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Petrology and whole-rock geochemistry of selected mafic and ultramafic suites from the Pilbara Block and Halls Creek Mobile Zone, Western Australia.

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CONTENTS

TABLES

FIGURES

ABSTRACT

Major and trace element determinations on seven Proterozoic mafic/ultramafic intrusives from the east Kimberleys and ten intrusives of Archaean age from the Pilbara Block show that:

(a) the east Kimberley volcanic /hypabyssal suites are tholeiites which, with the exception of the Toby Sill, are quartz normative. The oldest of these bodies, the Woodward Dolerite is a systematically fractionated sequence having an Mg# range from 67-46. In contrast volcanic/hybabyssal rocks from the Pilbara Block, represented by the Cooya Pooya Dolerite and volcanics from the Ruth Well Syclinorium, are respectively siliceous high-magnesium basalts and komatiites, both with associated tholeiitic end members.

(b) the plutonic mafic/ultramafic intrusives from the two regions also differ compositionally. The West Pilbara intrusives, notably the large well-fractionated Munni Munni and Andover complexes, are peridotite-pyroxenite-gabbro assemblages in which websterites form a substantial component of the ultramafic stratigraphy. Pyroxenites, on the other hand, are either absent, or have been poorly documented in the large east Kimberley mafic-ultramafic intrusions, such as the Panton and Lamboo sills. Geochemical criteria highlight these compositional differences between the two regions, including the Barberton-type trends of the larger Pilbara layered intrusives and the komatiitic trends of the west Pilbara high-level intrusives compared with the tholeiitic character of their Kimberley equivalents.

The comparatively lower Cr content of the west Pilbara mafic/ultramafic intrusives, contrasts with those from the Kimberleys. These differences may be due to differences in magma compositions and may, in part, be related to significant amounts of clinopyroxene-dominant pyroxenite in the Pilbara intrusives, which results in systematic depletion of Cr, owing to its greater incorporation into clinopyroxene relative to orthopyroxene. A significant positive correlation between hypersthene and Cr is evident in the Cooya Pooya Dolerite lithostratigraphic sequence.

The presence of volcanoclastic material in areas represented as Cooya Pooya Dolerite on 1:250 000 geological maps suggests that more detailed investigations of this unit are required in order to determine its lithostratigraphy.

INTRODUCTION

In 1983 the BMR, in collaboration with the Department of Geology, University of Melbourne, initiated a project with the objective of developing a greater understanding of controls on ores of orthomagmatic origin (platinum group elements (PGE), Cr, V, Ni) in Australian layered mafic-ultramafic intrusions.

A literature review by Hoatson (1984) concluded that PGE mineralization in Australia appeared to have greatest potential in three distinct geological settings:-

- the Palaeozoic serpentine belts of the Tasman Fold Belt.
- within large stratiform layered mafic-ultramafic intrusive complexes of stable Archaean-Proterozoic terrains.
- tectonically disturbed layered complexes of Proterozoic Mobile Zones.

Later reviews by Hoatson and Glaser (1989) and Hoatson (in press) downgraded the potential of the Palaeozoic serpentinite belts as a major resource of PGE but highlighted the potential for remobilised-hydrothermal PGE occurrences in north and northeastern Australia.

Given this framework it was believed that the variably deformed layered tholeiitic mafic-ultramafic intrusive complexes of the Yilgarn, Pilbara, Musgrave and Halls Creek provinces offered the best potential for a PGE-province study. Many of these intrusions display similar characteristics to the great overseas PGE-hosting stratiform complexes, such as the Bushveld (Transvaal, South Africa) Stillwater (Montana, USA) and the Great Dyke, (Zimbabwe). Additionally, the apparent association of intracontinental rift zones and tholeiitic dyke swarms showing favourable chemical-physical characteristics within possible sulphur-rich sedimentary units of the early Proterozoic Pine Creek Geosyncline, Halls Creek Mobile Zone and McArthur Basin, indicate these environments may be favourable for PGE mineralization of the Noril'sk-Talnakh, West Siberia type (Hoatson,1984).

To investigate the PGE potential of the layered complexes a field programme was undertaken throughout two of these provinces, the Halls Creek Mobile Zone and the Pilbara Block. Large tholeiitic dyke swarms of both areas were also sampled as potential hosts for Noril'sk-styled PGE mineralization. The main emphasis of the study was concerned with determining the precious metal potential of these provinces rather than focussing on individual intrusions. Later studies by Hoatson and England (1986), Hoatson and Keays (1989) and Hoatson (in prep) have concentrated on the PGE potential of individual intrusions.

Published geochemical data on the mafic/ultramafic complexes of interest to this investigation are generally sparse and incomplete. Efforts were therefore directed towards establishing a geochemical database representative of (a) a range of differentiates from the various layered intrusions and (b) fine-grained marginal phases which could be identified by means of major element, trace element and isotope studies as representing geochemically undifferentiated parental magma(s).

ANALYTICAL METHODS

Samples were analysed for a variety of major and trace elements in the BMR laboratories. X-ray fluorescence analyses (XRFS) were carried out using a Philips PW1450 spectrometer and atomic absorption analyses (AAS) using Varian AA-6 and AA-975 spectro-photometers.

Geochemical and geological data on the mafic/ultramafic intrusives, together with rock compositions and sample locations, are listed in Table 1 (East Kimberleys) and Table 2 (Pilbara).

1) **Major elements**

SiO_2, TiO_2, Al_2O_3, Fe_2O_3 (total), MnO, CaO, K_2O, P_2O_5 and S were determined by XRFS using fusion discs according to the method of Norrish and Hutton (1969). International rock standards were used for the calibration.

Na_2O was determined by AAS after digestion of the sample in hydrofluoric and perchloric acids. The analyte solution contained controlled amounts of hydrochloric acid and K^+, and calibration was against identical solutions prepared from secondary (BMR) rock standards.

FeO was determined by titration with standard potassium dichromate solution, after digestion of the sample in hydrofluoric acid in the absence of air.

2) **Trace elements**

As, Bi, Ga, Pb, Rb, Se, Sr, Th, U, W and Y (Mo target X-ray tube), and Ba, Ce, Cr, La, Mo, Nb, Nd, Pr, Sc, Sn, Ti, V and Zr (Au target tube) were determined by XRFS on pressed powder pellets using the method of Norrish and Chappell (1977) to convert raw counts into element concentrations. Calibration was by synthetic standards (except Rb by NBS-70A and Sr by AGV-1), and was verified against international and secondary rock standards. Mass absorption corrections were made using the Compton scatter method for wavelengths >1.94 A and by calculation from major element data for wave lengths <1.94 A.

Ag, Be, Co, Cr, Cu, Li, Ni and Zn were determined by AAS after digestion of the sample in hydrofluoric and perchloric acids, and with direct calibration against standard solutions (except Li). Non-atomic absorption corrections were made for low concentrations of Co, Ni and Zn. Li was determined by the method of standard additions. S was determined by Australian Mineral Development Laboratories, using their CODE J4 high-temperature evolution + titrimetric procedure.

ALTERATION

All of the rock suites sampled have been metamorphosed at grades ranging from lower greenschist to lower amphibolite facies. Additionally, a large proportion of the rocks have undergone some form of secondary alteration, either by low-temperature hydration processes or by higher-temperature processes such as hydration, carbonation, silicification, recrystallization and dehydration, due to burial or contact metamorphism.

The differing nature of element mobility and redistrubution behaviour in response to secondary processes makes interpretation of certain element dispersion patterns difficult. For example it is well known that alkali elements and alkali earth elements such as Na, K, Rb, Sr and Ba are mobile during weathering, hydrothermal and metamorphic alteration processes, and are therefore unsuitable as petrogenetic indicators in altered rocks. However Al and high field strength (HFS) cations such as Sc, Y, REE, Cr, V, Ti, Zr, Nb and Y have been shown to be relatively immobile under most metamorphic conditions and can be used as petrogenetic indicators (e.g. Pearce and Cann, 1973; Beswick, 1982).

In order to assess the suitability of the East Kimberley and Pilbara samples for the purpose of geochemical comparisons it is necessary to determine, at least qualitatively, the extent to which element redistrubution has occurred. Several schemes to determine and evaluate the degree of rock alteration have been proposed for volcanic rocks eg. Floyd and Winchester (1978); Beswick and Soucie (1978). These schemes are not however generally applicable to cumulate rocks. For these rocks more general qualitative criteria are employed, such as the preservation of primary mineralogical and textural features. Nesbitt et al (1979) have suggested that the best approach to identifying altered rocks is to search for consistency between elemental ratios such as Ti/Zr and Zr/Nb among a group of samples from the same area.

For this study a combination of petrographic evaluation and evidence of geochemical consistency was used to assess the suitability of samples for geochemical comparison. On this basis strongly altered samples from Pear Creek and Lionel in the east Pilbara were excluded from the rocks selected for comparative geochemical assessment. Strongly altered rocks such as the serpentinites from Bamboo Creek, east Pilbara, where the primary mineralogy has been destroyed appear, however, to satisfy the criteria for geochemical consistency.

SAMPLING PROCEDURES

In sampling these suites major considerations were (a) to locate contact margins and syngenetic dykes of the complexes and obtain fine-grained or chilled samples which might represent original magma compositions and (b) to identify and sample the major rock types making up these bodies, in particular those which were sulphide or Cr - bearing. No attempt was made to systematically sample all lithostratigraphic successions of the complexes investigated, and samples collected do not necessarily represent the complete range of rock types making up these complexes, nor their relative proportions. Rock types sampled from the various intrusions are listed in Table 3.

REGIONAL GEOLOGICAL SETTING

Halls Creek Mobile Zone

The Halls Creek Mobile Zone (HCMZ) is a polydeformed and variably metamorphosed orogenic sub-province lying at the western limit of the North Australian Craton (Plumb, 1979; Rutland, 1981). The sub-province was formed initially by sedimentation in the early Proterozoic, followed by orogeny, plutonism and finally by a relatively short period of tectonism about 1850 ± 100 Ma ago (Page and Hancock, 1988). It has been suggested that the HCMZ lies astride a geosuture separating an Archaean craton (whose nucleus underlies the Kimberley Block) and a province of wide-spread early Proterozoic orogeny (Hancock and Rutland, 1984).

As a result of its complex tectonic history (Dow & Gemuts, 1969; Plumb & Gemuts, 1976) the HCMZ has proved difficult to interpret, and some controversy exists as to an appropriate model for its evolution. Various workers have attempted to describe the evolution of the Halls Creek Mobile Zone on the basis of structural, petrological and metamorphic criteria (see discussions in Plumb, Allen and Hancock, 1985). Hancock and Rutland (1984) proposed a model based on sub-division of the mobile zone into several fault-bounded blocks, each largely characterized by its metamorphic grade.

Numerous magmatic episodes resulted in widespread emplacement of ultramafic/mafic and felsic extrusives and intrusive complexes throughout the HCMZ (Fig.1). Associated metamorphism imposed varying metamorphic imprints on the country rocks, ranging from greenschist to granulite facies. A possible correlation between northward migration of magmatism with times of peak metamorphism also implies a link between the magmatic and high-temperature heat sources (Plumb and others, 1985).

Mafic/ultramafic intrusives

Early Proterozoic mafic/ultramafic intrusives belonging to the Halls Creek Group and the Lamboo Complex form a substantial proportion of rock types in the HCMZ. These intrusive bodies fall into two major structural types. (a) hypabyssal dolerite-gabbro sills and dykes of the Woodward Dolerite intruding the Halls Creek Group sediments and volcanics. The middle Proterozoic Hart Dolerite which intrudes Carpentarian sediments and is confined to the Kimberley Block also belongs to this category. (b) broadly deformed sills, several kms in thickness, of the Lamboo Complex, represented by the Alice Downs Ultrabasics and the McIntosh Gabbro.

The term Lamboo Complex covers all of the early Proterozoic igneous and high-grade metamorphic rocks of the HCMZ which post-date the Halls Creek Group (Gemuts, 1971). The term is becoming less favoured with the discovery of overlapping relationships between these two groups, eg between Halls Creek Group metasediments and Lamboo Complex Tickalara Metamorphics.

Mafic-ultramafic intrusives sampled in the east Kimberley region included:-
Woodward Dolerite, Hart Dolerite, Alice Downs Ultrabasics (Panton Sill and Lamboo Sill) and McIntosh Gabbro, McIntosh Sill and Toby Sill. Sample localities and sample numbers are shown in Fig.1.

Descriptions of intrusives

The Woodward Dolerite comprises numerous tholeiitic basalt sills and dykes which intrude the Halls Creek Group. Their distribution is extensive, covering much of the HCMZ, in particular within the Biscay Formation and Olympio Formation southwest of Halls Creek. The sills are long and narrow and concordantly folded with the Halls Creek Group sediments; syndepositional emplacement prior to the 1920 Ma metamorphic event has been proposed by Hancock & Rutland (1984). Individual sills range from hundreds of metres to 20 km in length, and up to 600 m in thickness. The thickest sills are concentrated to the west of the Halls Creek Fault near Ruby Plains Homestead where they are domal in shape. The texture of the sills ranges from fine-grained and massive at the margin to vesicular coarse-grained and porphyritic towards the centre.

Most of the sills have been intensely uralitized. Petrographically the samples collected are similar; all have been metamorphosed up to amphibolite grade, represented by actinolite or tremolite, albite and quartz. Epidote commonly replaces felspar. Textures range from decussate to foliated. Magnetite and sphene are common accessories and Fe/Cu sulphides are usually present in trace amounts. The samples are all fine-grained except for #075 from the Mount Dockrell area, which is medium-grained and less intensely uralitized.

Sills and dykes of the Hart Dolerite (1800 Ma. age) are of great regional extent and are believed to underlie the whole 160 000 km^2 of the Kimberley Basin. The Hart Dolerite forms one of the major continental tholeiitic dolerite bodies of the world whose composition and differentiation trends closely parallel those of the more widely known Palisades Sill in New York State (Walker, 1969). The Hart Dolerite mostly intrudes the Speewah Group, a series of predominantly sandstone units laid down during the post-tectonic Carpentarian epoch. Individual sills are up to 1800 m thick but are commonly composite. Rock compositions range from olivine dolerite and gabbro through quartz dolerite and granophyre. Samples collected from the margin of the intrusion north of the Ord River crossing are Fe-rich tholeiitic dolerites, some of which are uralitized and chloritized.

Alice Downs Ultrabasics

The Panton Sill is a 1500 m thick differentiated layered lopolith with a surface area of ca 30 km^2, situated about 50 kms north of Halls Creek. The Sill was formed from fractional crystallization of a picritic magma at an estimated depth of 25-30 km (Hamlyn,1977); it comprises a basal ultramafic zone of olivine cumulates (ca 800 m) and an overlying gabbroic zone of similar thickness made up of plagioclase-clinopyroxene-olivine cumulates (Hamlyn, 1980). The Panton Sill is synclinally folded, fault-disrupted and sheared along its base.

A suite of samples representing the ultramafic zone and gabbro zone were collected form the north-western margin of the sill and along the southern fault-bounded area adjacent to the Panton River. Rocks sampled from the ultramafic zone were all classified on a normative basis as harzburgites. Samples with volatile contents of more than 10% are completely serpentinized; in others olivine is partly serpentinized and intercumulus bronzite is mostly replaced by chlorite. Accessory chomite is present commonly as small equant grains rimmed by magnetite.

Most of the gabbros collected were Al-spinel-bearing rocks with high (more than 15 percent) normative olivine. Modal olivine and orthopyroxene were, however, only found in sample #011. The gabbros consist primarily of laminar clots of Ca-amphibole and stumpy prismatic calcic plagioclase. Al-spinel is commonly present in the matrix either as small clusters of crystals or as thin discontinuous chains.

The Lamboo Sill, about 30 km south of Halls Creek, is a southerly-dipping elliptical layered ultramafic sill measuring 10 km by 6 km, surrounded by gabbros (Gemuts,1971). The western margin of the sill is intersected by the Springvale

Fault and primary structures such as rhythmic banding are disrupted by shearing.

The foliated ultramafic rocks are completely serpentinized peridotites which have retained their olivine and orthopyroxene cumulus texture. Chromite occurs throughout the ultramafic sequence, predominantly associated with the basal cumulates as thin discontinous bands and densely packed disseminated crystals. Pods of yellow chrysotile asbestos are present along shear planes and as crowded thin veinlets along foliations. Sample #026, from the gabbro adjacent to the ultramafic body, is an amphibolite petrographically similar to Woodward Dolerite amphibolite.

McIntosh Gabbro

McIntosh Gabbro is a collective term for a group of differentiated basic sills which together make up about 25 percent of the Lamboo Complex (Dow & Gemuts, 1969). The McIntosh Gabbro can be broadly sub-divided structurally and chronologically as (a) dismembered foliated sills and irregular bodies emplaced prior to the 1920 Ma metamorphic event which do not have any readily identifiable individual structural identity and (b) competent structural units - Toby Sill, McIntosh Sill, Armanda Sill, emplaced after the 1920 Ma metamorphic event, which form circular or elliptical bodies folded into shallow synclines or basins. Both of these groups are younger than the Alice Downs Ultrabasics. This investigation concentrated on sampling the McIntosh Sill, Toby Sill and parts of the undivided McIntosh Gabbro adjacent to the Panton Sill and further north at Tickalara Creek, near the Sally Malay Ni-Cu sulfide deposit (Thornett, 1981).

The McIntosh Sill was examined by Davies (in Gemuts, 1971) who described it as the best example of a differentiated gabbroic intrusion in the Lamboo Complex. This elliptical sill, which crops out over an area of 15 km by 5 km, is estimated by Mathison and Hamlyn (1987) to be about 6 km in thickness. It is divisible into a lower layered series of cumulates characterized by olivine gabbro and an upper layered series characterized by both orthopyroxene-dominant, and clinopyroxene-dominant gabbros. The sill has no exposed ultramafic component. Hamlyn (1980) showed on the basis of trace element criteria and different deformational history that, despite a close spatial relationship, the Panton Sill and McIntosh Sill were not comagmatic.

Sampling of the McIntosh Sill was confined to its northeastern margin. Samples #040-042 are metadolerites in which amphibole has replaced original ferromagnesian minerals. Strongly pleochroic granular hypersthene is more abundant than amphibole in #041. Samples of norite, troctolite and olivine gabbro were identified (#043-045): embayed olivines in the latter two rock-types have sub-solidus reaction coronas of hypersthene which in turn are commonly mantled by amphibole.

The Toby Sill, situated about 25 km west of the Panton Sill, is a layered basic intrusion with a surface area of some 100 km^2. The Toby Sill is fault-bounded in the west against early Proterozoic Whitewater Volcanics and elsewhere against felsic intrusives including Bow River Granite. A large part of the sill is concealed by alluvium, but aerial photographs show concentric lineations which probably reflect the layered structure of the sill.

Sampling of the Toby Sill concentrated on three areas - at Martys Bore near the northern margin, Sandy Creek near the centre of the sill, and around Toby Dam near the southern margin. Rocks collected were all dolerites which fall into one of the two categories (i) uralitized dolerite in which the primary igneous minerals have been recrystallized to amphibole ± hypersthene ± Ca plagioclase: outcrops were generally sheared and the rocks are foliated and commonly silicified and carbonated, and (ii) fresh hypersthene-clinopyroxene-Ca plagioclase-biotite dolerites. The ferromagnesian minerals are generally granular or form aggregates poikilitically enclosed by plagioclase. Intersertal biotite forms up to 5 percent of the mode in some samples.

Samples of the McIntosh Gabbro were obtained at localities near the Panton Sill, and at Tickalara Creek close to Salay Malay. At the Panton Sill localities, Fig Tree Well (#030-034) and Wild Dog Creek (#037-039), a series of dolerites intrude garnetiferous metasediments of the Tickalara Metamorphics. Dolerites from Tickalara Creek are fine-grained rocks situated near the contact with schistose Tickalara Metamorphics. Petrographically they are similar to the hypersthene-clinopyroxene-biotite dolerite and amphibolite found in the Toby Sill.

Pilbara Block

The Pilbara Block is an elongated granite-greenstone Archaean tectonic terrain which covers an area of some 60 000 km^2 and includes about 60 percent granitic batholiths (Hickman,1983). These domal batholiths are separated by synclines made up of Pilbara Supergroup volcanic and sedimentary successions and intrusives (Fig.2). The Pilbara Supergroup which is over 10 km thick in some areas, has been broadly subdivided into two stratigraphic units: (a) the Warrawoona Group, a predominantly volcanic assemblage of mafic, felsic and ultramafic rocks, overlain by (b) the Gorge Creek Group, a predominantly sedimentary sequence of sandstone, conglomerate, shale, greywacke and banded ironstone with subordinate basalt and gabbro. A third, mostly volcanic unit, the Whim Creek Group (ca 3.0Ga), unconformably overlies the Gorge Creek Group in the west Pilbara (Hickman,1983).

Mafic/ultramafic intrusions occur at many different stratigraphic levels within the Pilbara Block as concordant bodies in the Pilbara Supergroup successions and as discordant dykes and sheets. Hickman (1983) sub-divides the intrusives into two principal categories:-

(1) those forming thin, laterally extensive, essentially single rock-type sheets. This category is chiefly composed of peridotite, serpentinite and altered serpentinite (talc-tremolite-chlorite-carbonate) assemblages.

(2) those occurring in relatively thick, layered mafic-ultramafic intrusions. Many of these complexes, although much smaller, display several significant features in common with the great layered complexes of the world which are important hosts of PGE and chromite mineralization, e.g. Bushveld and Stillwater complexes.

Korsch and Gulson (1986) obtained an age of about 2.9 Ga for the Millindinna Complex of the Roebourne-Whim Creek area. The ages of most intrusions are, however, poorly constrained: detailed geochronology is required which will establish relationships within the stratigraphy of the Pilbara Block, particularly the volcanic units.

Fitton, Horwitz and Sylvester (1975) considered that all layered intrusions in the West Pilbara are cogenetic and could be grouped together as the Millindinna Complex. This concept of a coherent body occupying one stratigraphic horizon has, however, been rejected by subsequent observations that the various differentiated intrusions occur at different stratigraphic levels (see Hickman, 1983).

Mafic-ultramafic intrusives

This investigation focussed mainly on the **West Pilbara,** where a distinct group of Archaean layered peridotite-pyroxenite-gabbro complexes are located within a 50 km radius of Karratha and Roebourne (Fig.3). The most extensive of these bodies, the Andover (Mount Hall-Carlow Castle) Complex, together with the synclinally folded Ruth Well Complex, lies to the north of a major structural feature, the Sholl shear zone. The Munni Munni Complex, Dingo Complex and Mount Sholl Complex, form a closely spaced group of intrusive bodies to the south of the Sholl Shear Zone.

Collectively, these bodies lie along a belt measuring about 18 km wide and 40 km in length centred on a NE-SW trending magnetic lineament. Their layered structure, spatial association and similarities in mode of occurrence of Ni-Cu sulphide deposits, have led Mathison and Marshall (1981) to classify them as 'Sholl-type' intrusions, characterized by mainly gabbro + peridotite + minor granophyre assemblages.

Other intrusives sampled in the west Pilbara were the Gidley Granophyre and the Cooya Pooya Dolerite. In the east Pilbara mafic-ultramafic volcanic units listed by Hickman (1983) as belonging to the Warrawoona Group were sampled at three localities - Pear Creek, near Eginbah, Bamboo Creek and the Lionel Mining Centre, 27 km north of Nullagine.

Descriptions of intrusives
West Pilbara

The Munni Munni Complex (Sm-Nd model age of 2850 Ma, Sun, unpublished data) represents one of the best preserved layered mafic-ultramafic intrusions in Australia (Hoatson and England 1986; Hoatson and Keays, 1989). Covering an exposed area of 9 by 4 km, it is composed of a basal ultramafic zone (total thickness 1850 m) that contains rhythmically layered dunite, lherzolite, olivine websterite, clinopyroxenite and websterite, that grade into orthopyroxenite, norite and chromitite near the contact with overlying gabbroic lithologies. The gabbroic zone (thickness > 3630 m) consists of a lower uniform subzone of gabbronorites and an upper subzone of interlayered anorthositic gabbro and gabbronorite. Aeromagnetic and gravity data indicate the complex continues for a further 16 km to the southwest, beneath the Archaean Fortescue Group sediment and volcanic platform cover. The cumulus mineral paragenesis for the complex is olivine, olivine-clinopyroxene, clinopyroxene, orthopyroxene, and plagioclase-clinopyroxene-orthopyroxene. This sequence is at variance with the major overseas PGE-hosting intrusions, in which crystallisation of orthopyroxene generally precedes that of clinopyroxene. The late crystallisation of orthopyroxene at Munni Munni is significant since chromite mineralisation is associated with the appearance of cumulus orthopyroxene at the expense of cumulus clinopyroxene.

Sampling was carried out along the eastern margin of the ultramafic zone and the basal parts of the gabbroic zone. The Eastern Munni Munni Dyke near the eastern margin of the complex was also sampled (#154,155) together with granite outcrop adjacent to the complex (#139,144).

Most rocks from the eastern margin of the ultramafic zone are either websterites or olivine websterites in which clinopyroxene is dominant over orthopyroxene. These are clinopyroxene / olivine cumulates with intercumulus orthopyroxene, minor plagioclase and accessory biotite in which symplectic plagioclase-quartz intergrowths are common. Varied types of pyroxene exsolution phenomena are ubiquitous, reflecting unmixing of Ca-rich and Ca-poor pyroxenes during a process of slow cooling.

Samples from the gabbro zone are clinopyroxene + plagioclase + orthopyroxene (inverted pigeonite) cumulates with intersertal Fe-Ti oxides. Ca-rich/Ca-poor pyroxene exsolution and inversion textures are ubiquitous. Accessory phases are generally tremolite, quartz, K-feldspar, biotite and apatite. All gabbros contain traces of sulphides, in contrast to the ultramafic zone samples where sulphides were identified only in #148 and #149.

The two samples from the Eastern Munni Munni Dyke contrast significantly with the clinopyroxene-dominant Munni Munni ultramafic rocks in that they are respectively an orthopyroxene-dominant websterite and an olivine orthopyroxenite. The former is completely serpentinized but the latter is a fresh medium-grained rock consisting of cumulus olivine and platy bronzite with minor intersertal plagioclase, biotite and disseminated grains of chromite.

The Andover Complex, immediately south of Roebourne, covers an area of 150 km^2. Hickman (1983) notes that the complex, whose thickness is estimated at 2km consists of "sheets of dunite, peridotite, pyroxenite, gabbro and minor anorthosite..... field observations have established a general cyclicity conforming to magmatic differentiation trends (ie dunite-peridotite-pyroxenite-gabbro-anorthosite in ascending order). Individual cycles are approximately 100 m to 200 m in thickness. The complex is intruded by gabbro, dolerite, granitic rocks, quartz and pegmatite veins: the latter have been mined for beryl, tantalite and cassiterite. All the ultramafic rocks are serpentinized and chrysotile asbestos has been mined in the Mount Hall area". The eastern two-thirds of the complex dip at a shallow angle to the south-west and its western extremity is more steeply-dipping. A subeconomic deposit of titaniferous magnetite containing 0.95% V_2O_5 is located in the western part of the complex (Baxter, 1978).

Ten samples were collected from three different localities along the Roebourne - Cooya Pooya road. Ultramafic rocks (#173-175) included olivine websterite, websterite and peridotite: gabbroic rocks (#176-181) ranged from gabbro and anorthositic gabbro to anorthosite.

All ultramafic samples are strongly hydrated, but cumulus textures are preserved. Serpentinized cumulus olivine pseudomorphs rimmed by exsolved Fe oxides are recognizable but pyroxenes are uralitized. In the gabbroic rocks ferromagnesian minerals are also uralitized and amphibole is frequently chloritized. Interstitial myrmekite is preserved but felspars are saussuritized.

The Dingo Complex comprises a group of relatively small (less than 1 km^2) low-lying isolated outcrops of mafic/ultramafic rocks. The complex is located about 20 km south of Karratha adjacent to the Dampier-Mt Tom Price railway line. Mathison and Marshall (1981) describe this unit as a Ni-Cu bearing peridotite-pyroxenite body possibly related to extrusive komatiites at Ruth Well. Despite a close spatial association with the Radio Hill and Mt Sholl intrusions, the extent of the Dingo Complex and any mutual relationships which may exist are masked by extensive intervening alluvial cover.

A suite of samples seected from the Dingo Complex (#113-125) ranges from peridotite through to rocks of basaltic compositions. The peridotites are totally hydrated but cumulus textures are preserved as serpentinized olivine pseudomorphs. Intercumulus material consists of talc, probably after orthopyroxene, felted chlorite and minor amphibole. The presence of disseminated chromite is reflected by high values for Cr (up to 4500ppm). Samples #116 and #117 are orthopyroxenites in which the original orthopyroxene has been replaced by talc and amphibole replaces clinopyroxene. and augite twinning is preserved in part. Basic rocks are uralitized to fine-grained granular-textured assemblages of tremolite/actinolite and sericitized albite.

The Mount Sholl intrusion is a series of sheet-like melagabbros, gabbros and felspathic pyroxenites derived from a basaltic komatiite parent magma; disseminated and minor massive pyrrhotite, pentlandite and chalcopyrite are present mainly in gabbros near the basal contacts (Mathison and Marshall, 1981).

Two samples were collected from the pyroxenite zone. These are both relatively fresh clinopyroxene-dominated plagioclase websterites. Cumulus augite is unaltered, orthopyroxene is altered to talc and intercumulus plagioclase partly saussuritized. Ilmenite, magnetite and biotite are accessory phases.

The Ruth Well Complex, 9 km north of Mt Sholl, is a metamorphosed series of extrusive and plutonic ultramafic/mafic rocks cropping out over an area of 10 km^2. The rocks comprise metabasalts, gabbro, pyroxenite, serpentinized peridotite and dunite concordant within Talga Talga sub-group strata and synclinally folded about an easterly trending axis. The extrusive volcanics include komatiites, komatiitic basalts and ultramafic pyroclastics (Nisbet and Chinner, 1981). Associated massive peridotite and pyroxenite cumulates host magnetite-rich Ni-Cu sulphides (Tomich, 1974).

Eight samples were collected form the Ruth Well Complex. Six of these (#107-111) are fine-grained basalts of intermediate composition, #112 is a serpentinite, and #196 is a spinifex-textured komatiite. The metabasalts are tremolite/actinolite rocks in which uralitized stumpy clinopyroxenes and plagioclase form glomeroporphyritic aggregates within an amorphous sub-microscopic groundmass. Sample #112 is a mesh-textured serpentinite, overprinted with flakes of chlorite. The komatiite sample consists of well-defined segregations of amphibole, serpentinite and opaque minerals which form a distinct fine-grained spinifex-textured rock with accessory sulphides.

Some 120 km east of the 'Sholl-type' intrusives, a sequence of ultramafic sills crops out in the Millindinna area, about 20 km south of the coastal highway between Roebourne and Port Hedland. The steeply-dipping sills are concordantly folded within Mallina Formation greywackes and argillites belonging to the Gorge Creek Group. The sills crop out as sinuous ridges averaging 300 m across, notably in the area around Millindinna Hill, Mt Satirist and Mt Langenbeck. The little available published information on the 'Millindinna' suite suggests that the sills were intruded penecontemporaneously with sedimentation in the early stages of formation of a 15 km-thick sedimentary trench (Kriewaldt and Ryan, 1967, Miller, 1975). At Mt Langenbeck, an olivine-rich layered sequence consists of peridotite overlain by olivine pyroxenite and gabbro (Jones, 1971). Elsewhere the upper gabbro zone is either absent or masked by alluvium, and exposure is confined to peridotite which in places grades to dunite.

Of five samples collected from the Millindinna area four (#163,164,167,168) are harzburgites and #161 is an olivine websterite. The harzburgites are serpentinized olivine and orthopyroxene cumulates with minor intersertal saussurite after felspar. Fe oxides delineate the relict crystal shape of original olivine crystals. In the olivine websterite iddingsite forms the cores of pseudomorphed olivines as well as exsolved magnetite: intercumulus epidote-clinozosite is more abundant compared to the harzburgite samples, an indication of higher original plagioclase.

Samples of gabbro and granophyre were collected from the Gidley Granophyre at Hearson Cove, and from White Peak road cutting 2 km south of Dampier. The Gidley Granophyre is a ca 3000 m-thick high-level intrusion of granophyre and associated quartz gabbro, emplaced along the basal unconformity of the Fortescue Group (de Laeter and Trendall, 1971). Hickman and de Laeter, (1977) determined the age of the body as 2.6 Ga by Rb-Sr dating.

Differentiated coarse-grained gabbro at the base of the intrusion, commonly grading to felspathic diorite and quartz diorite, is overlain by fine-medium grained blue-grey granophyre which forms the major component of the intrusion.

Three gabbro samples collected comprise (a) a ferroan micro-gabbro consisting of partly chloritized amphibole, sodic plagioclase, quartz and minor biotite (#100); (b) a micro-gabbro containing clinopyroxene, quartz, saussuritized sodic plagioclase, together with incipient myrmekite developoment in the mesostasis (#103). (c) coarse-grained gabbro in which large crystals of platy, partly uralitized clinopyroxene, sub-ophitically enclose sodic plagioclase and quartz, which in places are micrographically intergrown.

Two differing varieties of granophyre were sampled. #99 and #102 are medium-grained rocks consisting predominantly of complexly intergrown strained quartz and potassium felspar. Common boundaries between these two minerals are diffuse owing to development of fine radiating micrographic intergrowths, giving the rock its distinctive granophyric texture. Scattered accessory clinopyroxene is commonly zoned, ophitic with respect to K felspar and sub-ophitically encloses rare albite which is mostly altered to sericite. Sample #106 from a felsite dyke intruding granophyre at Hearson Cove is an equigranular microcrystalline quartz-felspar rock with accessory amphibole and traces of apatite.

The <u>Cooya Pooya Dolerite</u> is described by Kriewaldt and Ryan (1967) as a 100 m-thick sill, probably of the same age as the Gidley Granophyre, emplaced along the contact between the Hardey Sandstone and the overlying Kylena Basalt. It crops out as mesas and black hills over an area of over 1800 km^2 in the area around Cooya Pooya, about 30 km south of Roebourne.

Samples of Cooya Pooya Dolerite which were collected from its northern margin at Lockyer Gap represent the lower (#88,89) middle (#90-92) and upper (#93,94,95,98) stratigraphic levels of the unit. Two samples were also taken for comparison from Table Hill (#96,97) which is also mapped as Cooya Pooya Dolerite on the Pyramid 1:250 000 Geological Map.

The Cooya Pooya samples can be sub-divided into rocks having the composition of siliceous high-magnesian basalt (SHMB) and rocks of tholeiitic composition. Some samples of both categories are pyroclastic in origin.

Samples #88 and #89 are both quench-textured clinopyroxene rocks. Sample #88 consists largely of serpentinized olivine enclosed by talc, dolomite and subsidiary chlorite. Clinopyroxene is present as (a) uralitized skeletal rods which form a moderately well developed quench texture and as (b) unaltered platy phenocrysts poikilitically enclosing numerous small talc/chlorite pseudomorphs after orthopyroxene and olivine. Elongate laths of saussuritized plagioclase are aligned sub-parallel to quench-textured clinopyroxene. Quartz, chromite and secondary magnetite are accessory phases. Sample #89 is a carbonated and hydrated rock in which primary cumulus minerals are altered to dolomite. Quench texture is observed as sheaves of chlorite after clinopyroxene accompanied by sub-parallel trains of small, chromite and magnetite grains.

Samples #90 and #91 consist primarily of talc/carbonate pseudomorphs after olivine and orthopyroxene. Unaltered subordinate clinopyroxene is present as an intercumulus phase together with minor saussuritized felspar and accessory quartz and chromite.

Samples #93 and #94 are very fine-grained rocks comprising equigranular microcrystalline talc, clinopyroxene and saussurite with accessory chromite. Lithic material, or possibly lapilli, are an important constituent of #93 which, taken together with the equant fine particulate texture, identify the material as well sorted, winnowed volcanic ash.

Rocks of tholeiitic composition are present in the middle (#92) and upper (#95, 98) part of the Lockyer Gap section and at Table Hill. In contrast to the high-magnesian basalts the tholeiites contain much more plagioclase. Subophitic clinopyroxene is commonly zoned and is altered to actinolite and chlorite in places. Felspar is altered to epidote. Orthopyroxene, which is subsidiary to clinopyroxene, is altered to chlorite. Sample #97 from the summit of Table Hill is an extremely fine-grained tholeiitic cryptocystalline tuff, texturally similar to #94: constituent minerals identified by X-Ray diffraction are chlorite, mica, felspar, quartz, pyroxene and dolomite.

East Pilbara

Sampling was carried out in the deformed metamorphosed mafic/ ultramafic belt which extends for 10 km from Pear Creek to Bamboo Creek. The belt has been disrupted by a major east/west trending fault. The rocks, mainly peridotite, high-magnesian basalt and dolerite, are altered to serpentinite, talc, chlorite, amphibole, carbonate assemblages which are generally sheared, foliated and schistose. Serpentinized peridotite at Pear Creek (#183, 184) hosts thin (<0.2m) podiform chromite horizons that pinch and swell over short distances. Leses of chromite are also hosted by interbedded schistose metabasic rocks, represented by samples #185 and #186.

Most samples obtained from the eastern part of the ultramafic belt at Bamboo Creek are altered peridotites consisting of felty, reticulate serpentine minerals and minor chlorite, talc, amphibole (anthophyllite), carbonate and magnetite are also present. In contrast to the ultramafic rocks, gabbros are relatively fresh and undeformed. Samples #134 and #135 from the gabbro zone are saussuritized plagioclase cumulates with sub-ophitic augite, altered in places to chlorite and containing substantial intersertal myrmekite.

Ultramafic rocks at the Lionel Mining Centre occur as sills of serpentinized peridotite which intrude a succession of Salgash Sub-Group basalts and dolerites and Gorge Creek Group metasediments. Deposits of chrysotile asbestos derived from the ultramafic rocks were formerly mined in places where asbestos made up almost 30 percent of the rock (Blockley, 1976). Two ultramafic samples (#187, 188) collected from the complex are strongly hydrated and probably represent altered pyroxenites.

GEOCHEMISTRY

The diverse range of rock types obtained from the Kimberleys and Pilbara, comprising fine-grained to coarse-grained, mafic to ultramafic, cumulus to non-cumulus, volcanic, hypabyssal and plutonic associations, are presented in Table 3. Symbols denoting the various rock units are shown in Fig.4. The geochemical diversity of the rocks, as represented by variations in Mg# (100 Mg/Mg + Fe_{tot}) is illustrated and contrasted in Fig. 5. Other indices such as Colour Index, 100An/An + Ab (normative plagioclase) and Differentiation Index are also useful discriminants for comparing members of the various rock suites though less reliable than Mg# where alteration has occurred.

Major element and trace element analyses and CIPW Norms for 74 east Kimberley and 81 Pilbara rocks are presented in Tables 1 and 2.

Samples have been broadly sub-divided for comparative purposes on the basis of their volcanic/hypabyssal or plutonic character. This allows comparison of the layered intrusions of both regions and also their respective high-level suites. Thus the Woodward Dolerite, Hart Dolerite and Toby Sill suites from the Kimberleys are compared with Pilbara basaltic associations from Ruth Well and Cooya Pooya.

All samples with the exception of some anorthosites are hypersthene-normative (Fig.6). They also plot in the sub-alkaline field on an Na_2O+K_2O vs SiO_2 diagram (Fig.7). The tholeiitic rather than calc-alkaline affinities of the Pilbara and Kimberley rocks are shown by their Fe-enrichment trends on an AFM diagram (Fig.8)

Dolerites

Woodward Dolerite amphibolites and Hart Dolerite samples are quartz-normative but Toby Sill dolerites comprise both quartz-normative and olivine-normative basaltic rocks. The anomalous siliceous character of some Toby Sill rocks (eg #57), results from secondary alteration, notably silicification. The Woodward Dolerite samples show an Mg# range of 46-67: good correlations between Mg# and major and trace elements eg. CaO, P_2O_5, Cr, Zr suggests that the samples represent a systematically fractionated igneous succession (Fig.9). The Hart Dolerite samples are strongly fractionated rocks, having Mg# in the range 43-49.

In contrast to the uniformly tholeiitic character of the Kimberley dolerites, the Pilbara Cooya Pooya and Ruth Well volcanics are distinctly bimodal in character: both comprise an ultramafic series and an associated tholeiitic component. Apart from their common bimodality however, the Ruth Well and Cooya Pooya rocks differ with regard to their ultramafic rock types. The Ruth Well ultramafics are komatiitic (Nisbet and Chinner 1981), whereas the Cooya Pooya ultramafic rocks are high-magnesian basalts with close similarities to siliceous high-magnesian basalts (SHMB) such as the nearby Negri Volcanics (Sun and Nesbitt, 1978).

Petrographic examination of the Cooya Pooya "Dolerite" samples obtained for this investigation suggests that some are extrusive in origin and not hypabyssal as implied by their stratigraphic title. However, as this study only examined a limited part of the large area represented as Cooya Pooya Dolerite on 1:250 000 geological maps, the full extent of such sub-aerial lithological units is speculative.

It is clear that more detailed investigation of the Cooya Pooya Dolerite is required in order to determine its lithostratigraphy.

The Cooya Pooya high-magnesian basalts are characterized by MgO between 12-21% and are strongly hypersthene-normative (>40% normative Hy) compared to the associated tholeiites (<25% normative Hy). The cumulus character of the SHMB is reflected by high Mg# between 73-80, compared to the slightly fractionated tholeiitic members which have Mg# between 62-71.

Plutonic rocks

Samples from the Panton Sill and Lamboo Sill are predominantly harzburgites. Al-spinel-bearing gabbros with Mg# 75 are present as later-stage members of the Panton Sill gabbroic zone (Hamlyn, 1980). The McIntosh Gabbro suite in contrast consists of diverse gabbroic rocks with Mg# 25-73, ranging from olivine gabbros to ferrogabbros . The least fractionated members of this suite are rocks from the McIntosh Sill, notably ol-normative norite, troctolite and olivine gabbro. Hamlyn (1977) and Mathison and Hamlyn (1987) have described the geochemistry of the McIntosh Sill in detail and the Panton Sill geochemistry has also been studied by Hamlyn (1975; 1977; 1980) and Hamlyn & Keays (1979).

The Archaean Pilbara plutonic successions appear to include a higher proportion and greater variety of ultramafic rocks compared to the early Proterozoic Kimberley groups. Differences are mainly due to the greater amount of pyroxene-dominant ultramafic rocks, such as websterites and clinopyroxenites in the Munni Munni and Andover intrusions. Websterites and gabbros from Munni Munni are all quartz-normative and the pyroxenites have Mg# ranging from 61-80 compared to Mg# 49-54 for the gabbros. Andover gabbros are anorthositic and magnesia-rich in comparison (Mg# greater than 65).

Clinopyroxenites, orthopyroxenites and clinopyroxene - orthopyroxene-dominant cumulates, such as websterites, are poorly documented from layered intrusions in the east Kimberleys. This feature represents a fundamental difference between the ultramafic assemblages of layered intrusions from the two provinces and possibly reflects differences in magma source characteristics and petrogenetic history of the

Munni Munni and Andover complexes in comparison with, for example, the Panton Sill.

In common with the Kimberley peridotites the Pilbara peridotites, with the exception of one lherzolite from Munni Munni, are all olivine/orthopyroxene dominant. In contrast, later-stage pyroxenites and gabbros are characterized by higher proprtions of clinopyrozene.

Major Elements

Compositions of rocks making up the various groups are summarized by means of selected major elements (Fig. 10). Peridotitic rocks have MgO contents ranging from 30% to 38%, Al_2O_3 from 1% to 5% and CaO up to 3%. Most of these peridotites have undergone extensive hydration, amounting up to 13% LOI in some samples. Fig.10 illustrates the greater spread of Pilbara major element values compared to the Kimberley groups, reflecting the greater compositional range of rock-types.

The compositional ranges of the different rock suites are illustrated by means of MgO-CaO-Al_2O_3 ternary diagrams (Fig.11). The Kimberley intrusives are essentially bimodal cumulate peridotite/gabbro associations characterized by Al_2O_3/CaO ratios greater than 1. Gabbroic rocks typically fall in the tholeiitic field, delineated by Al_2O_3/CaO ratios greater than 1, MgO/CaO less than 1 and Al_2O_3/(MgO+CaO) greater than 0.5. Anorthosites and anorthositic gabbros plot in the tholeiitic field closest to the Al_2O_3 apex reflecting plagioclase accumulation. Spinel-bearing gabbros from the Panton Sill are displaced out of the tholeiitic field towards the MgO apex, reflecting olivine accumulation.

Fig. 11a illustrates the compositions of Pilbara rocks and highlights, in particular, the distribution of Munni Munni and Andover pyroxenites in relation to the fields of peridotites and gabbros. This distribution trend correlates well with the trend of similar rock associations (websterites, gabbronorites, anorthositic gabbros) from various Archaean ultramafic complexes e.g., the Barberton Mountain Land (Anhaeusser, 1983). Barberton peridotites, dunites and some orthopyroxenites, occupy a field similar to that occupied by equivalent Kimberley/Pilbara rocks.

Separate plots of Kimberley and Pilbara dolerites and volcanics (Fig.11) highlight the significant geochemical differences between the Ruth Well and Cooya Pooya basaltic-rock groups and the Woodward Dolerite, Toby Sill and Hart Dolerite. The Kimberley dolerites are typically tholeiitic; the least-fractionated Woodward Dolerite rocks plot closest to the olivine-control line and the relatively more evolved Hart Dolerite plots closest to the Al_2O_3 apex, reflecting its relatively higher plagioclase component.

In contrast to the unimodal Kimberley tholeiites, the Cooya Pooya and Ruth Well basaltic suites consist of both ultramafic and tholeiitic components. On an MgO-CaO-Al_2O_3 diagram (Fig. 11b) these two suites plot close to a trend defined by the Hanging-Wall Basalts from Kambalda which are associated with komatiites (Arndt and Jenner, 1986). This trend is characterized by Al2O3/CaO ratios > 1 which increase progressively with fractionation. The Kambalda rocks and the Cooya Pooya high-magnesian basalts are similar with respect to their spinifex quench textures, MgO range (4% to 20%), relatively high (up to 54%) SiO_2, LREE enrichment, TiO_2 (less than 1%), P_2O_5 (less than 0.1%) and high Cr/Ni ratios (greater than 4), suggesting a common parentage.

Trace elements

Correlation of Ni and Cr with MgO for all suites is consistent with olivine fractionation and separation of either chromite or chrome-bearing minerals (eg. Cr-diopside) from the magmas (Fig.12), resulting in low concentrations of Cr and Ni in late differentiates. Overall depletion trends are consistent with universal fractionation behaviour of Cr and Ni in all the complexes investigated.

Ni concentrations for Bamboo Creek serpentinites are lower than in peridotitic rocks of similar MgO content from the other Pilbara complexes and in the Panton and Lamboo Sills all of which are Ni-rich when compared to estimated Ni concentrations in the mantle. Ni versus MgO trends for Munni Munni and Andover pyroxenites lie on the same trend as the Kambalda Hanging-Wall Basalts (Arndt and Jenner, 1986).

Cr in the Panton Sill and Lamboo Sill peridotites is higher than estimated mantle compositions as would be expected because of their higher pyroxene/olivine ratio compared to pyrolite. Fig.12 shows that pyroxenites of the Pilbara rock groups lie on two different trends: - (1) a trend which is consistent with mantle Cr/MgO, and (2) a Cr-enriched trend. Bamboo Creek serpentinites and most Munni Munni pyroxenites lie on trend (1), while the Cooya Pooya suite and most of the Andover samples fall on trend (2). Further evidence of Cr-enrichment in Cooya Pooya high-magnesian basalts is the presence of accessory chromite in some samples.

In almost all Cr-enriched (trend 2) rocks normative hypersthene/diopside ratios are close to, or greater than 1. Trend (1) (Cr-'normal') rocks in contrast have hypersthene/diopside normative ratios less than 1. The relationship between normative hypersthene and Cr appears to be particularly evident for the Cooya Pooya series (Fig. 13), and to a lesser extent for Bamboo Creek.

It is suggested that the two apparent trends of Cr content in Pilbara rocks are related to their pyroxene-dominated mineralogy and specifically to clinopyroxene /orthopyroxene ratios of rocks in the MgO 10-30% range. Pyroxenes have a high affinity for Cr compared to other rock forming silicates, with the exception of amphiboles. The Cr mineral/liquid partition co-efficient of clinopyroxene (K_d up to 15) is almost three times greater than that for orthopyroxene (Sun et al, 1979). In rocks of pyroxenitic composition therefore, in the absence of amphibole and where magnetite content is low, clinopyroxene crystallization will remove relatively more Cr from the system than orthopyroxene. Thus free chromite is more likely to occur in an orthopyroxene-dominated crystallizing system. Olivine and plagioclase, both having relatively low partition co-efficients for Cr, (Kds < 1) are insignificant Cr-collectors compared to the pyroxenes.

Disseminated chromite and chromite cycles are present throughout most of the olivine cumulates of the Panton Sill ultramafic zone (Hamlyn & Keays, 1979). Disseminated to massive banded chromite mineralization has also been identified in the Lamboo Sill together with associated PGE mineralization (Hunter Resources Ltd 1987). No such chromite occurrences have been identified in the west Pilbara suites covered in this report, except at Munni Munni in a sheared dunite lens near the contact between the ultramafic and gabbro zones (Hoatson and Keays, 1989). This suggests that chromite accumulations observed in the Kimberley mafic/ultramafic complexes may reflect a real difference between the Kimberley and Pilbara rock suites, perhaps related to differences in parental magma compositions.

Ti and V and to a lesser extent Sc, all display negative correlation with MgO in all rock suites (Figs. 14&15). This correlation is consistent with crystal fractionation trends as reflected by increasing Fe/Mg ratios, as Ti and V are essentially incompatible until they preferentially enter the lattices of magnetite and ilmenite during the latter stages of magmatic crystallization. Such late-stage crystallization of Ti and V is manifested at the Andover Complex by the presence of concordant vanadiferous titanomagnetite segregations associated with gabbros, and at the Munni Munni Complex, where disseminated magnetite-ilmenite aggregates attain 10% modal volume in gabbronorites near the top of the gabbro zone.

A comparison between Ti and V in the Pilbara and Kimberley basalt/dolerite rocks shows that the Hart Dolerite and Toby Sill fall on a more Ti-rich trend than the Woodward Dolerite and Cooya Pooya rocks (Fig.15). The Hart Dolerite is somewhat poorer in Sc than the Woodward Dolerite and Toby Sill. This may be related either to the greater degree of fractionation (Mg#39-44) of the Hart Dolerite rocks, or may point to differences in degree of partial melting of this relatively much younger rock unit.

Incompatible elements

Overall concentrations of LIL elements Rb, Ba, Th, K, are generally widely dispersed and inconsistent, particularly in altered ultramafic rocks. These mobile elements are therefore considered unreliable with regard to determining the primary chemical nature of the rocks. On primordial mantle-normalized plots all rock assemblages show depletion in Nb relative to La, a characteristic of Archaean basaltic rocks, and are enriched in LREE (Fig.16).

Fig. 16 shows that Andover, Munni Munni and McIntosh Gabbro groups are characterized by wide ranges (from 1 to 100-times-primordial mantle) of enrichment of some of the most incompatible elements (Rb, Ba, Th). Ranges of enrichment for less mobile elements (Nb, LREE, Sr, P, Zr, Ti, Y) are generally much lower for all groups. Broad negative correlations between the degree of enrichment and Mg#, particularly in dolerites and basaltic rocks, illustrate a general relationship between incompatible element enrichment and the degree of fractionation of the rock.

Similarities between Cooya Pooya Dolerite La/Nb, Ti/Zr and La/Y ratios suggest that the tholeiitic and high-magnesian rocks are genetically related. The rocks are therefore likely to represent a fractionated continuum, rather than a bimodal assemblage derived from different sources.

High field strength (HFS) elements, notably Ti, Zr and Nb, for the Ruth Well komatiite sample #196 show a slightly depleted pattern, close to primordial mantle values, whereas the more incompatible elements of the Ruth Well komatiite are, in contrast, enriched by from 2 to 10- times primordial mantle. Primordial mantle values and ratios of refractory lithophile elements such as Ti/Zr (110), Ti/Y (290), Y/Zr (0.39), as shown by the Ruth Well samples, are similar to those of peridotitic komatiites (Nesbitt, et al, 1979).

SUMMARY

Major and trace element analyses were determined on seven selected Proterozoic mafic/ultramafic intrusives from the east Kimberleys and ten intrusives of Archaean age from the Pilbara Block. The purpose of the sampling was to establish a representative data base from which to assess the PGE potential of these two areas in Western Australia. For comparative purposes the intrusives are subdivided as either high-level (volcanic/hypabyssal) or plutonic in character.

The east Kimberley volcanic /hypabyssal suites are tholeiites which, with the exception of the Toby Sill, are quartz normative. The oldest of these bodies, the Woodward Dolerite is a systematically fractionated sequence having an Mg# range from 67-46. In contrast volcanic/hybabyssal rocks from the Pilbara Block, represented by the Cooya Pooya Dolerite and volcanics from the Ruth Well Syclinorium, are respectively siliceous high-magnesium basalts and komatiites, both with associated tholeiitic end members.

The plutonic mafic/ultramafic intrusives from the two regions also differ compositionally. The West Pilbara intrusives, notably the large well-fractionated Munni Munni and Andover complexes, are peridotite-pyroxenite-gabbro assemblages in which websterites form a substantial component of the ultramafic stratigraphy. Pyroxenites, on the other hand, are either absent, or have been poorly documented in the large east Kimberley mafic-ultramafic intrusions, such as the Panton and Lamboo sills. Geochemical criteria highlight these compositional differences between the two regions, including the Barberton-type trends of the larger Pilbara layered intrusives and the komatiitic trends of the west

Pilbara high-level intrusives compared with the tholeiitic character of their Kimberley equivalents. Komatiitic trends are characterized by Al_2O_3/CaO ratios > 1 increasing with fractionation, in contrast to Barberton-type trends, where the pyroxenite components of the layered assemblage have Al_2O_3/CaO ratios < 1.

The comparatively lower Cr content of the west Pilbara mafic/ultramafic intrusives, contrasts with those from the Kimberleys. These differences may be due to differences in magma compositions and may, in part, be related to significant amounts of clinopyroxene-dominant pyroxenite in the Pilbara intrusives, which results in systematic depletion of Cr, owing to its greater incorporation into clinopyroxene relative to orthopyroxene. Additionally, a general relationship between normative hypersthene/diopside ratios and Cr content is illustrated by a significant positive correlation between hypersthene and Cr in the Cooya Pooya Dolerite lithostratigraphic sequence.

The presence of volcanoclastic material in areas represented as Cooya Pooya Dolerite on 1:250 000 geological maps, suggests that more detailed investigations of this unit are required in order to determine its lithostratigraphy.

This report is intended primarily as a preliminary presentation of geochemical data on selected east Kimberley and Pilbara mafic/ultramafic intrusive and extrusive rock units, together with a summary of their geological setti ngs. A more detailed analysis of the geochemistry of these units and implications for their PGE potential is presented by Wallace, Sun, Hoatson and Keays (1990) and Sun, Wallace, Hoatson, Glikson and Keays, (1990).

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TABLE 1

EAST KIMBERLEY GEOCHEMICAL DATA

Sample number	83330003	83330006	83330007	83330008	83330009	83330011	83330012	83330013
Stratigraphic group	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex
Stratigraphic unit	Alice D UB Panton S	Alice D UB Panton S	Alice D UB Panton S	Alice D UB Panton S	Alice D UB Panton S	Alice D UB Panton S	Alice D UB Panton S	Alice D UB Panton S
Lithology	perid[hz]	perid[hz]	perid[hz]	perid[hz]	perid[hz]	ol gabbro	sp gabbro	sp gabbro
Map name	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh
Grid reference	CF757369	CF762373	CF762371	CF764365	CF765375	CF741319	CF741319	CF744319
SiO2	40.95	40.90	34.73	36.26	35.79	46.15	46.65	42.70
TiO2	.30	.27	.13	.15	.18	.22	.17	.12
Al2O3	5.05	4.78	2.24	2.19	3.04	13.65	18.52	21.73
Fe2O3	4.31	3.39	9.81	11.30	4.27	1.64	.93	2.27
FeO	6.86	8.20	1.73	1.89	6.93	6.86	4.15	4.61
MnO	.14	.12	.11	.14	.12	.12	.08	.07
MgO	31.16	30.90	34.83	33.46	35.07	15.72	10.43	13.18
CaO	3.24	2.98	.77	.36	1.89	11.52	15.87	12.14
Na2O	.13	.08	.02	.03	.05	.65	.76	.91
K2O	.02	<.01	<.01	<.01	<.01	.16	.11	.12
P2O5	.03	.03	.02	.02	.02	.02	.02	.02
LOI	6.41	7.16	13.98	12.13	10.41	2.35	1.39	1.12
Rest	1.16	1.12	.91	1.28	1.13	.20	.28	.23
Total	99.76	99.93	99.28	99.21	98.90	99.26	99.36	99.22

Trace elements in parts per million

Ba	17	3	17	22	15	32	26	26
Li	3	2	1	2	1	3	3	3
Rb	5	<2	<2	<2	2	5	2	2
Sr	26	24	6	5	20	108	116	138
Pb	4	3	2	3	4	3	<2	2
Th	2	1	<1	1	2	<1	<1	<1
U	1	<1	<1	2	<1	1	<1	<1
Zr	28	25	10	9	14	14	8	8
Nb	<2	<2	<2	<2	<2	<2	<2	<2
Y	7	8	3	2	5	6	5	3
La	4	4	3	2	4	3	2	3
Ce	6	3	<3	<3	<3	<3	<3	3
Nd	<3	<3	<3	<3	<3	<3	<3	4
Sc	17	17	10	10	11	28	25	8
V	90	98	50	55	69	93	80	31
Cr	4806	4624	4170	5378	5575	782	1353	1007
Ni	2045	1634	2023	2655	2240	240	197	343
Cu	230	476	143	222	44	77	83	60
Zn	73	50	43	159	49	18	28	10
Ga	4	6	2	4	4	9	12	13
As	2	158	29	7	5	<1	<1	1
S	1300	1200	50	850	-	-	-	-

Table 1 (contd)

Sample number	83330015	83330016	83330017	83330018	83330020	83330022	83330023	83330024
Stratigraphic group	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex
Stratigraphic unit	Alice D UB Panton S	Alice D UB Panton S	Alice D UB Panton S	Alice D UB Panton S	Alice D UB Panton S	Alice D UB Lamboo S	Alice D UB Lamboo S	Alice D UB Lamboo S
Lithology	gabbro	anorth	sp gabbro	anorth	sp gabbro	perid[hz]	perid[hz]	perid[hz]
Map name	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	Angelo	Angelo	Angelo
Grid reference	CF737324	CF738323	CF732322	CF741322	CF744319	CE239581	CE240577	CE240577
SiO2	45.33	46.52	41.01	48.24	43.16	36.65	39.53	36.59
TiO2	1.92	.64	.10	.33	.12	.11	.18	.18
Al2O3	14.73	27.37	17.67	17.68	20.22	2.81	3.11	2.91
Fe2O3	4.02	1.42	4.09	.90	2.53	10.98	6.98	9.95
FeO	11.93	2.84	6.71	4.58	4.54	1.13	3.67	1.21
MnO	.14	.04	.10	.10	.07	.07	.07	.07
MgO	6.32	1.81	17.33	8.24	14.57	35.49	33.23	35.81
CaO	11.25	14.62	9.39	17.74	11.91	.03	.17	.15
Na2O	1.20	2.56	.49	.76	.90	.02	.02	.02
K2O	.57	.34	.15	.07	.09	.01	.01	.01
P2O5	.07	.14	.02	.02	.02	.01	.02	.04
LOI	1.81	1.45	2.61	1.52	1.60	11.57	11.65	11.64
Rest	.29	.09	.05	.19	.22	.76	.94	.97
Total	99.58	99.84	99.72	100.37	99.95	99.64	99.58	99.55
				Trace elements in parts per million				
Ba	115	83	25	23	40	15	75	72
Li	7	5	2	2	2	1	3	1
Rb	15	24	8	12	2	4	3	2
Sr	149	299	110	155	115	2	7	8
Pb	6	3	<2	6	2	<2	4	<2
Th	4	3	<1	<1	<1	<1	<1	<1
U	<1	1	<1	<1	<1	<1	<1	1
Zr	46	30	7	17	8	7	17	16
Nb	2	2	<2	<2	<2	2	<2	<2
Y	15	11	1	8	<1	19	4	7
La	9	9	3	5	3	29	3	6
Ce	13	18	<3	<3	<3	<3	<3	<3
Nd	6	8	<3	3	<3	25	<3	<3
Sc	50	11	9	40	10	10	11	10
V	922	112	24	154	39	52	66	57
Cr	17	9	24	717	931	3174	3771	4497
Ni	42	12	156	45	370	1926	2186	1667
Cu	285	8	5	59	75	216	154	244
Zn	91	19	17	41	14	29	10	20
Ga	21	25	10	16	12	5	3	4
As	1	1	2	1	1	4	3	2
S	150	-	-	-	-	<20	550	400

Table 1 (contd)

Sample number	83330026	83330193	83330194	83330029	83330030	83330031	83330032	83330033
Stratigraphic group	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex
Stratigraphic unit	Alice D UB Lamboo S	Alice D UB Lamboo S	Alice D UB Lamboo S	McIntosh Gabbro	McIntosh Gabbro	McIntosh Gabbro	McIntosh Gabbro	McIntosh Gabbro
Lithology	amphib	dunite	perid[hz]	dolerite	dolerite	dolerite	dolerite	dolerite
Map name	Angelo	Angelo	Angelo	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh
Grid reference	CE215573	CE240597	CE240597	CF827327	CF827327	CF827327	CF827327	CF828325
SiO2	48.71	30.99	37.16	47.67	49.08	51.37	49.90	53.14
TiO2	.80	.18	.09	.99	1.09	2.01	1.05	.92
Al2O3	15.82	2.13	1.87	15.86	16.24	14.48	14.63	14.60
Fe2O3	4.48	19.24	10.95	2.33	1.18	6.20	3.27	2.49
FeO	5.82	2.97	.82	8.51	9.57	10.50	9.81	9.04
MnO	.13	.02	.03	.17	.15	.25	.20	.20
MgO	7.56	29.76	36.06	8.19	8.00	2.53	5.54	5.73
CaO	9.25	.58	.03	11.69	11.33	9.22	11.79	10.56
Na2O	2.29	.02	.03	1.41	1.97	1.11	.85	.71
K2O	.06	<.01	<.01	.42	.15	.17	.34	.24
P2O5	.05	.02	<.01	.10	.08	.27	.14	.19
LOI	4.26	10.30	11.23	1.78	1.09	1.40	1.71	1.63
Rest	.17	2.94	1.07	.16	.24	.10	.15	.13
Total	99.40	99.15	99.34	99.28	100.17	99.61	99.38	99.58

Trace elements in parts per million

Ba	301	246	17	169	105	92	177	59
Li	7	1	-	7	3	6	7	11
Rb	2	<2	<2	13	2	5	5	3
Sr	149	7	2	269	213	153	215	76
Pb	3	3	4	6	4	4	7	5
Th	1	1	1	<1	<1	2	3	2
U	1	<1	<1	1	1	<1	2	2
Zr	43	5	6	37	28	143	85	87
Nb	2	<2	<2	3	2	8	4	6
Y	17	<2	3	17	17	40	30	34
La	5	3	2	9	8	13	11	17
Ce	6	5	<3	11	13	24	22	32
Nd	5	<3	<3	10	9	20	14	19
Sc	36	8	8	31	33	31	37	37
V	212	99	44	199	192	53	226	210
Cr	296	14000	4972	195	167	12	56	139
Ni	57	3162	2531	102	89	5	24	44
Cu	32	3531	3	14	54	4	4	8
Zn	61	29	25	78	80	144	139	116
Ga	15	3	2	16	14	20	15	15
As	<1	4	3	<1	<1	2	5	1
S	-	-	-	-	1000	-	-	-

Table 1 (contd)

Sample number	83330034	83330037	83330038	83330039	83330040	83330041	83330042	83330043
Stratigraphic group	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex
Stratigraphic unit	McIntosh Gabbro	McIntosh Gabbro	McIntosh Gabbro	McIntosh Gabbro	McIntosh Gabbro Mc.Sill	McIntosh Gabbro Mc.Sill	McIntosh Gabbro Mc.Sill	McIntosh Gabbro Mc.Sill
Lithology	dolerite	amphib	amphib	amphib	amphib	amphib	amphib	troctolite
Map name	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh
Grid reference	CF829324	CF753284	CF753284	CF754285	CF888428	CF888428	CF871426	CF863456
SiO2	50.21	48.78	53.62	48.28	48.19	44.99	49.83	47.69
TiO2	1.53	1.41	1.29	1.73	1.06	1.05	.73	.17
Al2O3	13.94	12.79	14.17	17.15	17.16	13.94	15.05	26.55
Fe2O3	1.94	.16	2.26	2.91	2.94	5.88	2.21	.94
FeO	10.82	9.45	7.42	8.37	7.94	8.21	8.24	2.64
MnO	.15	.20	.16	.13	.12	.15	.15	.04
MgO	5.75	2.95	3.93	4.39	7.66	10.22	7.97	4.49
CaO	11.29	15.17	10.52	12.33	10.33	11.93	11.58	14.12
Na2O	1.45	2.17	3.06	2.78	2.23	1.46	1.36	2.51
K2O	.19	.28	.38	.62	.09	.05	.27	.09
P2O5	.14	.20	.18	.20	.02	.02	.08	.03
LOI	1.98	6.14	2.40	1.49	1.52	1.59	1.79	.60
Rest	.18	.14	.16	.17	.15	.24	.19	.10
Total	99.57	99.84	99.55	100.55	99.41	99.73	99.45	99.97

Trace elements in parts per million

Ba	282	113	292	176	92	149	94	51
Li	14	4	7	6	8	3	8	3
Rb	3	<2	5	8	<2	<2	2	2
Sr	192	205	233	234	441	322	106	477
Pb	3	7	3	<2	2	<2	3	2
Th	2	6	2	1	<1	<1	1	<1
U	<1	2	<1	1	<1	<1	<1	<1
Zr	94	157	133	115	10	10	45	7
Nb	6	9	7	8	<2	<2	4	<2
Y	24	40	37	29	6	13	17	3
La	11	18	12	11	2	3	8	4
Ce	21	34	23	18	6	3	9	7
Nd	14	22	16	15	6	6	7	4
Sc	38	23	33	35	27	33	34	8
V	285	203	230	250	226	349	194	23
Cr	129	88	88	177	72	420	574	106
Ni	31	8	18	34	82	220	78	41
Cu	54	3	3	7	48	133	64	53
Zn	90	74	57	50	66	69	68	19
Ga	20	17	17	20	16	12	13	17
As	2	<1	1	2	1	1	<1	<1
S	-	-	-	-	-	-	42	-

Table 1 (contd)

Sample number	83330044	83330045	83330081	83330082	83330083	83330084	83330085	83330086
Stratigraphic group	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex
Stratigraphic unit	McIntosh Gabbro Mc.Sill	McIntosh Gabbro Mc.Sill	McIntosh Gabbro Mc.Sill	McIntosh Gabbro	McIntosh Gabbro	McIntosh Gabbro	McIntosh Gabbro	McIntosh Gabbro
Lithology	norite	ol gabbro	dolerite	dolerite	amphib	amphib	dolerite	amphib
Map name	McIntosh	McIntosh	Turkey Ck	Turkey Ck	Turkey Ck	Turkey Ck	Turkey Ck	Turkey Ck
Grid reference	CF865456	CF868456	CF952761	CF947758	CF945761	CF943762	CF961747	CF959748
SiO2	50.75	48.33	49.16	49.94	51.97	48.54	48.19	49.48
TiO2	1.25	.48	2.15	.69	.12	2.07	1.15	.27
Al2O3	18.59	17.58	13.37	17.26	14.77	13.31	15.50	16.02
Fe2O3	2.62	1.87	2.76	1.05	2.59	2.70	1.06	1.78
FeO	6.75	8.47	11.07	7.24	9.36	10.76	10.53	8.25
MnO	.13	.15	.18	.13	.18	.18	.16	.14
MgO	6.08	7.27	5.26	7.56	6.25	5.17	8.56	8.08
CaO	9.30	11.53	9.02	11.17	10.25	8.99	12.15	10.71
Na2O	3.70	2.74	2.46	1.94	1.74	2.21	1.35	1.66
K2O	.08	.03	1.12	.41	.30	1.20	.24	.89
P2O5	.02	.01	.31	.11	.06	.24	.14	.01
LOI	.69	1.14	2.25	1.76	1.59	3.66	1.28	2.44
Rest	.11	.14	.29	.18	.20	.22	.18	.15
Total	100.07	99.74	99.40	99.44	99.38	99.25	100.49	99.88
Trace elements in parts per million								
Ba	42	12	406	255	226	394	150	224
Li	5	3	6	3	4	5	3	2
Rb	<2	<2	36	12	3	47	6	26
Sr	375	281	149	74	320	140	163	178
Th	<1	<1	4	<1	2	4	1	1
U	<1	<1	<1	<1	1	1	<1	<1
Zr	<2	3	149	74	320	140	69	12
Nb	<2	<2	12	4	2	12	4	<2
Y	1	5	31	19	42	29	24	9
La	<2	<2	25	15	21	22	9	4
Ce	<3	<3	47	27	35	44	18	8
Nd	<3	<3	31	16	28	27	13	6
Sc	21	23	30	34	48	33	37	45
V	176	211	302	141	96	313	227	177
Cr	71	220	544	314	270	64	260	216
Ni	29	102	31	90	73	31	128	54
Cu	2	64	52	40	16	54	61	42
Zn	50	59	125	80	127	141	91	79
Ga	19	17	21	16	17	18	16	14
As	<1	2	<1	<1	1	1	1	<1
S	-	-	-	-	-	-	-	-

Table 1 (contd)

Sample number	83330046	83330047	83330048	83330049	83330050	83330051	83330052	83330053
Stratigraphic group	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex
Stratigraphic unit	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill
Lithology	amphib	dolerite	dolerite	dolerite	dolerite	dolerite	dolerite	dolerite
Map name	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh
Grid reference	CF872543	CF568541	CF569543	CF572546	CF572546	CF544623	CF545623	CF549622
SiO2	43.97	49.10	46.46	50.27	49.19	48.15	48.73	47.85
TiO2	1.47	1.07	.89	1.18	1.20	1.30	1.17	1.20
Al2O3	16.32	16.23	13.59	14.92	15.60	15.24	15.21	15.69
Fe2O3	1.49	1.71	1.19	1.79	1.82	1.91	1.86	1.91
FeO	12.29	8.71	7.80	9.13	9.27	9.75	9.48	9.73
MnO	.15	.13	-	.14	.14	.14	.16	.16
MgO	8.69	7.70	7.04	7.14	7.73	7.59	7.50	7.94
CaO	7.48	10.87	11.80	10.37	10.41	11.58	11.52	10.91
Na2O	1.40	2.07	1.87	1.72	1.91	2.06	2.22	2.28
K2O	.60	.78	.14	.71	.74	.45	.46	.36
P2O5	.21	.16	.11	.17	.18	.26	.21	.13
LOI	4.99	1.09	8.41	1.60	.97	.98	1.03	1.23
Rest	.23	.29	.16	.22	.30	.21	.21	.14
Total	99.29	99.91	99.46	99.36	99.46	99.62	99.76	99.53
Trace elements in parts per million								
Ba	395	295	193	442	275	320	297	110
Li	12	8	21	11	11	9	9	3
Rb	50	38	7	31	32	13	17	10
Sr	150	213	138	167	143	260	218	180
Pb	3	5	7	9	7	6	6	4
Th	2	2	2	2	3	<1	1	<1
U	1	1	1	1	1	<1	<1	1
Zr	158	101	73	127	122	124	106	75
Nb	9	6	4	6	5	7	6	2
Y	35	25	24	34	29	31	28	23
La	22	19	14	23	20	27	25	8
Ce	44	33	23	43	35	52	45	13
Nd	25	19	12	24	20	29	23	11
Sc	33	27	29	34	29	33	34	34
V	204	178	176	191	181	211	213	209
Cr	335	254	320	305	276	263	275	122
Ni	138	107	21	86	122	71	73	69
Cu	14	54	21	50	56	53	59	49
Zn	73	80	76	85	87	85	90	89
Ga	16	16	15	17	17	17	20	17
As	1	1	13	1	1	<1	<1	1
S	-	950	-	-	1000	-	-	-

Table 2 (contd)

Sample number	83330155	83330156	83330157	83330158	83330159	83330160	83330172	83330173
Stratigraphic group	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Warrawoona	Warrawoona
Stratigraphic unit	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided Andover	Undivided Andover
Lithology	ol opyxte	webst	webst	gabbro	gabbro	gabbro	dolerite	ol webst
Map name	Pinderi H.	Pinderi H.	Pinderi H.	Pinderi H.	Pinderi H.	Pinderi H.	Roebourne	Roebourne
Grid reference	874614	875635	875635	873635	873635	873635	143978	143978
SiO2	45.92	54.33	51.61	53.66	52.07	53.56	52.63	44.83
TiO2	.15	.57	.67	.68	.91	.54	.93	.38
Al2O3	3.46	8.64	9.88	14.76	15.60	15.18	8.36	2.41
Fe2O3	2.23	1.39	1.70	2.37	1.59	1.44	1.11	8.54
FeO	6.68	8.95	10.36	8.20	8.85	8.44	9.49	4.24
MnO	.12	.18	.20	.14	.15	.13	.20	.17
MgO	31.77	9.16	10.81	4.75	4.92	4.66	10.41	24.84
CaO	2.48	11.25	8.99	8.30	7.33	8.28	10.75	8.33
Na2O	.20	2.09	2.14	3.47	3.61	3.45	2.97	.29
K2O	.32	.94	.47	.96	1.03	.97	.12	.11
P2O5	.01	.02	.02	.07	.07	.06	.10	.04
LOI	5.62	1.82	2.17	1.97	3.12	2.40	2.22	5.47
Rest	1.04	.22	.32	.21	.15	.20	.36	.64
Total	100.00	99.56	99.34	99.54	99.40	99.31	99.65	100.29
Trace elements in parts per million								
Ba	76	316	407	412	177	403	358	72
Li	4	7	6	4	11	5	24	2
Rb	11	42	37	25	31	24	6	4
Sr	38	272	279	493	198	489	206	71
Pb	2	6	4	6	5	6	5	2
Th	1	3	<1	4	3	4	5	1
U	<1	<1	<1	<1	<1	<1	<1	<1
Zr	15	51	<2	82	75	69	106	28
Nb	<2	2	<2	3	4	3	6	2
Y	3	13	12	13	12	12	13	6
La	3	8	5	16	15	14	18	5
Ce	4	15	6	27	28	24	35	7
Nd	<3	8	6	14	14	13	16	<3
Sc	13	27	22	17	15	16	24	22
V	64	164	141	126	159	105	153	104
Cr	5876	149	750	13	14	13	1021	2882
Ni	1127	248	411	91	91	87	325	1206
Cu	17	151	205	223	234	196	163	39
Zn	41	77	93	84	78	79	79	68
Ga	4	12	11	17	16	17	12	4
As	1	<1	<1	1	<1	<1	1	1
S	-	200	-	-	-	-	100	100

Table 1 (contd)

Sample number	83330054	83330055	83330056	83330057	83330058	83330059	83330060	83330061
Stratigraphic group	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Lamboo Complex	Halls Ck
Stratigraphic unit	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	McIntosh Gabbro Toby Sill	Woodward Dolerite
Lithology	dolerite	dolerite	amphib	amphib	amphib	amphib	dolerite	amphib
Map name	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	McIntosh	RubyPlains
Grid reference	CF574544	CF574544	CF585518	CF585518	CF585518	CF586519	CF586519	CE594472
SiO2	49.06	48.67	48.60	58.25	48.39	47.35	47.28	50.06
TiO2	1.40	1.57	1.28	1.16	1.19	1.60	1.71	1.23
Al2O3	15.36	15.03	13.90	8.49	14.49	14.53	14.47	13.84
Fe2O3	1.87	2.03	2.02	2.90	1.77	1.63	1.81	2.24
FeO	9.51	10.35	10.32	7.78	9.03	11.23	11.74	11.44
MnO	.14	.15	.19	.14	.16	.16	.17	.17
MgO	7.67	6.81	6.94	6.58	7.16	7.61	8.15	5.58
CaO	10.42	10.52	9.67	10.11	9.92	7.09	6.43	10.24
Na2O	2.03	2.53	1.80	1.45	1.42	3.24	3.10	2.10
K2O	.76	.56	.20	.15	.96	.27	.19	.26
P2O5	.24	.23	.18	.09	.17	.26	.27	.12
LOI	.87	.86	3.97	2.03	4.37	3.90	4.34	1.84
Rest	.31	.20	.17	.13	.19	.20	.21	.35
Total	99.64	99.51	99.24	99.26	99.22	99.07	99.87	99.47

Trace elements in parts per million

Ba	284	220	83	31	211	148	73	41
Li	10	11	10	2	15	13	14	5
Rb	32	21	6	<2	52	10	7	4
Sr	143	161	138	93	124	104	61	111
Pb	10	8	7	6	15	6	3	6
Th	3	3	2	2	4	3	4	4
U	1	1	1	2	2	2	2	2
Zr	161	164	127	75	116	166	168	92
Nb	8	9	7	4	6	9	10	5
Y	34	39	39	24	29	36	39	30
La	25	29	23	8	19	29	29	12
Ce	44	54	48	14	36	50	53	23
Nd	25	31	24	9	21	27	26	17
Sc	29	32	35	28	35	37	34	41
V	175	222	211	182	202	226	228	312
Cr	274	213	244	231	309	322	348	92
Ni	126	83	70	74	87	88	96	44
Cu	53	52	5	5	43	47	109	91
Zn	90	101	100	95	83	108	110	90
Ga	19	20	20	10	17	14	13	14
As	<1	1	10	<1	3	1	1	<1
S	1000	-	-	-	-	-	90	2000

Table 1 (contd)

Sample number	83330062	83330063	83330064	83330065	83330066	83330067	83330068	83330069
Stratigraphic group	Halls Ck	Halls Ck	Halls Ck	Halls Ck	Halls Ck	Halls Ck	Halls Ck	Halls Ck
Stratigraphic unit	Woodward Dolerite	Woodward Dolerite	Woodward Dolerite	Woodward Dolerite	Woodward Dolerite	Woodward Dolerite	Woodward Dolerite	Woodward Dolerite
Lithology	amphib	amphib	amphib	amphib	amphib	amphib	amphib	amphib
Map name	RubyPlains	RubyPlains	RubyPlains	RubyPlains	RubyPlains	RubyPlains	RubyPlains	RubyPlains
Grid reference	CE594472	CE593473	CE592475	CE534454	CE532457	CE529461	CE527463	CE523462
SiO2	51.76	51.48	51.98	50.52	49.39	50.75	50.26	51.60
TiO2	1.22	.62	1.23	.56	1.08	.54	.93	.53
Al2O3	13.44	12.82	13.59	14.39	14.23	14.11	13.87	14.52
Fe2O3	2.15	1.69	2.17	1.57	1.96	1.52	1.86	1.48
FeO	10.95	8.60	11.05	8.02	10.00	7.77	9.47	7.56
MnO	.17	.14	.17	.16	.15	.14	.16	.13
MgO	5.43	7.60	5.53	7.91	6.87	8.80	7.38	8.04
CaO	9.93	13.38	9.59	11.37	12.12	13.17	12.23	13.69
Na2O	1.78	.56	1.77	2.79	1.60	.98	1.19	.71
K2O	.29	.23	.24	.13	.13	.06	.12	.05
P2O5	.12	.08	.13	.06	.10	.06	.09	.05
LOI	1.85	2.53	2.08	1.59	1.59	1.56	1.70	1.42
Rest	.19	.19	.16	.18	.35	.25	.22	.15
Total	99.28	99.92	99.69	99.25	99.57	99.71	99.48	99.93

Trace elements in parts per million

Ba	90	210	151	73	33	24	180	16
Li	5	8	9	4	4	5	6	4
Rb	6	8	5	3	<2	<2	<2	<2
Sr	120	136	89	115	120	110	118	103
Pb	5	4	7	7	4	<2	4	3
Th	3	2	4	1	<1	2	1	2
U	1	1	1	1	1	1	<1	1
Zr	94	59	90	44	62	44	57	42
Nb	5	3	5	2	2	2	4	3
Y	29	17	29	15	25	13	21	14
La	10	7	12	7	5	7	7	8
Ce	18	12	20	12	10	11	12	9
Nd	13	7	15	7	7	9	8	7
Sc	40	33	39	38	39	36	41	36
V	305	201	301	201	310	199	257	191
Cr	90	450	95	481	209	514	232	390
Ni	45	69	46	119	87	118	76	94
Cu	44	41	55	77	91	86	75	81
Zn	93	63	95	60	81	59	69	55
Ga	15	11	18	12	17	11	12	12
As	<1	1	3	1	1	2	4	1
S	450	40	40	<20	1900	750	550	-

Table 1 (contd)

Sample number	83330070	83330071	83330073	83330074	83330075	83330076	83330077	83330078
Stratigraphic group	Halls Ck	Halls Ck	Halls Ck	Halls Ck	Halls Ck	Hart Dolerite	Hart Dolerite	Hart Dolerite
Stratigraphic unit	Woodward Dolerite	Woodward Dolerite	Woodward Dolerite	Woodward Dolerite	Woodward Dolerite	Undivided	Undivided	Undivided
Lithology	amphib	amphib	amphib	amphib	dolerite	dolerite	dolerite	dolerite
Map name	RubyPlains	RubyPlains	RubyPlains	RubyPlains	Dockerell	Remarkable	Remarkable	Remarkable
Grid reference	CE521464	CE518466	CE512468	CE483503	CE187253	CF498769	CF498749	CF796769
SiO2	49.97	49.92	50.23	49.97	49.24	51.66	51.66	50.99
TiO2	.56	.53	.93	1.07	1.05	1.29	1.53	1.46
Al2O3	14.24	13.80	13.72	13.72	13.19	14.37	13.27	13.71
Fe2O3	1.57	1.58	1.91	1.90	1.97	1.97	2.22	2.17
FeO	8.02	8.06	9.77	9.71	10.05	10.06	11.09	11.05
MnO	.14	.14	.15	.14	.16	.14	.16	.16
MgO	9.15	9.06	7.34	7.03	7.14	5.11	4.67	5.02
CaO	12.48	13.77	12.03	11.51	12.95	9.38	8.53	8.83
Na2O	1.36	.83	1.61	1.85	1.55	2.57	2.35	1.53
K2O	.15	.07	.17	.20	.11	1.17	1.47	1.21
P2O5	.05	.05	.09	.10	.09	.16	.20	.19
LOI	1.81	1.62	1.99	1.92	1.91	1.80	2.01	2.71
Rest	.18	.26	.19	.31	.26	.25	.29	.25
Total	99.68	99.69	100.13	99.43	99.67	99.93	99.45	99.28
				Trace elements in parts per million				
Ba	60	23	152	32	25	324	392	417
Li	4	4	8	6	20	9	12	24
Rb	6	<2	<2	4	3	44	43	40
Sr	85	86	126	101	144	209	215	206
Pb	2	4	3	2	8	6	7	6
Th	2	2	<1	<1	3	2	4	6
U	1	1	1	1	<1	1	1	2
Zr	45	43	53	64	51	124	154	147
Nb	3	2	2	3	2	5	7	7
Y	14	14	20	24	21	26	32	31
La	6	6	5	6	4	20	23	21
Ce	11	7	13	11	7	40	45	40
Nd	8	7	8	9	7	22	26	22
Sc	38	38	40	41	43	29	29	32
V	203	196	257	320	307	243	273	295
Cr	504	534	234	217	272	65	52	59
Ni	112	125	69	92	90	45	38	49
Cu	21	72	83	100	69	91	125	122
Zn	59	59	77	80	87	92	109	102
Ga	11	11	14	15	13	19	18	17
As	1	<1	4	1	45	3	2	2
S	50	800	300	1500	850	600	700	250

Table 1 (contd)

Sample number	83330079	83330080
Stratigraphic group	Hart Dolerite	Hart Dolerite
Stratigraphic unit	Undivided	Undivided
Lithology	dolerite	dolerite
Map name	Remarkable	Remarkable
Grid reference	CF499779	CF498774
SiO2	52.31	51.52
TiO2	1.36	1.31
Al2O3	13.86	14.24
Fe2O3	2.03	2.00
FeO	10.35	10.19
MnO	.16	.15
MgO	5.12	5.42
CaO	8.98	8.06
Na2O	2.57	2.26
K2O	1.35	1.37
P2O5	.18	.17
LOI	1.47	2.92
Rest	.25	.22
Total	99.99	99.83

Trace elements in parts per million

Ba	356	543
Li	8	19
Rb	45	42
Sr	195	207
Pb	7	8
Th	4	3
U	1	<1
Zr	143	138
Nb	4	5
Y	29	29
La	21	19
Ce	45	36
Nd	23	20
Sc	28	29
V	250	259
Cr	57	65
Ni	39	47
Cu	97	88
Zn	98	95
Ga	20	19
As	2	3
S	550	-

TABLE 2

PILBARA GEOCHEMICAL DATA

Sample number	83330136	83330137	83330138	83330140	83330141	83330142	83330143	83330145
Stratigraphic group	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic
Stratigraphic unit	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni
Lithology	gabbro	gabbro	webst	gabbro	webst	webst	webst	ol webst
Map name	Pinderi H.	Pinderi H.	Pinderi H.	Pinderi H.	Pinderi H.	Pinderi H.	Pinderi H.	Pinderi H.
Grid reference	872672	872672	870668	875667	875657	875667	875667	870660
SiO2	50.89	58.04	52.82	48.85	53.70	53.54	57.72	50.92
TiO2	1.00	.56	.27	.93	.78	.85	.23	.25
Al2O3	13.54	18.55	1.91	9.72	9.40	9.47	5.58	1.72
Fe2O3	1.89	1.45	1.20	1.10	1.57	1.71	1.21	1.94
FeO	10.41	3.60	7.57	8.19	9.59	9.63	6.52	7.22
MnO	.20	.07	.19	.16	.17	.17	.16	.18
MgO	6.72	2.93	17.23	5.12	8.61	8.46	11.39	19.49
CaO	7.41	6.87	16.68	11.50	9.80	9.61	12.13	15.38
Na2O	2.06	4.03	.50	1.41	2.37	2.37	1.30	.33
K2O	.56	.68	.16	.27	.41	.66	.94	.07
P2O5	.28	.16	.02	.07	.08	.09	.03	.01
LOI	4.44	2.17	1.20	11.73	3.15	2.64	2.64	1.61
Rest	.22	.15	.23	.29	.26	.28	.19	.31
Total	99.62	99.26	99.98	99.34	99.89	99.48	100.04	99.43

Trace elements in parts per million

Ba	584	200	52	365	348	469	265	40
Li	36	21	3	18	16	17	16	2
Rb	26	34	10	7	10	25	24	4
Sr	186	488	55	238	233	254	79	47
Pb	5	3	2	14	7	5	13	<2
Th	3	1	<1	2	2	2	8	<1
U	2	<1	<1	1	<1	<1	1	<1
Zr	66	62	15	84	64	67	61	14
Nb	9	3	<2	3	4	3	2	<2
Y	31	5	8	14	15	15	10	7
La	16	7	3	14	15	13	17	<2
Ce	32	16	8	27	31	27	28	<3
Nd	22	10	3	15	15	17	11	<3
Sc	29	15	39	25	20	20	32	35
V	221	100	186	188	151	154	145	171
Cr	101	24	622	561	454	482	174	901
Ni	78	32	596	333	308	312	429	958
Cu	74	45	23	149	180	145	82	23
Zn	115	64	48	100	97	94	60	50
Ga	18	19	4	<1	13	13	7	2
As	<1	1	<1	<1	1	1	2	<1
S	-	-	-	-	-	-	-	-

Table 2 (contd)

Sample number	83330146	83330147	83330148	83330149	83330150	83330151	83330152	83330154
Stratigraphic group	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic
Stratigraphic unit	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni	Undivided MunniMunni
Lithology	ol webst	ol webst	ol webst	lherz	webst	webst	webst	webst
Map name	Pinderi H.	Pinderi H.	Pinderi H.	Pinderi H.	Pinderi .	Pinderi H.	Pinderi H.	Pinderi H.
Grid reference	870660	870668	874659	874662	874662	874662	874662	874614
SiO2	50.84	51.56	50.55	39.65	51.62	51.47	51.97	53.28
TiO2	.27	.25	.36	.15	.65	.48	.50	.41
Al2O3	1.93	1.56	2.82	1.23	7.40	4.73	4.99	8.77
Fe2O3	2.69	1.94	1.47	7.45	1.62	1.33	1.04	1.40
FeO	6.33	7.03	6.49	7.85	10.74	9.66	9.40	7.67
MnO	.17	.18	.18	.15	.20	.21	.20	.15
MgO	19.17	17.99	19.05	27.65	11.08	14.05	13.64	15.90
CaO	15.13	16.60	15.49	3.53	12.12	12.70	12.69	6.15
Na2O	.33	.23	.35	.04	1.82	.81	.77	.89
K2O	.06	.02	.04	.01	.62	<.01	<.01	.62
P2O5	.01	.01	.02	.02	.06	.03	.03	.04
LOI	2.32	2.43	1.94	11.11	1.78	3.64	3.84	3.77
Rest	.33	.26	.52	.68	.23	.19	.18	.50
Total	99.58	100.06	99.28	99.52	99.94	99.30	99.25	99.55
Trace elements in parts per million								
Ba	40	15	26	16	336	19	22	177
Li	3	4	7	4	8	18	20	198
Rb	5	2	3	2	28	<2	<2	5
Sr	46	49	33	89	245	50	59	198
Pb	2	<2	2	2	4	3	4	5
Th	1	1	1	1	3	3	3	3
U	<1	<1	<1	1	<1	1	1	1
Zr	14	11	22	19	64	42	44	54
Nb	<2	<2	<2	19	3	2	3	2
Y	6	7	9	2	<1	11	11	10
La	3	<2	3	5	12	9	9	8
Ce	4	3	7	6	22	20	22	13
Nd	3	<3	<3	4	9	8	11	7
Sc	35	37	30	11	30	34	32	24
V	167	190	116	43	183	159	160	130
Cr	931	809	2187	1359	131	288	250	2118
Ni	874	680	784	2307	405	543	473	388
Cu	44	12	164	96	163	110	104	48
Zn	51	46	48	92	93	74	72	64
Ga	3	2	3	2	10	8	7	10
As	<1	1	<1	1	1	<1	<1	1
S	200	-	350	1300	-	-	-	-

Table 2 (contd)

Sample number	83330174	83330175	83330176	83330177	83330178	83330179	83330180	83330181
Stratigraphic group	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic
Stratigraphic unit	Undivided Andover	Undivided Andover	Undivided Andover	Undivided Andover	Undivided Andover	Undivided Andover	Undivided Andover	Undivided Andover
Lithology	webst	perid[hz]	gabbro	anorth gab	anorth gab	webst	gabbro	anorth
Map name	Roebourne	Roebourne	Roebourne	Roebourne	Roebourne	Roebourne	Roebourne	Roebourne
Grid reference	143978	143978	140958	140958	140958	140958	141956	141956
SiO2	46.81	35.60	47.41	45.95	49.09	51.46	47.85	45.06
TiO2	.99	.13	.76	.32	.32	.39	.23	.19
Al2O3	8.50	6.44	15.97	16.56	15.57	10.77	15.66	23.34
Fe2O3	5.55	6.47	1.36	4.78	.90	.31	1.02	1.45
FeO	6.77	7.59	8.26	2.00	6.37	8.25	6.48	2.00
MnO	.22	.15	.14	.11	.14	.13	.14	.05
MgO	11.15	28.03	8.57	9.29	9.79	13.49	10.03	5.58
CaO	16.08	4.06	11.18	14.68	11.24	8.46	12.73	14.01
Na2O	.11	.04	1.91	.80	1.57	.71	.87	2.09
K2O	.02	<.01	.17	.18	.28	.03	.23	.36
P2O5	.11	.02	.10	.02	.01	.05	.02	.02
LOI	3.62	10.80	3.28	5.34	3.78	4.81	4.04	5.80
Rest	.28	.55	.20	.21	.18	.44	.15	.27
Total	100.21	99.88	99.31	100.24	99.24	99.30	99.45	100.22
			Trace elements in parts per million					
Ba	41	68	62	51	78	44	94	91
Li	21	1	23	27	24	36	18	37
Rb	<2	<2	12	22	34	2	31	62
Sr	25	29	437	436	353	216	422	598
Pb	5	<2	2	12	3	8	3	3
Th	5	<1	<1	1	<1	5	<1	<1
U	1	<1	<1	<1	<1	1	<1	<1
Zr	109	3	33	17	8	60	15	12
Nb	7	<2	2	<2	<2	3	<2	<2
Y	15	2	15	7	6	12	8	2
La	19	<2	4	<2	<2	10	<2	<2
Ce	33	<3	10	<3	<3	19	4	<3
Nd	16	<3	6	<3	<3	6	3	<3
Sc	28	9	31	37	40	23	35	16
V	171	44	169	142	148	134	100	70
Cr	1027	1981	288	530	431	1920	151	854
Ni	266	1795	196	72	75	464	111	105
Cu	65	29	83	136	20	61	116	76
Zn	83	77	71	46	53	66	54	24
Ga	13	6	14	12	12	12	11	14
As	1	1	19	6	11	2	<1	3
S	-	-	-	-	50	-	-	-

Table 2 (contd)

Sample number	83330113	83330114	83330115	83330116	83330117	83330119	83330120	83330121
Stratigraphic group	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic
Stratigraphic unit	Undivided Dingo	Undivided Dingo	Undivided Dingo	Undivided Dingo	Undivided Dingo	Undivided Dingo	Undivided Dingo	Undivided Dingo
Lithology	perid[hz]	perid[hz]	amphib	opyxte	opyxte	altd basalt	altd basalt	perid[hz]
Map name	Dampier	Dampier	Dampier	Dampier	Dampier	Dampier	Dampier	Dampier
Grid reference	835832	835831	835829	834830	834830	834834	834834	834834
SiO2	36.57	38.43	49.96	52.87	52.82	42.73	42.27	39.59
TiO2	.19	.27	.74	.34	.30	1.45	1.49	.22
Al2O3	3.78	4.49	17.06	8.43	8.03	12.60	14.60	5.33
Fe2O3	4.42	4.43	1.43	.68	.77	3.08	3.11	3.60
FeO	8.63	7.93	6.50	7.43	7.85	13.02	12.45	7.03
MnO	.17	.16	.11	.13	.15	.15	.14	.14
MgO	29.23	29.61	8.14	19.96	19.73	10.72	9.69	31.17
CaO	3.51	2.20	10.17	3.95	4.29	11.67	11.27	.99
Na2O	.05	.05	2.18	.71	.53	1.14	1.41	.03
K2O	<.01	<.01	.43	.52	.43	.24	.39	<1.00
P2O5	.08	.01	.13	.07	.05	.05	.05	.02
LOI	11.96	10.85	2.46	4.01	3.87	2.48	2.44	10.33
Rest	.87	.93	.17	.40	.36	.21	.19	.92
Total	99.46	99.36	99.48	99.50	99.18	99.54	99.50	99.37
Trace elements in parts per million								
Ba	6	5	111	118	44	41	97	<3
Li	-	1	10	5	7	4	5	-
Rb	<2	<2	13	15	12	<2	4	<2
Sr	24	12	190	99	95	36	99	5
Pb	<2	<2	3	<2	<2	5	2	<2
Th	<1	1	1	1	1	3	<1	2
U	<1	<1	<1	<1	1	2	1	<1
Zr	29	27	73	42	41	44	49	17
Nb	<2	2	3	<2	2	3	2	<2
Y	4	4	13	7	7	35	33	3
La	5	<2	9	9	5	160	68	<2
Ce	8	<3	18	17	9	235	106	<3
Nd	6	<3	14	9	6	92	44	<3
Sc	11	12	29	22	23	41	38	11
V	58	69	145	97	102	364	331	62
Cr	4029	4237	295	1482	1473	119	123	4485
Ni	1895	1847	166	648	616	284	279	1803
Cu	-	5	54	105	26	4	12	-
Zn	135	125	61	59	65	69	67	137
Ga	5	5	13	9	9	17	18	5
As	2	1	<1	<1	<1	<1	1	4
S	-	400	-	150	-	-	-	-

Table 2 (contd)

Sample number	83330122	83330123	83330124	83330125	83330161	83330163	83330167	83330168
Stratigraphic group	Arch U-mafic	Arch U-mafic	Arch U-mafic	Arch U-mafic	Gorge Ck	Gorge Ck	Gorge Ck	Gorge Ck
Stratigraphic unit	Undivided Dingo	Undivided Dingo	Undivided Dingo	Undivided Dingo	Mallina M dinna	Mallina M dinna	Mallina M dinna	Mallina M dinna
Lithology	altd basalt	altd basalt	altd basalt	perid[hz]	ol webst	perid[hz]	perid[hz]	perid[hz]
Map name	Dampier	Dampier	Dampier	Dampier	Satirist	Satirist	Satirist	Satirist
Grid reference	834832	825838	825838	824837	134734	134764	132763	129760
SiO2	56.33	49.35	50.58	37.44	42.81	38.86	38.07	38.20
TiO2	.70	1.65	1.52	.21	.35	.32	.29	.28
Al2O3	17.44	16.54	15.54	5.29	2.21	2.17	1.93	1.90
Fe2O3	.76	1.78	2.51	4.34	9.43	7.09	10.14	6.59
FeO	4.59	6.68	7.94	6.09	3.81	5.24	4.10	5.79
MnO	.06	.14	.15	.12	.18	.13	.17	.14
MgO	4.72	8.08	6.78	31.09	26.28	32.92	32.33	33.79
CaO	6.70	9.25	9.34	2.99	6.92	1.99	1.67	1.52
Na2O	4.75	3.20	2.34	.03	.28	.06	.05	.04
K2O	1.82	.29	.35	.03	.06	.04	<.01	.05
P2O5	.10	.33	.30	.07	.03	.04	.03	.03
LOI	1.41	2.12	1.96	10.95	6.21	10.84	10.38	10.93
Rest	.29	.16	.15	.74	.70	.67	.81	.74
Total	99.67	99.57	99.46	99.39	99.27	100.37	99.97	100.00

Trace elements in parts per million

Ba	1154	67	62	4	163	10	19	-
Li	2	3	4	1	3	3	2	-
Rb	29	9	8	<2	2	2	<2	4
Sr	749	233	200	36	58	28	16	13
Pb	2	2	2	<2	2	-	<2	4
Th	3	1	1	1	1	<1	1	<1
U	<1	<1	<1	<1	<1	<1	<1	<1
Zr	106	90	96	26	27	29	26	26
Nb	3	4	5	<2	<2	2	2	<2
Y	11	23	24	6	5	4	4	4
La	12	8	10	5	9	5	3	3
Ce	23	18	25	10	9	9	4	5
Nd	10	16	17	10	4	3	3	<3
Sc	22	32	29	12	18	9	7	8
V	131	183	192	60	95	64	64	63
Cr	62	188	148	3086	3015	2292	3674	2826
Ni	59	173	128	1282	1449	2386	1899	2327
Cu	9	12	53	56	43	22	5	3
Zn	27	61	57	92	70	64	71	53
Ga	15	12	16	4	5	4	3	3
As	1	<1	<1	1	<1	1	<1	<1
S	-	-	-	850	70	-	20	-

Table 2 (contd)

Sample number	83330126	83330127	83330128	83330129	83330130	83330131	83330132	83330133
Stratigraphic group	Warrawoona	Warrawoona	Warrawoona	Warrawoona	Warrawoona	Warrawoona	Warrawoona	Warrawoona
Stratigraphic unit	TalgaTalga	TalgaTalga	TalgaTalga	TalgaTalga	TalgaTalga	TalgaTalga	TalgaTalga	TalgaTalga
	Bamboo Ck	Bamboo Ck	Bamboo Ck	Bamboo Ck	Bamboo Ck	Bamboo Ck	Bamboo Ck	Bamboo Ck
Lithology	serpte	serpte	serpte	serpte	serpte	serpte	serpte	serpte
Map name	Muccan	Muccan	Muccan	Muccan	Muccan	Muccan	Muccan	Muccan
Grid reference	085767	085767	085767	085767	085767	085767	085767	085767
SiO2	38.27	40.78	39.94	38.03	38.11	39.82	38.69	38.82
TiO2	.16	.14	.21	.08	.14	.12	.22	.22
Al2O3	2.46	2.25	3.34	1.63	2.24	2.14	3.94	3.97
Fe2O3	6.39	2.85	4.57	7.41	6.28	4.96	4.59	4.13
FeO	3.66	6.46	5.12	2.02	6.01	5.04	6.00	6.48
MnO	.09	.13	.12	.06	.13	.10	.11	.14
MgO	36.59	32.97	33.25	37.65	34.62	35.49	32.82	32.80
CaO	.09	1.57	1.57	.02	.04	.04	1.85	1.84
Na2O	.03	.03	.02	.04	.03	.03	.02	.02
K2O	.03	<.01	<.01	<.01	<.01	<.01	<.01	<.01
P2O5	.03	.04	.02	.01	.01	.02	.03	.03
LOI	11.24	11.41	10.60	11.76	11.21	11.19	10.71	10.74
Rest	.69	.81	.61	.35	.89	.70	.46	.51
Total	99.73	99.44	99.37	99.06	99.71	99.65	99.44	99.70
				Trace elements in parts per million				
Ba	15	9	67	14	41	36	28	11
Li	1	7	1	-	-	-	-	-
Rb	11	2	<2	<2	<2	<2	<2	<2
Sr	2	37	11	3	5	2	8	3
Pb	<2	24	<2	<2	2	4	<2	<2
Th	<1	2	<1	<1	<1	<1	<1	<1
U	<1	<1	<1	<1	<1	<1	<1	<1
Zr	20	19	23	8	10	11	21	19
Nb	<2	2	<2	<2	<2	<2	<2	2
Y	5	4	7	2	2	3	8	6
La	2	5	4	2	<2	<2	2	<2
Ce	3	4	4	<3	<3	<3	5	<3
Nd	5	4	5	<3	<3	<3	3	<3
Sc	9	9	13	9	11	12	18	17
V	59	63	68	31	58	49	80	61
Cr	3051	3454	2928	573	4919	3478	1993	2352
Ni	1671	1581	1151	1922	1136	1235	1030	1113
Cu	-	4	8	-	3	22	17	5
Zn	50	59	57	59	66	58	41	57
Ga	3	5	4	<2	4	3	4	4
As	2	549	1	5	1	9	2	1
S	-	<20	-	50	-	70	-	-

Table 2 (contd)

Sample number	83330134	83330135	83330100	83330103	83330104	83330088	83330089	83330090
Stratigraphic group	Warrawoona	Warrawoona	Gidley Granophyre	Gidley Granophyre	Gidley Granophyre	CooyaPooya Dolerite	CooyaPooya Dolerite	CooyaPooya Dolerite
Stratigraphic unit	TalgaTalga Bamboo Ck	TalgaTalga Bamboo Ck						
Lithology	serpte	gabbro	gabbro	gabbro	gabbro	HM basalt	HM basalt	HM basalt
Map name	Coongan	Coongan	Dampier	Dampier	Dampier	Roebourne	Roebourne	Roebourne
Grid reference			706124	789181	789181	085784	085784	085784
SiO2	40.04	52.10	50.40	49.10	50.24	46.96	43.93	44.82
TiO2	.18	.56	1.33	2.06	.39	.55	.51	.42
Al2O3	2.35	15.82	13.36	13.21	15.42	9.93	9.41	8.23
Fe2O3	2.63	1.51	4.04	3.09	1.83	1.80	.92	2.28
FeO	8.50	6.52	9.73	9.08	6.33	8.25	8.36	8.19
MnO	.15	.12	.18	.15	.14	.14	.14	.14
MgO	32.55	6.27	5.12	6.34	8.23	17.20	16.15	20.52
CaO	.33	11.12	8.47	10.34	11.86	6.54	5.05	7.01
Na2O	2.40	2.10	2.45	2.17	1.30	.90	.02	.15
K2O	<.01	.61	.81	.32	.73	.23	<.01	.15
P2O5	.03	.08	.15	.23	.05	.08	.06	.06
LOI	10.92	2.36	3.54	2.98	3.14	5.94	13.95	6.67
Rest	.21	.17	.26	.20	.15	.54	.54	.58
Total	100.29	99.34	99.84	99.27	99.81	99.06	99.04	99.22
Trace elements in parts per million								
Ba	344	220	910	115	159	363	73	109
Li	15	12	11	10	11	6	3	9
Rb	31	27	48	17	35	11	3	16
Sr	163	197	189	235	135	268	101	363
Pb	7	5	6	4	3	3	11	3
Th	5	2	2	2	2	1	1	1
U	2	<1	<1	<1	1	<1	<1	<1
Zr	106	65	101	138	29	47	42	39
Nb	5	3	5	13	<2	2	2	2
Y	22	15	28	25	9	11	11	9
La	20	12	10	15	5	5	5	4
Ce	34	22	18	32	11	6	7	7
Nd	18	10	15	24	7	7	8	5
Sc	27	26	36	32	31	24	29	23
V	188	145	277	289	154	148	171	126
Cr	245	241	64	180	232	2243	2593	2568
Ni	133	134	74	98	147	666	620	742
Cu	102	65	78	67	45	58	52	39
Zn	82	62	110	106	56	60	54	62
Ga	16	13	17	19	13	9	8	7
As	1	1	8	1	<1	1	1	<1
S	-	-	-	-	-	-	-	-

Table 2 (contd)

Sample number	83330091	83330092	83330093	83330094	83330095	83330096	83330097	83330098
Stratigraphic group	CooyaPooya Dolerite	CooyaPooya Dolerite	CooyaPooya Dolerite	CooyaPooya Dolerite	CooyaPooya Dolerite	CooyaPooya Dolerite	CooyaPooya Dolerite	CooyaPooya Dolerite
Lithology	HM basalt	basalt	HM basalt	HM basalt	basalt	basalt	basalt	basalt
Map name	Roebourne	Roebourne	Roebourne	CooyaPooya	Roebourne	CooyaPooya	CooyaPooya	CooyaPooya
Grid reference	085784	085784	085784	094778	086785	117736	117736	117736
SiO2	50.93	51.24	53.34	51.92	53.30	53.48	54.06	53.58
TiO2	.36	.53	.50	.57	.55	.57	.59	.57
Al2O3	6.32	14.93	10.45	10.92	14.75	14.75	14.70	14.82
Fe2O3	1.55	1.63	1.06	1.18	1.58	1.55	1.21	1.47
FeO	8.15	5.67	8.00	8.33	6.58	6.86	7.29	6.97
MnO	.14	.11	.13	.12	.11	.12	.12	.12
MgO	19.49	8.20	13.46	12.34	6.66	6.55	6.69	6.63
CaO	5.89	8.97	7.04	6.65	8.45	8.01	7.45	8.21
Na2O	.59	2.80	1.52	1.44	2.38	1.89	3.18	1.94
K2O	.10	1.35	.25	.55	.82	1.57	.96	1.35
P2O5	.04	.07	.06	.08	.08	.08	.08	.09
LOI	4.94	3.68	3.22	4.86	3.85	3.72	2.82	3.41
Rest	.61	.35	.40	.38	.16	.19	.19	.18
Total	99.11	99.53	99.43	99.34	99.27	99.34	99.34	99.34
				Trace elements in parts per million				
Ba	111	1192	203	315	172	259	305	230
Li	10	8	5	7	5	7	5	8
Rb	7	61	10	17	37	73	35	59
Sr	73	401	160	122	198	195	184	243
Pb	2	2	3	4	6	6	10	8
Th	1	2	2	2	5	5	5	5
U	<1	<1	<1	1	1	1	<1	1
Zr	34	48	51	62	75	79	82	82
Nb	<2	2	2	3	4	4	4	4
Y	7	11	12	13	14	14	14	13
La	3	7	6	9	13	12	13	12
Ce	3	13	10	15	22	24	24	25
Nd	3	11	8	11	11	12	14	14
Sc	26	27	27	27	26	24	27	24
V	148	144	149	154	137	135	151	136
Cr	3063	594	1590	1468	257	248	276	244
Ni	707	146	466	409	97	96	107	94
Cu	6	51	44	64	55	60	65	59
Zn	59	54	64	50	59	64	64	64
Ga	6	12	9	11	14	14	14	13
As	1	1	1	1	2	2	2	2
S	70	-	60	-	-	100	-	-

Table 2 (contd)

Sample number	83330107	83330108	83330109	83330110	83330111	83330112	83330196
Stratigraphic group	Warrawoona	Warrawoona	Warrawoona	Warrawoona	Warrawoona	Warrawoona	Warrawoona
Stratigraphic unit	TalgaTalga	TalgaTalga	TalgaTalga	TalgaTalga	TalgaTalga	TalgaTalga	TalgaTalga
	Ruth Well	Ruth Well	Ruth Well	Ruth Well	Ruth Well	Ruth Well	Ruth Well
Lithology	basalt	amphib	basalt	basalt	amphib	serpte	komatiite
Map name	Dampier	Dampier	Dampier	Dampier	Dampier	Dampier	Dampier
Grid reference	837924	875906	875906	864921	839924	837924	875986
SiO2	50.00	50.22	50.60	50.33	48.50	37.76	42.94
TiO2	1.93	1.93	1.92	1.19	1.22	.15	.38
Al2O3	12.93	16.19	12.78	16.24	14.62	2.12	3.78
Fe2O3	5.84	2.00	5.69	1.42	1.38	7.25	4.42
FeO	8.02	9.14	8.21	9.30	10.78	5.41	6.12
MnO	.14	.18	.16	.15	.16	.15	-
MgO	5.87	4.32	5.75	5.93	6.49	34.05	27.28
CaO	6.30	8.25	6.29	7.32	9.94	.34	6.15
Na2O	1.56	4.15	1.69	3.49	2.05	.06	.57
K2O	3.05	.28	2.85	.50	1.08	.01	.15
P2O5	.22	.71	.21	.09	.11	.04	.03
LOI	3.31	1.66	3.19	3.18	3.04	11.29	-
Rest	.58	.17	.53	.20	.28	.74	.77
Total	99.75	99.20	99.87	99.34	99.65	99.37	92.59
			Trace elements in parts per million				
Ba	2801	268	2606	179	654	50	24
Li	58	61	57	17	54	3	-
Rb	482	20	477	19	95	2	8
Sr	257	402	259	158	290	12	20
Pb	9	4	6	2	4	3	30
Th	1	1	<1	<1	<1	1	<1
U	<1	<1	<1	<1	<1	<1	<1
Zr	135	19	134	71	73	30	21
Nb	11	5	11	4	3	<2	<1
Y	22	26	21	27	25	3	6
La	11	19	12	<2	3	4	<2
Ce	31	43	34	8	6	3	<2
Nd	17	29	20	10	10	7	<2
Sc	37	29	39	41	39	5	19
V	335	197	331	316	305	44	111
Cr	118	33	112	333	188	2760	2493
Ni	75	19	79	118	121	2291	1536
Cu	73	-	77	3	82	-	70
Zn	102	113	103	72	99	96	80
Ga	18	21	16	14	15	3	5
As	1	1	2	3	1	2	1
S	200	-	-	-	90	50	1600

TABLE 3

ROCK TYPES SAMPLED

Rock Unit	Rock Types	No of Samples
East Kimberleys		
Panton Sill	peridotite(harzburgite) (5), gabbro (1), spinel gabbro (4), olivine gabbro (1) anorthosite (2)	13
Lamboo Sill	peridotite (harzburgite) (4), amphibolite (1) dunite (1)	6
McIntosh Gabbro	microgabbro (dolerite)(8), amphibolite(6)	14
McIntosh Sill	troctolite (1), norite (1), olivine gabbro (1)	21
	amphibolite (3)	6
Toby Sill	dolerite (10), amphibolite (5)	15
Woodward Dolerite	amphibolite (13, dolerite (1)	14
Hart Dolerite	dolerite (5)	5
Pilbara		
Munni Munni	lherzolite (1), olivine orthopyroxenite (1), olivine websterite (4), websterite (10), gabbro (6)	22
Andover	peridotite (harzburgite) (1), websterite (2), olivine websterite (1), anorthositic gabbro (2) gabbro (2), dolerite (1), anorthosite (1)	10
Dingo	peridotite (harzburgite) (4), orthopyroxenite (2), amphibolite (1), basalt/dolerite (5)	12
Millindinna	peridotite (harzburgite) (3), olivine websterite (1)	4
Bamboo Creek	serpentinite (8), gabbro (1)	9
Gidley Gabbro	gabbro (3)	3
Cooya Pooya Dolerite	siliceous high-magnesian basalt (6), tholeiitic basalt (5)	11
Ruth Well	komatiite (1), serpentinite (1), basalt (3), amphibolite (2)	7

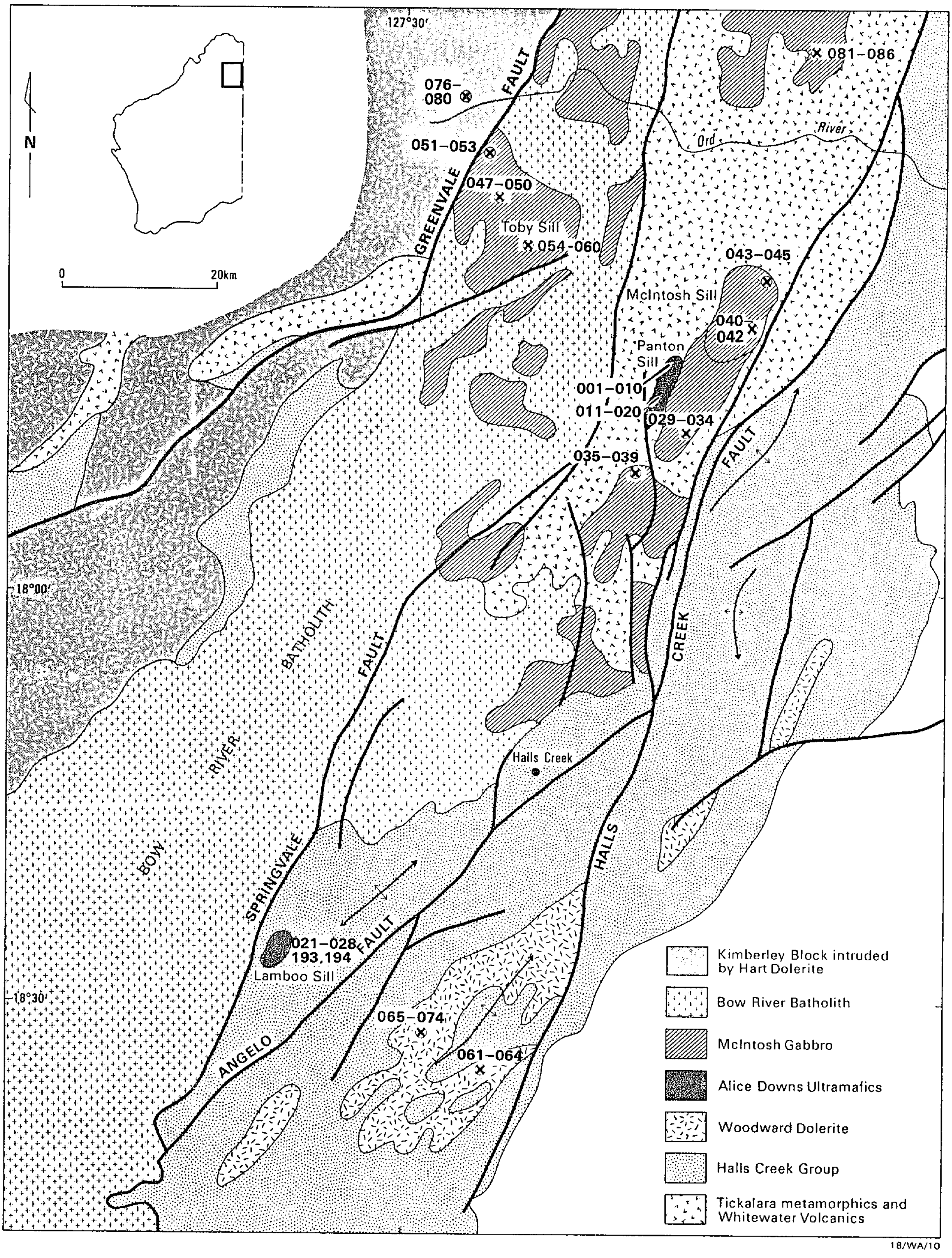

FIG.1: East Kimberley sample localities

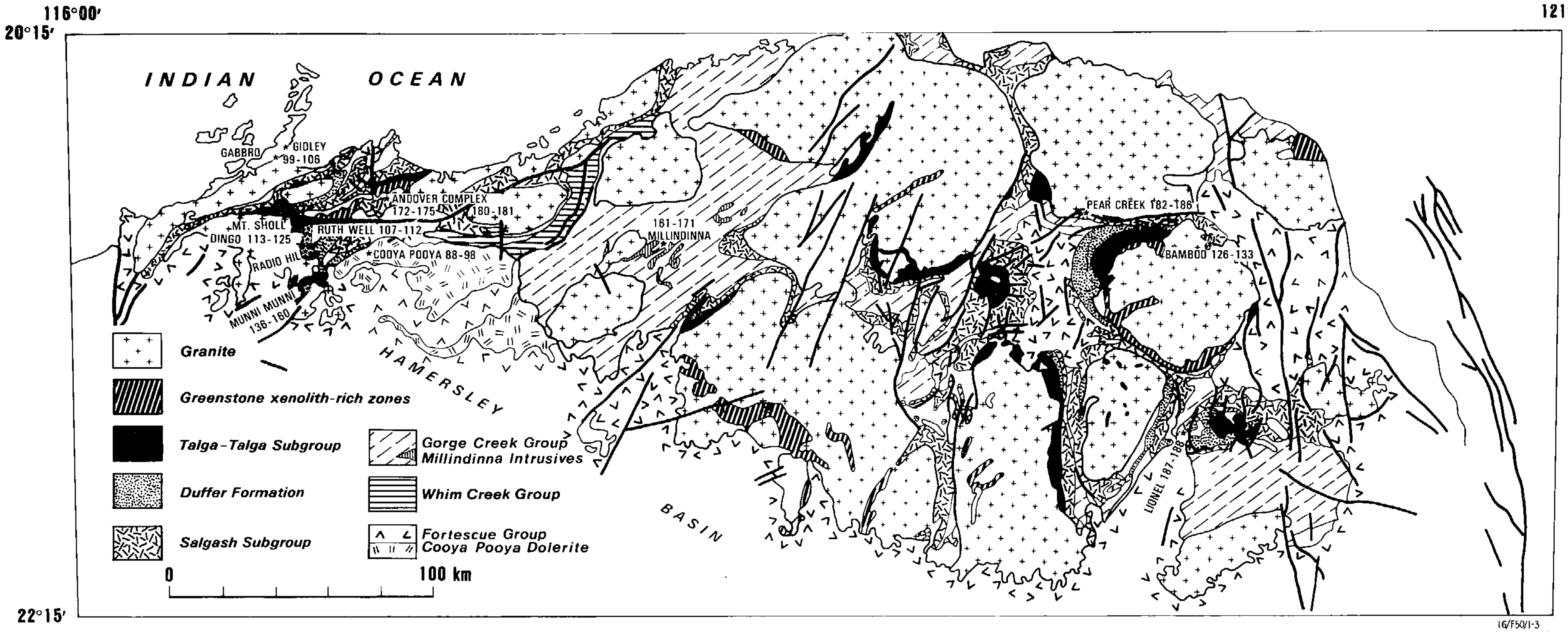

FIG.2: Pilbara sample localities

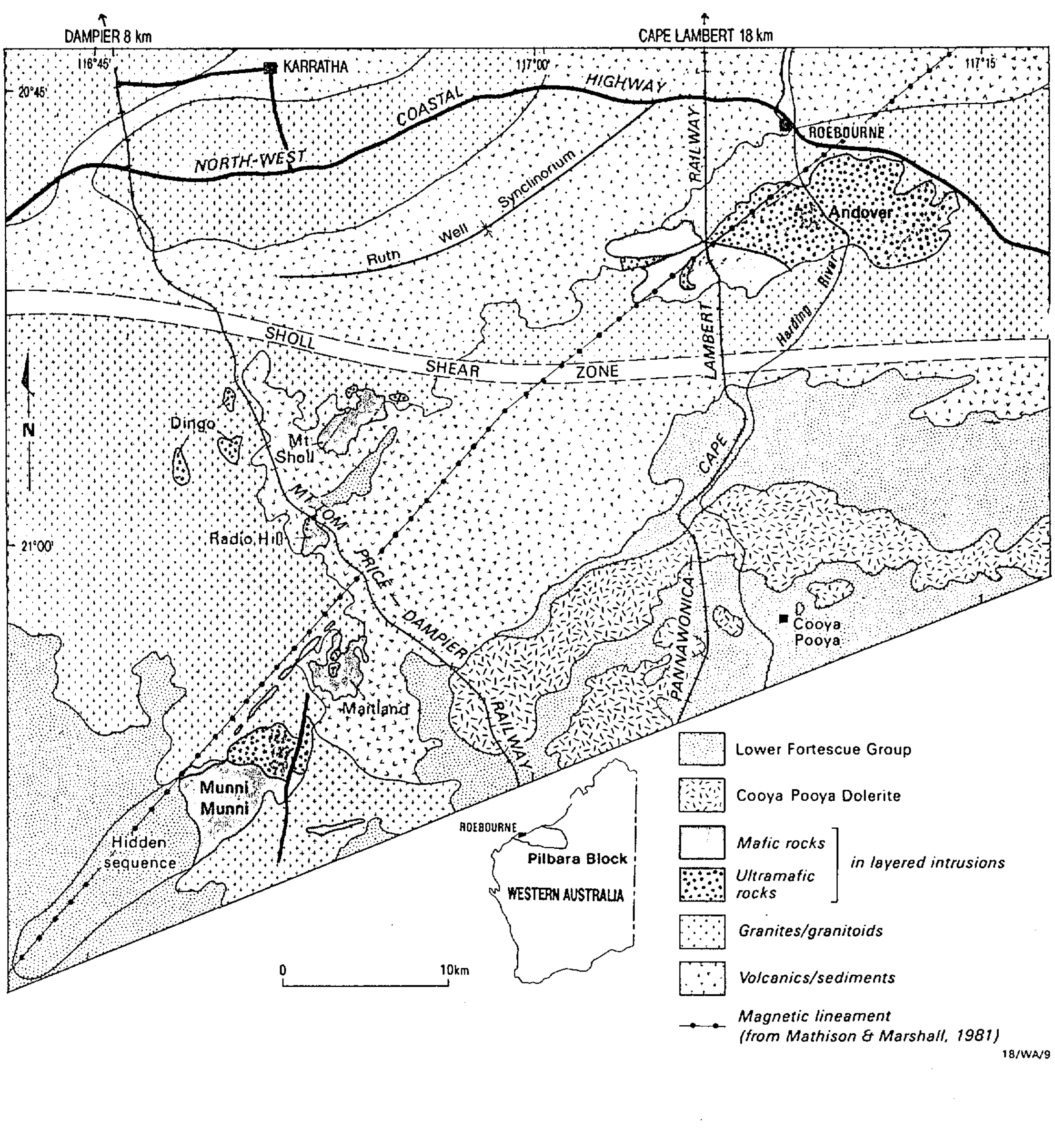

FIG.3: West Pilbara mafic/ultramafic rock units

KIMBERLEYS

+ Panton Sill
× Lamboo Sill
✳ McIntosh Gabbro
□ Toby Sill
◇ Woodward Dolerite
○ Hart Dolerite

PILBARA

△ Munnimunni
▽ Andover
✡ Dingo
■ Mt. Satirist
◆ Bamboo Creek
● Gidley Gabbro
▲ Cooyapooya
▼ Ruth Well

FIG.4: KEY TO ROCK GROUPS

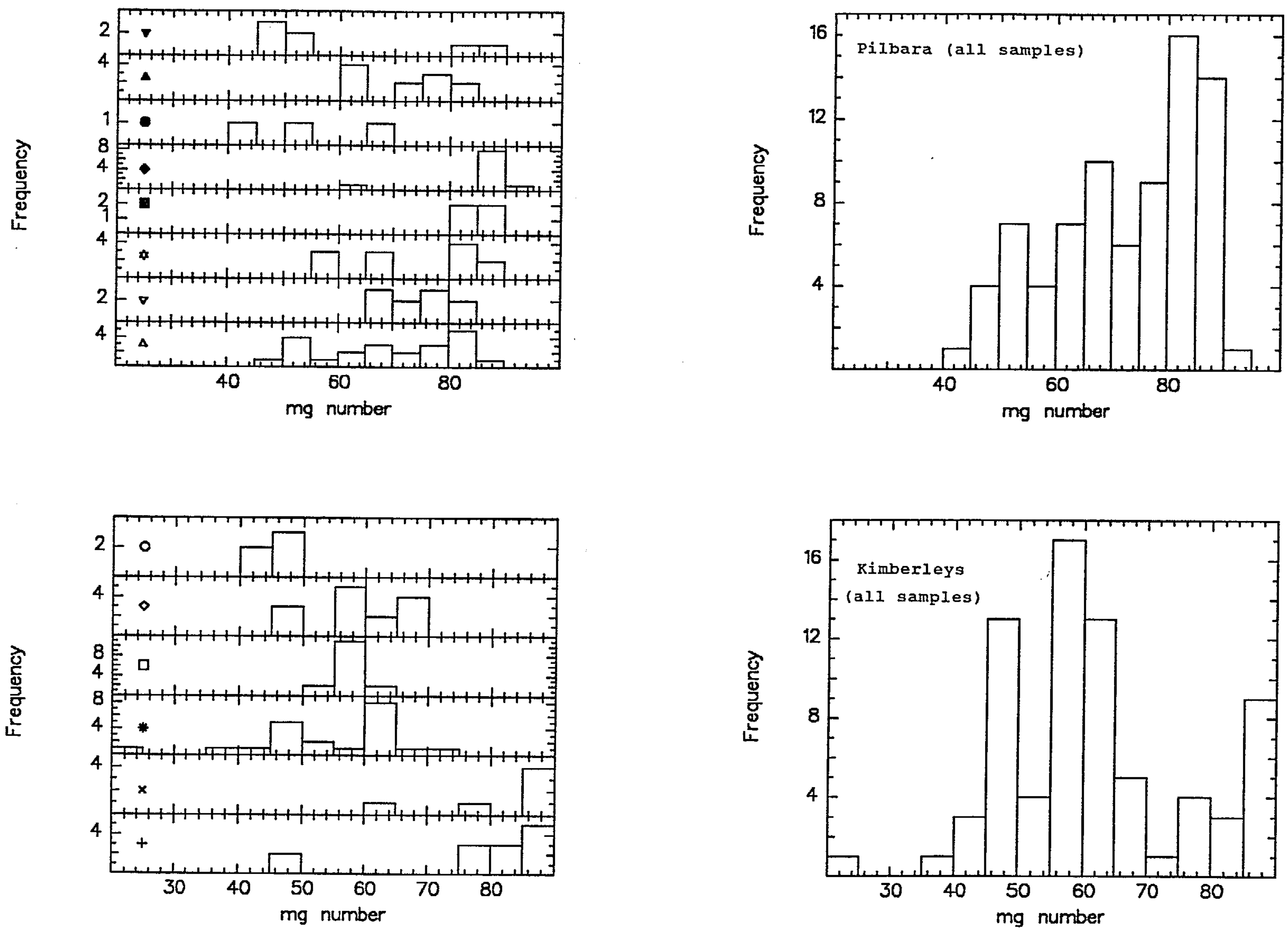

FIG.5: Mg numbers of the Pilbara and Kimberley rocks

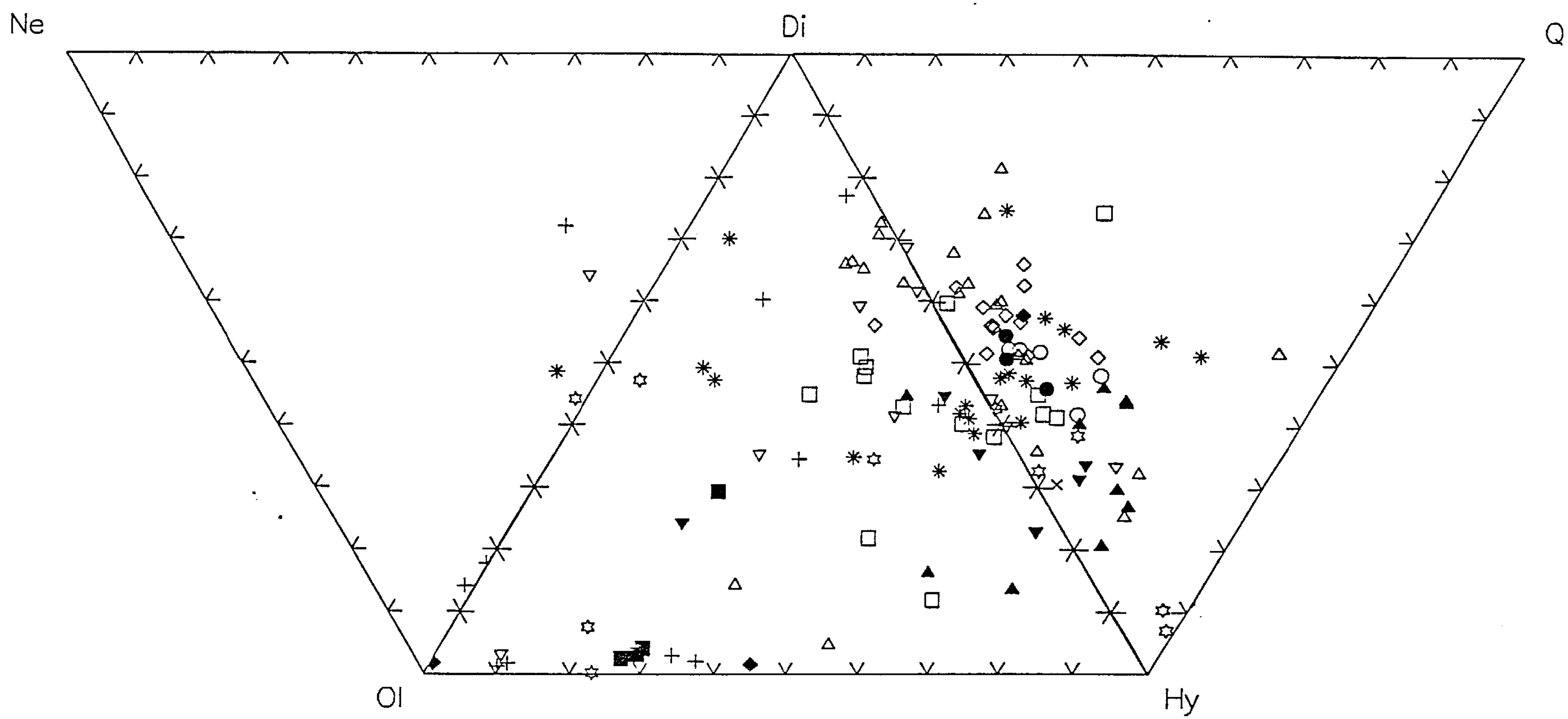

FIG.6: NORMATIVE Di-Ol-Hy-Q-Ne DIAGRAM

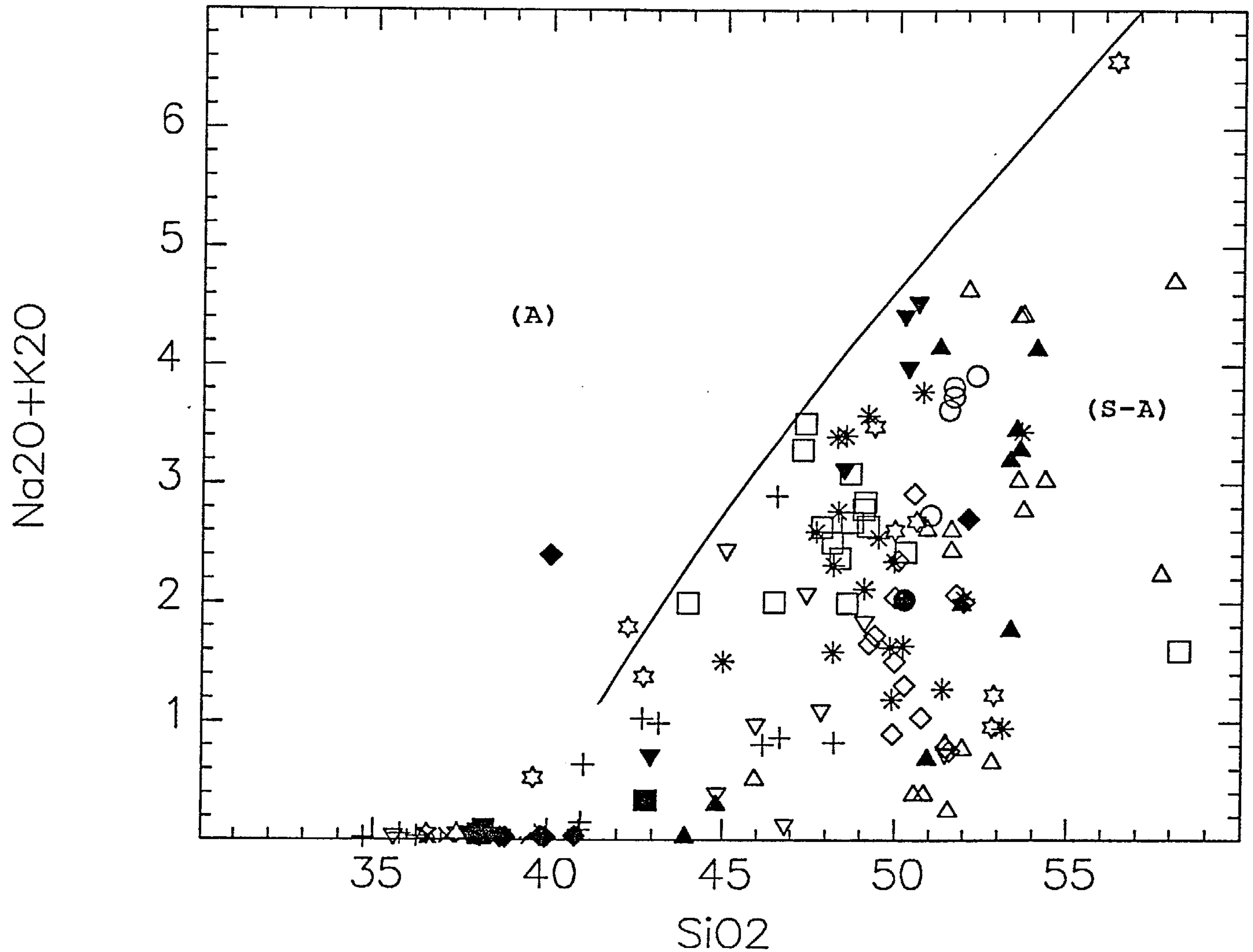

FIG.7: (NA2O + K2O) vs SIO2 DIAGRAM. (A) DENOTES THE FIELD OF ALKALINE ROCKS AND (S-A) THE FIELD OF SUB-ALKALINE ROCKS (IRVINE AND BARAGAR, 1971)

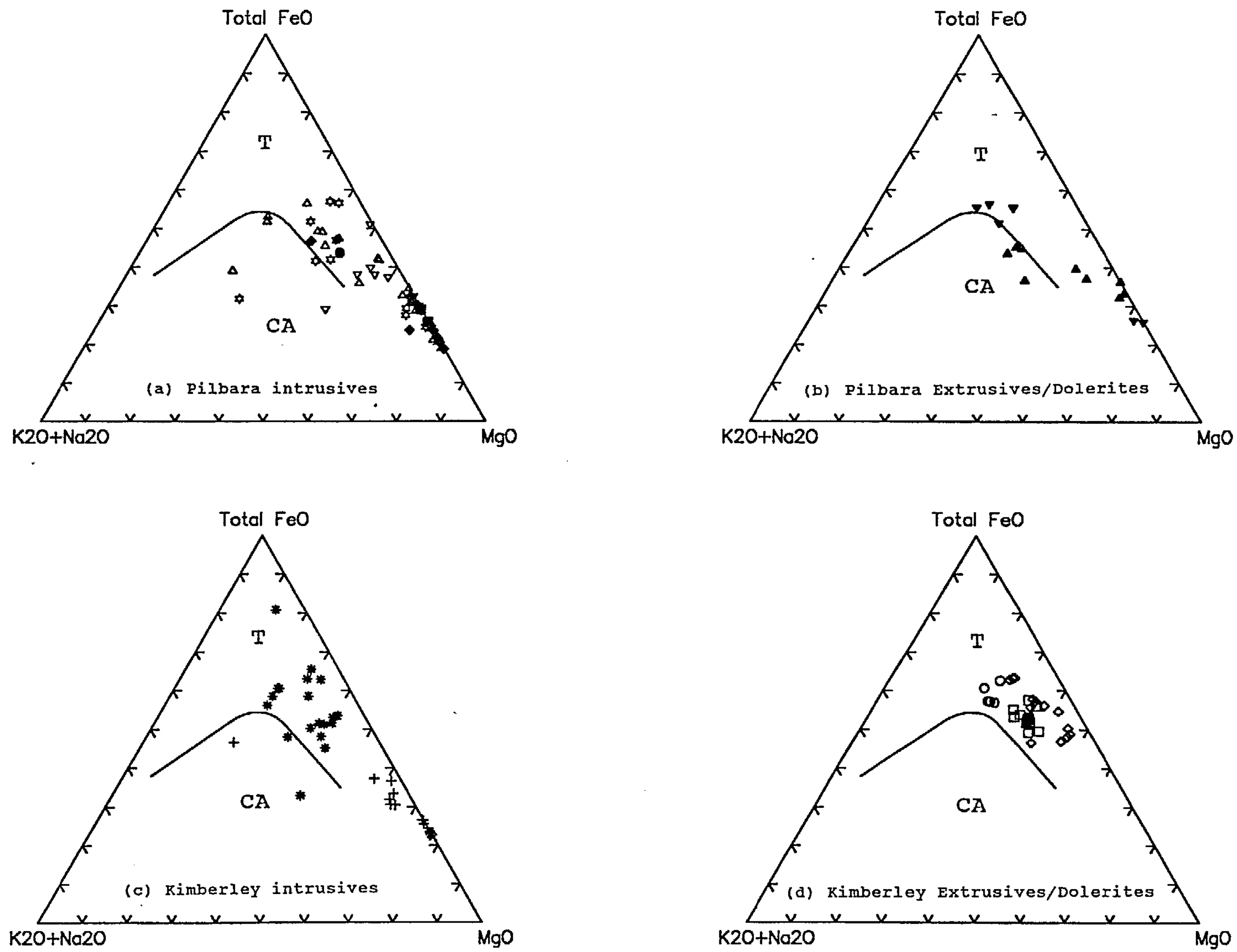

FIG.8: AFM DIAGRAM (K2O+NA2O-FeO(t)-MgO). Curved line separates tholeiites (T) from calc-alkaline (CA) rocks (Irvine & Baragar, 1971)

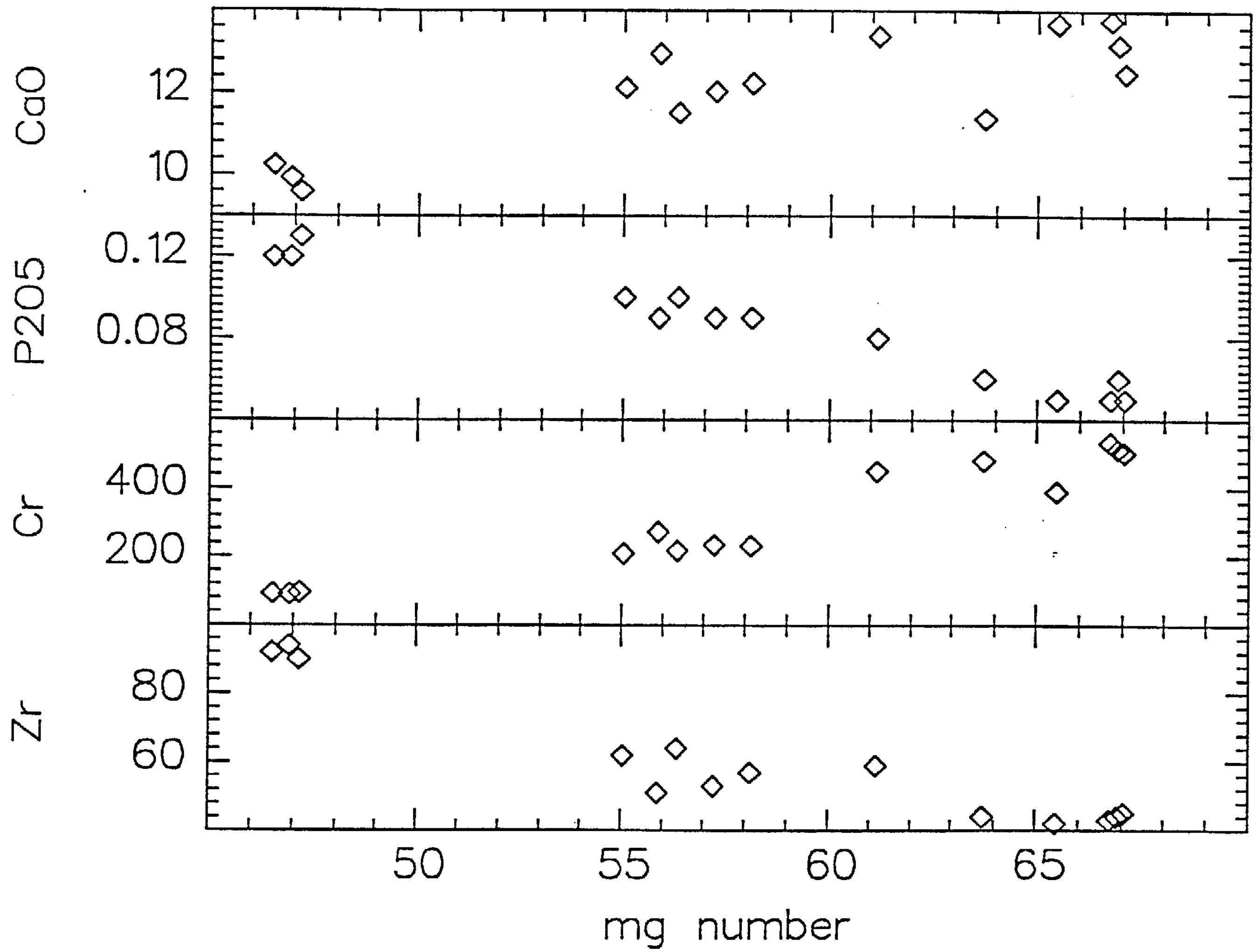

FIG.9: WOODWARD DOLERITE - PLOT OF CaO, P2O5, Cr AND Zr against MG NUMBER

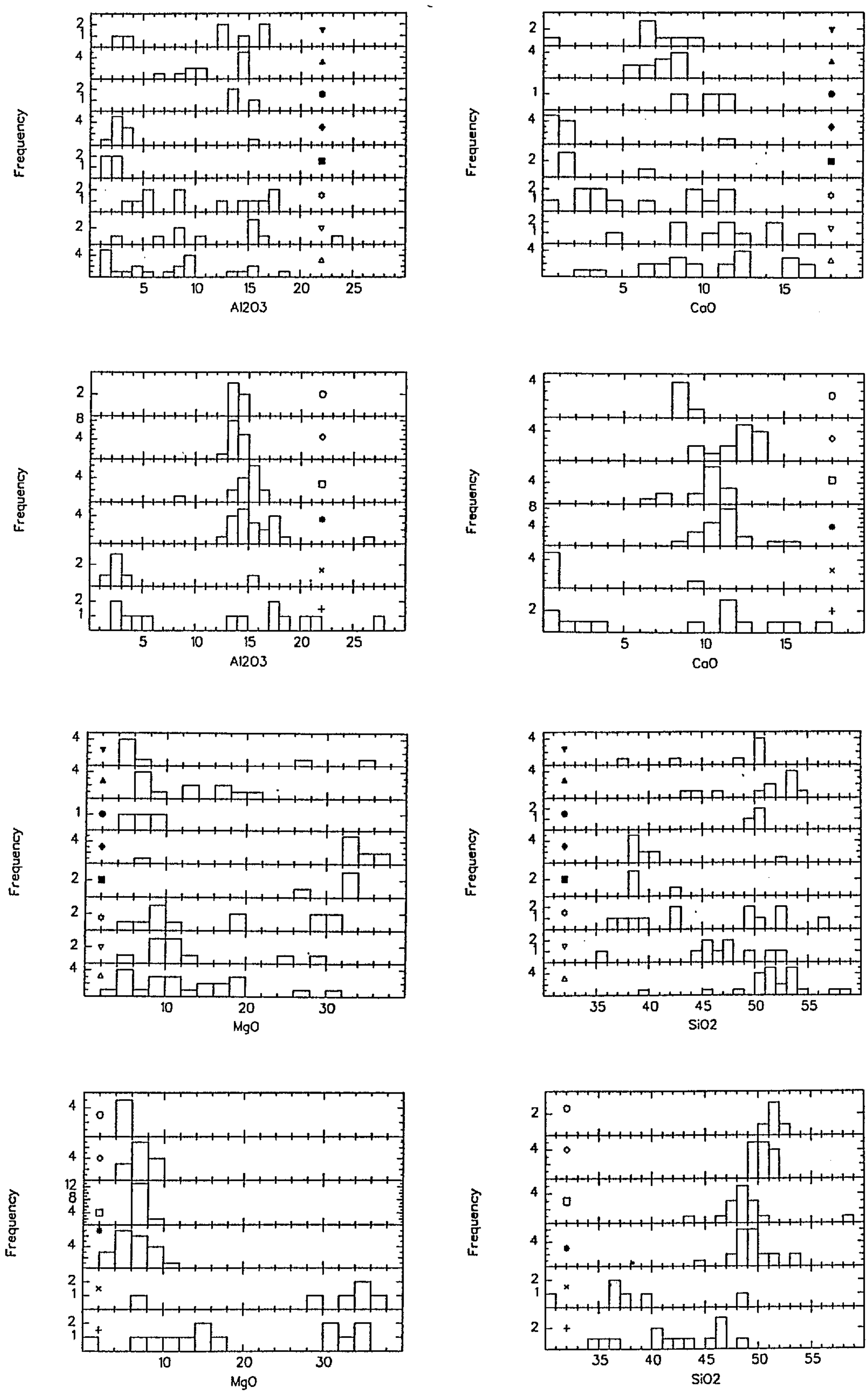

FIG.10: HISTOGRAMS OF MAJOR ELEMENTS FOR PILBARA AND KIMBERLEY ROCK GROUPS

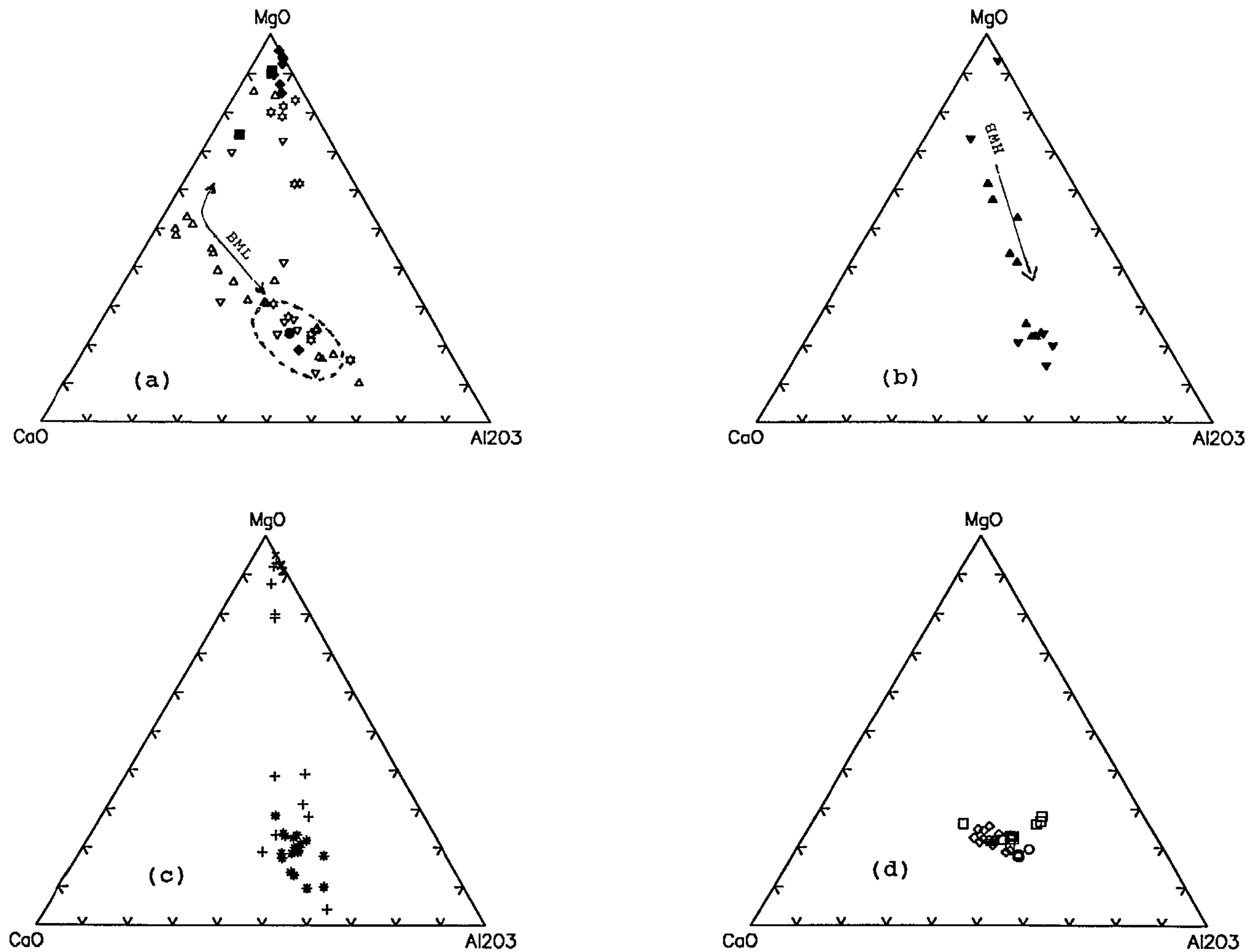

FIG.11: MgO-CaO-Al203 plot: (a) Pilbara intrusives; (b) Pilbara extrusives/dolerites; (c) Kimberley intrusives; (d) Kimberley extrusives/dolerites. Trends are shown for Kambalda Hanging Wall Basalts (HWB), (Arndt & Jenner, 1986) and Barberton Mountain Land ultramafics (BML) (Anhaeusser, 1983). Dashed lines in (a) enclose field of tholeiitic basalts.

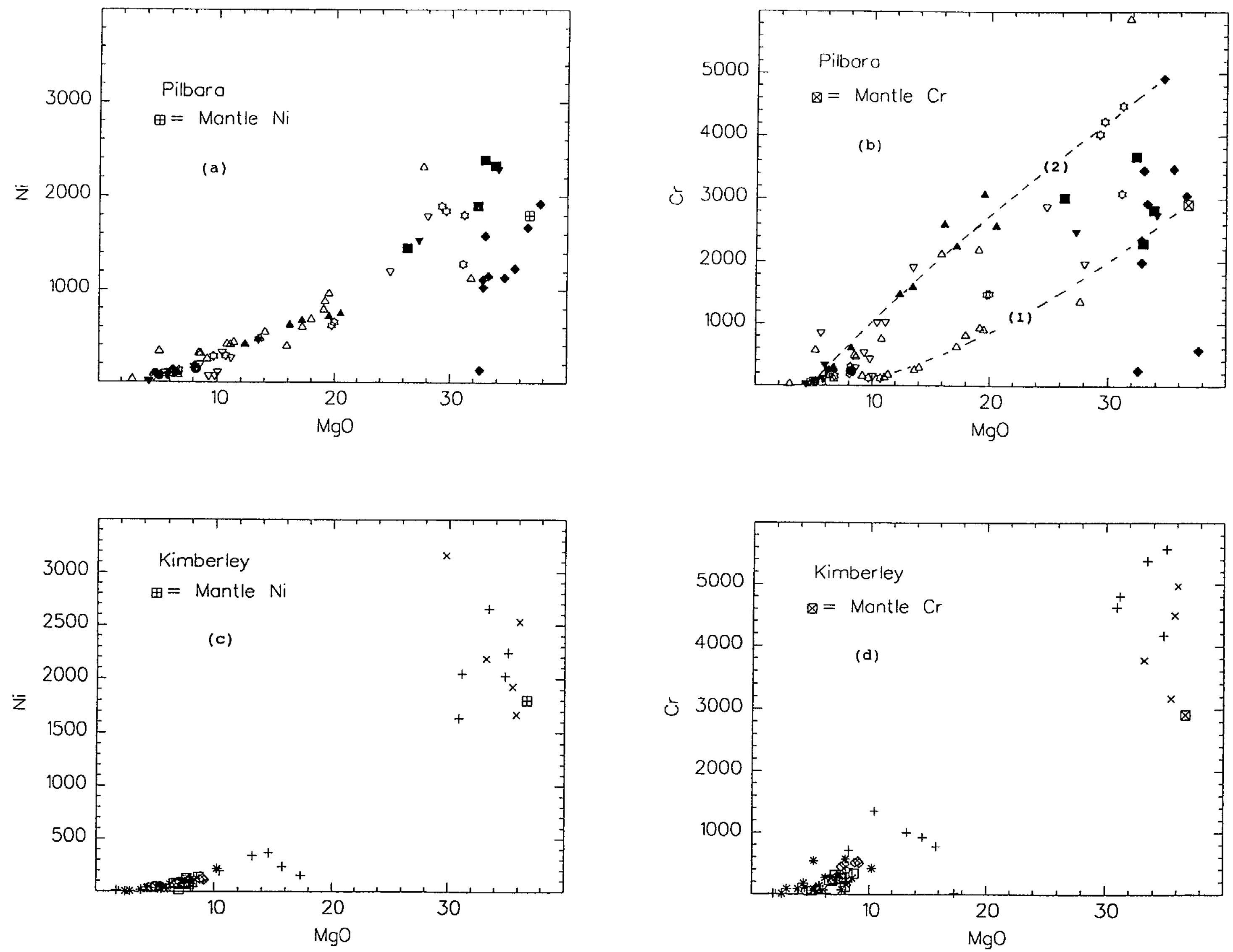

FIG.12: Plots of Ni vs MgO and Cr vs MgO. Trend (1) in (b) denotes mantle ratios and Trend (2) is that of Kambalda komatiites

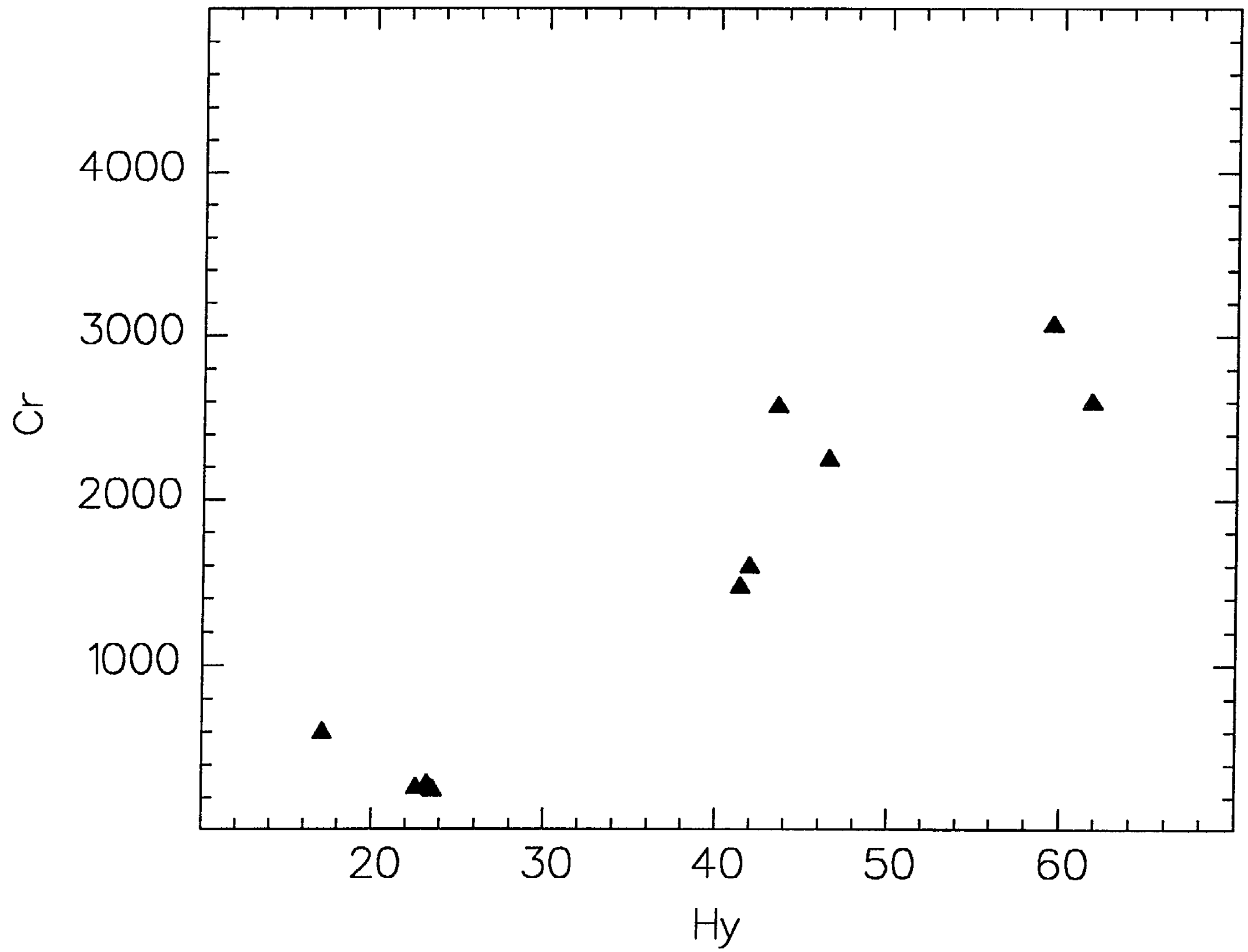

FIG.13: Cr vs normative Hypersthene - Cooya Pooya Dolerite

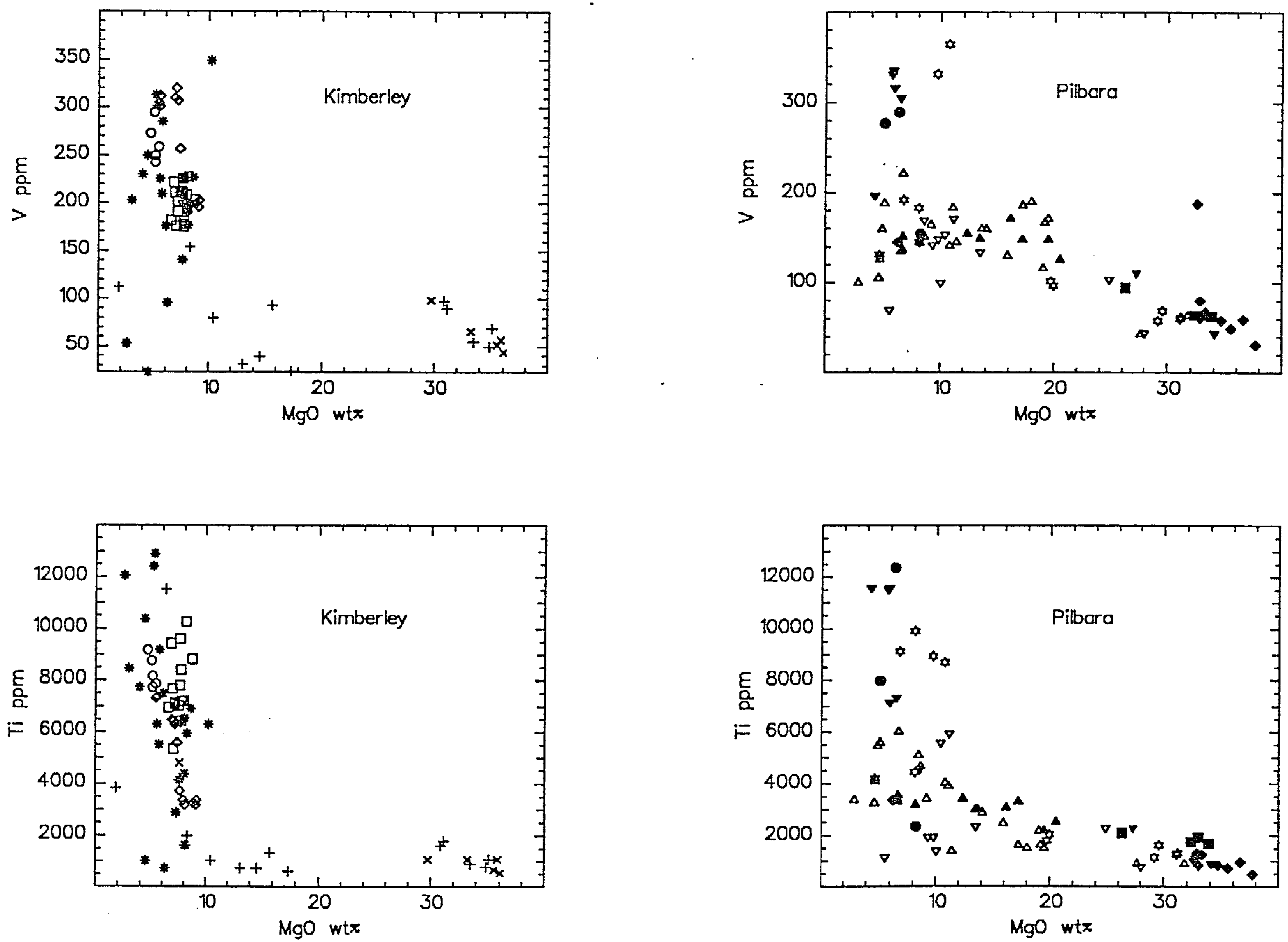

FIG.14: Plots of TiO2 vs MgO and V vs MgO

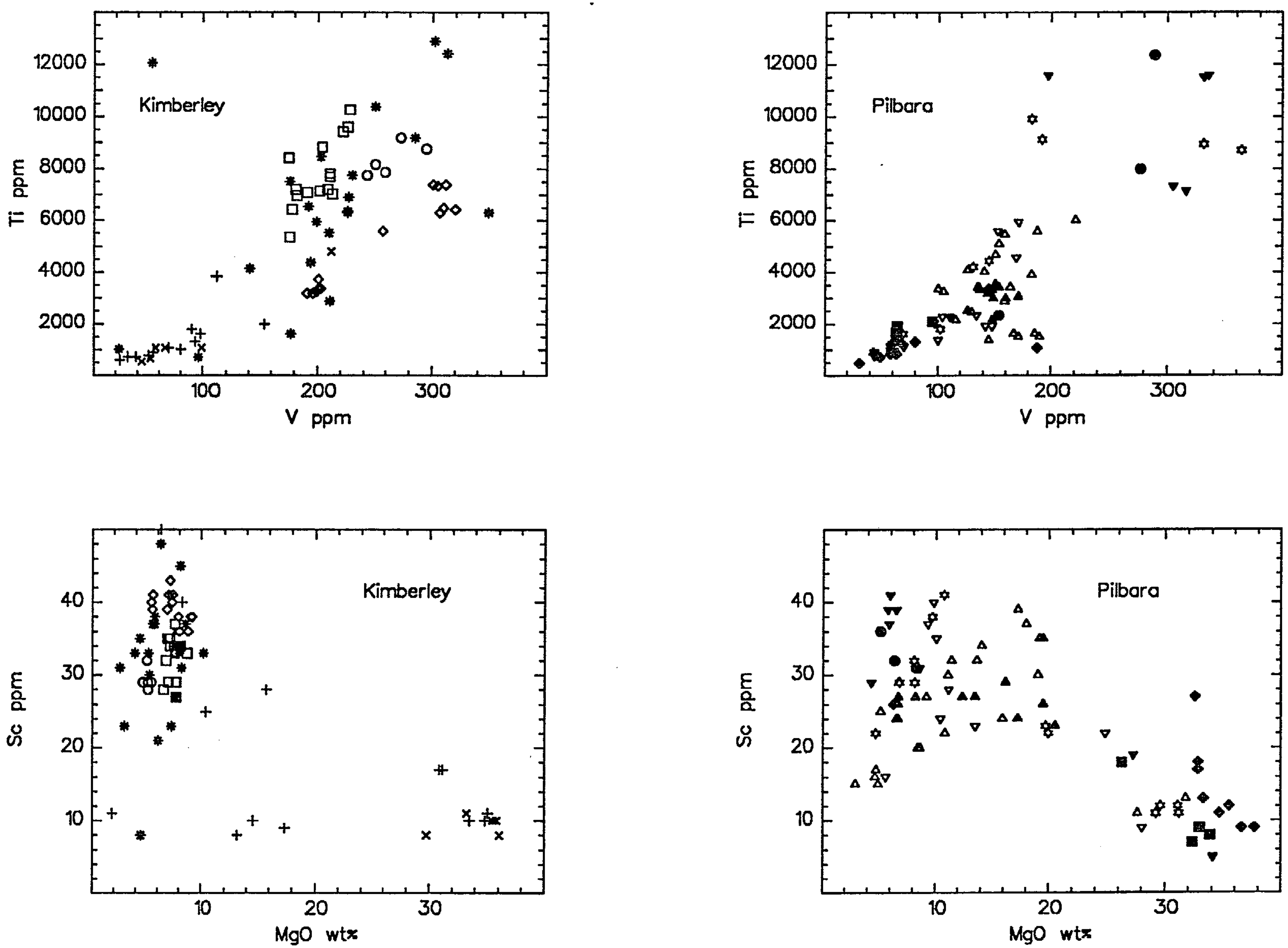

FIG.15: Plots of Sc vs MgO and Ti vs V

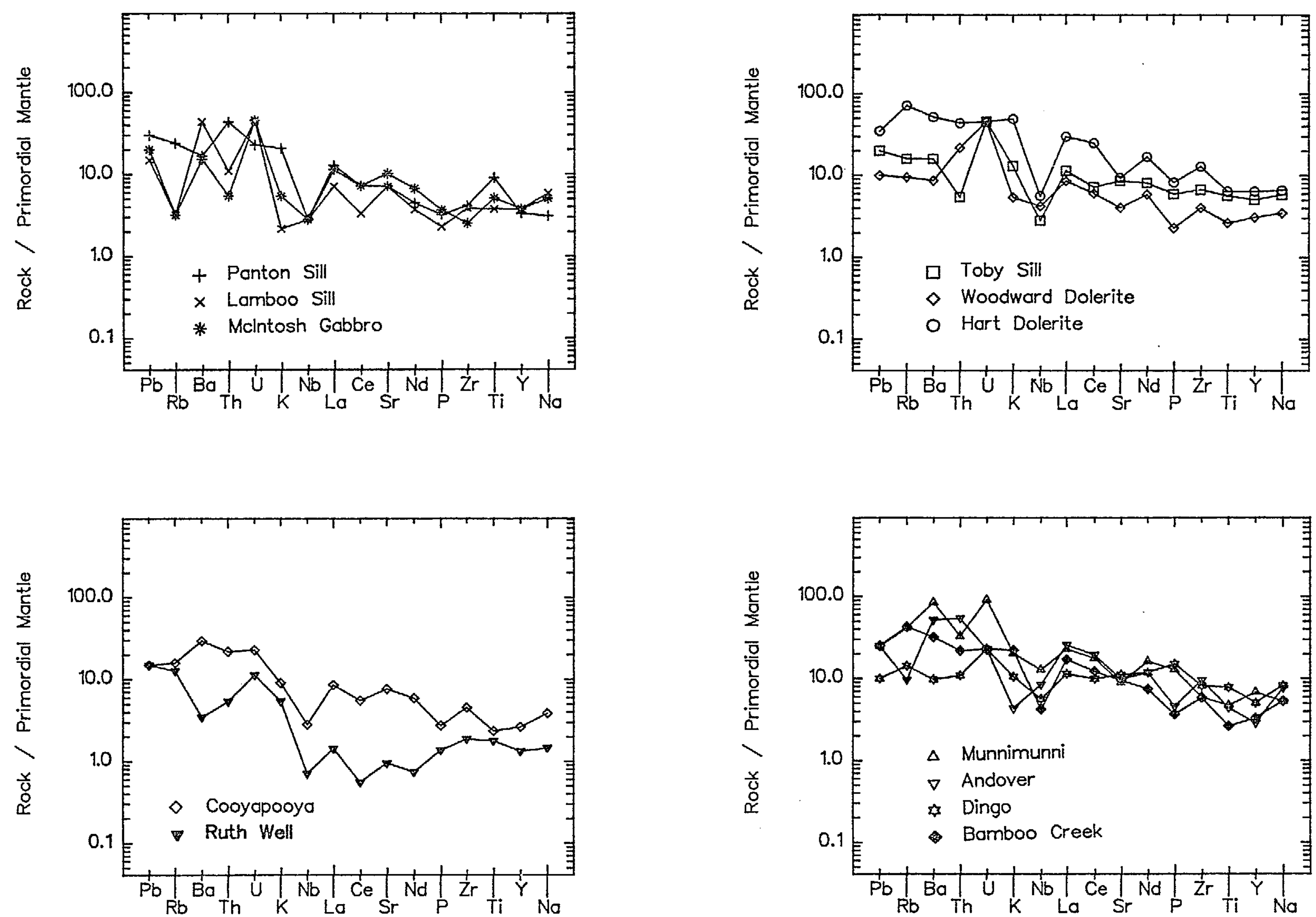

FIG.16: Mantle-normalized plots for representative rocks from each of the Pilbara and Kimberley mafic/ultramafic groups