



The University of Adelaide
Department of Geology and Geophysics

**A STUDY OF THE LITHOLOGY AND STRUCTURE
OF THE EASTERN ARUNTA INLIER
BASED ON AEROMAGNETIC INTERPRETATION.**

A lithological subdivision and structural history of the eastern Arunta Inlier, with particular emphasis on the relationship between magnetic mineral petrogenesis, rock magnetism and aeromagnetic signature.

by

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February, 1987

A thesis submitted to the University of Adelaide
in fulfilment of the requirements for the
degree of
Doctor of Philosophy
Awarded 10/12/87

Statement

To the best of the writer's knowledge and belief, and except where reference is made herein, this thesis contains no copy or paraphrase of previously published material nor any material that has been accepted for the award of any other degree or diploma in any University.

T.H. WHITING
February 1987.

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Acknowledgments

I wish to thank the many people who have helped with my thesis, and without whom this work would not have been possible.

I express my deep gratitude to Professor D.M. Boyd whose supervision and enthusiasm throughout this project were greatly appreciated. Professor P.J. Ypma and Dr F. Chamalaun contributed greatly to this work with fruitful discussions, and correction of various parts of the manuscript.

The Northern Territory Department of Mines and Energy and the Plenty River Mining Company contributed digital data and maps, and supported field work associated with the project. CRA Exploration Pty Ltd and the Northern Territory Department of Mines and Energy assisted in the preparation of diagrams.

I wish to also thank Dr P.I. Brooker, Dr P.R. James, Dr J.W. Paine and Mr A.B. Mitchell for their support during various stages of my research; Ms Sharon Proferes, Mr Evert Bleys and Mr Rick Barrett for drafting and photographic work; Mr A.J. Hosking, Mr M.J. Freeman, Mr B. Simmons and Mr P.Woyzbun for their assistance throughout the project. Personnel of the various laboratories at the University of Adelaide are thanked for invaluable technical assistance. My colleagues, in particular Miss Shanti Rajagopalan, are thanked for their willingness to help and their friendly companionship.

I wish to especially thank my parents whose sacrifices gave me my education, and my wife, Julie, for typing the manuscript and, for her patience and devotion during the past three years.

Abstract

A lithological subdivision and structural history is proposed for the eastern Arunta Inlier from the integration of aeromagnetic interpretation with geological and auxiliary geophysical data. Four major rock groups, having distinct magnetic signatures, are recognised. The first is regarded as a basement complex, and correlates with the oldest rocks in the study area. They have a complex magnetic signature, consisting of irregular or highly contorted anomalies, consistent with the predominance of meta-igneous rocktypes in this group, their high metamorphic grade and involved deformational history. The second group is a cover sequence, composed of metasediments and minor metavolcanics, unconformably or structurally overlying the basement. Multiple linear, to curvilinear anomalies typify this group and reflect its predominantly metasedimentary composition. The third consists of igneous bodies which intrude the first two groups. They give rise to rounded or elongate magnetic features with discordant contacts, which truncate neighbouring magnetic trends. Narrow linear magnetic features of the fourth group are related to mylonitic and retrograde rocks located in fault or shear zones.

In addition to these lithological divisions, the eastern Arunta Inlier is composed of four well-defined, spatially separate magnetic provinces, which have characteristic magnetic patterns and abrupt boundaries. One or more of the four rock groups described above are present in all provinces however, the composition of each province differs markedly. Where exposed, they correlate with tectonic provinces having markedly different depositional, intrusive, metamorphic and structural histories, whilst their boundaries correspond to major fault zones.

The contrasting magnetic signature of the four magnetic provinces reflects their different composition and reveals much concerning their separate, early intrusive and structural histories. Five major orogenic stages are envisaged in the development of the eastern Arunta Inlier. The first stage involved the formation of basement complexes through extrusion of felsic and mafic volcanic horizons and intrusion of granitic and granodioritic bodies, and their subsequent intense deformation which resulted in repeated isoclinal fold development. Deposition of a sedimentary and volcanic cover sequence on the basement and its subsequent metamorphism, deformation and intrusion marked the second stage. Superimposed fold patterns, evident in aeromagnetic trends, indicate the cover sequence and basement have been separately subjected to at least three phases of folding. In one province, folding of the cover sequence clearly remobilised the basement. Elsewhere these groups are separated by a structural break. Early ductile deformation accompanied regional metamorphism, and in some provinces, widespread intrusion and faulting on a local scale.

The third orogenic stage was markedly different from preceding stages. It began with juxtaposition of the provinces by displacement along major faults and continued with remobilisation through regional scale open folding, which resulted in the formation of major basement domes. During the fourth stage, earlier structures in all four magnetic provinces were offset or truncated by NW to WNW and N to NE trending faults. The final stage of deformation involved epeirogenesis, resulting in slight warping of the magnetic provinces, which form a series of convex arcs. WNW to NW elongation of many large structures may also be related to this late stage.

An important part of this research involved work linking magnetic mineral petrogenesis, rock magnetism and aeromagnetic response. Determination of the magnetic properties of representative rock types, indicates many lithologies possess distinct magnetic properties and may be regarded as magnetic lithostratigraphic marker horizons, supporting conclusions made from the correlation of aeromagnetic and geological data. Remanent magnetic intensity and direction are random for most rock types measured, indicating natural remanent magnetization does not contribute significantly to bulk rock magnetization responsible for aeromagnetic anomalies. However, many igneous rocks do exhibit well-defined remanent magnetizations. Random remanence directions appear to be due to a number of factors:

- 1) The influence of secondary components, not representative of bulk magnetization.
- 2) Multicomponent NRM residing in a variety of magnetic phases formed at different times.
- 3) The complex tectonothermal history of this region.

The magnetic properties of rocktypes investigated are dependent on their total iron content and the manner of its division between Fe,Mg-silicates and the oxides of iron and titanium. The partitioning of iron is controlled by oxygen fugacity and titanium content. All these parameters exhibit a well-defined dependence on weight percent SiO_2 , and as a result, the magnetic properties of most major rock groups are related to SiO_2 content. Granites and felsic metavolcanics have lower iron contents and are more oxidized than mafic suites (gabbros, basalts and ultramafics). The former typically contain 0.5-2.0% magnetite and hematite rich components whilst the latter contain 3-10% ulvospinel and ilmenite rich components. The magnetite content of igneous rocks in this area is generally low and they are weakly magnetic. However gabbros have relatively intense well-defined remanence due to quasi-exsolution of magnetite from pyroxene and oxidation of ulvospinel to form magnetite lamellae in ilmenite. Ultramafics are also commonly highly magnetic due to the formation of magnetite during high temperature hydrous alteration (serpentinization). Basement rocktypes exhibit a similar pattern to igneous rocks reflecting the high proportion of meta-igneous rocks in this group. SiO_2 poor metasediments have higher iron contents and more intermediate oxidation ratios, which favour the formation of magnetite, and are more magnetic than metasediments with abundant SiO_2 . Magnetite has commonly been martitised through late-stage retrogressive hydration, resulting in a reduction of the magnetic properties of many rocktypes.



Introduction

Thesis Topic

This study presents an interpretation of aeromagnetics data and its synthesis with rock property, geological and other geophysical information from an area covering approximately 30,000 km² of the eastern Arunta Inlier, Northern Territory.

Nature of the Problem

The Arunta Inlier is typical of Australian Precambrian terranes, complexly deformed, poorly exposed and enclosed by late Precambrian and Phanerozoic sedimentary cover. Consequently, although its better exposed parts have been mapped by many researchers, the geology is unknown across extensive areas and litho-stratigraphic correlations between locally established sequences are tentative.

Aeromagnetics coverage of the eastern Arunta Inlier is of high quality and relatively detailed, allowing the extension of geological mapping beyond basement outcrops and the correlation of widely separated areas. Hence, interpretation of the existing data was considered a potentially valuable aid to regional and detailed geological mapping. Most of this data has been recently acquired (1981-1983) and consequently has not been previously interpreted.

Aeromagnetic Interpretation

The primary objective of aeromagnetic interpretation is the extraction of geological information and its presentation in meaningful geological terms. Knowledge of major importance to studies of crustal evolution can be obtained from aeromagnetic maps as the formation and distribution of magnetic minerals in the earth's crust is dependent on the three fundamental geological processes of magmatic crystallization, sedimentation and metamorphism, and sensitive to environmental conditions influencing a variety of intrinsic parameters.

The successful application of the method is limited to the solution of problems characterised by a reasonable magnetization contrast. In addition, the extraction of geological information is hampered by two inherent problems. First, magnetics interpretation is ambiguous in that models which account for observed anomalies are always non-unique. Second, this ambiguity is furthered by the nature and incomplete understanding of the diverse, complex processes and parameters influencing the formation of magnetic minerals giving rise to aeromagnetic anomalies.

Measurements of the magnetic properties of rocks together with studies concerning the petrogenesis of magnetic minerals help resolve much of the ambiguity which afflicts the method by enabling the source, magnitude and direction of magnetization to be identified. When integrated with auxiliary geological and geophysical information, they result in more probable and geologically meaningful interpretation.

An understanding of the relationship between magnetic mineral petrogenesis, rock magnetism and aeromagnetic anomalies is therefore essential to thorough aeromagnetics interpretation. Unfortunately research in this field is relatively meagre, a fact commented upon by other writers (Zietz & Bhattacharyya 1975, Emerson 1979, Grant 1985.) Consequently aeromagnetics interpretation is at present hampered by a lack of clearly stated principles concerning the geological significance of aeromagnetic signatures. This is evident in the nature of information derived from interpretation, which is too frequently geologically unrealistic, consisting of vague tautological qualitative descriptions of aeromagnetic signatures or quantitative interpretation based wholly on data processing and computation.

The absence of interpretation guidelines is also evident from the lack of detailed information derived from aeromagnetic data. Despite the existence of high sensitivity, detailed digital data covering widespread areas, information regarding earth lithology and structure, extracted from interpretation, is usually of a gross regional nature. Furthermore, little attempt is made to extract information concerning earth history, in particular, the nature of geological processes responsible for the magnetic signature of various rocktypes and the relative timing of deformation events giving rise to structures delineated. Given the ever increasing quality of data acquisition, processing and interpretation, these goals may theoretically be achieved, but do require detailed analysis which is both time consuming and expensive.

As a result of the above deficiencies the vast majority of magnetics data has never been adequately interpreted, a situation which is unfortunate in a vast mining based country such as Australia, where prospective Precambrian terrain is typically covered by surficial material resulting in them being inadequately mapped and poorly understood. Consequently aeromagnetics is a highly utilised, potentially valuable, but generally under-interpreted aid to regional and detailed geological mapping.

Aims of this Study

This study was aimed at the problems outlined in the previous two sections:

First, as extensive deformation and poor continuity of outcrop seriously limit geological mapping, regional and detailed aeromagnetic interpretation was used to investigate the lithology, structure and tectonic history of the study area. To help constrain interpretation, the magnetic

properties of representative rock types were measured. An essential part of the aeromagnetics interpretation was its continued integration with available geological, rock property and other geophysical data to produce a final geologically meaningful interpretation. This synthesis provided a basis for review and expansion of current lithostratigraphic and tectonic concepts outlined in Chapter 1.

Second, as published work linking studies of magnetic petrophysics, rock magnetism and aeromagnetic interpretation is scarce, an attempt was made to investigate what kinds of information could be extracted from the aeromagnetics data by identifying the geological processes, parameters and conditions influencing rock magnetism.

Third, an effort was made to make a useful contribution to future mineral exploration in the area.

Finally, as there is a wealth of uninterpreted data within Australia, it was hoped that results would illustrate the usefulness of detailed aeromagnetic interpretation in Precambrian areas such as the Arunta Inlier and provide a model for further research.

Part I

GEOLOGY AND MAGNETIC ROCK PROPERTY STUDIES

The Geology of the Eastern Arunta Inlier

In this chapter, literature describing the geology of the eastern Arunta Inlier is summarised in order to:

- 1) Provide the reader with a current geological perspective of the study area.
- 2) Facilitate reference to geological units and structural features in forthcoming chapters.
- 3) Provide the basis for review and extension of mapping and concepts during subsequent integration of geological and geophysical information.

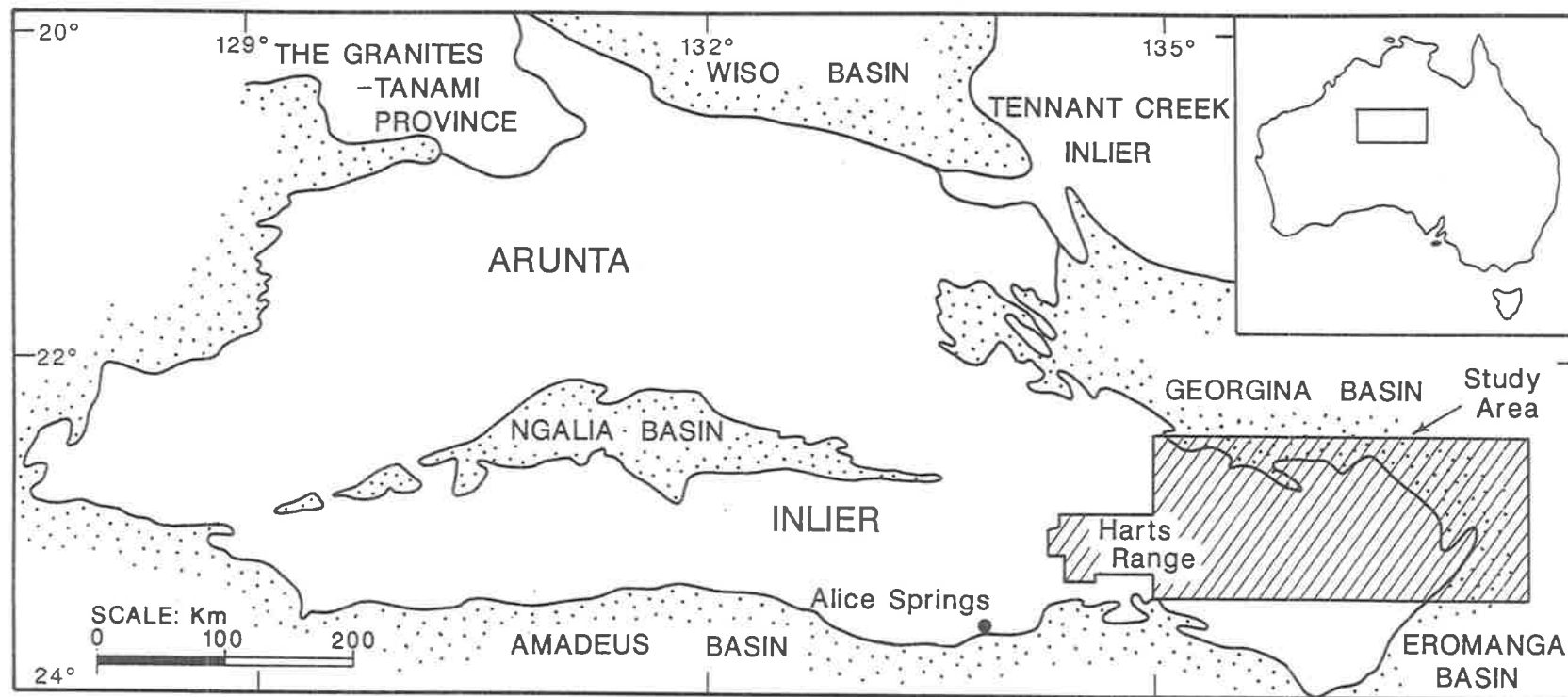


Figure 1.1 Location map of the study area.

1.1 INTRODUCTION

The study area covers the eastern part of the Arunta Inlier, a multiply deformed polymetamorphic Precambrian terrain covering approximately 200,000 km² of central Australia (Fig 1.1). It is surrounded on most sides and partially overlain by late Precambrian and Phanerozoic sediments of the Georgina, Amadeus, Wiso and Eromanga basins which separate it from the economically important Tennant Creek Inlier to the north and Mount Isa Inlier to the northeast.

The extent of outcrop in the study area varies considerably. The best exposures are found in the Harts Range to the southwest, and within a 20 km wide corridor stretching westward from longitude 136°30' along the northern boundary of the Inlier. Elsewhere, outcrop is poor, being sparse in the center and to the south and virtually non-existent in the east. Consequently, geological investigations to date have been largely restricted to the northern and western parts of the study area.

1.1.1 Regional Stratigraphic and Tectonic Framework of the Arunta Inlier

Early geological investigations were concerned with the Harts Range area (Hodge-Smith 1932; Jensen 1944, 1947; Joklik 1955). This work was modified and extended through systematic reconnaissance mapping by the Bureau of Mineral Resources (BMR) and the Northern Territory Geological Survey (NTGS), and supplementary studies by staff and students of the Australian National University, Monash University, the University of Queensland and the University of Adelaide.

The Arunta Inlier is considered by many to be a Proterozoic ensialic mobile belt. (Rutland 1981; Stewart et al., 1984; Shaw et al., 1984). Its stratigraphic subdivision has been described by Shaw et al (1975, 1979), Stewart et al (1980) and integrated by Stewart et al (1984). Three major stratigraphic groups (Divisions 1, 2 & 3) are recognised primarily on the basis of lithological associations and metamorphic character. Rocks assigned to each division broadly represent a lithogenetic facies and are tentatively regarded as chronological or stratigraphic correlatives, Division 1 being the oldest and Division 3 the youngest. Their distribution in the study area is shown in Figure 1.2. Where exposed, Division boundaries are commonly faulted, sheared, metamorphosed or intruded by granite.

Large elongate syntectonic granite plutons and smaller equant post-tectonic bodies of intermediate, mafic and ultramafic composition intrude the metamorphosed rocks of the three Divisions. Granitoid emplacement ages range from 930 Ma to 1750 Ma. Detailed descriptions of lithology, relationships and age are given in Shaw et al (1979) and Stewart et al (1980).

In addition to the three stratigraphic Divisions, the Arunta Inlier is also divided into three latitudinal tectonic provinces having markedly different lithological, metamorphic and structural histories (Shaw et al., 1984). They are bounded by major, well-defined zones of deformation which localised large scale movements from early in the Inlier's history. The Northern Tectonic Province consists mostly of Division 2 and 3 metasediments, extensively intruded by large granite plutons. The Central Tectonic Province is composed predominantly of Division 1 granulites in the center and west and Division 2 metasediments in the east. Granites are few and small. The Southern Tectonic Province is the smallest of the three, consisting of granitoid gneisses, lesser amounts of aluminous gneisses of Division 2, and quartzite and schist of Division 3. Only the Northern and Central Tectonic Provinces are considered to be present in

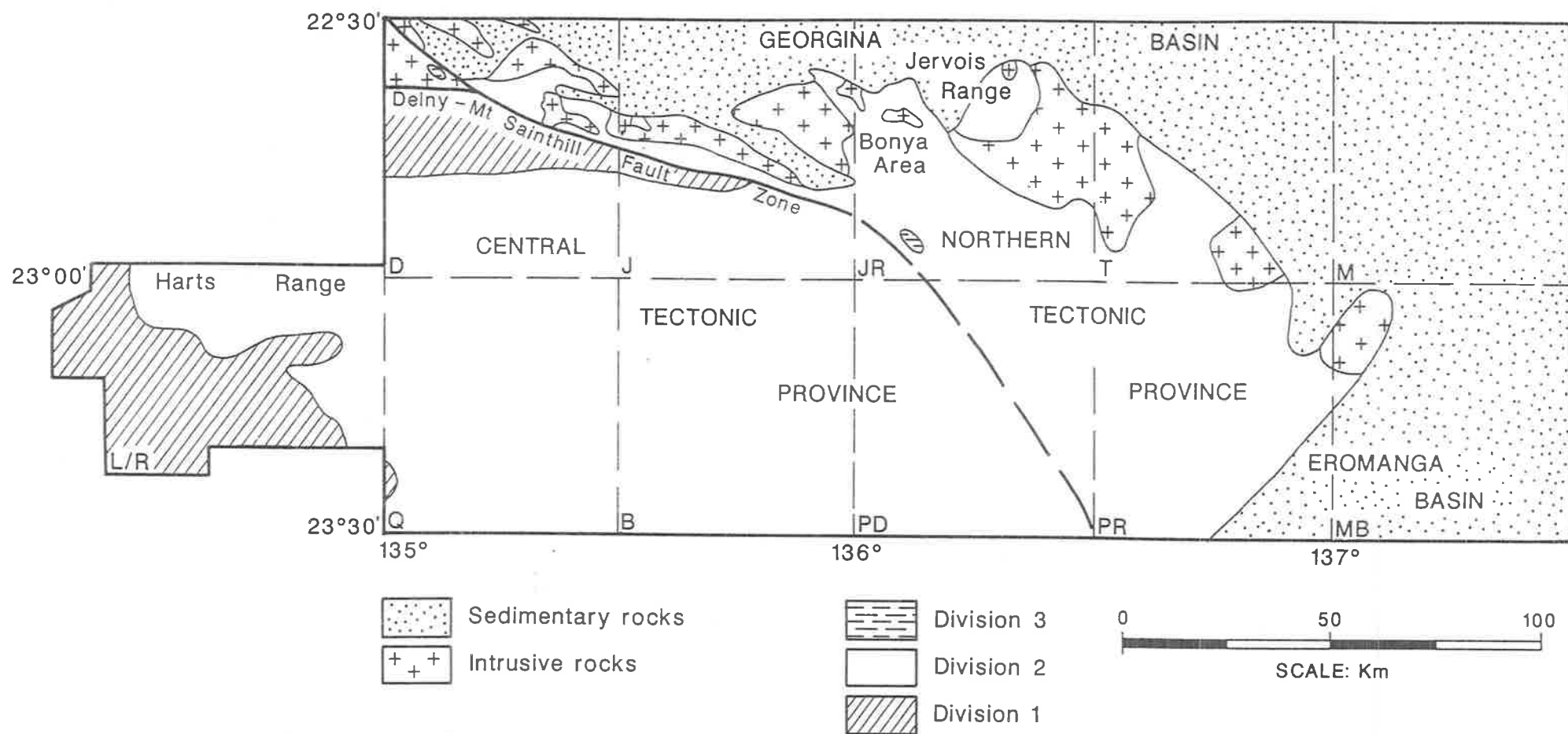


Figure 1.2 Generalised geological map of the study area showing major stratigraphic divisions and tectonic provinces. Letters denote 1:100,000 sheets; B - BRAHMA, D - DNEIPER, J - JINKA, JR - JERVOIS RANGE, L/R - LAUGHLEN/RIDDOCH, M - MARQUA, MB - MOUNT BARRINGTON, PD - PLENTY DOWNS, PR - PLENTY RIVER, Q - QUARTZ, T - TARLTON.

the study area (Fig. 1.2).

1.2 STRATIGRAPHY OF THE STUDY AREA

1.2.1 Division 1

Division 1 rocks consist of mafic, felsic and aluminous granulites and subordinate amounts of metamorphosed calc-silicate and pelitic rocks. They are considered to represent two lithogenetic facies: an early bimodal volcanic facies of mafic layers interpreted to be basalt flows together with felsic layers of granite to granodiorite composition, and a later shale-limestone facies representing the incoming of marine sediments as volcanism waned. The former rock types are inferred to be lower in the sequence whilst the latter are more dominant in the upper part. In the study area, Division 1 is represented by units of the Strangways Metamorphic Complex located to the southwest on *LAUGHLEN*, *RIDDOCH* * and the Kanandra Granulite, outcrops of which are confined to western *DNEIPER* and to slivers within the Delny-Mount Sainthill Fault Zone (Fig. 1.2). Detailed descriptions of these units are given in Table 1.1.

Table 1.1: Division 1 units, eastern Arunta Inlier

UNIT	DESCRIPTION	DISTRIBUTION	REMARKS
p _{csl}	Calc-silicate rocks, schistose biotite & sillimanite gneiss. Minor quartzofeldspathic gneiss, amphibolite	Central <i>RIDDOCH</i>	May overlie or be a facies equivalent of the Cadney Metamorphics
Cadney Metamorphics	Dominantly biotite-sillimanite gneiss, calc-silicate rock and felsic & mafic granulite. Subordinate quartzofeldspathic gneiss, amphibolite	Central <i>RIDDOCH</i>	
p _{est}	Dominantly quartzofeldspathic gneiss. Lenses of mafic granulite, biotite gneiss. Minor amphibolite, calc-silicate rock.	Northwestern <i>RIDDOCH</i>	Appears to conformably underlie Cadney Metamorphics
Bungitina Metamorphics	Fine grained sequence of predominantly quartzofeldspathic gneiss. Lesser biotite gneiss, mafic granulite, migmatite, and amphibolite	Central eastern <i>RIDDOCH</i>	Renamed Oonagalabi gneiss complex (Ding & James (1985))
Ongeva Granulite	Interlayered mafic & felsic granulite, quartzofeldspathic gneiss, biotite gneiss, sillimanite gneiss and migmatite	Western <i>RIDDOCH</i> , eastern <i>LAUGHLEN</i>	Gradational contact with Cadney Metamorphics. Distinguished by its higher mafic granulite content
Kanandra granulite	Fine grained mafic granulite, garnetiferous quartzofeldspathic gneiss and lesser metasediments	<i>DNEIPER</i>	

* Italicized names denote 1:100,000 or 1:250,000 sheets.

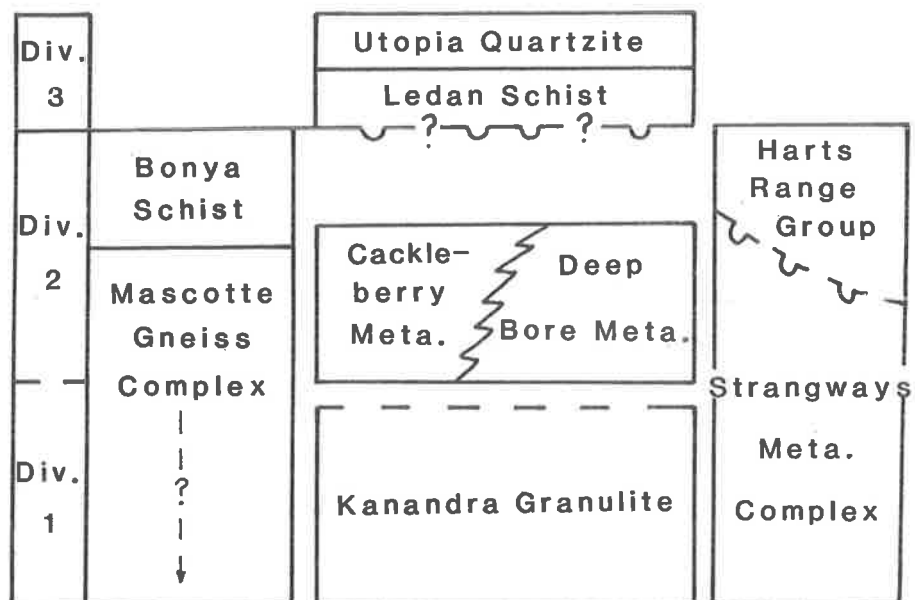


Figure 1.3 Tentative stratigraphic correlations between named units within the eastern Arunta Inlier (After Stewart et. al., 1984)

The Bungitina Metamorphics have been studied in detail by Rankin (1983) in the Oonagalabi Dome on central *RIDDOCH*, where he renamed it the Oonagalabi gneiss complex. As details of his work are referenced in the remainder of this study this name is subsequently adopted for simplicity.

Several unnamed units are tentatively assigned to Division 1 by Freeman (in prep). The first is restricted to the Delny-Mount Sainthill Fault Zone and bears a lithological and metamorphic similarity to the Cadney Metamorphics. The second, located on southern *JERVOIS RANGE* consists of isolated outcrops of quartzofeldspathic and biotite gneiss containing leucosomes of migmatite, and a variety of schists with minor layered quartz-magnetite rock. The unit is tentatively placed in Division 1 because it is inferred to unconformably underlie rocks of the Harts Range Group (Section 1.2.2).

1.2.2 Division 2

Division 2 is the most extensive of the three Divisions in the study area (Fig. 1.2). In the Northern Province, it is considered the flysh-like facies of the Arunta Inlier (Stewart et. al., 1984), being composed of abundant aluminous and silicic metasediments, lesser calcareous rocks and minor mafic flows or sills. Metamorphic facies varies from granulite grade in the west to amphibolite grade in the eastern part of the study area. In the Central Province, Division 2 consists of amphibolite facies aluminous metasediments and minor igneous rocks of the Harts Range Group. Figure 1.3 illustrates tentative stratigraphic correlations between named units of Division 1 and 2 according to Stewart et al (1984).

Division 2 of the Central Tectonic Province

Joklik (1955) named and defined the Harts Range Group as consisting of a conformable sequence of two quartzofeldspathic units, the Entia Gneiss and Bruna Gneiss, overlain by two pelitic units, the Irindina Gneiss and Brady Gneiss. As a result of detailed mapping in the Harts Range area, Ding and James (1985) revised this lithological subdivision and nomenclature, considering the Entia Gneiss together with units of the Division 1 Strangways Metamorphic Complex to be crystalline basement to a metasedimentary cover sequence consisting of the Irindina and Brady Gneiss. They renamed these units the Entia gneiss complex, the Irindina supracrustal assemblage and the Brady supracrustal assemblage. Descriptions of lithologies comprising these units are given in Table 1.2, and their distribution is illustrated in Figure 1.4.

Ding and James consider the Bruna Gneiss to be of igneous origin, occupying a restricted location along part of the basement, cover boundary. Its contacts with basement and cover are masked by a pervasive mylonitic fabric interpreted to be tectonic in origin. They recognise no formal stratigraphy in their cover sequence considering many major lithological contacts to be tectonic in nature. Within the Irindina supracrustal assemblage is the Harts Range meta-igneous complex (Table 1.2) which consists of layered amphibolites (the Riddock Amphibolite Member of Shaw et. al., 1982), rare pods of ultramafic and a horizon of anorthosite (the Entire anorthosite).

Isolated outcrops covering much of *BRAHMA* and *PLENTY DOWNS* to the east of the Harts Range are regarded as facies equivalents of the Irindina and Brady assemblages (Shaw et. al., 1982).

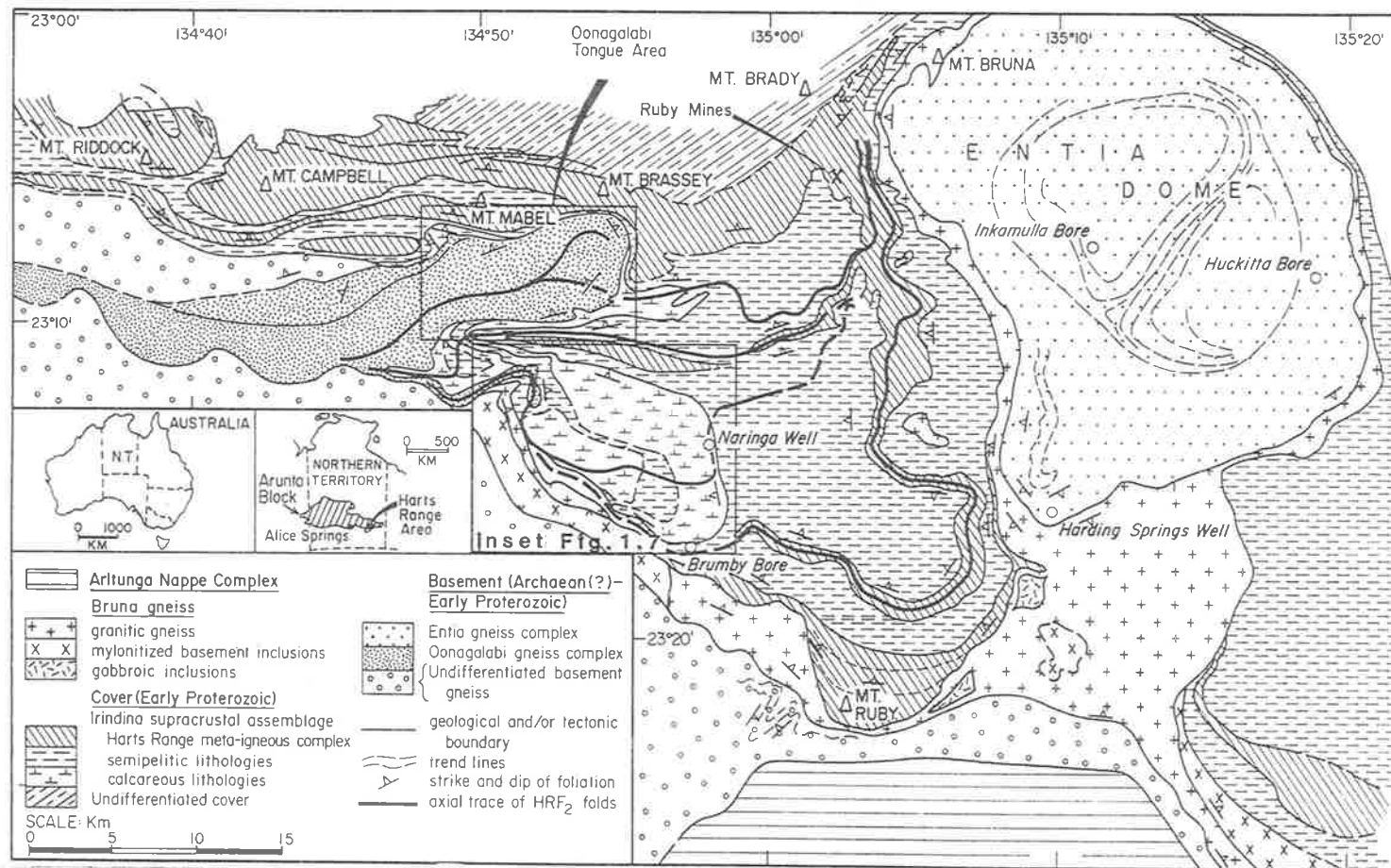


Figure 1.4 Simplified geological map of the Harts Range area (After Ding & James, 1985).

Table 1.2: Division 2 units, Central Tectonic Province

UNIT	DESCRIPTION	DISTRIBUTION	REMARKS
Brady supracrustal assemblage	Garnetiferous biotite gneiss & schist, calc-silicate rock, quartzite and amphibolite	Northern & eastern <i>QUARTZ</i>	Division 2 (Cover sequence)
Irindina supracrustal assemblage	Biotite gneiss, biotite schist, calc-silicate rock, amphibolite. Contains Riddock amphibolite & Entire anorthosite of the Harts Range meta-igneous complex	Extensive; northern & eastern <i>RIDDOCH</i> and <i>QUARTZ</i> . Correlatives on <i>BRAHMA</i> & <i>PLENTY DOWNS</i>	Division 2 (Cover sequence)
Bruna Gneiss	Granitic gneiss containing potash feldspar megacrysts. Numerous xenoliths of amphibolite, mafic granulite & charnockitic gneiss	Surrounds the Entia Dome on <i>QUARTZ</i> & forms much of the border between basement and cover	Tectonically emplaced igneous unit?
Entia gneiss complex	Dominantly quartzofeldspathic gneiss & interlayered hornblende gneiss. Subordinate amphibolite, calc-silicate rock. Minor migmatitic gneiss, kyanite- biotite schist.	Entia Dome, central, northern <i>QUARTZ</i>	Division 1? (basement)

Division 2 of the Northern Tectonic Province

Division 2 of the Northern Province is best exposed on *DNEIPER*, *JINKA* and *JERVOIS RANGE* within a narrow belt lying between the Delny-Mount Sainthill Fault Zone and the Georgina Basin. Shaw et al (In prep) subdivide it into a number of discrete metamorphic units on the basis of lithology and metamorphic grade. Lithologies comprising these units, and their distribution are described in Table 1.3. All units show the effects of a prograde metamorphic event which locally reached granulite grade in the west and amphibolite grade in the east. They were subsequently hydrated and partially retrogressed to lower amphibolite and greenschist facies (Freeman, in prep; Dobos, 1975).

Tentative stratigraphic correlations between units are shown in Figure 1.3. The Deep Bore Metamorphics and Cackleberry Metamorphics are compositionally similar and considered facies equivalents. The Mascotte Gneiss Complex is inferred to underlie the Bonya Schist. The granitoid and parts of the granitic gneiss of the former unit may be metamorphosed pre-tectonic igneous rock which is tentatively regarded as Division 1.

The Bonya Schist was mapped in detail in the Jervois Range area (Fig. 1.2) by Peters et al (1985), who recognise four major litho-stratigraphic units:

- 1) Gneissic suite of granite and rhyolite gneiss.
- 2) Mg-silicate suite comprising cordierite-biotite schist and chlorite-biotite schist.
- 3) Mine sequence suite of andalusite and cordierite schists (knotted

schists), quartz-sericite schist with distinct rhyolite remnants, and quartz-sericite-feldspar schist which contains lode horizons of magnetite quartzite, banded iron formation and calc-silicate rock (See Section 1.5).

4) Fe,Mg-silicate suite, consisting of quartz-chlorite schists containing intercalations of chlorite-magnetite-garnet quartzite.

All units contain amphibolite as extensive outcrops or intercalations. The Gneissic suite resembles and may be a correlative of the Mascotte Gneiss Complex. An unnamed unit (pes; Freeman, in prep) found on central *JINKA* adjacent to the Delny-Mount Sainthill Fault Zone may also be lithologically correlated with the Mascotte Gneiss Complex. It is composed of quartzofeldspathic gneiss of granitic appearance which is locally migmatitic and grades into biotite gneiss.

Table 1.3: Division 2 units, Northern Tectonic Province

UNIT	DESCRIPTION	DISTRIBUTION	REMARKS
Perenti Metamorphics	Well layered felsic granulite, quartzofeldspathic gneiss, quartz-silliminite-biotite-cordierite rock. Minor calc-silicate rock and meta-dolerite	Within Mt Swan Granite near western <i>DNEIPER</i>	Cannot be correlated with other Division 2 units
Deep Bore Metamorphics	Cordierite-bearing quartzofeldspathic gneiss, calc-silicate rock. Minor mafic granulite, quartzose rock & layered amphibolite	Western <i>JINKA</i>	Resembles the Bonya Schist
Cackleberry Metamorphics	Calc-silicate rock & quartzofeldspathic gneiss. Minor cordierite & hornblende quartzofeldspathic gneiss, layered amphibolite, anthophyllite-biotite-quartz-cordierite granofels	Eastern <i>DNEIPER</i>	Compositionally similar to the Deep Bore Metamorphics
Bonya Schist	Schist with biotite, chlorite, cordierite, silliminite, andalusite & garnet. Calc-silicate rock, quartz-magnetite rock. Amphibolite often as thick sequences (Kings Legend Amphibolite Member)	Central & western <i>JERVOIS RANGE</i>	
Mascotte Gneiss Complex	Granitoid, granitic gneiss & quartzofeldspathic gneiss. Minor leucogranite, biotite schist, biotite gneiss, amphibolite & hornblende gneiss	Southwest <i>JERVOIS RANGE</i>	Possibly pre-tectonic igneous rock. Division 1?

On *MARQUA*, Division 2 assigned to the Mount Smith Metamorphics is exposed within windows in platform cover of the Georgina Basin (Warren, 1981). This unit consists of arkose, minor pelite and calcareous rock metamorphosed to lower amphibolite grade. The potassic character of these rocks and the presence of widespread granite is considered by Warren to be typical of the Northern Province.

1.2.3 Division 3

Division 3 occurs only locally in the study area. Outcrops are found in the Northern Province on *DNEIPER* and southwestern *JERVOIS RANGE* (Fig. 1.2). The Ledan Schist and Utopia Quartzite consist dominantly of metapsammite and metapelite. Contacts between these and Division 2 units are considered unconformable (Shaw & Stewart, 1975; Fig. 1.3). Fine grained granofels of the Your Dam Metamorphics outcrop on eastern *MARQUA*, and are considered a lateral facies variant of the Ledan Schist and Utopia Quartzite (Warren, 1981).

1.2.4 Intrusives

Granites

Large granite plutons and small equidimensional post-tectonic stocks intrude metamorphic rocks of the Northern Province. They are grouped into formal units (Freeman, in press) described in Table 1.4.

Table 1.4: Granites of the Northern Tectonic Province

UNIT	DESCRIPTION	DISTRIBUTION	REMARKS
Mount Swan Granite	Porphyritic gneissic granite	Western <i>DNEIPER</i>	Contains large rafts of Perenti Metamorphics
Dneiper Granite	Distinctive grey, biotite rich gneissic granite	<i>DNEIPER</i>	Intruded by unnamed granites, dolerite, gabbro and possibly the Mt Swan Granite
Marshall Granite	A slightly gneissic leucogranite containing dykes & veins of aplite or microgranite & quartz veins with angular magnetite grains	western <i>JINKA</i>	
Jinka Granite	Coarse, even-grained, slightly gneissic granite	central <i>JINKA</i>	Rb-Sr ages 1690-1785 Ma. Intruded by Oorabra quartz reefs.
Jervois Granite	Several phases ranging from granite to granodiorite	<i>JERVOIS RANGE</i>	Possibly several intrusives. Roof pendants common. Rb-Sr age 1808 ± 80 Ma.
Xanten Granite	Coarse grained leucogranite	In fault bounded block, southern Jervois Range	
Unca Granite	Coarse leucocratic granite	<i>JERVOIS RANGE</i>	Small body intruding Bonya Schist. Rb-Sr age 1459 ± 10 Ma.
Mount Dobbie Granite	Muscovite-rich leucogranite	Near eastern <i>MARQUA</i> border	Intrudes Mount Smith Metamorphics
Mount Teitkens Granite Complex	Two phases: older medium, even-grained muscovite-biotite leucocratic granite; younger porphyritic leucocratic granite	Near eastern <i>MARQUA</i> border	Intrudes Mount Smith Metamorphics

Their location ranges from the Mount Swan Granite in the west to the Mount Dobbie Granite and Mount Teitkens Granite Complex in the east. Emplacement ages have been determined for certain granites. Ages ranging from 1690 - 1785 Ma were obtained for the Jinka Granite using the Rb-Sr method (Wilson et. al., 1960; Compston & Arriens, 1968). Black (1980) obtained a Rb-Sr total rock age of 1808 ± 80 Ma for the Jervois Granite, and 1459 ± 10 Ma for the Unca Granite. Many other granites thought to be part of the large suite of bodies intruded into the Northern Province have been mapped but not named. Details of their composition are contained in Stewart et al (1980).

Granites of the Central Tectonic Province are few and small. The Inkamulla and Huckitta Granodiorites intrude the Entia gneiss complex on QUARTZ. Both are gneissic and conformable with the contact and compositional layering in the Entia gneiss, suggesting they were emplaced before the main regional metamorphic event (Shaw et. al., 1982).

Intermediate, Mafic and Ultramafic Rocks

Pegmatites are common in the eastern Arunta Inlier and several groups are recognised (Freeman, in prep). The Samarkand Pegmatites occur in the Bonya Schist of the Northern Province and range in size from small veins to stocks covering up to 50ha. The Harts Range Pegmatites are small to large pegmatite dykes found within the Irindina and Brady supracrustal assemblages of the Central Province. An extensive suite of quartz reefs, the Oorabra Reefs, were emplaced as fissure veins and stockworks in tension fractures within the Jinka Granite.

Gabbroic, noritic and ultramafic intrusives are common, and range in size from small lenses to bodies several hundred metres across. They exhibit various degrees of metamorphic recrystallisation, and may have been emplaced during or slightly after regional metamorphism. The most conspicuous body of this type is the Attutra Metagabbro which covers an area of 140km^2 on central JERVOIS RANGE. Several plugs of vanadiferous magnetite up to 50m in diameter occur within outcrops of this intrusive. Metamorphosed dolerite dykes also occur throughout the region (Freeman, in press).

Metamorphosed ultramafic rocks have been reported at various localities during regional mapping (Freeman, 1979; in press), and exploration for diamondiferous kimberlites (B.H.P. Rpt., 1982; Harvey, 1982, 1983a-e). These bodies are commonly serpentized. Two notable intrusives located near the western border of the study area also warrant a brief mention. The Mordor Igneous Complex is a potassic - basic complex of kimberlitic affinities possibly intruded along the Woolanga Lineament, a prominent gravity lineament which coincides with a number of major faults. Langworthy and Black (1978) obtained a Rb-Sr whole rock age of 1210 ± 90 Ma for this intrusive. The Mud Tank Carbonatite similarly intrudes a fault zone not far from the Woolanga Lineament. This body consists of apatite, zircon, ilmenite, magnetite and large amounts of trace elements. Ages of 732 ± 5 Ma (U-Pb) and 735 ± 75 Ma (Rb-Sr whole rock) are reported by Black and Gulson (1978).

1.2.5 Late-Stage Retrograde Schist Zones

Schist zones related to recurrent activity over long periods in retrograde fault zones, occur throughout the Arunta Inlier. In the study area, they are found in broad belts up to 5km wide along the Delny-Mount Sainthill Fault Zone (Warren, 1978), and the Illogwa Schist Zone on southern QUARTZ

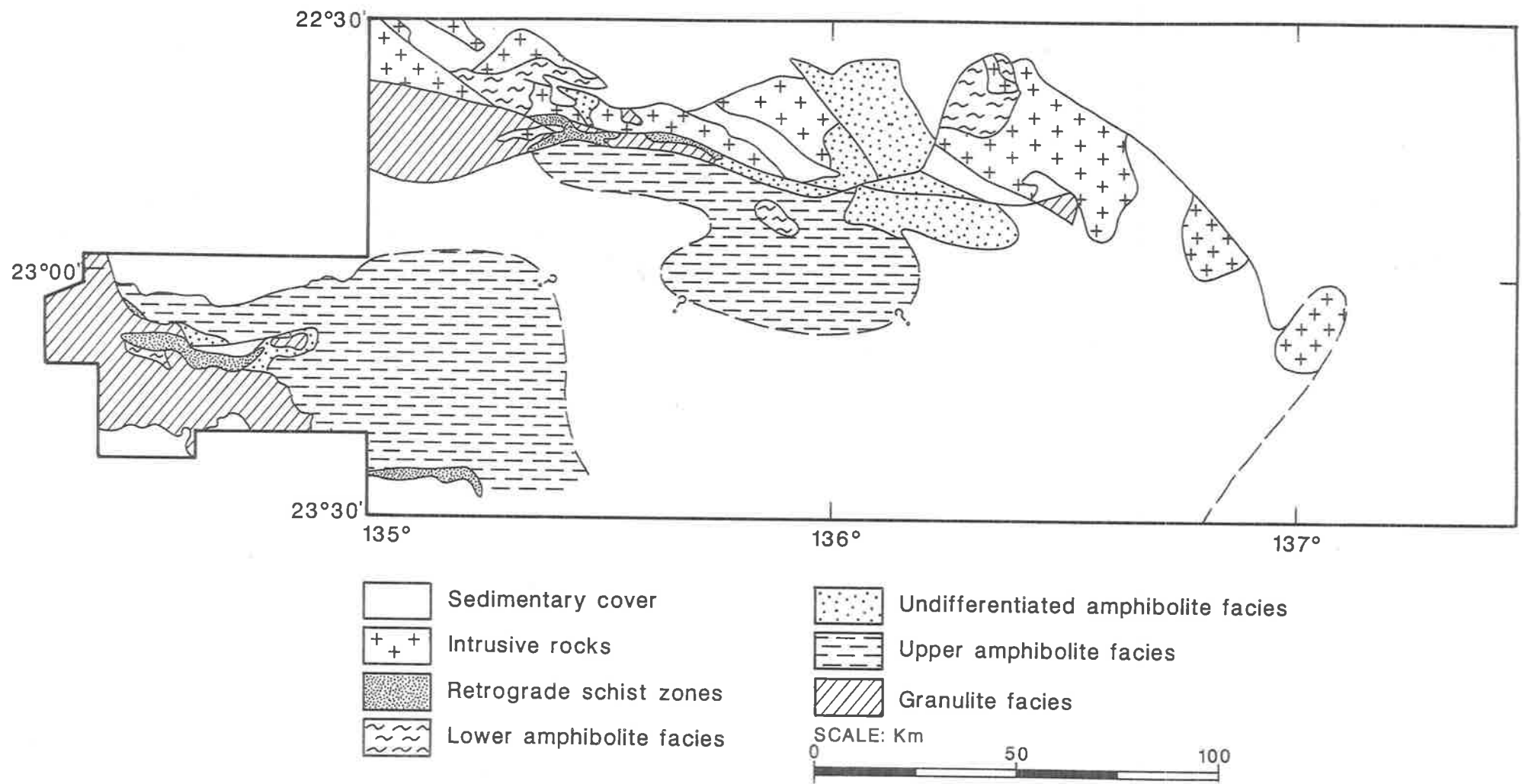


Figure 1.5 Generalised map showing the distribution of metamorphic facies in the study area.

(Shaw et. al., 1982). Rocktypes include mica schists, felsic chloritic schist, amphibolite and mylonite (Freeman, in press). Similar zones of sericitic quartzofeldspathic rock, foliated amphibolite, biotite schist and phyllonite are located on southeast *JERVOIS RANGE*. Schist belts on *ALICE SPRINGS* to the west, have Rb-Sr ages of 300 - 400 Ma (Armstrong & Stewart, 1975).

1.2.6 Late Precambrian and Phanerozoic Basins

In the late Proterozoic, shallow marine sediments were deposited near or over much of the Inlier. During Adelaidean time, argillites, arenites, glauconitic sediments and carbonates were deposited along the southern margin of the Georgina Basin in northwest trending half-grabens. These structures have fault-bounded northeast margins, with sediments overlying basement unconformably to the southwest. From the Cambrian onwards, sedimentation consisted primarily of carbonates and arenites and extended northwards into the Wiso and central Georgina Basins. Similar sediments were deposited in the Amadeus Basin and it is likely they originally extended between these basins. Only one drill hole in the study area penetrates the entire Georgina Basin sequence. Exoil No 1 on *JINKA*, reached basement at 1180m below surface. BMR 12 (Cockroach) on *MARQUA* terminated in the lower part of the stratigraphy at 1230 metres.

A thin sequence of Cretaceous Eromanga Basin and Cainozoic sediments cover the southeastern part of the study area. A number of drill holes intersected up to 235m of dark grey mudstone of the Wallumbilla Formation and sandstone of the Longsight Sandstone, Hooray Sandstone and Tarlton Formation (B.M.R. Rpt., 1971; French, 1981).

The Huckitta Basin, on southern *DNEIPER* is a narrow depression containing over 200m of clay and sand units deposited during the Tertiary period. A number of drill holes penetrate the sequence and the underlying basement (Howard, 1981).

1.3 METAMORPHISM

Rb-Sr data reveal a long and complex metamorphic history for the Arunta Inlier. Black and others (1983) document five metamorphic episodes, ranging in age from about 1800 Ma to 1000 Ma. The earliest of these, the Strangways Event is considered the major metamorphic episode affecting the eastern Arunta Inlier. In the Strangways Range, 50km west of the study area, it peaked at temperatures of 700 to 850°C and pressures of 7-9kb. An age of 1790 ± 35 Ma derived from the Kanandra Granulite on *DNEIPER* is considered the most reliable for this event (Black et. al., 1983). Other metamorphic episodes, with the exception of the Alice Springs Orogeny, were restricted to other parts of the Inlier.

The distribution of metamorphic rocks in the eastern Arunta Inlier is illustrated in Figure 1.5. The Division 1 Strangways Metamorphic Complex is in general metamorphosed to granulite facies. Division 2 of the Northern Province is metamorphosed to lower or upper amphibolite facies, although several units reached granulite grade (Section 1.2.2). Metamorphism of Division 2 of the Central Province is in general of upper amphibolite facies, although Shaw et al (1982) indicate it is upper greenschist, lower amphibolite in its poorly exposed southeastern part.

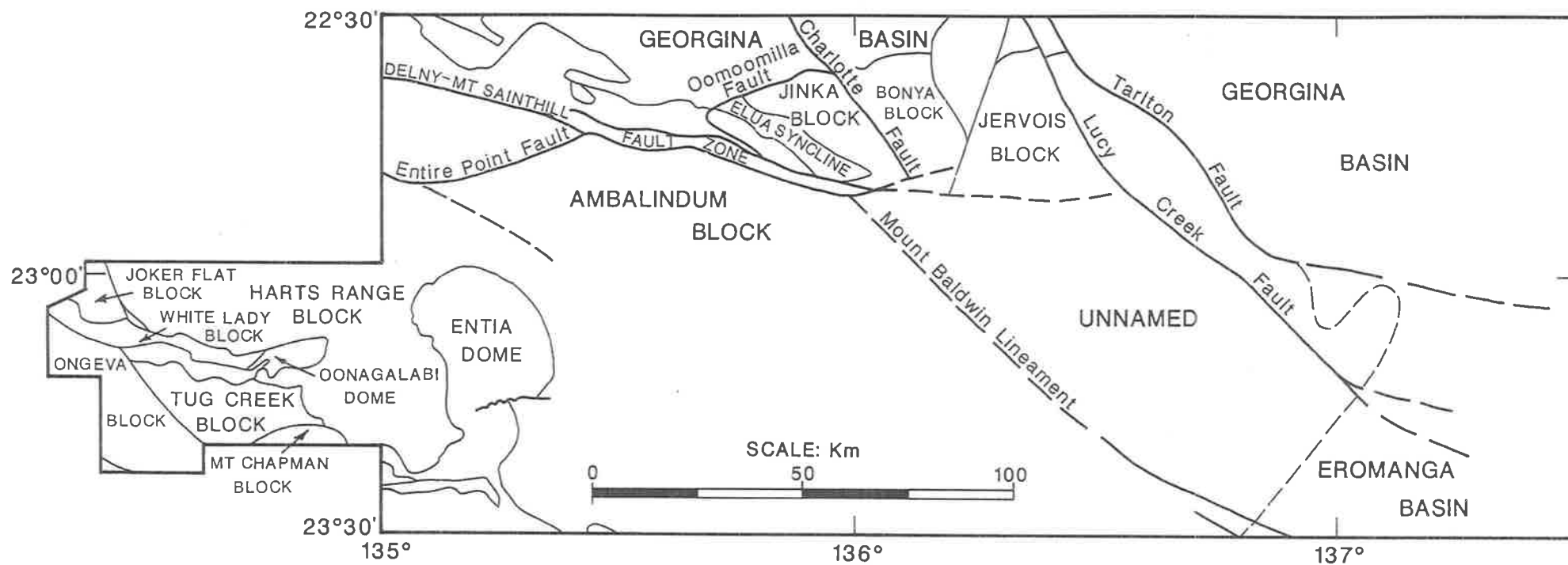


Figure 1.6 Major structural blocks and faults recognised in the study area.

A pervasive lower-temperature hydration event followed the prograde Strangways Event. Its effects on units of the Northern Province are described by Dobos (1978), Shaw and others (1984) and Freeman (in press). In the Central Province, the formation of muscovite within the Irindina supracrustal assemblage is thought to result from hydration produced by extensive pegmatitisation of this unit. This event might be correlated with the Alice Springs Orogeny (Shaw et al., 1979) of 300 - 400 Ma ago, which was characterised by thrust-faulting, greenschist facies metamorphism and local pegmatite formation. Metamorphism and faulting resulting from the Alice Springs Orogeny are most evident in retrograde schist zones (Section 1.2.5), in particular, within the Delny-Mount Sainthill Fault Zone and Illogwa Schist Zone.

1.4 STRUCTURE

The study area lies within the Northern and Central Tectonic Provinces of Shaw et al (1984), which have different stratigraphic, structural and metamorphic histories (Sections 1.1, 1.2 & 1.3). In the north they are separated by the Delny-Mount Sainthill Fault Zone (Section 1.4.1). In the east, their boundary is concealed, but is defined by Warren (1981) as the Mount Baldwin Lineament, a well-defined Landsat feature, and the approximately colinear Lake Caroline Gravity Ridge (Fig. 1.6).

Studies by Warren (1980, 1981), Shaw and Wells (1983) and Shaw et al (1984) further subdivide the area into structural blocks separated by major faults (Fig. 1.6). However, little is known concerning their inter-relationship and the shape and nature of their bounding structures. In the Harts Range area, this structural interpretation has been considerably modified by Ding and James (1985). They recognise two major lithological groups, representing crystalline basement and supracrustal cover sequence (Section 1.2.2), having separate early tectonothermal histories. Both groups were subsequently juxtaposed by large scale thrusting and remobilized as a single mobile zone. This interpretation questions the tectonic framework proposed by Shaw and others (1984), in particular the existence and nature of the Central Tectonic Province in the eastern Arunta Inlier.

1.4.1 Faulting

The major fault structure in the study area is the Delny-Mount Sainthill Fault Zone which extends WNW from southwest *JERVOIS RANGE* for some 150km to beyond the western boundary of *DNEIPER* (Fig. 1.6). The fault system has been described by Warren (1978) as a discontinuously exposed, anastomosing zone of deformed rocks locally encompassing slivers of undeformed rocks. Deformed zones are commonly half a kilometre wide and there is a marked change in metamorphic facies from granulite or upper amphibolite to lower amphibolite and greenschist in the vicinity of the fault zone. Lineations observed in deformed rocks indicate movement along the fault has been predominantly vertical with little transcurrent component. Evidence suggests that movement was initiated early in the history of the Inlier (Warren 1978, Black 1980) and has been intermittently reactivated during its subsequent history. Its last movement is tentatively correlated with the Carboniferous Alice Springs Orogeny. Warren considers, primarily from regional geophysical evidence (gravity & magnetics), that the Delny-Mount Sainthill Fault Zone ceases to be a major structure to the east of southeastern *JERVOIS RANGE*.

Other faults separating major crustal blocks occurs mostly along narrow, well-defined planes (Fig. 1.6). The Entire Point Fault separates the granulite facies Kanandra Granulite from amphibolite facies

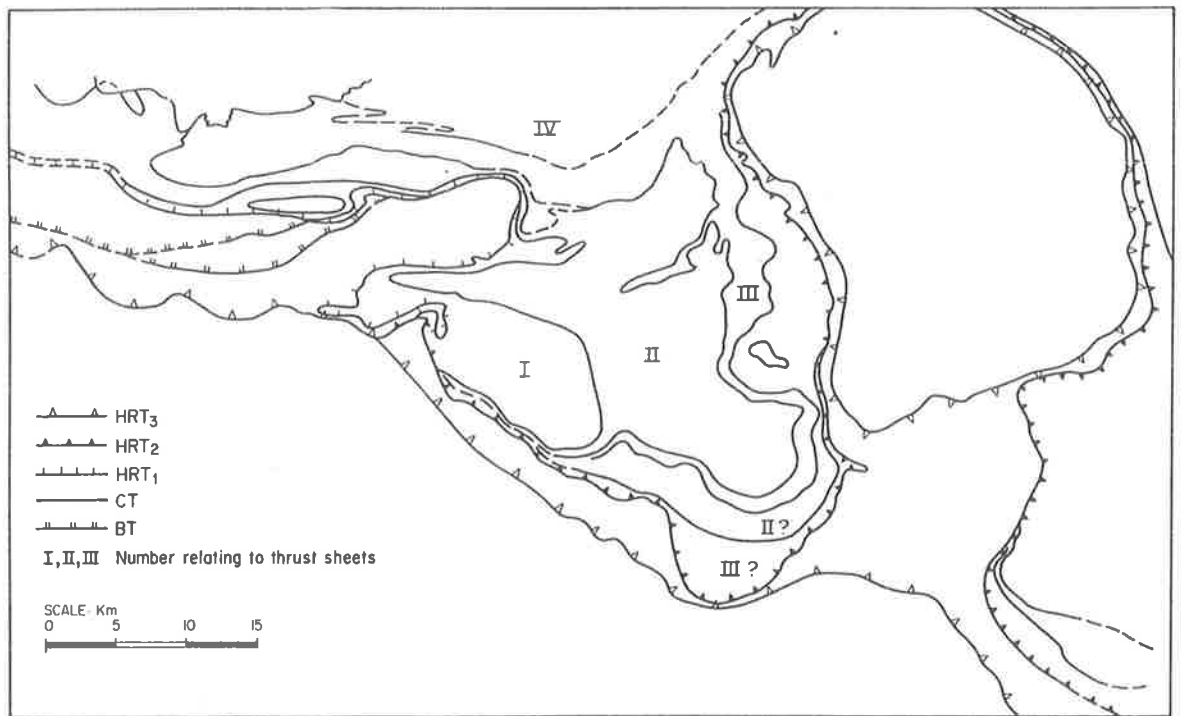


Figure 1.7 Simplified map showing major thrusts in the Harts Range area. (After Ding & James, 1985).

Harts Range Group. Its northeastern end broadens into an amphibolite facies retrograde fault zone, contains mylonite and has vertical to steep south dipping foliation. (Freeman, in press). The Oomoomilla Fault is a high angle reverse fault along which the south side is interpreted to have moved upwards at least 3.5km. The Charlotte Fault zone is up to 1km wide and varies from a single fault plane to two subparallel faults separated by juxtaposed and rotated blocks of Georgina Basin sediments or basement rocks.

Movement along the NNW trending Lucy Creek and Tarlton Faults is considered to be east side down. The Tarlton Fault is a complex structure which is thought to have existed by 1700 Ma and which has suffered intermittent movements, the most recent being in the early Eocene-late Oligocene (Warren, 1981). The Tarlton Fault and the Toomba Fault, located further east, are thought to have developed in a similar manner and as a result have similar forms with long transcurrent sections trending NNW, and arcuate westerly trending sections where overthrusting from the south occurred during the Alice Springs Orogeny (Walter, 1980; Wells & Moss, 1983).

In the Harts Range area, Ding and James (1985) propose an involved sequence of deformation events involving separate basement (BT) and cover thrusting (CT), and subsequent juxtaposition of basement and cover by progressive underthrusting of basement beneath the cover sequence (Fig. 1.7). The latter series of three thrusts (HRT_1 , HRT_2 & HRT_3) are interpreted to have developed sequentially, subsequently being incorporated in later ductile folding events. The tectonic emplacement of the Bruna Gneiss between basement and cover (Section 1.2.2) is considered the result of the latter two events (HRT_2 , HRT_3).

1.4.2 Folding

Fold structures have been studied in detail only in the well exposed Harts Range, Bonya and Jervois Range areas. Work by Ding and James (1985) in the Harts Range reveals an extremely complex history involving separate basement and cover folding and thrusting. Basement lithologies were deformed by three isoclinal fold events, BD_1 , BD_2 and BD_3 followed by tight inclined to upright folds trending in a NE direction. The cover sequence consisting of the Irindina supracrustal sequence is folded by three isoclinal events CD_1 , CD_2 and CD_3 . A thrusting event CT is interpreted as being responsible for the formation of a series of stacked nappes within the cover sequence (Fig. 1.7). It occurred prior to the last two of the ductile deformation events. Subsequent thrust events HRT_1 , HRT_2 and HRT_3 (Section 1.4.1) were all in turn folded by deformation events HRD_1 , HRD_2 and HRD_3 which affected both basement and cover sequences.

In the Jervois Range area, detailed mapping of the Bonya Schist by Ypma et al (1984) indicates this sequence has been affected by three stages of deformation. The oldest deformation (D_1) produced a layer or bedding-parallel schistosity (S_1), possibly due to a large nappe, recumbent folding or thrusting. The second deformation (D_2) resulted in tight isoclinal folding (F_2) of the sequence. The main regional metamorphic event, considered to be the Strangways Event (Freeman, in press) is probably coeval with D_2 . The folding mechanism of D_2 caused curvature of F_2 axes, boundinage and attenuation of fold limbs and thickening of layering in hinges. The final deformation was expressed in a regional shear fold mechanism (F_3) which resulted in an outcrop pattern resembling the letter J, commonly referred to as the 'J-structure'. This feature has a steep north plunging fold axis and is a synclinorium. In the Bonya Block (Fig. 1.6), an ESE-trending fold is outlined by repetition of the Kings Legend Amphibolite

Member. It is interpreted on the basis of available facing data to be an east plunging syncline (Freeman, in press).

1.5 MINERALISATION

Mineral occurrences are minor, but widespread and have been grouped by Stewart and Warren (1977) into the following types:

- 1) Stratabound: copper-lead-zinc in Division 1 and 2 metasediments
- 2) Pegmatitic: mainly copper, tin, tungsten and tantalum derived from granite, and mica in pegmatites formed by partial melting of metasediments
- 3) Metasomatic: tungsten, molybdenum, and minor copper in calc-silicate rocks adjacent to granite
- 4) Hydrothermal: gold in a zone of late Paleozoic deformation and retrogressive metamorphism, and fluorite-barite veins in zones of late Paleozoic warping
- 5) Magmatic: very minor copper, nickel, and chromium, in mafic and ultramafic rocks
- 6) Weathering: manganese and uranium in superficial Phanerozoic rocks.

Types 1, 3 and 5 are the best targets for aeromagnetic prospecting as each is associated with host rocks containing magnetite. In addition to these, magnetic diamondiferous kimberlites have been sought throughout the area, largely due to the inferred kimberlitic affinities of the Mordor Complex (Section 1.2.4). The region is considered prospective for stratabound base metals as host rocks and litho-stratigraphic sequences of known deposits bear a marked similarity to those of Broken Hill (Ypma et.al., 1984). The main occurrences are in the Jervois Range area within Division 2 Bonya Schist. Three types of mineralisation occur: 1) chalcopryrite lodes in magnetite-chlorite-garnet rocks; 2) small argentiferous galena lodes in similar host rock; 3) patches of scheelite in marbles and calc-silicate horizons. The main mineralisation occurs in or near quartz-sericite-feldspar schists considered to be of acid volcanogenic origin. Another stratabound deposit occurs in the Harts Ranges within the Division 1 Oonagalabi gneiss complex. It is also characterised by a distinctive lithological assemblage, in particular quartz-magnetite rock.

The largest of the known metasomatic tungsten occurrences, Molyhil, has been mined spasmodically over the past decade. Tungsten, associated with molybdenite and magnetite, occurs as scheelite in a roof-pendant of Division 2 calc-silicate rock, within the Jinka Granite.

Opaque Mineralogy, Magnetic Mineral Petrogenesis and Rock Magnetism

In this chapter, the magnetic properties of major rocktypes discussed in chapter 1 are related to their magnetic mineralogy, bulk rock chemistry and oxidation state. This is done for two reasons:

- 1) To provide knowledge of magnetization intensity and direction which reduce the ambiguity inherent in magnetic interpretation.
- 2) To identify the source of rock magnetism and provide an understanding of the geological processes and conditions influencing rock magnetism.

These studies provide insight into the geological significance of magnetic signatures and allow better correlation of geology and aeromagnetic anomalies.

2.1 INTRODUCTION

Rock magnetism is dependent on the abundance, composition and form of contained magnetic mineral grains. The petrogenesis of magnetic minerals is controlled by the geological processes of magmatic crystallization, sedimentation and metamorphism, and is sensitive to environmental conditions influencing a variety of intrinsic parameters. As this work involves observations and conclusions which draw on prior knowledge of these fields, it is deemed appropriate to briefly review aspects concerning them.

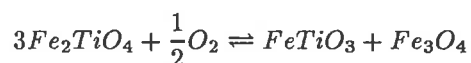
2.1.1 Magnetic Minerals and their Properties

Magnetic anomalies are due to the bulk magnetization of rocks resulting from the vector addition of a component induced by the earth's field (the product of magnetic susceptibility, k and the magnetizing force of the Earth's field, H) and the natural remanent magnetization (NRM) of intensity J . The relative magnitude of both components is the Koenigsberger Ratio,

$$Q = \frac{J}{kH}$$

which is an indication of the relative influence each component has in determining the nature of the observed magnetic anomaly, provided the remanence direction is consistent throughout the rock unit.

Rock magnetism is dependent on a small group of magnetic minerals which are minor constituents of most rocks. The most important of these belong to the solid solution series magnetite-ulvospinel (titanomagnetites, $Fe_{3-x}Ti_xO_4$, $0 \leq x \leq 1$) and hematite-ilmenite (titanoheamatites, $Fe_{2-x}Ti_xO_3$, $0 \leq x \leq 1$). The susceptibility of titanomagnetites varies considerably depending on titanium content. The curie temperature of ulvospinel is 120° K, well below normal earth temperatures, and as a result titanomagnetite compositions containing more than 75% ulvospinel have very low susceptibility at room temperature. The solid solution between magnetite and ulvospinel is continuous above 600° C. However with decreasing temperature, there is a broadening miscibility gap between the two end members of the series, and solid solutions which have crystallized at high temperatures tend to exsolve on slow cooling. As ulvospinel exsolves from solid solution, it has a tendency to oxidize to ilmenite and magnetite (Buddington & Lindsley, 1964) according to the reaction



producing a lamellar intergrowth of titaniferous magnetite and ferrian ilmenite. Both of the above processes make the rock more magnetic, although if cooling has been rapid, the iron and titanium oxides may stay in solid solution where they can remain in metastable equilibrium.

Titanomaghematites and pyrrhotite have susceptibilities of the same order as titanomagnetites, however their occurrence in the study area is rare in comparison to magnetite and their contribution to aeromagnetic anomalies can be safely ignored. Titanohematites have small susceptibilities, and so

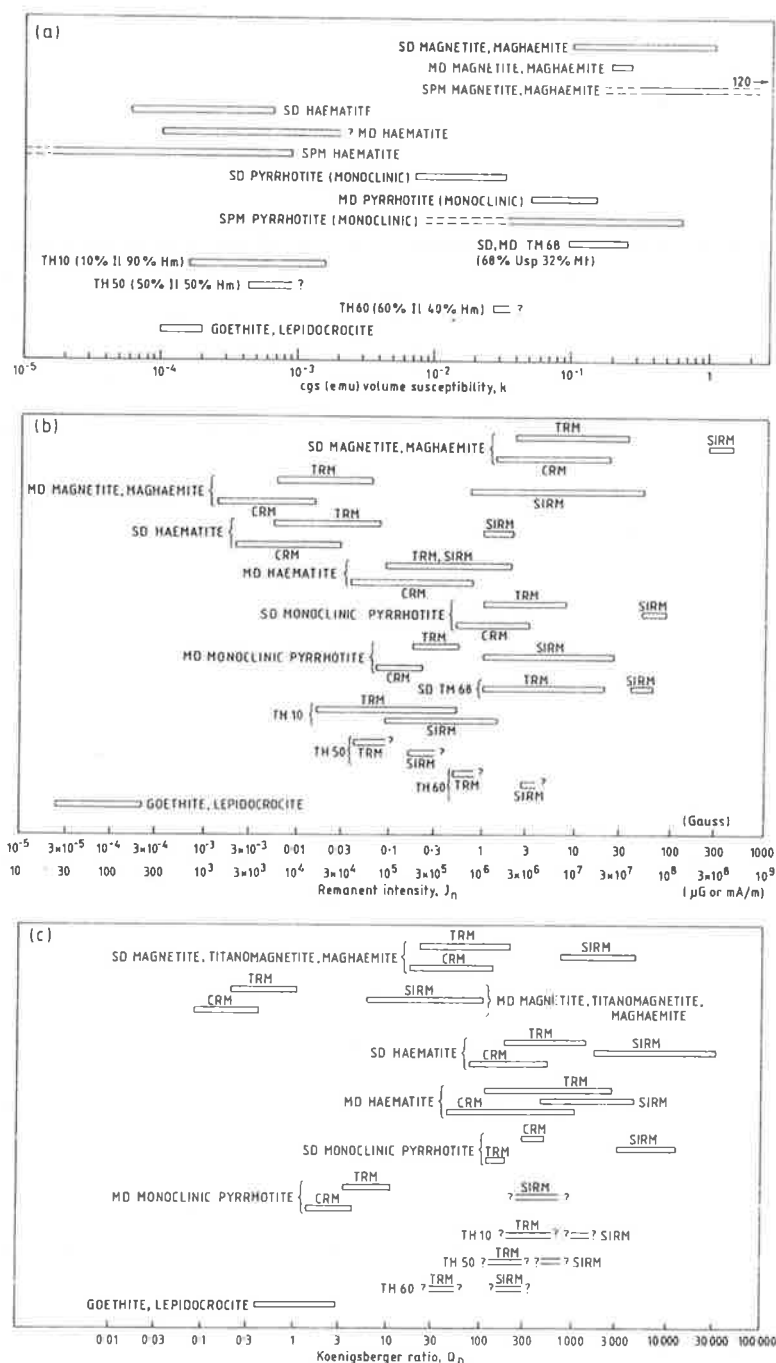


Figure 2.1

(a) Cgs (emu) susceptibility of magnetic minerals, referred to unit volume of magnetic material. (b) Intensity of NRM, J_n , referred to unit volume of magnetic material. (c) Koenigsberger ratios, Q_n , exhibited by various magnetic minerals as a function of domain state and remanence acquisition mechanism. SD = single domain, MD = multidomain, SPM = superparamagnetic, TRM = thermoremanent magnetisation, CRM = chemical remanent magnetisation, SIRM = saturation isothermal remanent magnetisation. Koenigsberger ratios are calculated assuming an ambient field intensity of 0.5 Oersted ($Q_n = J_n/0.5$ k). (After Clark 1983)

except in special cases the induced magnetization of rocks is directly proportional to their magnetite content.

In comparison with induced magnetization, relatively strong NRM can occur in titanium iron oxides of many compositions (Balsley & Buddington, 1958). The most important carriers of NRM seem to be magnetite and titanohematites of intermediate composition ($hem_{40}ilm_{60} \rightarrow hem_{85}ilm_{15}$). Dominantly ilmenitic titanohematites often exhibit "self-reversal", their NRM direction being antiparallel to that of the inducing field (Carmichael, 1961; Stacey & Banerjee, 1974). This phenomenon appears to be one of the most widespread causes of anomalous magnetizations, and is most prevalent in basic rocks which have become oxidized during or after emplacement (Grant, 1985).

The NRM of rocks is commonly complex with several components often present. At or near the time of formation, rocks may acquire a primary remanent magnetization, derived from and parallel to the then existing magnetic field at the site. This may be either thermoremanent magnetization (TRM) acquired when a rock cools from a high temperature in an applied field, or chemical remanent magnetization (CRM) acquired at low temperatures by submicroscopic mineral grains growing through their blocking volume (Dunlop, 1981). During its subsequent history the rock may acquire other secondary magnetizations, which together with the primary magnetization constitute the NRM of the rock, or may be completely remagnetized. Secondary components may be either viscous in origin (VRM) acquired parallel to the Earth's field over a long period of time by grains in which thermal fluctuations cause irreversible changes in domain alignment or domain wall position, isothermally induced (IRM) by fields associated with lightning strikes, or due to the processes of weathering. Secondary components of magnetization may cause dispersion of remanence directions resulting in attenuation of the contribution of remanence to bulk magnetization and resultant aeromagnetic anomalies. Only stable ancient magnetizations and superimposed viscous components are representative of a whole rock unit.

The susceptibility and remanence of rocks and their relative intensities are not only a function of the composition and abundance of constituent magnetic minerals, but are also sensitively dependent on the domain state of magnetic grains. This may be superparamagnetic (SPM), single domain (SD) or multidomain (MD) depending largely on grain size and temperature (Table 2.1). The dependence of magnetic properties on domain state is shown in Figure 2.1 and has been discussed by Dunlop (1981) and summarised by Clark (1983) as follows:

- 1) SPM grains possess very high susceptibility and zero remanence. A small fraction can disproportionately affect the magnetic properties of a rock.
- 2) SD grains have much lower susceptibility than corresponding SPM particles, but can carry a relatively intense remanence.
- 3) The susceptibility of MD grains is usually greater than SD grains, being due to domain wall translation as well as domain wall rotation, although that of highly magnetic minerals, such as magnetite is limited by self-demagnetization to ≤ 0.25 emu. Their NRM is generally much smaller than SD grains.
- 4) The properties of small MD grains, commonly called pseudo-single domain (PSD) grains, are intermediate between those of SD and true MD grains and vary systematically with grain size.

5) Rocks containing more than 10 volume percent of strongly magnetic material, highly clustered magnetic grains or large grains subdivided by lamellae have modified properties. Strongly interacting SPM particles behave as SD grains. Interactions increase susceptibility and reduce remanence for SD and PSD grains, but increase both susceptibility and remanence for MD grains.

Table 2.1: Domain Structure Transition Sizes

<i>Mineral</i>	<i>SPM Threshold Size (μm)</i>	<i>Critical SD Size (μm)</i>
Iron	< 0.008	0.023
Magnetite	0.03	0.06
Maghematite	0.02	0.06
Titanomagnetite (x=0.6)*	0.08	0.40
Titanomaghematite (x=0.6,z=0.4)*	0.05	0.75
Titanomaghematite (x=0.6,z=0.7)*	0.09	2.40
Hematite	0.03	15.0
Pyrrhotite	0.018	1.6

* Equidimensional particles assumed. After Clark, 1983.

2.1.2 Magnetic Mineral Petrogenesis and Rock Magnetism

Previous studies concerning rock magnetism have shown that the magnetic properties of a particular rocktype vary widely, especially between different regions (Puranen et. al., 1968; Henkel, 1976; Gupta & Burke, 1977 and Krutikhovskaya et. al., 1979). This is undoubtedly due to the dependence of rock magnetism not only on bulk chemistry, but also on environmental conditions influencing rocks during and subsequent to deposition or emplacement. Studies relating rock magnetism to magnetic mineralogy and magnetic mineral petrogenesis are therefore an integral part of aeromagnetic interpretation, enabling the geological significance of aeromagnetic features to be understood.

Publications concerning this field are relatively scarce. The mineralogy of magnetic oxides in sedimentary and metamorphic rocks has been discussed by Thompson (1972), Rumble (1976) and McIntyre (1980). Magnetic minerals in igneous rocks have been studied by Haggerty (1976, 1979), whilst Grant (1985) reviewed the subject of magnetic mineral petrogenesis and rock magnetism. Their work identifies the following factors as being the most influential in determining rock magnetism:

- 1) Total iron content. Iron-rich rocks have a higher magnetite producing potential than iron-poor rocks.
- 2) Oxidation state ($Fe^{3+}/(Fe^{3+} + Fe^{2+})$). Low oxidation ratios lead to iron silicate formation; intermediate ratios favour magnetite formation; high ratios favour hematite. In metamorphic rocks, oxidation state is largely inherited from the premetamorphic sediment, consequently magnetic surveying frequently delineates premetamorphic sedimentary

environments in metasediments.

3) Initial crystallization environment. Igneous rocks formed in an environment where no external supply of oxygen is available (usually anhydrous) tend to be more iron rich and less oxidized than those formed in an environment where oxygen availability has been maintained during fractional crystallization (usually orogenic). The basic suites (gabbro & basalt) of the former typically have large (5-10%) amounts of ulvospinel and ilmenite rich components whilst acidic suites (granite & rhyolite) of the latter contain small (1-3%) amounts of hematite and magnetite.

4) Degree of metamorphism. Iron-bearing rocks in general become more magnetic with increasing metamorphic grade as mechanical deformation and heating cause opaque minerals to recrystallize into coarser textures thereby increasing magnetic susceptibility. Another cause of this is the formation of secondary magnetite through the progressive breakdown of hydrous iron-rich silicates such as biotite and amphibole toward magnesium rich orthosilicates such as pyroxene.

5) Original composition of sediment. Pelitic metasediments derived from fine-grained argillaceous rocks invariably contain more iron (and more magnetite) than psammites, as colloidal ferric hydroxyls preferentially attach to fine particles of clay, silt and organic matter, but rarely to sand grains.

6) Degree of silica saturation. Rocks that are deficient in silica usually contain more magnetite and less ilmenite than silica-saturated rocks having the same amount of iron.

7) Excess aluminium. Excess aluminium in metasedimentary rocks favours the formation of muscovite and magnetite over biotite.

8) Titanium deficiency. Titanium rich rocks are generally less magnetitic due to the formation of titanium-iron oxides.

9) Magnesium deficiency. A low magnesium content in igneous rocks allows greater amounts of primary magnetite to form.

10) Absence of carbon. Carbon is a reducing agent and its presence inhibits the formation of magnetite. However many carbonaceous schists are rich in pyrrhotite and often highly magnetic.

In addition to these factors, the magnetization of rocks may be increased by processes which include: 1) mechanical deformation; 2) repeated metamorphism and 3) high-temperature hydrous alteration (serpentinization). Conditions that tend to destroy magnetite include: 1) low temperature alteration (carbonatization, chloritization, sericitization); 2) extreme oxidation and 3) granitization or metasomatism.

2.2 SAMPLE COLLECTION, PREPARATION AND MEASUREMENT

There were difficulties in obtaining samples for rock magnetism and magnetic mineralogy studies for the following reasons:

- 1) The size and inaccessible nature of the area.

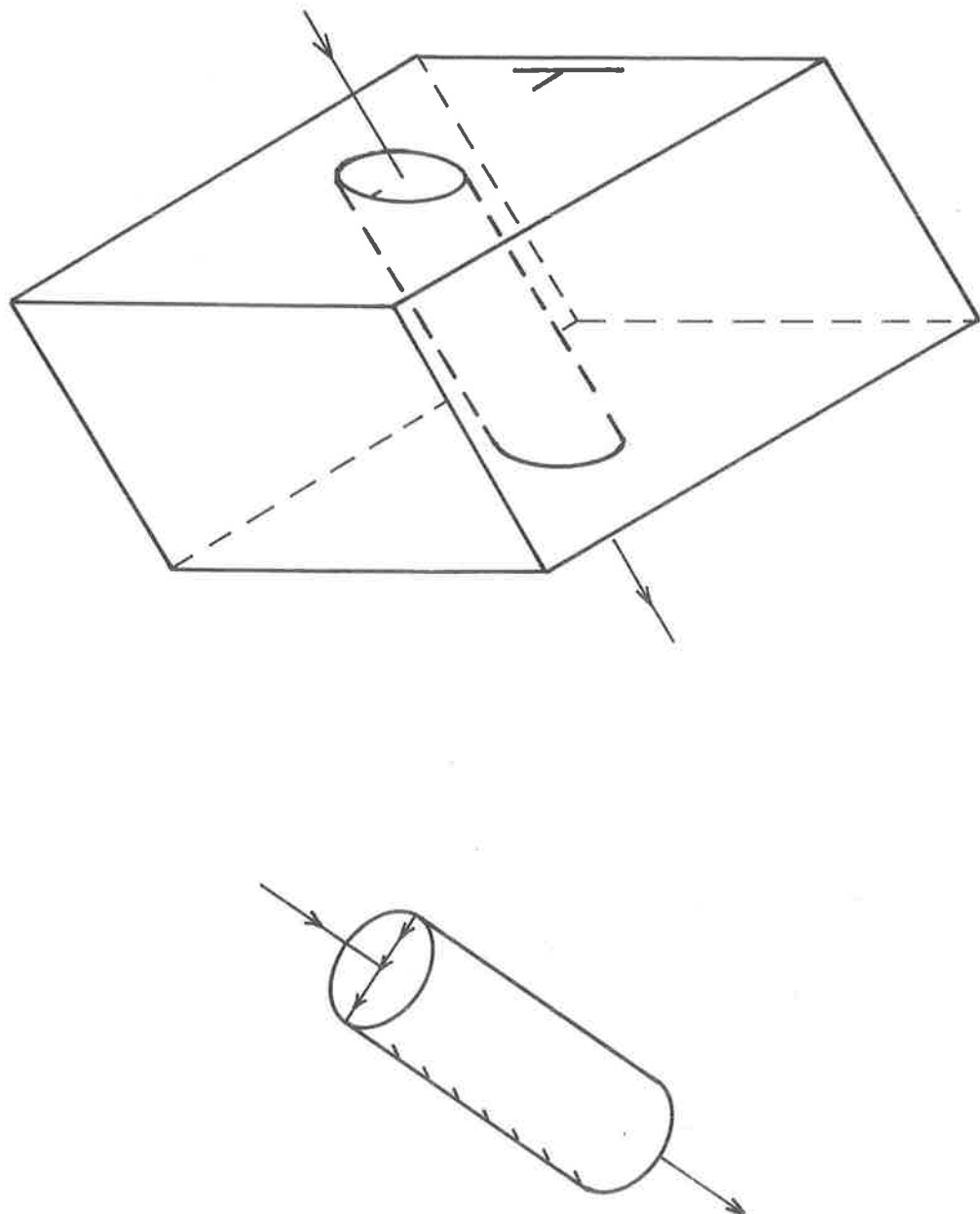


Figure 2.2 Orientation of cores extracted from field samples.

- 2) The large number of rocktypes to be investigated.
- 3) The sporadic distribution and often weathered nature of basement outcrop.
- 4) The limited time available for field work.

Investigations were restricted to two relatively accessible, well exposed regions; the Harts Range and Bonya-Jervois Range areas (Fig. 1.2). All major lithostratigraphic units are represented in these areas and geological mapping by various researchers provided a ready source of samples. Samples from the Harts Range included those from studies by Bowyer (1982), Rankin (1983), Martin (1983), Goscombe (1984), Sullivan (1985), Stewart (1985), Ding and James (1985) and Lawrence (In prep). Material from the Bonya-Jervois Range area included hand samples collected by the author, and by BMR and NTGS geologists during semi-regional mapping.

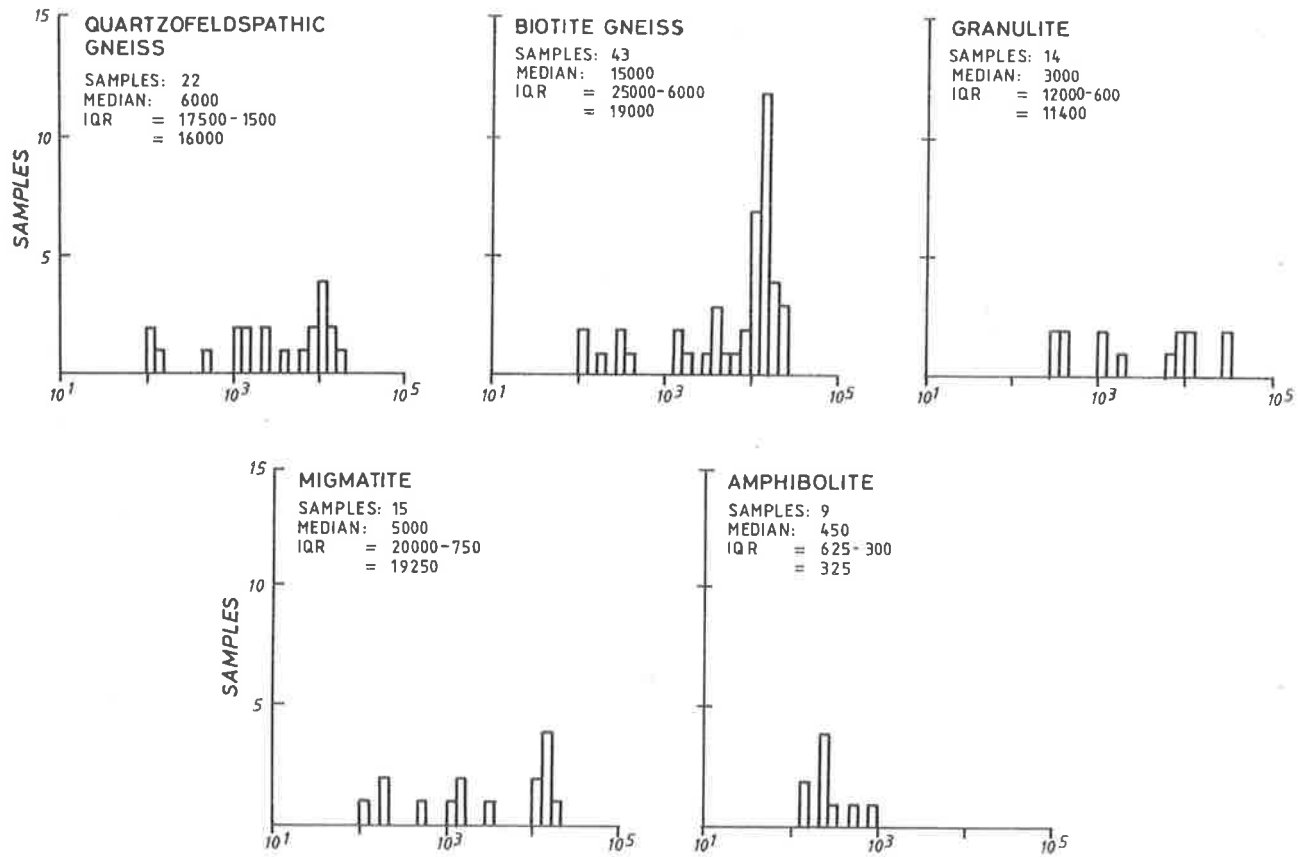
Magnetic susceptibility and NRM of samples were measured in order to ascertain the relative significance of induced and remanent magnetization. Magnetic susceptibility was measured in-situ on basement outcrops and on hand samples using a Geoinstruments JH-8 susceptibility meter. Measurements were obtained on 828 samples from the Harts Range area. Some 257 in-situ measurements had already been obtained in the Bonya-Jervois Range area by BMR and NTGS workers using an Elliot PP2A susceptibility meter (Horsfall, 1981). A further 1200 in-situ measurements were collected and supplemented by 178 measurements on hand samples.

Oriented samples were necessary to determine NRM intensity and direction. In the Harts Range area, 213 oriented samples had been collected for magnetic petrofabric studies (Rankin, 1983; Martin, 1983). A further 35 samples were collected in the Bonya-Jervois Range area. Care was taken to ensure samples were homogeneous and relatively unweathered. The dip and strike of their top surface was marked and noted. Cylindrical cores measuring 2.5cm in diameter and length were then extracted and their orientation marked as shown on Figure 2.2. In order to obtain reliable results, several cores were normally taken from the same or parallel drillcores. NRM intensity and direction were determined using a Schonstedt spinner magnetometer from the Department of Earth Sciences, Flinders University. Magnetic susceptibility of oriented cores was also measured using a susceptibility bridge developed by Flinders University. All instruments, with the exception of the Elliot PP2A susceptibility meter were periodically calibrated using standard blocks and oriented cores of known susceptibility and remanence provided by the CSIRO laboratory of mineral physics.

Polished thin sections of 118 samples and thin sections of 337 samples were prepared and studied in transmitted and reflected light in order to estimate the abundance, composition and form of opaque minerals. Grains and lamellae larger than a few micrometers could be resolved with confidence.

Major element and Ferrous iron abundance were determined for 118 and 60 samples respectively. Weathered sample surfaces were removed using a diamond saw. They were then ground to fine powder using a Siebtechnik tungsten carbide mill. Powder for whole rock analysis was ignited at 960° C to determine the percentage loss of volatiles. 280mg of ignited sample, 20mg of sodium nitrate and 1.5g of flux were mixed and fused in a platinum crucible, to form buttons. Whole rock analysis were then determined on a programmable Siemens XRF machine. Ferrous iron determinations were carried out by Mr. P. McDuié. Approximately 250 mg of powdered sample, 10ml of 50% V/V sulphuric acid and 5ml W/W hydrofluoric acid were heated in a platinum crucible at 350° C for approximately 20 minutes.

OONAGALABI GNEISS COMPLEX



CADNEY METAMORPHICS

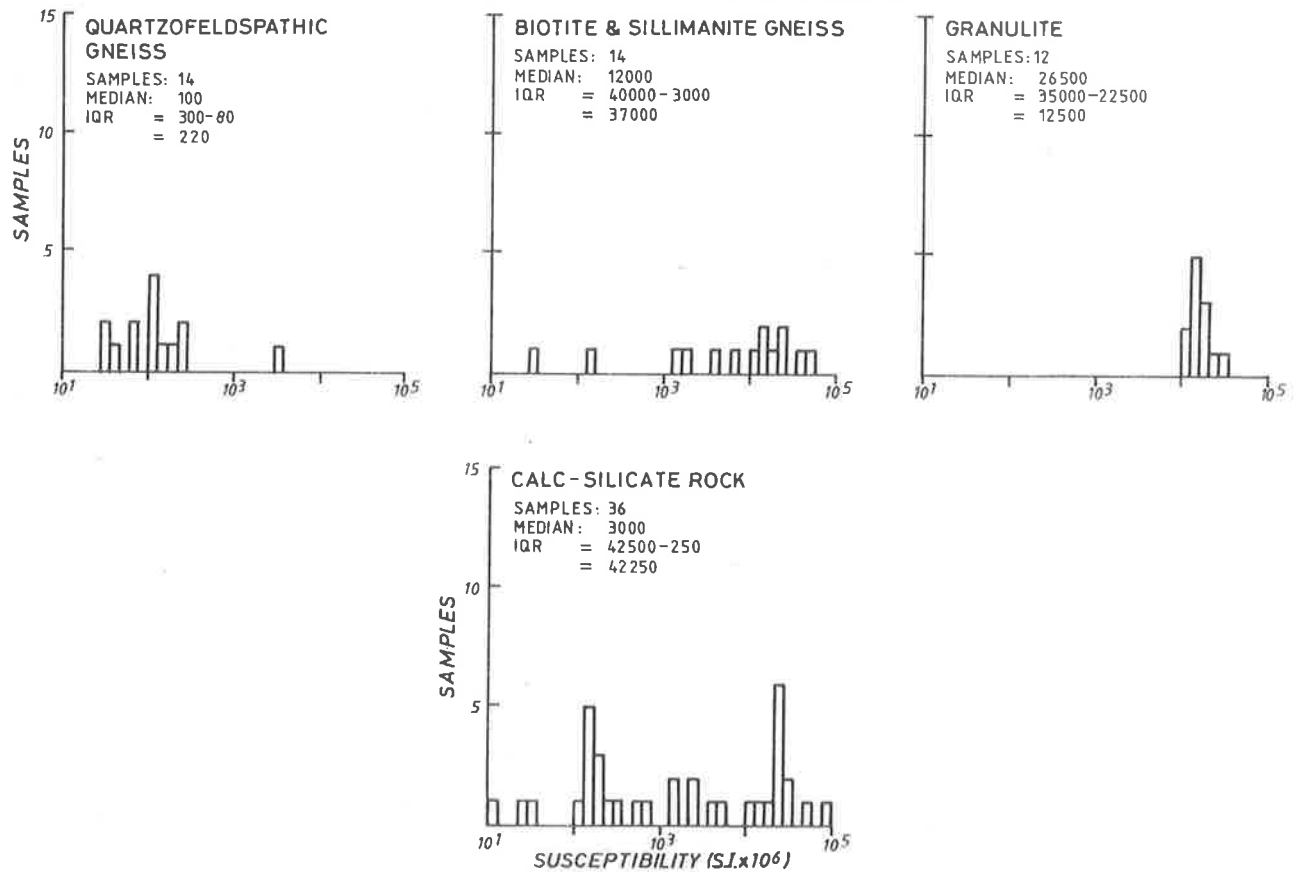


Figure 2.3 Magnetic susceptibility histograms for major lithologies comprising the Oonagalabi gneiss complex and Cadney Metamorphics.

This was added to 300ml of distilled water, 10ml sulphuric acid and 30ml saturated boric acid before titration with a standardized solution of 0.02 normal $CeSO_4$ and the indicator N-Phenyl anthranilic acid to determine ferrous iron content.

2.3 ROCK MAGNETISM

2.3.1 Division 1

Magnetic property measurements of units comprising the Division 1 Strangways Metamorphic complex were obtained from samples collected by several researchers (Section 2.2) in the Harts Range area. This work includes the Entia gneiss complex, considered by Ding and James (1985) a correlative of the Strangways Metamorphic Complex. It does not encompass the Ongeva and Kanandra Granulites, however rocktypes comprising these units are similar to those of other Division 1 units, and results should be a guide to their magnetic properties.

Figures 2.3 and 2.4 present histograms of magnetic susceptibility for major lithologies constituting the Oonagalabi gneiss complex, Cadney Metamorphics, and Entia gneiss complex (Table 1.1). The median ($k_{0.5}$), lower and upper quartiles and interquartile range (IQR) indicate the bulk susceptibility and spread of values for each lithology.

ENTIA GNEISS COMPLEX

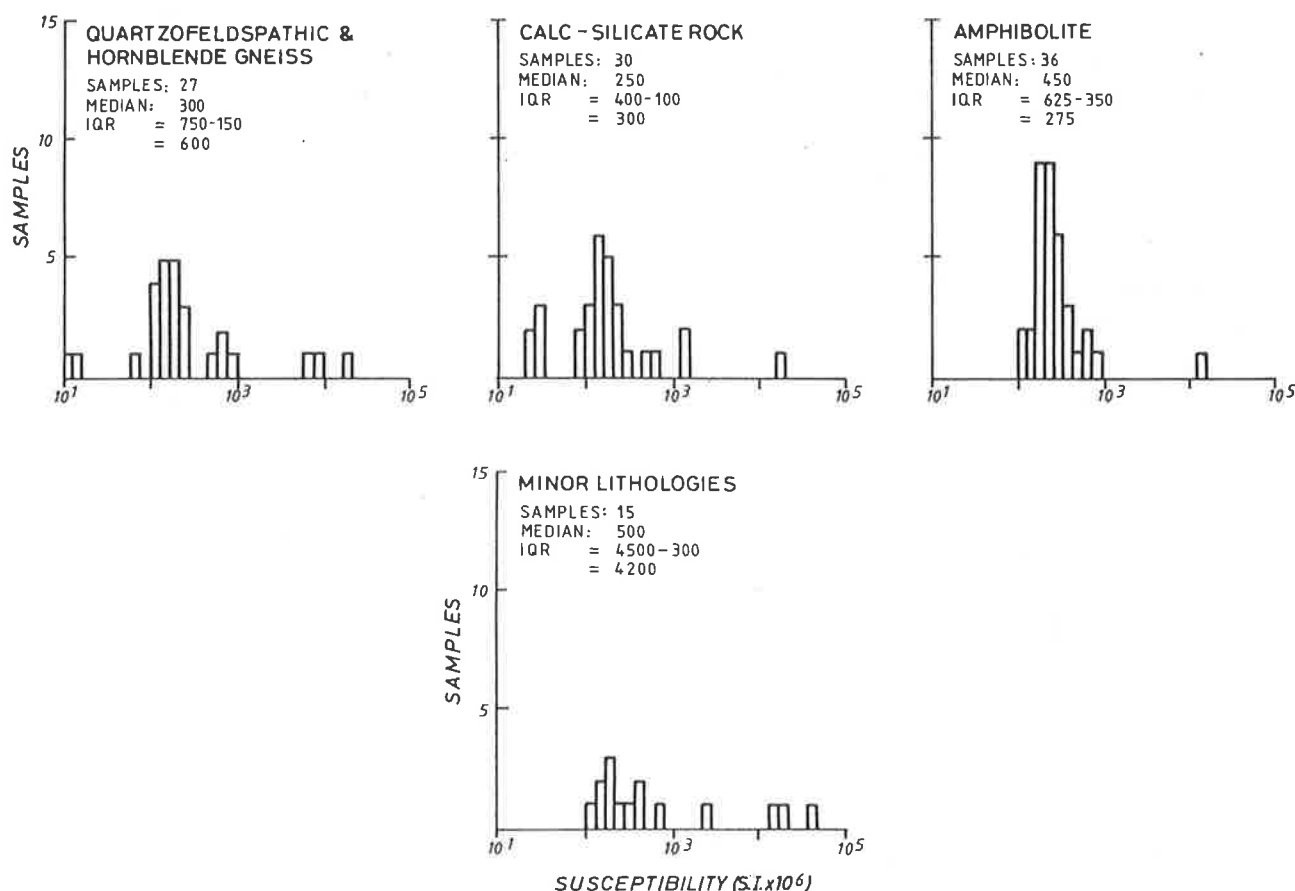
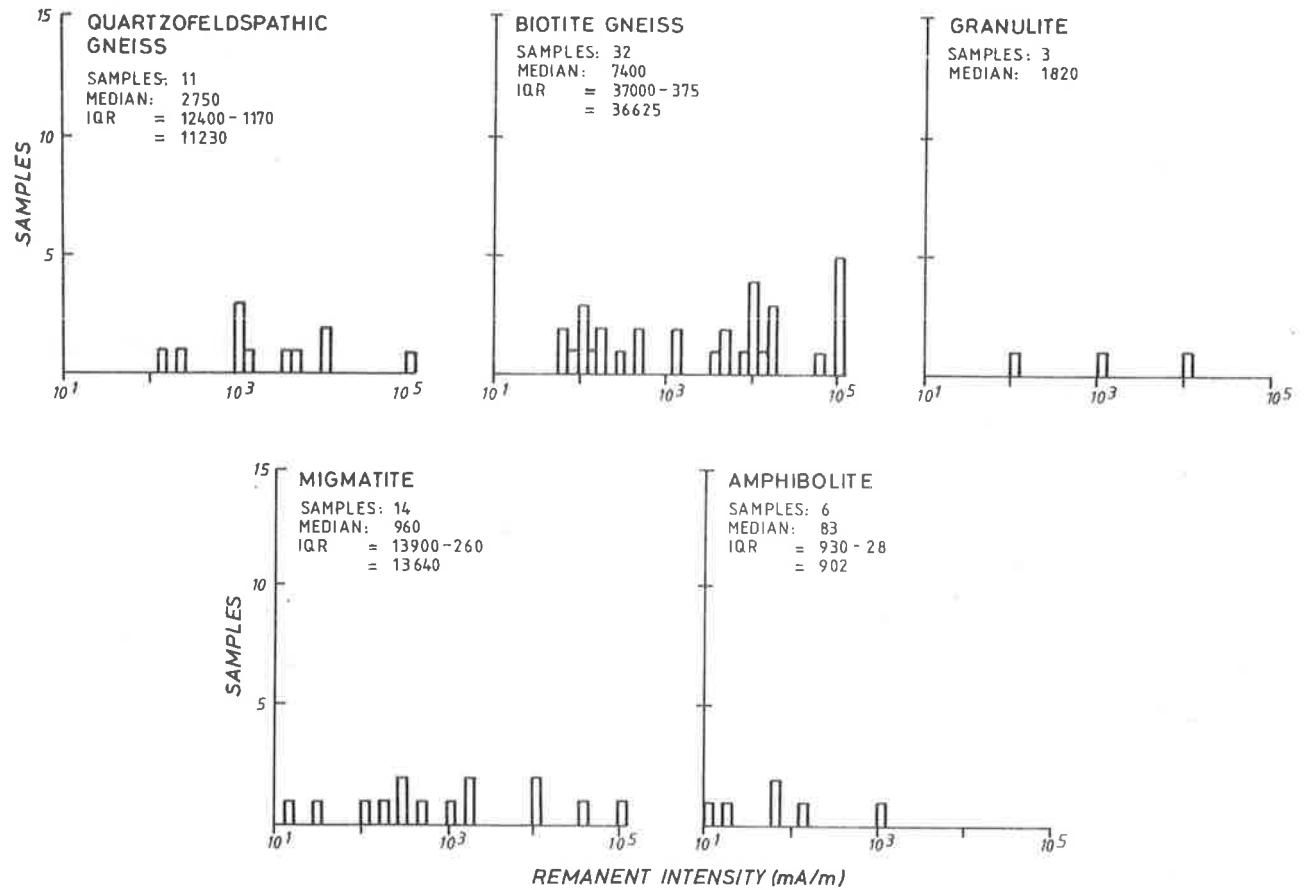


Figure 2.4 Magnetic susceptibility histograms for major lithologies comprising the Entia gneiss complex.

OONAGALABI GNEISS COMPLEX



ENTIA GNEISS COMPLEX

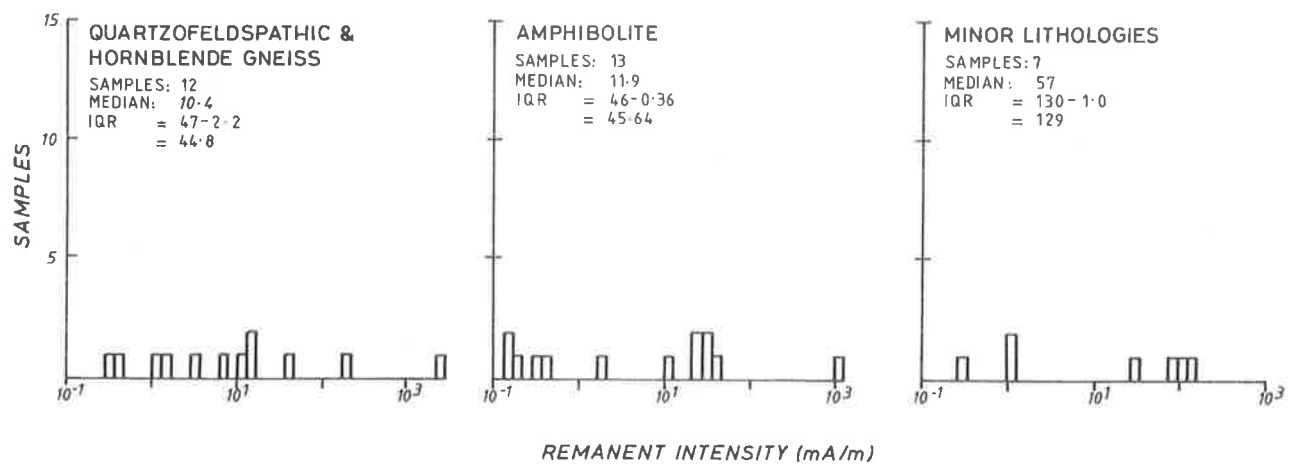


Figure 2.5 Histograms of NRM intensity for major lithologies comprising the Oonagalabi gneiss complex and Entia gneiss complex.

Most rocktypes comprising all three units have a narrow range of susceptibility, with lower and upper quartiles spanning one order of magnitude or less. The Oonagalabi gneiss complex and Cadney Metamorphics consist predominantly of lithologies of moderate to high susceptibility. In contrast, rocktypes constituting the Entia gneiss complex have uniform low susceptibilities, with few recorded high values.

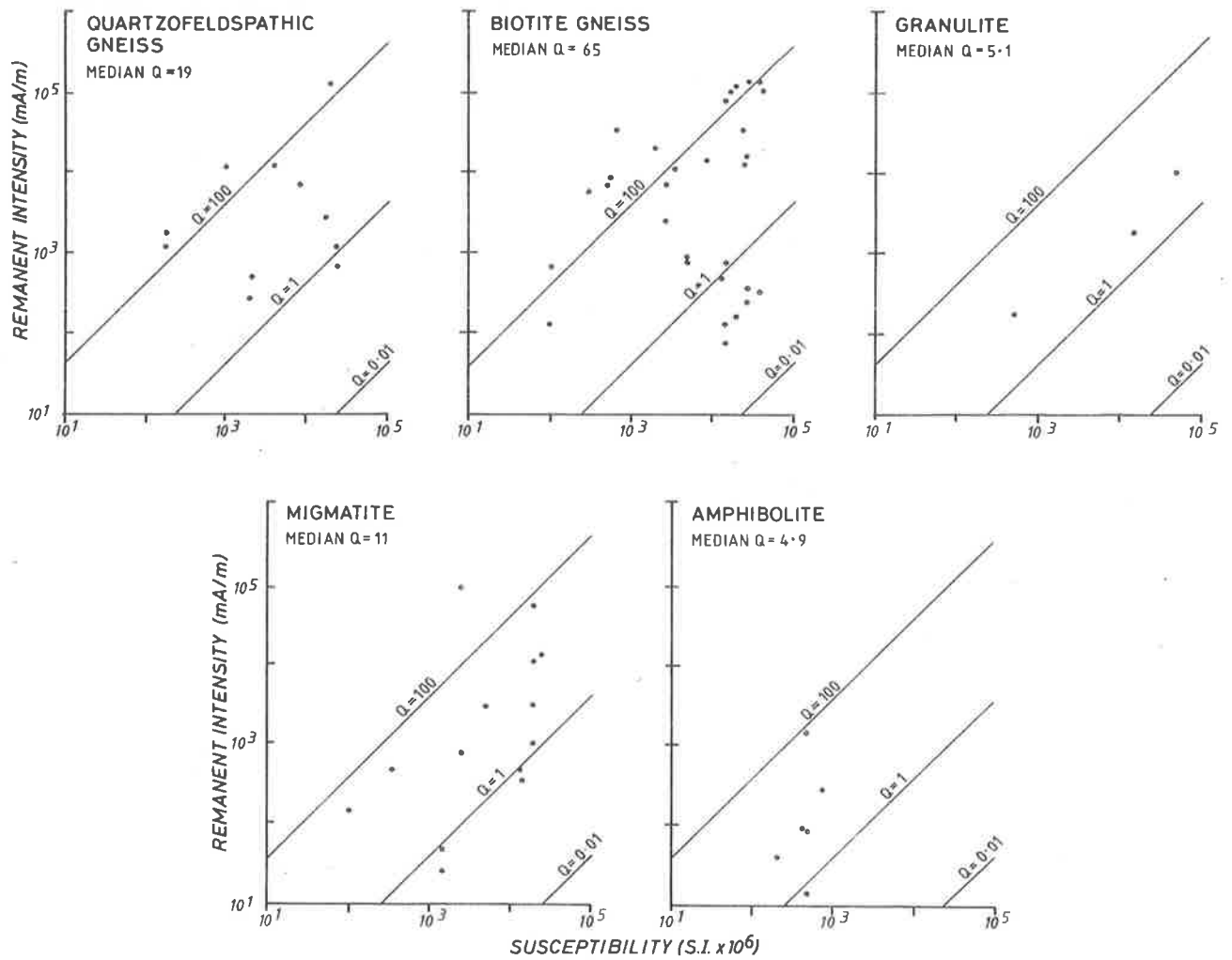
Rocktypes containing higher proportions of mafic minerals, such as biotite gneiss and granulite, possess high susceptibilities. Felsic quartzofeldspathic gneiss, in particular that of the Cadney Metamorphics ($k_{0.5} = 100 \times 10^{-6}$ S.I.) and Entia gneiss complex ($k_{0.5} = 300 \times 10^{-6}$ S.I.) have low values. Amphibolites exhibit uniform low susceptibilities with medians of 450×10^{-6} S.I. Migmatites of the Oonagalabi gneiss complex and calc-silicate rocks of the Cadney Metamorphics have a large spread of values.

Histograms of NRM intensity and graphs of remanent intensity versus magnetic susceptibility are shown in Figures 2.5 and 2.6. Oriented samples of the Cadney Metamorphics were not collected during field mapping and consequently no results are presented for this unit. The NRM of lithologies constituting the Oonagalabi gneiss complex and Entia gneiss complex are ill-defined compared with their susceptibility, exhibiting a spread of values over several orders of magnitude. However, their relative median NRM intensities are similar to their relative median susceptibilities. With the exception of amphibolite ($J_{0.5} = 83 \text{ mA/m}$), the Oonagalabi gneiss complex consists of lithologies having moderate to high median NRM values (960 - 7400 mA/m), and a predominance of Koenigsberger ratios well above unity (Fig. 2.6). Their NRM may have considerable influence on observed magnetic anomalies, provided it is representative of the bulk in-situ remanence, and directions are consistent. In contrast, rocktypes constituting the Entia gneiss complex have low median NRM intensities ($J_{0.5} = 10.4 - 57$) and a predominance of Koenigsberger ratios less than unity, implying together with their low susceptibilities that they are weakly magnetic.

Remanence directions of Division 1 rocks are in general random (Fig. 2.7). Amphibolites and migmatites of the Oonagalabi gneiss complex show some preference towards negative and low inclinations respectively. Quartzofeldspathic gneiss of the Entia gneiss complex exhibits a bias toward positive inclinations. However, the NRM intensity of these rocktypes is too low and direction too scattered to have considerable influence on aeromagnetic anomalies.

Random NRM directions probably have several sources. Extremely high NRM intensities and Q values most likely result from lightning strikes (IRM) as they are too large to be TRM or CRM (Fig. 2.1). A characteristic of lightning struck samples is a stable NRM vector which varies markedly in direction over short distances (Clark, 1983). This spatial inhomogeneity is a consequence of the localised and irregular paths followed by lightning currents crossing surface outcrops. However, exclusion of these samples did not improve observed NRM directions. It is unlikely random directions result from weathering as samples would be remagnetized by, and tend to cluster about, the present field direction. The NRM's of Division 1 rocks may represent multicomponent magnetizations carried by magnetically stable grains, reflecting the complex deformational and thermal history of these rocks, or may simply be paleomagnetic noise. Consequently, remanence is unlikely to contribute significantly to the bulk magnetization of Division 1 rocks, giving rise to aeromagnetic anomalies.

OONAGALABI GNEISS COMPLEX



ENTIA GNEISS COMPLEX

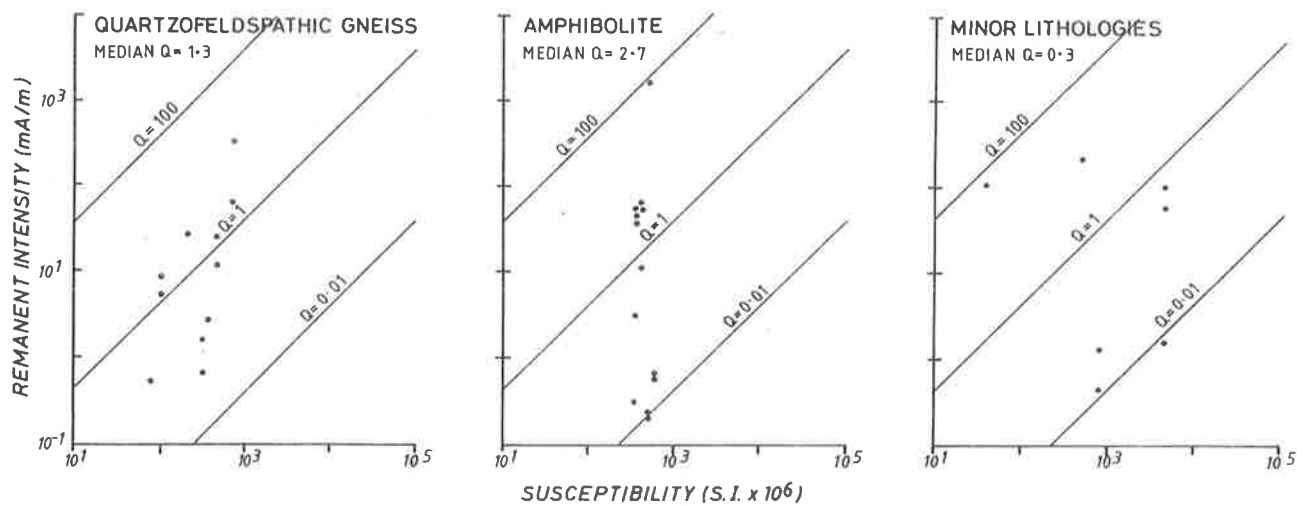
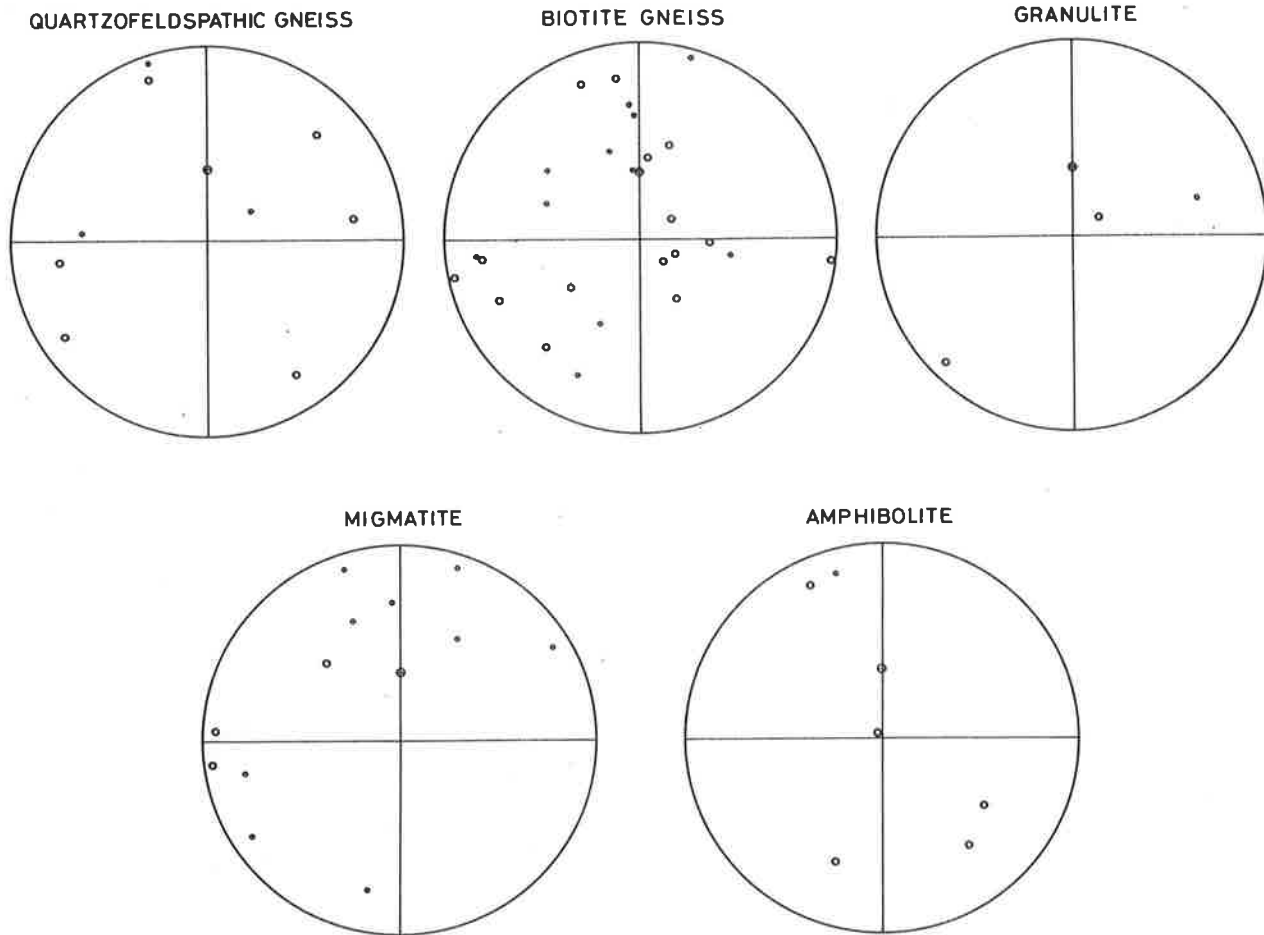


Figure 2.6 Graphs of remanent intensity versus magnetic susceptibility for major lithologies comprising the Oonagalabi gneiss complex and Entia gneiss complex.

OONAGALABI GNEISS COMPLEX



ENTIA GNEISS COMPLEX

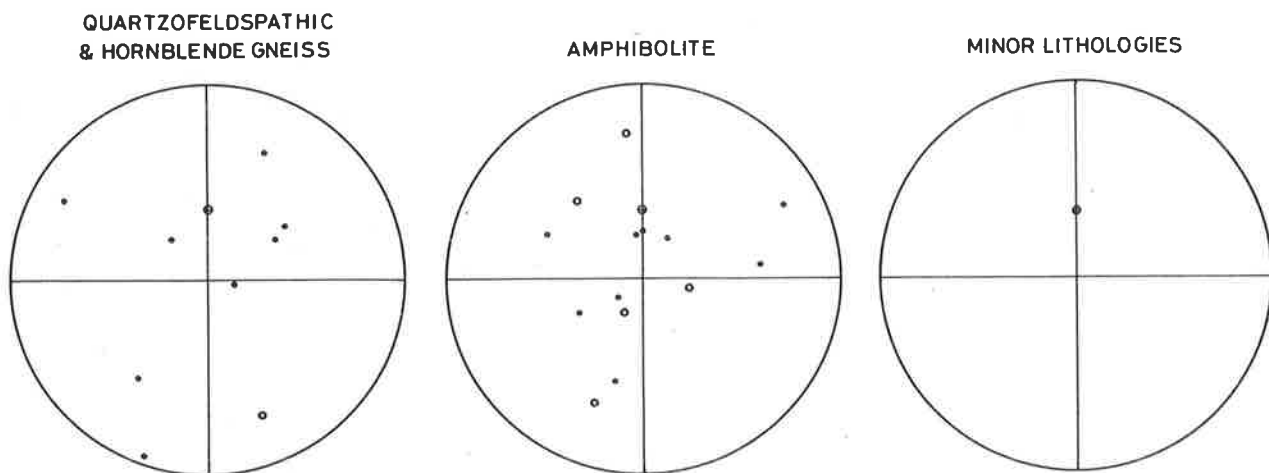
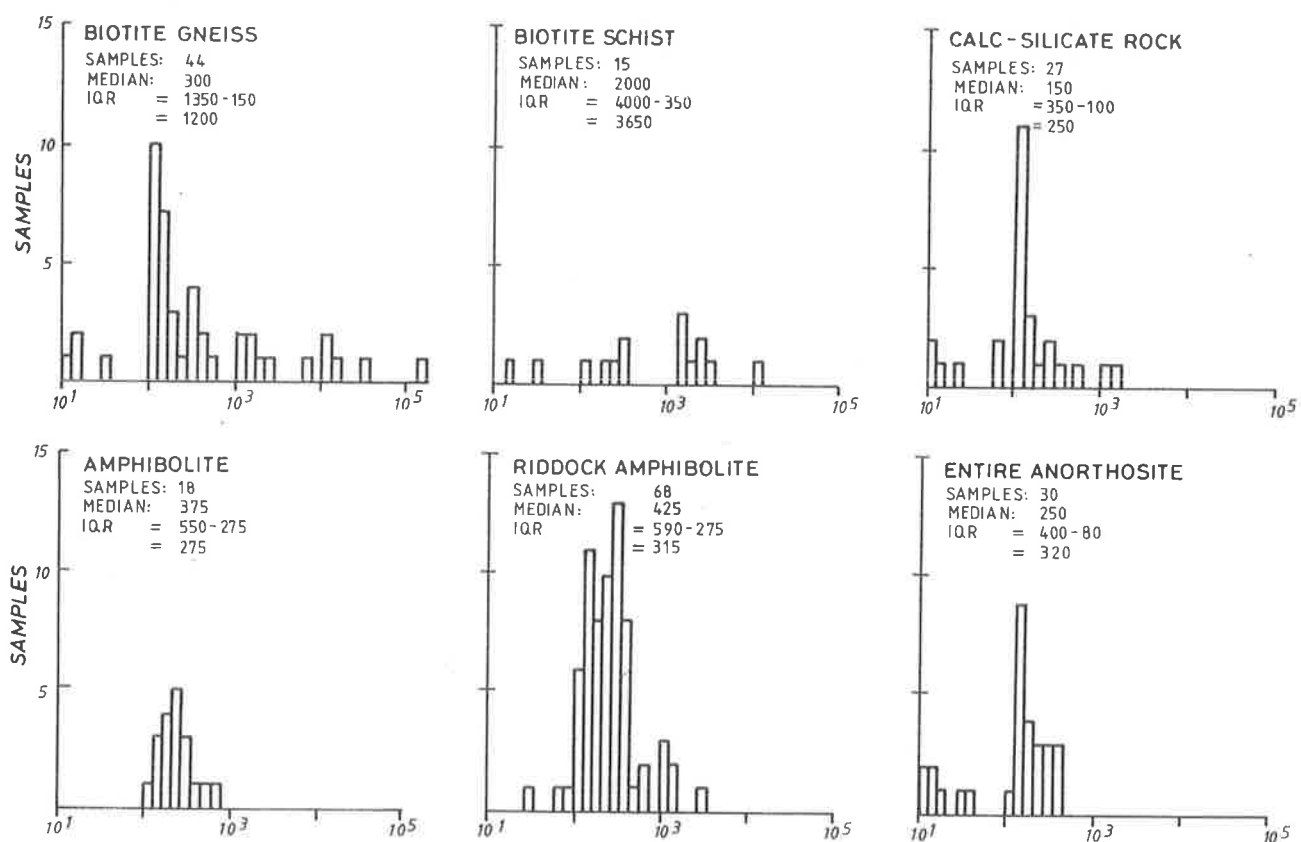


Figure 2.7 Equal area stereoplot of NRM directions for major lithologies comprising the Oonagalabi gneiss complex and Entia gneiss complex. (Negative inclination $\circ$; Positive inclination $\bullet$, Earth's field $\oplus$).

IRINDINA SUPRACRUSTAL ASSEMBLAGE



BRADY SUPRACRUSTAL ASSEMBLAGE

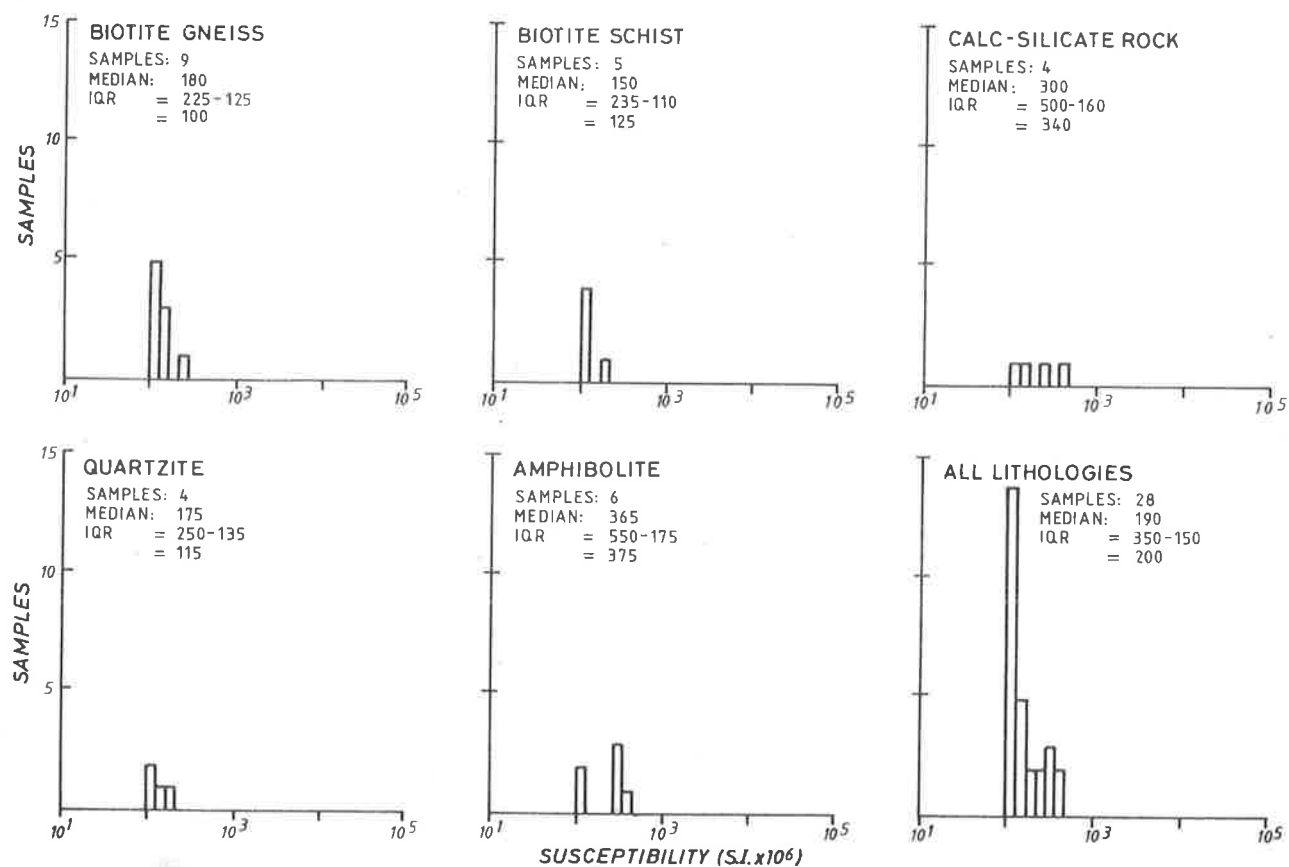


Figure 2.8 Magnetic susceptibility histograms for major lithologies comprising the Irindina and Brady supracrustal assemblages.

2.3.2 Division 2 of the Central Tectonic Province

The Irindina and Brady supracrustal assemblages are the major outcropping Division 2 units of the Central Province (Section 1.2.2). Most rock types comprising both assemblages have low, uniform susceptibilities confined within a narrow range (Fig. 2.8). Biotite gneiss and biotite schist of the Irindina record a small but significant number of higher values. The Riddock amphibolite of the Harts Range meta-igneous complex and similar intercalations within the Brady and Irindina, have low susceptibilities comparable to amphibolites within Division 1 units (Figs. 2.3 & 2.4).

Results of NRM measurements for these units are similar to those for Division 1 (Table 2.2, Figs. 2.9, 2.10 & 2.11). Irindina rocktypes have a broad range of NRM intensity, Q values predominantly greater than unity, and random directions. Their NRM is unlikely to contribute to bulk magnetization for the same reasons outlined for Division 1 rocktypes. The units low overall susceptibility and NRM intensity indicates it is weakly magnetic. Lithologies constituting the Brady assemblage have low NRM intensities ($J_{0.5} = 11.7\text{--}65$ mA/m). Together with their low susceptibility, they are weakly magnetic.

Table 2.2: NRM of the Brady Supracrustal Assemblage

LITHOLOGY	SAMPLES	MEDIAN k (S.I. $\times 10^6$)	NRM RANGE (mA/m)	MEDIAN NRM (mA/m)	Q RANGE	MEDIAN Q
Biotite Gneiss	2	180	58–67	62.5	11–14	12.2
Biotite Schist	*	150	*	*	*	*
Calc-Silicate	1	300	*	62	*	7.3
Quartzite	3	175	36–42000	65	5542	10.2
Amphibolite	1	365	*	11.7	*	0.5

* either not available or not applicable

2.3.3 Division 2 of the Northern Tectonic Province

Magnetic property measurements in the Northern Province were restricted to *JERVOIS RANGE* (Section 2.2) and encompassed two units; the Mascotte Gneiss Complex and the Bonya Schist.

In the Jervois Range area four major lithological suites are recognised by Peters et al (Section 1.2.2). Metasediments and metavolcanics comprising these suites have contrasting ($k_{0.5} = 80 - 65,000 \times 10^{-6}$ S.I.) but well-defined susceptibilities (Fig. 2.12). Gneissic suite rhyolite and granitic gneisses have low susceptibilities. This unit resembles and may be a correlative of the Mascotte Gneiss Complex. Both are considered to be derived from pre-metamorphic acid igneous rocks. Quartz-sericite schists of the Mine sequence suite, derived from similar acid volcanics, also have low susceptibilities. Chlorite-biotite and cordierite schists of the Mg-silicate suite have low to moderate susceptibilities.

Other rocktypes comprising the Mine sequence and Fe,Mg-silicate suites have susceptibilities several orders of magnitude higher. Quartz-sericite-feldspar schists exhibit the greatest spread of values,

IRINDINA SUPRACRUSTAL ASSEMBLAGE

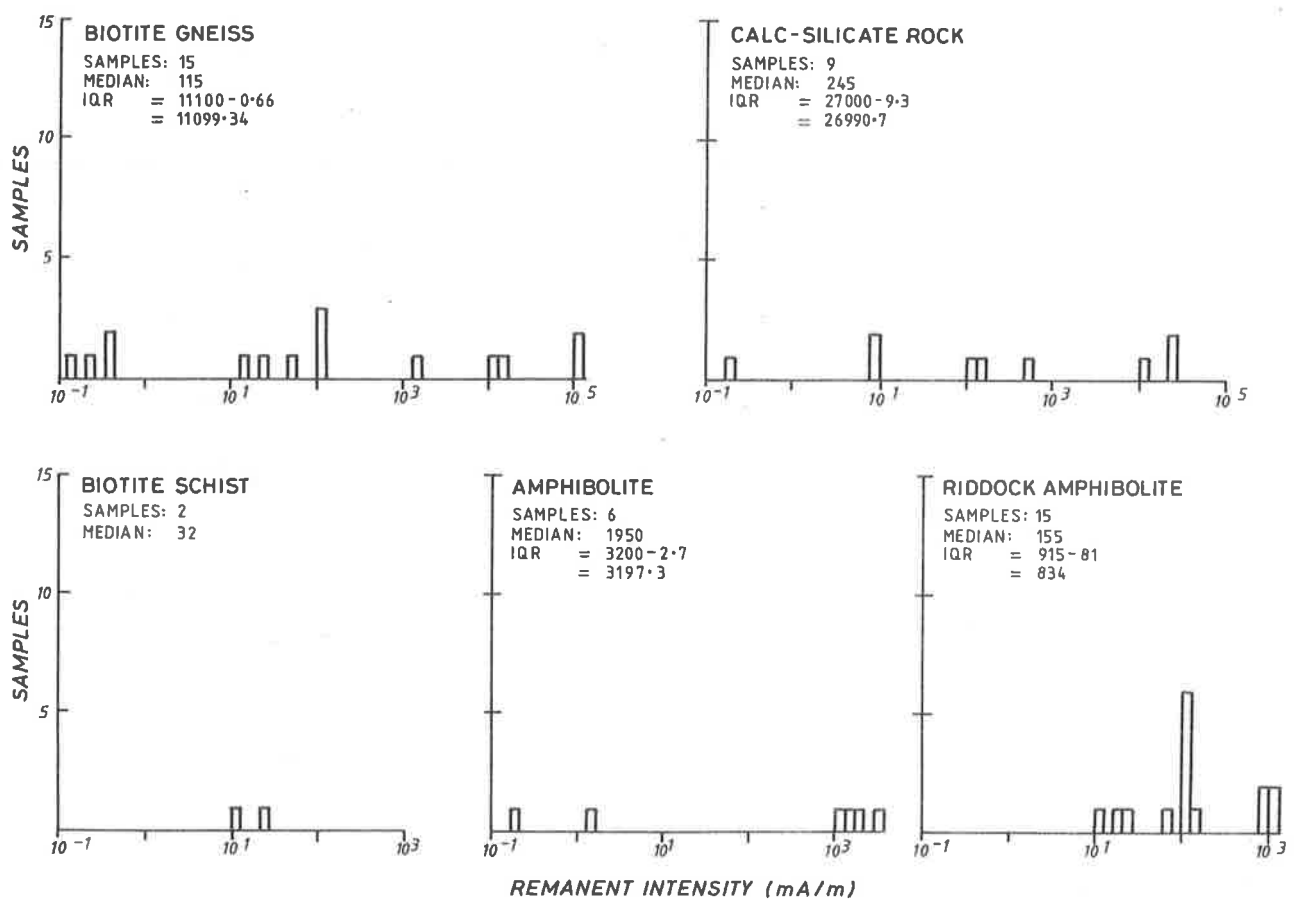
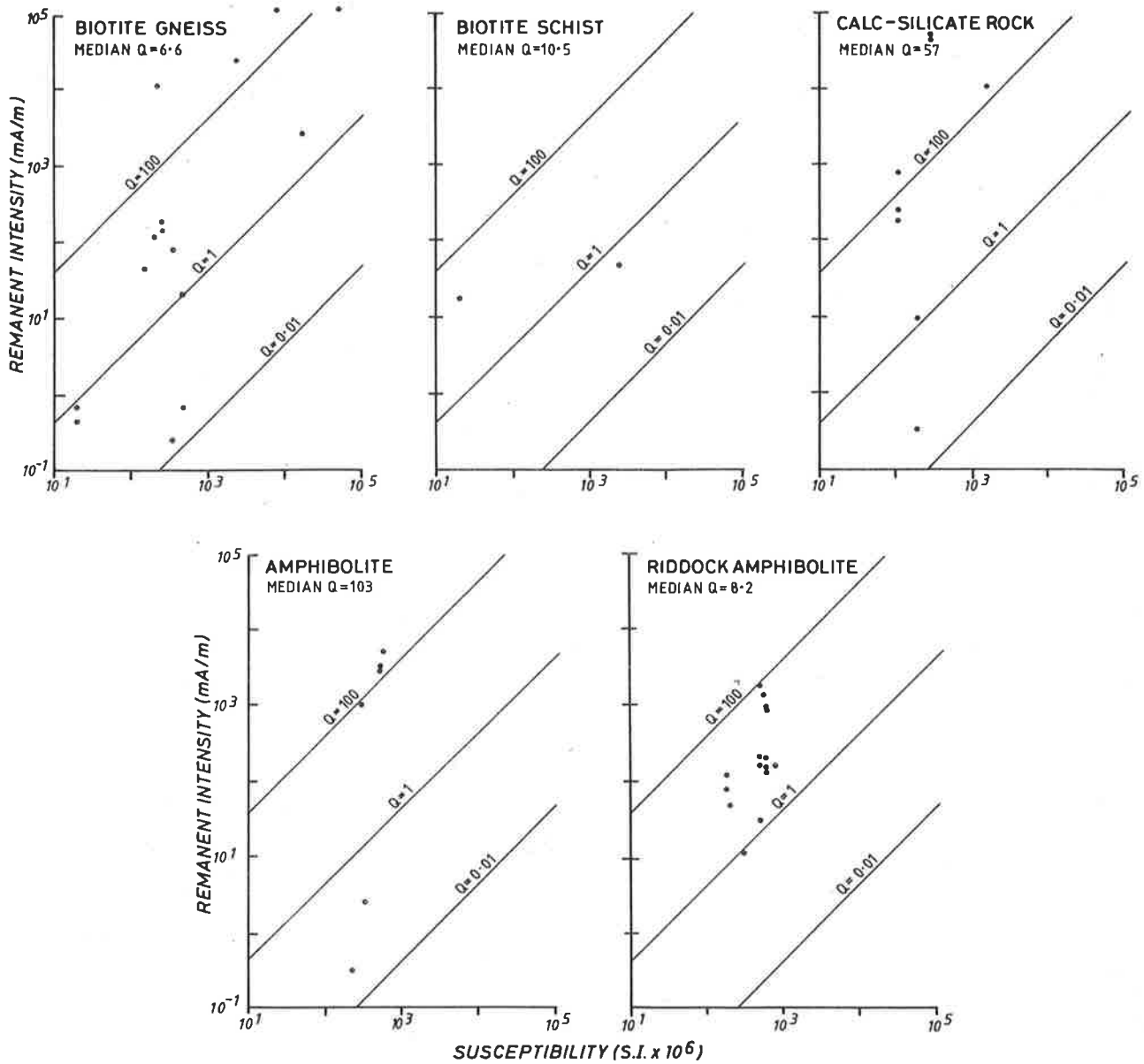


Figure 2.9 Histograms of NRM intensity for major lithologies comprising the Irindina supracrustal assemblage.

IRINDINA SUPRACRUSTAL ASSEMBLAGE



BRADY SUPRACRUSTAL ASSEMBLAGE

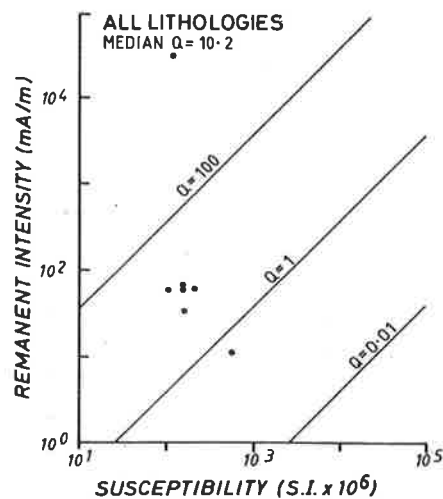
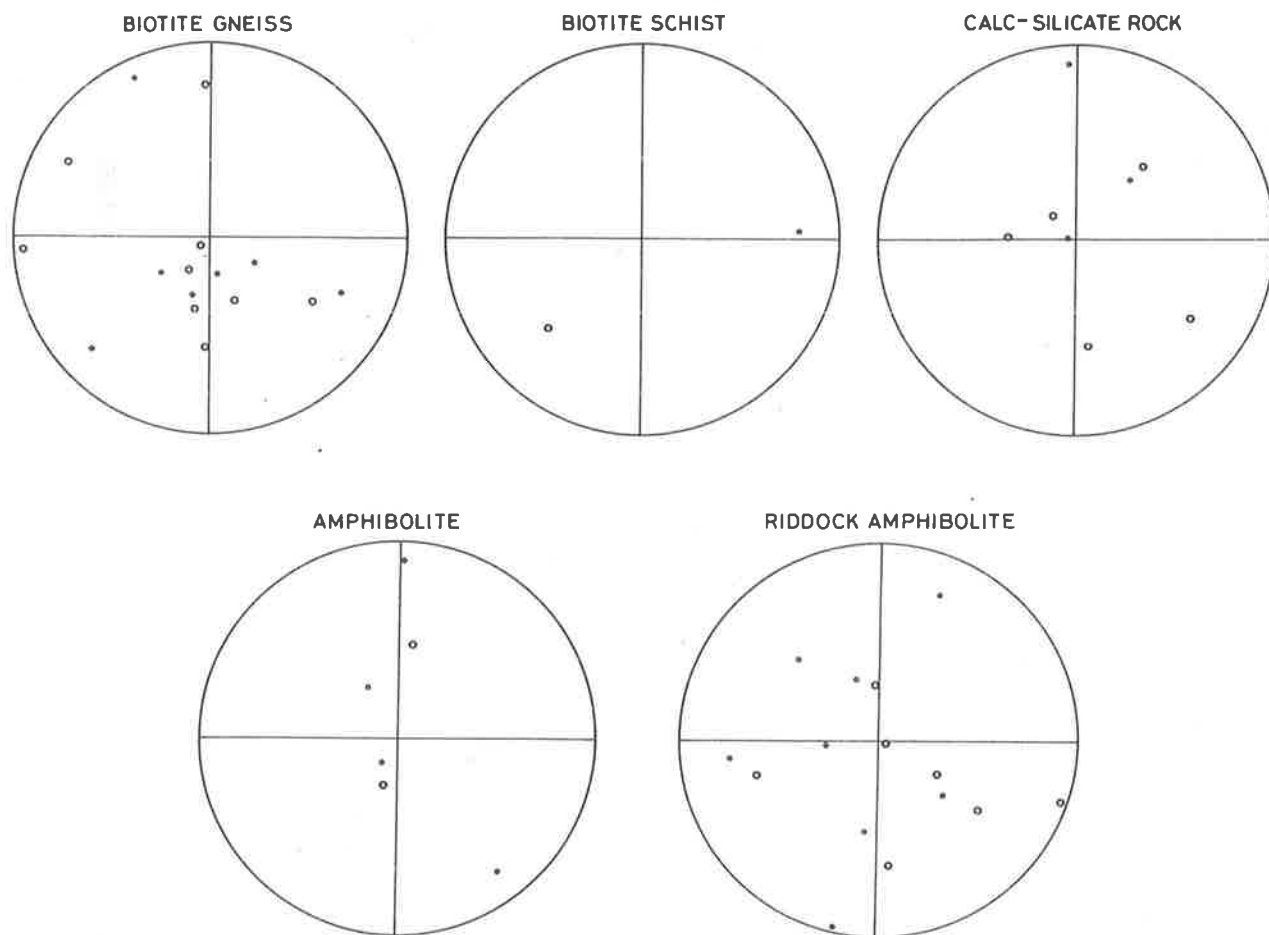


Figure 2.10 Graphs of remanent intensity versus magnetic susceptibility for major lithologies comprising the Irindina and Brady supracrustal assemblages.

IRINDINA SUPRACRUSTAL ASSEMBLAGE



BRADY SUPRACRUSTAL ASSEMBLAGE

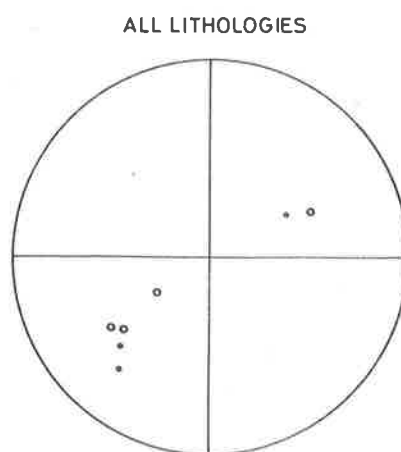
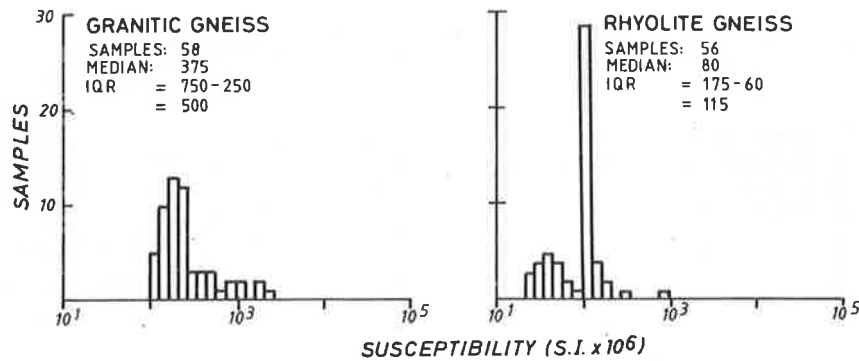


Figure 2.11 Equal area stereoplot of NRM directions for major lithologies comprising the Irindina and Brady supracrustal assemblages (Negative inclination $\circ$; Positive inclination $\bullet$, Earth's field $\oplus$).

GNEISSIC SUITE



BONYA SCHIST

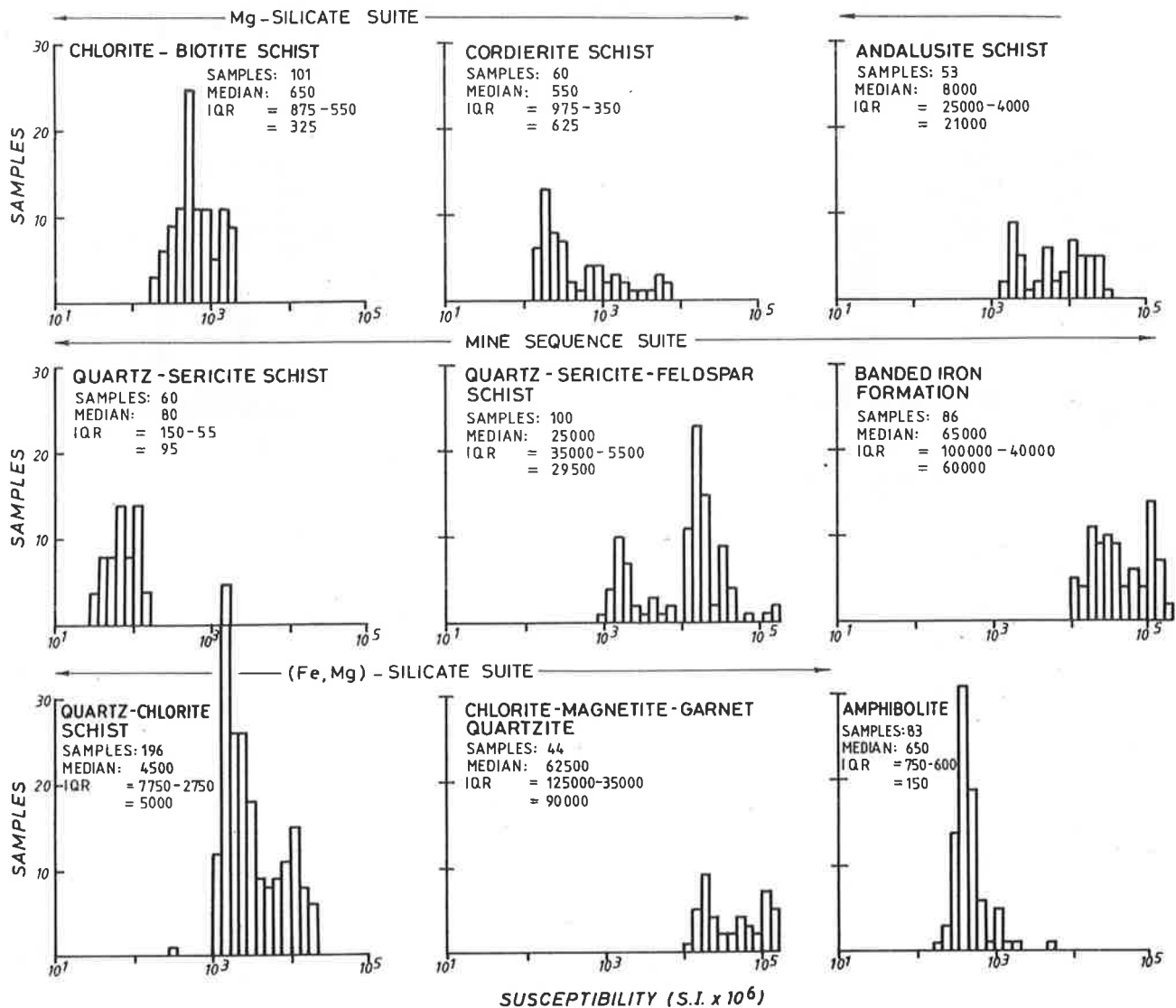
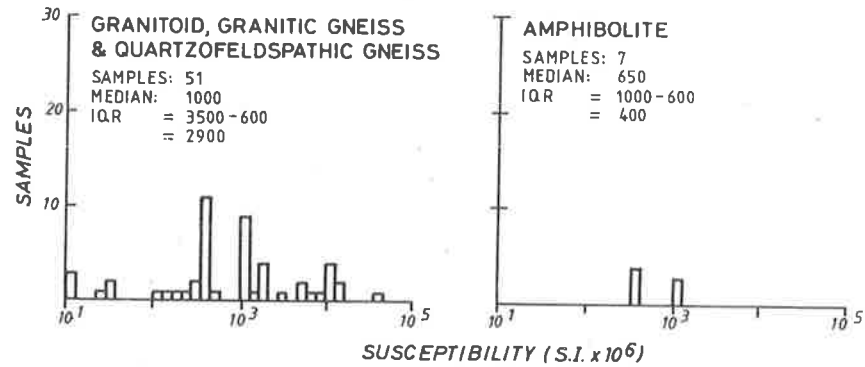


Figure 2.12 Magnetic susceptibility histograms for major lithologies comprising the Bonya Schist in the Jervois Range area.

MASCOTTE GNEISS COMPLEX



BONYA SCHIST

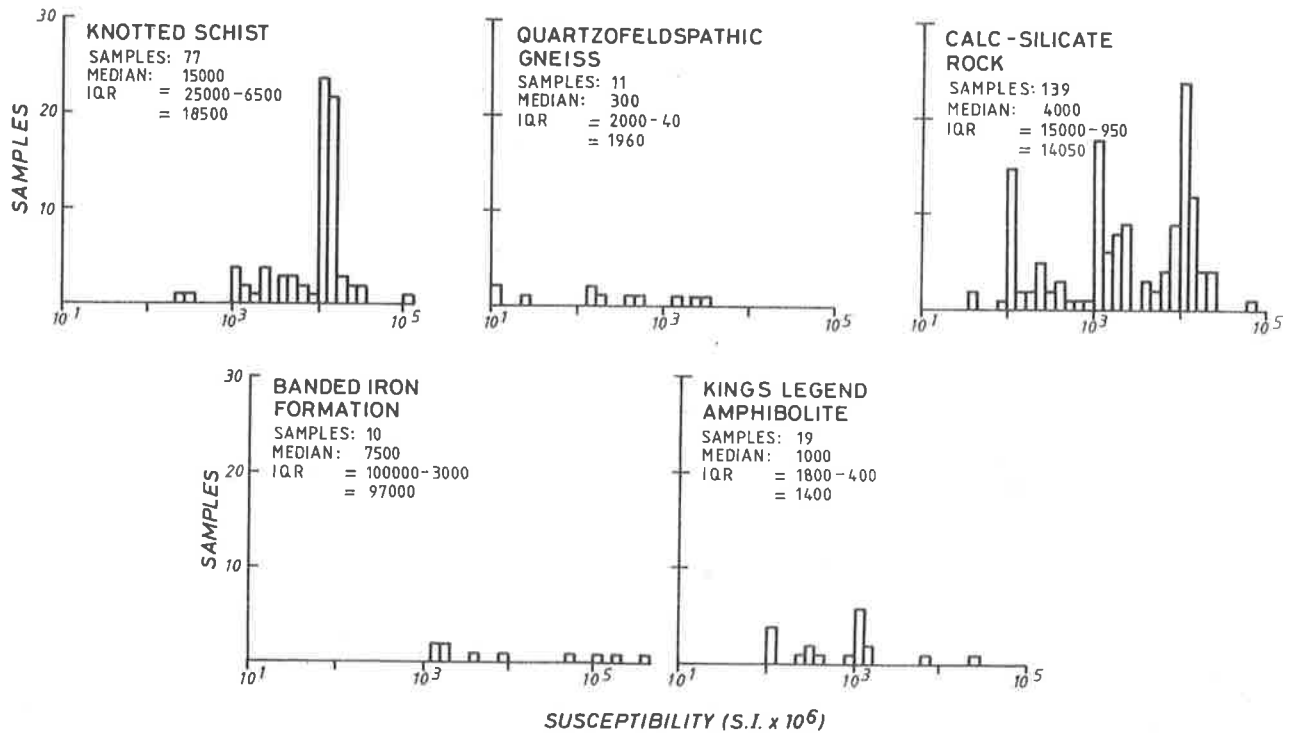


Figure 2.13 Magnetic susceptibility histograms for major lithologies comprising the Mascotte Gneiss Complex and Bonya Schist in the Bonya Hills area.

reflecting the frequent fine intercalation of magnetite rich (magnetite-quartzite) and magnetite poor (quartz-sericite schist) layers in this rocktype. Andalusite and quartz-chlorite schists have moderate to high susceptibilities. Banded iron formation and chlorite-magnetite-garnet quartzite are the most magnetically susceptible rocktypes within the Bonya Schist. Intercalations of amphibolite found in all suites have uniform low values.

These results may be compared with measurements taken in the Bonya Hills on western *JERVOIS RANGE* (Fig. 2.13). The Mascotte Gneiss Complex has a greater spread, but a similar median value to the Gneissic suite, supporting the ascertainment that they are correlatives. The moderate to high susceptibilities of knotted schists and banded iron formation are comparable to those of 'knotted' andalusite schist and banded iron formations of the Mine sequence suite. The King's Legend Amphibolite Member has a low susceptibility similar to all amphibolites discussed to date. Calc-silicate rocks have a wide range of values whilst quartzofeldspathic gneiss have low values comparable to Mg-silicate suite rocktypes.

NRM measurements for each rocktype are too few to make firm conclusions regarding their remanent properties (Table 2.3). However, with the exception of quartz-sericite-feldspar schist and cordierite schist their relative median remanent intensities are similar to their relative median susceptibilities (Fig. 2.14). Scattered negative inclinations predominate for Gneissic, Mine sequence and Mg-silicate suite rocktypes, whilst Fe,Mg-silicate suite lithologies have moderate positive inclinations (Fig. 2.15).

The stability of NRM was tested using alternating field demagnetization techniques. The progressive partial demagnetization of a sample by the application of an alternating field (A.F.) of progressively increasing field strength, allows the recognition of remanence components of different coercivity. A.F. paleomagnetic cleaning equipment from the Department of Earth Sciences, Flinders University was utilized for this purpose.

Typical A.F. demagnetization paths and curves are shown in Figure 2.16. Gneissic suite, Mine sequence suite and chlorite-biotite schist of the Mg-silicate suite exhibit rapid decay of NRM intensity and, in general, random changes in direction (excepting andalusite schist) during demagnetization, indicating their NRM is soft and unstable. The considerable scatter of raw NRM direction and intensity indicates their NRM may be paleomagnetic noise, however their negative inclinations indicate a tendency for these rocktypes to become remagnetized by the present earth field. Bulk rock magnetization giving rise to aeromagnetic anomalies is probably dominated by the induced component for these rocktypes, and any NRM component is likely to be aligned with the present field. Cordierite schist of the Mg-silicate suite has a hard, stable remanence. This is aligned in the direction of the present Earth field which may have completely remagnetized the samples measured.

NRM intensity of quartz-chlorite schist of the Fe,Mg-silicate suite initially decreases rapidly as the cleaning field increases, until a plateau occurs and NRM direction remains constant. This indicates the removal of a secondary NRM leaving a residual highly stable primary remanence. Results for chlorite-garnet-magnetite quartzite were similar, NRM intensity decreasing steadily whilst direction consistently moved away from the present earth field direction, indicating the secondary component was VRM. The intensity of NRM for rocktypes of the Fe,Mg-silicate suite (Table 2.3) indicates it is likely to have considerable influence on aeromagnetic response.

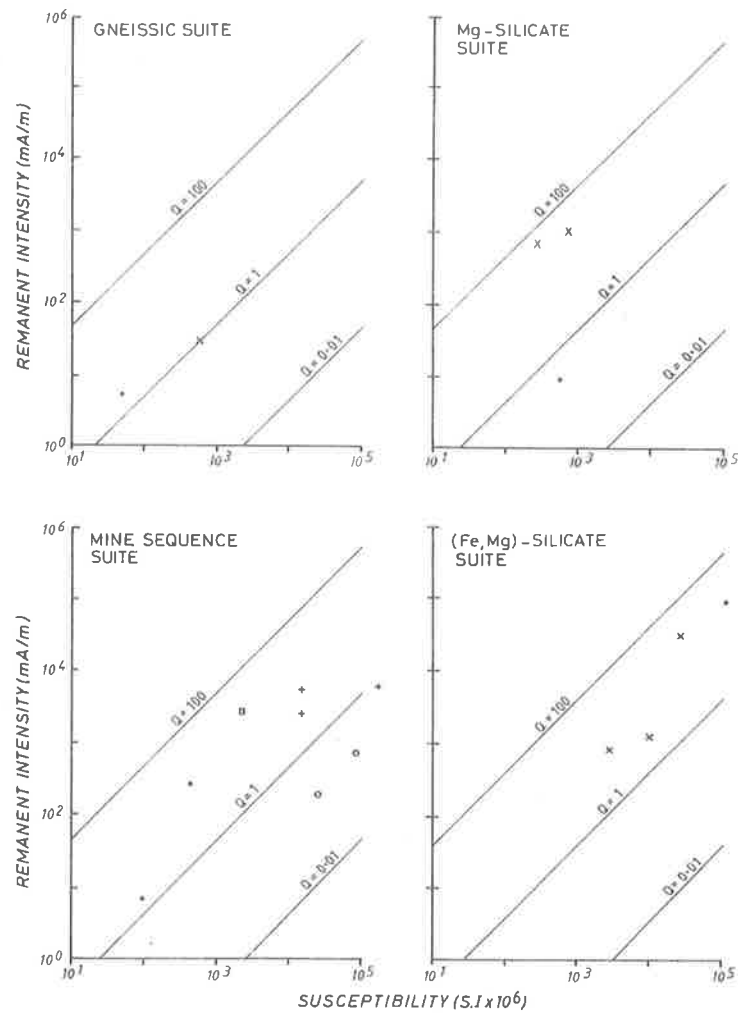


Figure 2.14 Graphs of remanent intensity versus magnetic susceptibility for major lithologies comprising the Bonya Schist.

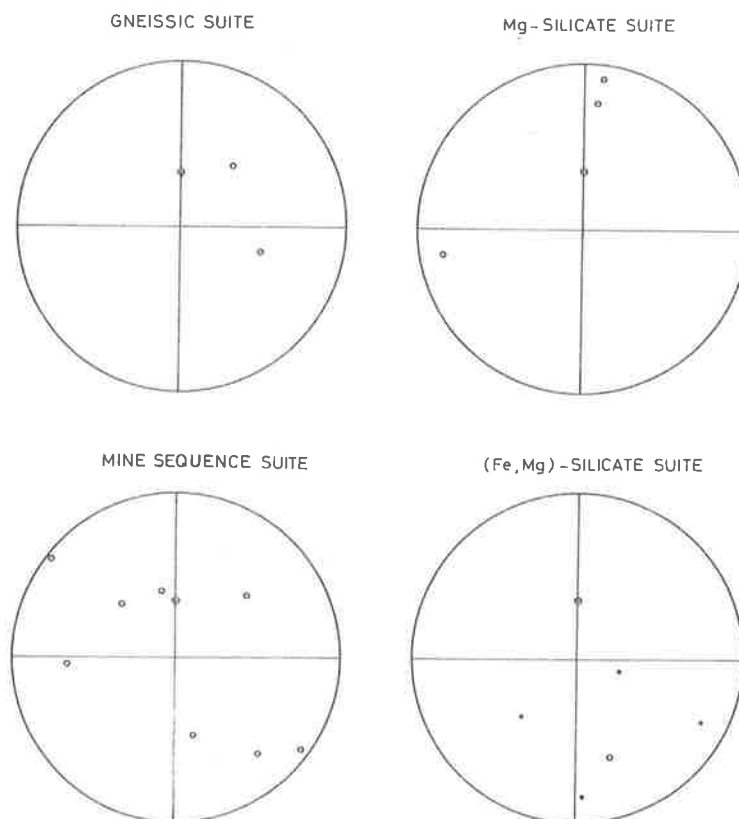


Figure 2.15 Equal area stereoplots of NRM directions for major lithologies comprising the Bonya Schist. (Negative inclination $\times$; Positive inclination $\bullet$, Earth's field $\oplus$).

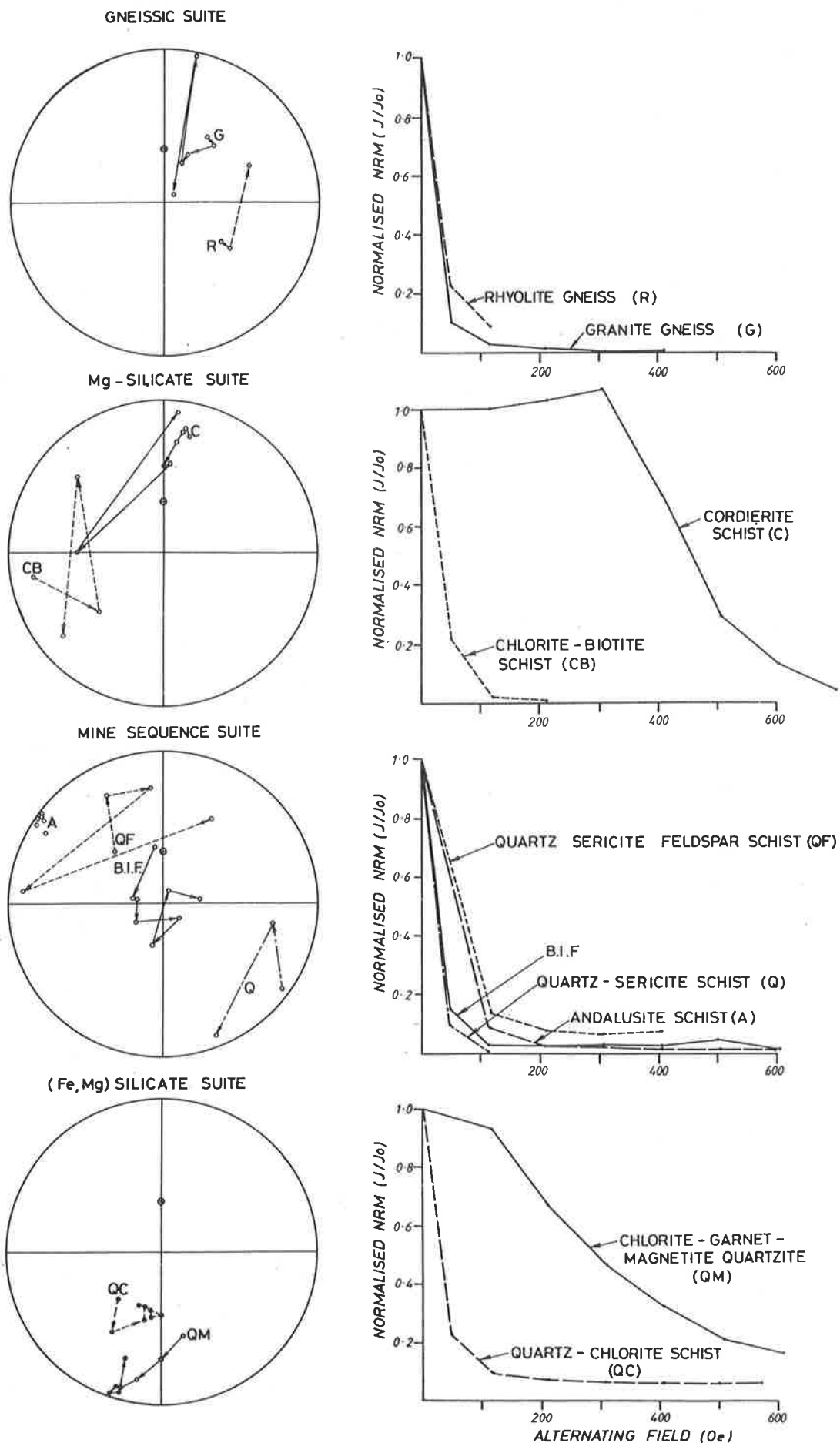


Figure 2.16 Typical equal area stereoplots of NRM directions and AF intensity decay curves during the course of AF demagnetization for major lithologies comprising the Bonya Schist. (Negative inclination ○; Positive inclination ●, Earth's field ⊙).

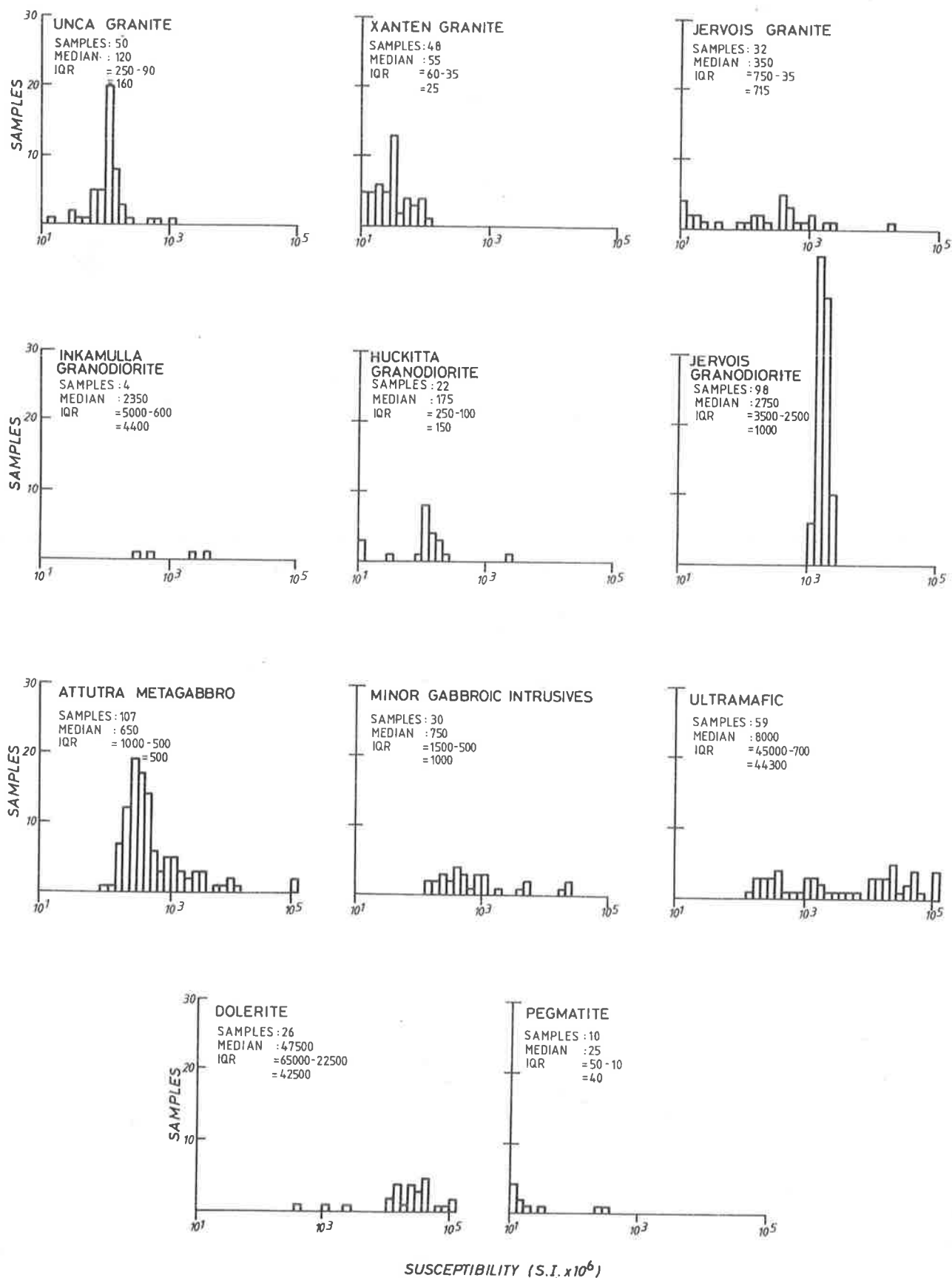


Figure 2.17 Magnetic susceptibility histograms for intrusive rocks.

Table 2.3: NRM of the Bonya Schist

Gneissic Suite

LITHOLOGY	SAMPLES	MEDIAN k (S.I. $\times 10^6$)	NRM RANGE (mA/m)	MEDIAN NRM (mA/m)	Q RANGE	MEDIAN Q
Granite Gneiss	1	375	10–135*	14.5	0.4–5.3*	0.57
Rhyolite Gneiss	1	80	1.5–7.6*	2.7	0.7–3.6*	1.3

Bonya Schist

Mg-silicate Suite

LITHOLOGY	SAMPLES	MEDIAN k (S.I. $\times 10^6$)	NRM RANGE (mA/m)	MEDIAN NRM (mA/m)	Q RANGE	MEDIAN Q
Chl-Bt-Schist	1	650	8.6–9.2*	8.9	0.37–0.4*	0.38
Cordierite Schist	2	550	545–990	780	26–52	37

Mine Sequence Suite

LITHOLOGY	SAMPLES	MEDIAN k (S.I. $\times 10^6$)	NRM RANGE (mA/m)	MEDIAN NRM (mA/m)	Q RANGE	MEDIAN Q
Andalusite Schist	2	8000	2230–2890	2520	16–21	18
Qtz-Sct-Schist	2	80	3.4–450	100	0.8–23	6.2
Qtz-Sct-Feld Schist	2	25000	175–670	420	0.17–0.19	0.18
Mgt-Quartzite	4	65000	2300–7670	5010	0.6–12	3.6

Fe,Mg-silicate Suite

LITHOLOGY	SAMPLES	MEDIAN k (S.I. $\times 10^6$)	NRM RANGE (mA/m)	MEDIAN NRM (mA/m)	Q RANGE	MEDIAN Q
Qtz-Chl-Schist	3	4500	680–1370	1030	2.9–6	4.4
Chl-Mgt-Gt Quartzite	2	62500	81900–365950	190000	19–46	29

* Measurements made on several cores from 1 sample

2.3.4 Intrusives

Figure 2.17 presents susceptibility histograms for intrusive rocks of varying composition outcropping in the Jervois Range and Harts Range areas. Granites (Unca, Xanten & Jervois) typically have low susceptibilities. Granodiorites have moderate values, although the Huckitta granodiorite has a low susceptibility similar to granites. Mafic intrusives exhibit a greater spread of values. Gabbros have a well-defined positively skewed distribution, with a low to moderate median. Ultramafic rocks exhibit an approximately bimodal distribution, one mode having low to moderate susceptibilities, the other, high values. Dolerites ($k_{0.5} = 47500 \times 10^{-6}$ S.I.) and pegmatites ($k_{0.5} = 25 \times 10^{-6}$ S.I.) are the most and least susceptible of all intrusives.

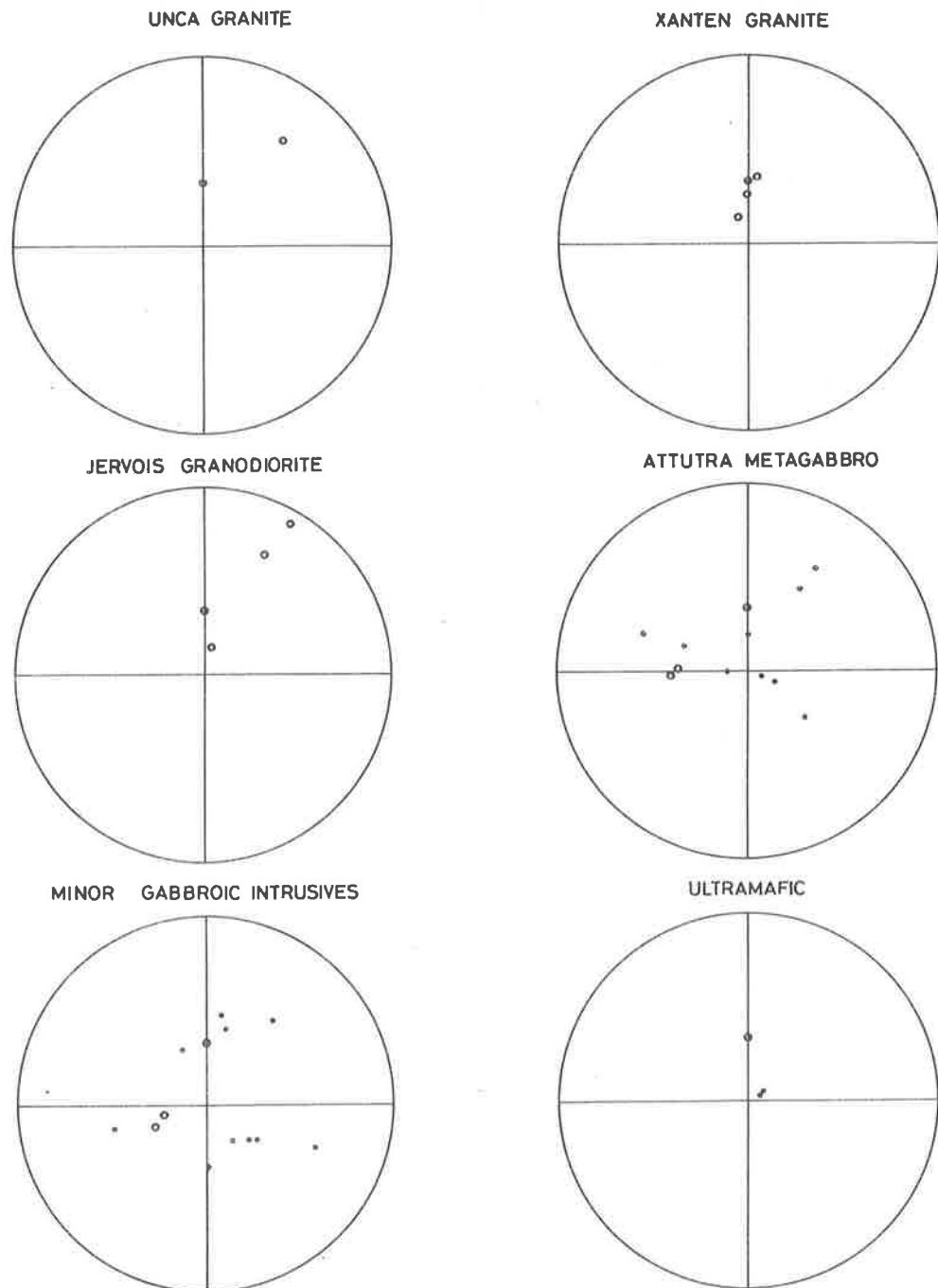


Figure 2.18 Equal area stereoplot of NRM directions for intrusive rocks. (Negative inclination $\circ$; Positive inclination $\bullet$, Earth's field $\odot$).

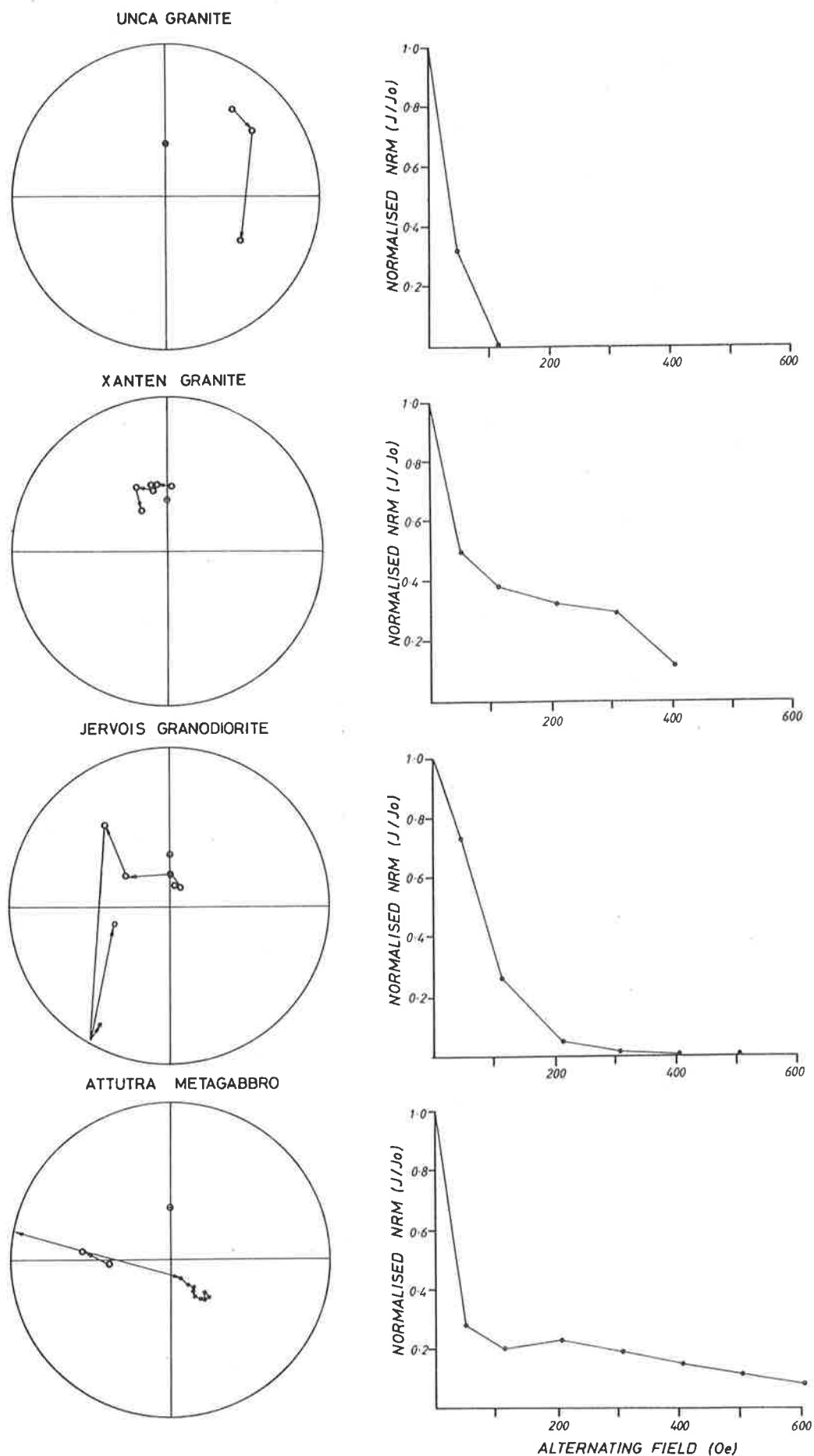


Figure 2.19 Typical equal area stereoplot of NRM directions and AF intensity decay curves during the course of AF demagnetization for intrusive rocks.

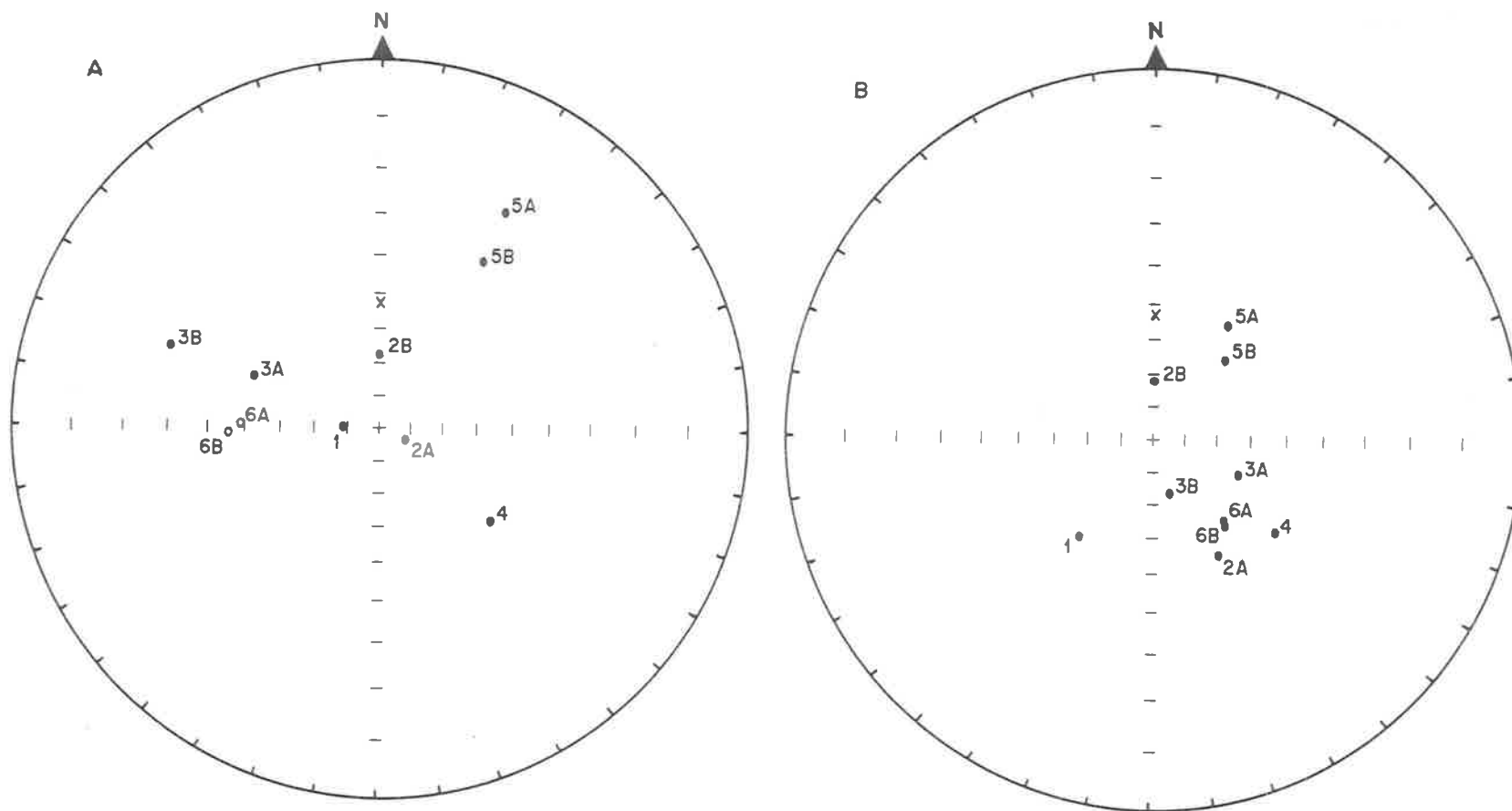


Figure 2.20 Equal area stereoplots of NRM directions for the Attutra Metagabbro prior to (A) and following (B) A.F. demagnetization. Numbers refer to sample locations shown on Figure 4.2. (Negative inclination o; Positive inclination •, Earth's field x).

Relative median NRM intensity is similar to relative median susceptibility for all intrusives investigated (Table 2.4). The remanence of granites is roughly oriented in the direction of the present field (Fig. 2.18). Alternating field demagnetization indicates their NRM is soft and probably viscous in origin (Fig. 2.19). Similar results are obtained for the Jervois Granodiorite. The feeble magnetization of granites indicates they are weakly magnetic whilst granodiorites are moderately magnetic.

Table 2.4: NRM of Intrusives

LITHOLOGY	SAMPLES	MEDIAN k (S.I. $\times 10^6$)	NRM RANGE (mA/m)	MEDIAN NRM (mA/m)	Q RANGE	MEDIAN Q
Unca Granite	1	120	*	25.7	*	5.9
Xanten Granite	2	55	2.1–5.5	3.6	0.98–1.8	1.3
Jervois Granodiorite	2	2750	630–1760	1150	5–17	10.2
Attutra Metagabbro	8	650	46–81780	5150	2.3–173	46
Minor Gabbroic Bodies	2	750	414–3542	2000	17.9–167	93
Ultramafic	1	8000	1051–12320**	6685	0.17–1.95**	1.1

* not applicable

** measurements made on several cores from 1 sample

Gabbro and ultramafics in general have steeply inclined positive NRM vectors. They are the only intrusives considered to have a well-defined stable remanent magnetization likely to have considerable influence on aeromagnetic anomalies. During demagnetization the NRM of Attutra Metagabbro samples systematically converged on a direction roughly opposed to that of the present earth field, with declination of 127° and inclination $+81^\circ$ (Figs. 2.19 & 2.20). The calculated virtual geomagnetic pole of 152° E, 33° S is consistent with results published by Plumb (1985) for 1700 Ma old Precambrian rocks. This is similar to the 1750–1800 Ma emplacement age for granites of the Northern Province (Section 1.2.4), suggesting the NRM may relate to the time of intrusion. However, the metamorphosed state of the body implies the magnetization is more likely an overprint from the time of final post-metamorphic cooling. The major prograde episode thought to affect the area, the Strangways Event (Section 1.3), is dated at 1790 ± 35 Ma indicating emplacement and metamorphism may have been synchronous. The similar NRM of small gabbroic bodies and ultramafics of the Harts Range (Fig. 2.18) indicates this magnetization event may be widespread.

2.3.5 Mylonitic Rocks associated with Faults

Mylonites investigated occurred along the zone of crustal dislocation separating basement and supracrustal cover of the Harts Range area (Fig. 1.4). The Bruna Gneiss which is considered by Ding and James (1985) to be a mylonitic megacrystic granitoid sheet tectonically emplaced along this boundary (Section 1.2.2), is included in this category.

Magnetic susceptibility of the Bruna Gneiss is well-defined, having a moderate to high median of 5500×10^{-6} S.I., although a significant group of lower susceptibilities ($100–300 \times 10^{-6}$ S.I.) were recorded (Fig. 2.21a). NRM intensity and Q values are highly scattered, with an interquartile range covering three

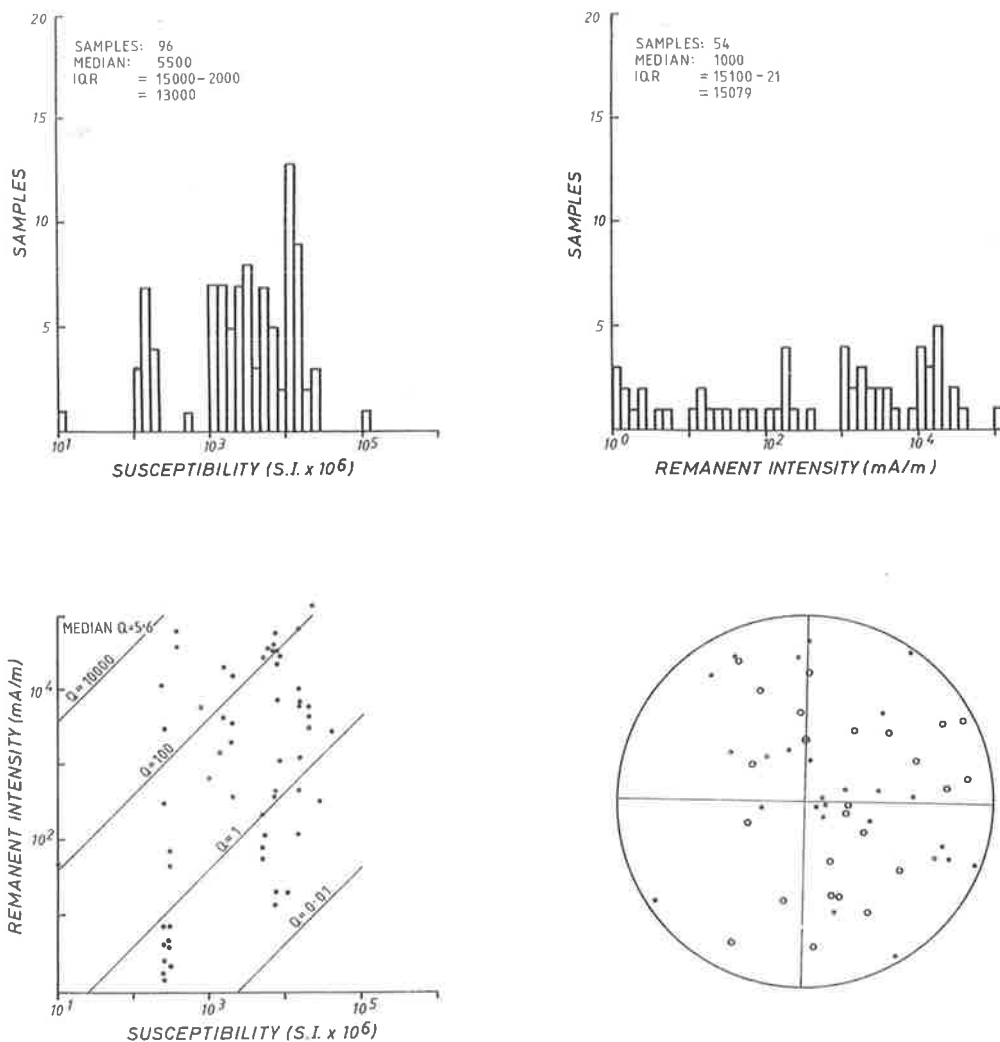


Figure 2.21a Histograms of magnetic susceptibility and NRM intensity; graphs of NRM intensity versus magnetic susceptibility and equal area stereoplots of NRM direction for the Bruna Gneiss. (Negative inclination ○; Positive inclination ●, Earth's field ⊕).

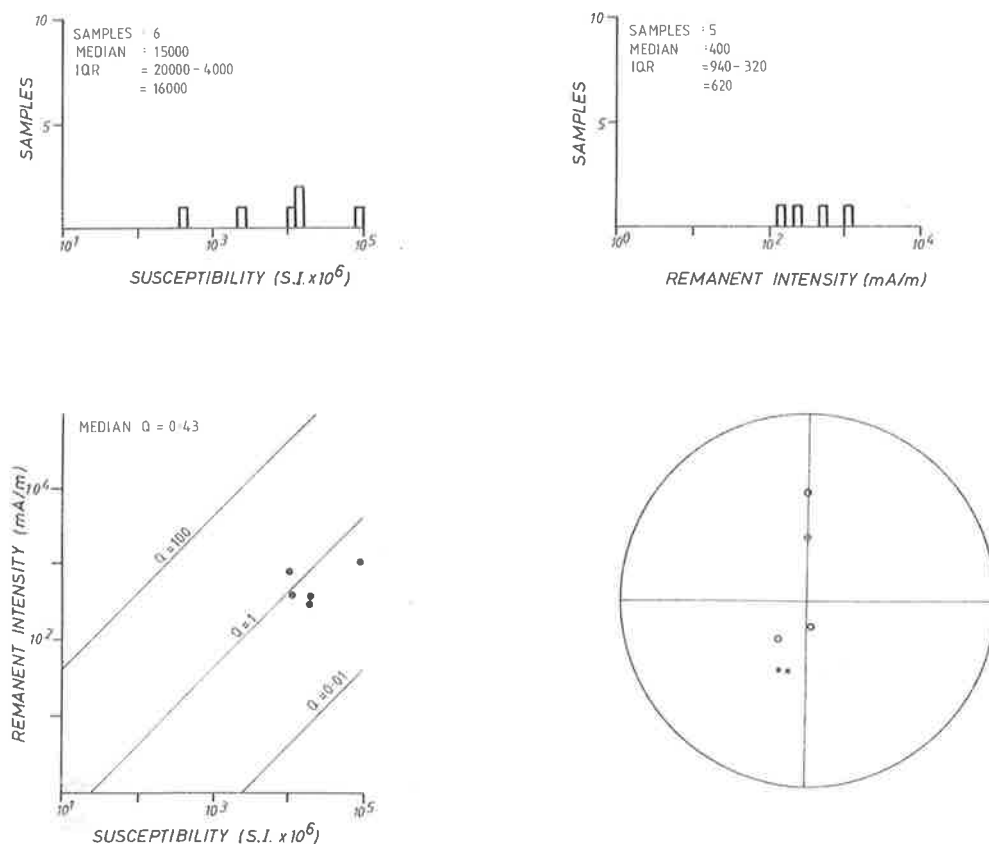


Figure 2.21b Histograms of magnetic susceptibility and NRM intensity; graphs of NRM intensity versus magnetic susceptibility and equal area stereoplots of NRM direction for mylonitic rocks ass-

orders of magnitude. Samples with extremely high NRM and Koeingsberger Ratios ($Q > 50$) are probably lightning affected and unrepresentative of the unit. Remanence directions are random, even excluding lightning struck samples, and it is unlikely remanence contributes significantly to bulk magnetization.

The number of samples of other mylonitic rocks is small, but results are similar to those for the Bruna Gneiss (Fig. 2.21b). Median susceptibility is high and although NRM intensity and Q values fall within a small range, remanent directions are inconsistent. The relatively high induced magnetization is therefore likely to be the dominant component influencing aeromagnetic response.

2.4 OPAQUE MINERALOGY AND PETROGENESIS

2.4.1 Division 1

Table 2.5 summarises estimates of mean volume percentage abundance, composition and form of opaque minerals from thin sections and polished thin sections of Division 1 rocktypes. Observed susceptibility (Section 2.3.1) is proportional to volume percentage magnetite (V) in accordance with empirical relationships relating these parameters such as that derived by Balseley and Buddington (1958)

$$k = 33 \times 10^{-3} V \quad S.I.$$

Moderate to highly magnetic rocktypes, namely biotite gneiss and granulite of the Oonagalabi gneiss complex and Cadney Metamorphics, contain a high percentage of opaque minerals (1.3 – 3.3%) which are predominantly magnetite and ilmenite. In contrast, weakly magnetic lithologies such as quartzofeldspathic gneiss of the Entia gneiss complex and Cadney Metamorphics, contain fewer opaques (0.1 – 0.25%), which are predominantly hematite. The weak magnetism of amphibolite is due to the predominance of titanium rich opaques such as ilmenite and pseudobrookite. Calc-silicates contain a variable percentage of opaque minerals consistent with their variable susceptibility and NRM. Ilmenite predominates, magnetite and hematite being secondary.

Median NRM intensity is in general proportional to the abundance of opaque minerals, but is also sensitively dependent on opaque composition and form. Five magnetic phases which may host significant remanence were observed in Division 1 rocktypes:

- 1) Large ($> 50\mu\text{m}$) subhedral to euhedral magnetite grains subdivided to varying degrees by lamellae into regions of PSD size or SD size ($< 15\mu\text{m}$; Fig. 2.22a).
- 2) Large grains of ilmenite hosting exsolution lenses of hematite (and vice-versa, 2b). The growth of large and fine lamellae results in a synneusis texture, with fine lenses of hematite distributed between thicker lenses of ilmenite (Fig 2.22b). The ability of this solid solution series to acquire remanence, in particular self-reversal, was briefly discussed in section 2.1.1.
- 3) Hematite and ilmenite lamellae in magnetite grains. (Figs. 2.22a &

Figure 2.22a.

Reflection microphotograph of a large magnetite grain subdivided by hematite lamellae. Secondary hematite occurs along grain margins and fractures. (Oil immersion, $0.5\text{mm} \times 0.335\text{mm}$)



Figure 2.22b.

Reflection microphotograph of synneusis texture, with fine layers of hematite distributed between thicker lenses of ilmenite and vica-versa. (Oil immersion, $0.5\text{mm} \times 0.335\text{mm}$)



Figure 2.22c.

Reflection microphotograph of ilmenite exsolution lamellae within a magnetite grain. (Oil immersion, $0.2\text{mm} \times 0.14\text{mm}$)



Figure 2.22d.

Reflection microphotograph of fine equidimensional and acicular grains, of secondary opaques associated with the partial decomposition of biotite. (Oil immersion, $0.2\text{mm} \times 0.14\text{mm}$)



Table 2.5: Opaque Mineralogy, Division 1 Lithologies.

Oonagalabi Gneiss Complex

LITHOLOGY	THIN	MEAN %	MEAN OPAQUE COMPOSITION							OPAQUE FORM*
	SECTIONS	OPAQUES	Mgt	Ilm	Hmt	Spinel	Psbrkt	Rutile	Others	
Quartzofeldspathic Gneiss	12	1.0	35	2	30	8	25	-	tr	(1) common, minor (3) & (2b)
Biotite Gneiss	28	3.2	73	15	9	1	2	-	tr	Dominantly (1) & (2). Minor (3) & (5)
Granulite	14	3.3	50	25	tr	tr	25	-	-	(1) & (3) common
Migmatite	3	1.0	35	-	10	40	15	-	-	Dominantly (5), minor (1)
Amphibolite	7	0.7	20	45	tr	-	35	-	tr	Large ilmenite grains ($\leq 0.2\text{mm}$). (1) & (5) common

Cadney Metamorphics

LITHOLOGY	THIN	MEAN %	MEAN OPAQUE COMPOSITION							OPAQUE FORM*
	SECTIONS	OPAQUES	Mgt	Ilm	Hmt	Spinel	Psbrkt	Rutile	Others	
Quartzofeldspathic Gneiss	3	0.1	10	-	85	-	-	-	5	(1) predominantly martitised, (5) common
Bt & Sill Gneiss	6	1.3	-	-	-	-	-	-	-	No representative polished thin sections
Granulite	3	3.2	23	75	2	-	tr	-	tr	(1), (2a) & (5) all common
Calc-Silicate Rock	3	2.7	-	-	-	-	-	-	-	No representative polished thin sections

Entia Gneiss Complex

LITHOLOGY	THIN	MEAN %	MEAN OPAQUE COMPOSITION							OPAQUE FORM*
	SECTIONS	OPAQUES	Mgt	Ilm	Hmt	Spinel	Psbrkt	Rutile	Others	
Quartzofeldspathic Gneiss	19	0.25	2	5	55	15	15	6	tr	Dominantly (2b) & (5). Minor (1)
Calc-Silicate Rock	26	0.25	30	60	10	-	tr	-	tr	(1) & (2a)
Amphibolite	17	0.2	2	40	5	6	6	40	tr	Dominantly (2a), minor (1)

* Refer to Section 2.4.1 for explanation of opaque form code.

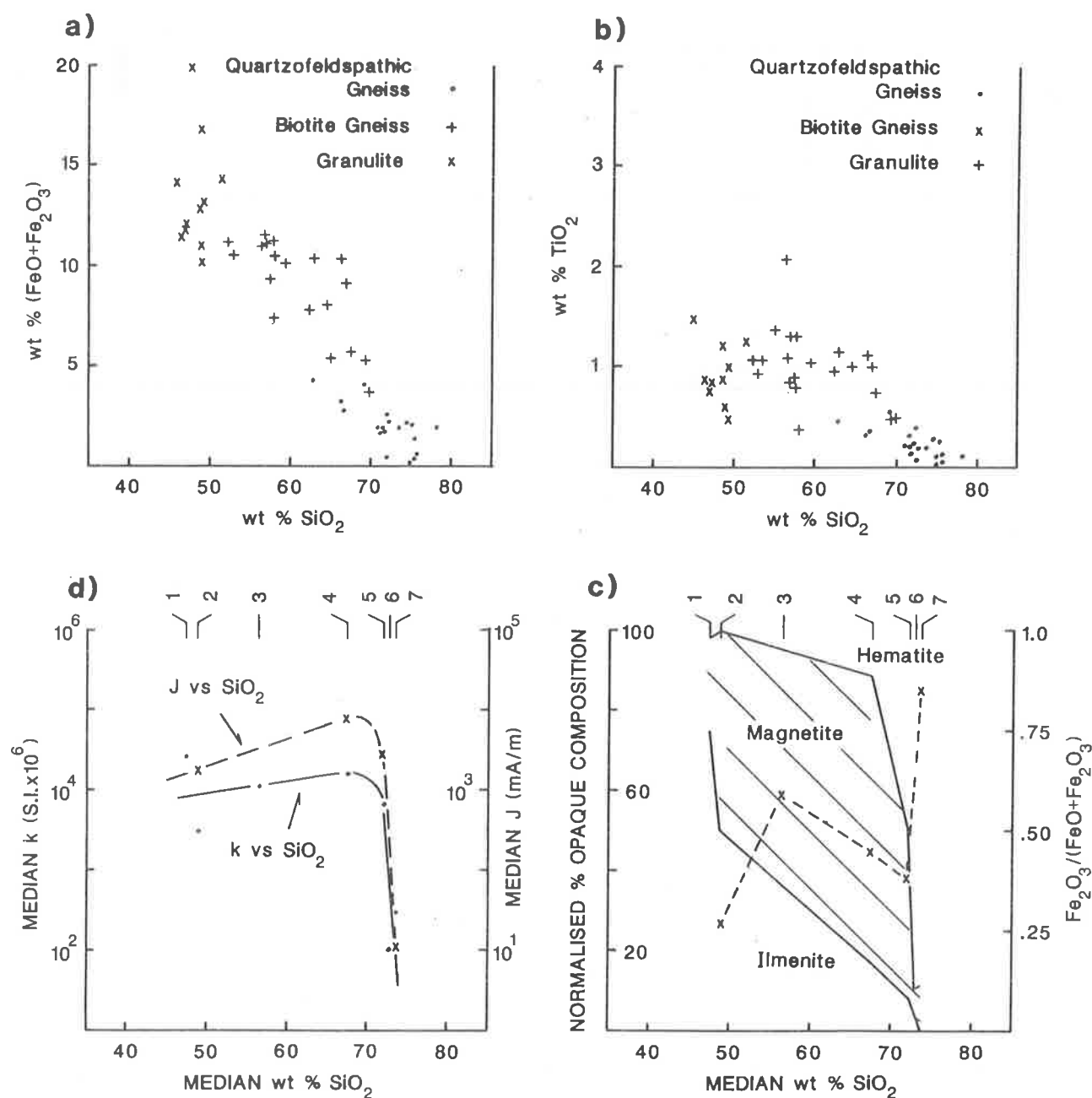


Figure 2.23 Graphs of a) weight percent total iron and b) titanium; c) oxidation state ratio and normalised opaque composition; and d) median magnetic susceptibility and NRM intensity versus weight percent SiO₂ for major Division 1 lithologies. 1- Granulite (Cadney Metamorphics); 2- Granulite (Oonagalabi gneiss complex); 3- Bt-gneiss (Cadney Metamorphics); 4- Bt-gneiss (Oonagalabi gneiss complex); 5- Qtz-feld gneiss (Oonagalabi gneiss complex); 6- Qtz-feld gneiss (Cadney Metamorphics); 7- Qtz-feld gneiss (Entia gneiss complex). Oxidation state ratio x— —x.

2.22c).

4) Widespread secondary hematite along margins and fractures of magnetite grains (Fig. 2.22a).

5) Fine equidimensional and acicular grains of secondary opaques of PSD and possibly SD size, associated with the partial decomposition of biotite, hornblende and pyroxene. The planes of exsolution are typically parallel to cleavage planes in the host silicate (Fig. 2.22d).

Their relative abundance in various rocktypes is indicated in Table 2.5.

The complex, scattered NRM of Division 1 rocks probably has several components residing in opaque grains formed at different times. Opaques are preferentially associated with fine layers of iron silicates, in particular biotite, hornblende and pyroxene. Large grains formed during prograde metamorphism of iron rich layers, from excess iron not taken up by silicates. Synneusis texture (Phase 2) in titanohematites is indicative of deep seated cooling, consistent with the intrusive origin and granulite grade metamorphism of many Division 1 rocktypes. Many opaques are of secondary origin. Martitisation of magnetite grains (Phases 1 and 4) results from late stage hydrous retrograde metamorphism (Section 1.3) and weathering. Phase 5 results from the alteration (dehydration?) of iron silicates.

Magnetite grains of a size consistent with true multidomain behaviour ($> 15\mu\text{m}$) are magnetically soft and prone to acquire paleomagnetic noise which may contribute to the observed random NRM. The Q values for TRM and CRM associated with these grains are typically less than unity (Fig. 2.1). They are considered the major source of magnetic susceptibility in Division 1 rocktypes.

Whole rock and FeO analysis determined major element and ferric, ferrous iron abundance of Division 1 rocktypes. Figure 2.23 presents plots of weight percent iron and titanium, median susceptibility and NRM intensity, and oxidation state ratio and normalised opaque composition against weight percent SiO_2 . Total iron increases uniformly for decreasing SiO_2 (Fig. 2.23a), explaining the observed low opaque abundance of SiO_2 rich rocktypes (quartzofeldspathic gneiss) and higher opaque abundance of SiO_2 deficient rocktypes (biotite gneiss, granulite). Similarly, titanium content increases (Fig. 2.23b) whilst oxidation state decreases (Fig. 2.23c) for diminishing weight percent SiO_2 . These trends result in the observed dominance of hematite in quartzofeldspathic gneiss, magnetite and subordinate ilmenite in biotite gneiss, and ilmenite and subordinate magnetite in granulite and amphibolite (Fig. 2.23c). The relative influence of all three factors results in a peak of volume percent magnetite, and therefore magnetic susceptibility and NRM intensity, for Division 1 rocktypes of intermediate SiO_2 content (Fig. 2.23d).

2.4.2 Division 2 of the Central Tectonic Province

The weak magnetism of rocktypes comprising the Irindina and Brady supracrustal assemblages (Section 2.3.2) is consistent with their low opaque mineral content and the dominance of weakly magnetic oxides, in particular ilmenite and hematite (Table 2.6). Only biotite gneiss and biotite schist of the Irindina supracrustal assemblage, which record a number of more magnetic samples (Fig. 2.8), contain a significant proportion of magnetite.

Table 2.6: Opaque Mineralogy, Division 2 of the Central Tectonic Province

Irindina Supracrustal Assemblage

LITHOLOGY	THIN SECTIONS	MEAN % OPAQUES	MEAN OPAQUE COMPOSITION							OPAQUE FORM*
			Mgt	Ilm	Hmt	Spinel	Psbrkt	Rutile	Others	
Biotite Gneiss	31	0.5	45	45	10	tr	-	-	-	(1) & (2b) predominate along with large ilmenite grains
Biotite Schist	14	0.9	50	5	35	10	tr	tr	-	(1) & (2b) predominate along with large ilmenite grains
Calc-Silicate Rock	18	1.1	tr	tr	50	50	-	-	tr	Large grains of hematite exsolving ilmenite & spinel
Amphibolite	17	2.0	5	tr	-	5	85	-	tr	Predominantly complex exsolutions of Fe,Ti oxides. Minor (1).
Riddock Amphibolite	46	1.6	10	88	-	2	-	-	-	Large ilmenite grains.Minor (1).
Entire Anorthosite	27	0.6	10	-	tr	30	60	-	tr	Predominantly complex exsolutions of Fe,Ti oxides. Minor (1).

Brady Supracrustal Assemblage

LITHOLOGY	THIN SECTIONS	MEAN % OPAQUES	MEAN OPAQUE COMPOSITION							OPAQUE FORM*
			Mgt	Ilm	Hmt	Spinel	Psbrkt	Rutile	Others	
Biotite Gneiss	5	0.6	tr	95	5	-	-	-	tr	Acicular ilmenite & hematite
Biotite Schist	4	0.3	tr	90	10	-	-	-	tr	Acicular ilmenite & hematite
Calc-Silicate Rock	4	0.4	tr	-	30	20	50	-	tr	Psuedobrookite associated with sphene alteration.(5) common
Calcic-Quartzite	4	2.3	tr	-	-	-	50	50	tr	Opaque as rims to sphene
Amphibolite	6	2.0	tr	99	tr	-	-	tr	tr	Ilmenite as cores to sphene

*Refer to Section 2.4.1 for explanation of opaque form code.

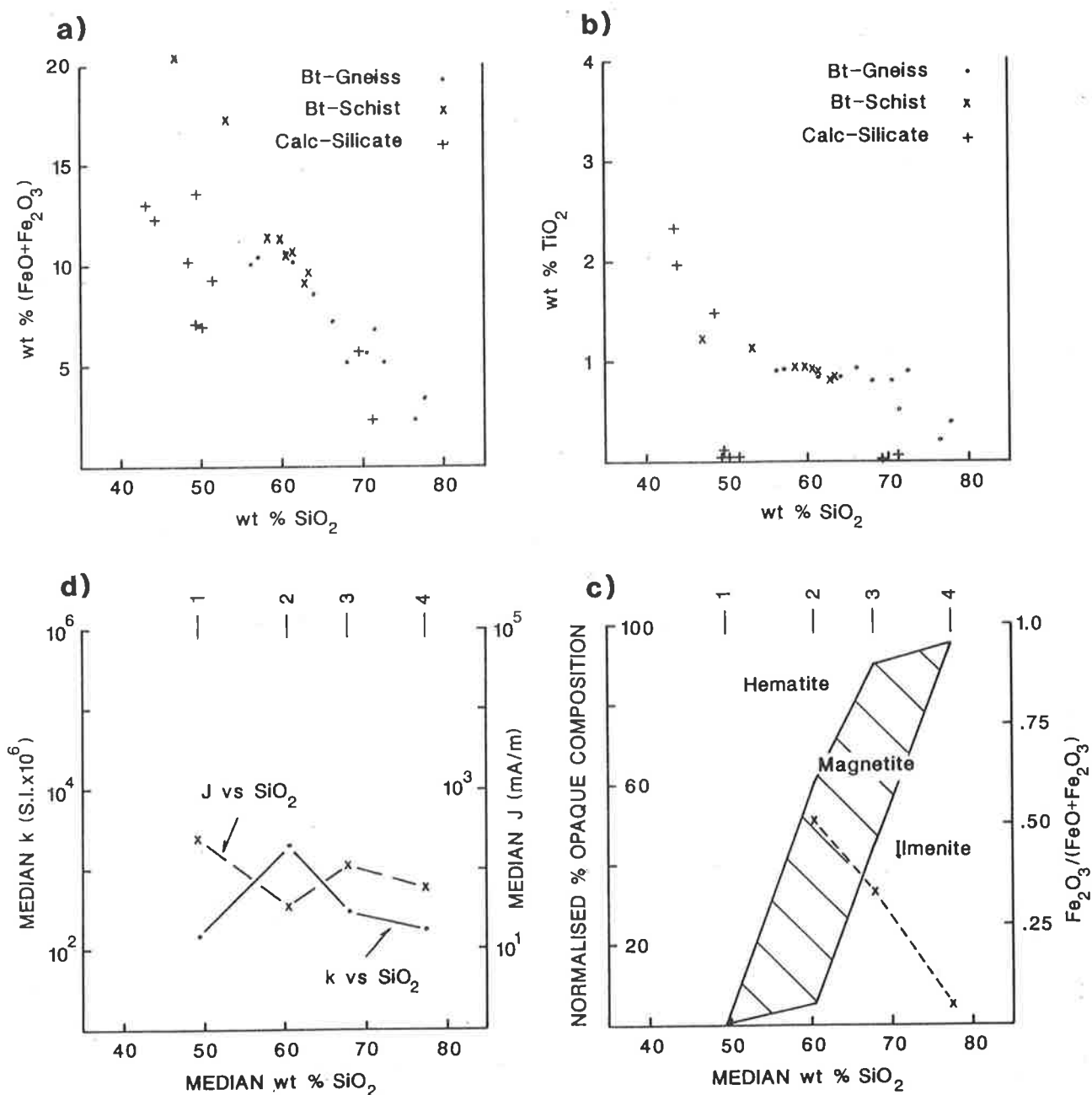


Figure 2.24 Graphs of a) weight percent total iron and b) titanium; c) oxidation state ratio and normalised opaque composition; and d) median magnetic susceptibility and NRM intensity versus weight percent SiO₂ for major Division 2 lithologies of the Central Tectonic Province. 1- Calc-silicate (Irindina supracrustal assemblage); 2- Bt-schist (Irindina supracrustal assemblage); 3- Bt-gneiss (Irindina supracrustal assemblage); 4- Bt-gneiss (Brady supracrustal assemblage). Oxidation state ratio x — x.

Table 2.7: Opaque Mineralogy, Division 2 of the Northern Tectonic Province

Gneissic Suite

LITHOLOGY	THIN	MEAN %	MEAN OPAQUE COMPOSITION							OPAQUE FORM
	SECTIONS	OPAQUES	Mgt	Ilm	Hmt	Spinel	Psbrkt	Rutile	Others	
Granite Gneiss	1	2.0	2	-	85	-	10	-	-	Large grains hematite. Minor martitised magnetite
Rhyolite Gneiss	1	1.0	-	-	50	50	-	-	-	Large grains hematite

Bonya Schist

Mg-silicate Suite

LITHOLOGY	THIN	MEAN %	MEAN OPAQUE COMPOSITION							OPAQUE FORM
	SECTIONS	OPAQUES	Mgt	Ilm	Hmt	Spinel	Psbrkt	Rutile	Others	
Chl-Bt-Schist	1	7.0	tr	-	100	-	-	-	-	Martitised magnetite grains
Cordierite Schist	2	8.5	1	-	99	-	-	-	-	Martitised magnetite grains

Mine Sequence Suite

LITHOLOGY	THIN	MEAN %	MEAN OPAQUE COMPOSITION							OPAQUE FORM
	SECTIONS	OPAQUES	Mgt	Ilm	Hmt	Spinel	Psbrkt	Rutile	Others	
Andalusite Schist	1	10	20	-	50	30	-	-	-	Euhedral martitised magnetite grains
Qtz-Sct Schist	2	1.2	-	-	40	60	-	-	-	Minor grains of hematite & spinel
Qtz-Sct-Feld Schist	2	10	70	-	30	-	-	-	tr	Martitised magnetite grains of all sizes
B.I.F.	4	40	15	-	85	-	-	-	tr	Thick platy sections hematite & martitised magnetite

Fe,Mg-silicate Suite

LITHOLOGY	THIN	MEAN %	MEAN OPAQUE COMPOSITION							OPAQUE FORM
	SECTIONS	OPAQUES	Mgt	Ilm	Hmt	Spinel	Psbrkt	Rutile	Others	
Qtz-Chl Schist	3	10	30	-	45	25	-	-	-	Martitised magnetite. Minor acicular opaque in bt & chl
Chl-Mgt-Gt Quartzite	2	25	50	-	30	20	-	-	-	Martitised magnetite. Abundant acicular opaque in bt & chl
Amphibolite	27	2.0	20	50	5	10	-	15	-	Large grains ilmenite & magnetite in hbl

Opaques are associated with fine layers of iron silicates. A variety of potentially magnetic phases, summarised in Table 2.6, were observed. Magnetic susceptibility is consistent with visual estimates of large MD grains of magnetite. As for Division 1 rocktypes their highly scattered NRM probably consists of several components residing in magnetic phases formed at different times. Widespread martitisation of magnetite may be the result of low-temperature hydration which followed the prograde Strangways Metamorphic Event (Section 1.3). In amphibolite, calc-silicate and calcic-quartzite of the Brady supracrustal assemblage Fe,Ti oxides are commonly associated with sphene ($CaTiSiO_6$).

Iron and titanium content is similar to that of Division 1 rocks and is again dependent on weight percent SiO_2 (Figs. 2.24a & b). The dominance of weakly magnetic oxides and their low abundance appears to result from the relatively high titanium content of most rocktypes, and relatively low oxygen availability during prograde metamorphism (Fig. 2.24c), which favoured the formation of iron silicates and Fe,Ti oxides. Subsequent low-temperature hydration oxidized available magnetite to hematite resulting in a further reduction of magnetic susceptibility and NRM intensity.

2.4.3 Division 2 of the Northern Tectonic Province

Opaque minerals associated with Division 2 rocks of the Northern Province are mainly hematite and magnetite, except for amphibolites in which ilmenite predominates (Table 2.7). Measured susceptibility is consistent with visual estimates of magnetite indicating these grains have predominantly multi-domain behaviour. Weakly magnetic felsic meta-igneous rocks such as Gneissic suite rocktypes, and quartz-sericite schist of the Mine sequence suite, contain few opaques (1 - 2%) which are mainly hematite. Metasediments contain abundant opaque oxides (7 - 40%), dominantly euhedral crystals of magnetite martitised by varying degrees to hematite (Fig. 2.25a). Their magnetic susceptibility is dependent on opaque abundance and the degree of martitisation, which is almost complete in weakly magnetic Mg-silicate suite rocktypes.

NRM intensity is proportional to opaque mineral abundance. The unstable NRM and scattered negative inclinations of Gneissic, Mg-silicate and Mine sequence suite rocktypes (Section 2.3.3) probably results from the predominance of large multi-domain grains of magnetite, which are magnetically soft and easily remagnetised by the present field. The well-defined stable NRM of Fe,Mg-silicate rocktypes is associated with quasi-exsolution of magnetite along cleavage planes in biotite (Fig. 2.25b).

The abundance of opaque minerals in various rocktypes again reflects the dependence of iron content on weight percent SiO_2 (Fig. 2.26a). The absence of ilmenite, except in amphibolites, is due to their relatively low titanium content (Fig. 2.26b). The high opaque abundance in metasediments is due to their high iron content, but may also be indicative of intermediate oxidation states during regional metamorphism favouring the formation of magnetite over iron silicates. Magnetite is considered to have formed from the reduction of chemically precipitated hematite originally present in sediments. Some original hematite within banded iron formation was recrystallized into thick platy sections of hematite, being prevented from reduction to magnetite through oxygen buffering within these layers. Martitisation of magnetite occurred during later retrograde hydration (Section 1.3), although some alteration at rims and along fractures within grains may be due to weathering. Oxidation state ratio is generally high and does not vary appreciably with SiO_2 content (Fig 2.26c). Slight variations reflect the degree of martitisation within individual rocktypes. Median susceptibility and NRM intensity increase with increasing total iron content (i.e. generally for decreasing SiO_2 content, Fig. 2.26d), but level off

Figure 2.25a.

Reflection microphotograph of a partially martitised euhedral magnetite grain, typical of metasediments of the Bonya Schist.
(Oil immersion, 0.13mm × 0.09mm)

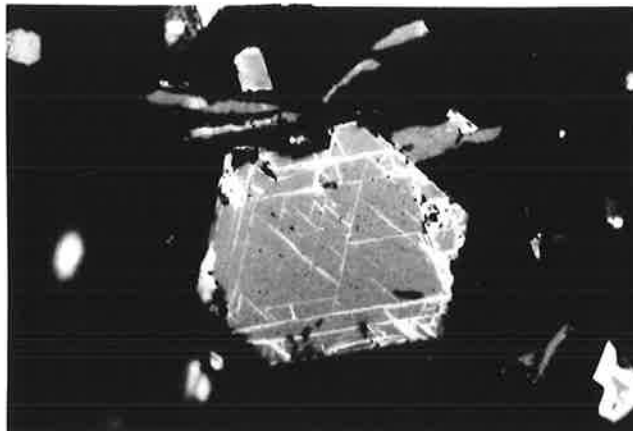
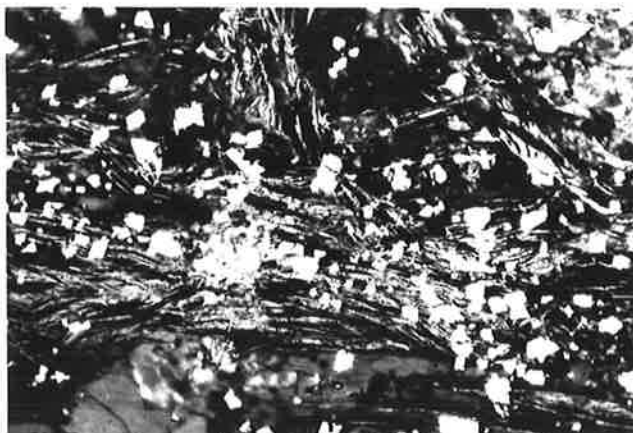


Figure 2.25b.

Reflection microphotograph of quasi-exsolution of magnetite from biotite within quartz-garnet-chlorite-magnetite rock of the Bonya Schist, Fe,Mg-silicate suite.
(Oil immersion, 0.2mm × 0.14mm)



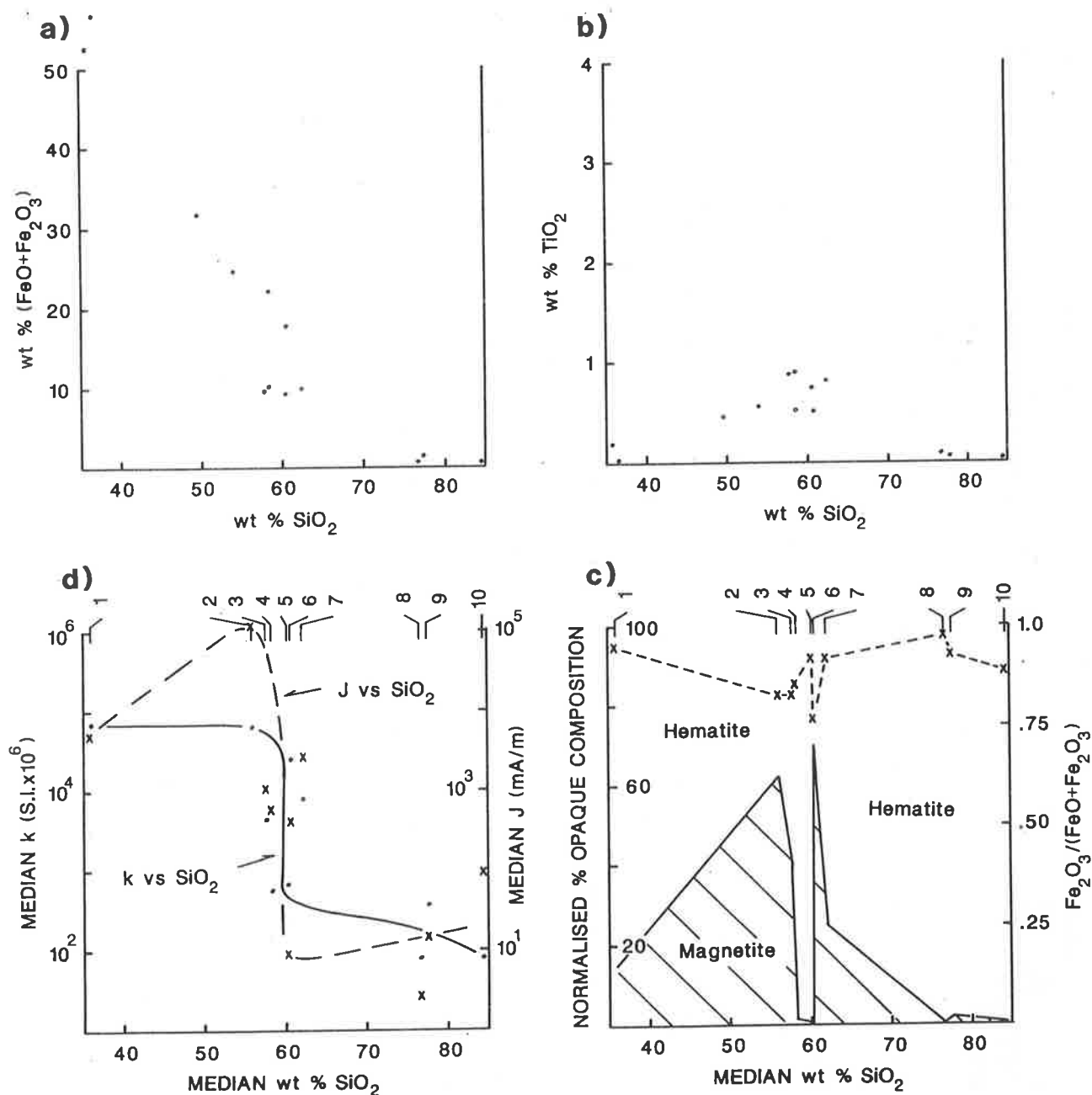


Figure 2.26 Graphs of a) weight percent total iron and b) titanium; c) oxidation state ratio and normalised opaque composition; and d) median magnetic susceptibility and NRM intensity versus weight percent SiO_2 for major Division 2 lithologies of the Northern Tectonic Province. 1- BIF; 2- Chl-mgt-gt quartzite; 3- Qtz-chl schist; 4- Cordierite schist; 5- Chl-bt schist; 6- Qtz-sct-feld schist; 7- Andalusite schist; 8- Rhyolite gneiss; 9- Granite gneiss; 10- Qtz-sct schist. Oxidation state ratio x — — x.

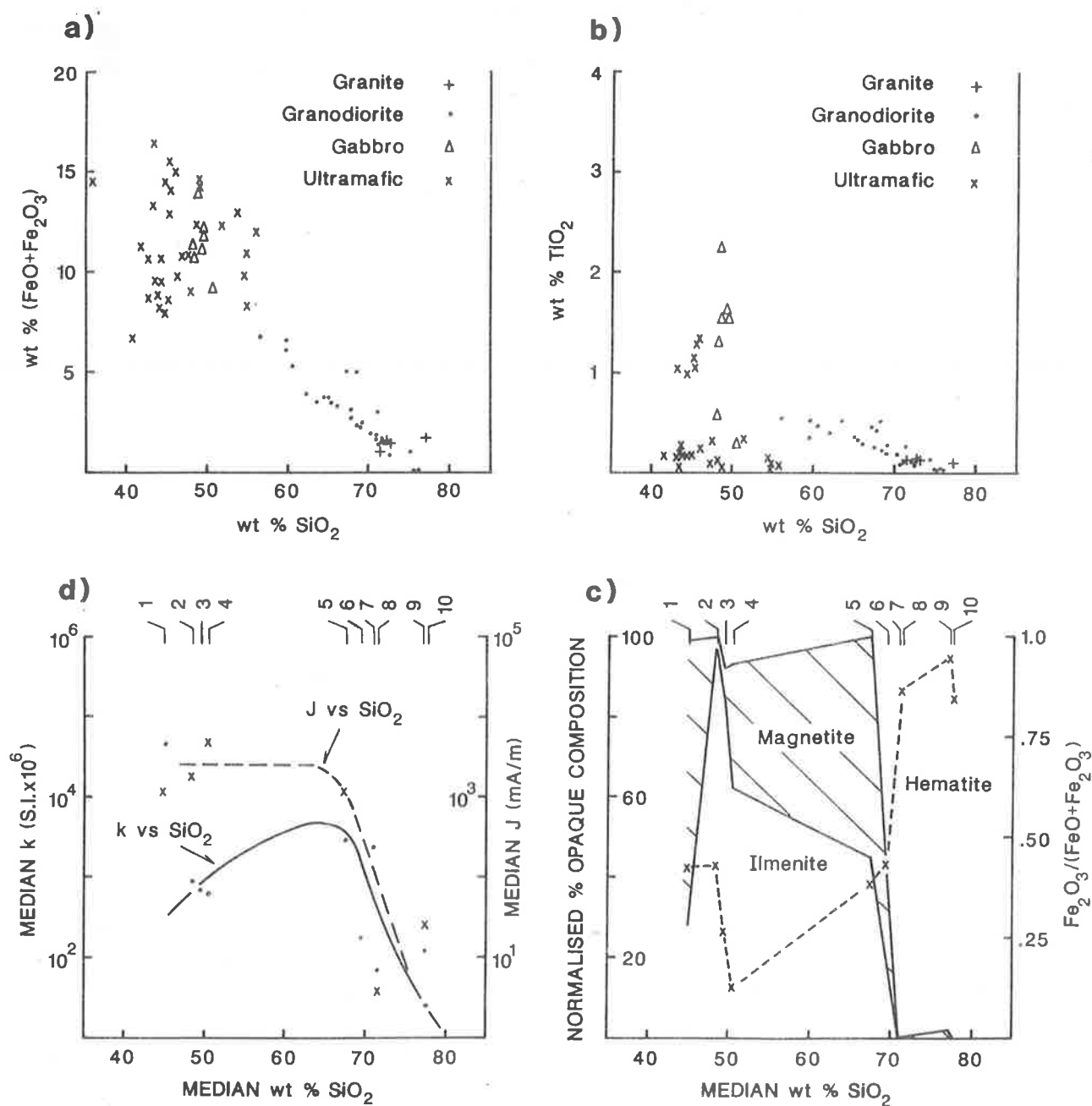


Figure 2.27 Graphs of a) weight percent total iron and b) titanium; c) oxidation state ratio and normalised opaque composition; and d) median magnetic susceptibility and NRM intensity versus weight percent SiO_2 for major Intrusives of the Northern Tectonic Province. 1- Ultramafic (serpentinized); 2- Gabbro; 3- Ultramafic (unaltered); 4- Attuttra Metagabbro; 5- Jervois Granodiorite; 6- Huckitta Granodiorite; 7- Inkamulla Granodiorite; 8- Xanten Granite; 9- Unca Granite; 10- Pegmatite. Oxidation state ratio x- -x.

at high iron content due to the influence of oxygen buffering which limits the formation of magnetite in banded iron formation and magnetite quartzite.

2.4.4 Intrusives

Intrusives exhibit a similar striking relationship between rock magnetism and weight percent SiO_2 as Division 1 rocktypes (Fig. 2.27d). Iron and titanium content increase (Figs. 2.27a & b) whilst oxidation state ratio generally decreases (Fig. 2.27c) for diminishing weight percent SiO_2 . Consequently opaque minerals are more abundant for increasingly mafic rocktypes and hematite predominates in granites, magnetite and ilmenite in granodiorites and ilmenite in gabbro and unaltered ultramafics. (Table 2.8; Fig. 2.27c). Magnetic susceptibility therefore peaks for intrusives of intermediate composition (Fig. 2.27d). Similar results derived from published data are reported by Grant (1985).

Two groups of ultramafic rocks are recognised on the basis of their observed bimodal susceptibility distribution (Section 2.3.4). Unaltered ultramafics have moderate susceptibilities. High temperature hydrous alteration (serpentinization) of these results in the decomposition of olivine and orthopyroxene into hydrous Fe,Mg-silicates and magnetite (Moody, 1976; Fig 2.28a & b) and greatly enhanced magnetic susceptibility and NRM intensity (Fig. 2.27d).

NRM intensity increases for decreasing SiO_2 content (Fig. 2.27d), largely due to the increasing abundance of fine grains of secondary magnetite in more mafic intrusives. Magnetites within granites and granodiorites are predominantly large multidomain grains, consistent with the low NRM intensity and soft VRM of these rocktypes. Magnetite in gabbro was observed in two forms, firstly as large (0.25mm downwards) multi-domain grains, and secondly as elongate quasi-exsolved grains within pyroxene (Fig. 2.28c) and exsolution lamellae within ilmenite. The latter are considered the source of stable remanence in gabbro's as magnetization processes in acicular grains are controlled by shape anisotropy resulting in single-domain behaviour (Hargraves & Young, 1969; Evans & McElhinny, 1969). Fine grained magnetite, the result of serpentinization, is considered the primary source of stable remanence in ultramafic rocks.

2.4.5 Mylonitic rocks associated with Faults

Magnetite is abundant in mylonitic rocks associated with faults (Table 2.9), consistent with their observed magnetic properties (Section 2.3.5). Ilmenite is also common in the Bruna Gneiss and together with its high susceptibility and NRM intensity suggests this igneous intrusive is of intermediate composition. As with Division 1 and 2 rocktypes of the Central Tectonic Province, their random NRM probably results from several components residing in magnetic phases formed at different times and their complex tectonothermal history.

2.5 SUMMARY AND CONCLUSIONS

The magnetic properties of rocktypes of the eastern Arunta Inlier are determined by their total iron content and the manner of its division between Fe,Mg-silicates and the oxides of iron and titanium. The partitioning of iron is controlled by oxygen fugacity and titanium content. All these parameters exhibit a well-defined dependence on weight percent SiO_2 , and as a result the magnetic properties of

Table 2.8: Opaque Mineralogy of Intrusives

LITHOLOGY	THIN SECTIONS	MEAN % OPAQUES	MEAN OPAQUE COMPOSITION							OPAQUE FORM
			Mgt	Ilm	Hmt	Spinel	Psbrkt	Rutile	Others	
Xanten Granite	2	0.8	-	-	80	-	-	-	20	Predominantly large hematite grains
Unca Granite	1	1.8	2	-	95	-	-	-	3	Predominantly large hematite grains
Inkamulla Granodiorite	1	0.4	-	-	100	-	-	-	-	Predominantly large hematite grains
Jervois Granodiorite	2	0.5	45	55	tr	-	-	-	tr	Martitised magnetite & ilmenite blebs
Attutra Metagabbro	9	3.0	20	45	5	23	-	6	1	Acicular grains in pyx. Blebs ilmenite & magnetite
Minor Gabbroic Bodies	2	2.8	2	88	-	tr	10	-	tr	Acicular grains in pyx. Blebs ilmenite & magnetite
Unaltered Ultramafic	3	5	3	30	3	47	15	-	2	Large ilmenite grains exsolving hematite. Minor magnetite
Altered Ultramafic	5	9	50	20	0.5	7	1	-	20	Magnetite with chl. Blebs ilm exsolving hmt. Acicular grains in pyx

Figure 2.28a.
Microphotograph of fine-grained magnetite
within antigorite?, formed from the
decomposition of olivine within ultramafic
rock. (Oil immersion, transmitted light,
crossed polars, 0.5mm $\times$ 0.335mm)



Figure 2.28b.
Microphotograph of magnetite within chlorite,
formed from the decomposition of olivine
within ultramafic rock. (Transmitted light,
crossed polars, 2.0mm $\times$ 1.43mm)

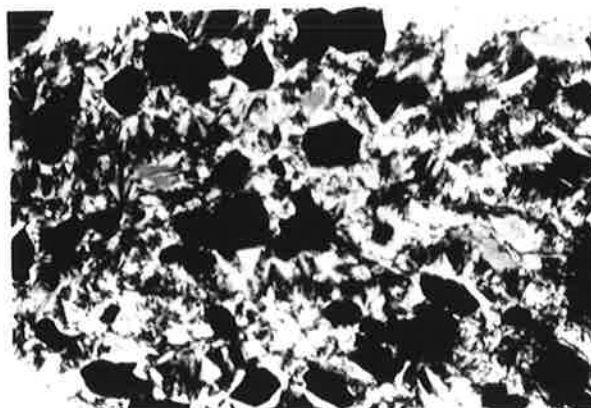
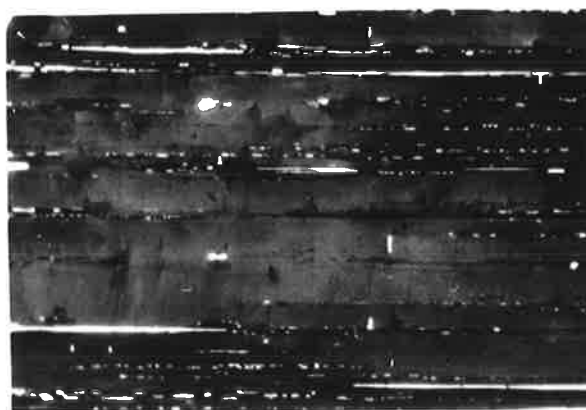


Figure 2.28c.
Reflection microphotograph of quasi-exsolution
of magnetite from pyroxene, the probable source
of remanence within the Attuttra Metagabbro.
(Oil immersion, 0.2mm $\times$ 0.14mm)



most major rock groups are related to SiO_2 content.

This relationship may be inherited from the environment of intrusion or deposition. In igneous rocks there is a well-established trend toward higher oxidation levels with increasing SiO_2 content (Haggerty 1976, 1979). This appears to be related to tectonic environment (Grant, 1985). Most iron and titanium enters differentiates of mafic or ultramafic composition to form weakly magnetic iron-titanium oxides. In acid igneous rocks, little iron and virtually no titanium remain, but because of higher oxygen availability this iron forms hematite and magnetite. Consequently, the highest values of magnetic susceptibility are found in intrusives of intermediate composition. The similar trend of Division 1 lithologies reflects the high proportion of meta-igneous rocktypes in this lithostratigraphic group.

Similarly, metasediments derived from SiO_2 poor, argillaceous rocks invariably contain more iron than SiO_2 rich metasediments, due to the tendency of colloidal iron to become attached to clay and silt particles during sedimentation. The low energy depositional environment of the former rocks is reducing, favouring the formation of ferrous compounds, whilst the latter is oxidizing favouring ferric compounds. The oxidation state during metamorphism is usually that inherited from the sediment (McIntyre, 1980). Low oxidation ratios lead to iron silicate formation; intermediate ratios favour magnetite formation; and high ratios favour hematite formation. Magnetic surveying thus frequently reflects premetamorphic sedimentary environments for metasediments.

The magnetite poor, mature metasediments of the Central Province are thought to have been deposited in a platformal, shallow shelf marine environment (Ding & James, 1985). The magnetite rich metasediments, chemical sediments (B.I.F., magnetite quartzite), felsic volcanogenic rocks and associated stratiform base metal deposits of the Northern Province Bony Schist, are indicative of a submarine environment with precipitation of magnetite and base metals from hot solutions originating from submarine volcanic fumaroles (Large, 1977; Stanton, 1976).

Exceptions to the above trends are normally due to late-stage alteration involving hydration or dehydration resulting in a change of oxygen fugacity. Widespread, low temperature, hydrous retrograde metamorphism caused widespread oxidation of magnetite to hematite, and a corresponding reduction in the magnetism of most major rocktypes, especially Division 2 rocktypes. Conversely, oxidation of many ultramafic bodies through high temperature hydrous alteration (serpentinization) greatly enhanced their magnetic properties through the formation of secondary magnetite from the decomposition of olivine and orthopyroxene. Quasi-exsolution of magnetite from Fe,Mg-silicates in many rocktypes, may be the result of dehydration during regional prograde metamorphism.

Magnetic property measurements indicate induced magnetization will exert the greatest influence over aeromagnetic response for Division 1 and 2 lithologies of the Central Province and mylonites associated with faults. Their NRM intensity and direction is highly scattered due to a number of factors:

- 1) The influence of secondary components, (e.g. IRM) not representative of bulk magnetization.
- 2) Multicomponent NRM residing in a variety of magnetic phases formed at different times.
- 3) The highly deformed nature of these rocktypes.

Table 2.9: Opaque Mineralogy of Fault-Related Features

LITHOLOGY	THIN	MEAN %	MEAN OPAQUE COMPOSITION							OPAQUE FORM
	SECTIONS	OPAQUES	Mgt	Ilm	Hmt	Spinel	Psbrkt	Rutile	Others	
Bruna Gneiss	50	2.4	65	30	tr	tr	5	-	tr	Large grains martitised magnetite & ilmenite exsolving hematite
Mylonite	3	28	50	50	tr	-	tr	-	-	Large ilmenite & magnetite grains with fine hematite exsolution

Intrusives high in SiO_2 (granite, granodiorite) and most rocktypes of the Bonya Schist, have soft unstable NRM with predominantly negative inclinations indicating a tendency for these lithologies to be remagnetized by the present earth field. Their NRM is unlikely to significantly contribute to aeromagnetic anomalies, but if it does, it will tend to align with and add to the induced component. Intrusives low in SiO_2 (gabbro, ultramafics) and Fe,Mg-silicate suite rocktypes of the Bonya Schist have relatively intense, well-defined NRM roughly reversed in direction to the present earth field. Their NRM would be expected to considerably influence aeromagnetic response.

It is apparent most geological units are composed of many lithologies having contrasting magnetic properties. Their aeromagnetic signature is likely to be complex, but distinctive, reflecting the relative proportion and distribution of lithologies with different magnetic properties. Rock property measurements indicate Division 1 mafic gneiss and granulite are highly magnetic whilst quartzofeldspathic gneiss and amphibolite are weakly magnetic. Calc-silicates have variable magnetic properties. Most units contain all these rocktypes and consequently will have highly variable aeromagnetic responses. However, units with a high proportion of mafic gneiss and granulite, such as the Ongeva and Kanandra Granulites and Cadney Metamorphics, will be more magnetic than those predominantly composed of quartzofeldspathic gneiss and amphibolite, such as the Oonagalabi gneiss complex and Entia gneiss complex.

Division 2 units of the Central Province have quite different magnetic properties than those of the Northern Province. The former are uniformly weakly magnetic with the possible exception of biotite gneiss and schist of the Irindina supracrustal assemblage, which record a number of magnetic samples. The Bonya Schist of the Northern Province is composed of a number of lithologies having different magnetic properties. Metavolcanic rocktypes are weakly magnetic, whilst metasediments exhibit a wide range of susceptibility and NRM intensity.

Part II

INTERPRETATION

Interpretation was based on data processing and interpretation techniques discussed in Appendix A. Continual integration with geological data (Chapter 1), rock property studies (Chapter 2) and auxiliary geophysical data was an essential part of interpretation procedure. Where possible, results are presented in diagrammatic form on 1:100,000 scale aeromagnetic interpretation maps (Plates 12 to 22) enclosed at the back of this thesis. The following chapters supplement these maps, summarising the lithological subdivisions and structural history recognised from the synthesis of geophysical and geological data.

Initial discussion (Chapter 3) focuses on the regional lithological and structural framework of the study area derived from data synthesis. Subsequent chapters (Chapters 4-7) deal with detailed interpretation, results of which provide much of the supporting evidence for the regional overview of chapter 3. Chapter 8 concludes by summarising the geological history of the eastern Arunta Inlier, using all the evidence presented in previous chapters.

Regional Lithological and Structural Framework of the Eastern Arunta Inlier

Figure 3.1 shows contours of total magnetic intensity for the study area. These may be compared to the BMR's regional stratigraphic and tectonic subdivision (Section 1.1.2; Fig. 1.2). Near surface rocks of the Arunta Inlier have a distinctive, complex magnetic signature which reflects their multiply deformed nature and polymetamorphic history. This pattern contrasts with the broad attenuated response arising from magnetic basement buried beneath the Georgina Basin.

Marked differences in magnetic response are also evident within the eastern Arunta Inlier. These fall into two categories:

- 1) Zones having distinctive magnetic signatures, comprising anomalies of characteristic shape.
- 2) Spatial magnetic subdivisions with well-defined boundaries having an often heterogeneous but characteristic magnetic pattern.

In well exposed areas, the former correlate with major lithostratigraphic divisions and the latter

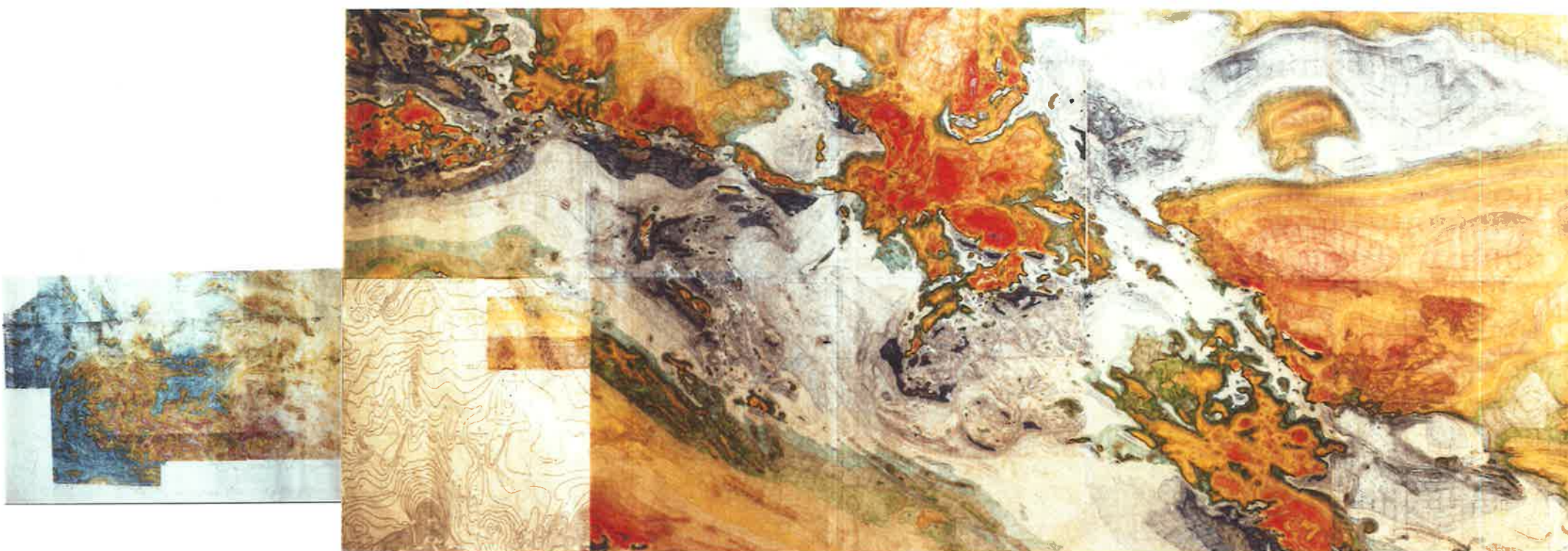


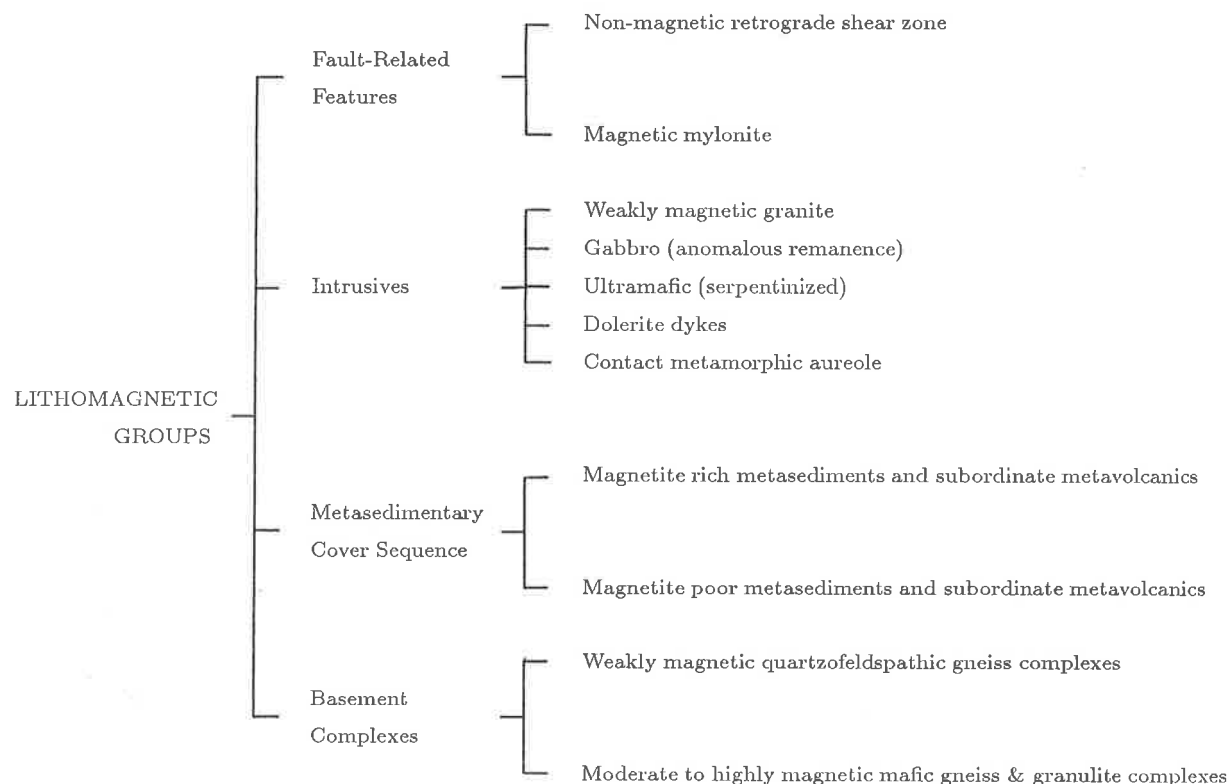
Figure 3.1 Total magnetic intensity map of the study area.

with distinctly different tectonic provinces recognised during regional mapping. Their recognition and further subdivision on the basis of total magnetic intensity, geological correlations and magnetic rock property studies forms the foundation for the lithological and structural subdivision of the study area discussed in subsequent sections.

3.1 LITHOMAGNETIC SUBDIVISION OF THE EASTERN ARUNTA INLIER

Four distinctive magnetic signatures are recognised from total intensity contour maps of the study area. They are termed "lithomagnetic groups" as the characteristic form of anomalies comprising them reflect the lithological similarity and common genesis of rocktypes giving rise to them. Each lithomagnetic group is further subdivided on the basis of total magnetic intensity, resulting in the lithomagnetic subdivision illustrated in Figure 3.2. Where exposed, each subgroup correlates with a different rocktype association. Rocktype associations have contrasting magnetic properties, which result from differences in bulk rock chemistry and oxidation state. They are indicative of different intrusive, depositional or metamorphic environments.

Figure 3.2: Lithomagnetic Subdivision of the Eastern Arunta Inlier



3.1.1 Basement Complexes

A complex magnetic signature characterised by an irregular or highly contorted magnetic contour pattern of variable intensity is typical of this lithomagnetic group. It occurs throughout the study area but predominates in the west where it correlates with Division 1 rocktypes of Stewart et al (1984), and the Entia gneiss complex of Ding and James (1985). Its signature reflects the predominance of meta-igneous rocktypes (Section 1.2.1), their high metamorphic grade (Section 1.3) and involved deformation history (Section 1.4). They are considered to represent crystalline basement, consistent with the interpretation proposed by Ding and James (Section 1.2.2), the inferred older age of Division 1 rocktypes (Section 1.2.1) and detailed aeromagnetics interpretation presented in subsequent chapters.

Two basement subgroups having similar complex magnetic signatures but different intensities are recognised (Fig 3.2). Extensive low intensity zones with discrete irregular anomalies of low to moderate amplitude ($<200\text{nT}$), correlate with dominantly granitic or quartzofeldspathic gneiss complexes containing variable quantities of minor amphibolite, mafic gneiss, mafic granulite, calc-silicate rock and other subordinate rocktypes. These contrast with complex high intensity zones containing areas of anomalous low intensity and gradients commonly in excess of 2000 nT , which correlate with dominantly mafic granulite and/or mafic gneiss complexes with minor quartzofeldspathic gneiss, amphibolite, calc-silicate rock and other subordinate rocktypes.

The magnetic intensity of basement complexes is consistent with the measured magnetic properties of their predominant rocktypes (Section 2.3.1), and reflect differences in bulk rock chemistry and oxidation state. SiO_2 rich quartzofeldspathic gneiss complexes are weakly magnetic due to their overall low iron content and high oxidation state which favours the formation of small amounts of hematite. SiO_2 deficient mafic granulite/mafic gneiss complexes have moderate to high intensities due to their higher overall iron content and lower oxidation states which favour the formation of a higher volume percentage of magnetite. Minor interlayers of quartzofeldspathic gneiss within granulite/mafic gneiss complexes, and vice-versa, give rise to anomalous variations in magnetic intensity within both basement complexes. As discussed in Section 2.5 the dependence of magnetic response on bulk rock chemistry and oxidation state probably results from the different intrusive and depositional environment of mafic and felsic meta-igneous and metasedimentary rocktypes.

Further subdivisions of basement subgroups are recognised through minor variations in magnetic signature and intensity, which reflect differences in the relative proportion of meta-igneous to metasedimentary material and the quantity of subordinate rocktypes having contrasting magnetic properties. These are discussed in detail in chapter 6.

3.1.2 Metasedimentary Cover Sequences

Multiple linear to curvilinear anomalies of variable amplitude typify this lithomagnetic group and reflect the predominantly metasedimentary composition of Division 2 rocktypes with which it correlates. Detailed interpretation (Whiting, 1986; Section 4.1.2) demonstrates anomalies arise from lithologies having distinct magnetic properties. These magnetic stratigraphic marker horizons are often extensive, with strike lengths of up to 50 km, and commonly delineate fold structures.

Two lithomagnetic subgroups are recognised through differences in total magnetic intensity, geological correlations and magnetic property data (Fig. 3.2). Magnetically subdued areas with discrete curvilinear anomalies of 200 nT or less correlate with magnetite poor Division 2 rocktypes of the Central Tectonic Province (excluding the Bruna Gneiss and Entia gneiss complex), consistent with the observed low magnetization of these units (Section 2.3.2). In contrast, Division 2 units of the Northern Tectonic Province are associated with generally higher but variable total intensities with amplitudes commonly in excess of 2000 nT. This is consistent with the large range and contrasting magnetizations of these lithologies (Section 2.3.3). In addition, the structural style of these subgroups as delineated by magnetic stratigraphic marker horizons differs markedly (Section 4.2 & 5.2).

As discussed in section 2.4, the difference in magnetic intensity between these subgroups may be attributed to the overall higher iron, lower titanium content and higher oxidation state of Division 2 metasediments of the Northern Province. This is considered a result of their different depositional environments (Section 2.5).

3.1.3 Intrusives

Rounded or elongate magnetic features with discordant contacts which truncate neighbouring magnetic trends are indicative of, and correlate with, intrusive bodies. Anomaly shape, intensity and areal extent is characteristic of intrusive composition and form. Granites ranging in size from large plutons to small stocks and irregular blebs, have characteristic low intensities and subdued magnetic activity consistent with their weak magnetism (Section 2.3.4). This is not readily apparent for some large granite masses outlined on Figure 1.2, as many of these are comprised of small, sporadically outcropping blebs of granite which intimately intrude magnetic metasediments which are weathered and concealed below overburden (Section 4.1.3). These scattered outcrops have been interpreted as large continuous granite plutons. Large bodies of pegmatite have a similar signature to granites. This response reflects the low iron content and high oxidation state of acid intrusives, which favours the formation of small amounts of hematite (Section 2.4.4). Intrusives of this composition are the silica rich, iron poor end members of the calc-alkaline series that are characteristic of orogenic belts (Osborn, 1962; Grant, 1985). Several granite plutons have magnetic aureoles (Section 4.1.3).

Most outcropping mafic and ultramafic intrusives are smaller than the flight line spacing, making direct correlation with aeromagnetics data difficult. The few bodies studied all had relatively intense characteristic anomalies due to the formation of secondary magnetite through late-stage alteration. Gabbro's are associated with anomalous magnetic lows, consistent with their measured reverse remanent direction and high Q values (Section 2.3.4 & 4.1.3). Ultramafic rocks are generally associated with equidimensional magnetic anomalies of variable amplitude. Their shape is often indicative of strong remanent magnetization, which resides in fine SD grains of magnetite formed during serpentinization (Section 2.4.4). Extensive linear magnetic features, often displaying abnormal anomaly shapes due to strong remanence are common, but occur in areas of poor outcrop prohibiting correlation with geology. They are interpreted to arise from dolerite dykes.

3.1.4 Fault-Related Features

Magnetic features correlating with fault or shear zones are typically linear and discordant with

neighbouring magnetic trends, often truncating or offsetting them. Two types are recognised:

- 1) Linear magnetic highs associated with magnetic mylonites
- 2) Linear magnetic lows associated with retrograde shear zones.

The magnetic intensity of the former is in agreement with the moderate to high magnetic susceptibility of these rocktypes (Section 2.3.5). As in the case of the Bruna Gneiss, they are often due to intrusive bodies emplaced along zones of crustal weakness. However Beach and Fyfe (1972) indicate linear magnetic highs may arise from the formation of magnetite through the action of large quantities of relatively cooler oxidizing water flowing in highly permeable shear zones. Conversely, the second type may result from the destruction of magnetite in a shear zone through the action of hot reducing metamorphic fluids (Beach & Fyfe, 1972), or oxidation of magnetite to hematite through preferential deep weathering (Henkel & Guzman, 1977).

3.2 MAGNETIC PROVINCES WITHIN THE EASTERN ARUNTA INLIER

Four spatially separate magnetic provinces are recognised in the eastern Arunta Inlier by their distinctly different magnetic patterns and well-defined boundaries (Fig. 3.3). Where exposed, they correlate with different tectonic provinces recognised by Shaw et al (1984) and Ding and James (1985), whilst their abrupt boundaries correspond to major fault or shear zones. Their distinctive magnetic character reveals much concerning their different lithologic composition, metamorphic grade, structural history and degree of intrusion, which are described in detail in subsequent chapters.

The Northern Magnetic Province has a characteristic heterogeneous magnetic pattern (Fig. 3.3), which results from the distinctly different magnetic signatures and scattered distribution of lithomagnetic groups which comprise it. Where exposed, it correlates with outcrops of the Northern Tectonic Province of Shaw et al (1984) and consequently the name Northern Magnetic Province has been adopted for consistency. Its distinguishing characteristics include:

- 1) A widespread, previously unrecognised, weakly magnetic quartzo-feldspathic or granitic basement complex. Highly magnetic mafic granulite is restricted to slivers along the Delny-Mount Sainthill Fault Zone.
- 2) A magnetite rich metasedimentary cover sequence. Magnetic stratigraphic marker horizons reveal a distinctive structural style, the result of three generations of polyphase folding.
- 3) Extensive intrusion by weakly magnetic granite bodies.

The boundary of the Northern Magnetic Province is well defined on magnetic intensity maps (Fig. 3.3). Although an unconformity in parts, the northeastern boundary with the Georgina Basin is mainly faulted. The southwestern boundary correlates with the Delny-Mount Sainthill Fault Zone in the well exposed north. Further southeast it is not exposed, but is clearly discernable as an abrupt, curvilinear contact separating two regions of contrasting magnetic character. This contact does not coincide with the Mount Baldwin landsat lineament and Lake Caroline Gravity Ridge, considered by Warren (1980) to mark the boundary between the Northern and Central Tectonic Provinces. Details concerning the nature of these boundaries are discussed in chapter 4.

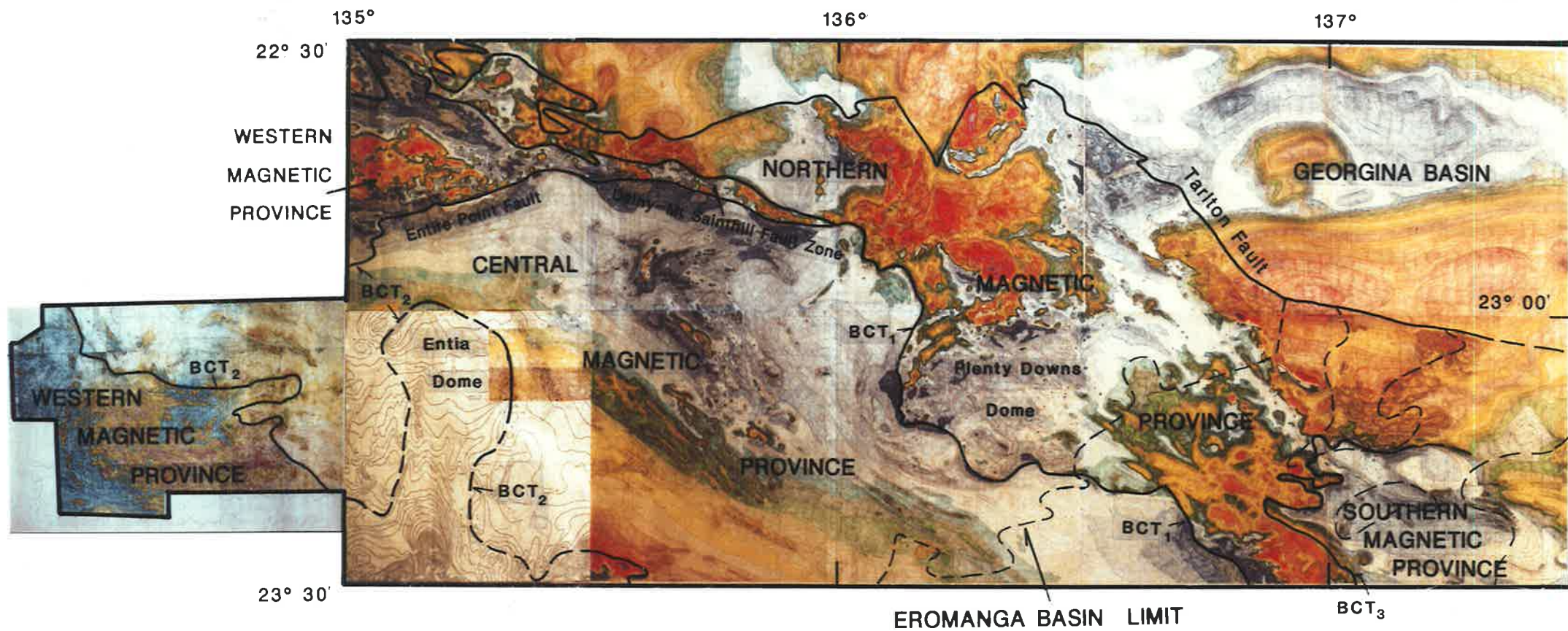


Figure 3.3 Magnetic provinces recognised in the study area

In contrast, the Central Magnetic Province has a predominantly homogeneous magnetic response characterised by weak curvilinear anomalies superimposed on a regional gradient. It correlates with magnetite poor Division 2 metasediments and metavolcanics of the Central Tectonic Province of Shaw et al (1984). Magnetic stratigraphic marker horizons delineate a different structural style to the more contorted magnetic trends associated with neighbouring provinces (Chapter 5). The apparent absence of a basement is also distinctive as is the complete absence of large granite plutons.

Contrasting strongly with the subdued response of the rest of the province is a complex magnetic area which dominates its central part. Exposure is poor in this area not allowing confident correlation of geology and aeromagnetics. This zone is tentatively considered a more magnetite rich metasedimentary unit, possibly delineating a different depositional environment. However it is structurally more complex than the rest of the province and may alternatively represent a complexly deformed basement to the enclosing, weakly magnetic metasediments.

The Central Magnetic Province shares its northeastern boundary with the Northern Magnetic Province as described in the previous section. Its western boundary separates it from the Western Magnetic Province. In the Harts Range area on *QUARTZ* and *RIDDOCH*, this contact is the thrust boundaries HRT_1 and HRT_2 of Ding and James (Section 2.4.1). On *DNEIPER*, in the northwest it is the Entire Point Fault (Section 2.4.1).

The Western Magnetic Province is composed of complex zones of contrasting magnetic intensity. These correspond with weakly magnetic quartzofeldspathic and highly magnetic granulite and mafic gneiss complexes. The Western and Central Magnetic Provinces together form part of the Central Tectonic Province of Shaw et al (1984). Detailed structural mapping by Ding and James (1985) and aeromagnetic interpretation discussed in chapter 6 support their separate recognition on the basis of their:

- 1) Profoundly different lithological assemblages.
- 2) Separate early deformation histories.
- 3) Well-defined faulted boundary.

The Southern Magnetic Province is the smallest and most homogeneous of the four provinces comprising the study area. It is covered by up to 300 metres of Eromanga Basin sediments, preventing correlation of aeromagnetics and geology. However, it is considered part of the Southern Tectonic Province of Shaw et al (1984) for several reasons:

- 1) Its low featureless magnetic level is similar to that of quartzofeldspathic gneiss and syn to pre-tectonic granites of the Southern Tectonic Province. This magnetic unit is tentatively correlated with similar basement quartzofeldspathic gneiss complexes of the Northern and Western Magnetic Provinces, which have a similar magnetic signature.
- 2) Curvilinear magnetic anomalies are interpreted to be a deformed suite of dolerite dykes, possibly correlatives of similar, westerly trending deformed dykes of the Southern Tectonic Province.

Detailed aeromagnetic interpretation (Chapters 4–7) reveals each province had a separate early geologic history. They were subsequently juxtaposed by displacement along well-defined boundaries and finally remobilised and disrupted by several stages of late deformation. The evolution of the eastern Arunta Inlier, outlined from synthesis of aeromagnetic and geological data is summarised in chapter 8.

Northern Magnetic Province

The Northern Magnetic Province describes a broad arcuate, magnetically heterogeneous belt of variable intensity, covering approximately one quarter of the study area along the north, northeast boundary of the eastern Arunta Inlier (Fig. 3.3). Exposure varies from good in the north, where outcrops belong to the Northern Tectonic Province of Shaw et al (1984), to non-existent in the southeast, where the Inlier is overlain by sediments of the Eromanga Basin.

Aeromagnetic interpretation reveals much concerning the lithology and structure of the Northern Magnetic Province. Most of this information is expressed diagrammatically on the aeromagnetic interpretation maps enclosed as plates at the rear of this thesis. The following discussion attempts to summarise the major lithomagnetic subdivisions, their geological correlations and relative age, together with the nature and sequence of major deformation events recognised from the synthesis of aeromagnetic, geological and other geophysical data.

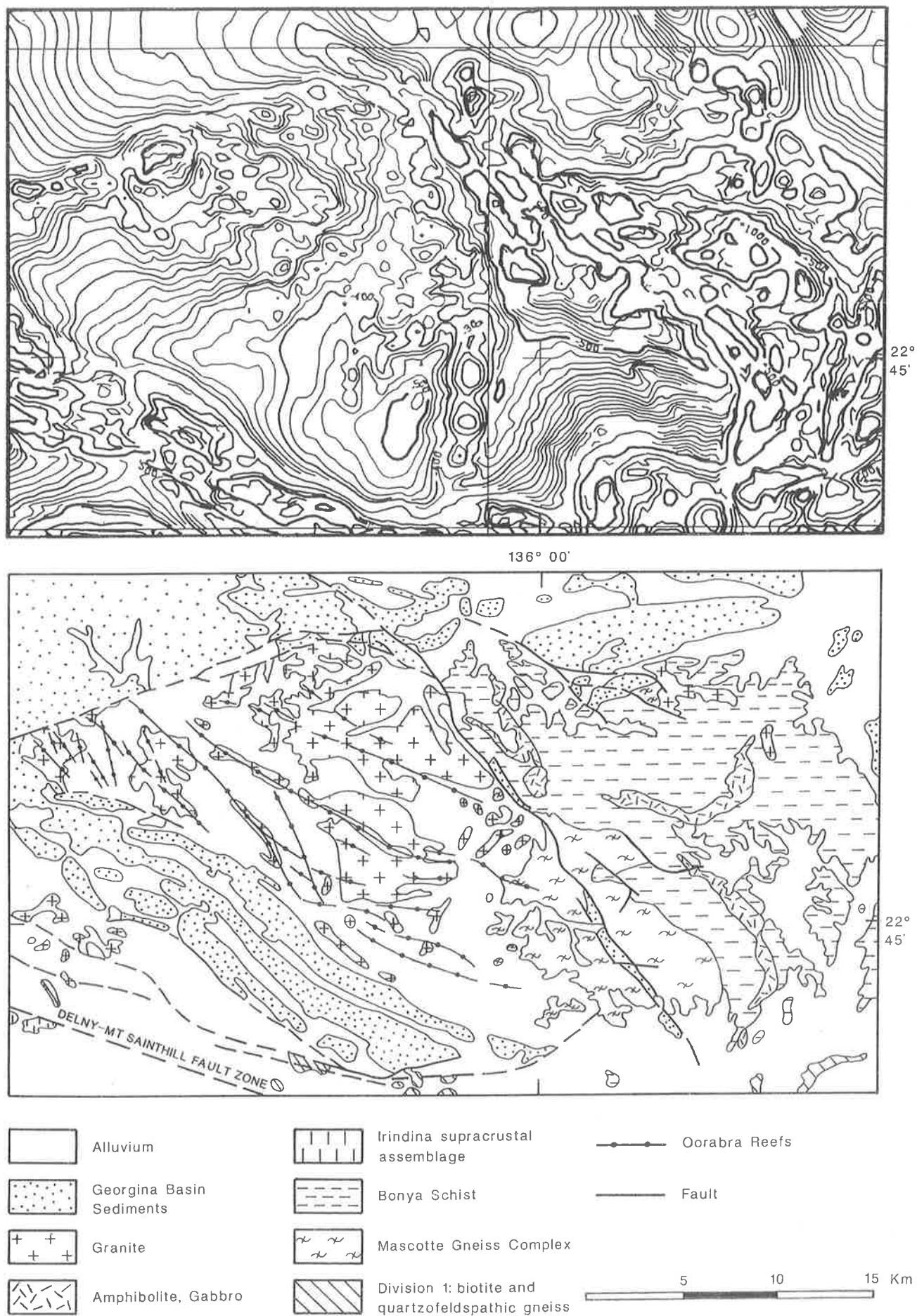


Figure 4.1 Correlation between aeromagnetics and the geology of the Bonya Hills and Jinka Plain.

4.1 LITHOMAGNETIC SUBDIVISION OF THE NORTHERN MAGNETIC PROVINCE

All four major lithomagnetic groups, discussed in section 3.1, are present in the Northern Magnetic Province. It is their distinctly different magnetic signatures and scattered distribution which gives rise to its characteristic heterogeneous pattern. Further subdivisions recognised by differences in magnetic intensity, are summarised on the legends of aeromagnetic interpretation maps enclosed at the rear of this thesis, and described in detail, together with their geological correlations, in the following sections.

4.1.1 Basement Complexes (BQF, BGM)

One of the distinguishing characteristics of the Northern Magnetic Province is the widespread occurrence of low intensity zones which enclose irregular magnetic anomalies, generally of less than 200nT amplitude. Where exposed, they are typically associated with weakly magnetic quartzofeldspathic or granitic complexes (BQF). Two subdivisions are recognised, depending on magnetic anomaly abundance; BQF_1 contains very few anomalies, BQF_2 has a higher abundance.

On *JERVOIS RANGE*, unit BQF_1 correlates with the gneissic granitoid Mascotte Gneiss Complex (Fig. 4.1) and the similar Gneissic suite of the Bonya Schist (Figs. 4.2 & 4.3). Within the Delny-Mount Sainthill Fault Zone on *JINKA* and *DNEIPER* it correlates with the dominantly quartzofeldspathic or granitic gneiss unit *pes*. Their similar composition and aeromagnetic signature supports their interpretation as similar, if not the same rockgroup. The low magnetic intensity of these units is consistent with the low susceptibility and NRM intensity of their predominant rocktypes (Section 2.3.3). Rare magnetic highs arise from intercalations of minor magnetic lithologies. Within the Gneissic suite, these are mafic schists and quartz-epidote rocks which have variable in-situ susceptibilities ($100 - 45,000 \times 10^{-6}$ S.I.). The irregular and often contorted shapes of anomalies, reflect the igneous origin of many rocktypes comprising these units (i.e. they were of limited lateral extent) and their complex deformation history.

Evidence suggesting these units represent an older crystalline basement is substantial.

- 1) The Mascotte Gneiss Complex is considered to underlie the neighbouring predominantly metasedimentary Bonya Schist. Whilst tentatively assigning it to Division 2, Stewart et al (1984) indicate the Mascotte Gneiss Complex may be Division 1 (Fig. 1.3). Similarly, Peters et al (pers. comm.) consider the Gneissic suite to be older and more complexly deformed than other suites of the Bonya Schist.
- 2) Predominant rocktypes (granite gneiss, granitoid & rhyolite gneiss) are considered to be pre-metamorphic felsic igneous rocks. Metasediments are minor. Rocktype associations are therefore similar in composition and inferred origin to dominantly quartzofeldspathic units of the Western Magnetic Province, considered to be crystalline basement by Ding and James (1985). Consistent with this, their aeromagnetic signature is almost identical (Chapter 6).
- 3) The complex interlayering, folding and faulting of metamorphosed igneous and sedimentary rocks observed during detailed geological map-

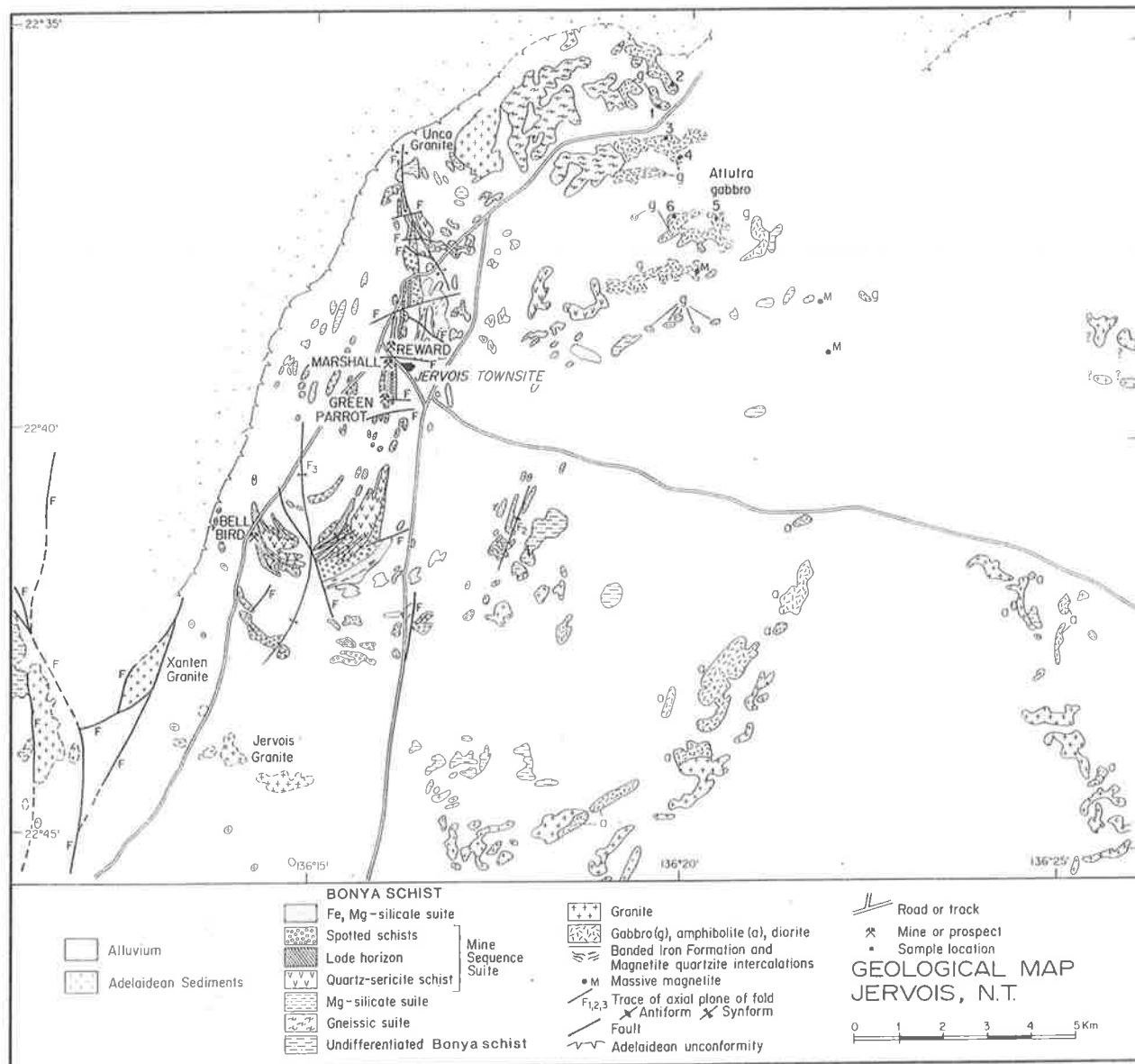


Figure 4.2 Outcrop geology map illustrating the extent of rock suites in the Jervois Range area.

ping of the Gneissic suite (Peters et. al., 1985), cannot be explained by the relatively simple deformation phases observed in adjacent Division 2 units. This suggests the existence of a separate early deformation history (Section 4.2.1).

4) The contact between basement complexes and metasedimentary cover sequence often appears to be unconformable or an ancient fault, as indicated by the abrupt termination of magnetic trends on either side of it.

Elsewhere in the Northern Magnetic Province, the magnetic signature which characterises units BQF_1 and BQF_2 is widespread, but outcrop is sparse or non-existent. Correlations established in the Western Magnetic Province (Chapter 6), show rocktypes comprising unit BQF_2 are similar to those of BQF_1 , consistent with their similar low magnetic intensity. However, BQF_2 contains a higher proportion of subordinate magnetic lithologies, such as mafic gneiss, schist and granulite, explaining its greater abundance of anomalies. Susceptibility contrasts derived from quantitative interpretation of these anomalies, are typically in the range $6,000 - 60,000 \times 10^{-6}$ S.I.

The major basement feature outlined from aeromagnetic interpretation of the Northern Magnetic Province, occupies the northeast quarter of *PLENTY DOWNS* (Plates 8 & 19). This circular magnetic feature, termed the Plenty Downs Dome, correlates with scattered outcrops of granitic gneiss and lesser pelitic metasediments. Afmeco drill hole ATB4 (French, 1981), which penetrates this structure on eastern *PLENTY DOWNS*, also intersected granitic gneiss containing minor intercalations of schist. The Plenty Downs Dome has a similar size, shape, magnetic signature and low magnetic intensity as the Entia Dome located on central, northern *QUARTZ*, and is considered to be comprised of a weakly magnetic quartzofeldspathic or granitic gneiss basement complex, similar to the Entia gneiss complex of the Entia Dome (Section 6.1.1). Both structures, which are interpreted to be basement gneiss domes, are associated with gravity lows consistent with the low density of granitic rocks.

Quartzofeldspathic basement is also considered to be widespread on *PLENTY RIVER*. Interpretation of this area is difficult due to overlying Eromanga Basin sediments, which attenuate the magnetic response of the underlying Arunta Inlier.

Within the Delny-Mount Sainthill Fault Zone, on *JINKA* and southwest *JERVOIS RANGE*, are slivers of the highly magnetic basement lithomagnetic unit, BGM_1 . Their complex magnetic signature is similar to that associated with the Kanandra Granulite (Section 6.1.1), and they are considered to be faulted sections of mafic granulite translated upwards in the fault zone.

4.1.2 Metasedimentary Cover Sequence (NMS)

Another distinguishing feature of the Northern Magnetic Province is its magnetically variable metasedimentary and metavolcanic sequence. It is considered to be a metamorphosed cover to widespread weakly magnetic quartzofeldspathic basement. The contact between basement and cover often appears discordant, as indicated by the truncation of magnetic trends on either side of it, and might be an unconformity or deformed fault boundary, as is the case in the Harts Range area (Section 1.2.2).

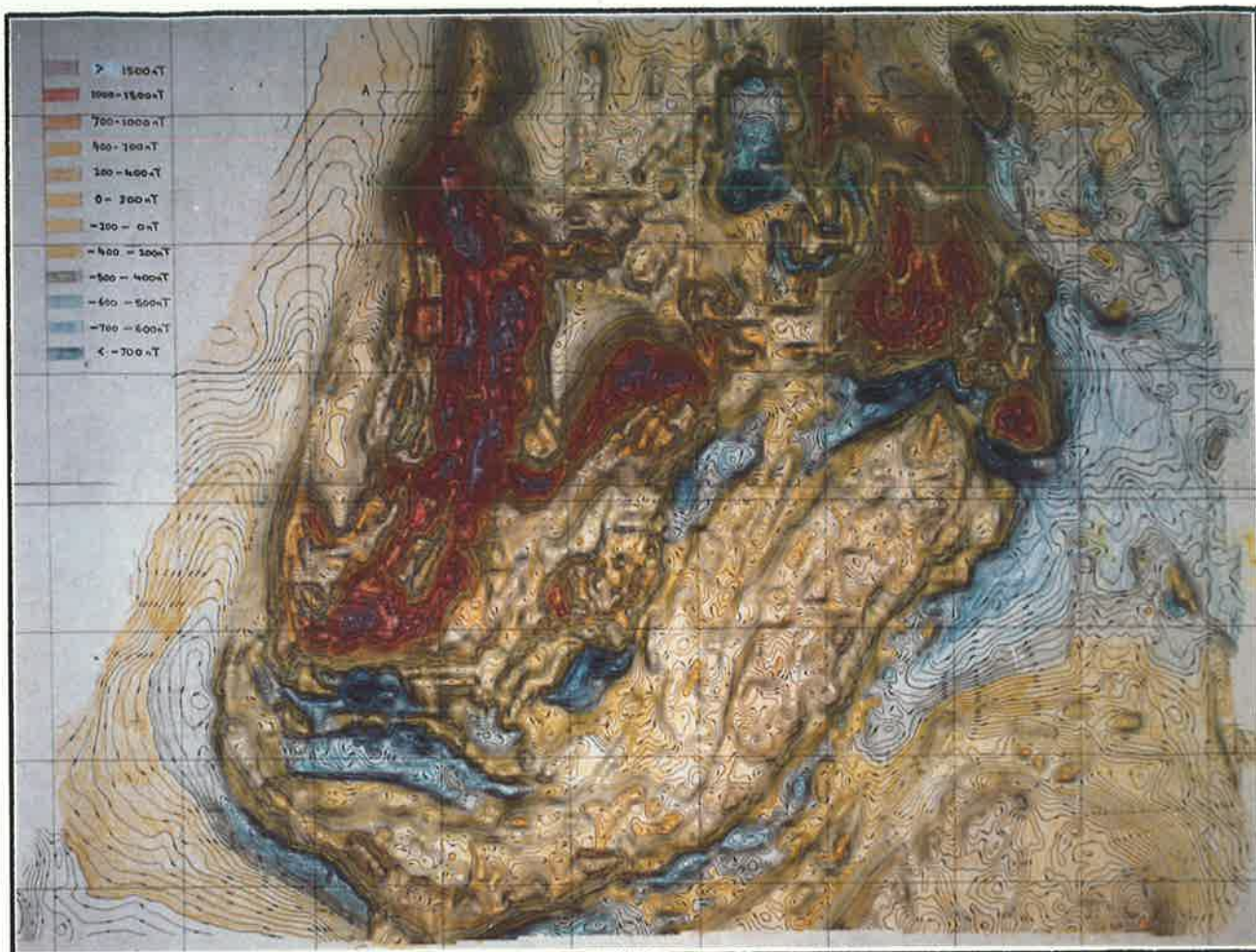


Figure 4.3 Total magnetic intensity map of the Jervois Range area.
(Basic contour interval 20nT).

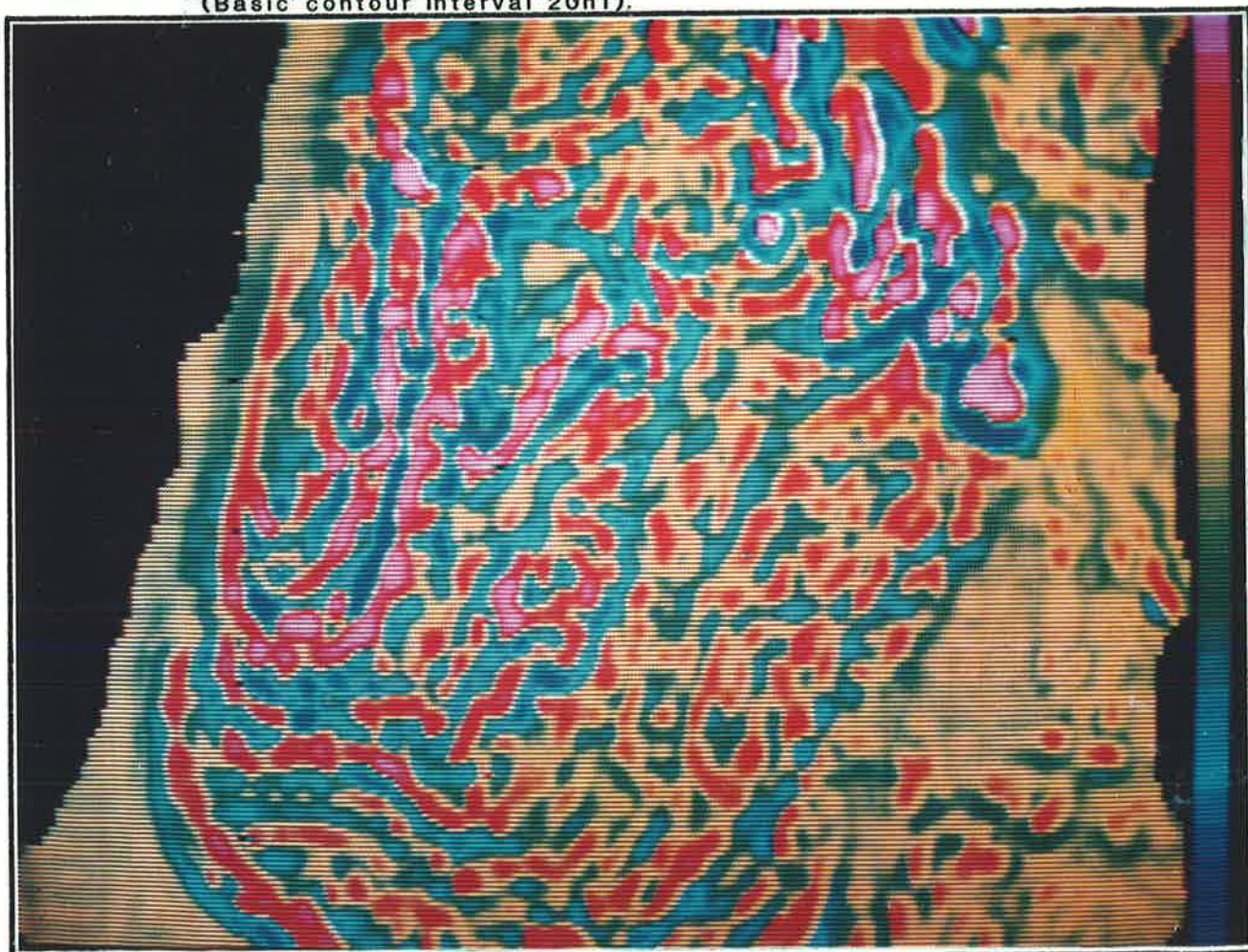


Figure 4.4 Computed vertical magnetic gradient image of the Jervois Range area.

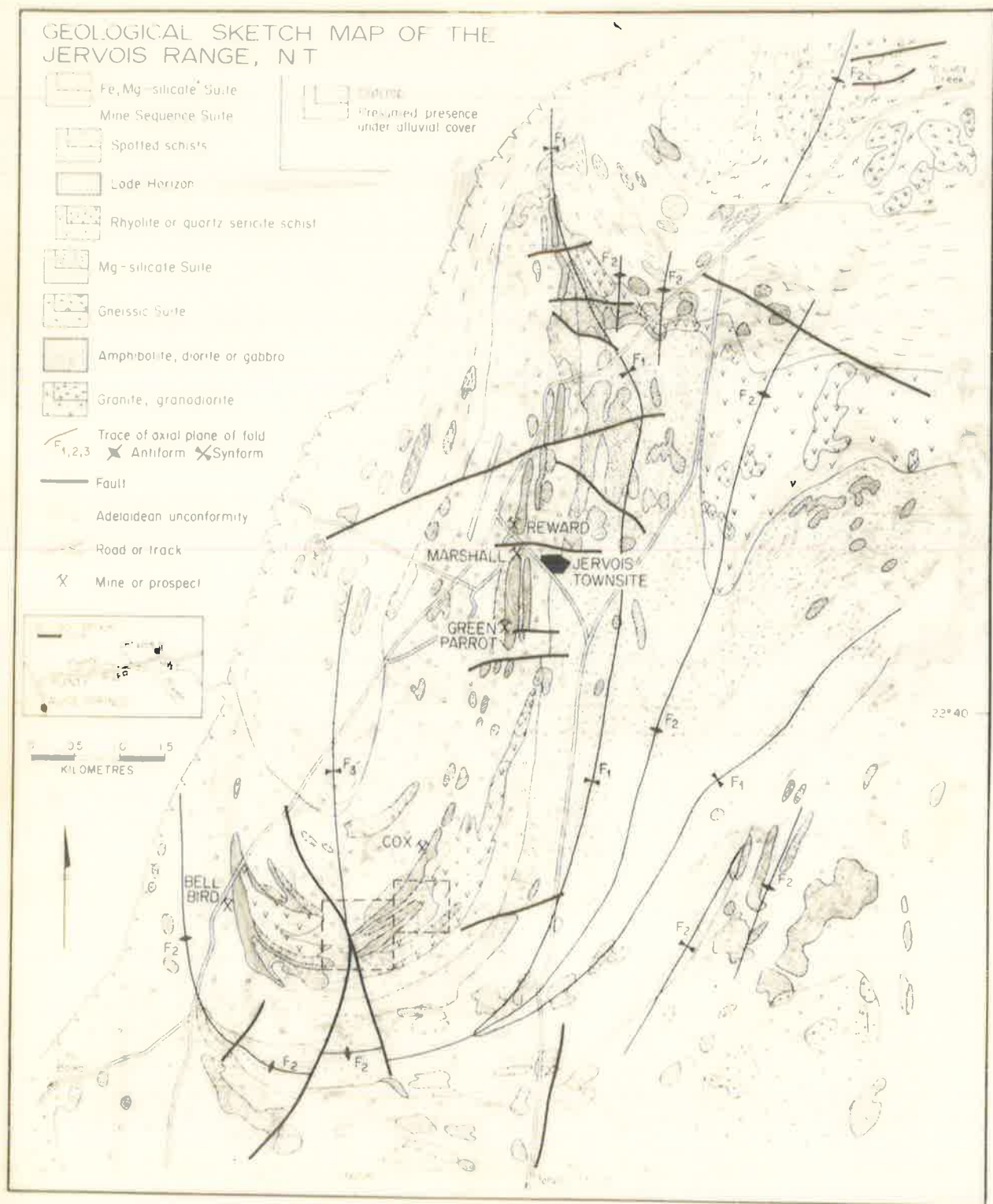


Figure 4.5 Detailed correlation of aeromagnetics and geology in the vicinity of the "J-structure" of the Jervois Range area.

Three lithomagnetic subdivisions are recognised from differences in magnetic intensity and interpreted susceptibility contrasts. In well-exposed areas they correlate with lithologies, or groups of lithologies, having different bulk rock chemistries. This is best demonstrated in the Jervois Range area, where aeromagnetic coverage (Appendix A) and geological mapping (Peters et. al., 1985) is particularly detailed. Figure 4.2 illustrates the outcropping geology described in section 1.2.2. Other published accounts are given by Morgan (1959), Smith (1963), Watson (1975), Dobos (1975) and Ypma (1984). Mineralisation is discussed in section 1.5, and magnetic property measurements in section 2.3.3. A detailed aeromagnetic interpretation published by the author (Whiting, 1986), is enclosed at the rear of this thesis. This interpretation is reviewed and extended in the light of further work, in the following discussion.

Contours of total magnetic intensity (Fig. 4.3) exhibit the characteristic heterogeneous response of the Northern Magnetic Province, bounded to the west by the non-magnetic response of the Georgina Basin. Areas of highest total magnetic intensity correlate with outcropping Division 2 Bonya Schist. Detailed examination reveals a pattern of multiple linear anomalies of variable intensity, particularly well-defined on the vertical gradient image of Figure 4.4.

Individual anomalies correlate with different lithologies comprising the Bonya Schist, (Fig. 4.5). Relatively magnetically undisturbed areas of low to moderate intensity correlate with scattered outcrops of Mg-silicate suite rock-types, consistent with the low to moderate median susceptibility of these units ($k_{0.5} = 650 \text{ \& } 550 \times 10^{-6}$ S.I. respectively). Their metasedimentary nature is apparent from subtle linear magnetic anomalies ($<10\text{nT}$ amplitude) delineated from vertical gradient profiles. Quantitative analysis of these features fitted near surface, steeply dipping magnetic sheets with apparent susceptibilities of less than $12,000 \times 10^{-6}$ S.I. The magnetic signature, low intensity and susceptibility contrast of these rocktypes are typical of the weakly magnetic metasedimentary cover unit (NMS₁) of the Northern Magnetic Province.

This response contrasts with neighbouring variable intensities associated with Mine sequence suite rocktypes. Highly magnetic magnetite-quartzite of the lode horizon ($k_{0.5} = 65,000 \times 10^{-6}$ S.I.) gives rise to linear magnetic highs of up to 2000nT . Quantitative interpretation indicates these horizons approximate steeply dipping sheets with susceptibility typically in the range $40,000 - 250,000 \times 10^{-6}$ S.I., in good agreement with observed dips and measured susceptibility (Section 2.3.3). Outcrops of quartz-sericite schist are associated with intense elongate magnetic lows, consistent with this units low median susceptibility of 80×10^{-6} S.I. Both units are enclosed by other Mine sequence suite rocktypes, associated with moderate magnetic intensities, consistent with their measured susceptibility (andalusite schist, $k_{0.5} = 8,000 \times 10^{-6}$ S.I.; quartz-sericite-feldspar schist, $k_{0.5} = 25,000 \times 10^{-6}$ S.I.).

Fe,Mg-silicate suite rocktypes have a similar magnetic signature to the Mine sequence suite. Quartz-chlorite schist ($k_{0.5} = 4500 \times 10^{-6}$ S.I.) correlates with moderate magnetic intensities. Interpreted susceptibility contrasts are typically in the range associated with moderately magnetic metasediments (unit NMS₂). Intercalations of highly magnetic ($k_{0.5} = 62,500 \times 10^{-6}$ S.I.) chlorite- magnetite-garnet quartzite give rise to an intense linear magnetic high of approximately 15km strike length. Interpreted dips and apparent susceptibility contrasts are similar to those of Mine sequence suite magnetite-quartzites, and are in good agreement with dips and susceptibilities measured in the field.

The good agreement of measured dip and magnetic susceptibility, with those derived from quan-

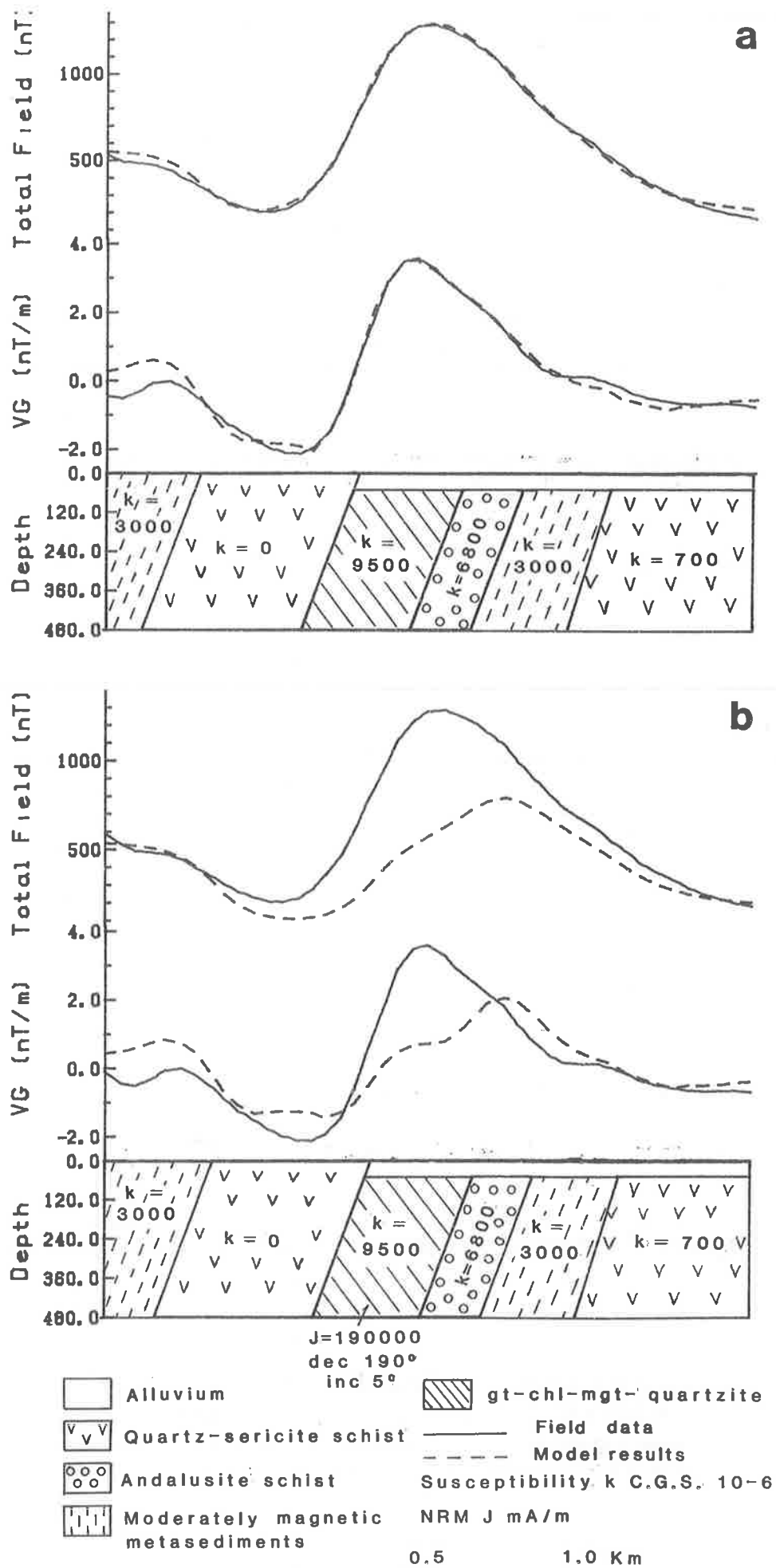


Figure 4.6 Comparison between the observed magnetic anomaly associated with chlorite- magnetite- garnet quartzite intercalations of the Fe,Mg-silicate suite, and computed response due to a) induced magnetization only b) induced and remanent magnetization. Both total magnetic field and computed vertical magnetic gradient are modelled.

titative interpretation implies magnetic anomalies arise from the component of magnetization induced by the earth's field. This is consistent with the unstable NRM of Mine sequence and Mg-silicate suite rocktypes, and their tendency to be remagnetized by the present field (Section 2.3.3). However, Fe,Mg-silicate rocktypes have a well-defined NRM roughly opposed to the present earth field, and high Q values. Figure 4.6 illustrates the computed total magnetic intensity expected from the induced component of magnetization and that including the measured NRM vector. The former is clearly a better fit to the observed field, implying the measured NRM is not representative of the bulk magnetization of these units. This inconsistency remains unresolved, but is possibly a consequence of the small number of samples collected. Despite this, the consistent, distinctive magnetic character of many lithologies over large distances, often covered with alluvial material, illustrates their value as magnetic lithostratigraphic marker horizons.

The generally high magnetic intensity associated with the Bonya Schist reflects the high iron content, low titanium content and high oxidation state of most of its constituent rocktypes, which favoured the formation of abundant magnetite (Section 2.4.3). The aeromagnetic response of individual lithologies reflects their bulk rock chemistry and oxidation state. Metasedimentary lithologies are associated with magnetic intensities consistent with their high iron content and the degree of martitisation of magnetite by late-stage retrograde hydration. The weak magnetism of quartz-sericite schist is consistent with this felsic metavolcanic units low iron content and high oxidation state, which favoured the formation of small amounts of hematite, whilst the strong magnetism of magnetite-quartzites is largely due to their high iron content. The latter units intimate association with stratiform concentrations of silver and base metals, indicates their distinctive magnetic signatures are excellent indicators of potential host rocks of these deposits.

Elsewhere in the Northern Magnetic Province, geological mapping and aeromagnetic coverage (500m line spacing) is semi-regional, and correlation of the detail achieved in the Jervois Range area, where the line spacing is 250 metres, is not possible. In the Bonya Hills, on western *JERVOIS RANGE*, the magnetic signature of outcropping Bonya Schist is almost identical to that in the Jervois Range area (Fig. 4.1). Again, it has been subdivided into areas underlain by weakly magnetic (NMS_1) and moderately magnetic (NMS_2) metasediments (Plate 14).

Curvilinear magnetic highs are associated with intercalations of magnetite-quartzite, consistent with in-situ susceptibility measurements presented in section 2.3.3. The Kings Legend Amphibolite Member corresponds with a well-defined linear magnetic low, similar to the response associated with amphibolites of the Jervois Range area (Figs. 4.2 & 4.3), and consistent with their low measured susceptibility ($k_{0.5} = 1,000; 650 \times 10^{-6}$ S.I.).

Other Division 2 units of the Northern Tectonic Province, which outcrop sporadically on *JINKA* and *DNEIPER* (Section 1.2.2), typically give rise to moderate magnetic intensities. Their associated curvilinear magnetic anomalies clearly show that they are metasediments, however, they lack the intense gradients associated with the Bonya Schist. This reflects the lack of highly magnetic magnetite-quartzite and thick, weakly magnetic mafic (amphibolite) and felsic (quartz-sericite schist) metavolcanic horizons, and may be indicative of a different depositional environment. These units are often poorly exposed and extensively intruded by bodies of granite of various shape and size. This often leads to an apparent poor correlation of geology and aeromagnetism, as weakly-magnetic granites are more indurate to weathering than the deeply weathered, moderately magnetic metasediments, and therefore outcrop more frequently,

yielding the impression that there are extensive areas of sub-cropping moderately magnetic granites.

Metasediments are widespread in areas of poor outcrop on southern *JERVOIS RANGE*, *PLENTY DOWNS*, *TARLTON*, *PLENTY RIVER* and *MOUNT BARRINGTON*. Highly magnetic curvilinear anomalies, typically associated with magnetite-quartzite of the Bonya Schist, occur extensively on southern *JERVOIS RANGE*, northern *PLENTY DOWNS* and southeastern *PLENTY RIVER*. As in the Jervois Range area, these units are considered potential host rocks to stratiform silver and base metal deposits. Similar magnetic units occur in moderately magnetic metasediments on *TARLTON* and *MOUNT BARRINGTON*, but these appear less extensive and less magnetic than those of the Bonya and Jervois Range areas.

In many areas, in particular those covered by thick basin sediments or where the geological strike is subparallel to the aeromagnetic flight direction, it is difficult to distinguish between weakly magnetic metasediments, quartzofeldspathic basement and granite. This is due to attenuation of weak magnetic anomalies of characteristic shape and abundance which typify these units.

4.1.3 Intrusives

Metamorphosed basement and cover rocks of the Northern Magnetic Province are extensively intruded by granitic plutons and smaller bodies of mafic and ultramafic composition. Granites have characteristic low intensities and subdued magnetic activity, consistent with their weak magnetism (Section 2.3.4). Two types having distinctive characteristics are recognised:

Type 1

The distinguishing characteristics of type 1 granites are:

- 1) Low magnetic intensity, but with irregular variations typically of less than 50nT amplitude, and interpreted susceptibility contrasts of less than $6,000 \times 10^{-6}$ S.I.
- 2) Oval shape with well-defined discordant contacts.
- 3) Coincident gravity low.
- 4) Contact metamorphic aureole at boundaries with basement quartzofeldspathic gneiss complexes.
- 5) Lack of roof-pendants of country rock.

Type 2

Type 2 granites are characterised by their:

- 1) Uniform, non-magnetic response.
- 2) Irregular shape and size.
- 3) Lack of an obvious contact aureole or associated gravity anomaly.
- 4) Contacts which commonly appear to be folded.

- 5) Numerous roof pendants. These granites extensively intrude surrounding country rocks.

The Jinka Granite is typical of type 1. Associated with a large, roughly oval area of low magnetic intensity, it displays subdued, but characteristic, irregular internal variations in magnetic activity (Fig. 4.1). These variations probably reflect internal differences in magnetite distribution, although one circular feature in the northwest section of the pluton, may be a later intrusive of more intermediate composition. There is no obvious correlation with the Oorabra Reefs, an extensive complex of quartz veins emplaced in the granite. A coincident gravity low of some 40 mgal, indicates the intrusive extends to great depth. Its northern and southern boundaries are the Oomoomilla Fault and Delny-Mount Sainthill Fault Zone respectively. To the east, its contact with the Mascotte Gneiss Complex is marked by a northerly trending magnetic high. This feature, which is concealed beneath surficial overburden, may be a roof pendant of moderately magnetic country rock, but its position suggests it is a contact metamorphic aureole. The magnetic and gravity signature of the Jinka Granite and Mascotte Gneiss Complex are very similar, although the oval shape of the granite is quite characteristic.

Another oval-shaped magnetic feature, considered to outline a similar granite pluton, is located on central *PLENTY RIVER* (Plate 18). Its geophysical signature resembles that of the Jinka Granite, exhibiting irregular internal variations in magnetic intensity, and a coincident gravity low of approximately 30 mgal. In addition, its northwestern contact with quartzofeldspathic basement of the Plenty Downs Dome, is marked by a curvilinear anomaly interpreted to be a contact metamorphic aureole. The Eromanga Basin sediments which cover this area are up to 180 metres thick. Afmeco drill hole ATB2, located near the southern margin of this feature, intersected granite below 164m of sediment (French, 1981).

Type 2 granites typically correlate with extensive, featureless areas of low magnetic intensity. This is the case in the southwest corner of the Jervois Range area (Figs. 4.2 & 4.3), where scattered outcrops of the Jervois and Xanten Granites are associated with subdued magnetic activity. A similar response is observed over the alaskitic Unca Granite, located 5km north of the Jervois townsite (Fig 4.5). This is consistent with the weak susceptibility and remanent intensity of these intrusives (Section 2.3.4). Weak NS striking linear magnetic anomalies within the Jervois Granite, delineated from vertical gradient profiles, are most likely due to dykes, possibly emplaced along fractures. A system of quartz dykes do intrude the granite, but as with the Oorabra Reefs of the Jinka Granite, no obvious correlation exists. Quantitative interpretation of these magnetic anomalies fits near surface steeply dipping sheet models with susceptibilities of $450 - 7,000 \times 10^{-6}$ S.I. These bodies do not appear to intrude metasediments to the northeast, possibly due to their differing mechanical properties. However, this may imply the granite, metasediment boundary is a tectonic boundary, the metasediments having been faulted or thrust into contact with the granite at a time postdating emplacement of the dykes.

The contact between intrusives and neighbouring metasediments is clearly delineated, particularly on vertical gradient profiles and images (Fig. 4.4). The border between the Unca Granite and Gneissic suite rocks is well-defined due to magnetic intercalations of schist and quartz-epidote rock within the latter. As indicated by magnetic property measurements (Sections 2.3.3 & 2.3.4) their magnetic response would otherwise be indistinguishable. The interpreted contact between the Jervois Granite and Bonya Schist is clearly folded by the third deformation event affecting the area (Fig. 4.7; Section 4.2.2), implying the granite was intruded prior to this event.

An alternative interpretation of the poorly exposed, non-magnetic southwest corner of the Jervois Range area, is that it is underlain not by granite but by basement quartzofeldspathic gneiss (unit BQF_1), intruded by small bodies of outcropping granite. The weak linear anomalies interpreted as arising from dolerite dykes may be due to magnetic layers in the basement complex. This uncertainty highlights the difficulty, often encountered, in distinguishing quartzofeldspathic gneiss complexes from granite.

Elsewhere on *JERVOIS RANGE* (Plate 14) scattered outcrop of Jervois Granite correlates with small irregular areas of subdued magnetic activity, typically associated with granites, but with a higher intensity more characteristic of moderately magnetic metasediments. These bodies are considered to be small irregular blebs of granite intruding a thick, moderately magnetic metasedimentary pile. This is consistent with the irregular outcrop pattern of the Jervois Granite, the abundance of roof pendants of metasedimentary country rock, and the lack of an associated gravity low, all of which are indicative of intermixing of metasediment and intruding granite. The Mount Swan, Dneiper and Marshall Granites also appear to be a network of small irregularly shaped bodies, probably of shallow depth extent, intruding moderately magnetic metasediments of the Perenti, Deep Bore and Cackleberry Metamorphics. As in the Jervois Range area their contacts often appear to be folded. Type 2 granites on northern *DNEIPER* are interpreted to be more extensive and of greater depth extent.

Adjacent to, and to the east of, the Lucy Creek Fault on *TARLTON* and *PLENTY RIVER*, extensive areas interpreted as underlain by granite, form northwest trending, fault-bounded sheets. Their irregular contact with metasediments, abundance of roof pendants, non-magnetic response, and lack of an associated gravity expression are all characteristic of Type 2 granites.

Type 2 granites such as the Mount Swan, Dneiper, Marshall and Jervois Granites may be the exposed, disjointed, irregular roots of a once large batholith. Alternatively, they may be small blebs of granitic magma formed from the partial melting of nearby sediments, squeezed out as a result of their lower density and greater mobility into surrounding country rock with the aid of deformation accompanying regional metamorphism. The latter theory is consistent with the often high metamorphic grade of intruded metasediments (up to granulite facies), and the gneissic texture (Table 1.4) and geophysical characteristics of these granites.

Type 1 granites, such as the Jinka and Plenty River Granites, are large discrete bodies, probably formed from the merging of smaller granitic magmas during migration upward through the crust. Their magnetic aureole indicates they were emplaced into cooler country rock at a relatively high crustal level. Their large size caused slower cooling, resulting in coarse textures (Table 1.4). Weak internal magnetic anomalies, characteristic of these bodies, may result from enhanced magnetic susceptibility due to the crystallization of large MD grains of magnetite during slow cooling. The Unca and Xanten Granites may be smaller Type 1 intrusives. Where dates (Rb-Sr) are available, type 1 granites (Jinka, 1690-1785 Ma; Unca, 1459 ± 10 Ma) are younger than type 2 granites (Jervois, 1808 ± 80 Ma).

Most mafic and ultramafic intrusives, outcropping in the Northern Magnetic Province, are small in comparison with the aeromagnetic flight line spacing, making correlation with aeromagnetic data difficult. However there are several exceptions. In the Jervois Range area, the Attutra Metagabbro is associated with a roughly circular anomalous magnetic low, which truncates and disrupts trends arising from the Bonya Schist which it intrudes (Figs. 4.2 & 4.3). This signature is consistent with its reverse remanent direction, high Q values, and relatively high median remanent intensity of 5150 mA/m



(Section 2.3.4). Intense circular magnetic highs within the gabbro correlate with small vanadiferous magnetite deposits. Interpretation of these anomalies fits shallow, thin plate models with susceptibility contrasts of $100,000 - 650,000 \times 10^{-6}$ S.I., in good agreement with measured in-situ susceptibilities of $30,000 - 600,000 \times 10^{-6}$ S.I. Intense magnetic lows within the gabbro may outline zones of intense reverse remanence, possibly associated with intrusives of different composition. Extensive outcrops of amphibolite in the Jervois Range area, correlate with similar zones of low magnetic intensity. Many have gabbroic textures suggesting a genetic link with the Attutra Metagabbro.

A large plug of gabbro located in the Bonya area near the border of *JERVOIS RANGE* and *JINKA*, is associated with a similar anomalous magnetic low. Although no magnetic property measurements of this body were taken, this response probably results from a similar well-defined reversed NRM, as that of the Attutra Metagabbro. Small gabbroic bodies from the Harts Range area also have reversed NRM's (Section 2.3.4) indicating this magnetization and the event responsible for its formation may be widespread. A circular, anomalously low magnetic feature on northwestern *MOUNT BARRINGTON* (AMG 7435000mN; 709000mE) may be associated with a similar intrusive.

Many small equidimensional magnetic anomalies outlined during aeromagnetic interpretation may possibly be associated with ultramafic intrusions. Several similar features in the Central Magnetic Province were drilled during exploration for kimberlites, and intersected ultramafic bodies (Section 5.1.3). In areas of no outcrop, it is difficult to distinguish between ultramafics and other magnetic bodies of short strike length, in particular roof pendants of magnetic metasediments in granites. However, magnetic anomalies associated with ultramafics commonly have abnormal shapes which cannot result from induced magnetization alone, and therefore are due to strong remanent magnetization. Intense, elongate features associated with major faults, common in the Northern Magnetic Province, are thought to be due to ultramafic bodies intruded along fault planes. If linear in shape, these features are often classified as fault-related (next section). Significant examples are located at:

- 1) AMG 7455000mN; 687000mE (*TARLTON, PLENTY RIVER*)
- 2) AMG 7420000mN; 655000mE (*PLENTY RIVER*)
- 3) AMG 7441250mN; 678500mE (*PLENTY RIVER*)

Ultramafic intrusions are of potential economic significance as host rocks to diamonds, copper, nickel, chromium or rare earths (Section 1.5).

4.1.4 Fault-Related Features

Linear magnetic lows and highs associated with faults occur throughout the Northern Magnetic Province. They are almost always associated with truncation or offset of magnetic trends, and commonly separate areas of contrasting magnetic character.

Linear magnetic lows correlate with retrograde schist zones along the Delny-Mount Sainthill Fault Zone. Retrograde rocktypes have undergone hydration and minor metamorphism (Freeman, in press), probably oxidizing magnetite to hematite. The best example marks the unexposed eastern extension of the Delny-Mount Sainthill Fault Zone across southern *JERVOIS RANGE*. Other well-developed examples are associated with splays of the Lucy Creek Fault on *MOUNT BARRINGTON*.

Table 4.1: Orogenic Stages and associated structures recognised in the Northern Magnetic Province

DEFORMATION (D)		FOLD (F)	FAULT (T)	INTRUSION
LATE PROTEROZOIC AND PHANEROZOIC FAULTING			Major NW to WNW and N to NE faulting	Ultramafic bodies
BASEMENT - COVER REMOBILISATION	BCD_2^* BCD_1	Plenty Downs Dome		
-----			BCT_1	-----
METASEDIMENTARY COVER DEFORMATION	NPD_3^{**} NPD_2 NPD_1	NPF_3 NPF_2 NPF_1	NPT_3	Type 1 granites Type 2 granites
EARLY BASEMENT DEFORMATION	Pre- NPD_1			

* BCD denotes basement-cover remobilisation event

** NPD denotes Northern Magnetic Province deformation

Similar retrograde rocks on southeast *JERVOIS RANGE*, correlate with a linear magnetic high associated with the interpreted extension of the Delny-Mount Sainthill Fault. Magnetic mylonitic rocks, similar to those in the Harts Range area (Section 2.3.5) may be the source of the magnetic anomaly in this case (Section 3.1.4). Other fault-related features with magnetic expressions occur in unexposed areas. The most important of these is the linear magnetic feature associated with the Lucy Creek Fault which runs for some 50km on *TARLTON*. Similar linear bodies occur to the southeast along much of the Lucy Creek Fault and its numerous branches and subparallel faults. Some of those listed in the previous section are probably related to intrusive bodies emplaced along these fault planes.

4.2 STRUCTURAL HISTORY OF THE NORTHERN MAGNETIC PROVINCE

The correlation of geological and aeromagnetic maps, together with results of magnetic property measurements, has demonstrated that many lithologies and geological units have characteristic magnetic signatures. They may be regarded as magnetic lithostratigraphic marker horizons, and their delineation outlines major structures controlling their distribution. From detailed aeromagnetics interpretation, presented in Plates 12 to 22 and available geological information, a sequence of deformation events may be constructed as shown in Table 4.1.

4.2.1 Early Basement Deformation

Separate, early deformation of the basement is inferred to account for the complex interlayering, folding and faulting of metamorphosed igneous and sedimentary rocktypes within basement units (Peters et. al., 1985), which cannot be explained by the relatively simple deformation phases affecting the metasedimentary cover sequence. The form and small scale of structures associated with this deformation, prevents their elucidation from aeromagnetics, but their deformed nature is obvious from the irregular, contorted magnetic anomalies associated with basement complexes. Basement folds delineated from geological mapping in the Western Magnetic Province (Section 6.2.1), have similar complex magnetic signatures.

Two fold events, one isoclinal, and the other tight to isoclinal, affect quartzofeldspathic basement of the Plenty Downs Dome (Plate 19). They resemble folds delineated in the overlying metasediments, and are considered to be related to basement remobilisation by later deformation events discussed in the following section.

4.2.2 Deformation of the Metasedimentary Cover Sequence

Folding of the metasedimentary cover sequence is best developed in the Jervois Range area which is relatively undisturbed by faulting and intrusion. Synthesis of aeromagnetic interpretation and geology resulted in the interpretation map of Figure 4.7, and indicates the area has been subjected to three phases of deformation.

The oldest (NPD_1), produced one structure delineated through aeromagnetic interpretation. Magnetite-quartzites of the lode horizon, located within an NPF_1 fold hinge, gives rise to the intense elongate anomaly in the northwest corner of the survey area (Fig. 4.5). This fold axis may be traced to the

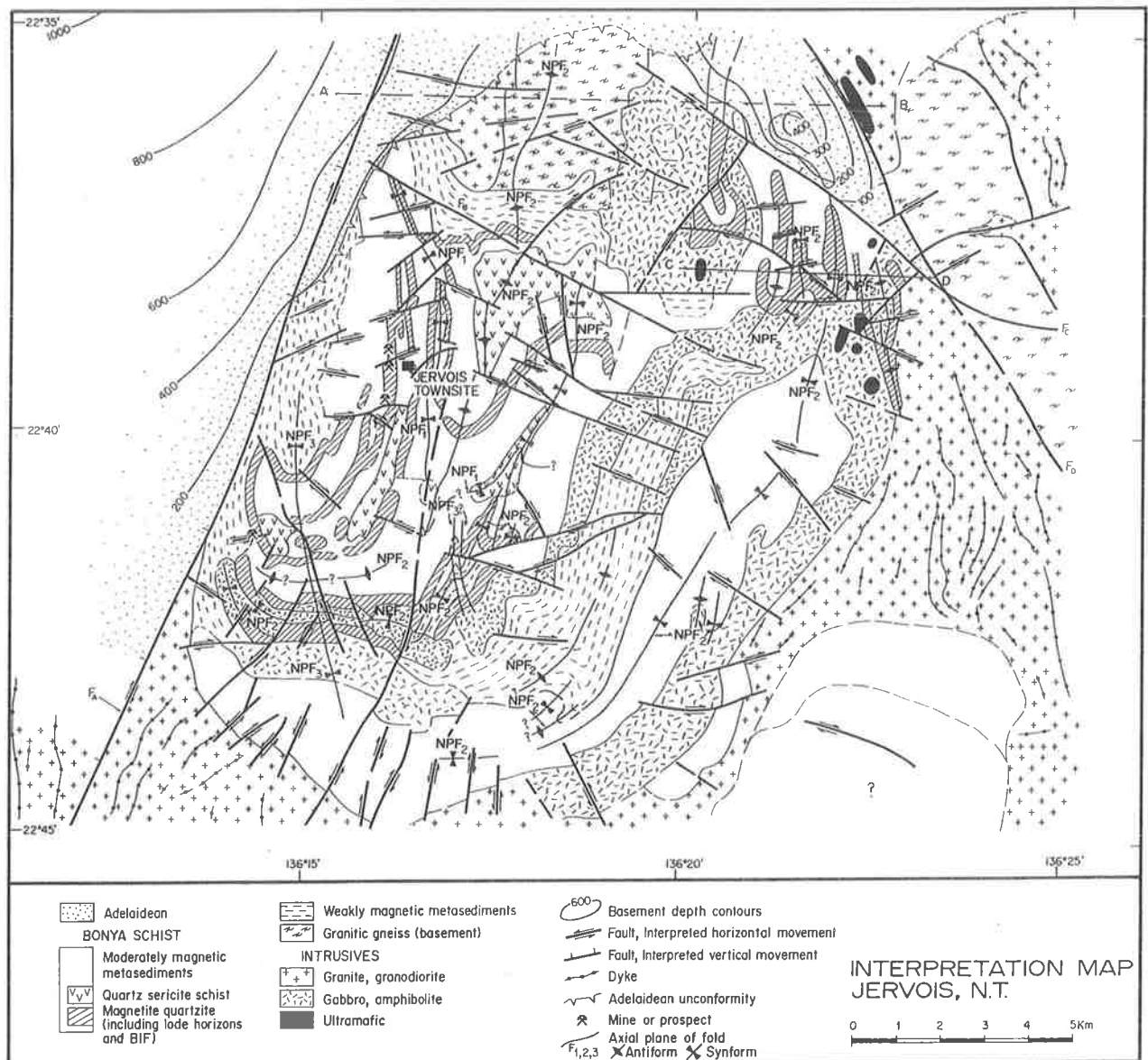


Figure 4.7 Aeromagnetic interpretation map of the Jervois Range area.

southeast. Its early age is inferred from its tight aspect and interpreted refolding of its limbs by SSW oriented NPF_2 folds further east. Pinching and resultant isolation of magnetic horizons within the fold hinge, occurs directly north of the Jervois townsite and west of a thick competent body of quartz-sericite schist. Geological evidence of the folds earlier age includes:

- 1) The presence of a planar fabric (NPS_1) in the north which could not be correlated with NPD_2 or NPD_3 .
- 2) Overprinting of the fold by the axial plane schistosity NPS_2 .
- 3) Parasitic NPF_2 folds with sinistral vergences, observed on both limbs (superimposed folding; Ypma et. al., 1984).

Further south, direct evidence for the existence or position of this fold is not obvious and has been inferred through consideration of the orientation of NPS_1 and the distribution of rocktypes.

Tight isoclinal folding resulting in thickened hinges and narrow sheared fold limbs is characteristic of the second deformation (NPD_2). This is reflected in the intense circular to elongate anomalies associated with parasitic NPF_2 fold hinges and the weak to moderate linear anomalies of the limbs (see dashed boxes on Fig. 4.5). Strong, elongate anomalies correlating with mineralized prospects, result from similar small scale parasitic NPF_2 folds, which structurally control mineralization, exemplifying the potential economic importance of anomalies with this signature.

Regional NPF_2 folds illustrated in Figure 4.7, are outlined by magnetic stratigraphic marker horizons. These folds also exhibit thickened hinges and sheared limbs, as evidenced by the extensive body of quartz-sericite schist thickened within the NPF_2 fold hinge, 2.5 km ENE of the Jervois townsite. This body is at the same stratigraphic level as similar intercalations to the SE.

Gneissic suite rocks further north are also folded by NPD_2 and contain the planar fabric NPS_1 . Thus basement and cover in the Northern Magnetic Province appear to have been in contact, possibly unconformably, prior to deformation of the cover sequence. This is in contrast to basement and supracrustal cover of the Harts Range, which have separate early deformation histories, being subsequently juxtaposed by later thrusting (Sections 1.4 & 6.2.2).

Tight isoclinal folding (NPF_2) and WNW faulting of metasediments is evident in the contorted magnetic pattern immediately east of the Attutra Metagabbro (Figs. 4.2 & 4.3). Outcrop in this area is poor, but a strongly magnetic horizon, possibly the same chlorite-magnetite-garnet quartzite horizon found within Fe,Mg-silicate suite rocks to the SW, allows delineation of structural features. The nature of folding is illustrated in the modelled geological cross-section C-D of Figure 4.8. Initial values of body depth, width, dip, strike extent and susceptibility were derived from initial quantitative interpretation (Appendix A) then refined through forward 3D-modelling. Both total field and vertical gradient response are modelled, the latter proving invaluable in reducing interference between closely spaced bodies. An excellent agreement between field data and modelled results was obtained. These folds are interpreted to be parasitic 'M' and 'W' vergence folds within the hinge of a regional NPF_2 synform (Fig. 4.7).

Subsequent folding of NPF_2 fold axes and development of the gentle regional warp which dominates aeromagnetic trends of the Jervois Range area, corresponds to the final deformation phase NPD_3 . This

MODELLED STRUCTURAL X-SECTIONS JERVOIS AREA

Vertical exaggeration 2.5

FIELD DATA ———
MODEL RESULTS ———
SUSCEPTIBILITY K C.G.S. $\times 10^6$

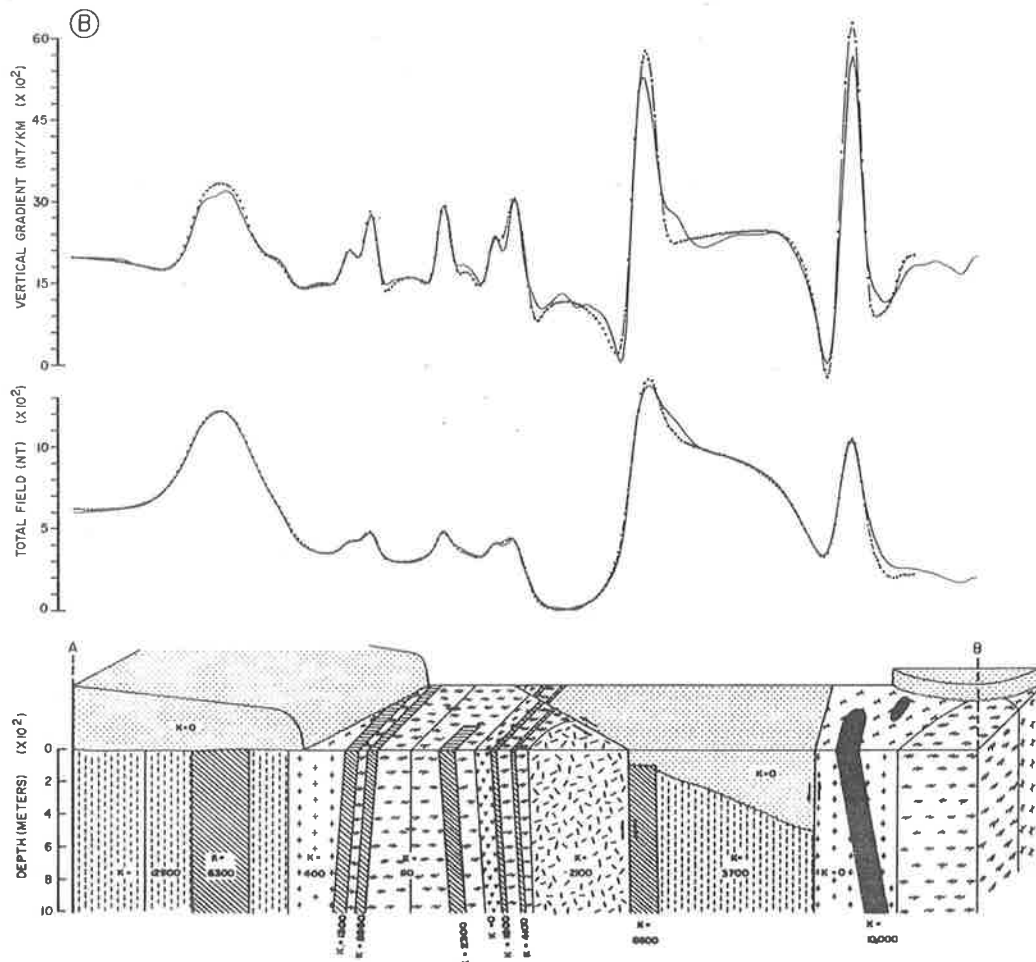
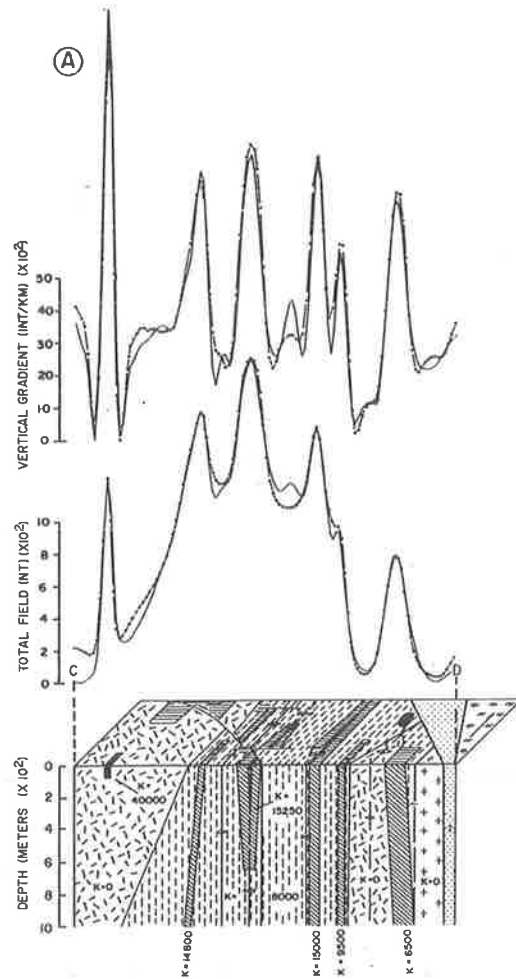
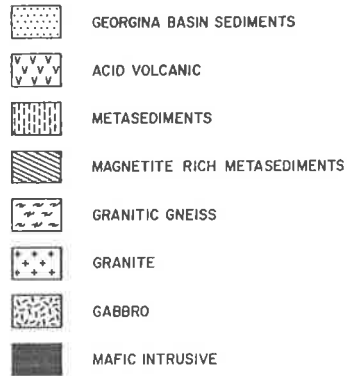


Figure 4.8 Modelled structural cross-sections illustrating the fit between actual magnetic data and computed magnetic data along profiles shown on Figures 4.3 and 4.7. Both total magnetic field and computed vertical magnetic gradient are modelled.

feature, a synclorium with a steep north plunging fold axis (Ypma et. al., 1984) may be related in part to dextral/right-lateral strike slip movement along the Jervois Fault (labelled F_A). Magnetic features are noticeably deformed near this fault, widely spaced EW striking horizons being dragged northwards along the fault zone, resulting in bifurcation of magnetic anomalies and the illusion of tight fold hinges (Fig. 4.4).

The Jervois Fault is collinear with the Arunta Inlier, Georgina Basin unconformity for some distance, suggesting it may have been active during the deposition of the latter sediments. Depth to magnetic basement increases dramatically within the Georgina Basin as indicated on Figure 4.7, being 600 to 1000 metres west of the fault. Further north, on the eastern side of the fault, highly magnetic rocks of the Bonya Schist strike northwards beneath the unconformity, which is marked by a NE striking escarpment of some 150-200m elevation. Depth to magnetic basement in this vicinity varies from 200m at the escarpment to 370m some 2km to the north, indicating the contact between the Arunta Inlier and overlying sediments is unconformable and not faulted as it may be further south and west. This relationship is illustrated at the western extremity of the modelled geological cross-section A-B (Fig. 4.8). As with profile C-D an excellent agreement is observed between field and modelled data.

Of note is the good correlation between mapped faults and the dislocation of magnetic trends (Fig. 4.5). Considering the scattered nature of outcrop, delineation of faults, particularly their orientation, is best achieved from the aeromagnetic map. Faults radiating outwards south of the J-structure have probably resulted from extension stresses in the hinge of the NPF_3 fold and shear movement along the Jervois Fault. Minor SE and SW oriented faults are common and are probably related to, or post-date, NPD_3 . Regional N to NE striking faults such as $F_{A,B,C,D}$ are well developed throughout the Northern Magnetic Province. The latter three faults are part of the extensive Lucy Creek Fault system which is discussed further in Section 4.2.4.

Similar structures attributed to NPD_1 , NPD_2 and NPD_3 occur throughout the Northern Magnetic Province. In the Bonya Hills, on western *JERVOIS RANGE* (Plate 14), isoclinal folds resemble NPF_2 structures of the Jervois Range area. One correlates with an east plunging syncline, interpreted from the repetition of the Kings Legend Amphibolite Member (Freeman, in prep). The attitude of neighbouring folds, outlined from aeromagnetic interpretation, assumes a similar easterly plunge. Only one (NPF_1), appears to be earlier, being refolded by NPD_2 . This feature, which contains the Kings Legend Amphibolite within its hinge, may be illusory, its southern closure, which is quite obvious on total intensity maps, being the result of shearing along a NNE striking fault. Regional, open folding (NPF_3) of earlier structures about an EW axis, is similar to that due to NPD_3 in the Jervois Range area. Quartzofeldspathic basement (Mascotte Gneiss Complex) occupies the NPF_3 fold hinge further west, implying this structure is an easterly plunging anticline. Consistent with this interpretation, Hill (1972) postulates the existence of a mid-Paleozoic EW trending anticline in the Jinka Granite to the west, and suggests the Oorabra Reefs were emplaced along tension fractures within its axial plane.

Other notable examples of superimposed folding occur on southern *JERVOIS RANGE*, northern *PLENTY DOWNS* and southern *PLENTY RIVER*. Highly magnetic horizons (magnetite-quartzite) delineate type II and III interference patterns of Ramsay (1967), considered to develop from superposition of NPF_1 and NPF_2 folds. NPF_2 folds on southern *JERVOIS RANGE*, are more open than those further north, and alternatively, may be attributed to NPD_3 . Elongate magnetic highs on *PLENTY RIVER*, resemble those corresponding to mineralised prospects in the Jervois Range area. They may be indicative

of lode horizon rocks thickened in parasitic NPF_2 fold hinges (this section), and may therefore be of economic importance.

Elsewhere, folding is ill-defined due to extensive faulting and granite intrusion. On *DNEIPER* and *JINKA*, contacts between granite and metasediments often appear folded, implying intrusion was synchronous with, or prior to deformation. These isoclinal folds are attributed to NPD_2 . Similarly the contact between the Jervois Granite and Bonya Schist, is folded by NPD_3 (Fig. 4.7). Consistent with this, the Rb-Sr emplacement age of 1808 ± 80 Ma, for the Jervois Granite, is approximately synchronous with the 1790 ± 35 Ma date for the Strangways Event, considered the main regional metamorphic event affecting the eastern Arunta Inlier (Section 1.3).

4.2.3 Basement and Cover Remobilisation

Following early deformation of the basement and metasedimentary cover sequence, the Northern and Central Magnetic Provinces were brought into contact by faulting along the well-defined magnetic lineament BCT_1 (Fig. 3.3), which truncates all earlier structures on either side of it. This fault was then intruded by a mafic igneous body, interpreted to give rise to the curvilinear magnetic high on eastern *PLENTY DOWNS*, western *PLENTY RIVER*, and then subsequently incorporated in late open folding.

At least two open fold phases are thought to have affected the Northern Magnetic Province. Interference between them formed the Plenty Downs Dome (Fig. 3.3), which dominates the central part of the province on northeastern *PLENTY DOWNS*. This structure, which has a diameter of approximately 40 km, probably developed at the mutual culmination of two orthogonal regional antiforms. Evidence for this open folding is also apparent from the curvilinear shape of the magnetic contact BCT_1 , and magnetic trends in the adjacent Central Magnetic Province (Section 5.2.2).

Another, smaller oval magnetic feature, mapped as unit BQF_2 in the southern part of the Plenty Downs Dome, may be a similar, smaller scale domal structure. Alternatively, it may be a deformed intrusive of more intermediate composition, similar to the Inkamulla and Huckitta Granodiorites within the Entia Dome. These structures, and to some degree, the Plenty Downs and Entia Domes themselves, resemble mantled gneiss domes. An explanation of these granite gneiss structures (Eskola, 1949), suggests synkinematic granite was intruded into rocks undergoing metamorphism, subsequently denuded and unconformably overlain by sediments (metasedimentary cover sequence) and the whole reactivated during later orogenic events causing the older gneissic rocks to become mobile, and intrude and dome-up the younger cover rocks.

4.2.4 Late Proterozoic and Phanerozoic Deformation

Late deformation in the Northern Magnetic Province involved dislocation and truncation of earlier structures and Georgina Basin sediments, along NW to WNW and later N to NE trending faults. Shaw and others (1984) consider many of these faults to have formed early in the Inliers history, being subsequently intermittently reactivated. However, little evidence for their earlier age is found in the aeromagnetic maps, which indicate they formed after the middle Proterozoic Strangways Event and subsequent open folding, and prior to, or during the Carboniferous Alice Springs Orogeny. This is not entirely unexpected, as aeromagnetism will date a structure according to its final obvious movement.

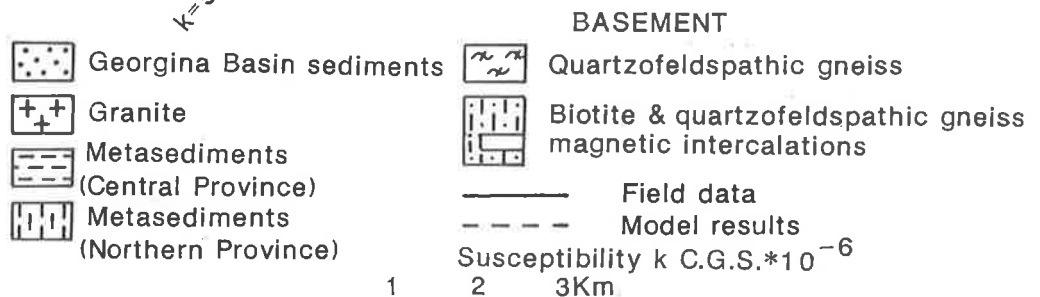
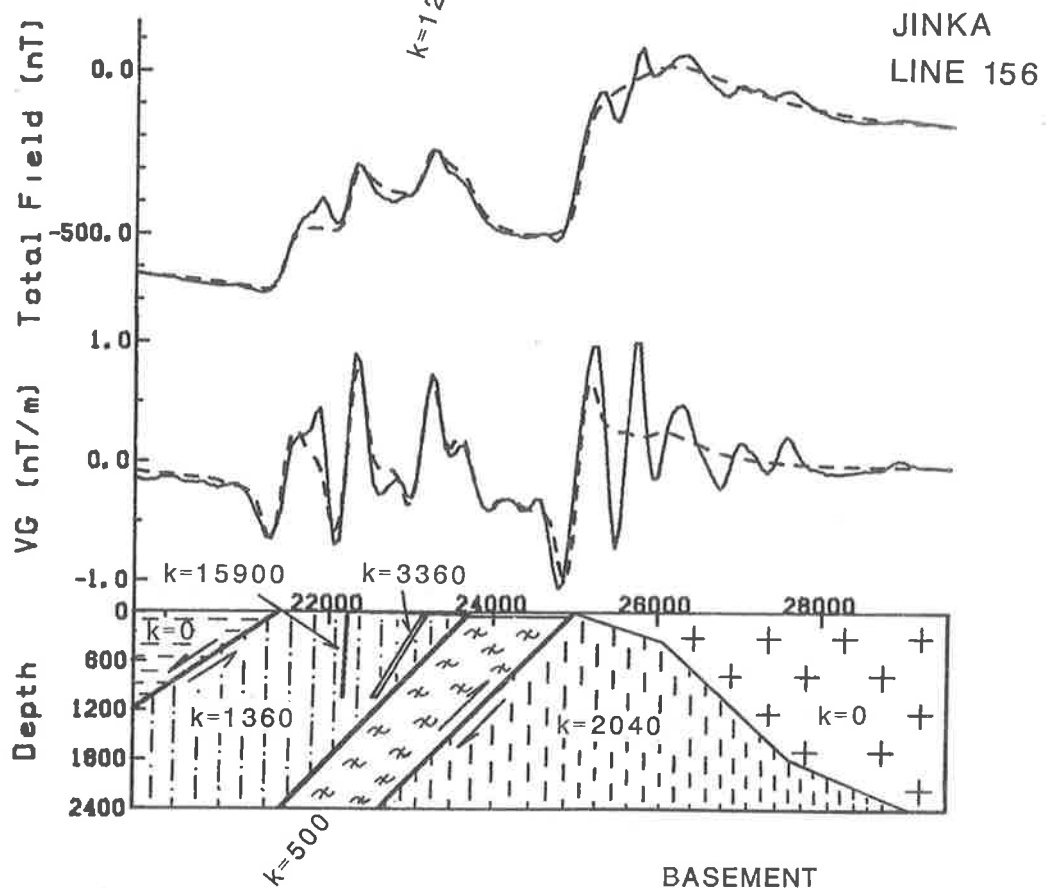
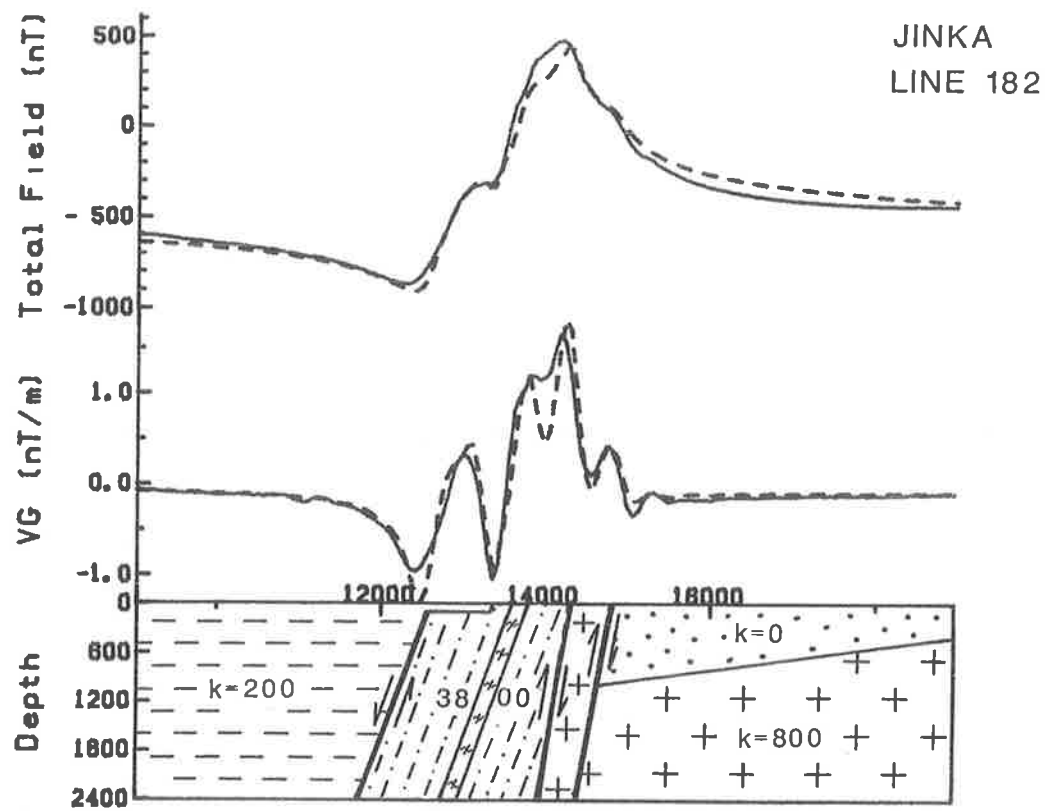


Figure 4.9 Modelled structural cross-sections illustrating the fit between actual magnetic data and computed magnetic data along profiles 156 and 182 shown on Plate 13. Both total magnetic field and computed vertical magnetic gradient are modelled.

There is an excellent correlation between mapped and interpreted faults. The dominant feature is the Delny-Mount Sainthill Fault Zone, which trends WNW, outcropping intermittently for some 150 km from southwest *JERVOIS RANGE* to beyond the western border of *DNEIPER* (Section 1.2.5). It is well-defined on magnetic maps as a complex interconnected network of subparallel faults, encompassing slivers of contrasting magnetic character in a zone up to 5 km wide. On *DNEIPER* and *JINKA*, it forms the boundary with the Western and Central Magnetic Provinces respectively. Further east, the zone of deformation narrows (approximately 1 km) and may be traced across southern *JERVOIS RANGE* as a linear zone, along which magnetic trends are offset or truncated. It swings to the southeast on *TARLTON* and *PLENTY RIVER*, where it appears to form a narrow fault plane.

Quantitative interpretation indicates the fault zone dips moderately south ($45 - 60^\circ$) on *DNEIPER* and *JINKA*, to near vertical on *TARLTON* and *PLENTY RIVER* ($75^\circ \text{SW} - 90^\circ$). The interpreted widespread occurrence of units *BQF*_{1&2} and *BGM*₁ within the fault zone indicates movement has been essentially upward. Geological evidence concurs with this, slivers of Division 1 Kanandra Granulite being common in the fault zone, and fault rock lineations indicating movement was vertical with little transcurrent component (Freeman, in prep). Occurrence of high temperature kornepine bearing rocks at one locality, enclosed within lower grade metamorphic rocks (Warren & McColl, 1983), is also indicative of upward displacement. However, some slivers of Adelaidean sedimentary rocks have been translated downwards. The last phase of movement along the Delny-Mount Sainthill Fault post-dates the Late Cambrian Arinthrunga Formation of the Georgina Basin and is correlated with the Alice Springs Orogeny (Stewart, 1971; Freeman, in prep).

Northwest striking splays of the Delny-Mount Sainthill Fault Zone form the southern boundary of the Elua Syncline on central *JINKA*. The relationship between the syncline, the Delny-Mount Sainthill Fault Zone and Jinka Granite, is illustrated in the modelled structural cross-sections of Figure 4.9. Profile locations are shown on Plate 13. The Elua Syncline is asymmetric with a gently dipping northern limb (7°S) and near vertical southern limb (Freeman, in prep). Interpreted thickness of the sedimentary sequence, as indicated from estimates of depth to magnetic basement, increases toward the south, being up to 680m near the synclines center. Depths adjacent to its southern margin are much deeper, weak magnetic anomalies arising from the Jinka Granite below, being completely attenuated. Further NW, the syncline appears to continue below the Georgina Basin as a graben-like structure. Depth to magnetic basement increases from approximately 500m on the flanks of this feature, to over 900m within it. Diamond drillhole Exoil Huckitta No.1, intersected Arunta basement at 1180m within this graben, in reasonable agreement with nearby interpreted depths.

During Adelaidean time, sediments were deposited in similar WNW trending half-grabens, located on northern and eastern *DNEIPER* (Freeman, in prep). Depth to magnetic basement contours clearly outline these features, which have fault-bounded northeastern margins and contain up to 650m of sediment unconformably overlying the Arunta Inlier.

Other faulting occurs along well-defined planes which commonly extend into the Georgina Basin, or separate it from the Arunta Inlier. Several northerly trending faults on *JINKA* and *JERVOIS RANGE* are truncated by, and therefore pre-date, the Delny-Mount Sainthill Fault Zone. The most obvious of these is the Jervois Fault, which may have formed during *NPD*₃ (Section 4.2.2). It is collinear with the Arunta Inlier, Georgina Basin unconformity for some distance, implying it may have been active during or subsequent to deposition of the latter sediments. Further south, it is evident as a linear zone of low

magnetic intensity, probably related to retrograde metamorphism or preferential deep weathering within the fault zone.

The Charlotte Fault (Section 1.4.1) has a similar orientation. In the north, it separates the Bonya Schist from the Jinka Granite. Further south, it is offset by a westerly trending strike-slip fault, which correlates with one of the Oorabra Reefs emplaced along fractures in the Jinka Granite. Geological mapping (Freeman, in prep) indicates it crosses the Mascotte Gneiss Complex to the south. Here, it has no geophysical signature due to the lack of a detectable magnetization contrast. Within the Georgina Basin, depth to magnetic basement increases by several hundred metres from west to east across this structure.

The eastern half of the Northern Magnetic Province is fractured into elongate crustal blocks by numerous major NW trending faults. The most important of these are the Lake Caroline, Lucy Creek and Tarlton Fault systems, and the interpreted southeastern extension of the Delny-Mount Sainthill Fault Zone. Most have numerous, sub-parallel splays, and with the exception of the Tarlton Fault, have steep southerly to vertical dips. On *JERVOIS RANGE*, the Lucy Creek Fault splays and extends into the Georgina Basin, forming a wedge-shaped graben (Fig. 4.7). Depth to magnetic basement increases from near surface to 200-400m between the fault splays, F_C and F_D . Their probable structure in relation to the neighbouring Attutra Metagabbro and Bonya Schist is shown in Figure 4.8.

On *MOUNT BARRINGTON*, these faults trend WNW-ESE, and can be traced below up to 1200m of overlying Georgina and Eromanga Basin sediments. The faults do not appear to offset or control sedimentation here, possibly because much of this sequence is part of the younger Eromanga Basin.

The large regional anomaly which lies along the border of *MARQUA*, *TARLTON* and *MOUNT BARRINGTON*, arises from a deep intra-basement source, approximately 13km below the surface of the Georgina Basin. Complex aeromagnetic patterns, associated with near surface rocks of the Arunta Inlier, are superimposed on this regional anomaly. Whilst near surface rocks at this location are truncated by the Tarlton Fault, this deeper intrabasement source is not. Regional aeromagnetic trends arising from the latter are instead truncated by the Lucy Creek Fault, some 12-15km southwest of the Arunta Inlier, Georgina Basin boundary. This indicates the Tarlton Fault is a shallowly dipping ($< 45^\circ$ SW) reverse fault, the Arunta Inlier lying between the Lucy Creek and Tarlton Faults being a relatively thin wedge thrust to the northeast over the Georgina Basin. This agrees with the east side down movement and overthrusting from the south, thought to have occurred along the Tarlton Fault during the Alice Springs Orogeny (Section 1.4.1). The crustal block lying between the Lucy Creek and Tarlton Faults, differs from the remainder of the Northern Magnetic Province in several other ways.

- 1) Lack of an extensive basement complex.
- 2) Different structural style due to extensive granite intrusion, and disruption by NW and NE trending faults.

Major WNW to NW trending faults are offset by NE oriented strike-slip faults (and occasionally vice-versa). They may represent two separate generations of faulting or possibly formed at the same time as a conjugate set. Northeast trending faults often extend into the Georgina Basin, where they influence the thickness of the sedimentary sequence. Contours of depth to magnetic basement, particularly on

MARQUA, may not coincide with the base of the Georgina Basin, due to the presence of weakly magnetic metasediments (Mount Smith Metamorphics, section 1.2.2) within the underlying Arunta Inlier. This unit is near surface on southeast *MARQUA* where it is associated with weak magnetic anomalies.



Central Magnetic Province

The Central Magnetic Province lies immediately south and west of the Northern Magnetic Province, and covers approximately one third of the study area. In contrast with neighbouring provinces, it is predominantly magnetically homogeneous (Fig. 3.3). Northwesterly trending, curvilinear anomalies of up to 200nT amplitude are common and are superimposed on a southwesterly increasing regional gradient of approximately 75nT/km. Exposure is good in the west, but increasingly sparse to the east, where the province is overlain by sediments of the Eromanga Basin. All outcrops are Division 2 metasediments and metavolcanics of the Central Tectonic Province of Shaw et al (1984).

Aeromagnetic coverage of the Central Magnetic Province varies in its detail and sensitivity (Appendix A). The eastern two-thirds is covered by relatively detailed, low level, digital data, the remainder by several older analogue surveys (Fig. 3.3). The latter were low level, and relatively detailed on *LAUGHLEN-RIDDOCH* and northeastern *QUARTZ*, but regional and flown at high altitude for the rest of *QUARTZ*. As the original analogue records for these older surveys were unavailable, interpretation of the western part of the province was qualitative in nature.

5.1 LITHOMAGNETIC SUBDIVISION OF THE CENTRAL MAGNETIC PROVINCE

The Central Magnetic Province is mainly composed of metasediments having uniform magnetic properties, and this is reflected in its relatively homogeneous magnetic response. Lithomagnetic subdivisions recognised from differences in magnetic intensity and signature are summarised on the legends of interpretation maps enclosed at the back of this thesis. A distinguishing characteristic of this province is the lack of a clearly recognisable basement. Apart from minor intrusive and fault-related features, most magnetic anomalies are curvilinear, and characteristic of the metasedimentary cover sequence with which they correlate. The lack of deep-seated magnetic anomalies implies this sequence is extremely thick and magnetically uniform, or that the underlying basement is weakly magnetic (quartzofeldspathic?).

5.1.1 Metasedimentary Cover Sequence (CMS)

There are two major magnetic subgroups of the metasedimentary cover sequence. One is predominantly magnetite poor, the other more magnetite rich. They also appear to have different structural styles (Section 5.2).

Most of the Central Magnetic Province belongs to the magnetite poor subgroup and is typified by extensive, curvilinear magnetic anomalies of less than 200nT amplitude, distributed within an otherwise, featureless magnetic background. In the Harts Range area, this magnetic signature correlates with magnetite poor lithologies comprising the Brady and Irindina supracrustal assemblages (Section 2.4.2). The former unit has a uniform, featureless magnetic response, consistent with its weakly magnetic lithologies (Section 2.3.2). The latter unit has a variable response dependent on lithology:

- 1) Areas largely devoid of magnetic anomalies correspond with calcareous rocktypes (e.g. the Naringa Calcareous Member of Stewart et. al., 1980) and the Harts Range meta-igneous complex.
- 2) Pelitic metasediments (biotite gneiss and biotite schist) correspond with areas having a similar subdued magnetic background, but containing an abundance of discrete, curvilinear anomalies.
- 3) Discrete magnetic lows, on western *LAUGHLEN-RIDDOCH*, correlate with large beds of quartzite.

This response is consistent with the weak magnetic properties of calcareous and meta-igneous rocktypes of the Irindina supracrustal assemblage (Section 2.3.2). The subdued magnetic background associated with pelitic metasediments is consistent with their predominantly weak magnetic properties. Discrete, curvilinear anomalies correlating with these rocktypes follow structural trends indicating they are due to stratigraphically bound magnetite-bearing horizons. These horizons probably account for the significant number of magnetic samples of pelitic metasediment of the Irindina supracrustal assemblage (Section 2.3.2).

The abundance of magnetic horizons and their distribution within the metasedimentary cover sequence, therefore reflect differences in lithology related to different depositional environments, and may be used as a basis for subdividing the metasedimentary cover sequence. However, boundaries between

pelitic metasediments and weakly magnetic calcareous and meta-igneous rocktypes are commonly difficult to delineate, due to frequent interlayering of these lithologies on a small scale. Consequently, areas largely devoid of magnetic anomalies (unit CMS_1) are interpreted to outline predominantly calcareous or meta-igneous rocktypes, whilst those with abundant, discrete curvilinear anomalies (unit CMS_2) are considered to outline predominantly pelitic metasediments. Boundaries between these magnetic units are often gradational along strike, possibly reflecting facies changes.

Magnetic horizons resemble steep to moderately dipping, near surface sheets, with median susceptibility contrasts of approximately $6,000 \times 10^{-6}$ S.I. Where direct correlation is possible, interpreted dips are in agreement with measured dips, indicating aeromagnetic anomalies arise from the induced component of magnetization. This is in accordance with the observed random NRM intensity and direction of rocktypes comprising the Brady and Irindina supracrustal assemblages (Section 2.3.2).

Contrasting strongly with the subdued magnetic response of most of the Central Magnetic Province, is a complex magnetic area on southern *JINKA*, northern *BRAHMA* (Fig. 3.3). Magnetic anomalies comprising this zone have amplitudes frequently in excess of 1000nT, and although curvilinear, they are more complexly deformed than magnetic horizons elsewhere in the Central Magnetic Province. Three magnetic subdivisions are recognised in this magnetite rich magnetic subgroup:

- 1) Low intensity areas, largely devoid of magnetic anomalies (CMS_3).
- 2) Zones having multiple linear anomalies of less than 200nT. Interpreted susceptibility contrasts are typically less than 12000×10^{-6} S.I. (CMS_4).
- 3) Discrete, curvilinear magnetic highs with amplitudes commonly in excess of 1000nT. Susceptibility contrasts from quantitative interpretation are typically between $12,000 - 100,000 \times 10^{-6}$ S.I. (CMS_5).

These three units are interlayered, and enclosed by the predominantly magnetite poor metasediments and metavolcanics (units CMS_1 & CMS_2) of the remainder of the province.

Exposure in this area is poor, scattered outcrops being categorised as Irindina supracrustal assemblage or undifferentiated Harts Range Group. The magnetic signatures of CMS_3 and CMS_4 , resemble those of CMS_1 and CMS_2 , respectively. These units may be facies equivalents or part of the same unit. Their magnetic response is in keeping with that associated with the Irindina or Brady assemblages. However, the magnetic response and interpreted susceptibility contrasts of CMS_5 are inconsistent with the measured magnetic properties of outcropping rocktypes of the Central Magnetic Province. Only the Bruna Gneiss, of the Harts Range Group, possesses a magnetic susceptibility of this order (Section 2.3.5). However, Ding and James (1985) consider the Bruna Gneiss to be a plutonic body, occupying a restricted location along the thrust boundary separating the Central and Western Magnetic Provinces (Section 1.2.2). It is therefore unlikely to be the source of an extensive, highly deformed unit such as CMS_5 .

Unit CMS_5 is most likely a previously unrecognised, deformed magnetite-rich horizon located within the otherwise, weakly magnetic metasedimentary and metavolcanic sequence. It may have been deposited in an iron-rich environment, having intermediate oxidation levels which favoured the formation of mag-

netite during subsequent prograde metamorphism. A similar result might occur from the formation of magnetite through dehydration of iron rich horizons during regional metamorphism, although contacts with surrounding metasediments would probably be more gradational than observed. Of note, are highly magnetic quartz-feldspar-biotite-magnetite schists, intersected during drilling of an isolated magnetic high on western *BRAHMA* (Section 5.1.2). Although only a minor occurrence, this or similar rocktypes may be the source of *CM S₅*.

An alternative interpretation of the well-defined, complex magnetic zone which dominates the center of the province (i.e. units *CM S_{3,4&5}*) is that it is a basement complex to the enclosing metasedimentary sequence. Several of its characteristics reinforce this interpretation:

- 1) Its magnetic signature is similar to that associated with immature Division 1 metasediments of the Western Magnetic Province basement.
- 2) Its magnetic horizons outline superimposed fold patterns not obvious elsewhere in the Central Magnetic Province, possibly indicative of a separate early deformation history (Section 5.2).

5.1.2 Intrusives

Intrusives are numerous, but small and mostly of ultramafic composition. There are no obvious large granite plutons, as evidenced by the regular distribution and undisrupted nature of extensive curvilinear anomalies arising from metasediments.

Ultramafic bodies are reported at several locations. Two suites are recognised on geological and geochemical grounds (Harvey, 1982; 1983 a,b,c,d); first, green-black pyroxenite, considered to be emplaced at a late-stage penecontemporaneous with metamorphism; and second, highly altered dunitic ultramafics which occur in a variety of concordant and discordant structural settings, similar to alpine-type ultramafic of Phanerozoic age. They are commonly deeply weathered, serpentinized, and associated with equidimensional or elongate magnetic anomalies of varying amplitude and extent.

Numerous similar anomalies occur throughout the Central Magnetic Province. Many have been investigated during exploration for diamondiferous kimberlites. Drilling at Crossing Bore on western *BRAHMA*, intersected a phlogopite bearing dunitic ultramafic in four holes, at depths varying from 12-30m (B.H.P. Rpt., 1982). A similar, neighbouring, elongate magnetic anomaly is associated with quartz-feldspar-biotite-magnetite schist. This illustrates the difficulty in distinguishing anomalies associated with intercalations of magnetic metasedimentary rock, from ultramafic intrusives. However, anomalies often have abnormal shapes indicative of strong remanence, commonly associated with mafic or ultramafic bodies (Section 2.3.4). The most notable of these, is a complex circular magnetic feature of approximately 4 km diameter, located near Carmencita Bore on central *DNEIPER*. Its heterogeneous magnetic response includes zones of anomalous low intensity, indicative of a variable composition. This feature is possibly an igneous ring complex, formed from multiple intrusion or fractional crystallization, and may be similar to the Mordor Complex (Section 1.2.4), which has kimberlitic affinities.

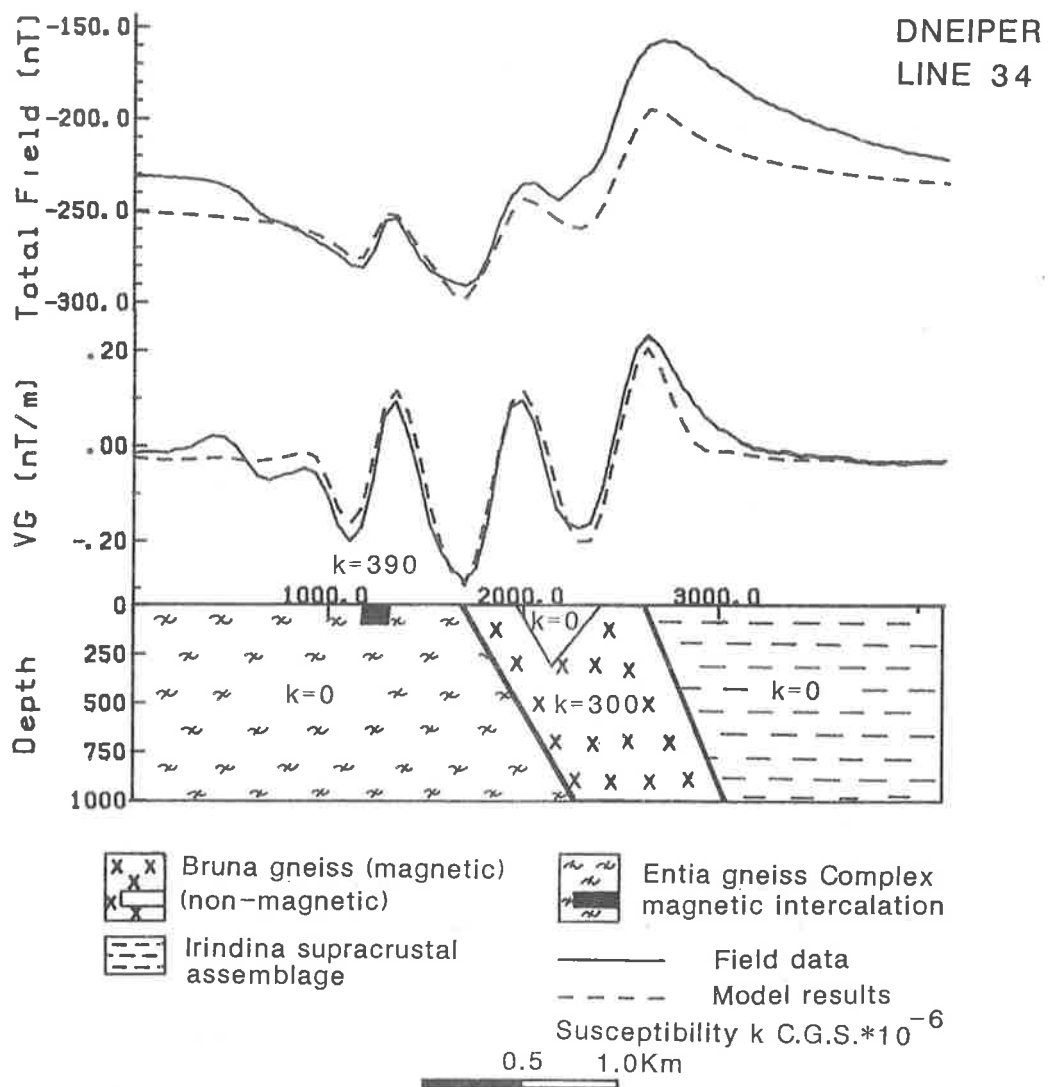
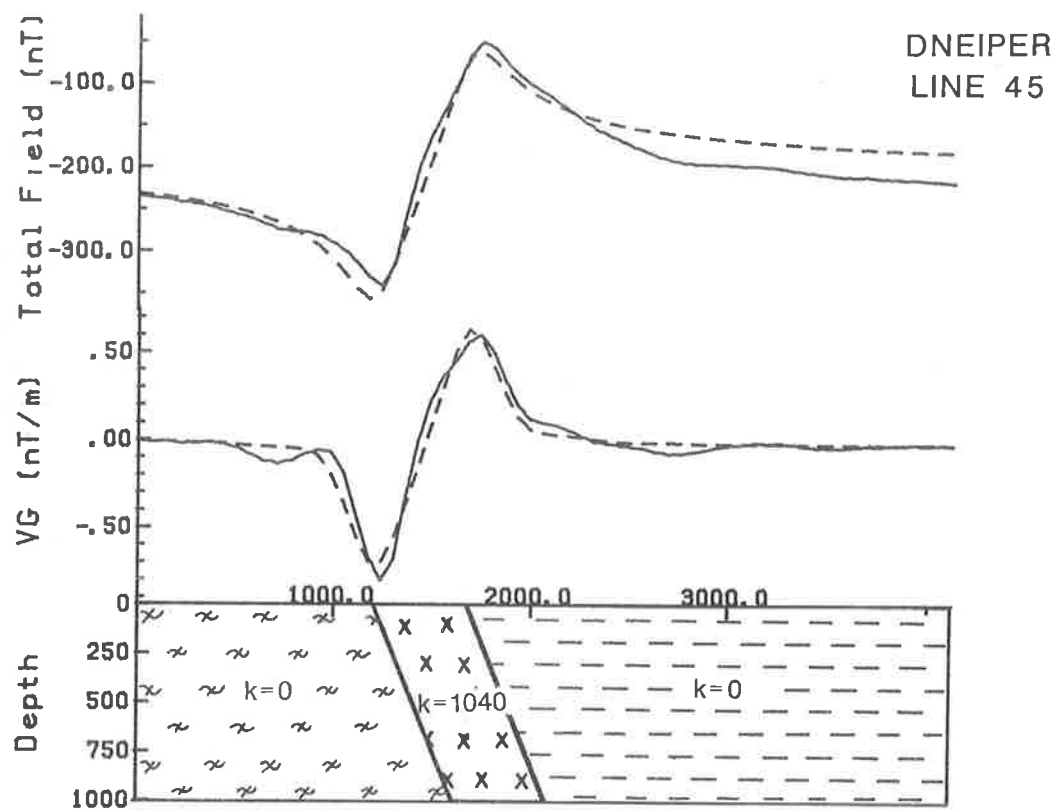


Figure 5.1 Modelled structural cross-sections over outcropping Bruna Gneiss illustrating the fit between actual magnetic data and computed magnetic data along profiles 34 and 45 shown on Plate 10. Both total magnetic field and computed vertical magnetic gradient are modelled. Good agreement between modelled and measured dip, width and susceptibility contrast indicate the magnetic anomaly is due to induced magnetization.

5.1.3 Fault-Related Features

Fault-related mylonite or retrograde rocks (Section 3.1.4) do not appear to be present within the Central Magnetic Province. However, they are associated with its boundaries, reinforcing their interpretation as faults.

Retrograde schist zones of the Delny-Mount Sainthill Fault Zone have already been described (Section 4.1.4). Similar features occur along the Entire Point Fault on central *DNEIPER*, which separates the Central and Western Magnetic Provinces.

On *QUARTZ* and *LAUGHLEN-RIDDOCH*, curvilinear magnetic highs correlate with the Bruna Gneiss and other mylonitic rocks, considered to occupy a restricted location along sections of the boundary separating basement of the Western Magnetic Province and metasedimentary cover of the Central Magnetic Province (Section 1.2.2). The Bruna Gneiss is ill-defined on much of *QUARTZ* due to the five mile aeromagnetic line spacing, but is still discernable as a weak magnetic high enclosing the Entia Dome. Figure 5.1 presents modelled cross-sections of the Bruna Gneiss on southern *DNEIPER* (Plate 12). A good agreement between modelled and field data is observed for both the total field and computed vertical gradient. Results indicate the Bruna Gneiss resembles a wide magnetic sheet (480m to 520m) with susceptibility contrasts of 3800 to 13000×10^{-6} S.I., dipping 60° - 70° N. This is in excellent agreement with its measured susceptibility ($k_{0.5} = 5,500 \times 10^{-6}$ S.I.) and dip (60° N), supporting the conclusion that the apparent random NRM of the Bruna Gneiss does not contribute to observed magnetic anomalies (Section 2.3.5).

A curvilinear magnetic high located along part of the Central and Northern Magnetic Province boundary on western *PLENTY RIVER*, eastern *PLENTY DOWNS* is considered to be a similar plutonic body to the Bruna Gneiss, emplaced along this contact.

5.2 STRUCTURAL HISTORY OF THE CENTRAL MAGNETIC PROVINCE

As in the Northern Magnetic Province, most magnetic anomalies are due to stratabound magnetite and may be regarded as magnetic stratigraphic marker horizons, which outline structures controlling their distribution. Table 5.1 summarises the sequence of deformation events recognised from aeromagnetic interpretation of the Central Magnetic Province.

5.2.1 Deformation of the Metasedimentary Cover Sequence

Magnetic marker horizons delineate superimposed fold patterns within metasediments and metavolcanics, and indicate they were subjected to at least two phases of early deformation, prior to later remobilisation (Section 5.2.2). Folding is best developed in the central complex magnetic zone of southern *JINKA*, northern *BRAHMA*, where there are abundant intense, curvilinear anomalies.

The oldest deformation, CPD_1 , resulted in tight isoclinal folding (CPF_1) of units CMS_3 , CMS_4 and CMS_5 . These structures are difficult to recognise due to their tight aspect and subsequent refolding, but typically, multiple magnetic horizons of CPF_1 limbs merge toward fold closures, where magnetic

Table 5.1: Orogenic stages and associated structures recognised in the Central Magnetic Province

DEFORMATION (D)		FOLD (F)	FAULT (T)	INTRUSION
LATE PROTEROZOIC AND PHANEROZOIC FAULTING			Major NW to WNW and N to NE faulting	Ultramafic bodies
BASEMENT - COVER REMOBILISATION	BCD_3^*	Open folding of BCT_1 and BCT_2 BCF_1		
	BCD_2 BCD_1			
			BCT_1 BCT_2	
METASEDIMENTARY COVER DEFORMATION	$CPD_3^{**?}$	$CPF_3^?$ CPF_2 CPF_1	pre- BCT_1	
	CPD_2 CPD_1			

* BCD denotes basement-cover remobilisation event

** CPD denotes Central Magnetic Province deformation

trends abruptly terminate. The parallel limbs of CPF_1 folds are refolded by predominantly NW to WNW trending CPF_2 folds. Unit CMS_5 displays rounded CPF_2 closures, whilst those of CMS_4 are tight, and more difficult to recognise. This indicates CMS_4 is less competent and possibly more pelitic than CMS_5 , supporting their interpretation as different lithologies.

The axial planes of CPF_1 and CPF_2 are generally parallel. Superposition of these structures results in type III interference patterns of Ramsay (1967). They are best developed within units CMS_5 on central *BRAHMA* (Plate 20) and CMS_4 on southeastern *JINKA* (Plate 13). However, the southernmost occurrences of these units, on central southern *BRAHMA*, form crescent shaped magnetic patterns reminiscent of Ramsay type II interference patterns. These may form where CPF_1 axial surfaces and limbs are arched upwards by later CPF_2 folds (Ramsay, 1967). Both type II and III interference patterns develop where recumbent folds are refolded by new structures with steeply inclined axial surfaces. The different patterns observed may have resulted from a local change in the axial orientation of either fold generation.

Interpreted and measured dips are dominantly moderate to steeply northeast. The only fold outlined during field mapping of this region, an anticline located on eastern *BRAHMA*, is also overturned to the northeast. It correlates with a magnetic anomaly whose source plunges shallowly northwest (Plate 20), consistent with the anticlines measured plunge. Seven kilometers to the southwest, a similar magnetic feature also plunges northwest, suggesting together with the nature of superimposed fold patterns, that folding may be moderate to steeply inclined to the northeast, whilst plunging shallowly to the northwest.

CPD_1 and CPD_2 were probably synchronous with regional metamorphism (Strangways Event). The limbs of folds formed during these events are occasionally refolded by small, northerly trending flexure folds (CPF_3). It is unclear whether these structures formed immediately after CPD_1 and CPD_2 or during later remobilisation, which resulted in regional scale open folding discussed in the next section.

Structures associated with early deformation events are not as apparent elsewhere in the Central Magnetic Province. This is largely due to the widespread occurrence of unit CMS_1 which lacks magnetic marker horizons. However extensive curvilinear anomalies, characteristic of unit CMS_2 , delineate a different structural style to that described above. This might be due to its composition, thought to be predominantly pelitic (Section 5.1.1), which possibly results in extremely tight isoclinal folding, difficult to recognise from aeromagnetic trends. This may be consistent with the common bifurcation of magnetic anomalies along strike within this unit. Early structures may also have been flattened and stretched by later open folding. This is apparent on *PLENTY DOWNS* and *PLENTY RIVER* (Plates 18 & 19), where curvilinear anomalies of CMS_2 , wrap about the Plenty Downs Dome. Similar flattening of early structures is observed in the vicinity of the Entia Dome (Lawrence, unpublished). Alternatively, the different structural style of CMS_1 and CMS_2 may indicate units CMS_3 , CMS_4 and CMS_5 have a separate early deformation history, supporting the alternative view that they represent an older basement terrain (Section 5.1.1).

In the Harts Range area, on northern *LAUGHLEN-RIDDOCH* and western *QUARTZ*, the metasedimentary cover sequence of the Central Magnetic Province, has been studied by Ding and James (1985). They recognise two isoclinal fold events, developed under amphibolite facies metamorphism. Folding here, is best developed in calcareous rocks of the Naringa Well area, which are weakly magnetic, containing virtually no magnetic marker horizons (unit CMS_1). Consequently aeromagnetic interpretation

revealed little concerning these structures. Folding is better defined on aeromagnetic maps, to the north (northeast *LAUGHLEN-RIDDOCH*; Plate 22), where rocktypes are more pelitic (unit *CMS₂*). Magnetic trends outline a large, EW oriented, crescent shaped interference fold pattern (Type II; Ramsay, 1967), formed from the superposition of an early isoclinal structure and a later EW trending, tight to isoclinal, regional scale fold. These are tentatively correlated with *CPF₁* and *CPF₂* folds further east.

5.2.2 Remobilisation

Following early deformation of the metasedimentary cover sequence, the Central Magnetic Province was brought into contact with the Northern and Western Magnetic Provinces, by displacement along the faults *BCT₁* and *BCT₂* (Fig. 3.3). Evidence for this lies in the different lithomagnetic composition and style of early structures in all three provinces, and the truncation of these structures by *BCT₁* and *BCT₂*. All three provinces were subsequently incorporated in ductile open folding.

At least three phases of late open folding deformed the Central Magnetic Province. Folds are typically kilometers in amplitude and influence the orientation of earlier *CPF₁* and *CPF₂* structures. On northeastern *BRAHMA*, *CPF₁* and *CPF₂* folds are refolded by a major *BCF₁* fold, which appears to undergo a pitch reversal westwards, to plunge in the opposite direction on southwestern *JINKA*. These two closures are separated by ENE trending faults and may be separate *BCD₁* structures. One of these faults is itself folded by this feature, indicating if formed during or prior to *BCD₁*. Fanning outward from the *BCF₁* fold on southeastern *JINKA*, are small syn-*BCD₁* strike-slip faults, a result of extension stresses within the fold hinge. There is no direct evidence suggesting these structures post-date formation of *BCT₁* and *BCT₂*, however, the style of deformation is similar to open folds which deform these faults.

The regional distribution of units *CMS₃*, *CMS₄* and *CMS₅* on *BRAHMA*, appears to outline a similar *BCF₁* fold. However, this feature may be an illusion as earlier *CPF₁* and *CPF₂* folds are not refolded by it. The observed distribution of magnetic units is thought to result from numerous *CPF₂* folds and sinistral, strike-slip movement along the major NW trending fault at this location (Plate 20).

Folds of similar amplitude and wavelength to the southeast, on *PLENTY DOWNS* and *PLENTY RIVER*, are also considered to have formed during *BCD₁*. As with other magnetic trends in this area, their axial planes describe arcs which are concentric about the neighbouring Plenty Downs Dome. Magnetic trends are warped in a similar manner about the Entia Dome on *QUARTZ*. Both domes are considered to have formed at the mutual antiforms of orthogonally oriented, regional open folds. Similarly, the complex magnetic area which dominates the center of the Central Magnetic Province, describes a basin-like structure, possibly formed at two mutual synforms of the same regional folds.

5.2.3 Faulting

Several generations of faulting are evident from aeromagnetic interpretation. Short, strike-slip faults associated with early isoclinal folds, may have formed during *CPD₁* or *CPD₂*. Pre or syn-*BCD₁* faulting, on southern *JINKA*, is described in the previous section. Strike-slip faults, offsetting the Bruna Gneiss on northeastern *QUARTZ*, might be related to late open folding responsible for the development of the Entia Dome. The latter faults exhibit an excellent correlation with mapped faults and shears.

One other structure may predate open folding which formed the Plenty Downs and Entia Domes. Located on northeastern *QUARTZ*, this wide, NNW trending magnetic unit has a similar magnetic signature and orientation as the Bruna Gneiss, to the west. In the south, it is near surface, and truncates WNW trending magnetic anomalies to the east. Further north, it plunges to a depth of 2100m on southern *DNEIPER*, where it is discordant with near-surface (50-200m), EW magnetic trends associated with BCD_1 folding, which it therefore appears to post-date. Its magnetic signature and orientation suggests it is a similar plutonic body to the Bruna Gneiss, emplaced along a major discordant fault prior to the formation of the Entia Dome.

All structures described to date are offset by several major NW trending faults, and numerous, smaller, NE trending strike-slip faults. These are considered to have formed at the same time as similar late Proterozoic and Phanerozoic faults of the Northern Magnetic Province.

5.2.4 Basin Sediments

On southern *DNEIPER*, the Arunta Inlier is overlain by a thick sequence of Tertiary sand and clay deposits of the Huckitta Basin. Contours of depth to magnetic basement clearly outline the basin as a narrow EW trending feature, containing up to 500m of non-magnetic sediments, overlying weakly magnetic metasediments of the Central Magnetic Province (Plate 12). Further east, on *PLENTY RIVER*, similar metasediments are overlain by up to 280m of Eromanga Basin sediments (Plate 18). Two drill holes penetrate basement below this sequence. BMR No.3, intersected pyritic greenschist and pyritic quartz-biotite gneiss at 183m below surface (BMR, 1971). Afmeco ATB1 intersected banded calcareous gneiss and metaquartzite at 45m (French, 1981). In both cases, interpreted depth to basement in the vicinity of these drillholes is in good agreement with actual depth to basement.

Western Magnetic Province

This complex, magnetically heterogeneous province is situated in the western part of the study area (Fig. 3.3). Its magnetic pattern contrasts strongly with that of other provinces, being characterised by highly contorted curvilinear, or irregularly shaped magnetic anomalies of variable intensity. Exposure is good across most of the province, consisting of outcropping Entia gneiss complex and units of the Division 1, Strangways Metamorphic Complex.

The Central and Western Magnetic Provinces together form part of the Central Tectonic Province of Shaw et al (1984). Detailed mapping by Ding and James (1985), and aeromagnetic interpretation described in this chapter, support their recognition as separate provinces on the basis of their:

- 1) Different lithological assemblages.
- 2) Separate early deformation histories.
- 3) Well-defined faulted boundary.

Contour maps of total magnetic intensity were the only form of aeromagnetic data available for *LAUGHLEN - RIDDOCH* and *QUARTZ* (Appendix A). Consequently, interpretation of these sheets was qualitative in nature.

6.1 LITHOMAGNETIC SUBDIVISION OF THE WESTERN MAGNETIC PROVINCE

Stewart et al (1984) subdivide rocks of the Western Magnetic Province into a number of separate Division 1 units, defined within fault bounded blocks. They make only tentative lithological correlations between these blocks and thus Division 1 units. In contrast, Ding and James (1985) make no clear distinction between these metamorphic units, classifying all, along with their Entia gneiss complex, as basement (Section 1.2).

From the integration of aeromagnetic interpretation with rock property and geological data, these conflicting interpretations are revised, geological units and regional correlations being classified according to their magnetic signature and intensity. As shown on magnetic interpretation maps (Plates 12-22), basement complexes predominate and are characteristic of the Western Magnetic Province. Zones of contrasting magnetic intensity, which give this province its heterogeneous character, correlate with weakly magnetic quartzofeldspathic and highly magnetic granulite or mafic gneiss complexes. These are further subdivided through differences in magnetic anomaly abundance, signature and intensity, as described in the following section.

6.1.1 Basement Complexes

Granulite and Mafic Gneiss Complexes (BGM)

Magnetically complex areas, with variations in intensity frequently in excess of 2000nT, correlate with Division 1 units composed predominantly of highly magnetic mafic gneiss and/or mafic granulite, and minor weakly magnetic quartzofeldspathic gneiss and amphibolite. Three subdivisions, recognised through differences in magnetic signature and intensity, correlate with mapped units containing different proportions of meta-igneous and metasedimentary rocktypes.

Unit *BGM*₁ is characterised by irregularly shaped anomalies of predominantly moderate to high intensity, which correlate with scattered outcrops of Kanandra Granulite on central *DNEIPER*. Geological mapping here, is semi-regional, not allowing accurate correlation of aeromagnetic anomalies with individual rocktypes comprising this unit (Table 1.1). However mafic granulite is considered to give rise to high intensities, in keeping with its highly magnetic properties (Section 2.3.1). Low intensity areas are interpreted as underlain by subordinate, weakly magnetic quartzofeldspathic gneiss, amphibolite and possibly felsic granulite. Susceptibility contrasts between high and low intensity zones, derived from quantitative interpretation, are typically in the range 40,000 - 200,000 $\times 10^{-6}$ S.I., in good agreement with measured susceptibility differences between these two groups of lithologies (Section 2.3.1). Small, irregular bodies of granite, which intrude the Kanandra Granulite, also correlate with areas of low magnetic intensity.

Irregular anomaly shapes, which characterise this unit, reflect the igneous origin and highly deformed nature of most rocktypes comprising the Kanandra Granulite. Mafic granulites are thought to have been basalt flows (Stewart et. al., 1984). They typically form tabular bodies 3 to 10m thick and up to several hundred meters long, and are multiply folded. The predominance of high magnetic intensities implies this is the major rocktype comprising the Kanandra Granulite, indicating it is similar to the Enbra

and Utalanama Granulites, which are composed of up to 70% mafic granulite. They are considered to form the lower part of the Strangways Metamorphic Complex, which is dominantly meta-igneous. Mafic granulite complexes (BGM_1) are not extensive elsewhere in the study area. Slivers occur within the Delny-Mount Sainthill Fault Zone, indicating movement in places was upward. The unexposed southwest corner of *BRAHMA* has a complicated magnetic signature resembling that of the Kanandra Granulite, and is considered to be underlain by a similar unit.

Unit BGM_2 exhibits similar extreme variations in magnetic intensity as BGM_1 . However, although highly contorted, anomalies are more curvilinear in shape. This magnetic signature correlates with the Cadney Metamorphics, on central *LAUGHLEN-RIDDOCH*, considered part of the predominantly metasedimentary upper section of the Strangways Metamorphic Complex (Stewart et. al., 1984). Further west, it correlates with the Ongeva Granulite, considered part of the middle section of the Strangways Metamorphic Complex, which contains a high proportion of both metasedimentary and meta-igneous rocktypes. These two units cannot be confidently separated using aeromagnetic data and consequently are grouped together as unit BGM_2 .

Within unit BGM_2 , curvilinear magnetic anomalies of different intensity arise from interlayered rocktypes having contrasting magnetic properties. Horizons of quartzofeldspathic gneiss and amphibolite correlate with curvilinear magnetic lows, consistent with their weak magnetic properties (Section 2.3.1). Calc-silicate rocks correspond with low to moderate intensities, consistent with their variable magnetic properties. Highly magnetic mafic granulite and mafic gneiss are associated with high intensities. Felsic granulites have variable magnetic intensities, possibly depending on whether they are derived from igneous rocks of acid or intermediate composition. Interlayered felsic and mafic granulite of the Ongeva Granulite, are associated with contorted curvilinear anomalies, similar to those of metasediments. However, as with the Kanandra Granulite, areas of massive granulite correlate with zones of irregularly shaped anomalies. These are generally of limited extent.

Subdivision of unit BGM_2 into layers of weakly and highly magnetic rocktypes was not attempted due to the relatively wide aeromagnetic line spacing (0.25 mile) and the lack of profiled data. This may not have been possible even with detailed digital magnetic data, due to the frequent fine interlayering of magnetically contrasting rocktypes and their complex deformation.

The magnetic signature of BGM_3 is similar to that of BGM_2 , but exhibits peculiar, anomalous, curvilinear magnetic lows. It correlates with the unnamed Division 1 unit *p_{esl}* (Table 1.1). The similar magnetic signatures of BGM_2 and BGM_3 , reflects their dominantly metasedimentary compositions and supports the ascertainment that unit *p_{esl}* may be a facies equivalent of the Cadney Metamorphics (Shaw & Wells, 1983). Magnetic property measurements were not carried out on lithologies comprising unit *p_{esl}* and geological mapping is too regional to allow detailed correlation with aeromagnetics. However, results from other Division 1 units indicate magnetic highs are probably due to schistose biotite gneiss and minor mafic granulite. Quartzofeldspathic gneiss and amphibolite are most likely weakly magnetic and associated with aeromagnetic lows. Anomalous, curvilinear lows, which characterise this unit, disrupt or truncate neighbouring magnetic trends. They are possibly due to retrograde fault zones, where magnetite has been oxidized to hematite through preferential deep weathering. Alternatively, their anomalous intensity might result from a well defined remanence acquired by magnetite formed within shear zones. However, elsewhere in the Western Magnetic Province, NRM does not appear to unduly influence aeromagnetic anomalies, consistent with its measured random direction and intensity

(Section 2.3.1).

Quartzofeldspathic Gneiss Complexes (BQF)

Extensive zones of low intensity containing contorted curvilinear, or irregularly shaped magnetic anomalies of low to moderate amplitude ($<200\text{nT}$), correlate with dominantly granitic or quartzofeldspathic units. As with similar units of the Northern Magnetic Province (Section 4.1.1), two subdivisions are recognised depending on magnetic anomaly abundance (Units BQF_1 & BQF_2). These correspond with quartzofeldspathic units containing different proportions of subordinate magnetic rocktypes.

Low intensity areas, largely devoid of aeromagnetic anomalies (BQF_1), correlate with the Entia Gneiss complex of the Entia Dome, on *QUARTZ*, and unnamed unit *pest* on central western *LAUGHLIN-RIDDOCH*. This is in accordance with the measured weak magnetism of the former unit (Section 2.3.1), and the similar dominantly quartzofeldspathic composition of unit *pest*. Correlation of discrete magnetic anomalies with the geology of the Entia Dome is difficult due to the regional nature of aeromagnetic coverage over most of this structure. Within unit *pest*, discrete magnetic highs correlate with lenses of mafic granulite.

Unit BQF_1 is difficult to distinguish from the similar, neighbouring unit CMS_1 , of the Central Magnetic Province. Both have a featureless background response, but magnetic horizons within CMS_1 are generally more numerous, curvilinear and less deformed. This reflects the predominantly metasedimentary composition of CMS_1 and meta-igneous composition of BQF_1 , and their separate deformation histories. In addition, they are separated by linear magnetic highs associated with the Bruna Gneiss and other mylonitic rocks, located along sections of the Western and Central Magnetic Province boundary. A high sensitivity caesium vapour magnetometer survey may allow better discrimination of these units through recognition of the characteristic magnetic signatures of weakly magnetic horizons contained within them. Much of the existing digitally acquired data (Appendix A) could be reprocessed with this aim in mind.

Magnetic anomalies are more abundant within unit BQF_2 , which correlates with the Oonagalabi gneiss complex and the equivalent Bungitina Metamorphics (Section 1.2.1). Ding and James (1985) perceive no clear distinction between these units and the Entia gneiss complex, except for their distinctly higher proportion of mafic gneiss and granulite. The similar magnetic signatures of BQF_1 and BQF_2 , and their subdivision due to the increased abundance of discrete magnetic anomalies within BQF_2 is consistent with this interpretation.

6.1.2 Intrusives

As in the Central Magnetic Province, intrusives are numerous, small and generally of ultramafic composition, being associated with equidimensional or elongate magnetic anomalies. These anomalies are difficult to distinguish from those due to small blebs of mafic granulite or mafic gneiss within basement complexes, especially where these are poorly exposed.

The Inkamulla and Huckitta Granodiorites, which intrude the Entia gneiss complex on *QUARTZ*,

Table 6.1: Orogenic stages and associated structures recognised in the Western Magnetic Province

	DEFORMATION (D)	FOLD (F)	FAULT (T)	INTRUSION
LATE PROTEROZOIC AND PHANEROZOIC FAULTING			Major NW to WNW and N to NE faulting	Ultramafic bodies
BASEMENT - COVER REMOBILISATION	BCD_3^* BCD_2 BCD_1	Entia Dome BCF_1		
EARLY BASEMENT DEFORMATION	WPD_3^{**} WPD_2 WPD_1 Pre- WPD_1	WPF_3 WPF_2 WPF_1	BCT_2 BT	

* BCD denotes basement-cover remobilisation event

** WPD denotes Western Magnetic Province deformation

are the only intrusives of granitic composition within the Western Magnetic Province. Little can be deduced concerning their magnetic signature due to the regional aeromagnetic coverage here, although they cannot be distinguished from the Entia gneiss complex at the flying height of 2000ft. This is not unexpected considering the relatively weak magnetic properties of these units (Section 2.3.4).

6.1.3 Fault-Related Features

Curvilinear magnetic highs associated with the Bruna Gneiss and other mylonitic rocks, located along the boundary between the Western and Central Magnetic Provinces, are described and modelled in section 5.1.3. Similar magnetic highs disrupt or truncate magnetic trends arising from basement units on *LAUGHLEN-RIDDOCH*. They are also considered to be due to magnetic mylonitic rocks associated with faults.

Retrograde schist zones trend EW across outcropping basement on central *LAUGHLEN-RIDDOCH*, and are associated with the bounding faults of the Kanandra Granulite, on eastern *DNEIPER*. The magnetic signature of the former zone is dependent on which basement unit it transects. Where it separates the Cadney Metamorphics (BGM_2) from unit psl (BGM_3), it is obvious as a zone of low background intensity, containing numerous, subparallel anomalies. Low intensities are considered to result from oxidation of magnetite through hydration along retrograde fault zones. Linear magnetic highs within this zone are probably associated with slivers of non-retrogressed basement, or magnetic mylonites. This zone of retrogression cannot be recognised further west on total intensity contour maps, where it intersects dominantly quartzofeldspathic basement units. This is undoubtedly due to the low magnetite content of these rocks which is a result of their low iron content and high oxidation state. Linear magnetic lows on eastern *DNEIPER* are considered to be associated with hydration and retrogression along fault planes of the Delny-Mount Sainthill Fault Zone and the Entire Point Fault.

6.2 STRUCTURAL HISTORY OF THE WESTERN MAGNETIC PROVINCE

Table 6.1 summarises the sequence of deformation events recognised from the integration of aeromagnetic interpretation discussed in the following sections, and detailed field mapping of several areas within the Western Magnetic Province, described by Ding and James (1985).

6.2.1 Early Basement Deformation

The geology of the Oonagalabi area of central eastern *LAUGHLEN-RIDDOCH*, has been mapped in detail by Rankin (1983). One tight (BF_4) and two isoclinal (BF_2 & BF_3) ductile fold generations, coaxially refold an intense early (BD_1), layer parallel tectonothermal fabric. Comparison of the mapped geology with aeromagnetic contours (Fig. 6.1), provides insight into the characteristic magnetic response of the Oonagalabi gneiss complex and similar dominantly quartzofeldspathic units (Section 6.1.1). Irregularly shaped anomalies arise from highly deformed lenses of moderate to highly magnetic mafic granulite and biotite gneiss. Amphibolite and quartzofeldspathic gneiss are weakly magnetic as is the enclosing Irindina supracrustal cover assemblage of the Central Magnetic Province. The small amplitude and complex form of superimposed folding, together with the comparatively wide aeromagnetic traverse spacing (1/4 mile), precludes delineation of most fold structures. However, as observed in the Northern Magnetic Province (Section 4.2.1), irregular anomaly shapes are indicative of early, complex deformation of the

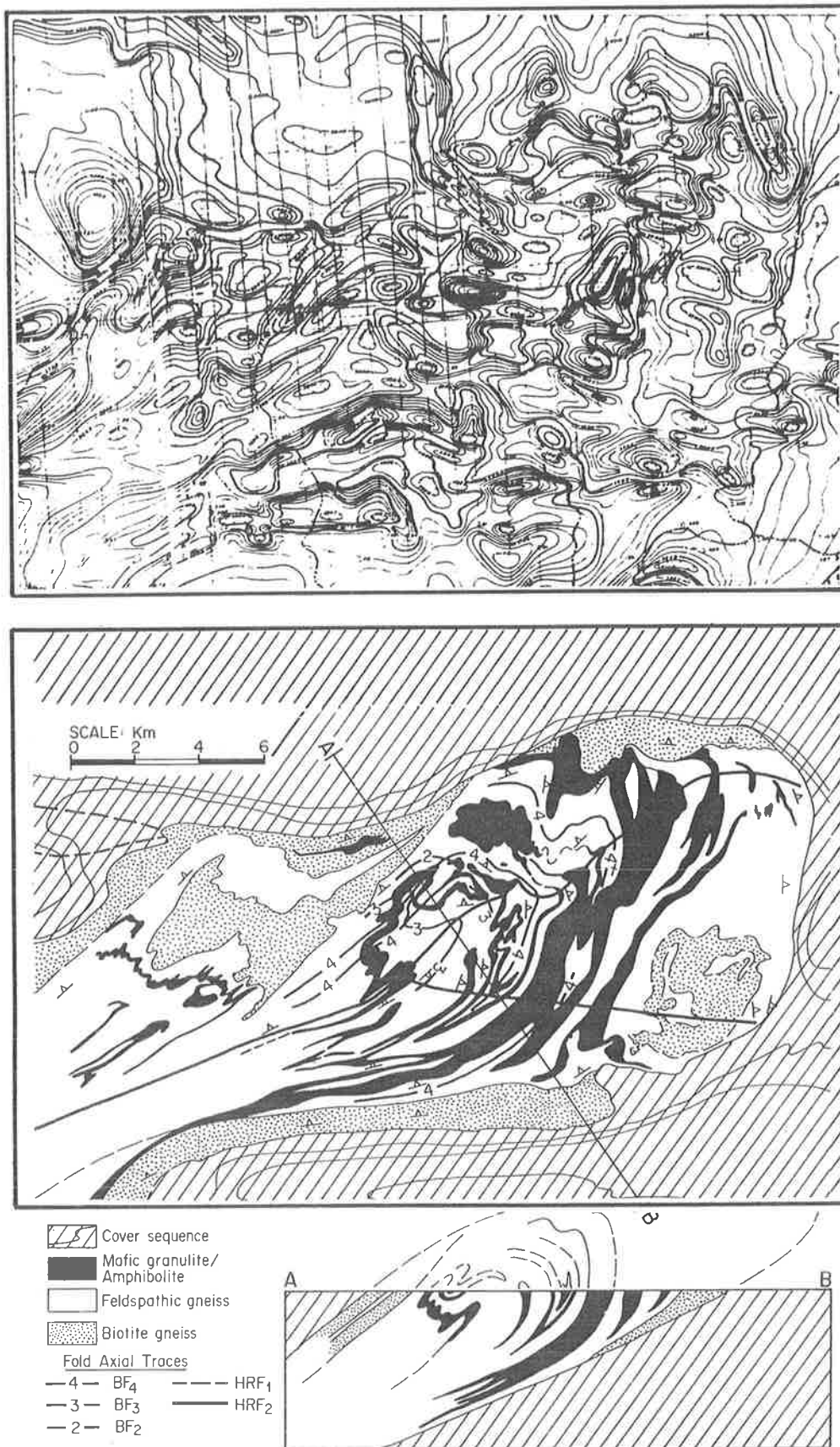


Figure 6.1 Detailed correlation of aeromagnetic data and the geology of the Oonagalabi Tongue.

basement.

The structural history of the Entia Dome, and Mount Ruby area of southeastern *LAUGHLEN-RIDDOCH*, appears to be identical to that of the Oonagalabi Tongue (Ding & James, 1985). Consistent with this, the magnetic signature of all three areas is similar (BQF_1 & BQF_2). Their predominantly weakly magnetic lithologies and complex structural history, together with the relatively coarse aeromagnetic coverage, do not allow the delineation of superimposed fold structures from aeromagnetic maps. However, as in the Oonagalabi area, characteristic irregular anomaly shapes are indicative of complex deformation.

Further west on *LAUGHLEN-RIDDOCH*, numerous, curvilinear magnetic marker horizons of unit BGM_2 , outline structures within the Cadney Metamorphics and Ongeva Granulite, similar to those of areas described above. The earliest deformation resulted in tight isoclinal folds with small, but well-defined closures, and long continuous parallel limbs (WPF_1). WPF_1 limbs are refolded by coaxial WPF_2 folds, with closures that are tight but well-defined in the dominantly metasedimentary Cadney Metamorphics, but which become more rounded and ill-defined in the Ongeva Granulite. This is probably a result of the different proportion of metasedimentary to meta-igneous rocktypes in these units, which influences their competence and resultant mechanical properties. Superposition of these structures results in type III interference patterns of Ramsay (1967), which are most evident on aeromagnetic maps where interlayered felsic and mafic granulites are deformed by WPD_1 and WPD_2 (e.g. southwest *LAUGHLEN-RIDDOCH*).

WPF_1 and WPF_2 possibly correlate with BF_3 and BF_4 structures of Ding and James (1985), in the Oonagalabi Tongue, which have similar styles and interference patterns. Earlier, small scale BF_2 folds may also be present (pre- WPD_1), possibly causing many of the discontinuous, irregular magnetic patterns observed within unit BGM_2 .

Extensive, linear magnetic trends arising from the subparallel limbs of WPF_1 and WPF_2 folds, are refolded about the regional structure WPF_3 , located on central *LAUGHLEN-RIDDOCH*. This EW trending fold, is closed and well-defined within the Cadney Metamorphics, but becomes more open and ill-defined further west, within the Ongeva Granulite. As observed for WPF_2 fold closures, this reflects the dominantly metasedimentary composition and corresponding lower competence of the Cadney Metamorphics compared to the Ongeva Granulite, which contains a higher proportion of meta-igneous rocktypes.

Ductile folding was followed by the development of schist and mylonite zones, which truncate earlier structures. These are marked by a linear zone of variable, but generally low magnetic intensity, trending ENE through units BGM_2 , BGM_3 and BQF_2 on northern, central *LAUGHLEN-RIDDOCH*. Ding and James (1985) consider them to be semi-ductile basement overthrusts (BT), dipping moderately NNW. This zone is possibly similar to the Redbank Deformed Zone, on *ALICE SPRINGS* and *HERMANSBURG*, which initially formed about 1620 Ma ago (Marjoribanks & Black, 1974).

6.2.2 Remobilisation

Following separate early deformation, basement of the Western Magnetic Province and metasedi-

mentary cover of the Central Magnetic Province were brought into contact by progressive underthrusting of basement beneath the cover sequence. This deformation, termed the Harts Range Event by Ding and James (1985), is thought to have involved a series of three sequentially developed thrusts, which were subsequently incorporated in ductile folds. Many structures associated with these events are clearly evident on aeromagnetic maps.

The first two thrusts (HRT_1 , HRT_2) form the boundary between the Western and Central Magnetic Provinces (Fig. 1.7). On aeromagnetic maps they are evident as a curvilinear contact, separating the complex signature of the former province from the subdued response of the latter. Magnetic trends in the basement are clearly discordant along much of this contact, and early structures (WPF_1 , WPF_2 , WPF_3 & BT) are truncated by it. Trends within unit BGM_3 on central *LAUGHLEN-RIDDOCH* are sheared into parallelism with HRT_1 , which is marked along much of its length, by linear magnetic highs associated with magnetic mylonites developed within the thrust plane. However, apart from these, there is little evidence on the aeromagnetic map to suggest HRT_1 and HRT_2 are separate structures. This magnetic contact exhibits a marked similarity to BCT_1 , which forms part of the boundary between the Central and Northern Magnetic Provinces (Fig. 3.3), and may join with this structure beneath the Central Magnetic Province. Consequently the boundary separating the Western and Central Magnetic Provinces is referred to as BCT_2 .

In the Oonagalabi area, BCT_2 is clearly folded along with basement of the Western Magnetic Province and metasedimentary cover of the Central Magnetic Province (Fig. 6.1 & Plate 22). These folds (BCF_1) are isoclinal with rounded closures, and recumbent with shallow, northerly inclinations evident from the gradually diminishing magnetic gradient immediately north of the Oonagalabi Tongue. They are HRF_2 folds of Ding and James (1985). Earlier (HRF_1) and later (HRF_3) structures of the Harts Range Event, are evident from the contorted BCT_2 boundary, south of the Oonagalabi Tongue. These folds cannot be clearly outlined from aeromagnetics interpretation, due to their complexity and the relatively wide traverse spacing. Detailed correlation between aeromagnetics and geology in this area is poor, a problem which remains unresolved and requires further field examination.

At least two phases of late open folding resulted in regional folding of BCT_2 and the formation of the Entia Dome. BCT_2 closes on northwestern *LAUGHLEN-RIDDOCH*, southern *ALCOOTA* and can be traced eastward to southwestern *DNEIPER*, where it separates the Western and Central Magnetic Provinces, until truncated by the Entire Point Fault. On *DNEIPER*, BCT_2 dips moderately ($45 - 50^\circ$) south below the Central Magnetic Province, re-emerging further south where it has a moderate to steep northerly dip. The boundary between the Central and Western Magnetic Provinces is therefore interpreted to be a keel or basin-like structure in the western part of the study area.

6.2.3 Late-Stage Faulting

All earlier structures described in the preceding sections are offset by WNW trending faults, and numerous, smaller NNE trending strike-slip faults. They are considered to have formed at the same time as similar late Proterozoic and Phanerozoic faults which occur throughout the eastern Arunta Inlier (Sections 4.2.4 & 5.2.3).

Southern Magnetic Province

The Southern Magnetic Province occupies the southern half of *MOUNT BARRINGTON* in the south-east corner of the study area (Fig. 3.3). It is the smallest, most magnetically homogeneous province within the eastern Arunta Inlier, being devoid of anomalies except for discrete equidimensional and WNW trending curvilinear features. Eromanga Basin sediments are up to 300m thick in this area, preventing correlation of aeromagnetism and geology, and making interpretation difficult.

7.1 LITHOMAGNETIC SUBDIVISION OF THE SOUTHERN MAGNETIC PROVINCE

Consistent with its uniform magnetic character, the Southern Magnetic Province is considered to be lithologically homogeneous, as shown on Plate 17. Its lithomagnetic subdivision is summarised, along with that of other provinces, on interpretation map legends.

Extensive, curvilinear anomalies outline tight, to isoclinal folds and unusual ring structures. These magnetic horizons approximate thin dipping sheets with susceptibility contrasts of up to $90,000 \times 10^{-6}$ S.I., and are interpreted to be folded dolerite dykes as;

- 1) Their discrete nature is not typical of metasediments, which normally give rise to multiple magnetic anomalies of variable width and strike length.
- 2) Several (southern, central *MOUNT BARRINGTON*), display abnormal magnetic anomaly shapes, indicative of strong remanence typically associated with mafic or ultramafic intrusives of the eastern Arunta Inlier (Section 2.3.4).
- 3) Interpreted susceptibility contrasts are consistent with the measured susceptibility of dolerite dykes (Section 2.3.4).

Ellipsoidal structures may be ring dykes, emplaced along cone-shaped, tension fractures associated with intrusion of brittle country rocks at shallow depths (Anderson, 1942). Alternatively, these features might be dome or basin structures, formed from the superposition of orthogonally oriented, upright folds. Their WNW elongation is parallel to the axial direction of folding (Section 7.2), and may have resulted from flattening during deformation.

Magnetic property measurements together with geological correlations throughout the study area, suggest the low featureless magnetic level of most of the province is due to rocks of granitic composition. This country rock has been deformed along with magnetic horizons which either intrude it, or are contained within it, and is therefore tentatively correlated with weakly magnetic quartzofeldspathic basement complexes of the Northern and Western Magnetic Provinces (Sections 4.1.1 & 6.1.1).

The Southern Magnetic Province is considered part of the Southern Tectonic Province of Shaw et al (1984), due to the similar magnetic signature of quartzofeldspathic gneiss and syn to pre-tectonic granites of the latter, and their extensive intrusion by dolerite dykes. Quartzofeldspathic gneisses are of granite to granodiorite composition and contain abundant amphibolite, silliminite gneiss and calc-silicate rock. They are considered to be metamorphosed felsic volcanic flows or sills (Offe & Shaw, 1983), and are provisionally placed in Division 2, but could equally be the upper part of Division 1 (Stewart et. al., 1984), supporting the tentative correlation of non-magnetic country rock of the Southern Magnetic Province with basement complexes of the Northern and Western Magnetic Provinces. The Stuart Dyke Swarm, which is widespread on *ALICE SPRINGS*, has been dated at 897 ± 9 Ma by Black et al (1980). These dykes strike north and are undeformed apart from widespread retrogressive metamorphism, associated with the 300 - 400 Ma Alice Springs Orogeny. Unnamed dykes located further west on *MOUNT LEIBIG* and western *HERMANNSBURG*, bear a stronger resemblance to deformed

Table 7.1: Orogenic stages and associated structures recognised in the Southern Magnetic Province

DEFORMATION (D)		FOLD (F)	FAULT (T)	INTRUSION
LATE PROTEROZOIC AND PHANEROZOIC FAULTING			Major NW to WNW and N to NE faulting	Ultramafic bodies
BASEMENT - COVER REMOBILISATION	BCD_1^* ?	BCF_1 ?		
EARLY BASEMENT DEFORMATION		SPF_1	SPT_1	Dolerite dyke intrusion?
	SPD_1^{**} Pre- SPD_1 ?		BCT_3	

* BCD denotes basement-cover remobilisation event

** SPD denotes Southern Magnetic Province deformation

magnetic features of the Southern Magnetic Province. They are westerly trending, closely spaced, commonly bifurcate and are folded in places. Black et al (1980) suggest they may be of equivalent age to the Stuart Dyke Swarm.

Equidimensional magnetic features of the Southern Magnetic Province are probably associated with mafic or ultramafic bodies. Bosses of gabbro and norite, together with dolerite plugs of the Stuart Dyke Swarm, are common in the Southern Tectonic Province.

7.2 STRUCTURAL HISTORY OF THE SOUTHERN MAGNETIC PROVINCE

Table 7.1 shows the sequence of deformation events evident from aeromagnetic interpretation of the Southern Magnetic Province. Curvilinear magnetic anomalies and ring structures, considered to be dolerite dykes and ring dykes, are the only magnetic marker horizons which aid the delineation of structural features. Early deformation of country rock (Pre-SPD₁), may have occurred prior to dolerite dyke intrusion, but is not obvious from aeromagnetics data due to its non-magnetic nature.

Intrusion by dolerite dykes is postulated to have occurred prior to juxtaposition of the Northern and Southern Magnetic Provinces, as indicated by the absence of similar magnetic features in the Northern Magnetic Province. The two provinces were brought into contact by displacement along the magnetic boundary *BCT*₃ (Fig. 3.3), which although less well-defined, bears a definite resemblance to *BCT*₁ and *BCT*₂ (Sections 4.2.3 & 6.2.2). All three boundaries are considered to have formed during the same period of deformation.

Magnetic marker horizons, considered to be dolerite dykes, clearly outline tight to isoclinal folds (*SPF*₁). It is unclear whether deformation of these bodies occurred prior to, or following juxtaposition with the adjacent Northern Magnetic Province, although apparent folding of *BCT*₃ may have been synchronous with *SPD*₁. If magnetic horizons are dolerite dykes of similar age to the Stuart Dyke Swarm (897 ± 9 Ma), then folding is quite young and possibly correlates with late folding (*BCF*₁) observed in other provinces. The number of fold phases influencing these bodies is also unclear. Ring structures may be dome or basin structures formed as a result of superposition of fold generations, or may simply be ring dykes. If they are ring dykes, their WNW elongation might have resulted from flattening during *SPD*₁, whose folds have a similar axial orientation. However, ring structures are normally intruded into brittle rocks, in contradiction with evidence of ductile folding of magnetic marker horizons.

Quantitative aeromagnetic interpretation indicates the main *SPF*₁ fold, outlined on southern *MOUNT BARRINGTON*, is a N to WNW plunging, asymmetric synform. However, an intense curvilinear magnetic low, located on the southern limb of this feature, displays an abnormal shape indicative of strong NRM. Dips interpreted from aeromagnetic profiles assuming no significant NRM may therefore be inaccurate, and the above interpretation incorrect. Moving eastward, the axial direction of *SPF*₁ folds swings from ESE toward the south, and fold closures become more rounded, but limbs remain tight to isoclinal.

As in other provinces, several generations of faulting are evident from aeromagnetic interpretation. Small strike-slip faults fanning outward from *SPF*₁ folds (*SPT*₁) are probably syn-*SPD*₁, and bear a strong resemblance to *BCT*₁ and *NPT*₃ faults of the Central and Northern Magnetic Provinces respectively (Sections 4.2.2 & 5.2.2). These faults and all earlier structures are offset by WNW to NW trending

faults, which also transect the Northern Magnetic Province (Section 4.2.4). The Lucy Creek Fault is the most major of these. Across most of the province it is marked by an intra-basement magnetic contact of uncertain origin, lying at depths of between 1000-1250m below surface. It clearly disrupts near surface curvilinear magnetic trends. The northern boundary of the Southern Magnetic Province is a branch of the Lucy Creek Fault. As in other provinces, NW trending faults are offset by short NE trending strike-slip faults.

Concluding Discussion: Geologic History of the Eastern Arunta Inlier

8.1 OROGENIC STAGES RECOGNISED IN THE EASTERN ARUNTA INLIER

The contrasting magnetic signature of the four magnetic provinces comprising the eastern Arunta Inlier, reflect their different composition and separate, early intrusive and structural histories. Five major stages are envisaged in the development of the eastern Arunta Inlier.

The first involved the formation of basement complexes of the Western, Northern and Southern Magnetic Provinces, through extrusion of felsic and mafic volcanic horizons and intrusion of granitic and granodioritic bodies (units BGM_1, BQF_1). Shaw et al (1984) consider these units (Division 1) formed during an episode of lithospheric extension and taphrogenesis, resulting in rifting and the introduction of abundant tholeiitic magma from the asthenosphere. In the Western and to a lesser extent the Northern Magnetic Province, this igneous phase was followed by deposition of a shale-limestone facies (units BGM_2, BGM_3 & $BQF_2?$), thought to represent the incoming of marine sediments as volcanism waned (Stewart et. al., 1984). Both predominantly meta-igneous and metasedimentary basement units were subsequently intensely deformed, resulting in repeated isoclinal fold development. Deformation of basement in the Northern and Western Magnetic Provinces is thought to have occurred at the same time and was part of the same orogenic stage. Featureless magnetic areas of the Southern Magnetic Province,

interpreted as underlain by basement rocks, might also have been deformed during this event. Ductile thrusting (BT) in the Oonagalabi area (Ding & James, 1985) of the Western Magnetic Province was one of the final events of stage 1.

The second stage involved deposition of the sedimentary and volcanic sequences of the Central and Northern Magnetic Provinces, and their subsequent metamorphism, deformation and intrusion. The environment and conditions in which these occurred were very different for the two provinces, indicating their early development was separate. Stewart et al (1984) consider the metasedimentary sequence of the Northern Tectonic Province to be the flysch-like facies of the Arunta Inlier. The interpreted widespread occurrence of magnetite rich metasediments, chemical sediments (B.I.F., magnetite-quartzite) and felsic volcanics throughout the Northern Magnetic Province, and their association with stratiform base metal deposits in the Jervois Range area, is indicative of extensive sea-floor hydrothermal activity associated with volcanism (Stanton 1976, Large 1977). This sequence was deposited on a dominantly quartzofeldspathic basement (Mascotte Gneiss Complex, Gneissic suite), metamorphosed to amphibolite and in places granulite grade, and subsequently subjected along with the basement to three phases of ductile deformation (Section 4.2.2). Granite intrusion accompanied or closely followed deformation, type 2 granites possibly being syn- NPD_2 and type 1, syn- NPD_3 (Section 4.1.3).

Deposition and deformation of the metasedimentary cover sequence of the neighbouring Central Magnetic Province seems to have been temporally or spatially separate from that of the Northern Magnetic Province, as indicated by:

- 1) Their different composition and the deficiency of magnetite in metasediments of the Central Magnetic Province in comparison to those of the Northern Magnetic Province.
- 2) Their different structural style and metamorphic grade.
- 3) Their separation by the fault BCT_1 .
- 4) The lack of granite plutons in the Central Magnetic Province.
- 5) The apparent lack of a basement in the Central Magnetic Province.

Ding and James (1985) consider this assemblage to be similar to a geosynclinal basin sequence, varying from platform shelf-facies (orthoquartzite-carbonate) to deeper water monotonous pelites and semi-pelites, possibly deposited within a simple aulacogen developed on an underlying rifted crystalline basement complex. They consider its orogenic evolution typical of compressional/ collision tectonics of a continental margin.

The third orogenic stage is markedly different from preceding stages. It began with juxtaposition of the provinces through displacement along the fault or thrusts BCT_1 , BCT_2 and BCT_3 . This occurred after early isoclinal folding in all provinces, granite emplacement in the Northern Magnetic Province (1700 - 1850 Ma) and inferred dolerite dyke intrusion in the Southern Magnetic Province. These faults have been folded and truncated by subsequent deformation so that only sections of them are still evident on aeromagnetic maps. Mylonites developed along BCT_2 , which is considered by Ding and James to be a basal decollement separating basement of the Western Magnetic Province from the metasedimentary cover sequence of the Central Magnetic Province. Both the BCT_1 and BCT_2 fault planes are intruded by magnetic igneous bodies (Bruna Gneiss) and may form a single decollement surface below the Central Magnetic Province, separating it from the underlying basement.

BCT_2 and BCT_3 were subsequently subjected to isoclinal to tight folding (BCF_1), and then together with BCT_1 , to at least two phases of open, upright folding which remobilised the basement and cover of all four magnetic provinces and formed the Entia and Plenty Downs Domes (Fig. 3.3). Isoclinal to tight folding of magnetic marker horizons in the Southern Magnetic Province may have been synchronous with BCF_1 , particularly if these magnetic features are dolerite dykes of the Stuart Dyke Swarm (897 ± 9 Ma). The change in deformation from displacement along the faults BCT_1 , BCT_2 and BCT_3 to ductile folding of these features is thought to have been due to crustal thickening and associated isostatic subsidence (Ding & James, 1985).

The fourth stage of deformation involved dislocation and truncation of earlier structures, in all four magnetic provinces, along NW to WNW and N to NE trending faults. Shaw et al (1984) consider many of these faults to have formed early in the Inliers history, being subsequently intermittently reactivated. The fourth orogenic phase possibly culminated during the Alice Springs Orogeny (300 - 400 Ma) with NE thrusting of the Arunta Inlier over the Georgina Basin along the Tarlton Fault. Similar thrusting elsewhere in the Arunta Inlier is also attributed to the Alice Springs Orogeny (Shaw et. al., 1984). Many NW-trending strike-slip faults probably formed to accomodate shortening in the upper crust during thrusting and their development was accompanied by greenschist facies retrogression along fault planes.

The final stage of deformation involved epeirogenesis, resulting in slight warping of the magnetic provinces, which form a series of convex arcs. WNW to NW elongation of many large structures may also be related to this late stage.

8.2 CONCLUDING REMARKS AND RECOMMENDATIONS

In geology we deal with natural systems which are extremely complex and data which is at best fragmentary. Our understanding of geological processes and systems can only advance through the patient, objective accumulation of facts and their progressive supplementation and re-evaluation. The importance of formulating ideas which fit the available facts, through deduction and inspiration is an important part of this process. However, any scientific theory should deliberately be tested and if necessary, modified, in order to gain credence and eventually may be accepted or refuted on the basis of available fact. The aeromagnetic interpretation presented here, and its integration with rock property, geological and other geophysical data, has provided a basis for the review and expansion of current lithostratigraphic and tectonic concepts of the eastern Arunta Inlier. It is hoped the lithological subdivision and structural history proposed as a result of this data synthesis will provide a model for further geological investigation and a stimulus for exploration in this region. The relevance of this interpretation will be tested, and the model modified, by future work, for this is part of the "scientific method". Rock property and magnetic petrophysics observations of chapter 2, and much of the information on the interpretation maps enclosed at the rear of this thesis, provide more lasting factual information which may be utilized and extended by future researchers.

Reprocessing of the existing digital aeromagnetic data is highly recommended prior to future interpretation. Image processing leading to the production of total field and derivative images at various scales, would be invaluable in providing different perspectives of the area. This may alleviate problems experienced in distinguishing weakly magnetic units and small scale structures. Future collection of high sensitivity aeromagnetic data at a close line spacing and lower flying height would, of course, also

alleviate these problems. It is recommended that in future, gridded tapes of aeromagnetic and radiometric data, produced during compilation, be requested as standard products along with the located data tapes. This would facilitate ease of subsequent 1-D or 2-D reprocessing. The gridding interval should be carefully chosen to extract the maximum information from the data, rather than for ease of compilation and presentation as often appears to be the case.

Finally it is hoped the interpretation procedure employed here will help guide future aeromagnetic interpretation. The collection of magnetic property and magnetic petrophysics data is considered a necessary part of this procedure, but is rarely included in most studies. Considering its invaluable contribution to the understanding of the magnetic properties of rocks and their associated aeromagnetic signatures, it is recommended that the collection of rock property data in conjunction with geological mapping should be standard practise. This data should be used to create an Australia wide rock property data base readily accessible to the mineral and other industries. At present the aeromagnetic method remains a highly utilized but under-interpreted aid to regional and detailed geological mapping, largely wasting the capital spent on acquisition. This is largely due to the time, labour and expense required to thoroughly interpret the vast amount of data collected. As in this case, possibly what is needed is closer co-operation between government organisations, industry and universities in a concerted effort to extract the wealth of geological information contained in this data.

Bibliography

ALLEN A.R. & BLACK L.P. 1979. The Harry Creek Deformed Zone, a retrograde schist zone of the Arunta Block, Central Australia. *J. Geol. Soc. Aust.* 26, 17-28.

ALLEN A.R. & STUBBS D. 1982. An $\text{Ar}^{40}/\text{Ar}^{39}$ study of a polymetamorphic complex in the Arunta Block, Central Australia. *Contrib. Mineral. Petrol.* 79, 319-332.

ANDERSON. 1942. The dynamics of faulting and dyke formation with applications to Britain. *Oliver & Boyd, London*, 206pp.

ANTILOFF W. & SHAW R.D. 1973. The gravity effects of three large uplifted granulite blocks in separate Australian shield areas. *Symp. Earth's Gravity Field and Secular Variations in Position, Proc. pp.* 273-289.

ANTILOFF W. 1978. Discussion. Gravity trends and the growth of Australia: a tentative correlation. *J. Geol. Soc. Aust.* 25, 2.

ARMSTRONG R.L. & STEWART A.J. 1975. Rubidium-Strontium dates and extraneous argon in the Altunga Nappe Complex, Northern Territory. *J. Geol. Soc. Aust.* 22, 103-115.

BALSLEY J.R. & BUDDINGTON A.F. 1958. Iron-titanium oxide minerals, rocks, and aeromagnetic anomalies of the Adirondack area, New York. *Econ. Geol.* 53, 777-805.

BARRACLOUGH D. 1979. E.L. 1727. Molyhill West final report. Anaconda Australia Inc. *N.T.G. S. open file Rpt. CR 79/156*.

BEACH A. & FYFE W.S. 1972. Fluid transport and shear zones at Scourie, Southerland: evidence of overthrusting? *Contrib. Mineral. Petrol.* 36, 175-180.

BHATHAL R.S. 1971. Magnetic Anisotropy In Rocks. *Earth Sci. Review.* 7.

BHATTACHARYYA B.K. 1972. Design of spatial filters and their application to high resolution aeromagnetic data. *Geophys.* 37, No. 1.

B.H.P. PTY. LTD. 1982. Exploration Licence 3510. Crossing Bore. *N.T.G.S. open file Rpt. CR*

82/287.

B.H.P. PTY. LTD. 1984. Exploration Licence 4072 and 4073. Atulu West and Atulu East, N.T. final report. *N.T.G.S. open file Rpt. CR 84/6*.

B.H.P. PTY. LTD. 1984. Lucy Creek, N.T. Exploration Licence 4189. Huckitta 1:250,000 sheet. Final report for 12 month period ending 10th May 1984. *N.T.G.S. open file Rpt. 84/89A*.

BLACK L.P. 1975. Present status of geochronological research in the Arunta Block, N.T. *Geol. Soc. Aust., 1st Aust. Geol. Conv., Abstr. p. 37*.

BLACK L.P. 1980. Rb-Sr geochronology of the Jervois Range area in the eastern part of the Arunta Block, N.T. *BMR J. Aust. Geol. Geophys. 5, 265-270*.

BLACK L.P. 1984. Rb-Sr geochronological study in the Proterozoic Tennant Creek Block, Central Australia. *BMR J. Aust. Geol. Geophys. 2, 111-122*.

BLACK L.P. & GULSON B.L. 1978. The age of the Mud Tank Carbonatite, Strangways Range, Northern Territory. *BMR J. Aust. Geol. Geophys. 3, 227-232*.

BLACK L.P., SHAW R.D. & OFFE L.A. 1980. The age of the Stuart Dyke Swarm and its bearing on the onset of Late Precambrian sedimentation in Central Australia. *J. Geol. Soc. Aust. 27, 151-155*.

BLACK L.P., SHAW R.D., & STEWART A.J. 1983. Rb-Sr geochronology of Proterozoic events in the Arunta Inlier, Central Australia. *BMR J. Aust. Geol. Geophys. 8, 129-138*.

BLACK L.P. & McCULLOCH M.T. 1984. Sm-Nd ages of the Arunta, Tennant Creek, and Georgetown Inliers of Northern Australia. *Aust. J. Earth Sci. 31, 49-60*.

BMR. 1971. *Aust. Bur. Miner. Resour., Geol. Geophys., Rec. 120*.

BOTT M.H.P. 1982. The Mechanism of Continental Splitting. *Tectonophysics. 81, 301-309*.

BOWEN B.K., HENSTRIDGE D.A. & PAINE G.G. 1972. A note on the geology of scheelite mineralization, Gonya Bore area. N.T. Central Pacific Minerals N.L. *N.T.G.S. open file Rpt. CR 72/104*.

BOWYER D.G. 1982. The Geology of the Harts Range N.T. Aust. Petrology, Geochemistry and Structure. *Hons. Thesis, University Adelaide (unpublished)*.

BUDDINGTON A.F. & LINDSLEY D.H. 1964. Iron-titanium oxide minerals and synthetic equivalents. *J. Petrol. 5, 310-357*.

CARMICHAEL C.M. 1961. The magnetic properties of ilmenite-haematite crystals. *Proc. R. Soc. 263, 508-530*.

CLARK D.A. 1983. Comments on Magnetic Petrophysics. *Aust. Soc. Explor. Geophys. Bull. 14, 40-62*.

- COMPSTON W. & ARRIENS P.A. 1968. The Precambrian geochronology of Australia. *Can. J. Earth Sci.* 5, 561-583.
- CROHN P.W. 1971. Investigations at the Strangways Range carbonatite locality N.T. 1969-1970. *N.T.G.S. Rec.* 1.
- DING P. & JAMES P.R. 1985. Structural evolution of the Harts Range area and its implications for the development of the Arunta Block, Central Australia. *Precam. Res.* 27, 251-276.
- DOBOS S.K. 1975. Metamorphism in the northeast Arunta Block N.T. *Geol. Soc. Aust. Inc., 1st. Aust. Geol. Conv., Abstr.*
- DOBOS S.K. 1978. Phase relations, element distributions, and geochemistry of metamorphic rocks from the eastern Arunta Block, Northern Territory. *Ph.D. thesis, Macquarie University. (unpublished).*
- DOOLEY J.C. 1976. Variation of crustal mass over the Australia region. *BMR J. Aust. Geol. Geophys.* 1, 291-296.
- DUFF B.A. & LANGWORTHY A.P. 1974. Orogenic zones in Central Australia: intraplate tectonics? *Nature.* 249, 645-647.
- DUNLOP D.J. 1981. The rock magnetism of fine particles. *Phys. Earth Planet. Inter.* 13, 1-26.
- EMERSON D.W. 1979. Comments on applied magnetics in mineral exploration. *Aust. Soc. Explor. Geophys. Bull.* 10, 3-5.
- EVANS M.E. & McELHINNEY M.W. 1969. An investigation of the origin of stable remanence in magnetite-bearing igneous rocks *J. Geomag. Geoelect.* 21, 757-766.
- FORMAN D.J. & SHAW R.D. 1973. Deformation of crust and mantle in Central Australia. *Aust., Bur. Miner. Resour., Geol. Geophys., Bull.* 144.
- FREEMAN M.J. 1979. Dneiper, Middle Dam locality - completion report on DDH MD1. *N.T.G.S. Rpt. GS79/20. (unpublished).*
- FREEMAN M.J. 1:250,000 Geological Map Series explanatory notes, Huckitta SF53-11. *Government printer, N.T.G.S. (in press).*
- FRENCH D.J. 1981. Drilling in the Plenty River Area - 1980. AFMECO Pty. Ltd. *N.T.G.S. open file Rpt., CR81/96.*
- FRENCH D.J. 1981. Drilling in the Illogwa Creek Area - 1980. AFMECO Pty. Ltd. *N.T.G.S. open file Rpt., CR 81/94.*
- GEDDE R. 1971. Final report for prospecting authority 2190, Huckitta. Vam Ltd. *N.T.G.S. open file Rpt. CR 71/68.*
- GOSCOMBE B.D. 1984. The structure, metamorphism, petrology and geochemistry of the Par-

adise Well area in the Harts Ranges, eastern Arunta Block. *Hons. Thesis, University of Adelaide. (unpublished).*

GRANT F.S. 1985. Aeromagnetism, geology and ore environments, I. Magnetite in igneous, sedimentary and metamorphic rocks: an overview. *Geoexploration*. 23, 303-333.

GUPTA V.K. & BURKE K.B.S. 1977. Density and magnetic susceptibility measurements in southeastern New Brunswick. *Can. J. Earth Sci.* 14, 1281-1293.

HAGGERTY S.E. 1976. Opaque mineral oxides in terrestrial igneous rocks. In: D. Rumble III (Editor), *Oxide Minerals. Miner. Soc. Am., Short Course Notes, Hg 101-300.*

HAGGERTY S.E. 1979. The aeromagnetic mineralogy of igneous rocks. *Can. J. Earth Sci.* 16, 1281-1293.

HARGRAVES R.B. & YOUNG W.M. 1969. Source of stable remanent magnetism in Lambertville diabase. *Am. J. Sci.* 267, 1161-1177.

HARVEY B.E. 1982. E.L. 2789 Macdonald Downs, N.T. CRAE annual report. *N.T.G.S. open file Rpt. CR 82/195.*

HARVEY B.E. 1983a. E.L. 2788 Fraser Creek, N.T., Arunta Block. CRAE final report, *N.T.G.S. open file Rpt. CR 83/298.*

HARVEY B.E. 1983b. E.L. 4074, Huckitta Creek, Arunta Block. CRAE final report. *N.T.G.S. open file CR 83/297.*

HARVEY B.E. 1983c. E.L. 4018, Atula Bore, Arunta Block. CRAE final report. *N.T.G.S. open file Rpt. CR 83/296.*

HARVEY B.E. 1983d. E.L. 4017, Red Tank, Arunta Block. CRAE final report. *N.T.G.S. open file Rpt. CR 83/295.*

HARVEY B.E. 1983e. E.L. 2789, Macdonald Downs, N.T. CRAE final report. *N.T.G.S. open file Rpt. CR 83/294.*

HENKEL H. 1976. Studies of density and magnetic properties of rocks from northern Sweden. *Pure Appl. Geophys.* 114, 235-249.

HENKEL H. & GUZMAN M. 1977. Magnetic features of fracture zones. *Geoexploration* 15, 173-181.

HILL J.H. 1972. Progress report NT34 on AP 2283 and 3158, with special reference to fluorite potential, Jinka Plain and Oorabra, N.T. Central Pacific Minerals N.L. *N.T.G.S. open file Rpt. CR 72/13.*

HODGE-SMITH T. 1932. Geological and mineralogical observations in central Australia. *Aust. Mus., Rec.* 18, 415-442.

HORSFALL C.L. 1981. Notes on ground magnetometer and scintillometer traverses 1 and 2, Jervois Range area, Huckitta 1:250,000 sheet SF53-11. *N.T.G.S. Rpt. GS 81/27 (unpublished)*.

HOWARD R.W. 1981. Exploration for uranium in the Huckitta Basin, Central Australia, 1980. *N.T.G.S. open file report CR 81/180*.

JENSEN H.I. 1944. The geology of central Australia. *R. Soc. Qld., Proc.* 56, 85-94.

JENSEN H.I. 1947. The origin, distribution and mode of occurrence of mica in central Australia. *R. Soc. Qld., Proc.* 57, 37-52.

JOKLIK G.F. 1955. The geology and mica fields of the Harts Range, central Australia. *Aust. Bur. Miner. Resour., Geol. Geophys., Bull.* 26.

KATZ M.B. 1981. Note on the layered anorthosite complex of the Harts Range ruby deposit in the Arunta Block, central Australia. *J. Geol. Soc. Aust.* 28, 247-248.

KRUTIKHOUSKAYA Z.A., SILINA I.M., BONDAREVA N.M. & PODOLYANKO S.M. 1979. Relation of magnetic properties of the Ukrainian Shield to their composition and metamorphism. *Can. J. Earth Sci.* 16, 984-991.

LAMBECK K. 1983. Structure and evolution of the intracratonic basins of central Australia. *Geophys. J.* 74.

LAMBECK K. 1984. Structure and evolution of the Amadeus, Officer and Ngalia Basins of central Australia. *Aust. J. Earth Sci.* 31, 25-49.

LANGWORTHY A.P. & BLACK L.P. 1978. The Mordor Complex: a highly differentiated potassic intrusion with kimberlite affinities in central Australia. *Contrib. Mineral. Petrol.* 67, 51-62.

LARGE R.L. 1977. Chemical evolution and zonation of massive sulphide deposits in volcanic terrains. *Econ. Geol.* 72, 549-572.

LAWRENCE, R. The structure and metamorphism of the Irindina supracrustal assemblage on the western side of the Entia Dome, Harts Range, central Australia. *Ph.D. Thesis, University Adelaide (in prep., unpublished)*.

MARJORIBANKS R.W. & BLACK L.P. 1974. Geology and geochronology of the Arunta Complex north of Ormiston Gorge. Central Australia. *J. Geol. Soc. Aust.* 21, 291-300.

MARTIN A. 1983. The geology and structural geology of the Harts Range Group on the east flank of the Entia Dome, eastern Arunta Block, N.T. *Hons. Thesis, University Adelaide. (unpublished)*.

MATHUR S.P. 1976. Relation of Bouguer anomalies to crustal structure in southwestern and central Australia. *BMR J. Aust. Geol. Geophys.* 1, 277-286.

McGRATH P.H. 1975. A two-dimensional first vertical derivative operator. *Geol. Surv. Can. Paper.* 75-1, part A.

McINTYRE J.I. & WYATT B.W. 1978. Contributions to the regional geology of the Broken Hill area from geophysical data. *BMR J. Aust. Geol. Geophys.* 3, 265-280.

McINTYRE J.I. 1980. Geological significance of magnetic patterns related to magnetite in sediments and metasediments - a review. *Aust. Soc. Explor. Geophys. Bull.* 11, 19-33.

McINTYRE J.I. 1981. Accurate display of fine detail in aeromagnetic data. *Aust. Soc. Explor. Geophys. Bull.* 12.

MOODY J.B. 1976. Serpentinization: a review. *Lithos.* 9, 125-138.

MORGAN W.R. 1959. The petrology of the Jervois Range mining area. *Aust. Bur. Miner. Resour., Geol. Geophys., Rec.* 1959/109.

MURTHY G.S., PATZOLD R. & BROWN C. 1981. Source of stable remanence in certain intrusive rocks. *Phys. Earth Planet. Inter.* 26, 72-80.

MUTTON A.J. & SHAW R.D. 1979. Physical property measurements as an aid to magnetic interpretation in basement terrains. *Aust. Soc. Explor. Geophys. Bull.* 10.

MUTTON A.J., SHAW R.D. & WILKES P.G. 1983. Analyses of geological, geophysical and physical property data from the southwest Arunta Block, N.T. *Aust. Bur. Miner. Resour., Geol. Geophys., Rec.* 1.

OFFE L.A. & SHAW R.D. 1983. Alice Springs region 1:100 000 Geological Series. *Aust. Bur. Miner. Resour., Geol. Geophys., Map Commentary.*

OSBORNE E.F. 1962. Reduction series for subalkaline igneous rocks based on different oxygen pressure conditions. *Am. Miner.* 57, 211-226.

PAINE J.W. 1986. A comparison of methods for approximating the vertical gradient of one-dimensional magnetic field data. *Geophysics*, 51, 1725-1735.

PETERS M., KEHRENS P. & VAN GILS H. 1985 Geology and mineralisation of the Jervois Range, Northern Territory. *MSc. Thesis, State University of Utrecht*, 128pp.

PLUMB K.A. 1979. Structure and tectonic style of the Precambrian shields and platforms of northern Australia. *Tectonophysics*, 58, 291-325.

PLUMB K.A. 1979. The tectonic evolution of Australia. *Earth Sci. Rev.* 14, 205-249.

PLUMB K.A. 1985. Subdivision and correlation of late Precambrian sequences in Australia. *Precamb. Res.* 29, 316-326.

PURANEN M., MARMO V., & HAMALAINEN U. 1968. On the geology, aeromagnetic anomalies and susceptibilities of Precambrian rocks in the Virrat region (central Finland). *Geoexploration* 6, 163-184.

- RAMSAY J.G. 1967. Folding and fracturing of rocks. *McGraw-Hill, New York, 568pp.*
- RANKIN L.R. 1983. The structural geology and fabric development in the Mt. Mabel area of the Harts Range, eastern Arunta Block. *Hons. Thesis, University Adelaide. (unpublished).*
- ROBERTSON W.A. 1959. Jervois Range copper-lead deposits, Northern Territory. *Aust. Bur. Miner. Resour., Geol. Geophys., Rec. 1959/103.*
- RUMBLE D. III. (ed). 1976. Oxide minerals. *Mineral. Soc. Am., Short Course Notes. (Washington).*
- RUTLAND R.W.R. 1981. Structural framework of the Australian Precambrian. In: D.R. Hunter (ed). *Precambrian of the Southern Hemisphere.*
- SHAW R.D. & STEWART A.J. 1973. Regional geology of the Precambrian Arunta Block. *Aust. Bur. Miner. Resour., Geol. Geophys., Rec. 94, (unpublished).*
- SHAW R.D. & STEWART A.J. 1975. Towards a stratigraphy of the Arunta Block. *Geol. Soc. Aust., 1st Aust. Geol. Conv., Abstr., p35.*
- SHAW R.D., LANGWORTHY A.P., OFFE L.A., STEWART A.J., ALLAN A.R., SENIOR B.R. & CLARK D. 1979. Geological report on 1:100 000 scale mapping of the southeastern Arunta Block, N.T. *Aust. Bur. Miner. Resour., Geol. Geophys., Rec. 47, (unpublished).*
- SHAW R.D., FREEMAN M.J., OFFE L.A. & SENIOR B.R. 1982. Geology of the Ilogwa Creek 1:250 000 Sheet area. Central Australia. *Aust. Bur. Miner. Resour., Geol. Geophys., Rec. 23, (unpublished).*
- SHAW R.D. & WELLS A.J. 1983. Explanatory notes, Alice Springs, Northern Territory (2nd Ed). *Aust. Bur. Miner. Resour., Geol. Geophys., 1:250 000 Geol. Series. Sheet SF-14.*
- SHAW R.D., STEWART A.J. & BLACK L.P. 1984. The Arunta Inlier: a complex ensialic mobile belt in central Australia. Part 2: tectonic history. *Aust. J. Earth Sci. 31, 457-484.*
- SHAW R.D., STEWART A.J. & RICKARD M.J. in prep. Geology of the Arltunga - Harts Range region, N.T. *Aust. Bur. Miner. Resour., Geol. Geophys., 1:100 000 Geol. Map Commentary.*
- SMITH K.G. 1963. Explanatory notes, Huckitta, N.T. *Aust. Bur. Miner. Resour., Geol. Geophys., 1:250 000 Geol. Series, Sheet SF/53-11.*
- STACEY F.D. & BANERJEE S.K. 1974. The physical principles of rock magnetism. *Developments in solid earth geophysics, 5, Elsevier, Amsterdam.*
- STANTON R.L. 1976. Petrochemical studies of the ore environment at Broken Hill, N.S.W. *Inst. Min. Met. (London) Trans./Section B. 85, 36-46, 118-131, 131-141, 221-233.*
- STEWART A.J. 1971. K-Ar dates from the Arltunga Nappe Complex, N.T. *J. Geol. Soc. Aust. 17, 205-211.*

STEWART A.J. & WARREN R.G. 1977. The mineral potential of the Arunta Block, central Australia. *BMR J. Aust. Geol. Geophys.* 2, 21-34.

STEWART A.J., SHAW R.D., OFFE L.A., LANGWORTHY A.P., WARREN R.G., ALLEN A.R. & CLARKE D.B. 1980. Stratigraphic definitions of named units in the Arunta Block, N.T. *Aust. Bur. Miner. Resour., Geol. Geophys., Rep.* 216.

STEWART A.J., SHAW R.D. & BLACK L.P. 1984. The Arunta Inlier: a complex ensialic mobile belt in central Australia. Part 1: stratigraphy, correlations and origin. *Aust. J. Earth Sci.* 31, 445-456.

STEWART K.P. 1985. The petrological significance of calc-silicate and associated gneisses, Inkamulla Bore area, Entia Dome, Harts Range, eastern Arunta Block. *Hons. Thesis, University Adelaide*. (unpublished).

SULLIVAN S.J. 1985. A detailed geological investigation of the Entia gneiss and leucocratic gneiss intrusive, northern Entia Dome, Harts Ranges, eastern Arunta Block. *Hons. Thesis, University Adelaide*. (unpublished).

THOMPSON J.B. 1972. Oxides and sulphides in regional metamorphism of pelitic schists. *24th Inter. Geol. Cong.*, 10, 27-35.

TSAY L.J. 1978. A spatial analysis of upward continuation of potential field data. *Geophys. Prospecting* 26, 822-840.

WALTER M.R. 1980. Adelaidean and early Cambrian stratigraphy of the southwestern Georgina Basin: Correlation chart and explanatory notes. *Aust. Bur. Miner. Resour., Geol. Geophys., Rep.* 214.

WARREN R.G., STEWART A.J. & SHAW R.D. 1975. Arunta Block - mineralization. In Knight C.L. (ed), *Ec. Geol. Aust. Papua New Guinea. Aus. I.M.M. Monograph*.

WARREN R.G. 1978. Delny-Mount Sainthill Fault System, eastern Arunta Block, central Australia. *BMR J. Aust. Geol. Geophys.* 3, 76-79.

WARREN R.G. 1980. Summary descriptions of mineral deposits by commodities in the Alice Springs 1:250 000 sheet area, N.T. *Aust. Bur. Miner. Resour., Geol. Geophys., Rec.* 44.

WARREN R.G. 1980. The Arunta Block in the Huckitta 1:250 000 sheet area: a review to June 1980. *Aust. Bur. Miner. Resour., Geol. Geophys., Rec.* 45.

WARREN R.G. 1981. Tectonic setting of the easternmost Arunta Block. *Aust. Bur. Miner. Resour., Geol. Geophys., Rep.* 221.

WARREN & McCOLL D.H. 1983. Occurrences of boron-bearing kornerupine in the western Harts Range and near Mount Baldwin, Arunta Block, central Australia. *BMR J. Aust. Geol. Geophys.* 8, 93-96.

WARREN R.G. 1983. Metamorphic and tectonic evolution of granulites, Arunta Block, central Australia. *Nature*, 305.

WATSON D.P. 1975. Attuttra copper lead and scheelite zone Jervois Range. In Knight C.L. (ed), *Geol. Aust. Papua New Guinea. Aus. I.M.M. Monograph.*

WELLMAN P. 1976. Gravity trends and the growth of Australia: a tentative correlation. *J. Geol. Soc. Aust.* 23, 11-14.

WELLS A.T. & MOSS F.J. 1983. The Ngalia Basin, Northern Territory: stratigraphy and structure. *Aust. Bur. Miner. Resour., Geol. Geophys., Bull.* 212.

WHITING T.H. 1986. Aeromagnetism as an aid to geological mapping - a case history from the Arunta Inlier, Northern Territory. *Aust. J. Earth Sci.* 33, 271-286.

WILSON A.F., COMPSTON W., JEFFERY P.M. & RILEY G.H. 1960. Radioactive ages from the Precambrian rocks of Australia. *J. Geol. Soc. Aust.* 6, 179-195.

YPMA P., DeBOORDER H., Van GILS H., KEHRENS P., ORMSBY W. & PETERS M. 1984. Geology and mineralisation of the Jervois Range, N.T. *Aus. I.M.M. Conference, Darwin, N.T.*, 319-321.

ZEITZ I. & BHATTACHARYYA R.K. 1975. Magnetic anomalies over the continents and their analyses. *Rev. Geophys. Space Phys.* 13, 176-179.

Appendix A

Data Processing and Interpretation Technique

Aeromagnetic coverage of the eastern Arunta Inlier varies in its quality and detail. This appendix outlines the sources of this data, the accuracy of acquisition methods used and subsequent reprocessing and interpretation techniques applied during the course of this study. The methodology employed for data processing and interpretation was not unique, but incorporated some of the best techniques currently available, in an overall interpretation procedure designed to achieve the stated aims of the thesis.

Auxiliary geophysical information, which is largely radiometrics and gravity data, were of secondary importance in comparison to the aeromagnetic data, due to the masking effect of extensive overburden on the former and the coarse sampling interval and resultant regional nature of the latter. Consequently no reprocessing and only limited interpretation of this data was attempted.

INDEX TO 1:100 000 SHEETS AND AEROMAGNETIC SURVEYS

	Flown by Aero Service Ltd, under contract to BMR, 1962.	Traverse Line Spacing — 5 miles Traverse Line Direction — EW Nominal Terrain Clearance — 2000 feet	Nominal Sampling Interval — Continuous analogue recording Navigation and Recovery — Conventional photography
	Flown by Geophysical Resources Development Company, under contract to Russgar N.L., 1970.	Traverse Line Spacing — 1/4 mile Traverse Line Direction — NS Nominal Terrain Clearance — 300 feet	Nominal Sampling Interval — Continuous analogue recording Navigation and Recovery — Conventional photography onto photomosaic
	Flown by Geophysical Resources Development Company, under contract to Arcadia Minerals Ltd, 1970.	Traverse Line Spacing — 1/8 mile Traverse Line Direction — EW Nominal Terrain Clearance — 300 feet	Nominal Sampling Interval — Continuous analogue recording Navigation and Recovery — Conventional photography onto photomosaic
	Flown by EG & G Geometrics International Corporation, under contract to N.T. Department of Mines and Energy, 1981.	Traverse Line Spacing — 500 metres Tie Line Spacing — 5000 metres Traverse Line Direction — NS Nominal Terrain Clearance — 100 metres Nominal Sampling Interval — 55 metres	Acquisition Interval — 1.0 second Navigation and Recovery — Conventional photography, Doppler assisted Proton Magnetometer Sensitivity 0.5nT Precision 1.0nT
	Flown by Austrex International Ltd, under contract to N.T. Department of Mines and Energy, 1983.	Traverse Line Spacing — 500 metres Tie Line Spacing — 5000 metres Traverse Line Direction — NS Nominal Terrain Clearance — 100 metres Nominal Sampling Interval — 50 metres	Acquisition Interval — 0.7 second Navigation and Recovery — Conventional photography; Doppler assisted Proton Magnetometer Sensitivity 00.1nT Precision 0.5nT
	Flown by Austrex International Ltd, under contract to the Plenty River Mining Company Ltd, 1983.	Traverse Line Spacing — 250 metres Tie Line Spacing — 2500 metres Traverse Line Direction — EW Nominal Terrain Clearance — 80 metres Nominal Sampling Interval — 50 metres	Acquisition Interval — 0.7 second Navigation and Recovery — Conventional photography; Doppler assisted Proton Magnetometer Sensitivity 00.1nT Precision 0.5nT

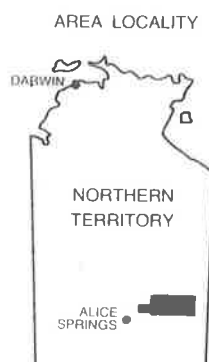
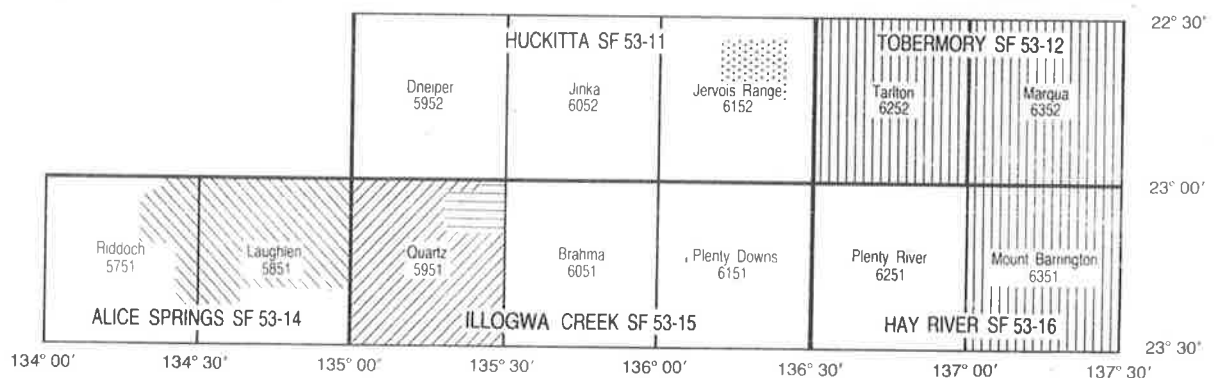


Figure A.1 Location of aeromagnetic surveys covering the study area.

A.1 DATA PROCESSING

The location of surveys used for interpretation, and details of survey specifications are shown in Figure A.1.

Surveys 2 and 3 were not digitally recorded, and as original analogues were unavailable, no reprocessing of this data was possible, interpretation being limited to qualitative scrutiny of contour maps supplied (NTGS open file). The high survey altitude and coarse sampling interval of survey 1 did not allow detailed interpretation and consequently reprocessing of this data was also not attempted. The remaining 80% of the study area is covered by relatively detailed (250-500m line spacing), digitally acquired aeromagnetic data (Surveys 4, 5 & 6). Total field contour maps and profiles were produced at a scale of 1:100,000 during compilation of surveys 4 and 5. The scale of presentation, wide grid interval and poor contour dropouts of these maps resulted in a significant loss of detail which made reprocessing desirable. Similarly, although 1:25,000 scale total intensity contour maps were compiled for survey 6, no profiled data suitable for detailed interpretation was available.

Reprocessing primarily consisted of plotting multiparameter profiles from located data tapes supplied by the NTGS (Surveys 4 & 5) and the Plenty River Mining Company (Survey 6). A profiling program utilizing the Adelaide University Cyber 173 processor linked to a 80cm Calcomp drum plotter was written for this purpose. Each profile is presented on a separate sheet at a horizontal scale of 1:50,000 for surveys 4 and 5 (except *MARQUA*, produced at 1:100,000) and 1:25,000 for survey 6. Five parameters were plotted with the following vertical scales:

- Trace 1; Altitude at a vertical scale dependent on the range of values recorded.
- Trace 2; Computed vertical gradient at a vertical scale of 100 or 200nT/km/cm depending on the range of values recorded.
- Trace 3; Fine total magnetic intensity at a vertical scale of 10 or 20nT/cm depending on the range of values recorded.
- Trace 4; Coarse total magnetic intensity at a vertical scale of 50 or 100nT/km depending on the range of values recorded.
- Trace 5; Total magnetic intensity upward continued to 1000 metres and presented at a vertical scale of 20nT/cm.

Values of latitude, determined for each sample on located data tapes, were used for horizontal scaling to ensure profiles were of a uniform scale. Fiducials are marked every 10 readings to allow correlation with flight path and contour maps. Approximately 1000 profiles were produced and are available for inspection and copying from the NTGS, Darwin.

Total field data was presented at two vertical scales so that large and small amplitude anomalies could be interpreted conveniently. Vertical gradient was computed along each profile through weighting the total field data (sampling interval of 1, differencing interval of 4) using coefficients determined by Paine (1986). The vertical gradient improves resolution of closely spaced magnetic bodies, emphasizes shallower markers superimposed on deeper regional trends and amplifies minor geological contrasts not easily detectable on total field data. Its superior resolution is readily apparent from the comparison of

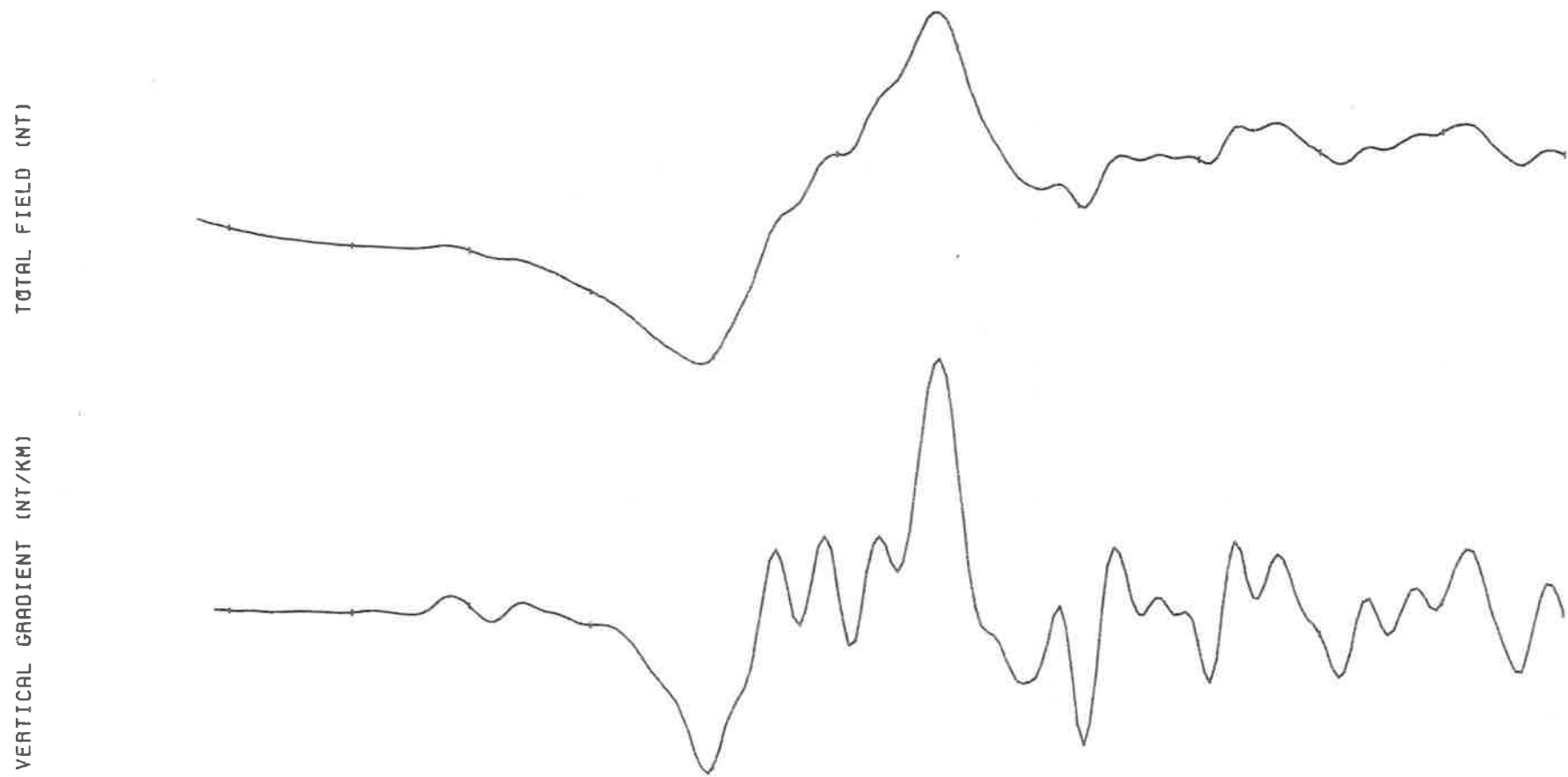


Figure A.2 Aeromagnetic profile demonstrating the superior resolution of vertical gradient over total field data.

total field and vertical gradient profiles illustrated in Figure A.2. For the converse case of emphasizing deeper anomalies masked by shallow sources, total field data was upward continued to 1000 metres using an operator developed by Tsay (1978).

Gridded data used to produce residual total magnetic intensity contours for survey 6 was utilized to produce grey scale and colour images of the total field data and computed vertical gradient. Software for the LANDSAT imaging facility at the Department of Geology and Geophysics, Adelaide University was modified for this purpose. A two-dimensional operator developed by the Geological Survey of Canada (McGrath, 1975) was used to compute the vertical gradient. Gridded tapes of surveys 4 and 5 were not available, and since no gridding and contouring package was accessible to the author, no 2D reprocessing of these surveys was attempted. Instead, published total intensity contour and flight path maps were superimposed and enlarged to a working scale of 1:50,000, for ease of reference with multi-profiles of the same scale. However, considering the wide grid interval and poor contour dropouts used in the production of contour maps (in particular survey 4), reprocessing of this data to produce total intensity and derivative contours and/or images at more detailed scales and contour intervals is highly recommended.

As a final step prior to interpretation, contour maps of all surveys were reduced to several uniform scales (1:250,000 & 1:1,000,000), spliced together and coloured to vary the perception of magnetic features not obvious at smaller scales

A.2 INTERPRETATION TECHNIQUE

Interpretation of surveys 4 and 5 was carried out at a working scale of 1:50,000. Much of surveys 2, 3 and 6 are covered by detailed geological mapping, and so interpretation was at a scale of 1:25,000. In order to limit interpretation maps to a practical number and convenient size, the final scale of presentation was 1:100,000. This scale still enables relatively detailed interpretation results to be portrayed.

Figure A.3 outlines the interpretation technique employed. Following the production of multiprofiles, contour maps and images of various parameters at appropriate scales, interpretation could proceed. The routine of interpretation consisted of three stages:

- 1) The study of contour maps and profiled data with regard to anomaly shape, magnitude, strike and density (qualitative interpretation).
- 2) Analysis of anomalies to determine the shape and magnetic properties of their source (quantitative interpretation).
- 3) Integration of aeromagnetic interpretation with geological and auxiliary geophysical data and presentation of results in geological terms.

Prior to qualitative interpretation, the magnetic response expected from bodies of various shape and strike, at the magnetic inclination of the study area (-53°), was studied so that they could be readily recognised. Once established, initial qualitative interpretation involved tracing all positive and negative magnetic axes, no matter how subtle, from profile to profile and carefully marking them on clear overlays to superimposed flight path and contour maps. The computed vertical gradient is invaluable for this purpose due to its superior resolution of closely spaced and superimposed magnetic anomalies.

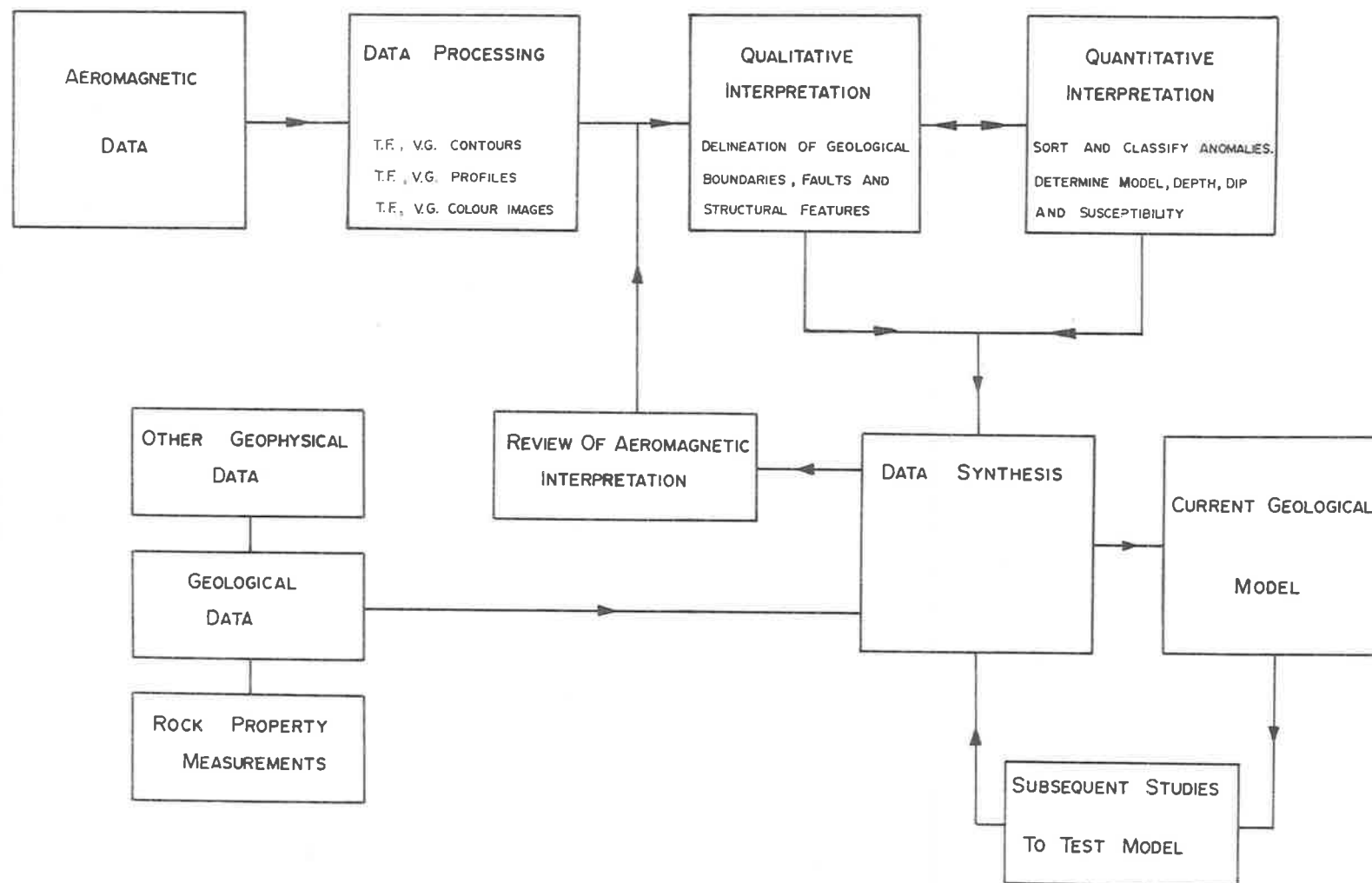


Figure A.3 Diagram outlining the interpretation technique employed.

This process highlighted the magnetic signature of various geological units enabling areas underlain by a common rocktype to be outlined and aiding the delineation of structural features. Major magnetic unit boundaries were outlined by tracing their inflection points on magnetic profiles. Faults were typically interpreted from abrupt terminations and/or displacements of magnetic axes. The relationship between major units and structures was then studied in detail to extract information concerning the relative ages of units and the sequence of structural events. In particular, superimposed fold patterns and the relative timing of faulting, as evidenced from folding of magnetic marker horizons and the relative displacement and/or truncation of faults, was noted. At the conclusion of qualitative interpretation, all significant magnetic anomalies had been recognised and marked on interpretation overlays, and initial ideas regarding the nature and composition of major units and the sequence of structural events was obtained.

The next stage of interpretation involved quantitative interpretation, the prime objective of which was to sort and classify all significant magnetic anomalies according to the depth, width, susceptibility contrast, dip and depth extent of their sources. Since the study area is predominantly one of Precambrian outcrop, most magnetic bodies are near surface and the diagnostic physical parameters of the magnetic survey are the susceptibility contrast, which is a guide to lithology, and the dip and depth extent which provide structural information.

The main quantitative interpretation technique used was the Inflection Tangent Intersection (ITI) method for the interpretation of two-dimensional magnetic anomalies. In this graphical technique, a number of horizontal and vertical parameters of magnetic anomalies are compared to those of theoretical anomalies presented in the form of pre-calculated master charts. Master charts for both total field and computed vertical gradient data are available for the following models:

- 1) Dyke for varying ratios of half width/depth.
- 2) Horizontal thin plate of thickness less than one tenth of the depth to its top surface.
- 3) Thick plate of thickness equal to the depth to its top.
- 4) Step with various ratios of depth to its lower surface/depth to its upper surface.

Many geological features such as extensive dykes or vertically dipping units, faults or contacts, and thin volcanic flows exhibit characteristic patterns on contour maps which dictate the choice of model. In addition, for a given magnetic inclination and excluding the presence of remanence, each model gives rise to magnetic anomalies of different shape. Anomaly amplitude and interpreted susceptibility contrast also guide the choice of model. Corrections were applied for variations from perpendicular in the angle between the strike of the body and that of the magnetic traverse, and for the bodies strike extent.

The main advantage of the ITI method is the number of parameters which may be used for calculation of body depth, width, depth extent, susceptibility contrast and dip. However, where possible ITI calculations were checked using the more conventional maximum-minimum distance, half-amplitude width and half-slope distance methods. At the conclusion of quantitative interpretation, values of depth, apparent susceptibility contrast and dip for all significant magnetic units and bodies were marked on interpretation overlays. Several thousand calculations of this kind are recorded on the magnetic interpretation maps enclosed at the rear of this thesis.

During the final stage of interpretation, the qualitative and quantitative interpretations were related to and synthesized with the known geology, rock property measurements and auxiliary geophysical data. Consistency in relating one magnetic feature with another and the geology was most important during this phase. Model alternatives were reconsidered and the qualitative and quantitative interpretations reviewed. At the culmination of this process detailed analysis of anomalies of particular interest was attempted. This was done through forward modelling or inversion of field data using an interactive graphics program developed by Dr. J. Paine at the University of Adelaide. Model estimates obtained from the ITI method were used as first approximations for the parameters of bodies modelled in these profiles.

The interpretation maps presented in this thesis are therefore the product of qualitative and quantitative aeromagnetic interpretation integrated with geological, rock property and auxiliary geophysical data. They show the distribution and form of major magnetic bodies, units and structures as well as their calculated depth, apparent susceptibility contrast and dip. These maps have been compiled with the aims of the interpretation in mind, in order to combine all available geophysical and geological data from the study area into a consistent and geologically realistic interpretation.

Whiting, T.H. (1986). Aeromagnetism as an aid to geological mapping - a case history from the Arunta Inlier, Northern Territory. *Australian Journal of Earth Sciences*, 33(2), 271-286.

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<http://dx.doi.org/10.1080/08120098608729364>