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ROCKS FROM THE KANMANTOO TROUGH NEAR SEDAN HILL INCLUDING POSSIBLE EQUIVALENTS TO THE TRURO VOLCANICS

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by

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ABSTRACT

A collection of rock specimens from various localities near Sedan Hill in the South Mount Lofty Ranges is heterogeneous in both original rock type and the extent of metamorphic and metasomatic alteration. Considerable variation in the alteration of rocks from relatively close outcrops may indicate movement on intervening faults which is substantial enough to bring representatives of widely different depths of burial into juxtaposition. Strong granitic metasomatism may indicate the presence of substantial granitoid plutons which are not known in outcrop and some of which apparently antedate at least the latest episode of deformation. Confirmation of the continuation of significant andesitic volcanism during Heatherdale Shale times suggests the need for a reappraisal of the nomenclature and concept of the Truro Volcanics.

INTRODUCTION

Twenty one hand specimens with thin sections were received for petrographic examination from Colin Gatehouse of the Regional Geology Branch. The specimens were collected from the Kanmantoo Trough on the east side of the Mount Lofty Ranges at localities to the south and to the east of Sedan Hill. Sedan Hill is approximately fifteen kilometres east-south-east of Angaston and seventy kilometres north east of Adelaide. Some of the specimens are of volcanic origin and may be equivalent to the Early Cambrian Truro Volcanics, in this instance forming part of the Heatherdale Shale unit.

PETROGRAPHY

Specimen 6728 RS 36, TS C43693, 3132/66/2a

Rock name Calc silicate gneiss or hornfels.

Hand specimen

The specimen is lenticular in external shape and exhibits a weakly crenulated foliation based on a compositional banding. This is visible on the weathered faces of the specimen but is more clearly defined on the sawn face. Individual grains are not well defined and the rock presents a continuous texture and rather vitreous lustre. Scattered grains with a metallic lustre include bronze coloured pyrrhotite, brassy pyrite and a steel coloured reflecting mineral which may be ilmenite.

Thin Section

Compositional zoning is seen in thin section to be the result of variation in the relative proportions of dolomite, pyroxene, amphibole, plagioclase and quartz. These are the main constituents of three basic mineral assemblages, a dolomitic assemblage, a pyroxene-amphibole assemblage and a plagioclase-quartz assemblage. The relative proportions of minerals within the assemblages vary and none of the minerals is restricted to one assemblage only but may occur as inclusions in any assemblage.

The dolomite occurs in coarse grained, ellipsoidal crystals which are seen to be deformed as curved twin and cleavage planes are strongly marked by fine grained, opaque inclusions. Coarser grained inclusions of minerals and aggregates from the silicate assemblages are common but vary in abundance from band to band of the dolomite. Dolomite also occurs as a matrix to silicate minerals in some bands which represent an assemblage in which the inclusions are more abundant than the dolomite. Rare discordant veins carry dolomite as a filling.

The most abundant mineral assemblage seen in thin section, which may or may not be representative of the whole formation, consists of three pyroxenes, two amphiboles, chlorite, sphene and apatite. The most abundant pyroxene is a colourless diopside but a second common species is akin to pigeonite with an optic axial angle of close to 0°. These occur as single crystals of a rounded shape and, less often, as large irregular sub-ophitic plates. In a few places pyroxenes are continuous over a wide area. A less abundant pyroxene is green and pleochroic and occurs as scattered grains. In one band very coarse grained, elongated, curved grains of the green pyroxene are associated with a large, irregular patch of a steel grey, opaque mineral which is probably ilmenite. The colour of the pyroxene is very patchy and a colourless rim has grown on a few of the grains. The pyroxene is soda-rich but varies in composition between aegerine augite and diopside.

The amphibole is mainly colourless and probably of tremolitic composition. Local patches of amphibole are pleochroic from green to yellow brown and are probably of soda hornblende rather than riebeckite composition. Amphibole occurs as single grains of simple outline but is commonly present as large, ophitic plates in which the cavities are filled with diopside, dolomite and plagioclase. A form which appears to be intermediate between individual grains and a large ophitic mass consists of contiguous domains with diffuse boundaries and similar but not exactly consistent optical orientation. Together they form a large continuous mass but the orientation of original pyroxene grains has not been changed sufficiently by recrystallisation to form an optically continuous crystal of tremolite.

The amphiboles and pyroxenes are the most abundant components of this assemblage but chlorite is occasionally present as an alteration product and sphene is common in irregular grains. A few grains of apatite are also present.

The third basic assemblage is a closely interlocked mosaic of quartz and plagioclase grains. The plagioclase is not sharply twinned but exhibits weak, diffuse, shadowy bands in a parallel arrangement which are probably incipient polysynthetic twins. Many grains can only be identified in conoscopic illumination by biaxial optics. The quartz in the same assemblage is often strained and exhibits imprecise, undulose extinction and poorly defined optics. The relative proportions of these two minerals are uncertain but plagioclase appears to dominate the assemblage. The grains are closely juxtaposed in a mosaic with simple grain boundaries, often meeting in 120° junctions. The mosaics form compositional bands but other minerals such as amphiboles and chlorite are common inclusions and small veins of dolomite cut the bands.

Comment

The specimen was collected from an outcrop of the 'Milendella Limestone Member' in which a quartz-albite lithology is shown as occurring. This is confirmed in thin section, with evidence that the carbonate is dolomite rather than calcite. The composition of the plagioclase could not be determined. The petrographic evidence also indicates compositional bands of magnesium silicates are intimately associated with the two mapped lithologies. It is not clear from the petrographic evidence whether compositional banding is the result of metamorphic differentiation or was inherited from variation in the composition of the original sediments. Field evidence of mappable units of the three lithologies suggests that compositional banding in the metamorphosed rocks is the result principally of the variation in calcium and silica in the original dolomitic and siliceous limestone. If this is so the rock may perhaps be more correctly designated a hornfels than a gneiss.

Specimen 6728 RS 37, TS C 43694, 3132/66/2b

Rock name Foliated dolomite with calc silicate inclusions

Hand specimen

The shape of the specimen is determined by foliation planes and there is a marked preferred orientation evident in the fabric of both broken and sawn faces. Colour bands are relatively thin and are only weakly delineated in shades of brown and grey. Individual grains of green and brown are seen as inclusions in the yellow brown matrix.

Thin section

The rock is essentially a dolomite with silicate inclusions in contrast with RS 36 in which dolomite is subordinate to silicates. This probably implies a lower silica content in the carbonate sediment.

The dolomite is deformed and occurs in elongated ellipsoidal grains, often with minor granulation along the grain boundaries. Limonitic staining has penetrated some grain boundaries. Some dolomite crystals exhibit flow on the evidence of distorted planes delineated by opaque inclusions. Flow lines often deflect around silicate inclusions, indicating that the deformation may post date the metamorphic episode responsible for the formation of the silicates. The rock may have originally been a hornfels without an oriented fabric.

The silicate grains include pyroxene, amphibole, plagioclose, sphene and a pale brown, pleochroic biotite or iron bearing phlogopite. The silicates are distributed in single grains and small patches throughout the specimen but in higher concentrations in some bands than others.

Comment

The specimen is similar to RS 36 in its origin as a carbonate sediment metamorphosed to a hornfels but differs in its lower silica content and in the presence of mica which indicates that clay was an original component. The evidence suggests that the prograde metamorphism which produced dominantly magnesian silicates from reaction between quartz and carbonate antedated completely or partially the regional deformation. The sediments may have been hornfelsed by heat flow related to igneous intrusion within the deeper and more easterly part of the Kanmantoo Trough before at least the final stages of the Delamerian orogeny.

Specimen 6728 RS 38, TS C 43695

Rock name Biotite phyllite

Hand specimen

The specimen is composed of two distinct parts. The larger part is a coarse grained, quartz-biotite rock containing many light coloured, lenticular pods a few millimetres in diameter. The smaller part is a dark grey, fine grained sandstone with a high proportion of well oriented biotite. The latter part is separated from the former by a plane which is parallel to the foliation but which is almost certainly a bedding plane. A few light coloured, lenticular pods similar to those in the coarser rock have been incorporated in the dark, fine grained rock. These are oriented at random. The pods in the coarse grained rock are consistently oriented parallel to the plane separating the two rock types and to the foliation. If the few pods in the dark rock have been incorporated after removal from the light rock, the dark rock must be younger than the light rock and the time interval between them must have been sufficient for the lenticular pods to have become coherent entities. This implies at least partial lithification. Surface dessication of the coarse grained, light rock prior to the influx of deep water and fine sediment is possible.

A fine, light coloured veinlet cuts the rock at a shallow angle to the bedding and foliation.

Thin section

In many respects examination of the thin section is less informative than the hand specimen or the outcrop. The distinction between the two rock types is seen to be restricted largely to grain size variation and the abundance of biotite. The light, lenticular pods are not as sharply distinct from the host-rock as appears in hand specimen. Their boundaries are transitional and are marked by the alteration of biotite progressively through chlorite to clay minerals. The plane separating the coarse and fine grained parts of the specimen is somewhat uneven due to the light lenses.

One feature which is not obvious in hand specimen but is clear in thin section is that the framework of the rock includes a considerable proportion of feldspar. Orthoclase is common and a few grains of plagioclase are also present. The rock has been substantially recrystallised and the quartz grains are in close contact with each other along relatively plane boundaries. Triple junctions are common and often approach 120°. Feldspars tend to be less regular in shape. Some grains are altered.

Biotite occurs in fresh, well shaped, fine grained flakes with a strong preferred orientation.

A few fine grains of sphene and zircon are present, mainly in the coarser grained lithology. Fine grained apatite is relatively common throughout.

The white patches are distinguished by the absence of biotite. As already noted, the margins of the patches are marked by progressive alteration of biotite to a green chlorite and of the chlorite to clay. At the same time the feldspar alters to sericitic mica so that the pod is marked by a proliferation of low temperature platy minerals, produced presumably by hydrous solutions.

The discordant veinlet seen in hand specimen contains a dolomitic carbonate. It is a light brown colour and probably contained some iron. The walls of the veinlet are marked by alteration of feldspar to sericite and underlines the abundance of feldspar in the sediment.

Comment

The rock has been designated as a phyllite rather than a schist to emphasise that deformation has not been extreme and that foliation planes are not strongly enough developed to produce a schistose cleavage. Recrystallisation has been strong and the containing pressure during alteration was high but the gross sedimentary structures have been preserved.

The finer structures, such as the light coloured lenticular pods, may have been modified enough to conceal their origins. In the coarse grained rock the only feature distinguishing the light patches is a hydrous alteration. It is clear that such alteration in the wall rock of the veinlet is associated with solutions which are epigenetic on the scale of the hand specimen. It is not clear why solutions should have a selective effect on the main body of the rock.

Light coloured lenticular pods in the dark, biotite rich, fine grained rock are not only depleted in biotite but also coarser grained than the surrounding rock. If the pods are not removed from the underlying sediment and incorporated in the younger sediment, there must be a process capable of introducing coarser grains as well as hydrothermally altering the minerals. Possbily two quite distinct processes are involved. It has been suggested that one such process may be bioturbation.

Specimen 6728 RS 39, TS C 43696

Rock names Biotite phyllite and micaceous quartzite.

Hand specimen

Two lithologies are evident in the hand specimen. A lens of coarse grained, light-coloured, quartz rich rock is surrounded by finer grained, dark coloured, biotitic rock with a strong foliation. The boundary between the two lithologies is sharply defined on the cut surface of the specimen. Several coarse flakes of a colourless mica are distributed through the quartzitic lithology and are concentrated along the contact between the two rocks.

Thin section

The light coloured rock consists mainly of a closely interlocked mosaic of coarse quartz grains but also includes orthoclase, muscovite, opaque minerals, occasional dolomite grains and relics of a green biotite, most of which is altered to green chlorite. The chlorite is of penninite type with anomalous birefringence. Some grains are pseudomorphous after biotite but others are of fibrous structure. Radiating clusters of fibres are common. Some of the colourless mica occurs as large, irregular plates with a sieve texture enclosing quartz grains. Rare grains of apatite and epidote are also present. A weak orientation is evident in elongated quartz but not in the mica.

The dark rock consists of strictly oriented biotite flakes in a mosaic of quartz grains of about one third the grain size of those in the quartzite. Rare grains of plagioclase, orthoclase and muscovite are also present, with occasional grains of epidote, apatite and zircon. At the margin of the quartzite lens the biotite flakes retain the same orientation as in the rest of the rock but have increased in grain size about three times.

Comment

The major lithology of the hand specimen, and probably of the sedimentary unit it was collected from, is the strongly oriented biotite schist or phyllite. The pod of coarse quartz and muscovite with a much less marked orientation appears to be the product of a post-tectonic episode of recrystallisation rather than an initial sedimentary variation. The removal of biotite and precipitation of muscovite within the light coloured rock is probably linked with the growth of coarse biotite in the dark rock surrounding the pod. The marginal zone is also marked by the concentration of coarse muscovite, in both the light and dark coloured rock. The nature of the medium promoting recrystallisation is uncertain, as is the control determining the limits of the process itself.

Specimen 6728 RS 40, TS C 43697

Rock name Micaceous argillite

Hand specimen

The rock is fine grained with a soft and smooth texture and very little quartz. Some faces of the specimen appear to fracture conchoidally but others are plane surfaces controlled by joints, bedding or foliation. The rock is coloured yellow brown with a few patches varying between red brown and grey.

Thin section

The rock consists largely of strictly oriented biotite but much of the platy mineral is very fine grained, of very weak pleochroism and of low to moderate birefringence. The mica is probably altered to varied extents and the softness of the hand specimen is probably due to a substantial clay content. Some fine grained quartz is present, together with scattered coarser grained flakes of muscovite. Prismatic opaque minerals, weakly translucent amorphous brown limonite and paler, more dispersed iron oxide give the rock the various shades of brown seen in hand specimen.

Comment

The rock is probably a regionally altered mudstone in which micas are reverting to clays due to weathering processes. During prograde alteration the sediment probably reached a grade comparable with that of the other sediments collected from the area.

Specimen 6728 RS 41, TS C 43698

Rock name Agglomerate

Hand specimen

The rock is composed of angular fragments, up to 15 mm in diameter, of fine grained lithologies in a matrix of smaller fragments and a mass of fine, platy minerals. No erosional rounding is evident and no size sorting of fragments has occurred.

Thin section

Evidence of a volcanic origin is abundant. The lithic fragments consist of feldspathic lithologies in which porphyritic plagioclase is the dominant constituent. Plagioclase crystals vary in size and shape from fine, often preferentially oriented laths to relatively coarse grained, square shaped plates. The crystals occur in groundmasses varying from glassy to well crystallised. As far as may be determined from the small number of plagioclase grains in which alteration is light enough and the orientation is suitable for the measurement of symmetrical extinction angles, plagioclase compositions are in the range of oligoclase. A few feldspars are without visible polysynthetic twinning and may have been potassic. However, the possibility that they may have been untwinned plagioclase cannot be excluded and alteration is too heavy for clear evidence of composition to be retained.

Quartz is rare and where it does occur it often appears to be a late addition to the sediment. In places the silica is apparently of chalcedonic origin.

A few flakes of both brown and colourless mica may have been original constituents but are possibly alteration products of potash feldspar and ferromagnesium minerals.

The matrix of the agglomerate consists of fine lithic fragments and abundant mica flakes. The mica is brown and weakly pleochroic. It is probably a poorly-crystalline biotite. Occasionally plagioclase fragments occur within the matrix and at a few points the material between the lithic fragments contain abundant fine, consistently oriented plagioclase laths which appear to have grown within the interstitial ash.

Comment

The specimen is incontestably of volcanic origin and consists of fragments of lava and welded tuff in a matrix of former ash and fine fragments which is now largely biotite. The rock is the product of explosive volcanism and was probably deposited relatively close to the original vent. As far as may be determined from a non-altered mineral content, the composition of the volcanics was largely andesitic but may have included some variations towards a more potassic composition, either trachytic or dacitic, depending on how much of the small quartz content is original.

Specimen 6728 RS 42, TS C 43699

Rock name Vesicular andesite

Hand specimen

The specimen is so highly vesicular that is appears in hand specimen to be scoriaceous. The decision to avoid the name of pumice or scoria is based on the relatively coarse grain size of the rock as well as the ratio between rock and voids. The rock is pale grey and visibly granular. The vesicles are lined, and some are filled, by limonite. A few vesicles are seen on the sawn surface to be filled by fine biotite flakes.

Thin Section

The rock consists largely of plagioclase and is compositionally homogeneous. The plagioclase occurs in a variety of grain sizes and in two habits. It forms a ground mass of closely interlocked mosaic grains and also occurs as coarse and fine laths of moderately good shape. Very rarely, large felspar grains appear to be simply rather than polysynthetically twinned. These may be orthoclase but are perhaps more likely to be plagioclase with Carlsbad twinning. They are not distinguished from the other plagioclase by alteration or other features.

Quartz is more common in this specimen than in RS 41 but is more clearly of late stage introduction. It does not occur as phenocrysts but is present as finely granular mosaics, usually in, or in the vicinity of, vesicles. Quartz sometimes occurs in association with biotite clusters in the form seen in hand speciment as biotite - filled vesicles.

Biotite is relatively abundant both as widely scattered single flakes and as clusters of flakes, often with quartz as just noted. Biotite clusters are often associated with voids and are themselves penetrated by open cavities. The association of biotite with both quartz and vesicles suggests that the mineral may, like quartz, be the product of late stage replacement and alteration. This may apply to the disseminated biotite as well as aggregated clusters of flakes. The development of some biotite may be located by original ferromagnesium minerals in the andesite but in the vesicles it may be assumed that all the constituents have been introduced.

Opaque and translucent iron oxides are common in both prismatic and irregular grains and patches. Limonite also fills a system of fine veinlets. The mineral is probably related to weathering processes.

A few large crystals of low birefingence associated with the vesicles are probably zeolites.

Comment

The specimen is petrographically an andesite but chemical analysis would almost certainly indicate a composition approaching or within the dacite field. Textural evidence is stronger in this specimen than in RS 41 that both silica and potash have been introduced at a stage later than the emplacement of the rock. The mode of emplacement may have been as a lava or as a welded tuff with a high gas content. The absence of flow structures suggest the latter as the most likely origin.

Specimen 6728 RS 43, TS C 43700

Rock name Silicified andesite

Hand specimen

The specimen is rusty brown, highly weathered and very friable but is similar in appearance to the vesicular andesite. The concentration of vesicles is so great in some patches that the name of pumice is probably justified, particularly because the alteration is so intense that granularity is not visible. Part of the specimen has been stressed enough to produce a marked foliation.

Thin section

The intense silicification of the lithology is evident in thin section. The major part of the rock consists of fine to very fine mosaics of closely intergrown quartz, forming a matrix to the rock.

A few coarse plagioclase laths with corroded, irregular margins are still visible but most of the original fabric has been replaced.

Part of the thin section is rich in biotite. Fine flakes of the mineral with a strict preferred orientation are concentrated in a series of lenticular pods which, taken together, form an irregular band or zone. This is probably the part of the rock showing a foliated fabric in hand specimen.

Much of the biotite has been altered by weathering into a brown chlorite without birefringence.

Opaque to translucent prisms and irregular grains of iron oxide are abundant throughout the specimen. Patches of limonite are common and a weak limonite staining permeates the whole fabric.

Comment

The replacement of most of the rock by quartz and biotite represents a more advanced stage of the same alteration which was indicated from less prominent evidence in the vesicular andesite RS 42. In this specimen the preferred orientation of the biotite suggests the alteration was part of a regional metamorphic process. The rock was possibly a highly volatile rich lava but the alteration produced by metamorphism and weathering has obliterated most evidence of the original nature of the rock.

Specimen 6728 RS 44, TS C 43701

Rock name Silicified andesite

Hand specimen

The rock is similar to RS 43 but is much fresher. It is buff coloured except on joint faces where limonite staining is evident. It is hard and coherent rather than soft and friable. The specimen is possibly a volcanic bomb as it is massive in the centre but highly vesicular on at least the upper surfaces. The vesucles tend to be flattened parallel to the length of the hand specimen. Surfaces which are not vesicular are controlled by joint planes.

Thin section

The rock is similar to both RS 42 and RS 43 but is fine grained and highly, but not completely, silicified.

Plagioclase phenocrysts were probably not common in the magma at the time the rock was extruded and only scattered relict laths are still distinguishable. They are fine grained and tend to be preferentially oriented, probably by flow. The ground mass of the rock is probably feldspathic but is very fine grained and partially obscured by opaque granules. It is probably a devitrified glass.

Quartz is abundant in fine grained masses. Some of the quartz occurs in thin lenticular bands with the same orientation as the plagioclase laths. The bands may be related to flow structures but much of the quartz is probably of metamorphic origin.

Biotite is not abundant but occurs in irregular bands with a probably metamorphic preferred orientation and in scattered subspherical to lenticular clusters.

The whole rock is heavily dusted with very fine opaque granules, presumably of iron oxide. There is a tendency for these to be distributed with a preferred orientation forming flow lines. Coarser grains of opaque oxide are widely distributed in prismatic to irregular form but tend to be concentrated in some bands of quartz.

Small flakes of a clay with moderate to low birefringence form radiating clusters around the margins of some of the vesicles.

Comment

Several elements of an oriented fabric are evident. These comprise plagioclase phenocrysts, quartz lenses and bands, biotite bands and pods, lines of granules and flattened versicles. All the elements appear to have the same orientation but, while some of them probably relate to flow in a plastic magma, others are related to regional metamorphism by analogy with the other specimens examined. It is clear that the rock originated as a rapidly chilled magma with a few small phenocrysts and a high volatile content. The specimen may have been a volcanic bomb and the flattening of the vesicles may have been the result of rolling while the bubble - filled glass round the margin was still soft.

Specimen 6728 RS 45, TS C 43702

Rock name Diopside hornfels

Hand specimen

The rock is greenish grey on the fresh surface but rusty brown on the weathered surface. It has a hackly weathering with patches of limonitic, cellular porosity. Parts of the specimen are composed of a siliceous and ferruginous boxwork. Other parts consist of a porcellanous green material.

Thin section

The thin section consists almost entirely of a closely interlocked mosaic of fine to medium grained diopside. The crystals are irregular to prismatic and the latter form sometimes occurs as radiating clusters.

Quartz occurs as large irregular patches of extremely fine grain, as a matrix with fine diopside and as sharply bounded grains and patches of a coarse grained mosaic. The latter form is probably the filling of solution cavities and dates from long after the prograde metamorphic episode which formed the calcium and magnesium silicates from a siliceous dolomite.

Scattered clusters of a mineral which is probably a biaxial idocrase form mosaic patches randomly distributed thoughout the rock.

Large cavities are relatively common and are probably solution cavities. They are often lined or filled with limonite.

Comment

The rock is probably part of the Milendella Limestone and is a thermally metamorphosed, dolomitic, siliceous limestone.

Specimen 6728 RS 46, TS C 43703

Rock name Quartz - mica schist

Hand specimen

The specimen is a hard and coherent, fine grained grey rock with a weak foliation. In close examination the grey colour is resolved into black and white spots while scattered reflections from the cleavage planes of fine muscovite flakes appear as the specimen is viewed from different angles. The specimen is bounded by joint planes but the weathered surface displays a foliated structure.

Thin section

A metamorphic fabric is evident in the preferred orientation of elongated quartz grains and in thin bands of oriented mica. The latter is dominantly biotite but scattered flakes of muscovite are also present.

The quartz is fine grained and closely interlocked along intergranular sutures which vary from simple to moderately complex. The grains vary from equidimensional to elongated. Most strain has been annealed by recrystallisation and extinction is sharp. Triple junctions at 120° are frequent.

Fine mica flakes are interstitial and are particularly concentrated in bands between quartz-rich bands. Biotite is much more abundant than muscovite and tends to be finer in grain size. Biotite occurs in all orientations and along grain boundaries running in all directions. However, there is a strong tendency for flakes to be preferentially oriented in the same plane as the elongation of quartz grains and to be concentrated in bands in the same plane.

Plagioclase is recognisably the third most abundant mineral present and a few grains in which polysynthetic twinning is weak or virtually absent suggest that the total amount of feldspar may be underestimated. Potash feldspar may be included.

A few grains of zircon, tourmaline and apatite are present. Rare, coarse, cubic grains of limonite are probably pseudomorphs after pyrite.

Comment

The rock appears to be a normal greywacke which has been regionally metamorphosed. There is no evidence of a volcanic contribution and the specimen probably represents Kanmantoo type of sedimentation.

Specimen 6728 RS 47, TS C 43704, 3132/62/1

Rock name Weakly gneissic diorite

Hand specimen

The specimen is medium grained, rich in feldspar and with scattered dark green minerals. A banded structure is discernible in places but is not prominent throughout the specimen. The foliation is pronounced enough to give rise to plane joint surfaces however.

Thin section

The main fabric of the rock consists of a closely interlocking mosaic of plagioclase feldspars. Some grains are moderately well shaped but the majority are irregular. Zoning is common and alteration is widespread. From crystals exhibiting symmetrical extinction of polysynthetic twins the composition appears to be within the oligoclase range. Not all grains exhibit twinning and it is possible that some potash feldspar is present. In the zoned crystals the core is often strongly altered but the margin is often completely fresh. More commonly the alteration is patchy and distributed randomly.

Quartz is much less common than the plagioclase and occurs as scattered, small, interstitial, multigranular patches. Intergranular sutures between quartz grains are complex and many grains exhibit an undulose extinction and weakly delineated fracturing. Grain boundaries of quartz against plagioclase often show embayment of the plagioclase and indicate a late stage replacement origin for the quartz.

The most abundant ferromagnesian mineral is a green amphibole but green epidote is almost as abundant. Both minerals occur as irregular and fragmentary interstitial grains and patches. Both display a weak preferred orientation of individual grains and of the elongation of the patches.

Sphene is a moderately common accessory and occurs as ragged and irregular grains, closely associated with and often rimmed by ilmenite. Scattered opaque grains without attendant sphene are also probably ilmenite.

Fine grains of apatite are widely distributed.

Comment

The rock is very rich in calcium and may have developed from a calcareous and siliceous sediment by substantial metamorphism. Alternatively the sediment may originally have been a greywacke or even an andesite.

Specimen 6728 RS 48, TS C 42705

Rock name Dolomite

Hand specimen

The rock is creamy in colour, weakly bedded and penetrated by a system of branched tubular cavities. The weak bedding is marked by a slight ridging on the weathered surface and by a preferred orientation of the tubular cavities on the sawn surface. There is no systematic variation in the material making up the rock, either in grain size or in composition. The walls of the cavities are often lined with crystalline material but the major part of the rock is fine grained and apparently amorphous.

Thin section

The major part of the rock consists of massive, fine grained carbonate with a heavy impregnation of semi-opaque material, probably including both clay and iron oxide. From the absence of staining with alizarin dye, it is assumed that the carbonate is dolomite.

Almost all of the numerous open cavities are lined with a clean, fibrous carbonate with the fibres perpendicular to the cavity walls. On rotation of the microscope stage the margins of these crystals remain sharply defined. Both refractive indices are distinct from that of the mounting resin and the carbonate is probably magnesite rather than dolomite.

Quartz occurs as highly corroded remnants which are widely distributed but quantitatively not abundant. Plagioclase is even less abundant but occurs in a similar manner.

Both biotite and a colourless mica occur in well shaped flakes scattered sparsely through the massive carbonate. The colourless mica may be phlogopite rather than muscovite and is not corroded.

Shadowy outlines of almost completely replaced grains of both opaque and translucent minerals are relatively common.

Comment

Abundant evidence for the replacement of all minerals except phlogopite by the dolomitic carbonate suggests that the rock is the product of dolomitisation. The abundant voids indicate that solutions remained active after the dolomitisation and suggest that the dolomitisation may have been a process of duricrust formation rather than a regional replacement at depth.

The original sediment was probably a greywacke.

Specimen 6728 RS 49, TS C 43706

Rock name Amphibolite

Hand specimen

The rock consists of coarsely tabular porphyritic feldspar crystals in a mass of fine grained black and white minerals. The fine grained minerals display a preferentially oriented fabric in which many cleavage faces reflect the light at the same angle.

Thin section

The rock consists of a mass of fine grained amphiboles and plagioclase surrounding and partially replacing coarse grained, porphyritic plagioclase. The porphyritic feldspars are also replaced by a wide range of alteration products. Sericitic alteration is sometimes so complete that the possibility exists that the original feldspar may have been a potassic type.

On balance of evidence it is unlikely that potash feldspars were present in the original rock. The association is essentially calcic and some patches of sericite are present in feldspars which are certainly plagioclase. Symmetrical extinction angles indicate that the plagioclase is a labradorite and hence that the environment in which it equilibrated was calcium-rich and of relatively high temperature. From this evidence the rock was probably a coarsely porphyritic dolerite.

Plagioclase in the ground mass consists of fine grains which are largely without twinning. It is closely interlocked with fine grained amphibole and varies in abundance reciprocally with the amphibole. Many plagioclase grains are in contact with other plagioclase along very simple grain boundaries, often meeting in 120° triple junctions. Boundaries against amphibole grains are irregular and usually indicate replacement of plagioclase by the amphibole. The amphibole appears to be a replacive alteration rather than a substitution in place for original pyroxene. Many plagioclase grains retain a shape in which the overall dimensions are those of a lath shape although the margins on a fine scale are irregular.

The amphibole is a green hornblende which is pleochroic from yellow green through plain green to blue green. It occurs in forms varying from subhedral prisms to irregular patches and exhibits a strong, though not all inclusive, preferred orientation. From textural evidence the amphibole has replaced ground mass minerals, possibly including pyroxenes of which not even relics are now visible, and certainly including both groundmass and porphyritic plagioclase to a limited extent. At a few points amphibole crystals follow the line of the margins of porphyritic crystals of plagioclase. It is not entirely clear whether this orientation is the result of flow lines in an original magma or of the marginal alteration of plagioclase phenocrysts.

There is no textural evidence of the original existence of ferromagnesian phenocrysts, now replaced by amphibole.

Only limited alteration of plagioclase phenocrysts has been effected by amphibole but the total alteration of the phenocrysts is considerable. Other alteration products are scapolite, melilite, clinozoisite and sericite. Scapolite replaces plagioclase phenocrysts from the margins inwards. It forms large, irregular patches consisting of irregular grains. The patches are sometimes continuous round the margins of the phenocrysts and at some points leave little or no plagioclase as an internal remnant. The composition of the scapolite appears to vary within one grain as the polarisation colours are mottled. The maximum birefringence is in the second order, indicating a relatively calcium-rich composition which reflects that of the parent plagioclase.

The centres of some plagioclase phenocrysts are so rich in calcium that the alteration product is melilite. This occurs as ragged areas with a very low birefringence, a somewhat elevated refractive index and an anomalous blue polarisation colour. Clinozoisite occurs in a similar form in similar circumstances. It is distinguished by even higher relief and an anomalous yellow-green polarisation colour.

Sericite is abundant in some plagioclase phenocrysts, possibly those with an initially more sodic composition or those in which the calcium has been incorporated in epidote or melilite. Intergrowths of sericite and melilite are common. It is probable, however, that the sericite is an indication of metasomatic alteration since the original rock is unlikely to have contained substantial potassium.

Another indication of potassium metasomatism is the presence of biotite. Small flakes of biotite are distributed throughout the specimen but tend to be concentrated in clusters at the margins of some plagioclase phenocrysts. The disseminated biotite flakes tend to display a preferred orientation but many flakes are distributed in random orientations.

Frequent very irregular grains and patches of sphene are scattered throughout the specimen, usually with a strong preferred orientation. A few of the grains contain opaque inclusions and it is probable that these are relics of ilmenite from which the sphene was formed. All the sphene may be the product of alteration of ilmenite. Scatterd grains of amorphous limonite possibly represent the iron component of the original ilmenite.

Comment

The extensive amphibolitisation and alteration of plagioclase with the more limited potash metasomatism have obscured much of the original nature of the rock. Enough evidence remains to indicate that the parental material was igneous with porphyritic plagioclase and a groundmass which included medium grained plagioclase. The composition of the groundmass plagioclase is not known but apparently unaltered parts of the phenocrysts are of labradorite composition. The rock was originally a dolerite dyke or sill, or less probably a very thick lava flow. In view of the proximity of the Black Hill norite pluton there appears to be a strong probability that the minor intrussive may be related to the norite. Time relationships between major and minor basic intrusives, and the range of composition within the basic magmas, are not well enough known for the affinity of the specimen to be defined.

Specimen 6728 RS 50, TS C 43707

Rock name Metasiltstone

Hand specimen

The specimen has a slaty cleavage which is displayed on the weathered surface but appears more massive and flinty on the sawn surface. One foliation plane has been accentuated by cleavage and pods of a pale lemon yellow powdery mineral have been introduced along the plane. The surface of the specimen is formed by cleavage planes and by joint planes.

Thin section

The rock has been subject to strong recrystallisation. Quartz grains merge at the margins with a dusty matrix and the flinty texture of the hand specimen is clearly the result of the permeation of the whole fabric by mobilised silica.

The major part of the rock consists of material of low birefringence which is probably quartz. Because of a general dustiness the full optical properties of much of the material are concealed and it is possible that untwinned feldspar may be present. The opaque granules which form the dusty material are concentrated at the margins of the framework grains and grain boundaries are indefinite. The shapes of the grains are in any case controlled by the processes of recrystallisation rather than sedimentation.

Biotite is the other main constituent and consists of fine, pale and weakly pleochroic flakes which are concentrated in fine bands with a strong preferred orientation.

Limonite is distributed unevenly throughout the rock and tends to be more abundant in bands where recrystallisation has formed pods of coarser grained quartz and biotite. The limonite occurs as pods, irregular patches and fine veinlets which generally conform to the orientation of the fabric of the rock. The yellow, powdery material noted in the hand specimen is an expansion of one such fine veinlet. Some of the material may be jarosite rather than limonite.

Comment

Little evidence remains of the original sedimentary features of the rock but it was probably a finely bedded quartz siltstone. Regional metamorphism imparted a foliation to the sediment but subsequent silicification reduced the importance of the cleavage and produced an essentially massive texture. Such cleavage as is now visible is the result of an even later process in which fracturing along some early cleavage planes re-emphasized the metamorphic fabric and introduced iron, probably as a sulphide, in a few places.

Specimen 6728 RS 51, TS C 43708

Rock name Metasiltstone

Hand specimen

Foliation is more pronounced and more complex in this specimen than in RS 50 although the basic lithology is very similar. At least two intersecting planar fabrics are evident and the absence of silicification has preserved them. A third cleavage direction has produced planar jointing at a high angle to both the foliation planes. The structural features of the rock have been accentrated by weathering and iron impregnation which is more advanced in this specimen than in RS 50.

Thin section

The intersection of two directional fabrics at relatively low angles has produced a structure of lenticular zones outlined partly by metamorphic cleavage and partly by compositional variation. The main metamorphic foliation is defined by the dominant orientation plane of biotite flakes. In places it is a slaty cleavage with parting along the foliation plane. The second planar fabric is outlined largely by bands in which the quartz content is much higher than average. These bands are possibly original sedimentary beds but appear to contain oriented mica which may have a metamorphic rather than a sedimentary origin. The main preferred orientation of mica within the quartz-rich bands is the same as the main metamorphic foliation in the biotite-rich zones and if the secondary foliation is metamorphic in origin it must relate to a weaker phase of deformation.

The biotite itself is more abundant overall, coarser in grain size and more pleochroic than that of RS 50. This may relate to the original composition of the siltstone but may be the result of stronger potash metasomatism during metamorphism.

The relatively high content of limonitic iron oxide occurs as a widely disseminated staining, a concentration in patches of coarse recrystallisation of quartz and biotite and the filling of veins both conformable and discordant to the main fabric. Some linear grains of opaque oxide material are aligned with the dominant metamorphic fabric.

Comment

The specimen is essentially similar to RS 50 but has been affected by stronger metamorphism and weaker silicification.

Specimen 6728 RS 52, TS C 43709

Rock name Quartz mica schist

Hand specimen

The rock is a coarse grained quartzite with strongly oriented mica distributed through it and concentrated in bands aligned along the planes of schistosity. It is similar to part of specimen RS 39. Reflections from some cleavage planes among the vitreous grains suggest the presence of some feldspar. Most of the mica is biotite but a little muscovite is recognisable.

Thin section

Plagioclase is much more abundant than was apparent from the hand specimen. It is not as abundant as quartz but in some parts of the rock it is more abundant than the mica.

Quartz and plagioclase are closely intergrown and make up the main framework of the rock. The grains are coarse, well crystallised and in contact along simple boundaries. The plagioclase is fresh and within the oligoclase range of composition. Most grains of both quartz and plagioclase are close to equidimensional but the few elongated grains do not display a preferred orientation. Some quartz grains are spheroidal.

The mica occurs as well shaped flakes of coarse grain size and unaltered composition. The biotite is dark brown and strongly pleochroic. The muscovite is closely intergrown with the biotite in the bands where both are concentrated. Some flakes are partly composed of biotite and partly of muscovite. The bands themselves are gently crenulated and consist of bundles of sub-parallel flakes. Outside the bands of concentrated mica the individual flakes of both micas are randomly distributed but display a preferred orientation at a high angle to the mica bands.

Comment

The fabric displayed in this coarse grained metamorphic rock appears to exhibit two directional fabrics and in this gives support to the suggestion of two deformational episodes which arose from the examination of the fine grained metamorphic RS 51.

Specimen 6728 RS 53, TS C 43710

Rock name Quartz mica schist

Hand specimen

The rock is very similar to RS 52. Mineralogically it is identical in consisting of a main framework of quartz and minor feldspar with bands of biotite and a little muscovite.

Thin section

The average grain size of the minerals is slightly finer than in RS 52 but the four phases present are the same. The framework is again an intergrowth of quartz and plagioclase while a directional fabric is imposed by biotite in bands and individual flakes. Minor muscovite also occurs in the two habits.

An indication of a second preferred orientation is found in some scattered biotite flakes.

Comment

The specimen may be grouped with RS 52 as a typical metamorphosed Kanmantoo sediment.

Specimen 6728 RS 54, TS C 43711

Rock name Granitic gneiss

Hand specimen

The gneissic texture is displayed by variations in the biotite content of compositional bands. The bands which are poor in biotite contain abundant quartz and less abundant feldspar but variations between these components does not appear to be systematic. The biotite in concentrated bands is strictly oriented.

Thin section

The abundance of quartz is confirmed in thin section. Plagioclase and microcline are the feldspars. Biotite is not as abundant in the part of the specimen that has been sectioned as in the specimen as a whole.

Quartz grains are large, irregular and somewhat strained. They occur as small, round inclusions, as medium sized interstitial grains and as large, multigrained masses in contact along boundaries which are relatively simple but often fractured. The distribution of the quartz is uneven but the variation does not appear to be systematic and is certainly not related to gneissic bands.

Plagioclase grains are also large and are mainly irregular in shape but with a tendency in some grains to approach tabular outlines. Some grains are zoned and the zoning is accentuated by alteration.

Microcline occurs as finer and less altered grains than plagioclase. It tends to be interstitial in habit but occasionally occurs as round inclusions in plagioclase.

The compositional banding and preferred orientation of the biotite content of the gneiss is not as prominent in thin section as in the hand specimen. Concentrations of biotite flakes take the form of clots rather than bands. Linear aggregations tend to form meandering stringers without a unique preferred orientation of the flakes or of the stringers.

Minor and trace constituents, largely within or adjacent to biotite clusters, include opaque minerals, probably ilmenite, sphene, zircon and apatite.

Alteration products of plagioclase include fine epidote and muscovite. The inner zones of plagioclase grains are often altered while the margins remain fresh.

Patches of myrmekite are not uncommon.

Comment

The composition of the granitic gneiss is similar to that of the quartz-mica schists apart from the microcline content. The gneiss may be the product of metasomatic addition of potash feldspar, possibly with some additional quartz, to a normal Kanmantoo sediment during metamorphic recrystallisation. The process is akin to granitisation.

Specimen 6728 RS 55, TS C 43712

Rock name Granite gneiss

Hand specimen

The specimen has a strongly gneissic texture, displayed prominently by bands of biotite. The banding is compositional and does not constitute a schistose cleavage despite a preferred orientation of biotite along the foliation. Feldspars are recognisable by occasional cleavage planes which catch the light but where they do not exhibit cleavage planes they are too vitreous to be distinguished from quartz.

Thin section

The oriented texture is less prominent in thin section. No directional fabric is visible in the main framework of quartz and feldspar and even the biotite is not as consistently oriented nor as well concentrated in bands as it appears to be in hand specimen.

Quartz occurs as fine, round inclusions, as medium grained, very irregular and closely interlocked grains and as very coarse grained patches of several grains, usually strained, in contact along moderately complex sutures.

Plagioclase crystals are occasionally well shaped, porphyritic or porphyroblastic and coarser in grain size than the quartz patches. Most plagioclase grains are of medium grain size, of irregular shape and closely interlocked with quartz. The coarsest plagioclase grains tend to be altered in the centre but most of the finer grains are clean and glassy. Even the polysynthetic twins are faint.

Microcline is considerably less abundant than plagioclase and is distributed patchily as interstitial grains. The grains are unaltered.

Myrmekite is common in the vicinity of microcline.

The ferromagnesian minerals include biotite, a strongly pleochroic blue-green amphihole and a blue green chlorite. The biotite is a yellow brown type but in places has been replaced pseudomorphously by the chlorite so that half a grain is brown and half green. The amphibole is not blue enough to be a riebeckite but may be a sodium-bearing hornblende.

Sphene is a very common accessory mineral, usually associated with biotite. Zircon and apatite are also included in or adjacent to biotite clusters.

Comment

The composition of the rock is probably closer to that of a granodiorite than a granite but is probably the product of an episode of granitisation, or potash-silica metasomatism, possibly of a geywacke of intermediate composition.

Specimen 6728 RS 56, TS C 43717

Rock name Granitic gneiss

Hand specimen

The specimen is similar in texture to the quartz-mica schist, RS 53, but the bands of concentrated biotite do not constitute a slaty cleavage. Since the banding is more gneissic than schistose, the specimen is identified as a gneiss despite the much finer grain size than RS 55. The granite composition is evident in thin section.

Thin section

The major framework of the rock consists of a closely-intergrown mosaic of quartz, microcline and a little plagioclase. No systematic orientation is detectable in the mosaic. The oriented fabric is formed by mica, mainly biotite but with appreciable muscovite, which displays a tendency, both to a preferred orientation of individual flakes and to a slight concentration in bands.

Quartz is still the most abundant mineral present but microcline is almost as abundant. Plagioclase with polysynthetic twinning is very much scarcer but untwinned feldspar is relatively common and may be plagioclase rather than orthoclase. Both quartz and feldspars occur as irregular, closely interlocked grains which are mainly equidimensional.

Biotite and muscovite are mainly distributed as individual, well-shaped flakes with a preferred but not exclusive orientation. Small clusters with a linear arrangement constitute a relatively weak compositional banding.

Relatively coarse grained and well shaped opaque grains probably consist of iron oxide after pyrite.

Comment

The dominance of microcline over plagioclase indicates that the specimen has probably undergone potash metasomatism although it has escaped the recrystallisations into a coarse grained assemblage that was encountered in specimen RS 54. The final result has been closer to a granitic composition than RS 55.

DISCUSSION

The specimens were collected from widespread localities and are heterogeneous not only in original rock type but also in the nature and extent of subsequent alteration. The original rock types varied from igneous intrusive through pyroclastic to carbonate and silicate sediments. Alteration was produced both by regional deformation and by metasomatic granitisation. Isochemical recrystallisation is not always definitively distinguished from metasomatism. The original potassium content of what are now mica schists may or may not have been the same as the present content, but in many rocks, for example the altered dolerites, biotite has almost certainly been introduced. Similarly both silica and potash have probably been added to the andesitic volcanics.

The range of severity in the effects of stress, heat and chemical mobility suggests that the specimens were separated during alteration not only by horizontal distance but also by depth of burial. Proximity to substantial intrusions not visible in outcrop may account for the evidence of thermal and metasomatic alteration in some rocks relative to others. If rocks relatively close in horizontal distance are significantly different in the extent of alteration, there must be at least a strong possibility of a substantial fault between the two localities which results in the adjacent outcrop of rocks with originally very different depths of burial. The time relationships between metamorphism and metasomatism are varied and complex but the evidence suggests that some granitisation occurred before the last episode of Delamerian deformation.

The specimens of volcanic origin, which were a particular interest in the investigation, represent more substantial outcrops of volcanic material than has been reported in the past from the Heatherdale Shale. Occurrences of scoriaceous volcanics have previously been attributed to boulders derived from the underlying Truro Volcanics. The specimens here describe provide evidence that andesitic volcanism occurred during the deposition of the Heatherdale Shale and may suggest a re-interpretation of the evidence at Truro. Some changes may be necessary in the nomenclature or in the concept of the Truro Volcanics.