BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

RECORD 1987/ 20

STRUCTURAL GEOLOGY OF THE TOMMY CREEK AREA, MOUNT ISA INLIER, NW QUEENSLAND

by

E.J. HILL

RECORD 1987/ 20

STRUCTURAL GEOLOGY OF THE TOMMY CREEK AREA, MOUNT ISA INLIER, NW QUEENSLAND

by

E.J. HILL

CONTENTS

ABSTRACT

A folded and metamorphosed Proterozoic sequence of thick and generally massive felsic ignimbrite interlayered with calc-silicate rocks, sandstone, marble and carbonaceous pelitic sediments, overlain conformably by mafic and intermediate volcanics and tuffs, is exposed in the Tommy Creek area.

The sequence was first deformed by two phases of thrust faulting and recumbent and inclined folding (D1a and D1b); accompanied by amphibolite facies metamorphism of the sillmanite zone and resulting in anatectic granitic veins and pegmatites. D1a is associated with the formation of a strong to mylonitic axial plane foliation, breccias and shear zones. This early phase of deformation is overprinted by the regional, upright, north-south folds characteristic of most of the Mount Isa Inlier (D2). The possibility of pre-D1 extension is discussed.

Unexpectedly young U-Pb zircon ages of 1600 to 1620 Ma obtained on felsic volcanics (Page 1983) probably date the D1 metamorphism. Rocks previously mapped as "Tommy Creek Microgranite" (Derrick et al, 1971)) are reinterpreted on the basis of field evidence and thin section studies as recrystallised porphyritic ignimbrite.

INTRODUCTION

The Tommy Creek area is located in the centre of the Marraba 1:100 000 Sheet (No. 6956) in the Mount Isa Inlier, northwest Queensland (Fig.1). It is bounded by latitudes 20°38' and 20°47', and longitudes 140°9' and 140°19', and consists of a multiply deformed sequence of metasediments and metavolcanics of the Precambrian Corella Formation (Mary Kathleen Group).

The area was first mapped in relative detail during the survey of the Marraba 1:100 000 Sheet (Derrick and others, 1971; Derrick, 1980). The area has been the subject of one unpublished honours thesis from the University of Queensland (Klemm, 1975), and two unpublished honours theses submitted to the University of Adelaide in 1984.

This report describes the results of a detailed structural analysis of the Tommy Creek area carried out in May - September 1986 by the author. Mapping was carried out using colour aerial photographs, approximate scale 1:27 000, of the Cloncurry Series (southern part), runs 3-8 (QASCOPHOTO; 14 and 15/8/79). L.A.I. Wyborn is currently undertaking geochemical studies of metavolcanics exposed in the area.

Geological Setting

The Tommy Creek area is separated from the Mary Kathleen fold belt to the west and north by the Ballara - Corella River fault zone; and to the south and east it is faulted against the "Mitakoodi structure" (Fig.1).

The Mary Kathleen fold belt is dominated by north-south trending, tight to isoclinal folds (D2) which overprint an early extensional shearing event evident in the Wonga Belt, the antiformal core of the Mary Kathleen fold belt (R.J. Holcombe & P.J. Pearson, personal communication, University of Queensland 1986). The "Mitakoodi structure" is a major, north-northeast-plunging double antiform dominating the southern part of the Marraba Sheet, and is believed to be equivalent to the D2 folds in the Mary Kathleen fold belt (R. Loosveld, personal communication, A.N.U.)

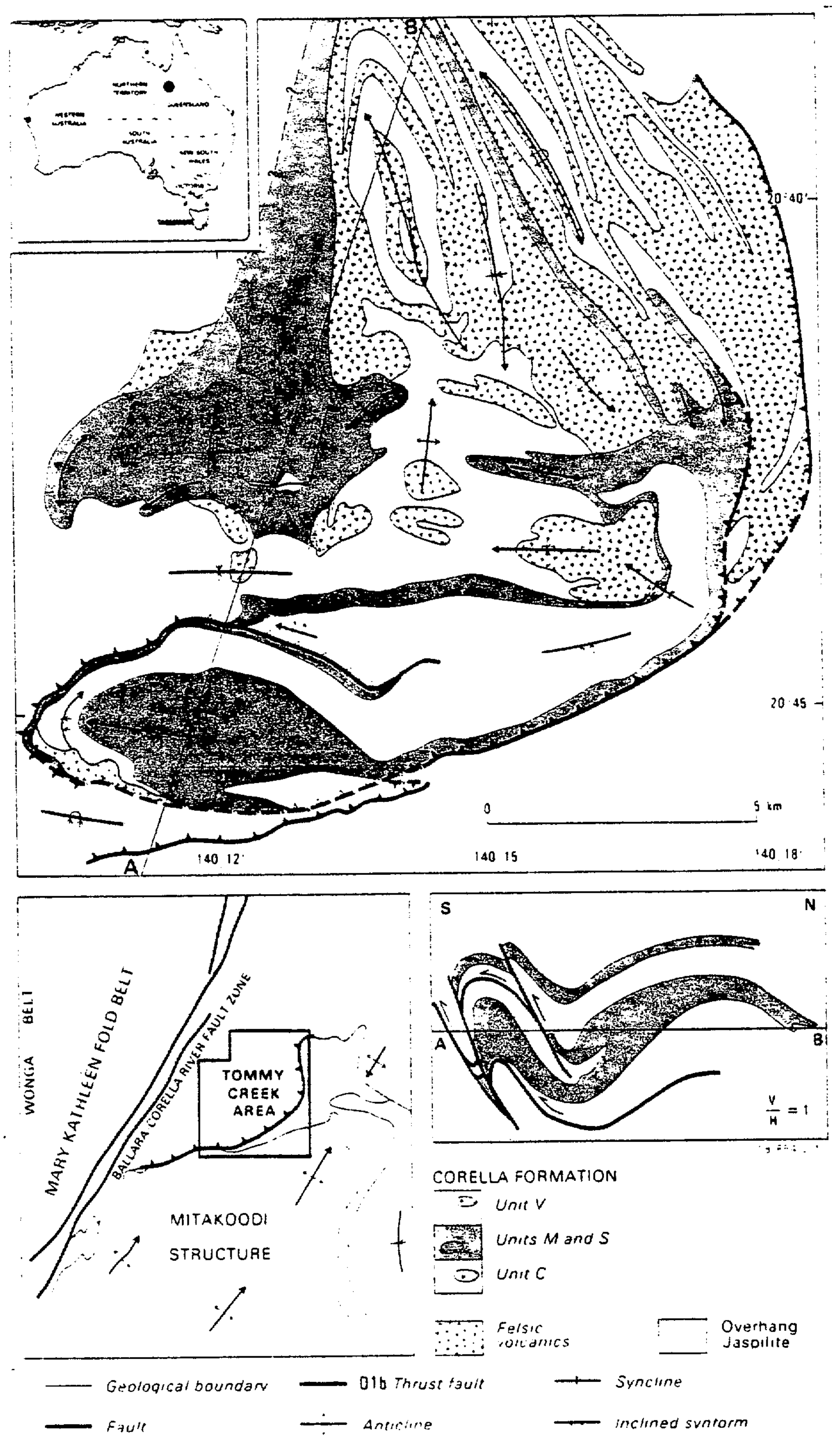


Fig.1 Simplified structural map and cross-section of the Tommy Creek area, and locality map.

6

GEOLOGY OF THE TOMMY CREEK AREA

Introduction

The sequence of metasediments and metavolcanics exposed in the Tommy Creek area has suffered an intense early deformation (D1a), which resulted in thrust faulting, mylonite development and formation of highly non-cylindrical recumbent folds, accompanied by amphibolite facies metamorphism of the sillimanite zone and development of anatectic granitic veins and pegmatites. The area has also been affected by a succeeding phase of reverse faulting and inclined folding (D1b); and later upright folding (D2). In addition, the possibility of a pre-D1 extension event must be considered.

The Tommy Creek sequence consists of bedded calc-silicate rocks, sandstone, marble, carbonaceous pelitic rocks, and thick, laterally discontinuous, generally massive bodies of felsic ignimbrite, overlain conformably by mafic and intermediate lavas and tuffs. The volcanism appears to have been subaqueous.

The entire Tommy Creek sedimentary and volcanic sequence is assigned to the Corella formation. It includes rocks previously mapped as "Tommy Creek microgranite" which are indicated from field evidence and thin section studies to be recrystallised porphyritic felsic volcanics. Unexpectedly young U-Pb ages of around 1600 to 1620 Ma obtained on these rocks by Page (1983b) probably date the D1 metamorphic event.

Stratigraphy

Corella Formation

The Corella Formation sequence of the Tommy Creek area can be divided into two parts (Table 1 and Fig.2): - a lower. of calc-silicate rocks (unit C) and porphyritic felsic volcanics (unit F1), and an upper part of pelitic and calcareous metasediments (unit M), schists (unit S), mafic and intermediate lavas and tuffs (unit V), and porphyritic felsic volcanics (unit F2). The sequence is faulted against marble, jaspilite and calcareous rocks of the Overhang Jaspilite to the south and east. Ridges of quartzite breccia near and on the fault are known as Chumvale Breccia.

Unit C: This unit consists mainly of layered, medium to fine grained calc-silicate granofels which may contain diopside or garnet pophyroblasts. Reddish to pinkish brown felsic layers, approximately 1-5 cm thick, consist of altered fdp (commonly mcl) + qz ± cal ± gn ± hbl ± diop. Greenish-black mafic layers, approximately 1-2 cm thick consist of diop + plag ± cal ± qz ± act ± gn ± hbl ± scap. Minor sph, ap and opaque minerals occur in some layers. Alteration minerals including biotite, chlorite, calcite, and epidote.

7

TABLE 1. STRATIGRAPHY OF THE TOMMY CREEK AREA

FORMATION		UNIT	SUB UNIT	LITHOLOGIES
CORELLA FORMATION	UPPER	F	F2	porphyritic felsic volcanics, generally micaceous
		V	Vm	porphyritic mafic lavas, fragmentary mafic and intermediate lava, minor sediments
			Vt	finely banded tuff
			Vi	massive intermediate lava
		S	Sg	graphitic schist, minor chert
			Sm	muscovite-garnet schist
		M	Mm	marble; minor siltstone, sandstone and calc-silicate rocks
			Mc	calc-silicate rocks; minor quartzite, marble, siltstone, sandstone
			Mq	quartzite conglomerate; minor sandstone, marble, quartzite
	LOWER	F	F1	porphyritic felsic volcanics
		C		calc-silicate rocks; minor mafic and felsic volcanics
FAULT BOUNDARY				
CHUMVALE BRECCIA		k		quartzite breccia
OVERHANG JASPILITE		j		jaspilite, limestone, shale, marl

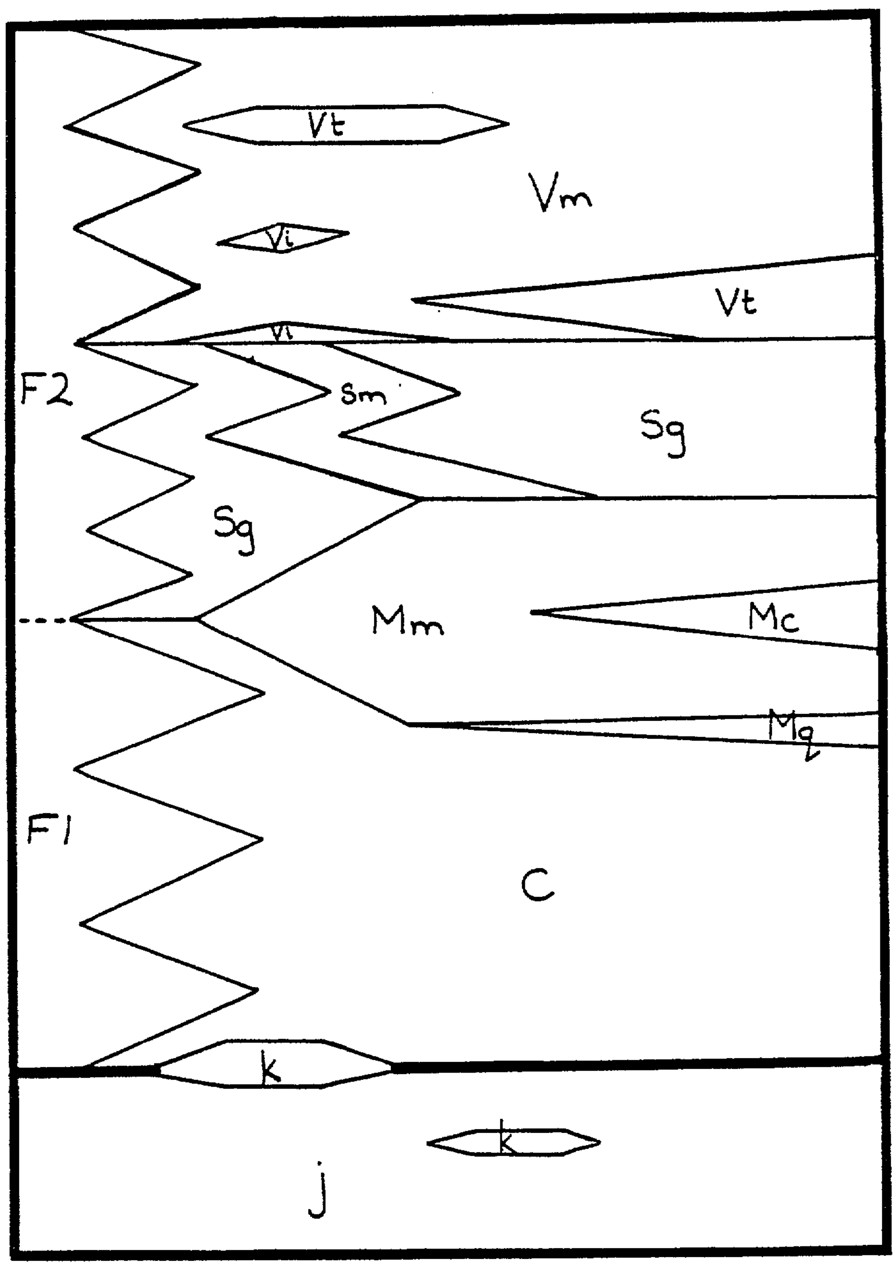


Fig.2 Diagrammatic relationships of stratigraphic rock units in the Tommy Creek area. For key to symbols see Table 1.

9

Layering is either bedding or, where deformation is most intense, transposed bedding. Abundant sedimentary structures are preserved in places, they include ripples, smale scale cross-bedding, halite casts and graded beds.

Breccia, made up of angular fragments (generally 5 - 10 cm across) of calc-silicate granofels and very fine grained quartzite in a calcareous matrix, occurs mostly around thrust fault boundaries. In a few places the breccia shows a D1 foliation.

Weak red-rock alteration occurs throughout the southern part of the area, where it is associated with large irregular zones of post-D2 breccia.

In the northern part of the area, dark green calc-silicate rocks (plag + hbl or diop ± qz) are commonly interbedded with lesser amounts of pink or white felsic volcanic bands (qz + plag + hbl or diop ± cal, generally 5 cm - 1 m thick; Fig.3) and very dark, thin layers of mafic volcanics (mcl or plag + hbl ± diop ± qz ± scap,generally about 1 cm thick, mcl or plag + hbl ± diop ± qz ± scap), with the felsic volcanics commonly forming elongate or flattened lenses within the mafic volcanic layers.

Unit M: This unit consists dominantly of marble, but also includes quartzite; black to grey slate; biotite-quartzite; metasiltstone; dark grey, massive calc-silicate rocks; pale grey, laminated calc-silicate rocks with diopside porphyroblasts; pebbly conglomerate; coarse and fine grained sandstone, and minor tuff. Sedimentary structures are abundant in the northwest and include graded bedding, ripple marks, mud-cracks, cross-bedding, and scour marks. The quartzite may be mylonitised or brecciated. In quartzite breccias a foliation is generally apparent, indicated by elongate or flattened fragments, but the matrix (generally Fe and Mn stained chalcedony,) is not foliated.
Unit M is divided into the following 3 sub-units

Subunit Mm: dominantly marble (medium grained, granoblastic cal + foliated woll + poikiloblastic vesuv + minor opaque minerals); also minor finely laminated siltstone; interbedded siltstone and sandstone with trough cross-bedding (beds about 20 cm thick); and laminae of sandstone grading through to siltstone and marl.

Subunit Mc: dominantly calc-silicate rocks (fine-grained, granoblastic fdp, large poikiloblastic diop, and minor sph; also retrograde chlor, cal, biot and ep) commonly with alternating fdp-rich and diop-rich laminae; also quartzite (Fig.4); siltstone; graded layers of quartz-pebble sandstone through to quartz sandstone and siltstone; chert; coarse sandstone with graded bedding and ripples; and conglomerate.

Subunit Mq: dominantly conglomerate with quartzite clasts (± biot, ± act, ± cal, ± opaque minerals), also calc-silicate clasts (cal + act or biot + opaque minerals), in matrix of quartz sandstone ± act ± biot ± cal; minor graded laminae of fine sandstone, siltstone, and marl; minor marble, quartzite and siltstone (often with cross-bedding).

Unit S: This unit consists dominantly of pelitic schist, slate and phyllite, generally crenulated, but also includes minor quartz-pebble sandstone (probably volcaniclastic), chert and tuff. It is divided into two sub-units:

Subunit Sg: graphitic schist (Fig.5) and slate (dark bluish grey to bluish black, medium to fine grained, qz + graphite + plag + minor musc, biot & chlor ± porphyroblasts of stau and gn); minor thin layers of grey to white chert; and rare tuff.

Subunit Sm: pinkish to reddish brown mica schist and phyllites (fine to medium grained, musc + qz ± biot ± sill as fibrolitic masses largely replaced by sericite + minor opaque minerals ± gn porphyroblasts); minor, probably volcaniclastic, qz-pebble sandstone (large, flattened, rounded clasts of qz in matrix of qz + mcl + biot + minor opaque minerals).

Unit V: This unit consists of interbedded schistose tuff, strongly foliated basalt, massive and layered intermediate volcanics, strongly flattened fragmentary felsic, intermediate and mafic volcanics, and minor sediments. It is divided into 3 sub-units:

Subunit Vm: dark, fine grained basalt (diop or hbl + plag + abundant opaque minerals ± biot) commonly with abundant plagioclase phenocrysts (Fig.6); fragmentary volcanics (Figs.7, 8) of mafic to felsic composition (mafic: hbl or diop + minor plag + abundant large gn porphyroblasts; felsic: mcl ± opaque minerals); lenticular pods of bright green (epidotic) altered basalt; banded intermediate lava (medium to fine grained, foliated, mcl + qz + biot + opaque minerals ± poikiloblastic gn porphyry); fragmentary lava with flattened and lenticular fragments of generally 0.5 to 5 cm thick and 5 to 20 cm long; intermediate to felsic composition (intermediate: plag + biot + opaque minerals; felsic: mcl + qz ± biot ± cal ± musc ± gn + minor opaque minerals; minor calc-silicate rocks, graphitic schist and coarse quartz sandstone.

Subunit Vi: massive, laterally discontinuous intermediate lava (medium to fine grained, granoblastic plag + qz + biot + opaque minerals) generally with abundant clots of biotite up to 15 cm in diameter and about 5 mm thick which maybe inclusions of mafic magma.

Subunit Vt: yellowish grey schist and finely banded tuff (qz + musc ± fdp ± biot ± gn porphyroblasts ± cal) which are generally muscovite rich and contain small, felsic lenses about 1-10 cm long (mcl; mcl + qz; or qz

//

+ musc ± biot).

Unit F: This unit consist of large, discontinuous masses of porphyritic felsic volcanics, which show no flow banding and only rare internal layering, occuring througout units C, M, S and V. In subunit F1 (previously mapped as Tommy Creek Microgranite (Derrick, 1980)), in the lower part of the Tommy Creek sequence (unit C) the felsic volcanics form large masses containing up to 50% phenocrysts and also in many cases small mica-rich patches which may originally have been pieces of pumice (fiamme). In the upper part of the sequence (units M, S, V) and also in the upper part of unit C, the felsic volcanic bodies (subunit F2) generally contain more muscovite and less phenocrysts, may show layering, and are commonly schistose. They vary in thickness from a few centimetres to 2 or 3 kilometres. These volcanics contain phenocrysts of flattened or elongate quartz and microcline in a medium grained, weakly foliated, or fine grained, strongly foliated groundmass (qz + mcl ± musc, biot, hbl; minor zircon, gn & opaque minerals; retrograde ep, chlor and cal; mcl is generaly altered and cloudy; opaque minerals include abundant pyrite). Quartz phenocrysts are much more flattened than microcline phenocrysts, and only small remnants are evident in highly recrystallised rocks. Minor, thin, mafic layers occur in some areas (Fig.9).

Overhang Jaspilite and Chumvale Breccia

The Overhang Jaspilite consists of thinly layered (5-10 cm) fine grained quartzite, calc-silicate rocks, chert, jaspilite, marble and abundant breccia. Sedimentary structures occur including ripple marks and halite casts. Two types of breccia are present; One type consists of angular fragments of quartzite, chert, jaspilite and calc-silicates in a calcareous matrix; the other type forms prominant ridges, is commonly foliated (S1a), has a matrix of Fe and Mn stained chalcedony which is not foliated. In places the breccia merges with unit C. This latter breccia has been mapped as Chumvale Breccia (Derrick, 1980), and is believed to have formed by brecciation and leaching of carbonate and extensive silicification related to faulting, folding and recent laterite development (Derrick et al., 1971).

Tommy Creek Microgranite"

Most of the felsic rocks in the Tommy Creek area were previously mapped as "Tommy Creek Microgranite"(Derrick et al, 1971; Derrick, 1980). However field studies show that the "microgranite" grades into rocks previously mapped as "rhyolite" and on a small scale is interlayered with, not intrusive into, adjacent sedimentary rocks. Thin sections show that relict quartz and microcline phenocrysts are abundant in the felsic rocks which are strongly recrystallised. The "Tommy Creek Microgranite" is therefore considered to represent extensively recrystallised,

12

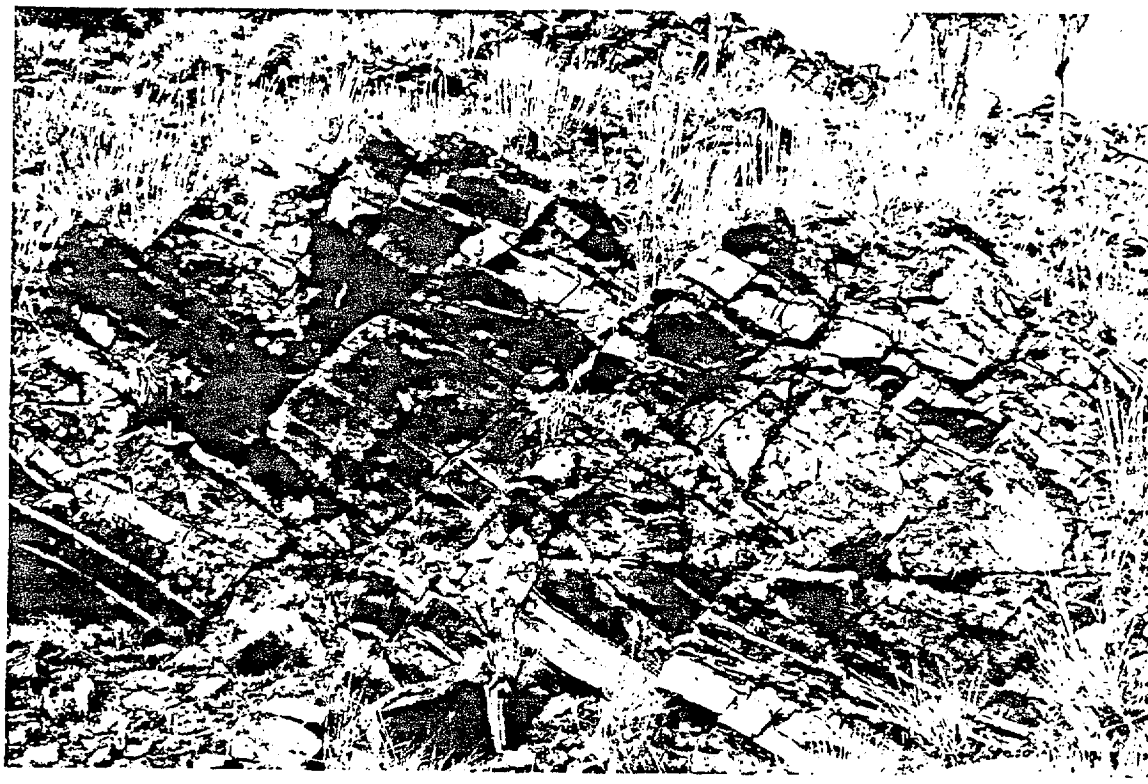


Fig.3 Unit C, Corella Formation: pale layers of felsic volcanics interbedded with darker calc-silicate rocks at GR 193156. Scale given by hammer on left. (GB 3361)

Fig.4 Unit Mc: interlayered quartzite and calc-silicate rocks in a symmetrical recumbent D1a fold refolded by an upright D2 antiform, at GR 176130. Scale given by pencil near top, (GB 3364)

13

Fig. 5 Unit Sg: graphitic schist showing D2 crenulations and folds of D1a foliation, at GR 252096. (GB 3365)

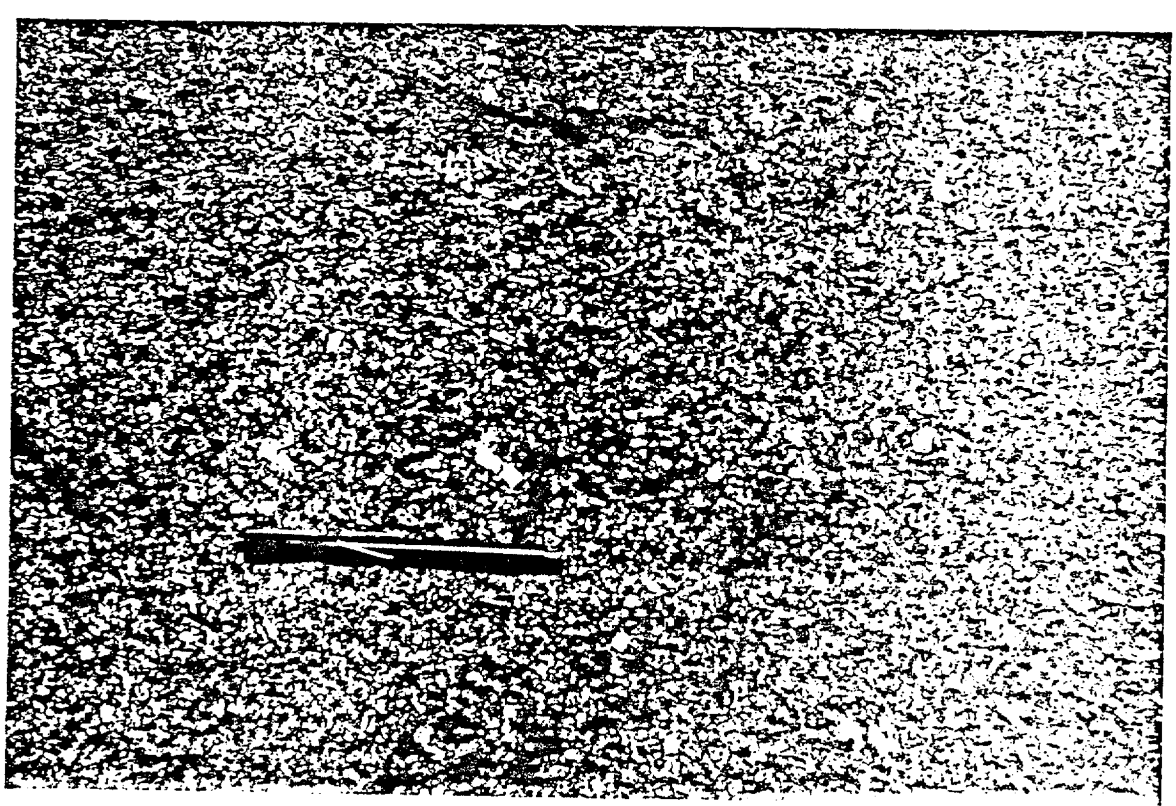


Fig.6 Unit Vm: basalt with abundant plagioclase phenocrysts, at GR 215045. (GB 3363)

14

Fig.7 Unit Vm: fragmets of intermediate and felsic volcanics in basaltic matrix, at GR 232060. (GB3359)

Fig.8 Unit VM: typical frugmentary volcanic rock, at GR 240062. (GB 3357)

15

Fig.9 Unit F: lenticular layers of porphyritic felsic volcanics separated by thin mafic layers, at GR 232137. (GB 3370)

porphyritic felsic volcanics, probably of ignimbritic origin (unit F1).

Igneous Intrusions

Dolerite

Two types of dolerite are present. The oldest forms irregular bodies and sills which are folded, foliated, and metamorphosed. The younger type forms late cross-cutting dykes which are neither foliated nor metamorphosed. The foliated dolerite bodies are generally very coarse grained and weakly foliated in their centres and fine grained and schistose at the margins. They consist of amphibole + plag + opaque minerals ± biot, sericite, sph, ap. These bodies may be similar in age to the 1740 Ma old Lunch Creek Gabbro, whereas the late dykes are probably equivalent to the 1116 Ma old Lakeview Dolerite (Page, 1983).

Granite

Several small bodies of granite cropout on the western side of the area. They are foliated, and are probably equivalent in age to the Burstall Granite (1720-1740 Ma). The granite is fine to medium grained, and consists of mcl + plag + qz + hbl.

Pegmatites

Abundant granitic and pegmatitic veins ranging from a few millimetres to several metres in width and folded by D1 occur throughout the area, they appear to be unrelated to the granite bodies to the west. Pink alkali-fdp + qz pegmatite occurs in the felsic volcanics and in calc-silicate rocks near large felsic volcanic bodies. Qz + musc + white alkali-fdp pegmatite occurs in pelitic schists and tuffs. The relationship of vein composition to host rock suggests that the pegmatite was derived from the host rock.

Structure

Introduction

Three major phases of deformation involving folding, and faulting, have been recognised in the Tommy Creek area: D1a, D1b and D2 (Figs.1, 4, 5, 10, 11, 12). Because of similarities in styles of folding and faulting, and coincidence of location and movement directions, D1a and D1b are considered to be different phases of the same main deformation event. D2 is correlated with the deformation that resulted in the major north-south trending folds found throughout the Mount Isa Inlier.

D1a is characterised by recumbent, isoclinal folds with approximately east-west trending axial planes, and associated with a strong to mylonitic axial plane foliation, and an extension lineation. D1a breccias and shear zones along the boundary between the Corella calc-silicate rocks and the Overhang Jaspilite mark the position of a major thrust fault. Isoclinal D1 sheath folds are found in the Overhang Jaspillite near the thrust, to the south and southwest of the Tommy Creek area (Fig.13), but D1 structures are not found further south in the Mitakoodi area (R. Loosveld and R.J. Holcombe, personal communication). D1a postdates the intrusion of granite and metadolerite bodies. D1b is restricted to the southern area, where small reverse faults and inclined folds overprint D1a structures and are associated with an axial plane crenulation cleavage. D1b structures have not been found south of the Overhang Jaspilite-Unit C boundary.

D2 folds are broad, open structures in the south, but become tight towards the north and isoclinal in the northwest. D2 crenulation cleavage is pervasive in the schists in the central and northern areas, but is weaker and patchy in the south. The D2 foliation and fold axial planes are upright and trend NNW to NNE. Variation in orientation is due to overprinting of D2 on earlier folding events.

At least 2 generations of minor, post-D2 crenulations and small folds occur in scattered areas in the schists.

Deformation is inhomogeneous and folding patterns vary from north to south due to the increasing intensity of D1a and D1b deformation and decreasing intensity of D2 deformation southwards. There is also a less pronounced trend towards increasing D1a intensity and decreasing D2 intensity of deformation from west to east. These trends are evident in the north-south and east-west cross-sections. In the southern part of the area, bedding dips northwards, and folds plunge towards the northwest; in the central part, bedding dips southward, and folds plunge towards the southeast, south or southwest; in the eastern part, bedding dips westwards, and folds plunge generally westwards; in the northern part bedding dips west or east, and folds plunge north or south.

Pre-tectonic layering/bedding, S0

In the pelitic schists original bedding is generally undetectable except where chert bands are present. In the least deformed parts of the area, bedding and sedimentary structures such as planar and trough cross-beds, ripple marks, scour surfaces, graded beds, laminate beds, mud cracks, and halite casts are preserved in sandstone, marl, siltstone, shale, calc-silicate rocks and conglomerate. Much of the finely banded layering in the calc-silicate rocks is transposition layering (S1a).

Most of the felsic volcanic rocks show no internal layering except those of the upper part of the Corella sequence which have muscovite-rich layers and lenses generally 1 to 100 cm thick. Fragmentary mafic and intermediate lavas are generally broadly layered, and tuffs commonly show fine banding.

First phase of deformation, D1a

D1a resulted in the formation of an axial plane foliation parallel to thrust faults (S1a), an extension lineation

(L_{ext}) ,an intersection lineation or fold hinge orientation (L1a0), mylonites and shear zones, small-scale folds (F1a), thrust faults, and macroscopic folds (Fig.14A).

S1a: generally formed at a low angle to S0; decreases in intensity away from the southern and eastern thrust boundaries. Found as:

- a schistosily in pelites, tuffs, and other mica-rich felsic and mafic volcanics.
- a cleavage and preferred mineral orientation (amphibole, plag, opaque minerals and micas) in calc-silicate rocks and mafic and felsic volcanics.
- streakiness in mylonites and shear zones within quartzite and felsic volcanics.
- flattening of quartz phenocrysts in felsic volcanics garnet poikiloblasts in felsic and mafic volcanics, and pebbles in coarse sediments.
- transposition layering in calc-silicate rocks and mixtures of calc-silicate rocks, volcanics, and marble (Figs 15, 16).
- flattening of biotite clots in intermediate volcanics and muscovite clots in felsic volcanics.
- flattening of fragments in fragmentary volcanics.
- weak cleavage in quartzites and marbles.

L_{ext}: generally weak to moderate in the south except in D1a mylonites and shear zones, where it is quite strong; increases towards the north. Found as:

- elongate quartz phenocrysts in felsic volcanics (Fig.17).
- rodding in quartzite, chert and mylonites
- pressure shadows around garnets
- boudinage in garnet and staurolite porphyroblasts.
- preferred orientation of elongate minerals (amphibole, plagioclase, quartz) in calc-silicate rocks, felsic volcanics, metadolerite and pegmatite.
- elongate clots of biotite in intermediate volcanics and muscovite in felsic volcanics.
- elongate fragments of felsic volcanics
- elongate fragments in breccia, and elongate clasts in conglomerate and pebbly sediments.

L1a0: fold hinges are abundant in calc-silicate rocks, marble and quartzite, but rare in schist and volcanics. The intersection lineation between S0 and S1a is generally measurable in calc-silicate rocks, mixed calc-silicate and volcanic rocks, and occasionally in schist and volcanics. L1a0 is generally sub-parallel to L_{ext}, especially in mylonites and shear zones.

F1a: small-scale folds. In the south and central parts of the area they are moderate to steeply dipping and strongly non-cylindrical (Fig.18), and have approximately east-west trending axial planes; in the north they are generally gently plunging to sub-horizontal with gently dipping to horizontal (i.e., recumbent) axial planes, but can have quite variable orientations due to refolding by D2 (Figs. 19-22). F1a folds are very rare near thrust faults, probably due to transposition effects.

Mylonites: form zones in felsic volcanics, chert-rich graphitic schist and quartzite; typically have a very fine grained, foliated groundmass commonly with elongate patches of remnant coarser grained material of the original rock (Fig.23) However, many mylonites have been recrystallised during D2. Recrystallised mylonites are fine to medium grained and may have a second overprinting foliation (S2). Characteristics of mylonites in different rock types are described below.

In felsic volcanics (Fig.24): very fine grained, foliated groundmass of qz + mcl ± musc or hbl, relict phenocrysts represented by small microcline grains or extremely flattened quartz grains are common. Commonly retrogressed to greenish biotite, chlorite and reddish-yellow alteration material.

In chert-rich graphitic schist: very fine grained foliated quartzite with extremely abundant, very fine grained graphite flakes. Remnant, coarser-grained, elongate relicts of the original rock may contain quartz, opaque minerals, muscovite, sericite, microcline, chlorite, calcite and biotite.

In quartzite: similar texture and composition to mylonite in graphitic-chert except graphite is absent; may contain abundant quartz veins parallel to S1a, S1b or S2 foliations, if these are present.

Breccia: Breccias related to D1a are widespread, their characteristics in different rock types are described below.

In felsic volcanics fragments are flat or elongate, strongly foliated, and may be mylonitic; matrix is dominantly act + sph ± scap, chlor, opaque minerals, fdp, cal, ap, diop, qz, sericite, commonly foliated.

In quartzite fragments are flat or elongate; matrix (commonly with Fe and Mn staining) is never foliated indicating post deformational cementation.

In graphitic schist fragments are chaotic and irregular; matrix is fine graphite with abundant calcite veins. The breccia is commonly partially silicified with Fe and Mn staining, and may be foliated.

In calcareous sediment of the Corella formation and Overhang Jaspilite abundant breccia occurs with irregular fragments of calc-silicate rocks and quartzite in a calcareous matrix. Some of these breccias have a weak D1a foliation, however many are unfoliated and may be post-D1a breccias or reactivated D1a breccias. Foliated and unfoliated breccias are otherwise identical in appearance. Some patches of Chumvale Breccia also contain the D1a foliation, these patches are probably remnants of original D1a breccias. Silicification and Fe and Mn staining of breccia post dates D1a, and maybe Phanerozoic rather than Precambrian.

Macroscopic folds. Large, recumbent, non-cylindrical D1a folds have approximately east-west axial planes, and verge towards the south. The southern part of the area is a major D1a syncline which is refolded by D1b and appears again in the central part of the area inverted as an antiform (Fig.14b).

Faults: D1a faults are low angle thrusts. They are marked by breccias and shear zones (Fig.25), and towards the north they disappear into parallel mylonites and shear zones.
There are three main interconnected thrusts.
(1) between calc-silicate rocks and felsic volcanics of units C and F1, and Overhang Jaspilite in the south and east;
(2) between calc-silicate rocks of unit C and marble of unit Mm in the southeast;
(3) between graphitic schist of unit Sg and calc-silicate rocks of unit C in the south.
All these thrusts are folded by D1b. They thrust the Corella Formation over the Overhang Jaspilite and Mitakoodi Quartzite.

Second phase of deformation, D1b

D1b resulted in macroscopic and mesoscopic folds (F1b) with an axial plane foliation (S1b) parallel to the fault planes, intersection lineations (L1a1b, L1b0), faults and breccias. Deformation associated with D1b is localised, and is restricted to the southern part of the area.

F1b: mesoscopic folds generally associated with D1b faults, where they are tight to isoclinal, and become more open away from the faults; also occur in one area in southeast, not associated with faulting, where they are tight to isoclinal.

Macroscopic D1b folds are tight in the south and become more open towards the north. They have inclined, approximately east-west axial planes, and verge southwards; they refold D1a folds and cause steepening of D1a structures. A large D1b antiform in the southwest folds the major D1a syncline and associated thrust fault, while in the southeast the same D1a syncline is refolded by a D1b synform (Fig.14b).

S1b: crenulation cleavage in schistose volcanics and pelitic sediments; cleavage in massive, mafic volcanics, intensity decreases rapidly away from D1b faults.

L1a1b L1b0: intersection lineations between S1a & S1b, and S0 & S1b respectively, and hinges along crenulations and folds in S1a.

Faults: two steeply inclined reverse faults associated with D1b structures occur in the southwest, one trending

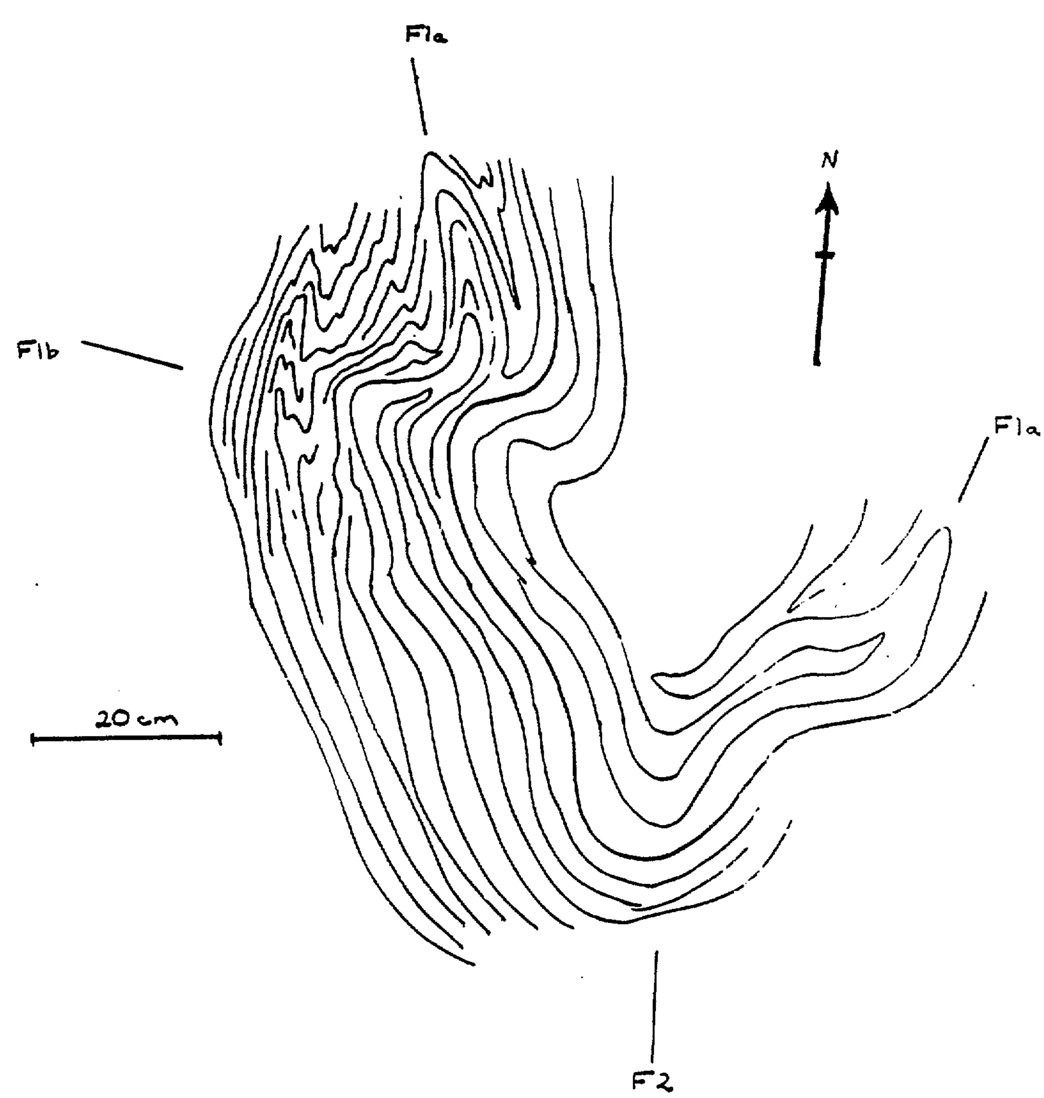


Fig.10 Isoclinal D1a folds refolded by open D1b and D2 folds in calc-silicate rocks, southwestern Tommy Creek area. F=fold axis.

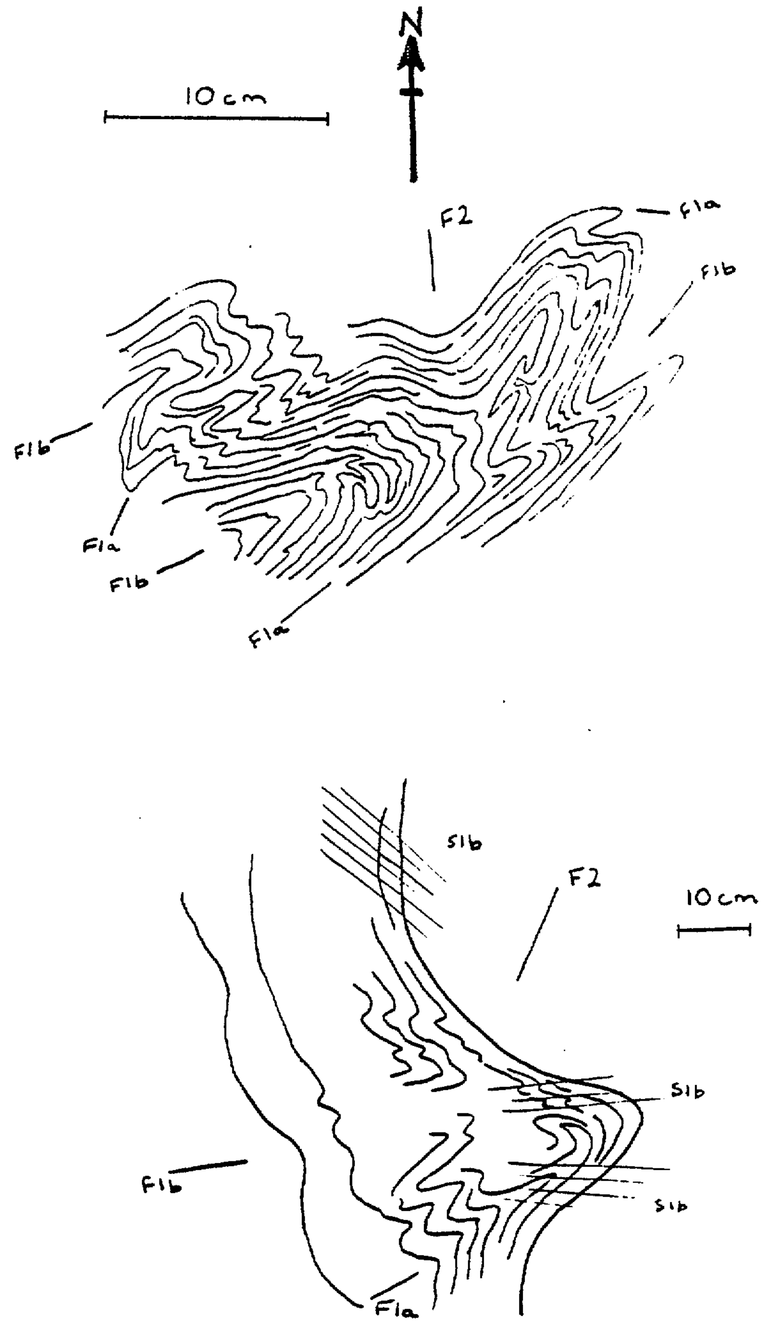


Fig 11 Folds in graphitic schist interbanded with chert, southwest part of area. A, isoclinal D1a folds refolded by tight to isoclinal D1b folds, which are in turn refolded by an open D2 fold. B, isoclinal D1a folds refolded by D1b folds and overprinted by a crenulation cleavage, S1b, which is folded by an open D2 fold.

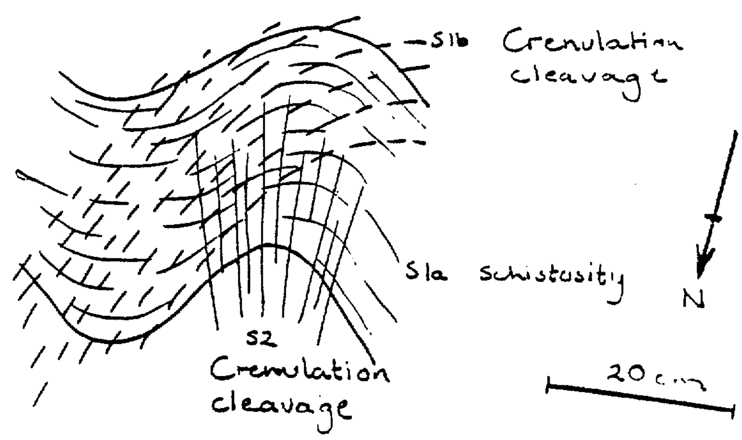


Fig.12 Two sets of crenulations forming cleavages, S1b and S2, in S1a schistosity; graphitic schist in southwest.

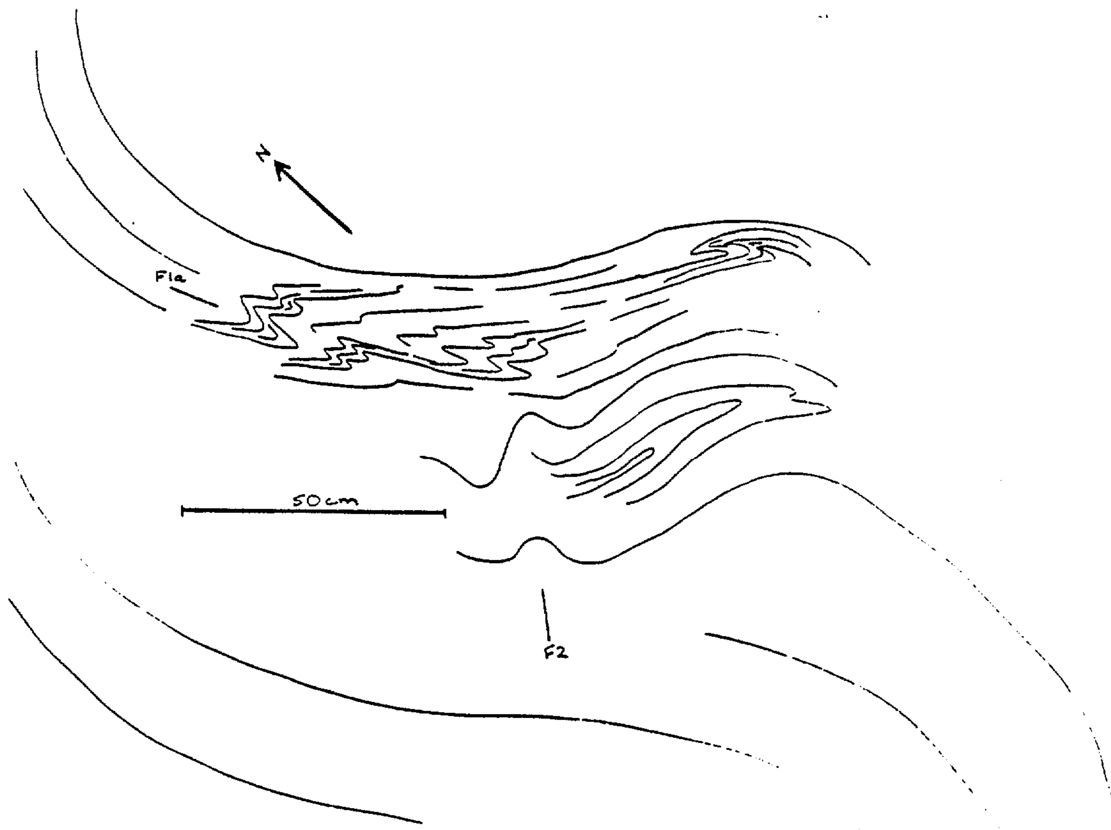


Fig. 13 D1a folds in the Overhang Jaspilite south of the Tommy Creek area, near the boundary of this formation with unit C.

25

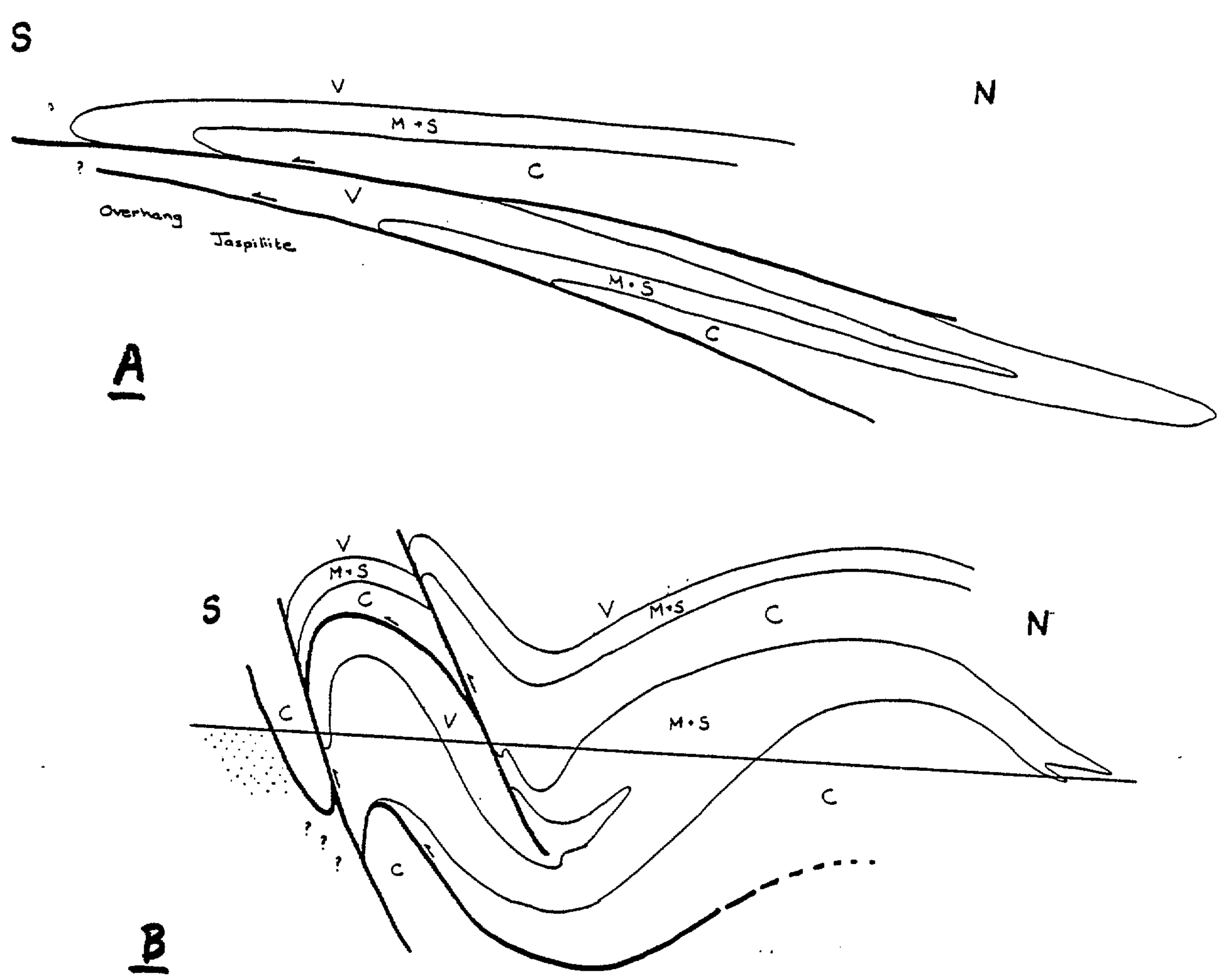


Fig. 14 Simplified north-south cross-sections across the Tommy Creek area. A, hypothetical post-D1a/pre-D1b section showing D1a thrusts and recumbent folds. B, present day situation: D1a folds folded by D1b folds and cut by D1b faults.

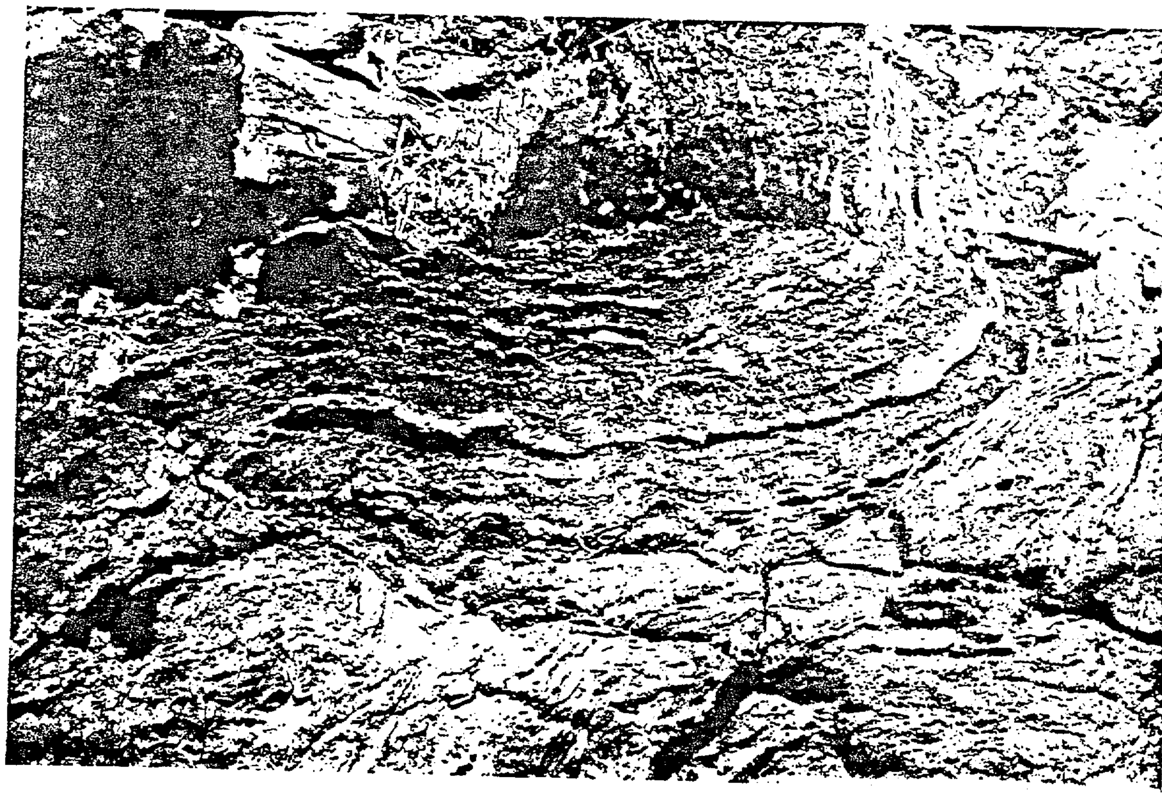


Fig.15 Sla transposition layering folded by D2 in quartzite and marble of unit M, at GR 139100. (GB 3368)

Fig.16 Sla transposition layering of muscovite-rich and muscovite-poor layers in felsic volcanics of unit F, at GR 185085. (GB 3369)

27

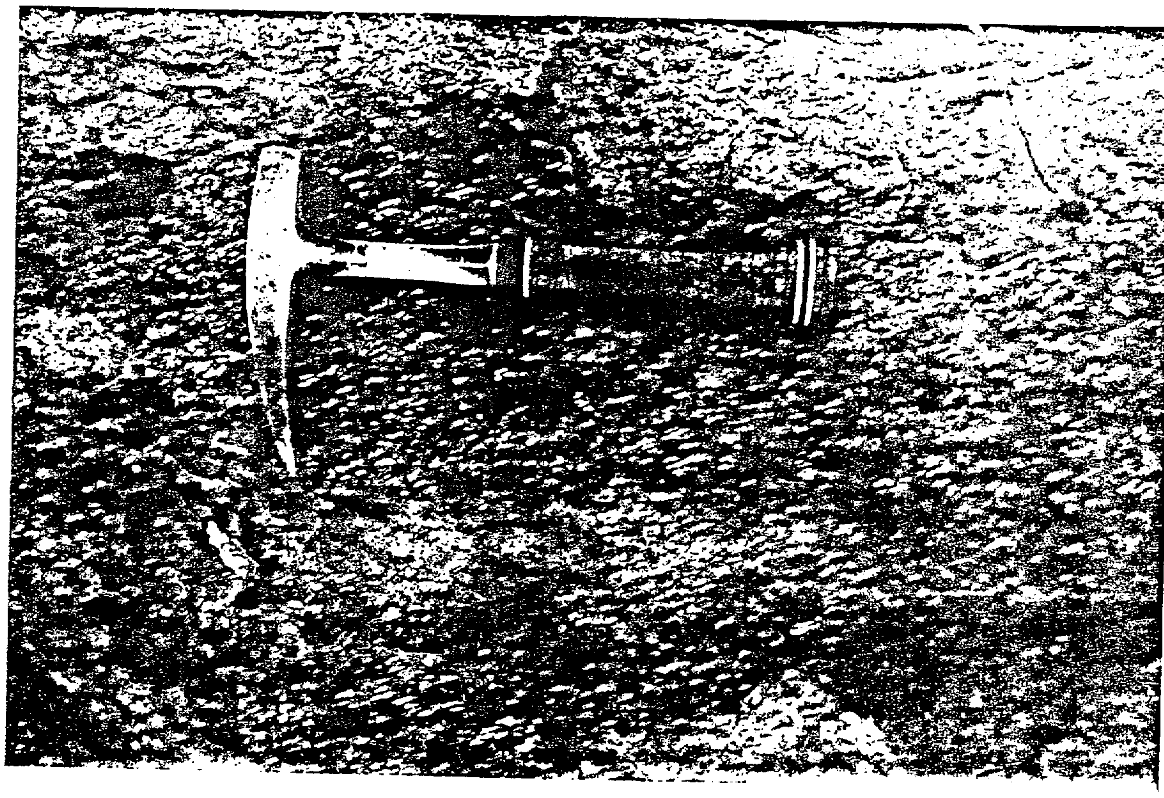


Fig.17 Elongate quartz phenocrysts in felsic volcanics (Unit F) defining extension lineation, at GR 236137. (GB 3362)

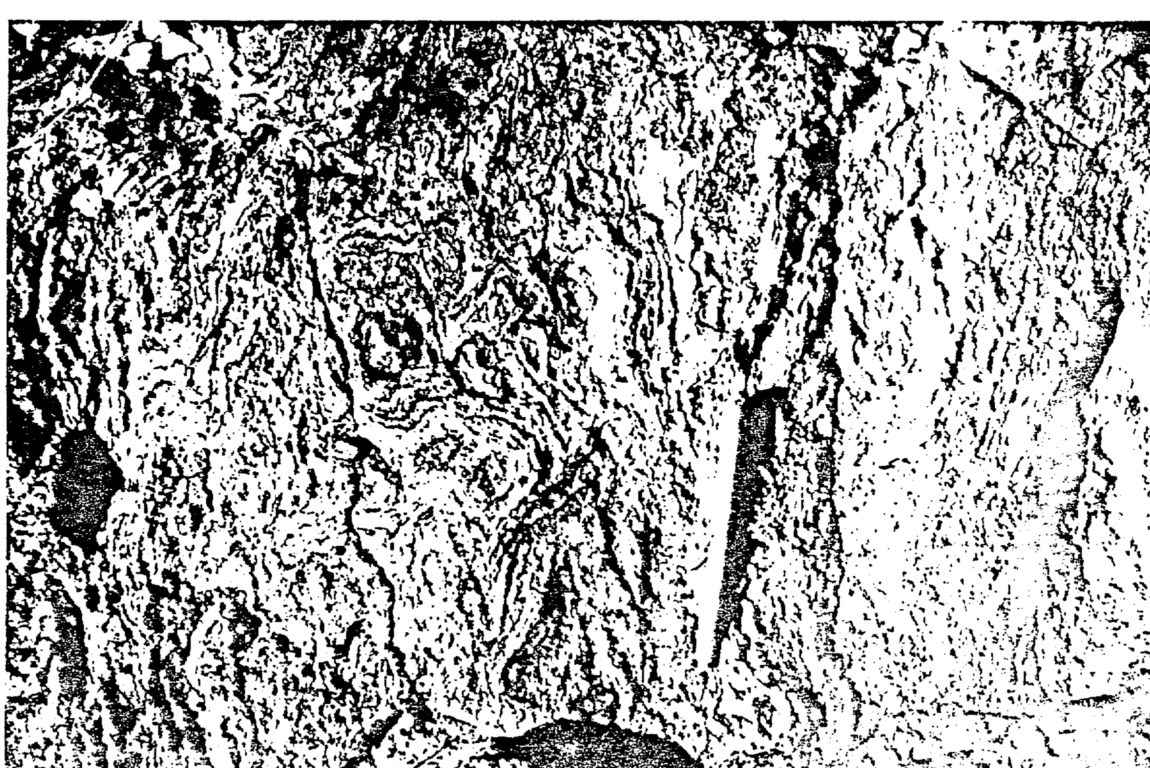


Fig.18 Swirly pattern of highly non-cylindrical small-scale D1a folds in calc-silicate rocks of unit C, at GR 163075. (GB 3356)

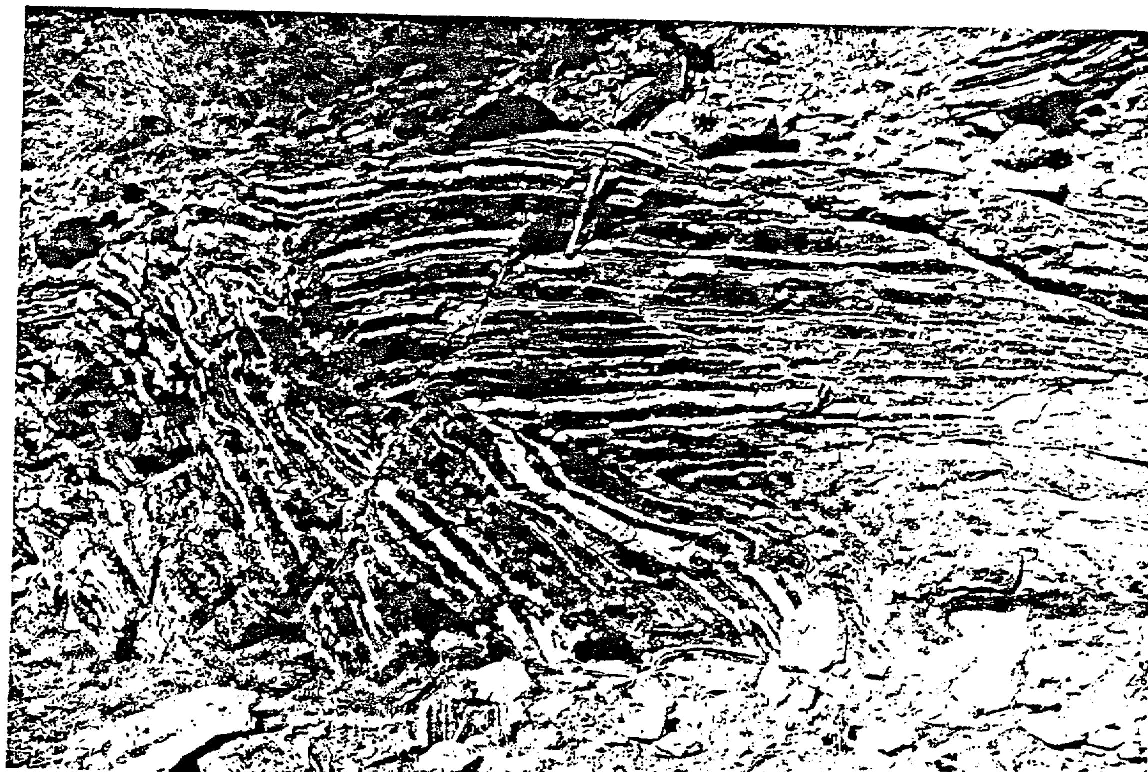


Fig.19 Recumbent D1a fold in quartzite and calc-silicate rocks of unit M, at GR 256078. (M2772/1)

Fig.20 Asymmetric recumbent D1a fold on hinge of D2 antiform in quartzite and calc-silicate rocks of unit M, at GR176130. (GB3366)

Fig.21 D1a recumbent folds refolded by upright D2 folds in quartzite and calc-silicates rocks of Unit M, at GR 183121. (GB 3360)

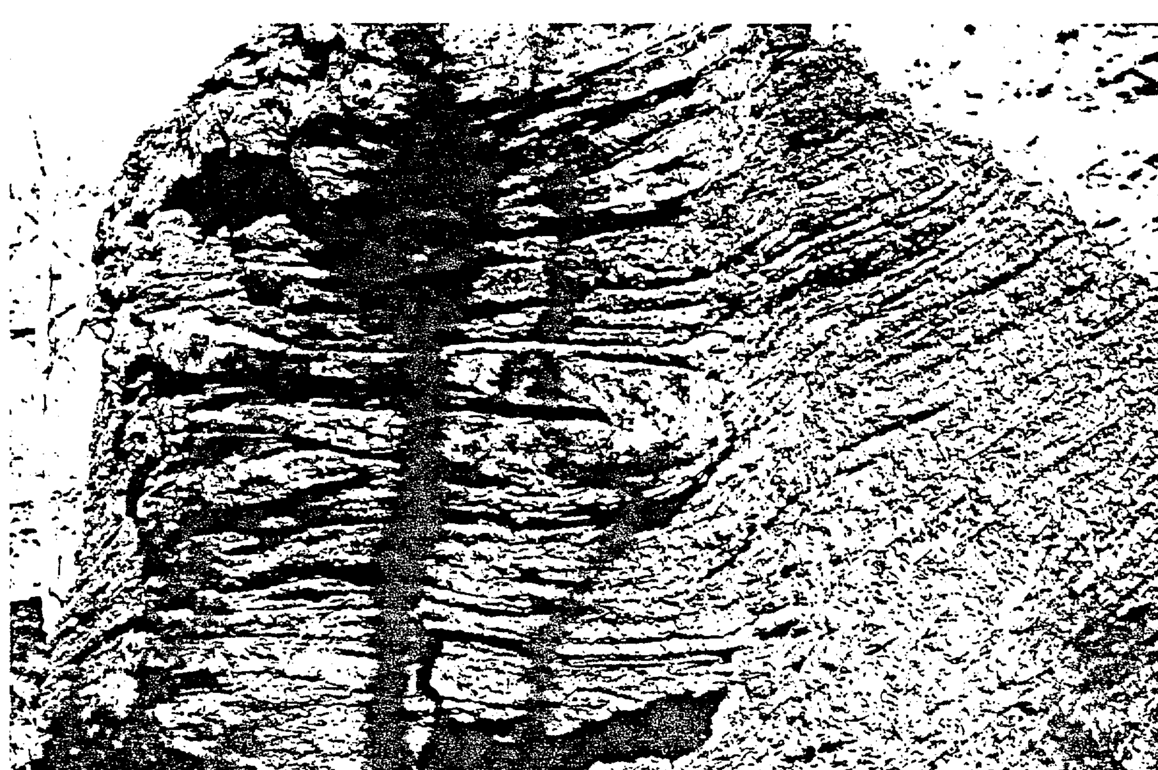


Fig.22 Recumbent isoclinal D1a fold in marble and calc-silicate rocks of unit M, at GR 149087. (GB 3358)

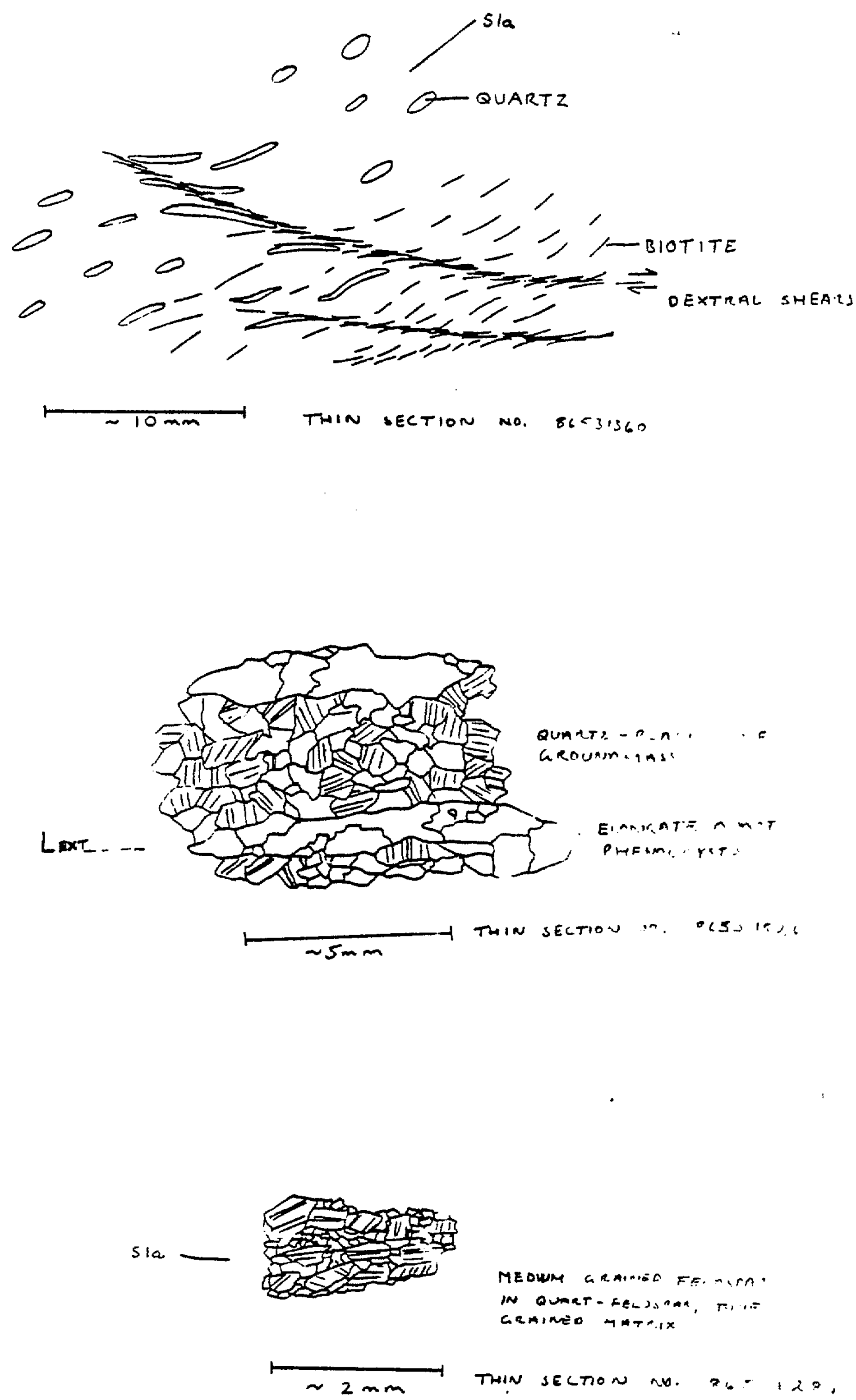


Fig.23 Stages in mylonitisation of porphyitic felsic volcanics.

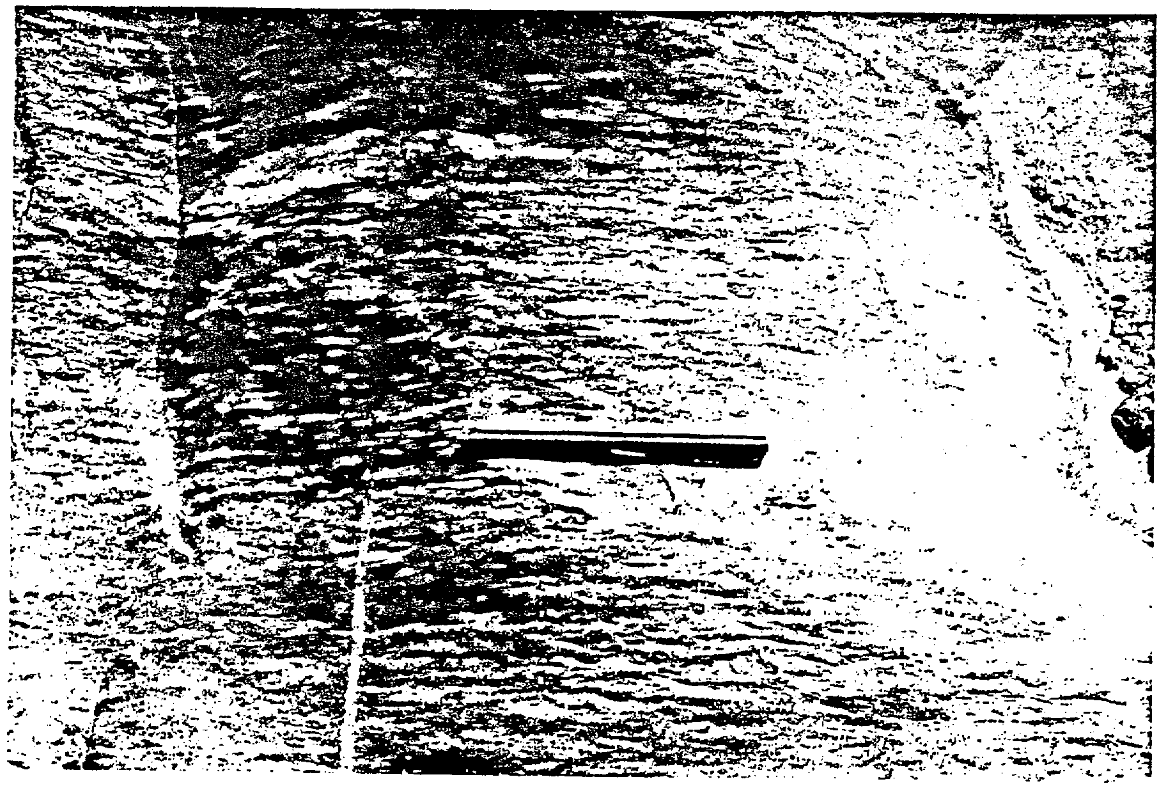


Fig.24 Mylonitic felsic volcanics of unit F. (M2772/16)

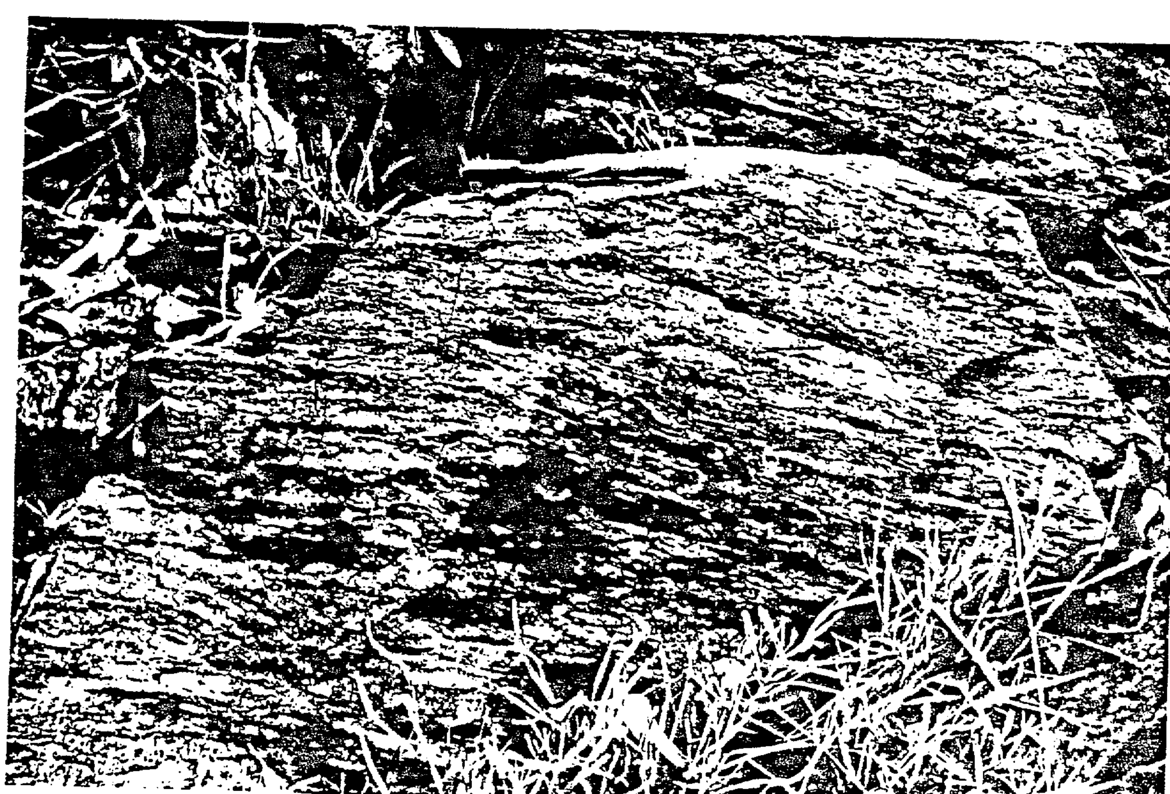


Fig.25 Mylonitised shear marking a major D1a thrust, at GR 271145. (GB 3367)

approximately east-west, and the other WNW, due to reorientation by D2.

Breccias: brecciation of graphitic schists associated with partial silicification and Fe and Mn staining has occured along the northern fault. Some brecciation of calc-silcates in the south may be associated with the southern fault; the breccias may have formed during faulting or as later surficial weathering effects concentrated along old faults.

Third phase of deformation, D2

Deformation resulting from D2 increases in intensity from the south to the north and northwest. It resulted in the development of mesoscopic and macroscopic folds (F2) with a weak axial plane foliation (S2).

S2: generally occurs as a crenulation cleavage in schist (Fig.5), weak in the south, becomes more pervasive towards the central and northern parts of the area; less common as a cleavage in calc-silicate rocks, marble and volcanics.

L21a, L20: intersection lineations between S1a & S2, and S0 & S2 respectively. Also hinges along crenulations and folds in S0 & S1a. L21a and L20 are generally almost parallel due to the small angle between S0 and S1a.

F2 Mesoscopic folds: rare, small, open folds in the south in schist and calc-silicate rocks; open to tight folds common in central part; abundant tight to isoclinal folds in the west and northwest. They refold D1a (Fig.4) and D1b folds, schistosity (Fig.5) and transposition layering (Fig.22).

Macroscopic folds: broad and open in south, tighter to north and northwest; generally non-cylindrical due to overprinting on an already folded surface.

Post-D2 Deformation

Crenulations. At a number of isolated localities in the graphitic schists two post-D2 sets of crenulations occur. One consists of northwest and northeast trending crenulations with vertical axial planes, and is probably a conjugate set. The other set has a sub-horizontal axial plane and an associated sub-horizontal crenulation cleavage.

Breccia and alteration. Late brecciation in the calc-silicate rocks is associated with retrograde "red-rock" alteration (alkali feldspar and haematite). The breccias are chaotic and consist of angular fragments of various sizes which occur in irregular zones.

Faults. Several small, late faults cut across all other structures in the area.

Heterogeneity of D1 Strain

The southern part of the Tommy Creek area is dominated by flattening or plane finite strains which increase in intensity towards thrust contacts and in mylonites and shear zones.

Flattening may be shown by breccia fragments, porphyroblasts, phenocrysts (especially quartz phenocrysts in felsic volcanics), pebbles in conglomerates and coarse sandstones, fragmental volcanics.

Plane and flattening strains in quartz phenocrysts has resulted in typical dimensional ratios of 1:5:10 and 1:10:15. And dimensional ratios for volcanic fragments of around 1:4:4 and 1:5:5 occur in felsic volcanics and 1:15:15 and 1:17:17 in intermediate and mafic volcanics.

In the north, constrictional finite strains are dominant. Constriction has caused elongation of phenocrysts (especially those of quartz in felsic volcanics), volcanic fragments, pebbles in conglomerate and sandstone, and breccia fragments; and also boudinage of competent layering and phenocrysts. Typical dimensional ratios for quartz phenocrysts in the north are about 1:2:15.

South of the major D1a thrust fault separating the calc-silicate rocks of unit C from the Overhang Jaspilite, effects of D1a strain disappear rapidly. Some small asymetric D1a folds occur to the south of the Tommy Creek area, and a few highly non-cylindrical folds have been found to the southwest and east of the Tommy Creek area, in the Overhang Jaspilite.(R.Loosveld & R.Holcombe, personal communitcation). No evidence for D1 has been found south of the Overhang Jaspilite, in the Mitakoodi Quartzite or Marimo Slates (R.Loosveld personal communication).

Heterogeneity on a small scale. In thick sequences of felsic volcanics in the east of moderately developed S1a foliation forms anastomosing zones around pods (about 50 m long) having weak or no S1a. A strong S1a schistosity has developed in small dolerite bodies and on the margins of large dolerite bodies. However the schistosity decreases rapidly to non-existence towards the centre of large dolerite bodies.

Heterogeneity of D2 Strain

D2 becomes stronger towards the north and northwest, crenulation cleavage becomes more pervasive and folding gets tighter i.e., D2 strain increases as D1 decreases. D2 strain variation is probably due to mechanical difficulties associated with refolding of a previously folded surface at right angles to the earlier folding direction.

Direction of D1a Thrusting

Direction of D1a thrusting is uncertain because of overprinting of D1a fabrics by later events. If the S1a surface was originally very shallowly dipping, as is assumed, only slight rotation by D1b and D2 could cause reasonably large changes in S1a orientation. However, in the south D2 is quite weak and S1a orientation is inferred to closely reflect the original orientation, i.e., dips towards 340°. D1b is assumed to have a movement direction almost parallel to D1a and to have caused only steepening of S1a and not rotation of strike. Major F1a folds verge southwards (as do F1b folds), therefore the thrusting direction was most likely towards the south-southeast. However post-D2 strike-slip movement along the Pilgrim Fault and Ballara-Corella River Fault Zone to the west appears to have caused rotation of the Mitakoodi area by about 30-40° clockwise, resulting in an original movement direction towards the southeast.

Metamorphism, metasomatism and alteration

Metamorphism

Peak metamorphism of mid to upper amphibolite facies and minor anatectic melting was associated with D1a. Further minor mineral growth occured during D1b, and mineral growth and extensive recrystallisation took place during D2. Minor post-D1a metasomatism and pervasive retrograde alteration has also occured.

Typical D1a metamorphic assemblages for the various rock types are as follows.

(1)Pelites:	musc + qz
	qz + musc + biot + sillm
	qz + staur + graphite + plag + gn
(2)Carbonates:	cal + woll + vesuv
(3)Calc-Silicate rocks:	plag + act + cal
	plag + diop + gn
(4)Felsic volcanics:	qz + mcl ± minor musc, hbl, biot, plag
(5)Amphibolites (Metadolerite):	hbl + plag
(6)Mafic volcanics:	plag + hbl ± gn
	plag + diop + biot + gn
(7)Intermediate volcanics:	qz + mcl + biot + gn

An estimate for pressure and temperature conditions is obtained by plotting these assemblages on a petrogenetic grid (Fig.26).

Temperature: The presence of staurolite and almandine and absence of chlorite in pelites give a low temperature boundary of approx. 550°c. The presence of anatectic granite veins and pegmatites indicate temperatures around 650°c.

Pressure: The sillimanite stability field and break down of muscovite indicate pressures of at least 3 kb.

The Tommy Creek area contrasts strongly to surrounding areas where the metamorphic grade is much lower: lower greenschist facies in the Mitakoodi area, and lower to upper greenschist facies in the adjacent rocks of the Corella Formation (Fig.27; Derrick et al, 1980).

Metasomatism and alteration

Scapolite has a patchy distribution in the area. It occurs in mafic volcanics, calc-silicate rocks and some D1a breccias and shear zones. Scapolite crystals cut D1a fabrics and are probably associated with D2.

Weak red-rock alteration (retrograde metasomatism including the formation of epidote, and fine grained haematite in feldspar, imparting a red colour to the rocks), occurs throughout the calc-silicate rocks, and is generally associated with post-D2 brecciation. Strong red-rock alteration is associated with large bodies of felsic volcanics or granite, where pure haematite veins are common.

Large quartz veins are abundant in felsic and intermediate volcanics and in sediments adjacent to the volcanics. Smaller quartz veins are abundantly in the calc-silicate rocks.

Sulphides occur as grains and veinlets of pyrite in felsic volcanics. Pyrite is especially common in D1a mylonites, breccias and shear zones. Sulphides probably formed syngenetically with the volcanics and were later remobilised during D1a deformation.

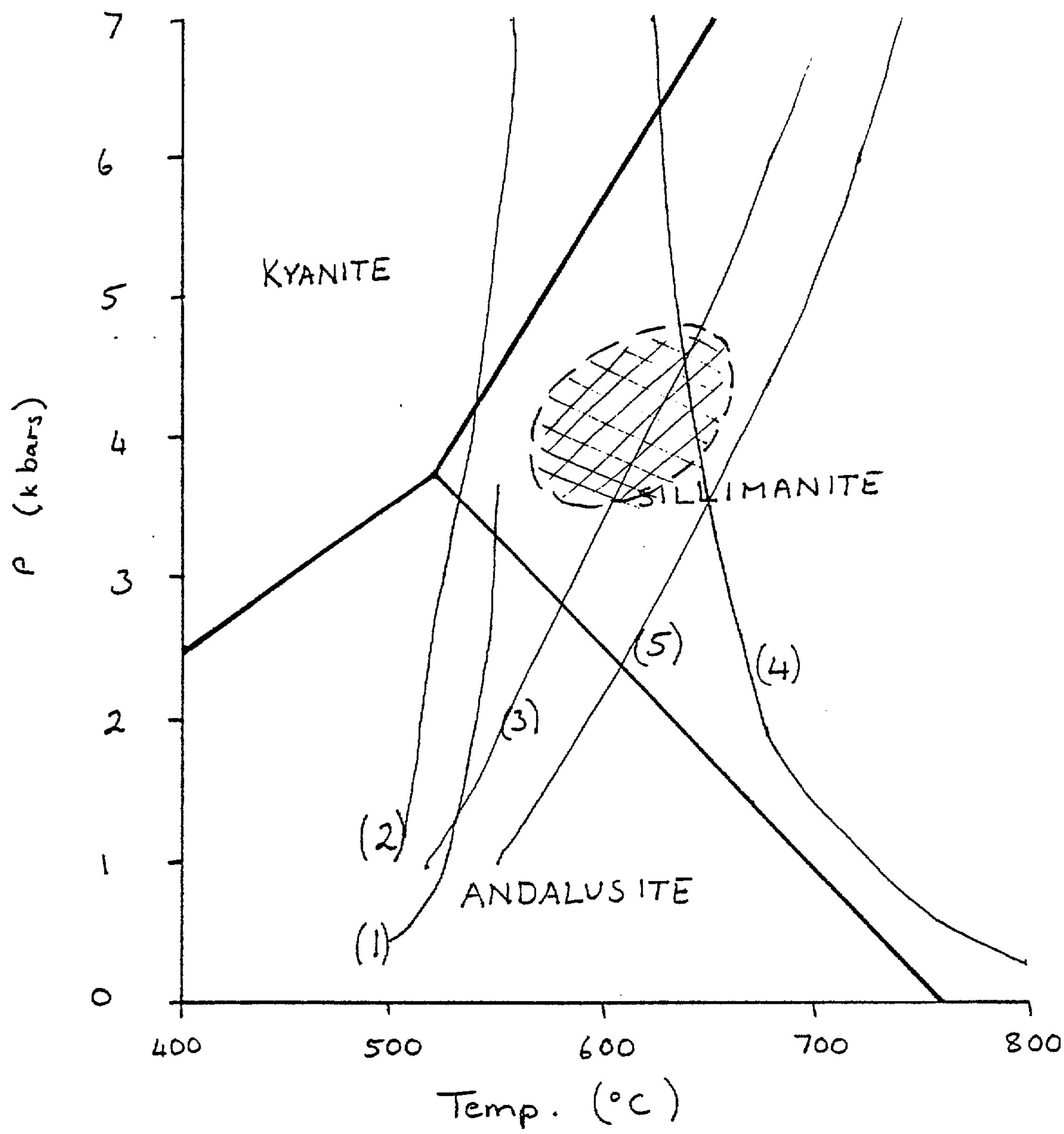
Geochronology

U-Pb zircon age determinations for the Tommy Creek "rhyolite" and "microgranite" by Page (1983b) show a multi-stage U-Pb evolution. Two ages were obtained for the "microgranite": 1624 and 1600 Ma, and one for the "rhyolite" of 1603 Ma. However these dates are unlikely to indicate the depositional age of the host Corella Formation, because the small granite bodies intruding the formation in the west are believed to be phases of the 1730-1740 Ma Burstall granite. However zircon ages determined for the Tommy Creek rocks correlate closely to the 1610 Ma age determined for D1 metamorphism in the Sybella Granite (Page & Bell, 1986) west of Mount Isa.

The foliated metadolerite bodies are believed to be comparable in age to the 1740 Ma Lunch Creek Gabbro associated with the Burstall Granite, and the late, undeformed dolerite dykes are probably equivalent to the Lakeview Dolerite, dated at about 1116 Ma (Page 1983a).

West of the Tommy Creek area the Corella Formation overlies the Argylla Formation, which is dated at approximately 1780 Ma (Page 1983a)

It is considered, therefore, that all the quartzo-feldspathic igneous rocks in the Tommy Creek area, except for the pegmatite and also granite in the far west are felsic volcanics are 1780 to 1740 Ma old, which have been subsequently extensively recrystallised and metamorphosed



1. Chlor + Qz → Alm + H_2O
2. Staurolite — lower limit
3. St + mu + qz → Al_2SiO_5 + Biot + H_2O
4. H_2O – sat. granite melting
5. Mu + qz → kfs + Al_2SiO_5 + H_2O

Fig.26 Petrogenetic grid showing metamorphic grade for the Tommy Creek area (cross-hatched.

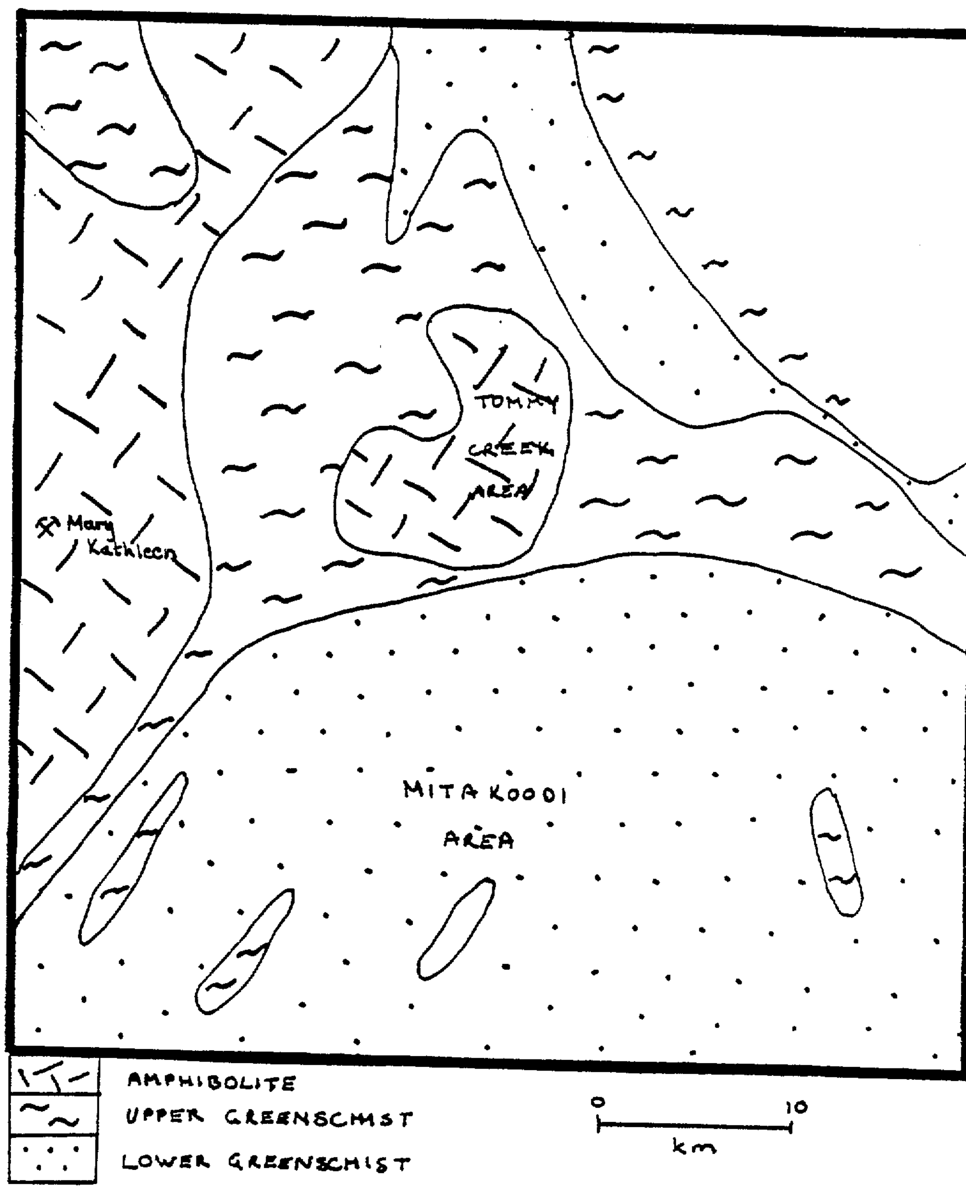


Fig.27 Metamorphic map of the Marraba 1:000,000 sheet area (from Derrick et al., 1971). The map shows that much higher grade rocks occur in the Tommy Creek area than in surrounding areas.

during D1a between 1600 and 1624 Ma ago.

D2 and D3 metamorphism have been dated at around 1544 Ma and 1510 Ma respectively (Page & Bell, 1986) in the western part of Mount Isa Inlier.

Summary of geochronological interpretations

1116 Ma:	intrusion of late dolerite dykes
1510 Ma:	D3-crenulation, folding and retrograde metamorphism.
1544 Ma	D2-crenulation, folding and metamorphism
1600 - 1624 Ma	D1a & D1b: thrusting, recumbent folding; peak of metamorphism in the area.
1730 - 1740 Ma	intrusion of small granite bodies and irregular, now foliated, dolerite bodies.
1740 - 1780 Ma	deposition of Corella Formation in the Tommy Creek area.

Evidence for pre-D1 Deformation.

The D1 thrusting model proposed here for the Tommy Creek area fails to account for four features.

(1) The major thrust boundary between the calc-silicate rocks of unit C and the Overhang Jaspilite to the south and east is one around which lithologies are missing rather than repeated. On the southern boundary the calc-silicate rocks of unit C are considerably thinner than elsewhere in the area, and on the eastern boundary a mixed sequence of calc-silicate rocks and felsic volcanics of unit C are cut off by the fault but not repeated. To the southwest of the Tommy Creek area, except in some small fault blocks, the Overhang Jaspilite is largely missing, so that unit C lies directly on top of the Mitakoodi Quartzite.

(2) According to the thrust model the Corella Formation is thrust over the older Mitakoodi Quartzite, however in such models older units are generally thrust over younger rocks, not vice versa.

(3) In the north the intensity of the extension lineation does not correspond to the positions of the D1a thrust faults. Instead the extension lineation increases with increasing distance from the faults.

(4) Metamorphic grade is much higher in the Tommy Creek area than in surrounding areas, although the Tommy Creek sequence is believed to be stratigraphically younger.

The higher metamorphic grade of the Tommy Creek area relative to the Mitakoodi area suggests that the rocks exposed in the Tommy Creek area were at deeper levels than those now exposed in the Mitakoodi area when thrusting of the Tommy Creek rocks commenced.

Another factor to be considered is the possible existence of a pre D1 extension event, when a detachment fault may have been developed. In the Mary Kathleen fold belt to the west early extension has resulted in detachment faulting between the Ballara Quartzite and the Argylla formation in the Wonga Belt (P.Pearson & R.Holcombe, personal communication). Early extension features have also been found to the southwest by Passchier (1986), and on the western side of the Mitakoodi structure (P. Williams personal communication).

To the southeast of the Tommy Creek area a possible correlative of part of the Corella Formation, the Marimo Slate, thins abruptly and disappears westwards around the hinge of the Mitakoodi structure. Also the Mitakoodi Quartzite does not outcrop in the Mary Kathleen fold belt west of the Mitakoodi structure, although the Ballara Quartzite in the Wonga belt could be a thin, strongly deformed remnant of the Mitakoodi Quartzite. These features may be explained by late faulting, or lateral facies changes made more abrupt by late faulting. However, they could also be due to early extensional faulting as suggested as an explanation for rapid thining of the Argylla Formation further west (Passchier, 1986).

Structural evidence for early extension in the Tommy Creek area could have been largely obliterated by the intense D1 deformation. However, the present major thrust boundary between unit C and the Overhang Jaspilite, could represent a reactivated part of the detachment fault. The extension lineation in the northern area may be associated with this early extension event and could indicate the presence of an extension fault overlying or underlying the Tommy Creek area, with a movement direction approximately towards the NW.

Conclusions - geological history

(1) Shallow shelf sedimentation, associated with evaporites and felsic and mafic volcanism which included ignimbrite flows; after 1780 Ma but before 1740 Ma.

(2) Intrusion of small granite bodies and irregular dolerite bodies and sills, probably associated with extension, at 1720-1740 Ma. Possible detachment faulting between the Corella Formation and the Mitakoodi Quartzite.

(3) North-south compression resulting in two phases of thrusting and recumbent folding (D1a and D1b), accompanied by amphibolite grade metamorphism and production of mylonites, breccias and anatectic pegmatites; probably at around 1600 Ma. Scapolite developed from evaporitic sediments.

(4) East-west compression (D2) resulting in upright folding and associated with further scapolitisation; probably at around 1550 Ma.

(5) Late folds and crenulations; red-rock alteration and brecciation; minor faulting; silicification of breccias.

REFERENCES

DERRICK, G.M., WILSON, I.H., HILL, R.M. & MITCHELL, J.E., 1971-Geology of the Marraba 1:100 000 Sheet area, NW Queensland. BMR Rec. Aust. Geol. Geophys. 56.

DERRICK, G.M., 1980-Marraba, Queensland. Bureau of Mineral Resources Australia, 1:100 000 Geological Map Commentary.

JACQUES, A.L., BLAKE, D.M., DONCHAK, P.J.T., 1981-Regional metamorphism in the Selwyn Range area, N.W. Queensland. BMR J. Aust Geol. Geophys. 7: 181-196.

KLEMM, M., 1975-The geology of the Lalor Prospect area, Cloncurry, NW Queensland. Univ. Qld Hons. thesis (unpublished).

LISTER, G.S. & PRICE, G.P., 1978-Fabric development in a quartz-feldspar mylonite. Tectonophysics 49: 37-78.

MIYASHIRO, A., 1973-Metamorphism and metamorphic belts. Allen & Unwin, London.

PAGE, R.W., 1978-Response of U-Pb zircon and Rb-Sr total rock and mineral systems to low-grade regional metamorphism in Proterozoic igneous rocks, Mount Isa, Australia. J. Geol. Soc. Aust 25: 141-164.

PAGE, R.W., 1983a-Chronology of magmatism, skarn formation, and uranium mineralisation, Mary Kathleen, Queensland, Australia. Econ. Geol. 78: 838-853.

PAGE, R.W., 1983b-Timing of superposed volcanism in the Proterozoic Mount Isa Inlier, Australia. Prec. Res. 21: 223-245.

PAGE, R.W. & BELL, T.H., 1986-Isotopic and structural responses of granite to successive deformation and metamorphism. J. Geol. 94: 365-379.

PASSCHIER, C.W., 1986-Proterozoic deformation in the Duchess Belt, Australia: A contribution to the BMR Mount Isa Regional Tectonic History Program. Geologie en Mijnbouw 65: 47-56.

WINKLER, H.G.F., 1974-Petrogenesis of metamorphic rocks. Springer-Verlag, Berlin.

APPENDIX A: LIST OF ABBREVIATIONS USED FOR MINERAL NAMES

actinolite	act
apatite	ap
biotite	biot
calcite	cal
chlorite	chlor
diopside	diop
epidote	ep
feldspar	fdp
garnet	gn
hornblende	hbl
microcline	mcl
muscovite	musc
plagioclase	plag
quartz	qz
scapolite	scap
sillimanite	sillm
sphene	sph
staurolite	staur
vesuvianite	vesuv
wollastonite	woll

43

APPENDIX B: THIN-SECTIONED ROCK SAMPLES

Sample no (Prefix 8653)	Location (grid ref.)		
		CALC-SILICATES OF UNIT C:	
1659	132039		plag + diop + gn
1891	161078		mcl + act + cal + scap
1719	144026		fdp + cal + gn + ep
			fdp + cal + diop
1932	146034		plag + cal + act
		MIXED CALC-SILICATES & VOLCANICS OF UNIT C:	
1506	198130	felsic volc.	plag + qz
		calc-silicate	qz + plag + act
1569	193156	felsic volc.	qz + plag + diop
		calc-silicate	plag + diop
2022	233136	felsic volc.	qz + plag + hbl
		mafic volc.	hbl + plag + qz
1618	206172	felsic volc.	mcl + scap ± diop ± hbl
		mafic volc.	mcl + scap + diop + hbl
		SEDIMENTS OF UNIT M:	
1989	145092	calc-silicate	fdp + diop
2081 (A&B)	153207	conglomerate: clasts	± qz ± biot ± act ± cal
		matrix	act + biot + qz
1748	179037	marble	cal + woll + vesuv
		SCHIST & SANDSTONE OF UNIT S:	
1470	190092	sillimanite schist	qz + musc + biot + sillm
1179	183080	muscovite schist	musc + qz
1836	198069	quartz-pebble sandstones: matrix	qz + fdp + biot
1856	182067	quartz-pebble sandstones: matrix	qz + biot
1845	187057	graphitic schist	qz + staur + plag + gn.
		FELSIC VOLCANICS OF UNIT F	
1227 (A,B&C)	187085		qz + mcl + musc
1360	187080		qz + mcl + biot
1359	188080		qz + mcl + musc
1352	169085		qz + mcl + plag
1198	207085		qz + fdp + amph + biot
1526	209138		plag + qz
1284	197111		qz + ab + hbl
		VOLCANICS & SEDIMENTS OF UNIT V	
1244	181090	intermediate volc.	qz + biot
			plag + qz + biot
1729	150036	tuff	musc + biot + qz + gn
			qz + musc + gn
			qz + musc + biot
2023	213045	tuff	qz + fdp + musc + cal
1638	150036	tuff	mcl
			mcl + qz
			qz + mcl + biot + gn

2156	240062	fragmentary volc.	qz + mcl + musc
			qz + mcl + biot
1753	189052	fragmentary volc.	qz + biot
			plag + biot + gn
1701	181066	fragmentary volc.	diop + fdp
			mcl
			fdp + diop + biot + gn
1800	248062	fragmentary volc.	qz + mcl + musc
			mcl + biot + qz + gn
1755	187054	intermediate volc.	mcl + biot + qz + gn + cal
			mcl + biot + qz
1784	213045	mafic volc.	hbl + plag
1083	745090	mafic volc.	plag + hbl + gn
2020	241065	calc-silicate	qz + diop + act
2021	248063	quartz-pebble sandstone	qz
		AMPHIBOLITE:	
1576	182147		plag + hbl
1451	178128		hbl + plag
1643	162044		hbl + plag

MYLONITIC, BRECCIATED AND SHEARED FELSIC VOLCANICS

2109	174121
2055	150097
1620	140031
1608	248111
1458	221134
1698	177069
1312	178119
1144	189105
2208 (A,B&C)	271146
2078	153112
1310	181117
2054	151097

MYLONITIC QUARTZITE & GRAPHITIC SCHIST

1346	174096
1337	177097
1358	179082
1073	744093
1734	165032
1953	134050

APPENDIX C: SELECTED STEREOGRAPHIC PROJECTIONS

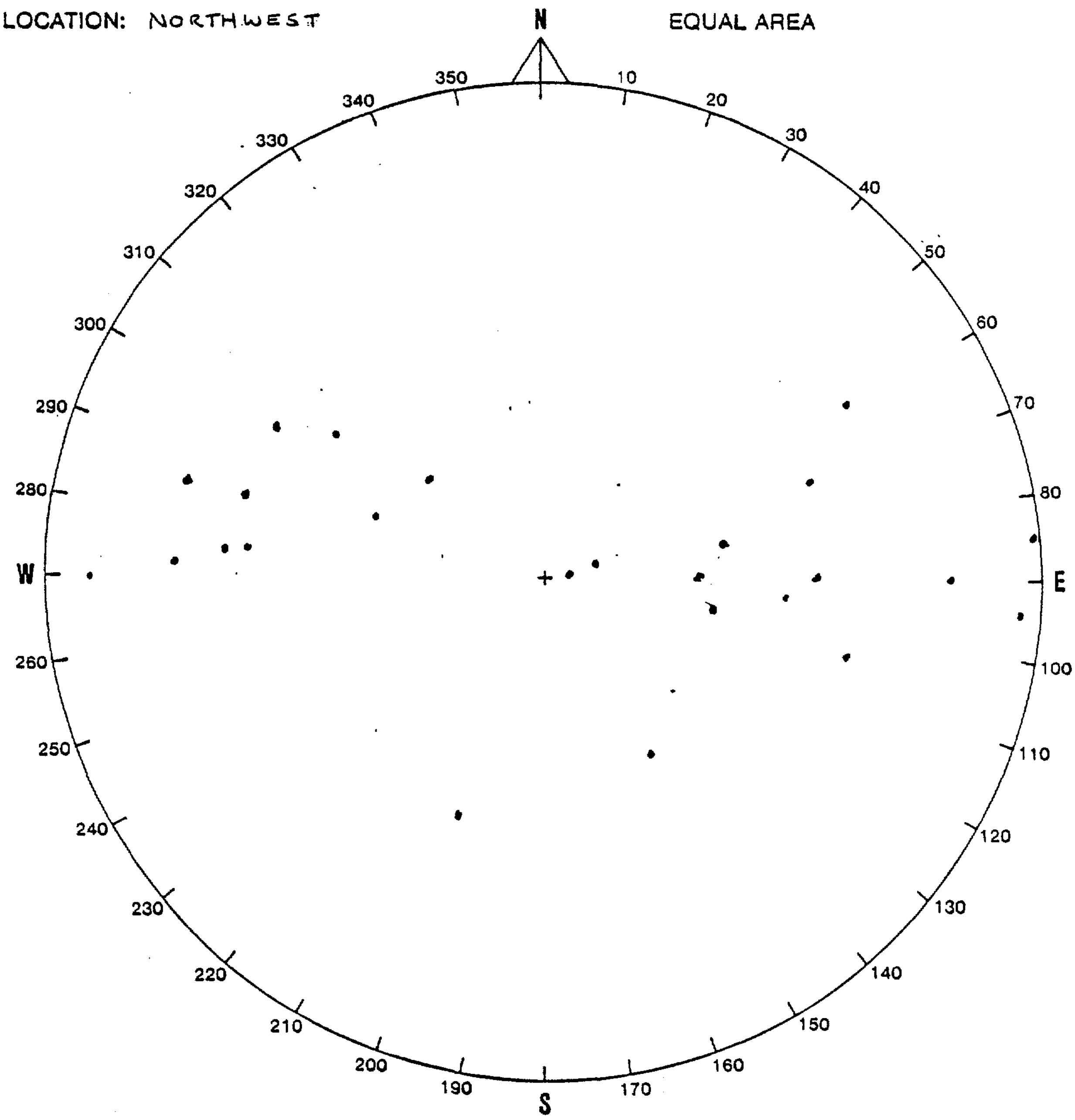
1. SO in northwest. generally parallel to S1a.
2. S1a in south: generally trends about east-west; scatter is due to D1b and minor D2 effects.
3. S1a in centre: broad range of orientations due to increasing effects of D2 folding towards the north.
4. S1a in northwest: approximately east-west trending, as almost completely reoriented by north-south D2 folding.
5. Foliations overprinting D1a structures: distinctive orientations can be defined for different post-D1a foliations. D1b faults have different orientations in the north and south because they are on either side of an open D2 fold. S2 in the Corella Formation differs from that in the Overhang Jaspilite because of D1a and D1b folding in the Corella Formation.
6. LIneations overprinting D1a structures: L20 in the Corella Formation differs from that in the Overhang Jaspilite because of greater interference with D1a and D1b in the Corella Formation.
7. Extension lineations: trend north-northwest - south-southeast in northern part of area. A, north; B, northeast.

47

I.

LOCATION: NORTHWEST

EQUAL AREA

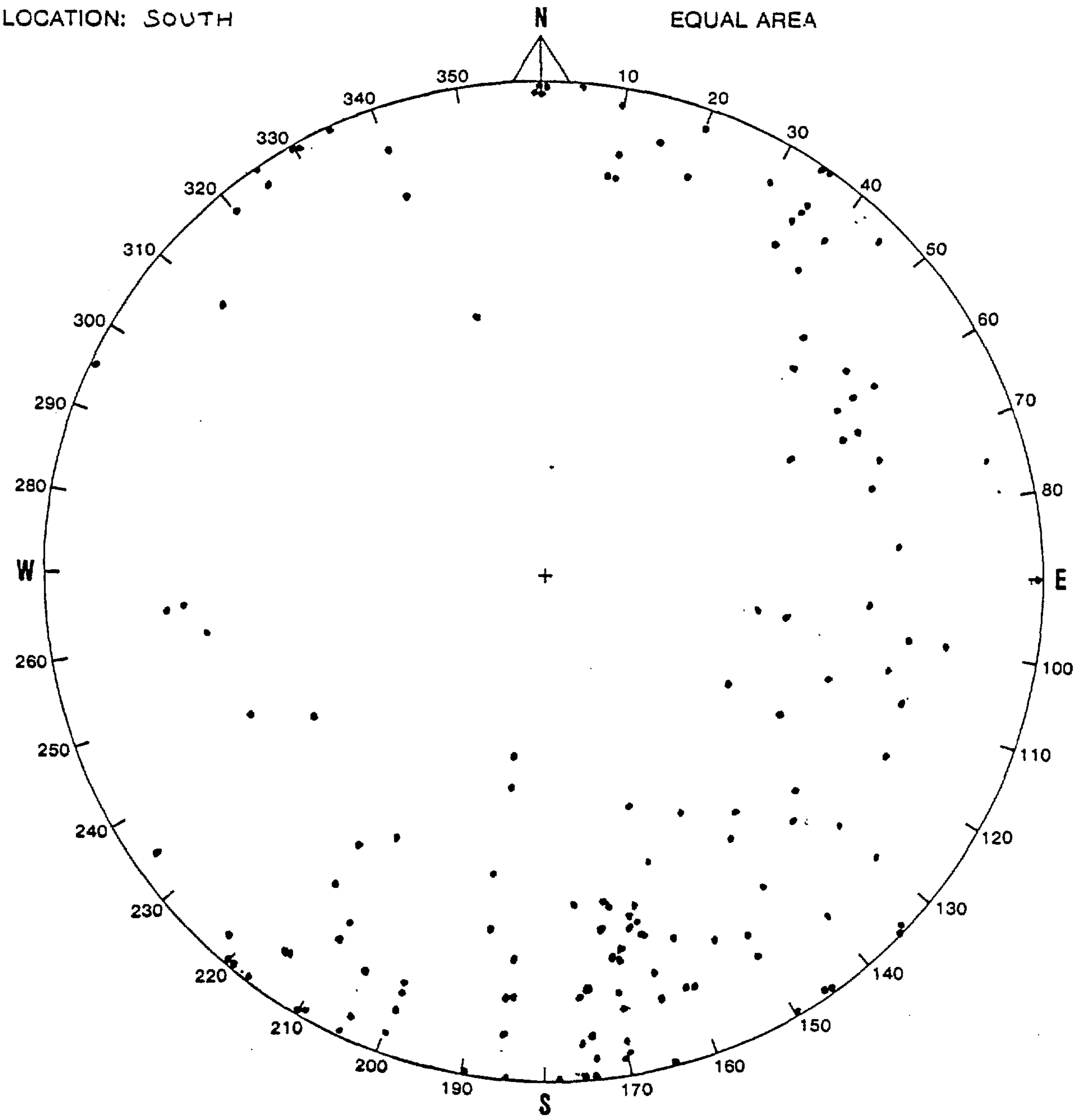


• 50

2.

LOCATION: SOUTH

EQUAL AREA

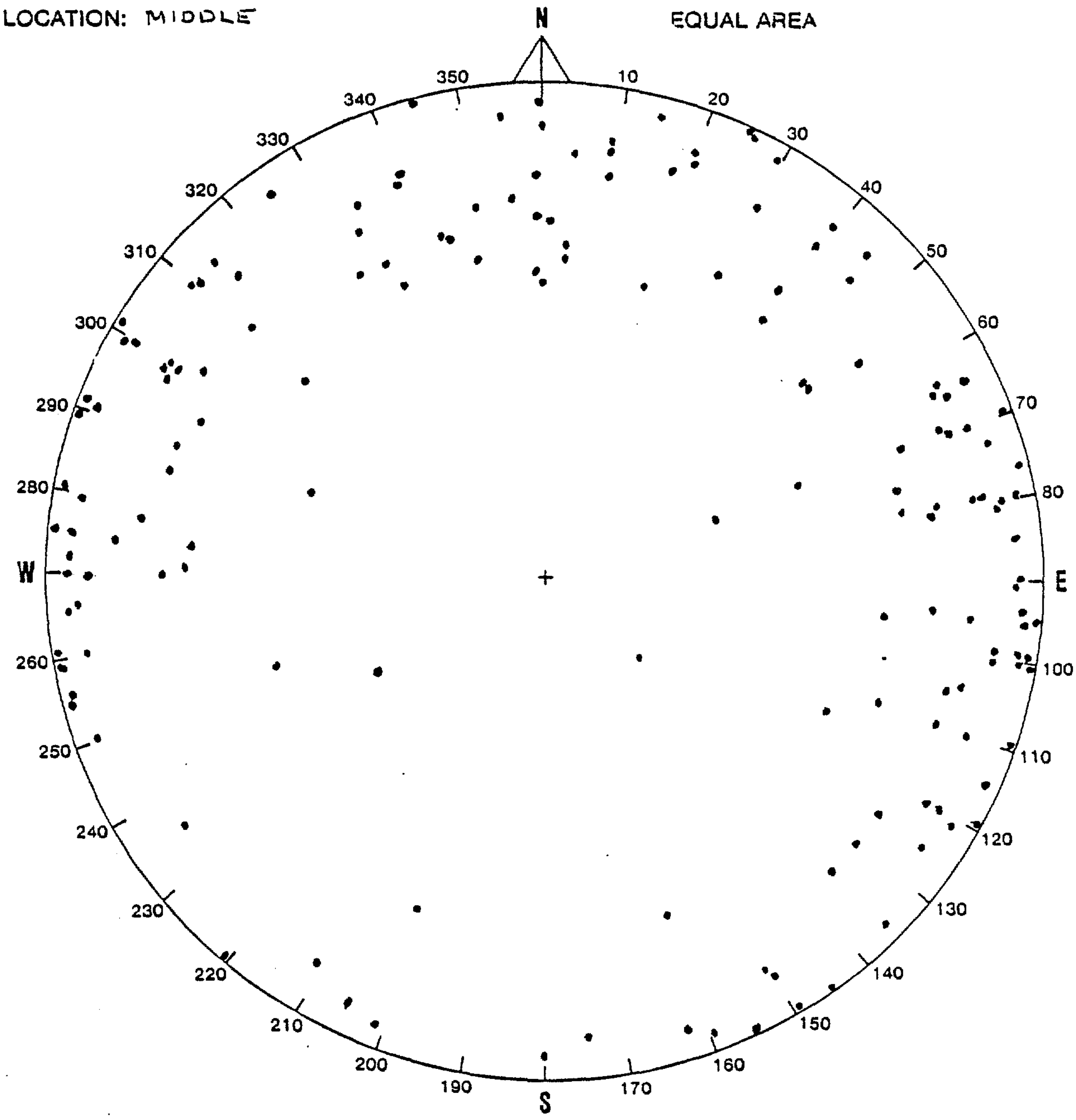


• S1a

3.

LOCATION: MIDDLE

EQUAL AREA



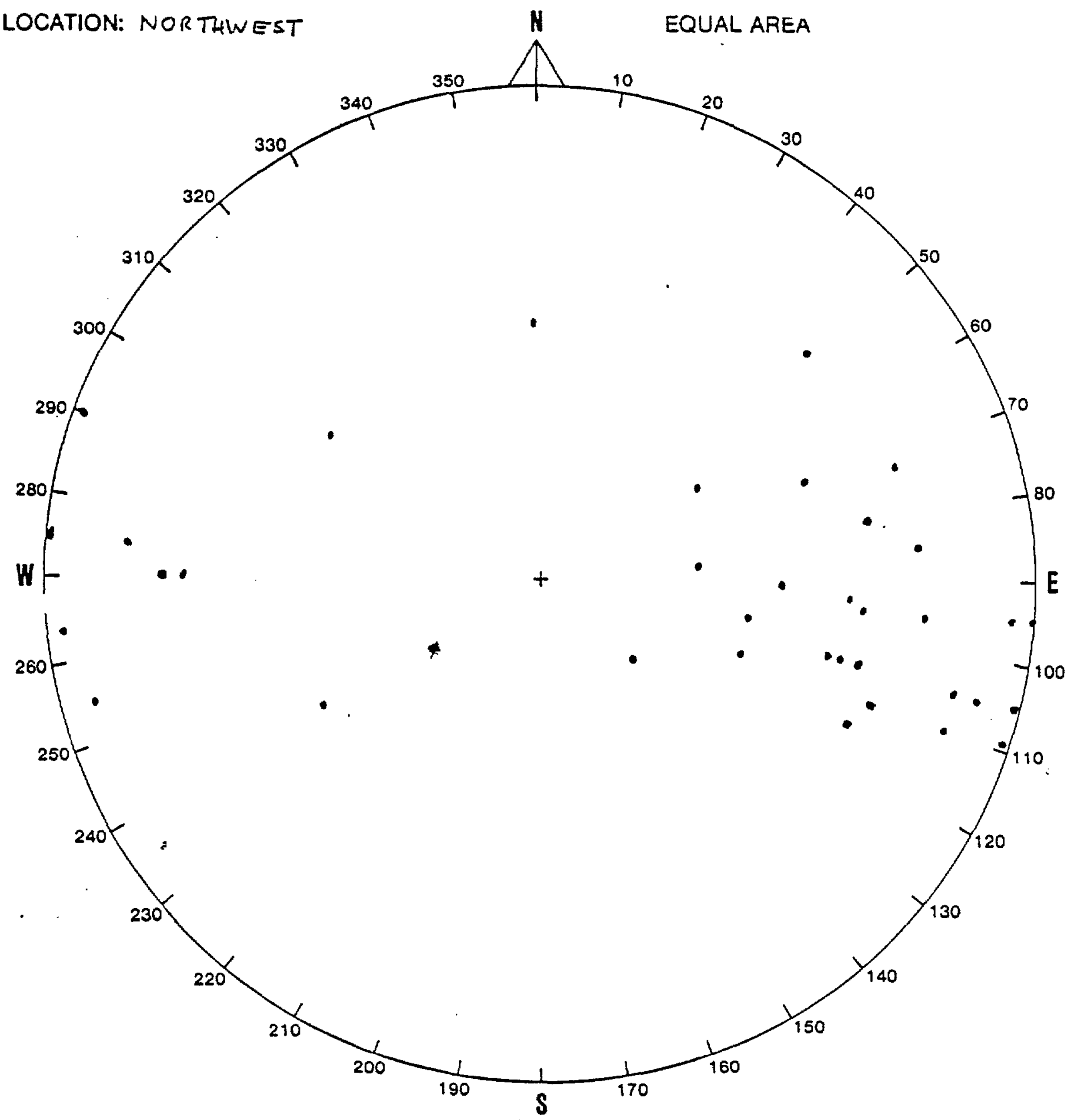
• S1a

50

4.

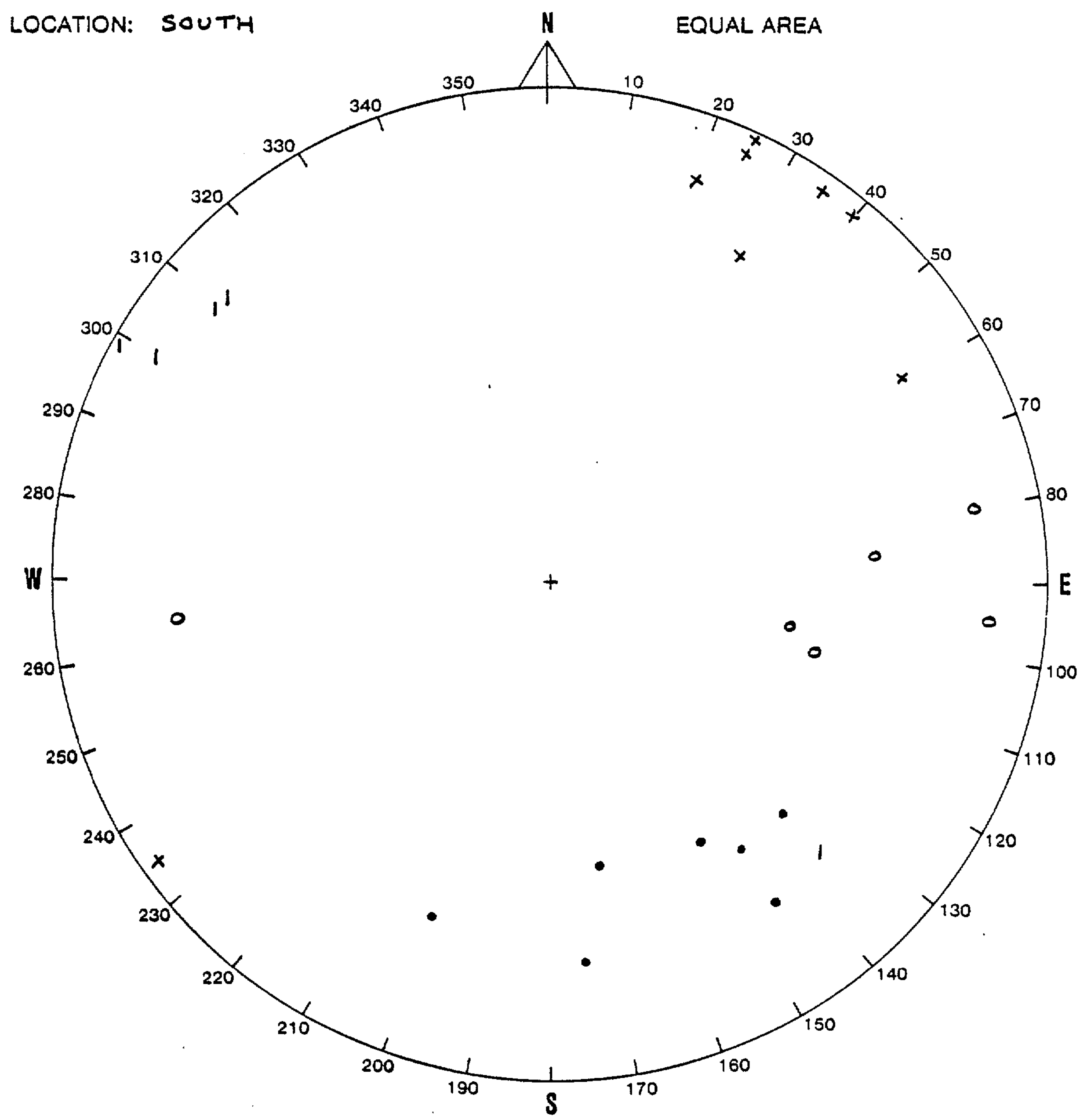
LOCATION: NORTHWEST

EQUAL AREA



• Sla

5. FOLIATIONS OVERPRINTING D1a STRUCTURES

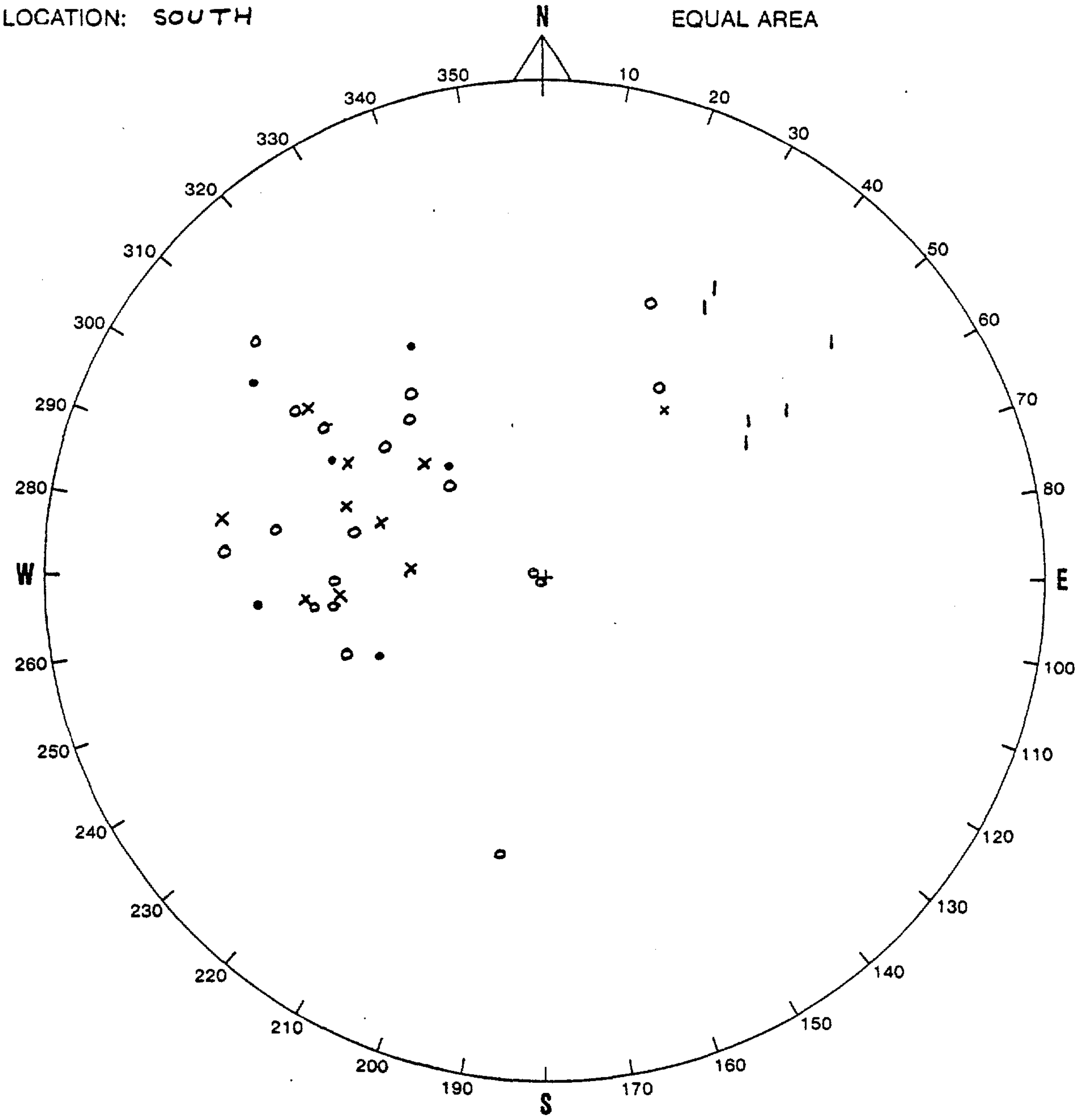


• S1b: around southern D1b fault; o S2: in Corella Formation

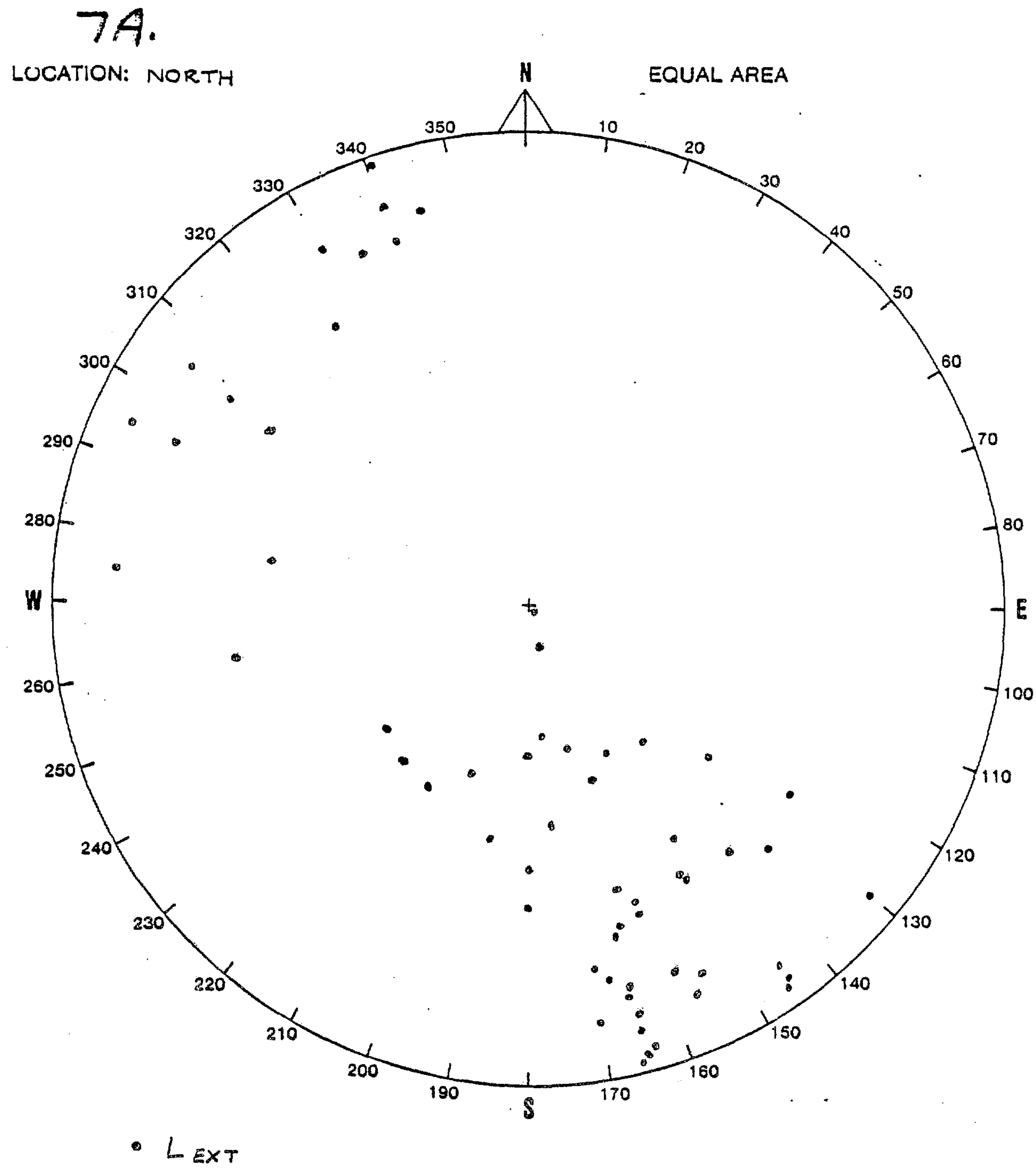
x S1b: around northern D1b fault; I S2: in Overhang Jaspilite

6. LINEATIONS OVERPRINTING D1a STRUCTURES

LOCATION: SOUTH EQUAL AREA



• L1a1b : around southern D1b fault ; o L2O : in Corella Formation ;
x L1a1b : around northern D1b fault ; I L2O : in Overhang Jaspilite.

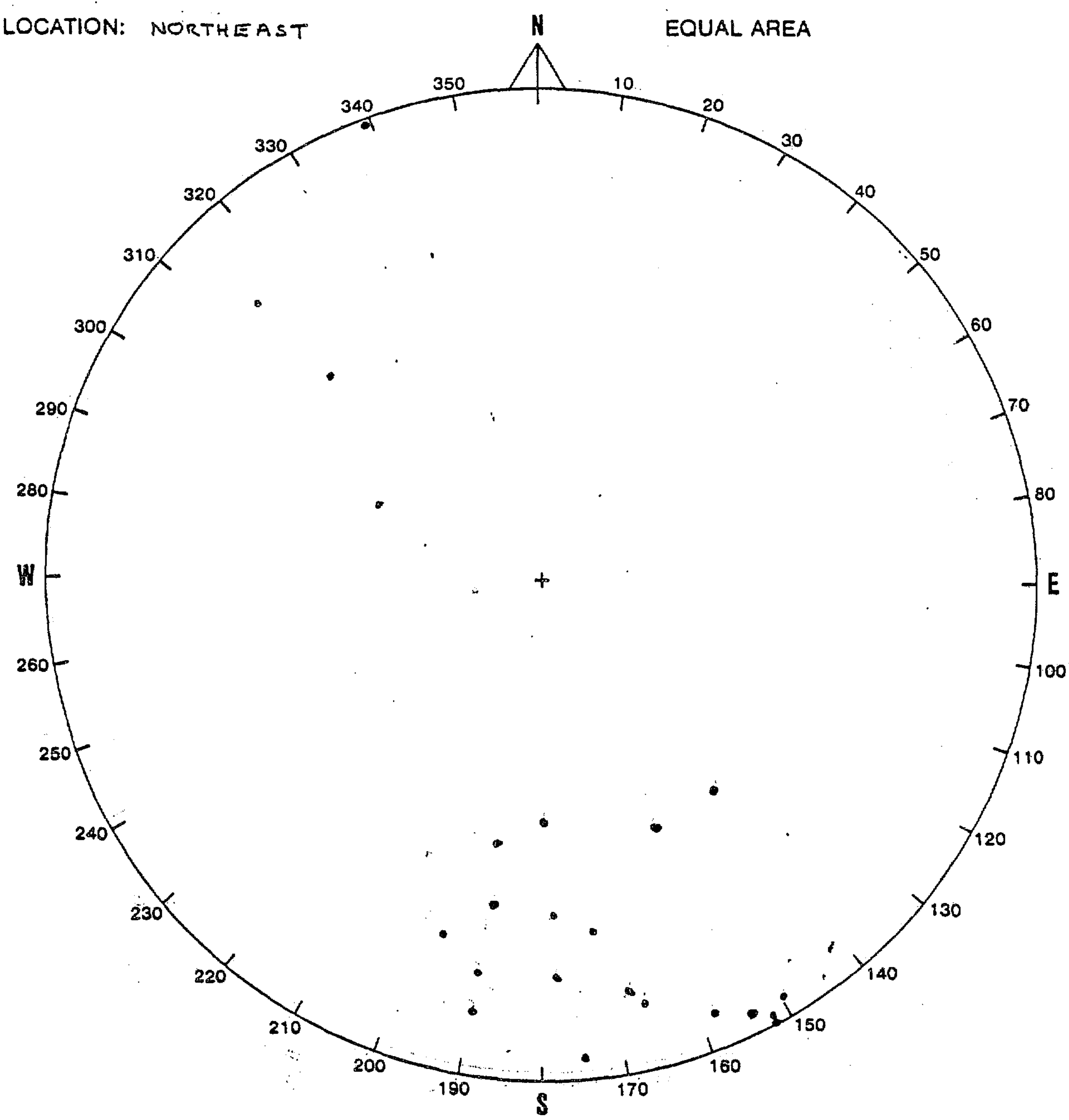

7A.
LOCATION: NORTH
N
EQUAL AREA
350
10
340
20
330
30
320
40
310
50
300
60
290
70
280
80
W
E
260
100
250
110
240
120
230
130
220
140
210
150
200
160
190
170
S
L EXT

54

7B.

LOCATION: NORTHEAST

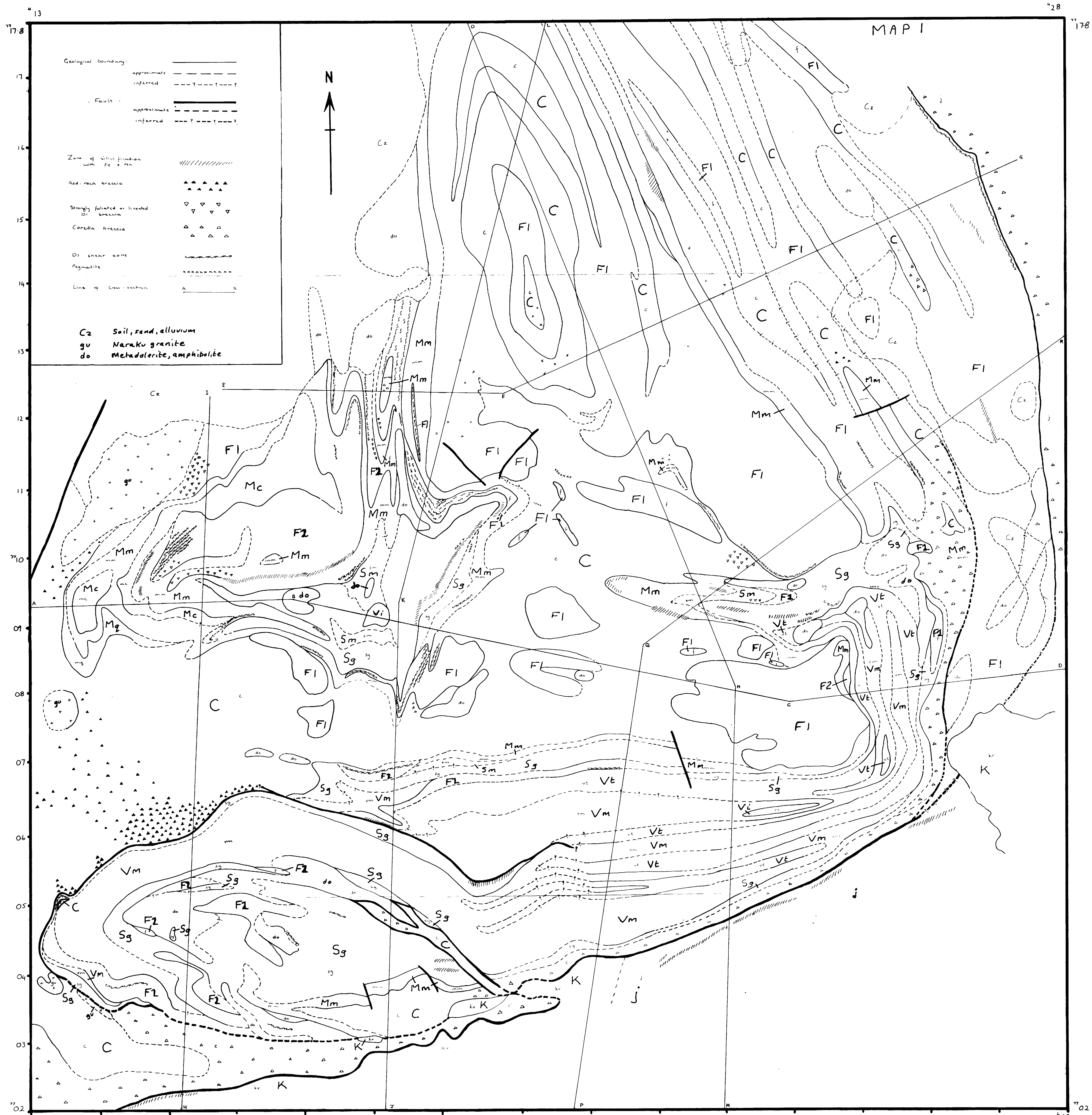
EQUAL AREA



• L EXT

McAULAY ENTERPRISES
Pat. 507266 Aust.
254125 U.S.A.

55



SCALE 1:27 000

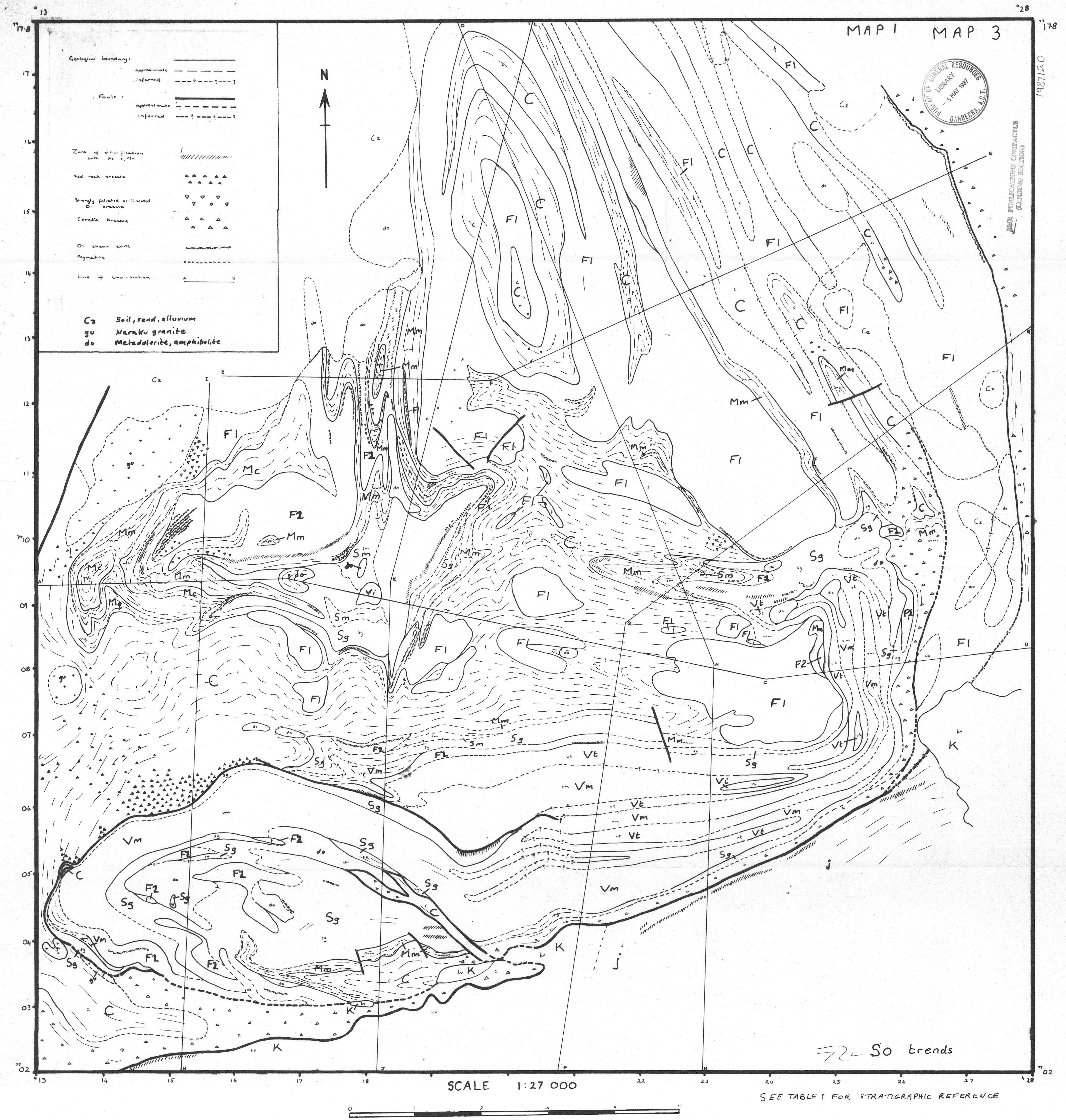
0 1 2 3 4 5
KILOMETRES

SEE TABLE 1 FOR STRATIGRAPHIC REFERENCE

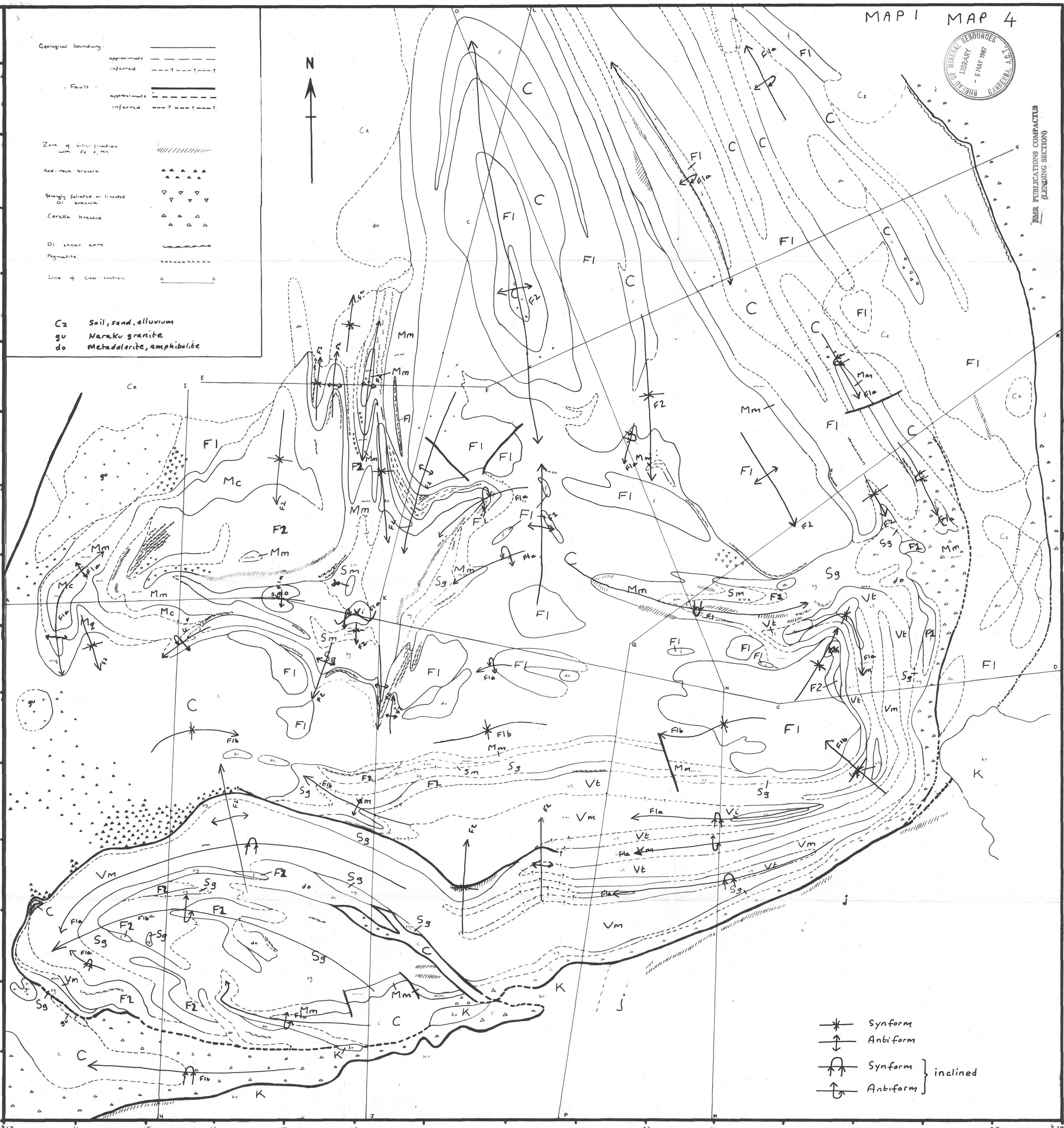
R8702002

MAP 1 MAP 2

SEE TABLE 1 FOR STRATIGRAPHIC REFERENCE


MAP 1
MAP 3
1987/20
Geological boundary:
approximate
inferred
Fault:
approximate
inferred
Zone of silicification with Fe + Mn
Red-rock breccia
Strongly foliated or lineated D1 breccia
Corella breccia
D1 shear zone
Pegmatite
Line of Cross-section
A
B
Cz Soil, sand, alluvium
gu Naraku granite
do Metadolerite, amphibolite
N
SCALE 1:27 000
0
1
2
3
4
5
KILOMETRES
So trends
SEE TABLE 1 FOR STRATIGRAPHIC REFERENCE

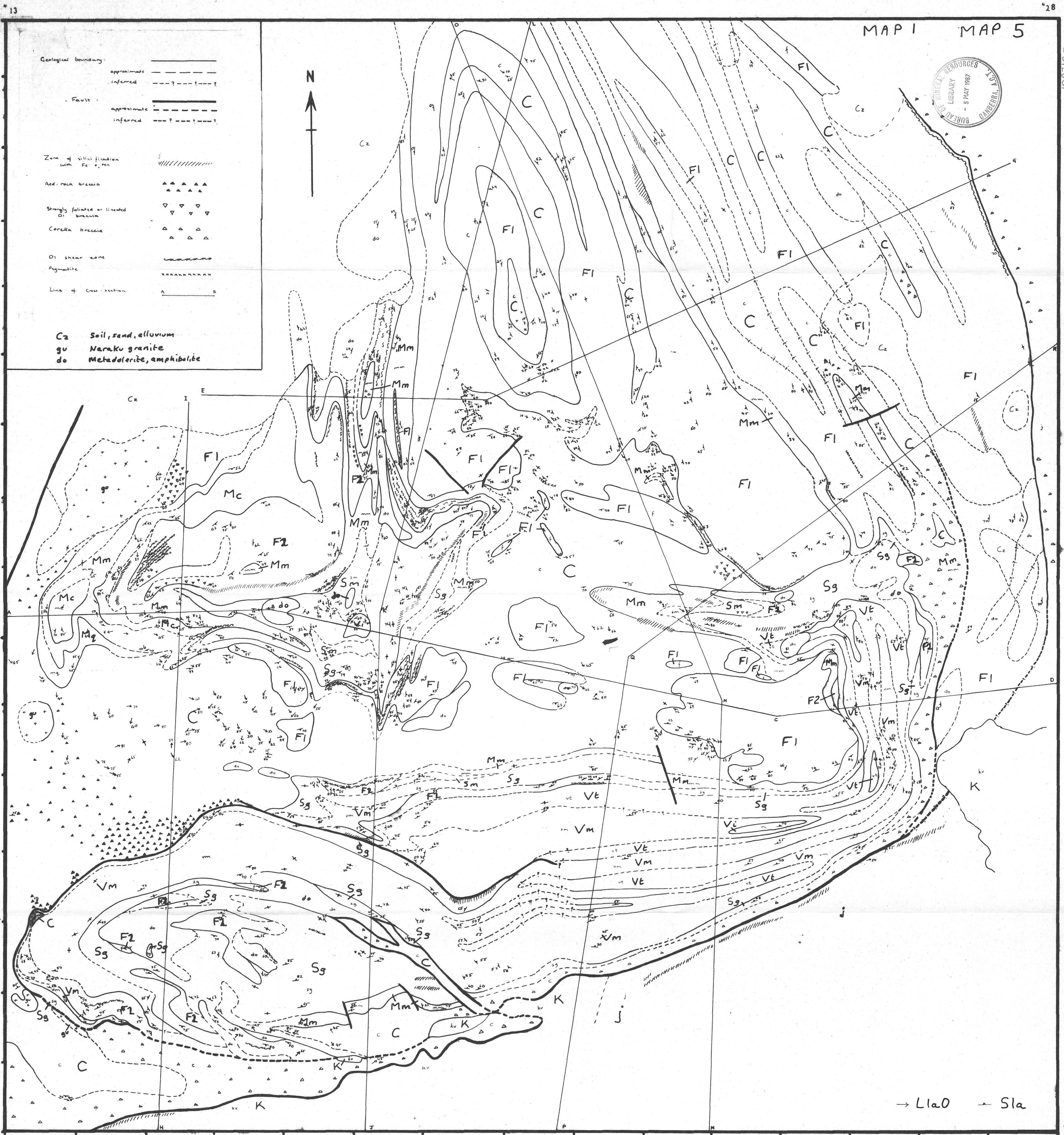
MAP 1 MAP 4



SCALE 1:27 000

0 1 2 3 4 5
KILOMETRES

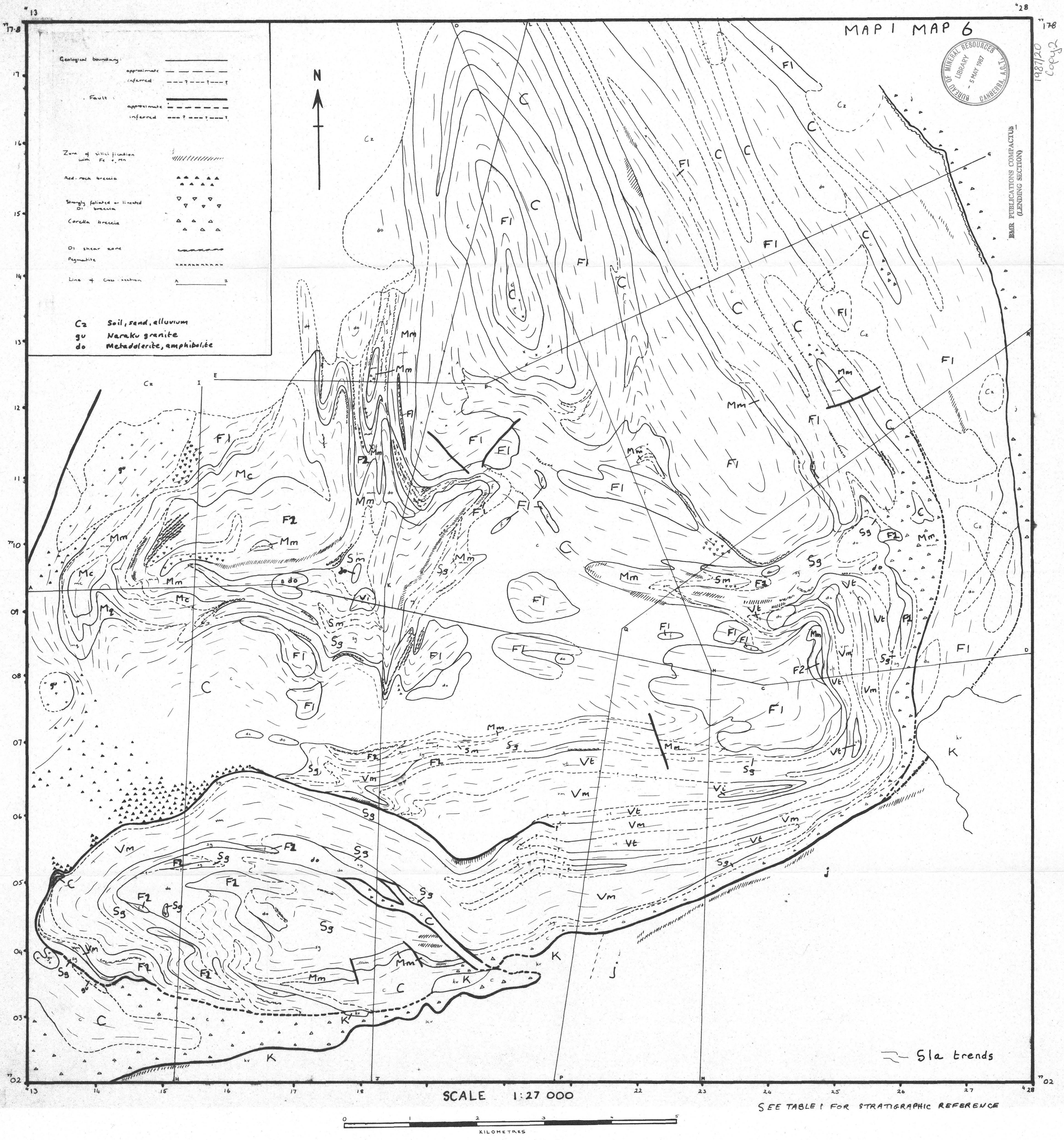
SEE TABLE 1 FOR STRATIGRAPHIC REFERENCE



SCALE 1:27 000

0 1 2 3 4 5
KILOMETRES

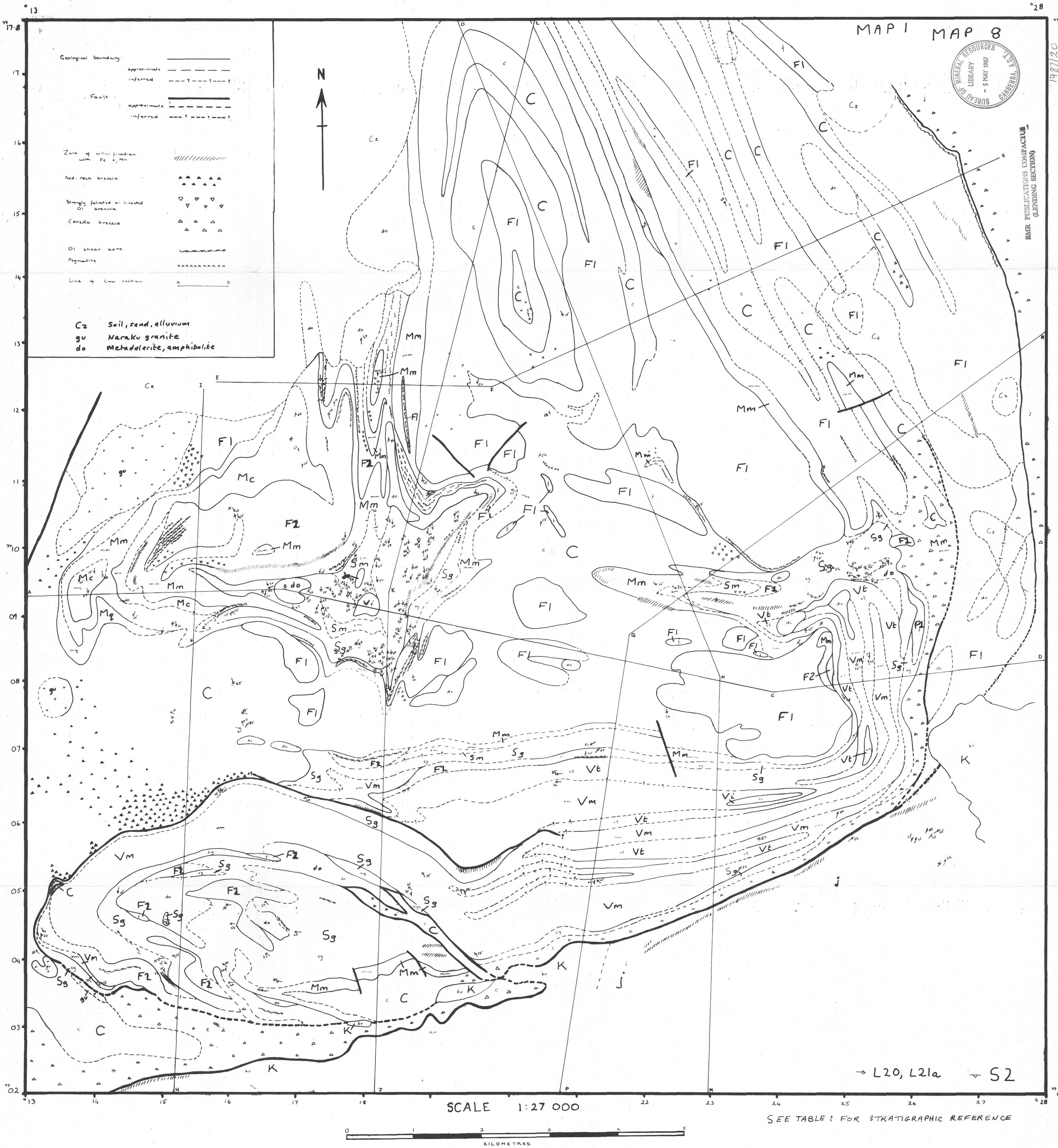
SEE TABLE 1 FOR STRATIGRAPHIC REFERENCE


MAP 1 MAP 6
N
Geological boundary:
approximate
inferred
Fault:
approximate
inferred
Zone of silicification with Fe + Mn
Red-rock breccia
Strongly foliated or lineated D1 breccia
Corella breccia
D1 shear zone
Pegmatite
Line of Cross-section
A B
Cz Soil, sand, alluvium
gu Naraku granite
do Metadolerite, amphibolite
S1a trends
SCALE 1:27 000
KILOMETRES
SEE TABLE 1 FOR STRATIGRAPHIC REFERENCE

SCALE 1:27 000

0 1 2 3 4 5
KILOMETRES

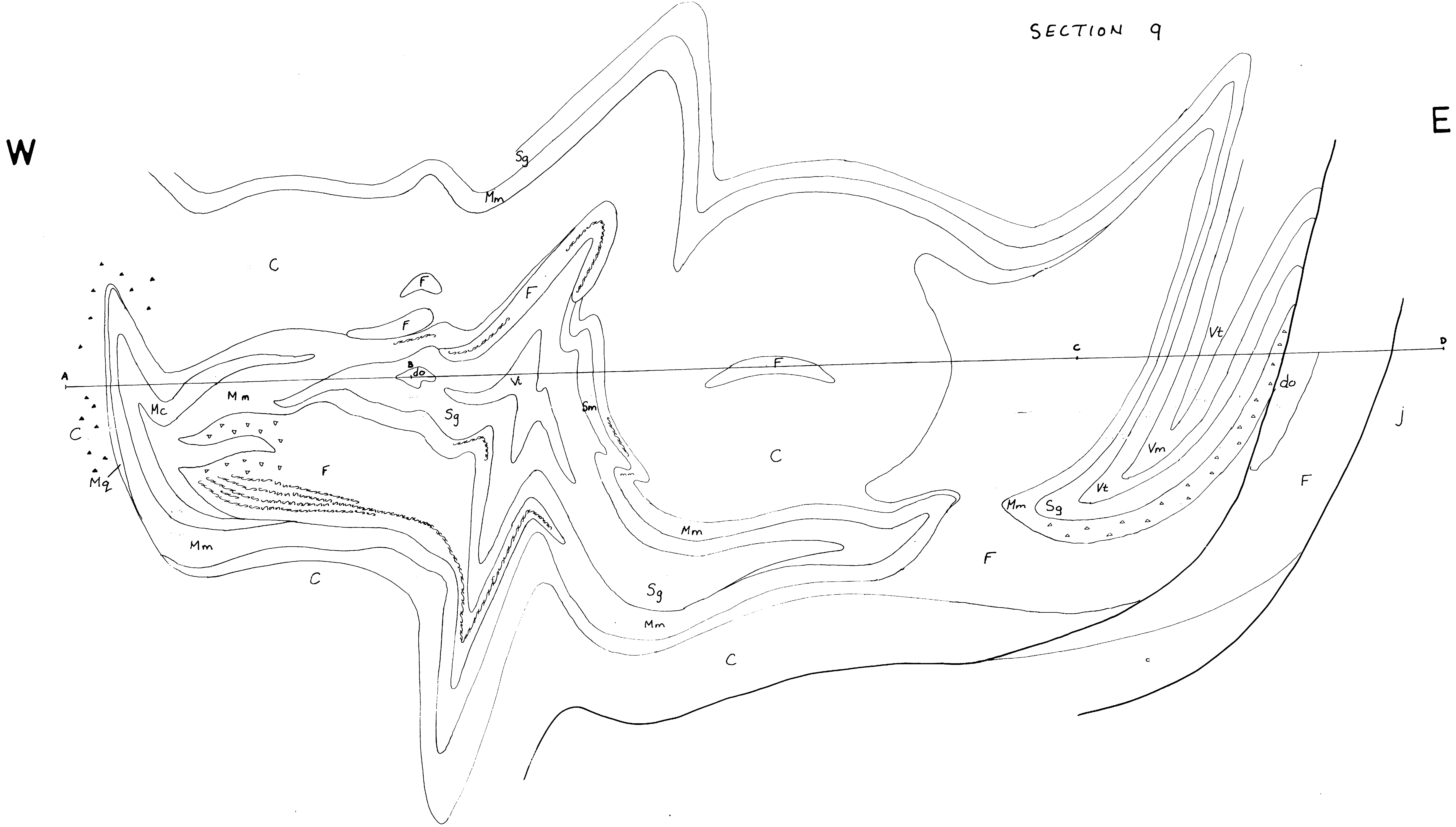
SEE TABLE 1 FOR STRATIGRAPHIC REFERENCE



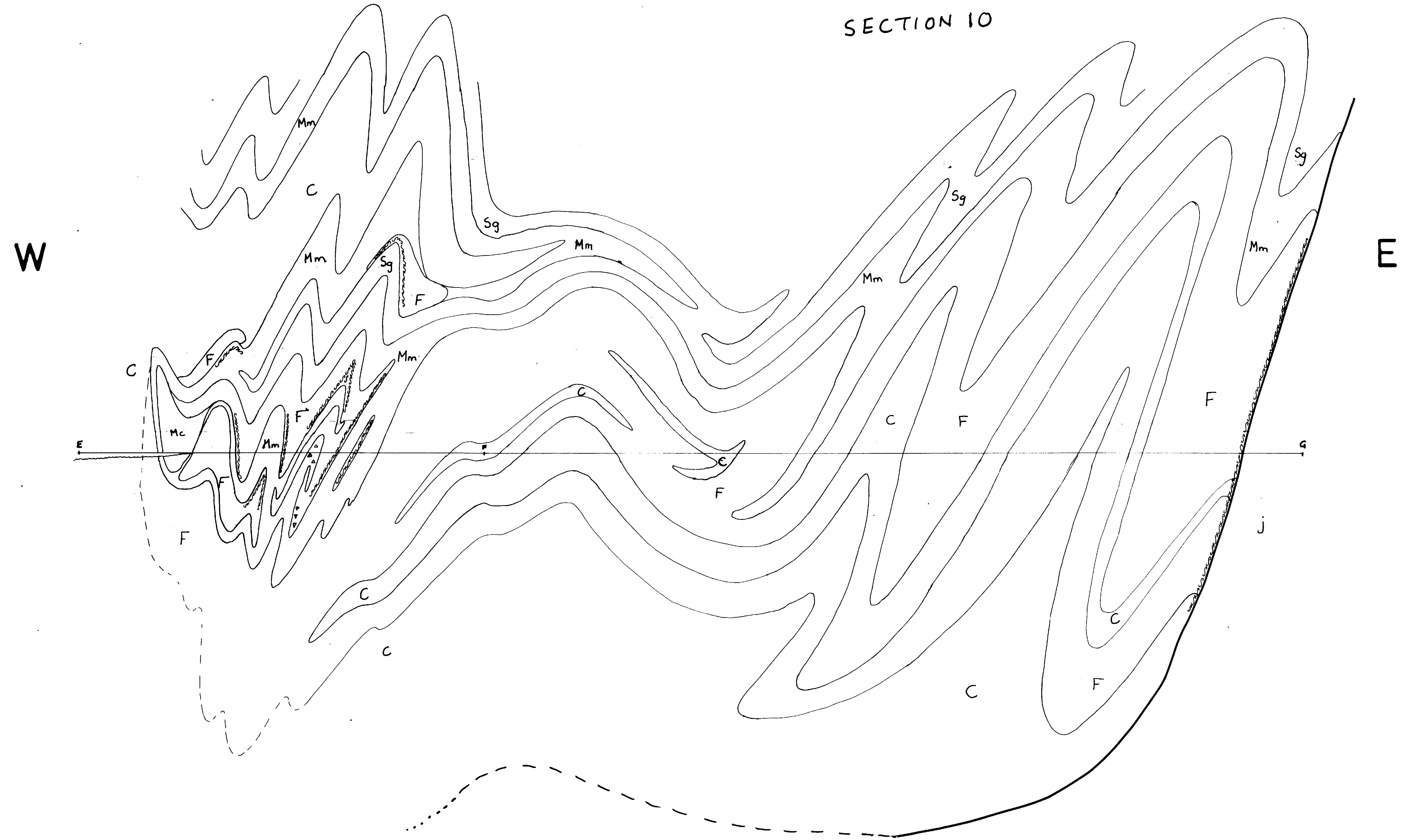
SCALE 1:27 000

SEE TABLE I FOR STRATIGRAPHIC REFERENCE

SECTION 9

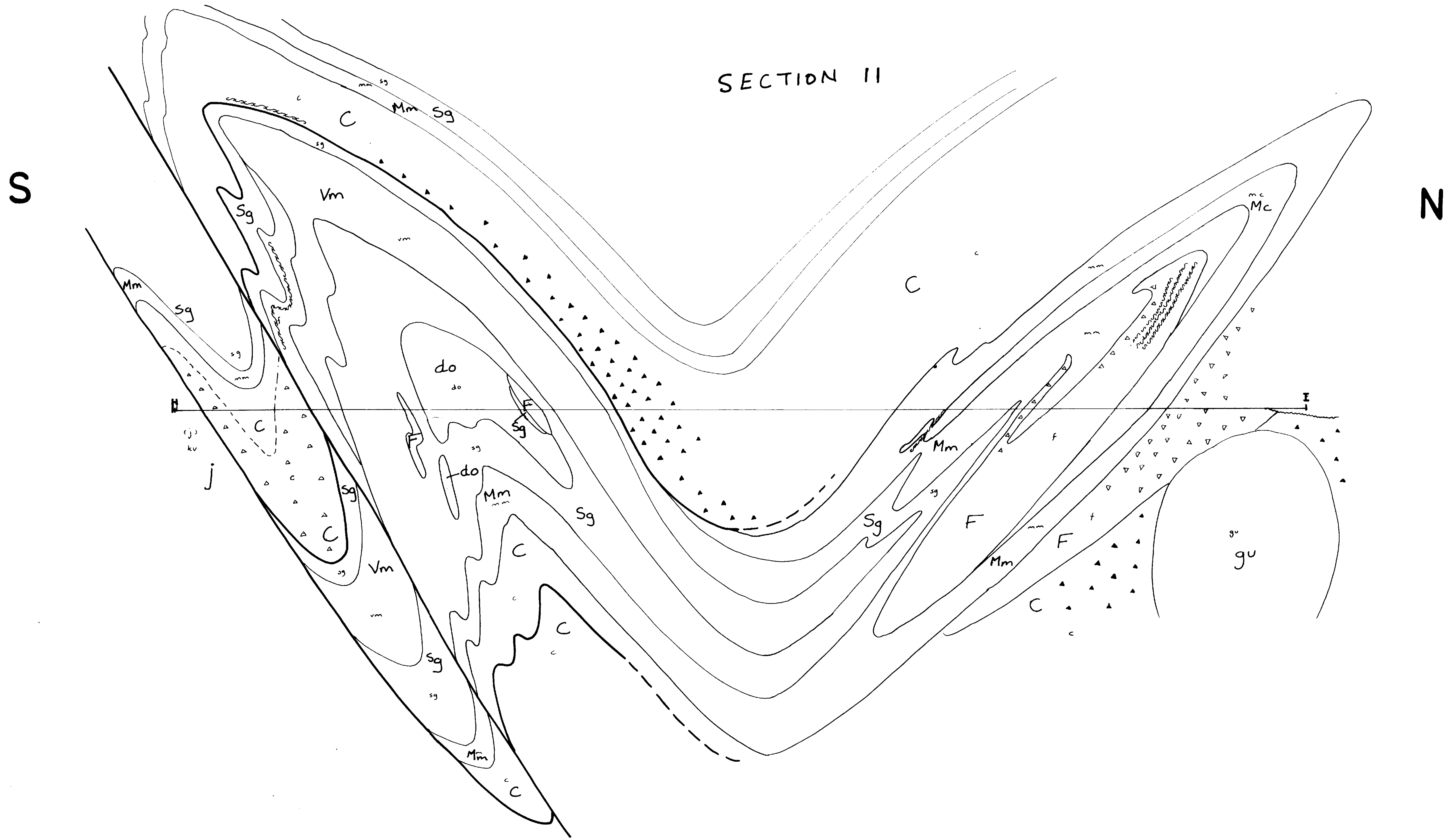

W
E
Sg
Mm
C
F
F
F
B
do
A
Vi
Sm
F
C
D
Vt
do
Mc
Mm
Sg
C
F
Mq
Vm
j
Vt
Mm
Sg
Mm
Mm
F
F
C
Sg
Mm
C
c

SECTION 10



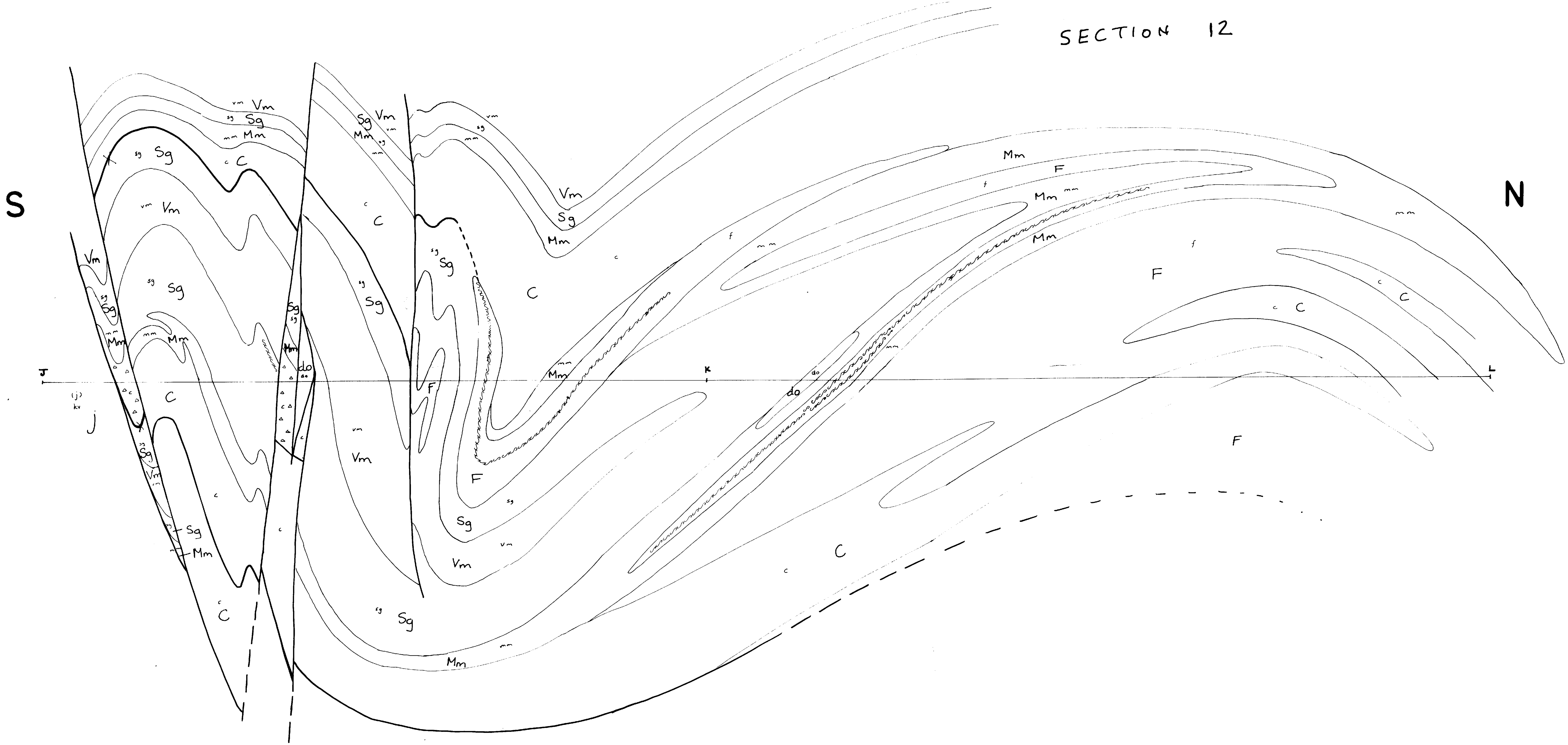
R8702010

SECTION II

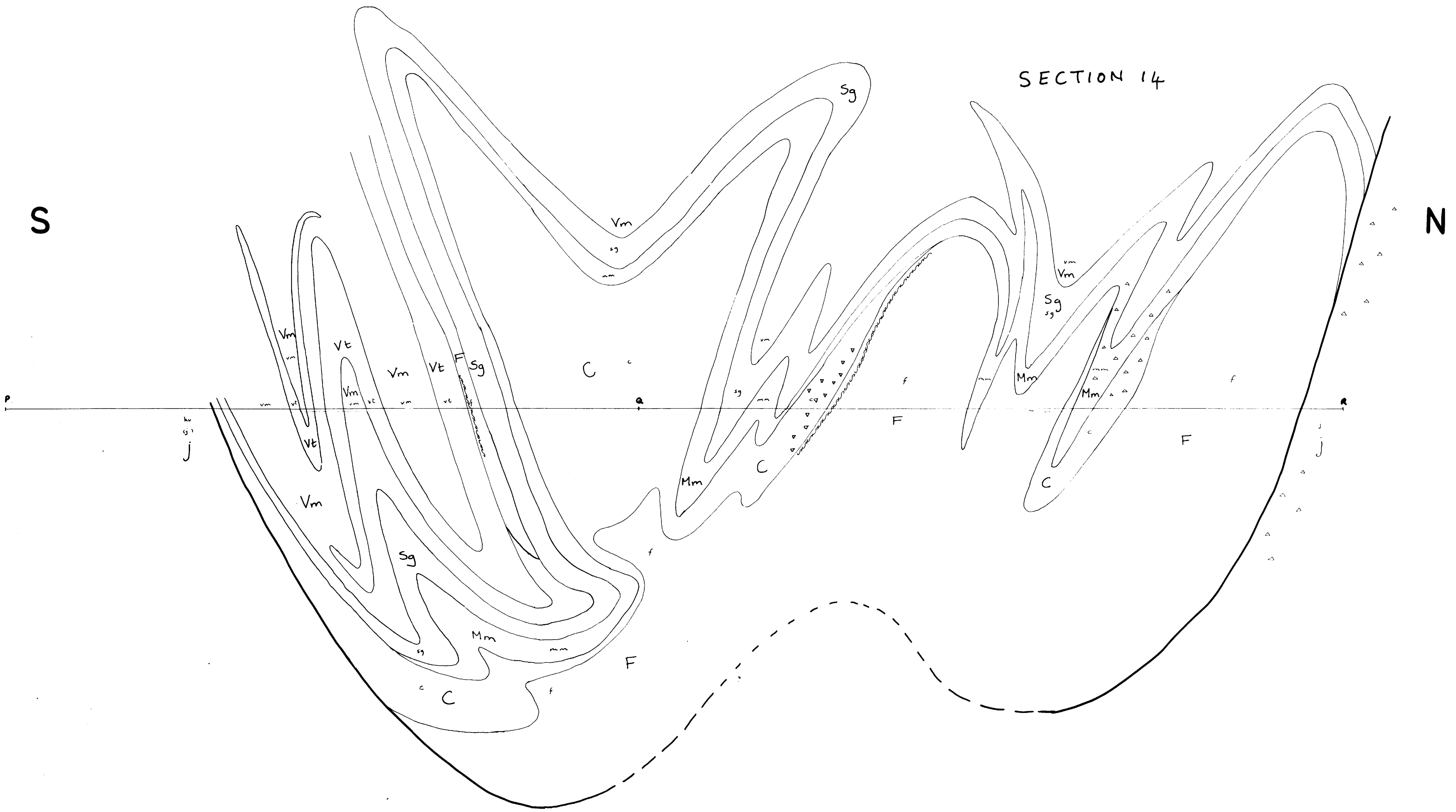


R8702013

SECTION 12



SECTION 13


SECTION 14
S
N
P
Q
R
Sg
Vm
Vt
F
C
Mm
j
f