DEPARTMENT OF MINES

SOUTH AUSTRALIA

REPORT ON THE GEOLOGY OF THE ALBERGA 4-MILE MILITARY SHEET.

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EXPLANATORY NOTES TO ACCOMPANY

ALBERGA 4-MILE MILITARY SHEET.

INTRODUCTION

The Alberga 4-mile military sheet, situated in the far northwest of the State is bounded by 132 deg. to 133½ deg. E longitude and 26 deg. to 27 deg. S latitude. It embodies the following 1 mile sheets: Giles, Ernabella, Indulkana, Kenmore, Alcurra, Moorilyanna, Eateringinna, Marryat, Officer, Echo, De Rose, Parcora. Giles, Ernabella, and Indulkana were published in 1955 and the Alberga 4-mile in 1959. The mapping of the area was carried out in 1955 in conjunction with the search for uranium mineralisation, using Department of Lands photos of scale 60 chains = 1 inch.

The Alberga area consists mainly of granitic rocks of probable Archaean age. In the southeast Upper Proterozoic glacigene rocks occur. Overlying them with a strong angular unconformity is a flat lying series of arenaceous sediments which lithologically indicate correlation with the Ordovician of Central Australia.

Flat topped residuals of Tertiary or Cretaceous age occur in the eastern part of the area.

PHYSIOGRAPHY

TOPOGRAPHY

The area consists for the most part of a plain of average altitude 2,000 feet locally broken by abrupt protrusions of granitic rocks. Isolated outcrops of Proterozoic and Ordovician sediments in the southeast form the Indulkana Range.

Flat topped residuals of Tertiary or Cretaceous sediments occur in the eastern part of the area forming the western limit of the Great Artesian Basin. These sediments are capped by a hard siliceous crust the "duricrust" which is very resistent to erosion. Removal of the soft underlying sediments by erosion leads to the formation of characteristic "breakaway country".

The north-west of the Alberga sheet is occupied by the eastern extremity of the rugged and strongly dissected Mann-Musgrave Chain, terminating in low isolated hills such as Sentinel Hill. The southern limit of the [illegible] area includes the northernmost portion of the picturesque Everard Ranges which consist of east-west trending whale back ridges of adamellite.

The rock types have exercised a strong control in the formation of the present topography, the more resistant sandstones, quartzites and granitic rocks forming the stronger relief, the slates and shales producing a much more subdued topography. Wind action appears to have been an important factor in the erosion of the area. This erosion is due to corrasion by sand blast and the windblown transport of fine sand and dust.

Stream erosion has probably played a lesser role because of the very low rainfall and the low stream gradients. An exception to this is in the strongly dissected Musgrave Ranges which has a higher rainfall than the surrounding area.

DRAINAGE

The region receives almost its entire rainfall from thunderstorms during the summer months, consequently the streams are ephemeral. Only in exceptionally wet seasons do the streams come down in flood. Smaller streams rapidly dwindle in volume due to the loss of water by evaporation and downward percolation into the sandy soil, and soon become dissipated. The drainage gradient of the streams decreases to almost zero on reaching the plains so that the larger drainages assume ill-defined meandering courses.

The major part of the area is drained by the Alberga and its tributaries the Alcurra, Marryat, Kateringinna, Tarcoonyinna and Indulkana Creeks which flow eastward into Lake Eyre.

The major fault zones, being very susceptible to erosion have exercised a strong control on the topography. An example of this is the valley south of Ernabella Mission which the Ernabella Creek has excavated in the major east-north-east trending crush zone in this area. The course of the Marryat in its upper reaches appears to be controlled by a similar shear zone. Streams rising in the Indulkana Range have preferentially eroded the softer shaley limestone of the Ordovician sequence resulting in a concentric drainage pattern outlining the structure of these rocks.

CLIMATE AND VEGETATION

The area is outside the influence of monsoonal and temperate cyclonic influences and consequently receives a low unreliable rainfall. Rainfall averages 5 to 6 inches on the plains but is slightly higher in the ranges (average for Ernabella Mission is 10.5 inches).

The climate is characterised by a marked diurnal variation in temperature, the region experiencing the high day and low night temperatures typical of a continental climate. Consequently the vegetation consists of very hardy types including Mulga (Acacia spp), principally on the sand plains, eucalypts fringing the creeks, native figs (Ficus platypoda) and stunted pines (Calitris sp.) on rocky outcrops and salt bush (Atriplex sp.) on the argillaceous soils of the creek flats and clay pans. Other herbaceous plants include Parakylia (Calandrinia Balonnensis) and native grasses (Panicum effusum, Aristida sp. etc.).

PREVIOUS INVESTIGATIONS

H.Y.L. Brown (1905) investigated the extreme southeast of the area and recognised sediments of possible Ordovician age. R.L. Jack (1915) traversed most of the area under discussion and published a generalised map of the area. His observations and conclusions have proved to be fundamentally correct and of great value as a basis for more detailed mapping. A.F. Wilson (1947, 1948, 1950, 1952, 1954, 1958, 1959), has investigated the Ernabella area and carried out detailed field and petrographic studies of the charnockitic rocks.

STRATIGRAPHY

QUATERNARY

Alluvial Deposits, Sand Plain and Sand Dunes (Qrs)

These deposits consist predominantly of clays, sands, silts and gravels comprising the superficial deposits of the drainage lines, flood plains, hill slopes and sand plain. Two levels of gravels (gibbers) are recognisable in the area, comprising a low level deposit occurring as unconsolidated outwash and scree deposits around the margins of the ranges and duricrust residuals composed of rock types derived from these sources and a high level deposit.

The high level gravels are often gypseous and kunkarised. The high level deposits may be equivalent to Plio-Pleistocene upper level deposits recognized elsewhere in South Australia.

The sand plain is best developed in the central part of the area. Here the sand ridges trend west-northwest but gradually swing to an east-northeast trend in the Mt. Howe area.

TERTIARY

These sediments occur in flat topped residuals and are often capped by the duricrust. Residuals of this type are a feature of the country in the vicinity of Granite Downs.

Laterite (T fe)

The laterite consists of heavily ferruginised sands, shales and bedrock, often underlain by a bleached and mottled zone. It is occasionally interstratified with porcellanised horizons as at Mt. Mystery. The presence of a bleached and mottled zone beneath the ferruginous horizon indicates that these are true lateritic profiles.

Porcellanite (Tsi)

This term is here used to describe silicified sandstones and shales.

The porcellanite occurs mainly as a hard surface capping of chalcedonic silica up to 10 feet in thickness but also as irregularly silicified lenses in underlying shales.

It owes its origin to secondary silicification processes with related bleaching and kaolinisation of the underlying sediments. Replacement of shales by silica produces a cryptocrystalline or amorphous porcellanite and with arenaceous rocks a dense duricrust. The upper porcellanite contains re-cemented boulders and also vertical pipe-like structures similar to those developed during the process of soil formation.

Figure 1

PROFILE IN TERTIARY (?) SEDIMENTS, MT. MYSTERY.
15 MILES EAST OF GRANITE DOWNS H.S.

CRETACEOUS-TERTIARY (K-T1)

These rocks are of doubtful age and consist essentially of shales and sands which underlie lateritised and porcellanised horizons. The shales have yielded indeterminate strap-like plant remains. This unit may represent in part the Blythesdale Group of Upper Jurassic to Lower Cretaceous age.

Isolated outcrops of these rocks occur west of Sundown H.S. and in the Granite Downs area.

ORDOVICIAN (O)

Mt. Chandler Sandstone

The Mt. Chandler Sandstone (Wilson 1952) occurs in the extreme southeast of the area forming gently folded erosional remnants overlying units of the Adelaide System. The formation occurs again to the south on the adjoining Everard 4-mile sheet forming the Mt. Johns Range. Possible equivalents may also be traced intermittently as far west as the Western Australian border.

The formation as represented in the Indulkana Range forms a widespread "blanket" deposit, approximately 500 feet in thickness, and consists predominantly of light coloured sandstones and quartzites. Thin red and pink argillaceous limestones occur in the middle part of the sequence while intercalations of grits and conglomerates occur close to the base. Current bedding and ripple marks indicate a shallow water environment of deposition. Another primary structure is lumping which occurs in the sandstone below the limestone horizon and indicates slumping towards the south. The sandstone is medium to coarse grained and often strongly jointed.

The succession is poorly fossiliferous and no diagnostic fossils have been discovered to indicate the age of the formation. Wurm tubes (Scolithus type) which lie normal to the bedding plains occur in the sandstone immediately beneath the limestone horizon. Poorly preserved trilobite burrows have been identified by Dr. B. Daily. Other structures of possible organic origin occur near Mt. Chandler in the form of disc-like structures.

In the absence of diagnostic fossils a correlation with other formations is necessarily tentative. The Mt. Chandler Sandstone has been correlated by Wopfner (1961) with the Stairway and Pacoota Sandstones of the Amadeus Trough. In thickness of these units, which include the fossiliferous Horn Valley limestone and shales, in the type area is approximately 4600 feet compared with a maximum of 500 feet for the Indulkana sections. Also in the Amadeus Trough the Ordovician is considered to be conformable with the Cambrian which in turn conformably overlies Adelaide System equivalents. However in the Indulkana Range it rests on Adelaide System units with strong unconformity.

Photo H. Wopfner

Figure 2

Block Weathering Along Joints In Flat Bedded Mt. Chandler Sandstone.

PROTEROZOIC

STURTIAN SERIES (Ps)

Moorilyanna Conglomerate

The Moorilyanna Conglomerate, representing a sequence of conglomerates, arkosic grits, quartzites and slates, outcrops to the north and northeast of Moorilyanna Hill. The unit was first recognised by Jack (1915) and subsequently described and formally named by Wilson (1952).

The basal members of the sequence outcrop seven miles northeast of Moorilyanna Hill where they can be seen to rest with angular unconformity on the gneisses of the crystalline basement.

The succession commences with lenticular purple slates and dolomites which are overlain by a thin quartzite. The quartzite is succeeded by approximately 1000 feet of conglomerate. The conglomerate forms low round outcrops similar to those produced by the granitic rocks.

The constituent pebbles are well rounded often showing a high degree of sphericity and are generally of constant size, being approximately two inches in diameter. The pebbles are set in a green shaly matrix which is sometimes chloritised and epidotised. Numerous facetted pebbles were found suggesting a glacial origin for these rocks.

The conglomerate has been derived exclusively from basement rocks and pebbles include micro gabbros, gneisses and adamellites. The conglomerate is overlain by at least 6,500 feet of coarse arkosic grit which contains minor intercalations of conglomerate, slate and sandstone. A faulted contact of these grits with the basement occurs about two miles north of Moorilyanna Hill so that the full succession is not present. The form of the original basin of deposition of the Moorilyanna Conglomerate appears to have been controlled by a system of northwest faults which were active during deposition. These faults successively step down the floor of the basin to the west resulting in a deepening of the basin in this direction. This interpretation is suggested by the increase in thickness of sediments across these structures. (See figure 4).

Photo C.F. Wegner

Figure 3

MOORILYANNA CONGLOMERATE SHOWING ROUNDED AND FACETTED BOULDERS OF GRANITIC ROCKS AND MICROGABBROS IN A SHALE MATRIX.

Figure 4

DETAILED GEOLOGY OF THE MOORILYANNA AREA ILLUSTRATING THICKENING AND UNCONFORMITY OF THE MOORILYANNA CONGLOMERATE.

Chambers Bluff Tillite

The glacigene character of this unit was first recognised by Jack (1915) and correlated with the Sturtian Tillite (Lower Glacial). It has subsequently been described in detail by Wilson.(1952).

Lithologically it consists essentially of haematitic and calcareous boulder tillite, quartzites and gritty and pebbly slates. A few red haematitic varve like bands occur near the top of the boulder tillite. Erratics are commonly facetted and sometimes striated, of great variety in size and type, and consist of dolomites, quartzites, basic volcanics, granitic rocks and microgabbros.

The presence of erratics of unmetamorphosed dolomites, quartzites and volcanics suggest a derivation from a pre-existing Adelaide System terrain. At two localities on the published Chandler 1 mile sheet (Everard 4 mile), namely Chambers Bluff and Wahtapella Swamp the tillite is overlain by amygdaloidal basalt and melaphyre tuffs. At the former locality the basalt is underlain by a dolomite and overlain by an iron rich quartzite which in turn is succeeded by a monotonous succession of slates. A similar association has been described by Carey (1946) and Scott (1950) from King Island (Montana Melaphyre Volcanics). Carey correlates the tillite with the Sturtian.

The underlying succession of quartzites, dolomitic shales and dolomites, which contain rare halite pseudomorphs, appear to be more structurally disturbed than the tillite. According to Wilson (1952) the tillite appears to be conformable with these beds, however the presence of halite, the occurrence of reworked basic volcanics in the tillite.the disturbed nature of the beds and their outcrop pattern on air photographs suggest the possibility that they may be of Willouran age.

In colour the Chambers Bluff Tillite resembles the Elatina Tillite (Mawson 1939). In facies, however, it resembles both the Upper and Lower Glacials. Arkosic grits and quartzites which occur in the overlying strata may be the equivalent of the Upper Glacial Sequence and the Chambers Bluff Tillite may therefore represent the Lower Glacial Sequence.

ARCHAEAN (A)

The crystalline basement is made up of a great variety of rock types, predominantly gneissic granites. Other rock types include garnet gneisses, amphibolites, pyroxene granulites and gneisses and augen gneisses.

The gneissic complex can be divided into two main provinces, namely the northwest or Ernabella province characterised by pyroxene bearing rocks (charnockitic suite) and the south east or Granite Downs province characterised by normal granitic types. Definite metasediments have been recognized in the Granite Downs province where glassy quartzites and amphibolites occur.

The origin of the granitic gneisses is obscure. Wilson suggests that the charnockitic gneisses of the Ernabella area are metasediments. However, it is the author's opinion that these rocks, together with the granitic gneisses of the Granite Downs province, may in part represent stressed igneous rocks as suggested by Jack (1915).

GNEISSIC GRANITES

The gneissic granites occur in the Granite Downs province where they are associated with granitic gneisses.

The gneissic granites are generally xenomorphic - granular in texture but are sometimes granoblastic. They are usually medium grained but may be quite coarse.

Foliation is poorly developed, due to the paucity of flaky and platy minerals. This structure is shown by occasional lenses of quartz or mafic minerals.

Constituent minerals have been strongly stressed and in thin section show a marked undulose extinction. The gneissic granites consists essentially of microcline, plagioclase and quartz. Magnetite and apatite are common constituents but hornblende and biotite are rare.

A feature of these rocks is a poikiloblastic texture consisting of numerous corroded blebs of quartz enclosed in felspar indicating the later crystallization of the felspar. This structure also occurs, in the gneissic pyroxene adamellites, massive hyperthene adamellites and some of the gneissic granites near Crockers Well.

Figure 5

PHOTOMICROGRAPH OF GNEISSIC GRANITE SHOWING POIKILOBLASTIC TEXTURE (x30)

GNEISSIC PYROXENE ADAMELLITES

These rock types are restricted to the Ernabella province on the Alberga sheet and may be distinguished in the field from the gneissic granites by their darker colour and a greater percentage of mafic constituents. They consist essentially of hypersthene and diopside together with orthoclase or microcline, plagioclase and quartz. The ratio of plagioclase to potash felspar falls within the prescribed limits for an adamellite, namely 2:1 and 1:2. Biotite and hornblende are sometimes present but only in minor amount.

A poikiloblastic texture is also evident in these rocks but is not as well developed as in the gneissic granites. These rocks exhibit a well developed foliation.

The gneissic pyroxene adamellites are considered by Wilson (1959) to be of metasedimentary origin representing deep seated, thermally metamorphosed and granitised greywackes.

GRANITIC GNEISSES

The granitic gneisses show a well developed foliation. They have a similar composition to the gneissic granites but are notably richer in mafic constituents, chiefly biotite. They appear to pass along strike into the gneissic granites.

Photo C. F. Wegener

Figure 6

CONTORTED GRANITIC GNEISS, GRANITE DOWNS AREA.

PYROXENE GNEISS AND GRANULITE

These rocks are restricted to the Ernabella province.

In the hand specimen they are dark, heavy gneissose (pyroxene gneiss) or granulose (pyroxene granulite) rocks, consisting essentially of plagioclase, hypersthene and diopside. The more basic types contain bytownite or anorthite, while the more acid varieties are characterised by andesine.

The association of free quartz with basic plagioclase in the basic gneisses, together with the bedded appearance of these rocks in the field would suggest that they are of sedimentary origin, possibly derived by high grade thermal metamorphism (pyroxene facies) from calc-magnesium sediments.

AMPHIBOLITES

Amphibolites of metasedimentary origin occur two to three miles west of Granite Downs H.S. They show relict bedding and are underlain by glassy quartzites. The amphibolites are fine to medium grained, often strongly epidotised and contain hornblende in a matrix of quartz and felspar.

Hornblendites occur in the Ernabella province as lenses concordant with the gneissic pyroxene adamellites. Wilson suggests that they may represent an older period of basic intrusion or vulcanism.

IGNEOUS ROCKS

ADAMELLITES

These rocks occur in the form of discrete intrusive masses, showing in plan a pronounced northsouth elongation and preserving, in general, concordant relationships with the enclosing gneissic formations. It is also a notable feature that these intrusions occur in the cores of synclinal structures. It is suggested that the adamellites have formed in sheet-like intrusions, essentially concordant with the gneissic adamellites and have subsequently been folded with them.

There is a marked resemblance in mineralogical and chemical composition between the gneissic and massive adamellites, suggesting a genetic relationship.

In the massive adamellites diopside may occur with hypersthene, biotite and hornblende but rarely does hypersthene occur with hornblende or biotite. Thus it would appear that the pyroxene adamellites have crystallised under dry conditions, the hornblende and biotite types occupying the higher levels of the intrusion where a greater concentration of mineralisers, and therefore more hydrous conditions suitable to the crystallisation of these minerals, would be expected. It is a feature that the pyroxene adamellites give rise to very few pegmatites. It may be expected also that the mafic minerals of highest specific gravity (hypersthene 3.4 - 3.5) would occur towards the base of the intrusion due to gravitative differentiation and the lighter constituents (biotite 2.7 - 3.1) towards the top.

Xenoliths of the enclosing gneissic granites showing slight reaction occur at the contact indicating the intrusive character of the massive adamellites.

The adamellites are widespread in occurrence. In the Ernabella province, hypersthene adamellite occurs in a large ovoid intrusion, approximately 24 miles long and 11 miles wide in the vicinity of Ernabella Mission. Diopside adamellite occurs in a small intrusion on the Finke Road, seven miles southwest of Victory Downs H.S., at Mt. Howe in the east and has also been recorded from Mt. Illbillee in the Everards. Hornblende and biotite types occur at Sentinel Hill, Moorilyanna and in the Ayers Range near Victory Downs H.S.

On the basis of field relationships and mineralogical composition four varieties of adamellite are recognized and classified according to the dominant mafic mineral namely hypersthene, diopside, hornblende and biotite.

Micrometric analyses of three of these have been made by the writer. The modal analysis ofthe gneissic pyroxene adamellite is included for comparison with the massive types.

	I	II	III	IV
Quartz	28	23	19	36.3
Potash Felspar	27	26	23	29.3
Plagioclase	37	35	46	31.4
Hypersthene	4	3.3		1.6
Diopside	3	5.1		
Hornblende	1			
Mica	trace	trace	7.3	0.2
Accessories	4.8	6.1	5.4	2.0

I Hypersthene adamellite

II Diopside adamellite

III Biotite adamellite

IV Hyperstheneic acid granulite Wilson 1960.

(= gneissic pyroxene adamellite)

The ratio of potash felspar to plagioclase in the above rocks falls within the limits prescribed for an adamellite, namely 2:1 and 1:2 although III is bordering on a granodiorite. The adamellites do in fact pass locally into these rocks.

Another notable feature of the massive adamellites is the high percentage of accessories present. This is substantiated by the abundance of these minerals in creek sands derived from these rocks and include iron ore, zircon, apatite, xenotime, rutile, monazite, sphene and orthite. These minerals occur in aggregates in the adamellites and often as inclusions in the mafic mineral.

Photo A. R. Crawford

Figure 7

OUTCROP OF MASSIVE HYPERSTHENE ADAMELLITE, 10 MILES NORTHEAST OF ERNABELLA MISSION. GNEISSIC PYROXENE ADAMELLITES FORM THE HILLS IN THE BACKGROUND.

Hypersthene Adamellite (Charnockitic Granodiorite - Wilson 1947)

The hypersthene adamellite forms massive outcrops and is characterised by its blue-grey colour and greasy lustre. Numerous pale blue phenocrysts of plagioclase set in a ground mass of potash felspar, plagioclase and pyroxene are evident in the hand specimen. In thin section the rock is seen to consist of large phenocrysts of plagioclase (basic oligoclase to acid andesine) in a medium to coarse grained ground mass of perthitic orthoclase, plagioclase, quartz and pyroxenes (hypersthene and diopside). The plagioclase is often antiperthite.

Diopside Adamellite

The diopside adamellite is lighter in colour than its hypersthene equivalent. It is a coarse grained porphyritic rock containing phenocrysts of pearly orthoclase or microcline and bluish plagioclase. Quartz occurs in pale blue crystals and the diopside in aggregates of grass-green crystals.

Hornblende Adamellite

This is a light grey, porphyritic rock consisting of blue-grey plagioclase, pearly orthoclase or microcline, hornblende in black resplendent crystals and bluish grey quartz.

Quartz occurs either in irregular crystals or included in the potash felspar (poikilitic texture). Hornblende is commonly partially replaced by biotite. Felspars are basic oligoclase and orthoclase or microcline.

Biotite Adamellite

In the hand specimen this rock is coarse grained, and porphyritic, containing subhedral phenocrysts of blue plagioclase and pearly microcline or orthoclase. Quartz occurs in large irregular crystals. Biotite is common and contains inclusions of accessory minerals.

Pegmatites

Pegmatites derived from the adamellites are uncommon and are usually only one to two feet in width. However they are important because they carry primary uranium minerals. Pegmatites occur rarely along the eastern margin of the hypersthene adamellite occupying fractures in the gneissic pyroxene adamellite. Pegmatites of an adamellite composition occur more abundantly in association with the hornblende and biotite types. Such pegmatites occur at Mica Pass, one mile east of Sentinel Hill in gneissic pyroxene granites and gneisses. They consists essentially of well twinned oligoclase, grey orthoclase (occasionally in well formed crystals up to one foot in length) bluish quartz and some mica. They carry an interesting suite of accessory minerals namely hematite, ilmenite, rutile, almandite, orthite, cyrtolite, euxenite, sphene, monazite (rare) and beryl (rare).

<u>Aplite</u>

Aplite occurs in small masses in the Indulkana shear zone on the northern side of the Indulkana Range. These masses show a definite linear distribution suggesting that the shear zone has controlled the emplacement of the aplite. The aplite shows evidence of shearing, indicating a later faulting. The rock is medium grained and equigranular consisting entirely of quartz and potash felspar.

<u>Micro-norite</u>

Micro-norite is developed in plug-like masses in the vicinity of Mt. Warrabillinna, south of Ernabella Mission. Here the micro-norites are associated with hypersthene adamellite, while to the west at Mt. Woodroffe, Wilson records an association with hypersthene diorites. While they are genetically related to both these rocks, the exact relationship is not clear (See Wilson 1947, in which he discusses this relationship). In the hand specimen they are tough, rather heavy, medium grained, grey-black, equigranular, speckled rocks consisting of pink or grey plagioclase, hypersthene showing a marked metalloidal lustre, and green diopside. A few flakes of bronzy mica occur in some specimens. The texture is usually hypidiomorphic-granular but may be doleritic in which case the plagioclase occurs in laths. In a few specimens these laths show a parallel orientation indicative of flow structure. The plagioclase is acid labradorite constituting 50 to 60 per cent of the rock and often contains poikolitic inclusions of the earlier formed pyroxenes. Hypersthene is generally in excess of diopside. Brown hornblende is sometimes present. Specks of pyrite were noticed in a few specimens.

<u>Micro-gabbros</u> (Dolerites)

The micro-gabbros occur in narrow wall like dykes. They occur as reworked boulders in the Moorilyanna conglomerate clearly predating the deposition of this formation (see figure 4).

The dykes are generally steep dipping but in the Alcurra dyke swarm dips as flat as 30 degrees occur. These dykes may be divided into two main systems one striking east southeast, and the other not so strongly developed northeast, corresponding to the two main shear directions of the area.

Figure 8

PLOT OF THE PRINCIPAL MICRO-GABBRO DYKES ON THE ALBERGA SHEET SHOWING TWO WELL DEFINED SYSTEMS.

These rocks are dark grey to black in colour, medium to fine grained and consist essentially of clear laths of plagioclase and dark green to black pyroxene. Olivine is often present and may be distinguished by its lighter green colour. Hypersthene occurs in some rocks but is always subordinate to the clino pyroxene (pigeonite or augite). Iron ore is abundant both as primary grains and also as a deuteric alteration product of the olivine. Anorthoclase, apatite and quartz (in subordinate amount) occur rarely. The presence of pigeonite in these rocks indicates that they have been quickly chilled as the mineral is unstable under conditions of slow cooling. In fastfine grained, almost glassy chilled margins to the dykes are common and show as a darker outcrop on air photos. The micro-gabbros generally have either an ophitic or poikilitic texture. In the latter case earlier formed minerals occur as inclusions in the felspars. The micro-gabbros have been classified as follows:

1. Microgabbros with olivine
2. Microgabbros without olivine.

Microgabbros with Olivine

These rocks predominate in the area. Olivine occurs as euhedral to subhedral crystals which are sometimes skeletal in outline. It often contains dusty inclusions and dendritic growths of iron ore. It is generally neutral to colourless but occasionally exhibits a moderately strong pleochroism (light grey to pale fawn). The olivine bearing types may be further subdivided according to the presence or absence of hypersthene.

Olivine microgabbros with hypersthene

Hypersthene is fairly common in these rocks but is subordinate to the clinopyroxene (pigeonite). It occurs in zoned crystals and exhibits a strong pleochroism pale green to rose pink, the intensity of the pleochroism increasing towards the margins of the crystal.

Olivine microgabbros without hypersthene

These rocks commonly have an ophitic texture. Pigeonite tends to occur in aggregates and occasionally shows reaction rims of hornblende. Plagioclase shows a well defined zoning with an outer zone of acid andesine and a core of labradorite. Pigeonite is sometimes intergrown with plagioclase.

Microgabbros without Olivine

These rocks commonly have an ophitic texture. Pigeonite tends to occur in aggregates and occasionally shows reaction rims of hornblende. Plagioclase shows a well defined zoning with an outer zone of acid andesine and a more calcic core of labradorite.

TECTONICS

FOLDING

Four distinct orogenies may be recognized in the area.

1. Orogenic movements which folded the Archaean rocks.

The Archaean is generally steeply dipping and tightly folded along sub-meridional fold axes. Folding is sometimes isoclinal with overfolding to the west occurring locally.

2. A strong Upper Proterozoic and pre-Ordovician folding.

The Adelaide System occurs in open folds south of Chambers Bluff but the intensity of folding increases towards the north where the folds become tighter and finally isoclinal and overturned in the vicinity of a faulted contact with the Archaean. This fault trends northeast, parallel to the fold axes of the Adelaide System.

3. A mild orogeny which warped the Ordovician along northeast axes.

The Ordovician, although resting on the Adelaide System with a strong unconformity of approximately 45 degrees has been gently warped along fold zones paralleling those of the Adelaide System.

South of Erlywanywanya rockhole, to the west of Ernabella, Adelaide System trends are south easterly again paralleling the major faults in this area. South of the major crush zone near Mt. Murrabillinna north easterly en echelon trends occur in the Archaean. To the north of this structure normal meridional trends occur with little sign of these impointed younger structures. These northeast trends in the Archaean are parallel to the Adelaide System trends in the Granite Downs area and are attributable to later deformation by differential movements of the fault blocks.

It would appear therefore that the folding of the Adelaide System and Ordovician and the younger folding of the Archaean has been restricted to well defined zones which coincide with the major fault blocks in the Archaean. The folding can be explained by differential movements along these structures.

Gravity work by Mumme in the Granite Downs area has indicated the presence of a regional gravity low corresponding with the distribution of the Adelaide System and Ordovician. The steep gradient of the gravity profile at the contact of the Archaean and Adelaide System indicates a sudden deepening of the latter sediments. The Ordovician being a superficial deposit would have little influence on the gravity picture. It would appear therefore that the Adelaide System rocks are largely responsible for the gravity deficiency. The axis of the anomaly is northeast corresponding with the major shear direction.

4. Epeirogenic movements which tilted the Cretaceous and Tertiary rocks in the area, probably culminating in the Plio-Pleistocene uplift which gave rise to the Alps in eastern Australia (Kosciusko Uplift.)

Figure 9

VERTICAL AIR PHOTOGRAPH OF THE WESTERN END OF THE INDULKANA RANGE SHOWING ARCHAEAN-PROTEROZOIC, ARCHAEAN-ORDOVICIAN, PROTEROZOIC-ORDOVICIAN UNCONFORMITIES. (Scale 60 ch. = 1 m.)

FAULTING

The first period of faulting predates the emplacement of the massive adamellites. The linear distribution of the adamellites to the northeast of Kenmore Park H.S. and the aplites in the Indulkana area suggest intrusion along old weaknesses.

The second period of faulting predates the deposition of the Moorilyanna Conglomerate. Dykes of microgabbro have subsequently intruded these shear zones and shear joints associated with them.

A third phase of intense faulting coinciding with these old fractures has produced strong crushing and mylonisation of the gneissic rocks, adamellites, aplites and microgabbros. These crush zones are characterised by the presence of pseudotachylite, a black glassy substance formed by fusion of the deformed rocks during faulting. Some fault zones are strongly epidotised, resulting from the deformation of the microgabbros.

In the Moorilyanna area thereis evidence of active fault movements contemporaneous with the deposition of the Moorilyanna Conglomerate (See Figure 4).

ECONOMIC GEOLOGY

MINERALISATION

The area is essentially a uranium-rare earth province representing a deep level of erosion of an old mountain core.

The region is devoid of any notable base metal mineralisation and appears to be an unfavourable environment for the occurrence of large ore bodies. However the occurrence of primary uranium mineralisation associated with pegmatites and adamellites offers some prospects for further exploration in the area.

Copper-Gold

Minor copper and gold mineralisation occurs in the Indulkana fault zone on the northern side of the Indulkana Range.

Jack (1915) records copper mineralisation in quartz reefs cutting "Cambrian slates" four miles south-southeast of Wantapella Well with malachite chalcocite, chalcopyrite and pyrite."

Uranium and Rare Earths

Primary uranium and rare earth minerals are common in pegmatites associated with the adamellites. The following uranium rare-earth minerals have been recorded from these pegmatites.

Orthite (complex silicate of Ca, Fe, Al, rare earths) occurs abundantly in large crystals up to 1½ inches in length. It has a black glassy appearance when fresh but acquires a rusty coat of iron oxides on weathering. The mineral is usually tabular in habit but may occur in long slender acicular crystals. Large crystals were obtained from pegmatites at Mica Pass and at a locality 2 miles west of Moorilyanna H.S. ruins. Orthite also occurs in gneisses in the Granite Downs area.

Euxenite (a niobate, columbate and titanate of Yttrium, Erbium Cerium, uranium (9.6% UO_3) and thorium (2.7% ThO_2)) occurs in dark honey coloured tabular crystals up to 1 inch in length or fillings in long curving cracks in the pegmatite. Euxenite occurs in the pegmatites at Mica Pass and Ernabella.

Cyrtolite ((a uranium (0.2 per cent UO_3, thorium (0.4 per cent ThO_2)) variety of zircon, red-brown in colour and occurs abundantly as prismatic crystals in the Mica Pass pegmatites.

Scheelite ($CaWO_4$) occurs rarely as fluorescing grains in amphibolites near Granite Downs.

Tantalite ((Fe, Mn) (Nb, Ta)$_2$ O$_6$)) occurs in small black crystals in pegmatites at Windmill Well, 6 miles west of Granite Downs H.S.

HYDROLOGY

The area is entirely outside the Artesian Basin, consequently water supply is reliant on wells, dams, soaks, and waterholes. The quality of the groundwater is very variable as may be seen from the following analyses.

Well	Total Salinity (grains per gallon)
Dinnertime	10
Kangaroo	62
Rockhole	160
Mount Chandler	212
Mispersons	365

Well sites containing the best supplies of water appear to be in the strongly fractured zones which have a relatively high porosity. These waters however tend to be rather saline. Such a zone occurs south and east of Ernabella in which Gilpin Well and well No. 6 are situated. Future well sites should be situated where a main drainage crosses these fault zones. Another possible site is at the base of strongly jointed hills, suitably sited to provide maximum intake from runoff. Water quality at these sites is generally good (e.g. Dinnertime Well) but because of the limited intake large supplies could not be expected. Shallow water with limited supplies should be obtainable in alluvial deposits of the Alberga and the Officer and their tributaries, particularly after replenishment by heavy rains. The quality of the waters should be better in the vicinity of the creeks, the saline waters being flushed out by the influx of fresh waters.

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