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THE GEOLOGY AND LITHOGEOCHEMISTRY OF THE PALAEOZOIC SEVENTY MILE RANGE GROUP AT MT FARRENDEN, CHARTERS TOWERS, NORTH QUEENSLAND, AUSTRALIA

by

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THE GEOLOGY AND LITHOGEOCHEMISTRY OF THE LOWER PALAEOZOIC SEVENTY MILE RANGE GROUP AT MT FARRENDEN, CHARTERS TOWERS, NORTH QUEENSLAND, AUSTRALIA.

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ABSTRACT

The Cambro-Ordovician Seventy Mile Range Group occurs as an east-west trending volcano-sedimentary sequence which is host to several significant volcanic-hosted massive sulphide (VHMS) deposits. In the Mt Farrenden area the base of the Group is comprised of the fine sedimentary units of the Puddler Creek Formation. These continent-derived units were deposited into a back-arc environment. This Formation is overlain conformably by the rhyolite-dominated Mt Windsor Volcanics, and by the Trooper Creek Formation with mixed andesitic, volcaniclastic sedimentary and dacitic units. Whole rock geochemistry of a limited sample suite supports a subduction-related relatively low-K calc-alkaline volcanic arc environment for the latter two Formations. The recognised volcanic textures are not unequivocal in their support for a subaerial to subaqueous environment for the Mt Windsor Volcanics, although there is better evidence for a deeper water (submarine?) environment for the Trooper Creek Formation. The uppermost part of the Group, the Rollston Range Formation, is not represented here.

In the Mt Farrenden area the Seventy Mile Range Group is exposed in a prominent south plunging syncline which is a major deviation from the otherwise general east-west trend of the Group. The fold axis contains the thinnest development of the Mt Windsor Volcanics, and a part of the largest outcrop area of andesite within the Group in the Trooper Creek Formation. Intrusion of the Black Jack Granodiorite in the northeast and Policeman Creek Granodiorite in the west occurred during the Late Silurian-Early Devonian.

Massive, coarsely crystalline barite occurs in a small (30m by 7m) outcrop at the contact between the Puddler Creek Formation and the overlying Mt Windsor Volcanics. The barite may represent the remnants of a submarine hydrothermal vent of the type associated with volcanic-hosted massive sulphide deposits. However, hydrothermal alteration, in general, is very poorly developed within the study area.

CONTENTS

INTRODUCTION

The Seventy Mile Range Group is a volcano-sedimentary terrane of Late Cambrian to Early Ordovician age occurring as a series of inliers in the northern Tasman Orogenic Zone ***(Henderson, 1986)***. The terrane forms a relatively long (160km) and narrow (10km) discontinuous east-west oriented belt from Ravenswood in the east to Pentland in the west (Fig 1). A major convex-north buckle occupies the centre of the belt. This discrete belt was termed the Mt Windsor Subprovince ***(Henderson, 1980)***. Intrusion of the Ordovician (to Devonian) Ravenswood Granodiorite Complex mainly along its northern boundary has fragmented the terrane. To the south the terrane underlies the Carboniferous Drummond Subprovince ***(Henderson, 1986)***. Both sequences may be covered by up to 120m of Tertiary fluviatile, clay-rich, moderately consolidated immature sands and silts known as the Campaspe Formation ***(Nind, 1988; van Eck, 1991; Martin, 1993)***. Much of the western portion of the Seventy Mile Range Group, between Mt Leyshon and Pentland, is covered completely by the Campaspe Formation ***(Wyatt et al, 1971)***.

Historically, the dominantly rhyolitic outcrops forming the Seventy Mile Range and Mt Windsor itself were assigned to the Ordovician Mt Windsor Volcanics ***(Wyatt et al, 1971)***. The abundant sedimentary rocks underlying these rhyolitic units were assigned to the 'lower' Cape River Beds. The mixed volcanic and sedimentary units overlying the rhyolitic units were assigned to the 'upper' Cape River Beds of Cambro-Ordovician age ***(Wyatt et al, 1971)***.

Henderson (1986) redefined the Formations as, in ascending order, the Puddler Creek Formation (continent-derived sedimentary

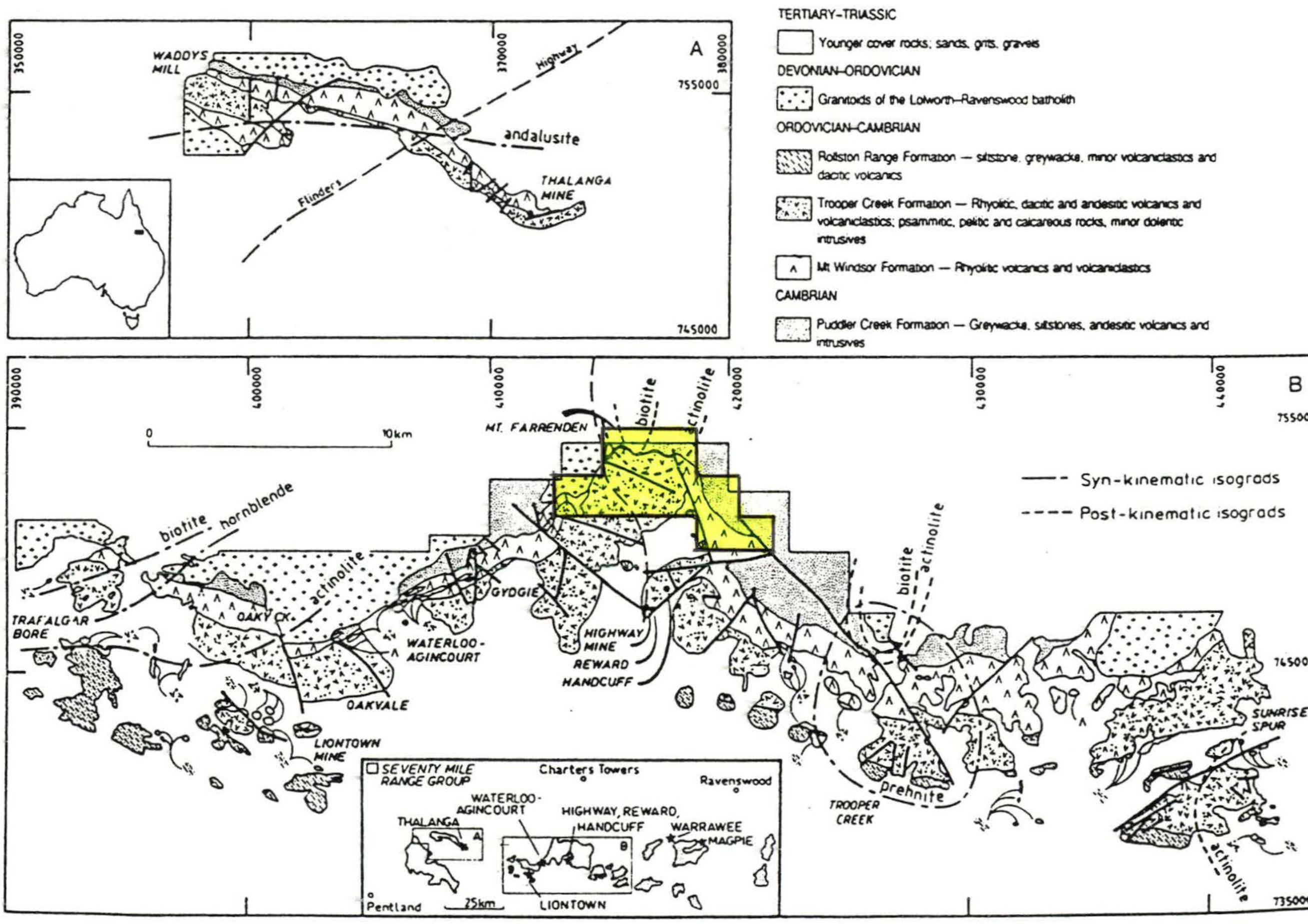


Fig 1: Location of the Mt Farrenden area

After Berry et al (1992)

units), the Mt Windsor Volcanics (dominated by rhyolitic rocks), the Trooper Creek Formation (mixed sedimentary and volcanic units) and the Rollston Range Formation (sedimentary units of volcanic derivation).

In 1992, as part of a base metals exploration programme, a 30km^2 area of the Seventy Mile Range Group around Mt Farrenden (Fig 1) was mapped geologically by the author at 1:5,000 scale ***(van Eck, 1993).*** Mt Farrenden is located approximately 30km south of the historical gold mining centre of Charters Towers in North Queensland. Despite a 25 year history of mineral exploration no thorough mapping programmes were undertaken in the Mt Farrenden area.

Thus, the main aim of this thesis is to describe, for the first time, the lithostratigraphy of the Mt Farrenden area. Whole-rock geochemistry of a limited sample suite is used to assess correlations among felsic units and among the more basic units. These data together with observations of volcanic textures are used to support the general environments of deposition proposed by previous workers ***(Henderson, 1986; Berry et al, 1992).*** The analytical data are compared also to the major features of the database prepared by the University of Tasmania ***(Berry et al, 1992).*** Throughout this thesis the stratigraphic nomenclature of ***Henderson (1986)*** is used, except for the Rollston Range Formation which is not represented in the Mt Farrenden area.

REGIONAL SETTING AND STRUCTURE

The Mt Windsor Subprovince forms the southern part of the structural terrane known as the Lolworth-Ravenswood Block, in North Queensland (Fig 2). The Subprovince occurs at the northern

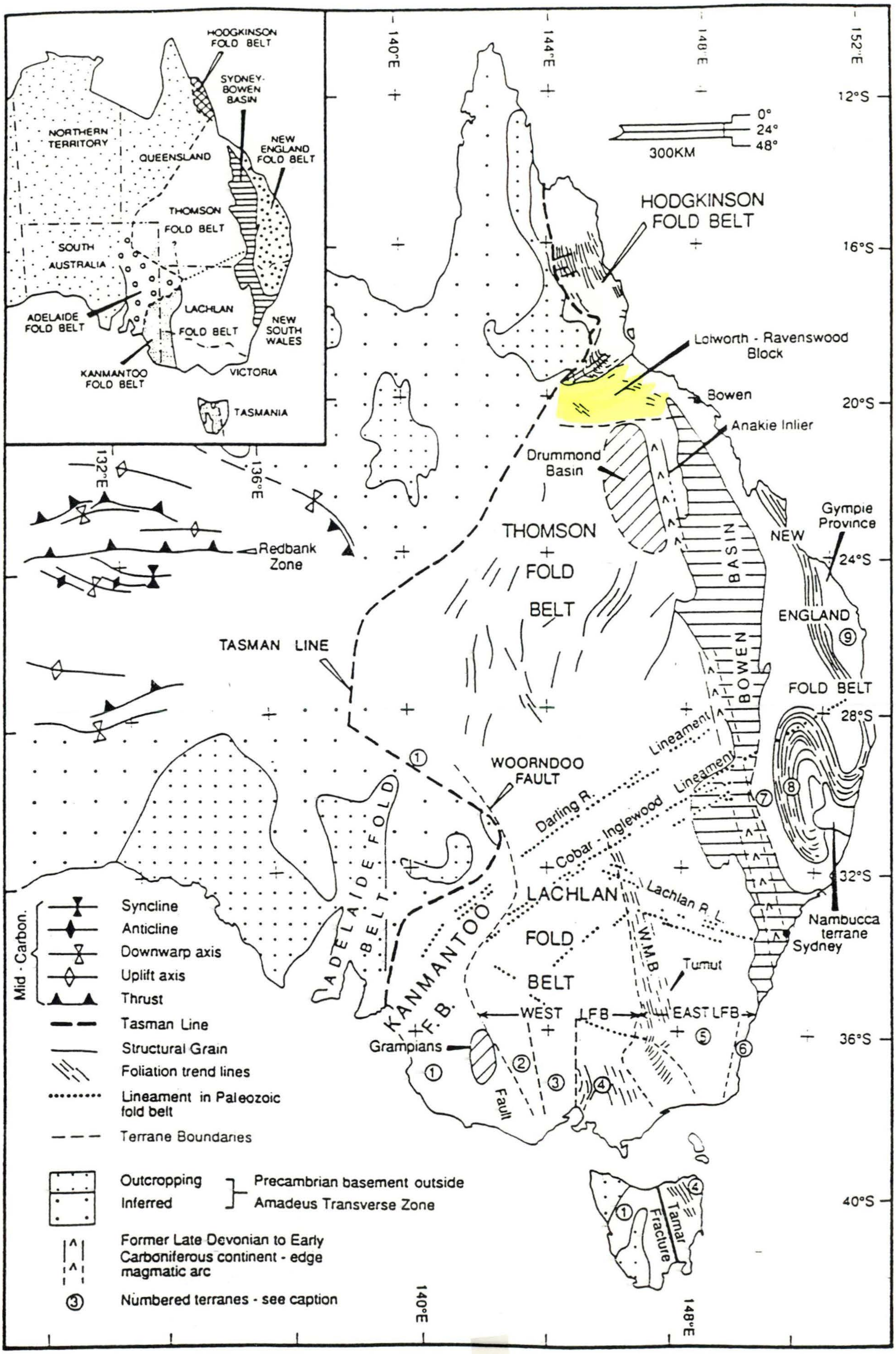


Figure 2

Tectonic sketch of eastern half of Australia showing the broad tectonic divisions of Tasman Fold Belt; modified from Powell *et al.* (1990, fig. 1).

end of Thomson Fold Belt which in turn forms the northern half of the Tasman Fold Belt. The Tasman Fold Belt as exposed in Eastern Australia extends from North Queensland, to Tasmania in the South ***(Murray, 1990)*** (Fig 2).

The major feature of the subprovince is a generally east-west trending and steeply south-dipping and south-facing fold limb ***(Berry et al, 1992).*** The southern part of the subprovince is covered by the Carboniferous Drummond Basin ***(Henderson, 1986).***

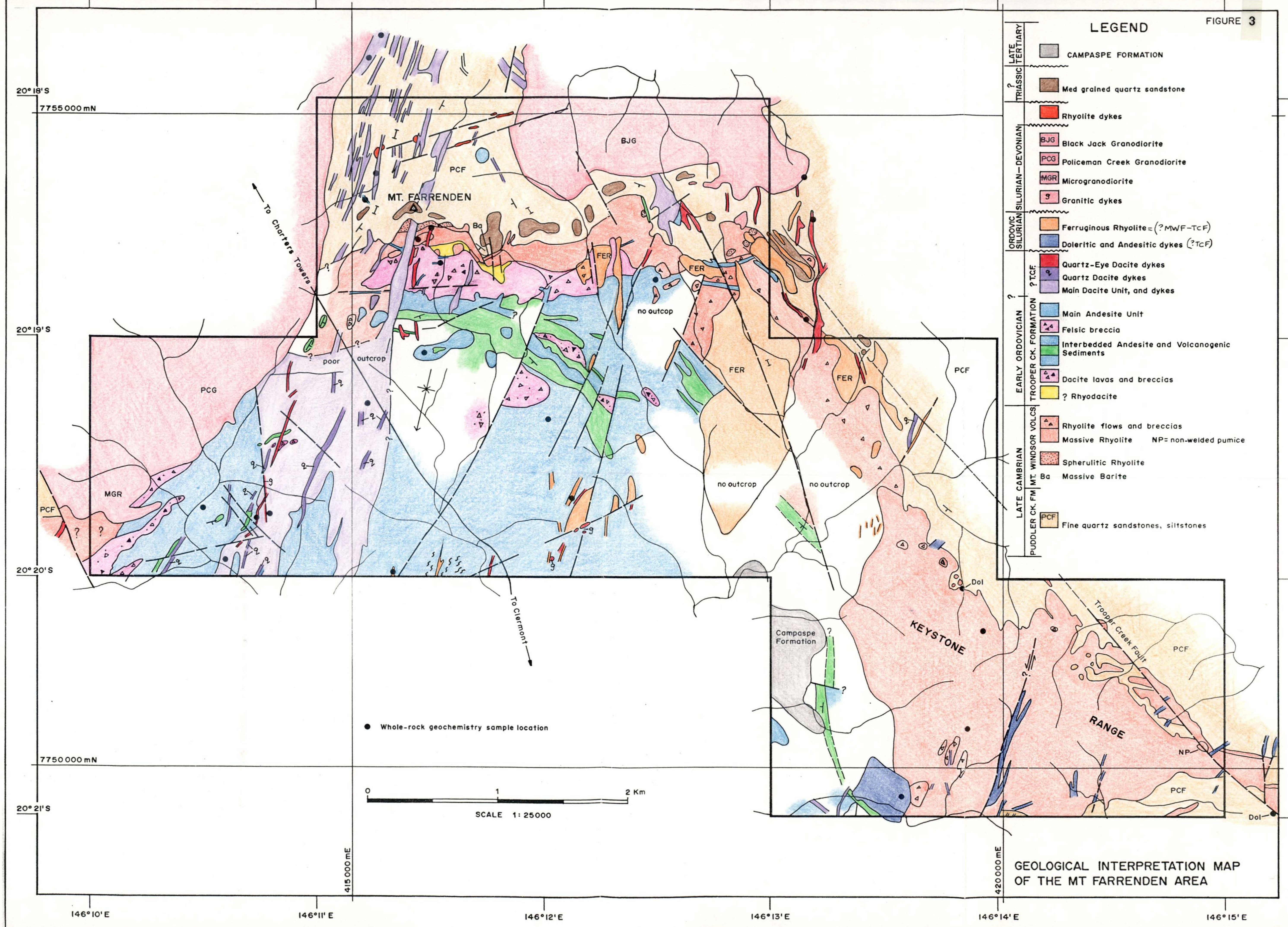
The Mt Farrenden area is located in a southward-plunging synformal buckle in the otherwise E-W trend of the subprovince. The Seventy Mile Range Group is host to several significant volcanic-hosted massive sulphide base metal deposits of which the Thalanga Base Metal Mine is the largest. Two subeconomic occurrences, the Reward and Highway massive pyrite-chalcopyrite deposits, occur 5km to the south of Mt Farrenden (See Fig 1).

PUDDLER CREEK FORMATION

The Puddler Creek Formation forms the base of the Seventy Mile Range Group and is assigned a Cambrian age on the basis of the fossil evidence from the overlying Trooper Creek Formation ***(Henderson, 1986).*** A likely maximum thickness of 9000m for the Puddler Creek Formation is estimated by ***Henderson (1986)***, although its base is not exposed anywhere in the sub-province due to the granitoid intrusions to the north.

Within the Mt Farrenden area the Puddler Creek Formation is dominated by moderately micaceous and very fine grained quartz sandstones, greywackes and siltstones (Fig 3). Bedding thicknesses range from finely laminated to thickly bedded and individual beds show no high energy cross-bedding features in outcrop. Recent core drilling, 750m ESE of Mt Farrenden, ***(van***

FIGURE 3



GEOLOGICAL INTERPRETATION MAP OF THE MT FARRENDEN AREA

Eck, 1993) show most of the apparent bedding to be irregular, possibly as a result of soft sediment movement. Oriented core measurements support a moderate southerly dip. The sedimentary units of the Puddler Creek Formation are described as having no volcanic component, being derived from a continental, granitic basement *(Henderson, 1986)*.

Adjacent to the intruding Black Jack Granodiorite in the northeast and Policeman Creek Granodiorite in the west *(Hutton and Crouch, 1993)* the commonly mauve to brown coloured fine sandstones are variably hornfelsed to a grey, more competent, indurated rock. The finer grained siltstones may be altered to a more slaty, grey-brown coloured rock. Some thin, infill-style quartz veins may accompany the hornfels such as those noted at a series of small gold workings (?Clarkin's Gold Mine, *pers. comm., JR Kay, 1992*) located near to the western edge of the Black Jack Granodiorite. The quartz veins at Clarkin's are near vertical and trend 320°M.

The nature of the contact of the Puddler Creek Formation with the overlying volcanic suites has not been resolved fully due to poor outcrop. However, the core drilling data *(van Eck, 1993)* suggest that the contact may be conformable. Farther eastward from Mt Farrenden the sedimentary units have strikes parallel to the eastern limit of the overlying rhyolitic rocks and moderate southerly dips and facings. No definitive dip and strike data could be measured within the rhyolites. The contact here is inferred to be relatively conformable.

To the immediate west of Mt Farrenden the NNE strike and steep easterly dip of the sedimentary units contrasts with the inferred ENE strike of the overlying rhyolitic rocks. On the basis of strike alone there may be some local unconformity. No definitive dip measurements could be made within the rhyolites.

MT WINDSOR VOLCANICS

The Mt Windsor Volcanics (Formation) has an inferred Late Cambrian age ***(Henderson, 1986)*** based on the presence of fossils of Early Ordovician age in the upper part of the immediately overlying Trooper Creek Formation. However, an Early Ordovician age for the rocks cannot be discounted.

Rhyolites dominate the Mt Windsor Volcanics in the study area. These can be fine grained, massive and featureless, flow-banded or brecciated, the latter by volcanic or hydraulic means. Small (1mm) quartz phenocrysts are present commonly, although they are variable in their distribution. Feldspar phenocrysts are extremely rare.

From Mt Farrenden and eastwards towards the Keystone Range the Mt Windsor Volcanics occurs as a narrow zone of outcrop seldom more than 200m wide (Fig 3). At some localities the Formation may be absent. To the north of the Keystone Range the Formation is represented mainly by siliceous rhyolitic mass-flow breccia and autobreccia.

The Mt Windsor Volcanics outcrop widens rapidly to over 1.5km to form the Keystone Range. The highest point on the Range is approximately 100m above the surrounding plains and is formed almost entirely of fine grained massive (partly flow-banded) rhyolite. In the extreme SE of the study area the Formation thins to around 300m adjacent to a major NW-trending fault (the Trooper Creek Fault).

Pumiceous and rhyolitic breccias commonly occur as localised outcrops where the massive coherent rhyolites are thin.

Dacitic and andesitic dykes intrude the rhyolites throughout the area, with doleritic dykes apparently restricted to the east.

Quartz veining of the infill style is relatively common within the rhyolites and iron oxides may accompany the veins along with small, cubic, oxide-coated voids (?ex-pyrite). Fresh pyrite may occur as tiny specks within the rhyolites themselves.

Spherulitic Rhyolite Unit

This unit crops out discontinuously immediately above the Puddler Creek Formation from the base of Mt Farrenden and eastward for approximately 2.5km. The contact with the Puddler Creek Formation is not exposed. Abundant Fe-stained spheres ranging in size from 2mm to 5mm characterise this unit in hand specimen ***(Beams, 1991; van Eck, 1993).*** Petrographic studies ***(Mason, 1992; Stolz, 1992)*** have not identified the spherical shapes conclusively as devitrification features (or accretionary lapilli). However, ***Dr JV Wright (pers. comm. RJ Morrison, 1992)*** has suggested that devitrification is the most likely cause. Petrographically, the groundmass is very finely and evenly grained, and has been described as a recrystallised ash rather than a homogeneous crystalline or glassy groundmass. Alteration was described as moderate with sericite and silica being prominent in the groundmass. This represents the highest level of alteration described petrographically in the study area.

The interpreted maximum width of the unit of approximately 50m occurs near the base of Mt Farrenden ***(van Eck, 1993).*** From here it can be traced discontinuously eastwards and rarely exceeds 20m in width. The spherulitic unit is inferred to be only a few metres in actual thickness, although there is no information on the dip of the unit to qualify this observation.

Several spherulitic rhyolite outcrops occur within a ferruginous rhyolite unit, discussed below, which is inferred to be younger than the Mt Windsor Volcanics. These outcrops are interpreted as topographical highs at the time of deposition of the ferruginous rhyolite unit.

Massive Barite

Massive, coarsely crystalline (5 to 20mm) barite occurs in an ENE-trending lenticular outcrop 30m long and a maximum of 7m wide approximately 750mm ESE of Mt Farrenden. Infill-style veins of slightly finer grained barite cut the outcrop. The massive barite outcrop is present at, and parallel to, the contact between the Puddler Creek Formation and a weathered, partly siliceous, fine, massive rhyolite which forms the base of the volcanic sequence here. Two other small (5m long and 2m wide) outcrops of massive barite and baritic rhyolite are present in the same area and in the same stratigraphic location.

Flow-banded Rhyolite and Rhyolitic Breccia Unit

This unit is comprised of flow-banded, siliceous rhyolite lavas and a breccia of flow banded, angular rhyolitic clasts. The unit directly overlies the Spherulitic Rhyolite Unit where it is present but otherwise is inferred to overlie conformably the Puddler Creek Formation ***(van Eck, 1993)***. The Flow-banded Rhyolite and Rhyolitic Breccia Unit has an E-W trend and can be traced continuously from its hornfelsed western limit adjacent to the Policeman Creek Granodiorite for approximately 2.5km to the east. The actual contact with the granodiorite is not exposed anywhere within the study area. Outcrop width of the unit varies from 20m in the centre of the area to a local maximum of 400m near its eastern limit. Within this zone cohesive flow-banded rhyolite forms approximately 70% of the outcrop. The remaining 30% is dominated by breccias of matrix-supported, angular, randomly oriented, monomictic flow-banded rhyolite clasts (<30mm diameter) of varying shapes. No flow-banding of the matrix was observed. A shatter (?hydraulic) breccia composed of angular, fine rhyolitic clasts in a silica matrix occurs near the western limit of the Flow-banded and Rhyolite Breccia Unit with many of the clasts demonstrating a jigsaw fit with adjacent clasts.

Also present within this unit are several small hills comprised of flow-banded and comparatively quartz phenocryst-rich rhyolite with some feldspar phenocrysts. These outcrops are interpreted as local subvolcanic domes or feeders to the rhyolite flows. A quartz-feldspar porphyry unit also occurs adjacent to the eastern-most of these outcrops. The relationship between the two units is unclear.

Farther to the southwest towards the Keystone Range rhyolitic breccias similar to those described above dominate the Flow-banded Rhyolite and Rhyolitic Breccia Unit ***(van Eck, 1993)***. Minor cohesive flow-banded rhyolites are present locally and flow-banding in the matrix of some breccia outcrops is present. These rocks crop out very poorly resulting in a very discontinuous outcrop pattern to the immediate north of the Keystone Range.

Weathered and cleaved felsic mass-flow-type breccias as described above occur in the Keystone Range area ('volcani-clastics' of ***Beams, 1990***) where the coherent rhyolites have been eroded, and in isolated locations along the northern limit of the Keystone Range where the coherent rhyolites are inferred to be relatively thin. It is possible that some of these breccias form the base to the Keystone Range and can be correlated with the rhyolitic breccias to the north.

Massive Rhyolite Unit

The Keystone Range provides the greatest accumulation of rhyolitic rocks within the study area where a maximum outcrop width of 1.5km is attained. Actual thickness of the rhyolite accumulation is unknown but must be at least 120m, this being the approximate height of the Range above the surrounding plains. No unequivocal dip measurements were recorded on the Keystone Range which appears to overlie conformably the Puddler Creek Formation The latter displays southerly dips in excess of 50^{0} adjacent to the contact. If such a dip can be applied to the maximum outcrop width of the rhyolites then an accumulated thickness approaching 1200m could be inferred.

Most of the rhyolites appear to be very fine grained and variably, finely flow-banded. Massive fine rhyolites are also very common and may exhibit poorly developed columnar jointing. Quartz phenocrysts are relatively common and generally around 1mm to 2mm in size, although their distribution is highly variable. Feldspar phenocrysts are extremely rare.

Fresh fine pyrite may be present within the rhyolite and there is abundant evidence for the former presence of pyrite in the form of small Fe-oxide filled cubic voids.

Quartz veining of the rhyolites is relatively common, and well demonstrated on the western edge of the Range. Veining is accompanied commonly by local silicification, as seen on the high ground towards the southern limit of the study area.

Small and apparently isolated outcrops of volcaniclastic breccia occur just below the summit of the Keystone Range and near to the Puddler Creek Formation contact. In hand specimen, elongate fragments with tapered ends are common in these outcrops as are flattened disc-like shapes many of which appear to be clay-rich and pale green in colour. A zone of non-welded, pumice-rich outcrops occurs near the inferred base of the massive rhyolites in the extreme SE of the study area. No petrographical description of these rocks was undertaken.

TROOPER CREEK FORMATION

In accordance with the classification of ***Henderson (1986)*** the Trooper Creek Formation continues to be defined on the basis of the first appearance of dacitic lava. Graptolite fossils indicate an Early Ordovician age for the upper part of the Trooper Creek Formation ***(Henderson, 1986).***

Near Mt Farrenden the Trooper Creek Formation is represented by an E-W trending unit of siliceous dacite lavas and breccias, and alternating andesites and fine grained, very thinly bedded and laminated, southward dipping volcaniclastic sedimentary units. These units appear to overlie conformably the Mt Windsor Volcanics although dip measurements have not been possible within the latter Formation.

Farther south and southwest of Mt Farrenden is a large area where outcrop is absent, beyond which are extensive outcrops of andesitic and dacitic rocks forming discrete zones.

To the SE of Mt Farrenden this Formation is dominated by andesitic lavas which give way to a variable sequence of andesites, felsic rocks and extremely fine grained siliceous siltstones. The latter provide NW trends and SW dips. This sequence appears similar to that described near Mt Farrenden.

To the west of the Keystone Range finely laminated siltstones, and fine sandstones have a N-S trend and steep westerly dip and facing. Further southwards similar sedimentary units occupy a more NW trend.

Hydrothermal alteration of the form that accompanies significant volcanic-hosted massive sulphide base metal mineralisation has not been recorded in the Trooper Creek Formation in the study area. Although chlorite, sericite, silica and epidote all have been identified in thin section ***(Mason, 1992; Stolz, 1992)*** and in outcrop ***(van Eck, 1993)***, feldspar phenocrysts, where present, are preserved with only minor replacement by phyllosilicates. The thin section studies also indicated metamorphic recrystallisation at lower greenschist facies conditions. Fine biotite in random orientation supports a contact metamorphic overprint.

Dacitic Breccia and Lava Unit

Dark grey and siliceous dacite lavas and breccias occupy a 2km-long E-W trend along the southern boundary of, and conformably overlying, the Flow-banded and Rhyolite Breccia Unit of the Mt Windsor Volcanics. The dacite unit is approximately 250m in average outcrop width with local topographical variations suggesting that the unit has a thickness in excess of 10m. The dip of the unit is not known.

Subdivision of the unit is possible into predominantly brecciated and non-brecciated zones. In the Mt Farrenden area the breccia unit is composed of finely flow-banded, dacitic, squat to elongate clasts generally no larger than 10mm in diameter. The clasts are angular, both matrix and grain supported, comparatively poorly sorted and randomly oriented in a siliceous matrix that resists weathering. Clast size reaches a maximum near the centre-east of the outcrop zone with subrounded, poorly sorted and grain supported clasts to 300mm in diameter (**Fig 4**). Basaltic clasts may be present ***(Mason, 1992; Stolz, 1992)*** as well as small clasts of pink and highly siliceous, fine grained material.

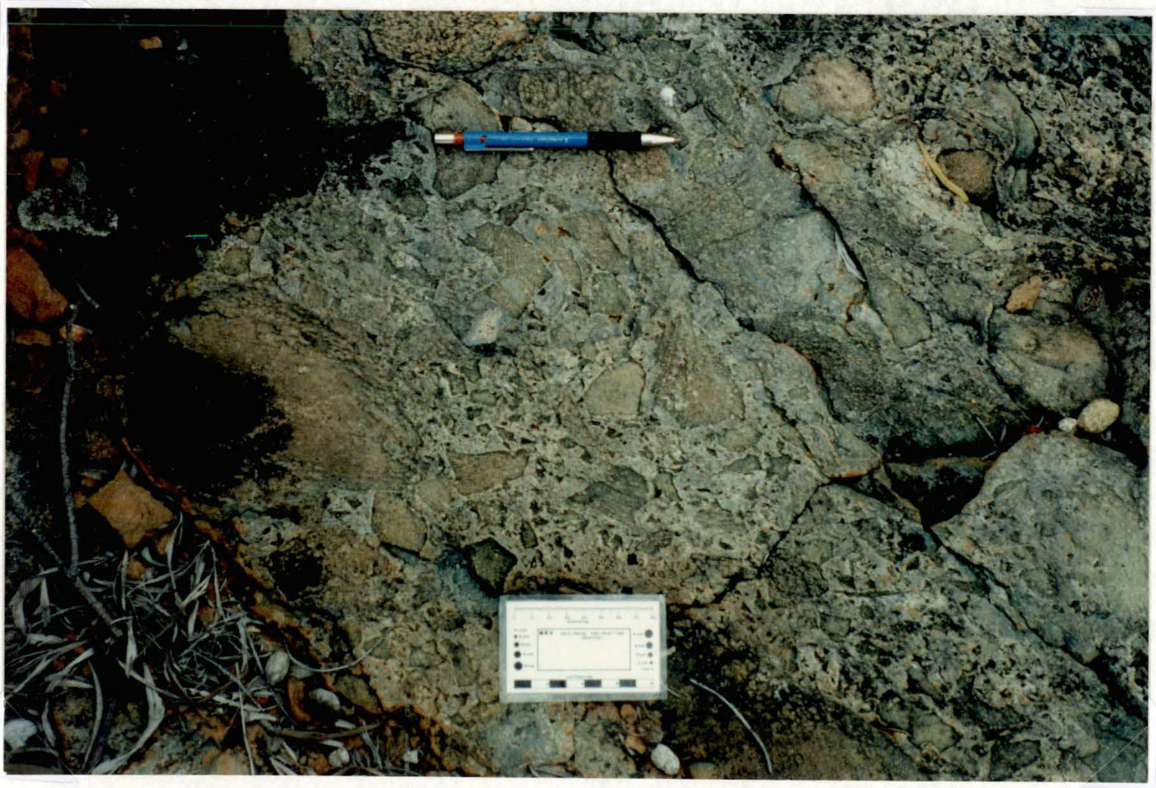
The less brecciated occurrences are composed of a very hard, dark grey dacitic lava which may have incorporated up to 10% of basaltic clasts either as a result of flow over a mafic brecciated lava surface ***(Stolz, 1992)*** or, as suggested by ***Mason (1992)***, by "magma-mingling", the coexistence of acid and basic magmas during volcanism. These 'breccia-poor' dacites dominate the central part of the Dacitic Breccia and Lava Unit.

Interbedded Andesite Lavas and Volcaniclastic Sedimentary Units

An E-W trending zone of andesitic lava forms the basal part of this sequence immediately overlying the dacitic breccia and lava. Much of the western part of the andesite outcrop is characterised by a distinctive black exterior and a fine grained texture. In the extreme west the andesite is very hard, fine grained, unaltered and grey in colour. In the east the base of the sequence is a fine grey andesite with a highly variable amygdale-vesicle content.

Very thinly bedded to laminated siltstones and very fine grained sandstones (?volcaniclastic) occur in an E-W trending and southerly dipping sequence overlying the basal andesite units. These sedimentary units are oxidised, grey to pale brown in colour with some graded bedding, confirming a southerly facing (**Fig 5**). There is no evidence of the silicification which accompanies the sediment float at surface.

Subrounded to rounded, large clasts (to 10cm) of finely banded felsics, with smaller subangular to angular clasts in matrix. Note poor sorting and matrix support of clasts. Locality 49, 416485E, 7753705N



Angular clasts of finley banded felsics, poorly sorted and matrix supported. Matrix variably silicified and slightly more resistant to weathering than clasts.
Locality 49, 416485E, 7753705N

Figure 4

Laminated and very thinly bedded siltstone, volcaniclastic?
416850E, 7753035N

Figure 5

Farther east the strike of the sedimentary units changes from ESE to SE and outcrop becomes rare. At one locality the sedimentary units appear to overlie directly the Mt Windsor Volcanics. The presence of sedimentary units here is indicated by siliceous finely laminated surface rubble. Locally, small weathered outcrops display definitive SW dips.

Massive siliceous siltstones with finely disseminated pyrite also occur with the laminated sedimentary units. One such sample from the west of the study area was described petrographically as a fine devitrified ash ***(Mason, 1992)***.

Felsic Breccia Unit

This is an ill-defined unit occurring in the centre of the study area. The single largest outcrop zone appears to be stratigraphically above the Interbedded Andesite and Volcaniclastic Unit. It consists of angular, randomly oriented, matrix to clast supported and moderately siliceous fragments of fine felsic (?dacitic) rock. Clasts of differing compositions are also present locally although masked somewhat by the silicification and weathering.

Within the Interbedded Andesite and Volcaniclastic Unit are several occurrences of felsic breccias. Again the clasts are angular, matrix supported and unoriented. These breccias are distinguished by the presence of varying proportions of fine grained angular basaltic clasts **(Fig 6)**. These polymict breccias are similar in appearance to the polymict breccias in the SW of the study area where moderately welded textures were observed in thin section ***(Mason, 1992; Stolz, 1992)***. Here, the polymict breccias grade southward into a felsic (mass-flow-type) breccia and possible felsic autobreccia.

Siliceous volcaniclastic breccia showing felsic (dominant) and basaltic clasts. Outcrop appearance is very similar to the Dacite Lava and Breccia Unit near Mt Farrenden.
Locality 305, 417110E, 7752710N

As above, showing local increase in basaltic clast content.
Locality 305, 417110E, 7752710N

Figure 6

Massive Andesite Unit

Andesite lavas cover a large proportion of the centre and west of the study area and is part of the largest andesite outcrop zone in the subprovince. Early exploration mapping *(Jododex, 1972)* infers that the andesites continue southwards from the study area for a further 1.5km. In the central part of the study area the andesites commonly are enriched in feldspar phenocrysts and small vesicles which may be filled with calcite and quartz. No particular outcrop orientations are apparent although the larger feldspar-phyric and vesicular-amygdaloidal outcrops tend to occur in north-trending zones within the unit. The eastern and northern limits of the main andesite unit are obscured at its contact with the mixed andesites and sedimentary units described above by soil and transported sediment cover.

In the west the andesites are considerably less vesicular and contain fewer feldspar phenocrysts than in the east. While no particular outcrop orientations are apparent there is a strong structural grain which follows a NNE trend. One isolated but unconvincing example of pillow development was located in this area. Coarse, poorly sorted andesite breccias also occur along the southern limit of the study area.

Malachite staining was observed at several locations within the main andesite unit.

Massive Dacite and Dacitic Dykes

Large continuous outcrop areas of fine dacite *(Mason, 1992)* occur in the west of the study area forming most of the low hills here. Individual outcrops commonly show a NNE trend that is not cross cut by features such as flow-banding or grainsize changes. Along with the main andesite unit the dacite units dominate the outcrop in this area. The dacites appear to intrude and locally silicify the larger andesite outcrops.

Farther north the same dacitic unit is expressed as a series of discontinuous, NNE trending (015° to 025°M) elongate, narrow outcrops. Extensive soil cover obscures most of the outcrop here.

To the west and north of Mt Farrenden elongate, narrow, dyke-like outcrops of dacite are common within the Puddler Creek Formation. These dykes are grouped along the margin of the Policeman Creek Granodiorite with the inferred eastern limit of the dacitic dyke swarm corresponding to the eastern limit of the larger dacitic outcrops in the south. The dykes are inferred to be subvertical, between 2m and 30m wide and with a strike between 010° to 020°M. In common with the larger dacitic outcrops to the south these dyke rocks appear well preserved and unaltered in comparison to the rhyolitic units discussed above.

Thin dacitic dykes also cut across the Mt Windsor Volcanics and the Trooper Creek Formation in the centre and east of the study area. These have the same physical appearance and orientation as those to the west. In addition, numerous quartz-dacite dyke-like outcrops occur within the massive dacite units and in the centre and east of the study area. Abundant small quartz phenocrysts (1mm to 2mm) characterise these dykes which occur commonly as 1 to 5m-wide linear NNE-trending outcrops within the massive dacite occurrences. Some were recorded in the dacite dyke swarm to the west and north of Mt Farrenden where they display the same NNE trend and orientations. In the centre-east of the study area both dacite and quartz dacite dykes are present as individual and isolated outcrops with a NNE trend.

Quartz-phyric dacitic, thin (1 to 10m) dyke-like bodies occur within the Puddler Creek Formation, the Mt Windsor Volcanics (near Mt Farrenden), and the Trooper Creek Formation including the massive dacite units. These dykes are characterised by prominent, rounded quartz "eyes" between 3mm and 5mm in diameter. Petrographically, the groundmass is very fine grained and dacitic in composition ***(Mason, 1992)***, and may display feldspar phenocrysts to 2mm in length. The dykes appear to be subvertical with a northerly strike, varying between NNW and NNE, and cross-cut apparent bedding, or flow trends in the massive dacite outcrops. These, and other, dacitic dykes are not found within the Black Jack Granodiorite and Policeman Creek Granodiorite intrusive bodies.

FERRUGINOUS RHYOLITE UNIT

The main occurrence (see Fig 3) is a broadly N-S trending zone in the centre-east of the study area which produces several topographical highs. Such an orientation for a large outcrop (2km by 750m) is uncommon. The zone appears to cross-cut the trend of the Flow-banded Rhyolite and Rhyolite Breccia Unit and a SE trending scree and outcrop zone of fine siliceous siltstones of the basal Trooper Creek Formation. The contact relationships of these units are unclear. A late syn- or post- Trooper Creek Formation age could be inferred although the lack of felsic or mafic dykes could infer a much younger age. Alternatively, the rhyolites could represent a pre-existing topographical feature around which the Flow-banded Rhyolite and Rhyolite Breccia Unit and the siliceous siltstones were deposited. This would infer a Mt Windsor Volcanics age.

The zone itself consists of mostly massive and coherent rhyolite, with abundant Fe-oxides after pyrite which gives the unit a colour range from orange to mauve. Quartz phenocrysts are relatively common throughout with feldspars poorly developed (?preserved). Near the tops of the hills formed by the unit the rhyolites appear to be more silica-rich. The reason for the formerly elevated pyrite content and its apparent restriction to this unit is unknown. No lithogeochemical samples were taken from this unit.

A rhyolitic sandstone (volcaniclastic) ***(Mason, 1992)*** also occurs as smaller outcrops adjacent to the main rhyolite zone and commonly as very narrow (5 to 15m-wide) ?fault-bounded north trending linear outcrops. Fe-oxides are a relatively common but very variable component of these clastic rocks.

To the west of the main outcrop area is a smaller outcrop of ferruginous rhyolite composed of both massive and breccia material. The breccia appears to be of the mass-flow type since no massive or flow rhyolite occurs between the unoriented and poorly sorted clasts. Breccias are uncommon within the ferruginous rhyolite unit in general.

To the east of the main outcrop is a NW-trending, narrow hill-forming outcrop of rhyolite which appears to overlie (or intrude?) an Fe-oxide stained quartz sandstone-greywacke unit. The rhyolite itself contains a moderate amount of Fe-oxide but cannot be assigned confidently to the Ferruginous Rhyolite Unit.

Related to the main outcrop phase may be the iron oxide-rich and rhyolitic dykes that occur in several parts of the study area. Most of these occurrences have NNE to NE trends. It is possible that the North trending dyke-like and gossanous outcrops at the northern end of the Keystone Range are part of the Ferruginous Rhyolite Unit.

A prominent hill of rhyolitic outcrop occurs on the SW boundary of the study area. While the outcrop has similarities to some of the rhyolites near Mt Farrenden there remains the possibility that it is related to the Ferruginous Rhyolite Unit. This is discussed in terms of lithogeochemistry, below. Ferruginous rhyolite-volcaniclastic linear outcrops also occur near to this prominent hill.

To the North of Mt Farrenden are several short but elongate, as well as isolated, outcrops of siliceous but iron oxide-rich rhyolite which are interpreted as occupying an ENE trend. The elongate outcrops also trend ENE. These trends appear to offset (inconclusively) portions of the dacite dyke swarm in this area, as well as the Black Jack Granodiorite to the east. It is inferred that these rhyolite dykes are younger than the granodiorite.

DYKE-LIKE INTRUSIVES

Andesitic Dykes

Dyke-like bodies of andesitic rock occur within all of the Formations of the Seventy Mile range Group within the study area. In the north thin (0.5- to 3m-wide) dykes are present. The strike orientations of these dykes vary considerably, with occurrences in the Puddler Creek Formation being invariably small and ill-defined providing little orientation information.

Within the Mt Windsor Volcanics and the Dacite Lava and Breccia Unit of the Trooper Creek Formation to the south of Mt

Farrenden thin andesite dykes have been recorded with E-W, NW, WNW and NNW trends. Several of these trends are similar to fault trends in the area. Most of the andesitic dyke-like outcrops within the massive dacite outcrops in the SW of the study area have NNE trends consistent with the trend of the dacitic dykes and the trends within the massive dacites themselves. Since these dykes have not been characterised geochemically it is uncertain whether they are remnants of the massive andesite units here or are related to the andesitic dykes near Mt Farrenden.

The term 'andesite' used here for the dykes is a field term. As such it encompasses the lithogeochemical andesite and basaltic andesite fields discussed below. The relationship of these dykes with the Trooper Creek Formation is also discussed below.

Doleritic Dykes

Abundant thin doleritic (field term) dykes intrude the Puddler Creek Formation in the SE of the study area. Their previous description as a dyke swarm ***(Beams, 1990)*** remains unchallenged here due to the concentration of mapping on the overlying formations.

Doleritic dykes (chemically, basaltic andesites; ***van Eck, 1993***) occur in the SE of the study area commonly where the rhyolites of the Mt Windsor Volcanics appear to be relatively thin. In the extreme east the dykes have a NE trend and may be over 10m in thickness (see Fig 3).

A N-S trending zone of doleritic dykes was recorded within massive rhyolites near the SE boundary of the study area. These dykes could not be traced farther northward as the rhyolite became more elevated topographically (?thicker). In the centre of the Keystone Range a NNE trending fault zone hosts narrow doleritic dykes that can be traced almost to the highest part of the range. A single development of dolerite was recorded in the north while at least 2 dolerite zones were recorded within the southern part of the fault zone.

A large outcrop area containing highly vesicular and locally pillowed dolerite **(Fig 7)**, and fine grained massive andesite (basaltic andesite) occurs at the intersection of the southern limit of the study area and the western edge of the Keystone Range. Whole rock geochemistry ***(van Eck, 1993)*** **(Appendix 1)** suggests that these mafic volcanic rocks and the dykes are from a different source to those distinguished by high phosphorus and niobium contents ***(Berry et al, 1992)*** within the Puddler Creek Formation. As discussed below these mafic rocks are also distinguishable from the massive andesites in the Trooper Creek Formation.

Doleritic dykes appear to be absent from the remainder of the study area, where andesitic dykes are dominant. The age of the mafic dyke rocks is uncertain. It could be reasonably inferred that the age ranges from late Mt Windsor Volcanics-early Trooper Creek Formation to post-Trooper Creek Formation.

Granitoid Dykes

In the SW of the study area and within the main dacitic outcrop occurs a thin (1m) dyke-like body of fine to medium grained granitic (dioritic?) rock. Its southern end trends NNE into a NW trending fault. To the north of the fault the dyke has a NNW trend which appears to coincide with the contact between the Massive Andesite and Massive Dacite Units (see Fig 3).

A small outcrop of similar rock occurs approximately 400m to the west of the southern end of the main dyke. Both occurrences

Small pillow structures in highly vesicular basaltic andesite. Locality 299, 418965E, 7749865N

Pillow structures in highly vesicular basaltic andesite, Note fine grained rind at top of pillow.
Locality 299, 418965E, 7749865N

Figure 7

may be related to larger body of microdiorite mapped in the adjoining exploration tenement and about 1km to the south.

In the centre-south of the study area are several small outcrops of weathered fine grained granitic rock. One group of outcrops has a short dyke-like appearance with a vague NE trend which coincides with a subdued air photo linear.

RAVENSWOOD GRANODIORITE COMPLEX

Black Jack Granodiorite

The Black Jack Granodiorite ***(Hutton and Crouch, 1993)*** occurs in the NE of the study area and intrudes the Puddler Creek Formation. The intrusive is characterised by, and distinguished from the Policeman Creek Granodiorite, by its large (3 to 5mm) rounded quartz "eyes" in a quartz-feldspar-hornblende-(biotite) assemblage. Significantly, the prominent quartz crystals are not described by ***Hutton and Crouch (1993)*** in their formal definition of the intrusive. At several localities adjacent to the contact with Puddler Creek Formation the granodiorite has a distinctive white outcrop colour as a result of secondary silicification. A Late Silurian to Early Devonian age is assigned by ***Hutton and Crouch (1993)*** and a Devonian age by ***Laing (1992).***

There is evidence for the assimilation of thin, fine andesite/dolerite dykes.

A relatively passive emplacement process for the Black Jack Granodiorite is suggested by the lack of mechanical, brittle deformation of the Puddler Creek Formation.

Policeman Creek Granodiorite

A 5km long and 2km wide body of medium grained biotite-hornblende granodiorite forms the western boundary of the study area. It intrudes the sedimentary units of the Puddler Creek

Formation in the north possibly steepening their already easterly dip, and the Trooper Creek Formation (and possibly the Mt Windsor Volcanics) in the south. A Late Silurian to Early Devonian age is assigned by ***Hutton and Crouch (1993)*** and a Devonian age by ***Laing (1992)***.

Within the study area the granodiorite does not appear to be intruded by any form of dyke. However, in the south, are exposures of very narrow, fine doleritic (?basaltic andesite) bodies that have been assimilated into the granodiorite.

Microgranodiorite

A small (700m by 300m) body of microgranodiorite with intergrown feldspar and quartz abuts the southern limit of the Policeman Creek granodiorite. Where exposed, the contact with the larger intrusive is sharp. Quartz phenocryst content in the microgranodiorite is generally low although there are significant concentrations towards the centre of the body.

Around the edges of the microgranodiorite are outcrops of partially assimilated fine doleritic (?andesitic) material similar to those found in the larger Black Jack and Policeman Creek Granodiorite bodies. ***Hutton and Crouch (1993)*** do not mention the microgranodiorite but it is possible that the body is of similar age to the larger intrusives.

TRIASSIC? QUARTZ SANDSTONE UNIT

Along the southern limit of the Puddler Creek Formation is a discontinuous line of individual topographical highs of which Mt Farrenden is the most prominent (see Fig 3). These hills are topped by blocky, jointed, medium to thickly bedded quartz sandstones which are coarser in grain size than the sedimentary units typical of the Puddler Creek Formation. The sandstones are commonly impregnated with silica and cut by thin (<1cm) quartz veins and stockworks. Fe-oxides are also common possibly as a result of the weathering of pyrite which is inferred by the presence of abundant cubic voids within the veins and, to a lesser extent, within the sandstone groundmass.

No dyke rocks were recorded and no significant cleavage noted. Bedding orientation is inferred to be subhorizontal to very shallowly south dipping. This contrasts with the moderate to steep dips measured within the finer Puddler Creek Formation units. It is inferred that these coarser sandstones post-date the Seventy Mile Range Group, the doleritic dykes and possibly the granodiorite intrusions. A Triassic age may be applicable in view of the extensive outcrops of sandstones of the Galilee Basin to the W and SW of the study area. The observation that these sandstones overlie only the fine sedimentary units of the Puddler Creek Formation has not been adequately explained.

CAMPASPE FORMATION

Isolated outcrops of semi-consolidated, poorly bedded, fluviatile sandstones (and conglomerates) occur in the central southern part of the study area where outcrop of Seventy Mile Range Group units is lacking (see Fig 3). These outcrops are assigned to the Campaspe Formation of Late Tertiary age ***(Nind, 1988; Henderson, 1986)***. The thickness of these sediments here is unknown.

STRUCTURE

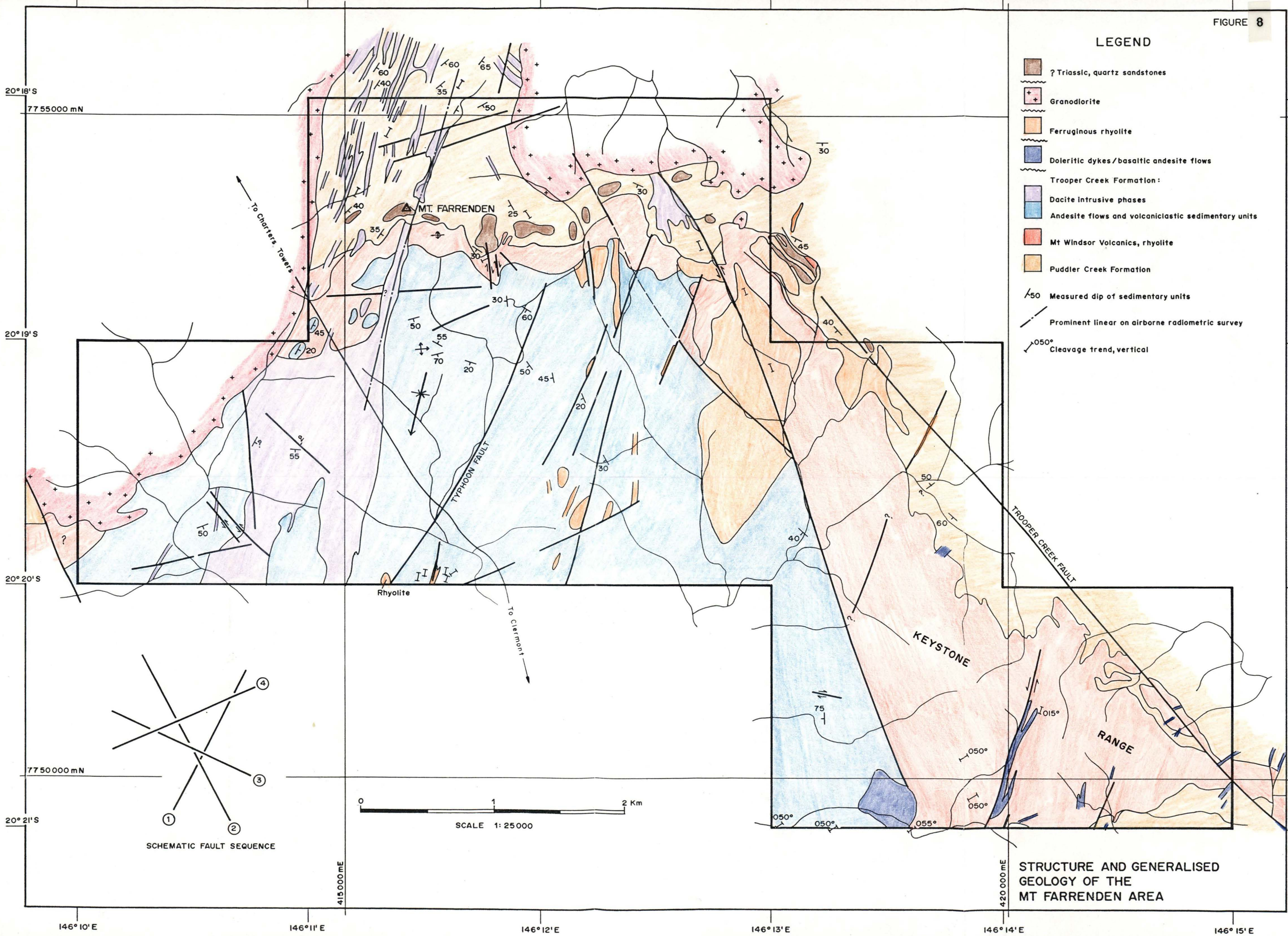
The study area is located within a southward plunging synform that represents a significant diversion from the general E-W trend of the Seventy Mile Range Group. Dip measurements on sedimentary units within the Puddler Creek and Trooper Creek

Formations support the concept of a broad synclinal structure (Fig 8). To the east and west of the study area the Puddler Creek and Trooper Creek Formations display dips and strikes *(Berry et al, 1992)* consistent with a broad synform. The NNE-trending axis of the synform occurs between the Policeman Creek and Black Jack Granodiorite bodies.

As discussed above the contacts between the Puddler Creek, Mt Windsor Volcanics and the Trooper Creek Formations are inferred to be relatively conformable, with the possible exception of at least a part of the Puddler Creek Formation-Mt Windsor Volcanics contact between Mt Farrenden and the Policeman Creek Granodiorite (see Fig 8). Here, an angular unconformity could be inferred from the E to ESE trend of the Mt Windsor Volcanics that immediately overlie the NNE strike and steep easterly dips of the Puddler Creek Formation. This could infer that folding of the Puddler Creek Formation had started before deposition of the Mt Windsor Volcanics. Definitive dips and strikes were not recorded within the rhyolites here.

To the west and north of Mt Farrenden and between the Black Jack Granodiorite and Policeman Creek Granodiorite bodies (see Figs 3 and 8) the sedimentary units of the Puddler Creek Formation strike approximately 010°M to 025°M and dip to the east at between 30° and 65° with most of the dips measuring less than 50°. Cleavage is well developed within these units and is significantly more intense in the siltstones than in the sandstones. Cleavage has a subvertical dip with a strike generally subparallel to bedding and to the dacitic dyke swarm. This feature could represent axial plane cleavage.

FIGURE 8



STRUCTURE AND GENERALISED GEOLOGY OF THE MT FARRENDEN AREA

To the east of Mt Farrenden, along the southern edge of the Black Jack Granodiorite, the Puddler Creek Formation sedimentary units strike approximately 295°M and dip to the south at approximately 30°.

Within the Farrenden area the dominant cleavage direction is towards the NNE (010°M to 025°M) with a subvertical dip. This cleavage is developed particularly well in the NW within the sedimentary units of the Puddler Creek Formation which have a similar strike but with shallower (35° to 65°) stratigraphic dips to the East. Such vergence is consistent with a synform to the east. A similar strike to the outcrop orientation in the SW, as well as the trend of dacitic dykes in the north, may be cleavage-controlled.

Cleavage striking 345°M was recorded in the area to the east of Mt Farrenden. This is the same orientation as small outcrop linears and trends within the Ferruginous Rhyolites Unit.

In the Keystone Range area a prominent subvertical cleavage striking 050°M is developed locally. Here the cleavage is well exposed in weathered rhyolitic breccias within the massive rhyolite sequence, and also within flow andesites and some sediments of the Trooper Creek Formation to the immediate SW of the range. This cleavage regime appears to envelope the Reward and Highway sulphide deposits (see Fig 1) farther to the SW and postdates the NNE cleavage regime.

Approximately 700m to the west of the bitumen road on the southern edge of the study area is a zone of strong cleavage with trends varying from 010°M to 050°M. The more northerly directions (010°M to 030°M) predominate. Faults with orientations within the former range are present also in this area.

Most cleavages are cut by a joint/fracture cleavage striking approximately 290°M which may be related to the NW trending faults. At one location in the SW this trend is occupied by a 0.5m to 1m wide malachite-bearing quartz vein.

At least 4 stages of faulting are apparent within the study area, most of which are visible as linears on aerial photographs (see Fig 8). A NNE trending fault set (030°M to 040°M), which includes the conjectural Typhoon Fault, occurs mainly within the centre of the area and could be one of the earliest deformation phases present. A sinistral (?strike slip) movement is proposed for the Typhoon Fault and a NNE trending fault set through the centre of the Keystone Range. These faults may represent the remnants of the Yarraman Structural Corridor of ***Laing (1992)***. Subordinate NNE faults offset the sedimentary units of the Trooper Creek Formation in the centre of the study area with predominantly dextral movements.

Prominent NNW faults (320°M to 345°M linears) approximate to partial outcrop boundaries to the east and west of the area. In the east, a single major linear runs along the eastern limit of the rhyolite massif of the Keystone Range. Some indication of dextral strike-slip movement was inferred in the extreme SE of the study area on the basis of the outcrop pattern of the rhyolites. However, the outcrop patterns of the doleritic (basaltic andesite) dykes infer a sinistral movement. This agrees with the sinistral movement recorded by ***Berry et al (1992)*** farther to the SE of the study area. They termed this linear the Trooper Creek Fault. ***Laing (1992)*** assigned a Devonian to Permian age to these linears. The varying outcrop patterns could infer multiple movements along the Trooper Creek Fault. Outcrop patterns west of the western limit of the study area support a sinistral movement along NNE linears.

On the western edge of the Keystone Range a NNE trending fault has been inferred between the massive rhyolites of the Mt Windsor Volcanics and the poorly exposed sedimentary, andesitic and ?dacitic units of the Trooper Creek Formation. Creek linears and mapped sinistral offsets occur within and to the north of the major ferruginous rhyolite outcrops along the same trend as the inferred fault. This linear corresponds to the Handcuff Fault of ***Berry et al (1992)***.

Smaller NW trending faults with an orientation around 290°M to 300°M transect the SW part of the study area showing small, generally sinistral offsets of the quartz-phyric dacite dykes. Such fault orientations were not recorded or interpreted elsewhere.

An ENE fault set (050°M to 070°M) is poorly developed and is difficult to detect on the available 1:25,000 scale airphotos. However, some indication of ENE faulting is provided by a prominent creek linear within, and an apparent offset of, the western margin of the Black Jack Granodiorite. This linear appears to correspond reasonably well with at least one set of inferred, but inconclusive, offsets in the dacitic dyke swarm to the west of the intrusive. In addition, several outcrops of iron oxide-rich rhyolitic rock occur along these linears. A second parallel linear, without an airphoto signature, occurs 150m to the North. This orientation appears to be the result of the latest period of faulting, an observation which is supported by ***Laing (1992)*** who proposes a Carboniferous-Permian age for these linears. Small scale faults with a similar orientation are proposed for the area of andesite and volcaniclastic sediments 1km to the south of Mt Farrenden Prospect.

A N-S fault set is also present within the study area although these are difficult to interpret from aerial photographs, satellite imagery or airborne magnetics data. Geological mapping has inferred small-scale dextral faulting near the massive barite outcrop and the western limit of the Ferruginous Rhyolite Unit.

A rare E-W linear trend occurs to the immediate SSW of Mt Farrenden in the form of a very narrow (1m-wide) but continuous andesite dyke. To the east of the dyke are terminations of dacitic dykes and the apparent dextral offset of a prominent dacite dyke which could infer the eastward extension of the fracture hosting the andesite dyke. There is no apparent offset of the major (50m to 100m-wide) dacite dyke that trends southward from Mt Farrenden.

Small scale folding with E-W axes may occur to the immediate east of Mt Farrenden and farther south within a prominent andesite outcrop. Southerly dips predominate within the sedimentary units of the Trooper Creek Formation. However, it is possible that at least some of the outcrop patterns, which could infer an interbedded relationship between the sedimentary and andesitic units, may be a result of folding, again about E-W axes.

LITHOGEOCHEMISTRY

Sampling Strategy

The sampling programme was designed originally to determine whether simple correlations based on minor and trace elements could be made between the major dacite units in the west and the dacitic dyke-like bodies to the west and north of Mt Farrenden. Sampling was gradually extended to include the mafic rocks given the apparent historical restriction of 'doleritic' dyke rocks to the east and andesitic dyke and flow rocks to the centre and west of the study area ***(Beams, 1986, 1990).*** A comprehensive lithogeochemical study of the Farrenden area was not planned, although the sample suite was enlarged further to include some rhyolitic phases, and a single sample of the Black Jack Granodiorite. No samples were taken from the Policeman Creek Granodiorite.

As a consequence of this exercise treatment of the analytical data was extended to the production of chondrite-normalised Rare Earth Element (REE) plots ***(Taylor and Gorton, 1977)*** and MORB-normalised multi-element plots ***(Sun and McDonough, 1989).*** Alteration by hydrothermal and metamorphic processes can obscure the mineralogical and chemical identities of rocks in volcanic sequences particularly through the mobilisation of the alkali elements, as well as Mg, and, to some extent, SiO_2. The effects of alteration can be offset substantially by comparing the more immobile elements. Such comparisons facilitate the identification of the rock (eg., basalt, andesite, rhyolite), its affinities (eg., tholeiitic, calc-alkaline) and the establishment of volcanic-tectonic settings ***(Winchester and Floyd, 1977; Wilson, 1989; MacLean and Barrett, 1993).***

Analytical Methods

Each of 25 1kg rock samples was cut in half by diamond saw. One half was retained in tact for future reference, and the other submitted for analysis at Australian Laboratory Services, Brisbane. The latter portion was crushed and pulverised completely to -75 micron size before the analytical subsample was selected.

Oxide analyses were completed by a combination of classical and instrumental methods with a detection limit of 0.1%. Major and trace elements were analysed by ICPAES, Ba, Nb, Rb and Zr by XRF and the rare earth elements by ICPMS (Appendix 1).

The oxide data only were normalised to 100% anhydrous to remove variations due to loss on ignition (LOI). The normalised results indicate a silica range between 50% and 83% (Appendix 1). However it is considered that those samples in excess of 78% SiO_2 have been subjected to secondary silicification. High silica results affect 7 of the 25 samples in the dacite and rhyolite categories. Significantly, the Nb/Y-Zr/TiO_2 (after ***Winchester and Floyd, 1977***) plots demonstrate the use of immobile elements in restricting the silica-enriched samples to their respective rock-type categories **(Figs 9 to 12)**. In general terms the Mt Farrenden data set form a reasonable subset of the regional data set produced by ***Berry et al (1992)***.

Comparison of Mafic Units

SiO_2-K_2O data for the Mt Farrenden area **(Figs 11 and 12)** indicate that the mafic samples plot within the andesite and basaltic andesite fields and have low-K values. Differences between the Trooper Creek Formation andesitic flow rocks, and the 'doleritic' rocks and andesitic dykes are more apparent on the SiO_2-Th, SiO_2-Zr/Ti and SiO_2-P_2O_5 plots **(Figs 13 to 16)**. The latter plot may indicate some form of fractionation of a source melt different from the flow andesites. This is supported by the TiO_2 plots **(Fig 17 to 19)** which also emphasises their high TiO_2 content (>1.4%). These differences are highlighted further in

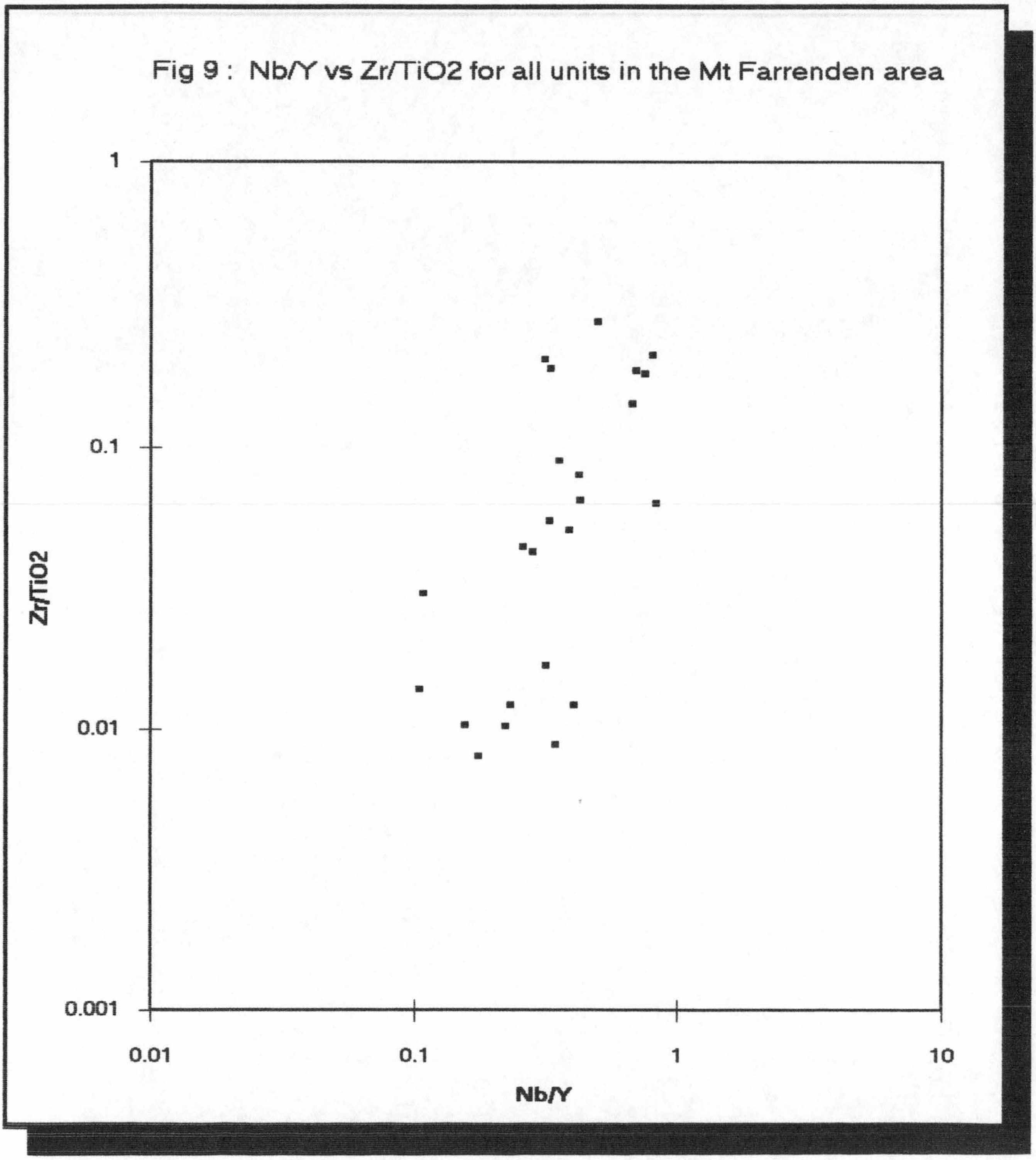


Fig 9 : Nb/Y vs Zr/TiO2 for all units in the Mt Farrenden area
1
0.1
0.01
0.001
Zr/TiO2
0.01
0.1
1
10
Nb/Y

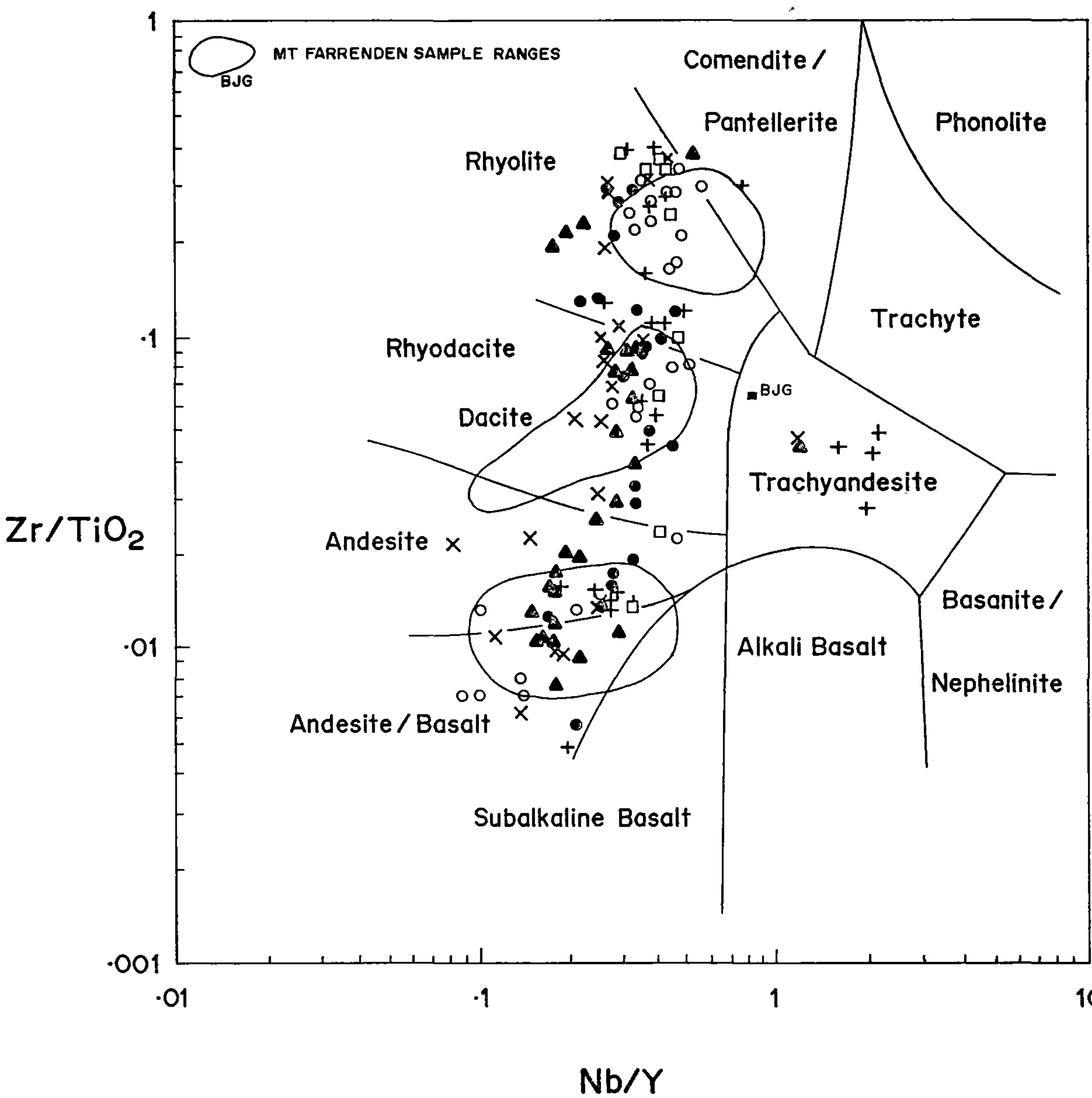


Fig 10 : Nb/Y vs Zr/TiO_2 plot comparing Mt Farrenden data with regional data by Berry et al (1992)

After Berry et al (1992)

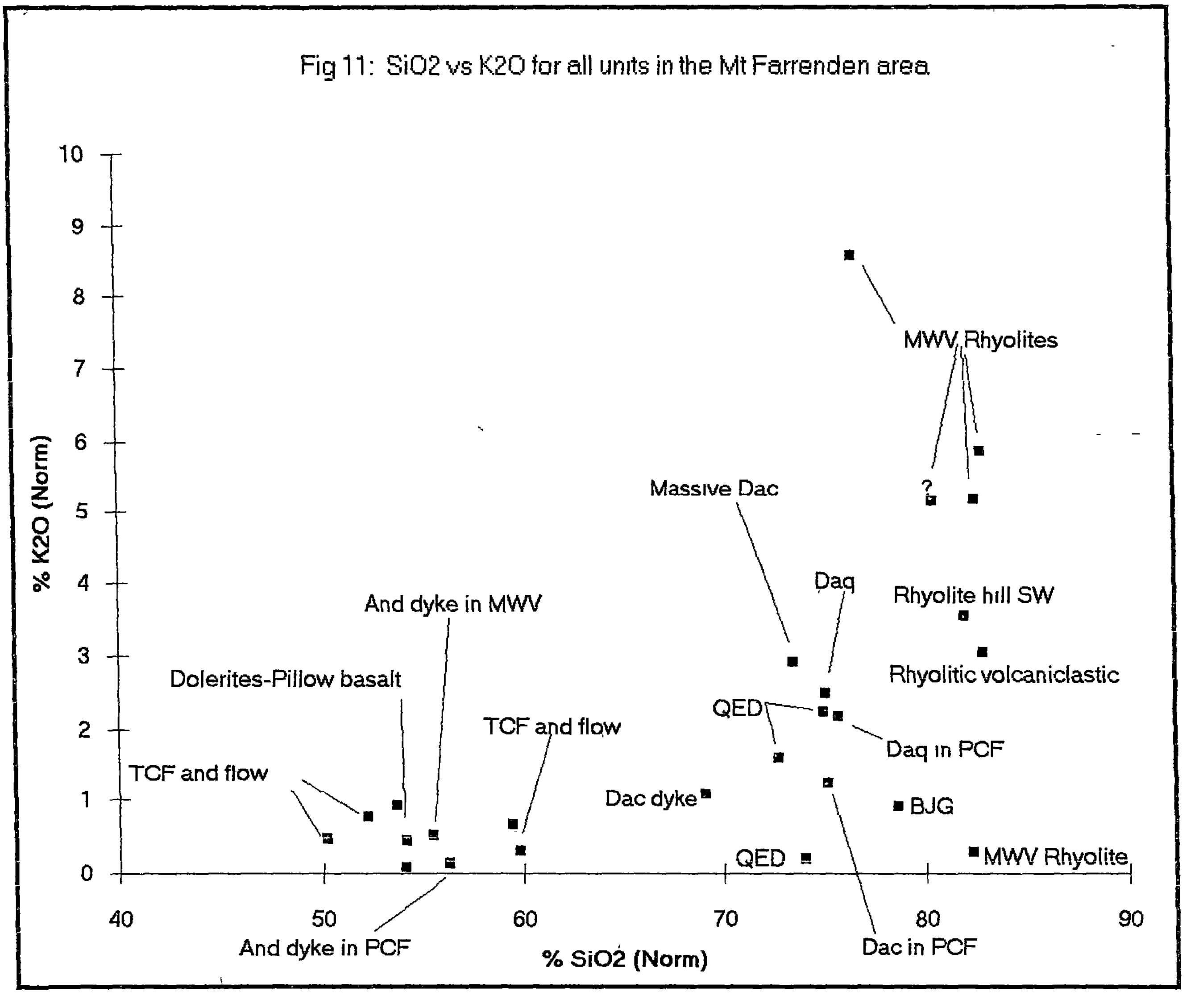


Fig 11: SiO2 vs K2O for all units in the Mt Farrenden area
% K2O (Norm)
% SiO2 (Norm)
10
9
8
7
6
5
4
3
2
1
0
40
50
60
70
80
90
MWV Rhyolites
?
Massive Dac
Daq
Rhyolite hill SW
Rhyolitic volcaniclastic
And dyke in MWV
Dolerites-Pillow basalt
QED
TCF and flow
Daq in PCF
TCF and flow
Dac dyke
BJG
QED
MWV Rhyolite
And dyke in PCF
Dac in PCF

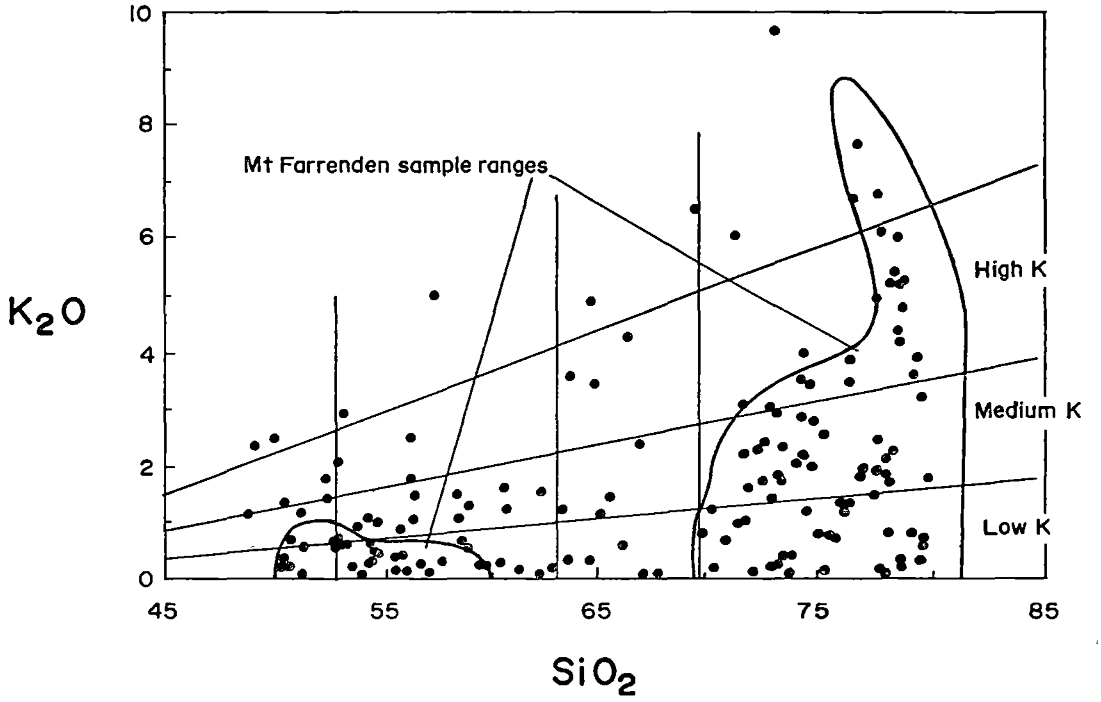
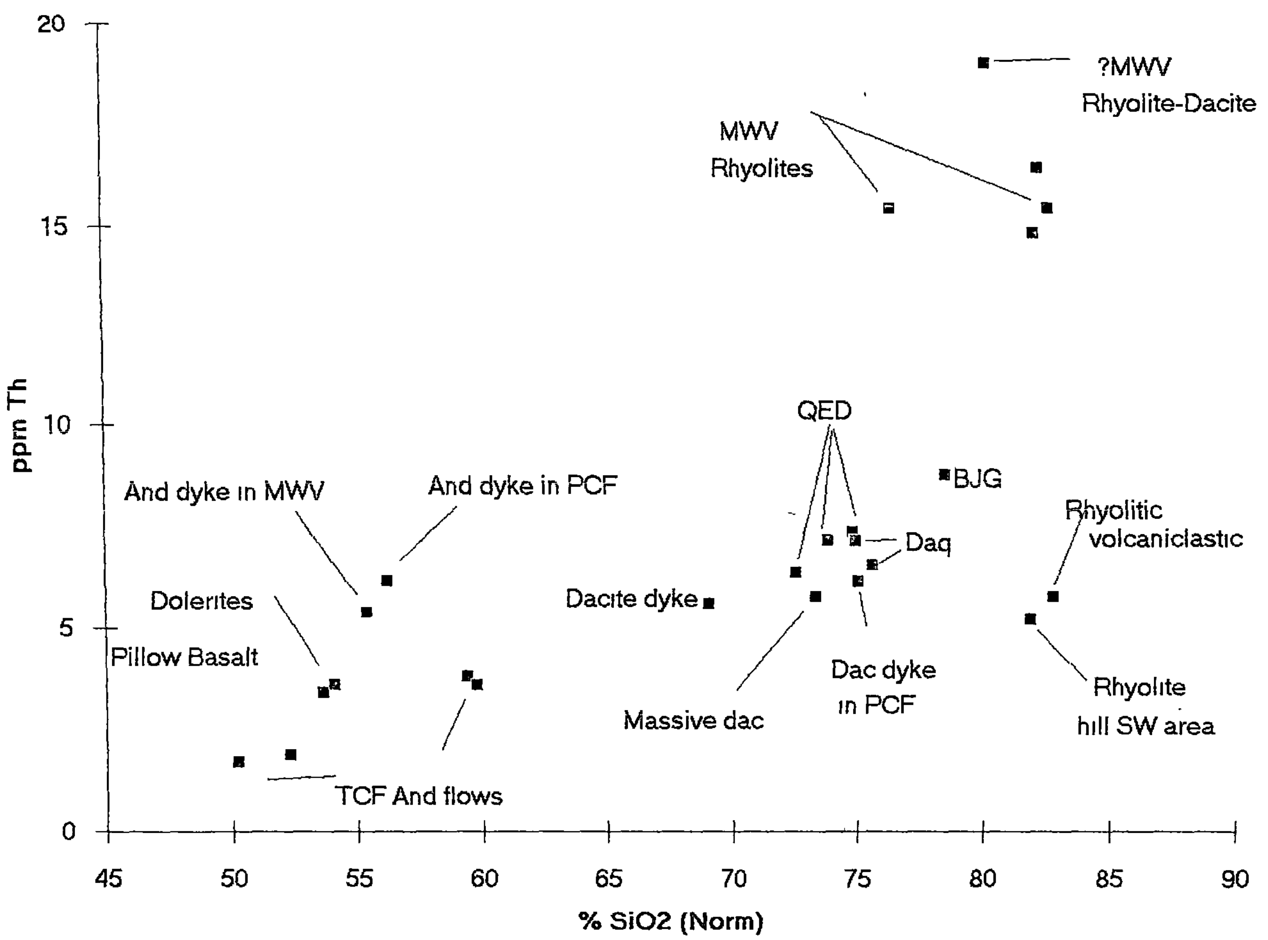


Fig 12: SiO_2 vs K_2O plot comparing Mt Farrenden data with regional data by Berry et al (1992)

After Berry et al (1992)

Fig 13   SiO2 vs Th for all units in the Mt Farrenden area



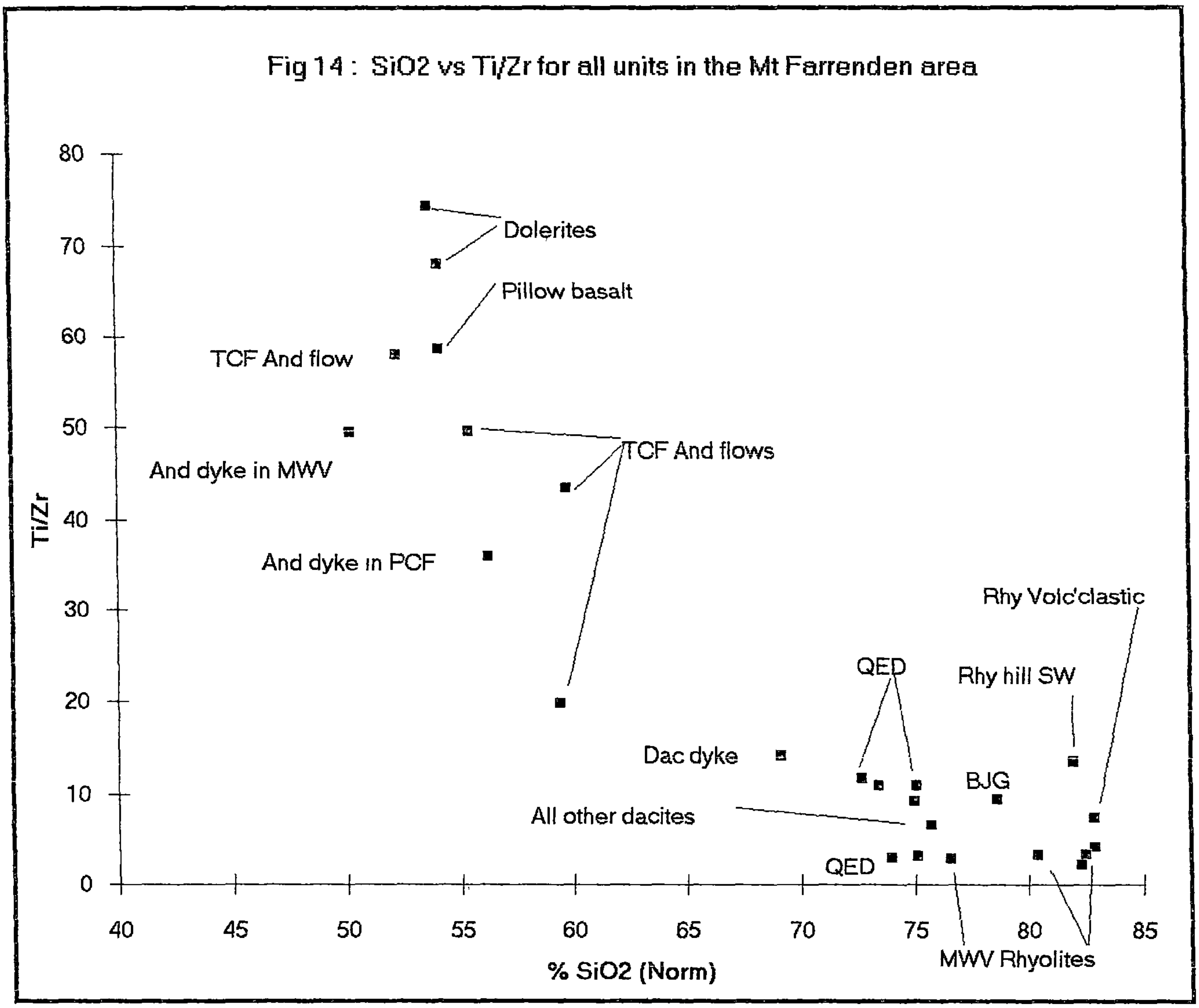


Fig 14 : SiO2 vs Ti/Zr for all units in the Mt Farrenden area
Dolerites
Pillow basalt
TCF And flow
And dyke in MWV
TCF And flows
And dyke in PCF
Rhy Volc'clastic
QED
Rhy hill SW
Dac dyke
BJG
All other dacites
QED
MWV Rhyolites
Ti/Zr
% SiO2 (Norm)
0
10
20
30
40
50
60
70
80
40
45
50
55
60
65
70
75
80
85

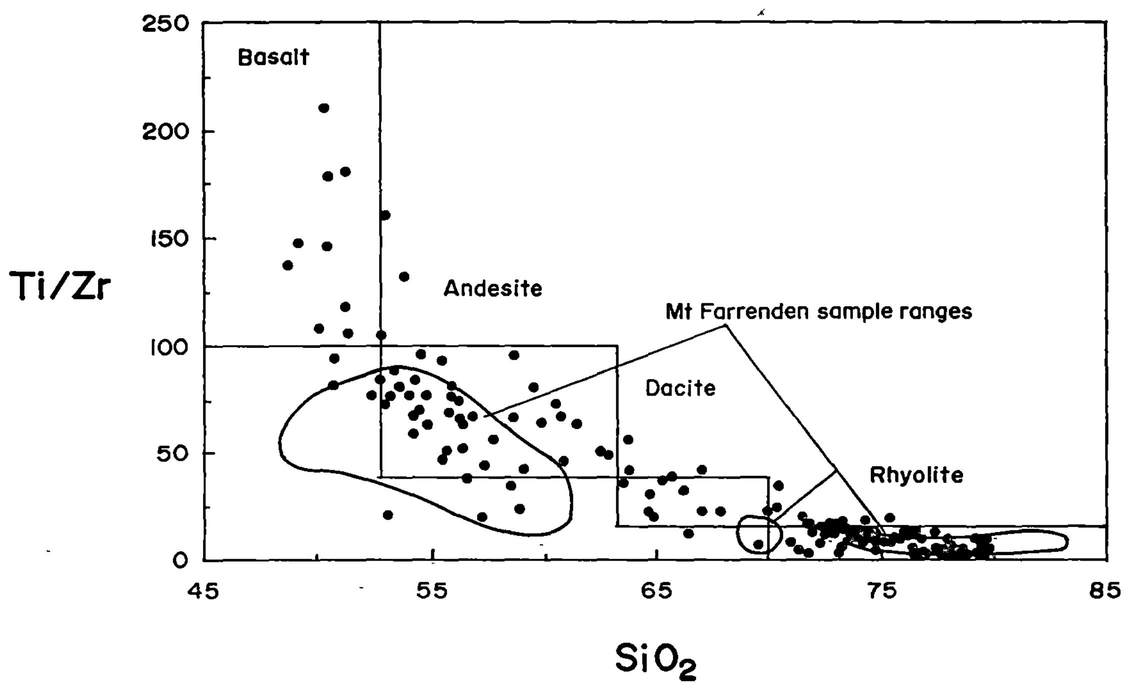


Fig 15: SiO_2 vs Ti/Zr plot comparing Mt Farrenden data with regional data by Berry et al (1992)

After Berry et al (1992)

Fig 16 : SiO_2 vs P_2O_5 for all units in the Mt Farrenden area

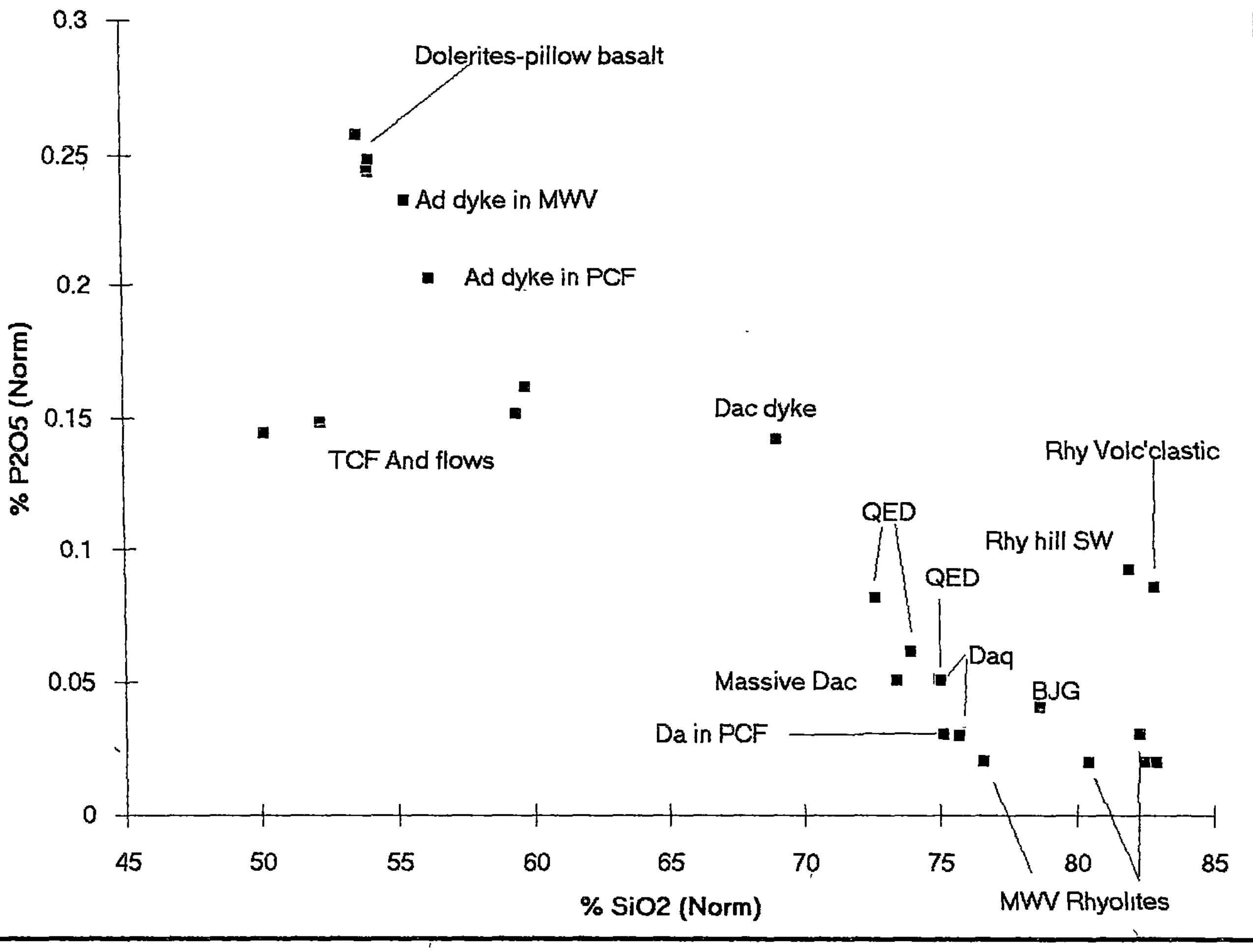


Fig 17 . MgO vs TiO2 for all units in the Mt Farrenden area

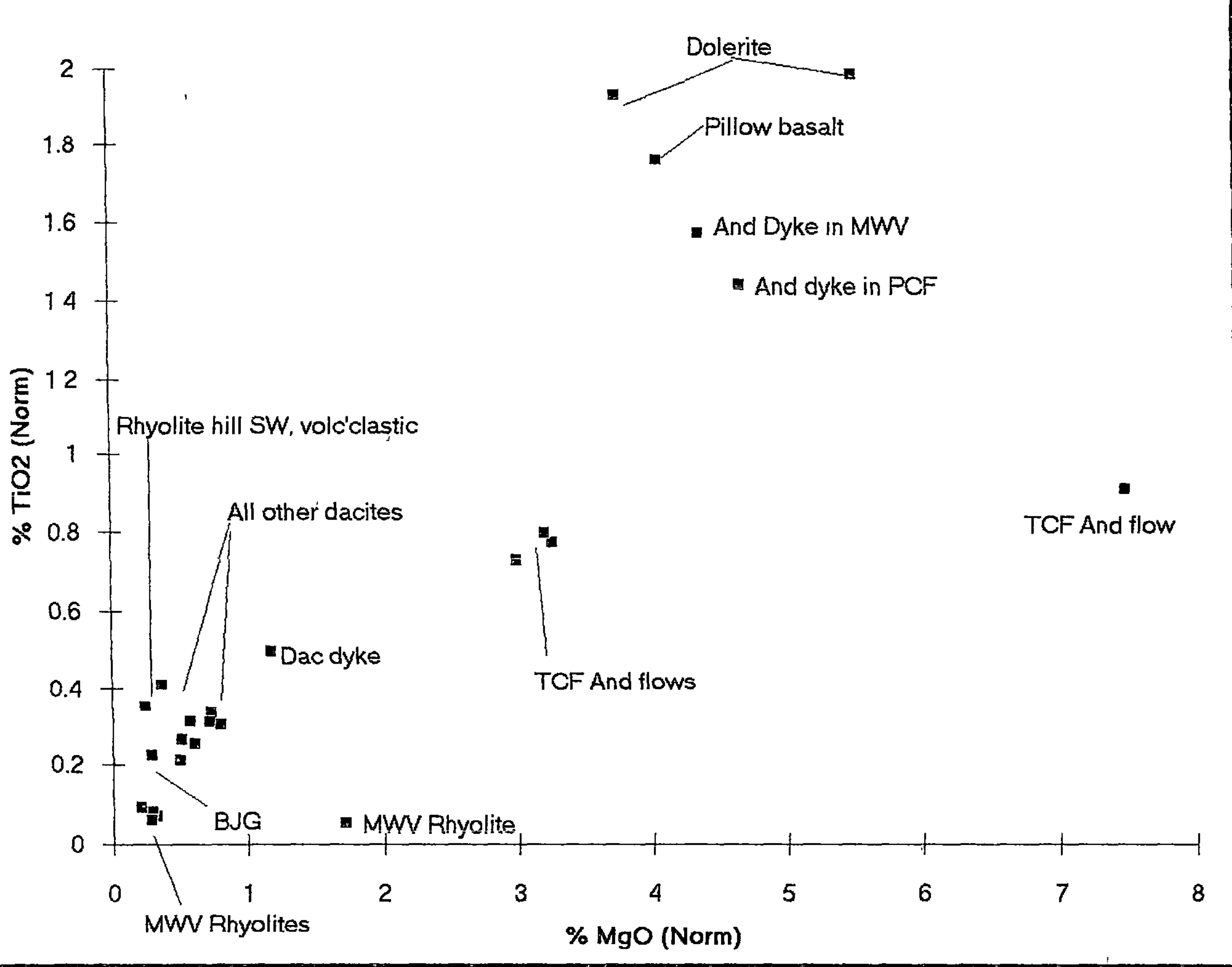
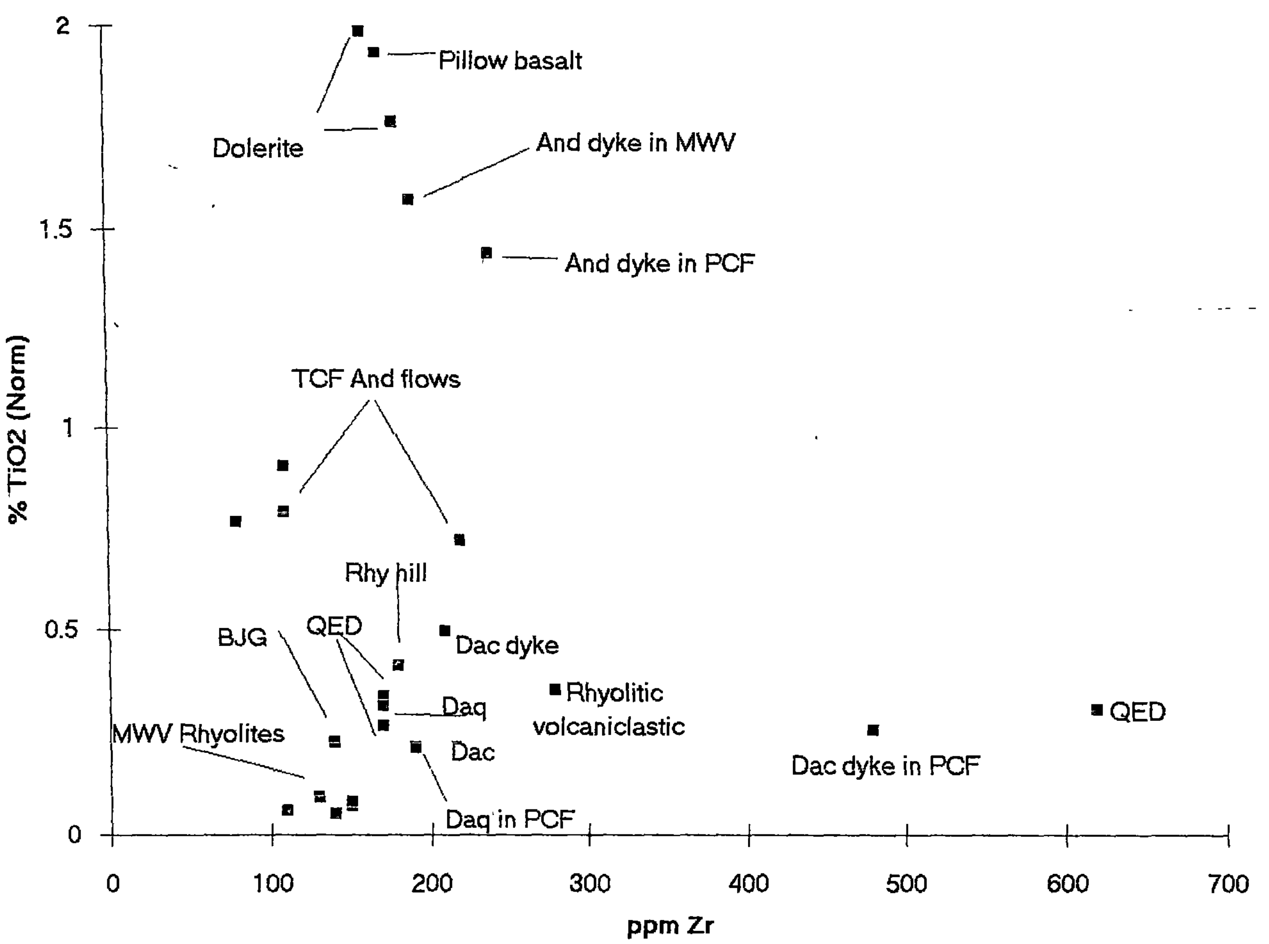


Fig 18 : Zr vs TiO2 for all units in the Mt Farrenden area



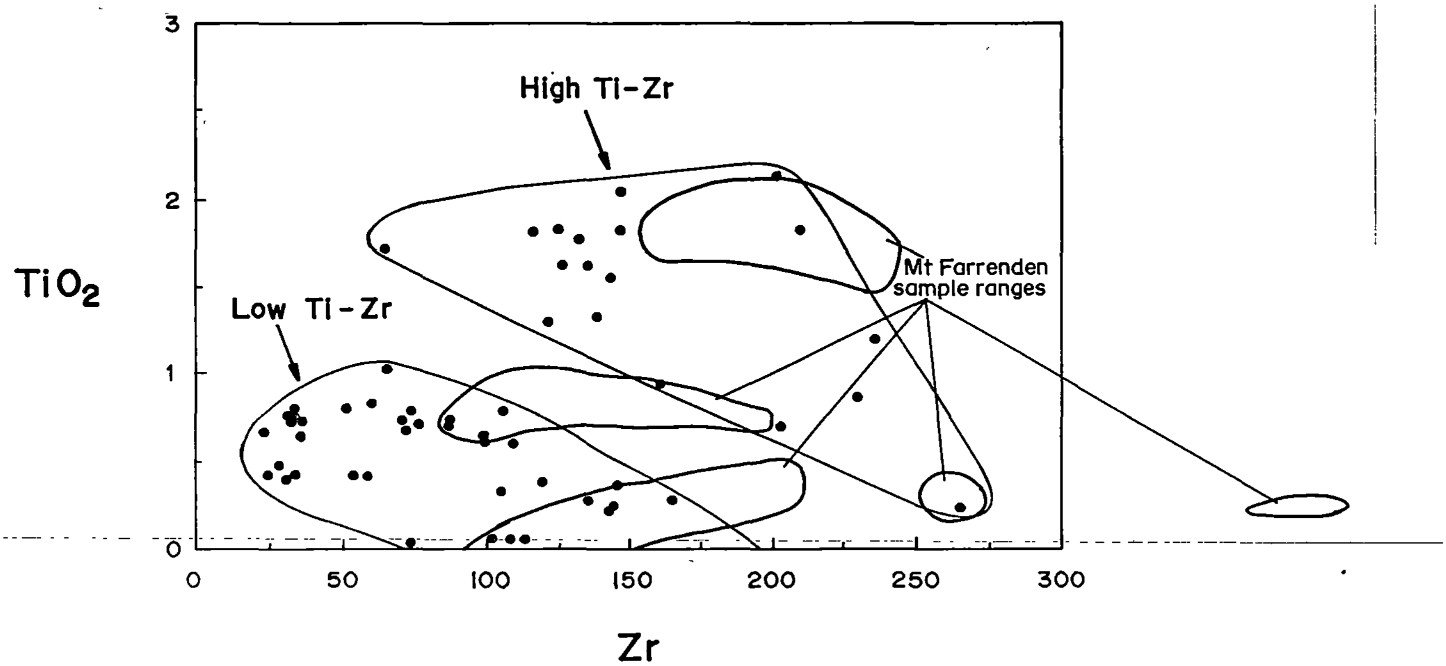


Fig 19 Zr vs TiO_2 plot comparing Mt Farrenden data with regional data by Berry et al (1992)

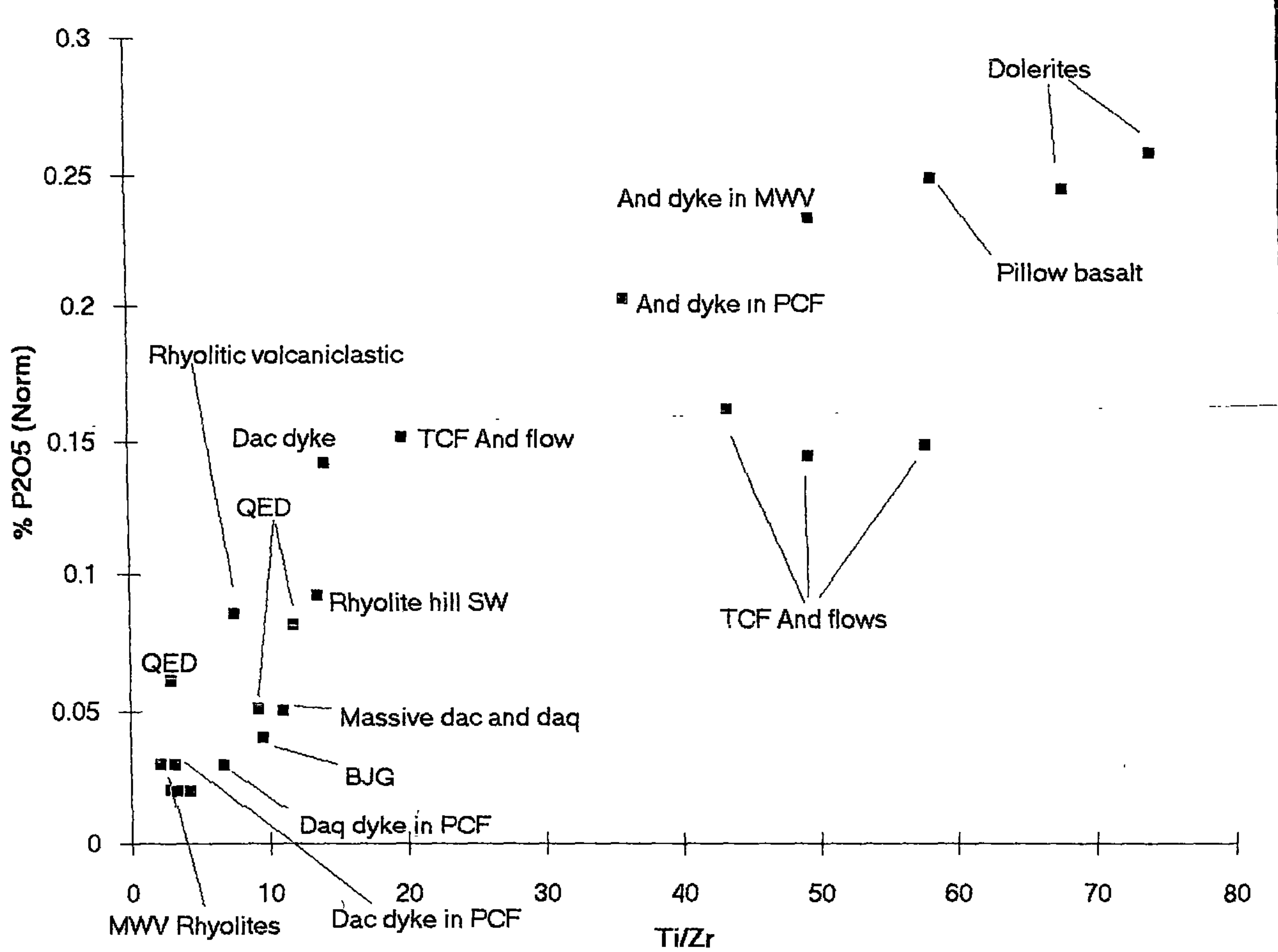
After Berry et al (1992)

the P_2O_5 plots (>= 0.2% P_2O_5) **(Figs 20 and 21)** but are quite distinct from the "Puddler Creek Andesite" field of ***Berry et al (1992)*** which is based on high P_2O_5 (>0.4%) and Nb (>40ppm) **(Figs 22 and 23)**.

Two of the 'doleritic' samples are from dykes in the north and extreme east of the Keystone Range (see Fig 3). The third is from a large outcrop comprised of highly vesicular locally pillowed dolerite (?basalt) as well as massive fine 'andesite' (?basaltic andesite) similar in appearance to, but slightly finer grained than, the 'dolerite' dykes (see Fig 3). These 3 samples tend to form a group on all of the scatter plots. Two andesitic dyke samples from within the Puddler Creek Formation and the Mt Windsor Volcanics in the Mt Farrenden area also plot near to the 'doleritic' samples. As discussed briefly above the andesite dykes may be related to the 'doleritic' rocks through fractionation of the same source, as shown by the linear presentation of these data (see Figs 16 and 17).

These mafic rocks do not show a clear subduction-related signature on the MORB-normalised multi-element plots **(Figs 24 to 25)**. They show high Ti, Nb and P contents similar to those that could be expected from extensional intra-plate settings ***(Wilson, 1989; Tas Uni, 1992)***. To the NE of the Keystone Range the abundance of doleritic dykes ('dyke swarm', **Beams, 1990**) is considered to be consistent with the intra-plate (Continental Flood Basalt setting, **Stolz, pers. comm., 1993**) interpretation. However, their high Zr/Nb ratio (=20) is unusual for this setting but could be explained by reaction with continental crust ***(Wilson, 1989)***. In the context of the scatterplots, and REE data discussed below, the Trooper Creek Formation andesite flow rocks

Fig 20. Ti/Zr vs P2O5 for all units in the Mt Farrenden area



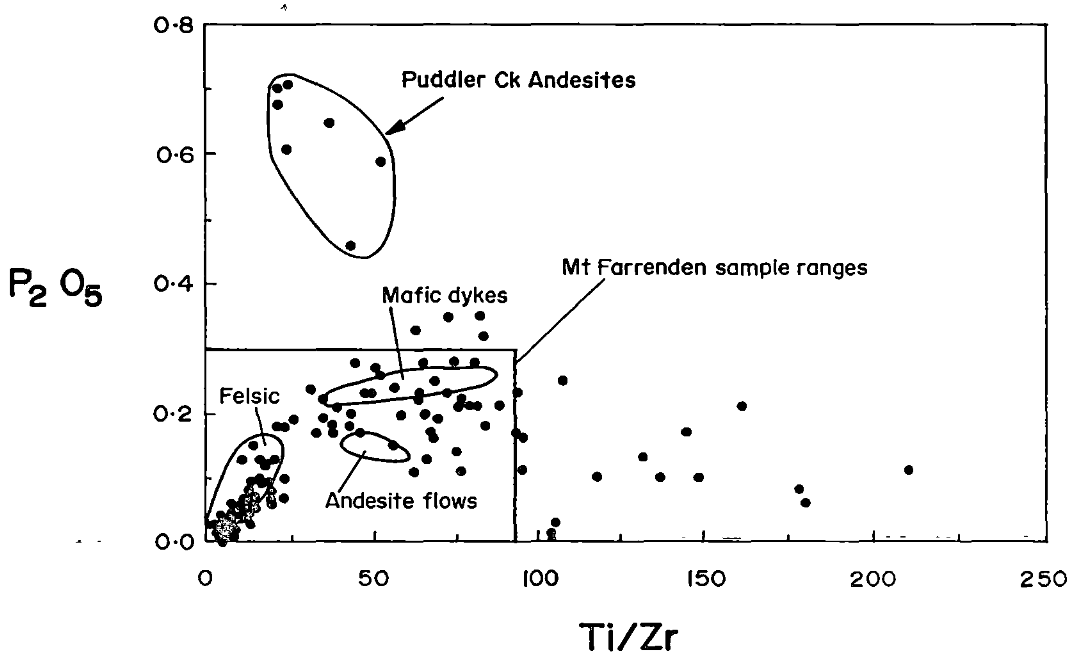


Fig 21 : Ti/Zr vs P_2O_5 plot comparing Mt Farrenden data with regional data by Berry et al (1992)

After Berry et al (1992)

Fig 22 : Zr vs Nb for all units in the Mt Farrenden area

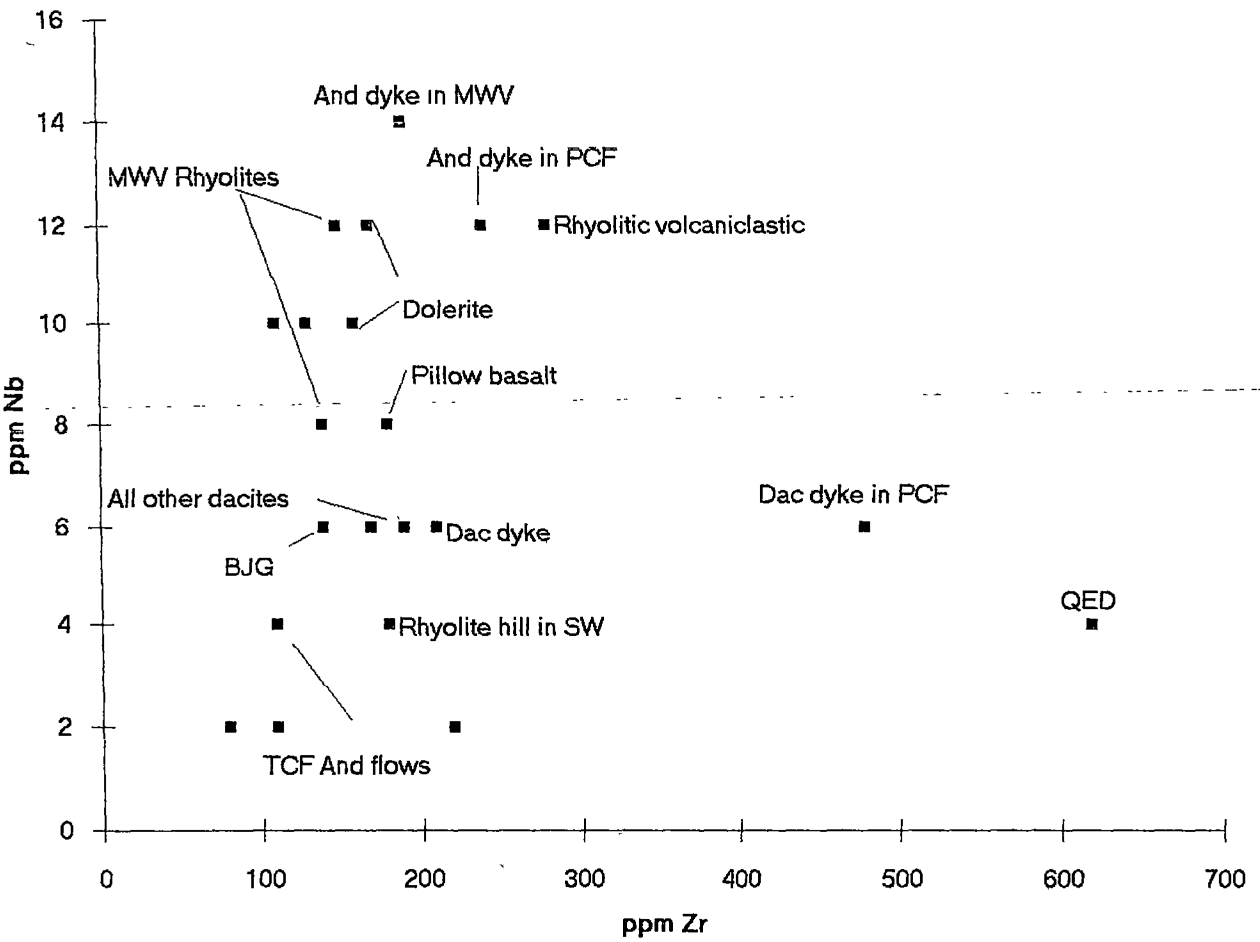


Fig 24: MORB-normalised multi-element plots for all mafic units in the Mt Farrenden area

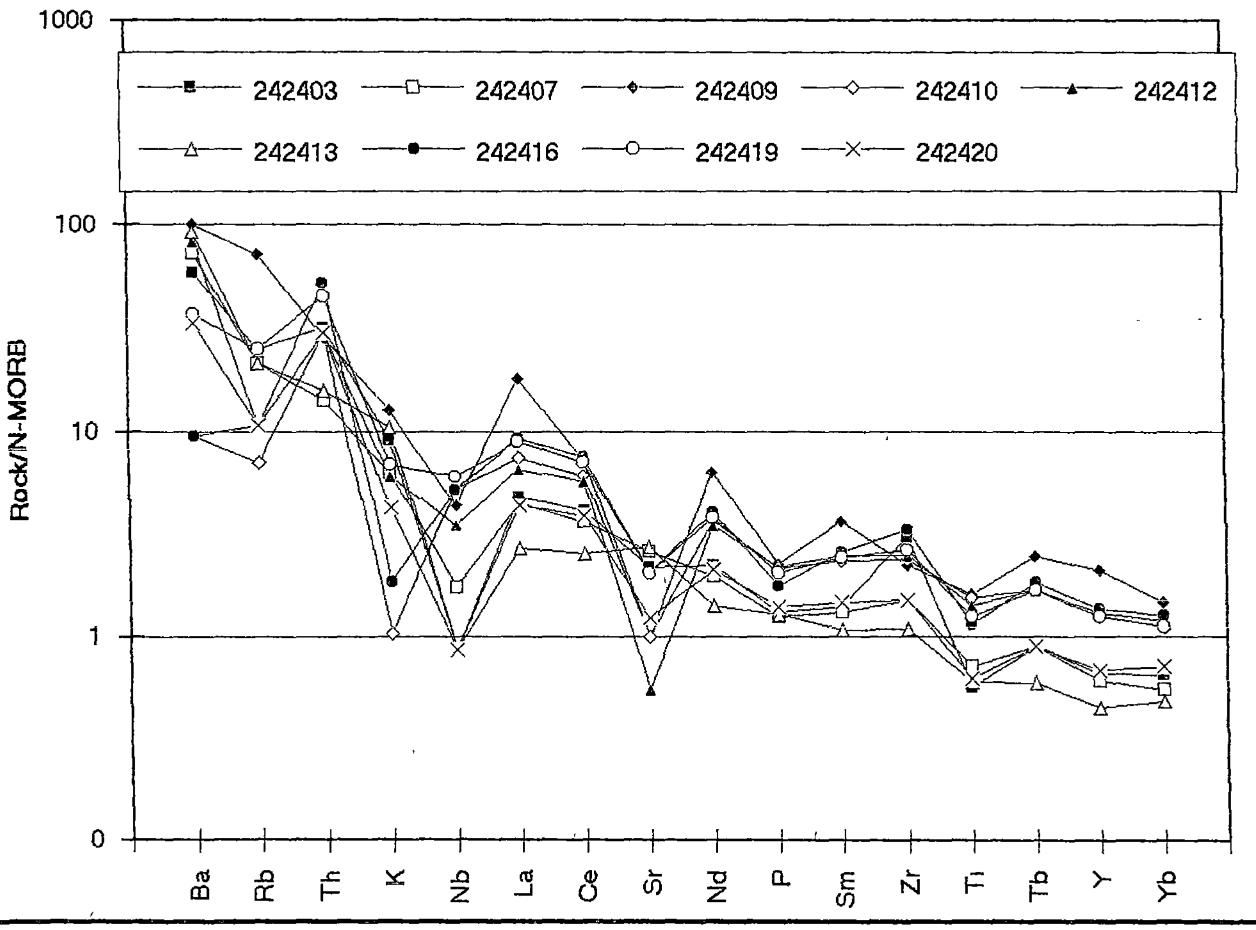
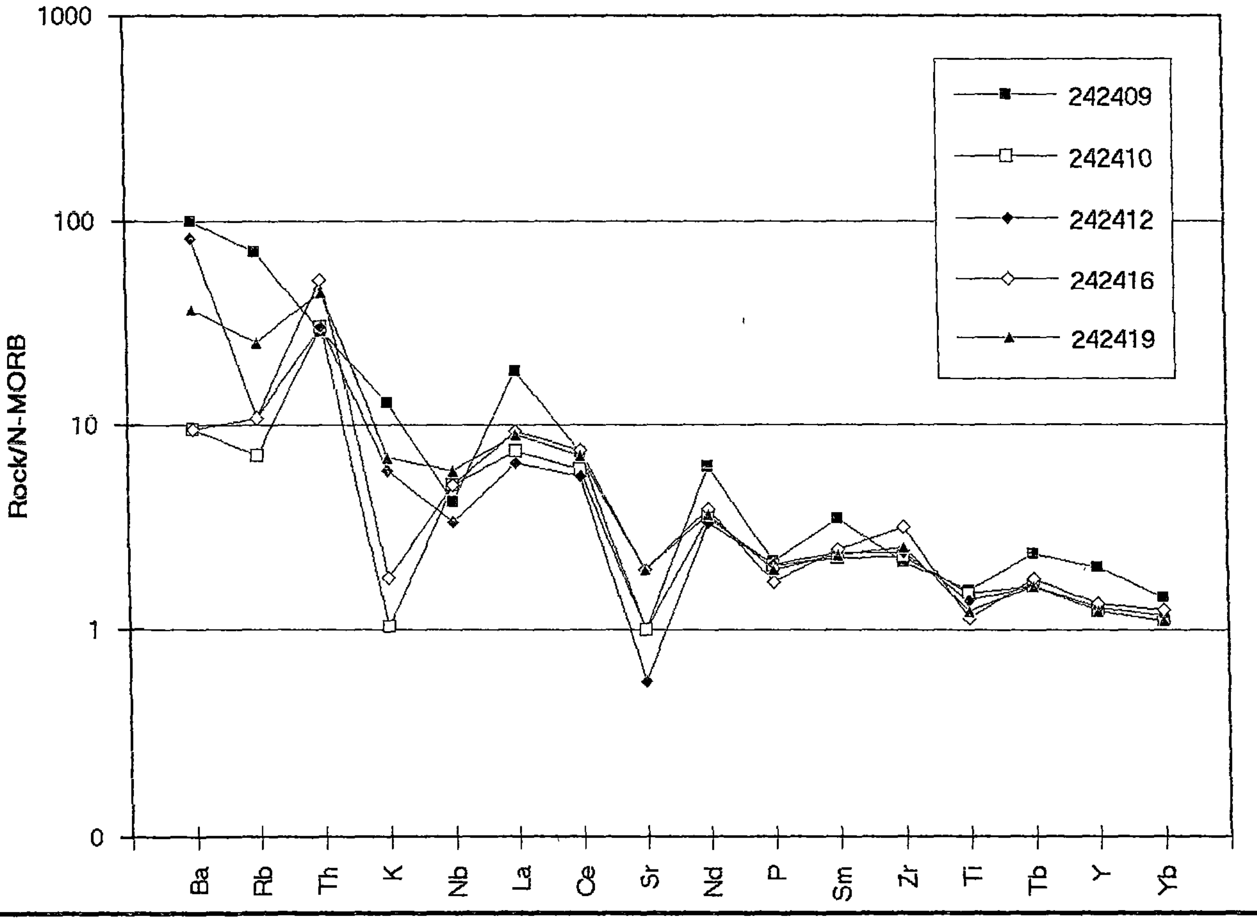


Fig 25: MORB-normalised multi-element plots for dolerite and andesite dykes in the Mt Farrenden area



have a reasonably clear subduction-related signature **(Fig 26)** highlighted by negative Nb and, to a lesser extent, negative Ti responses.

REE plots for all mafic rock samples show slightly enriched and consistent responses with values in the range 10x to 100x chondrite. There is also a noticeable separation of the flow andesites from the doleritic and andesite dyke rocks. The former suite displays patterns with 10x to 50x chondritic abundances and the latter shows higher overall REE levels (25x to 100x chondrite). The dyke suite also shows a slight relative enrichment of LREE over HREE, and a slight negative Eu signature not seen in the flow andesites of the Trooper Creek Formation. In general, these plots **(Figs 27 to 29)** represent a moderately LREE-enriched pattern which could be expected in convergent margin settings ***(Wilson, 1989)***. ***Wilson (1989)*** also provides examples of slightly LREE-enriched traces for a variety of intra-plate flood basalt occurrences.

Comparison of Dacite Units

Included in this suite are the massive dacites from the SW of the study area as well as the quartz-phyric ("quartz-eye") dacite dykes ('QED' on the scatterplots and spidergrams), and the fine-quartz-bearing ('daq') and fine dacite dykes hosted by the Puddler Creek Formation, the Mt Windsor Volcanics and the massive dacite outcrop area.

All of the scatterplots based on SiO_2 (see **Figs 11 to 16**) show a spread of values across the dacite and rhyolite fields. This is a reflection of secondary silicification. Petrographic studies ***(Mason, 1992)*** provided general confirmation of the 'dacite' field names used during the mapping, and the presence of

Fig 26: MORB-normalised multi-element plots for TCF andesite flows in the Mt Farrenden area

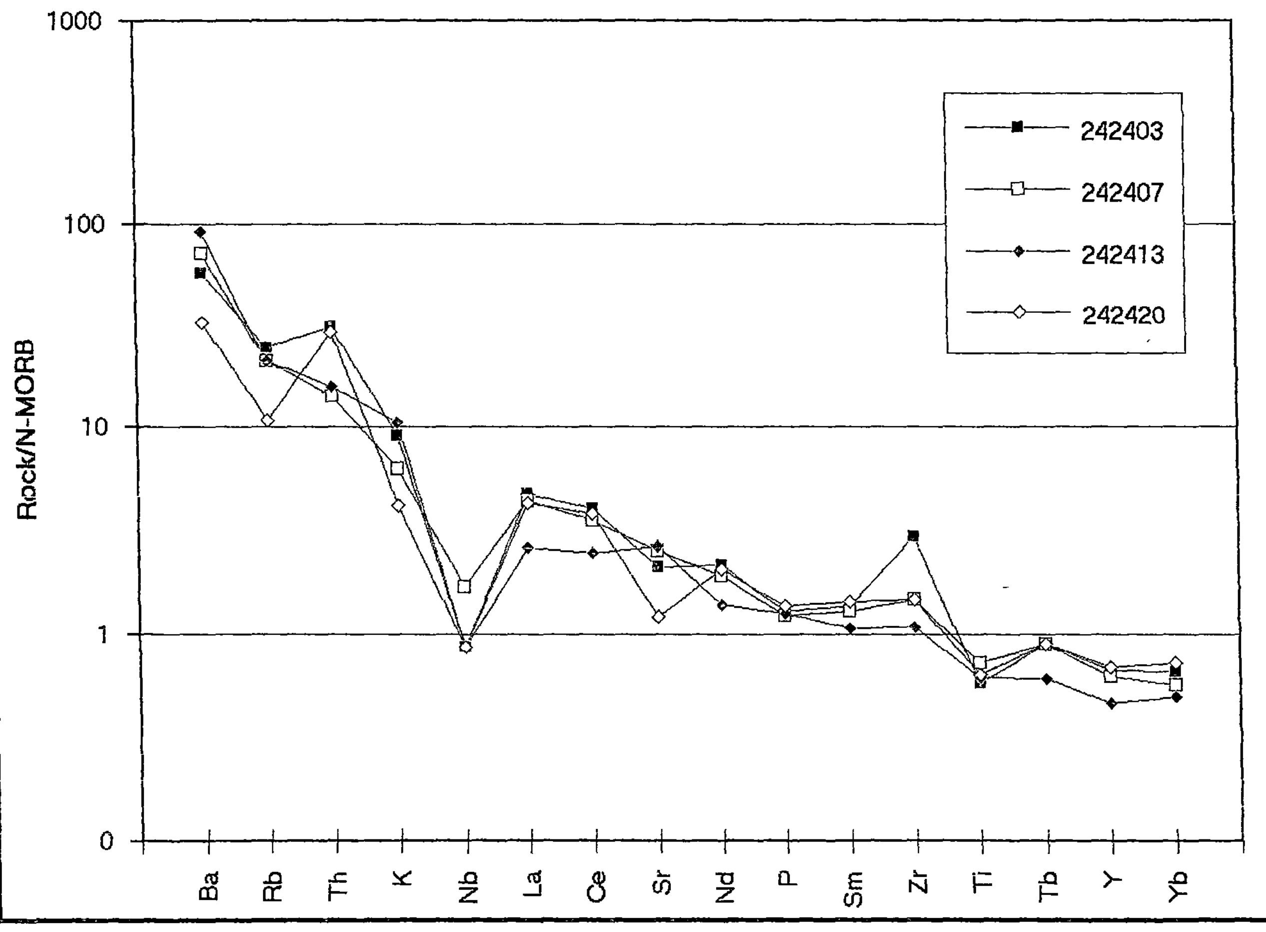
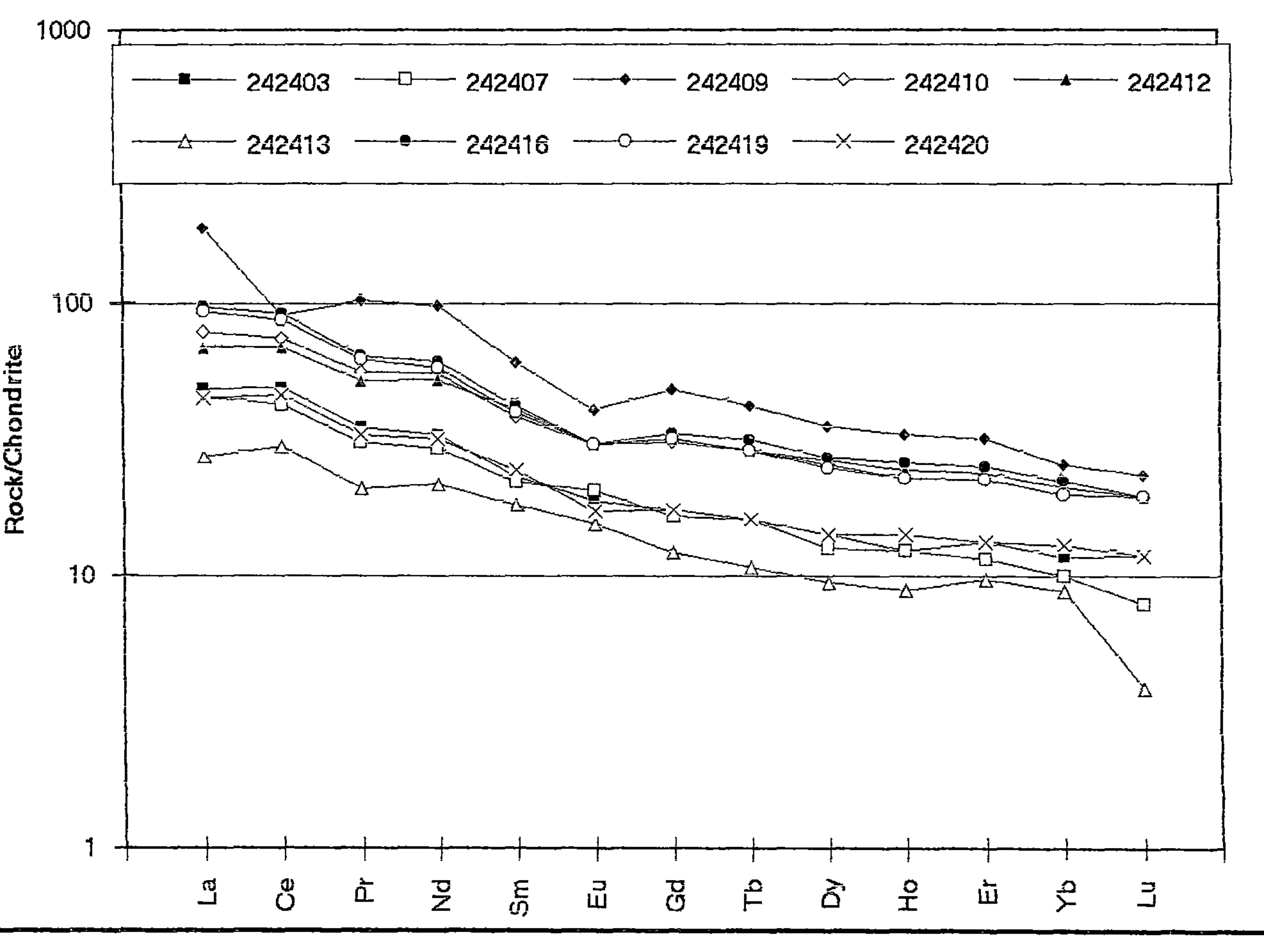


Fig 27: Chondrite-normalised REE plots for all mafic units in the Mt Farrenden area



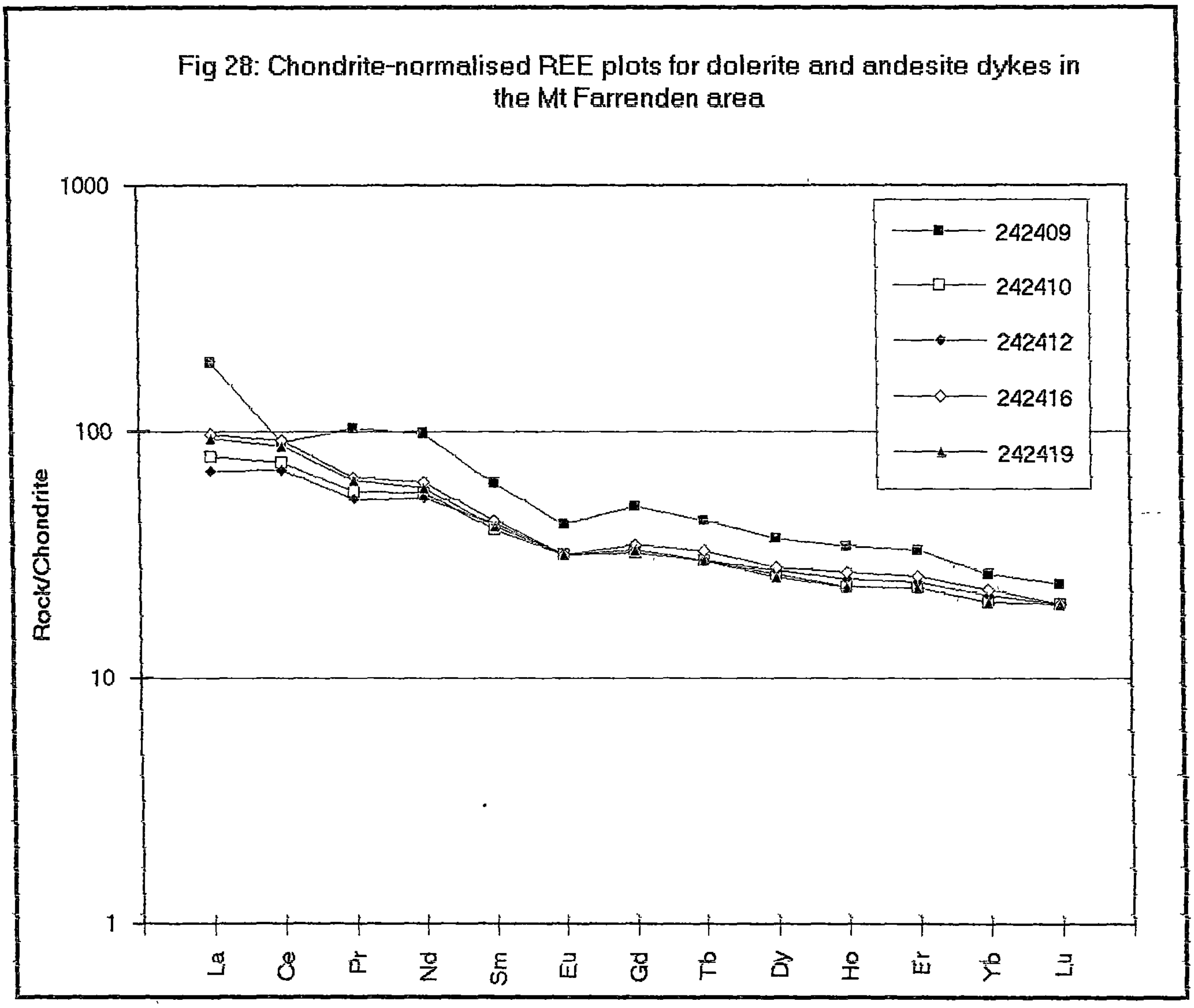
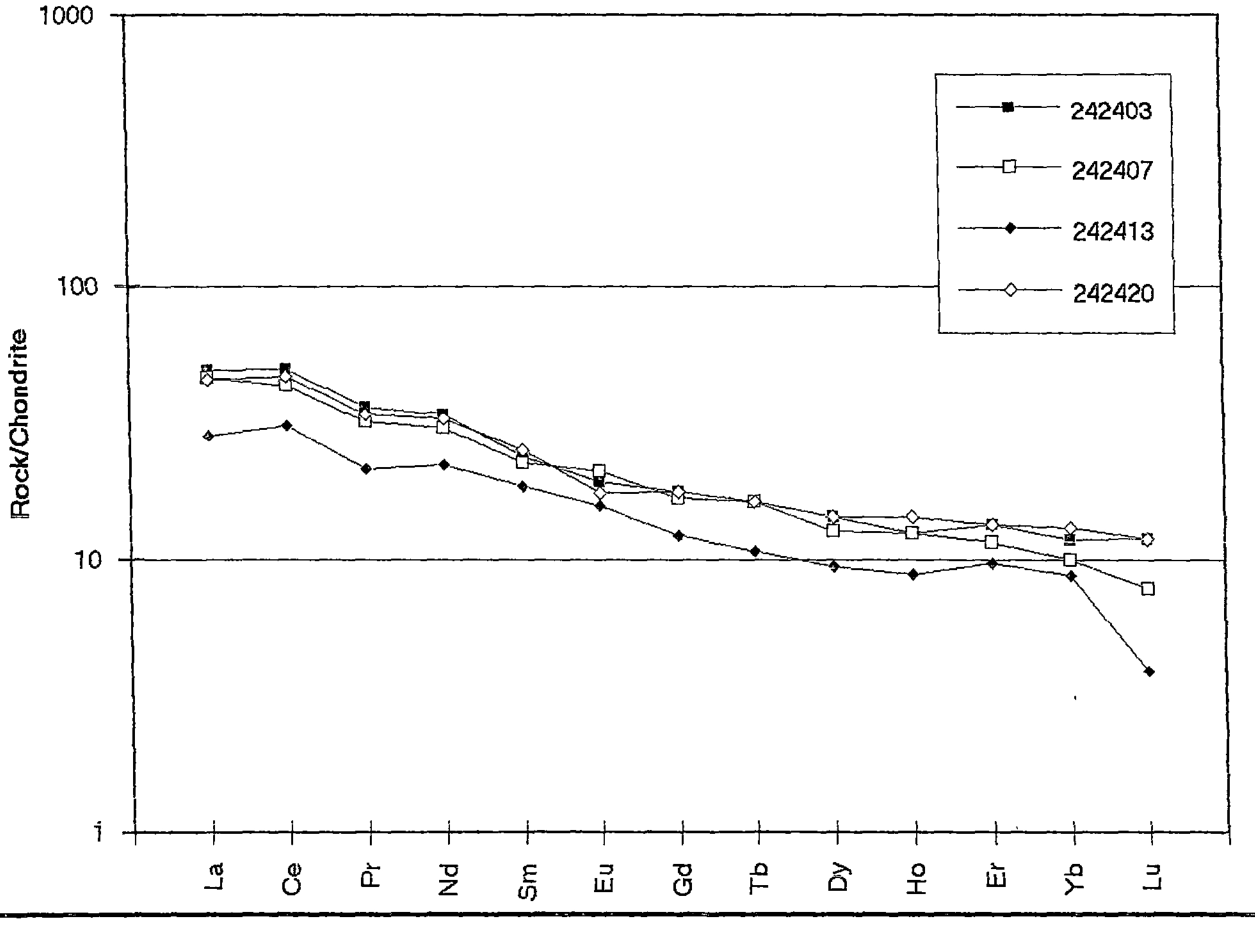


Fig 28: Chondrite-normalised REE plots for dolerite and andesite dykes in the Mt Farrenden area
1000
100
10
1
Rock/Chondrite
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Yb
Lu
242409
242410
242412
242416
242419

Fig 29: Chondrite-normalised REE plots for TCF andesite flows in the Mt Farrenden area



fine silica in the groundmass. The data spread, however, confirms the close geochemical grouping of almost all of these dacitic rocks. The single sample from the Black Jack Granodiorite ('BJG') falls within the ranges of values defined by the dacitic samples. Differences occur in Zr content **(Figs 18, 19 and 22, 23)** which highlight a quartz-phyric dyke 2km north of the Keystone range and a fine dacite (?)dyke adjacent to the Gregory Developmental Road south of Mt Farrenden. The latter sample occurs towards the northern limit of outcrop of the massive dacite unit exposed in the SW of the study area. However, the Ti/Zr ratios for all dacitic samples show little variation. These 2 samples also show increased P_2O_5 **(Figs 16, 20 and 21)**.

REE traces **(Fig 30)** for all dacite samples including the Black Jack Granodiorite have a very similar pattern in the range 10x to 90x chondrite. There is slight enrichment in LREE relative to HREE with a noticeable inflection at Eu. The Black Jack Granodiorite has the lowest multi-element abundances of all the samples.

In general the lithogeochemical data suggest that the massive dacites in the SW of the study area and the various dacitic dykes within the Puddler Creek Formation and the Mt Windsor Volcanics were produced from a similar source. The quartz-bearing dacites may reflect continued fractionation of the parent magma. This is consistent with the slightly cross-cutting relationship between the quartz-phyric dykes and the massive dacite occurrences.

Further sampling may elucidate any relationship between the dacites and the Black Jack Granodiorite. Such a relationship

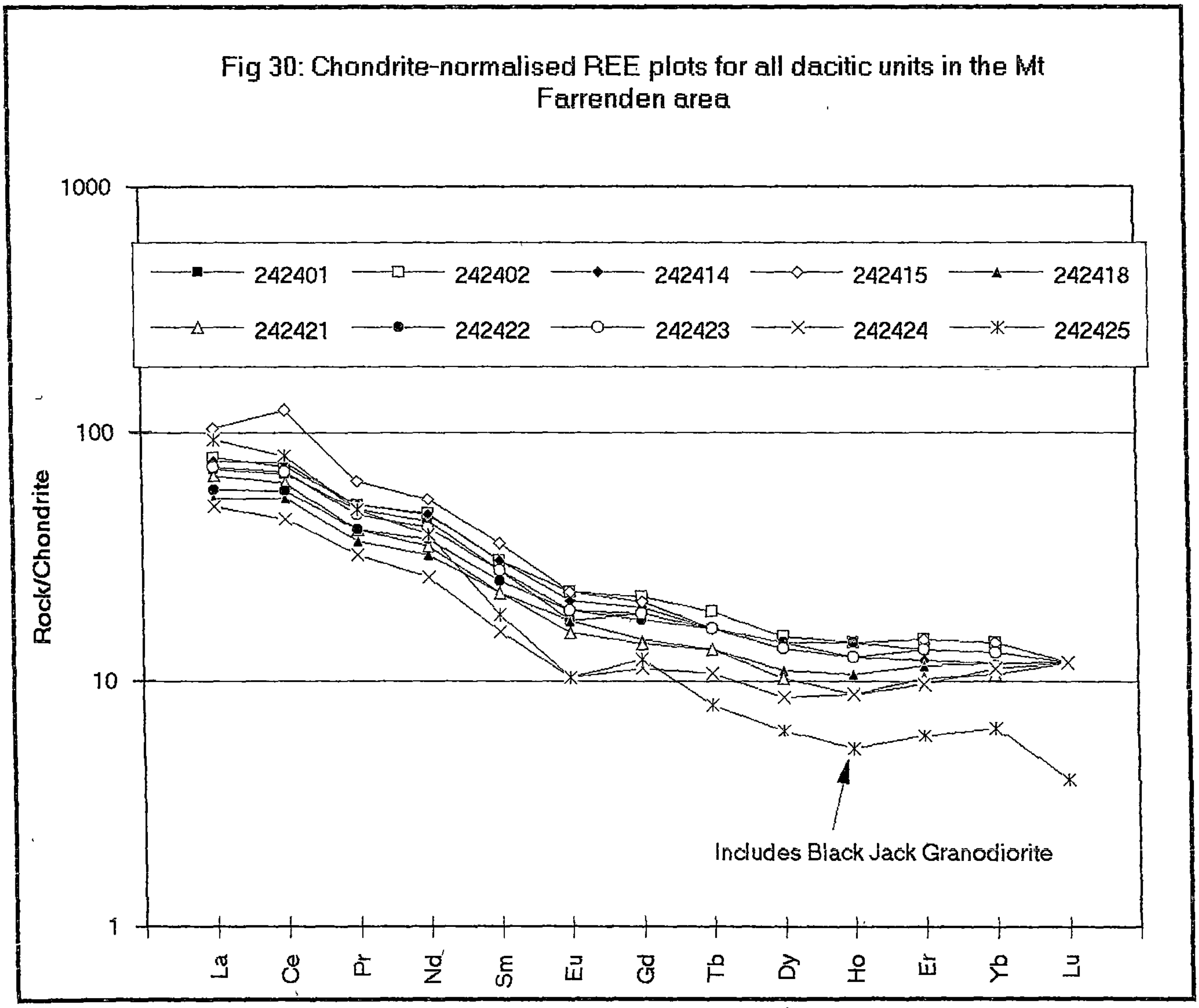


Fig 30: Chondrite-normalised REE plots for all dacitic units in the Mt Farrenden area
1000
100
10
1
Rock/Chondrite
242401
242402
242414
242415
242418
242421
242422
242423
242424
242425
Includes Black Jack Granodiorite
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Yb
Lu

would have important implications for the timing and affiliation of the dacitic units which are considered to be part of the Trooper Creek Formation.

Comparison of Rhyolitic Units

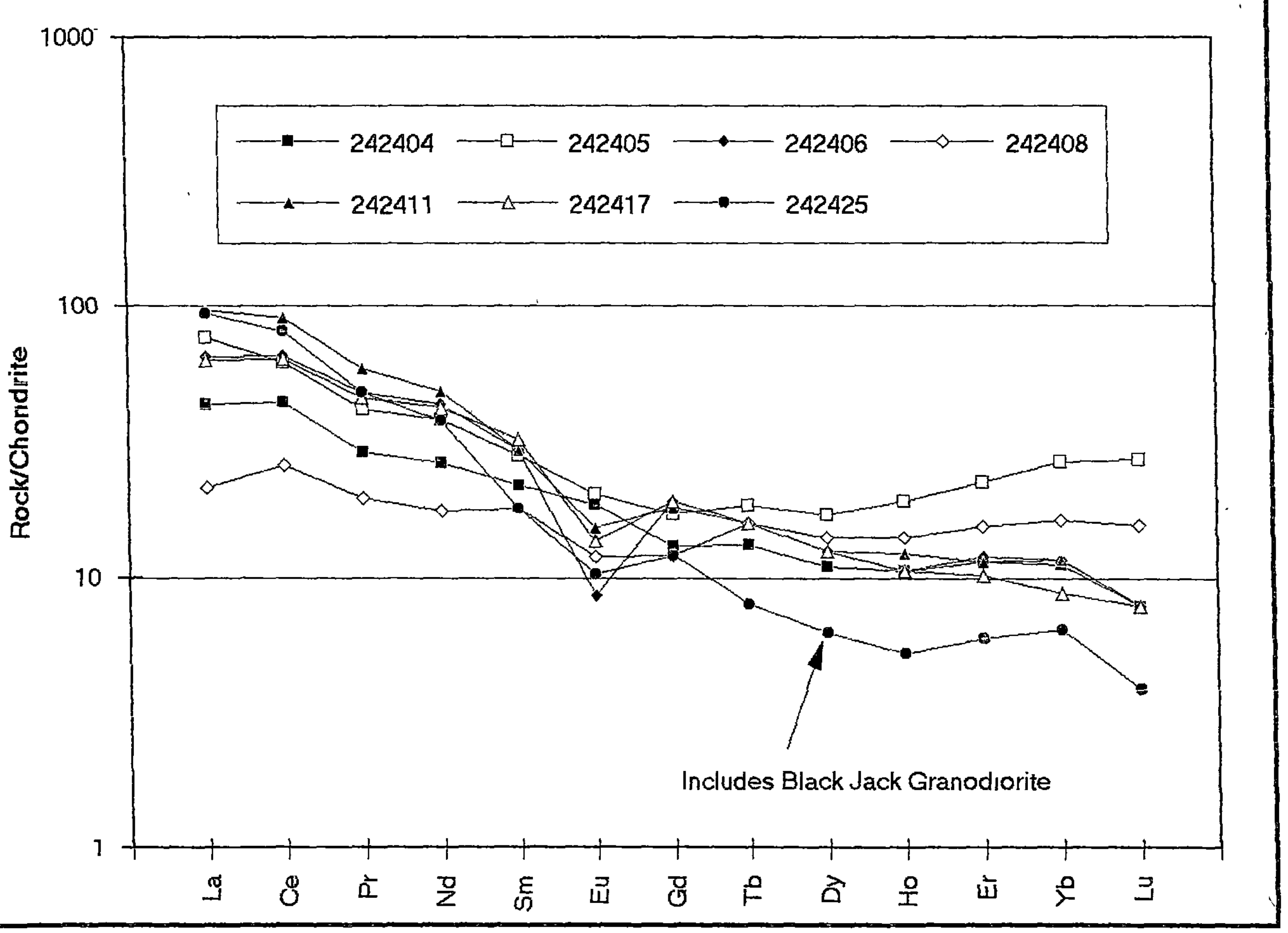
K_2O values **(Figs 9 and 10)** greater than 3% and up to 9% occur in all but one of the rhyolitic samples and are not restricted to those samples with silica contents above 78%. The high K values are generally associated with very low Na_2O values (generally <0.3%; **Appendix 1**) suggesting that some alteration apart from silicification has occurred.

High Th values **(Fig 11)** provide the most obvious difference between the rhyolites of the Mt Windsor Volcanics and all other rocks. **Stolz (pers. comm., 1993)** has found that Th is a useful discriminant with Th >10ppm for the Mt Windsor Volcanics rhyolites and Th <10ppm for the silicic phases of the Trooper Creek Formation.

All other scatterplots **(Figs 12 to 21)** show that the Mt Windsor Volcanics rhyolites form probably the closest grouping of any of the rock suites. Rhyolite from a prominent hill on the southern limit of the study area to the west of the Gregory Developmental Road, and a rhyolitic quartz-crystal volcaniclastic sandstone ***(Mason, 1992)*** from the centre of the area consistently plot away from the Mt Windsor Volcanics rhyolites. These two samples have Th <10ppm, and higher P and Ti.

REE plots **(Figs 31 to 33)** show negative Eu signatures for 4 of the 5 Mt Windsor Volcanics samples. One of these samples, from the northern end of the Keystone Range, shows an almost horizontal chondrite-normalised REE trace which contrasts to the slightly LREE-enriched (10x to 100x chondrite) trend of the

Fig 31: Chondrite-normalised REE plots for all rhyolitic units in the Mt Farrenden area



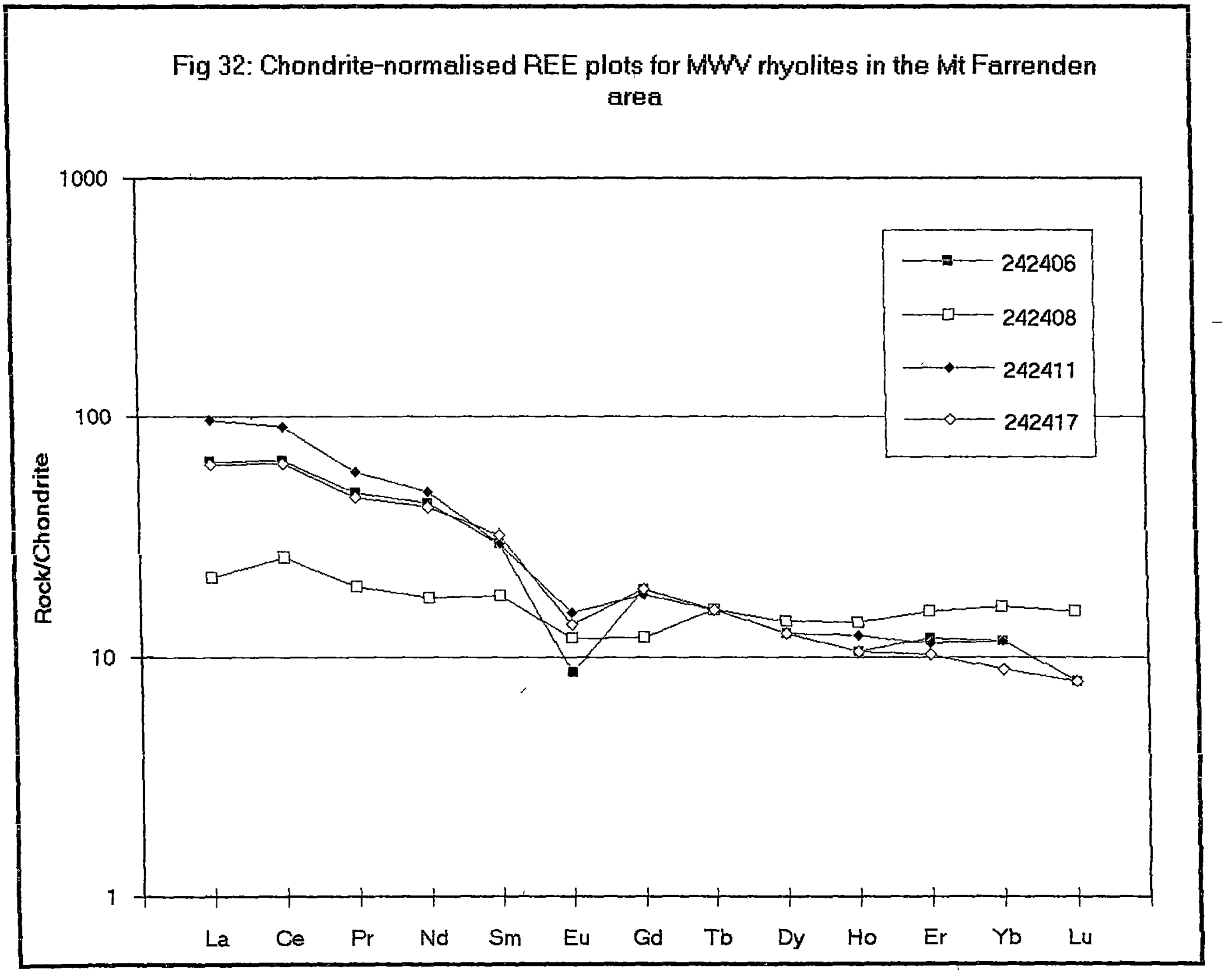
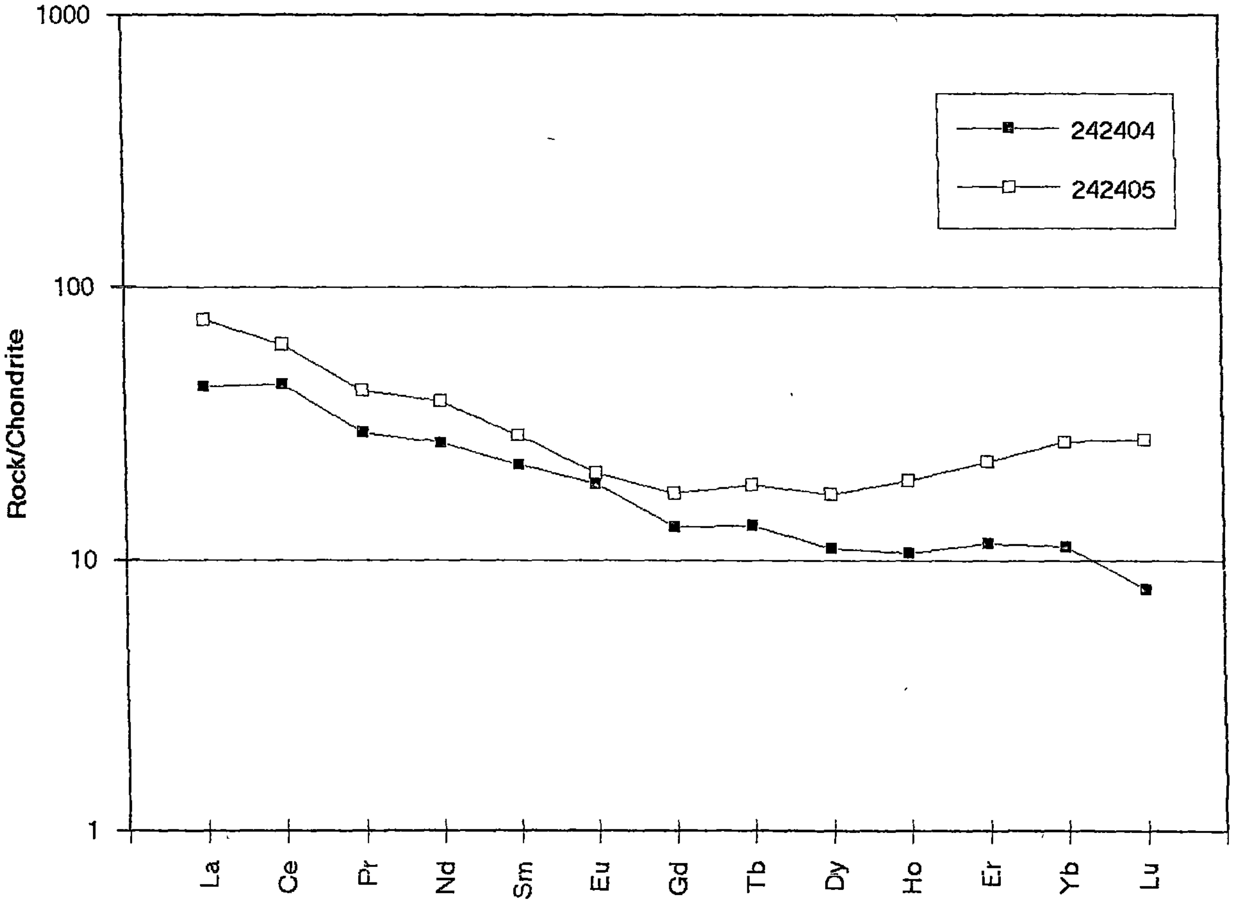


Fig 32: Chondrite-normalised REE plots for MWV rhyolites in the Mt Farrenden area
1000
100
10
1
Rock/Chondrite
242406
242408
242411
242417
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Yb
Lu

Fig 33: Chondrite-normalised REE plots for rhyolitic volcaniclastic, and rhyolite hill in the SW of the Mt Farrenden area



remainder. The fifth sample shows no negative Eu signature although it has the highest abundance of LREE. While this sample of flow-banded rhyolite has much in common with the other Mt Windsor Volcanics rhyolites its location at the NE extremity of the mapping area, within the Puddler Creek Formation, may cast some suspicion on its affiliation with the Mt Windsor Volcanics. However, there are sufficient chemical similarities to support its assignment as a part of the Mt Windsor Volcanics.

DISCUSSION

The limited whole rock assay data collected during this study, and those collected by ***Berry at al, (1992)***, support a low to medium K, calc-alkaline volcanic arc-convergent margin setting for the Mt Windsor Volcanics and the overlying Trooper Creek Formation. Negative MORB-normalised niobium and titanium values for the andesitic lavas suggest that subduction-related processes were active during the deposition of the Trooper Creek Formation ***(Wilson, 1989)***. The silicic nature a large proportion of the rocks comprising the Group are indicative of their formation over continental crust.

Deposition of the basal unit of the Seventy Mile Range Group, the Puddler Creek Formation, probably took place in a back-arc basin ***(Henderson, 1986)*** or marginal sea ***(Murray, 1990)*** environment formed as a result of continental extension in response to the subduction. These sedimentary units are regarded as being derived from continental basement ***(Henderson, 1986)*** sources. The relatively thin bedding, presence of siltstones and fine sandstones and the relative lack of high-water-energy features within the study area suggests the deposition of sediments into relatively deep water. ***Henderson (1986)*** also noted the presence of deeper water depositional features on a more regional scale. The intense folding or other high degrees of deformation that could be related to a location at the continental edge (ie, a flysch wedge) are lacking regionally further supporting the interpretation of a back-arc environment. ***Henderson (1986)*** suggested that the Mt Windsor Subprovince was the result of deposition in a N-S trending zone, much of which is now overlain by the Drummond Basin. This proposed structural orientation is consistent with the N-S trends of the major structural entities of the Tasman Orogenic Zone (See Fig 2; ***Murray, 1990***). The present E-W trend of the Subprovince may relate in part to the emplacement of the Ravenswood Granodiorite Complex which forms the northern limit of the Seventy Mile Range Group.

Rhyolites dominate the Mt Windsor Volcanics throughout the subprovince and suggests that this material was derived from the melting of continental crust. The melting may have been caused by heat generated during the relatively early stages of subduction. Flow-banding and less common columnar jointing recorded in the Keystone Range suggest a lava-like or flow-dome emplacement of certain parts of the rhyolite sequence. Scattered small outcrops of non-welded pumice-rich rocks (for example, 'NP' in Fig 3) on the eastern side of the Keystone Range could suggest that at least some subaerial (or very shallow water), explosive volcanism ***(Cas and Wright, 1988, 1991; Cas, 1992)*** occurred during the formation of the Mt Windsor Volcanics. However, further work is required if these clastic rocks are to be linked directly with the coherent Mt Windsor Volcanics rhyolites. As such, no reference to possible subaerial explosive volcanism within the Mt

Windsor Volcanics rhyolites can be made. Elsewhere in the study area are large outcroppings of angular, unoriented, rhyolitic clast-supported breccias which of probable a mass-flow origin. Such an interpretation infers the presence of water as a transporting medium, but without any real indication of the depth of the water.

The Keystone Range, and the massive rhyolites forming Mt Windsor itself, some 4km SSW of Mt Farrenden are the major rhyolite accumulations in the local area. Thicknesses well in excess of 1km are possible here. Near Mt Farrenden, however, the rhyolite sequence appears to be of the order of several tens of metres in thickness. Accordingly, the 2 major accumulations probably represent local volcanic (subvolcanic) centres.

The Trooper Creek Formation is a lithologically diverse sequence of basaltic andesites, andesites, dacites and sedimentary units of probable volcanic derivation. The sedimentary units are finely laminated and devoid of cross-bedding, ripple marks, or high energy features although minor graded bedding has been recorded ***(van Eck, 1993)***. This may suggest deposition below wave base between episodes of andesitic volcanism given the close association of sedimentary and andesitic units in the centre of the study area. At one locality near a small-scale E-W fold finely laminated rock grades rapidly downward into andesitic breccia and amygdaloidal andesite. This feature may represent a resedimented hyaloclastite, or the settling out of fines following mass-flow deposition of the breccia. The presence of coherent andesites however supports the former interpretation.

Higher eruption rates of andesitic lavas produced the substantial flow outcrops in the south and SW of the area. As discussed above these flow rocks display chemical signatures consistent with their formation by subduction-related processes. The andesitic and doleritic dykes, along with a pillowed 'basalt' occurrence have a significantly different chemical signature in terms of P, Ti, Zr and Mg. Their Mg and P signatures suggest strongly that the dyke rocks are related by fractionation of a source different to that of the flow rocks. The dykes with a fine 'doleritic' appearance appear restricted to the eastern part of the study area and intrude both the Puddler Creek Formation and the Mt Windsor Volcanics. 'Doleritic 'dykes have not been recorded within the Trooper Creek Formation although andesite dykes with similar chemical signatures occur within the Dacite Lava and Breccia unit near Mt Farrenden. Compared to the Puddler Creek Andesites of ***Berry et al (1992)*** the 'dolerites' have lower P and Nb signatures but it is still unclear whether they can be related directly. From the admittedly restricted distribution of the samples the possibility exists that these dyke rocks are associated with Mt Windsor Volcanics or the early stages of the Trooper Creek Formation. Thus, the dyke rocks could predate the andesite flows. Such an interpretation would require the sampling of additional mafic dyke material, especially of those dyke-like forms within the massive dacite units in the SW.

Associated chemically with the andesite and 'dolerite' dykes is a localised but relatively large occurrence of pillowed basaltic andesite lavas on the SW flank of the Keystone Range (see Figs 3 and 7). These features are indicative of subaqueous deposition (with no inference of water depth). The pillowed 'basalts' are highly vesicular and are associated with (overlie?; emanate from?) fine massive andesites (basaltic andesite?).

The dacitic rock suite forms relatively discrete groupings in most of the scatterplots. Included within each of these groups is the single sample from the Black Jack Granodiorite ('BJG') which has been assigned a Silurian-Devonian age ***(Hutton and Crouch, 1993).*** Outcrop relationships suggest that the granodiorite post-dates the feldspar-phyric dacites along its western and southern edges. Dacitic (or other) dykes are not found within either of the granodiorite bodies.

To the W and N of Mt Farrenden the dacites occur as dyke-like bodies with a NNE trend which is subparallel to the cleavage in the host sedimentary units of the Puddler Creek Formation. Dip of the cleavage and the dykes appears to be subvertical to very steeply east-dipping. A 50m- to 100m-wide linear dacitic outcrop zone appears to form the eastern edge of the dyke swarm (see Figs 3 and 8). A lineation here is observable on detailed airborne radiometric contour maps and imagery ***(van Eck, 1992).*** The southward continuation of this trend also coincides with the eastern limit of the massive dacite outcrops in the SW.

It is considered that the dacites are intrusive into the flow andesites of the Trooper Creek Formation. However, the timing of these intrusive episodes is uncertain although it appears to predate the granodiorite intrusions. Given the relative chemical similarities of the dacites in the Mt Farrenden area and the felsic rocks in the regional database of ***Berry et al (1992)*** it could be inferred that the dacites in the study area are a part of the Trooper Creek Formation. There is some indication of a fractionation trend in the REE plots between the flow andesites and the dacites, with the latter being slightly enriched in total REE. The low HREE, elevated Th and low Y of the Black Jack Granodiorite which may distinguish it from the dacites.

The massive dacite outcrops are themselves intruded by fine-quartz bearing and quartz-phyric dacite dykes. The latter appear to cross-cut their host at a shallow angle. Fractionation may account for the presence of quartz phenocrysts and the obviously later timing of the quartz-phyric bodies.

The general structure of the Mt Farrenden area is inferred mainly from the dip, strike and facing observations on the sedimentary units associated with the flow andesites in the central portion of the area. These data support the presence of a southward plunging syncline. The syncline predates the Black Jack and the Policeman Creek Granodiorite bodies. The linearity of the intruding dacitic dyke swarm in the same area suggests that some folding had occurred before emplacement of the dacites. The inferred NNE-trending axis parallels the cleavage in the Puddler Creek Formation here. The cleavage may have been exploited by the intruding dacite dykes. The axial zone of the syncline occurs where the rhyolites of the Mt Windsor Volcanic are thinnest. It is possible that andesite accumulation was restricted to the zone between the Keystone Range and the Mt Windsor rhyolite centres. Accumulation of the denser material may have initiated warping of the thinner rhyolite substrata and continued andesite deposition into the deepening depression.

The small outcrops of laminated silica-rich sediment and dacitic breccia within the massive dacites in the SW are considered to be remnants of larger units deposited prior to the intrusion of the dacite.

Berry (pers. comm, 1992; Berry et al, 1992) proposes a growth fault at the southern foot of Mt Farrenden to account for a perceived thickening of the Trooper Creek Formation in this area. The proposed fault has a listric geometry with an eastern edge along the western flank of the Keystone Range (the Handcuff Fault). In the Mt Farrenden area the fault would provide an E-W trend along which deposition could occur. Evidence for faulting along the contact between the Puddler Creek Formation and the Mt Windsor Volcanics was not recorded during this study.

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APPENDIX 1

WHOLE ROCK GEOCHEMISTRY DATA

APPENDIX 1
MT FARRENDEN AREA, CHARTERS TOWERS, NTH QLD
WHOLE ROCK GEOCHEMISTRY DATA

SAMPLE NO	242401	242402	242403	242404	242405	242406	242407	242408	242409	242410	242411	242412	242413	242414	242415	242416	242417	242418	242419	242420	242421	242422	242423	242424	242425
Fld Name	Dac dyke	Dacite	And flow	Rhy hill	Rhyolitic	Rhyolite	And flow	Rhyolite	Dolerite	Dolerite	Rhyolite	Dolerite?	And flow	Qtz dac	Dac dyke	And dyke	Rhyolite	QED	And dyke	And flow	QED	Mass dac	Qtz dac	QED	BlackJack
Form'n	in PCF	dyke	TCF	in SW	v-clastic	MWV	TCF	MWV	dyke	dyke	MWV	Bas-andes	TCF	in PCF	in PCF	in PCF	MWV	dyke	in MWV	TCF	dyke	??TCF	dyke	dyke	G-diorite
%	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual
SiO_2	74.10	68.10	58.80	80.30	77.90	81.00	48.70	75.20	50.00	51.00	81.80	52.30	49.30	75.10	79.60	55.50	81.60	71.60	54.70	59.20	74.20	72.80	74.60	72.90	77.60
Al_2O_3	13.30	13.90	15.50	11.50	7.23	9.22	16.30	12.90	13.80	14.30	9.10	14.20	18.70	12.60	10.60	14.90	9.70	13.80	15.00	15.50	12.90	13.10	12.70	13.50	12.30
Fe_2O_3	3.01	5.80	9.82	1.54	4.87	2.02	10.40	0.97	13.90	13.70	1.37	13.70	10.30	3.09	1.58	12.20	1.48	3.76	11.90	10.20	3.07	4.33	3.21	3.16	1.04
CaO	0.70	2.64	5.26	0.05	0.24	0.37	9.71	0.05	4.75	4.59	0.10	4.85	6.36	0.99	0.21	7.64	0.29	2.56	7.08	5.39	1.67	1.13	1.06	2.48	1.62
MgO	0.60	1.16	2.97	0.36	0.23	1.69	7.27	0.32	5.15	3.55	0.21	3.93	3.09	0.49	0.29	4.62	0.28	0.72	4.32	3.18	0.51	0.71	0.57	0.79	0.29
TiO_2	0.25	0.49	0.72	0.40	0.33	0.05	0.88	0.07	1.85	1.82	0.09	1.70	0.73	0.21	0.08	1.42	0.06	0.33	1.55	0.79	0.26	0.31	0.31	0.30	0.22
Na_2O	5.36	5.12	4.85	0.20	0.19	3.68	2.95	0.21	2.45	4.78	0.18	5.14	4.86	4.42	1.45	1.70	0.33	4.00	3.01	4.08	4.04	3.72	4.36	5.17	4.61
K_2O	1.22	1.06	0.65	3.47	2.87	0.28	0.44	8.43	0.86	0.07	5.79	0.42	0.72	2.16	5.09	0.13	5.12	1.57	0.50	0.30	2.22	2.90	2.49	0.19	0.90
P_2O_5	0.03	0.14	0.15	0.09	0.08	0.03	0.14	0.02	0.24	0.23	0.02	0.24	0.14	0.03	0.02	0.20	0.02	0.08	0.23	0.16	0.05	0.05	0.05	0.06	0.04
MnO	0.05	0.11	0.22	0.01	0.01	0.03	0.20	0.01	0.21	0.23	0.01	0.19	0.15	0.07	0.02	0.33	0.02	0.08	0.40	0.22	0.03	0.07	0.03	0.02	0.02
LOI	1.06	1.16	1.06	1.88	5.68	1.43	2.85	0.74	6.53	5.72	0.83	2.61	4.80	0.75	0.74	0.96	2.00	1.35	1.27	1.05	0.93	1.09	0.76	1.35	1.17
TOTAL	99.68	99.68	100.00	99.80	99.63	99.80	99.84	98.92	99.74	99.99	99.50	99.28	99.15	99.91	99.68	99.60	100.90	99.85	99.96	100.07	99.88	100.21	100.14	99.92	99.81

SAMPLE NO	242401	242402	242403	242404	242405	242406	242407	242408	242409	242410	242411	242412	242413	242414	242415	242416	242417	242418	242419	242420	242421	242422	242423	242424	242425
%	Norm*	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm	Norm
SiO_2	75.14	69.12	59.43	82.01	82.92	82.34	50.21	76.59	53.64	54.10	82.90	54.10	52.25	75.74	80.45	56.27	82.51	72.69	55.43	59.79	74.99	73.45	75.07	73.96	78.67
Al_2O_3	13.49	14.11	15.67	11.74	7.70	9.37	16.81	13.14	14.81	15.17	9.22	14.69	19.82	12.71	10.71	15.11	9.81	14.01	15.20	15.65	13.04	13.22	12.78	13.70	12.47
Fe_2O_3	3.05	5.89	9.93	1.57	5.18	2.05	10.72	0.99	14.91	14.53	1.39	14.17	10.92	3.12	1.60	12.37	1.50	3.82	12.06	10.30	3.10	4.37	3.23	3.21	1.05
CaO	0.71	2.68	5.32	0.05	0.26	0.38	10.01	0.05	5.10	4.87	0.10	5.02	6.74	1.00	0.21	7.75	0.29	2.60	7.17	5.44	1.69	1.14	1.07	2.52	1.64
MgO	0.61	1.18	3.00	0.37	0.24	1.72	7.50	0.33	5.53	3.77	0.21	4.07	3.28	0.49	0.29	4.68	0.28	0.73	4.38	3.21	0.52	0.72	0.57	0.80	0.29
TiO_2	0.25	0.50	0.73	0.41	0.35	0.05	0.91	0.07	1.98	1.93	0.09	1.76	0.77	0.21	0.08	1.44	0.06	0.34	1.57	0.80	0.26	0.31	0.31	0.30	0.22
Na_2O	5.44	5.20	4.90	0.20	0.20	3.74	3.04	0.21	2.63	5.07	0.18	5.32	5.15	4.46	1.47	1.72	0.33	4.06	3.05	4.12	4.08	3.75	4.39	5.25	4.67
K_2O	1.24	1.08	0.66	3.54	3.05	0.28	0.45	8.59	0.92	0.07	5.87	0.43	0.76	2.18	5.14	0.13	5.18	1.59	0.51	0.30	2.24	2.93	2.51	0.19	0.91
P_2O_5	0.03	0.14	0.15	0.09	0.09	0.03	0.14	0.02	0.26	0.24	0.02	0.25	0.15	0.03	0.02	0.20	0.02	0.08	0.23	0.16	0.05	0.05	0.05	0.06	0.04
MnO	0.05	0.11	0.22	0.01	0.01	0.03	0.21	0.01	0.23	0.24	0.01	0.20	0.16	0.07	0.02	0.33	0.02	0.08	0.41	0.22	0.03	0.07	0.03	0.02	0.02
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Normalised for Loss on Ignition (LOI)

SAMPLE NO	242401	242402	242403	242404	242405	242406	242407	242408	242409	242410	242411	242412	242413	242414	242415	242416	242417	242418	242419	242420	242421	242422	242423	242424	242425
Fld Name	Dac dyke	Dacite	And flow	Rhy hill	Rhyolitic	Rhyolite	And flow	Rhyolite	Dolerite	Dolerite	Rhyolite	Dolerite?	And flow	Qtz dac	Dac dyke	And dyke	Rhyolite	QED	And dyke	And flow	QED	Mass dac	Qtz dac	QED	BlackJack
Form'n	in PCF	dyke	TCF	in SW	v-clastic	MWV	TCF	MWV	dyke	dyke	MWV	Bas-andes	TCF	in PCF	in PCF	in PCF	MWV	dyke	in MWV	TCF	dyke	??TCF	dyke	dyke	G-diorite
PPM	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual
Cu	<5	<5	10	<5	<5	<5	80	<5	35	55	10	20	35	5	30	20	<5	10	<5	95	20	<5	<5	<5	5
Pb	<5	<5	5	5	15	<5	<5	10	5	<5	125	<5	<5	5	15	<5	25	15	15	<5	<5	<5	<5	<5	<5
Zn	20	40	75	10	<5	<5	95	20	220	110	30	45	35	35	20	95	10	80	130	30	<5	20	5	<5	<5
Ag	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cr	60	230	140	90	50	220	100	110	20	30	130	10	20	160	180	120	240	170	80	90	230	200	200	160	210
Ni	<5	5	5	<5	<5	<5	45	<5	5	10	<5	5	<5	<5	<5	15	<5	<5	5	<5	<5	<5	<5	<5	<5
S	20	50	1650	360	1.31%	190	150	60	170	10	340	60	120	450	50	2400	430	200	50	170	70	40	30	480	140
Sr	60	150	190	<10	20	50	230	10	90	90	<10	50	240	110	30	180	20	140	180	110	120	90	90	160	110
V	<10	40	210	20	20	<10	230	<10	310	290	10	280	260	10	<10	250	<10	30	280	200	20	10	10	50	20
Ba	290	430	370	1000	880	120	460	1100	630	60	690	520	580	630	1350	60	1100	680	230	210	630	500	640	140	200
Nb	6	6	2	4	12	8	4	12	10	12	10	8	2	6	12	12	10	6	14	2	6	6	6	4	6
Rb	22	22	14	60	50	4	12	210	40	4	134	6	12	46	118	6	128	32	14	6	30	50	40	4	20
Zr	480	210	220	180	280	140	110	150	160	170	130	180	80	190	150	240	110	170	190	110	170	170	170	620	140
Th	6.2	5.6	3.8	5.2	5.8	14.8	1.7	15.4	3.4	3.6	15.4	3.6	1.9	6.6	19.0	6.2	16.4	6.4	5.4	3.6	7.4	5.8	7.2	7.2	8.8
Sc	11.0	19.2	32.4	10.4	11.2	6.2	39.8	10.2	36.8	37.0	5.2	34.6	36.2	12.0	7.0	32.4	4.6	12.2	36.4	32.2	8.0	12.0	11.6	11.8	4.8
Y	18.2	21.2	18.6	15.4	28.2	16.0	17.2	15.0	57.4	34.6	14.8	36.0	12.8	16.8	17.2	37.8	13.2	15.4	34.4	19.2	14.0	18.6	18.4	12.8	7.2
La	16.8	18.8	11.8	10.4	18.2	15.4	11.0	5.2	44.8	18.8	23.0	16.4	6.6	18.2	24.6	23.2	15.0	12.8	22.4	10.8	15.8	13.8	17.2	11.8	22.4
Ce	41.8	44.8	30.6	27.2	38.2	40.2	26.6	16.2	55.4	46.0	55.8	42.6	18.6	46.2	75.8	56.8	39.2	33.0	53.8	28.8	38.0	35.4	42.4	27.0	49.6
Pr	4.6	4.8	3.4	2.8	4.0	4.6	3.0	1.9	9.8	5.4	5.6	5.0	2.0	4.8	6.0	6.2	4.4	3.4	6.0	3.2	3.8	3.8	4.4	3.0	4.6
Nd	20.2	21.8	15.8	12.6	18.0	20.4	14.0	8.4	46.0	26.4	22.8	24.8	10.2	21.6	25.0	29.0	19.8	14.8	27.4	15.2	16.0	17.0	19.0	12.0	17.8
Sm	4.2	4.6	3.6	3.4	4.4	4.6	3.4	2.8	9.4	6.0	4.6	6.4	2.8	4.6	5.4	6.6	5.0	3.4	6.2	3.8	3.4	3.8	4.2	2.4	2.8
Eu	1.0	1.3	1.1	1.1	1.2	0.5	1.2	0.7	2.4	1.8	0.9	1.8	0.9	1.2	1.3	1.8	0.8	1.0	1.8	1.0	0.9	1.1	1.1	0.6	0.6
Gd	3.8	4.4	3.6	2.7	3.6	4.0	3.4	2.5	10.1	6.5	3.8	6.7	2.5	4.0	4.2	7.0	4.0	3.0	6.7	3.6	2.9	3.6	3.8	2.3	2.5
Tb	0.6	0.7	0.6	0.5	0.7	0.6	0.6	0.6	1.6	1.1	0.6	1.1	0.4	0.6	0.6	1.2	0.6	0.5	1.1	0.6	0.5	0.6	0.6	0.4	0.3
Dy	3.6	3.8	3.6	2.8	4.4	3.2	3.2	3.6	9.2	6.6	3.2	6.8	2.4	3.4	3.6	7.0	3.2	2.8	6.4	3.6	2.6	3.6	3.4	2.2	1.6
Ho	0.7	0.8	0.7	0.6	1.1	0.6	0.7	0.8	1.9	1.3	0.7	1.4	0.5	0.7	0.8	1.5	0.6	0.6	1.3	0.8	0.5	0.8	0.7	0.5	0.3
Er	2.2	2.4	2.2	1.9	3.8	2.0	1.9	2.6	5.4	3.8	1.9	4.0	1.6	2.0	2.4	4.2	1.7	1.9	3.8	2.2	1.7	2.2	2.2	1.6	1.0
Yb	2.2	2.4	2.0	1.9	4.6	2.0	1.7	2.8	4.4	3.4	2.0	3.6	1.5	2.0	2.4	3.8	1.5	2.0	3.4	2.2	1.8	2.2	2.2	1.9	1.1
Lu	0.3	0.3	0.3	0.2	0.7	0.2	0.2	0.4	0.6	0.5	0.2	0.5	0.1	0.3	0.3	0.5	0.2	0.3	0.5	0.3	0.3	0.3	0.3	0.3	0.1
Ti/Zr	3.17	14.20	19.83	13.61	7.52	2.18	49.45	2.85	74.37	68.08	4.21	58.57	57.98	6.68	3.23	35.96	3.31	11.81	49.56	43.48	9.27	11.03	11.00	2.94	9.55
Zr/Ti	0.32	0.07	0.05	0.07	0.13	0.46	0.02	0.35	0.01	0.01	0.24	0.02	0.02	0.15	0.31	0.03	0.30	0.08	0.02	0.02	0.11	0.09	0.09	0.34	0.10
Zr/Nb	80.00	35.00	110.00	45.00	23.33	17.50	27.50	12.50	16.00	14.17	13.00	22.50	40.00	31.67	12.50	20.00	11.00	28.33	13.57	55.00	28.33	28.33	28.33	155.00	23.33
Zr/Y	26.37	9.91	11.83	11.69	9.93	8.75	6.40	10.00	2.79	4.91	8.78	5.00	6.25	11.31	8.72	6.35	8.33	11.04	5.52	5.73	12.14	9.14	9.24	48.44	19.44
Nb/Y	0.33	0.28	0.11	0.26	0.43	0.50	0.23	0.80	0.17	0.35	0.68	0.22	0.16	0.36	0.70	0.32	0.76	0.39	0.41	0.10	0.43	0.32	0.33	0.31	0.83

SAMPLE NO	242401	242402	242403	242404	242405	242406	242407	242408	242409	242410	242411	242412	242413	242414	242415	242416	242417	242418	242419	242420	242421	242422	242423	242424	242425
Fld Name	Dac dyke	Dacite	And flow	Rhy hill	Rhyolitic	Rhyolite	And flow	Rhyolite	Dolerite	Dolerite	Rhyolite	Dolerite?	And flow	Qtz dac	Dac dyke	And dyke	Rhyolite	QED	And dyke	And flow	QED	Mass dac	Qtz dac	QED	BlackJack
Form'n	in PCF	dyke	TCF	in SW	v-clastic	MWV	TCF	MWV	dyke	dyke	MWV	Bas-andes	TCF	in PCF	in PCF	in PCF	MWV	dyke	in MWV	TCF	dyke	??TCF	dyke	dyke	G-diorite
PPM	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm	C1 Norm
La	70.89	79.32	49.79	43.88	76.79	64.98	46.41	21.94	189.03	79.32	97.05	69.20	27.85	76.79	103.80	97.89	63.29	54.01	94.51	45.57	66.67	58.23	72.57	49.79	94.51
Ce	68.30	73.20	50.00	44.44	62.42	65.69	43.46	26.47	90.52	75.16	91.18	69.61	30.39	75.49	123.86	92.81	64.05	53.92	87.91	47.06	62.09	57.84	69.28	44.12	81.05
Pr	48.42	50.53	35.79	29.47	42.11	48.42	31.58	20.00	103.16	56.84	58.95	52.63	21.05	50.53	63.16	65.26	46.32	35.79	63.16	33.68	40.00	40.00	46.32	31.58	48.42
Nd	43.25	46.68	33.83	26.98	38.54	43.68	29.98	17.99	98.50	56.53	48.82	53.10	21.84	46.25	53.53	62.10	42.40	31.69	58.67	32.55	34.26	36.40	40.69	25.70	38.12
Sm	27.45	30.07	23.53	22.22	28.76	30.07	22.22	18.30	61.44	39.22	30.07	41.83	18.30	30.07	35.29	43.14	32.68	22.22	40.52	24.84	22.22	24.84	27.45	15.69	18.30
Eu	17.24	22.41	18.97	18.97	20.69	8.62	20.69	12.07	41.38	31.03	15.52	31.03	15.52	20.69	22.41	31.03	13.79	17.24	31.03	17.24	15.52	18.97	18.97	10.34	10.34
Gd	18.49	21.41	17.52	13.14	17.52	19.46	16.55	12.17	49.15	31.63	18.49	32.60	12.17	19.46	20.44	34.06	19.46	14.60	32.60	17.52	14.11	17.52	18.49	11.19	12.17
Tb	16.04	18.72	16.04	13.37	18.72	16.04	16.04	16.04	42.78	29.41	16.04	29.41	10.70	16.04	16.04	32.09	16.04	13.37	29.41	16.04	13.37	16.04	16.04	10.70	8.02
Dy	14.17	14.96	14.17	11.02	17.32	12.60	12.60	14.17	36.22	25.98	12.60	26.77	9.45	13.39	14.17	27.56	12.60	11.02	25.20	14.17	10.24	14.17	13.39	8.66	6.30
Ho	12.37	14.13	12.37	10.60	19.43	10.60	12.37	14.13	33.57	22.97	12.37	24.73	8.83	12.37	14.13	26.50	10.60	10.60	22.97	14.13	8.83	14.13	12.37	8.83	5.30
Er	13.29	14.50	13.29	11.48	22.96	12.08	11.48	15.71	32.63	22.96	11.48	24.17	9.67	12.08	14.50	25.38	10.27	11.48	22.96	13.29	10.27	13.29	13.29	9.67	6.04
Yb	12.94	14.12	11.76	11.18	27.06	11.76	10.00	16.47	25.88	20.00	11.76	21.18	8.82	11.76	14.12	22.35	8.82	11.76	20.00	12.94	10.59	12.94	12.94	11.18	6.47
Lu	11.81	11.81	11.81	7.87	27.56	7.87	7.87	15.75	23.62	19.69	7.87	19.69	3.94	11.81	11.81	19.69	7.87	11.81	19.69	11.81	11.81	11.81	11.81	11.81	3.94

SAMPLE NO	242401	242402	242403	242404	242405	242406	242407	242408	242409	242410	242411	242412	242413	242414	242415	242416	242417	242418	242419	242420	242421	242422	242423	242424	242425
	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual
PPM																									
Ba	290	430	370	1000	880	120	460	1100	630	60	690	520	580	630	1350	60	1100	680	230	210	630	500	640	140	200
Rb	22	22	14	60	50	4	12	210	40	4	134	6	12	46	118	6	128	32	14	6	30	50	40	4	20
Th	6.2	5.6	3.8	5.2	5.8	14.8	1.7	15.4	3.4	3.6	15.4	3.6	1.9	6.6	19.0	6.2	16.4	6.4	5.4	3.6	7.4	5.8	7.2	7.2	8.8
K	10266	8929	5452	29408	25351	2362	3765	71255	7657	616	48697	3606	6333	18077	42693	1094	42962	13227	4204	2514	18619	24280	20793	1600	7572
Nb	6	6	2	4	12	8	4	12	10	12	10	8	2	6	12	12	10	6	14	2	6	6	6	4	6
La	16.8	18.8	11.8	10.4	18.2	15.4	11.0	5.2	44.8	18.8	23.0	16.4	6.6	18.2	24.6	23.2	15.0	12.8	22.4	10.8	15.8	13.8	17.2	11.8	22.4
Ce	41.8	44.8	30.6	27.2	38.2	40.2	26.6	16.2	55.4	46.0	55.8	42.6	18.6	46.2	75.8	56.8	39.2	33.0	53.8	28.8	38.0	35.4	42.4	27.0	49.6
Sr	60	150	190	<10	20	50	230	10	90	90	<10	50	240	110	30	180	20	140	180	110	120	90	90	160	110
Nd	20.2	21.8	15.8	12.6	18.0	20.4	14.0	8.4	46.0	26.4	22.8	24.8	10.2	21.6	25.0	29.0	19.8	14.8	27.4	15.2	16.0	17.0	19.0	12.0	17.8
P	133	620	662	401	372	133	630	89	1124	1065	88	1084	648	132	88	885	88	355	1017	705	221	220	220	266	177
Sm	4.2	4.6	3.6	3.4	4.4	4.6	3.4	2.8	9.4	6.0	4.6	6.4	2.8	4.6	5.4	6.6	5.0	3.4	6.2	3.8	3.4	3.8	4.2	2.4	2.8
Zr	480	210	220	180	280	140	110	150	160	170	130	180	80	190	150	240	110	170	190	110	170	170	170	620	140
Ti	1520	2982	4363	2449	2106	305	5440	427	11899	11574	547	10543	4639	1270	485	8631	364	2009	9416	4783	1575	1875	1870	1825	1337
Tb	0.6	0.7	0.6	0.5	0.7	0.6	0.6	0.6	1.6	1.1	0.6	1.1	0.4	0.6	0.6	1.2	0.6	0.5	1.1	0.6	0.5	0.6	0.6	0.4	0.3
Y	18.2	21.2	18.6	15.4	28.2	16.0	17.2	15.0	57.4	34.6	14.8	36.0	12.8	16.8	17.2	37.8	13.2	15.4	34.4	19.2	14.0	18.6	18.4	12.8	7.2
Yb	2.2	2.4	2.0	1.9	4.6	2.0	1.7	2.8	4.4	3.4	2.0	3.6	1.5	2.0	2.4	3.8	1.5	2.0	3.4	2.2	1.8	2.2	2.2	1.9	1.1

SAMPLE NO	242401	242402	242403	242404	242405	242406	242407	242408	242409	242410	242411	242412
Fld Name	Dac dyke	Dacite	And flow	Rhy hill	Rhyolitic	Rhyolite	And flow	Rhyolite	Dolerite	Dolerite	Rhyolite	Dolerite?
Form'n	in PCF	dyke	TCF	in SW	v-clastic	MWV	TCF	MWV	dyke	dyke	MWV	Bas-andes
PPM	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB
Ba	46.0	68.3	58.7	158.7	139.7	19.0	73.0	174.6	100.0	9.5	109.5	82.5
Rb	39.3	39.3	25.0	107.1	89.3	7.1	21.4	375.0	71.4	7.1	239.3	10.7
Th	51.7	46.7	31.7	43.3	48.3	123.3	14.2	128.3	28.3	30.0	128.3	30.0
K	17.1	14.9	9.1	49.0	42.3	3.9	6.3	118.8	12.8	1.0	81.2	6.0
Nb	2.6	2.6	0.9	1.7	5.2	3.4	1.7	5.2	4.3	5.2	4.3	3.4
La	6.7	7.5	4.7	4.2	7.3	6.2	4.4	2.1	17.9	7.5	9.2	6.6
Ce	5.6	6.0	4.1	3.6	5.1	5.4	3.5	2.2	7.4	6.1	7.4	5.7
Sr	0.7	1.7	2.1	0.0	0.2	0.6	2.6	0.1	1.0	1.0	0.0	0.6
Nd	2.8	3.0	2.2	1.7	2.5	2.8	1.9	1.2	6.3	3.6	3.1	3.4
P	0.3	1.2	1.3	0.8	0.7	0.3	1.2	0.2	2.2	2.1	0.2	2.1
Sm	1.6	1.7	1.4	1.3	1.7	1.7	1.3	1.1	3.6	2.3	1.7	2.4
Zr	6.5	2.8	3.0	2.4	3.8	1.9	1.5	2.0	2.2	2.3	1.8	2.4
Ti	0.2	0.4	0.6	0.3	0.3	0.0	0.7	0.1	1.6	1.5	0.1	1.4
Tb	0.9	1.0	0.9	0.7	1.0	0.9	0.9	0.9	2.4	1.6	0.9	1.6
Y	0.6	0.8	0.7	0.6	1.0	0.6	0.6	0.5	2.0	1.2	0.5	1.3
Yb	0.7	0.8	0.7	0.6	1.5	0.7	0.6	0.9	1.4	1.1	0.7	1.2

SAMPLE NO	242413	242414	242415	242416	242417	242418	242419	242420	242421	242422	242423	242424	242425
Fld Name	And flow	Qtz dac	Dac dyke	And dyke	Rhyolite	QED	And dyke	And flow	QED	Mass dac	Qtz dac	QED	BlackJack
Form'n	TCF	in PCF	in PCF	in PCF	MWV	dyke	in MWV	TCF	dyke	??TCF	dyke	dyke	G-diorite
PPM	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB	N-MORB
Ba	92.1	100.0	214.3	9.5	174.6	107.9	36.5	33.3	100.0	79.4	101.6	22.2	31.7
Rb	21.4	82.1	210.7	10.7	228.6	57.1	25.0	10.7	53.6	89.3	71.4	7.1	35.7
Th	15.8	55.0	158.3	51.7	136.7	53.3	45.0	30.0	61.7	48.3	60.0	60.0	73.3
K	10.6	30.1	71.2	1.8	71.6	22.0	7.0	4.2	31.0	40.5	34.7	2.7	12.6
Nb	0.9	2.6	5.2	5.2	4.3	2.6	6.0	0.9	2.6	2.6	2.6	1.7	2.6
La	2.6	7.3	9.8	9.3	6.0	5.1	9.0	4.3	6.3	5.5	6.9	4.7	9.0
Ce	2.5	6.2	10.1	7.6	5.2	4.4	7.2	3.8	5.1	4.7	5.7	3.6	6.6
Sr	2.7	1.2	0.3	2.0	0.2	1.6	2.0	1.2	1.3	1.0	1.0	1.8	1.2
Nd	1.4	3.0	3.4	4.0	2.7	2.0	3.8	2.1	2.2	2.3	2.6	1.6	2.4
P	1.3	0.3	0.2	1.7	0.2	0.7	2.0	1.4	0.4	0.4	0.4	0.5	0.3
Sm	1.1	1.7	2.1	2.5	1.9	1.3	2.4	1.4	1.3	1.4	1.6	0.9	1.1
Zr	1.1	2.6	2.0	3.2	1.5	2.3	2.6	1.5	2.3	2.3	2.3	8.4	1.9
Ti	0.6	0.2	0.1	1.1	0.0	0.3	1.2	0.6	0.2	0.2	0.2	0.2	0.2
Tb	0.6	0.9	0.9	1.8	0.9	0.7	1.6	0.9	0.7	0.9	0.9	0.6	0.4
Y	0.5	0.6	0.6	1.4	0.5	0.6	1.2	0.7	0.5	0.7	0.7	0.5	0.3
Yb	0.5	0.7	0.8	1.2	0.5	0.7	1.1	0.7	0.6	0.7	0.7	0.6	0.4

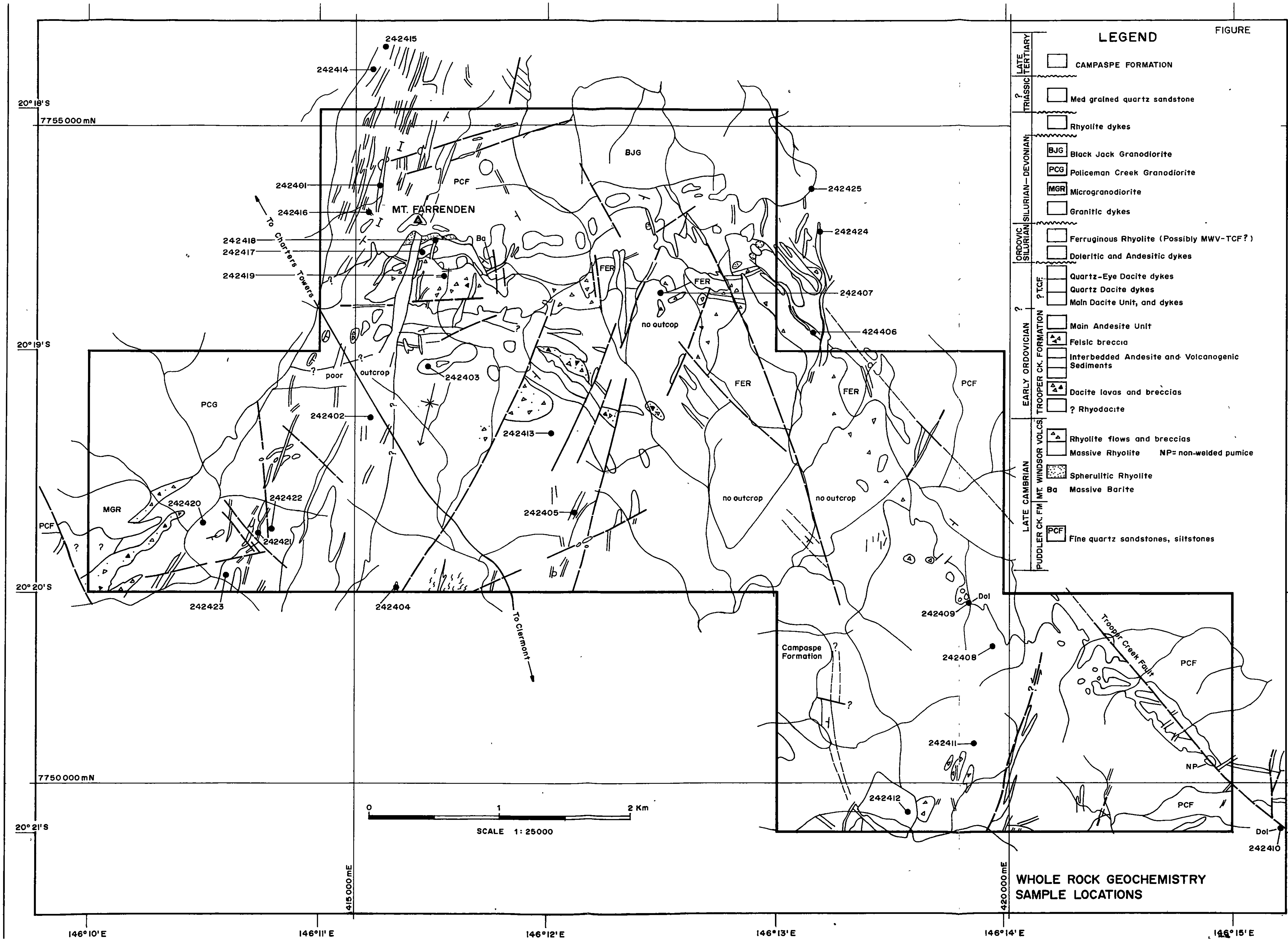
FIGURE
LEGEND
LATE TERTIARY
CAMPASPE FORMATION
? TRIASSIC
Med grained quartz sandstone
SILURIAN—DEVONIAN
Rhyolite dykes
BJG Black Jack Granodiorite
PCG Policeman Creek Granodiorite
MGR Microgranodiorite
Granitic dykes
ORDOVIC SILURIAN
Ferruginous Rhyolite (Possibly MWV-TCF?)
Doleritic and Andesitic dykes
? EARLY ORDOVICIAN
TROOPER CK. FORMATION
?T.C.F.
Quartz-Eye Dacite dykes
Quartz Dacite dykes
Main Dacite Unit, and dykes
Main Andesite Unit
Felsic breccia
Interbedded Andesite and Volcanogenic Sediments
Dacite lavas and breccias
? Rhyodacite
LATE CAMBRIAN
MT. WINDSOR VOLCS.
Rhyolite flows and breccias
Massive Rhyolite NP= non-welded pumice
Spherulitic Rhyolite
Ba Massive Barite
PUDDLER CK. FM
PCF Fine quartz sandstones, siltstones
WHOLE ROCK GEOCHEMISTRY
SAMPLE LOCATIONS
MT. FARRENDEN
To Charters Towers
To Clermont
Troooper Creek Fault
Campaspe Formation
poor outcrop
no outcop
no outcrop
BJG
PCF
PCG
MGR
FER
Ba
Dol
NP
242401
242402
242403
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242425
424406
20°18'S
20°19'S
20°20'S
20°21'S
7755000mN
7750000mN
415000mE
420000mE
146°10'E
146°11'E
146°12'E
146°13'E
146°14'E
146°15'E
0 1 2 Km
SCALE 1: 25000