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8th March, 1977

The Director,
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PO Box 151,
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THE METAL-BEARING POTENTIAL OF FELSIC INTRUSIVE ROCKS IN SOUTH AUSTRALIA

Progress Report No.1

Investigation and Report by: Dr B.G. Steveson

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K. J. Henley

for F.R. Hartley
Director

mhb

1. INTRODUCTION

The objective of this project is to assess the value of analysing biotite concentrates from acid plutonic igneous rocks for certain elements so as to provide a method of determing whether or not the pluton in which the biotite occurs may be mineralised. Several hundred biotite concentrates have been prepared for the South Australian Department of Mines for the purposes of potassium-argon geochronology; furthermore, a literature survey carried out by Amdel (1.1.119; report No. 708) showed that much of the tin in granites occurs in biotite. The combination of having many concentrates already available and evidence that analysis of these could be a preliminary prospecting tool led to the present project.

The present progress report will describe the techniques which are being used in mineral separation and analysis and will give the results obtained so far. A small survey of available literature will be given subsequently.

2. TECHNIQUES

The rock sample employed is commonly a fresh granitic rock weighing (preferably) about 1 kg; the following steps are normally carried out.

1. The rock is crushed to -0.42 mm and a 30 gm aliquot is riffled out for analysis.

2. The remainder is washed and wet-sieved at 0.105 mm to obtain a clean +0.105 mm fraction for mineral separation.

3. The +0.105 mm fraction is subjected to flotation at pH 3.0 using Armac 12 conditioner; from this process, a mica concentrate is obtained (usually rather impure but with high recovery). Several flotations may have to be carried out if there is more than about 600 g of +0.105 mm material.

4. The washed and dried overflow product is purified by means of heavy liquid separation (using tetrabromoethane or density gradient columns) and magnetic separations.

5. The final concentrate is examined in temporary grain mounts and only concentrates of more than about 98% purity are accepted.

The biotite concentrate and the rock sample are assayed for Sn, Mo, W, Pb, Zn and Cl by X-ray fluorescence techniques and for Cu and Au by atomic absorption spectroscopy (after fire assay, in the case of Au).

3. RESULTS

The samples treated to date are as follows:

Sample	Location
1	Anabama; DDH4, 177.5 to 179 m.
3	Anabama; DDH5, 64-65 m.
10	Bendigo; BD4, 231-234' biotite granodiorite.
15	Bendigo; BD7, 539-542' biotite granodiorite with minor pyrite and chalcopyrite.
20	Anabama; DDH AN1, 455-460'.
22	Anabama; DDH AN2, 445-450'.
P1124/74	Point Brown; mafic-rich adamellite.
P1747/75	Mudnawatana Granite; 3/4 km N of Paralana Hot Springs.
P507/74	Duffield 1:50,000 sheet; porphyritic granite.
P1218/74	North East Olive Island; granite.
P144/70	Meningie Granite; 5 miles NNE of Meningie.
P1729/75	2 km W of Pidgeon Springs; adamellite.
P30/71	Buckleboo 1 mile sheet, near Cortlinye R.H., granite
P945/71	3 miles NW of Norowie, Cowell sheet; granite.

Of these the first six are from (copper-) mineralised granitic rocks, whereas the remainder are nominally "barren".

The results are given in Table 1; 'head' refers to the whole rock sample and all values are in parts per million.

4. WORK IN PROGRESS

Twenty-two samples were collected from the Bendigo and Anabama core material and separations were attempted on ten; in six cases only were satisfactory biotite concentrates obtained. Twenty-six "barren" samples have been crushed and biotite separation has been attempted on these; analyses of eight concentrates are given in Table 1 of this progress report and a further seven concentrates are currently being obtained. Hence from 26 samples, 15 sets of (head and biotite) analyses will be reported.

The most evident omission from the data set will be that of samples from granitic rocks associated with tin (and tungsten) mineralisation. Discussion with Mr Faulkes and Mrs Daly of the South Australian Mines Department makes it clear that sufficiently fresh material is not available from the Earea Dam/South Lake area. It is recommended therefore that granitic material be obtained from areas of tin mineralization outside South Australia (e.g. Queensland). The author has worked on the tin-bearing granites of the Herberton district in Queensland and could readily obtain suitable material. The results are likely to be of more than local significance and applicable to the South Australian situation.

TABLE 1: ANALYSES OF ROCKS AND BIOTITES FROM SELECTED GRANITIC ROCKS

Sample		Element (ppm)							
		Sn	Mo	W	Cu	Pb	Zn	Cl	Au
1	Head	<4	8	<10	65	12	60	170	<0.1
	Biotite	12	<4	<10	10	4	310	580	<0.1
3	Head	<4	6	<10	105	10	85	270	<0.1
	Biotite	8	<4	<10	8	10	330	740	<0.1
10	Head	<4	8	<10	105	16	30	430	<0.1
	Biotite	<4	4	<10	30	8	65	3250	<0.1
15	Head	4	16	<10	70	12	10	120	<0.1
	Biotite	12	<4	<10	16	6	48	1350	<0.1
20	Head	6	6	<10	145	12	42	130	<0.1
	Biotite	16	<4	<10	16	4	380	800	<0.1
22	Head	4	4	<10	460	10	65	120	<0.1
	Biotite	20	16	<10	75	14	290	600	<0.1
P1124/74	Head	10	4	<10	40	380	75	120	<0.1
	Biotite	4	4	<10	14	10	545	220	<0.1
P1747/75	Head	8	<4	<10	55	26	18	320	<0.1
	Biotite	60	4	55	25	28	135	2550	<0.1
P507/74	Head	10	4	<10	35	34	90	50	<0.1
	Biotite	26	<4	<10	16	8	400	240	<0.1
P1218/74	Head	<4	4	<10	30	55	36	130	<0.1
	Biotite	8	<4	<10	20	12	900	850	<0.1
P144/70	Head	8	4	<10	30	20	36	140	0.010
	Biotite	22	<4	20	40	20	380	1700	0.015
P1729/75	Head	<4	4	<10	580	32	130	110	<0.005
	Biotite	6	<4	<10	20	22	550	1400	0.035
P30/71	Head	10	<4	<10	50	46	70	220	0.010
	Biotite	50	<4	10	45	36	550	3550	0.005
P945/71	Head	18	<4	<10	50	65	30	340	0.020
	Biotite	180	<4	20	1090	80	420	1850	<0.005

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20 June, 1977

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THE METAL-BEARING POTENTIAL OF FELSIC INTRUSIVE ROCKS
IN SOUTH AUSTRALIA

Progress Report No. 2

Investigation and Report by: Dr B.G. Steveson

Officer in Charge, Mineralogy/Petrology Section: Dr K.J. Henley

for Brian S. Hickman
Acting Managing Director

k.

TABLE 16: MEANS (WEIGHTED) AND NUMBER OF ANALYSES, COMPUTED FROM DATA OF TABLES 1 TO 15

Element	Barren or Mineralized	In biotites	In plutonic, igneous rocks	In metamorphics
Au (ppb)	(B	6(171)	5.2(781)	1(140)
	(M	4(4)	3.4(77)	34(827)
Cl (ppm)	(B	1470(138)	285(381)	313(92)
	(M	3300(20)	700(2)	-
Sn (ppm)	(B	28(294)	3(320)	-
	(M	123(181)	11(2745)	-
Pb (ppm)	(B	20(185)	23(1220)	17(3793)
	(M	17(67)	-	-
Cu (ppm)	(B	80(619)	11(6548)	22(1411)
	(M	960(132)	-	-
Zn (ppm)	(B	584(541)	50(1106)	124(47)
	(M	258(67)	-	-

1. INTRODUCTION

The object of this project is to provide some preliminary data on the relationship between certain ore metal concentrations in biotites and granites and the extent of potential mineralization associated with the granitic rocks. Data have been obtained on selected samples of both barren and mineralized granite from South Australia and this Progress Report contains the results of a brief literature search aimed at providing comparative data. With the limited resources available, particular attention has been paid to obtaining analytical data rather than providing a detailed interpretation and discussion of these data. All the data obtained are given in Tables 1 to 15 and are summarized in Table 16.

2. TUNGSTEN AND MOLYBDENUM

In general, insufficient data have been obtained from the literature to provide meaningful comparisons with the analyses presented in other Progress Reports. References to the abundance of molybdenum in granitic rocks are given in Davy (1970), but there is little indication of the relative levels of molybdenum in barren and mineralized rock or of molybdenum in biotite. Similarly, the data for tungsten are meagre and the work of Jeffrey (1959) is all that can be usefully cited here. Jeffrey analysed rocks and mineral concentrates from Uganda for tungsten and found that barren granitic rocks contained an average of 1.4 ppm tungsten whereas selected mineralized rocks from Singo have tungsten values ranging from 2.6 to 12 ppm tungsten. A biotite from a carbonatite contains 2.8 ppm tungsten, whereas a biotite from a gneissic rock contains 6 ppm; since these values are all obtained from a relatively restricted area of the earth's crust, little value can be attached to them in the light of the objective of this project.

Briefly, it may be pointed out that both tungsten and molybdenum are soluble in magmatic water-rich phases possibly by means of tungstate and molybdate ions. It is possible also that transport in such a phase may be partly by unassociated H_2WO_4, Na_2WO_4 or heteropolytungsten acids, e.g. $H_8Si(W_2O_7)_6$, and the corresponding molybdenum compounds. The possibility of transport of tungsten and molybdenum in a fluorine-bearing solution has been discussed by Grundlach and Thosmann (1960) and Ivanova and Khodakovsky (1968).

3. TIN

There has been a considerable amount of work on the concentration of tin in barren and mineralized granitic rocks and the minerals obtained from these rocks. This is reflected in the number of analyses of barren and mineralized granites compared to the paucity of such data in the case of other elements considered in this report. The data for tin are shown in Tables 1, 2 and 3 and weighted average values are given in Table 16.

Davy (1970) and Davy and Steveson (1972) summarize data on tin and indicate the suitability of prospecting by means of the analysis of both granites and biotites obtained therefrom. The contention in these reports and in much of the data from which they were derived, is that a tin concentration greater than about 10 ppm in a granitic rock is an indication that the granite has potential for tin mineralization, whereas the background level for tin in such rocks is less than 5 ppm. This is borne out by the data given in Tables 2, 3 and 16 where it can be seen that the average tin content of 320 unmineralized granites is 3 ppm, whereas more than 2,500 mineralized granites give an average tin value of 11 ppm. The distinction between barren mineralized rocks is shown even more in the analysis of the biotite concentrates; almost 200 biotite concentrates obtained from mineralized granites have an average tin content of 123 ppm whereas almost 300 biotites from barren granites have an average tin content of approximately 30 ppm. It is clear from the data in Tables 2 and 3 that there is a fairly restricted range of values of tin in barren granitic rocks; no values greater than about 8 ppm were obtained and the average value for granites from different parts of the earth's crust nowhere exceeds 4 ppm (Table 2). Mineralized granites, however, have rather a wide range of tin content and 2,500 samples analysed by Dahn et al. (1968) have an average value of only 10 ppm, whereas seven samples analysed by Hosking (1965) have an average tin content of 105 ppm. Furthermore, the range of values in mineralized granite is extremely wide, ranging from approximately 2 ppm to 500 ppm. It is clear, therefore, that the tin concentration in mineralized granite varies, probably depending on the type of mineralization and its relationship to the granite and possibly depending also on whether or not the granite occurs in a tin-rich part of the earth's crust. Several authors report that in Malaya, for example, barren granitic rocks may contain more than 10 ppm tin and this is interpreted as being a reflection of the relatively high tin content of magmatic material in this part of the world.

That biotites from barren granitic rocks contain less than 30 ppm tin is proved by the evidence shown in Table 1, although the data of Chauris (1965) probably bear closer examination since he found that biotites from barren granitic rocks contain 100 ppm tin, whereas biotites from mineralized rocks contain an average of 62 ppm tin. All other data cited in the table confirm that biotites from mineralized granites contain more than 30 ppm tin and values recorded range up to 500 ppm. As a result it is clear that the analysis of biotite concentrates can provide a useful preliminary prospecting tool for certain types of tin deposits.

There is little or no data on the tin concentrations in acid metamorphic rocks.

4. COPPER

Copper is a chalcophile element which is probably concentrated in aqueous solutions obtained from the last differentiates of acid magma. The vapour pressure of copper sulphides in steam from granitic melts is too low for transport in the gas phase but experimental work (mainly by Helgeson, 1969) suggests that copper sulphides are sufficiently soluble in chloride solution to provide the necessary accumulation of copper to form ore deposits. Leaching experiments have also been carried out in an attempt to remove copper from, for example, andesite and shale using sodium chloride solutions. At temperatures of 400 to 500^{o}C and concentrations of 2 to 4 M sodium chloride, copper concentrations of up to 100 ppm of copper have been obtained. This work shows, above all, the importance of the presence of certain complexing elements, in this case chlorine. (Parry (1972) is especially relevant to this discussion.)

The data obtained on the level of copper in biotites, acid igneous rocks and metamorphic rocks are shown in Tables 4, 5 and 6. Copper shows considerable concentration in biotites obtained from mineralized granitic rocks compared to the values in biotites from barren granites; the values are summarized in Table 16. There has been a considerable amount of work on the use of biotite as a prospecting tool for porphyry-type copper deposits and the paper by Lovering et al. (1970) is particularly relevant. These authors demonstrate a consistent increase in the copper content of biotite as mineralization becomes stronger.

Only barren igneous and metamorphic rocks have been analysed for copper but there is a considerable amount of data in each case, as is shown in Tables 5, 6 and 16. The average value in different rock types is similar from place to place in the earth's crust and few average values (for particular provinces) are greater than twice the overall average. In the case of granitic rocks, 6548 samples give an average copper value of 11 ppm and the highest individual average shown in Table 5 is 40 ppm (although it is interesting that values are as high as 300 ppm in individual samples). Schists and gneisses show an even greater consistency of averages from place to place and all are between 13 and 62 ppm and the average of 1411 values is 22 ppm of copper.

5. LEAD

As is the case for other ore metals, lead in ore bodies associated with igneous rocks is derived either from partitioning between silicate melt and associated aqueous phases or is derived from leaching of the country rocks by hydrothermal solutions of some kind. Holland (1972) showed that lead partitioning into the aqueous part of a magmatic system is proportional to the chlorine content of the aqueous phase. Leaching experiments carried out on andesite with sodium chloride solutions at temperatures of 350° to 500°C resulted in solutions which contain up to 4 ppm of lead and it is thought that such solutions are sufficiently concentrated for the potential development of lead ore bodies.

The data on lead in biotites and in metamorphic rocks are given in Tables 7 and 8 but the unusually abundant information on lead in granitic rocks is merely summarized below, rather than being tabulated. For the sake of completeness, the following is a list of references which give values for the lead content of granitic rocks:

Ahrens, 1954
Brauer, 1970
Clifford et al., 1969
Cuturic and Karamata, 1967
Deleon and Ahrens, 1957
Fershtater et al., 1969
Gavrilin et al., 1965
Gavrilin et al., 1972
Golubchina and Rabinovich, 1957
Gundlach et al., 1967
Heinrichs, 1974
Hugi, 1956
Kolbe and Taylor, 1966
Kuroda and Gorai, 1956
Moenke, 1960
Moorbath and Welke, 1969
Nockolds and Allen, 1953, 1954
Okada, 1955
Rosholt and Bartel, 1969
Sandell and Goldich, 1943
Savul et al., 1956
Shibata et al., 1960
Shimizu, 1970
Tauson and Pevstova, 1955
Wedepohl, 1956
Welke et al., 1968
Werner, 1970
Wodzicki, 1971
Zartman and Wasserburg, 1969
Zhirov and Urosova, 1962
Zlobin et al., 1965

These authors show that 1,220 acid igneous rocks have a mean lead content of 23 ppm, whereas 320 granites (sensu stricto) have a mean content of 24 ppm lead, and 245 granodiorites contain an average of 15 ppm lead. The apparently significant difference between granites and granodiorites is interpreted as being a reflection of the proportion of potassium feldspar in these rocks, since most of the lead in granitic rocks is contained in the lattice of potassium feldspar where it substitutes for potassium. These results imply that the lead content of acid igneous rocks is caused by the proportion of potassium feldspar which crystallizes from the magma and is not a reflection of, for example, the overall lead content of the magmatic system. This contention has considerable implications for most of the elements considered in this report. This is particularly so, in that the partition coefficient of lead between the silicate melt and the aqueous part of the system appears to be controlled by the nature of the silicate minerals crystallizing from the system. If a large proportion of lead in granites is in fact contained in potassium feldspar, then the nature of the crystallizing phases may well control the amount of lead in the late differentiates which may result in the formation of associated lead concentrations in mineralization associated with the igneous bodies. In the case of other elements it is possible that there is not such a strong control of this partition coefficient by one mineral, since the element is dispersed subequally in different silicate phases and hence the nature of the minerals crystallizing from the melt, although it may have some effect on the partition coefficient, may not affect the overall partition of the metal between the silicates and the late differentiate aqueous phase which may result in the development of concentrations of the metal in ore bodies. It seems to the author that there is need for a critical examination of the contention that the lead content of granitic rocks is, in fact, controlled by the amount of potassium feldspar they contain, but this, and consideration of the implications, is outside the scope of this report.

The average lead content of almost 4,000 metamorphic rocks is 17 ppm and the individual averages cited in Table 8 range up to 44 ppm, which is less than three times the overall average. As a result, there is a reasonable control on the average and expected range of values of lead in metamorphic rocks.

With respect to lead in biotite, the only samples from mineralized granitic rocks are those obtained by Parry and Nackowski, (1963) and these 67 biotites have an average lead content of 17 ppm compared with an average lead content of 20 ppm in 185 biotites from barren igneous rocks. In view of the fact that the mineralized samples all come from one area, there is probably insufficient statistical control on the difference (if any) between mineralized and barren material with respect to the lead content of biotite. It is interesting that in the area studied by Parry and Nackowski the mineralized samples contained more than three times as much lead in the biotites as do the barren samples (see Table 7). It is also interesting that the distribution of lead between biotite and the granitic rocks is different from most elements in that there are similar concentrations of lead in granites and in biotites, whereas for most of the other elements selected there is a preferred concentration of the metal in biotite with respect to the total granitic rock.

6. ZINC

Zinc has a similar behaviour to that of copper in the magmatic environment in that it tends to be concentrated in the residual aqueous phase rather than in the silicate melts and there is considerable evidence (for example, Hemley et al., 1967) of the possibility of transport of zinc in chloride solutions at temperatures of the order of 300° to 500°C. Such solutions may contain more than 5 ppm zinc and hence provide potential for the development of zinc ore bodies associated with acid igneous rocks. The data obtained for zinc in biotite and in metamorphic rocks are shown in Tables 9 and 10 respectively. There is a large amount of data on the concentration of zinc in acid igneous rocks and, as in the case of lead, a list of relevant references is given:

Azzaria, 1963
Belt, 1960
Butler and Thompson, 1967
Gavrilin and Pevstova, 1963
Gundlach et al., 1967
Haack, 1969
Huff, 1952
Morita, 1955
Okrusch and Richter, 1967
Okrusch and Richter, 1969
Putnam and Burnham, 1963
Sandell and Goldich, 1943
Savul et al., 1956
Smith, 1964
Tauson, 1964
Tauson and Kravchenko, 1956
Tauson and Pevstova, 1955
Wodzicki, 1971
Zlobin et al., 1965
Zlobin and Pevstova, 1964

The papers listed contain 1,106 analyses of barren granitic rocks and these have an average zinc content of 50 ppm. There is little differentiation between granites (sensu stricto) and granodiorites and these two types have means of 48 ppm and 52 ppm zinc respectively.

Biotite shows relatively high values of zinc and 541 biotites from granitic igneous rocks have an average zinc content of 580 ppm; the only data on biotites from mineralized granitic rocks are those obtained by Parry and Nackowski (1963) and 67 biotites they analysed have an average zinc content of approximately 260 ppm. As in the case of lead, these values for biotites from mineralized rocks should probably be compared not with the overall average for barren rocks but with the average for barren granitic rocks in the same area from which the mineralized samples were obtained. The last two lines of Table 9 show that, in fact, in the area considered by Parry and Nackowski the biotites from mineralized granitic rocks contain more than ten times the amount of zinc compared to biotites from barren granites. On the other hand, it is noticeable that the 23 ppm (average of 18 values) of zinc obtained by Parry and Nackowski for biotites from barren rocks is much lower than the overall average obtained by other analysts, and it appears to be lower than any other single value obtained (see Table 9).

There is a small amount of data on the concentration of zinc in metamorphic rocks and this is given in Table 10. The average value obtained from 47 schists and gneisses is 124 ppm of zinc; this value is significantly higher than that obtained for granitic rocks but it is noticeable that it depends largely on 29 samples analysed by Van de Kamp (1970) and hence may not be a good average figure for schists and gneisses overall.

7. GOLD

There is a considerable amount of information on the possible mechanism of transport and deposition of gold in magmatic and hydrothermal environments. Relevant papers are those of Helgeson and Garrels (1968), Barnes and Czamanske (1967), Anderson and Burnham (1964), Henley (1972) and Weissberg (1970). There appears to be considerable room for debate concerning the mode of transport of gold and both chloride and sulphide complexes have been invoked. Work has been both of an experimental and theoretical nature and it seems clear that solutions obtained from leaching experiments, in particular, have sufficient gold to provide potential for the development of gold ore bodies.

Tables 11, 12 and 13 show the data obtained from the literature on the concentration of gold in biotites, acid plutonic rocks and metamorphic rocks respectively.

The data on the concentration of gold in biotites obtained from mineralized rocks have been obtained only from Shcherbakov (1967) and hence may not be a good indication of the level of gold in such biotites overall. There is a considerable amount of information on the level of gold in biotites from barren rocks and the average concentration obtained from 171 biotite concentrates is 6 ppb gold. Most of the information is obtained from the Soviet Union but it is likely that it represents a wide geographical range and probably a wide range of different types of granitic rocks and hence the average figure is probably fairly reliable. In addition, most of the information is relatively recent and hence the analyses are probably of an acceptable precision. None of the papers referred to gives information on the way in which gold occurs in the biotite concentrates and there is no evidence, for example, that gold is actually contained in the lattice of the biotite.

Altogether, almost 900 analyses of gold in granitic rocks have been obtained and these are shown in Table 12. Seventy-seven of these rocks are nominally mineralized and these have an average gold content of 3.4 ppb whereas 781 barren granites have an average gold content of 5.2 ppb. To a certain extent the value for barren rocks is inflated by data obtained by Shilin (1968) and Rozhkov et al. (1970). These authors obtained gold values which have an average of from 15 to 29 ppb, whereas the highest values obtained by other authors are only 11 ppb gold (an average of several determinations in each case). Another feature of the values for gold in plutonic acid rocks is the apparent presence of a small number of unexpectedly high values, particularly in samples variously referred to as porphyrites, aplites and greisens. Conventional granites, granodiorites, etc. generally show values of less than 10 ppb, whereas there are clearly occasional values as high as 40 or 60 ppb in porphyrites, aplites and greisens, etc. Whether these few high values represent mineralized samples or whether, more likely, they are the result of the difficulties in sampling rock units for gold, cannot be determined from perusal of the relevant literature. In general, it is considered that the data indicate that the average content of gold in granitic rocks is about 4 ppb and there is no evidence of a satisfactory distinction between mineralized and barren rocks, although it probably is valuable to separate granites, adamellites and granodiorites from late differentiates such as aplites and greisens and regard these as two separate populations.

There is a surprising amount of information on the gold content of metamorphic rocks and almost 1,000 values are recorded in Table 13 (note that 800 of these are obtained from one reference). Loshchinin (1971) obtained an average content of 35 ppb for the gold content of mineralized schists and this strongly influences the value of 34 ppb quoted as an average for such mineralized samples in Table 16. The other group of mineralized metamorphic rocks consists of 27 samples with an average of 17 ppb and this is much larger than the average for 140 barren metamorphic rocks, which is 1 ppb gold. As a result, therefore, it appears that there is a fairly representative group of data on the gold content of metamorphic rocks and the evidence suggests that such rocks are enhanced in gold when the schist or gneiss is associated with gold mineralization.

8. CHLORINE

Chlorine is not a valuable element in ore bodies associated with igneous rocks but is considered here because of the important position of chlorine with respect to the possible modes of transport of the ore metals. Chlorine is concentrated in magmatic processes in the residual fluid, although there is unlikely to be an extremely large partitioning coefficient because some chlorine occurs in the hydroxyl positions in hydroxysilicates and also in apatite. In addition, chlorine may be available in the ore-forming process from chlorine leached from volcanic and sedimentary rocks by magmatic residual fluids. The hot brines of the Salton Sea, Red Sea and Cheleken in the U.S.S.R. are precipitating ore minerals (Tooms, 1970) and similar processes to those suggested in these areas may account for ancient ores (White, 1968; Dunham, 1970). The chlorine content of biotite is shown in Table 14 and the concentration of chlorine in acid igneous rocks is shown in Table 15. Only one group of results is available for biotite in mineralized granitic rocks and this shows an average chlorine content in biotite of 3,300 ppm compared with biotites from barren granitic rocks which have an average content of 1,500 ppm. The data for barren rocks are taken from several references and probably provide a reasonable average value whereas, although there are 20 values for biotites from mineralized rocks, these, as mentioned above, have been derived from only one reference (Stollery et al., 1971). This reference provides a fairly detailed account of the distribution of chlorine in a mineralized igneous body and suggests that analysis for chlorine in granitic rocks and biotites might provide a useful prospecting tool. It is interesting to note in Table 14 the wide range of chlorine contents in biotite and that values of as little as 20 ppm chlorine have been recorded and Haack (1969) records a range of 80 to 11,000 ppm chlorine in 51 biotite concentrates.

Stollery et al. provide the only data on the chlorine levels in mineralized granitic rocks and their two analyses have an average of 700 ppm. The average values for chlorine in barren granitic rocks is 285 ppm (an average of 381 values). As in other cases in this report, it is unlikely that two values from one area provide any kind of indication of the likely level of chlorine in mineralized granites.

Data on the chlorine content of metamorphic rocks are not abundant but Johns and Huang (1967) analysed 68 schists which have mean value of 350 ppm whereas 24 gneissic rocks have a mean value of 210 ppm chlorine. It is possible that there is a wider range of values of chlorine in barren metamorphic rocks compared with granites, since there is probably a wider range of apatite, biotite and scapolite in metamorphic rocks than in common igneous rocks.

9. DISCUSSION

In general, it is most likely that metals are carried in aqueous solutions (rather than in the vapour phase) derived from the late stages of magmatic processes; this is because the vapour pressure of likely compounds is rather low. Data have accumulated to indicate that it is most likely that ore-forming solutions contain the chloride ion but there is also a little evidence that some metals may be carried in sulphide complexes and others in relatively large ions and undissociated complexes (this applies particularly to tungsten, molybdenum and possibly tin). The assumption is commonly made that the solutions in which ore metals are carried are of direct magmatic origin but it is possible also that the ore-forming liquids are mixtures of magmatic vapour, condensation products and connate water, or that the liquid is connate water in the country rocks which is heated and 'activated' by igneous intrusion, or finally that the liquid is partly derived from geothermal waters and brines. Needless to say, it is generally difficult to determine the relative importance of these possible sources in any one mineralized granitic rock, although stable isotope studies provide one means of ascertaining the relative contributions of igneous as opposed to connate fluids.

Commonly it has been tacitly assumed that igneous rocks associated with mineralization are likely to contain a relatively high content of the metals found in the ore bodies but, as the complexity of ore-forming processes and particularly the spatial, genetic and temporal relations of ores and igneous rocks have been realized, there has been more discussion of the assumption of high metal values in mineralized rocks (see especially Hesp (1971) and Tilling et al., (1973)). It seems likely that mineralized igneous rocks will contain relatively high values of the ore metals if the metals were introduced into the igneous rock and the ore bodies together from some source outside the immediate magmatic system (and associated aqueous and vapour phases). If, however, the metal is derived by leaching (by chloride-rich solutions of some kind) from the igneous rock after or during crystallization, then it is possible that mineralized igneous rocks would contain a relatively low concentration of the metals found in the associated ore deposits. The general assumption has been made that the ore metals are derived from the country rock and are introduced into the vicinity of the magmatic rock and hence, in this case, the magmatic rock is likely to contain enhanced values of the ore metal. Many experimental investigations have been referred to above in which andesite and sedimentary rocks have been leached by analogues of hydrothermal solutions in order to obtain solutions sufficiently enriched in ore metals. There appears now to be consideration of some kind of auto-leaching process in which some at least of the ore metal is obtained from the igneous bodies which originally gave rise to the hydrothermal leaching solution.

The data described above suggest that there may be enhanced values of ore metals in mineralized igneous rocks and the biotites obtained from them in the case of tin and copper and that the concentration of chlorine in mineralized rocks may also be a valid indication of the potential for mineralization. In the case of gold, lead and zinc, however, it is unlikely, on the information available, that the analyses of either biotites or granites would provide a suitable means of even preliminary exploration. In the case of lead, this is probably due to the controlling effects of the concentration of potassium feldspar on the level of lead in igneous rocks and certainly the data suggest that in exploration for lead ores biotite is not the right mineral to select for analysis. It is not easy to explain why there should be such a difference in the pattern of zinc distribution in biotites from mineralized and barren granitic rocks compared with that of copper, since both metals have similar geochemical characteristics.

10. WORK IN PROGRESS

Several more barren samples (of both granite and biotite) have been submitted for analysis but, in the light of results reported in Progress Report No. 1, analyses for molybdenum and tungsten have been discontinued. On completion of these analyses a brief comparison will be made of the results obtained from South Australia with the results given in this Progress Report.

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TABLE 1: SUMMARY OF PUBLISHED ANALYSES OF TIN IN BIOTITE (ppm)

No. of Samples	Rock-Type	Range	Mean	Reference	B/M
16	granite	80-390		Barsukov, 1957	M
5	granodiorite	<30-43		Barsukov, 1957	M?
4	granite	<30-45		Barsukov, 1957	B
-	granites		44	Bradshaw and Stoyel, 1969	M
-	granitoids		11	Bradshaw and Stoyel, 1969	B
-	granite		62	Chauris, 1965	M
>15	granite		100	Chauris, 1965	B
10	granite	50-85	67	Jedwab, 1953, 1955	B
25	granite	32-165	110	Jedwab, 1953, 1955	M
40	granitoids	50-500	260	Nedashkovskii & Narnov, 1968	M
70	granitoids	3-45	20	Nedashkovskii & Narnov, 1968	B
6	various	5-30		Rattigan, 1963	B
9	granite	75-325		Rattigan, 1963	M
⩾100	granite	60-100		Varlomoff, 1969	M
⩾100	granite	<30		Varlomoff, 1969	B
38	metamorphines		7	DeVore, 1955a & b	B
3	"basic rocks"	2-12	7	Hellwege, 1956	B
4	granites	150-300	230	Hellwege, 1956	?B
22	granites	3.2-6.5		Kolbe, 1965	B
21	granites	3.2-6.5	4	Kolbe and Taylor, 1966	B

B = Barren

M = Mineralized

TABLE 2: SUMMARY OF PUBLISHED ANALYSES OF TIN IN BARREN GRANITIC ROCKS (ppm)

No. of Samples	Range	Mean	Reference
15		1	Noddack & Noddack, 1931
70		3	Onishi and Sandell, 1957
35		3	Hamaguchi et al., 1964
35	1.1-3.3	2	Petrova and Legeydo, 1965
77	2.0-4.4		Kolbe, 1965
22	1.4-8.2	4	Petrova and Legeydo, 1965
66	2.0-4.2	3	Kolbe and Taylor, 1966

TABLE 3: SUMMARY OF PUBLISHED ANALYSES OF TIN IN MINERALIZED GRANITIC ROCKS (ppm)

No. of Samples	Range	Mean	Reference
8		25	Barsukov & Pavlenko, 1956
1		16	Barsukov & Pavlenko, 1956
2500		10	Dahn et al., 1968
41	2.5-500	32	Hosking, 1965
25	2.5-60	22	Hosking, 1965
7	2.5-500	105	Hosking, 1965
22		14	Nedashkovskii & Narnov, 1968
10	5-45	20	Rattigan, 1963
5	8-35		Sainsbury, 1968
11		93	Stemprok and Sulcek, 1969
15		56	Stemprok and Sulcek, 1969
11		4	Tauson, 1967
64		6	Tauson, 1967
11		7	Tauson, 1967
19		3	Tauson, 1967

TABLE 4: SUMMARY OF PUBLISHED ANALYSES OF COPPER IN BIOTITE (ppm)

No. of Samples	Rock-Type	Range	Mean	Reference	B/M
35	gneisses	1-37	7	Haack, 1969	B
39	schists, gneisses	4-290	57	DeVore, 1955a, b	B
22	gneisses	9-160	40	Engel and Engel, 1960	B
20	gneisses, schists	12-295	67	Moxham, 1965	B
220	granites etc.	6-2050	99	Putman and Burnham, 1963	B*
9	granites etc.	10-300	43	Nockolds and Mitchell, 1948	B
29	granites	1-121	17	Haack, 1969	B
16	granites	1-62	15	Haack, 1969	B
9	granites	1-24	9	Haack, 1969	B
33	quartz monzonites etc	8-480	152	Dodge et al., 1969	B
18	quartz monzonites		8	Parry and Nackowski, 1963	B
67	quartz monzonites		1050	Parry and Nackowski, 1963	M
9	granites	8-65	27	Dodge and Ross, 1971	B
151	granodiorites	?	105	Putman and Alfors, 1967	B
61	quartz monzonites	6-4390	700	Al-Hashimi and Brownlow, 1970	M
9	granodiorites etc	30-200	90	Lovering et al., 1970	B
4	quartz latites	700-7000	3400	Lovering et al., 1970	M
22	granites	7-28	?	Kolbe, 1965	B
67	quartz monzonites		1050	Parry and Nackowski, 1963	M

B = Barren

B* = Mostly Barren

M = Mineralized

TABLE 5: SUMMARY OF PUBLISHED ANALYSES OF COPPER IN PLUTONIC ACID ROCKS (ppm)

No. of Samples	Rock-Type	Range	Mean	Reference	B/M
3687	granites		8	Emslie and Holman, 1966	B
1811	granodiorites		10	Emslie and Holman, 1966	B
35	granites	5-75	34	Smith, 1964	B?
386	granodiorites	5-295	40	Smith, 1964	B?
39	granites	0.6-36	11	Herz and Dutra, 1960	B
20	granites		11	Hamaguchi et al., 1961	B
79	granites	5-40	13	Wedepohl (unpublished)	B
32	granites, granodiorites	1-73	18	Kolbe and Taylor, 1966	B
34	granites	1-29	8	Kolbe and Taylor, 1966	B
272	granites		12	Isnard, 1970	B
20	granites	<10-50	~10	Hugi and Swaine, 1963	B
75	granites and granodiorites		20	Serykh, 1963	B
58	granites and granodiorites	2-200	17	Grohmann, 1965	B

B = Barren

M = Mineralized

TABLE 6: SUMMARY OF PUBLISHED ANALYSES OF COPPER IN SCHISTS AND GNEISSES (ppm)

No. of Samples	Rock-Type	Range	Mean	Reference	B/M
15	mica schists	20-110	62	MacPherson, 1958	B*
9	mica schists	14-58	34	Taylor, 1955	B
420	schists, gneisses		33	Emslie and Holman, 1966	B
700	gneisses, migmatites		18	Emslie and Holman, 1966	B
20	schists, medium grade	1-85	24	Shaw, 1954	B
30	schists, etc. high grade	1-43	13	Shaw, 1954	B
12	gneisses, medium grade	8-40	17	Engel and Engel, 1958	B
12	gneisses, high grade	3-25	14	Engel and Engel, 1958	B
20	gneisses	1-98	16	Okrusch and Richter, 1967	B
49	gneisses	2-200	16	Grohmann, 1965	B
16	gneisses	1-32	16	Werner, 1970	B

B = Barren
B* = Mostly barren
M = Mineralized

TABLE 7: SUMMARY OF PUBLISHED ANALYSES OF LEAD IN BIOTITES (ppm)

No. of Samples	Range	Mean	Reference	B/M
35	7-39	23	DeVore, 1955	B
18		5	Parry & Nackowski, 1963	B
67		17	Parry & Nackowski, 1963	M
21	7-95	27	Kolbe and Taylor, 1966	B
91	10-94	16	Haack, 1969	B
348	23-89	48	Tischendorf et al., 1969	?
14	<10-94	43	Brauer, 1970	B
3	14-20	18	Tauson & Kravchenko, 1956	B
3	10-36	19	Rabinovich & Baskova, 1959	B

B = Barren
M = Mineralized

TABLE 8: SUMMARY OF PUBLISHED ANALYSES OF LEAD IN METAMORPHIC ROCKS (ppm)

No. of Samples	Rock-Type	Range	Mean	Reference
72	gneiss		30	Lambert and Heier, 1968
404	gneiss & schist (para)		20	Eade and Fahrig, 1973
158	gneiss & schist (ortho)		11	Eade and Fahrig, 1973
2621	migmatite, granite gneiss		17	Eade and Fahrig, 1973
24	gneiss, schist	25-65	44	Dethier and Schlesmiger, 1973
30	gneiss, schist	5-61	27	Shaw, 1954
73	gneiss	6-25	12	Engel and Engel, 1958
5	granite gneiss	23-41	32	Engel and Engel, 1958
5	gneiss	10-27	20	Zartman, 1955
7	pelitic schist	12-21	16	Banno and Chappell, 1969
16	schist	<1-25	7	Heinrichs, 1974
23	gneiss, schist	<10-150	32	Werner, 1971b
36	gneiss, migmatite	<3-35	13	Werner, 1971a
25	gneiss	<3-38	15	Werner, 1970
40	gneiss		18	Drury, 1973
254	gneiss	<4-37	13	Sheraton, 1970

TABLE 9: SUMMARY OF PUBLISHED ANALYSES OF ZINC IN BIOTITES (FROM ACID IGNEOUS AND METAMORPHIC ROCKS) (ppm)

No. of Samples	Range	Mean	Reference	B/M
7	450-870	630	Tauson and Kravchenko, 1956	B
19	50-700	270	DeVore, 1955(a)	B
16	34-720	180	DeVore, 1955(b)	B
151		440	Putman and Alfors, 1967	B
226	500-800	720	Putman and Burnham, 1963	B
35	40-1220	445	Haack, 1969	B
53	290-1520	700	Haack, 1969	B
10	420-1000	580	Dodge et al., 1969	B
6	965-5100	2540	Butler and Thompson, 1967	B
18		23	Parry and Nackowski, 1963	B
67		258	Parry and Nackowski, 1963	M

B = Barren
M = Mineralized

TABLE 10: SUMMARY OF PUBLISHED ANALYSES OF ZINC IN METAMORPHIC ROCKS (ppm)

No. of Samples	Rock-Type	Range	Mean	Reference
29	schists	103-233	174	Van de Kamp, 1970
3	gneisses	62-83	71	Haack, 1969
3	gneisses	44-74	54	Okrusch & Richter, 1967
12	gneisses	8-82	34	Okrusch & Richter, 1967

TABLE 11: SUMMARY OF PUBLISHED ANALYSES OF GOLD IN BIOTITES (ppb)

No. of Samples	Rock-Type	Range	Mean	Reference	B/M
120	granitoids		7	Davletov, 1970	B
7	gabbro, diorite	9-18	13	Zvereva & Gavrilenko, 1971	B
11	quartz monzonite etc.	0-16	3	Gottfried et al., 1972	B
4	?	2-7	4	Shcherbakov, 1967	M
24	granites	<1-6	2	Bushlyakov, 1971	B
5	granodiorites, tonalites	2-3	2	Moiseenko et al., 1971	B
4	granites etc.	3-9	5	Paley et al., 1967	B

B = Barren

M = Mineralized

TABLE 12: SUMMARY OF PUBLISHED ANALYSES OF GOLD IN PLUTONIC ACID ROCKS (ppb)

No. of Samples	Rock-Type	Range	Mean	Reference	B/M
27	granites	0.5-2	1	Anoshin & Potapyev, 1966	B
10	granites	1-4	3	Shcherbakov, 1967	M
8	granites	∿1	1	Gottfried et al., 1972	B
21	granites	<1-2	1	Gottfried et al., 1972	B
1	granite		<1	Gottfried et al., 1972	B
7	granites	1-5	3	Davletov & Dzhakshibayev, 1970	B
3	granites	2-5	3	DeGrazia & Haskin, 1964	B
67	granites		2	Voskresenskaya & Zvereva, 1968	B
107	granites	<1-10	2	Moiseenko et al., 1971	B
12	porphyries	<1-4	2	Moiseenko et al., 1971	B
14	granite	<1-7	2	Shcherbakov, 1967	M
22	granite	<1-13	2	Anoshin et al., 1970	B
17	granite	1-20	6	Kushmuradov, 1970	B
27	granite		15	Shilin, 1968	B
5	granite	2-9	4	Voskresenskaya & Zvereva, 1968	B
6	granite and granophyre	<1-1	1	Gottfried et al., 1972	B
60	granodiorite	<1-5	1	Gottfried et al., 1972	B
6	granodiorite and adamellite	2-7	4	Davletov & Dzhakshibayev, 1970	B
3	granodiorite	3-5	4	Rozhkov et al., 1970	B
84	granodiorite		1	Voskresenskaya & Zvereva, 1968	B
47	granodiorite	1-10	3	Mantei et al., 1970	M
98	granodiorite		20	Shilin, 1968	B
12	granodiorite and granite	<1-32	3	Anoshin et al., 1970	B
55	granodiorite, granite	<1-15	5	Moiseenko et al., 1971	B
100	granodiorite		3	Shilin, 1968	B
13	porphyrites	5-40	11	Kushmuradov, 1970	B
5	granite-aplite	2-3	2	Spiridonov, 1970	B
6	aplite and greisen	2-36	11	Shcherbakov, 1967	M
11	aplite, granite		1	Voskresenskaya & Zvereva, 1968	B
3	aplite, granite	8-60	29	Rozhkov et al., 1970	B
1	aplite		3	DeGrazia and Haskin, 1964	B

B = Barren

M = Mineralized

TABLE 13: SUMMARY OF PUBLISHED ANALYSES OF GOLD IN METAMORPHIC ROCKS (ppb)

No. of Samples	Rock-Type	Range	Mean	Reference	B/M
29	schist	0.6-17	3	Shcherbakov, 1967	B
16	schist	0.4-2	1	Petrov et al., 1972	B
12	schist	5-100	29	Kushmuradov, 1970	?
800	schist	?-5000	35	Loshchinin, 1971	M
21	schist	0.4-33	3	Gavrilenko & Garifulin, 1971	B
27	schist	4-65	17	Gavrilenko & Garifulin, 1971	M
46	schist	0.5-1	1	Petrov et al., 1970	B
12	gneiss	0.4-8	2	Moiseenko et al., 1971	B
7	granite gneiss	0.2-22	5	Gavrilenko & Garifulin, 1971	B
9	gneiss etc.	1.5-5	2	Voskresenskaya & Zvereva, 1968	B

B = Barren

M = Mineralized

TABLE 14: SUMMARY OF PUBLISHED ANALYSES OF CHLORINE IN BIOTITE* (%)

No. of Samples	Range	Mean	Reference	B/M
1		.053	Behne, 1953	B
30	<.005-.66	.065	Gillberg, 1964	B
7	.002-.1	.038	Sugiura, 1968	B
51	.008-1.1	.168	Haack, 1969	B
15	.11-.3	.20	Kostetskaya & Mordinova, 1965	B
20	.17-.47	.33	Stollery et al., 1971	M
34	.035-.61	.19	Haack, 1969	B

* all from granites, granodiorites or gneisses

B = Barren

M = Mineralized

TABLE 15: SUMMARY OF PUBLISHED ANALYSES OF CHLORINE IN ACID PLUTONIC ROCKS (ppm)

No. of Samples	Rock-Type	Range	Mean	Reference	B/M
2	granodiorite	300-790	545	Selivanov, 1940	B
16	granodiorite	190-580	400	Kokubu, 1956	B
2	granodiorite	500-900	700	Stollery et al., 1971	M
16	granodiorite	20-500	220	Johns and Huong, 1967	B
4	granite	90-400	275	Selivanov, 1940	B
18	granite		106	Behne, 1953	B
99	granite		220	Kuroda and Sandell, 1953	B
4	granite	200-910	420	Kokubu, 1956	B
3	granite	60-250	160	Hoering and Parker, 1961	B
6	granite	10-100	43	Sugiura, 1968	B
90	granite	75-1180	510	Fuge and Power, 1969(b)	B
123	granite	30-500	200	Johns and Huong, 1967	B

B = Barren
M = Mineralized

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23 June, 1977

The Director,
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THE METAL-BEARING POTENTIAL OF FELSIC INTRUSIVE ROCKS
IN SOUTH AUSTRALIA

Progress Report No. 3.

Investigation and Report by: Dr B.G. Steveson

Officer in Charge, Mineralogy/Petrology Section: Dr K.J. Henley

for Brian S. Hickman
Acting Managing Director

k.

1. INTRODUCTION

The introductions to Progress Reports 1 and 2 outline the nature of this investigation. In this final progress report more data are presented on nine samples and an analysis is made of the data obtained for this project with respect to that available from the literature.

2. RESULTS

The samples which have been examined are as follows:

P1349/76	Biotite gneiss, Mt. Woods Inlier
P1353/76	Porphyritic adamellite, Mt. Woods Inlier
P1460/76	Acid gneiss, Trans-Australia Railway, E of Wilgena siding
P1468/76	Gneiss, Wynbring Rocks
P1470/76	Granitic gneiss, Wynbring Rocks
P1472/76	Granitic gneiss, Wynbring Rocks
P1492/76	Acid gneiss, Mt. Woods Inlier
P1587/76	Acid gneiss, Berry Bay, SW Yorke Peninsula
P1592/76	Acid gneiss, Pt. Annie, SW Yorke Peninsula

The analyses for 'head', i.e. the granite or gneiss itself and for the biotite concentrate, are given in Table 1.

This data, when combined with that given in Progress Report No. 1, gives the average values (assuming a lognormal distribution of the elements) summarized in Table 2. In this table igneous and metamorphic rocks have not been distinguished since the South Australian samples range from granites, through partly recrystallized "granitoids", to gneisses. Furthermore, mineralized in the context of Table 2 includes only the batch of samples collected from Anabama and Bendigo cores; such rocks can hardly be regarded as mineralized when considering, say, the data for tin.

Possibly it is rather surprising to observe the low values for copper and chlorine in these mineralized samples; the values are low (for biotites especially, and for chlorine in rocks) when compared with the abundant data even for barren rocks (Table 16 of Progress Report No. 2). Levels of tin, lead and zinc in South Australian rocks are similar to those for world-wide barren rocks.

Anomalous individual values (taken as approximately twice the means for barren world-wide samples) are as follows:

Sample	In rock	In biotite	Location
1	Cu		Anabama
3	Cu		Anabama
10	Cu	Cl	Bendigo
15	Cu		Bendigo
20	Cu		Anabama
22	Cu		Anabama
P1124/74	Sn, Cu		Point Brown
P1747/75		Sn	Mudnawatana Granite
P507/74	Sn		Duffield 1:50,000
P1218/74	Pb		N.E. Olive Island
P1729/75	Cu		Pidgeon Springs
P30/71	Sn	Cl	Buckleboo
P945/71	Sn, Pb	Sn, Cu, Pb	Norowie
P1349/76	Pb	Cl	Mt. Woods
P1353/76	Cl		Mt. Woods
P1592/76	Cl		Pt. Annie

With gold values having a relatively high detection limit, it is difficult to assess the significance of a few high values. Gold in P945/71, P1472/76 and P1587/76 and in biotite in P144/70, P1349/76, P1472/76, P1587/76 and P1592/76 may be anomalously high.

These results suggest that the Anabama and Bendigo (mineralized) rocks do contain anomalously high copper contents and hence could have been selected as at least potentially mineralized on this basis alone. Other results, listed above, suggest that it would be a valuable exercise to examine more hand specimens of the granite 3 miles NW of Norowie (Cowell sheet, P945/71). Perhaps five hand specimens could be obtained (their distribution and number will probably depend on the extent of outcrop, etc.), biotites separated and the rocks and biotites analysed for tin, lead, copper and gold. The results would indicate both whether the granite is potentially associated with base metal mineralization and the likely variation in trace elements from place to place in granitic rocks.

It is rather difficult to assess whether analyses of rock and/or biotite samples could usefully be used as an exploration tool by the Mines Department. Tin, copper and chlorine could be employed without difficulty in the case of rocks since, say, 10 gms could easily be split from material being used for geochronology; however, in most samples there is probably insufficient biotite to analyse for these three elements. Selected geochronology samples (granitic rocks) could certainly be analysed, using suites of, say, three to ten rocks from various areas being intensively studied by geochronology.

TABLE 1: ANALYSES OF ROCKS AND BIOTITES FROM SELECTED GRANITE ROCKS

Sample		Element (ppm)					
		Sn	Cu	Pb	Zn	Cl	Au
P1349/76	Head	4	26	110	75	570	0.01
	Biotite	66	26	18	360	9500	0.03
P1353/76	Head	4	28	50	65	800	<0.005
	Biotite	<4	38	15	350	1300	<0.005
P1460/76	Head	<4	21	17	50	340	<0.005
	Biotite	14	22	4	340	2100	0.005
P1468/76	Head	4	22	15	60	80	0.005
	Biotite	6	17	22	540	370	0.02
P1470/76	Head	<4	26	17	55	70	0.005
	Biotite	<4	14	5	610	440	0.025
P1472/76	Head	<4	20	24	40	40	0.025
	Biotite	4	15	5	640	270	0.31
P1492/76	Head	<4	48	26	70	170	0.01
	Biotite	6	40	10	370	400	0.01
P1587/76	Head	4	34	46	75	210	0.055
	Biotite	8	50	8	500	750	0.38
P1592/76	Head	6	22	48	60	750	0.055
	Biotite	16	30	9	530	260	0.075

TABLE 2: AVERAGES OF CONCENTRATIONS FROM SOUTH AUSTRALIAN SAMPLES

Element	*B/M	Values in biotites (ppm)	Values in rocks (ppm)
Cl	(B	900	182
	(M	980	182
Sn	(B	12	4
	(M	9.5	3
Pb	(B	11	39
	(M	7	12
Cu	(B	31	38
	(M	19	122
Zn	(B	447	55
	(M	181	40

* B = barren; M = mineralized; i.e. Bendigo and Anabama samples