Paleomagnetic Studies of the Late Miocene Mangapoike River Section, Northern Hawke's Bay, New Zealand

by

Ian Craig Wright

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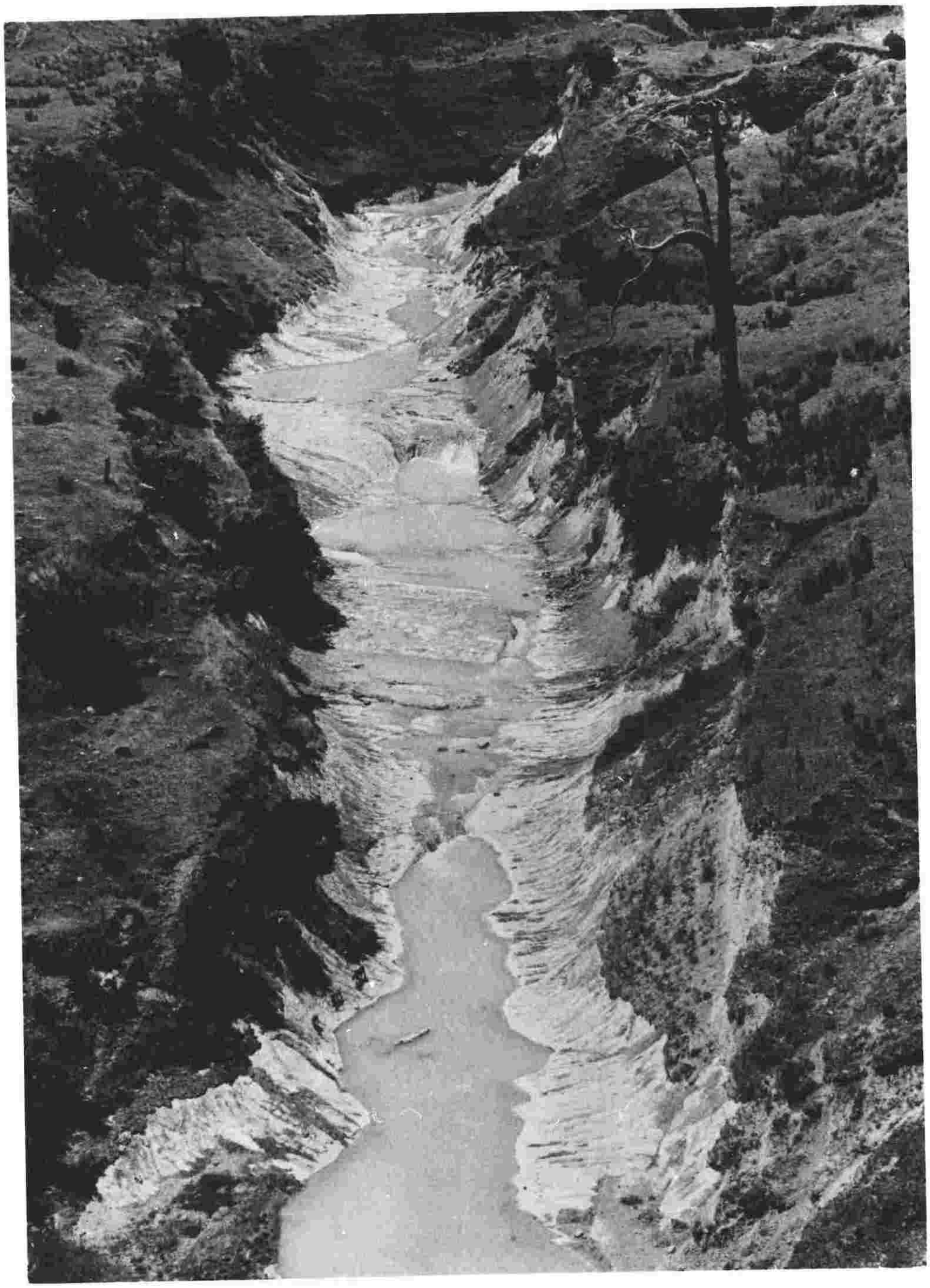
Dedication

This thesis is dedicated to Barby, when I should have been at home and dedicated.



"... the increasing number of Swiss-cheese outcrops in scenic country is disturbing but perhaps unavoidable ..."

Chan and Alvarez (1983).

ABSTRACT

The Mangapoike River section (38.9°S, 177.6°E), on the eastern limb of the Wairoa Syncline, northern Hawke's Bay, is a thick (> 4000 m) and well exposed sequence of Waiauan to Waipipian sediments in which foraminiferal and radiolarian biostratigraphy and silicic tuff lithostratigraphy are well known. An Early Pliocene magnetostratigraphy has been determined by Kennett and Watkins (1974). The present study extends the magnetostratigraphy to the Middle - Late Miocene, and establishes a Late Miocene to Early Pliocene 3000 m magnetostratigraphic reference column for New Zealand.

The only identifiable remanence carrying magnetic mineral in the Mangapoike sediments is titanomagnetite. Its chemistry does not vary with grain size. Oxidation of the titanomagnetite is deuteric, and thus pre-depositional. Fluctuations of titanomagnetite concentration between 10^{-3} to 10^{-4} wt% are the main influence on the variation of NRM intensity. Viscous magnetisations characterised by both the alignment of NRM directions in a general present day field direction and remanence decay and aquisition over laboratory time were recognised in 85% of the 1204 paleomagnetic specimens. Secondary magnetisations were removed by thermal demagnetisation at temperatures varying between 200°C and 320°C. AF demagnetisation was not effective in removing viscous magnetisations, even at peak alternating fields of 35 mT, since the coercivities of the primary and secondary magnetisations overlap completely. The random relationship between the degree of bioturbation and in-site dispersion at individual sites indicates the magnetisation is acquired after bioturbation, and thus is a post-depositional detrital magnetisation. The time lag between deposition and acquisition of the magnetisation is approximately 1000 yrs.

Six normal (MN1 - MN6) and seven reversed (MR1 - MR7) polarity magnetozones are identified within the late Miocene at Mangapoike. Only one normal magnetozone (MN6) is recognised in the stratigraphic interval equivalent to that from which Kennett and Watkins (1974) reported two normal zones (C1 and C2). MN6 is correlated to C2. C1 is inferred to be an uncleaned normal overprint. The magnetozones are correlated to Chrons 11 to 4, which implies an average sedimentation rate of 64 cm/1000 yrs. The previously known Miocene - Pliocene 3° angular unconformity at Mangapoike (Hornibrook 1977) represents the period from 6.3 Ma to at least 5.41 Ma. A previously unrecognised unconformity from at least 6.86 to at least 6.42 Ma is postulated, based on the preferred magnetostratigraphic interpretation. The presence of the unconformity is supported by radiolarian and benthic foraminiferal biostratigraphy.

Three distinct lithological events at Mangapoike, based both on the synchroneity with deep-sea benthic $\delta^{18}O$ records and unconformities of the Vail-curve, are inferred to result from glacioeustatism. At Mangapoike, the Waiauan - Tongaporutuan boundary, as defined by the incoming of *Bolivinita cf pohana*, has a magnetostratigraphic age of 10.3 Ma. Both the LAD of *Loxostomum truncatum* and the FAD of *Bolivinita cf pohana* are less than 42,000 yrs. younger than the late Waiauan glacioeustatic event. The Waiauan - Tongaporutuan boundary is thus postulated to result from glacioeustatism. Glacioeustatism may also explain the excellent age correlation between the base of the Tongaporutuan and the base of the Tortonian stratotype.

Correlation of the late Miocene and early Pliocene magnetostratigraphies and biostratigraphies of on-shore New Zealand with either of the magnetostratigraphic interpretations of DSDP Site 594 results in an unacceptably high diachroneity of some planktic taxa of 1.8 Ma over 3.6° of latitude. Of four possiblities to resolve the anomaly, incorrect magnetostratigraphic correlations at Site 594 is the most likely. The previously determined age of 6.2 Ma for the LAD of *Globoquadrina dehiscens* in New Zealand is erroneous. A magnetostratigraphic age for the LAD of *G. dehiscens* at Mangapoike is 9.2 Ma. This age is not an extinction date for the taxon throughout New Zealand, and the LAD may well be erratic and diachronous within New Zealand.

The Wairoa Syncline, a forearc basin within the Hikurangi margin, has a rotation rate as determined from declination directions, of 7-8°/Ma for the last 5 Ma. Of this less than 1.5°/Ma is due to apparent polar wander of the Australian plate. Extrapolation of this rate towards the present is consistent with a present day rotation rate of 7°/Ma derived from strain analysis of geodetic data. Prior to 10 Ma the rate of tectonic rotation is poorly constrained and may vary between 3°/Ma and 0°/Ma. The change in the rate of rotation of the Wairoa Syncline around 5 Ma is probably related to a marked change in regional tectonic regime involving opening and spreading to the north of New Zealand and compression and shortening to the south.

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My Mum and Dad, Charles and Helen, and friends have been encouraging throughout. Finally, I thank my wife, Barby, whose support and humour has made the experience almost pleasant. I dedicate this thesis to her.

Chapter I
INTRODUCTION

1.1 STUDY AIMS

This thesis establishes a Late Miocene (10.3 to 5.3 Ma) magnetostratigraphic reference column for the New Zealand region. It provides a chronology for the local biostratigraphy allowing worldwide correlation, with a precision of 10^4 years. Isochroneity of planktic biostratigraphic datums is verified. Rock magnetic and microprobe data are used to determine the nature and origin of the observed magnetisation and confirm it is acquired at the time of deposition. Declination directions which are better constrained in age and direction supplement previous paleomagnetic data showing the timing and rate of tectonic rotation within the Wairoa Syncline.

1.2 INTRODUCTION

The thick and well-exposed marine Neogene strata of New Zealand yield an unusually complete record of temperate biostratigraphic and paleoclimatic events (Hoskins, ed. 1982, references therein, and Figs. 1.1 and 1.2). Local planktic microfossil zones (Hornibrook 1958, 1981a, 1984a; Geiger 1962; Jenkins 1967, 1971; Scott 1972; Edwards 1982a; Ashby 1985) are well developed with at least 50 bioevents now recognised within the Neogene (Jenkins 1966; Hornibrook and Edwards 1971; Hornibrook 1981b, 1984b; Edwards 1985). During the Late Cenozoic a global latitudinal provincialism of planktic taxa and the evolution of an endemic benthic fauna within New Zealand has restricted the correlation of the local biostratigraphy to overseas zonal schemes and to the international stratotypes (Hornibrook 1958, 1981b). Diachroneity of some local and international biostratigraphic planktic datums (Kennett 1968; Hornibrook 1981b; Hoskins 1982) has also impeded correlation. Previous quantitative dating of New Zealand Neogene sediments has been based on a few paleomagnetic reversal sequences and a few radiometric (K-Ar and fission-track ages), for most of which the stratigraphy was not rigorously controlled.

SERIES	STAGES		MAP SYMBOL		INTERNATIONAL	
Hawera					Pleistocene	L
Wanganui	Putikian	Castlecliffian	Wu	Wc		
	Okehuan		Wk			
	Marahauan	Nukumaruan	Wa	Wn		E
	Hautawan		Wh			
	Mangapanian	Waitotaran	Wm	Ww	Pliocene	
	Waipipian		Wp			
	Opoitian			Wo		
Taranaki	Kapitean			Tk	Miocene	L
	Tongaporutuan			Tt		
Southland	Waiauan			Sw		
	Lillburnian			Sl		M
	Clifdenian			Sc		
Pareora	Altonian			Pl		E
	Otaian			Po		
Landon	Waitakian			Lw		
	Duntroonian			Ld	Oligocene	
	Whaingaroan			Lwh		

Fig. 1.1 New Zealand uppermost Paleogene and Neogene series and stages (after Hornibrook 1984b).

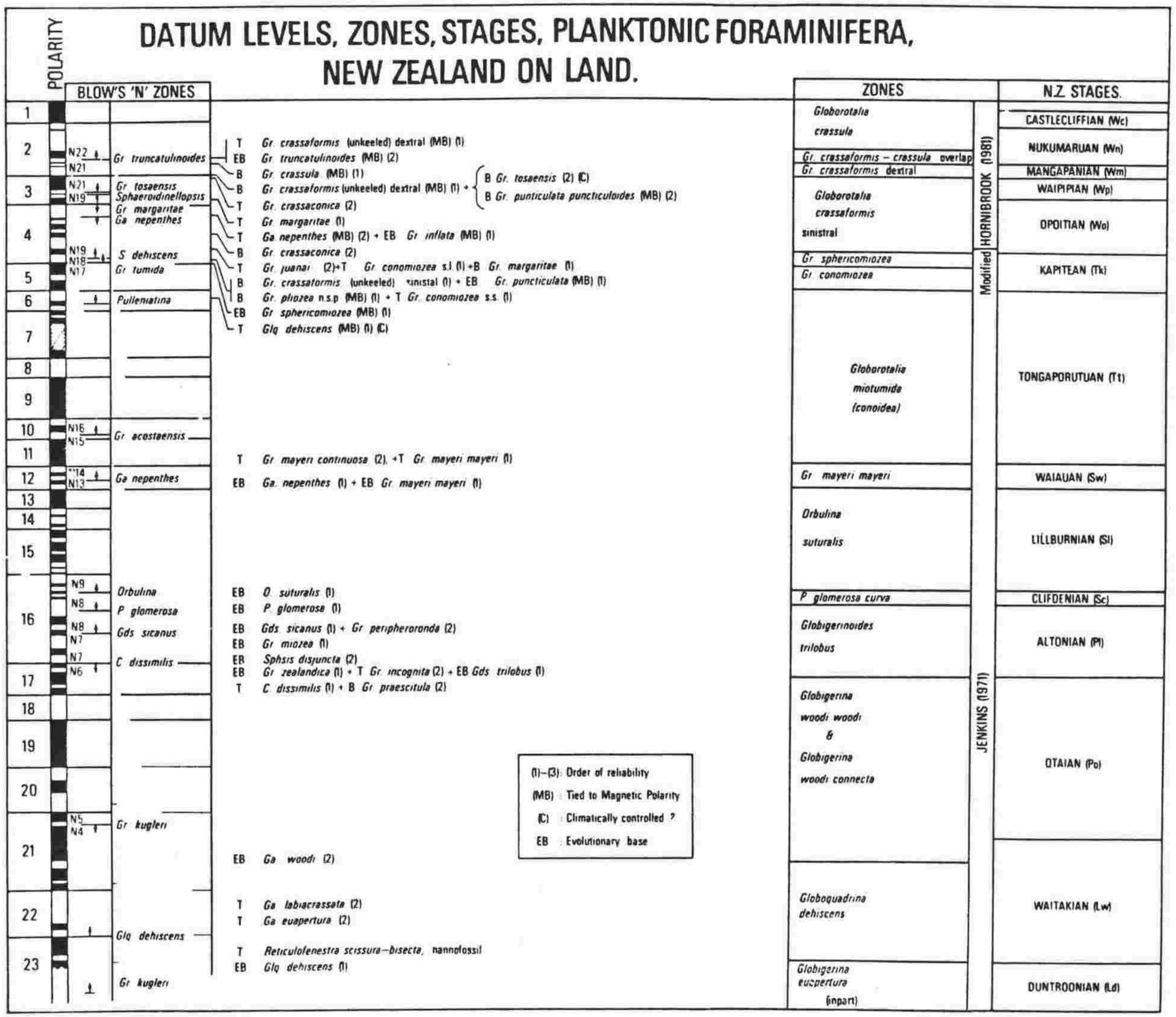

Fig. 1.2 New Zealand Neogene planktic foraminiferal zones and dated bioevents (after Hornibrook 1984b). Ages for the base of *Globorotalia crassaformis* (dextral), base of *Globorotalia punticulata puncticuloides*, and base of *Globorotalia tosaensis* are revised in Edwards (1985) from those shown in the diagram, and the age of the top of *Globoquadrina dehiscens* is revised in this thesis (chapter 6).

1.3 RADIOMETRIC DATING

Reliable radiometric ages of the New Zealand Neogene are few in number (McDougall and Page 1975; Hornibrook 1981b). The most reliable are K-Ar ages from interbedded volcanics (Bandy *et al.* 1970; Stipp and Thompson 1971; Grindley *et al.* 1977). Not all are well controlled stratigraphically (Stipp *et al.* 1967; Stipp and McDougall 1968; McDougall and Coombs 1973).

Glauconite K-Ar ages (Lipson 1956, 1958; Adams 1975) have uncertainties due to argon loss in some cases and argon retention in others (Adams 1975) and in any case all are from pre-Upper Miocene strata and have no direct relevance to the present study.

Fission-track dating of tuffs has been almost totally restricted to upper Neogene sediments (Seward 1974, 1975; Hornibrook 1984b; Gosson 1986). The first fission-track ages were determined from volcanic glass (Seward 1974) but were subsequently found unreliable because of track annealling when compared with zircon fission-track ages (Seward 1979).

1.4 MAGNETOSTRATIGRAPHY

1.4.1 Principles

Magnetostratigraphy is a powerful stratigraphic technique because magnetic reversals were synchronous global events. The magnetic polarity timescale is a history and chronology of changes in the direction of the earth's magnetic field. Paleomagnetism allows the establishment of local magnetic polarity zones in a stratigraphic section. If the local zones can be compared and correlated with the currently accepted polarity timescale the local stratigraphic section can be dated. There is an important difference between the polarity timescale and magnetostratigraphy. The former was developed by organising radiometrically dated samples of known polarity according to their isotopic age and not their stratigraphic relationships.

Because of the non-unique character of individual reversals, correlation is based on the relative lengths of the polarity time-scale zones. Incomplete sequences require independent dating criteria to accurately correlate the polarity zones.

1.4.2 Assumptions

The following assumptions are made, with varying degrees of certainty.

1. The earth's magnetic field has always approximated a dipolar field.

2. The mean direction of permanent magnetisation of a rock is the same as the mean direction of the geomagnetic field at the time the rock was formed. This is not always valid since the time of magnetisation may have been later.

3. The sampled specimen precisely represents the orientation of the sediment at the time of deposition.

4. The stratigraphic interval between adjacent like-polarity points has the same polarity.

5. All unconformities are recognised.

1.4.3 Nomenclature

A supplementary chapter of the International Stratigraphic Guide published by the IUGS International Subcommission on Stratigraphic Classification and IUGS/IAGA Subcommission on Magnetic Polarity Time Scale (Hedberg *et al.* 1979) proposed a magnetostratigraphic classification, which is followed here.

The basic magnetostratigraphic unit is defined as a local body of rock strata which is unified by its magnetic polarity and termed a magnetozone, with upper and lower boundaries termed transitions. Local magnetozones are designated in some manner by symbols chosen by an author for ease of discussion. Subsequent work might enable delineation of subzones or grouping of a number of magnetozones into a superzone. Geochronologic and chronostratigraphic equivalents are termed chrons and chronozones respectively.

1.5 MAGNETOSTRATIGRAPHY IN NEW ZEALAND

In the New Zealand Neogene, magnetostratigraphy has been examined previously in four sedimentary sections (Fig. 1.2), (Kennett *et al.* 1971; Lienert *et al.* 1972; Kennett and Watkins 1974) and three volcanic sequences (Coombs and Hatherton 1959; Evans 1970; Murphy and Seward 1981). Magnetostratigraphy by Kennett *et al.* (1971) has been integrated with oxygen isotope data (Devereux *et al.* 1970), tephrochronology (Seward 1979; Vella and Collen 1984), and that by Kennett and Watkins (1974) with oxygen and carbon isotope data (Loutit and Kennett 1979).

A spinner magnetometer was used in the early magnetic polarity measurements, with a resolution only slightly less than the average intensity of magnetisation of the sediments being measured (Kennett *et al.* 1971; Lienert *et al.* 1972; Kennett and Watkins 1974). Reliable determination of normal and reversed polarities need less

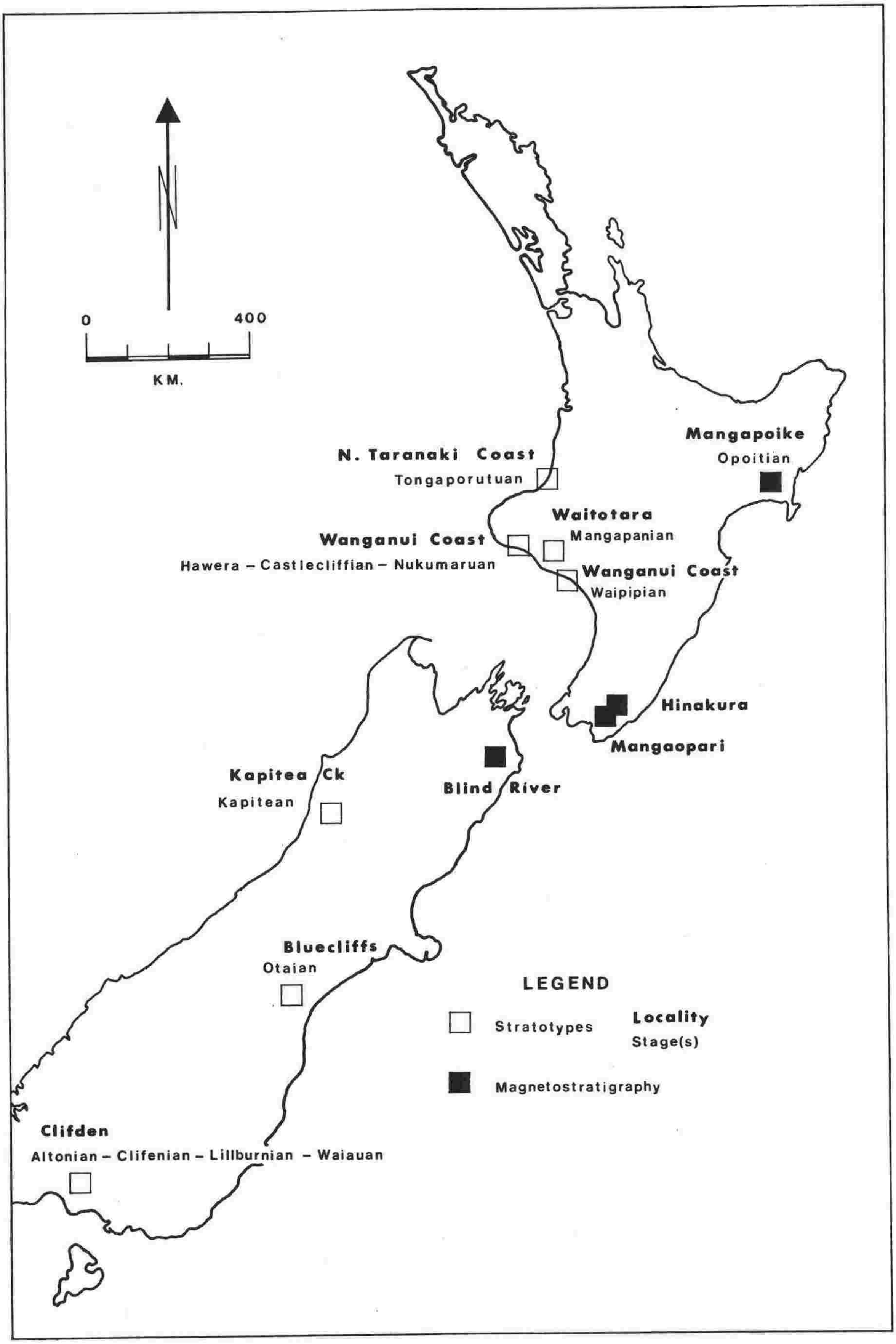

Fig. 1.3 Location map of both New Zealand Neogene stage stratotypes and localities with sedimentary magnetostratigraphies.

precise measurment than the determination of paleopole positions, but some of the polarity measurments made using the spinner magnetometer on New Zealand marine sediments were suspect (eg. Kennett *et al.* 1971). This and the failure to recognise unconformities (eg. Kennett and Watkins 1974) caused problems in correlating with the magnetic polarity timescale. Subsequent reinterpretation of the polarity zones has been based on microfossil biostratigraphy (Hornibrook 1977, 1983, 1984b; Edwards 1985) and stable isotope stratigraphy (Loutit and Kennett 1979).

1.6 REGIONAL DEEP-SEA STRATIGRAPHY

A detailed Neogene biostratigraphy has been established from over 200 deep-sea sediment cores around New Zealand (Kennett 1970, 1973; Keany and Kennett 1975; Jenkins 1975; Edwards and Perch-Nielsen 1975; Weaver 1976; Srinivasan and Kennett 1981a, 1981b). Magnetostratigraphy has been determined in many of the cores (Hays and Opdyke 1967; Goodell and Watkins 1968; Kennett and Watkins 1970; Watkins and Kennett 1971, 1972a, 1972b; Theyer 1972; Osborn *et al.* 1983, Fig. 1.3). However the stratigraphy is generally limited in range. The use of piston coring to recover undisturbed continuous core for paleomagnetic measurement is mainly restricted to the latest Miocene to Recent (Chron 5? to Brunhes), with little penetration below the latest Miocene because of compaction. Even with the use of the extended core barrel (XCB) in the Deep Sea Drilling Project below the latest Miocene sediments, weak intensities of magnetisation and post-depositional chemical remanences (Barton and Bloemendal 1986) in the recovered sediments mostly restrict magnetostratigraphic determinations to the latest Miocene to Recent.

The establishment of a late Miocene magnetostratigraphic reference column from New Zealand on-land sequences provides a much needed chronology for at least part of the existing off-shore biostratigraphy.

1.7 MAGNETOSTRATIGRAPHIC CRITERIA

From this study a number of criteria have been developed for the selection of a sedimentary succcession for magnetostratigraphy. These are presented here as suggested guidelines for any future magnetostratigraphic study in New Zealand.

1. The section must have a well established and detailed biostratigraphy or the magnetostratigraphy must be able to be combined with a biostratigraphic study.

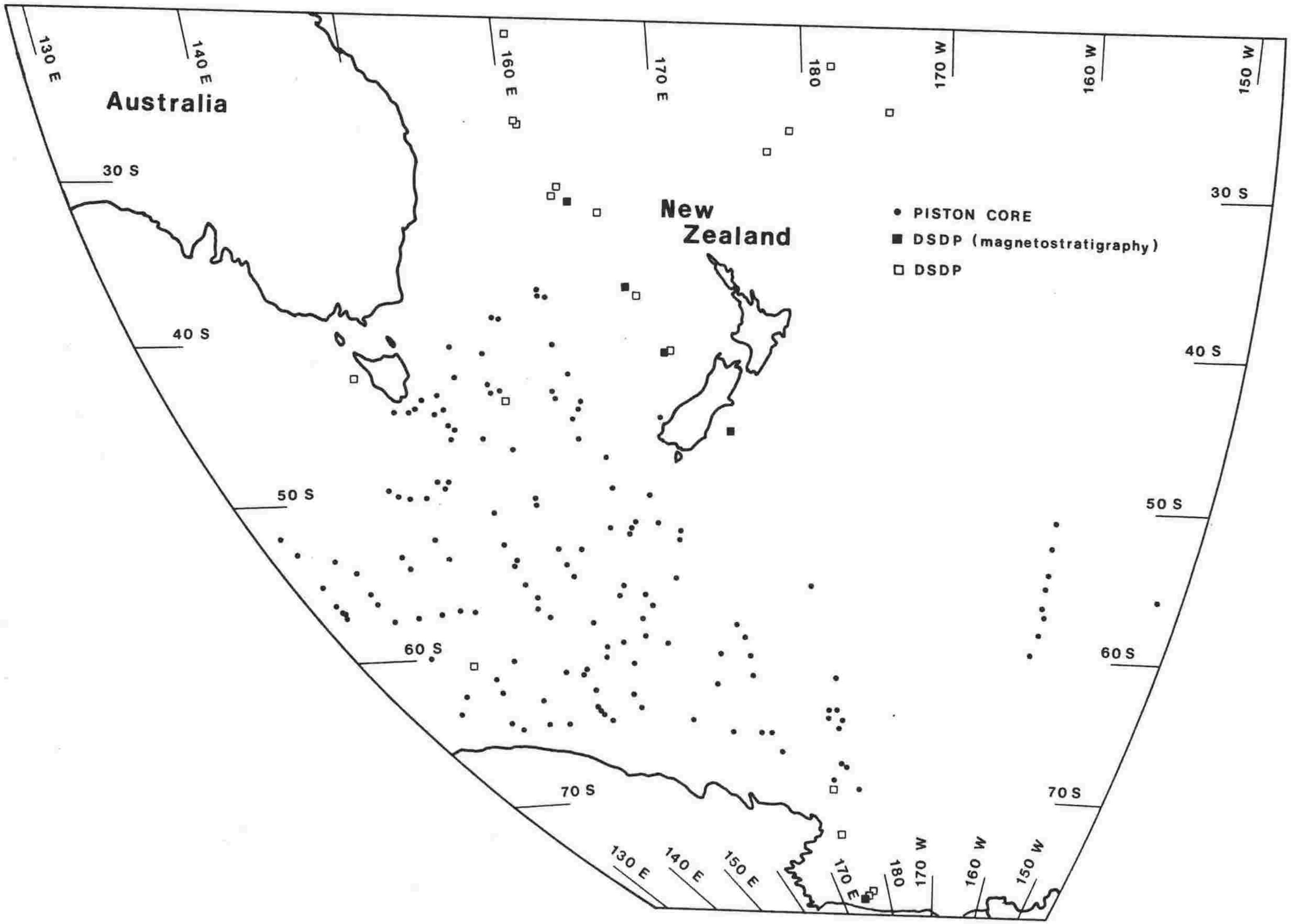

Fig. 1.4 Location map of Deep Sea Drilling Project (DSDP) sites and piston cores in the southwest Pacific and Southern Oceans (oblique Hamner projection).

2. The lithology must have a stable and recognisable primary magnetisation.

3. The primary magnetisation must have been acquired at or close to the physical age of the rock.

4. Hiatuses in sedimentation are known and their age ranges can be accurately determined.

5. The sequence has a near uniform lithology, and sedimentation rates can be assumed to be near linear.

6. The magnetostratigraphic column can be established in one thick section to negate the problems of inter-section correlation.

7. The sequence has a sedimentation rate of at least tens of cm/1,000 yrs.

8. Structure of the sequence is not complex and is well understood.

9. The sequence has at least 70% exposure.

10. The sequence has a number of well-defined bedding planes to accurately determine tectonic corrections of the magnetisation directions.

11. The sequence is being actively eroded to ensure that unweathered rock can be sampled.

13. The natural remanent magnetisation (NRM) of the rocks sampled is greater than 1.5-2.0 x 10^{-5} Am^{-1}

Chapter II

MANGAPOIKE RIVER: STRATIGRAPHY AND LITHOLOGY

2.1 INTRODUCTION

The Mangapoike River section (38.9°S, 177.6°E) on the southeast limb of the Wairoa Syncline, Northern Hawke's Bay (Fig. 1.3) was selected for this study on the basis of the previously described criteria (section 1.7). The Mangapoike section is over 4000 m in thickness representing a period from the Lillburnian to the Mangapanian. The strata have a proven stable magnetic remanence (Kennett and Watkins 1974) in the uppermost Tongaporutuan to Opoitian.

The section extends from the base of the Makaretu sandstone in Tukemokihi Stream (NZMS 1:N106/015077),* westwards along Tukemokihi Stream and Mangapoike River, through Haupatanga Gorge to Kotare Road (NZMS 1:N106/916107, Fig. 2.1). The section is informally divided into the lower and upper Mangapoike sections by the Miocene - Pliocene boundary. The Miocene - Pliocene boundary is poorly exposed in the Mangapoike River, but a road cut exposure (N106/970086) 10 m above the river exposes an angular unconformity. The mapping of tuff beds above and below the unconformity from the road cut exposure to the river indicates the river section is approximately 30 m thicker.

The substantial logistical investment needed for magnetostratigraphy necessitated that only the Mangapoike River section was studied.

2.2 STRATIGRAPHY

2.2.1 Previous Work

The Mangapoike River was first geologically mapped by Macpherson (1927). Regional mapping in the Opoiti and Nuhaka survey districts by Ongley (1928, 1930) defined the Ormond, Opoiti, Mapiri and Tutamoe series, Awamoan to Taranakian in age. Osborne (1934) also defined formation names for northern Hawke's Bay including a Mangapoike Formation. Finlay (1939) designated the Opoiti survey district as the type area for the Opoitian stage and Watson (1957) proposed Mangapoike as the type section. Petroleum reports (Kicinski 1958; Wellman 1958; Haw 1959a, 1959b; Stoneley 1959; Brown 1961,

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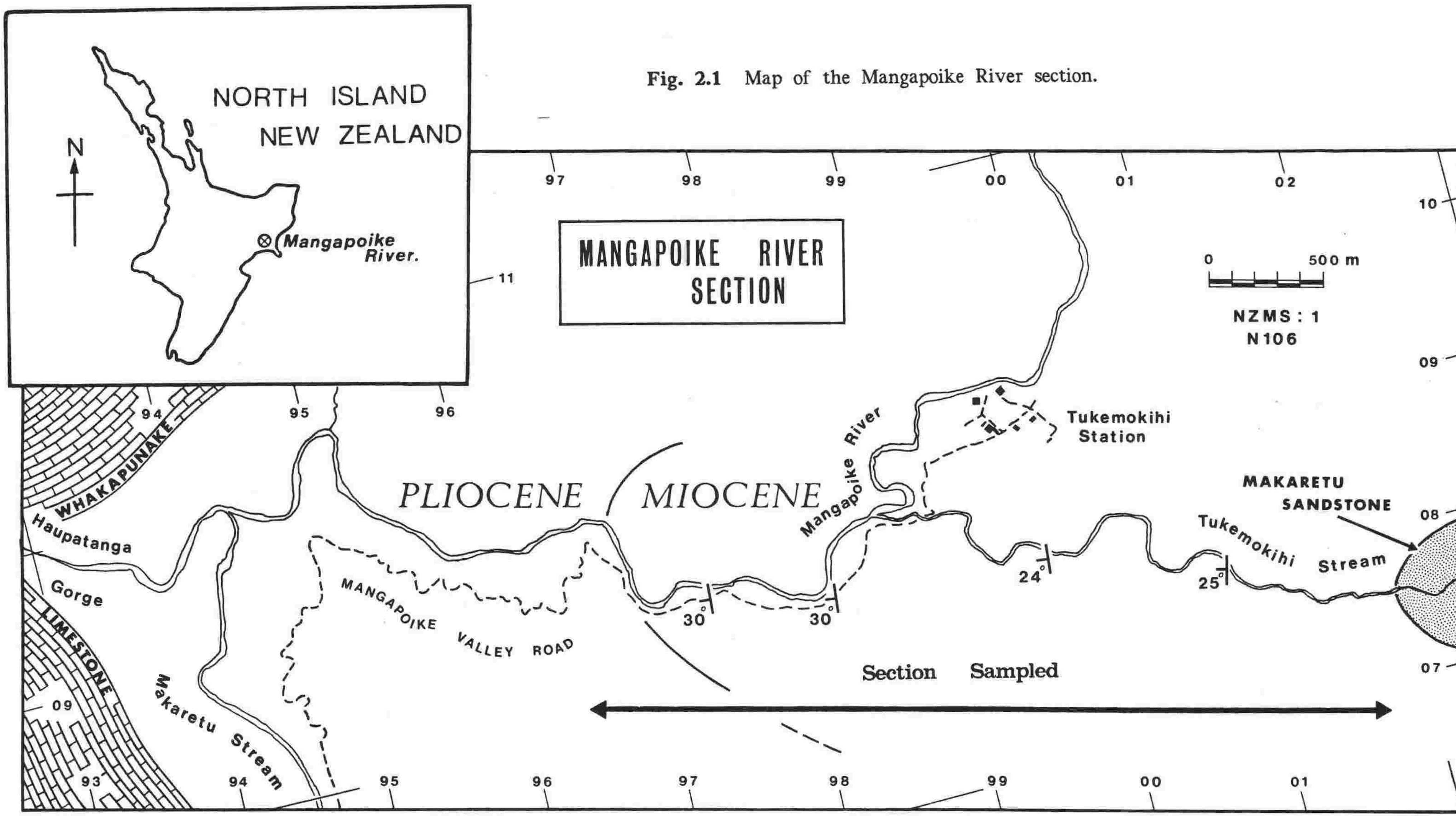
* Grid references are given as eight figures and are derived from an enlarged base map.

Fig. 2.1 Map of the Mangapoike River section.



1962; Brunstroam 1962; Ferrand 1965) include paleocurrent data, structural data and isopach maps of Taranakian sediments of the Mangapoike section and surrounding areas.

McInnes (1964, 1965) described planktic foraminiferal zones which he considered to range from Tongaporutuan to Waitotaran in age. Hornibrook (1968, 1976) nominated part of the upper Mangapoike section as the Opoitian type section, but the paleontological definition of the lower boundary remained ambiguous because of transitional forms in the *Globorotalia inflata* lineage.

Kennett and Watkins (1974) determined magnetostratigraphic polarities in 850 m of mainly the upper section, in sites along the Mangapoike Valley Road. They identified Gilbert and lower Gauss ages on the evidence of the evolutionary sequence of *Globorotalia miozea conoidea* Walters to *Globorotalia puncticulata* Deshayes. They proposed an age of 4.3 Ma for the Miocene - Pliocene boundary in New Zealand, which contrasted with the estimated 5 Ma age for the Miocene - Pliocene boundary in Italy by biostratigraphic correlation with magnetostratigraphy in equatorial deep-sea cores (Ryan *et al.* 1974). Hornibrook (1977) and Hornibrook in Grindley *et al.* (1977) partially resolved the anomaly by recognising that most of the *Globorotalia conomiozea* zone is missing from the biostratigraphic sequence at Mangapoike River. His conclusion stemmed from a 5.2 Ma K-Ar age for fossiliferous basal Pliocene sediments at the Chatham Islands (Grindley *et al.* 1977) and the discovery of a low angle unconformity at Mangapoike (Hornibrook 1983, 1984b, Plate 6.2). Weaver (1976) had reached a similiar conclusion after reinterpreting the Mangapoike magnetostratigraphy by correlating the % *Neogloboquadrina pachyderma* abundance curve at Mangapoike with the silicoflagellate paleotemperature curve of the Southern Ocean. Subsequent detailed foraminiferal biostratigraphy indicates that the uppermost Tongaporutuan and lower part of the Kapitean is missing (Hornibrook 1983, 1984a; Edwards 1985, in prep.).

Ashby (1985, 1986) described New Zealand Neogene radiolarian biostratigraphy recognising the *Didymocyrtis sp.* A Zone and the *Lychnocanium grande* Sub-Zone of the *Didymocyrtis tetrathalmus tetrathalmus* Zone (Ashby 1985) at Mangapoike. Tephrostratigraphy described by Gosson (1986) from the East Coast Basin, including the Mangapoike section, records Neogene silicic volcanism.

2.2.2 Stratigraphy

The chronostratigraphy accepted in this thesis (Fig. 2.2) is based chiefly on biostratigraphy by Hornibrook (1983, 1984a), Ashby (1986) and Hoskins (pers. comm. 1985).

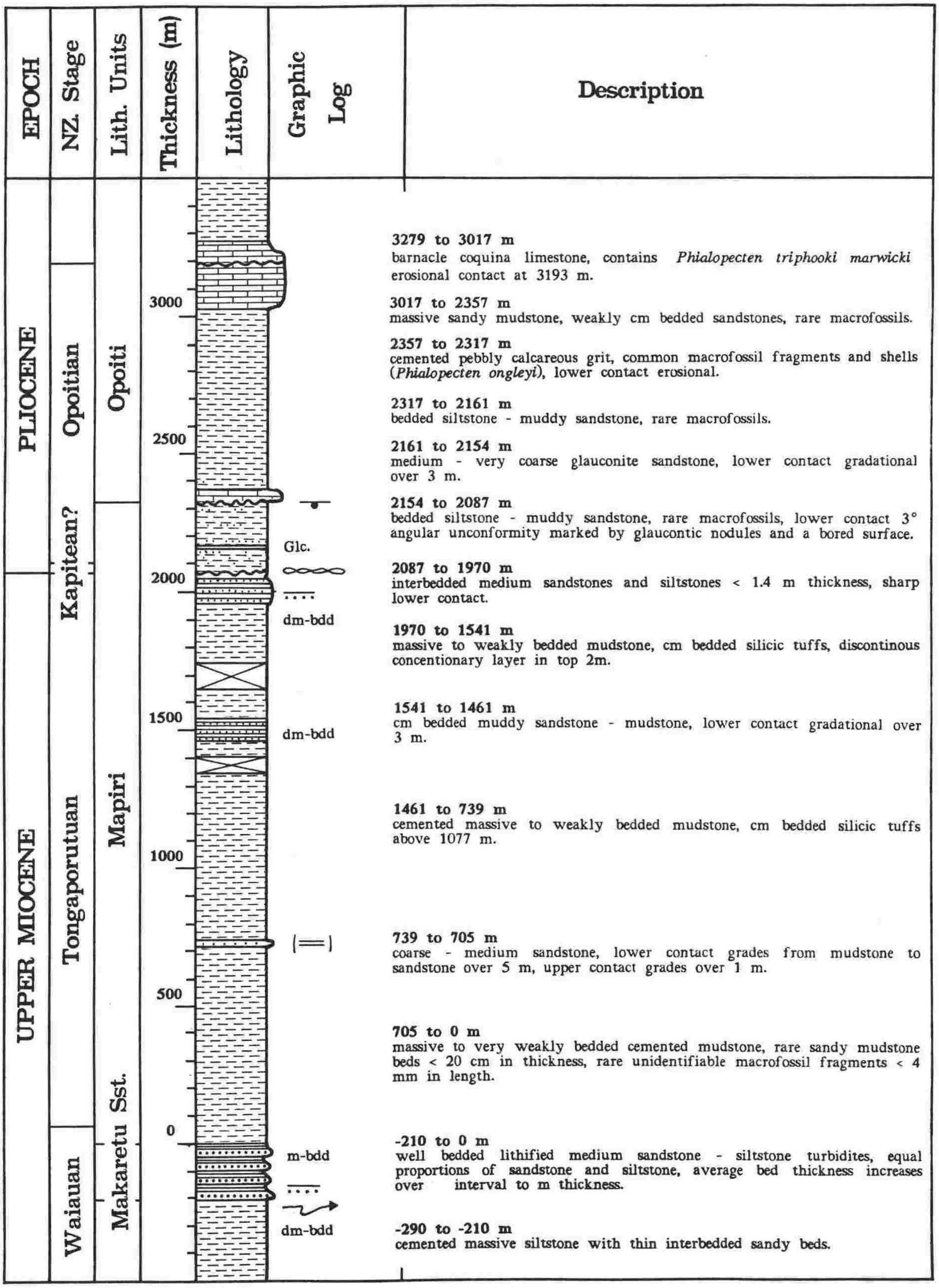


Fig. 2.2 Chronostratigraphy and lithostratigraphy of the Mangapoike River section. Stratigraphic heights are referenced to the top of the Makaretu sandstone.

Tongaporutuan

Definition of the Tongaporutuan stage was originally based on distinct changes in mollusca (Allan 1933; Finlay and Marwick 1940). Finlay and Marwick (1940) also recognised the first appearance of the benthic foraminifera *Bolivinita sp.* as an important datum. Hornibrook (in Fleming, 1959) and Gibson (1967) used the first appearance of the *Bolivinita quadrilatera* lineage as the primary criterion for distinguishing the Tongaporotuan stage from the underlying Waiauan stage. Scott (1979a) suggested that *Bolivinita quadrilatera* is probably facies dependent, preferring bathyal environments, however he recommended the continued use of *B. quadrilatera* at the present time.

The base of the Tongaporutuan in the Mangapoike sequence as recognised by the incoming of *B. quadrilatera* lineage is 27 m above the Makaretu sandstone.

Kapitean

The base of the Kapitean stage was defined by the first appearance of the mollusca *Sectipecten wollastoni*, *Struthiolaria cincta* and *Austrofusus coerulescens* (=*tuberculatus*) (Finlay and Marwick 1947). Foraminiferal definition (Kennett 1966a, 1966b, 1967) was based on the plantkic *Globorotalia conomiozea-puncticulata* bioseries. Subsequent taxonomic review (Scott 1976, 1979b, 1979c, 1980, 1982a; Hornibrook 1981a, 1982) allowed finer biostratigraphic definition (Hornibrook 1983, 1984a; Scott 1983) with a gradational transition from *Globorotalia conoidea* to *Globorotalia conomiozea* as the accepted base of the Kapitean.

Opoitian

The original definition of the Opoitian stage (Finlay 1939) based on foraminiferal fossils, largely corresponded to that of the Opoiti series (Ongley 1930). Finlay and Marwick (1947) defined the Kapitean-Opoitian boundary by the first appearance of *Globorotalia inflata*. Again, later taxonomic revision (eg. Scott, 1976) has superceded the original paleontological definitions. A review of the Kapitean-Opoitian boundary by Scott (1982b) offered two options for consideration in defining the base of the Opoitian, with no definite acceptance of either as yet. The first is the appearance of *Globorotalia puncticulata sphericomiozea* and the second is the lowest joint occurrence of *Globorotalia puncticulata puncticulata* and *Globorotalia crassaformis*. Both alternatives for the base of the Opoitian are given by Hornibrook (1983, 1984a).

2.3 LITHOLOGY

The Mangapoike section is dominated by massive moderately cemented mudstones. Interbedded sandy limestones, tuffs and sandstones are subordinate lithologies (Fig. 2.2), and provide the only clear bedding attitudes ranging from 356/W/25 to 018/W/30. (Appendix 2). The lithostratigraphic units recognised are a combination of formations and informal names in current usage, and although some units are not defined with respect to a type section and one is recommended to be abandoned (Gosson 1986), all have been included for the sake of completeness and to avoid ambiguity in locating paleomagnetic sites.

Thirty selected paleomagnetic specimens from Mangapoike are grouped into five classes: not bioturbated, weakly bioturbated, moderately bioturbated, strongly bioturbated and completely bioturbated (Plate 2.1), and are used as a standard of comparison for all bioturbation in the Mangapoike sequence. The classes correspond to those of Andrews (1982). A log of the degree of bioturbation through the lower part of the sequence (Fig. 2.3) shows that most of the section is weakly bioturbated. Certain stratigraphic horizons are moderately to strongly bioturbated, especially in the lower Tongaporutuan. The effects of bioturbation on the paleomagnetic data are discussed in section 5.6.

2.4 SAMPLING AND SITE LOCATIONS

The section sampled for the present study extends from the top of the Makaretu sandstone (N106/019076) westwards along Mangapoike River to above the Miocene - Pliocene unconformity (N106/002085, Plate 2.2 a, b, c; Appendix 1), and ranges in age from latest Waiauan to early Opoitian. Three hundred and forty-three paleomagnetic sites were located at approximately 5 m stratigraphic intervals, over 2158 m, using a Jacob's staff and Abney level. The sampled section includes sites which are stratigraphically equivalent to adjacent strata from which Kennett and Watkins (1974) delineated their C1 and C2 normal events. All stratigraphic heights are above the top of the Makaretu sandstone. Two intervals from 1345 to 1403 m and 1650 to 1751 m were not sampled. The first is covered, and the second was inaccessible for paleomagnetic sampling, but has no significant change in lithology.

Sites were located near water level wherever possible. The outcrop was cut back to a depth of 20-30 cm to eliminate surficial weathered sediment, although stream and river banks are estimated to erode 10-20 cm every winter. A portable motor-powered diamond drill was used and at least three cores 2.5 cm in diameter and an average

Plate 2.1 Representative paleomagnetic specimens showing variation of bioturbation within the Mangapoike sediments.

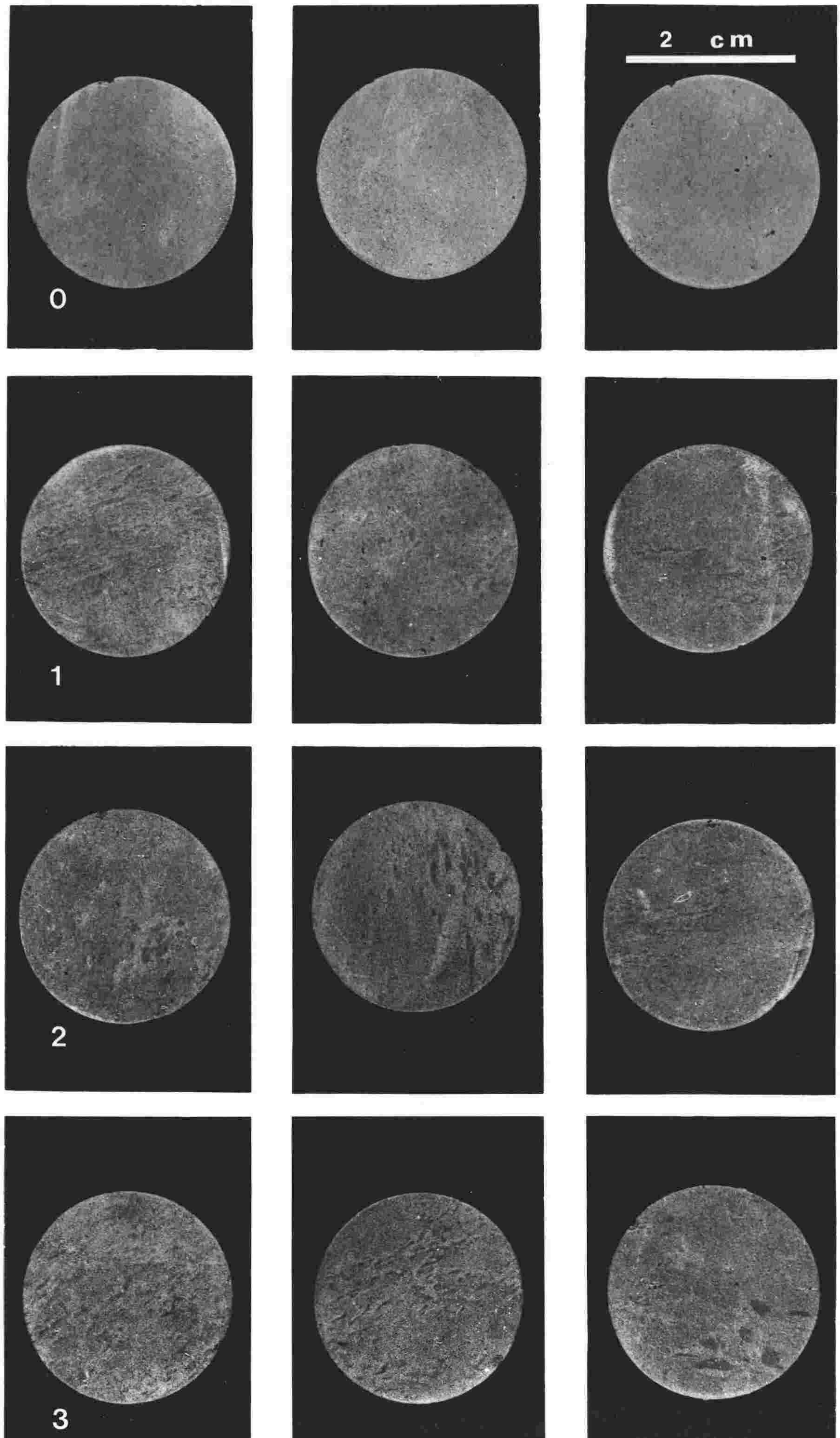
Class 0: No visible bioturbation (0%)

Class 1: Weak bioturbation (0 - 30%)

Class 2: Moderate bioturbation (30 - 60%)

Class 3: Strong bioturbation (60 - 95%)

Class 4: Complete bioturbation (not seen).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3

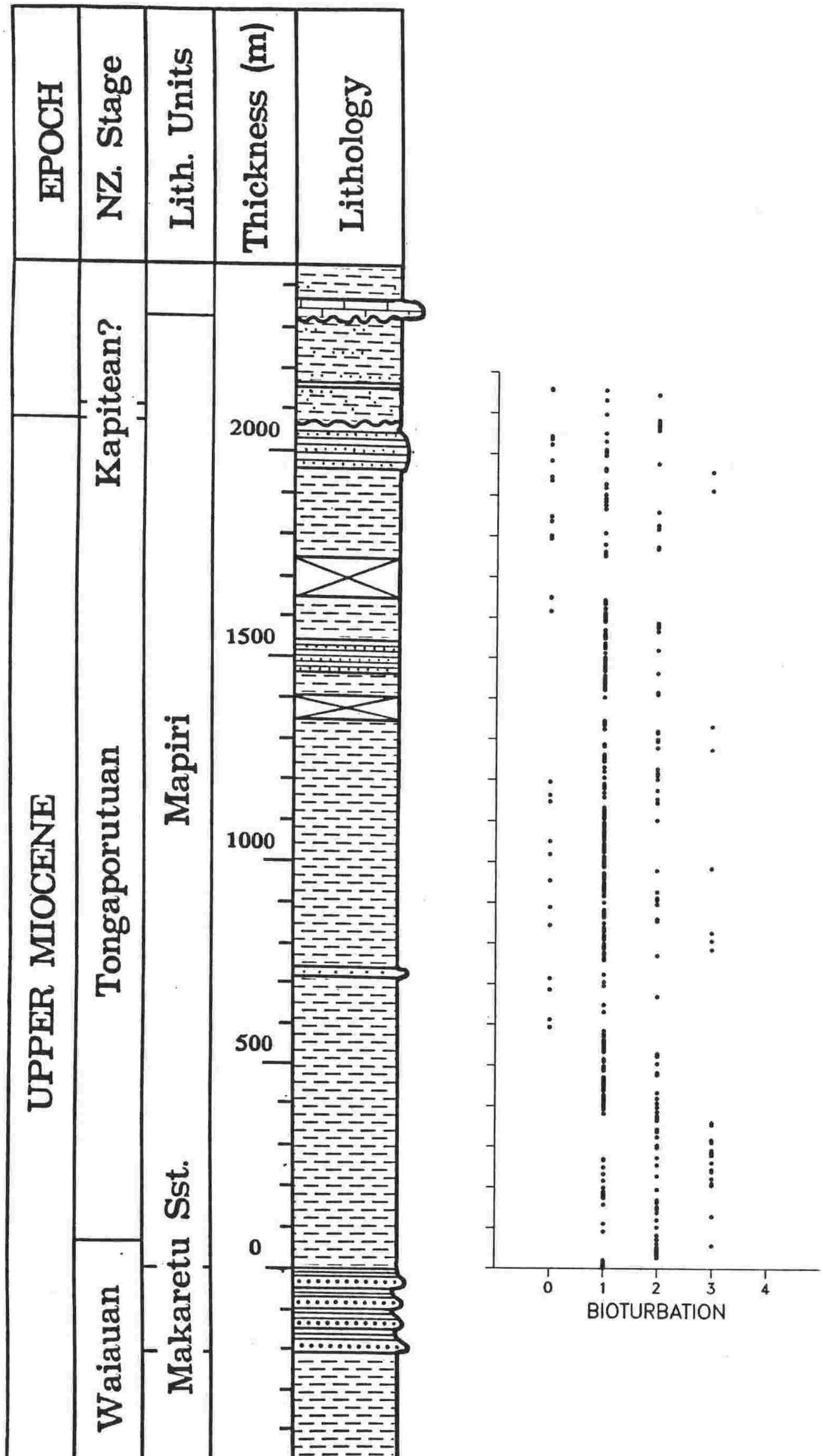


Fig. 2.3 A log of the degree of bioturbation in lower Mangapoike section.

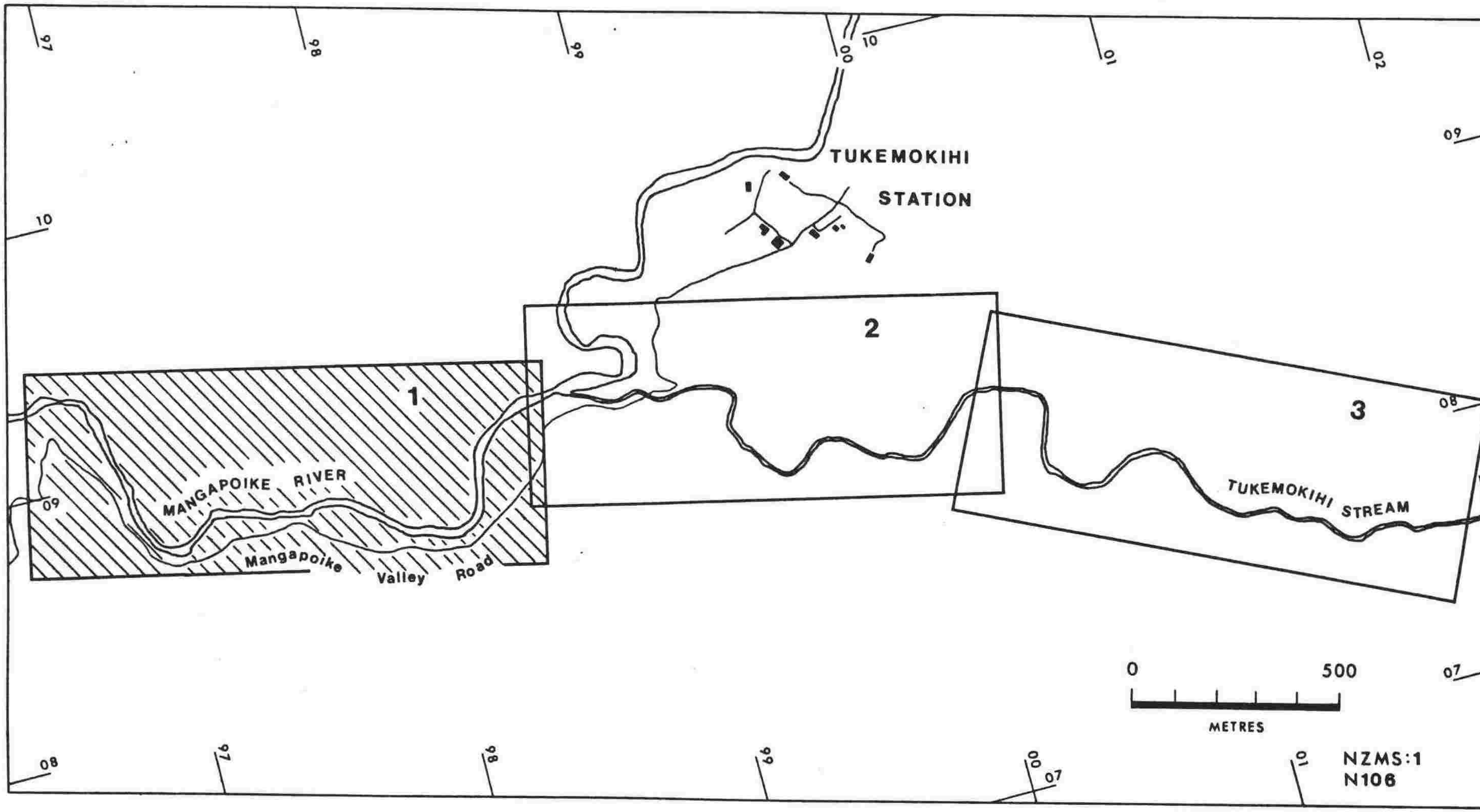
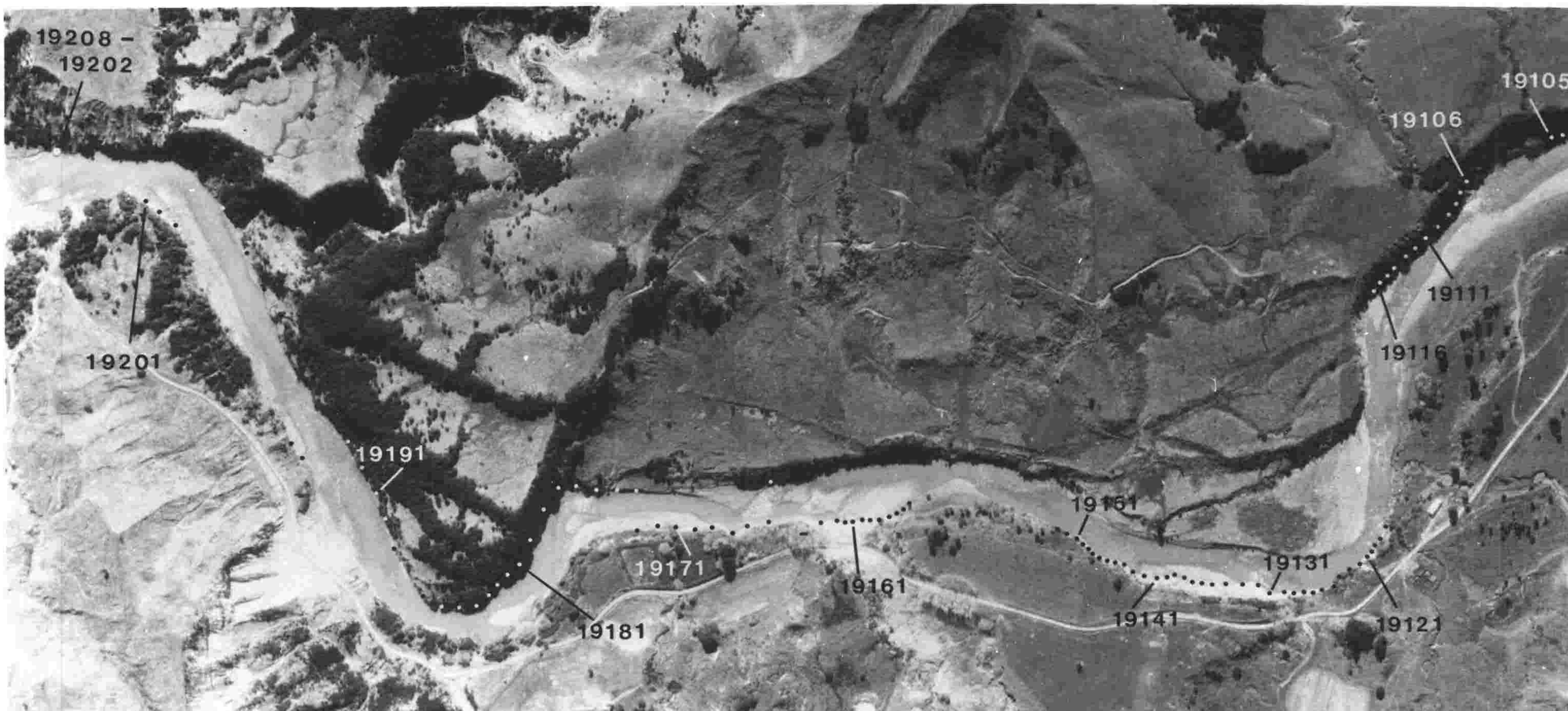


Plate 2.3 a Locations of sites 19106 - 19208.



19208 -
19202
19201
19191
19181
19171
19161
19151
19141
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19121
19116
19111
19106
19105

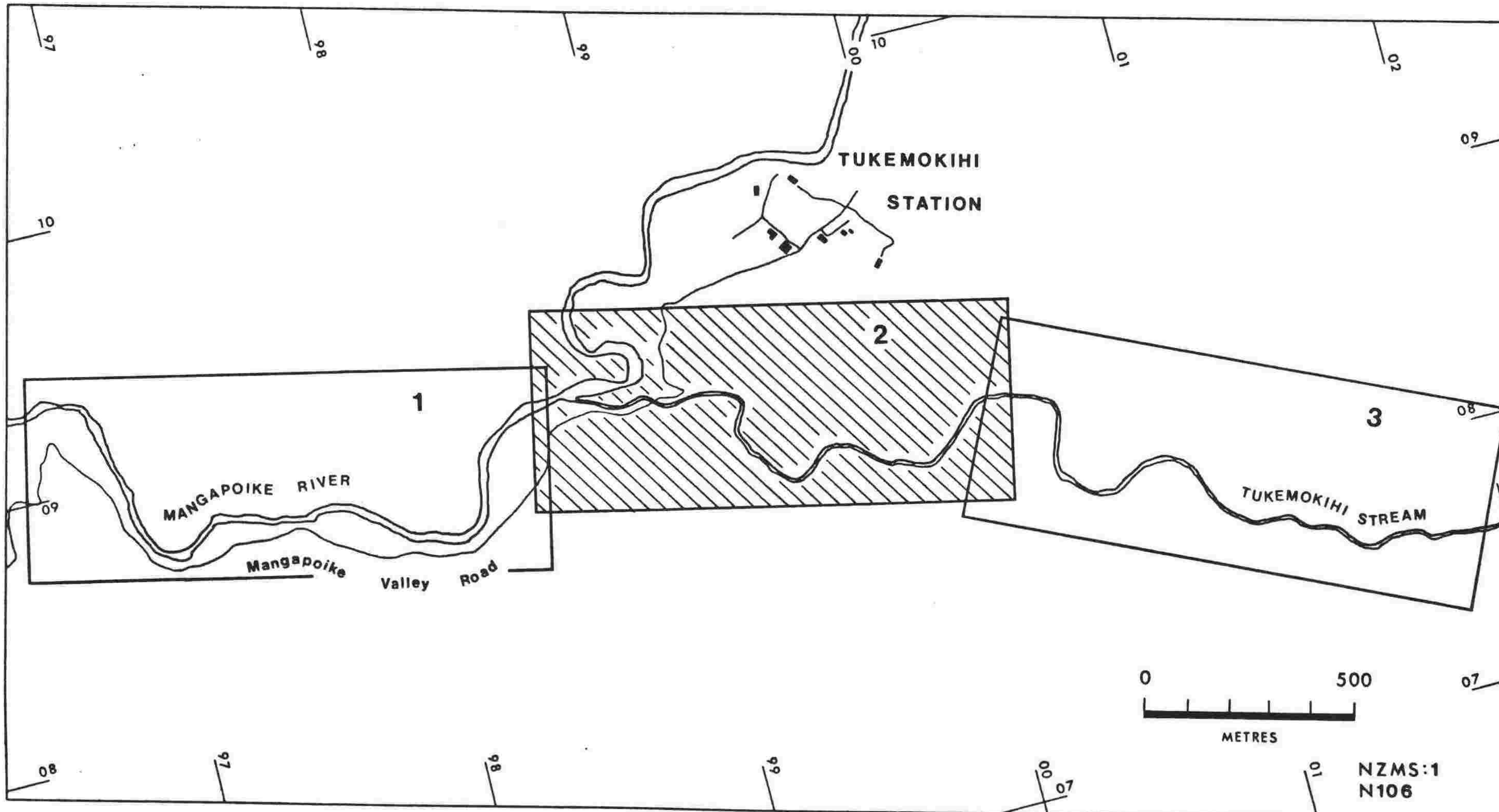
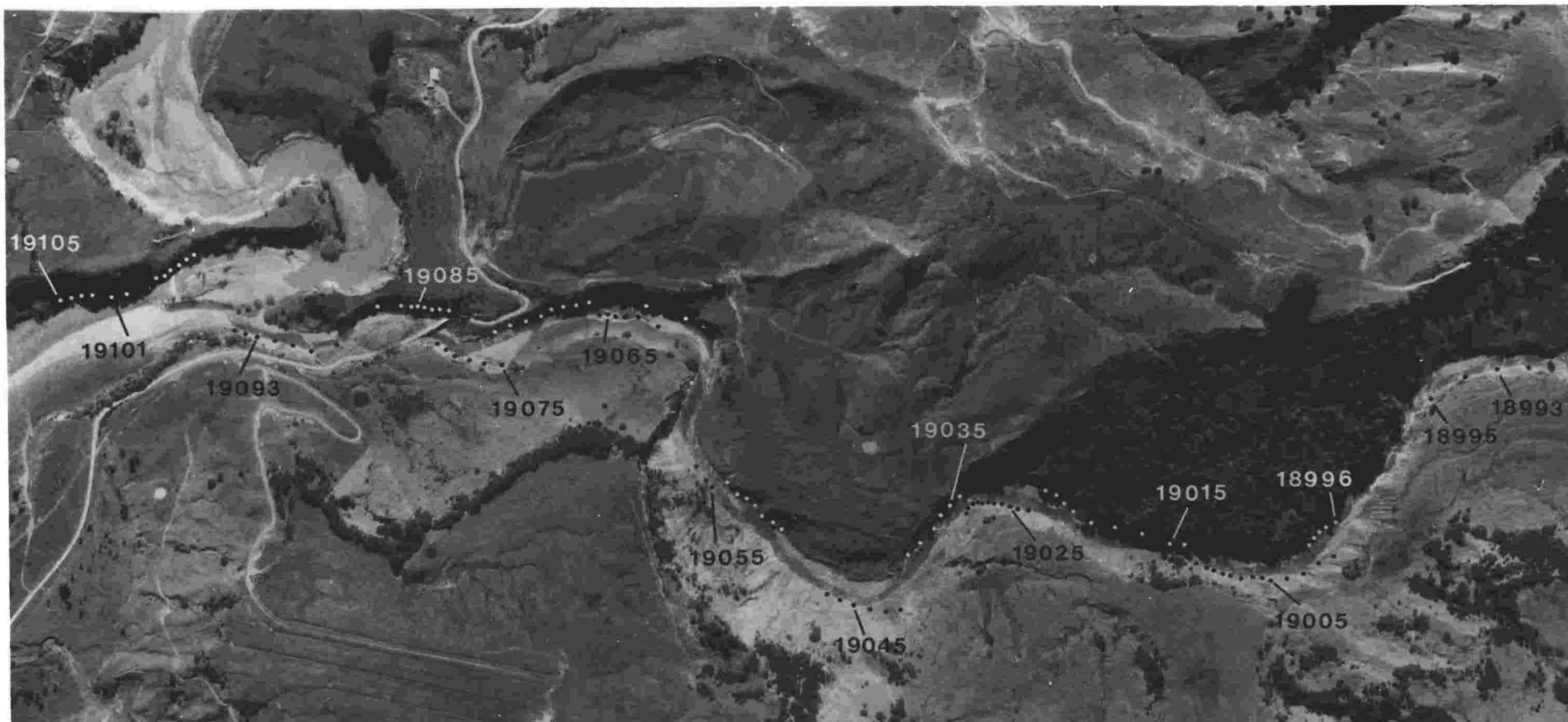


Plate 2.3 b Locations of sites 18994 - 19105.


19105
19101
19093
19085
19075
19065
19055
19045
19035
19025
19015
19005
18996
18995
18993

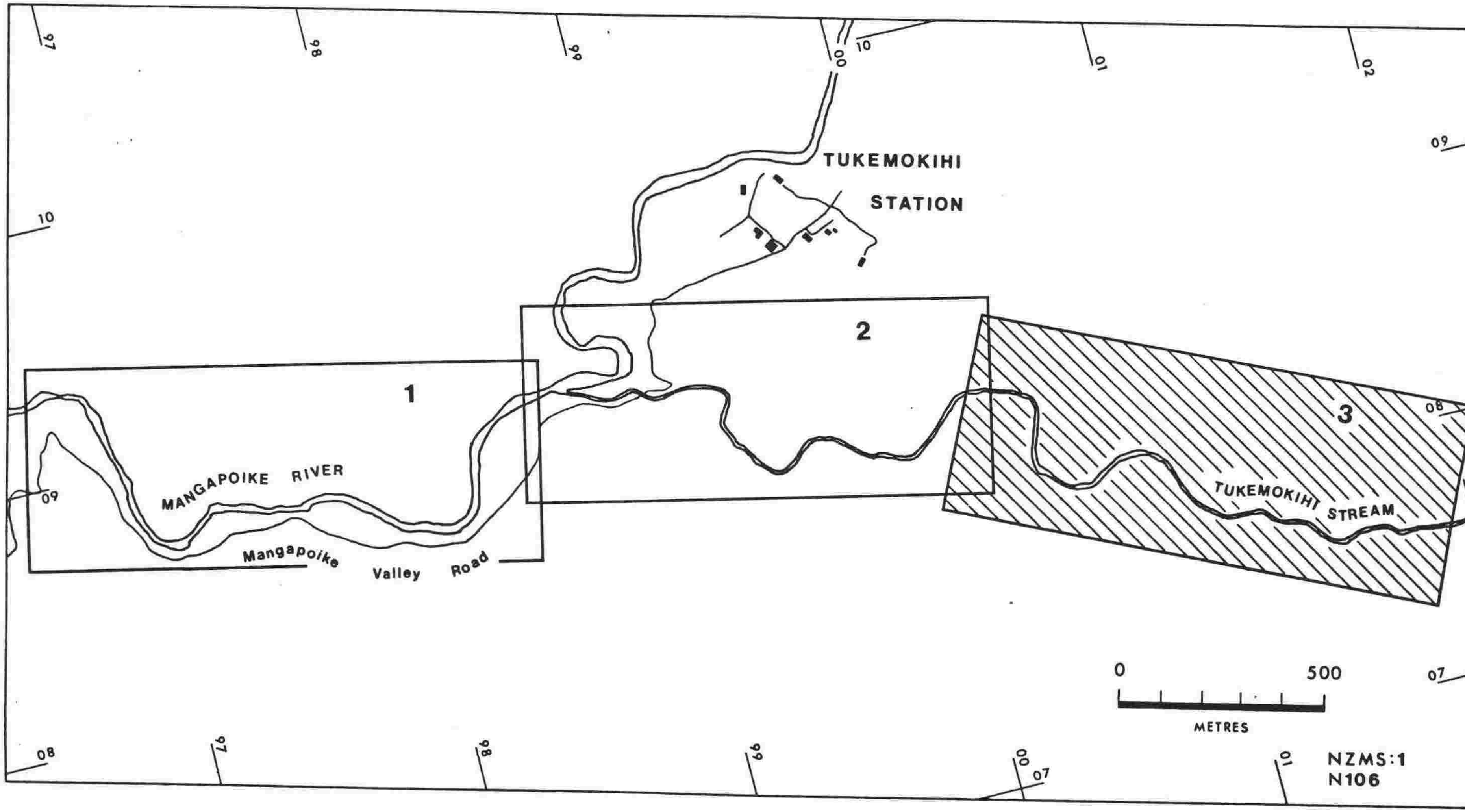
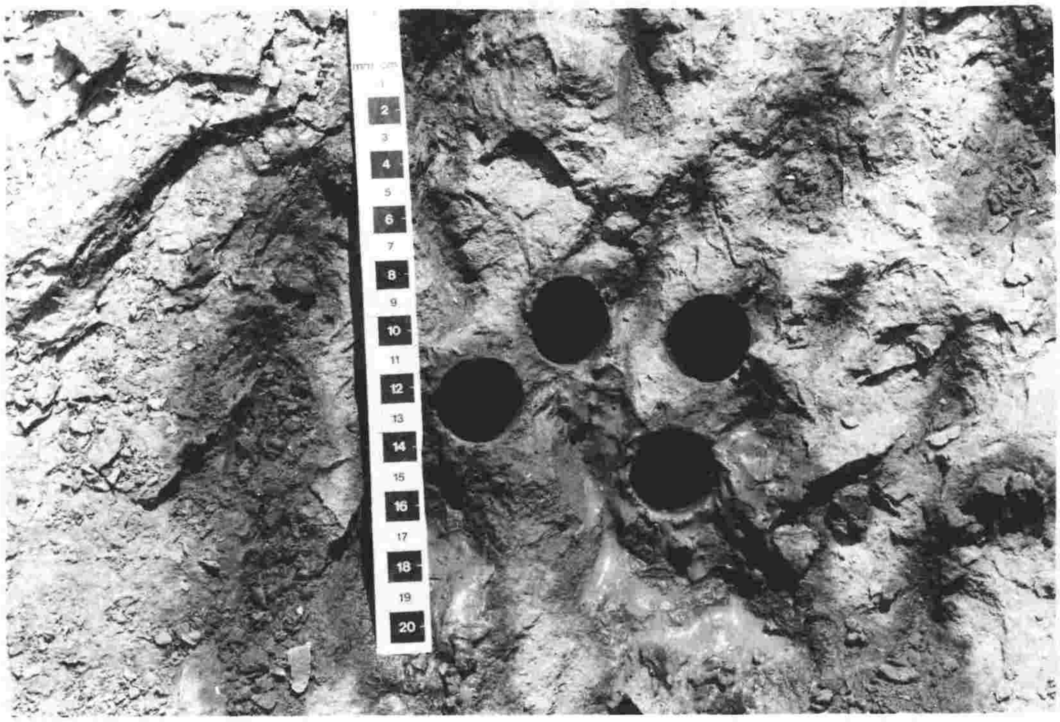


Plate 2.3 c Locations of sites 18870 - 18993.


18873 – 18870
18878
18888
18898
18908
18918
18928
18938
18948
18958
18968
18978
18988
18993

Plate 2.3 Stratigraphic separation of cores within a paleomagnetic site.

Plate 2.4 Iron-stained silicic tuff.


mm cm
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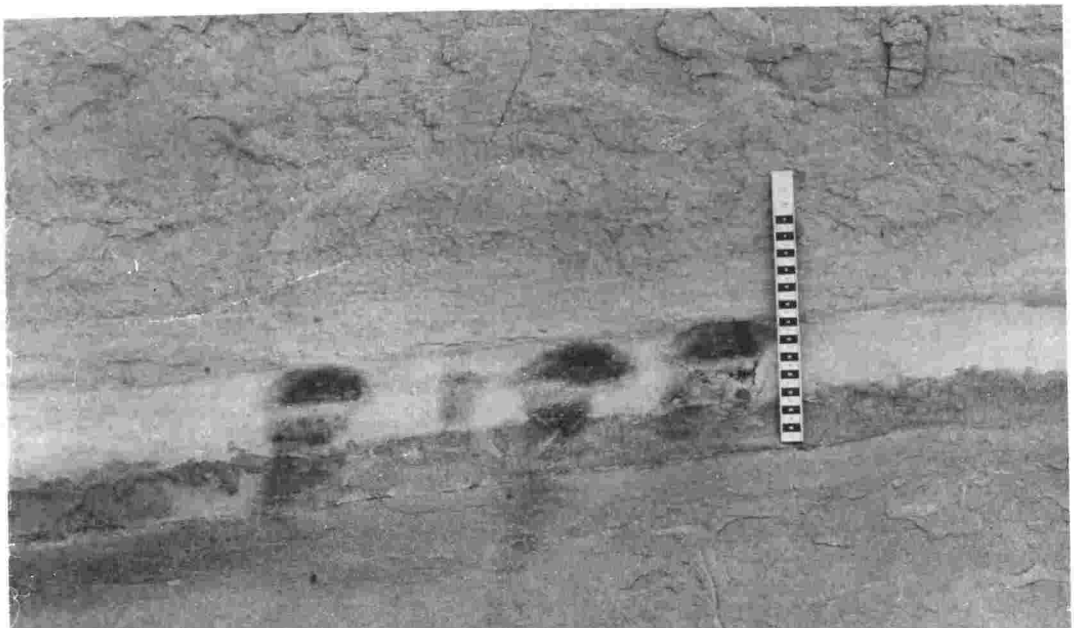


of 6 cm in length were taken at each site. At each site stratigraphic separation of the cores was no greater than 20 cm and the horizontal separation no greater than 1 m (Plate 2.3). Field orientation of the cores are estimated to have errors not greater than ±2°. Tuffs were not sampled, because they are generally coarser grained than the enclosing sediment and act as aquifers, and were consequently iron stained (Plate 2.4), although other studies (Kato *et al.* 1971; Yamazka *et al.* 1973; Wright and Mutti 1981) have obtained coherent paleomagnetic data from tuffs within marine sediments.

Ten samples (Appendix 3) were collected for magnetomineralogy. They were taken from sandstone beds for ease of disaggregation, concentration and petrographic description (chapter 3).

Chapter III

ROCK MAGNETISM AND MAGNETOMINERALOGY

3.1 INTRODUCTION

Theoretical and experimental rock magnetism on both synthetic and natural minerals in the last twenty years (O'Reilly 1984, and references therein) have revealed the processes by which magnetic remanences are acquired and retained. The identification of the magnetic minerals in paleomagnetic samples (Lovlie *et al.* 1972; Tauxe *et al.* 1980; Lovlie and Larsen 1981; Papamarinopoulos *et al.* 1982) can provide critical data on the timing, significance and stability of the remanent magnetisations (Elston and Purucker 1979; Walker *et al.* 1981; Liebes and Shive 1982; McIntosh *et al.* 1985). Both the electron microprobe (Ade-Hall 1963, 1964; Wright and Lovering 1965; Smith 1967; Creer and Ibbetson 1970) and rock magnetic properties (Akimoto 1962; O'Reilly 1976, 1984) have been used to characterise magnetic minerals. Rock magnetic properties are especially useful in fine-grained and magnetically dilute specimens where petrological analysis is difficult (Dunlop 1971; Lowrie and Alvarez 1977).

In order to clearly demonstrate that the age of the magnetisation is the same or very close to the age of deposition of the sediments, as is required for magnetostratigraphy, chemical analyses and rock magnetic properties were used to determine the magnetic minerals. The data are discussed below and show that the only recognised magnetic mineral is titanomagnetite. The magnetisation of most specimens includes a soft viscous remanence, and a hard stable remanence.

3.2 DEFINITIONS AND TERMINOLOGY

There has been, and still is, considerable confusion and variation within the literature in the definition of various magnetic properties, including the units of measurement (Shive 1986). The following is a definition of parameters and terms used here. All units of measurement are SI.

All minerals have some magnetic properties (O'Reilly 1976), but the term **magnetic mineral** is restricted here, unless otherwise stated, to those minerals which retain a remanent magnetism. **Paramagnetism** is the partial alignment of magnetic moments in a mineral along an applied magnetic field direction. **Spontaneous magnetisation** is the property by which a magnetic vector is retained after the removal of an applied field. It includes ferromagnetism, ferrimagnetism and antiferromagnetism. **Ferromagnetism** is the parallel coupling of all unpaired electrons within a mineral, producing a very strong magnetisation which readily follows changes of the applied field. **Ferrimagnetism** is the net magnetisation from two antiparallel but imbalanced sublattices within a mineral. Ferrimagnetism is weaker than ferromagnetism. When the two antiparallel sublattices are identical having equal magnetic dipoles, the resultant net zero magnetism is termed **antiferromagnetism.** Rarely are the antiparallel lattices perfect, and they have a small residual magnetisation which is termed **parasitic ferromagnetism.**

Magnetic susceptibility of a sample is the proportionality constant between an applied field and the resultant magnetisation and is defined by the relation:

$$M = kH$$

where M = induced magnetisation per unit volume

k = volume magnetic susceptibility

H = applied field

It is termed initial susceptibility when measured in low fields (< 1 mT).

A number of useful magnetic properties can be defined from the analysis of a magnetic hysteresis loop (Fig. 3.1). A hysteresis loop traces out the induced magnetisation of a sample subjected to progressively higher applied fields; the resultant magnetisation when measured subsequently outside of the applied field, is termed an **isothermal remanent magnetisation** (IRM). At some point the magnetisation does not increase with higher applied fields and the sample is saturated and is termed **saturation isothermal remanent magnetisation.** If the induced magnetisation is saturated and measured when the sample is still within an applied field (ie not a remanent magnetisation) then it is termed a **saturation magnetisation.** The **coercive force** is the reversed field required to reduce the saturated magnetisation to zero and the **coercivity of remanence** is the reversed field, applied and then withdrawn, required for the isothermal magnetisation to be zero. **Anhysteretic remanent magnetisation** (ARM) is the magnetisation acquired in a low uniform field, within an ever decreasing alternating field.

For a more detailed account of definitions and experimental methods used in rock magnetisation the reader is referred to Banerjee (1981).

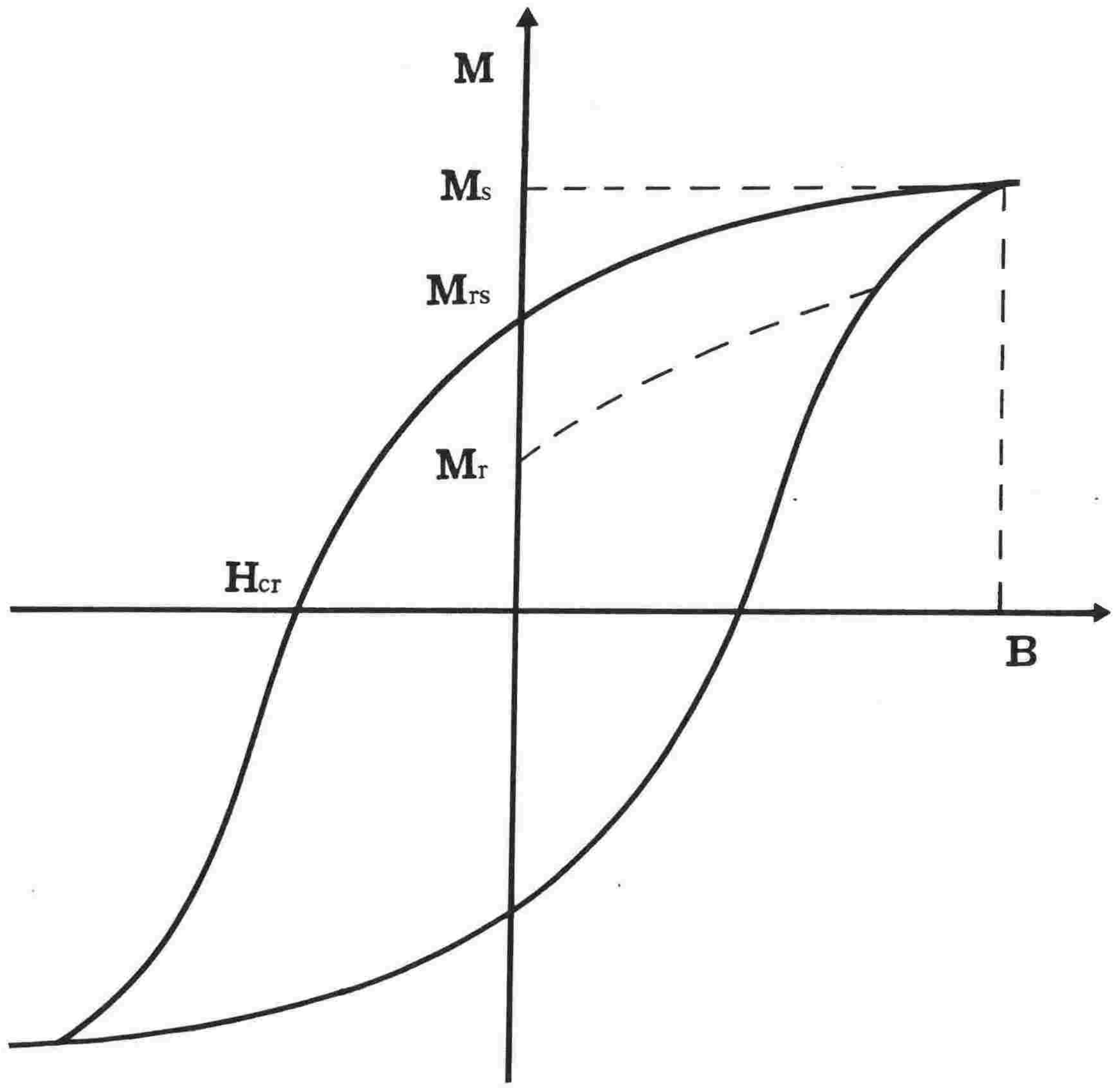


Fig. 3.1 Magnetic hysteresis loop: a graphical representation of the induced magnetisation (M) at higher applied fields (H). M_r (isothermal remanent magnetisation), M_{rs} (saturation isothermal remanent magnetisation), M_s (saturation magnetisation), and H_{cr} (coercivity of remanence).

3.3 GENERAL

The most abundant terrestrial magnetic minerals are the Fe-Ti oxides within the FeO-TiO_2-Fe_2O_3 ternary system (Nicholls 1955; Nagata 1961; Lindsley *et al.* 1966; O'Reilly 1976, 1984). Within the titanomagnetites (Fig. 3.2) solid solution of the end members, magnetite (Fe_3O_4) and ulvospinel (Fe_2TiO_4), only occurs above 600°C. Naturally occurring titanomagnetites are not perfectly stoichiometric (ie the cation/anion ratio is not 3/4) and invariably Mg, Al and Mn are substituted cations. Consequently the usage of the term titanomagnetite follows that of O'Reilly (1984) and is restricted to compostions where substituted cations are less than 10% of the total cations and the oxidation parameter (z) is $0 < z < 0.1$.

Magnetism within the titanomagnetites ranges at room temperature from paramagnetism in ulvospinel to the ferrimagnetism in magnetite. Changes of bulk composition result in a steady gradation of various magnetic parameters; Curie temperature (Nagata 1961; Akimoto 1962; Stephenson 1972), saturation magnetism (Akimoto 1962; O'Reilly and Banerjee 1965; Stephenson 1969), coercive force (Robins 1972; Day *et al.* 1977) and susceptibility (Robins 1972; Day *et al.* 1977).

The metastable titanomaghemites are produced by either deuteric oxidation (Buddington and Lindsley 1964; Hauptman 1974) or low temperature oxidation (maghemitisation) (Johnson and Merrill 1973; O'Reilly 1983). Increasing non-stoichiometry (increasing z) results in a decrease in susceptibility and an increase in Curie temperature, saturation magnetisation and coercive force (Readman and O'Reilly 1972; O'Donovan and O'Reilly 1978; Manson *et al.* 1979; Keefer and Shive 1981; Ozdemir and O'Reilly 1981).

The titanohaematites ($yFeTiO_3(1\text{-}y)Fe_2O_3$) are a solid solution series between ilmenite and haematite. Magnetism of the titanohaematites varies markedly with composition (y), from the antiferromagnetism of haematite, through the ferrimagnetism of intermediate compositions to the paramagnetism of ilmenite. Variation of Curie temperature with composition is linear (Nagata and Akimoto 1956; Westcott-Lewis and Parry 1971) but other magnetic properties show far less consistent trends (Nagata and Akimoto 1956; Ishikawa and Akimoto 1958; Dunlop 1971).

Pyrrhotite (FeS_{1+x}) and goethite (α FeOOH) are also magnetic (Neel 1955; Hedley 1968, 1971; Strangway *et al.* 1968; Schwarz and Vaughan 1972; Schwarz 1975).

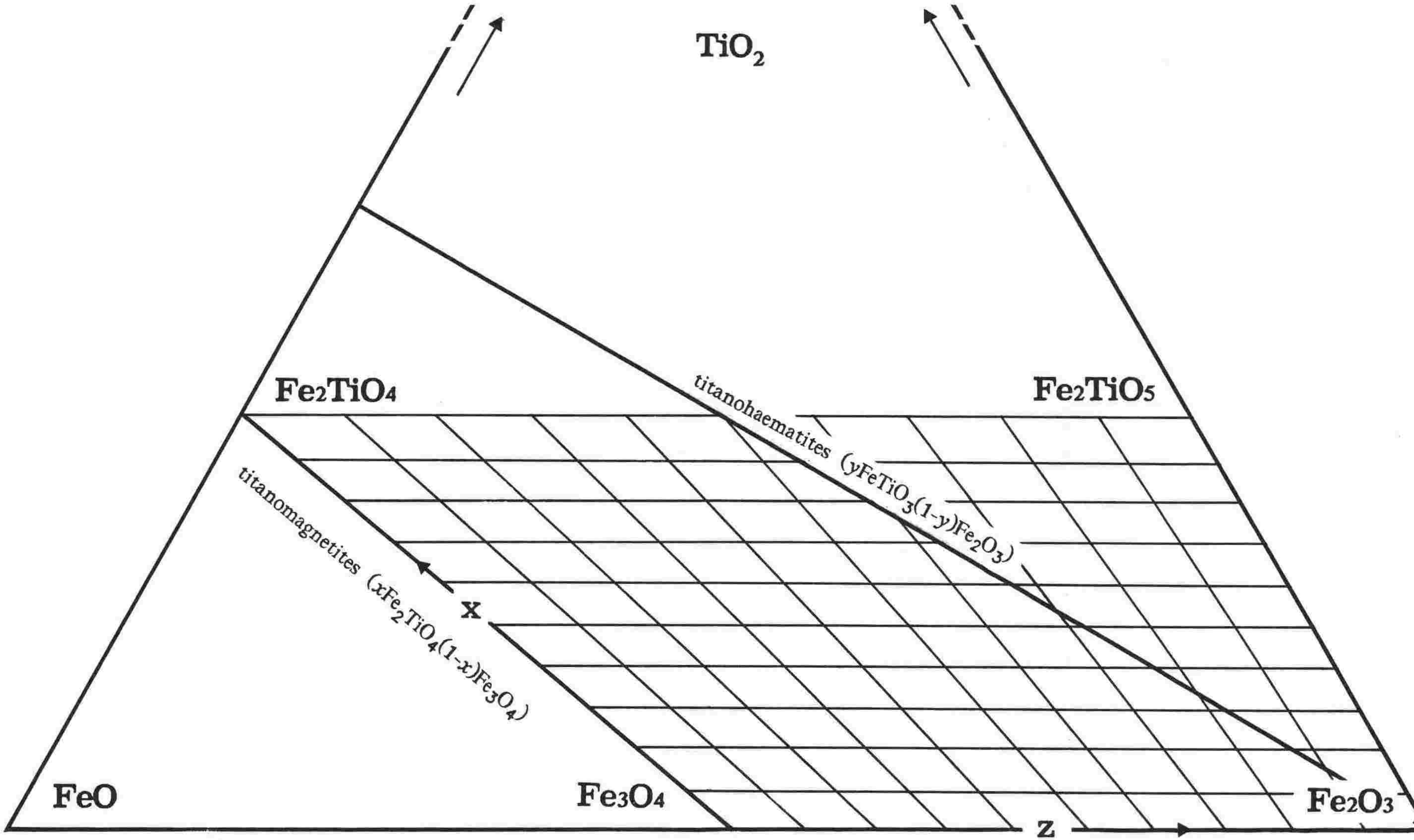


Fig. 3.2 The Fe_3O_4 - Fe_2TiO_4 - Fe_2TiO_5 - Fe_2O_3 quadrilatera within the FeO - TiO_2 - Fe_2O_3 ternary system. Variation in both composition (x) of the titanomagnetites and the non-stoichiometry oxidation parameter (z) of the magnetite - maghemite series, defines any point within the quadrilatera.

3.4 METHODS AND TECHNIQUES

3.4.1 Introduction

Ten representative magnetic separates were analysed with an electron probe microanalyser. Isothermal remanent magnetisation (IRM) curves of 21 representative paleomagnetic specimens were used to confirm the electron probe microanalyser data and demonstrate their relationship to the observed remanent magnetisations. Initial susceptiblity data were used to relate variations in the concentration of magnetic minerals to fluctuations in magnetisation intensity.

Magnetic remanence measurements using the ScT magnetometer are described in section 3.5.

3.4.2 Sample Storage and Preparation

Most paleomagnetic cores were placed in sealed plastic bags when collected and stored in Mumetal shields, with fields of less than 50 nT, to minimise both moisture loss and the acquistion of a viscous remanence (Johnson *et al.* 1975; Henshaw and Merrill 1979; Verosub *et al.* 1979). Cores collected initially during field sampling (sites 18996-19045) were not stored in Mumetal shields and were allowed to dry in the ambient magnetic field for four months before measurement. Subsequent evidence of a post-sampling viscous remanence in Neogene sediments from the Wairoa Syncline (Walcott pers. comm. 1982; Walcott and Mumme 1982) led the author to store all cores in Mumetal shields.

should be diameter

Cores were cut 22 mm in length, with the length/radius ratio 0.80 < 1/~~r~~ d < 0.90 so as to approximate a dipole at the specimen centre. The specimens were numbered according to stratigraphic site and core number (Fig. 3.3).

Samples of the magnetic minerals were prepared for electron microprobe analysis following, essentially, the method of Froggatt and Gosson (1982). The only difference was that in order to enable both detrital and diagenetic minerals to be recognised, samples were not chemically cleaned by reagents. All samples were wet sieved to 30μ and air dried below 30°C to prevent maghemitisation before analysis. The magnetic fraction was recovered with both a permanent magnet (magnetic field 5.5×10^5 T) and a Frantz isodynamic separator, with a side slope of 20°C, forward slope of 30° and an amperage of 0.4. This was repeated three times for each sample. Subsequent microscopic examination of each separated 'magnetic' fraction revealed the presence of glass and micas with titanomagnetite inclusions and ilmenite. The separated 'magnetic' fraction was weighed and determined as a wt% of the > 30μ size fraction.

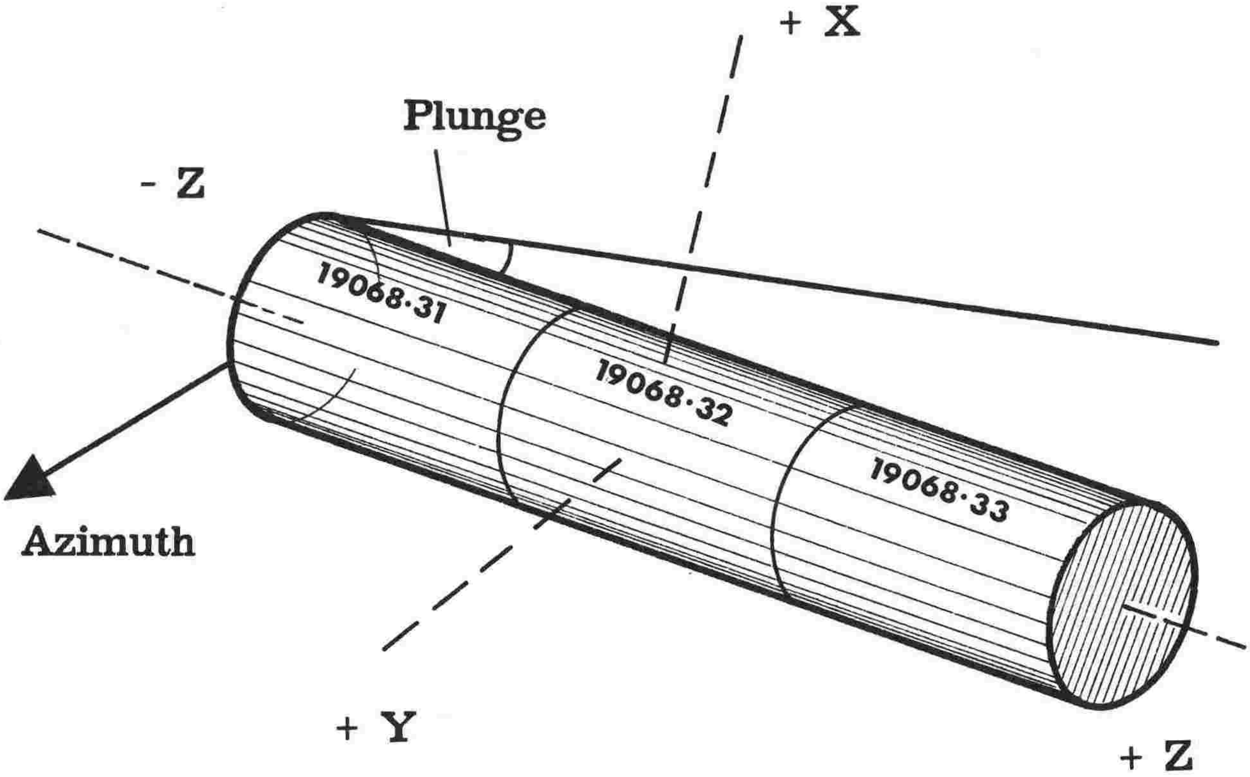


Fig. 3.3 Diagrammatic representation of numbered specimens and the relationship between field orientation and magnetometer reference axes.

3.4.3 Electron Probe Microanalysis

A computer driven JEOL 733 superprobe (Analytical Facility, Victoria University of Wellington) was used for all chemical analyses. Its operation (including corrections for absorption, fluorescence and atomic number) and calibration of standards has been decribed elsewhere (Morris 1979; Watanabe *et al.* 1981; Froggatt and Gosson 1982; Grapes and Watanabe 1984). An accelerating potential of 15 kV, a beam current of 1.0-2.0 x 10^{-8} amps and beam diameter of 3μ was used for all oxide analyses. A 25 kV accelerating potential was used for analysing sulphides (pyrite/pyrrhotite) to ensure the excitation of sulphur. The ilmenite standard (USNM 96819 Jarosewich *et al.* 1980) was analysed before and after each analysis period; the standard analysis and statistical deviations are presented in Table 3.1. All analyses with recalculated totals (Stormer 1983) in the range 99.0 - 101.0 wt% were accepted.

3.4.4 Initial Volume Susceptibility

Initial volume suceptibilities were measured for each specimen using a Bartington susceptibility meter. An alternating field (0.1 mT) was applied with an operating frequency of 0.5 kHz. The meter was calibrated to 10 gm of manganese carbonate with a known specific susceptibility of -0.048 x 10^{-6} m^3kg^{-1} and reset to zero before each measurement. Individual readings were corrected for specimen volume and averaged for the site (Appendix 9).

$$k = R \times 10 \times 10^{-3}$$

where R = meter reading

k = volume susceptibility

The susceptibility meter was not available until after most specimens from sites 18996 to 19145 were thermally demagnetised. All other specimens were measured after NRM measurement and before thermal demagnetisation. A comparison of volume susceptibilities up to 300°C and non-demagnetised specimens (Table 3.2) indicates no significant difference.

3.4.5 Isothermal Remanence Measurements

Twenty-one representative specimens were given an incremental isothermal remanent magnetisation (IRM) with a maximum direct field of 1.5 T (Appendix 4). All measurements were made by Dr. C. Laj and S. Guitton of Centre Des Faibles Radioactivities, Paris.

Table 3.1

Ilmenite Standard USNM 96819

	Microprobe Analysis N=15 Mean	Std.Dev.	Chemical Analysis*	
SiO_2	0.00	.		0.00
Al_2O_3	0.00	.		0.00
TiO_2	46.11	0.43		45.70
Fe_2O_3 }	47.34	0.53	47.70 {	11.60
FeO				36.10
MnO	4.47	0.21		4.77
MgO	0.31	0.03		0.31
CaO	0.00	.		0.00
Nb_2O_5				0.92
Total	97.12			98.24

* Jarosewich *et al.* (1980).

Total: not recalculated for Fe_2O_3 and FeO.

Difference in totals between chemical analysis and microprobe analysis is 0.92% Nb_2O_5

Table 3.2

Comparison of Volume Susceptibilities of Thermally Demagnetised Specimens (up to 300°C) and NRM Specimens from the same Site.

(values 10^{-3})

Specimen	Volume Susceptibility of Thermally Demagnetised Specimens	Volume Susceptibility of NRM Specimens
19020.11	188	.
19020.12	225	.
19020.21	.	207
19020.22	.	188
19022.21	169	.
19022.22	188	.
19022.31	.	169
19022.32	.	188
19041.11	282	.
19041.12	263	.
19041.21	.	244
19041.22	.	244
19060.1	.	150
19060.2	.	169
19060.31	150	.
19060.32	169	.
19090.11	226	.
19090.12	207	.
19090.41	.	226
19090.42	.	207
19094.21	188	.
19094.22	207	.
19094.3	.	169
19094.4	.	169
19115.1	132	.
19115.2	113	.
19115.3	.	132
19115.4	.	132

3.5 MEASUREMENT OF MAGNETIC REMANENCES

A two-axis ScT cryogenic magnetometer with on-line computer measured the natural remanent magnetisation. Before each period of measurement the Mylar sample holder was placed in a deionised ultrasonic water bath to dislodge any magnetic material present from previous use. The specimens were placed in the magnetometer with the positive Z-axis downwards and rotated through four 90° angles. Two SQUIDs (superconducting quantum interference device) one horizontal and one vertical measured the intensities of magnetisation of the two X, two Y and four Z axis components which are averaged. The intensity of magnetisation of the previously measured sample holder without a specimen was subtracted. Because of the weak intensities of magnetisation recorded, all specimens were inverted (negative Z-axis downwards) and remeasured, and the normal and inverted measurements again averaged.

The Fortran programme, NUCRYO.SAV was used to compute the magnetisation intensities for X, Y and Z components which were recorded on floppy disks. The programme corrected for core orientation and bedding attitude (Appendix 2). Measurement of a 'zero-reference level' before and after each specimen measurement indicated any magnetic drift. When the magnetic drift exceeded 5.0×10^{-6} Am^{-1} the measurement was rejected and repeated. Helmholtz coils reduced the ambient field at the magnetometer mouth to less than 100 nT.

When measuring weakly magnetised specimens it is desirable to assess measurement quality (Heller 1977; Channell 1977; Lowrie and Alvarez 1977; Harrison 1980; Lowrie *et al.* 1980). Lowrie *et al.* (1980) showed that progressive internal dispersion (ψ63) of each measurement increases as magnetisation intensity decreases. However, the basis of any acceptance criterion must be the repeatability of the measurement. For these reasons criteria for initial acceptance were:

1. the averaged intensity of magnetisation of the specimen exceeded 1.5×10^{-5} Am^{-1}

2. the angular difference between the normal and inverted modes of measurement did not exceed 15°

Large angular differences between normal and inverted measurements due to specimen inhomogeneity (probably bioturbation) as opposed to inherent magnetic instability are discussed in section 5.6.

3.6 DETRITAL MAGNETOMINERALOGY

3.6.1 Introduction

The only chemical data from Neogene sediments of the East Coast Deformed Belt relevant to this study is that of Gosson (1986) and Roser (unpublished). Previous studies (Orbell 1965; Bates 1967; Chaproniere 1969; Webb 1979; Kenny 1980, 1984; Blom 1982) have been petrographic descriptions where the Fe-Ti oxides have been included in the 'accessories' in modal counts. Only Ghent and Henderson (1966) detailed the mineralogy of the accessory minerals, recognising both anhedral and euhedral magnetite, the latter having an inferred volcanic source. However the 90 modal analyses from the above references give proportions of accessory minerals no greater than 4% and mostly below 1% in siltstones and sandstones. The magnetic fraction of the accesssory minerals is inferred to be < 1% within East Coast Neogene sediments. None of these petrographic studies gives chemical analyses of opaque or accessory minerals.

Gosson (1986) analysed with the microprobe volcanic glass and plagioclase from tuffs, and plagioclase and micas from the enclosing sediment. He showed that sediment from the East Coast Deformed Belt has at least three provenances; silicic volcanic tuffs and detritus, Torlesse Supergroup greywacke detritus eroded from the axial ranges and schist detritus from an as yet unrecognised source. Roser (unpublished data) analysed by X-ray fluorescence 35 Tongaporutuan siltstones from the Mangapoike section at sampled paleomagnetic sites. By titration he determined the absolute wt% of both FeO and Fe_2O_3 in each of the samples. The % of Fe^{3+} as a proportion of the total iron atoms can be expressed as an oxidation ratio, and ranges from 26.9% to 1.3%, with an average of 13.5%. This oxidation ratio is the whole rock Fe^{3+} total, in a range of different mineral species (chlorite, clays, micas and Fe-Ti oxides). It provides a gross indication of the degree of Fe oxidation in the Mangapoike sediments, which on average is small.

3.6.2 Chemistry

Titanomagnetite ($x Fe_2TiO_4(1-x)Fe_3O_4$) is the sole identifiable detrital magnetic mineral (Appendix 5) in the Mangapoike sequence. Titanium content varies between 5.87 wt% and 12.82 wt% (x=0.17-0.37, assuming impurities replace Fe) from the 30 accepted microprobe analyses (Fig. 3.4). Substituted cations vary antipathetically and are predominantly Al, Mg and Mn, being always less than 0.07 of the cation total. The

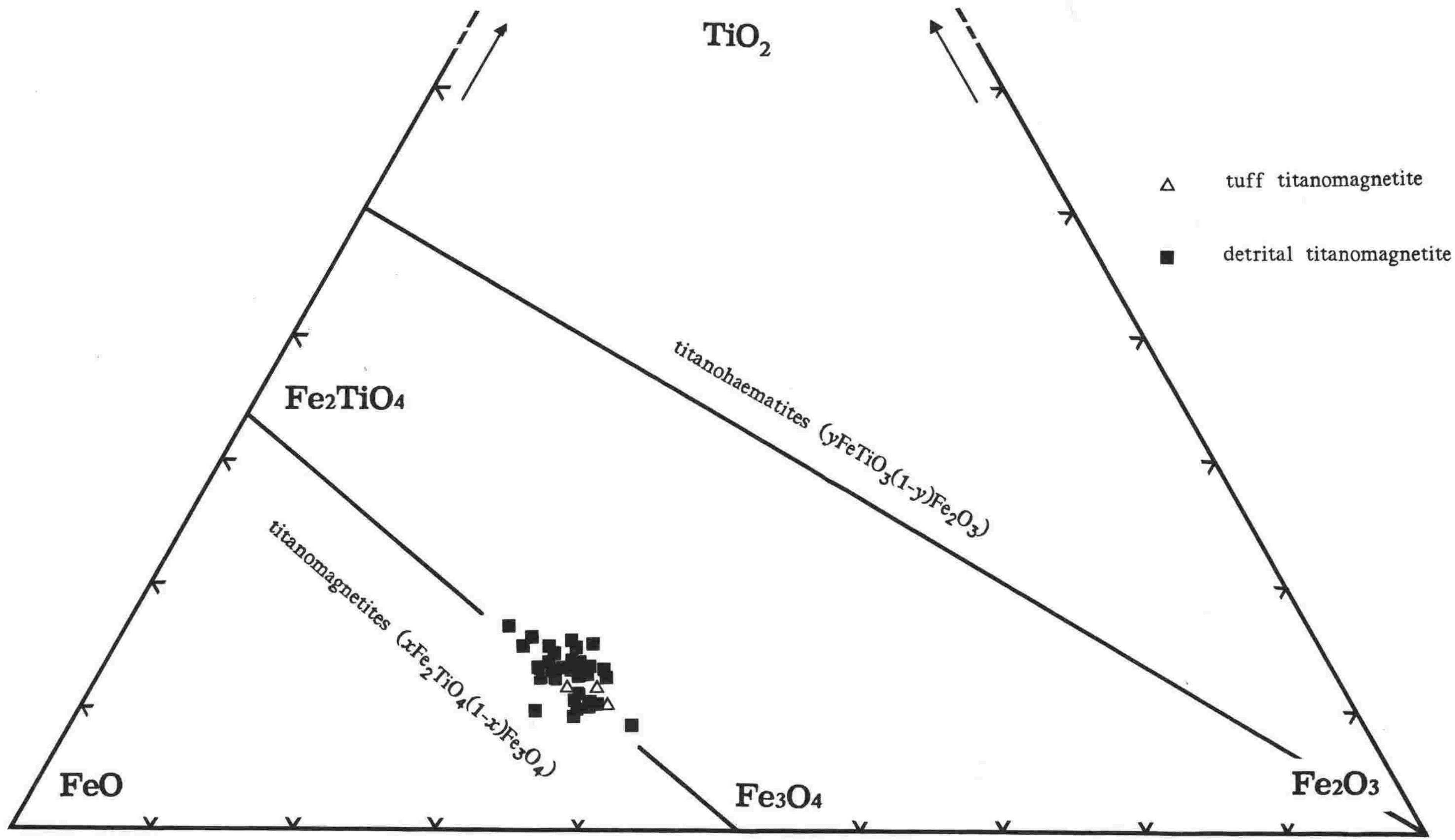
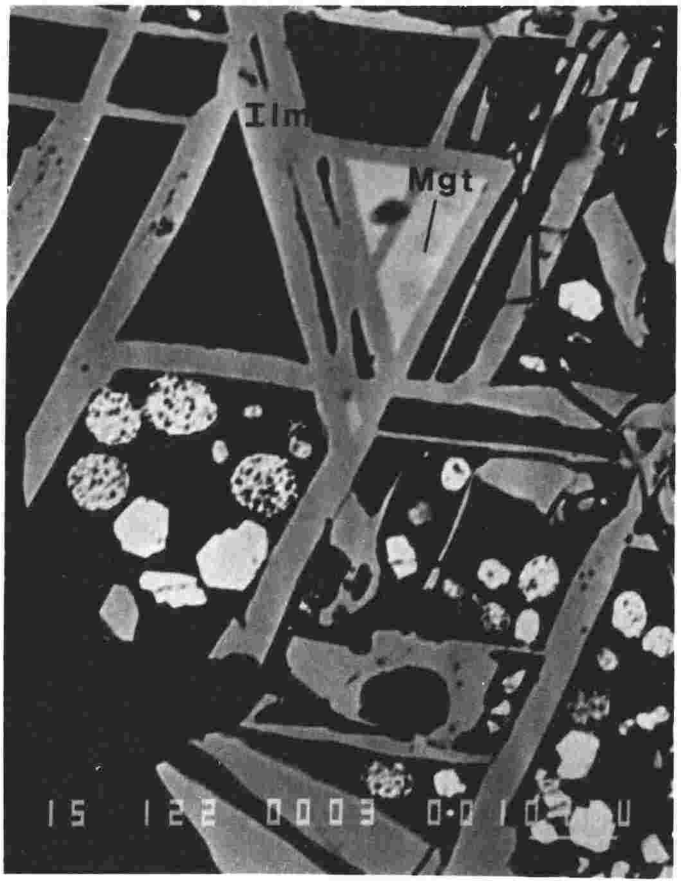


Fig. 3.4 Plot of the 30 accepted microprobe titanomagnetite analyses, including three tuff titanomagnetite analyses within the FeO - TiO_2 - Fe_2O_3 ternary system.

Plate 3.1 Exsolved ilmenite (Ilm) lamellae within host titanomagnetite (Mgt). Background black is the mounting epoxy resin. Scale bar (lower right) is 10 microns.

Plate 3.2 Authigenic framboidal pyrite (Pyr). Scale bar (bottom) is 100 microns.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Mgt
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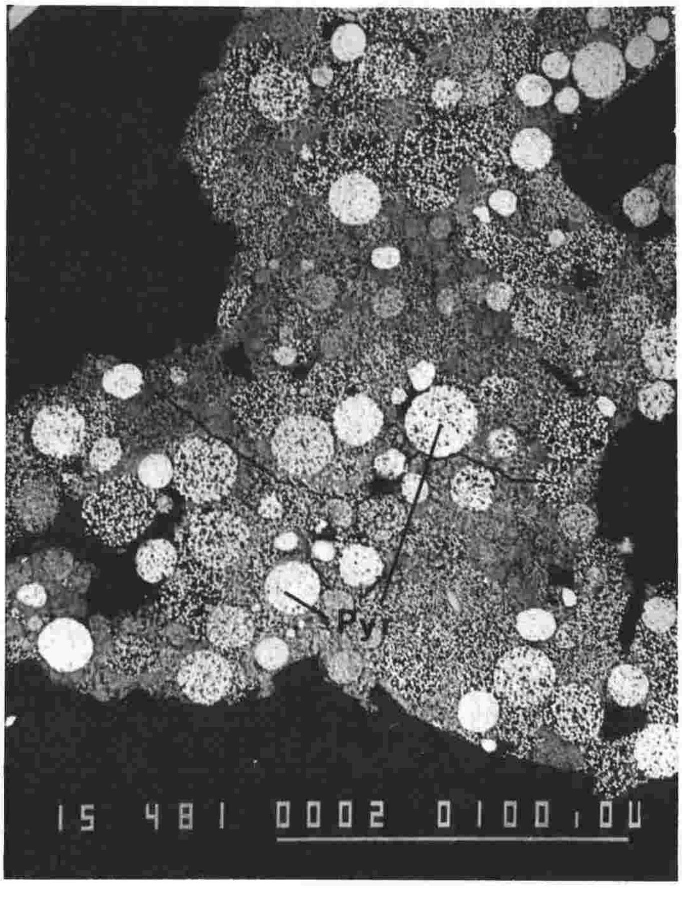

Pyr
15 481 0002 0100,0U

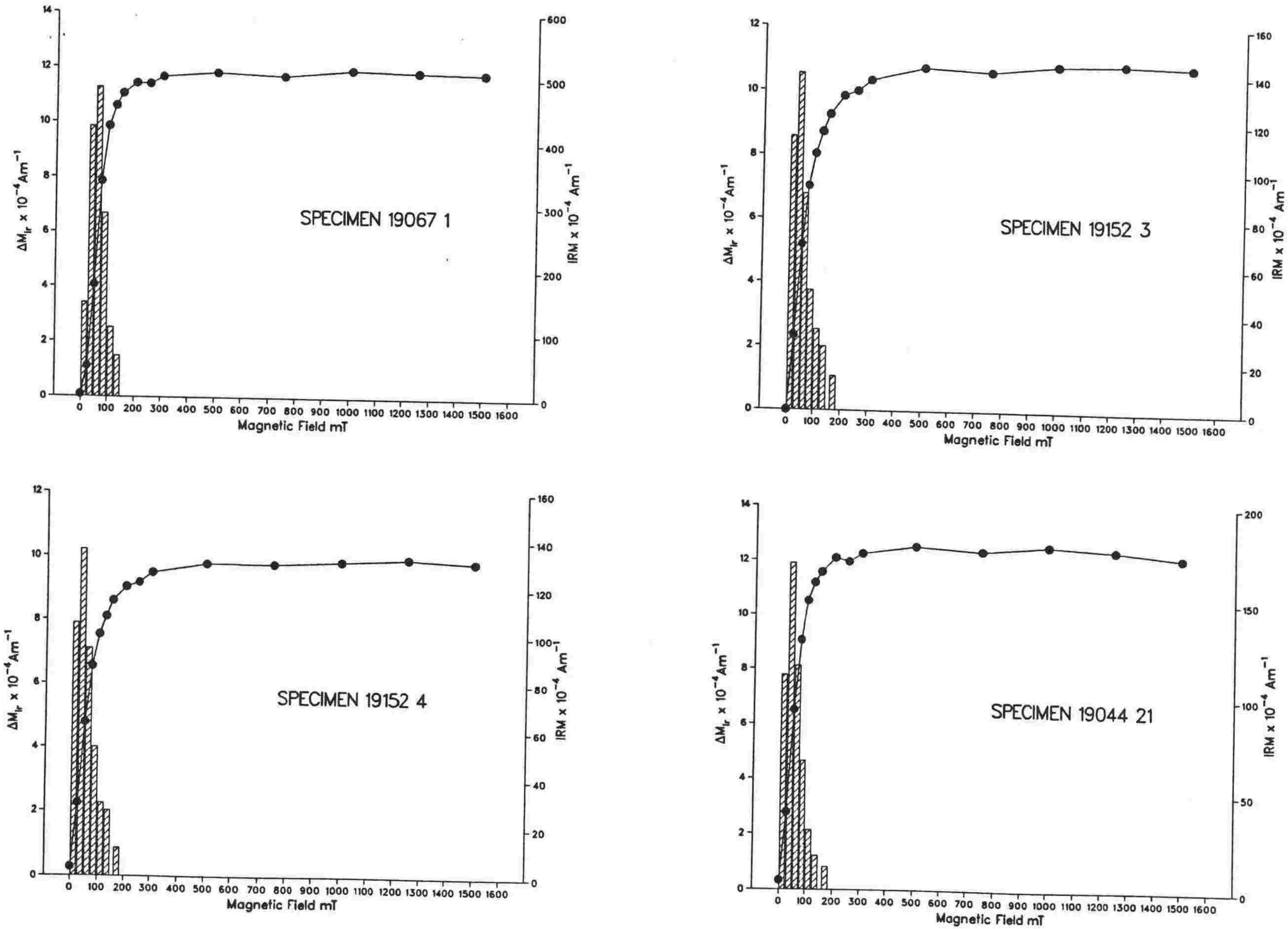
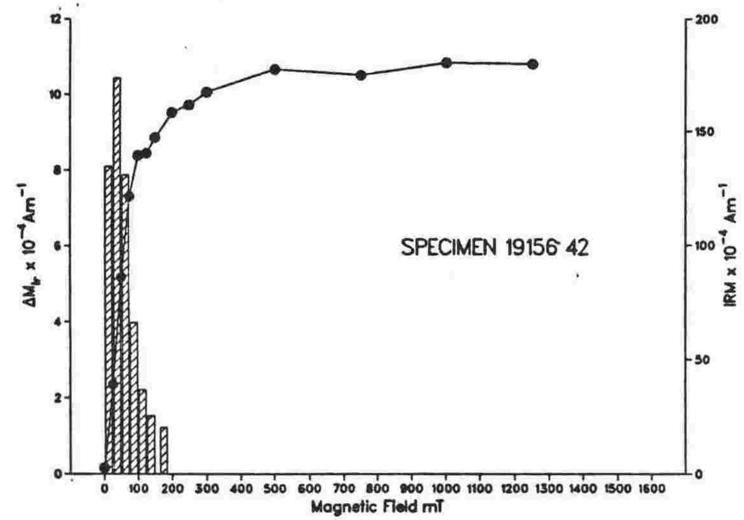
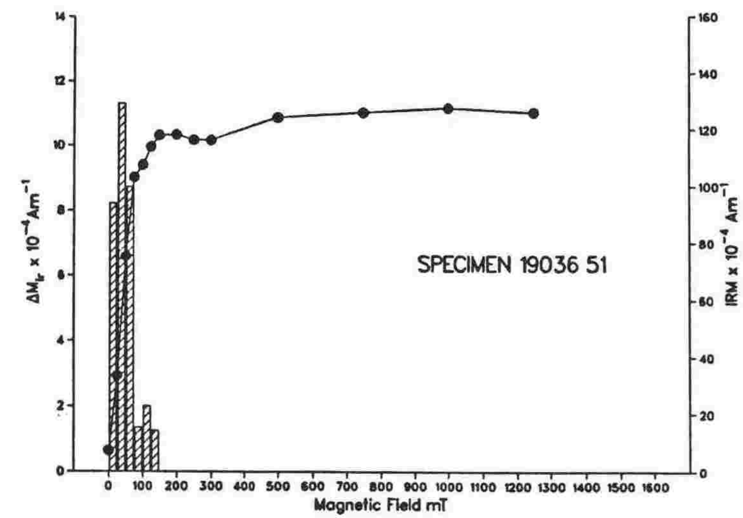
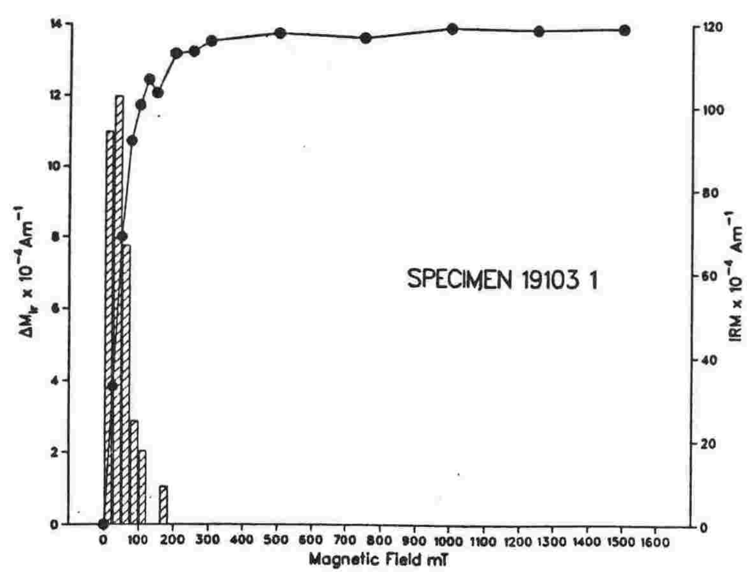


Fig. 3.5 Isothermal remanent magnetisation (IRM) curves (right axes) and incremental coercivity spectra (left axis) of 8 representative specimens. All specimens are saturated within a direct field of 200 mT.







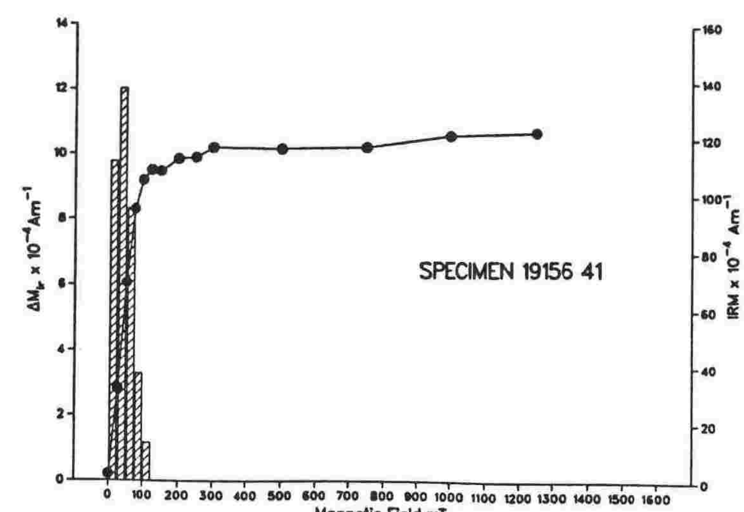


Fig. 3.5 (continued).

paragenesis of titanomagnetite is accepted to occur by crystallisation at magmatic temperatures (O'Reilly 1976), although Scotese *et al.* (1982) have suggested low temperature authigenesis of magnetite is possible. It is inferred that the identified titanomagnetite is detrital in origin, and their directions of magnetisation were aligned preferentially in the sediments at the time of or very soon after deposition. Deuteric oxidation is recognised in one titanomagnetite grain (Plate 3.1) with exsolved lamellae of ilmenite. The ilmenite lamellae are equivalent to the C3 oxidation stage of Haggerty (1976) and represent early subsolidus oxidation during magma cooling at about 600°C (Lindsley 1962; Buddington and Lindsley 1964; Haggerty 1976). All other titanomagnetite grains were homogeneous when viewed with back-scattered electron imagery (BEI). Ilmenite (paramagnetic) is the only other identified Fe-oxide.

Isothermal remanent magnetisation (IRM) curves support the microprobe data. Both the IRM curves and their incremental coercivity spectra (Dunlop 1972) were saturated within direct fields of 200 mT (Fig. 3.5), in the 22 representative specimens tested (Appendix 4), indicating that magnetite, or titanomagnetite is the only magnetic mineral. Higher fields do not appear to saturate other magnetic components and it is inferred that haematite, maghemite and goethite are not present (Dunlop 1972).

Roser and Korsch (1985) and Roser and Rowe (in press) have shown that framework and matrix mineralogy and whole rock geochemistry can vary with grain size in sediments. Total Fe_2O_3 and TiO_2 varied 5% and 0.6% respectively between greywacke sandstones and argillites of the Torlesse Supergroup. Similiar trends are seen within a Miocene graded bed (Roser and Korsch in prep). No such trend was shown by titanomagnetite chemistry at Mangapoike (Fig. 3.6) supporting a conclusion by Roser (pers. comm.) that hydrodynamic differentiation is minimal within a mineral species. It follows that the chemistry of the titanomagnetites within the > 30μ size fraction is representative of that of the total grain size range.

3.6.3 Concentration

The amount of titanomagnetite in the Mangapoike sediments is extremely low being in the order of 10^{-3} - 10^{-4} wt%. The estimate is based on the wt% of the 'magnetic' separate and the ratio of ferrimagnetic to paramagnetic grains within the extracted fraction (Table 3.3). It assumes that there has been a complete separation of 'magnetic' and non-magnetic minerals in the > 30μ size fraction and that the concentration of 'magnetic' minerals in the > 30μ size fraction (Table 3.3) is the same as that of the < 30μ size fraction.

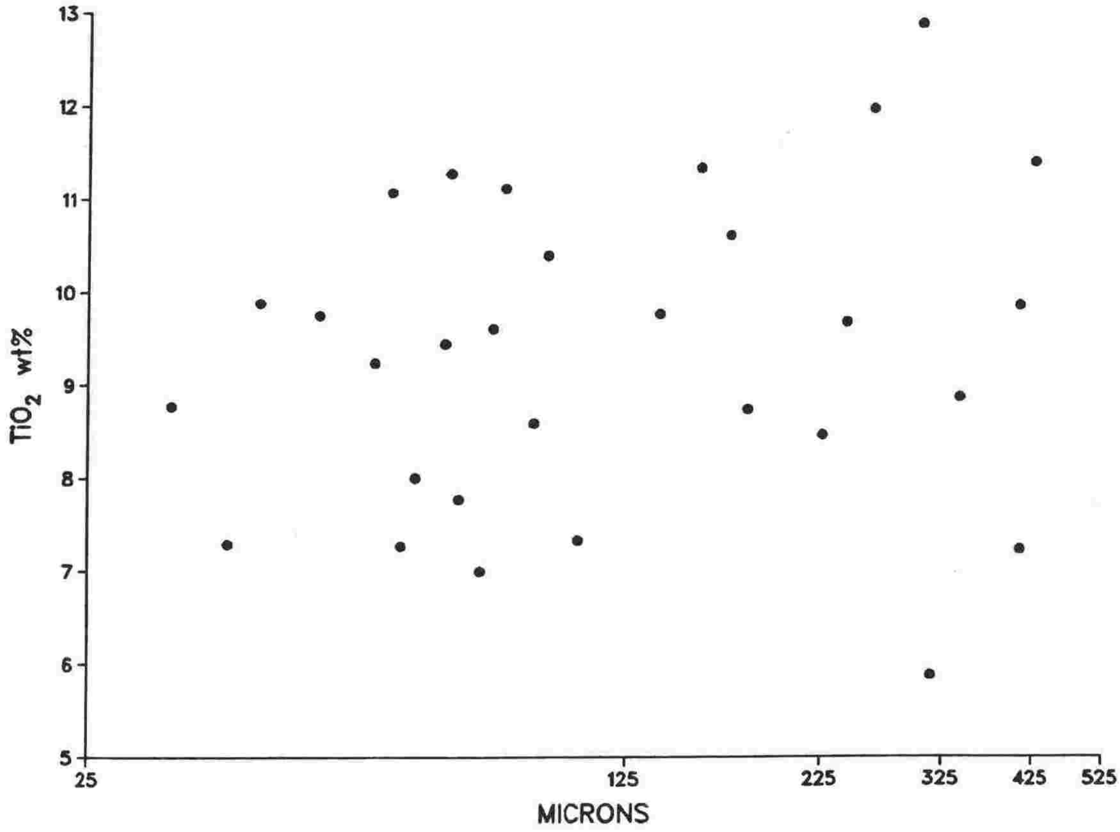


Fig. 3.6 Plot of Mangapoike titanomagnetites showing no correlation between TiO_2 wt% and grain size (microns) indicating hydrodynamic differation of the grains does not occur.

Table 3.3

Titanomagnetite Concentration

$> 30\mu$ Size Fraction

Sample	Wt% "Magnetic" Fraction of Total Sample*	Estimated Ratio of Titanomagnetite:Ilmenite in "Magnetic" Fraction
19210	0.001%	1:30
19211	0.009%	1:50
19212	0.002%	1:60
19213	0.003%	1:100
19214	0.0008%	1:50
19215	0.004%	1:60
19216	0.002%	1:80
19217	0.003%	1:70
19218	0.001%	1:40
19219	0.0008%	1:60

* Includes both paramagnetic ilmenite and ferrimagnetic titanomagnetite.

A comparison of the volume susceptibility of the original sample and the remaining non-magnetic fraction before and after extraction (Table 3.4) indicates a separation efficiency ranging from 60% to 75%. Since the volume susceptibility measurements both before and after extraction have contributions from ferrimagnetic and paramagnetic minerals (Collinson 1983), volume susceptiblity is not an accurate measure of magnetic mineral content. An error of ±10% is thus assigned to the separation, as measured by volume susceptibility, based on the observed ratio of paramagnetic ilmenite to ferrimagnetic titanomagnetite (Table 3.3) within the separated 'magnetic' fraction and the calculated susceptibilities of pure titanomagnetite and ilmenite, 1.0904 and 0.1900 respectively (Collinson 1983). Thus the estimated 55% to 80% separation efficiency compares favourably with other magnetic mineral extractions (Lovile *et al.* 1971 Kent and Lowrie 1974) which have varied between 5% and 60%, as measured by susceptiblity and saturation IRM data. The better extraction is ascribed to using the > 30μ size fraction since the problems of flocculation and electrostatic attraction are reduced when compared with very fine grained samples.

3.6.4 Source

The low TiO_2 (5.87-12.82 wt%) content of the titanomagnetites indicates one or more silicic sources (Buddington and Lindsley 1964; Carmichael 1967; Haggerty 1976). The continuum of TiO_2 content over the range of wt% (Fig. 3.4) indicates that TiO_2 cannot be used as a discriminator for sediment provenance. On the basis of the three major substituted cations Al, Mn and Mg within the titanomagnetites, three distinct fields are recognised (Fig. 3.7). These three fields do not represent the three sediment provenances (silicic volcanism, greywacke detritus and schist detritus) of Gosson (1986), but are a function of temporal and/or spatial variation solely within the volcanic terrane. Detrital titanomagnetite has not been identified from Torlesse greywacke rocks (Grapes pers. comm.) and phase calculations show that titanomagnetite is in disequilibrium at prehnite / pumpellyite grade metamorphism, reverting to sphene. For the same reason titanomagnetite from a schist terrane is unlikely. Metabasites within the Torlesse Supergroup (Roser 1984) can also be discounted as a titanomagnetite source, since high TiO_2 (20-25 wt%) titanomagnetites from basalts (Buddington and Lindsley 1964; Carmicheal 1967; Haggerty 1976) are not identified within the Mangapoike sediments.

Field 1 (Fig. 3.7) definitely represents titanomagnetites from a silicic volcanic source, with the three titanomagnetite analyses from a silicic tuff plotting in this field.

Table 3.4

Comparison of Volume Susceptibility during Extraction

(values 10^{-3})

Sample	Volume Susceptibility of Original Sample	Volume Susceptibility of Non-Magnetic Sample after Extraction
19210	233.3	74.6
19211	192.5	75.1
19212	252.7	68.2
19213	246.2	61.6
19214	170.5	56.2
19215	187.2	63.8
19216	182.3	72.9
19217	160.7	45.0
19218	164.9	57.7
19219	162.9	57.0

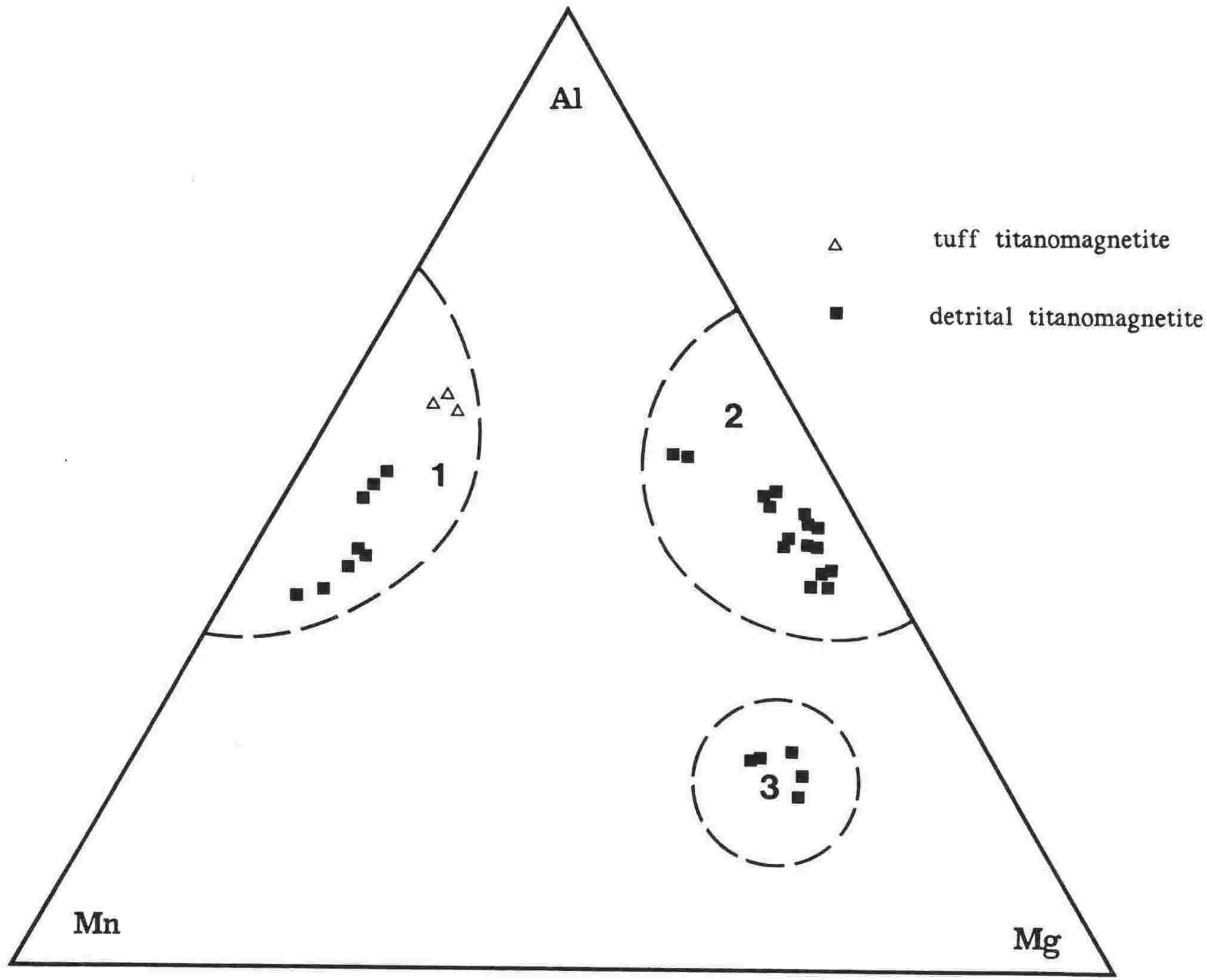


Fig. 3.7 Plot of the three major substituted cations, Al, Mn and Mg (atomic %) of the Mangapoike titanomagnetites showing three distinct fields, inferred to represent spatial and temporal variation of silicic volcanism within the Hauraki Volcanic Region.

Titanomagnetite analyses comparable to those presented here have been reported from known dacitic and rhyolitic tuffs (Kohn 1970; Moll 1981; Froggatt 1982; Westgate *et al.* 1985). Gosson (1986) has argued convincingly that the Hauraki Volcanic Region (Skinner 1986) is the source, and his interpretation is accepted here. Fields 2 and 3 are also argued to be silicic products from the same volcanic region because of the low TiO_2 wt% of the titanomagnetites and the presumed absence of titanomagnetite in either greywacke or schist terranes. Lack of comparative data from the Hauraki Volcanic Region however prevents a positive correlation of fields 2 and 3 with a Hauraki source. Compositional variablity of substituted cations within titanomagnetites have been indicative of temporal and/or spatial variation of Quaternary pyroclastic rocks (Kohn and Topping 1978; Westgate and Evans 1978; Hodder 1985).

3.7 DIAGENETIC AND AUTHIGENIC MAGNETOMINERALOGY

3.7.1 Haematite, Maghemite and Goethite

Low temperature oxidation (maghemitisation, martitisation and oxyhydration) is not recognised in any of the analysed grains. Characteristic secondary or replacement textures (Bose 1958; Nickel 1958; Ramdor 1969; Evans and Wayman 1970; Haggerty 1976) are not recognised as inhomogeneties when viewed with back-scattered imagery. Neither haematite/maghemite nor goethite were recognised in any of the 74 oxide microprobe analyses (Appendix 5). The IRM curves (section 3.6.2) support the absence of haematite, maghemite and goethite.

3.7.2 Pyrrhotite

Iron sulphide (Plate 3.2) is an abundant authigenic mineral in New Zealand Cenozoic mudstones and sandstones. No pyrrhotite was detected in 40 electron probe analyses (Appendix 5).

3.8 REMANENCE STABILITY

3.8.1 Introduction

A number of field and laboratory stability tests can be used to identify viscous decay of the primary magnetisation over geologic time and/or the subsequent acquisition of a viscous magnetisation (VRM) in the present field direction. Reversed polarity directions, the fold test (Graham 1949), conglomerate test (Graham 1949), and baked contacts (Irving 1964; McElhinny 1973) have all been used as field stability tests (Irving and Runcorn 1957; Wilson 1962; Lowrie and Alvarez 1977; Purucker *et al.* 1980). Various laboratory stability test have been devised and include a comparison of induced magnetisation intensity (Konigsberger 1938; Irving 1964) and study of either induced or natural remanent coercivity (Petrova 1961; Radhakrishnamurty and Sahasrabudhe 1965; Stacey and Banerjee 1974).

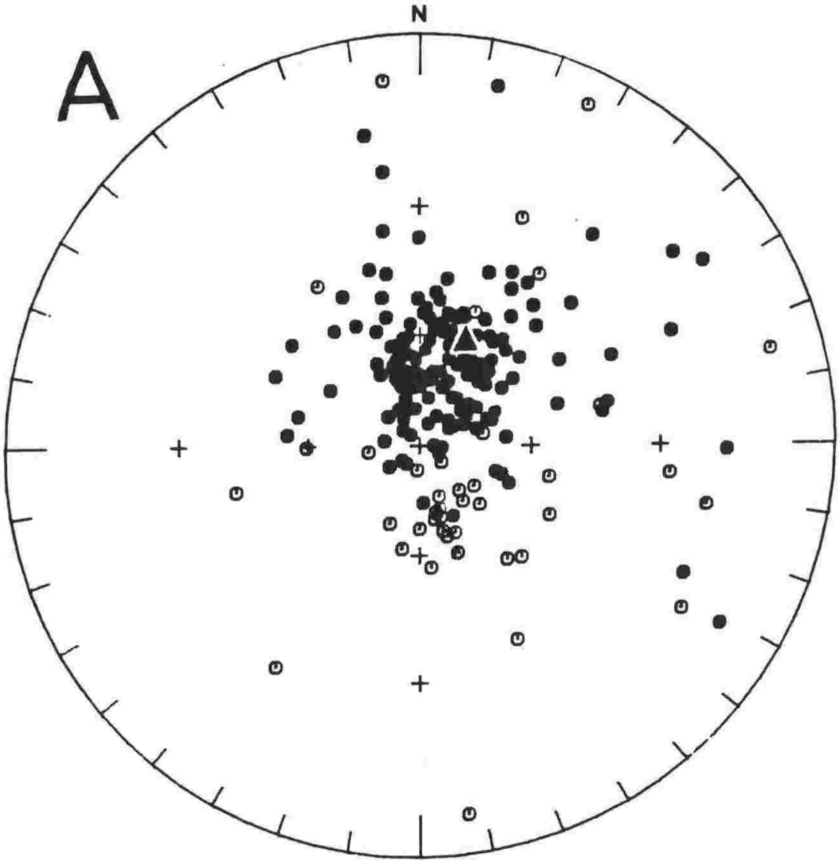
3.8.2 NRM Directions

Most (85%) of the NRM directions in the Mangapoike section, before tectonic correction, group near a the present field direction (declination 022, inclination -59, Fig. 3.8). The remaining 15% having reversed polarity directions. Two explanations can be made; 1. all of the specimens have the same spectra of remanent stability, in both normal and reversed NRM directions, and coincidently lie near the present field direction; 2. the specimens have different remanent stability spectra, and most have a secondary viscous normal overprint in the present field direction. The second explanation is favoured because of both the anomalous NRM directions, with positive inclinations but present field declinations, (Fig. 3.8) and the less than 180° between mean normal and reversed NRM directions (Fig. 3.9). Both indicate the presence of a secondary component of magnetisation. Further evidence for the presence of a secondary component is the acquistion (section 3.7.3) and decay (section 3.7.4) of a viscous remanence within laboratory time.

A fold test could not be be applied to the Mangapoike data, because there are no significant variations in bedding orientation (Appendix 2). The data of Walcott and Mumme (1982) from more steeply dipping strata from the Wairoa Syncline could not be used because of the acquistion of a post-sampling viscous magnetisation.

3.8.3 VRM Acquistion

Viscous remanent magnetisation (VRM) acquired after sampling of New Zealand Cenozoic sediments has been described by Walcott and Mumme (1982) and Mumme and Walcott (1985). The magnetisation is aligned along the Z axis of the specimen in a negative sense, while stored on end in the present magnetic field, producing a strong correlation between NRM declination and core azimuth as decsribed by the relationship: $D = \tan^{-1}\{ y/(z\cos\theta + x\sin\theta) + (\Phi-90)\}$, where θ is the core plunge and Φ is the core azimuth (Walcott and Mumme 1982, see their Fig. 3). The data could have been ascribed to a drilling induced remanence as described by Sallomy and Briden (1975), but tests by Mumme and Walcott (1985) with dry and wet specimens from the same core stored in both shielded and non-shielded states confirmed the component to be a



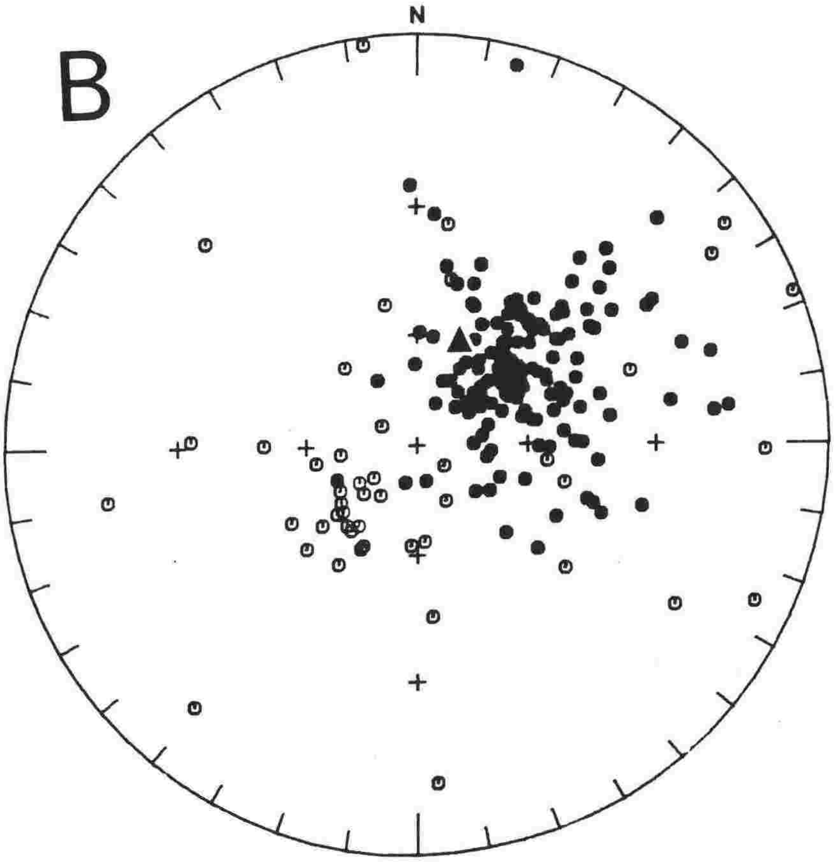


Fig. 3.8 Representative NRM directions, (a) not corrected for tectonic rotation and (b) corrected for tectonic rotation. Closed symbols upper hemisphere and open symbols lower hemisphere. Triangle, present day field direction.

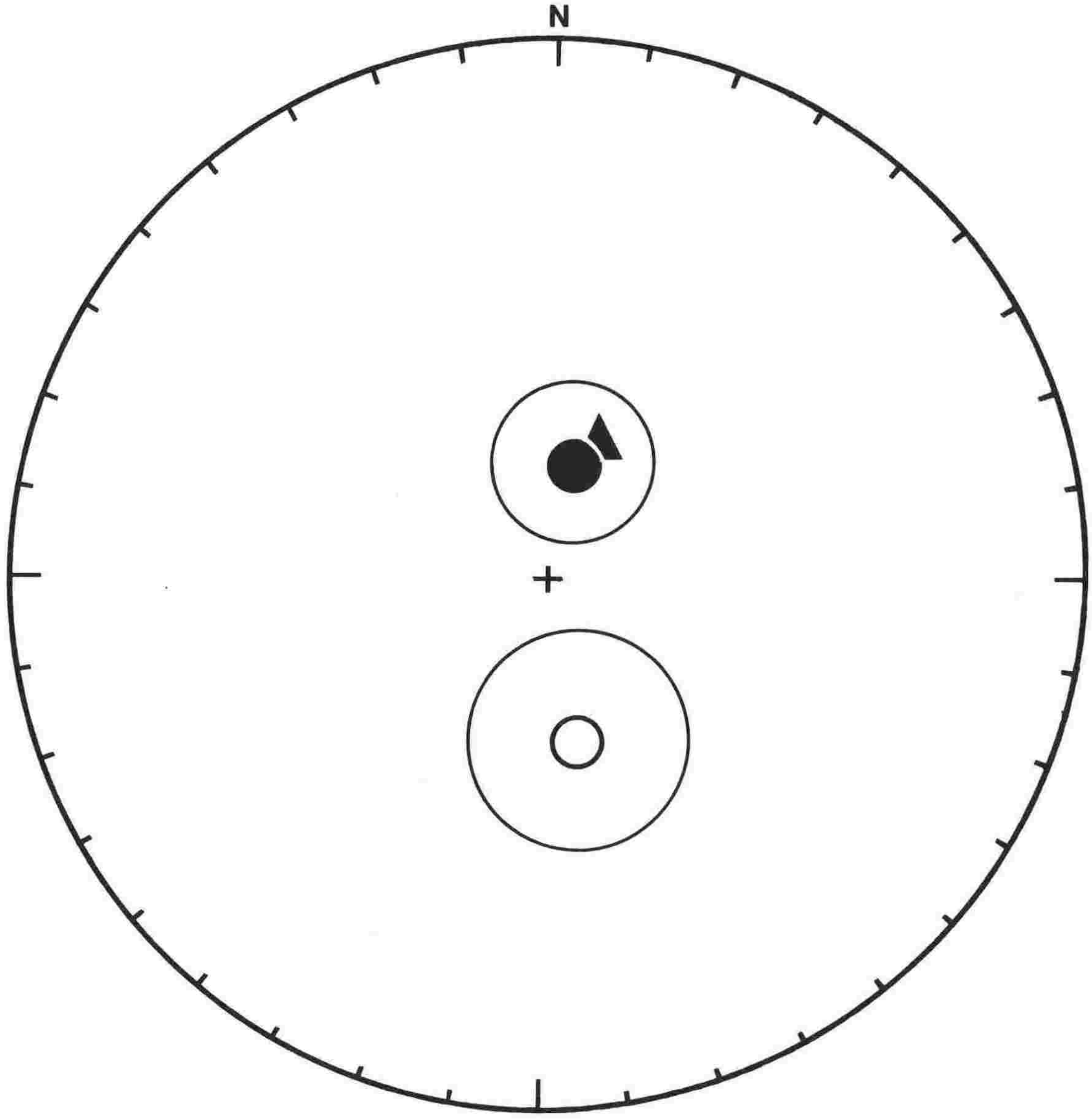


Fig. 3.9 Mean normal and reversed NRM directions, with α95's of representative specimens from Fig. 3.8. Symbol convention is that of Fig. 3.8.

VRM, and that both drying and non-shielding were factors in its acquistion.

Similiar behaviour is recognised in Mangapoike specimens which were not stored in Mumetal shields (Fig. 3.10). The correlation between NRM declination and core azimuth is, however, not as pronounced as that of Walcott and Mumme (1982), suggesting that the post-sampling VRM component is not the predominant NRM magnetisation. Specimens stored in Mumetal shields showed no correlation between NRM declination and core azimuth (Fig. 3.11) and were inferred to have no significant post-sampling VRM component.

Drying and non-shielding are factors in imparting the post-sampling VRM (Mumme and Walcott 1985) but the physical mechanisms or phase changes in the mineralogy are unclear. Drying of sediment slurries (40-60% water) in an applied field has imparted significant VRM components in laboratory experiments (Johnson *et al.* 1975; Henshaw and Merrill 1979; Verosub *et al.* 1979; Otofuji *et al.* 1982). Comparison of that drying effect with the well cemented mudstones studied here, with water contents of less than 3% (Table 3.5) is however questionable. Constant values of volume susceptibility during thermal demagnetisation at temperatures below 300°C (Table 3.2 and see section 4.2.3) with resultant water loss, suggest no detectable changes in the mineralogy. The magnetic characteristics of the post-sampling VRM are also unclear. It has a low coercivity of acquistion (0.5 mT, the earth's magnetic field) but requires either moderate temperatures (200°C - 250°C) or AF fields (30 mT) for its removal (Walcott and Mumme 1982; Mumme and Walcott 1985).

3.8.4 VRM Decay

Zero-field demagnetisation (storage test) is the measurement of magnetisation while stored in a zero-field at progressively longer intervals of time. The decay of NRM with time indicates the presence of a viscous remanence, the contributions of which become randomised. Twelve representative specimens were placed in a Mumetal shield (field $<$ 50 nT) and were initially used as an internal calibration to check SQUID orientation and sign before each measurement period.

Two types of remanent stability were recognised in these specimens over a period of 18 months. Because the magnetometer was available for use only at irregular intervals the specimens could not be measured at equal time intervals, but at 319 and 418 days of shield storage. Type I specimens show an average 45% decay in magnetisation intensity (Fig. 3.12) and thus are inferred to have a VRM component, and have magnetic viscosity coefficients (S_d) greater than 0.250 (Table 3.6). Type II

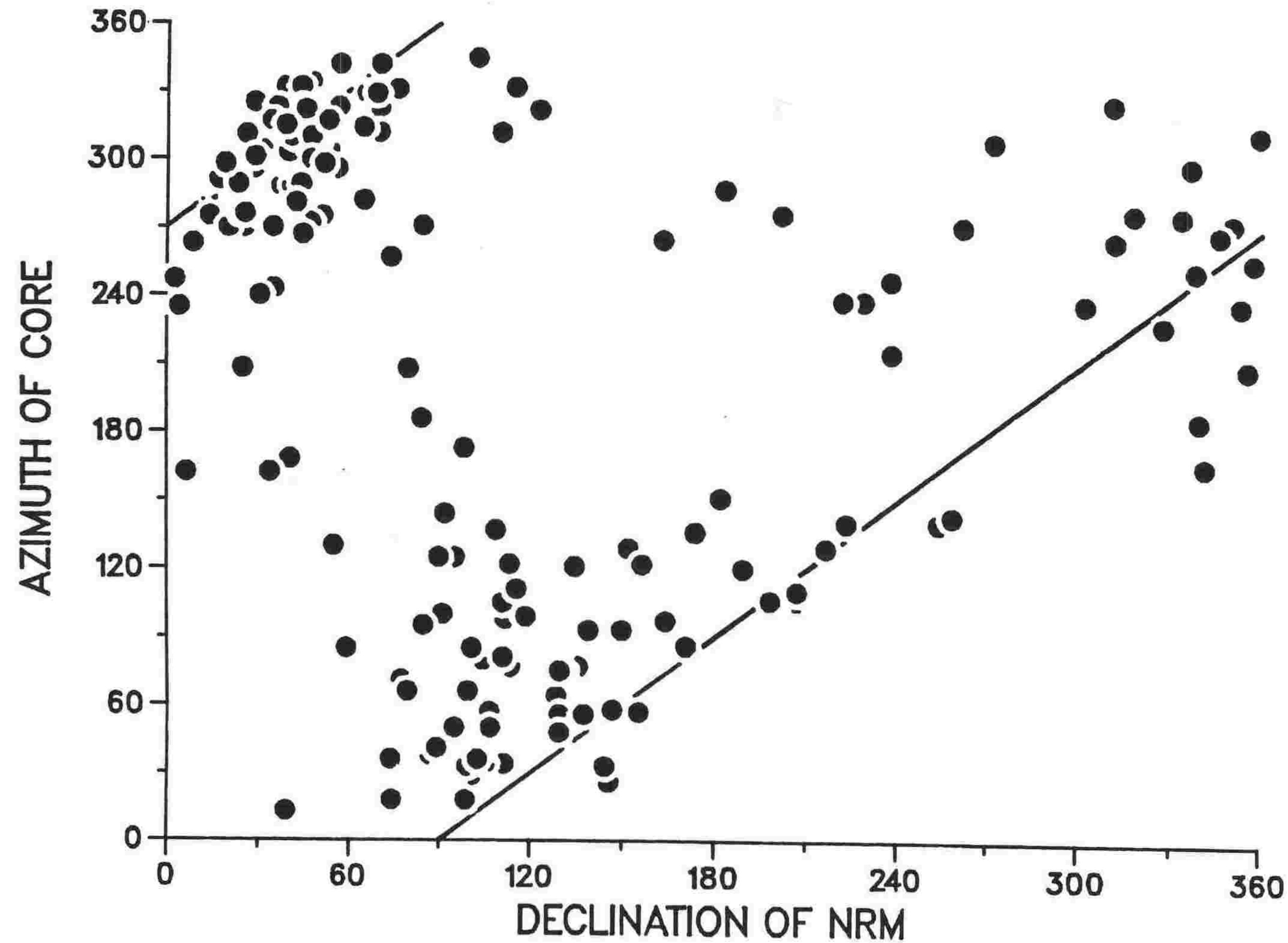


Fig. 3.10 Plot of NRM declination of specimens (18996-19045) not stored in Mumetal shields. Lines are the expected correlations of $D = \tan^{-1}\{ y/(z\cos\theta + x\sin\theta) + (\Phi\text{-}90)\}$, see text.

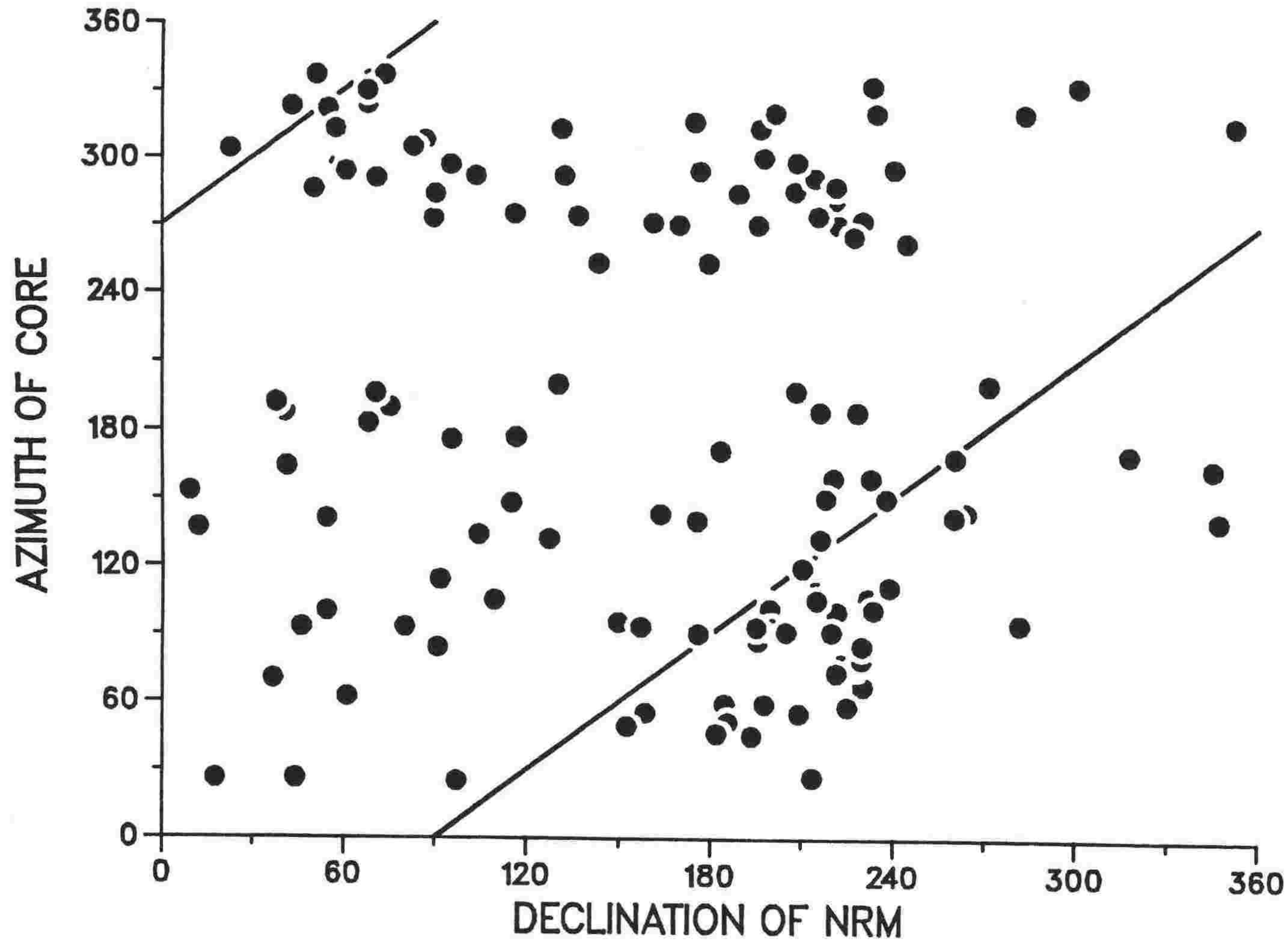


Fig. 3.11 Plot of NRM declination of representative specimens (19046-19094) stored in Mumetal shields. Lines are the expected correlations of $D = \tan^{-1}\{ y/(z\cos\theta + x\sin\theta) + (\Phi\text{-}90)\}$, see text.

specimens showed no significant decrease in intensity, have viscosity coefficients less than 0.130 and correspondingly are assumed to have no significant VRM components.

The two types of remanent stability are related to NRM polarity. All type I specimens have normal NRM polarity, while all type II specimens have reversed NRM polarity (Table 3.5 and Fig. 3.12). Reversed NRM polarity of type II specimens is consistent with their low viscosity coefficients, which ensure that they retain their reversed polarity and do not acquire a viscous normal overprint. The converse, that all specimens with high viscosity coefficients have normal NRM polarity need not be true. It is expected that some normal NRM polarity specimens have not acquired a viscous overprint but have simply retained their normal primary magnetisation and consequently should have low viscosity coefficients. The observation that all of the high coefficient specimens have normal NRM polarity is thus considered to be a sampling problem. This is confirmed when it is observed that all of the normal NRM polarity specimens have a reversed primary magnetisation and none of the twelve specimens has a normal primary magnetisation (chapter 4 and Appendix 8).

3.8.5 Discussion

The acquired viscous remanent magnetisation (VRM_A) and the decaying viscous remanent magnetisation (VRM_D) as described in the previous sections are considered to be one viscous magnetisation. Both the VRM_A and the VRM_D are highly viscous over laboratory time and have similiar coercivity spectra, making it unlikely that two components with the same viscosities would resolve into two different magnetisations. The assumption that decay and acquisition viscosities are the same (ie $S_A = - S_D$) is supported by complementary viscous acquisition and decay experiments on the same sample made by Creer (1957). The characteristics of acquisition and decay of this viscous magnetisation are interpreted as different responses to either non-shielding or shielding with Mumetal.

The viscous magnetisation aligned in the present field direction (section 3.8.2) has a different relaxation time from the highly viscous laboratory magnetisation (cf. 720,000 yrs and 18 months) and is thus inferred to have different coercivity spectrum. Further evidence for differences in the coercivity spectra is provided in chapter 4 where evidence is shown that the viscous magnetisation aligned in the present field direction is randomised at 250-300°C and the laboratory magnetisation is randomised at 200-250°C during demagnetisation.

Table 3.5

Water Content of Specimens % Dry at 300°C (values in grams).

Specimen	20°C	300°C	% Dry Weight
18998.11	19.134	18.735	2.13
18998.12	20.059	19.531	2.70
19000.41	19.716	19.284	2.24
19000.42	19.537	19.119	2.19
19010.31	20.216	19.853	1.83
19010.32	19.208	18.749	2.45
19048.1	19.317	18.861	2.42
19048.4	19.803	19.615	0.96
19094.21	19.546	19.191	1.85
19094.22	18.619	18.153	2.57
19012.11	18.742	18.490	1.36
19012.12	19.128	18.817	1.65
19032.2	20.265	19.749	2.61
19019.2	19.634	19.047	3.08
19034.2	18.898	18.572	1.76
19061.4	19.275	18.918	1.89
19062.3	18.719	18.413	1.66

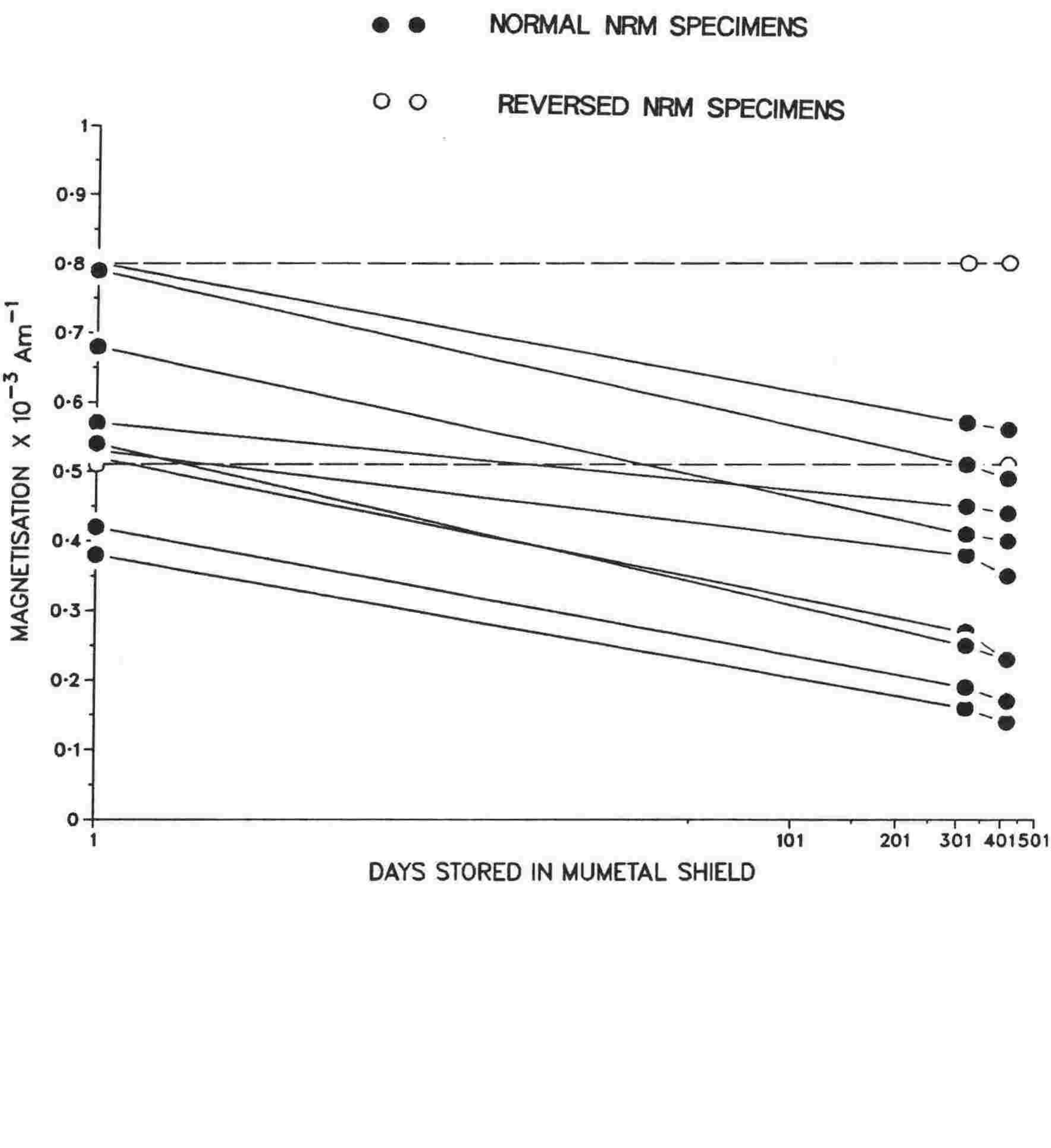


Fig. 3.12 Plot of magnetisation intensity against days of Mumetal shield storage (log scale), showing an exponential decay with time.

Table 3.6

Specimen	ΔJ_{VRM}	$\Delta(\log\ t)$	Rate of VRM Decay Viscosity Coefficient (S_d)	NRM Polarity
19029 33	3.10	7.5576	0.410	N
19032 1	3.09	7.5576	0.409	N
19041 5	3.41	7.5576	0.451	N
19054 42	1.44	7.5576	0.191	N
19056 4	2.03	7.5576	0.269	N
19060 22	2.99	7.5576	0.396	N
19061 31	2.75	7.5576	0.364	N
19063 1	2.58	7.5576	0.341	N
19070 41	0.16	7.5576	0.021	R
19074 31	0.81	7.5576	0.107	R
19077 3	3.27	7.5576	0.433	N

ΔJ_{VRM} = difference in magnetisation intensity between 1 and 419 days of shield storage (units x 10^{-4} Am^{-1})

$\Delta(\log\ t)$ = log of 419 days in seconds.

NRM Polarity, N = normal and R = reversed.

$S_d = \Delta J_{VRM} / \Delta(\log\ t)$.

VRM, and that both drying and non-shielding were factors in its acquistion.

Similiar behaviour is recognised in Mangapoike specimens which were not stored in Mumetal shields (Fig. 3.10). The correlation between NRM declination and core azimuth is, however, not as pronounced as that of Walcott and Mumme (1982), suggesting that the post-sampling VRM component is not the predominant NRM magnetisation. Specimens stored in Mumetal shields showed no correlation between NRM declination and core azimuth (Fig. 3.11) and were inferred to have no significant post-sampling VRM component.

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Since titanomagnetite is the sole magnetic mineral identified by electron microprobe analysis and IRM curves, it is the magnetic carrier of both the stable and viscous magnetisations. This variation of magnetic stability within one mineral species can be attributed to either differences in particle size and domain state or variation in cation substitution within the titanomagnetite structure. The multidomain theories of VRM (Neel 1955; Stacey 1963) where viscosity (S) is particle size dependent have been confirmed by experimental data (Dunlop 1973). The correlation of coercivity and saturation remanences with cation substitution within titanomagnetites has been reported (Creer and Stephenson 1972; Richards *et al.* 1973). Patel and Palmer (1982) also suggested that increasing magnetic instability correlates with increasing cation substitution. In Mangapoike specimens direct correlations have not been made between magnetic viscosity and the grain size of the magnetic fraction and/or the degree of cation substitution because of a lack of data from all 343 sites. Since logarithmic decay of a VRM with time is predicted by multidomain viscous theory (Neel 1955; Stacey 1963) and such a decay is observed within the Mangapoike specimens (Fig. 3.12), it is inferred that viscous magnetisations reside in multidomain titanomagnetite.

3.9 NRM INTENSITY

3.9.1 Introduction

Variations of NRM intensity in a rock are assumed to be a function of both the strength of the geomagnetic field when the rock was formed (paleofield intensity) and the concentration of magnetic minerals in the rock. Determination of the absolute magnetic mineral content, and hence its contribution to the NRM intensity, is difficult, and especially so in fine grained sediments. A number of magnetic properties (initial susceptibility, isothermal remanent magnetisation, saturated isothermal magnetisation and anhysteretic remanent magnetisation) have been used as normalising parameters (Harrison 1966; Opdyke *et al.* 1973; Levi and Banerjee 1976; Johnson *et al.* 1975; Creer *et al.* 1976) assuming the measured property is proportional to the magnetic mineral content.

Initial volume susceptibility is used in this study since other magnetic properties could not be measured for all sites sampled, because of equipment limitations. Initial susceptibility is not an absolute measure of the remanent-carrying mineral content, since it has contributions from ferrimagnetic and paramagnetic minerals (Collinson 1983). This is important with the Mangapoike sediments, in which the amount of paramagnetic ilmenite and the very low concentration of titanomagnetite in the extracted 'magnetic' fraction (Table 3.7) indicates that paramagnetic susceptibility contributes up to 10% (section 3.7.2) of the initial volume susceptibility.

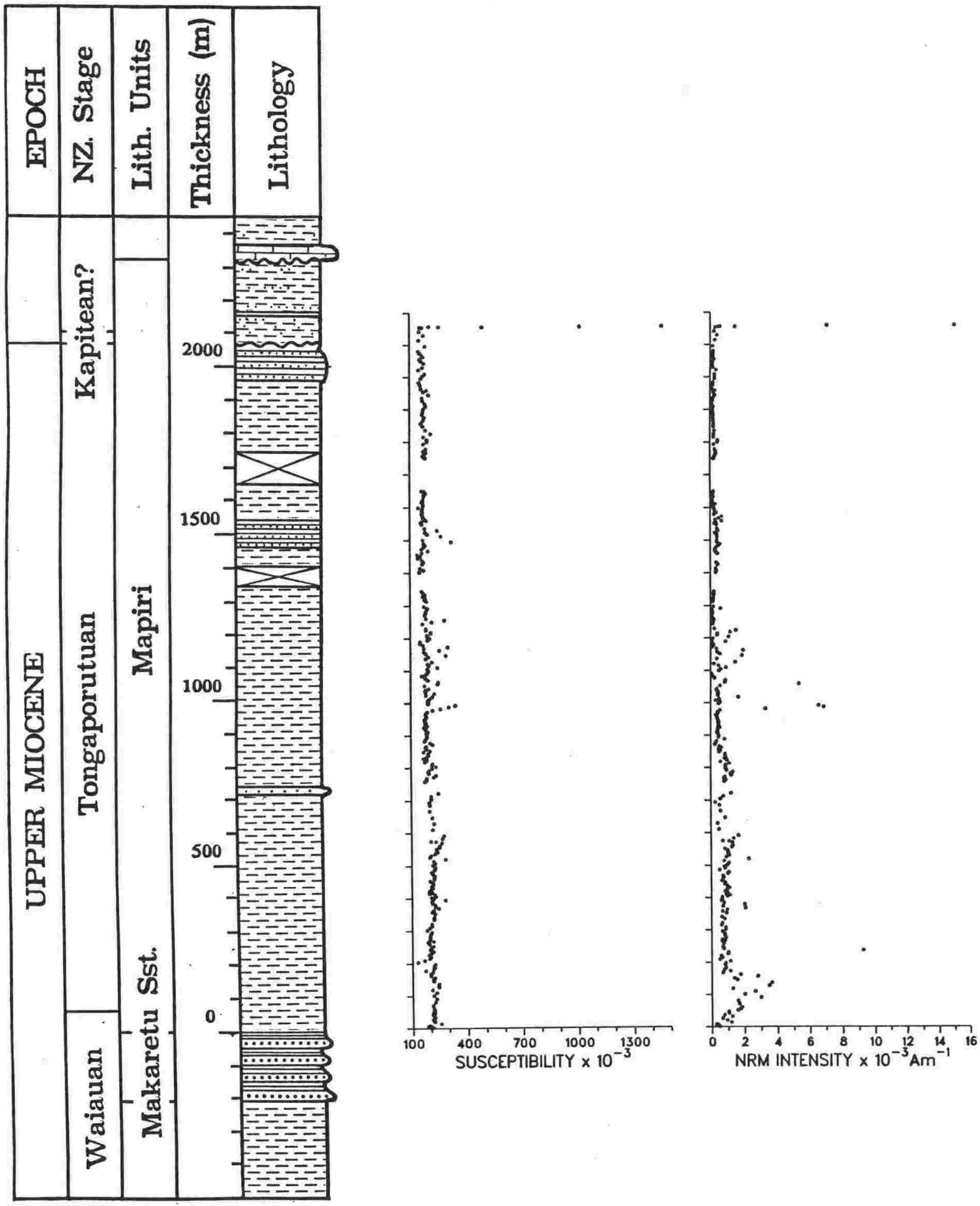


Fig. 3.13 Stratigraphic log of volume susceptibility and NRM intensity.

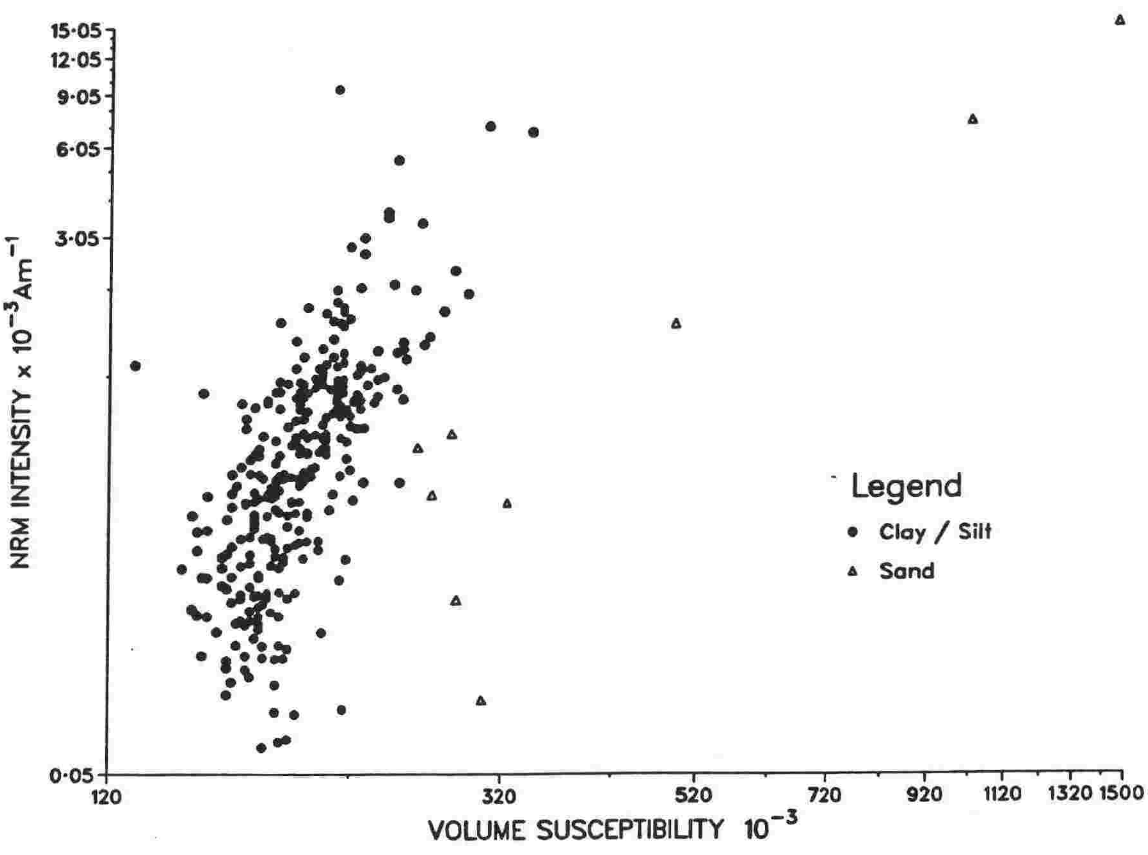


Fig. 3.14 Volume susceptibility - NRM intensity plot (log-log scale) of sandstones and mudstones (silt and claystones) from Mangapoike River.

3.9.2 NRM Intensity

A general correlation of NRM intensity with volume susceptibility (with its paramagnetic and ferrimagnetic components) (Fig. 3.13), indicates as a first approximation, that variations of NRM intensity are lithologically controlled, and are not a function of paleofield intensity variation. Both NRM intensity and volume susceptibility show a decrease in magnitude with increasing stratigraphic height, and variations of NRM intensity are generally matched by variations of susceptibility.

The relationship between NRM intensity and volume suceptibility is complicated by grain size. Sandstones have higher susceptiblities relative to their NRM intensity (Fig. 3.14), because of domain wall movements of the multidomain components within the coarser grained size fraction during susceptibility measurement.

Previous paleomagnetic studies have generally recognised that volcanic ash has higher magnetic susceptibilities and intensities of magnetisation than the enclosing sediment (Opdkye 1972; Lovlie *et al.* 1971). This relationship is expected to vary with ash composition; basaltic ashes will have higher concentrations of Fe-Ti oxides and consequently will have higher susceptiblities and magnetisation intensities than silicic ashes.

The presence of silicic volcanic detritus, including 2-30 cm thick tuffs (Gosson 1986) and dispersed glass shards within the enclosing sediment (Ashby 1985; Gosson 1986) above 1077 m within the Mangapoike sequence does not influence the general trend of decreasing volume susceptibility and NRM intensity with increasing stratigraphic height (Fig. 3.13). Average volume susceptibilities of 188 and 206 above and below 1077 m, respectively, reflect this general trend and volume susceptibilities do not increase with the incoming of silicic volcanic detritus at 1077 m. Measured volume susceptibilities of the tuffs themselves (Appendix 11) are similiar to those of the enclosing sediment. NRM intensity also has a similiar relationship with average values of 5.1 x $10^{-4}Am^{-1}$ and 1.1 x $10^{-3}Am^{-1}$ above and below 1077 m. The low values of both volume susceptibility and NRM intensity above 1077 m, where it is expected to have higher values because of the presence of volcanic detritus, cannot be solely ascribed to the silicic composition of the tuffs. Froggatt (1982) and Gosson (1986) have described abundant magnetite in Miocene - Pliocene rhyolitic pyroclastic flows. Gosson (1986) recognised the East Coast Basin tuffs to be mineral depleted (including Fe-Ti oxides) and argued that a combination of elutriation of the pyroclastic flow during eruption, aeolian fractionation with distance from source (30-50 km) and winnowing by fluvial processes before final deposition have produced glass enriched tuffs. His observation is consistent with the magnetic data presented here. Low values of volume susceptibility and NRM intensity reflect the depletion of Fe-Ti oxides from the tuffs.

3.10 CONCLUSIONS

The following conclusions are drawn:

1. The remanent magnetisation is carried by detrital titanomagnetite, which is the sole magnetic mineral indicated by electron microprobe analysis and isothermal remanent magnetisation curves.
2. Pre-depositional oxidation is deuteric, with ilmenite exsolution lamellae within host titanomagnetite.
3. Post-depositional oxidation (low temperature) is not recognised.
4. Chemistry (TiO_2) of the titanomagnetites is invariant with grain size.
5. The amount of titanomagnetite in the rocks is extremely small (10^{-3}-10^{-4} wt%) and variations of titanomagnetite content are the main influence on NRM intensity variation.

Chapter IV
DEMAGNETISATION METHODS

4.1 INTRODUCTION AND PRINCIPLES

The natural remanent magnetisation (NRM) of a rock is usually a combination of a primary magnetisation acquired at or near the time of the physical formation of the rock, and secondary magnetisations acquired subsequently. Removal of the secondary remanent magnetisation by magnetic cleaning (demagnetisation) is necessary for the identification of the primary component. Secondary magnetisations can be successfully separated only when their stabilities are lower than that of the primary magnetisation (Nagata 1961; Stacey 1963; Banerjee 1981). In rocks with multiphase magnetisations in which the magnetic components have similiar stabilities, it might not be possible to isolate the primary magnetisation (Roy and Lapointe 1978; Claesson 1978). Either an alternating magnetic field (AF demagnetisation) or heat (thermal demagnetisation) is applied to overcome the lower magnetostatic energy of the secondary magnetisations (Nagata 1961; Stacey and Banerjee 1974; Banerjee 1981; O'Reilly 1984). Thermal demagnetisation increases the temperature of the specimen in discrete steps, successively unblocking and randomising progressively higher blocking temperature components, leaving the more stable (usually primary) magnetisation intact. Cooling the rock in a zero magnetic field after each cleaning step fixes the random orientation of the unblocked magnetisation, which then no longer contributes to the rock's magnetic remanence. AF demagnetisation involves the cycling of a rock through magnetic hysteresis loops in steps of progressively higher alternating fields so as to randomise magnetic domain directions, by either domain rotation of single domain grains or domain wall movement within multidomain grains (Stacey and Banerjee 1974).

The two different demagnetisation techniques have given conflicting results. Watkins *et al.* (1974) were unable to identify the primary magnetisation in specimens from the Calabrian type section in Italy, because of the presence of a younger normal overprint. In the same section Nakagawa *et al.* (1975) identified normal and reversed magnetozones. The conflicting results were attributed to different demagnetisation methods (Kukla and Nakagawa 1977).

For any particular suite of paleomagnetic specimens the suitability of either thermal or AF demagnetisation to remove secondary magnetisations, and thus allow identification of the primary magnetisation can not be predicted. To determine the optimum demagnetisation method for the Mangapoike sediments 36 pilot specimens were stepwise demagnetised, 20 using thermal demagnetisation and 16 using AF demagnetisation. The 36 pilot specimens represent 3% of the total number of specimens finally measured, and 576 m of the total 2158 m sampled.

4.2 THERMAL DEMAGNETISATION

4.2.1 Introduction

Thermal demagnetisation has been the preferred method of demagnetisation in paleomagnetic studies of Cenozoic sediments in New Zealand (Lienert *et al.* 1972; Kennett and Watkins 1974; Walcott *et al.* 1981; Walcott and Mumme 1982). This has been a result of, until recently, incoherent data from the available AF demagnetising equipment. The primary component of magnetisation in these studies has been isolated at low to moderate temperatures (100°C to 280°C).

4.2.2 Techniques

The demagnetisation equipment used in this study was developed and built by D.A. Christoffel and E. Broughton.

A horizontal cylindrical gas oven, aligned normal to the major vertical and horizontal components of the ambient field direction, enclosed in a double Mumetal shield, with a field less than 20 nT, was used for all thermal demagnetisation. Three nickel-chromium v copper-nickel thermocouples referenced to iced water indicated the temperature. Adjustment of the gas flame ensured the temperature difference between the front and rear of the oven was no greater than 5°C. Specimens were held at the designated temperature for a minimum of 10 minutes, and allowed to cool to below 200°C before applying an air hose to accelerate cooling. After cooling to room temperature specimens were stored in a Mumetal shield until the remanence was measured.

The twenty pilot specimens were demagnetised at 50°C increments, up to 300°C, and then at 320°C and 340°C. Three specimens from two weakly cemented siltstones (sites 19054 and 19069) disaggregated at 200°C and were rejected from the analysis.

4.2.3 Mineralogical Alteration

Thermal demagnetisation may cause chemical alteration of the remanent carrying minerals, and thus possibly the primary magnetisation. The mineralogical alteration may include oxidation of titanomagnetite or magnetite to haematite, dehydration of goethite to haematite or a phase change from maghemite to haematite (Buddington and Lindsley 1964; O'Reilly 1983). Alteration of the magnetic mineralogy is assumed to reflect a change in magnetic properties. Changes in magnetic properties (initial susceptibility, induced magnetisation) are thus used to detect mineralogical alteration (Stephenson 1969; Dunlop 1972). The non-repeatability of remanence measurements after a second heating to the same temperature may also indicate mineralogical alteration.

Initial susceptibility has been the most widely used magnetic property to detect mineralogical alteration (Lowrie and Heller 1982) because of the ease of measurement. Initial volume susceptibility is used in this study for the same reason, and was measured in all pilot specimens at each demagnetisation temperature, after remanence measurement.

Mineralogical alteration during thermal demagnetisation of New Zealand Cenozoic sediments has not been demonstrated in previous studies, largely because other magnetic properties were not measured, but has been assumed to have occured (Kennett and Watkins 1974; Walcott and Mumme 1982). Kennett and Watkins (1974) suggested that dehydration of goethite to haematite explained an increase in magnetisation intensity and an increase in the in-site dispersion above 300°C of Pliocene samples from Mangapoike River.

Similiar behaviour is recognised in the pilot specimens from the present study and is confirmed as being a result of mineralogical alteration. An increase of magnetisation intensity is matched by a 5 fold increase in the volume susceptibility at temperatures between 300°C and 340°C (Fig. 4.1). The temperature at which specimens alter (the alteration temperature) varies within a site, and even within one core (Table 4.1). This variation does not reflect varying lengths of time at a particular demagnetisation temperature, since all pilot specimens were heated within the same batch, but is inferred to reflect inhomogeneties, caused by bioturbation, in the distribution of the remanence carrying titanomagnetite. The product of the alteration is assumed to be derived from the titanomagnetite, and is most likely to be haematite, formed by oxidation of the titanomagnetite.

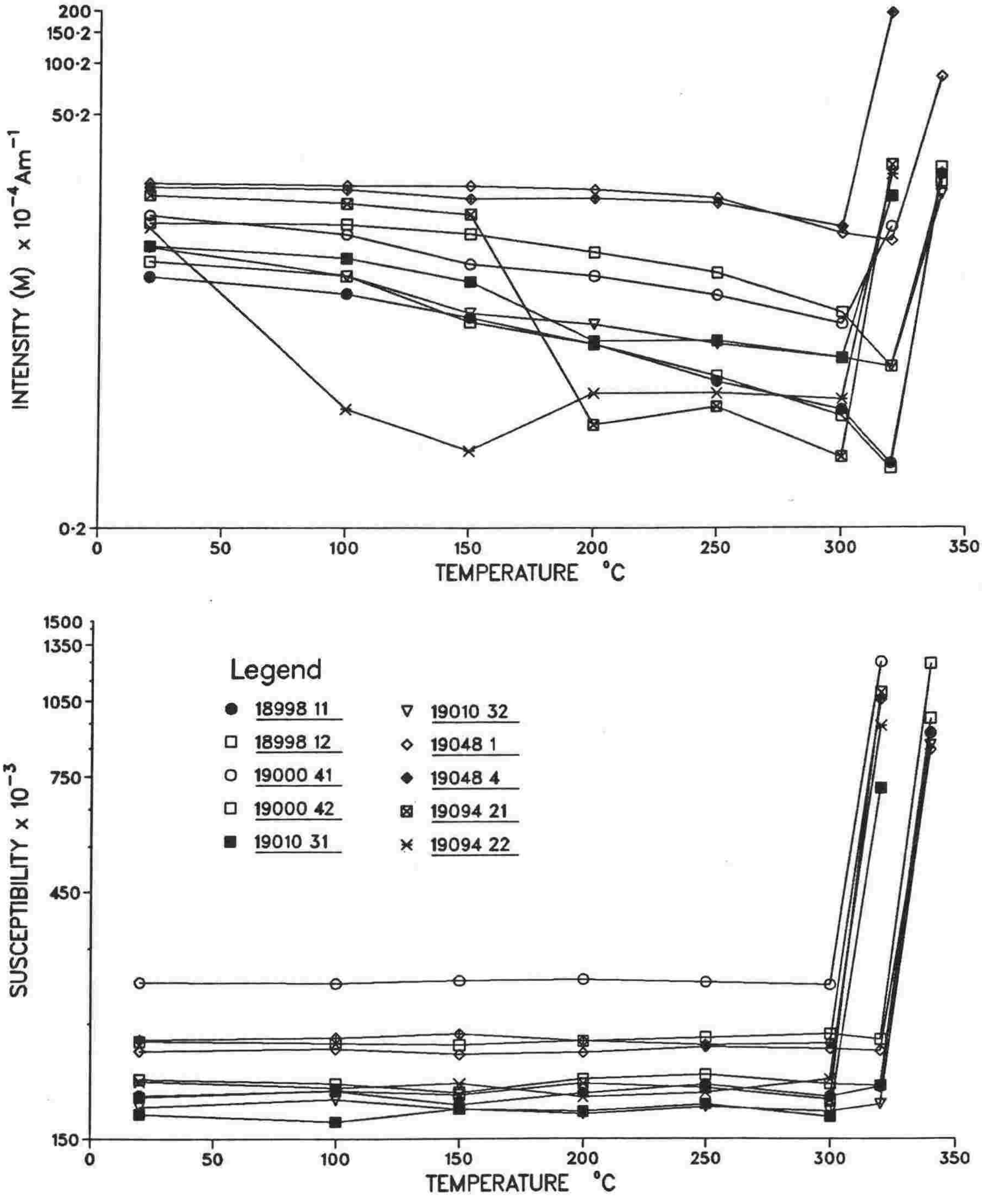


Fig. 4.1 Volume susceptibilities and magnetisation intensities of representative pilot specimens during thermal demagnetisation.

Table 4.1

Volume Susceptibility and Magnetisation
Intensities of Representative Pilot Specimens

SPEC	20°C	100°C	150°C	200°C	250°C	300°C	320°C	340°C
18998.11	5.7E-04	4.5E-04	3.3E-04	2.3E-04	1.4E-04	9.6E-05	4.7E-05	1.2E-03
	181.1	*185.4*	*174.6*	*183.6*	*190.8*	*181.0*	*189.0*	*907.2*
18998.12	7.0E-04	5.7E-04	3.1E-04	2.3E-04	1.5E-04	8.8E-05	4.4E-05	1.4E-03
	195.5	*191.8*	*184.2*	*195.5*	*199.3*	*191.4*	*190.0*	*968.4*
19000.41	1.3E-03	9.9E-04	6.7E-04	5.7E-04	4.4E-04	3.0E-04	1.1E-03	
	300.8	*298.9*	*302.7*	*304.6*	*300.8*	*297.0*	*1247.4*	
19000.42	1.7E-03	1.3E-03	1.0E-03	7.8E-04	5.9E-04	3.5E-04	1.7E-04	9.8E-03
	231.2	*229.4*	*227.5*	*231.2*	*235.0*	*238.8*	*233.1*	*1235.5*
19010.31	8.6E-04	7.2E-04	5.3E-04	2.4E-04	2.4E-04	1.9E-04	6.5E-04	
	167.3	*161.7*	*171.1*	*169.2*	*174.8*	*165.4*	*711.2*	
19010.32	8.5E-04	5.7E-04	3.5E-04	3.0E-04	2.3E-04	1.9E-04	1.7E-04	6.8E-03
	172.9	*178.6*	*171.1*	*167.3*	*172.9*	*169.2*	*174.8*	*856.7*
19048.1	2.0E-03	1.9E-03	1.9E-03	1.8E-03	1.6E-03	1.0E-03	9.1E-04	8.1E-03
	221.8	*223.7*	*218.1*	*219.9*	*225.6*	*223.7*	*221.8*	*842.8*
19048.2	1.9E-03	1.8E-03	1.6E-03	1.6E-03	1.5E-03	1.1E-03	2.9E-02	
	233.1	*235.0*	*238.8*	*231.2*	*227.5*	*229.4*	*1055.2*	
19094.21	1.7E-04	1.5E-04	1.3E-04	7.9E-05	1.0E-04	5.1E-05	1.9E-03	
	180.5	*186.1*	*182.4*	*191.7*	*188.0*	*178.6*	*1089.5*	
19094.22	1.1E-04	9.7E-05	5.6E-05	1.2E-04	1.2E-04	1.1E-04	2.2E-03	
	193.6	*188.0*	*191.8*	*180.5*	*184.2*	*195.5*	*938.5*	

Magnetisation units Am^{-1}
Volume Susceptibility ($x\ 10^{-3}$).

Remanence measurements were rejected for the temperatures at which volume susceptibilities increased.

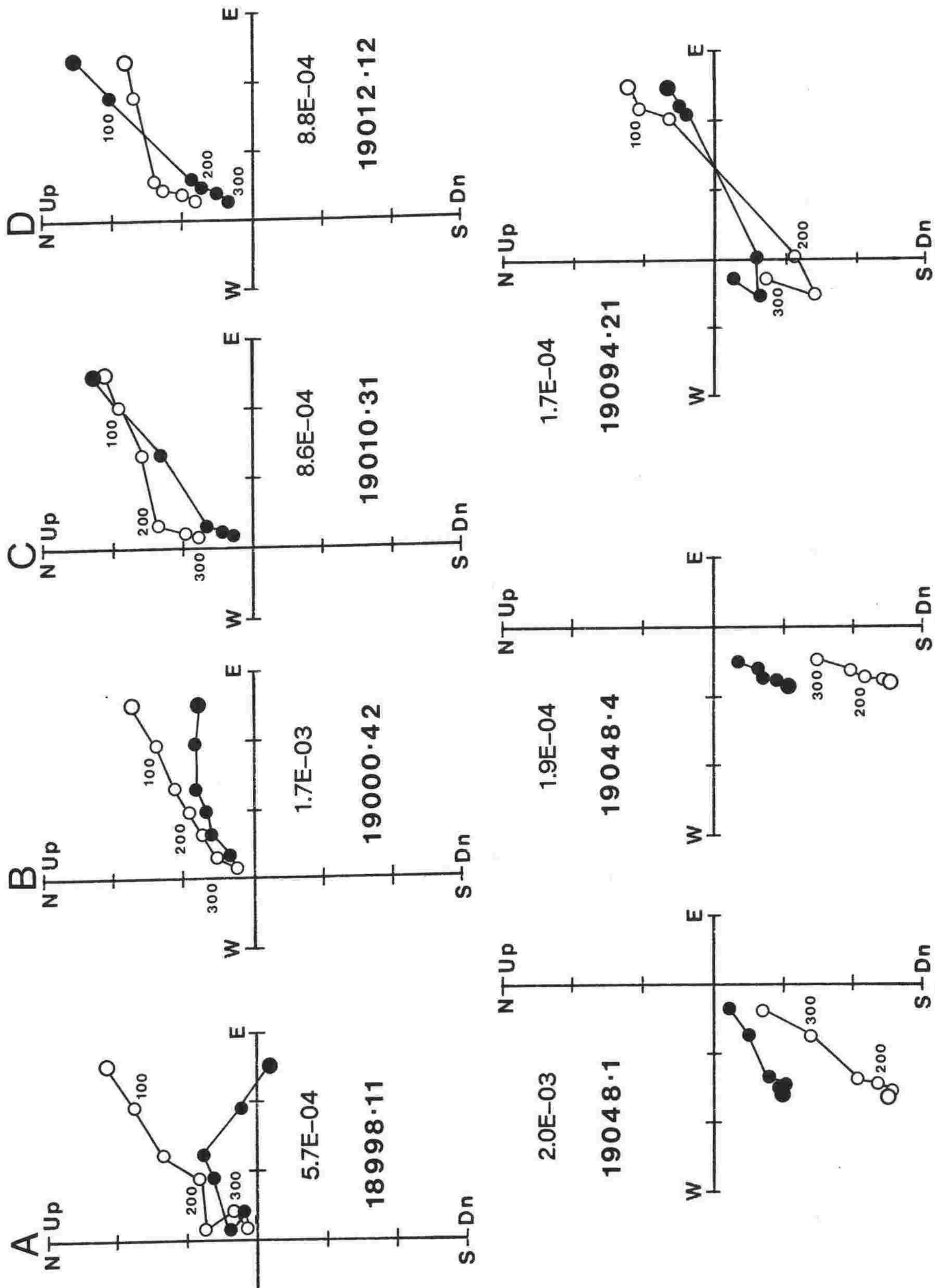
4.2.4 Thermal Demagnetisation: Results

Thermal demagnetisation proved effective in removing secondary magnetisations at temperatures between 200°C and 320°C (Appendix 6). However the unambigious identification, from Zijderveld plots, of a primary magnetisation with both normal and reversed polarity directions, is recognised in only seven of the sixteen pilot specimens. These specimens show ideal linear decay of the horizontal and vertical components (Fig. 4.2) to the origin (Zijderveld 1967) and have well defined end-points. Two of these specimens, having reversed NRM directions, retain a clockwise deviation from the geomagnetic axial dipole in a reversed direction during demagnetisation to temperatures of 300°C and 320°C (Fig. 4.2 e,f). This is inferred to represent a real primary direction and not a partially uncleaned overprint. The same deviation is recognised in the one specimen with a normal NRM direction and a subsequent reversed direction upon demagnetisation (Fig. 4.2 g) and is interpreted in a similar manner. Remanent directions of all seven specimens show this deviation (Fig. 4.2). It is only the presence of the three reversed specimens which confirms that the magnetisation is primary and not an uncleaned hard secondary magnetisation.

A further eight of the sixteen pilot specimens (Fig. 4.3) show non-ideal linear decay during demagnetisation of the horizontal and vertical components on the Zijderveld plots. Consequently from Zijderveld plots, the primary magnetisation of these specimens could not be identified. However, these specimens are interpretated as being or very close to the primary remanent direction, based on 1) the presence of reversed remanent directions above the 200°C demagnetisation temperature, 2) the close proximity of these reversed directions to the reversed directions in specimens exhibiting linear decay to the Zijderveld origin, and 3) the close proximity of normal directions to the normal directions in specimens exhibiting linear decay to the Zijderveld origin (Fig. 4.4).

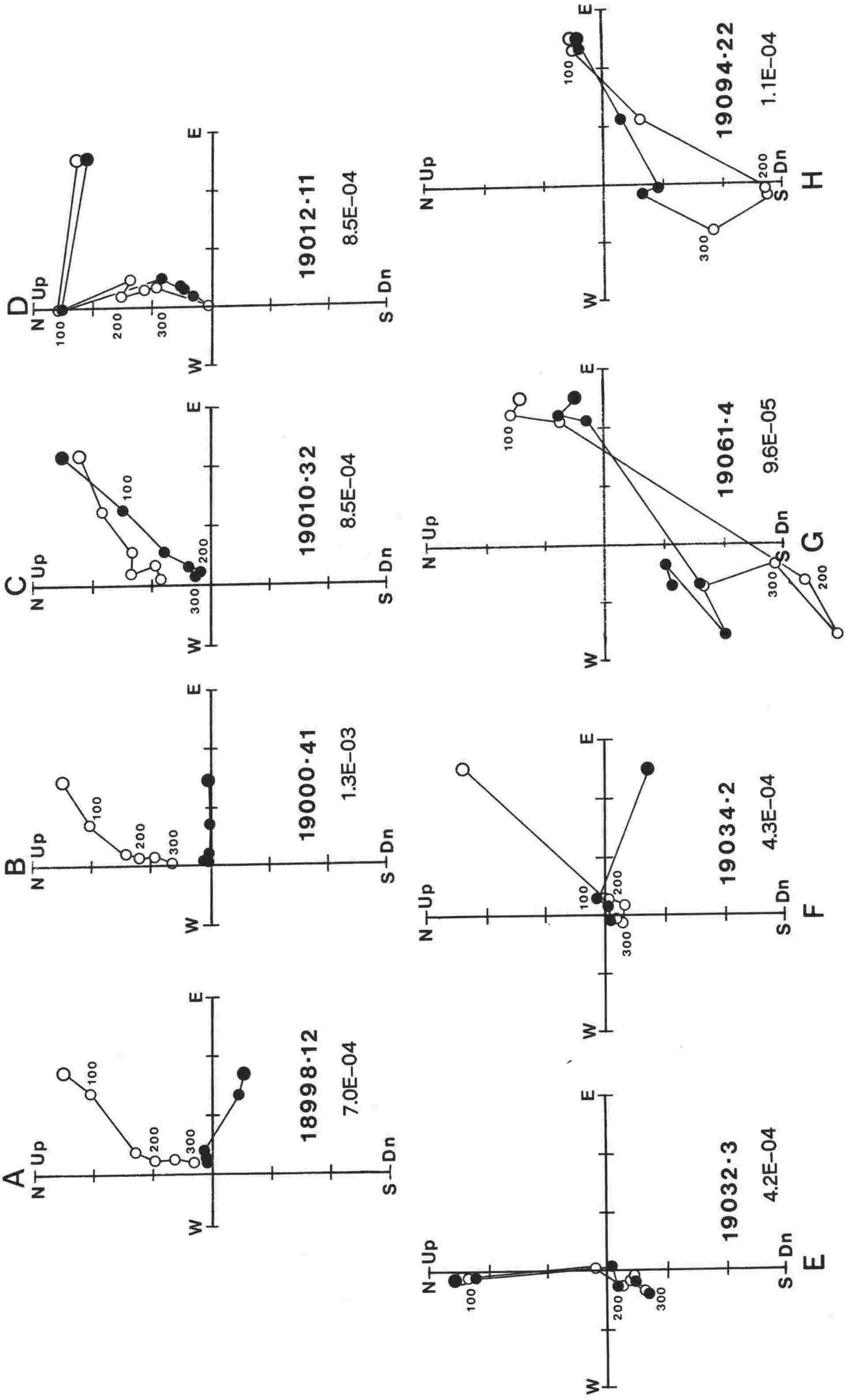
Demagnetisation temperatures at which the primary magnetisation is recognised varies within these fourteen specimens. The primary magnetisation of specimen 19094.21 (Fig. 4.2 g) is not recognised until the 250°C demagnetisation temperature, whereas the primary magnetisation of specimens 19048.1 and 19048.4 (Fig. 4.2 e,f) is the respective NRM directions. The variation of the temperature at which the primary magnetisation is revealed is interpretated as resulting from the varying degrees of

Fig. 4.2 Zijderveld plots of thermally demagnetised pilot specimens with a well defined primary magnetisation. Solid circles are the projection onto the horizontal (E, W, N, S) plane and open circles are the projection onto the vertical (E, W, Up, Dn) plane. The larger circles are the values for NRM and the small numbers are the subsequent demagnetisation levels in °C. Intensities of magnetisation are NRM values in Am^{-1}



A
5.7E-04
18998·11
B
1.7E-03
19000·42
C
8.6E-04
19010·31
D
8.8E-04
19012·12
E
2.0E-03
19048·1
F
1.9E-04
19048·4
G
1.7E-04
19094·21
N
Up
S
Dn
E
W
100
200
300

Fig. 4.3 Zijderveld plots of thermally demagnetised pilot specimens with a poorly defined primary magnetisation. Symbol convention follows that of Fig. 4.2.


A
18998·12
7.0E-04
B
19000·41
1.3E-03
C
19010·32
8.5E-04
D
19012·11
8.5E-04
E
19032·3
4.2E-04
F
19034·2
4.3E-04
G
19061·4
9.6E-05
H
19094·22
1.1E-04
N
Up
S
Dn
W
E
100
200
300

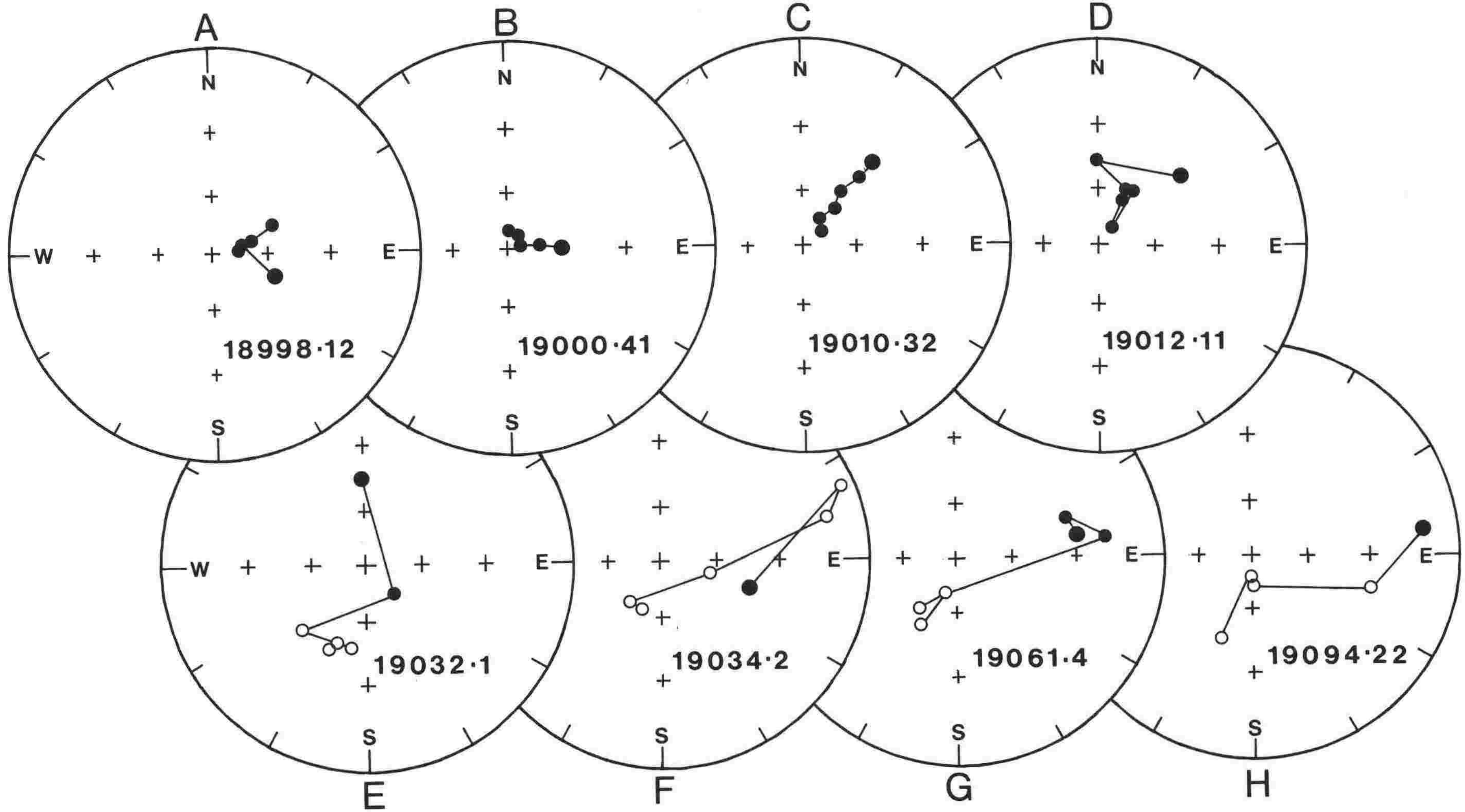
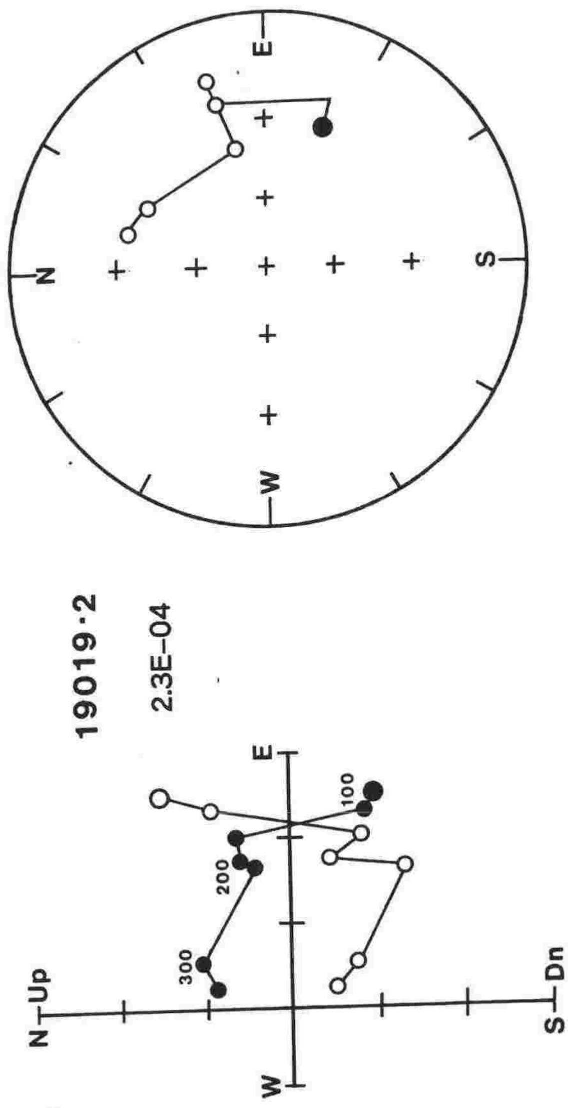
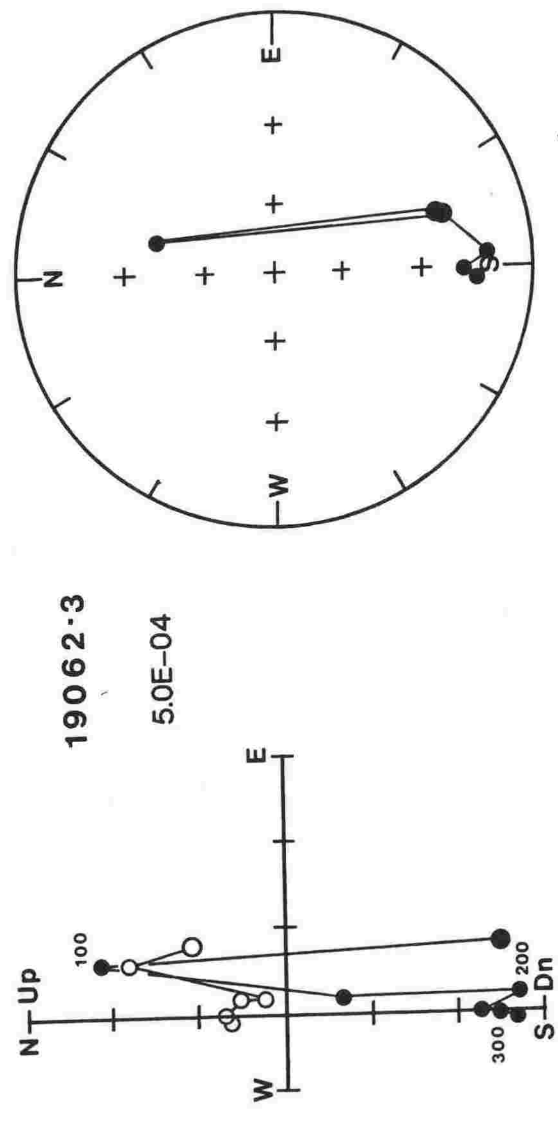


Fig. 4.4 Equal-area stereographic projections of thermally demagnetised pilot specimens with poorly defined primary magnetisation directions, showing both normal and reversed polarity. Closed circles are the upper hemisphere and open circles are the lower hemisphere.

Fig. 4.5 Zijderveld and equal-area stereographic projections of thermally demagnetised pilot specimens with either unstable or unremoved secondary magnetisations. Symbol convention follows that of Figs. 4.2 and 4.4.


19019·2
2.3E-04
N
E
S
W
Up
Dn
100
200
300


19062·3
5.0E-04
N
E
S
W
Up
Dn
100
200
300

overlap of the blocking temperatures of the primary and secondary magnetisations. Specimens without a secondary magnetisation have no overlap of the blocking temperatures of the primary and secondary magnetisations and consequently the primary component can be recognised at NRM measurements. In contrast, specimens with hard secondary magnetisations where the blocking temperature almost completely overlaps that of the primary magnetisation, require higher demagnetisation temperatures for removal of the secondary magnetisations. In most specimens the primary magnetisation is recognised at temperatures of 200°C and above.

The remaining two specimens show neither stable demagnetisation behaviour nor normal or reversed polarity directions (Fig. 4.5) at temperatures of 300°C. These specimens are magnetically unstable and a primary magnetisation can not be recognised.

It is concluded that:

1. Thermal demagnetisation is effective in removing secondary magnetisations.
2. Unambiguous identification of a primary magnetisation as indicated by ideal linear decay to the origin of Zijderveld plots is recognised within only half of the pilot specimens.
3. A hard and stable magnetisation which exhibits non-ideal linear decay to the Zijderveld origin is also recognised, having either normal or reversed polarity and thus is inferred to be the primary magnetisation.
4. The secondary magnetisations have variable blocking temperatures and consequently the primary magnetisation is recognised at a range of temperatures above 200°C.
5. The removed secondary magnetisations are normal in polarity and have similiar directions, but are not specifically related to the present day geomagnetic field direction.

4.3 AF DEMAGNETISATION

4.3.1 Introduction

Alternating field (AF) demagnetisation of New Zealand Cenozoic sediments, although successful (Kennett *et al.* 1971; Mumme and Walcott 1985) has been restricted. At Victoria University the main problem, until recently (Christoffel pers. comm. 1985) has been incoherent data, especially at higher fields, resulting from the suspected acquisition of spurious magnetisations during AF cleaning with the available equipment. The successful AF cleaning programmes used peak alternating fields of 5 mT to 30 mT (Kennett *et al.* 1971; Mumme and Walcott 1985).

4.3.2 Techniques

A 19 cm long solenoid within three orthogonal pairs of square coils one metre in length, with a residual field of less than 30 nT, was used for all AF demagnetisation. The multi-layered solenoid (2936 turns) was powered by a series tuned 50 Hz mains supply. Sixteen pilot specimens were demagnetised along the three orthogonal specimen axes at 5 mT increments up to a peak alternating field of 35 mT. At progressively higher fields the decay period (ramp time) was increased. Specimens were stored in a Mumetal shield before remanence measurements.

4.3.3 AF Demagnetisation: Results

AF demagnetisation was ineffective in removing a secondary magnetisation aligned in a normal polarity direction and consequently a primary magnetisation was recognised in only four of the sixteen pilot specimens (Appendix 7). Two of the specimens, where the primary magnetisation was recognised, have reversed polarity NRM directions and have stable directions during demagnetisation (Fig. 4.6 a,b). However the primary magnetisation of these two specimens, as indicated by linear decay of the vertical and horizontal components of the Zijderveld plot, is not identified until peak alternating fields of 30 to 35 mT. At 40 mT the remaining remanent intensities were below 1.5 x $10^{-5}Am^{-1}$ and thus unmeasurable, indicating the coercivity spectra of the primary magnetisation is between 30 and 40 mT. The clockwise deviation from the geomagnetic axial dipole of the two reversed specimens is the same as recognised by thermal demagnetisation and is again interpreted as being a real primary direction. The other two specimens although normal in polarity show linear decay to the Zijderveld origin, having a marked decrease in intensity at peak fields of 30 and 35 mT, and their magnetisation is interpretated as being primary (Fig. 4.6). The near zero magnetic intensity of the two specimens at fields of 30 and 35 mT is consistent with the inference, from the reversed specimens, that the coercivity spectra of the primary magnetisation is between 30 and 40 mT.

A further eight AF pilot specimens have an inferred reversed primary magnetisation with an incompletely removed normal overprint, even at peak alternating fields of 35 mT, above which the remaining remanence is too weak to measure. Zijderveld plots reveal similiar changes of both the vertical and horizontal components during demagnetisation (Fig. 4.7), but decay to the origin is not linear. Stereographic projections (Fig. 4.8) clearly show a change of declination from normal directions at NRM, to reversed directions at 30 to 35 mT, matched by a shallowing of the negative

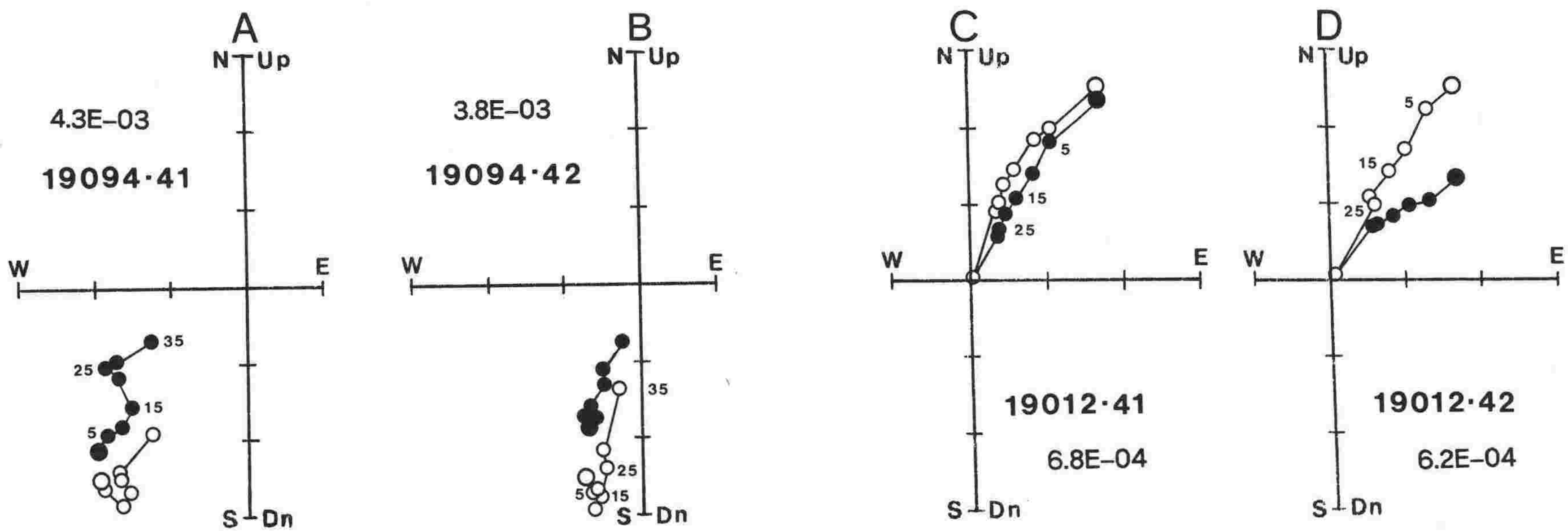


Fig. 4.6 Zijderveld plots of AF demagnetised pilot specimens with a well defined primary magnetisation. Solid circles are the projection onto the horizontal (E, W, N, S) plane and open circles are the projection onto the vertical (E, W, Up, Dn) plane. The larger circles are the values for NRM and the small numbers are the subsequent demagnetisation levels in mT. Intensities of magnetisation are NRM values in Am^{-1}

Fig. 4.7 Zijderveld plots of AF demagnetised pilot specimens with an inferred reversed primary magnetisation with an incompletely removed normal overprint. Symbol convention follows that of Fig. 4.6.

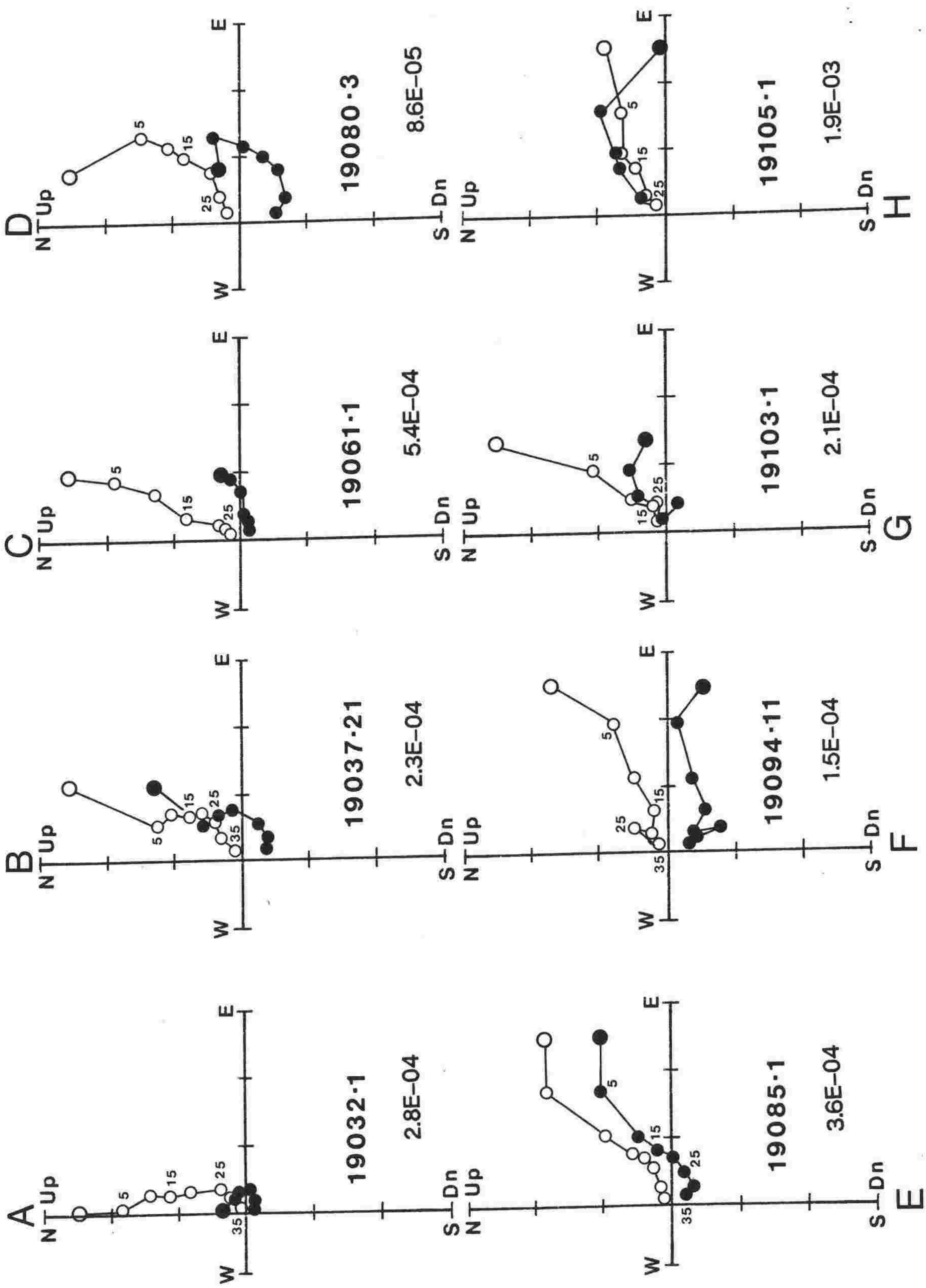
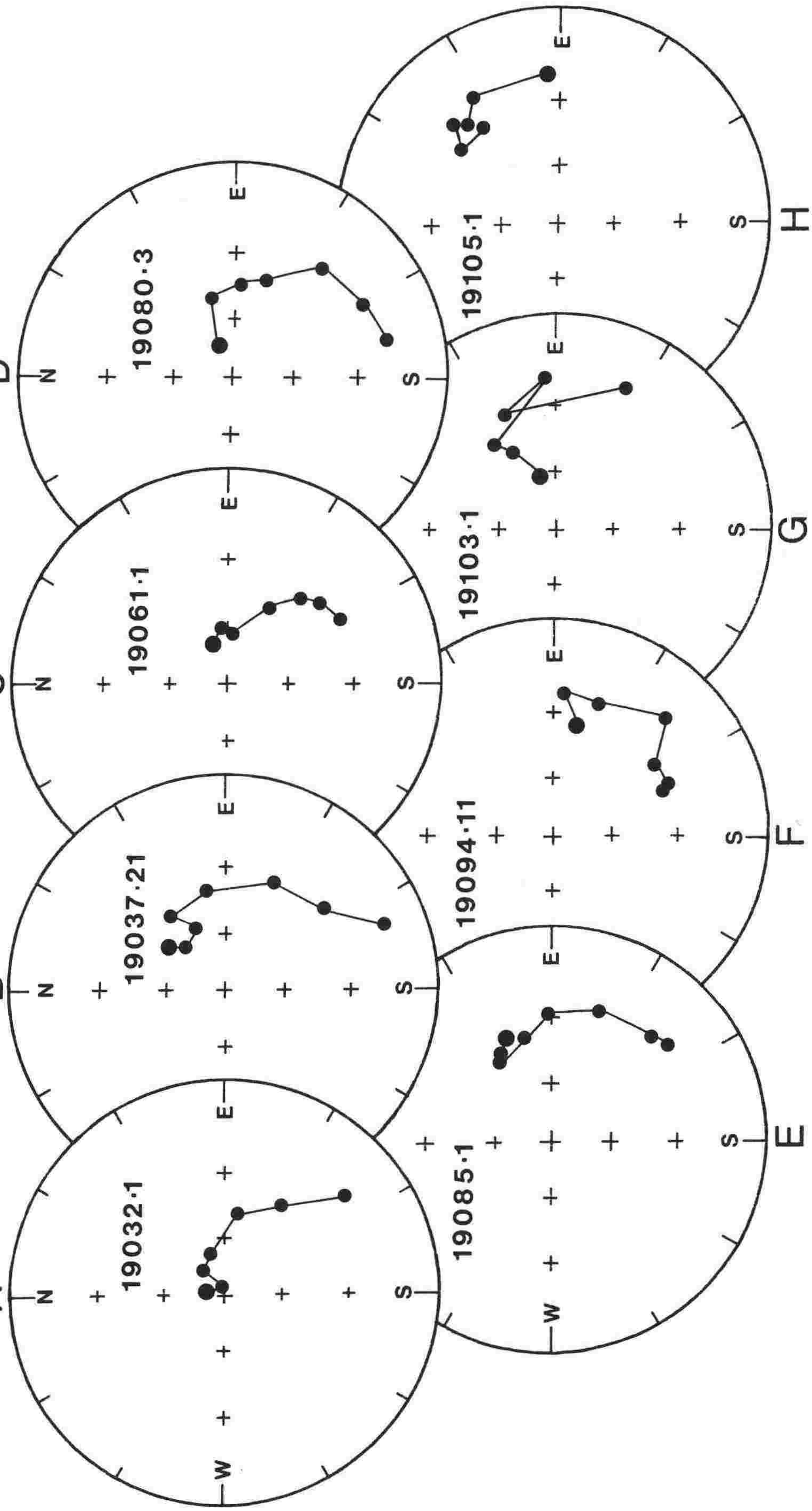

A
19032·1
2.8E-04
B
19037·21
2.3E-04
C
19061·1
5.4E-04
D
19080·3
8.6E-05
E
19085·1
3.6E-04
F
19094·11
1.5E-04
G
19103·1
2.1E-04
H
19105·1
1.9E-03
N
S
E
W
Up
Dn

Fig. 4.8 Equal-area stereographic projections of AF demagnetised pilot specimens with an incompletely removed normal overprint. Symbol convention follows that of Fig. 4.4.


A
19032·1
B
19037·21
C
19061·1
D
19080·3
E
19085·1
F
19094·11
G
19103·1
H
19105·1
N
E
S
W

inclinations. This is interpretated as movement towards a reversed direction, as in the two reversed AF specimens, but the secondary overprint is not entirely removed before the specimens become unmeasurable. This indicates that part of the coercivity spectra of the secondary magnetisation is also between 30 and 35 mT, matching that of the primary magnetisation, and consequently the primary magnetisation can not be resolved. The partially removed secondary magnetisation, up to fields of 35 mT, has a normal direction (Fig. 4.9), but again is not specifically related to the present day field direction.

The four remaining AF pilot specimens show neither stable demagnetisation behaviour nor normal or reversed polarity directions (Fig. 4.10) even at a peak alternating field of 35 mT. These specimens are magnetically unstable and the primary magnetisation can not be recognised.

It is concluded that:

1. The primary magnetisation can not be routinely identified with AF demagnetisation.
2. The coercivity spectra of the primary and secondary magnetisations overlap even at a peak alternating field of 35 mT.
3. At fields above 35 mT the intensity of the residual remanent magnetisation is less than 1.5×10^{-5} Am^{-1} (the accepted noise level of the cryogenic magnetometer in this study) and unmeasurable.
4. The partially removed secondary magnetisations are normal in polarity, and have similiar directions, but are not specifically related to the present day geomagnetic field direction.

4.4 COMPARISON OF THERMAL AND AF DEMAGNETISATION

Theoretical studies (Wilson and Smith 1968; Dunlop 1969, 1973; Biquand and Prevort 1971) predict that a viscous magnetisation (VRM) is more effectively removed by

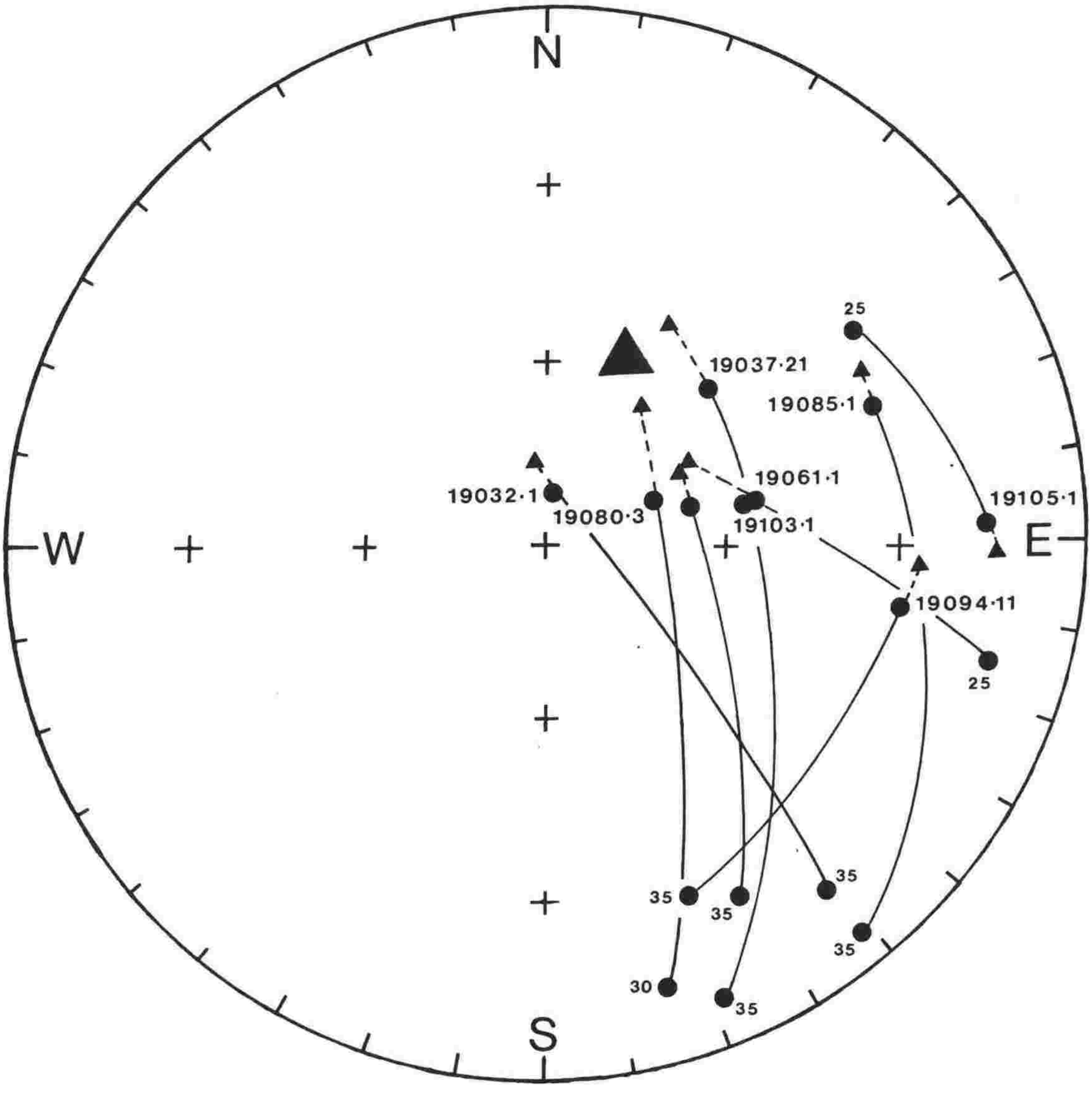


Fig. 4.9 Equal-area stereographic projection of removed components from AF demagnetised pilot specimens with an incompletely removed normal overprint. Specimen numbers are referenced to NRM directions. Circles with small numbers are the directions at the respective peak alternating fields in mT. Small triangles are the directions of the removed magnetisation to the respective peak alternating fields. Large triangle is present day geomagnetic field direction.

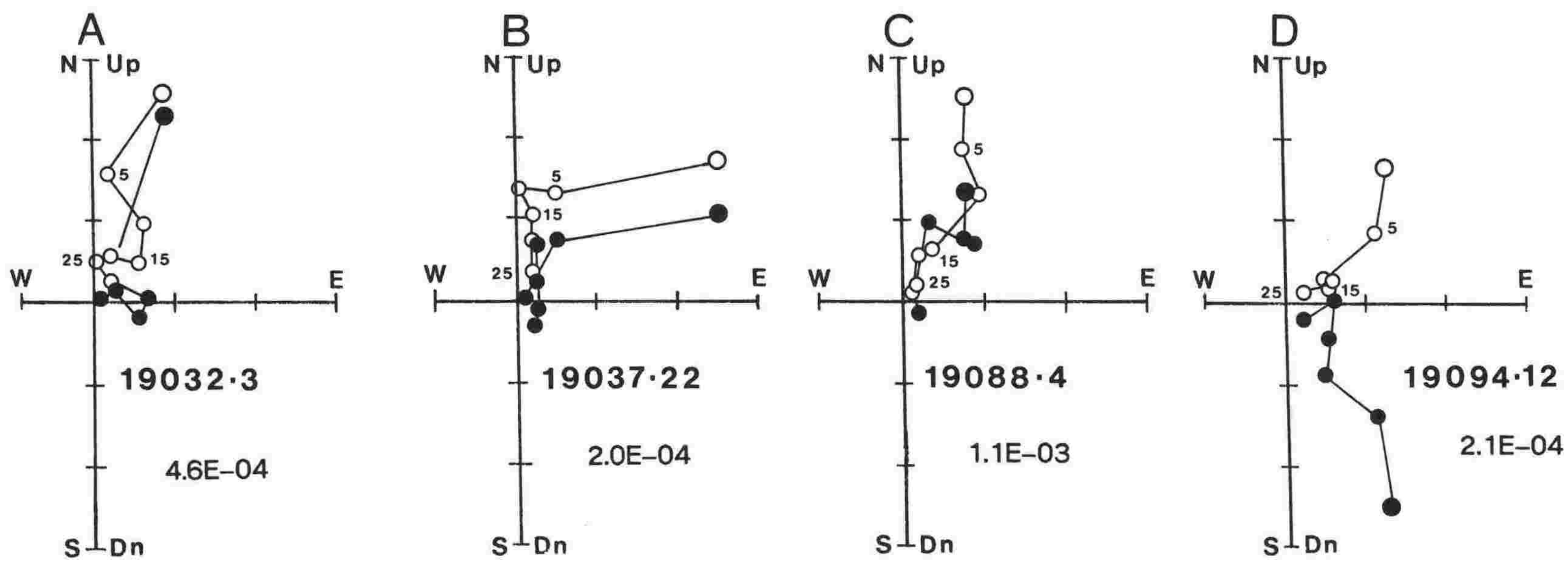


Fig. 4.10 Zijderveld plots of AF demagnetised pilot specimens with an unstable magnetisation. Symbol convention follows that of Fig. 4.6.

H_C = coercive force

$Q = 23.7$

as shown by the VRM acquisition curves of Fig. 4.11a at t_0 to t_3

The unblocking curves of any subsequent zero-field demagnetisation coincide with the original blocking curves and the VRM decays logarithmically. Thermal demagnetisation of a VRM has unblocking curves also obeying the above equation, and is analogous to viscous decay (Dunlop 1973) as defined by:

$$\frac{\partial J_r}{\partial \log t_d} \bigg/ \frac{\partial J_r}{\partial T} = \frac{T_0}{Q + \log t_0}$$

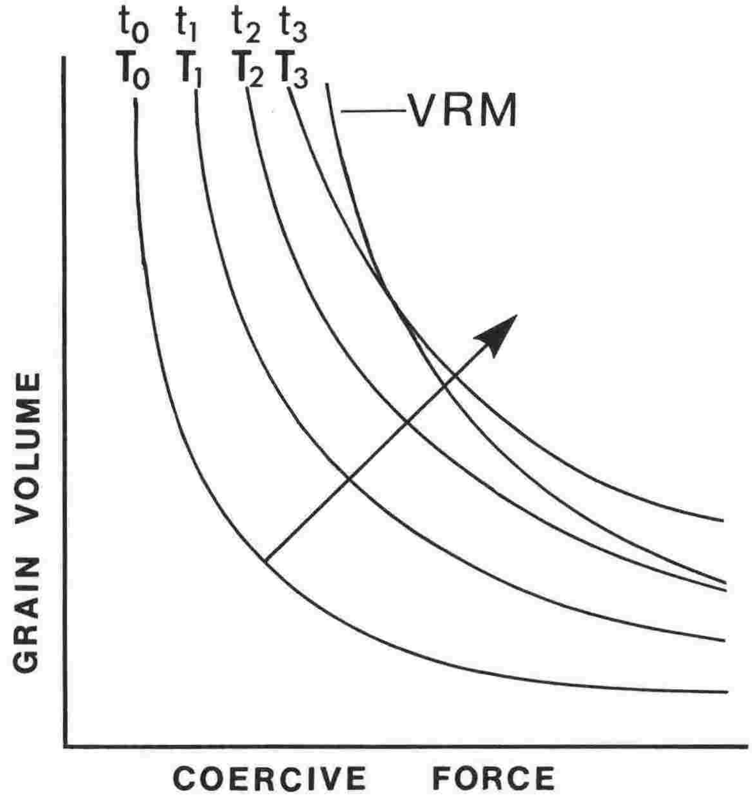
where

J_r = remanent magnetisation

t_d = decay time

Thus the blocking/unblocking curves for a VRM (Fig. 4.11a) are the same with either the influence of time (t) or temperature (T). Consequently thermal demagnetisation is efficient in removing VRM's. In contrast to viscous decay or thermal demagnetisation, unblocking curves representing AF demagnetisation at increasing peak fields have a different form (Fig. 4.11b). During AF demagnetisation the largest grains are demagnetised first leaving a VRM within the smaller grains as a resistent magnetisation. Higher AF peak fields are required to remove this resistant VRM. Field studies have also shown a VRM to be more effectively removed by thermal than AF demagnetisation (Ouliac 1976).

Direct comparison of thermally and AF demagnetised pilot specimens from the Mangapoike data demonstrate that VRM's are removed by thermal demagnetisation but not AF demagnetisation. Reversed remanent directions of four thermal pilot specimens from three sites are resolved at 200°C and above (Fig. 4.12 e-h), but are not found in specimens from the same three sites (Fig. 4.12 a-d) following AF demagnetisation to peak fields of 35 mT. The blocking temperatures of the primary and secondary magnetisation are therefore partially overlapping, whereas the coercivities are completely overlapping.



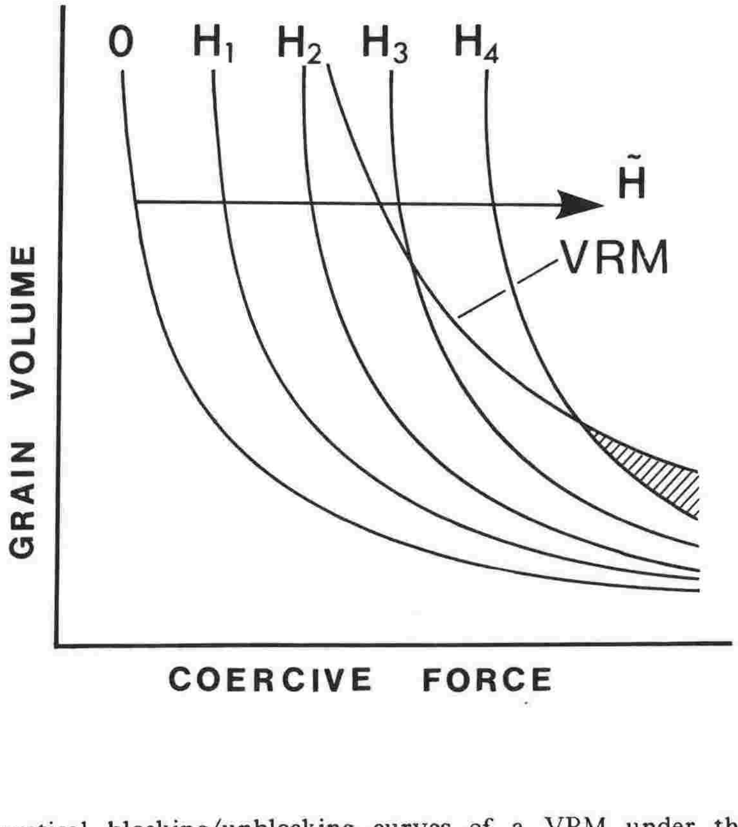
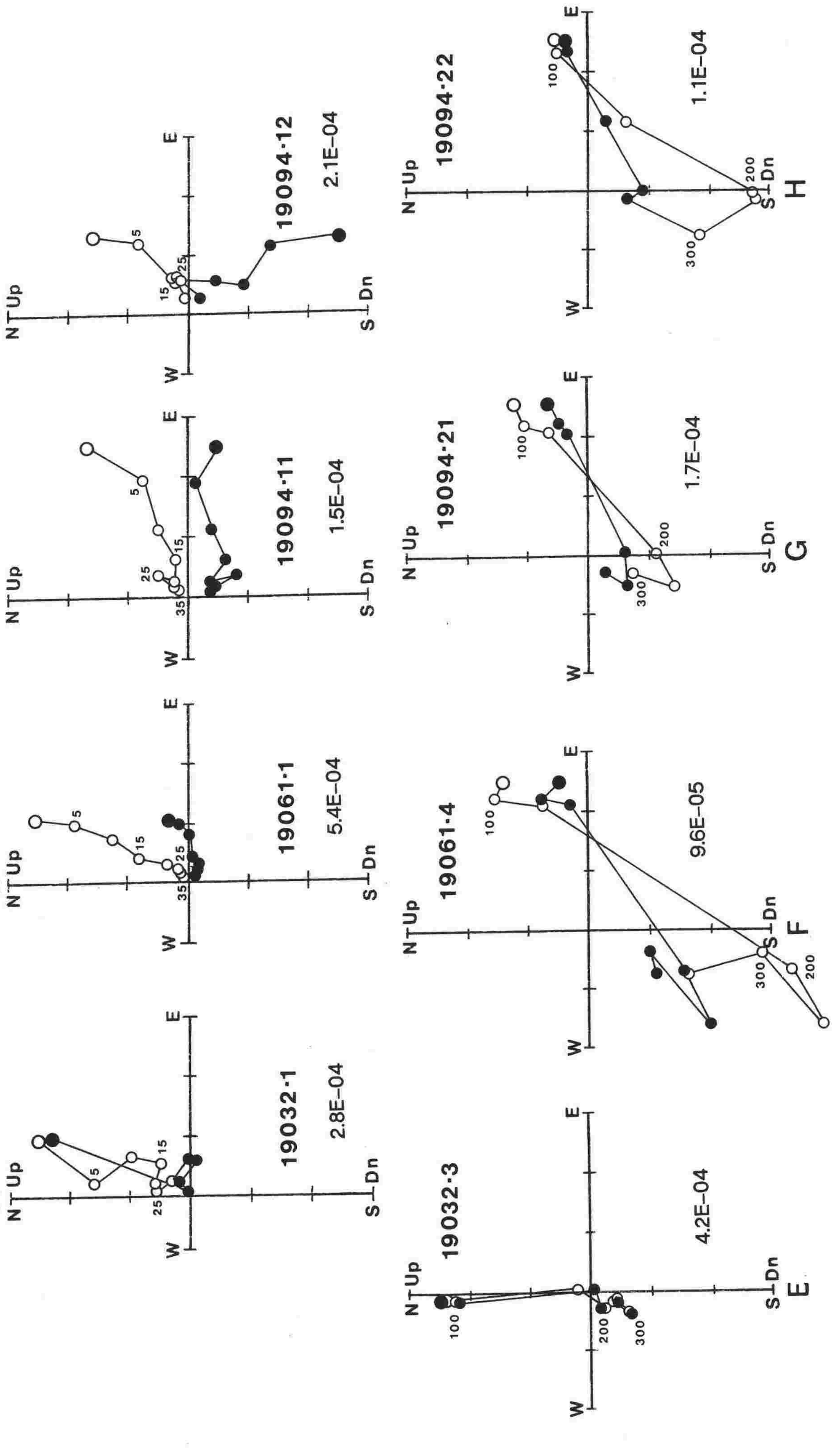


Fig. 4.11 Theoretical blocking/unblocking curves of a VRM under the influence of either thermal or AF demagnetisation. Unblocking curves under the influence of either time (t) or temperature (T) are the same, whereas the unblocking curves with an increasing coercive force (H) are different. Shaded area is the resistant VRM fraction unremoved by AF demagnetisation.

Fig. 4.12 Comparative Zijderveld plots of thermally and AF demagnetised pilot specimens from the same paleomagnetic site, a-d symbol convention follows that of Fig. 4.6 and e-h symbol convention follows that of Fig. 4.2.


A
19032·1
2.8E–04
B
19061·1
5.4E–04
C
19094·11
1.5E–04
D
19094·12
2.1E–04
E
19032·3
4.2E–04
F
19061·4
9.6E–05
G
19094·21
1.7E–04
H
19094·22
1.1E–04
N
Up
S
Dn
W
E

4.5 GENERAL DEMAGNETISATION

4.5.1 General Techniques

Since thermal demagnetisation was the only method capable of removing secondary magnetisations in the Mangapoike specimens, and thus allowing identification of the primary magnetisation, it was used for general demagnetisation of all remaining 1168 specimens (Appendix 8). The remanence of all specimens was measured at a minimum of three of the 200°C, 250°C, 300°C and 320°C demagnetisation temperatures. After remanence measurement, at the 300°C and 320°C temperatures, volume susceptibility was measured in order to detect mineralogical alteration: remanence measurements were discarded when a greater than 50% increase of volume susceptibility was recorded.

4.5.2 Selection of Representative Direction

A range of selection procedures exists to determine a representative direction from a suite of demagnetisation data. Vector diagrams (Zijderveld 1967; Dunlop 1979) remagnetisation circles (Halls 1976, 1978) vector substraction (Roy and Park 1974; Hoffman and Day 1978; Stuparsky and Symons 1978) stability indices (Tarling and Symons 1967; Briden 1972; Symons and Stuparsky 1974; Giddings and McElhinny 1976; Lowrie and Alvarez 1977) and minimum in-site dispersion have all been used to extract representative directions. Previous studies in New Zealand Cenozoic sediments have used either in-site dispersion (Kennett *et al.* 1971; Lienert *et al.* 1972; Kennett and Watkins 1974), Zijderveld plots (Walcott *et al.* 1981) or stability indices (Walcott and Mumme 1982; Mumme and Walcott 1985).

A two-level method using Zijderveld plots and the stability index of Lowrie and Alvarez (1977) proved effective here. Firstly the Zijderveld plot for each specimen was examined to identify the primary magnetisation indicated by linear decay of the horizontal and vertical components to the origin (Zijderveld 1967). The stability index of Lowrie and Alvarez (1977) was used to select an optimum direction from those specimens where linear decay of the primary component to the origin of the Zijderveld plot could not be demonstrated because of large secondary components or ill-defined endpoints. The Lowrie - Alvarez index defines the angle between two successive demagnetised remanent directions i and j as

$$\delta\theta = \cos^{-1}(l_i \, l_j + m_i \, m_j + n_i \, n_j).$$

where the direction cosines are

$$l = \cos D \cos I$$

$$m = \sin D \cos I$$

$$n = \sin I$$

The angle ($\delta\theta$) was divided by the increment of the demagnetising temperature (δT) to obtain the average angular rate of change during the demagnetisation step. The optimum direction was the highest increment of two successive directions where ($\delta\theta/\delta T$) is a minimum. Specimens with ($\delta\theta/\delta T$) greater than 1°/1.5°C above the 200°C demagnetisation temperature were rejected from the analysis.

Since the temperature varies at which the primary magnetisation is recognised, as shown by the pilot specimens, it is expected the optimum temperature for general demagnetisation will also vary. Differences in the selected demagnetisation temperature were thus accepted, even within the same site or core. Selection of data from different demagnetisation levels within samples has been used elsewhere in paleomagnetism (Lowrie and Alvarez 1977).

Site means were calculated using Fisher statistics (Fisher 1953) from specimens accepted on the above criteria (Appendix 9). Those sites with less than three specimens were rejected from the analysis.

In summary, the following rejection criteria were used in this study:

1. The remanent magnetisation was less than 1.5×10^{-5} Am^{-1}

2. The angular difference between normal and invert modes of remanent measurement was greater than 15°.

3. No stability of direction or change of direction where ($\delta\theta/\delta T$) was greater than 1°/1.5°C.

4. Less than three specimens from each site.

From these criteria, 286 specimens (24%) were rejected from the final analysis.

Chapter V

MAGNETOZONES AND CORRELATION TO THE MAGNETIC POLARITY TIMESCALE

5.1 INTRODUCTION

This chapter discusses the polarity magnetozones and their correlation with the magnetic polarity timescale.

Section 5.2 reviews various magnetic polarity timescales that have been published and outlines the criteria used to select the Ness *et al.* (1980) timescale as the best standard for comparison. Section 5.3 discusses the delineation of the magnetozones. A statistical comparison of the observed number of reversals and the expected number of reversals (section 5.5) indicates that all known polarity reversals are recognised. Section 5.4 gives the dated stratigraphic events used to correlate the magnetostratigraphic zones and also describes a previously unrecognised unconformity at Mangapoike River. The effects of bioturbation on the paleomagnetic record are discussed in the final section (5.6) concluding that the detrital magnetisation is acquired about 1000 yrs. after deposition.

5.2 'STANDARD' MAGNETIC POLARITY TIMESCALE

During the last 20 years progressive refinement of polarity definition (Cox 1969; Opdyke 1972; Blakely 1974) and of radiometric age determinations (McDougall and Chamalaun 1966; Harrison *et al.* 1979; McDougall *et al.* 1984) has led to a succession of slightly different magnetic polarity timescales. Reviews by Watkins (1972), McDougall (1977) and Ness *et al.* (1980) record the progressive development.

Published magnetic polarity timescales have been established from either radiometrically dated lava successions (McDougall and Tarling 1963; McDougall *et al.* 1976a; McDougall *et al.* 1977; Saemundsson *et al.* 1980; McDougall *et al.* 1984) or ocean-floor magnetic anomaly profiles with dated calibration points, assuming a constant spreading rate (Heirtzler *et al.* 1968; Talwani *et al.* 1971; Blakely and Cox 1972; Cande and LaBrecque 1974; LaBrecque *et al.* 1977; Mankinen and Dalrymple 1979; Ness *et al.* 1980) or biostratigraphic, chronostratigraphic and magnetostratigraphic compilations, with radiometrically dated calibration ages (Berggren 1972, 1981, 1984a; Berggren and Van Couvering 1974; Ryan *et al.* 1974). The various magnetic polarity timescales proposed have resulted in confusion and criticism (Berggren 1981).

The anomaly derived timescale of Ness *et al.* (1980) is selected as the standard magnetic polarity timescale for this study for three reasons. Firstly it is empirically derived and is solely a 'magnetochronology' (terminology follows that of Berggren 1984a). It has a minimum number of assumptions and construction steps and hence minimises potential error. The use of a magnetochronologic timescale, as opposed to a timescale which is derived from biostratigraphic, magnetostratigraphic and K-Ar data (a 'biomagnetoradiochronology', Berggren 1984a) is preferred here, since it avoids circular arguments. The Ness *et al.* (1980) timescale has been widely used in magnetostratigraphy (Berggren *et al.* 1984; Shibata *et al.* 1984; Nigrini and Lombari 1984; Hornibrook 1984a; Edwards 1985) thus allowing direct correlation to other magnetostratigraphic studies. It is detailed, and provides ages for all recognised reversals.

There is only minor disparity (±0.10 Ma within the Late Miocene) in age estimates of polarity transitions, when corrected for the new (Steiger and Jager 1977) K-Ar decay constants (cf. Cande and LaBrecque 1974; McDougall *et al.* 1976a; LaBrecque *et al.* 1977; McDougall *et al.* 1977; Mankinen and Dalrymple 1979; Ness *et al.* 1980; Berggren 1984a; Berggren *et al.* 1985). Only the recent timescale of McDougall *et al.* (1984) is different with Late Miocene polarity intervals consistently 1 Ma older. However, for the purposes of correlation in the following chapters, magnetostratigraphic age data based on polarity timescales other than Ness *et al.* (1980) have been corrected where possible to the Ness *et al.* (1980) timescale. Presented K-Ar dates have been corrected to the revised decay constants (Steiger and Jager 1977). Those data that could not be corrected to either the Ness *et al.* (1980) timescale or the new K-Ar decay constants are indicated with an asterix (ie 6.2* Ma).

Recently published timescales (Miller *et al.* 1985; Berggren *et al.* 1985; Barron *et al.* 1985) have correlated Anomaly 5 with Chron 11 based on new biostratigraphic - magnetostratigraphic studies from South Atlantic DSDP sites (Poore *et al.* 1984; Hsu *et al.* 1984; Khan *et al.* 1985)) as opposed to the previously accepted correlation of Anomaly 5 with Chron 9 (Ryan *et al.* 1974; Theyer and Hammond 1974; LaBrecque *et al.* 1977). This alternative correlation using Anomaly 5 = Chron 11 (Foster and Opdyke 1970) results in Chrons 7 through to Chron 14 being reassigned with magnetic anomalies; shortening Chron 7 to include only the three normal events of Anomaly 4 (Fig. 5.2). As noted by Barron *et al.* (1985), adoption of this revised chron - anomaly correlation results in more uniform sedimentation rates during the late Miocene than rates estimated from the traditional timescales in which Anomaly 5 was correlated with Chron 9. The ambiguity in using the same numbering with either the Anomaly 5 = Chron 9 or the Anomaly 5 = Chron 11 correlation can be circumvented by using the revised chron nomenclature of Tauxe *et al.* (1983). This nomenclature names chrons from correlative magnetic anomalies which extend from the youngest reversal boundary of one anomaly to the youngest reversal boundary of the next anomaly, and are prefixed with the letter C: ie Anomaly 6 = Chron C6. Since a large body of literature exists using the Anomaly 5 = Chron 9 correlation, this and both the Anomaly 5 = Chron 11 and the Tauxe *et al.* (1983) correlations are presented (Fig. 5.2) for ease of reference, however all references within the text will follow the new chron nomenclature of Anomaly 5 = Chron 11.

5.3 MAGNETOZONES

The polarity magnetozones are clearly defined by the declination and inclination logs (Fig. 5.1). Virtual geomagnetic pole (VGP) latitudes were not required to determine the polarity zones. Each of the magnetozones is designated with the following notation MR1, MN1, MR2, MN2 etc (Fig. 5.1); where MR refers to Mangapoike reversed and MN to Mangapoike normal. They are numbered consecutively upward from the base of the sampled sequence. Magnetozones MR2 and MR3 are each based on only one site, but are considered to represent true geomagnetic polarity zones because they have reversed polarity after demagnetisation. Single reversed specimens are recognised at sites 18991, 19005, 19018 (686, 805 and 868 m respectively) and also probably represent reversed magnetic polarity zones, but were rejected from the final analysis on the basis of the previously described criteria (sections 3.5 and 4.5).

Only one normal magnetozone (MN6, 1760 to 1880 m, Fig. 5.1) was detected in the stratigraphic interval equivalent to that from which Kennett and Watkins (1974) reported two normal zones designated as C1 and C2. Magnetozone MN6 is correlated with the C2 (lowermost normal) event of Kennett and Watkins (1974) (Fig. 5.2). Their supposed C1 event is based on three low VGP latitudes that are here considered to represent reversed sites with incompletely cleaned normal overprints. Shallow inclinations in some reversed polarity sites of the present study, especially between 1500 and 2156 m, are also attributed to incomplete cleaning of specimens with weak primary magnetisations.

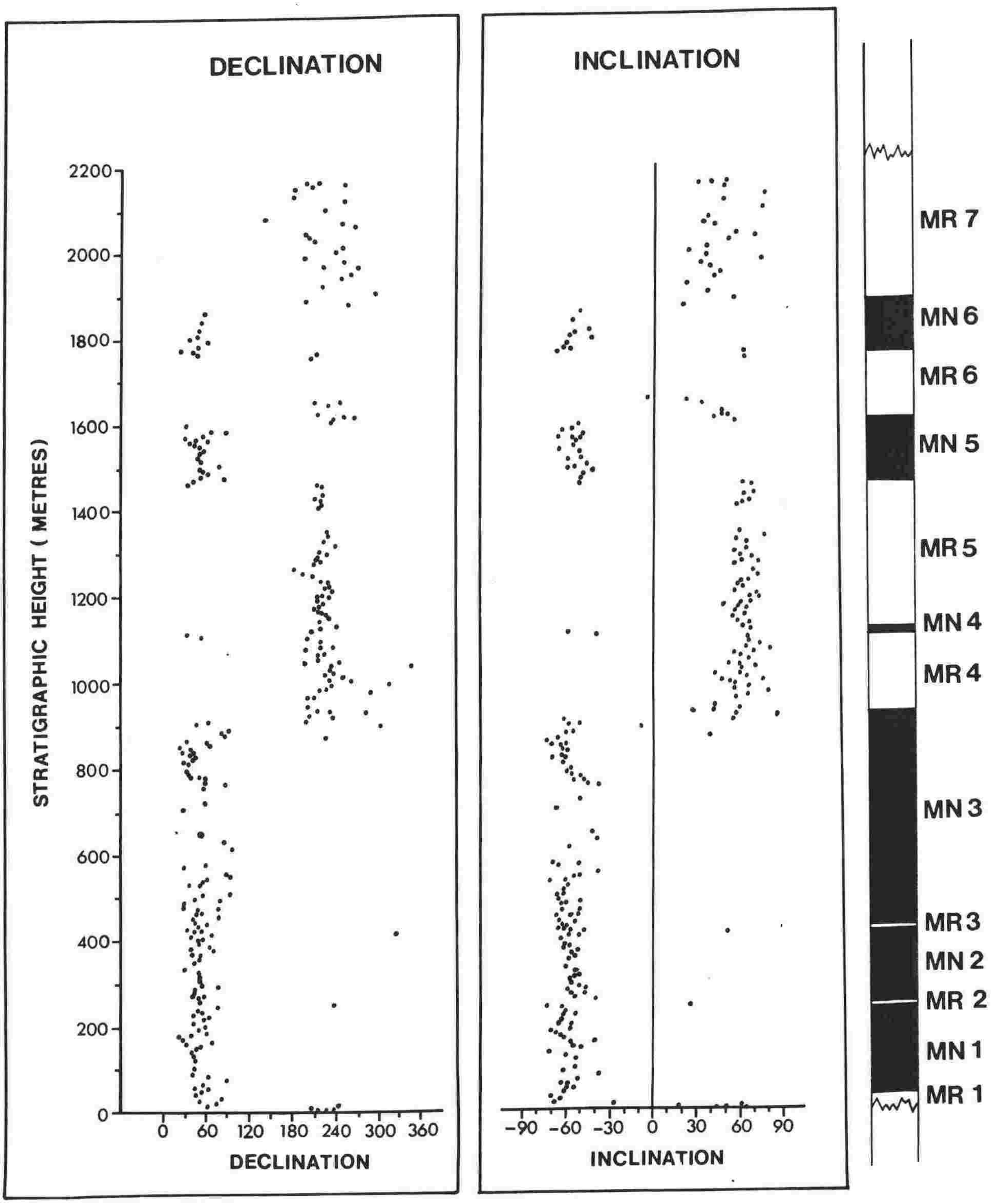


Fig. 5.1 Late Miocene Mangapoike polarity magnetozones. For notation of MR1, MN1 etc refer to text. Black is normal polarity.

5.4 CORRELATION WITH THE MAGNETIC POLARITY TIMESCALE

The following biostratigraphic datums and fission-track age from the Mangapoike sequence are used as preliminary approximate dating.

1. The first appearance datum (FAD) of *Globigerina nepenthes* Todd is 300 m below the base of the paleomagnetically sampled sequence (Hoskins pers. comm.) The FAD of *G. nepenthes* in New Zealand is a well established biostratigraphic datum (Jenkins 1966, 1967; Hornibrook and Edwards 1971; Hornibrook 1981b, 1984b) coinciding with the base of the Waiauan Stage (Hoskins 1982). Elsewhere the FAD of *G. nepenthes* defines the base of Zone N14 in the late Middle Miocene (Banner and Blow 1965; Blow 1969) in the tropics, correlating to the upper parts (Srinivasan and Kennett 1981a) of the cool subtropical *Globorotalia mayeri* Zone (Jenkins 1971, 1975; Kennett 1973) and the warm subtropical *Globorotalia mayeri* Zone (Srinivasan and Kennett 1981a). Hornibrook (1981b, 1984b) suggested a 12.7* Ma age for the *G. nepenthes* datum in New Zealand based on the stratigraphic position of *Loxostomum truncatum* to the K-Ar dated Dunedin Volcanics (McDougall and Coombs 1973). Elsewhere the *G. nepenthes* datum has age estimates ranging from 12.7 to 11.6 Ma (Berggren and Van Couvering 1974, 1978; Van Couvering and Berggren 1977; Saito 1977; Chiji and Konda 1978; Takayanagi *et al.* 1978; Keller 1980; Miller *et al.* 1985; Berggren *et al.* 1985).

2. The last appearance datum (LAD) of *Globoquadrina dehiscens* (Chapman, Parr and Collins) is at 759 m in the sampled sequence (Hoskins pers. comm. 1985). The disappearance of *G. dehiscens* in New Zealand within the Tongaporutuan is generally accepted (Kennett 1968; Hornibrook and Edwards 1971; Jenkins 1971; Hornibrook 1984b) although younger occurrences have been recorded (Hornibrook 1961; Collen and Vella 1973). Diachroneity of this datum within New Zealand is probable (Kennett 1968; Kennett and Watkins 1974), but as yet undetermined. The *G. dehiscens* datum in New Zealand has been dated magnetostratigraphically at Blind River at 6.2* Ma (Hornibrook 1981b, 1984b) and in equatorial regions at about 5.3 Ma (Saito *et al.* 1975), thus having a known diachroneity (Hornibrook 1981b, 1984b; Berggren 1984b) between temperate and tropical regions. Provisionally a 6.2* Ma age for this datum in New Zealand is accepted here for preliminary dating. Inconsistent ages of the *G. dehiscens* LAD within New Zealand are described in the following chapter.

3. A fission track age of 5.80±0.55 Ma from zircons in a tuff below the Miocene - Pliocene unconformity (Seward in Hornibrook 1984a) in an adjacent road exposure is equivalent to a stratigraphic height of 2070 m in the sampled sequence.

4. The first appearance datum (FAD) of *Globorotalia sphericomiozea* Walters is at 2088 m (the Miocene - Pliocene unconformity) in the sampled sequence. *G. sphericomiozea* is part of the *Globorotalia miozea* plexus (Scott 1979b, 1980; Hornibrook 1984a) having a short range within the Kapitean - Opoitian in both on land sequences and DSDP 284 (Hornibrook 1981a, 1982, 1983, 1984a; Scott 1983). An estimated age of 5.4 Ma (Hornibrook 1981a, 1981b, 1984a; Edwards 1985) for the FAD of *G. sphericomiozea* is based on its occurrence just above Chron 5 from the reinterpreted magnetostratigraphy of Blind River (Loutit and Kennett 1979).

The above data constrain correlation of the magnetozones to a time interval between 11.0 and 5.0 Ma.

Individual magnetozones are correlated with chrons by their relative lengths, assuming a constant or nearly constant sedimentation rate. The long interval of normal polarities (MN1, MN2, MN3) interrupted by the very thin reversed intervals (MR1, MR2) are correlated with Chron 11. The remaining magnetozones up to MN5 are progressively correlated up the polarity timescale with Chrons 10 and 9 (Fig. 5.). This implies an average sedimentation rate of 64 cm/1000 yr. MR2 and MR3 are correlated with the two lower reversed subchrons in Chron 11. Above 1857 m only one recognised normal magnetozone (MN6) is present whereas the polarity timescale contains three normal subchrons of Chron 7 and the one normal subchron of Chron 6. From this a significant unconformity is inferred in the upper Tongaporutuan at Mangapoike. At present two interpretations (A and B) are considered for the correlation of MN6 with the polarity timescale (Fig. 5.2). Interpretation A follows the progressive correlation up the polarity timescale, correlating MN6 with the short subchron (7.44 to 7.39 Ma) in lower Chron 7, and gives a sedimentation rate of 200 cm/1000 yr for MN6. From this the non-appearance of the higher normal subchrons indicates the period from at least 7.34 to 6.42 Ma is missing in the unconformity. Interpretation B correlates MN6 with the longer subchron (7.34 to 6.94 Ma) in upper Chron 7, and the shorter normal subchron below it with the unsampled interval from 1650 to 1751 m (Fig. 5.2). This interpretation gives a 26 cm/1000 yr sedimentation rate for MN6. The non-appearance of the higher normal subchrons indicates the absence of strata representing the period from at least 6.86 to 6.42 Ma. From the comparison of the sedimentation rates (200 and 26 cm/1000 yr) from the two

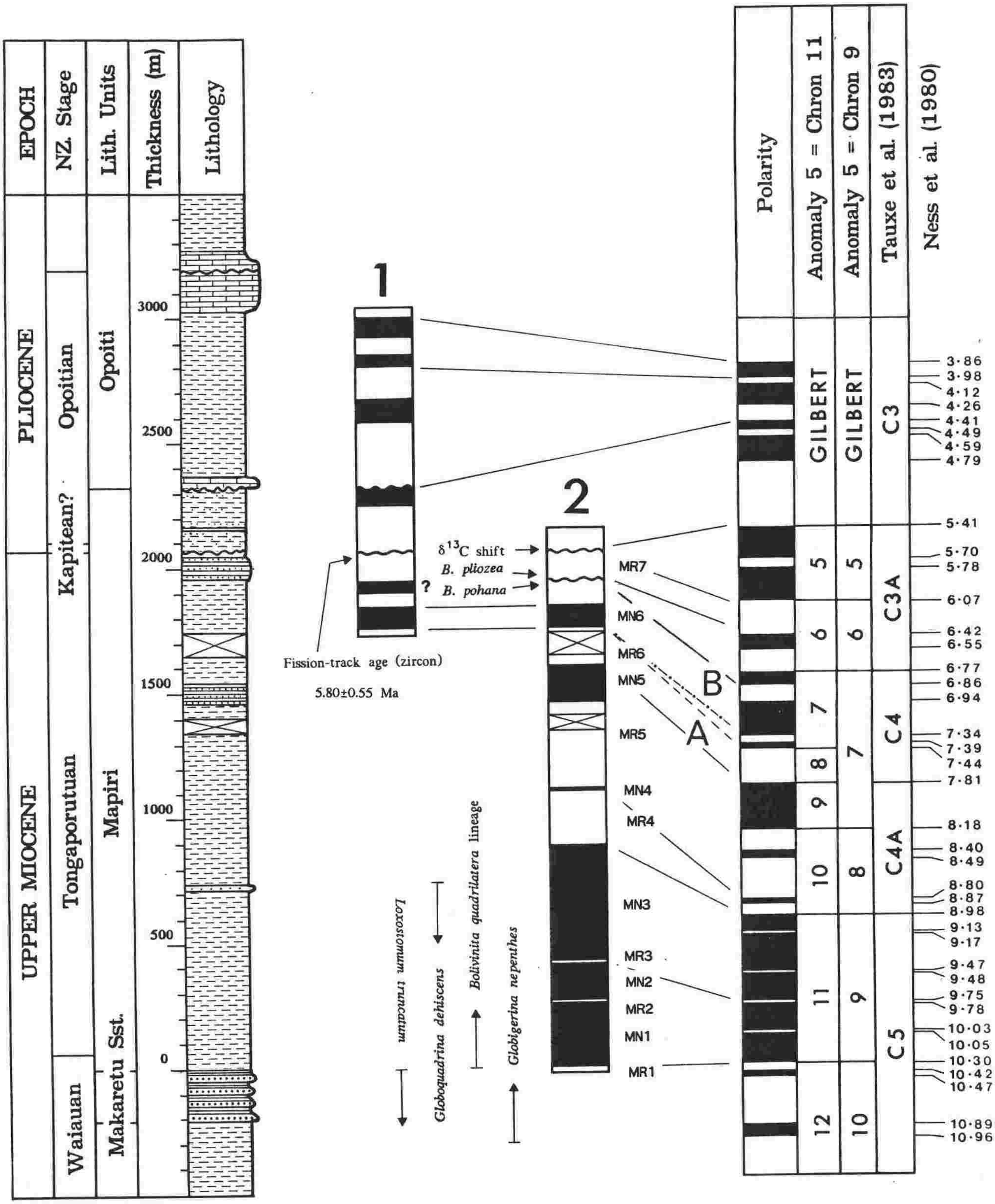


Fig. 5.2 Correlation of the Mangapoike magnetozones to the magnetic polarity timescale of Ness *et al.* (1980). Black is normal polarity. Column 1: magnetic polarities determined by Kennett and Watkins (1974) and reinterpreted by Edwards (1985, in prep.) Fission-track age from Hornibrook (1984b). Column 2: magnetozones and correlations determined in this thesis. *Bolivinita pohana - pliozea* transition determined by Scott (1978). Other foraminiferal datums determined by Hoskins (pers. comm. 1985). A and B refer to the respective magnetostratigraphic correlations described in the text.

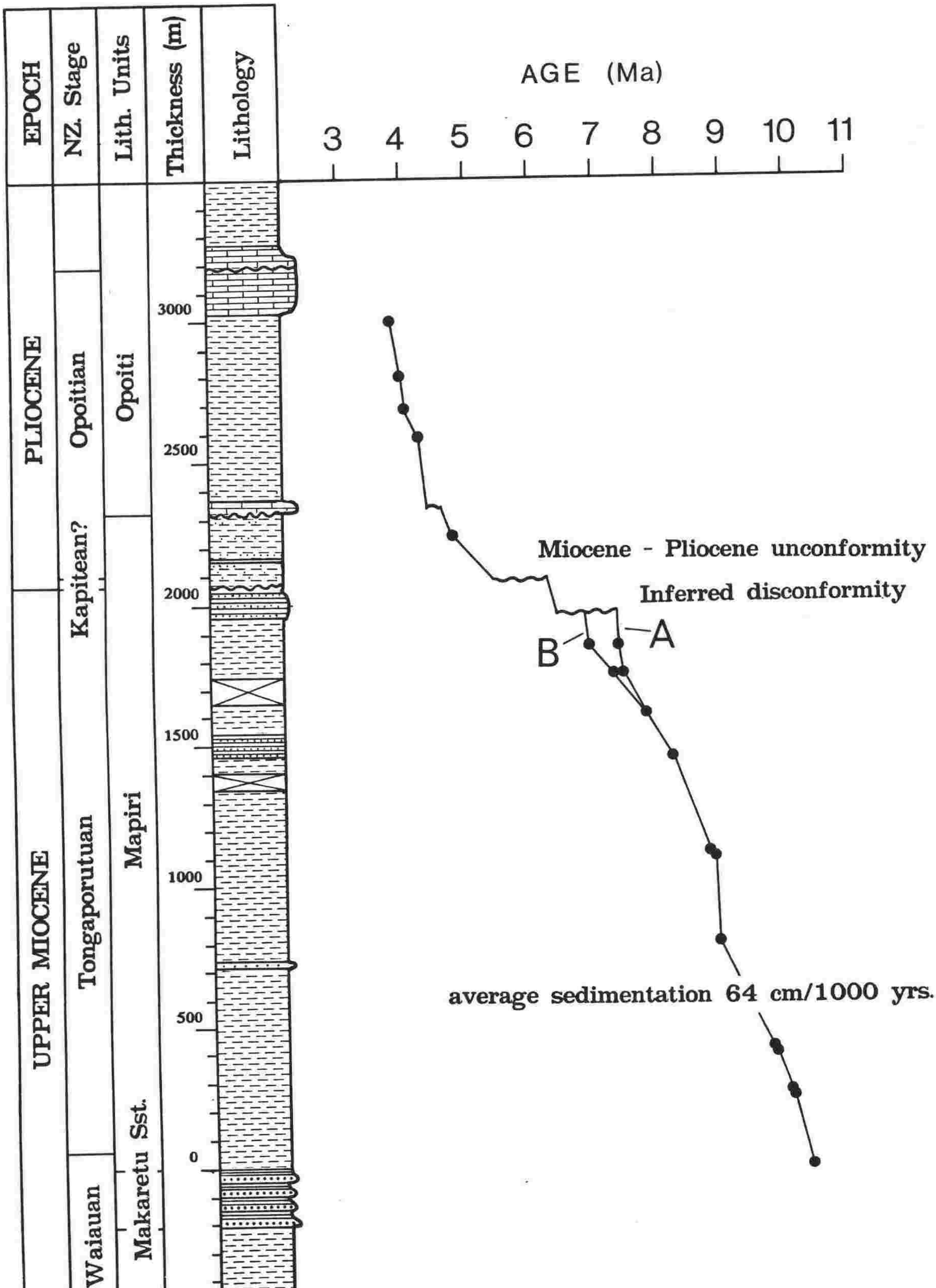


Fig. 5.3 Sedimentation rate of the Mangapoike section based on the magnetostratigraphic correlations of Edwards (1985) for the upper Mangapoike section and this thesis for the lower Mangapoike section. A and B refer to the respective magnetostratigraphic correlations described in the text.

interpretations with the average sedimentation rate (64 cm/1000 yr) from the lower part of the section (Fig. 5.3), the second interpretation (B) is preferred.

The inferred unconformity mentioned above is assumed to be at 1970 m where a lithological change from massive mudstones to bedded turbidites occurs (Fig. 2.2 and Plate 6.2). Biostratigraphic evidence supports the presence of the unconformity. The *Bolivinita pohana - pliozea* "transition", although not yet phylogenetically understood, is a gradual but recognisable change in *Bolivinita* test morphology within the upper Tongaporutuan in New Zealand. As reported by Edwards (1985) the *B. pohana - pliozea* 'transition' at Blind River (Scott 1978) occurs with the normal event of Chron 6 (6.55 to 6.42 Ma) of the revised Blind River magnetostratigraphy (Loutit and Kennett 1979). The morphological change of *B. pohana* to *B. pliozea* at Mangapoike, as determined by Scott (1978) does not coincide with any normal event recognised in the present study. The sampling sites used by Scott (1978), were located on the large base map used for the present study, and the morphological change from *B. pohana* to *B. pliozea* was found to occur between two samples at 1964 m and 2023 m (Fig. 5.2), the stratigraphic interval containing the inferred unconformity at 1970 m. Thus as inferred solely from the biostratigraphic correlation, both the normal event of Chron 6 and the coincident *B. pohana - pliozea* 'transition' as recognised from Blind River, are missing at Mangapoike, indicating that at a minimum the period from 6.55 to 6.42 Ma is missing, and that the hiatus occurs between 1964 m and 2023 m.

Ashby (1986) tabulated nine radiolarian taxa (*Cladococcus dentata, Antarctissa conradae, Desmospyrs sp. A, Cyrtocapsella japonica, Cyrtocapsella tetrapera, Lampromita tiara, Lamprocyclas sp. E, Phormostichoartus sp. A,* and *Siphosticharctus corona*) with local disappearances at or just below the inferred unconformity. The most distinctive disappearances are *Cyrtocapsella japonica* and *Cyrtocapsella tetrapera,* which show persistent records below the unconformity and only one positive identification of *C. tetrapera* above.

The gradational change in lithology, over 3 m, from massive mudstone to bedded sandstones and mudstones at 1461 m may represent a break in sedimentation. The lithological change is at or very close to the polarity reversal from MR5 to MN5. At present without further evidence, it is assumed that there is no unconformity at this stratigraphic interval.

The angular unconformity (3° discordance) at the Miocene - Pliocene boundary (Hornibrook 1977, 1981b, 1983, 1984a) is within the reversed magnetozone MR7 at

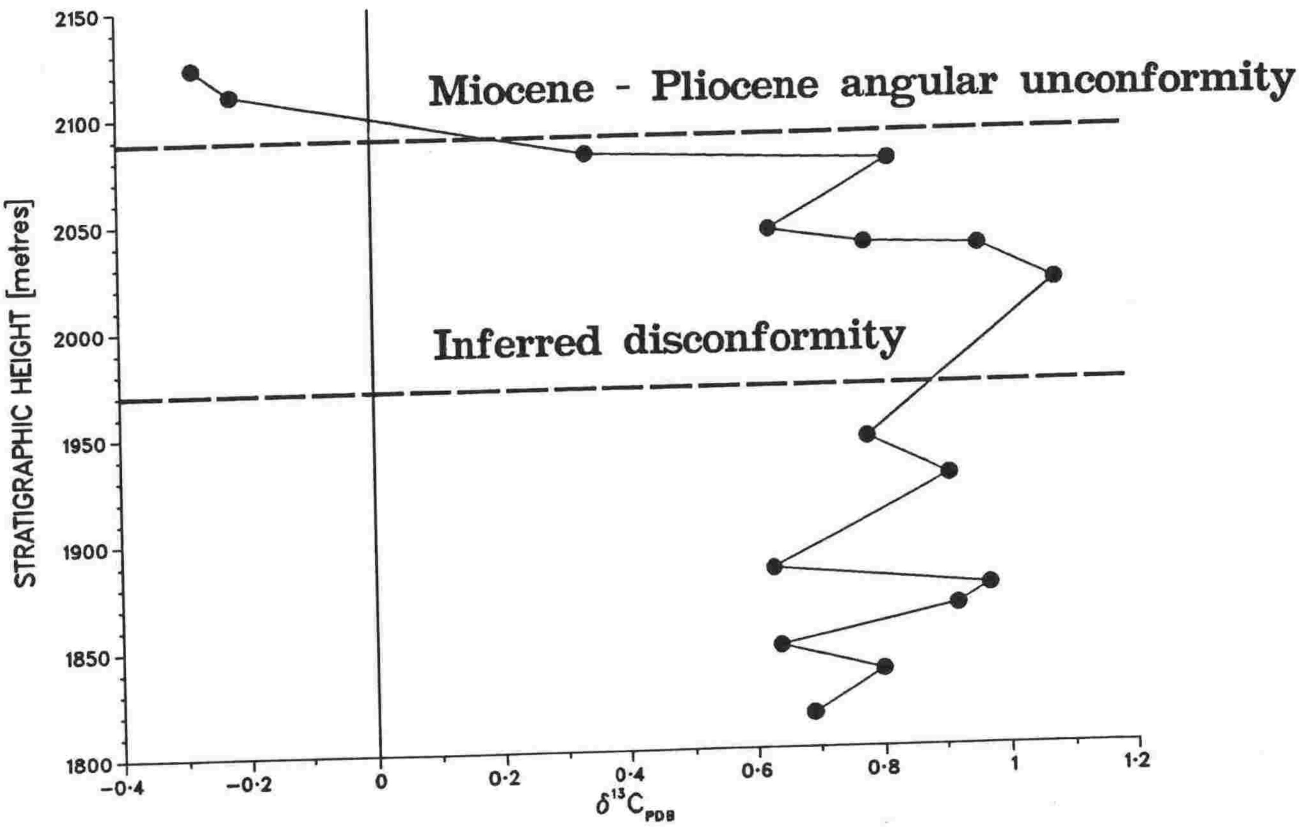


Fig. 5.4 Mangapoike $\delta^{13}C$ data bounding the Miocene - Pliocene angular unconformity. $\delta^{13}C$ values have been normalised to *Cibicidoides wuellerstorfi* (Savin *et al.* 1981) to correct for the disequilibrate fractionation of carbon in *Uvigerina spp.*

2088 m. Based on the foraminiferal biostratigraphy, as discussed previously, and the magnetostratigraphic correlations outlined above, the reversed polarity zone below the unconformity is correlated with the upper reversed subchron of Chron 6 and the reversed polarity zone above the unconformity is correlated with the lower reversed subchron of the Gilbert (Fig. 5.2). This correlation follows that of Edwards, in Hornibrook (1984a, 1984b) and Edwards (1985). The implied absence of the normal subchrons of Chron 5 indicates that the minimum time missing (6.07 to 5.41 Ma) is 660,000 yrs at the Miocene - Pliocene boundary in the Mangapoike sequence.

Carbon isotopic data based on analyses of *Uvigerina spp.* from the Mangapoike sequence (Appendix 10) indicates that the Miocene - Pliocene unconformity is significantly longer in time than estimated from the magnetostratigraphy. The Late Miocene carbon 'shift' is a significant -0.5 to -1.0 depletion in $\delta^{13}C$ as determined from benthic foraminifera (Keigwin 1979; Kennett *et al.* 1979; Loutit and Kennett 1979; Loutit *et al.* 1983) and is accepted as an isochronous datum dated at 6.2 Ma (Haq *et al.* 1980; Vincent *et al.* 1980; Keigwin and Shackleton 1980). Examination of the limited $\delta^{13}C$ data from the Mangapoike (Fig. 5.4) indicates that the depletion occurs across the Miocene - Pliocene unconformity, although it is suggested that the early part of the carbon shift is recorded at 2080 m. Consequently it is inferred that the greater part of the carbon 'shift' is within the unconformity and thus it is concluded from the combined evidence of the magnetostratigraphy and the carbon isotope stratigraphy that the Miocene - Pliocene unconformity at Mangapoike represents a time interval of at least 890,000 yrs. from <5.41 Ma to 6.3 Ma.

5.5 SAMPLING EFFICIENCY

Statistical evaluation of magnetostratigraphic studies for sampling efficiency and stratigraphic completeness (Sadler 1981; Johnson and McGee 1983; Hall and Butler 1983; May *et al.* 1985) is a recent adjunct in paleomagnetism. Cox (1968, 1981) defined reversals of the geomagnetic field as an exponential probability distribution function with $P(\tau) = \lambda \exp(-\lambda\tau)$

where τ = time between reversals

λ = mean frequency of reversals over time

$P(\tau)$ = proportion of polarity intervals whose lengths lie between τ and $\tau + \partial\tau$

assuming that the length of successive polarity intervals is statistically independent and that the reversals have a Poisson distribution with time. Johnson and McGee (1983) used this distribution function to statistically define, with error limits, the number of expected reversals within a given time interval with N sampling sites, using a uniform, random or exponential sampling strategy. Hall and Butler (1983) defined a stochastic model to evaluate stratigraphic completeness and thus the reliability of the magnetostratigraphy. Using the technique of Sadler (1981), May *et al.* (1985) showed that, within different depositional environments, stratigraphic completeness at different timescales could be evaluated and used as a test of the magnetostratigraphic correlation. The statistical procedures of Sadler (1981), Hall and Butler (1983) and May *et al.* (1985) are not used in the present study since firstly, the Mangapoike sequence is mostly massive in lithology (section 2.3 and Appendix 1), with little or no bedding, and breaks in deposition between successive beds (Ager 1973; Dott 1983) are considered to be minimal, apart from the two unconformities (Fig. 5.2) and secondly the recognition of MR2 and MR3 indicates stratigraphic completeness, when correlated with the timescale of Ness *et al.* (1980), at a scale of at least 10^4 years.

The Johnson and McGee (1983) model is used here to calculate the expected success of the Mangapoike sampling programme given the number of paleomagnetic sites (N), the distribution of the sites, an estimate of the geologic time span sampled (Δt), and the mean length of the magnetic polarity zone (τ). From those data it is possible to compare the number of observed and expected reversals. Accepting the quantitatively dated biostratigraphic datums and the magnetostratigraphic correlation as discussed (section 5.3) an estimated time span for the sampled sequence of 4.9 Ma can be derived from the base of Chron 9 (10.30 Ma) and the base of the Gilbert (5.41 Ma). The mean length of magnetic polarity zones for the Late Neogene is 0.12 Ma (Harrison 1969; Lowrie and Kent 1983; Johnson and McGee 1983 based on data from Watkins and Walker 1977). Assuming a uniform sampling distribution, the expected number of reversals (Table 5.1a) of 17.1±4.03 is greater than the 12 reversals observed. The discrepancy is attributed to the unconformities in the sequence (section 5.4). The estimated 0.89 Ma represented by the Miocene - Pliocene angular unconformity, the 0.44 Ma represented by the inferred unconformity at 1970 m, and the 0.10 Ma within the total of 108 m of covered and non-sampled intervals greater than 5 m (based on the average sedimentation rate of 64 cm/1000 yrs) totals 1.2 Ma. Subtracting 1.2 Ma from the inferred total time span of 4.9 Ma represented by the section leaves 3.7 Ma which has been sampled. The expected number of reversals is 12.0±3.4 (Table 5.1b) which is in agreement with the 12 observed reversals. It is concluded that the sampling programme (chapter 2) and the demagnetisation techniques (chapter 4) have recognised all of the polarity reversals within the section sampled.

Table 5.1

Johnson and McGee (1983) Model Calculations

a) Uniform Sampling

$\Delta t = 4.9$ Ma

$N = 343$

$\tau = 1.2 \times 10^5$

$p = \frac{1}{2}(1-e^{-2\Delta t/\tau N}) = 0.05$

$R = p(N-1) = 17.10$

$\sigma = \frac{1}{2}(p(1-p)(N-1)) = 4.03$

ie Expected Reversals 17.10±4.03

b) Uniform Sampling

$\Delta t = 3.47$ Ma

$N = 343$

$\tau = 1.2 \times 10^5$

$p = \frac{1}{2}(1-e^{-2\Delta t/\tau N}) = 0.035$

$R = p(N-1) = 12.0$

$\sigma = \frac{1}{2}(p(1-p)(N-1)) = 3.40$

ie Expected Reversals 12.0±3.40

N = number of paleomagnetic sites placed within Δt

p = probability that a given sample set will cross magnetic reversal

R = expected number of reversals discovered by the sample set

τ = mean time length of polarity intervals over a long time period

Δt = time increment of stratigraphic interval

5.6 BIOTURBATION

The possible effects of bioturbation, by a benthic fauna, on the paleomagnetism of sediments has been recognised (Keen 1963; Harrison 1966; Watkins 1968). The main concerns have been the vertical mixing of sediment with the consequent alteration or obliteration of polarity events (Watkins 1968) and the primary magnetic fabric in susceptibility anisotropy studies (Rees *et al.* 1968, 1982; Kent and Lowrie 1975) and the time lag between deposition of the sediment and acquisition of the final magnetisation (Lowrie 1975). It is recognised that detrital remanent magnetisation (DRM) can be a combination of grain alignment during settling through the water column (Nagata 1953; Graham 1949; King 1955; Griffths *et al.* 1960) and also subsequent alignment within the sediment slurry by grain rotation (Graham 1954; Irving 1957; Irving and Major 1964; Kent 1973; Otofuji and Sasajima 1981) termed as depositional DRM and postdepositional DRM, respectively (Verosub 1977).

Keen (1963) and Harrison (1966) recognised that extensive bioturbation of deep-sea sediments would obliterate the depositional DRM, and the observed magnetisation must be postdepositional in origin. Verosub (1977) in his review of sediment magnetisation concluded that the directional coherence of deep-sea cores as documented by Opdyke (1972) supported a postdepositional origin of magnetisation. It is argued further here that varying degrees of bioturbation, as described (section 2.7), will result in a positive correlation with direction dispersion, as measured by $\alpha95$, if the magnetisation is a depositional DRM. If no such correlation is exhibited, and bioturbation is obvious in the sediment at the site(s) sampled then it is concluded that the magnetisation post dates the bioturbation and thus is post-depositional in origin. The Mangapoike data exhibit no correlation between the amount of visible bioturbation and $\alpha95$ (Fig. 5.5) and thus the magnetisation is considered to be a post-depositional DRM.

An estimate of the time lag between deposition and magnetisation acquisition can be derived from the sedimentation rate and the depth from the sediment/water interface of the faunal mixing zone. A maximum bioturbation depth of 60 cm determined by measurements on deep-sea sediments (Ninkovich *et al.* 1966; Glass 1969; Ruddiman and Glover 1972; Rhoads and Boyer 1982) combined with the average Mangapoike sedimentation rate of 64 cm/1000 yrs indicates an approximate 1000 year lag between deposition and magnetisation in the Mangapoike sediments. This could be an over estimate of the time lag, since the maximum known depth of bioturbation in the Mangapoike sequence is 25 cm, measured by a burrow from the base of a tuff. However the burrow itself is incomplete, by an unknown amount, with the top

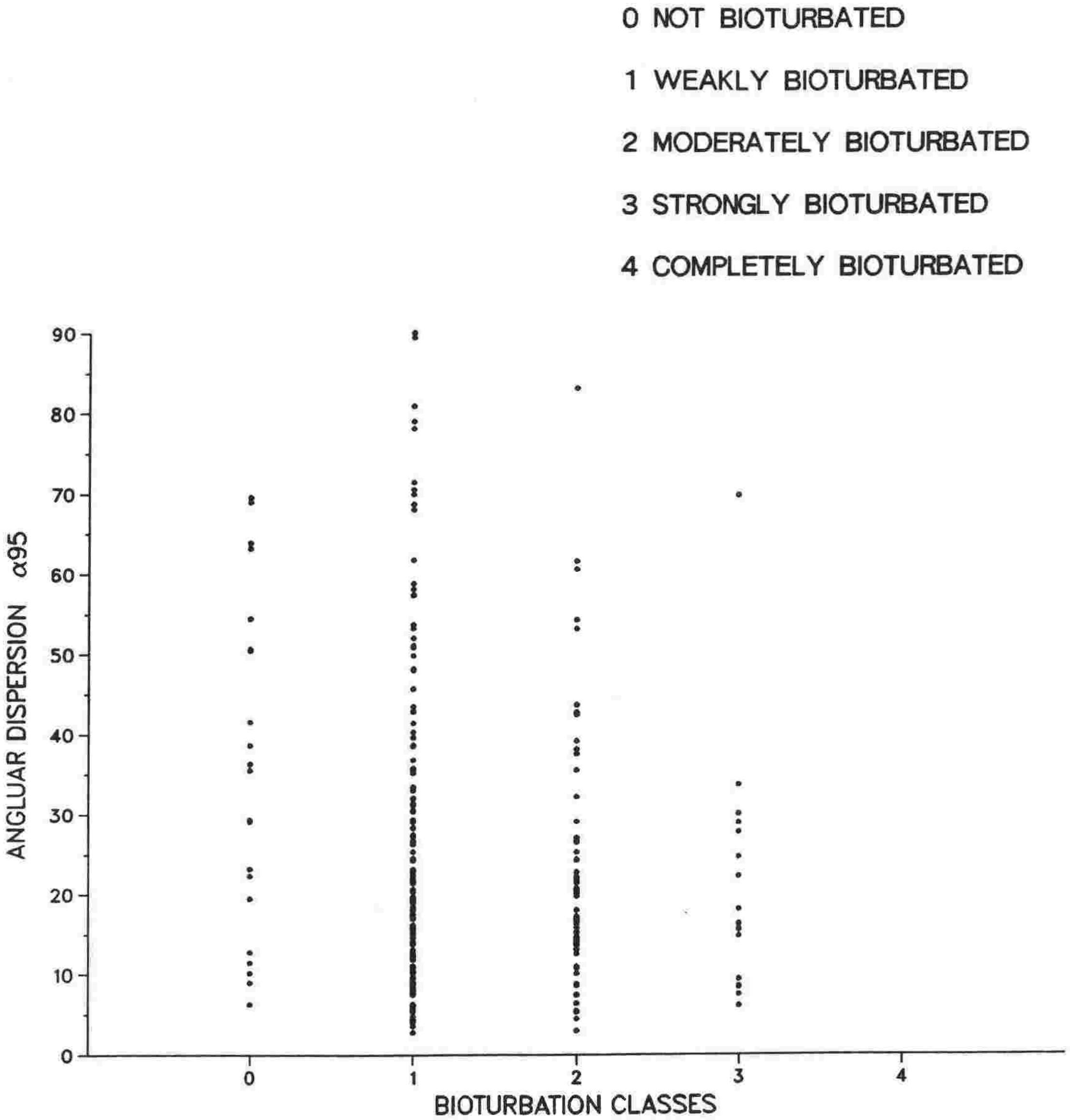


Fig. 5.5 Plot of $\alpha95$'s against the degree of bioturbation.

unlocated, and for the present 1000 years remains the best estimate of the time lag between deposition and magnetisation of the Mangapoike sediments.

Modification of polarity events by bioturbation as described by Watkins (1968) is considered not to be significant, in the Mangapoike paleomagnetic record. Accepting both that polarity reversals occur on a timescale of 10^4 to 10^6 years and that the shortest recognised polarity event in the Late Miocene from Ness *et al.* (1980) is 14000 yrs and the maximum interval of bioturbation of the Mangapoike sediments is 1000 yrs, then theoretically all polarity events should be recorded. The admixture of reversed and normal polarity specimens at sites 18991, 19005 and 19018, which were rejected from the final analysis, could be attributed to inhomogeneous vertical mixing by a benthic fauna soon after a polarity transition. However, the post-bioturbation timing of magnetisation of the Mangapoike sediments, as described, indicates that mixed polarities are not a function of bioturbation, and are more likely to be product of incomplete demagnetisation of some specimens at sites where a normal overprint is superimposed on a primary reversed magnetisation.

Chapter VI

LATE MIOCENE CORRELATIONS

6.1 INTRODUCTION

This chapter discusses Late Miocene glacioeustatic, magnetostratigraphic, biostratigraphic and chronostratigraphic correlations derived from the Mangapoike magnetostratigraphy. Section 6.2 describes three inferred glacioeustatic events within the late Waiauan to earliest Opoitian interval of the Mangapoike section, which are synchronous with positive deep-sea benthic $\delta^{18}O$ values and with low sea-levels postulated by Vail *et al.* (1977). The three events could be attributed to relative sea-level changes caused by intermittent temporary reversals of tectonic subsidence to tectonic uplift, but there is no supporting evidence for such tectonic reversals. Section 6.3 shows the correlation of the Mangapoike magnetostratigraphy to other Late Miocene - Early Pliocene magnetostratigraphies of New Zealand, including DSDP Site 594. Sections 6.4 and 6.5 discuss the age determinations from Mangapoike, for the first appearance datum (FAD) of the *Bolivinita quadrilatera* lineage (the base of the Tongaporutuan Stage) and the last appearance datum (LAD) of *Globoquadrina dehiscens*. The former is correlated to the base of the international Tortonian stratotype and associated tropical microfossil zones.

6.2 GLACIOEUSTATIC SEA-LEVEL CHANGES

6.2.1 Introduction

Eustatic sea-level control of marine sedimentation has been recognized from the presence of sedimentary cycles and bounding uncomformities within the rock record (Wells 1960; Vella 1965; Rona 1973). Turbidites also may often correlate to low sea level (Shanmugan and Moiola 1982). Interludes of coastal onlap and offlap sedimentation, as shown by seismic profiles, have been interpreted as eustatic rises and falls, respectively, of sea-level, resulting chiefly from glaciation (Vail *et al.* 1977; Vail and Hardenbol 1979). The Phanerozoic eustatic sea-level curve of Vail and Hardenbol has been criticised with respect to the methodology of its construction (Maill 1986), the implied relative rates of sea-level rise and fall (Hallam 1981) and the significant lack of a glacial record, especially within the Triassic and Jurassic when large sea-level changes are postulated. Other mechanisms causal to sea-level flucuations have been suggested (Russell 1968, Valentine and Moore 1970; Hays and Pitman 1973; Pitman 1978).

The oxygen and carbon isotope stratigraphy for the Neogene (Savin *et al.* 1981) is interpreted as an ice volume record (Woodruff *et al.* 1981) showing that at least from the middle Miocene to the present, sea-level changes shown on the Vail curve are probably truly glacioeustatic.

Within New Zealand, chronostratigraphic subdivision of the Cenozoic was originally defined by mollusca and benthic foraminifera (Allan 1933; Finlay and Marwick 1940, 1947); taxa which are influenced by eustatic sea-level changes. By implication the New Zealand stages are possibly related to eustatism (Loutit and Kennett 1981).

6.2.2 Mangapoike Glacioeustatic Events

Event 1: <10.3 Ma (upper Chron 12) Turbidites.

The 210 m thick Makaretu sandstone (Plate 6.1) immediately below the sampled sequence is tentatively identified as resulting from glacioeustatism, based on lithological inferences and the near age synchroneity with other known glacioeustatic events (Fig. 6.1). The 'sandstone' is a series of rhythmically bedded turbiditic sandstones and mudstones. Sandstones and mudstones are equal in proportion, and sandstones beds have erosional bases. Flute casts are commonly observed. The unit is bounded stratigraphically, grading over 9-6 m at both the base and top, by at least 300 m thick massive to very weakly bedded mudstone. The Makaretu sandstone is recognised throughout the Wairoa Syncline (Wellman 1958).

Increased frequency and magnitude of turbidite deposition has been correlated to low eustatic sea-levels (Damuth 1977; Vail and Hardenbol 1979; Shanmugan and Moiola 1982). Increased erosion due to glaciation and exposure of the continental shelf results in larger volumes of coarse detritus being fed to bathyal sites.

The Makaretu sandstone (latest Waiauan) is within upper Chron 12, immediately below the Chron 11 - Chron 12 transition, and has an estimated age of 11 to 10.3 Ma. A significant glacioeustatic event has been inferred to occur between 11 and 9 Ma. Vail *et al.* (1977) and Vail and Hardenbol (1979) recognised a major uncomformity attributed to a low eustatic sea-level at 9.92 Ma (= 9.8 Ma of Blakely 1974; timescale in Vail and Hardenbol 1979). Two episodes of marked $\delta^{18}O$ enrichment in benthic foraminifera have been recognised close to the middle - late Miocene boundary (Savin *et al.* 1981; Burckle *et al.* 1982; Kennett 1986) and are interpreted as the result of increases in ice volume on Antarctica (Woodruff *et al.* 1981). Savin *et al.* (1981) estimated an age of 11.8 to 10.5 Ma for the younger $\delta^{18}O$ enrichment, on the evidence of foraminiferal, coccolith, radiolarian and diatom

Plate 6.1 Glacioeustatic event 1: turbidite beds of the Makaretu sandstone.

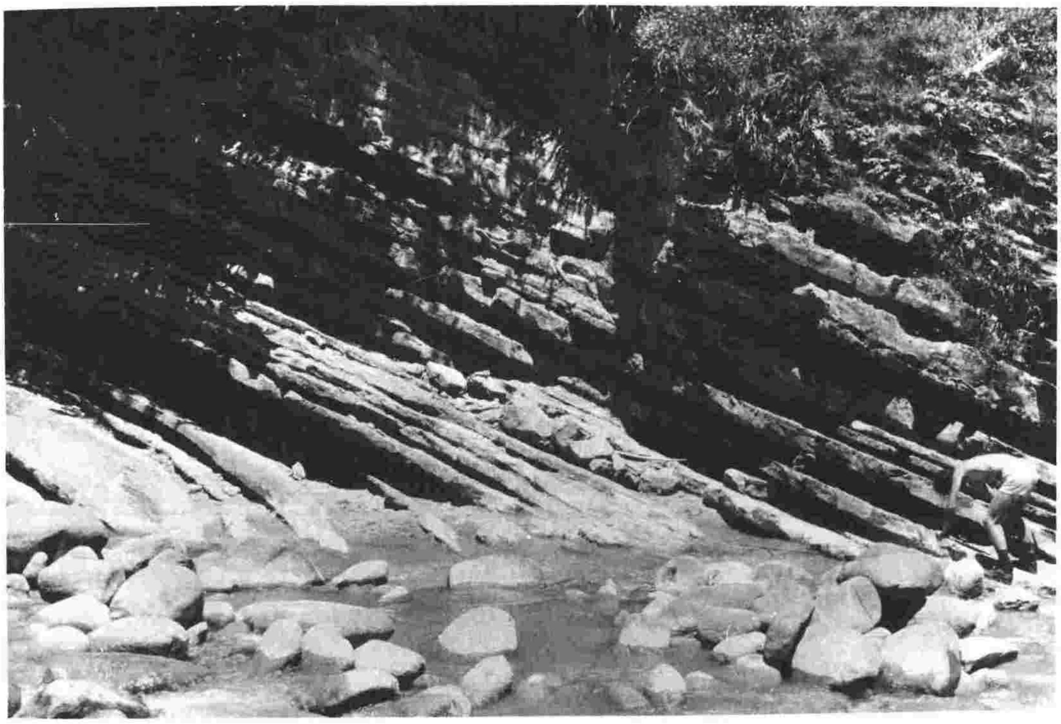
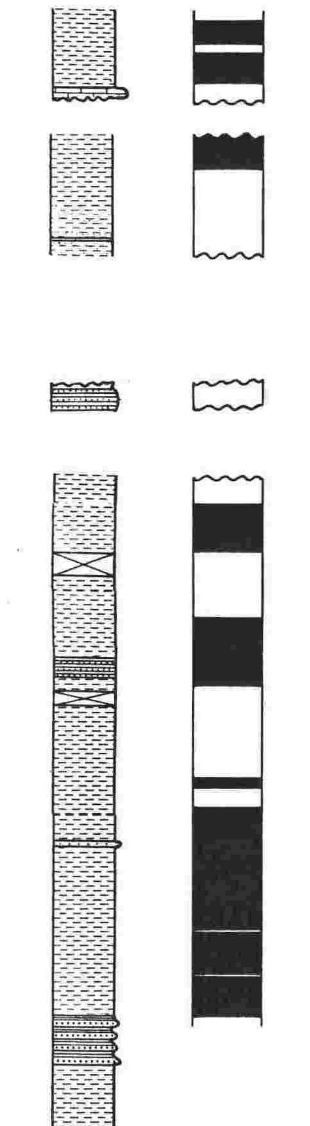


Fig. 6.1 Glacioeustatic correlation of Mangapoike River lithologies with deep-sea $\delta^{18}C$ enrichments and the Vail curve. The lithostratigraphy is presented with respect to time and not stratigraphic thickness. Black is normal polarity.

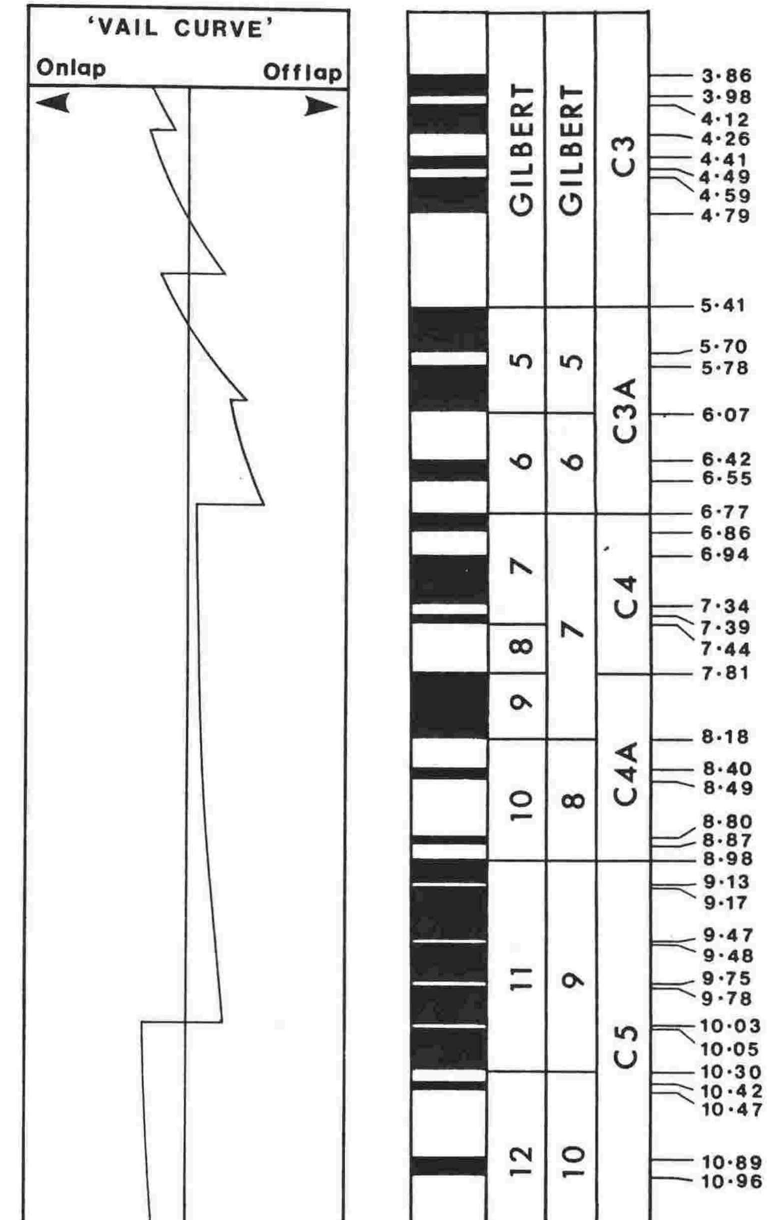
MANGAPOIKE



$\delta^{18}O$ benthic enrichment (Kennett *et al.* 1979; Savin *et al.* 1981; Woodruff *et al.* 1981; Kennett 1986; Hodell *et al.* 1986), $\delta^{18}O$ planktic enrichment (Shackleton and Kennett 1975; Loutit and Keigwin 1982; Kennett 1986; Elmstrom and Kennett 1986), marine regression (Kennett 1967; Berggren and Haq 1976; Adams *et al.* 1977; Loutit and Kennett 1979), 'Messinian salinity crisis' (Hsu *et al.* 1973; Cita 1976), $\delta^{13}C$ 'shift' (Loutit *et al.* 1983; Woodruff and Savin 1985).

$\delta^{18}O$ benthic enrichment (Kennett *et al.* 1979; Woodruff *et al.* 1981),

$\delta^{18}O$ benthic enrichment (Savin *et al.* 1981; Woodruff *et al.* 1981; Burckle *et al.* 1982; Kennett 1986), deep-sea carbonate dissolution (Keller 1981; Srinivasan and Kennett 1981b; Keller and Barron 1983).



correlations. Burckle *et al.* (1982) identified the same isotopic event within Chron 12 (= Chron 10 of their paper). An increase in carbonate dissolution within deep-sea sediments occurred at the same time (Keller 1981; Srinivasan and Kennett 1981b) and is inferred to represent increased erosive intensity and corrosiveness of bottom waters due to increasing Antarctic glaciation (Keller and Barron 1983). Based on the inferred correlation of low glacioeustatism being causal to increased turbidite deposition and the near temporal synchroneity with a marked $\delta^{18}O$ enrichment, deep-sea carbonate dissolution, and a major unconformity of the Vail curve, the Makaretu sandstone, with fair confidence, is interpreted as resulting from glacioeustatism.

Hoskins (1978) recognised a marine shallowing during the late Waiauan throughout New Zealand, and this correlated to the inferred glacioeustatic event.

Sudden uplift immediately followed by sudden subsidence to produce a coarse grained well-bedded unit sharply bounded by fine grained detritus is unlikely in both mechanism and product. Consequently tectonism is discounted as causal to the Makaretu sandstone.

Event 2: 6.86 to 6.42 Ma Disconformity

The unconformity placed at the distinct lithological change at 1970 m, as inferred from the preferred magnetostratigraphic correlation and the biostratigraphy has a minimum period of non-deposition from 6.86 to 6.42 Ma.

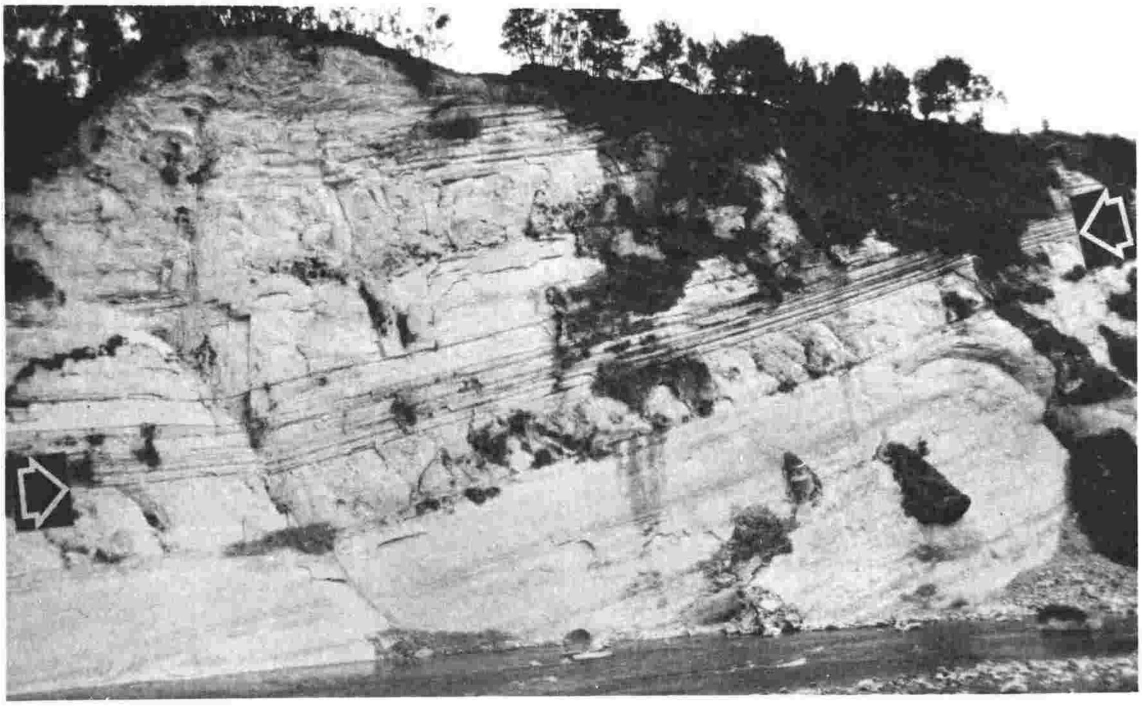
Vail *et al.* (1977) and Vail and Hardenbol (1979) infer a low sea-level at 6.7 Ma (= 6.6 Ma of Talwani *et al.* 1971; timescale in Vail and Hardenbol 1979). A small $\delta^{18}O$ enrichment in benthic foraminifera has been recognised by Kennett *et al.* (1979) and Woodruff *et al.* (1981), at both equatorial and temperate sites, within planktic foraminiferal zone N17 (upper Tongaporutuan), and has estimated age of 7 to 6 Ma.

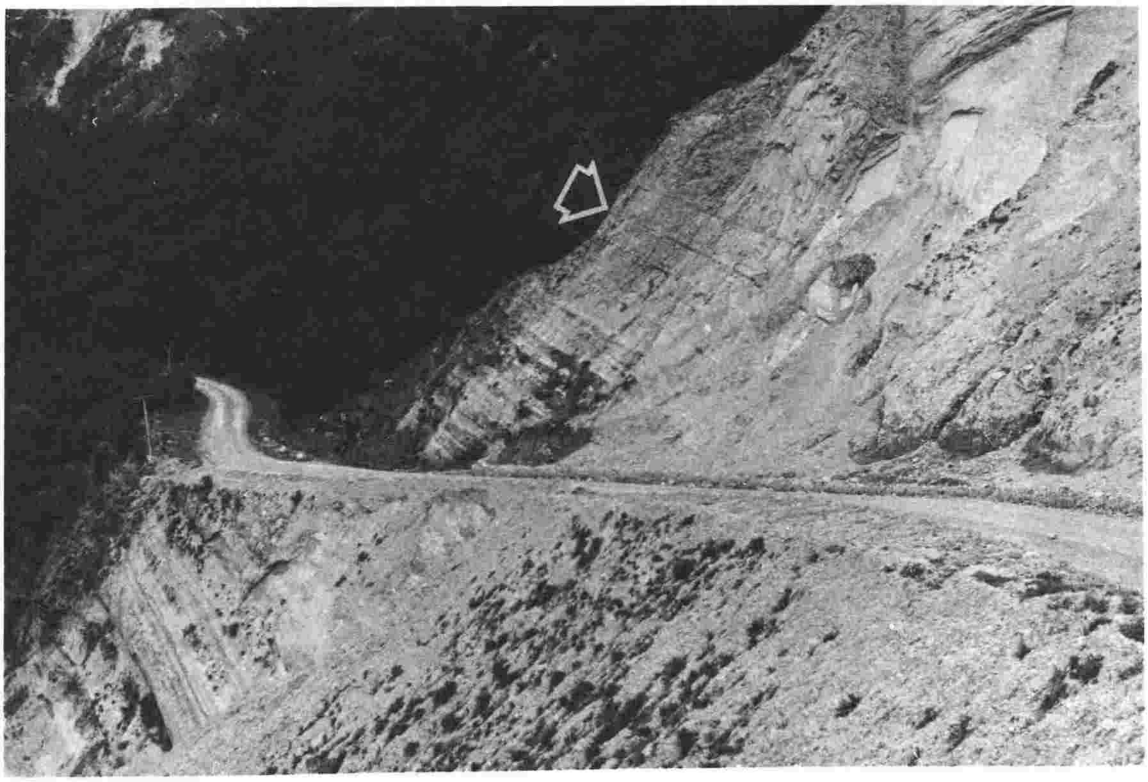
The unconformity is interpreted as resulting from glacioeustatism based solely on the age synchroneity of these events. The disappearance of the radiolaria *Cyrtocapsella japoncia* and *C. tetrapera* at the unconformity, which are generally accepted to be warm water taxa, supports a climatic cooling and associated sea-level fall at this horizon. The stratigraphic position of the unconformity within the bedded sandstones interval is not precisely defined by either the biostratigraphy or the magnetostratigraphy, and placing it at the base of the sandstone is solely for convenience.

Event 3: 5.41 to 6.3 Ma Miocene - Pliocene Angular Unconformity

Plate 6.2 Glacioeustatic event 2: inferred unconformity at the lithological change from massive mudstones to bedded sandstones (arrowed). The bed approximately 3-4 m below the lithological break is a silicic tuff. (Photo G. Gosson).

Plate 6.3 Glacioeustatic event 3: the Miocene - Pliocene 3° angular unconformity (arrowed). (Photo G. Gosson).





The Miocene - Pliocene angular unconformity at Mangapoike (Hornibrook 1977, 1983) is correlated to the latest Miocene climatic cooling and its associated low eustatic sea-level.

Global cooling during the latest Miocene that has been inferred from biogeography is well documented (Ingle 1967; Kennett 1967). Large but variable benthic $\delta^{18}O$ values between 6.5 to 4.5 Ma (Kennett *et al.* 1979; Savin *et al.* 1981; Woodruff *et al.* 1981; Kennett 1986) associated with a synchronous enrichment of planktic $\delta^{18}O$ (Shackleton and Kennett 1975; Loutit and Keigwin 1982; Kennett 1986; Elmstrom and Kennett 1986) are interpreted as the result of a major expansion of Antarctic ice cover (Hodell *et al.* 1986). A marine regression of 40 - 80 m (Kennett 1967; Berggren and Haq 1976; Adams *et al.* 1977; Loutit and Kennett 1979; Vail and Hardenbol 1979) at this time (6.0 to 5.2 Ma) was sufficient to isolate the Mediterranean, initiating the 'Messinian salinity crisis' between 5.7 and 5.2 Ma (Hsu *et al.* 1973; Cita 1976). The late Miocene carbon 'shift' has also been ascribed as resulting from this regression (Loutit *et al.* 1983; Woodruff and Savin 1985). Kennett (1986) has described a mechanism whereby fractionation between continental and oceanic organic carbon reservoirs could increase at times of regression when continental shelves are exposed.

Based on synchroneity and the proposed causal mechanism of the $\delta^{13}C$ 'shift', the Mangapoike Miocene - Pliocene unconformity is correlated with the latest Miocene cooling.

6.2.3 Discussion

The glacioeustatic correlations are based primarily on the synchroneity of both the benthic $\delta^{18}O$ record and the Vail curve with distinct lithological events within the Mangapoike sequence. The inferred unconformity (0.44 Ma time-break) and the Miocene - Pliocene unconformity (0.89 Ma time-break) at the periods of inferred glacioeustatism will severely restrict the establishment a more direct record of glacioeustatism/cooling at Mangapoike. Isotopic ($\delta^{18}O$) data from Mangapoike (Fig. 6.2) may also prove to be ambiguous. The limited benthic $\delta^{18}O$ data obtained from Mangapoike, in association with determining the $\delta^{13}C$ shift, do not record significant periods of cooling in the late Miocene. The only significant climatic change recorded from the Mangapoike $\delta^{18}O$ data is an earliest Pliocene warming. $\delta^{18}O$ data from benthic tests records ocean bottom-water temperature and is inferred to be a direct record of continental ice volume (Woodruff *et al.* 1981), whereas planktic $\delta^{18}O$ data may also record seasonal temperature fluctuations. For this reason, benthic $\delta^{18}O$ data is more readily interpreted as reflecting periods of warming (depletion of $\delta^{18}O$) and cooling (enrichment of $\delta^{18}O$).

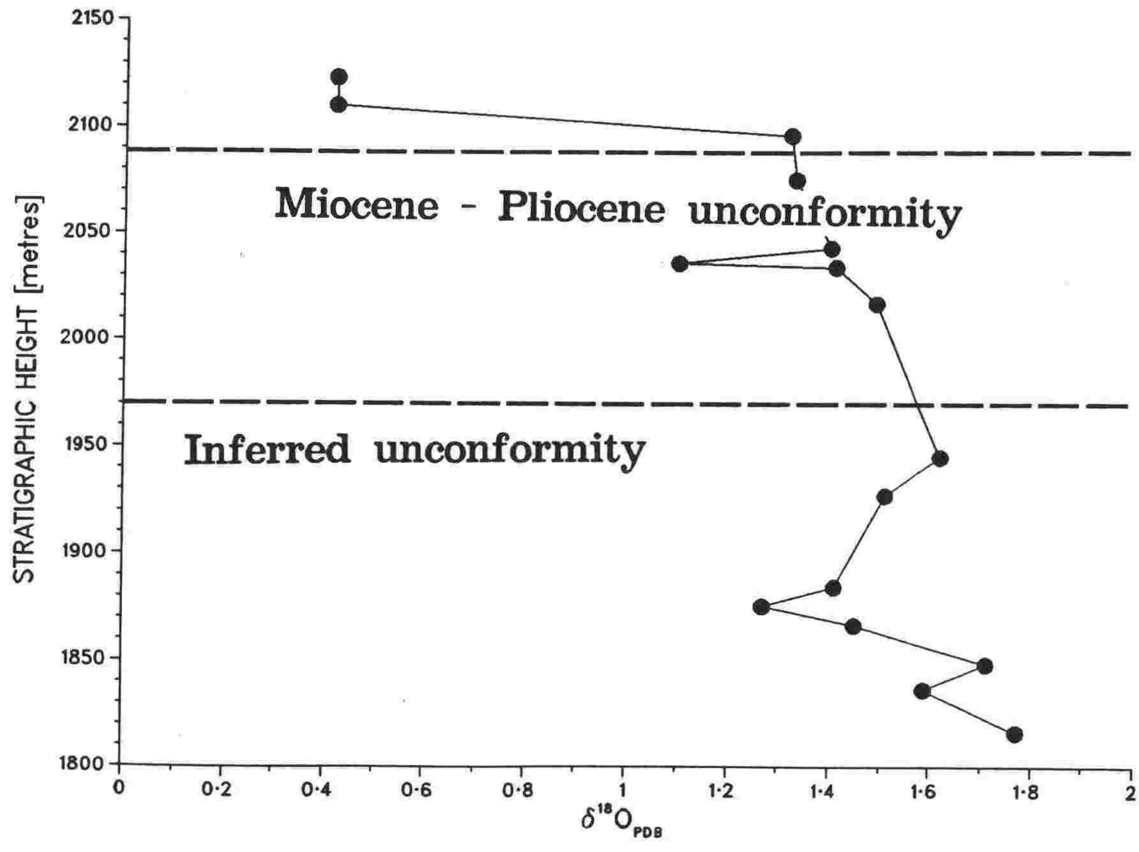


Fig. 6.2 Stable oxygen isotope data bounding the Mangapoike Miocene - Pliocene unconformity and the inferred unconformity.

Benthic data from neritic depths of deposition (ie Mangapoike) will not however truly reflect the temperature of bottom water and thus ice volume. Loutit and Kennett (1979) described a mechanism whereby a warming of the neritic benthos results from a reduced water depth due to a glacioeustatic cooling to explain the absence of a $\delta^{18}O$ enrichment within the latest Miocene of Blind River. A similiar mechanism may need to be invoked for Mangapoike.

6.3 NEW ZEALAND CORRELATIONS

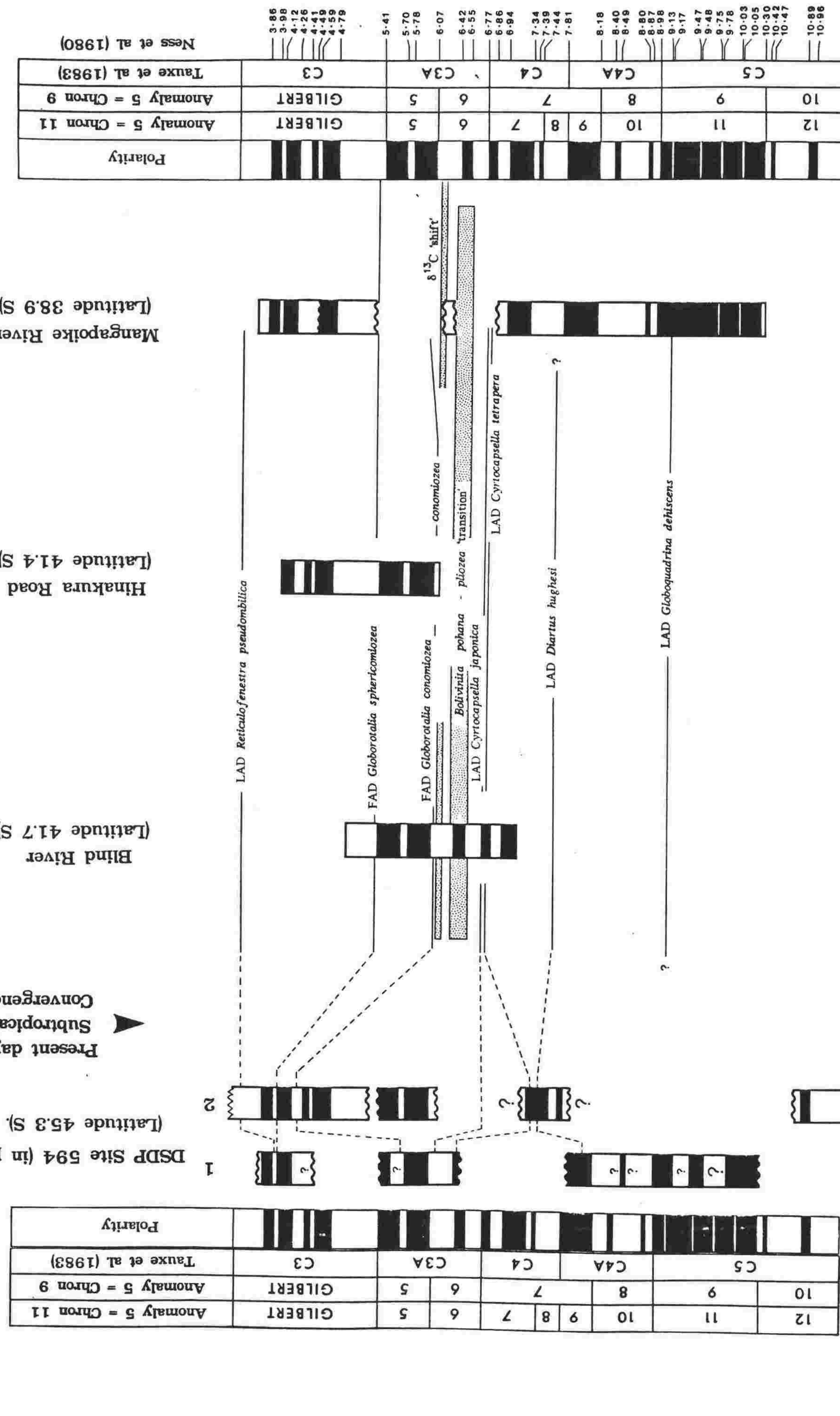
Integration of biostratigraphic, lithostratigraphic, magnetostratigraphic, radiometric and stable isotope data by Edwards (1985, in prep.) including data from DSDP Site 284 in the Tasman Sea, has produced a coherent correlation model for the latest Miocene to Pleistocene in New Zealand. This model is followed here for the magnetostratigraphy and biostratigraphy of the Hinakura Road and Blind River sections. The independently derived and correlated Late Miocene Mangapoike magnetostratigraphy and carbon isotope stratigraphy in this thesis does not conflict with the correlation model of Edwards (1985). Consequently the magnetostratigraphies and biostratigraphies of Mangapoike River, Hinakura Road and Blind River show a high level of consistency (Fig. 6.2).

Correlation of the biostratigraphy derived from New Zealand, including DSDP Site 284, to either of the magnetostratigraphic interpretations at DSDP Site 594 (Barton and Bloemendal 1986), 200 km southeast of Blind River, results in a marked diachroneity of foraminiferal, radiolarian and calcareous nannofossil bioevents. Four possibilities can be proposed to resolve the anomaly.

1. The diachroneity between New Zealand and Site 594 biostratigraphy is real, and results from the position of the Subtropical Convergence zone between the two locations.
2. The first and last appearance datums (FAD's and LAD's) recognised at a number of on-shore sections are not at their true stratigraphic position at Site 594 due to poor preservation or reworking, and thus the inferred diachroneity is an artifact.
3. The integration of biostratigraphy, magnetostratigraphy and isotope stratigraphy from the on-shore sections and DSDP Site 284 is wrong and one or the other of the magnetostratigraphic interpretations at Site 594 is correct.
4. Both of the magnetostratigraphic interpretations of Site 594 are wrong and the integration of on-shore data is correct.

The FAD's of *Globorotalia conomiozea conomiozea* and *Globorotalia sphericomiozea* have been dated at Blind River (Loutit and Kennett 1979) at 6.1 and 5.4 Ma, and are

Fig. 6.3 New Zealand Late Miocene and earliest Pliocene magnetostratigraphic and biostratigraphic correlations. Black is normal polarity. Mangapoike River: Magnetostratigraphy (Kennett and Watkins 1974; Edwards 1985; and this thesis), foraminiferal biostratigraphy (Hornibrook 1977, 1981a, 1982, 1983, 1984b; Scott 1978), nannofossil biostratigraphy (Edwards in Hornibrook 1983; Edwards 1985), radiolarian biostratigraphy (Ashby 1986), isotope stratigraphy (this thesis). Hinakura Road: Magnetostratigraphy (Lienert *et al.* 1972; Edwards 1985), foraminiferal biostratigraphy (Collen and Vella 1973), radiolarian biostratigraphy (Ashby 1986). Blind River: Magnetostratigraphy (Kennett and Watkins 1974; Loutit and Kennett 1979; Edwards 1985), foraminiferal biostratigraphy (Kennett 1966; Scott 1978, 1979b, 1980a) radiolarian biostratigraphy (Ashby 1986), isotope stratigraphy (Kennett and Loutit 1979). DSDP Site 594: Magnetostratigraphy (1, interpretation based on diatom biostratigraphy, Barton and Bloemendal 1986; 2, interpretation based on calcareous nannofossils, Barton and Bloemendal 1986), foraminiferal biostratigraphy (Jenkins and Srinivasan 1986), calcareous nannofossil biostratigraphy (Lohman 1986), radiolarian biostratigraphy (Caulet 1986), diatom stratigraphy (Ciesielski 1986).


Ness et al (1980)
Tauxe et al (1983)
Anomaly 5 = Chron 9
Anomaly 5 = Chron 11
Polarity
GILBERT
C3
C3A
C4
C4A
C5
Mangapoike River
(Latitude 38.9 S).
Hinakura Road
(Latitude 41.4 S).
Blind River
(Latitude 41.7 S).
Present day
Subtropical
Convergence
DSDP Site 594 (in part)
(Latitude 45.3 S).
LAD Reticulofenestra pseudombilica
FAD Globorotalia sphericomiozea
FAD Globorotalia conomiozea
conomiozea
Bolivinita pohana - pliozea 'transition'
LAD Cyrtocapsella japonica
LAD Cyrtocapsella tetrapera
LAD Diartus hughesi
LAD Globoquadrina dehiscens
$\delta^{13}C$ 'shift'
3·86
3·98
4·12
4·26
4·41
4·49
4·59
4·79
5·41
5·70
5·78
6·07
6·42
6·55
6·77
6·86
6·94
7·34
7·39
7·44
7·81
8·18
8·40
8·49
8·80
8·87
8·98
9·13
9·17
9·47
9·48
9·75
9·78
10·03
10·05
10·30
10·42
10·47
10·89
10·96

accepted within New Zealand as reliable datums (Hornibrook 1981b, 1984b; Edwards 1985). At Site 594, depending on the magnetostratigraphic interpretation the FAD'S of the *G. conomiozea* group (= *G. conomiozea conomiozea*) and *G. sphericomiozea* can have inferred ages of 4.3 and 3.9 Ma, resulting in a maximum of 1.8 Ma diachroneity over 3.6° of latitude, (Fig. 6.2). If that degree of diachroneity is real then it is the largest recorded, being one order of magnitude greater than the largest previously recorded: the 1.7 Ma diachroneity of the FAD of the *Globorotalia truncatulinoides* between equatorial and subantarctic regions (Kennett 1970). The inferred diachroneity cannot be ascribed to Blind River and Site 594 being in two different water masses, since during the latest Miocene and early Pliocene the Subtropical Convergence may have lain to the north of Blind River (Kennett and Watkins 1974) and both locations were under subantarctic waters. There is no apparent diachroneity of *G. conomiozea conomiozea* and *G. sphericomiozea* between Mangapoike River and Blind River, (Fig. 6.2) across the Subtropical Convergence. That there was diachroneity of planktic taxa within the same water mass in the order of 2 to 1 Ma over the 3.6° latitude between New Zealand and Site 594 is unacceptable.

It can not be assumed that the FAD's and LAD's of calcareous and siliceous microfossils at Site 594 have been displaced stratigraphically higher or lower because of poor preservation or reworking. From late middle Miocene to Pleistocene the planktic foraminifera at Site 594 are well preserved (Kennett, von der Borch *et al.* 1986) and have clearly identified zonal markers including the FAD of the *G. conomiozea* group. Radiolaria are rare but are well preserved throughout the core. Calcareous nannoplankton and diatoms are variable in abundance but again are well preserved. The displacement of six bioevents from their true stratigraphic position at Site 594 is thus considered unlikely.

The magnetostratigraphy of DSDP Site 594 is poorly defined and ambiguous (Barton and Bloemendal 1986). Both magnetostratigraphic interpretations proposed by Barton and Bloemendal are therefore suspect, and in view of the biostratigraphic evidence are considered to be incorrect. The Edwards (1985, in prep.) correlation model, including his magnetostratigraphic interpretations are here considered to be the best possible at present.

6.4 BASE OF THE TONGAPORUTUAN STAGE

6.4.1 Stratigraphy

The Tongaporutuan Stage was formally defined by Finlay and Marwick (1940) with its type section at the Tongaporutu Coast, north Taranaki. Paleontological definition from the then underlying Awamoan Stage and the overlying Urenian Stage was primarily based on molluscan fossils, and amongst the foraminifera only the first appearance of the benthic *Bolivinita spp.* was recognised as an important datum. Further chronostratigraphic division of the Cenozoic (Finlay and Marwick 1947) defined the Waiauan Satge immediately underlying the Tongaporutuan and the replacement of the Urenuian with the Kapitean Stage. The Waiauan was defined by the presence of the benthic foraminifer *Loxostomum truncatum* and the Kapitean was defined by the presence of the mollusca *Sectipectan wollastoni* and *Austrofusus coerulescens* (= *tuberculatus*).

Further foraminiferal biostratigraphy (Hornibrook 1958; Gibson 1967; Kennett 1966a, 1966b, 1966c, 1967a, 1967b), including a three-fold subdivision of the Tongaporutuan by Vella (1954), confirmed the incoming of the *Bolivinita quadrilatera* lineage as the primary criterion for recognising the base of the Tongaporutuan.

6.4.2 Correlation and Dating

To date, correlation of the Tongaporutuan Stage to overseas stratotypes and fossil zones has been primarily based on foraminiferal biostratigraphy. When defining the Tongaporutuan, Finlay and Marwick (1940) considered it to be Late Miocene in age. Subsequent foraminiferal biostratigraphy (Finaly 1947; Hornibrook 1958; Gibson 1967; Kennett 1967a, 1967b; Jenkins 1967, 1971; Hornibrook and Edwards 1971) paralled by similar work in the Mediterranean and tropics (Banner and Blow 1965; Blow 1969; Cita and Blow 1969; Bolli 1970) has confirmed the Late Miocene age. Only a few bioevents are useful for correlation. From biostratigraphic correlation, age estimates for the base of the Tongaporutuan have ranged from 12.0 to 9.8 Ma (Berggren 1972, 1981, Berggren and Van Couvering 1974; Edwards and Hornibrook 1980; Loutit and Kennett 1981; Edwards 1982b). Previous to this study the only radiometric age relevant in determining an age for the Waiauan - Tongaporutuan, is a 12.9 Ma K-Ar whole rock date from the Dunedin Volcanics (McDougall and Coombs 1973). The dated volcanics occur within the overlap zone of *Globorotalia peripheroronda* and *Globorotalia mayeri* (Hornibrook 1977). Hornibrook (1981b) indirectly related the volcanics above the FAD of *Globigerina nepenthes*, by the appearance of the Waiauan index species *Loxostomum* *truncatum*, and based on the relative stratigraphic position, estimated a 11.7* Ma for the Waiauan - Tongaporutuan boundary.

At Mangapoike the LAD of *Loxostomum truncatum* (X19/f100) and the FAD of *Bolivinita cf pohana* (X19/f98) occur 5 m below and 15 above, respectively , the Chron 12 - Chron 11 transition dated at 10.3 Ma. Hoskins (pers. comm. 1985) has not recognised *Bolivinita quadrilatera* within the Mangapoike section. This may not invalidate the biostratigraphic definition of the Tongaporutuan at Mangapoike as Scott (1979a) recognises morphological similarity of *B. quadrilatera* and *B. cf pohana* and suggests they are closely related. Further Scott (1979a) has recognised *B. cf pohana* in other lowermost Tongaporutuan sections, suggesting that the Tongaporutuan invasion by *Bolivinita* may have included both species. The LAD of *Loxostomum truncatum* and the FAD of *B. cf pohana* are within 32,000 yrs. of each other, as derived from the sedimentation rate. The base of the Tongaporutuan is placed at the FAD of *B. cf pohana*, which at Mangapoike is dated at 10.3 Ma.

The Waiauan - Tongaporutuan boundary is postulated to result from glacioeustatism. Both the LAD of *L. truncatum* and the FAD of *B. cf pohana* are less than 42,000 yrs. younger than the top of the Makaretu sandstone: the late Waiauan glacioeustatic event.

The type section of the Late Miocene Tortonian stratotype is at Rio Mazzapiedi, northern Italy. The base of the tropical foraminiferal Zone N16 (Blow 1969), the FAD of *Neogloboquadrina acostaensis*, occurs slightly above the base of the section (Cita and Blow 1969). The base of the Tortonian can also be placed within the calcareous nannofossil Zone NN9 (Martini 1971), on the evidence of *Discoaster hamatus* in the lower Tortonian section. Indistinct microfossil assemblages in the lowest Tortonian however may mean the occurrences of *N. acostaensis* and *D. hamatus* may not be true appearance and disappearance datums. Consequently, Ryan *et al.* (1974) and Berggren *et al.* (1985), with supporting data from Berggren and Van Couvering (1978), have placed the base of the Tortonian at the base of the underlying Zone N15 (LAD of *Globorotalia mayeri*) and within the NN8 (*D. coalitus*). Recent DSDP data (Poore *et al.* 1984; Hsu *et al.* 1984; Miller *et al.* 1985; Khan *et al.* 1985) has required a revised correlation of nannofossil zones with the magnetic polarity timescale, which in turn results in a revised age estimate for the base of the Tortonian. In detailing the new correlations, Berggren *et al.* (1985) places the Serravallian - Tortonian boundary at the base of Chron 11, giving an age 10.3 Ma (=10.4 Ma of Berggren *et al.* 1985). Accepting this correlation, the base of the Tongaporutuan is the same age as the base of the Tortonian. This magnetostratigraphic correlation is very close to a previous biostratigraphic correlation (Berggren 1972) suggesting the Serravallian - Tortonian and the Waiauan - Tongaporutuan boundaries were isochronous at 10.5 Ma. Glacioeustatism may account for their isochroneity. The base of the Tongaporutuan is thus also correlated with the base of foraminiferal Zone N15 and with an horizon within calcareous nannofossil Zone NN8.

This magnetostratigraphic correlation of the base of the Tongaporutuan equating with the base of N15 agrees with previous biostratigraphic correlations. When defining New Zealand Neogene foraminiferal zones, Jenkins (1967) considered the *Globorotalia miotumida miotumida* Zone to be broadly equivalent to the Tongaporutuan, with the base of the zone (the LAD of *Globorotalia mayeri*) at or very close to the base of the stage. This is still accepted at present (Hoskins 1982). The base of N15, also defined by the LAD of *G. mayeri* has been correlated (Srinivasan and Kennett 1981b) via intermediate zonal schemes to the base of the temperate *G. miotumida miotumida* Zone (ie approximate base of the Tongaporutuan).

6.5 GLOBOQUADRINA DEHISCENS: LAST APPEARANCE

6.5.1 Stratigraphy

The last appearance of *Globoquadrina dehiscens* (Chapman, Parr and Collins) is the most widely used planktic foraminiferal datum within the Tongaporutuan Stage in New Zealand. Low extinction and speciation rates of taxa within the Tongaporutuan, especially within the foraminiferas (Hoskins 1982; Hornibrook 1984b) and the recognition that the Tongaporutuan is the longest Neogene stage (approximatley 4.5 Ma) has made the last appearance of *G. dehiscens* a significant biostratigraphic datum in New Zealand Neogene stratigraphy. A late Tongaporutuan age for the disappearance of *G. dehiscens* has been generally determined (Gibson 1963, 1967; Kennett 1965, 1966a, 1966b, 1967a, 1967b; Jenkins 1967, 1971) and has been accepted as a last appearance datum (LAD) by Kennett (1968), Hornibrook and Edwards (1971), Jenkins (1971) and Hornibrook (1981b, 1984b). Within the Tongaporutu type section, a mid to late Tongaporutuan age can be inferred for *G. dehiscens* from the relative stratigraphic thicknesses of Tongaporutuan strata above and below the datum (Gibson 1963, 1967). The LAD of *G. dehiscens* is one of a number of warm-water planktic foraminifera inferred by Kennett (1968) and Kennett and Watkins (1974) to be diachronous within New Zealand, due to the northward movement of the Antarctic Convergence associated with a climatic cooling in the uppermost Tongaporutuan and Kapitean (Kennett 1967c).

Younger sporadic records have been reported from Kapitean and Opoitian sediments from three localities (Kennett 1965; Hornibrook 1961; Collen and Vella 1973). The record of *G. dehiscens* from Blind River by Kennett (1965) is discussed in section 6.5.2. Hornibrook (1961) described *G. dehiscens* from Kaawa Creek, west Auckland from lower Opoitian sediments. Collen and Vella (1973) tabulated records of *G. dehiscens* from Hinakura Road, south Wairarapa, from Kapitean sediments. These sporadic records of *G. dehiscens* have been interpreted either as reworking, especially those of Kaawa Creek (Hornibrook 1961; Kennett 1968; Jenkins 1971) or as warm-water re-entrants (Collen and Vella 1973; Wright *et al.* 1985) and have cast some doubt on whether the disappearance of *G dehiscens* within the Tongaporutuan is a reliable biostratigraphic datum in New Zealand. Recent re-examination of Kaawa Creek and Hinakura Road samples (Hornibrook pers. comm. 1985; Scott pers. comm. 1985; Edwards in prep.) concludes that these records of *G. dehiscens* have been reworked and misidentified, respectively, as previously interpreted (Hornibrook 1961; Kennett 1968; Jenkins 1971).

Scott (1985) has reported from an off-shore well, in the south Taranaki Basin, rare non-typical *G. dehiscens* morphotypes 100 m above the extinction of typical *G. dehiscens* specimens within the Tongaporutuan. He has suggested that the rare non-typical forms were warm water re-entrants appearing after the extinction of the typical *G. dehiscens* population in New Zealand.

Although not clearly established, the last appearance of *G. dehiscens* within New Zealand seems to be erratic and possibly diachronous. Rare non-typical forms are recorded in the New Zealand region and may represent one or more periods of warm-water re-entry. Dating of the taxon's last appearance within any one section may thus not represent the age of disappearance throughout New Zealand.

Elsewhere a similar erratic termination of *G. dehiscens* is recorded (Berggren 1984b) and has been used as a biostratigraphic datum in middle to late Miocene sediments (Jenkins and Orr 1972; Berggren 1973; Kennett 1973; Jenkins 1975; Kennett and Srinivasan 1981a, 1981b; Keller *et al.* 1982; Saito 1984). Early Pliocene records of *G. dehiscens* have also been reported (Blow 1970; Srinivasan and Srivastava 1974; Kennett and Srinivasan 1975).

6.5.2 Dating

The last appearance of *G. dehiscens* in New Zealand has been paleomagnetically dated from only Blind River previous to this study. The age was based on rare occurrences of *G. dehiscens* as tabulated by Kennett (1965). Polarity determinations were by Kennett and Watkins (1974) which were subsequently reinterpreted by Loutit and Kennett (1979) using the Late Miocene carbon shift ($\delta^{13}C$). Based on the revised magnetostratigraphy, Hornibrook (1981b, 1984b) reported a 6.2* Ma age for the last appearance of *G. dehiscens* in New Zealand. Re-examination of Kennett's original material, including faunal slides and washes (Hornibrook pers. comm. 1985; Vella pers. comm. 1985) and subsequent resampling of the Blind River section (Scott 1976, 1979b, 1980; Morgans 1980) has not verified the presence of *G. dehiscens*. Thus as concluded by Edwards (1985) and Wright *et al.* (1985), *G. dehiscens* is not present at Blind River and consequently the last appearance is older than 6.6 Ma (Edwards 1985), and the reported age of 6.2 Ma (Hornibrook 1981b, 1984b) is erroneous.

A 9.2 Ma magnetostratigraphic age (Wright *et al.* 1985) for the last appearance of *G. dehiscens* at Mangapoike is presented. Correlation of the magnetozones (MN1, MN2, MN3) to the magnetic polarity timescale (Ness *et al.* 1980), at the disappearance of *G. dehiscens* is confidently placed to the base of Chron 11 through to the base of Chron 10 (Fig. 5.2). The age is derived by the interpolation, over 906 m, from the six accepted polarity transitions within Chron 10 implying a sedimentation rate of 68cm/1000 yrs. This rate is extrapolated downwards from the nearest polarity transition (Chron 11 - Chron 10 at 8.98 Ma) through a uniform lithology of mudstone, giving an age of 9.2 Ma for the datum (X19/f98). The datum was derived from closely spaced samples (Hoskins pers. comm. 1985), and based on the average sedimentation rate, the disappearance of *G. dehiscens* occurs within a period of 25,000 yrs.

The disappearance of *G. dehiscens* at Mangapoike is postulated to be a function of changing climatic conditions (Wright *et al.* 1985). The stratigraphic position of the datum is 3 m above a medium-coarse sandstone (Fig. 5.2). This 34 m thick sandstone is the only lithological change in an otherwise monotonous 1450 m thick sequence of mudstone. It is suggested here that the sandstone represents a response to a period of cooling with a lowering of sea-level, and that the disappearance of *G. dehiscens* is related to a corresponding change in paleoceanographic conditions.

Elsewhere, the last appearance of *G. dehiscens* has been magnetostratigraphically dated from 18.3* to 5.3* (Saito *et al.* 1975; Keller 1980; Berggren *et al.* 1983; Poore *et al.* 1983).

6.5.3 Discussion

The 9.2 Ma date is considered to be the age of the last appearance of *G. dehiscens* at Mangapoike, and not an extinction date for the taxon throughout New Zealand. Tongaporutuan sections, other than Mangapoike, have ratios of stratigraphic thickness of the 'lower' to 'upper' Tongaporutuan (pre- and post last appearance of *G. dehiscens*, respectively) of 2:1 to 3:1. In contrast the ratio at Mangapoike is 1:3, indicating the stratigraphic position of the datum is lower within the Tongaporutuan at Mangapoike, and consequently older than elswhere in New Zealand. Acceptance of the Mangapoike date as a synchronous extinction age within the Gisborne region, less than 100 km northeast of Mangapoike, requires sedimentation rates of 140 cm/1000 yr and 18 cm/1000 yr for 'lower' and 'upper' Tongaporutuan, respectively (Francis pers. comm. 1986). This disparity in the sedimentation rate is not reflected by changes in lithology. Within the Tongaporutu type section similiar changes in the sedimentation rate are implied if the Mangapoike date is accepted as a synchronous extinction age.

The older disappearance of *G. dehiscens* at Mangapoike need not be inconsistent with the inference that it is related to a climatic cooling at that locality. The Mangapoike foraminiferal fauna indicates a restricted oceanic circulation (Hoskins pers. comm. 1985) and as suggested by Ashby (1986) the Wairoa Syncline could well have had a structure similiar to the present day, with closure to the north. A restricted circulation may have produced paleoceanographic conditions close to the ecological threshold of *G. dehiscens*. Further restriction of circulation, resulting from the inferred cooling event and associated sea-level drop, would intensify the unfavourable paleoceanographic conditions and result in the disappearance of the taxon from Mangapoike. At other localities (ie Gisborne, Tongaporutu Coast) the same cooling event does not result in the disappearance of *G. dehiscens* at this time, due to their presumed open oceanic circulation.

Thus it is suggested the last appearance of *G. dehiscens* in New Zealand is erratic, and at present the age range of this event is between 9.2 and > 6.6 Ma.

Chapter VII

TECTONIC ROTATIONS

This chapter is a co-authored manuscript discussing the tectonic rotations of the Wairoa Syncline as submitted to the journal *Earth and Planetary Science Letters.* The second author collected and measured cores from locality 13, and contributed to sections 5 and 6 of the paper. The paper was written by the first author and jointly edited.

LARGE TECTONIC ROTATION OF PART OF NEW ZEALAND IN THE LAST 5 Ma.

Wright, I. C. and Walcott, R. I.

Research School of Earth Sciences
Victoria University of Wellington
Wellington, New Zealand.

Abstract

Detailed paleomagnetic data from the Wairoa Syncline, a middle to late Miocene forearc basin on the East Coast of the North Island, New Zealand, show that the rate of clockwise rotation for the last 5 Ma has been 7-8°/Ma of which less than 1.5°/Ma is due to apparent polar wander. This rotation is similar to a present day rate of 7°/Ma determined from geodetic data. Between 5 and 20 Ma ago the rate of tectonic rotation is poorly determined and may be between 0° and 2°/Ma.

The change in the rate of rotation of the Wairoa Syncline around 5 Ma is probably related to a markedly different tectonic style in the New Zealand region within the last 5 Ma, associated with a change in position of the Euler poles of rotation for the Pacific - Australian plates.

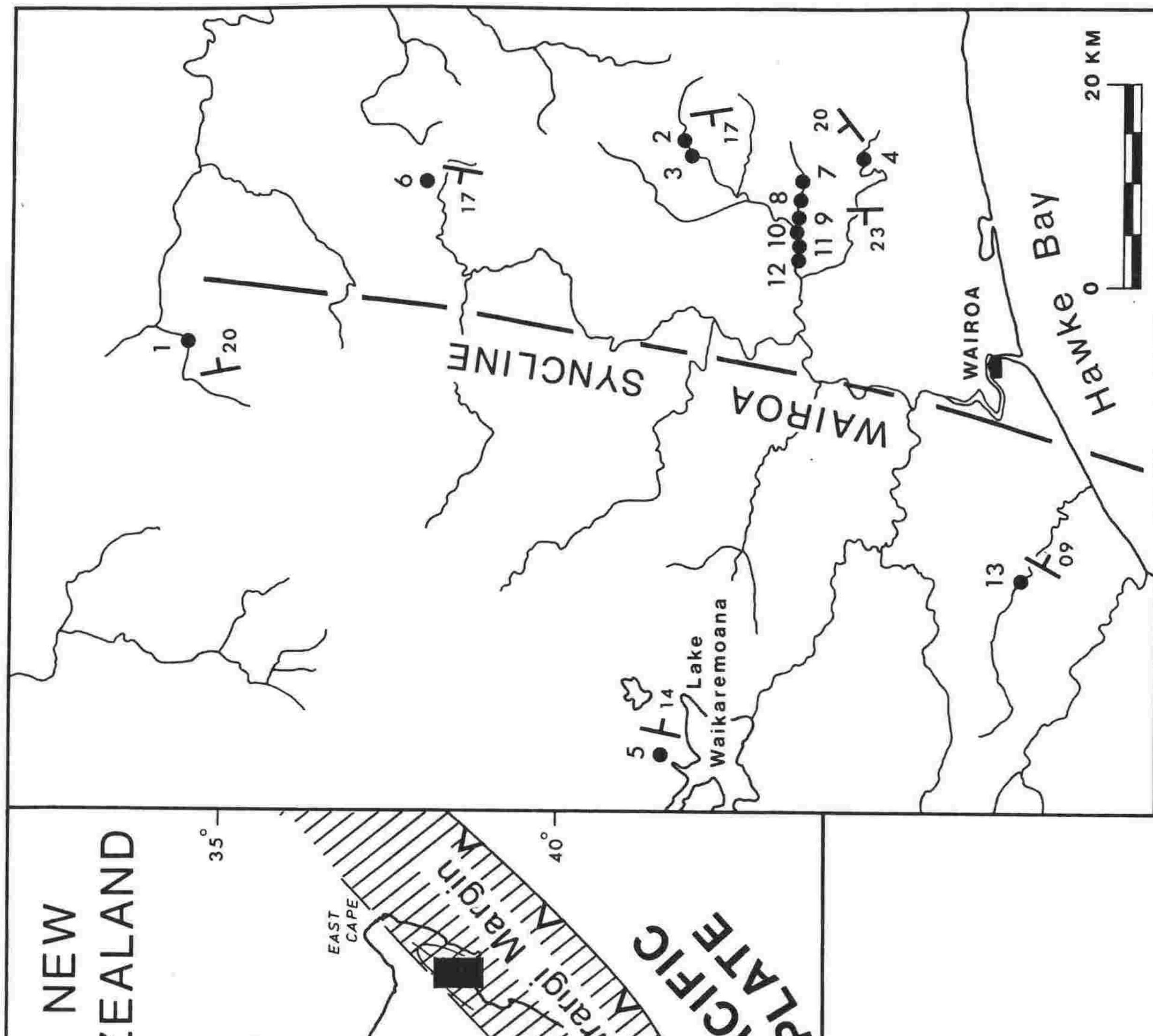
1. Introduction

Substantial rotation of the Hikurangi - Kermadec subduction zone between 40 Ma and the present day is suggested by plate reconstructions of the New Zealand region [1,2] based on finite rotations of identified magnetic anomalies along the Antarctic Plate boundary [3]. The position and orientation of the major Kermadec zone is determined by the age of oceanic crust whereas the Hikurangi margin is defined by a zone of deformation in the New Zealand land area (Fig. 1). Paleomagnetic studies of New Zealand Late Cenozoic sediments [4,5,6] have identified a clockwise tectonic rotation of the Hikurangi margin. This zone of Late Cenozoic rotation coincides with a zone of high shear strain rate of > 3 x 10^{-6}/a [7,8] indicating this deformation continues at present. These data give the orientation and sense of rotation of the Hikurangi plate margin during the Late Cenozoic. The main emphasis of the earlier work has been determining the geographic extent of the deforming zone. The purpose of this paper is to present detailed paleomagnetic data from part of the East Coast of the North Island, New Zealand in the Wairoa Syncline (Fig. 1). These are better constrained in both age and declination and show an increase in the rate of rotation towards the present.

2. Sampling

Data from localities 1-6, 11 and 12 (Fig. 1) have been reported previously [5,6] but are included here in the final analysis. The new localities (7-10) are situated within the Mangapoike River section (38.9°S, 177.6°E), northern Hawkes Bay (Fig. 1) apart from locality 13 which is situated at Waihua Valley, 40 km southeast of Mangapoike River.

Figure 1 Location maps of the Wairoa Syncline: a middle to late Miocene forearc basin within the Hikurangi margin (diagonal lines). Paleomagnetic sites and bedding attitudes within the Wairoa Syncline are shown.


NEW ZEALAND
AUSTRALIAN PLATE
PACIFIC PLATE
Hikurangi Margin
EAST CAPE
KAIKOURA
Alpine Fault
35°
40°
175°
WAIROA SYNCLINE
Lake Waikaremoana
WAIROA
Hawke Bay
20 KM
0

The Mangapoike section is a 5000 m thick clastic sequence on the eastern limb of the Wairoa Syncline extending from NZMS 1 N106/088177 westwards to N106/916107. The predominant lithology of mudstone is interbedded with sandstones, tuffs and limestones and ranges in age from the Clifdenian Stage (16 Ma) to the Mangapanian Stage (2 Ma). Localities 7-10 are derived from 343 paleomagnetic sites (having at least 3 cores per site) sampled every 5 m stratigraphically over a 2200 m part of the Mangapoike sequence where a Late Miocene (10-5 Ma) magnetostratigraphy is being established [9]. Precise site locations and bedding corrections are given in Wright [10]. Locality 10 is the mean of new data and that previously reported [5] from Mangapoike River. Magnetostratigraphic sites were grouped at 1 Ma intervals into localities 7-10 with ages derived from the magnetostratigraphic correlation (Table 1).

The Waihua locality (NZMS 1 N115/641939) on the western limb of the Wairoa Syncline consists of ten cores (thirty-one specimens) sampled over a 10 m stratigraphic interval from metre bedded calcareous mudstones and sandstones. Bedding is 252/SE/09 in attitude. The first appearance of the planktic foraminifera *Globorotalia crassula* (base of the Nukumaruan Stage) occurs within 20 m stratigraphically above the sampled site and an age of 2.4-2.2 Ma for this locality is assigned accordingly [11].

3. Paleomagnetic Measurements

All of the orientated specimens (23-25 mm in length) were measured on the two axis ScT cryogenic magnetometer at Victoria University of Wellington. Specimens were measured positive Z-axis down (normal) and negative Z-axis down (inverted) and the four independent X components, four Y components and eight Z components averaged. If the angular difference between normal and inverted modes exceeded 15° the specimen was rejected. Measurements with magnetisation intensities less than 1.5×10^{-5} Am^{-1} were also rejected. A set of Helmholtz coils reduced the ambient field at the magnetometer mouth to less than 100 nT.

Specimens from localities 7-10 were thermally demagnetised at 200°C, 250°C, 300°C, 320°C and 340°C, with a viscous magnetisation aligned in the present field direction being removed between 250°C and 320°C (Fig. 2). Data from mineralogically altered specimens at the 320°C and 340°C increments, as inferred from a 5 fold increase in volume susceptibility and a 3 fold increase in the magnetisation intensity, were rejected from the analysis. Zijderveld plots were used to assess the optimum demagnetisation step for each individual specimen, and a site mean was calculated using Fisher statistics. Specimens without a clearly established stable end-point were rejected.

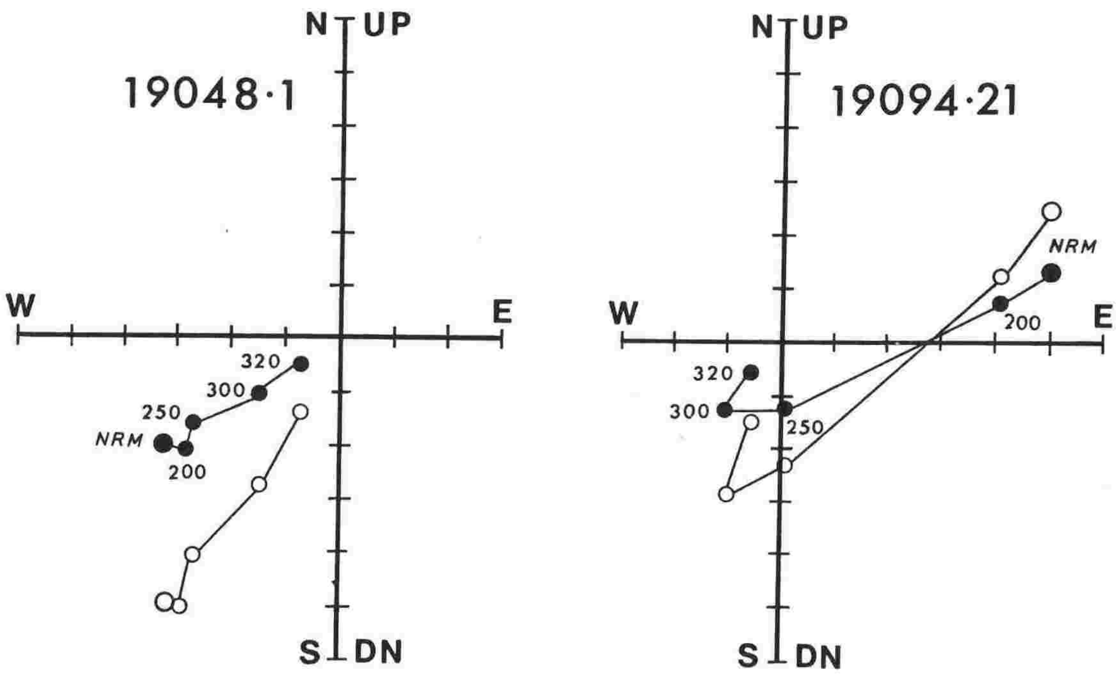


Figure 2 Zijderveld plots of thermally demagnetised specimens. Closed symbols are the projection onto the horizontal plane (E,W,N,S) and open symbols are the projection onto the vertical plane (E,W,Up,Dn). Larger symbols are NRM values, with smaller symbols subsequent demagnetisation levels in °C. Intensities are units of 2.5×10^{-4} Am^{-1}

Specimen numbers refer to the VUW collection.

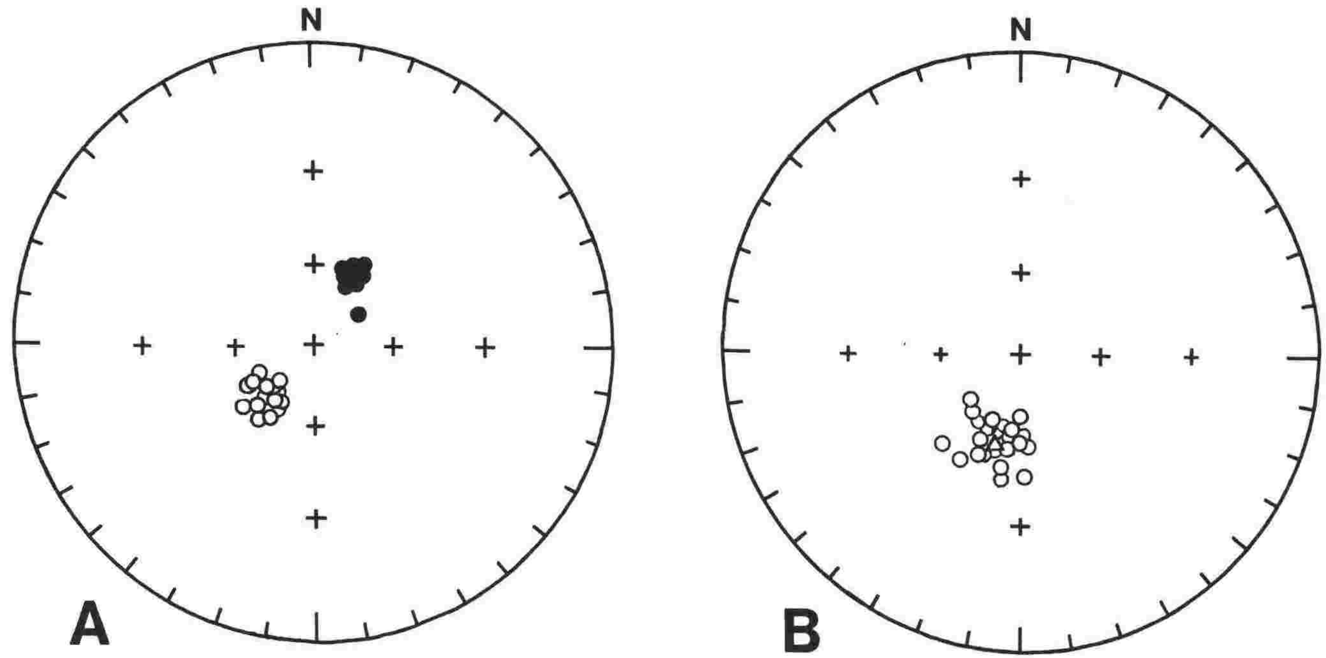


Figure 3 (a) Normal and reversed sites of locality 8 with $\alpha95$'s less than 15°. (b) Reversed specimens of locality 13 at 20 mT, triangle is mean direction. Symbol convention; upper hemisphere closed symbols and lower hemisphere open symbols.

Normal and reversed polarity sites with $\alpha95$'s less than 15° (Fig. 3a), within each 1 Ma interval (localities 7-10), were again averaged to produce a mean locality direction.

Locality 13 specimens were AF demagnetised at peak fields of 5, 10, 20 and 30 mT. NRM directions were not measured. The minimal scatter of reversed directions at the 20 mT increment (Fig. 3b) was accepted as the representative direction, and were averaged for the locality mean.

4. Results

Mean directions and associated Fisher statistics of the thirteen localities, including those reported previously are given in Table 1. Localities dated by foraminifera have been assigned age error limits consistent with the present knowledge of New Zealand Late Cenozoic biostratigraphy. Deviation in the strike of bedding from the regional trend, at locality 4, indicates localised deformation [5] which could explain the anomalously large declination.

5. Interpretation

The mean declination direction (Table 1) is the result of both tectonic rotation and any apparent polar wander of the reference geomagnetic pole. A revised Australian Cenozoic apparent polar wander path [13] shows northern apparent movement along the 120°E meridian with increasing age. For localities on the Australian plate in New Zealand with a latitude of 38.9°S a 1.5°/Ma and 1°/Ma clockwise rotation of the declination is calculated for rocks 12-0 Ma and 26-12 Ma in age respectively. Pacific paleomagnetic pole positions at 35 Ma and 5 Ma show no apparent polar wander [14] and consequently the expected declination at localities within New Zealand on the Pacific plate is north/south. As the sampling localities lie in the plate boundary zone it is not clear which polar wander path is applicable. The data are presented as the total declination for an axial dipole, (Fig. 4) of which the apparent polar wander for points within the plate boundary zone could be equal to or less than 1.5°/Ma. The paleomagnetic data extrapolated towards the present is consistent with a present day rotation rate of 7°/Ma, derived from the strain analysis of geodetic data which integrating gives a differential velocity of 75mm/a directed perpendicular to the Hikurangi margin [2]. Comparison of three discrete time intervals at 25-23 Ma, 10-8 Ma and 2-0 Ma shows the rates of rotation are 2°/Ma, 3-4°/Ma and 7-8°/Ma, respectively, of which less than 1.5°/Ma is apparent pole rotation.

Table 1

Wairoa Syncline Paleomagnetic Data

Locality	Reference	Age(Ma)	Number of Sites(Specimens)	D(°)	I(°)	k	α95	d±δ
1	[6]	24±1.0	40	070.4	-50.3	6.4	8.8	70±12
2	[5]	16±0.5	27	062.7	-63.3	25.1	5.4	63±10
3	[5]	15±0.5	6	224.9	50.2	20.8	5.4	45±16
4	[5]	15±0.5	6	094.7	-62.3	14.2	15.2	95±27
5	[5]	12±0.5	16	249.7	67.0	6.4	13.9	70±30
6	[5]	11±0.5	24	044.5	-43.8	15.9	7.2	45±8
7	This paper	10±0.05	30(102)	047.2	-57.1	76.9	3.0	47±4
8	This paper	9±0.05	3(110)	039.7	-61.5	174.4	2.0	40±3
9	This paper	8±0.05	19(70)	041.2	-60.9	110.1	3.2	41±5
10	This paper	6±0.05	39(100)	205.7	53.8	8.4	8.4	26±11
11	[5]	5±0.05	31	040.5	-41.9	5.2	9.4	40±10
12	[5]	4±0.05	43	021.7	-51.9	8.1	8.9	22±11
13	This paper	2.3±0.1	1(31)	197.4	56.7	65.1	3.1	17±5

D = Mean declination
I = Mean inclination
k = Fisher statistic
α95 = radius of 95% confidence cone about mean
d = clockwise rotation from the axial dipole
δ = standard error of declination rotation = $0.8(\sin^{-1}(\sin\alpha95/\cos I))$ as corrected by Demarest [12].

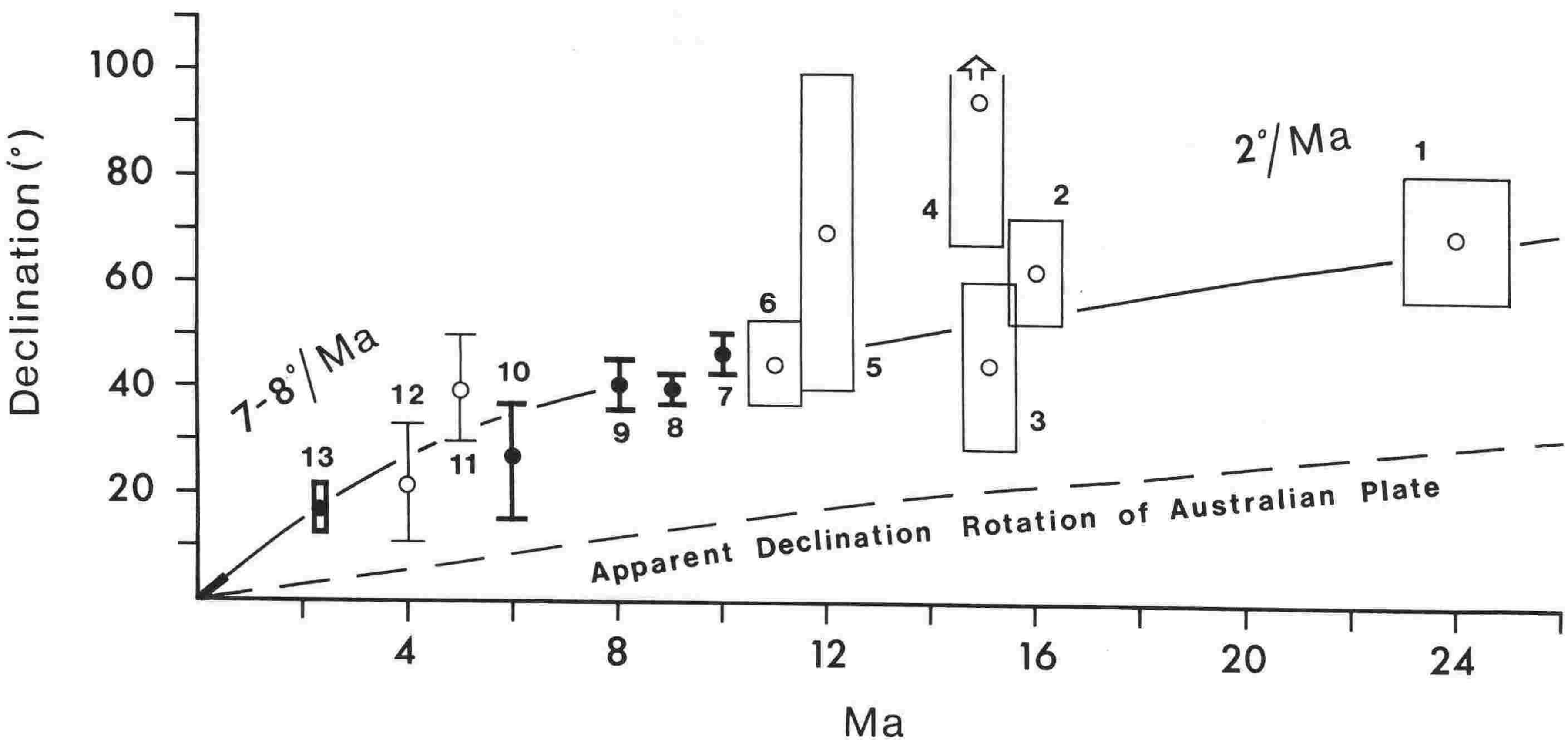


Figure 4 Plot of age - declination and associated errors of the Wairoa Syncline data. Solid lines represent new paleomagnetic data presented in this paper and light lines are data reported previously [5,6]. Solid bar at the origin is the present day shear strain rate derived from geodetic data. A visual best-fit curve through the data is shown.

6. Conclusions

The Wairoa Syncline, within the Hikurangi margin, shows an increasing rate of clockwise rotation towards the present. The uncertainties in the older data from the Wairoa Syncline are sufficiently large that the rate of rotation prior to about 5 Ma ago could be anywhere between 0° and 2°/Ma. Indeed, all of the tectonic rotation of some 35° seen in the Mangapoike River section could have occurred in the last 5 Ma ie. at the same rate as that shown at the present day from geodetic data. Although all of the Hikurangi margin appears to have experienced clockwise rotation, it is possible that the rate may vary from locality to locality.

There is a markedly different tectonic style today than that of the greater part of the Cenozoic which is expressed most generally by the shift in poles of rotation of the Pacific with respect to the Australian Plate. The Euler vector of present day rotation [15,16] is located some 12° to the southwest of the Euler poles of finite rotation for anomalies 5, 6, 13 and 18, all of which are located within 5° one another [3]. The shift in the Euler vectors describing the instantaneous rotation will have been even greater.

Major tectonic features of the New Zealand region that have been developing since anomaly 5 (8.9 Ma ago) and which are continuing to develop today include opening of the Lau and Havre Basins [17] starting around 4 Ma; opening and volcanicity of the Taupo Volcanic Zone [18] starting about 1 Ma; and the growth of the axial ranges of the North Island [19] starting around 0.3 Ma, and the Southern Alps [20] around 2 Ma. To this list we may add the transcurrent faults of the North Island and the Marlborough region, which also possibly started less than 10 Ma.

The change in rate of rotation of the Wairoa Syncline around 5 Ma ago (Fig. 4) may represent a much more general change in tectonism of the New Zealand region, involving opening and spreading to the north of New Zealand and compression and shortening to the south. In this sense the rotation of the Wairoa Syncline is a rotation of the whole of the Hikurangi margin.

Acknowledgements

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REFERENCES

1 R.I. Walcott, The kinematics of the plate boundary zone through New Zealand: a comparison of short and long-term deformation, Geophys. J. R. astr. Soc. 79, 613-633, 1984.

2 R.I. Walcott, Geodetic strain and the deformational history of the North Island of New Zealand during the Late Cenozoic, Proc. R. Soc. Lon. in press.

3 J. Stock and P. Molnar, Uncertainties in the relative positions of the Australia, Antarctica, Lord Howe and Pacific Plates since the Late Cretaceous, J. Geophys. Res. 87, 4679-4714, 1982.

4 R.I. Walcott, D.A. Christoffel and T.M. Mumme, Bending within the axial tectonic belt of New Zealand in the last 9 Ma from paleomagnetic data, Earth Planet. Sci. Lett. 52, 427-434, 1981.

5 R.I. Walcott and T.M. Mumme, Paleomagnetic study of the Tertiary sedimentary rocks from the East Coast of the North Island, New Zealand, Dept. Sci. Ind. Res. Geophys. Div. Rep. 189, 44pp, 1982.

6 T.M. Mumme and R.I. Walcott, Paleomagnetic studies at Geophysics Division 1980-1983. Dept. Sci. Ind. Res. Geophys. Div. Rep. 204, 62pp, 1985.

7 R.I. Walcott, Present tectonics and Late Cenozoic evolution of New Zealand, Geophys. J. R. astr. Soc. 52, 137-164, 1978.

8 H.M. Bibby, Geodetically determined strain across the southern end of the Tonga - Kermadec - Hikurangi subduction zone, Geophys. J. R. atr. Soc. 66, 513-533, 1981.

9 I.C. Wright, Mangapoike River: A Late Miocene magnetostratigraphic reference column for New Zealand, Hornibrook Symposium, extended abstracts, N.Z. Geol. Surv. Rec. 9, 105-107, 1985.

10 I.C. Wright, Paleomagnetic studies of the Late Miocene Mangapoike River section, northern Hawke's Bay, New Zealand, Unpublished PhD thesis, Victoria University of Wellington, in prep.

11 N de B. Hornibrook, Globorotalia (planktic Formainiferida) in the Late Pliocene and Early Pleistocene of New Zealand, N.Z. J. Geol. Geophys. 24, 263-292, 1981.

12 H.H. Demarest, Error analysis for the determination of tectonic rotation from paleomagnetic data, J. Geophys. Res. 88, 4321-4328, 1983.

13 M. Idnurm, Late Cretaceous and Cenozoic paleomagnetism of Australia -I. a redetermined apparent polar wander path, Geophys. J. R. astr. Soc. 83, 399-418, 1985.

14 G.W. Grindley, C.J.D. Adams, J.L. Lumb and W.A. Watters, Paleomagnetism, K-Ar dating and tectonic interpretation of Upper Cretaceous and Cenozoic volcanic rocks of the Chatham Islands, N.Z. J. Geol. Geophys. 20, 425-467, 1977.

15 C.J. Chase, Plate kinematics: the Americas, East Africa and the rest of the world, Earth Planet. Sci. Lett. 37, 353-368, 1978.

16 J.B. Minster and T.H. Jordan, Present-day plate motions, J. Geophys. Res. 83, 5331-5354, 1978.

17 A. Malahoff, R.H. Foden and H.S. Fleming, Magnetic anomalies and tectonic fabric of marginal basins north of New Zealand, J. Geophys. Res. 87, 4109-4125, 1982.

18 J.W. Cole, Distribution and tectonic setting of Late Cenozoic volcanism in New Zealand, in: Late Cenozoic Volcanism in New Zealand, I.E.M. Smith, ed., Roy. Soc. of N.Z. Bull. 23, pp 8-20, 1986.

19 M.A. Ghani, Late Cenozoic vertical crustal movements in the central part of New Zealand, N. Z. J. Geol. Geophys. 21, 117-125, 1978.

20 R.I. Walcott, Plate motion and shear strain rates in the vicinity of the Southern Alps, in: The Origin of the Southern Alps, R.I. Walcott and M.M. Cresswell, eds., Roy. Soc. of N.Z. Bull. 18, pp 5-12, 1979.

Chapter VIII

MAIN CONCLUSIONS AND FUTURE WORK

8.1 MAIN CONCLUSIONS

1. At present, magnetostratigraphy is the most effective means of establishing a chronology for New Zealand's Cenozoic fauna.

2. The Mangapoike River section, northern Hawke's Bay, is an extremely thick and well exposed record of Neogene sedimentation. The finely delineated biostratigraphy of a number of taxa, combined with a magnetostratigraphy, makes the Mangapoike section an important reference sequence in New Zealand Neogene stratigraphy.

3. Titanomagnetite (x=0.17-0.37), is the sole identifiable remanent magnetic mineral in the Mangapoike sediments, the chemistry of which does not vary with grain size. Oxidation of the titanomagnetite is deuteric, and thus pre-depositional. Authigenic or diagenetic remanent carrying minerals are not recognised.

4. Fluctuations of titanomagnetite concentration between 10^{-3} to 10^{-4} wt% are the main influence on NRM intensity variation. The presence of silicic tuffs, within the Mangapoike sequence, does not influence either volume susceptibility of NRM intensity.

5. A viscous remanence is recognised within the NRM measurements of some specimens, and is characterised by both viscous decay and acquisition over laboratory time. A viscous magnetisation aligned in the present field direction is also recognised. These viscous magnetisations are residing in either multidomain titanomagnetite or titanomagetite with a high degree of cation substitution. Some specimens have reversed polarity NRM directions and thus a remanent stability at least greater than 0.72 Ma.

6. Secondary magnetisations are removed by thermal demagnetisation at variable temperatures between 200°C and 320°C. Mineralogical alteration occurred at temperatures between 300°C and 340°C as indicated by both a five fold increase in volume susceptibility and a three fold increase in magnetisation intensity.

7. Six normal (MN1 - MN6) and seven reversed (MR1 - MR7) polarity magnetozones are identified within the late Miocene at Mangapoike. Only one normal magnetozone (MN6) is recognised in the stratigraphic interval equivalent to that from which Kennett and Watkins (1974) reported two normal zones, correlated as C1 and C2. MN6 is correlated to C2. Magnetozone C1 of Kennett and Watkins (1974) is inferred to be an uncleaned normal overprint.

8. Biostratigraphic data and a fission-track age at Mangapoike constrain correlations of the magnetozones to a time interval between 11 and 5 Ma. The magnetozones are correlated to Chrons 11 to 4, with an average sedimentation rate of 64 cm/1000 yrs. Based on the preferred magnetostratigraphic interpretation, a previously unrecognised unconformity is inferred from at least 6.86 to at least 6.42 Ma. The presence of the unconformity is supported by benthic foraminiferal and radiolarian biostratigraphy. The Miocene - Pliocene 3° angular unconformity at Mangapoike represents the period from 6.3 Ma to at least 5.41 Ma.

9. The random relationship between the degree of bioturbation and in-site dispersion at individual sites indicates that the magnetisation is acquired after bioturbation, and thus is a post-depositional detrital magnetisation. The time lag between deposition and magnetisation acquistion is about 1000 yrs. Bioturbation has not modified the reversal stratigraphy.

10. Three distinct lithological events at Mangapoike, based on the age synchroneity with both deep-sea benthic $\delta^{18}O$ records and the 'Vail - curve', are inferred to result from glacioeustatism. Confirmation of the three postulated correlations from a direct record of glacioeustatism at Mangapoike may prove difficult.

11. Correlation of the late Miocene and early Pliocene magnetostratigraphies and biostratigraphies of on-shore New Zealand with either of the magnetostratigraphic interpretations of DSDP Site 594 produces an unacceptably high diachroneity of some planktic taxa of 1.8 Ma over 3.6° of latitude. Of four possiblities, to resolve the anomaly, incorrect magnetostratigraphic correlations at Site 594 is the most likely.

12. The last appearance datum (LAD) of *Globoquadrina dehiscens* is an important bioevent in New Zealand's Neogene biostratigraphy. The previous age of 6.2 Ma for this datum in New Zealand is erroneous. A magnetostratigraphic age for the LAD of *G. dehiscens* at Mangapoike is 9.2 Ma. This age is not the extinction date for the taxon throughout New Zealnd. The datum may also be diachronous within New Zealand.

13. The Waiauan - Tongaporutuan boundary, as recognised by the incoming of *Bolivinita cf pohana* lineage, has a magnetostratigraphic age of 10.3 Ma. Both the LAD of *Loxostomum truncatum* and the FAD of *Bolivinita cf pohana* are less than 42,000 yrs. younger than the late Waiauan glacioeustatic event. The Waiauan - Tongaporutuan boundary is thus postulated to result from this glacioeustatic event. Based on age synchroneity, the base of the Tongaporutuan is correlated with the base of the Tortonian stratotype, base of foraminiferal Zone N15 and within calcareous nannofossil Zone NN8. Glacioeustatism may explain the excellent age correlation between the base of the Tongaporutuan and the base of the Tortonian stratotype.

14. Declination directions from the Wairoa Syncline show the rate of clockwise rotation for the last 5 Ma has been 7-8°/Ma of which less than 1.5°/Ma is due to apparent polar wander. Extrapolation of the 7-8°/Ma rotation rate for the last 5 Ma towards the present, is consistent with a present day rate of 7°/Ma derived from strain anaylsis of geodetic data. The rotation rate prior to 10 Ma is not well constrained and may vary between 3°/Ma and 0°/Ma. The change in the rate of rotation at about 5 Ma is associated with a markedly different tectonic regime in New Zealand, and in particular a shift in the Euler pole of rotation for the Australian - Pacific plates.

8.2 FUTURE WORK

Further magnetostratigraphic study of New Zealand Cenozoic sediments is critical in establishing a reliable local chronology for Cenozoic biostratigraphy and paleoclimatology. This is especially important, with respect to the present correlation programme of the New Zealand Geological Survey's Upper Cretaceous and Cenozoic Project (CCP). To date, correlation of New Zealand's Cenozoic marine and terrestrial sequences has been difficult, and magnetostratigraphy may prove to be the only means of precise correlation. The assumed isochroneity of certain taxa and the diachroneity of others has not been fully tested within New Zealand, even though these taxa are used extensively in biostratigraphic correlation. A local chronology would validate these assumptions. The development of an older magnetostratigraphy in New Zealand would provide chronological constraint on the regional off-shore deep-sea stratigraphy. New Zealand's exposed Cenozoic sequences may also provide the only means of establishing a detailed record of paleoceanographic and paleoclimatic changes associated with Antarctic glaciation.

The integration of future magnetostratigraphy with stable isotope stratigraphy, lithostratigraphy and detailed macro and micro biostratigraphy in a co-operative project is strongly recommended. Relevant data on the mineralogy, timing and stability of the remanent magnetisation must also be an integral part of any future magnetostratigraphic study. A clear understanding of the origin of the remanent magnetisations may result in a need for varied demagnetisation proceedures and the recognition of magnetozones in other wise rejected sections.

The following suggestions for future research are ranked in importance and are:

1. Establish magnetostratigraphic reference columns for each of the New Zealand Cenozoic stages in both marine and terrestrial sequences. Although ambitious, such a long term study would provide a precise chronology for paleoceanographic, paleoclimatic and paleogeographic studies of the New Zealand Cenozoic. Specific problems in New Zealand stratigraphy would also be resolved (ie the position of the Oligocene - Miocene boundary in New Zealand.

2. Establish a Tongaporutuan magnetostratigraphy in the southern South Island. A Tongaporutuan magnetostratigraphy at a higher paleolatitude would validate the isochroneity of planktic and benthic datums in New Zealand. The assumed diachroneity of the last appearnace of *Globoquadrina dehiscens* within New Zealand could also be demonstrated.

3. Establish a oxygen and carbon isotope stratigraphy at Mangapoike from both planktic and benthic taxa. This would provide the first dated and quantitative paleoclimatic record for the Tongaporutuan. Such an isotopic record may also validate the postulated glacioeustatic correlations.

4. Establish a magnetostratigraphy in the Tongaporutuan type section. An age for the Waiauan - Tongaporutuan boundary, as defined by the incoming of *Bolivinita quadrilatera* in the type section would reveal any diachroneity of this taxon between the east and wast coasts of the North Island. The erratic and assumed diachroneity of the last appearance of *Globoquadrina dehiscens* would also be established.

REFERENCES

Adams, C.G., Benson, R.H., Kidd, R.B. Ryan, W.B.F. and Wright, R.C., 1977. The Messinian salinity crisis and evidence of late Miocene eustatic changes in the world ocean. *Nature* 269: 383-386.

Adams, C.J.D., 1975. New Zealand potassium-argon age list - 2. *New Zealand Journal of Geology and Geophysics* 18: 443-467.

Ade-Hall, J.M., 1963. Election probe microanalyses of basaltic titanomagnetites and their significance to rock magnetism. *Geophysical Journal of the Royal Astronomical Society* 8: 301-312.

Ade-Hall, J.M., 1964. A correlation between remanent magnetisation and petrology and chemical properties of Tertiary basalts from Mull, Scotland. *Geophysical Journal of the Royal Astronomical Society* 8: 403-423.

Ager, D.V., 1973. *The Nature of the Stratigraphic Record.* New York, Macmillan. 114p.

Akimoto, S., 1962. Magnetic properties of FeO-Fe_2O_3-TiO_2 system as a basis of rock magnetism. *Journal of the Physical Society of Japan* 17: 706-710.

Allan, R.S., 1933. On the System and Stage names applied to subdivisions of Tertiary strata in New Zealand. *Transactions of the New Zealand Institute* 63: 81-108.

Andrews, P.B., 1982. Revised guide to recording field observations in sedimentary sequences. *New Zealand Geological Survey Report 102.* 74pp.

Ashby, J.N., 1985. Upper Neogene radiolarian zonation for the East Coast Deformed Belt, New Zealand. In: Hornibrook Symposium, 1985, extended abstracts, *New Zealand Geological Record* 9: 5-7.

Ashby, J.N., 1986. Upper Neogene Radiolarian from the East Coast Deformed Belt, New Zealand. Unpublished PhD Thesis, Victoria University of Wellington.

Bandy, O.L., Hornibrook, N. de B. and Schofield, J.C., 1970. Age relationships of the *Globigerinoides trilobus* zone and the andesite at Muriwai Quarry, New Zealand. *New Zealand Journal of Geology and Geophysics.* 13: 980-995.

Banerjee, S.K., 1981. Experimental methods of rock magnetism and paleomagnetism. In: Saltzman (Ed.) *Advances in Geophysics* 23: 25-99.

Banner, F.T. and Blow, W.H., 1965. Progress in the planktic foraminiferal biostratigraphy of the Neogene. *Nature* 208: 1164-1166.

Barron, J.A., Keller, G. and Dunn, D.A., 1985. A multiple microfossil biochronolgy for the Miocene. In Kennett, J.P. (Ed.) *The Miocene Ocean: Paleoceanography and Biogeography.* Geological Society of America Memoir 163: 21-36.

Barton, C.E. and Bloemendal, J., 1986. Paleomagnetism of sediments collected during Leg 90, Southwest Pacific. In: Kennett, J.P., von der Borch, C.C., et al., *Initial Reports DSDP, 90*: Washington (US Government Printing Office) pp 1273-1316.

Bates, T.E., 1967. The geology of the northern Aorangi Range and part of the Palliser Bay Sheet N165. Unpublished MSc Thesis, Victoria University of Wellington.

Berggren, W.A., 1972. A Cenozoic time-scale: some implications for regional geology and paleobiogeography. *Lethaia* 5: 195-215.

Berggren, W.A., 1973. The Pliocene Time Scale: Calibration of planktonic foraminiferal and calcareous nannoplankton zones. *Nature* 243: 391-397.

Berggren, W.A., 1981. Correlation of Atlantic, Mediterranean and Indo-Pacific Neogene stratigraphies: Geochronology and chronostratigraphy. *Proceedings of the International Correlation Programme (IGCP 114) International Workshop on Pacific Neogene Biostratigraphy*. 6th International Working Group Meeting 1981, Osaka, Japan.

Berggren, W.A., 1984a. Correlation of Atlantic, Mediterranean, and Indo-Pacific Neogene stratigraphies: Geochronology and chronostratigraphy. In: Ikebe, N. and Tsuchi, R. (Eds.), *Pacific Neogene Datum Planes: Contributions to Biostratigraphy and Chronology (IGCP -114)*. University of Tokyo Press. pp 93-110.

Berggren, W.A., 1984b. Neogene planktonic foraminiferal biostratigraphy and biogeography: Atlantic, Mediterranean, and Indo-Pacific regions. In: Ikebe, N. and Tsuchi, R. (Eds.), *Pacific Neogene Datum Planes: Contributions to Biostratigraphy and Chronology (IGCP -114)*. University of Tokyo Press. pp 111-161.

Berggren, W.A., Aubry, M-P. and Hamilton, N., 1983. Neogene magnetostratigraphy of DSDP Site 516 (Rio Grande Rise, South Atlantic). In: Barker, P., Johnson, D., et al., *Initial Reports DSDP, 72*: Washington (US Government Printing Office). pp 675-706.

Berggren, W.A. and Haq, B.U., 1976. The Andalusian Stage (late Miocene): biostratigraphy, biochronology and paleoecology. *Palaeogeography, Palaeoclimatology, Palaeoecology* 20: 67-129.

Berggren, W.A., Kent, D.V. and Van Couvering, J.A., 1985. Neogene geochronology and chronostratigraphy. In: Snelling, N.J., (Ed.) Geochronology and the geologic time scale. *Geological Society of London, Memior* 20. pp 211-260.

Berggren, W.A., Nakagawa, N., Saito, T., Shackleton, N.J. and Shibata, K., 1984. Neogene magnetostratigraphy and chronostratigraphy. In: Ikebe, N. and Tsuchi, R. (Eds.), *Pacific Neogene Datum Planes: Contributions to Biostratigraphy and Chronology (IGCP -114)*. University of Tokyo Press. pp 83-84.

Berggren, W.A. and Van Couvering, J.A., 1974. The Late Neogene: biostratigraphy, geochronology, and paleo-climatology of the last 15 million years in marine and continential sequences. *Palaeogeography, Palaeoclimatology, Palaeoecology* 16: 1-216.

Berggren, W.A. and Van Couvering, J.A., 1978. Biochronology. In Cohee, G.V., Glaessner, M.F. and Hedberg, H.D. (Eds.) Contributions to the Geologic Timescale. *American Association of Petroleum Geologists, Studies in Geology* 6: 39-55.

Biquand, D. and Prevort, M. 1971. AF demagnetisation of viscous remanent magnetisation in rocks. *Journal of Geophysics* 37: 471-485.

Blakely, R.J., 1974. Geomagnetic reversals and crustal spreading rates during the Miocene. *Journal of Geophysical Research* 79: 2979-2985.

Blakely,. R.J. and Cox, A., 1972. Evidence for short geomagnetic polarity intervals in the early Cenozoic. *Journal of Geophysical Research* 77: 7065-7072.

Blom, W.M., 1982. Sedimentology of the Tokomaru Formation, Waiapu Subdivision, Raukumara Peninsular. Unpublished Msc Thesis, University of Auckland.

Blow, W.H., 1969. Late middle Eocene to Recent planktic foraminiferal biostratigraphy. In: Bronnimann, P. and Renz, H.H., (Eds.) *First International Conference on Planktic Microfossils* Geneva. pp 199-421.

Blow, W.H., 1970. Deep Sea Drilling Project, Leg 3 , foraminifera In: Maxwell, A.E., et al., *Initial Reports DSDP, 3*: Washington (US Govermnet Printing Office) pp 629-661.

Briden, J.C., 1972. A stability index of remanent magnetism. *Journal Geophysical Research* 77: 1401-1405.

Brown, B.R., 1961. Mangaone-1. BP Shell and Todd Development LTD. Petroleum Report No. 320.

Brown, B.R., 1962. Miocene sedimentation in the Wairoa Basin and adjacent areas. BP Shell and Todd Development LTD. Petroleum Report No. 372.

Brunstrom, R.G.W., 1962. Isopach/facies maps of the region from Te Aute to East Cape, North Island, New Zealand. BP Shell and Todd Development LTD. Petroleum Report No. 374.

Bolli, H.M., 1970. The foraminifera of Sites 23-31. In: Bader, R.G., et al., *Initial Reports DSDP, 4*: Washington (US Government Printing Office) pp 577-643.

Bose, M.K., 1958. Goethite-hematite relation - an ore microscope observation. *American Mineralogist*. 43: 989.

Buddington, A.F. and Lindsley, D.H., 1964. Iron-titanium oxide minerals and synthetic equivalents. *Journal of Petrology* 5: 310-357.

Burckle, L.H., Keigwin, L.D. and Opdyke, N.D., 1982. Middle and late Miocene stable isotope stratigraphy: correlations to the paleomagnetic reversal record. *Micropaleontology* 28: 329-324.

Cande, S. and LaBrecque, J.L., 1974. Behaviour of the earth's paleomagnetic field from small scale marine magnetic anomalies. *Nature* 247: 26-28.

Carmicheal, I.S.E., 1967. The iron-titanium oxides of salic volcanic rocks and their associated ferromagnesian silicates. *Contributions to Mineralogy and Petrology* 14: 36-64.

Caulet, J.P., 1986. Radiolarians from the southwest Pacific. In: Kennett, J.P., von der Borch, C.C., et al., *Initial Reports DSDP, 90*: Washington (US Government Printing Office) pp 835-861.

Ciesielski, P.F., 1986. Middle Miocene to Quaternary diatom biostratigraphy of Deep Sea Drilling Project Site 594, Chatham Rise, southwest Pacific. In: Kennett, J.P., von der Borch, C.C., et al., *Initial Reports DSDP, 90*: Washington (US Government Printing Office) pp 863-885.

Channell, J.E.T., 1977. Paleomagnetism of limestones from the Gargano Peninsula (Italy) and the implications of these data. *Geophysical Journal of the Royal Astronomical Society* 51: 605-616.

Chaproniere, G.C.H., 1969. Geology of the Te Araroa Area, East Cape. Unpublished MSc Thesis, University of Auckland. 146pp.

Chiji, M. and Konda, I., 1978. Planktic foraminiferal biostratigraphy of the Tomioka Group and the Nishiyatsushiro and Shizukawa Groups, Central Japan, with some considerations of the Kaburan Stage (Middle Miocene). *Cenozoic Geology of Japan*. Osaka. pp 73-92.

Cita, M.B., 1976. Biodynamic effects of the Messinian salinity crisis on the evolution of planktic foraminifers in the Mediterranean. *Palaeogeography, Palaeoclimatology, Palaeoecology* 20: 23-42.

Cita, M.B. and Blow, W.H., 1969. The biostratigraphy of the Langhian, Serravallian and Tortonian Stages in the type sections in Italy. *Rivista Italiana Paleontologia* 75: 549-603.

Claesson, C., 1978. Swedish Ordovician limestones: problems in clarifying their directions of magnetisations. *Physics of Earth and Planetary Interiors* 16: 65-72.

Collen, J.D. and Vella, P.P., 1973. Pliocene planktonic foraminifera, southern North Island, New Zealand. *Journal of Foraminiferal Research* 3: 13-29.

Collinson, D.W., 1983. *Methods In Rock Magnetism and Paleomagnetism: Techniques and Instrumentation.* Chapman and Hall, New York, 503pp.

Coombs, D.S. and Hatherton, T., 1959. Paleomagnetic studies of Cenozoic volcanic rocks in New Zealand. *Nature* 184: 883-884.

Cox, A., 1968. Lengths of geomagnetic polarity intervals. *Journal of Geophysical Research* 73: 3247-3260.

Cox, A., 1969. Geomagetic reversals. *Science* 163: 237-245.

Cox, A., 1981. A stochastic approach towards understanding the frequency and polarity bias of geomagnetic reversals. *Physics of Earth and Planetary Interiors* 24: 178-190.

Creer, K.M., 1957. The remanent magnetisation of unstable Keuper marls. *Philosophical Transactions of the Royal Society of London* A250: 130-143.

Creer, K.M., Anderson, T.W. and Lewis, C.M.F., 1976. Late Quaternary geomagnetic stratigraphy recorded in Lake Erie sediments. *Earth and Planetary Science Letters* 31: 37-47.

Creer, K.M. and Ibbetson, J., 1970. Electron microprobe analyses and magnetic properties of non-stoichiometric titanomagnetites in basaltic rocks. *Geophysical Journal* 21: 485-511.

Creer, K.M. and Stephenson, A., 1972. Some consequences of aluminium and magnesium impurities in naturally occurring titanomagnetites. *Journal of Geophysical Research* 77: 3698-3710.

Damuth, J.E., 1977. Late Quaternary sedimentation in the western equatorial Atlantic. *Geological Society of America Bulletin* 88: 695-710.

Day, R., Fuller, M. and Schmidt, V.A., 1977. Hysteresis properties of titanomagnetites: grain size and compositional dependence. *Physics of Earth and Planetary Interiors* 13: 260-267.

Devereux, I., Hendy, C.H. and Vella, P.P., 1970. Pliocene and early Pleistocene sea temperature fluctuations, Mangaopari Stream, New Zealand. *Earth and Planetary Science Letters* 8: 163-168.

Dott, R.H. Jr., 1983. Episodic sedimentation-How normal is average? How rare is rare? Does it matter? *Journal of Sedimentary Petrology* 53: 5-23.

Dunlop, D.J., 1969. Comments on a paper by R.L. Wilson and P.J. Smith: The nature of secondary natural magnetisations in igneous and baked rocks. *Journal of Geomagnetism and Geoelectricity* 21: 797-799.

Dunlop, D.J., 1971. Magnetic properties of fine-particle haematite. *Annales de Geophysique* 27: 269-293.

Dunlop, D.J., 1972. Magnetic mineralogy of unheated and heated red sediments by coercivity spectrum analysis. *Geophysical Journal Royal Astronomical Society* 27: 37-55.

Dunlop, D.J., 1973. Theory of the magnetic viscosity of lunar and terresterial rocks. *Reviews of Geophysics and Space Physics* 11: 855-901.

Dunlop, D.J., 1979. On the use of Zijderveld vector diagrams in multicomponent paleomagnetic studies. *Physics of the Earth and Planetary Interiors* 20: 12-24.

Edwards, A.R., 1982a. International correlation. In: Hoskins, R.H. (Ed.) Stages of the New Zealand marine Cenozoic: A synopsis. *New Zealand Geological Survey Report 107*. pp 18-22.

Edwards, A.R., 1982b. Caleareous nannofossils. In: Hoskins, R.H. (Ed.) Stages of the New Zealand Marine Cenozoic: A synopsis. *New Zealand Geological Survey Report 107*. pp 23-27.

Edwards, A.R., 1985. A new integrated stratigraphy model for the Late Neogene of New Zealand. In Hornibrook Symposium, 1985, extended abstracts. *New Zealand Geological Survey Record* 9: 41-43.

Edwards, A.R., in prep. An integrated biostratigraphy, magnetostratigraphy and oxygen isotope stratigraphy for the late Neogene of New Zealand.

Edwards, A.R. and Hornibrook, N. de B., 1980. An integrated bio- and magneto-stratigraphy of the Late Miocene to Pleistocene of the New Zealand Region. abstract. *Geological Society of New Zealand, Christchurch Conference 1980*. p 35.

Edwards, A.R. and Perch-Nielsen, K., 1975. Calcareous nannofossils from the southern southwest Pacific. In: Kennett, J.P., Houtz, R.E. et al. *Initial Reports DSDP, 29*: Washington (US Government Printing Office) pp 469-539.

Elmstrom, K.M. and Kennett, J.P., 1986. Late Neogene paleoceanographic evolution of Site 590: southwest Pacific. In Kennett, J.P., von der Borch, C.C. et al., *Initial Reports DSDP, 90*: Washington (US Government Printing Office) pp 1361-1381.

Elston, D.P. and Purucker, M.E., 1979. Detrital magnetisation in red beds of the Moenkopi Formation (Triassic), Gray Mountain, Arizona. *Journal of Geophysical Research*. 84: 1653-1665.

Evans, A.L., 1970 Geomagnetic polarity reversals in a Late Tertiary lava sequence from the Akaroa volcano, New Zealand. *Geophysical Journal of the Royal Astronomical Society* 21: 163-183.

Evans, M.E. and Wayman, M.L., 1970. An investigation of small magnetic particles by means of electron microscopy. *Earth and Planetary Science Letters* 9: 365-370.

Ferrand, J., 1965. The Mangaone - Morere uplift; geology and oil prospects. NZ Aquitaine Petroleum LTD. Petroleum Report No. 470.

Finlay, H.J., 1939. New Zealand foraminifera: Key species in the stratigraphy. *Royal Society New Zealand Transactions* 68: 530.

Finlay, H.J. and Marwick, J., 1940. The division of the Upper Cretaceous and Tertiary in New Zealand. *Transactions of the Royal Society of New Zealand* 70: 77-135.

Finlay, H.J. and Marwick, J., 1947. New divisions of the New Zealand Upper Cretaceous and Tertiary. *New Zealand Journal of Science and Technology* 28: 228-236.

Fisher, R.A., 1953. Dispersion on a sphere. *Proceedings of the Royal Society of London* 217: 295.

Foster, J.H. and Opdyke, N.D., 1970. Upper Miocene to Recent magnetic stratigraphy in deep-sea sediments. *Journal of Geophysical Research* 75: 4465-4473.

Froggatt, P.C., 1982. A study of some aspects of the volcanic history of the Lake Taupo area, North Island, New Zealand. Unpublished PhD Thesis, Victoria University of Wellington.

Froggatt, P.C. and Gosson, G.J., 1982. Techniques for the preparation of tephra samples for mineral and chemical analysis and radiometric dating. *Geology Department Internal Publication No. 23*, VUW. 12pp.

Geiger, M.E., 1962. Planktic foraminiferal zones in the Upper Tertiary of Taranaki, New Zealand. *New Zealand Journal of Geology and Geophysiscs* 5: 304-308.

Ghent, E.D. and Henderson, R.A., 1966. Petrology, sedimentation and paleontology of Middle Miocene graded sandstones, and mudstones, Kaiti Beach, Gisborne. *Transactions of the Royal Scoiety, Geology* 4: 147-169.

Gibson, G.W., 1963. Some Miocene stratigraphy and paleontology: the Tongaporutuan Stage. Unpublished PhD Thesis, Victoria University of Wellington.

Gibson, G.W., 1967. Foraminifera and stratigraphy of the Tongaporutuan Stage in the Taranaki Coast and six other sections. *Transactions of the Royal Society of New Zealand, Geology* 5: 1-70.

Giddings, J.W. and McElhinny, M.W., 1976. A new index of paleomagnetic stability for magnetite bearing rocks. *Geophysical Journal of the Royal Astronomical Society* 44: 239-252.

Glass, B.P., 1969. Reworking of deep-sea sediments as indicated by the vertical dispersion of the Australian and Ivory Coast microtektite horizons. *Earth and Planetary Science Letters* 6: 409-415.

Goodell, H.G. and Watkins, N.D., 1968. The paleomagnetic stratigraphy of the Southern Ocean. *Deep-Sea Research* 15: 89-112.

Graham, J.W., 1949. The stability and significance of magnetism in sedimentary rocks. *Journal of Geophysical Research* 54: 131-167.

Graham, J.W., 1954. Rock magnetism and the earth's magnetic field during the Paleozoic time. *Journal of Geophysical Research* 59: 215-222.

Grapes, R.H. and Watanabe, T., 1984. Al-Fe^{3+} and Ca-Sr^{2+} epidotes in metagreywacke-quartzfeldspathic schist, Southern Alps, New Zealand. *American Mineralogist* 69: 490-498.

Griffiths, D.H., King, R.F., Rees, A.I. and Wright, A.E., 1960. The remanent magnetism of some recent varved sediments. *Proceedings of the Royal Society of London* A256: 359-383.

Grindley, G.W., Adams, C.J.D., Lumb, J.T. and Watters, W.A., 1977. Paleomagnetism, K-Ar dating and tectonic interpretation of Upper Cretaceous and Cenozoic volcanic rocks of the Chatham Islands, New Zealand. *New Zealand Journal of Geology and Geophysics* 20: 425-467.

Gosson, G.J., 1986. Miocene and Pliocene silicic tuffs in marine sediments of the East Coast Basin, New Zealand. Unpublished PhD thesis, Victoria University of Wellington. 137pp.

Haggerty, S.E., 1976. Oxidation of opaque mineral oxides in basalts In: Rumble, D. (Ed.), Oxide Minerals. *Mineralogy Society of America. Short Course Notes* No. 3. pp Hg 1 - Hg 98.

Hall, S.A. and Butler, J.C., 1983. Potential problems in the magnetostratigraphic studies of shallow water sequences. *Journal of Geology* 91: 693-705.

Hallam, A., 1981. A revised sea-level curve for the early Jurassic. *Geological Society of London Journal* 138: 735-743.

Halls, H.C., 1976. A least-squares method to find a remanence direction from converging remagnetisation circles. *Geophysical Journal of the Royal Astronomical Society* 45: 297-304.

Halls, H.C., 1978. The use of converging remagnetisation circles in paleomagnetism. *Physics of the Earth and Planetary Interiors* 16: 1-11.

Haq, B.U., 1980. Biogeographic history of Miocene calcareous nannoplankton and paleoecology of the Atlantic Ocean. *Micropaleontology* 26: 414-443.

Haq, B.U., Worsley, J.R., Burckle, L.H., Douglas, R.G., Keigwin, L.D., Opdyke, N.D., Savin, S.M., Sommer, M.A., Vincent, E. and Woodruff, F., 1980. Late Miocene marine carbon-isotope shift and synchroneity of some phytoplanktic biostratigraphic events. *Geology* 8: 427-431.

Harrison, C.G.A., 1966. The paleomagnetism of deep-sea sediments. *Journal of Geophysical Research* 71: 3033-4043.

Harrison, C.G.A., 1969. What is the true rate of reversals of the Earth's magnetic field? *Earth Planetary Sciences Letters* 6: 186-188.

Harrison, C.G.A., 1980. Analysis of the magnetic vector in a single rock specimen. *Geophysical Journal of the Royal Astronomical Society* 60: 489-492.

Harrison, C.G.A., McDougall, I. and Watkins, N.D., 1979. A geomagnetic field reversal timescale back to 13.0 million years before present. *Earth and Planetary Science Letters* 42: 143-152.

Hauptman, Z., 1974. High temperature oxidation, range of non-stoichiometry and Curie point variation of cation deficient titanomagnetite $Fe_{2}4Ti_{0}6O_{4+Y}$

Geophysical Journal of the Royal Astronomical Society 38: 29-47.

Haw, D., 1959a. Compilation report on the Kauhauroa structure. BP Shell and Todd Development LTD. Petroleum Report No. 309.

Haw, D., 1959b. Geological compilation report on the Mangaone - Waingake uplift, including the Waerenga-o-kuri culmination. BP Shell and Todd Development LTD. Petroleum Report No. 315.

Hays, J.D.and Opdyke, N.D., 1967. Antarctic Radiolaria, magnetic reversals, and climatic change. *Science* 158: 1001-1011.

Hays, J.D. and Pitman, W.C., 1973. Lithospheric plate motion, sea-level changes and climatic and ecological consequences. *Nature* 246: 18-22.

Hedberg, H.D., Salvador, A. and Opdyke, N.D., 1979. Magnetostratigraphic polarity units - A supplementary chapter of the ISSC International Guide. *Geology* 7: 578-583.

Hedley, I.G., 1968. Chemical remanent magnetisation in the FeOOH, Fe_2O_3 system. *Physics of Earth Planetary Interiors* 1: 103-121.

Hedley, I.G., 1971. The weak ferromagnetism of goethite (FeOOH). *Journal of Geophysics* 37:409-420.

Heirtzler, J.R., Dickson, G.O., Herron, E.J., Pitman, W.C. and LePichon, X., 1968. Marine magnetic anomalies, geomagnetic field reversals, and motions of the ocean floor and continents. *Journal of Geophysical Research* 73: 2119-2136.

Heller, F., 1977. Paleomagnetism of Upper Jurassic limestones from Southern Germany. *Journal of Geophysics* 42: 475-488.

Henshaw, P.C. and Merrill, R.T., 1979. Characteristics of drying remanent magnetisation in sediments. *Earth and Planetary Science Letters* 43: 315-320.

Hodder, P., 1981. Titanomagnetites in tephras : some implications from crystal field theory. *Chemical Geology* 32: 103-118.

Hodell, D.A., Elmstrom, K.M. and Kennett, J.P., 1986. Latest Miocene benthic $\delta^{18}O$ changes, global ice volumes, sea level and the Messinian salinity crisis. *Nature* 320: 411-414.

Hoffman, K.A. and Day, R., 1978. Separation of multicomponent NRM: a general method. *Earth and Planetary Science Letters* 40: 433-438.

Hornibrook, N. de B., 1958. New Zealand Upper Cretaceous and Tertiary foraminiferal zones and some overseas correlations. *Micropaleontology* 4: 25-38.

Hornibrook, N. de B., 1959. Tongaporutuan Stage. In: Fleming, C.A., ed., *Lexique Strati. Inter. Oceanie, fascicule 4 New Zealand.*

Hornibrook, N. de B., 1961. Tertiary Foraminifera from Oamaru District (NZ) Part 1. Sysematics and distribution. *New Zealand Geological Survey Paleontology Bulletin 34* 192pp.

Hornibrook, N. de B., 1968. Stratotypes of New Zealand Tertiary stages. Stage Conference, Christchurch.

Hornibrook, N. de B., 1976. Kapitean - Opoitian boundary. *Geological Society of New Zealand Abstracts* Hamilton Conference 1976.

Hornibrook, N. de B., 1977. The Neogene (Miocene-Pliocene) of New Zealand. In: *Proceedings, First International Congress on Pacific Neogene Stratigraphy*. Tokyo. Kaiyo Shuppan Co. pp 145-150.

Hornibrook, N. de B., 1981a. Globorotalia (planktic foraminiferida) in the late Miocene and early Pleistocene of New Zealand. *New Zealand Journal of Geology and Geophysics* 24: 263-292.

Hornibrook, N. de B., 1981b. Evaluation of Pacific southern mid latitude and equatorial latitude planktic foraminiferal datum levels. New Zealand Geological Survey. Paleontology Report 42. 13 pp. For: *Proceedings of the International Geological Correlation Programme (IGCP) Project 114 International Workshop on Pacific Neogene Biostratigraphy*. 6th International Working Group Meeting, 1981, Osaka, Japan.

Hornibrook, N. de B., 1982. Late Miocene to Pleistocene *Globorotalia* (Foraminiferida) from DSDP Leg 29, Site 284, southwest Pacific. *New Zealand Journal of Geology and Geophysics* 25: 83-99.

Hornibrook, N. de B., 1983. Guide Book for Tour B1, Neogene Geology-North Island East Coast Basin. In: 15th Pacific Science Congress and 3rd International Meeting on Pacific Neogene Stratigraphy, Dunedin, 1983. 28pp.

Hornibrook, N. de B., 1984a. *Globorotalia* (Planktic foraminifera) at the Miocene/Pliocene boundary in New Zealand. *Palaeogeography, Palaeoclimatology, Palaeoecology* 46: 107-117.

Hornibrook, N. de B., 1984b. Neogene stratigraphy and planktic foraminiferal datum planes in New Zealand. In: Ikebe, N. and Tsuchi, R. (Eds.), *Pacific Neogene datum Planes: Contributions to Biostratigraphy and Chronology (IGCP - 114)*. University of Tokyo Press. pp 179-186.

Hornibrook, N. de B. and Edwards, A.R., 1971. Integrated planktonic foraminiferal and calcareous nannoplankton datum levels in the New Zealand Cenozoic. In: Farinacci, A. (Ed.) *Proceedings of II Planktonic Conference*. Roma, pp 649-657.

Hoskins, R.H., 1978. New Zealand Middle Miocene foraminifera: the Waiauan Stage (2 volumes) Unpublished PhD Thesis. University of Exeter. 388pp.

Hoskins, R.H., 1982. (Ed.). Stages of the New Zealand marine Cenozoic: A synopsis. *New Zealand Geological Survey Report 107*. 74pp.

Hsu, K.J., Cita, M.B. and Ryan, W.B.F., 1973. The origin of the Mediterranean evaporites. In Ryan, W.B.F., Hsu, K.J. et al., *Initial Reports DSDP, 13*: Washington (US Government Printing Office) pp 1203-1231.

Hsu, K.J., LaBrecque, J., Percival, S.F., Wright, R.C., Gombos, A.M., Pissiotto, K., Tucker, P., Petersen, N., McKenzie, J.A., Weissert, H., Karpoff, A.M., Carman, M.F. and Schreiber, E., 1984. Numerical ages of Cenozoic biostratigraphic datum levels: Results of South Atlantic Leg 73 drilling. *Geological Society of America Bulletin* 95: 863-876.

Ingle, J.C., 1967. Foraminiferal biofacies variation and the Miocene - Pliocene boundary in Southern California. *Bulletin of American Paleontology* 52: 217-394.

Irving, E., 1957. The origin of the paleomagnetism of the Torridonian sandstone series of North-West Scotland. *Philosophical Transactions of the Royal Society of London* A250: 100-110.

Irving, E., 1964. *Paleomagnetism and its Applications to Geological and Geophysical Problems.* John Wiley and Sons Inc., New York.

Irving, E. and Major, A., 1964. Post-depositional detrital remanent magnetisation in a synthetic sediment. *Sedimentology* 3: 135-143.

Irving, E. and Runcorn, S.K., 1957. Analysis of the paleomagnetism of the Torridonian sandstone series of North-West Scotland. *Philosophical Transactions of the Royal Society of London* A250: 83-99.

Ishikawa, Y. and Akimoto, S., 1958. Magnetic property and crystal chemistry of ilmenite ($MeTiO_3$) and haematite (Fe_2O_3) system, 2: Magnetic property. *Journal of the Physics Society of Japan* 13: 1298-1310.

Jarosewich, E., Nelen, J.A. and Norberg, J.A., 1980. Reference samples for Electron microprobe analysis. *Geostandards Newsletter* 4: 43-47.

Jenkins, D.G., 1966. Planktic foraminiferal datum planes in the Pacific and Trinidad Tertiary. *New Zealand Journal of Geology and Geophysics* 9: 424-427.

Jenkins, D.G., 1967. Planktic foraminiferal zones and new taxa from the Lower Miocene to the Pleistocene of New Zealand. *New Zealand Journal of Geology and Geophysics* 10: 1064-1078.

Jenkins, D.G., 1971. New Zealand Cenozoic planktic foraminifera. *New Zealand Geological Survey Paleontology Bulletin* 42: 278 pp.

Jenkins, D.G., 1975. Cenozoic planktic foraminiferal biostratigraphy of the southwestern Pacific and Tasman Sea -DSDP Leg 29. In: Kennett, J.P., Houtz, R.E., et al., *Initial Reports DSDP, 29*: Washington (US Government Printing Office) pp 449-467.

Jenkins, D.G. and Orr, W., 1972. Planktonic foraminiferal biostratigraphy of the eastern equatorial Pacific. In: Hays, J.D., et al., *Initial Reports DSDP, 9*: Washington (Us Government Printing Office) pp 1059-1193.

Jenkins, D.G. and Srinivasan, M.S., 1986. Cenozoic planktic foraminifera from the equator to the subantarctic of the Southwest Pacific. In Kennett, J.P., von der Borch, C.C. et al., *Initial Reports DSDP, 90*: Washington (US Government Printing Office) pp 795-834.

Johnson, H.P., Kinoshita, H. and Merrill, R.T., 1975. Rock magnetism and paleomagnetism of some North Pacific deep-sea sediments. *Geological Society of America Bulletin* 86: 412-420.

Johnson, H.P. and Merrill, R.T., 1973. Low-temperature oxidation of titanomagnetite and the implications for paleomagnetism. *Journal of Geophysical Research* 78: 4938-4949.

Johnson, N.M. and McGee, V.E., 1983. Magnetic polarity stratigraphy: stochastic properties of data, sampling problems, and the evaluation of interpretations. *Journal of Geophysical Research* 88: 1213-1221.

Kato, I., Muroi, I., Yamazaki, T., and Abe, M., 1971. Subaqueous pyroclastic flow deposits in the Upper Donzurubo Formation, Nijosan District, Osaka, Japan. *Journal of the Geological Society of Japan* 77: 193-206.

Keany, J. and Kennett, J.P., 1975. Pliocene-Pleistocene radiolarian biostratigraphy and paleoclimatology at DSDP Site 278 on the Antarctic Convergence. In: Kennett, J.P. and Houtz, R.E., et al., *Initial Reports DSDP, 29* Washington (US Government Printing Office) pp 757-767.

1981

Keefer, C.M. and Shive, P.N., 1974. Curie temperature and lattice constant reference contours for synthetic titanomagnetites. *Journal of Geophysical Research* 86: 987-998.

Keen, M.J., 1963. The magnetisation of sediment cores from the eastern basin of the North Atlantic Ocean. *Deep-Sea Research* 10: 607-622.

Keigwin, L.D. Jr., 1979. Late Cenozoic stable isotope stratigraphy and paleoceanography of DSDP sites from the east equatorial and central North Pacific Ocean. *Earth and Planetary Science Letters* 45: 361-382.

Keigwin, L.D. Jr. and Shackleton, N.D., 1980. Uppermost Miocene carbon isotope stratigraphy of a piston core in the equatorial Pacific. *Nature* 284: 613-614.

Keller, G., 1980. Early to Middle Miocene planktonic foraminiferal datum levels of the equatorial and subtropical Pacific. *Micropaleontology* 26: 372-391.

Keller, G., 1981. Miocene biochronology and paleoceanography of the North Pacific. *Marine Micropaleontology* 6: 249-281.

Keller, G. and Barron, J.A., 1983. Paleoceanographic implications of Miocene deep-sea hiatuses. *Geological Society of America Bulletin* 94: 590-613.

Keller, G., Barron, J.A. and Burckle, L.H., 1982. North Pacific Late Miocene correlations using microfossils, stable isotopes, percent $CaCO_3$ and magnetostratigraphy. *Marine Micropaleontology* 7: 327-357.

Kennett, J.P., 1965. The Kapitean Stage (Upper Miocene) of New Zealand. Unpublished PhD Thesis. Victoria University of Wellington.

Kennett, J.P., 1966a. The *Globorotalia crassaformis* bioseries in North Westland and Marlborough, New Zealand. *Micropaleontology* 12: 235-245.

Kennett, J.P., 1966b. Stratigraphy and fauna of the type section and neighbouring sections of the Kapitean Stage, Greymouth, New Zealand. *Transactions of the Royal Society of New Zealand, Geology* 4: 83-102.

Kennett, J.P., 1966c. Faunal succession in two Upper Miocene - Lower Pliocene sections, Marlborough, New Zealand. *Transactions of the Royal Society of New Zealand, Geology* 3:197-213.

Kennett, J.P., 1966d. Four Upper Miocene to Lower Pliocene sections, Hawke's Bay to East Cape, New Zealand. *Transactions of the Royal Society of New Zealand, Geology* 4:109-209.

Kennett, J.P., 1967a. Recognition and correlation of the Kapitean Stage (Upper Miocene, New Zealand). *New Zealand Journal of Geology and Geophysics* 10: 1051-1063.

Kennett, J.P., 1967b. Planktonic foraminiferal zones and new taxa from the Danian to Lower Pliocene of New Zealand. *New Zealand Journal of Geology and Geophysics* 8: 1088-1126.

Kennett, J.P., 1968. Paleo-oceanographic aspects of the foraminiferal zonation in the Upper Miocene - Lower Pliocene of New Zealand. In: Proceedings IV Session, Bolonga 1967, *Giornale di Geologia* 35: 143-156.

Kennett, J.P., 1970. Pleistocene paleoclimates and foraminiferal biostratigraphy in subantarctic deep-sea cores. *Deep-Sea Research* 17: 125-140.

Kennett, J.P., 1973. Middle and Late Miocene planktic foraminiferal biostratigraphy of the southwest Pacific - DSDP Leg 21. In: Burns, R.E., Andrews, J.E., et al., *Initial Reports DSDP, 21* Washington (US Government Printing Office) pp 575-639.

Kennett, J.P., 1986. Miocene to Early Pliocene oxygen and carbon isotope stratigraphy in the southwest Pacific, Deep Sea Drilling Project Leg 90. In: Kennett, J.P., von der Borch, C.C., et al., *Initial Reports DSDP, 90*: Washington (US Government Printing Office) pp 1383-1411.

Kennett, J.P., Shackleton, N.J., Margolis, S.V., Goodney, D.E., Dudley, W.C. and Kroopnick, P.M., 1979. Late Cenozoic oxygen and carbon isotope history and volcanic ash stratigraphy: DSDP site 284, South Pacific. *American Journal of Science* 279: 52-69.

Kennett, J.P. and Srinivasan, M.S., 1975. Stratigraphic occurrences of the Miocene planktic foraminifera *Globoquadrina dehiscens* in early Pliocene sediments of the Indian Ocean. *Revista Espanola Micropaleontologia* 7: 5-14.

Kennett, J.P., von der Borch, C.C., et al., 1986. *Initial Reports DSDP, 90*: Washington (US Government Printing Office).

Kennett, J.P. and Watkins, N.D., 1970. Geomagnetic polarity change, volcanic maxima and faunal extinction in the South Pacific. *Nature*. 227: 930-934.

Kennett, J.P. and Watkins, N.D., 1974. Late Miocene - Early Pliocene paleomagnetic stratigraphy, paleoclimatic and biostratigraphy in New Zealand. *Geological Society of America Bulletin* 85: 1385-1398.

Kennett, J.P., Watkins, N.D. and Vella, P., 1971. Paleomagnetic chronology of Pliocene - early Pleistocene climates and the Plio-Pleistocene boundary in New Zealand. *Science* 171: 276-279.

Kenny, J.A., 1980. Geology of the Ihungia Catchment, Raukumara Peninsula. Unpublished Msc Thesis, University of Auckland.

Kenny, J.A., 1984. Petrography of Cretaceous and Tertiary sedimentary rocks of the Ihungia catchment, Raukumara Peninsular, North Island, New Zealand. *New Zealand Journal of Geology and Geophysics* 27: 291-298.

Kent, D.V., 1973. Post-depositional remanent magnetisation in deep-sea sediment. *Nature* 246: 32-34.

Kent, D.V. and Lowrie, W., 1974. Origin of magnetic instability in sediment cores from central North Pacific. *Journal of Geophysical Research* 79: 2987-3000.

Kent, D.V. and Lowrie, W., 1975. On the magnetic susceptibility anisotropy of deep-sea sediments. *Earth Planetary and Science Letters* 28: 1-12.

Khan, M.J., Kent, D.V. and Miller, K.G., 1985. Magnetostratigraphy of Oligocene to Pleistocene sediments, Sites 558 and 563. In: Bougault, H., Cande, S.C. et al., *Initial Reports DSDP, 82*: Washington (US Government Printing Office). pp 385-392.

Kicinski, F.M., 1958. Report on correlation of stratigraphic columns from north-east coast of the North Island, New Zealand. BP Shell and Todd Development LTD. Petroleum Report No. 306.

King, R.F., 1955. Remanent magnetism of artificially deposited sediments. *Monthly Notices of the Royal Astronomical Society, Geophysical Supplement* 7: 115-134.

Kohn, B.P., 1970. Studies of New Zealand Quaternary Pyroclastic Rocks. Unpublished PhD thesis, Victoria University of Wellington.

Kohn, B.P. and Topping, W.W., 1978. Time-space relationships between late Quaternary rhyolitic and andesitic volcanism in the southern Taupo zone, New Zealand. *Geological Society of America Bulletin* 89: 1265-1271.

Konigsberger, J.G., 1938. Natural residual magnetism of eruptive rocks. *I Terrestrial Magnetism and Atmospheric Electricity* 43: 119-127.

Kukla, G. and Nakagawa, H., 1977. Late Cenozoic magnetostratigraphy: comparisons with bio-, climato-, and lithozones. *Quaternary Research* 7: 283-293.

LaBrecque, J.L., Kent, D.V. and Cande, S.C., 1977. Revised magnetic polarity timescale for Late Cretaceous and Cenozoic time. *Geology* 5: 330-335.

Levi, S. and Banerjee, S.K., 1976. On the possibility of obtaining relative intensities from lake sediments. *Earth and Planetary Science Letters* 29: 219-226.

Liebes, E. and Shive, P.N., 1982. Magnetisation acquisition in two Mesozoic red sandstones. *Physics of Earth and Planetary Interiors* 30: 396-404.

Lienert, B.R., Christoffel, D.A. and Vella, P., 1972. Geomagnetic dates on a New Zealand Upper Miocene-Pliocene section. *Earth and Planetary Science Letters* 16: 195-199.

Lindsley, D.H., 1962. Investigations in the system FeO-Fe_2O_3-TiO_2 *Carnegie Institute Year Book*. Washington.

Lindsley, D.H., Anderson, G.E. and Balsley, J.R., 1966. Magnetic properties of rocks and minerals. *Geological Society of America Bulletin* 97: 544-552.

Lipson, J., 1956. K-Ar dating of sediments. *Geochimica et Cosmochimica Acta* 10: 149-151.

Lipson, J., 1958. Potassium-argon dating of sedimentary rocks. *Geological Society of America Bulletin.* 69: 137-150.

Lohman, W.H., 1986. Calcareous nannoplankton biostratigraphy of the southern Coral Sea, Tasman Sea, and southwestern Pacific Ocean, Deep Sea Drilling Project Leg 90: Neogene and Quaternary. In: Kennett, J.P., von der Borch, C.C., et al., *Initial Reports DSDP, 90*: Washington (US Government Printing Office) pp 763-793.

Loutit, T.S. and Keigwin, L.D., 1982. Stable isotopic evidence for latest Miocene sea-level fall in the Mediterranean region. *Nature* 300: 163-166.

Loutit, T.S. and Kennett, J.P., 1979. Application of carbon isotope stratigraphy to late Miocene shallow marine sediments, New Zealand. *Science* 204: 1196-1199.

Loutit, T.S. and Kennett, J.P., 1981. Australasian Cenozoic sedimentary cycles, global sea level changes and the deep sea sedimentary record. *Oceanologica Acta*, 26th International Geological Congress, Paris, 1980. 18pp.

Loutit, T.S., Pisias, N.G. and Kennett, J.P., 1983. Pacific Miocene carbon isotope stratigraphy using benthic foraminifera. *Earth and Planetary Science Letters* 66: 48-62.

Lovlie, R. and Larsen, E., 1981. Paleomagnetism and magnetomineralogy of a Holocene lake sediment from Vagsoy, western Norway. *Physics of the Earth and Planetary Interiors* 27: 143-150.

Lovlie, R., Lowrie, W. and Jacobs, M., 1972. Magnetic properties and mineralogy of four deep-sea cores. *Earth Planetary Science Letters* 15: 157-168.

Lowrie, W. and Alvarez, W., 1977. Late Cretaceous polarity sequence: Detailed rock and paleomagnetic studies of the Scaglai Rossa limestone at Gubbio, Italy. *Geophysical Journal of the Royal Astronomical Society* 51: 561-582.

Lowrie, W., Channell, J.E.T. and Heller, F., 1980. On the credibility of remanent magnetisation measurements. *Geophysical Journal of the Royal Astronomical Society* 60: 493-496.

Lowrie, W. and Heller, F., 1982. Magnetic properties of marine limestones. *Reviews of Geophysics and Space Physics* 20: 171-192.

Lowrie, W. and Kent, D.V., 1983. Geomagnetic reversal frequency since the Late Cretaceous. *Earth and Planetary Science Letters* 62: 305-313.

Macpherson, E.O., 1927. Geological report on area 15 (Morere) and area 20 (Mangaone). Taranaki Oilfields LTD. Petroleum Report No. 87.

Mankinen, E.A. and Dalrymple, G.B., 1979. Revised geomagnetic polarity timescale for the interval 0 to 5 my B.P. *Journal of Geophysical Research* 84: 615-626.

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: Farinacci, A. (Ed.) *Proceedings of II Planktonic Conference.* Roma, pp 739-785.

Manson, A.J., O'Donovan, J.B. ans O'Reilly, W., 1979. Magnetic rotational hysteresis loss in titanomagnetites and titanomaghemites- application to non-destructive mineral identification in basalts. *Journal of Geophysics* 46: 185-199.

May, S.R., Butler, R.F. and Roth, F.A., 1985. Magnetic polarity stratigraphy and stratigraphic completeness. *Geophysical Research Letters* 12: 341-344.

McDougall, I., 1977, The present status of the geomagnetic polarity timescale. In McElhinny, M.E. (Ed.) *The Earth: Its Origin, Structure and Evolution.* New York. Academic Press. pp 543-565.

McDougall, I. and Chamalaun, F.H., 1966. Geomagnetic polarity scale of time. *Nature* 212: 1415-1418.

McDougall, I. and Coombs, D.S., 1973. Potassium-argon ages for the Dunedin Volcano and out-lying volcanics. *New Zealand Journal of Geology and Geophysics* 16: 179-188.

McDougall, I., Kristjannson, L. and Saemundsson, K., 1984. Magnetostratigraphy and geochronology of northwest Iceland. *Journal of Geophysical Research* 89: 7029-7060.

McDougall, I. and Page, R.W., 1975. Toward a physical time-scale for the Neogene-Data from the Australian region. In: Saito, T. and Burckle, L.H., (Eds.) *Late Neogene Epoch Boundaries.* Micropaleontology Press, New York. pp 75-84.

McDougall, I., Salmundson, K., Johanneson, H., Watkins, N.D. and Kristjansson, L., 1977. Extension of the geomagnetic polarity timescale to 6.5 myr: K-Ar dating, geological and paleomagnetic study of a 3500m lava succession in Western Iceland. *Geological Society of America Bulletin* 88: 1-15.

McDougall, I. and Tarling, D.H., 1963. Dating of polarity zones in the Hawaiian Islands. *Nature* 200: 54-56.

McDougall, I., Watkins, N.D. and Kristjansson, L., 1976a. Geochronology and paleomagnetism of a Miocene - Pliocene lava sequence at Bessastada, Eastern Iceland. *American Journal of Science* 276: 1078-1095.

McDougall, I., Watkins, N.D., Walker, G.P.L. and Kristjansson, L., 1976b. Potassium-argon and paleomagetic analysis of Icelandic lava flows: on the age of anomaly 5. *Journal Geophysical Research* 81: 1505-1512.

McElhinny, M.E., 1973. *Paleomagnetism and Plate Tectonics.* Cambridge University Press.

McInnes, B.A., 1964. A detailed examination of microfaunas from a Miocene-Pliocene (Taranakian-Opoitian-Waitotaran) section on the Mangapoike River,Northern Hawkes Bay. B.P. Shell and Todd Petroleum Development LTD Paleontological Note. 32.

McInnes, B.A., 1965. *Globorotalia miozea* Finlay as an ancestor of *Globorotalia inflata* (d'Orbigny). *New Zealand Journal of Geology and Geophysics.* 8: 104-108.

McIntosh, W.C., Hargraves, R.B. and West, C.L., 1985. Paleomagnetism and oxide mineralogy of Upper Triassic to Lower Jurassic red beds and basalts in the Newark Basin. *Geological Society of the America Bulletin.* 96: 463-480.

Miall, A.D., 1986. Eustatic sea level changes interpretated from seismic stratigraphy: A critique of the methodology with particular reference to the North Sea Jurassic record. *American Association of Petroleum Geologists* 70: 131-137.

Miller, K.G., Aubry, M.P., Khan, M.J., Melillo, A.J., Kent, D.V. and Berggren, W.A., 1985. Oligocene-Miocene biostratigraphy, magnetostratigraphy and isotopic stratigraphy of the western North Atlantic. *Geology* 13: 257-261.

Moll, E.J., 1981. Geochemistry and petrology of mid-Tertiary ash flows tuffs from the Sierra el Virulento area, eastern Chihuahua, Mexico. *Journal of Geophysical Research* 86: 10321-10334.

Morgans, H.E.G., 1980. Stratigraphy of the Neogene sequence at Blind River, Marlborough. *New Zealand Geological Survey Paleontology Report 36.* 18pp.

Morris, P., 1979. Electron microprobe analyses of minerals from volcanic rocks from the Chatham Islands. *Geology Department Internal Publication No. 12,* VUW.

Mumme, T.C. and Walcott, R.I., 1985. Paleomagnetic studies at Geophysics Division 1980-1983. *Geophysics Division Report* 204. 62pp. Department of Scientific and Industrial Research, New Zealand.

Murphy, R.P. and Seward, D., 1981. Stratigraphy, lithology, paleomagnetism, and fission track ages of some ignimbrite formations in the Matahana Basin, New Zealand. *New Zealand Journal of Geology and Geophysics* 24: 325-331.

Nagata, T., 1961. *Rock Magnetism.* Maruzen, Tokyo. 350pp.

Nagata, T. and Akimoto, S., 1956. Magnetic properties of ferromagnetic ilmenites. *Geofis. Pura e Appl* 34: 35-50.

Nakagawa, H., Niistsuma, N., Kitamura, N. Matoba, Y., Takayama, T. and Asano, K., 1974. Preliminary results on magnetostratigraphy of Neogene stage stratotypes sections in Italy. *Rivista Italiana Paleontologia* 80: 615-630.

Neel, L., 1955. Some theoretical aspects of rock magnetism. *Advances in Physics* 4: 191-243.

Ness, G., Levi, S. and Couch, R., 1980. Marine magnetic anomaly timescales for the Cenozoic and Late Cretaceous: a precis, critique and synthesis. *Reviews of Geophysics and Space Physics* 18: 753-770.

Nicholls, G.D., 1955. The mineralogy of rock magnetism. *Advances in Physics* 4: 113-190.

Nickel, E.H., 1958. The composition and microtexture of an ulvospinel-magnetite intergrowth. *Canadian Mineralogist 6: 191-199.*

Nigrini, C. and Lombari, G., 1984. *A Guide to Miocene Radiolaria.* Cushman Foundation for Foraminiferal Research Special Publication 22. 308 pp.

Ninkovich, D., Opdyke, N.D., Heezen, B.C. and Foster, J.H., 1966. Paleomagnetism stratigraphy, rates of deposition and tephrochronolgy in North Pacific deep-sea sediments. *Earth and Planetary Science Letters* 1: 476-492.

O'Donovan, J.B. and O'Reilly, W., 1978. Cation distribution in synthetic titanomagnetites. *Physics of Earth and Planetary Interiors* 16:200-208.

Ongley, M., 1928. Wairoa Subdivision. *New Zealand Geological Survey 22nd Annual Report*: 7.

Ongley, M., 1930. Wairoa subdivision. *New Zealand Geological Survey 24th Annual Report*: 9.

Opdyke, N.D., 1972. Paleomagnetism in deep sea cores. *Reviews of Geophysics and Space Physics* 10: 213-249.

Opdkye, N.D., Kent, D.V. and Lowrie, W., 1973. Details of magnetic polarity transitions recorded in a high deposition rate deep-sea core. *Earth and Planetary Science Letters* 20: 315-324.

Orbell, G.E., 1965. Petrology and clay mineralogy of some sedimentary rocks from the Mauriceville District. *New Zealand Journal of Geology and Geophysics* 8: 548-559.

O'Reilly, W., 1976. Magnetic minerals in the crust of the Earth. *Reports on Progress in Physics* 39: 857-908.

O'Reilly, W., 1983. The identification of titanomaghemites: model mechanisms for the maghemisation and inversion processes and their magnetic consequences. *Physics of the Earth and Planetary Interoirs* 31: 65-76.

O'Reilly, W., 1984. *Rock and Mineral Magnetism.* Chapman and Hall, New York. 220 pp.

O'Reilly, W. and Banerjee, S.K., 1965. Cation distribution in titanomagnetites. *Physics Letters* 17: 237-238.

Osborn, N.I., Ciesielski, P.F. and Ledbetter, M., 1983 Disconformities and paleoceanography in the south east Indian Ocean during the past 5.4 million years. *Geological Society of American Bulletin.* 94: 1345-1358.

Osborne, N., 1934. Report on the geology of the north east portion of the Hawke Bay depression, New Zealand. Vacuum Oil Co. Petroleum Report No. 122.

Otofuji, Y., Katsura, I. and Sasjima, S., 1982. Decay of a post-depositional remanent magnetisation in wet sediment due to the effect of drying. *Geophysical Journal of the Royal Astronomical Society* 70: 191-203.

Otofuji, Y. and Sasajima, S., 1981. A magnetisation process of sediments: laboratory experiments on post-depositional remanent magnetisation. *Geophysical Journal of the Royal Astronomical Society* 66: 241-259.

Ouliac, M., 1976. Removal of secondary magnetisation from natural remanent magnetisation of sedimentary rocks: Alternating field of thermal demagnetisation technique? *Earth and Planetary Science Letters* 29: 65-70.

Ozdemir, O. and O'Reilly, W., 1981. Laboratory synthesis of aluminium-substituted titanomagnetites and their characteristic properties. *Journal of Geophysics* 49: 93-100.

Papamarinopoulous, S., Readman, P.W., Maniatis, Y. and Simopoulosa, A., 1982. Magnetic characterization and Mossbauer spectroscopy of magnetic concentrates from Greek lake sediments. *Earth and Planetary Science Letters* 57: 173-181.

Patel, J.P. and Palmer, H.C., 1982. Chemical magnetic overprinting in the Ordovician redbeds of Bucaco (Portugal). abstract. *Physics of the Earth and Planetary Interiors* 30: 373.

Petrova, G.N., 1961. Various laboratory methods of determining the geomagnetic stability of rocks. *Bulletin of the Academy of Sciences (USSR), Geophysical Series* 703-709.

Pitman, W.C., 1978. Relationships between eustacy and stratigraphic sequences of passive margins. *Geological Society of America Bulletin* 89: 1389-1403.

Poore, R.Z., Tauxe, L., Percival, S.F., LaBrecque, J.P., Wright, R., Petersen, N.P., Smith, C.C., Tucker, P. and Hsu, K.J., 1983. Late Cretaceous - Cenozoic magnetostratigraphic and biostratigraphic correlations of the South Atlantic Ocean: DSDP Leg 73. *Palaeogeography, Palaeoclimatology, Palaeoecology* 42: 127-149.

Purucker, M.E., Elston, D.P. and Shoemaker, E.M., 1980. Early acquisition of characteristic magnetisation in red beds of the Moenkopi Formation (Triassic). *Journal of Geophysical Research* 85: 997-1001.

Radhakrishnamurty, C. and Sahasrabudhe, P.W., 1965. Instruments and techniques for the study of magnetic stability in rocks. *Journal of the Indian Geophysical Union* 2: 5-15.

Ramdohr, P., 1969. *The Ore Minerals and Their Intergrowths.* Pergamon Press.

Readman, P.W. and O'Reilly, W., 1972. Magnetic properties of oxidised (cation deficient) titanomagnetites $(Fe,Ti)_3O_4$. *Journal of Geomagnetism and Geoelectricity* 24: 69-90.

Rees. A.I., Brown, C.M., Hailwood, E.A. and Riddy, P.J., 1982. Magnetic fabric of bioturbated sediment from the Northern Rockall Trough: comparison with modern currents. *Marine Geology* 46: 161-173.

Rees, A.I., Von Rad, U. and Shepard, F.P., 1968. Magnetic fabric of sediments from the La Jolla submarine canyon and fan, California. *Marine Geology* 6: 145-178.

Richards, J.W., O'Donovan, J.B., Hauptman, Z., O'Reilly, W. and Creer, K.M., 1973. A magnetic study of titanomagnetite substituted by magnesium and aluminium. *Physics of the Earth and Planetary Interiors* 7: 437-444.

Robins, B.W., 1972. Remanent magnetisation in spinel iron oxides. Unpublished PhD Thesis, University of New South Wales.

Rona, P.A., 1973. Worldwide uncomformities in marine sediments related to eustatic changes of sea-level. *Nature* 244: 25-26.

Roser, B.P., 1983. Comparative studies of Cu and Mn mineralisation, Torlesse, Waipapa and Haast Schist terranes, New Zealand. (2 volumes). Unpublished PhD Thesis. Victoria University of Wellington.

Roser, B.P. and Korsch, R.J., 1985. Plate tectonics and geochemical composition of sanstones: A discussion. *Journal of Geology* 93: 81-84.

Roser, B.P. and Korsch, R.J., in prep. A graded Miocene bed: Geochemistry and petrography.

Roy, J.L. and Lapointe, P.L., 1978. Multiphase magnetisations: problems and implications. *Physics of the Earth and Planetary Interiors* 16: 20-37.

Roy, J.L. and Park, J.K., 1974. The magnetisation process of certain red beds: vector analysis of chemical and thermal results. *Canadian Journal of Earth Science* 11: 437-471.

Ruddiman, W.F. and Glover, L.K., 1972. Vertical mixing of ice-rafted volcanic ash in North Atlantic sediments. *Geological Society of America Bulletin* 83: 2817-2836.

Russell, K.L., 1968. Oceanic ridges and eustatic changes in sea level. *Nature* 218: 861-862.

Ryan, W.B.F., Cita, M.B., Rawson, M.D., Burkle, L.H. and Saito, T., 1974. A paleomagnetic assignment of Neogene stage boundaries and the development of isochronous datum planes between the Mediterranean, the Pacific and Indian Oceans in order to investigate the response of the world to the Mediterranean "salinity crisis". *Rivista Italiana Paleontologia* 80: 631-688.

Sadler, P.M., 1981. Sediment accumulation rates and the completeness of stratigraphic sections. *Journal of Geology* 89: 569-584.

Saemundsson, K., Kristiansson, L., McDougall, I. and Watkins, N.D., 1980. K-Ar dating, geological and paleomagnetic study of a 5km lava succussion in Northern Iceland. *Journal of Geophysical Research* 85: 3628-2646.

Saito, T., 1977. Late Cenozoic planktonic foraminiferal datum levels: The present state of knowledge towards accomplishing pan-Pacific stratigraphic correlation. *Proceedings, First International Congress on Pacific Neogene Stratigraphy*. Tokyo, Kaiyo Shuppan Co. pp 61-80.

Saito, T., 1984. Planktonic foraminiferal datum planes for biostratigraphic correlation of Pacific Neogene sequences - 1982 status report. In: Ikebe, N. and Tsuchi, R. (Eds.), *Pacific Neogene Datum Planes: Contributions to Biostratigraphy and Chronology (IGCP -114)*. University of Tokyo Press. pp 3-10.

Saito, T., Burckle, L.H. and Hays, J.D., 1975. Late Miocene to Pleistocene biostratigraphy of equatorial Pacific sediments. In: Saito, T. and Burckle, L.H., (Eds.) *Late Neogene Epoch Boundaries* Micropaleontology Press, New York. pp 226-244.

Sallomy, J.T. and Briden, J.C., 1975. Paleomagnetic studies of Lower Jurassic rocks in England and Wales. *Earth and Planetary Science Letters* 24: 369-376.

Savin, S.M., Douglas, R.G., Keller, G. Killingley, J.S., Shanghnessy, L., Sommer, M.A., Vincent, E. and Woofruff, F., 1981. Miocene benthic foraminiferal isotope records: A synthesis. *Marine Micropaleontology* 6: 423-450.

Schwarz, E.J., 1975. Magnetic properties of pyrrhotite and their use in applied geology and geophysics. *Geological Survey of Canada, Paper 74.*

Schwarz, E.J. and Vaughan, D.J., 1972. Magnetic phase relations of pyrrhotite. *Journal of Geomagnetism and Geoelectricity* 22: 463-470.

Scotese, C.R., Van der Voo, R. and McCabe, C., 1982. Paleomagnetism of the Upper Silurian and Lower Devonian carbonates of New York State: evidence for secondary magnetisation residing in magnetite. *Phyiscs of Earth and Planetary Interiors* 30: 385-395.

Scott, G.H., 1972. Revision of Hutchinsonian, Awamoan and Altonian stages (Lower Miocene, New Zealand -2). *New Zealand Journal Geology and Geophysics* 15: 49-70.

Scott, G.H., 1976. Variation in *Globorotalia punticulata sphericomiozea* from New Zealand (Foraminiferida, Neogene). *New Zealand Journal Geology and Geophysics* 19: 855-869.

Scott, G.H., 1978. Early history of *Bolivinita pliozea* Finlay (Foraminiferida, Neogene, New Zealand). *New Zealand Journal of Geology and Geophysics* 21: 717-634.

Scott, G.H., 1979a. Variation in *Bolivinita quadrilatera* (Foraminiferida, upper Neogene, New Zealand). *New Zealand Journal of Geology and Geophysics* 22: 509-519.

Scott, G.H., 1979b. The late Miocene to early Pliocene history of the *Globorotalia miozea* plexus from Blind River, New Zealand. *Marine Micropaleontology* 4: 341-361.

Scott, G.H., 1979c. Variation in *Globorotalia puncticulata sphericomiozea* from New Zealand(Foraminiferida, Neogene) *New Zealand Journal of Geology and Geophyiscs* 19: 855-869.

Scott, G.H., 1980. *Globorotalia inflata* lineage and *G. crassaformis* from Blind River, New Zealand: recognition, relationship and use in uppermost Miocene - Lower Pliocene biostratigraphy. *New Zealand Journal of Geology and Geophyiscs* 23: 665-677.

Scott, G.H., 1982a. Tempo and stratigraphic record of speciation in *Globorotalia puncticulata. Journal of Foraminiferal Research* 12: 1-12.

Scott, G.H., 1982b. Review of Kapitean stratotype and boundary with Opoition Stage (upper Neogene, New Zealand). *New Zealand Journal of Geology and Geophysics* 25: 475-485.

Scott, G.H., 1983. Biostratigraphy and histories of Upper Miocene - Pliocene *Globorotalia*, south Atlantic and southwest Pacific. *Marine Micropaleontology* 7: 364-383.

Scott, G.H., 1985. Biostratigraphic revision of Maui-2 offshore well south Taranaki Basin. *New Zealand Geological Survey Paleontology Report 99.* 44pp.

Seward, D. 1974. Age of New Zealand Pleistocene substages by fission-track dating of glass shards from tephra horizons. *Earth and Planetary Science Letters* 24: 242-248.

Seward, D., 1975. Fission track ages of some tephras from Cape Kidnappers, Hawkes Bay, New Zealand. *New Zealand Journal of Geology and Geophysics* 18: 507-510.

Seward, D., 1979. Comparison of zircon and glass fission-track ages from tephra horizons. *Geology* 7: 479-482.

Shackleton, N.J. and Kennett, J.P., 1975. Late Cenozoic oxygen and carbon isotope changes at DSDP 284: implications for glacial history of the Northern Hemisphere and Antarctica. In: Kennett, J.P., Houtz, R.E., et al., *Initial Reports DSDP 29*: Washington (US Government Printing Office) pp 801-807.

Shanmugam, G. and Moiola, R.J., 1982. Eustatic control of turbidites and winnowed turbidites. *Geology* 10: 231-235.

Shibata, K., Nishimura, S. and Chinzei, K., 1984. Radiometric dating related to Pacific Neogene planktic datum planes. In: Ikebe, N. and Tsuchi, R. (Eds.), *Pacific Neogene Datum Planes: Contributions to Biostratigraphy and Chronology (IGCP -114)*. University of Tokyo Press. pp 85-89.

Shive, P.N., 1986. Suggestions for the use of SI units in magnetism. *Eos* January, p 25.

Skinner, D.N.B., 1986. Neogene volcanism of the Hauraki Volcanic Region. In: Smith, I.E.M. (Ed.) *Late Cenozoic Volcanism in New Zealand*. Royal Society of New Zealand Bulletin 23. pp 21-47.

Smith, P.J., 1967. The intensity of the ancient geomagnetic field: A review and analysis. *Journal of Geophysics* 12: 321-362.

Srinivasan, M.S. and Kennett, J.P., 1981a. Neogene planktonic foraminiferal biostratigraphy and evolution: equatorial to subantarctic, South Pacific. *Marine Micropaleontology* 6: 499-533.

Srinivasan, M.S. and Kennett, J.P., 1981b. A review of Neogene planktonic foraminiferal biostratigraphy: applications in the equatorial and South Pacific. In: Warme, J.E., Douglas, R.G. and Winterer, E.L., (Eds.) *The Deep Sea Drilling Project: A Decade of Progress*. Society of Economic Paleontologists and Mineralogists. Special Publication No. 32. pp 395-432.

Srinivasan, M.S. and Srivastava, S.S., 1974. *Sphaeroidinella dehiscens* datum and the Miocene - Pliocene boundary. *American Association of Petroleum Geologists Bulletin* 58: 304-311.

Strangeway, D.W., Honea, R.M., McMahon, B.E. and Larson, E.E., 1968. The magnetic properties of naturally occurring goethite. *Geophysical Journal of the Royal Astronomical Society* 15: 345-359.

Stacey, F.D., 1963. The physical theory of rock magnetism. *Advances in Physics* 12: 45-133.

Stacey, F.D. and Banerjee, S.K., 1974. *The Physical Principles of Rock Magnetism*. Elsevier, Amsterdam.

Steiger, R.H. and Jager, E., 1977. Subcommission on Geochronology: Convention on the use of decay constants in geo- and cosmochronolgy. *Earth and Planetary Science Letters* 36: 359-362.

Stephenson, A., 1969. The temperature dependent cation distribution in titanomagnetite. *Geophysical Journal of the Royal Astronomical Society* 18: 199-210.

Stephenson, A., 1972. Spontaneous magnetisation curves and Curie points of spinels containing two types of magnetic ion. *Philosophical Magazine* 25: 1213-1232.

Stipp, J.J., Chappel, J.M.A. and McDougall, I., 1967. K/Ar age estimates of the Pliocene - Pleistocene boundary in New Zealand. *American Journal of Science* 265: 462-474.

Stipp, J.J. and McDougall, I., 1968. Geochronology of the Banks Peninsula volcanoes, New Zealand. *New Zealand Journal of Geology and Geophysics* 11: 1239-1260.

Stipp, J.J. and Thompson, B.N., 1971. K/Ar ages from the volcanics of Northland, New Zealand. *New Zealand Journal of Geology and Geophysics* 14: 403-413.

Stoneley, H.M.W., 1959. Report on the paleontological examination of samples from Mangaone - Waingake uplift, including the Waerega-o-kuri culmination. BP Shell and Todd Development LTD. Petroleum Report No. 340.

Stormer, J.C.(Jr.), 1983. The effects of recalculation on estimates of temperature and oxygen fugacity from analyses of multicomponent iron-titanium oxides. *American Mineralogist* 68: 586-594.

Stupavsky, M. and Symons, D.T.A., 1978. Separation of magnetic components from AF step demagnetisation data by least-squares methods. *Journal of Geophysical Research* 83: 4925-4931.

Symons, D.T.A. and Stupavsky, M., 1974. A rational paleomagnetic stability index. *Journal of Geophysical Research* 79: 1718-1720.

Takayangi, Y., Sakai, T., Oda, M. Takayama, T., Oriyama, J. and Kaneko, M., 1978. Problems relating to the Kaburan Stage. *Cenozoic Geology of Japan.* Osaka. pp 93-111.

Talwani, M., Windisch, C.C and Langseth, M.G., 1971. Reykjanes Ridge Crest: A detailed geophysical study. *Journal of Geophysical Research* 76: 473-517.

Tarling, D.H. and Symons, D.T.A., 1967. A stability index of remanence in paleomagnetism. *Geophysical Journal of the Royal Astronomical Society* 12: 443-448.

Tauxe, L., Kent, D.V. and Opdyke, N.D., 1980. Magnetic components contributing to the N.R.M. of Middle Siwalik Red Beds. *Earth Planetary Science Letters* 47: 279-284.

Tauxe, L., Tucker, P., Petersen, N.P. and LaBrecque, J.P., 1983. The magnetostratigraphy of Leg 73 sediments. *Palaeogeography, Palaeoclimatology, Palaeoecology* 42: 65-90.

Theyer, F., 1972. Paleomagnetism and planktonic zonation of late Neogene subantarctic cores. *Antarctic Journal of the United States* 7: 195-197.

Theyer, F. and Hammond, S.R., 1974. Paleomagnetic polarity sequence and radiolarian zones, Brunhes to Polarity Epoch 20. *Earth and Planetary Science Letters* 22: 307-319.

Vail, P.R., Mitchum, R.M. and Thompson, S.III., 1977. Global cycles of relative changes of sea level. In: Seismic stratigraphy- applications to hydrocarbon exploration: *American Association of Petroleum Geologists Memoir* 26: 83-97.

Vail, R.R. and Hardenbol, J., 1979. Sea-level changes during the Tertiary. *Oceanus* 22: 71-79.

Valentine, J.W. and Moores, F.M., 1970. Plate-tectonic regulation of faunal diversity and sea-level: A model. *Nature* 228: 657-659.

Van Couvering, J.A. and Berggren, W.A., 1977. Biostratigraphic basis of the Neogene timescale. In: Kauffman, E.G. and Hazel, J.E. (Eds.) *Concepts and Methods in Biostratigraphy*. Dowden, Hutchinson and Ross, Stroudsburg. pp 283-306.

Vella, P.P., 1954. Tertiary mollsuca from southeast Wairarapa. *Transactions of Royal Society of New Zealand* 81: 539-555.

Vella, P.P., 1965. Sedimentary cycles correlation and stratigraphic classification. *Transactions of Royal Society of New Zealand, Geology* 3: 1-9.

Vella, P.P. and Collen, J.D., 1984. Four rhyolitic tuff marker beds, Lower Pliocene, Wairarapa, New Zealand. *Journal of the Royal Society of New Zealand* 14: 133-138.

Verosub, K.L., 1977. Depositional and postdepositional processes in the magnetisation of sediments. *Reviews of Geophysics and Space Physics* 15: 129-143.

Verosub, K.L., Ensley, R.A. and Ulrick, J.S., 1979. The role of water content in the magnetisation of sediments. *Geophysical Research Letters* 6: 226-228.

Vincent, E., Killingley, J.S. and Berger, W.H., 1980. The magnetic epoch 6 carbon shift: A change in the ocean's $^{13}C/^{12}C$ ratio 6.2 million years ago. *Marine Micropaleontolgy* 5: 185-203.

Walcott, R.I., Christoffel, D.A. and Mumme, T.C., 1981. Bending within the axial tectonic belt of New Zealand in the last 9 My from paleomagnetic data. *Earth and Planetary Science Letters* 52: 427-434.

Walcott, R.I. and Mumme. T.C., 1982. Paleomagnetic study of the Tertiary sedimentary rocks from the east coast of the North Island, New Zealand. *Geophysics Division Report 189*, Department of Scientific and Industrial Research, New Zealand. 44pp.

Walker, T.R., Larson, E.E. and Hoblitt, P.R., 1981. The nature and origin of haematite in the Moenkopi Formation (Triassic), Colorado Plataeu: A contribution to the origin of magnetisation in red beds. *Journal of Geophysical Research* 86: 317-333.

Watanabe, T., Grapes, R.H. and Palmer, K., 1981. Quantitative analyses of rock forming minerals by JXA-733 electron probe x-ray microanalyser. *JEOL News* 19e: 15-19.

Watkins, N.D., 1968. Short period geomagnetic polarity events in deep-sea sedimentary cores. *Earth and Planetary Science Letters* 4: 341-349.

Watkins, N.D., 1972. A review of the development of the geomagnetic polarity timescale and a discussion of prospects for its finer definition. *Geological Society of America Bulletin* 83: 551-574.

Watkins, N.D. and Kennett, J.P., 1971. Antarctic bottom water: Major change in velocity during the late Cenozoic between Australia and Antarctica. *Science* 173: 813-818.

Watkins, N.D. and Kennett, J.P., 1972a. Continuing paleomagnetic and micropaleontological dating of Eltanin deep-sea sedimentary cores. *Antarctic Journal of the United States* 7: 202-203.

Watkins, N.D. and Kennett, J.P., 1972b. Regional sedimentary disconformities and Upper Cenozoic changes in bottom water velocities between Australia and Antarctica. *Americian Geophysical Union: Antarctic Research Series* 19: 273-293.

Watkins, N.D., Kester, D.R. and Kennett, J.P., 1974. Paleomagnetism of the type Pliocene - Pleistocene boundary section at Santa Maria De Catanzaro, Italy, and the problem of post-depositional precipitation of magnetic minerals. *Earth and Planetary Science Letters* 24: 113-119.

Watkins, N.D. and Walker, G.P.L., 1977. Magnetostratigraphy of eastern Iceland. *American Journal of Science* 277: 513-584.

Watson, J.F., 1957. The Opoitian Stage: A proposal for a type section. BP Shell and Todd Development LTD. Petroleum Report No. 355.

Weaver, F.M., 1976. Late Miocene and Pliocene radiolarian paleobiogeography and biostratigraphy of the Southern Ocean. Unpublished Ph.D. thesis, Florida State University. 175 pp.

Webb, C., 1979. The geology of eastern Mahia Peninsula, Hawke's Bay. Unpublished MSc Thesis. Auckland University.

Wells, A.J., 1960. Cyclic sedimentation: A review. *Geological Magazine* 97: 389-403.

Wellman, H.W., 1958. Flute cast directions in the middle and upper Miocene and in the Cretaceous, upper Senonian, Raukumara Series. BP Shell and Todd Development LTD. Petroleum Report No. 361.

Westcott-Lewis, M.F. and Parry, L.G., 1971. Magnetism in rhombohedral iron-titanium oxides. *Australian Journal of Physics* 24: 719-734.

Westgate, J.A. and Evans, M.E., 1978. Compositional variability of Glacier Peak tephra and its stratigraphic significance. *Canadian Journal of Earth Sciences* 15: 1554-1567.

Westgate, J.A., Walter, R.C., Pearce. G.W., and Gorton, M.P., 1985. Distribution, stratigraphy, petrochemistry, and paleomagnetism of the late Pleistocene Old Crow tephra in Alaska and the Yukon. *Canadian Journal of Earth Sciences* 22: 983-906.

Wilson, R.L., 1962. The paleomagnetism of baked contact rocks and reversals of the Earth's magnetic field. *Geophysical Journal of the Royal Astronomical Society* 7: 194-202.

Wilson, R.L. and Smith, P.J., 1968. The nature of secondary natural magnetisation in some igneous and baked rocks. *Journal of Geomagnetism and Geoelectricity* 20: 367-380.

Woodruff, F. and Savin, S.M., 1985. $\delta^{13}C$ values of Miocene Pacific benthic foraminifera: correlations with sea level and biological productivity. *Geology* 13: 119-122.

Woodruff, F., Savin, S.M. and Douglas, R.G., 1981. Miocene stable isotope record: A detailed deep Pacific Ocean Study and its paleoclimatic implications. *Science* 212: 665-668.

Wright, I.C., 1985. Mangapoike River: A late Miocene magnetostratigraphic reference column for New Zealand. In: Hornibrook Symposium, 1985, extended abstracts, *New Zealand Geological Record* 9: 105-107.

Wright, I.C., Ashby, J.N. and Hoskins, R.H., 1985. An age for the sudden disappearance of *Globoquadrina dehiscens* from Mangapoike River. In: Hornibrook Symposium, 1985, extended abstracts, *New Zealand Geological Record* 9: 102-104.

Wright, J.B. and Lovering, J.F., 1965. Electron probe microanalysis of iron-titanium oxides in some New Zealand ironsands. *Mineral Magazine* 35: 604-621.

Wright, J.V. and Mutti, E., 1981. The Dali Ash, Island of Rhodes, Greece: a problem in interpreting submarine volcanigenic sediments. *Bulletin Volcanology* 44: 153-167.

Yamazka, T., Kato, I. and Abe, M., 1973. Textural anaylsis and flow mechanism of the Donzurubo subaqueous pyroclastic flow deposits. *Bulletin Volcanology* 37: 231-244.

Zijderveld, J.D.A., 1967. AC demagnetisation of rocks: analysis of results. In: Collinson, D.W., Creer, K.M. and Runcorn, S.K. (Eds.), *Methods in Paleomagnetism*. Elsevier, Amsterdam. pp 254-286.

APPENDIX 1: SITE LOCATIONS AND DESCRIPTIONS.

SITES

All paleomagnetic sites sampled are described, including those with an unstable and/or weak intensity of magnetisation. Some sites were inaccessible for sampling, but numbering was kept consectutive so as to indicate the stratigraphic interval not sampled.

LOCATIONS

Sites are located in both imperial and metric grid references. Imperial coordinates refer to sheet N106 (NZMS 1) and metric coordinates refer to the unpublished sheet X19. A map based on an enlarged aerial photograph, with an approximate scale of 1:10,500 allowed coordinates to be given as eight figure references.

DESCRIPTIONS

Lithological descriptions are based on field observations, including relevant data on outcrop condition and suitability for paleomagnetic study. Grain size classification and abbreviations follow Andrews (1982) NZGS Report 102, Revised Guide To Recording Field Observations In Sedimentary Sequences and are:

bdd	bedded	biv	bivavle
bur	burrow	cm-bdd	cm bedded
dm-bdd	dm bedded	frac	fractured
frag	fragment	gn	green
ibdd	interbedded	len	lense
mass	massive	mod	moderate
o'cp	outcrop	pell	pellet
unwthd	unweathered	sepng	seeping
surf	surface	sst	sandst.
stn	stained	tf	tuff
wk	weak	(frac)	slighty fractured
frac	strongly fractured		

SITE	IMPERIAL GRID REF.	METRIC GRID REF.	DESCRIPTION
18870	N106/01930757	X19/11354386	clay siltst. LB.unwthd,2m below site 18871 same grd bd, (frac).
18871	N106/01930757	X19/11354386	clay siltst. LB.unwthd,5.5m grd bd, (frac).
18872	N106/01930757	X19/11354386	clay siltst. LB.unwthd,1m grd bd, (frac).
18873	N106/01920757	X19/11344386	silty clayst. LB.unwthd,1.2m grd bd, frac.
18874	N106/01910757	X19/11334386	clay siltst. LB.unwthd,1.5m grd bd, frac.
18875	N106/01890757	X19/11324386	clay siltst. LB.unwthd,2.5m grd bd, frac.
18876	N106/01870759	X19/11304388	clay siltst. RB.unwthd,mass,frac.
18877	N106/01850759	X19/11284388	clay siltst. RB.unwthd,mass,frac.
18878	N106/01830759	X19/11264388	clay siltst. RB.unwthd,mass,frac.
18879	N106/01810760	X19/11244389	clay siltst. RB.unwthd,mass,frac, biotur.
18880	N106/01790760	X19/11224389	clay siltst. RB.unwthd,mass,frac.
18881	N106/01760760	X19/11204389	clay siltst. RB.unwthd,mass,frac.
18882	N106/01730760	X19/11174389	clay siltst. RB.unwthd,mass,frac.
18883	N106/01710760	X19/11154389	clay siltst. RB.unwthd,mass,frac,Fe stn frac surf,biotur.
18884	N106/01680762	X19/11134391	clay siltst. RB.unwthd,mass,frac.
18885	N106/01670763	X19/11124392	clay siltst. RB.unwthd,mass,frac.
18886	N106/01660763	X19/11114392	clay siltst. RB.unwthd,bdd,frac.
18887	N106/01640764	X19/11094394	clay siltst. RB.unwthd,bdd,frac.
18888	N106/01620764	X19/11074394	clay siltst. RB.unwthd,bdd,frac.

18889	N106/01600764	X19/11054394	clay siltst. RB.unwthd,bdd,frac.
18890	N106/01580764	X19/11034394	clay siltst. RB.unwthd,mass,frac.
18891	N106/01560764	X19/11014394	clay siltst. RB.unwthd,mass,frac, Fe stn frac surf.
18892	N106/01530764	X19/10984394	clay siltst. RB.unwthd,mass,frac, Fe stn frac surf.
18893	N106/01510763	X19/10964392	silty clayst. RB.unwthd,mass,frac.
18894	N106/01480762	X19/10944391	clay siltst. RB.unwthd,bdd,frac, biotur.
18895	N106/01460763	X19/10924392	clay siltst. RB.unwthd,bdd,frac, biotur.
18896	N106/01450763	X19/10914392	clay siltst. RB.unwthd,mass,frac.
18897	N106/01450762	X19/10914391	silty clayst. LB.unwthd,mass,frac.
18898	N106/01430763	X19/10894392	clay siltst. LB.unwthd,mass,(frac), biotur.
18899	N106/01410765	X19/10874394	clay siltst. LB.unwthd,mass,(frac), biotur.
18900	N106/01390767	X19/10854396	clay siltst. LB.unwthd,mass,(frac).
18901	N106/01370769	X19/10844398	clay siltst. LB.unwthd,mass,(frac).
18902	N106/01370770	X19/10844399	silty clayst. LB.unwthd,mass,frac, Fe stn frac surf.
18903	N106/01370772	X19/10844401	silty clayst. RB.unwthd,mass,frac, Fe stn frac surf.
18904	N106/01350773	X19/10824402	silty clayst. RB.unwthd,mass,frac, Fe stn frac surf.
18905	N106/01340775	X19/10814404	clay siltst. RB.unwthd,wk bddd,frac.
18906	N106/01330774	X19/10804403	clay siltst. LB.unwthd,mass,frac.

18907	N106/01320774	X19/10794403	clay siltst. LB.unwthd,mass,frac.
18908	N106/01300774	X19/10774403	clay siltst. LB.unwthd,mass,frac.
18909	N106/01280774	X19/10754403	silty clayst. LB.unwthd,mass,frac, Fe stn frac surf.
18910	N106/01260775	X19/10734404	clay siltst. LB.unwthd,mass,frac.
18911	N106/01240776	X19/10724405	clay siltst. LB.unwthd,mass,frac.
18912	N106/01230777	X19/10714406	clay siltst. LB.unwthd,wk bdd,frac, biotur.
18913	N106/01210778	X19/10694407	clay siltst. LB.unwthd,mass,frac.
18914	N106/01200779	X19/10684408	clay siltst. LB.unwthd,mass,frac.
18915	N106/01190780	X19/10674409	clay siltst. LB.unwthd,mass,frac, (Fe stn frac surf).
18916	N106/01180782	X19/10664411	clay siltst. RB.unwthd,mass,frac.
18917	N106/01170783	X19/10654412	silty clayst. RB.unwthd,mass,frac, Fe stn frac surf.
18918	N106/01130783	X19/10624412	clay siltst. RB.unwthd,mass,frac, biotur.
18919	N106/01100783	X19/10594412	clay siltst. RB.unwthd,mass,frac.
18920	N106/01070783	X19/10574412	clay siltst. RB.unwthd,mass,frac.
18921	N106/01060783	X19/10564412	clay siltst. RB.unwthd,mass,frac, biotur.
18922	N106/01030785	X19/10534414	clay siltst. RB.unwthd,mass,frac, biotur.
18923	N106/01010786	X19/10514415	clay siltst. RB.unwthd,mass,(frac), biotur.
18924	N106/00990788	X19/10504417	clay siltst. RB.unwthd,mass,(frac).

18925	N106/00980789	X19/10494418	clay siltst. RB.unwthd,mass,frac, biotur.
18926	N106/00950791	X19/10474420	clay siltst. RB.unwthd,mass,frac.
18927	N106/00940791	X19/10474420	clay siltst. LB.unwthd,mass,frac, Fe stn frac surf.
18928	N106/00930793	X19/10464422	silty clayst. LB.unwthd,mass,frac, Fe stn frac surf.
18929	N106/00930794	X19/10464423	silty clayst. LB.unwthd,mass,frac, Fe stn frac surf,biotur.
18930	N106/00920795	X19/10454424	silty clayst. LB.unwthd,mass,frac, Fe surf stn,biotur.
18931	N106/00920796	X19/10454425	clay siltst. LB.unwthd,mass,frac.
18932	N106/00910797	X19/10454426	clay siltst. LB.unwthd,mass,frac.
18933	N106/00910799	X19/10454427	clay siltst. LB.unwthd,mass,frac.
18934	N106/00910802	X19/10454429	clay siltst. LB.unwthd,mass,frac.
18935	N106/00900802	X19/10444430	clay siltst. LB.unwthd,mass,frac, (Fe stn frac surf).
18936	N106/00910804	X19/10454432	silty clayst. RB.unwthd,mass,frac, biotur.
18937	N106/00910805	X19/10454433	clay siltst. RB.unwthd,mass(frac), biotur.
18938	N106/00910806	X19/10454434	clay siltst. RB.unwthd,mass(frac), biotur.
18939	N106/00900807	X19/10444435	clay siltst. RB.unwthd,mass,frac, biotur.
18940	N106/00890808	X19/10434436	silty clayst. RB.unwthd,mass,frac.
18941	N106/00880809	X19/10424437	silty clayst. RB.unwthd,mass,frac.

18942	N106/00870810	X19/10414438	clay siltst. RB.unwthd,mass,(frac).
18943	N106/00860811	X19/10404439	clay siltst. RB.unwthd,mass,frac.
18944	N106/00850812	X19/10394440	silty clayst. RB.unwthd,mass,frac.
18945	N106/00840813	X19/10384441	silty clayst. LB.unwthd,mass,frac, (Fe stn frac surf).
18946	N106/00830814	X19/10374442	silty clayst. RB.unwthd,mass,frac, Fe stn frac surf.
18947	N106/00820814	X19/10364442	clay siltst. Rb.unwthd,mass,frac.
18948	N106/00820813	X19/10364441	clay siltst. LB.unwthd,mass,frac, (Fe stn frac surf).
18949	N106/00810813	X19/10354441	clay siltst. LB.unwthd,mass,frac.
18950	N106/00790813	X19/10334441	clay siltst. LB.unwthd,mass,frac.
18951	N106/00790815	X19/10334443	clay siltst. RB.unwthd,mass,(Fe surf stn.
18952	N106/00780815	X19/10324443	clay siltst. RB.unwthd,mass,(Fe surf stn.
18953	N106/00760815	X19/10304443	clay siltst. RB.unwthd,mass,frac.
18954	N106/00750815	X19/10294443	clay siltst. RB.unwthd,mass,frac.
18955	N106/00730815	X19/10274443	clay siltst. RB.unwthd,mass,frac.
18956	N106/00720815	X19/10264443	clay siltst. RB.unwthd,mass,(frac).
18957	N106/00710815	X19/10254443	clay siltst. RB.unwthd,mass,(frac).
18958	N106/00700814	X19/10244442	clay siltst. RB.unwthd,mass,(frac).
18959	N106/00680814	X19/10224442	clay siltst. RB.unwthd,mass,(frac).
18960	N106/00650811	X19/10194439	clay siltst. RB.unwthd,mass,(frac).

18961	N106/00620809	X19/10164437	clay siltst. RB.unwthd,mass,(frac), water sepng o'cp.
18962	N106/00570807	X19/10134435	clay siltst. RB.unwthd,mass,(frac).
18963	N106/00570806	X19/10134434	clay siltst. LB.unwthd,mass,(frac).
18964	N106/00560806	X19/10124434	clay siltst. LB.unwthd,mass,(frac), Fe stn frac surf.
18965	N106/00540806	X19/10104434	clay siltst. LB.unwthd,mass,(frac).
18966	N106/00520807	X19/10084435	clay siltst. LB.unwthd,mass,frac.
18967	N106/00500809	X19/10064437	clay siltst. RB.unwthd,mass,(frac).
18968	N106/00480809	X19/10044437	clay siltst. RB.unwthd,mass,(frac).
18969	N106/00470810	X19/10034438	clay siltst. LB.unwthd,mass,(frac).
18970	N106/00450812	X19/10014440	clay siltst. LB.unwthd,mass,(frac).
18971	N106/00440813	X19/10004441	clay siltst. LB.unwthd,mass,(frac).
18972	N106/00430814	X19/09994442	clay siltst. LB.unwthd,mass,(frac).
18973	N106/00410815	X19/09974443	clay siltst. LB.unwthd,mass,(frac).
18974	N106/00400816	X19/09964444	clay siltst. LB.unwthd,mass,(frac).
18975	N106/00390818	X19/09954446	clay siltst. LB.unwthd,mass,(frac).
18976	N106/00400821	X19/09964449	clay siltst. RB.unwthd,mass,frac.
18977	N106/00380825	X19/09944453	clay siltst. LB.unwthd,mass,frac.
18978	N106/00450843	X19/10014471	siltst. LB.unwthd,mass,(frac), cem.
18979	N106/00440844	X19/10004472	siltst. LB.unwthd,mass,(frac).
18980	N106/00430845	X19/09994473	siltst. LB.unwthd,mass,(frac).

18981	N106/00440846	X19/10004474	silty fine sandst. RB.unwthd,mass.
18982	N106/00430847	X19/09994474	clay siltst. RB.unwthd,mass,frac.
18983	N106/00420848	X19/09984475	clay siltst. RB.unwthd,mass,frac, Fe stn frac surf.
18984	N106/00410848	X19/09974475	clay silst. RB.unwthd,mass,frac.
18985	N106/00390849	X19/09954476	clay siltst. RB.unwthd,mass,frac, (Fe surf stn).
18986	N106/00380849	X19/09944476	clay siltst. LB.unwthd,mass,frac.
18987	N106/00360849	X19/09924476	clay siltst. LB.unwthd,mass,frac, biotur.
18988	N106/00340850	X19/09904477	clay siltst. LB.unwthd,mass,frac.
18989	N106/00320851	X19/09884478	clay siltst. LB.unwthd,mass,frac.
18990	N106/00300852	X19/09864479	clay siltst. LB.unwthd,mass,frac.
18991	N106/00290852	X19/09854479	clay siltst. LB.unwthd,mass,(frac), Fe surf stn.
18992	N106/00260852	X19/09824479	clay siltst. LB.unwthd,mass,frac, Fe surf stn.
18993	N106/00230850	X19/09794480	clay siltst. LB.unwthd,wk bdd,(frac).
18994	N106/00190853	X19/09764480	clay siltst. LB.unwthd,mass,(frac), Fe stn frac surf.
18995	N106/00150853	X19/09724480	clay siltst. LB.unwthd,wk bdd,(frac).
18996	N106/00080847	X19/09674474	silty fine sandst. RB.unwthd,wk dm-bdd, (frac).
18997	N106/00030843	X19/09634471	silty clayst. RB.unwthd,mass.
18998	N106/00010841	X19/09614469	silty clayst. RB.unwthd,mass,(frac).

18999	N106/99990839	X19/09594466	silty clayst. RB.unwthd,mass,mod frac.
19000	N106/99960838	X19/09554465	silty clayst. RB.unwthd,mass.
19001	N106/99960834	X19/09554461	silty clayst. LB.unwthd,mass,(Fe stn frac surf).
19002	N106/99950833	X19/09544460	silty clayst. LB.unwthd,mass.
19003	N106/99930832	X19/09534459	silty clayst. LB.unwthd,mass,(frac).
19004	N106/99900832	X19/09504459	silty clayst. LB.unwthd,mass.
19005	N106/99880834	X19/09494461	silty clayst. LB.unwthd,mass.
19006	N106/99870837	X19/09484464	silty clayst. LB.unwthd,mass.
19007	N106/99850837	X19/09454464	silty clayst. LB.unwthd,mass.
19008	N106/99300838	X19/09434465	silty clayst. LB.unwthd,mass,(frac).
19009	N106/99820839	X19/09424466	silty clayst. LB.unwthd,mass,(frac).
19010	N106/99790839	X19/09404466	silty clayst. LB.unwthd,len gn cm-bdd sst.
19011	N106/99780841	X19/09394469	silty clayst. LB.unwthd,mass,(frac).
19012	N106/99760841	X19/09394469	silty clayst. LB.unwthd,len mm-bdd zst.
19013	N106/99740841	X19/09344469	silty clayst. LB.unwthd,mass,(frac).
19014	N106/99740844	X19/09344472	clay siltst. RB.unwthd,ibdd cm-bdd sst.
19015	N106/99730844	X19/09334472	clay siltst. RB.unwthd,mass.
19016	N106/99710845	X19/09324473	clay siltst. RB.unwthd,mass,(frac).
19017	N106/99700845	X19/09314473	clay siltst. RB.unwthd,mass.

19018	N106/99690846	X19/09304474	silty clayst. RB.unwthd,mass,(frac).
19019	N106/99680847	X19/09294474	silty clayst. RB.unwthd,mass.
19020	N106/99660848	X19/09274475	silty clayst. RB.unwthd,mass,mod frac.
19021	N106/99650849	X19/09264476	silty clayst. RB.unwthd,mass,(frac).
19022	N106/99630850	X19/09244477	silty clayst. RB.(wthd),mass,Fe stn 5 cm bd.
19023	N106/99600848	X19/09204475	silty clayst. LB.unwthd,mass.
19024	N106/99590848	X19/09214475	clay siltst. LB.unwthd,mass.
19025	N106/99580848	X19/09204475	clay siltst. LB.unwthd,mass.
19026	N106/99570848	X19/09184475	clay siltst. LB.unwthd,mass.
19027	N106/99560848	X19/09174475	silty clayst. LB.unwthd,mass,biv frag.
19028	N106/99560848	X19/09174475	silty clayst. LB.unwthd,mass.
19029	N106/99550848	X19/09164475	silty clayst. LB.unwthd,mass.
19030	N106/99550849	X19/09164476	silty clayst. LB.unwthd,mass.
19031	N106/99550850	X19/09164477	siltst. LB.unwthd,mass,biv frag, ibdd cm-bdd sst.
19032	N106/99540850	X19/09154477	silty clayst. LB. unwthd,mass.
19033	N106/99540851	X19/09154478	silty clayst. LB.unwthd,mass.
19034	N106/99550851	X19/09164478	silty clayst. RB.unwthd,mass.
19035	N106/99530852	X19/09144479	siltst. RB.unwthd,wk bdd,biv frag.
19036	N106/99510848	X19/09124475	clay siltst. RB.unwthd,mass.

19037	N106/99480846	X19/09114474	siltst. RB.(wthd),wk bdd,biv frag,Fe stn bur,Fe stn tf bd.
19038	N106/99460844	X19/09104472	siltst. RB.(wthd),wk bdd,(frac), surf Fe stn.
19039	N106/99440843	X19/09084471	fine silty sandst. RB.(wthd),wk bdd,(Fe stn bur).
19040	N106/99430842	X19/09074470	fine silty sandst. RB.(wthd),wk bdd,(Fe stn frac surf).
19041	N106/99420841	X19/09064469	siltst. RB.(wthd),ibdd cm-bdd sst.
19042	N106/99420837	X19/09064464	clay siltst. LB.unwthd,mass.
19043	N106/99400838	X19/09054465	clay siltst. LB.unwthd,wk bdd,biv frag.
19044	N106/99390840	X19/09044468	clay siltst. LB.unwthd,ibdd cm-bdd yel sst.
19045	N106/99380841	X19/09034469	clay siltst. LB.unwthd,wk bdd,mod frac,Fe stn sst pell.
19046	N106/99370842	X19/09024470	silty clayst. LB.unwthd,mass.
19047	N106/99340844	X19/08994472	silty clayst. LB.unwthd,mass,frac.
19048	N106/99310850	X19/08964477	silty clayst. RB.unwthd,mass.
19049	N106/99310852	X19/08964479	silty clayst. RB.unwthd,mass,water sepng o'cp.
19050	N106/99300854	X19/08954481	silty clayst. RB.unwthd,mass,biv frag.
19051	N106/99290856	X19/08944483	silty clayst. RB.unwthd,mass.
19052	N106/99280856	X19/08934483	silty clayst. RB.unwthd,mass,biv frag.
19053	N106/99270858	X19/08924485	silty clayst. RB.unwthd,mass.

19054	N106/99260860	X19/08914487	fine silty sandst. RB.unwthd,mass,frac.
19055	N106/99240862	X19/08894489	clay siltst. LB.unwthd,mass,mod frac.
19056	N106/99230863	X19/08884490	clay siltst. LB.unwthd,mass.
19057	N106/99220864	X19/08874491	silty clayst. LB.unwthd,mass,mod frac.
19058	N106/99260872	X19/08914497	silty clayst. LB.unwthd,mass.
19059	N106/99280880	X19/08934506	sandy siltst. RB.unwthd,mass,mod frac.
19060	N106/99250878	X19/08904503	clay siltst. LB.unwthd,mass.
19061	N106/99260881	X19/08914507	clay siltst. RB.unwthd,mass.
19062	N106/99240879	X19/08894504	clay siltst. LB.unwthd,mass,mod frac.
19063	N106/99220880	X19/08874506	clay siltst. LB.unwthd,mass,mod frac.
19064	N106/99210880	X19/08864506	clay siltst. LB.unwthd,mass,mod frac.
19065	N106/99190882	X19/08844509	clay siltst. LB.unwthd,mass,(frac).
19066	N106/99170882	X19/08824509	clay siltst. LB.unwthd,mod frac, (Fe stn frac surf).
19067	N106/99160883	X19/08814510	silty clayst. RB.unwthd,mod frac.
19068	N106/99140883	X19/08794510	silty clayst. RB.unwthd,mod frac.
19069	N106/99130883	X19/08784510	clay siltst. RB.unwthd,mass,cem.
19070	N106/99110883	X19/08764510	silty clayst. RB.unwthd,mass,cem, (frac).
19071	N106/99100883	X19/08754510	clay siltst. RB.unwthd,mass,(frac).
19072	N106/99070883	X19/08734510	clay siltst. RB.unwthd,mass,frac.
19073	N106/99050883	X19/08714510	clay siltst. RB.unwthd,mass,frac.

19074	N106/99030883	X19/08694510	clay siltst. RB.unwthd,mass,(frac).
19075	N106/99020878	X19/08694503	clay siltst. LB.(wthd),mass,(frac), (Fe stn).
19076	N106/98990880	X19/08684506	clay siltst. LB.unwthd,mass,frac.
19077	N106/98980881	X19/08674507	clay siltst. LB.unwthd,mass,(frac).
19078	N106/98970882	X19/08864509	clay siltst. LB.unwthd,mass,(frac).
19079	N106/98960883	X19/08654510	clay siltst. LB.unwthd,mass,(frac).
19080	N106/98950883	X19/08644510	clay siltst. LB.unwthd,mass,(frac).
19081	N106/98960885	X19/08654512	clay siltst. RB.unwthd,mass,frac.
19082	N106/98950885	X19/08644512	clay siltst. RB.unwthd,mass,mod frac, Fe surf stn.
19083	N106/98940886	X19/08634513	siltst. RB.unwthd,mass,(frac), cem.
19084	N106/98930886	X19/08624513	clay siltst. RB.unwthd,mass,(frac), cem.
19085	N106/98920887	X19/08614514	clay siltst. RB.unwthd,mass,(frac), biv frag.
19086	N106/98910887	X19/08604514	clay siltst. RB.unwthd,mass,mod frac.
19087	N106/98900887	X19/08594514	clay siltst. RB.unwthd,mass,mod frac.
19088	N106/98880887	X19/08574514	clay siltst. RB.unwthd,wk bdd,mod frac.
19089	N106/98850884	X19/08544511	clay siltst. LB.unwthd,mass,cem.
19090	N106/98820884	X19/08514511	silty clayst. LB.unwthd,mass.
19091	N106/98790884	X19/08494511	clay siltst. LB.unwthd,wk bdd,(frac).

19092	N106/98730888	X19/08434515	silty clayst. LB.unwthd,mass,frac, Fe stn frac surf.
19093	N106/98700889	X19/08404516	silty clayst. LB.unwthd,mass,mod frac, (sl Fe stn).
19094	N106/98680889	X19/08384516	silty clayst. LB.unwthd,wk bdd,(frac).
19095	N106/98660890	X19/08364517	clay siltst. LB.unwthd,wk bdd,mod frac.
19096	N106/98750898	X19/08454525	clay siltst. RB.unwthd,mass,(frac).
19097	N106/98720898	X19/08424525	silty clayst. RB.unwthd,mass,frac, (sl Fe stn),biotur.
19098	N106/98700897	X19/08404524	silty clayst. RB.unwthd,wk bdd,frac, biotur.
19099	N106/98650896	X19/08354523	silty clayst. RB.unwthd,mass,frac, biotur.
19100	N106/98640896	X19/08344523	clay siltst. RB.unwthd,wk bdd,(frac).
19101	N106/98630895	X19/08334522	clay siltst. RB.unwthd,wk bdd,frac.
19102	N106/98610895	X19/08314522	clay siltst. RB.unwthd,mass,biotur.
19103	N106/98600894	X19/08304521	clay siltst. RB.unwthd,wk bdd,mod frac,biv frag.
19104	N106/98650894	X19/08294521	silty clayst. RB.unwthd,wk bdd,frac, (sl Fe stn).
19105	N106/98580894	X19/08284521	clayst. RB.unwthd,mass,frac.
19106	N106/98390889	X19/08144516	silty clayst. RB.unwthd,mass,frac, Fe stn frac surf.
19107	N106/98380888	X19/08134515	clay siltst. RB.unwthd,mass,frac, Fe stn frac surf.
19108	N106/98360888	X19/08114515	clay siltst. RB.unwthd,mass.

19109	N106/98340887	X19/08094514	clay siltst. RB.unwthd,mass,frac.
19110	N106/98330877	X19/0804514	clayst. RB.unwthd,mass,frac, Fe stn frac surf.
19111	N106/98320886	X19/08074513	clay siltst. RB.unwthd,mass,mod frac.
19112	N106/98320886	X19/08074513	clay siltst. RB.unwthd,wk bdd,mod frac,Fe stn frac surf.
19113	N106/98310885	X19/08064512	clay siltst. RB.unwthd,wk bdd,Fe stn frac surf.
19114	N106/98300884	X19/08054511	silty clayst. RB.unwthd,wk bdd,frac, Fe stn frac surf.
19115	N106/98290883	X19/08044510	clayst. RB.unwthd,wk bdd,frac, Fe stn frac surf.
19116	N106/98280882	X19/08034509	clayst. RB.unwthd,mass.(Fe surf o'cp stn).
19117	N106/98270881	X19/08024507	silty clayst. RB.unwthd,mass,(frac),Fe stn,biotur.
19118	N106/98170849	X19/07924476	silty clayst. LB.unwthd,bdd,(frac).
19119	N106/98160849	X19/07914476	silty clayst. LB.unwthd,bdd,(frac),Fe stn frac surf.
19120	N106/98150848	X19/07904475	fine sandst. LB.unwthd,(frac),cem.
19121	N106/98140848	X19/07984475	fine sandst. LB.(wthd),(frac),Fe stn.
19122	N106/98130848	X19/07884475	silty clayst. LB.unwthd,mass,mod frac, Fe stn frac surf.
19123	N106/98120848	X19/07874475	clay siltst. LB.unwthd,wk bdd,mod frac,biotur.
19124	N106/98110848	X19/07864475	silty clayst. LB.unwthd,wk bdd,mod frac,Fe stn frac surf.
19125	N106/98100848	X19/07854475	silty clayst. LB.unwthd,wk bdd,mod frac.

19126	N106/98090848	X19/07844475	clay siltst. LB.unwthd,wk bdd,mod frac.
19127	N106/98080849	X19/07834476	clay siltst. LB.unwthd,wk bdd,mod frac.
19128	N106/98070849	X19/07824476	silty clayst. LB.unwthd,wk bdd,mod frac.
19129	N106/98060849	X19/07814476	silty clayst. LB.unwthd,wk bdd,mod frac.
19130	N106/98060850	X19/07814477	silty clayst. LB.unwthd,wk bdd,frac.
19131	N106/98050850	X19/07804477	silty clayst. LB.unwthd,wk bdd,(frac), Fe stn frac surf.
19132	N106/98040850	X19/07794477	silty clayst. LB.unbwthd,mass,frac.
19133	N106/98030851	X19/07784478	silty clayst. LB.unwthd,wk bdd,mod frac,(Fe stn).
19134	N106/98020851	X19/07774478	clayst. LB.unwthd,wk bdd,(frac).
19135	N106/98010851	X19/07764478	silty clayst. LB.unwthd,mass,(frac), (Fe stn).
19136	N106/98010851	X19/07764478	silty clayst. LB.unwthd,wk bdd,mod frac,(Fe stn).
19137	N106/98000852	X19/07754478	clay siltst. LB.unwthd,mass,mod frac, biotur.
19138	N106/97980852	X19/07734479	clay siltst. LB.unwthd,mass,(frac), (Fe stn).
19139	N106/97970852	X19/07724479	clay siltst. LB.unwthd,mass,(frac), biotur.
19140	N106/97960852	X19/07714479	clay siltst. LB.unwthd,mass,(frac), Fe stn frac surf.
19141	N106/97959852	X19/07704479	clay siltst. LB.unwthd,mass,(frac), (Fe stn).

19142	N106/97940852	X19/07694479	silty clayst. LB.unwthd,mass,mod frac, Fe stn,biotur,biv frag.
19143	N106/97930852	X19/07684479	clay siltst. LB.unwthd,wk bdd,mod frac.
19144	N106/97920853	X19/07674480	clay siltst. LB.unwthd,wk bdd,(frac), (Fe stn),biotur.
19145	N106/97910854	X19/07664481	clay siltst. LB.unwthd,mass,(frac), (Fe stn),biotur.
19146	N106/87890855	X19/07654482	clay siltst. LB.unwthd,mass,(frac), (Fe stn frac surf).
19147	N106/97880856	X19/07644483	clay siltst. LB.unwthd,wk bdd,(frac), biotur.
19148	N106/97870856	X19/07634483	clay siltst. LB.unwthd,mass,frac.
19149	N106/97860857	X19/07624484	clay siltst. LB.unwthd,wk bdd,(frac), (Fe stn frac surf).
19150	N106/97850858	X19/07624485	silty clayst. LB.unwthd,mass,(frac), (Fe stn frac surf).
19151	N106/97840859	X19/07614486	silty clayst. LB.unwthd,mass,frac, Fe stn frac surf.
19152	N106/97830860	X19/07604487	clay siltst. LB.unwthd,mass,frac, (Fe stn frac surf).
19153	N106/97820861	X19/07604488	silty clayst. LB.unwthd,mass,frac, Fe stn frac surf.
19154	N106/97820863	X19/07604490	silty clayst. LB.unwthd,mass,frac.
19155	N106/97810864	X19/07594491	clay siltst. LB.unwthd,mass,frac.
19156	N106/97590870	X19/07394497	clay siltst. LB.unwthd,wk bdd,frac, (Fe stn frac surf).
19157	N106/97590869	X19/07394496	clay siltst. LB.unwthd,wk bdd,(frac).
19158	N106/97580869	X19/09384496	clay siltst. LB.unwthd,mass,(frac),

19159	N106/97570870	X19/07374497	clay siltst. LB.unwthd,mass,(frac).
19160	N106/97560870	X19/07364497	clay siltst. LB.unwthd,mass,frac.
19161	N106/97550871	X19/07354498	clay siltst. LB.unwthd,wk bdd,(frac).
19162	N106/97530871	X19/0718879498	clay siltst. LB.unwthd,wk bdd,(frac).
19163	N106/97510872	X19/0718899499	clay siltst. LB.unwthd,mass,frac,cem, biotur.
19164	N106/07490872	X19/07304499	clay siltst. LB.unwthd,mass,frac, cem,biotur.
19165	N106/97480874	X19/0718899501	silty clayst. RB.unwthd,wk bdd,(frac), biotur.
19166	N106/97470872	X19/0718889499	clay siltst. LB.unwthd,mass,(frac), biotur.
19167	N106/97450872	X19/07304499	clay siltst. LB.unwthd,mass,(frac).
19168	N106/97420872	X19/07274499	clay siltst. LB.unwthd,mass,(frac), biotur.
19169	N106/97400873	X19/07254500	clay siltst. LB.unwthd,mass(frac), biotur.
19170	N106/97370874	X19/07224501	clay siltst. LB.unwthd,mass,frac, Fe stn frac surf.
19171	N106/9718883874	X19/07184501	clay siltst. LB.unwthd,mass,frac, Fe stn frac surf.
19172	N106/97310876	X19/07164503	clay siltst. LB.unwthd,mass,(frac), Fe stn frac surf.
19173	N106/97290876	X19/07144503	clay siltst. LB.unwthd,mass,(frac).
19174	N106/97280879	X19/07134506	clay siltst. RB.unwthd,mass,(frac).
19175	N106/97260880	X19/07114507	clay siltst. RB.unwthd,mass,(frac).

19176	N106/97240880	X19/07094507	clay siltst. RB.unwthd,mass,(frac), Fe stn frac surf.
19177	N106/97230880	X19/07084507	clay siltst. RB.unwthd,mass,frac, Fe stn frac surf.
19178	N106/97210880	X19/07064507	clay siltst. RB.unwthd,mass.
19179	N106/97190877	X19/07044504	clay siltst. RB.unwthd,wk bdd.
19180	N106/97170876	X19/07024503	clay siltst. RB.unwthd,bdd,(frac).
19181	N106/97150874	X19/07014501	clay siltst. RB.unwthd,mass.
19182	N106/97108712	X19/06994499	clay siltst. RB.unwthd,wk bdd,(frac), biotur.
19183	N106/97110871	X19/06974498	clay siltst. RB.unwthd,wk bdd,frac, surf Fe stn,biotur.
19184	N106/97070870	X19/06934497	clay siltst. RB.unwthd,gr bd.
19185	N106/97040870	X19/06894497	clay siltst. RB.unwthd,inter bdd tuf, biotur.
19186	N106/97010871	X19/06864498	clay siltst. RB.unwthd,bdd,(frac), biotur.
19187	N106/96990872	X19/06844499	clay siltst. RB.unwthd,wk bdd,(frac).
19188	N106/96970874	X19/06824501	silty fine sandst. RB.unwthd,wk bdd,(frac), carb.
19189	N106/96950877	X19/06804504	clay siltst. RB.unwthd,mass,(frac).
19190	N106/96940881	X19/06794508	clay siltst. RB.unwthd,mass,frac, Fe stn frac surf,biotur.
19191	N106/96930887	X19/06784413	silty clayst. RB.unwthd,mass,(frac), biotur.
19192	N106/96920890	X19/06774416	sandy siltst. RB.unwthd,bdd,(frac), biotur.

19193	N106/96920894	X19/06774421	sandy siltst. RB.unwthd,mass,(frac), biotur.
19194	N106/96900891	X19/06754417	clay siltst. LB.unwthd,grd bd,(frac).
19195	N106/96900895	X19/06754422	clay siltst. LB.unwthd,grd bd,(frac).
19196	N106/96870913	X19/06714540	clay siltst. RB.unwthd,bdd,(frac), biotur.
19197	N106/96870918	X19/06714545	clay siltst. RB.unwthd,mass,frac,Fe stn frac surf,biotur.
19198	N106/96850924	X19/06694551	clay siltst. RB.unwthd,mass,frac,Fe stn frac surf,biotur.
19199	N106/96810923	X19/06664550	clay siltst. LB.unwthd,mass,frac,Fe stn frac surf,biotur.
19200	N106/96800926	X19/06654553	clay siltst. LB.unwthd,mass,frac,Fe stn frac surf,biotur.
19201	N106/96790929	X19/06644556	sandy siltst. LB.unwthd,mass,frac, Fe stn frac surf.
19202	N106/96680937	X19/00574562	sandy siltst. RB.unwthd,grd bd,cem.
19203	N106/96680937	X19/06574562	sandst. RB.unwthd,bdd,frac.
19204	N106/96680937	X19/06574562	sandst. RB.unwthd,bdd,frac.
19205	N106/96670937	X19/06564562	sandst. RB.unwthd,bdd,(frac).
19206	N106/96670937	X19/06564562	sandst.(glc). RB.unwthd,mass.
19207	N106/96670937	X19/06564562	sandst.(glc). RB.unwthd,mass.
19208	N106/966770937	X19/06564562	sandst.(glc). RB.unwthd,mass.

APPENDIX 2: BEDDING ATTITUDES FOR TECTONIC CORRECTION

The Mangapoike River is on the eastern limb of the Wairoa Syncline, with bedding attitudes striking north/south and dipping 24-30°. A simple tectonic correction about strike is assumed. Bedding attitudes for individual site corrections are given below:

18870 - 18884	199/W/25
18885 - 18926	193/W/25
18927 - 18954	193/W/24
18955 - 18981	192/W/24
18982 - 18995	191/W/25
18996 - 19045	186/W/25
19046 - 19116	186/W/27
19117 - 19131	185/W/30
19132 - 19144	185/W/29
19145 - 19173	186/W/30
19174 - 19185	189/W/30
19186 - 19199	181/W/27
19200 - 19208	183/W/26

APPENDIX 3: MAGNETOMINERALOGY SAMPLES

Stratigraphic Datum = Top of Makaretu Sandstones

VUW No	Stratigraphic Height (m)	Comments
19210	346	fine medium sandst.
19211	730	well cemented medium-coarse sandst.
19212	745	well cemented medium-coarse sandst.
19213	1257	medium-fine sandst.
19214	1465	coarse-medium sandst.
19215	1519	medium-coarse sandst.
19216	1763	medium-fine sandst.
19217	1998	fine-medium sandst.
19218	2071	medium sandst.
19219	2150	medium-fine sandst.

APPENDIX 4: ISOTHERMAL REMANENT DATA

Units of magnetisation x 10^{-4} Am^{-1}

FIELD (mT)	SPECIMENS					
	19012.41	19012.42	19036.51	19036.52	19041.51	19041.52
0	2.3	3.5	7.3	2.3	2.7	4.8
25	40.7	46.2	33.5	33.6	246	219
50	88	101	75.2	76.8	1694	1348
75	115	133	103	104	3187	2507
100	127	138	107	112	3854	3162
125	.	146	114	116	3957	.
150	137	138	118	116	3927	3618
200	141	145	118	117	3986	3620
250	143	145	116	117	4010	3709
300	144	146	116	113	4077	3748
500	145	153	124	120	4252	3819
750	146	156	126	118	4276	3857
1000	147	159	128	118	4252	3856
1250	147	159	126	119	4275	3868
1500	149	.	.	.	.	3894

FIELD (mT)	SPECIMENS					
	19044.21	19044.22	19066.2	19067.1	19097.1	19097.2
0	4.8	2.4	1.5	4.2	2.0	1.8
25	39.7	39	47.9	47.9	49.8	52.1
50	93	81	187	174	169	169
75	129	122	377	337	313	309
100	150	141	466	423	401	393
125	160	.	.	455	.	.
150	165	157	524	474	456	451
200	173	156	549	490	473	478
250	171	159	575	489	477	495
300	175	160	578	500	484	496
500	179	162	576	507	491	494
750	177	163	580	503	490	497
1000	179	163	583	513	497	504
1250	177	164	581	510	498	509
1500	174	165	581	508	497	520

FIELD (mT)	SPECIMENS				
	19105.1	19103.1	19152.3	19152.4	19014.3
0	3.7	0.1	0.1	3.7	2.5
25	83	32.9	31.1	29.9	40
50	89	69	69	64	87
75	118	92	94	87	106
100	136	101	107	101	119
125	.	107	116	108	.
150	151	103	124	115	129
200	151	113	131	121	131
250	157	113	133	123	131
300	158	116	138	127	133
500	160	118	143	130	134
750	162	117	141	130	135
1000	161	120	144	132	135
1250	162	119	145	133	136
1500	163	119	144	131	136

APPENDIX 5: ELECTRON MICROPROBE ANALYSES

Detrital Titanomagnetite Analyses

Sample	19210	19210	19210	19211	19211	19211
SiO2	0.07	0.00	0.00	0.00	0.00	0.00
TiO2	9.82	8.44	8.71	8.56	9.57	7.75
Al2O3	3.11	4.29	3.01	3.94	3.17	2.98
Fe2O3	47.47	48.91	50.11	49.79	48.80	52.25
FeO	34.82	33.56	35.04	3.56	35.16	34.30
MnO	0.65	0.55	0.72	0.63	0.68	0.53
MgO	3.31	3.42	2.56	3.58	2.67	2.64
Total	99.26	99.17	100.15	100.06	100.85	100.46
Usp/Mt	0.27	0.24	0.24	0.24	0.27	0.22
Grainsize (microns)	409	226	181	95	84	76

Sample	19211	19211	19211	19212	19213	19213
SiO2	0.07	0.07	0.00	0.10	0.07	0.00
TiO2	9.21	9.72	8.67	10.57	8.84	12.84
Al2O3	4.05	3.11	4.47	1.53	3.24	1.45
Fe2O3	48.35	47.61	48.56	46.12	49.29	42.04
FeO	34.52	34.61	33.40	38.06	34.01	39.81
MnO	0.48	0.65	0.59	2.48	0.63	2.84
MgO	3.46	3.31	3.70	0.28	3.30	0.19
Total	100.08	99.17	99.39	99.14	99.38	99.17
Usp/Mt	0.27	0.24	0.25	0.31	0.25	0.37
Grainsize (microns)	59	50	32	171	342	305

Sample	19213	19213	19214	19214	19214	19214
SiO2	0.70	0.00	0.09	0.10	0.00	0.08
TiO2	10.35	11.07	7.31	7.98	11.03	9.86
Al2O3	0.71	0.64	3.57	1.94	0.76	3.24
Fe2O3	47.41	47.90	52.09	51.28	48.16	47.30
FeO	38.64	38.38	34.18	36.47	38.43	35.11
MnO	0.92	0.79	0.69	2.10	0.82	0.53
MgO	1.43	1.53	2.49	0.24	1.56	3.28
Total	100.16	100.32	100.41	100.11	100.76	99.40
Usp/Mt	0.29	0.30	0.21	0.24	0.30	0.28
Grainsize (microns)	99	87	109	67	62	42

Detrital Titanomagnetite Analyses

Sample	19215	19217	19217	19217	19217	19217
SiO2	0.12	0.00	0.10	0.10	0.09	0.10
TiO2	11.23	7.21	9.73	6.98	7.25	7.28
Al2O3	1.59	3.47	1.72	1.78	2.68	2.76
Fe2O3	45.01	52.26	48.07	52.83	51.93	51.51
FeO	38.96	33.96	38.18	35.20	35.23	35.10
MnO	2.37	0.57	2.00	2.21	0.82	0.93
MgO	0.28	2.46	0.21	0.21	1.37	1.35
Total	99.56	99.94	100.01	99.31	99.37	99.03
Usp/Mt	0.33	0.21	0.29	0.21	0.22	0.22
Grainsize (microns)	74	410	138	81	64	38

Sample	19217	19217	19218	19219	19219	19219
SiO2	0.07	0.00	0.10	0.00	0.05	0.00
TiO2	11.35	5.87	9.41	11.93	9.65	11.29
Al2O3	0.69	3.52	1.59	1.51	3.07	0.57
Fe2O3	46.65	55.30	48.25	43.93	47.78	47.64
FeO	38.60	32.63	37.02	39.00	34.65	38.55
MnO	0.95	0.72	2.39	2.78	0.79	0.84
MgO	1.40	2.56	0.31	0.26	3.19	1.54
Total	99.71	100.60	99.06	99.41	99.18	100.43
Usp/Mt	0.31	0.17	0.28	0.35	0.27	0.31
Grainsize (microns)	428	315	73	263	243	156

Tuff Titanomagnetite Analyses

Sample	G/55	G/55	G/55
SiO2	0.07	0.18	0.11
TiO2	6.43	7.73	7.33
Al2O3	1.22	1.39	1.23
Fe2O3	54.65	51.91	52.45
FeO	35.85	37.26	36.72
MnO	0.88	0.21	0.93
MgO	0.15	0.21	0.14
Total	99.19	99.70	98.91
Usp/Mt	0.19	0.23	0.22
Grainsize (microns)	325	226	181

Detrital Ilmenite Analyses (Representitative)

Sample	19219	19219	19211	19211	19211	19211
SiO2	0.07	0.00	0.00	0.00	0.00	0.00
TiO2	48.35	42.27	52.02	52.40	43.06	47.15
Al2O3	0.08	0.21	0.01	0.00	0.09	0.21
Fe2O3	8.21	21.66	0.27	0.13	19.65	11.75
FeO	40.22	33.48	44.71	45.39	34.99	37.87
MnO	0.98	0.41	2.04	1.39	0.48	1.13
MgO	1.19	2.31	0.00	0.18	1.82	1.90
Total	99.14	100.34	99.06	99.49	100.09	100.01
Il/Hmt	0.92	0.78	0.99	0.99	0.81	0.88

Sample	19212	19212	19213	19213	19217	19217
SiO2	0.00	0.00	0.00	0.00	0.00	0.31
TiO2	42.96	41.99	39.01	50.88	50.75	44.23
Al2O3	0.30	0.29	0.19	0.05	0.00	0.29
Fe2O3	21.07	21.75	27.94	3.60	3.78	16.81
FeO	32.14	33.81	30.52	44.40	44.19	35.73
MnO	0.76	0.47	1.02	0.67	0.74	0.24
MgO	3.21	1.95	1.98	0.38	0.39	2.34
Total	100.44	100.26	100.66	99.98	99.85	99.95
Il/Hmt	0.78	0.79	0.99	0.99	0.96	0.83

Sample	19217	19218
SiO2	0.00	0.00
TiO2	44.69	43.51
Al2O3	0.16	0.10
Fe2O3	15.92	19.44
FeO	35.84	35.24
MnO	0.37	0.39
MgO	2.23	1.96
Total	99.20	100.64
Il/Hmt	0.84	0.81

Sulphide Analyses (Representitative Pyrite)

Sample	19211	19211	19212	19212	19213	19213
Fe	44.39	46.04	45.29	44.73	45.34	44.76
S	54.07	53.75	53.38	54.57	53.20	54.12
Mn	0.72	0.69	0.33	0.62	0.68	0.48
Total	99.18	100.48	99.00	99.92	99.22	99.36

Sample	19214	19214	19215	19215	19216	19216
Fe	44.49	45.49	44.74	46.11	45.37	45.78
S	54.63	53.64	54.56	53.68	53.30	53.29
Mn	0.31	0.54	0.51	0.59	0.63	0.41
Total	99.43	99.67	99.82	100.38	99.30	99.48

Sample	19217	19217	19218	19218	19219	19219
Fe	44.60	44.85	45.34	46.07	45.82	44.70
S	53.94	54.61	54.70	53.59	53.84	54.03
Mn	0.54	0.39	0.42	0.57	0.59	0.66
Total	99.08	99.85	100.46	100.23	100.25	99.39

APPENDIX 6: THERMAL PILOT DEMAGNETISATION DATA

SPEC.	PLUNGE/ AZIMUTH	NRM D	NRM I	NRM J(A/m)	100 C D	100 C I	100 C J(A/m)	150 C D	150 C I	150 C J(A/m)	200 C D	200 C I	200 C J(A/m)
18998.11	31 050	095	-40	5.7E-04	083	-42	4.5E-04	058	-44	3.3E-04	056	-37	2.3E-04
18998.12	31 050	107	-54	7.0E-04	109	-55	5.7E-04	071	-73	3.1E-04	074	-76	2.3E-04
19000.41	26 036	088	-61	1.3E-03	085	-72	9.9E-04	074	-83	6.7E-04	063	-84	5.7E-04
19000.42	26 036	074	-33	1.7E-03	068	-32	1.3E-03	060	-35	1.0E-03	028	-66	7.8E-04
19010.31	19 310	048	-32	8.6E-04	047	-35	7.2E-04	045	-40	5.3E-04	026	-60	3.4E-04
19010.32	19 310	041	-34	8.5E-04	040	-43	5.7E-04	035	-54	3.5E-04	046	-79	3.0E-04
19012.11	25 309	050	-35	8.7E-04	359	-45	7.8E-04	029	-56	3.6E-04	030	-77	3.4E-04
19012.12	25 309	042	-28	8.7E-04	041	-23	7.2E-04				029	-56	3.5E-04
19019.2	31 124	112	-29	2.3E-04	110	-20	2.0E-04	073	22	1.7E-04	072	15	1.4E-04
19032.3	43 256	357	-44	4.2E-04	357	-45	4.0E-04	137	-68	2.3E-05	226	42	5.0E-05
19034.2	35 066	107	-42	4.3E-04				068	03	3.5E-05	076	10	3.5E-05
19048.1	59 111	238	53	2.0E-03	238	53	1.9E-03	238	55	1.9E-03	235	53	1.9E-03
19048.4	53 085	219	63	1.9E-03	222	64	1.8E-03				228	65	1.6E-03
19061.4	39 093	080	-28	9.6E-05	071	-32	9.3E-05	083	-18	7.4E-05	204	70	1.7E-04
19062.3	49 271	162	-22	5.0E-04	016	-40	5.0E-04	163	-20	1.3E-04	176	-10	5.0E-04
19094.21	34 317	075	-25	1.7E-04	078	-25	1.5E-04	080	-17	1.3E-04	176	62	7.9E-05
19094.22	34 317	081	-12	1.1E-04	082	-12	9.7E-05	105	29	5.6E-05	182	72	1.2E-04

SPEC.	250 C D	250 C I	250 C J(A/m)	300 C D	300 C I	300 C J(A/m)	320 C D	320 C I	320 C J(A/m)
18998.11	021	-62	1.4E-04	064	-38	9.6E-05	065	-38	4.7E-05
18998.12	070	-66	1.5E-04	054	-65	8.8E-05			
19000.41	055	-81	4.4E-04	009	-80	3.0E-04			
19000.42	043	-65	5.9E-04	046	-49	3.5E-04	047	-48	1.7E-04
19010.31	026	-62	2.3E-04	027	-68	1.9E-04			
19010.32	039	-62	2.3E-04	034	-73	1.9E-04			
19012.12	035	-60	2.7E-04	033	-62	2.1E-04			
19012.11	028	-62	2.9E-04	033	-55	2.4E-04	033	-55	1.2E-05
19019.2	076	39	1.6E-04	028	34	1.1E-04	016	31	7.9E-05
19032.3	202	46	6.6E-05	206	42	1.1E-04	193	46	5.5E-05
19034.2	104	63	4.5E-05	220	62	3.6E-05	205	63	2.2E-05
19048.1	239	52	1.6E-03	235	57	1.0E-03	236	57	5.3E-04
19048.4	225	66	1.5E-03	236	69	1.1E-03			
19061.4	219	57	1.6E-04	201	70	1.0E-04	211	50	7.1E-05
19062.3	180	-17	4.2E-04	182	-13	4.9E-04			
19094.21	218	61	1.0E-04	224	62	5.1E-05			
19094.22	190	78	1.2E-04	201	42	1.1E-04			

APPENDIX 7: AF PILOT DEMAGNETISATION DATA

SPEC.	PLUNGE/ AZIMUTH	NRM D	NRM I	NRM M(A/m)	5 mT D	5 mT I	5 mT M(A/m)	10 mT D	10 mT I	10 mT M(A/m)	15 mT D	15 mT I	15 mT M(A/m)
19012.41	44 302	036	-41	6.8E-04	031	-44	5.2E-04	031	-49	4.4E-04	029	-50	3.4E-04
19012.42	44 302	051	-50	6.2E-04	052	-53	5.2E-04	046	-50	4.2E-04	044	-51	3.4E-04
19030.2	23 309	021	-46	4.6E-04	034	-78	2.1E-04	087	-57	1.5E-04	105	-37	9.6E-05
19032.1	20 160	010	-82	2.8E-04	041	-87	2.1E-04	061	-76	1.6E-04	058	-75	1.3E-04
19037.21	33 011	041	-56	2.3E-04	048	-60	1.1E-04	068	-54	9.7E-05	054	-44	8.4E-05
19037.22	33 011	067	-32	2.0E-04	033	-56	9.8E-05	088	-87	8.5E-05	045	-74	6.8E-05
19061.1	34 101	074	-67	5.4E-04	082	-63	4.1E-04	090	-59	2.9E-04	098	-63	1.8E-04
19080.3	49 198	067	-72	8.7E-05	074	-47	6.5E-05	095	-42	5.1E-05	109	-38	4.4E-05
19085.1	38 091	068	-35	3.6E-04	058	-43	1.6E-04	075	-35	1.1E-04	091	-27	8.7E-05
19088.4	36 098	031	-58	1.1E-03	046	-61	8.1E-04	054	-48	6.6E-04	020	-30	4.4E-04
19094.11	45 086	101	-33	1.5E-04	094	-21	1.0E-04	108	-23	6.5E-05	133	-14	4.5E-05
19094.12	45 086	153	-30	2.1E-04	139	-25	1.3E-04	149	-16	6.8E-05	126	-16	4.7E-05
19094.41	39 086	223	41	4.3E-03	224	45	4.3E-03	224	49	4.2E-03	226	51	3.9E-03
19094.42	39 086	202	52	3.8E-03	200	56	3.9E-03	204	56	4.0E-03	199	58	4.0E-03
19103.1	49 106	079	-60	2.1E-04	062	-45	1.1E-04	056	-37	5.7E-05	085	-18	2.9E-05
19105.1	35 069	088	-20	1.9E-04	059	-19	1.3E-04	052	-28	9.3E-05	047	-25	7.5E-05

SPEC.	20 mT D	20 mT I	20 mT M(A/m)	25 mT D	25 mT I	25 mT M(A/m)	30 mT D	30 mT I	30 mT M(A/m)	35 mT D	35 mT I	35 mT M(A/m)
19012.41	028	-53	2.8E-04	030	-54	2.2E-04	030	-53	2.0E-04	028	-54	1.6E-05
19012.42	037	-51	2.6E-04	038	-44	2.5E-04	037	-49	2.0E-05	040	-50	1.6E-05
19030.2	055	-66	8.0E-05	130	-87	7.3E-05	048	-40	5.6E-05			
19032.1	070	-67	1.0E-04	216	-82	5.9E-05	121	-38	3.4E-05	141	-20	2.1E-05
19037.21	080	-39	6.8E-05	115	-32	5.0E-05	141	-28	4.2E-05	158	-12	3.2E-05
19037.22	013	-29	5.4E-05	099	-76	4.9E-05	142	-46	3.0E-05			
19061.1	119	-46	8.9E-05	130	-35	6.4E-05	138	-31	4.9E-05	150	-28	2.8E-05
19080.3	127	-38	3.4E-05	150	-21	2.7E-05	165	-17	1.9E-05			
19085.1	091	-27	8.7E-05	110	-23	6.5E-05	135	-21	4.7E-05	141	-19	2.5E-05
19088.4	120	-67	2.2E-04	078	-46	1.0E-04	025	-34	8.4E-05	084	-67	6.2E-05
19094.11	145	-29	2.6E-05	155	-29	5.1E-05	155	-33	2.4E-05	159	-31	1.7E-05
19094.12	091	-28	4.4E-05	080	-23	4.3E-05	122	-20	2.1E-05			
19091.41	236	50	3.6E-03	243	51	3.8E-03	241	50	3.5E-03	241	53	2.7E-03
19091.42	203	60	4.1E-03	201	60	3.3E-03	205	60	3.3E-04	202	61	1.9E-03
19103.1	067	-29	1.8E-05	115	-17	3.7E-05						
19105.1	041	-31	3.7E-05	056	-32	2.1E-05						

APPENDIX 8: GENERAL DEMAGNETISATION DATA

The general demagnetisation data is presented in this appendix. Remanence measurements for each specimen are given as declination (D), inclination (I) and magnetisation intensity (M), and are corrected for tectonic tilt (Appendix 2). Only the NRM data is given for those specimens rejected from the analysis following the criteria in chapters 3 and 4. The optimum remanence data for each specimen is marked by an asterisk.

SPEC.	PLUNGE/ AZIMUTH		NRM D	I	M(A/m)	150 D	I	M(A/m)	200 D	I	M(A/m)	250 D	I	M(A/m)	300 D	I	M(A/m)	320 D	I	M(A/m)
18870.21	51	312	038	-71	4.8E-04				151	-73	7.8E-05	227	-45	8.1E-05	224	-06	1.4E-04	*212	47	5.9E-05*
18870.22	51	312	048	-69	5.1E-04				206	-79	9.5E-05	214	-30	7.0E-05	173	-72	1.2E-04	*212	48	6.1E-05*
18870.3	52	293	089	-48	4.1E-04				076	-76	9.5E-05	162	-36	4.2E-05	287	89	5.4E-05	*313	89	2.6E-05*
18871.1	39	279	058	-23	3.5E-04				115	-70	8.5E-05	076	-68	8.7E-05	222	25	9.1E-05	*218	27	4.6E-05*
18871.21	29	300	004	-31	3.9E-04				009	-46	1.2E-04	292	-23	5.3E-05	*239	64	4.4E-05*	241	10	7.6E-05
18871.22	29	300	359	-26	3.9E-04				029	-55	6.7E-05	260	-09	1.1E-04	221	28	4.5E-05	*228	39	2.7E-05*
18872.21	36	300	047	-13	2.3E-04				106	-35	7.3E-05	291	37	1.2E-04	*241	61	6.0E-05*			
18872.22	36	300	073	-17	3.0E-04				188	-39	3.4E-05	185	72	4.4E-05	*187	72	2.2E-05*			
18872.31	38	310	010	-43	3.7E-04				282	-82	8.7E-05	225	10	2.8E-05	*261	56	2.3E-05*	179	10	5.0E-05
18872.32	38	310	020	-40	3.8E-04															
18873.1	40	348	084	-18	2.2E-04				075	-37	9.5E-05	077	44	9.2E-05	*237	45	2.9E-05*			
18873.31	42	341	056	-70	3.1E-04				078	-65	8.5E-05	055	-52	6.4E-05	*238	53	5.5E-05*			
18873.32	42	341	069	-65	4.6E-04				063	-82	1.4E-04	042	-48	8.6E-05	*236	55	5.9E-05*	240	57	4.3E-05
18874.21	63	207	111	-39	3.3E-04				134	-27	9.7E-05	203	15	2.4E-05	*203	16	2.3E-05*			
18874.22	63	207	109	-42	2.8E-04				129	-38	1.1E-04	132	-17	8.4E-05	*193	18	5.8E-05*			
18874.31	71	223	035	-44	2.7E-04				110	-44	3.2E-05	038	50	5.0E-05	*222	19	3.8E-05*			
18874.32	71	223	056	-36	3.3E-04															
18875.2	45	309	075	-41	3.4E-04															
18875.3	63	336	056	-31	3.3E-04															
18875.41	64	329	012	-66	3.7E-04															
18875.42	64	329	002	-59	3.9E-04															
18876.1	57	111	095	-43	2.2E-04				147	-88	4.9E-05	288	-53	7.4E-05	241	74	7.5E-05	*239	72	3.8E-05*
18876.2	63	191	048	-64	2.7E-04				152	-22	5.5E-05	054	45	2.1E-04	263	69	8.4E-04	*262	64	1.2E-04*
18876.3	62	112	135	-56	2.7E-04				240	-47	6.0E-05	142	-15	1.5E-04	236	41	1.7E-04	*225	49	8.3E-05*
18877.1	52	140	089	-47	1.3E-03				068	-40	5.6E-04	024	-54	4.5E-04	*046	-11	1.7E-04*			
18877.2	54	174	054	-44	1.3E-03				084	-42	5.0E-04	078	-27	5.1E-04	*081	-36	4.4E-04*			
18877.3	59	146	075	-70	9.0E-04				043	-47	5.0E-04	043	-23	5.6E-04	*053	-32	3.3E-04*	043	-64	3.4E-04
18878.2	59	113	089	-75	8.1E-04				061	-61	4.9E-04	072	-53	3.9E-04	038	-51	3.1E-04			
18878.3	70	153	079	-57	1.1E-03				068	-67	4.3E-04	091	-62	4.0E-04	042	-59	3.1E-04			
18878.4	73	130	051	-60	8.8E-04				051	-68	4.3E-04	076	-69	3.6E-04	*104	-74	3.8E-04*			
18879.21	63	151	359	-68	7.1E-04				058	-59	4.1E-04	*053	-60	3.8E-04*	044	-28	2.2E-04	059	-57	1.9E-04
18879.22	63	151	330	-69	7.1E-04				014	-77	3.8E-04	066	-83	2.9E-04	*047	-79	1.4E-04*	066	-83	2.9E-04
18879.31	61	144	108	-59	6.0E-04				035	-53	2.7E-04	026	-52	2.6E-04	*045	-54	1.8E-04*			
18879.32	61	144	131	-48	5.4E-04															
18880.1	43	081	108	-43	1.3E-03				116	-51	6.6E-04	107	-49	4.6E-04	139	-41	3.6E-04	*113	-47	1.9E-04*
18880.2	48	080	092	-54	1.3E-03															
18880.31	50	068	129	-69	1.1E-03				074	-70	4.5E-04	057	-77	3.7E-04	055	-70	3.2E-04	*058	-75	2.6E-04*
18880.32	50	068	123	-66	1.1E-03				068	-65	4.9E-04	047	-68	3.7E-04	*019	-73	2.4E-04*			
18881.11	66	096	067	-45	5.2E-04															
18881.12	66	096	049	-30	8.3E-04															
18881.3	63	082	035	-48	9.4E-04															
18882.21	69	154	058	-73	9.5E-04				025	-68	4.7E-04				061	-54	2.7E-04	*037	-63	2.8E-04*
18882.22	69	154	045	-75	1.0E-03				043	-68	4.7E-04	015	-76	3.7E-04	*029	-67	3.5E-04*	076	-45	1.3E-04
18882.3	68	166	073	-59	1.1E-03				074	-63	4.7E-04	086	-57	3.3E-04	077	-80	4.0E-04	*043	-63	3.2E-04*
18882.4	64	135	059	-70	1.0E-03				063	-59	4.9E-04	*061	-51	4.1E-04*	052	-52	3.9E-04	038	-46	3.0E-04
18883.1	72	126	070	-52	1.0E-03				053	-56	5.0E-04	057	-58	4.0E-04	*033	-67	3.3E-04*	040	-65	3.4E-04
18883.2	72	123	082	-72	9.1E-04				068	-58	5.2E-04	053	-64	4.1E-04	077	-70	4.0E-04	*064	-60	3.4E-04*
18883.3	69	127	057	-53	1.1E-03				051	-52	5.1E-04	052	-48	3.9E-04	072	-56	4.0E-04	*054	-51	2.6E-04*
18884.1	44	090	074	-50	1.5E-03				060	-52	9.8E-04	044	-55	8.4E-04	*069	-50	7.2E-04*	048	-56	6.2E-04
18884.2	56	115	100	-71	1.5E-03				064	-62	1.1E-03	057	-59	8.5E-04	*062	-57	7.1E-04*	040	-60	6.6E-04
18884.3	52	107	071	-48	1.8E-03				070	-54	9.4E-04	*051	-58	7.7E-04*	047	-51	6.9E-04			
18885.11	49	082	066	-61	2.0E-03				053	-61	1.2E-03	*049	-60	9.3E-04*	048	-61	7.6E-04			
18885.12	49	082	063	-58	1.6E-03				041	-59	8.4E-04	048	-55	7.3E-04	*034	-55	5.5E-04*			
18885.2	53	062	067	-62	1.7E-03				051	-59	9.4E-04	*049	-61	7.2E-04*	052	-58	6.4E-04			
18886.1	65	154	069	-63	1.6E-03				055	-58	8.1E-04	048	-56	7.5E-04	059	-58	6.4E-04	*049	-60	4.6E-04*
18886.21	59	132	072	-62	2.1E-03				042	-60	1.1E-03	*057	-63	9.0E-04*	064	-58	6.7E-04			
18886.22	59	132	064	-62	1.6E-03				041	-57	7.6E-04	027	-58	6.9E-04	*040	-65	6.0E-04*			
18886.3	60	128	068	-63	2.0E-03				060	-64	9.2E-04	075	-60	7.8E-04	*073	-67	7.5E-04*			
18887.1	58	131	076	-56	1.6E-03				076	-50	7.3E-04	055	-45	5.7E-04	*064	-48	4.9E-04*			
18887.2	64	178	112	-59	1.7E-03				107	-48	7.5E-04	089	-43	6.6E-04	*109	-43	4.8E-04*			
18887.3	71	114	055	-77	1.8E-03				070	-50	7.9E-04	086	-49	6.3E-04	*085	-61	5.3E-04*			
18888.1	60	141	072	-65	1.6E-03				063	-59	8.6E-04	060	-55	7.6E-04	*069	-61	6.3E-04*			
18888.21	64	079	074	-51	1.4E-03				064	-53	6.3E-04	062	-41	5.6E-04	*071	-37	4.3E-04*	063	-51	3.7E-04
18888.22	64	079	070	-58	1.9E-03				060	-55	1.0E-03	*059	-55	7.4E-04*	084	-59	5.5E-04	060	-41	2.8E-04
18888.3	62	133	065	-61	1.5E-03				054	-51	7.4E-04	045	-56	5.7E-04	044	-62	3.8E-04	*044	-57	2.9E-04*
18889.11	73	062	055	-60	3.4E-03				045	-60	2.1E-03	045	-61	1.8E-03	*049	-59	1.3E-03*			
18889.12	73	062	053	-58	3.4E-03				032	-65	2.2E-03	025	-66	1.6E-03	*022	-67	1.3E-03*			
18889.2	62	105	036	-59	3.0E-03				045	-57	1.7E-03	038	-58	1.2E-03	*047	-64	8.4E-04*			
18889.3	76	127	046	-54	2.1E-03				051	-53	1.0E-03	055	-56	7.3E-04	038	-58	5.6E-04	*039	-58	2.9E-04*
18890.1	62	024	064	-52	1.8E-03				050	-50	8.2E-04	047	-56	6.4E-04	069	-54	5.3E-04	*050	-55	3.1E-04*
18890.2	66	056	062	-56	2.2E-03				054	-55	1.1E-03	046	-55	8.5E-04	*044	-59	7.5E-04*			
18890.3	69	062	064	-55	2.0E-03				049	-52	1.0E-03	036	-47	6.5E-04	007	-77	1.2E-03	*030	-46	2.8E-04*
18891.11	67	051	053	-60	2.0E-03				038	-56	1.3E-03	040	-50	7.9E-04	*035	-52	5.4E-04*			
18891.12	67	051	061	-57	2.6E-03				051	-54	1.3E-03	054	-56	8.4E-04	*052	-59	6.8E-04*			
18891.3	71	154	066	-57	3.3E-03															
18892.1	58	066	076	-58	1.4E-04				055	-66	6.7E-04	*052	-59	5.8E-04*	074	-62	4.9E-04	056	-55	2.9E-04
18892.2	53	062	065	-43	1.1E-03				032	-44	5.7E-04	*031	-41	5.0E-04*	040	-38	3.3E-04			
18892.3	50	060	071	-55	1.3E-03				051	-56	6.8E-04	052	-54	5.5E-04	*054	-58	3.9E-04*			
18893.1	46	049	070	-61	3.3E-03				054	-69	1.8E-03	056	-72	1.5E-03	*060	-69	1.2E-03*			
18893.2	45	063	056	-59	4.1E-03				040	-60	2.6E-03	*040	-60	2.2E-03*	024	-66	1.8E-03			
18893.31	71	169	045	-57	3.3E-03				041	-53	2.0E-03	*040	-53	1.7E-03*	040	-53	1.4E-03			
18893.32	71	169	046	-60	3.2E-03				034	-59	1.9E-03	028	-57	1.6E-03	*035	-58	1.1E-03*			
18894.1	51	018	061	-53	4.8E-03				045	-66	2.6E-03	048	-69	1.7E-03	058	-67	1.3E-03	*049	-68	8.0E-04*
18894.2	58	019	067	-53	3.8E-03															
18894.31	63	085	074	-57	3.0E-03				055	-62	1.6E-03	054	-63	9.1E-04	030	-62	5.3E-04	*055	-63	4.6E-04*
18894.32	63	085	069	-56	2.8E-03				049	-64	1.5E-03	033	-65	9.0E-04	021	-75	7.6E-04	*035	-65	4.5E-04*
18895.2	60	123	078	-54	1.4E-03				043	-46	6.0E-04	041	-42	4.9E-04	041	-33	2.6E-04	*041	-42	2.4E-04*
18895.31	60	145	082	-63	1.3E-03															
18895.32	60	145	078	-62	2.0E-03				056	-58	9.4E-04	054	-60	6.5E-04	062	-49	6.1E-04	*057	-60	3.1E-04*
18895.4	59	063	074	-36	1.6E-03				044	-42	7.0E-04	*041	-46	5.9E-04*	017	-44	4.3E-04	037	-46	3.1E-04
18896.11	61	214	051	-65	1.6E-03				025	-61	6.1E-04	030	-64	4.6E-04	*030	-63	4.0E-04*			
18896.12	61	214	061	-75	1.3E-03															
18896.31	64	235	053	-55	1.4E-03				058	-49	6.4E-04	058	-47	5.6E-04	069	-52	4.8E-04	*057	-44	2.8E-04*
18896.32	64	235	053	-58	1.2E-03				051	-56	3.1E-04	059	-57	2.7E-04	072	-56	3.6E-04	*061	-56	1.2E-04*
18897.11	65	303	051	-50	2.5E-03															

SPEC.	PLUNGE/ AZIMUTH		NRM D	NRM I	NRM M(A/m)	150 D	150 I	150 M(A/m)	200 D	200 I	200 M(A/m)	250 D	250 I	250 M(A/m)	300 D	300 I	300 M(A/m)	320 D	320 I	320 M(A/m)
18897.12	65	303	037	-51	3.1E-03				026	-57	.21E-03	*020	-57	1.7E-03*	012	-60	1.4E-03	024	-57	8.7E-04
18897.2	55	295	032	-46	3.1E-03				024	-50	2.1E-03	018	-49	1.8E-03	*011	-48	1.6E-03*			
18897.3	61	317	056	-54	2.4E-03				062	-57	1.4E-03	065	-59	1.2E-03	*069	-59	1.1E-03*			
18898.11	51	349	059	-45	1.7E-03				050	-63	7.6E-04	060	-65	6.1E-04	*063	-60	4.8E-04*			
18898.12	51	349	055	-44	1.7E-03				043	-54	7.9E-04	*042	-56	6.4E-04*	024	-56	5.0E-04	015	-79	3.0E-04
18899.1	49	343	039	-57	6.8E-04				009	-57	2.2E-04	*014	-57	1.1E-04*	013	-55	5.6E-05			
18899.2	45	305	046	-61	7.6E-04				042	-69	3.3E-04	148	-68	1.7E-04	080	-53	8.9E-05	*081	-53	4.6E-05*
18899.31	60	065	048	-69	6.1E-04				329	-62	2.3E-04	356	-49	1.6E-04	277	-01	1.3E-04			
18899.32	60	065	057	-70	6.4E-04				325	-58	2.0E-04	*345	-56	1.3E-04*	338	-49	1.5E-04			
18900.1	69	027	050	-60	1.3E-03				018	-68	5.2E-04	011	-64	5.7E-04	*012	-62	2.8E-04*			
18900.2	60	018	033	-66	9.8E-04				048	-69	4.6E-04	037	-68	3.9E-04	*034	-66	2.0E-04*			
18900.3	47	333	042	-56	1.2E-03				028	-68	4.1E-04	*018	-65	3.2E-04*	036	-61	2.9E-04			
18901.21	74	031	070	-60	7.9E-04				086	-61	2.6E-04	082	-64	2.3E-04	055	-74	1.2E-04	*055	-74	6.0E-05*
18901.22	74	031	059	-69	7.5E-04				328	-68	2.6E-04	117	-84	3.2E-04	026	-58	1.3E-04	*026	-58	6.4E-05*
18901.31	67	348	052	-54	7.2E-04				041	-57	2.4E-04	034	-70	2.0E-04	*047	-68	1.2E-04*			
18901.32	67	348	050	-57	7.4E-04				011	-61	2.8E-04	039	-63	2.6E-04	*033	-63	1.3E-04*			
18902.1	35	325	060	-56	1.1E-03				063	-65	4.9E-04	049	-62	4.0E-04	*059	-56	3.1E-04*			
18902.2	42	294	049	-55	9.8E-04				050	-62	3.7E-04	080	-57	3.2E-04	*022	-79	1.7E-04*			
18903.2	49	112	078	-55	5.7E-04				073	-48	1.3E-04	101	-71	1.8E-04	*102	-41	1.7E-04*			
18903.3	51	121	093	-61	5.6E-04				081	-67	2.3E-04									
18904.2	68	148	072	-53	8.2E-04				053	-45	3.3E-04	056	-53	3.0E-04	*063	-56	2.7E-04*			
18904.31	64	163	060	-62	8.2E-04				042	-58	3.3E-04	028	-62	2.9E-04	053	-62	2.8E-04	*053	-61	1.4E-04*
18904.32	64	163	056	-60	7.8E-04				045	-57	4.2E-04	*034	-54	2.9E-04*	048	-21	2.0E-04			
18905.1	59	134	068	-66	8.7E-04				066	-65	4.3E-04	*063	-71	3.5E-04*	063	-51	2.5E-04			
18905.2	47	123	067	-63	8.1E-04				056	-61	3.9E-04	*044	-43	2.6E-04*	033	-46	2.6E-04			
18905.3	60	127	078	-51	8.7E-04				068	-44	3.4E-04	077	-49	3.6E-04	*074	-53	2.9E-04*			
18906.1	60	285	042	-62	1.1E-03				032	-61	7.6E-04	033	-60	6.5E-04	*028	-64	5.2E-04*			
18906.31	75	337	045	-63	1.1E-03				050	-65	7.3E-04	049	-64	6.0E-04	*048	-68	4.8E-04*			
18906.32	75	337	051	-60	1.2E-03				048	-64	8.3E-04	048	-64	6.8E-04	*049	-64	5.1E-04*			
18907.1	61	236	035	-62	3.4E-04															
18907.2	72	254	045	-59	5.0E-04															
18907.3	62	263	039	-62	5.4E-04															
18907.4	63	258	081	-74	5.9E-04															
18908.1	62	244	068	-65	5.7E-04				036	-63	1.3E-04	*047	-63	1.7E-04*	017	-57	1.4E-04			
18908.2	61	251	070	-65	7.0E-04				070	-51	1.5E-04	084	-38	1.1E-04	038	-57	1.1E-04	*038	-56	5.0E-05*
18908.3	72	235	068	-60	6.9E-04				061	-51	1.9E-04	094	-65	1.4E-04	*089	-64	7.5E-05*			
18908.4	78	272	078	-65	6.6E-04															
18909.1	46	343	041	-47	5.8E-04				006	-59	9.9E-05	061	-49	2.1E-04	*051	-47	9.0E-05*			
18909.31	61	264	057	-66	5.3E-04				076	-47	1.6E-04	055	-56	1.2E-04	*072	-51	8.6E-05*			
18909.32	61	264	046	-70	6.1E-04				045	-61	1.8E-04	062	-63	1.7E-04	*064	-61	8.4E-05*			
18910.1	53	320	056	-43	9.8E-04				050	-61	3.8E-04	023	-61	2.8E-04	*027	-60	1.5E-04*			
18910.2	52	316	302	-77	9.0E-04				195	-85	3.2E-04	*033	-66	2.0E-04*	042	-84	1.8E-04			
18910.3	67	014	067	-60	1.1E-03				057	-58	3.3E-04	*060	-58	2.4E-04*	031	-63	1.6E-04			
18911.1	57	008	067	-53	8.2E-04				049	-62	2.7E-04	049	-55	1.9E-04	*047	-52	1.8E-04*			
18911.2	65	355	076	-51	9.6E-04															
18911.31	70	009	075	-53	1.1E-03				053	-64	2.7E-04	041	-75	1.8E-04	*063	-71	1.0E-04*			
18911.32	70	009	069	-50	1.2E-03				062	-54	3.4E-04	*061	-61	1.9E-04*	045	-66	2.1E-04			
18912.1	44	345	060	-44	9.5E-04				053	-46	2.6E-04	016	-51	2.6E-04	*020	-49	1.4E-04*			
18912.21	46	340	064	-43	9.9E-04				068	-56	3.2E-04	*063	-54	2.6E-04*	065	-61	2.6E-04			
18912.22	46	340	061	-56	9.3E-04				049	-65	3.1E-04	*089	-77	2.3E-04*	078	-60	1.9E-04			
18912.3	43	329	054	-39	8.3E-04															
18913.11	64	216	042	-69	6.2E-04				058	-52	1.6E-04	092	076	6.6E-05	*096	-78	3.4E-05*			
18913.12	64	216	057	-69	7.4E-04				089	-69	2.1E-04	*092	-65	1.4E-04*	057	-41	8.8E-05			
18913.31	61	254	040	-51	9.0E-04															
18913.32	61	254	037	-56	7.4E-04				051	-55	1.4E-04	041	-60	1.4E-04	*039	-70	1.2E-04*			
18914.11	65	215	057	-44	5.3E-04				086	-06	2.3E-04	083	-13	1.7E-04	088	36	1.5E-04	*237	23	2.9E-05*
18914.12	65	215	051	-57	6.7E-04				040	-16	1.1E-04	032	-73	1.0E-04	238	25	5.7E-05	*240	24	2.9E-05*
18914.2	67	231	069	-65	7.9E-04				057	-41	2.1E-04	046	-36	1.7E-04	*229	30	7.0E-05*			
18915.21	72	206	060	-60	9.5E-04															
18915.22	72	206	066	-70	8.3E-04															
18915.31	69	193	057	-54	9.0E-04															
18915.32	69	193	052	-52	9.5E-04															
18916.1	75	172	066	-66	6.9E-04				035	-49	1.7E-04	*035	-39	1.6E-04*	062	-27	9.9E-05			
18916.2	70	158	069	-55	8.6E-04				070	-41	2.0E-04	*070	-40	2.3E-04*	063	-28	1.2E-04			
18916.31	73	151	089	-68	7.1E-04															
18916.32	73	151	104	-70	6.8E-04				056	-51	2.0E-04	047	-41	1.6E-04	*043	-39	1.4E-04*			
18917.11	62	172	048	-61	6.6E-04				068	-66	2.4E-04	036	-49	1.8E-04	065	-48	9.7E-05	*066	-48	4.8E-05*
18917.12	62	172	071	-66	6.0E-04															
18917.31	64	201	074	-56	6.9E-04				070	-40	2.3E-04	070	-34	2.2E-04	043	-52	2.0E-04	*045	-57	5.9E-05*
18917.32	64	201	072	-56	5.9E-04				075	-47	2.1E-04	029	-55	1.3E-04	*073	-45	1.3E-04*			
18918.11	54	049	070	-62	7.1E-04				018	-52	1.8E-04	052	-50	1.2E-04	*017	-12	4.5E-05*			
18918.12	54	049	083	-56	7.2E-04															
18918.31	54	063	095	-56	7.0E-04				079	-63	2.1E-04	037	-70	1.5E-04	030	-48	1.2E-04	*028	-48	6.6E-05*
18918.32	54	063	098	-53	6.4E-04				059	-45	1.4E-04	042	-32	9.0E-05	*044	-43	7.8E-05*			
18919.11	43	080	076	-68	8.1E-04				062	-52	2.8E-04	043	-72	2.9E-04	054	-55	1.5E-04	*053	-56	7.6E-05*
18919.12	43	080	075	-65	9.2E-04				036	-59	4.6E-04	*038	-61	3.0E-04*	037	-21	1.6E-04			
18919.3	54	071	094	-51	9.2E-04				072	-58	3.5E-04	025	-50	1.9E-04	*037	-57	1.1E-04*			
18920.11	63	066	072	-55	7.6E-04				043	-49	1.4E-04	*040	-57	2.0E-04*	358	-23	1.5E-04			
18920.12	63	066	078	-55	7.9E-04				051	-54	2.7E-04	*041	-43	1.7E-04*	337	-21	1.3E-04			
18920.2	64	216	115	-62	7.7E-04															
18920.3	66	137	093	-64	8.7E-04				070	-51	2.7E-04	094	-14	1.3E-04	048	-39	1.8E-04	*048	-40	9.2E-05*
18921.11	59	111	095	-51	8.0E-04				099	-32	3.5E-04	087	-13	3.1E-04	*081	-27	2.1E-04*			
18921.12	59	111	090	-51	8.6E-04				110	-38	3.8E-04	*104	-43	3.1E-04*	097	-39	3.0E-04			
18921.21	52	137	055	-75	7.9E-04				038	-53	3.3E-04	*040	-55	2.3E-04*	061	-53	2.1E-04			
18921.22	52	137	110	-79	7.1E-04				049	-68	3.5E-04	081	-76	2.7E-04	059	-70	2.1E-04	*059	-71	1.0E-04*
18922.11	53	102	087	-72	6.3E-04				056	-57	2.3E-04	056	-56	1.9E-04	*048	-59	1.8E-04*			
18922.12	53	102	113	-74	5.9E-04				035	-71	2.1E-04	043	-71	1.9E-04	*038	-69	9.3E-05*			
18922.2	62	065	080	-51	7.2E-04				033	-48	3.6E-04	017	-64	3.1E-04	052	-59	2.0E-04	*049	-58	1.1E-04*
18923.11	60	162	071	-65	9.3E-04				045	-60	4.5E-04	*041	-58	4.4E-04*	059	-51	3.3E-04	040	-50	1.3E-04
18923.12	60	162	069	-72	8.2E-04				042	-60	3.6E-04	065	-60	3.4E-04	*041	-53	2.6E-04*			
18923.2	61	171	061	-67	8.3E-04				046	-46	3.7E-04	*069	-57	2.3E-04*	060	-71	1.8E-04			
18924.11	68	097	047	-78	8.1E-04				007	-62	4.1E-04	011	-51	3.1E-04	*019	-46	2.4E-04*			
18924.12	68	097	118	-78	8.9E-04				020	-72	3.3E-04	344	-55	2.4E-04	*005	-61	2.1E-04*			
18924.21	62	105	108	-57	9.8E-04															
18924.22	62	105	094	-59	8.0E-04				099	-33	3.7E-04	097	-25	2.7E-04	*101	-26	2.1E-04*			

SPEC.	PLUNGE/	AZIMUTH	NRM D	I	M(A/m)	150 D	I	M(A/m)	200 D	I	M(A/m)	250 D	I	M(A/m)	300 D	I	M(A/m)	320 D	I	M(A/m)
18925.1	49	123	090	-62	7.0E-04				051	-49	2.7E-04	042	-49	2.5E-04	*047	-46	1.7E-04*			
18925.21	41	096	107	-59	5.8E-04				076	-44	2.6E-04	065	-43	2.1E-04	*063	-20	1.8E-04*			
18925.22	41	096	089	-43	5.9E-04															
18925.3	46	089	088	-63	5.3E-04				020	-53	2.5E-04	*022	-55	2.4E-04*	012	-68	1.2E-04			
18926.21	40	076	102	-41	7.2E-04				048	-64	3.1E-04	042	-62	2.1E-04	*052	-57	1.3E-04*			
18926.22	40	076	091	-55	6.4E-04				056	-56	2.5E-04	025	-68	1.7E-04	*024	-61	1.5E-04*			
18926.31	29	086	100	-48	6.9E-04				059	-55	2.9E-04	069	-54	2.6E-04	*064	-48	1.5E-05*			
18926.32	29	086	098	-57	5.5E-04				045	-45	2.8E-04	*049	-44	2.5E-04*	068	-65	2.1E-04			
18928.1	47	346	064	-44	8.2E-04				031	-64	1.9E-04	046	-28	1.8E-04	*034	-42	1.5E-04*			
18928.2	45	339	051	-41	7.0E-04				034	-62	1.7E-04	*038	-80	1.3E-04*	093	-80	6.2E-05			
18928.31	55	325	047	-51	8.8E-04				022	-71	2.7E-04	043	-59	2.2E-04	*041	-59	1.1E-04*			
18928.32	55	325	059	-40	8.1E-04				042	-46	2.2E-04	*028	-48	1.5E-04*	026	-49	7.5E-05			
18929.1	53	312	285	-81	5.4E-04															
18929.2	42	316	260	-78	6.2E-04															
18929.3	47	320	043	-48	7.3E-04															
18931.21	59	354	065	-46	9.1E-04				064	-51	3.5E-04	*059	-53	2.9E-04*	056	-55	2.2E-04			
18931.22	59	354	073	-48	8.5E-04				061	-57	3.3E-04	*063	-59	2.7E-04*	075	-63	2.8E-04			
18931.31	65	358	061	-58	9.1E-04				048	-65	3.5E-04	*038	-68	2.8E-04*	033	-69	1.3E-04			
18931.32	65	358	052	-52	9.5E-04				022	-50	3.6E-04	*023	-47	3.4E-04*	049	-08	1.7E-04			
18932.11	43	359	082	-55	5.1E-04				048	-67	1.9E-04	*077	-54	1.7E-04*	068	-52	1.5E-04			
18932.12	43	359	059	-42	6.3E-04				030	-66	2.2E-04	*051	-48	2.1E-04*	049	-46	1.0E-04			
18932.31	50	350	063	-40	8.1E-04				015	-55	2.2E-04	356	-56	2.6E-04	046	-45	2.1E-04	*044	-45	1.1E-04*
18932.32	50	350	310	-71	7.1E-04															
18933.11	56	041	062	-49	9.2E-04				054	-62	4.8E-04	*056	-63	4.3E-04*	057	-63	2.2E-04			
18933.12	56	041	066	-50	9.6E-04				051	-57	5.0E-04	080	-51	3.6E-04	042	-43	3.3E-04	*041	-45	1.7E-04*
18933.31	56	022	075	-56	9.2E-04				047	-61	4.8E-04	*041	-67	3.9E-04*	038	-66	3.1E-04			
18933.32	56	022	064	-47	1.1E-03				061	-51	4.9E-04	*059	-51	3.8E-04*	050	-64	2.6E-04			
18934.21	52	297	045	-66	2.2E-03				033	-74	1.5E-03	*011	-78	1.3E-03*	016	-76	6.4E-04			
18934.22	52	297	041	-48	2.1E-03				045	-52	1.4E-03	*044	-46	1.1E-03*	044	-46	8.6E-04			
18934.31	60	259	085	-54	2.0E-03															
18934.32	60	259	047	-50	2.0E-03				043	-42	1.2E-03	*041	-34	8.4E-04*	041	-34	7.7E-04			
18935.1	62	332	054	-45	6.4E-04				033	-51	2.2E-04	061	-56	2.2E-04	*045	-51	9.4E-05*			
18935.2	70	358	062	-63	7.2E-04															
18935.3	65	360	067	-57	7.8E-04				050	-60	2.9E-04	036	-73	1.7E-04	*040	-67	1.6E-04*			
18935.4	68	356	062	-61	6.7E-04				028	-70	2.7E-04	034	-65	2.3E-04	*022	-71	1.8E-04*			
18936.11	73	157	061	-53	1.4E-03				076	-52	7.0E-04	*082	-47	5.8E-04*	089	-43	3.6E-04			
18936.12	73	157	072	-63	1.8E-03				073	-61	9.9E-04	*077	-61	9.6E-04*	095	-64	5.8E-04			
18936.31	74	192	067	-57	2.4E-03				068	-56	1.7E-03	*070	-54	1.5E-03*	073	-55	1.3E-03			
18936.32	74	192	050	-66	2.6E-03				039	-63	1.9E-03	*036	-64	1.6E-03*	039	-65	1.3E-03			
18937.11	55	129	083	-62	7.3E-04				062	-57	2.1E-04	026	-54	1.2E-04	*067	-57	1.4E-04*	360	-79	1.7E-04
18937.12	55	129	101	-62	7.6E-04				065	-60	2.7E-04	046	-67	2.2E-04	*042	-67	1.1E-04*			
18937.21	60	146	101	-60	8.5E-04				091	-57	3.1E-04	084	-52	2.2E-04	*085	-52	1.1E-04*			
18937.22	60	146	088	-65	8.0E-04				057	-59	3.4E-04	*057	-62	2.1E-04*	054	-62	2.3E-04			
18938.21	61	003	068	-46	7.6E-04				043	-47	2.3E-04	059	-52	1.8E-04	*070	-54	8.7E-05*			
18938.22	61	003	065	-49	8.8E-04															
18938.31	61	019	081	-51	7.9E-04				053	-68	2.6E-04	120	-76	1.8E-04	049	-56	1.7E-04	*053	-56	8.9E-05*
18938.32	61	019	075	-44	8.0E-04				051	-58	2.8E-04	*048	-58	1.8E-04*	054	-54	9.3E-04			
18939.11	48	216	090	-51	6.1E-04															
18939.12	48	216	090	-59	6.1E-04															
18939.21	54	219	086	-59	6.1E-04															
18939.22	54	219	073	-70	5.8E-04															
18940.21	58	152	056	-63	7.0E-04				044	-33	1.9E-04	050	-40	1.1E-04	*061	-48	8.9E-05*	011	-71	9.4E-05
18940.22	58	152	083	-71	7.2E-04				062	-62	2.1E-04	*025	-63	1.2E-04*	011	-72	1.8E-04			
18940.31	56	140	096	-69	6.0E-04															
18940.32	56	140	117	-69	6.4E-04				059	-77	2.0E-04	*022	-70	1.9E-04*	316	-80	1.1E-04			
18941.11	57	155	095	-64	6.5E-04															
18941.12	57	155	088	-68	6.6E-04															
18941.31	54	145	071	-67	6.3E-04															
18941.32	54	145	080	-67	6.5E-04															
18942.21	50	138	110	-71	6.8E-04				061	-61	2.7E-04	*066	-62	2.2E-04*	060	-29	1.1E-04			
18942.22	50	138	105	-64	6.4E-04				050	-50	2.9E-04	*056	-48	2.2E-04*	061	-35	2.0E-04			
18942.3	65	138	109	-59	6.4E-04				039	-43	1.9E-04	*034	-45	1.3E-04*	043	-43	9.9E-05			
18942.4	59	125	089	-67	6.6E-04				044	-52	2.5E-04	*043	-49	1.8E-04*	039	-55	2.1E-04			
18943.11	67	163	036	-77	9.5E-04															
18943.12	67	163	076	-75	9.0E-04				017	-55	2.9E-04	*007	-55	2.7E-04*	015	-43	2.2E-04			
18943.21	64	124	102	-56	9.8E-04				071	-52	3.7E-04	*071	-50	3.2E-04*	061	-32	2.2E-04			
18943.22	64	124	101	-52	1.1E-03				058	-55	3.4E-04	*068	-39	1.9E-04*	060	-52	1.9E-04			
18944.11	52	182	060	-79	9.8E-04				048	-64	4.3E-04	*036	-59	2.6E-04*	022	-66	2.4E-04			
18944.12	52	182	076	-81	1.0E-03				050	-70	4.7E-04	037	-69	3.6E-04	*044	-71	3.2E-04*			
18944.21	60	206	057	-66	1.1E-03				045	-56	5.6E-04	039	-43	4.0E-04	*038	-50	3.5E-04*			
18944.22	60	206	052	-68	1.4E-03				041	-54	6.6E-04	*041	-55	5.5E-04*	035	-57	4.3E-04			
18945.11	39	320	015	54	8.6E-04				328	55	6.4E-04	327	51	4.8E-04	*334	49	3.9E-04*			
18945.12	39	320	354	49	8.9E-04				317	55	6.8E-04	*317	43	5.0E-04*	321	51	4.7E-04			
18945.21	38	326	007	60	8.9E-04				319	55	7.2E-04	*314	55	6.1E-04*	347	66	4.4E-04			
18945.22	38	326	358	51	9.6E-04				321	56	7.4E-04	319	50	5.1E-04	*315	53	4.9E-04*			
18946.1	72	060	043	-16	4.2E-04				058	-55	2.8E-04	*061	-48	2.2E-04*	055	-59	1.8E-04			
18946.21	75	079	086	-53	9.3E-04				066	-49	3.2E-04	076	-36	1.6E-04	*078	-39	8.1E-05*			
18946.22	75	079	077	-52	1.6E-03				065	-55	1.0E-03	065	-56	8.2E-04	*058	-56	3.6E-04*			
18947.1	48	176	076	-71	9.7E-04				061	-53	3.6E-04	085	-57	2.6E-04	034	-58	2.3E-04	*037	-59	1.1E-04*
18947.21	61	104	086	-58	9.3E-04				060	-58	3.5E-04	061	-66	3.0E-04	*061	-66	1.5E-04*			
18947.22	61	104	090	-59	9.6E-04				060	-52	3.9E-04	*055	-47	2.5E-04*	045	-58	2.3E-04			
18947.3	65	080	090	-71	9.0E-04															
18948.1	57	278	049	-58	9.2E-04															
18948.2	56	277	047	-59	8.8E-04				059	-72	2.5E-04	*092	-62	1.8E-04*	093	-54	1.3E-04			
18948.31	50	290	042	-49	8.0E-04				045	-56	2.6E-04	030	-52	1.3E-04	*030	-52	6.2E-05*			
18948.32	50	290	054	-50	7.6E-04				053	-66	2.4E-04	*040	-63	1.5E-04*	040	-56	2.1E-04			
18949.11	61	202	044	-74	9.8E-04															
18949.12	61	202	069	-76	9.1E-04				051	-64	3.1E-04	052	-70	2.3E-04	*054	-68	1.1E-04*			
18949.21	61	186	069	-76	9.2E-04				069	-66	3.6E-04	074	-63	2.6E-04	051	-67	2.3E-04	*045	-63	1.1E-04*
18949.22	61	186	086	-77	8.8E-04				037	-59	2.4E-04	034	-67	2.4E-04	*031	-65	1.2E-04*			
18950.11	54	194	034	-76	8.7E-04				054	-60	3.0E-04	*047	-53	2.1E-04*	058	-46	1.2E-04			
18950.12	54	194	032	-72	9.7E-04				037	-64	3.1E-04	029	-59	2.8E-04	*021	-61	1.9E-04*			
18950.2	58	187	041	-70	9.2E-04				024	-59	3.0E-04	*028	-57	2.1E-04*	034	-58	2.1E-04			
18950.3	51	203	031	-77	1.0E-03				033	-66	3.0E-04	*032	-69	2.8E-04*	033	-62	2.0E-04			
18951.11	63	073	095	-45	1.1E-03				046	-56	3.4E-04	*058	-60	2.3E-04*	063	-51	2.0E-04			

SPEC.	PLUNGE/	AZIMUTH	NRM D	NRM I	NRM M(A/m)	150 D	150 I	150 M(A/m)	200 D	200 I	200 M(A/m)	250 D	250 I	250 M(A/m)	300 D	300 I	300 M(A/m)	320 D	320 I	320 M(A/m)
18951.12	63	073	089	-52	1.0E-03				043	-58	3.7E-04	057	-74	3.0E-04	*053	-67	2.6E-04*			
18951.31	61	061	096	-58	1.2E-03				053	-62	4.4E-04	051	-60	3.6E-04	*070	-61	2.2E-04*			
18951.32	61	061	097	-50	1.1E-03				028	-61	3.6E-04	*010	-56	2.7E-04*	017	-47	2.0E-04			
18952.11	41	061	104	-34	1.0E-03				072	-49	3.5E-04	*073	-39	2.4E-04*	065	-35	2.4E-04			
18952.12	41	061	097	-48	1.1E-03				064	-62	3.8E-04	058	-62	3.5E-04	*056	-62	1.8E-04*			
18952.2	48	052	097	-34	8.2E-04				069	-66	2.1E-04	052	-60	1.9E-04	*051	-60	9.3E-05*			
18953.11	55	105	121	-58	7.0E-04				060	-64	2.0E-04	055	-64	1.8E-04	*054	-64	8.9E-05*			
18953.12	55	105	108	-58	8.1E-04															
18953.21	59	075	105	-51	9.2E-04				063	-62	3.2E-04	056	-56	2.9E-04	*053	-57	2.5E-04*			
18953.22	59	075	102	-51	8.3E-04				040	-69	2.4E-04	022	-75	2.4E-04	*012	-72	1.3E-04*			
18954.1	55	068	097	-55	7.8E-04				037	-57	2.9E-04	038	-56	2.2E-04	*037	-55	1.1E-04*			
18954.21	65	084	097	-55	8.7E-04				079	-73	3.0E-04	058	-71	2.3E-04	047	-63	2.1E-04	*047	-62	1.0E-04*
18954.22	65	084	099	-49	8.5E-04				061	-56	2.4E-04	044	-54	2.1E-04	*043	-53	1.0E-04*			
18954.3	55	047	096	-40	9.3E-04															
18955.11	47	138	100	-71	6.0E-04				089	-64	4.2E-04	051	-52	1.2E-04	*051	-49	7.5E-05*			
18955.12	47	138	080	-70	6.4E-04				071	-58	3.8E-04	036	-70	1.5E-04	*031	-71	7.4E-05*			
18955.3	64	157	103	-66	7.1E-04				010	-62	4.7E-04	142	-47	1.5E-04	*141	-56	1.6E-04*			
18956.11	52	058	087	-51	7.2E-04				069	-54	3.2E-04	031	-55	1.8E-04	*034	-55	8.4E-05*			
18956.12	52	058	081	-56	6.5E-04															
18956.21	38	056	086	-42	7.2E-04				081	-48	2.2E-04	074	-52	2.1E-04	*059	-53	1.5E-04*	109	-86	7.1E-05
18956.22	38	056	085	-40	7.4E-04				080	-43	3.4E-04	041	-45	1.8E-04	*041	-45	8.7E-05*			
18957.1	48	030	085	-26	9.3E-04				068	-31	3.7E-04	057	-37	2.4E-04	*058	-39	1.2E-04*			
18957.2	50	049	081	-55	7.7E-04															
18957.31	48	052	082	-43	6.8E-04				078	-59	2.9E-04	071	-54	1.7E-04	*073	-52	8.2E-05*			
18957.32	48	052	079	-49	6.9E-04				048	-48	2.0E-04	022	-57	1.1E-04	*021	-56	5.3E-05*			
18958.1	44	085	098	-47	5.8E-04				085	-48	3.3E-04	077	-50	1.5E-04	*075	-49	7.4E-05*			
18958.2	52	040	101	-52	6.2E-04				096	-51	2.8E-04	096	-68	1.1E-04	035	-73	9.9E-05	*037	-73	5.0E-05*
18958.3	51	049	085	-41	8.9E-04				074	-40	4.9E-04	055	-51	2.5E-04	*018	-58	1.2E-04*	019	-58	6.0E-05
18959.11	48	064	091	-44	1.0E-03				092	-56	5.4E-04	090	-69	3.9E-04	*103	-75	2.8E-04*			
18959.12	48	064	093	-45	1.2E-03				084	-47	4.3E-04	061	-52	4.2E-04	079	-58	2.5E-04	*079	-58	1.3E-04*
18959.31	40	068	087	-45	8.9E-04				082	-48	3.3E-04	070	-54	2.7E-04	*062	-54	1.3E-04*			
18959.32	40	068	088	-46	9.1E-04															
18960.21	50	060	080	-49	1.0E-03															
18960.22	50	060	080	-47	1.1E-03				064	-52	5.7E-04	033	-56	3.7E-04	*032	-56	1.9E-04*			
18960.31	51	062	074	-67	1.1E-03				048	-71	4.4E-04	004	-70	4.5E-04	*006	-59	3.0E-04*			
18960.32	51	062	079	-59	1.1E-03				062	-60	6.0E-04	045	-62	4.1E-04	*047	-63	3.0E-04*			
18961.1	40	039	057	-49	5.3E-04				056	-47	3.2E-04	050	-44	2.3E-04	*050	-44	1.2E-04*			
18961.2	42	057	060	-48	5.4E-04				052	-49	2.5E-04	039	-44	1.8E-04	*025	-51	1.3E-04*	084	-55	8.6E-05
18961.31	46	065	070	-52	4.6E-04				062	-53	1.1E-04	023	-40	6.4E-05	*004	-53	3.2E-05*			
18961.32	46	065	083	-42	5.0E-04															
18962.1	68	172	051	-67	7.9E-04				043	-65	3.0E-04	015	-68	2.8E-04	*016	-69	1.4E-04*			
18962.2	63	196	069	-66	9.0E-04				065	-63	3.8E-04	108	-60	2.7E-04	*107	-61	1.4E-04*			
18962.31	74	332	053	-56	9.1E-04				048	-52	4.0E-04	088	-54	2.6E-04	*088	-54	1.3E-04*			
18962.32	74	332	060	-54	8.5E-04															
18963.1	58	221	045	-56	7.5E-04				042	-60	3.0E-04	057	-60	2.2E-04	*063	-60	1.5E-04*			
18963.2	49	260	050	-51	8.3E-04				051	-62	4.4E-04	056	-67	2.1E-04	*059	-77	1.7E-04*			
18963.3	52	243	036	-61	8.5E-04				032	-58	2.1E-04	018	-43	3.0E-04	020	-58	2.1E-04	*020	-58	1.1E-04*
18964.11	66	282	047	-59	7.8E-04				061	-62	4.2E-04	087	-63	1.6E-04	*087	-63	7.9E-05*			
18964.12	66	282	052	-52	9.3E-04				048	-51	3.3E-04	037	-53	1.6E-04	*035	-54	8.2E-05*			
18964.2	70	254	044	-62	1.5E-03				043	-64	4.2E-04	028	-49	1.5E-04	*046	-66	7.6E-05*			
18964.3	76	306	058	-51	7.7E-04															
18965.11	60	178	027	-72	1.2E-03				032	-69	4.6E-04	008	-65	3.1E-04	053	-78	2.8E-04	*051	-77	1.3E-04*
18965.12	60	178	025	-72	1.0E-03				039	-74	5.2E-04	062	-75	2.0E-04	*059	-75	9.9E-05*			
18965.2	64	184	093	-66	1.0E-03				073	-64	3.0E-04	089	-18	2.0E-04	*109	-28	2.9E-04*			
18965.3	63	179	052	-69	1.1E-03															
18966.21	62	271	035	-55	8.5E-04															
18966.22	62	271	046	-67	7.9E-04															
18966.3	66	277	031	-53	7.3E-04															
18967.21	38	067	101	-51	2.6E-03															
18967.22	38	067	123	-67	2.5E-03															
18967.41	46	060	087	-53	2.3E-03															
18967.42	46	060	101	-55	1.9E-03															
18968.1	50	124	107	-72	8.9E-04				035	-61	2.3E-04	*035	-61	1.2E-05*	032	-62	5.6E-05			
18968.2	47	096	096	-62	1.0E-03				060	-52	2.7E-04	031	-51	3.1E-04	*029	-44	1.9E-04*			
18968.3	34	102	128	-58	8.2E-04				076	-65	2.7E-04	006	-75	1.1E-04	*067	-68	6.6E-05*			
18969.31	56	177	030	-78	1.1E-03															
18969.32	56	177	065	-76	1.1E-03				032	-62	4.4E-04	042	-54	3.2E-04	*042	-55	1.6E-04*			
18969.41	59	189	014	-81	1.1E-03				025	-74	2.1E-04	*026	-73	1.0E-04*	026	-73	4.9E-05			
18969.42	59	189	066	-78	1.0E-03				074	-49	3.3E-04	068	-46	3.6E-04	*070	-46	1.9E-04*			
18970.21	44	246	048	-70	9.7E-04				141	-82	1.2E-04	*130	-82	6.6E-05*	140	-83	3.3E-05			
18970.22	44	246	034	-61	9.7E-04															
18970.41	53	286	048	-49	1.0E-03				067	-54	2.3E-04	039	-59	2.1E-04	*039	-58	1.1E-04*			
18970.42	53	286	049	-54	1.2E-03				084	-62	3.1E-04	056	-65	1.2E-04	*057	-65	6.0E-05*			
18971.1	48	294	043	-46	1.0E-03															
18971.21	48	316	053	-48	1.4E-03				*072	-76	2.8E-04*	348	-52	1.4E-04	227	-79	5.3E-05			
18971.22	48	316	054	-46	1.0E-03				110	-48	1.9E-04	112	-30	1.8E-04	*113	-29	8.7E-05*			
18971.4	51	012	066	-36	7.7E-04				006	-22	1.5E-04	*006	-21	1.3E-04*	039	-32	8.6E-05			
18972.11	68	333	070	-50	1.1E-03				102	-31	3.2E-04	*102	-35	2.4E-0*	090	-19	1.3E-04			
18972.12	68	333	073	-49	9.2E-04				088	-58	1.6E-04	*087	-44	1.2E-04*	087	-44	5.6E-05			
18972.31	60	316	060	-55	1.1E-03				021	-89	1.9E-04	015	-18	1.9E-04	070	-72	1.4E-04	*071	-72	7.1E-05*
18972.32	60	316	039	-50	9.4E-04															
18973.21	54	342	067	-43	9.1E-04				063	-65	2.2E-04	062	-53	1.8E-04	*062	-53	9.0E-05*			
18973.22	54	342	066	-40	8.7E-04				089	-40	1.6E-04	103	-25	1.2E-04	*108	-23	6.7E-05*			
18973.31	48	349	076	-45	7.5E-04															
18973.32	48	349	058	-38	8.6E-04				070	-30	1.7E-04	086	-37	1.3E-04	*086	-37	6.5E-05*			
18974.1	40	213	359	-78	1.3E-03															
18974.2	49	217	017	-50	1.3E-03															
18974.3	54	255	042	-61	1.3E-03															
18975.31	44	342	061	-40	1.4E-03															
18975.32	44	342	071	-43	1.3E-03															
18975.41	49	325	053	-42	1.3E-03															
18975.42	49	325	059	-50	1.3E-03															
18976.1	54	186	122	-77	7.1E-04				068	-60	1.9E-04	*087	-62	7.3E-05*	096	-19	2.4E-04			
18976.2	47	187	009	-75	7.3E-04				028	-75	1.4E-04	030	-76	6.9E-05	*029	-76	3.4E-05*			
18976.3	63	179	059	-74	7.4E-04				044	-46	2.1E-04	101	-52	2.7E-04	039	-68	1.5E-04	*039	-68	7.3E-05*

SPEC.	PLUNGE/		NRM			150			200			250			300			320		
	AZIMUTH		D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)
18976.4	64	167	109	-75	7.0E-04															
18977.1	48	052	098	-35	1.1E-03				070	-28	2.4E-04	*023	-58	8.8E-05*	023	-59	4.4E-05			
18977.21	46	054	116	-51	1.1E-03				032	-72	3.7E-04	*027	-71	1.9E-04*	029	-72	9.1E-05			
18977.22	46	054	091	-52	1.5E-03				036	-66	4.6E-04	*037	-64	2.3E-04*	037	-66	1.2E-04			
18977.3	71	107	114	-62	1.5E-03															
18978.11	51	302	043	-51	1.1E-03				037	-63	2.6E-04	008	-69	2.4E-04	*012	-69	1.2E-04*			
18978.12	51	302	049	-57	1.2E-03				042	-46	2.5E-04	031	-45	2.1E-04	*031	-45	1.1E-04*			
18978.2	54	304	053	-40	1.2E-03															
18978.3	55	260	019	-61	9.7E-04				035	-15	2.0E-04	*040	-15	2.2E-04*	072	-17	1.1E-04			
18980.21	57	296	047	-54	1.7E-03															
18980.22	57	296	047	-47	1.6E-03															
18980.31	54	250	013	-62	1.2E-03															
18980.32	54	250	355	-74	1.1E-03															
18981.1	63	109	129	-68	1.8E-03				164	-31	2.1E-04	230	-08	4.6E-04	215	21	2.3E-04	*215	22	1.6E-05*
18981.2	58	118	098	-42	1.8E-03				084	21	4.1E-04	098	01	3.4E-04	*186	24	1.6E-04*			
18981.3	64	133	095	-61	1.6E-03															
18981.4	61	107	119	-67	1.6E-03				290	-29	1.4E-04	277	-25	2.9E-04	335	33	1.4E-04	*335	35	1.9E-05*
18983.21	63	117	084	065	5.5E-04				037	-52	1.1E-04	107	-73	3.5E-05	069	-35	6.3E-05	*070	-34	3.2E-05*
18983.22	63	117	043	-34	3.5E-04															
18983.31	65	143	109	-70	5.0E-04				137	-48	9.9E-05	150	-35	9.5E-05	*148	-39	5.6E-05*			
18983.32	65	143	120	-60	5.4E-04				050	-62	1.4E-04	030	-70	8.8E-05	*027	-73	4.4E-05*			
18985.11	26	075	078	-51	4.2E-04															
18985.12	26	075	108	-47	4.4E-04				136	-51	1.1E-04	128	-26	1.2E-04	147	-20	1.2E-04	*146	-20	5.7E-05*
18985.21	23	085	104	-56	3.2E-04				037	-52	1.1E-04	039	-50	7.2E-05	*034	-57	6.4E-05*			
18985.22	23	085	088	-52	4.3E-04				031	-54	1.5E-04	005	-32	1.0E-04	057	-13	7.0E-05	*057	-12	2.5E-05*
18987.1	51	271	062	-42	9.8E-04				060	-48	2.1E-04	022	-58	1.5E-04	*026	-61	7.8E-05*			
18987.2	62	285	055	-41	8.7E-04				042	-27	2.3E-04	028	-25	1.8E-04	*033	-49	8.1E-05*			
18987.3	60	264	054	-53	7.7E-04				055	-45	1.3E-04	078	-14	9.0E-05	*082	-08	5.3E-05*			
18987.4	65	300	026	-62	9.4E-04															
18989.1	62	271	052	-51	4.3E-04				225	24	3.3E-05	221	-03	6.6E-05	257	48	1.0E-04	*257	48	5.1E-05*
18989.2	62	302	083	-51	4.5E-04															
18989.3	64	296	055	-47	5.9E-04				054	-37	7.7E-05	*056	-37	5.1E-05*	062	-35	1.7E-05			
18989.4	61	271	058	-54	5.1E-04				114	-13	8.5E-05	303	-43	4.9E-05	*312	-36	2.7E-05*			
18991.11	33	306	053	-42	4.7E-04				347	-19	4.0E-05	007	16	4.4E-05	095	23	9.7E-05	*095	23	4.9E-05*
18991.12	33	306	054	-30	5.0E-04				093	-03	6.1E-05	071	-29	7.5E-05	103	55	7.5E-05	*103	54	3.8E-05*
18991.21	38	294	051	-37	5.9E-04															
18991.22	38	294	060	-43	5.0E-04				159	-56	2.1E-05	225	-09	7.4E-05	178	31	8.2E-05	*178	32	4.1E-05*
18992.2	50	285	053	-55	5.4E-04															
18992.3	49	276	134	-24	1.5E-04															
18992.4	41	283	176	-27	9.0E-05															
18993.11	37	242	035	-54	5.6E-04				034	-37	1.3E-04	004	-69	6.3E-05	*003	-68	3.2E-05*			
18993.12	37	242	038	-48	5.2E-04															
18993.21	40	228	026	-52	5.7E-04				007	-62	3.7E-05	*006	-61	1.9E-05*	012	-56	1.6E-05			
18993.22	40	228	002	-63	6.6E-04				080	-69	9.9E-05	077	-66	3.7E-05	*070	-61	2.5E-05*			
18994.11	36	229	030	-69	7.1E-04															
18994.12	36	229	011	-68	7.7E-04															
18994.2	44	264	029	-60	7.9E-04															
18995.11	66	275	060	-44	1.4E-03				073	-31	4.6E-04	061	-52	3.8E-04	*058	-42	3.5E-04*			
18995.12	66	275	063	-45	1.2E-03				075	-33	3.6E-04	086	-38	3.2E-04	*085	-39	1.7E-04*			
18995.21	60	239	045	-47	1.2E-03				033	-42	3.3E-04	038	-28	2.9E-04	*012	-59	1.5E-04*			
18995.22	60	239	052	-64	1.2E-03															
18996.1	46	041	089	-47	1.0E-03	066	-36	4.0E-04	055	-30	3.0E-04	*053	-37	1.6E-04*	343	-50	2.1E-05			
18996.2	41	036	103	-28	6.8E-04	081	-43	2.4E-04	*071	-49	1.4E-04*	100	-08	1.1E-04	085	-08	1.4E-04			
18996.3	54	066	079	-57	7.4E-04	062	-40	2.0E-04	*047	-28	8.0E-05*	055	-15	1.4E-05	124	-37	6.5E-05			
18996.5	24	097	164	-64	7.4E-04															
18997.21	34	018	099	-34	8.3E-04															
18997.22	34	018	074	-41	1.3E-03	060	-40	6.1E-04	*056	-41	4.2E-04*	066	-12	3.2E-04	072	-39	1.5E-04			
18997.31	30	075	130	-39	7.5E-04				*104	-48	1.1E-04*	079	-30	9.0E-05	153	-63	8.2E-05			
18997.32	30	075	131	-45	7.5E-04	126	-43	2.7E-04	135	-21	2.3E-04	*099	-44	1.5E-04*	101	-37	1.1E-04			
18998.11	31	050	095	-40	5.7E-04	058	-43	3.3E-04	*056	-37	2.3E-04*	021	-62	1.4E-04	064	-38	9.6E-05			
18998.12	31	050	107	-54	7.0E-04	071	-73	3.1E-04	074	-76	2.3E-04	*070	-66	1.5E-04*	065	-54	8.8E-05			
18998.3	22	085	101	-27	1.2E-03	082	-21	6.1E-04	079	-19	4.2E-04	082	01	2.7E-04	*051	-40	1.6E-04*			
18998.4	22	085	059	-73	7.1E-04															
18999.1	25	081	111	-39	9.2E-04	069	-58	3.4E-04	076	-38	3.0E-04	*061	-48	1.2E-04*	009	-38	4.2E-05			
18999.3	22	080	104	-44	1.1E-03	083	-48	5.4E-04	079	-51	3.9E-04	*067	-53	2.3E-04*	143	-63	1.3E-04			
18999.4	32	099	118	-57	5.8E-04	053	-64	2.7E-04	071	-58	1.9E-04	078	-35	1.7E-04	*036	-60	9.3E-05*			
19000.1	24	054	087	-32	8.5E-04	053	-39	4.7E-04	065	-44	3.4E-04	051	-26	2.2E-04	*032	-58	1.3E-04*			
19000.2	33	038	080	-16	1.2E-03				053	-09	3.6E-04	*065	-03	1.8E-04*	037	-26	1.5E-04			
19000.41	26	036	088	-61	1.3E-03	073	-83	6.7E-04	*063	-84	5.6E-04*	055	-81	4.4E-04	009	-80	3.0E-04			
19000.42	26	036	074	-33	1.7E-03	060	-36	1.0E-03	057	-37	7.8E-04	049	-39	5.9E-04	*046	-49	3.5E-04*			
19001.1	12	263	009	-38	1.2E-03	025	-49	5.9E-04	042	-53	4.7E-04	*023	-56	3.4E-04*	084	-71	2.1E-04			
19001.2	24	270	035	-39	1.2E-03	051	-51	5.5E-04	050	-51	5.0E-04	*047	-57	3.4E-04*	014	-51	3.1E-04			
19001.3	11	237	353	-40	1.2E-03	010	-58	5.1E-04	016	-55	3.9E-04	057	-32	2.5E-04	*040	-51	1.9E-04*			
19001.4	21	281	043	-40	1.3E-03	045	-56	5.4E-04	*040	-59	4.5E-04*	056	-45	3.2E-04	037	-69	1.8E-04			
19002.11	24	298	034	-28	9.8E-04	050	-42	3.7E-04	068	-44	2.7E-04	047	-46	2.0E-04	*041	-54	1.7E-04*			
19002.12	24	298	052	-38	2.1E-03	061	-42	1.4E-03	061	-44	1.0E-03	063	-46	6.9E-04	*051	-53	2.8E-04*			
19002.21	38	235	004	-64	1.0E-03															
19002.3	41	276	026	-40	1.1E-03	010	-68	4.1E-04	*003	-66	3.0E-04*	052	-69	1.7E-04	001	-58	1.5E-04			
19003.11	20	289	044	-22	1.0E-03	042	-26	4.8E-04	047	-33	3.5E-04	028	-40	2.9E-04	*031	-54	2.2E-04*			
19003.12	20	289	023	-31	9.5E-04	032	-46	3.5E-04	024	-52	2.7E-04	036	-50	2.3E-04	*034	-43	2.2E-04*			
19003.4	20	301	029	-38	1.0E-03	030	-63	4.6E-04	012	-66	3.1E-04	054	-45	2.8E-04	*038	-69	1.9E-04*			
19003.5	40	317	053	-40	9.1E-04				*038	-58	2.8E-04*	058	-42	2.6E-04	060	-62	2.0E-04			
19004.1	28	276	024	-34	9.5E-04															
19004.2	30	247	003	-45	7.0E-04															
19004.3	24	209	355	-74	1.0E-03															
19004.4	27	270	039	-43	9.4E-04															
19005.1	34	257	074	-61	6.0E-04															
19005.2	28	282	065	-62	8.8E-04															
19005.3	30	296	056	-32	1.1E-03															
19005.4	34	240	031	-48	1.0E-03															
19006.1	30	300	048	-43	8.9E-04	039	-57	4.9E-04	025	-60	4.2E-04	*032	-62	3.2E-04*	061	-50	3.9E-04			
19006.2	34	243	035	-48	1.0E-03	037	-56	5.5E-04	034	-60	4.5E-04	*036	-66	3.1E-04*	055	-65	2.4E-04			
19006.3	08	311	044	-32	8.3E-04	047	-54	4.3E-04	044	-56	3.5E-04	062	-45	2.5E-04	*036	-60	2.2E-04*			
19007.1	32	315	039	-46	1.1E-03	031	-64	4.0E-04	038	-58	3.7E-04	*034	-68	2.3E-04*	015	-55	2.7E-04			
19007.2	43	288	041	-45	1.0E-03				*027	-66	3.1E-04*	062	-51	2.9E-04	062	-60	1.9E-04			

SPEC.	PLUNGE/ AZIMUTH		NRM D	I	M(A/m)	150 D	I	M(A/m)	200 D	I	M(A/m)	250 D	I	M(A/m)	300 D	I	M(A/m)	320 D	I	M(A/m)
19007.3	30	304	031	-43	1.3E-03	028	-54	4.4E-04	*023	-50	3.0E-04*	030	-36	2.4E-04	001	-44	2.0E-04			
19008.1	32	308	272	-73	4.2E-04	034	-68	3.2E-04	*026	-65	2.1E-04*	028	-63	2.5E-05	016	-64	2.2E-04			
19008.2	45	267	077	-55	2.6E-04	074	-60	3.3E-04	*066	-64	2.0E-04*	056	-56	1.9E-04	073	-43	1.7E-04			
19008.3			273	-87	1.2E-03															
19008.4	33	270	020	-48	1.1E-03	046	-74	4.7E-04	*025	-70	3.1E-04*	076	-60	2.7E-04	063	-54	1.9E-04			
19009.21	19	322	046	-41	1.1E-03	043	-52	4.6E-04	042	-55	4.2E-04	*042	-58	2.9E-04*	057	-48	2.9E-04			
19009.51	27	329	069	-49	9.7E-04	045	-64	4.1E-04	*036	-64	3.3E-04*	054	-51	1.8E-04	027	-60	1.8E-04			
19009.52	27	329	066	-43	9.3E-04	037	-60	4.1E-04	039	-65	3.1E-04	058	-45	2.7E-04	*046	-63	2.0E-04*			
19010.31	19	310	048	-32	8.6E-04				040	-68	3.0E-04	026	-62	2.4E-04	*027	-67	1.9E-04*			
19010.32	19	310	041	-34	8.5E-04	035	-54	3.5E-04	032	-50	3.0E-04	*039	-62	2.3E-04*	034	-73	1.9E-04			
19010.41	13	286	025	-28	8.3E-04	048	-57	2.8E-04	*051	-66	2.2E-04*	075	-41	1.5E-04	017	-73	1.3E-04			
19010.42	13	286	023	-41	8.5E-04	036	-58	3.1E-04	*030	-53	2.4E-04*	063	-44	1.8E-04	090	-74	1.6E-04			
19011.31	29	317	034	-42	8.2E-04	049	-57	3.2E-04	038	-58	2.6E-04	*025	-54	1.9E-04*	007	-59	1.4E-04			
19011.32	29	317	047	-43	8.8E-04	045	-59	3.2E-04	*041	-62	2.3E-04*	046	-66	1.9E-04	040	-48	1.5E-04			
19011.41	40	314	065	-44	9.9E-04															
19011.42	40	314	053	-50	1.0E-03	034	-54	3.3E-04	*054	-65	2.7E-04*	068	-35	2.0E-04	001	-53	1.6E-04			
19012.11	25	309	050	-35	8.5E-04	029	-56	3.6E-04	034	-54	3.4E-04	*028	-62	2.9E-04*	033	-55	2.4E-04			
19012.12	25	309	042	-28	8.8E-04	033	-54	3.9E-04	030	-56	3.5E-04	015	-60	2.7E-04	*013	-62	2.1E-04*			
19012.31	29	303	054	-41	8.6E-04															
19012.32	29	303	040	-39	8.8E-04	035	-62	3.7E-04	*037	-61	3.4E-04*	061	-46	2.7E-04	051	-60	2.3E-04			
19013.1	47	275	014	-57	9.6E-04	026	-60	3.9E-04	*032	-60	3.1E-04*	036	-55	2.6E-04	033	-54	2.4E-04			
19013.2	39	272	047	-35	7.9E-04	046	-58	3.5E-04	*050	-61	3.1E-04*	043	-63	2.2E-04	054	-59	2.2E-04			
19013.3	42	269	043	-39	8.9E-04															
19013.5	41	323	036	-47	9.0E-04	030	-68	3.1E-04	*028	-67	2.6E-04*	070	-58	1.8E-04	012	-70	1.1E-04			
19014.1	30	136	174	-74	4.8E-04															
19014.2	24	166	341	-72	4.3E-04	038	-54	1.6E-04	015	-53	9.6E-05	049	-16	7.7E-05	*030	-52	4.0E-05*			
19014.51	31	162	006	-85	5.1E-04	011	-67	1.7E-04	*024	-72	1.6E-04*	043	-63	9.0E-05						
19014.52	31	162	034	-72	6.3E-04	003	-68	2.1E-04	358	-53	1.7E-04	034	-65	1.1E-04	*012	-62	1.1E-04*			
19015.1	38	121	134	-85	6.0E-04	053	-68	2.4E-04	*071	-71	2.0E-04*	031	-67	1.2E-04	080	-85	1.3E-04			
19015.2	54	130	055	-67	7.6E-04	054	-66	3.0E-04	040	-63	2.2E-04	*043	-65	1.8E-04*	359	-75	1.5E-04			
19015.4	60	095	085	-81	8.4E-04															
19015.5	55	144	092	-64	8.6E-04	083	-67	2.4E-04	*084	-71	2.5E-04*	062	-47	1.4E-04	099	-57	1.5E-04			
19016.1	30	143	258	-82	4.6E-04	060	-74	2.5E-04	*092	-69	1.5E-04*	015	-71	1.3E-04	342	-65	1.5E-04			
19016.3	29	140	223	-77	4.6E-04	015	-71	2.2E-04	077	-77	1.7E-04	*031	-78	1.1E-04*	079	-57	7.3E-05			
19016.4	20	122	156	-73	4.2E-04	017	-61	1.7E-04	037	-65	1.5E-04	077	-61	1.1E-04	*046	-60	9.0E-05*			
19016.5	27	110	207	-78	6.1E-04	110	-74	2.5E-04	077	-84	2.1E-04	067	-60	1.6E-04	*090	-84	1.1E-04*			
19017.1	40	137	109	-84	6.5E-04	054	-68	3.0E-04	019	-64	1.8E-04	060	-73	1.5E-04	*047	-66	1.2E-04*			
19017.2	25	111	115	-72	7.1E-04	070	-79	3.9E-04	084	-88	2.9E-04	035	-65	1.9E-04	*019	-71	1.5E-04*			
19017.3	29	105	111	-69	6.3E-04	040	-63	1.9E-04	*031	-61	1.6E-04*	058	-57	1.0E-04						
19017.4	34	122	113	-74	5.6E-04															
19018.1	37	140	254	-39	7.9E-04	252	-16	4.2E-04	246	-14	4.2E-04	242	-05	4.6E-04	*247	-06	4.2E-04*			
19018.2	29	151	182	-48	5.5E-04	155	-05	1.6E-04	160	26	1.7E-04	160	41	2.3E-04	*154	42	2.0E-04*			
19018.3	36	093	139	-71	5.7E-04															
19018.4	34	120	189	-27	2.7E-04	239	55	1.8E-04	*256	52	2.2E-04*	250	38	2.5E-04	274	60	1.4E-04			
19019.2	32	098	112	-29	2.3E-04															
19019.3	23	086	171	-82	3.2E-04															
19019.4	21	093	150	-53	2.2E-04															
19020.11	14	208	080	-80	3.2E-04	108	-47	1.2E-04	104	-54	7.0E-05	128	-43	4.5E-05	*142	-61	1.6E-05*			
19020.12	14	208	025	-67	2.7E-04	097	-45	8.3E-05	*098	-53	5.7E-05*	082	-55	4.5E-05	349	-46	4.1E-05			
19020.21	19	129	217	-72	3.1E-04	060	-53	9.4E-05	*032	-51	7.2E-05*	054	-02	4.7E-05	042	-38	7.5E-05			
19020.22	19	129	152	-73	2.9E-04	077	-60	6.4E-05	089	-80	5.6E-05	*084	-50	3.5E-05*	010	-21	1.8E-05			
19021.1	43	168	041	-70	3.3E-04	077	-35	1.1E-04	074	-53	8.0E-05	075	-41	5.6E-05	*067	-18	2.5E-05*			
19021.4	36	100	091	-66	3.1E-04															
19021.51	39	186	339	-81	3.6E-04	052	-71	1.4E-04	*073	-74	1.1E-04*	071	-72	4.5E-05	066	-64	5.8E-05			
19021.52	39	186	084	-82	3.5E-04	088	-71	1.1E-04	128	-65	1.0E-04	*122	-65	4.9E-05*	140	-58	4.6E-05			
19022.21	38	125	090	-12	1.2E-03	086	-05	1.1E-03	085	01	8.4E-04	*084	-02	4.4E-04*	079	01	3.3E-04			
19022.22	38	125	095	-10	7.8E-04	088	04	6.4E-04	095	06	5.0E-04	*097	04	2.6E-04*	095	15	1.6E-04			
19022.31	24	173	098	-41	9.0E-04	097	-23	5.8E-04	091	-23	4.0E-04	064	-42	1.3E-04	*089	-29	5.8E-05*			
19022.32	24	173	100	-62	4.2E-04															
19023.21	37	325	311	-52	7.0E-04	272	-37	5.9E-04	272	-40	5.1E-04	*278	-43	2.6E-04*	327	-62	1.4E-04			
19023.22	37	325	029	-51	4.8E-04															
19023.41	47	342	071	-28	3.7E-04	003	-53	9.6E-05	*008	-72	6.0E-05*	317	-70	5.1E-05	014	-65	5.0E-05			
19023.42	47	342	057	-37	3.7E-04	326	-40	1.1E-04	*302	-49	8.0E-05*	329	-69	7.0E-05	295	-48	4.3E-05			
19024.21	33	323	044	-33	4.7E-04	042	-42	1.5E-04	026	-49	1.3E-04	288	-81	1.2E-04	*025	-53	7.8E-05*			
19024.22	33	323	057	-20	5.5E-04	071	-30	1.5E-04	064	-28	1.3E-05	*073	-11	8.6E-05*	081	01	6.0E-05			
19024.31	40	298	042	-39	4.6E-04	020	-73	1.4E-04	*350	-72	1.0E-04*	291	-87	7.1E-05	327	-76	4.6E-05			
19024.32	40	298	336	-41	3.7E-04															
19025.2	41	288	038	-42	4.1E-04															
19025.3	39	317	048	-36	4.5E-04	045	-60	9.6E-05	045	-51	5.7E-05	*056	-63	4.0E-05*	010	-62	1.5E-05			
19025.41	39	310	058	-30	4.6E-04	062	-51	1.7E-04	045	-57	1.5E-04	*073	-53	6.2E-05*	110	-78	5.4E-05			
19025.42	39	310	036	-37	4.2E-04	052	-58	1.1E-04	022	-62	1.0E-04	039	-55	6.1E-05	*045	-69	3.9E-05*			
19026.41	38	265	332	-05	3.2E-04															
19026.42	38	365	163	26	6.9E-04				*182	33	9.9E-04*	185	36	9.3E-05	181	36	8.0E-04			
19026.51	41	268	346	-44	2.1E-04	233	29	2.0E-04	229	35	2.8E-04	*229	41	2.2E-04*	227	44	3.6E-04			
19026.52	41	268	041	35	2.5E-04	137	79	4.4E-04	155	82	5.3E-04	*149	79	5.0E-04*	158	75	6.0E-04			
19027.1	30	252	338	44	5.6E-04	327	78	6.6E-04	304	76	7.1E-04	*314	77	6.6E-04*	323	73	7.1E-04			
19027.4	20	235	007	65	4.6E-04	139	85	4.9E-04	*116	79	5.3E-04*	258	69	5.4E-04	151	79	4.3E-04			
19027.5	38	284	041	03	2.3E-04	221	76	2.9E-04	*223	73	3.1E-04*	216	74	3.5E-04	205	68	2.3E-04			
19028.11	31	271	085	-18	3.4E-04	146	20	2.7E-04	160	23	3.3E-04	*162	26	2.8E-04*	168	30	3.8E-04			
19028.12	31	271	262	41	2.8E-04	231	41	5.8E-04	232	43	6.5E-04	*237	44	5.3E-04*	235	42	7.2E-04			
19028.51	33	312	111	25	5.3E-04	151	48	5.4E-04	160	49	5.7E-04	169	54	6.1E-04	*166	50	5.1E-04*			
19028.52	33	312	359	53	5.5E-04	276	62	6.6E-04	285	61	7.1E-04	*288	59	5.8E-04*	300	56	4.7E-04			
19029.21	22	273	350	-30	7.8E-04	346	-24	4.5E-04	020	-08	3.6E-04	022	02	1.1E-04	*301	16	3.6E-05*			
19029.22	22	273	020	-23	7.1E-04	019	-12	4.4E-04	324	-15	3.6E-04	*300	06	1.0E-04*	014	10	5.8E-05			
19029.3	40	277	041	-31	4.0E-04															
19029.4	43	287	183	-05	1.7E-04	178	-33	5.0E-05	198	09	4.6E-05	211	18	4.9E-05	*216	42	5.0E-05*			
19030.1	27	296	029	-22	5.0E-04	023	-12	3.8E-05	264	26	3.3E-05	242	30	8.3E-05	*224	19	6.0E-05*			
19030.3	26	291	017	-34	4.5E-04	233	24	6.1E-05	196	33	8.2E-05	188	16	1.2E-04	*194	28	9.7E-05*			
19030.51	30	332	044	-25	5.0E-04	031	-21	7.8E-05	011	17	2.1E-05	112	76	6.2E-05	*257	48	7.7E-05*			
19030.52	30	332	039	-22	4.9E-04	009	-38	9.9E-05	301	-23	4.6E-05	*263	54	2.4E-05*	222	26	4.3E-05			
19031.1	45	228	327	-54	4.6E-04	049	-48	4.8E-05	107	02	1.7E-05	340	71	2.8E-05	*146	60	2.3E-05*			
19031.2	44	295	040	-36	4.8E-04	345	08	4.5E-05	288	30	7.1E-05	*282	41	6.7E-05*	253	36	7.6E-05			
19031.3	35	331	076	-28	4.7E-04	131	-07	5.7E-05	162	20	5.2E-05	179	45	5.4E-05	*177	47	4.7E-05*			
19031.4	22	334	047	-20	4.9E-04	066	61	3.0E-05	204	75	5.8E-05	213	47	7.5E-05	*223	41	7.8E-05*			
19032.2	44	283	022	-28	3.5E-04	294	33	9.3E-05	263	28	1.4E-04	279	32	1.5E-04	*270	34	1.8E-04*			

			NRM			150			200			250			300			320		
SPEC.	PLUNGE/ AZIMUTH		D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)
19032.3	43	256	357	-44	4.2E-04	137	-68	2.3E-05	226	42	5.0E-05	202	46	6.6E-05	*206	42	1.1E-04*			
19032.4	40	265	008	-35	4.4E-04															
19032.5	36	312	070	-25	6.1E-04	111	-17	1.3E-04	128	-03	1.1E-04	160	-01	9.0E-05	*143	09	7.5E-05*			
19033.11	43	270	033	-36	4.7E-04															
19033.12	43	270	025	-35	5.0E-04															
19033.51	40	275	051	-27	4.9E-04															
19033.52	40	275	041	-34	5.1E-04															
19034.2	24	057	107	-42	4.3E-04															
19034.3	35	066	099	-42	4.8E-04															
19034.5	32	075	128	-44	3.7E-04															
19035.21	36	048	096	-19	3.6E-04															
19035.22	36	048	130	-07	4.5E-04															
19035.41	38	033	099	-52	3.0E-04															
19035.42	38	033	126	-38	5.3E-04															
19036.11	46	077	113	-29	3.9E-04	106	-09	8.2E-05	106	07	6.2E-05	164	54	5.3E-05	*137	52	6.0E-05*			
19036.12	46	077	136	-34	3.6E-04	128	-03	7.4E-04	138	38	6.1E-05	159	39	1.1E-04	*184	60	1.0E-04*			
19036.21	46	034	105	-43	3.6E-04	117	-42	4.7E-05	143	-05	3.3E-05	274	09	1.9E-05	*245	25	3.0E-05*			
19036.22	46	034	111	-17	3.6E-04															
19037.11	21	056	138	-22	2.0E-04	154	35	5.4E-05	174	64	6.9E-05	183	17	7.6E-05	*208	59	6.0E-05*			
19037.12	21	056	130	-32	2.6E-04	145	05	4.5E-05	159	53	6.9E-05	196	44	7.0E-05	*208	60	9.1E-05*			
19037.41	35	029	101	-24	3.2E-04	097	23	3.4E-05	084	78	5.4E-05	*239	72	4.9E-05*	161	57	5.5E-05			
19037.42	35	029	077	-22	4.5E-04	131	65	1.6E-05	231	49	3.3E-05	186	60	5.4E-05	*209	59	4.0E-05*			
19038.51	47	016	073	-34	4.6E-04															
19038.52	47	016	072	-55	4.0E-04															
19039.21	24	058	108	-09	3.3E-04	021	46	9.0E-05	352	47	9.8E-05	305	56	1.3E-04	*311	53	1.8E-04*			
19039.22	24	058	147	-17	2.7E-04	242	61	1.9E-04	252	63	2.2E-04	247	62	2.4E-04	*268	63	3.0E-04*			
19039.51	24	064	129	27	4.7E-04															
19039.52	24	064	127	33	5.4E-04	095	83	4.8E-04	*150	85	5.8E-04*	178	85	5.7E-04	137	81	3.2E-04			
19040.21	36	057	146	37	8.1E-04	171	50	5.5E-04	170	47	5.2E-04	173	50	4.5E-04	*172	49	4.7E-04*			
19040.22	36	057	156	21	4.8E-04	185	49	3.9E-04	185	51	3.7E-04	200	45	3.8E-04	*196	52	3.4E-04*			
19040.4	36	026	146	-02	4.1E-04	209	52	2.8E-04	*220	55	2.8E-04*	244	50	1.7E-04	312	04	5.5E-05			
19040.5	34	040	087	79	5.2E-04	276	55	7.0E-04	275	46	7.0E-04	274	40	5.9E-04	*267	41	2.7E-04*			
19041.11	41	106	198	49	3.3E-03	214	59	3.2E-03	211	58	3.2E-03	*212	63	2.7E-03*	211	61	2.8E-03			
19041.12	41	106	207	48	4.0E-03	214	58	3.6E-03	214	57	4.1E-03	*218	58	3.4E-03*	219	54	3.7E-03			
19041.21	42	112	205	59	2.7E-03	239	67	2.7E-03	*239	66	2.5E-03*	240	68	1.9E-03	251	63	1.2E-03			
19041.22	42	112	204	59	3.3E-03	231	70	3.3E-03	*239	72	3.1E-03*	228	74	2.3E-03	221	77	1.8E-03			
19042.2	18	247	238	46	5.3E-03	249	62	5.6E-03	146	-53	5.1E-03	226	54	2.8E-03	*231	54	1.8E-03*			
19042.3	39	215	238	38	6.5E-03	236	46	6.7E-03	*237	42	6.0E-03*	244	38	4.3E-03	247	37	3.1E-03			
19042.41	17	238	222	64	9.7E-03	211	65	1.1E-02	207	64	9.9E-03	*209	65	7.2E-03*	206	63	7.8E-03			
19042.42	17	238	229	68	6.1E-03	220	62	7.4E-03	223	61	7.2E-03	*234	61	5.2E-03*	226	59	5.6E-03			
19043.11	46	276	333	48	8.9E-03	320	51	9.2E-03	318	54	8.8E-03	*319	54	7.1E-03*	311	56	6.9E-03			
19043.12	46	276	202	25	1.9E-03	212	55	4.3E-03	311	59	1.1E-02	*320	58	7.4E-03*	318	59	7.9E-03			
19043.2	51	237	302	42	6.2E-03	308	55	6.4E-03	302	51	6.1E-03	302	50	4.7E-03	*300	48	3.5E-03*			
19043.4	52	277	318	46	9.5E-03	310	54	9.7E-03	312	54	9.3E-03	311	54	7.4E-03	*314	52	5.7E-03*			
19044.41	16	280	023	-07	5.0E-04	338	46	1.1E-04	326	54	1.0E-04	277	69	1.1E-04	*264	65	1.3E-04*			
19044.42	16	280	017	-16	4.4E-04	001	14	6.4E-05	313	48	5.0E-05	019	69	8.3E-05	*295	77	1.2E-04*			
19044.51	15	323	070	-13	4.7E-04	104	75	6.3E-05	*207	78	7.3E-05*	224	62	7.7E-05	136	85	7.1E-05			
19044.52	15	323	069	-02	5.1E-04															
19045.2	37	345	103	12	3.9E-04	201	37	2.5E-04	220	37	3.1E-04				*227	36	3.2E-04*			
19045.3	25	332	115	67	1.0E-03	209	71	1.1E-03	226	70	9.2E-04	216	69	7.7E-04	*220	67	7.9E-04*			
19045.5	40	322	123	53	3.0E-04	228	51	7.5E-04	*237	36	5.4E-04*	234	21	4.2E-04	242	16	2.7E-04			
19046.1	35	302	083	-16	6.1E-05				231	39	2.3E-04	235	49	2.0E-04	*247	49	1.5E-04*			
19046.2	34	294	061	67	3.7E-04				327	85	4.3E-04	*311	81	3.4E-04*	003	74	2.4E-04			
19046.3	37	295	240	66	4.4E-04				239	55	7.1E-04	235	55	6.8E-04	*234	58	6.0E-04*			
19047.3	50	294	177	11	2.9E-04				197	26	4.7E-04	*196	23	4.5E-04*	182	22	4.2E-04			
19047.5	44	315	352	01	1.3E-04				270	46	2.2E-04	*264	47	2.1E-04*	261	56	2.3E-04			
19047.7	43	265	227	50	1.1E-03				226	47	1.0E-03	*223	45	8.6E-05*	214	33	6.0E-04			
19048.1	59	111	239	51	2.0E-03				236	51	1.9E-03	240	51	1.6E-03	*236	55	1.0E-03*			
19048.4	52	073	222	61	1.9E-03				230	64	1.6E-03	*228	64	1.4E-03*	238	67	1.1E-03			
19048.5	53	085	230	62	1.2E-03				243	58	1.2E-03	*244	60	1.0E-03*	252	63	7.8E-04			
19049.1	45	143	229	63	3.4E-04				232	59	4.5E-04	234	61	4.2E-04	*231	61	2.9E-04*			
19049.2	36	159	233	63	4.8E-04				238	58	5.2E-04	*236	59	4.7E-04*	251	60	4.0E-04			
19049.41	39	150	238	71	3.6E-04				237	64	4.1E-04	*231	63	3.6E-04*	228	71	3.0E-04			
19049.42	39	150	218	61	5.4E-04				227	58	5.9E-04	*227	57	5.2E-04*	231	56	3.6E-04			
19050.21	48	200	272	33	5.3E-04				272	36	6.6E-04	*269	36	6.5E-04*	275	28	6.7E-04			
19050.22	48	200	130	40	5.6E-04				134	50	5.4E-04	*121	45	5.5E-04*	095	51	6.5E-04			
19050.3	53	168	261	62	3.0E-04				243	59	4.6E-04	*252	62	4.0E-04*	243	62	2.9E-04			
19051.1	42	137	012	45	5.6E-04				348	62	6.7E-04	*357	56	6.6E-04*	341	56	5.3E-04			
19051.2	39	153	008	33	3.9E-04				344	58	4.4E-04	*356	56	4.2E-04*	017	56	4.1E-04			
19051.3	40	141	347	51	3.9E-04				301	57	5.1E-04	*313	58	4.9E-04*	291	72	4.4E-04			
19052.1	42	141	054	05	2.1E-04															
19052.2	38	148	115	06	2.6E-04				142	28	3.1E-04	137	27	2.9E-04	*140	29	2.7E-04*			
19052.32	51	159	221	11	2.8E-04				222	28	4.8E-04	*237	28	4.3E-04*	228	34	4.2E-04			
19052.4	59	140	178	64	5.3E-04				214	67	5.4E-04	*215	68	4.4E-04*	230	61	4.2E-04			
19053.1	42	170	318	61	6.3E-04				297	59	7.7E-04	301	62	7.1E-04	*292	64	5.9E-04*			
19053.2	42	142	260	16	1.5E-04				*247	35	3.5E-04*	250	42	3.1E-04	244	24	3.4E-04			
19053.4	46	132	127	81	3.2E-04				157	69	5.1E-04	144	66	4.8E-04	*154	67	4.3E-04*			
19055.1	65	197	208	59	5.8E-04				217	57	6.7E-04	*217	57	5.6E-04*	210	52	3.9E-04			
19055.2	61	171	183	63	4.9E-04				201	59	6.1E-04	*186	55	4.5E-04*	168	52	2.7E-04			
19055.31	58	188	216	63	6.5E-04				229	61	7.4E-04	*228	60	6.1E-04*	227	64	5.2E-04			
19055.32	58	188	228	71	5.4E-04				235	64	6.8E-04	*230	62	5.5E-04*	236	70	4.2E-04			
19056.2	38	298	209	58	3.7E-03				207	58	3.3E-03	*203	57	2.8E-03*	194	60	1.8E-03			
19056.3	67	272	230	57	6.1E-03				230	55	5.5E-03	*230	56	4.9E-03*	233	58	3.6E-03			
19056.4	53	027	214	52	6.3E-03				213	50	5.7E-03	*212	48	5.1E-03*	208	48	3.7E-03			
19057.11	39	332	301	79	8.2E-04				277	73	9.5E-04	*291	72	8.8E-04*	284	72	7.2E-04			
19057.12	39	332	233	64	1.0E-03				234	61	1.1E-03	*241	62	1.0E-03*	248	68	7.5E-04			
19057.4	37	316	175	44	7.7E-04				182	50	8.8E-04	*182	50	8.1E-04*	184	48	7.6E-04			
19058.1	44	025	097	55	6.0E-04				*101	62	5.9E-04*	080	38	5.6E-04	075	19	5.7E-04			
19058.2	40	049	153	73	1.0E-03				164	68	1.0E-03	*159	69	8.3E-04*	141	65	6.8E-04			
19058.3	34	043	271	49	1.1E-03				268	46	1.3E-03	*270	44	1.2E-04*	278	45	1.0E-03			
19059.1	34	101	234	75	2.0E-04				227	55	2.9E-04	*222	59	2.3E-04*	248	67	2.0E-04			

SPEC.	PLUNGE/ AZIMUTH		NRM D	NRM I	NRM M(A/m)	150 D	150 I	150 M(A/m)	200 D	200 I	200 M(A/m)	250 D	250 I	250 M(A/m)	300 D	300 I	300 M(A/m)	320 D	320 I	320 M(A/m)
19059.2	38	144	264	69	2.7E-04				256	64	3.7E-04	*271	64	2.8E-04*	271	62	2.6E-04			
19059.3	33	132	216	73	2.7E-04				220	64	3.0E-04	*215	62	2.6E-04*	199	62	2.2E-04			
19060.1	31	291	071	33	8.9E-05				*211	77	1.9E-04*	245	80	1.1E-04	324	66	6.8E-05			
19060.2	47	313	057	10	1.2E-04				*246	79	1.8E-04*	179	73	1.2E-04	228	73	1.5E-04			
19060.32	52	330	068	01	1.3E-04				177	73	1.7E-04	*211	61	1.1E-04*	153	51	1.4E-04			
19061.2	36	084	091	10	6.4E-05				*206	67	2.2E-04*	155	68	2.2E-04	226	68	2.5E-04			
19061.4	39	093	080	-26	9.6E-05				*208	69	1.7E-04*	221	55	1.6E-04	210	79	1.6E-04			
19061.51	39	105	215	58	6.1E-05				*217	60	2.6E-04*	200	68	2.3E-04	234	65	2.8E-04			
19061.52	39	105	110	13	3.4E-05				207	64	2.1E-04	*238	67	1.6E-04*	234	62	2.1E-04			
19062.1	46	286	050	-16	5.2E-04															
19062.3	49	271	161	-21	5.0E-04															
19062.4	53	296	061	-06	6.2E-04															
19063.1	57	287	221	81	5.8E-04				226	75	5.5E-04	*208	79	4.2E-04*	174	86	3.2E-04			
19063.21	56	253	143	49	2.3E-04				189	56	2.4E-04	*186	48	1.8E-04*	188	22	5.0E-05			
19063.22	56	253	179	55	3.9E-04				198	51	4.4E-04	172	59	3.1E-04	*170	58	2.5E-04*			
19063.3	51	262	245	69	8.0E-04				246	65	8.5E-04	*252	63	6.7E-04*	254	65	5.2E-04			
19064.11	34	337	074	-44	4.8E-04				093	-46	3.2E-04	082	-50	4.1E-04	*079	-54	3.8E-04*			
19064.12	34	337	051	-29	4.9E-04				049	-29	4.3E-04	*048	-32	5.9E-04*	035	-34	6.1E-04			
19064.2	44	324	068	-15	5.4E-04															
19064.4	50	323	043	-31	9.4E-04				040	-30	7.5E-04	043	-29	8.8E-04	*039	-31	7.7E-04			
19065.1	45	320													*032	-62	3.8E-04*			
19065.21	38	026													*027	-56	4.8E-04*			
19065.22	38	026										*036	-61	1.3E-03*						
19066.11	49	320	235	78	5.5E-04				245	69	6.0E-04	212	73	5.2E-04	*242	72	4.3E-04*			
19066.12	49	320	201	64	5.9E-04				210	61	7.0E-04	217	62	6.0E-04	*212	63	5.0E-04*			
19066.31	42	313	131	45	3.3E-04				168	57	3.7E-04	150	45	2.5E-04	*160	55	2.7E-04*			
19066.32	42	313	197	65	4.7E-04				*222	63	5.8E-04*	219	66	5.5E-04	223	60	4.3E-04			
19067.21	35	093	046	79	1.0E-04															
19067.22	35	093	157	74	2.6E-04				174	75	3.3E-04	164	83	2.8E-04	*176	76	2.0E-04*			
19067.31	46	055	159	56	1.2E-04				*217	58	2.1E-04*	248	50	8.5E-04	166	84	1.0E-04			
19067.32	46	055	209	49	3.0E-04				226	48	3.7E-04	232	35	2.6E-04	*230	46	2.6E-04*			
19068.31	47	091	205	63	1.7E-03				210	59	1.0E-03	*214	64	6.3E-04*	217	67	4.9E-04			
19068.32	47	091	220	57	1.9E-03				239	60	8.6E-04	284	73	4.6E-04	*246	67	3.5E-04*			
19068.4	43	106	232	65	1.0E-03				258	65	5.8E-04	316	45	2.5E-04	*263	80	1.6E-04*			
19070.1	22	046	182	64	2.0E-04				222	55	2.9E-04	*218	55	2.2E-04*	208	66	1.9E-04			
19070.3	22	051	186	60	5.4E-04				208	60	5.3E-04	*207	62	4.0E-04*	187	62	2.7E-04			
19070.4	26	045	194	60	3.9E-04				216	55	4.1E-04	*225	58	3.3E-04*	211	68	2.4E-04			
19071.21	40	095	282	-11	4.9E-05															
19071.22	40	095	150	77	6.1E-04															
19071.3	55	109	215	75	5.9E-04															
19071.4	45	062	061	17	2.3E-04															
19072.1	46	079	230	54	2.8E-03				*232	54	2.2E-03*	255	56	1.7E-03	224	54	1.3E-03			
19072.2	50	077	223	52	2.7E-03				226	48	2.2E-03	*227	48	1.7E-03*	228	49	1.3E-03			
19072.4	40	070	037	-06	3.8E-04				224	46	5.8E-04	229	55	8.6E-04	*222	60	5.7E-04*			
19073.2	56	076	228	64	6.8E-04				229	62	6.9E-04	241	55	6.2E-04	*248	64	5.0E-04*			
19073.3	51	034	185	67	4.8E-04				213	57	4.8E-04	*210	60	3.4E-04*	214	55	2.9E-04			
19073.4	60	059	198	59	5.5E-04				206	57	5.4E-04	217	56	4.7E-04	*217	61	4.3E-04*			
19074.2	52	119	210	55	5.0E-04				217	51	5.3E-04	*221	53	4.6E-04*	245	62	3.4E-04			
19074.41	54	093	195	52	2.3E-04				219	54	3.4E-04	*213	51	3.3E-04*	228	61	2.4E-04			
19074.42	54	093	200	59	3.8E-04				211	59	4.6E-04	*219	60	3.3E-04*	214	60	2.7E-04			
19074.5	54	100	222	56	4.8E-04				225	57	5.3E-04	231	56	4.6E-04	*236	56	3.9E-04*			
19075.2	31	274	216	62	2.5E-03				*213	64	1.7E-03*	198	67	1.2E-03	170	77	9.7E-04			
19075.3	28	270	222	74	1.5E-03				*190	75	9.7E-04*	180	66	1.2E-03	183	46	7.1E-04			
19075.4	31	274	230	53	1.9E-03				*226	50	1.4E-03*	230	50	1.1E-03	224	51	7.8E-04			
19076.3	28	284	189	39	8.5E-04				197	43	8.8E-04	*196	43	8.8E-04*	197	42	7.4E-04			
19076.4	30	274	136	71	1.6E-04				*225	64	2.8E-04*	228	62	2.4E-04	216	54	2.1E-04			
19076.5	28	281	221	80	3.1E-04				*219	63	3.4E-04*	237	63	2.7E-04	207	61	2.5E-04			
19076.6	30	284	090	63	1.3E-04				*205	58	2.3E-04*	191	56	2.4E-04	211	48	2.4E-04			
19077.1	19	297	095	42	7.7E-05				197	56	2.0E-04	*203	55	2.5E-04*	202	50	2.2E-04			
19077.2	18	308	087	14	5.5E-05				221	60	1.5E-04	*208	50	5.0E-04*	235	31	4.9E-04			
19077.3	23	322	055	00	1.6E-04				105	71	1.3E-04	195	71	1.4E-04	*210	29	6.3E-04*			
19077.4	18	304	022	48	5.6E-05				*227	56	1.8E-04*	237	47	2.1E-04	211	53	1.9E-04			
19078.11	44	270	170	83	1.5E-04				*224	67	2.3E-04*	271	75	1.9E-04	240	63	2.2E-04			
19078.12	44	270	196	67	1.9E-04				218	58	2.8E-04	205	62	2.7E-04	*215	58	2.4E-04*			
19078.2	58	291	214	62	2.0E-04				227	53	3.2E-04	*230	56	2.7E-04*	231	59	2.5E-04			
19078.3	57	285	208	59	2.2E-04				*216	53	3.1E-04*	228	53	2.2E-04	221	47	2.4E-04			
19078.4	59	300	198	68	2.2E-04				*219	63	3.1E-04*	231	56	2.6E-04	224	65	2.5E-04			
19079.1	59	275	116	57	1.1E-04				*201	65	2.2E-04*	202	62	1.7E-04	202	67	1.5E-04			
19079.2	63	273	090	69	1.1E-04				226	69	2.3E-04	*212	64	2.0E-04*	224	66	2.0E-04			
19079.3	65	297	058	74	1.3E-04				224	66	2.5E-04	195	72	2.2E-04	*220	66	1.8E-04*			
19079.41	69	292	104	63	1.2E-04				*226	66	2.3E-04*	210	72	1.8E-04	232	60	1.9E-04			
19079.42	69	292	132	58	1.5E-04				200	60	2.2E-04	219	53	1.8E-04	*210	62	1.8E-04*			
19080.1	48	196	071	-36	8.6E-05				200	56	1.2E-04	207	47	1.1E-04	*199	56	1.3E-04*			
19080.2	65	183	068	-29	8.5E-05				*234	72	1.1E-04*	193	74	1.5E-04	222	61	1.4E-04			
19080.4	68	190	075	-42	9.6E-05				230	71	1.2E-04	258	51	1.2E-04	*227	64	1.3E-04*			
19080.5	69	192	038	-36	1.0E-04				179	66	8.3E-05	205	58	9.2E-05	*203	65	1.1E-04*			
19081.21	66	164	041	77	9.3E-05				*238	70	1.5E-04*	250	68	1.3E-04	248	76	1.6E-04			
19081.22	66	162	345	87	4.2E-05				249	61	1.4E-04	228	36	1.4E-04	*222	59	1.4E-04*			
19081.32	52	188	040	22	1.0E-04				298	82	1.5E-04	245	74	1.4E-04	*227	84	1.7E-04*			
19082.1	56	114	092	54	3.6E-05				*214	68	1.0E-04*	195	66	9.2E-05	245	67	1.4E-04			
19082.2	63	134	105	68	3.9E-05				*224	65	1.4E-04*	222	51	1.5E-04	229	65	1.6E-04			
19082.31	35	176	096	74	1.0E-04				*244	83	1.5E-04*	238	73	1.8E-04	158	78	1.7E-04			
19082.42	34	177	117	88	8.8E-05				208	67	2.0E-04	*215	63	2.3E-04*	216	64	2.0E-04			
19083.2	39	058	225	58	9.0E-04				236	57	7.8E-04	*234	57	6.3E-04*	238	57	5.5E-04			
19083.3	41	070	221	56	1.8E-03				228	57	1.5E-03	220	55	1.1E-03	*229	58	7.5E-04*			
19083.4	34	067	230	54	6.3E-04				238	52	5.9E-04	230	51	4.5E-04	*234	52	3.9E-04*			
19084.1	32	090	176	63	3.2E-04															
19084.2	33	087	196	85	5.4E-04															
19084.4	33	100	054	17	3.4E-04															
19085.2	31	101	200	59	4.8E-04				211	58	5.5E-04	221	60	4.4E-04	*216	59	3.1E-04*			
19085.3	44	103	200	66	3.5E-04				210	71	3.9E-04	*211	70	3.4E-04*	210	75	3.0E-04			
19085.4	57	105	218	60	4.4E-04				234	60	4.7E-04	229	53	3.8E-04	*233	51	3.1E-04*			
19086.1	23	125	226	55	1.3E-03				224	56	1.0E-03	216	55	4.8E-04	*226	55	4.2E-04*			
19086.2	61	134	227	59	1.7E-03				229	57	1.2E-03	228	61	5.7E-04	*232	59	4.7E-04*			
19086.3	44	112	232	62	1.0E-03				228	61	9.0E-04	219	57	5.2E-04	*227	58	4.3E-04*			
19086.4	55	083	220	63	8.8E-04				232	62	7.1E-04	*231	58	4.3E-04*	244	62	3.1E-04			
19087.1	27	037	208	64	9.2E-04				217	60	8.6E-04	220	50	4.2E-04	*216	52	3.2E-04*			
19087.2	29	052	216	71	1.6E-03				227	73	1.3E-03	*232	66	6.9E-04*	244	68	5.6E-04			
19087.3	25	053	229	66	2.2E-03				234	60	1.7E-03	*237	57	8.2E-04*	238	59	7.5E-04			

			NRM			150			200			250			300			320		
SPEC.	PLUNGE/ AZIMUTH		D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)	D	I	M(A/m)
19088.1	36	098	177	74	5.0E-04				218	74	4.1E-04	*216	73	3.8E-04*	232	77	3.7E-04			
19088.2	22	093	047	10	1.5E-05				*224	68	9.4E-05*	224	44	1.2E-04	256	56	1.1E-04			
19088.31	21	018	189	57	1.7E-04				220	60	2.1E-04	217	55	2.2E-04	*223	56	2.0E-04*			
19088.32	21	018	199	62	2.8E-04				*212	62	3.1E-04*	193	60	2.3E-04	225	58	1.5E-04			
19089.21	63	227	028	-34	1.5E-04				193	77	8.6E-05	*239	68	0.6E-05*	252	69	1.1E-04			
19089.22	63	227	052	-21	1.2E-04				180	68	1.1E-04	235	61	9.8E-05	*210	69	8.4E-05*			
19089.31	64	284	062	-28	1.1E-04				*199	63	1.2E-04*	222	54	1.9E-04	188	62	6.9E-05			
19089.32	64	284	059	-12	1.5E-04				*191	74	1.2E-04*	221	66	1.9E-04	142	83	1.2E-04			
19089.4	64	222	045	-16	1.3E-04				*176	76	1.2E-04*	194	77	9.5E-05	167	65	9.4E-05			
19090.11	73	343	080	-21	9.1E-05				199	54	1.2E-04	*157	41	1.1E-04*	132	19	1.3E-04			
19090.12	73	343	058	34	7.5E-05				*241	69	1.7E-04*	245	64	2.0E-04	213	67	1.5E-04			
19090.2	66	247	066	-14	9.0E-05															
19090.3	70	259	086	29	1.0E-04															
19090.41	74	326	040	01	8.0E-05				*233	73	1.3E-04*	341	45	1.2E-04	234	43	2.5E-04			
19090.42	74	326	060	06	7.7E-05															
19091.11	70	300	055	-41	1.9E-04															
19091.12	70	300	057	-48	2.3E-04															
19091.21	74	310	062	-45	1.7E-04															
19091.22	74	310	057	-43	1.7E-04															
19091.3	70	324	057	-45	1.8E-04															
19092.1	43	309	070	-41	1.7E-04				138	43	4.9E-05	201	50	7.8E-05	*180	57	5.1E-05*			
19092.2	35	315	059	-40	1.8E-04				137	62	4.2E-05	215	47	6.9E-05	*217	48	1.1E-04*			
19092.3	19	323	062	-35	1.7E-04				143	45	4.6E-05	173	59	6.1E-05	*181	52	4.4E-05*			
19092.4	22	324	064	-32	1.5E-04				130	41	5.9E-05	156	48	1.1E-04	*151	53	9.9E-05*			
19093.31	34	287	085	25	8.7E-05				167	71	1.3E-04	181	79	1.5E-04	147	73	1.1E-04			
19093.32	34	287	097	-26	4.9E-05				195	44	9.2E-05	*211	46	1.2E-04*	221	39	1.2E-04			
19093.33	34	287	073	22	6.2E-05				184	74	8.7E-05	*212	63	8.9E-05*	203	81	7.9E-05			
19093.4	35	267	081	37	4.7E-05				223	62	1.3E-04	216	50	1.4E-04	*214	57	1.3E-04*			
19094.21	24	317	075	-23	1.7E-04				180	61	7.9E-05	*220	59	1.0E-04*	198	75	8.1E-05			
19094.22	24	317	081	-10	1.1E-04				188	72	1.2E-04	*198	77	1.2E-04*	117	75	1.1E-04			
19094.3	32	320	050	-10	1.0E-05				222	74	7.8E-05	*269	81	1.3E-04*	180	88	8.4E-05			
19094.4	25	330	064	-06	1.0E-04				*213	63	1.2E-04*	222	55	1.4E-04	188	61	1.1E-04			
19095.11	39	282	114	65	1.1E-04				*215	67	2.7E-04*	217	60	2.5E-04	211	76	2.1E-04			
19095.12	39	282	123	56	9.7E-05				*205	63	2.5E-04*	217	58	2.6E-04	210	66	2.2E-04			
19095.2	28	329	057	27	1.2E-04				*221	68	2.3E-04*	219	74	2.0E-04	216	71	2.3E-04			
19095.3	38	301	028	-28	7.0E-05				*217	67	1.9E-04*	210	57	2.0E-04	207	70	1.8E-04			
19096.11	52	051	081	22	9.2E-05				199	68	1.9E-04	224	63	2.1E-04	*215	60	2.2E-04*			
19096.12	52	051	113	26	6.9E-05				214	55	2.0E-04	*209	48	2.1E-04*	199	50	1.8E-04			
19096.21	45	059	118	17	4.7E-05				*229	68	2.2E-04*	230	70	2.3E-04	209	61	1.8E-04			
19096.22	45	059	103	46	5.3E-05				215	66	2.2E-04	*207	58	2.1E-04*	248	61	2.0E-04			
19097.1	29	067	224	54	4.0E-04															
19097.2	22	038	222	68	6.1E-04															
19097.31	24	009	224	63	5.5E-04				233	56	7.2E-04	220	56	6.3E-04	*221	55	5.7E-04*			
19097.32	24	009	222	59	7.1E-04				226	53	8.4E-04	*225	53	7.6E-04*	226	49	6.7E-04			
19097.41	25	056	228	56	5.7E-04				225	56	7.6E-04	*227	54	6.6E-04*	223	51	6.1E-04			
19097.42	25	056	216	64	5.9E-04				230	58	7.6E-04	*225	58	7.2E-04*	223	56	6.1E-04			
19098.1	34	029	125	77	1.6E-04															
19098.2	31	040	165	62	2.3E-04				*199	57	3.8E-04*	207	62	3.7E-04	191	55	3.1E-04			
19098.3	32	012	148	83	1.7E-04				222	64	3.3E-04	*223	67	3.1E-04*	194	65	2.8E-04			
19098.41	31	030	121	71	2.0E-04				210	68	3.2E-04	*209	66	3.4E-04*	208	64	3.0E-04			
19098.42	31	030	214	74	1.4E-04				232	59	3.0E-04	*227	59	3.4E-04*	215	56	3.0E-04			
19099.2	65	060	076	-08	1.1E-04				237	61	1.5E-04	245	35	1.6E-04	*252	56	1.3E-04*			
19099.31	70	063	074	-53	1.5E-04				261	70	1.4E-04	*230	77	1.6E-04*	228	62	1.9E-04			
19099.32	70	063	096	-44	1.3E-04				*227	57	1.5E-04*	250	60	1.3E-04	223	60	1.8E-04			
19100.1	40	122	052	-27	1.6E-04															
19100.2	36	107	046	-33	1.3E-04				218	84	9.1E-05	221	55	1.1E-04	*223	68	9.5E-05*			
19100.3	30	142	048	-18	1.2E-04				*248	65	8.7E-05*	252	59	5.5E-05	345	72	1.1E-04			
19100.41	33	127	061	-40	1.4E-04															
19100.42	33	127	059	-39	1.1E-04															
19101.1	35	070	066	-29	1.8E-04				255	52	8.8E-05	*237	49	1.2E-04*	202	58	1.1E-04			
19101.2	40	079	054	-12	1.6E-04				156	73	6.8E-05	*234	65	9.5E-05*	198	22	3.8E-05			
19101.3	31	085	077	-17	1.8E-04				*198	50	1.1E-04*	234	58	1.0E-04	163	29	7.8E-05			
19102.1	40	088	034	-20	3.0E-04				024	37	1.2E-04	020	51	1.3E-04	349	48	1.5E-04			
19102.2	29	106	057	-53	2.0E-04				214	42	2.8E-05	253	23	1.7E-05	078	57	6.9E-05			
19102.3	26	085	038	-40	2.3E-04				360	02	8.7E-05	350	29	8.9E-05	350	29	1.1E-04			
19102.4	51	079	067	-34	2.5E-04				067	57	6.1E-05	085	40	3.9E-05						
19103.1	49	106	054	-30	1.7E-04															
19103.21	47	114	053	-43	2.4E-04				057	02	3.7E-05	239	40	2.4E-05	*223	68	7.4E-05*			
19103.22	47	114	046	-49	1.9E-04				156	42	2.0E-05	235	59	4.6E-05	*223	72	6.7E-05*			
19103.31	37	114	069	-34	2.0E-04															
19103.32	37	114	077	-42	1.7E-04				080	35	3.5E-05	134	64	5.5E-05	*269	86	6.7E-05*			
19104.1	61	155	077	-35	1.7E-04				114	77	3.0E-05	211	53	8.6E-05	*187	76	7.2E-05*			
19104.21	64	118	063	-37	1.5E-04				079	62	2.1E-05	*225	66	6.3E-05*	241	52	6.6E-05			
19104.22	64	118	048	-32	1.7E-04				102	80	3.5E-05	201	34	9.5E-05	*185	60	9.3E-05*			
19104.3	64	110	072	-53	1.7E-04															
19104.4	69	160	087	-47	2.1E-04															
19105.1	35	069	054	-12	2.1E-04															
19105.2	40	086	065	-32	1.5E-04															
19105.31	55	072	048	-15	2.3E-04				024	-26	6.4E-05	335	66	2.4E-05	*232	52	3.4E-05*			
19105.32	55	072	059	-13	2.1E-04				034	-18	4.9E-05	298	30	5.1E-05	*266	10	7.8E-05*			
19105.41	45	070	057	-19	2.0E-04				076	-04	5.8E-05	013	-11	5.5E-05	*228	59	2.2E-05*			
19106.1	63	178	054	-45	2.9E-04															
19106.2	62	166	069	-38	3.5E-04				068	08	8.0E-05	132	73	1.4E-05	*207	44	5.3E-05*			
19106.3	70	239	055	-47	3.4E-04				079	-35	7.0E-05	278	38	1.7E-05	*196	64	8.9E-05*			
19106.4	70	217	059	-52	3.1E-04				072	-63	6.3E-05	172	09	4.5E-05	*239	58	4.8E-05*			
19107.2	45	058	058	-39	3.3E-04				061	-25	8.9E-05	023	-12	7.4E-05	*221	56	5.8E-05*			
19107.4	30	029	056	-38	3.1E-04				096	-28	6.9E-05	078	-45	8.5E-05	*249	66	1.1E-04*			
19107.5	47	034	064	-38	3.4E-04															
19107.6	58	025	058	-41	4.2E-04				046	-28	6.3E-05	024	-40	8.6E-05	*194	-53	8.3E-05*			
19108.1	52	030	067	-57	3.0E-04															
19108.2	66	026	073	-47	3.0E-04				099	-34	1.2E-04	046	-39	8.2E-05	*222	66	3.2E-05*			

SPEC.	PLUNGE/ AZIMUTH		NRM D	NRM I	NRM M(A/m)	150 D	150 I	150 M(A/m)	200 D	200 I	200 M(A/m)	250 D	250 I	250 M(A/m)	300 D	300 I	300 M(A/m)	320 D	320 I	320 M(A/m)
19108.3	38	020	069	-48	2.2E-04				027	-60	9.7E-05	328	-29	5.8E-05	*218	62	4.8E-05*			
19108.4	70	353	044	-46	4.0E-04				054	-46	1.0E-04	093	-48	4.7E-05	*211	66	8.0E-05*			
19109.1	30	011	053	-43	4.2E-04															
19109.2	46	355	045	-53	4.1E-04															
19109.4	25	045	052	-37	4.5E-04															
19110.1	40	041	061	-48	4.6E-04				048	-51	1.3E-04	147	06	4.2E-04	*245	58	7.8E-05*			
19110.2	40	058	065	-54	4.1E-04				060	-58	1.5E-04	166	-28	3.2E-04	*204	54	6.8E-05			
19110.3	38	026	062	-56	4.6E-04															
19110.4	35	054	051	-52	5.0E-04				056	-59	1.4E-04	009	02	4.4E-04	*179	63	4.8E-05*			
19111.1	48	029	039	-78	3.3E-04				126	-71	9.1E-05	188	43	7.3E-05	*163	62	5.6E-05*			
19111.2	40	101	169	14	3.0E-04				162	34	8.4E-05	200	51	7.7E-05	*238	59	7.3E-05*			
19111.3	38	085	070	-55	4.3E-04				040	-56	1.3E-05	230	49	2.8E-05	*250	68	3.7E-05*			
19112.1	50	067	053	-49	3.7E-04															
19112.2	58	064	062	-53	3.9E-04															
19112.3	29	064	051	-47	4.2E-04															
19112.41	34	071	056	-55	4.3E-04															
19112.42	34	071	052	-55	4.1E-04															
19114.21	32	027	037	-53	4.2E-04				004	-50	9.9E-04	340	-20	8.2E-05	*269	63	4.1E-05*			
19114.31	34	043	059	-42	3.9E-04				131	03	2.0E-04	196	47	7.8E-05	*209	52	5.6E-05*			
19114.32	34	043	049	-58	3.8E-04				103	-26	1.4E-04	160	-10	5.1E-05	*180	69	3.0E-05*			
19115.1	38	072	054	-29	3.7E-04				120	-14	1.2E-04	220	47	8.1E-05	*218	58	7.2E-05*			
19115.2	48	058	038	-60	4.0E-04				069	-42	2.3E-04	150	-09	9.2E-05	*225	64	6.0E-05*			
19115.4	41	019	041	-52	3.6E-04				140	22	7.2E-04	180	43	4.6E-05	*203	61	9.0E-05*			
19116.1	44	057	035	-28	5.4E-04				023	-27	3.8E-04	*012	-28	2.0E-04*	012	-34	2.7E-04			
19116.2	40	073	051	-54	3.7E-04				043	-61	1.8E-04	*046	-57	8.9E-05*	047	-39	7.2E-05			
19116.41	43	052	057	-53	3.6E-04				036	-64	1.1E-04	355	-69	8.9E-05	*042	-65	6.4E-05*			
19116.42	43	052	044	-50	4.4E-04				080	-64	3.1E-04	*047	-52	2.3E-04*	048	-59	7.6E-05			
19117.11	37	037	066	-37	2.8E-04				047	-42	8.5E-05	*031	-46	5.5E-05*	038	-52	2.7E-05			
19117.12	37	037	057	-47	3.3E-04				049	-62	7.5E-05	151	-68	1.4E-04	*039	-63	4.8E-05*			
19117.2	50	044	052	-38	2.6E-04				*048	-44	7.3E-05*	099	-28	5.3E-05	039	-55	4.8E-05			
19117.4	49	034	051	-44	3.1E-04															
19118.2	65	199	052	-46	3.6E-04				054	-55	1.2E-04	051	-53	6.3E-05	*049	-56	5.0E-05*			
19118.3	54	197	064	-47	3.2E-04				*078	-55	7.7E-05*	132	-54	5.9E-05	061	-62	4.1E-05			
19118.4	51	198	083	-47	3.9E-04				096	-25	1.3E-04	108	-31	8.7E-05	*111	-30	5.8E-05*			
19119.1	67	177	069	-38	2.8E-04				*068	-54	1.2E-04*	047	-70	6.7E-05	065	-13	3.2E-05			
19119.2	63	195	057	-52	3.5E-04				067	-55	1.0E-04	046	-66	8.3E-05	*045	-67	6.7E-05*			
19119.4	58	131	043	-56	3.5E-04				001	-53	8.9E-05	050	-29	7.7E-05	*047	-26	1.5E-05*			
19120.1	56	180	069	-30	4.8E-04				077	-23	1.6E-04	*074	-26	9.6E-05*	080	-15	6.7E-05			
19120.2	55	158	064	-40	4.8E-04				038	-46	1.2E-04	056	-19	3.5E-05	*050	-44	5.3E-05*			
19120.4	53	178	056	-45	4.5E-04				045	-51	1.3E-04	*053	-55	9.6E-05*	039	-66	5.4E-05			
19121.11	51	196	066	-63	7.9E-04				*054	-67	4.4E-04*	024	-59	2.8E-04	056	-49	1.6E-04			
19121.12	51	196	072	-57	5.0E-04				057	-64	2.4E-04	050	-59	1.5E-04	*043	-65	9.2E-05*			
19121.4	56	179	061	-51	4.2E-04				050	-59	2.2E-04	053	-50	1.1E-04	*058	-47	7.5E-05*			
19122.11	48	270	071	-57	3.9E-04				059	-56	1.7E-04	072	-39	3.0E-04	*058	-55	9.4E-05*			
19122.12	48	270	066	-61	2.8E-04				030	-51	1.5E-04	031	-54	1.8E-04	*031	-51	8.2E-05*			
19122.21	45	277	063	-49	4.3E-04															
19122.22	45	277	049	-43	3.7E-04				*065	-54	1.7E-04*	074	-52	1.5E-04	101	-25	1.4E-04			
19123.1	40	223	080	-47	4.8E-04				*099	-44	1.6E-04*	111	-26	8.5E-05	359	-66	7.6E-05			
19123.2	46	246	045	-41	3.3E-04				*065	-29	8.6E-05*	068	-30	5.7E-05	058	-29	6.5E-05			
19123.4	41	228	054	-59	3.8E-04				069	-52	1.3E-04	066	-63	6.8E-05	*063	-63	4.5E-05*			
19125.2	40	202	066	-53	3.9E-04				*078	-49	1.5E-04*	105	-37	9.5E-05	083	-56	8.7E-05			
19125.3	50	259	044	-48	4.3E-04				*043	-56	1.5E-04*	022	-63	1.6E-04	041	-54	7.6E-05			
19125.4	43	208	070	-76	4.3E-04				091	-83	1.6E-04	020	-63	1.6E-04	*019	-67	9.1E-05*			
19126.1	59	244	050	-41	3.2E-04				031	-55	1.1E-04	044	-44	1.1E-04	*045	-43	8.2E-05*			
19126.2	45	244	071	-58	3.2E-04				*040	-64	1.2E-04*	085	-60	1.2E-04	025	-61	8.3E-05			
19126.3	47	280	054	-48	5.7E-04				053	-39	1.7E-04	055	-41	1.2E-04	*049	-39	9.2E-05*			
19126.4	57	253	050	-57	3.8E-04				068	-57	1.3E-04	341	-29	3.5E-05	*055	-55	8.7E-05*			
19127.1	49	119	111	-75	2.6E-04				089	-74	9.5E-05	085	-29	4.6E-05	148	-54	9.6E-05			
19127.2	52	248	057	-60	3.1E-04				055	-62	1.1E-04	078	-39	6.1E-05	037	-60	9.9E-05			
19127.3	49	271	037	-59	2.6E-04				028	-56	9.9E-05	035	-13	7.9E-05	102	-66	1.9E-05			
19128.1	54	261	068	-56	3.9E-04				055	-54	2.0E-04	051	-41	1.9E-04	*054	-41	9.3E-05*			
19128.3	61	244	053	-56	5.3E-04				047	-56	2.6E-04	*046	-65	1.9E-04*	053	-72	9.8E-05			
19128.4	57	231	056	-59	4.7E-04				058	-57	2.1E-04	045	-58	1.9E-04	*048	-58	9.3E-05*			
19129.3	47	230	037	-60	3.8E-04				113	-68	6.2E-05	336	-52	7.5E-05	*106	-81	3.8E-05*			
19129.41	47	230	060	-51	4.0E-04				*077	-49	1.4E-04*	109	-50	8.4E-05	074	-56	7.3E-05			
19129.42	47	230	057	-52	4.6E-04				*066	-54	1.4E-04*	196	-60	6.3E-05	073	-52	6.6E-05			
19131.2	54	246	041	-57	3.6E-04				*008	-73	1.3E-04*	290	-58	8.4E-05	019	-74	6.8E-05			
19131.3	55	277	045	-53	4.1E-04				045	-37	8.5E-05	*056	-32	5.8E-05*	055	-33	4.9E-05			
19131.4	49	291	058	-45	4.0E-04				055	-45	1.5E-04	056	-65	1.1E-04	*059	-58	7.7E-05*			
19132.21	34	288	042	-49	2.8E-04				026	-58	1.4E-04	*023	-51	8.1E-05*	032	-44	7.3E-05			
19132.22	34	288	054	-50	2.2E-04				077	-60	1.2E-04	*061	-63	4.6E-05*						
19132.3	42	321	043	-52	2.4E-04				045	-52	1.2E-04	*087	-84	5.2E-05*	053	-33	4.3E-05			
19133.2	57	290	049	-56	3.4E-04				*052	-61	1.5E-04*	336	-75	6.5E-05	049	-57	5.6E-05			
19133.3	59	308	037	-54	3.4E-04				*024	-47	1.0E-04*	003	-42	7.9E-05	044	-44	6.4E-05			
19133.41	66	330	048	-51	3.8E-04				360	-74	9.0E-05	016	-61	4.7E-05	*036	-61	3.4E-05*			
19133.42	66	330	037	-37	3.4E-04				*044	-48	1.4E-04*	032	-23	7.7E-05	031	-55	5.6E-05			
19134.1	45	252	048	-54	3.9E-04				060	-50	2.1E-04	*068	-55	9.2E-05*	092	-69	7.0E-05			
19134.2	52	256	068	-47	4.4E-04				*064	-55	1.8E-04*	021	-49	9.5E-05	091	-61	1.0E-04			
19134.31	38	289	054	-45	1.5E-03				046	-49	3.7E-04	*066	-56	1.6E-04*	068	-59	1.1E-04			
19134.32	38	289	069	-51	4.9E-04				*044	-60	2.1E-04*	341	-63	6.7E-05	033	-43	5.7E-05			
19135.11	50	314	054	-52	2.7E-04				036	-42	1.4E-04	*024	-69	3.7E-05*	030	-68	2.9E-05			
19135.12	50	314	050	-55	2.3E-04				042	-62	1.0E-04	113	-12	5.7E-05	*041	-60	5.1E-05*			
19135.3	49	316	047	-56	3.2E-04				076	-65	1.8E-04	165	-70	4.1E-05	*060	-67	3.8E-05*			
19135.4	43	299	069	-64	3.6E-04				067	-57	1.1E-04	129	-67	3.6E-05	*059	-68	3.2E-05*			
19136.1	35	270	010	-29	1.2E-03				020	-41	3.0E-04	019	-49	1.0E-04	*019	-44	7.8E-05*			
19136.2	36	285	044	-53	2.7E-04				*044	-54	1.5E-04*	055	-57	7.9E-05	030	-41	5.4E-05			
19136.3	35	254	035	-54	2.5E-04				028	-42	8.9E-05	*028	-54	6.3E-05*	021	-51	5.0E-05			
19136.4	38	261	072	-42	2.9E-04															
19137.1	48	287	058	-52	5.0E-04				*058	-48	2.3E-04*	099	-43	1.1E-04	054	-47	7.6E-05			
19137.2	49	292	041	-31	5.9E-04				094	-57	1.8E-04	055	-47	1.0E-04	*054	-53	7.8E-05*			
19137.4	42	345	068	-22	1.4E-03															

SPEC.	PLUNGE/ AZIMUTH		NRM D	NRM I	NRM M(A/m)	150 D	150 I	150 M(A/m)	200 D	200 I	200 M(A/m)	250 D	250 I	250 M(A/m)	300 D	300 I	300 M(A/m)	320 D	320 I	320 M(A/m)
19137.5	50	315	045	-50	3.0E-04				050	-70	1.3E-04	047	-54	4.6E-05	*054	-49	3.6E-05*			
19138.2	43	292	063	-47	2.1E-04				073	-44	1.1E-04	101	-83	3.6E-05	*108	-82	2.5E-05*			
19138.3	48	266	077	-51	2.4E-04				100	-51	9.1E-05	*090	-50	1.7E-05*						
19138.4	49	287	052	-45	2.2E-04				*070	-57	5.7E-05*	056	-34	3.6E-05	074	-55	3.1E-05			
19139.11	37	294	066	-30	2.7E-04				*093	-45	1.4E-04*	096	-34	7.4E-05	094	-48	6.2E-05			
10139.12	37	294	044	-23	5.6E-04				*055	-41	1.3E-04*	005	-70	4.2E-05	054	-39	3.7E-05			
19139.3	54	314	047	-45	3.9E-04															
19139.4	42	292	046	-38	3.5E-04				037	-53	1.3E-04	*031	-81	3.3E-05*	025	-83	3.1E-05			
19140.1	51	254	040	-54	2.1E-04															
19140.3	44	270	048	-45	2.3E-04															
19140.4	60	283	085	-51	4.1E-04															
19141.1	36	261	028	-53	3.1E-04				086	-72	1.1E-04	*019	-66	4.8E-05*	012	-60	4.1E-05			
19141.2	41	284	056	-60	2.2E-04				113	-60	1.4E-04	037	-50	4.8E-05	*033	-48	4.5E-05*			
19141.3	44	271	039	-58	2.6E-04				048	-71	1.3E-04	035	-45	5.2E-05	*034	-44	5.1E-05*			
19141.4	39	279	058	-47	1.8E-04															
19142.2	34	269	023	-50	2.1E-04															
19142.3	45	286	029	-58	2.2E-04															
19142.4	44	284	053	-44	2.8E-04															
19143.1	29	301	059	-24	1.1E-04				174	46	2.6E-05	255	35	7.0E-05	*254	33	4.5E-05*			
19143.2	34	307	048	-26	1.1E-04				128	34	3.2E-05	201	50	5.8E-05	*200	57	2.9E-05*			
19143.3	28	316	062	-43	9.7E-05				178	11	3.0E-05	218	60	6.1E-05	*229	60	4.3E-05*			
19143.5	35	295	052	-35	1.1E-04				214	21	6.6E-05	230	52	5.0E-05	*230	58	3.8E-05*			
19144.2	44	319	069	-21	1.3E-04				201	20	7.0E-05	218	38	8.6E-05	*230	34	6.0E-05*			
19144.3	51	309	058	-40	3.8E-04				159	23	3.1E-05	101	45	4.4E-05	205	44	4.0E-05	*208	46	2.9E-05*
19144.4	64	339	056	-40	6.9E-05				208	29	6.2E-05	195	44	5.4E-05	222	44	3.9E-05	*220	48	3.1E-05*
19145.1	48	295	041	-28	1.0E-04				281	62	3.7E-05	*240	60	3.1E-05*	251	44	3.4E-05			
19145.2	44	288	015	-03	5.9E-05				281	60	4.4E-05	*242	46	4.8E-05*	222	44	7.4E-05			
19145.3	37	290	315	19	2.3E-04				294	33	2.7E-04	*293	35	2.4E-04*	303	37	2.2E-04			
19146.1	65	271	057	-36	1.4E-04				207	53	2.1E-05	190	22	2.6E-05	249	45	5.1E-05	*252	45	2.7E-05*
19146.2	63	243	082	-40	7.8E-05															
19146.3	49	250	014	-46	9.3E-05				263	42	5.8E-05	231	31	4.9E-05	*234	36	4.5E-05*			
19146.4	66	250	122	17	9.0E-05				220	44	6.4E-05	241	62	4.2E-05	269	53	6.6E-05	*268	53	3.5E-05*
19147.2	49	316	091	-45	9.2E-05				205	38	4.6E-05	200	12	3.3E-05	219	41	4.8E-05	*219	43	2.5E-05*
19147.3	50	328	090	-43	1.6E-04				178	12	6.1E-05	176	29	3.6E-05	*172	29	2.0E-05*			
19147.4	50	329	051	-42	8.4E-05				260	45	4.4E-05	*262	47	4.4E-05*	262	47	2.3E-05			
19149.1	49	259	037	-37	2.2E-04															
19149.2	51	271	023	-35	1.9E-04															
19149.3	42	245	010	-24	1.4E-04															
19149.4	50	251	083	-27	1.1E-04															
19150.2	57	308	049	-23	1.3E-04															
19150.41	62	252	056	-43	1.8E-04															
19150.42	62	252	042	-46	1.6E-04															
19151.1	47	356	072	-33	1.1E-04				059	80	6.1E-06	135	24	1.6E-05	*182	13	1.5E-05*			
19151.21	69	308	095	-70	1.1E-04															
19151.22	69	308	020	-45	1.7E-04				272	-27	4.5E-05	272	-02	2.7E-05	*229	29	5.2E-05*			
19151.4	70	330	024	-77	9.8E-05				238	-26	4.5E-05	236	-23	4.0E-05	*288	34	1.9E-05*			
19152.11	32	346	047	-58	1.7E-04				108	-70	4.2E-05	041	-64	5.3E-05	274	13	3.0E-05	*270	12	1.6E-05*
19152.12	32	346	054	-41	1.9E-04															
19152.21	20	305	047	-41	1.6E-04				099	-74	6.8E-05	053	-64	6.5E-05	*214	12	1.6E-05*			
19152.22	20	305	060	-62	2.1E-04				196	-83	6.9E-05	167	-62	9.0E-05	296	-56	3.4E-05	*255	36	2.3E-05*
19153.1	39	301	046	-45	2.2E-04				062	-56	7.7E-05	079	-59	1.1E-04	208	-13	3.2E-05	*209	-12	1.7E-05*
19153.2	24	007	077	-46	1.4E-04				117	-61	7.5E-05	122	-58	8.0E-05	197	-21	4.8E-05	*197	-20	2.4E-05*
19153.4	74	294	052	-55	2.0E-04				043	-47	8.8E-05	058	-64	9.0E-05	038	-22	3.3E-05	*220	21	1.8E-05*
19156.21	51	174	064	-59	2.9E-04				048	-64	1.5E-04	075	-63	1.4E-04	*068	-67	6.4E-05*			
19156.22	51	174	059	-52	3.2E-04				059	-55	1.8E-04	*062	-65	1.5E-04*	045	-87	8.9E-05			
19156.31	55	198	105	50	2.5E-04															
19156.32	55	198	075	-62	3.6E-04				078	-65	1.6E-04	093	-62	1.6E-04	009	-67	8.8E-05	*010	-66	4.3E-05
19157.1	54	282	043	-45	3.3E-04				062	-46	1.8E-04	061	-53	1.7E-04	*055	-58	9.9E-05*			
19157.2	52	273	038	-45	3.9E-04				043	-59	1.8E-04	054	-61	1.8E-04	*040	-54	5.9E-05*			
19157.31	67	214	045	-56	3.6E-04				*041	-58	2.1E-04*	056	-62	2.0E-04	029	-66	1.1E-04			
19157.32	67	214	047	-60	3.5E-04				*047	-61	1.5E-04*	061	-60	1.5E-04	037	-73	9.8E-05			
19158.11	48	261	048	-50	3.5E-04				043	-53	1.4E-04	055	-59	1.4E-04	019	-49	3.6E-05	*018	-49	1.7E-05*
19158.12	48	261	042	-54	3.9E-04				*032	-66	1.7E-04*	044	-64	1.6E-04	027	-69	6.0E-05			
19158.31	50	256	056	-66	1.5E-04				073	-68	1.4E-04	073	-68	1.4E-04	031	-76	6.0E-05	*035	-76	2.8E-05*
19158.32	50	256	033	-45	3.1E-04															
19159.21	44	250	038	-47	2.6E-04				025	-48	1.2E-04	036	-59	1.1E-04	*036	-57	5.8E-05*			
19159.22	44	250	039	-41	2.6E-04				049	-43	1.4E-04	058	-58	1.4E-04	*062	-52	7.4E-05*			
19159.31	55	259	045	-47	3.1E-04															
19159.32	55	259	038	-51	2.9E-04				039	-58	1.2E-04	054	-60	1.3E-04	043	-75	5.1E-05	*043	-75	2.5E-05*
19159.33	55	259	041	-46	2.9E-04															
19161.11	43	285	048	-39	2.3E-04				050	-55	8.2E-05	063	-51	9.4E-05	*068	-38	4.6E-05*			
19161.12	43	285	047	-32	2.3E-04				052	-39	6.6E-05	054	-45	7.8E-05	*067	-48	3.7E-05*			
19161.31	43	289	047	-39	2.5E-04				063	-50	8.1E-05	077	-56	8.7E-05	055	-48	5.1E-05	*055	-47	2.5E-05*
19161.32	43	289	047	-45	2.1E-04															
19162.1	63	234	049	-56	3.4E-04				042	-57	1.3E-04				020	-56	6.2E-05	*021	-57	3.2E-05*
19162.2	59	255	041	-57	6.0E-04				043	-56	2.9E-04	047	-55	2.2E-04	*049	-55	8.9E-05*			
19162.3	62	263	044	-58	3.4E-04				028	-32	2.9E-04	*042	-62	1.6E-04*	055	-63	8.5E-05			
19162.4	55	249	057	-58	5.2E-04															
19163.1	33	315	040	-56	5.6E-04				045	-57	4.0E-04	*034	-59	3.0E-04*	024	-49	1.2E-04			
19163.2	41	296	052	-46	4.1E-04				050	-47	2.9E-04	054	-46	2.1E-04	*055	-50	1.1E-04*			
19163.3	26	301	049	-52	4.3E-04				056	-48	3.2E-04	047	-56	2.0E-04	*054	-59	1.0E-05*			
19164.1	38	298	059	-40	2.2E-04				058	-42	8.7E-05	056	-30	6.4E-05	*056	-30	3.4E-05*			
19164.2	31	288	054	-47	2.2E-04				062	-32	1.3E-04	076	-54	8.2E-05	052	-44	4.2E-05	*056	-46	2.0E-05*
19164.31	31	309	039	-54	2.2E-04															
19164.32	31	309	048	-53	2.3E-04				042	-48	1.0E-04	*033	-57	7.0E-05*	069	-49	3.6E-05			
19165.1	21	099	115	-60	2.0E-04															
19165.2	15	109	095	-54	2.2E-04															
19165.31	40	076	052	-50	2.5E-04															
19165.32	40	076	055	-48	2.2E-04															
19166.11	31	306	064	-59	2.4E-04															
19166.12	31	306	044	-53	2.7E-04				046	-57	1.2E-04	056	-58	8.2E-05	*057	-59	3.7E-05*			
19166.31	48	282	064	-51	2.9E-04				068	-57	2.0E-04	056	-47	1.1E-04	*047	-58	3.2E-05*			
19166.32	48	282	055	-50	2.5E-04				056	-52	1.2E-04	055	-54	9.6E-05	*054	-53	4.4E-05*			
19167.21	62	177	047	-44	2.0E-04															
19167.22	62	177	044	-45	2.2E-04															

SPEC.	PLUNGE/ AZIMUTH		NRM D	I	M(A/m)	150 D	I	M(A/m)	200 D	I	M(A/m)	250 D	I	M(A/m)	300 D	I	M(A/m)	320 D	I	M(A/m)
19167.31	62	194	042	-50	2.0E-04															
19167.32	62	194	070	-47	2.2E-04															
19168.1	39	320	053	-48	2.3E-04				051	-50	8.4E-05	057	-44	6.1E-05	*061	-50	2.9E-05*			
19168.2	63	346	053	-59	2.1E-04				059	-48	9.6E-05	051	-63	8.0E-05	*057	-54	5.4E-05*			
19168.3	63	326	052	-51	2.0E-04				050	-54	8.9E-05	*053	-50	8.3E-05*	030	-40	1.7E-05			
19168.4	62	316	050	-52	2.1E-04															
19169.21	57	251	044	-52	2.2E-04															
19169.22	57	251	040	-55	2.1E-04															
19169.31	49	238	065	-56	1.8E-04															
19169.32	49	238	045	-64	1.7E-04															
19169.33	49	238	049	-60	2.1E-04															
19170.31	52	285	059	-52	2.2E-04				057	-52	8.7E-05	045	-49	3.8E-05	234	14	6.2E-05	*234	14	3.2E-05*
19170.32	52	285	051	-53	1.7E-04				062	-19	6.2E-05	285	-32	1.8E-05	234	17	6.5E-05	*234	16	3.4E-05*
19170.41	51	276	050	-58	1.6E-04				073	-02	6.2E-05	316	-18	3.6E-05	*307	21	2.2E-05*			
19170.42	51	276	056	-54	2.2E-04															
19171.21	42	256	059	-51	1.9E-04															
19171.22	42	256	054	-52	1.5E-04				051	-40	7.3E-05	061	-25	4.2E-05	130	27	4.1E-05	*130	27	2.1E-05*
19171.31	48	280	058	-30	2.1E-04				059	-28	4.0E-05	055	-23	5.6E-05	*259	71	2.7E-05*			
19171.32	48	280	059	-48	2.1E-04				073	-40	4.2E-05	094	-41	3.6E-05	*214	50	1.5E-05*			
19171.33	48	280	064	-48	1.9E-04				053	-45	8.1E-05	047	-41	4.4E-05	217	29	2.2E-05	*221	26	1.6E-05*
19172.21	33	299	041	-42	1.5E-04															
19172.22	33	299	045	-42	1.5E-04															
19172.31	31	304	045	-40	1.8E-04															
19172.32	31	304	051	-50	1.6E-04															
19173.21	28	300	060	-52	1.5E-04				130	-09	7.5E-05	295	-31	2.5E-06	253	50	6.1E-05	*253	47	3.2E-05*
19173.22	28	300	058	-48	1.5E-04				063	-38	5.8E-05	074	-36	2.0E-05	311	40	3.2E-05	*311	40	1.7E-05*
19173.23	28	300	065	-49	1.6E-04															
19173.31	23	268	050	-51	1.5E-04															
19173.32	23	268	068	-47	1.5E-04				070	-02	6.7E-05	075	15	3.9E-06	*307	12	1.8E-05*			
19174.11	38	097	090	-26	2.0E-04															
19174.12	38	097	099	-33	2.1E-04															
19174.31	51	112	113	-29	1.9E-04															
19174.32	51	112	101	-32	1.7E-04															
19175.11	59	030	293	38	7.7E-05				328	46	5.1E-05	163	52	2.8E-05	*195	27	3.2E-05*			
19175.12	59	030	263	48	6.7E-05															
19175.21	46	096	296	41	8.7E-05				272	59	3.7E-05	214	-23	1.5E-05	*194	09	4.5E-05*			
19175.22	46	096	283	57	7.2E-05				245	68	5.9E-05	251	-03	2.6E-05	*274	16	3.2E-05*			
19175.23	46	096	282	23	9.8E-05				326	21	3.2E-05	088	-20	4.6E-05	354	10	7.5E-05			
19176.21	64	100	063	-57	1.2E-04															
19176.22	64	100	079	-58	1.1E-04															
19176.41	55	071	066	-41	1.4E-04															
19176.42	55	071	059	-39	1.3E-04															
19177.21	67	025	069	-42	1.6E-04				086	-35	4.4E-05	081	-36	2.6E-05	262	47	3.0E-05	*262	47	1.6E-05*
19177.22	67	025	059	-41	1.6E-04															
19177.23	67	023	052	-48	1.7E-04				050	-50	5.4E-05	271	37	1.5E-05	*250	54	1.9E-05*			
19177.31	70	022	068	-41	1.6E-04															
19177.32	70	022	069	-49	1.6E-04				067	-48	3.6E-05	218	-19	2.5E-05	*234	17	1.5E-05*			
19178.31	58	095	061	-45	2.3E-04				074	-52	8.6E-05	*057	-54	3.0E-05*	013	-14	2.4E-05			
19178.32	58	095	088	-55	2.6E-04				107	-27	7.4E-05	108	-36	4.1E-05	259	36	4.7E-05	*260	39	2.5E-05*
19178.41	60	181	054	-55	3.7E-04				326	-80	1.1E-04	001	-69	3.2E-05	281	39	6.8E-05	*293	39	3.4E-05*
19179.11	43	070	063	-39	2.0E-04															
19179.12	43	070	052	-50	2.0E-04															
19179.21	40	041	064	-36	2.0E-04															
19179.22	40	041	063	-44	1.8E-04															
19180.11	46	057	081	-45	2.8E-04				153	-33	8.0E-05	144	-58	5.5E-05	*327	33	5.5E-05*			
19180.12	46	057	057	-48	2.6E-04				264	-77	6.3E-05	249	29	7.4E-05				*259	35	2.1E-05*
19180.31	44	013	051	-49	2.8E-04															
19180.32	44	013	070	-26	3.3E-04				100	19	1.4E-04	128	52	1.0E-04	*132	55	8.5E-05*			
19181.21	71	112	070	-54	1.3E-04															
19181.22	71	112	121	-57	8.0E-05				203	-02	4.9E-05	235	16	3.1E-05	218	07	3.5E-05	*226	18	1.9E-05*
19181.31	63	058	110	-59	9.7E-05				181	-34	5.4E-05	197	-16	9.2E-05	181	-13	6.6E-05	*243	26	3.1E-05*
19181.32	63	058	042	-53	6.5E-05				273	21	2.1E-05	218	46	2.6E-05	173	42	4.1E-05	*188	45	2.1E-05*
19182.11	52	100	055	-35	1.8E-04				061	-05	5.1E-05	351	29	4.6E-05	309	45	4.4E-05	*307	46	2.3E-05*
19182.12	52	100	074	-50	1.6E-04															
19182.21	56	165	067	-46	1.3E-04							218	-13	3.0E-05	195	81	3.7E-05	*198	77	2.0E-05*
19182.22	56	165	065	-41	1.2E-04				280	-24	1.3E-05	311	30	1.2E-05	285	34	1.6E-05	*197	59	2.2E-05*
19183.11	46	035	067	-36	1.6E-04				078	-29	9.5E-05	151	41	1.6E-05	*188	18	2.6E-05*			
19183.12	46	035	063	-42	1.6E-04				112	-53	4.0E-05	158	12	3.0E-05	*160	31	1.3E-05*			
19183.21	45	057	094	-43	1.9E-04				122	-37	4.3E-05	215	30	2.6E-05	*210	34	2.8E-05*			
19184.11	45	020	067	-28	3.0E-04															
19184.12	45	020	076	-29	2.4E-04															
19184.13	45	020	075	-32	2.4E-04															
19184.21	50	047	088	-46	2.5E-04				046	-41	4.1E-05	107	23	1.5E-05	182	-34	1.8E-05			
19184.22	50	047	087	-48	2.7E-04				110	-41	5.6E-05	145	-19	5.3E-05	188	-38	3.1E-05			
19185.1	41	050	093	-39	3.8E-04				079	-28	1.0E-04	122	-15	7.1E-05	*233	11	9.9E-05*			
19185.21	48	053	084	-37	3.2E-04				107	18	6.5E-05	135	48	5.8E-05	*328	53	6.2E-05*			
19185.22	48	053	085	-59	4.1E-04															
19185.23	48	053	100	-37	3.6E-04				149	33	8.4E-05	151	50	9.8E-05	*168	54	1.9E-05*			
19186.11	58	217	110	-48	2.0E-04															
19186.12	58	217	117	-45	2.7E-04															
19186.21	59	143	074	-55	2.4E-04															
19186.22	59	143	064	-43	3.5E-04															
19188.21	59	149	103	-54	1.0E-04				175	-06	3.3E-05	199	17	6.1E-05	*183	33	3.5E-05*			
19188.22	59	149	324	-51	4.0E-05															
19188.31	63	184	328	-81	8.3E-05				249	-33	4.6E-05	197	26	4.2E-05	*225	56	3.2E-05*			
19188.32	63	184	075	-54	1.1E-04				105	-41	4.9E-05	181	-02	4.1E-05	*231	56	3.4E-05*			
19189.11	53	161	081	-45	1.8E-04				106	-08	4.8E-05	120	12	5.6E-05	162	42	5.7E-05	*168	42	2.8E-05*
19189.12	53	161	066	-50	1.6E-04															
19189.21	59	203	049	-16	1.0E-04				356	08	2.3E-05	280	57	6.7E-05	*285	62	7.4E-05*			
19189.22	59	203	041	-48	1.9E-04				056	-38	3.3E-05	191	30	4.1E-05	184	74	1.2E-04	*193	69	5.7E-05*
19190.11	53	233	029	-17	1.3E-04				036	17	3.5E-05	202	72	6.1E-05	*201	72	3.0E-05*			
19190.12	53	233	021	-38	1.5E-04															
19190.21	62	259	013	-48	1.4E-04				023	-22	3.8E-05	231	-06	3.1E-05	181	40	2.4E-05	*184	40	2.3E-05*
19190.22	62	259	033	-40	6.4E-05				231	01	2.0E-05	221	46	6.4E-05	*216	52	9.1E-05*			
19191.11	23	138	047	-39	1.2E-04				040	-30	6.2E-05	256	39	3.3E-05	*249	31	2.9E-05*			

SPEC.	PLUNGE/	AZIMUTH	NRM D	NRM I	NRM M(A/m)	150 D	150 I	150 M(A/m)	200 D	200 I	200 M(A/m)	250 D	250 I	250 M(A/m)	300 D	300 I	300 M(A/m)	320 D	320 I	320 M(A/m)
19191.12	23	138	065	-50	8.5E-05				091	-48	4.2E-05	149	05	3.3E-05	190	29	2.8E-05	*182	38	2.0E-05*
19191.13	23	138	056	-39	1.2E-04															
19191.21	32	139	049	-50	1.6E-04															
19191.22	32	139	028	-49	1.3E-04				051	-38	7.0E-05	350	-53	1.7E-05	*274	03	1.6E-05*			
19192.11	51	191	054	-49	1.3E-04															
19192.12	51	191	066	-46	1.3E-04				054	-28	4.0E-05	077	-20	2.6E-05	249	25	2.4E-05			
19192.21	49	185	097	-51	9.3E-05				254	-83	2.3E-05				216	24	2.7E-05	*212	17	2.0E-05*
19192.22	49	185	091	-54	1.2E-04				263	-49	2.2E-05	275	21	2.3E-05	281	27	2.3E-05	*280	28	2.1E-05*
19193.21	55	187	045	-62	1.6E-04				071	-38	5.7E-05	164	-39	2.4E-05	155	12	4.4E-05	*264	38	2.4E-05*
19193.22	55	187	044	-57	2.0E-04				054	-46	1.4E-04	064	-15	3.3E-05	265	39	4.9E-05	*263	39	4.0E-05*
19193.31	44	186	066	-50	2.5E-04				077	-49	1.3E-04	048	-71	2.3E-05	095	52	5.8E-05	*263	62	3.0E-05*
19193.32	44	186	073	-49	2.8E-04															
19194.11	20	308	045	-39	1.5E-04				012	-52	4.9E-05	296	-08	2.0E-05	*246	60	1.7E-05*			
19194.12	20	308	054	-39	1.6E-04				063	-49	7.5E-05	063	-55	1.5E-05	*226	41	2.6E-05*			
19194.21	22	351	076	-41	1.2E-04															
19194.22	22	351	062	-39	1.3E-04				048	-24	6.1E-05	130	-05	3.1E-05	*261	-04	1.9E-05*			
19195.21	41	315	055	-32	1.7E-04															
19195.22	41	315	057	-45	1.3E-04															
19195.23	41	315	049	-49	1.8E-04															
19195.3	41	303	044	-27	1.6E-04															
19196.21	40	171	058	-58	1.6E-04				090	-56	5.4E-05	140	-18	4.1E-05	*146	39	2.0E-05*			
19196.22	40	171	026	-56	1.4E-04															
19196.31	43	218	043	-43	1.9E-04				054	-41	9.1E-05	074	-45	2.9E-05	*137	35	2.5E-05*			
19196.32	43	218	039	-32	1.7E-04				062	-33	5.8E-05	161	10	9.3E-05	*136	35	2.4E-05*			
19197.21	44	149	022	-69	1.6E-04															
19197.22	44	149	034	-37	1.7E-04															
19197.3	47	169	003	-72	2.0E-04															
19198.1	60	103	302	-55	1.2E-04				320	-64	5.9E-05	020	-16	3.9E-05	*280	76	3.2E-05*			
19198.2	49	138	322	-47	1.9E-04				025	-72	7.7E-05	209	-28	5.2E-05	*284	78	3.1E-05*			
19198.4	40	200	327	-27	8.4E-04				321	-20	3.0E-05	328	-40	1.3E-05	*191	45	1.8E-05*			
19199.11	48	326	052	-45	2.6E-04				012	-15	5.4E-05	009	08	2.0E-05	249	48	8.1E-05	*245	49	4.0E-05*
19199.12	48	326	039	-30	2.7E-04															
19199.21	52	330	029	-42	3.0E-04				054	-10	5.8E-05	001	38	9.8E-05	254	45	1.1E-04	*252	45	5.3E-05*
19199.22	52	330	029	-42	3.0E-04				049	-46	1.1E-04	165	-25	7.1E-05	252	43	1.2E-04	*249	43	5.9E-05*
19200.11	32	341	046	-43	3.8E-04				047	-21	1.4E-04	330	-67	8.1E-05	*198	82	7.0E-05*			
19200.12	32	341	065	-31	4.3E-04				078	-09	1.8E-04	154	14	7.6E-05	*168	72	4.2E-05*			
19200.21	52	330	048	-49	4.4E-04				065	-23	7.0E-05	047	-09	1.4E-04	*185	69	6.5E-05*			
19200.22	52	330	048	-41	3.9E-04															
19201.11	40	326	059	-33	2.2E-04				341	-02	2.1E-05	281	-44	4.3E-05	175	50	4.6E-05	*176	51	2.3E-05*
19201.12	40	326	071	-22	1.8E-04				073	31	5.8E-05				179	71	1.7E-04	*179	69	8.6E-05*
19201.31	44	312	036	-21	2.5E-04				053	-05	1.3E-04	029	23	5.1E-05	*186	16	7.6E-05*			
19201.32	44	312	037	-42	2.5E-04															
19202.1	28	078	070	-48	3.4E-04				134	-65	1.1E-04	272	12	7.6E-05	*182	36	1.1E-04*			
19202.21	48	083	071	-71	2.6E-04															
19202.22	48	083	071	-38	3.4E-04				102	-15	1.6E-04	119	52	6.8E-05	*221	24	9.4E-05*			
19202.3	44	087	082	-34	2.7E-04				109	-13	9.9E-05	327	41	9.0E-05	*214	24	6.6E-05*			
19203.2	28	053	064	-44	3.6E-04															
19203.31	23	040	053	-45	4.5E-04															
19203.32	23	040	082	-35	3.6E-04															
19203.4	25	058	072	-44	5.0E-04															
19204.11	37	087	058	-64	1.3E-03				158	-15	3.7E-04	191	-42	3.7E-04	266	20	1.3E-04	*267	20	6.6E-05*
19204.12	34	087	061	-38	8.2E-04				164	47	7.9E-05	191	-23	2.4E-04	268	19	1.2E-04	*270	20	6.1E-05*
19204.21	45	056	081	-45	2.3E-03				161	15	1.2E-03	183	22	1.3E-03	205	37	9.3E-04	*205	36	4.8E-04*
19204.22	45	056	073	-41	1.8E-03															
19205.21	42	083	061	-51	4.0E-04															
19205.22	42	083	094	-13	6.1E-04															
19025.31	54	094	072	-40	6.1E-04															
19205.32	54	094	095	-56	6.8E-04															
19206.11	52	081	058	-48	5.6E-04															
19206.12	52	081	059	-37	5.6E-04				071	02	1.2E-04	028	-36	6.0E-05	161	28	1.5E-04	*166	30	8.5E-05*
19206.21	51	083	047	-38	6.9E-04				030	-12	9.8E-05	050	39	1.4E-04	230	49	3.6E-04	*232	49	1.8E-04*
19206.22	51	083	042	-26	5.9E-04				001	57	1.9E-04	090	77	2.3E-04	242	17	4.7E-04	*241	18	2.4E-04*
19207.11	52	098	064	-44	7.1E-03				074	-49	4.8E-03	131	-37	2.1E-03	234	24	2.7E-04	*233	24	1.4E-04*
19207.12	52	098	060	-59	7.4E-03															
19207.21	50	071	056	-46	7.4E-03				059	-46	4.9E-03	063	-18	2.3E-03	*164	52	2.7E-03*			
19207.22	50	071	044	-44	7.0E-03				055	-41	5.3E-03	045	-33	2.3E-03	*186	54	1.2E-03*			
19208.21	50	124	218	-70	8.4E-03															
19208.22	50	124	146	-72	9.2E-03															
19208.31	55	099	091	-63	2.6E-02															
19208.32	55	099	055	-56	1.7E-02															

APPENDIX 9: SUMMARY SITE STATISTICS

(1) VUW collection number.

(2) Stratigraphic height (m) above the Makaretu sandstone.

(3) Average degree of bioturbation at the site, (see Plate 2.1 and section 2.3).

(4) Number of specimens used in the final analysis and does not include those specimens which were rejected.

(5) Average initial volume susceptibility of all specimens sampled at the site (values x 10^{-3}).

(6) Average magnetisation intensity of all specimens sampled at the site (values Am^{-1}).

(7) Mean declination (°) of specimens accepted from the site.

(8) Mean inclination (°) of specimens accepted from the site.

(9) Average magnetisation intensity of specimens accepted from the site (values Am^{-1}).

(10) k, Fisher's precision parameter

(11) $\alpha95$, radius (°) of the 95% confidence cone about the mean direction.

(12) R, resultant vector length of mean direction.

(13) Polarity, N = normal and R = reversed.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
18870	2.0	1	3	195.52	4.7E-04	213.0	61.2	4.9E-05	10.8	39.5	2.8149	R
18871	3.0	1	3	208.68	3.8E-04	226.3	43.4	3.9E-05	16.6	31.2	2.8798	R
18872	4.0	1	3	193.64	3.2E-04	238.0	65.9	3.5E-05	22.6	26.5	2.9116	R
18873	5.0	1	3	188.00	3.3E-04	237.2	50.7	4.8E-05	235.9	8.0	2.9915	R
18874	6.0	1	3	180.48	3.0E-04	205.9	18.1	4.0E-05	32.3	22.0	2.9382	R
18875	7.0	1	.	197.40	3.6E-04	.	.	.	.	.	.	
18876	9.0	1	3	186.12	2.5E-04	239.7	62.7	8.1E-05	29.4	23.1	2.9321	R
18877	15.0	1	3	251.92	1.2E-03	58.8	-27.2	3.1E-04	15.1	32.9	2.8677	N
18878	21.0	1	3	216.20	9.2E-04	73.5	-67.9	4.0E-04	62.2	15.7	2.9679	N
18879	27.0	2	3	206.80	6.4E-04	48.4	-64.2	2.3E-04	36.9	20.6	2.9459	N
18880	33.0	2	3	216.20	1.2E-03	80.9	-70.1	2.3E-04	11.0	39.0	2.8188	N
18881	38.0	2	.	214.32	7.6E-04	.	.	.	.	.	.	
18882	43.0	2	4	204.92	1.0E-03	44.5	-61.7	3.4E-04	69.5	11.0	3.9569	N
18883	48.0	2	3	216.20	1.0E-03	51.5	-59.6	3.1E-04	54.5	16.9	2.9633	N
18884	52.0	2	3	210.56	1.6E-03	60.9	-55.3	7.3E-04	150.3	10.1	2.9867	N
18885	57.0	3	3	216.20	1.8E-03	43.2	-59.1	7.3E-04	210.6	8.5	2.9905	N
18886	62.0	2	4	212.44	1.8E-03	54.2	-64.3	6.8E-04	156.2	7.4	3.9808	N
18887	72.0	2	3	206.80	1.7E-03	86.8	-51.6	5.0E-04	22.0	27.0	2.9090	N
18888	82.0	2	4	219.96	1.6E-03	61.5	-37.2	5.2E-04	37.2	15.3	3.9193	N
18889	92.0	1	4	227.48	3.0E-03	39.8	-62.3	9.4E-04	141.7	7.7	3.9788	N
18890	102.0	2	3	212.44	2.0E-03	40.6	-53.6	4.5E-04	79.5	13.9	2.9749	N
18891	111.0	1	.	227.48	2.6E-03	.	.	.	.	.	.	
18892	120.0	2	3	204.92	1.3E-03	43.6	-53.1	4.9E-04	40.3	19.7	2.9504	N
18893	129.0	3	4	240.64	3.5E-03	42.1	-60.1	1.6E-03	97.2	9.4	3.9691	N
18894	138.0	2	3	240.64	3.6E-03	40.4	-72.9	6.6E-04	52.7	17.2	2.9620	N
18895	147.0	2	3	214.32	1.6E-03	45.0	-49.8	3.8E-04	54.2	16.9	2.9631	N
18896	152.0	2	3	210.56	1.4E-03	51.3	-55.0	2.7E-04	37.8	20.3	2.9470	N
18897	158.0	1	3	219.96	2.8E-03	30.3	-57.2	1.4E-03	20.1	28.2	2.9006	N
18898	163.0	2	3	197.40	1.8E-03	67.1	-41.3	6.0E-04	5.1	61.4	2.6080	N
18899	169.0	2	3	195.52	6.7E-04	26.2	-62.0	9.7E-05	9.5	42.4	2.7897	N
18900	174.0	1	3	206.80	1.1E-03	20.6	-64.4	2.7E-04	232.8	8.1	2.9914	N
18901	179.0	1	4	169.20	7.5E-04	37.6	-65.8	9.3E-05	90.5	9.7	3.9669	N
18902	184.0	1	3	212.44	8.6E-04	60.2	-68.6	2.4E-04	31.3	22.4	2.9362	N
18903	189.0	1	.	218.08	5.7E-04	.	.	.	.	.	.	
18904	194.0	2	3	216.20	8.1E-04	49.9	-57.3	2.3E-04	81.8	13.7	2.9756	N
18905	199.0	1	3	221.84	8.5E-04	58.7	-56.3	3.0E-04	22.9	26.4	2.9125	N
18906	205.0	3	3	127.84	1.1E-03	41.3	-65.7	5.0E-04	218.3	8.4	2.9908	N
18907	210.0	3	.	163.56	4.9E-04	.	.	.	.	.	.	
18908	216.0	1	3	191.76	6.5E-04	55.9	-62.9	9.9E-05	37.8	20.3	2.9471	N
18909	221.0	3	3	197.40	5.7E-04	62.1	-53.2	8.7E-05	63.7	15.6	2.9686	N
18910	227.0	2	3	188.00	9.8E-04	40.7	-61.9	2.0E-04	71.8	14.6	2.9721	N
18911	232.0	1	3	201.16	1.0E-03	55.7	-61.3	1.6E-04	59.1	16.2	2.9662	N
18912	238.0	3	3	212.44	9.3E-03	47.8	-62.7	2.1E-04	14.5	33.6	2.8625	N
18913	243.0	3	3	195.52	7.5E-04	75.3	-72.7	9.8E-05	47.5	18.1	2.9579	N
18914	249.0	1	3	201.16	6.7E-04	235.5	25.8	4.3E-05	170.6	9.5	2.9883	R
18915	254.0	2	.	212.44	9.1E-04	.	.	.	.	.	.	
18916	260.0	3	3	191.76	7.4E-04	49.6	-40.0	1.1E-04	31.8	22.2	2.9371	N
18917	266.0	1	3	182.36	6.4E-04	48.2	-55.0	6.5E-05	42.8	19.1	2.9532	N
18918	272.0	2	3	191.76	6.4E-04	41.9	-47.7	8.8E-05	90.1	13.1	2.9778	N
18919	278.0	3	3	195.52	8.8E-04	43.2	-57.9	1.1E-04	217.0	8.4	2.9908	N
18920	284.0	3	3	193.64	8.1E-04	43.2	-46.7	8.9E-05	70.5	14.8	2.9716	N
18921	290.0	3	4	197.40	8.0E-04	75.8	-50.9	2.1E-04	10.3	30.0	3.7096	N
18922	297.0	2	3	204.92	6.5E-04	52.2	-56.7	1.3E-04	89.6	13.1	2.9777	N
18923	303.0	2	3	178.60	8.6E-04	50.7	-56.8	2.4E-04	80.9	13.8	2.9753	N
18924	310.0	3	3	193.64	8.7E-04	49.5	-53.2	2.2E-04	4.2	69.7	2.5248	N
18925	316.0	3	3	206.80	6.0E-04	50.0	-52.2	1.8E-04	20.8	27.7	2.9039	N
18926	323.0	2	4	204.92	6.5E-04	49.2	-53.5	1.3E-04	44.1	14.0	3.9320	N
18927	330.0	.	.	.	.	.	.	.	.	.	.	
18928	336.0	2	4	218.08	8.1E-04	30.2	-60.1	1.7E-04	19.3	21.4	3.8449	N
18929	342.0	2	.	218.08	6.3E-04	.	.	.	.	.	.	
18930	348.0	.	.	.	.	.	.	.	.	.	.	
18931	353.0	3	4	223.72	9.0E-04	44.9	-57.8	3.0E-04	32.8	16.3	3.9085	N
18932	359.0	3	3	206.80	6.7E-04	48.0	-55.0	2.0E-04	19.3	28.9	2.8963	N
18933	364.0	2	4	216.20	9.6E-04	49.0	-56.7	3.4E-04	49.1	13.2	3.9389	N
18934	370.0	2	3	244.40	2.1E-03	38.4	-53.0	1.1E-03	11.9	37.4	2.8325	N
18935	375.0	2	3	227.48	7.0E-04	38.5	-62.4	1.7E-04	38.6	20.1	2.9482	N
18936	381.0	1	4	225.60	2.0E-03	68.6	-57.5	1.1E-03	39.8	14.7	3.9247	N
18937	385.0	2	4	210.56	7.8E-04	65.3	-60.3	1.4E-04	54.2	12.6	3.9446	N
18938	269.0	1	3	212.44	8.1E-04	57.2	-56.3	1.2E-04	144.9	10.3	2.9862	N
18939	392.0	1	.	206.80	6.0E-04	.	.	.	.	.	.	
18940	396.0	2	3	282.00	6.6E-04	48.8	-63.8	1.4E-04	22.5	26.6	2.9112	N
18941	399.0	1	.	214.32	6.5E-04	.	.	.	.	.	.	
18942	403.0	1	4	204.92	6.5E-04	48.3	-51.4	1.9E-04	49.8	13.1	3.9398	N
18943	406.0	2	3	229.36	9.7E-04	52.3	-51.4	2.6E-04	11.6	38.0	2.8277	N
18944	409.0	1	4	225.60	1.1E-03	39.2	-58.5	3.7E-04	76.9	10.5	3.9696	N
18945	412.0	1	4	223.72	9.0E-04	320.2	50.4	5.0E-04	105.3	9.0	3.9715	R
18946	415.0	1	3	193.64	1.0E-03	66.6	-47.8	2.2E-04	53.7	17.0	2.9628	N
18947	418.0	2	3	208.68	9.4E-04	51.1	-57.8	1.7E-04	47.8	18.0	2.9582	N
18948	421.0	1	3	193.64	8.4E-04	51.1	-61.8	1.3E-04	22.0	23.0	2.9089	N
18949	424.0	1	3	193.64	9.2E-04	43.0	-65.4	1.1E-04	218.7	8.4	2.9909	N
18950	427.0	1	4	201.16	9.5E-04	32.6	-60.3	2.2E-04	82.1	10.2	3.9635	N
18951	432.0	2	4	212.44	1.1E-03	46.5	-63.2	2.4E-04	34.8	15.8	3.9139	N
18952	438.0	1	3	204.92	9.8E-04	61.9	-54.2	1.7E-04	30.3	22.8	2.9340	N
18953	443.0	1	3	214.32	8.3E-04	43.4	-65.1	1.2E-04	45.8	18.4	2.9563	N
18954	449.0	1	3	212.44	8.6E-04	42.2	-57.0	1.0E-04	215.5	8.4	2.9907	N
18955	454.0	1	3	197.40	6.5E-04	75.8	-67.2	1.0E-04	7.7	47.9	2.7401	N
18956	460.0	1	3	219.96	7.1E-04	44.5	-51.3	1.1E-04	71.6	14.6	2.9721	N
18957	465.0	1	3	219.96	7.7E-04	52.5	-50.9	8.5E-05	19.1	29.0	2.8952	N
18958	470.0	1	3	223.72	7.0E-04	47.4	-62.7	8.2E-05	17.4	30.5	2.8852	N
18959	476.0	2	3	212.44	1.0E-03	76.1	-62.9	1.8E-04	32.9	21.9	2.9390	N
18960	481.0	2	3	204.92	1.1E-03	28.0	-60.6	2.6E-04	56.5	16.6	2.9646	N
18961	487.0	1	3	219.96	5.1E-04	27.5	-51.0	1.9E-04	26.7	24.3	2.9252	N
18962	492.0	1	3	225.60	8.6E-04	78.9	-65.7	1.4E-04	14.7	33.4	2.8639	N
18963	497.0	1	3	225.60	8.1E-04	43.7	-66.5	1.4E-04	29.7	23.0	2.9326	N
18964	503.0	2	3	212.44	9.8E-04	53.9	-62.9	7.9E-05	32.1	22.1	2.9377	N

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
18965	509.0	1	3	225.60	1.1E-03	90.7	-63.1	1.8E-04	6.9	51.9	2.7098	N
18966	515.0	1	.	218.08	7.9E-04	.	.	.	.	.	.	
18967	521.0	2	.	283.88	2.3E-03	.	.	.	.	.	.	
18968	527.0	2	3	197.40	9.1E-04	39.4	-58.5	8.9E-05	26.7	24.3	2.9251	N
18969	532.0	1	3	203.04	1.1E-03	51.4	-59.0	1.5E-04	20.0	28.3	2.9002	N
18970	537.0	1	3	223.72	1.1E-03	54.9	-71.0	7.9E-04	23.2	26.2	2.9137	N
18971	542.0	1	3	238.76	1.0E-03	59.8	-54.1	1.7E-04	2.6	78.9	2.2336	N
18972	547.0	1	3	235.00	1.0E-03	91.0	-50.8	1.4E-04	14.8	33.3	2.8649	N
18973	552.0	1	3	233.12	8.5E-04	88.4	-38.7	7.4E-05	12.3	36.7	2.8379	N
18974	557.0	1	.	250.04	1.3E-03	.	.	.	.	.	.	
18975	562.0	1	.	250.04	1.3E-03	.	.	.	.	.	.	
18976	576.0	1	3	204.92	7.2E-04	57.5	-70.4	6.0E-05	36.9	20.6	2.9459	N
18977	571.0	1	3	263.20	1.3E-03	28.6	-64.8	1.6E-04	126.9	11.0	2.9842	N
18978	575.0	1	3	231.24	1.1E-03	29.6	-51.8	1.1E-04	23.2	26.2	2.9139	N
18979	580.0	.	.	.	.	.	.	.	.	.	.	
18980	584.0	1	.	266.96	1.4E-03	.	.	.	.	.	.	
18981	593.0	0	3	276.36	1.7E-03	.	.	5.5E-05	.	.	.	
18982	602.0	.	.	.	.	.	.	.	.	.	.	
18983	612.0	0	3	214.32	4.9E-04	94.5	-58.4	4.4E-05	4.2	69.5	2.5272	N
18984	621.0	.	.	.	.	.	.	.	.	.	.	
18985	630.0	1	3	221.84	4.0E-04	83.1	-39.7	4.8E-05	2.4	67.9	2.1634	N
18986	639.0	.	.	.	.	.	.	.	.	.	.	
18987	648.0	1	3	212.44	8.7E-04	54.2	-42.6	7.1E-05	5.1	61.6	2.6065	N
18988	658.0	.	.	.	.	.	.	.	.	.	.	
18989	668.0	2	3	197.40	5.8E-04	.	.	4.2E-05	.	.	.	
18990	677.0	.	.	.	.	.	.	.	.	.	.	
18991	686.0	0	3	199.28	5.1E-04	125.0	42.9	4.3E-05	4.3	68.9	2.5327	R
18992	695.0	1	.	195.52	2.6E-04	.	.	.	.	.	.	
18993	705.0	1	3	206.80	5.7E-04	27.0	-66.8	2.5E-05	22.5	26.6	2.9110	N
18994	714.0	0	.	206.80	7.6E-04	.	.	.	.	.	.	
18995	723.0	1	3	246.28	1.2E-03	57.3	-50.4	2.2E-04	10.5	40.2	2.8093	N
18996	759.0	1	3	172.96	8.2E-04	55.9	-38.4	1.2E-04	34.4	21.4	2.9148	N
18997	764.0	1	3	182.36	9.2E-04	85.9	-46.4	2.3E-04	17.7	30.3	2.8867	N
18998	769.0	2	3	184.24	8.1E-04	56.8	-48.0	1.8E-04	22.9	26.4	2.9127	N
18999	773.0	1	3	221.84	8.6E-04	56.4	-54.2	1.5E-04	53.7	17.0	2.9628	N
19000	778.0	1	4	235.00	1.3E-03	51.9	-50.1	3.0E-04	5.6	42.8	3.4622	N
19001	783.0	3	4	195.52	1.2E-03	37.0	-56.1	3.3E-04	150.7	7.5	3.9801	N
19002	788.0	1	3	191.76	1.4E-03	35.3	-59.2	2.5E-04	32.3	22.0	2.9382	N
19003	793.0	1	4	195.52	9.8E-04	34.8	-56.3	2.3E-04	55.3	12.5	3.9460	N
19004	799.0	1	.	212.44	9.1E-04	.	.	.	.	.	.	
19005	805.0	3	.	235.00	8.9E-04	.	.	.	.	.	.	
19006	810.0	1	3	212.44	9.2E-04	34.7	-62.5	2.9E-04	674.5	4.8	2.9970	N
19007	815.0	1	3	216.20	1.1E-03	27.1	-61.3	2.8E-04	61.5	15.9	2.9675	N
19008	820.0	1	3	174.84	6.0E-04	39.8	-67.3	2.4E-04	64.9	15.4	2.9692	N
19009	825.0	3	3	184.24	1.0E-03	41.2	-61.7	2.7E-04	414.3	6.1	2.9952	N
19010	830.0	1	4	167.32	8.5E-04	36.2	-62.3	2.2E-04	106.9	8.9	3.9719	N
19011	835.0	1	3	184.24	9.2E-04	38.7	-60.7	2.3E-04	77.6	14.1	2.9742	N
19012	840.0	1	3	193.64	8.7E-04	26.3	-61.7	2.8E-04	192.7	8.9	2.9896	N
19013	845.0	0	3	191.76	8.8E-04	37.1	-62.9	2.9E-04	147.7	10.2	2.9865	N
19014	850.0	1	3	167.32	5.2E-04	23.0	-61.2	1.0E-04	53.3	17.1	2.9625	N
19015	854.0	2	3	203.04	5.8E-04	63.9	-69.8	2.1E-04	88.2	13.2	2.9773	N
19016	859.0	2	4	184.24	4.9E-04	61.5	-74.1	1.2E-04	37.3	15.2	3.9195	N
19017	864.0	1	3	176.72	6.6E-04	33.2	-66.4	1.4E-04	128.3	10.9	2.9844	N
19018	868.0	1	3	182.36	5.4E-04	224.4	38.6	2.8E-04	2.4	70.4	2.1665	R
19019	873.0	1	.	218.08	2.6E-04	.	.	.	.	.	.	
19020	878.0	1	4	203.04	3.0E-04	85.9	-59.9	4.5E-05	10.9	29.2	3.7242	N
19021	883.0	1	3	172.96	3.4E-04	81.5	-55.3	6.0E-05	5.7	57.3	2.6489	N
19022	889.0	0	3	178.60	8.5E-04	90.0	-8.8	4.3E-05	19.0	29.1	2.8946	N
19023	895.0	2	3	186.12	4.7E-04	300.9	-58.7	1.2E-04	9.6	42.3	2.7906	N
19024	900.0	1	3	186.12	4.9E-04	45.3	-50.3	8.8E-05	4.2	69.8	2.5239	N
19025	906.0	2	3	184.24	4.4E-04	60.5	-62.2	4.7E-05	58.6	16.3	2.9659	N
19026	911.0	2	3	191.76	3.7E-04	198.3	54.3	5.7E-04	6.5	53.0	2.6913	R
19027	916.0	1	3	182.36	4.2E-04	232.3	85.2	5.0E-04	24.9	25.3	2.9196	R
19028	921.0	1	4	178.60	4.2E-04	201.3	56.3	4.8E-04	4.4	49.7	3.3168	R
19029	925.0	2	3	171.08	5.5E-04	280.5	25.8	3.2E-04	3.3	83.0	2.3942	R
19030	929.0	1	4	189.88	4.8E-04	230.0	40.5	7.5E-05	7.7	35.5	3.6087	R
19031	934.0	1	4	176.72	4.8E-04	212.4	58.8	5.6E-05	5.0	45.6	3.4047	R
19032	939.0	1	3	182.36	4.6E-04	200.9	41.4	1.3E-04	2.2	58.0	2.0826	R
19033	944.0	1	.	174.84	4.9E-04	.	.	.	.	.	.	
19034	949.0	1	.	172.96	4.3E-04	.	.	.	.	.	.	
19035	954.0	0	.	180.48	4.1E-04	.	.	.	.	.	.	
19036	958.0	1	3	184.24	3.7E-04	198.3	56.0	6.5E-05	4.1	71.3	2.5090	R
19037	963.0	1	4	178.60	3.1E-04	207.3	63.8	6.4E-05	56.3	12.3	3.9473	R
19038	968.0	1	.	180.48	4.3E-04	.	.	.	.	.	.	
19039	973.0	1	3	189.88	4.0E-04	286.3	78.0	2.4E-05	12.4	27.2	3.7576	R
19040	978.0	2	4	218.08	5.5E-04	214.7	55.0	3.4E-05	9.2	32.1	3.6727	R
19041	983.0	3	4	261.32	3.3E-03	225.2	65.0	2.9E-03	95.8	9.4	3.9680	R
19042	988.0	1	4	308.32	6.9E-03	229.3	55.7	5.1E-03	45.2	13.8	3.9336	R
19043	993.0	1	4	344.04	6.6E-03	312.6	53.3	5.9E-03	137.4	7.9	3.9782	R
19044	998.0	1	3	193.64	4.8E-04	259.5	75.6	1.1E-04	40.2	19.7	2.9502	R
19045	1003.0	1	3	193.64	5.8E-04	229.6	46.4	6.3E-04	18.8	29.3	2.8936	R
19046	1008.0	1	3	193.64	2.9E-04	248.3	64.3	3.6E-04	15.9	32.0	2.8741	R
19047	1013.0	1	3	201.16	5.2E-04	223.9	41.6	5.1E-04	7.6	48.1	2.7383	R
19048	1019.0	0	3	216.20	1.7E-03	236.1	59.9	1.2E-03	187.1	9.0	2.9893	R
19049	1024.0	1	4	182.36	4.3E-04	231.3	60.1	4.1E-04	659.2	3.6	3.9955	R
19050	1030.0	1	3	227.48	4.6E-04	231.5	69.0	5.1E-04	3.0	89.4	2.3235	R
19051	1035.0	1	3	180.48	4.5E-04	342.5	58.2	5.2E-04	36.8	20.6	2.9457	R
19052	1040.0	1	3	178.60	3.6E-04	195.0	51.1	3.8E-04	3.4	80.8	2.4157	R
19053	1045.0	1	3	197.40	3.7E-04	242.2	65.0	4.5E-04	5.5	58.7	2.6357	R
19054	1050.0	0	.	.	.	.	.	.	.	.	.	
19055	1054.0	1	4	174.84	5.7E-04	214.2	60.0	5.4E-04	53.3	12.7	3.9437	R
19056	1060.0	1	3	246.28	5.4E-03	214.7	54.4	4.3E-03	78.6	14.0	2.9746	R
19057	1065.0	1	3	250.04	8.7E-04	223.6	67.8	9.1E-04	10.0	41.3	2.7993	R
19058	1071.0	1	3	193.64	9.0E-04	196.6	80.0	5.1E-04	4.4	67.9	2.5429	R
19059	1077.0	1	3	180.48	2.5E-04	234.4	63.7	2.6E-04	33.6	21.6	2.9405	R

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
19060	1084.0	1	3	161.68	1.1E-04	217.8	72.8	1.6E-04	50.6	17.5	2.9605	R
19061	1090.0	1	4	184.24	6.4E-05	217.3	66.2	2.0E-04	134.0	8.0	3.9776	R
19062	1095.0	1	.	193.64	5.5E-04	.	.	.	.	.	.	
19063	1100.0	2	4	195.52	5.0E-04	198.6	65.6	3.8E-04	15.4	24.2	3.8053	R
19064	1105.0	1	3	189.88	6.2E-04	52.6	-39.9	5.8E-04	16.8	31.1	2.8808	N
19065	1110.0	1	3	246.28	9.4E-04	31.6	-59.8	7.1E-04	386.3	6.3	2.9948	N
19066	1116.0	1	4	199.28	4.8E-04	203.6	66.7	4.5E-04	23.1	19.5	3.8701	R
19067	1121.0	1	3	191.76	2.0E-04	216.7	60.9	2.2E-04	18.7	29.3	2.8933	R
19068	1127.0	1	3	216.20	1.5E-03	239.0	66.2	5.2E-04	71.5	14.7	2.9720	R
19069	1132.0	1	.	.	.	.	.	.	.	.	.	
19070	1137.0	.	3	182.36	3.8E-04	216.8	58.4	3.2E-04	198.4	8.8	2.9899	R
19071	1142.0	2	.	197.40	4.8E-04	.	.	.	.	.	.	
19072	1147.0	0	3	293.28	1.9E-03	227.4	54.3	1.5E-03	147.7	10.2	2.9865	R
19073	1152.0	2	3	184.24	5.7E-04	224.1	62.8	4.3E-04	74.3	14.4	2.9731	R
19074	1157.0	1	4	172.96	4.0E-04	219.4	55.2	4.1E-04	259.9	5.7	3.9885	R
19075	1163.0	0	3	257.56	2.0E-03	215.0	63.6	1.3E-03	31.6	22.3	2.9368	R
19076	1168.0	1	4	172.96	3.6E-04	208.9	57.2	4.3E-04	44.9	13.9	3.9332	R
19077	1173.0	2	4	304.56	8.8E-05	214.7	48.1	3.9E-04	31.3	16.7	3.9043	R
19078	1179.0	1	5	167.32	2.0E-04	220.6	59.6	2.7E-04	159.4	6.1	4.9749	R
19079	1184.0	1	5	152.28	1.2E-04	213.6	64.8	2.0E-04	350.5	4.1	4.9886	R
19080	1190.0	1	4	152.28	9.2E-04	213.2	64.8	2.0E-04	69.9	11.1	3.9571	R
19081	1195.0	0	3	191.76	7.9E-05	228.6	71.1	1.5E-04	41.1	19.5	2.9513	R
19082	1200.0	2	4	204.92	1.5E-04	220.5	69.8	1.6E-04	73.9	10.8	3.9594	R
19083	1205.0	1	3	191.76	1.1E-03	232.3	55.6	5.9E-04	523.8	5.4	2.9962	R
19084	1210.0	2	.	189.88	4.0E-04	.	.	.	.	.	.	
19085	1215.0	2	3	210.56	4.2E-04	222.3	60.5	3.2E-04	53.9	17.0	2.9629	R
19086	1220.0	1	4	210.56	1.2E-03	228.7	57.7	4.4E-04	1040.8	2.8	3.9971	R
19087	1225.0	2	3	184.24	1.6E-03	227.4	58.9	6.1E-04	76.7	14.2	2.9739	R
19088	1230.0	1	4	184.24	2.4E-04	219.0	64.6	4.6E-04	102.3	9.1	3.9707	R
19089	1245.0	1	5	165.44	1.3E-04	205.4	71.1	1.1E-04	78.6	8.7	4.9491	R
19090	1250.0	1	3	216.20	8.2E-05	193.6	67.1	1.4E-04	8.4	45.5	2.7625	R
19091	1256.0	1	.	285.76	1.9E-04	.	.	.	.	.	.	
19092	1261.0	1	4	184.24	1.7E-04	182.7	54.5	6.6E-04	24.3	19.0	3.8763	R
19093	1272.0	3	4	176.72	6.1E-05	207.0	59.3	1.1E-04	26.2	24.6	2.9236	R
19094	1277.0	2	4	182.36	1.2E-04	218.2	71.2	1.2E-04	40.0	14.7	3.9251	R
19095	1282.0	1	4	182.36	9.9E-05	212.9	66.9	2.4E-04	439.2	4.4	3.9932	R
19096	1287.0	1	4	188.00	6.5E-05	213.5	58.8	2.1E-04	73.9	10.8	3.9594	R
19097	1293.0	2	4	193.64	6.0E-04	224.3	55.0	6.8E-04	937.1	3.0	3.9968	R
19098	1298.0	2	4	174.84	1.8E-04	214.1	63.1	3.4E-04	114.4	8.6	3.9738	R
19099	1314.0	2	3	188.00	1.3E-04	237.8	63.4	1.5E-04	36.4	20.7	2.9450	R
19100	1319.0	2	.	176.72	1.3E-04	.	.	.	.	.	.	
19101	1324.0	1	3	180.48	1.7E-04	221.9	55.9	1.1E-04	26.4	24.5	2.9244	R
19102	1329.0	3	.	169.20	2.5E-04	.	.	.	.	.	.	
19103	1334.0	1	3	178.60	2.0E-04	227.0	75.8	9.5E-05	63.0	15.7	2.9683	R
19104	1339.0	1	3	171.08	1.7E-04	.	.	7.6E-05	.	.	.	R
19105	1345.0	1	3	161.68	2.1E-04	226.5	58.8	2.7E-05	107.6	11.9	2.9814	R
19106	1403.0	1	3	150.40	3.2E-04	214.1	56.2	6.3E-05	26.9	24.2	2.9258	R
19107	1409.0	2	3	172.96	3.5E-04	217.6	60.0	8.2E-05	27.0	24.2	2.9259	R
19108	1415.0	2	3	154.16	3.2E-04	217.2	64.7	5.3E-05	535.0	5.3	2.9963	R
19109	1421.0	1	.	158.24	4.3E-04	.	.	.	.	.	.	
19110	1427.0	1	3	165.44	4.5E-04	210.7	61.0	6.5E-05	22.4	26.7	2.9108	R
19111	1433.0	1	3	172.96	3.6E-04	218.7	67.7	5.6E-05	16.0	31.9	2.8751	R
19112	1439.0	1	.	165.44	4.0E-04	.	.	.	.	.	.	
19113	1445.0	1	.	.	.	.	.	.	.	.	.	
19114	1450.0	1	3	154.16	4.0E-04	219.2	65.7	4.2E-05	15.0	33.0	2.8699	R
19115	1456.0	1	3	139.12	3.7E-04	215.1	61.4	7.4E-05	184.0	9.1	2.9891	R
19116	1461.0	2	4	163.56	4.3E-04	33.4	-51.5	1.5E-04	17.4	22.7	3.8273	N
19117	1467.0	1	3	197.40	3.0E-04	39.5	-51.5	4.9E-05	46.8	18.2	2.9572	N
19118	1473.0	1	3	161.68	2.7E-04	83.9	-49.9	6.2E-05	10.0	41.3	2.7998	N
19119	1479.0	1	3	172.96	3.3E-04	53.2	-49.6	6.6E-05	13.0	35.7	2.8460	N
19120	1485.0	1	3	182.36	4.7E-04	60.3	-42.3	8.2E-05	21.4	27.4	2.9065	N
19121	1490.0	1	3	172.96	5.7E-04	52.9	-59.8	7.0E-05	48.1	18.0	2.9584	N
19122	1495.0	1	3	325.24	3.9E-04	50.6	-54.4	1.2E-04	52.4	17.2	2.9618	N
19123	1501.0	1	3	169.20	4.0E-04	76.2	-46.3	9.9E-05	13.4	35.1	2.8505	N
19124	1507.0	.	.	.	.	.	.	.	.	.	.	
19125	1512.0	1	3	268.84	4.2E-04	51.1	-59.4	1.3E-04	21.2	27.4	2.9057	N
19126	1518.0	2	4	193.64	4.0E-04	47.7	-50.2	9.5E-05	45.0	13.8	3.9334	N
19127	1524.0	1	.	182.36	2.8E-04	.	.	.	.	.	.	
19128	1530.0	1	3	248.16	4.6E-04	50.0	-51.6	1.5E-04	68.2	15.1	2.9707	N
19129	1536.0	1	3	178.60	4.1E-04	53.8	-66.1	1.1E-04	23.2	26.2	2.9137	N
19130	1542.0	.	.	.	.	.	.	.	.	.	.	
19131	1548.0	1	3	163.56	3.8E-04	49.0	-56.0	9.0E-05	11.4	38.4	2.8244	N
19132	1552.0	1	3	159.80	2.4E-04	42.6	-54.7	6.0E-05	16.5	31.3	2.8791	N
19133	1556.0	1	4	161.68	3.5E-04	38.2	-54.7	1.1E-04	60.9	11.9	3.9507	N
19134	1560.0	1	4	188.00	7.1E-04	61.0	-56.6	1.6E-04	149.6	7.5	3.9700	N
19135	1564.0	2	4	180.48	3.0E-04	46.1	-66.8	3.9E-05	110.2	8.8	3.9728	N
19136	1569.0	1	3	171.08	4.9E-04	29.5	-51.0	9.8E-05	67.0	15.2	2.9702	N
19137	1574.0	2	3	169.20	7.0E-04	55.5	-50.1	1.2E-04	736.4	4.5	2.9973	N
19138	1580.0	2	3	163.56	2.3E-04	83.5	-63.6	3.6E-05	19.1	29.0	2.8953	N
19139	1585.0	2	3	169.20	3.9E-04	69.6	-57.5	1.0E-04	9.4	42.6	2.7879	N
19140	1590.0	1	.	163.56	2.8E-04	.	.	.	.	.	.	
19141	1595.0	1	3	167.32	2.4E-04	30.1	-52.7	4.8E-05	41.9	19.3	2.9523	N
19142	1599.0	1	.	144.76	2.4E-04	.	.	.	.	.	.	
19143	1604.0	1	4	171.08	1.1E-04	231.5	53.9	3.9E-05	18.9	21.7	3.8412	R
19144	1608.0	1	3	172.96	1.9E-04	234.2	41.3	5.6E-05	43.5	18.9	2.9541	R
19145	1612.0	1	3	171.08	3.1E-04	261.7	50.1	1.0E-04	11.3	38.6	2.8224	R
19146	1616.0	0	3	163.56	1.0E-04	249.8	45.3	3.5E-05	29.3	23.2	2.9317	R
19147	1622.0	1	3	169.20	1.1E-04	213.5	45.7	2.3E-05	5.6	58.0	2.6420	R
19148	1627.0	.	.	.	.	.	.	.	.	.	.	
19149	1633.0	1	.	174.84	1.7E-04	.	.	.	.	.	.	
19150	1638.0	1	.	174.84	1.6E-04	.	.	.	.	.	.	
19151	1643.0	1	3	186.12	1.2E-04	228.7	32.5	2.9E-05	3.0	90.0	2.3293	R
19152	1649.0	0	3	176.72	1.8E-04	245.9	21.8	1.8E-05	7.1	50.4	2.7163	R
19153	1650.0	0	3	163.56	1.9E-04	208.6	-3.8	2.0E-05	11.2	38.6	2.8222	R
19154	1751.0	1	3	184.24	2.0E-04	204.6	60.3	1.8E-05	185.3	9.1	2.9892	R

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
19155	1757.0	1	3	171.08	2.5E-04	209.3	60.2	1.8E-05	241.2	8.0	2.9917	R
19156	1762.0	1	3	176.72	3.0E-04	47.2	-68.1	8.5E-05	41.6	19.4	2.9519	N
19157	1767.0	2	4	188.00	3.6E-04	45.5	-58.0	1.3E-04	275.3	5.5	3.9891	N
19158	1772.0	2	3	172.96	3.5E-04	25.9	-63.9	7.1E-05	33.5	21.6	2.9404	N
19159	1779.0	1	3	188.00	2.8E-04	48.7	-62.0	5.2E-05	33.9	21.5	2.9409	N
19160	1787.0	.	.	.	.	.	.	.	.	.	.	
19161	1794.0	0	3	174.84	2.3E-04	63.5	-44.3	3.6E-05	116.4	11.5	2.9828	N
19162	1801.0	0	3	193.64	4.5E-04	37.5	-58.6	9.3E-05	94.3	12.8	2.9788	N
19163	1807.0	1	3	193.64	4.7E-04	48.1	-56.1	1.7E-04	96.3	12.6	2.9793	N
19164	1816.0	2	3	174.84	2.2E-04	50.1	-45.0	4.1E-05	24.9	25.2	2.9197	N
19165	1825.0	2	.	214.32	2.2E-04	.	.	.	.	.	.	
19166	1836.0	0	3	186.12	2.6E-04	52.9	-56.9	3.8E-05	389.8	6.3	2.9949	N
19167	1848.0	0	.	171.08	2.1E-04	.	.	.	.	.	.	
19168	1857.0	2	3	159.80	2.1E-04	56.4	-52.4	5.7E-05	370.6	6.4	2.9946	N
19169	1866.0	1	.	172.96	2.0E-04	.	.	.	.	.	.	
19170	1875.0	1	3	178.60	1.9E-04	256.2	20.1	2.9E-05	4.3	68.6	2.5345	R
19171	1884.0	1	4	167.32	1.9E-04	197.9	53.2	2.0E-05	4.0	53.1	3.2439	R
19172	1892.0	1	.	171.08	1.6E-04	.	.	.	.	.	.	
19173	1901.0	1	3	174.84	1.5E-04	293.7	36.0	2.2E-05	6.9	51.0	2.7104	R
19174	1909.0	3	.	188.00	1.9E-04	.	.	.	.	.	.	
19175	1918.0	1	3	182.36	8.0E-05	219.3	21.3	3.6E-05	3.5	78.9	2.4340	R
19176	1927.0	1	.	169.20	1.2E-04	.	.	.	.	.	.	
19177	1936.0	0	3	167.32	1.6E-04	246.7	40.3	1.7E-05	12.6	36.3	2.8410	R
19178	1945.0	0	3	203.04	2.8E-04	259.9	45.0	2.8E-05	9.9	41.5	2.7976	R
19179	1954.0	3	.	174.84	2.0E-04	.	.	.	.	.	.	
19180	1959.0	1	3	191.76	2.9E-04	267.3	38.1	5.9E-05	3.6	78.0	2.4427	R
19181	1964.0	1	3	161.68	9.2E-05	221.9	31.4	2.3E-05	9.1	43.4	2.7809	R
19182	1975.0	2	3	157.92	1.5E-04	250.2	72.2	2.2E-05	6.3	54.1	2.6803	R
19183	1984.0	0	3	150.40	1.7E-04	193.9	34.9	2.3E-05	4.9	63.1	2.5914	R
19184	1996.0	1	3	159.80	2.6E-04	239.2	22.7	2.5E-05	5.7	57.2	2.6504	R
19185	2004.0	1	3	171.08	2.7E-04	247.0	35.4	6.0E-05	7.0	50.7	2.7139	R
19186	2010.0	1	.	182.36	2.6E-04	.	.	.	.	.	.	
19187	2017.0	.	.	.	.	.	.	.	.	.	.	
19188	2023.0	0	3	148.52	3.6E-04	208.5	50.4	3.4E-05	13.1	35.5	2.8476	R
19189	2030.0	1	3	169.20	1.6E-04	201.5	67.3	5.3E-05	6.4	53.6	2.6855	R
19190	2036.0	0	3	.	1.2E-04	198.6	55.4	4.8E-05	18.8	29.3	2.8934	R
19191	2043.0	0	.	176.72	1.2E-04	.	.	.	.	.	.	
19192	2050.0	1	.	161.68	1.2E-04	.	.	.	.	.	.	
19193	2056.0	2	3	154.16	2.2E-04	264.0	39.6	3.4E-05	13.2	35.4	2.8482	R
19194	2063.0	2	3	172.96	1.4E-04	246.2	33.8	2.1E-05	5.2	60.4	2.6184	R
19195	2069.0	2	.	165.44	1.6E-04	.	.	.	.	.	.	
19196	2075.0	2	3	154.16	1.7E-04	139.5	36.4	2.3E-05	268.8	7.5	2.9926	R
19197	2081.0	2	.	148.52	1.8E-04	.	.	.	.	.	.	
19198	2096.0	1	3	184.24	1.3E-04	223.6	72.7	2.7E-05	9.4	42.7	2.7871	R
19199	2115.0	.	3	150.40	2.8E-04	248.8	45.6	5.1E-05	520.4	5.4	2.9962	R
19200	2130.0	1	3	174.84	4.1E-04	180.6	74.4	5.9E-05	109.0	11.9	2.9817	R
19201	2142.0	2	3	152.28	2.2E-04	181.5	45.9	6.2E-05	9.1	43.5	2.7803	R
19202	2154.0	1	3	167.32	3.0E-04	206.7	28.8	7.4E-05	17.5	30.4	2.8858	R
19203	2155.0	0	.	154.16	4.2E-04	.	.	.	.	.	.	
19204	2156.0	0	3	494.44	1.5E-03	250.6	28.3	5.8E-05	6.2	54.4	2.6778	R
19205	2156.5	0	.	259.44	6.0E-04	.	.	.	.	.	.	
19206	2157.0	0	3	204.92	6.0E-04	213.4	37.3	1.7E-04	4.8	63.8	2.5841	R
19207	2157.5	0	3	1024.60	7.2E-03	199.7	47.5	1.4E-03	7.0	50.6	2.7144	R
19208	2158.0	0	.	1472.04	1.5E-02	.	.	.	.	.	.	

APPENDIX 10: CARBON AND OXYGEN ISOTOPE DATA

Carbon Isotope Data

VUW No	Stratigraphic Height (m)	Analytical $\delta^{13}C$	Corrected $\delta^{13}C$
19221	2123	-0.84	-0.28
19220	2110	-0.78	-0.22
19197	2081	-0.22	0.34
19196	2075	0.26	0.82
19191	2043	0.07	0.63
19190	2036	0.22	0.78
19189	2030	0.40	0.96
19187	2017	0.52	1.08
19178	1945	0.22	0.78
19176	1927	0.35	0.91
19171	1884	0.07	0.63
19170	1875	0.41	0.97
19169	1866	0.39	0.92
19167	1848	0.08	0.64
19166	1836	0.24	0.80
19164	1816	0.13	0.69

Corrected values are the analytical values normalised to *Cibicidoides wuellerstorfi* by the addition of 0.56 $\delta^{13}C$.

Oxygen Isotope Data

VUW No	Stratigraphic Height (m)	Analytical $\delta^{18}O$
19221	2123	0.42
19220	2110	0.42
19197	2081	1.32
19196	2075	1.33
19191	2043	1.40
19190	2036	1.10
19189	2030	1.41
19187	2017	1.49
19178	1945	1.62
19176	1927	1.51
19171	1884	1.41
19170	1875	1.27
19169	1866	1.45
19167	1848	1.71
19166	1836	1.59
19164	1816	1.77

All samples were analysed by Dr. C. Nelson on the Waikato University VG Micromass 602E mass spectrometer.

APPENDIX 11: SUSCEPTIBILITIES OF SILICIC TUFFS (MANGAPOIKE)

Tuff*	Value 1	Value 2	Value 3	Mean
G161	159.2	164.6	163.2	162.3
G159	190.2	203.4	191.8	195.1
G156	174.5	174.9	166.0	171.8
G153	173.9	182.8	178.3	178.3
G152	198.7	184.6	196.8	193.8
G74	163.6	171.2	170.9	168.6
G71	220.8	224.1	226.5	223.8
G62	180.3	178.4	187.6	182.1
G55	190.8	192.7	189.4	191.0
G171	213.7	221.4	209.1	214.7

Susceptibility values are x 10^{-3}

* G number refers to the field numbers of Gosson (1986).