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MAGNETIC AND RADIOMETRIC PROPERTIES OF THE MOUNT LEYSHON INTRUSIVE COMPLEX, THE TUCKERS IGNEOUS COMPLEX AND THE RAVENSWOOD BATHOLITH

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TABLE OF CONTENTS

List of Tables

List of Figures

Executive Summary

This report presents petrophysical data from the palaeomagnetic, rock magnetic and radiometric studies carried out on the Charters Towers 1:250,000 Sheet area by D. Clark and B. Dickson as part of P425/426, incorporating results from the earlier AMIRA projects P96C and P263. The magnetic, density and radiometric properties of the samples collected for this study have been incorporated into petrophysical databases which have been supplied in various formats to all sponsors of P425.

The petrophysical databases are essential tools for interpreting the geophysical signatures of the Mount Leyshon Intrusive Complex (MLIC) and the Tuckers Igneous Complex (TIC). Clear relationships between physical properties and lithology, alteration and rock age have been established, which can add insights to the geological interpretations as well as constrain geophysical models.

The oxidised nature of the magmas that generated the TIC and MLIC account for the moderate to high susceptibilities of the mafic to moderately felsic igneous rocks of these systems, provided they are relatively unaltered. Only the most felsic and fractionated phases (aplites and rhyolites) are weakly magnetic, due to exhaustion of magnetite. Emplacement of the MLIC and TIC occurred during a period of reverse geomagnetic polarity and the magnetic signatures of both complexes include pronounced negative magnetic anomalies, where the rocks are capable of retaining a strong and stable remanent magnetisation that dominates the induced component. The magnetic low rimming the TIC is due to thermal resetting of the remanence carried by the Heathfield West Tonalite and similar country rocks.

Alteration has a pronounced effect on physical properties. Potassic (biotite) alteration is associated with enhanced susceptibilities and reversed remanent magnetisation. At Mount Leyshon, the reversed remanence associated with early potassic alteration of metasedimentary and dolerite country rocks is largely responsible for the prominent magnetic low over the SW portion of the MLIC. Phyllic, albitic and intense propylitic alteration are magnetite destructive within the MLIC, reducing susceptibilities to paramagnetic levels and also substantially reducing rock densities.

Radiometric and chemical determinations of radioelement contents of rock samples have yielded similar results. Future sampling for radiometric properties should therefore concentrate on weathered rocks and soils to examine the effects of weathering and transport on radioelement concentrations.

Radiometric properties from the Mount Leyshon area suggest that the Mount Leyshon mineralisation should be distinguished by a zone depleted in eU and eTh, with K being particularly depleted in alunite zones within the breccia but enriched in zones adjacent to the mineralisation. To the south the Wallaby Porphyry should be prominent with its high K content.

1. Introduction

This study represents part of AMIRA P425, "Magmatic and Hydrothermal Evolution of Intrusive-related Gold Deposits." A second AMIRA project P426, "Magnetic Petrology applied to Geological Interpretation of Magnetic Surveys" is linked to the geochemical/geological project. All sponsors of P426 are also sponsors of P425 and the results from P425 are available to P426 to aid an integrated approach to exploration for intrusive-related gold deposits.

This report presents petrophysical data from the palaeomagnetic, rock magnetic and radiometric studies carried out on the Charters Towers 1:250,000 Sheet area by D. Clark and B. Dickson as part of P425/426, incorporating results from the earlier AMIRA projects P96C and P263. The magnetic, density and radiometric properties of the samples collected for this study have been incorporated into a petrophysical database which has been supplied to all sponsors of P425. Sampling was carried out in consultation and collaboration with G. Morrison, P. Blevin and S. Beams, who are responsible for geological and geochemical aspects of P425. Interpretations of magnetic and radiometric data, incorporating the petrophysical properties, are the subject of a separate report, which will be distributed to sponsors of P426.

2. Geology of the Ravenswood Batholith

The Ravenswood Batholith of northeast Queensland is the major element of the Lolworth-Ravenswood Province (Fig. 1), which is bounded to the north by the Broken River Province, with Precambrian inliers to the northwest (Georgetown) and south (Anakie). The Drummond and Bowen Basins define the southern boundary. The northernmost New England Fold Belt forms the eastern boundary of the province. Laing (1994) has discussed the structural framework of northeastern Queensland in detail and, in particular, has placed the Lolworth-Ravenswood Province in its regional tectonic context.

It has often been noted that the E-W elongation and tectonic grain of the Lolworth-Ravenswood Province appear discordant to the general meridional trends of the Tasman Orogen. The E-W trend of the Seventy Mile Range Group is a particularly striking feature. The overall shape of the province, 450 km E-W by 150 km N-S, is partly a result of exposure, as it is bounded to the south by the Devonian-Carboniferous Drummond Basin and Permo-Triassic Bowen Basin. The Lolworth-Ravenswood Province lies at the northern end of the Thompson Fold Belt. Its relationship with the Broken River Province of the Hodgkinson Fold Belt is uncertain. The Thompson Fold Belt and Lachlan Fold Belt have broadly similar geological histories and it seems likely that the lower crust beneath the Thompson Fold Belt resembles that underlying the Lachlan Fold Belt and that the tectonic setting of the two orogens is similar.

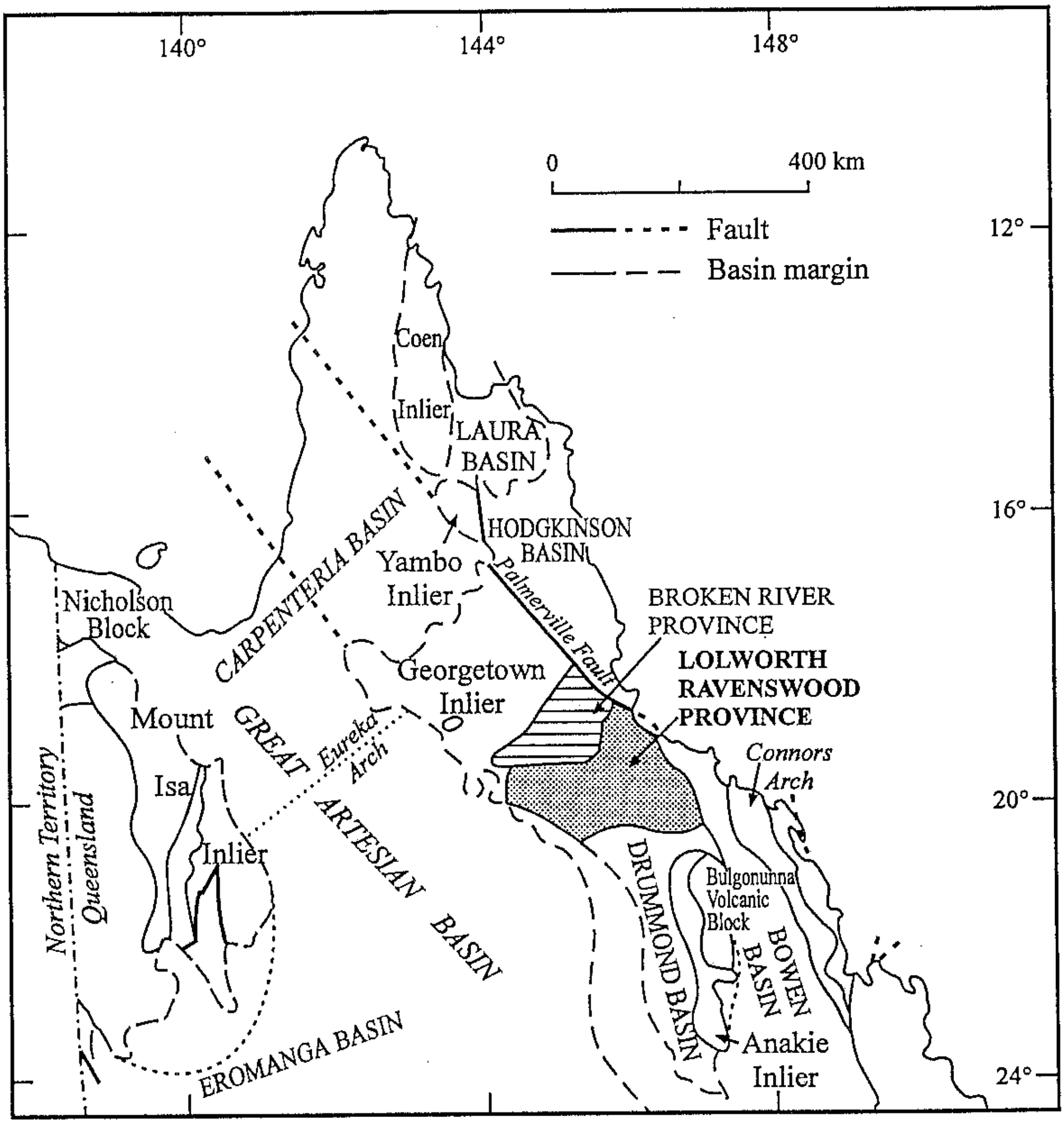


Fig. 1. Regional geological setting of the Lolworth-Ravenswood Province (after Hutton *et* al., 1994)

Analysis of regional gravity and magnetic data confirms the distinct tectonic grain of the upper crust in the Lolworth-Ravenswood Province (Wellman, 1995) and allows province boundaries in the Tasman Orogen to be accurately located even when obscured by younger cover. According to Wellman's (1995) analysis, the Lolworth-Ravenswood Province exhibits elongate E-W, large amplitude, long wavelength magnetic and gravity anomalies. The eastern portion of the province, adjacent to the northernmost New England Fold Belt, is a "reworked zone" of enhanced magnetisation, with an associated gravity anomaly, that exhibits predominantly meridional trends of the younger belt to the east. The Broken River Province in the north is characterised by relatively weak and inconsistent trends, both short and long wavelength, compared to the Lolworth-Ravenswood Province. The eastern margin of the Precambrian Australian Craton, which bounds the Lolworth-Ravenswood Province to the west, is characterised by a wide zone of reworking with NE trends, reflecting the dominant fabric of the western Thompson Fold Belt. South of the Lolworth-Ravenswood Province, however, the trends of the eastern Thompson Fold Belt are predominantly NNW. Wellman (1995) interprets the geophysical patterns as indicating progressive eastward growth and cratonisation of the Tasman Orogen between the Cambrian and the Carboniferous. The geophysical trends were acquired at the time of deformation and cratonisation, which in the case of the Lolworth-Ravenswood Province occurred in the Ordovician.

Within the Lolworth-Ravenswood Province the Ravenswood Batholith is the easternmost of three batholiths, with the Reedy Springs Batholith in the west and the Lolworth Batholith in the centre. Hutton et al. (1996) discuss the implications of radiogenic isotope systematics for the basement of the Lolworth-Ravenswood Province. The ages of Siluro-Devonian granitoids in all three batholiths and in the Georgetown Province are similar. Inherited zircons in the Reedy Springs Batholith have similar ages to those reported for the Georgetown Inlier (~2000 Ma and 1500-1550 Ma) and isotopic data suggest similar protolith compositions for the granites of the two areas. The Lolworth Batholith has similar inherited zircon ages, but in addition exhibits a population with ages of ~1100 Ma. The isotopic data suggest that the source material of the Ravenswood Batholith has an age corresponding to the latter "Grenvillian" magmatic event. Thus the Lolworth Ravenswood Province is underlain by Proterozoic continental crust, varying in composition from west to east, but with clear links to the Australian craton. This supports an autochthonous development for the Lolworth-Ravenswood Province from the mid-Silurian or earlier.

Early mapping of the study areas has been described by Wyatt et al. (1971) and Clarke (1971). Hutton et al. (1994) have recently summarised the geology of the Ravenswood Batholith. The southeast portion of the batholith, within the Ravenswood 1:100,000 Sheet area, is analysed in detail by Rienks et al. (1995). Peters (1987) gives a detailed discussion of the geology of the Charters Towers Goldfield. Figure 2 shows the regional geological setting of the Ravenswood Batholith. As defined by Hutton et al. (1990), the Ravenswood Batholith comprises granitoids and gabbroic rocks that range in age from the Early Ordovician to the Middle Devonian. These authors assign the later episode of magmatism, in the Middle Carboniferous to the Late Permian, to the North Queensland Volcanic and Plutonic Province of Day et al. (1983). For this reason the Permo-Carboniferous igneous rocks have been termed "post-batholithic".

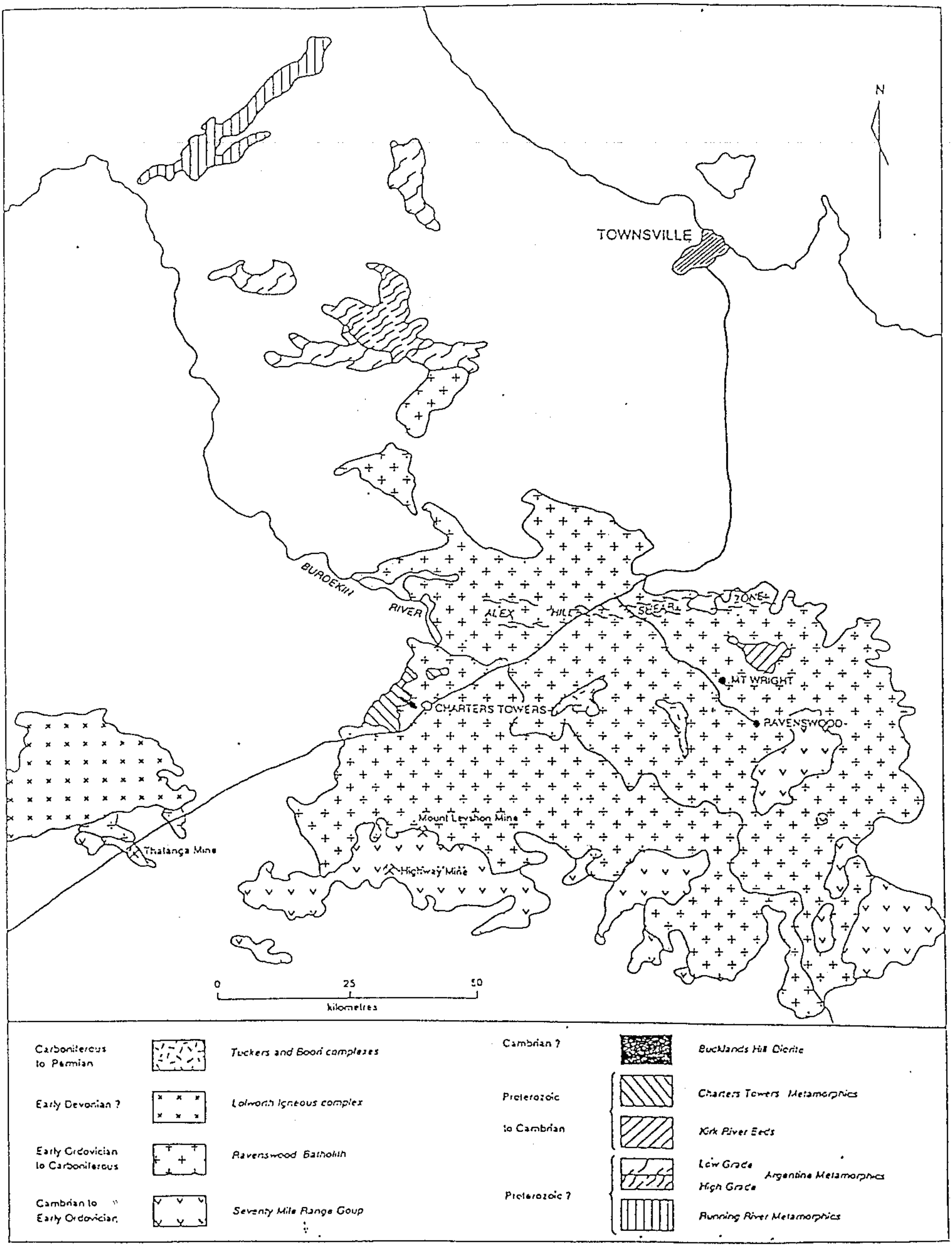


Fig. 2. Regional geological setting of the Ravenswood Batholith (after Hutton *et al.*, 1994)

In the south, the granitoids intrude the Late Cambrian to Early Ordovician Seventy Mile Range Group, which comprises the Puddler Creek Formation, Mount Windsor Volcanics, Trooper Creek Formation and the Rollston Range Formation. In the central and northern parts of the batholith the granitoids intrude metamorphic rocks (Charters Towers Metamorphics, Argentine Metamorphics and Kirk River Beds), which occur as isolated large rafts.

The oldest granitoids in the batholith have been dated at 490 ± 6 Ma. A major phase of magmatism ensued, with emplacement of medium- to high-K, calc-alkaline, predominantly monzogranitic to granodioritic intrusions between the Early and Middle Ordovician (490-460 Ma). The felsic intrusions tend to be biotite-dominant in the west and hornblende-dominant in the Ravenswood area, to the east. Mafic rocks are intimately associated with the Early to Middle Ordovician granitoids. In some cases, these rocks are inferred to represent gabbroic plutons coeval with the more felsic intrusions. Other mafic bodies, however, may represent roof pendants and screens of older rocks. Peters (1987) assigned many of the dioritic to gabbroic bodies to "pre-Ordovician" intrusions within the Charters Towers Group, which consists of metapelitic schists, quartzites and calc-silicate rocks of the Charters Towers Metamorphics, together with undifferentiated basement complex. The metamorphic rocks are interlayered with gabbros and diorites. Metamorphic grade in the Charters Towers Metamorphics ranges from greenschist (chlorite + muscovite) grade to upper amphibolite grade (sillimanite zone).

North to northeasterly-striking microdiorite or dolerite dykes intrude the batholith and country rocks in the Charters Towers town area and are particularly common in the southern part of the Charters Towers 1:100,000 Sheet area, where they occur within the Seventy Mile Range Group and Ordovician granitoids, but are rare within Siluro-Devonian granitoids.

The batholith was deformed between the Middle Ordovician and the mid-Silurian, producing major shear zones and local development of foliations. A second major episode of granitoid intrusion occurred between the mid-Silurian and the Middle Devonian (426-382 Ma), with the majority of ages falling between 418 Ma and 406 Ma. The Siluro-Devonian granitoids are predominantly medium- to high-K, calc-alkaline, hornblende-biotite granodiorites to tonalites and constitute ~60% of the outcrop area of the batholith. These granitoids are generally not foliated or recrystallised, but some local ductile deformation zones occur. Some of the mafic intrusions into the Batholith are also thought to be of Siluro-Devonian age.

The granitoids of all generations within the batholith are overwhelmingly oxidised, magnetite-series I-type granitoids. Magnetic properties of rocks from the Ravenswood Batholith and its country rocks are discussed by Lackie et al. (1992), Haywood (1993), Hutton et al. (1994) and Tenison Woods and Rienks (1992).

The mesothermal granite-hosted mineralisation at Charters Towers post-dates the 425 Ma Millchester Creek Tonalite, which is the youngest of the host intrusives. The veins are cut by Early Carboniferous (346 ± 10 Ma; Webb, 1969) porphyritic trachyte dykes. Morrison (1988) dated hydrothermal muscovite from the alteration around the veins as 397-416 Ma. Charters Towers-type mineralisation occurs in several areas scattered throughout the Ravenswood Batholith, indicating that the mineralising event was of regional extent.

Carboniferous to Permian igneous rocks make up about 6% of the batholith, predominantly in the east and southeast. This study concentrates mainly on a prominent ENE-trending corridor of Permo-Carboniferous igneous rocks, the Leyshon-Tuckers corridor (Figs.3,4).

3. Geology of the Permo-Carboniferous Leyshon-Tuckers Corridor

Figure 3 shows the geological context of the Leyshon-Tuckers corridor and Fig. 4 shows the geology in more detail. The Leyshon-Tuckers Corridor (or Mount Leyshon Corridor) is defined by an alignment of several Permo-Carboniferous intrusions and volcanic complexes (Morrison et al., 1988; Hartley et al., 1989), including Mount Leyshon, the Fenian Diorite, Matthews Pinnacle, Seventy Mile Range, the Cornishman Complex and the Tuckers Igneous Complex (TIC). The northern boundary of this corridor coincides with the linear northern margin of the TIC. This feature is visible in regional aeromagnetic images, but is less prominent than a slightly more easterly-trending lineament, the Boori lineament (Tenison-Woods and Rienks, 1992), that passes through Mount Leyshon and Rishton, intersecting the southern end of the TIC and the northern end of the Boori Complex, which is an Early Permian intrusive complex that is very similar in character to the coeval TIC.

The geophysical expression of the Boori lineament is a zone of ENE-trending magnetic anomalies, particularly elongated zones of relative magnetic lows within magnetic granitoids. These magnetic lows are attributable to reversed remanent magnetisation. Reverse polarity is characteristic of stable remanence acquired during the Kiaman Reverse Superchron, which lasted from ~310 Ma to ~250 Ma.

The Leyshon-Tuckers Corridor/Boori Lineament may represent an ancient basement structure that has localised emplacement of Permo-Carboniferous intrusions and associated mineralising fluids. Gold mineralisation of differing ages occurs within these zones at Mount Leyshon (Permian), the Hadleigh Castle/Disraeli/Rishton (?Devonian or ?Permian) group of mines and, to the SW, at Highway/Reward (Ordovician).

4. Geology of the Mount Leyshon Intrusive Complex

The most recent summary of the geology of the Mount Leyshon Intrusive Complex (MLIC) has been produced by Morrison and Blevin (1995). That report builds on earlier detailed studies of Morrison et al. (1988), Wormald et al. (1991), Wormald (1993) and Orr (1994, 1995), as well as incorporating the new data acquired as part of AMIRA P425. A recent paper (Sexton et al., 1995) also summarises the geology and analyses the magnetic signature of the complex. Figure 5 shows a plan view of the geology of the Mount Leyshon Intrusive Complex and Fig. 6 shows schematic relationships between breccia units and intrusives, as well as the distribution of alteration types. The chart in Fig. 7 summarises the timing relationships between breccia phases, intrusive phases, alteration and mineralisation. Mount Leyshon is the largest current gold producer in Australia (233,491 oz. in 1994).

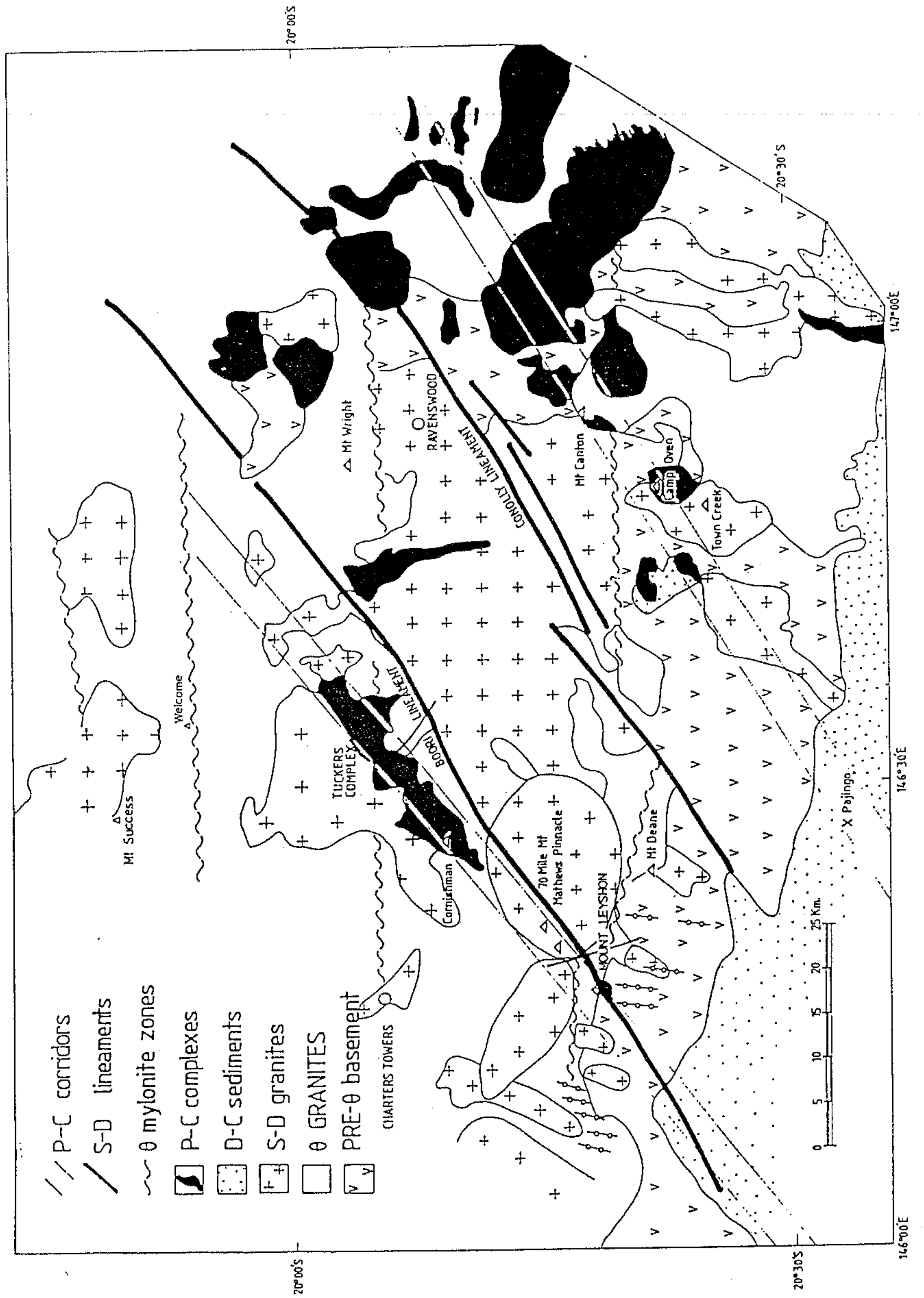
The Mount Leyshon Intrusive Complex is localised by:

- the ENE-trending Permo-Carboniferous (Leyshon-Tuckers) igneous corridor
- a boundary of Siluro-Devonian igneous domains
- a Siluro-Devonian magnetic lineament
- a NNE-trending ?Silurian dolerite dyke swarm
- an Ordovician stitching pluton (the Fenian Granite) on a major E-W basement contact.

These structures suggest the potential for deeply sourced magma to exploit a combination of crustal-scale features. Comparable corridors, lineaments and igneous bodies occur within the Ravenswood Batholith, some of which host breccia gold occurrences.

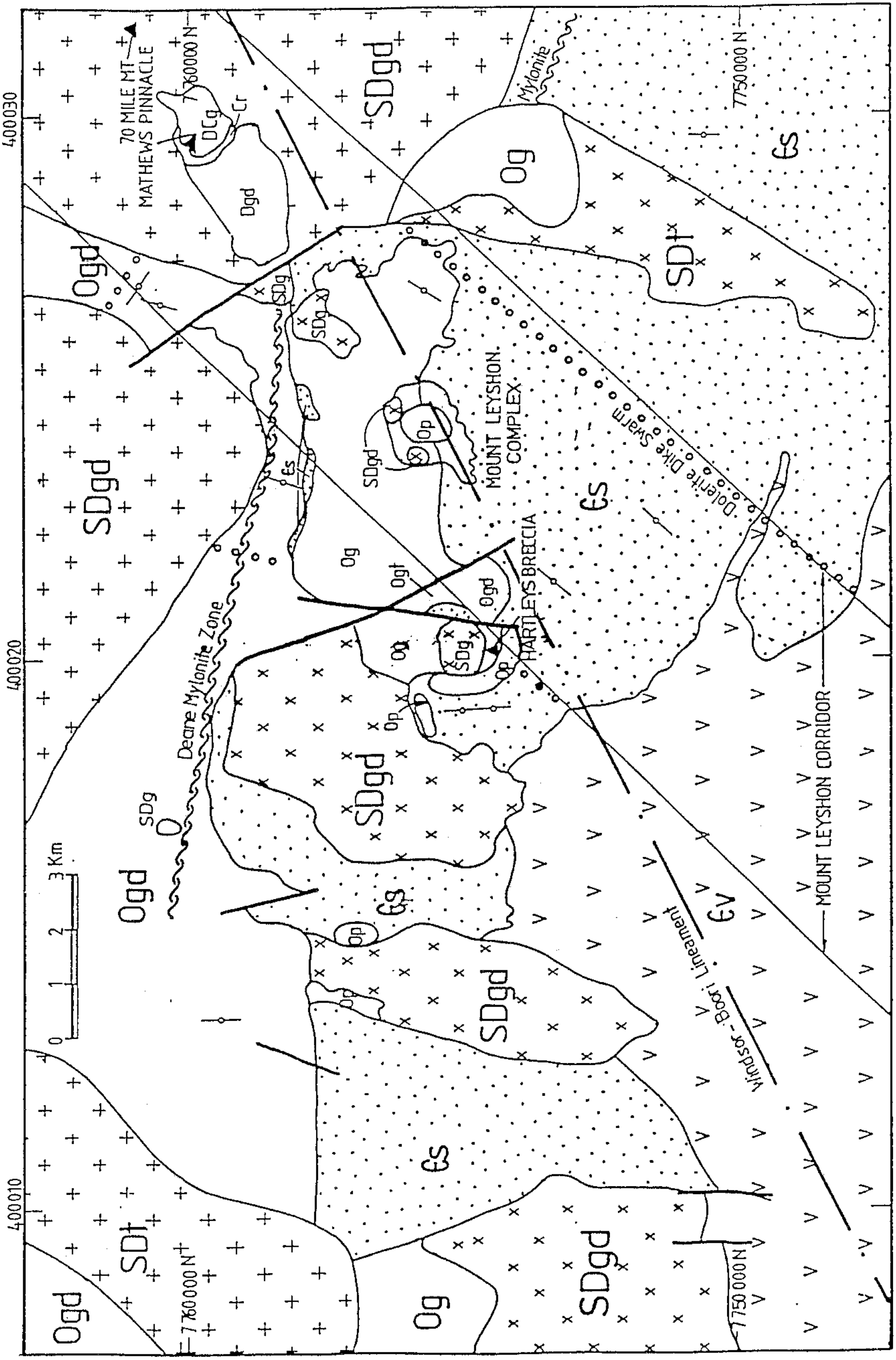
The Mount Leyshon Intrusive Complex straddles the contact between the Ordovician Fenian Granite and the Late Cambrian Puddler Creek Formation. The Fenian Granite is a medium-grained, pink to red, biotite granite. Although it is an oxidised I-type, magnetite-series granite, the amount of magnetite is restricted by the felsic composition to ≤ 0.1% by volume. The magnetic response of this granite is accordingly rather subdued. In the Mount Leyshon area the Puddler Creek Formation consists of siltstones, sandstones and greywackes, metamporphosed to greenschist facies. Both the Fenian Granite and the Puddler Creek Formation are extensively intruded by dolerite dykes. Mount Leyshon lies within, and truncates, a NE-trending swarm of these dykes. The age of the dykes is poorly constrained (Ordovician to Devonian). Palaeomagnetic data from the samples collected for P425 indicate that two generations of dykes are present (Clark, 1996). The interpreted ages of the dyke sets are mid- to Late Silurian and Early Devonian. Clasts of Fenian Granite, Puddler Creek metasediments and dolerite dykes are abundant in the breccias of the Mount Leyshon Intrusive Complex. Within these breccias clasts of other country rocks are also found, indicating that the Mount Leyshon breccias have dredged a more complex basement geology than is exposed at the surface. These unexposed units include an Ordovician porphyritic rhyolite body, granodiorite comparable to nearby Siluro-Devonian granitoids, gneissic granodiorite similar to the Ordovician Schreibers Granodiorite and volcanic rocks that are similar to regional Ordovician or Carboniferous units.

The Mount Leyshon Intrusive Complex has undergone a complex history of magmatic, brecciation and hydrothermal events. Radiometric dating suggests that the evolution of the MLIC occurred between 292 Ma and 280 Ma, i.e. in the earliest Permian. Wormald et al. (1991) and Wormald (1993) subdivided the complex into three main elements: "basement", "Main Pipe Breccia" and an "interactive breccia/magma sequence". The earliest breccia event formed the Main Pipe Breccia, which is the most volumetrically significant unit within the MLIC. The Main Pipe Breccia is a predominantly matrix-supported breccia consisting of clasts and matrix derived from basement lithologies.



Simplified geology of the Ravenswood Batholith based on Hutton *et al* (1994) showing Ordovician, Siluro-Devonian and Permo-Carboniferous lineaments and breccia hosted gold occurrences.

Fig. 3. Geological context of the Leyshon-Tuckers corridor



Map of basement geology and major structural features in the vicinity of Mount Leyshon. Lithologic units based on Hutton (1992) modified by mapping of Mount Leyshon Gold Mines and S.D. Beams (pers comm, 1994). Interpreted basement geology shown within Mount Leyshon Complex.

Fig. 4. Geology of the Leyshon-Tuckers Corridor

The interactive breccia/magma sequence includes four recognised intrusive events (porphyry phases I-IV) and three breccia phases: the Mount Leyshon Breccia, the Mount Hope Breccia, and late-stage brecciation that resulted in two distinct facies, "tuffisite dykes" and "breccia dykes". The latter are termed "Dog's Breakfast Breccias" by Morrison and Blevin (1995). Early Dykes are associated with porphyry phase I. The Mount Leyshon Breccia is a predominantly clast-supported breccia that consists of rebrecciated Main Pipe Breccia, basement lithologies and early intrusive phases. It contains significant void space and hosts most of the gold mineralisation. The Mount Leyshon and Mount Hope Breccias postdate porphyry phase I, predate porphyry phase IV and appear to be closely associated with porphyry phase III. A suite of Late Dykes emanates from the main porphyry phase IV body. Tuffisites and "Dog's Breakfast Breccia" are produced by fluid phase separation during emplacement of the Late Dykes. A porphyritic basalt dyke, formerly termed "trachyandesite", post-dates mineralisation and is the latest intrusion within the complex. Compositions of the main porphyry and dyke phases range from hornblende-bearing trachytes/rhyolites to felsic rhyolites.

Wormald (1993) recognised 16 stages of mineral paragenesis. Stage I predates formation of the Main Pipe Breccia, stages II to V postdate the Main Pipe Breccia but occurred before the formation of the Mount Leyshon Breccia, and stages VI to XVI postdate the Mount Leyshon Breccia. Hydrothermal alteration is intimately related to breccia and porphyry evolution.

Early potassic (secondary biotite-magnetite) alteration is extensively developed in basement metasediments and dolerite dykes and in the Main Pipe Breccia. This alteration is pervasive in the SW portion of the complex, but was either less well-developed, or has been overprinted by intense phyllic alteration, in the NE half of the complex. The distribution of the early potassic and propylitic alterations in the Main Pipe Breccia suggests the presence of an intrusion underlying the western part of the complex. Cross-cutting and overprinting relationships allow this alteration to be linked to Wormald's (1993) paragenetic stage IIIa.

The effect of the early potassic alteration on the metasediments and dolerites is to produce a substantial increase in susceptibility associated with fine-grained magnetite accompanying biotite, together with granular magnetite in quartz-magnetite veinlets (Sexton et al., 1995). In the dolerites primary pyroxene is replaced by biotite, liberating iron which is precipitated as magnetite. This secondary magnetite supplements primary ilmeno-magnetite in the dolerites. The unaltered metasediments contain negligible amounts of detrital magnetic minerals, so the substantial susceptibility of altered metasediments is almost entirely attributable to secondary magnetite. The secondary magnetite is sufficiently fine-grained to carry intense, stable remanent magnetisation with reversed polarity (Lackie et al., 1991; Sexton et al., 1995; Clark, 1995). Sexton et al. (1995) present evidence that the prominent magnetic low associated with the Mount Leyshon Intrusive Complex is largely attributable to secondary magnetite associated with this potassic alteration. In the Fenian Granite the alteration assemblage associated with the early potassic alteration is K-feldspar-sericite, with little secondary magnetite. However, dolerites within the granite locally develop secondary magnetite.

Phyllic and potassic (K-feldspar) alteration associated with Early Dykes overprints early potassic and propylitic alterations in the fine Main Pipe Breccia. The Early Dykes and Mine Porphyry have pervasive phyllic alteration, which extends into the Mount Leyshon Breccia along zones of permeability. The Late Dykes exhibit complex internal textural and alteration zoning. The outer sparse and lath porphyry phases tend to have green propylitic (chlorite-sericite-pyrite) alteration, the normal porphyry phase has phyllic alteration and the crowded core has feldspathic (quartz-albite/K-feldspar-haematite) alteration. Chemical analyses have shown that abundances of relatively immobile elements in the igneous rocks have been little affected by alteration and even for mobile elements coherent fractionation trends are apparent (Blevin and Morrison, 1995). An exception is iron in the strongly propylitically altered dykes. FeO in these felsic rocks increases from the background level of $\leq 2\%$ up to 11% in the most altered samples.

Gold mineralisation is associated with mineral paragenetic stage XIV, coinciding with intrusion of the Late Dykes and occurs mainly in the Mount Leyshon Breccia and its partially rebrecciated host rocks, tuffisites and dog's breakfast breccias. Early Cu-Mo mineralisation is associated with K-feldspar-quartz alteration that accompanied emplacement of the Early Dykes and marginal phase of the Mine Porphyry.

5. Geology of the Tuckers Igneous Complex

The Tuckers Igneous Complex (TIC) is a T-shaped feature in outcrop plan (Fig. 8), with a NE-axis of 13.5 km, oriented parallel to the Leyshon-Tuckers Corridor, and a SE-oriented axis, 5 km in length. A small outlier occurs SE of the main complex, 1.5 km N of Hadleigh Castle. Earlier mapping of the TIC has been discussed by Clarke (1971) and Hutton et al. (1994). Detailed re-mapping of the TIC was carried out in 1994 by Simon Beams, as part of AMIRA P425 (Beams, 1994). This mapping was co-ordinated with the geochemical and palaeomagnetic/petrophysical sampling.

The mapping and petrological data gathered during P425 have established that the TIC is a nest of very hot, oxidised, melt-rich comagmatic intrusions, which evolved by fractional crystallisation at depth and were then intruded as batches with compositions ranging from dry mafic diorite and gabbro, through quartz monzodiorite to relatively quartz-poor, more fluid-rich granodiorite. Minor aplites are also present. There is also evidence of some internal zoning within intrusions, due to *in situ* differentiation. The early intrusions were so hot that they converted country rock granitoids at the contacts of the complex into anhydrous pyroxene hornfels. Fluids derived from these dehydration reactions, possibly mixed with magmatic fluids, moved farther out into the aureole, forming a secondary amphibole and biotite hornfels zone. Secondary magnetite was produced in both the pyroxene and biotite hornfelses. The alteration in the biotite hornfels zone is similar to the early potassic alteration at Mount Leyshon.

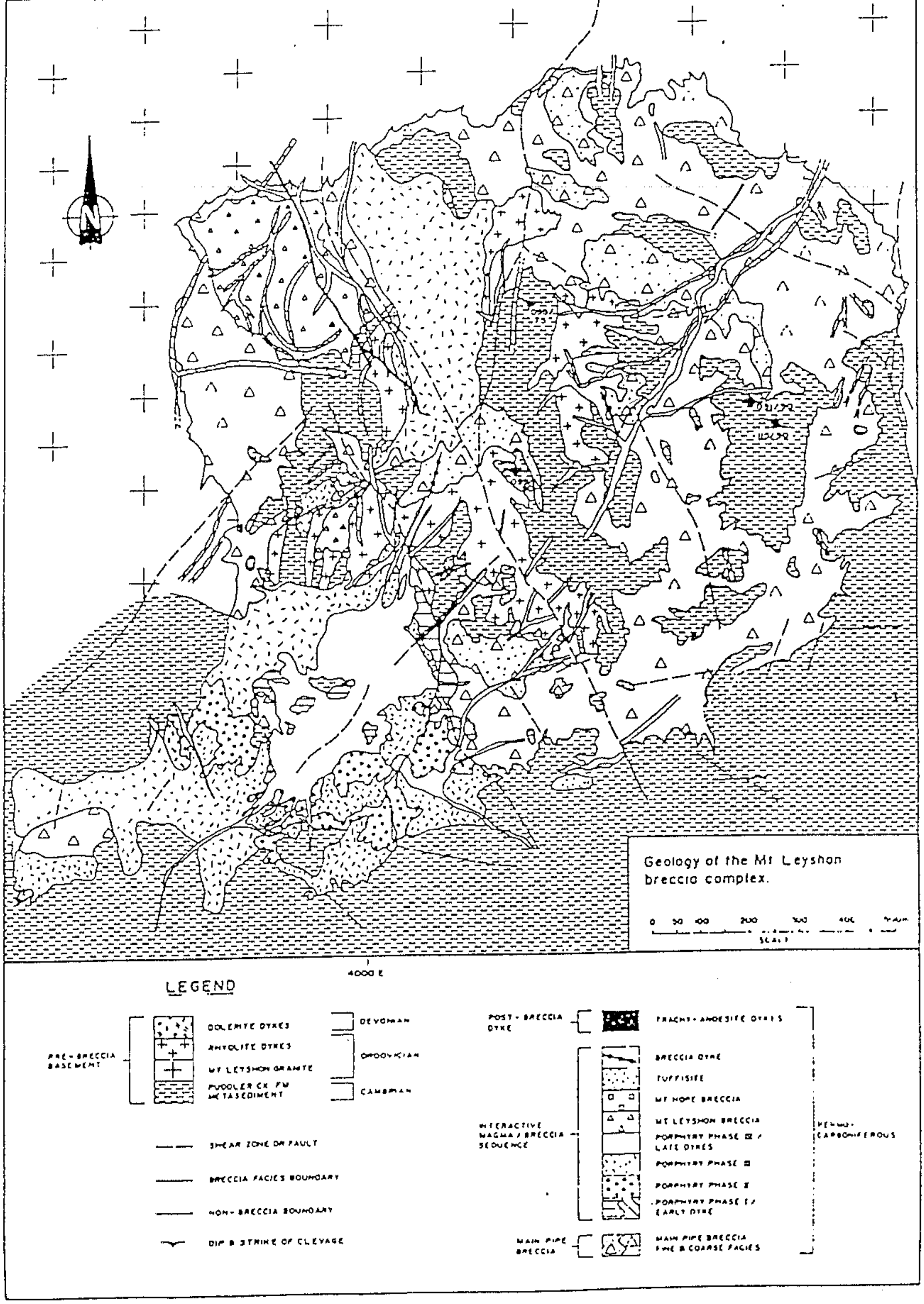
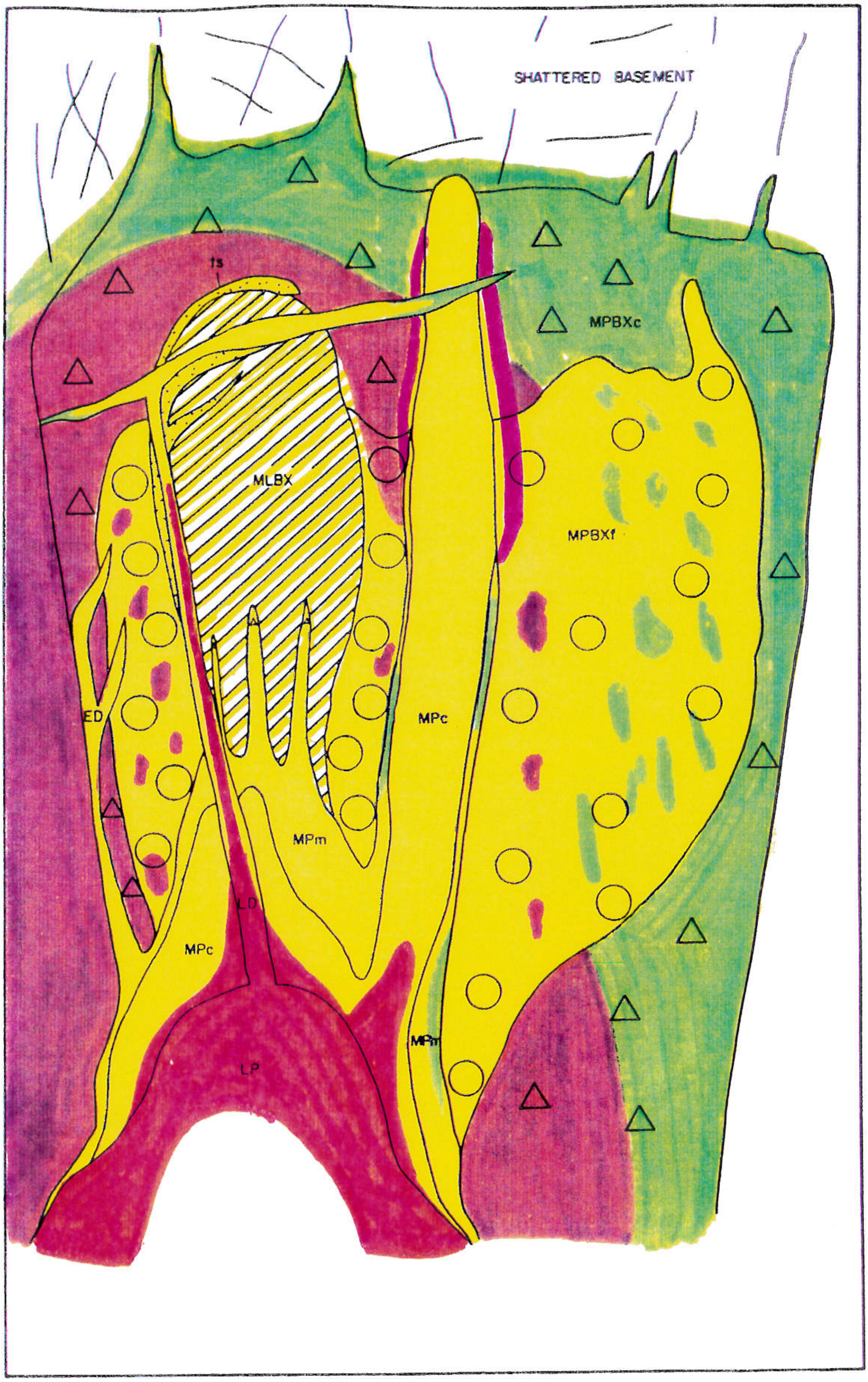
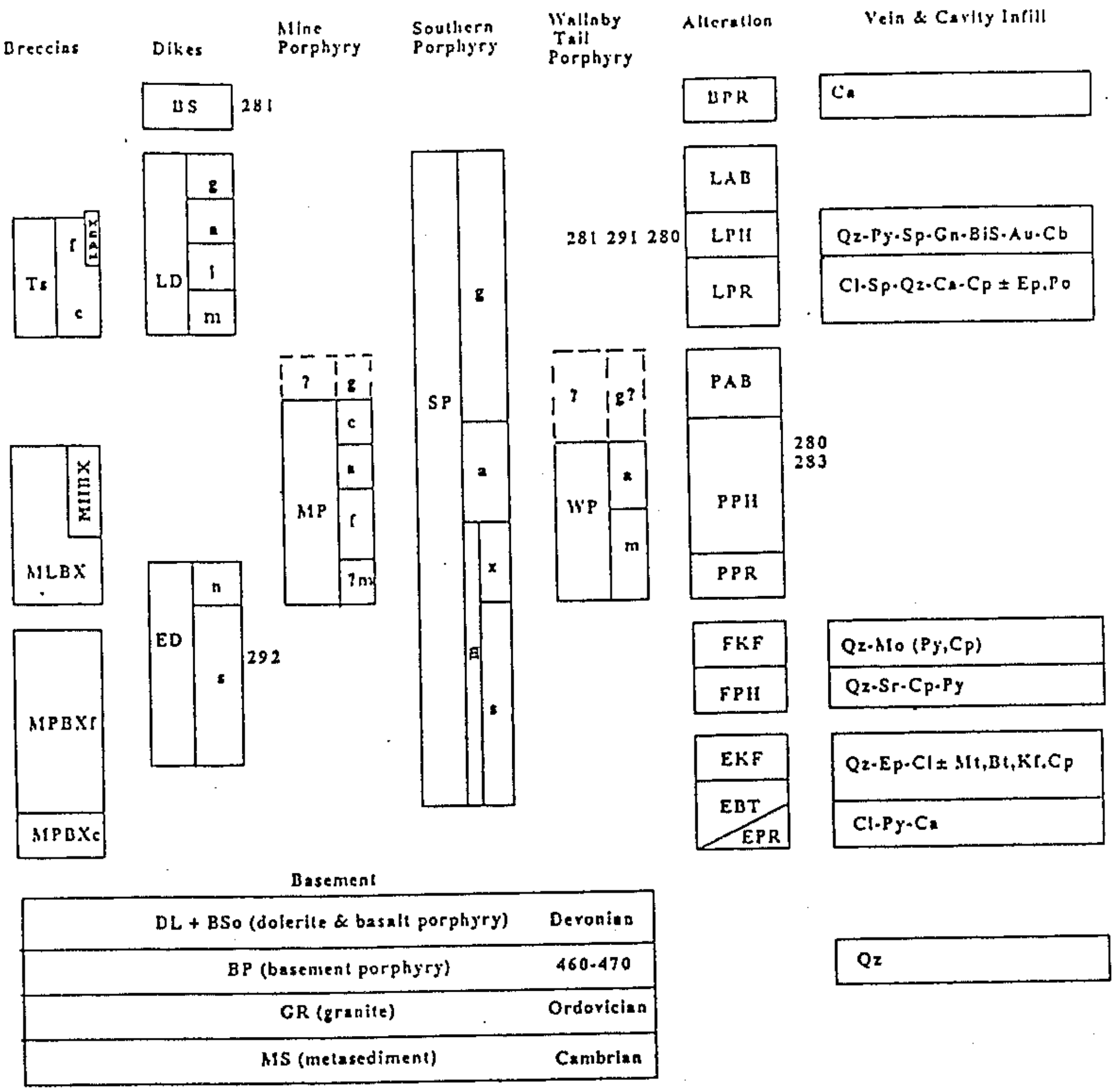


Fig. 5. Geology of the Mount Leyshon Intrusive Complex (Wormald *et al.*, 1991)

Fig. 6 (next page). Schematic relationships between breccia units and intrusives and distribution of alteration types within the Mount Leyshon Intrusive Complex (Morrison and Blevin, 1995).



Schematic relationships between breccia units and intrusives in the Mount Leyshon Complex and distribution of alteration types. Green = propylitic; brown = biotite; yellow = phyllic; pink = K-feldspar; orange = albitic.



Mount Leyshon Radiometric Ages on Rock-Alteration-Mineralisation Chart

Units

LDBX = Late dike related breccia
Ts = Tuffisite
MHBX = Mt Hope breccia
MLBX = Mt Leyshon breccia
MPBX = Main Pipe Breccia
BS = Basalt
LD = Late dike
ED = Early dikes
MP = Mine porphyry
SP = Southern porphyry
WP = Wallaby Tail porphyry

Alteration

AB = Albitic (albite-quartz)
BT = Biotitic (biotite-quartz ± K feldspar, actinolite, magnetite)
KF = K-feldspar-quartz ± sericite or epidote
PH = Phyllic (quartz-sericite-pyrite-carbonate)
PR = Propylitic (chlorite-sericite-carbonate ± epidote)

Lithologic Subunits

a = aphanitic
c in breccia = coarse clasts
c = crowded (>30% phenos)
f in breccia = fine clasts
f = fine phenos (<2mm)
g = granular matrix
l = lath phenos
m = marginal
n = normal
q = quartz
s = sparse (<10% phenos)
x = xenolithic

Infill

Au = gold
BiS = bismuth sulfides
Bt = biotite
Ca = calcite
Cb = carbonate
Cl = chlorite
Cp = chalcopyrite
Ep = epidote
Gn = galena
Kf = K-feldspar
Mo = molybdenite
Mt = magnetite
Po = pyrrhotite
Py = pyrite
Qz = quartz
Sp = sphalerite
Sr = sericite

Fig. 7. Timing relationships between breccia phases, intrusive phases, alteration and mineralisation in the Mount Leyshon Intrusive Complex.(Morrison and Blevin, 1995).

A prominent magnetic low rims much of the TIC. Lackie *et al.* (1992) showed that this feature is associated with reversed thermoremanent magnetisation in the country rocks, acquired during emplacement of the TIC. The magnetic low lies slightly outboard of the metasomatised contact aureole, suggesting that it reflects thermal resetting of the remanence carried by the country rocks.

Orthopyroxene, plagioclase and pigeonitic pyroxene were the dominant early crystallising phases. Olivine may have been present in the gabbros. Biotite and magnetite crystallised over a long time interval and range of composition. K-feldspar and quartz were interstitial phases that gradually became more abundant as magma composition evolved from quartz diorite/quartz monzodiorite to granodiorite. This evolution was accompanied by a build up in volatile content of the magma, which resulted in hydration of pyroxenes into biotite and hornblende in the granodiorites. Late stage exsolution of volatiles resulted in local development of quartz-sericite-pyrite alteration and breccia zones in the granodiorites. Sulphide-bearing miarolitic cavities in the aplites indicate that these last differentiates of the TIC crystallised under volatile-saturated conditions.

The mafic units of the TIC (quartz diorite and gabbro) occupy the margins of the complex, suggesting that the initial intrusion was of mafic composition, but was largely stoped out by the later intrusions. Inclusions of quartz diorite composition are common within the younger intrusions, supporting this hypothesis. The main quartz monzodiorite phase occurs as a relatively mafic rind around most of the complex and as a screen separating the two granodiorite masses.

Geochemical analyses have established that the intrusive phases of the TIC are comagmatic with each other and with the andesitic volcanics that abut the SW end of the complex (Blevin and Morrison, 1995). The andesites appear to be extrusive equivalents of the quartz diorites. The TIC has intruded its volcanic equivalents and has produced a biotite hornfels zone within the andesites adjacent to the margin of the complex. Andesitic and rhyolitic dyke swarms are associated with the TIC. They occur outside the TIC and are cut by the main intrusive phases. The andesite dykes are usually oriented parallel to the NW-SE trend that includes the short axis of the TIC and the intrusive outliers near the Hadleigh Castle mine.

A key finding of the geochemistry component of P425 is that the Mount Leyshon intrusive phases may be regarded as the felsic extension of the TIC suite. These coeval and chemically related magmas probably arise from an underlying batholith. The TIC and Mount Leyshon Intrusive Complex are both derived through fractional crystallisation from a calk-alkaline, oxidised, metaluminous, medium- to high-K magma.

Webb (1969) obtained a K-Ar age of 283 ± 9 Ma for the TIC, which is indistinguishable from the age of the Boori Complex (284 ± 9 Ma; Webb, 1969) and the MLIC (286 ± 6 Ma; see Fig. 7). The granodiorite phases have recently been precisely dated as part of AMIRA P425. The U-Pb age obtained is 287.4 ± 3.6 Ma, based on analysis of 27 zircons. This confirms that the TIC and the MLIC are coeval.

6. Sampling and Palaeomagnetic Methods

Magnetic Petrophysical Sampling

Magnetic petrophysical sampling of the Ravenswood Batholith, Tuckers Range and the Mount Leyshon area was carried out during previous AMIRA projects (Lackie *et al.*, 1991, 1992a). As part of P425/426 this sampling was supplemented by substantial collections of oriented samples from Tuckers Range, the Mount Leyshon area and a number of other localities within the Leyshon-Tuckers corridor (including the Cornishman Complex, Matthews Pinnacle, the Fenian Diorite and the Mountain View Granodiorite). Sampling of the MLIC included a large collection of partially oriented drill core samples, as well as additional samples from in and around the Mount Leyshon pit. An important objective of the sampling programme was to characterise the magnetic properties of the host rocks to the MLIC as a function of distance from the complex. This provides information on the effects of the alteration system on the magnetic petrology and magnetic signature of the MLIC and constrains ages of palaeomagnetic components carried by rocks of the complex, altered host rocks and unaltered country rocks. A similar study was also carried out for the TIC.

Appendix II lists the oriented samples collected during this AMIRA project, as well as all relevant samples collected for previous studies. Appendix III lists the drill core samples from Mount Leyshon, which provide supplementary information on the palaeomagnetic signature of the Mount Leyshon Intrusive Complex. Figure 9 shows the relative locations of Mount Leyshon, the TIC and Charters Towers with all relevant sampling sites plotted to provide an indication of areal coverage and sampling density. Numerous other samples collected for the earlier AMIRA project that are not discussed in this report are not plotted in Fig. 9, but Fig. 10 shows the regional geology of the Lolworth-Ravenswood Province, with earlier sampling localities indicated. Figures 11-12 show more detailed geology and previous sampling locations for the western Ravenswood Batholith and the Charters Towers town area respectively. Figure 13 plots all outcrop sampling localities around Mount Leyshon on a simplified geology and Fig. 14 shows all sampling sites in the Tuckers Range area, superimposed on the detailed geology map of the TIC that was produced for P425.

Magnetic Petrophysical Methods

Standard palaeomagnetic sampling methods and laboratory techniques were used for this study (Butler, 1992). Wherever possible a sun compass, as well as a magnetic compass, was used to determine strike directions. Several standard cylindrical palaeomagnetic specimens (25 mm diameter, 22mm height) were prepared from each sample. A CTF cryogenic (SQUID) magnetometer was used to measure remanent magnetisation, except for very intense remanences, which were measured using a modified Digico spinner fluxgate magnetometer interfaced to a PC. Remanence components of differing stabilities were distinguished using alternating field (AF) and

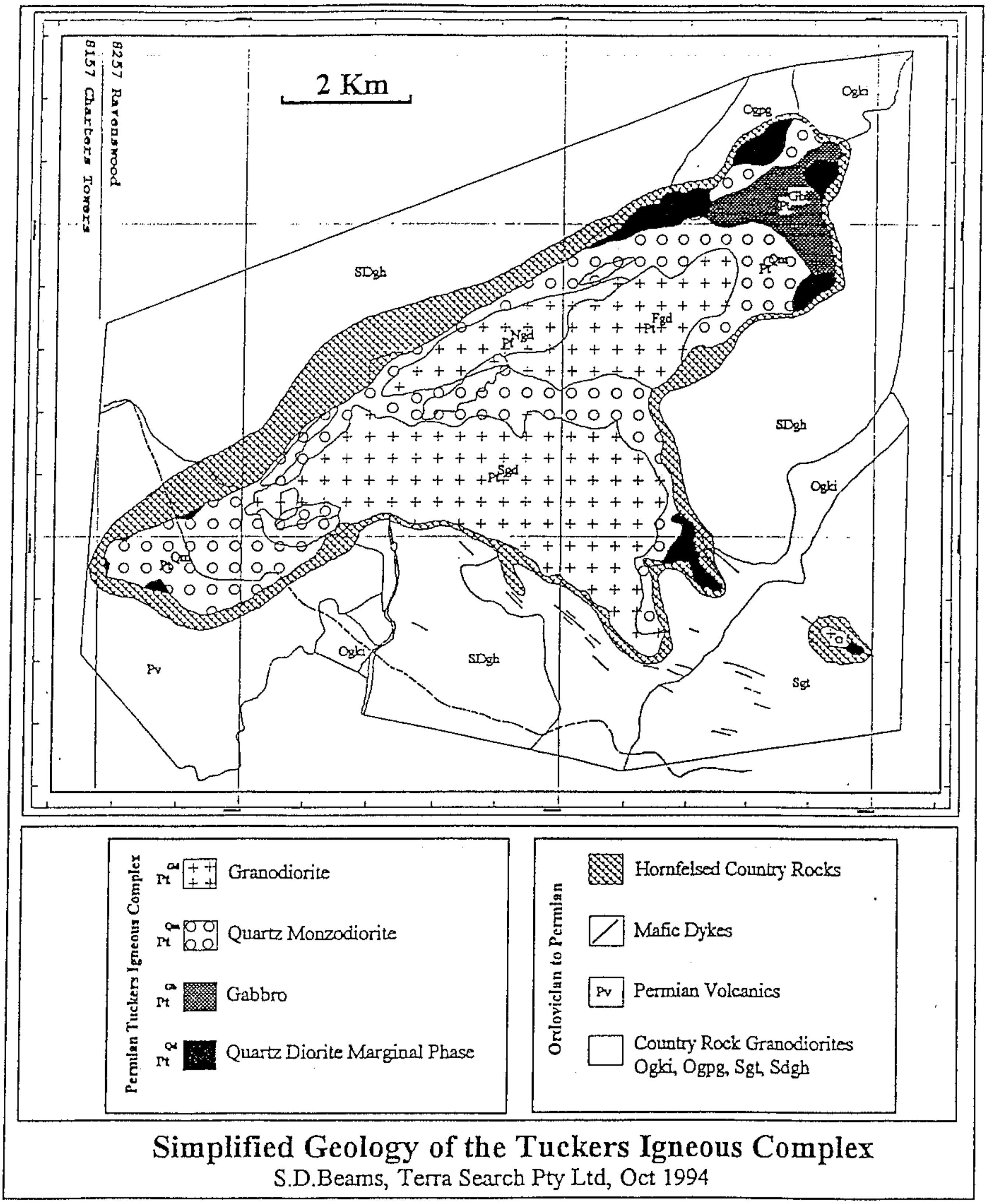


Fig. 8. Geology of the Tuckers Igneous Complex (after Beams, 1994).

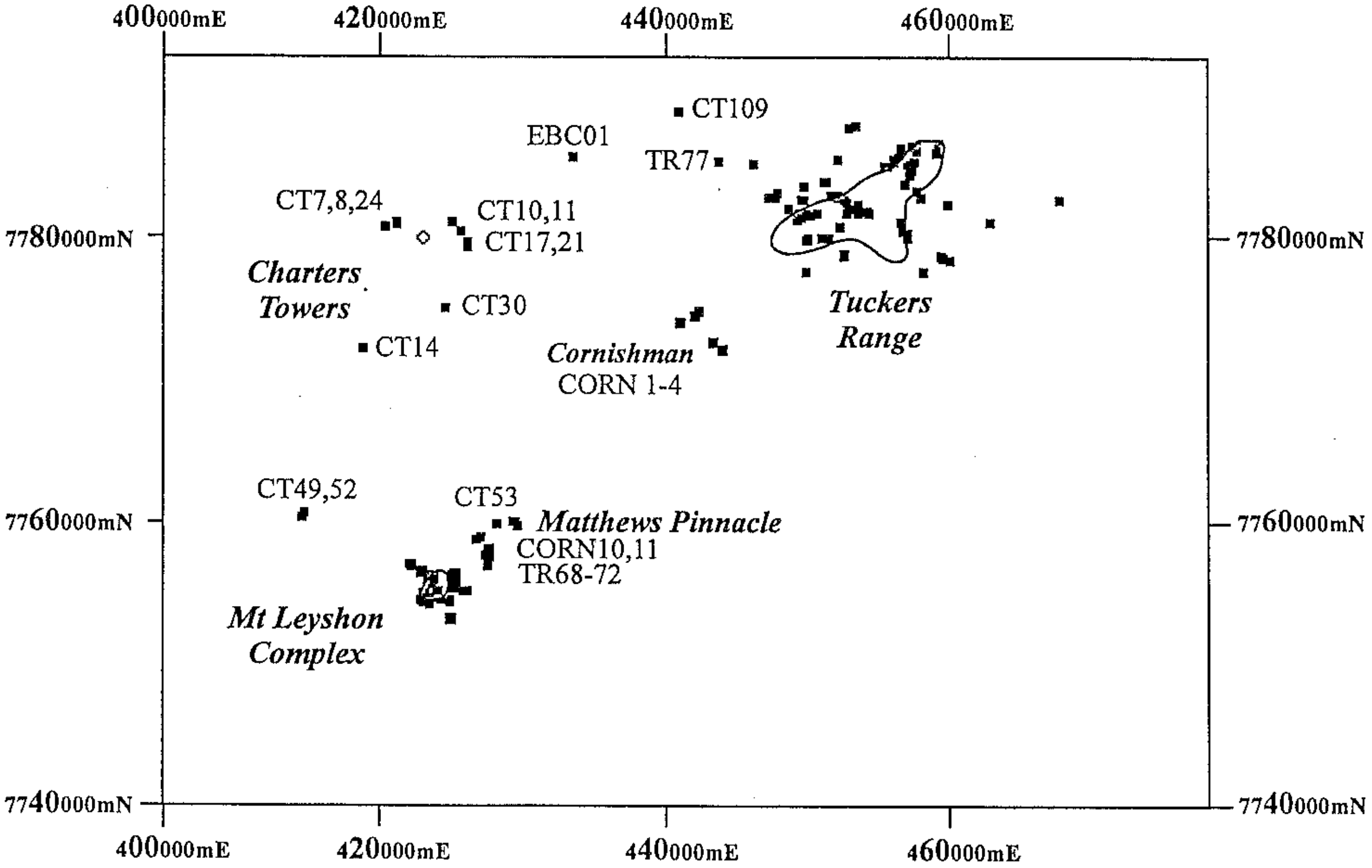


Fig. 9. Distribution of P425 sampling sites in the Leyshon/Tuckers Corridor

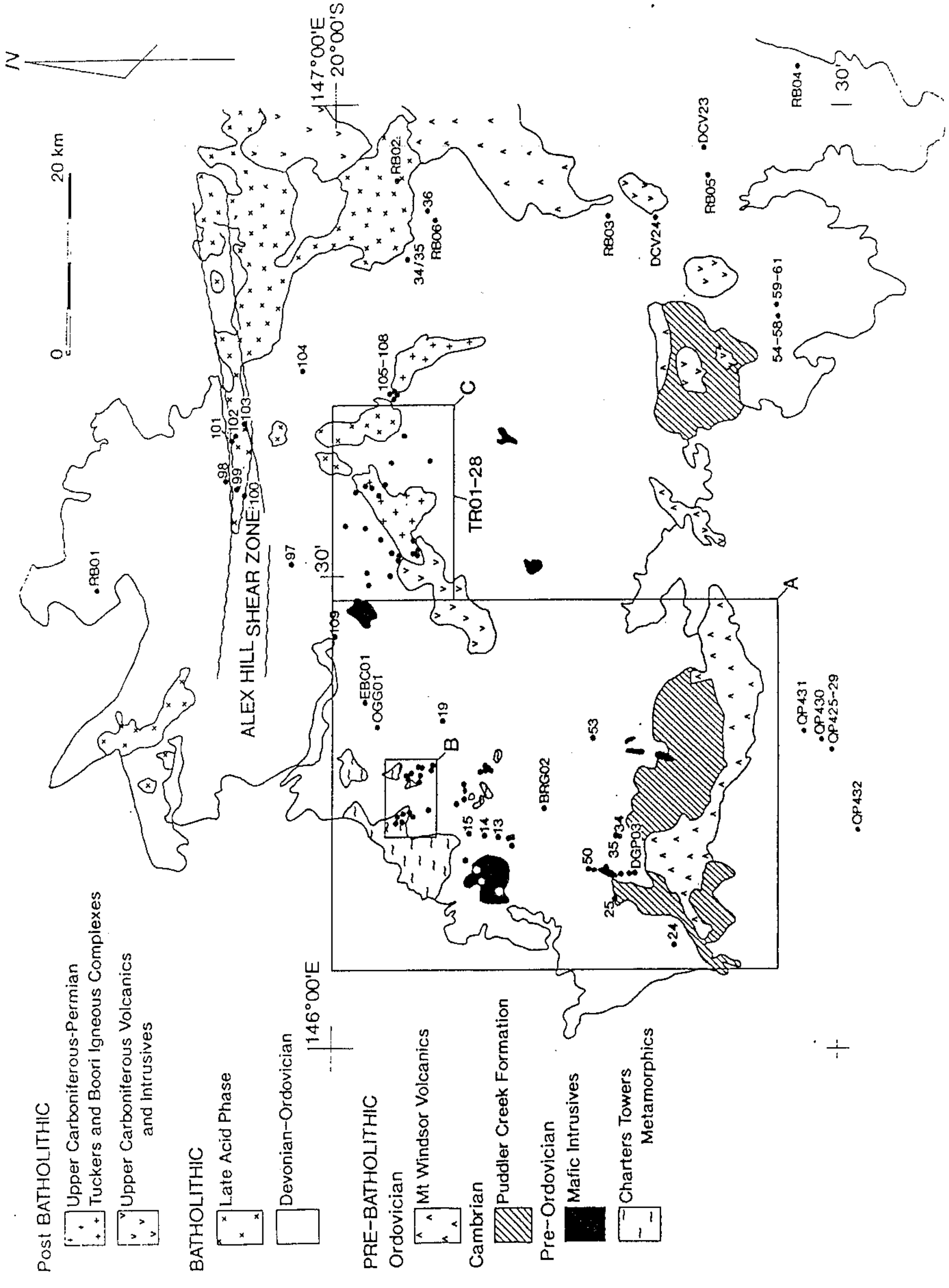


Fig. 10. Regional geology of the Lolworth-Ravenswood Province with magnetic petrophysical sampling sites of P96C

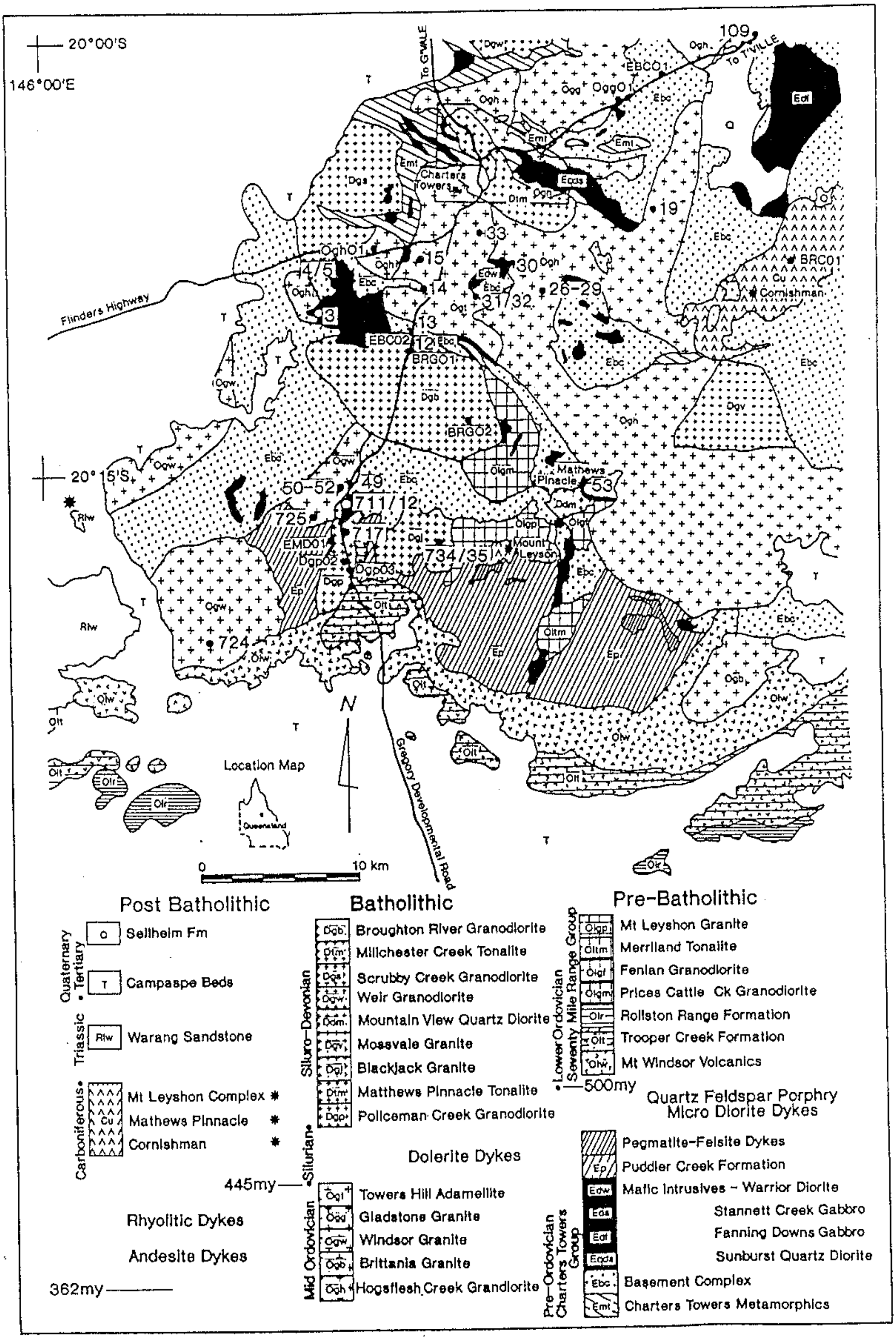


Fig. 11. Geology of the western Ravenswood Batholith with P96C sampling sites

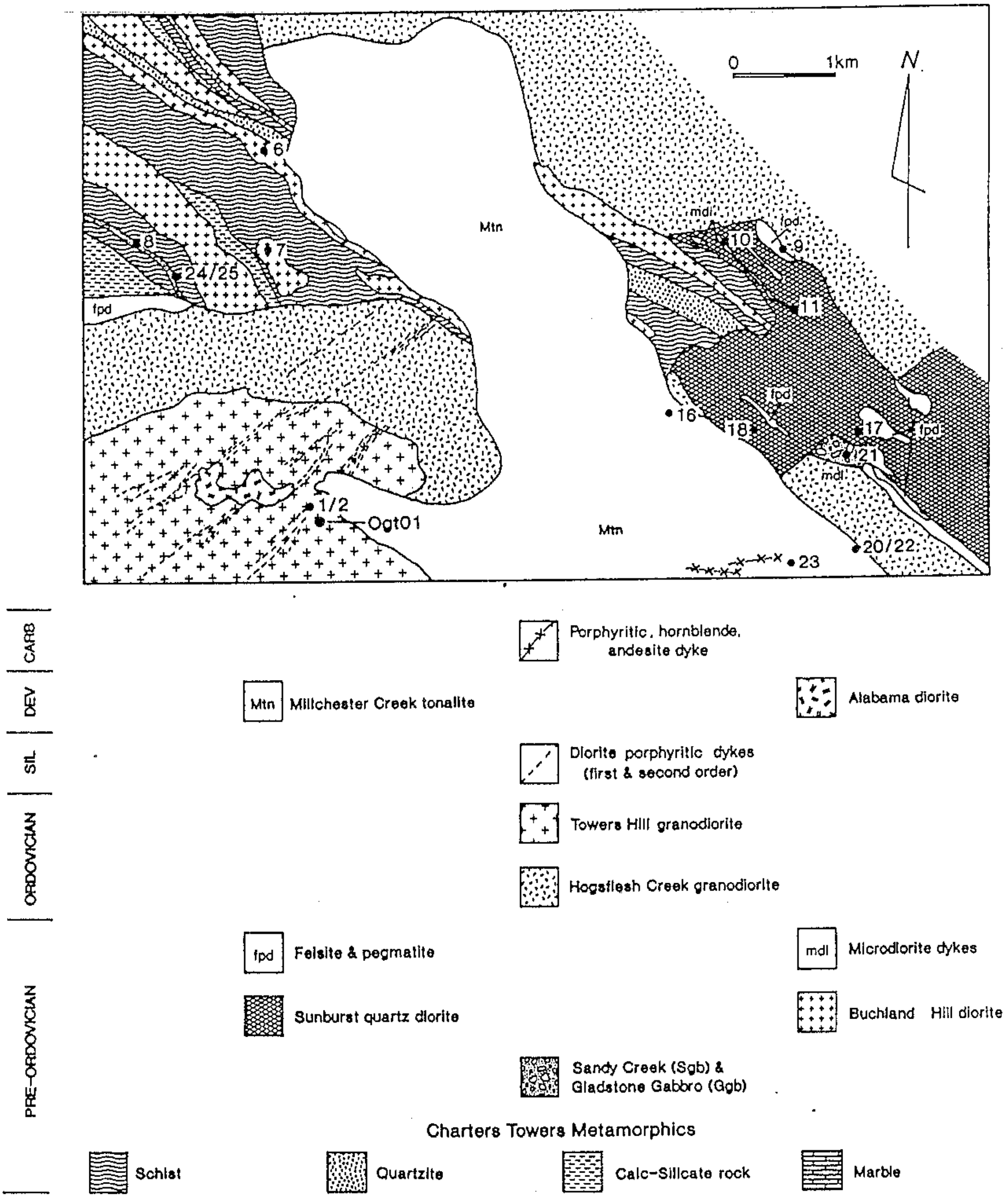


Fig. 12. Geology of the Charters Towers town area with P96C sampling sites

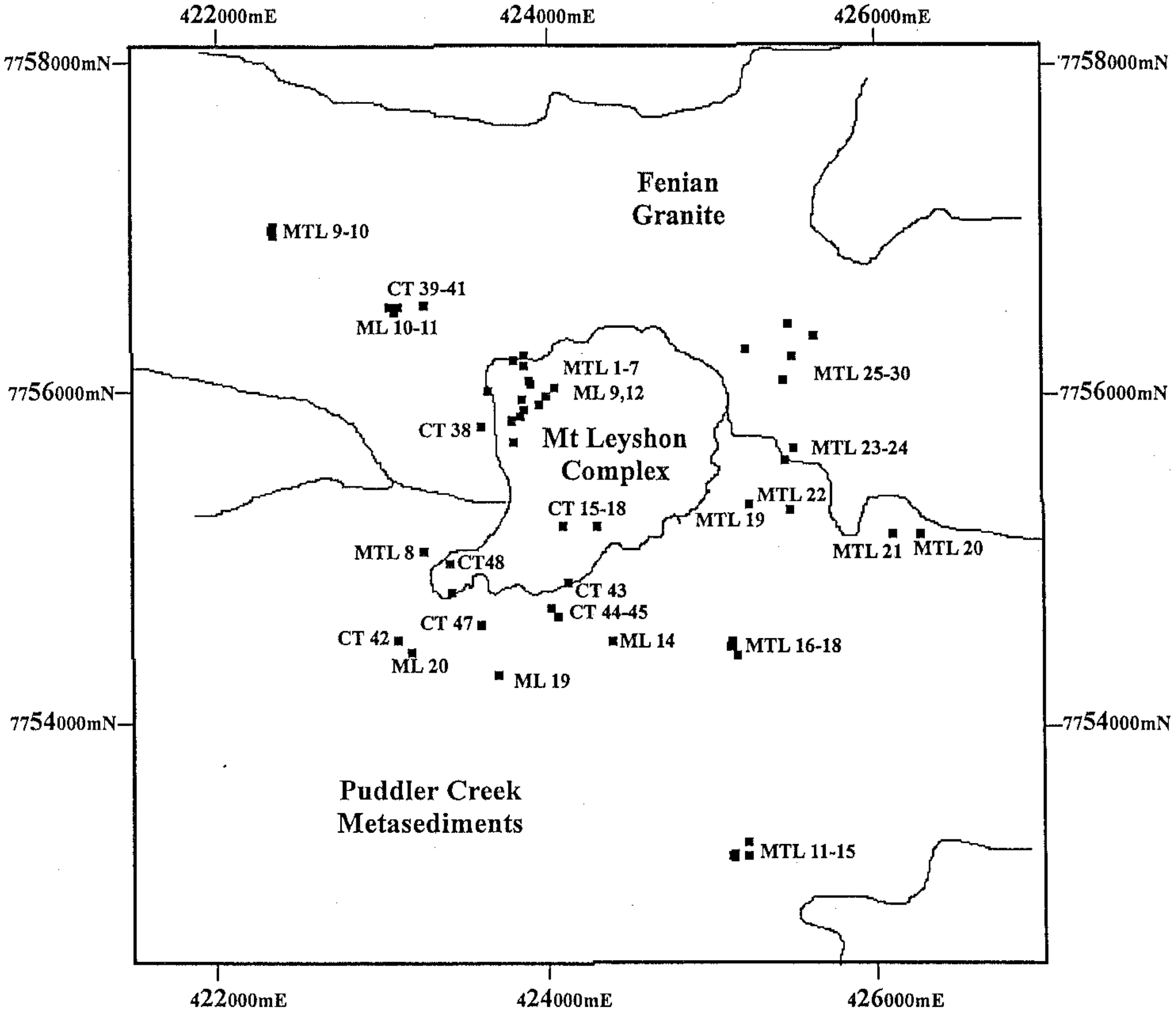


Fig. 13. Distribution of outcrop and pit sampling sites around Mount Leyshon

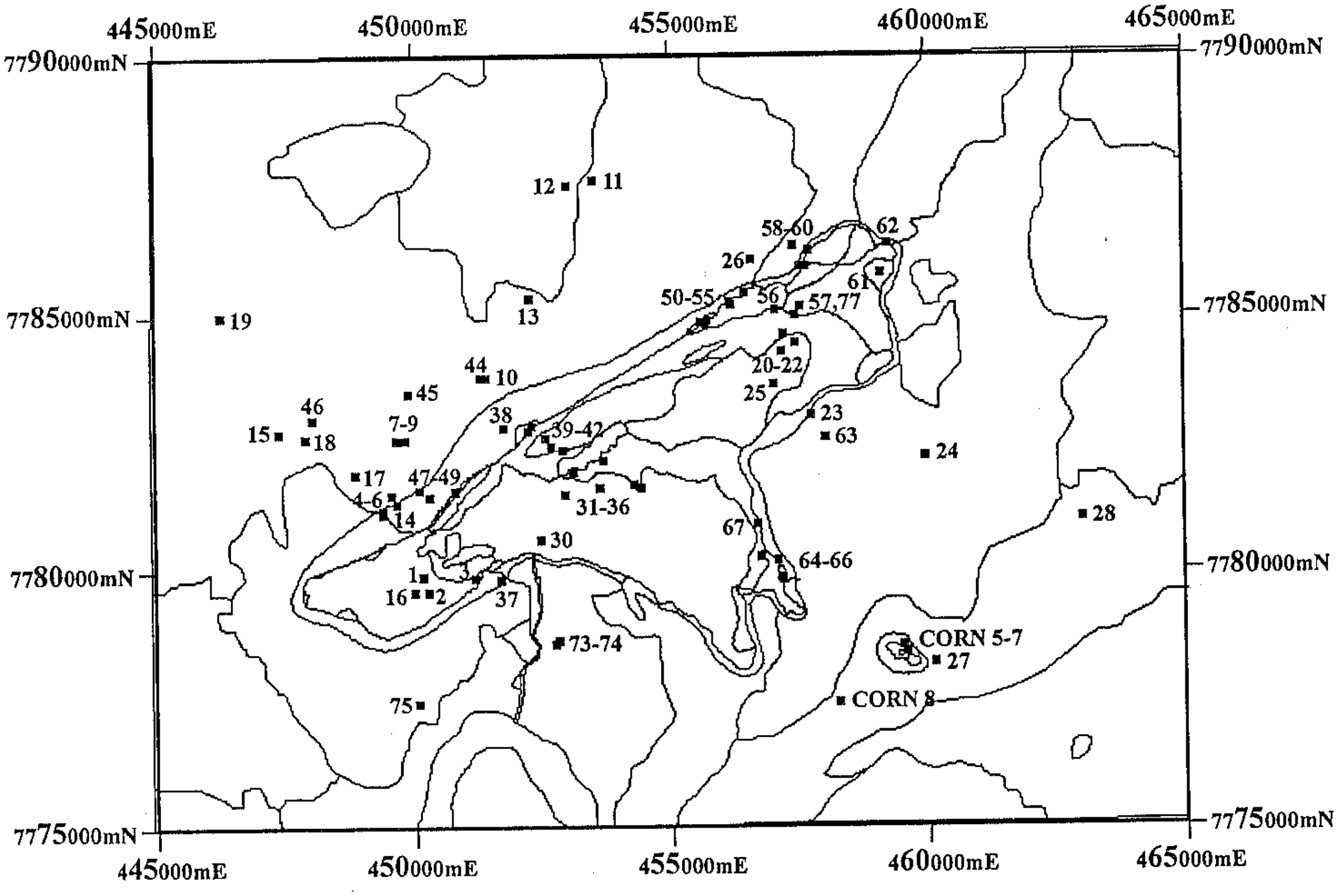


Fig. 14. Distribution of sampling sites around the TIC

thermal demagnetisation for all samples. Typically at least one specimen from each sample was treated using the standard palaeomagnetic demagnetisation treatments or combinations of treatments. Magnetic susceptibilities of palaeomagnetic specimens were measured using the CSIRO transformer susceptibility bridge (Ridley and Brown, 1980), which operates at 211 Hz.

Radiometric Sampling

The samples for which radiometric properties were determined in this study were collected over many years and include pre-mining surface samples. The majority of surface samples from the immediate area of Mt. Leyshon were collected by Keith Scott and Steve Fraser, CSIRO Division of Exploration Geoscience, during 1983 prior to the start of mining operations. Subsurface and drill samples, collected for previous AMIRA palaeomagnetic studies, and samples of the Mt Leyshon pit, the Cornishman and Tuckers Ranges collected for this project were included for analysis. A final set of soil and rock samples was collected in September, 1995 to determine the effects of dolerite weathering on the radiometric signatures and fill some gaps in the radiometric database. Together these sampling programmes provided 152 outcrop, 40 drill core and 56 soils with 41 pebble (sieved >2mm) fractions.

Radiometric determination of K, eU and eTh

The samples were analyzed using gamma-ray spectrometry to measure potassium (K), gamma-equivalent uranium (eU) and gamma-equivalent thorium (eTh). The terms eU and eTh stand for "gamma-equivalent" U and Th respectively and indicate that the measurements are made of gamma-ray emitting daughters of these two isotopes. In this case, because the samples are sealed and stored, eU and eTh are actually measurements of ^{226}Ra and ^{228}Ra, respectively. These are long-lived daughters of U and Th which are generally close to radioactive equilibrium with their parents in most rocks and soils (Dickson, 1995).

The measurements for small samples (eg drill core) were made by sealing 50g of crushed sample in a 50ml metal can, whereas for soil samples, 250g was sealed in a 300ml can. Samples of outcrop in early studies were also crushed and sealed in 250 g cans but, for more recent samples, a ~300 g piece of the sample has been cut and counted whole in the spectrometer. Extensive testing has shown this method to give satisfactory results for rock samples. All samples were stored for at least 30 days to allow radon (^{222}Rn), which may be lost during sample crushing and drying, to re-establish equilibrium with its parent ^{226}Ra.

The gamma-ray energy spectrum of each sample was measured with a 100x100mm NaI(Tl) detector which is housed in a 12cm thick lead shield. Full 256 channel spectra were accumulated with counting times of 5000 secs. At regular intervals both background counts (using a 300ml can filled with NaCl to duplicate the shielding effect of the samples themselves) and three standards comprising potassium sulfate, and two, internationally-calibrated, concretes doped with eU and eTh, were run. The concentrations of eU and eTh in these standards were determined by a series of international measurements.

Complete radiometric data for all the rocks and soils along with a brief description are given in the database attached to this report.

7. Petrophysical Properties of the Mount Leyshon Intrusive Complex and Host Rocks

Magnetic Properties and Densities

Magnetic properties, densities and, where radiometric determinations were made on equivalent samples, radiometric analyses of samples from the Mount Leyshon area were entered into Paradox databases. MTLEYREG.DB (Appendix II) contains data from mine pit and outcrop samples and MTLEYDDH.DB (Appendix III) includes data from drill core samples. Figure 15 shows histograms of magnetic susceptibilities for each of the major rock types from the Mount Leyshon area and Table 1 summarises the susceptibilities, Koenigsberger ratios and densities of each rock type.

From the database the following conclusions can be drawn about the breccia phases of the Mount Leyshon Intrusive Complex (the volumetrically dominant Main Pipe Breccia (MPBX) and the Mount Leyshon Breccia (MLBX):

- magnetic properties of the breccias are very heterogeneous, reflecting variations in dominant clast lithology and in degree and type of alteration,
- the average susceptibility of relatively unaltered MPBX is ~300 μG/Oe (3800×10^{-6} SI),
- the early potassic (biotite) alteration boosts the average susceptibility to ~1400 ($17{,}600 \times 10^{-6}$ SI),
- propylitically altered MPBX also appears to be somewhat more magnetic than the unaltered breccia, although this may partly reflect relative proportions of dolerite clasts in the samples,
- intense phyllic alteration overprinting potassic or propylitic alteration destroys magnetite and drastically reduces the susceptibility to paramagnetic levels,
- MLBX is generally weakly magnetic due to pervasive phyllic alteration
- potassic alteration produces little change to the density of the MPBX, but the density is reduced by about 0.07 g/cm^3 by propylitic or phyllic alteration.

There is a distinct difference in magnetic properties between the most felsic of the intrusive phases and the relatively mafic hornblende-bearing intrusives. The trachytic porphyries are substantially more magnetic than the rhyolitic porphyries, unless they are strongly altered. Unaltered trachytic porphyries have moderate susceptibilities (~600 μG/Oe = 7500×10^{-6} SI) and carry a relatively strong Early Permian remanent magnetisation, which is directed south and steeply downwards. The Q values are generally greater than unity, averaging ~3, so the total magnetisation of these rocks has reversed polarity. Intense albite alteration destroys the primary magnetite in these rocks and reduces the susceptibility to very low values, as well as reducing the density. The properties of the Late Dykes are similar to those of the trachyte porphyries. Tuffisite dykes, on the other hand, although related to the Late Dykes, are pervasively phyllically altered and are weakly magnetic and less dense. The most mafic intrusive phase of the Mount Leyshon Intrusive Complex, the basalt dyke (formerly termed "trachyandesite"), has high susceptibility and density, but it is a very minor phase of the complex and makes negligible contribution to geophysical signatures.

The most felsic and fractionated phases at Mount Leyshon (rhyolite porphyries and Early Dykes) contain at most traces of primary magnetite and have low susceptibilities. Phyllic alteration therefore has little effect on the susceptibility, although it reduces the density.

The major host lithologies to the Mount Leyshon Intrusive Complex, the Fenian Granite and the Puddler Creek metasediments, are weakly magnetic, unless altered. However these rocks are extensively intruded by Silurian/Devonian dolerite dykes, which are variably, sometimes strongly, magnetic. The effects of alteration on the magnetic properties of the country rocks are crucial for explaining the Mount Leyshon magnetic anomaly (Sexton et al., 1995). The early potassic alteration, which is intensely developed in the SW portion of the MLIC, has little effect on the magnetic properties of the Fenian Granite, as it deposits secondary K-feldspar without magnetite. In the Puddler Creek metasediments and dolerites, however, this alteration deposits magnetite in association with biotite, greatly enhancing the susceptibility. The secondary magnetite is very fine-grained and carries an intense reversed remanent magnetisation. The effects of alteration on the metasediments and dolerites are summarised below:

- the early potassic (biotite) alteration increases the susceptibility of the metasediments from paramagnetic levels (~20 μG/Oe = 250 × 10^{-6} SI) to much higher, but very variable, values (averaging ~4000 μG/Oe = 50,300 × 10^{-6} SI),
- the average susceptibility of the dolerites is increased by addition of secondary magnetite to the variable amounts of primary magnetite, boosting the average susceptibility from ~650 μG/Oe (8200 × 10^{-6} SI) to ~5000 μG/Oe (63,000 × 10^{-6} SI),
- propylitic alteration, particularly with intense development of chlorite, of the dolerites destroys magnetite and reduces the susceptibility to paramagnetic levels,
- potassic alteration is associated with intense reversed remanence and high Koenigsberger ratios (Q ~ 2-3),
- potassic and propylitic alteration do not greatly change the densities of metasediments and dolerites.

Radiometric Properties

Detailed analysis of the chemical composition of the Tuckers Igneous Complex (TIC) and Mt Leyshon Igneous Complex (MLIC) are given by Blevin and Morrison (1995). A comparison was made between the chemical and radiometrically-determined K, eU and eTh values for 51 samples, mostly from the TIC (Fig. 16). This shows generally good agreement between the two methods and calls into question the need to measure radioelement contents when a similar rock is being chemically analysed. Rather it is recommended that, for the remainder of this project, more effort be placed on analysing soils and weathered rocks and only rocks from lithologies not covered by chemical analyses be measured radiometrically.

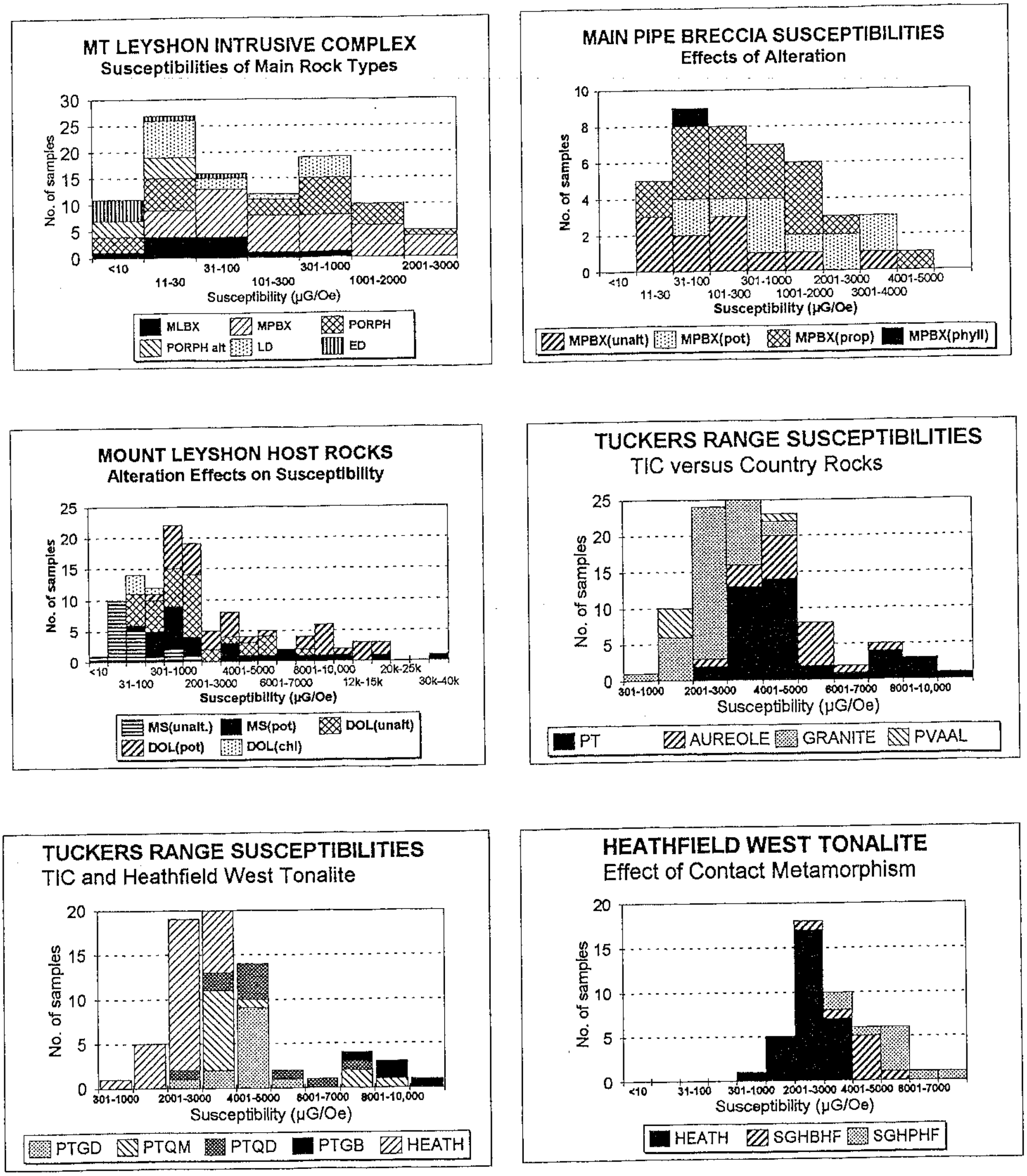


Fig. 15. Histograms of magnetic susceptibility versus rock type for TIC and MLIC samples

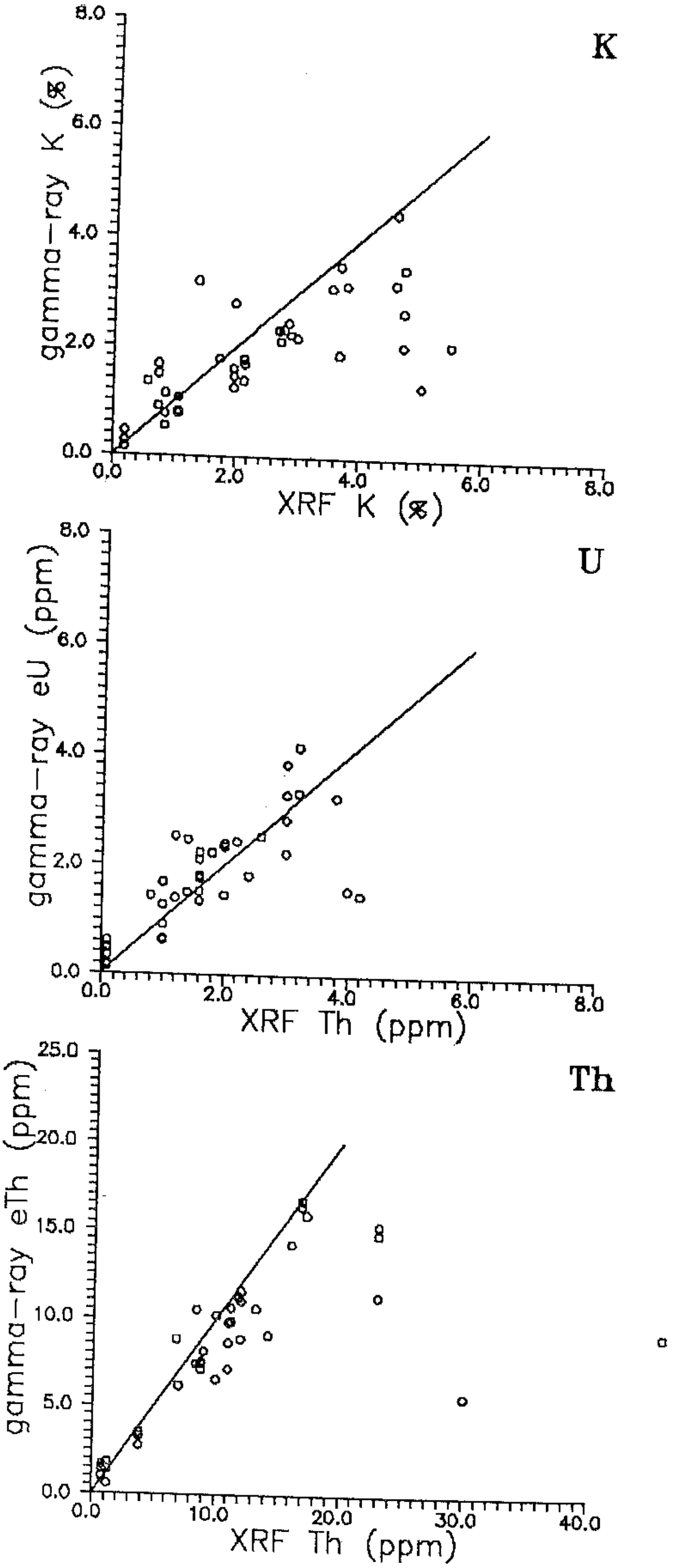


Fig. 16. Correlation between radiometric and chemically analysed K, eU and eTh.

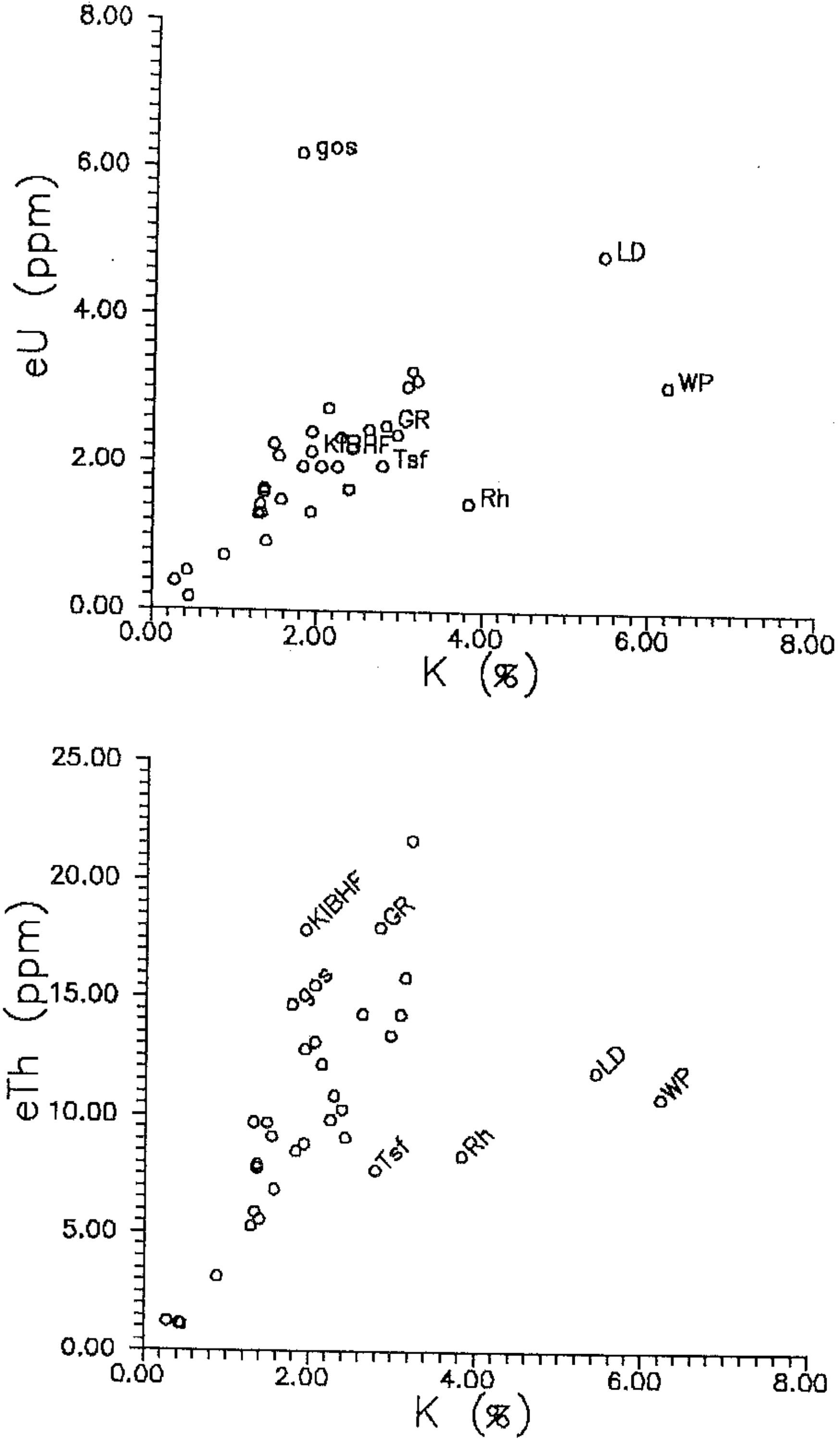


Fig. 17. (a) K vs eU and (b) K vs eTh for all rock units in the TIC and MLIC.

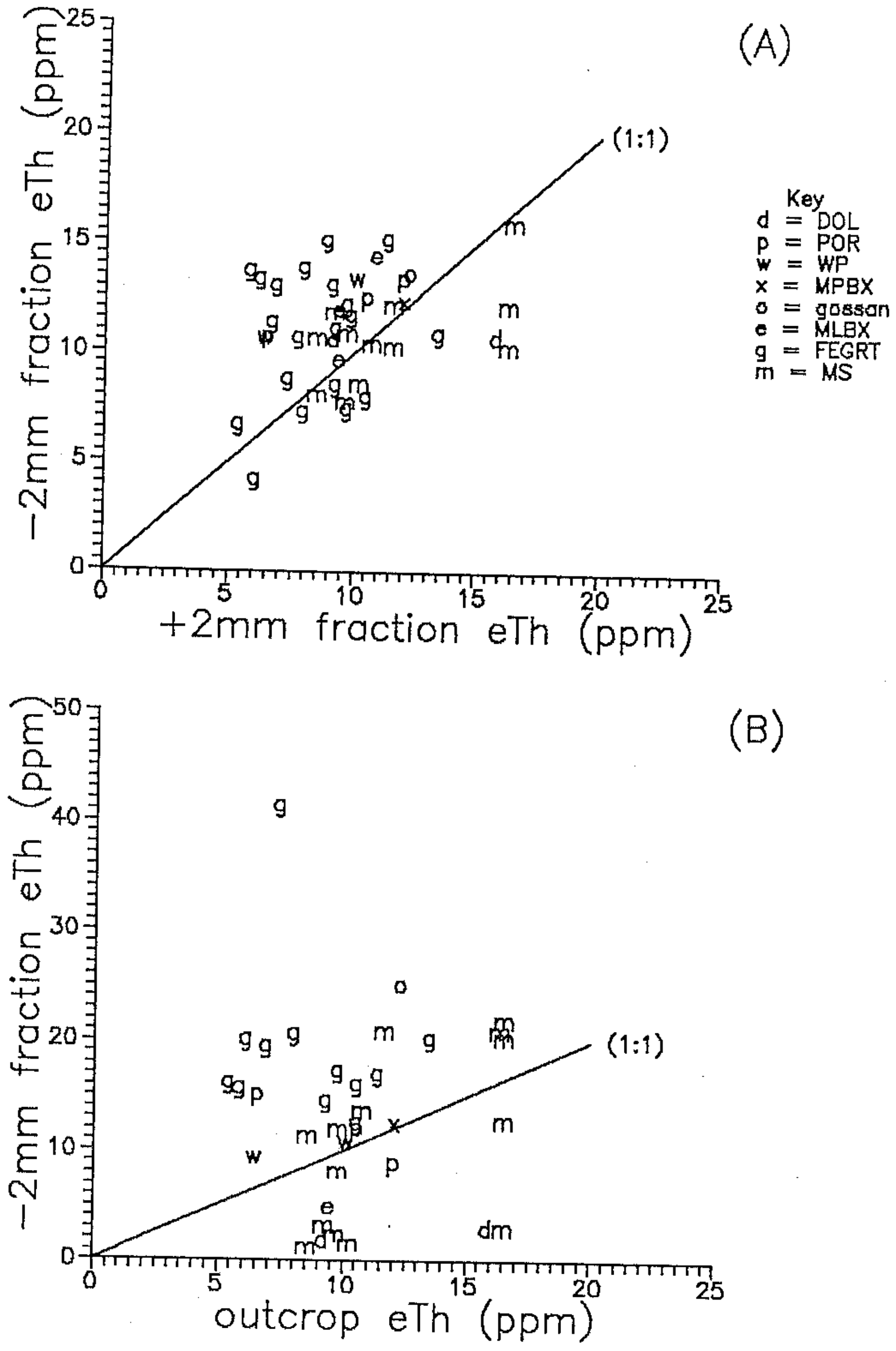


Fig. 18. Correlation between radioelement contents of soils (<2 mm) with those in adjacent outcrop.

Data from all samples are listed in the MTL_RAD.DB. The results obtained from 136 samples of rocks from the Mt Leyshon Intrusive Complex and surrounding country rocks are listed in Table 3, grouped into 13 lithological classes. In addition the chemical results from Blevin and Chappell (1995) are summarized. Comparison between the radiometric and chemical values show there are significant differences between the two data sets for the Southern Porphyry and Fenian Granite though for the former this may relate to small sample size for chemical values. For the granite samples, high K levels (up to 4 %) close to the Mount Leyshon Intrusive Complex were noted in a previous study (Dickson and Scott, 1992) and high eTh (20 - 30 ppm) levels were found in the granite on the eastern side of Mount Leyshon. The difference is thus probably due to sampling - the P425 set has 3 samples collected close to the Mount Leyshon Intrusive Complex whereas the radiometric set has 32 surface samples collected over a wide area.

It is important to note that most of the P425 samples are fresh, from depth, whereas the majority of the radiometric samples are from the surface and partly weathered. This can account for lower K and eU in the radiometric results for example with the Mine Porphyry samples but not for variation in eTh levels seen in Southern and Basement Porphyries. Possibly the acidic conditions of weathering at the surface (which resulted in the extensive development of alunite and jarosite) also resulted in some loss of eTh from surface rocks. Some of that eTh may have been captured or retained in surface gossans.

To enable comparison of the various rock types in the TIC and the MLIC, plots of K versus eU and K versus eTh are given in Fig. 17a and Fig. 17b, respectively. In these two graphs, the simultaneous increases in radioelements is clearly seen and allows units falling off the main trend to be identified.

The following observations can be drawn from the radiometric data:

- K contents of rocks decrease in the order: Wallaby Porphyry > Late Dykes > Mine Porphyry ~ Fenian Granite > metasediments ~ MLBX > MPBX > Basalt dykes ~ Southern Porphyry > dolerite dykes. A similar order is also obtained from the chemical data. The Wallaby Porphyry and Late Dykes are particularly notable for their high K content (see also Fig. 17). There is some evidence that the granite is K-enriched on its western margin with the MLIC.
- The eU contents were very high in the gossan (6.2 ppm), distinguishing these samples from all others (Fig. 17a). The Late Dykes also had high eU (4.9 ppm) whereas the Fenian Granite, MPBX and Mine Porphyry have similar eU contents (2.3 - 2.7 ppm) with the Wallaby Porphyry somewhat higher at 3.1 ppm. The values in MLBX, Southern and Basement Porphyry and metasediments were lower at around 1.3 ppm. The lowest eU values were found in the dolerites.
- The highest eTh values were found in the Fenian Granite but high values were also found with the surface gossans as seen in Fig. 17b where the granite (GR) and gossan (sg) data fall above the K -Th trend line. Thorium contents in the main complex rock types decrease in order: Mine porphyry ~ metasediments > Wallaby Porphyry ~ Basement Porphyry ~ MPBX ~ MLBX > basement porphyry >> dolerite. In the K - eTh plot (Fig. 17b), most of the units in the MLIC fall along the same trend line as the TIC rocks. However, the tuffisite dykes (Tsf) show as having

higher K than the trend whereas the Basement Porphyry (BP) appears to be depleted in K.

These results suggested that the Mt. Leyshon mineralisation should be distinguished by a zone depleted in eU and eTh, with K being particularly depleted in alunite zones within the breccia but enriched in zones adjacent to the mineralisation. To the south the Wallaby Porphyry should be prominent with its high K content.

Previous studies (Dickson and Scott, 1992) found that soils over the Fenian Granite were lower in radioelement content than the underlying rock and showed no correlation with the rock values. In contrast there was a good correlation between radioelements in the fine (<4mm) and coarse (>4mm) fractions of the soil. Such a lack of correlation between the radioelements in the coarse fraction and rocks suggested that the soils were at least partially derived from other sources. Further, the soils over the granite showed the presence of amphibole, a constituent of dolerite but not granodiorite. The Fenian Granite has a distinctive streaky texture in air photos due to intrusion by numerous dolerite dykes (Hutton and Crouch, 1993), and Dickson and Scott (1992) suggested that the likely source of much of the soil is these more readily weathered dolerite which dilutes the radiometric signature of the Fenian Granite. The dolerites do not intrude the Mt Leyshon Intrusive Complex.

Further sampling, particularly concentrating on soils, was undertaken over both the Fenian Granite and Puddler Creek Metasediments to investigate the effect of dolerite weathering. The results (Table 4) show that for the Puddler Creek Metasediments the average radioelement contents of both the fine (<2mm) and coarse (>2mm) fractions of the soil are close to that of the outcrops. In contrast, the results for the Fenian Granite show decreasing radioelement contents in the order outcrop > fine soil > coarse soil. Figure 18 shows plots of the eTh content of fine soils versus a) the coarse soil fraction and b) the outcrop. Whereas a correlation exists between the two soil fractions, the soil has variable eTh content compared to the granite which is relatively constant. This behaviour is in agreement with the granite soil being contaminated by a low-radioelement material.

Soil collected over the Wallaby Tail Porphyry shows loss of K due to weathering but the fine material has a remarkable increase in eU in the fine fractions (two samples had 4 & 8 ppm eU). Weathering of the porphyry produces rock fragments with many voids. The increase in eU could represent residual concentration of a U-bearing but not Th-bearing mineral as the eTh concentration does not increase in a similar fashion. Similarly, soil over the Mt Leyshon breccia (MLBX) has higher eU than the rock whereas soils collected over the Mine Porphyry have radioelement contents similar to that of the outcrop. Soil collected over dolerite within the metasediments shows the effect of contamination from adjacent more extensive radioelement rich rocks.

8. Petrophysical Properties of the TIC and its Aureole

Magnetic Properties and Densities

Petrophysical data from samples collected from the Tuckers Range area for magnetic property measurements are included in MTLEYREG.DB (Appendix II). The susceptibilities, Koenigsberger ratios and densities of each of the rock types from the TIC and its host rocks are summarised in Table 2. The Q values listed are averages of Koenigsberger ratios for individual samples, without regard for remanence direction. Because the remanent magnetisation of the Tuckers Range samples is usually multicomponent, remanence directions tend to be somewhat scattered. Some high Q values are also probably due to lightning strikes. Thus the representative bulk Koenigsberger ratio for most Tuckers Range rock units is substantially lower than the values in Table 2 and $Q < 1$ for most rock types. By contrast, the data in Table 1 are mainly derived from drill core or pit samples, which are unaffected by lightning. Furthermore the remanence carriers of the strongly magnetic rocks are generally quite stable and the remanence directions are less scattered. Thus the Q values in Table 1 are reasonably representative of bulk values.

The initial magma that generated the TIC was very hot, dry and oxidised, with calc-alkaline chemistry (Beams, 1994), which led to early and continuing precipitation of magnetite throughout the evolution of the TIC. The TIC gabbro has the highest magnetite content, and therefore the highest susceptibility, but magnetite is also abundant in the more evolved phases, which have similar susceptibilities to each other, apart from the aplites, which contain only about 0.1% magnetite by volume because the precipitation of magnetite was almost exhausted. The average susceptibility of the TIC gabbro is ~ 9400 μG/Oe (0.12 SI), the dioritic to granodioritic phases and associated andesitic volcanics have k ~ 4000 μG/Oe (0.05 SI) and the aplites have susceptibilities of ~ 300 μG/Oe (3800×10^{-6} SI).

The main country rock phase, the Heathfield West Tonalite, has moderate susceptibility, about half the typical TIC values, except in the pyroxene hornfels and biotite hornfels zones adjacent to the TIC, where secondary magnetite enhances the susceptibility to levels that are comparable to the TIC. Within the metasomatised aureole of the TIC, the remanent magnetisation is completely overprinted by an Early Permian magnetisation that is identical in direction to that of the TIC. Outboard of the metasomatised zone, purely thermal resetting of the remanence has occurred. The Heathfield West Tonalite contains fine-grained magnetite that is an ideal palaeomagnetic recorder. Far from the TIC, the remanence direction is dominated by a primary Silurian component, whereas in the thermally reset zone the remanence is dominated by an intense reversed polarity Early Permian component that produces the pronounced magnetic low rimming the TIC hornfels zone. The Q values within the hornfels zone are less than unity and thus the magnetic signature of the hornfels is similar to that of the TIC itself.

The Ordovician granites are substantially less magnetic than the Siluro-Devonian tonalites. Of the TIC phases, only the gabbro has fine-grained magnetite, in the single domain to pseudosingle domain size range (< 10 μm), capable of producing a magnetisation dominated by remanence ($Q > 1$). The more felsic phases of the TIC generally have $Q < 1$, because the magnetite is in the large multidomain size range (> 20 µm), which is associated with lower Koenigsberger ratios and lower palaeomagnetic stability than single domain grains. The lower stability of remanence results in overprinting of the primary reversed remanence by later normal polarity remanence and the resultant intensity of remanence is accordingly lower.

There is little density contrast between the TIC and its country rocks, whereas the more felsic intrusive phases of the MLIC have distinctly lower densities, particularly where they are strongly phyllically or albitically altered. The alteration around the TIC, which resembles the early potassic alteration at Mount Leyshon, has had little effect on the density of the Heathfield West Tonalite.

Radiometric Properties

The results obtained from 51 samples of rocks from the Tuckers Complex are listed in Table 5, grouped into various lithological classes. For comparison the chemical data for 36 equivalent samples from Blevin and Chappell (1995) are also listed. Data from each sample are included in MTL_RAD.DB (Appendix IV). The results show the simultaneous increases in the three radioelements as the rock silica content increases. In the TIC area, the altered Kirklea Granite rocks (KIBHF) are the only rocks that lie off both the K versus eU and K versus eTh trends (Fig. 17a, b). The data in Table 5 show some difference between the altered and unaltered Heathfield granodiorite which suggests that there are effects on radioelement contents due to the metamorphism following emplacement of the TIC into older rocks. This is a weak trend of increasing eU and eTh with increasing alteration and K in the pyroxene hornfelsed rocks are higher. The statistical significance of these variations is probably small.

9. Petrophysical Properties of Samples from the Leyshon/Tuckers Corridor

Magnetic Properties and Densities

Petrophysical data from samples collected from the Leyshon/Tuckers Corridor for magnetic property measurements are included in MTLEYREG.DB (Appendix II). Table 2 summarises the susceptibilities, Koenigsberger ratios and densities of each of the rock types. The intrusions are all oxidised, magnetite-series, I-type granitoids with moderate to high susceptibilities. Magnetisations are generally dominated by induction rather than remanence ($Q < 1$). The Fenian Diorite and Matthews Pinnacle Tonalite, have similar palaeomagnetic signatures to the TIC and MLIC and are interpreted to be coeval (Clark, 1996).

Radiometric Properties

Radioelement contents of a limited collection of 11 samples of rocks from the Matthews Pinnacle and Cornishman Complex and 8 samples of the surrounding country rocks are listed in Table 6. The Matthews Pinnacle rocks have lower eU & eTh but higher K than the surrounding Deane Granodiorite. Of the country rocks, the Fenian Diorite has the lowest radioelement contents of any rock in the area (Fd in Fig.

17). Figure 17 also shows that the rhyolite dyke at Matthews Pinnacle (Rh), which is the latest igneous phase of this complex, has an usually high K content.

10. Petrophysical Properties of the Ravenswood Batholith

Magnetic Properties and Densities

Petrophysical data from samples collected for a reconnaissance study of the Ravenswood area are included in RAVENSWD.DB. Radiometric measurements have also been made on these samples and these are included in RAVENSWD.DB.

Lackie *et al.* (1992) reported magnetic petrophysical properties from Ravenswood Batholith as part of AMIRA P96C. Selected data from the western portion of the Ravenswood Batholith, originally reported by those authors, are included in MTLEYREG.DB. The main conclusions that can be drawn from the combined data sets are:

- The great majority of intrusions are oxidised, magnetite-series, I-type granitoids with moderate to high susceptibilities.
- The mean susceptibility of the granitoids tends to increase from ≤ 2000 μG/Oe in the west to ≥ 3000 μG/Oe in the east. A similar pattern applies to both the Ordovician and Siluro-Devonian granitoids. This increase in susceptibility correlates with the transition from biotite-dominant to hornblende-dominant granodiorites.
- Overall tonalites tend to have higher susceptibilities than granodiorites, which in turn have higher susceptibilities than granites. Minor mafic intrusions have the highest susceptibilities.
- Within the Alex Hills Shear Zone, which cuts E-W across the northern part of the batholith, suceptibilities of the granitoids are distinctly lower (~ 400 μG/Oe) than outside the shear zone. This is attributed to deeper weathering of the sheared granitoids and accounts for the distinctive linear magnetic low zone associated with the Alex Hills shear zone.
- Most Ordovician and Siluro-Devonian granitoids in the batholith carry relatively weak remanence without any consistent direction. Thus magnetisations are generally dominated by induction rather than remanence ($Q < 1$).
- Many mafic rock units within the batholith carry a characteristic remanence that is directed WNW and shallow up. Silurian granitoids in the Tuckers Range area also show the same direction, after any Permian overprinting by the TIC is removed. This characteristic remanence is interpreted as a Silurian magnetisation which is primary in the Silurian plutons and an overprint in the Ordovician and older mafic rocks (Clark, 1996).

Radiometric Properties

A limited number of radiometric measurements were made on outcrop samples collected for palaeomagnetism measurements. These are included in RAVENSWD.DB. The samples show a wide range of radioelement contents with all three increasing as the rocks become more felsic. A plot of K vs eU and K vs eTh

(Fig. 19) illustrates the sympathetic behaviour of K and Th. The K vs U correlation shows greater scatter, probably reflecting U loss from weathered samples. Several samples lying off the trend lines are both rhyolites; sample RAV16A has a particularly high K content of 5.9% and RAV04B has a high eU content of 8.0 ppm.

11. Conclusions

The petrophysical databases are essential tools for interpreting the geophysical signatures of the Mount Leyshon Intrusive Complex and the Tuckers Igneous Complex. Clear relationships between physical properties and lithology, alteration and rock age have been established, which can add insights to the geological interpretations as well as constrain geophysical models.

The oxidised nature of the magmas that generated the TIC and MLIC account for the moderate to high susceptibilities of the mafic to moderately felsic igneous rocks of these systems, provided they are relatively unaltered. Only the most felsic and fractionated phases (aplites and rhyolites) are weakly magnetic, due to exhaustion of magnetite. Emplacement of the MLIC and TIC occurred during a period of reversed geomagnetic polarity and the magnetic signatures of both complexes include pronounced negative magnetic anomalies, where the rocks are capable of retaining a strong and stable remanent magnetisation that dominates the induced component. The magnetic low rimming the TIC is due to thermal resetting of the remanence carried by the Heathfield West Tonalite and similar country rocks.

Alteration has a pronounced effect on physical properties. Potassic (biotite) alteration is associated with enhanced susceptibilities and reversed remanent magnetisation. At Mount Leyshon, the reversed remanence associated with early potassic alteration of metasedimentary and dolerite country rocks is largely responsible for the prominent magnetic low over the SW portion of the MLIC. Phyllic, albitic and intense propylitic alteration are magnetite destructive within the MLIC, reducing susceptibilities to paramagnetic levels and also substantially reduce rock densities.

Radiometric and chemical determinations of radioelement contents of rock samples have yielded similar results. Future sampling for radiometric properties should therefore concentrate on weathered rocks and soils to examine the effects of weathering and transport on radioelement concentrations.

Radiometric properties from the Mount Leyshon area suggest that the Mt. Leyshon mineralisation should be distinguished by a zone depleted in eU and eTh, with K being particularly depleted in alunite zones within the breccia but enriched in zones adjacent to the mineralisation. To the south the Wallaby Porphyry should be prominent with its high K content.

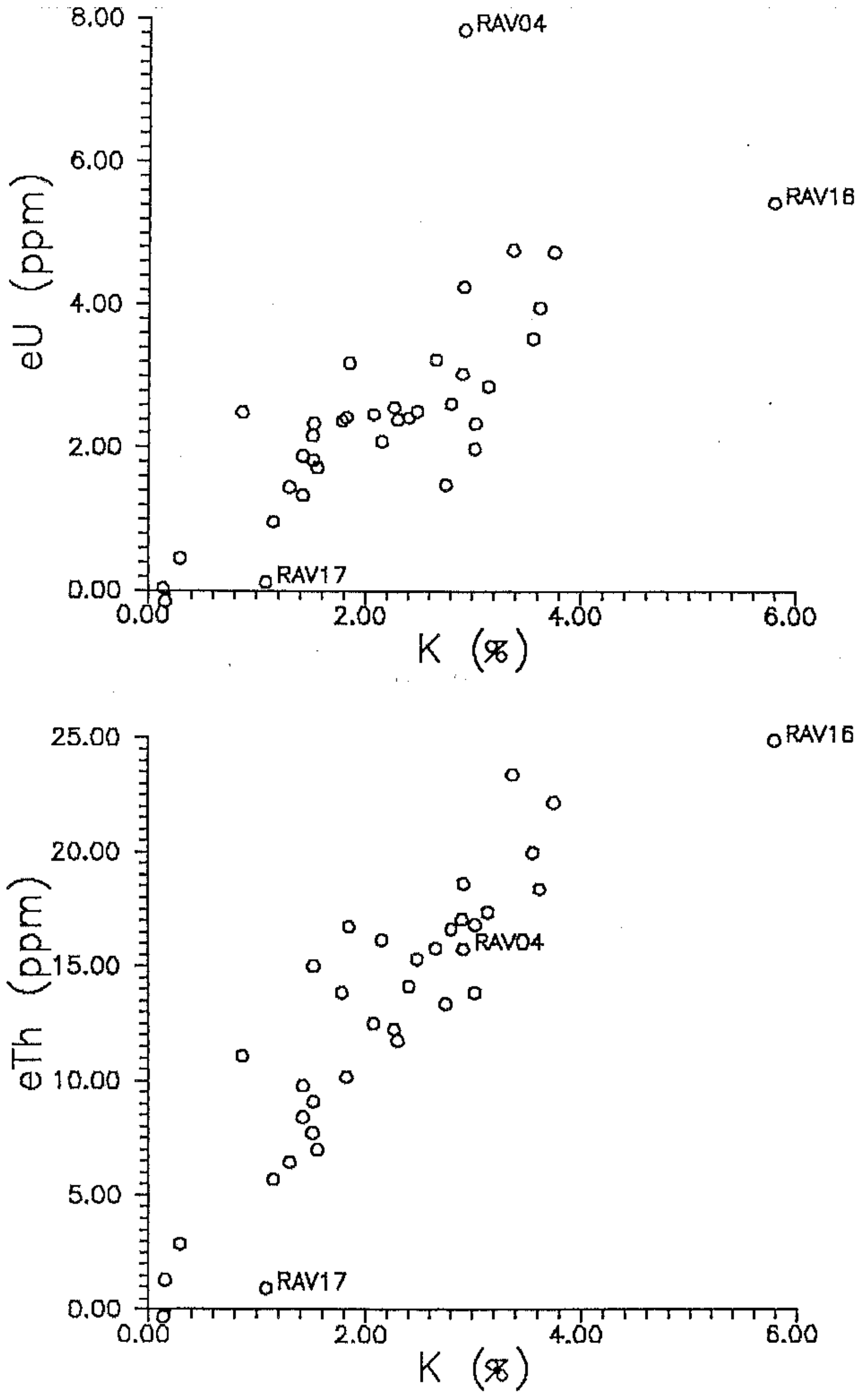


Fig. 19. (a) K vs eU and (b) K vs eTh for all rock units in the Ravenswood area

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Table 1. Magnetic Properties and Densities of Rock Types from the Mount Leyshon Area

Rock Type	Susceptibility (μG/Oe)	Susceptibility (10^{-6} SI)	Koenigsberger Ratio (Q)	Density (g/cc)
Mt Leyshon rhyolite porphyries (unaltered)	12	150	2.0	2.53 ± 0.02
Mt Leyshon rhyolite porphyries (phyllic alteration)	9	110	4.5	2.45 ± 0.01
Mt Leyshon trachyte porphyries (unalt.)	600	7540	3.3	2.65 ± 0.04
Mt Leyshon trachyte porphyries (albite alteration)	11	140	2.5	2.58 ± 0.03
Mt Leyshon MPBX (average)	~870	10,900	0.78	2.70 ± 0.02
Mt Leyshon MPBX (unaltered)	~300 (20-1200)	3800 (250-15,000)	0.66	2.75 ± 0.03
Mt Leyshon MPBX (potassic alteration)	~1400 (50-4000)	17,600 (630-50,000)	0.69	2.73 ± 0.02
Mt Leyshon MPBX (propylitic alteration)	~900 (50-3000)	11,300 (630-38,000)	0.72	2.66 ± 0.02
Mt Leyshon MPBX (phyllic alteration)	~70	880	~0.8	2.69 ± 0.02
Mt Leyshon Breccia	50	630	0.64	2.73 ± 0.05
Mt Leyshon Early Dykes	17	210	0.07	2.66 ± 0.02
Mt Leyshon Late Dykes	410	5150	0.30	2.63 ± 0.02
Mt Leyshon Tuffisite	60	750	1.2	2.59 ± 0.02
Mt Leyshon Basalt ("Trachyandesite")	3360	42,200	0.34	2.80 ± 0.04
Fenian Granite	105	1320	1.2	2.62 ± 0.01
Puddler Creek MS (unaltered)	23	290	0.26	2.74 ± 0.05
Puddler Creek MS (potassic alteration)	~3800 (30-32,000)	48,000 (500-400,000)	2.2	2.78 ± 0.02
Dolerite dykes (unaltered)	~650 (40-4600)	8200 (500-58,000)	0.4	2.83 ± 0.02
Dolerite dykes (potassic alteration)	4780	60,100	3.1	2.83 ± 0.01
Dolerite dykes (propylitic alteration)	80	1000	0.88	2.86 ± 0.03
Dolerite dykes (intense chlorite alteration)	~70	880	0.7	2.87 ± 0.05

Table 2. Magnetic Properties and Densities of Rock Types from the Leyshon-Tuckers Corridor

Rock Type	Susceptibility (µG/Oe)	Susceptibility (10^{-6} SI)	Koenigsberger Ratio (Q)	Density (g/cc)
TIC Gabbro	9380	118,000	3.4	2.89 ± 0.02
TIC Quartz Diorite	4640	58,300	3.0	2.84 ± 0.02
TIC Quartz Monzodiorite	4570	57,400	4.0	2.76 ± 0.006
TIC Northern Granodiorite	4260	53,500	0.65	2.79 ± 0.004
TIC Southern Granodiorite	3900	49,000	2.9	2.68 ± 0.01
TIC Felsic Granodiorite	4530	56,900	1.5	2.75 ± 0.015
TIC Andesite	3020	38,000	2.0	2.73 ± 0.002
TIC Andesite Biotite Hornfels	4000	50,300	1.5	2.80 ± 0.004
Heathfield West Tonalite	2500	31,400	0.60	2.73 ± 0.006
Heathfield West Tonalite (Pyroxene Hornfels)	5010	63,000	0.92	2.74 ± 0.02
Heathfield West Tonalite (Biotite Hornfels)	4260	53,500	2.4	2.75 ± 0.05
Andesitic Dykes	1040	13,100	0.44	2.86 ± 0.007
Kirklea Granite	1640	20,600	0.66	2.76 ± 0.02
Ordovician Porphyritic Granite	2270	28,500	2.3	2.66 ± 0.01
Ordovician Porphyritic Granite (Biotite Hornfels)	1820	22,900	3.1	2.63 ± 0.03
Matthews Pinnacle Tonalite	1500	18,800	0.26	2.70 ± 0.03
Mountain View Granodiorite	2440	30.700	0.10	2.69 ± 0.01
Fenian Diorite	11,200	141,000	0.61	2.89 ± 0.015
Ordovician Gabbro	1040	13,100	6.2	2.94 ± 0.007
Deane Granodiorite	4640	58,300	0.47	2.76 ± 0.04

Table 3. Summary of K, eU and eTh in rock units of the Mt Leyshon Intrusive Complex and Host Rocks.

Lithology	Unit	No of values	K %	eU ppm	eTh ppm	eU/eTh
(a) radiometric data						
surface gossan		5	1.78	6.20	14.7	0.42
Basalt dyke	Bs	6	1.39	0.93	5.6	0.17
tuffisite dyke	Tsf	2	2.80	1.97	7.7	0.26
Late dyke	LD	2	5.44	4.85	11.9	0.41
Mt Leyshon Breccia	MLBX	13	1.93	1.33	8.8	0.15
Main Pipe Breccia	MPBX	11	1.54	2.09	9.1	0.23
Southern porphyry	SP	4	1.29	1.30	5.3	0.25
Mine porphyry	MP	19	2.98	2.39	13.4	0.18
Basement porphyry	BP	6	1.31	1.43	9.7	0.15
Wallaby Tail Porphyry	WP	4	6.22	3.08	10.8	0.29
Devonian dolerite	DOL	11	0.43	0.51	1.16	0.44
Fenian Granite	FEGRT	35	2.84	2.51	18.0	0.14
Puddler Creek metasediments	MS	15	2.06	1.95	13.1	0.15
(b) Chemical data (From Blevin and Chappell, 1995)						
Basalt dyke	Bs	2	2.17	0.60	4.40	0.14
Basalt porphyry dyke	BSo	1	1.02	0.01	2.00	
Early Dyke	ED	7	4.53	3.37	14.07	0.24
Late Dyke	LD	13	4.02	2.80	14.02	0.20
Late Dyke	LDa	5	4.40	3.72	16.68	0.22
Late Dyke	LDg	3	4.89	3.07	14.00	0.22
Late Dyke	LDi	2	5.10	2.10	10.90	0.19
Late Dyke	LDm	6	3.39	2.65	16.38	0.16
Mine Porphyry	MP	13	4.79	3.76	14.47	0.26
Southern Porphyry	SP	11	2.42	2.67	12.49	0.21
Wallaby Tail Porphyry	WP	1	5.38	2.00	11.00	0.18
Basement Porphyry	BP	4	3.48	3.25	23.75	0.14
"dolerite" dyke	DOL	2	0.63	0.51	3.00	0.17
Granodiorite clast in MPBX		1	2.02	0.01	3.00	
Fenian Granite	FEGRT	3	3.67	4.67	23.83	0.20

Table 4: Radioelement contents of outcrop and soil fractions from the Mt Leyshon area

Unit	#	outcrop			soil -2mm fraction				soil +2mm fraction			
	#	K	eU	eTh	#	K	eU	eTh	#	K	eU	eTh
MS	15	2.06	1.95	13.1	10	1.45	1.86	11.5	9	1.92	1.94	11.7
DOL	11	0.43	0.51	1.16	2	1.83	2.45	10.7	2	2.80	2.08	12.5
WP	4	6.22	3.08	10.8	2	3.09	6.00	11.7	2	4.66	2.33	7.6
MP	25	2.98	2.39	13.4	8	2.59	2.18	11.5	4	2.82	1.86	9.7
MPBX	11	1.54	2.09	9.1	3	2.25	2.03	10.8	1	2.17	2.63	12.1
MLBX	13	1.93	1.33	8.8	4	2.53	1.87	12.6	2	2.82	2.40	9.9
FEGRT	35	2.84	2.51	18.0	26	2.37	1.64	11.2	20	1.57	1.25	8.6

Table 5. Summary by lithology of the Tuckers Range radiometric (K, eU, eTh) and chemical (K, U Th) results.

Lithology[3]	Laboratory gamma-ray				Chemical (XRF)[1]			
	No	K %	eU ppm	eTh ppm	No	K_2O %	U ppm	Th ppm
KIBHF	3	1.94	2.15	17.86				
PGBHF	5	3.10	3.04	14.3	2	2.39	2.30	14.5
PTNGD	3	1.57	1.50	6.85	2	2.90	2.70	18.5
PTSGD	5	2.63	2.46	14.32	3	2.44	20.7	12.40
PTFGD	1	2.43	2.20	9.08				
PTPQM	1	3.15	3.25	15.89	1	3.15	3.80	17.20
PTQD	7	1.33	1.31	5.90	3	1.23	0.54	5.53
PTGB	3	0.45	0.16	1.11	1	0.29	0.01	1.0
PTQM	5	2.29	2.34	10.84	3	2.05	1.40	10.20
PVAAL					1	0.73	0.80	4.80
PVABHF	1	1.36	1.60	7.76				
SGH(west)[2]	1	3.22	3.12	21.7				
SGH	4	1.83	1.95	8.50	6	1.78	1.67	11.47
SGHBHF	7	1.48	2.25	9.67	6	1.78	2.63	12.93
SGHPHF	5	2.14	2.74	12.17	6	1.37	2.77	12.70

[1] Data summarized from Blevin andChappell, 1995.

[2] Sample collected north of east end of Tuckers Range

[3] Lithology codes are given in Appendix I

Table 6: Summary of rock radioelement contents by lithology for the Matthews Pinnacle and Cornishman Complex areas.

Lithology	No of values	K %	eU ppm	eTh ppm
(a) Cornishman Complex				
Dacitic breccia	1	2.39	1.64	10.25
andesitic dykes	6	1.36	1.65	7.90
(b) Matthews Pinnacle				
Deane G/d	2	1.94	2.42	12.80
Tonalite	2	2.25	1.95	9.82
Rhyolitic dyke	2	3.84	1.47	8.34
(c) Country rocks				
Fenian Diorite	3	0.28	0.37	1.23
metamor. G/d	3	0.88	0.73	3.15

Table 7: Summary of rock radioelement contents by lithology for samples from the Ravenswood area.

Lithology[1]	No of values	K %	eU ppm	eTh ppm
Cpglp2	1	2.66	3.24	15.79
Cpglp3	1	2.30	2.40	11.75
Cpgmc	4	2.77	2.33	15.36
Cpgmo	2	3.66	4.13	21.10
Cpgr1	2	3.27	3.81	20.41
Cpgr2	1	2.93	4.26	18.63
Cpvmc	4	2.79	4.22	15.25
Cgb	2	2.75	2.25	14.61
Dgj	5	1.35	1.52	10.41
Ost	6	1.88	2.27	11.06
Pdfp	3	1.95	2.41	10.84
Pgfp1	2	1.41	1.64	7.77
Sdd	1	0.14	0.03	-0.33
Sdgco	1	1.42	1.34	8.41
Sdgki	1	1.55	1.73	7.01

[1] Lithology codes are given in Appendix I

APPENDIX I: DESCRIPTION OF THE PETROPHYSICAL DATABASES

List of Databases

Six separate physical property databases have been created using Paradox for Windows (v.4.5) and then exported into various other formats. The databases are:

(i) Magnetic, density and radiometric properties of samples collected from outcrop and pit exposures in the Mount Leyshon/Tuckers corridor (MTLEYREG.*),

(ii) Magnetic and density properties of drill core samples from Mount Leyshon (MTLEYDDH.*),

(iii) Radiometric properties of all rock and soil samples collected in the Mount Leyshon/Tuckers corridor (MTL_RAD.*).

(iv) Magnetic, density and radiometric properties of samples collected from outcrop in the Ravenswood area (RAVENSWD.*),

(v) Radiometric properties of all rock and soil samples collected in the Ravenswood area (RAV_RAD.*)

Data collected in the course of previous studies have been incorporated into these databases.

Structure of Paradox Databases

1. MTLEYDDH.DB

Field 1: MLD # (Mt Leyshon DDH no.) - A5 (up to 5 alphanumeric characters)
Field 2: DEPTH (m) - N (numeric)
Field 3: Lithology - (A10)

BP - Basement Porphyry
BPBX - brecciated Basement Porphyry
Bs - Basalt dykes (latest intrusive phase - formerly called trachyandesite)
BSo - Basement basalt porphyry (not used)
DOL - Silurian or Devonian dolerite dykes intruding the Fenian Granite or MS
ED - early dykes
FEGRT - Mt Leyshon (Fenian) Granite
GRBX - brecciated Mt Leyshon (Fenian) Granite
LD - late dykes
MHBX - Mount Hope Breccia
MLBX - Mount Leyshon Breccia
MP - Mine Porphyry
MPBX - Main Pipe Breccia
MS - greenschist grade metasediments of the Cambrian Puddler Creek Formation
SEDBX - brecciated MS
SP - Southern Porphyry

Tsf - Tuffisite (fine)
WP - Wallaby Tail Porphyry
WPBX - Brecciated Wallaby Tail Porphyry

Field 4: AGSO LITHOLOGY (A4 - generic lithology codes as used in AGSO databases, described in "The AGSO Field Geological Note Books - a User's Guide", AGSO Record 1993/46)

Field 5: AGSO LITH QUAL (A4 - AGSO lithological qualifier)

Field 6: ALTERATION (A20)

Field 7: AGSO ALTERATION 1 (A2 - AGSO alteration code for initial alteration)

Field 8: AGSO ALTERATION 2 (A2 - AGSO alteration code for overprint alteration)

Field 9: DESCRIPTION (A120)

Field 10: SUSCEPTIBILITY (μG/OE) - (N; CGS susceptibility in μG/Oe:
1 μG/Oe = 10-6 G/Oe (CGS) = 12.56 × 10-6 SI)

Field 11: SUSCEPTIBILITY (1E-3 SI) - (N; susceptibility expressed as 10-3 SI)

Field 12: NRM INTENSITY (μG) - (N; intensity of natural remanent magnetisation in μG
1 μG = 1 mA/m SI)

Field 13: Q(NRM) - (N; Koenigsberger ratio of NRM: Q = NRM/(Susceptibility × Field)

Field 14: NRM INC WRT DDH - (N; inclination of NRM vector with respect to down-hole direction, positive downwards)

Field 15: DENSITY (G/CC) - (N; dry bulk density determined by weighing in air and water)

Field 16: GEOCHEM # (A12; corresponding geochemical sample field no.)

Field 17: AMG EASTING (N; AMG mE, zone 55)

Field 18: AMG NORTHING (N; AMG mN, zone 55)

Field 19: RL (N; relative level in metres)

2. MTLEYREG.DB

Field 1: SAMPLE # - A10; CSIRO Field No.

Field 2: ROCK UNIT - A10 (Terra Search rock unit codes plus some new codes)

BHDRT - Bucklands Hill Diorite
BKGB - Black Knob Gabbro (informal name)
CTM - Charters Towers Metamorphics
DEANE - Deane Granodiorite (also called Bluff Granodiorite)
FEGRT - Fenian Granite
GCGB - Gladstone Creek Gabbro
HEATH - Heathfield West Tonalite
KIBHF - Kirklea Granite, biotite hornfels zone
MFDYK - Mafic dyke, undifferentiated
MPDYK - rhyolite dyke at Matthews Pinnacle
MPRHY - Mathews Pinnacle rhyolite porphyry
MPTON - Matthews Pinnacle Tonalite
MVGRD - Mountain View Granodiorite
PFEDRT - Fenian Diorite
PGBHF - Megaquartz Granite Porphyry, biotite hornfelsed
PVAAL - Permo-Carboniferous andesite lavas of Cornishman Complex
PVABHF - Biotite hornfelsed PVAAL
PTFGD - Tuckers Complex Felsic Granodiorite
PTGB - Tuckers Complex Gabbro
PTNGD - Tuckers Complex Northern Granodiorite
PTPQM - Tuckers Complex Porphyritic Quartz Monzodiorite
PTQD - Tuckers Complex Quartz Diorite marginal phase
PTQM - Tuckers Complex Quartz Monzodiorite
PTSGD - Tuckers Complex Southern Granodiorite
RBOGi - Kirklea Granite
RBOGO - unnamed ?Ordovician gabbro NW of TIC
RBOGPG - Ravenswood Batholith: Megaquartz Granite Porphyry
SBGRD - Sunburst Granodiorite
SCGB - Sandy Creek Gabbro
SDGBe - Beasley Creek Tonalite
SGHBHF - Heathfield West Tonalite, biotite hornfelsed
SGHPHF - Heathfield West Tonalite, pyroxene hornfelsed
WARDRT - Warrior Diorite
Mount Leyshon Mine rock unit codes: see MTLEYDDH

Field 3: LITHOLOGY - (A20)

Field 4: AGSO LITHOLOGY (A4 - generic lithology codes as used in AGSO databases, described in "The AGSO Field Geological Note Books - a User's Guide", AGSO Record 1993/46)

Field 5: AGSO LITH QUAL (A4 - AGSO lithological qualifier)

Field 6: ALTERATION (A12)

Field 7: AGSO ALTERATION 1 (A2 - AGSO alteration code for initial alteration)

Field 8: AGSO ALTERATION 2 (A2 - AGSO alteration code for overprint alteration)

Field 9: DESCRIPTION (A255)

Field 10: SUSCEPTIBILITY (μG/OE) - (N; CGS susceptibility in μG/Oe:
1 μG/Oe = 10-6 G/Oe (CGS) = 12.56 × 10-6 SI)

Field 11: SUSCEPTIBILITY (1E-3 SI) - (N; susceptibility expressed as 10-3 SI)

Field 12: NRM INTENSITY (μG) - (N; intensity of natural remanent magnetisation in μG
1 μG = 1 mA/m SI)

Field 13: NRM DECLINATION (N; in degrees positive clockwise from TN)

Field 14: NRM INCLINATION (N; in degrees, positive downwards)

Field 15: KOENIGSBERGER RATIO - (N; Q value of NRM: Q = NRM/(Susceptibility × Field)

Field 16: RADIOMETRIC # (A25; Radiometric sample no.)

Field 17: K(%) - (N; radiometrically determined potassium)

Field 18: EU(PPM) - (N; radiometrically determined equivalent Uranium, in ppm)

Field 19: ETH(PPM) - (N; radiometrically determined equivalent Thorium, in ppm)

Field 20: DENSITY (G/CC) - (N; dry bulk density determined by weighing in air and water)

Field 21: GEOCHEM # (A12; corresponding geochemical sample field no.)

Field 22: AMG EASTING (N; AMG mE, zone 55)

Field 23: AMG NORTHING (N; AMG mN, zone 55)

3. MTL_RAD.DB

Field 1: Sample (A7; radiometric laboratory no.)

Field 2: Site (A9; palaeomagnetic site no.)

Field 3: Group (A10; radiometric classification - usually equivalent to Terra Search/Mt Leyshon Mine codes)
SGH - Heathfield West Tonalite
RHY - rhyolite dyke, Mt Leyshon - Mt Hope area
gossan - surface gossan from Mt Leyshon - Mt Hope area
por - undifferentiated volcanics from surface in Mt Leyshon - Mt Hope area

Field 4: Type (A9; outcrop, soil or drillcore)

Field 5: K % - (N; radiometrically determined potassium)

Field 6: EU ppm - (N; radiometrically determined equivalent Uranium, in ppm)

Field 7: ETH ppm - (N; radiometrically determined equivalent Thorium, in ppm)

Field 8: Easting (N; AMG mE, zone 55)

Field 9: Northing (N; AMG mN, zone 55)

Field 10: Geolog. unit (A62; description of sample)

Field 11: Comments (A52; rock type)

4. RAVENSWD.DB

Field 1: SAMPLE # - A6; CSIRO Field No.

Field 2: ROCK UNIT - A5 (GSQ codes)
CPglp2 - Lulu Pocket Granite, phase 2
CPglp3 - Lulu Pocket Granite, phase 3
CPgmc - Mount Canton Granite
CPgmo - Molybdenite Creek Granite
CPgr1 - Porphyritic margin of Robey Range Granite
CPgr2 - Granodiorite core to Robey Range Granite
CPvmc - Mount Canton Volcanics, flow-banded rhyolite
Cgb - Bogie Creek Granite
Dgj - Jessup Creek Tonalite
Ost - Hornfelsed fine-grained felsic volcanic country rock adjacent to First Pocket Complex

Pdfp - Diorite phase of First Pocket Intrusive Complex
Pgfp1 - Grey tonalite phase of First Pocket Complex
SDd - Fine-grained mafic rock, occurring within Jessup Creek Tonalite
SDgco - Carse-o-Gowrie Granite
SDgki - Kirkton Tonalite

Field 3: LITHOLOGY - (A20)

Field 4: AGSO LITHOLOGY (A4 - generic lithology codes as used in AGSO databases, described in The AGSO Field Geological Note Books - a User's Guide, AGSO Record 1993/46)

Field 5: AGSO LITH QUAL (A4 - AGSO lithological qualifier)

Field 6: ALTERATION (A12)

Field 7: AGSO ALTERATION 1 (A4 - AGSO alteration code for initial alteration)

Field 8: AGSO ALTERATION 2 (A4 - AGSO alteration code for overprint alteration)

Field 9: DESCRIPTION (A150)

Field 10: SUSCEPTIBILITY (μG/OE) - (N; CGS susceptibility in μG/Oe:
1 μG/Oe = 10-6 G/Oe (CGS) = 12.56 × 10-6 SI)

Field 11: SUSCEPTIBILITY (1E-3 SI) - (N; susceptibility expressed as 10-3 SI)

Field 12: NRM INTENSITY (μG) - (N; intensity of natural remanent magnetisation in μG; 1 μG = 1 mA/m SI)

Field 13: NRM DECLINATION (N; in degrees positive clockwise from TN)

Field 14: NRM INCLINATION (N; in degrees, positive downwards)

Field 15: KOENIGSBERGER RATIO - (N; Q value of NRM: Q = NRM/(Susceptibility × Field)

Field 16: RADIOMETRIC # (A12; Radiometric sample no.)

Field 17: K(%) - (N; radiometrically determined potassium)

Field 18: EU(PPM) - (N; radiometrically determined equivalent Uranium, in ppm)

Field 19: ETH(PPM) - (N; radiometrically determined equivalent Thorium, in ppm)

Field 20: DENSITY (G/CC) - (N; dry bulk density determined by weighing in air and water)

Field 21: GEOCHEM # (A9; corresponding geochemical sample field no.)

Field 22: AMG EASTING (N; AMG mE, zone 55)

Field 23: AMG NORTHING (N; AMG mN, zone 55)

5. RAV_RAD.DB

Field 1: Sample (A7; radiometric laboratory no.)

Field 2: Site (A9; palaeomagnetic site no.)

Field 3: Geology (A10; radiometric classification - equivalent to GSQ codes above)

Field 4: Type (A9; outcrop, soil or drillcore)

Field 5: K % - (N; radiometrically determined potassium)

Field 6: eU ppm - (N; radiometrically determined equivalent Uranium, in ppm)

Field 7: eTh ppm - (N; radiometrically determined equivalent Thorium, in ppm)

Field 8: Easting (N; AMG mE, zone 55)

Field 9: Northing (N; AMG mN, zone 55)

Field 10: Field (A62; description of sample)

Field 11: Comments (A52; rock type)

List of Files and Formats

The 1.44 MB floppy discs provided to sponsors carries a full set of files, representing a range of data formats that can be read by a variety of commercial software packages.

1. Relational Databases

Paradox for Windows (*.DB plus related files: *.TV, *.FAM, *.PX)
dBase (*.DBF)
Access (*.MDB)

2. Spreadsheets

QuattroPro for Windows (*.WB1)
QuattroPro for DOS (*.WQ1)
Lotus 2.x (*.WK1)
Excel 3.0/4.0 (*.XLS)

3. Text File

Delimited text (*.TXT) - fields are separated by commas; text fields only are delimited by quotes.