DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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GEOCHRONOLOGICAL INVESTIGATIONS OF THE WILLYAMA COMPLEX, SOUTH AUSTRALIA

GEOLOGICAL SURVEY

By

D.J. FLINT
South Australian Geological Survey

and

A.W. WEBB
Australian Mineral Development Laboratories

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ABSTRACT

Attempts to date granites and metamorphics within the Outalpa Willyama Inlier of South Australia were made in order to determine isotopic ages of events within the Proterozoic Olarian Orogeny.

Two conformable adamellitic to granodioritic gneisses give a Rb-Sr whole-rock age of 1466 ± 185 Ma with an initial Sr^{87}/Sr^{86} ratio of 0.7055 ± 0.0507. Petrography, and comparison with age determinations for gneisses elsewhere in the Willyama and Gawler Domains, suggest that this is not the age of gneissosity development, but an updated age during a final phase of the Proterozoic Olarian Orogeny.

Micaceous schist, displaying a second deformation phase schistosity (S_2), gives an apparent whole-rock age of 1000 ± 197 Ma with an initial Sr^{87}/Sr^{86} ratio of 0.8577 ± 0.0692. The age is interpreted to be not equivalent to the time of schistosity development; younger intrusive granites give an older age than the S_2 schists. The young age is interpreted to be from updating, but this cannot be related to any mesoscopic and microscopic texture or structure. Previously dated Crocker Well adamellite and granodiorite give a comparable age: 1076 ± 100 Ma from a ten sample Rb-Sr isochron.

Porphyritic granites were intruded during and after the final phase (D_3) of the Olarian Orogeny. These give a Model 2 isochron whole-rock age of 1503 ± 233 Ma with an initial ratio of 0.7157 ± 0.1440, which is indistinguishable from the two suites of D_1 gneisses. Widespread partial recrystallisation and Sr-isotopic transfer probably occurred throughout the Outalpa Block at this time.

Selected areas of the Olary subdomain underwent Sr-isotopic homogenisation during the Ordovician Delamerian Orogeny. Lithologies which give ages corresponding to the Delamerian Orogeny exhibit extensively-sericitised feldspars.

INTRODUCTION

Thirty eight samples from six suites of Willyama Complex lithologies were collected during June 1977 for geochronological investigation. This report presents those results, together with petrographic descriptions and multi-element analyses. A report on a geometric structural analysis is in preparation.

Samples were collected, with the assistance of J.F. Drexel (Geologist, S. Aust. Dept. Mines and Energy), by hand-held Cobra drilling followed by blasting with ANFO. Sample localities (Figs. 1-3) are all on the Bimbowrie and Outalpa pastoral stations. As Outalpa station encompasses most of the exposed Willyama Complex inlier in the Outalpa-Olary-Bimbowrie area, the inlier is informally called the Outalpa Block. Each suite of samples is informally named after local features i.e. Peryhumuck Mine, East Doughboy Bore, Tommie Wattie Bore, Tietz Dam, Poodla Hill and Tonga Hill. For other localities mentioned in the text see Figures 3 and 4.

All references in the text to Rb-Sr results of other workers have been recalculated using the decay constant of Rb^{87} as 1.42×10^{-11}/year. Unless otherwise stated, all references in the text are to multi-sample Rb-Sr total-rock isochrons.

BACKGROUND AND OBJECTIVES

The aim of the geochronological investigation was to obtain isotopic dates for various metamorphic and structural events within the Olarian Orogeny from the S. Aust. Willyama Complex. This Proterozoic orogeny encompasses all known deformational, metamorphic and plutonic events prior to deposition of the Adelaidean Burra and Umberatana Groups.

Classification of these events as the Olarian Orogeny follows that of Thomson (1969) and Glen et al. (1977). This report collates all information relating to dating specific deformation phases within the Olarian Orogeny and presents new data for the Olary area.

As the area examined is within the known Ordovician fold belt, whole-rock rubidium-strontium (Rb-Sr) geochronology was used. The approach adopted was wherever possible, to date directly a structural fabric. In these cases the fabric present was a schistosity or gneissosity. Even though intensity of deformation varies across the area, deformations are widespread in extent and there is very little confusion of specific events. Where the deformation phase produced dominantly crenulations, granites with a known relationship to the deformation phase were used. It was presumed that samples containing a superimposed schistosity were favourable for obtaining a reset total-rock age. A similar type of study for the Georgetown Inlier in Queensland, found that a schistosity was an important factor in obtaining a Rb-Sr isochron for a metamorphic unit (Black et al., 1979). Sampling sites were concentrated in areas where a particular foliation is dominant and in which mesoscopic evidence for subsequent deformation is minimal. For sampling granitoids, massive outcrops free of joints, fractures, late veins and weathering features were chosen, wherever possible.

Pre-Adelaidean deformation phases in the Outalpa area (Berry et al., 1978) and in the New South Wales portion of the Willyama Domain (Glen et al., 1977) have been classified into three main episodes. The terminology here follows that of their work; D_1 to D_3 for deformation phases and S_1 to S_3 for the respective axial plane structures. Although the relative timing of these deformations has been established, their absolute or radiometric age is very poorly known. Following Glen *et al.* (1977), the terms Gawler and Willyama Orogenic Domains are used, for which the latter is subdivided into the Olary and Broken Hill subdomains.

First deformation phase (D_1).

An upper amphibolite facies metamorphic event during the first deformation phase (D_1) produced an initial layer-parallel schistosity and gneissosity. D_1 folds are very rare but the schistosity or gneissosity is always present and parallel to layering. Instances of S_1 at an angle to the compositional banding (relict bedding) and as axial plane to large D_1 folds, as recorded near Broken Hill (Glen & Laing, 1975), have not been observed in the Outalpa area. The gneissosity age, particularly within the Olary subdomain, is poorly known. Estimates for the gneissosity age at Broken Hill are:

- 1690 ± 35 Ma from Pb-Pb (Reynolds, 1971)
- 1640 ± 40 Ma from Rb-Sr (Pidgeon, 1967)
- 1659 ± 21 Ma from Rb-Sr (Shaw, 1968).

Following correlation of the Willyama and Gawler Orogenic Domains (Glen *et al.*, 1977) then further estimates of the earliest high-grade metamorphic event were obtained. Granite gneiss from lower Eyre Peninsula, lower Yorke Peninsula and islands in Spencer Gulf yield slightly older Rb-Sr isochron ages:-

1816 ± 40 Ma (Cooper *et al.*, 1976)
1742 ± 120 Ma (Compston & Arriens, 1968)
1808 ± 18 Ma (Webb & Steveson, 1977; Webb, 1978)
1794 ± 40 Ma (Webb & Steveson, 1977; Webb, 1978).

Upper Eyre Peninsula yields estimates of D_1 from the Cowell/Cleve area of 1688 ± 76 Ma and 1697 ± 65 Ma (Parker, 1978; Webb, 1978).

In order to date the first deformation/metamorphic episode within the Olary subdomain, two conformable gneiss horizons in the Outalpa area were chosen.

Second deformation phase (D_2).

The second deformation phase in the Outalpa area has apparently produced tight to isoclinal folds. Only in the close proximity to regional D_2 fold hinges are mesoscopic and microscopic D_2 structures strongly evident. Locally an S_2 schistosity is present which completely obliterates the S_1 schistosity and is poorly overprinted by an S_3 crenulation. For the Olary subdomain schists containing a strong S_2 schistosity without the S_1 schistosity are rare; these provide a good opportunity to date directly the D_2 deformation and metamorphic event. Geochronology in the Broken Hill subdomain has been unable, so far, to distinguish between the two early high-grade schistosities in that area (Rutland & Etheridge, 1975; Glen et al., 1977). Within the Gawler Domain the only estimate for the age of D_2 is from the Cowell/Cleve area where a syn-D_2 granite, the Middlecamp granite, produces a Model 1 Rb-Sr isochron of 1650 ± 35 Ma (Parker, 1978; Webb, 1978).

Third deformation phase (D_3).

A third deformation phase (D_3) in the Outalpa area, which produced macroscopic and mesoscopic open folds in earlier structures, is predominantly a crenulating phase. However, D_3 can be dated indirectly because of widespread syn- to slightly post-D_3 granite intrusions. These instrusions are massive, boldly outcropping, vary from poorly to highly porphyritic and often show no evidence of superimposed S_3 structures. Such late-kinematic igneous activity provides an opportunity to obtain an upper time limit of the Olarian Orogeny in the Olary subdomain.

Late- and post-D_3 granitoid activity is widespread in both the Willyama and Gawler Domains. Granites which locally display an S_3 foliation and have been assigned to D_3 are the Narridy Creek and Carpa granites (Glen et al., 1977; Parker, 1978). Four samples of the Carpa granite produced a Model 1 isochron of 1677 ± 125 Ma with an initial Sr^{87}/Sr^{86} ratio of 0.7124 ± 0.0050 (Webb, 1978). Other late- and post-D_3 granites in the Gawler Domain are:

- The Charleston granite, dated by Rb-Sr at 1556 ± 30 Ma (Compston et al., 1966).

- The Buckleboo granite, dated by Rb-Sr at 1477 ± 34 Ma (Webb, 1978).

Within the Willyama Domain, two granites have been dated radiometrically; Mundi Mundi granite at c. 1502 Ma (Shaw, 1968) and Triangle Hill granite at 1500-1550 Ma by using assumed initial ratios for each of four samples (Radke & Webb, 1975).

Syn- and post-orogenic volcanics.

Minimum ages for the Olarian Orogeny are obtained also from the Moonabie and Gawler Range Volcanics. Two suites of Moonabie volcanics are dated at:-

1615 ± 29 Ma, initial Sr^{87}/Sr^{86} = 0.7073 ± 0.0010

1645 ± 15 Ma, initial Sr^{87}/Sr^{86} = 0.7159 ± 0.0021

which are apparently synchronous with late events of the Olarian Orogeny (Webb, 1979). Pulses of the younger and distinctly post-D_3 Gawler Range Volcanics have been dated by Rb-Sr methods at:-

1502 ± 25 Ma (Compston et al., 1966)

1529 ± 33 Ma (Webb, 1978 & 1979)

1511 ± 9 Ma (Webb, 1978 & 1979)

1525 ± 15 Ma (Webb, 1978).

The Hiltaba granite, which intrudes these volcanics, has been dated at 1478 ± 38 Ma with an initial Sr^{87}/Sr^{86} ratio of 0.7041 ± 0.0130 (Webb, 1978). Some of the post-orogenic granites in the Olary subdomain may be synchronous with the Buckleboo, Charleston, Tarcoola and Hiltaba granites.

Two intrusive bodies at Tonga Hill and Poodla Hill were sampled to test petrological and age relationships. Tonga Hill is comprised of a soda-syenite, which crops out sporadically throughout the Olary subdomain. The hybrid granodiorite at Crocker Well (Steveson, 1977) has some mineralogical and textural similarities to the Tonga Hill soda-syenite. Invariably, the intrusive plugs of soda-syenite occur near, or along strike from, well-layered calc-silicate and albitite.

Ordovician Delamerian Orogeny.

The Willyama Domain is within the known Delamerian fold belt where metamorphic conditions in Adelaidean sediments reached the biotite zone of the greenschist facies (Talbot, 1967; Berry et al., 1978). Rb-Sr and K-Ar updating of at least some Willyama Complex lithologies occurred during the Ordovician orogeny. Updating of Willyama Complex lithologies is indicated by results of:-

- 474 Ma by K-Ar for muscovite from quartzo-feldspathic gneiss at Luxemburg Mine, while Rb-Sr on whole rock gives 370 ± 330 Ma and an initial ratio of 0.7973 ± 0.0260 (Webb, 1977).
- a spread of K-Ar ages from 459 Ma to 1328 Ma for biotite and muscovite from pegmatites and granites in the Alconie Hill-Bimbowrie Homestead area (Webb & Lowder, 1971).
- 450-550 Ma by Rb-Sr and K-Ar on biotite and muscovite samples from the Mundi Mundi granite and high-grade gneiss near Broken Hill (Richards & Pidgeon, 1963).

Intrusives, synchronous with the Delamerian Orogeny have also been examined by Rb-Sr geochronology giving results of:-

- 463 ± 3 Ma, Anabama granite (Compston et al., 1966)
- 458 ± 62 Ma, Anabama granite (Webb, 1976a)
- 425 ± 55 Ma, Netley Gap microtonalite (Compston et al., 1966)
- 454 ± 84 Ma, Bendigo granite (Webb, 1976a).

Many Delamerian intrusives elsewhere in the State have been analysed; most Rb-Sr and K-Ar ages group around 480 Ma but with a long tail of K-Ar ages down to 400 Ma (White et al., 1967; Dasch et al., 1971; Webb & Lowder, 1972; Webb, 1976 a, b and c; Milnes et al., 1977). Although the samples collected in this study were primarily to test events within the Olarian Orogeny, they also illustrate the extent of Sr-isotopic homogenisation during the Delamerian Orogeny.

PETROGRAPHY

Petrographic examination of all samples was performed by Dr. B. Steveson at the Australian Mineral Development Laboratories. Full descriptions are within progress report No. 16 in the S. Aust. Dept. Mines and Energy open file Envelope 2136 (unpublished); the information is summarised below. Samples are divided into six suites and discussed in interpreted order of decreasing age. A geological plan of the Outalpa-Bimbowrie area (Fig. 2) illustrates the regional field relationships and trend of the lithological layering and first phase schistosity/gneissosity.

Two textural terms often used and which need defining are granoblastic and granuloblastic. Definitions here are as used in Joplin (1968).

Granoblastic: mosaic of irregular grains or xenoblasts normally with well sutured boundaries.

Granuloblastic: mosaic of xenoblasts with smooth intergranular boundaries or straight edges approximating to a polygonal arrangement.

A rock comprised essentially of a granoblastic or granuloblastic mosaic is classified as a granofels.

Peryhumuck adamellite gneiss.

The gneiss forms a conformable stratigraphic horizon to the east-northeast of Ameroo Hill and near the Peryhumuck Mine (Fig. 2). S_1 gneissosity is the only structural fabric present.

Composition of the gneiss varies from granitic to granodioritic with no K-feldspar, but is mostly an adamellite gneiss. Mica content varies from 2-12% and is predominantly biotite; muscovite is present only in trace amounts while chlorite abundance may be up to 2%. Very low muscovite content is quite unusual for Willyama Complex quartz + feldspar + mica gneiss which is often partially retrogressed to assemblages containing sericitic muscovite. Apatite is unusually abundant at 1% and occurs as either coarse grains or as intergranular cuspate crystals. Fluorite and molybdenite were observed on a joint surface on sample 6933 RS 809.

The present average grain size varies from 0.3 mm to 0.6 mm; relict larger crystals exhibit a 2-3 mm average grain size. In hand specimen, samples are obviously gneissic and apparently coarse grained; the microscopic fine grain size is from subgrain development with extensive nucleation and recrystallisation. Excluding micas, the present texture is distinctly allotriomorphic granular or granoblastic. Crystals show interlocking relationships with neither straight nor gently curved grain boundaries. Quartz grains exhibit the greatest tendency towards developing gently curved boundaries and triple points, and hence towards a granuloblastic texture.

Myrmekitic quartz and plagioclase is developed along the margins of some K-feldspar grains. Biotites occur as disseminations and impart a lepidoblastic texture which, with the relict coarse grain size, defines the gneissosity. Compositional banding is not present. Note that the term "gneiss", as used here, does not imply the presence of any banding.

East Doughboy leucocratic sodic gneiss.

The gneiss forms a conformable stratigraphic horizon to the south of East Doughboy Bore (Fig. 2). As for the Peryhumuck adamellite gneiss, this gneiss only exhibits the S_1 gneissosity and not later deformational structures. Gneissosity is often poorly developed, especially when biotite abundance is low, and is always more evident in hand specimens than in thin sections. Sample 6933 RS 886 has petrographic characteristics similar to the Peryhumuck adamellite gneiss and it is not included in the petrographic summary of the East Doughboy sodic gneiss.

The composition is marked by abundant and subequal amounts of quartz and sodic plagioclase; these often comprise 85-90% by volume. K-feldspar is rarely present while biotite abundance varies from 3-10%. Biotite has marked pale pleochroism and even at maximum extinction position it is only pale brown. Opaques, chlorite, allanite and epidote form minor to trace components and occur within biotite aggregates.

Three distinct textural features are present: micrographic intergrowths, granoblastic mosaics and porphyroblasts. All three features are often present in one sample. Porphyroblasts are present to a maximum of 10%, have an average size of 3mm, exhibit strongly serrated margins and appear to represent the original gneiss average grain size. Present average grain size is 0.2-0.4 mm. Porphyroblasts consist of either plagioclase (single crystal) or monomineralic quartz agrregates; these are interpreted as originally coarser grains which have undergone subgrain development. A second contributing factor to the texture is a distinctive micrographic intergrowth of quartz in plagioclase; resembling that of igneous granophyres. This grades to a granoblastic mosaic of interlocking quartz and sodic plagioclase. Biotite, average grain size of 0.2-0.4 mm, typically forms a decussate arrangement which is not discernible in hand specimen.

Although apparently coarse grained in hand specimen, the present small average grain size of 0.2-0.4 mm reflects strong recrystallisation and perhaps metasomatism. The porphyroblasts are the only relicts of the original gneiss texture.

Tommie Wattie micaceous schist.

The schist forms a stratigraphic horizon to the southwest of Tommie Wattie Bore (Fig. 2). Outcrop area is near the hinge of a regional D_2 synform. Distinctive in some hand specimens from this area is the absence of an S_1 schistosity but the presence of an S_2 schistosity. In the same outcrop area some micaceous schists contain an S_2 crenulation cleavage superimposed on the S_1 schistosity. Overprinting by the D_3 crenulation phase is only evident in 6933 RS 880 where mica recrystallisation along the S_3 trace is not observed.

Component minerals are quartz, very-poorly-twinned sodic plagioclase, biotite and muscovite. Plagioclase has only rare albite twinning and a refractive index similar to that of quartz so in the volume percent estimates, the two are not distinguished. Muscovite is usually more abundant than biotite and the total mica content varies from 25 to 75%. Tourmaline, to 2%, occurs as subhedral disseminated crystals while apatite and chlorite are present in trace amounts.

A near-equilibrium schistose fabric is developed where biotite and muscovite define a very good preferred orientation. Quartz and plagioclase occur as equant anhedra, average size of 0.15-0.4 mm, where their boundaries are controlled by adjacent micas. When quartz and plagioclase occur in aggregates, granuloblastic textures tend to develop with triple points and smooth grain boundaries with little interlocking being evident. An exception to the near-equilibrium texture is sample 6933 RS 876 where some biotites are aligned at an angle to the foliation. These biotites probably indicate a relict S_1 schistosity.

Tietz granite.

The samples examined here are from a poorly-porphyritic suite of intrusives in the Tietz Dam-Tommie Wattie Bore-Varischetti's Claim area (Fig. 2). The largest intrusive is near Tietz Dam, hence the informal name - Tietz granite. Contacts are poorly exposed but the intrusives are interpreted as late- to slightly-post D_3.

The granites are fairly uniform in composition and consist of subequal amounts of quartz, microcline and plagioclase but with microcline slightly more abundant. Micas constitute important phases and vary from 10-20%, and apatite is present to 2%. Chlorite and opaques are present in trace amounts and occur as individual crystals or with biotite.

Microcline phenocrysts are often to 8 mm long, rarely to 15 mm long, and consist of microcline microperthite with poorly-developed cross-hatched twinning and some ribbon perthite. Margins to the phenocryst are either myrmekitic, highly irregular from embayment by the matrix or mantled by clear ?K-feldspar (mantles up to 0.4 mm thick) which is not in optical continuity with the phenocryst. Matrix consists of a granoblastic mosaic of quartz, microcline and plagioclase with some subrectangular partly-tabular crystals with well-developed albite twinning. Grain size varies widely from 0.2 mm to 1.5 mm. Quartz occurs in a variety of forms and grainsize; from bulbous protrusions into microcline, as myrmekitic intergrowths, as interlocking granular crystals averaging between 0.2 mm and 1.5 mm and as large mono-mineralic aggregates to the same size as phenocrysts. Within these aggregates quartz crystals vary from 0.2 mm to 1.5 mm; largest grains have undulose extinction while finer grained zones define a granoblastic mosaic. Muscovite occurs as relatively large equant crystals to 2 mm and are interpreted as late- to post-magmatic (metasomatic). Biotite, as small dark brown pleochroic crystals, is a primary mineral.

Reactivity of quartz and feldspar in a magmatic or post-magmatic stage is indicated by abundant fine grained quartz and feldspar, myrmekitic intergrowths and quartz lobes into microcline, and broad reaction rims around microcline.

Tonga Hill soda-syenite and Poodla Hill adamellite.

Two intrusive bodies at Tonga Hill and Poodla Hill (Fig. 3) were sampled to test age relationships.

Tonga Hill is comprised of a soda-syenite; similar sodic and hornblende-bearing intrusives crop out sporadically throughout the Willyama Complex. Sodic plagioclase (65-75%) and hornblende (15-25%) are the dominant minerals with both K-feldspar and quartz present to less than 5%. Occurring in from trace amounts to 3% are epidote, sphene, opaques and apatite. Quartz and feldspar form a granoblastic mosaic with extremely irregular and serrated crystal margins. With complex interlocking and extensive subgrain development, grain size estimates are approximate; grain size varies from 0.02 mm to 1 mm with an average of 0.4 mm. Plagioclase, possibly as phenocrysts, occurs as elongate crystals to 2 mm. Complex twin patterns within sodic plagioclase indicate a possible deformational origin. Hornblende occurs as prismatic crystals to 1 mm and as smaller equant and ragged anhedra. Sphene, opaques and apatite occur with an average size of less than 0.2 mm intergrown with each other.

Poodla Hill consists of altered and metamorphosed adamellite. Quartz, K-feldspar and plagioclase exist in subequal amounts and form a granoblastic mosaic of average grain size 0.2 mm. Some large untwinned feldspar to 2 mm indicate a weak porphyritic phase. Feldspars, particularly plagioclase, are extensively sericitised; some large K-feldspars have sericitised cores and clear perthitic rims. Some sericitic muscovite aggregates to 2 mm are probably formed from completely altered feldspars; these may represent up to 30-35% of the total rock volume. Quartz aggregates also form a granoblastic mosaic but with an average grain size of less than 0.1 mm. Biotite, to 0.2 mm, occurs with finer grained opaques, epidote and sphene within sericitic aggregates while chlorite forms small dispersed flakes.

GEOCHEMISTRY

Analysis was by semi-quantitative emission spectroscopy by Amdel. Results are tabulated in Appendix B and a classification of selected elements versus rock type is presented in Table 1. The only anomalous analyses are for molybdenum but there are distinct geochemical trends related to rock type and mineralogy. Strong patterns are present for barium and phosphorous with less distinct patters for cobalt, chromium, manganese, lead and zinc.

Barium, based on observed mineralogy, is likely to be present from substituting for potassium in K-feldspar, biotite and/or muscovite. Barium is highest in Peryhumuck adamellite gneiss, Tommie Wattie micaceous schist and Poodla Hill adamellite. Although Tietz granite contains appreciable K-feldspar and muscovite, no detectable barium is present, hence biotite in the other suites may contain most of the barium.

Phosphorous is notably more abundant in Tietz granite and Tonga Hill soda-syenite, both of which contain apatite to 2% and 3% respectively. Peryhumuck adamellite gneiss which contains apatite to 1% is indistinguishable from non-apatite-bearing lithologies.

Chromium is most abundant in Tommie Wattie micaceous schist which contains abundant muscovite and tourmaline (to 2%). Chromium is most probably present from substituting for octahedral aluminium in muscovite and/or substituting for octahedral magnesium, iron, manganese, lithium or aluminium in tourmaline.

The trend in manganese, notably less abundant in East Doughboy leucocratic sodic gneiss, is difficult to explain because of the multiple possible substitutions; for Fe^{++} in biotite, for Ca^{++} in apatite, or for Fe^{+++} in epidote and allanite.

Molybdenum detections of 30 ppm and 50 ppm (Appendix B; A1425/77, A1459/77) were recorded in one sample from the Peryhumuck adamellite gneiss which contained visible molybdenite on a joint surface.

Lead abundances are uniform except for a low abundance within Tommie Wattie mica schist. Zinc patterns are more obscure because of a higher detection limit of 20 ppm.

GEOCHRONOLOGY

Analyses were made by A.W.W. at the Australian Mineral Development Laboratories. Rb/Sr ratios of the total rock samples were determined by x-ray fluorescence spectrography and the Sr^{87}/Sr^{86} ratios measured on unspiked samples with an MS-12 mass spectrometer. Analytical details are given in Webb (1978) Sr^{87}/Sr^{86} ratios are normalised to $Sr^{88}/Sr^{86} = 8.3752$ and replicate analyses of Eimer and Amend $SrCO_3$ give a value of Sr^{87}/Sr^{86} of 0.7080 ± 0.00008. Other constants used in the age calculation are $Rb^{85}/Rb^{87} = 2.600$ and $\lambda Rb^{87} = 1.42 \times 10^{-11} y^{-1}$.

Several samples from each rock unit were analysed and the Rb^{87}/Sr^{86} and Sr^{87}/Sr^{86} ratios were regressed to produce isochrons, following the procedure of McIntyre et al. (1966). This mathematical analysis tests the assumption that all samples from the same rock unit had the same initial Sr^{87}/Sr^{86}, and that they have been closed systems to Rb and Sr since their time of formation. When the dispersion of the data about the isochron is equal to or less than the expected analytical variance, the mean square of weighted deviates (M.S.W.D.) will be less than or equal to one. An M.S.W.D. of greater than one implies a geological effect that has invalidated one or both of the assumptions made above. The greater the value of M.S.W.D., the greater has been the isotopic disturbance and the more difficult the interpretation of the data becomes.

When the M.S.W.D. is less than or equal to one, the regression is called a Model 1 fit. When the M.S.W.D. is greater than one, the programme carries out a series of calculations assuming firstly, a geological error proportional to Rb^{87}/Sr^{86} and secondly, a variation in Sr^{87}/Sr^{86} independent of Rb^{87}/Sr^{86}. These regressions will produce lines of differing slope (and therefore of different age) and with different intercepts on the Sr^{87}/Sr^{86} axis. The former regression is a Model 2 fit, where geological errors can be attributed to a loss of radiogenic Sr^{87} or to rocks having different ages (times of closure to Rb and Sr migration). The other regression is a Model 3 fit and is caused by the samples having different initial values of Sr^{87}/Sr^{86}. This occurs frequently with shales and metamorphic rocks.

The calculation also decides which of the Model 2 and Model 3 fits is the more appropriate and where neither fit is indicated, a Model 4 calculation is made which combines the sources of errors of both Models 2 and 3.

Peryhumuck adamellite gneiss.

Seven samples were analysed and the data are plotted in Figure 5. Although the data show a linear relationship, two samples (6933 RS 806 & 808) show a marked departure from the straight line defined by the remaining samples. Both samples are petrographically very similar to samples which plot on the line.

Regression of all seven samples produced a Model 3 isochron (M.S.W.D. = 318) of 1466 ± 185 Ma with an initial Sr^{87}/Sr^{86} ratio of 0.7055 ± 0.0507. If samples 6933 RS 806 and 808 are omitted from the regression then the uncertainty would be reduced but there is no justification for rejecting those data. The petrography suggests that the gneiss may have an igneous origin. However, the low mean value of initial Sr^{87}/Sr^{86}, which could be taken to support a dominantly igneous origin, has a very large uncertainty that restricts the application of the initial ratio as an indicator of source material.

East Doughboy leucocratic sodic gneiss.

The seven samples analysed (Fig. 6) exhibit strong textural differences though all are leucocratic and sodic, or granodioritic, in composition. Petrography indicates three contributing factors to the texture; porphyroblasts, granoblastic mosaics and micrographic intergrowths.

Samples show a considerable scatter but most plot close to the isochron defined by the Peryhumuck adamellite gneiss. Two samples, 6933 RS 884 and 885, which are from the same locality, appear to be unrelated to the others. The reason for this is not known. Results tend to indicate a comparable age for both Peryhumuck adamellite gneiss and East Doughboy leucocratic sodic gneiss. If the analyses, excluding those for 6933 RS 884 and 885, are combined with those of the Peryhumuck adamellite gneiss a Model 4 regression (M.S.W.D. = 359) gives an age of 1471 $\pm$ 103 Ma with an initial ratio of 0.7042 $\pm$ 0.0204.

Tommie Wattie micaceous schist.

Five samples were analysed and results are plotted in Figure 7. These analyses show a considerable scatter, far in excess of experimental error, about the isochron (MSWD = 154). If the alignment represents a geological event, it is one not evident in the other suites investigated. A Model 3 regression of the data indicates an age of 1000 $\pm$ 197 Ma with an initial Sr^{87}/Sr^{86} ratio of 0.8577 $\pm$ 0.0692. This abnormally high initial ratio suggests that during the 1000 Ma event, a rock that was much older and enriched in radiogenic strontium underwent fairly complete equilibration of the strontium isotopes.

Tietz granite.

Five samples from this suite were analysed (Fig. 8). Regression of the data produced a Model 2 isochron with a residual variance smaller than those for the schists and gneisses (M.S.W.D. = 42) and an age of 1503 ± 233 Ma with an initial ratio of 0.7157 ± 0.1440. The large error limits of both age and initial ratio prevent any distinction being made between this intrusive granite and the Peryhumuck adamellite gneiss.

All samples of this granite have extremely high Rb/Sr ratios which renders the age insensitive to variations in initial Sr^{87}/Sr^{86}. Thus, if an initial ratio of 0.705 (which would be compatible with a rock of igneous origin) is assumed for the granite, the apparent age would increase by less than 20 million years.

Four analyses of the Triangle Hill granite (Radke & Webb, 1975) are plotted in Figure 8 and can be seen to lie close to the Tietz granite isochron. Regression of the combined data produces an isochron with an initial Sr^{87}/Sr^{86} of 0.6938 ± 0.0348 which is lower than that which could be reasonably expected, even for a rock derived entirely from the upper mantle 1500 Ma ago. Regression of the combined data would therefore appear to be invalid and the two granites should be regarded as isotopically distinct.

Tonga Hill soda-syenite and Poodla Hill adamellite.

Samples from the Tonga Hill soda-syenite contain very low Rb/Sr ratios of less than 0.3 (Fig. 9) and are too low to use. A plot of the three isotopic analyses for the Poodla Hill adamellite samples shows a strong linearity. The slope of a line fitted by eye to these analyses corresponds to an age of 490 Ma and an initial Sr^{87}/Sr^{86} ratio of 0.795. It appears that the rubidium and strontium isotopes equilibrated during the Ordovician Delamerian Orogeny, and the high initial Sr^{87}/Sr^{86} ratio at this time is consistent with isotopic equilibration of a much older rock.

DISCUSSION

First deformation phase (D_1).

Peryhumuck gneiss, which forms a conformable stratigraphic horizon, consists predominantly of adamellite gneiss but varies in composition from granitic to granodioritic. Fine average grain size and tendency for granoblastic and granuloblastic textures to develop indicate extensive recrystallisation. The age obtained of 1466 ± 185 Ma is interpreted to be an updated age from an early-orogenic age to one which corresponds to a final phase of the Olarian Orogeny. This should be equivalent to a D_3 or slightly post-D_3 age.

East Doughboy leucocratic sodic gneiss also forms a conformable stratigraphic horizon. Although consistently rich in quartz and sodic plagioclase it contains a variety of textures including combinations of granodioritic igneous, micrographic and granoblastic intergrowths of quartz and plagioclase. Isotopic analyses show a considerable scatter but with a pronounced similarity to Peryhumuck adamellite gneiss. Also similar are the present fine average grain size and strong tendency for development of a granoblastic quartz and plagioclase mosaic. East Doughboy sodic gneiss has had a similar history and provides a similar geochronological result, as that for the Peryhumuck adamellite gneiss. The age obtained from these two gneiss horizons is significantly younger than D_1 ages elsewhere in the Willyama and Gawler Domains. Three previous attempts in the Willyama Domain from near Broken Hill have produced results which range from 1650 to 1700 Ma, while four attempts from the Gawler Domain give older ages ranging from 1740 to 1820 Ma. The Peryhumuck and East Doughboy gneiss horizons have been updated during a final phase of the Olarian Orogeny.

Second deformation phase (D_2).

Tommie Wattie micaceous schist consists predominantly of quartz, poorly-twinned plagioclase, muscovite and biotite arranged in a near-equilibrium lepidoblastic texture. The schistosity present (S_2) almost completely obliterates S_1, in the samples selected, and the overprinting S_3 crenulation is minor. Isotopic age obtained of 1000 ± 197 is much younger than expected and does not apparently correspond to mesoscopic or microscopic features.

A very similar age has been obtained by Rb-Sr geochronology of ten adamellite and granodiorite samples from Crocker Well; 1076 ± 100 Ma with an initial Sr^{87}/Sr^{86} ratio of .7322 ± .0065 (Webb, 1977). The scatter of points indicates a largely reset Rb-Sr system. A similar result by Rb-Sr and K-Ar geochronology has been obtained for the updated Wirriecurrie Granite in the Peake and Denison Ranges (Ambrose et al., 1980), but has not been obtained elsewhere in South Australia. If the geological event is real then it may be related to tectonism and thermal events prior to and at the onset of sedimentation and basal basic volcanism in the Adelaide Geosyncline, which is interpreted to have occurred at around that time (Cooper & Compston, 1971; Preiss, 1977; Mason et al., 1978; Webb & Coats, 1980). The isotopic age is interpreted as an update age and not the age of S_2 schistosity development. From field evidence the Tietz granite and S_3 crenulation are younger than the S_2 schistosity yet the granite yields an age considerably older than the Tommie Wattie schist. A high initial Sr^{87}/Sr^{86} ratio of 0.8577 ± 0.0692 supports the concept of updating an older schist enriched in radiogenic strontium. Alternative explanations for field relationships and the relative timing of deformations are all unlikely.

Third deformation phase (D_3).

A massive weakly-porphyritic granite containing abundant late magmatic muscovite intrudes the sequence containing Tommie Wattie micaceous schist, Peryhumuck adamellite gneiss and East Doughboy leucocratic sodic gneiss. Petrography indicates reactivity of quartz and feldspars in a late- or post-magmatic stage. Isotopic analyses yield an age of 1503 $\pm$ 233 Ma which is indistinguishable from results for the metamorphic gneisses. This age is interpreted as a formation age corresponding to a final phase of the Olarian Orogeny. The two gneiss suites examined are concluded to have been updated at this time. It is possible that most, if not all, of the Willyama Complex in this area has undergone partial isotopic equilibration and recrystallisation during the final phase of the Olarian Orogeny. Petrography of Crocker Well adamellite and granodiorite (Steveson, 1977) show the same modified textures as the Peryhumuck adamellite gneiss and the East Doughboy sodic gneiss: recrystallised monomineralic aggregates and tendency for granuloblastic textures to develop in these aggregates. Isotopic equilibration and partial recrystallisation is probably associated with widespread emplacement of late- to post-D_3 porphyritic granites in the Olary subdomain e.g. Triangle Hill, Bimba Hill, Ethiudna Well, Tietz Dam area and southeast from Antro Woolshed. These granites are equated to late- and post-orogenic granites in the Gawler Domain such as the Buckleboo and Charleston granites, and the Mundi Mundi granite of the Broken Hill subdomain. These all yield very similar ages to the Tietz granite. Because of the large uncertainty in the Tietz granite age, the result is also very similar to ages of the Gawler Range Volcanics.

Tonga Hill consists of a soda-syenite, comprising 65-75% sodic plagioclase and 15-25% hornblende with only minor quartz and K-feldspar. Quartz and feldspar form a granoblastic mosaic with extremely irregular and serrated crystal margins. An unusual feature associated with this sodic and hornblende-bearing granitoid is that it tends to occur on, or in close proximity to, stratigraphic horizons containing calc-silicate and albitite. A possible correlative is a hybrid granodiorite at Crocker Well which shows similar mineralogical, textural and isotopic features excepting that hornblende is replaced by biotite (Steveson, 1977; Webb, 1977).

Poodla Hill consists of an extensively-sericitised and weakly-porphyritic meta-adamellite. Sericitised feldspars form up to 30-35% of the rock's volume. Isotopic analysis indicates an age of metamorphism at approximately 490 Ma which corresponds to the Ordovician Orogeny. A very high initial Sr^{87}/Sr^{86} ratio of 0.795 is consistent with updating during the Delamerian Orogeny of a much older adamellite; probably a late Olarian Orogeny intrusive. Gneiss samples from the Luxemburg Mine also exhibit extensively-sericitised feldspars and yield a K-Ar age in muscovite of 474 Ma (Steveson, 1977; Webb, 1977).

CONCLUSIONS

Rb-Sr geochemistry throughout the Olary subdomain has so far been unsuccessful in obtaining early Olarian Orogeny ages. Fairly complete isotopic homogenisation and partial recrystallisation occurred during final phases of the Olarian Orogeny at around 1500 Ma. Broadly synchronous with this is the widespread emplacement of late-and post-orogenic porphyritic granites. Micaceous schist shows isotopic updating around 1050 Ma which is not apparently related to mesoscopic or microscopic features. This result is supported as indicating a real geological event by a similar result on a ten sample Rb-Sr isochron for adamellite and granodiorite at Crocker Well. The extent of Sr-isotopic homogenisation of Willyama Complex lithologies during the Delamerian Orogeny varies widely. A lithology containing extensively-sericitised feldspars is likely to have been updated during the Delamerian Orogeny and give a young Rb-Sr isochron age.

ACKNOWLEDGEMENTS

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D.J. Flint

DJF:AWW/GU

D.J. FLINT

A.W.W. per D.J.F.

A.W. WEBB

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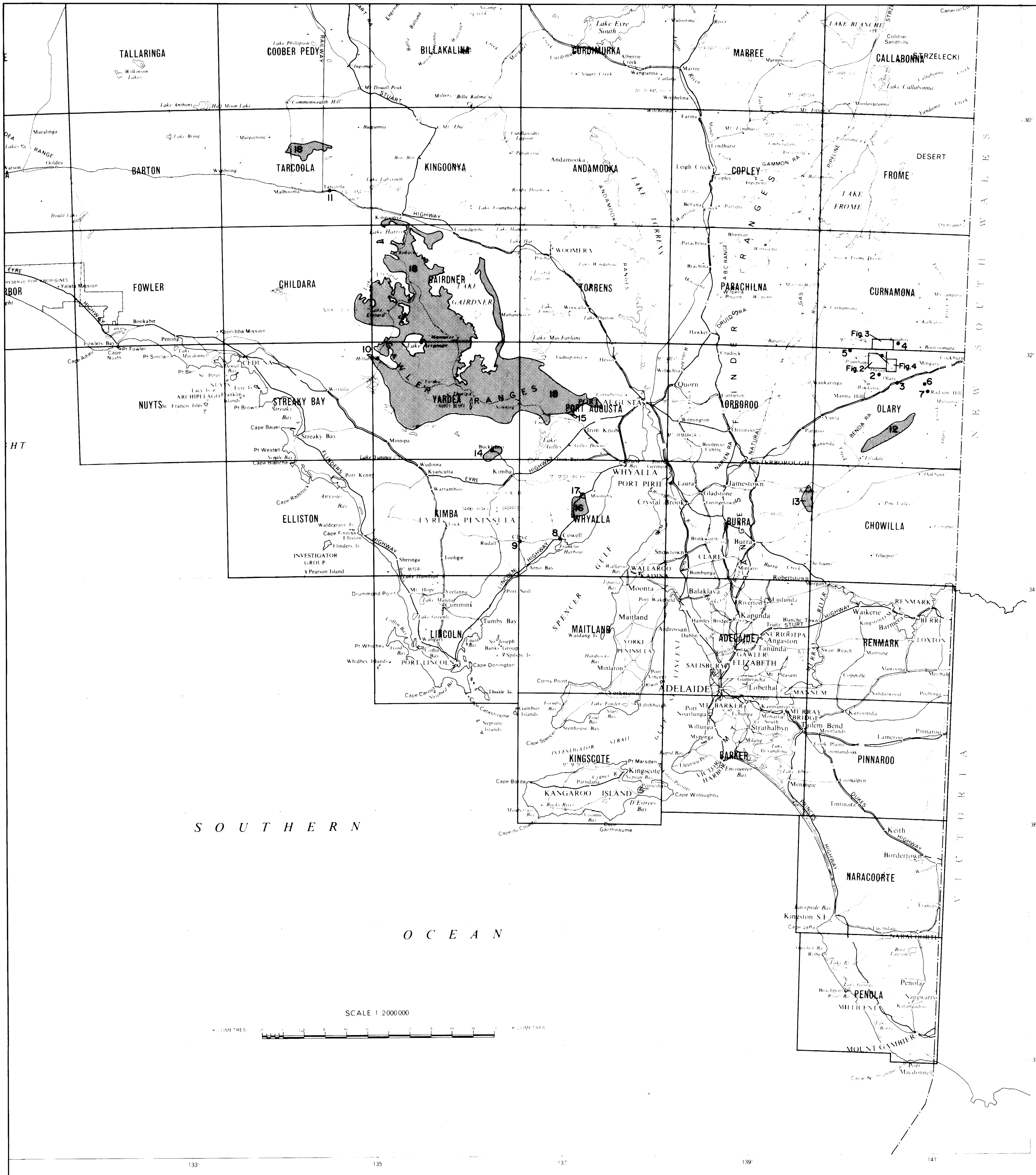
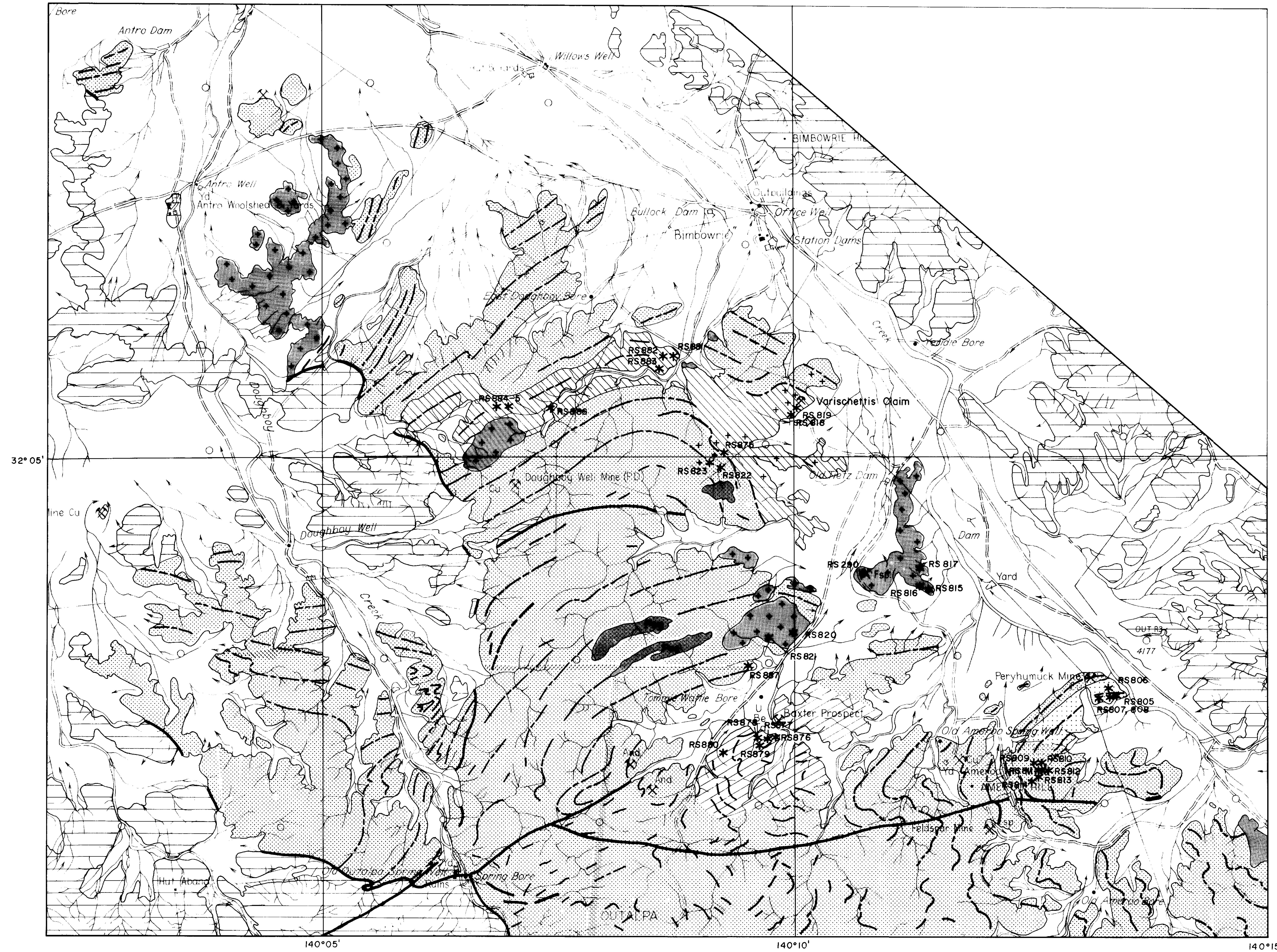


1 Bimbowrie
2 Outalpa
3 Olary
4 Kalabity
5 Crocker Well / Ethiudna
6 Luxemburg Mine
7 Radium Hill
8 Cowell
9 Cleve
10 Hiltaba
11 Tarcoola
12 Delamerian intrusives – Anabama & Netley Hill
13 Delamerian intrusives – Bendigo
14 Buckleboo
15 Burkitt Granite
16 Charleston Granite
17 Moonabie Volcanics
18 Gawler Range Volcanics
FIG.2 Part of Outalpa 6933-IV
FIG.3 Part of Kalabity 6934
FIG.4 Part of Bulloo 6933-I

Fig. 1

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE: 1:2000000
COMPILED: D.FLINT · DRN: M.B. · CKD · 4·8·80 — GEOCHRONOLOGY–WILLYAMA COMPLEX / GENERAL LOCALITY PLAN	DATE: 6-11-79 · PLAN NUMBER 79-780



SCALE

METRES 1000 0 1 2 3 4 5 KILOMETRES

LEGEND

- Quaternary.
- Adelaidean: undifferentiated Burra and Umberatana Group metasediments.
- Tietz granite.
- Pegmatite.
- Small granite plugs.
- Tommie Wattie micaceous schist.
- East Doughboy leucocratic sodic gneiss.
- Peryhumuck adamellite gneiss.
- Undifferentiated Willyama Complex.
- Trend of lithological layering and first phase schistosity/gneissosity.
- * Sample locality: all sample numbers prefixed by 6933.
- Fault.

Fig. 2

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED D. FLINT	4.8.80 C.D.O. DATE
GEOCHRONOLOGY – WILLYAMA COMPLEX	DRAWN M.B.	SCALE 1: 50 000
REGIONAL GEOLOGICAL SKETCH AND SAMPLE LOCALITY PLAN	DATE 31-10-79	PLAN NUMBER
part of OUTALPA 6933-IV	CHECKED	79-773

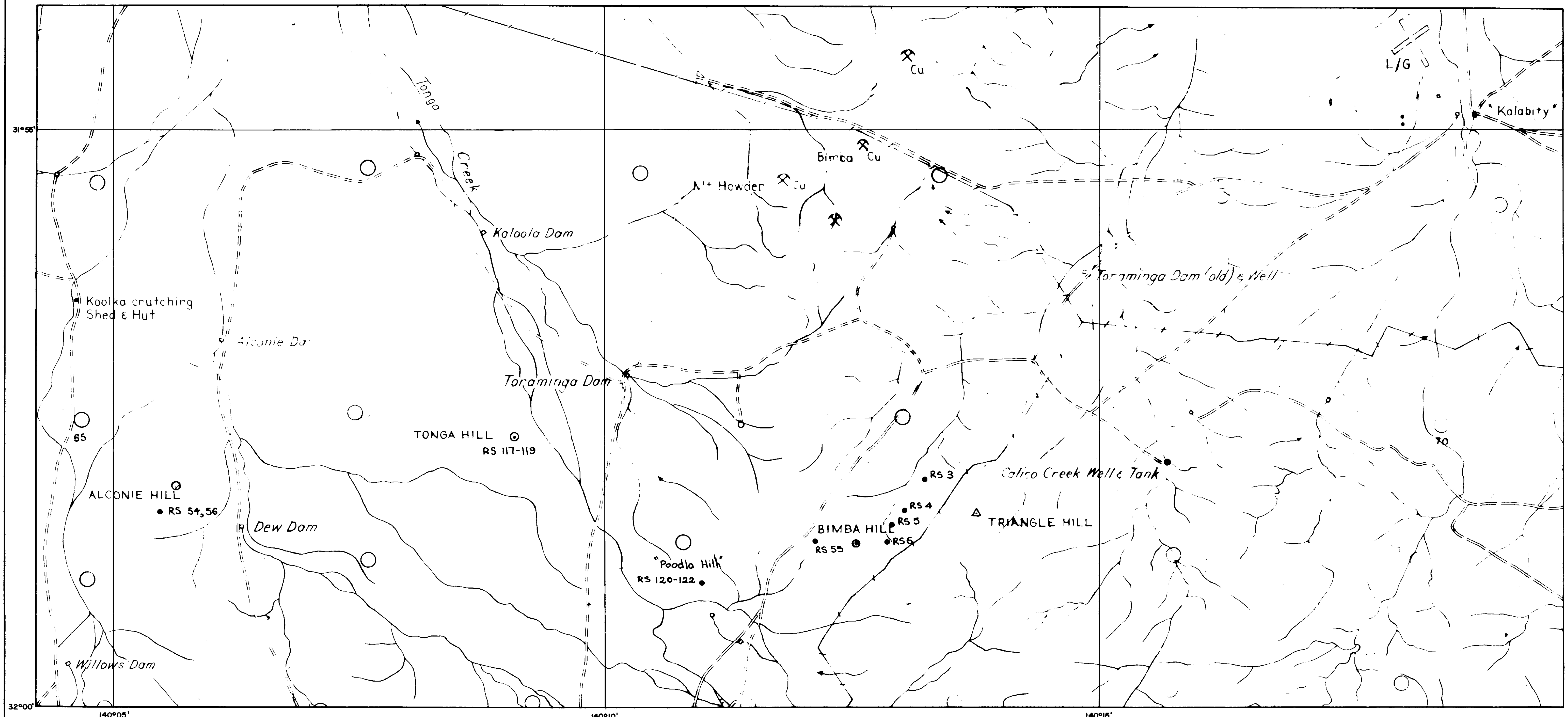


Fig. 3

SCALE

METRES 1000 0 1 2 3 4 5 KILOMETRES

All RS numbers prefixed by 6934

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE 1:50000
COMPILED D. FLINT	GEOCHRONOLOGY - WILLYAMA COMPLEX	DATE 5-11-79
DRN M.B. | CKD	SAMPLE LOCALITY PLAN	PLAN NUMBER
4·8·80	part of KALABITY 6934	79-779

	Ba	Co	Cr	Mn	Mo	Ni	V	Cu	Pb	Sn	Zn	P
PERYHUMUCK ADAMELLITE GNEISS	200	–	50	70	–	150	300	10	10	3	–	–
	300	–	20	150	–	80	150	10	10	2	80	–
	–	–	20	80	–	5	100	5	10	1	–	300
	–	5	–	80	–	30	80	10	80	1	–	500
	300	5	20	150	30	20	100	10	10	1	30	–
	500	5	30	100	–	70	100	10	30	1	–	–
	–	–	30	100	–	30	100	10	10	1	–	–
	500	10	80	100	5	250	250	10	20	1	50	–
	–	–	30	100	–	10	100	10	10	1	50	–
	–	–	20	30	–	30	80	5	20	2	–	500
EAST DOUGHBOY LEUCOCRATIC SODIC GNEISS	–	5	30	20	–	30	100	5	20	3	–	300
	–	–	–	30	–	50	100	3	10	2	–	300
	–	5	–	20	–	30	70	10	5	1	–	–
	–	–	20	30	–	30	100	5	10	1	–	300
	–	10	70	30	5	200	250	5	10	2	–	–
	–	–	50	30	3	100	250	5	3	2	–	–
	–	10	30	10	5	50	200	5	30	5	100	–
	–	–	–	20	–	30	80	5	10	1	–	–
	–	20	30	30	–	5	70	50	10	2	–	–
TOMMIE WATTIE MICA SCHIST	1000	50	150	100	–	100	200	30	5	3	–	300
	300	20	100	100	–	80	100	10	1	2	–	–
	700	30	100	100	–	80	100	10	5	1	–	300
	200	20	80	100	–	20	80	3	1	2	–	300
	500	20	100	100	–	30	100	10	5	2	–	–
TIETZ GRANITE	–	5	30	150	–	30	100	20	30	2	–	500
	–	5	30	100	–	20	80	10	30	2	30	500
	–	5	20	100	–	5	150	10	30	2	50	1000
	–	–	–	100	–	30	100	5	30	3	50	1000
	–	–	–	100	–	5	100	20	20	1	–	1000
	–	–	80	100	–	150	200	10	20	2	50	1000
	–	5	30	100	–	30	100	10	20	3	50	300
	–	5	30	100	–	20	150	30	30	3	50	1000
TONGA HILL GRANITOID	–	10	30	80	–	30	100	10	10	5	–	1000
	–	10	50	100	–	30	100	20	10	1	–	300
	–	20	70	100	–	100	200	20	10	2	–	–
POODLA HILL GRANITOID	1000	30	70	200	3	80	150	30	5	2	–	500
	300	10	50	150	3	10	200	30	5	5	–	300
	1000	30	80	150	–	50	150	30	10	1	–	300
DETECTION LIMITS	200	5	20	10	3	5	100	1	1	1	20	100

TABLE I	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE:
COMPILED D. FLINT	GEOCHRONOLOGY– WILLYAMA COMPLEX COMPARISON OF GEOCHEMISTRY AND LITHOLOGY	DATE 16–11–79
DRN M.B. / CKD:		PLAN NUMBER
4·8·80		S14463

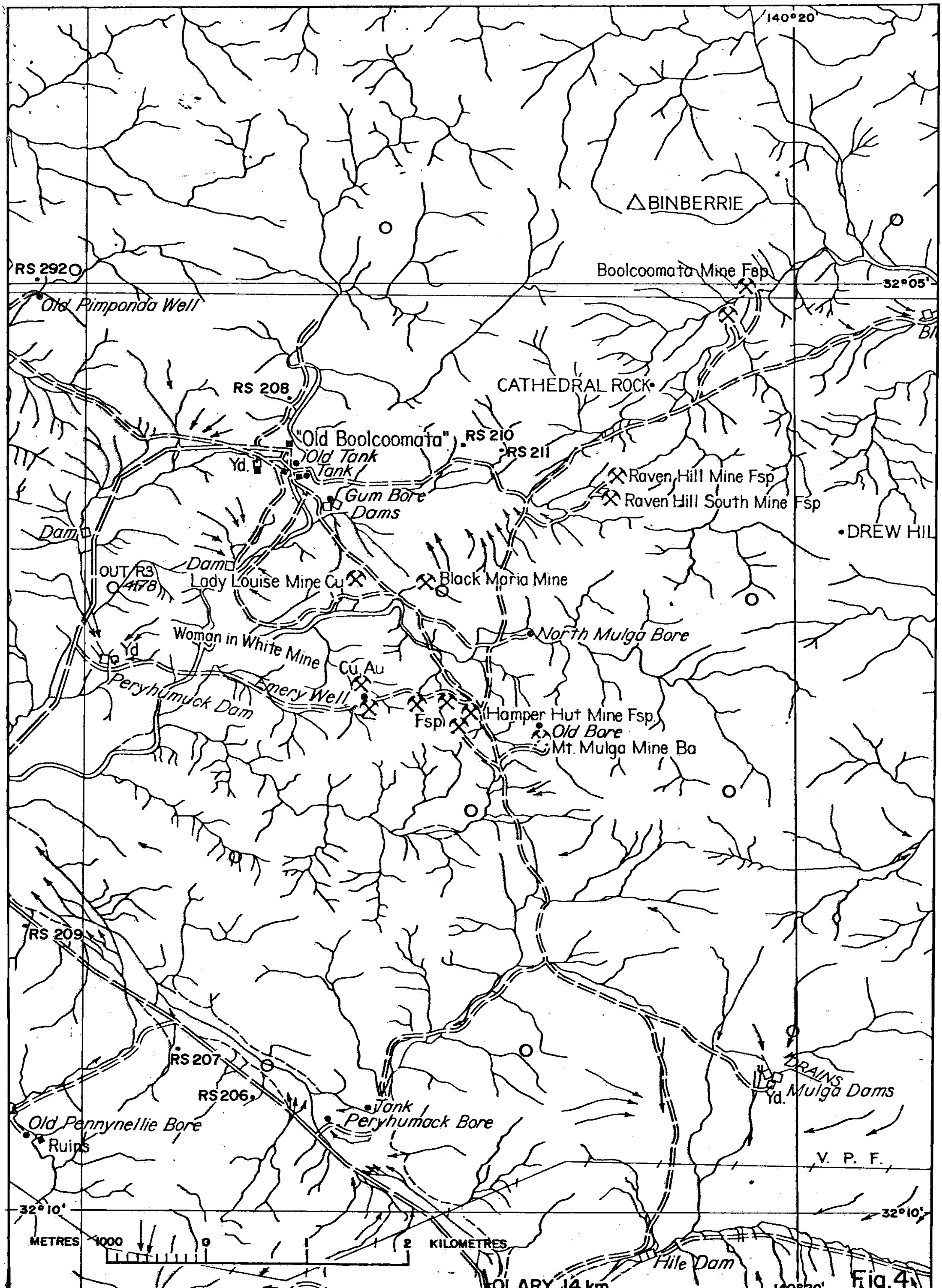


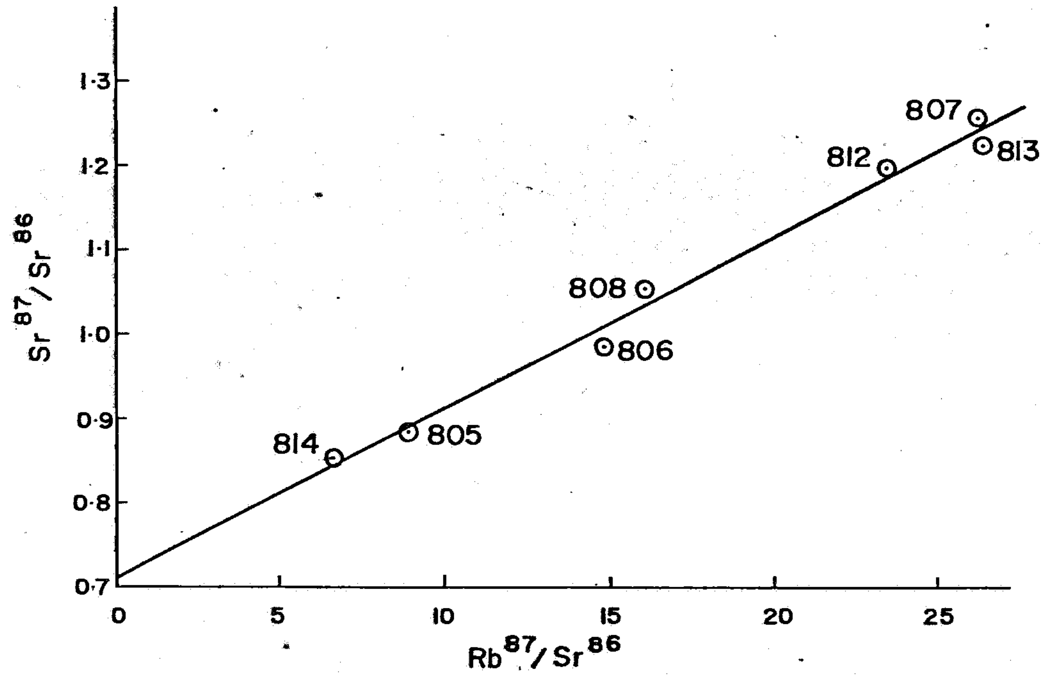
Fig. 4

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE: 1 : 50 000
COMPILED: D. FLINT — GEOCHRONOLOGY – WILLYAMA COMPLEX	DATE: 1-11-79
DRN: M. B. CKD: — SAMPLE LOCALITY PLAN part of BULLOO 6933-I	PLAN NUMBER S14402

B 4·8·80

AGE: 1466 ± 185 Ma.

Initial Sr^{87}/Sr^{86} : 0·7055 ± 0·0507



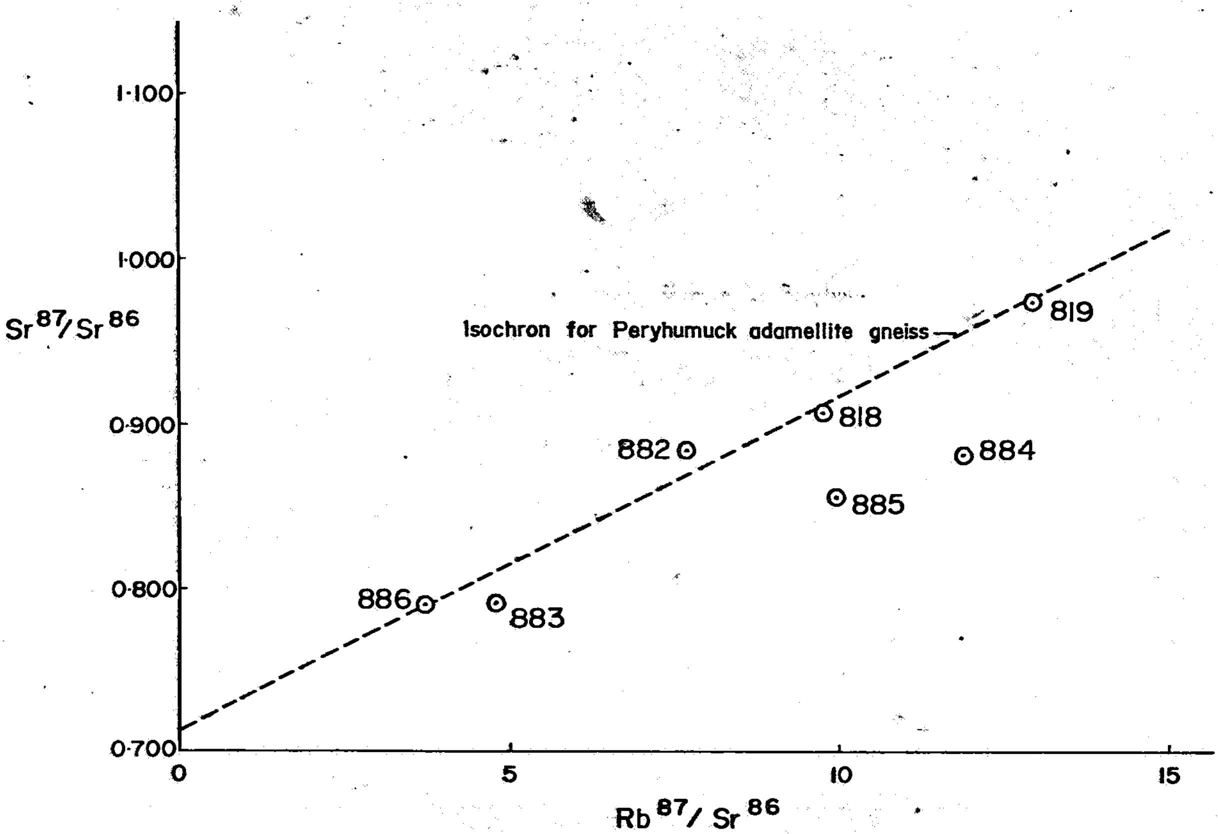
All sample numbers prefixed by 6933 R.S.

SAMPLE NO.	Rb/Sr	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}
805	3·03	8·9022	0·8863
806	5·01	14·862	0·9873
807	8·84	26·964	1·2836
808	5·52	16·520	1·0802
812	7·79	23·593	1·2069
813	8·85	26·928	1·2570
814	2·19	6·4116	0·8496

Fig. 5

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE:
COMPILED O.FLINT	GEOCHRONOLOGY–WILLYAMA COMPLEX	DATE 19–11–79
DRN M.B. / CKD:	GEOCHRONOLOGICAL RESULTS ·	PLAN NUMBER
B 4·8·80	PERYHUMUCK ADAMELLITE GNEISS	S14458

AGE: Probably comparable to Peryhumuck adamellite gneiss 1466 ± 185 Ma.



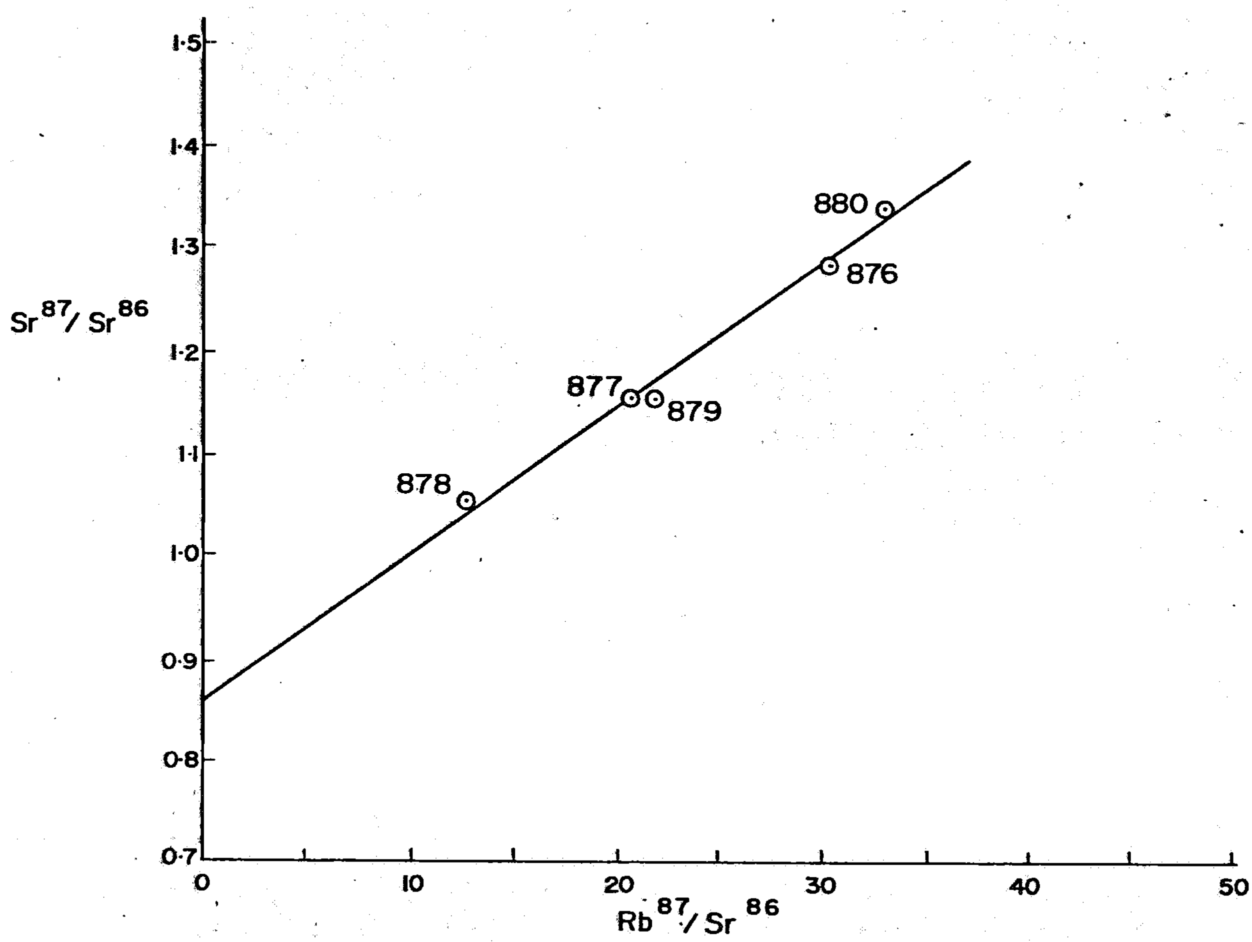
All sample numbers prefixed by 6933 R.S.

SAMPLE NO.	Rb/Sr	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}
818	3·31	9·7436	0·9063
819	4·35	12·889	0·9745
882	2·60	7·6364	0·8830
883	1·66	4·8318	0·7896
884	4·04	11·863	0·8807
885	3·40	9·9591	0·8548
886	1·29	3·7539	0·7870

Fig. 6

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE
COMPILED D. FLINT	GEOCHRONOLOGY – WILLYAMA COMPLEX	DATE: 6–11–79
DRN M.B. / CKD	GEOCHRONOLOGICAL RESULTS	PLAN NUMBER
B 4·8·80	EAST DOUGHBOY LEUCOCRATIC SODIC GNEISS	S14459

AGE: 1000 ± 197 Ma
Initial Sr^{87}/Sr^{86}: 0·8577 ± 0·0692

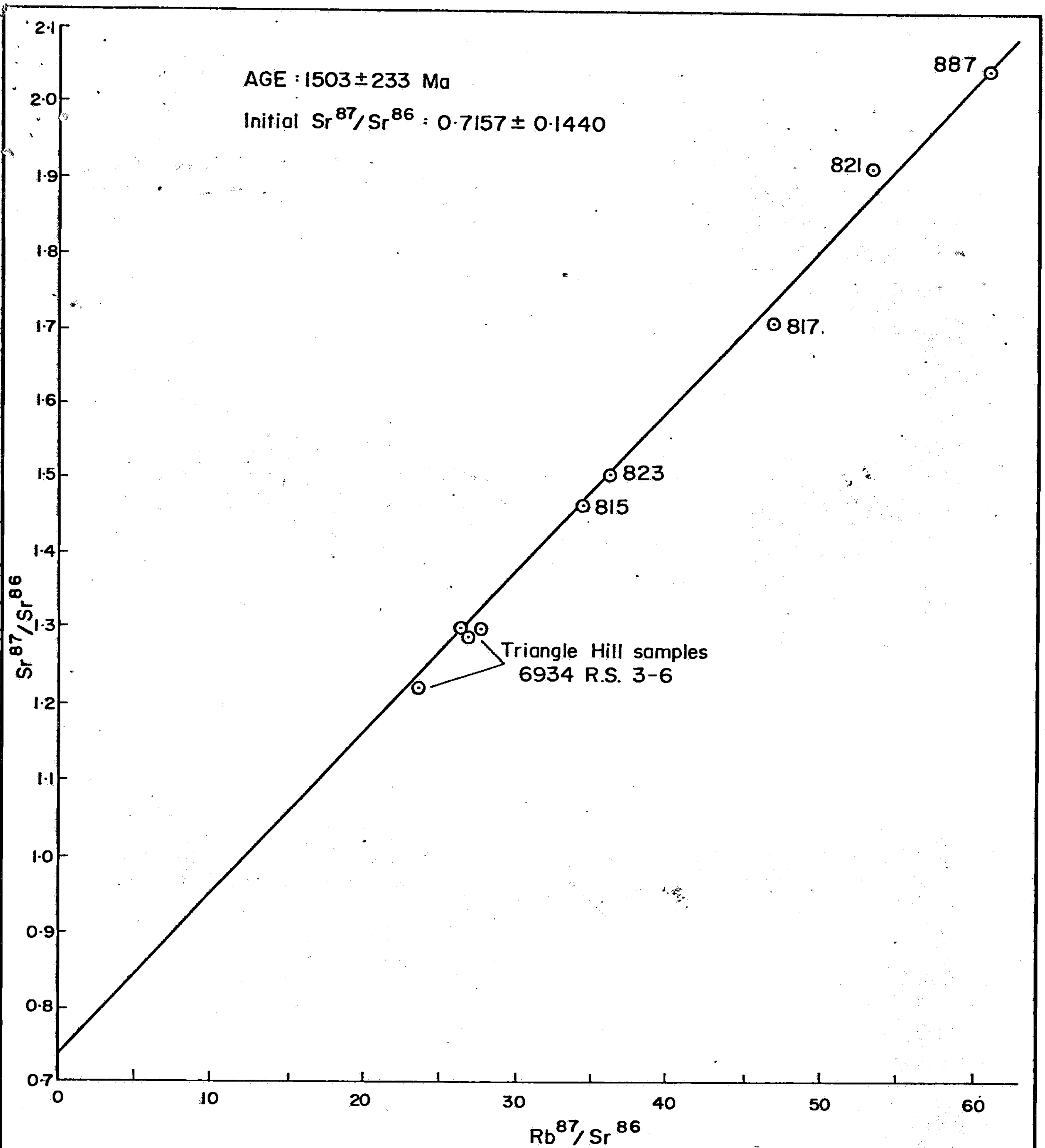


All sample numbers prefixed by 6933 R.S.

SAMPLE NO.	Rb/Sr	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}
876	9·90	30·202	1·2851
877	6·91	20·820	1·1517
878	4·27	12·745	1·0516
879	7·22	21·755	1·1522
880	10·71	32·838	1·3397

Fig. 7

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE:
COMPILED D.FLINT	GEOCHRONOLOGY – WILLYAMA COMPLEX	DATE: 7-11-79
DRN M.B. CKD:	GEOCHRONOLOGICAL RESULTS	PLAN NUMBER
B 4·8·80	TOMMIE WATTIE MICACEOUS SCHIST	S14460



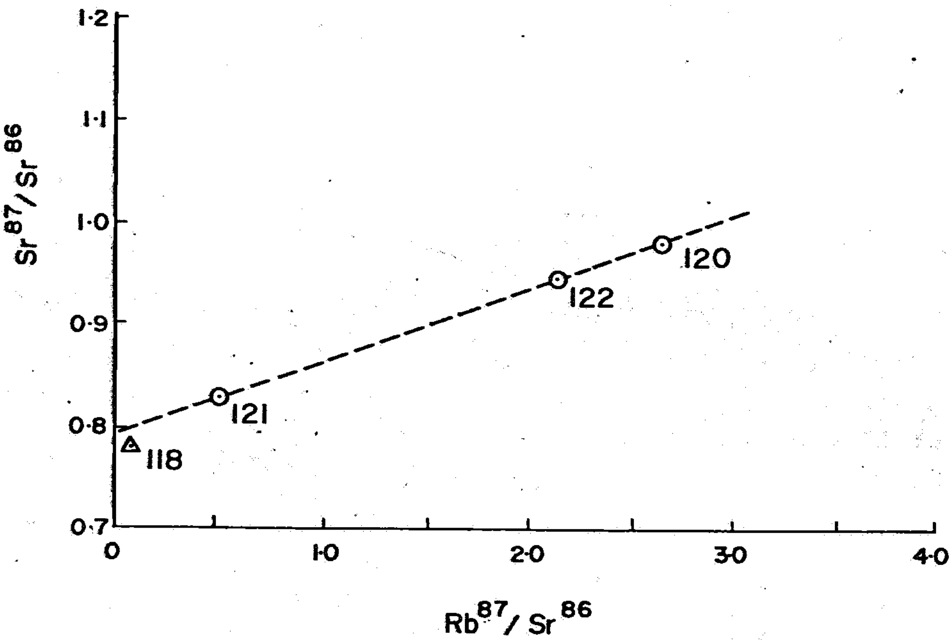
All sample numbers prefixed by 6933 R.S.

SAMPLE NO.	Rb/Sr	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}
815	11·18	34·667	1·4625
817	14·87	47·124	1·7042
887	18·89	61·636	2·0364
821	16·68	53·822	1·9084
823	11·66	36·294	1·5047

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	Fig. 8
COMPILED D. FLINT	GEOCHRONOLOGY – WILLYAMA COMPLEX	DATE 7-11-79
DRN M.B. / CKD: B 4·8·80	GEOCHRONOLOGICAL RESULTS TIETZ GRANITE	PLAN NUMBER S14461

AGE (Poodla Hill adamellite): ≈ 490 Ma

Initial Sr^{87}/Sr^{86}: 0·795



All sample numbers prefixed by 7934 R.S.

SAMPLE NO.	Rb/Sr	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}
	Tonga Hill	soda-syenite	
117	~0·15	—	—
118	0·270	0·7810	0·7248
119	~0·21	—	—
	Poodla Hill	adamellite	
120	8·92	26·42	0·9708
121	1·69	4·9380	0·8291
122	7·23	21·36	0·9454

Fig. 9

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE:
COMPILED: D. FLINT	GEOCHRONOLOGY– WILLYAMA COMPLEX	DATE: 12–11–79
DRN: M. B. CKD:	GEOCHRONOLOGICAL RESULTS– TONGA HILL	PLAN NUMBER
B 4·8·80	SODA-SYENITE & POODLA HILL ADAMELLITE	S14462

APPENDIX A

CORRELATION TABLE OF
DEPARTMENTAL SAMPLE NUMBERS

R.S. No.	D.J.F. No.	Pet. No.	Anal. No.
6933-805	G 1	P334/77	A1421/77
6	2	5	2
7	3	6	3
8	4	7	4
9	5	8	A1425/77 & A1459/77
810	6	9	A1426/77
1	7	P340/77	7
2	8	1	8
3	9	2	9
4	10	3	A1430/77
5	11	4	1
6	12	5	2
7	13	6	3
8	14	P389/77	4
9	15	90	5
820	16	P347/77	6
887	17	8	7
821	18	9	8
2	19	50	9
3	20	51	A1440/77
875	21	P391/77	1
6	22	2	2
7	23	3	3
8	24	4	4
9	25	5	5
880	26	6	6
1	27	7	7
2	28	8	8
3	29	9	9
4	30	P400/77	A1450/77
5	31	1	1
6	32	2	2
6934-117	33	P352/77	3
118	34	3	4
119	35	4	5
120	36	5	6
121	37	6	7
122	G38	7	8

Samples referred to in Radke and Webb (1975)

<u>in</u> S. Aust. Dept. Mines & Energy open file Env. 2136 - progress report No. 8.

<u>"Granodiorite"</u> (gneiss near Old Pennynellie Bore)

6933 R.S. 206	P505/73
207	6
209	8

<u>Triangle Hill granite</u>

6934 R.S. 3	P510/73
4	1
5	2
6	3

<u>Binberri adamellite</u>

6933 R.S. 208	P507/73
210	P509/73
211	P518/73

APPENDIX B

MULTI-ELEMENT EMISSION SPECTROSCOPY

<u>In</u>

Amdel Report AN 11/78

amdel
The Australian Mineral Development Laboratories
Flemington Street, Frewville, South Australia 5063
Phone Adelaide 79 1662, telex AA 82520

Pilot Plant Osman Place, Thebarton, Sth Aust
Phone Adelaide 43 8053
Branch Offices Perth and Sydney
Associated with Professional Consultants Australia Pty Ltd

Please address all correspondence to Frewville.
In reply quote: AN 1/15/11/0 - 11/78

NATA CERTIFICATE 28 July 1977

The Director,
Department of Mines,
Box 151,
EASTWOOD SA 5063

A 60/77

REPORT AN 11/78

YOUR REFERENCE:	Application dated 28/6/77
LOCATION:	Outalpa 1:50000 6933 IV 8
IDENTIFICATION:	As listed
DATE RECEIVED:	1 July 1977

Enquiries quoting AN 11/78 to the Manager please

The Manager, Analytical Division: D. K. Rowley

for Brian S. Hickman
Acting Managing Director

AMDEL ANALYTICAL SERVICE

FORM 6 JOB 11/78

Results in ppm unless otherwise stated

BATCH NO. 1/2

TT	Sample No.			Au					
1	A 1421/77			<0.05					
2	2			<0.05					
3	3			<0.05					
4	4			<0.05					
5	5			<0.05					
6	26 x			<0.05					
7	7			<0.05					
8	8			<0.05					
9	9			<0.05					
10	30			<0.05					
11	1			<0.05					
12	2			<0.05					
13	3			<0.05					
14	4			<0.05					
15	STD.								
16	5			<0.05					
17	6			<0.05					
18	7			<0.05					
19	A 1438/77			<0.05					
20	26 x								

AMDEL ANALYTICAL SERVICE

FORM 6 JOB 11/78

Results in ppm unless otherwise stated

BATCH NO. 2

TT	Sample No.			Au					
1	A 1439/77			<0.05					
2	40			<0.05					
3	1			<0.05					
4	2			<0.05					
5	3			<0.05					
6	4			<0.05					
7	STD.								
8	5			<0.05					
9	6			<0.05					
10	7			<0.05					
11	8			<0.05					
12	9			<0.05					
13	50			<0.05					
14	1			<0.05					
15	2			<0.05					
16	53 x			<0.05					
17	4			<0.05					
18	5			<0.05					
19	A 1456/77			<0.05					
20	53 x								

SAMPLE No.	Au
A 1457/77	<0.05
8	"
9	"
STD.	

PROJECT No | PROJECT ID | PROJECT NAME GEOCHRONOLOGY - WILLYAMA COMPLEX | CARD PUNCH PRINT yes [ ] no [ ] | VERIFY yes [ ] no [ ]

ID/NUMBER	Ba (200)	Co (5)	Cr (20)	Mn (10)	Mo (3)	Ni (5)	V (100)	W (50)	Ag (0.1)	As (50)	Bi (1)	Cu (1)	Pb (1)	Sb (30)	Sn (1)	Zn (20)	Au (3)	P (100)
421/77	200	X	50	70	X	150	300	X	X	X	X	10	10	X	3	X	X	X
22	300	X	20	150	X	80	150	X	X	X	X	10	10	X	2	60	X	X
23	X	X	20	80	X	5	100	X	X	X	X	5	10	X	1	X	X	300
24	X	5	X	80	X	30	80	X	X	X	X	10	80	X	1	X	X	500
25	300	5	20	150	30	20	100	X	X	X	X	10	10	X	1	30	X	X
26	500	5	30	100	X	70	100	X	X	X	X	10	30	X	1	X	X	X
27	X	X	20	100	X	30	100	X	X	X	X	10	10	X	1	50	X	X
28	500	10	80	100	5	250	250	X	X	X	X	10	20	X	1	50	X	X
29	X	X	20	100	X	10	100	X	X	X	X	10	10	X	1	[illegible]	X	X
30	X	X	20	30	X	30	80	X	X	X	X	5	20	X	2	X	X	500
31	X	5	30	150	X	20	100	X	X	X	X	20	[illegible]	X	2	X	X	[illegible]
32	X	5	30	100	X	20	80	X	X	X	X	10	30	X	2	30	X	500
33	X	5	20	100	X	5	150	X	X	X	X	10	30	X	2	50	X	1000
34	X	5	30	20	X	30	100	X	X	X	X	5	30	X	3	X	X	300
35	X	X	X	30	X	50	100	X	X	X	X	3	10	X	2	X	X	300
36	X	X	X	100	X	30	100	X	X	X	X	5	50	X	3	50	X	1000
37	X	X	X	100	X	5	100	X	X	X	X	20	30	X	1	X	X	1000
38	X	X	80	100	X	150	200	X	X	X	X	10	[illegible]	X	2	[illegible]	X	1000
39	X	5	30	100	X	30	100	X	X	X	X	10	20	X	3	50	X	300
40	X	5	50	100	X	20	150	X	X	X	X	30	20	X	[illegible]	50	X	1000
41	X	5	X	20	X	20	70	X	X	X	X	10	5	X	1	X	X	[illegible]
42	1000	50	150	100	X	100	200	X	X	X	X	50	5	X	3	X	X	[illegible]
43	300	20	100	100	X	50	100	X	X	X	X	10	1	X	[illegible]	X	X	[illegible]
44	700	30	100	100	X	80	100	X	X	X	X	10	1	X	1	X	X	300
1445/77	200	20	20	100	X	20	[illegible]	X	X	X	X	3	1	X	[illegible]	X	X	[illegible]

THE AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES
80 COLUMN CARD PUNCH LAYOUT

DATA LAYOUT FOR: METTL

PROJECT Nº	PROJECT ID.	PROJECT NAME	CARD PUNCH PRINT	VERIFY	DATE OUT
		GEOCHRONOLOGY — WILLYAMA COMPLEX	yes [ ] no [ ]	yes [ ] no [ ]	

IDENTIFICATION A/NUMBER	Ba (200)	Co (5)	Cr (20)	Mn (10)	Mo (3)	Ni (5)	V (100)	W (50)	Ag (0.1)	As (50)	Bi (1)	Cu (1)	Pb (1)	Sb (30)	Sn (1)	Zn (20)	Au (3)	P (100)
1446/77	500	20	100	100	X	30	100	X	X	X	X	10	5	X	2	X	X	X
47	X	X	20	30	X	30	100	X	X	X	X	5	10	X	1	X	X	300
48	X	10	70	30	5	200	250	X	X	X	X	5	10	X	2	X	X	X
49	X	X	50	30	3	100	250	X	X	X	X	5	3	X	2	X	X	X
50	X	10	30	10	5	50	200	X	1.0	X	X	5	30	X	5	100	X	X
51	X	X	X	20	X	30	80	X	X	X	X	5	10	X	1	X	X	X
52	X	20	30	30	X	5	70	X	X	X	X	50	10	X	2	X	X	X
53	X	10	30	30	X	30	100	X	X	X	X	10	10	X	5	X	X	1000
54	X	10	50	100	X	30	100	X	X	X	X	20	10	X	1	X	X	300
55	X	20	70	100	X	100	200	X	X	X	X	20	10	X	2	X	X	[illegible]
56	1000	30	70	200	3	50	150	X	X	X	X	30	5	X	2	X	X	500
57	300	10	50	150	3	10	200	X	X	X	X	30	5	X	5	X	X	300?
58	1000	30	80	150	X	50	150	X	X	X	X	30	10	X	1	X	X	300?
A1459/77	300	X	30	150	50	10	150	X	X	X	X	10	10	X	1	X	X	