

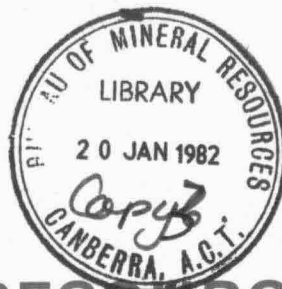
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GEOCHEMISTRY OF ARCHAEOAN VOLCANIC SUCCESSIONS,
EASTERN PILBARA BLOCK, WESTERN AUSTRALIA

A.Y. Glikson & A.H. Hickman

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Abstract

A geochemical investigation of the Archaean volcanic successions of the Warrawoona Group and Gorge Creek Group in the eastern Pilbara Block was carried out jointly by the BMR and GSWA. 442 rock samples were analyzed for major elements, Ba, Rb, Sr, U, Th, Zr, Nb, La, Ce, Y, Li, Ni, Co, Cr, V, Cu, Zn, Ga and S. The results allow the construction of a regional geochemical-stratigraphic framework for the volcanic successions as mapped previously and defined by the GSWA, and facilitate applications of whole-rock geochemical parameters as criteria for stratigraphic identification of isolated volcanic rock bodies. A screening method discriminating between altered and least altered samples was designed using LMPR (log molecular proportion) plots, and the data of least-altered rocks were computed to investigate magmatic fractionation models and estimate mantle composition. The geochemical data reveal vertical stratigraphically controlled trends relevant to the evolution and zonation of the Archaean mantle and secondary redistribution patterns. Concomitant migration of volatiles (H_2O & CO_2), alkalies, sulphur and copper toward tops of volcanic sequences is indicated, with implications for the development and localization of base metals.

The lowermost Talga-Talga Subgroup (3556 ± 32 m.y.) is dominated by tholeiitic basalt and dolerite of high Ti and low K, Al, Ni and Cr. Qz-normative high-Mg basalts are closely interspersed with the tholeiites. Lenticular units of high-Al dacite-andesite occur below the thin sedimentary McPhee Formation between the North Star Basalt and Mount Ada Basalt. Overlying the latter is the Duffer Formation (3452 ± 16 m.y.) which consists of predominantly pyroclastic Na-dacite, K-dacite, Na-rhyolite, K-rhyolite, and andesite volcanics accompanied by minor basalt and dolerite intercalations. The Duffer Formation is capped by a stratigraphically consistent unit of chert - the Towers Formation (Marble Bar Chert). Overlying greenstones of the Salgash Subgroup consist of a lower mafic unit (Apex Basalt) in places containing peridotite komatiites and an upper unit (Euro Basalt) of tholeiitic and high-Mg basalts. Minor dacite--rhyolite lenses are present. The Wyman Formation - the stratigraphically uppermost unit of the Warrawoona Group - typically consists of ultrapotassic quartz porphyry. Thin tholeiitic basalt units (Charteris Basalt and Honeyeater Basalt) occur within the sedimentary sequence of the Gorge Creek Group, and are typically low in Ti, and some of the rocks are high in Al and K. A general depletion in Fe, Ti, P, Zr, and Y with time is manifest, both as an

overall trend and as repeated cycles in individual volcanic units. Similar trends have been observed in South Africa and Canada (Glikson, 1979). These trends are the reverse of tholeiitic crystal fractionation trends, and may reflect secular depletion of the mantle in siderophile and lithophile elements due to extraction of basic melts.

The LMPR alteration screening method shows that a majority of basic volcanic rocks plot within the field of least-altered modern volcanics, whereas silicic volcanics commonly show strong Ca depletion. Correlation coefficients, standard deviations, frequency distribution relations and stratigraphic variations suggest high mobility of Ca, Na, K, Ba, Rb, and Sr, and relative stability of the siderophile (Fe, Ti, Mn, V), magnesium-related (Ni, Cr, Co), some lithophile (P, Zr, Nb, Y), and in some instances rare earth (Ce, La) and chalcophile (Cu, Zn) elements. The concentration of volatiles, alkalies and Cu toward the tops of sequences is attributable to either late synvolcanic carbonization or/and secondary upward volatile migration associated with leaching of copper from the basic volcanic rocks.

Petrogenetic model calculations suggest iron-rich mantle source compositions (Mg number in the range 80-90). Peridotitic komatiites (PK) formed by greater than 50% melting of mantle peridotite, during temporally distinct high-temperature diapiric events. As suggested by compositional gaps between PK and high-Mg basalts (HMB), these magmas are not generally inter-related by crystal fractionation. The HMB formed by 30-50% melting of mantle peridotite in a shallow (ca. 60 km) Archaean equivalent of the modern low velocity zone. As suggested by a continuous chemical spectrum between high-Mg basalts and tholeiitic basalts, the latter could form from primary high-Mg magma by 25-65% crystal fractionation, leaving modelled residues of olivine, clinopyroxene, orthopyroxene and plagioclase. The low-LIL (large iron lithophile elements) dacites of the Duffer Formation probably formed by partial melting of basic source materials - such as may be represented by the Talga-Talga Subgroup - but late-magmatic hydrothermal addition of Si and K is required for the rhyolites. Elvan-type quartz porphyries of the Wyman Formation were related to late-stage pneumatolitic activity. The high-K values of tholeiitic basalts of the Gorge Creek Group may represent effects of sialic contamination. Some similarities exist between Talga-Talga Subgroup tholeiitic basalts and modern mid-ocean ridge basalts, and between Gorge Creek Group tholeiitic basalts and arc-trench or Andean high-Al basalts. These changes may reflect progressive

crustal thickening during the Archaean, i.e. from a simatic regime to a continental or continental-margin regime. However, the Talga Talga Subgroup differs from ocean floor basalts by its high Ti and low Cr and Ni. Comparisons between chondrite-normalized plots of the Archaean tholeiitic basalts and modern basalts indicate significant differences between these suites. No strictly uniformitarian interpretation of the geochemical data in terms of modern tectonic environments is justified.

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INTRODUCTION

The northern part of the Pilbara Block, northwestern Western Australia, consists of thick sequences of low-grade metamorphosed volcanic rocks and overlying sedimentary units, intruded by granitic batholiths (Noldart & Wyatt, 1962; Ryan, 1965; Ingram, 1972; Hickman & Lipple, 1975; Hickman, 1975; Lipple, 1975; Fitton et al., 1975). Isotopic age determinations indicate an Archaean* age for these rocks (Greenhalgh & Jeffery, 1959; Leggo & others, 1965; Compston and Arriens, 1968; deLaeter and Trendall, 1970; Arriens, 1971; deLaeter and Blockley, 1972; deLaeter et al., 1975, 1977; Oversby, 1976). Recent U-Pb zircon data, Pb model data and Sm-Nd isochron data indicate a ca 3.5 b.y. age for the lower part of the sequence (Sangster & Brook, 1977; Richards, 1977; Pidgeon, 1978a, 1978b; Hamilton & others, 1981; Jahn & others, 1981). The Archaean supracrustal rocks form successions up to 14 km thick, and are in places well exposed and amenable to detailed study. By 1975, advances in regional 1:250,000-scale mapping of the eastern part of the Pilbara Block by the Geological Survey of Western Australia (GSWA) had provided a regional geological framework. Subsequently, the Bureau of Mineral Resources, Geology and Geophysics (BMR) jointly with the GSWA commenced a geochemical study of the Archaean volcanic formations, as a contribution to the IGCP** project Archaean Geochemistry (74/1/92). The investigation was planned in two phases: the first phase, whose results are reported below, has centred on constructing a geochemical-stratigraphic data framework based on volcanic type-sections in the eastern Pilbara. In the second phase (started August, 1980) the study is extended into the west Pilbara and also includes the late Archaean Whim Creek Group and Fortescue Group. The principal aims of the project are:

- (1) Document principal major and trace-element features of the various volcanic rock types and obtain abundance estimates of the latter in the various stratigraphic units.
- (2) Correlate geochemical characteristics with the stratigraphy, in a search for diagnostic "fingerprints" and trends allowing the application of geochemistry as a stratigraphic aid in areas where the relation of volcanic rocks to the regional sequence is unknown due to poor outcrop or structural discontinuities.

* In this report the term Archaean refers to the pre-2600 m.y. era and the term early Archaean to ca 3500 m.y. and older.

** International Geological Correlation Programme.

- (3) Attempt discrimination between least-altered and altered samples to enable the elucidation of original igneous characteristics and secondary features caused by lava-seawater interaction, burial and thermal metamorphism, and related element dispersions.
- (4) Classify the primary igneous affinities of the volcanic rocks, investigate magmatic processes as indicated by major and trace element data, compare the rocks with Phanerozoic volcanics and infer mantle-crust relations and the tectonic framework.
- (5) Examine implications of primary and secondary element redistribution patterns for the migration and concentration of economically significant metals.

Earlier studies of Pilbara volcanic rocks were accompanied by limited geochemical data. A whole-rock geochemical orientation study was conducted by Hallberg (1974); 369 samples were collected from 15 localities, mainly near mining centres, and 28 ultramafic to andesitic volcanic samples analyzed for major elements, Co, Cr, Cu, Ga, Nb, Ni, Rb, Sr, Y, Zn and Zr. Carbonatization was found to be pervasive, retarding the investigation of primary igneous compositions. Hickman & Lipple (1975) reported 34 analyses of dacite and rhyolite samples from the Warrawoona Group. Sun & Nesbitt (1978a) published three major element and rare earth element (REE) analyses of high-Mg basalt (komatiite) from the late Archaean Negri Volcanics, western Pilbara Block. Some unpublished whole-rock geochemical data are included in exploration company reports and theses of the University of Western Australia.

In the present study, sampling traverses were conducted along 13 sections in the Marble Bar, Nullagine, and southeast corner of the Port Hedland 1:250,000 Sheet areas (Fig. 1.2). A total of 575 samples were collected, of which 442 volcanic rocks and 16 granites were analyzed for Si, Ti, Al, Fe⁺³, Fe⁺², Mn, Mg, Ca, Na, K, P, CO₂, H₂O⁺, H₂O⁻, Ba, Rb, Sr, Pb, Th, U, Zr, Nb, Y, La, Ce, Li, V, Cr, Co, Ni, Cu, Zn, Ga and S. The analyzed samples are classified according to stratigraphy and rock-type in Table 1.1, mean compositions are given in Table 6.1, and individual analyses presented in Appendix I. Sampling methods, analytical precision and accuracy controls, and computing methods are reported in section 3. A series of BASIC computer programs were written for the Hewlett-Packard 9825A system to enable data processing, tabulation and plotting. This report presents the principal results of phase 1 of the project; further treatment of the data will be made in publications, including results of REE and isotopic analyses currently underway (Glikson & Hickman, 1981; Hamilton & others, 1981; Jahn & others, 1981).

TABLE 1:1. Classification of Pilbara Supergroup sample according to formation and rock type

Group and Subgroup	Formation	Traverse Numbers ⁺	Samples Analysed							Total	
			PK	HMB	TB and HALB	DG	And	Dac	Rhy		Other
WHIM CREEK GROUP	Negri Volcanics										
	Louden Volcanics										
	Rushall Slate										
	Mons Cupri Volcanics										
	Warambie Basalt										
GORGE CREEK GROUP	Mosquito Creek Formation										
	Lalla Rookh Sandstone										
	Honeyeater Basalt	9		7	21	12				40	
	Cleaverville Formation										
	Charteris Basalt	8		6	15	5	1			27	
WARRAWOONA GROUP	Corboy Formation										
	Wyman Formation	11,12,13							23	23	
	Euro Basalt	5,7		4	9	2				15	
	Panorama Formation										
	Apex Basalt	1,5,6,7	5	23	14	11	5	1		3	62
	Towers Formation	1					1				1
	Duffer Formation	1,6,10		1	5	4	12	42	22	5	91
	Mount Ada Basalt	1,2,3,4	5	9	45	16	3	2		10	90
	McPhee Formation										
	North Star Basalt	1,2,3,4	5	7	39	24	5	8	1	4	93
		Total:	15	57	148	74	27	53	46	22	442

⁺ traverse lines shown on Fig. 1.2.

⁺ traverse lines shown on Fig. 1.2.

PK - peridotitic komatiite; HMB - high-Mg basalt; TB - tholeiitic basalt; HALB - high-Al basalt; DG - dolerite and gabbro; AND - andesite; DAC - dacite; Rhy - rhyolite; Other - pyroxenite, intrusive porphyry, schist, etc.

2. GEOLOGY

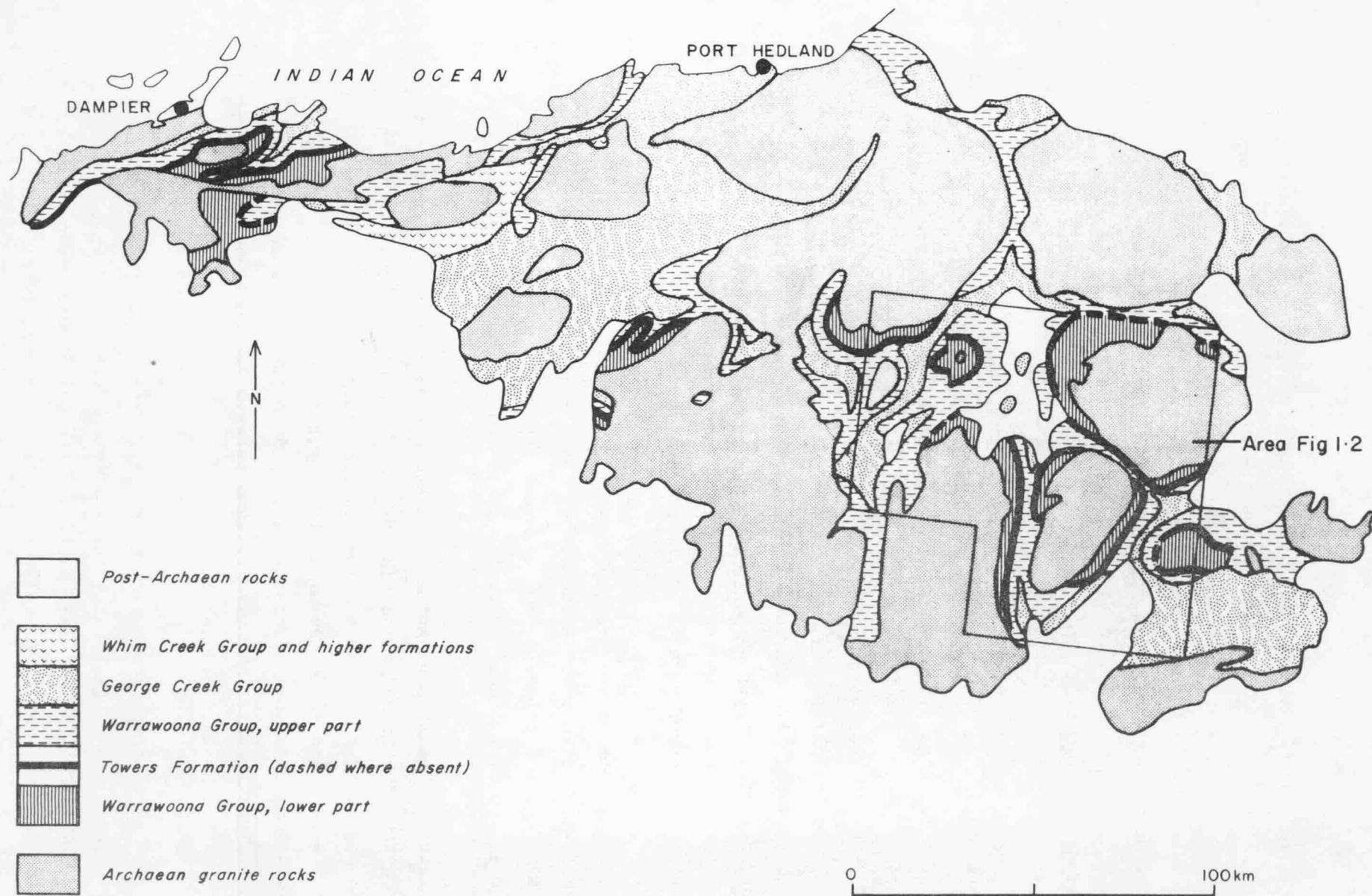
The Pilbara Block occupies 60 000 km² of northwestern Australia. It consists of domal granitic batholiths separated by volcanic-sedimentary synclinal outliers, or 'greenstone belts' which collectively comprise the 'Pilbara Supergroup' (Hickman, in press) (Fig. 1.1). The metamorphic facies of the supracrustal successions in greenschist to lower amphibolite.

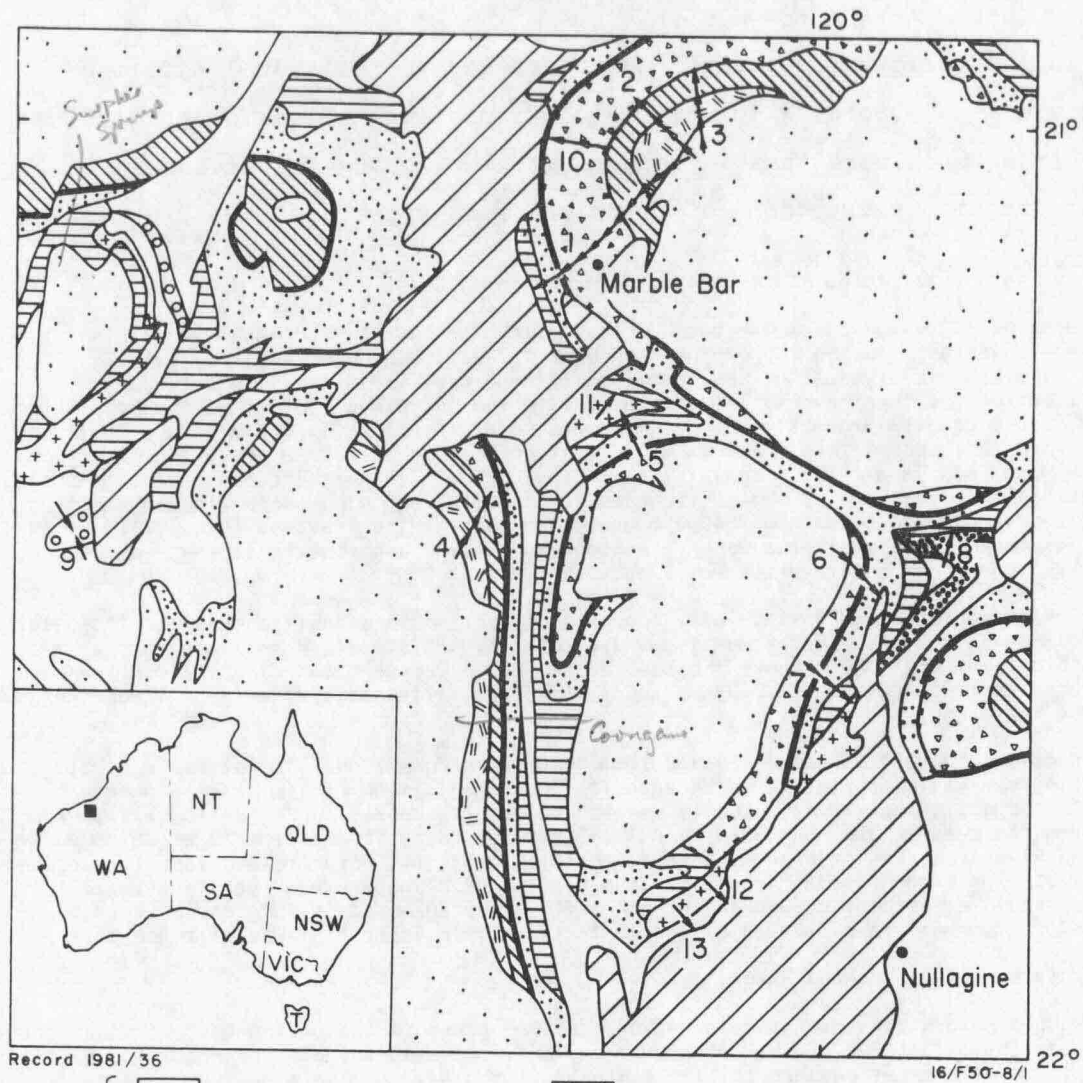
2.1 Regional geology

About 60 per cent of the Pilbara Block consists of granitic rocks (Fig. 1.1), including three main categories: (1) 3.5 - 2.9 b.y. migmatitic, gneissic and foliated trondhjemite and granite (s.s.) with minor tonalite and adamellite, (2) foliated porphyritic trondhjemite and granite (s.s.) mostly effected by major thermal events about 3.0 b.y. (as shown by Rb-Sr and Pb-Pb isotopes), and (3) unfoliated, post-tectonic tonalite, granodiorite and adamellite (commonly tin-bearing) currently considered to be between 2.7 and 2.6 b.y., but in part possibly as old as 2.83 b.y. (Pidgeon, 1978b). The foliation of categories 1 and 2 is of tectonic origin and varies from a weak biotite alignment to a stronger parallel orientation of quartz, sericite and mafic minerals. It commonly crosses internal plutonic contacts at high angles, grades into cataclastic schist and protomylonite, and shows a strong geometrical concordance with the overall structure of the domes. Oversby (1976), Pidgeon (1978b) and Cooper & others (1980) consider that the domes were emplaced at about 3.0 - 2.95 b.y., though magmatic intrusion may have occurred earlier.

Whereas the maximum total thickness of the Pilbara Supergroup is about 30 km, the true thickness in individual areas is generally only 10 to 15 km. Stratigraphic correlations across the Pilbara Block are facilitated by good exposure and fairly high degree of continuity between greenstone belts. The stratigraphic succession was first established in the Marble Bar-Nullagine area (Hickman & Lipple, 1975), and correlations between the sections sampled in the present study are well established.

The stratigraphic succession of the Pilbara Supergroup is in Table 1.1. Geochronological data suggest that the Warrawoona Group is 3.6 to 3.3 b.y. old, the Gorge Creek Group 3.3 to 2.95 b.y., and the Whim Creek Group about 2.7 b.y. old (Pidgeon, 1978a; Richard, 1977; Sangster & Brooks, 1978; Hamilton & others, 1981; Jahn & others, 1981; Hickman, 1980).





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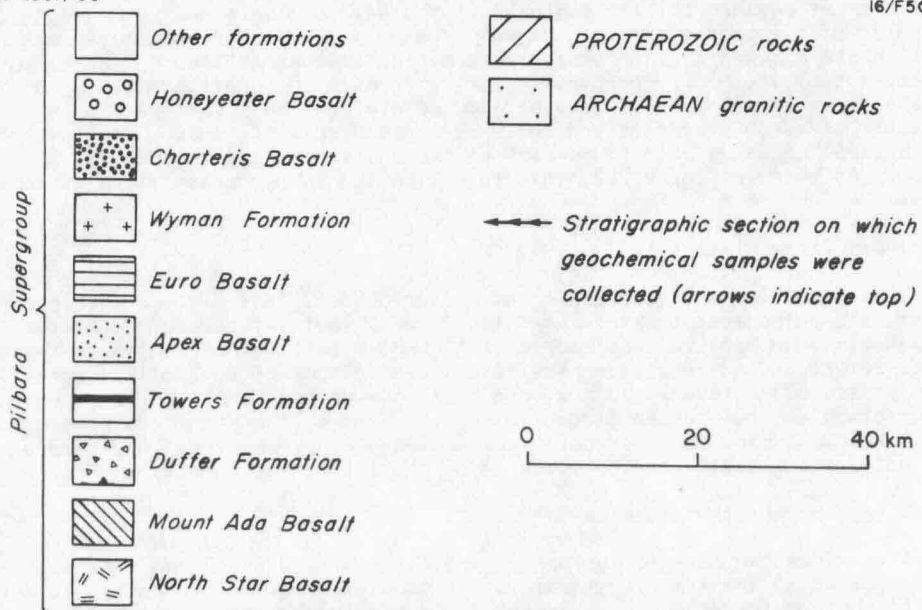


Fig 1-2 Geochemical sampling traverses in the East Pilbara Block

2.2 Sampling traverses

In the following descriptions, reference to individual sampling traverses are made according to numbers on Figure 1.2. Stratigraphic columns of traverses from which more than 10 samples were collected are presented in Figure 2.1. Petrographic descriptions of principal rock types are given in Section 4.

2.2.1 Traverse No. 1: Talga River-Coongan River-Chinaman Creek

Traverse No. 1 extends from the base of the North Star Basalt (NSB) near Talga River at a hill termed The Sisters to the top of the Apex Basalt (AB) in Chinaman Creek (Fig. 1.2). The NSB along this traverse is atypical of the formation elsewhere by virtue of more extensive recrystallization, as the traverse is juxtaposed with the intrusive contact of the Mount Edgar Batholith, and a greater proportion of dacite-andesite at the top. Three samples of peridotitic komatiite were obtained on this traverse at a stratigraphic level 1000 m above the formation's base. The Mount Ada Basalt (MAB) contains peridotitic komatiite near its base, passing upwards into an alternating sequence of tholeiitic basalt, dolerite, and minor andesite and dacite. High-Mg basalt and pyroxenite occur about 4000 m above the base of the traverse (Fig. 2.1.a). As in the NSB, metamorphic grade attains upper greenschist to lower amphibolite facies, and is appreciably higher than on traverses Nos 2 and 3.

The Duffer Formation (DF) is chiefly composed of dacitic to andesitic crystal lithic tuffs and subordinate lava flows. Both rock types are commonly schistose. Rhyolite occurs at a stratigraphic level of 1500 m above the base of the DF in Duffer Creek near its confluence with the Coongan River (75040046 I, L). Dykes and sills of dolerite and pyroxenite intrude the lower part of the Formation.

One sample (75040072 B) was collected from the Towers Formation. On the basis of SiO_2 content this rock would be classed as an andesite, but examination of its trace element geochemistry suggests that it is actually an altered basalt. A similar situation exists for samples from the base of the Apex Basalt (AB) (75040073 A, G, - 75 B). The AB at Chinaman Creek and Coongan River consists of high-Mg basalt, tholeiitic basalt, dolerite and locally pyroxenite (Fig. 2.1.c). The high-Mg basalt contains long needles of clinopyroxene (partly altered to amphibole) set in a feathery groundmass of tremolite and plagioclase with granular epidote. Pillow structures are common. This section of the AB includes thin intercalations of black chert.

2.2.2. Traverse No. 2: McPhee Reward

The McPhee Reward traverse (samples 45062 - 45096) presents one of the best sections through the North Star Basalt (NSB), the McPhee Formation (MF) (not sampled) and the Mount Ada Basalt (MAB). Both basalt formations are chiefly composed of tholeiitic basalt and subordinate dolerite. An altered ultramafic unit composed of talc-serpentine and talc-carbonate-chlorite rocks occurs at the 500 m level in the NSB and is interpreted as a peridotitic komatiite. High-Mg basalt occurs only near the top of the NSB. Porphyritic dacite forms a 20 m unit at the top of the North Star Basalt and felsic schist was sampled at the 2760 m level in the MAB. The NSB is metamorphosed to upper greenschist facies and the MAB to greenschist facies. Green amphibole (acinolite to hornblende) makes up 35 - 55 percent of the basaltic rocks in the NSB, but is uncommon in the MAB. As seen in Fig. 6.2.2, this formation is highly carbonatized as compared to the NSB.

2.2.3 Traverse No. 3: Talga River

Traverse No. 3 examines the same succession as traverse No. 2, and is located approximately 4 km to the northeast, along the west bank of the Talga River. Tholeiitic basalt and dolerite again predominate in the North Star Basalt. One sample of high-Mg basalt was collected near the base of the formation (Fig. 2.1.a) and a tremolite-chlorite ultramafic rock of peridotitic komatiite composition occurs at the 600 m level. In traverse No. 3 the McPhee Formation is represented by chert, banded iron-formation, pelite and carbonite schist. Above, the Mount Ada Basalt is similar to that in traverse No. 2, except for the additional presence of pyroxenite. One sample of high-Mg basalt was collected and andesite occurs 500 m below the top of the formation (Fig. 2.1.a).

2.2.4 Traverse No. 4: Sharks mining centre

Traverse No. 4 examines the same formations as traverses Nos. 2 and 3 and the lower part of traverse 1, and is located at Shark mining centre, 35 km southwest of Marble Bar. The North Star Basalt is similar to that on traverse No. 2, except for a greater proportion of dolerite and

gabbro, and greater prominence of epidote and sphene. High-Mg basalt occurs at the base of the Mount Ada Basalt (MAB) which otherwise consists of tholeiitic basalt, dolerite, gabbro and dacite. Thin units of pelite, chert and banded iron-formation within the MAB were sampled but not analysed. Fresh clinopyroxene is commonly preserved in basic rocks of the MAB.

2.2.5 Traverse No. 5: Camel Creek

Traverse 5 is located on the western side of Camel Creek, about 20 km south of Marble Bar, and provides a section through the Apex Basalt and the Euro Basalt. Tholeiitic basalt, high-Mg basalt and serpentinite alternate in the lower 250 m of the Apex Basalt, and are overlain by a 400 m-thick unit of extrusive peridotite (samples 49328 - 49332). Above the 650 m level is a 500 m-thick succession of commonly pillowed high-Mg basalt flows. The upper 350 m of the formation is composed of tholeiitic basalt, dolerite, chert and a laterally impersistent ultramafic unit. Primary textures are very poorly preserved in most of the rocks. However, some peridotite samples exhibit relict cumulate texture, and in high-Mg basalts acicular amphibole defines a palimpsest texture after spherulitic and quenched clinopyroxene.

The Euro basalt is composed of tholeiitic basalt, high-Mg basalt and dolerite. The lower 600 m of the formation was not sampled. It is inferred it includes a basal unit of peridotite, high-Mg basalt or possibly dolerite. Metamorphic recrystallization of the basaltic rocks has resulted in a relatively coarse-grained assemblage of tremolite, chlorite, clinozoisite and carbonate.

2.2.6 Traverse No. 6: Sandy Creek

Sandy Creek is situated about 50 km southeast of Marble Bar and provides a section through the upper part of the Duffer Formation (DF), the Towers Formation and the lower Apex Basalt (AB). Figure 2.1.b shows that much of the DF is composed of rhyolitic agglomerate and debris flow material. Intercalated with these coarse fragmental units are thinner members of dacite, dacite tuff and minor chert. The upper part of the Formation consists of debris-flow and cross-bedded tuffaceous units. All rocks of the DF are extensively altered and contain secondary epidote, clinozoisite and carbonate. Plagioclase phenocrysts are heavily clouded by sericite, which has totally replaced the feldspar of the groundmass.

The Towers Formation consists of silicified laminated rocks (possible original carbonates?), tuff and chert. Domal laminated structures (? stromatolites) and structures resembling ripple marks are well preserved. The contact between the Towers Formation and the overlying Apex Basalt is intruded by dolerite. Pillowed high-Mg basalt occurs at the base of the AB, and is intercalated with tholeiitic basalt at higher levels. The rest of the formation consists of pillowed tholeiitic basalt with minor dolerite. Pyroxenite and gabbro intrude the basaltic pile at the 650 m level. Some of the basalts are porphyritic with altered clinopyroxene phenocrysts, and some are vesicular.

2.2.7 Traverse No. 7: Spinaway Creek

Traverse No. 7 is located along Spinaway Creek, 15 km south of Sandy Creek, and provides a section through the central and upper parts of the Apex Basalt. The base of the traverse is defined by a unit of grey chert which occurs at the top of traverse No. 6. Thus, sample 49233 (traverse No. 7) is stratigraphically about 100 m above sample 49232 (traverse No. 6). High-Mg basalt occurs immediately above the grey chert and forms the bulk of the highest 400 m of the section (e.g. 49241 and 49242). Apart from two extensively silicified rocks the other samples from traverse No. 7 are similar to the tholeiitic basalts.

2.2.8 Traverse No. 8: Charteris Creek

The Charteris Basalt was sampled around the headwaters of Charteris Creek. Massive and pillowed tholeiitic basalt is intruded by dolerite and gabbro in the lower 500 m, whereas the higher succession is more heterogeneous with alternating units of pillow tholeiitic basalt, high-Mg basalt, dolerite, felsic lava and chert (Fig. 2.1.d). The high-Mg basalts exhibit a relict quench texture, chlorite pseudomorphs after needles of pyroxene being set in a feathery or plumose groundmass. The gabbros and dolerites show well preserved igneous textures. Both the volcanic and hypabyssal rocks possess original clinopyroxene, altering firstly to tremolite and secondly to chlorite. Except for the scarcity of peridotitic komatiites, the Charteris Basalt is lithologically similar to the Apex Basalt.

2.2.9 Traverse No. 9: Soanesville

The Honeyeater Basalt is well exposed along Honeyeater Creek, located about 70 km west-southwest of Marble Bar (Fig. 1.2). The traverse was made across both limbs of the Soanesville Syncline and the two sections are combined in Fig. 2.1.d. High-Mg basalt and dolerite occur in the lower and central parts of the formation, whereas at higher levels dolerite is intercalated with tholeiitic basalt. The central and upper parts of the formation are pillowed. Metamorphism is of very low-grade and several samples contain fine-grained pumpellyite and prehnite (e.g. 49378). Some of the basalts contain amphibole and serpentine pseudomorphs probably after hypersthene phenocrysts, the remaining minerals being augite and saussuritized plagioclase with minor chlorite, clinozoisite and epidote. Quartz is ubiquitous and thought to be chiefly secondary.

2.2.10 Traverse No. 10: Bowls Gorge

Traverse No. 10 is the type section of the Duffer Formation, and is situated at Bowls Gorge, 14 km north of Marble Bar. The lower 1000 m of the 3 750 m thick succession is chiefly composed of andesite with minor dacite and basalt. Thin basaltic units also occur at the 1 050, 1 600, 1 850 and 3 550 m levels. Upwards from the 1 050 m level, dacite becomes progressively more common than andesite, and fragmental units of agglomerate, tuff and debris-flow material predominate (Fig. 2.1.b). The upper 500 m of the Duffer Formation is composed of ignimbrite and well-bedded tuff, which in four samples is rhyolitic. The tuff commonly displays graded bedding, cross bedding and ripple marks, and has clearly been reworked by water action. The upward petrological change from andesite and basalt at the base of the formation to dacite and rhyolite at the top is accompanied by clearly defined geochemical trends (Fig. 6.4.1.).

2.2.11 Traverse No. 11: Wyman Well

The type area of the Wyman Formation is about Camel Creek, 3 km southwest of Wyman Well. Traverse No. 11 is situated on a northern tributary of Camel Creek and provides a 300 m section through columnar porphyritic rhyolite. The petrography of the rock is described in section 4.1.6.

2.2.12 Traverse No. 12: Emu Creek

The Wyman Formation at Emu Creek is represented by ultrapotassic (K_2O levels of 11.05 to 12.54 percent) rhyolite composed of quartz, K-feldspar and sericite. A parallel alignment of small laths of K-feldspar in the groundmass of the rhyolite imparts a trachytic texture. Secondary silica occurs in veins and clots.

2.2.13 Traverse No. 13L Budjan Creek

The Wyman Formation along Budjan Creek displays greater alteration than in traverses Nos 11 and 12. K-feldspar phenocrysts are almost entirely altered to sericite or muscovite, and silicification is widespread. Carbonate is also more conspicuous than in the other two traverses through the formation, although carbonate minerals form only 2-3 percent of the rocks sampled.

Figure 2.1

Key to symbols

---	Boundary uncertain
—┐—	Unconformity
—┐—	Intrusive contact
P	Proterozoic rocks
Gr	Granite rock
▧	Discordant intrusion
⊗	Porphyry
●	Pillow structures
▲	Agglomerate and debris-flow
□	Tuff
▬	Chert
▬	Shale
▧	Sandstone and siltstone
⊙	Rhyolite
▧	Dacite
▧	Andesite
□	Basalt
▧	Dolerite/gabbro
▧	High-rig basalt
▧	Pyroxenite
▧	Peridotite
▧	Altered ultramafic rock
1	Sample traverse

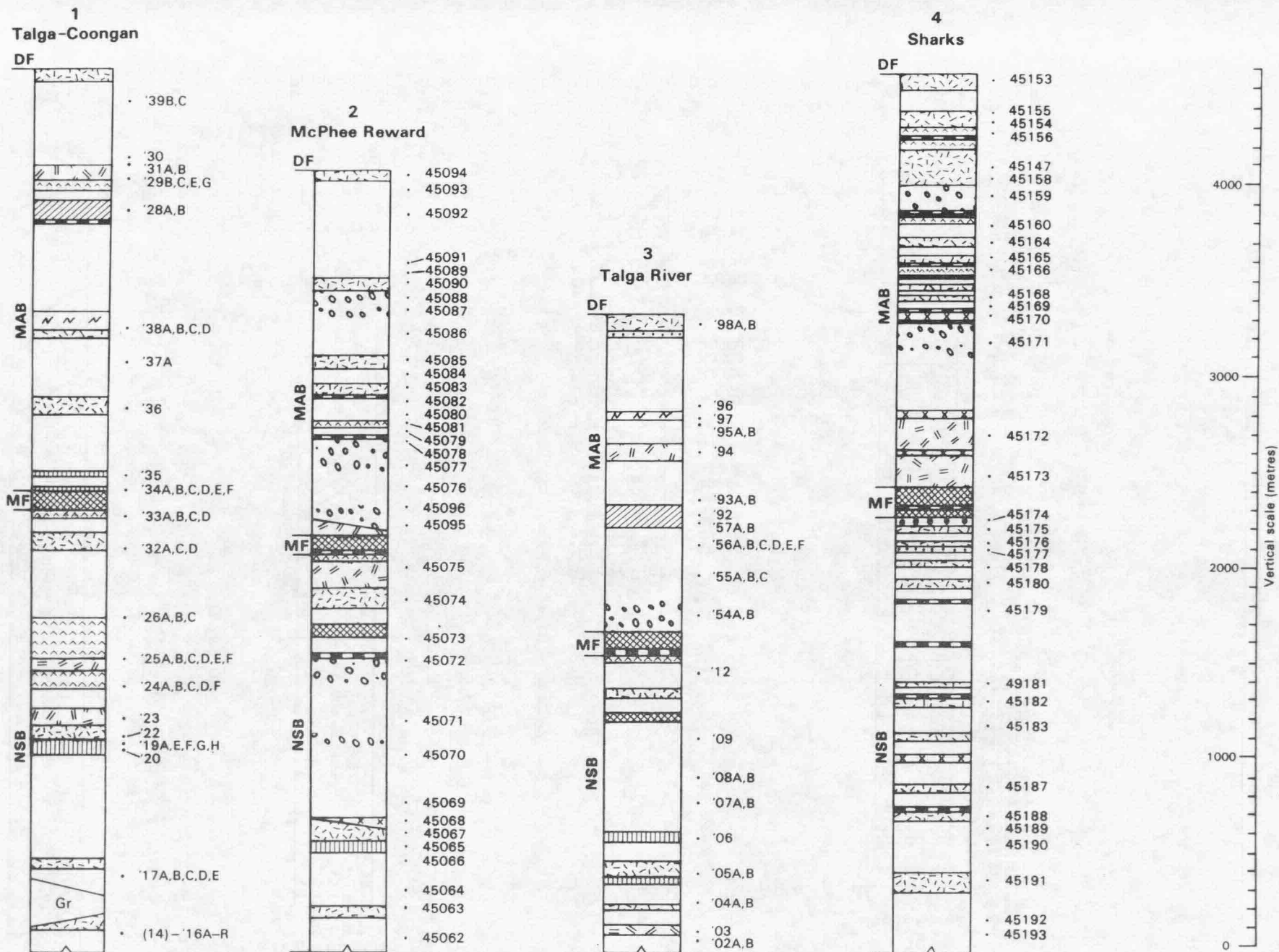


Figure 2.1.a Stratigraphic columns indicating position of samples
(for section position refer to Fig. 1.2)

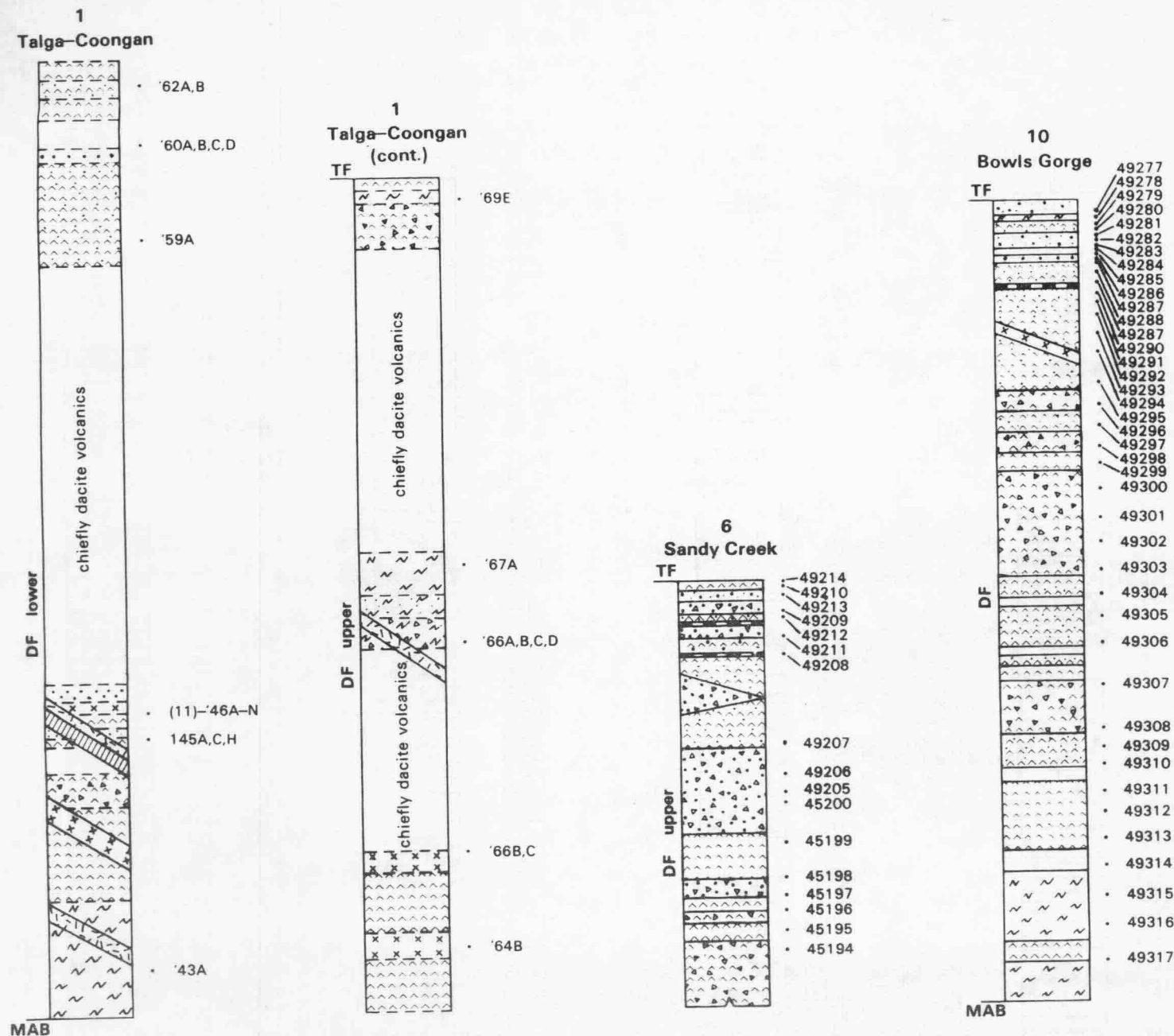
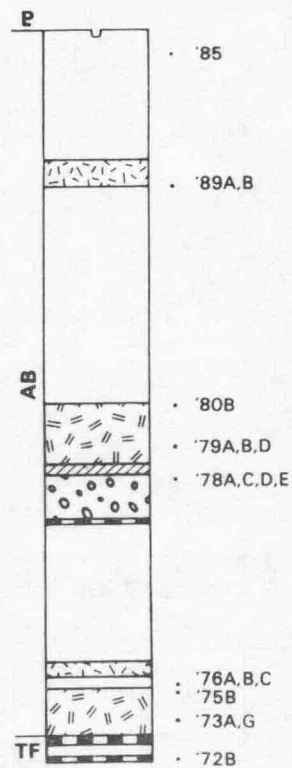
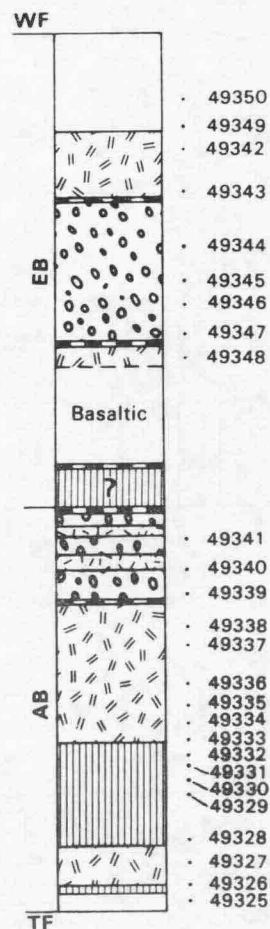


Figure 2.1.b Stratigraphic columns indicating position of samples (cont.)

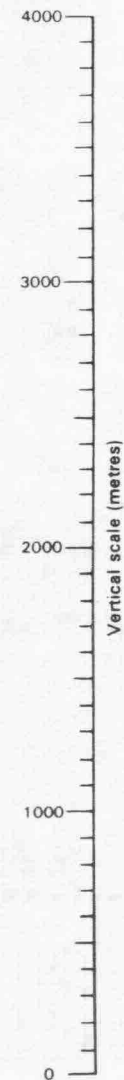
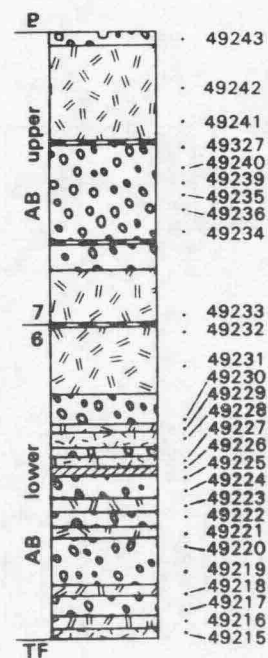
1
Talga-Coongan



5
Camel Creek



6-7
Sandy Creek-
Spinaway Creek



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Figure 2.1.c Stratigraphic columns indicating position of samples (cont.)

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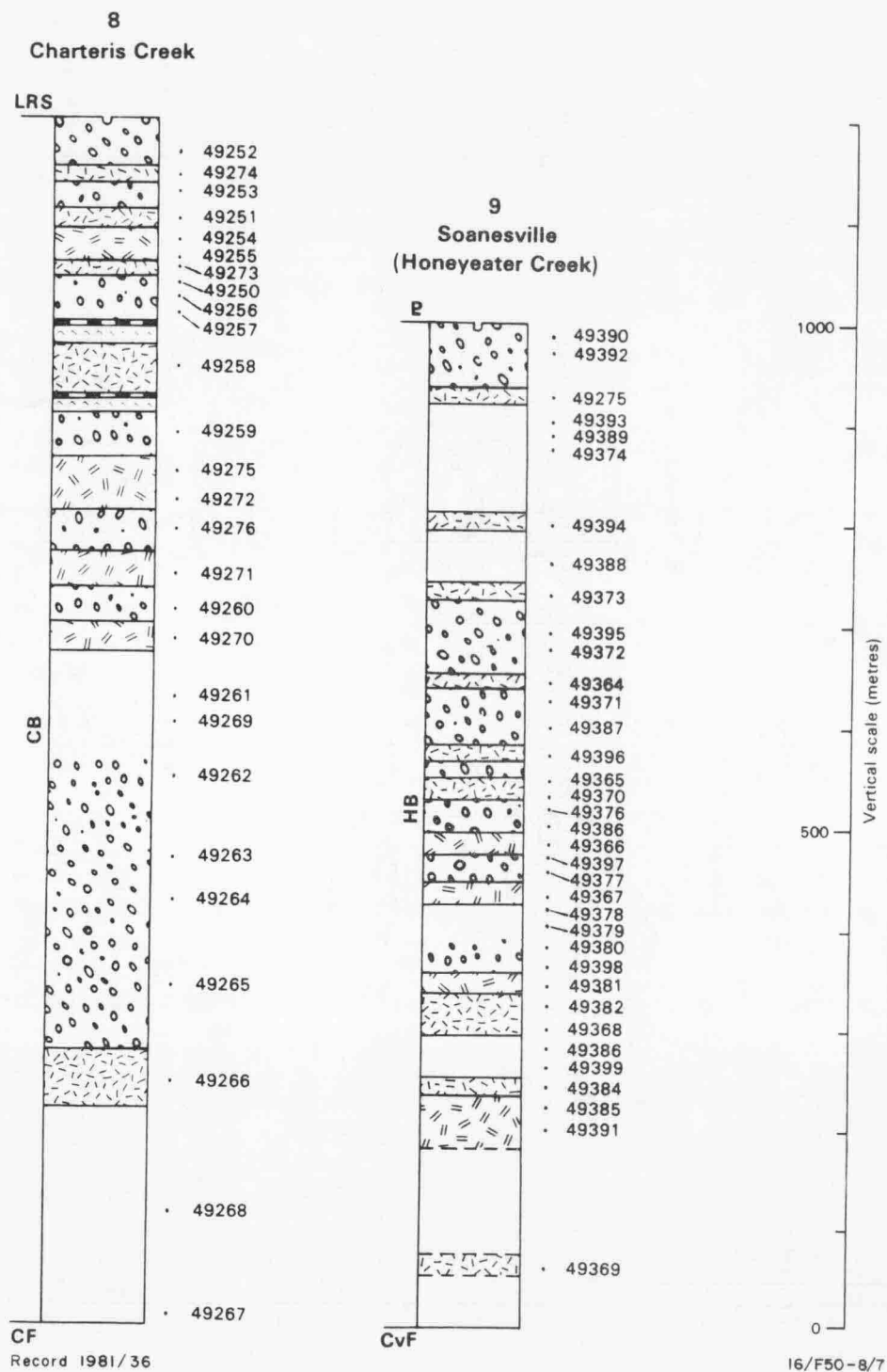


Figure 2.1.d Stratigraphic columns indicating position of samples(cont.)

3. METHODS

3.1 Sampling Procedures

Major considerations which controlled the planning of the geochemical sampling were (1) the size of the terrain - the Archaean outcrops in the Pilbara Block being about 60 000 km² in area; (2) the number of stratigraphic units to be sampled, i.e. eight main formations, and the lithological uniformity or variability of each unit; (3) degree of outcrop and the identification of field relations of the sampled material, i.e. the desirability of avoiding poor outcrops where possible; (4) avoidance of rock bodies juxtaposed with intrusive contacts or transected by shear zones, which may cause major secondary geochemical alteration; (5) the need to spread collections over a reasonably large area in order to obtain a regionally representative sample population, and (6) avoidance of any unforeseeable systematic bias. However, not all of these conditions can be met, and some of these requirements may only be achieved at the expense of other criteria. For example, whereas well-exposed sections allow detailed sampling on the outcrop scale - which results in a collection of a large number of samples relative to other areas - the area may be geochemically unrepresentative. If a representative sample suite from any particular area or unit is desirable, sheared contact metamorphosed and altered rocks must not be ignored, particularly as such rocks may form hosts of base- and precious metal mineralization. Any single sample collected from any one site may or may not be representative, especially where details of outcrop are obscured, a problem requiring multiple sampling in single localities. However, multisample-per-point collections may achieve different results from statistically-representative regular sampling at even distances along traverse lines. A major constraint is posed by the limits on the number of samples which could be analyzed in this study.

In the light of these difficulties, two sampling procedures have been applied in the present study:

- (1) Single sample per point collections at regular intervals across strike. Stratigraphic intervals of about 100 m were aimed at, but commonly intervals of 50-150 m applied, as allowed by outcrop and availability of suitable fresh samples.
- (2) Multiple sample per point collections at frequent intervals with preferred selection of least-carbonated, chloritized and sheared material. Number of samples per point varied according to the degree of exposure and lithological heterogeneity. In this procedure, sampling was controlled partly by geological criteria and partly by the need for regular coverage. Hydrochloric acid (10 mol) was used to screen highly carbonated rocks, which were sampled less frequently than uncarbonated rocks.

As shown by the results, the two methods prove mutually complementary, namely, the application of the first method allows a regional coverage to be achieved within the limits placed on the number of analyses, while the second method increases the proportion of least-altered samples and demonstrates the existence of outcrop-scale geochemical heterogeneities. Single point per sample traverses were carried out along the McPhee Reward, Bowls Gorge, Camel Creek, Shark Centre, Sandy Creek, Charteris Creek, Spinaway Creek, Emu Creek, Budjan Creek and Honeyeater Creek (Soanesville) sections (Fig. 1.2). Multiple sample per point sampling was conducted between Talga River and Coongan River north of Marble Bar and along Chinaman Creek west of this township (Fig. 6.2.1.).

Because of their fine grain size, volcanic rocks can be geochemically sampled by ca 0.5 kg specimens (Hutchison, 1974, p. 127). Considerably larger samples (1-2 kg) are generally derived from gabbroic and porphyritic rocks. These procedures were followed in this study.

3.2 Sample Preparation, Analytical Methods, Accuracy and Precision

The BMR rock specimens were broken down in a jaw crusher. 1-3 cm large chips were selected, avoiding any red-coloured and discoloured material affected by weathering and joint-related alteration effects. The fresh chips were recrushed and possibly contaminated dust finer than 5 mesh was sieved away using compressed air jet. The cleaned chips were rechecked for discoloured fragments and milled in tungsten carbide vessels for about 1 minute. Sample batches intended for Co analysis were pulverized in steel chrome vessels. It is estimated that, by the above selection, sieving and cleaning procedure, about 99% of the visibly discoloured altered material was removed. Although this cleaning procedure involves loss of finer dust fractions, and is thus unsuitable for coarse grained rocks, it is considered appropriate for fine grained volcanic rocks where chip/grain size ratio of 500 or higher apply. Because the metadolerites and metagabbros included in the volcanic suites are strongly recrystallized and thus mineralogically homogenized, the same procedure was also applied to these rocks. The GSWA rock specimens were cleaned in the field. The method used was to select a large (up to 30 kg) sample, typical of the locality and as free as possible of vein and weathered material, and break this until a 1-2 kg fresh, unveined sample was obtained. No composite samples were collected. In the laboratory a 100 gm sample was taken for thin section work and future reference while the remainder of each specimen was crushed and milled; no fine material was removed. Samples 45062 - 45096 were powdered using an agate mortar, and other GSWA samples were powdered in a tungsten carbide mill.

Chemical analysis were conducted in three batches:

batch no. 1: 194 samples from the Marble Bar area (collected in 1975);
batch no. 2: 35 samples from McPhee Reward (collected in 1975);
batch no. 3: 235 samples (collected in 1976).

The analytical work was carried out partly in the BMR laboratories and partly by AMDEL (Australian Mineral Development Laboratories), as follows:

	silicate analysis	XRF trace elements	AA trace elements	CO ₂ & S
batch no. 1 -	BMR	BMR	BMR	AMDEL
batch no. 2 -	BMR	BMR	BMR	AMDEL
batch no. 3 -	AMDEL	BMR	BMR	AMDEL

Si, Ti, Al, Fe (total as Fe₂O₃), Mn, Mg, Ca, Na, K, P, Ga, Rb, Sr, Y, Zr, Ba, La, Ce, Pb, Th, and U determined in the BMR laboratories were measured using a Philips PW-1210 automated X-ray spectrometer (analyst - J. Pyke). Major elements (except for Na) were determined on fusion discs, and Na₂O and trace-elements on pressed powder pellets according to the methods of Norrish & Hutton (1969)² and Norrish & Chappell (1967). Direct measurements of mass-absorption coefficients were made with each sample and empirical interfering element corrections were made where necessary. Detection limits (Table 3.1) were calculated at the 95 percent confidence level using the relation given by Jenkins & deVries (1967). The effects of machine drift were eliminated by relating each element to a reference standard. Each determination was carried out in duplicate, and was repeated if significant differences between the readings occurred. Precision control was further achieved through concomitant readings of BMR standards calibrated against international standards with each sample batch (Table 3.2). Accuracy controls were obtained through parallel analyses of international standards (Flanagan, 1973) (Table 3.3). The most severe discrepancies are observed near lower detection limits. For this reason, the lithophile element abundances in the ultramafic volcanic rocks are subject to larger errors. To help to assess the accuracy of AMDEL's X-ray fluorescence spectrometry results, Table 3.4 compares results obtained by this method with those from rapid chemical and wet chemical methods performed on the international standard BCR-1. Comparisons between AMDEL's and BMR's major elements X-ray fluorescence results are given in Table 3.2.

Li, Cr, Co, Ni, Cu, and Zn were determined by atomic absorption spectrometry in the BMR laboratories (analysts: T. Slezak, J. Fitzsimmons) using a Varian-Techtron spectrophotometer. Precision and accuracy comparisons are given in Tables 3.2^c and 3.3, respectively. CO₂ and SO₃ were determined on all samples by AMDEL. CO₂ was determined by acid treatment and gravimetric measurement. The precision up to 3.0% absolute is $\pm 0.05\%$; between 3 and 6% absolute it is $\pm 0.1\%$, and over 6% absolute it is $\pm 0.25\%$. SO₃ was determined by combustion in a tube furnace and volumetric measurement. Estimated precision is $\pm 0.01\%$ for less than 0.1% S, and $\pm 0.03\%$ for 0.1 - 1.0% S.

3.3. Computing Methods

Major and trace-element data and relevant sample information (number, formation, rock type, mineralogy, locality) were stored on magnetic tape cartridges using a Hewlett-Packard 9825A desktop calculator, and on Hollerith punch cards. A Storage and Retrieval program (author: M.J. Owen) was used in conjunction with the HP system, applying integer-precision data storage in 1380-byte size strings. Every string accommodates 10 analyses, each retrievable according to any chosen search word in an alpha-numeric 70 word large title group. The program allows modifications and corrections to be carried out and forms the basis for all subsequent data manipulations, tabulation and plotting, the two latter achieved using the HP9871A printer and HP9872A plotter. The punch cards were used in conjunction with the CSIRO Cyber 76 computer.

A series of BASIC programs written for the HP9825A (+ peripherals) system by M.J. Owen were used to obtain sample statistics, XY and XYZ plots, regression analysis, CIPW norms, CIPW plots, and related petrochemical indices. In addition, a series of petrological and special plot programs were written by A.Y. Glikson. The geochemical and petrochemical principles underlying these programs are discussed in relevant sections of this report. In the following, the principal features of each program are summarized:

Tabulation: The chemical data and relevant titles (sample number, rock type, mineralogy, location) are tabulated vertically as 10 analyses per-sheet, as retrieved from tape storage according to any title group specification, allowing deletion of unrequired data.

Mean, Standard Deviation, Maximum-Minimum values and Correlation Coefficients: Samples are retrieved according to chosen search words and are sequentially printed along with maximum and minimum values for the group, mean, S.D. and the number of samples (Appendix II). Printouts of major/major, major/trace and trace/trace element correlation coefficients follow - only values greater than 0.5 or less than -0.5 being printed.

X-Y Plots and Linear Regression: Samples are retrieved from individual data files to a 15000 bytes master file according to selected parameters, and plotted on chosen scale, pen colour and symbol type. A and B parameters can be specified as single values, $A+B$, $A-B$, $A*B$, A/B , $A/\text{constant}$, $\log A$ and/or $\log B$, and major element A divided by trace element B. Regression line is plotted, equation printed, and confidence limits outlined. Accompanying printouts provide the following sample statistics: mean A and mean B; variance and S.D. for A and B; regression line slope and standard error; regression line intercept and standard error; correlation coefficient; sum of squares; degrees of freedom; mean square; F-test statistics.

X-Y-Z Plots: Samples are selected as for the XY plots program and are plotted on chosen scale, pen colour, and symbol type, either as single values or combinations as for the XY program.

CIPW Norm: The norm calculated according to Hutchison (1974) is printed, along with oxide weight percent, cation percent, plagioclase an%, Si index (Chappell & White, 1974), Differentiation Index, Solidification Index, Crystallization Index, total Fe and FeO, K_2O/Na_2O , and Mg number ($100MgO/(MgO+FeO)$ in mol%). Fe_2O_3 for norm calculation is calculated as 0.2 of total iron. Sample information is printed above each norm.

CIPW Plots: Normative values are calculated and plotted in chosen combinations as for the X-Y and X-Y-Z Plot Programs.

The following programs were written by A.Y. Glikson in conjunction with this project:

Frequency Distribution Plots: Data for a chosen chemical element or element/element ratio are retrieved according to chosen search words, a frequency distribution or percent frequency distribution is calculated, and a curve plotted according to chosen line type. Cumulative frequency curves can also be plotted. A legend is printed whereby each group is denoted by a corresponding title and line-type symbol.

Geochemical-Stratigraphic Columnar Plots: The stratigraphic level (in metres) of each sample is stored as part of the title group of the respective analyses. The program retrieves these values and plots the abundance of any chosen element or element/element ratio (X-axis) against the corresponding stratigraphic level (Y-axis) on a columnar diagram. The plot symbol corresponds to the rock type as identified from the title group.

LMPR (Log molecular proportion) Plots and Deviation Indices: The program plots $\log$ (Major element A/K_2O) versus $\log$ (Major element B/K_2O) (Beswick & Soucie, 1978), and calculates any deviation in $\log$ units from the least-altered modern field limits for the particular type of plot (section 5). Field limits data are stored in the program. The printed deviation indices facilitates screening of chemically anomalous and probably altered rocks. The latter are then coded in the title group of stored analyses and thus can be avoided in programs concerned with primary igneous characteristics of the rocks.

Chondrite-Normalized Element Ratio Curves: The program calculates the ratios of any chosen sequence of elements relative to chondritic abundance (or any other reference values) and plots them as curves, facilitating comparisons.

Mantle Mg Number from FeO-MgO Plots: From these plots (in mol%) the pyrolite liquidus temperature (T) and fraction partial melting (F) are read from a grid by Hanson & Langmuir (1978) (Fig. 10.2), and entered from keyboard. The following output is calculated and tabulated: MgO(mol%), FeO(mol%), Mg number ($100MgO/(FeO+MgO)$) of the sample, F read from 0 kb grid, F read from 30 kb grid, T read from 0 kb grid, T read from 30 kb grid, MgO(mol%) of mantle source, FeO(mol%) of mantle source, FeO(mol%) of mantle source, mantle Mg number, F value obtained by FeO-MgO mass balance, F value obtained by Zr-based calculation. The F value used for derivation of mantle Mg number is applied by mass-balance, since this corresponds most closely to experimental results of A.L. Jacques (pers. comm., 1980). Samples which plot outside the primary melt field are marked by a corresponding statement on the output (section 10.2).

Mantle Trace-Elements Abundance: The program calculates mantle-source levels for any given trace element using procedures outlined in section 10.2. The fraction of partial melting (F) is calculated by $(FeO+MgO)$ mass-balance. The norm of refractory residues is calculated from the difference between the analysis and pyrolite composition, and the bulk-partition-coefficient (Kd) of the residue calculated by averaging cited mineral/melt partition coefficients (D) according to the norm. Tabulated outputs list the sample trace-element level, mantle trace-element level, F, normative residue (Ol, Opx and Cpx), and bulk K_d values.

Fractional Crystallization and Primary Magma Trace-Element Levels: The program is based on Allegre & others (1977) method for derivation of bulk-distribution-coefficients Kd from $\log e$ versus $\log i$ (e - trace-element; i - incompatible trace-element) plots (section 10.1). Degrees of fractionation (F) are obtained from ratios of assumed primary i element level / determined i element level in rocks. Rayleigh's Nonequilibrium Law is applied. Output lists for the selected element give: (1) trace-element abundance in the rock; (2) trace-element abundance in the primary magma; (3) liquid fraction (F); (4) norm of residual cumulates (Cpx, Opx, Ol, Il, Plg), and calculated bulk-Kd (in addition to the value read from $\log e - \log i$ plots). The norm of cumulates is obtained assuming the major-element composition of the parent-magma and calculating the difference from the analysis by mass-balance.

General Equilibrium Partial-Melting: For a given rock analysis and an assumed source-rock major element composition, the program calculates the norm of refractory residues (Cpx, Opx, Ol, Pl) and deficiencies of SiO_2 and K_2O . The fraction of melting (F) is derived by calculations based on an incompatible element such as Zr (section 10.4). The program is particularly suited for modelling derivation of dacite-rhyolite magma by partial-melting of basic source rocks.

The following programs were applied to Pilbara data using the Cyber 76 computer:

- (1) R-mode Factor Analysis, documented in Dixon (1971), and using an oblique rotation method by Hendrickson & White (1964) (not reported here).
- (2) Cluster Analysis, documented by Bonham-Carter (1967).
- (3) QMAS Tetrahedron Program, documented by Lenthall & others (1974) (not reported here).

4. PETROGRAPHY

The volcanic and hypabyssal rocks analysed in this study range in composition from peridotitic komatiite to ultrapotassic rhyolite. The mineralogy of individual samples is indicated in the titles of individual analyses (Appendix I).

4.1 Petrographic/petrochemical nomenclature

In view of the metamorphosed state of the volcanic rocks, involving replacement and/or recrystallization of the bulk of the original igneous mineralogy, the nomenclature used in this report is mainly based on (1) relict igneous textures and (2) geochemistry. In the following, definitions are given of the volcanic and hypabyssal rock types described in this report. Although the prefix "meta" is not used, all the rocks discussed below have been metamorphosed.

4.1.1 - ultramafic and mafic rocks

Peridotitic komatiite (PK): Porphyritic and/or quench-textured (spinifex-textured) volcanic rock with higher than 20% MgO.

High-Mg basalt (HMB): Porphyritic, aphanitic or quench-textured volcanic rock with MgO between 10%-20%, or MgO between 8%-20% if MgO/Al_2O_3 greater than 0.6.

Pyroxenite (PYX): Cumulate-textured rocks with relict pyroxene or pseudomorphs of amphibole after pyroxene and compositional range of high-Mg basalts.

Tholeiitic basalt (TB): Amphibolite or epidote-chlorite rocks with porphyritic or intergranular texture, compositional range with less than 10% MgO (or less than 8% MgO if MgO/Al_2O_3 is greater than 0.6). Either normative quartz or normative olivine may be present. The boundary with andesite is defined at 55% SiO_2 .

High-Al basalt (HALB): as for TB, with Al_2O_3 higher than 16%.

Dolerite (D): Medium-grained amphibolite with ophitic or subophitic texture; compositional range as for TB, HALB or HMB.

Gabbro (G): Coarse grained amphibolite with ophitic texture; compositional range as for TB, HALB or HMB.

4.1.2 Silicic and intermediate rocks

A classification of silicic volcanic rocks was conducted on the basis of the An-Ab-Or ternary (O'Connor, 1965) and SiO_2 values (Fig. 4.1). The following definitions apply:

Na-rhyolite: Ab/An higher than 3; SiO_2 above 70%

Na-dacite: Ab/An higher than 3; SiO_2 60-70%

Dacite: Ab/An of 3 to 1; SiO_2 60-70%

Ca-dacite: Ab/An less than 1; SiO_2 above 60%

Andesite: Ab/An less than 1; SiO_2 55-60%

Rhyodacite: Ab/An less than 3; Or/Ab between 2.3-4

Qz latite: Ab/An less than 3; Or/Ab between 1-2.3

K-rhyolite: Ab/An higher than 3; Or/Ab higher than 2.3; SiO_2 above 70%

K-dacite: Ab/An higher than 3; Or/Ab higher than 2.3; SiO_2 between 60-70%.

4.2 Peridotitic komatiite

Peridotitic komatiite, with MgO higher than 20% and textures similar to those described from the type locality of the Barberton Mountainland, South Africa (Viljoen and Viljoen, 1969), was sampled in the traverses at Camel Creek (Apex Basalt), Talga River (North Star Basalt) and Pyramid Well (Mount Ada Basalt). Elsewhere in the Pilbara such rocks are known to occur within the Euro Basalt at Pilbara well (Hallberg, 1974; Fitton and Fitton, 1976) and in the Talga-Talga Subgroup at Ruth Well (Tomich, 1974; Hallberg, 1974). At Camel Creek, massive fine-grained peridotite forms a 400 m-thick pile passing upwards into high-Mg basalt (Fig. 2.1c). Microscopic examination reveals large olivine crystals set in a matrix of tremolite, chlorite, clinozoisite, carbonate and opaque oxides. Lower levels of the succession are extensively serpentinized. At Talga River and Pyramid Well the rocks consist of tremolite, serpentine and chlorite with variable carbonate. Although the general chemistry of the Pilbara peridotitic komatiites is similar to that of the Onverwacht Group of South Africa, normative Q-Op-Cp-Ol plots suggest a possible original predominance of clinopyroxene over orthopyroxene in the Pilbara rocks (cf. Fig. 9.3 with Fig. 1 of Glikson, 1979).

4.3 Pyroxenite

Pyroxenites were described from the NSB, MAB, DF and AB units. They correspond to the compositional range of high-Mg basalt (Section 4.4) but display distinct cumulate texture. The rocks consist mostly of partly or completely altered equant medium-grained clinopyroxene and/or actinolite-tremolite pseudomorphs after pyroxene set in microcrystalline matrices of amphibole, chlorite, plagioclase leucoxene and opaque iron oxides. Porphyroblastic pseudomorphs may occur. Some of the least altered pyroxenites are recognized in the MAB, where fresh clinopyroxene and leucoxene-altered sphene abound. Some pyroxenites contain ophitically-enclosed saussuritized plagioclase, approaching gabbroic compositions. The pyroxenites are interpreted as coarsely crystallized hypabyssal equivalents of the high-Mg basalts, and in some instances ultramafic bases of dolerite sills.

4.4 High-Mg basalt

High-Mg basalt, although defined chemically (section 4.1), can generally be distinguished by textural and mineralogical criteria. The principal constituents are typically tremolite and chlorite and the rocks exhibit quench-like textures with intermeshing skeletal or dendritic blades of tremolite as pseudomorphs after pyroxene, or serpentine as pseudomorphs after olivine. Original clinopyroxene, and less commonly orthopyroxene, are locally preserved in the Apex Basalt, Euro Basalt and Honeyeater Basalt. Plagioclase is less abundant than in tholeiitic basalt. Secondary alteration products such as clinozoisite, epidote and carbonate are similar to those in tholeiitic basalts. Apart from texture (metamorphism of tholeiite locally produces a somewhat similar texture) high-Mg basalt can commonly be distinguished from tholeiitic basalt in the field by virtue of its darker green colour. Some high-Mg basalt is pillowed, as at Camel Creek, Sandy Creek, Chinaman Creek and Marble Bar Pool, and variolitic textures are locally present.

4.5 Tholeiitic basalt, dolerite and gabbro

As shown in Table 1.1 - basalt, dolerite and gabbro collectively comprise about 60 percent of all samples and almost 80 percent of six of the volcanic formations. These proportions are considered representative of the actual composition of the volcanic succession of the Pilbara Supergroup, since in most cases sampling was conducted at regular intervals across strike.

Pillow basalt appears to be more common in the Pilbara Block than in the Yilgarn Block, and is particularly well developed in Apex Basalt and Euro Basalt, which also contain numerous thin chert units. However, it is possible that this impression is obtained due to poor outcrop and surface retention of pillow structures in the Yilgarn Block. The pillow structures generally fit closely together and are separated by interstices filled by dark aphanitic material. The pillows range in size up to about 3 m in diameter and 1.5 m in vertical depth. Cross-sections are variously lenticular, planoconvex and concavoconvex and in three dimensions the structures are discoid, balloon-like, sausage-shaped or T-shaped. Stratigraphic tops are generally convex whereas bases are flat, concave or form cusped 'tails'. Some pillows appear to have burst shortly after formation and are connected to smaller pillows formed by the exuded lava. Radial jointing is common and varioles and vesicles are clustered close to pillow margins, tending to be most numerous toward pillow tops (a feature also noted by Henderson, 1953). Vesicles are commonly elongate or tubular, long axes radiating from the pillow cores, and may be partly or completely filled by quartz, chalcedony or calcite. Each pillow possesses a chilled, grey-green cryptocrystalline 'skin', about 2 to 10 mm thick. On its outer surface this skin may be smooth, spotted with spherules or polygonally cracked. Grain size increases towards the cores which consist of acicular amphibole and xenoblastic plagioclase. On weathered surfaces pillow cores are normally the darkest parts of the structures, but pale spotting is produced by patchy concentrations of feldspar. Interstitial material occupying the spaces between the pillows is composed of crystalline chloritic rock, palagonite, chert or altered tuff. The best exposures of pillow basalt occur at Marble Bar Pool, Chinaman Creek and Sandy Creek, although virtually all traverses include some pillow lava.

Flows of massive basalt can be difficult to distinguish from sills of dolerite; indeed the distinction is probably not important because most of the sills appear to be cogenetic and penecontemporaneous with the surrounding volcanics, an interpretation supported by geochemistry. It is possible that some of the dolerite and gabbro are coarsely crystallized central portions of thick slowly cooled basalt flows. Systematic traverses across basalt formations have revealed that, on the basis of petrographic criteria, up to 30 percent of such formations is composed of stratiform dolerite or gabbro. Sills are most numerous in the oldest part of the succession, the Talga Talga Subgroup.

Massive basalt typically forms darker outcrops than pillow basalt partly because of coarser grain size and less alteration. Alteration visible in the field includes silicification and carbonatization, both features being more pervasive in pillow lavas. Massive basalt is generally jointed at 0.5 to 2 m intervals. A rectilinear to polygonal joint system is developed normal to bedding and another set is oriented parallel to bedding. Vertical joint surfaces are commonly lined with calcite, which also veins the lavas along discontinuous cracks. Columnar jointing is uncommon and poorly developed.

Microscopic examination reveals that the basaltic rocks have been partly to completely recrystallized by greenschist-to-amphibolite facies metamorphism. Relict clinopyroxene phenocrysts are locally preserved but more commonly replacement by amphibole is complete. Plagioclase is extensively saussuritized, original labradorite or andesine having been replaced by albite. Lime and alumina released by this process have probably contributed to the formation of secondary amphibole, epidote, clinozoisite and prehnite. Mineral assemblages generally consist of amphibole (actinolite, tremolite, or hornblende), quartz (largely secondary), albite, epidote, chlorite and minor sericite, sphene, clinozoisite, carbon minerals, opaque oxides, prehnite and pumpellyite. Texture ranges from microporphyritic, ophitic or subophitic, in which microphenocrysts of pyroxene are set in a fine-grained to microcrystalline intergranular groundmass of pyroxene, plagioclase and minor quartz. Advanced recrystallization produces crystalloblastic aggregates of metamorphic minerals. Actinolite, forming anhedral, commonly fibrous aggregates up to 2 mm long, usually makes up over half the rock. Interstitial material includes fine-grained albite accompanied by flakes of amphibole and small porphyroblasts of epidote. Ilmenite is replaced by leucoxene and sphene. Vesicles are infilled by chlorite, carbonate, quartz, feldspar and rare apatite.

Bodies of metadolerite and metagabbro generally show less alteration, veining, jointing or foliation than adjacent basalt lava flows, and consequently are more resistant to weathering. They crop out as low ridges or scarps fringed by boulders and large angular blocks. Most metadolerite sills are only a few metres thick and grain-size is relatively fine. Larger bodies exhibit coarser grained centres and some gabbro sills are over 100 metres thick. Evidence of transgressive intrusive contacts is rare, but as yet the sills have not been studied in detail. Dolerite dykes abound in certain areas, for example between Marble Bar and Talga Talga, and many of these may constitute feeders to the stratiform intrusions.

Ophitic and subophitic textures are well preserved in many samples of metadolerite, and primary clinopyroxene, orthopyroxene and plagioclase are locally retained. The mineralogy is essentially secondary, orthopyroxene being replaced by serpentine and amphibole, clinopyroxene by amphibole and chlorite and plagioclase by saussurite with varying amounts of chlorite, albite, sericite, and calcite. Quartz dolerite is common, especially in the Apex Basalt and Honeyeater Basalt. Despite alteration, such as saussuritization and carbonatization, original textures in gabbro are generally well preserved. Clinopyroxene is variably replaced by actinolite or hornblende and orthopyroxene by serpentine. Cumulate textures are present in some sills (e.g. 45158). Plagioclase is saussuritized and epidote, carbonate and sphene are commonly important constituents. Quartz gabbro and norite occur in some areas.

Tectonic deformation and thermal metamorphism have locally transformed basalt and stratiform dolerite into mafic schist or into massive, medium-grained, granular, totally recrystallized amphibole-plagioclase rock. The rocks vary from green to almost black; plagioclase may be visible in hand specimen but in many samples is difficult to detect due to clouding.

The observed mineralogy of recrystallized amphibolites is largely secondary. In thin section massive amphibolite consists of randomly oriented assemblage of variably altered plagioclase (original composition generally labradorite) and pyroxene pseudomorphed by hornblende and/or actinolite which may enclose relics of the primary mineral. Glikson (1972b, p.167) attributed similar replacement in dolerite of the Kalgoorlie area to either late magmatic uranization and metamorphic replacement upon which alumina released by saussuritization of plagioclase contributes to the conversion of pyroxene to hornblende and of secondary actinolite to hornblende. Lime and silica released by uranization are represented by calcite and quartz, although calcium may be partly taken up in the conversion of ilmenite to sphene which is typically cored by relict ilmenite. Minor components of amphibolite include chlorite, apatite, phlogopite, rutile and opaques. Some fine-grained massive amphibolite (metabasalt or metadolerite) consists of a mosaic of green hornblende, diopside and altered plagioclase. Large crystals of hornblende may contain cores of relict pyroxene, clinozoisite, granular sphene (after ilmenite), quartz and chlorite. Scapolite is a rare constituent. Amphibolite schist is strongly foliated and consists chiefly of felted to granoblastic actinolite or hornblende with subordinate plagioclase, chlorite, epidote, and minor quartz, opaque oxides and carbonates.

4.6 Andesite

Andesite was collected from the North Star Basalt, Mount Ada Basalt, Duffer Formation and Apex Basalt, but is relatively uncommon. Many rocks outwardly resembling andesite are, in fact, altered basalt, and their major elements geochemical classification, based mainly on SiO_2 content, almost certainly includes some silicified basalts in this category. Examples include rocks from the upper part of the Duffer Formation, the Towers Formation and the Apex Basalt near Marble Bar Pool which contain vanadium in excess of 200 ppm and Ni between 100-300 ppm. Likely authentic andesites occur within the Duffer Formation, and less commonly within the upper part of the North Star Basalt and the Mount Ada Basalt. Chief mineral constituents are plagioclase, amphibole, rare relict pyroxene and varying amounts of albite, epidote, chlorite, quartz and carbonate. Saussuritization and carbonatization are widespread.

4.7 Dacite

The majority of dacite samples were collected from the Duffer Formation, while eight were obtained from the upper part of the North Star Basalt, two from the Mount Ada Basalt and one from the Apex Basalt. In the Duffer Formation most dacitic rocks are crystal lithic tuffs and consist of coarse euhedral albite laths, up to 3.5 mm long, commonly fractures and broken, autolithic fragments and minor anhedral quartz grains set in a groundmass of quartz, albite, sericite and minor epidote, chlorite and opaque oxides. All sections include moderately well preserved vitric tuff units containing devitrified glass shards (now chlorite), and such rocks are particularly well developed in the Bowls Gorge section. Concentrations of plagioclase crystals commonly gives rise to weakly defined layering. Common throughout the pyroclastic units are plagioclase-phyric dacite flows in which small microlites of plagioclase define a flow structure. Although the rocks of the Duffer Formation have undergone weak metamorphism to greenschist facies primary textures are well preserved. Alteration includes carbonatization and widespread replacement of plagioclase by sericite.

Dacite from other formations is generally porphyritic, showing plagioclase phenocrysts set in a groundmass of quartz, sericite, chlorite and amphibole. Two of the samples (75040024 E and 75040078 D) could be interpreted as altered basalt on the basis of their high ferromagnesian trace element composition.

4.8 Rhyolite

With the exception of a rhyolitic schist sample (45174) from the North Star Basalt, all samples of rhyolite analysed came either from the Duffer Formation (22) and the Wyman Formation (23).

Rhyolite occurs in all traverses through the Duffer Formation but, with the exception of some samples from Sandy Creek, is less potassic than the Wyman Formation and is generally represented by pyroclastic rocks rather than massive lava. Alteration is more extensive than in the Wyman Formation, with sericite, epidote, clinozoisite and carbonate being common. Fine-grained tuff is generally bedded and laminated, and lava exhibits flow-banding. Some of the samples provisionally classified as rhyolite (e.g. 750400100 A and B) possess unusually high concentrations of trace elements normally associated with mafic rocks (e.g. V, Cr and Ni), and probably represent metasomatized basalt or andesite.

The Wyman Formation is composed almost entirely of rhyolite. Corroded phenocrysts of beta-quartz and euhedral phenocrysts of K-feldspar are set in a groundmass of quartz, simply-twinned K-feldspar and sericite with minor epidote and carbonate. K-feldspar phenocrysts are commonly perthitic and may have been anorthoclase inverted to microcline and exsolved sodic plagioclase. K-feldspar is partly altered by sericite. The quartz phenocrysts are embayed and partly resorbed and are surrounded by corona of microcrystalline feldspar. As discussed later, these rhyolites are similar to elvan-type quartz porphyrities described by Henley (1972). Sericite and laths of K-feldspar in the groundmass commonly exhibit a parallel alignment corresponding to flow-banding visible in hand specimen. Rhyolites from Emu Creek show a perlitic texture, and secondary silica in the form of veins and clots is a feature of samples from both Emu Creek and Budjan Creek.

5. DISTINCTIONS BETWEEN IGNEOUS AND SECONDARY COMPOSITIONS

The single most difficult question inherent in geochemical studies of metamorphosed volcanic rocks is the discrimination between primary (igneous) and secondary (post-consolidation) element distribution patterns. Secondary migration may be due to lava-surface water interaction, burial metamorphism and attendant hydrous alteration, thermal metamorphism, attendant metasomatism, and/or dehydration (Vallance, 1960, 1967; Walker & others, 1960; Smith, 1968, 1969; Hart, 1971; Miyashiro, 1972; 1973; Jolly & Smith, 1972; Smith & Smith, 1976; Condie & others, 1977; Glikson & Derrick, 1978; Glikson, 1979). As shown in this study, the composition of basalts, dolerites and gabbro are very similar. Since the hypabyssal rocks did not come in contact with surface water, this suggests that, in the main, alteration is of metamorphic origin. Because of the differential nature of open-chemical redistribution behaviour of the various elements, namely mobility of alkali and alkaline earth elements compared to relative stability of some lithophile and ferromagnesian elements (Smith & Smith, 1976; Condie & others, 1977; Sun & Nesbitt, 1978a), references to rock-bodies as "fresh" or "altered" must be qualified with respect to the element in question. In this report rocks are defined as "least altered" or "altered" on the basis of their major-element characteristics as revealed on LMPR (log molecular proportion) plots (Beswick & Soucie, 1978). Because of the variability of both the original igneous chemistry and superposed alteration effects, it is not possible to determine the primary composition of any individual altered rock. However, comparisons between altered suites and least-altered modern volcanic rocks whose primary mineral assemblages are little modified are significant to the identification of the degree of alteration of the metamorphosed suites. Beswick & Soucie (1978) have shown that least-altered modern oceanic, arc-trench, and calc-alkaline volcanic rocks plot within well-defined fields on log (major element A/alkali element) vs log (major element B/alkali element) plots. In this study, the following criteria are used to discriminate degrees of alteration:

- (1) The mineralogy of the rocks and the proportion of phases formed by addition of H_2O or CO_2 , which may have been associated with introduction and removal of other elements. The most important indicators in this regard are carbonate, sericite, chlorite, epidote, and prehnite.

- (2) The data were plotted on LMPR diagrams and compared to least-altered modern volcanic fields (Fig. 5.1) (see discussion in section 5.1 regarding the validity of such comparisons). Using a computer program (section 3.3) the deviation of anomalous samples from the modern field boundaries are measured and such samples are accordingly denoted as "divergent". The corresponding analyses are marked in the title groups of the storage files, given distinct symbols on subsequent XY and XYZ plots, and screened out in calculations relating to igneous petrogenesis. The differences between "divergent" samples and those which fall within least-altered modern fields can thus be further examined by means of major and trace-element relations.
- (3) The degrees of concentration/scatter of sample populations on frequency distribution diagrams (Fig. 6.1) are potentially significant with regard to alteration. Well-defined modal distribution peaks reflect greater stability than those showing greater scatter, although the latter may also represent a primary igneous scatter. The degree of dispersion is also shown by chondrite-normalized plots (Fig. 11.5).
- (4) Correlation coefficients between the various elements reflect coherent retention, covariant migration, or differential redistribution - provide a measure for the preservation or disturbance of primary magmatic patterns and the extent of alteration (Appendix II).
- (5) Where systematic stratigraphic-geochemical variation trends pertain, insofar as the latter can be accounted for by magmatic factors and are unlikely to arise from secondary dispersion, such trends militate for overall retention of original chemical characteristics (Figs 6.1-6.5).

5.1 Log Molecular Proportion Plots

Beswick & Soucie (1978) plotted a wide range of Phanerozoic volcanic rocks on $\log (A/K_2O)$ vs $\log (B/K_2O)$ diagrams, A-B oxide pairs being $SiO_2-Al_2O_3$, $CaO-SiO_2$, SiO_2-FM ($FM = FeO_{total} + MgO$), and $CaO-FM$. Two important features are reflected by these plots: (1) least-altered basalts, andesites, dacites, and rhyolites from a variety of tectonic environments plot within well-defined fields, including 450 volcanic rocks from Chile, Mexico, Lesser Antilles, North Atlantic Deep Drill Project, Hawaii, and northwest Iceland; (2) because the rationing oxides are K_2O or Na_2O , changes in the abundance of these mobile components would result in dislocation of points mainly within the least-altered field limits, and only alteration which effects other major elements is represented by deviations from these fields. However, a serious limitation of the method is the lack of data for least-altered igneous fields for the high-Mg basalt-peridotitic komatiite compositional range, ultrapotassic rhyolites, shoshonites, etc. This renders assessment of degrees of alteration of metamorphosed equivalents of such compositions impossible. On the other hand, the fact that the basalt-rhyolite chemical spectrum from diverse tectonic environments plot within these fields supports a test of this method in relation to the Archaean data. Beswick and Soucie (1978) devised a correction procedure to derive original composition of individual samples, assuming little or no migration of SiO_2 and Al_2O_3 . An application of this method to Pilbara samples is being pursued by A.E. Beswick (pers. comm., 1978). In the present study, the deviation of samples from the main Phanerozoic field has been measured by computer program (section 3.3).

Warrawoona Group and Gorge Creek Group data were plotted on five types of LMPR plots (Fig. 5.1), and data for each volcanic formation were plotted and compared separately (Figs. 5.2-5.6). The $SiO_2-Al_2O_3$ plots yield the least scatter. Basalts and andesites correspond closely to the main Phanerozoic field, whereas komatiites, pyroxenites, and high-K rhyolites often plot above this field, reflecting high Si/Al ratios. Basalts correspond also closely to the least-altered $CaO-SiO_2$ field; however, many samples in the andesite-dacite range tend to have low Ca/Si ratios, probably due to lime loss upon alteration. The $CaO-Al_2O_3$ plot likewise indicates CaO loss of the andesites and dacites, and high Ca/Al ratios of the komatiites and pyroxenites - a characteristic feature of Archaean ultramafic suites (Viljoen & Viljoen, 1969;

Brooks & Hart, 1974; Arndt & others, 1977; Nisbet & others, 1977). Many potassic rhyolites of the Wyman Formation (WF) show extreme depletion of Ca relative to Al and Si (Fig. 5.3, 5.4). Plots of the Si-Fm diagram indicate close agreement with the least-altered field for basalts, generally high SiO_2/FM ratios of andesites and dacites, and low SiO_2/FM ratios of komatiites. Generally good fits for the basalt-andesite-dacite range are observed on the Ca-FM diagram, while many ultramafic rocks show low CaO/FM ratios. It may be concluded that, in the basalt-andesite-dacite range, only minor deviations from the least-altered Phanerozoic main field occur, and such are likely to represent secondary processes. On the other hand, as noted above, the degree of alteration of komatiites and high-K rhyolites can not be assessed with reference to LMPR diagrams.

Plots of individual formations and sampling sections allow comparisons of compositional ranges and overall alteration temporally and spatially (Figs 5.2-5.6). Si-Al relations indicate there is a greater proportion of altered rocks in the Mount Ada Basalt (MAB) than in the North Star Basalt (NSB), particularly north and west of Marble Bar. The alteration involved loss of potassium from carbonated basalts (Section 6.1). In the Duffer Formation (DF), scatter increases toward low $\text{SiO}_2/\text{K}_2\text{O}$ values, suggesting that extensive alteration affected the more potassic silicic volcanic rocks. The relatively high degree of alteration of many samples in the Salgash Subgroup (SS), as shown on other plots, is only partly manifested on the Si/Al diagram. This diagram suggests little alteration of the Gorge Creek Group basalts. However, plots on the $\text{CaO}-\text{SiO}_2$, $\text{CaO}-\text{Al}_2\text{O}_3$, SiO_2-FM diagrams are more diagnostic of alteration, since they involve elements more mobile than Si and Al, in particular calcium. The NSB conform best to the least-altered field, although some samples have low CaO relative to silica, alumina and FM, and some samples have high Si/FM. The MAB includes many samples of low Ca/Si, either low or high Ca/Al, high Si/FM, and some with high Ca/FM. Silicic volcanics of the DF show extensive CaO loss relative to Si, Al and FM, and a wide scatter of SiO_2/FM ratios. In the Apex Basalt (AB) some chloritized basalts show marked depletion of CaO relative to Si, Al and FM, whereas lesser degrees of lime mobility are indicated for the Euro Basalt (EB). The ultrapotassic rhyolites of the Wyman Formation (WF) show extreme depletion in CaO, forming clusters opposite extensions of the modern least-altered fields. It is not clear whether the very

low lime abundances in WF is a primary or secondary feature. Excellent agreement is observed between the Gorge Creek Group basalts - Charteris Basalt (CB) and Honeyeater Basalt (HB) - and the least-altered field.

All samples which significantly deviate from the main fields of Beswick & Soucie (1978) have been allotted special symbols (crosses) in subsequent plots. XY and XYZ plots confirm the validity of the LMPR method because in many instances divergent samples also display anomalous trace element characteristics (Figs 7.1-7.70). Some of the notable instances are listed below:

Basic volcanic rocks: Many of the samples which deviate from the main field are silicified basalts. Some have high or low TiO_2 compared to the main range, or depart from main data clusters with regard to Ni and Cr . Chloritized basalts plot toward the Al apex on the $\text{FeO}-\text{MgO}-\text{Al}_2\text{O}_3$ ternary, and some show strong CaO loss relative to MgO and Al_2O_3 . Some divergent MAB basalts show iron depletion. Some show Ti depletion and Zr enrichment, and some have low Ce/Y ratios. Some divergent AB basalts have high Zn. Enrichment in alkalis relative to CaO and enrichment in Ba are common in divergent samples.

Silicic volcanic rocks: Many altered dacites and rhyolites are characterized by strong CaO depletion, as reflected on the $\text{CaO}-\text{SiO}_2$ diagram (Fig. 7.41), which may also reflect secondary silicification. Potassium and sodium are enriched relative to calcium in divergent samples. Some divergent DF rocks plot toward the Ba apex on the $\text{Rb}-\text{Sr}-\text{Ba}$ ternary. Some divergent acid volcanics show high K/Sr ratios, reflecting K addition and/or Sr loss. There is some evidence for addition of uranium upon alteration. Some divergent samples have high levels of Zr and Nb. Some divergent dacites tend to have low Mg and Ni values. Copper is depleted in some altered DF rocks.

The above relations corroborate the significance of LMPR plots in designating overall degree of alteration and screening of suspected samples; however, with the exception of chloritized basic rocks there is no clear correlation between the major element anomalies and the volatile contents of these rocks. It follows that the disturbance of igneous element patterns is not necessarily or solely related to hydration. Possibly, dehydration upon prograde metamorphism has served to mask such a relationship.

5.2 Frequency distributions and correlation coefficients as empirical alteration indicators

Natural volcanic associations, inherent in which are continuous transitions between petrochemical rock types, are rarely amenable to meaningful pigeon-holed classifications. Open chemical redistribution tends to increase the compositional heterogeneity of rock bodies due to the differential nature of alteration, for example due to differential structural control of chemical migration. For these reasons, high standard deviations may reflect either primary and/or secondary scatter. By contrast, where well-defined modal maxima occur, it is unlikely that large-scale redistribution has occurred with respect to the element in question, i.e. low variance is suggestive of little alteration. Furthermore, post-consolidation dispersion can be expected to disturb magmatically coherent patterns of at least the more mobile elements, as reflected by the generally poor correlation coefficients of alkali and alkaline earth elements. Thus, dispersion patterns and correlation coefficients, while not specifying degrees of alteration for any single sample, provide useful guides for the overall extent of secondary redistribution.

Frequency percent distribution curves for basic volcanic units (Fig. 6.1) indicate that best defined modal peaks pertain to SiO_2 , Al_2O_3 , TiO_2 , MnO , P_2O_5 , Zr, Nb, Y, V, Ni, Co, Zn and Ga. A considerable scatter, reflecting high variance, is shown by CaO , Na_2O , K_2O , Rb, Ba, Sr, Ce, Cu and S. These relations support the view of silica and alumina as relatively stable components (Beswick & Soucie, 1978), and are consistent with references to some LIL elements (Ti, Mn, Mg, V, Ni, Co, Zn, Ga) as least-mobile during alteration (Pearce & Cann, 1973; Pearce, 1975; Floyd & Winchester, 1975, 1978; Winchester & Floyd, 1976; Nesbitt & Sun, 1976; Condie & others, 1977; Floyd, 1977). They equally support the view of alkali and alkali and alkaline earth elements (Ca, Na, K, Rb, Ba, Sr) as highly mobile upon alteration (Hart, 1971; Smith, 1968, 1969; Smith & Smith, 1976; Glikson & Derrick, 1978). The light rare earth element Ce shows a wider scatter than Y, in accord with the differential mobility of the rare earth elements (Floyd, 1977; Sun & Nesbitt, 1978; Condie & others, 1977; Collerson & Fryer, 1978). The wide dispersions of Cu and S are significant to sulphide mineralization (Section 12.3). The conclusions arising from the frequency distribution diagrams are supported by standard deviations (Table 6.1) and by compositional ranges as

reflected by chondrite-normalized plots (Fig. 11.5). These plots show tight distribution of smaller-radii elements (Ti, Y, Zr, P, Sr) as compared to wider scatter of larger radii elements (Pb, Rb, Ba, Th, U, Nb, K, La, Ce), indicating considerably wider secondary mobility of the latter.

These observations are corroborated by correlation coefficients (Appendix II). The best positive correlations ($r > 0.75$) for tholeiites, dolerites and gabbros are given by the following pairs:

Fe-Ti, Fe-Y, Fe-V, Fe-P, Fe-Zr, Fe-Ga;

Ti-Zr, Ti-Y, Ti-P, Ti-Ga, Ti-Ce, Ti-Nb;

Zr-Y, Zr-Nb, Zr-Ga, Zr-Ce; Y-V, Y-Ga; P-Zr, P-Y, P-Ce, P-Ga; Ni-Cr, Ce-La, K-Rb

Evidently, close sympathetic relations exist between the siderophile elements (Fe, Ti, V) and large-ion-lithophile and rare earth elements (P, Zr, Y, Ce). On the other hand, the only alkali pair whose correlation is consistently strong is K-Rb, which suggests that any original magmatically-coherent relations within the alkali and alkaline earth groups (K, Na, Rb, Ba, Sr) have been obliterated by secondary redistribution.

Considerable secondary migration of alkali and alkaline earth elements relative to ferromagnesian elements is also suggested for the silicic volcanic rocks. Frequency distribution diagrams indicate relatively well defined modes for Si, Al, Ti, Mn, P, Pb, Y, and Ga, but wider scatter for Mg, Ca, Na, K, Rb, Ba, Sr, Li, Zr, Nb, La, Ce, Ni, Cr, Co, Zn, Cu and S (Fig. 6.1). Thus, in distinction from the basic volcanic rocks, large dispersions pertain also to the light LIL elements, chalcophile elements, and magnesium-group elements, which suggests higher degrees of alteration of the silicic volcanics. As for the basic rocks, light-REE appear to have been more mobile than heavy REE. The more stable components in the silicic volcanics are the siderophile and mg-group elements - Ti, V, Ni, and Cr, i.e. $r > 0.75$ for Ti-Fe, Ti-Zn, Ti-V. Further, correlation coefficients for dacites and rhyolites of the Duffer Formation suggest close coherence of the LIL and REE elements, i.e. $r > 0.75$ for Nb-Zr, Y-Zr, Nb-Y, La-Ce (Appendix II); the only consistently good alkali correlation is between K and Rb. The overall comparison between basic and silicic volcanics thus suggests greater alteration in the latter, though retention of primary relations of siderophile, magnesian, large-ion-lithophile, and rare earth elements is evident in many instances. Thus, while alteration remains a major problem with regard to the identification of secondary modification in individual samples, as groups the data are amenable to discussion in terms of the original dispersion of the least mobile components.

6. STRATIGRAPHICALLY CONTROLLED GEOCHEMICAL VARIATIONS

6.1 - Basic Volcanic Rocks

The following account considers inter-formational geochemical variations shown by percentage frequency distribution diagrams (Fig. 6.1) and intraformational variations shown by columnar stratigraphic-geochemical diagrams (Fig. 6.2). Both types of diagrams represent wide compositional spectra from peridotitic komatiite to rhyolite, showing overall geochemical distributions and trends. Because most samples of the Talga-Talga Subgroup and Gorge Creek Group are tholeiitic basalts, these diagrams also reflect comparisons between the tholeiites of these units. The main aim of the comparisons below is to examine possible stratigraphic and thus temporal trends. The elements are discussed in terms of chemically related groups, i.e. major lithophile elements (Si, Al), siderophile elements (Fe, Ti, Mn, V), major basic elements (Mg, Ca), magnesium-related trace-elements (Ni, Cr, Co), alkali and alkaline earth elements (K, Na, Rb, Ba, Sr) and lithium (Li), incompatible large-ion-lithophile (LIL) elements (Th, U, Zr, Nb, P), rare earth elements (La, Ce, Y), chalcophile elements (Cu, Zn, Pb, Ga, S), and volatiles (H_2O^+ , H_2O^- , CO_2).

6.1.1 - Variations between formations

Both Si and Al display well-defined modal peaks and little stratigraphically-controlled variation on frequency distribution diagrams (Fig. 6.1). A narrow Si distribution range pertains, modes being in the 48-52% interval. A similarly tight distribution applies to alumina, in line with the above-suggested low secondary mobility of this component. Distribution curves for Al_2O_3 are commonly negatively skewed, reflecting the role of low-Al komatiites. Most Al values are in the 12-15% range; high Al values pertain to some MAB basalts. Little systematic stratigraphic variation is evident, except for the high Al (ca 16%) of some basalts of the Gorge Creek Group (GCG).

Distribution patterns of iron and related siderophile elements show a general though irregular decrease in total Fe as FeO from the Talga-Talga Subgroup (TS) to the overlying Salgash Subgroup (SS) and the GCG. This trend reflects a decrease in the FeO/MgO ratio and in siderophile trace-element levels of the tholeiitic basalts (Fig. 6.1). However, this trend is irregular:

in the TS the level of FeO^t in basalts actually increases upward, from a mode of 11-12% in the North Star Basalt (NSB) to 12-15% in the Mount Ada Basalt (MAB). The Apex Basalt (AB) of the SS has a modal peak at 9-10% and the Euro Basalt (EB) of the SS a wide range distribution including high FeO^t values. In the GCG the Charteris basalt (CB) has a shallow peak at 8-9% and the Honeyeater Basalt (HB) a maximum in the range of 9-11% FeO^t . The general decline in the abundance of iron is accompanied by decreases in Ti, Mn and V (Figs 6.1.2, 6.1.5, 6.1.22). TiO_2 yields a well-defined mode of 1.0-1.2% for the NSB, a wide range of 0.8-1.6%² (modes at 0.8-1.0%) for the MAB, 0.4-0.6% for the AB, a bimodal distribution for the EB, and 0.4-0.8% for the CB and HB - indicating an overall decrease by about a factor of two. Modal peaks for MnO decrease from 0.18-0.22% for the TS to 0.16-0.22 in the SS and GCG successions. Vanadium decreases with stratigraphic level from 225-375 ppm in the NSB and 250-350 ppm in the MAB (which has also samples with higher values), to 200-250 ppm in the AB, a distinctly bimodal distribution in the EB (225-250, 300-350 ppm), 150-200 ppm in the CB, and 225-275 ppm V in the HB. The significance of these trends are discussed in Section 12.

Tholeiitic basalts show some stratigraphically controlled MgO variations, the mode for the TS (4-8%) being less than for the GCG (6-10%) (Fig. 6.1.6). Thus, the upward decrease in FeO^t/MgO results from variation in both iron and magnesium. Little stratigraphic variation is shown by CaO (Fig. 6.1.7), which due to its considerable secondary mobility is expressed by shallower modal maxima. Well-defined high-CaO modes pertain in the NSB (10-11%) and MAB (8-10%), in part due to retention of calcium in little-altered amphibolites and possibly due to addition of CaO upon carbonatization. The latter factor accounts for very high CaO levels in some MAB rocks (e.g. McPhee Reward), though no consistent CaO- CO_2 correlation is shown. There is no evidence of overall additions of CaO^2 to the formation. Very shallow frequency distribution curves of the SS reflect the strong second redistribution of CaO in altered ultramafic rocks.

The magnesian trace elements - Ni, Cr, and Co (Figs 6.1.25, 6.1.23, 6.1.24) are probably relatively stable during secondary processes (Section 5). This is supported by well defined Ni modes for the NSB (50-75 ppm), although wider maxima (25-100 ppm) apply to the MAB, possibly reflecting its higher degree of alteration. The higher Ni values of tholeiites and higher proportion of komatiites in the SS are responsible for its higher Ni modes (75-125 ppm),

whereas a lower mode pertains in the stratigraphically higher GCG (50-75 ppm Ni). Ni closely follows MgO, and is depleted in the low-MgO MAB rocks of the McPhee Reward section. Three groupings are noted with respect to the MgO/Ni ratios: the NSB, MAB and DF basic rocks have ratios averaging 960-980, the AB, EB and CB 500-800 and the HB 1100. Modal distribution of chromium is 50-100 ppm in the NSB and 0-50 ppm in the MAB. Wide scatter distribution applies in the SS and the CB, while the HB shows a conspicuous Cr mode at 0-50 ppm. Some of the volcanic rocks show very low levels of Ni and Cr by comparison to other Archaean and younger terrains (section 11). Cobalt has a remarkably symmetrical normal distribution (Fig. 6.1.24), with modes invariably between 40-50 ppm, with the exception of komatiites with 80-90 ppm Co.

Whereas the dispersion patterns of the alkali and alkaline earth elements reflects the secondary mobility, little confidence exists regarding the original igneous abundances of these elements. Sodium shows a positively skewed curve for the NSB, with modal peak at 1.5-2.0% Na₂O (Fig. 6.1.8). The MAB has a marked concentration of values about 2.5-3.0%. Bimodal to irregular frequency distribution patterns occur in the SS. A pronounced K₂O mode of 0.3-0.4% is shown by the NSB (Fig. 6.1.9). Very low potassium abundances, however, pertain to many MAB samples (below 0.1%), principally where intense carbonatization effected removal of alkalis, e.g. McPhee Reward section. Similarly low K₂O levels apply in the SS, where the positively skewed configuration of the curves suggest potassium migration. The Honeyeater Basalt of the GCG includes many tholeiite basalts with high (above 0.5%) K₂O. Rubidium behaves likewise; it is mostly below 20 ppm in basalts of the Warrawoona Group (WG) and somewhat higher (mode above 20 ppm) in the Gorge Creek Group. Barium modes are 50-100 ppm for the NSB, 0-100 ppm for the MAB, below 50 ppm for the AB and EB (which have positively skewed curves). This element has a wide distribution range and many high values (300 ppm Ba) in the Honeyeater Basalt, which is of possible significance in view of the occurrence of barite-rich sandstones in the GCG sequence (Hickman, 1977). Well-defined Sr maxima of 100-150 ppm apply in the NSB and the MAB, but this element shows a wide dispersion and thus likely secondary mobility in the SS and the GCG, where in some instances it has been strongly depleted. Lithium has well defined positively skewed modal peaks of 5-10 ppm in all mafic volcanic units.

Table 6.1 Average compositions and standard deviations of eastern Pilbara volcanic rock types: (a) ultramafic-mafic rocks

Peridotitic komatiites			
	NSB	MAB	AB
N =	5	4	5
SiO ₂	41.47 (1.62)	41.64 (2.52)	42.36 (1.69)
TiO ₂	0.35 (0.18)	0.66 (0.14)	0.18 (0.04)
Al ₂ O ₃	5.51 (1.43)	4.66 (0.93)	4.10 (0.80)
FeO _t	11.07 (1.02)	13.83 (0.68)	8.73 (0.59)
MnO	0.18 (0.02)	0.25 (0.01)	0.14 (0.01)
MgO	28.70 (4.28)	25.64 (3.05)	31.56 (3.09)
CaO	4.02 (2.16)	5.63 (2.25)	4.06 (2.20)
Na ₂ O	0.05 (0.01)	0.05 (0.02)	0.27 (0.15)
K ₂ O	0.03 (0.02)	0.02 (0.01)	0.02 (0.01)
P ₂ O ₅	0.03 (0.01)	0.06 (0.02)	0.03 (0.01)
Ba	19 (16)	27 (19)	
Rb			
Sr	17 (7)	17 (5)	16 (11)
Pb	3		
Th			
U	1		
Zr	24 (10)	35 (8)	6 (2)
Nb			
Y	6 (3)	9 (2)	5 (1)
La	3 (1)		2 (1)
Ce	5		13 (15)
Li	3 (1)	3 (1)	4 (2)
V	122 (43)	173 (38)	92 (18)
Cr	4350 (861)	3721 (2334)	1322 (281)
Co	94 (14)	112 (17)	
Ni	1435 (451)	1771 (354)	1435 (195)
Cu	30 (14)	50 (20)	14 (15)
Zn	58 (8)	68 (9)	34 (5)
Ga	7 (3)	10 (2)	
S	160 (113)	200 (160)	120 (75)

NSB - North Star Basalt

MAB - Mount Ada Basalt

AB - Apex Basalt

EB - Euro Basalt

CB - Charteris Basalt

HB - Honeyeater Basalt

Table 6.1 (contd)

High-Mg basalts

NSB	MAB	AB	EB	CB	HB
6	9	20	3	6	5
50.40 (1.21)	49.99 (1.68)	50.09 (1.55)	46.90 (5.20)	47.83 (1.84)	49.29 (1.50)
0.61 (0.12)	0.96 (0.29)	0.58 (0.18)	1.03 (0.35)	0.55 (0.05)	0.60 (0.18)
11.44 (3.84)	10.15 (2.51)	11.50 (1.97)	9.41 (3.32)	14.24 (0.67)	9.65 (1.39)
9.82 (1.35)	11.50 (1.19)	10.19 (1.20)	10.90 (1.04)	9.52 (1.03)	9.84 (1.04)
0.22 (0.03)	0.20 (0.03)	0.19 (0.03)	0.19 (0.02)	0.19 (0.02)	0.18 (0.02)
11.27 (2.27)	10.15 (2.21)	11.01 (2.37)	10.08 (2.23)	9.52 (0.67)	11.06 (1.28)
10.67 (2.57)	10.90 (2.20)	10.11 (1.50)	10.60 (2.07)	10.14 (1.83)	12.77 (3.49)
0.77 (0.59)	1.65 (0.84)	2.12 (0.99)	0.99 (0.91)	2.22 (0.83)	1.19 (0.55)
0.37 (0.30)	0.24 (0.16)	0.17 (0.14)	0.25 (0.28)	0.44 (0.34)	0.36 (0.33)
0.10 (0.15)	0.08 (0.04)	0.06 (0.03)	0.09 (0.03)	0.06 (0.01)	0.08 (0.01)
77 (76)	58 (38)	45 (75)	11 (9)	106 (137)	346 (236)
20 (14)	9 (9)	10 (6)	23	141 (9)	20 (8)
71 (4)	110 (43)	109 (60)	98 (49)	164 (94)	41 (35)
6	3 (1)	2			
	2	3			
2	4	3 (1)			2
59 (19)	74 (30)	32 (13)	58 (11)	28 (3)	32 (14)
4 (1)	3 (1)	4 (3)	0		
16 (3)	21 (6)	12 (2)	16 (1)	11 (1)	14 (4)
5 (2)	5 (2)	4 (2)	4 (1)	3 (1)	4 (1)
8 (4)	11 (8)	16 (8)	21 (4)	13 (3)	16 (4)
31 (15)	14 (15)	18 (14)	12 (6)	20 (13)	6 (3)
264 (47)	258 (47)	219 (23)	264 (63)	203 (28)	268 (29)
875 (439)	784 (567)	749 (431)	783 (625)	697 (117)	926 (383)
51 (11)	47 (3)	49 (8)			
216 (122)	137 (48)	198 (110)	198 (136)	177 (61)	158 (29)
90 (35)	92 (42)	85 (33)	151 (98)	84 (3)	63 (71)
69 (9)	75 (17)	67 (11)	76 (10)	60 (7)	55 (13)
11 (1)	12 (4)	11 (2)			
200 (221)	163 (88)	205 (153)	127 (99)	317 (173)	115 (128)

Table 6.1 (contd)

Tholeiitic basalts					
NSE	MAB	AB	EB	CB	HB
37	36	13	5	10	12
51.19 (1.91)	48.22 (1.71)	49.71 (2.01)	48.12 (1.18)	48.92 (1.58)	50.47 (1.72)
1.24 (0.50)	1.61 (0.47)	0.87 (0.31)	1.22 (0.26)	0.53 (0.17)	0.81 (0.16)
13.88 (0.71)	12.86 (1.02)	13.46 (0.61)	13.75 (1.04)	14.90 (0.99)	14.38 (0.61)
11.88 (1.99)	13.52 (1.86)	10.86 (1.66)	13.32 (1.13)	9.16 (1.02)	10.83 (1.27)
0.23 (0.04)	0.21 (0.03)	0.20 (0.02)	0.21 (0.02)	0.17 (0.02)	0.21 (0.03)
6.28 (1.38)	5.39 (1.13)	6.62 (1.07)	6.31 (1.11)	7.71 (1.39)	6.31 (1.62)
9.97 (1.37)	8.69 (1.68)	10.31 (3.04)	8.48 (1.08)	10.48 (2.13)	8.15 (2.10)
2.20 (0.75)	2.14 (0.69)	1.96 (0.73)	2.30 (0.56)	1.94 (0.75)	1.78 (0.66)
0.38 (0.22)	0.22 (0.21)	0.31 (0.64)	0.17 (0.09)	0.24 (0.40)	0.73 (0.50)
0.12 (0.06)	0.15 (0.06)	0.08 (0.04)	0.13 (0.03)	0.06 (0.01)	0.10 (0.04)
110 (94)	93 (72)	55 (65)	19 (12)	52 (47)	401 (615)
13 (12)	7 (7)	14 (18)	6 (4)	15 (17)	21 (17)
140 (45)	142 (42)	129 (44)	112 (39)	175 (57)	119 (69)
5 (3)	6 (3)				
2 (1)	3 (1)				2
1	1		2	2	3
103 (35)	122 (40)	51 (21)	74 (23)	29 (4)	66 (32)
5 (2)	6 (2)	2 (1)	3 (1)		3 (1)
26 (6)	29 (8)	18 (6)	23 (2)	11 (1)	24 (5)
7 (4)	9 (14)	5 (2)	6 (2)	3 (1)	5 (2)
17 (14)	21 (11)	19 (5)	22 (5)	16 (2)	18 (5)
28 (19)	20 (8)	17 (10)	8 (2)	16 (8)	9 (3)
327 (50)	350 (70)	280 (43)	324 (12)	201 (41)	317 (30)
169 (175)	128 (91)	236 (132)	109 (56)	414 (183)	176 (166)
45 (4)	44 (4)	32			
66 (35)	58 (19)	104 (37)	98 (34)	156 (70)	53 (22)
47 (33)	72 (32)	90 (46)	162 (14)	77 (27)	74 (32)
97 (28)	108 (29)	80 (16)	102 (9)	54 (10)	84 (14)
17 (3)	18 (4)	14			
278 (461)	672 (558)	417 (445)	515 (728)	268 (159)	168 (176)

Table 6.1 (contd)

Dolerites				Gabbros	
NSB	MAB	AB	NB	NSB	MAB
14	11	5	11	10	4
50.62 (1.89)	48.64 (0.75)	50.17 (1.38)	50.00 (1.53)	49.59 (0.91)	49.45 (1.21)
1.25 (0.55)	1.53 (0.21)	0.95 (0.47)	0.61 (0.24)	1.16 (0.32)	1.36 (0.87)
14.47 (1.32)	13.31 (1.08)	13.69 (0.47)	14.92 (1.35)	14.20 (1.00)	14.76 (1.92)
11.65 (2.03)	14.03 (1.11)	10.96 (2.47)	9.91 (1.05)	12.33 (1.69)	11.31 (2.57)
0.20 (0.04)	0.22 (0.03)	0.21 (0.03)	0.18 (0.03)	0.21 (0.03)	0.18 (0.03)
6.77 (1.44)	6.22 (1.20)	7.53 (1.45)	7.96 (1.29)	6.65 (1.10)	6.16 (1.47)
9.12 (0.31)	8.54 (1.59)	9.14 (0.91)	8.83 (1.40)	10.01 (1.32)	9.34 (1.24)
2.42 (0.75)	1.99 (0.93)	2.53 (0.64)	1.87 (0.76)	2.44 (0.80)	2.52 (0.59)
0.48 (0.25)	0.28 (0.20)	0.43 (0.24)	0.51 (0.22)	0.41 (0.26)	0.64 (0.49)
0.12 (0.07)	0.13 (0.03)	0.09 (0.07)	0.08 (0.03)	0.09 (0.04)	0.15 (0.09)
133 (64)	119 (111)	769 (1167)	242 (241)	98 (56)	212 (147)
28 (17)	8 (7)	9 (6)	13 (7)	20 (16)	29 (25)
188 (74)	192 (116)	179 (69)	153 (66)	179 (65)	240 (153)
2	5 (3)			3 (2)	5 (4)
2	2			3 (1)	3 (1)
1					
37 (28)	104 (17)	55 (27)	43 (31)	83 (32)	95 (61)
4 (1)	5 (1)	3 (1)	3 (1)	4 (2)	5 (2)
24 (7)	29 (4)	19 (8)	17 (7)	22 (5)	24 (12)
8 (5)	6 (2)	5 (3)	5 (3)	7 (3)	11 (9)
21 (12)	22 (9)	85 (147)	17 (6)	21 (9)	29 (9)
43 (34)	15 (8)	19 (12)	8 (2)	46 (45)	25 (29)
293 (104)	340 (67)	282 (61)	256 (43)	328 (58)	267 (100)
227 (247)	190 (160)	276 (217)	134 (135)	141 (113)	142 (120)
45 (9)	50 (4)	47 (4)		49 (6)	43 (4)
87 (56)	72 (22)	74 (37)	80 (29)	84 (41)	90 (77)
72 (35)	76 (32)	134 (41)	60 (13)	57 (43)	51 (38)
94 (25)	102 (25)	76 (10)	64 (13)	94 (12)	89 (32)
16 (2)	18 (2)	14 (1)		18 (3)	21 (5)
390 (406)	600 (672)	188 (152)	107 (74)	500 (520)	615 (929)

Table 6.1b - Average Compositions and Standard Deviations of least-altered
Silicic Volcanic Components of the Warrawoona Group.

	Andesites		dacites		qz latite		rhyolites		tuff
	UNSB 3	DF 10	DF 26	UNSB 8	DF 5	DF 6	WF 23	DF 17	
SiO ₂	57.92 (0.45)	55.77 (2.52)	62.59 (3.37)	62.98 (2.69)	63.34 (3.70)	70.25 (1.31)	77.91 (3.69)	61.83 (5.37)	
TiO ₂	0.99 (0.26)	1.03 (0.30)	0.58 (0.13)	0.65 (0.11)	0.58 (0.06)	0.35 (0.5)	0.16 (0.18)	0.63 (0.26)	
Al ₂ O ₃	16.50 (0.54)	15.55 (1.18)	14.98 (1.44)	16.60 (0.31)	16.72 (0.75)	12.89 (0.96)	11.49 (1.31)	13.92 (1.14)	
FeO _t	7.57 (0.40)	7.43 (1.88)	4.16 (1.66)	4.98 (1.55)	3.48 (1.82)	2.88 (0.82)	0.57 (0.24)	5.18 (1.65)	
MnO	0.15 (0.02)	0.15 (0.04)	0.11 (0.04)	0.10 (0.01)	0.08 (0.06)	0.08 (0.03)	0.03 (0.04)	0.12 (0.05)	
MgO	3.42 (0.87)	3.16 (0.84)	2.20 (0.85)	2.13 (0.91)	1.78 (0.81)	1.03 (0.21)	0.34 (0.16)	2.60 (0.98)	
CaO	7.57 (0.51)	5.63 (1.23)	4.36 (1.52)	5.28 (1.29)	4.03 (2.18)	2.31 (0.50)	0.30 (0.33)	3.95 (1.65)	
Na ₂ O	2.96 (0.46)	3.37 (0.98)	3.58 (1.53)	4.86 (1.26)	1.60 (1.13)	1.98 (1.81)	0.35 (0.79)	3.08 (1.36)	
K ₂ O	0.39 (0.27)	2.06 (1.14)	2.14 (1.75)	0.77 (0.32)	5.47 (2.23)	5.36 (2.79)	7.11 (2.79)	2.61 (1.93)	
P ₂ O ₅	0.22 (0.12)	0.24 (0.11)	0.15 (0.04)	0.11 (0.03)	0.20 (0.07)	0.07 (0.04)	0.05 (0.08)	0.15 (0.07)	
Ba	459 (570)	736 (326)	780 (950)	352 (278)	684 (600)	674 (296)	247 (171)	550 (343)	
Rb	17 (14)	47 (30)	62 (43)	26 (13)	123 (35)	100 (54)	146 (50)	66 (48)	
Sr	408 (168)	337 (121)	218 (199)	390 (110)	166 (156)	169 (185)	13 (9)	165 (125)	
Pb	7 (6)	6 (3)	6 (4)	10 (10)	7 (1)	4 (1)	9 (9)	7 (4)	
Th	9 (8)	6 (2)	7 (3)	5 (5)	9 (1)	9 (3)	18 (10)	8 (3)	
U	2 (1)	1 (0)	2 (1)	2 (1)	1	2	3 (2)	2 (1)	
Zr	150 (59)	150 (58)	147 (32)	143 (47)	202 (30)	217 (61)	113 (35)	162 (45)	
Nb	7 (3)	6 (3)	5 (2)	6 (2)	7 (2)	9 (3)	7 (3)	6 (3)	
Y	19 (5)	23 (8)	14 (4)	18 (8)	19 (5)	25 (16)	21 (5)	18 (9)	
La	43 (31)	25 (9)	27 (8)	26 (21)	34 (7)	37 (16)	23 (8)	32 (12)	
Ce	73 (56)	50 (15)	53 (14)	42 (36)	67 (19)	69 (25)	50 (14)	61 (20)	
Li	78 (41)	10 (4)	12 (7)	41 (27)	21 (11)	8 (3)	5 (4)	10 (3)	
V	106 (70)	145 (62)	71 (29)	99 (56)	70 (12)	43 (33)	16 (16)	85 (53)	
Cr	50 (34)	60 (41)	42 (25)	103 (144)	43 (16)	19 (12)	6 (6)	37 (20)	
Co	23 (8)	30 (14)	20 (4)	19 (9)	16	6 (2)	3 (1)	17 (8)	
Ni	68 (0)	52 (54)	27 (14)	63 (66)	20 (8)	11 (6)	4 (2)	29 (14)	
Cu	31 (23)	44 (37)	32 (45)	45 (51)	34 (19)	11 (8)	10 (11)	33 (49)	
Zn	68 (10)	84 (16)	57 (21)	54 (16)	45 (14)	36 (18)	13 (8)	65 (23)	
Ga	18 (1)	17 (1)	18 (2)	18 (3)	18	16 (1)	14 (2)	17 (1)	
S	187 (92)	267 (241)	142 (151)	450 (493)	68 (18)	137 (130)	168 (219)	192 (166)	

UNSB - Upper part of North Star Basalt

DF - Duffer Formation

WF - Wyman Formation.

Uranium, thorium, and lead - because of their very low abundance levels in basic rocks and their secondary mobility - are not considered here with reference to their stratigraphic distribution. The other LIL (large ion lithophile) elements - Zr and Nb, have well-defined modes which reflect a general decrease with time: the NSB has a modal range of 80-90 ppm Zr and 3-4 ppm Nb. The MAB has a three modal distribution of Zr with peaks at 80-90 ppm, 130-140 and 170-180 ppm, and a positively skewed Nb peak at 2-3 ppm (with many values in the 4-7 ppm range). The AB and GCG have Zr modes of 20-40 ppm and a wide Nb dispersion which decrease toward the 1-3 ppm range in the uppermost units. The EB has higher Zr and Nb. These trends (Table 6.1) also occur on intraformational scale. Modal peaks for phosphorous are between 0.04-0.10% P_2O_5 although upward decrease is evident on both interformational and intraformational scales (Table 6.1, Fig. 6.2.2).

La has consistently low modes of less than 5 ppm throughout the volcanic sequence but mean tholeiite compositions (Table 6.1) reveal an upward decrease in concentration, from about 8 in TS to about 4 in GCG. Ce shows a wide main distribution range of up to 30 ppm in the TS, a well-defined 15-20 ppm maxima in the AB, a shallow peak of 20-25 ppm in the EB, and 10-15 ppm in the GCG. A similar overall decrease pertains to yttrium, with a mode of 20-25 ppm in the NSB, bimodal peaks in the 15-30 ppm range in the MAB, a mode of 10-15 ppm for the AB, a wide range to 25 ppm in the EB, and a well defined positively skewed mode of 10-15 ppm for the GCG.

The chalcophile elements show little systematic variation with stratigraphic level. Cu increases somewhat upward, from a mode of 50-75 ppm in the NSB to 50-100 ppm in the MAB and stratigraphically higher volcanics. By contrast, Zn decreases from well-defined modes of 75-100 ppm in the TS to modes of 50-75 ppm in the SS and GCG. Modal peaks for S are invariably below 100 ppm, while many samples of the MAB have high S values (ca 400 ppm). Ga which generally follows Al has a peak at 15-20 ppm and shows little stratigraphic control.

The volatile components H_2O and CO_2 have variable distribution patterns. CO_2 has marked modes below 0.5%, but many individual analyses with higher values; in the MAB extensive carbonization results in values as high as 10%. By contrast the NSB appears to be relatively free of carbonization. The

significance of carbonatization is considered in section 12 (see also Hallberg, 1974). The proportion of H_2O^+ increases upwards with stratigraphic level from a modal range of 0.5-1.5% in the NSB to 0.5-3.5% in the MAB - indicating a close relation between water and CO_2 . Modal ranges of 2.5-3.0% H_2O^+ pertains to the AB, 3.5-4.0% to the EB, and 3.5-4.5% to the GCG. The increase in H_2O^+ with time may have arisen by (1) progressively longer breaks between extrusions and thus greater opportunity for lava-seawater interaction; (2) it may reflect the larger volumes of hydrated clastic sediments associated with the GCG volcanic units and which could form the source of aqueous solutions during metamorphism, and (3) dehydration effects of stratigraphically lowermost volcanic units (NSB) associated with intrusive plutons.

6.1.2 Variations within formations

The above account examines variations between volcanic units; internal trends in individual successions are considered below (Fig. 6.2). The detection of such trends depends critically on sampling density (section 3.1). Single-point sampling in regular intervals commonly shows systematic stratigraphic trends. By contrast, multiple-point sampling (several samples per locality), i.e., along the Talga River to Coongan River section (including the TS, DF, and AB units), reveals wide compositional ranges at individual localities (Fig. 6.2.1). Here local scatter obscures possible vertical variations, except for the general upwards increase in the range of H_2O^+ and CO_2 and weakly defined decrease in La and Ce. This raises the question whether single point sampling trends would be preserved had multiple-point sampling been carried out in all areas. The multiple-point method has successfully confirmed that local variations are considerable, but in doing so has by necessity used the skill of the sampler to obtain a selection of rock types from each locality. Thus atypical samples have been given equal prominence to typical, and overall geochemical trends may have been obscured. The chief requirements of the single-point method is to collect only samples which are judged to be representative of the most common rock type at each locality. If general vertical trends are present over hundreds or thousands of metres this method should reveal them, even if one or two atypical samples are inadvertently included.

In addition to multiple-point sampling along the Talga River-Coongan River section, single-point sampling traverses in the same general area north of Marble Bar were carried out along the 4200 m thick McPhee Reward section (NSB and MAB units) and the 3000 m thick Talga River section (NSB and MAB units). In the following, trends are described for the basic rocks, i.e., tholeiitic basalts, dolerites and gabbros. Significant trends are revealed by the McPhee Reward data (Fig. 6.2.2) including a geochemical discontinuity between the NSB and MAB. the NSB shows a general upward decrease in Ti, Fe, Na, K, P, Rb, Zr, Nb, Y, La, Ce, Zn, and Ga (best-pronounced trends are underlines), and a general increase in H_2O (total). At its base the overlying MAB has higher Ti, Fe, Mn, Na, P, Sr, Zr, Nb, Y, La, Li, V, Cu, Zn, Ga, S, CO_2 , and H_2O , and lower Si, K, Rb and Ba, than the underlying NSB. Upwards, the MAB section shows a decrease in Ti, Fe, Mn, Na, P, Sr, Zr, Nb, Y, La, Ce, Li and Zn. The most important overall differences between the NSB and the MAB in this area are the high H_2O , CO_2 , and S levels in the latter unit - with implications to mineralization (section 12.3). Thus, two cycles, each showing upward decrease in siderophile, large-ion-lithophile, rare earth, and some chalcophile elements, occur in the McPhee Reward section. Superposed on these are associated effects of carbonatization and hydration, i.e. alkali depletion and possibly introduction of sulphur.

The significance of the above trend is enhanced by similar patterns in the Talga River section (Fig. 6.2.3). In this area the NSB and/or the MAB show upward decreases in Ti, Fe, Na, K, P, Ba, Zr, Nb, Y, La, Ce, Zn, Ga and S. It is significant that, whereas Si and Mg levels decrease upward (partly due to the diluting effect of volatiles), Ca shows little stratigraphic variation in the McPhee Reward and Talga River sections. This suggests that only in some instances was CaO added along with CO_2 . It is not clear whether the sharp increase in LIL and REE elements upwards across the chemical break between the NSB and MAB reflects a primary igneous cyclicity or is due to carbonatization. The latter interpretation would imply carbonatite-like affinities of the introduced volatiles, i.e. concomitant enrichment of CO_2 , Zr, Nb, Y, La and Ce. However, XY plots reveal little positive correlation between CO_2 and these elements. Because the systematic decrease in siderophile and lithophile elements occurs in both carbonated and uncarbonated successions, a primary (igneous) nature of these trends is clearly favoured and the role of carbonate must be regarded as secondary. These intraformational trends are similar to the previously discussed interformational siderophile and lithophile element depletion, indicating that the long-term depletion involved repeated local depletion cycles.

Trends are weakly manifest in the 4300 metres-thick Shark Gully section of the Talga-Talga Subgroup (Fig. 6.2.4). The overall trend from the NSB to the MAB, and within each of these units, includes a weakly defined decrease in Ti, Nb, Sr, V, Y and Zr, and an increase in K, CO_2 , H_2O^+ , Ba, Rb, Cr, Ni, Cu and S. Figure 6.2.4 reveals no systematic trends within NSB and MAB at Shark other than a general upward decrease in CO_2 and an upward increase in Cu. This lack of trends appears to be chiefly due to the large number of dolerite and gabbro samples collected. When only basalt is examined clear trends of the same type as at McPhee Reward are exhibited by the NSB. The MAB is chemically more uniform except with respect to Mg, Ni and Cr which decrease upwards.

A detection of trends in the Salgash Subgroup (SS) is hampered by its wider compositional range, i.e. from tholeiitic basalt to peridotitic komatiite.

In the 3000 metres-thick Camel Creek section (Fig. 6.2.5) the Apex Basalt (AB) shows an upward decrease in Mg, Ni, and Cr, and an increase in Al, Ca, Na, K, Sr, Rb, Y, Ce, Cu and S. The Euro Basalt (EB) shows an upward increase in Ti, P, and Zr. Compared to the AB, and EB has high Ti, Fe, P, CO_2 , Sr, Zr, Y, La, Ce, V, Cu, and Zn, and low Mg. Clearly, this trend is the reverse of those of the Talga-Talga Subgroup and is produced by petrological variations involving the upward decrease in komatiites. Thus, peridotitic komatiites occur up to the 600 metres level, high-Mg basalts to about 1100 metres above base, and basic rocks dominate the upper part of the AB and most of the EB. Geochemical variations within single rock types must be investigated to elucidate trace-element variations. Little or no obvious stratigraphic-geochemical variations are shown by the Apex Basalt in the Sandy Creek section (Fig. 6.2.6).

Columnar plots for the Gorge Creek Group volcanics (GCG) are portrayed in Figs 6.2.7 and 6.2.8. The Charteris Basalt (CB) shows an upward increase in Na, K, Ba, Rb, V and H_2O - indicating alkali enrichment with hydration at high stratigraphic levels. The Honeyeater Basalt (HB) shows a weak upward decrease in Mg, Ca, K, Rb and Zr and an increase in H_2O^+ and Cu. The latter trend, though not clearly pronounced, indicates base metal enrichment associated with addition of volatiles.

It is instructive to examine variations in element ratios (Fig. 6.5). The $\text{CaO}/\text{Al}_2\text{O}_3$ ratio shows a well-defined modal peak of 0.6-0.8 for all volcanic units except HB, although values of some komatiites of the SS and other units may be higher than 1.0. Marked stratigraphic variations pertain to the $\text{Al}_2\text{O}_3/\text{TiO}_2$ and CaO/TiO_2 ratios: both the NSB and the MAB have markedly lower ratios than stratigraphically higher volcanics, i.e. 6-14 for $\text{Al}_2\text{O}_3/\text{TiO}_2$ and 2-12 for CaO/TiO_2 , mainly owing to their high Ti levels. A concentration of high $\text{Al}_2\text{O}_3/\text{TiO}_2$ ratios is shown by the AB, whose komatiites have ratios of about 22-24, similar to chondrites (Sun and Nesbitt, 1978). A wide $\text{CaO}/\text{Al}_2\text{O}_3$ ratio range is shown by GCG basalts, reflecting Al and Ca variability.

Komatiites of the Apex Basalt (AB) commonly have high Cr/Ni ratios (3-4) compared to tholeiitic basalts (1-3). Ti/V ratios in the MAB (20-30) are greater than for stratigraphically higher units, whereas the Ti/Zr ratios of the NSB and MAB are low (70-80) compared to stratigraphically higher volcanics (90-130). Zr/Y ratios of the TS basalts (3-4) are higher than for the younger SS and GCG basalts (1-3). Low K/Rb ratios (150-200) pertain to the NSB, reflecting relatively high Rb levels, whereas due to their strong Rb depletion the MAB have higher K/Rb ratios (450-500). Accordingly, some Rb/Sr ratios of the NSB (0.025-0.1) are higher than for the MAB (0.025-0.05). However, these variations are probably related to K and Rb depletion upon carbonatization, and are not of igneous significance.

Comparisons between elemental ratios of the main rock types (Fig. 6.3) reveals that peridotitic komatiites (PK) have a wide range of and commonly high $\text{CaO}/\text{Al}_2\text{O}_3$ (mode - 1.0-1.2) bimodal $\text{Al}_2\text{O}_3/\text{TiO}_2$ distribution (6-8, 22-24), commonly low CaO/TiO_2 (8-12), low Cr/Ni (1-4), wide Ti/V distribution, high Ti/Zr (100-120), Zr-Y mode at 3-4, high K-Rb (350-450) and variable Rb/Sr. High-Mg basalts (HMB), tholeiitic basalts (TB), dolerites (D) and gabbros (G) have $\text{CaO}/\text{Al}_2\text{O}_3$ modes of 0.6-0.8. The $\text{Al}_2\text{O}_3/\text{TiO}_2$ and CaO/TiO_2 ratios of basaltic to high-Mg rocks are highly variable, depending on the TiO_2 abundances of the unit in question (see above). High variability pertains also to the Cr/Ni ratios of these rock types, while Ti/V ratios concentrate in the 15-20 mode. Ti/Zr values of basaltic to high-Mg volcanics are mostly lower than for PK, Zr/Y ratios similar to or lower than PK. K/Rb ratios are mostly lower than for PK and Rb/Sr highly variable.

6.2 Silicic Volcanic Rocks

6.2.1 Variations between formations

Owing to extensive alteration, the geochemistry of silicic volcanic rocks - in particular porous pyroclastic deposits - is difficult to interpret in terms of igneous composition. The effects of alteration are manifested mineralogically by widespread development of sericite, chlorite, and carbonate, and geochemically by strong deviation from least-altered fields on LMPR diagrams (section 5). The silicic volcanics studied occur in three principal units: the felsic member of the NSB (FNSB) (basalt-andesite-dacite), the Duffer Formation (DF) (basalt-andesite-dacite-rhyolite-potassic rhyolite), and the Wyman Formation (WF) (ultra-potassic rhyolite), in ascending stratigraphic order. By far the most voluminous is the DF, which was therefore more widely studied (92 analyses) compared to the FNSB (15 analyses) and the WF (23 analyses). Owing to the extreme alteration of silicic volcanics of the Salgash Subgroup (Panorama Formation, Kelly Formation), no sampling was carried out in these units. Analyses of silicified pillow lava at approximately this stratigraphic level at Soanesville were reported by Hickman and Lipple (1975).

Frequency distribution curves (Fig. 6.1) reveal a general increased differentiation with higher stratigraphic units, reflected by variation in silica and alkalis. SiO_2 modes increase from 60-62% (FNSB) to 62-64% (DF) and 78-80% (WF), and K_2O modes from 0.5-1.0% (FNSB) to 1.5-2.0% (DF) to a wide dispersion of 3.0-9.0%² in the WF. Alumina modes decline from high-Al FNSB dacite (16-17% Al_2O_3) to a wide range for DF (12-18%) and low values for WF (11-12%) rocks. A wide distribution range applies to sodium (up to 5% in the DF), reflecting both igneous and secondary scatter. Similarly wide dispersions pertain to Rb, Ba, and Sr. There is a well-pronounced increase in Rb (20-30 to 120 ppm) and decrease in Sr (60-460 to less than 30 ppm) from the FNSB to the WF. A systematic decrease pertains to lithium, with 14-28 ppm in the FNSB, 6-8 ppm in the DF, and 2-4 ppm in the WF, as contrasted to the behaviour of alkalis and more akin to variations in trace metals in the acid units (see below). The low Li abundances in the WF militate against comagmatic relations between this unit and late-stage tin-bearing granites in the eastern Pilbara Block.

Mg and Ca decrease from the DF to the WF, which have negatively skewed modes of 2.5-3.0% and less than 0.5% MgO, respectively. Although lime shows a wide secondary scatter associated with carbonatization, it retains a stratigraphic decrease. Magnesium-group elements (Ni, Cr, Co) and siderophile elements (Fe, Mn, Ti, V) display a secular decrease. Nickel, chromium and cobalt show a wide scatter, but well-defined modes pertain to MnO (0.5-0.10%), TiO₂ (0.5-0.6%), and V (60-70 ppm) in the DF. These siderophile element abundances are notably high for dacitic-rhyolitic compositions. The chalcophile elements Cu, Zn, and S also display a stratigraphic decrease upward. Cu shows a bimodal distribution in the DF, with peaks below 30 ppm and between 40-50 ppm - a feature pertaining to the Marble Bar, Bowls Gorge, and Sandy Creek sections. A similar bimodality appears to hold for the FNSB notwithstanding the small number of samples. Zinc shows a wide and uniform distribution, with shallow negatively-skewed modes of 60-70 ppm for the FNSB, 70-80 ppm for the DF and 0-20 ppm for the WF. Pb shows a marked concentration in the 4-6 ppm range in the DF and a wide dispersion in the other volcanic units. All the three acid volcanic units have Ga modes between 15-20 ppm. Sulphur has a wide scatter, the mode in the DF being 50-100 ppm and many samples having values in the 200-400 ppm range. The marked abundance fluctuations of chalcophile elements in the DF have implications to sulphide mineralization in this formation.

LIL (large-ion-lithophile) element abundances of the silicic volcanic units show an increase with higher stratigraphic level. Thorium modes increase from 0-8 ppm in the FNSB to 4-10 ppm in the DF, while very high values (22-32 ppm) pertain to some WF rhyolites. Uranium follows a similar pattern and is up to 7 ppm high in the WF. By contrast, P₂O₅ abundances decline from a 0.12% mode in the DF to below 0.02% in the WF. Zirconium shows also a decline from the DF (120-120 ppm) to the WF whose mode, largely determined by the Camel Creek section rocks, is 80-90 ppm, while higher levels (130-140 ppm) pertain in the Budjan Creek section. Niobium shows a scatter in the DF (0-10 ppm), and has a bimodal distribution in the WF, Camel Creek rhyolites having high values.

Rare earth elements (REE) show a wide scatter in the three volcanic units. Modes for the DF are 20-25 ppm La and 30-60 ppm Ce, and for the WF 15-20 ppm La and 40-50 ppm Ce. Yttrium increases from 10-15 ppm in the DF to 20-25 ppm in the WF, which indicates a general decrease in the LREE/HREE (light to heavy REE) ratio with time, in accord with unpublished data (Jahn et al.,

1981). The high Y levels may indicate occurrence of basic rocks in the source of WF rhyolites. Marked negative Europium anomalies are shown by the latter rocks, suggesting considerable fractionation of plagioclase.

The distribution of volatiles in the silicic volcanic rocks is of special interest in the light of the widespread alteration. The largely pyroclastic rocks of the DF have a symmetrical frequency distribution pattern centering about 2.0-2.5% H_2O^+ , which is significantly higher than the FNSB dacites (0.5-1.5%) and the WF rhyolites (up to 1.5%), and is probably related to the higher porosity of DF tuffs and agglomerates. Similar relations hold for CO_2 , which may be high in the DF (up to about 6%) but is mostly less than 1.0% in FNSB dacites and WF rhyolites.

The possibility that many of the above trends merely reflect lithological differences between the FNSB-DF rocks (chiefly composed of dacite and andesite) and the WF (potassic rhyolite) can be initially examined by removing or significantly reducing differences between individual samples. When the mean composition of nine samples of potassic rhyolite from the DF is compared to that of the WF (Hickman, in press) all the trends are maintained except those for Na, K and Rb, and to a lesser degree Sr and Zn. Even where these exceptions occur element ratios still differ, K/Rb being relatively high in the DF and Rb/Sr high in the WF.

6.2.2. Variations within formations

Intraformational variations in the Duffer Formation are shown on columnar diagrams (Fig. 6.4). The Bowls Gorge section contains an andesite-dacite-rhyolite assemblage accompanied by basic intercalations, while the Sandy Creek section consists mainly of pyroclastic and brecciated rhyolites. The 3750 metres thick Bowls Gorge sequence displays a general increase in silica toward the top, where highly siliceous potassic rhyolitic tuffs occur. Basic components such as Mg, Ca and Mn show concomitant cyclic variations. There is a general increase upwards in CO_2 , in analogy with basic volcanic successions discussed above. This may represent increased degree of contact with sea water or, alternatively, upward migration of volatiles during burial or thermal metamorphism. Rb and Ba increase upward parallel to increase in potassium and decrease in Sr. Upward alkali enrichment is considered to be a primary feature

(rather than due to secondary migration associated with carbonatization) because it is accompanied by compatible changes in relatively immobile elements such as Th, La, Ce, V and Ni and in diagnostic ratios such as Zr/TiO_2 and Zr/TiO_2 : Nb/Y (Hickman, in press). Th, La, Ce, and to a lesser extent Zr show concomitant cyclic increases between the 2000-2700 metres levels and the 2700-3500 metres levels. Cu and S display maximum scatter toward the top of the succession, S levels reaching about 1000 ppm in some cases - relations of obvious economic significance. The 3400 metre level in the Bowls Gorge section - marked by a chert horizon - is an important geochemical boundary, as geochemical ranges above this point are considerably wider than below. A wide compositional spectrum at high stratigraphic levels is also observed in the DF Sandy Creek section particularly with regard to Si, K, Ba, Zr, La, Ce and CO_2 . Marked changes occur in this section about the 900 metres level, where a sharp increase followed by a gradual decrease occurs with respect to P, Rb, Zr, Nb, Y, La, Ce and Zn. The sympathetic behaviour of these elements, which constitute a magmatically-coherent group, militates against their extensive redistribution upon burial or thermal metamorphism.

7. INTER-ELEMENT RELATIONSHIPS

The relations within and between major and minor elements are investigated here by means of XY and XYZ plots, linear regressions, and correlation coefficients. Interpretations of the observed relations and their comparisons with modern volcanic suites are made in Sections 9-12.

7.1 Basic Volcanic Rocks

Figs 7.1-7.6 display major-element relations in the tholeiitic basalt-komatiite association. The best discrimination between high-Mg basalts (HMB) (basaltic komatiites) and peridotitic komatiites (PK) is obtained on the Al_2O_3 -Mg number* diagram (Fig. 7.1), on which these groups are separated by a compositional gap in the range of 7-10% Al_2O_3 for the North Star Basalt (NSB), and 8-10% for the Mount Ada Basalt (MAB) and the Apex Basalt (AB). The HMB merge continuously with tholeiitic basalts. These relations are also manifest on the FeO - MgO - Al_2O_3 ternary (Fig. 7.2). Chloritized MAB basalts plot toward the Al_2O_3 apex of this diagram. PK and HMB are separated from each other on the MgO - Al_2O_3 -CaO ratios. This plot reveals marked CaO-depletion and Al_2O_3 -enrichment in the altered** samples (marked by crosses on the diagrams), especially in the AB. The TiO_2 - Al_2O_3 relations accentuate the HMB-PK separation, and show that a wide TiO_2 range applies to the tholeiitic basalts (up to 3.0%) in contrast to the HMB (up to 1.0%) and the PK (less than 0.7%). A temporal decrease in TiO_2 is well represented on these plots. A marked compositional gap between HMB and PK with respect to MgO is displayed on the FeO - MgO diagram (Fig. 7.5), values in the 15-20% range being scarce. By contrast, FeO levels in the HMB and the tholeiitic basalts overlap. A decrease in FeO with stratigraphic level and in some altered MAB basalts is evident. The SiO_2 -Mg number diagram (Fig. 7.6) indicates high SiO_2 values of 55% and higher for altered NSB, MAB, and AB basalts. This suggests secondary silicification, as supported by the high ferromagnesian trace element concentrations of some of the "andesites" in these units.

* Mg-number: $100\text{MgO}/(\text{FeO} + \text{MgO})$ in wt%

** the term "'altered'" as defined here refers to samples departing from central least-altered fields on LMPR diagrams (section 5), and may therefore include some possible original igneous compositions.

Correlation coefficients between the major components - Si, Al, Fe, Mg, and Ca - are of limited significance in view of the statistical problem posed by their mutual compensation within the 100% total. Correlation coefficient (r) values for these elements are mostly less than 0.50 and therefore not shown. By far the best correlations are shown by siderophile and some lithophile elements - Ti, V, Zn, Zr, Nb, and P, and between these components and Fe (Appendix II). Some of the highest r values are yielded by Ti-Zr, i.e. $r = 0.79$ (NSB), 0.49 (MAB), 0.78 (AB), 0.93 (EB), 0.95 (CB) and 0.93 (HB), and even better correlations are obtained if altered samples are deleted (Fig. 7.7). Altered rocks tend to plot below the main field on the Ti/Zr vs Mg number diagram (Fig. 7.8), indicating Ti depletion and possibly Zr enrichment. High-Mg basalts tend to have Ti/Zr ratios similar to or higher than tholeiitic basalts. Vanadium shows a negative correlation with the Mg number, and many altered samples are characterized by relative V depletion (Fig. 7.9). Well pronounced sympathetic V-Ti relations pertain (Fig. 7.10), i.e. $r = 0.75$ (NSB), 0.84 (MAB), 0.74 (AB), 0.65 (EB), 0.70 (CB) and 0.63 (HB). Positive correlations are observed between Nb and Zr (Fig. 7.11), r values being 0.85 (NSB), 0.86 (MAB), 0.84 (AB) and 0.75 (EB). P_2O_5 shows good correlations with Ti, i.e. $r = 0.69$ (NSB), 0.90 (MAB), 0.67 (AB), 0.85 (EB), 0.87 (CB) and 0.84 (HB). Altered samples show marked deviations from the main data clusters (Fig. 7.12).

Sympathetic correlations pertain between rare earth elements (REE) and siderophile and lithophile elements. Ce/La ratios are fairly constant and overlapping relations hold between tholeiite basalt and high-Mg basalts (Fig. 7.13), whereas Ce/Y ratios show a wider scatter. Low Ce/Y basalts are principally confined to lowermost stratigraphic units - NSB and MAB. Some altered samples tend to have low Ce/Y ratios, possibly due to concomitant Y and Zr enrichment. Yttrium correlates positively with FeO , i.e. $r = 0.61$ (NSB), 0.54 (MAB), 0.51 (AB), 0.71 (EB), 0.78 (CB) (Fig. 7.14)^t, and shows the closest covariance with TiO_2 (Fig. 7.15) and Zr (Fig. 7.16). Thus, for Y-Ti $r = 0.88$ (NSB), 0.85 (MAB), 0.88 (AB), 0.70 (EB), 0.95 (CB), and 0.92 (HB). For Y-Zr, $r = 0.79$ (NSB), 0.66 (MAB), 0.88 (AB), 0.63 (EB), 0.98 (CB), and 0.94 (HB). Y levels in high-Mg basalts are significantly lower than in tholeiitic basalts with similar FeO . Little or no systematic variation is observed between Ce and Y (Fig. 7.17)^t. As is generally the case for basalts, Ce/Y ratios decrease with higher Y.

The Ni-Cr-Co ternary (Fig. 7.19) reflects the very high Cr-Ni ratios and Cr/Co ratios in HMB and PK relative to tholeiitic basalts. Strong positive correlations pertain between log Ni and Mg number (Fig. 7.20), log Cr and Mg number (Fig. 7.21), and log Ni and log Cr (Fig. 7.22). Some altered rocks show marked Ni loss and either gain or loss in Cr. The log Ni - log Cr curve shows a marked swing toward high Ni/Cr ratios in the komatiite field, where the ratios of these components can be about unity. Very high correlation coefficients hold between log Ni and log Cr, i.e. $r = 0.80$ (NSB), 0.86 (MAB), 0.58 (AB), 0.93 (EB), 0.85 (CB) and 0.64 (HB). Cobalt levels vary little for tholeiitic basalts (30-60 ppm) and are similar or higher for komatiites (ca 100 ppm) (Fig. 7.23).

The Cu-Pb-Zn ternary (Fig. 7.24) shows a wide range of Cu/Zn ratios (0.1-1.5) and little variations in Pb-Zn and Pb-Cu ratios, which are about 0.05 or lower. Weak positive correlations exist between Cu and log S (Fig. 7.25). Cu levels of altered samples tend to be low, i.e. in the AB and EB units. Zinc has a positive correlation with FeO , i.e. $r = 0.63$ (NSB), 0.77 (MAB), 0.77 (AB), 0.75 (EB), 0.64 (CB) and 0.61 (HB) (Fig. 7.26). Altered samples of the AB have high Zn levels (above 150 ppm). Close sympathetic relations hold between Zn and Ti, i.e. $r = 0.59$ (NSB), 0.69 (MAB), 0.59 (AB), 0.63 (EB), and 0.79 (CB) (Fig. 7.27). Gallium has good correlations with FeO , Ti (Fig. 7.28), Zr, V, and Y (Fig. 7.29). With the exception of three dolerite samples, only altered rocks of the AB have Ga values above the detection limits, which suggests enrichment in this element due to secondary processes.

Generally poor correlations occur within the alkali and alkaline earth groups, reflecting the secondary mobility of these elements (section 5). The $\text{CaO-Na}_2\text{O-K}_2\text{O}$ triangle (Fig. 7.30) reveals a concentration of least-altered basalts near the CaO-apex of the $\text{CaO-Na}_2\text{O}$ join. Least-altered samples of the HB unit show relatively high potassium. Altered samples commonly show marked enrichment in K_2O , i.e. in the AB and CB units, and also high Na_2O in the NSB, MAB, EB, and CB units, possibly due to spilitization. The Rb-Sr-Ba ternary (Fig. 7.31) shows a concentration of samples along the Sr-Ba join, Rb/Sr ratios being mainly below 0.03. Altered samples tend to be enriched in Ba, and less commonly in Rb, relative to Sr. The only consistently strong correlation within the alkali-alkaline earth group is between K and Rb, r values being 0.93 (NSB), 0.95 (MAB), 0.69 (AB), 0.80 (EB), 0.86 (CB), and 0.90 (HB) (Fig. 7.32). K/Rb ratios vary in the range of 100-1000, showing a general decrease with higher K

levels in the NSB and MAB (Fig. 7.33). Rb/Sr ratios are sympathetically related to K (Fig. 7.34), the ratios for K levels above 5000 ppm being higher than 0.1. There is a wide dispersion of Sr and Ba, which show a weak positive correlation with each other (Fig. 7.35). Lithium shows an equally wide scatter and has a weak positive correlation with K. Li values in the NSB and MAB (up to 80 ppm) are significantly higher than in stratigraphically higher units, i.e. the HB have only about 10 ppm (Fig. 7.36). Altered samples of the AB tend to have high Li values.

Some of the best correlations (r greater than 0.75) are now summarized. The closest coherence with Fe is shown by Ti, Y, V, P, Zr and Ga. The best correlation with Ti is shown by Zr, Y, P, Ga, Ce and Nb. The best correlations with Zr is shown by Y, Nb, Ga and Ce. Yttrium correlates most closely with V, Ga and P. Phosphorous correlates best with Zr, Y, Ce and Ga. Excellent correlations pertain within the Ni-Cr-Co group and between Ni-Mg (especially for komatiites), Cr-Mg, and Co-Mg. Good correlations occur between Ce-La and K-Rb. The close sympathetic relations between the siderophile, LIL, and REE groups pertain in all rock types - i.e. tholeiitic basalt, dolerite, gabbro, and komatiite - suggesting that they stem from original igneous relations rather than from secondary redistribution which varies between these rock types. It is probable that the retention of primary inter-element ratios arises from the stability of minor components in which they reside, i.e. ilmenite (Fe-Ti), magnetite (Fe-Mn-Ti-V), zircon (Zr-Nb-REE) and apatite (P-REE). Likewise, metamorphism may not have in many instances severely disturbed magmatic Ni-Cr-Co-Mg relations. Potassium and rubidium, both highly mobile, appear to have migrated together.

7.2 Silicic Volcanic Rocks

Major-element relations of the silicic volcanic units shown on the FAM diagram (Fig. 7.37) suggest prevalent calc-alkaline affinities of the rhyolite-dacite-andesite assemblage and tholeiitic affinities of basic components of the Duffer Formation (DF). Rhyolites of the Wyman Formation (WF) plot very close to the A apex, which underlines the geochemical distinction between this unit and the DF. The Al_2O_3 -FeO-MgO ternary (Fig. 7.38) suggests an increase in FeO/MgO with differentiation and an extreme depletion of basic elements in

the WF. Strong negative correlations pertain to $\text{FeO} - \text{SiO}_2$ and $\text{MgO} - \text{SiO}_2$ (Figs. 7.39 & 7.40), i.e. for DF dacites $r(\text{FeO} - \text{SiO}_2) = -0.89$, and $r(\text{MgO} - \text{SiO}_2) = -0.66$. Negative correlations also apply to $\text{SiO}_2 - \text{CaO}$ (Fig. 7.41), i.e. for the DF tuffs $r = 0.76$. Many altered dacites plot in a lower CaO range than unaltered samples, suggesting lime removal. A marked concentration of altered samples also plot toward high SiO_2 values, possibly reflecting secondary silicification.

Although the alkali and alkaline-earth elements were probably highly mobile during secondary processes (section 5) - K, Na, Rb, Ba and Sr constitute essential components in the study of the acid volcanics. The $\text{CaO} - \text{NaO} - \text{K}_2\text{O}$ ternary diagram (Fig. 7.42) confirms the generally low $\text{CaO}/(\text{NaO} + \text{K}_2\text{O})$ ratios of altered samples in relation to least-altered samples - the former including some highly potassic rhyolites. The plot shows that the andesites and the dacites have similar alkali-lime ratios. The Rb-Sr-Ba ternary diagram (Fig. 7.43) draws attention to the contrasted geochemistry of the FNSB-DF and the WF, i.e. samples of the first two units plot on the Sr-Ba join and samples of the WF along the Rb-Ba join. Rb/Sr ratios of the DF rocks tend to concentrate toward the Ba apex. No pronounced trend is observed on the K/Rb vs K diagram (Fig. 7.44), K/Rb ratios being in the 200-400 range for andesites, dacites, and rhyolites of the FNSB and DF, and 200-800 for WF rhyolites, the latter showing a bimodal distribution. There is no clear separation between altered and least-altered rocks on this plot. Rb/Sr ratios are very low for FNSB andesites and dacites (less than 0.2), increase markedly up to about 0.6 for DF rocks with more than 10000 ppm K, $r(\text{Rb/Sr} - \text{K})$ being 0.85 (Fig. 7.45). The Rb/Sr ratios of dacites are higher than those of andesites with similar K levels, and some altered samples tend to have high Rb/Sr ratios. WF rhyolites have sympathetic Rb/Sr - K correlation, Rb/Sr ratios being up to 30. there is a positive relation between K/Ba and K in the DF, ratios being up to about 80, and in the WF where K/Ba ratios are up to 1200 (Fig. 7.46). K/Sr ratios are plotted against $\text{H}_2\text{O} + \text{CO}_2$ to investigate possible relations between this ratio and volatile addition, showing high K/Sr ratios of some altered samples, probably due to both K addition and Sr leaching (Fig. 7.47). Extreme depletion of Sr in WF rhyolites is expressed by K/Sr ratios in the 2000-8000 range. These rocks also have very high Ba/Sr ratios (5-30) as compared to DF silicic volcanics (up to about 10) (Fig. 7.48). In summary, there is an increase in potassium from the FNSB to the DF and the WF, and potassic rhyolites of the latter unit are depleted in Rb, Ba, and Sr relative to K, and in Sr relative to Ba.

Uranium levels in dacites of FNSB and DF units are up to 4 ppm, and the relative abundance of altered samples with U above detection limits suggests a secondary enrichment of this element (Fig. 7.49). U levels in WF rhyolites are in the 2-8 ppm range. Thorium abundances are up to about 13 ppm in the DF, and the WF has a bimodal distribution - including a high-Th group of a 23-33 ppm range (Fig. 7.50). Th/U ratios in the DF and the WF are about 2-10, but Nb/(Th+U) ratios in the WF are diagnostically lower than in the DF (Fig. 7.51). In the DF K/U ratios rise with higher K levels (Fig. 7.52). Zr-SiO₂ plots show similar ranges for the DF (50-200 ppm Zr) and the WF (50-150 ppm), while few altered samples have high Zr levels (300-400 ppm) (Fig. 7.53) and high Nb levels (10-20 ppm) (Fig. 7.54). The WF is low in phosphorous (less than 0.10% P₂O₅) as compared to the DF (0.10-0.20% P₂O₅) (Fig. 7.55).

A study of rare earth element patterns in silicic volcanic units has yielded the following observations (Jahn et al., 1981) (Fig. 7.56):

- (1) FNSB dacites have La_N/Yb_N ratios of 10-20, with steep light REE curve sections. An andesite sample is less fractionated ($\text{La}_N/\text{Yb}_N = 7$).
- (2) DF dacites have La_N/Yb_N ratios of about 8-20, with relatively highly fractionated light REE and little fractionated heavy REE curve segments. Two DF rhyolites have negative Eu anomalies.
- (3) Two WF rhyolites have extreme negative Eu anomalies.
- (4) Two dacites of the Panorama Formation (Salgash Subgroup) have almost flat REE curves (La_N/Yb_N about 1) and positive Eu anomalies.

The Y-La-Ce ternary (Fig. 7.57) shows main concentrations of Ce/La ratios about 2, Ce/Y ratios about 1-4 and La/Y ratios about 0.5-4.0. Some, though not all, of the basic members of the FNSB and DF have considerably higher Y/(Ce+La) ratios than the silicic volcanic rocks with which they are associated. No distinct differences with regard to this ratio occur between the DF and WF dacites and rhyolites. The negative slope on the Ce/Y vs Y diagram (Fig. 7.58) indicates that the decrease in this ratio arises mainly from Y increase rather than Ce decrease. Chondrite-normalized Ce_N vs Y_N plots (Fig. 7.59) display a progressive decrease in Ce_N and increase in Y_N from dacites to andesites to basic rocks, in this order.

The distribution of TiO_2 in the silicic volcanics is clearly related to FeO_t (Fig. 7.60), the correlation coefficient in the DF being $r(\text{TiO}_2 - \text{FeO}_t) = 0.69$. Ti/Zr ratios in the DF decrease with higher silica, from about 40 in basic rocks and some andesites to 10-40 for dacites and rhyolites (Fig. 7.61). Distinctly low Ti/Zr ratios (less than 10) pertain to WF rhyolites. Vanadium ($\log V$) shows a good correlation with titanium ($\log \text{Ti}$), and Ti/V ratios are about 100 (Fig. 7.62). Plots on the 0.01 Ti-V-Cr ternary (Fig. 7.63) reflect relatively high $\text{Ti}/(\text{V}+\text{Cr})$ ratios in the DF dacites relative to basic rocks, and even higher ratios in the WF. Nickel ($\log \text{Ni}$) correlates positively with magnesium ($\log \text{Mg}$), with $r = 0.79$ in the DF, the Mg/Ni ratio being approximately 1000 (Fig. 7.64). Andesites show a wider Ni scatter than dacites and basalts. Chromium correlates positively with Mg, $r(\log \text{Cr} - \log \text{Mg})$ being 0.72 (Fig. 7.65). Some altered dacites tend to have low Ni and Mg values, but many are similar to little-altered dacites. Both diagrams indicate the extremely Ni and Cr depleted composition of the WF rhyolites, i.e. less than 10 ppm of each element.

The Zn/Cu ratios of DF dacites and andesites are in the 1-10 range. Pb/Zn ratios of dacites (up to 0.25) are higher than of andesites and basalts (0.1 and less) (Fig. 7.66) - no distinction between little-altered and altered samples is evident in this regard. The WF rhyolites display a wide scatter on the Cu-Pb-Zn ternary, and existence of high $\text{Cu}/(\text{Pb}+\text{Zn})$ and low $\text{Cu}/(\text{Pb}+\text{Zn})$ groups is suggested, the latter showing a wide range of Pb/Zn ratios. The $\log \text{Cu}$ vs FeO_t diagram for the DF (Fig. 7.67) shows a weak positive correlation between these components, whereas in the WF the wide range of Cu variation (up to 1000 ppm) is unrelated to FeO_t values, which are mostly below 1.0%. In the DF similar Cu abundances pertain to dacites, andesites, and basalts, whereas many altered samples are depleted to levels of below 20 ppm. Generally positive relations pertain between Cu and S (Fig. 7.68), i.e. $r(\log \text{Cu} - \log \text{S}) = 0.60$ (FNSB), 0.40 (DF) and 0.58 (WF), hinting at their combination in sulphides.

Plots on the CO_2 - H_2O diagram (Fig. 7.69) indicate little correlation ($r = 0.26$) between the volatiles. However, in contrast to basic rocks (Section 7.1) altered samples are not necessarily characterized by high H_2O or CO_2 abundances. Notably low volatile levels are characteristic of the WF rhyolites, i.e. CO_2 and H_2O are each less than 1.0%. No clear relation between total H_2O and the FeO_2/FeO ratio is observed in the DF samples, whereas the WF rhyolites show some positive correlation in this regard (Fig. 7.70).

Correlation coefficients for silicic volcanic units (Appendix II)

indicate close sympathetic relations between some LIL elements, REE elements, and transition metals. The best correlations (r greater than 0.75) in the DF dacites include K-Rb, K-Ce, Th-Zr, Th-La, Th-Ce, Zr-Nb, Nb-Y, La-Ce. High correlations (r greater than 0.75) observed in DF tuffs include Ti-Fe, Ti-P, Ti-V, Fe-Mn, Fe-Mg, Fe-Ca, Fe-V, Mn-Ca, K-Rb, Rb-Th, Rb-Ce, Th-La, Th-Ce, Zr-Nb, Zr-Y, Zr-La, Zr-Ce, Nb-Y, La-Ce, and Cr-Ni. Best correlations in the WF vary between the Camel Creek and the Budjan Creek sections, and many of the correlations are difficult to interpret in terms of primary igneous coherence. The common observation of little understood correlations in silicic volcanic rocks, e.g. Al-Mg, Mn-Ca or Li-Co, may be partly due to metasomatic alteration. On the other hand, it is noteworthy that the most consistent correlations, i.e. those observed in all the DF groups, reflect magmatic coherence arising from coresidence in phases such as zircon, rutile, apatite, and magnetite. This conclusion supports the consideration of certain LIL, REE, and metallic elements in terms of primary abundances.

8. CLUSTER ANALYSES

The cluster method (Bonham-Carter, 1967) classifies objects (Q-mode) or observations made on these objects (R-mode) using a weighted or unweighted pair-group clustering procedure. As a measure of affinity between chemical analyses correlation coefficients or coefficients of proportional similarity are used. At each clustering cycle the column corresponding to the highest coefficient is scanned to ensure that the highest value between each pair of analyses is obtained. Such analyses are linked as pairs and each pair represented by a single parameter of intermediate value in the subsequent cycle. Similarity values are calculated between groups of analyses by taking the arithmetic average of the similarity coefficients between their component members. With the weighted method an equal weight is assigned to each group being linked irrespective of the number of samples that each contains. With the unweighted technique equal importance is assigned to each sample, so that larger groups are given more weight than smaller groups. The successive linkages are represented as a two-dimensional hierarchy diagram (dendrograms) with the samples equispaced on one axis and the degree of similarity on the other axis (Figs 8.1-8.10).

Cluster analyses of Pilbara geochemical data was conducted in several batches according to (1) Rock type and (2) Formation. Rock type runs are intended to test how effectively the method discriminates between rock types within each volcanic formation. Formation runs are intended to test whether individual rock types differ systematically in accordance with their stratigraphic classification, cf. whether high-Mg basalts of the Apex Basalt vary from those of the Charteris Basalt, etc. Most batches split into several blocks and subblocks, suggesting natural major and trace element geochemical divisions. The significance of the clusters is in some instances evident - namely, peridotitic komatiites, high-Mg basalts, tholeiitic basalts, andesites - dacites, and rhyolites may plot as separate groups. In other instances overlaps occur and mixed groups are observed. In the following, some of the principal clusters outlined by rock type tests and by formation tests are discussed.

8.1 Rock type tests

Cluster analysis was carried out in 10 batches, based on both formation and section locality, the purpose being to examine unbiased geochemical clustering within individual units and the geochemical basis for such groupings. In the following the dendograms of each batch are discussed in terms of (1) groups (major clusters) and (2) blocks (smaller clusters within groups). Only groups and blocks for which geochemical distinctions are identified are discussed below.

Batch No. 1 - NSB (North Star Basalt) and MAB (Mount Ada Basalt) (Talga-Coongan), 114 analyses (Fig. 8.1).

Group A (blocks 1-4) consists of NSB and MAB basic rocks (tholeiitic basalt, dolerite, gabbro) and minor intermediate components, whereas group B (blocks 5-9) is dominated mainly by komatiitic volcanics. Thus group 1 has relatively high Si, Ti, Al, Na, P, Ba, Sr, Zr, La, Ce and S, whereas group B has relatively high Mg, H₂O, V, Ni, Cr and Co. Block 1 consists of basic rocks characterized by high S. Blocks 2 and 3 contain mainly tholeiitic basalts and only few dolerites and gabbros. Blocks 1, 2 and 3 consist chiefly of low-Mg basic rocks with high Fe, Ca, V, Cr and Cu as compared to Block 4, which is distinct in consisting of dacites (6), andesites (6), high-Al basalts (4) and other basic rocks, containing high Si, Al, K, Rb, Ba, Sr, Pb, Zr, Th, Ce and La.

In group B Blocks 5 and 6 contain both basic and high-Mg basic rocks with high La, Ce and Ga. Block 6 has high Al and S, Blocks 5, 6 and 7 have high Si, Ti, Al, Ca, Na, K, Ba, Rb, Zr, Nb, Y, Li, and V. Block 7 contains high-Mg basalts and pyroxenites. Block 8 consists exclusively of peridotitic komatiites. Both blocks 7 and 8 show very high internal correlation coefficients (r values). Block 9 is characterized by high-Ba basic and high-Mg rocks.

Batch No. 2 - NSB and MAB (McPhee Reward, 35 analyses (Fig. 8.2)

Three blocks are distinguished, each containing both NSB and MAB rocks. Block 1 (5 samples) consists of tholeiite basalts of high K, Ba and Rb. Block 2 consists principally of carbonated basalts of the MAB (15 samples) with high CO₂, Sr, Cu and S and high internal r values. Block 3 (8 basalt, dolerite, gabbro and andesite samples) consists of basic to intermediate rocks characterized by high Al, Mg, Ca, K, Ba and Cr. Both Blocks 1 and 2 have high Fe, P, Pb and S and Blocks 2 and 3 have high Na.

Batch No. 3 - NSB and MAB (Sharks): 34 analyses (Fig. 8.3)

Two principal groups are distinguished. Group A is dominated by MAB basic rocks (14 out of 18) whereas group B consist mainly of NSB basic rocks (12 out of 16). The principal distinctions between the groups are the high Mg, K, Ba, Rb, La, Cr, Ni, Cu and S in group A and high Mn, CO₂, Zr, Ce and V in group B. Group A includes 3 distinct blocks: Block 1 is characterized by low-Mg dolerites of high S, block 2 by high Mg and Ni basalts and block 3 by low-Mg, high Ba MAB basic rocks. Within group B, block 4 (mainly NSB) has basic rocks with high Fe, Na, K, Rb, V and Cr, block 5 has two schists and block 6 contains hypabyssal basic rocks of high Si, Fe, Sr and Cu. A seventh block is defined by 3 silicic volcanic rocks.

Batch No. 4 - DF (Duffer Formation) and granitoids of Mount Edgar Batholith near Marble Bar; 39 analyses (Fig. 8.4).

Three small blocks can be defined. Block 1 consists of 5 samples including 3 of the Mount Edgar Batholith, noted by high Li. Block 2 consists of 4 DF samples marked by high Ba, Sr, V and Zn and Block 3 consists of 5 DF samples marked by high Si, Rb, Th, Zr, Nb, Y, La, Ce and S. The rest of the group can only be divided by low r values, though a basic to ultrabasic block consisting of 8 analyses is outlined as block 4.

Batch No. 5 - DF (Bowls Gorge); 41 analyses (Fig. 8.5)

The dendogram contains four blocks. Block 1 consists of 9 dacites and rhyolites. Block 2 consists of 5 dacites characterized by high S. Block 3 consists of high-Al dacites and 2 andesites with typically high Ca, Na, V and Cu. All the three blocks have high K, CO₂, Ba and Rb compared to block 4. The latter consists of 5 high-Al dacites and one andesite with high Ca, Na, Sr and Ni.

Batch No. 6 - DF (Sandy Creek 17 analyses, and Apex Basalt (AB) (Sandy Creek) 18 analyses (Fig. 8.6).

The dendrogram includes Sandy Creek section samples of both the DF and the Apex Basalt, showing a clear separation from one another. The diagram thus constitutes an example of the degree of discrimination cluster analyses allows between basic and acid compositions. The DF group includes two blocks. Block 1 is characterized by high K rhyolites and rhyodacites and block 2 by high Ba basic and acid compositions. Principal component comparison reveals the high Si, K, Ba, Rb, Th, Zr, Nb, La and Ce of the DF blocks and high Ti, Fe, Mg, Ca, H₂O, V, Cr, Ni and Co of the AB. Dolerite sample 49215 is an exception in that it groups with the DF block 2.

Batch No. 7 - Salgash Subgroup (Camel Creek); 26 analyses (Fig. 8.7).

This group contains four distinct blocks: Block 1 contains 7 tholeiitic basalts and dolerites of the Euro Basalt; Block 2 consists of 4 high-Mg basalts and a dolerite of the Apex Basalt, characterized by relatively high Al, Sr, Cu and S. Block 3 consists of 9 samples of mainly high-Mg basalts of the Apex Basalt. Block 4 consists of 5 peridotitic komatiites of the Apex Basalt, typically high in Mg, H₂O, Cr and Ni.

Batch No. 8 - Wyman Formation; 20 analyses (Fig. 8.8).

The dendrogram allows an effective discrimination between Wyman Formation rhyolites derived from Camel Creek (samples 49318-49324), Budjan Creek (49351-49359), and Emu Creek (49360-49363). The Budjan Creek block has typically high Si. The Emu Creek rhyolites have relatively high Ti, Al, Mn, Sr, Zr, Ni, Cu, Zn, S, and the Camel Creek rhyolites have relatively high Fe, Ca, CO₂, Rb, Pb, Th, U, Nb, La, Ce and Li. The K levels of both Emu and Camel Creek rhyolites are extremely high.

Batch No. 9 - Charteris Basalt (Charteris Creek); 27 analyses (Fig. 8.9).

The dendrogram can be divided into three well defined blocks. Block 1 (6 samples) contains tholeiitic basalts with high Ca and Sr. Block 2 contains high-Mg and tholeiitic basalts of relatively high Al, Na, Ba, Y, and Cr. Both blocks have high Mg and Ni. Block 3 contains five high-Mg and tholeiitic basalts with high Fe, P and S. Basalts of blocks 2 and 3 are characterized by high Si, Mn, K, Ba, Zr and V.

Batch No. 10 - Honeyeater Basalt (Soanesville); 36 analyses (Fig. 8.10).

Four blocks are geochemically defined. Block 1 consists of 4 dolerites and one basalt. The second Block consists of 4 tholeiitic basalts and one dolerite characterized by relatively high Si, Fe, V and Cu. Block 3 contains 4 tholeiitic and high Al basalts and block 4 consists of 2 high-Al basalts, 2 tholeiitic basalts and one dolerite with high K and Ba and some with high Al. Blocks 1 and 2 have high Fe while Blocks 3 and 4 have high Na, Rb, Zr, La and Cr. Low-r clusters between blocks 3 and 4 contain 5 high-Mg basalts.

General conclusions arising from the observed clustering are discussed in section 8.3.

8.2 Formation tests

In an attempt of discerning stratigraphically controlled overall geochemical differences within the major rock types, all tholeiitic basalts, dolerites, gabbros and high-Mg basalt from areas except the Talga-Coongan section were run in four respective batches (Figs. 8.11, 8.12, 8.13, 8.14). These are discussed below:

Tholeiitic basalts: 80 tholeiitic basalts from the McPhee Reward, Sharks, Camel Creek, Sandy Creek, Spinaway Creek, Charteris Creek and Soanesville sections were run for cluster analysis. The dendrogram splits into 9 blocks, but only in few cases is correspondence observed between the stratigraphic and geographic distribution of the samples and these clusters (Fig. 8.11). Block 1 consists mainly of MAB tholeiites of the McPhee section. Block 2 includes a coherent cluster of 5 MAB tholeiites of the McPhee section. Block 5 includes coherent clusters of 5 HB and 3 NSB tholeiites. Block 7 consists of 4 HB tholeiites, block 8 of 6 CB tholeiites and block 9 of 6 AB tholeiites.

Dolerites: 32 dolerites were run for cluster analyses (Fig. 8.12). Six blocks can be distinguished. However, little correspondence is observed between the stratigraphic and geographic distribution and these blocks and these clusters. Block 4 (6 samples) include 3 HB dolerites, block 5 (7 samples) includes 5 HB dolerites and block 6 (5 samples) included 4 MAB dolerites.

Gabbros: 14 gabbro analyses were run for cluster analysis (Fig. 8.13). No distinct blocks are observed and no differentiation according to stratigraphic unit or section locality is observed.

High-Mg basalts: 37 high-Mg basalts were run. The dendrogram is amenable to division in terms of 4 blocks, to which, however, the stratigraphic and geographic distribution of the high-Mg basalts shows little correspondence. Block 2 (7 samples) include 5 AB samples and block 3 (10 samples) includes 5 AB samples.

8.3 Conclusions

For the Pilbara samples of the present study cluster analysis has proven an efficient method of discriminating between geochemically distinct rock types, for example peridotitic komatiite, high-Mg basalt, tholeiitic basic rocks, dacite-andesite and high-K rhyolite. However, exceptions occur, as reflected by the occasional inclusion of distinctly different lithological types within the same block. Thus, an overlap is observed between tholeiites and high-Mg basalts; in some instances the distinction between these types is reflected by their varying proportion in the various clusters, rather than in complete separation (Figs. 8.1, 8.3, 8.7, 8.9). This is in accord with their compositionally continuous range. By contrast, peridotitic komatiites plot in distinct blocks on the dendograms (Figs. 8.1, 8.7). Little or no separation is observed between tholeiitic basalt, dolerite and gabbro. Likewise, andesites and dacites tend to fall within the same clusters (Fig. 8.5) as do dacites and rhyolites (Figs. 8.4, 8.5). In other instances good separation is achieved between dacites and rhyolites (Fig. 8.6) or between same rock types with different chemical attributes, i.e. high-Al dacites (Fig. 8.5) or high-Ba dacites (Fig. 8.6). Some separation is obtained between some trondhjemites of the Mount Edgar Batholith and Duffer Formation dacites and rhyolites (Fig. 8.4), suggesting some chemical differences. Potassic rhyolites of the Wyman Formation plot in three distinct clusters in accordance with their geographic derivation from three different sections (Fig. 8.8).

By way of contrast with the rock type test runs, Formation runs were aimed at investigating possible overall geochemical differences within single rock types in accordance with their stratigraphic (volcanic unit) and geographic (section) derivation. The results have proven disappointing, in that little overall correspondence is observed between single rock type attributes and stratigraphic/geographic source. However, this result cannot be interpreted in terms of detailed similarities. Thus, it is known that distinct units have diagnostic element characteristics, e.g. the high Ti and low K of NSB and MAB tholeiites, high Al and K of some Gorge Creek Group tholeiites, low Zr in the Ab and GCG and high Zr in the EB tholeiites, low Cr in the HB tholeiites, etc. (Chapter 6). It is concluded that these minor, but highly significant, differences are "swamped" by the otherwise overall similarities within individual rock types.

9. PETROCHEMICAL AND NORMATIVE CLASSIFICATIONS

The major-element characteristics of least-altered samples (section 5) allow an idea to be gained of the petrochemical affinities of the metamorphosed volcanic suites, using diagrams such as: (1) $\text{Na}_2\text{O}+\text{K}_2\text{O}$ vs SiO_2 , on which the fields of alkali basalt, high-Al basalt and tholeiitic basalt are defined (Kuno, 1966); (2) FAM ternary (FeO_{t} -Alk-MgO), separating the fields of tholeiitic basalt and calc-alkali basalt (Irvine & Baragar, 1971); (3) normative Qz-Cpx-Opx-Ol quaternary, allowing distinction of quartz-hypersthene tholeiites from olivine-hypersthene tholeiites; (4) normative An-Ab-Or ternary (O'Connor, 1965), allowing classification of dacite (tonalite), Na-rhyolite (trondhjemite), rhyodacite (granodiorite), quartz-latitude (adamellite), and K-rhyolite (granite). Other useful plots include differentiation-index (Qz-Or-Ab-Ne-Lc) vs crystallization-index (An+Di+Fs+Sp). For silicic volcanics, the normative corundum (C) versus normative quartz (Q) plot, Qz-Ab-Or ternary, and the SI index ($\text{Al}_2\text{O}_3/(\text{Na}_2\text{O}+\text{K}_2\text{O}+\text{CaO})$ (mol%)) yield useful petrogenetic information. The SI index (Chappell & White, 1974) discriminates between magmas derived directly from igneous materials (SI below 1.1) and those derived from materials which underwent a sedimentary cycle (SI higher than 1.1).

Plots of basic volcanics of the Warrawoona and Gorge Creek Groups on the Alk vs SiO_2 diagram (Fig. 9.1) indicate an absence of alkaline basalts in the Archaean suites. The FAM diagram suggests the contrasted affinities of basalts and the andesite-dacite-rhyolite suites of the Warrawoona Group. The majority of basic rocks plot within the tholeiite field, although some overlap the boundary with the calc-alkaline field, whereas the more silicic to intermediate compositions concentrate in the calc-alkaline field (Fig. 9.2). Alkali enrichment of altered basalt samples is manifest. The above contrast also pertains between basic components (basalt and dolerite) and the predominant silicic to intermediate components of the Duffer Formation, which argues against a fractional crystallization relationship between these end members.

The Qz-Cpx-Opx-Ol quaternary (Fig. 9.3) indicates a predominance of quartz-hypersthene-normative compositions among the basalts and the dolerites of the Warrawoona and Gorge Creek Groups, olivine-hypersthene-normative compositions being minor. The majority of komatiitic lavas are olivine-hypersthene normative, but some high-Mg basalts are quartz-hypersthene normative. This feature distinguishes the Archaean komatiites from picrites, e.g. Hawaiian picrite basalts (Table 11.1). The compositional gap observed between high-Mg basalts and peridotitic komatiites of the Onverwacht Group (Barberton Mountain Land, Transvaal) (Glikson, 1979) may also pertain to the Pilbara suite, as suggested by the gap between Ol-Opx-dominated komatiites and Cpx-Opx-dominated komatiites of the North Star Basalt (NSB), Mount Ada Basalt (MAB), and Apex Basalt (AB). However, insufficient data for peridotitic komatiites are available to confirm this division.

An-Ab-Or plots of silicic to intermediate compositions (Fig. 9.4) indicate according to O'Connor's (1965) classification a predominantly Na-rhyolite (trondhjemitic) affinity of Duffer Formation rocks, although dacitic (tonalitic) and K-rhyolitic (granitic) compositions are also common. The Wyman Formation consists of K-rich rhyolites. Rhyodacites and quartz-latices are uncommon. A comparison between the Duffer and Wyman Formations on the Qz-Ab-Or ternary (Fig. 9.5) points out the fundamental distinction between these units. Wyman Formation rhyolites are almost devoid of normative albite and show a wide spread of Qz/Or ratios. Andesites display a wide spread on both the An-Ab-Or and Qz-Ab-Or ternaries, and although they concentrate in the fields of dacite their scatter suggests that at least some of these rocks are secondarily silicified.

Plots of the differentiation index (DI) versus the crystallization index (CI) (Fig. 9.6) reveal the distinction between tholeiites and komatiites, and support the suggested compositional gap between high-Mg basalts and peridotitic komatiites. In distinction from other units, the MAB includes a group of tholeiitic basalts of very low CI (about 10) and high DI (about 40) values. The DI and CI indices show strong negative correlation with each other, as expected. A wide scatter of Euro Basalt points out the relative alteration of this unit. DI values of dacites of the Duffer Formation (DF) concentrate about 60-80 and rhyolites about 80-90. K-rich rhyolites of the Wyman Formation (WF) have DI values between 90-1000 and CI values less than 2 - representing the extremely siliceous, alkali-rich and ferromagnesian-poor composition of these rocks (Fig. 9.6).

Plots of normative corundum (C) versus normative quartz (Qz) (Fig. 9.7) reveal the high C values of many rhyolites, dacites, and andesites of the DF and rhyolites of the WF. A distinct positive correlation is shown between the C and Qz values in the latter unit. The DF and WF display distinctly different dispersions of SI indices and C values; the SI/C ratios of the WF unit are consistently higher than of the DF. The better SI-C correlation shown by the WF may be interpreted in terms of lower degree of alteration. The commonly very high C values in the DF, and the lack of a good SI-C correlation in this unit, may be interpreted as the result of secondary redistribution, involving carbonatization (which results in excess C in the norm) and leaching of alkalis. For this reason, it is questionable whether the high C and commonly high SI indices (above 1.1) reflect a prior sedimentary cycle.

10. IGNEOUS PETROGENESIS AND MANTLE COMPOSITION

The dominance of metamorphic minerals and paucity of relict igneous phases in the Pilbara greenstones requires that investigations of magmatic processes hinge on whole-rock geochemical data. Only least-altered samples, as screened by the LMPR method (Section 5), are considered here. The role of fractional crystallization will be tested using $\log e - \log Zr$ plots (e - any trace element) after Allegre & others (1977), which allows the deduction of bulk-distribution-coefficients (K_d), and from that of the parental magma composition (C_o^e), fraction of residual liquid (F), and the mineral composition of the residue. The CMAS tetrahedron scheme of O'Hara (1968) is used to discern fractionation trends and the controlling residual minerals. A discrimination between primary magmas (mantle melt product) and fractionally crystallized magmas is achieved through Hanson & Langmuir's (1978) $MgO-FeO$ (mol%) diagram, which allows reading of degree of partial-melting of pyrolite (F) and liquidus temperatures at 0 kb and 30 kb, applying D_{Fe} and D_{Mg} mineral/melt partition coefficients of Roeder & Emslie (1970) and Bickle & others (1977). These parameters allow calculations of trace-element abundances and Mg values of the mantle. Finally, the implications of these models to Archaean mantle geochemistry will be discussed.

10.1 Fractional Crystallization of basic magmas

Olivine tholeiite magma may form by 20-30% melting of mantle peridotite, leaving a residue of olivine, orthopyroxene $\pm$ spinel (Green & Ringwood, 1967; Green, 1971). Alternatively, this composition may arise by fractional crystallization of picritic or komatiitic liquids (Arndt & others, 1977). Allegre & others (1977) modelled the derivation from whole-rock trace-element data of (1) the bulk partition coefficient K_d^e for any element (e) from $\log e$ vs $\log i$ plots (i - incompatible "hygromagmatophile" element whose K_d^i relative to mantle residues is practically 0). According to Rayleigh's disequilibrium fractionation law (Neumann & others, 1954):

$$C_l^e = C_o^e (K_d^e - 1) \quad \dots(1)$$

C_1^e - rock (analysis); F - wt% residual liquid

C_o^e - primary magma

where the K_d^i for an incompatible element (i) is about nil, the approximation pertains:

$$C_1^i = \frac{C_o^i}{F}, \text{ or } F = \frac{C_o^i}{C_1^i} \quad \dots(2)$$

substituting for F in Rayleigh's equation:

$$C_1^e = C_o^e \left(\frac{C_o^i}{C_1^i} \right)^{(K_d^e-1)} \text{ or } C_o^e = \frac{C_1^e}{\left(\frac{C_o^i}{C_1^i} \right)^{(K_d^e-1)}} \quad \dots(3)$$

to derive the parent-magma composition C_o^e , the partition coefficient K_d^e and the initial abundance of the incompatible element C_o^i must be known. As a derivation from equation (3) above:

$$\log(C_1^e) = \log C_o^e + (K_d^e-1)\log(C_o^i) - (K_d^e-1)\log(C_1^i) \quad \dots(4)$$

$\frac{\log(C_1^e)}{\log(C_1^i)}$
since $\frac{\log(C_1^e)}{\log(C_1^i)} = 1 - K_d^e$, the slope of straight line on the $\log(D_1^e)$ vs $\log(C_1^i)$ plot, representing a constant K_d^e , is used to derive this value (Fig. 10.1). If the slope is positive, the slope equals $(1 - K_d^e)$ and K_d^e is less than unity. To derive C_o^i the assumption is made that Ni level in the parent magma is 450 ppm (Allegre & others, 1977; Jaques & others, 1978), and

the abundance of (i) is read from a log (i) - log Ni diagram. Primary magma abundances of other elements can then be computed according to equation 3, or can be read directly from log(e) - log(i) graphs. The residual liquid fraction (f) can be calculated from equation 1:

$$F = (K_d^e - 1) \sqrt{C_1^e / C_o^e} \quad \dots(5)$$

The mineral composition of the fractionated solids may be inferred from the measured K_d^e values, and from $D_{\text{mineral/melt}}^e$ coefficients cited from the literature, by means of solving simultaneous equations for more than one element:

$$\begin{aligned} K_d^a &= D_1^a X_1 + D_2^a X_2 \\ K_d^b &= D_1^b X_1 + D_2^b X_2 \end{aligned} \quad \dots(6)$$

a - element a; b - element b; 1 - mineral no 1;
2 - mineral no 2; X_1 - fraction of mineral no 1;
 X_2 - fraction of mineral no 2.

In the present study Zr was selected as the reference incompatible element (i), thanks to the low K_d^{Zr} relative to residual mantle phases (Allegre & others, 1977; Frey & others, 1978) and the analytical accuracy of this element (Section 3.2). Log (e) vs log (Zr) plots (Fig. 10.1) allow the derivation of K_d^e coefficients, listed in Table 10.1. Only least-altered basalts are included in these plots, whereas deviate samples (section 5) and ultramafic, andesitic, and dacitic compositions were deleted. this was done in view of the possibility that the high-Mg basalts may not be related to a fractional-crystallization sequence, and that the dacitic rocks may have been derived from distinct sources. Only K_d^e values derived from well-defined regressions are listed. Good positive correlations are obtained for Ti-Zr, P-Zr, Nb-Zr, La-Zr, Y-Zr, Zn-Zr and V-Zr, and negative correlations for Ni-Zr and Cr-Zr. Poor correlations pertain to Sr-Zr, Ba-Zr, Rb-Zr, and Ce-Zr. From the K_d^e values, the C_o^e , F values, and residue norms were computed (section 3.3);

the results are presented in Table 10.2. Only K_d^e values read from regressions whose correlation coefficients are better than 0.5 were considered. Where the slope exceeds 1.0, factors other than crystal fractionation probably operated (Allegre & others, 1977).

Good regressions, and thus probably valid K_d values, are derived for Ti, Y, P, Ga and Nb, and in some volcanic units for Zn. The North Star Basalt and Mount Ada Basalt show higher correlation coefficients than higher units, reflecting either lesser degrees of alteration in the lower volcanics, or alternatively an increasingly heterogeneous nature of the source with time. For the calculation of F, the C_{Zr}^o of the primary magma is derived from average values of the high-Mg basalts of the corresponding units, as shown in Table 6.1. For the calculation of normative residual mineralogy, the parental magma was assumed to be a high-Mg basalt of the composition:

SiO₂ = 51%; TiO₂ = 0.6%; Al₂O₃ = 11%; FeO_{total} = 12%; MnO = 0.2%; MgO = 13%; CaO = 11%; Na₂O = 1.0%; K₂O = 0.2%. The bulk partition coefficient K_d^e read from the log-log graphs has been compared with calculated bulk K_d^e values derived from equation 6, using D^e values from the literature. Very poor correspondence between the observed and calculated K_d^e values is obtained, probably reflecting the uncertainty in selection D values for the actual P and T conditions pertaining to the rocks in question.

The results of the above model calculations are summarized according to the various formations (Table 10.2):

North Star Basalt: For 37 tholeiitic basalts, the cumulate fraction separated from a parental high-Mg basalt magma consists of 31% Cpx, 35% Ol, 20% Opx, and 13% Plg. Computed trace element levels of the primary magma are: Ti = 4227 ppm; Y = 18 ppm; V = 281 ppm; Zn = 69 ppm.

Mount Ada Basalt: For 36 tholeiitic basalts the modal residue consists of 35% Cpx, 24% Ol, 19% Opx, and 20% Plg. Average parental magma values are: Ti = 6227 ppm; Y = 21 ppm; V = 299 ppm; Zn = 91 ppm.

Apex Basalt: For 13 tholeiitic basalts, the average residue contains 31% Cpx, 26% Ol, 28% Opx, and 16% Plg, and the model parental magma contains 3428 ppm Ti, 13 ppm Y, 247 ppm V, and 65 ppm Zn.

Euro Basalt: For 5 tholeiitic basalts, the average normative residue contains Cpx, 23% Opx, 19% Ol and 19% Plg, and the model primary magma contains 6227 ppm Ti, and 22 ppm Y.

Plots of F versus percentage normative plagioclase yield a negative linear correlation, indicating a progressively ultramafic nature of the residue with increasing melting, as expected. Primary magma model abundances of Ti, V, Y and Zn (Table 10.2) show generally excellent correlations with the unit averages of high-Mg basalt (Table 6.1), supporting the validity of the above calculations.

It may be concluded that the tholeiitic basalts and dolerites are likely products of fractional crystallization of olivine, clinopyroxene and plagioclase from high-Mg primary magmas (direct mantle melts), which are represented by the broadly equivalent high-Mg basalts interspersed with the tholeiites. This view is supported by the continuous transition, and lack of a compositional gap, between the fields of tholeiitic and high-Mg basalts (Figs 7.1-7.36). The model primary high-Mg magma considered here may form by about 33% melting of pyrolite composition, as calculated by MgO-FeO mass balance (equation 4 in section 10.2). In view of the availability of analytical data for the komatiites, estimates of mantle composition are best made with reference to these rocks rather than by calculations based on the model primary magma composition.

10.2 Partial Melting of the mantle

The abundance in Archaean greenstone sequences of high-Mg to peridotitic komatiite lavas allows a direct investigation of mantle source composition. Cumulate ultramafic rocks (pyroxenites) are ruled out from these calculations (on textural basis) as they can not be direct mantle derivatives. Hanson & Langmuir (1978) calculated a FeO-MgO (mol%) grid from which primary partial melts of pyrolite (Ringwood, 1976) can be discriminated from products of fractional crystallization, and degrees of partial melting and liquidus temperatures can be read (Fig. 10.2). The method assumes equilibrium batch melting according to Henry's law (Shaw, 1970; Arth, 1976), which is applicable to major elements within stoichiometric limits:

$$C_1^e / C_0^e = 1 / (K_d^e (1-F) + F) \quad \dots(1)$$

C_1^e - element abundance in primary melt; C_0^e - element abundance in mantle; K_d^e - bulk partition coefficient; F - fraction of melting

K_d values for Fe and Mg for partial melting at 0 kb are after Roeder & Emslie (1970) and at 30 kb from Bickle & others (1977), C_1^e is represented by the komatiite data, and F read from the FeO-MgO grid. This enables the derivation of mantle FeO and MgO levels and, given appropriate K_d values, of any trace element abundance, from:

$$C_o^e = C_1^e (K_d^e (1-F) + F) \quad \dots(2)$$

Inherent in the method are uncertainties arising from the assumption of pyrolite source and composition and of equilibrium melting, and the incomplete knowledge of variations in $D_{\text{mineral/melt}}$ coefficients with pressure, temperature, and melt composition. Thus, it is likely that complex melting relations, including dynamic melting, disequilibrium fractional melting, continuous melting, and magma mixing (Langmuir & others, 1977; Arndt & others, 1977) have operated. However, in the absence of experimental data pertaining to the Pilbara suite, the method outline below allows a useful approximation of melting processes.

In calculating mantle trace-element abundances, the bulk partition coefficient K_d^e of the residual mineral assemblage is given by:

$$K_d^e = D_{ol}^e X_{ol} + D_{opx}^e X_{opx} + D_{cpx}^e X_{cpx} + D_{sp}^e X_{sp} \dots \text{etc} \quad \dots(3)$$

X - fraction of the mineral relative to total solids

In order to obtain the X values, the normative composition of the residue, obtained by subtracting the magma (rock) composition from pyrolite (Ringwood, 1976) composition by mass balance, was calculated. D values were cited from Allegre & others (1977) and Frey & others (1978) (Table 10.3). The results are presented in Table 10.4, which lists degree of partial melting (F) obtained by mass balance (see below), normative composition of residues and source-pyrolite element abundance.

Assuming that, within stoichiometric limits, mantle levels of FeO and MgO can be derived by applying Henry's law equation (Hanson & Langmuir, 1978), an attempt has been made to estimate mantle Mg values from the komatiite data. As an approximation it is assumed that, for high degrees partial melting (over 40%), only olivine remains in the residue. This assumption is also applicable if the residue contains orthopyroxene with a Fe/Mg ratio similar to the olivine. C_o^{Fe} and C_o^{Mg} can be derived from equation 2, applying F and T values read from the FeO-MgO grid and D_{ol}^{Fe} and D_{ol}^{Mg} derived from Roeder & Emslie's (1970) temperature-dependent equations. However, because inherent in the construction

of the grid is an assumed pyrolite composition - which is not necessarily valid in detail for the Archaean source - an independent test of the mantle Mg value requires an independent derivation of F.

One method for deriving F is by means of using an incompatible (i) element with very low K_d relative to mantle residues, such as Zr (Arth, 1976). If $K_d^i = 0$, as a derivation from equation 2, $F = C_o^i / C_i^i$ (equation 2 in section 10.1). Another method for the derivation of F is through mass balance calculation of major element partitioning between the mantle source, partial melt (primary magmatic rock), and residual minerals. Assuming, for komatiitic liquid, a residue consisting mainly of olivine, the following equation pertains to the Mg+Fe distribution:

$$F C_{\text{liquid}}^{\text{Mg+Fe}} + (1-F) C_{\text{Ol}}^{\text{Mg+Fe}} = C_{\text{mantle}}^{\text{Mg+Fe}} \quad \dots(4)$$

According to Ringwood (1976) the MgO+FeO (mol%) of pyrolite is 53.15%; as stoichiometrically the molecular proportion of MgO+FeO in olivine is 66.6%, the fraction of partial melting (F) is given by:

$$F = (53.15 - 66.6) / (C_{\text{liquid}}^{\text{Mg+Fe}} - 66.6) \quad \dots(5)$$

The knowledge of F allows an independent derivation of the mantle Mg value ($100 C_o^{\text{Mg}} / (C_o^{\text{Mg}} + C_o^{\text{Fe}})$) (in mol%), deducing initial mantle levels by:

$$C_o^{\text{Mg}} = C_1^{\text{Mg}} (D_{\text{Ol}}^{\text{Mg}} (1-F) + F); \quad C_o^{\text{Fe}} = C_1^{\text{Fe}} (D_{\text{Ol}}^{\text{Fe}} (1-F) + F) \quad \dots(6)$$

The D values are derived from Roeder & Emslie's (1970) temperature-dependant formulas:

$$\log D_{\text{Ol}}^{\text{Mg}} = 3740/T - 1.87; \quad \log D_{\text{Ol}}^{\text{Fe}} = 3911/T - 2.50 \quad \dots(7)$$

T (liquidus temperature) is estimated from Hanson & Langmuir's (1978) FeO-MgO grid. However, as the liquidus temperature varies with source composition and pressure, this constitutes a weakness of the method. The application of the above procedure to 18 basaltic to high-Mg basaltic compositions obtained by experimental partial melting of pyrolite under temperatures of 1150-1550°C, pressures of 2-15 kb, and 16-51% melting (A.L. Jaques, pers. comm., 1979), suggests a remarkably good agreement: For 11 compositions, the mean deviation of the calculated F value from the observed F value (found by a combination of SEM* and modal analysis**) is +0.04. The mean deviation of the T values read from Hanson and Langmuir's diagram and the measured T values is $\pm 50^{\circ}\text{C}$. Mantle Mg values deduced from the experimental data by equations 4 and 5 are in the range 88-91, in agreement with the starting pyrolite composition used in the experiments.

Excluding data which plot outside the primary melt field (which suggests crystal fractionation) as well as data whose MgO+FeO (mol%) exceeds 53.15% (which suggests crystal accumulation), calculation results for 12 peridotitic komatiites are presented in Table 10.4. The data include three samples from the North Star Basalt (NSB), four samples from the Mount Ada Basalt (MAB), four samples from the Apex Basalt (AB) and one from the Euro Basalt (EB). Mg numbers range from 76 to 86. Degrees of partial melting vary in the range of 46-95%, although it is likely that the highermost values reflect crystal accumulation effects. The normative residues are dominated by olivine (ca 90-100%). Calculated mantle Mg numbers for low-P and low-T $D_{\text{ol}}^{\text{MgO}}$ and $D_{\text{ol}}^{\text{FeO}}$ coefficients are in the range of 85-91 with an average of 87.2, and for high-P and high-T D values in the range of 78-89, the average Mg number being 84.9. Because of the probable high temperature origin of komatiitic magmas (Green & others, 1975), the latter values are considered more likely. It therefore appears that, in agreement with earlier suggestions (Glikson, 1972; Green et al., 1975; Sun & Nesbitt, 1977; Bickle & others, 1977; Glikson, 1979), the Archaean mantle may have been characterized by high FeO_t/MgO ratios relative to modern mantle (section 10.3). Further comparisons between the calculated Archaean trace element abundances and modern mantle and carbonaceous chondrite abundances are made in the following section.

* scanning electron microscope

** the experimental liquid composition was obtained by point count of analyzed phenocrysts and mass balance calculation assuming $\text{Fe}/\text{Mg}(\text{ol/liquid})$ of 0.3.

10.3 Inferences on Archaean Mantle Composition

Principal methods of estimating mantle composition are based on the study of lherzolite and harzburgite inclusions in kimberlites and alkali basalts, deduction of initial isotopic ratios of mantle-derived magmatic rocks ($^{87}\text{Sr}/^{86}\text{Sr}$, $^{207}\text{Pb}/^{206}\text{Pb}$, $^{238}\text{U}/^{204}\text{Pb}$, $^{143}\text{Nd}/^{144}\text{Nd}$), theoretical derivations from the composition of carbonaceous chondrites and stellar spectra, thermodynamic implications of phase equilibria, and high-pressure experimental petrological work (Urey, 1960; Anders, 1968; Anderson, 1968; Brett, 1971; Ringwood, 1975). The discovery in Archaean terrains of peridotitic lavas (Viljoen & Viljoen, 1969; Naldrett & Mason, 1968; Lewis, 1971; Nesbitt, 1971) has allowed a new approach to the study of early mantle geochemistry. Nesbitt & Sun (1976) and Sun & Nesbitt (1977, 1978a, 1978b) have studied the relatively immobile LIL (large ion lithophile) and siderophile elements - Zr, Nb, P, Y, REE, Ti, and V in spinifex-textured peridotitic komatiites (STPK) (above 20% MgO), with implications to the primary mantle ratios of these elements. The underlying rationale is related to the very low K_d coefficients of these elements relative to mantle residues (mainly olivine, accompanied by orthopyroxene and possibly clinopyroxene), i.e. the strong partitioning of these components into komatiitic melts has resulted in a retention of original mantle trace element ratios in the latter. Comparisons between these ratios and those of chondrites lend support to this suggestion.

Table 10.5 lists some of incompatible element ratios of interest - Ti/Zr, Ti/Y, Ti/V, Cr/V, Zr/Y, V/Zr, Cr/Ni, Cr/Co, and Ni/Co, as based on Table 10.4, with comparison to Nesbitt & Sun's (1976) spinifex-textured peridotitic komatiites (STPK) and to chondritic ratios. In Fig. 10.3 the Zr-Ti, Y-Ti, Y-Zr, Nb-Zr, Nb-Ti, V-Ti, Zr-V and $\text{P}_2\text{O}_5\text{-TiO}_2$ relations are compared to chondritic ratios. The $\text{Al}_2\text{O}_3/\text{TiO}_2$ vs TiO_2 and CaO/TiO_2 vs TiO_2 relations are compared in Fig. 10.4, after Sun & Nesbitt (1978b). The following observations are allowed by these data:

- (1) There is a general increase in the calculated mantle Mg number, and a decrease in model mantle Ti, Cr, V, and possibly Zn from the Talga-Talga Subgroup to the Salgash Subgroup. Likewise, there is an increase in Ti/Zr and V/Zr, and a decrease in Ti/Y, Zr/Y, Ti/Y, Cr/V, and Cr/Ni with time.

- (2) The mean Pilbara mantle model composition is similar to Nesbitt & Sun's (1976) average STPK with respect to Co, Cr, Ti, Zr, Zr/Y, V/Zr, and Cr/V. It is very similar to Ringwood's (1976) pyrolite with respect to Ni, Cr and Co. It is low in Ti and Zr and high in Cr compared to the model mantle peridotite (3/4 average peridotite and 1/4 average basalt) of Turekian & Wedepohl (1964), but little confidence can be placed on the latter average. Cr/Ni and Ni/Co model mantle ratios are similar to those of pyrolite.
- (3) Excellent correlation is shown between Pilbara Komatiites and average chondrite with respect to ratios of LIL and siderophile elements (Zr, Y, Ti) (Fig. 10.3). The Zr-Ti regression line of Pilbara komatiites and pyroxenites ($r = 0.93$) nearly coincides with the chondritic ratio line ($\text{Ti/Zr} = 100$), although many samples have Ti/Zr and Ti/Y ratios somewhat higher than chondrites. High Ti/Y ratios pertain to some komatiites of the Mount Ada Basalt. The Y-Zr plot reveals the tendency of Talga-Talga Subgroup komatiites for high Zr/Y ratios, whereas stratigraphically younger units have ratios closer to the chondrite value of 2.5. Zr/Nb ratios are close to the chondrite values of 16, but not enough data for Nb is available for this comparison. However, Ti/V and Zr/V ratios are conspicuously high compared to the average chondritic ratios of 10 and 1/12 (respectively), due to the high Ti and often Zr of the komatiites relative to chondrites. There is a strong departure of $\text{TiO}_2/\text{P}_2\text{O}_5$ ratios of the komatiites from chondrites, suggesting possible primary differences between the mantle and chondrites with respect to this ratio.
- (4) The Ti-Al-Ca relations (Fig. 10.4) are investigated relative to chondritic and mantle pyrolite ratios. Komatiites of the Mount Ada Basalt have high $\text{TiO}_2/\text{Al}_2\text{O}_3$ and TiO_2/CaO ratios relative to stratigraphically higher komatiites whose values are more akin to the chondritic ratio of 0.05. These differences reflect the high Ti abundances of the Talga-Talga Subgroup volcanics, as also reflected by high Ti levels in associated tholeiitic basalts (section 6.1). The comparison on Ca/Ti vs Ti and Al/Ti vs Ti diagrams (Sun & Nesbitt, 1978b) emphasises the Ti-rich composition of products of high percentage melting of the Archaean mantle relative to modern pyrolite.

10.4 Petrogenesis of felsic Volcanic Rocks

Contrary to basic and ultrabasic igneous rocks, whose origin by partial melting of mantle and further crystal fractionation is experimentally established (Green, 1972; Ringwood, 1976), silicic magmas are capable of arising by anatexis of a variety of source compositions, including basic rocks, older silicic igneous rocks, sediments and their metamorphosed derivatives. Discriminations between products of these processes hinge on isotopic data, major element ratios and trace element data: the higher the initial $^{87}\text{Sr}/^{86}\text{Sr}$ isotopic composition, the lower the $^{143}\text{Nd}/^{144}\text{Nd}$, and the higher the concentration of LIL (large ion lithophile) elements, the more likely it is that the magma was derived from a sialic source. Alternatively, highly differentiated compositions may arise by advanced crystal settling from basic and acid magmas. A distinction between melts formed by equilibrium batch melting according to Henry's law and by nonequilibrium fraction according to Rayleigh's law (Gast, 1968; Shaw, 1970) is not generally possible. The melt fraction (F) is generally derived from incompatible element (i) relations, where $K = 0$, assuming that little or no Zr is left in the ultramafic residue. The equation pertaining to both partial melting and fractional crystallization is

$$\text{thus } F = \frac{D_o^i}{C_i^i} \dots(1)$$

C_o^i - concentration in source; C_i^i - concentration in melt

To derive the composition of the fractionated residues in relation to any assumed source rock or parent magma, mass balance equations for major elements can be used:

$$C_s^e = FC_l^e + (1-F)C_r^e \dots(2)$$

(C_s^e - source concentration; C_l^e - liquid concentration;

C_r^e - residue concentration, for major element e)

Substituting for F from equation (1), the composition of the residue is given by

$$C_r^e = (C_s^e - C_l^e D_o^i / C_i^i) / (1 - D_o^i / C_i^i) \dots(3)$$

It is thus possible to test if a derivation of any given magmatic rock from an assumed source composition is consistent with stoichiometric mineral formula requirements, i.e. whether sufficiently high levels of any particular element/s exist in the assumed source to give rise to the directly observed (analysed) rock. An indicated deficiency of any element would suggest derivation or addition from other sources, i.e. the abundance in the assumed model parent would be insufficient to account for the observed composition. Such additions may ensue by zone refining, wall-rock contamination, magma mixing, heterogenous source melting, hydrothermal activity and metasomatism.

Assuming a basic source similar to the average NSB tholeiite (Table 6.1a) ($\text{SiO}_2 = 52.00$; $\text{TiO}_2 = 1.3$; $\text{Al}_2\text{O}_3 = 14.00$; $\text{FeO} = 12.00$; $\text{MnO} = 0.2$; $\text{MgO} = 7.00$; $\text{CaO} = 10.50$; $\text{Na}_2\text{O} = 2.60$; $\text{K}_2\text{O} = 0.40$), and using Zr as the reference (i) element due to its relatively immobile nature and analytical accuracy, mass balance calculations were carried out. The following conclusions regarding the degree of melting (F), normative residue compositions, and principal normative deficiencies, pertain:

Upper North Star Basalt dacites and andesites: The average F for 8 dacites is 0.76; residues of dacites shows some deficiencies in K_2O and Na_2O , implying that, had the silicic melts been derived from basic source, extraneous addition of alkali elements to the melt was required.

Duffer Formation andesites, dacites and rhyolites: The average F value for 6 rhyolites is 0.49, for 26 dacites is 0.72, and for 10 andesites 0.73. Though in the right order, these values indicate that, either these rocks were derived from different sources, or alternatively the Zr values offer a poor basis for derivation of F. The residue is of ultramafic composition and for rhyolites shows marked deficiencies in K_2O and in Na_2O .

The above results cast doubt on models of basic source melting with respect to highly potassic and siliceous rocks. It is likely that some of the excess SiO_2 and K_2O in high-K rhyolites reflect advanced fractional crystallization of plagioclase and late magmatic concentration of alkali-rich siliceous fluids. Rare earth element evidence (Jahn & others, 1981) indicates a fundamental difference between rhyolites of the Duffer Formation and the ultrapotassic rhyolites of the Wyman Formation (Fig. 7.56). The first group is

characterized by moderate light/heavy REE fractionation accompanied in some instances by weak negative Eu anomalies. The second group displays strong negative Eu anomalies. Both groups display little fractionation within the heavy REE range (see section 7.2). These features indicate a controlling role of plagioclase fractionation for Wyman Formation rhyolites, i.e. due to high $D_{\text{Plg}}^{\text{Eu}}$ (2.1 for dacitic melts: Arth, 1976). The fractionated light REE patterns suggests separation of ferromagnesian minerals whose D values for intermediate REE is higher than for light REE, i.e. pyroxene, amphibole and/or garnet (Arth & Hanson, 1972, 1975; Condie & Hunter, 1975; Arth & Barker, 1976; Frey & others, 1978; O'Nions & Pankhurst, 1978). This suggests basic minerals fractionation, but could also be an inherited feature from a silicic source. The relatively flat heavy REE curve is contrasted to the commonly fractionated pattern of these elements in many Archaean silicic rocks (Collerson & Fryer, 1978; Glikson, 1979). It may represent extensive contribution from a little-fractionated basic source with flat chondritic REE patterns, and militates against fractionation of garnet, whose D (ca 40) is significantly higher than D values for the intermediate REE ($D_{\text{gnt}}^{\text{Sm}} = 2.66$; $D_{\text{gnt}}^{\text{Gd}} = 10.5$; Arth, 1976).

It is thus likely that remelting of silicic source rocks, or wall-rock contamination by such materials, has contributed to the silicic volcanic magmas, particularly the Wyman Formation. However, for the andesites and sodic dacites this process is constrained by the low abundance of LIL elements except if total melting of a silicic source of tonalitic composition is assumed. Thus, North Star Basalt dacites (average of 8 samples: $K_2O = 0.77\%$; Rb = 26 ppm) and Duffer Formation dacites (average of 26 samples: $K_2O = 2.14\%$; Rb = 62 ppm) (Appendix II) are unlikely to have arisen from a silicic source, as this could be expected to result in higher levels of alkalis and other LIL elements, unless total simultaneous melting occurred. The $D^{\text{K}} = 0.26$, $D^{\text{Rb}} = 0.048$, and $D_{\text{plg}}^{\text{Ba}} = 0.36$ values for dacite melts (Arth, 1976) must result in strong enrichment in these components in melts arising by ensialic anatexis. Such enrichment of K and Rb is evident in Wyman Formation rhyolites (average of 23 rhyolites: $K_2O = 7.11\%$; Rb = 146 ppm), which could well have formed by acid source anatexis. By contrast, even the most differentiated members of the Duffer Formation have significantly lower alkali abundances, i.e. the average of 6 rhyolites being: $K_2O = 5.36\%$; Rb = 100 ppm and of 17 tuffs being $K_2O = 2.61\%$; Rb = 66 ppm. It may be argued that, due to secondary

redistribution, alkali element abundances can not be used as differentiation guides. However, because the variations indicated between units and between rock types appear to be consistent, whereas individual samples may be altered (Table 5.1) these averages are still meaningful, i.e. secondary redistribution processes took place on a local scale but did not necessarily result in en-mass depletion of large rock bodies in any particular element.

The above considerations are consistent with field observations, as to date no sialic rocks which predate the Duffer Formation and Talga Talga Subgroup and which could act as potential source for silicic magmas have been directly observed. The continuous geochemical spectrum from andesites to rhyolite in the Duffer Formation is suggestive of comagmatic relationships, either by varying degrees of partial melting of basic source regions, or as products of fractional crystallization of basic magmas. The presence of intercalations of tholeiitic basalt and dolerite in the Duffer Formation could lend support to the latter interpretation. The calc-alkaline affinities of the silicic volcanics as contrasted to the tholeiitic affinities of the basic rocks argues for separate derivation of these magmas, i.e. by concomitant ensimatic anatexis and mantle melting events. Alternatively, the calc-alkaline affinities of the silicic lavas have resulted from oxidation or iron and separation of magnetite attendant on an increased oxygen fugacity in hydrous silicic melts.

11. COMPARISON WITH MODERN VOLCANIC SUITES AND TECTONIC SETTING

Kuno (1966) and Dickinson & Hatherton (1967) demonstrated an increase in Al_2O_3 and K_2O levels across oceanic - arc-trench - continental margin boundaries with increasing depth to the Benioff zone. Condie & Potts (1969) applied this method to infer the palaeo-thickness of the Archaean crust in North America. On the basis of K_2O-SiO_2 relations in andesites from eight Canadian greenstone belts, they suggested a palaeo-thickness in the range 10-25 km. However, Arculus & Johnson (1978) pointed out significant departures from the alkali element level - Benioff zone depth correlation from studies in the Lesser-Antilles and Papua-New Guinea. The low-K levels of Archaean tholeiitic basalt were pointed out as possible evidence of ocean-floor affinity of these rocks (Hart & others, 1970; Glikson, 1970, 1971) - a correlation supported by Ti-Zr-Y relations (Hallberg & Williams, 1972; Pearce & Cann, 1971) and rare earth elements (Sun and Nesbitt, 1978a). Several authors suggested an arc-trench origin of Archaean tholeiites (Folinsbee & others, 1968; Green and Baadsgaard, 1971; Goodwin, 1978; White & others, 1971). Stratigraphic-geochemical trends in Archaean greenstone sequences were used to infer secular evolution of tectonic environments and changes in mantle composition (Baragar, 1966, 1968; Condie & Harrison, 1976; Wilson & Morrice, 1978; Gelinas & others, 1978; Glikson, 1979). However, inherent in attempted assignments of ancient volcanic suites to tectonic environments are three types of problems:

- (1) A correlation between modern basalt classes and tectonic environments is not well established. With further accumulation of data, major and trace element compositional ranges for each type of tectonic domain increase, which correspondingly decreases the diagnostic value of the various chemical parameters. Green (1971) suggested that variations in the LIL and other incompatible trace elements in basic magmas principally result from vertical and lateral mantle heterogeneities due to chemical migration in the low velocity zone and/or earlier melting events. This concept is supported by geochemical variations observed in ca 3.5 b.y. old komatiites of the Barberton Mountain Land (Glikson, 1979) and in the present study (section 6). If evolution of mantle composition is a factor, the tectonic significance of geochemical parameters may be doubtful.

- (2) The correlation between ancient volcanic suites with modern tectonic environments involves a uniformitarian assumption. However, it is probable that temporally-unique tectonic domains existed in the Precambrian which fundamentally differed from modern tectonic regimes. This is supported, for example, by the unique occurrences of peridotitic komatiites and the abundance of high-Mg basalts in the Archaean. For this reason, the use of chemical parameters established in modern tectonic environments to identify ancient domains is uncertain. On the other hand, as geochemical parameters are inherently diagnostic of source composition, they allow an identification of the crustal geochemical environment in question, e.g. as either simatic or sialic.
- (3) Because of possible addition and secondary migration of alkalies through sea water-lava reaction, burial, and thermal metamorphism (Hart, 1971; Jolly & Smith, 1972; Condie & others, 1977), the use of K and Rb in primary igneous classifications and thereby identification of tectonic environments is uncertain (Smith & Smith, 1976). At the same time, because potassium is usually added to, rather than removed from, the volcanic rocks, its abundance provides an upper limit for the original composition.

In view of these considerations, it is unwarranted to classify Archaean geochemical data strictly in terms of modern tectonic domains. Nevertheless, comparisons between ancient volcanics and modern rock types constitute a useful exercise, and may allow identification of temporally-unique geochemical features not observed in the Phanerozoic rocks. In the following, element distributions in basic volcanic suites of the eastern Pilbara Block and modern or Phanerozoic rock types (Table 11.1) are compared:

Major lithophile elements (Si, Al) - The dominance of Qz-saturated normative compositions among the Pilbara volcanics (Fig. 9.3) is an essential characteristic of this Archaean suite. By contrast to modern picrites, i.e. Hawaiian picrites (Gunn, 1971), Archaean high-Mg basalts are mainly Qz-normative as reflected by higher SiO_2 levels (48-52%) compared to the Hawaiian rocks (46-48%). The high-Si tendency of Archaean rocks may suggest little or no fractionation of orthopyroxene has occurred, thus hinting at low pressure crystal-melt equilibration. The North Star Basalt (NSB) and Mount Ada Basalt (MAB) are dominated by low-alumina tholeiites (13-14% Al_2O_3) (although some high-Al tholeiites occur in the MAB, whereas high-alumina tholeiites (15-17%) are more common in the Gorge Creek Group. High-alumina tholeiites occur among Mid-Ocean Ridge Basalts (MORB), Ocean Island Basalts (OIB) and Arc-Trench Basalts (ATB), whereas low-Al levels appear to be more characteristics of Continental Plateau Basalts (CPB). An increase with time in the importance of high-Al basalts was reported from the Abitibi belt, Superior Province, by Baragar (1968). According to Green & others (1979) high-Al olivine tholeiites arise by olivine fractionation of tholeiitic picrite equilibrated with harzburgitic residue at about 20 kb. The comparative scarcity of high-alumina basalts in the Talga-Talga Subgroup supports low-pressure fractionation, in agreement with the Qz-normative composition of the high-Mg basalts.

Siderophile elements (Ti, Fe, Mn, V) - Ti shows a systematic decrease with stratigraphic level, from a mode of 1.0-1.2% TiO_2 in the NSB to 0.4-0.6% in the GCG. These ranges are well below those of CPB and OIB (Table 11.1), but accord with a transition from MORB to ATB. The Ti and Al evidence could be amenable to a uniformitarian interpretation in terms of a temporal transition from low-Al MORB to high-Al ATB. The Ti abundances in early Pilbara greenstones are generally higher than in greenstones of the Kalgoorlie Province of the Yilgarn Block (Hallberg, 1971). There is a general decrease in total iron as FeO, from a mode of 11-12% FeO in the NSB and 12-15% in the MAB to 8-9% in the Charteris Basalt (CB) and 9-11% in the Honeyeater Basalt (HB). Total iron values in the Talga Talga Subgroup (TS) are thus higher than MORB (main range of 8-11%), and similar to OIB (main range of 11-14%), higher than ATB (9-11%), and similar to CPB (11-14%). Gorge Creek Group (GCG) values are similar to island-arc tholeiites. The NSB and MAB show MnO modes in the 0.18-0.24% range, which tends to be higher than modern basalt groups. Vanadium shows well-defined peak values for the NSB (300-375 ppm) and MAB (225-350 ppm), and overlap with the main ranges of modern MORB, OIB and CPB. V decreases with stratigraphic level, the modes for the Salgash Subgroup (SS) being 225-250 ppm. The Charteris Basalt (CB) peaks at 150-200 ppm, in analogy to high-Al basalt and andesite of arc-trench domains (Taylor & others, 1969).

Major basic elements (Mg, Ca) - Modal MgO peak values for the NSB and MAB are in the range of 4-8% and for the GCG basalts in the range of 6-10%. The abundance levels of the TS tholeiites are lower than MORB and OIB but commensurate with those of ATB and CPB. Because of the wide range of MgO in the tholeiite-high-Mg basalt-peridotitic komatiite range, little correlation can be achieved with modern picrites. Because of its mobility in the metamorphosed basalts, Ca is of uncertain diagnostic value. The main range in the TS (8-11% CaO) is commensurate with that in MORB, lower than some OIB, and higher than some ATB and CPB.

Alkali and alkaline earth elements (Na, K, Rb, Ba, Sr) - Sodium shows a regular concentration range of 1.5-3.0% Na_2O in both Archaean tholeiites and the modern groups, being of little diagnostic value. Potassium levels in Warrawoona Group basalts are mostly below 0.4%, whereas the Gorge Creek Group includes many samples have 0.7 to 0.9% K_2O . Assuming that K is generally added to, rather than depleted from, basalts upon alteration (Hart, 1971), these values provide the upper limits of original abundances. The Warrawoona Group tholeiites are therefore akin to the MORB-OIB range, and the Gorge Creek Group tholeiites to the ATB-CPB range. Rubidium modes in the NSB (0-20 ppm) and the MAB (below 10 ppm) are distinctly higher than MORB, with the exception of carbonated samples of the MAB from which Rb was probably secondarily removed. The Salgash Subgroup basalts show a wide distribution range, a likely indication of open chemical migration, whereas the GCG basalts have a bimodal dispersion with peaks at 20-25 (HB) and below 5 ppm (CB). As for potassium, these abundances provide only upper limits of original levels, suggesting more continental-like affinities for the stratigraphically uppermost basalts. However, since it is probable that rubidium has been secondarily remobilized, little confidence can be attached to the primary significance of the determined abundances.

Barium distribution maxima for the NSB and MAB are 50-75 and 25-150 ppm, respectively, above the common range of MORB (5-20 ppm), below or similar to OIB (100-200 ppm), analogous to ATB, and lower than CPB (200-400 ppm). The Gorge Creek Group Honeyeater Basalt has some samples of high Ba levels commensurate with CPB. For strontium, distinct distribution peaks at 100-150 ppm pertain to the NSB and MAB, while wide ranges likely to reflect open system migration pertain to the SS and GCG basalts. The Sr levels of the TS basalts are comparable to MORB, and are clearly lower than OIB (150-300 ppm) and CPB (150-500 ppm). The Honeyeater Basalt has a peak at 50-100 ppm, suggesting a decrease in Sr parallel to the increase in Rb shown by the Gorge Creek Group.

Large-ion-lithophile elements (Zr, Nb, P) - Thanks to the well-pronounced modal maxima, zirconium is a most useful element in these comparisons. The sharp 80-100 ppm maximum of the NSB and MAB is comparable to, or higher than, MORB values and OIB values, is higher than ATB values, and is distinctly lower than CPB values (100-400 ppm). Salgash Subgroup and Gorge Creek Group peaks fall in the 2-50 ppm range, representing a marked decline compared to the Talga-Talga Subgroup - a trend interpreted in terms of mantle depletion (section 12). The NSB has a Niobium peak of 3-4 ppm and the MAB a main distribution range of 2-7 ppm, values similar to or higher than MORB, but significantly lower than OIB (10 ppm and above). Nb levels for higher units are mostly below 5 ppm. The general decline in P_2O_5 from the Talga-Talga Subgroup (0.02-0.22%) to the Gorge Creek Group (0.04-0.06%), is possibly similar to the change from OIB to ATB.

Yttrium and the rare earth elements (La, Ce) - Well-defined principal distribution ranges of Y apply to the NSB (15-25 ppm), MAB (15-30 ppm), AB (10-15 ppm), and GCG (10-15 ppm). Y values are lower or similar to MORB (20-40 ppm), overlap OIB and ATB, and are lower than CPB (30-50 ppm). The Y levels of the stratigraphically high units are anomalously low, although some Viti-Levu and Iceland basalts have likewise low values (Table 11.1). This accords with the low-Y characteristics of the Archaean igneous suites as pointed out by Lambert & others (1976). Modal La peaks for all eastern Pilbara volcanic units are below 5 ppm, which is in accord with MORB but less than OIB and CPB. A main Ce distribution range of up to about 20-30 ppm pertains to the TS, whereas the AB has a well-defined maximum of 15-20 ppm and the GCG basalts of 10-15 ppm. These levels are in part similar to and in part higher than MORB.

Magnesium-related trace elements (Ni, Co, Cr) - Nickel levels in Pilbara tholeiitic basalts are low compared to MORB and OIB tholeiites, but are higher than those of ATB and similar to those of CPB. Modes for the NSB and MAB (50-75 ppm) and the GCG (50-75 ppm) show little stratigraphic variation. Tholeiitic basalts of the Eastern Goldfields, Yilgarn Block, have Ni levels higher by about a factor of 2 (80-170 ppm; Hallberg, 1972; Hallberg & Glikson, 1981). A well-defined Co modal peak of 40-50 ppm applies to all the eastern Pilbara units, in similarity to MORB and higher than ATB. These

values are somewhat lower than the average of 83 Norseman tholeiites (60 ppm) and 13 Coolgardie tholeiites (54 ppm) (Hallberg, 1972). Chromium abundances of eastern Pilbara basalts are surprisingly low in comparison to MORB, OIB and CPB tholeiites, but are commensurate with typical arc-trench high-Al basalts and andesites. Distribution frequency peaks for the TS are 50-100 ppm for the NSB and below 50 ppm for the MAB. A wide range pertains to the SS rocks, reflecting the abundance of komatiites. The HB has a maximum below 50 ppm, whereas the CB shows a wide dispersal. These modes contrast with the characteristic MORB, OIB and CPB range of 200-500 ppm. Cr-depleted basalts and andesites of island arc domains are discussed by Taylor & others (1969). Tholeiitic basalts from the Eastern Goldfields province, Yilgarn Block, have generally high Cr levels in the 300-400 ppm range (Hallberg, 1972; Hallberg & Glikson, 1981).

Chalcophile elements (Cu, Zn) - There is little variation between the principal Cu ranges of the eastern Pilbara basalts (below 100 ppm) and the values of MORB, OIB and ATB, whereas CPB have generally somewhat higher Cu abundances. Higher levels (100-200 ppm) pertain to the komatiites. The average Cu level of 429 Eastern and Murchison Goldfields basalts is only slightly higher (103 ppm; Hallberg & Glikson, 1981). Zn yields sharp bimodal distribution maxima between 60-100 ppm for the TTS rocks, 50-100 ppm for the SS rocks and 50-75 ppm for the GCG basalts. The higher abundances are generally similar to OIB.

The above comparisons indicate affinities between Talga-Talga Subgroup tholeiites and Mid-Ocean Ridge basalts with respect to Ti, Ca, K, Sr, Zr, Nb, Y, La, and Ce, and between Gorge Creek Group tholeiites and arc-trench basalts with respect to Ti, Al, Fe, K, P, Y, V, Cr, and possibly Ni. However, important departures from these correlations are evident, e.g. the high Ti and low Ni and Cr of many TS basalts. To test possible geochemical-tectonic correlations further, the data were plotted on the $0.01\text{Ti}-\text{Zr}-3\text{Y}$ ternary and $0.01\text{Ti}-\text{Zr}-0.5\text{Sr}$ ternary (Pearce & Cann, 1973) (Figs 11.1 and 11.2), the $\text{TiO}_2-\text{K}_2\text{O}-\text{P}_2\text{O}_5$ ternary (Pearce & others, 1975) (Fig. 11.3), and the $\text{FeO}-\text{MgO}-\text{Al}_2\text{O}_3$ ternary (Pearce & others, 1977) (Fig. 11.4). These authors showed that many modern basalts concentrate in separate fields according to their tectonic setting, i.e. mid-ocean ridge, ocean island, spreading-centre-island, arc-trench, orogenic, and continental environments. The Ti-Zr-Y diagram shows a strong concentration of eastern Pilbara basic rocks in the MORB field, although boundaries with other fields are commonly transgressed. The Ti-Zr-Sr diagram indicates a concentration of NSB and MAB samples in the Oceanic field, Apex Basalt samples in the fields of oceanic and arc-trench low-K tholeiites, Euro Basalt samples in the oceanic field, and Charteris Basalt samples in arc-trench low-K tholeiite field. As the continental basalt field is not defined on this diagram, a correlation with this class is not possible. The Ti-K-P diagram shows a strong coincidence of Warrawoona Group samples with the oceanic field and a transgression of Gorge Creek Group basalts across the boundary of oceanic basalts and non-oceanic basalts. The Fe-Mg-Al diagram reveals a concentration of Talga-Talga Subgroup points about the boundary between continental and ocean island basalts, i.e. in the combined field of within-plate basalts. Apex Basalt samples plot across the MORB-ocean island-continental fields, Charteris Basalt data in the MORB field, and Honeyeater Basalt data across the MORB and

continental fields. These ternaries generally support oceanic affinities of Talga-Talga Subgroup basalts and arc-trench or non-oceanic affinities for Gorge Creek Group basalts, the Fe-Mg-Al diagram constituting an exception.

Sun & others (1979) have characterised the chondrite-normalised trace and rare earth element features of depleted mid-ocean ridge basalts (MD), enriched mid-ocean ridge basalts (ME), arc-trench tholeiitic basalts (AT), and arc-trench calc-alkaline basalts (AC), indicating distinct distribution patterns for each type. Comparisons between the Pilbara data and these patterns with respect to Pb, Rb, Ba, Th, U, Nb, K, La, Ce, Sr, P, Zr, Ti and Y (in order of decreasing ionic radius) are shown in Fig. 11.5. In view of secondary mobility of the larger-radius elements, little reliance is placed on patterns shown by the alkali and LIL elements (Pb to K), and as confirmed by their wide scatter on the diagrams. By contrast, coherent patterns are often shown in the K to Y range, reflecting characteristic elemental levels and ratios, as follows:

Peridotitic komatiites (PK) (Fig. 11.5.1): Contrasting patterns pertain to the NSB, MAB, and AB - the first two showing Sr depletion attributable to secondary leaching. None of the patterns is similar to Nesbitt & Sun's (1976) spinifex-textured peridotitic komatiites - which reflects possible mantle heterogeneity.

High-Mg basalts (HMB) (Fig. 11.5.2): Both the NSB and the MAB show enrichment of Zr and Y relative to Ti and P, although to varying degrees. Significantly smoother profiles pertain to the AB and CB, but HMB of both units show strong Sr and Ce enrichment not shown in the lower units. All HMB patterns for the small-radius elements are more depleted than those of mid-ocean ridge basalts (MORB).

Tholeiitic basalts (TB) (Fig. 11.5.3): Chondrite-normalised patterns for both the NSB and the MAB show consistent enrichment in Zr relative to Ti, Y and P, quite unlike modern MORB. Large-radius alkali elements (Ba, Rb, Pb) are significantly enriched relative to MORB. AB and GCG tholeiites show Y, Ti, Zr and P depletion relative to MORB, though Euro Basalt tholeiites fit more closely into this field. As for some HMB, Sr and Ce are distinctly enriched in some units (CB).

Andesite and dacite (Fig. 11.5.4): Andesites and dacites of the upper NSB and the Duffer Formation (DF) show very close pattern similarities to arc-trench calc-alkaline basalts, though they tend to be even more enriched than the latter in the incompatible trace elements. Thus, marked positive K, U and Th anomalies and negative Nb anomalies pertain to the Archaean and modern curves. By contrast, the Archaean Zr/Ti ratios are significantly higher than modern values.

While the above geochemical-stratigraphic variations are significant to mantle source composition and petrogenetic processes, as discussed at the outset they are not necessarily diagnostic of specific modern-type tectonic domains.

12. DISCUSSION AND CONCLUSIONS

The major and minor element study of 442 volcanic rocks from Archaean successions of the eastern Pilbara Block allows an insight into the chemical constitution, igneous petrogenesis and secondary alteration of these rocks. The geochemical data show that the Talga-Talga Subgroup (TS) is dominated by high-Ti, low-Ni and Cr, low-K, tholeiitic basalts and dolerites. Only about 10 percent of the TS sample population consists of ultramafic rocks, i.e. high-Mg basalts and peridotitic komatiites and pyroxenites. Minor dacite and andesine lenses underlie chert between the North Star Basalt (NSB) and Mount Ada Basalt (MAB). The Duffer Formation (3452 ± 16 m.y.; Pidgeon, 1978a) consists of sodic to potassic dacitic to rhyolitic and some andesitic agglomerate and tuff, interspersed with minor basalt and dolerite. The silicic volcanics are of calc-alkaline affinity whereas the basic rocks are of tholeiitic lineage - implying different origins. The overlying Salgash Subgroup (SS) has a significantly higher ultramafic component than the Talga-Talga Subgroup, with about one quarter of the samples being high-Mg basalt, peridotitic komatiite, and pyroxenite. The rest of the SS consists of tholeiitic basalt and dolerite, and, in places, of dacite-rhyolite lenses. The ultrapotassic rhyolites of the overlying Wyman Formation are chemically distinct from those of the Duffer Formation. Basic volcanic units intercalated with the clastic sediments of the Gorge Creek Group - the uppermost Archaean succession of the Pilbara Block - consist of Ti-poor, K-rich, high-Al tholeiitic basalt and dolerite showing some affinity to arc-trench to continental basalts, and minor high-Mg basalt. An overall geochemical-stratigraphic siderophile and certain lithophile-element depletion trend is apparent, i.e. the basic rocks show an upward decrease in Ti, Fe (total iron as FeO), V, P, Zr, and Y independently of the MgO values of these rocks. Similar smaller-scale geochemical cycles are also shown within individual successions, i.e. in the Talga-Talga Subgroup, showing that the overall trend is composed of local repeated depletions. These features can be used as stratigraphic aids for identification of volcanic sectors whose relation to the regional sequence is unknown. In the following, implications of the data for igneous petrogenesis, mantle evolution, diagenetic and metamorphic processes, and economic mineralization are discussed.

12.1 Igneous Petrogenesis

From mass-balance (Fe+Mg) calculations the peridotitic komatiites incorporated in the Warrawoona Group (Mg number above 75) can form by over 50 percent melting of mantle peridotite (section 10.2). The physical conditions for such extreme degrees of fusion are not clear, however, and the ascent of peridotitic liquids to the surface without crystal fraction must have been very rapid. It is possible that, in part, peridotitic komatiites resulted from olivine accumulation and subsequent remelting in shallow-level magma chambers, but this mechanism requires extreme geothermal gradients and is therefore unlikely. The generally fine-grained texture of these rocks and the occurrence of skeletal "spinifex-textured" features corroborates the view of PK as quench products of liquidus temperature or superheated ultramafic liquids (Naldrett & Mason, 1968; Lewis, 1971; Nesbitt, 1971; Arndt & others, 1977). Green (1972) inferred that the catastrophically high melting indicated by some peridotitic komatiites of the Barberton Mountain Land (sample 49J, MgO = 30.05%) could result from extraterrestrial impacts and rapid adiabatic melting. However, the occurrence of similar rocks at stratigraphically-high positions and in the late Archaean suggests endogenetic factors (Green & others, 1975; Glikson, 1976). This is the case in the eastern Pilbara, where peridotitic komatiites are comparatively abundant in the Salgash Subgroup. Conceivably the ascent to the surface of highly magnesian magmas without olivine fractionation is best accounted for by superheating, i.e. peridotitic liquids may represent adiabatic fusion at shallow levels of mantle diapirs derived from depth greater than 200 km. The steeper the Archaean geothermal gradient, the less the required derivation depth of such diapirs. With a gradient of about 40°C/km, the maximum gradient derived from metamorphic and structural considerations (Glikson & Lambert, 1976; Lambert, 1976), dry liquidus temperatures (1650°C) would be achieved at a depth of ca 40 km. With a more conservative gradient of 15°C/km such temperatures would be attained at a depth greater than 100 km. From Green & others (1975) PT diagrams, 50 percent melting of dry mantle peridotite (0.1% H₂O) would occur at about 1400°C at atmospheric pressure and about 1850°C at 50 kb. With mantle H₂O contents of 0.1-0.2%, 50 percent melting would occur at somewhat lower temperatures. During such events, very high geothermal gradients of 35-40°C/km would pertain in the vicinity of mantle diapirism. If Archaean mantle peridotite was more Fe-rich than modern pyrolite, as indicated in this report (Table 10.4) (see Sun & Nesbitt, 1977; Bickle & others, 1977; Glikson, 1979), lower liquidus temperatures would apply.

The compositional gaps between peridotitic komatiites (PK) and high-Mg basalts (HMB) with regard to Al_2O_3 (7-10%), Mg Number (60-70), MgO (15-25%), Ni (above 1000 ppm in PK), V (about 100 ppm or less for PK) (Fig. 7) on the OL-Op-Cp-Qz diagram (Fig. 9.3) and on CI-DI plots (Fig. 9.6) is inconsistent with an interpretation of HMB as crystal fractionation product of PK magmas, as in this case a continuous compositional spectrum should have been observed. On the other hand, the geochemical overlap between HMB and tholeiitic basalts and dolerites (Fig. 7; Fig. 9.3) suggests their relation by fractional crystallization. The HMB can be modelled on the basis of major elements as either a product of olivine fractionation from PK liquids, or of 30-50 percent melting of mantle peridotite and subsequent olivine fractionation, but the PK-HMB compositional break favours the latter. Liquidus temperatures of HMB liquids range between 1200-1500°C for dry melting and 0 kb, and lower for higher partial- H_2O pressures. The intimate spatial association of high-Mg basalts and tholeiitic basalts in the field, as well as their compositional continuity, favour a view of HMB as approximate primary magmas which underwent small to moderate degrees of olivine fractionation. The quartz-normative chemistry of many of these rocks argues against equilibration with (siliceous) orthopyroxene-bearing refractory residues, and suggests that partial melting occurred at less than 20 kb. The evolution of tholeiitic basic magmas by fractional crystallization of primary high-Mg melts has probably taken place at yet shallower depths because the scarcity of high-Al basalts in the Warrawoona Group requires equilibration of parental tholeiitic picrite with harzburgitic residues under pressures of less than 20 kb (Green & others, 1979). This may have been the depth of the Archaean low velocity zone. Under higher geothermal gradients it can be expected that incipient melting would occur at shallower depths than the ca 100 km deep modern low velocity zone. Thus, the extrusion of HMB-TB lavas can be expected to have been a more continuous process than that of PK melts, whose generation depended on transient mantle diapirism. Modal calculations based on Rayleigh's non-equilibrium fractionation law (section 10.1) indicate that the tholeiitic basic magmas have formed by 1/4 and 2/3 fractionation of clinopyroxene, olivine, orthopyroxene, and plagioclase (in order of abundance), from a parental high-Mg magma ($\text{MgO} = 15\%$; $\text{Al}_2\text{O}_3 = 9\%$).

Andesitic-dacitic-rhyolitic units occur as units and lenses generally discrete from the tholeiitic basalt - high-Mg basalt association, e.g. the upper part of the North Star Basalt, Duffer Formation, Kelly and Panorama Formations of the SS, and Wyman Formation. The low-LIL element abundances of the sodic

dacites argue against but do not preclude their origin by anatexis of sialic source rocks, and are consistent with partial melting of basic rocks or fractional crystallization of basic magma. Henry's Law equilibrium melting calculations, assuming a basic source (Al_2O_3 - 14%; FeO_t - 12%; MgO - 8%; CaO - 10%), suggest that the LIL-depleted sodic dacites of the North Star Basalt and Duffer Formation could form by 40-50 percent melting of such source, leaving a residue of plagioclase, clinopyroxene, and olivine. Rhyolites would either form by about 25 percent melting of such source, or, more likely, by fractional crystallization of plagioclase from dacitic magma. However, melting or fractionation of basic materials can not provide all of the Si and K of the rhyolites, which must have been derived from external sources, i.e. by wall-rock reaction, pneumatolitic or hydrothermal late or post-magmatic activity. The role of volatiles is emphasised by the fragmented pyroclastic nature of the bulk of the Duffer Formation. The general concentration toward the top of the Bows Gorge section of this Formation of Si, K, Rb, Ba, and CO_2 -rich rhyolitic tuffs may be a primary igneous feature reflecting late-stage extrusion of differentiated, silica and alkali-rich hydrous pyroclastics. The concomitant increase in Cu and S at this level points out the economic significance of this process.

The ultrapotassic rhyolites of the Wyman Formation are geochemically distinct even from the most differentiated rhyolites of the Duffer Formation. these rocks have a close affinity to elvan type quartz porphyrites (Henley, 1972), and in analogy with the latter are characterized by embayed, partly-resorbed, phenocrysts of quartz. The exclusive concentration of the rhyolites along the Qz-Or join in the Qz-Ab-Or ternary (Fig. 9.5), and their high normative corundum, agree with features of elvan dykes, interpreted in terms of late stage pneumatolitic replacement of upper granitic cupola sectors by Si and K-rich fluids. In this process, albite is replaced by K-feldspar and muscovite. The high volatile pressures result in fracture and escape of hydrous magma to higher levels, where decrease in pressure then causes resorption of quartz phenocrysts (Henley, 1972; Green, 1968). The Wyman Formation could therefore be a volcanic manifestation of late-stage development of the Pilbara batholiths. However, the marked difference in lithium levels of the Moolyella granite (190 ppm; Hickman & Lipple, 1975) and Wyman Formation rhyolites (5 ppm or less) is inconsistent with comagmatic relations.

Andesites are a significant component of the North Star Basalt and Duffer Formation, forming about 1/6 of the latter. The commonly high-alumina composition of these rocks (higher than 16% Al_2O_3) suggests they are primary andesites rather than silicified basalts. It is unknown whether the andesites and the associated sodic dacites have arisen by high-degree melting of basic source or by fractional crystallization of basic magma. Although the occurrence of tholeiitic basalt intercalations in dacite-dominated low stratigraphic levels of the Duffer Formation may support fractional crystallization, the calc-alkaline affinity of the silicic volcanics is inconsistent with this interpretation. The andesites display a wide range of trace metal abundances, including some rocks with high Ni, Cr, and V values, as distinct from trace metal-depleted modern arc-trench andesites (Jakes & White, 1972; Gill, 1970). Taylor & Hallberg (1977) compared Archaean andesites from Marda, central Yilgarn Block, to Andean calc-alkaline volcanics. It is uncertain whether geotectonic conclusions can be derived from the andesitic components of the North Star Basalt and Duffer Formation. On the other hand, the high-Al low-Ti, high-K tholeiitic basalts intercalated with the clastic sediments of the Gorge Creek Group may signify crustal thickening toward the close of the Archaean, i.e. the high Al levels may indicate equilibration at depths of about 60 km (Green & others, 1979), and the high-K levels may have arisen by sialic contamination.

12.1 Secular Geochemical Evolution

The eastern Pilbara basic rocks reflect an overall secular decrease in siderophile and certain lithophile elements, namely, lower TiO_2 , FeO_t , P_2O_5 , Zr, and Y abundances with higher stratigraphic level (section 6.1; Table 6.1; Fig. 6.1). This trend is analogous to those reported from the Tjakastad Subgroup, lower Onverwacht Group, Transvaal (Glikson, 1979), from comparison of Hallberg's (1972) data for low and high greenstone units west and northwest of Lake Lefroy, the Duparquet and Aigubelle sections in the Abitibi belt, Ontario-Quebec (Baragar, 1968), and the Kenogami-Matheson, Birch-Uchi, and Lake of the Woods greenstone belts of the Superior Province (Baragar & Goodwin, 1969). However, reverse geochemical trends showing increases in FeO_t , MnO , TiO_2 , V, Zr, Y, and related elements - reflecting a tholeiitic liquid line of descent - were recorded in the Abitibi belt by Gelinas & others (1978) and in

the Snake Lake-Kakagi Lake area of southwestern Ontario by Wilson & Morrice (1978). A comparison between the averages of stratigraphically low and high greenstone successions in the Yilgarn Block (Hallberg & Glikson, in press) also indicates an increase in Fe, Ti, Mn, P, Zn, Nb, Y, V, and Zn. The latter trends are akin to Proterozoic-type iron-enrichments, e.g. basic volcanic successions in the Mackenzie District, Canada (Baragar, 1969), and Mount Isa area, Queensland (Glikson & Derrick, 1979). Whereas iron-enrichment trends are explained by crystal-fractionation of olivine, owing to the low K_d values of siderophile and lithophile elements (relative to mantle residues) crystal fractionation does not explain the decrease in these components in successive melt fractions. The similarity between the MgO levels of tholeiitic basalts of the Talga-Talga Subgroup, Salgash Subgroup, and Gorge Creek Group, indicates that the decrease in FeO_t and TiO_2 in these rocks are unlikely to be related to crystal fractionation effects. The most likely explanation of these variations is, therefore, in terms of progressive removal of siderophile and lithophile elements from mantle source regions through successive melting events. Phanerozoic analogues of this process have been reported by Smewing & others (1975), Church & Riccio (1977), and Sun & Nesbitt (1978b). The commonly low TiO_2 abundances of arc-trench basalts (Table 11.1) may likewise be ascribed to remelting of lithosphere previously depleted beneath mid-ocean ridges or back-arc spreading centres. It would be of interest to examine whether early Proterozoic basic volcanic rocks in the eastern Pilbara show further depletion, or whether by analogy to other Proterozoic basalts they are rich in siderophile elements (Baragar, 1969; Glikson & Derrick, 1979), implying mantle replenishment events in post-Archaeon times.

12.3 Metamorphic Processes and Implications to Mineralization

The metamorphic assemblages documented in Pilbara greenstone sequences (section 4.3) could have developed during (1) late-magmatic hydrothermal activity effecting uranitization of pyroxene and clouding of feldspar; (2) interaction between lava and seawater (3) sea-floor diagenesis; (4) burial metamorphism, and (5) dynamo-thermal metamorphism. Although a distinction between geochemical results of these processes is not generally possible, the similarity between the compositions of basalts and hypabyssal dolerites suggests a relatively minor role of processes (2) and (3). As indicated by the decrease in metamorphic grade away from intrusive contacts, the low-grade metamorphic mineralogy must have developed in association with thermal effects induced by

the batholiths. An important clue for the nature of secondary processes is furnished by systematic stratigraphic-geochemical variations in individual areas. Thus, the increase in H_2O and CO_2 with higher stratigraphic levels in sections of the North Star Basalt, Mount Ada Basalt, Duffer Formation, Charteris Basalt, and Honeyeater Basalt, and less consistently in the Salgash Subgroup, is clearly related to vertical redistribution of mobile elements, i.e. alkalis, alkaline earth elements, sulphur, copper and zinc. This feature is capable of two alternative interpretations:

- (1) Uppermost volcanic flows became more heavily hydrated and carbonated possibly due to a lower rate of extrusion and greater opportunity for lava-sea-water interaction or due to late-stage hydrothermal activity.
- (2) Upward migration of volatiles, alkalis, and base metal during metamorphically-induced dehydration, resulted in the concentration of these constituents toward stratigraphically-high levels or beneath relatively impermeable units.

Both processes may have operated. However, the existence of sharp breaks between little-carbonates volcanic units and heavily carbonated units, i.e. the NSB-MAB transition in the Marble Bar area (section 6.1; Fig. 6.2.2.), is difficult to interpret in terms of secondary volatiles redistribution, i.e. an interpretation in terms of mechanism no (2) is unlikely because of the absence of gradational relations between the non-carbonated and carbonated units. It appears more likely that, in this instance, syn- or post-volcanic addition of CO_2 has occurred with respect to the Mount Ada Basalt, and that the North Star Basalt was originally relatively free of carbonate. Hallberg (1974) suggested that the carbonated volcanics formed by permeating CO_2 -rich fluids which affected the volcanic piles during deposition. On the other hand, the increases in CO_2 in the Duffer Formation section at Bowls Gorge and the Salgash Subgroup section of Chinaman's Creek (both west of Marble Bar) are more gradational (Fig. 6.5) and could involve considerable secondary upward migration. Furthermore, the occurrence of carbonated hypabyssal dolerites suggests secondary redistribution of CO_2 , as these rocks were unlikely to react with sea-water.

Whether carbonatization occurred by syn-volcanic magmatically-related processes and/or by post-burial diagenesis and metamorphism, it was invariably associated with strong hydration, and in several instances with addition of sulphur. Other concomitant element migration patterns appear to have been highly variable. Thus, the carbonatization of the MAB in the Marble Bar area has involved extreme leaching and removal of K and Rb, whereas in the Shark Gully section of the Talga-Talga Subgroup concomitant increase in CO_2 and K is recorded (section 6.1). In the Bowls Gorge section of the Duffer Formation, a parallel increase in CO_2 and K is observed. The significantly wider compositional ranges observed for most elements toward the carbonated higher parts of the volcanic sequences establish the considerable mobility imparted on the rocks by volatile migration. As shown by the weakly-defined frequency distribution curves (section 6.2) and the very poor correlation coefficients (below 0.50) of alkali and alkaline-earth elements in the silicic volcanics (section 7.2), these components were highly mobile. LMPR diagrams (Fig. 5.1-5.6) suggest considerable loss of Ca from these rocks. On the other hand, relatively coherent relations are shown between Ti, Fe, V, Ni, Cr, Zr, Nb, Y, P, and Ga (Appendix II), which suggests their relatively stable behaviour even in silicic volcanics. The relative stability of siderophile, magnesium-related, and some LIL elements is better pronounced in the basic volcanic rocks, where well-defined frequency distribution curves pertain to Al, Ti, Mn, Mg, P, Zr, Nb, Y, V, Ni, Co, Zn and Ga, and high correlation coefficients occur between Fe, Ti, Mn, V, P, Zr, Nb; Ce, La, Y, and Cu, Zn, Ga, S. Among the alkali and alkaline earth elements, the only good correlation observed is between K and Rb.

It has been noted above (sections 5.1 and 7.1) that altered basic rocks - as defined on LMPR diagrams - tend to have low Cu abundances. On the other hand, Cu is commonly enriched toward the top of both basic and silicic volcanic sequences, commonly along with H_2O , CO_2 , S and/or alkali elements (Figs 6.2 and 6.5). This is the case in the McPhee Reward Section (MAB), Shark Gully section (TS), Bowls Gorge section (DF), Talga-Coongan section (SS), Camel Creek Section (SS), and Soanesville Section (HB). These components do not vary sympathetically in all cases; however, the pattern is well pronounced within the limitations of the number of samples studied to suggest base-metal leaching and concentration upwards by alkali-bearing carbonate-rich aqueous solutions. The upward concentration of base metals and sulphur in these regions thus renders them favourable loci for sulphide mineralization. This mechanism is

commensurate with Cu-leaching and consequent copper-carbonate ore formation at Mount Isa (Smith and Walker, 1971). The transport of Cu may have taken place through its complexing with CO_2 molecules (see Collerson and Fryer, 1978).

The whole-rock geochemical orientation study of Pilbara volcanics by Hallberg (1974) demonstrated pervasive carbonatization spatially associated with mineralized centres, e.g. Pear Creek, Big Stubby, Pilgangoora, Soanesville, Sherlock, Hong Kong, Roebourne, Mt Sholl. The distribution of mineralization therefore appears, in many instances, to be closely related to CO_2 influx. Following the widening of the geochemical data base to include the western Pilbara and the Fortescue Group in the eastern Pilbara (Phase II), a stratigraphical-geochemical positioning of the various mineralized centres in terms of the regional stratigraphy (Hickman & Lipple, 1975; Hickman, 1975; Lipple, 1975) and the vertical geochemical trends indicated in this report is planned (Phase III). This investigation, including the study of along-strike geochemical transitions from least-altered into carbonated and mineralized loci, should allow an insight to be gained into the geochemical distribution patterns associated with metal concentration as possible guides for exploration.

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Appendix I(a)
Samples titles listing

East Pilbara Volcanics Sample titles

SAMPLE NO.	FORMATION	ROCK TYPE	LOCATION	STRAT. POSITION		
75040002A	North Star	Basalt	am. cl. ep.	al. TB	11951:2101	TR0m
75040002B	North Star	Basalt	am. cl. ep.	al. TB	11951:2101	TR0m
75040003C	North Star	Basalt	sp. ep. tr.	HMB	11951:2100	TR100m
75040004A	North Star	Basalt	am. sa. al.	dolerite	11951:2100	TR250m
75040004B	North Star	Basalt	am. qz. al.	TB	11951:2100	TR250m
75040005A	North Star	Basalt	am. al. ep.	dolerite	11951:2100	TR400m
75040005B	North Star	Basalt	am. sa. al.	qz. TB	11951:2100	TR400m
75040007A	North Star	Basalt	sp. am. qz.	al. TB	11951:2100	TR780m
75040007B	North Star	Basalt	am. cl. al.	qz. TB	11951:2100	TR780m
75040008A	North Star	Basalt	am. cl. al.	qz. TB	11951:2100	TR900m
75040008b	North Star	Basalt	am. sa. al.	qz. TB	11951:2100	TR900m
75040009	North Star	Basalt	am. sa. al.	qz. TB	11951:2100	TR1100m
75040012	North Star	Basalt	am. sa. al.	TB	11951:2059	TR1450m
75040012a	North Star	Basalt	am. sa. al.	qz. doler.	11950:2103	MC0m
75040016B	North Star	Basalt	am. sa. al.	TB	11950:2103	MC0m
75040016D	North Star	Basalt	saussur.	dolerite	11950:2103	MC0m
75040016E	North Star	Basalt	saussur.	dolerite	11950:2103	MC0m
75040016F	North Star	Basalt	am. sa. al.	qz. TB	11950:2103	MC0m
75040016G	NORTH STAR	Basalt DC	am. al. qz.	ch. ep. and.	11950:2103	MC0m
75040016H	North Star	Basalt	tr. sa.	TB	11950:2103	MC0m
75040006	North Star	Basalt	tr. ch.	PK	11951:2100	TR600m
75040016I	North Star	Basalt	tr. sa.	TB	11950:2103	MC0m
75040016J	North Star	Basalt	tr. sa.	TB	11950:2103	MC0m
75040016N	North Star	Basalt	saussur.	dolerite	11950:2103	MC0m
75040016O	North Star	Basalt	saussur.	TB	11950:2103	MC0m
75040016P	North Star	Basalt	sa. tr.	HMB	11950:2103	MC0m
75040016Q	North Star	Basalt	cpx.	TB	11950:2103	MC0m
75040016R	North Star	Basalt	il.	dolerite	11950:2103	MC0m
75040017A	North Star	Basalt	am.	TB	11949:2103	MC400m
75040017B	North Star	Basalt	sp. ac. ep.	TB	11949:2103	MC400m
75040017C	North Star	Basalt	sa. am.	dolerite	11949:2103	MC400m
75040017D	North Star	Basalt	am. yd. al.	TB	11949:2103	MC400m
75040017E	North Star	Basalt	am.	TB	11949:2103	MC400m
75040019A	North Star	Basalt	gabbro		11949:2104	MC700m
75040019E	NORTH STAR	Basalt DC	chlorite	schist	11949:2104	MC1100m
75040019F	North Star	Basalt	ch. tr.	PK	11949:2104	MC1100m
75040019G	North Star	Basalt	ep.	gabbro	11949:2104	MC1100m
75040019H	North Star	Basalt	ch. tr.	PK	11949:2104	MC1100m
75040020	North Star	Basalt	ta. ch.	PK	11949:2104	MC1050m
75040022	North Star	Basalt	sp. high. Mg	gabbro	11949:2104	MC1140m

75040023	North Star	Basalt	am. cl.	HMB	11949:2104	MC1220m
75040024A	North Star	Basalt[U]	ch. tr.	TB	11949:2104	MC1400m
75040024B	North Star	Basalt[U]	am. pl. sa.	qs. and.	11949:2104	MC1400m
75040024C	North Star	Basalt[U]	ca. tr.	HMB	11949:2104	MC1400m
75040024D	North Star	Basalt[U]	am. pl.	andesite	11949:2104	MC1400m
75040024E	North Star	Basalt[U]	al. qz. cl.	ca-dacite	11949:2104	MC1400m
75040025A	North Star	Basalt[U]	am. pl.	dacite	11949:2104	MC1540m
75040025B	North Star	Basalt[U]	ch.	Na-dacite	11949:2104	MC1540m
75040025C	North Star	Basalt[U]	am. ch. pl.	dacite	11949:2104	MC1540m
75040025D	North Star	Basalt[U]	ch. tr.	HMB	11949:2104	MC1540m
75040025E	North Star	Basalt[U]		Na-dacite	11949:2104	MC1540m
75040025F	North Star	Basalt[U]		andesite	11949:2104	MC1540m
75040026A	North Star	Basalt[U]	am. sa.	TB	11948:2104	MC1750m
75040026B	North Star	Basalt[U]	am. sa.	TB	11948:2104	MC1750m
75040026C	North Star	Basalt[U]	am. pl.	dacite	11948:2104	MC1750m
75040026A	Mount Ada	Basalt		pyroxenite	11948:2107	MC3880m
75040028B	Mount Ada	Basalt		pyroxenite	11948:2107	MC3880m
75040029B	Mount Ada	Basalt	am. pl.	HALB	11947:2107	MC4040m
75040029C	MOUNT ADA	Basalt DCF	qt. pl.	felsite	11947:2107	MC4040m
75040029E	Mount Ada	Basalt	am.	HMB	11947:2107	MC4040m
75040029G	Mount Ada	Basalt	ap. am.	HMB	11947:2107	MC4040m
75040030	Mount Ada	Basalt	tr. cpx.	HMB	11947:2107	MC4150m
75040031A	Mount Ada	Basalt	qz. am.	TB	11947:2107	MC4100m
75040031B	Mount Ada	Basalt	qz. am.	TB	11947:2107	MC4100m
75040032A	North Star	Basalt[U]	am. pl.	HALB	11948:2104	MC2100m
75040032C	North Star	Basalt[U]		gabbro	11948:2104	MC2100m
75040032D	North Star	Basalt[U]		gabbro	11948:2104	MC2100m
75040033A	North Star	Basalt[U]	am.	HALB	11948:2104	MC2300m
75040033B	North Star	Basalt[U]	am.	dolerite	11948:2104	MC2300m
75040033C	North Star	Basalt[U]	am.	dacite	11948:2104	MC2300m
75040033D	North Star	Basalt[U]	am.	dacite	11948:2104	MC2300m
75040034A	Mount Ada	Basalt	am.	TB	11948:2105	MC3400m
75040034B	Mount Ada	Basalt	am.	dolerite	11948:2105	MC3400m
75040034C	Mount Ada	Basalt	ch. tr.	FK	11948:2105	MC3400m
75040034D	MOUNT ADA	Basalt	ta. se.	FK	11948:2105	MC3400m
75040034E	Mount Ada	Basalt	tr. ep. ch.	PK	11948:2105	MC3400m
75040034F	Mount Ada	Basalt	ch. tr.	PK	11948:2105	MC3400m
75040035	Mount Ada	Basalt	ch. tr.	PK	11948:2105	MC3500m
75040036	Mount Ada	Basalt	am.	dolerite	11948:2105	MC2850m
75040037A	Mount Ada	Basalt	am.	TB	11948:2105	MC3100m
75040038A	Mount Ada	Basalt	am.	andesite	11948:2105	MC2430m
75040038B	Mount Ada	Basalt	am.	HALB	11948:2105	MC3250m
75040038C	Mount Ada	Basalt	am.	andesite	11948:2105	MC3250m
75040038D	Mount Ada	Basalt		gabbro	11948:2105	MC3250m
75040039B	Mount Ada	Basalt	ep.	TB	11947:2107	MC4450m
75040039C	Mount Ada	Basalt	ep.	TB	11947:2107	MC4450m
75040047A	Mount Ada	Basalt	cpx. pl. sa.	pyroxenite	11945:2102	MC4180m
75040047B	Mount Ada	Basalt	ch. tr.	HMB	11945:2102	MC4180m
75040047C	Mount Ada	Basalt	ep. ch. tr.	HMB	11945:2102	MC4180m
75040047D	Mount Ada	Basalt	ch. tr.	HMB	11945:2102	MC4180m
75040047E	Mount Ada	Basalt	ch. tr.	TB	11945:2102	MC4180m
75040054A	Mount Ada	Basalt	ca. al. ch.	TB	11950:2059	TR1750m
75040054B	Mount Ada	Basalt	ca. al. ch.	TB	11950:2059	TR1750m
75040055A	Mount Ada	Basalt	am. ep.	TB	11950:2059	TR1980m
75040055B	Mount Ada	Basalt	am. ep. sp.	TB	11950:2059	TR1980m
75040055C	Mount Ada	Basalt	ch. am.	TB	11950:2059	TR1980m
75040056A	Mount Ada	Basalt	ep. sp. am.	TB	11950:2058	TR2140m
75040056B	Mount Ada	Basalt	am.	TB	11950:2058	TR2140m
75040056C	Mount Ada	Basalt	ca. ch.	TB	11950:2058	TR2140m
75040056D	Mount Ada	Basalt	ep. am.	TB	11950:2058	TR2140m

75040056E	Mount Ada	Basalt	sp. ep. am.	TB	11950:2058	TR2140m
75040056F	Mount Ada	Basalt	ep. am.	TB	11950:2058	TR2140m
75040057A	Mount Ada	Basalt	cpx. am. ep.	pyroxenite	11950:2058	TR2240m
75040057B	Mount Ada	Basalt	am. cpx. ep.	pyroxenite	11950:2058	TR2240
75040092	Mount Ada	Basalt	am.	pyroxenite	11950:2058	TR2300m
75040093A	MOUNT ADA	Basalt DC	su. ep. ch.	TB	11951:2058	TR2360m
75040092B	Mount Ada	Basalt		pyroxenite	11951:2058	TR2360m
75040094	Mount Ada	Basalt	ca. ch. ep.	HMB	11951:2058	TR2600m
75040095A	Mount Ada	Basalt	ca. ch.	TB	11951:2058	TR2760m
75040095B	MOUNT ADA	Basalt UC	ca. ch.	TB	11951:2058	TR2760m
75040096	MOUNT ADA	Basalt DA	ca. ch.	TB	11951:2057	TR2850m
75040097	MOUNT ADA	Basalt DCF	ch. al.	andesite	11951:2057	TR2800m
75040098A	Mount Ada	Basalt	ch. sa. qz.	il. doler.	11951:2057	TR3280m
75040098B	Mount Ada	Basalt	ch. sa. qz.	il. doler.	11951:2057	TR3280m
75040043A	Duffer	Formation	am. ep.	dolerite	11946:2107	CO200m
75040045A	Duffer	Formation	am. ep. sa.	pyroxenite	11945:2107	CO1300m
75040045C	Duffer	Formation	sa.	pyroxenite	11945:2107	CO1300m
75040045H	Duffer	Formation	am. ep. sa.	ch. TB	11945:2107	CO1300m
75040046A	Duffer	Formation	ch. sa. am.	pyroxenite	11945:2106	CO1400m
75040046C	DUFFER DC	Formation	ep. al.	Na-dacite	11945:2106	CO1400m
75040046E	DUFFER DC	Formation	Na-dacite	tuff	11945:2106	CO1400m
75040046F	DUFFER DC	Formation	Na-dacite	tuff	11945:2106	CO1400m
75040046G	Duffer	Formation	il. sa. am.	dolerite	11945:2106	CO1400m
75040046H	Duffer	Formation	ch. sa.	pyroxenite	11945:2106	CO1400m
75040046I	Duffer	Formation	se. ca. al.	tu. rhyol.	11945:2106	CO1400m
75040046J	Duffer	Formation	sa. ch. il.	dolerite	11945:2106	CO1400m
75040046L	Duffer DC	Formation	al. tuff	Na-rhyol	11945:2106	CO1400m
75040046M	Duffer DC	Formation	al. tuff	Na-rhyol	11945:2106	CO1400m
75040046N	Duffer	Formation	ep. ch. al.	andesite	11945:2106	CO1400m
75040059A	Duffer	Formation	ca. tuff	Na-dacite	11944:2108	CO3600m
75040060A	Duffer	Formation	tuff	K-dacite	11944:2108	CO4100m
75040060B	DUFFER DC	Formation		K-rhyol	11944:2108	CO4100m
75040060C	Duffer	Formation		TB	11944:2108	CO4100m
75040060D	Duffer	Formation	il. ch. al.	TB	11944:2108	CO4100m
75040062A	Duffer	Formation	sa. ep.	qz-latite	11944:2108	CO4400m
75040062B	Duffer DC	Formation	sa. ch.	dacite	11944:2108	CO4400m
75040064B	DUFFER DC	Formation	se.	Na-dacite	11944:2108	CO4800m
75040065B	DUFFER DC	Formation	ca. ch.	Na-dacite	11943:2109	CO5240m
75040065C	DUFFER DC	Formation	se.	Na-dacite	11943:2109	CO5240m
75040066A	Duffer	Formation	ep. ch. ca.	andesite	11943:2109	CO6200m
75040066B	Duffer	Formation	ch. tuff	andesite	11943:2109	CO6200m
75040066C	Duffer	Formation	il.	dolerite	11943:2109	CO6200m
75040065D	Duffer	Formation	ca. agglom.	andesite	11943:2109	CO6200m
75040067A	DUFFER DC	Formation	al. ch.	andesite	11943:2109	CO6600m
75040069E	Duffer	Formation	ch. al.	andesite	11942:2110	CO8300m
75040072B	TOWER DCA	Formation	ch. al.	andesite	11942:2110	
75040100A	DUFFER DC	Formation	qz. sa.	rhyolite	12021:2136	Nullagine
75040100B	DUFFER DC	Formation	qz. sa.	rhyolite	12021:2136	Nullagine

75040073A	APEX DC US	Basalt	ch. al.	andesite	11942:2111	CC200m
75040073G	APEX DC US	Basalt	qz. al. ch.	andesite	11942:2111	CC200m
75040075B	APEX DC	Basalt	ch.	andesite	11942:2110	CC300m
75040076A	Apex	Basalt	cpx. il.	dolerite	11942:2110	CC340m
75040076B	Apex	Basalt	cpx. il.	dolerite	11942:2110	CC340m
75040076C	Apex	Basalt	am.	gabbro	11942:2110	CC340m
75040078A	Apex	Basalt	cpx. ch. ta.	pyroxenite	11941:2110	CC1100m
75040078C	Apex	Basalt	ch.	dacite	11941:2110	CC1100m
75040078D	APEX DCUS	Basalt	ch. tr. cpx.	HMB	11941:2110	CC1100m
75040078E	Apex	Basalt			11941:2110	CC1100m
75040079A	Apex	Basalt	cpx. ch. sl.	HMB	11941:2110	CC1220m
75040079B	Apex	Basalt	cpx. ch.	HMB	11941:2110	CC1220m
75040079D	Apex	Basalt	cpx. ch. sl.	HMB	11941:2110	CC1220m
75040080B	Apex	Basalt	pl. ch.	TB	11941:2110	CC1400m
75040083F			ch. se. al.	andesite	11942:2111	
75040083I			ch. al. se.	TB	11942:2111	
75040083K			ch.	TB	11942:2111	
75040083L			ch. al. se.	andesite	11942:2111	
75040083M		Basalt	ch. al. se.	andesite	11942:2111	
75040083O		Basalt	amygdal.	ch. HALB	11942:2111	
75040083Q			amygdal.	ch. and.	11942:2111	
75040085	APEX DC	Basalt	tr. pl. cpx.	andesite	11941:2112	CC2700m
75040089A	APEX UC	Basalt	ca. ch. cpx.	dolerite	11941:2112	CC2200m
75040089B	APEX UC	Basalt	ca. ch. cpx.	dolerite	11941:2112	CC2200m
75040105A	Wyman	Formation	qz.	rhyolite	11946:2118	Marble Bar
75040105B	Wyman	Formation	qz.	rhyolite	11946:2118	Marble Bar
75040105C	Wyman	Formation	qz.	rhyolite	11946:2118	Marble Bar
75040106B	Honeyeater	Basalt UC		HMB	11916:2114	North Shaw
75040106D	Honeyeater	Basalt UC		HMB	11916:2114	North Shaw
75040106E	Honeyeater	Basalt DC		TB	11916:2114	North Shaw
75040106F	Honeyeater	Basalt DC		TB	11916:2114	North Shaw

Sample titles

SAMPLE NO.	FORMATION	ROCK TYPE	LOCATION	STRAT. POSITION
45062	North Star	Basalt	ch. am. pl.	70
45063	North Star	Basalt	am. ch. pl.	200
45064	North Star	Basalt	am. ch. ep.	300
45065	North Star	Basalt	sr. ca. ta.	500
45066	North Star	Basalt	am. sa. al.	420
45067	North Star	Basalt	am. sa. ep.	650
45068	North Star	Basalt	am. sa. al.	770
45069	North Star	Basalt	tr. ch. al.	880
45070	North Star	Basalt	am. ch. sp.	1030
45071	North Star	Basalt	tr. sa. ch.	1210
45072	North Star	Basalt	am. al. sa.	1450m
45073	North Star	Basalt	am. cl. ep.	1500m
45074	North Star	Basalt	am. sa. qz.	1800m
45075	North Star	Basalt	ch. ca. ep.	1970m
45076	Mount Ada	Basalt	ca. al. ch.	2430m
45077	Mount Ada	Basalt	al. ch. ca.	2510m
45078	MOUNT ADA	Basalt DF	ca. al. ch.	2660m
45079	Mount Ada	Basalt	ca. al. ch.	2720m
45080	Mount Ada	Basalt DC	ca. al. ch.	2800m
45081	MOUNT ADA	Basalt DC	se. qz. al.	2760m
45082	Mount Ada	Basalt	ca. al. ch.	2870m
45083	MOUNT ADA	Basalt DA	ca. ch. il.	2930m
45084	Mount Ada	Basalt	ca. al. ch.	3000m
45085	Mount Ada	Basalt	ca. al. ch.	3100m
45086	Mount Ada	Basalt DA	ca. al. ch.	3220m
45087	MOUNT ADA	Basalt UC	ca. tr. ch.	3330m
45088	Mount Ada	Basalt	ca. ch. al.	3410m
45089	Mount Ada	Basalt	ca. ch. mu.	3530m
45090	Mount Ada	Basalt	ep. ch. qz.	3460m
45091	Mount Ada	Basalt DA	ca. sa. ch.	3560m
45092	Mount Ada	Basalt DA	ch. tr. ep.	3810m
45093	Mount Ada	Basalt	ca. al. ch.	4000m
45094	Mount Ada	Basalt	al. ch. ep.	4170m
45095	Mount Ada	Basalt	ca. al. ch.	2230m
45096	Mount Ada	Basalt	ca. al. ch.	2330m
45153	Mount Ada	Basalt	cpx. pl. ch.	2100m
45154	Mount Ada	Basalt	cpx. sa. qz.	1900m
45155	Mount Ada	Basalt	cpx. sa. ep.	1940m
45156	MOUNT ADA	Basalt DC	ca. pl. ch.	1830m
45157	Mount Ada	Basalt	py. ac. sa.	1660m
45158	MOUNT ADA	Basalt DAUC	cpx. sr.	1570m
45159	Mount Ada	Basalt	cpx. ca.	1500m
45160	Mount Ada	Basalt	px. amygdi.	1380m
45164	Mount Ada	Basalt	cpx. ep.	1290m
45165	Mount Ada	Basalt	ca. sr. ep.	1180m

45166	MOUNT ADA	Basalt DC	pl. dacite	tuff	11936:2114	1180m
45168	Mount Ada	Basalt	sa.px.sr.	gabbro	11936:2114	1020m
45169	Mount Ada	Basalt DC	ep.ch.sa.	TB	11936:2120	970m
45170	MOUNT ADA	Basalt DCF	qz.pl.ca.	dacite	11936:2125	930m
45171	MOUNT ADA	Basalt LC	ca.	TB	11936:2125	780m
45172	Mount Ada	Basalt	cpx.ch.ca.	HMB	11936:2125	300m
45173	Mount Ada	Basalt	cpx.ch.ca.	HMB	11936:2125	50m
45174	North Star	Basalt[U]	qz.mu.	rhyolite	11936:2126	2250m
45175	North Star	Basalt	ep.ch.sp.	gabbro	11936:2126	2190m
45176	NORTH STAR	Basalt DA	cpx.am.ep.	HMB	11936:2126	2120m
45177	NORTH STAR	Basalt DCF	se.qz.	schist	11936:2127	2070m
45178	NORTH STAR	Basalt DC	ch.se.qz.	schist	11936:2127	2020m
45179	NORTH STAR	Basalt DCA	ch.ep.qz.	schist	11936:2127	1760m
45180	North Star	Basalt	ac.ep.sp.	dolerite	11936:2127	1900m
45181	North Star	Basalt	ep.sp.	dolerite	11936:2127	1380m
45182	North Star	Basalt		dolerite	11935:2127	1300m
45183	North Star	Basalt	cpx.tr.ep.	TB	11935:2127	1170m
45187	North Star	Basalt	am.pl.ep.	sp.doler.	11935:2127	860m
45188	North Star	Basalt	am.pl.ep.	sp.gabbro	11935:2127	720m
45189	North Star	Basalt	ca.ep.	TB	11935:2127	670m
45190	North Star	Basalt	ep.sp.	TB	11935:2127	590m
45191	North Star	Basalt	ep.ca.sp.	dolerite	11935:2127	360m
45192	North Star	Basalt	am.pl.qz.	TB	11935:2127	170m
45193	North Star	Basalt	am.sp.	TB	11935:2129	90m

45194	DUFFER UC	Formation	qz.fl.se.	rhyodacite	12002:2127	250m
45195	Duffer DC	Formation	qz.fl.bi.	mu.dacite	12002:2127	350m
45196	Duffer	Formation	cl.qz.fl.	qz-latite	12002:2127	450m
45197	DUFFER DC	Formation	qz.fl.mu.	K-rhyolite	12002:2127	520m
45198	Duffer	Formation	qz.fl.mu.	Ca-dacite	12002:2127	600m
45199	Duffer	Formation	ep.cl.ep.	rhyodacite	12002:2127	750m
45200	Duffer UC	Formation	qz-latite	agglom.	12002:2127	930m
49205	Duffer	Formation	qz-latite	agglom.	12002:2127	970m
49206	Duffer	Formation	qz-latite	agglom.	12002:2127	1070m
49207	DUFFERUCDF	Formation	ca.ep.tuff	rhy.tuff	12002:2127	1220m
49208	Duffer	Formation	ca.	rhyolite	12002:2127	1630m
49209	Duffer	Formation	ca.	dacite	12003:2127	1820m
49210	Duffer DC	Formation		dacite	12003:2127	1925m
49211	Duffer	Formation	ca.	rhyolite	12003:2128	1710m
49212	DUFFERDAUC	Formation	ca.	rhyolite	12003:2128	1800m
49213	DUFFER UC	Formation	ca.ep.	tuff	12003:2128	1890m
49214	DUFFER DA	Formation	ca.ep.	tuff	12003:2128	1940m

49215	Apex	Basalt	cpx	dolerite	12003:2128	10m
49216	Apex	Basalt	ac.cl.ca.	HMB	12003:2128	50m
49217	Apex	Basalt	ep.	HMB	12003:2128	90m
49218	Apex	Basalt	ep.ch.sp.	HMB	12003:2128	160m
49219	Apex	Basalt	ep.ch.sp.	TB	12003:2128	260m
49220	Apex	Basalt	ep.ca.	TB	12003:2128	340m
49221	Apex	Basalt	cpx.ep.ch.	HMB	12003:2128	390m
49222	Apex	Basalt	ca.	TB	12003:2128	450m
49223	Apex	Basalt	ep.ch.sp.	HMB	12003:2128	500m
49224	Apex	Basalt	ep.sp.	TB	12003:2128	550m

49225	Apex	Basalt	ep.ca.	TB	12003:2128	600m
49226	Apex	Basalt	ep.tr.ca.	pyroxenite	12003:2128	630m
49227	Apex	Basalt	cpx.tr.sa.	gabbro	12003:2128	650m
49228	APEX UC	Basalt	ca.ch.	dolerite	12003:2128	770m
49229	Apex	Basalt	ep.ca.sp.	dolerite	12003:2128	730m
49230	Apex	Basalt	ca.ep.sp.	TB	12003:2128	800m
49231	APEX UC DA	Basalt	tr.sp.	HMB	12003:2128	1000m
49232	Apex	Basalt		HMB	12004:2128	1120m
49233	Apex	Basalt	cpx.sr.sa.	pl.HMB	12001:2135	40m
49234	Apex	Basalt	cpx.ep.sp.	sa.TB	12001:2135	320m
49235	Apex	Basalt	cpx.ep.ca.	TB	12001:2135	460m
49236	Apex	Basalt	ep.ch.sp.	TB	12001:2135	410m
49237	APEX DC	Basalt	se.qz.	rock	12001:2135	650m
49239	Apex	Basalt	ep.cl.ch.	sp.TB	12001:2135	500m
49240	Apex	Basalt	cpx.ch.ep.	TB	12001:2135	560m
49241	Apex	Basalt	cpx.ca.	HMB	12001:2135	750m
49242	APEX UC	Basalt	ca.ch.qz.	HMB	12001:2135	860m
49243	APEX DCUS	Basalt	silicified	basalt	12002:2135	1070m
49244	EURO DC	Basalt	ch.se.	HALB	12006:2131	Nullagine
49245	EURO DA	Basalt	ca.ch.	TB	12006:2131	Nullagine
49246	EURO DC	Basalt	ca.ch.	TB	12006:2131	Nullagine
49247	EURO	Basalt	ac.ch.ca?	HMB	12006:2131	Nullagine
49248	EURO DSUC	Basalt	ca.ch.	basalt	12006:2131	Nullagine
49249	Euro	Basalt	ca.ch.	HMB	12006:2131	Nullagine
49250	Charteris	Basalt	ca.ch.qz.	TB	12009:2127	1030m
49251	Charteris	Basalt	ca.	gabbro	12009:2127	1090m
49252	Charteris	Basalt	ca.	andesite	12009:2127	1160m
49253	Charteris	Basalt	cpx.ep.	por.basalt	12009:2127	1110m
49254	Charteris	Basalt	cpx.	HMB	12009:2127	1060m
49255	Charteris	Basalt	ep.	HMB	12009:2127	1050m
49256	Charteris	Basalt	cpx.	TB	12009:2127	1020m
49257	CHARTERIS	Basalt DC	ch.ca.sp.	HALB	12009:2127	1010m
49258	CHARTERIS	Basalt DA	ca.ch.	TB	12009:2127	960m
49259	Charteris	Basalt	ca.ch.	TB	12009:2127	880m
49260	Charteris	Basalt	ca.ch.	TB	12009:2127	720m
49261	Charteris	Basalt	cpx.ch.ep.	TB	12009:2127	620m
49262	Charteris	Basalt	ca.	TB	12009:2128	550m
49263	Charteris	Basalt	ep.sa.ch.	HMB	12009:2128	470m
49264	Charteris	Basalt	ca.	TB	12009:2128	420m
49265	Charteris	Basalt	ep.ch.sp.	TB	12009:2128	330m
49266	Charteris	Basalt	cpx.pl.qz.	gabbro	12009:2128	240m
49267	CHARTERIS	Basalt USDC	silicified	basalt	12009:2128	30m
49268	CHARTERIS	Basalt DC	cpx.	TB	12009:2128	110m
49269	Charteris	Basalt	ol.se.	TB	12010:2128	600m
49270	Charteris	Basalt	cpx.ch.ep.	HMBdoler.	12010:2128	680m
49271	Charteris	Basalt	ca.	HMB	12010:2128	750m
49272	Charteris	Basalt	ep.	HMB	12010:2128	820m
49273	CHARTERIS	Basalt DC	ca.ch.	gabbro	12010:2127	1045m
49274	CHARTERIS	Basalt DC	ca.	dolerite	12010:2127	1130m
49275	Charteris	Basalt	ep.	HMB	12009:2128	850m
49276	Charteris	Basalt	cpx.cl.	TB	12009:2128	790m

49277	DUFFER DC	Formation	rhyolite	tuff	11941:2103	3670m
49278	DUFFER DS	Formation	ca. K-rich	porphyry	11941:2103	3650m
49279	Duffer	Formation	ca. porph.	andesite	11941:2103	3630m
49280	Duffer	Formation	ca. porph.	dacite	11941:2103	3610m
49281	Duffer	Formation	ca. tuff	rhyolite	11941:2103	3580m
49282	DUFFER UC	Formation	ca. dacite	tuff	11941:2103	3560m
49283	DUFFER DC	Formation	rhyolite	tuff	11941:2103	3550m
49284	DUFFER DC	Formation	ca.	TB	11941:2103	3540m
49285	Duffer	Formation	ca. sa. se.	TB	11941:2103	3540m
49286	DUFFER DC	Formation	rhyolite	tuff	11941:2103	3510m
49287	Duffer	Formation	ca. tuff	K-dacite	11941:2103	3490m
49288	Duffer	Formation	ca. tuff	K-dacite	11941:2103	3450m
49289	DUFFER DC	Formation	ca. tuff	dacite	11941:2103	3420m
49290	Duffer	Formation	ca. tuff	dacite	11941:2103	3380m
49291	Duffer	Formation	ca. tuff	K-dacite	11941:2103	3350m
49292	DUFFER DC	Formation	ca. tuff	dacite	11941:2103	3220m
49293	DUFFER DC	Formation	dacite	tuff	11941:2103	3150m
49294	Duffer	Formation	ca. tuff	dacite	11941:2103	3050m
49295	Duffer DC	Formation	ca. tuff	dacite	11941:2103	2900m
49296	Duffer DC	Formation	ca. tuff	dacite	11941:2103	2800m
49297	DufferDCA	Formation	ca. tuff	dacite	11941:2103	2700m
49298	Duffer	Formation	ca. tuff	dacite	11941:2103	2600m
49299	DUFFER DC	Formation	ca. sa.	dacite	11942:2103	2520m
49300	DUFFER DC	Formation	pl.	dacite	11942:2103	2400m
49301	Duffer	Formation	ca. pl.	andesite	11942:2103	2240m
49302	DUFFER DC	Formation	ca. tuff	dacite	11942:2103	2140m
49303	Duffer	Formation	ca. tuff	dacite	11942:2103	2040m
49304	Duffer UC	Formation	ca. ch. py.	andesite	11942:2103	1920m
49305	Duffer DC	Formation	ca. tuff	andesite	11943:2103	1800m
49306	Duffer	Formation	ca. pl. qz.	dacite	11943:2103	1625m
49307	DufferDFC	Formation	ep. ca. pl.	dacite	11943:2103	1450m
49308	Duffer	Formation	ca. ep.	dacite	11943:2103	1280m
49309	Duffer DF	Formation	ep.	dacite	11943:2103	1180m
49310	Duffer	Formation	ca. ep. pl.	dacite	11943:2103	1120m
49311	Duffer DF	Formation	ca. pl. am.	dacite	11943:2103	980m
49312	DUFFER DFC	Formation	pl.	dacite	11944:2103	840m
49313	Duffer	Formation	ca. pl.	dacite	11944:2103	720m
49314	Duffer	Formation	am. ch.	TB	11944:2103	600m
49315	DUFFER UA	Formation	pl. ep. cl.	andesite	11944:2102	480m
49316	Duffer DC	Formation	ep. pl.	andesite	11944:2102	350m
49317	DUFFER DFC	Formation	ep. pl. ca.	dacite	11944:2103	200m

49325	Apex	Basalt	tr. cl. ca.	TB	11947:2121	50m
49326	Apex	Basalt	ch. ep. ac.	HMB	11947:2121	120m
49327	Apex	Basalt	ca.	HMB	11947:2121	200m
49328	Apex	Basalt	ca. sr.	PK	11947:2121	270m
49329	Apex	Basalt	ol.	PK	11947:2121	450m
49330	Apex	Basalt	ol. tr.	PK	11947:2121	500m
49331	Apex	Basalt	tr. ol.	PK	11947:2121	560m
49332	Apex	Basalt	tr. ol.	PK	11947:2121	610m
49333	Apex	Basalt	tr. ch.	HMB	11947:2121	650m
49334	Apex	Basalt	tr. ch. ep.	HMB	11947:2121	730m

49335	Apex	Basalt	tr.ch.	HMB	11947:2121	800m
49336	Apex	Basalt	ch.tr.	HMB	11947:2121	890m
49337	Apex	Basalt	ch.tr.	HMB	11947:2121	1030m
49338	Apex	Basalt	ch.tr.	HMB	11947:2120	1110m
49339	APEX UCDA	Basalt UCDA	ch.tr.cl.	ca.TB	11947:2120	1210m
49340	Apex	Basalt	ch.tr.cl.	HMBgabbro	11947:2120	1300m
49341	Apex	Basalt	ch.tr.cl.	dolerite	11947:2120	1400m
49342	Euro	Basalt	tr.ep.ca.	HMBdoler.	11945:2120	2850m
49343	Euro	Basalt	px.ep.ca.	HMB	11945:2120	2700m
49344	Euro	Basalt	tr.ch.cl?	TB	11945:2120	2470m
49345	Euro	Basalt	sp.	TB	11945:2120	2390m
49346	Euro	Basalt	ep.ca.sp.	TB	11945:2120	2300m
49347	Euro	Basalt	ep.tr.sp.	TB	11945:2120	2210m
49348	Euro	Basalt	ep.tr.sp.	HMB	11946:2120	2100m
49349	Euro	Basalt	ca.ch.qz.	TB	11945:2119	2960m
49350	EURO DC	Basalt DC	ca.	dolerite	11946:2119	3040m

49318	Wyman	Formation	qz.or.se.	rhyolite	11946:2118	Marble Bar
49319	Wyman	Formation	qz.or.se.	rhyolite	11946:2118	Marble Bar
49320	Wyman	Formation	qz.or.se.	rhyolite	11946:2118	Marble Bar
49321	Wyman	Formation	qz.or.se.	rhyolite	11946:2118	Marble Bar
49322	Wyman	Formation	qz.or.se.	rhyolite	11946:2118	Marble Bar
49323	Wyman	Formation	qz.or.se.	rhyolite	11946:2118	Marble Bar
49324	Wyman	Formation	qz.or.se.	rhyolite	11946:2118	Marble Bar
49351	Wyman	Formation	qz.pl.ca.	rhyolite	11951:2150	Split Rock
49352	Wyman	Formation	se.qz.pl.	rhyolite	11951:2150	Split Rock
49353	Wyman	Formation	qz.pl.se.	rhyolite	11951:2150	Split Rock

49354	Wyman	Formation	qz.	rhyolite	11951:2150	Split Rock
49355	Wyman	Formation	qz.	rhyolite	11951:2150	Split Rock
49356	Wyman	Formation	se.qz.pl.	rhyolite	11951:2150	Split Rock
49357	Wyman	Formation	se.qz.pl.	rhyolite	11951:2150	Split Rock
49358	Wyman	Formation	se.qz.	rhyolite	11951:2150	Split Rock
49359	Wyman	Formation	se.qz.	rhyolite	11951:2150	Split Rock
49360	Wyman	Formation	qz.se.pl.	rhyolite	11959:2142	Split Rock
49361	Wyman	Formation	qz.pl.se.	rhyolite	11959:2142	Split Rock
49362	Wyman	Formation	qz.pl.se.	rhyolite	11959:2142	Split Rock
49363	Wyman	Formation	qz.se.pl.	rhyolite	11959:2142	Split Rock

49364	Honeyeater	Basalt	px.sr.tr.	ep.HMBdoler	11910:2125	630m
49365	Honeyeater	Basalt	ep.sr.ca.	pl.doler.	11910:2125	540m
49366	Honeyeater	Basalt	cpx.sa.ch.	HMB	11909:2125	480m
49367	Honeyeater	Basalt	cpx.ep.ch.	HMB	11909:2125	435m
49368	Honeyeater	Basalt	cpx.pl.	dolerite	11909:2125	290m
49369	Honeyeater	Basalt	cpx.sr.pl.	dolerite	11909:2125	60m
49370	Honeyeater	Basalt	cpx.sr.	dolerite	11909:2125	525m
49371	Honeyeater	Basalt	ca.	HALB	11909:2126	620m
49372	Honeyeater	Basalt	ca.	HALB	11909:2126	670m
49373	Honeyeater	Basalt	sa.sr.	dolerite	11909:2126	720m

49374	HONEYEATER	Basalt DC	sa.sr.	dolerite	11909:2126	870m
49375	Honeyeater	Basalt	sa.sr.	dolerite	11909:2126	920m
49376	Honeyeater	Basalt	ca.	HALB	11909:2126	520m
49377	Honeyeater	Basalt	ca.	HALB	11909:2126	450m
49378	HONEYEATER	Basalt UC	cpx.pr.pu.	ca.TB	11909:2126	420m
49379	Honeyeater	Basalt	cpx.	TB	11909:2126	400m
49380	Honeyeater	Basalt	cpx.ca.	TB	11909:2126	380m
49381	Honeyeater	Basalt	cpx.ch.ca.	HMB	11909:2126	340m
49382	Honeyeater	Basalt	cpx.sa.ch.	al.HMBdoler	11909:2126	320m
49383	Honeyeater	Basalt	cpx.pr.pu.	TB	11909:2126	270m

49384	Honeyeater	Basalt	ch.	HMBoler	11909:2126	240m
49385	Honeyeater	Basalt	cpk.sr.	HMB	11910:2126	220m
49386	HONEYEATER	Basalt UCDA	cpk.ch.ca.	basalt	11909:2126	500m
49387	Honeyeater	Basalt	ca.	TB	11909:2126	600m
49388	HONEYEATER	Basalt DC	ca.	TB	11909:2127	770m
49389	Honeyeater	Basalt	pl.ca.	TB	11909:2127	880m
49390	Honeyeater	Basalt	ca.	TB	11909:2127	990m
49391	Honeyeater	Basalt	cpk.ch.se.	HMB	11908:2126	200m
49392	Honeyeater	Basalt	ca.ep.ch.	qz.TB	11909:2127	970m
49393	Honeyeater	Basalt	ep.ch.qz.	TB	11909:2127	900m
49394	Honeyeater	Basalt	cpk.am.sr.	dolerite	11909:2127	800m
49395	Honeyeater	Basalt	ch.	TB	11909:2127	680m
49396	Honeyeater	Basalt	px.am.sr.	dolerite	11909:2127	570m
49397	Honeyeater	Basalt	cpk.ca.	TB	11909:2127	460m
49398	Honeyeater	Basalt	px.	TB	11909:2127	360m
49399	Honeyeater	Basalt	ca.	TB	11909:2128	260m

Appendix I(b)
Geochemical data tables

track 0; file 2 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Talga-Coongan

Sample no.	75040002A	75040002B	75040003C	75040004A	75040004B	75040005A	75040005B	75040007A	75040007B	75040008A
Formation	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star
Rock Type	Basalt am.cl.ep. al.TB	Basalt am.cl.ep. al.TB	Basalt sp.ep.tr. HMB	Basalt am.sa.al. dolerite	Basalt am.qz.al. TB	Basalt am.al.ep. dolerite	Basalt am.sa.al. qz.TB	Basalt sp.am.qz. al.TB	Basalt am.cl.al. qz.TB	Basalt am.cl.al. qz.TB
Gr or photo pt.	11951:2101	11951:2101	11951:2100	11951:2100	11951:2100	11951:2100	11951:2100	11951:2100	11951:2100	11951:2100
Stratig. level	TR0m	TR0m	TR100m	TR250m	TR250m	TR400m	TR400m	TR780m	TR780m	TR900m
SiO ₂	49.54	49.22	49.68	51.21	49.72	50.69	51.13	50.49	50.64	52.58
TiO ₂	1.59	1.62	0.68	1.08	1.67	0.67	1.33	1.14	1.07	1.23
Al ₂ O ₃	13.96	13.55	5.84	15.95	14.46	15.28	13.84	14.42	13.79	14.20
Fe ₂ O ₃	16.07	16.30	12.44	11.84	15.14	10.43	14.01	12.96	13.01	11.97
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.22	0.24	0.24	0.17	0.36	0.18	0.22	0.22	0.20	0.23
MgO	5.32	6.07	13.91	6.01	4.76	8.85	6.06	6.91	7.61	6.33
CaO	10.77	9.08	14.94	9.10	8.94	9.37	10.46	10.33	10.45	8.49
Na ₂ O	1.58	2.42	0.42	3.18	4.02	2.66	2.00	2.45	2.14	3.48
K ₂ O	0.37	0.30	0.22	0.49	0.37	0.88	0.32	0.19	0.23	0.32
P ₂ O ₅	0.17	0.17	0.40	0.15	0.16	0.05	0.16	0.10	0.09	0.11
H ₂ O+	0.80	0.90	0.38	1.16	0.47	1.33	0.78	0.90	0.83	1.15
H ₂ O-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.05	0.05	0.24	0.05	0.04	0.02	0.07	0.08	0.06	0.12
TOTAL	100.44	99.92	99.39	100.39	100.11	100.41	100.38	100.19	100.12	100.21
Ra	81	538	36	216	52	232	106	105	82	67
Rb	11	11	2	32	12	57	8	4	8	10
Sr	317	258	26	336	115	191	144	119	115	107
Pb	2	2								
Th										
U	1									
Zr	137	145	29	84	147	46	129	1	1	
Nb	5	7		5	8	2	6	96	81	106
Y	33	35	14	21	33	16	32	5	4	4
La	5	5		12	10	3	5	26	24	25
Ce	28	29		23	24		13	4	4	2
Li	31	36	13	32	16	39	21	3	5	12
V	374	352	324	229	391	248	312	19	17	21
Cr	132	116	1400	146	187	865	52	349	332	302
Co	49	51	66	40	50	40	42	199	194	70
Ni	62	57	399	65	87	109	56	41	42	49
Cu	99	99	236	63	8	69	46	71	71	51
Zn	106	120	64	86	121	64	103	64	75	33
Ga	22	20	9	17	20	13	17	90	87	88
S	1040	480	640	160	40	80	80	40	40	16

track 0: file 3 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Talga-Coongan

Sample no.	75040008b	75040009	75040012	75040016a	75040016B	75040016D	75040016E	75040016F	75040016G	75040016H
Formation	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star	NORTH STAR	North Star
Rock Type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt DC	Basalt
Gr or photo pt.	am.sa.al.	am.sa.al.	am.sa.al.	am.sa.al.	am.sa.al.	saussur.	saussur.	am.sa.al.	am.al.qz.	tr.sa.
Stratig. level	qz.TB	qz.TB	TB	qz.doler.	TB	dolerite	dolerite	qz.TB	ch.ep.and.	TB
	11951:2100	11951:2100	11951:2059	11950:2103	11950:2103	11950:2103	11950:2103	11950:2103	11950:2103	11950:2103
	TR900m	TR1100m	TR1450m	MC0m	MC0m	MC0m	MC0m	MC0m	MC0m	MC0m
SiO ₂	50.67	53.26	53.37	48.22	49.31	53.61	47.53	50.58	57.79	51.46
TiO ₂	1.24	1.22	1.09	1.75	1.25	0.76	0.33	0.70	1.03	0.59
Al ₂ O ₃	14.54	13.84	13.36	13.37	13.81	14.83	16.65	14.86	16.59	15.08
Fe ₂ O ₃	12.48	12.72	13.17	17.49	15.42	9.96	12.61	10.46	9.22	10.66
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.25	0.23	0.21	0.27	0.25	0.16	0.22	0.19	0.16	0.21
MeO	7.01	5.84	7.59	5.89	6.78	7.27	8.99	8.19	3.00	8.13
CaO	8.14	8.35	7.56	9.04	10.59	9.88	9.08	10.64	6.38	9.96
Na ₂ O	3.43	3.32	2.18	1.61	1.49	1.64	1.69	1.73	3.79	1.26
K ₂ O	0.22	0.36	0.34	0.46	0.46	0.49	0.77	0.59	0.68	0.93
P ₂ O ₅	0.10	0.12	0.10	0.13	0.08	0.05	0.04	0.06	0.11	0.04
H ₂ O ⁺	1.42	1.09	1.99	0.84	0.61	1.20	1.67	1.06	1.16	1.55
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.29	0.13	0.03	0.05	0.10	0.09	0.14	0.11	0.18	0.08
TOTAL	99.79	100.48	100.99	99.12	100.15	100.04	100.42	99.17	100.09	99.97
Ba	65	51	104	71	103	112	137	134	290	183
Rb	6	8	6	16	10	30	46	35	28	49
Sr	103	146	155	120	120	140	232	130	473	165
Pb		2				2	3		2	
Th										
U				1	1					
Zr	104	98	86	109	74	65	40	62	123	77
Nb	4	4	4	4	3	2	2	3	5	4
Y	25	23	24	32	26	18	16	19	19	21
La	3	3	3						4	3
Ce	7	6	6	5	8				25	3
Li	27	18	40	56	50	76	75	67	71	67
V	345	321	323	454	385	293	155	288	150	250
Cr	78	45	55	94	147	240	341	320	28	316
Co	47	45	40	53	52	38	58	40	28	44
Ni	52	40	36	76	95	81	250	93	16	105
Cu	88	75	75	117	61	81	63	47	23	56
Zn	95	68	86	131	95	61	150	64	62	66
Ga	16	17	16	18	17	13	14	13	19	13
S	40	40	80	1000	1040	240	320	240	320	80

track 0; file 4 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Talga-Coongan

Sample no.	75040006	75040016I	75040016J	75040016N	75040016O	75040016P	75040016Q	75040016R	75040017A	75040017B
Formation	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star
Rock Type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
	tr.ch.	tr.sa.	tr.sa.	saussur.	saussur.	sa.tr.	cpx.	il.	am.	sp.ac.ep.
Gr or photo pt.	PK	TB	TB	dolerite	TB	HMB	TB	dolerite	TB	TB
Stratig. level	11951:2100	11950:2103	11950:2103	11950:2103	11950:2103	11950:2103	11950:2103	11950:2103	11949:2103	11949:2103
	TR600m	MCOm	MCOm	MCOm	MCOm	MCOm	MCOm	MCOm	MC400m	MC400m
SiO ₂	43.56	51.25	51.32	50.87	49.51	51.57	53.86	48.25	52.23	52.84
TiO ₂	0.67	0.59	0.59	1.14	1.04	0.59	0.74	1.53	1.10	1.09
Al ₂ O ₃	6.88	15.02	15.02	15.87	14.07	14.92	14.79	14.14	13.46	13.57
Fe ₂ O ₃	14.12	10.22	10.43	12.68	14.49	10.28	9.46	16.53	12.73	11.94
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.19	0.21	0.21	0.20	0.23	0.22	0.23	0.27	0.19	0.23
MgO	22.20	8.26	8.07	6.57	7.02	9.00	6.05	6.31	7.10	5.33
CaO	7.64	9.89	10.39	8.72	10.87	9.39	12.02	9.83	8.65	11.98
Na ₂ O	0.04	1.22	1.25	2.06	1.66	1.69	2.41	1.90	1.95	1.58
K ₂ O	0.04	1.12	0.84	0.37	0.57	0.31	0.44	0.43	0.34	0.41
P ₂ O ₅	0.04	0.04	0.04	0.06	0.07	0.04	0.05	0.11	0.10	0.10
H ₂ O ⁺	4.16	1.57	1.47	1.51	0.80	1.62	0.29	0.68	1.16	0.35
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.05	0.13	0.12	0.33	0.10	0.06	0.06	0.05	0.02	0.07
TOTAL	99.59	99.52	99.75	100.38	100.43	99.69	100.41	100.03	99.03	99.49
Ba		185	153	56	175	70	168	75	49	27
Rb		49	43	19	15	14	15	15	16	20
Sr	10	163	179	298	121	100	144	131	104	116
Pb		2		2				2		
Th										
U	1									2
Zr	40	77	76	68	62	76	63	94	94	88
Nb		4	5	2	2	4	2	5	5	4
Y	10	20	19	21	23	20	21	28	27	24
La				5		7	2	2		6
Ce		2	6	4		5	7	9	11	9
Li	3	62	57	127	53	49	12	46	54	15
V	193	244	246	212	354	241	272	403	364	324
Cr	3330	313	319	172	161	430	965	181	77	86
Co	89	45	43	44	51	44	44	54	41	40
Ni	1210	102	101	80	99	127	206	88	50	52
Cu	51	45	47	57	43	115	46	65	57	8
Zn	67	63	62	103	95	66	68	122	66	88
Ga	12	12	13	17	15	12	13	18	16	16
S	40	60	80	1200	240	120	40	840	160	40

track 0; file 5 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Talga-Coongan

Sample no.	75040017C	75040017D	75040017E	75040019A	75040019B	75040019F	75040019G	75040019H	75040020	75040022
Formation	North Star	North Star	North Star	North Star	NORTH STAR	North Star	North Star	North Star	North Star	North Star
Rock Type	Basalt sa.am. dolerite	Basalt amygdal. TB	Basalt am. TB	Basalt gabbro	Basalt DC chlorite schist	Basalt ch.tr. PK	Basalt ep. gabbro	Basalt ch.tr. PK	Basalt ta, ch. PK	Basalt sp.high-Mg gabbro
Gr or photo pt.	11949:2103	11949:2103	11949:2103	11949:2104	11949:2104	11949:2104	11949:2104	11949:2104	11949:2104	11949:2104
Stratig. level	MC400m	MC400m	MC400m	MC700m	MC1100m	MC1100m	MC1100m	MC1100m	MC1050m	MC1140m
SiO ₂	51.40	55.25	52.12	49.75	27.46	41.46	49.84	42.50	39.54	50.09
TiO ₂	1.14	1.05	1.10	1.16	1.18	0.27	1.16	0.28	0.23	1.03
Al ₂ O ₃	14.19	13.37	14.00	14.81	20.21	6.09	14.30	6.18	5.21	12.45
Fe ₂ O ₃	13.48	11.22	13.36	13.25	16.97	11.45	13.03	11.57	11.67	13.99
FeO	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00
MnO	0.21	0.20	0.22	0.22	0.17	0.30	0.22	0.21	0.17	0.23
MgO	6.50	5.56	7.19	6.08	22.66	28.33	5.93	28.11	31.28	8.25
CaO	10.54	10.44	8.36	10.77	0.87	3.46	10.61	4.09	2.13	11.24
Na ₂ O	1.58	2.52	2.70	2.84	0.05	0.05	2.88	0.04	0.06	1.77
K ₂ O	0.47	0.23	0.34	0.34	0.01	0.01	0.32	0.01	0.01	0.70
P ₂ O ₅	0.11	0.10	0.10	0.07	0.20	0.01	0.07	0.02	0.00	0.08
H ₂ O ⁺	0.62	0.33	0.91	0.75	10.12	7.70	0.71	7.26	9.28	0.49
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.09	0.05	0.01	0.03	0.02	0.02	0.07	0.03	0.03	0.16
TOTAL	100.33	100.32	100.41	100.07	99.92	99.05	99.14	100.30	99.61	100.48
Ba	63	66	59	54		4	43	29	7	84
Rb	25	9	10	17			17			31
Sr	135	157	122	195	6	25	192	25	14	148
Pb	3	2	2	2			2			
Th										
U			1		2					1
Zr	95	89	89	68	194	23	68	23	17	84
Nb	5	4	3	3	7		3			3
Y	27	24	24	19	10	6	19	6	4	25
La	2	2	4		27	3		4	2	
Ce	13	8	9		42					
Li	43	18	36	65	220	5	68	4	3	10
V	344	319	337	355	220	114	362	120	80	312
Cr	85	77	92	57	29	4250	58	4170	5720	126
Co	44	37	43	43	85	85	46	88	89	54
Ni	53	48	61	57	452	1148	59	1163	1440	168
Cu	84	7	57	13	4	25	19	21	33	18
Zn	34	73	90	91	119	56	92	64	54	96
Ga	17	15	18	19	27	6	19	6	5	18
S	880	160	160		80	40		240	280	

track 0: file 6 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Talga-Coongan

Sample no.	75040023	75040024A	75040024B	75040024C	75040024D	75040024E	75040025A	75040025B	75040025C	75040025D
Formation	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star
Rock Type	Basalt am.cl. HMB	Basalt[U] ch.tr. TB	Basalt[U] am.pl.sa. qz.and. HMB	Basalt[U] ta.tr. HMB	Basalt[U] am.pl. andesite	Basalt[U] al.qz.cl. ca-dacite	Basalt[U] am.pl. dacite	Basalt[U] ch. Na-dacite	Basalt[U] am.ch.pl. dacite	Basalt[U] ch.tr. HMB
Gr or photo pt.	11949:2104	11949:2104	11949:2104	11949:2104	11949:2104	11949:2104	11949:2104	11949:2104	11949:2104	11949:2104
Stratig. level	MC1220m	MC1400m	MC1400m	MC1400m	MC1400m	MC1400m	MC1540m	MC1540m	MC1540m	MC1540m
SiO ₂	49.97	51.30	57.40	50.77	58.12	64.49	60.84	66.75	60.60	51.79
TiO ₂	0.81	0.58	0.84	0.56	0.83	0.63	0.71	0.48	0.71	0.52
Al ₂ O ₃	7.44	14.02	16.19	14.39	16.19	16.10	16.73	16.60	16.76	13.60
Fe ₂ O ₃	13.08	10.47	8.14	10.32	8.13	3.78	6.56	3.27	6.98	10.04
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.25	0.25	0.14	0.21	0.14	0.10	0.11	0.09	0.11	0.20
MgO	14.29	8.61	3.85	9.64	3.99	1.76	2.58	0.85	2.58	10.82
CaO	12.69	10.15	7.67	9.67	8.02	7.35	5.75	3.57	5.83	8.77
Na ₂ O	0.43	1.64	3.43	1.16	2.52	3.21	4.61	6.56	3.55	0.82
K ₂ O	0.30	0.30	0.20	0.49	0.27	0.73	0.83	0.93	1.21	0.89
P ₂ O ₅	0.05	0.04	0.15	0.03	0.15	0.04	0.13	0.11	0.12	0.03
H ₂ O ⁺	0.75	1.33	1.19	1.76	1.34	1.70	1.46	0.69	0.97	2.24
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.39	0.04	0.11	0.03	0.07	0.15	0.02	0.13	0.18	0.11
TOTAL	100.45	99.53	99.31	99.03	99.82	100.04	100.33	100.08	99.00	99.83
Ba	13	79	89	105	173	148	225	978	423	214
Rb	19	10	8	23	10	43	21	31	42	40
Sr	44	71	363	112	268	185	430	567	417	111
Pb			4		4		4	12	3	
Th			4		5		3	17	3	
U			2		1		1	2	2	
Zr	41	77	127	74	125	84	115	223	117	67
Nb		4	6	4	5	5	5	9	5	3
Y	15	20	16	19	16	18	12	24	12	17
La		8	25	5	26	8	16	74	18	2
Ce		7	42	15	39	8	29	121	21	3
Li	13	46	93	42	110	81	27	15	27	41
V	325	240	144	237	149	222	95	22	92	225
Cr	1450	361	69	634	71	449	66	5	67	752
Co	64	46	27	43	28	31	19	5	24	44
Ni	345	115	68	138	68	189	23	24	24	146
Cu	43	20	46	18	42	52	6	15	161	12
Zn	86	72	66	71	59	25	64	41	65	61
Ga	12	12	19	13	18	12	17	13	13	11
S	80	40	240	80	240	400	460	240	1640	80

track 0; file 7 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Talga-Coongan

Sample no.	75040025E	75040025F	75040026A	75040026B	75040026C	75040028A	75040028B	75040029B	75040029C	75040029E
Formation	North Star	North Star	North Star	North Star	North Star	Mount Ada	Mount Ada	Mount Ada	MOUNT ADA	Mount Ada
Rock Type	Basalt(U)	Basalt(U)	Basalt(U)	Basalt(U)	Basalt(U)	Basalt	Basalt	Basalt	Basalt DCF	Basalt
Gr or photo pt.	Na-dacite	andesite	TB	TB	dacite	pyroxenite	pyroxenite	HALB	felsite	HMB
Stratig. level	11949:2104	11949:2104	11948:2104	11948:2104	11948:2104	11948:2107	11948:2107	11947:2107	11947:2107	11947:2107
	MC1540m	MC1540m	MC1750m	MC1750m	MC1750m	MC3880m	MC3880m	MC4040m	MC4040m	MC4040m
SiO ₂	66.92	58.23	50.57	51.32	61.39	48.35	47.73	50.01	70.11	48.68
TiO ₂	0.49	1.29	1.38	0.58	0.69	0.85	0.81	1.50	0.26	1.64
Al ₂ O ₃	17.05	17.13	13.52	14.85	16.75	5.74	6.04	17.28	15.80	12.34
Fe ₂ O ₃	3.37	8.92	15.78	10.81	6.62	15.64	15.52	13.26	2.66	14.59
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.09	0.17	0.25	0.32	0.11	0.26	0.26	0.20	0.02	0.13
MgO	0.78	2.42	6.15	7.69	2.58	16.58	16.05	4.67	0.60	9.21
CaO	3.45	7.01	9.58	11.83	5.99	11.28	11.45	8.42	3.16	9.28
Na ₂ O	6.37	2.92	1.47	0.85	3.91	0.50	0.54	2.77	5.53	2.41
K ₂ O	0.94	0.70	0.35	0.27	0.90	0.12	0.14	0.82	0.81	0.14
P ₂ O ₅	0.14	0.35	0.13	0.03	0.12	0.05	0.05	0.39	0.03	0.16
H ₂ O ⁺	0.68	1.01	1.00	1.17	0.85	1.04	1.05	1.01	0.83	1.17
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.05	0.04	0.12	0.10	0.10	0.04	0.03	0.13	0.03	0.25
TOTAL	100.33	100.19	100.30	99.82	100.01	100.45	99.67	100.46	99.84	100.00
Ba	431	1115	89	18	275	14	10	296	260	27
Rb	24	33	5	3	27	2	2	58	31	2
Sr	329	594	130	95	449	20	21	502	328	74
Pb	8	14	2		5		2	4	2	
Th	7	19			2			5	4	
U		2		1					2	
Zr	201	229	105	77	119	50	50	144	298	137
Nb	10	10	4	2	5	3	3	9	8	6
Y	36	24	29	19	13	18	18	26	32	36
La	36	79		5	13			59	22	7
Ce	65	138	4	6	28			114	39	13
Zi	16	32	21	26	23	7	9	54	29	8
V	70	26	420	278	90	274	242	233	15	374
Cr	7	11	74	331	75	1930	1930	28	7	280
Co	5	14	54	51	19	73	71	45	8	47
Ni			56	108	23	320	351	75	5	84
Cu	19	5	82	7	42	63	30	61	10	91
Zn	41	78	91	122	65	96	100	92	13	57
Ga	21	18	21	14	18	7	9	19	18	19
S	360	80	360		240	120	120	440		240

track 2: file 8 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Talga-Coongan

Sample no.	75040029G	75040030	75040031A	75040031B	75040032A	75040032C	75040032E	75040033A	75040033B	75040033C
Formation	Mount Ada	Mount Ada	Mount Ada	Mount Ada	North Star	North Star	North Star	North Star	North Star	North Star
Rock Type	Basalt	Basalt	Basalt	Basalt	Basalt[U]	Basalt[U]	Basalt[U]	Basalt[U]	Basalt[U]	Basalt[U]
	sp.am.	tr.cpx.	qz.am.	qz.am.	am.pl.			am.	am.	am.
Gr or photo pt.	HMB	HMB	TB	TB	HALB	gabbro	gabbro	HALB	dolerite	dacite
Stratig. level	11947:2107	11947:2107	11947:2107	11947:2107	11948:2104	11948:2104	11948:2104	11948:2104	11948:2104	11948:2104
	MC4040m	MC4150m	MC4100m	MC4100m	MC2100m	MC2100m	MC2100m	MC2300m	MC2300m	MC2300m
SiO ₂	51.55	52.05	49.89	48.82	50.49	48.70	48.10	50.13	53.74	62.03
TiO ₂	0.68	0.69	2.00	2.03	1.15	1.13	1.18	1.52	1.29	0.74
Al ₂ O ₃	6.52	6.58	12.93	12.44	18.15	15.71	14.98	18.58	15.42	16.57
Fe ₂ O ₃	10.81	10.95	18.65	19.57	11.32	12.96	14.31	12.02	11.95	6.62
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.22	0.22	0.28	0.28	0.20	0.20	0.23	0.21	0.22	0.10
MgO	14.12	13.53	4.63	4.62	4.41	6.60	7.46	3.63	5.52	2.65
CaO	14.42	14.59	8.15	7.41	8.79	11.19	10.19	9.02	7.73	5.12
Na ₂ O	0.95	1.00	2.92	3.00	4.33	1.94	2.06	4.10	3.21	5.36
K ₂ O	0.32	0.31	0.38	0.39	0.33	0.94	0.54	0.40	0.77	0.33
P ₂ O ₅	0.04	0.04	0.10	0.17	0.18	0.06	0.09	0.23	0.22	0.11
H ₂ O ⁺	0.35	0.41	0.37	0.63	0.74	0.83	0.83	0.31	0.96	0.72
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.05	0.04	0.05	0.04	0.07	0.14	0.03	0.08	0.39	0.08
TOTAL	100.03	100.41	100.43	99.40	100.16	100.40	100.00	100.23	101.42	100.47
Ba	99	96	83	60	106	193	180	126	159	205
Rb	23	19	7	7	6	55	23	9	40	12
Sr	92	90	148	155	330	245	145	325	274	383
Pb			5	4	3			4	2	32
Th					5			4	2	5
U										
Zr	40	39	160	137	137	59	73	156	99	145
Nb	2	2	7	6	6	2	3	7	5	6
Y	16	15	43	36	25	20	22	30	24	16
La			5	6	29			33	17	19
Ce			16	17	46	6		60	34	29
Zr	52	9	36	45	94	105	133	30	47	68
V	258	248	430	455	224	360	355	222	239	98
Cr	1730	1760	62	67	27	352	169	11	127	42
Co	40	47	46	55	36	44	52	35	33	22
Ni	188	185	36	41	36	91	123	12	41	38
Cu	8	96	100	155	9	127	82	5	10	57
Zn	47	56	187	199	75	83	94	76	79	66
Ga	8	7	19	20	20	17	16	21	17	19
S		80	720	320	40	440	350	40	360	240

track 0; file 9 - Pilbara, N.A./Warracona Group/Talga Subgroup/Talga-Coongan

Sample no.	75040033D	75040034A	75040034B	75040034C	75040034D	75040034E	75040034F	75040035	75040036	75040037A
Formation	North Star	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada
Rock Type	Basalt[U]	Basalt	Basalt	Basalt	BASALT	Basalt	Basalt	Basalt	Basalt	Basalt
Gr or photo pt.	am.	am.	am.	ch.tr.	ta.se.	tr.se.ch.	ch.tr.	ch.tr.	am.	am.
Stratig. level	dacite	TB	dolerite	PK	PK	PK	PK	PK	dolerite	TB
	11948:2104	11948:2105	11948:2105	11948:2105	11948:2105	11948:2105	11948:2105	11948:2105	11948:2105	11948:2105
	MC2300m	MC3400m	MC3400m	MC3400m	MC3400m	MC3400m	MC3400m	MC3500m	MC2850m	MC3100m
SiO ₂	60.78	49.40	49.69	42.07	21.52	39.12	44.95	40.41	48.99	50.71
TiO ₂	0.74	1.38	1.42	0.79	0.35	0.50	0.75	0.58	1.41	1.29
Al ₂ O ₃	16.22	14.16	14.14	5.58	2.46	3.57	5.27	4.23	14.01	13.92
Fe ₂ O ₃	7.07	15.05	14.94	15.85	8.65	15.58	14.25	15.80	15.61	14.47
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.12	0.19	0.24	0.25	0.14	0.25	0.24	0.27	0.26	0.24
MgO	3.24	6.98	6.56	23.45	23.31	28.67	22.61	27.82	5.97	5.61
CaO	5.14	9.39	9.38	6.90	17.21	4.10	8.19	3.42	10.22	9.97
Na ₂ O	5.32	2.78	2.88	0.07	0.03	0.06	0.06	0.02	2.68	2.57
K ₂ O	0.26	0.30	0.32	0.03	0.03	0.01	0.02	0.01	0.59	0.24
P ₂ O ₅	0.12	0.10	0.11	0.07	0.04	0.04	0.07	0.04	0.10	0.12
H ₂ O ⁺	0.63	0.55	0.50	4.41	3.69	7.37	3.49	6.90	0.59	0.38
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.30	0.03	0.05	0.03	21.90	0.71	0.03	0.12	0.05	0.07
TOTAL	99.94	100.31	100.23	99.40	99.33	99.98	99.93	99.62	100.48	99.49
Ba	127	76	72	9	16	53	17	28	144	38
Rb	8	8	6						25	4
Sr	358	144	163	17	121	23	12	15	127	163
Pb	4	2	2							
Th	4									
U		1								
Zr	142	88	87	42	19	26	41	29	86	193
Nb	5	4	4						5	5
Y	16	27	28	11	5	7	11	8	24	27
La	20	4	4		2					6
Ce	33	13	10						8	15
Li	67	32	26	3	2	3	3	4	20	10
V	104	409	416	203	93	132	208	149	208	330
Cr	113	176	179	4780	2640	5650	4100	352	192	78
Co	24	46	49	107	61	127	90	124	50	47
Ni	82	76	69	1480	1030	2093	1450	2061	76	49
Cu		18	99	58	23	20	62	59	17	108
Zn	68	79	85	58	45	66	69	79	113	198
Ga	19	15	17	12	4	8	11	9	16	17
S	80	40	320	40	80	200	360	40	40	40

track 0; file 10 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Talga-Coongan

Sample no.	75040038A	75040038B	75040038C	75040038D	75040039B	75040039C	75040047A	75040047E	75040047C	75040047D
Formation	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada
Rock Type	Basalt am. andesite	Basalt am. HALB	Basalt am. andesite	Basalt gabbro	Basalt ep. TB	Basalt ep. TB	Basalt cpx.pl.sa. pyroxenite	Basalt ch.tr. HMB	Basalt ep.ch.tr. HMB	Basalt ch.tr. HMB
Gr or photo pt.	11948:2105	11948:2105	11948:2105	11948:2105	11947:2107	11947:2107	11945:2102	11945:2102	11945:2102	11945:2102
Stratig. level	MC2430m	MC3250m	MC3250m	MC3250m	MC4450m	MC4450m	MC4180m	MC4180m	MC4180m	MC4180m
SiO ₂	57.91	53.05	58.39	50.89	50.31	50.69	50.66	50.50	49.84	51.34
TiO ₂	1.03	1.04	1.11	0.96	0.87	1.14	0.51	0.90	0.77	0.83
Al ₂ O ₃	16.62	16.77	16.53	15.32	12.76	13.71	9.62	13.17	11.88	12.12
Fe ₂ O ₃	8.66	9.96	8.91	10.88	12.91	13.75	10.52	13.36	13.01	11.85
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.13	0.16	0.15	0.18	0.20	0.22	0.21	0.21	0.22	0.20
MgO	2.70	4.30	2.53	7.21	6.87	6.38	12.48	8.45	9.71	7.95
CaO	5.86	8.82	6.22	8.63	12.21	10.28	11.95	9.41	10.72	10.70
Na ₂ O	4.79	4.09	3.96	2.81	1.21	2.06	2.00	1.71	1.51	1.91
K ₂ O	1.06	0.84	1.06	1.23	0.29	0.51	0.22	0.10	0.18	0.24
P ₂ O ₅	0.19	0.20	0.23	0.15	0.08	0.08	0.05	0.07	0.05	0.08
H ₂ O ⁺	0.96	0.64	0.83	1.15	0.90	0.43	1.80	2.36	2.32	1.06
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.03	0.02	0.04	0.05	0.44	0.17	0.51	0.03	0.22	1.93
TOTAL	99.94	99.89	99.96	99.47	99.05	99.42	99.63	100.27	100.43	100.21
Ba	255	486	565	428	45	70	51	36	57	120
Rb	39	39	44	58	12	13	4		2	4
Sr	548	564	458	458	119	128	63	103	101	115
Pb	4	4	5	2		2			3	
Th	7	6	7	3						
U			1				1			
Zr	165	121	171	88	69	70	39	71	53	75
Nb	8	5	8	4	3	3	2	3	2	3
Y	24	23	26	19	20	23	14	20	17	23
La	31	35	33	24		3		3		3
Ce	55	60	61	40	3	9			4	
Pr	56	37	64	68	11	14	7	10	8	7
V	164	193	154	167	286	337	254	253	235	218
Cr	12	55	10	84	356	162	2320	409	653	447
Co	54	32	24	45	45	45	43	47	50	45
Ni	15	31	14	136	84	81	145	74	134	94
Cu	6	10	38	17	78	126	72	109	62	116
Zn	73	103	95	102	98	91	61	91	87	79
Ga	20	18	20	17	13	16	8	12	12	12
S	320	40	80	40	320	840	120	120	120	280

Track 0; file 11 - Pilbara, W.A./Warrawoona Group/Taiga Subgroup/Taiga-Coongan

Sample no.	75040047E	75040054A	75040054B	75040055A	75040055B	75040055C	75040056A	75040056B	75040056C	75040056D
Formation	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada
Rock Type	Basalt ch.tr. TB	Basalt ca.al.ch. TB	Basalt ca.al.ch. TB	Basalt am.ep. TB	Basalt am.ep.sp. TB	Basalt ch.am. TB	Basalt ep.sp.am. TB	Basalt am. TB	Basalt ca.ch. TB	Basalt ep.am. TB
Gr or photo pt.	11945:2102	11950:2059	11950:2059	11950:2059	11950:2059	11950:2059	11950:2058	11950:2058	11950:2058	11950:2058
Stratig. level	MC4180m	TR1750m	TR1750m	TR1980m	TR1980m	TR1980m	TR2140m	TR2140m	TR2140m	TR2140m
SiO ₂	50.33	47.59	48.08	49.38	48.76	49.91	48.85	48.49	48.77	49.61
TiO ₂	0.86	2.09	2.11	2.00	1.90	1.95	1.89	1.43	2.17	1.97
Al ₂ O ₃	12.92	12.86	12.72	13.83	13.35	13.70	13.80	13.53	12.11	13.65
Fe ₂ O ₃	12.86	17.46	16.67	13.94	14.21	14.57	15.56	16.22	18.12	15.90
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.19	0.23	0.20	0.20	0.20	0.19	0.23	0.24	0.21	0.23
MgO	7.54	4.28	3.30	6.36	6.18	6.26	5.71	6.55	3.94	5.39
CaO	10.28	6.30	6.55	8.44	9.08	8.06	8.95	8.34	6.12	8.92
Na ₂ O	1.98	2.06	2.36	3.02	2.65	2.75	2.42	2.58	2.28	2.27
K ₂ O	0.20	0.35	0.20	0.22	0.22	0.26	0.25	0.09	0.30	0.27
P ₂ O ₅	0.07	0.22	0.22	0.17	0.16	0.17	0.15	0.11	0.25	0.17
H ₂ O ⁺	1.90	2.60	2.12	1.91	2.10	1.92	1.96	2.09	2.21	1.89
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.47	4.35	4.70	1.00	1.63	0.46	0.25	0.76	2.60	0.11
TOTAL	99.60	100.39	99.23	100.47	100.44	100.10	100.02	100.43	99.08	100.38
Ba	90	250	48	139	105	117	130	74	370	163
Rb	3	6	3	2	3	3	4		6	5
Sr	107	171	126	73	85	98	163	138	95	172
Pb		2	2		2		3			3
Th										
U		1								
Zr	69	174	172	123	132	141	135	95	163	146
Nb	3	7	8	6	6	6	7	5	8	7
Y	19	37	34	35	36	39	35	28	45	38
La	2	10	10	3	3	5	4	4	4	4
Ce		22	21	11	15	13	9	13	28	19
Li	9	20	17	14	15	13	20	17	24	20
V	246	385	332	434	410	425	424	345	442	440
Cr	337	71	34	218	210	220	160	232	38	146
Co	44	40	39	41	40	44	43	51	43	44
Ni	76	45	36	56	57	61	74	87	20	67
Cu	80	50	49	7	34	97	36	61	63	52
Zn	90	131	125	69	72	76	117	117	98	115
Ga	13	23	21	19	20	19	19	17	23	19
S	400	40	1560	40	160	40	440		1880	1400

track 0; file 12 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Talga-Coongan

Sample no.	75040056E	75040056F	75040057A	75040057B	75040092	75040093A	75040093B	75040094	75040095A	75040095B
Formation	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada
Rock Type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt DC	Basalt	Basalt	Basalt	Basalt UC
	sp.ep.am.	ep.am.	cpx.am.ep.	am.cpx.ep.	am.	su.ep.ch.	pyroxenite	ca.ch.ep.	ca.ch.	ca.ch.
Gz or photo pt.	TB	TB	pyroxenite	pyroxenite	pyroxenite	TB	HMB	TB	TB	TB
Stratig. level	11950:2058	11950:2058	11950:2058	11950:2058	11950:2058	11951:2058	11951:2058	11951:2058	11951:2058	11951:2058
	TR2140m	TR2140m	TR2240m	TR2240	TR2300m	TR2360m	TR2360m	TR2600m	TR2760m	TR2760m
SiO ₂	48.02	49.30	50.19	50.79	50.91	47.74	50.23	46.60	44.94	44.51
TiO ₂	1.50	1.96	0.68	0.76	0.70	1.73	0.96	1.02	1.08	0.97
Al ₂ O ₃	13.56	13.73	7.05	7.19	7.49	13.72	10.14	10.90	12.08	11.40
Fe ₂ O ₃	15.10	16.04	11.35	11.67	10.83	16.32	13.04	12.84	12.41	11.54
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.23	0.23	0.22	0.23	0.22	0.23	0.23	0.21	0.20	0.22
MgO	6.08	5.34	12.62	12.76	12.19	6.06	10.02	9.12	4.67	4.22
CaO	9.06	8.07	14.55	14.26	14.79	5.99	12.22	9.76	10.92	12.45
Na ₂ O	2.97	2.30	1.05	1.13	1.45	2.95	1.33	0.15	1.89	1.64
K ₂ O	0.08	0.24	0.09	0.07	0.08	0.04	0.09	0.01	0.19	0.04
P ₂ O ₅	0.11	0.16	0.04	0.03	0.04	0.14	0.07	0.07	0.04	0.08
H ₂ O ⁺	1.80	1.92	0.82	0.85	0.45	2.87	1.71	4.09	2.79	3.03
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	1.08	0.14	0.42	0.52	0.42	1.26	0.17	4.70	8.30	9.55
TOTAL	99.59	100.43	99.08	100.26	99.57	99.05	100.21	99.47	99.51	99.65
Ba	66	109	147	134	117	69	95	12	37	19
Rb		4							6	
Sr	142	165	92	60	61	98	130	198	131	138
Pb		3				3		2		
Th								2		
U								2		
Zr	98	143	40	45	43	132	74	82	86	73
Nb	6	6	3	2		6	3	4	4	3
Y	28	38	16	17	16	35	21	22	23	21
La	8	3			4	3	2	3	3	
Ce	8	16				12	4	5	8	6
Li	14	19	7	7	6	18	9	18	19	18
V	340	444	236	250	216	355	251	277	282	265
Cr	211	142	1340	1340	1710	82	54	385	101	100
Co	48	45	47	49	46	48	54	50	43	39
Ni	78	69	178	173	176	54	143	111	60	57
Cu	121	46	63	84	52	77	81	71	89	93
Zn	104	116	59	64	58	115	81	86	86	77
Ga	16	19	8	9	9	18	12	13	14	14
S	240	1080	760	206	116	360	40	80	80	560

track 0; file 13 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Talga-Coongan

Sample no.	75040096	75040097	75040098A	75040098B						
Formation	MOUNT ADA	MOUNT ADA	Mount Ada	Mount Ada						
Rock Type	Basalt DA	Basalt DCF	Basalt	Basalt						
	ca.ch.	ch.al.	ch.sa.qz.	ch.sa.qz.						
Gr or photo pt.	TR	andesite	il.doler.	il.doler.						
Stratig. level	11951:2057	11951:2057	11951:2057	11951:2057						
	TR2850m	TR2800m	TR3280m	TR3280m						
SiO ₂	46.68	60.48	48.93	49.22	0.00	0.00	0.00	0.00	0.00	0.00
TiO ₂	1.06	0.96	1.85	1.63	0.00	0.00	0.00	0.00	0.00	0.00
Al ₂ O ₃	11.69	15.55	13.79	14.25	0.00	0.00	0.00	0.00	0.00	0.00
Fe ₂ O ₃	11.37	7.64	16.58	15.96	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.19	0.09	0.24	0.22	0.00	0.00	0.00	0.00	0.00	0.00
MgO	4.83	2.56	5.79	6.18	0.00	0.00	0.00	0.00	0.00	0.00
CaO	10.89	2.82	7.00	6.28	0.00	0.00	0.00	0.00	0.00	0.00
Na ₂ O	1.77	5.32	0.59	1.04	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.01	0.29	0.08	0.06	0.00	0.00	0.00	0.00	0.00	0.00
P ₂ O ₅	0.09	0.14	0.14	0.11	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁺	2.57	1.91	3.82	3.72	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	8.35	1.80	1.70	1.26	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	99.50	99.56	100.51	99.95	0.00	0.00	0.00	0.00	0.00	0.00
Ba		28	31	428						
Rb		8	2	2						
Sr	112	143	333	481						
Pb	2		3	4						
Th		5								
U		1								
Zr	85	177	127	107						
Nb	4	7	5	5						
Y	21	26	33	29						
La	3	15		3						
Ce	6	34	10							
Li	26	14	21	19						
V	273	120	400	391						
Cr	86	31	137	157						
Co	41	20	52	53						
Ni	56	28	68	79						
Cu	121	9	62	68						
Zn	77	44	120	125						
Ga	14	17	27	17						
S	80	240	160	240						

track 0; file 14 - Pilbara, W.A./Warrawoona Group/Duffer Formation/Marble Bar

Sample no.	75040043A	75040045A	75040045C	75040045H	75040046A	75040046C	75040046E	75040046F	75040046G	75040046H
Formation	Duffer Formation	Duffer Formation	Duffer Formation	Duffer Formation	Duffer Formation	DUFFER DC Formation	DUFFER DC Formation	DUFFER DC Formation	Duffer Formation	Duffer Formation
Rock Type	am.ep. dolerite	am.ep.sa. pyroxenite	sa. pyroxenite	am.ep.sa. ch.TB	ch.sa.am. pyroxenite	ep.dl. Na-dacite	Na-dacite tuff	Na-dacite tuff	il.sa.am. dolerite	ch.sa. pyroxenite
Gr or photo pt.	11946:2107	11945:2107	11945:2107	11945:2107	11945:2106	11945:2106	11945:2106	11945:2106	11945:2106	11945:2106
Stratig. level	CO200m	CO1300m	CO1300m	CO1300m	CO1400m	CO1400m	CO1400m	CO1400m	CO1400m	CO1400m
SiO ₂	50.29	50.30	51.22	52.66	50.01	62.60	61.85	62.25	50.21	50.59
TiO ₂	1.35	0.60	1.16	0.97	0.38	0.70	0.53	0.50	1.08	0.38
Al ₂ O ₃	13.78	10.71	9.55	15.91	12.36	15.09	16.94	16.42	14.58	12.57
Fe ₂ O ₃	15.32	12.68	12.07	11.28	10.62	6.76	5.62	5.61	13.57	10.59
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.22	0.23	0.23	0.16	0.18	0.12	0.21	0.18	0.22	0.19
MgO	5.86	10.86	12.22	5.37	12.50	2.56	2.76	2.58	6.61	12.41
CaO	9.09	10.82	11.54	8.01	7.83	2.44	2.98	2.80	9.72	9.00
Na ₂ O	2.51	1.70	1.23	2.54	0.83	4.65	4.47	6.17	2.26	0.50
K ₂ O	0.56	0.25	0.44	0.64	0.31	1.80	1.35	0.25	0.25	0.98
P ₂ O ₅	0.08	0.04	0.02	0.12	0.02	0.12	0.10	0.09	0.07	0.02
H ₂ O ⁺	0.96	1.18	1.05	2.20	3.38	2.08	2.25	1.61	1.71	2.71
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.33	0.38	0.22	0.34	0.75	0.03	1.13	1.47	0.00	0.25
TOTAL	100.35	99.87	100.29	100.20	99.17	99.95	99.49	100.03	100.28	100.19
Ba	836	140	211	309	226	868	397	88	80	776
Rb	24	7	13	16	6	28	43	10	5	14
Sr	186	163	131	367	75	381	315	221	243	91
Pb				5	3	6	4		7	9
Th				2		8	3			
U	1					1	1	1		
Zr	83	30	29	127	19	164	115	104	56	19
Nb	3	2		6		7	5	4	3	
Y	26	12	12	25	10	18	10	9	19	11
La				14	3	22	19	19		
Ce				28		37	32	31		
Li	14	6	6	14	19	6	7	6	8	17
V	41	161	250	163	216	109	77	81	342	229
Cr	151	215	953	146	1150	16	47	54	147	1010
Co	42	51	52	37	49	15	18	17	45	47
Ni	84	211	236	76	219	12	44	49	104	213
Cu	110	94	81	57	68	24	5	4	114	85
Zn	107	80	75	79	76	73	151	122	98	75
Ga	16	10	9	15	10	17	18	19	16	11
S	320	40	60	280	200		280	130		440

track 0; file 15 - Pilbara, W.A./Warrawoona Group/Duffer Formation/Marble Bar

Sample no.	75040046I	75040046J	75040046L	75040046M	75040046N	75040059A	75040060A	75040060B	75040060C	75040060D
Formation	Duffer	Duffer	Duffer DC	Duffer DC	Duffer	Duffer	Duffer	DUFFER DC	Duffer	Duffer
Rock Type	se.ca.al.	sa.ch.il.	al.tuff	al.tuff	ep.ch.al.	ea.tuff	tuff	Formation	Formation	Formation
Gr or photo pt.	tu.rhyol.	dolerite	Na-rhyol	Na-rhyol	andesite	Na-dacite	K-dacite	K-rhyol	TB	TB
Stratig. level	11945:2106	11945:2106	11945:2106	11945:2106	11945:2106	11944:2108	11944:2108	11944:2108	11944:2108	11944:2108
	CO1400m	CO1400m	CO1400m	CO1400m	CO1400m	CO3600m	CO4100m	CO4100m	CO4100m	CO4100m
SiO ₂	69.24	50.04	71.15	70.84	59.27	56.04	58.65	74.48	51.94	50.14
TiO ₂	0.33	1.33	0.33	0.32	0.84	0.93	0.73	0.23	0.87	2.33
Al ₂ O ₃	12.94	13.29	13.82	13.74	15.16	14.48	14.33	12.94	13.82	12.71
Fe ₂ O ₃	4.26	16.23	3.82	3.74	7.41	7.83	6.86	2.76	12.54	17.93
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.14	0.25	0.06	0.06	0.12	0.14	0.11	0.05	0.21	0.25
MgO	1.32	6.43	0.94	0.99	3.82	3.65	4.45	0.56	6.86	4.40
CaO	3.01	8.86	2.23	2.48	5.92	6.07	3.19	0.99	10.52	7.75
Na ₂ O	1.16	1.64	4.15	4.11	3.37	3.17	2.44	2.96	1.37	2.23
K ₂ O	3.13	0.22	3.03	2.77	0.82	0.88	2.82	2.64	0.43	0.06
P ₂ O ₅	0.04	0.09	0.04	0.03	0.22	0.23	0.14	0.01	0.07	0.19
H ₂ O+	1.81	1.80	0.38	0.67	1.97	2.37	2.43	1.35	1.53	2.35
H ₂ O-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	2.30	0.20	0.00	0.03	0.93	4.30	3.85	0.70	0.04	0.04
TOTAL	99.68	100.37	99.98	99.78	99.85	100.09	99.75	99.67	100.20	100.38
Ba	988	84	750	369	858	356	496	599	175	31
Rb	54	5	119	24	47	28	63	75	11	
Sr	332	190	76	470	361	352	104	127	131	287
Pb	5	6	4	5	5	7	6	3	4	7
Th	10		13	5	9	4	5	17		
U	2		2	2	2	1	1	3		
Zr	281	84	300	217	304	144	146	398	80	168
Nb	12	3	13	10	12	7	6	20	4	8
Y	40	27	49	21	41	22	19	60	23	44
La	37		68	29	40	27	26	63	3	4
Ce	69	9	120	55	72	47	42	119	10	27
Li	7	8	7	6	12	10	10	4	6	8
V	23	394	16	103	24	143	127	7	282	519
Cr	11	154	14	12	129	85	67	7	225	223
Co	4	45	8	7	22	22	23	5	43	39
Ni	6	89	12	12	75	51	51	3	60	37
Cu	11	87	5	5	13	7	218	5	60	45
Zn	52	115	25	23	68	89	84	19	97	150
Ga	17	16	17	15	18	16	17	21	15	21
S	40	320	40	40	80	120	320	400	290	40

track 0; file 16 - Pilbara, W.A./Warrawoona Group/Duffer Formation/Marble Bar

Sample no. Formation	75040062A Duffer Formation	75040062B Duffer DC Formation	75040064B DUFFER DC Formation	75040065B DUFFER DC Formation	75040065C DUFFER DC Formation	75040066A Duffer Formation	75040066B Duffer Formation	75040066C Duffer Formation	75040066D Duffer Formation	75040067A DUFFER DC Formation
Rock Type	sa.ep. qz-laticite	sa.ch. dacite	sa.ch. dacite	sa.ch. Na-dacite	sa.ch. Na-dacite	ep.ch.ca. andesite	ch.tuff andesite	il. dolerite	ca.agglom. andesite	al.ch. andesite
Gr or photo pt. Stratig. level	11943:2108 CO4400m	11944:2108 CO4400m	11944:2108 CO4800m	11943:2109 CO5240m	11943:2109 CO5240m	11943:2109 CO6200m	11943:2109 CO6200m	11943:2109 CO6200m	11943:2109 CO6200m	11943:2109 CO6600m
SiO ₂	63.08	62.68	75.52	69.39	76.27	52.98	53.44	49.66	55.76	56.26
TiO ₂	0.62	0.69	0.17	0.37	0.31	1.58	1.37	2.18	1.22	1.01
Al ₂ O ₃	16.63	15.90	12.97	14.06	11.56	23.10	14.65	13.47	14.02	15.71
Fe ₂ O ₃	5.42	5.48	2.30	4.90	2.48	11.24	9.45	16.95	9.70	9.29
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.08	0.09	0.05	0.08	0.06	0.21	0.19	0.24	0.18	0.17
MgO	1.66	2.04	0.32	0.56	0.37	4.16	3.31	4.85	3.20	4.86
CaO	3.55	3.23	1.23	1.53	1.87	5.13	7.11	7.22	6.45	2.39
Na ₂ O	2.94	4.61	3.72	4.80	2.87	2.56	2.34	2.25	2.75	2.86
K ₂ O	3.13	1.50	1.98	1.80	2.13	2.09	2.80	0.47	1.57	1.26
P ₂ O ₅	0.13	0.13	0.00	0.04	0.04	0.35	0.30	0.18	0.24	0.15
H ₂ O ⁺	1.62	2.71	1.10	1.83	1.01	2.54	2.00	2.14	2.03	2.84
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.19	1.43	1.04	0.04	1.39	1.46	3.05	0.82	2.20	2.65
TOTAL	99.25	100.49	100.48	99.45	100.36	100.40	100.01	100.43	99.32	99.45
Ba	1667	426	719	498	742	1020	783	358	541	341
Rb	66	41	62	63	51	42	31	22	23	51
Sr	443	199	125	77	142	324	256	321	379	84
Pb	8	2	4	7	6	8	6	6	10	3
Th	8	5	20	12	15	4	5	5	5	5
U	1	1	3	2	3	1	1	1	1	1
Zr	158	167	389	265	350	125	106	140	115	163
Nb	5	6	18	13	16	7	8	6	3	7
Y	15	13	51	47	53	26	28	35	24	24
La	27	20	78	52	61	22	30	7	21	25
Ce	43	36	149	89	109	45	55	19	06	42
Li	7	8	1	3	3	10	8	9	8	14
V	87	100	5	12	16	183	228	434	180	165
Cr	15	18	8	9	8	74	16	250	14	45
Co	16	15	4	5	4	28	23	45	22	27
Ni	9	23	3	5	6	7	6	49	6	47
Cu	3	5	6	5	5	12	25	52	41	4
Zn	48	59	17	83	34	114	91	123	89	159
Ga	18	20	18	15	21	16	18	18	17	29
S	40	40	200	40	200	80	280	1440	440	40

track 0; file 17 - Pilbara, W.A./Warrawoona Group/Duffer Formation/Marble Bar

Sample no.	75040069E	75040072B	75040100A	75040100B						
Formation	Duffer	TOWER DCA	DUFFER DC	DUFFER DC						
Rock Type	ch.al.	ch.al.	qz.se.	qz.se.						
Gr or photo pt.	andesite	andesite	rhyolite	rhyolite						
Stratig. level	11942:2110 CO8300m	11942:2110	12021:2136 Nullagine	12021:2136 Nullagine						
SiO ₂	56.11	64.07	68.91	66.40	0.00	0.00	0.00	0.00	0.00	0.00
TiO ₂	1.15	0.87	1.46	1.57	0.00	0.00	0.00	0.00	0.00	0.00
Al ₂ O ₃	14.08	8.20	16.22	17.28	0.00	0.00	0.00	0.00	0.00	0.00
Fe ₂ O ₃	10.89	12.23	3.11	3.65	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.16	0.09	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
MgO	1.80	7.13	2.54	2.75	0.00	0.00	0.00	0.00	0.00	0.00
CaO	5.65	1.23	0.15	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Na ₂ O	3.11	0.04	0.21	0.24	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.85	0.01	4.03	4.28	0.00	0.00	0.00	0.00	0.00	0.00
P ₂ O ₅	0.17	0.06	0.23	0.17	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁺	2.04	3.64	2.99	3.21	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	4.15	1.62	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	100.16	99.19	99.89	99.71	0.00	0.00	0.00	0.00	0.00	0.00
Ba	420	7	419	274						
Rb	23		86	37						
Sr	228	12	54	492						
Pb	8	2		3						
Th	2		2	4						
U	1		1	1						
Zr	158	70	159	171						
Nb	7	3	8	8						
Y	24	16	27	26						
La	19	4	15	17						
Ce	39		37	32						
Li	20	13	57	62						
V	220	219	272	116						
Cr	76	816	223	226						
Co	54	54	8	8						
Ni	186	215	49	58						
Cu	90	104	2114	1718						
Zn	92	80	47	47						
Ga	17	10	19	20						
S	720	480	240	280						

track 0; file 18 - Pilbara, W.A./Warrawoona Group/Salgash Subgroup/Marble Bar

Sample no.	75040073A	75040073G	75040075B	75040076A	75040076B	75040076C	75040078A	75040078C	75040078D	75040078E
Formation	APEX DC US	APEX DC US	APEX DC	Apex	Apex	Apex	Apex	Apex	APEX DCUS	Apex
Rock Type	Basalt ch.al. andesite	Basalt gz.al.ch. andesite	Basalt ch. andesite	Basalt cpx.il. dolerite	Basalt cpx.il. dolerite	Basalt am. gabbro	Basalt cpx.ch.ta. pyroxenite	Basalt	Basalt ch. dacite	Basalt ch.tr.cpx. HMB
Gr or photo pt.	11942:2111	11942:2111	11942:2110	11942:2110	11942:2110	11942:2110	11941:2110	11941:2110	11941:2110	11941:2110
Stratig. level	CC200m	CC200m	CC300m	CC340m	CC340m	CC340m	CC1100m	CC1100m	CC1100m	CC1100m
SiO ₂	59.08	56.52	59.66	49.07	50.11	50.87	45.76	56.33	61.32	50.23
TiO ₂	1.08	1.06	0.89	0.81	1.09	1.42	0.37	1.22	1.19	0.46
Al ₂ O ₃	12.00	12.98	13.64	14.31	13.50	12.17	6.62	15.23	14.73	9.74
Fe ₂ O ₃	12.49	14.73	12.94	11.90	14.51	16.59	12.01	16.73	13.36	11.26
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.07	0.09	0.07	0.19	0.24	0.22	0.21	0.13	0.10	0.20
MgO	9.06	8.56	6.84	8.10	6.47	6.67	20.65	2.82	2.08	12.95
CaO	0.41	0.44	0.15	9.36	7.90	5.78	9.36	0.44	0.32	9.56
Na ₂ O	0.05	0.01	0.11	3.10	2.75	1.91	0.05	3.13	3.83	1.04
K ₂ O	0.05	0.03	0.81	0.37	0.41	0.78	0.00	0.15	0.28	0.04
P ₂ O ₅	0.25	0.25	0.05	0.04	0.06	0.10	0.01	0.22	0.16	0.01
H ₂ O ⁺	5.03	5.11	4.71	2.58	2.25	2.56	4.61	3.12	2.38	3.09
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.06	0.11	0.05	0.16	0.38	0.04	0.03	0.03	0.03	0.68
TOTAL	99.63	99.89	99.92	99.99	99.67	99.11	99.68	99.55	99.78	99.26
Ba	2		134	91	91	89	5	138	215	24
Rb	15		24	6	7	9		2	8	
Sr	14	11	9	149	128	130	10	66	114	55
Pb								43		
Th	2							3		
U								1		
Zr	183	178	53	45	61	91	18	172	168	24
Nb	9	8	2	2	4	4		7	7	
Y	32	38	17	16	22	30	7	26	24	9
La	13	14					3	10	13	4
Ce	25	25						24	18	
Li	58	55	43	14	12	14	9	27	22	19
V	245	202	344	278	360	438	147	250	235	186
Cr	98	958	246	244	21	24	2330	152	144	1430
Co	52	63	50	44	49	49	84	66	82	60
Ni	217	274	123	93	45	35	736	195	189	354
Cu	10	177	96	161	173	159	69	106	91	58
Zn	102	135	104	63	83	84	60	122	94	59
Ga	17	16	15	13	15	16	7	21	16	9
S	200	890	40	80	80	680		1600	520	520

track 0; file 19 - Pilbara, W.A./Warrawoona Group/Salgash Subgroup/Marble Bar

Sample no.	75040079A	75040079B	75040079D	75040080B	75040083F	75040083I	75040083K	75040083L	75040083M	75040083O
Formation	Apex Basalt	Apex Basalt	Apex Basalt	Apex Basalt						
Rock Type	cpx.ch.sl. HMB	cpx.ch. HMB	cpx.ch.sl. HMB	pl.ch. TB	ch.se.al. andesite	ch.al.se. TB	ch. TB	ch.al.se. andesite	Basalt ch.al.se. andesite	Basalt amygdal. ch.HALD
Gr or photo pt.	11941:2110	11941:2110	11941:2110	11941:2110	11942:2111	11942:2111	11942:2111	11942:2111	11942:2111	11942:2111
Stratig. level	CC1220m	CC1220m	CC1220m	CC1400m						
SiO ₂	48.23	51.28	52.52	54.34	54.88	50.11	52.35	63.25	65.31	53.77
TiO ₂	0.66	0.57	0.62	0.73	1.03	1.74	0.97	0.95	0.97	1.17
Al ₂ O ₃	11.46	12.93	12.76	14.02	14.28	15.23	13.28	13.36	13.60	16.65
Fe ₂ O ₃	13.18	10.17	10.60	10.96	12.30	18.56	18.76	10.99	10.26	14.68
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.20	0.16	0.16	0.15	0.12	0.18	0.14	0.09	0.08	0.16
MgO	11.04	9.11	8.96	4.54	6.70	2.21	7.81	4.73	4.34	3.23
CaO	9.92	9.17	8.09	4.09	0.10	3.22	0.48	0.06	0.06	1.69
Na ₂ O	3.20	3.39	4.33	2.30	0.05	3.19	0.02	0.11	0.10	3.72
K ₂ O	0.03	0.05	0.04	2.38	1.57	0.20	0.02	1.84	2.07	0.45
P ₂ O ₅	0.03	0.03	0.04	0.05	0.02	0.08	0.08	0.00	0.00	0.14
H ₂ O ⁺	2.13	2.55	1.99	2.96	4.42	2.86	5.03	3.88	3.66	2.83
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.06	0.28	0.23	2.50	0.11	1.36	0.44	0.03	0.03	1.19
TOTAL	100.14	99.69	100.34	99.06	99.58	99.04	99.38	99.29	100.48	99.68
Ba	12	8	20	225	149	169	14	144	158	308
Rb				37	57	4		58	64	10
Sr	116	198	64	48	12	98	8	11	12	127
Pb						13				12
Th						8				5
U						2				1
Zr	35	36	32	44	91	263	85	84	84	180
Nb	2		2	2	4	11	4	4	4	7
Y	13	13	13	13	25	26	9	11	11	25
La			4			17		4	3	8
Ce						37		9	3	20
Li	9	10	9	16	36	27	42	28	26	26
V	250	211	246	289	293	275	278	283	285	242
Cr	407	390	232	72	432	43	867	348	355	164
Co	50	44	42	32	45	64	76	41	37	53
Ni	108	93	91	36	81	107	168	82	77	125
Cu	92	84	104	127	34	54	126	39	42	76
Zn	69	56	60	89	162	111	141	180	165	93
Ga	12	10	12	14	16	22	16	14	14	19
S	240	288	280	40	800	240	5280	40	320	320

track 0; file 20 - Pilbara, W.A./Warrawoona Group/Salgash Subgroup/Marble Bar

Sample no.	75040083Q	750400855	75040089A	75040089B						
Formation		APEX DC	APEX UC	APEX UC						
Rock Type	amygdal.	Basalt	Basalt	Basalt						
Gr or photo pt.	ch.and.	tr.pl.cpx.	ca.ch.cpx.	ca.ch.cpx.						
Stratig. level	11942:2111	andesite	dolerite	dolerite						
	CC2700m	CC2200m	CC2200m	CC2200m						
SiO ₂	61.84	55.72	49.74	47.94	0.00	0.00	0.00	0.00	0.00	0.00
TiO ₂	0.92	0.98	0.59	0.54	0.00	0.00	0.00	0.00	0.00	0.00
Al ₂ O ₃	13.15	13.76	13.20	13.44	0.00	0.00	0.00	0.00	0.00	0.00
Fe ₂ O ₃	14.07	11.78	10.81	10.45	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.11	0.15	0.21	0.22	0.00	0.00	0.00	0.00	0.00	0.00
MgO	4.85	7.20	6.47	6.55	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.07	4.96	13.48	15.15	0.00	0.00	0.00	0.00	0.00	0.00
Na ₂ O	0.07	4.73	0.83	0.78	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	1.44	0.04	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
P ₂ O ₅	0.01	0.08	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁺	3.85	0.93	2.73	2.43	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.05	0.07	2.25	2.35	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	100.43	99.70	100.35	99.88	0.00	0.00	0.00	0.00	0.00	0.00
Ba	115	19								
Rb	48									
Sr	10	46	115	141						
Pb										
Th										
U										
Zr	80	92	32	30						
Nb	3	5	2							
Y	10	21	12	12						
La	4	5	3	3						
Ce	3	14								
Li	25	10	13	12						
V	272	246	236	225						
Cr	361	91	156	414						
Co	61	31	41	39						
Ni	98	49	80	101						
Cu	37	96	85	83						
Zn	193	59	57	57						
Ga	14	13	11	12						
S	1200	240	200	400						

track 0; file 22 - Pilbara, W.A./Gorge Creek Group/Honeyeater Basalt/Soanesville

Sample no.	75040106B	75040106D	75040106E	75040106F						
Formation	Honeyeater	Honeyeater	Honeyeater	Honeyeater						
Rock Type	Basalt UC	Basalt UC	Basalt DC	Basalt DC						
	HMB	HMB	TB	TB						
Gr or photo pt.	11916:2114	11916:2114	11916:2114	11916:2114						
Stratig. level	North Shaw	North Shaw	North Shaw	North Shaw						
SiO ₂	50.12	50.61	46.34	51.22	0.00	0.00	0.00	0.00	0.00	0.00
TiO ₂	0.61	0.61	0.60	0.65	0.00	0.00	0.00	0.00	0.00	0.00
Al ₂ O ₃	10.44	10.23	14.38	15.01	0.00	0.00	0.00	0.00	0.00	0.00
Fe ₂ O ₃	10.87	11.01	11.80	14.91	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.24	0.25	0.19	0.28	0.00	0.00	0.00	0.00	0.00	0.00
MgO	8.74	9.00	5.86	6.56	0.00	0.00	0.00	0.00	0.00	0.00
CaO	14.86	12.83	5.17	4.63	0.00	0.00	0.00	0.00	0.00	0.00
Na ₂ O	0.34	0.72	1.86	1.75	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.13	0.04	0.12	0.10	0.00	0.00	0.00	0.00	0.00	0.00
P ₂ O ₅	0.03	0.03	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁺	3.40	2.59	3.41	4.03	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.41	1.72	0.10	0.54	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	100.19	100.44	99.86	99.72	0.00	0.00	0.00	0.00	0.00	0.00
Ba	267	282	18	135						
Rb			2							
Sr	16	19	81	64						
Pb										
Th										
U										
Zr	33	33	35	37						
Nb		2	2							
Y	13	13	17	18						
La										
Ce										
Li	7	9	9	12						
V	251	254	267	265						
Cr	728	728	304	73						
Co	45	48	43	49						
Ni	134	133	49	56						
Cu	82	78	98	98						
Zn	64	64	72	90						
Ga	9	12	11	12						
S	200	20	400	520						

track 0: file 27 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/McPhee Reward

Sample no.	45062	45063	45064	45065	45066	45067	45068	45069	45070	45071
Formation	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star
Rock Type	Basalt ch.am.pl. qz.TB	Basalt am.ch.pl. gabbro	Basalt am.ch.ep. al.TB	Basalt tr.ca.ta. PK	Basalt am.sa.al. sp.TB	Basalt am.sa.sp. al.gabbro	Basalt am.sa.al. qz.TB	Basalt tr.ch.al. qz.TB	Basalt am.ch.sp. qz.TB	Basalt tr.sa.ch. qz.TB
Gr or photo pt.	11951:2101	11951:2101	11950:2101	11950:2101	11950:2101	11950:2101	11950:2101	11950:2100	11950:2100	11950:2100
Stratig. level	70	200	300	500	420	650	770	880	1030	1210
SiO ₂	48.17	50.73	49.87	40.30	54.73	49.04	50.96	53.59	52.54	52.14
TiO ₂	2.31	1.75	1.56	0.29	1.56	1.18	1.16	1.07	1.24	1.06
Al ₂ O ₃	12.84	12.94	13.01	3.19	12.83	13.78	13.81	13.02	13.28	13.42
Fe ₂ O ₃	18.29	16.69	15.81	12.69	13.03	14.39	13.60	11.49	13.26	12.36
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.26	0.20	0.22	0.15	0.17	0.21	0.22	0.17	0.24	0.20
MgO	5.68	5.38	6.05	33.58	4.19	6.30	6.98	5.03	5.81	6.02
CaO	6.95	6.74	6.76	2.76	8.91	10.63	10.21	11.38	12.82	10.34
Na ₂ O	1.96	3.92	2.33	0.00	2.43	2.53	1.65	2.40	1.84	2.01
K ₂ O	0.61	0.21	0.56	0.06	0.28	0.37	0.31	0.12	0.22	0.15
P ₂ O ₅	0.23	0.20	0.16	0.03	0.18	0.06	0.08	0.11	0.11	0.10
H ₂ O ⁺	1.50	0.77	1.18	2.31	0.96	1.04	0.80	1.11	1.15	1.33
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.30	0.20	0.50	3.75	0.15	0.10	0.05	0.10	0.10	0.20
TOTAL	99.80	99.73	100.01	99.11	99.44	99.63	100.03	99.59	100.63	99.33
Ba	182	97	234	37	104	111	242	46	158	48
Rb	19	5	17		8	14	6	2	5	3
Sr	123	102	125	11	188	140	120	122	116	129
Pb	9	6	9	3	8	4	6	7	3	6
Th	2	2	2			3	4		2	2
U					2				2	
Zr	210	169	138	16	151	73	92	95	106	91
Nb	9	7	7		7	3	4	5	4	4
Y	39	33	29	3	29	18	22	23	24	22
La	19	11	14	4	10	4	9	10		3
Ce	52	34	46	5	32	19	24	23		21
Li	51	30	35	2	19	12	10	6	8	12
V	407	341	324	102	320	406	363	277	357	338
Cr	19	140	120	4280	153	22	90	78	75	69
Co	42	50	52	118	41	57	44	42	41	42
Ni	4	36	56	2214	51	65	49	46	37	49
Cu	13	63	30	17	137	25	84	46	17	68
Zn	139	105	205	48	89	107	94	70	90	88
Ga	25	21	19	6	20	22	18	17	18	18
S	300	1400	400	200	2400	200	300	260	100	300

track 0; file 28 - Pilbara, W.A./Warlawoona Group/Talga Subgroup/McPhee Reward

Sample no.	45071	45073	45074	45075	45076	45077	45078	45079	45080	45081
Formation	North Star 1800m	North Star Basalt	North Star Basalt	North Star Basalt	Mount Ada Basalt	Mount Ada Basalt	MOUNT ADA Basalt DF	Mount Ada Basalt	Mount Ada Basalt DC	MOUNT ADA Basalt DC
Rock Type	am.al.sa. qz.and.	am.cl.ep. qz.TB	am.sa.qz. mu.gabbro	ch.ca.ep. qz.HMB	ca.al.ch. TB	al.ch.ca. TB	ca.al.ch. TB	ca.al.ch. TB	ca.al.ch. TB	se.qz.al schist
Gr or photo pt.	11950:2100	11950:2100	11948:2100	11949:2100	11949:2100	11949:2100	11948:2059	11948:2059	11948:2059	11948:2059
Stratig. level	1450m	1600m	1800m	1970m	2430m	2510m	2660m	2720m	2800m	2760m
SiO ₂	55.54	50.71	51.10	48.63	45.27	49.71	50.96	46.76	48.14	74.33
TiO ₂	1.02	0.96	0.50	0.49	1.99	1.55	1.89	2.05	2.08	0.30
Al ₂ O ₃	13.04	13.79	15.05	12.45	12.00	13.04	11.34	12.43	12.66	14.78
Fe ₂ O ₃	10.87	12.15	9.32	9.28	15.97	13.80	12.63	10.11	17.55	3.36
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.17	0.21	0.14	0.18	0.22	0.22	0.30	0.26	0.19	0.01
MgO	5.09	5.52	8.61	9.96	4.44	4.18	2.96	3.09	4.24	0.94
CaO	9.30	11.84	9.80	8.55	6.43	9.89	8.70	8.72	5.41	0.10
Na ₂ O	3.81	1.43	1.01	0.07	2.63	2.08	1.94	1.92	1.89	0.40
K ₂ O	0.23	0.19	0.46	0.02	0.04	0.07	0.02	0.04	0.14	3.63
P ₂ O ₅	0.11	0.08	0.05	0.04	0.20	0.15	0.21	0.21	0.21	0.04
H ₂ O ⁺	1.44	2.17	3.33	5.13	2.56	1.84	2.21	2.30	2.54	2.38
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.10	1.15	0.20	4.55	8.35	2.90	6.65	6.10	4.20	0.10
TOTAL	99.72	100.20	99.57	99.35	99.10	99.43	99.81	98.99	99.25	100.37
Ba	71	51	126	21	45	27	4	55	77	635
Rb	5	4	10						5	104
Sr	143	144	103	35	239	146	193	139	168	43
Pb		8	3	6	7	6	7	9	7	5
Th	5				2	2	2		3	7
U				2						
Zr	86	74	66	67	169	133	169	171	182	322
Nb	5	3	4	4	9	7	9	9	9	10
Y	19	17	14	12	28	24	26	29	31	27
La	3	12	5	4	84	7	11	14	17	20
Ce	23	14	20	11	34	25	43	29	48	43
Li	7	14	19	25	24	18	27	24	36	16
V	321	282	227	231	294	351	300	354	368	15
Cr	41	52	286	583	37	54	46	71	48	13
Co	40	45	42	43	44	41	36	42	47	7
Ni	36	52	117	141	41	42	31	41	42	8
Cu	72	10	62	57	66	38	45	36	67	16
Zn	82	98	66	65	136	100	115	125	136	42
Ga	13	13	13	11	23	20	18	21	26	16
S	300	200	100	200	1200	600	600	1400	1600	500

track 0; file 29 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/McPhee Reward

Sample no.	45082	45083	45084	45085	45086	45087	45088	45089	45090	45091
Formation	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada
Rock Type	Basalt	Basalt DA	Basalt	Basalt	Basalt DA	Basalt UC	Basalt	Basalt	Basalt	Basalt DA
	ca.al.ch.	ca.ch.il.	ca.al.ch.	ca.al.ch.	ca.al.ch.	ca.tr.ch.	ca.ch.al.	ca.ch.mu.	ep.ch.qz.	ca.sa.ch.
Gr or photo pt.	11948:2058	11948:2058	11948:2058	11948:2058	11948:2058	11948:2058	11948:2058	11948:2058	11948:2058	11948:2058
Stratig. level	2870m	2930m	3000m	3100m	3220m	3330m	3410m	3530m	3460m	3560m
SiO ₂	47.29	44.50	48.89	46.88	48.85	46.77	44.82	47.42	49.14	45.39
TiO ₂	2.12	1.26	1.60	1.83	1.02	1.09	0.98	1.09	1.76	0.92
Al ₂ O ₃	12.04	9.67	12.67	12.40	11.51	12.07	10.90	11.31	12.80	10.33
Fe ₂ O ₃	17.27	13.85	14.79	15.41	12.65	12.05	12.40	11.79	18.08	11.30
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.21	0.17	0.17	0.20	0.17	0.16	0.16	0.17	0.26	0.20
MgO	3.99	6.88	5.17	4.38	5.95	4.69	5.36	5.19	5.21	6.66
CaO	7.21	10.09	6.56	8.05	8.81	14.24	11.32	9.91	7.83	12.14
Na ₂ O	1.19	0.43	1.77	1.42	1.00	1.02	1.53	0.51	1.01	0.49
K ₂ O	0.05	0.02	0.04	0.14	0.03	0.03	0.03	1.15	0.10	0.03
P ₂ O ₅	0.19	0.12	0.18	0.16	0.07	0.10	0.09	0.10	0.18	0.07
H ₂ O ⁺	2.80	4.32	3.52	3.20	3.77	2.57	2.93	3.22	2.90	3.82
H ₂ O ⁻	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	5.05	7.75	3.10	5.25	5.20	4.85	8.65	7.25	1.10	8.00
TOTAL	99.41	99.06	98.46	99.02	99.03	99.64	99.17	99.11	100.37	99.41
Ba	88	15	141	61	13	22	14	252	65	104
Rb								38	3	
Sr	164	171	97	95	90	309	79	111	189	135
Pb	6	13	10	7	8	6	15	6	9	5
Th		2	2			4			2	
U										
Zr	162	99	146	132	77	85	78	89	117	66
Nb	7	5	7	7	5	5	4	5	6	3
Y	34	23	30	27	20	19	17	18	31	16
La	12	5	9	8	4	8	2	4	9	2
Ce	43	27	30	30	21	22	26	29	31	9
Li	22	21	20	28	18	12	20	25	11	24
V	474	341	303	414	257	292	308	330	386	256
Cr	13	482	28	13	69	151	197	30	72	217
Co	44	46	43	42	47	40	39	35	54	42
Ni	22	106	47	31	71	73	79	41	48	89
Cu	66	84	55	92	100	87	78	96	99	56
Zn	97	93	93	112	89	75	91	85	127	86
Ga	20	15	15	20	14	18	13	15	20	12
S	1800	300	300	200	1100	900	1100	600	2000	300

track 0; file 30 - Pilbara, W.A./Warraoona Group/Talga Subgroup/McPhee Reward

Sample no.	45092	45093	45094	45095	45096					
Formation	Mount Ada	Mount Ada	Mount Ada	Mount Ada	Mount Ada					
Rock Type	Basalt DA	Basalt	Basalt	Basalt	Basalt					
	ch.tr.ep.	ca.al.ch.	al.ch.ep.	ca.al.ch.	ca.al.ch.					
Gr or photo pt.	ca.TB	il.TB	il.gabbro	il.TB	TB					
Stratig. level	11948:2058	11948:2058	11948:2058	11951:2058	11951:2058					
	3810m	4000m	4170m	2230m	2330m					
SiO ₂	49.25	46.00	49.96	45.26	45.92	0.00	0.00	0.00	0.00	0.00
TiO ₂	0.79	2.17	2.56	2.05	2.21	0.00	0.00	0.00	0.00	0.00
Al ₂ O ₃	12.33	11.85	12.04	12.13	12.52	0.00	0.00	0.00	0.00	0.00
Fe ₂ O ₃	12.00	15.95	16.76	16.70	17.83	0.00	0.00	0.00	0.00	0.00
FeO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.18	0.26	0.22	0.23	0.27	0.00	0.00	0.00	0.00	0.00
MgO	7.77	4.90	4.08	4.53	4.88	0.00	0.00	0.00	0.00	0.00
CaO	9.19	7.79	8.32	7.84	6.25	0.00	0.00	0.00	0.00	0.00
Na ₂ O	1.30	2.16	1.85	1.73	2.23	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.01	0.03	0.04	0.12	0.16	0.00	0.00	0.00	0.00	0.00
P ₂ O ₅	0.06	0.19	0.27	0.22	0.22	0.00	0.00	0.00	0.00	0.00
H ₂ O+	3.64	2.84	0.00	2.77	2.43	0.00	0.00	0.00	0.00	0.00
H ₂ O-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	2.75	5.55	3.05	3.55	4.25	0.00	0.00	0.00	0.00	0.00
TOTAL	99.27	99.69	99.25	99.13	99.53	0.00	0.00	0.00	0.00	0.00
Ba	22	43	105	76	50					
Rb				2	3					
Sr	176	113	235	240	230					
Pb	10	5	8	8	7					
Th		4	2	2						
U										
Zr	61	154		174	184					
Nb	3	5	7	10	10					
Y	14	31	41	28	32					
La	13	15	11	11	9					
Ce	15	28	32	36	35					
Li	15	14	11	28	24					
V	194	390	404	329	319					
Cr	271	48	7	40	44					
Co	45	44	40	38	46					
Ni	79	47	13	43	45					
Cu	99	69	42	46	69					
Zn	86	88	115	141	147					
Ga	14	18	24	21	26					
S	400	200	2000	700	1100					

track 0; file 31 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Shark Centre

Sample no.	45153	45154	45155	45156	45157	45158	45159	45160	45164	45165
Formation	Mount Ada	Mount Ada	Mount Ada	MOUNT ADA	Mount Ada	MOUNT ADA	Mount Ada	Mount Ada	Mount Ada	Mount Ada
Rock Type	Basalt	Basalt	Basalt	Basalt DC	Basalt	Basalt DAUC	Basalt	Basalt	Basalt	Basalt
Gr or photo pt.	cpx.pl.ch.	cpx.sa.gz.	cpx.sa.ep.	ca.pl.ch.	px.ac.sa.	cpx.st.	cpx.ca.	px.amygd.	cpx.ep.	ca.sr.ep.
Stratig. level	11936:2123	11936:2123	11936:2123	11936:2124	11936:2124	11936:2124	11936:2124	11936:2124	11936:2124	11936:2124
	2100m	1900m	1940m	1830m	1660m	1570m	1500m	1380m	1290m	1180m
SiO ₂	48.97	48.57	48.43	62.70	48.76	49.83	47.62	48.27	48.09	48.16
TiO ₂	1.27	1.43	1.58	0.59	0.92	0.85	1.28	1.30	1.31	1.39
Al ₂ O ₃	10.97	13.54	12.50	15.12	15.10	6.52	14.56	14.87	14.29	14.06
Fe ₂ O ₃	2.61	3.24	3.82	1.03	2.26	2.60	3.05	3.19	4.60	2.33
FeO	10.70	11.00	11.50	6.00	8.70	9.50	9.85	9.80	9.30	9.95
MnO	0.20	0.20	0.22	0.03	0.15	0.21	0.20	0.19	0.19	0.16
MgO	9.05	9.90	5.80	2.18	7.20	12.60	5.85	5.05	6.20	7.35
CaO	11.25	9.59	9.47	1.84	9.32	13.67	9.21	10.16	8.41	6.50
Na ₂ O	1.56	2.30	2.02	4.70	3.18	1.36	2.58	2.82	2.86	3.48
K ₂ O	0.23	0.64	0.34	1.87	0.65	0.16	0.48	0.27	0.40	0.13
F ₂ O ₅	0.12	0.14	0.17	0.13	0.10	0.08	0.11	0.12	0.12	0.13
H ₂ O+	2.97	3.12	3.26	2.65	3.45	2.52	3.60	2.96	3.40	4.08
H ₂ C-	0.13	0.12	0.16	0.15	0.13	0.08	0.06	0.04	0.08	0.12
CO ₂	0.10	0.20	0.10	0.70	0.10	0.20	1.50	0.80	0.70	1.70
TOTAL	100.13	99.99	99.37	99.69	100.04	100.18	99.35	99.84	99.95	99.54
Ba	72	148	129	432	174	112	129	76	132	31
Rb	4	14	5	39	14	3	10	8	9	3
Sr	121	124	145	190	148	27	125	193	209	123
Pb										
Th										
U				5					5	
Zr	90	99	112	136	59	47	81	86	85	97
Nb	3	5	4	3	3			3	3	
Y	27	29	37	12	17	19	24	24	26	30
La	9	6	4	27	5	4	6	9	7	4
Ce	27	27	31	52	24	24	23	30	23	22
Li	8	11	10	9	12	9	8	7	8	5
V	285	322	313	82	237	275	278	269	281	327
Cr	639	211	197	39	202	1730	136	139	153	144
Co										
Ni	121	80	73	23	84	203	67	69	81	71
Cu	103	87	83	387	40	64	106	103	105	20
Zn	113	93	126	48	43	116	109	102	68	49
Ga										
S	140	1320	180	440	280	520	920	340	1480	520

Track 0; file 32 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Shark Centre

Sample no.	45166	45168	45169	45170	45171	45172	45173	45174	45175	45176
Formation	MOUNT ADA	Mount Ada	Mount Ada	MOUNT ADA	MOUNT ADA	Mount Ada	Mount Ada	North Star	North Star	NORTH STAR
Rock Type	Basalt DC	Basalt	Basalt DC	Basalt DC	Basalt DC	Basalt	Basalt	Basalt[U]	Basalt	Basalt DA
Gr or photo pt.	pl.dacite	ss.px.sr.	ep.ch.sa.	gz.pl.ca.	ca.	cpx.ch.ca.	cpx.ch.ca.	gz.mu.	ep.ch.sp.	cpx.am.ep.
Stratig. level	tuff	gabbro	TR	dacite	TR	HMB	HMB	rhyolite	gabbro	HMB
	11936:2124	11936:2124	11936:2124	11936:2125	11936:2125	11936:2125	11936:2125	11936:2126	11936:2126	11936:2126
	1180m	1020m	970m	930m	780m	300m	50m	2250m	2190m	2120m
SiO ₂	63.44	48.22	49.32	65.78	46.62	50.13	49.18	81.01	49.26	51.00
TiO ₂	0.57	0.88	1.28	0.49	1.28	1.07	1.04	0.05	1.00	0.78
Al ₂ O ₃	15.49	16.55	13.99	15.59	13.76	8.91	8.90	11.96	14.13	7.11
Fe ₂ O ₃	0.74	3.35	5.26	2.16	3.07	3.44	3.63	0.53	5.16	2.73
FeO	4.55	6.60	8.10	2.15	10.60	9.25	9.25	0.05	8.20	8.45
MnO	0.01	0.16	0.19	0.03	0.23	0.22	0.20	0.01	0.21	0.21
MgO	4.28	6.15	6.15	1.55	6.25	8.00	10.50	0.25	6.15	11.60
CaO	0.95	11.09	8.59	2.06	5.07	10.88	8.36	0.04	9.39	13.49
Na ₂ O	5.10	2.24	3.18	6.30	2.70	2.42	2.76	0.27	2.56	1.49
K ₂ O	0.38	0.65	0.33	0.94	0.23	0.57	0.26	3.50	0.06	0.05
P ₂ O ₅	0.13	0.07	0.12	0.12	0.10	0.11	0.10	0.01	0.09	0.07
H ₂ O+	3.22	2.30	3.23	1.68	4.75	2.37	3.26	1.60	3.13	2.24
H ₂ O-	0.14	0.10	0.15	0.04	0.09	0.13	0.10	0.06	0.09	0.06
CO ₂	0.85	0.70	0.10	1.15	4.70	1.15	2.50	0.05	0.20	0.20
TOTAL	99.85	100.04	99.99	100.10	99.45	99.45	100.04	99.49	99.63	99.48
Ba	64	139	77	234	53	41	36	78	28	14
Rb	12	15	10	28	8	7	4	270		
Sr	153	119	147	312	56	157	61	18	308	190
Pb				7				8		
Th	5			6				25	2	
U	3							5		
Zr	123	50	85	125	78	84	83	67	73	62
Nb	4			3	3	4		28		
Y	10	18	27	9	23	21	20	18	18	18
La	26	4	6	22	3	6	8	2	9	8
Ce	50	20	21	43	19		22	13	24	19
Li	2	7	7	6	26	6	9	3	7	6
V	79	261	316	59	335	235	222	2	227	225
Cr	35	276	145	31	145	583	312	4	10	676
Co										
Ni	19	67	76	18	71	173	193		72	171
Cu	3	105	86	6	42	141	138	1	128	62
Zn	29	94	84	51	116	84	92	23	95	70
Ga										
S		140	220		40	290	100			140

track 0; file 33 - Pilbara, W.A./Warrawoona Group/Talga Subgroup/Shark Centre

Sample no.	45177	45178	45179	45180	45181	45182	45183	45187	45188	45189
Formation	NORTH STAR	NORTH STAR	NORTH STAR	North Star	North Star	North Star	North Star	North Star	North Star	North Star
Rock Type	Basalt DCF se.gz. schist	Basalt DC ch.se.gz. schist	Basalt DCA ch.ep.gz. schist	Basalt ac.ep.sp. dolerite	Basalt ep.sp. dolerite	Basalt dolerite	Basalt cpx.tr.ep. TB	Basalt am.pl.ep. sp.doler.	Basalt am.pl.ep. sp.gabbro	Basalt ca.ep. TB
Gr or photo pt.	11936:2127	11936:2127	11936:2127	11936:2127	11936:2127	11935:2127	11935:2127	11935:2127	11935:2127	11935:2127
Stratig. level	2070m	2020m	1760m	1900m	1380m	1300m	1170m	860m	720m	670m
SiO ₂	69.60	63.45	58.31	49.38	49.43	52.18	52.70	50.71	49.26	48.60
TiO ₂	0.61	0.77	2.03	2.70	1.66	0.92	0.86	1.36	1.53	1.65
Al ₂ O ₃	24.36	16.97	10.28	12.41	14.70	13.93	12.79	13.70	11.81	14.92
Fe ₂ O ₃	0.04	1.00	2.97	6.05	3.53	3.54	3.21	3.48	3.52	2.89
FeO	0.05	6.75	15.70	8.25	8.45	7.20	6.95	9.55	10.10	9.45
MnO	0.01	0.06	0.09	0.16	0.18	0.17	0.16	0.19	0.23	0.35
MgO	0.03	4.48	4.24	5.35	5.95	6.20	7.70	5.45	7.70	3.22
CaO	0.04	0.13	0.07	8.23	9.09	10.18	9.94	8.91	9.52	11.75
Na ₂ O	0.22	1.60	0.02	4.04	3.10	1.84	1.86	2.60	2.87	3.18
K ₂ O	0.13	0.31	0.04	0.29	0.18	0.08	0.07	0.16	0.17	0.25
P ₂ O ₅	0.01	0.02	0.02	0.25	0.17	0.10	0.09	0.18	0.13	0.15
H ₂ O ⁺	4.28	4.53	5.54	2.20	3.03	2.89	3.18	2.60	2.32	1.38
H ₂ O ⁻	0.07	0.07	0.16	0.08	0.09	0.01	0.16	0.04	0.19	0.02
CO ₂	0.05	0.00	0.10	0.06	0.05	0.25	0.05	0.20	0.05	2.60
TOTAL	99.50	100.14	99.67	99.39	99.63	99.49	99.74	99.21	99.40	99.81
Ba	27	96	42	176	65	34	18	51	60	32
Rb	3	12	3	5	3				3	2
Sr	10	72	5	113	162	148	139	234	207	84
Pb			54							
Th			2							
U										
Zr	65	93	122	126	104	97	73	130	96	105
Nb			4	5	3	4		3		4
Y	9	21	38	36	31	24	19	30	27	27
La	5	5	7	11	7	9	6	12	5	6
Ce	13	16	25	32	29	29	28	35	25	20
Li	2	28	14	5		10	11	7	6	5
V	295	275	447	511	335	221	245	259	335	356
Cr	94	453	24	40	158	25	421	30	189	207
Co										
Ni	4	128	54	44	71	49	74	47	50	58
Cu	3	30	31	105	40	68	64	151	36	6
Zn	4	74	35	84	84	86	76	95	106	127
Ga										
S	20		40	100	80	40	60	100		20

track 0; file 34 - Pilbara, W.A./Warrawoona group/Talga Subgroup/shark Centre

Sample no.	45190	45191	45192	45193						
Formation	North Star	North Star	North Star	North Star						
Rock Type	Basalt	Basalt	Basalt	Basalt						
Gr or photo pt.	ep.sp.	ep.ca.sp.	am.pa.qz.	ep.sp.						
Stratig. level	TB	dolerite	TB	TB						
	11935:2127	11935:2127	11935:2127	11935:2129						
	590m	360m	170m	90m						
SiO ₂	45.64	51.41	51.47	49.30	0.00	0.00	0.00	0.00	0.00	0.00
TiO ₂	1.80	0.61	2.57	2.55	0.00	0.00	0.00	0.00	0.00	0.00
Al ₂ O ₃	13.60	12.10	13.44	12.63	0.00	0.00	0.00	0.00	0.00	0.00
Fe ₂ O ₃	4.17	1.03	3.57	4.62	0.00	0.00	0.00	0.00	0.00	0.00
FeO	10.20	8.45	11.40	10.60	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.22	0.17	0.25	0.28	0.00	0.00	0.00	0.00	0.00	0.00
MgO	5.50	9.80	4.08	3.05	0.00	0.00	0.00	0.00	0.00	0.00
CaO	12.05	7.97	7.46	10.40	0.00	0.00	0.00	0.00	0.00	0.00
Na ₂ O	2.79	2.50	3.57	2.88	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.29	0.81	0.53	0.32	0.00	0.00	0.00	0.00	0.00	0.00
P ₂ O ₅	0.19	0.06	0.26	0.25	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁺	1.95	3.32	1.51	1.47	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁻	0.01	0.04	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	1.25	1.15	0.05	0.75	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	99.57	99.42	100.21	99.37	0.00	0.00	0.00	0.00	0.00	0.00
Ba	63	141	127	21						
Rb	4	43	13	20						
Sr	187	115	160	131						
Pb	5									
Th										
U										
Zr	123	54	203	128						
Nb	3		8	5						
Y	34	15	45	33						
La	6	6	13	11						
Ce	31	21	48	37						
Li	5	25	12	5						
V	404	198	322	126						
Cr	117	667	5	21						
Co										
Ni	42	160	10	27						
Cu	22	37	4	7						
Sn	114	83	149	133						
Ga										
S		60								

track 0; file SS - Pilbara, W.A./Warravoonna Group Duffer Formation/Sandy Creek

Sample no.	45194	45195	45196	45197	45198	45199	45200	49205	49206	49207
Formation	DUFFER UC	Duffer DC	Duffer	DUFFER SC	Duffer	Duffer	Duffer UC	Duffer	Duffer	DUFFERUCDF
Rock type	qz.fl.se.	qz.fl.bi.	cl.qz.fl.	qz.fl.m.	qz.fl.mu.	ep.cl.ep.	qz-latite	qz-latite	qz-latite	ca.ep.tuff
Gr or photo pt.	12612:2127	12002:2127	12002:2127	12001:2127	12007:2127	12002:2127	12002:2127	12002:2127	12002:2127	12002:2127
Stratig. level	250m	350m	450m	520m	600m	750m	930m	970m	1070m	1220m
SiO ₂	63.09	67.10	66.37	72.66	65.16	63.01	57.08	64.71	65.45	65.37
TiO ₂	0.49	0.51	0.55	0.52	0.44	0.47	0.61	0.63	0.48	0.38
Al ₂ O ₃	16.41	17.22	17.81	17.76	16.52	17.32	15.70	16.69	16.77	11.79
FeO	1.33	0.57	0.85	0.55	0.78	1.24	2.35	0.84	0.80	0.31
MnO	1.00	1.80	1.85	0.10	0.45	1.50	3.80	1.45	1.05	1.80
MgO	0.14	0.06	0.06	0.01	0.06	0.10	0.18	0.05	0.05	0.16
CaO	1.51	1.53	1.68	0.18	1.47	2.72	3.10	1.07	1.17	2.36
Na ₂ O	10.09	2.89	2.36	0.20	6.61	6.28	7.80	3.69	2.75	5.58
K ₂ O	1.39	4.44	2.00	0.67	1.82	1.31	0.33	2.20	0.52	0.31
P ₂ O ₅	2.36	1.99	3.58	4.54	1.73	2.77	6.41	5.59	8.63	9.42
H ₂ O ⁺	0.14	0.12	0.15	0.13	0.13	0.12	0.26	0.28	0.16	0.12
H ₂ O ⁻	1.26	1.46	2.35	2.32	1.53	2.57	1.60	1.46	1.66	0.63
CO ₂	0.02	0.10	0.11	0.08	0.09	0.09	0.06	0.06	0.06	0.05
TOTAL	0.40	0.10	0.10	0.05	0.60	0.85	0.40	0.50	0.45	1.20
	99.63	99.91	99.82	99.87	99.69	99.99	99.88	99.22	100.00	99.48
Ba	562	285	811	715	1309	1556	296	167	481	479
Rb	69	62	118	15	66	78	155	141	137	135
Sr	157	172	113	64	191	205	80	111	83	45
Pb	5	8	5		6	6	7	8	6	2
Th	9	9	9	8	10	11	10		9	6
U	2					2				2
Zr	177	180	193	197	187	182	220	237	202	139
Nb	4	5	5	5	6	5	9	10	7	5
Y	13	12	12	12	12	14	25	23	19	13
La	33	31	29	27	31	28	43	38	31	22
Ce	68	62	56	58	57	57	95	79	68	51
Li	11	31	36	17	17	27	16	21	25	7
V	62	67	53	69	53	78	68	71	70	37
Cr	72	33	50	45	41	48	52	54	42	24
Co										
Ni	15	7	17	2	12	14	72	32	19	6
Cu	16	40	26	4	4	3	52	42	46	29
Zn	27	26	32	2	25	53	66	49	32	26
Ga										
S	200	20	60		80	20	80	80	80	40

track 0; file 36 - Pilbara, W.A./Warrawoona Group/Duffer Formation/Sandy Creek

Sample no.	49208	49209	49210	49211	49212	49213	49214			
Formation	Duffer Formation	Duffer Formation	Duffer DC Formation	Duffer Formation	DUFFERDAUC Formation	DUFFER UC Formation	DUFFER DA Formation			
Rock type	ca. rhyolite	ca. dacite	dacite	ca. rhyolite	ca. rhyolite	ca/ep. tuff	ca/ep. tuff			
Gr or photo pt.	12002:2127	12003:2127	12003:2127	12003:2128	12003:2128	12003:2128	12003:2128			
Stratig. level	1630m	1620m	1925m	1710m	1800m	1590m	1940m			
SiO ₂	68.03	69.07	67.68	71.07	75.67	59.68	62.59	0.00	0.00	0.00
TiO ₂	0.42	0.49	0.57	0.31	0.13	0.27	0.58	0.00	0.00	0.00
Al ₂ O ₃	13.42	13.73	16.07	11.62	7.26	8.29	8.98	0.00	0.00	0.00
Fe ₂ O ₃	0.37	0.79	1.07	0.23	0.28	0.25	0.40	0.00	0.00	0.00
FeO	1.90	1.00	0.75	1.45	0.95	0.90	1.95	0.00	0.00	0.00
MnO	0.08	0.11	0.09	0.06	0.21	0.31	0.23	0.00	0.00	0.00
MgO	0.95	1.32	1.57	0.75	3.06	4.18	4.78	0.00	0.00	0.00
CaO	1.91	3.88	2.75	1.61	3.60	10.96	8.00	0.00	0.00	0.00
Na ₂ O	0.18	3.30	5.55	0.21	0.09	0.10	0.07	0.00	0.00	0.00
K ₂ O	10.15	3.12	1.81	9.76	3.62	3.53	2.55	0.00	0.00	0.00
P ₂ O ₅	0.12	0.13	0.16	0.09	0.04	0.09	0.05	0.00	0.00	0.00
H ₂ O ⁺	0.90	1.22	1.34	0.80	1.74	1.60	2.97	0.00	0.00	0.00
H ₂ O ⁻	0.04	0.04	0.02	0.04	0.06	0.60	0.05	0.00	0.00	0.00
CO ₂	1.00	1.50	0.20	1.45	2.60	8.30	5.30	0.00	0.00	0.00
TOTAL	99.47	99.70	99.63	99.45	99.31	99.06	99.00	0.00	0.00	0.00
Ba	1045	4410	2603	454	5304	7757	5365			
Rb	174	99	54	129	72	71	88			
Sr	64	91	97	24	41	106	57			
Pb	2				2					
Th	6	8	10	8	6	4				
U			2		2	5				
Zr	153	167	213	174	76	86	28			
Nb	6	6	8	5	3	3				
Y	14	18	20	13	10	14	17			
La	28	30	35	27	18	16	3			
Ce	57	55	62	58	38	40	14			
Li	15	21	23	6	18	26	50			
V	60	63	60	21	25	49	189			
Cr	25	24	24	10	9	60	921			
Co										
Ni	13	15	23	3	3	18	225			
Cu	18	18	25	3	3	22	49			
Zn	56	32	33	15	10	33	219			
Ga										
S	120	80	40	360	20	80	80			

track 0; file 37 - Pilbara, W.A./Warrawoona Group/Salgash Subgroup/Sandy Creek

Sample no.	49215	49216	49217	49218	49219	49220	49221	49222	49223	49224
Formation	Apex	Apex	Apex	Apex	Apex	Apex	Apex	Apex	Apex	Apex
Rock Type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
	cpx	ac.cl.ca.	ep	ep.ch.sp.	ep.ch.sp.	ep.ca.	cpx.ep.ch.	ca.	ep.ch.sp.	ep.sp.
Gr or photo pt.	dolerite	HMB	HMB	HMB	TB	TB	HMB	TB	HMB	TB
Stratig. level	12003:2128	12003:2128	12003:2128	12003:2128	12003:2128	12003:2128	12003:2128	12003:2128	12003:2128	12003:2128
	10m	50m	90m	160m	260m	340m	390m	450m	500m	550m
SiO ₂	48.70	51.02	51.56	50.64	48.99	51.60	50.96	48.19	50.61	50.47
TiO ₂	1.70	0.55	0.58	0.57	0.61	0.61	0.60	0.59	0.60	0.53
Al ₂ O ₃	13.35	11.25	13.41	12.98	14.36	13.63	13.41	13.32	13.53	13.33
Fe ₂ O ₃	3.50	1.32	2.12	2.25	2.50	1.75	2.69	2.34	2.61	3.61
FeO	10.60	8.85	7.65	7.85	7.85	7.70	7.30	6.40	7.45	5.00
MnO	0.20	0.18	0.17	0.18	0.25	0.21	0.15	0.19	0.19	0.21
MgO	5.80	10.40	8.15	9.40	7.95	7.55	8.45	5.90	8.80	6.50
CaO	9.32	7.83	9.61	9.49	10.63	9.84	11.07	14.57	10.69	14.89
Na ₂ O	1.74	3.00	2.88	2.14	2.98	1.16	1.15	1.82	1.66	0.57
K ₂ O	0.71	0.32	0.48	0.18	0.08	0.59	0.27	0.08	0.24	0.13
P ₂ O ₅	0.22	0.04	0.04	0.05	0.06	0.06	0.05	0.06	0.06	0.06
H ₂ O ⁺	3.36	3.53	2.63	3.35	2.84	3.62	3.39	3.00	3.40	2.62
H ₂ O ⁻	0.08	0.05	0.03	0.11	0.14	0.08	0.11	0.10	0.10	0.12
CO ₂	0.20	1.25	0.20	0.15	0.10	1.00	0.05	3.50	0.10	0.15
TOTAL	99.48	99.59	99.51	99.34	99.34	99.44	99.65	100.06	100.04	99.18
Ba	2507	309	107	41	25	73	25	5	30	9
Rb	4	9	17	10	2	45	25		9	3
Sr	250	51	184	185	78	92	166	72	119	150
Pb			2							
Th										
U			3							
Zr	99	29	33	31	47	35	31	34	33	29
Nb	4									
Y	33	13	12	12	18	13	13	12	13	12
La	6		2	5	3		6	4	3	3
Ce	305	5	12	15	17	13	19	16	14	16
Li	22	33	34	44	32	40	36	23	37	18
V	314	206	234	237	246	234	244	237	239	214
Cr	164	504	323	458	348	343	331	349	383	345
Co										
Ni	97	131	99	125	109	102	101	101	107	97
Cu	86	90	82	81	61	84	86	78	79	49
Zn	89	64	64	69	66	65	61	62	66	54
Ga										
S	440	160	100	100	100	100	120	220	100	140

track 01 file 38 - Pilbara, W.A./Warrawoona Group/Salgash Subgroup/Sandy Creek

Sample no.	49225	49226	49227	49228	49229	49230	49231	49232		
Formation	Apex	Apex	Apex	APEX UC	Apex	Apex	APEX UC DA	Apex		
Rock Type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt		
	ep.ca.	ep.tr.ca.	cpx.tr.sa.	ca.ch.	ep.ca.sp.	ca.ep.sp.		tr.sp.		
Gr or photo pt.	TB	pyroxenite	gabbro	dolerite	dolerite	TB	HMB	HMB		
Stratig. level	12003:2128	12003:2128	12003:2128	12003:2128	12003:2128	12003:2128	12003:2128	12004:2128		
	600m	630m	650m	770m	730m	800m	1000m	1120m		
SiO ₂	49.74	41.72	48.22	43.02	50.81	52.25	51.70	50.93	0.00	0.00
TiO ₂	0.58	0.75	1.25	0.52	0.56	1.13	0.32	0.40	0.00	0.00
Al ₂ O ₃	13.60	4.75	13.61	14.77	13.22	12.90	10.66	14.04	0.00	0.00
Fe ₂ O ₃	1.68	4.36	2.13	1.50	0.91	2.95	2.27	1.82	0.00	0.00
FeO	7.50	10.45	11.50	6.65	7.00	10.60	5.60	7.35	0.00	0.00
MnO	0.20	0.24	0.20	0.19	0.23	0.24	0.19	0.15	0.00	0.00
MgO	7.06	18.50	6.60	6.80	9.50	4.90	8.60	10.10	0.00	0.00
CaO	10.04	10.63	8.65	18.79	8.75	6.47	16.21	9.47	0.00	0.00
Na ₂ O	2.80	0.35	2.84	0.60	3.08	3.20	0.27	1.19	0.00	0.00
K ₂ O	0.09	0.05	1.23	0.20	0.56	0.22	0.04	0.39	0.00	0.00
F ₂ O ₅	0.07	0.08	0.12	0.05	0.06	0.10	0.03	0.03	0.00	0.00
H ₂ O ⁺	3.47	3.67	3.21	4.15	3.26	3.43	3.02	4.06	0.00	0.00
H ₂ O ⁻	0.09	0.09	0.09	0.09	0.16	0.19	0.08	0.10	0.00	0.00
CO ₂	2.80	1.75	0.05	2.15	0.70	1.00	0.30	0.10	0.00	0.00
TOTAL	99.72	97.39	99.70	99.48	98.80	99.78	99.29	100.13	0.00	0.00
Ba	49		399	137	387	243	6	180		
Rb	4	3	28	3	17	5		19		
Sr	189	46	424	75	203	159	143	170		
Pb										
Th										
U										
Zr	33	44	75	33	34	66	19	20		
Nb			3							
Y	14	12	16	11	13	21	11	21		
La	5	3	8	2	7	7	3	2		
Ce	18	27	28	27	16	26	15	10		
Li	21	9	26	25	39	22	19	41		
V	254	160	191	254	213	361	183	231		
Cr	345	899	14	273	597	13	866	508		
Co										
Ni	97	673	181	89	25	42	18	100		
Cu	84	104	247	3	93	14	30	54		
Zn	64	86	81	45	70	123	50	61		
Ga										
S	120	480	260		120	320	60	20		

track 0; file 39 - Pilbara, W.A./Warrawoona Group/Salgash Subgroup/Spinaway ch

Sample no.	49233	49234	49235	49236	49237	49239	49240	49241	49242	49243
Formation	Apex	Apex	Apex	Apex	APEX DC	Apex	Apex	Apex	APEX UC	APEX DCUS
Rock Type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
	cpx.sr.sa.	cpx.ep.sp.	cpx.ep.ca.	ep.ch.sp.	se.qz.	ep.cl.ch.	cpx.ch.ep.	cpx.ca.	ca.ch.qz.	silicified
Gr or photo pt.	pl.HMB	sa.TB	TB	TB	rock	sp.TB	TB	HMB	HMB	basalt
Stratig. level	12001:2135	12001:2135	12001:2135	12001:2135	12001:2135	12001:2135	12001:2135	12001:2135	12001:2135	12002:2135
	40m	320m	260m	410m	650m	500m	560m	750m	860m	1070m
SiO ₂	51.96	48.06	49.22	47.79	79.85	48.41	47.39	47.77	41.36	71.49
TiO ₂	0.64	0.92	0.97	1.00	1.41	1.66	1.60	1.07	0.80	0.91
Al ₂ O ₃	12.68	13.72	13.69	13.90	14.56	13.29	13.31	7.48	6.05	6.35
Fe ₂ O ₃	1.88	3.57	2.92	3.14	0.21	3.25	3.47	1.76	0.67	1.00
FeO	7.60	8.45	9.30	9.25	0.05	10.19	8.95	12.30	10.40	8.90
MnO	0.23	0.17	0.19	0.19	0.00	0.20	0.19	0.29	0.18	0.05
MgO	9.10	7.35	6.45	7.40	0.03	5.85	6.85	11.30	11.80	5.45
CaO	9.30	11.43	11.39	10.55	0.04	10.50	11.64	11.39	9.74	0.91
Na ₂ O	2.20	1.55	2.00	1.90	0.14	1.82	1.54	2.25	0.02	0.02
K ₂ O	0.04	0.03	0.03	0.06	0.30	0.04	0.24	0.05	0.01	0.01
P ₂ O ₅	0.06	0.07	0.09	0.08	0.01	0.19	0.08	0.11	0.08	0.07
H ₂ O ⁺	3.75	3.72	3.29	3.83	2.91	3.32	4.18	2.97	3.68	3.59
H ₂ O ⁻	0.11	0.12	0.07	0.11	0.11	0.14	0.14	0.39	0.08	0.11
CO ₂	0.40	0.25	0.25	0.05	0.05	0.35	0.50	0.90	14.60	0.65
TOTAL	99.95	99.41	99.86	99.35	99.67	99.72	99.48	99.73	99.47	99.51
Ba	46	37	32	34	32	26	63	5		12
Rb					10		4			
Sr	183	178	108	150	5	157	159	84	197	14
Pb										
Th										
U								3		
Zr	44	45	51	56	103	109	58	68	54	56
Nb				2	3	3		7	4	3
Y	14	18	21	22	22	33	22	17	14	9
La	3	4		3		8	4	11	12	6
Ce	18	17	18	17	9	29	18	41	32	16
Li	20	11	10	13	3	11	8	15	12	6
V	220	305	308	320	344	303	310	198	235	189
Cr	527	168	166	158	84	152	158	349	78	1235
Co										
Ni	104	181	126	119	11	97	121	270	194	
Cu	58	144	140	139	32	91	142	164	114	140
Zn	67	88	84	90	6	92	87	78	74	97
Ga										
S	140	1320	1040	1080	80	560	360	240	220	560

track 0; file 40 - Pilbara, W.A./Warrawoona Group/Salgash Subgroup/Spinaway ck.

Sample no.	49244	49245	49246	49247	49248	49249				
Formation	EURO DC	EURO DA	EURO DC	EURO	EURO DSUC	Euro				
Rock Type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt				
	ch.se.	ca.ch.	ca.ch.	ac.ch.ca?	ca.ch.	ca.ch.				
	HALS	TB	TB	HMB	basalt	HMB				
Gr. or photo pt.	12006:2131	12006:2131	12006:2131	12006:2131	12006:2131	12006:2131				
Stratig. level	Nullagine	Nullagine	Nullagine	Nullagine	Nullagine	Nullagine				
SiO ₂	45.62	52.03	50.02	46.51	29.48	41.60	0.00	0.00	0.00	0.00
TiO ₂	2.39	1.24	1.96	1.43	1.06	1.00	0.00	0.00	0.00	0.00
Al ₂ O ₃	16.18	10.31	12.96	10.79	8.01	7.77	0.00	0.00	0.00	0.00
Fe ₂ O ₃	1.98	1.48	1.14	1.78	1.32	1.08	0.00	0.00	0.00	0.00
FeO	19.10	8.65	16.55	10.80	15.90	10.30	0.00	0.00	0.00	0.00
MnO	0.15	0.17	0.29	0.23	0.38	0.20	0.00	0.00	0.00	0.00
MgO	5.05	7.55	4.16	9.55	8.10	9.30	0.00	0.00	0.00	0.00
CaO	0.42	7.68	3.10	7.72	12.33	9.63	0.00	0.00	0.00	0.00
Na ₂ O	0.03	3.12	0.01	2.02	0.02	0.03	0.00	0.00	0.00	0.00
K ₂ O	0.91	0.05	0.68	1.25	0.35	0.57	0.00	0.00	0.00	0.00
P ₂ O ₅	0.20	0.17	0.18	0.10	0.05	0.07	0.00	0.00	0.00	0.00
H ₂ O+	7.02	2.99	5.82	4.61	3.84	3.77	0.00	0.00	0.00	0.00
H ₂ O-	0.18	0.13	0.08	0.07	0.10	0.09	0.00	0.00	0.00	0.00
CO ₂	0.20	3.00	2.50	2.45	18.30	14.20	0.00	0.00	0.00	0.00
TOTAL	99.43	98.57	99.45	99.41	99.24	99.61	0.00	0.00	0.00	0.00
Ba	13	26	13	389		4				
Rb	19		15	21	12	23				
Sr		118	33	72	28	41				
Pb										
Th										
U										
Zr	136	104	134	87	68	66				
Nb	4	5	5	5	4					
Y	45	29	23	24	23	15				
La		11	8	6	6	5				
Ce	8	30	29	24	31	24				
Li	45	11	38	15	20	19				
V	527	250	447	301	256	228				
Cr	25	570	23	656	1236	401				
Co										
Ni	56	175	42	183	431	133				
Cu	120	137	195	230	116	121				
Zn	193	108	140	92	92	86				
Ga										
S	1440	1560	1120	680	960	240				

track 0: file 41 - Pilbara, W.A./Gorge Creek Group/Charteris Basalt/Charteris ck

Sample no.	49250	49251	49252	49253	49254	49255	49256	49257	49258	49259
Formation	Charteris Basalt	Charteris Basalt	Charteris Basalt	Charteris Basalt	Charteris Basalt	Charteris Basalt	Charteris Basalt	Charteris Basalt DC	Charteris Basalt DA	Charteris Basalt
Rock Type	ca.ch.qz. TB	ca. gabbro	ca. andesite	cpx.ep. per.basalt HMB	cpx. HMB	ep. HMB	cpx. TB	ch.ca.sp. HALB	ca.ch. TB	ca.ch. TB
Gr or photo pt.	12009:2127	12009:2127	12009:2127	12009:2127	12009:2127	12009:2127	12009:2127	12009:2127	12009:2127	12009:2127
Stratig. level	1030m	1090m	1160m	1110m	1060m	1050m	1020m	1010m	960m	880m
SiO ₂	50.96	48.17	53.38	50.41	48.54	47.94	49.66	49.73	47.91	51.67
TiO ₂	0.75	0.31	0.65	0.68	0.56	0.50	0.54	0.52	1.08	0.65
Al ₂ O ₃	12.95	14.50	16.40	13.16	14.24	13.68	14.61	16.80	11.05	14.69
Fe ₂ O ₃	3.26	1.85	1.08	1.94	1.77	2.07	1.99	0.81	1.98	1.97
FeO	8.55	6.15	2.85	9.70	8.00	7.80	7.40	7.00	11.60	7.65
MnO	0.15	0.16	0.15	0.21	0.19	0.18	0.16	0.14	0.22	0.15
MgO	4.08	6.95	2.10	7.70	9.10	10.10	8.20	8.65	6.45	6.90
CaO	6.45	9.51	8.83	9.48	9.77	10.83	10.64	4.69	7.83	7.29
Na ₂ O	2.20	3.64	5.46	2.93	2.55	2.05	2.64	4.06	1.44	1.73
K ₂ O	1.31	1.11	1.21	0.10	0.90	0.39	0.17	0.95	0.03	0.05
P ₂ O ₅	0.05	0.04	0.07	0.06	0.05	0.05	0.05	0.06	0.11	0.06
H ₂ O ⁺	3.93	3.06	2.16	2.88	3.34	3.53	3.44	4.22	4.75	4.25
H ₂ O ⁻	0.05	0.12	0.12	0.06	0.12	0.11	0.06	0.22	0.17	0.25
CO ₂	4.75	3.55	4.95	0.45	0.10	0.10	0.25	1.45	5.35	2.70
TOTAL	99.44	99.22	99.41	99.84	99.23	99.33	99.81	99.30	99.97	100.01
Ba	128	386	127	44	384	67	51	286	2	2
Rb	43	28	44	4	24	11	5	28		
Sr	71	384	140	116	109	256	197	112	68	161
Pb										
Th										
U				2						
Zr	37	9	36	34	27	23	25	23	71	35
Nb										
Y	12	6	17	14	11	10	11	10	22	13
La		2	6	5			3	2	8	3
Ce	12	10	15	18	12	14	14	13	23	16
Li	23	16	9	9	13	16	12	36	16	20
V	283	155	268	254	221	187	260	173	301	255
Cr	5	47	833	74	642	810	390	313	8	260
Co										
Ni	31	64	150	71	96	222	101	160	62	80
Cu	5	11	90	97	86	85	91	77	168	98
Zn	35	39	54	75	63	59	60	48	105	67
Ga										
S	40	20	300	360	360	300	160	100	200	400

track Q; file 42 - Pilbara, W.A./Gorge Creek Group/Charteris Basalt/Charteris ck

Sample no.	49260	49261	49262	49263	49264	49265	49266	49267	49268	49269
Formation	Charteris Basalt	Charteris Basalt	Charteris Basalt	Charteris Basalt	Charteris Basalt	Charteris Basalt	Charteris Basalt	Charteris BasaltUSDC	Charteris Basalt DC	Charteris Basalt
Rock Type	ca.ch. TB	cpx.ch.ep. TB	ca. TB	ep.sa.ch. HMI	ca. TB	ep.ch.sp. TB	cpx.pl.gz. gabbro	silicified basalt	cpx. TB	ol.se. TB
Gr or photo pt.	12009:2127	12009:2127	12009:2128	12009:2128	12009:2128	12009:2128	12009:2128	12009:2128	12009:2128	12010:2128
Stratig. level	720m	620m	550m	470m	420m	330m	240m	30m	110m	600m
SiO ₂	47.51	48.42	47.38	48.02	46.88	49.59	51.08	77.43	50.09	49.13
TiO ₂	0.57	0.10	0.51	0.49	0.53	0.56	0.95	0.80	1.75	0.54
Al ₂ O ₃	13.51	15.84	15.47	15.49	15.67	15.05	13.85	6.00	15.21	15.31
Fe ₂ O ₃	2.42	2.14	2.27	1.97	2.62	2.36	3.03	0.96	3.87	1.24
FeO	0.00	6.15	6.30	6.00	6.45	6.25	8.00	6.50	10.80	7.65
MnO	0.21	0.16	0.16	0.15	0.16	0.17	0.17	0.02	0.19	0.16
MgO	7.35	8.65	8.32	8.25	8.60	8.30	7.50	4.06	5.45	8.40
CaO	11.80	12.38	11.64	12.86	12.39	12.20	8.45	0.14	6.05	9.44
Na ₂ O	1.93	1.60	1.13	1.02	1.59	0.87	2.60	0.04	3.14	3.46
K ₂ O	0.13	0.19	0.04	0.03	0.02	0.02	0.09	0.03	0.03	0.03
P ₂ O ₅	0.08	0.06	0.06	0.06	0.07	0.05	0.11	0.05	0.23	0.06
H ₂ O ⁺	3.36	3.58	3.62	3.82	3.95	3.87	3.60	3.61	3.82	4.04
H ₂ O ⁻	0.24	0.12	0.06	0.06	0.15	0.06	0.36	0.05	0.28	0.08
CO ₂	2.80	0.20	1.63	0.10	0.50	0.05	0.10	0.05	0.30	0.15
TOTAL	99.92	99.59	98.61	99.32	99.48	99.40	99.89	99.74	99.21	99.69
Ba	69	72	15	13	2		12	8	7	13
Rb		7	2				2			
Sr	144	242	190	302	223	239	124	2	156	98
Pb										
Th										
U	2									
Zr	30	26	28	27	28	25	63	47	127	29
Nb									3	
Y	12	9	10	9	10	11	22	13	41	11
La	2	5	3	4	3	3	5	4	9	3
Ce	17	18	13	18	19	19	24	16	32	14
Li	7	12	13	9	8	12	10	33	10	22
V	227	177	159	160	169	176	331	207	341	175
Cr	419	462	704	622	492	527	140	54	61	477
Co										
Ni	157	188	263	244	204	203	63	226	51	192
Cu	88	86	87	85	73	75	51	53	98	69
Zn	68	51	53	49	56	45	72	78	114	52
Ga										
S	560	260	280	600	440	180	60	80	2120	116

track 0; file 43 - Pilbara, W.A./Gorge Creek Group/Charteris Basalt/Charteris ck

Sample no.	49270	49271	49272	49273	49274	49275	49276			
Formation	Charteris	Charteris	Charteris	Charteris	Charteris	Charteris	Charteris			
Rock Type	Basalt	Basalt	Basalt	Basalt DC	Basalt DC	Basalt	Basalt			
Gr or photo pt.	cpx.ch.ep.	ca.	ep.	ca.ch.	ca.	ep.	cpx.cl.			
Stratig. level	HMDoler.	HMB	HMB	gabbro	dolerite	HMB	TB			
	12010:2128	12010:2128	12010:2128	12010:2127	12010:2127	12009:2128	12009:2128			
	680m	750m	820m	1045m	1130m	850m	790m			
SiO ₂	45.79	44.22	49.07	52.35	51.35	49.16	47.99	0.00	0.00	0.00
TiO ₂	0.39	0.54	0.58	0.79	0.61	0.61	0.50	0.00	0.00	0.00
Al ₂ O ₃	16.13	14.35	13.68	13.30	13.73	14.01	15.91	0.00	0.00	0.00
Fe ₂ O ₃	1.76	1.99	1.63	3.61	2.31	1.35	1.85	0.00	0.00	0.00
FeO	6.10	7.35	8.65	9.15	8.05	9.60	7.25	0.00	0.00	0.00
MnO	0.15	0.19	0.21	0.18	0.11	0.21	0.17	0.00	0.00	0.00
MgO	11.10	10.60	8.90	6.55	7.15	9.15	8.25	0.00	0.00	0.00
CaO	10.79	10.57	9.50	3.89	4.36	7.28	10.59	0.00	0.00	0.00
Na ₂ O	0.63	1.87	2.28	4.62	2.58	3.54	2.24	0.00	0.00	0.00
K ₂ O	0.72	0.25	0.81	0.64	1.87	0.28	0.46	0.00	0.00	0.00
P ₂ O ₅	0.04	0.06	0.06	0.06	0.07	0.05	0.06	0.00	0.00	0.00
H ₂ O+	4.89	4.79	3.34	2.84	4.50	3.81	3.74	0.00	0.00	0.00
H ₂ O-	0.07	0.15	0.06	0.36	0.40	0.17	0.12	0.00	0.00	0.00
CO ₂	0.85	2.30	0.50	1.25	2.95	0.10	0.20	0.00	0.00	0.00
TOTAL	99.41	99.23	99.27	99.89	100.07	99.32	99.33	0.00	0.00	0.00
Ba	132	51	59	121	141	64	112			
Rb	22	6	23	10	27	5	18			
Sr	297	151	86	63	64	77	182			
Pb										
Th										
U										
Zr	19	27	31	38	30	32	30			
Nb										
Y	8	12	12	14	13	13	11			
La	2	2	3	4	3	4	3			
Ce	11	9	11	15	13	16	15			
Li	34	23	13	1	15	44	33			
V	141	200	210	424	272	242	177			
Cr	449	853	547	3	6	710	407			
Co										
Ni	244	227	139	24	33	134	133			
Cu	70	87	80	3	4	90	89			
Zn	46	58	63	50	51	69	56			
Ga										
S	100	180	360	20		100	240			

Track 0, file 44 - Pilbara, W.A./Warrawoona Group/Duffer Formation/Bowls Gorge

Sample no.	49277	49278	49279	49280	49281	49282	49283	49284	49285	49286
Formation	DUFFER DC Formation	DUFFER DS Formation	Duffer Formation	Duffer Formation	Duffer Formation	DUFFER UC Formation	DUFFER DC Formation	DUFFER DC Formation	Duffer Formation	DUFFER DC Formation
Rock Type	rhyolite tuff	ca.K-rich porphyry	ca.porph. andesite	ca.porph. dacite	ca.tuff rhyolite	ca.dacite tuff	rhyolite tuff	ca. TB	ca.sa.se. TB	rhyolite tuff
Gr or photo pt.	11941:2103	11941:2103	11941:2103	11941:2103	11941:2103	11941:2103	11941:2103	11941:2103	11941:2103	11941:2103
Stratigraphic level	3575m	3650m	3630m	3610m	3580m	3560m	3550m	3540m	3540m	3510m
SiO ₂	78.38	53.09	55.32	63.18	71.18	59.94	73.00	48.48	47.20	67.14
TiO ₂	0.37	1.11	1.06	0.84	0.40	0.43	0.39	1.18	1.16	0.49
Al ₂ O ₃	12.11	17.87	16.56	16.21	11.81	13.23	12.56	15.41	14.80	15.70
Fe ₂ O ₃	1.12	1.39	1.45	0.76	0.81	0.70	0.73	1.59	1.00	0.94
FeO	0.40	3.55	3.55	1.15	2.05	2.45	2.40	9.25	11.20	2.30
MnO	0.01	0.11	0.12	0.07	0.07	0.17	0.04	0.13	0.14	0.03
MgO	0.50	1.59	2.04	1.11	1.24	1.45	1.35	5.05	5.15	1.23
CaO	0.11	4.84	5.17	3.44	2.61	7.09	1.13	5.01	6.54	1.22
Na ₂ O	0.08	0.09	3.22	3.23	2.04	2.46	2.28	3.10	1.11	1.77
K ₂ O	4.31	9.03	3.95	3.96	3.33	3.41	3.12	1.78	1.93	5.40
P ₂ O ₅	0.08	0.29	0.47	0.21	0.12	0.12	0.11	0.11	0.11	0.14
H ₂ O ⁺	1.93	2.92	2.79	2.03	1.69	2.21	2.08	4.09	3.52	2.31
H ₂ O ⁻	0.07	0.04	0.05	0.05	0.03	0.05	0.04	0.27	0.30	0.13
CO ₂	0.05	3.60	3.65	2.55	2.00	5.65	0.80	2.90	5.15	0.85
TOTAL	99.52	99.52	99.40	99.52	99.38	99.36	100.03	98.35	99.31	99.65
Ba	465	1173	500	470	439	608	510	3375	339	1048
Rb	102	151	115	105	99	32	79	36	56	124
Sr	6	95	92	64	50	98	29	204	138	39
Pb	9	5	2	3	4	3	3			24
Th	8	4	7	6	9	10	8			12
U							4			3
Zr	149	130	178	157	174	165	149	40	56	180
Nb	6	4	8	5	6	6	5			6
Y	11	19	23	17	13	13	9	17	18	14
La	24	15	34	32	31	33	25	8	10	41
Ce	49	44	74	59	57	61	51	23	27	77
Li	2	11	12	7	9	9	10	13	28	9
V	35	175	121	100	33	42	44	232	222	47
Cr	24	194	119	100	40	42	41	181	177	30
Co										
Ni	10	166	65	20	20	17	20	123	118	16
Cu	5	54	47	43	22	21	11	103	100	22
Zn	12	104	91	63	44	49	49	77	101	58
Ga										
S	20	400	520	280	220	80	20	920	750	100

track 0; file 45 - Pilbara, W.A./Warrawoona Group/Duffer Formation/Bowls Gorge

Sample no, Formation	49287 Duffer Formation	49288 Duffer Formation	49289 DUFFER DC Formation	49290 Duffer Formation	49291 Duffer Formation	49292 DUFFER DC Formation	49293 DUFFER DC Formation	49294 Duffer Formation	49295 Duffer DC Formation	49296 Duffer DC Formation
Rock Type	ca.tuff K-dacite	ca.tuff K-dacite	ca. tuff dacite	ca. tuff dacite	ca. tuff K-dacite	ca. tuff dacite	ca. tuff dacite	ca. tuff dacite	ca. tuff dacite	ca. tuff dacite
Gr or photo pt. Stratig. level	11941:2103 3490m	11941:2103 3450m	11941:2103 3420m	11941:2103 3380m	11941:2103 3350m	11941:2103 3220m	11941:2103 3150m	11941:2103 3050m	11941:2103 2900m	11941:2103 2800m
SiO ₂	64.32	63.48	63.87	60.28	59.70	61.60	62.83	58.47	60.02	63.52
TiO ₂	0.53	0.53	0.51	0.51	0.61	0.57	0.62	0.81	0.47	0.57
Al ₂ O ₃	15.35	15.10	15.15	14.37	14.42	17.32	15.30	14.92	12.85	13.48
Fe ₂ O ₃	0.88	0.68	0.79	0.80	0.73	0.91	1.16	1.14	1.01	1.36
FeO	3.35	2.90	3.45	4.10	3.95	3.30	3.90	4.25	5.80	3.40
MnO	0.06	0.08	0.05	0.07	0.13	0.06	0.09	0.14	0.23	0.14
MgO	1.73	2.58	2.98	2.98	2.60	2.24	2.36	2.12	3.14	2.48
CaO	1.73	2.04	1.39	2.97	3.32	1.61	2.23	5.65	4.19	3.15
Na ₂ O	1.37	1.99	2.60	2.24	1.05	3.74	4.08	1.08	4.42	3.60
K ₂ O	6.03	5.04	3.79	4.55	6.02	3.79	2.17	3.35	0.19	1.71
P ₂ O ₅	0.17	0.13	0.17	0.16	0.24	0.15	0.14	0.20	0.14	0.12
H ₂ O ⁺	2.21	2.27	2.64	2.32	2.07	2.47	2.30	3.38	3.07	2.21
H ₂ O ⁻	0.15	0.09	0.16	0.12	0.25	0.15	0.12	0.18	0.09	0.11
CO ₂	1.75	2.85	1.85	4.20	4.65	1.75	1.80	4.45	3.55	3.25
TOTAL	99.63	99.76	99.40	99.67	99.74	99.66	99.10	100.14	99.17	99.10
Ba	928	713	421	542		1030	556	1358	951	258
Rb	131	129	116	113	136	125	66	100	6	67
Sr	45	57	65	73	47	121	150	101	189	139
Pb	11	4	5	4	5	15	6	8	6	6
Th	11	11	13	11	9	13	11	11	7	7
U	3	2	3	4	3	3	4	4		
Zr	186	158	192	161	154	189	166	194	131	152
Nb	7	5	7	5	7	7	6	9	4	4
Y	14	13	14	13	15	15	15	26	13	14
La	42	38	42	38	39	41	37	37	23	24
Ce	86	71	77	73	77	78	70	70	50	50
Li	12	11	14	13	11	13	1	18	16	10
V	56	61	61	63	64	62	77	103	66	82
Cr	35	35	30	34	47	38	30	27	19	28
Co										
Ni	25	27	20	26	37	21	26	17	24	30
Cu	22	17	16	17	11	20	22	27	23	48
Zn	51	59	75	68	68	93	78	88	88	93
Ga										
S	720	200	120	80	220	120	40	260	280	80

track 0; file 46 - Pilbara, W.A./Warrawoona Group/Duffer Formation/Bowls Gorge

Sample no.	49297	49298	49299	49300	49301	49302	49303	49304	49305	49306
Formation	Duffer DCA Formation	Duffer Formation	DUFFER DC Formation	DUFFER DC Formation	Duffer Formation	DUFFER DC Formation	Duffer Formation	Duffer UC Formation	Duffer DC Formation	Duffer Formation
Rock Type	ca. tuff dacite	ca. tuff dacite	ca. sa. dacite	pl. dacite	ca. pl. andesite	ca. tuff dacite	ca. tuff dacite	ca. ch. py. andesite	ca. tuff andesite	ca. pl. qz. dacite
Gr or photo pt.	11941:2103	11941:2103	11942:2103	11942:2103	11942:2103	11942:2103	11942:2103	11942:2103	11943:2103	11943:2103
Stratig. level	2700m	2600m	2520m	2400m	2240m	2140m	2050m	1920m	1800m	1625m
SiO ₂	64.01	56.94	61.22	60.02	58.29	64.78	62.62	50.91	56.43	55.59
TiO ₂	0.55	0.62	0.63	0.56	0.61	0.50	0.50	0.91	0.85	0.48
Al ₂ O ₃	12.00	12.66	15.10	18.51	16.35	13.96	12.86	17.34	15.31	14.03
Fe ₂ O ₃	1.78	1.60	1.43	1.16	1.63	1.37	1.49	2.51	1.59	1.50
FeO	3.00	5.65	3.30	3.45	3.25	2.80	2.80	5.20	5.75	2.15
MnO	0.15	0.20	0.07	0.05	0.10	0.07	0.11	0.15	0.14	0.08
MgO	2.60	2.84	3.44	3.34	2.26	2.96	2.60	3.32	3.88	2.01
CaO	4.29	6.50	2.04	0.68	4.55	2.76	4.80	7.78	4.83	3.78
Na ₂ O	5.10	3.74	3.92	7.10	5.10	5.00	4.80	2.34	4.64	4.10
K ₂ O	0.32	0.79	2.32	1.39	2.88	1.47	0.78	3.34	0.73	1.81
P ₂ O ₅	0.12	0.18	0.14	0.13	0.18	0.13	0.11	0.17	0.17	0.12
H ₂ O+	1.84	2.70	2.58	2.71	2.05	2.13	2.03	3.43	3.28	2.03
H ₂ O-	0.14	0.10	0.16	0.13	0.09	0.03	0.13	0.15	0.14	0.19
CO ₂	3.45	5.20	2.35	0.35	1.95	1.25	3.65	1.55	1.90	1.65
TOTAL	99.35	99.72	99.70	99.58	99.29	99.21	99.36	99.10	99.64	99.52
Ba	89	81	476	172	1281	475	358	1124	336	662
Rb	11	28	73	55	67	37	26	69	19	47
Sr	140	186	109	298	513	249	171	435	348	245
Pb	5	18	6	15	8	8	4	3	8	2
Th	5	6	8	9	9	9	6	4	7	6
U	3		2	2		4	2			3
Zr	119	123	134	168	131	129	124	122	124	97
Nb	3	2		4	3	3	3	5	4	3
Y	12	11	12	13	13	11	12	24	18	9
La	22	27	32	34	33	26	21	22	21	24
Ce	39	54	61	60	61	53	44	45	49	46
Li	9	11		8	6	7	8	11	9	6
V	57	87	87	73	114	81	12	147	138	50
Cr	61	20		38	50	53	48	60	34	29
Co										
Ni	38	37		36	38	41	36	29	49	26
Cu	23	20		21	55	10	41	122	27	5
Zn	35	79		95	57	60	52	87	70	43
Ga										
S	200	40	100		60	200	100	160	60	100

track 0; file 47 - Pilbara, W.A./Warrawoona Group/Duffer Formation/Bowls Gorge

Sample no.	49307	49308	49309	49310	49311	49312	49313	49314	49315	49316
Formation	DufferDFC Formation	Duffer Formation	Duffer DF Formation	Duffer Formation	Duffer DF Formation	DUFFER DFC Formation	Duffer Formation	Duffer Formation	DUFFER UA Formation	Duffer DC Formation
Rock Type	ep.ca.pl. dacite	ca.ep. dacite	ep. dacite	ca.ep.pl. dacite	ca.pl.am. dacite	pl. dacite	ca.pl. dacite	am.ch. TB	pl.ep.cl. andesite	ep.pl. andesite
Gr or photo pt.	11943:2103	11943:2103	11943:2103	11943:2103	11943:2103	11944:2103	11944:2103	11944:2103	11944:2102	11944:2102
Stratig. level	1450m	1280m	1180m	1120m	980m	840m	720m	600m	480m	350m
SiO ₂	64.50	65.40	61.37	59.89	59.69	59.49	62.71	58.47	53.22	58.16
TiO ₂	0.46	0.41	0.48	0.55	0.62	0.36	0.53	0.46	0.74	0.75
Al ₂ O ₃	15.74	14.81	16.22	15.55	16.34	15.81	16.36	11.05	18.84	16.93
Fe ₂ O ₃	2.20	1.44	2.56	2.81	2.08	1.03	1.73	1.16	2.40	1.80
FeO	1.45	1.65	2.70	2.80	3.45	1.15	2.05	6.25	4.25	4.60
MnO	0.07	0.07	0.09	0.13	0.11	0.02	0.09	0.16	0.11	0.12
MgO	1.04	1.32	2.56	1.93	2.16	0.42	0.75	7.85	3.73	3.84
CaO	4.54	4.51	5.24	7.78	5.52	3.06	4.94	5.71	7.71	3.71
Na ₂ O	7.00	3.58	4.64	4.20	5.20	6.15	4.22	2.66	4.32	4.26
K ₂ O	0.20	2.28	0.39	0.26	0.42	0.46	2.20	0.84	0.64	1.55
P ₂ O ₅	0.10	0.11	0.10	0.15	0.14	0.11	0.14	0.07	0.14	0.12
H ₂ O+	1.19	1.76	2.31	1.98	2.11	1.02	1.78	3.54	2.94	2.24
H ₂ O-	0.11	0.16	0.11	0.06	0.03	0.08	0.08	0.16	0.04	0.80
CO ₂	1.30	2.15	0.45	1.95	1.50	0.15	2.10	0.75	0.55	0.35
TOTAL	99.90	99.65	99.22	100.04	99.37	99.31	99.68	99.12	99.63	99.23
Ba	89	347	218	125	307	234	359	811	236	501
Rb	5	97	11	7	12	12	80	15	10	32
Sr	490	390	65	870	655	534	311	230	531	434
Pb	8	5	6	13	5	2		2	7	3
Th	7	5	5	5	3		3	5	2	
U	3							3	2	
Zr	126	116	90	114	104	127	123	61	109	99
Nb	3	3	2	4	2	2	3	2	2	2
Y	10	8	8	10	11	10	12	13	13	12
La	27	18	21	20	17	12	11	9	14	11
Ce	50	43	43	45	34	31	31	24	35	26
Li	4	4	7	6	10	7	4	14	6	7
V	10	56	81	72	95	21	54	122	109	91
Cr	34	32	50	115	31	6	7	710	79	24
Co										
Ni	26	2	39	59	24	1	6	183	74	52
Cu	3	8	16	113	3	3	63	54	11	7
Zn	32	39	62	62	65	28	39	58	74	79
Ga										
S	20		60	60	60	120	60	520	120	

track 0; file 48 - Pilbara, W.A./Warrawoona Group/Duffer Formation/Bowls Gorge

Sample no. 49317
 Formation DUFFER DFC
 Formation
 Rock Type ep.pl.ca.
 dacite
 Gr or photo pt. 11944:2103
 Stratig. level 200m

SiO ₂	62.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO ₂	6.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al ₂ O ₃	14.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe ₂ O ₃	2.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	2.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MgO	3.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	4.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na ₂ O	4.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P ₂ O ₅	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁺	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H ₂ O ⁻	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO ₂	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	99.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Ba	236
Rb	10
Sr	585
Pb	3
Th	2
U	
Zr	117
Nb	3
Y	11
La	16
Ce	33
Li	6
V	65
Cr	74
Co	
Ni	82
Cu	26
Zn	68
Ga	
S	20

track 0: file 49 - Pilbara, W.A./Warrawoona Group/Salgash Subgroup/Camel ck

Sample no.	49325	49326	49327	49328	49329	49330	49331	49332	49333	49334
Formation	Apex Basalt	Apex Basalt	Apex Basalt	Apex Basalt	Apex Basalt	Apex Basalt	Apex Basalt	Apex Basalt	Apex Basalt	Apex Basalt
Rock Type	tr.cl.ca. TB	ch.ep.ac. HMB	ca. HMB	ca.sr. PK	ol. PK	ol.tr. PK	tr.ol. PK	tr.ol. PK	tr.ch. HMB	tr.ch.ep. HMB
Gr or photo pt.	11947:2121	11947:2121	11947:2121	11947:2121	11947:2121	11947:2121	11947:2121	11947:2121	11947:2121	11947:2121
Stratig. level	50m	120m	200m	270m	450m	500m	560m	610m	660m	730m
SiO ₂	49.76	50.42	46.65	39.40	42.89	43.65	42.87	42.99	50.21	49.72
TiO ₂	0.99	1.01	0.38	0.12	0.19	0.19	0.19	0.23	0.47	0.48
Al ₂ O ₃	11.86	11.86	6.92	2.70	4.30	4.38	4.47	4.67	10.01	9.98
Fe ₂ O ₃	2.90	1.98	1.27	2.85	4.44	3.39	3.03	4.50	0.98	1.19
FeO	8.05	10.00	10.50	5.20	4.85	5.60	6.35	5.25	8.85	6.15
MnO	0.21	0.18	0.19	0.12	0.15	0.15	0.14	0.15	0.18	0.21
MgO	7.75	8.05	16.10	36.00	31.50	27.40	32.20	30.70	14.80	13.20
CaO	14.15	9.12	8.98	0.46	4.39	6.47	4.81	4.15	9.70	13.06
Na ₂ O	1.70	3.60	1.31	0.07	0.29	0.48	0.31	0.18	1.90	1.18
K ₂ O	0.09	0.08	0.04	0.01	0.04	0.02	0.02	0.02	0.08	0.22
P ₂ O ₅	0.14	0.11	0.05	0.01	0.04	0.02	0.02	0.03	0.06	0.05
H ₂ O ⁺	1.61	2.25	4.08	11.23	6.51	5.15	5.26	6.73	2.50	0.33
H ₂ O ⁻	0.15	0.25	0.26	0.07	0.27	0.11	0.22	0.33	0.18	3.00
CO ₂	0.50	0.95	2.10	0.95	0.10	0.20	0.10	0.15	0.05	0.10
TOTAL	100.14	99.80	98.83	99.19	99.96	97.21	100.00	100.08	99.97	100.87
Ba	7	9	6						12	7
Rb									3	6
Sr	136	51	26	2	15	27	9	25	31	100
Pb										
Th										
U										
Zr	62	62	17	3	5	8	6	8	23	22
Nb	2									
Y	19	18	8		4	4	5	5	9	10
La	6	5	5		2	2		3	2	
Ce	27	18	8	7	5	11	3	39	10	15
Li	2	5	7	1	3	4	6	5	5	5
V	254	260	190	61	94	107	98	106	198	185
Cr	447	349	1518	951	1630	1285	1176	1570	1456	1248
Co										
Ni	128	118	291	1770	1396	1275	1411	1325	376	305
Cu	19	132	77	16	7	39	5	4	70	20
Zn	85	106	76	27	39		31	34	63	65
Ga										
S	20	160	20	140	200	120	20		160	120

track 0; file 50 - Pilbara, W.A./Warrawoona Group/Salgash Subgroup/Camel ck

Sample no.	49335	49336	49337	49338	49339	49340	49341	49342	49343	49344
Formation	Apex Basalt	Apex Basalt	Apex Basalt	Apex Basalt	APEX UCDA BasaltUCDA	Apex Basalt	Apex Basalt	Euro Basalt	Euro Basalt	Euro Basalt
Rock Type	tr.ch. HMB	ch.tr. HMB	ch.tr. HMB	ch.tr. HMB	ch.tr.cl. ca.ta	ch.tr.cl. HMGabbro	ch.tr.cl. dolerite	tr.ep.ca. HMDoler.	px.ep.ca. HMB	tr.ch.cl? TB
Gr or photo pt.	11947:2121	11947:2121	11947:2121	11947:2120	11947:2120	11947:2120	11947:2120	11945:2120	11945:2120	11945:2120
Stratig. level	800m	890m	1030m	1110m	1210m	1300m	1400m	2850m	2700m	2470m
SiO ₂	49.65	51.11	47.80	48.56	51.79	50.56	52.14	49.67	47.10	49.27
TiO ₂	0.48	0.51	0.45	0.50	0.47	0.37	0.59	1.21	1.39	1.03
Al ₂ O ₃	9.77	12.18	11.51	12.18	10.82	12.81	14.05	9.29	7.23	14.53
Fe ₂ O ₃	1.08	0.99	1.77	1.64	2.43	2.26	2.06	2.44	2.22	2.56
FeO	9.20	8.70	8.45	8.25	6.35	5.80	7.60	8.79	9.70	10.30
MnO	0.19	0.19	0.18	0.18	0.22	0.16	0.17	0.24	0.19	0.19
MgO	14.00	12.00	13.00	11.30	7.75	10.50	7.20	8.40	12.60	7.45
CaO	10.65	9.28	12.83	12.96	16.33	12.59	10.39	12.16	12.98	8.20
Na ₂ O	1.67	2.26	0.94	1.18	0.34	0.97	1.97	2.60	1.10	1.84
K ₂ O	0.14	0.15	0.26	0.34	0.05	0.84	0.08	0.36	0.07	0.28
P ₂ O ₅	0.08	0.06	0.07	0.07	0.08	0.08	0.07	0.14	0.12	0.10
H ₂ O ⁺	2.57	2.23	1.66	2.56	1.72	2.74	2.70	2.36	3.24	3.90
H ₂ O ⁻	0.03	0.07	0.12	0.08	0.08	0.18	0.08	0.20	0.30	0.24
CO ₂	0.40	0.05	0.10	0.10	1.40	0.10	0.15	2.10	1.10	0.15
TOTAL	99.91	99.78	100.15	99.90	100.03	99.94	99.85	99.87	99.34	100.04
Ba	8	14	12	27	12	57		90	22	37
Rb	3	4	9	14		21		5		10
Sr	39	64	144	156	117	70	125	111	124	76
Pb										
Th										
U										
Zr	26	29	37	27	23	18	34	77	63	60
Nb								2		
Y	10	12	11	11	9	8	13	17	16	22
La	2	2	4	5	2	2	2	8	3	8
Ce	19	17	15	13	18	16	17	29	16	21
Li	7	6	8	8	1	6	8	5	10	10
V	201	214	198	223	183	192	238	240	337	340
Cr	1183	827	1116	858	920	578	356	551	1504	160
Co										
Ni	308	267	385	227	217	155	109	161	355	126
Cu	65	60	150	76	50	54	156	207	260	140
Zn	70	66	63	58	58	50	74	80	76	98
Ga										
S	80	340	320	600	100	40	220	1520	80	40

track 0; file 51 - Pilbara, W.A./Warrawoona Group/Salgash Subgroup/Camel ck

Sample no.	49345	49346	49347	49348	49349	49350				
Formation	Euro	Euro	Euro	Euro	Euro	EURO DC				
Rock Type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt DC				
	sp.	ep.ca.sp.	ep.tr.sp.	ep.tr.sp.	ca.ch.qz.	ca.				
Gr or photo pt.	TB	TB	TB	HMB	TB	dolerite				
Stratig. level	11945:2120	11945:2120	11945:2120	11946:2120	11946:2119	11946:2119				
	2390m	2300m	2210m	2100m	2960m	3040m				
SiO ₂	48.46	47.85	48.80	52.00	45.22	51.64	0.00	0.00	0.00	0.00
TiO ₂	1.17	1.11	1.11	0.69	1.67	2.32	0.00	0.00	0.00	0.00
Al ₂ O ₃	14.14	13.67	14.40	13.24	11.99	12.68	0.00	0.00	0.00	0.00
Fe ₂ O ₃	3.12	3.68	2.33	2.35	5.32	8.37	0.00	0.00	0.00	0.00
FeO	10.40	9.30	10.80	7.60	10.50	8.40	0.00	0.00	0.00	0.00
MnO	0.22	0.18	0.22	0.17	0.22	0.14	0.00	0.00	0.00	0.00
MgO	6.65	5.85	7.00	8.35	4.62	3.50	0.00	0.00	0.00	0.00
CaO	9.44	9.74	7.88	9.20	7.16	3.70	0.00	0.00	0.00	0.00
Na ₂ O	2.04	1.96	2.46	1.83	3.22	4.08	0.00	0.00	0.00	0.00
K ₂ O	0.09	0.16	0.25	0.10	0.08	0.44	0.00	0.00	0.00	0.00
P ₂ O ₅	0.13	0.12	0.12	0.09	0.17	0.26	0.00	0.00	0.00	0.00
H ₂ O+	3.55	4.06	3.94	3.74	3.89	3.00	0.00	0.00	0.00	0.00
H ₂ O-	0.11	0.14	0.18	0.18	0.17	0.24	0.00	0.00	0.00	0.00
CO ₂	0.35	2.15	0.30	0.20	4.75	1.20	0.00	0.00	0.00	0.00
TOTAL	99.87	99.97	99.79	99.74	99.98	99.97	0.00	0.00	0.00	0.00
Ba	10	14	25	8	7	293				
Rb		3	6			8				
Sr	159	145	106	129	74	56				
Pb						28				
Th										
U		2								
Zr	67	64	62	46	115	167				
Nb	2		2		4	6				
Y	22	22	22	16	26	26				
La	4	6	6	4	8	11				
Ce	17	18	25	22	30	38				
Li	6	5	9	7	9	8				
V	309	329	317	228	323	267				
Cr	94	89	167	443	33	18				
Co										
Ni	105	101	120	107	43	17				
Cu	172	173	158	72	169	61				
Zn	109	92	115	67	97	88				
Ga										
S	200	1600	220	60		120				

track 0; file 52 - Pilbara, W.A./Warrawoona Group/Wyman Fm/Camel & Budjan cks

Sample no.	49318	49319	49320	49321	49322	49323	49324	49351	49352	49353
Formation	Wyman	Wyman	Wyman	Wyman	Wyman	Wyman	Wyman	Wyman	Wyman	Wyman
Rock Type	qz.or.se.	qz.or.se.	qz.or.se.	qz.or.se.	qz.or.se.	qz.or.se.	qz.or.se.	qz.pl.ca.	se.qz.pl.	qz.pl.se.
Gr or photo pt.	11946:2118	11946:2118	11946:2118	11946:2118	11946:2118	11946:2118	11946:2118	11951:2150	11951:2150	11951:2150
Stratig. level	Marble Bar	Marble Bar	Marble Bar	Marble Bar	Marble Bar	Marble Bar	Marble Bar	Split Rock	Split Rock	Split Rock
SiO ₂	78.21	73.14	76.88	76.6	76.95	75.70	76.22	76.77	81.50	85.48
TiO ₂	0.05	0.04	0.05	0.05	0.04	0.04	0.04	0.26	0.06	0.05
Al ₂ O ₃	11.36	11.11	11.23	11.16	11.16	11.16	10.53	11.87	11.12	8.53
Fe ₂ O ₃	0.69	0.24	0.74	0.50	0.4	0.49	0.32	0.30	0.27	0.20
FeO	0.10	0.05	0.15	0.15	0.15	0.30	0.30	0.35	0.05	0.05
MnO	0.00	0.01	0.02	0.03	0.03	0.04	0.05	0.02	0.00	0.00
MgO	0.50	0.18	0.38	0.35	0.37	0.56	0.68	0.32	0.30	0.33
CaO	0.01	0.24	0.55	0.63	0.54	0.93	1.09	0.86	0.05	0.04
Na ₂ O	0.17	0.13	0.40	0.40	0.27	0.30	0.23	3.69	0.99	0.08
K ₂ O	7.08	9.18	7.88	8.62	8.37	8.44	8.11	3.14	4.72	3.88
P ₂ O ₅	0.03	0.03	0.02	0.03	0.03	0.03	0.02	0.05	0.02	0.02
H ₂ O+	1.13	0.32	0.65	0.41	0.29	0.48	0.53	0.86	1.33	1.25
H ₂ O-	0.07	0.03	0.07	0.09	0.10	0.08	0.09	0.14	0.15	0.13
CO ₂	0.05	0.35	0.70	0.85	0.80	1.25	1.60	0.60	0.00	0.05
TOTAL	99.45	100.05	99.73	99.91	99.53	99.80	99.87	99.23	99.66	100.09
Ba	65	70	67	63	60	59	72	405	493	442
Rb	211	180	197	190	179	194	189	82	91	72
Sr	4	6	7	6	5	9	9	46	11	6
Pb	19	10	14	13	11	13	11	3	5	3
Th	28	31	31	29	31	32	29	9	13	13
U	3	7	6	5	4	4	6	2	4	
Zr	86	82	82	81	80	84	80	114	86	62
Nb	8	10	10	10	11	11	9	3	4	5
Y	24	23	22	27	25	24	22	10	16	19
La	13	19	23	33	27	26	31	23	19	17
Ce	41	47	54	77	67	65	75	43	47	40
Eu	15	3	9	8	7	7	7	3	4	3
V	3							18	2	
Cr		3	4	3	3		4	6	1	3
Co										
Ni	2		1	2						
Cu								4	4	1
Zn	21	3	20	10	2	1	1	4	3	16
Ga					11	7	7	23	5	5
S	20		20	40	20	40		40	160	

track 0; file 53 - Piltara, W.A./Warrawoona Group/Wyman Fm/Budjan & Emu cks

Sample no.	49354	49355	49356	49357	49358	49359	49360	49361	49362	49363
Formation	Wyman	Wyman	Wyman	Wyman	Wyman	Wyman	Wyman	Wyman	Wyman	Wyman
Rock Type	Formation	Formation	Formation	Formation	Formation	Formation	Formation	Formation	Formation	Formation
Gr or photo pt.	qz.	qz.	se.qz.pl.	se.qz.pl.	se.qz.	se.qz.	qz.se.pl.	qz.pl.se.	qz.pl.se.	qz.se.pl.
Stratig. level	rhyolite	rhyolite	rhyolite	rhyolite	rhyolite	rhyolite	rhyolite	rhyolite	rhyolite	rhyolite
	11951:2150	11951:2150	11951:2150	11951:2150	11951:2150	11951:2150	11959:2142	11959:2142	11959:2142	11959:2142
	Split Rock	Split Rock	Split Rock	Split Rock	Split Rock	Split Rock	Split Rock	Split Rock	Split Rock	Split Rock
SiO ₂	81.89	81.35	81.27	80.30	82.06	79.34	70.81	70.21	73.36	73.38
TiO ₂	0.11	0.11	0.18	0.19	0.10	0.11	0.52	0.59	0.50	0.48
Al ₂ O ₃	10.59	10.76	10.69	11.11	9.62	11.19	13.74	14.58	13.11	13.25
Fe ₂ O ₃	0.49	0.54	0.05	0.56	0.33	0.43	0.13	0.20	0.08	0.07
FeO	0.10	0.20	0.15	0.25	0.15	0.15	0.30	0.35	0.15	0.05
MnO	0.00	0.00	0.00	0.00	0.00	0.01	0.17	0.03	0.02	0.01
MgO	0.50	0.54	0.33	0.45	0.26	0.36	0.11	0.13	0.12	0.08
CaO	0.04	0.05	0.04	0.04	0.10	0.03	0.55	0.11	0.21	0.03
Na ₂ O	0.06	0.08	0.08	0.07	0.10	0.11	0.16	0.23	0.14	0.15
K ₂ O	3.68	3.60	4.77	4.41	5.75	6.62	12.97	12.54	11.05	11.25
P ₂ O ₅	0.02	0.02	0.02	0.02	0.03	0.02	0.36	0.09	0.07	0.08
H ₂ O+	1.79	1.82	1.37	1.81	1.25	1.21	0.27	0.54	0.35	0.48
H ₂ O-	0.03	0.12	0.08	0.14	0.05	0.15	0.00	0.06	0.03	0.02
CO ₂	0.00	0.00	0.00	0.05	0.00	0.00	0.40	0.15	0.25	0.00
TOTAL	99.30	99.19	99.33	99.40	99.80	99.73	99.49	99.81	99.44	99.33
Ba	302	110	183	232	471	480	375	445	442	422
Rb	88	91	90	114	136	127	120	122	122	117
Sr	12	10	6	10	21	9	26	18	22	18
Pb	9	5	2	3	46	7	7	6	5	7
Th	10	11	8	9	12	11	6	5	6	6
U	3	2	2	2	3	2	3	2	2	2
Zr	125	134	119	132	147	139	127	193	177	173
Nb	4	4	4	4	5	5	4	7	4	5
Y	12	19	13	15	24	22	22	23	18	17
La	21	26	17	20	19	24	9	20	15	20
Ce	38	53	37	42	41	47	26	45	36	39
Li	2	3	3	3	3	3	2	2	2	1
V	2		7	14			32	43	37	38
Cr	1	1	4	3			11	22	18	17
Co										
Ni	2	2	2	3	3	2	5	11	7	3
Cu	3	5	11	9	6	3	43	29	24	15
Zn	8	11	8	14	11	11	37	18	8	5
Ga										
S	20	20			480	40	600	720	280	40

track 0; file 54 - Filbara, W.A./Gorge Creek Group/Honeyeater Basalt/Soanesville

Sample no.	49364	49365	49366	49367	49368	49369	49370	49371	49372	49373
Formation	Honeyeater	Honeyeater	Honeyeater	Honeyeater	Honeyeater	Honeyeater	Honeyeater	Honeyeater	Honeyeater	Honeyeater
Rock Type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
	px.sr.tr.	ep.sr.ca.	cpx.sa.ch.	cpx.sp.ch.	cpx.pl.	cpx.sr.pl.	cpx.sr.	ca.	ca.	sa.sr.
Gr or photo pt.	11910:2125	11910:2125	11909:2125	11909:2125	11909:2125	11909:2125	11909:2125	11909:2126	11909:2126	11909:2126
Stratig. level	630m	640m	680m	438m	290m	60m	525m	620m	670m	720m
SiO ₂	49.51	51.05	51.27	47.06	51.07	50.36	49.39	46.05	49.41	51.01
TiO ₂	0.38	0.90	0.45	0.40	0.65	0.69	1.08	0.40	0.43	0.44
Al ₂ O ₃	14.89	13.60	8.76	7.99	15.12	14.26	14.30	16.13	16.21	15.77
Fe ₂ O ₃	2.08	1.28	2.28	2.81	1.38	1.41	2.76	1.12	1.73	2.89
FeO	8.35	8.40	7.30	7.10	7.20	7.55	8.70	7.95	7.50	7.30
MnO	0.19	0.22	0.18	0.17	0.15	0.14	0.19	0.29	0.29	0.19
MgO	9.28	6.80	10.50	12.60	7.83	7.05	7.85	7.05	6.85	7.13
CaO	7.66	9.64	14.88	27.70	8.54	11.25	8.47	7.94	7.84	9.04
Na ₂ O	1.11	2.80	1.27	0.23	3.02	3.60	1.80	2.28	1.76	0.65
K ₂ O	0.32	0.23	0.09	0.61	0.77	0.38	0.80	0.61	0.57	0.26
P ₂ O ₅	0.05	0.12	0.08	0.08	0.08	0.09	0.13	0.04	0.05	0.05
H ₂ O ⁺	5.51	3.62	2.85	3.02	3.40	3.16	4.10	5.08	4.66	4.62
H ₂ O ⁻	0.29	0.16	0.23	0.26	0.16	0.34	0.36	0.20	0.18	0.16
CO ₂	0.05	1.05	0.30	0.50	0.45	0.35	0.05	3.80	2.60	0.25
TOTAL	99.67	99.87	100.08	99.93	99.82	99.83	99.98	98.94	100.08	99.76
Ba	74	79	6		311	305	345	240	158	51
Rb	9	6			23	11	22	23	19	5
Sr	205	157	8	3	217	152	289	85	96	160
Pb										
Th										
U										
Zr	19	95	19	17	36	40	98	25	24	22
Nb		2					3			
Y	11	29	10	9	16	15	31	12	13	13
La	2	6	3	4	5	13	5	3	5	
Ce	15	26	11	17	19	19	22	17		10
Li	11	6	4	3	6	5	7	12	11	11
V	237	264	238	261	219	275	338	234	159	228
Cr	50	272	893	1507	88	134	191	170	133	39
Co										
Ni	108	45	136	192	77	55	43	92	82	86
Cu	55	50	9	34	70	55	65	47	49	63
Zn	65	70	38	50	49	52	81	62	62	65
Ga										
S	200	120		40	200	80	240	40	40	60

track 0: file 55 - Pilbara, W.A./Gorge Creek Group/Honeyeater Basalt/Soanesville

Sample no.	49374	49375	49376	49377	49378	49379	49380	49381	49382	49383
Formation	HONEYEATER	Honeyeater	Honeyeater	Honeyeater	HONEYEATER	Honeyeater	Honeyeater	Honeyeater	Honeyeater	Honeyeater
Rock Type	Basalt DC	Basalt	Basalt	Basalt	Basalt UC	Basalt	Basalt	Basalt	Basalt	Basalt
	sa.sr.	sa.sr.	ca.	ca.	cpx.pr.pu.	cpx.	cpx.ca.	cpx.ca.ca.	cpx.sa.ch.	cpx.pr.pu.
Gr or photo pt.	dolerite	dolerite	HALB	HALB	ca.TB	TB	TB	HMB	al.HMDoler	TB
Stratig. level	11909:2126	11909:2126	11909:2126	11909:2126	11909:2126	11909:2126	11909:2126	11909:2126	11909:2126	11909:2126
	870m	920m	520m	450m	420m	400m	360m	340m	320m	270m
SiO ₂	50.97	46.78	48.80	49.06	51.83	50.38	47.46	49.18	49.01	51.71
TiO ₂	0.55	0.31	0.41	0.42	0.65	0.99	0.87	0.66	0.81	0.78
Al ₂ O ₃	14.72	18.47	16.28	16.19	11.14	14.52	14.47	9.87	13.93	13.39
Fe ₂ O ₃	2.42	2.39	1.72	1.54	2.27	1.52	1.51	1.11	1.66	2.90
FeO	9.75	7.60	7.60	7.90	8.55	9.10	9.15	7.80	8.10	7.50
MnO	0.19	0.18	0.20	0.19	0.15	0.20	0.21	0.21	0.18	0.14
MgO	6.65	7.45	8.55	8.00	6.20	8.15	8.10	10.40	10.20	3.92
CaO	6.36	9.14	6.38	6.85	11.41	7.22	9.44	11.75	9.29	13.31
Na ₂ O	2.10	1.45	1.55	1.90	1.52	2.04	2.22	1.55	1.50	0.13
K ₂ O	0.17	0.39	1.08	1.38	1.53	1.29	1.18	0.39	0.80	0.02
P ₂ O ₅	0.05	0.04	0.05	0.05	0.07	0.14	0.12	0.07	0.12	0.09
H ₂ O ⁺	5.31	5.48	5.10	5.19	3.41	3.95	3.47	3.21	3.53	4.67
H ₂ O ⁻	0.39	0.38	0.28	0.25	0.07	0.27	0.13	0.07	0.29	0.07
CO ₂	0.05	0.05	1.40	0.80	0.90	0.15	1.60	3.50	0.45	0.35
TOTAL	99.68	100.11	99.40	99.72	99.70	99.92	99.93	99.77	99.87	98.98
Ba	90	87	500	1528	65	1642	1615	367	666	
Rb	3	7	35	39	24	33	28	11	21	
Sr	27	91	132	135	14	150	185	87	152	5
Pb										
Th										
U										2
Zr	30	14	21	17	34	93	78	37	74	44
Nb										
Y	18	10	13	14	14	28	25	16	24	19
La		2	2		2	7	6	3	5	2
Ce	12	13	9	10	18	22	21	21	23	17
Li	6	10	12	12	3	10	9	6	9	3
V	285	200	233	232	258	316	279	249	266	350
Cr	20	31	148	188	48	327	451	583	461	5
Co										
Ni	59	87	86	86	59	53	114	157	128	28
Cu	77	46	43	51	21	54	50	183	48	32
Zn	70	50	65	57	44	79	77	74	73	58
Ga										
S	100	40	40	40	60	60	100	300	40	100

track 0; file 56 - Pilbara, W.A./Gorge Creek Group/Honeyeater Basalt/Soanesville

Sample no.	49384	49385	49386	49387	49388	49389	49390	49391	49392	49393
Formation	Honeyeater	Honeyeater	HONEYEATER	Honeyeater	HONEYEATER	Honeyeater	Honeyeater	Honeyeater	Honeyeater	Honeyeater
Rock Type	Basalt	Basalt	Basalt UCDA	Basalt	Basalt DC	Basalt	Basalt	Basalt	Basalt	Basalt
Gr or photo pt.	ch.	cpx.sr.	cpx.ch.ca.	ca.	ca.	pl.ca.	ca.	cpx.ch.se.	ca.ep.ch.	ep.ch.qz.
Stratig. level	HMDoler	HMB	basalt	TB	TB	TB	TB	HMB	qz.TB	TB
	11909:2126	11910:2126	11909:2126	11909:2126	11909:2127	11909:2127	11909:2127	11908:2126	11909:2127	11909:2127
	240m	220m	500m	600m	770m	880m	990m	200m	970m	900m
SiO ₂	49.12	49.30	52.95	50.52	50.71	48.19	50.76	49.64	53.06	50.55
TiO ₂	0.49	0.63	0.60	0.93	0.56	0.55	0.58	0.84	0.64	0.68
Al ₂ O ₃	13.74	9.95	9.87	13.72	15.04	14.97	14.84	11.66	15.01	15.01
Fe ₂ O ₃	1.54	1.08	2.58	2.27	2.18	2.24	0.87	1.76	2.88	3.42
FeO	7.55	9.35	5.35	8.05	10.10	9.00	8.70	9.80	8.15	10.70
MnO	0.15	0.19	0.16	0.22	0.26	0.26	0.23	0.17	0.20	0.26
MgO	9.20	12.20	6.80	7.60	6.93	4.78	4.70	9.60	4.62	5.55
CaO	10.46	9.95	15.74	8.33	5.80	9.82	6.75	9.56	6.16	5.79
Na ₂ O	2.50	1.52	0.20	2.50	1.31	1.79	1.95	1.40	1.50	1.14
K ₂ O	0.68	0.72	0.02	0.79	0.11	0.12	1.60	0.64	0.93	0.84
P ₂ O ₅	0.05	0.07	0.06	0.13	0.06	0.06	0.06	0.10	0.06	0.06
H ₂ O ⁺	3.52	3.62	3.49	3.60	5.65	4.36	4.25	4.41	4.27	4.89
H ₂ O ⁻	0.36	0.36	0.11	0.22	0.15	0.28	0.15	0.33	0.19	0.25
CO ₂	0.05	0.35	1.30	0.70	0.65	3.55	4.51	0.10	1.75	0.00
TOTAL	99.41	99.29	99.23	99.58	99.51	99.97	99.95	100.01	99.42	99.14
Ba	667	486		310	28	39	179	523	27	74
Rb	10	27		21	3	3	62	22	24	17
Sr	9	54	9	172	102	260	40	54	88	68
Pb										
Th										
U					3					
Zr	22	33	34	98	32	27	30	52	36	36
Nb				2						
Y	11	14	15	29	18	17	16	19	22	21
La	6	4	3	5	3	2		6	3	3
Ce	11	13	15	19	13	11	14	17	14	11
Li	7	1	3	9	11	13	13	8	12	7
V	243	281	246	275	296	305	324	311	319	350
Cr	147	1060	434	311	19	16	15	589	11	
Co										
Ni	79	182	96	61	62	61	55	123	47	38
Cu	44	18	56	44	76	100	86	73	123	119
Zn	46	57	41	74	87	79	113	58	73	98
Ga										
S	20	20	440	60	100	160	520	100	80	120

track 0; file 57 - Pilbara, W.A./Gorge Creek Group/Honeyeater Basalt/Soanesville

Sample no.	49394	49395	49396	49397	49398	49399				
Formation	Honeyeater Basalt	Honeyeater Basalt	Honeyeater Basalt	Honeyeater Basalt	Honeyeater Basalt	Honeyeater Basalt				
Rock Type	cpx.am.sr. dolerite	ch. TB	px.am.sr. dolerite	cpx.ca. TB	px. TB	ca. TB				
Gr or photo pt.	11909:2127	11909:2127	11909:2127	11909:2127	11909:2127	11909:2128				
Stratig. level	800m	680m	570m	460m	360m	260m				
SiO ₂	49.79	53.21	52.68	50.88	49.31	49.57	0.00	0.00	0.00	0.00
TiO ₂	0.39	0.80	0.62	0.95	1.01	0.95	0.00	0.00	0.00	0.00
Al ₂ O ₃	14.98	14.00	15.07	13.51	14.91	14.15	0.00	0.00	0.00	0.00
Fe ₂ O ₃	2.94	3.84	3.28	2.16	2.57	2.13	0.00	0.00	0.00	0.00
FeO	7.95	9.50	9.05	7.90	8.50	8.20	0.00	0.00	0.00	0.00
MnO	0.19	0.22	0.22	0.17	0.20	0.20	0.00	0.00	0.00	0.00
MgO	8.90	5.35	5.90	7.55	7.80	7.65	0.00	0.00	0.00	0.00
CaO	7.26	6.10	6.37	9.00	7.81	8.10	0.00	0.00	0.00	0.00
Na ₂ O	1.46	1.47	1.69	1.83	2.46	2.30	0.00	0.00	0.00	0.00
K ₂ O	0.48	0.06	0.55	0.41	0.87	0.68	0.00	0.00	0.00	0.00
P ₂ O ₅	0.05	0.08	0.05	0.15	0.15	0.13	0.00	0.00	0.00	0.00
H ₂ O ⁺	5.04	4.49	4.37	3.61	3.66	3.75	0.00	0.00	0.00	0.00
H ₂ O ⁻	0.62	0.25	0.33	0.19	0.32	0.35	0.00	0.00	0.00	0.00
CO ₂	0.05	0.05	0.10	0.85	0.05	0.95	0.00	0.00	0.00	0.00
TOTAL	100.10	99.42	100.28	99.16	99.62	99.11	0.00	0.00	0.00	0.00
Ba	17	6	61	60	261	194				
Rb	10	2	11	9	19	17				
Sr	92	108	72	92	137	121				
Pb										
Th										
U					3					
Zr	22	45	31	101	103	100				
Nb				3	4	3				
Y	12	25	19	30	31	29				
La	2	4	2	8	6	6				
Ce	19	12	8	25	25	23				
Li	8	6	7	8	8	9				
V	223	372	321	286	327	300				
Cr	47	8	9	248	292	250				
Co										
Ni	110	30	56	47	56	49				
Cu	75	109	86	59	61	54				
Zn	69	93	83	81	90	87				
Ga										
S	100	80	80	560	100	80				

Appendix II - Mean values,
maximum and minimum values
and correlation coefficients

North Star Basalt - tholeiites

Sample no	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040002A	49.54	1.59	13.96	16.01	0.00	14.46	0.22	5.22	10.77	1.58	0.37	0.17
75040002B	49.22	1.62	13.55	16.30	0.00	14.67	0.24	6.07	9.08	2.42	0.30	0.17
75040004B	49.72	1.67	14.46	15.14	0.00	13.63	0.36	4.74	7.94	4.02	0.37	0.16
75040005B	51.13	1.33	13.84	14.01	0.00	12.61	0.22	6.06	10.46	2.00	0.32	0.16
75040007A	50.49	1.14	14.42	12.96	0.00	11.66	0.22	6.91	10.33	2.45	0.19	0.10
75040007B	50.64	1.07	13.79	13.01	0.00	11.71	0.20	7.61	10.45	2.14	0.23	0.09
75040008A	52.58	1.23	14.20	11.97	0.00	10.77	0.23	6.33	8.49	3.48	0.32	0.11
75040008B	50.67	1.24	14.54	12.48	0.00	11.23	0.25	7.01	8.14	3.43	0.22	0.10
75040009	53.26	1.22	13.84	12.72	0.00	11.45	0.23	5.84	8.35	3.32	0.36	0.12
75040012	53.37	1.09	13.36	13.17	0.00	11.85	0.21	7.59	7.56	2.18	0.34	0.10
75040016B	49.31	1.25	13.01	15.42	0.00	13.88	0.25	6.78	10.59	1.49	0.46	0.08
75040016F	50.58	0.70	14.86	10.46	0.00	9.41	0.19	8.19	10.64	1.73	0.59	0.06
75040016H	51.46	0.59	15.08	10.66	0.00	9.59	0.21	8.13	9.96	1.26	0.95	0.04
75040016J	51.25	0.59	15.02	10.22	0.00	9.20	0.21	8.26	9.89	1.22	1.12	0.04
75040016J	51.32	0.59	15.02	10.43	0.00	9.39	0.21	8.07	10.39	1.25	0.84	0.04
75040016G	49.51	1.04	14.07	14.49	0.00	13.04	0.23	7.02	10.87	1.66	0.57	0.07
75040016D	53.86	0.74	14.79	9.46	0.00	8.51	0.24	6.05	12.02	2.41	0.44	0.05
75040017A	52.23	1.10	13.46	12.73	0.00	11.46	0.19	7.10	8.15	1.95	0.34	0.10
75040017B	52.84	1.09	13.57	11.94	0.00	10.75	0.23	5.33	11.93	1.58	0.41	0.10
75040017D	55.25	1.05	13.37	11.22	0.00	10.10	0.20	5.56	10.44	2.52	0.23	0.10
75040017F	52.12	1.10	14.00	13.36	0.00	12.02	0.22	7.19	8.35	2.70	0.34	0.10
75040024A	51.30	0.58	14.82	10.47	0.00	9.42	0.25	8.61	10.25	1.64	0.30	0.04
75040026A	50.57	1.38	13.52	15.78	0.00	14.20	0.25	6.15	9.51	1.47	0.35	0.13
75040026B	51.32	0.58	14.85	10.81	0.00	9.73	0.32	7.69	11.83	0.85	0.27	0.03
45062	48.17	2.31	12.84	18.99	0.00	17.09	0.26	5.68	6.95	1.96	0.61	0.23
45064	49.87	1.56	13.01	15.81	0.00	14.23	0.22	6.05	8.76	2.33	0.56	0.16
45066	54.73	1.56	12.83	13.03	0.00	11.73	0.17	4.19	8.91	2.45	0.28	0.18
45068	50.96	1.16	13.81	13.60	0.00	12.24	0.22	6.98	10.21	1.85	0.31	0.08
45069	53.59	1.07	13.02	11.49	0.00	10.34	0.17	5.03	11.38	2.40	0.12	0.11
45070	52.54	1.24	13.28	13.26	0.00	11.93	0.26	5.81	10.82	1.84	0.22	0.13
45071	52.14	1.05	13.42	12.36	0.00	11.12	0.20	6.02	10.34	2.01	0.15	0.10
45073	50.71	0.96	13.79	12.15	0.00	10.94	0.21	5.52	11.84	1.43	0.19	0.08
45183	52.70	0.86	12.79	3.21	6.95	9.84	0.16	7.70	9.94	1.88	0.07	0.09
45189	48.60	1.65	14.92	2.89	9.45	12.05	0.35	3.22	11.75	1.18	0.25	0.15
45190	45.64	1.80	13.60	4.17	10.70	13.95	0.22	5.50	12.05	2.70	0.29	0.19
45192	51.47	2.57	13.44	3.57	11.40	14.61	0.25	4.08	7.46	3.57	0.53	0.26
45193	49.50	2.55	12.63	4.62	10.60	14.76	0.28	3.05	10.40	2.88	0.32	0.25
Mean	51.19	1.24	13.88	11.74	9.72	13.56	0.23	6.28	9.97	2.20	0.38	0.12
Maximum	55.25	2.57	15.08	18.99	11.40	17.09	0.36	8.61	12.05	4.22	1.12	0.26
Minimum	45.64	0.58	12.63	2.89	6.95	8.51	0.16	3.05	6.95	0.85	0.07	0.03
S. Dev.	1.91	0.50	0.71	3.81	1.70	1.90	0.04	1.38	1.37	0.71	0.22	0.06

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040002 A	81	11	317	2		1	137	5	33	5	28	31	374	132	49	62	99	106	22	1040
75040002 B	538	11	258	2			145	7	35	5	29	36	352	116	51	57	99	120	20	480
75040004 B	52	12	115				147	8	33	10	24	16	391	187	50	87	8	121	20	40
75040005 B	106	8	144				129	6	32	5	13	21	312	52	42	56	46	103	17	80
75040007 A	105	4	119			1	96	5	26	4	3	19	349	199	41	71	64	90	17	40
75040007 B	82	8	115			1	81	4	24	4	5	17	332	194	42	71	75	87	18	40
75040008 A	67	10	107				106	4	25	2	12	21	302	70	49	51	33	88	16	
75040008 B	65	6	103				104	4	25	2	7	27	345	78	47	52	88	95	16	40
75040009	51	8	146	2			98	4	23	3	6	18	321	45	45	40	75	88	17	40
75040012	104	6	155				86	4	24	3	6	40	323	55	40	36	75	86	16	80
75040016 B	103	10	120			1	74	3	26		8	50	385	147	52	95	61	95	17	1040
75040016 F	134	35	130				62	3	19			67	288	320	40	93	47	64	13	240
75040016 H	183	49	165				77	4	21	3	3	67	250	316	44	105	56	66	13	80
75040016 J	185	49	163	2			77	4	20		2	62	244	313	45	102	45	63	12	80
75040016 J	153	43	179				76	5	19		6	57	246	319	43	101	47	62	13	80
75040016 O	175	15	121				62	2	23			53	354	161	51	99	43	95	15	240
75040016 P	168	15	144				63	2	21	2	7	12	272	985	44	206	46	68	13	40
75040017 A	49	16	104				94	5	27		11	54	364	77	41	50	57	86	16	160
75040017 B	27	20	116		2		88	4	24	6	9	15	324	86	40	52	8	88	16	40
75040017 D	66	9	157	2			89	4	24	2	8	18	319	77	37	48	7	73	15	160
75040017 E	59	10	122	2		1	89	3	24	4	9	36	337	92	43	51	57	90	18	160
75040024 A	79	10	71				77	4	20	8	7	46	240	361	46	115	20	72	12	40
75040026 A	89	5	130	2			105	4	29		4	21	420	74	54	56	82	91	21	360
75040026 B	18	3	95			1	77	2	19	5	6	26	278	331	51	108	7	122	14	
45062	182	19	123	9	2		210	9	39	19	52	51	407	19	49	9	13	139	25	300
45064	234	17	125	9	2		138	7	29	14	46	35	324	120	52	56	30	205	19	400
45066	104	8	188	8		2	151	7	29	10	32	19	320	139	41	51	137	89	20	2400
45068	242	6	120	6	4		92	4	22	9	24	10	363	90	44	49	84	94	18	300
45069	46	2	122	7			95	5	23	10	23	6	277	78	42	46	46	70	17	200
45070	158	5	116	3	2	2	106	4	24			8	357	75	41	37	17	98	18	100
45071	48	3	129	6	2		91	4	22	3	21	12	338	69	42	49	68	88	18	300
45073	51	4	144	8			74	3	17	12	14	14	282	95	45	52	10	99	13	200
45183	18		139				72		19	6	28	11	245	421		74	64	76		60
45189	32	2	84				105	4	27	6	20	5	356	207		58	6	127		20
45190	63	4	187	5			123	3	34	6	31	5	404	117		42	22	114		
45192	127	13	160				203	8	45	13	48	12	322	5		10	4	149		
45193	21	20	131				128	5	33	11	37	5	396	21		27	7	133		
Mean	110	13	140	5	2	1	103	5	26	7	17	28	327	169	45	66	47	97	17	278
Maximum	538	49	317	9	4	2	210	9	45	19	52	67	420	985	54	206	137	205	25	2400
Minimum	18	2	71	2	2	1	62	2	17	2	2	5	240	5	37	9	4	62	12	20
S. Dev.	94	12	45	3	1	0	35	2	6	4	14	19	50	175	4	35	33	28	3	461

Number of samples is 37

North Star Basalt - Golerites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040004 A	51.21	1.08	15.95	11.84	0.00	10.66	0.17	6.01	9.10	3.18	0.49	0.15
75040005 A	50.69	0.67	15.28	10.43	0.00	9.39	0.18	8.85	8.37	2.66	0.88	0.05
75040016 A	48.22	1.75	13.37	17.49	0.00	15.74	0.27	5.89	9.04	1.61	0.46	0.13
75040016 D	53.61	0.76	14.83	9.96	0.00	8.96	0.16	7.37	9.88	1.64	0.49	0.05
75040016 E	47.53	0.83	16.65	12.61	0.00	11.35	0.22	8.99	9.08	1.89	0.77	0.04
75040016 N	50.87	1.14	15.87	12.68	0.00	11.41	0.20	6.57	8.72	2.06	0.37	0.06
75040016 R	48.25	1.53	14.14	16.53	0.00	14.88	0.27	6.31	9.83	1.90	0.43	0.11
75040017 C	51.40	1.14	14.19	13.48	0.00	12.13	0.21	6.50	10.54	1.58	0.47	0.11
75040033 B	53.74	1.29	15.42	11.95	0.00	10.76	0.22	5.52	7.73	3.21	0.77	0.22
45180	49.38	2.70	12.41	6.05	8.25	13.70	0.16	5.35	8.23	4.04	0.29	0.25
45181	49.43	1.66	14.70	3.55	8.45	11.65	0.18	5.95	9.09	3.10	0.18	0.17
45182	52.18	0.92	13.93	3.54	7.20	10.39	0.17	6.20	10.18	1.80	0.08	0.10
45187	50.71	1.36	13.70	3.48	9.55	12.68	0.19	5.45	8.91	2.68	0.16	0.18
45191	51.41	0.61	12.10	1.03	8.45	9.38	0.17	9.80	7.97	2.50	0.81	0.06
Mean	50.62	1.25	14.47	9.62	8.38	11.65	0.20	6.77	9.12	2.42	0.48	0.12
Maximum	53.74	2.70	16.65	17.49	9.55	15.74	0.27	9.80	10.54	4.04	0.88	0.25
Minimum	47.53	0.61	12.10	1.03	7.20	8.96	0.16	5.35	7.73	1.58	0.08	0.04
S. Dev.	1.89	0.55	1.32	5.20	0.83	2.03	0.04	1.44	0.81	0.75	0.25	0.07

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040004 A	216	32	336				84	5	21	12	23	32	229	146	40	65	63	86	17	160
75040005 A	232	57	191				46	2	16	3		39	248	865	40	109	69	64	13	80
75040016 A	71	16	120			1	109	4	32		5	56	454	94	55	76	117	131	18	1000
75040016 D	112	30	140	2			65	2	18			76	293	240	38	81	81	61	13	240
75040016 E	137	46	232	3			40	2	16			75	155	341	58	250	63	150	14	320
75040016 N	56	19	298	2			68	2	21	5	4	127	212	172	44	80	57	103	17	1200
75040016 R	75	15	131	2			94	5	28	2	9	46	403	181	54	88	65	122	18	840
75040017 C	63	25	135	3			95	5	27	2	13	43	344	85	44	53	84	94	17	880
75040033 B	159	40	274	2	2		99	5	24	17	34	47	239	127	33	41	10	79	17	360
45180	176	5	113				126	5	36	11	32	5	511	40		44	100	84		100
45181	65	3	162				104	3	31	7	29	9	335	158		71	40	84		80
45182	34		148				97	4	24	9	29	10	221	25		49	68	86		40
45187	51		234				130	3	30	12	36	7	259	30		47	151	95		100
45191	141	43	115				54		15	6	21	25	198	667		160	37	83		60
Mean	113	28	188	2	2	1	87	4	24	8	21	43	293	227	45	87	72	94	16	390
Maximum	232	57	336	3	2	1	130	5	36	17	36	127	511	865	58	250	151	150	18	1200
Minimum	34	3	113	2	2	1	40	2	15	2	4	5	155	25	33	41	10	61	13	40
S. Dev.	64	17	74	1	1	1	28	1	7	5	12	34	104	247	9	56	35	25	2	406

Number of samples is 14

North Star Basalt - dolerites (major elements)

	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot.Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
SiO ₂												
TiO ₂												
Al ₂ O ₃												
Fe ₂ O ₃												
FeO												
Tot.Fe	-0.58	0.74										
MnO	-0.51			0.75	0.67	0.71						
MgO		-0.70				-0.55						
CaO					-0.51							
Na ₂ O		0.51						-0.65				
K ₂ O							0.70					
P ₂ O ₅		0.79					-0.78			0.3		
Ba										0.55	0.67	
Rb		-0.80				-0.66	0.73			0.96	-0.53	
Sr			0.74		0.63							
Pb							0.56					
Th												
U												
Zr		0.77				0.63	-0.89			-0.72	0.85	
Nb		0.51			-0.50		-0.67				0.67	
Y		0.91				0.79	-0.82			-0.68	0.78	
La	0.52						-0.51	-0.60	0.65		0.73	
Ce				-0.70		-0.62			0.70		0.68	
Li			0.56	0.61					-0.51		-0.56	
V		0.84	-0.55			0.74	-0.53				0.52	
Cr		-0.57				-0.52	0.87			0.75	-0.58	
Co	-0.95			0.71		0.71	0.68		-0.60			
Ni							0.82			0.58	-0.64	
Cu					0.56							
Zn	-0.78				0.63	0.63	0.74					
Ga		0.90		0.76		0.76	0.64	-0.85		-0.58	0.65	
S				0.76	0.76	0.53	0.71			-0.53		

	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
Ba																				
Rb	0.59																			
Sr																				
Pb																				
Th																				
U																				
Zr	-0.80																			
Nb							0.62													
Y	-0.86						0.93	0.57												
La																				
Ce										0.80										
Li							-0.54				-0.75									
V	-0.73	-0.58					0.64		0.81											
Cr	0.56	0.75					-0.77	-0.54	-0.71											
Co										-0.77	-0.83									
Ni	0.53			0.53			-0.76	-0.53	-0.63	-0.51				0.56	0.62					
Cu															0.52					
Zn				0.50							-0.76				0.92	0.50				
Ga	-0.74						0.65	0.76	0.85		-0.51		0.50	-0.73						
S										-0.88	0.69							0.51	0.68	

North Star Basalt - gabbro

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040019 A	49.75	1.16	14.81	13.25	0.00	11.93	0.22	6.08	10.77	2.84	0.34	0.07
75040019 G	49.84	1.16	14.30	13.03	0.00	11.73	0.22	5.93	10.61	2.88	0.32	0.07
75040022	50.09	1.03	12.45	13.99	0.00	12.59	0.23	8.25	11.24	1.77	0.70	0.08
75040032 A	48.70	1.13	15.71	12.96	0.00	11.66	0.20	6.60	11.19	1.94	0.94	0.06
75040032 B	48.10	1.18	14.98	14.31	0.00	12.88	0.23	7.46	10.19	2.06	0.54	0.09
45063	50.73	1.73	12.94	16.69	0.00	15.02	0.20	5.38	6.74	3.94	0.21	0.20
45067	49.04	1.18	13.78	14.39	0.00	12.95	0.21	6.30	10.63	2.53	0.37	0.06
45074	51.10	0.50	15.05	9.32	0.00	8.39	0.14	8.61	9.80	1.01	0.46	0.05
45175	49.26	1.00	14.13	5.16	8.20	12.84	0.21	6.15	9.39	2.56	0.06	0.09
45188	49.26	1.53	13.81	3.52	10.10	13.27	0.23	5.70	9.53	2.87	0.17	0.13
Mean	49.59	1.16	14.20	11.65	9.15	12.33	0.21	6.65	10.01	2.44	0.41	0.09
Maximum	51.10	1.73	15.71	16.69	10.10	15.02	0.23	8.61	11.24	3.94	0.94	0.20
Minimum	48.10	0.50	12.45	3.52	8.20	8.39	0.14	5.38	6.74	1.01	0.06	0.05
S. Dev.	0.91	0.32	1.00	4.29	1.34	1.69	0.03	1.10	1.32	0.80	0.26	0.04

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040019 A	54	17	195	2			68	3	19			65	355	57	54	57	13	91	19	
75040019 G	43	17	192	2			68	3	19			68	362	58	54	59	19	92	19	
75040022	84	31	148			1	84	3	25			10	312	126	54	168	18	96	18	
75040032 A	193	55	245			1	59	2	28		6	105	360	352	44	91	127	83	17	440
75040032 B	180	23	145				73	3	22			133	355	169	52	123	82	94	16	360
45063	97	5	102	6	2		169	7	33	11	34	30	341	140	50	36	63	105	21	1400
45067	111	14	140	4	3		73	3	18	4	19	13	406	22	57	65	25	107	22	200
45074	126	18	103	3			66	4	14	5	20	19	227	286	42	117	62	66	13	100
45175	28		308	2			73		18		24	7	227	10		72	128	95		
45188	60	3	207				96		27	5	25	6	335	189		50	36	106		
Mean	98	20	179	3	3	1	83	4	22		21	46	328	141	49	84	57	94	18	560
Maximum	193	55	308	6	3	1	169	7	33	11	34	133	406	352	57	168	128	107	22	1400
Minimum	28	3	102	2	2	1	59	2	14	4	6	6	227	10	42	36	13	66	13	100
S. Dev.	56	16	65	2	1	0	32	2	5	3	9	45	58	113	6	41	43	12	3	520

Number of samples is 10

North Star Basalt - gabbro (major elements)

	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
SiO ₂												
TiO ₂												
Al ₂ O ₃												
Fe ₂ O ₃												
FeO		1.00	-1.00	-1.00								
Tot. Fe		0.90	-0.58		1.00							
MnO	-0.59	0.59			1.00	0.69						
MgO		-0.78			-1.00	-0.66						
CaO		-0.52			1.00							
Na ₂ O		0.88			1.00	0.80		-0.91	-0.61			
K ₂ O					1.00			0.55	0.59	-0.58		
P ₂ O ₅		0.81	-0.54		1.00	0.75		-0.53	-0.88	0.75		
Ba					1.00						0.75	
Rb									0.61	-0.54	0.97	-0.53
Sr				-0.57	-1.00							
Pb		0.61	-0.79	0.64		0.54			-0.78			0.76
Th	-1.00	-1.00	1.00	-1.00		-1.00	1.00	1.00	1.00	-1.00	1.00	-1.00
U												
Zr		0.72	-0.63		1.00	0.67			-0.88	0.70		0.95
Nb	0.62								-0.97	0.57	-0.63	0.88
Y		0.85	-0.63		1.00	0.80			-0.61	0.66		0.91
La			-0.55		-1.00	0.54			-0.88	0.64	-0.60	0.74
Ce	0.56		-0.90		1.00	0.52			-0.91	0.68	-0.86	0.80
Li	-0.56		0.65		-1.00						0.52	
V		0.57		0.57	1.00		0.54					
Cr					1.00						0.64	
Co			-0.65	0.62		0.62	0.51					
Ni		-0.59			-1.00			0.92	0.51	-0.80	0.64	
Cu					-1.00							
Zn		0.82	-0.64		1.00	0.91	0.74	-0.65		0.74		0.57
Ga		0.77	-0.54	0.78		0.70	0.54	-0.78		0.80		
S		0.85	-0.67	0.74		0.74		-0.76	-0.87	0.89		0.97

North Star Basalt - gabbro (trace elements)

	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
Ba																				
Rb	0.64																			
Pb	0.52	-0.93	-0.68																	
Th	1.00	1.00	1.00	-1.00																
U																				
Zr		-0.52		0.87	-1.00															
Nb		-0.67	-0.71	0.86	-1.00		0.93													
Y				0.78	-1.00		0.87	0.68												
La					-1.00		0.72	0.99	0.57											
Ce	-0.71	-0.90		0.69	-1.00		0.81	0.96	0.61	0.85										
Li	0.63	0.52			-1.00					0.50	-0.72									
V					1.00															
Cr	0.72	0.55			-1.00						-0.53									
Co				0.56	1.00															
Ni		0.52			1.00						-0.65									
Cu		0.60	0.51		-1.00					0.62										
Zn					1.00		0.50		0.64				0.53	-0.57	0.78					
Ga					1.00								0.78	-0.71	0.35	-0.60		0.90		
S				0.97	-1.00		0.95	0.81	0.97	0.98	0.68					-0.75		0.51		

North Star Basalt - High-Mg Basalt

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040003C	49.68	0.68	5.84	12.44	0.00	11.20	0.24	13.91	14.94	0.42	0.22	0.40
75040016P	51.57	0.59	14.92	10.28	0.00	9.25	0.22	9.00	9.39	1.69	0.31	0.04
75040023	49.97	0.81	7.44	13.08	0.00	11.77	0.25	14.29	12.69	0.43	0.30	0.05
75040024C	50.77	0.56	14.39	10.32	0.00	9.29	0.21	9.64	9.67	1.16	0.49	0.03
75040025P	51.79	0.52	13.60	10.04	0.00	9.04	0.20	10.82	8.77	0.82	0.89	0.03
45075	48.63	0.49	12.45	9.28	0.00	8.35	0.18	9.96	8.35	0.07	0.02	0.04
Mean	50.40	0.61	11.44	10.91	0.00	9.82	0.22	11.27	10.67	0.77	0.37	0.10
Maximum	51.79	0.81	14.92	13.08	0.00	11.77	0.25	14.29	14.94	1.69	0.89	0.40
Minimum	48.63	0.49	5.84	9.28	0.00	8.35	0.18	9.00	8.55	0.07	0.02	0.03
S. Dev.	1.21	0.12	3.84	1.50	0.00	1.35	0.03	2.27	2.57	0.59	0.30	0.15

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040003C	36	2	26				29		14			13	324	1400	66	399	236	64	9	640
75040016P	70	14	100				76	4	20	7	5	49	241	430	44	127	115	66	12	120
75040023	13	19	44				41		15			13	325	1450	64	845	43	86	12	80
75040024C	105	23	112				74	4	19	5	11	42	237	634	43	138	18	71	13	80
75040025P	214	40	111				67	3	17	2	3	41	225	752	44	146	12	61	11	80
45075	21		35	6		2	67	4	12	4	11	29	231	583	43	141	57	65	11	200
Mean	77	20	71	6	0	2	59	4	16	5	8	31	264	875	51	216	80	69	11	200
Maximum	214	40	112	6	0	2	76	4	20	7	11	49	325	1450	66	399	236	86	13	640
Minimum	13	2	26	6	0	2	29	3	12	2	3	13	225	430	43	127	12	61	9	80
S. Dev.	76	14	40	\$\$\$\$\$	0	\$\$\$\$\$	19	1	3	2	4	15	47	439	11	122	85	9	1	221

Number of samples is 6

UPPER NORTH STAR BASALT - andesites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot.Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040024 B	57.40	0.84	16.19	8.14	0.00	7.33	0.14	3.85	7.67	3.43	0.20	0.15
75040024 D	58.12	0.83	16.19	8.18	0.00	7.36	0.14	3.99	8.02	2.52	0.27	0.15
75040025 F	58.23	1.29	17.13	8.92	0.00	8.03	0.17	2.42	7.01	2.92	0.70	0.35
Mean	57.92	0.99	16.50	8.41	0.00	7.57	0.15	3.42	7.57	2.96	0.39	0.22
Maximum	58.23	1.29	17.13	8.92	0.00	8.03	0.17	3.99	8.02	3.43	0.70	0.35
Minimum	57.40	0.83	16.19	8.14	0.00	7.33	0.14	2.42	7.01	2.52	0.20	0.15
S. Dev.	0.45	0.26	0.54	0.44	0.00	0.40	0.02	0.87	0.51	0.46	0.27	0.12

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040024 B	89	8	363	4	4	2	127	6	16	25	42	93	144	69	27	68	46	66	19	240
75040024 D	173	10	268	4	5	1	125	5	16	26	39	110	149	71	28	68	42	59	18	240
75040025 F	1115	33	594	14	19	2	229	10	24	79	138	32	26	11	14	68	5	78	18	80
Mean	458	17	408	7	9	2	160	7	19	43	73	78	106	50	23	68	31	68	18	187
Maximum	1115	33	594	14	19	2	229	10	24	79	138	110	149	71	28	68	46	78	19	240
Minimum	89	8	268	4	4	1	125	5	16	25	39	32	26	11	14	68	5	59	18	80
S. Dev.	170	14	168	6	8	1	59	3	5	31	56	41	70	34	8	0	23	10	1	92

Number of samples is 3

UPPER NORTH STAR BASALT - dacites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040024 <i>E</i>	64.49	0.63	16.10	3.78	0.00	3.40	0.10	1.76	7.35	3.21	0.73	0.04
75040025 <i>A</i>	60.84	0.71	16.73	6.56	0.00	5.90	0.11	2.58	5.75	4.61	0.83	0.13
75040025 <i>B</i>	66.75	0.48	16.60	3.27	0.00	2.94	0.09	0.85	3.57	6.56	0.98	0.13
75040025 <i>C</i>	60.60	0.71	16.76	6.98	0.00	6.28	0.11	2.58	5.83	3.55	1.21	0.12
75040025 <i>E</i>	66.92	0.49	17.05	3.37	0.00	3.03	0.09	0.78	3.45	6.37	0.94	0.14
75040026 <i>C</i>	61.39	0.69	16.75	6.62	0.00	5.96	0.11	2.58	5.99	3.91	0.90	0.12
75040033 <i>C</i>	62.03	0.74	16.57	6.62	0.00	5.86	0.10	2.69	5.12	5.36	0.33	0.11
75040033 <i>D</i>	60.78	0.74	16.22	7.07	0.00	6.36	0.12	3.24	5.14	5.32	0.26	0.12
Mean	62.98	0.65	16.60	5.53	0.00	4.98	0.10	2.13	5.28	4.86	0.77	0.11
Maximum	66.92	0.74	17.05	7.07	0.00	6.36	0.12	3.24	7.35	6.56	1.21	0.14
Minimum	60.60	0.48	16.10	3.27	0.00	2.94	0.09	0.78	3.45	3.21	0.26	0.04
S. Dev.	2.69	0.11	0.31	1.72	0.00	1.55	0.01	0.91	1.29	1.26	0.32	0.03

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040024 <i>E</i>	148	43	185		2	1	84	5	18	8	8	81	222	449	31	189	52	25	12	400
75040025 <i>A</i>	225	21	430	4	3	1	115	5	12	16	29	27	95	66	19	23	6	64	17	400
75040025 <i>B</i>	978	31	567	12	17	2	223	9	24	74	121	15	22	5	5		15	41	18	240
75040025 <i>C</i>	423	42	417	3	3	2	117	5	12	18	21	27	92	67	24	24	161	65	18	1640
75040025 <i>E</i>	431	24	329	8	7		201	10	36	36	65	16	70	7	5		19	41	21	360
75040026 <i>C</i>	275	27	444	5	2		119	5	13	18	28	23	90	76	19	23	42	65	18	240
75040033 <i>C</i>	205	12	283	32	5		145	6	16	19	29	68	98	42	22	38	57	66	19	240
75040033 <i>D</i>	127	8	358	4	4		142	5	16	20	33	67	104	113	24	82	7	68	19	80
Mean	352	26	390	10	5	2	143	6	18	26	42	41	99	103	19	63	45	54	18	450
Maximum	978	43	567	32	17	2	223	10	36	74	121	81	222	449	31	189	161	68	21	1640
Minimum	127	8	185	3	2	1	34	5	12	8	8	15	22	5	5	23	6	25	12	80
S. Dev.	278	13	110	10	5	1	47	2	6	21	36	27	56	144	9	66	51	16	3	493

Number of samples is 8

Mount Adz Basalt - tholeiites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040031 A	49.89	2.00	12.93	18.65	0.00	16.79	0.28	4.63	8.15	2.92	0.38	0.18
75040031 B	48.82	2.03	12.44	19.57	0.00	17.61	0.28	4.62	7.41	3.00	0.39	0.17
75040034 A	49.40	1.38	14.16	15.05	0.00	13.55	0.19	6.98	9.39	2.78	0.30	0.10
75040037 A	50.71	1.29	13.82	14.47	0.00	13.02	0.24	5.61	9.97	2.57	0.24	0.13
75040039 B	50.31	0.87	12.76	12.91	0.00	11.62	0.20	6.87	12.21	1.21	0.29	0.08
75040039 C	50.69	1.14	13.71	13.75	0.00	12.38	0.22	6.38	10.28	2.06	0.51	0.08
75040047 E	50.33	0.86	12.92	12.86	0.00	11.57	0.19	7.54	10.28	1.98	0.20	0.07
75040054 A	47.59	2.09	12.86	17.46	0.00	15.71	0.23	4.28	6.30	2.06	0.35	0.22
75040054 B	48.08	2.11	12.72	16.67	0.00	15.00	0.20	3.30	6.55	2.36	0.20	0.22
75040055 A	49.38	2.00	13.83	13.94	0.00	12.55	0.20	6.36	8.44	3.02	0.22	0.17
75040055 B	48.76	1.90	13.35	14.21	0.00	12.79	0.20	6.18	9.08	2.65	0.22	0.16
75040055 C	49.91	1.95	13.70	14.57	0.00	13.11	0.19	6.16	8.06	2.75	0.26	0.17
75040056 A	48.85	1.89	13.80	15.56	0.00	14.00	0.23	5.71	8.95	2.42	0.25	0.15
75040056 B	48.49	1.43	13.53	16.22	0.00	14.60	0.24	6.55	8.34	2.58	0.09	0.11
75040056 C	48.77	2.17	12.11	18.12	0.00	16.31	0.21	3.94	6.12	3.28	0.30	0.25
75040056 D	49.61	1.97	13.65	15.90	0.00	14.31	0.23	5.39	8.92	2.27	0.27	0.17
75040056 E	48.02	1.50	13.56	15.10	0.00	13.59	0.23	6.08	9.06	2.97	0.08	0.11
75040056 F	49.30	1.96	13.73	16.64	0.00	14.44	0.23	5.34	9.07	2.30	0.24	0.16
75040095 A	44.94	1.08	12.08	12.41	0.00	11.17	0.20	4.67	10.92	1.89	0.19	0.04
45076	45.27	1.99	12.00	15.97	0.00	14.37	0.22	4.44	6.43	2.63	0.04	0.20
45077	49.71	1.55	13.04	13.80	0.00	12.42	0.22	4.18	9.89	2.08	0.07	0.15
45079	46.76	2.05	12.43	15.11	0.00	13.60	0.26	3.09	8.72	1.92	0.04	0.21
45080	48.14	2.08	12.66	17.55	0.00	15.80	0.19	4.24	5.41	1.89	0.14	0.21
45082	47.29	2.12	12.04	17.27	0.00	15.54	0.21	3.99	7.21	1.19	0.05	0.19
45084	48.89	1.60	12.67	14.79	0.00	13.31	0.17	5.17	6.56	1.77	0.04	0.18
45086	48.85	1.02	11.51	12.65	0.00	11.39	0.17	5.95	8.81	1.00	0.03	0.07
45088	44.82	0.98	10.90	12.40	0.00	11.16	0.16	5.36	11.32	1.53	0.03	0.09
45089	47.42	1.09	11.31	11.79	0.00	10.61	0.17	5.19	9.91	0.51	1.15	0.10
45091	45.39	0.92	10.33	11.30	0.00	10.17	0.20	6.66	12.14	0.49	0.03	0.07
45092	49.25	0.79	12.33	12.00	0.00	10.80	0.18	7.77	9.19	1.30	0.01	0.06
45093	46.00	2.17	11.85	15.95	0.00	14.36	0.26	4.90	7.79	2.16	0.03	0.19
45095	45.26	2.05	12.13	16.70	0.00	15.03	0.23	4.53	7.04	1.23	0.12	0.22
45096	45.92	2.21	12.52	17.89	0.00	16.10	0.27	4.88	6.25	2.23	0.16	0.22
45159	47.62	1.28	14.56	3.05	9.85	12.60	0.20	5.85	9.21	2.56	0.48	0.11
45160	48.27	1.30	14.87	3.19	9.80	12.67	0.19	5.05	10.16	2.82	0.27	0.12
45169	49.32	1.28	13.99	5.26	8.10	12.83	0.19	6.15	8.59	3.18	0.33	0.12
Mean	48.22	1.61	12.86	14.17	9.25	13.52	0.21	5.39	8.69	2.14	0.22	0.15
Maximum	50.71	2.21	14.87	19.57	9.85	17.61	0.28	7.77	12.21	3.18	1.15	0.25
Minimum	44.82	0.79	10.33	3.05	8.10	10.17	0.16	3.09	5.41	0.49	0.01	0.04
S. Dev.	1.71	0.47	1.02	3.78	1.00	1.86	0.03	1.13	1.68	0.69	0.21	0.06

Sample no.	Ba	K	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S	13
75040031A	83	7	148	5		1	160	7	43	5	16	36	430	62	46	36	100	187	19	720	
75040031B	60	7	155	4			137	6	36	6	17	45	455	67	55	41	155	199	20	320	
75040034A	76	8	144	2		1	88	4	27	4	13	32	409	176	46	76	10	79	15	40	
75040037A	38	4	163				103	5	27	6	15	10	330	78	47	49	108	108	17	40	
75040039B	45	12	119				69	3	20		3	11	288	356	45	84	78	98	13	320	
75040039C	70	13	128	2			76	3	23	3											
75040047F	90	3	107				69	3	19	2	9	14	337	162	45	81	128	91	16	840	
75040054A	250	6	171	2		1	174	7	37	10	22	9	246	337	44	76	80	90	13	400	
75040054B	48	3	128	2			172	8	34	10	21	17	385	71	48	45	50	131	23	40	
75040055A	139	2	73				123	6	35	3	11	14	332	34	39	26	49	125	21	1560	
75040055B	105	3	85	2			132	6	36	3	15	15	434	218	41	56	7	69	19	40	
75040055C	117	3	98				141	6	39	5	13	13	410	210	40	57	34	72	20	160	
75040056A	130	4	163	3			135	7	35	4	9	20	425	220	44	61	97	76	19	40	
75040056B	74		138				95	5	28	4	13	17	424	160	43	74	36	117	19	440	
75040056C	370	6	95			1	163	8	45	4	28	24	345	232	51	87	61	117	17		
75040056D	163	5	172	3			146	7	38	4	19	20	442	38	43	20	63	98	23	1880	
75040056E	66		142				98	6	28	8	19	20	440	146	44	67	52	115	19	1400	
75040056F	109	4	165	3			143	6	38	3	16	19	340	211	48	78	121	104	16	240	
75040095A	37	6	131				86	4	23	3	8	19	444	142	45	69	46	116	19	1080	
45076	45		239	7	2		169	9	28	84	34	24	282	101	43	60	89	86	14	80	
45077	27		146	6	2	2	133	7	24	7	25	18	294	37	44	41	66	136	23	1200	
45079	55		139	9			171	9	29	14	29	24	351	54	41	42	38	100	20	600	
45080	77	5	168	7	3		182	9	31	17	48	36	354	71	42	41	36	125	21	1400	
45082	88		164	6			162	7	34	12	43	22	368	48	47	42	67	136	26	1600	
45084	141		97	10	2		146	7	30	9	30	20	474	13	44	22	66	97	20	1800	
45086	18		90	8			77	5	20	4	21	18	27	69	47	71	55	95	15	300	
45088	14		79	15			78	4	17	2	26	20	257	69	47	71	100	89	14	1100	
45089	252	38	111	6			89	5	18	4	29	25	308	197	39	78	76	91	13	1100	
45091	104		135	5			66	3	16	2	9	24	330	30	35	41	96	85	15	600	
45092	22		176	10			61	3	14	13	15	15	256	217	42	89	56	86	12	300	
45093	43		113	5	4		154	5	31	15	28	14	194	271	45	76	99	86	14	400	
45095	76	2	240	8	2		174	10	28	11	36	28	390	48	44	47	69	88	18	200	
45096	50	3	230	7			184	10	32	9	35	24	329	40	38	43	46	141	21	700	
45159	129	10	125				81		24	6	23	8	319	44	46	45	69	147	26	1100	
45160	76	8	193				86	3	24	9	30	7	278	136		67	106	109		920	
45169	77	10	147				85		27	6	21	7	269	139		69	103	102		340	
Mean	93	7	142	6	3	1	122	6	29	9	21	7	316	145		76	86	84		220	
Maximum	370	38	240	15	4	2	184	10	45	84	48	45	350	128	44	58	72	108	18	672	
Minimum	14	2	73	2	2	1	61	3	14	2	3	7	194	356	55	39	155	199	26	1880	
S. Dev.	72	7	42	3	1	0	40	2	8	14	11	8	70	91	4	20	7	69	12	40	

Number of samples is 36

Mount Ada Basalt - Dolerites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040034 B	49.69	1.42	14.14	14.94	9.00	13.45	0.24	6.56	9.38	2.88	0.32	0.11
75040036	48.99	1.41	14.01	15.61	0.00	14.05	0.26	5.97	10.22	2.68	0.59	0.10
75040098 A	48.93	1.85	13.79	16.58	0.00	14.92	0.24	5.79	7.00	0.59	0.08	0.14
75040098 B	49.22	1.63	14.25	15.96	0.00	14.36	0.22	6.18	6.28	1.04	0.08	0.11
45085	46.88	1.83	12.10	15.41	0.00	13.87	0.20	4.38	8.05	1.42	0.14	0.16
45090	49.14	1.76	12.80	18.08	0.00	16.27	0.26	5.21	7.83	1.01	0.10	0.18
45153	48.97	1.27	10.97	2.61	10.70	13.05	0.20	9.05	11.25	1.56	0.23	0.12
45154	48.57	1.43	13.54	3.24	11.00	13.92	0.20	5.90	9.59	2.30	0.64	0.14
45155	48.43	1.58	12.50	3.82	11.50	14.94	0.22	5.80	9.47	2.02	0.34	0.17
45164	48.09	1.31	14.29	4.60	9.30	13.44	0.19	6.20	8.41	2.86	0.40	0.12
45165	48.16	1.39	14.06	2.33	9.95	12.05	0.16	7.35	6.50	3.48	0.13	0.13
Mean	48.64	1.53	13.31	16.29	10.49	14.03	0.22	6.22	8.54	1.99	0.28	0.13
Maximum	49.69	1.85	14.29	18.08	11.50	16.27	0.26	9.05	11.25	3.48	0.64	0.18
Minimum	46.88	1.27	10.97	2.33	9.30	12.05	0.16	4.38	6.28	0.59	0.08	0.10
S. Dev.	0.75	0.21	1.08	6.74	0.87	1.11	0.03	1.20	1.59	0.93	0.20	0.03

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040034 B	72	8	163	2			87	4	28	4	10	26	415	179	49	69	99	85	17	320
75040036	144	25	127				86	5	24		8	20	208	192	50	76	17	113	16	40
75040098 A	31	2	333	3			127	5	33		10	21	400	137	52	68	62	120	17	160
75040098 B	428	2	481	4			107	5	29	3		19	391	157	53	79	68	115	17	240
45085	61		95	7			132	7	27	8	30	28	414	13	42	31	92	112	20	200
45090	65	3	189	9	2		127	6	31	9	31	11	386	72	54	48	99	127	20	2000
45153	72	4	121				90	3	27	9	27	8	285	639		121	103	113		140
45154	148	14	124				99	5	29	6	27	11	322	211		80	87	93		1320
45155	129	5	145				112	4	37	8	31	10	313	197		73	83	126		180
45164	132	9	209	5			85	3	26	7	23	8	281	153		81	105	68		1480
45165	31	3	123				97		30	4	22	5	327	144		71	20	49		520
Mean	119	8	192	5	2	0	104	5	29	6	22	15	340	190	50	72	76	102	18	600
Maximum	428	25	481	9	2	0	132	7	37	9	31	28	416	639	54	121	105	127	20	2000
Minimum	31	2	95	2	2	0	85	3	24	3	8	5	208	13	42	31	17	49	16	40
S. Dev.	111	7	116	3		0	17	1	4	2	9	8	67	160	4	22	32	25	2	672

Number of samples is 11

Mount Ada Basalt - dolerites (major elements)

	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
SiO ₂												
TiO ₂												
Al ₂ O ₃												
Fe ₂ O ₃		0.68										
FeO	0.60	0.67	-0.58									
Tot. Fe		0.68		0.57	0.65							
MnO	0.58			0.76	0.70	0.75						
MgO		-0.73		-0.56		-0.59						
CaO		-0.54			0.54							
Na ₂ O		-0.74		-0.52	-0.67	-0.70						
K ₂ O		-0.56							0.66	0.53		
P ₂ O ₅		0.61			0.77	0.59						
Ba												
Rb									0.53		0.87	
Sr					-0.61				-0.61	-0.52		
Pb			-0.75			0.59		-0.75				0.85
Th												
U												
Zr		0.95			0.81	0.55		-0.62		-0.73	-0.58	0.72
Nb		0.80		0.66	0.60			-0.78				
V					0.71							0.65
La			-0.80						0.55			0.66
Ce			-0.63		0.92							0.73
Li		0.51		0.77	0.64			-0.51				
V		0.68							-0.56		-0.67	
Cr		-0.61	-0.53	-0.51				0.88	0.66			
Co	0.81		0.56	0.63		0.63	0.67	0.55				
Ni		-0.74		-0.57				0.88				-0.54
Cu												
Zn		0.58		0.50	0.83	0.79	0.69			-0.81		
Ga	-0.59	0.65	-0.92					-0.84		-0.55	0.92	
S					-0.52							

Mount Ada Basalt - dolerites (trace elements)

[illegible]

Mount Ada Basalt - gabbro

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040038	50.89	0.96	15.33	10.88	0.00	9.79	0.18	7.21	8.63	2.81	1.23	0.15
45094	49.96	2.66	12.04	16.76	0.00	15.08	0.22	4.08	8.32	1.85	0.04	0.27
45157	48.76	0.93	15.10	2.26	8.70	10.73	0.15	7.20	9.13	3.18	0.65	0.10
45168	48.20	0.88	16.55	3.35	6.60	9.62	0.16	6.15	11.09	2.24	0.65	0.07
Mean	49.45	1.36	14.76	8.31	7.65	11.31	0.18	6.16	9.34	2.52	0.64	0.15
Maximum	50.89	2.66	16.55	16.76	8.70	15.08	0.22	7.21	11.09	3.18	1.23	0.27
Minimum	48.20	0.88	12.04	2.26	6.60	9.62	0.15	4.08	8.32	1.85	0.04	0.07
S. Dev.	1.21	0.67	1.92	6.81	1.48	2.57	0.03	1.47	1.24	0.59	0.49	0.09

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040038	428	58	458	2	3		88	4	19	24	40	68	167	84	45	196	17	102	17	40
45094	105		235	8	2		184	7	41	11	32	11	404	7	40	13	42	115	24	2000
45157	174	14	148				59	3	17	5	24	12	237	202		94	40	43		280
45168	139	15	119				50		18	4	20	7	261	276		67	105	94		140
Mean	212	29	240	5	3	0	95	5	24	11	29	25	267	142	43	90	51	89	21	615
Maximum	428	58	458	8	3	0	184	7	41	24	40	68	404	276	45	196	105	115	24	2000
Minimum	105	14	119	2	2	0	50	3	17	4	20	7	167	7	40	13	17	43	17	40
S. Dev.	147	25	153	4	1	0	61	2	12	9	9	29	100	120	4	77	38	32	5	929

Number of samples is 4

Mount Ada Basalt - High-Mg Basalt

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040029 <i>F</i>	48.68	1.64	12.34	14.59	0.00	13.13	0.13	9.21	9.28	2.41	0.14	0.16
75040029 <i>G</i>	51.55	0.68	6.52	10.81	0.00	9.73	0.22	14.12	14.42	0.95	0.32	0.04
75040030	52.05	0.69	6.58	10.95	0.00	9.86	0.22	13.53	14.59	1.00	0.31	0.04
75040047 <i>B</i>	50.50	0.90	13.17	13.36	0.00	12.02	0.21	8.45	9.41	1.71	0.10	0.07
75040047 <i>C</i>	49.84	0.77	11.88	13.01	0.00	11.71	0.22	9.71	10.72	1.51	0.18	0.05
75040047 <i>D</i>	51.34	0.83	12.12	11.25	0.00	10.67	0.20	7.95	10.70	1.91	0.24	0.08
75040094	46.60	1.02	10.90	12.84	0.00	11.56	0.21	9.12	9.76	0.15	0.01	0.07
45172	50.13	1.07	8.91	3.44	9.25	12.35	0.22	8.80	10.88	2.42	0.57	0.11
45173	49.18	1.04	8.90	3.63	9.25	12.52	0.20	10.50	8.36	2.76	0.26	0.10
Mean	49.99	0.95	10.15	10.50	9.25	11.50	0.20	10.15	10.90	1.65	0.24	0.08
Maximum	52.05	1.64	13.17	14.59	9.25	13.13	0.22	14.12	14.59	2.76	0.57	0.16
Minimum	46.60	0.68	6.52	3.44	9.25	9.73	0.13	7.95	8.36	0.15	0.01	0.04
S. Dev.	1.68	0.29	2.51	4.12	0.00	1.19	0.03	2.21	2.20	0.84	0.16	0.04

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040029 <i>F</i>	27	2	74				137	6	36	7	13	8	374	280	47	84	91	57	19	240
75040029 <i>G</i>	99	23	92				40	2	16			52	258	1730	40	188	8	47	8	
75040030	96	19	90				39	2	15			9	248	1760	47	185	96	56	7	80
75040047 <i>B</i>	36		103				71	3	20	3		10	253	409	47	74	109	91	12	120
75040047 <i>C</i>	57	2	101	3			53	2	17		4	8	235	653	50	134	62	87	12	120
75040047 <i>D</i>	120	4	115				75	3	23	3		7	218	447	45	94	116	79	12	280
75040094	12		198	2	2		82	4	22	3	5	18	277	385	50	111	71	86	13	80
45172	41	7	157				84	4	21	6		6	235	583		173	141	84		280
45173	36	4	61			4	83		20	8	22	9	222	812		193	138	92		100
Mean	58	9	110	3	2	4	74	3	21	5	11	14	258	784	47	137	92	75	12	163
Maximum	120	23	198	3	2	4	137	6	36	8	22	52	374	1760	50	193	141	92	19	280
Minimum	12	2	51	2	2	4	39	2	15	3	4	6	218	280	40	74	8	47	7	80
S. Dev.	38	9	43	1	1	1	30	1	6	2	8	15	47	567	3	48	42	17	4	88

Number of samples is 9

Mount Ada Basalt - Peridotitic komatiites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040034 C	42.07	0.79	5.58	15.85	0.00	14.27	0.25	25.45	6.80	0.07	0.03	0.07
75040034 E	39.12	0.50	3.57	15.58	0.00	14.02	0.25	28.67	4.10	0.06	0.01	0.04
75040034 F	44.95	0.75	5.27	14.25	0.00	12.83	0.24	22.61	8.19	0.06	0.02	0.07
75040035	40.41	0.58	4.23	15.80	0.00	14.22	0.27	27.82	3.42	0.02	0.01	0.04
Mean	41.64	0.66	4.66	15.37	0.00	13.83	0.25	25.64	5.63	0.05	0.02	0.06
Maximum	44.95	0.79	5.58	15.85	0.00	14.27	0.27	28.67	8.19	0.07	0.03	0.07
Minimum	39.12	0.50	3.57	14.25	0.00	12.83	0.24	22.51	3.42	0.02	0.01	0.04
S. Dev.	2.52	0.14	0.93	0.76	0.00	0.68	0.01	3.05	2.25	0.02	0.01	0.02

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040034 C	9		17				42		11			3	203	4780	107	1480	58	58	12	40
75040034 E	53		23				26		7			3	132	5650	127	2093	20	66	8	200
75040034 F	17		12				41		11			3	208	4100	90	1450	62	69	11	360
75040035	28		15				29		8			4	149	352	124	2061	59	79	9	
Mean	27	0	17	0	0	0	35	0	9	0	0	3	173	3721	112	1771	50	68	10	200
Maximum	53	0	23	0	0	0	42	0	11	0	0	4	208	5650	127	2093	62	79	12	360
Minimum	9	0	12	0	0	0	26	0	7	0	0	3	132	352	90	1450	20	58	8	40
S. Dev.	19	0	5	0	0	0	8	0	2	0	0	1	38	2334	17	354	20	9	2	160

Number of samples is 4

DUFFER FORMATION - tholeiitic basalts [TB]

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040045 H	52.66	0.97	15.91	11.28	0.00	10.15	0.16	5.37	8.01	2.54	0.64	0.12
75040060 C	51.94	0.87	13.82	12.54	0.00	11.29	0.21	6.86	10.52	1.37	0.43	0.07
75040060 D	50.14	2.33	12.71	17.93	0.00	16.14	0.25	4.40	7.75	2.23	0.06	0.19
49285	47.20	1.16	14.80	1.00	11.20	12.10	0.14	5.15	6.54	1.11	1.93	0.11
49314	58.47	0.46	11.05	1.16	6.25	7.29	0.16	7.85	5.71	2.66	0.84	0.07
Mean	52.08	1.16	13.66	8.78	8.73	11.39	0.18	5.93	7.71	1.98	0.78	0.11
Maximum	58.47	2.33	15.91	17.93	11.20	16.14	0.25	7.85	10.52	2.66	1.93	0.19
Minimum	47.20	0.46	11.05	1.00	6.25	7.29	0.14	4.40	5.71	1.11	0.86	0.07
S. Dev.	4.15	0.70	1.88	7.46	3.50	3.22	0.05	1.40	1.83	0.70	0.70	0.05

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040045 H	389	16	367	5	2		127	5	25	14	28	14	163	146	37	76	57	79	15	280
75040060 C	175	11	131	4			80	4	23	3	10	6	282	225	43	60	60	97	15	200
75040060 D	31		287	7			168	8	44	4	27	8	519	223	39	37	45	150	21	40
49285	339	56	138				56		18	10	27	28	222	177		118	100	101		760
49314	811	15	230	2	5	3	61	2	13	9	24	14	122	710		183	54	58		520
Mean	349	25	231	5	4	3	98	5	25	8	23	14	262	296	40	95	63	97	17	360
Maximum	811	56	367	7	5	3	168	8	44	14	28	28	519	710	43	183	100	150	21	760
Minimum	31	11	131	2	2	3	56	2	13	3	10	6	122	146	37	37	45	58	15	40
S. Dev.	294	21	100	2	2	2	48	3	12	5	8	9	156	234	3	57	21	34	3	283

Number of samples is 5

DUFFER FORMATION - dolerites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040043 A	50.29	1.35	13.78	15.32	0.00	13.79	0.22	5.86	9.09	2.51	0.56	0.08
75040046 G	50.21	1.08	14.58	13.57	0.00	12.21	0.22	6.61	9.72	2.26	0.25	0.07
75040046 J	50.04	1.33	13.28	16.23	0.00	14.61	0.25	6.43	8.86	1.64	0.22	0.09
75040066 C	49.66	2.18	13.47	16.95	0.00	15.26	0.24	4.85	7.22	2.25	0.47	0.18
Mean	50.05	1.49	13.78	15.52	0.00	13.97	0.23	5.94	8.72	2.17	0.38	0.11
Maximum	50.29	2.18	14.58	16.95	0.00	15.26	0.25	6.61	9.72	2.51	0.56	0.18
Minimum	49.66	1.08	13.28	13.57	0.00	12.21	0.22	4.85	7.22	1.64	0.22	0.07
S. Dev.	0.28	0.48	0.57	1.46	0.00	1.31	0.02	0.79	1.07	0.37	0.17	0.05

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040043 A	836	24	186			1	83	3	26			14	414	151	42	84	110	107	16	320
75040046 G	80	5	243	7			56	3	19			8	342	147	45	104	114	98	16	
75040046 J	84	5	190	6			84	3	27		9	8	394	154	45	89	87	116	16	920
75040066 C	368	22	321	6		1	144	6	35	7	19	9	434	250	45	49	52	123	18	1440
Mean	342	14	235	6	0	1	92	4	27	7	14	10	396	176	44	82	91	111	17	893
Maximum	836	24	321	7	0	1	144	6	35	7	19	14	434	250	45	104	114	123	18	1440
Minimum	80	5	186	6	0	1	56	3	19	7	9	8	342	147	42	49	52	98	16	320
S. Dev.	356	10	63	1	0	0	37	2	7\$\$\$\$\$	7	3	40	50	2	25	28	11	1		560

Number of samples is 4

DUFFER FORMATION - andesites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot.Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040046 <i>N</i>	59.27	0.84	15.16	7.41	0.00	6.67	0.12	3.82	5.92	3.37	0.82	0.22
75040056 <i>A</i>	53.98	1.58	15.10	11.24	0.00	10.12	0.21	4.16	5.13	2.56	2.09	0.35
75040066 <i>B</i>	53.44	1.37	14.65	9.45	0.00	8.51	0.19	3.31	7.11	2.34	2.80	0.30
75040066 <i>D</i>	55.76	1.22	14.02	9.70	0.00	8.73	0.18	3.20	6.45	2.75	1.57	0.24
75040069 <i>E</i>	56.11	1.15	14.08	10.89	0.00	9.80	0.16	1.80	5.65	3.11	0.85	0.17
49279	55.32	1.06	16.56	1.45	3.55	4.86	0.12	2.04	5.17	3.22	3.95	0.47
49301	58.29	0.61	16.35	1.63	3.25	4.72	0.10	2.26	4.55	5.10	2.88	0.18
49304	50.91	0.91	17.34	2.51	5.20	7.46	0.15	3.32	7.78	2.34	3.34	0.17
49305	56.43	0.85	15.31	1.59	5.75	7.18	0.14	3.88	4.83	4.64	0.73	0.17
49316	58.16	0.75	16.93	1.88	4.60	6.22	0.12	3.84	3.71	4.26	1.55	0.12
Mean	55.77	1.03	15.55	5.77	4.47	7.43	0.15	3.16	5.63	3.37	2.06	0.24
Maximum	59.27	1.58	17.34	11.24	5.75	10.12	0.21	4.16	7.78	5.10	3.95	0.47
Minimum	50.91	0.61	14.02	1.45	3.25	4.72	0.10	1.80	3.71	2.34	0.73	0.12
S. Dev.	2.52	0.30	1.18	4.31	1.06	1.88	0.04	0.84	1.23	0.98	1.14	0.11

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040046 <i>N</i>	858	47	361	5	9	2	304	12	41	40	72	12	24	129	22	79	13	68	18	80
75040056 <i>A</i>	1020	42	324	8	4	1	125	7	26	22	45	10	183	74	28	7	12	114	16	80
75040066 <i>B</i>	783	31	256	6	5	1	146	8	28	30	55	8	228	16	23	6	25	91	18	280
75040066 <i>D</i>	541	23	379	10	5	1	115	8	24	21	36	8	180	14	22	6	41	89	17	440
75040069 <i>E</i>	420	23	228	8	2	1	158	7	24	19	39	20	220	76	54	186	90	92	17	720
49279	500	115	92	2	7		178	8	23	34	74	12	121	119		65	47	91		520
49301	1281	57	513	6	9		131	3	13	33	61	6	114	50		38	55	57		60
49304	1124	69	435	3	4		123	5	24	22	45	11	147	60		29	122	87		160
49305	336	19	348	8	7		124	4	18	21	49	9	138	34		49	27	70		60
49316	501	32	434	3			99	2	12	11	26	7	91	24		52	7	79		
Mean	736	47	337	6	6	1	150	6	23	25	50	10	145	60	30	52	44	84	17	267
Maximum	1281	115	513	10	9	2	304	12	41	40	74	20	228	129	54	186	122	114	18	720
Minimum	336	19	92	2	2	1	99	2	12	11	26	6	24	14	22	6	7	57	16	60
S. Dev.	326	30	121	3	2	0	58	3	8	9	15	4	62	41	14	54	37	16	1	241

Number of samples is 10

DUPPER FORMATION - andesites (major elements)

	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot.Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
SiO ₂												
TiO ₂	-0.54											
Al ₂ O ₃		-0.57										
Fe ₂ O ₃		0.79	-0.83									
FeO												
Tot.Fe		0.78	-0.69	0.86	0.96							
MnO	-0.61	0.93	-0.58	0.79	0.87	0.90						
MgO					0.88							
CaO	-0.70											
Na ₂ O	0.73	-0.77		-0.63		-0.63	-0.74		-0.77			
K ₂ O	-0.53		0.56		-0.64							
P ₂ O ₅		0.57								0.56		
Ba												
Rb			0.63		-0.68	-0.64				0.81	0.59	
Sr		-0.51									-0.74	
Pb			-0.76	0.54		0.52						
Th	0.66	-0.66		-0.58	-0.62	-0.82	-0.73			0.66		
U	0.87	-0.80	0.58	-0.86		-0.86	-0.85			0.73	-0.53	
Zr					-0.51							
Nb			-0.52	0.58						-0.57		
Y				0.55					0.55	-0.59		
La					-0.67							
Ce					-0.57	-0.50						0.56
Li												
V	-0.62	0.70		0.54		0.69	0.75					
Cr					-0.51							
Co				0.55		0.55						
Ni							-0.83					-0.55
Cu	-0.53						-0.56		0.53			
Zn	-0.63	0.90		0.60		0.70	0.82			-0.78		0.53
Ga		-0.66		-0.82		-0.82	-0.63		0.73			
S							-0.71					

DUFFER FORMATION - andesites (trace elements)

	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
Ba																				
Rb																				
Sr	0.53																			
Pb		-0.63																		
Th																				
U		0.70		-0.69	0.89															
Zr						0.98														
Nb						0.97	0.79													
Y						0.97	0.81	0.94												
La	0.52				0.79	0.88	0.76	0.62	0.57											
Ce	0.65				0.77	0.87	0.71	0.52		0.95										
Li		-0.55		-0.54																
V				-0.82	-0.97	-0.55														
Cr	0.59				0.78	0.77	0.57	0.55	0.61	0.69	0.53									
Co	-0.59	-0.71		-0.73					-0.54		0.93									
Ni											0.86									
Cu															0.87					
Zn															0.86					
Ga		-0.51		-0.76	-0.78								0.62							
S	-0.59	-0.68		-0.67	0.59	0.53	0.60	0.66	0.60	0.74	0.67							-0.84		
				-0.55								0.67			0.76	0.59				

DUFFER FORMATION - dacites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040059A	56.04	0.93	14.48	7.83	0.00	7.05	0.14	3.65	5.07	3.17	0.88	0.23
75040060A	58.65	0.78	14.83	6.86	0.00	6.17	0.11	4.45	3.19	2.44	2.02	0.14
75040062B	62.68	0.69	15.90	5.48	0.00	4.93	0.09	2.04	3.23	4.61	1.56	0.13
45195	67.10	0.51	17.22	0.57	1.80	2.31	0.06	1.53	2.89	4.46	1.99	0.12
45198	67.26	0.44	16.52	0.78	0.45	1.15	0.06	1.47	6.61	1.82	1.73	0.13
45199	63.01	0.47	17.33	1.24	1.50	2.62	0.10	2.72	6.28	1.34	2.37	0.12
49209	69.07	0.49	13.73	0.79	1.00	1.71	0.11	1.32	3.88	3.39	3.12	0.13
49210	67.68	0.57	16.07	1.07	0.75	1.71	0.09	1.57	2.75	5.55	1.81	0.16
49280	63.18	0.84	16.21	0.76	1.15	1.83	0.07	1.11	3.44	3.96	3.96	0.21
49287	64.32	0.53	15.35	0.88	3.35	4.14	0.06	1.73	1.73	1.37	6.03	0.17
49288	63.48	0.53	15.10	0.68	2.90	3.51	0.08	2.58	2.04	1.99	5.04	0.13
49290	60.28	0.51	14.37	0.60	4.10	4.82	0.07	2.98	2.97	2.24	4.55	0.16
49291	59.70	0.61	14.42	0.73	3.95	4.61	0.13	2.60	3.32	1.05	6.02	0.24
49294	58.47	0.81	14.92	1.14	4.25	5.28	0.14	2.12	5.65	1.08	3.38	0.20
49295	60.02	0.47	12.85	1.01	5.80	6.71	0.23	3.14	4.19	4.42	0.19	0.14
49296	63.52	0.57	13.48	1.36	3.40	4.62	0.14	2.48	3.15	3.69	1.71	0.12
49297	64.01	0.55	12.00	1.78	3.00	4.60	0.15	2.60	4.29	5.10	0.32	0.12
49298	56.94	0.62	12.56	1.60	5.65	7.09	0.20	2.84	6.50	3.74	0.79	0.18
49303	62.62	0.50	12.86	1.48	2.80	4.14	0.11	2.60	4.80	4.88	0.78	0.11
49306	65.59	0.48	14.03	1.50	2.15	3.50	0.08	2.01	3.78	4.10	1.81	0.12
49307	64.50	0.46	15.74	2.20	1.45	3.43	0.07	1.04	4.54	7.00	0.20	0.10
49308	65.40	0.41	14.81	1.44	1.65	2.95	0.07	1.32	4.51	3.58	2.28	0.11
49309	61.37	0.48	16.22	2.56	2.70	5.00	0.09	2.56	5.24	4.64	0.39	0.10
49310	59.89	0.55	15.55	2.81	2.80	5.33	0.13	1.93	7.78	4.20	0.26	0.15
49311	59.69	0.62	16.34	2.08	3.45	5.32	0.11	2.16	5.52	5.20	2.42	0.14
49313	62.71	0.53	16.36	1.73	2.05	3.61	0.09	0.75	4.94	4.22	2.20	0.14
Mean	62.59	0.58	14.98	1.97	2.70	4.16	0.11	2.20	4.36	3.58	2.14	0.15
Maximum	69.07	0.93	17.33	7.83	5.90	7.09	0.23	4.45	7.78	7.00	6.03	0.24
Minimum	56.04	0.41	12.00	0.57	0.45	1.15	0.06	0.75	1.73	1.05	0.19	0.10
St. Dev.	3.37	0.13	1.44	2.68	1.44	1.66	0.04	0.85	1.52	1.53	1.75	0.04

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040059A	356	20	152	7	4	1	144	7	22	27	47	10	143	85	22	51	7	89	16	120
75040060A	496	53	104	6	5	1	146	6	19	27	42	10	127	67	23	51	218	84	17	320
75040062B	426	41	199	2	5	1	167	6	15	20	36	8	100	18	15	23	5	59	20	40
45195	285	62	172	8	9		180	5	12	31	62	31	67	33		7	40	26		20
45196	1309	66	191	5	10		187	6	12	31	57	17	53	41		12	4	25		80
45199	1556	78	205	6	11	2	187	5	14	28	57	27	78	48		14	3	53		20
49209	4410	99	91		8		167	6	18	30	56	21	63	24		15	18	32		80
49210	2603	54	97		10	2	213	6	20	35	62	23	60	24		23	25	33		40
49280	470	105	64	3	6		157	5	17	32	59	7	100	100		20	43	63		280
49287	928	131	45	11	11	3	186	7	14	42	86	12	36	35		25	22	51		720
49288	713	129	57	4	11	2	158	5	13	38	71	11	61	35		27	17	59		200
49290	542	113	73	4	11	4	161	5	13	38	73	13	63	34		26	17	68		80
49291		136	47	5	9	3	154	7	15	39	77	11	64	47		37	11	68		220
49294	1356	100	101	8	11	4	194	9	26	37	70	18	103	27		17	27	88		260
49295	951	6	189	6	7		131	4	13	23	50	16	66	19		24	23	88		280
49296	258	67	139	6	7		152	4	14	24	50	10	82	28		30	48	93		80
49297	89	11	140	5	5	3	119	3	12	22	39	9	57	61		38	23	35		200
49298	81	28	186	19	6		123	2	11	27	54	11	87	29		37	20	79		40
49303	358	26	171	4	6	2	124	3	12	21	44	8	12	48		36	41	52		100
49306	662	47	245	2	6	3	97	3	9	24	46	6	50	29		26	5	43		100
49307	89	5	490	8	7	3	126	3	10	27	50	4	10	34		26	3	32		20
49308	347	97	390	5	5		116	3	8	18	43	4	56	32		2	8	39		
49309	218	11	55	6	5		90	2	8	21	43	7	81	50		39	16	62		60
49310	125	7	870	13	5		114	4	10	20	45	6	72	115		59	113	62		60
49311	307	12	665	5	3		104	2	11	17	34	10	85	31		24	3	65		80
49313	559	20	311		3		123	3	12	11	31	4	54	7		6	63	39		60
Mean	780	62	218	6	7	2	147	5	14	27	53	12	71	42	20	27	32	57	18	142
Maximum	4410	136	870	18	11	4	213	9	26	42	86	31	143	115	23	59	218	93	20	720
Minimum	81	5	45	2	3	1	90	2	8	11	31	4	10	7	15	2	3	25	16	20
S. Dev.	950	43	199	4	3	1	32	2	4	8	14	7	29	25	4	14	45	21	2	151

Number of samples is 26

[illegible]

DUFFER FORMATION - dacitas (trace elements)

	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
Ba																				
Rb																				
Sr		-0.53																		
Pb																				
Th		0.60	-0.51																	
U																				
Zr	0.53				0.54															
Nb	0.51	0.55			0.76															
Y		0.53			0.59		0.85													
La							0.65	0.84												
Ce		0.65	-0.56		0.86		0.70	0.69												
Li	0.55	0.71	-0.51		0.88	0.55	0.65	0.61		0.95										
V					0.63		0.71													
Cr									0.57											
Co				0.95																
Ni						-0.98			0.85	0.97	0.83	0.99	0.88	0.93						
Cu														0.63	0.99					
Zn															0.60					
Ga													0.64		0.96	0.50				
S			-1.00	0.69			0.99	-0.69	-0.98	-0.99	-0.97	-0.97	-0.99	-1.00	-0.94	-0.97		-1.00		
															0.80				-0.53	

DUFFER FORMATION - qz latites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	H ₂ O	P ₂ O ₅
75040062	63.08	0.62	16.63	5.42	0.00	4.88	0.08	1.86	3.55	2.94	3.13	0.13
45196	66.37	0.55	17.81	0.85	1.85	2.62	0.06	1.88	2.36	2.00	3.58	0.15
45200	57.08	0.61	15.70	2.35	3.80	5.92	0.18	3.10	7.80	0.33	6.41	0.26
49205	64.71	0.63	16.69	0.84	1.45	2.21	0.05	1.07	3.69	2.20	5.59	0.28
49206	65.45	0.48	16.77	0.80	1.05	1.77	0.05	1.17	2.75	0.52	8.63	0.16
Mean	63.34	0.58	16.72	2.05	2.04	3.48	0.08	1.78	4.03	1.60	5.47	0.20
Maximum	66.37	0.63	17.81	5.42	3.80	5.92	0.18	3.10	7.80	2.94	8.63	0.28
Minimum	57.08	0.48	15.70	0.80	1.05	1.77	0.05	1.07	2.36	0.33	3.13	0.13
S. Dev.	3.70	0.06	0.75	1.99	1.22	1.82	0.06	0.81	2.18	1.13	2.23	0.07

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040062	1667	66	443	8	8	1	158	5	15	27	43	7	87	15	16	9	5	48	18	40
45196	811	118	113	5	9		193	6	12	29	56	36	53	50		17	26	32		60
45200	296	155	80	7	10		220	9	25	43	90	16	68	52		23	52	66		80
49205	167	141	111	8	10		237	10	23	38	79	21	71	54		32	42	49		80
49206	481	137	83	6	9		202	7	19	31	68	25	70	42		19	46	31		80
Mean	684	123	166	7	9	1	202	7	19	34	67	21	70	43	16	20	34	45	18	68
Maximum	1667	155	443	8	10	1	237	10	25	43	90	36	87	54	16	32	52	66	18	80
Minimum	167	66	80	5	8	1	158	5	12	27	43	7	53	15	16	9	5	31	18	40
S. Dev.	600	55	156	1	1	1	30	2	5	7	19	11	12	16	16	8	19	14	18	18

Number of samples is 5

DUFFER FORMATION - rhyolites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	P ₂ O ₅	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040046 Z	69.24	0.33	12.94	4.26	0.00	3.83	0.14	1.32	3.01	1.16	3.13	0.04
75040046 F	71.15	0.33	13.82	3.82	0.00	3.44	0.06	0.94	2.23	4.15	3.03	0.04
75040046 M	70.84	0.32	13.74	3.74	0.00	3.37	0.06	0.99	2.48	4.11	2.77	0.03
49208	68.03	0.42	13.42	0.37	1.90	2.23	0.08	0.95	1.91	0.18	10.15	0.12
49211	71.07	0.31	11.52	0.23	1.45	1.66	0.06	0.75	1.61	0.21	9.76	0.09
49281	71.18	0.40	11.81	0.81	2.05	2.78	0.07	1.24	2.61	2.04	3.33	0.12
Mean	70.25	0.35	12.89	2.21	1.86	2.88	0.08	1.03	2.31	1.98	5.36	0.07
Maximum	71.15	0.42	13.82	4.26	2.05	3.83	0.14	1.32	3.01	4.15	10.15	0.12
Minimum	68.03	0.31	11.52	0.23	1.45	1.66	0.06	0.75	1.61	0.18	2.77	0.03
S. Dev.	1.31	0.05	0.96	1.92	0.31	0.82	0.03	0.21	0.50	1.81	3.66	0.04

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040046 Z	988	54	332	5	10	2	281	12	40	37	69	7	23	11	4	6	11	52	17	40
75040046 F	750	119	76	4	13	2	300	13	49	68	120	7	16	14	8	12	5	25	17	40
75040046 M	369	24	470	5	5	2	217	10	21	29	55	6	103	12	7	12	5	23	15	40
49208	1045	174	64	2	6		153	6	14	28	57	15	60	25		13	18	58		120
49211	454	129	24		8		174	5	13	27	58	6	21	10		3	3	15		360
49281	439	99	50	4	9		174	6	13	31	57	9	33	40		20	22	44		220
Mean	674	100	169	4	9	2	217	9	25	37	69	9	43	19	6	11	11	36	16	137
Maximum	1045	174	470	5	13	2	300	13	49	68	120	15	103	40	8	20	22	58	17	360
Minimum	369	24	24	2	5	2	153	5	13	27	55	6	16	10	4	3	3	15	15	40
S. Dev.	296	54	185	1	3	0	61	3	16	16	25	3	33	12	2	6	8	18	1	130

Number of samples is 6

DUFFER FORMATION - tuffs

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040046 L	71.15	0.33	13.82	3.82	0.00	3.44	0.06	0.94	2.23	4.15	3.03	0.04
75040046 H	70.84	0.32	13.74	3.74	0.00	3.37	0.06	0.93	2.48	4.11	2.77	0.03
75040059 A	56.04	0.93	14.48	7.83	0.00	7.05	0.14	3.65	6.07	3.17	0.88	0.23
75040060 A	58.65	0.78	14.83	6.86	0.00	6.17	0.11	4.45	3.19	2.44	2.02	0.14
75040066 B	53.44	1.37	14.65	9.45	0.00	8.51	0.19	3.31	7.11	2.34	2.88	0.30
49281	71.18	0.40	11.81	0.81	2.05	2.78	0.07	1.24	2.61	2.04	3.33	0.12
49287	64.32	0.53	15.35	0.88	3.35	4.14	0.06	1.73	1.73	1.37	6.03	0.17
49288	63.48	0.53	15.10	0.68	2.90	3.51	0.08	2.58	2.04	1.99	5.04	0.13
49290	60.28	0.51	14.37	0.80	4.10	4.82	0.07	2.98	2.97	2.24	4.55	0.16
49291	59.70	0.61	14.42	0.73	3.95	4.61	0.13	2.60	3.32	1.05	6.02	0.24
49294	58.47	0.81	14.92	1.14	4.25	5.28	0.14	2.12	5.65	1.08	3.35	0.20
49295	60.02	0.47	12.85	1.01	5.80	6.71	0.23	3.14	4.19	4.42	0.19	0.14
49296	63.52	0.57	13.48	1.36	3.40	4.62	0.14	2.48	3.15	3.60	1.71	0.12
49297	64.01	0.55	12.00	1.78	3.00	4.60	0.15	2.60	4.22	5.10	0.32	0.12
49298	56.94	0.62	12.66	1.60	5.65	7.09	0.20	2.84	6.50	3.74	0.79	0.18
49303	62.62	0.50	12.86	1.49	2.80	4.14	0.11	2.60	4.80	4.88	0.78	0.11
49305	56.43	0.85	15.31	1.59	5.75	7.18	0.14	3.88	4.83	4.64	0.73	0.17
Mean	61.83	0.63	13.92	2.68	3.92	5.18	0.12	2.60	3.95	3.08	2.61	0.15
Maximum	71.18	1.37	15.35	9.45	5.80	8.51	0.23	4.45	7.11	5.10	6.03	0.30
Minimum	53.44	0.32	11.81	0.68	2.05	2.78	0.06	0.94	1.73	1.05	0.19	0.03
S. Dev.	5.37	0.26	1.14	2.76	1.25	1.65	0.05	0.98	1.65	1.36	1.93	0.07

Sample no.	Ba	Kb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040046 L	750	119	76	4	13	2	300	13	49	68	120	7	16	14	8	12	5	25	17	40
75040046 H	369	24	470	5	5	2	217	10	21	29	55	6	103	12	7	12	5	23	15	40
75040059 A	356	28	352	7	4	1	144	7	22	27	47	10	143	85	22	51	7	89	16	120
75040060 A	411	63	104	6	5	1	146	6	19	26	42	10	127	67	23	51	218	84	17	320
75040066 B	783	31	256	6	5	1	146	8	28	30	55	8	228	16	23	6	25	91	18	280
49281	439	99	50	4	9		174	6	13	31	57	9	33	40		20	22	44		220
49287	926	131	45	11	11	3	186	7	14	42	86	12	56	35		25	22	51		720
49288	713	129	57	4	11	2	158	5	13	38	71	11	61	35		27	17	59		200
49290	542	113	73	4	11	4	161	5	13	38	73	13	63	34		26	17	68		80
49291		136	47	5	9	3	154	7	15	39	77	11	64	47		37	11	68		220
49294	1358	100	101	8	11	4	194	9	26	37	70	18	103	27		17	27	88		260
49295	951	6	189	6	7		131	4	13	33	50	16	66	19		24	23	88		280
49296	258	67	139	6	7		152	4	14	24	50	10	82	28		30	48	93		80
49297	89	11	140	5	5	3	119	3	12	22	39	9	57	61		38	23	35		200
49298	81	28	186	18	6		123	2	11	27	54	11	87	29		37	20	79		40
49303	358	26	171	4	6	2	124	3	12	21	44	8	12	48		36	41	52		100
49305	336	19	348	8	7		124	4	18	21	49	9	138	34		49	27	70		60
Mean	550	66	165	7	8	2	162	6	18	32	61	10	85	37	17	29	33	65	17	192
Maximum	1358	136	470	18	13	4	300	13	49	68	120	18	228	85	23	51	218	93	18	720
Minimum	81	6	45	4	4	1	119	2	11	21	39	6	12	12	7	6	5	23	15	60
S. Dev.	343	48	125	4	3	1	45	3	9	12	20	3	53	20	8	14	49	23	1	166

Number of samples is 17

DEEPER FORMATION - tuffs (major elements)

	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
SiO ₂												
TiO ₂	-0.82											
Al ₂ O ₃												
Fe ₂ O ₃		0.67										
FeO	-0.86	0.53										
Tot. Fe	-0.89	0.81		0.54	0.97							
MnO	-0.69				0.72	0.76						
MgO	-0.84	0.64			0.73	0.77	0.54					
CaO	-0.76	0.74			0.59	0.81	0.76					
Na ₂ O			-0.50									
K ₂ O							-0.59		-0.55	-0.82		
P ₂ O ₅	-0.83	0.83				0.70	0.52	0.55	0.64			
Ba										-0.60	0.50	
Rb						-0.55	-0.62		-0.61	-0.76	0.90	
Sc					0.65					0.51	-0.52	
Pb					0.55							
Th				-0.53		-0.52	-0.51		-0.54		0.68	
U				-0.91	0.88							
Zr	0.64					-0.52	-0.60	-0.72				
Nb								-0.51				
Y												
La							-0.52	-0.55			0.60	
Ce								-0.57			0.64	
Li												
V	-0.68	0.89		0.73	0.71	0.78		0.56	0.61			0.64
Cr					-0.57			0.51				
Co	-0.97	0.88	0.98	0.93		0.93	0.86	0.97	0.75	-0.95	-0.58	0.87
Ni								0.69				
Cu								0.53				
Zn	-0.83	0.67			0.65	0.74	0.67	0.71	0.57			0.71
Ga	-0.53	0.64	0.58	0.59		0.59	0.61			-0.65		0.57
S										-0.53		

DUFFER FORMATION - tuffs (trace elements)

	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
Ba																				
Rb																				
Sr		-0.74																		
Pb																				
Th	0.58	0.85	-0.67																	
U					0.59															
Zr		0.51			0.61															
Nb	0.51						0.89													
Y							0.79	0.85												
La		0.73			0.79		0.86	0.74	0.71											
Ce		0.75			0.85		0.82	0.68	0.62	0.98										
Li	0.63					0.66														
V			0.54		-0.52															
Cr																				
Co				0.85	-0.60	-1.00	-0.88	-0.87		-0.60	-0.65	0.86	0.75	0.66						
Ni	-0.52						-0.60	-0.56						0.80	0.56					
Cu																				
Zn							-0.52					0.54	0.57		1.00					
Ga	0.85		-0.70												0.53			0.50		
S	0.52														0.85				0.66	

DUFFER FORMATION - agglomerates

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅								
75040066	55.76	1.22	14.02	9.70	0.00	8.73	0.18	3.20	6.45	2.75	1.57	0.24								
45200	57.08	0.61	15.70	2.35	3.80	5.92	0.18	3.10	7.80	0.33	6.41	0.26								
49205	64.71	0.63	16.69	0.84	1.45	2.21	0.05	1.07	3.69	2.20	5.59	0.29								
49206	65.45	0.48	16.77	0.80	1.05	1.77	0.05	1.17	2.75	0.52	8.63	0.16								
Mean	60.75	0.74	15.80	3.42	2.10	4.66	0.12	2.14	5.17	1.45	5.55	0.24								
Maximum	65.45	1.22	16.77	9.70	3.80	8.73	0.18	3.20	7.80	2.75	8.63	0.28								
Minimum	55.76	0.48	14.02	0.80	1.05	1.77	0.05	1.07	2.75	0.33	1.57	0.16								
S. Dev.	5.04	0.33	1.28	4.25	1.49	3.29	0.08	1.17	2.35	1.21	2.95	0.05								

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040066	541	23	379	10	5	1	115	8	24	21	36	8	180	14	22	6	41	89	17	440
45200	296	155	80	7	10		220	9	25	43	90	16	68	52		23	52	66		80
49205	167	141	111	3	10		237	10	23	38	79	21	71	54		32	42	49		80
49206	481	137	83	6	9		202	7	19	31	68	25	70	42		19	46	31		80
Mean	371	114	163	8	9	1	194	9	23	33	68	18	97	41	22	20	45	59	17	170
Maximum	541	155	379	10	10	1	237	10	25	43	90	16	68	52	22	23	52	66	17	440
Minimum	167	23	80	6	5	1	115	7	19	21	36	8	68	14	22	6	41	31	17	80
S. Dev.	172	61	145	2	2	2	54	1	3	10	23	7	55	18	22	11	5	25	17	180

Number of samples is 4

Apex Basalt - tholeiites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040080	54.34	0.73	14.02	10.96	0.00	9.86	0.19	4.54	4.09	2.30	2.38	0.05
49219	48.99	0.51	14.36	2.50	7.85	10.10	0.25	7.95	10.63	2.98	0.08	0.06
49220	51.60	0.61	13.63	1.79	7.70	9.31	0.21	7.55	9.84	1.16	0.59	0.06
49222	48.19	0.59	13.32	2.34	6.40	8.51	0.19	5.90	11.57	1.82	0.08	0.06
49224	50.47	0.53	13.33	3.61	6.00	9.25	0.21	6.50	14.89	0.57	0.13	0.05
49225	49.74	0.58	13.60	1.68	7.50	9.01	0.20	7.06	10.04	2.80	0.09	0.07
49230	52.25	1.13	12.90	2.95	10.60	13.26	0.24	4.90	6.47	3.20	0.22	0.10
49234	48.06	0.92	13.72	3.57	8.45	11.66	0.17	7.35	11.43	1.55	0.03	0.07
49235	49.22	0.97	13.69	2.12	9.30	11.93	0.19	6.45	11.39	2.00	0.03	0.09
49236	47.79	1.00	13.90	3.14	9.25	12.08	0.19	7.40	10.65	1.90	0.06	0.08
49239	48.41	1.66	13.29	3.15	10.70	13.54	0.20	5.85	10.50	1.92	0.04	0.19
49240	47.39	1.00	13.31	3.47	8.95	12.07	0.19	6.85	11.64	1.54	0.24	0.08
49325	49.76	0.99	11.86	2.90	8.05	10.66	0.21	7.75	14.45	1.70	0.09	0.12
Mean	49.71	0.87	13.46	3.46	8.40	10.86	0.20	6.62	10.81	1.96	0.31	0.08
Maximum	54.34	1.66	14.36	10.96	10.70	13.54	0.25	7.95	14.89	3.20	2.38	0.19
Minimum	47.39	0.53	11.86	1.68	6.00	8.51	0.17	4.54	4.09	0.57	0.03	0.05
S. Dev.	2.01	0.31	0.61	2.34	1.46	1.66	0.02	1.07	3.04	0.73	0.64	0.04

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040080	125	37	48				44	2	13			16	289	72	32	36	127	89	14	40
49219	25	2	78				47		18	3	17	32	246	348		109	61	66		100
49220	73	45	92				35		13		13	40	234	343		102	84	65		100
49222	5		72				34		12	4	16	23	237	349		101	78	62		220
49224	9	3	150				29		12	3	16	18	214	345		97	49	54		140
49225	49	4	189				33		14	5	18	21	254	345		97	81	64		120
49230	243	5	159				66		21	7	26	22	361	13		42	14	113		320
49234	37		178				45		18	4	17	11	305	168		181	144	88		1320
49235	22		108				51		21		18	10	308	166		126	140	84		1040
49236	34		150				56	2	22	3	17	13	320	158		119	139	90		1080
49239	26		157				109		33	8	29	11	303	152		97	91	92		560
49240	63	4	159				58		22	4	18	8	310	158		121	142	87		360
49325	7		136				62	2	19	6	27	2	254	447		128	19	85		20
Mean	55	14	129	0	0	0	51	2	18	5	19	17	280	236	32	104	90	80	14	417
Maximum	243	45	189	0	0	0	109	3	33	8	29	40	361	447	32	181	144	113	14	1320
Minimum	5	2	48	0	0	0	29	2	12	3	13	2	214	13	32	36	14	54	14	20
S. Dev.	65	18	44	0	0	0	21	1	6	2	5	10	43	132	37	37	46	16	14	445

Number of samples is 13

Apex Basalt - dolerites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040076 A	49.07	0.81	14.31	11.90	0.00	10.71	0.19	8.10	9.36	3.10	0.37	0.04
75040076 B	50.11	1.09	13.50	14.51	0.00	13.06	0.24	6.47	7.90	2.75	0.41	0.06
49215	48.70	1.70	13.35	3.50	10.60	13.75	0.20	5.80	9.32	1.74	0.71	0.22
49229	50.81	0.56	13.22	0.91	7.00	7.82	0.23	9.50	8.75	3.08	0.56	0.06
49341	52.14	0.59	14.05	2.06	7.60	9.45	0.17	7.80	10.39	1.97	0.08	0.07
Mean	50.17	0.95	13.69	6.58	8.40	10.96	0.21	7.53	9.14	2.53	0.43	0.09
Maximum	52.14	1.70	14.31	14.51	10.60	13.75	0.24	9.50	10.39	3.10	0.71	0.22
Minimum	48.70	0.56	13.22	0.91	7.00	7.82	0.17	5.80	7.90	1.74	0.08	0.04
S. Dev.	1.38	0.47	0.47	6.19	1.93	2.47	0.03	1.45	0.91	0.64	0.24	0.07

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040076 A	91	6	149				45	2	16			14	278	244	44	93	161	63	13	80
75040076 B	91	7	128				61	4	22		3	12	366	21	49	45	173	83	15	80
49215	2507	4	290				99	4	33	6	305	22	314	164		97	86	89		440
49229	387	17	203				34		13	7	16	39	213	597		25	93	70		120
49341			125				34		13	2	17	8	238	356		109	156	74		220
Mean	769	9	179	0	0	0	55	3	19	5	85	19	282	276	47	74	134	76	14	188
Maximum	2507	17	290	0	0	0	99	4	33	7	305	39	366	597	49	209	173	89	15	440
Minimum	91	4	125	0	0	0	34	2	13	2	3	8	213	21	44	25	86	63	13	80
S. Dev.	1167	6	69	0	0	0	27	1	8	3	147	12	61	217	4	37	41	10	1	152

Number of samples is 5

Apex Basalt - High-Mg Basalt

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040078 <i>F</i>	50.23	0.46	9.74	11.26	0.00	10.13	0.20	12.95	9.56	1.04	0.04	0.01
75040079 <i>A</i>	48.23	0.66	11.46	13.18	0.00	11.86	0.20	11.04	9.92	3.20	0.03	0.03
75040079 <i>B</i>	51.28	0.57	12.93	10.17	0.00	9.15	0.16	9.11	9.17	3.39	0.05	0.03
75040079 <i>D</i>	52.52	0.62	12.76	10.60	0.00	9.54	0.16	9.96	8.09	4.33	0.04	0.04
49216	51.02	0.55	11.25	1.32	8.85	19.04	0.18	10.40	7.83	3.00	0.32	0.04
49217	51.56	0.58	13.41	2.12	7.65	9.56	0.17	8.15	9.61	2.88	0.48	0.04
49218	50.64	0.57	12.98	2.25	7.85	9.88	0.18	9.40	9.49	2.14	0.18	0.05
49221	50.96	0.60	13.41	2.69	7.30	9.72	0.15	8.45	11.07	1.15	0.27	0.05
49223	50.61	0.60	13.53	2.61	7.45	9.80	0.19	8.80	10.69	1.66	0.24	0.06
49232	50.93	0.40	14.04	1.82	7.35	8.99	0.15	10.10	9.47	1.19	0.39	0.03
49233	51.96	0.64	12.68	1.88	7.60	9.29	0.23	9.10	9.30	2.20	0.04	0.06
49241	47.77	1.07	7.48	1.76	12.50	13.88	0.29	11.30	11.39	2.25	0.05	0.11
49326	50.42	1.01	11.80	1.98	10.00	11.78	0.18	8.05	9.12	3.60	0.08	0.11
49327	46.65	0.38	6.92	1.27	10.50	11.64	0.19	16.10	8.98	1.31	0.04	0.05
49333	50.21	0.47	10.01	0.98	8.85	9.73	0.18	14.80	9.70	1.90	0.08	0.06
49334	49.72	0.48	9.92	1.19	8.15	9.22	0.21	13.20	13.06	1.18	0.22	0.05
49335	49.65	0.48	9.77	1.05	9.20	10.17	0.19	14.00	10.65	1.67	0.14	0.08
49336	51.11	0.51	12.18	0.99	8.70	9.59	0.19	12.00	9.28	2.26	0.15	0.06
49337	47.80	0.46	11.51	1.77	8.45	10.04	0.18	13.00	12.83	0.22	0.26	0.07
49338	48.56	0.50	12.18	1.64	8.25	9.73	0.18	11.30	12.96	1.18	0.34	0.07
Mean	50.09	0.58	11.50	3.63	8.65	10.19	0.19	11.01	10.11	2.12	0.27	0.06
Maximum	52.52	1.07	14.04	13.18	12.30	13.88	0.29	16.10	13.06	4.33	0.48	0.11
Minimum	46.65	0.38	6.92	0.98	7.30	8.99	0.15	8.05	7.83	0.94	0.03	0.01
S. Dev.	1.55	0.18	1.97	4.00	1.34	1.20	0.03	2.37	1.50	0.99	0.14	0.03

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040078 <i>F</i>	24		55				24		9	4		19	156	1430	60	354	58	59	9	520
75040079 <i>A</i>	12		116				35	2	13			9	250	407	50	108	92	69	12	240
75040079 <i>B</i>	8		198				36		13			10	211	390	44	93	84	56	10	280
75040079 <i>D</i>	20		64				32	2	13	4		9	246	232	42	91	104	60	12	280
49216	309	9	51				29		13		5	33	206	584		131	90	64		160
49217	107	17	184	2		3	33		13	2	12	34	234	323		99	52	64		100
49218	41	10	185				31		12	5	15	44	237	458		125	81	69		100
49221	25	16	166				31		13	6	19	36	244	331		101	86	61		120
49223	30	9	119				33		13	3	14	37	239	383		107	79	66		100
49232	180	19	170				20		11	2	16	41	231	508		100	54	61		20
49233	46		183				44		14	3	18	20	220	527		104	68	67		140
49241	5		84		3		68	7	17	11	11	15	198	849		270	164	78		240
49326	9		51				62		16	5	18	5	260	349		110	132	106		160
49327	6		26				17		8	5	8	7	190	1518		291	77	76		20
49333	12	3	31				23		9	2	10	5	198	1456		376	70	63		160
49334	7	6	100			2	22		10		15	5	185	1248		305	20	65		120
49335	8	3	39				26		10	2	17	7	201	1183		308	65	70		80
49336	14	4	64				29		12	2	27	6	214	827		267	60	66		340
49337	12	9	144				27		11	4	15	8	198	1116		385	150	63		320
49338	27	14	156				27		11	5	13	8	223	858		227	76	58		600
Mean	45	10	109	2	3	3	32	4	12	4	15	18	219	749	49	198	85	67	11	205
Maximum	309	19	198	2	3	3	68	7	18	11	41	44	260	1518	60	395	164	106	12	600
Minimum	5	3	26	2	3	2	17	2	8	2	5	5	185	232	42	91	20	56	9	20
S. Dev.	75	6	60				13		2	2	5	14	23	431	8	110	33	11	2	153

Number of samples is 20

Apex Basalt - Peridotitic komatiites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
49328	39.40	0.12	2.70	2.85	5.20	7.77	0.12	36.00	0.46	0.07	0.01	0.01
49329	42.89	0.19	4.30	4.44	4.85	8.85	0.15	31.50	4.39	0.29	0.04	0.04
49330	43.65	0.19	4.38	3.39	5.60	8.65	0.15	27.40	6.47	0.48	0.02	0.02
49331	42.87	0.19	4.47	3.03	6.35	9.08	0.14	32.20	4.81	0.31	0.02	0.03
49332	42.99	0.23	4.67	4.50	5.25	9.30	0.15	30.70	4.15	0.18	0.02	0.03
Mean	42.36	0.18	4.10	3.64	5.45	8.73	0.14	31.56	4.06	0.27	0.02	0.03
Maximum	43.65	0.23	4.67	4.50	6.35	9.30	0.15	36.00	6.47	0.48	0.04	0.04
Minimum	39.40	0.12	2.70	2.85	4.85	7.77	0.12	27.40	0.46	0.07	0.01	0.01
S. Dev.	1.69	0.04	0.80	0.78	0.57	0.59	0.01	3.09	2.20	0.15	0.01	0.01

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
49328			2				3				7	1	61	951		1770	16	27		140
49329			15				5		4	2	5	3	94	1630		1396	7	39		200
49330			27				8		4	2	11	4	102	1285		1275	39	37		120
49331			9				6		5		4	6	98	1176		1411	5	31		20
49332			25				8		5	3	39	5	106	1570		1325	4	34		
Mean	0	0	16	0	0	0	6	0	5	2	13	4	92	1322	0	1435	14	34	0	120
Maximum	0	0	27	0	0	0	8	0	5	3	39	6	106	1630	0	1770	39	39	0	200
Minimum	0	0	2	0	0	0	3	0	4	2	3	1	61	951	0	1275	4	27	0	20
S. Dev.	0	0	11	0	0	0	2	0	1	1	15	2	18	281	0	195	15	5	0	75

Number of samples is 5

Euro Basalt - tholeiites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
49344	49.27	1.03	14.53	2.56	10.30	12.60	0.19	7.45	8.20	1.84	0.28	0.10
49345	48.46	1.17	14.14	3.12	10.40	13.21	0.21	6.65	9.44	2.04	0.09	0.13
49346	47.85	1.11	13.67	3.68	9.30	12.61	0.18	5.85	9.74	1.96	0.16	0.12
49347	48.80	1.11	14.40	2.33	10.80	12.90	0.22	7.00	7.88	2.46	0.25	0.12
49349	46.22	1.67	11.99	5.32	10.50	15.29	0.22	4.62	7.16	3.22	0.08	0.17
Mean	48.12	1.22	13.75	3.40	10.26	13.32	0.21	6.31	8.48	2.30	0.17	0.13
Maximum	49.27	1.67	14.53	5.32	10.80	15.29	0.22	7.45	9.74	3.22	0.28	0.17
Minimum	46.22	1.03	11.99	2.33	9.30	12.60	0.18	4.62	7.16	1.84	0.08	0.10
S. Dev.	1.18	0.26	1.04	1.19	0.57	1.13	0.02	1.11	1.08	0.56	0.09	0.03

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
49344	37	10	76				60		22	8	21	10	340	160		126	140	98		40
49345	10		159				67	2	22	4	17	6	309	94		105	172	109		200
49346	14	3	145			2	64		22	6	18	5	329	89		101	173	92		1600
49347	25	6	106				62	2	22	6	25	9	317	167		120	158	115		220
49349	7	6	174				115	4	26	8	30	9	323	33		40	169	97		
Mean	19	6	112	0	0	2	115	4	26	8	22	8	324	103	0	98	162	102	0	515
Maximum	37	10	159	0	0	2	115	4	26	8	30	10	340	167	0	126	173	115	0	1600
Minimum	7	3	74	0	0	2	60	2	22	4	17	5	309	33	0	40	140	92	0	40
S. Dev.	12	4	39	0	0	0	23	1	2	2	5	2	12	56	0	34	14	9	0	728

Number of samples is 5

Buro Basalt - High-Mg Basalt

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Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
49249	41.60	1.90	7.77	1.08	10.30	11.27	0.20	9.30	9.63	0.03	0.57	0.07
49343	47.10	1.39	7.23	2.22	9.70	11.70	0.19	12.60	12.98	1.10	0.07	0.12
49348	52.00	0.69	13.24	2.35	7.60	9.72	0.17	8.35	9.20	1.83	0.10	0.09
Mean	46.90	1.03	9.41	1.88	9.20	10.90	0.19	10.08	10.60	0.99	0.25	0.09
Maximum	52.00	1.39	13.24	2.35	10.30	11.70	0.20	12.60	12.98	1.83	0.57	0.12
Minimum	41.60	0.69	7.23	1.08	7.60	9.72	0.17	8.35	9.20	0.03	0.07	0.07
S. Dev.	5.20	0.35	3.32	0.70	1.42	1.04	0.02	2.23	2.07	0.91	0.28	0.03

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Co	Ni	Cu	Zn	Ga	S
49249	4	23	41				66		15	5	24	19	228		133	121	86		240
49343	22		124				63		16	3	16	10	337		355	260	76		80
49348	8		129				46		16	4	22	7	228		443	72	67		160
Mean	11	23	98	0	0	0	58	0	16	4	21	12	262	0	197	151	76	0	127
Maximum	22	23	129	0	0	0	66	0	16	5	24	19	337	0	355	260	86	0	240
Minimum	4	23	41	0	0	0	46	0	15	3	16	7	228	0	107	72	67	0	60
S. Dev.	9\$\$\$\$\$		49	0	0	0	11	0	1	1	4	6	63	0	136	98	10	0	99

Number of samples is 3

WYMAN FORMATION - rhyolites

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Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040105A	79.12	0.07	12.11	1.09	0.00	0.98	0.02	0.28	0.07	0.00	6.07	0.00
75040105B	78.11	0.07	11.96	0.99	0.00	0.89	0.02	0.25	0.40	0.00	6.34	0.00
75040105C	78.27	0.08	12.36	1.09	0.00	0.98	0.02	0.43	0.22	0.00	6.11	0.00
49318	78.21	0.05	11.36	0.69	0.10	0.72	0.00	0.50	0.01	0.17	7.08	0.03
49319	78.14	0.04	11.11	0.24	0.05	0.27	0.01	0.18	0.24	0.13	9.18	0.03
49320	76.88	0.05	11.23	0.74	0.15	0.82	0.03	0.38	0.55	0.40	7.88	0.02
49321	76.64	0.05	11.16	0.50	0.15	0.60	0.03	0.35	0.63	0.40	8.62	0.03
49322	76.95	0.04	11.02	0.47	0.15	0.57	0.03	0.37	0.54	0.27	8.37	0.03
49323	75.70	0.04	11.16	0.49	0.30	0.74	0.04	0.56	0.93	0.30	8.44	0.03
49324	76.22	0.04	11.53	0.32	0.30	0.59	0.05	0.68	1.09	0.29	8.11	0.02
49351	76.77	0.26	11.87	0.30	0.35	0.62	0.02	0.32	0.86	3.69	3.14	0.05
49352	81.59	0.06	11.15	0.27	0.05	0.29	0.00	0.30	0.05	0.09	4.72	0.02
49353	85.48	0.05	8.53	0.20	0.05	0.23	0.00	0.33	0.04	0.08	3.88	0.02
49354	81.89	0.11	10.59	0.49	0.10	0.54	0.00	0.50	0.04	0.06	3.60	0.02
49355	81.35	0.11	10.76	0.54	0.20	0.69	0.00	0.54	0.05	0.08	3.60	0.02
49356	81.27	0.18	10.69	0.35	0.15	0.47	0.00	0.33	0.04	0.08	4.77	0.02
49357	80.30	0.19	11.11	0.56	0.25	0.75	0.00	0.45	0.04	0.07	4.41	0.02
49358	82.06	0.10	9.63	0.33	0.15	0.45	0.00	0.26	0.10	0.10	5.75	0.03
49359	79.34	0.11	11.19	0.43	0.15	0.54	0.01	0.36	0.03	0.11	6.62	0.02
49360	70.81	0.52	13.74	0.13	0.30	0.42	0.17	0.11	0.55	0.16	11.97	0.36
49361	70.21	0.59	14.58	0.20	0.35	0.53	0.03	0.13	0.11	0.23	12.54	0.09
49362	73.36	0.50	13.11	0.08	0.15	0.22	0.02	0.12	0.21	0.14	11.05	0.07
49363	73.38	0.48	13.25	0.07	0.05	0.11	0.01	0.08	0.03	0.15	11.25	0.08

Mean	77.91	0.16	11.49	0.46	0.18	0.57	0.03	0.34	0.30	0.35	7.11	0.05
Maximum	85.48	0.59	14.58	1.09	0.35	0.98	0.17	0.68	1.09	3.69	12.54	0.36
Minimum	70.21	0.04	8.53	0.07	0.05	0.11	0.01	0.08	0.01	0.06	3.14	0.02
S. Dev.	3.59	0.18	1.31	0.30	0.10	0.24	0.04	0.16	0.33	0.79	2.79	0.08

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
75040105A	131	211	10	5	24	4	102	10	27	36	61	11	3	4	3	5	5	16	13	
75040105B	146	207	12	7	24	7	101	10	27	37	65	9	3	4	2	5	4	14	13	200
75040105C	135	220	12	5	25	4	101	10	29	37	62	12	3	3	3	5	5	19	17	240
49318	65	211	4	19	28	3	86	8	24	13	41	15	3			2		21		20
49319	70	180	6	10	31	7	82	10	23	19	47	3		3				3		
49320	67	197	7	14	31	6	82	10	22	23	54	9		4		1		20		20
49321	63	190	6	13	29	5	81	10	27	33	77	8		3		2		10		40
49322	60	179	5	11	31	4	80	11	25	27	67	7		3				11		20
49323	59	194	9	13	32	4	84	11	24	26	65	7					2			40
49324	72	189	9	11	29	6	80	9	22	31	75	7		4			1	7		40
49351	405	82	46	3	9	2	114	3	10	23	43	3	18	6		4	4	23		40
49352	493	91	11	5	13	4	86	4	16	19	47	4	2	1		4	3	5		160
49353	442	72	6	3	13		62	5	19	17	40	3		3		1	16	5		40
49354	302	88	12	9	10	3	123	4	12	21	36	2	2	1		2	3	8		20
49355	110	91	10	5	11	2	134	4	19	26	53	3		1		2	5	11		20
49356	183	90	6	2	8	2	119	4	13	17	37	3	7	4		2	11	8		
49357	232	114	10	3	9	2	132	3	15	20	42	3	14	3		3	9	14		
49358	471	136	21	46	12	3	147	5	24	19	41	3				3	6	11		480
49359	480	127	9	7	11	2	139	5	22	24	47	3				2	3	11		40
49360	375	120	26	7	6	3	127	4	22	9	26	2	32	11		5	43	37		600
49361	445	122	18	6	5	2	193	7	23	20	45	2	43	22		11	29	18		720
49362	442	122	22	5	6	2	177	4	18	15	36	2	37	18		7	24	6		280
49363	422	117	18	7	6		173	5	17	20	39	1	36	17		3	15	5		40

Mean	247	146	13	9	18	3	113	7	21	23	50	5	16	6	3	4	10	13	14	168
Maximum	493	220	46	46	32	7	193	11	29	37	77	15	43	22	3	11	43	37	17	720
Minimum	59	72	4	2	5	2	62	3	10	9	26	1	2	1	2	1	1	3	13	20
S. Dev.	171	50	9	9	10	2	35	3	5	8	14	4	16	6	1	2	11	8	2	219

Number of samples is 23

WYMAN FORMATION - rhyolites (major elements)

	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot.Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
SiO ₂												
TiO ₂	-0.70											
Al ₂ O ₃	-0.87	0.78										
Fe ₂ O ₃		-0.54										
FeO	-0.51											
Tot.Fe				0.91	0.51							
MnO	-0.54											
MgO		-0.67	-0.56									
CaO					0.59							
Na ₂ O												
K ₂ O	-0.87	0.61	0.70					-0.52				
P ₂ O ₅	-0.60	0.65	0.60				0.41	-0.50			0.54	
Ba		0.56		-0.57		-0.59		-0.54				
Rb				0.66		0.61						
Sr		0.58								0.75		
Pb												
Th		-0.71		0.52								
U		-0.52										
Zr		0.81	0.59					-0.50				
Nb				0.55		0.51						
Y				0.51								
La				0.72		0.67						
Ce		-0.57		0.51		0.53			0.54			-0.53
Li		-0.54		0.79		0.72						
V	-0.90	0.99	0.84	-0.73		-0.61		-0.80			0.83	
Cr	-0.79	0.92	0.79					-0.69			0.77	
Co	0.62	0.50	0.79	1.00		1.00		0.63	-0.89		-0.99	
Ni	-0.66	0.67	0.78		0.57			-0.59			0.57	
Cu	-0.58	0.84	0.53				0.67	-0.68			0.65	0.83
Zn					0.54		0.71					0.72
Ga		1.00	0.93	0.50		0.50		0.99				
S		0.64	0.55				0.54	-0.62			0.53	0.62

WYMAN FORMATION - rhyolites (trace elements)

	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
Ba																				
Rb	-0.71																			
Sr	0.54																			
Pb																				
Th	-0.82	0.85	-0.53																	
U	-0.57	0.61			0.79															
Zr	0.59				-0.76	-0.72														
Nb	-0.75	0.91			0.91	0.69	-0.53													
Y		0.83			0.64			0.80												
La		0.57			0.52			0.62	0.51											
Ce	-0.66	0.67			0.75	0.53	-0.51	0.78	0.59	0.86										
Li	-0.67	0.84			0.75		-0.56	0.71	0.64	0.51	0.57									
V	0.66				-0.71	-0.60	0.90				-0.51	-0.62								
Cr	0.55				-0.51		0.81						0.96							
Co	-0.97	0.74	-0.50	-1.00	0.50	1.00	0.50		0.50	-0.50	-0.97	0.94		-0.50						
Ni							0.59						0.60	0.72						
Cu					-0.58					-0.65	-0.64		0.79	0.71	1.00					
Zn															0.80		0.55			
Ga		0.95	0.50	-0.50	1.00	0.50	-0.50		1.00	0.50		0.76		-1.00	0.50		0.50	0.92		
S							0.55						0.58	0.65	1.00	0.78	0.72		1.00	

Charteris Basalt - tholeiites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
49250	50.96	0.75	12.95	3.26	8.55	11.48	0.15	4.08	6.45	2.20	1.31	0.05
49256	49.66	0.54	14.61	1.99	7.40	9.19	0.16	8.20	10.64	2.64	0.17	0.05
49259	51.67	0.65	14.69	1.97	7.65	9.42	0.15	6.90	7.29	1.73	0.05	0.06
49260	47.51	0.57	13.51	2.43	8.00	10.19	0.21	7.35	11.80	1.93	0.13	0.08
49261	48.42	0.10	15.84	2.14	6.15	8.08	0.16	8.65	12.30	1.60	0.19	0.06
49262	47.38	0.51	15.47	2.27	6.30	8.34	0.16	8.32	11.64	1.13	0.04	0.06
49264	46.88	0.53	15.67	2.62	6.45	8.81	0.16	8.60	12.39	1.59	0.02	0.07
49265	49.59	0.56	15.05	2.36	6.35	8.37	0.17	8.30	12.20	0.87	0.02	0.05
49269	49.13	0.54	15.31	1.24	7.65	8.77	0.16	8.40	9.44	3.46	0.03	0.06
49276	47.99	0.50	15.91	1.85	7.25	8.92	0.17	8.25	10.59	2.24	0.46	0.06
Mean	48.92	0.53	14.90	2.21	7.17	9.16	0.17	7.71	10.48	1.94	0.24	0.06
Maximum	51.67	0.75	15.91	3.26	8.55	11.48	0.21	8.65	12.39	3.46	1.31	0.08
Minimum	46.88	0.10	12.95	1.24	6.15	8.08	0.15	4.08	6.45	0.87	0.02	0.05
S. Dev.	1.58	0.17	0.99	0.53	0.84	1.02	0.02	1.39	2.13	0.75	0.40	0.01

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
49250	128	43	71				37		12		12	23	283	5		31	5	35		40
49256	51	5	197				25		11	3	14	12	200	390		101	91	60		160
49259	2		161				35		13	3	16	20	255	260		80	98	67		400
49260	69		144			2	30		12	2	17	7	227	419		157	86	68		560
49261	72	7	242				26		9	5	18	12	177	462		199	86	51		260
49262	15	2	190				28		10	3	13	13	159	704		263	87	53		280
49264	2		223				28		10	3	19	8	169	492		204	83	56		440
49265			239				25		11	3	19	12	176	527		203	75	45		180
49269	13		98				29		11	3	14	22	175	477		192	69	52		116
49276	112	18	168				30		11	3	15	33	187	407		133	89	56		240
Mean	52	15	175	0	0	2	29	0	11	3	16	16	201	414	0	156	77	54	0	268
Maximum	128	43	242	0	0	2	37	0	13	5	19	33	283	704	0	263	98	68	0	560
Minimum	2	2	71	0	0	2	25	0	9	2	12	7	159	5	0	31	5	35	0	40
S. Dev.	47	17	57	0	0	0	4	0	1	1	2	8	41	183	0	70	27	10	0	159

Number of samples is 10

Chanteris Basalt - High-Mg Basalt

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
49254	48.54	0.56	14.24	1.77	8.00	9.59	0.19	9.10	9.77	2.55	0.90	0.05
49255	47.94	0.50	13.68	2.07	7.80	9.65	0.18	10.10	10.83	2.05	0.39	0.05
49263	48.02	0.49	15.49	1.97	6.00	7.77	0.15	9.25	12.86	1.02	0.03	0.06
49271	44.22	0.54	14.35	1.99	7.35	9.14	0.19	10.60	10.57	1.87	0.25	0.06
49272	49.07	0.58	13.68	1.53	8.65	10.12	0.21	8.90	9.50	2.28	0.81	0.06
49275	49.16	0.61	14.01	1.35	9.60	10.82	0.21	9.15	7.28	3.54	0.28	0.05
Mean	47.83	0.55	14.24	1.80	7.90	9.52	0.19	9.52	10.14	2.22	0.44	0.06
Maximum	49.16	0.61	15.49	2.07	9.60	10.82	0.21	10.60	12.86	3.54	0.90	0.06
Minimum	44.22	0.49	13.68	1.35	6.00	7.77	0.15	8.90	7.28	1.02	0.03	0.05
S. Dev.	1.84	0.05	0.67	0.27	1.22	1.03	0.02	0.67	1.83	0.83	0.34	0.01

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
49254	384	24	109				27		11		12	13	221	642		96	86	63		360
49255	67	11	256				23		10		14	16	187	310		222	85	59		300
49263	13		302				27		9	4	18	9	160	622		244	85	49		600
49271	51	6	151				27		12	2	9	23	200	853		227	87	58		180
49272	59	23	86				31		12	3	11	13	210	547		139	80	63		360
49275	64	5	77				32		13	4	16	44	242	710		134	80	69		100
Mean	106	14	164	0	0	0	28	0	11	3	13	20	203	697	0	177	84	60	0	317
Maximum	384	24	302	0	0	0	32	0	13	4	18	44	242	853	0	244	87	69	0	600
Minimum	13	5	77	0	0	0	23	0	9	2	9	9	160	547	0	96	80	49	0	100
S. Dev.	137	9	94	0	0	0	3	0	1	1	3	13	28	117	0	61	3	7	0	173

Number of samples is 6

Honeyeater Basalt - tholeiites

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Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
49379	50.30	0.99	14.52	1.52	9.10	10.47	0.20	8.15	7.22	2.04	1.29	0.14
49380	47.46	0.87	14.47	1.51	9.15	10.51	0.21	8.10	9.44	2.22	1.18	0.12
49383	51.71	0.78	13.39	2.90	7.50	10.11	0.14	3.92	13.31	0.13	0.02	0.09
49387	50.52	0.93	13.72	2.27	8.05	10.09	0.22	7.60	8.33	2.50	0.79	0.13
49389	48.19	0.55	14.97	2.24	9.00	11.02	0.26	4.78	9.82	1.79	0.12	0.06
49390	50.76	0.58	14.84	0.87	8.70	9.48	0.23	4.70	6.75	1.95	1.60	0.06
49392	53.06	0.64	15.01	2.88	8.15	10.74	0.20	4.62	6.16	1.50	0.93	0.06
49393	50.55	0.68	15.01	3.42	10.70	13.78	0.26	5.55	5.79	1.14	0.84	0.06
49395	53.21	0.80	14.00	3.84	9.50	12.96	0.22	5.35	6.10	1.47	0.06	0.08
49397	50.88	0.95	13.51	2.16	7.90	9.84	0.17	7.55	9.00	1.83	0.41	0.15
49398	49.31	1.01	14.91	2.57	8.50	10.81	0.20	7.80	7.81	2.46	0.87	0.15
49399	49.57	0.95	14.15	2.13	8.20	10.12	0.20	7.65	8.10	2.30	0.68	0.13
Mean	50.47	0.81	14.38	2.36	8.70	10.83	0.21	6.31	8.15	1.78	0.73	0.10
Maximum	53.21	1.01	15.01	3.84	10.70	13.78	0.26	8.15	13.31	2.50	1.60	0.15
Minimum	47.46	0.55	13.39	0.87	7.50	9.48	0.14	3.92	5.79	0.13	0.02	0.06
S. Dev.	1.72	0.16	0.61	0.84	0.85	1.27	0.03	1.62	2.10	0.66	0.50	0.04

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
49379	1642	33	150			2	93	3	28	7	22	10	316	327		53	54	79		60
49380	1615	28	185				78		25	6	21	9	279	451		114	50	77		100
49383			5		2		44		19	2	17	3	350	5		28	32	58		100
49387	310	21	172				98	2	29	5	19	9	275	311		61	44	74		60
49389	39	3	260				27		17	2	11	13	305	16		61	100	79		160
49390	179	62	40				30		16		14	13	324	15		55	86	113		520
49392	27	24	88				36		22	3	14	12	319	11		47	123	73		80
49393	74	17	68				36		21	3	11	7	350			38	119	98		120
49395	6	2	108				45		25	4	12	5	372	3		30	109	93		80
49397	60	9	92				101	3	30	8	25	8	286	248		47	53	81		560
49398	261	19	137			3	103	4	31	6	25	8	327	292		56	61	90		100
49399	194	17	121				100	3	29	6	23	9	300	250		49	54	87		80
Mean	401	21	119	0	2	3	66	3	24	5	18	9	317	176	0	53	74	84	0	168
Maximum	1642	62	260	0	2	3	103	4	31	8	25	13	372	451	0	114	123	113	0	560
Minimum	6	2	5	0	2	2	27	2	15	2	11	3	275	5	0	28	32	58	0	60
S. Dev.	615	17	69	0	2	1	32	1	5	2	5	3	30	166	0	22	32	14	0	176

Number of samples is 12

Honeyeater Basalt - dolerites

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
49364	49.51	0.38	14.89	2.08	8.35	10.22	0.19	9.28	7.66	1.11	0.32	0.05
49365	51.05	0.90	13.60	1.28	8.40	9.55	0.22	6.80	9.64	2.80	0.23	0.12
49368	51.07	0.65	15.12	1.38	7.20	8.44	0.15	7.83	8.54	3.02	0.77	0.09
49369	50.56	0.69	14.26	1.41	7.55	8.82	0.14	7.05	11.25	2.60	0.38	0.09
49370	49.39	1.08	14.30	2.76	8.70	11.18	0.19	7.85	8.47	1.80	0.80	0.13
49373	51.01	0.44	15.77	2.89	7.30	9.90	0.19	7.13	9.04	0.65	0.26	0.05
49375	46.78	0.31	18.47	2.39	7.60	9.75	0.16	7.45	9.14	1.45	0.39	0.04
49382	49.01	0.81	13.93	1.66	8.10	9.59	0.18	10.20	9.29	1.40	0.80	0.12
49384	49.12	0.49	13.74	1.54	7.55	8.94	0.15	9.20	10.46	2.50	0.68	0.05
49394	49.79	0.39	14.98	2.94	7.95	10.60	0.19	8.90	7.26	1.46	0.48	0.05
49396	52.68	0.62	15.07	3.28	9.05	12.00	0.22	5.90	6.37	1.69	0.55	0.05
Mean	50.00	0.61	14.92	2.15	7.98	9.91	0.18	7.95	8.83	1.87	0.51	0.08
Maximum	52.68	1.08	18.47	3.28	9.05	12.00	0.22	10.20	11.25	3.02	0.80	0.13
Minimum	46.78	0.31	13.60	1.28	7.20	8.44	0.14	5.90	6.37	0.65	0.23	0.04
S. Dev.	1.53	0.24	1.35	0.73	0.60	1.05	0.03	1.29	1.40	0.76	0.22	0.03

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
49364	74	9	205				19		11	2	15	11	237	50		108	55	65		200
49365	79	6	157				95	2	29	6	26	6	264	272		46	50	70		120
49368	311	23	217				36		16	5	19	6	219	88		77	70	49		200
49369	305	11	152				40		15	13	19	5	275	134		55	55	52		80
49370	345	22	289				98	3	31	5	22	7	338	191		43	65	81		240
49373	51	5	160				22		13		10	11	228	39		86	63	65		60
49375	87	7	91				14		10	2	13	10	200	31		87	46	30		40
49382	666	21	152				74		24	5	23	9	266	461		128	48	73		40
49384	667	18	93				22		11	6	11	7	243	147		79	44	46		20
49394	17	10	92				22		12	2	19	8	223	47		110	75	69		100
49396	61	11	72				31		19	2	8	7	321	9		56	86	83		80
Mean	242	13	153	0	0	0	43	3	17	5	17	8	256	134	0	80	60	64	0	107
Maximum	667	23	289	0	0	0	98	3	31	13	26	11	338	461	0	128	86	83	0	240
Minimum	17	5	72	0	0	0	14	2	10	2	8	5	200	9	0	43	44	46	0	20
S. Dev.	241	7	65	0	0	0	31	1	7	3	6	2	43	135	0	28	13	13	0	74

Number of samples is 11

Honeyeater Basalt - dolerites (major elements)

[illegible]

Honeyeater Basalt - dolerites (trace elements)

[illegible]

Honeyeater Basalt - High-Mg Basalt

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
49366	51.27	0.45	8.76	2.28	7.00	9.05	0.18	10.50	14.38	1.27	0.03	0.08
49367	47.06	0.40	7.99	2.81	7.10	9.63	0.17	12.60	17.70	0.23	0.01	0.08
49381	49.18	0.66	9.87	1.11	7.80	8.80	0.21	10.40	11.75	1.55	0.39	0.07
49385	49.30	0.63	9.95	1.08	9.35	10.32	0.19	12.20	9.95	1.52	0.72	0.07
49391	49.64	0.84	11.66	1.76	9.80	11.38	0.17	9.60	9.56	1.40	0.64	0.10
Mean	49.29	0.60	9.65	1.81	8.21	9.84	0.18	11.06	12.77	1.19	0.36	0.08
Maximum	51.27	0.84	11.66	2.81	9.80	11.38	0.21	12.60	17.70	1.55	0.72	0.10
Minimum	47.06	0.40	7.99	1.08	7.00	8.80	0.17	9.60	9.56	0.23	0.01	0.07
S. Dev.	1.50	0.18	1.39	0.75	1.29	1.04	0.02	1.28	3.47	0.55	0.33	0.01

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
49366	6		8				19		10	3	11	4	238	893		136	9	38		
49367			3				17		9	4	17	3	261	1507		192	34	50		
49385	367	11	87			2	37		16	3	21	6	249	583		157	183	74		40
49385	486	27	54				33		14	4	13	11	281	1060		182	18	57		300
49391	523	22	54				52		19	6	17	8	311	589		123	73	58		20
Mean	346	20	41	0	0	2	32	0	14	4	16	6	268	926	0	158	63	55	0	115
Maximum	523	27	87	0	0	2	52	0	19	6	21	11	311	1507	0	192	183	74	0	300
Minimum	6	11	3	0	0	2	17	0	9	3	11	3	238	583	0	123	9	38	0	20
S. Dev.	236	8	35	0	0	0	14	0	4	1	4	3	29	383	0	29	71	13	0	128

Number of samples is 5