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A GEOCHEMICAL STUDY OF GRANITOIDS OF THE BODDINGTON GOLD MINE

Final Report to SRK (Australasia) Ltd

K.F. Cassidy, D.C. Champion & L.A.I. Wyborn

Minerals Division
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A Research Bureau of the Department of Primary Industries & Energy

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EXECUTIVE SUMMARY

The aim of the study was to determine the geochemical characteristics of a number of intrusive and extrusive lithologies from the Boddington gold mine and surrounding prospects. A number of suites have been delineated on the basis of their petrography, timing relations and wholerock geochemistry. Some of the more important conclusions are as follows:

- The 'Late' Granite and Aplite suites are comagmatic, and have distinct geochemistry to all other igneous rocks in the district. Petrographically there is two subgroups - biotite monzogranite and leuco-monzogranite/aplite); both subgroups have similar geochemistry. Overall, the suite has geochemistry similar to Low-Ca group of Champion & Sheraton (1997), but more similar to fractionated I-(granodiorite)-type Proterozoic granites spatially and temporally associated with gold mineralisation in the Telfer, Pine Creek and other regions. Specifically, the 'Late' granite suite is characterised by high K_2O, Th and U contents and a primitive-mantle normalised Sr-depleted, Y-undepleted signature. Low Sr and negative Eu anomalies, combined with high Y and HREE suggests derivation via anhydrous partial melting of tonalite at crustal pressures. Petrography reveals variable hydrothermal alteration and minor disseminated sulphides in some samples.
- The intermediate/felsic intrusive and extrusive lithologies throughout the Boddington area have similar wholerock geochemistry (with a few exceptions) and have been combined to form the 'Boddington Mine' group for the purposes of this report. This group comprises five (super)suites: Quartz-Diorite/Tonalite; 'Hybrid' Diorite; Microdiorite; 'Boddington' supersuite (combines five suites); and, Dacitic ?Tuff suites.
- The Quartz Diorite/Tonalite suite comprises samples from a (quartz-)diorite intrusion in the Wattle Prospect area. The suite has variable silica range that at the mafic end overlaps with the intermediate intrusive and extrusive suites and at the felsic end overlaps with the 'Late' Granite/Aplite suite. There is a positive correlation between silica and total REE content, and the suite has both a Sr-depleted, Y-undepleted (at felsic end-member) and Sr-undepleted, Y-depleted (at mafic end-member) signatures. The suite is probably derived through partial melting of a mafic amphibolite at depths greater than 35 km (residual garnet), with fractional crystallisation possibly involved to produce the felsic end-member.
- The 'Hybrid' Diorite suite forms part of a ca. 2675 Ma composite (quartz-)diorite intrusion in the north-east part in the Eastern Anomalies area and is characterised by lower silica content (53-58 wt% SiO_2) than other intermediate intrusive phases. The suite has a relatively Sr-undepleted, Y-depleted signature consistent with retention of garnet in the source region during partial melting. The characteristics of the 'Hybrid' Diorite that are common with the majority of intermediate intrusive/extrusive rocks in the Boddington Mine area invokes a genetic relationship. The'Hybrid' Diorite may form a more mafic suite of an intermediate supersuite through derivation by partial melting of the same source under different conditions. Alternatively, the 'Hybrid' Diorite may form part of a separate supersuite, resulting from a different melting event (at ca. 2675 Ma) under different conditions.
- The Microdiorite suite has distinct chemistry characterised by elevated TiO_2, LREE, Nb, Th, U, Y and Zr contents relative to the other intrusive and extrusive suites of the Boddington Mine group. This suite has many similarities with the Black Microdiorite and Microdiorite ('Mafic') suites dsecribed by Roth (1992). The suite exhibits a minor negative Eu anomaly and a relatively Sr-depleted, slightly Y-depleted signature, indicating that both plagioclase and garnet and/or clinopyroxene were important residual components during partial melting.

- The 'Boddington' supersuite comprises the majority of intermediate intrusive and extrusive lithologies in the Boddington Mine area. Five suites (Aphyric/'Early', Porphyritic/'Late', Intrusive Breccia/MP Diorite, Dacite, 'Andesitic'/Intermediate Fragmental) form the supersuite and have very similar wholerock chemistry, suggesting that they are comagmatic and probably derived from similar source rocks under similar conditions of partial melting.
- The vast majority of intermediate/felsic volcanic rocks at Boddington are dacites. This contrasts with Roth (1992) who stated that the major intermediate/felsic volcanic rock type was 'andesite'. Reinterpretation of Roths' geochemical data confirms that the majority of intermediate/felsic volcanic rocks are dacites, with minor andesite volcanism.
- In general, the 'Boddington' supersuite has compositions typical of dacite-dominated sequences in the Kalgoorlie Terrane (e.g., Black Flag Group). The geochemical characteristics (fractionated REE patterns without an Eu anomaly; Sr-undepleted, Y-depleted signature) and internal compositional variation of the supersuite is probably unrelated by fractional crystallisation, but is consistent with partial melting of a mafic source at depth leaving a residual mineralogy of garnet, plagioclase, amphibole and/or clinopyroxene.
- The Dacitic ?Tuff suite consists of one sample characterised by has elevated K_2O, P_2O_5, total REE, Cr, Nb, Pb, Sr, U, Th and Y contents relative to the other extrusive samples. The ?tuff has an elevated strongly fractionated REE profile and a moderately Sr-depleted and slightly Y-depleted signature. These characteristics contrast with the other suites and suggests that it forms a separate supersuite of the Boddington Mine Group.
- The Felsic Porphyry suite includes a number of quartz-feldspar-phyric 'dykes' from the mine area and the Wattle and Boomerang Prospects. This suite is rhyolitic in composition and may represent a discrete phase of intrusion or, perhaps, extrusion. They are similar in composition to the 'rhyodacites' described by Roth (1992) and may form part of an extensive rhyolitic volcanic event in the Boddington area. The REE and primitive-mantle-normalised patterns is consistent with vapour-absent partial melting of a tonalite at crustal pressures. The Felsic Porphyry suite is similar to rhyolitic volcanic rocks from the Jeedamya and Perkolilli area in the Eastern Goldfields Province.
- The Basalt and Archean Dolerite samples collected have wholerock geochemistry typical of mafic rocks in the Boddington area described by Roth (1992) and are similar to basalt and dolerite in the Eastern Goldfields Province.
- A sample of a large actinolite vein has geochemistry characterised by very low Cr, Ni which indicates that it is of hydrothermal origin. This is in contrast to the study of Allibone et al. (1998), who suggested that the um2 dykes were altered pyroxenite dykes.

The intermediate/felsic ('dioritic') intrusive suites at Boddington do not share many geochemical characteristics typically associated with the porphyry Cu-Au-related magmatic systems. For instance, although hydrothermal alteration has undoubtedly changed the wholerock geochemistry of some of the samples, the vast majority of intermediate/felsic suites are subalkaline and low-K to medium-K calc-alkaline. This contrasts with porphyry Cu-Au systems elsewhere (e.g., Lihir, Mesozoic Cu-Au in British Columbia, Ordovician Cu-Au in Lachlan Fold Belt). Likewise, the majority of granite-hosted gold deposits in the Eastern Goldfields are hosted by High-LILE subgroup of Mafic granites. In contrast, all but one of the intermediate/felsic intrusive suites at Boddington would belong to the Low-LILE subgroup of Mafic granites. If Cu-Au mineralisation at Boddington was related to the intermediate/felsic intrusive suites, then similar dacitic intrusive suites associated with intermediate/felsic volcanism in the Eastern Goldfields Province (e.g., Black Flag Group) should be equally prospective. Alternatively, Cu-Au mineralisation at Boddington may be related in some way to the late fractionated I-type granites, that are strikingly similar to Proterozoic granites at Telfer and Pine Creek.

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INTRODUCTION

The Boddington gold deposit in the Saddleback greenstone belt of the southwestern Yilgarn Craton is a major resource of gold of enigmatic origin. Although the deposit shares some characteristics with the majority of Archean lode gold deposits in the Yilgarn Craton, it is characterised by several significant features atypical of Archean gold deposits in general. These include:

- a Au-Cu-Mo metal association
- presence of calcic and highly saline ('magmatic') hydrothermal fluids
- mineralisation in complex stockworks and vein sets, and
- a spatial association with intermediate intrusive and extrusive lithologies.

Roth (1992) suggested a temporal and genetic relationship between the intermediate intrusive and extrusive lithologies and gold mineralisation at Boddington, particularly on the basis of the metal association and complex highly saline hydrothermal fluids present in the deposit. In contrast, Allibone et al. (1998), using structural and overprinting veining and alteration relationships, suggested that gold mineralisation was associated with several stages of ductile deformation, principally late in the deformation sequence, and possibly coeval with 'late' granite plutons. An understanding of the intermediate intrusive and extrusive lithologies and the 'late' granites may help gain a better understanding of the gold mineralisation at Boddington, especially in light of the two end-member genetic models for the deposit.

This study has two main aims:

- define the petrographic and geochemical characteristics of intermediate and/or felsic intrusive and selected extrusive lithologies in the Boddington gold mine and surrounding environs, and
- investigate the nature of the intermediate and/or felsic rock suites, in order to determine if a classification scheme can be established for these lithologies at Boddington.

Samples for the wholerock geochemistry study were collected during a four-day period at Boddington in March, 1998 (sample details listed in Appendix A). Collected samples are from drill core from various parts of the Boddington Gold Mine and from some prospects to grid-north (Wattle, Boomerang). For the region, 54 samples were collected, from which 51 were collected for wholerock geochemical analysis and the remainder for petrographic investigation of timing relations.

Wholerock geochemical analyses were undertaken on the samples chiefly by XRF, but also by ICP-MS. CO_2 and H_2O analyses were also undertaken on all samples. Wholerock geochemical analyses are tabulated in Appendix A.

Detailed polished thin section petrography was undertaken to:

- document petrography
- aid classification
- aid petrogenetic understanding
- relate geochemistry to petrography, and
- aid determination of effect of metamorphism, alteration and deformation.

All samples (54 polished thin sections) were classified and catalogued in a routine standard manner with emphasis on the following:

- textures
- primary mineral types
- phenocryst versus groundmass
- secondary mineral types
- vein mineralogy
- oxide and sulphide mineralogy

Shortened petrographic descriptions are provided in Appendix B. Rock names use the standard convention of listing lithological qualifiers in order of increasing modal abundance (for instance: biotite-amphibole quartz-diorite has more amphibole than biotite). However, mineral assemblages for phenocryst and/or groundmass minerals are listed in order of decreasing modal abundance. Vein and fracture mineralogy is given where present.

The rationale and approach to the classification of intermediate lithologies into suites and supersuites involves the following:

- identification of fundamental units based on field data, petrography and geochemistry
- 'grouping' of samples into suites by iterative splitting of the sample group into successively smaller groups on the basis of significantly differing characteristics
- grouping of suites into supersuites (partly achieved in the previous step)
- grouping supersuites into higher level groups and comparing with other rock classifications.

Many of the grouping are obvious and readily distinguished, particularly when classification is based on a combination of field, petrographic and geochemical data as was possible for this study. Using this approach, and with the provision of sampling rationale supplied to AGSO by SRK (Australasia) and Boddington Gold Mine personnel, the samples have been subdivided into a number of suites (Tables 1, 2).

A potential problem, given the complex metamorphosed and metasomatised environment, concerns the effect of metamorphism, alteration and deformation on geochemistry. Detailed petrography (and geochemistry) shows that many of the Boddington samples are moderately to strongly altered resulting in variable saussuritisation of plagioclase (to albite, sericite, epidote), development of secondary biotite, epidote/clinozoisite, amphibole, titanite, sericite, chlorite, oxides (ilmenite) and sulphides (pyrrhotite, chalcopyrite, pyrite) and destruction of primary minerals including plagioclase, K-feldspar, amphibole, biotite, oxides, and trace minerals (allanite, apatite). This alteration and possible resultant element mobility, means that a number of oxides and elements must be viewed with caution.

Empirical observations of element mobility have been documented elsewhere and these demonstrate that SiO_2, CaO, Na_2O, K_2O, Ba, Rb, Sr are generally mobile; a number of other trace elements including transition and base metals (Cu, Pb, Zn, V, Cr) are mobile to a variable degree. The data strongly support the concept of the immobility of several oxides and elements, including TiO_2, Zr, Nb, Y, Th, U, REE. Accordingly, the classification of the Boddington samples placed most weight on these and similar oxides and elements. Additionally, it appears that total alkali content (i.e., Na_2O+K_2O) did not change much as a result of the complex metamorphism and metasomatism. The effects of carbonation and hydrolysis appear to have been minimal with the majority of samples having <0.2 wt% CO_2 and <1.5 wt% H_2O^+.

Suite	Abbreviation	No. Samples
'Late' Granite	GRT	10
Aplite	APL	1
Quartz Diorite/Tonalite	QD	4
'Hybrid' Diorite	HYB	4
Intrusive Breccia/Mod-Porphyritic Diorite	IBX	3
Microdiorite	MD	3
Porphyritic/'Late' Diorite	LDRT	8
Aphyric/'Early' Diorite	ADRT	3
Felsic Porphyry	PHY	5
Dacitic ?Tuff	TUFF	1
Dacite	DAC	2
'Andesite'/ Intermediate Fragmental	AND	4
Basalt	BAS	1
Dolerite	DOL	1
Actinolite Vein	VN	1

Table 1. Suites of the Boddington Gold Mine and surrounding area.

Suite	**Sample No's** (all samples prefixed WB37*)
'Late' Granite	3715, 3716, 3717, 3729, 3731, 3732, 3734, 3743, 3744, 3757
Aplite	3728
Quartz Diorite/Tonalite	3712, 3754, 3755, 3756
'Hybrid' Diorite	3720, 3721, 3748, 3749
Intrusive Breccia/MP Diorite	3705, 3709, 3752
Microdiorite	3702, 3703, 3706
Porphyritic/'Late' Diorite	3711, 3723, 3725, 3736, 3737, 3739, 3740, 3742
Aphyric/'Early' Diorite	3708, 3730, 3741
Felsic Porphyry	3713, 3714, 3718, 3745, 3747
Dacitic ?Tuff	3719
Dacite	3701, 3704
'Andesite'/Int. Fragmental	3724, 3726, 3727, 3738
Basalt	3746
Dolerite	3753
Actinolite Vein	3710

Table 2. Classification of samples into suites.

Note: samples have been classified based on available information, petrography and wholerock geochemistry; therefore, some may have been wrongly classified. However, there is such similarity in the geochemistry of the potentially misclassified samples, that for the basis of this exercise, the findings will still hold.

GEOCHEMICAL CHARACTERISTICS OF INDIVIDUAL SUITES

The samples have been classified into a number of discrete suites using timing relations, petrography and wholerock geochemistry. The wholerock chemistry of each individual suite is summarised below (refer to unpaginated Figure 1-5 after this section):

'Late' Granite

Ten samples (#3715, 3716, 3717, 3729, 3731, 3732, 3734, 3743, 3744, 3757) of the 'Late' Granite suite were collected from several different drillholes collared in the Eastern Anomalies area. Petrographically there are two subgroups within the suite: (1) seriate to sparsely feldspar porphyritic, medium-grained biotite monzogranite/ syenogranite and (2) seriate, fine-grained, biotite leuco-monzogranite [or aplite]). Both subgroups have similar geochemistry, are considered to be comagmatic, and are discussed as a single suite.

These granites have distinct geochemistry to all other igneous rocks in the district. The 'Late' Granite suite are characterised by variable SiO_2 (68-76 wt%). For a given SiO_2, they have lower CaO and Na_2O and higher K_2O relative to all other intrusive groups at Boddington. They also have higher Be, Nb, Pb, Rb, Th, U, Y contents and Rb/Sr ratios, lower Sr contents and Zr/Y ratios, for a given silica content. The 'Late' Granite suite exhibits strong LREE and HFSE enrichment with distinct 'A-type' affinities (high Zr, La, Ce contents), with the more mafic members of the suite typically having the highest contents. The suite has high Y contents (33-92 ppm) and high to very high heat-producing elements (K_2O: 3.8-7.1 wt%, Th: 27-75 ppm, U: 14-41 ppm).

They have variable minor to highly-fractionated chondrite-normalised LREE (La_N - 30 to >300) with strong negative Eu anomalies[1] and relatively flat HREE (Lu_N - 20 to 35). The leuco-monzogranite subgroup has the least fractionated chondrite-normalised REE pattern, whereas the biotite monzogranite have increasing degree of LREE fractionation with decreasing silica content. Several elements (Rb, Th, Nb, Pb, Y) and Ga/Al increase with SiO_2, which is consistent with trends in fractionated I-type granites elsewhere (e.g., Champion & Chappell, 1992). Systematic variations in Rb/Sr and K/Rb suggest that fractionation was an important factor in their genesis. The degree of fractionation of the 'Late' Granite suite is illustrated on a Rb-Ba-Sr ternary diagram; the 'Late' Granites plot in the strongly fractionated field. The 'Late' Granite suite is characterised by ASI (molecular $Al_2O_3/[K_2O+CaO+Na_2O]$) values of <1.1, indicating that they are metaluminous to weakly peraluminous.

On the Log Rb vs Log Nb+Y diagram of Pearce et al. (1984) they plot in the 'within-plate' field, whereas on the 10,000*Ga/Al vs Zr+Nb+Ce+Y diagram of Eby (1990), the late granites straddle the boundary between fractionated and 'A-type' granitoids.

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[1] Eu anomalies are chiefly controlled by feldspars. The removal of feldspar from a felsic melt by crystal fractionation or the partial melting of a rock in which feldspar is retained in the source will give rise to a negative Eu anomaly in the melt. To a lesser extent, hornblende, titanite, clinopyroxene and garnet may contribute to a positive Eu anomaly. Enrichment in the middle REE relative to the LREE and HREE is mainly controlled by hornblende typically resulting in 'spoon-shaped' REE patterns. Fractionation of LREE relative to HREE may be caused by the presence of olivine, orthopyroxene and clinopyroxene, for the partition coefficients increase by an order of magnitude from La to Lu in these minerals. Extreme depletion of HREE typically indicates the presence of garnet in the source. Accessory phases such as titanite, allanite and zircon may strongly influence a REE profile, for although they may be present in only small quantities, their extremely high partition coefficients can have a disproportionate influence on the REE.

On primitive-mantle normalised (PMN) spidergrams (using the order and normalising values of Sun & McDonough, 1989), the 'Late' Granites are strongly depleted in Ba, Sr, P and Ti, variable LREE (La, Ce, Nd), enriched in Th and U and undepleted in Y. The 'Late ' Granites are characterised by a Sr-depleted and Y-undepleted signature[2].

Note that, in thin-section, many of the 'Late' Granite samples show moderate alteration including chlorite after biotite, epidote/clinozoisite, minor titanite, sericite and metamict allanite. Disseminated sulphides (pyrite±chalcopyrite) are present in some samples (#3743, 3757). Magnetite is the oxide phase commonly present in trace quantity.

Aplite

A sample (#3728) of an aplite dyke was collected from drillcore collared in the Eastern Anomalies area. The aplite dyke contained visible molybdenite, and in thin-section is a seriate fine-grained leuco-monzogranite with minor ferromagnesian minerals. The Aplite is characterised by high silica (75 wt% SiO_2), Na_2O+K_2O (≈10 wt%), Rb, U, Y and Nb, and low Ba, Sr, Zr, REE, Cu, Pb, Zn and Sn contents. On a Ba-Rb-Sr ternary diagram, it plots in the strongly fractionated field. The aplite has a flat chondrite-normalised REE pattern (La_N ≈30; Lu_N ≈20) with a large negative Eu anomaly. On a PMN spidergram, the Aplite is strongly depleted in Ba, Sr, P and Ti, enriched in K_2O, Rb and U and undepleted in Y.

Quartz-Diorite/Tonalite:

The 'Quartz-Diorite/Tonalite' suite comprises several samples (#3712, 3754, 3755, 3756) from a 'quartz-diorite' intrusion in the Wattle Prospect grid-north of the Boddington gold mine. In thin-section, this suite is a seriate to quartz-feldspar porphyritic, fine-grained biotite granodiorite to tonalite. It contains blue quartz 'eyes' in handspecimen, indicating that the intrusion has been metamorphosed. It is characterised by a large silica range (65.4-75.7 wt% SiO_2) that at the mafic end overlaps with other intermediate intrusive and extrusive suites and at the felsic end overlaps with the 'Late' Granite/Aplite suites. The granodiorite/tonalites are characterised by variable major oxide and trace element concentrations that overlap with the 'Late' Granite/Aplite suites at the felsic end and the Porphyritic/'Late' Diorite suite at the mafic end.

The suite is characterised by variable chondrite-normalised REE patterns that are strongly fractionated at moderate total REE contents (La_N ≈100; Lu_N ≈1.5) and moderately fractionated at higher total REE concentrations (La_N ≈200-300; Lu_N ≈10). There is an overall positive correlation between silica content and REE content, with the most felsic sample also containing the highest LREE (and highest HREE) contents, with the most mafic samples having the most fractionated REE profile and lowest LREE and HREE contents. The most felsic sample (#3755) has a slight negative Eu anomaly. Overall, the granodiorite/tonalites

[2] Y has similar elemental characteristics to the HREE and is used in PMN spidergrams to indicate the same sort of petrologic information. In addition, Sr is used in PMN spidergrams in much the same way as Eu in REE profiles. For instance, Sr/Sr* values <1 indicate that plagioclase is retained in the source through partial melting of a rock; whereas, Y/Y* values <1 indicate that garnet and/or clinopyroxene is retained in the source through partial melting of a rock. Plagioclase is typically retained during melting at intermediate pressures (<10 kbar corresponding to the mid-lower crust or depths <35 km), whereas, garnet is retained during melting at high pressures (>10 kbar corresponding to depths of >35 km). PMN spidergrams in conjunction with REE profiles are useful tools to indicate the depth of partial melting to produce the intermediate and felsic melts.

have similar PMN patterns, with distinctive slight increase from Pb to U, strong relative depletions of Nb, P and Ti, and variable depletions of Sr and Y. The relative depletion of Sr increases, and Y decreases, with increasing silica content. Therefore, this suite has both Sr-depleted, Y-undepleted (at the most felsic end-member) and Sr-undepleted, Y-depleted (at the mafic end-member) signatures.

'Hybrid' Diorite:

Four samples (#3720, 3721, 3748, 3749) are grouped as the 'Hybrid' Diorite suite. These samples are from a composite 'quartz-diorite' intrusion in the north-eastern part of the Eastern Anomalies area dated by Allibone et al. (1998) at ca. 2675 Ma. Petrographically, the 'Hybrid' Diorite is a seriate to sparsely-feldspar-porphyritic, fine-medium-grained, biotite-amphibole diorite/quartz-diorite. The suite has a limited silica range (53-58 wt% SiO_2) that is lower than other intermediate intrusive phases. The suite is characterised by high CaO, Cr, Ni and V, variable TiO_2, Na_2O, P_2O_5, LREE, Sr, Y, Zr and Zr/Y, and low K_2O, Nb, Th, U and Rb/Sr.

The 'Hybrid' Diorite suite is characterised by chondrite-normalised REE patterns that are moderately fractionated ($La_N \approx 65$-100; $Lu_N \approx 5$-9), with no to a slight negative Eu anomaly. All samples have similar PMN patterns, with distinctive slight relative enrichment of Rb and Na, slight to moderate depletions of Ba, K, Nb, Ti and Y, and variable depletion/enrichment of P and Zr. Overall, the suite has relatively Sr-undepleted, Y-depleted signature.

Intrusive Breccia/MP Diorite

The 'Intrusive Breccia/MP Diorite' suite comprises three samples (#3705, 3709, 3752) of moderately-porphyritic fine-grained (amphibole-)biotite (quartz-)diorite that form the matrix to surrounding breccias ('intrusive breccia') and forms part of the so-called 'Southern Diorite'. The samples are characterised by a narrow range in silica content (≈63-67 wt% SiO_2) that overlaps with the other intermediate intrusive and extrusive suites. The 'Intrusive Breccias' are characterised by oxide and trace element concentrations that are comparable to the other intermediate intrusive and extrusive suites, except for highly variable K_2O (0.7-4.0 wt%) and CaO (1.9-5.1 wt%) contents.

The samples of the 'Intrusive Breccia' suite have similar moderately-fractionated chondrite-normalised REE profiles ($La_N \approx 35$-45; $Lu_N \approx 3$-9), that are independent of silica content, that display a minor upward concave trend for the HREE. The 'Intrusive Breccias' have minor positive to negative Eu anomalies. On a PMN spidergram, the 'Intrusive Breccia' suite is characterised by distinctive relative moderate depletion in Ba, Nb, Ti and Y, and minor depletion in Sr and P. Rubidium, K_2O and to a lesser extent U show variable trends interpreted to reflect the effects of hydrothermal alteration. Overall, the suite has a relatively Sr-undepleted and Y-depleted signature.

Microdiorite

A series of microdiorite intrusions are present in the Boddington mine area. Three samples (#3702, 3703, 3706) of microdiorite were collected from drillcore; petrographically they are very fine-grained, aphyric diorites. They are characterised by very similar wholerock geochemistry that differs considerably from the other intermediate intrusive and extrusive rocks. They have relatively constant SiO_2 (about 62 wt%) and higher TiO_2, Fe_2O_3, Be, LREE, Hf, Li, Nb, Rb, Th, U, V, Y and Zr contents, lower Cr contents, slightly lower MgO and CaO contents, a higher Rb/Sr ratio, slightly lower Zr/Y, K/Rb ratios compared to the other intermediate suites.

The microdiorites have moderately- to highly-fractionated chondrite-normalised REE patterns ($La_N \approx 150$-200, $Lu_N \approx 10$) with negligible to small negative Eu anomalies. On PMN spidergrams, they are characterised by an increasing profile from Pb to U, with strongly enriched Rb, strongly depleted Nb, Sr (Sr/Sr* <1), P and Ti and slightly depleted Y. The suite has relatively Sr-depleted, and minor Y-depleted signature.

Porphyritic/'Late' Diorite

The Porphyritic/'Late' Diorite suite comprises a number of samples (#3711, 3723, 3725, 3736, 3737, 3739, 3740, 3742) from main part of the Boddington mine area and the Wattle prospect. In hand-specimen, the suite is visibly (quartz-)feldspar porphyritic and sometimes contains blue quartz 'eyes' indicating that the suite has been metamorphosed. In thin-section, the suite is a variably foliated, metamorphosed and altered, moderately- to strongly-quartz-feldspar-phyric biotite quartz diorite to tonalite. Variably recrystallised phenocrysts of saussuritised plagioclase and quartz and biotite-rich aggregates in a variably-recrystallised fine-grained quartzofeldspathic-biotite-rich groundmass.

The suite has a wide range in silica from 63.7 to 71.1 wt% SiO_2 and, with the exception of one sample (#3711), is characterised by higher LREE contents and Zr/Y and K/Rb ratios, and lower TiO_2, Fe_2O_3, MgO, CaO, P_2O_5, Cr, Nb, Rb, Sr, V and Y contents with increasing silica. The samples at the low silica end (<69 wt% SiO_2) have compositions overlapping with the dacitic volcanic rocks and other diorites. The suite is characterised by strongly-fractionated chondrite-normalised REE patterns ($La_N \approx 15$-85; $Lu_N \approx 1.5$-3), with no to moderate Eu anomalies. Some samples have an irregular HREE pattern (Gd to Lu) possibly reflecting the near chondrite concentrations of these element. On a PMN spidergram, the samples show a variable pattern from La to Y reflecting the fractionated pattern but variable concentration of REE. The spidergram also shows relative enrichment of Rb, Zr and Na, and variable depletion of Ba, Nb, P, Ti and Y. The variable Rb, Ba and to a lesser extent K is attributed to the effects of hydrothermal alteration. The Porphyritic/'Late' Diorite suite has an overall Sr-undepleted, Y-depleted signature.

One of the samples (#3711) is characterised by a distinct wholerock geochemistry. It has high TiO_2, Fe_2O_3, P_2O_5, Zr (>600 ppm), Nb, Y, Hf, and REE ($La_N \approx 150$; $Lu_N \approx 10$) concentrations relative to rest of the Porphyritic/'Late' Diorite suite and, in general, intermediate intrusive lithologies in the Boddington area. The sample also has a strongly-fractionated chondrite-normalised REE pattern that has a slight positive Eu anomaly. The extreme concentration of Zr is displayed by a large enrichment on a PMN spidergram. Note that this sample is from the Wattle Prospect, whereas the rest of the Porphyritic/'Late' Diorite suite is from the main mine area and its different wholerock geochemistry may reflect a different sequence in that area.

Aphyric/'Early' Diorite

Three samples (#3708, 3730, 3741) of Aphyric/'Early' Diorite suite were sampled from the Boddington mine area and Eastern Anomalies area. In hand-specimen, the suite is characterised by the aphyric nature of the diorite and the variable but distinctive 'albitisation' of the rock. In thin-section, the suite is a variably recrystallised, metamorphosed and altered, seriate to sparsely porphyritic, fine-grained biotite-amphibole (quartz-)diorite comprising a saussuritised plagioclase-amphibole-quartz-biotite-epidote±titanite. The modal quartz content of the Aphyric/'Early' Diorites suggests that they are predominantly tonalite and quartz-diorite rather than diorite.

The Aphyric/'Early' Diorite suite are characterised by compositions similar to the low-silica members of the Porphyritic/'Late' Diorite suite and many of the intermediate volcanic rocks. The Aphyric/'Early' Diorites have a limited silica range from 64.3 to 66.7 wt% SiO_2, and overlapping major oxide and trace element contents. They are characterised by moderately to strongly fractionated chondrite-normalised REE patterns ($La_N \approx 25$-50; $Lu_N \approx 3$) with small positive to small negative Eu anomalies. On PMN spidergrams, the patterns of the Aphyric/'Early' Diorites are similar, and characterised by enrichment of Sr, Na and Zr, variable enrichment/depletion of Rb, and variable depletion of Ba, Nb, Ti and Y. The suite has a Sr-undepleted, Y-depleted signature.

Felsic Porphyry

The Felsic Porphyry suite (samples #3713, 3714, 3718, 3745, 3747) includes a number of felsic quartz-feldspar-phyric 'dykes' from the northern part of the Boddington Mine area as well as from the Wattle and Boomerang Prospects grid-north of the mine area. In thin-section, they are variably foliated/mylonitised, metamorphosed and hydrothermally altered, quartz-albite-K-feldspar porphyries comprising variably recrystallised relict phenocrysts of quartz, plagioclase, K-feldspar and minor ex-ferromagnesian minerals in a variably recrystallised fine-grained quartzofeldspathic groundmass. A sample (#3747) collected as part of the Quartz Diorite/Tonalite suite has been reclassified as part of the Felsic Porphyry suite on the basis of location, petrography and geochemistry.

The porphyries are characterised by high silica contents (75.4-77.0 wt% SiO_2), variable Na_2O (1.62-5.56 wt%) and K_2O (1.35-4.40 wt%) but moderate Na_2O+K_2O contents, moderate Ba, Pb, U, Y and Zr, and low Nb, Rb, Sr, Zr/Y and Rb/Sr. On a N_2O-CaO-K_2O ternary diagram they show moderate sodium enrichment. They have strongly-fractionated chrondrite-normalised REE patterns ($La_N \approx 50$-250; $Lu_N \approx 3$-11) with moderate to large negative Eu anomalies. There is no clear correlation between silica content and enrichment of REE. On a PMN spidergram, the Felsic Porphyry suite has a distinct pattern, with a positive slope from Pb to U (some samples show minor relative depletion/enrichment of Rb and Ba, followed by a fractionated pattern from K to Na. The spidergram shows strong relative depletion of Nb, Sr, P and Ti and possible relative enrichment of Na. The suite has a Sr-depleted, Y-undepleted to slightly Y-depleted signature.

Dacitic ?Tuff

The sample (#3719) of a felsic volcaniclastic rock (?tuff) was collected from the Eastern Anomalies area. In thin-section it comprises a sheared, recrystallised and metamorphosed plagioclase-amphibole-phyric schist containing porphyroclasts of saussuritised plagioclase and amphibole-biotite±epidote±titanite-rich patches in a fine-grained quartzofeldspathic-rich material.

Geochemically, the ?tuff has a rhyodacitic composition with ≈69 wt% SiO_2, and is characterised by higher concentrations of K_2O, Ba, Cr, Nb, Pb, Sr, Th, U, Y, total REE, and lower Al_2O_3, Zr/Y, relative to other felsic volcanic rocks in the Boddington area. It is also characterised by an enriched (relative to other felsic volcanic rocks in the area) strongly-fractionated chrondrite-normalised REE pattern (La_N ~220, Lu_N ~9), with a slight negative Eu anomaly. On a PMN spidergram, the ?tuff shows a distinct pattern, with strong enrichment of

Th and U, moderate enrichment of Rb and LREE, slight depletion of Sr and Y, and strong depletion of Nb and Ti. It has a moderately Sr-depleted and slightly Y-depleted signature.

Dacite

Two samples (#3701, 3704) that represent a 'dacite' from the 'Southern Diorite' part of the Boddington mine area were collected. In thin-section, the dacites are foliated, metamorphosed and hydrothermally altered, (quartz-)feldspar porphyries comprising relict phenocrysts of quartz and feldspar in recrystallised quartzofeldspathic groundmass.

The Dacite suite is characterised by similar wholerock geochemistry with ≈66.0 wt% SiO_2, 0.52 wt% TiO_2, ≈1.95 wt% MgO, ≈4.0 wt% CaO, and 0.12 wt% P_2O_5. They have moderate trace elements to other intermediate intrusive and extrusive suites; however, they have slightly higher Sr contents (≈325-375 ppm). The dacites have very similar strongly-fractionated chondrite-normalised REE patterns (La_N ≈60; Lu_N ≈3), with no Eu anomaly. PMN spidergrams show similar patterns, with variable large enrichment of Rb, moderate enrichment of Zr and Na, and moderate to strong depletion of Nb, P, Ti and Y. They have a Sr-undepleted and moderately Y-depleted signature.

'Andesite'/Intermediate Fragmental

Four samples (#3724, 3726, 3727, 3738) were collected to represent 'andesitic' volcanic and intermediate fragmental rocks. One of the intermediate fragmental samples (#3738) comes from same drillhole interval where Roth (1992) a sample of volcaniclastic rock for SHRIMP U-Pb geochronology. This sample forms part of a volcano-sedimentary unit that contains numerous matrix-supported porphyritic volcanic clasts in a volcanic matrix. In thin-section, the 'Andesite'/Intermediate Fragmental suite comprises moderately to strongly recrystallised, foliated and altered, seriate to porphyritic, fine-grained, biotite-amphibole-epidote±sericite-rich quartzofeldspathic schists; the Intermediate Fragmental samples also contain common biotite- and/or amphibole-rich clasts. Note that most of the samples are not 'andesites' as they contain common quartz; they are probably meta-dacitic volcanic rocks.

The 'Andesite'/Intermediate Fragmental suite is characterised by silica contents ranging from 57.6 to 65.7 wt% SiO_2, although all but one sample (#3727) have silica contents between 63.6 and 65.7 wt% SiO_2. The majority of the suite are dacitic in composition, as inferred on the basis of their common modal quartz; sample #3727 with a silica content of ≈57.6 wt% SiO_2 is the only true 'andesite' sampled from Boddington during this study. The 'dacitic' members of the suite contain moderate TiO_2, Al_2O_3, FeO, MgO, CaO, P_2O_5, REE, Nb, Y and Zr, and variable Na_2O, K_2O, Ba, Cr, Pb, Rb, Sr and Zn contents. They overlap in composition with many of the other intermediate intrusive and extrusive suites at Boddington. The 'andesite' sample contains a higher TiO_2, MgO, CaO, P_2O_5, LREE, Nb, Sr, Th, V, Y, Zn and Zr, similar Ba, Pb, and a lower Al_2O_3, FeO, Na_2O, K_2O and Rb content than the 'dacitic' samples.

The 'dacitic' samples of the 'Andesite'/Intermediate Fragmental suite are characterised by strongly fractionated chondrite-normalised REE profiles (La_N ≈40-80; Lu_N ≈3) with no Eu anomaly. The 'andesite' sample is characterised by a similar, but more enriched, strongly-fractioned chondrite-normalised REE profile (La_N ≈120; Lu_N ≈6). On PMN spidergrams, the 'dacitic' and 'andesitic' samples have similar patterns, with a relatively flat pattern from Pb to K (except for highly variable Rb and to a lesser extent Ba and K), and weak to strong relative depletion of Nb, Sr, Ti, P and Y. The variable Rb, Ba and K is attributed to mobility during hydrothermal alteration. Overall, the suite has a slightly Sr-depleted and strongly Y-depleted signature.

Basalt

A sample (#3746) of 'clast' material in an matrix-supported 'intrusive-breccia' was collected from the main Boddington mine area. The matrix material was also sampled (#3748) from the same drillhole. In thinsection, the 'clast' material is a metamorphosed and ?altered, fine-grained amphiolite that is probably a meta-basalt.

The meta-basalt has wholerock geochemistry characterised by low SiO_2 (≈48.2 wt%), moderate-high MgO (8.4 wt%), CaO (11.3 wt%), K_2O (0.85 wt%), Cr (415 ppm) and Ni (115 ppm), moderate Al_2O_3, FeO, Na_2O, P_2O_5, Sr, V, Y and Zr. It has a relatively flat to slightly depleted chondrite-normalised REE pattern (La_N ≈8.5; Lu_N ≈9) without an Eu anomaly. On a PMN spidergram, the meta-basalt displays a flatish profile except for large positive anomalies in Rb, K_2O and to a lesser extent Pb and Ba, and minor negative anomalies of Nb and P. Positive anomalies of Rb, K_2O and to a lesser extent Pb and Ba are attributed to enrichment during hydrothermal alteration.

Archean Dolerite

An interval of drillcore (#3753) that had been logged as a 'fine-grained andesite', was collected about 5 m downhole from Andesite Fragmental sample (#3738). In thin-section, the sample is a metamorphosed and altered fine-grained amphibolite that retains a relict subophitic texture suggesting that it is an Archean Dolerite.

The Archean Dolerite samples is characterised by contains 50.1 wt% SiO_2, high TiO_2 (1.57 wt%), K_2O (2.45 wt%) and Rb (156 ppm), moderate MgO, CaO, Cr, Ni, V and low Na_2O and Sr concentrations. It has a slightly fractionated chondrite-normalised REE profile (La_N ≈30, Lu_N ≈12) without any Eu anomaly. On a PMN spidergram, the dolerite displays a large relative enrichment in Rb and K, a large depletion in Na and minor depletion in Nb, Sr and P. The relative enrichment in Rb and K is attributed to effects of hydrothermal alteration.

Actinolite vein

One sample (#3710) of a mineralised Actinolite Vein was collected for wholerock geochemical analysis. Allibone et al. (1998) suggested that the 'actinolite veins' are ultramafic (um2) dykes that had been hydrothermally altered. In thinsection, the vein comprises interlocking amphibole(actinolite)-clinozoisite-sulphides(chalcopyrite-pyrrhotite-pyrite± sphalerite)±titanite.

The vein is characterised by low SiO_2 (51 wt%), TiO_2 (0.2 wt%), Al_2O_3 (4.5 wt%), and P_2O_5 (0.05 wt%), and relatively high LREE (La: 15 ppm, Ce: 28 ppm). Importantly, the vein has high MgO (14 wt%) but very low Cr (40 ppm) and Ni (BLD) contents. The vein has a moderately-fractionated chondrite-normalised REE profile (La_N ≈50; Lu_N ≈1.5) with a small, but significant, positive Eu anomaly. On a PMN spidergram, the vein has a variable profile, with large relative depletions of Rb, Ba, K, Nb, Sr, P, Ti and Na and possible enrichment of U. The vein also contains significant mineralisation (Cu ≈0.7 wt%, Sn >250 ppm, Zn >400 ppm).

Figure 1. Harker variation diagrams for Boddington Gold Mine samples illustrating the geochemical features of the individual suites.

- **a** TiO_2 (wt%) versus SiO_2 (wt%)
- **b** MgO (wt%) versus SiO_2 (wt%)
- **c** CaO (wt%) versus SiO_2 (wt%)
- **d** Na_2O (wt%) versus SiO_2 (wt%)
- **e** K_2O (wt%) versus SiO_2 (wt%)
- **f** P_2O_5 (wt%) versus SiO_2 (wt%)
- **g** Ba (ppm) versus SiO_2 (wt%)
- **h** Ce (ppm) versus SiO_2 (wt%)
- **i** Cr (ppm) versus SiO_2 (wt%)
- **j** La (ppm) versus SiO_2 (wt%)
- **k** Nb (ppm) versus SiO_2 (wt%)
- **l** Ni (ppm) versus SiO_2 (wt%)
- **m** Pb (ppm) versus SiO_2 (wt%)
- **n** Rb (ppm) versus SiO_2 (wt%)
- **o** Sr (ppm) versus SiO_2 (wt%)
- **p** Th (ppm) versus SiO_2 (wt%)
- **q** U (ppm) versus SiO_2 (wt%)
- **r** V (ppm) versus SiO_2 (wt%)
- **s** Y (ppm) versus SiO_2 (wt%)
- **t** Zr (ppm) versus SiO_2 (wt%)

Legend

- Late Granite
- Aplite
- 'Hybrid' Rock
- Intrusive Breccia
- Microdiorite
- Qtz Diorite/Tonalite Qtz Diorite/Tonalite
- Porph/'Late' Diorite
- Aphy/'Early' Diorite
- Felsic Porphyry Felsic Porphyry
- Dacitic Tuff
- Dacite
- Andesite/Fragmentals
- Basalt
- Archean Dolerite
- Actinolite Vein

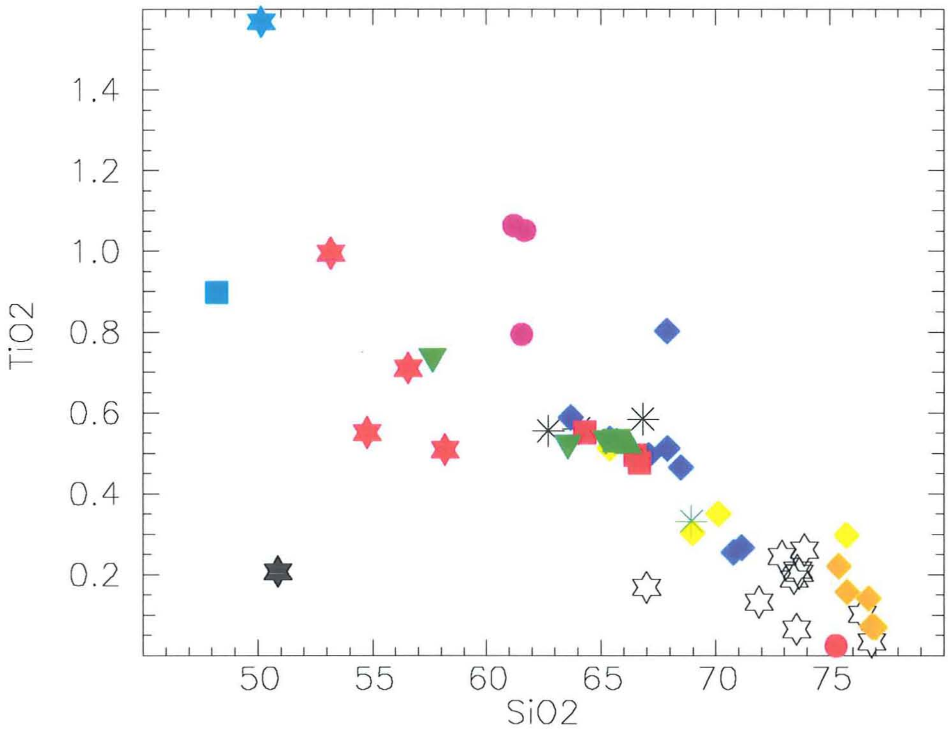


Figure 1a. TiO_2 (wt%) versus SiO_2 (wt%)

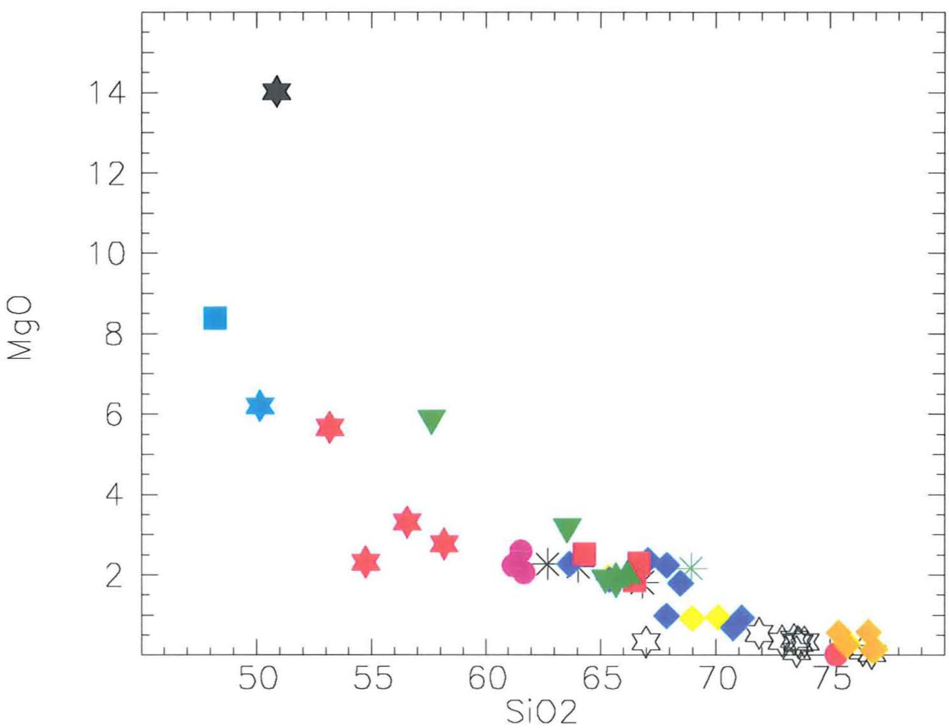


Figure 1b. MgO (wt%) versus SiO_2 (wt%)

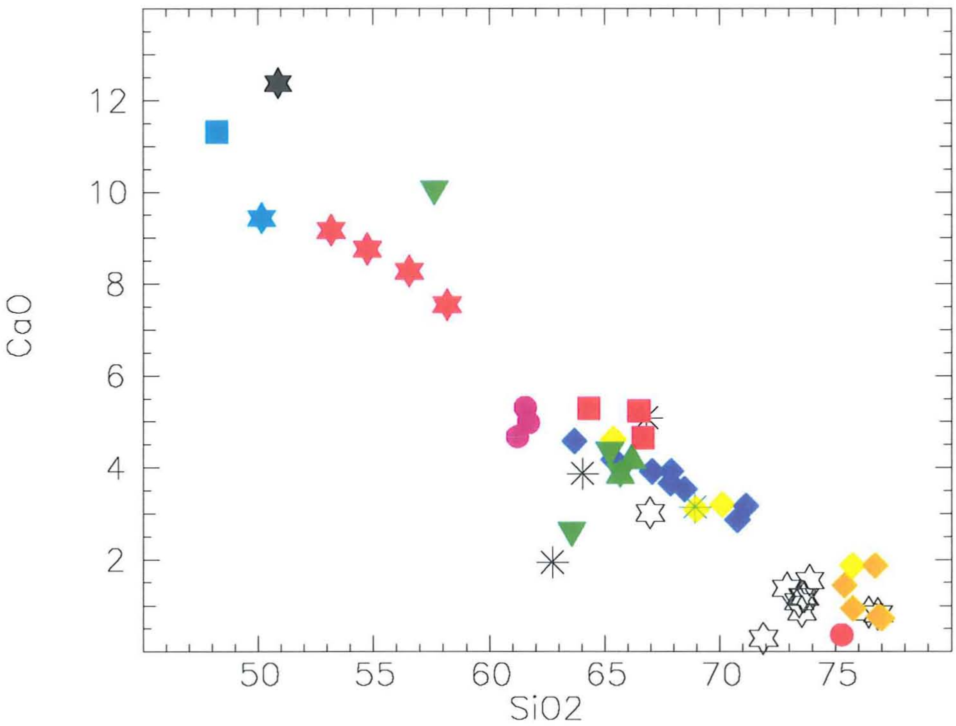


Figure 1c. CaO (wt%) versus SiO_2 (wt%)

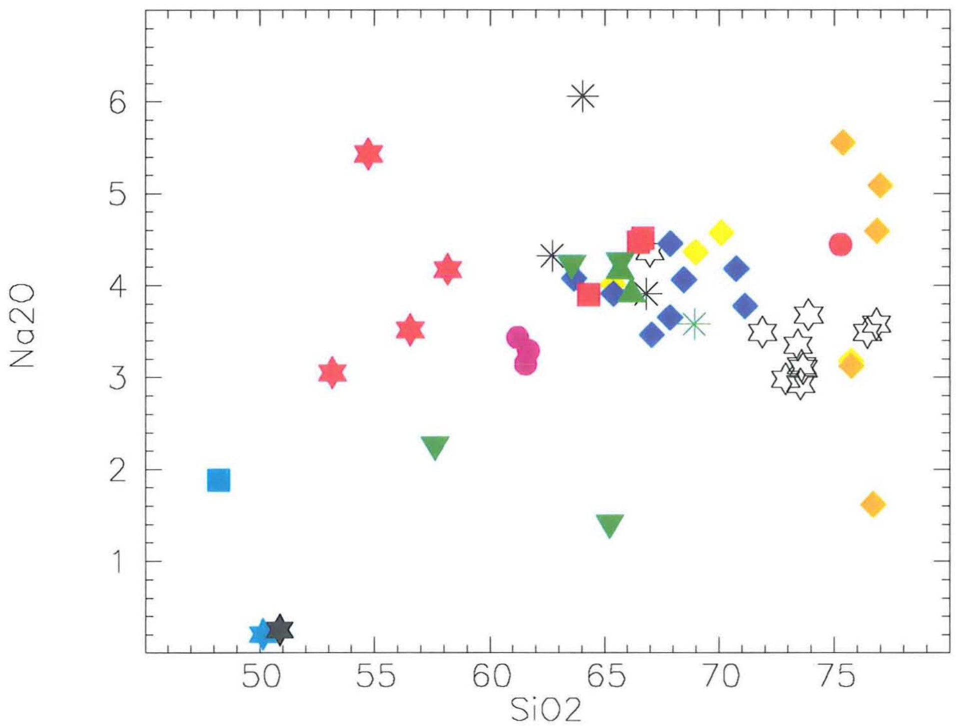


Figure 1d. Na_2O (wt%) versus SiO_2 (wt%)

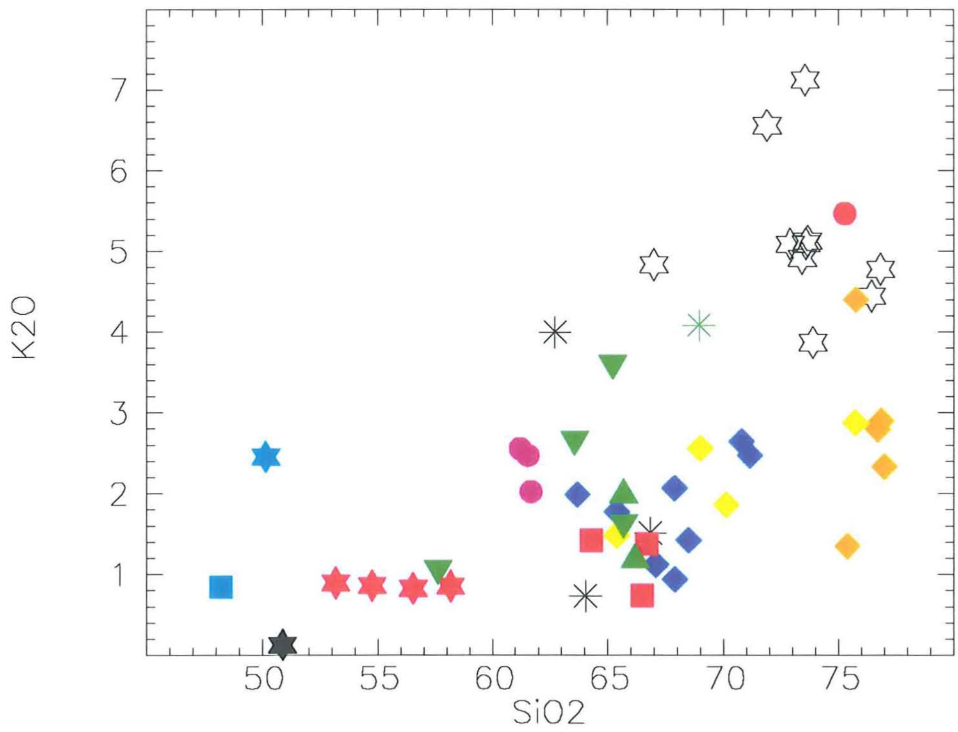


Figure 1e. K_2O (wt%) versus SiO_2 (wt%)

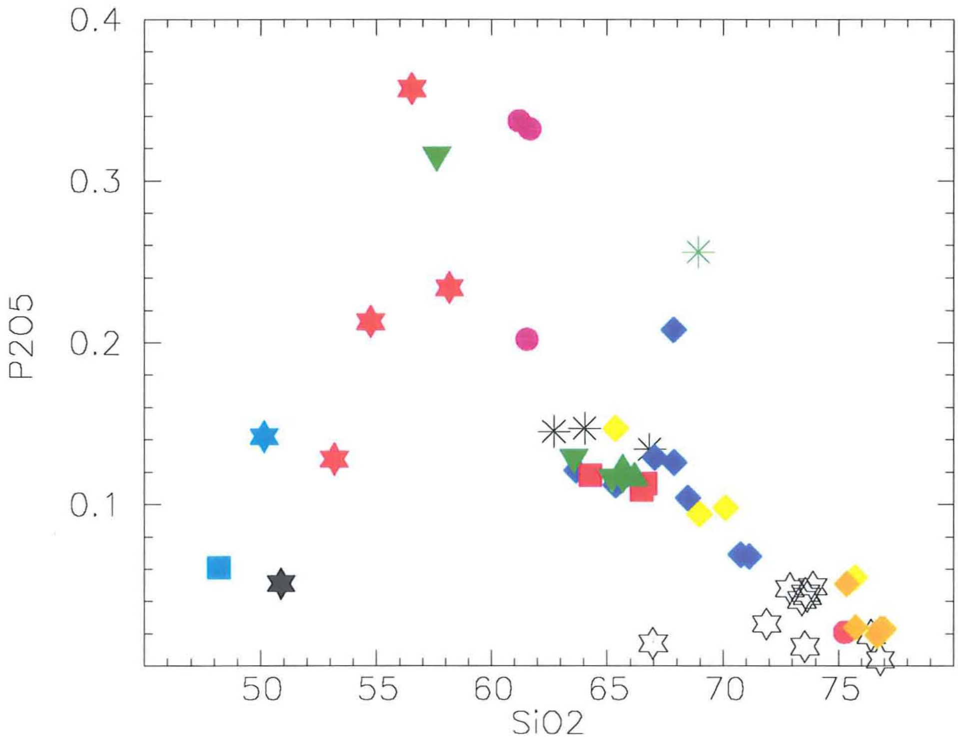


Figure 1f. P_2O_5 (wt%) versus SiO_2 (wt%)

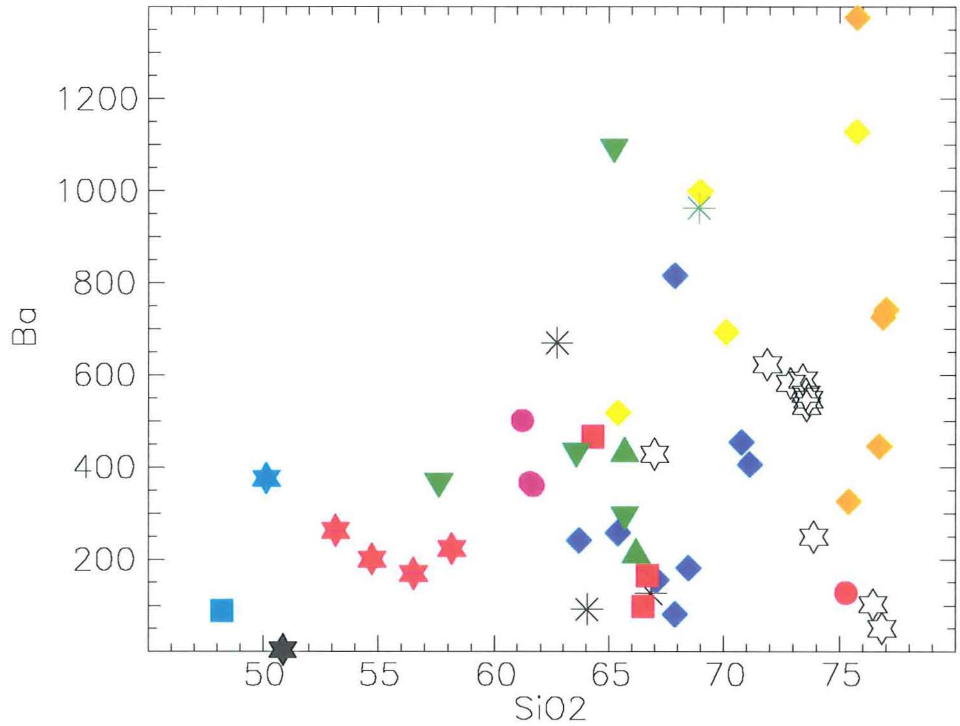


Figure 1g. Ba (ppm) versus SiO_2 (wt%)

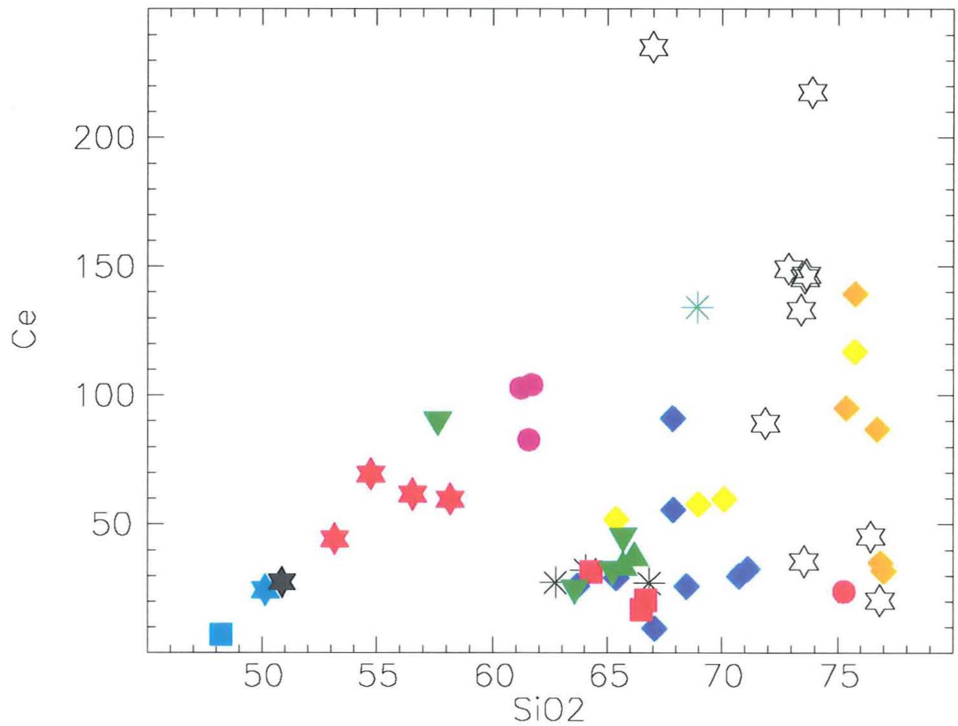


Figure 1h. Ce (ppm) versus SiO_2 (wt%)

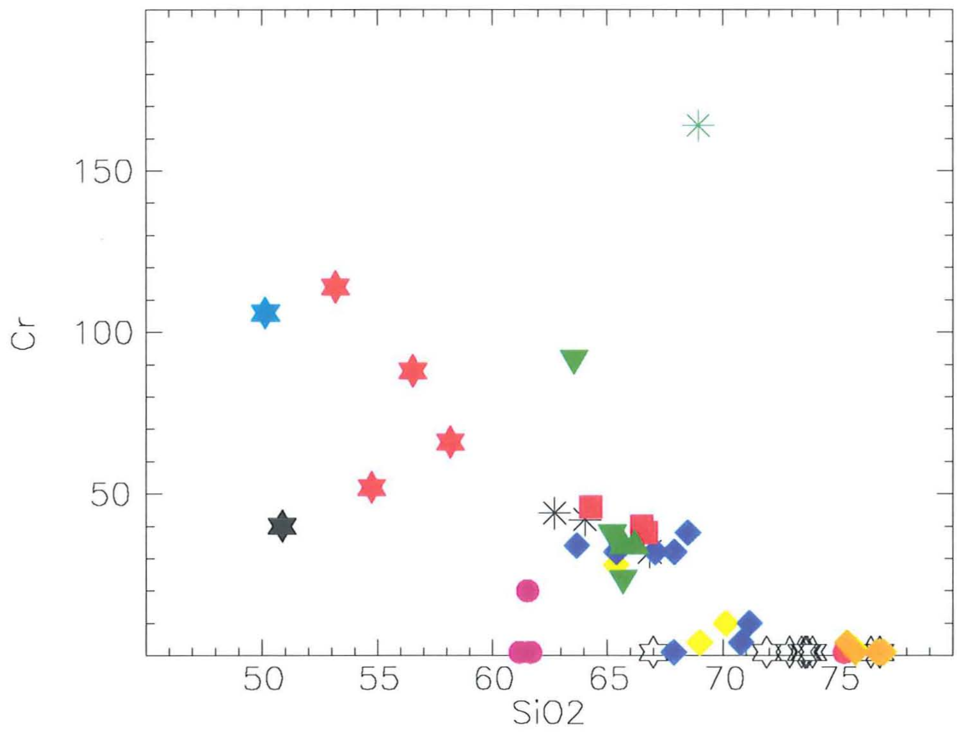


Figure 1i. Cr (ppm) versus SiO_2 (wt%)

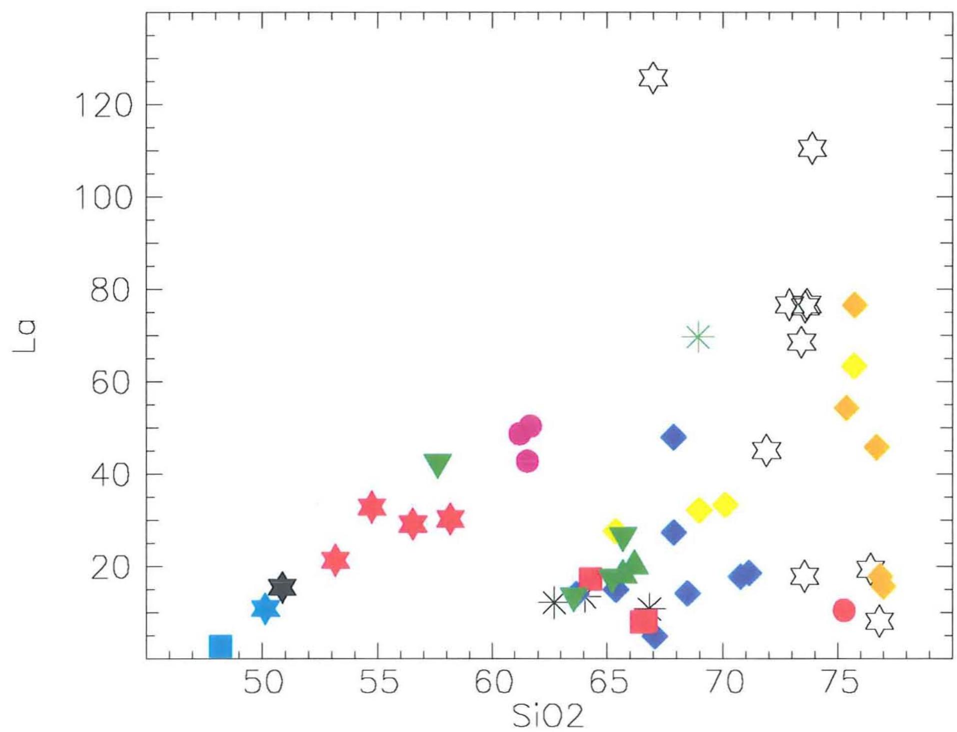


Figure 1j. La (ppm) versus SiO_2 (wt%)

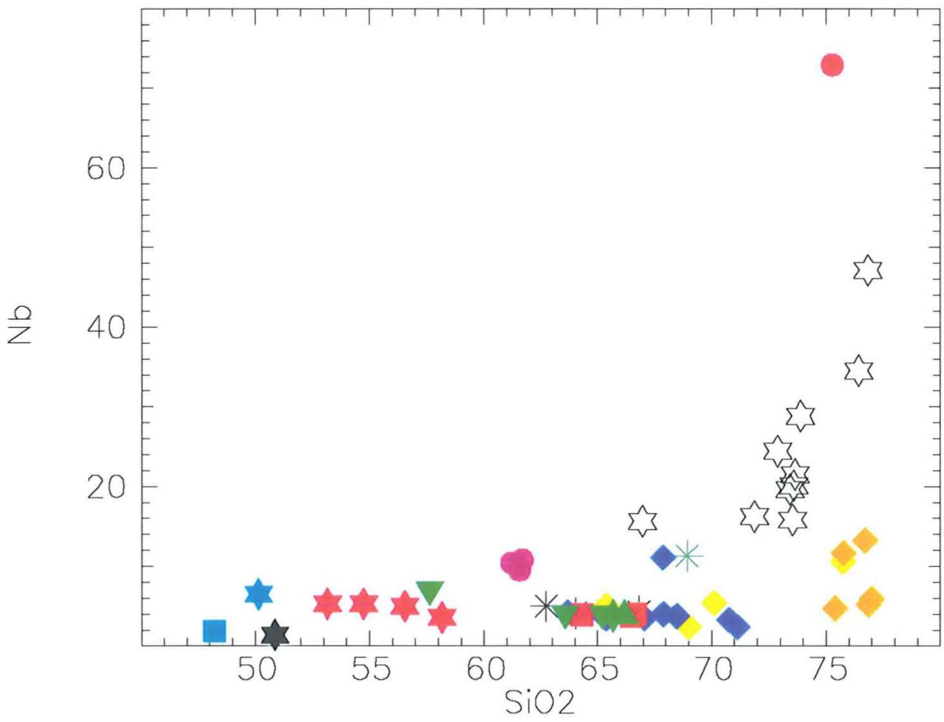


Figure 1k. Nb (ppm) versus SiO_2 (wt%)

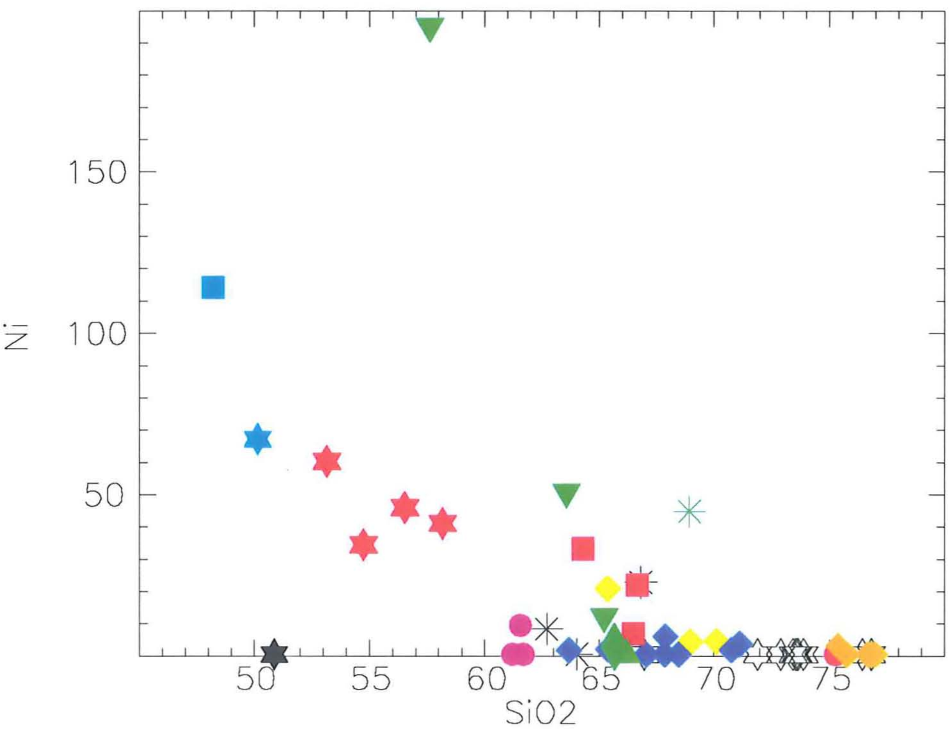


Figure 1l. Ni (ppm) versus SiO_2 (wt%)

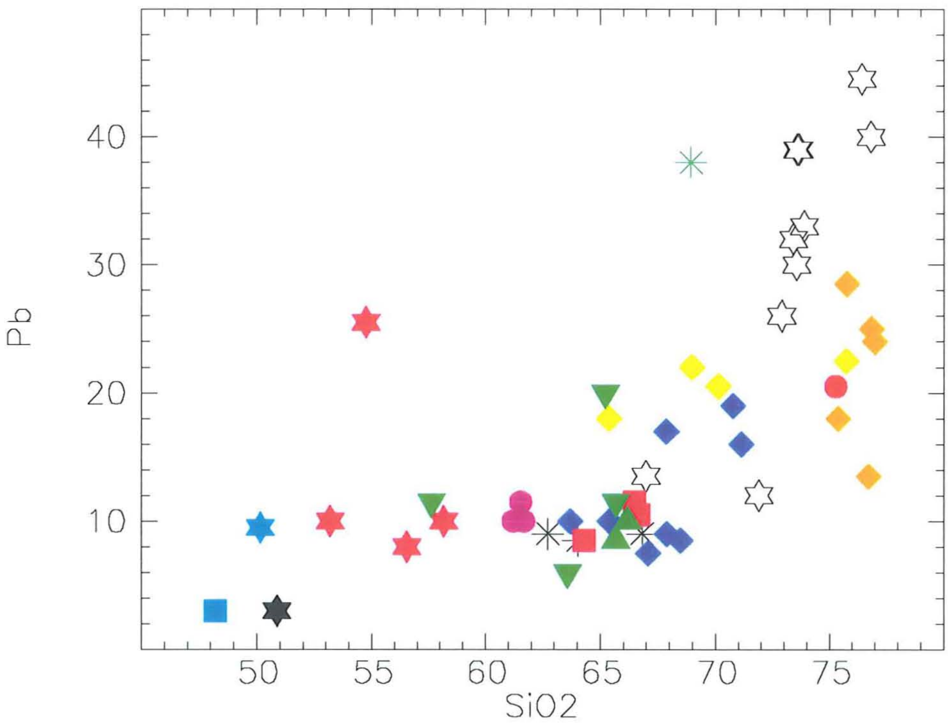


Figure 1m. Pb (ppm) versus SiO_2 (wt%)

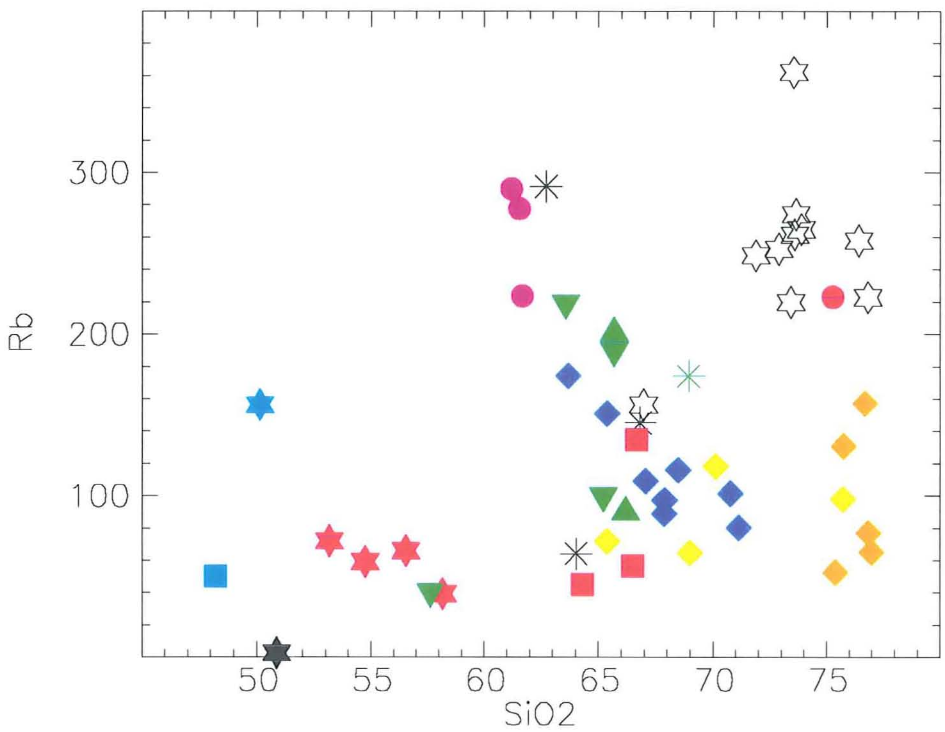


Figure 1n. Rb (ppm) versus SiO_2 (wt%)

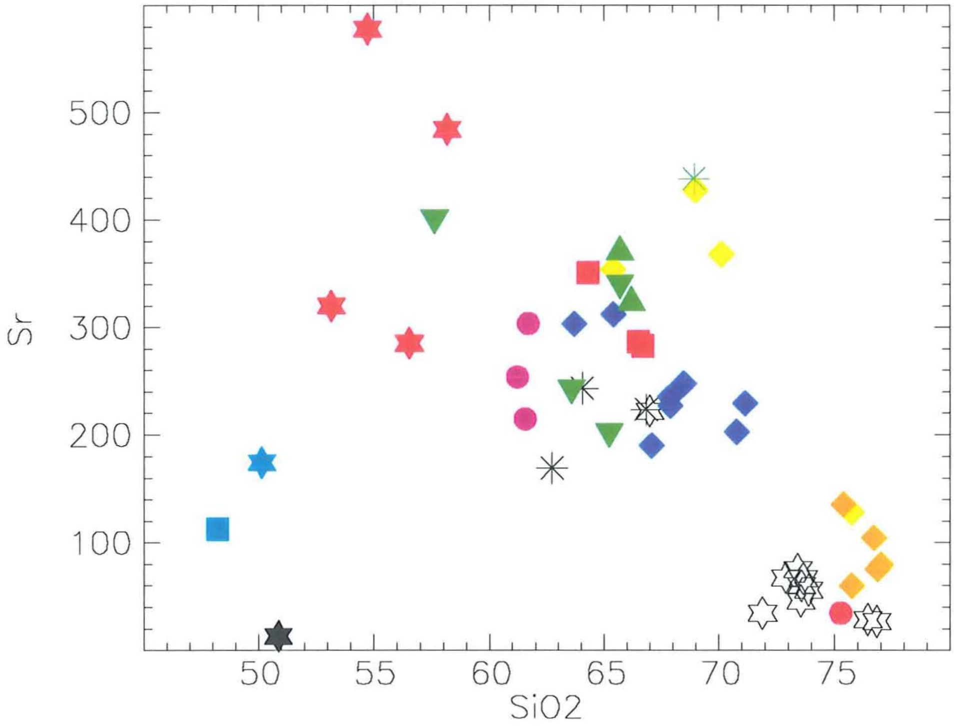


Figure 1o. Sr (ppm) versus SiO_2 (wt%)

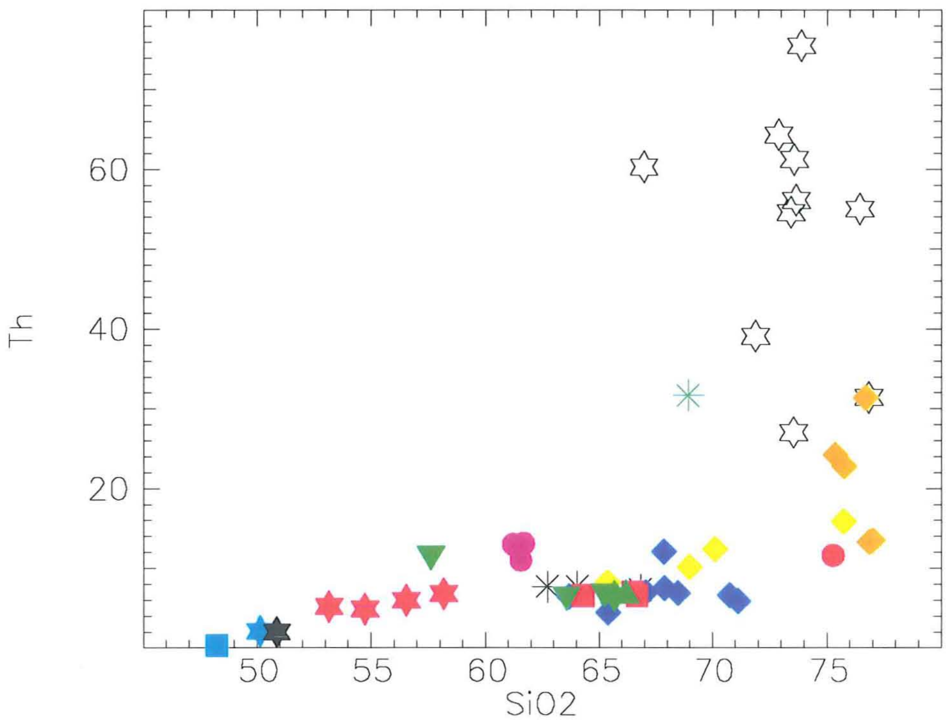


Figure 1p. Th (ppm) versus SiO_2 (wt%)

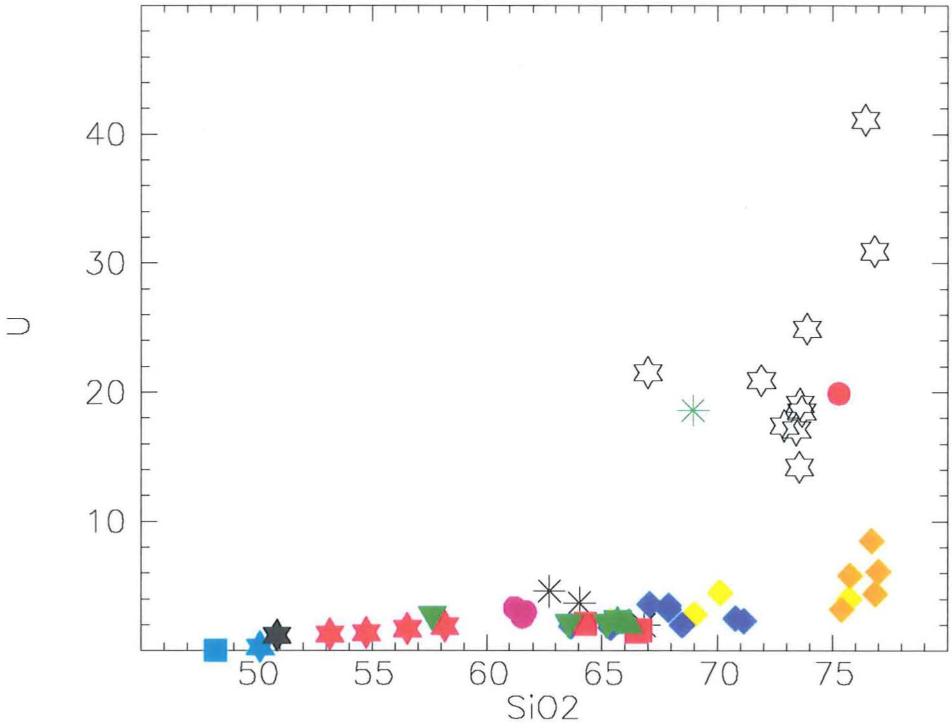


Figure 1q. U (ppm) versus SiO_2 (wt%)

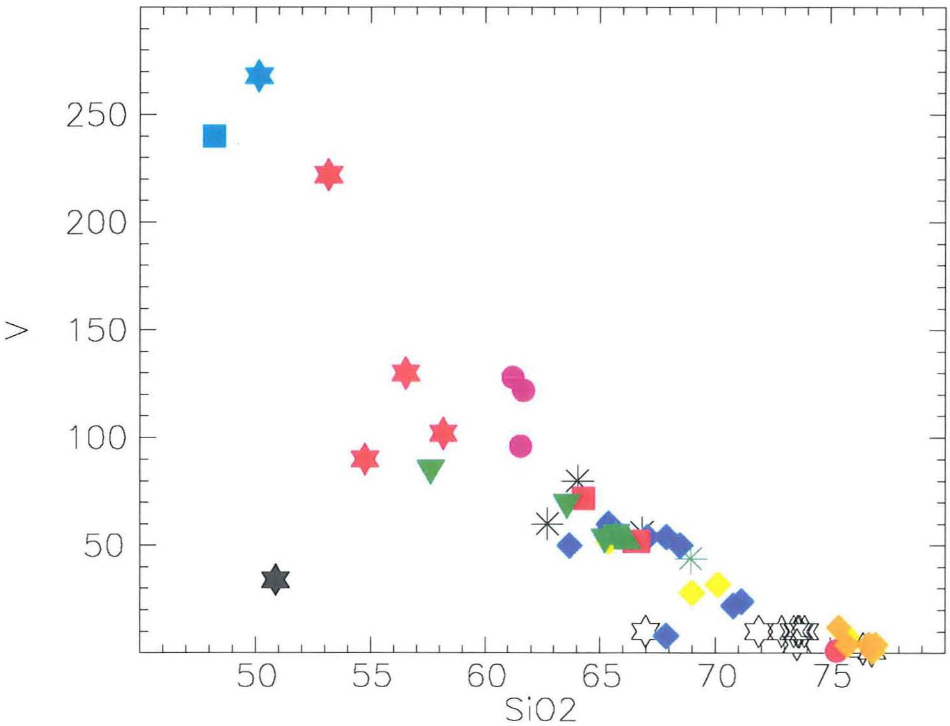


Figure 1r. V (ppm) versus SiO_2 (wt%)

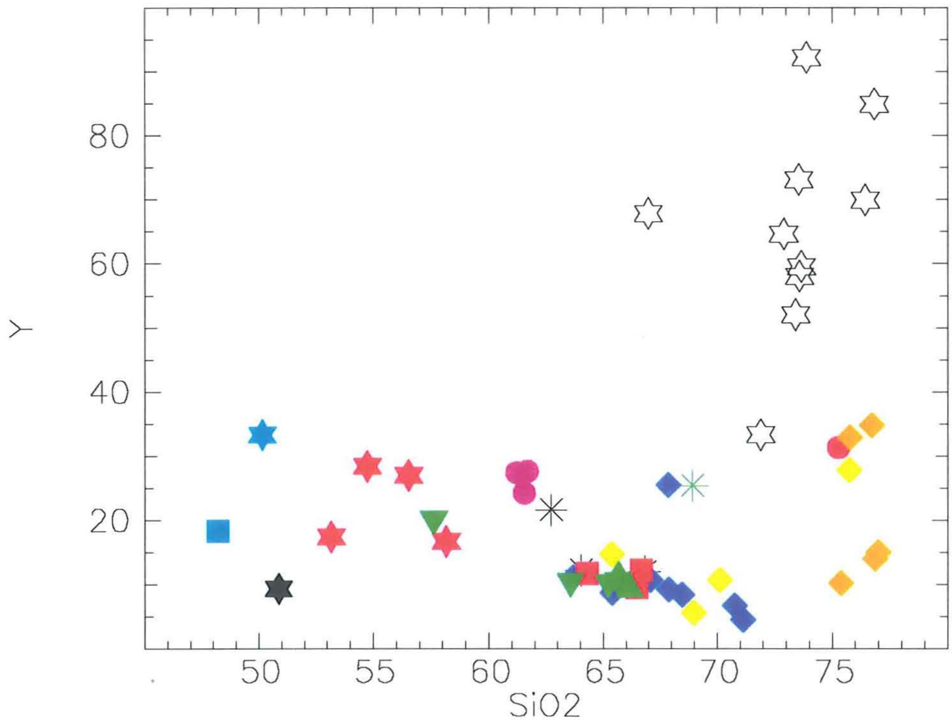


Figure 1s. Y (ppm) versus SiO_2 (wt%)

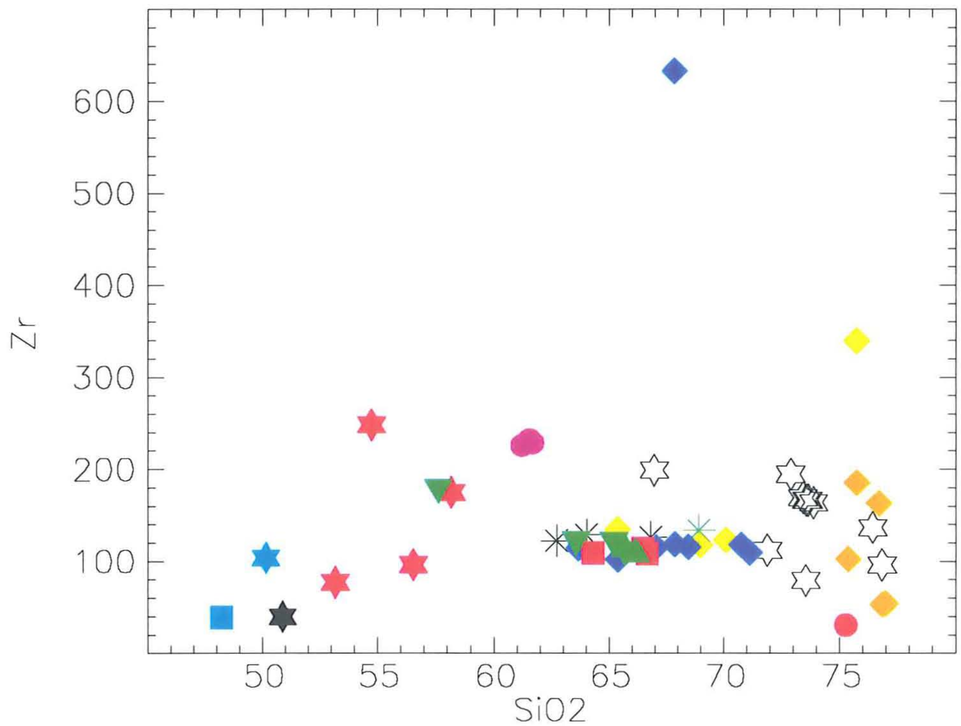


Figure 1t. Zr (ppm) versus SiO_2 (wt%)

Figure 2. X-Y plots for Boddington Gold Mine samples illustrating the geochemical features of the individual suites.

a Rb/Sr ratio versus SiO_2 (wt%)
b Zr/Y ratio versus SiO_2 (wt%)
c Rb/Sr ratio versus Zr/Y ratio
d Sr/Sr* ratio versus SiO_2 (wt%)
e Ce (ppm) versus TiO_2 (wt%)
f Y (ppm) versus TiO_2 (wt%)

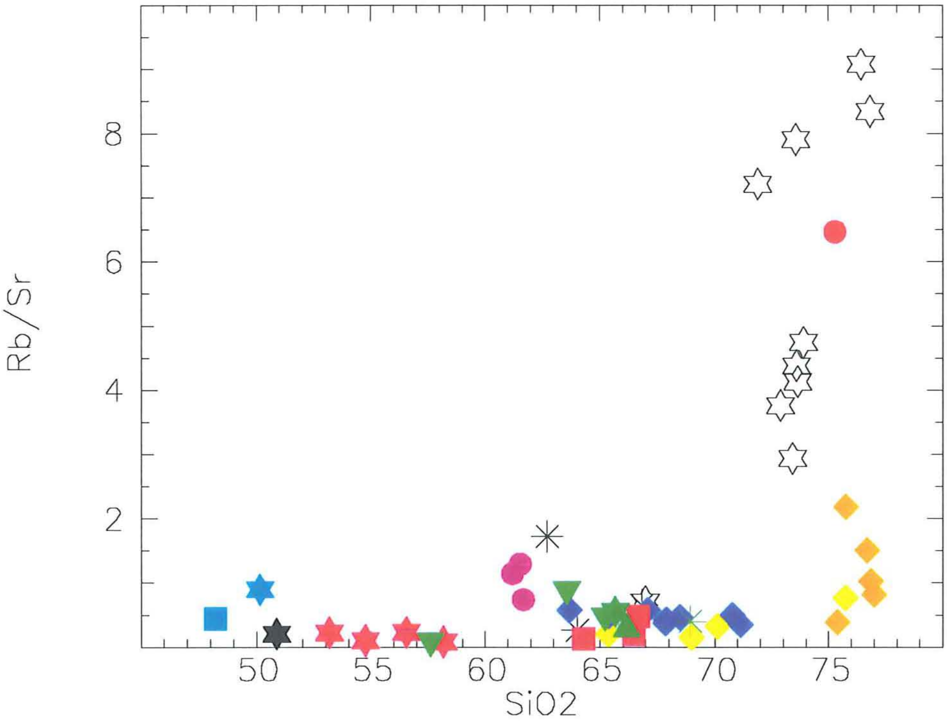


Figure 2a. Rb/Sr ratio vs SiO_2 (wt%)

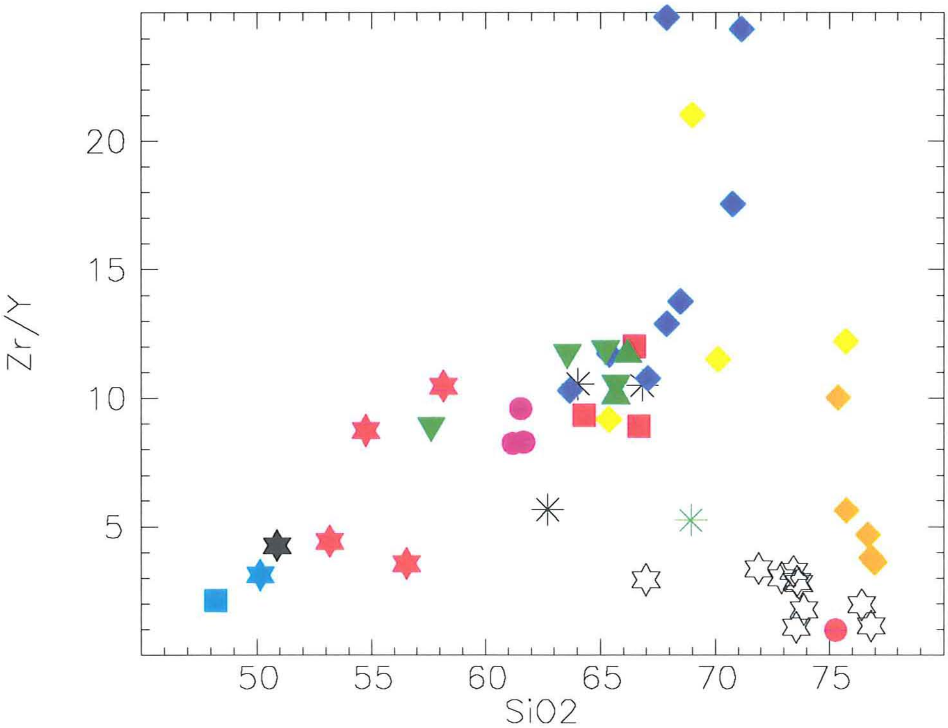


Figure 2b. Zr/Y ratio vs SiO_2 (wt%)

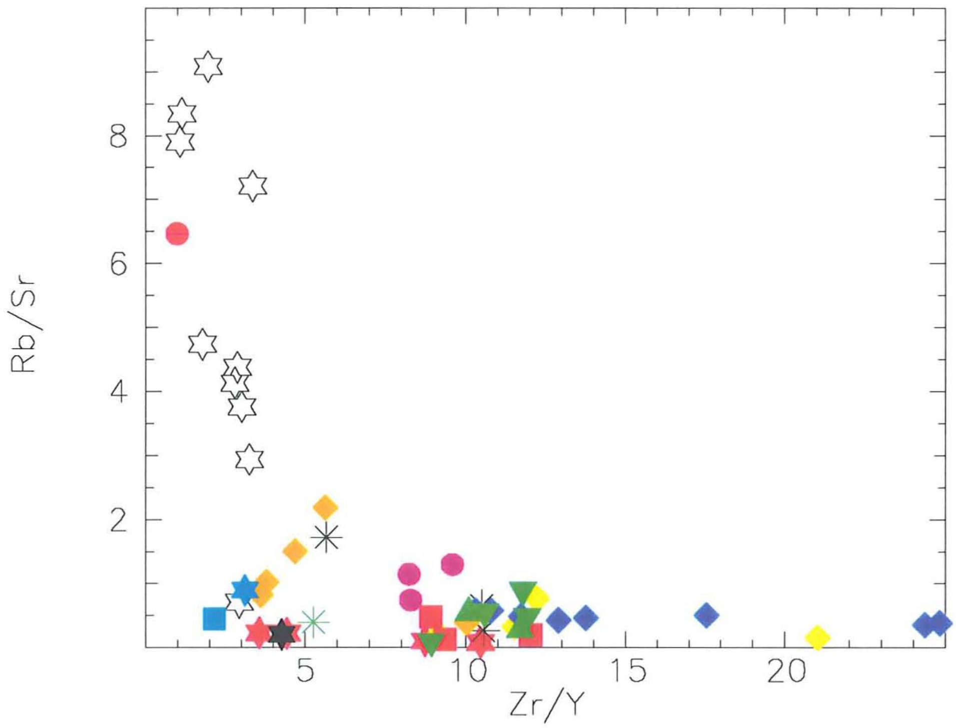


Figure 2c. Rb/Sr ratio vs Zr/Y ratio

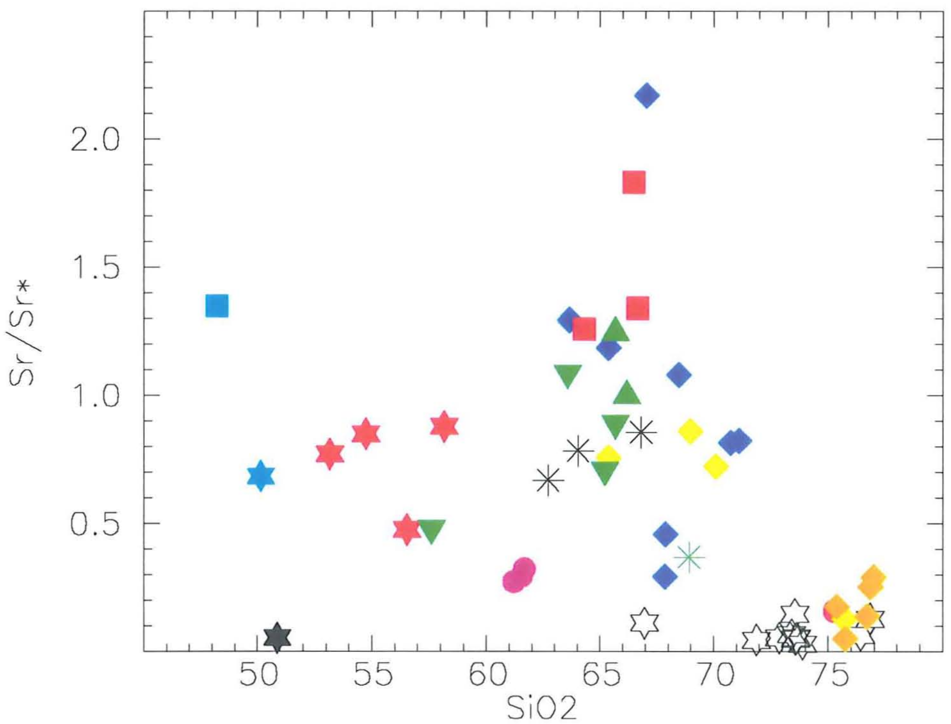


Figure 2d. Sr/Sr* ratio vs SiO_2 (wt%)

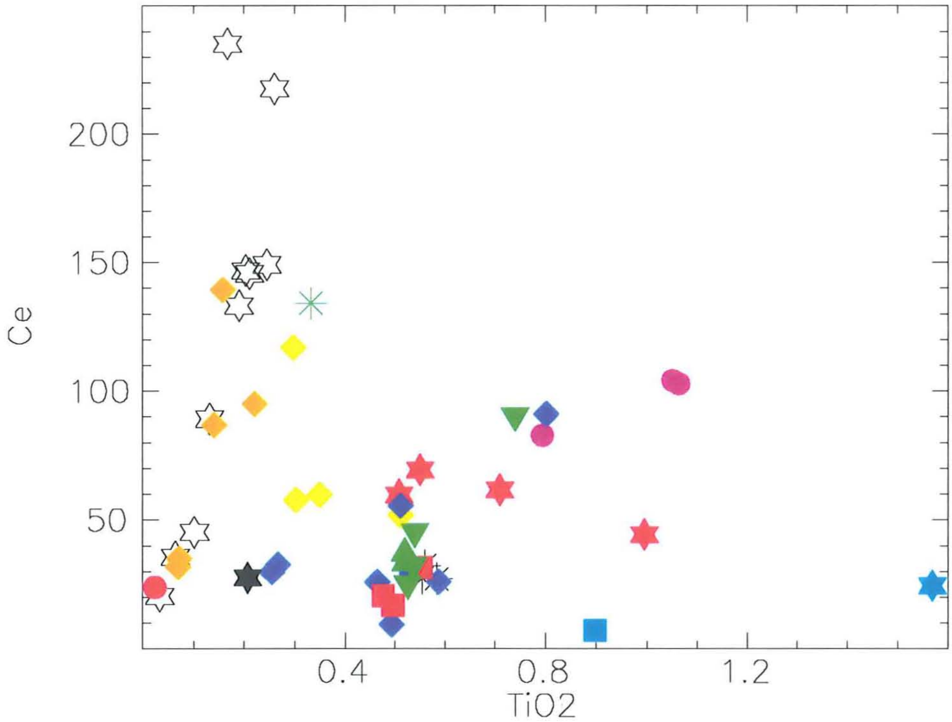


Figure 2e. Ce (ppm) vs TiO_2 (wt%)

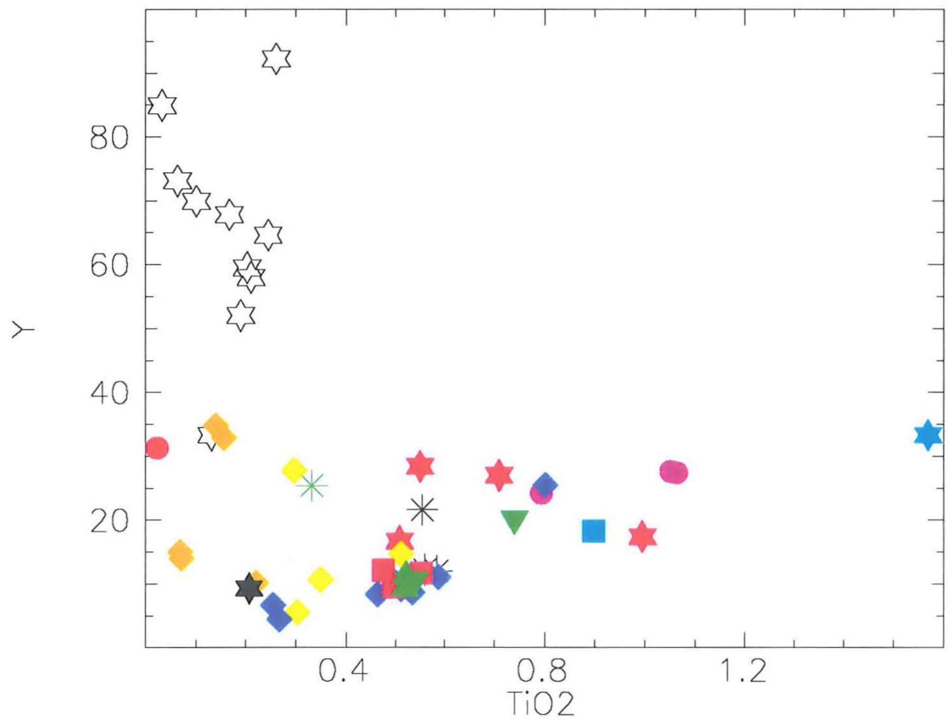


Figure 2f. Y (ppm) vs TiO_2 (wt%)

Figure 3. Binary and ternary plots for the various rock suites at the Boddington Gold Mine.

- **a** Alkalinity plot of total Na_2O+K_2O (wt%) versus SiO_2 (wt%) using the alkaline and subalkaline fields of Irvine & Baragar (1971). The plot illustrates the subalkaline nature of all rock types at Boddington.
- **b** TAS plot of total Na_2O+K_2O (wt%) versus SiO_2 (wt%) of Le Maitre et al. (1989) illustrating that the majority of the intermediate/felsic intrusive and extrusive lithologies at Boddington are 'dacites' and NOT 'andesites' as stated by Roth (1992). Note the rhyolitic composition of the Felsic Porphyry suite.
- **c** Subdivision of subalkaline rocks using the K_2O (wt%) versus SiO_2 (wt%) plot of Peccerillo & Taylor (1976). Note that the vast majority of intermediate/felsic intrusive and extrusive suites plot in the low-K and moderate-K calc-alkaline fields; Note that the Microdiorite suite straddles the boundary with the high-K calc-alkaline field.
- **d** Degree of Aluminium Saturation (ASI, molecular Al/[Ca+Na+K]) versus SiO_2 (wt%) plot illustrating the largely metaluminous (M) and peraluminous (P) character of all the rock types at Boddington.
- **e** Na_2O (wt%) versus K_2O (wt%) plot illustrating the K_2O-rich nature of the 'Late' Granite and Aplite suites, and the low-moderate but variable K_2O of the intermediate intrusive and extrusive suites. The variable K_2O content probably reflects variable degree of hydrothermal alteration.
- **f** Fe_2O_3/FeO versus Total Fe as FeO (wt%) plot illustrating the oxidation state of the various rock suites at Boddington using the fields of Champion & Heinemann (1994). The majority of the intermediate intrusive and extrusive suites plot in the 'reduced' field, whereas the 'Late' Granite suite plots predominantly in the 'oxidised' field.
- **g** Log Rb versus Log (Nb+Y) plot of Pearce et al. (1984) illustrating that all the intermediate intrusive and extrusive suites plot in the 'volcanic-arc granites' field, whereas the 'Late' Granite and Aplite plot mainly within the 'within-plate granite' field. Note that the fields do not necessarily correspond to the tectonic setting of the granite suites.
- **h** 10,000*Ga/Al versus Zr+Nb+Ce+Y (ppm) plot of Eby (1990) used to discriminate A-type granites. Note that most of the suites plot within the 'normal' granite field. The Microdiorite suite straddles the fields for 'normal' and 'A-type' granites based on Paleozoic granites, and the 'Late' Granite suite is predominantly in the 'A-type' field.
- **i** Ternary Rb (ppm) - Ba (ppm) - Sr (ppm) plot of El Bouseily & El Sokkary (1975) illustrating the degree of fractionation for the various rock suites. Note that the 'Late' Granite and Aplite suites plot in the field of strongly differentiated granites.
- **j** Ternary CaO (wt%) - Na_2O (wt%) - K_2O (wt%) classification plot. The various suites plot in different fields reflecting the wide range in composition and silica range for the various suites at Boddington. The rocks that plot in the 'Trondhjemite' field reflect significant Na metasomatism.

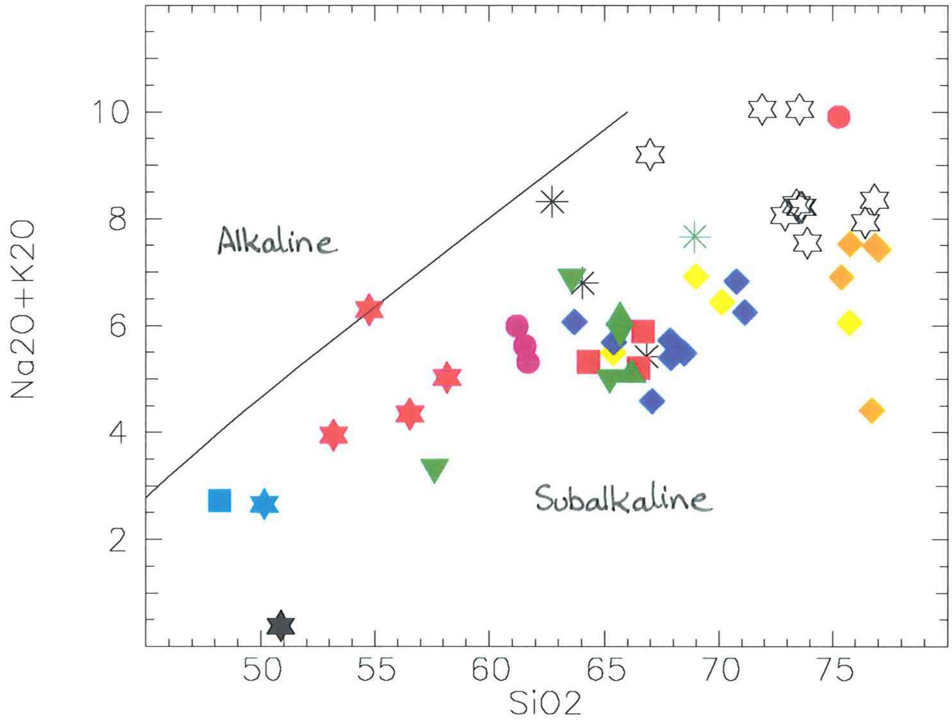


Figure 3a. Alkalinity plot (Na_2O+K_2O vs SiO_2) using fields of Irvine & Baragar (1971)

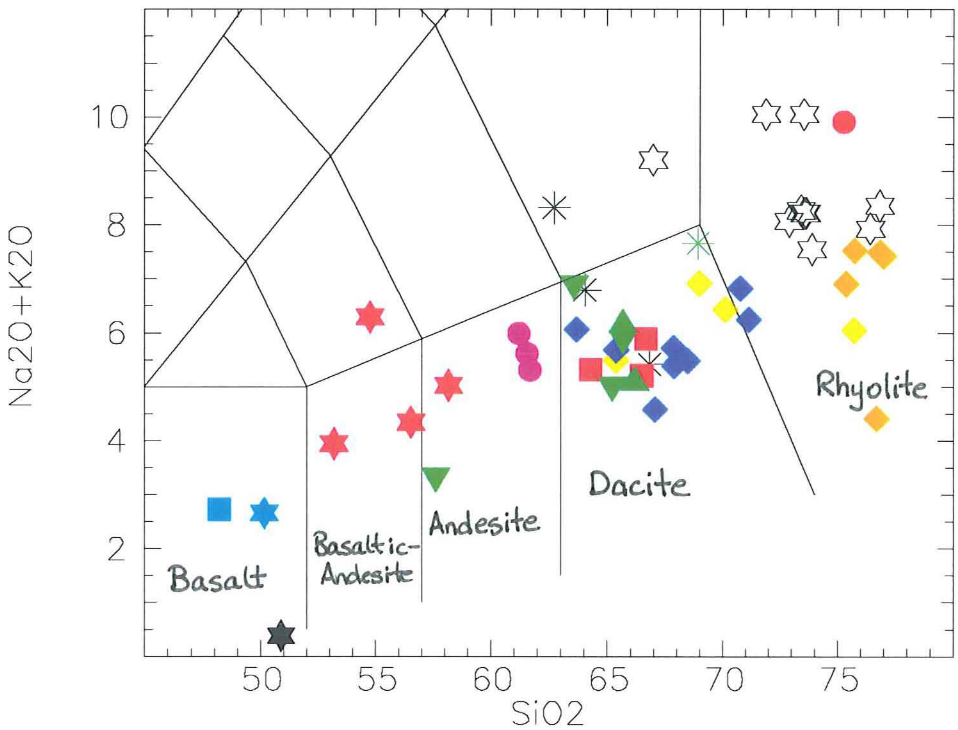


Figure 3b. TAS plot (Na_2O+K_2O vs SiO_2) of Le Maitre et al. (1989)

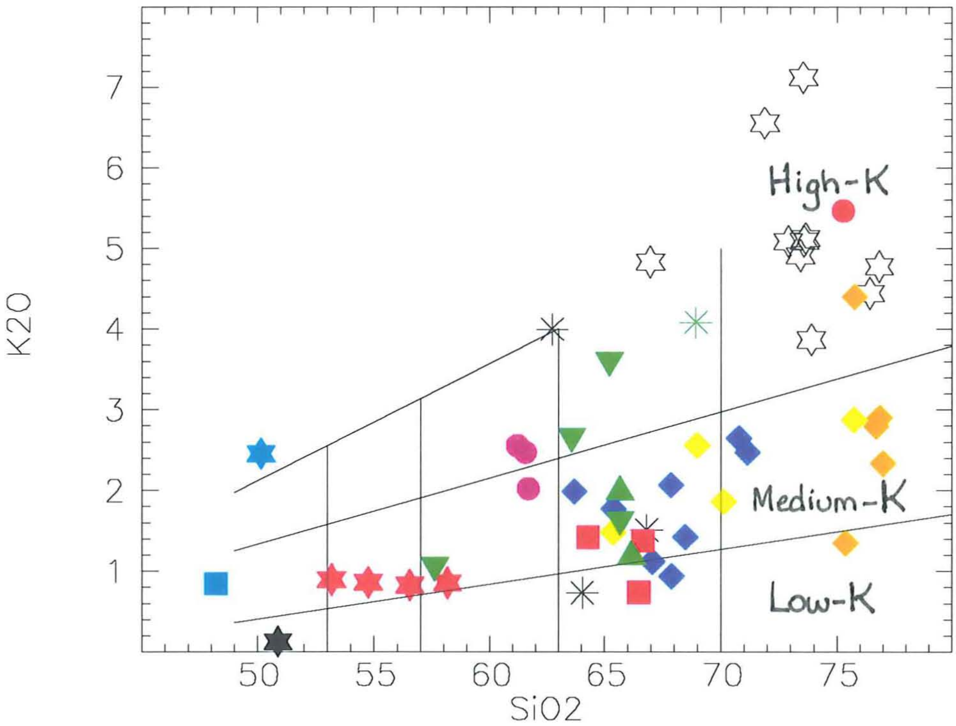


Figure 3c. Subdivision of subalkaline rocks (K_2O vs SiO_2) of Peccerillo & Taylor (1976)

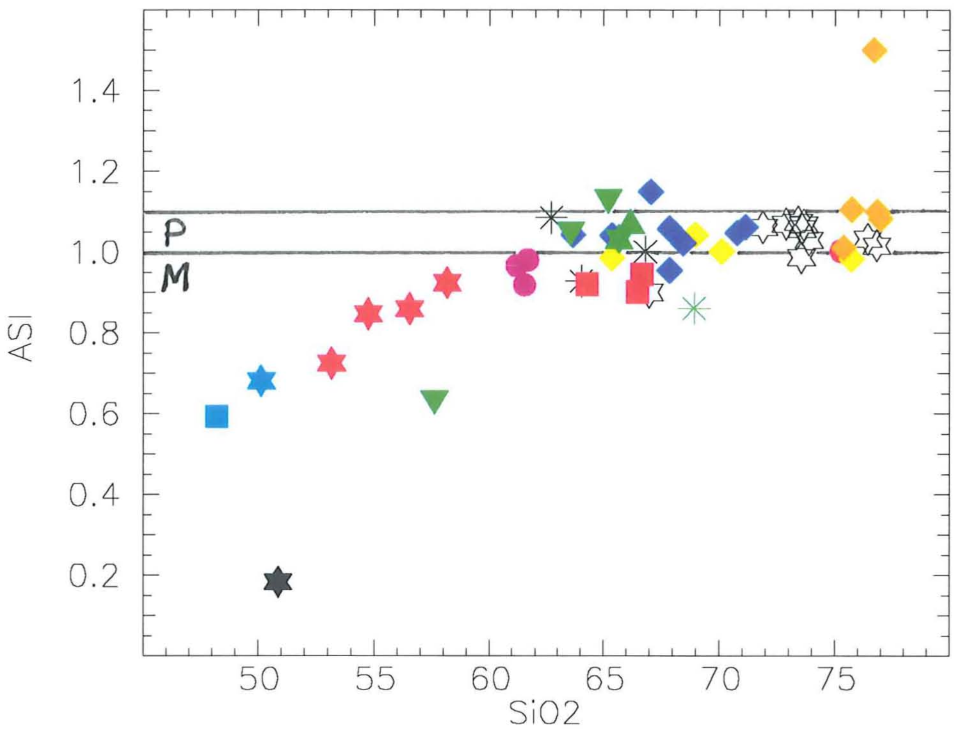


Figure 3d. Degree of aluminium saturation plot (ASI, molecular Al/[Ca+Na+K] vs SiO_2)

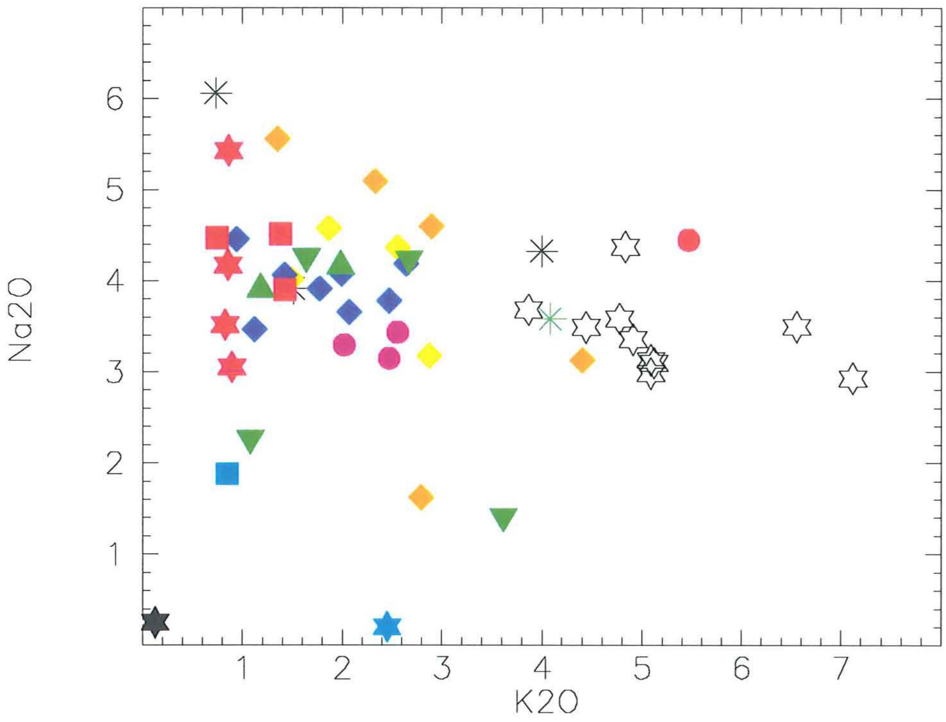


Figure 3e. Na_2O (wt%) versus K_2O (wt%)

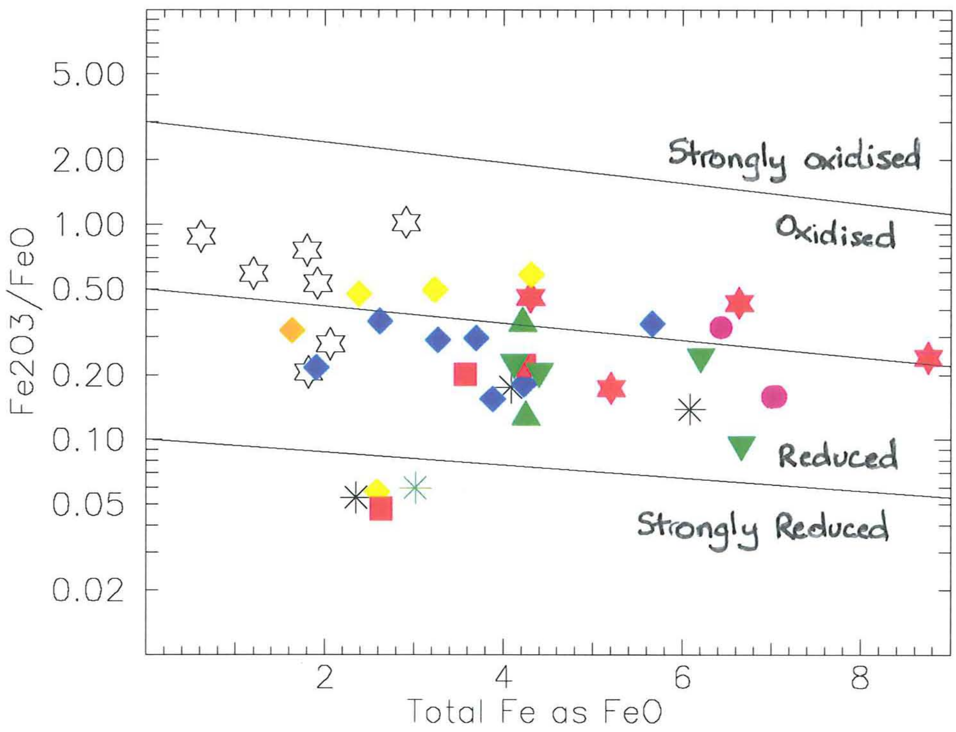


Figure 3f. Redox plot (Fe_2O_3/FeO vs Total Fe as FeO) of Champion & Heinemann (1994)

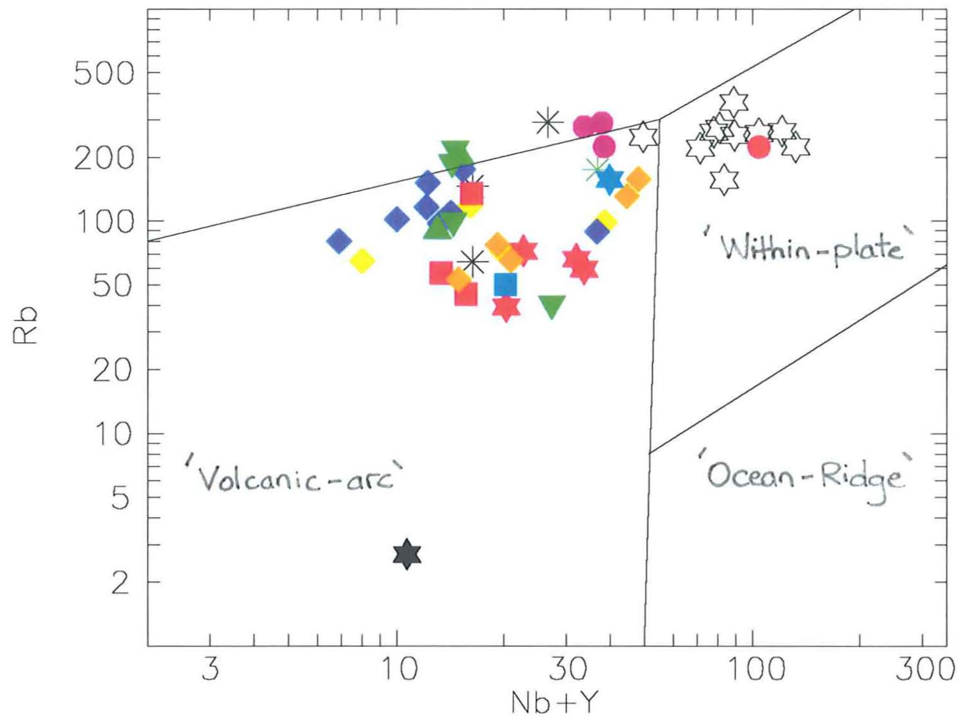


Figure 3g. Log Rb vs Log Nb+Y plot of Pearce et al. (1984)

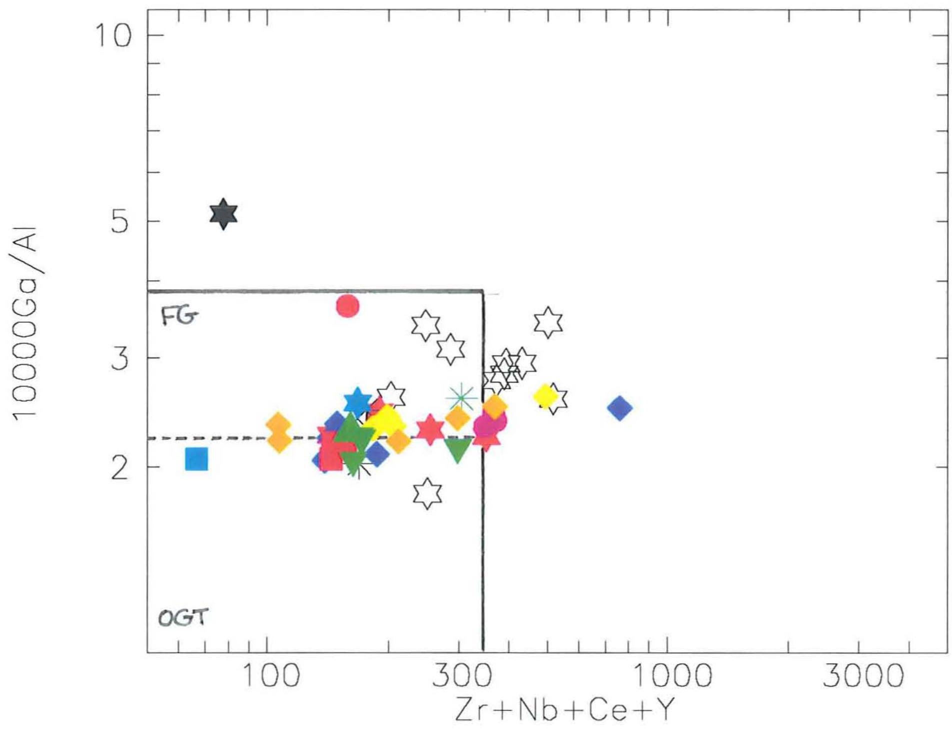


Figure 3h. A-type plot (10,000*Ga/Al vs Zr+Nb+Ce+Y) of Eby (1990)

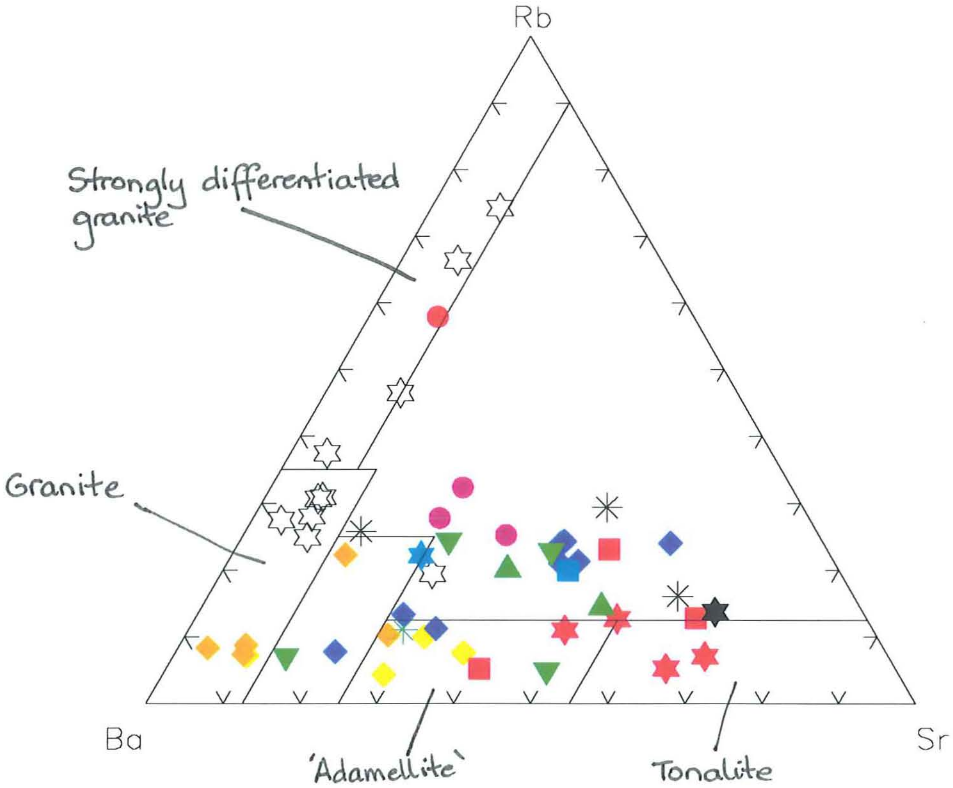


Figure 3i. Degree of fractionation (Rb-Ba-Sr plot of El Bouseily & El Sokkary, 1975)

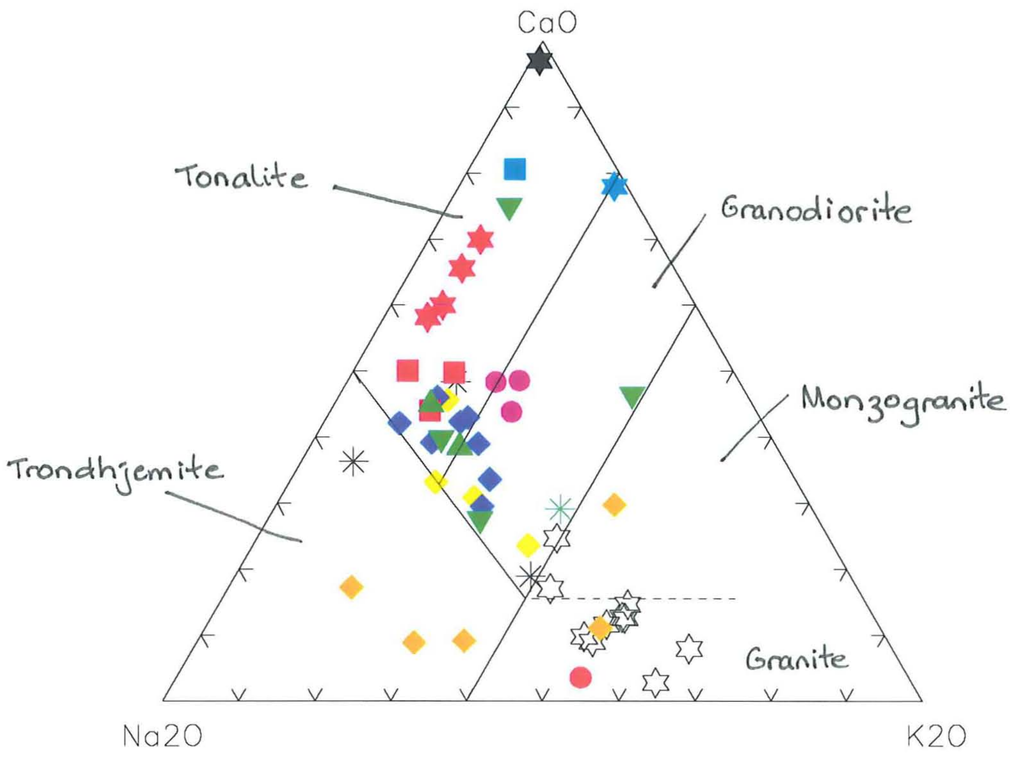


Figure 3j. Degree of fractionation (CaO-Na_2O-K_2O plot)

Figure 4. Box-whisker plots for the individual suites from the Boddington Gold Mine illustrating the geochemical variation of specific oxides and trace elements.

- **a** Box-whisker plot of SiO_2 (wt%)
- **b** Box-whisker plot of K_2O (wt%)
- **c** Box-whisker plot of Th (ppm)
- **d** Box-whisker plot of U (ppm)

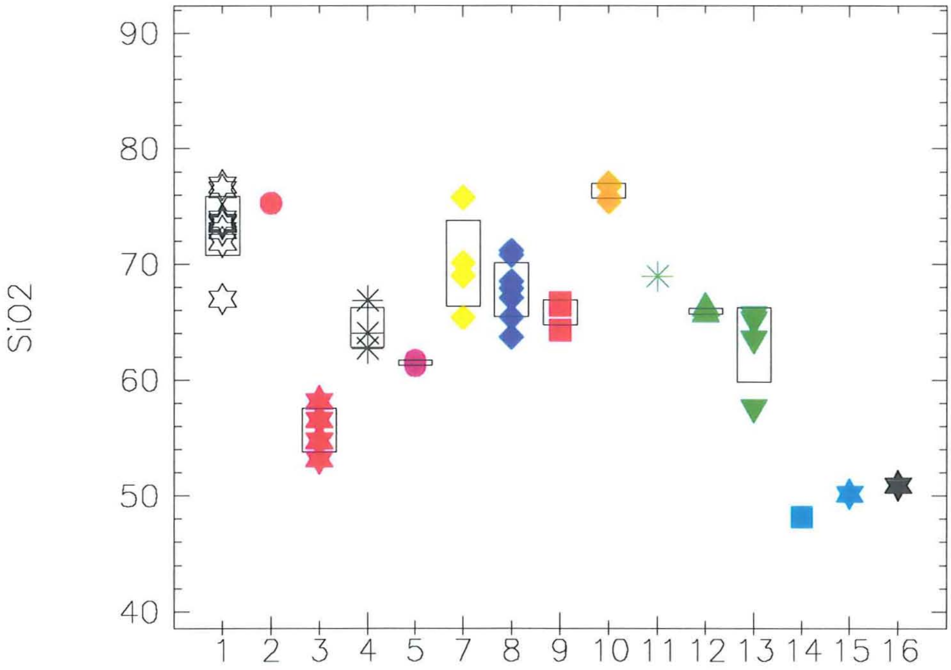


Figure 4a. Box-whisker plot of SiO_2 (wt%)

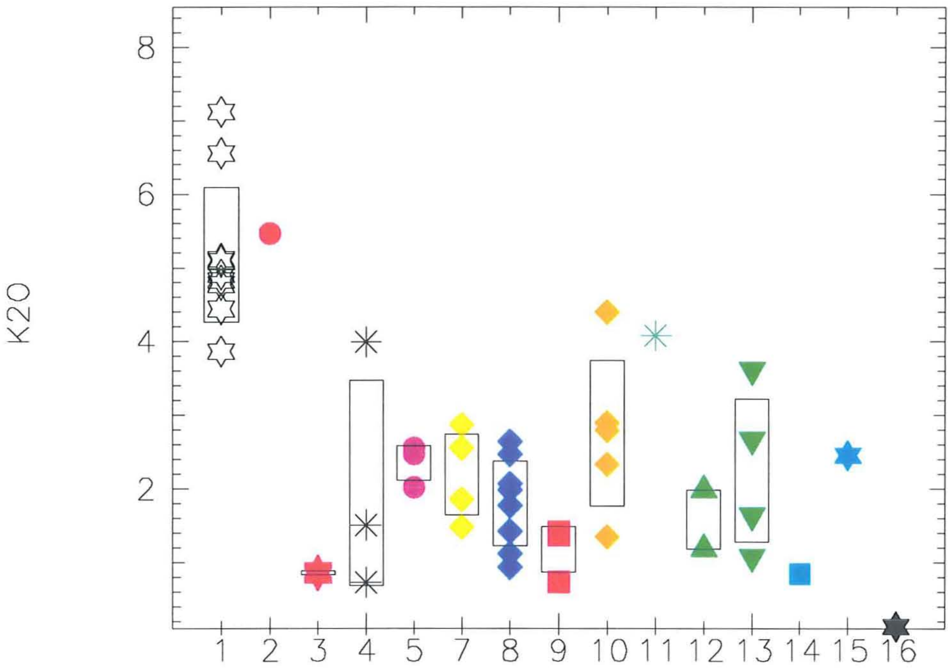


Figure 4b. Box-whisker plot of K_2O (wt%)

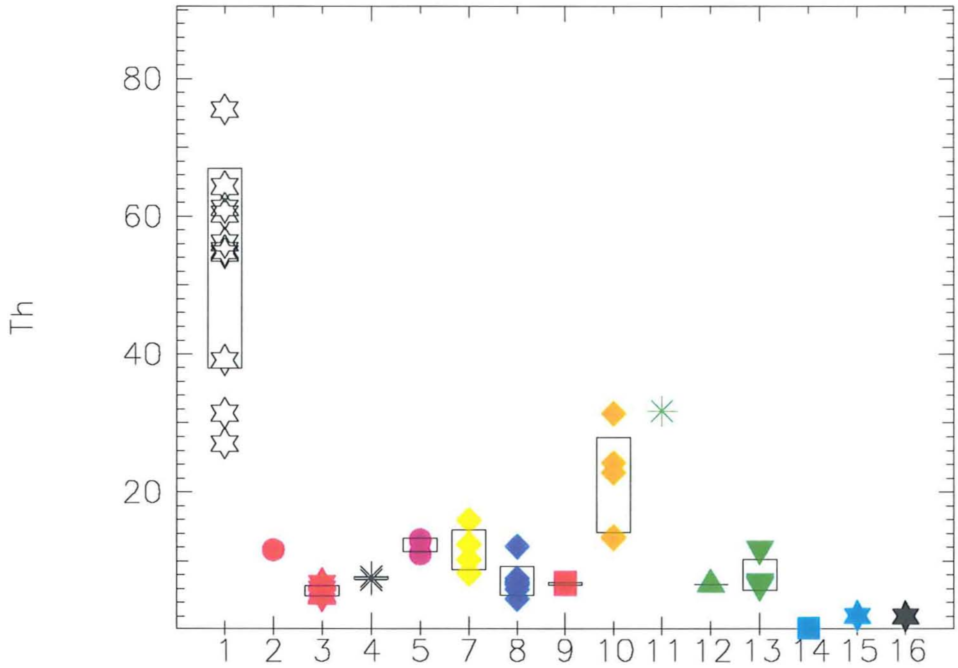


Figure 4c. Box-whisker plot of Th (ppm)

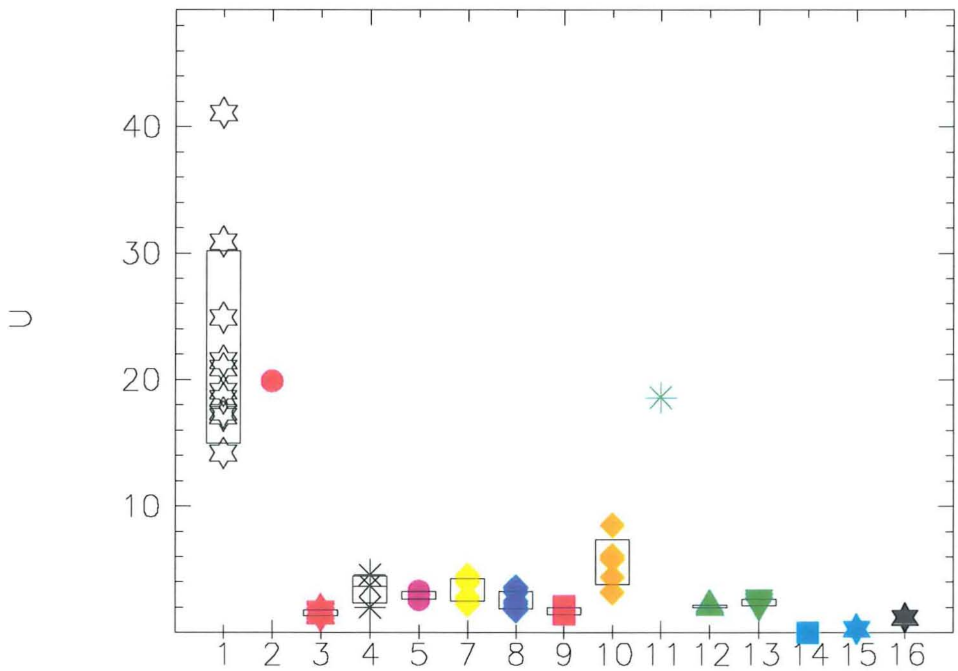
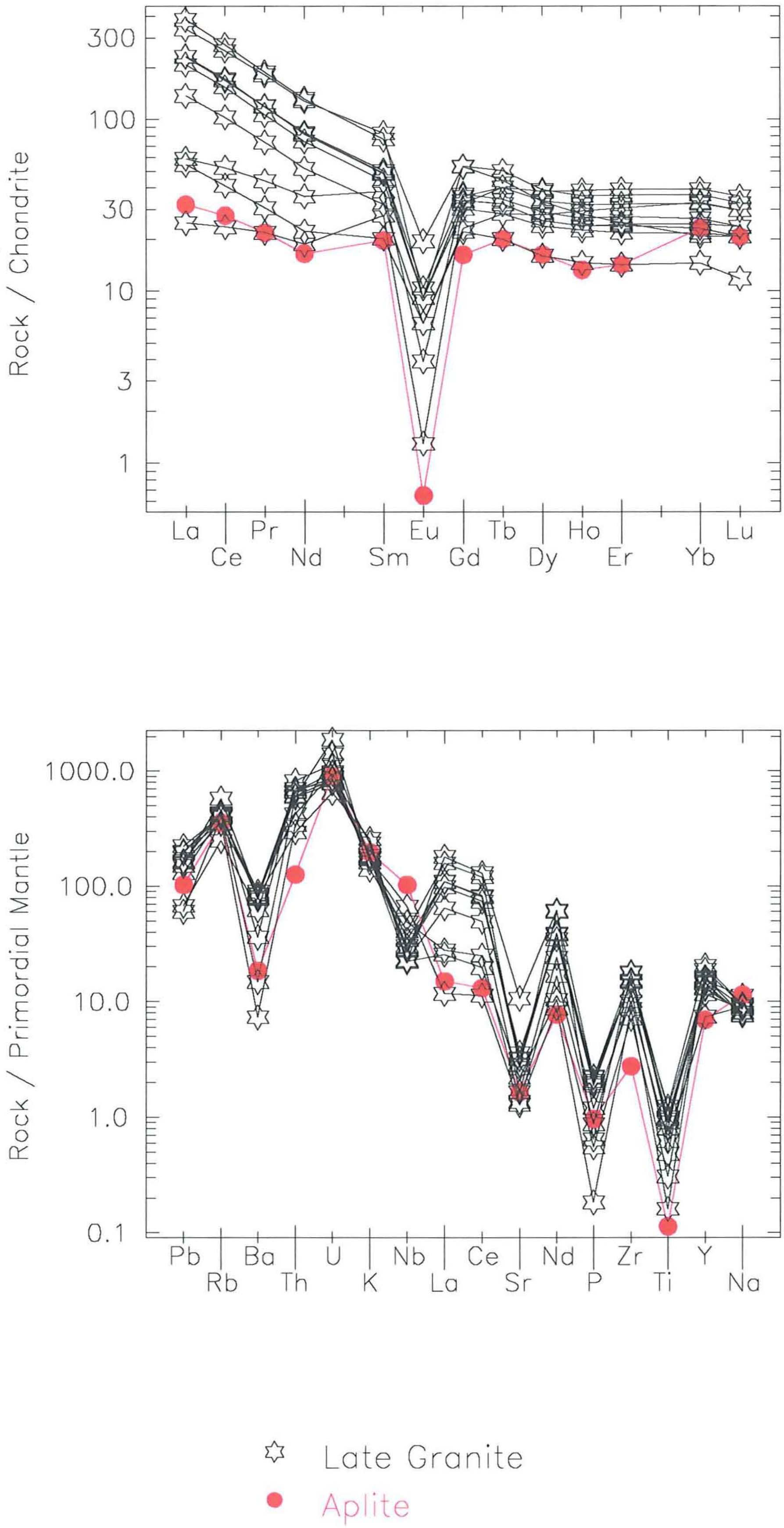
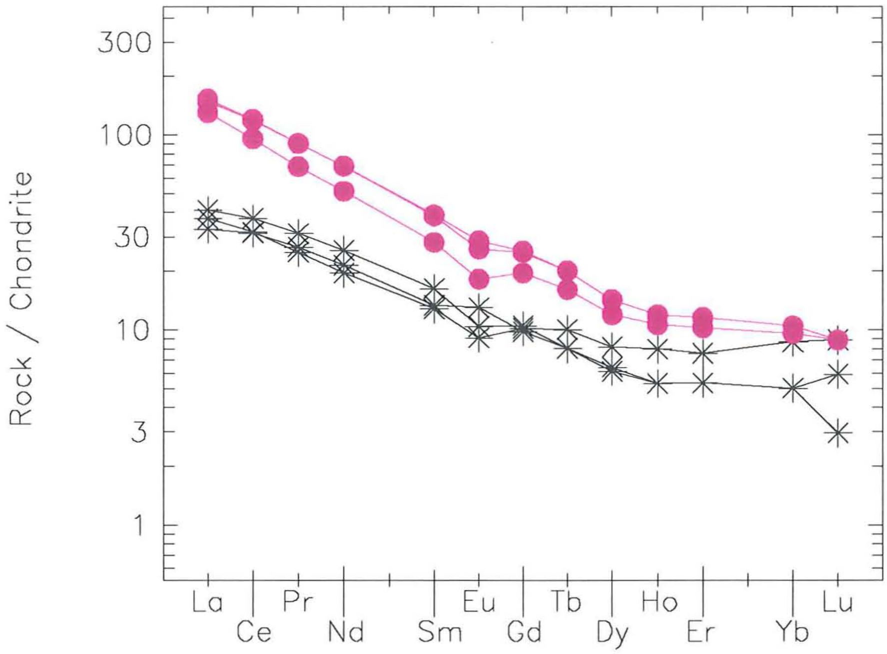


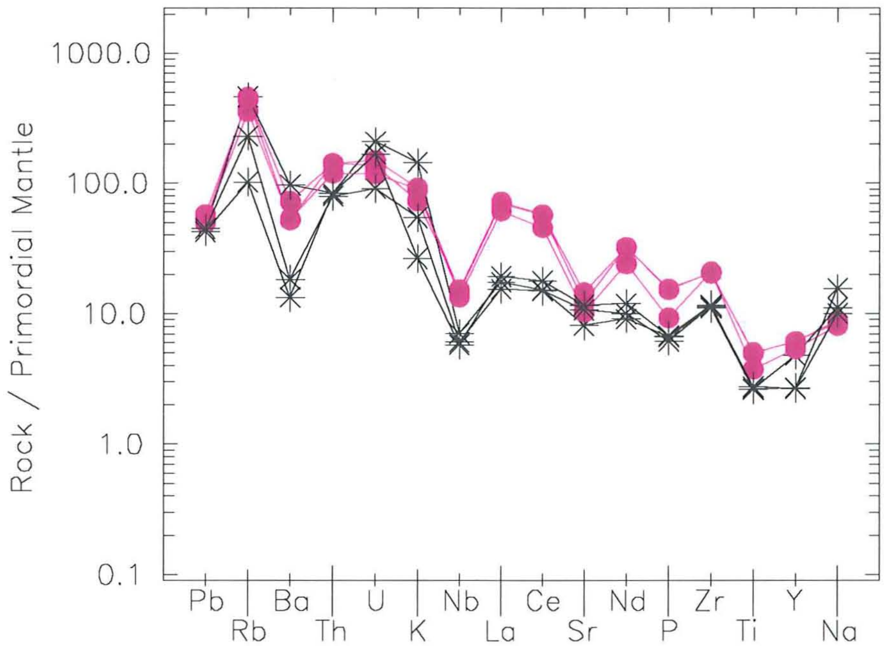
Figure 4d. Box-whisker plot of U (ppm)

Figure 5. Chondrite-normalised rare earth element diagrams and primitive mantle-normalised spidergrams for the various suites from the Boddington Gold Mine.

- **a** 'Late' Granite and Aplite suites
- **b** Intrusive Breccia/MP-Diorite and Microdiorite suites
- **c** 'Hybrid' Diorite and Quartz-Diorite/Tonalite suites
- **d** Porphyritic/'Late' Diorite and Aphyric/'Early' Diorite suites
- **e** Felsic Porphyry suite
- **f** Dacitic ?Tuff, Dacite and 'Andesite'/Intermediate Fragmental suites
- **g** Basalt, Archean Dolerite and Actinolite Vein suites

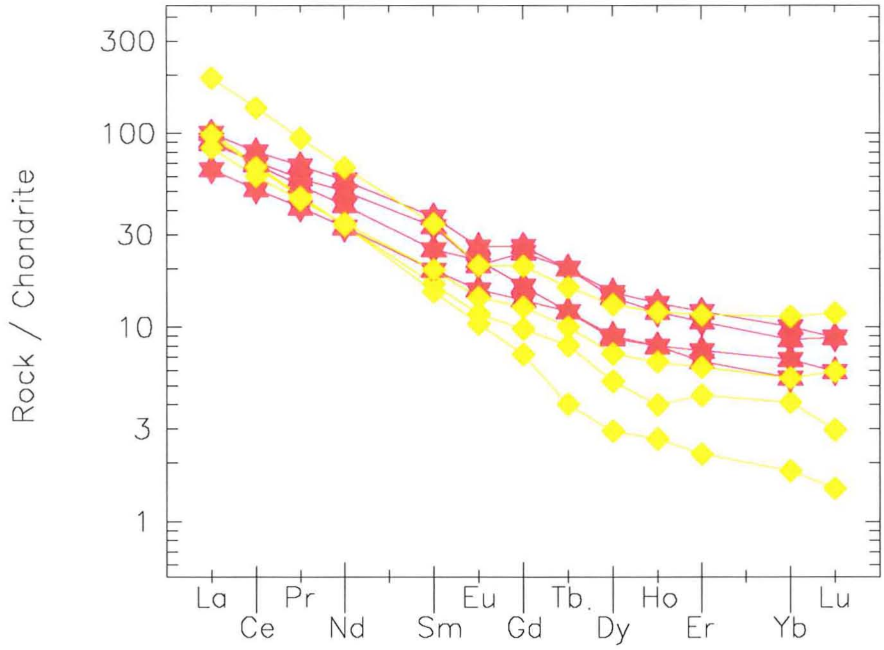

Rock / Chondrite
300
100
30
10
3
1
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Yb
Lu
Rock / Primordial Mantle
1000.0
100.0
10.0
1.0
0.1
Pb
Rb
Ba
Th
U
K
Nb
La
Ce
Sr
Nd
P
Zr
Ti
Y
Na
Late Granite
Aplite

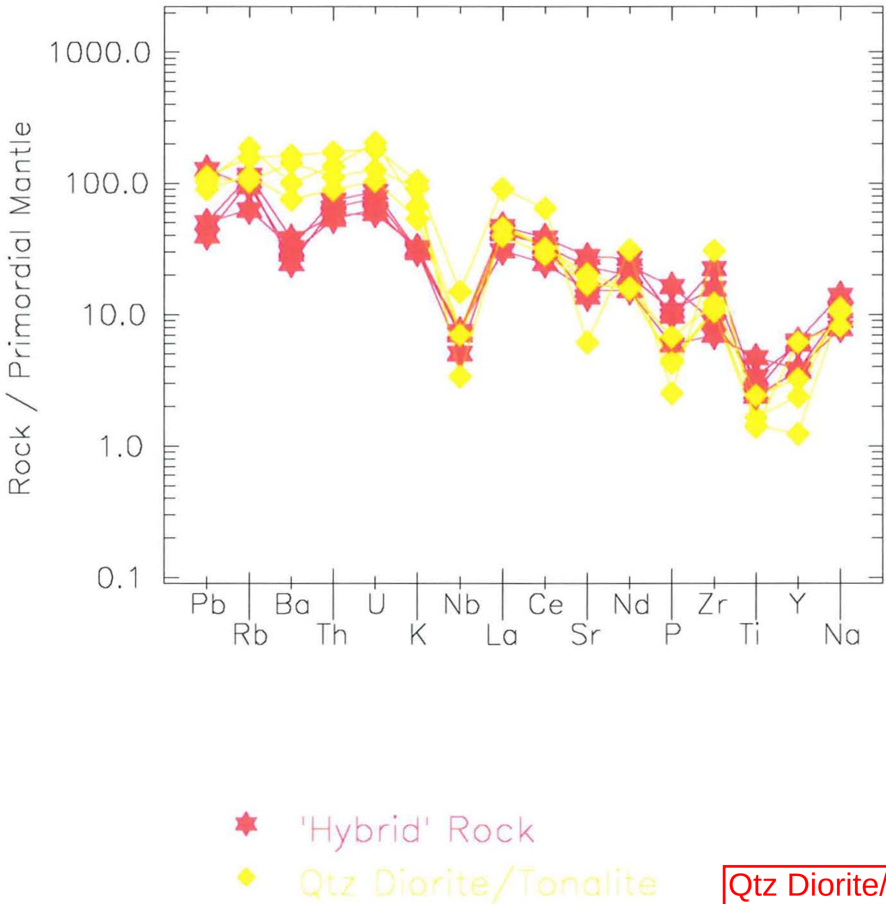




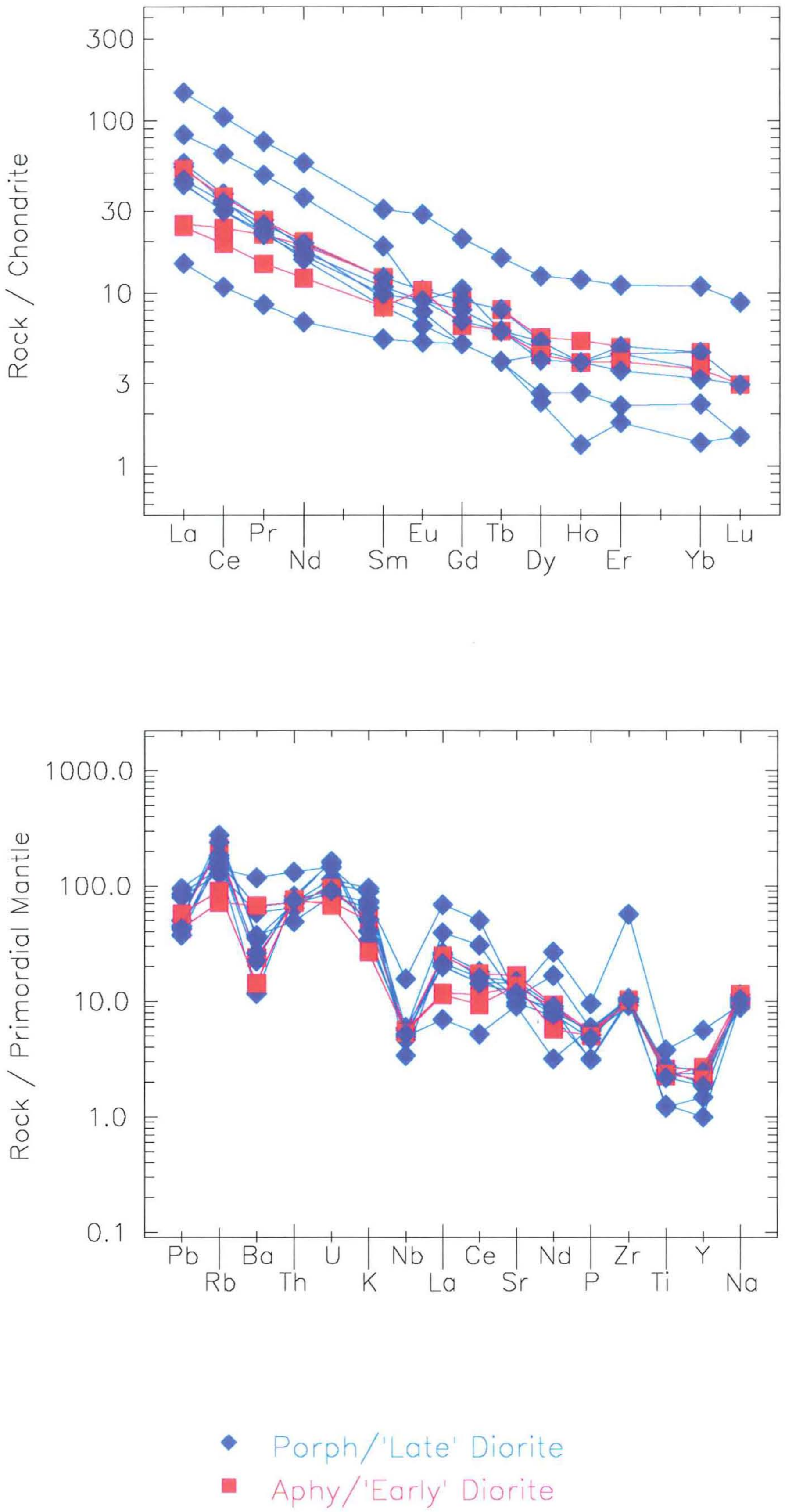
Intrusive Breccia

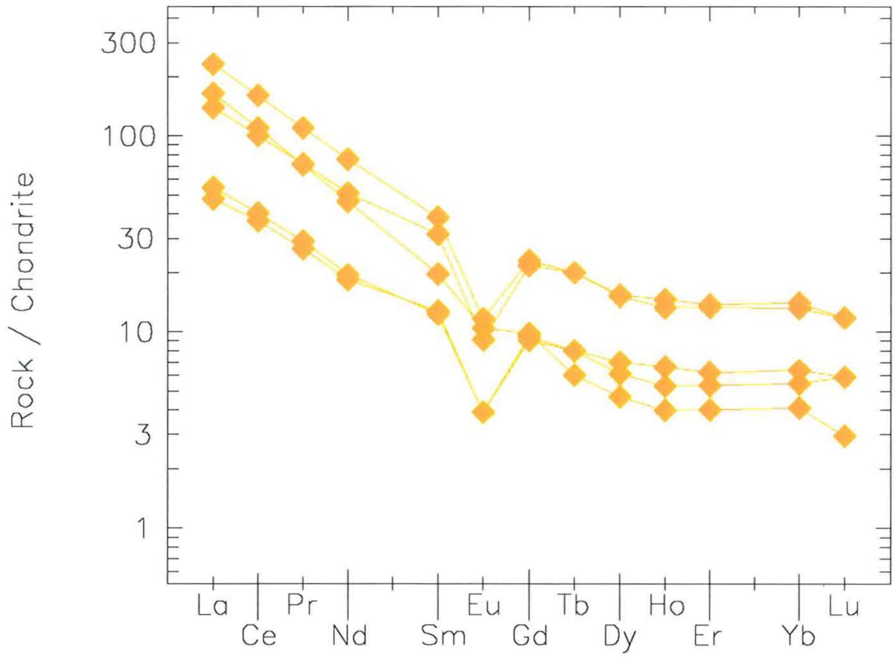
Microdiorite

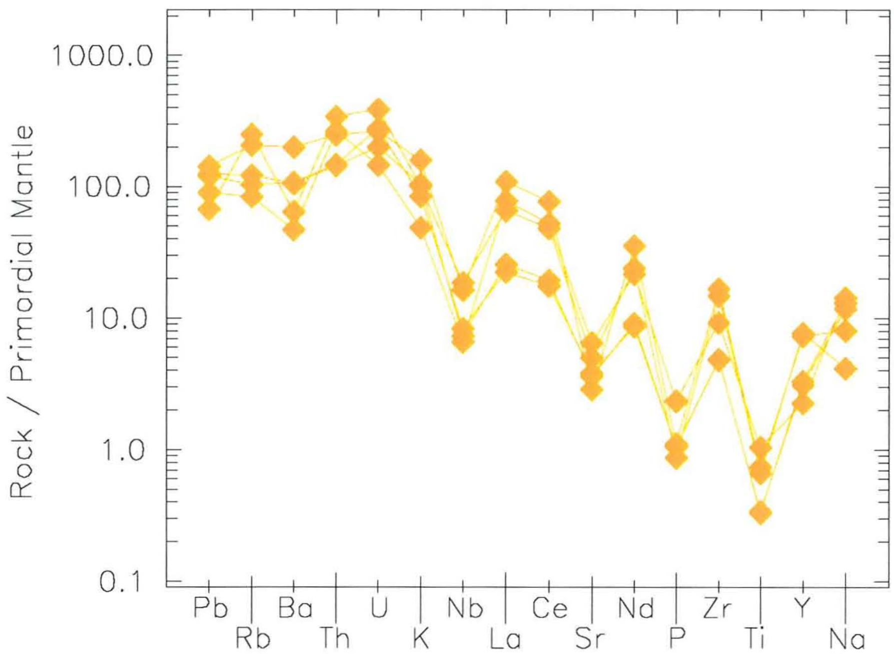




Qtz Diorite/Tonalite

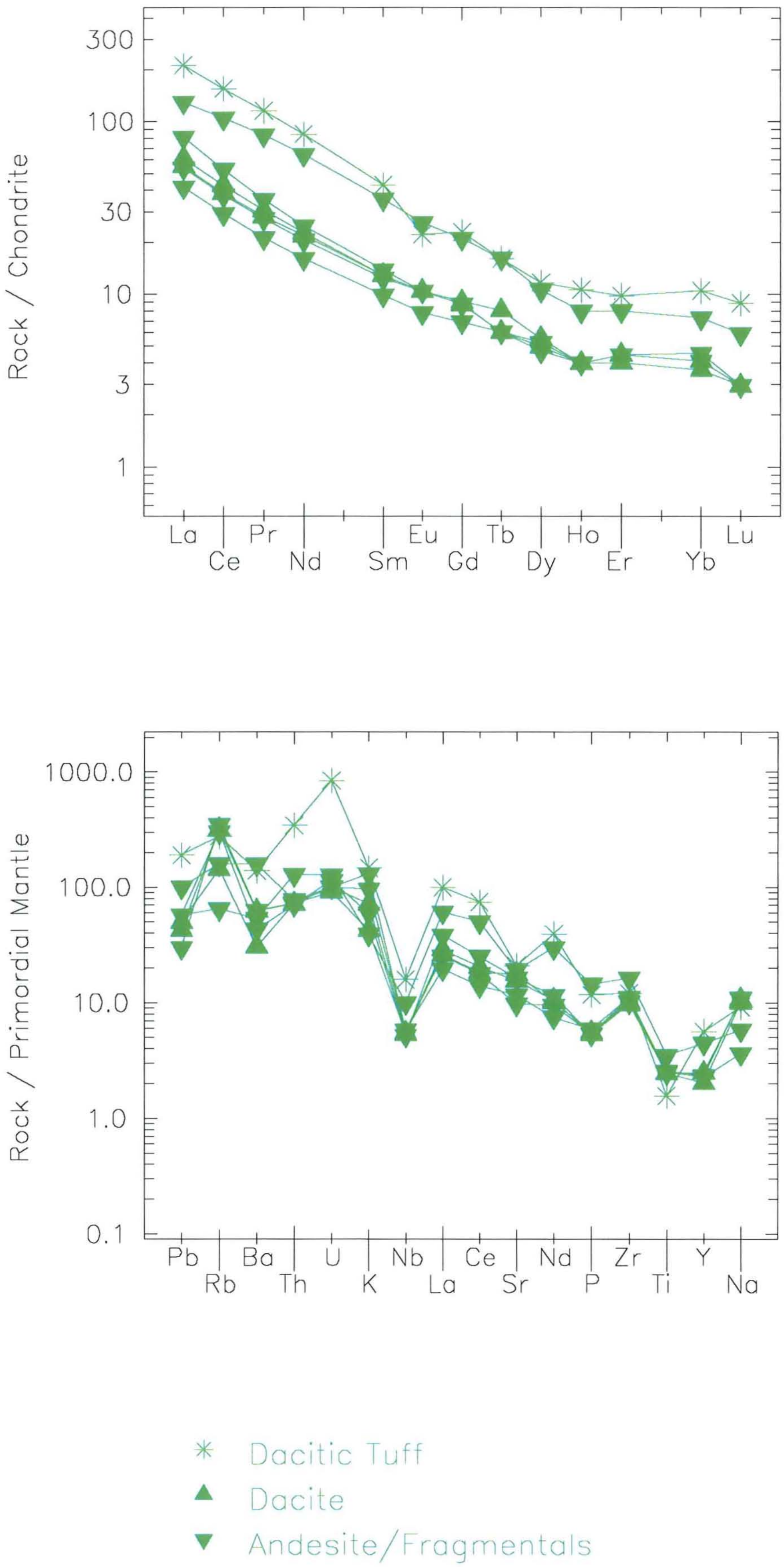

Rock / Chondrite
300
100
30
10
3
1
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Yb
Lu
Rock / Primordial Mantle
1000.0
100.0
10.0
1.0
0.1
Pb
Rb
Ba
Th
U
K
Nb
La
Ce
Sr
Nd
P
Zr
Ti
Y
Na
Porph/'Late' Diorite
Aphy/'Early' Diorite

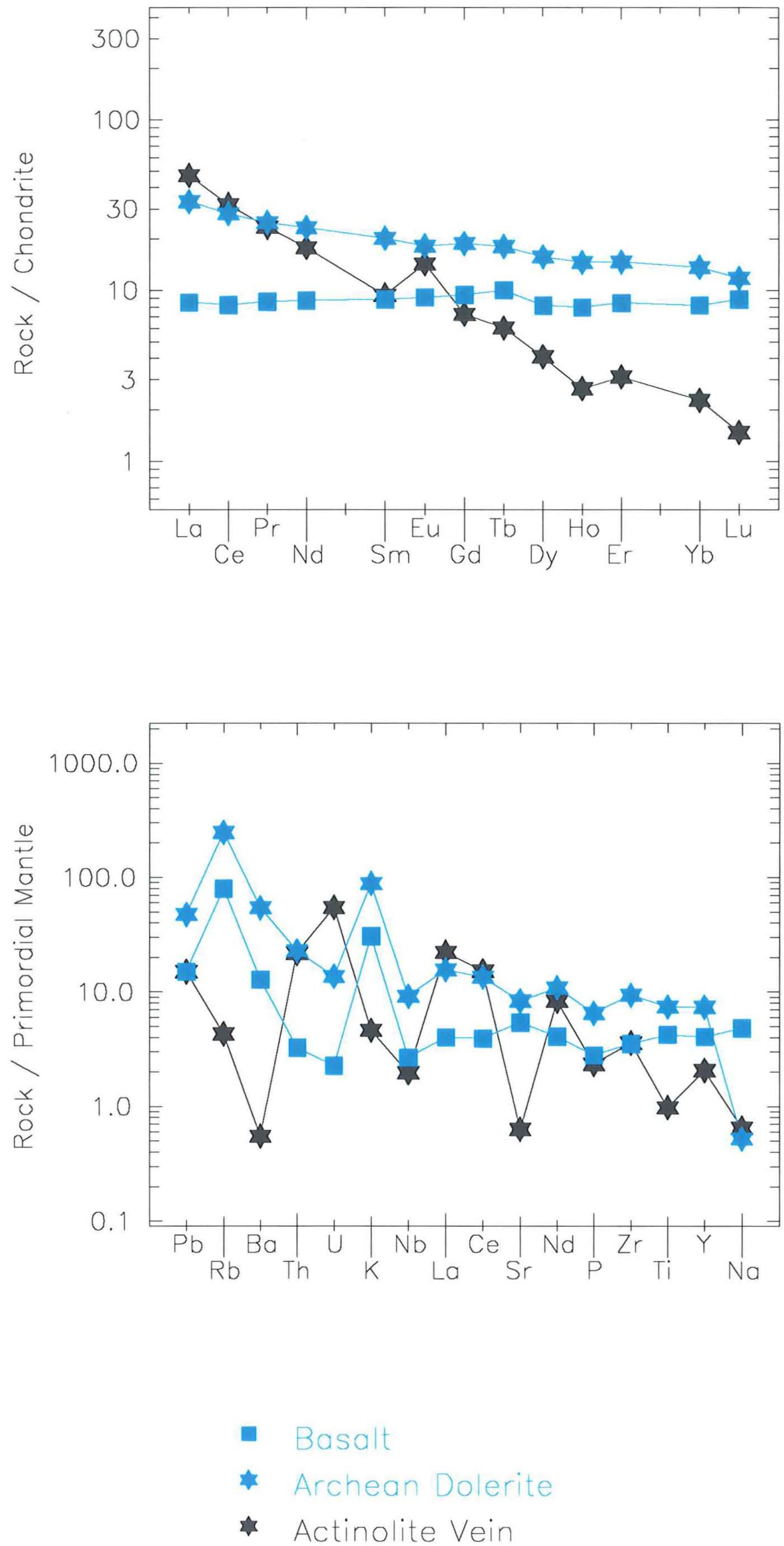




◆ Felsic Porphyry

Felsic Porphyry


Rock / Chondrite
300
100
30
10
3
1
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Yb Lu
Rock / Primordial Mantle
1000.0
100.0
10.0
1.0
0.1
Pb Rb Ba Th U K Nb La Ce Sr Nd P Zr Ti Y Na
Dacitic Tuff
Dacite
Andesite/Fragmentals


300
100
30
10
3
1
Rock / Chondrite
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Yb
Lu
1000.0
100.0
10.0
1.0
0.1
Rock / Primordial Mantle
Pb
Rb
Ba
Th
U
K
Nb
La
Ce
Sr
Nd
P
Zr
Ti
Y
Na
Basalt
Archean Dolerite
Actinolite Vein

DISCUSSION

On the basis of the wholerock geochemistry collected during this study and comparison with the data in Roth (1992), the various rocktypes in the Boddington mine area can be grouped into a number of suites, supersuites and groups. There is a clear geochemical distinction between the 'Late' Granite and the majority of intrusive dioritic and intermediate volcanic suites. The intermediate/felsic intrusive and extrusive suites (with the exception of the Felsic Porphyry) can be combined into the one major group, 'Boddington Mine' Group, for the purposes of this report. This group can be subdivided into five main supersuites (groups of suites):

- Quartz-Diorite/Tonalite.
- 'Hybrid' Diorite
- Microdiorite
- 'Boddington' supersuite: Intrusive Breccia/MP-Diorite, Porphyritic/'Late' Diorite, Aphyric/'Early' Diorite, Dacite, Andesite/Intermediate Fragmental
- Dacitic ?Tuff

There is overlap in major oxide composition between the Quartz-Diorite/Tonalite suite and both the 'Late' Granite and the dioritic suites; however, trace and rare-earth element contents of the mafic end-member samples indicates a closer affinity of these rocks with the dioritic rock suites. The Felsic Porphyry suite is also a discrete geochemical suite. Likewise, there is clear distinction between the mafic volcanic and intrusive rocks and the rest of the rock types at Boddington. Table 3 lists the lithological groups in the Boddington mine area, as well as listing component suites and supersuites.

Group/Supersuite	Component Suites/Units
'Late' Granite Supersuite	Biotite Monzogranite, Leuco-monzogranite (Aplite)
'Boddington Mine' Group	
Quartz Diorite/Tonalite supersuite	Quartz Diorite/Tonalite
'Hybrid' Diorite supersuite	'Hybrid' Diorite
Microdiorite supersuite	Microdiorite
'Boddington' supersuite	Intrusive Breccia/MP-Diorite, Porphyritic/ 'Late' Diorite, Aphyric/'Early' Diorite, Dacite, 'Andesite'/ Intermediate Fragmental
Dacitic ?Tuff supersuite	Dacitic ?Tuff
Felsic Porphyry Supersuite	Felsic Porphyry
Basalt	Basalt
Dolerite	Dolerite
Actinolite Vein	Actinolite Vein

Table 3. Lithological groups and component suites and supersuites of the Boddington Gold Mine and surrounding area. The mafic extrusive lithologies (basalt, dolerite) and the actinolite vein are included for completeness.

The 'Late' Granites and Aplite have wholerock geochemistry unusual for Archean granitoids in the Yilgarn Craton. The Aplite has a composition similar to the leuco-monzogranite subgroup of the 'Late' Granite suite, and is interpreted to be a dyke related to the 'Late' Granite supersuite. They have similar geochemistry to some granitoids of the 'low-Ca' group of Champion & Sheraton (1997), but are better compared with fractionated I-(granodiorite) Proterozoic granites spatially and temporally associated with gold mineralisation in the Telfer, Pine Creek and other regions. Specifically, these Proterozoic granites and the Boddington 'late granite' suite are characterised by high heat flow (high Th, U) and primitive-mantle normalised Y-undepleted and Sr-depleted (Sr/Sr* <0.5) chemistry (Figures 1-5). The suite is fractionated (Figure 3I) and plots in the 'oxidised' field (Figure 3f) on the Redox plot of Champion & Heinemann (1994). Note that petrography reveals variable hydrothermal alteration and minor disseminated sulphides in some samples of the 'Late' Granite suite.

The 'Late' Granites are typical of I-type granites produced by intracrustal melting (e.g., Chappell & Stephens, 1988). Champion & Sheraton (1997) interpret 'Low-Ca' group granites in the Eastern Goldfields Province to be the products of crustal reworking, possibly from a tonalitic to granodioritic protolith. The low Sr and negative Eu anomalies, combined with high Y and HREE suggests that the 'Late' Granites were generated under anhydrous melting conditions (cf., Rutter & Wyllie, 1988; Skjerlie & Johnston, 1992). Experimental studies on vapour-absent melting of tonalitic rocks at crustal pressures appear to produce melts with major element compositions similar to those of the 'Late' Granites (e.g., Skjerlie & Johnston, 1992).

Note: Similar intracrustal fractionated granites in the Telfer region contain high-U zircons that are not always suitable for U-Pb age dating. Dunphy & McNaughton (1998) demonstrated that titanites have SHRIMP U-Pb ages up to 30 m.y. older than ages obtained on zircons from the same sample. It is possible that the 'Late' Granites at Boddington may produce anomalous 'young' zircon ages due to the same problem of high-U zircons and it may be useful to test if titanite has the same age as zircon at Boddington.

The intermediate/felsic intrusive and extrusive lithologies throughout the Boddington Gold Mine area have very similar wholerock geochemistry and have been combined to form the 'Boddington Mine' group for the purposes of this report. The group comprises five supersuites (Table 3). The majority of the intermediate/felsic intrusive and extrusive suites can be combined into the 'Boddington' supersuite. The similar geochemistry of these suites suggests that they are probably derived via similar partial melting processes. There is overlap between this supersuite and members of the Quartz-Diorite/Tonalite suites. The 'Hybrid' Diorite, Microdiorite and Dacitic ?Tuff suites have distinct geochemistry.

The Quartz Diorite/Tonalite suite comprises several samples from a (quartz-)diorite intrusion in the Wattle Prospect north of the Boddington gold mine. The suite has variable silica range that at the mafic end overlaps with the 'Boddington' supersuite and at the felsic end overlaps with the 'Late' Granite supersuite. The mafic end-members have slightly higher Ba, LREE, Pb and Sr and plot in the 'oxidised' field on the redox plot (Figure 3f). The felsic end-member has characteristics consistent with minor fractionation (Figures 1). There is an overall positive correlation between silica content and REE content, with the most felsic sample also containing the highest LREE (and highest HREE) contents, with the most mafic samples having the most fractionated REE profile and lowest LREE and HREE contents (Figure 5c). This suite has both Sr-depleted, Y-undepleted (at the most felsic end-member) and Sr-undepleted, Y-depleted (at the mafic end-member) signatures (Figure 5c). These features suggest that feldspar fractionation may have been important in the genesis of the silica-rich end-members, rather than the partial melting from different source rocks.

The 'Hybrid' Diorite suite in the north-east part in the Eastern Anomalies area is characterised by lowest silica content (53-58 wt% SiO_2) of the intermediate intrusive phases. The suite is characterised by higher CaO, Cr, Ni and V and lower K_2O, Nb, Th, U contents (assuming that these oxides/elements have straight-line trends to higher silica contents) than the other intermediate intrusive phases (Figure 1). They plot in the 'oxidised' field on the Redox plot (Figure 3f) of Champion & Heinemann (1994). The suite has a relatively Sr-undepleted, Y-depleted signature (Figure 5c) consistent with retention of garnet in the source region during partial melting.

The common characteristics of the 'Hybrid' Diorite suite and the 'Boddington' supersuite argues for a genetic relationship. The 'Hybrid' Diorite may form a more mafic suite of an intermediate supersuite, with either derivation of the supersuite by melting of the same source under different conditions, or the more felsic suites were derived by fractionation of a common mafic parent. Alternatively, the 'Hybrid' Diorite may form part of a separate supersuite, resulting from a different melting event under different conditions. The interpreted age of ca. 2675 Ma supports the latter model.

The Microdiorite supersuite has distinct chemistry characterised by higher TiO_2, Fe_2O_3, LREE, Nb, Rb, Th, U, V, Y and Zr contents and lower Cr contents compared to the other intermediate suites (Figure 1). This suite has many similarities with the Black Microdiorite and Microdiorite ('Mafic') suites outlined by Roth (1992). Inclusion of these suites into the Microdiorite supersuite extends the silica range from about 57 to 66 wt% SiO_2. The distinctive geochemistry of the Microdiorites allows easy classification of this supersuite relative to the other intermediate intrusive suites.

The distinct chemistry is interpreted to indicate a different source to that for the other intermediate intrusive and extrusive suites. The suite exhibits a minor negative Eu anomaly on chondrite-normalised REE profile and a relatively Sr-depleted and minor Y-depleted signature on PMN spidergram (Figure 5b). These characteristics may indicate that both plagioclase and possibly garnet or clinopyroxene were important residual components during partial melting. The effects of fractional crystallisation from a more mafic source cannot be determined on the basis of the limited silica range observed for this suite.

The 'Boddington' supersuite includes the Intrusive Breccia/MP-Diorite, Porphyritic/'Late' Diorite, Aphyric/'Early' Diorite, Dacite, 'Andesite'/Intermediate Fragmental suites. There is considerable overlap in the geochemistry of these suites (see Figures 1-5), except for a couple of exceptions. Although the vast majority of samples fall within the 'dacite' field on a TAS plot (Figure 3b), the Porphyritic/'Late' Diorite has an extended silica range (63.7-71.1 wt% SiO_2), and the 'Andesite'/Intermediate Fragmental suite has one sample that has 57 wt% SiO_2.

In general, the suites of the 'Boddington' supersuite show similar trends on Harker diagrams (Figure 1) and have fundamentally similar REE and PMN spidergrams (Figure 5). They have moderately-fractionated chondrite-normalised REE patterns with no Eu anomaly, a Sr-undepleted and Y-depleted signature and moderate MgO, CaO, Cr, Pb, Sc, Sr, V and Zr contents. On the basis of the similar geochemistry it is suggested that these intrusive and extrusive suites are comagmatic; they are treated as one magmatic association in the following discussion.

However, on a suite by suite basis, there are several features of specific suites which are noteworthy. The Dacite and 'Andesite'/Intermediate Fragmental suites are characterised by silica contents ranging from 63 to 67 wt% SiO_2, except for the one sample with 57 wt% SiO_2 (Figure 1, 3b). The intermediate/felsic volcanic rocks present in the Boddington mine area are, therefore, predominantly **dacites**. This contrasts with Roth (1992), who states that the majority of intermediate volcanic rocks are 'andesites'. Reinterpretation of Roths' (1992) geochemical data concurs with this finding that the majority of intermediate volcanic rocks in the Boddington mine area are dacites, with minor andesite volcanism.

The Dacite and 'Andesite'/Intermediate Fragmental suites share the moderately fractionated chondrite-normalised REE profiles (La_N 40-90; $Lu_N \approx 3$) with no or negligible Eu anomaly and relatively consistent PMN spidergram profiles characterised by a Sr-undepleted and Y-depleted signature (Figure 5f). The exception is the sample of 'Andesite'/Intermediate Fragmental containing the lowest silica content (#3727: ≈57.5 wt% SiO_2). This sample is also characterised by a moderately fractionated chondrite-normalised REE profiles ($La_N \approx 120$; $Lu_N \approx 6$) with no negligible Eu anomaly and a Sr-undepleted and Y-depleted signature similar to the other members of the suite (Figure 5f). However, it is also characterised by an elevated total REE content relative to other extrusive samples, as well as higher MgO, CaO, Ni, Th and Zr contents.

The Aphyric/'Early' Diorite, 'Intrusive Breccia'/MP-Diorite and the majority of the Porphyritic/'Late' Diorites are characterised by compositions similar to the dacitic volcanic rocks, with a limited silica range from 63 to 71 wt% SiO_2, and overlapping major oxide and trace element contents (Figure 1-4). With the exception of one sample (discussed below), they show a range of chondrite-normalised REE profiles with variable La_N 15-90 and $Lu_N \approx 1.5$-10 and a small positive to small negative Eu anomalies (Figure 5b, d). Of note, is the slightly 'spoon-shaped' REE profile exhibited by the 'Intrusive Breccia'/MP-Diorite suite (Figure 5b). These suites share a predominantly Sr-undepleted and Y-depleted signature; although the 'Intrusive Breccia'/MP-Diorite has a minor relative Sr-depleted signature (Figure 5b).

An exception to the 'Boddington' supersuite is sample (#3711) of the Porphyritic/'Late' Diorite suite that has elevated TiO_2, Fe_2O_3, P_2O_5, Zr (>600 ppm), Nb, Y, Hf, and REE ($La_N \approx 150$; $Lu_N \approx 10$) concentrations relative to other members of the suite (Figure 1-3). The very high Zr concentration is displayed by a large relative enrichment on a PMN spidergram (Figure 5d). The sample also has a strongly-fractionated chondrite-normalised REE pattern that has a slight positive Eu anomaly (Figure 5d). Note that this sample is from the Wattle Prospect and its different geochemistry may indicate a different sequence in that area, and hence, that this sample belongs to another supersuite.

In general, the 'Boddington' supersuite has compositions typical of dacite-dominated sequences in the Kalgoorlie Terrane (e.g., Black Flag Group; Morris & Witt, 1997). By analogy with other studies (e.g., Johnston & Wyllie, 1989; Rapp et al., 1991; Morris & Witt, 1997), the variation in the supersuite is probably unrelated by fractional crystallisation, but resulted from partial melting of a mafic source at depth. The fractionated chondrite-normalised REE patterns with no Eu anomaly, and Sr-undepleted and Y-depleted signature of most of the suites is consistent with partial melting of amphibolite, leaving a residual mineralogy of garnet, plagioclase, amphibole and/or clinopyroxene. The 'spoon-shaped' chondrite-normalised REE profile of the 'Intrusive Breccia'/MP-Diorite suite and some of the Dacite and 'Andesite'/Intermediate Fragmental suite members may indicate a greater proportion of hornblende in the source. Residual garnet in the source of the 'Boddington' supersuite requires melting at depths greater than 35 km, which is at the base of or below the base of the present crust.

The final (super)suite of the 'Boddington Mine' Group is the Dacitic ?Tuff suite. Only one sample (#3719) was collected for this study and, thus, the extent and significance of the suite cannot be fully determined. The Dacitic ?Tuff sample has a rhyodacitic composition (Figure

3b), and contains elevated K_2O, P_2O_5, Ba, Cr, Nb, Ni, Pb, Sr, Th, U, Y and total REE contents, and a lower Al_2O_3 concentration and Zr/Y ratio relative to the other intermediate/ felsic extrusive samples of the 'Boddington Mine' Group (Figure 1). It plots in the High-K calc-alkaline subdivision of subalkaline rocks (Figure 3c) and in the 'strongly reduced' field on a Redox plot (Figure 3f). The elevated K_2O is attributed to hydrothermal alteration.

The Dacitic ?Tuff is also characterised by an elevated (relative to other intermediate/felsic volcanic rocks in the area) strongly-fractionated chrondrite-normalised REE pattern (La_N ~220, Lu_N ~9), with a slight negative Eu anomaly, and a moderately Sr-depleted and slightly Y-depleted signature. These characteristics contrast markedly with the other (super)suites of the 'Boddington Mine' group, indicating that this suite forms a separate supersuite and formed under different processes and/or partial melting conditions. The moderately Sr-depleted and slightly Y-depleted signature is consistent with melting under crustal conditions, with some residual plagioclase and perhaps minor residual clinopyroxene or amphibole in the source region.

The other suites sampled as part of this study (Felsic Porphyry, Archean dolerite, Basalt and Actinolite Vein) have distinctive chemistry and can be easily distinguished on a variety of geochemical characteristics.

The Feldspar Porphyry suite includes a number of felsic 'dykes' from the Boddington mine area as well as the Wattle and Boomerang Prospects to the north. Petrographic characteristics are consistent with either an intrusive or extrusive origin; the suite may represent a discrete phase of intrusion or felsic volcanism. This suite is rhyolitic in composition (Figure 3b) and characterised by its highly siliceous nature (75.5-77.0 wt% SiO_2), and moderate Na_2O+K_2O, Ba, LREE, Pb, Th, U, and Y contents, low Nb, Rb, Sr contents and low Zr/Y and Rb/Sr ratios (Figure 1-2). It does not display exponential trends on Harker diagrams (Figure1) nor plot in the fractionated granite fields on various binary and ternary diagrams (Figure 4), suggesting that the Felsic Porphyries are not a fractionated suite. Likewise, chondrite-normalised REE profiles (strongly fractionated [$La_N \approx$50-250; $Lu_N \approx$3-11] with moderate to large negative Eu anomalies) and PMN spidergrams (strongly Sr-depleted, Y-undepleted to slightly Y-depleted signature: Figure 5e) suggest that this suite did not result from low-pressure fractionation of a mafic or intermediate precursor magma and requires a different source to that proposed for the intermediate (dacitic) extrusive and intrusive suites.

Roth (1992) describes a series of 'rhyodacite' intrusions from the Pipeline, Pit E2 and western Pit A prospects. These 'rhyodacites' are thin, fine-grained, felsic intrusions which commonly contain equigranular and/or banded margins and quartz-feldspar-phyric cores. Although Roth (1992) did not describe the geochemistry of these 'intrusions', the number of partial wholerock analyses are tabulated in an Appendix. A comparison of these 'rhyodacites' with the Felsic Porphyry suite shows significant similarity. Roth (1992) also refers to rhyodacite volcanic rocks at the Nullaga prospect; these may also have similar wholerock geochemsitry to the Felsic Porphyry suite.

In hand-specimen, the Felsic Porphyries at Boddington resemble some of the quartz-feldspar ('rhyolitic') porphyries intrusive into greenstone belts in the Eastern Goldfields Province (cf. Witt, 1992). In particular, they have similar geochemistry to rhyolitic volcanic rocks from the Jeedamya and Perkolilli area in the Eastern Goldfields Province (see Morris & Witt, 1997). Morris & Witt (1997) suggest that such rock types are the product of anhydrous melting of tonalitic rocks at crustal pressures. The chondrite-normalised REE profiles and PMN spidergrams of the Felsic Porphyry suite are consistent with this interpretation. Note that the

'Late' Granite suite is interpreted to have been derived through a similar process. However, the strongly fractionated nature of the 'Late' Granite suite (e.g., exponential increase in Pb, Rb, Th, U, Y: Figure 1) is not present in the Felsic Porphyry suite, suggesting that late stage fractionation/differentiation was not an important process in their genesis. Also, note the differences in the chondrite-normalised REE profiles and PMN spidergrams of the Felsic Porphyry suite compared to the 'Late' Granite suite. The Felsic Porphyries have slightly to moderately fractionated heavy REE, and do not have either the extreme relative depletion of Ba, Sr, P and Ti nor the completely Y-undepleted signature of the 'Late' Granites. These differences suggest that slightly contrasting source rock compositions and/or conditions of partial melting took place for the Felsic Porphyries.

The samples of meta-basalt sample (#3746) and Archean dolerite (#3753) have basaltic compositions typical of other terranes in the Yilgarn Craton. Both samples are characterised by enrichment of several components, notably K_2O, Rb and to a lesser extent Ba and Pb, as a result of hydrothermal alteration. They show flat to slightly fractionated chondrite-normalised REE profiles and PMN spidergrams that have slight negative Nb and P anomalies.

Allibone et al. (1998) suggested that the large 'actinolite veins' throughout the mine area were ultramafic (um2) dykes that had been hydrothermally altered. However, on the basis of the high MgO (14 wt%) but very low Cr (40 ppm) and Ni (BLD) contents, and the relatively high LREE concentrations, the Actinolite Vein is undoubtedly hydrothermal in origin. It is highly unlikely that such veins are altered ultramafic dykes. The vein also contains significant mineralisation (Cu ≈0.7 wt%, Sn >250 ppm, Zn >400 ppm).

SYNTHESIS AND METALLOGENIC IMPLICATIONS

One of the end-member genetic models for Au-Cu mineralisation at Boddington is the syn-intermediate intrusion mineralisation model of Roth (1992). Roth (1992) suggests that Boddington has affinities with Phanerozoic porphyry Cu-Au systems, particularly those associated with dioritic intrusions. However, although the bulk-rock composition of the intermediate intrusive and extrusive rocks is 'dioritic', they have little of the wholerock geochemical characteristics typically associated with porphyry-style Cu-Au mineralisation. For instance, although moderate to intense hydrothermal alteration has undoubtedly changed the wholerock chemistry of some of the intermediate intrusive samples, the vast majority of intrusive and extrusive lithologies at Boddington are subalkaline and low-K to medium-K calc-alkaline (see Figure 3a-c). This contrasts with porphyry Cu-Au systems elsewhere that are associated with alkalic intermediate intrusive suites (e.g., Recent Cu-Au at Lihir: Thompson et al., 1995; Mesozoic Cu-Au in British Columbia: Lang et al., 1995, Cassidy et al., 1996) and/or subalkaline and dominantly high-K to very high-K calcalkaline intermediate to felsic magmatic complexes (e.g., Laramide Cu-Au in south-west North America: Lang & Titley, 1998; Ordovician Cu-Au in Lachlan Fold Belt: e.g., Blevin, 1998).

In many magmatic systems associated with porphyry Cu-Au mineralisation, there is a temporal progression of the system in terms of one or more of the following: wholerock geochemistry, style and texture of intrusion, isotope systematics. For example, Lang & Titley (1998) show for several Laramide-age magmatic complexes associated with porphyry Cu-Au mineralisation in Arizona, that REE display temporally systematic behaviour. Progressively younger intrusions in a given complex follow a path of decreasing concentration of REE, steepening profiles, greater upward concavity in heavy REE profiles, and changes in Eu anomaly from negative to either markedly less negative or positive. The REE data from individual complexes suggest an increasing petrographic involvement of amphibole, either in the restite of the source region or as a fractionating phase, and similar paths of petrogenetic evolution in spite of chronologic and trace element evidence which argues against completely comagmatic development.

At Boddington, neither do the intermediate intrusive and extrusive lithologies show any marked variation in REE profile with time (i.e., Porphyritic/'Late' and Aphyric/'Early' suites having overlapping REE profiles and similar profiles to intermediate extrusive suites), nor is there a significant inferred amphibole-signature for either the intermediate intrusive or extrusive suites. On this basis and the overall low-K to medium-K character of the diorites, the intermediate intrusive suites do not have the geochemical characteristics typically associated with porphyry Cu-Au magmatic systems.

Another interesting comparison is between the intermediate/felsic intrusive suites at Boddington and the Mafic Group of granitoids present in the Eastern Goldfields Province of the Yilgarn Craton (see Champion & Sheraton, 1997). Champion & Sheraton (1997) showed that there is significant differences between (super-)suites of the Mafic group in terms of their levels of LILE (i.e., K_2O, Ba, Rb, Sr, Pb, La, Ce), and further work (Champion & Cassidy, unpubl. data 1998) has subdivided the Mafic group into two subgroups: the Low-LILE and High-LILE subgroups.

The majority of granite-hosted gold mineralisation in the Eastern Goldfields are hosted by Mafic Group granites; although some Syenite and High-Ca Group granites also host gold (Cassidy, 1997; Champion & Sheraton, 1997; Cassidy et al., 1998). Notably, many of the

Mafic Group granites that host gold mineralisation (e.g., Granny Smith, Lawlers, Liberty, Porphyry) belong to the High-LILE subgroup. In addition, the majority of these High-LILE granites (e.g., Granny Smith, Liberty, Porphyry) of the Mafic Group have emplacement ages significantly younger (ca. 2.665-2650 Ma: Hill et al., 1992; Kent, 1994) than the intermediate/felsic volcanic sequences (e.g., Black Flag Group) within the same terranes.

In the Eastern Goldfields Province, there are many documented examples where intermediate/ felsic volcanic rocks have coeval subvolcanic granitic plutonism. For example, Hallberg (1985) and Morris & Witt (1997) document large areas of rhyodacitic to rhyolitic volcanism and coeval high-level intrusive equivalents in the Melita and Jeedamya districts; recent geochronology (e.g., Nelson, 1997; Champion and Black, unpubl. data, 1996) supports the contemporaneous nature of the volcanism and plutonism in the Melita and Kookynie areas. The predominantly dacitic volcano-sedimentary sequence that forms the Black Flag Group in the Kalgoorlie Terrane is interpreted to have formed at ca. 2685-2675 Ma (e.g., Nelson, 1997). Intruding into the Black Flag Group are coeval (ca. 2675 Ma) high-level porphyry dyke swarms. The geochemical composition of the porphyry dyke swarms is not well known, but on the basis of limited published data (e.g., Perring, 1989; Witt, 1992) they are predominantly 'dacitic' and possibly (probably) belong to the Low-LILE subgroup of the Mafic Group.

On the basis of this limited database, it is suggested that Low-LILE Mafic granites are the intrusive equivalents of the intermediate/felsic volcanic rocks in the Kaloorlie Terrane; in contrast, High-LILE Mafic granites were emplaced much later than the Low-LILE subgroup, and no coeval intermediate/felsic volcanic rocks have been documented for these intrusions. The Note that the High-LILE Mafic granites are closer in wholerock composition to High-K calc-alkaline granites typically associated with porphyry Cu-Au deposits.

At Boddington, the 'Hybrid' Diorite, Microdiorite, Intrusive Breccia, Quartz Diorite/Tonalite, Porphyritic/'Late' Diorite and Aphyric/'Early' Diorite suites all share geochemical characteristics that would place them in the Mafic Group of granites in the Eastern Goldfields Province. However, all but one of these suites belongs to the Low-LILE subgroup; only the Microdiorites overlap with the High-LILE subgroup. The coeval and probable comagmatic nature of the dacitic volcanic rocks at Boddington is then strikingly similar to that for the Black Flag Group in the Kalgoorlie Terrane. The metallogenic significance of this is not known. If an 'intrusion-related magmatic' exploration/genetic model is favoured for Boddington (as suggested by Roth, 1992), then potentially other areas in the Yilgarn Craton with similar rock types may be exploration targets in their own right.

Alternatively, the intermediate/felsic intrusive suites at Boddington may be the favoured host to the gold mineralisation in a similar way to that envisaged for the Mafic Group granites in the Eastern Goldfields. The available evidence suggests that the majority of deposits hosted by Mafic Group granites are not orthomagmatic in origin (see Cassidy et al., 1998). Given that gold deposits form as a result of the interplay of a number of critical chemical and physical processes (i.e., channelling of ore fluids, focussing of ore fluids, and deposition from ore fluid), the intermediate/felsic intrusive rocks may have been favourable hosts at Boddington for the following reasons:

- physical characteristics for structural relationship, including:
    - favourable competency for ground preparation and/or competency contrast,
    - favourable size and/or shape
    - depth of emplacement
- chemical trap
- indicators of suitable and favourable fluid pathways

- fortuitous

For instance, at Boddington, the spatial relationship of mineralisation with strongly porphyritic intermediate intrusive rocks may result from a competency contrast with surrounding (aphyric and weakly porphyritic) intermediate rocks, thus allowing brittle failure in the porphyritic diorites during focussed fluid flow. A corollary, is that some of the other so-called 'intrusion-related' characteristics of the deposit (e.g., complex highly saline ore fluids, metal association) may reflect sourcing of heat, fluids and/or metals from another (?more distal) magmatic event either synchronous with or after the intrusion of the intermediate suites.

The other suite with metallogenic potential at Boddington is the 'Late' Granite/Aplite suite. As stated above, this suite shares many geochemical characteristics with fractionated granites associated with Cu and Au mineralisation in the Telfer and Pine Creek regions. For instance, the 'Late' Granites show exponentially increasing trends for Nb, Pb, Rb, U, Th and Rb/Sr . The 'Late' Granites are moderately oxidised, metaluminous to weakly peraluminous which is characteristic of granites related to both Cu and Au mineralisation (e.g., Wyborn et al., 1998). There is evidence of the evolution of magmatic fluids in the 'Late' Granite/Aplite suite in the form of aplites, and the presence of moderate hydrothermal (?magmatic) alteration in some samples. The alteration appears to be patchy and does contain minor sulphides in places. This may or may not be significant. In other fractionated granite provinces (e.g., Cloncurry), sericite-altered granites contain fluorite, boron and sulphides as well as elevated base (Cu, Pb) and trace (Mo) metals. It is noteworthy, that the Aplite sample contains visible molybdenite.

By analogy with Cu and Au mineralisation in other regions in Australia, the 'Late' Granites may have been both the thermal, fluid and/or metal source for the Boddington deposit. Note that in the majority of fractionated granite-related mineral systems, the mineralisation is external and distal to the granitoid (e.g., Wyborn et al., 1998). The highly complex saline hydrothermal fluids present at Boddington does invoke an 'intrusion-related magmatic' exploration/genetic model. However, not enough is known about the 'Late' Granites to speculate if they could have produced such a hydrothermal fluid.

Further work on several aspects of the intrusive and extrusive suites at Boddington seems appropriate to help further determine the metallogenic significance of the intermediate 'diorite' suites and the fractionated 'Late' Granite suites. Such work may include:

- additional wholerock geochemistry on any of the major intermediate and felsic rock types not sampled (or undersampled) during this present study. For instance, the weakly-porphyritic diorites and some of the other intermediate volcanic rocks in the mine area.
- research on the effect of metamorphism and/or ?hydrothermal alteration event(s) on the geochemistry (e.g., changes to redox state through metamorphism, changes to alkalinity, etc.) of the intermediate intrusive suites.
- follow-up geochemistry on the 'Late' Granites to determine the spatial extent and overall significance of the hydrothermal alteration, aplites and/or veining. Note that the fractionated nature of the 'Late' Granite may result in the presence of high-U zircons that are either not suitable for age dating or may produce ages significantly younger than coexisting titanites.
- Nd and/or Pb isotopes of a selection of intermediate intrusive and extrusive samples and samples of the 'Late' Granite may assist in determining the age of the source rocks of these igneous suites. Similar studies in the Eastern Goldfields have demonstrated a 'basement' structure previously unrecognised through wholerock geochemical and/or xenocrystic zircon studies.

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APPENDIX A. SAMPLE DESCRIPTIONS AND WHOLEROCK GEOCHEMICAL DATA

Sample No	Loc Descr	1:100K	AMG_East	AMG_Nth	SF	SF	SF	ST	Hole Number	Mine_Nth	Mine_East	RL	Collar_Dip	Collar_DipD	Dpth_Frm	Dpth_To
WB373701	Boddington gold mine	2132	440329	6375429	TS	RC		CORE	WBD10505-002	10509.79	9989.56	269.68	-64	200	103.9	104.8
WB373702	Boddington gold mine	2132	440329	6375429	TS	RC		CORE	WBD10505-002	10509.79	9989.56	269.68	-64	200	80.4	81.0
WB373703	Boddington gold mine	2132	440329	6375429	TS	RC	GC	CORE	WBD10505-002	10509.79	9989.56	269.68	-64	200	82.5	83.5
WB373704	Boddington gold mine	2132	440329	6375429	TS	RC	GC	CORE	WBD10505-002	10509.79	9989.56	269.68	-64	200	53.0	54.1
WB373705	Boddington gold mine	2132	440329	6375429	TS	RC		CORE	WBD10505-002	10509.79	9989.56	269.68	-64	200	399.8	400.7
WB373706	Boddington gold mine	2132	440329	6375429	TS	RC		CORE	WBD10505-002	10509.79	9989.56	269.68	-64	200	406.0	406.8
WB373708	Boddington gold mine	2132	440329	6375429	TS	RC		CORE	WBD10505-002	10509.79	9989.56	269.68	-64	200	448.7	449.4
WB373709	Boddington gold mine	2132	440329	6375429	TS	RC		CORE	WBD10505-002	10509.79	9989.56	269.68	-64	200	618.3	618.8
WB373710	Boddington gold mine	2132	439134	6376126	TS	RC		CORE	WBD11830-001	11829.94	9575.27	277.30	-50	140	98.9	99.4
WB373711	Boddington gold mine	2132	438957	6381350	TS	RC		CORE	BXD15800-004	15812.20	12965.20	349.40	-52	220	114.0	115.0
WB373712	Boddington gold mine	2132	438957	6381350	TS	RC		CORE	BXD15800-004	15812.20	12965.20	349.40	-52	220	118.9	120.2
WB373713	Boddington gold mine	2132	439882	6378997	TS	RC		CORE	BXD13450-001	13448.95	12062.51	308.24	-50	230	109.4	110.4
WB373714	Boddington gold mine	2132	439882	6378997	TS	RC		CORE	BXD13450-001	13448.95	12062.51	308.24	-50	230	173.7	174.3
WB373715	Boddington gold mine	2132	441525	6376506	TS	RC		CORE	BXD10500-001	10500.03	11599.53	297.59	-60	200	58.6	59.0
WB373716	Boddington gold mine	2132	441525	6376506	TS	RC		CORE	BXD10500-001	10500.03	11599.53	297.59	-60	200	68.2	69.5
WB373717	Boddington gold mine	2132	441525	6376506	TS	RC		CORE	BXD10500-001	10500.03	11599.53	297.59	-60	200	145.8	146.5
WB373718	Boddington gold mine	2132	438981	6376081	TS	RC		CORE	WBD11900-015	11900.10	9431.50	295.90	-60	50	160.2	161.2
WB373719	Boddington gold mine	2132	442161	6377861	TS	RC		CORE	BXD11075-001	11073.15	12982.15	356.30	-50	50	81.5	82.4
WB373720	Boddington gold mine	2132	442161	6377861	TS	RC		CORE	BXD11075-001	11073.15	12982.15	356.30	-50	50	172.7	173.7
WB373721	Boddington gold mine	2132	442547	6377974	TS	RC		CORE	BXD10900-002	10896.39	13344.16	356.24	-50	230	74.8	75.7
WB373722	Boddington gold mine	2132	442547	6377974	TS			CORE	BXD10900-002	10896.39	13344.16	356.24	-50	230	75.7	75.9
WB373723	Boddington gold mine	2132	440933	6377185	TS	RC		CORE	BXD11400-005	11401.50	11619.10	321.60	-50	230	63.5	64.4
WB373724	Boddington gold mine	2132	440999	6377240	TS	RC		CORE	BXD11400-004	11396.86	11704.84	310.53	-50	230	86.8	87.5
WB373725	Boddington gold mine	2132	440999	6377240	TS			CORE	BXD11400-004	11396.86	11704.84	310.53	-50	230	101.0	102.0
WB373726	Boddington gold mine	2132	440158	6375531	TS	RC		CORE	WBD10700-008	10700.40	9930.90	264.58	-50	50	104.0	105.0
WB373727	Boddington gold mine	2132	440999	6377240	TS	RC		CORE	BXD11400-004	11396.86	11704.84	310.53	-50	230	78.7	79.7
WB373728	Boddington gold mine	2132	442759	6376270	TS	RC		CORE	BXD9500-002	9494.10	12352.60	322.20	-51	51	119.6	120.2
WB373729	Boddington gold mine	2132	441161	6376750	TS	RC		CORE	BXD10926-001	10925.66	11494.20	316.79	-50	55	166.4	167.7
WB373730	Boddington gold mine	2132	442759	6376270	TS	RC		CORE	BXD9500-002	9494.10	12352.60	322.20	-51	51	109.2	110.0
WB373731	Boddington gold mine	2132	441268	6376711	TS	RC		CORE	BXD10825-001	10824.92	11547.01	305.22	-50	50	114.8	115.8
WB373732	Boddington gold mine	2132	441369	6377317	TS	RC		CORE	BXD11200-007	11204.76	12030.17	318.56	-50	51	139.5	140.7
WB373733	Boddington gold mine	2132	441369	6377317	TS			CORE	BXD11200-007	11204.76	12030.17	318.56	-50	51	145.0	145.1
WB373734	Boddington gold mine	2132	441369	6377317	TS	RC		CORE	BXD11200-007	11204.76	12030.17	318.56	-50	51	145.1	145.8
WB373736	Boddington gold mine	2132	440283	6374902	TS	RC	GC	CORE	WBD10150-004	10150.80	9600.13	274.13	-50	52	77.8	78.5
WB373737	Boddington gold mine	2132	440283	6374902	TS	RC		CORE	WBD10150-004	10150.80	9600.13	274.13	-50	52	76.6	77.4
WB373738	Boddington gold mine	2132	440429	6375508	TS	RC		CORE	WBD10500-003	10501.00	10116.50	282.68	-50	53	114.6	115.5
WB373739	Boddington gold mine	2132	439949	6375714	TS	RC		CORE	MBC10975-008	10976.20	9900.70	257.50	-50	230	131.3	131.6
WB373740	Boddington gold mine	2132	439949	6375714	TS	RC		CORE	MBC10975-008	10976.20	9900.70	257.50	-50	230	134.2	134.5
WB373741	Boddington gold mine	2132	439949	6375714	TS	RC		CORE	MBC10975-008	10976.20	9900.70	257.50	-50	230	116.3	117.0
WB373742	Boddington gold mine	2132	439949	6375714	TS	RC		CORE	MBC10975-008	10976.20	9900.70	257.50	-50	230	121.3	122.0
WB373743	Boddington gold mine	2132	441564	6375595	TS	RC		CORE	WBD9800-006	9800.35	11014.41	289.12	-60	200	199.0	200.0
WB373744	Boddington gold mine	2132	441564	6375595	TS	RC	GC	CORE	WBD9800-006	9800.35	11014.41	289.12	-60	200	202.5	203.5
WB373745	Boddington gold mine	2132	438792	6381190	TS	RC		CORE	BXD15800-002	15804.84	12735.24	365.15	-50	226	117.1	118.3
WB373746	Boddington gold mine	2132	442232	6378376	TS			CORE	BXD11400-002	11406.14	13381.62	371.84	-50	228	129.5	130.5
WB373747	Boddington gold mine	2132	438957	6381350	TS	RC		CORE	BXD15800-004	15812.20	12965.20	349.40	-52	220	89.4	90.1
WB373748	Boddington gold mine	2132	442232	6378376	TS	RC		CORE	BXD11400-002	11406.14	13381.62	371.84	-50	228	105.4	106.3
WB373749	Boddington gold mine	2132	442188	6377887	TS	RC		CORE	BXD11075-002	11074.37	13019.70	363.46	-50	50	62.6	63.2
WB373751	Boddington gold mine	2132	442188	6377887	TS			CORE	BXD11075-002	11074.37	13019.70	363.46	-50	50	55.2	55.4
WB373752	Boddington gold mine	2132	440323	6375593	TS	RC	GC	CORE	WBD10635-002	10635.40	10095.11	241.07	-65	198	243.1	244.0
WB373753	Boddington gold mine	2132	440429	6375508	TS	RC		CORE	WBD10500-003	10501.00	10116.50	282.68	-50	53	126.2	126.9
WB373754	Boddington gold mine	2132	438992	6381391	TS	RC		CORE	BXD15800-001	15819.03	13018.78	353.15	-50	222	98.5	99.4
WB373755	Boddington gold mine	2132	438992	6381391	TS	RC		CORE	BXD15800-001	15819.03	13018.78	353.15	-50	222	165.3	166.9
WB373756	Boddington gold mine	2132	438992	6381391	TS	RC		CORE	BXD15800-001	15819.03	13018.78	353.15	-50	222	174.8	175.9
WB373757	Boddington gold mine	2132	441525	6376506	TS	RC		CORE	BXD10500-001	10500.03	11599.53	297.59	-60	200	64.0	65.0

Sample No	Lithology	Supersuite	Suite	SiO2	TiO2	Al2O3	FeO	Fe2O3	Fe2O3(	MgO	MnO	CaO	Na2O	K2O	P2O5	S	CO2	H2O+	OS	Total
WB373701	(quartz-)feldspar porphyry	BOD	DAC	66.19	0.52	15.96	3.14	1.09	4.58	1.97	0.04	4.15	3.91	1.18	0.12	0.34	0.06	1.57	-0.17	100.40
WB373702	aphyric microdiorite	MD	MD	61.21	1.06	15.55	6.09	0.97	7.74	2.23	0.08	4.67	3.43	2.56	0.34	0.58	0.08	1.28	-0.29	100.52
WB373703	aphyric microdiorite	MD	MD	61.68	1.05	15.52	6.06	0.96	7.70	2.06	0.08	4.97	3.29	2.02	0.33	0.34	0.14	1.43	-0.17	100.44
WB373704	(quartz-)feldspar porphyry	BOD	DAC	65.68	0.52	16.11	3.78	0.48	4.68	1.90	0.04	3.84	4.16	1.98	0.12	0.28	0.09	0.90	-0.14	100.15
WB373705	(quartz-)feldspar-phyric biotite schist	BOD	IBX	62.72	0.56	15.85	5.35	0.74	6.68	2.27	0.04	1.94	4.32	4.00	0.15	0.69	0.11	1.12	-0.34	100.09
WB373706	aphyric microdiorite	MD	MD	61.55	0.79	15.62	4.84	1.61	6.99	2.59	0.09	5.31	3.14	2.47	0.20	0.17	0.04	1.24	-0.08	100.12
WB373708	aphyric diorite	BOD	ADRT	66.67	0.48	16.16	2.51	0.12	2.91	2.29	0.04	4.65	4.52	1.38	0.11	0.02	0.20	0.94	-0.01	100.35
WB373709	feldspar-porphyritic diorite	BOD	IBX	66.83	0.58	17.00	2.23	0.12	2.60	1.81	0.03	5.08	3.91	1.51	0.13	0.02	0.05	0.75	-0.01	100.28
WB373710	actinolite vein	VN	VN	50.88	0.21	4.20	11.98	2.26	15.57	14.02	0.36	12.38	0.25	0.13	0.05	1.13	0.07	2.20	-0.57	100.88
WB373711	quartz-feldspar-phyric biotite quartz-diorite/tonalit	BOD	LDRT	67.87	0.80	13.74	4.22	1.46	6.15	0.98	0.09	3.66	3.65	2.07	0.21	0.11	0.10	0.88	-0.05	100.26
WB373712	biotite granodiorite	QD	QD	70.12	0.35	15.15	2.45	0.14	2.86	0.95	0.05	3.20	4.58	1.86	0.10	0.08	0.08	0.67	-0.04	99.98
WB373713	quartz-albite-K-feldspar porphyry	PHY	PHY	76.86	0.07	13.21	1.38	0.00	0.90	0.12	0.01	0.76	4.60	2.90	0.02	0.12	0.11	0.45	-0.06	100.06
WB373714	quartz-albite-K-feldspar porphyry	PHY	PHY	77.00	0.07	13.17	1.34	0.00	1.00	0.15	0.01	0.72	5.09	2.33	0.02	0.07	0.05	0.33	-0.03	99.98
WB373715	monzogranite	GRT	GRT	66.99	0.17	16.07	1.45	1.48	3.09	0.33	0.01	3.01	4.37	4.83	0.01	0.40	0.04	0.74	-0.20	99.87
WB373716	biotite syenogranite	GRT	GRT	73.43	0.19	13.64	1.51	0.31	1.99	0.40	0.02	1.08	3.35	4.91	0.04	0.08	0.03	0.72	-0.04	99.84
WB373717	biotite syenogranite	GRT	GRT	72.90	0.25	13.68	1.62	0.45	2.25	0.36	0.02	1.38	2.98	5.09	0.05	0.01	0.05	0.77	0.00	99.77
WB373718	quartz-feldspar porphyry	PHY	PHY	76.70	0.14	13.56	1.44	0.00	1.40	0.58	0.01	1.87	1.62	2.79	0.02	0.22	0.02	1.18	-0.11	99.99
WB373719	plagioclase-amphibole-phyric schist	TUFF	TUFF	68.93	0.33	13.26	2.85	0.17	3.34	2.17	0.06	3.14	3.58	4.08	0.26	0.04	0.08	0.52	-0.02	99.78
WB373720	amphibole-rich diorite	HYB	HYB	54.75	0.55	21.41	2.96	1.36	4.65	2.32	0.08	8.76	5.43	0.86	0.21	0.01	0.05	1.19	0.00	100.27
WB373721	amphibole diorite/quartz-diorite	HYB	HYB	53.18	1.00	16.20	7.07	1.70	9.56	5.67	0.13	9.17	3.05	0.90	0.13	0.09	0.05	1.84	-0.05	100.91
WB373722	amphibole diorite/quartz-diorite	HYB	HYB																	
WB373723	quartz-feldspar porphyry	BOD	LDRT	71.14	0.27	15.37	1.57	0.34	2.09	0.94	0.02	3.16	3.78	2.47	0.07	0.02	0.04	0.82	-0.01	100.17
WB373724	biotite-sericite-epidote quartzofeldspathic schist	BOD	AND	65.22	0.54	15.82	3.65	0.76	4.82	1.94	0.06	4.38	1.42	3.62	0.12	0.31	0.03	1.47	-0.15	99.58
WB373725	biotite-sericite quartzofeldspathic schist	BOD	LDRT	70.77	0.26	15.49	1.76	0.00	1.96	0.69	0.02	2.86	4.19	2.64	0.07	0.05	0.17	0.69	-0.03	99.82
WB373726	quartz-feldspar-phyric epidote-biotite schist	BOD	AND	65.68	0.54	16.19	3.36	0.77	4.51	1.84	0.03	3.92	4.27	1.64	0.12	0.35	0.04	0.95	-0.17	99.90
WB373727	epidote-biotite-amphibole schist	BOD	AND	57.63	0.74	14.33	6.09	0.58	7.35	5.90	0.14	10.07	2.27	1.08	0.32	0.12	0.03	1.08	-0.06	100.98
WB373728	leuco-monzogranite (aplite)	GRT	APL	75.27	0.02	13.87	0.80	0.00	0.15	0.02	0.00	0.36	4.45	5.47	0.02	0.01	0.03	0.24	-0.01	99.91
WB373729	biotite monzogranite	GRT	GRT	73.59	0.21	13.44	1.96	0.00	2.17	0.34	0.03	1.19	3.13	5.09	0.05	0.01	0.05	0.78	0.00	100.06
WB373730	aphyric diorite	BOD	ADRT	64.29	0.55	15.91	3.47	0.77	4.62	2.52	0.06	5.29	3.90	1.42	0.12	0.04	0.04	1.34	-0.02	100.09
WB373731	biotite monzogranite	GRT	GRT	73.65	0.20	13.53	1.26	0.67	2.07	0.30	0.03	1.19	3.09	5.12	0.04	0.01	0.06	0.72	-0.01	100.02
WB373732	biotite leuco-monzogranite	GRT	GRT	76.84	0.03	12.73	0.33	0.29	0.66	0.04	0.01	0.82	3.58	4.77	0.00	0.03	0.03	0.29	-0.02	99.82
WB373733	biotite leuco-monzogranite	GRT	GRT																	
WB373734	biotite leuco-monzogranite	GRT	GRT	76.44	0.10	12.44	0.76	0.45	1.29	0.12	0.02	0.86	3.49	4.44	0.02	0.02	0.03	0.45	-0.01	99.69
WB373736	quartz-feldspar-phyric biotite quartz-diorite	BOD	LDRT	67.89	0.51	16.05	1.94	0.69	2.84	2.25	0.03	3.92	4.46	0.94	0.13	0.17	0.04	1.11	-0.09	100.25
WB373737	quartz-K-feldspar-phyric biotite quartz-diorite	BOD	LDRT	67.07	0.49	15.76	2.54	0.74	3.56	2.36	0.03	3.91	3.47	1.12	0.13	0.37	0.03	1.53	-0.19	99.65
WB373738	epidote-biotite schist	BOD	AND	63.58	0.53	15.13	5.00	1.22	6.78	3.20	0.06	2.63	4.24	2.67	0.13	0.10	0.04	1.20	-0.05	100.23
WB373739	feldspar-porphyritic biotite quartz-diorite	BOD	LDRT	65.39	0.54	16.31	3.59	0.65	4.64	1.89	0.04	4.17	3.91	1.77	0.11	0.34	0.10	1.07	-0.17	100.09
WB373740	feldspar-porphyritic biotite quartz-diorite	BOD	LDRT	63.68	0.59	17.61	2.86	0.85	4.03	2.27	0.04	4.57	4.08	1.99	0.12	0.07	0.06	1.10	-0.03	100.17
WB373741	aphyric diorite	BOD	ADRT	66.48	0.50	15.70	2.98	0.60	3.91	1.87	0.07	5.23	4.47	0.74	0.11	0.21	0.15	0.86	-0.11	100.20
WB373742	feldspar-porphyritic biotite quartz-diorite	BOD	LDRT	68.48	0.47	14.73	3.37	0.52	4.27	1.80	0.03	3.53	4.06	1.42	0.10	0.51	0.05	0.85	-0.25	100.04
WB373743	biotite monzogranite	GRT	GRT	73.56	0.07	13.87	0.00	0.71	0.71	0.09	0.01	0.86	2.93	7.12	0.01	0.04	0.03	0.26	-0.02	99.52
WB373744	biotite monzogranite	GRT	GRT	73.89	0.26	13.31	2.36	0.00	2.47	0.33	0.03	1.55	3.68	3.87	0.05	0.03	0.06	0.50	-0.01	100.00
WB373745	abite-quartz porphyry	PHY	PHY	75.38	0.22	13.23	2.52	0.00	1.81	0.56	0.04	1.44	5.56	1.35	0.05	0.01	0.13	0.31	-0.01	100.08
WB373746	amphibolite	BAS	BAS	48.21	0.90	14.50	9.35	2.82	13.22	8.38	0.19	11.32	1.88	0.85	0.06	0.19	0.03	1.64	-0.09	101.26
WB373747	feldspar-quartz-phyric porphyry	PHY	PHY	75.76	0.16	12.76	1.24	0.40	1.78	0.26	0.03	0.94	3.13	4.40	0.02	0.08	0.13	0.38	-0.04	99.78
WB373748	biotite-amphibole diorite/quartz-diorite	HYB	HYB	56.55	0.71	17.94	4.65	2.01	7.18	3.32	0.08	8.28	3.52	0.83	0.36	0.44	0.05	1.30	-0.22	100.31
WB373749	biotite-amphibole diorite/quartz-diorite	HYB	HYB	58.17	0.51	19.35	4.44	0.77	5.71	2.77	0.06	7.55	4.17	0.86	0.23	0.13	0.05	0.80	-0.07	100.29
WB373751	amphibole-biotite quartz-diorite	BOD	IBX																	
WB373752	biotite quartz-diorite	BOD	IBX	64.04	0.56	16.18	3.48	0.61	4.48	2.21	0.04	3.87	6.06	0.73	0.15	0.77	0.05	0.52	-0.38	99.27
WB373753	amphibolite	DOL	DOL	50.15	1.57	13.48	9.74	3.59	14.41	6.21	0.17	9.43	0.20	2.46	0.14	0.15	0.04	2.40	-0.07	100.74
WB373754	quartz-feldspar-phyric granodiorite	QD	QD	68.99	0.30	15.98	1.62	0.77	2.58	0.92	0.03	3.09	4.36	2.56	0.09	0.13	0.15	0.58	-0.07	99.69
WB373755	quartz-feldspar-phyric tonalite	QD	QD	75.73	0.30	11.40	2.17	1.08	3.50	0.33	0.05	1.87	3.18	2.87	0.06	0.04	0.10	0.38	-0.02	99.77
WB373756	tonalite	QD	QD	65.38	0.51	16.00	2.73	1.60	4.63	1.94	0.07	4.61	4.01	1.48	0.15	0.02	0.07	1.11	-0.01	99.97
WB373757	biotite monzogranite	GRT	GRT	71.90	0.13	14.10	1.03	0.78	1.92	0.55	0.01	0.28	3.49	6.56	0.03	0.30	0.03	0.50	-0.15	99.65

Sample No	Ag	As	Ba	Be	Bi	Br	Cd	Ce	Cr	Cs	Cu	Dy	Er	Eu	Ga	Gd	Ge	Hf	Ho	I	In	La	Li
WB373701	0.5	1.4	209.8	1.4	0.5	0.5	0.3	36.9	34.0	-0.6	866.3	1.7	0.9	0.8	19.1	2.4	1.3	6.1	0.3	-0.3	-0.1	20.1	15.5
WB373702	0.5	1.1	500.9	3.2	0.7	0.4	0.2	102.8	-2.0	8.1	948.3	4.9	2.6	2.2	20.1	7	2	9.5	0.9	-0.3	-0.1	48.7	39
WB373703	-0.1	2.4	360.3	2.6	0.6	0.5	-0.1	104.1	-2.0	7.1	161.3	4.9	2.6	2	19.5	6.9	1.7	9.3	0.9	-0.3	-0.1	50.4	30
WB373704	0.1	1.4	430.2	2.8	0.4	0.7	0.2	33.2	34.0	5.6	561.7	1.9	1	0.8	19.7	2.5	1.2	-0.1	0.3	-0.3	-0.1	18.1	30.5
WB373705	0.9	1	669.4	2.8	0.5	0.4	0.3	27.4	44.0	8.2	1660.0	2.8	1.7	0.7	20.7	2.8	2.1	2.8	0.6	-0.3	-0.1	12.2	45.5
WB373706	0.3	2.7	366.1	3	0.6	0.4	0.2	82.7	20.0	5.6	306.8	4.1	2.3	1.4	19.2	5.4	1.8	11.9	0.8	-0.3	-0.1	42.8	60.5
WB373708	0.2	3.7	165.5	2.8	0.2	1.5	0.2	20.6	38.0	4.1	109.1	1.9	1.1	0.8	18.7	2.5	1.5	4.9	0.4	-0.3	-0.1	8.3	30
WB373709	0.2	2.4	126.5	1.6	0.2	1.8	0.2	27.1	32.0	3.7	58.8	2.1	1.2	1	18.2	2.7	1.4	7.0	0.4	-0.3	-0.1	10.8	28
WB373710	6.5	0.8	3.8	0.6	2.8	1.4	2.1	27.5	40.0	0.4	7247.0	1.4	0.7	1.1	11.4	2	8.2	-0.1	0.2	-0.3	0.9	15.5	3
WB373711	-0.1	13.5	815.3	1.5	1.3	0.5	0.3	91	-2.0	5.1	23.1	4.3	2.5	2.2	18.1	5.7	1.1	15.7	0.9	-0.3	-0.1	48	17.5
WB373712	-0.1	3.4	693.1	6.2	2.7	0.8	0.1	59.8	10.0	10.0	22.3	1.8	1	0.9	19.3	2.7	1.1	7.1	0.3	-0.3	-0.1	33.4	14.5
WB373713	-0.1	29.4	725.5	1.1	-0.1	0.6	0.1	35	-2.0	3.9	8.6	2.1	1.2	0.3	15.4	2.5	1.4	5.1	0.4	-0.3	-0.1	17.9	4
WB373714	-0.1	11.3	741.7	1.3	0.2	0.6	0.2	31.8	-2.0	0.8	22.6	2.4	1.4	0.3	16.3	2.6	1.6	4.4	0.5	-0.3	-0.1	15.7	3
WB373715	-0.1	0.7	428.0	2.5	0.2	4.1	0.1	235.1	-2.0	-0.6	-0.5	11.4	5.6	1.5	21.9	14.6	2	11.2	2.1	-0.3	-0.1	125.7	2.5
WB373716	-0.1	-0.2	589.8	3.8	-0.1	1.2	0.1	133.1	-2.0	-0.6	4.3	8.2	4.9	0.7	19.9	8.3	1.3	9.8	1.7	-0.3	-0.1	68.5	9
WB373717	-0.1	0.3	582.0	4.2	-0.1	1.7	-0.1	149.1	-2.0	-0.6	3.3	9.9	6.1	0.8	21.3	10.1	1.4	10.1	2	-0.3	-0.1	76.6	6
WB373718	-0.1	0.6	445.5	1.8	0.6	0.4	0.1	86.9	-2.0	1.2	58.8	5.3	3.1	0.7	17.2	6	1.3	9.0	1.1	-0.3	-0.1	45.8	13
WB373719	-0.1	1.7	962.8	2.6	0.4	0.3	0.1	134.2	164.0	5.6	10.4	4	2.2	1.7	18.1	6.3	1.4	7.8	0.8	-0.3	-0.1	69.7	16.5
WB373720	0.1	2.4	200.4	3	0.3	5.1	0.3	69.4	52.0	-0.6	4.8	5.2	2.7	2	25.4	7.2	1.3	9.7	1	-0.3	-0.1	32.9	16.5
WB373721	0.4	1.6	262.5	0.9	0.4	1.2	-0.1	44.3	114.0	4.2	55.3	3	1.7	1.2	19.3	3.8	1.4	5.3	0.6	-0.3	-0.1	21.4	23
WB373722																							
WB373723	-0.1	4.3	405.9	1.1	-0.1	0.5	0.1	32.7	10.0	2.6	7.6	0.8	0.4	0.6	19.1	1.4	1	6.0	0.1	-0.3	-0.1	18.6	10.5
WB373724	-0.1	2.4	1096.0	1.2	0.4	0.4	0.1	32.4	38.0	5.4	67.2	1.8	1	0.8	18.8	2.4	1.3	7.3	0.3	-0.3	-0.1	17.7	35.5
WB373725	-0.1	6.3	454.1	1.4	-0.1	0.5	0.2	29.8	4.0	3.2	17.5	0.9	0.5	0.5	18.1	1.4	1	5.8	0.2	-0.3	-0.1	17.8	24
WB373726	1.1	2.1	297.6	1.9	1.9	0.3	0.3	45.5	24.0	5.0	2388.0	1.8	1	0.8	19.1	2.4	1.2	-0.1	0.3	-0.3	-0.1	26.7	26
WB373727	-0.1	6.6	369.1	1.4	0.9	0.5	0.2	90.5	394.0	-0.6	35.0	3.6	1.8	2	16.3	5.8	1.3	7.2	0.6	-0.3	-0.1	42.6	12.5
WB373728	-0.1	-0.2	127.6	4.8	-0.1	1.5	0.1	23.8	-2.0	-0.6	-0.5	5.6	3.2	-0.1	26.7	4.5	2.1	8.2	1	-0.3	-0.1	10.5	1.5
WB373729	-0.1	0.3	532.9	4.2	-0.1	0.8	0.1	145.6	-2.0	0.6	-0.5	8.8	5.4	0.7	20.1	9.2	1.3	10.6	1.8	-0.3	-0.1	76.2	9
WB373730	-0.1	1.2	466.0	1.2	0.1	1.1	0.2	31.4	46.0	-0.6	18.4	1.9	1.1	0.8	18.1	2.5	1.2	5.4	0.4	-0.3	-0.1	17.3	13.5
WB373731	-0.1	-0.2	546.9	4.6	-0.1	0.7	-0.1	146.8	-2.0	-0.6	0.8	8.8	5.5	0.7	21	9.3	1.4	9.7	1.8	-0.3	-0.1	76.7	6.5
WB373732	0.1	0.5	50.6	6.2	-0.1	0.6	0.2	20.4	-2.0	0.3	15.0	13	8.8	0.1	22.8	8.9	1.9	9.3	2.9	-0.3	-0.1	8.2	2.5
WB373733																							
WB373734	-0.1	0.6	102.3	5.1	-0.1	0.8	0.2	45.2	-2.0	-0.6	1.2	11.5	7.2	0.3	20.4	9.8	1.4	9.7	2.4	-0.3	-0.1	19.4	5.5
WB373736	0.7	0.8	81.0	1.4	7.8	0.7	0.1	55.6	32.0	1.8	1239.0	1.6	0.9	0.7	17.8	2.9	1.6	-0.1	0.3	-0.3	-0.1	27.4	12
WB373737	1.2	0.7	154.8	1.3	6.4	1.0	0.3	9.4	32.0	1.0	2750.0	1.5	1	0.4	17.1	1.4	1.7	-0.1	0.3	-0.3	0.1	4.9	15
WB373738	0.4	0.9	434.8	1.2	0.6	0.4	-0.1	25.3	92.0	8.4	536.9	1.6	1	0.6	16.4	1.9	1.3	6.1	0.3	-0.3	-0.1	13.7	34.5
WB373739	0.3	5.3	257.1	1.5	1.1	1.0	0.2	29.1	32.0	5.1	643.9	1.8	1	0.8	19.2	2.5	1.4	-0.1	0.3	-0.3	-0.1	15	24.5
WB373740	0.4	3.5	241.1	2.1	0.4	1.2	0.3	26	34.0	6.2	352.9	1.8	1.1	0.7	20.4	2.2	1.8	-0.1	0.3	-0.3	-0.1	14	28.5
WB373741	0.5	4	98.4	1.3	3.4	1.3	0.3	16.8	40.0	1.9	695.6	1.5	0.9	0.8	17.1	1.8	2.5	5.6	0.3	-0.3	-0.1	8	14
WB373742	1.7	2.7	181.1	1.3	3.4	0.7	0.5	25.8	38.0	4.6	2816.0	1.4	0.8	0.7	17.9	1.9	2.2	-0.1	0.3	-0.3	-0.1	14.2	20.5
WB373743	-0.1	0.6	559.0	4.9	-0.1	0.7	0.1	35.5	-2.0	0.8	119.0	9.5	6.8	0.5	19	6.4	1.6	6.9	2.2	-0.3	-0.1	17.9	3.5
WB373744	-0.1	0.4	248.9	6.2	-0.1	0.3	-0.1	217.6	-2.0	-0.6	16.9	13.3	8.1	0.7	24.1	14.7	1.8	10.5	2.7	-0.3	-0.1	110.5	12.5
WB373745	-0.1	6.9	325.7	1.3	-0.1	0.9	0.1	95.1	4.0	-0.6	1.9	1.6	0.9	0.8	15.4	2.7	1.1	6.1	0.3	-0.3	-0.1	54.3	8
WB373746	0.6	1	88.6	0.2	0.4	0.5	0.3	7.1	412.0	8.7	185.7	2.8	1.9	0.7	15.8	2.6	1.9	3.0	0.6	-0.3	-0.1	2.8	20.5
WB373747	-0.1	15.6	1377.0	2.3	-0.1	0.4	-0.1	139.4	-2.0	8.8	5.1	5.2	3	0.9	16.9	6.4	1.1	8.5	1	-0.3	-0.1	76.6	5.5
WB373748	0.4	1	169.3	1.3	0.5	1.6	0.3	61.6	88.0	4.6	198.6	4.9	2.4	1.6	23.3	6.7	1.5	7.6	0.9	-0.3	-0.1	29.2	25
WB373749	-0.1	1.1	223.3	1.6	0.3	0.9	0.2	59.7	66.0	2.8	42.7	3.1	1.5	1.7	23.5	4.5	1.2	8.1	0.6	-0.3	-0.1	30.3	20
WB373751																							
WB373752	2.2	1.2	91.8	1.1	2.2	0.6	0.5	32.2	42.0	2.0	5318.0	2.2	1.2	0.8	19.8	2.9	2.4	-0.1	0.4	-0.3	-0.1	13.5	11.5
WB373753	0.6	3.6	375.5	0.7	0.3	0.5	0.4	24.4	106.0	3.7	236.1	5.4	3.3	1.4	18.1	5.2	2	3.7	1.1	-0.3	-0.1	10.9	34.5
WB373754	-0.1	11.2	998.0	1.3	0.1	1.0	0.2	57.8	4.0	4.4	11.8	1	0.5	0.8	19.5	2	0.9	6.9	0.2	-0.3	-0.1	32.2	12
WB373755	-0.1	19.6	1128.0	1.7	0.5	0.5	0.2	117	2.0	4.3	14.4	4.5	2.6	1.6	15.7	5.7	1.1	11.4	0.9	-0.3	-0.1	63.4	9
WB373756	0.1	6.1	517.7	2.1	0.2	1.2	0.1	51.9	28.0	-0.6	5.7	2.5	1.4	1.1	19.7	3.5	0.9	7.0	0.5	-0.3	-0.1	27.7	11.5
WB373757	-0.1	0.4	622.6	1.4	-0.1	2.5	0.1	89.1	-2.0	-0.6	1.9	5.5	3.2	0.5	13.5	6.1	0.9	8.1	1.1	-0.3	-0.1	45.1	5

Sample No	Lu	Mo	Nb	Nd	Ni	Pb	Pr	Rb	Sb	Sc	Se	Sm	Sn	Sr	Ta	Tb	Te	Th	U	V	Y	Yb	Zn	Zr
WB373701	0.1	3.4	3.8	14.3	-1.0	10	3.9	89.8	0.2	6.0	1.0	2.6	5	323.2	-0.5	0.3	-0.2	6.6	2	52.0	9.2	0.8	54.7	107.7
WB373702	0.3	1.4	10.4	43.6	-1.0	10	11.6	289.8	0.2	14.0	1.3	7.9	48	253.7	1	1	-0.2	13	3.3	128.0	27.4	2.3	86.5	225.8
WB373703	0.3	1.9	10.8	43.6	-1.0	10	11.6	223.6	0.2	14.0	0.5	7.8	14.5	303.3	1	1	-0.2	13.1	3	122.0	27.6	2.3	66.3	228.7
WB373704	0.1	5.4	3.9	13.7	5.2	8.5	3.6	200.6	0.1	6.0	1.1	2.6	12	370.3	-0.5	0.4	-0.2	6.6	2.2	54.0	11.2	0.9	47.6	113.0
WB373705	0.3	7.4	5	12.3	8.4	9	3.2	291.2	-0.1	8.0	1.4	2.6	14	169.3	0.5	0.5	-0.2	7.7	4.6	60.0	21.6	1.9	69.5	122.3
WB373706	0.3	4.6	9.5	32.4	9.5	11.5	8.8	277.6	0.1	12.0	0.5	5.7	55	214.6	1	0.8	-0.2	11	2.6	96.0	24.2	2.1	75.8	232.1
WB373708	0.1	3.2	4	11.9	22.0	10.5	2.8	134.7	0.2	8.0	-0.3	2.5	9.5	282.7	0.5	0.4	-0.2	6.6	1.6	52.0	12.2	1	39.8	108.7
WB373709	0.1	8.8	4.3	13.5	22.9	9	3.4	145.3	0.5	8.0	-0.3	2.7	10	223.4	0.5	0.4	-0.2	7.3	2	56.0	12	1.1	28.4	125.9
WB373710	-0.1	0.2	1.4	11.2	-1.0	3	3	2.7	1.9	-2.0	4.5	1.9	275	13.2	-0.5	0.3	-0.2	2	1.2	34.0	9.3	0.5	420.1	39.7
WB373711	0.3	2.7	11.1	36	-1.0	17	9.7	89.0	0.3	10.0	-0.3	6.2	1.5	235.1	1	0.8	-0.2	12.1	3.2	8.0	25.5	2.4	81.7	633.0
WB373712	0.1	0.7	5.4	21.2	4.6	20.5	6.1	118.3	0.2	4.0	0.3	3.4	13.5	367.6	1	0.4	-0.2	12.4	4.5	32.0	10.7	0.9	64.3	123.2
WB373713	0.2	0.1	5.2	12.3	-1.0	25	3.7	77.0	0.3	2.0	-0.3	2.5	1	75.2	0.5	0.4	-0.2	13.3	4.4	-2.0	14	1.2	16.0	53.2
WB373714	0.2	0.1	5.9	11.6	-1.0	24	3.4	65.2	0.2	4.0	-0.3	2.6	2	79.5	1	0.4	-0.2	13.5	6.1	4.0	15	1.4	18.5	54.2
WB373715	0.7	3.2	15.6	83	-1.0	13.5	24.1	156.2	-0.1	6.0	-0.3	15.5	10.5	222.0	1.5	2.2	-0.2	60.3	21.5	10.0	67.8	4.6	7.0	198.9
WB373716	0.7	0.1	19.6	46.9	-1.0	32	13.6	219.7	-0.1	4.0	-0.3	8.9	8.5	74.9	2.5	1.4	-0.2	54.6	17.1	10.0	52	4.8	15.1	169.0
WB373717	0.8	0.1	24.4	52.7	-1.0	26	15.2	252.6	-0.1	4.0	-0.3	10.2	9	67.3	3	1.7	-0.2	64.3	17.4	10.0	64.6	5.8	17.2	194.4
WB373718	0.4	0.5	13.2	32.2	-1.0	13.5	9.2	157.3	0.6	4.0	-0.3	6.4	7	104.3	1.5	1	-0.2	31.4	8.5	4.0	34.8	3.1	14.7	163.2
WB373719	0.3	0.7	11.3	53.3	44.8	38	14.8	174.2	0.2	8.0	0.3	8.7	2	438.0	3	0.8	-0.2	31.7	18.6	44.0	25.4	2.3	43.6	133.7
WB373720	0.3	0.6	5.3	36.1	34.5	25.5	8.7	59.3	0.4	20.0	-0.3	7.5	13	577.8	-0.5	1	-0.2	4.9	1.4	90.0	28.4	2.2	55.0	248.3
WB373721	0.2	0.8	5.3	20.6	60.3	10	5.3	72.1	0.2	28.0	-0.3	4	1.5	319.9	-0.5	0.6	-0.2	5.2	1.3	222.0	17.4	1.5	84.7	77.2
WB373722																								
WB373723	-0.1	-0.1	2.4	11.6	3.8	16	3.4	80.3	1	4.0	-0.3	1.9	2	229.2	-0.5	0.2	-0.2	5.9	2.3	24.0	4.5	0.3	35.3	109.6
WB373724	0.1	0.9	4.1	12.9	12.3	20	3.5	100.2	0.8	8.0	-0.3	2.5	1.5	203.3	-0.5	0.3	-0.2	7.1	2.2	54.0	10.3	0.9	60.4	122.8
WB373725	-0.1	0.1	3.3	9.9	1.9	19	2.9	101.5	1	2.0	-0.3	1.7	2	202.7	-0.5	0.2	-0.2	6.6	2.5	22.0	6.7	0.5	27.5	117.6
WB373726	0.1	21.4	3.7	15.6	-1.0	11.5	4.5	189.8	0.1	10.0	0.9	2.8	6	341.4	-0.5	0.3	-0.2	6.5	2.5	56.0	10.6	0.9	68.9	112.3
WB373727	0.2	0.4	7.1	40.4	195.3	11.5	10.7	40.8	2.5	14.0	-0.3	7.2	2	402.0	0.5	0.8	-0.2	11.8	2.8	86.0	20.2	1.6	101.1	180.5
WB373728	0.7	8.6	72.9	10.4	-1.0	20.5	2.8	223.0	-0.1	8.0	-0.3	4	2	34.5	19.5	1	-0.2	11.6	19.9	-2.0	31.3	5.1	5.8	30.6
WB373729	0.7	0.8	20.1	51.4	-1.0	39	15.3	261.5	-0.1	6.0	-0.3	9.8	8.5	59.8	3	1.6	-0.2	61.2	19.1	10.0	58	5.1	27.0	166.4
WB373730	0.1	1	3.9	12.6	33.3	8.5	3.4	45.2	0.2	12.0	-0.3	2.5	1	351.0	-0.5	0.4	-0.2	6.6	2.1	72.0	11.7	1	40.6	109.4
WB373731	0.8	-0.1	21.5	51.8	-1.0	39	15.2	274.0	-0.1	4.0	-0.3	9.9	8	66.4	3	1.6	-0.2	56.1	18.5	10.0	59.5	5.4	22.4	166.4
WB373732	1.2	2.6	47.1	11.8	-1.0	40	2.8	222.7	-0.1	-2.0	-0.3	5.6	2.5	26.7	6.5	2	-0.2	31.4	30.9	-2.0	84.9	8.6	10.4	96.0
WB373733																								
WB373734	1	0.6	34.5	22.4	-1.0	44.5	5.6	257.8	-0.1	4.0	-0.3	7.7	4.5	28.4	4.5	2	-0.2	55	41.1	2.0	69.9	7.1	18.2	136.7
WB373736	0.1	0.6	4	22.6	6.0	9	6.2	97.1	0.1	8.0	2.9	3.8	3.5	226.8	-0.5	0.3	3.2	7.5	3.5	54.0	9.2	0.8	48.1	118.7
WB373737	0.1	2.5	3.5	4.3	-1.0	7.5	1.1	109.2	-0.1	8.0	2.6	1.1	8.5	189.9	-0.5	0.2	2.8	7	3.6	54.0	10.7	1	75.1	115.3
WB373738	0.1	3.3	4.1	10.1	50.8	6	2.7	219.3	-0.1	12.0	0.5	2	5	243.7	-0.5	0.3	-0.2	6.7	2.2	70.0	10.5	1	89.2	123.7
WB373739	0.1	0.6	3.5	12.3	2.1	10	3.2	151.0	0.5	10.0	1.2	2.5	5.5	311.8	-0.5	0.4	-0.2	4.5	1.8	60.0	8.7	0.8	55.6	101.9
WB373740	0.1	2.8	4.2	10.9	1.8	10	2.9	174.3	0.5	10.0	0.5	2.2	12.5	303.2	-0.5	0.3	-0.2	6.5	1.9	50.0	11.1	1	54.4	114.4
WB373741	0.1	2.1	3.8	7.7	7.0	11.5	1.9	56.8	0.8	10.0	0.6	1.7	28	286.6	-0.5	0.3	-0.2	7	1.5	52.0	9.5	0.8	60.5	114.2
WB373742	0.1	15.4	3.7	10.4	-1.0	8.5	2.8	116.0	0.3	8.0	3.0	2	10	247.5	-0.5	0.3	-0.2	6.9	2	50.0	8.4	0.7	98.3	115.6
WB373743	1	29	15.8	14	-1.0	30	3.9	361.9	-0.1	2.0	-0.3	4.1	8	45.8	3	1.4	-0.2	27	14.2	4.0	73.1	7.2	14.6	78.9
WB373744	1.1	0.7	28.8	80.7	-1.0	33	23.2	264.7	-0.1	6.0	-0.3	16.9	19	55.9	5	2.5	-0.2	75.5	24.9	10.0	92.2	8	22.9	163.6
WB373745	0.1	0.4	4.7	29.1	3.1	18	9.1	52.7	0.4	4.0	-0.3	4	1	135.2	0.5	0.3	-0.2	24.2	3.2	12.0	10.2	0.9	29.3	102.3
WB373746	0.3	5.6	1.9	5.5	114.3	3	1.1	50.2	0.2	50.0	0.6	1.8	1	112.7	-0.5	0.5	-0.2	0.3	-0.1	240.0	18.3	1.8	77.6	39.2
WB373747	0.4	1.3	11.6	47.8	-1.0	28.5	14.1	130.8	0.5	4.0	-0.3	7.8	2	59.9	1	1	0.2	22.8	5.8	4.0	32.9	2.9	44.0	185.5
WB373748	0.3	11.3	5	31.5	46.0	8	7.5	66.0	0.1	22.0	-0.3	6.7	1.5	285.1	0.5	1	-0.2	6	1.7	130.0	27	1.9	50.9	96.3
WB373749	0.2	0.5	3.6	26.8	41.1	10	6.9	39.4	0.2	20.0	-0.3	5.1	1.5	484.3	-0.5	0.6	-0.2	6.8	1.9	102.0	16.7	1.2	45.7	174.8
WB373751																								
WB373752	0.2	85.2	4.1	16.1	-1.0	8.5	4	64.1	0.2	8.0	4.0	3.3	9	243.2	-0.5	0.4	0.3	7.7	3.7	80.0	12.2	1.1	76.2	128.8
WB373753	0.4	0.4	6.5	14.7	67.2	9.5	3.2	156.3	0.3	48.0	0.5	4.1	1.5	174.3	-0.5	0.9	-0.2	2.1	0.3	268.0	33.3	3	91.0	103.9
WB373754	-0.1	-0.1	2.4	21.1	4.4	22	6	64.7	1.1	4.0	-0.3	3.1	1	427.3	-0.5	0.2	-0.2	10.2	2.8	28.0	5.6	0.4	50.0	117.7
WB373755	0.4	2.4	10.6	42	-1.0	22.5	12.1	98.0	0.4	6.0	-0.3	6.9	3	128.0	1	0.8	-0.2	15.9	4	8.0	27.8	2.5	57.0	339.7
WB373756	0.2	0.2	5	21.7	20.9	18	5.8	71.9	0.3	8.0	-0.3	4	5.5	353.6	0.5	0.5	-0.2	8.2	2.3	52.0	14.7	1.2	65.9	134.8
WB373757	0.4	0.2	16.2	32.5	-1.0	12	9.4	248.6	-0.1	2.0	-0.3	6.5	3	34.5	3	1	-0.2	39.1	20.9	10.0	33.3	3.2	8.5	111.9

APPENDIX B. PETROGRAPHIC DESCRIPTIONS

Sample	Suite	Description
WB373701	DAC	Dacite (* - **descriptive name used in drillcore log**) Foliated metamorphosed and hydrothermally altered, **(quartz-)feldspar porphyry**. Relict phenocrysts (≈40%) of saussuritised plagioclase (≈40%) and quartz (trace to 2%) in a fine-grained, recrystallised groundmass of quartzofeldspathic material-biotite-chlorite-epidote-titanite±ilmenite/ 'leucoxene'±sulphides(disseminated pyrrhotite-chalcopyrite).
WB373702	MD	Microdiorite Metamorphosed and hydrothermally altered, **aphyric microdiorite**. Very fine-grained recrystallised assemblage comprising plagioclase-quartz-biotite-epidote-chlorite-ilmenite±titanite±sulphides(chalcopyrite, pyrrhotite). Cross-cutting veinlets of quartz-sulphide(pyrite, chalcopyrite, cubanite, pyrrhotite, sphalerite)-clinozoisite.
WB373703	MD	Microdiorite Metamorphosed and ?altered, **aphyric microdiorite**. Very fine-grained recrystallised assemblage comprising plagioclase-quartz-biotite-epidote-chlorite-ilmenite±titanite±sulphides(chalcopyrite, pyrrhotite). Several narrow chlorite-epidote±titanite and quartz-clinozoisite-sulphide(pyrrhotite-chalcopyrite) fractures.
WB373704	DAC	Dacite Foliated metamorphosed and hydrothermally altered, **(quartz-)feldspar porphyry**. Relict phenocrysts (≈40%) of saussuritised plagioclase (≈40%) and quartz (<5%) in a fine-grained, recrystallised groundmass comprising quartzofeldspathic mix-biotite-epidote-titanite±ilmenite/'leucoxene'-sulphides±apatite. Clinozoisite-sulphide(pyrite±chalcopyrite±pyrrhotite)-rich patches throughout rock (?replaced biotite).
WB373705	IBX	Moderately-porphyritic Diorite/Intrusive Breccia Foliated, metamorphosed and altered**, (quartz-)feldspar-phyric biotite schist**. Relict phenocrysts (≈40%) of saussuritised plagioclase (≈40%; now albite±K-feldspar±epidote) and quartz (trace) in a fine-grained, recrystallised groundmass comprising quartzofeldspathic material-biotite-epidote/clinozoisite-titanite(rims oxides)-K-feldspar± ilmenite/'leucoxene'. Clinozoisite-sulphide(pyrrhotite-chalcopyrite± sphalerite)-rich patches in rock and veinlets of quartz-titanite± sulphide±clinozoisite± biotite.
WB373706	MD	Microdiorite Weakly foliated, metamorphosed and ?altered, **aphyric microdiorite**. Similar to #3702, #3703, but finer-grained. Very fine-grained recrystallised assemblage comprising plagioclase-quartz-biotite-epidote-'leucoxene'± titanite±sulphides(disseminated pyrrhotite-chalcopyrite±pyrite).
WB373708	ADRT	Aphyric Diorite Metamorphosed and hydrothermally altered, seriate to very sparsely porphyritic **(aphyric) diorite**. Fine-grained recrystallised assemblage comprising plagioclase(minor zoned grains)-quartz-biotite-epidote-titanite±ilmenite. Veinlets of quartz-clinozoisite-sulphide(chalcopyrite-pyrrhotite). Clinozoisite-sulphide(chalcopyrite-pyrrhotite±sphalerite)-rich patches, particularly surrounding veinlets.

Sample	Suite	Description
WB373709	IBX	Moderately-porphyritic Diorite/Intrusive Breccia Metamorphosed and hydrothermally altered, moderately **feldspar-porphyritic** fine-grained **diorite**. Relict phenocrysts (≈30-35%) of saussuritised plagioclase (≈30%; now albite±epidote) and ex-FeMg silicates (>5%; now biotite-epidote-rich patches) in a fine-grained, recrystallised groundmass comprising quartzofeldspathic mix-biotite-epidote-titanite± ilmenite/'leucoxene'. Veinlet of clinozoisite±'leucoxene'±titanite±sulphide (chalcopyrite-pyrrhotite) with a biotite-rich wallrock selvage. Clinozoisite-sulphide(chalcopyrite-pyrrhotite)-rich patches in rock; mainly near veinlet.
WB373710	VN	Actinolite Vein **Hydrothermal vein** comprising interlocking amphibole(actinolite)-clinozoisite-sulphides±titanite. Sulphides are mainly chalcopyrite-pyrrhotite-pyrite±sphalerite. Close spatial association between clinozoisite and sulphides.
WB373711	LDRT	Strongly-porphyritic Diorite Foliated, metamorphosed and hydrothermally altered **quartz-feldspar-phyric biotite quartz-diorite/tonalite**. Relict phenocrysts (≈40-45%) of saussuritised plagioclase (30-35%) and quartz (8-10%) in a fine-grained, strongly recrystallised groundmass comprising quartzofeldspathic mix-biotite-epidote-titanite±ilmenite±sulphides(pyrrhotite±chalcopyrite)± amphibole(relict grains)±chlorite± allanite(rare, metamict). Sulphides are associated with clinozoisite in places; titanite associated with oxides.
WB373712	PHY	Granodiorite Metamorphosed and ?altered **K-feldspar-quartz-plagioclase-phyric** fine-grained **biotite granodiorite**. Relict phenocrysts (≈40%) of saussuritised plagioclase (≈20%), quartz (≈20%) and K-feldspar (<5%) in a fine-grained recrystallised groundmass of quartz-plagioclase-K-feldspar-biotite-epidote-titanite±ilmenite±sulphides(pyrrhotite,chalcopyrite)±allanite±apatite±zircon.
WB373713	PHY	Altered Porphyry Foliated/sheared, metamorphosed and hydrothermally altered **quartz-albite-K-feldspar porphyry**. Relict phenocrysts (≈25%) of quartz (10%; partially recrystallised), K-feldspar (≈10%; microcline), Albite (≈5-8%; sericitised) and ex-FeMg silicates (<2%; ? ex-biotite) in a recrystallised groundmass of quartzofeldspathic material-sericite-biotite-titanite/'leucoxene'-epidote± sulphides(pyrrhotite±chalcopyrite±pyrite)±carbonate. Relict K-feldspar phenocrysts appear to be partially replaced by albite.
WB373714	PHY	Altered Porphyry Weakly foliated, metamorphosed and hydrothermally altered **quartz-albite-K-feldspar porphyry**. Relict phenocrysts (≈30%) of quartz (≈10%), K-feldspar (≈5-7%; microcline partially replaced by albite), Albite (≈15%; albite-sericite±epidote±carbonate aggregates) and ex-FeMg silicates (<2%; aggregates of secondary biotite-epidote/clinozoisite-quartz±carbonate) in a recrystallised groundmass of quartzofeldspathic material-sericite-biotite-titanite/'leucoxene'-epidote±sulphides(pyrrhotite±pyrite±chalcopyrite)± carbonate. Relict K-feldspar phenocrysts are partially replaced by albite. Cross-cut by thin quartz-biotite-rich veinlets and epidote-filled fractures.

Sample	Suite	Description
WB373715	GRT	Altered Granite Hydrothermally altered (pink colouration in hand-specimen), seriate-textured, medium-grained **monzogranite**. Rock comprises K-feldspar (perthite, microcline)-quartz-plagioclase(altered to albite-epidote-sericite± chlorite)-chlorite-sericite-epidote/ clinozoisite±'leucoxene'/rutile±titanite± allanite(common, metamict)± zircon±hematite(trace). All FeMg silicates completely altered to chlorite-epidote±'leucoxene'± sericite. Minor recrystallisation and fractures filled with epidote±chlorite±sulphides(pyrite).
WB373716	GRT	Altered Granite Hydrothermally altered, seriate to sparsely K-feldspar porphyritic, medium-grained **biotite syenogranite**. Phenocrysts of K-feldspar (<1 cm) in a medium-grained, seriate-textured slightly recrystallised assemblage comprising K-feldspar-quartz-plagioclase(altered to albite-epidote-sericite± chlorite)-biotite-chlorite-epidote(coarse crystalline)-sericite±magnetite/ 'leucoxene'/ rutile±allanite(metamict)±sulphides(pyrite)±zircon. Several epidote/clinozoisite±sulphide(pyrite)-filled fractures.
WB373717	GRT	Altered Granite Hydrothermally altered, seriate to sparsely K-feldspar porphyritic, medium-grained **biotite syenogranite**. Similar to #3717, except for more intense alteration of plagioclase. Phenocrysts of K-feldspar (<1 cm) in a medium-grained, seriate-textured assemblage comprising K-feldspar-quartz-plagioclase(intensely altered to albite-sericite-epidote)-chlorite-biotite-epidote-amphibole(relict)-'leucoxene'/rutile/ilmenite±sericite±apatite± allanite(metamict)±zircon.
WB373718	PHY	Altered Porphyry Mylonitised, metamorphosed and altered **quartz-feldspar porphyry**. Intensively recrystallised throughout. Rare relict phenocrysts (≈5%) of quartz (5%; partially recrystallised), and feldspar (trace; ?albite), in a totally recrystallised groundmass of quartzofeldspathic material-sericite-epidote/ clinozoisite±biotite±'leucoxene'/rutile±titanite±sulphides(pyrrhotite±pyrite ±chalcopyrite)±zircon.
WB373719	TUFF	Tuff Sheared, recrystallised and metamorphosed **plagioclase-amphibole-phyric schist** (ex-felsic volcanic?). Porphyroclasts of saussuritised plagioclase (albite-epidote±epidote) and amphibole(?actinolite)-biotite±epidote± titanite±sulphides(pyrite)-rich patches in a fine-grained groundmass of quartzofeldspathic material-biotite-epidote-amphibole(actinolite)-titanite± sulphides(pyrite±chalcopyrite). Actinolite appears to replace biotite in places. The amount of quartz would suggest a rhyodacitic composition.
WB373720	HYB	Amphibole Diorite (?Hybrid) Weakly aligned, altered **amphibole-rich diorite**. Interlocking mosaic of saussuritised plagioclase (albite-epidote/clinozoisite) and amphibole (actinolite), with common clinozoisite/epidote, minor but ubiquitous titanite, minor chlorite and trace ilmenite and sulphides(pyrite±chalcopyrite); Also a thin vein of clinozoisite±plagioclase±quartz.

Sample	Suite	Description
WB373721	HYB	Amphibole Diorite (?Hybrid) ?Metamorphosed and/or moderately altered and partially recrystallised **amphibole diorite/quartz-diorite**. Assemblage comprises saussuritised plagioclase(albite-epidote±'leuxoxene'±sericite)-amphibole(actinolite; altered to chlorite)-epidote-biotite±chlorite±titanite±ilmenite±sericite± sulphides(pyrrhotite>chalcopyrite)±apatite(trace). Common biotite-amphibole-rich patches that contain ilmenite with overgrowths of titanite and minor sulphides(pyrrhotite±chalcopyrite). Some thin veinlets/fractures of epidote-titanite±'leucoxene'.
WB373722 **(T/S only)**	HYB	Amphibole Diorite (?Hybrid) ?Metamorphosed and/or moderately altered and partially recrystallised **amphibole diorite/quartz-diorite**. Very similar to #3721. Assemblage comprises intensely saussuritised plagioclase(albite-epidote±'leuxoxene'± sericite)-amphibole(actinolite; altered to chlorite)-epidote-biotite±chlorite± titanite±ilmenite±sulphides(pyrrhotite±chalcopyrite)±sericite±apatite. Common biotite-amphibole-rich patches that contain ilmenite with overgrowths of titanite and minor sulphides(pyrrhotite).
WB373723	LDRT	Porphyritic Diorite Intensely recrystallised, foliated, metamorphosed/hydrothermally altered **quartz-feldspar porphyry**. Partially to intensely recrystallised relict phenocrysts (≈30%) of ex-feldspar (?30%; altered to aggregates of sericite±albite±epidote) and quartz (≈2-3%) in a intensely recrystallised, fine-grained groundmass of quartzofeldspathic material-biotite-sericite-epidote±'leucoxene'/ilmenite±chlorite±?titanite±sulphides(pyrrhotite± chalcopyrite)±apatite. Cross-cutting epidote/clinozoisite±chlorite veinlet with selvage of chloritised wallrock.
WB373724	AND	Weakly-porphyritic Andesite Intensely recrystallised, foliated, altered **biotite-sericite-epidote quartzofeldspathic schist**; possibly a metadacite (too much quartz for it to be an andesite). Rock comprises a fine-grained, recrystallised assemblage of feldspar (?albite)-quartz-biotite-epidote-sericite-'leuxocene'-sulphides (pyrrhotite-chalcopyrite)±titanite±apatite. Aggregates of sericite-clinozoisite/epidote±sulphides(pyrrhotite>>chalcopyrite) common. Cross-cutting recrystallised quartz>>biotite-sulphide(pyrrhotite)±epidote veinlets.
WB373725	LDRT	Porphyritic Diorite Intensely recrystallised, metamorphosed and hydrothermally altered **biotite-sericite quartzofeldspathic schist**; probably a recrystallised, altered quartz-feldspar-phyric diorite. Recrystallised relict phenocrysts (≈25%) of saussuritised plagioclase (20%; albite-sericite±epidote) and quartz (<5%) in a fine-grained, strongly recrystallised groundmass comprising quartzo-feldspathic material-biotite-clinozoisite/epidote-sericite-chlorite±titanite± ilmenite/'leucoxene'±sulphides(pyrrhotite)±carbonate(trace)±tourmaline (rare). Some biotite-chlorite±epidote±sericite±titanite patches possibly ex-FeMg silicate phenocrysts. Patches of clinozoisite-sulphide(pyrrhotite>> chalcopyrite)±sericite.

Sample	Suite	Description
WB373726	AND	Porphyritic Andesite Recrystallised, strongly-foliated, altered **quartz-feldspar-phyric epidote-biotite schist**; probably a porphyritic metadacite (too much quartz for it to be an andesite). Rock comprises partially recrystallised relict phenocrysts (≈40%) of saussuritised plagioclase (≈35-40%; albite±epidote±sericite) and quartz (trace) in a fine-grained, foliated, recrystallised assemblage of quartzofeldspathic material-biotite-epidote/clinozoisite-'leuxocene'/ilmenite-sulphides(chalcopyrite-cubanite±pyrite±sphalerite±arsenopyrite)±?titanite. Aggregates of clinozoisite-sulphides(chalcopyrite-cubanite±pyrite)±quartz common. Cross-cutting clinozoisite-quartz-sulphide (chalcopyrite, pyrite±sphalerite)±biotite vein with distinctive biotite-rich wallrock alteration selvage.
WB373727	AND	Andesite Fragmental Strongly-recrystallised, foliated, altered **epidote-biotite-amphibole schist** with common amphibole and/or biotite-rich clasts; probably a meta-andesitic fragmental rock. Rock comprises partially recrystallised amphibole- and biotite-rich relict clasts (≈45%) in a fine-grained, foliated, recrystallised assemblage of amphibole(actinolite)-plagioclase-biotite-epidote/clinozoisite-'leuxocene'±titanite±sulphides(pyrrhotite>>chalcopyrite±pyrite). Some aggregates of clinozoisite±sulphides(pyrrhotite). Veinlets of quartz-amphibole±biotite.
WB373728	APL	Aplite Seriate, fine-grained **leuco-monzogranite** or aplite. K-feldspar(microcline, orthoclase)-albite-quartz consititute over 95% of rock. Minor (<5%) biotite-epidote-chlorite±'leucoxene'±magnetite.
WB373729	GRT	Monzogranite Weakly altered, seriate, medium-grained **biotite monzogranite**. Rock comprises K-feldspar(microcline>perthite)-plagioclase(moderately saussuritised)-quartz-biotite(partially altered)-chlorite-epidote±sericite±'leucoxene'±ilmenite±magnetite±apatite±zircon±allanite(metamict). Very minor recrystallisation and subgrain development.
WB373730	ADRT	Aphyric Diorite Metamorphosed and weakly altered, seriate to very sparsely porphyritic **(aphyric) diorite**. Fine-grained assemblage comprising saussuritised plagioclase(albite±epidote±sericite)-amphibole(actinolite; minor partially chloritised)-quartz-biotite-epidote-titanite±'leucoxene'/ilmenite±sulphides (pyrrhotite>>chalcopyrite). Recrystallised quartz±feldspar±amphibole±titanite veinlet, and cross-cutting amphibole-biotite-feldspar±quartz veinlet.
WB373731	GRT	Monzogranite Moderately altered, seriate to sparsely K-feldspar-porphyritic, medium-grained **biotite monzogranite**. Rock comprises K-feldspar(microcline, perthite; some grains partially albitised)-plagioclase(moderately saussuritised to albite±sericite±epidote±carbonate)-quartz-biotite(partially altered to chlorite±epidote±sericite)-epidote±chlorite±'leucoxene'±ilmenite±magnetite±sericite± apatite±zircon±allanite(metamict). Very minor recrystallisation and subgrain development.

Sample	Suite	Description
WB373732	GRT	Granite Weakly altered, seriate to very sparsely K-feldspar-porphyritic, fine-grained **biotite leuco-monzogranite**. Similar to Aplite (#3728). Rock comprises K-feldspar(microcline≈perthite; minor graphic intergrowth with quartz)-plagioclase(slightly saussuritised)-quartz±chlorite±biotite±epidote±sericite±'leucoxene'±apatite±zircon±actinolite(trace). FeMg-silicates constitute <5% by volume. Very minor recrystallisation and subgrain development. Minor sericite±epidote-filled fracture.
WB373733 **(T/S only)**	GRT	Granite Weakly altered, weakly foliated, seriate, fine-grained **biotite leuco-monzogranite**. Slightly more mafic than previous sample (#3732). Rock comprises K-feldspar(microcline, perthite)-plagioclase(slightly saussuritised to albite±sericite±epidote)-quartz± biotite±epidote±chlorite±'leucoxene'±ilmenite±magnetite±sericite±apatite±sulphides(pyrite)±zircon±allanite (metamict). FeMg-silicates constitute ≈5% by volume. Very minor recrystallisation and subgrain development.
WB373734	GRT	Granite Weakly altered, seriate to very sparsely K-feldspar-porphyritic, fine-grained **biotite leuco-monzogranite**. Rock comprises rare K-feldspar phenocrysts (<1 cm) in a fine-grained rock comprising K-feldspar(microcline, perthite)-plagioclase(very slightly saussuritised to albite±epidote±sericite)-quartz-biotite-epidote±chlorite±'leucoxene'±magnetite±ilmenite±sericite±apatite±sulphides(pyrite)±zircon±allanite(metamict). FeMg-silicates constitute 5-8% by volume.
WB373736	LDRT	Strongly-porphyritic Diorite Weakly foliated, metamorphosed and weakly altered **quartz-feldspar-phyric biotite quartz-diorite**. Relict phenocrysts (≈40%) of variably saussuritised oscillatory-zoned plagioclase (≈35%) and quartz (≈5%) in a fine-grained, recrystallised groundmass comprising quartzofeldspathic material-biotite-epidote±'leucoxene'/ilmenite±titanite±sulphides(pyrite±chalcopyrite). Sulphides are spatially associated with clinozoisite in places; trace titanite associated with ilmenite. Thin quartz-titanite±biotite±plagioclase veinlet and cross-cutting epidote±biotite±'leucoxene'-filled fracture.
WB373737	LDRT	Altered, Strongly-porphyritic Diorite Moderately foliated, metamorphosed/altered and strongly recrystallised, **quartz-K-feldspar-phyric biotite quartz-diorite**. Altered equivalent to #3736. Variably recrystallised relict phenocrysts (30-35%) of variably saussuritised plagioclase (<30%; albite±sericite±epidote±biotite) and quartz (rare) in a fine-grained, recrystallised groundmass comprising quartzofeldspathic material-biotite-chlorite-epidote±'leucoxene'. Common chlorite±epidote± 'leucoxene' patches throughout rock, possibly ex-FeMg phenocrysts; and some clinozoisite±sulphide(chalcopyrite±pyrite)-rich patches near veins. Veins of quartz-sulphides(chalcopyrite-cubanite-pyrite)-epidote/ clinozoisite±chlorite±titanite and late epidote±chlorite±sulphide (chalcopyrite)-filled fractures.

Sample	Suite	Description
WB373738	AND	Andesitic Fragmental Strongly-recrystallised, moderately foliated, fine-grained, altered **epidote-biotite schist** with common biotite-rich clasts; probably a meta-intermediate volcanic or volcaniclastic (fragmental) rock. Rock comprises partially recrystallised biotite-rich relict clasts (up to 2 cm length; ≈45%) in a fine-grained, foliated, recrystallised assemblage of plagioclase-quartz-biotite-epidote/clinozoisite-'leuxocene'. Some clasts are plagioclase-phyric; clasts are characterised by variable plagioclase, quartz and/or biotite. Vein of quartz(variably recrystallised)-amphibole± plagioclase±epidote±sulphides (chalcopyrite±pyrrhotite±pyrite±sphalerite)±titanite and cross-cutting quartz±clinozoisite±sulphide(pyrrhotite±chalcopyrite) fracture.
WB373739	LDRT	Strongly-porphyritic Diorite Metamorphosed and weakly altered, strongly **feldspar-phyric biotite quartz-diorite**. Relict phenocrysts (≈40%) of variably saussuritised plagioclase (≈40%; some oscillatory-zoned; altered to albite±epidote± sericite) in a fine-grained, slightly-recrystallised groundmass comprising feldspar-quartz-biotite-clinozoisite/epidote±titanite±'leucoxene'/ilmenite± sulphides(pyrrhotite±chalcopyrite). Sulphides are spatially associated with clinozoisite in places; trace titanite associated with ilmenite. Thin variably recrystallised quartz±biotite±clinozoisite±plagioclase veinlet and variably recrystallised quartz±sulphide(pyrrhotite-chalcopyrite±sphalerite)-clinozoisite±chlorite±titanite veinlets with clinozoisite-rich patches in adjacent wallrock.
WB373740	LDRT	Strongly-porphyritic Diorite Metamorphosed and weakly altered, strongly **feldspar-phyric biotite quartz-diorite**. Relict phenocrysts (≈40%) of variably saussuritised plagioclase (≈40%; some oscillatory-zoned; altered to albite±epidote± biotite) in a fine-grained, seriate, variably-recrystallised groundmass comprising quartzofeldspathic material-biotite-epidote/clinozoisite± 'leucoxene'/ilmenite±titanite±chlorite±sulphides(chalcopyrite±pyrrhotite); trace titanite associated with oxides. Thin veins of variably recrystallised quartz±clinozoisite±sulphide(chalcopyrite±pyrrhotite±sphalerite)±biotite± tourmaline with minor clinozoisite-rich patches in adjacent wallrock.
WB373741	ADRT	Aphyric Diorite Metamorphosed and altered, seriate to sparsely porphyritic **(aphyric) diorite**. Fine-grained, variably recrystallised assemblage comprising variably saussuritised plagioclase(albite±epidote±sericite)-quartz-biotite-amphibole (actinolite; minor partially chloritised)-epidote±titanite± 'leucoxene'/ ilmenite±sulphides(chalcopyrite±pyrrhotite. Amphibole± biotite±ilmenite-rich patches; titanite occurs where amphibole partially replaced by biotite-rich assemblage. Thin recrystallised quartz±biotite veinlet with wallrock selvage of biotite±clinozoisite±actinolite, cross-cut by irregular fractures filled with clinozoisite/epidote-quartz±biotite±actinolite± chlorite.

Sample	Suite	Description
WB373742	LDRT	Strongly-porphyritic Diorite Variably recrystallised, metamorphosed and altered, strongly **feldspar-porphyritic biotite quartz-diorite**. Relict phenocrysts (≈35%) of variably saussuritised plagioclase (≈35%; some oscillatory-zoned; altered to albite±epidote±biotite) in a fine-grained, variably-recrystallised groundmass (≈65%) comprising quartzofeldspathic material-biotite-epidote/clinozoisite±'leucoxene'/ilmenite±chlorite±titanite; trace titanite associated with oxides. Some clinozoisite-sulphide(chalcopyrite±pyrrhotite±pyrite±sphalerite±molybdenite)-rich patches throughout rock. Intersecting sets of thin variably recrystallised quartz±clinozoisite±sulphide(chalcopyrite±pyrite±pyrrhotite±sphalerite)±biotite±chlorite±ilmenite veinlets with minor cross-cutting pyrite-filled fractures.
WB373743	GRT	Monzogranite Moderately altered, seriate to moderately K-feldspar-porphyritic, medium-grained **biotite monzogranite**. Rock comprises K-feldspar(microcline>perthitic orthoclase)-plagioclase(moderately saussuritised to albite±sericite±epidote)-quartz-biotite(altered to chlorite±epidote±sericite)-chlorite-epidote-'leucoxene'±sericite±sulphides(disseminated pyrrhotite, pyrite, chalcopyrite)±apatite±ilmenite±magnetite±zircon±allanite(metamict). Very minor recrystallisation and subgrain development.
WB373744	GRT	Monzogranite Weakly altered, seriate to sparsely K-feldspar-porphyritic, medium-grained **biotite monzogranite**. Rock comprises K-feldspar(microcline≈perthitic orthoclase)-plagioclase(moderately saussuritised to albite±sericite±epidote±chlorite±carbonate)-quartz-biotite(variably altered to chlorite±epidote±sericite)-chlorite-epidote±'leucoxene'±magnetite±ilmenite±apatite±zircon±allanite(metamict). Minimal recrystallisation and subgrain development.
WB373745	PHY	Altered Porphyry Strongly foliated/sheared, strongly recrystallised, metamorphosed and altered **albite-quartz porphyry**. Relict phenocrysts (≈25%) of quartz (15%; partially recrystallised), Albite (>10%; sericitised) and ex-FeMg silicates (<2%; biotite-rich clots) in a recrystallised, fine-grained groundmass of quartzofeldspathic material-biotite-epidote±'leucoxene'/ilmenite±titanite±sulphides(chalcopyrite±sphalerite)±chlorite. Late actinolite±epidote±quartz-filled fractures cross-cut foliation.
WB373746	REX	Mafic Rock Metamorphosed and ?altered, fine-grained **amphibolite**; possibly a meta-basalt. Assemblage comprises amphibole(?actinolite)-plagioclase-biotite-'leucoxene'/ilmenite(±titanite rims?)±clinozoisite±sulphides(disseminated pyrrhotite±chalcopyrite). Several felsic-rich (plagioclase±quartz) segregations that are possibly recrystallised/metamorphosed amygdales. Thin vein of clinozoisite± sulphide(pyrrhotite±chalcopyrite)±biotite±quartz.

Sample	Suite	Description
WB373747	PHY	Foliated Quartz-diorite Foliated, recrystallised, metamorphosed and hydrothermally altered **feldspar-quartz-phyric porphyry** or volcaniclastic rock; ?similar to quartz-feldspar porphyry suite. Relict phenocrysts (≈30%) of quartz (15%; many have relict crystal shapes; some partially recrystallised), and totally recrystallised feldspar (≈15%; aggregates of sericite-quartz-albite±K-feldspar±biotite±carbonate) in a intensely recrystallised groundmass of quartzofeldspathic material-biotite-sericite±epidote±'leucoxene'/ilmenite± chlorite±sulphides(pyrrhotite±pyrite)±carbonate. Cross-cutting, thin clinozoisite-filled fracture.
WB373748	HYB	Biotite-Amphibole Diorite ?Metamorphosed and/or moderately altered, and partially recrystallised seriate to sparsely feldspar-porphyritic fine-medium-grained **biotite-amphibole diorite/quartz-diorite**. Thin-section is of contact between intrusive diorite and country rock (#3746 - metabasalt). Diorite has assemblage comprising plagioclase(variably saussuritised to albite-epidote)-amphibole(actinolite)-quartz-biotite-epidote/clinozoisite±'leucoxene'/ ilmenite±titanite. Some clinozoisite-sulphide(disseminated pyrrhotite>> chalcopyrite)±titanite-rich patches. Some biotite-amphibole-rich patches that contain ilmenite with overgrowths of titanite. Some thin veinlets/fractures of epidote-titanite±'leucoxene'.
WB373749	HYB	Biotite-Amphibole Quartz-Diorite ?Metamorphosed and/or very weakly altered and slightly recrystallised, seriate, fine-medium-grained **biotite-amphibole diorite/quartz-diorite**. Diorite has assemblage comprising plagioclase(relict oscillatory zoning; weakly saussuritised to albite±epidote)-amphibole(?hornblende/actinolite)-biotite-quartz±epidote±ilmenite±'leucoxene'/titanite±sulphides(pyrrhotite). Vein of quartz with minor amphibole (ex-wallrock slivers). A thin fracture of epidote-biotite±'leucoxene'.
WB373751 **(T/S only)**	IBX	Moderately-porphyritic Diorite/Intrusive Breccia Foliated, metamorphosed and/or hydrothermally altered, moderately feldspar-porphyritic, fine-grained **amphibole-biotite quartz-diorite**. Thin-section also has a ?xenolith/clast of biotite-amphibolite schist. Quartz-diorite comprises relict phenocrysts (≈30%) of weakly saussuritised plagioclase (≈30%; now albite±epidote; minor relict oscillatory zoning) in a fine-grained, recrystallised, foliated groundmass of plagioclase-biotite-quartz-amphibole± epidote±'leucoxene'/ilmenite±titanite±sulphides (pyrrhotite).
WB373752	IBX	Moderately-porphyritic Diorite/Intrusive Breccia Moderately recrystallised, metamorphosed and/or moderately altered, moderately feldspar-porphyritic, fine-grained **biotite quartz-diorite**. Quartz-diorite comprises relict phenocrysts (≈35%) of plagioclase (>25%; variably saussuritised to albite±epidote) and ex-FeMg silicate (≈10%; clinozoisite/ epidote-chlorite±biotite±'leucoxene') in a fine-grained, recrystallised, groundmass of quartzofeldspathic material-biotite±epidote± 'leucoxene'± chlorite±apatite. Some clinozoisite-sulphide(chalcopyrite)± chlorite-rich patches.

Sample	Suite	Description
WB373753	DOL	Archean Dolerite Metamorphosed and ?altered, fine-grained, **amphibolite**; probably a meta-Archean dolerite. The rock maintains a relict subophitic texture, even though there is moderate alteration/metamorphism. The dolerite comprises amphibole(?actinolite)-plagioclase(±quartz)-epidote/clinozoisite±biotite± 'leucoxene'±chlorite±sulphides(disseminated pyrite±chalcopyrite± pyrrhotite). Thin cross-cutting amphibole-quartz-sulphide(chalcopyrite-pyrite) veinlet.
WB373754	QD	Quartz-plagioclase-phyric Quartz-diorite Strongly recrystallised, metamorphosed and hydrothermally altered, quartz-feldspar porphyritic, fine-grained **granodiorite**; too much quartz for a quartz-diorite. Partially recrystallised relict phenocrysts (≈30%) of feldspar (≈25%; plagioclase>K-feldspar; now aggregates of albite-sericite-quartz±K-feldspar ±epidote±carbonate) and quartz (<5%; moderately recrystallised), in an intensely recrystallised and altered groundmass of quartzofeldspathic material-biotite-epidote±sericite±'leucoxene'/ilmenite±chlorite±titanite± sulphides(pyrrhotite>>pyrite)±zircon.
WB373755	QD	Quartz-plagioclase-phyric Quartz-diorite Strongly recrystallised, moderately-foliated, metamorphosed and ?altered, quartz-feldspar porphyritic, fine-grained **tonalite**; a felsic rock with far too much quartz for a quartz-diorite. Partially recrystallised relict phenocrysts (≈45%) of plagioclase (≈20%; moderately saussuritised to albite-epidote-quartz±sericite), quartz (≈20%; moderately recrystallised and rounded) and ex-FeMg silicate (<5%; now biotite-rich aggregates), in an intensely recrystallised, foliated groundmass of quartzofeldspathic material-biotite-epidote/clinozoisite±titanite±'leucoxene'/ilmenite±chlorite±carbonate± sulphides(pyrrhotite±chalcopyrite±arsenopyrite)±zircon. Some clinozoisite-sulphide(pyrrhotite±chalcopyrite)±ilmenite-rich patches.
WB373756	QD	Quartz-plagioclase-phyric Quartz-diorite Moderately recrystallised, weakly-foliated, metamorphosed and ?altered, seriate to sparsely feldspar porphyritic, medium-grained **tonalite**; too much quartz for a quartz-diorite. Tonalite comprises plagioclase(intensely saussuritised to albite-epidote±chlorite±sericite)-quartz-biotite-epidote/ clinozoisite-chlorite±titanite±'leucoxene'/ilmenite±amphibole(relict, trace)± sulphides(pyrrhotite)±zircon. Veins/fractures of epidote±chlorite±quartz.
WB373757	GRT	Altered (Pink) Granite Strongly altered, seriate to very sparsely K-feldspar-porphyritic, medium-grained **biotite monzogranite**. Rock comprises K-feldspar(microcline≈ microperthitic orthoclase)-plagioclase(moderately saussuritised to albite± sericite±epidote)-quartz-chlorite(?after biotite)±epidote-'leucoxene'± sulphides(disseminated pyrite)±apatite± zircon±allanite(metamict). In places, FeMg silicates are completely replaced by albite±'leucoxene'± chlorite.