite schist with ovoid and lenticular patches of coarser grained biotite. Fine grains of dolomite are scattered through the rock and a few coarser patches are present. Epidote and opaque minerals are also present as coarse and fine grains. The biotite is pale brown and grades from strongly pleochroic to almost isotropic. Fully isotropic

brown flakes are probably chlorite but may possibly be a biotite with a poorly crystalline structure. The platy minerals exhibit a strongly preferential orientation parallel to the contact.

The light coloured rock contains abundant quartz with minor feldspar, epidote, dolomite, muscovite, chlorite and opaque minerals. The quartz is distributed in irregular bands and lenticular patches of differing grain size with an approximately consistent orientation perpendicular to the core barrel. The patches are highly recrystallised with a mosaic fabric and simple intergranular contacts which often form 120° triple junctions.

Feldspar is moderately abundant and often occurs as single grains, sometimes coarse enough to be visible as pink crystals in hand specimen. Most of the grains are fresh enough to display an irregular polysynthetic twinning. Both parallel twins and a few cross-hatched twins are present and the feldspar may include both palgioclase and microcline. Some feldspar occurs in groups of grains rather than individually and are usually cloudy with alteration. These form the indistinct pinkish patches seen in hand specimen.

Epidote often occurs in the patches of altered feldspar as irregular grains and aggregates. Finer grains are distributed throughout the rock.

Dolomite occurs as relatively large, irregular patches with an apparently random distribution through the rock.

Muscovite is quite abundant and widely distributed, both as fine, disseminated flakes and coarser flakes which are often associated with coarse grained epidote and feldspar. The fine muscovite is generally oriented preferentially.

Green, pleochroic chlorite occurs as sparse, wispy flakes with a random distribution.

Opaque grains are less abundant than in the dark coloured rock and occur in scattered patches.

Comment

The high degree of recrystallisation again obscures the origin of the rocks. There is no evidence that the contact is other than sedimentary. The argillaceous rock contains carbonate which may be original but the carbonate in the arenaceous rock was almost certainly introduced. There appear to be two generations of feldspar in the arenaceous metasediment. Cloudy, altered feldspar in patchy aggregates may be the product of regional metamorphism, possibly redistributed from sedimentary clasts, but the unaltered feldspar may be metasomatic in origin. Biotite in the meta-argillite clearly indicates the effect of regional stress by preferential orientation but in the arenaceous rock a post-metamorphic recrystallisation has blurred the metamorphic foliation and superimposed another oriented fabric. The presence of unaltered feldspar suggests that this recrystallisation may have involved the introduction of some material, possibly both siliceous and feldspathic, in a metasomatic process.

Specimen 6728 RS 161, TS C 50394, 850' - 850'3" (c259.1 m)

Rock name Greisenised metasediment with ? volcaniclastic contribution.

Hand specimen

The section of core is terminated by fractures at about 60° to the length of the core. A zone of resealed fractures 7 mm wide near one end of the specimen dips in a parallel direction. The zone contains abundant biotite and pyrite. The major part of the rock is grey with scattered pink grains about 1 mm across.

Thin section

The rock consists largely of quartz and feldspar with minor muscovite and biotite and traces of chlorite, tourmaline, dolomite and opaque minerals. Fluorite is a major constituent of the vein system.

The major part of the rock consists of a close intergrowth of quartz and feldspar. Grain size varies with the extent of recrystallisation in patches which are distributed with a weakly preferential orientation. The proportions of quartz and feldspar are somewhat similar but quartz is slightly the more abundant.

While quartz grains are all anhedral, some of the larger grains of feldspar approximate to euhedral. Both parallel and cross-hatched polysynthetic twinning are evident in the feldspar but plagioclase appears to be more abundant than microcline. It is not possible to distinguish two generations of feldspar on the basis of intensity of alteration in this specimen. Some feldspar occurs with quartz in lenses of coarse recrystallisation which may be introduced.

Both muscovite and biotite occur as disseminated flakes but biotite forms bands of scattered flakes with a strict orientation. Muscovite is common in patches of coarse grained quartz and feldspar and in the zone of veins containing opaque minerals, quartz and fluorite. The orientation of the biotite bands is not exactly the same as that of the veins and of coarse quartz and muscovite.

Chlorite is an alteration product of biotite. Tourmaline occurs as scattered fine grains. Dolomite forms a few random patches.

Opaque grains are scattered sparsely through the rock but are concentrated in the fluorite veins. In this latter situation the mineral is pyrite.

Comment

Fluorite, pyrite, muscovite, quartz and feldspar occur in veins and some lenses where the evidence indicates that they have been introduced. Minerals such as intergrown quartz and feldspar forming the main part of the rock appear unlikely to have been introduced but the evidence is not definitive. Muscovite occurs in the main part of the rock but only as a minor component. This may have been introduced.

It is clear that a post-metamorphic greisenising process has been applied to an original sediment but the extent to which granitisation has occurred is obscure. Some of the almost euhedral feldspars may have been inherited from the original sediment. If so, there may have been a volcaniclastic contribution.

Specimen 6728 RS 162, TS C 50395, 875'6" - 875'9" (c266.9 m)

Rock name Feldspathic quartzite and altered greenstone.

Hand specimen

The specimen contains the contact between a patchy, pink, siliceous lithology and a patchy, greenish black lithology. The dark rock intrudes slightly the pink rock at the contact.

Thin section

The pink rock is essentially a fine grained, closely intergrown mosaic of quartz grains with feldspar, muscovite, dolomite, and sparse biotite, chlorite, zircon and opaque minerals. The dark rock consists of chlorite and altered feldspar with patches of muscovite, dolomite, quartz, clear feldspar and opaque minerals.

The quartz mosaic consists mainly of fine grains with simple intergranular sutures but patches of recrystallisation contain coarser grains with more complex margins. No directional fabric is evident.

Feldspar is abundant and includes both microcline and plagioclase. It occurs as fine grains closely intergrown with quartz and as coarse grains and mosaics up to 1.5 mm across. Both types of feldspar distinguished in specimen RS 160, fresh and cloudy, occur also in RS 162. Fresh feldspar occurs in close association with fine quartz grains, as single coarse crystals and as mosaics making up large patches which are often shaped like a single crystal. Feldspar which is cloudy from strong alteration occurs abundantly in the fine grained part of the lithology but rarely as large masses and grains. At the margins of a few large feldspar grains ordered intergrowths with quartz occur on the scale of myrmekite and of graphic microgranite.

Muscovite flakes of very irregular, ragged shape are scattered randomly through the pink rock. Some are isolated but others are closely associated with equally irregular dolomite crystals. Dolomite also occurs independently of muscovite, notably in discordant veins, but the two minerals are closely enough associated to suggest a genetic link.

Fine flakes of a purplish grey mica and of chlorite are disposed in the form of open bands which may include the original foliation of the sediment.

A few crystals of zircon and opaque minerals are distributed randomly in the pink rock.

The dark green rock consists mainly of a close intergrowth of oriented chlorite and interstitial cloudy feldspar. At the contact between the dark green and pink lithologies oriented chlorite is closely packed. A vein of chlorite cuts into the pink rock.

The lithology is complicated by the frequent occurrence of large (1 mm) crystals of dolomite in patches up to 5 mm across, by ragged muscovite flakes about 2 mm across and by patches of quartz and clear feldspar up to 3 mm across. The patches of all these minerals occur together in a wide zone and are probably associated.

Fine grains and intergranular sheets of opaque material are associated with chlorite.

Comment

Confirmation of two generations of feldspars and the simultaneous introduction of muscovite, dolomite, quartz and feldspar to the two contrasting lithologies indicates that at least two episodes of recrystallisation have taken place. The introduction of similar material to two contrasting host rocks confirms that metasomatism rather than simple recrystallisation of original minerals is the source of muscovite, dolomite, some quartz and some clear feldspar. The greenstone was originally magmatic rather than a carbonate sediment.

Specimen 6728 RS 163, TS C 50396, 920'-920'3" (c280.4 m)

Rock name ?Minor intrusive

Hand specimen

The rock is of medium, even grain size and is speckled in greenish brown and white. A thin, white vein cuts the core at about 45° and is bordered by zones of decreased colour

contrast. Grains of pyrite are sparsely distributed through the rock. There is no visible preferential orientation.

Thin section

The rock is essentially a closely interlocked fabric of mica and feldspar. Minor chlorite, quartz, carbonate, epidote, opaque minerals and sphene are also present.

The mica is mainly biotite of an olive green colour but muscovite is moderately abundant. Chlorite locally replaces biotite.

The feldspar is strongly altered and much of the muscovite content of the rock appears to be derived from the alteration of feldspar. The original nature of the feldspar is obscure. Patches of myrmekitic intergrowth have replaced feldspar grains at many points.

Irregular grains of quartz and dolomite are widely distributed as individual crystals or mosaic patches. Epidote is rare but occurs as a replacement of both mica and feldspar.

Opaque minerals are widespread as fine, anhedral grains and patches and occasionally present as large subhedral to euhedral crystals. The latter are probably pyrite. Sphene is largely associated with opaque material, possibly as an alteration product, but also occurs as independent crystals.

The vein which is visible in hand specimen contains continuous dolomite. Decolourisation of the wall rock observed in thin section is the result of alteration of biotite to chlorite.

Comment

The absence of a regional foliation but the presence of alteration and the probable introduction of both quartz and carbonate indicates that the rock probably originated as a post-Delamerian minor intrusion which antedated the major phase of plutonic intrusion in the area. The original composition of the rock is obscure but was probably considerably more basic than the present, post-metasomatic composition.

Specimen 6728 RS 164, TS C 50397, 921'3"-921'6" (c280.9 m)

Rock name ?Minor intrusive

Hand specimen

The rock is similar to RS 163 but with a less pronounced difference in shade between dark and light coloured minerals. Sulphide is more abundant in RS 164 than in RS 163. A band of olive green mineral at about 40° to the core barrel separates a corner of the core section in which dark minerals are more abundant than in the rest of the specimen.

Thin section

The major part of the section consists of a more strongly altered variant of RS 163. More biotite is altered to chlorite and more feldspar is altered to muscovite. More quartz and dolomite are present. Pyrite grains are more abundant, larger and of better shape.

The darker colour of one part of the section is due to a lesser degree of alteration in the biotite. Other constituents are similar to those in the lighter coloured part of the specimen.

Comment

A greater degree of alteration of the original biotite and plagioclase in the specimen than occured in RS 163 is linked to the introduction of additional muscovite, quartz, dolomite and pyrite. These are apparently the constituents of metasomatising fluids.

Specimen 6728 RS 165, TS C 50398, 1000'3" - 1000'6" (c305 m)

Rock name Quartzite with chlorite bands and quartz vein.

Hand specimen

The rock is grey and fine grained apart from chlorite bands up to 4 mm thick and a quartz vein at one end of the core section. The vein has disrupted the grey rock. The grey rock cleaves at about 40° to the core length but the quartz vein and chlorite bands trend at about 50° in the opposite direction to the foliation.

Thin section

The rock is a recrystallised quartz sandstone with one directional fabric defined by lines of opaque grains and green, pleochroic chlorite flakes and a second defined by a tendency to elongation of quartz grains. The quartz varies considerably in grain size but this is probably more the result of varied recrystallisation than of original bedding.

Tourmaline, zircon and biotite are minor constituents.

The chlorite band also includes opaque minerals, biotite, tourmaline and apatite. Thin selvedges of chlorite and opaque patches occur at the margin of the quartz vein. The latter consists of interlocking quartz crystals up to 12 mm across with thin interstitial patches of chlorite and rare carbonate.

Several thin fractures in random directions are filled with carbonate and occasional patches of chlorite and epidote.

Comment

Three different structural elements are distinguishable in the fabric. An episode which left its imprint on the plane of shearing of the rock and on bands of chloritised biotite is probably the Delamerian orogeny. Elongation of quartz grains and patches is oriented on a different plane. Intrusion by a quartz vein disrupted the rock and imposed a third directional fabric.

Thin veinlets of carbonate, chlorite and epidote merge with the chlorite selvedge and quartz vein and are possibly contemporary with it.

Prior to these episodes the rock was probably a quartz sandstone with a small clay content which later metamorphosed to biotite and finally retrogressed to chlorite.

DISCUSSION

a. Summary

All the specimens examined are characterised by extensive recrystallisation involving several episodes of varied types of alteration. Despite this it is possible to identify two main categories with reasonable confidence as to their origin; sedimentary and magmatic/pyroclastic respectively. A third category is identified tentatively as a greisenised arkosic metasandstone with a component of coarse grained alkali feldspar which may be either porphyroblastic or volcaniclastic in origin. This is the rock type identified initially by a consultant for North Broken Hill Ltd as a rhyolite, perhaps on the basis that the large alkali feldspar crystals are phenocrysts. Similar feldspars occur in a specimen of quartz-biotite schist which is undoubtedly metasedimentary and classification as a rhyolite appears untenable.

b. Lithological categories

1. Metasediments

Three major mineral components dominate the metasediments; quartz, biotite and feldspar. While none of these occurs without at least one of the others, the colour and grain size of the rocks depend on which of the three component minerals forms the main framework. Dominant quartz produces a grey and relatively coarse-grained rock. Examples are:

RS	Depth in feet
154	730
155	731
156	732
159	807
165	1 000

Biotite is dominant in fine grained black or dark greenish brown rocks. In the specimens selected, the dark lithology is generally in contact with light coloured lithologies. Examples are:

RS	Depth in feet
155	731
156	732
159	807
160	838

Feldspar usually imparts a pink tint to the rock and may also produce pink spots or patches if coarse-grained crystals are present. An exception to this rule is RS 161 in which the main framework of the rock is grey despite abundant feldspar; pink spots denote coarse feldspar grains in that specimen. Feldspar is identifiable in the quartzose metasediments and often appears to include two generations, one altered and the other fresh. Some feldspar may be present but below detection in the dark lithologies. Samples are listed in order of increasing feldspar content:

RS	Depth in feet
155	731
156	732
160	838
162	876
161	850

2. ?Metasediments

The specimen identified tentatively as a metasediment but in which some of the feldspar may possibly be of volcaniclastic origin is RS 161. Finely divided feldspar with little alteration is closely interlocked with quartz in the major part of the rock. Feldspar is almost as abundant as quartz. Coarse-grained feldspars, both microcline and plagioclase, with little alteration are also present as grains with shapes occasionally approaching a euhedral shape. A few grains consist of a mosaic of separate grains within the outline of one euhedral crystal. Feldspars such as these may possibly be recrystallised phenocrysts but porphyroblasts may also occur in euhedral form. Recrystallisation has been intense enough to make the origin uncertain. Since other specimens which are clearly not

volcanic in origin contain porphyroblastic feldspar, it appears unlikely that the rocks were originally rhyolites.

Similar rocks to RS 161 have been identified from the same drill hole, S1, by other workers. They are listed here:

Source	Number	Depth in feet
This study	6728 RS 161	850
Simon Turner (Adelaide Uni)	876-1	864
Tony Wegmann (" ")	775-89	885
Alec Whittle (North Broken Hill Ltd)	DDS 1	930

3. Metabasic rocks of igneous/pyroclastic origin

These rocks fall into three categories: amphibolites of tuffaceous origin, chloritic rock of probable hydrothermal origin and biotite - plagioclase rocks of probable minor intrusive origin. Of the amphibolitic rocks RS 157 is weakly amygdaloidal and was probably an ash-flow tuff while RS 158 is laminated and probably an ash - fall tuff. Depths are:

RS	Depth in feet
157	764
158	797

The chloritic rock, RS 162, is of slightly doubtful origin. The specimen contains quartzite as well as chloritic rock but the latter appears to be intrusive at the contact and may have igneous affinities. Chloritic bands in RS 165 appear to be related to a quartz vein and it seems likely that the chlorite in both specimens examined may be of hydrothermal origin. Depths of the specimens are:

RS	Depth in feet
162	876
165	1 000

Two rocks composed mainly of biotite and plagioclase are recrystallised but unfoliated. If this is taken to indicate an origin after the Delamerian Orogeny but before an episode of strong thermal metamorphism, the rocks are probably intrusive into pre-Delamerian sediments. Minor intrusive activity appears to have continued from before to after the Delamerian Orogeny.

The rocks are:

RS	Depth in feet	
	163	920
	164	921

c. Fabric and alteration

Contacts between dark and light coloured metasediments indicate the original bedding (RS 155) and in some specimens (RS 159) lamination is also probably of sedimentary origin. Flattened amygdales are probably a depositional fabric.

Superimposed on the sedimentary fabric is a foliation expressed by preferential orientation of mica flakes or elongated quartz grains. This fabric may be parallel to the bedding (RS 154) or at an angle to it (RS 155). The preferential orientation of mica may be the same as that of quartz (RS 154) or may differ (RS 165). Recrystallisation of a moderate severity but with a preferential orientation is ascribed to greenschist metamorphism associated with the Delamerian Orogeny. In the same episode opaque minerals were also recrystallised into elongated grains with a preferred orientation. Feldspars may be recrystallised but retrogress to a cloudy, probably argillaceous, poorly-crystalline material

Drill hole S1 is situated to the north of major subcrops of mafic-ultramafic intrusions and to the south of granitoid plutons such as the Long Ridge Granite. The heat flow consequent on the introduction of large volumes of basic to ultrabasic magmas in particular has effected a strong thermal recrystallisation on country rock in the area. Some recrystallisation has apparently occurred under directional

stress, possibly related to the intrusion process but possibly a late stage of the regional orogeny with a change in the stress vector, which has imposed preferential orientation on, for example, ovoid patches of mosaic quartz (RS 155). The intensity of thermal alteration varies through the drill hole intersection and may indicate an irregularity in the igneous contacts extreme enough to suggest a series of sheeted dykes or sills.

The greater the extent of thermal recrystallisation, the higher the probability of introduced constituents. Mobility of individual constituents may vary between redistribution within the area of one thin section to metasomatic reactions extending over kilometres. Minor redistribution may result in nothing more than elongated quartz grains (RS 154) but in lithologies such as RS 161 it is clear that fluorite, quartz, muscovite, feldspar and pyrite have been introduced in discordant veins. In some specimens (eg RS 160) part of the feldspar is altered and part fresh. While simple recrystallisation might have affected all the feldspar equally, to produce two generations of feldspar it appears necessary to introduce the fresh mineral. In that specimen it appears that quartz, muscovite and dolomite were introduced with new feldspar.

Muscovite occurs sparsely in some specimens (RS 154) as an interstitial constituent which is probably still in place. It occurs more abundantly in veins and patches of recrystallisation (RS 161) where it has almost certainly been introduced. The combination of muscovite, quartz and fluorite as mobile constituents suggests a weak greisenisation which may be associated with granitoid plutons rather than the basic-ultrabasic suite.

When dolomite occurs in veins and discordant patches (RS 163 and 160 respectively) it is clearly metasomatic in origin. Fine grains distributed through metasediments may have originated in place but evidence is ambivalent. Carbonate is too rare to support a sedimentary origin for the amphibolitic specimens. On balance the evidence suggests that dolomite became mobile at a late stage in the alteration of the sediments.

d. Conclusions

From extrapolation back through the episodes of alteration it seems possible that the majority of rocks intersected in drill hole S1 were originally sediments similar to those known in outcrop as the Kanmantoo Group. Both mature lithologies, in which the framework is composed of quartz and there is little or no matrix, and immature lithologies, with feldspar and clay minerals, are represented in S1, as they are in the Kanmantoo succession.

A volcanic component is not seen in the outcropping Kanmantoo sediments but substantial basic lavas and pyroclastics have been intersected in drilling of the Murray Basin basement rocks. These are possibly contemporary with sedimentation in the Kanmantoo Trough. Not enough data are available for a definitive conclusion, but it is at least possible that the amphibolite tuffs in S1 (RS 157 and 158) are equivalent to the much more abundant volcanic rocks to the south east. Transition between the two contrasting lithologies and environments may be through progressive interdigitation rather than a sharp tectonic or depositional contact.

The alternative hypothesis, that the succession in DDH S1 may be equivalent to the Early Cambrian Hawker and Normanville Groups rather than the later Cambrian Kanmantoo Group, cannot be dismissed at this stage. It is supported by a known volcanic component in the Truro Volcanics and the overlying Heatherdale Shale. However, the evidence against the hypothesis is at least equally compelling. The Kanmantoo metasediments are dominantly arenaceous. The Early Cambrian succession is dominated by carbonate sedimentation and arenaceous detritus is minor relative to argillaceous deposition. None of the evidence is definitive and neither hypothesis is conclusive.

The minor intrusives (RS 163 and 164) are of intermediate composition and may be hybridised magmas derived from basic plutons by assimilation of country rock.

The enigmatic 'rhyolite' appears on balance to be a metasediment which was originally feldspathic but which has been subjected to metasomatism as well as metamorphism. The metasomatism is at least partly a greisenising process but some of the fresh feldspar may be a product of this episode. An outside possibility remains that some porphyritic crystals may be pyroclastic in origin.

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