CENTRE FOR ORE DEPOSIT AND EXPLORATION STUDIES

STRUCTURE AND MINERALISATION OF WESTERN TASMANIA

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Structure and Mineralisation of Western Tasmania

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ABSTRACT

The project aims were to understand the regional structure of the Dundas Trough and to apply this understanding to ore deposit and exploration models. So far the Devonian structural history has been well determined for 4 regional sections and at Rosebery and Mt Lyell. The Cambrian structure has been partly determined with a clear Middle Cambrian extensional phase followed by a compressional or wrench phase in the Late Cambrian. The significance of these Cambrian events must be considered in the light of the synchronous compressional tectonics in South Australia and Northern Victoria Land. Tasmania was in an active tectonic zone in the Late Cambrian.

INTRODUCTION

The AMIRA project started with a number of aims. Primarily these were to understand the regional structure of the Dundas Trough and to apply this understanding to ore deposit and exploration models.

The regional component of the study is to consider 5 regional transects and the South Henty Fault system. The major aims were to define the Devonian fault history on these sections and to use the existing lithological database to produce restorable sections. The expectation was that this process would identify any Cambrian structures as anomalous areas in terms of the reconstructions.

The identified mine geology component was the Lyell and Rosebery mines. An assessment of the Mt Farrell deposit was included at the November 1991 meeting. The Lyell project concentrated on the controls on North Lyell style mineralisation and the overall structure of the mine lease based on surface exposures. The Rosebery study was a mine scale structural assessment largely based on core and level plans. The Mt Farrell deposit study is to be largely a consideration of existing data.

PROGRESS

The regional structural program is running nearly to schedule. As of this meeting a major report has been given on three regional sections and work is well underway on two more. The first section across Hellyer has been the subject of further consideration as part of Mr. D. Selley's Ph.D. program and resulting from a geophysical assessment. An updated version of this section is included in this volume and we expect further improvements. The Victoria Pass to Strahan section is completed with the western section in this volume. The King River section is reported here. The South Henty Fault system was considered in Keele (1991) but a more formal assessment will be provided in the final report. The section near Rosebery has been started. The northern section across the Dial Trough remains to be done.

The Rosebery Mine structural assessment is completed with the geochemical test case reported in this volume. The Lyell leases have been discussed over all three earlier reports. Some further geochemistry modelling is being carried out at North Lyell and a final overview will be given in the report at the end of the project but the major results are unlikely to change from the summary included in this volume. The Mt Farrell study is yet to be carried out.

RESULTS

Regional sections

The Mt Ramsay to Mt Cripps section was presented at the first meeting and emphasized the importance of the basin geometry in controlling the overall structure of western Tasmania. A major normal fault margin was suggested with up to 10 km section of Cambrian sedimentary rocks. A re-evaluation of this section, in the present, volume largely confirms this view with a slightly thinner Cambrian section (~7 km) suggested.

The King River section is included in this volume. The outstanding features are the complexity of faulting with complex interaction between ?early west directed thrusting and east directed thrusts. The faults wrap around more rigid masses such as the Strahan Conglomerate such that some steep faults have a normal sense of movement. Major out of section movement occurs on a dextral wrench zone just east of the Darwin Granite in this section, through the Jukes saddle.

The Strahan to Victoria Pass section is complicated by the intense D_2 shear zone along the Linda Trend. Thus the section has been broken into a number of segments linked by NNE trending sections. The western segment is south of the Linda Zone and is similar to the King River section. The eastern segment has been drawn over Mt Lyell and emphasizes the east directed thrusting in this section. No major west directed thrusts are recognised in the zone from the Tyndall Range to Mt Strahan. This is anomalous in terms of the whole belt with the Rosebery fault dominating the structure in the north and the Point Hibbs/Modder River shear zone south of Macquarie Harbour.

Rosebery Mine

The structure of Rosebery is dominated by footwall offsets produced by Cambrian normal faults and by Devonian thrusts, through G lens. The reconstructed Cambrian geometry of Rosebery shows the pattern of mineralisation has a moderate correlation with the normal fault pattern. The visible normal faults control the local distribution of high grade ore but is only a second order control over the primary WNW trend in the mineralisation.

The pattern of normal faulting can be interpreted as WSW–ENE regional stretching with a N–S component. Oblique extension against a N striking normal fault is also consistent with this pattern. The moderate correlation with the mineralisation suggest surface fault patterns are not the same as those at depth. However the mineralisation is consistent with a set of NW striking normal faults separated into discrete centres by transfer faults striking NE. This model suggests there may be substantial continuations of mineralisation down plunge and to the south of J lens. It does not explain the ore grade intersections made deep under A/B lens.

Ti/Zr ratio which has potential to accurately identify the boundary independent of alteration and therefore has helped resolve some of the conflicting interpretations of footwall position at Rosebery. In this test the Ti/Zr ratio was only affected by alteration within zones of intense silicification and provided a good marker within less intense alteration.

Mt Lyell

The Haulage Unconformity is the result of relatively shallow dips to the east at the western margin of Owen Conglomerate Deposition. The geometry is compatible with a normal fault margin with some normal drag at the margin. Regional data supports an active tectonic setting in the late Cambrian and the structure may vary very rapidly in both time and space.

The North Lyell mineralisation is an important focus for this study. Both Devonian cleavages (S_1 and S_2) are visible in the altered Owen Conglomerate. Both hematite and sericite alteration penetrates into Pioneer Sandstone. Sr isotopic evidence supports a Devonian age for the vein style barite at North Lyell. The findings here are compatible with an Devonian syn-D_1 metamorphogenic enrichment of the North Lyell ore bodies.

The Devonian deformation at Mt Lyell includes early N–S trending folds which nucleated on the Haulage upturn, NNW trending folds (D_1), and WNW trending folds associated with the Linda trend. All tight folds are due to Devonian structures as they postdate the Haulage Unconformity. Faults are very prominent in this area and are very variable in orientation reflecting the high variability in rock strength. No definite Delamerian fault structures were recognised.

The Lyell Lease has a grossly simple east facing structure NE of the Glen Lyell Fault. A Cambrian transfer fault along the Firewood Siding Fault and its extension to the east in about the position of the Owen Fault separates the Lyell lease from the more complexly folded structure to the south.

REGIONAL CONTEXT

Some recently reported work in other areas has modified the context in which the Mt Read Volcanic Belt needs to be considered.

Arthur Lineament/Zeehan thrust

Recent work Turner(1992) has emphasized the importance of the Arthur Lineament as a Cambrian structure. The K/Ar dating strongly supports the correlation of the Arthur Lineament structure with the emplacement of the mafic/ultramafic complexes which pre-date middle middle Cambrian Dundas Group sediments. The Arthur Lineament is related to the steep S3 cleavage in the Oonah Formation so this date does not imply the early recumbent folding is also Cambrian.

The recognition of major SE directed thrusting west of Zeehan (Findlay & Brown1992) has emphasized the difficulty of recognising thrusts under Tasmanian conditions. Findlay & Brown have suggested a Devonian age for this structure but at this stage we reject this conclusion. The structure is only known from Precambrian and allochthonous Cambrian lithologies. While the thrust has not been recognised before the intense cataclasites associated with it have been known from the Oonah Formation for some time (Berry et al 1990) but no equivalent intense cataclasite zones are known from younger rocks. The thrusts are reported to be folded about NNW trending Devonian folds but the only known Devonian structure with the correct orientation to produce these structures post-dates the NNW fold trends. None of these arguments proves the Zeehan thrust is a Cambrian structure but together they represent a strong argument.

The Cambrian Time Scale and the Delamerian Orogeny

Recent articles (Compston et al 1992, Cooper et al 1992) have indicated the early Cambrian is about 526 Ma rather than 580 Ma. The date on exotic ultramafic sheets in NSW (Aitchison et al 1992) indicate an age of 530 Ma which is probably a better date than the existing conventional zircon age for Tasmanian ultramafic rocks of 520 Ma (Brown 1986). These ages constrain the Mt Read volcanics to an even smaller time frame than previously suggested.

The work in South Australia has emphasized the short nature of the Kanmantoo sedimentation. Kanmantoo Group sedimentation began in a rapidly deepening basin soon after 526 Ma (Compston et al 1992). The thick sequence of sediments were deposited in time to be deformed at 516 Ma. and have major metamorphism and deformation over by the 487Ma (Foden et al 1991). The Kanmantoo cycle of deposition is apparently time equivalent to the emplacement of the mafic/ultramafic complexes. Either the deformation features are diachronous or the Dundas/CVC/Owen Conglomerate are being deposited at the same time as the Delamerian Orogeny.

Correlation of western Canada with the Adelaidean cycle of deposition (e.g. Young 1992) suggests the Precambrian history of Tasmania may be recorded in western North America. There is a hiatus in both sets of stratigraphies at about 720-750 Ma which may correlate with the Penguin Orogeny.

In Antarctica, the best correlation for the Penguin Orogeny is with the Beardmore Orogeny and the low grade metamorphics may correlate with the shallow water sedimentation of the Central Transantarctic Mountains (Tingey 1991, p78). These shallow water sediments have been interpreted as fans on the cratonic margin of the East Antarctic shield.

SUMMARY OF TECTONIC EVENTS

With this context in mind a summary of the tectonic history of western Tasmania is given below.

1 Late Proterozoic shallow water sedimentation on the eastern margin of the East Antarctic shield

2. Penguin Orogeny (700 ± 50 Ma) Recumbent tight folding with transport to the south and east.

3. Passive margin formation (Rifting away from western North America)(Early Cambrian)

4. 525–520 Ma Late Early to Early Mid Cambrian Arc continent collision to the east with obducted slices of forearc thrust across parts of Tasmania
   Initiation/reactivation of Arthur Lineament and Zeehan thrusting.
   Sag phase of Kanmantoo Basin-?due to tectonic loading of the shelf

5. Delamerian Orogeny 515–490 Ma
   Part 1 Middle Cambrian-extensional phase
      Initiation of Dundas Trough Mid Middle Cambrian
      Major post-collisional acid volcanism of the Mt Read Volcanics
      Henty Dyke swarm- EW extension
      Rosebery Mine- ?ENE-WSW extension
      Rosebery fault margin
   Part 2 Late Cambrian
      Miners Ridge Thrust
      Upright open folding
      End of large scale acid volcanism

Rapid extension of Denison Group deposition
Late Cambrian–Ordovician unconformities
Many local unconformities

7. Ordovician–Silurian sag phase

8. Early Devonian cycle of deposition

9. Middle Devonian orogenesis
   N–S faults at discrete old fault boundaries
   ?early low angle thrusting e.g Lyell flats
   Mt Farrell
   W directed thrust dominant early, E directed reverse faults more important later
   NNW trending folds (NNE trending in the north)
   NW trending folds and thrusts plus Granites
   Most replacement deposits about this age.
   Late brittle wrench faults NNW dextral and NNE sinistral
   Local return to E–W compression

10. Permian depositional cycle

11. Late Mesozoic wrench faulting

12. Eocene extensional structures

OUTSTANDING PROBLEMS

Late Cambrian Tectonics and structure

The major structural problem relate to the exact stress environment during the Late Cambrian which has equivocal evidence for both extension and compression. The options considered for this period are:

(a) Normal Fault Regime: This pattern was favoured in the first report and the interpreted geometry explained. For example, the Reconcavo Basin, Brazil, is an extensional basin marginal to the South Atlantic that has many similarities to the Dundas Trough. In terms of an extensional model the systematic shift in the locus of deposition and consistent onlap relation of the Owen and Tyndall Conglomerate suggests correlation with a ramp basin. The propagation of the basin is in the opposite direction to transport as it is fixed over the ramp. In this model the transport must be to the east.

(b) Reverse Fault Regime: An alternative model is a thrust controlled Owen deposition. This model is a slight modification of that proposed by Arnold (1985). There are many examples of foreland conglomerates (very similar in depositional style to the Owen Conglomerate) which are related to thrusting. The major feature of this type of conglomerate is that the sediment is derived from the upthrust block whereas in the Mt Lyell area the major source for the Owen Conglomerate is the metamorphic basement rocks to the east which would need to be interpreted as the foreland bulge. One advantage of this model is it explains the presence and orientation of sandstone dykes at Mt Lyell and Point Hibbs better.

(c) Oblique-slip mobile zones: Many major wrench faults produce rapidly deposited fanglomerates in basins of the size exposed in western Tasmania. According to Reading (1980) distinctive features of oblique slip regimes are "thick but not laterally extensive sedimentary piles ... localized uplift and erosion giving rise to unconformities of the same age as thick sedimentary fills nearby ... extreme lateral facies variations ... simultaneous development of extensional and compressional tectonics within the same belt ... little or no metamorphism". Many of these features have been reported for the Mt Read Belt. A Cainozoic area of this type and with some similarities to the Mt Read belt is North Island New Zealand . Such information as is available for orientation of Cambrian folds might be interpreted in terms of an en echelon pattern of folding (e.g. early folding in Surprise Creek Group, Clytie Cove Group and Tyler Creek beds). The major problem in applying this model is that no clear progression of basins has yet been recognised and the controlling fault structure remains elusive.

At this stage there is little direct evidence for extensional structures in the Late Cambrian. The major evidence is the shape of Owen depositional basins but this is equivocal. There is stronger evidence for compressional structures in the Late Cambrian especially folding and rare recognisable thrusts. The scatter in age of unconformities suggests this stress state persisted through most of the Late Cambrian. There is evidence for Late Cambrian wrench faulting at Osmiridium Beach but it is not clear how applicable this is to western Tasmania.

Devonian Deformation

The work so far has shown that the Devonian deformation is strongly effected by local variations in rock strength and by reactivation of older structures. The general history of an EW compression changing to NNE-SSW compression explains almost all structures but the style of these structures varies dramatically. For example (Fig. 1) the strong west directed thrust zones near Rosebery and south of Macquarie Harbour contrast with largely east directed thrusting near Queenstown. The major complexities need to be worked out in each locality and no general solution is possible.

SUMMARY

The project is running about 2 months behind schedule but most of the original aims are being met. The structural history determined has been tested over a large part of Western Tasmania and produces a workable structural synthesis. The Cambrian structure has been defined in a limited way but requires a substantial refining. The Rosebery structural study has resolved many anomalies in the mine and produced an overview with some exploration significance. The Mt Lyell structural study was more difficult due to the complexity of the later structures but a workable structural interpretation has been produced.

Remaining areas to be tackled are the structure of northern Tasmania, and an overview of all the Cambrian based on the sections so far produced and on the available maps. The relationship between sections will help to define anomalies in the structural interpretation.

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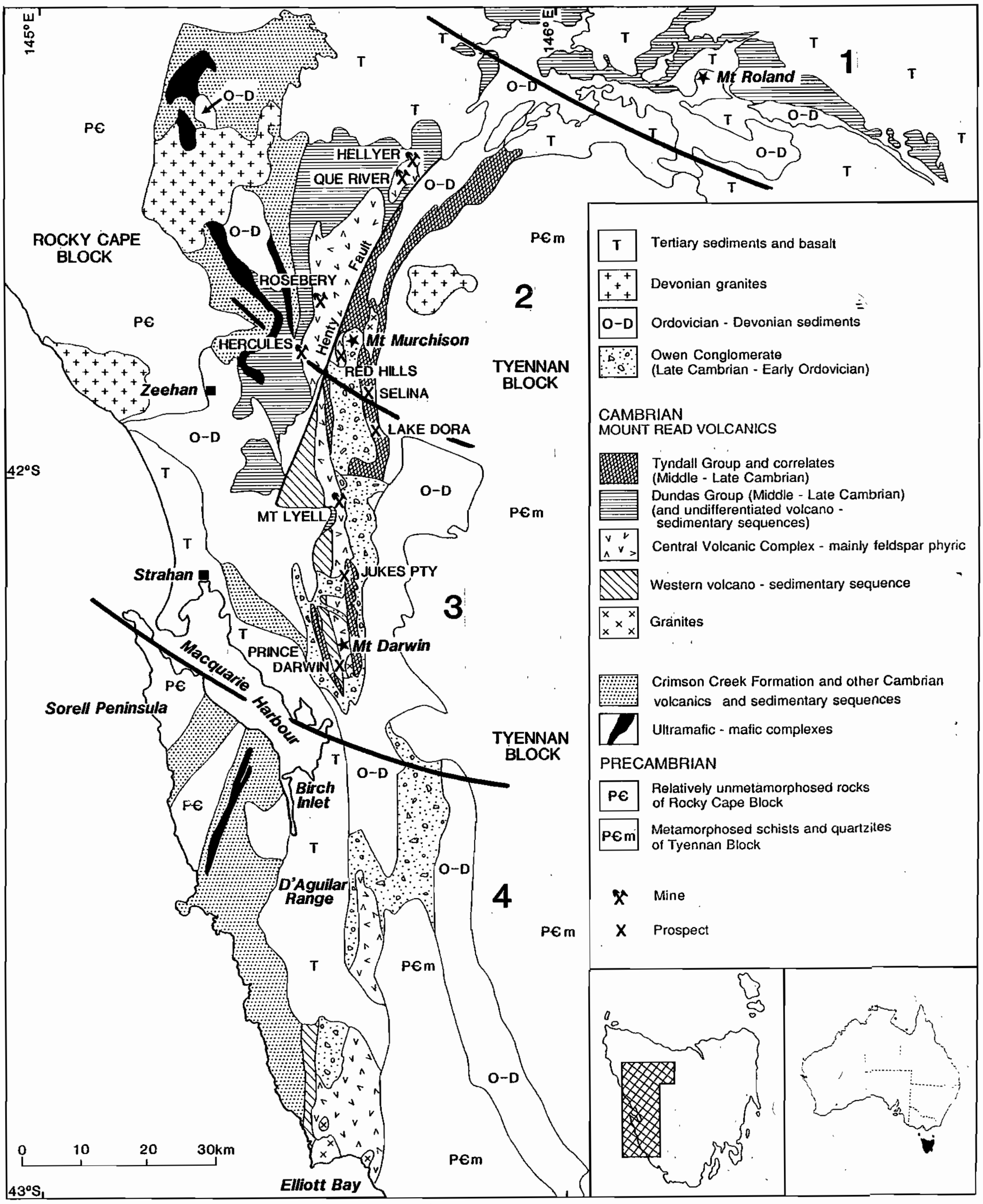

FIG. 1. Geology of the Western Tasmania showing subdivision into 4 distinct structural domains based on Devonian D_1 fault style. Zone 1 — Northern sector dominated by D2 overprinting. Zone 2 — Hellyer/Rosebery sector dominated by west-directed thrusting on the Rosebery Fault. Zone 3 — Zeehan/Queenstown sector. Zone 4 — Elliot Bay–Macquarie Harbour dominated by west-directed thrusting.

[NB: pages 7–10 omitted from volume]

The King River regional cross-section: a transect through the Dundas Trough

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ABSTRACT

The Cambrian Western Succession, comprising a 1.25 km thick sequence of volcaniclastics and lavas, together with the adjacent graben of Cambrian to Tertiary age, is underlain by a slab of mafic-ultramafic crust that dips at a shallow angle towards the east. Devonian thrusting in the western part of the King River section has largely been controlled by the edges of a Cambro-Ordovician basin in which a thick sequence of Owen Conglomerate had accumulated. The Teepookana and Mt Strahan Faults, which define the western and eastern limits of this basin, were initially re-activated as W-directed forward thrusts during D_1, but were later during the same event overprinted by a series of E-directed backthrusts.

The central volcanic belt, comprising coherent lavas and volcaniclastics of the CVC and Tyndall Group correlates, is underlain by a granite body whose placement is asymmetric with respect to the E and W verging thrusts which overlie it. Wrench faulting on the eastern side of the Darwin granite has produced a flower structure which has both positive (compressional) and negative (extensional) characteristics; normal faulting associated with this extensional regime occurs above the tip of the pluton in the Owen Conglomerate. The Great Lyell Fault, which can be seen as a 50 m wide zone of fault brecciation and cataclasis in Owen Conglomerate, is the principal structure along which D_2 reactivation has occurred despite the fact that it experienced only limited strike-slip movements.

The Tyennan nucleus which lies to the east of the Mt. Read volcanic belt has, after the effects of Middle Palaeozoic folding are removed, a residual domal structure which is suggestive of a metamorphic core complex. It is speculated that the fault separating the high-grade garnet-bearing metamorphics from the rocks of lower metamorphic grade assemblages is a normal detachment fault related to Late Cambrian extension.

Mineralisation related to the Cambrian granite may be interpreted as having an original component related to emplacement of the pluton and a secondary component due to remobilisation of the metals and sulphur during D_2 wrenching and metamorphism. The edges of the Strahan–Zeehan depocentre are favoured sites for circulating basinal and metamorphic fluids, e.g. the low-grade gold mineralisation near Harveys Creek along at the northern end of the Mt Strahan Fault.

INTRODUCTION

Most geological sections are interpretable to a depth of about 2 km with a reasonable level of confidence; beyond that, however, geophysical evidence may be necessary to extend the interpretation to depths of 6 km or more. The confidence levels that can be put on the interpreted results at these deeper levels are correspondingly much less, but nevertheless valid as long as the geological and geophysical evidence do not contradict one another.

The King River section, which stretches from Macquarie Harbour in the west to the Tyennan Block in the east (Fig. 1), was field checked at regular intervals over a distance of 20 km from the mouth of the river to the western shores of Lake Burbury. A 6 km section of the river below the power station was inaccessible due to Hydro Commission works, and an attempt to traverse the 7 km from the eastern shores of Lake Burberry to the Precambrian was aborted due to shortening days and a deterioration in weather conditions in the area.

Previous mapping in the area is by Calver et al. (1987) and Baillie et. al. (1977) in the 1:50,000 geological map series. The structural history of the area is essentially the same as the D_1 to D_3 events described by Berry (1989, 1990) and Keele (1991) for Devonian fault movements in the Rosebery-Henty and Queenstown areas to the north: D_1 is an E–W compression, D_2 is a N–S compression and D_3 represents a brief return to an E-W compressive stress field. On the major faults, D_1 is a dip-slip movement and D_2 is a strike-slip movement, although a transitional phase where some D_1 faults are activated as wrench faults, rather than reverse faults, is generally recognised. Other work in the region includes a study of the mineralisation at Jukes Pty by Doyle (1990) and an honours thesis on the Miners Ridge basalts by Dower (1991).

On the basis of structural style, age and rock type, the section has been broken down into four distinct elements, or domains, which include the following:

1. *The Western Cambrian Succession,*
2. *The Western Graben,*
3. *The Central Volcanic Uplift*
4. *Precambrian metamorphic complex.*

For the purposes of the report it is convenient to describe the structures of domains 1–3 in some detail, ignoring for the present the Precambrian because no field work was conducted there. The Central Uplift has been further broken down into three sections including the CVC, the Tyndalls and the contact zone between them, because of the marked changes in structural style that occur across this boundary. The Great Lyell Fault is described in some detail because of its importance as a structure controlling sedimentation and the excellent exposures of it between the Darwin and Crotty Dams; however, it is not put into a separate section because it is part of the wider zone of wrench faulting that occurs along the eastern side of the sub-cropping granite pluton.

WESTERN CAMBRIAN SUCCESSION

The western succession can be broadly sub-divided into three litho-facies associations: a lower *volcaniclastic sequence* comprising plag-phyric lavas and/or mass flow deposits grading upwards into shales, siltstones, laminated mudstones and black shales, and an upper *coherent lava* sequence comprising massive rhyolite to dacite lavas, with black shale bands at its base (Fig. 2). Although the base of the volcaniclastic sequence was not observed and the top of the lavas is a faulted contact, the true thickness of the western succession is probably not much greater than the 1250 m measured here. An allochthonous wedge of graded turbiditic sediments has been thrust up over the lavas from the east and probably represents a deeper water or basinward facies variant of the lower volcaniclastic sequence (Fig. 4).

The overall structure consists of a gently E-dipping monoclinal fold limb, which broadly reflects the shallow dips of the underlying mafic-ultramafic basement complex. A large-scale flexure in the sediments probably reflects faulting on the basement slab (Fig. 4); whilst a quarry on the side of the road (366500E, 5326960N) shows evidence of considerable bedding plane decollement structures with a dominant westward transport direction.

Approaching the major thrust plane the folds tighten up and the dips steepen considerably. In the railway cutting the thrust fault is 50–100 m wide and comprises anastomosing foliation surfaces, quartz veins and fibres, and slickensides. Two movement directions were observed including a sinistral and a reverse phase of movement, although their relative timings could not be determined.

All bedding-cleavage intersections in the western succession give sub-horizontal to gentle N-plunges, as do the poles to quartz veins in the lavas, indicating that the extension direction (σ_3) was approximately horizontal, paralleling the lineations and fold axes; whilst the principal compressive stress (σ_1) was directed ENE–WSW (Fig. 2). The dominant tectonic escape direction was, therefore, horizontal and parallel to the NW grain of the orogenic belt (compare this with the vertical escape direction for the Central Volcanic Uplift).

THE WESTERN GRABEN

The western and eastern boundaries of the graben are defined by the Teepookana and Mt Strahan Faults respectively — two major faults which together define the limits to the Zeehan-Strahan depocentre (Berry, this volume). Although the whole structure has dropped down by as much as 5 km in its central region, much of this is due to the accumulation of large thicknesses of Owen Conglomerate (up to 2–3 km) in the early Ordovician, thus probably at least half of this movement is taken up as early Cambrian growth faulting.

The core of the structure comprises two or three steeply NW plunging synclines bounded by normal faults, at least one of which — because of overturning in the Bell Shales and a westward dipping cleavage — has been reactivated as a high-angle back thrust during the Devonian (Figs 2, 4). The position of the backthrust has been controlled by the base of the thick pile of Owen Conglomerate which sits up against the Tepookana growth fault (Fig. 4). Fibres developed in a satelite fault immediately to the east of the Teepookana Fault (loc. 370250, 5327700) give normal and dextral sense of movement indicating that the region behind the backthrust had experienced extension. Note that the forward (i.e. west-directed) thrust is also controlled by the base of the growth fault; as a consequence this thrust surfaces in the Cambrian volcanics further to the west.

A large block of west-facing Cambro-Ordovician siliciclastics, which is overturned at its base exposing a slice of Tyndall volcanics in its core, represents the eastern margins of the Zeehan–Strahan depocentre. The Mt Strahan fault had a similar history to the Teepookana Fault, beginning life as a forward (i.e. W-directed) thrust and then being reactivated some time after the initial compressive pulse as a backthrust. The Mt Strahan Fault, however, was a weaker forward thrust than its counterpart on the other side of the graben, because there was no obvious place for it to sole into. The most likely place to the east was occupied by a Cambrian granite at the time. Consequently, backthrusting is well developed on the Mt Strahan Fault (e.g. at Harveys Creek: loc. 375760E, 5333600N). It probably also originated at the base of the Teepookana growth fault.

CENTRAL VOLCANIC UPLIFT

The central volcanic belt, although asymmetric with respect to the volcanic and sedimentary sequences, has a broad central uplift flanked by two synclines whose cores contain Siluro-Devonian strata (Fig. 4). The whole superstructure, which is underpinned by a Cambrian granite, comprises a number of anticlines and synclines developed between the Mt Strahan Fault and the Tyennan Block, indicating that the shortening across this part of the section is taken up by folding rather than faulting. An interpreted flower structure defines a zone of D_2 wrenching on the eastern side of the granite. The normal faulting above the tip of the granite (Calver et al., 1987) is shown here as an integral part of the the wrench fault, but equally it can be seen as due to stretching over the apex of the granite pluton.

The Great Lyell Fault (GLF) marks the eastern edge of the Tyndall–Murchison Late Cambrian depocentre which thins rapidly eastwards against the Precambrian terrain.

Central Volcanic Complex

The central part of the MRV, dominated by a 2 km thick sequence of vocaniclastics and coherent lavas, is well exposed on the Jukes Rd. The volcaniclastics are folded into a S-plunging syncline (52 towards 158), whilst the underlying lavas were tilted (and now young and dip) towards the NW, having suffered rigid block rotation during the folding (Fig. 3). The boundary between these two domains is a fault zone, exposed as a shale band on both sides of the road; on the western side of the fault the bedding/cleavage intersections plunge to the south, whilst on the eastern side they plunge to the north, due to movement (and/or rotation) on a NNW trending dextral wrench fault.

The dominant form of faulting in this domain is strike-slip. Both sinistral and dextral senses of movement are recorded along NW trending faults and shear joints implying that the movements belonged to both the transitional D_1 and D_2 phases of deformation (Fig 3). The faults which penetrate upwards into the overlying Owen Conglomerate show normal displacement implying that extension accompanied the strike-slip movements (Fig. 4). In contrast, the kinematic directions recorded in the Tyndal volcanics on the western side of the CVC, including fault fibres and shear bands, all support the N–S D_2 compressive stress field as being the dominant one here (Fig. 3).

The eastern CVC–Tyndall contact

The eastern contact between the coherent CVC lavas and the Tyndall Group volcanics is interpreted to be a faulted one; this is mainly because the style of faulting changes from strike-slip in the CVC to dip-slip in the Tyndalls. Therefore, using a strictly geometric criterion, and no other, there has to be a fault on such a surface. However, there is also a facing change from westwards to eastwards in the CVC lavas here, although where this change is, is hard to determine: it may be a fold which developed over the tip of the intrusive Cambrian granite, which from the geophysical evidence is interpreted to come within 1 km of the surface (Payne, 1992), or it may be at the inferred fault. At Jukes Pty, the contact between the lavas and the thin overlying quartz-bearing volcaniclastics — normally taken as the boundary between the two formations — is conformable (K. Corbett. pers. comm., 1992) and may well be east-facing, although no reliable stratigraphic or structural younging features are present to establish this. Doyle (1990) made this boundary an unconformity, because of a quartz-bearing intrusive porphyry that is seen to cut both the lavas and the quartz-rich volcaniclastics. However, if the quartz-bearing volcaniclastics are interpreted as part of the CVC, then the true base of the Tyndalls lies further to the east and the presence of an intrusive porphyry cannot necessarily be used as an argument against a faulted contact.

East of the CVC-Tyndall contact (including the Great Lyell Fault)

The Tyndal Group correlates, and their conformably overlying Owen Conglomerates, form the two major rock units in this domain. All movements recorded east of what I consider the true base of the Tyndalls — the strongly sericitised, quartz-felspar-phyric volcanics located some 100 m to the east — are dip-slip reverse, or where the beds are overturned, dip-slip normal (Fig. 3). This dip-slip regime extends as far as the Great Lyell Fault where quartz fibres on bedding surfaces and tension gash quartz veins in the more brittle sandstone beds on the margins of the fault, give SW block down movements (Fig 5f). The fact that the the fault, together with the beds, is overturned indicates that the GLF is an earlier structure which was reactivated and partially folded and thrusted during D_1 and D_2. The lack of any evidence for E-directed thrusting precludes back thrusting as a viable mechanism of tectonic escape here. This is an example of an overturned thrust which literally collapsed under its own weight.

The GLF is exposed along the western shores of Lake Burberry over a distance of 5 km. On the Darwin dam road, it is a 50 m wide zone of cataclasis and anastomosing shears cutting through Owen Conglomerate and Gordon Limestone. Of particular interest is the silica flooding and boudinaging of the rounded to angular conglomerate fragments, some of which are up to 2 m across; these boulders retain a unique fracturing and have a yellow to brown colouration due to sulphidic alteration (Fig 5b). Good exposures of the fault can also be found along the road to the Crotty dam. The 30–50 m wide fault zone comprises silica flooding in interbedded quartz-rich conglomerates and green sandstones of the middle Owen; also seen are quartz veins & fibres, fuchsitic alteration and a moderately well developed cleavage. In the peripheral regions away from the main fault, the pebbles are deformed with an elongation parallel to cleavage; however, closer in towards to the fault the pebbles are cut by a series of domainal fractures planes that are considered to be the precursor to a mylonite fabric (Fig. 5e). A particularly good outcrop between the roadway and the waterline, shows steep quartz fibres cutting strong horizontal quartz fibres (Fig. 5c). The horizontal fibres give no clear sense of movement suggesting that the GLF had experienced negligible strike-slip movements, an observation supported by the erratic distribution of fault fabrics along its length. In fact, the middle section of the fault, mid-way between the Darwin and Crotty dams, actually has its dominant fabric perpendicular to the fault plane; elsewhere it trends obliquely across the fault in sympathy with the NNW trending regional Devonian cleavage to suggest that there was some dextral reactivation along the fault (Fig. 3).

On the eastern side of the fault, below the base of the Crotty dam wall, a horizontal D_2 shear with slickensides, indicating transport of the top block to the north, is typical of the N-directed thrusts recorded along the Mt. Read belt as far north as the Henty Fault (Keele, 1991).

GRAVITY AND MAGNETIC PROFILES

In the initial modelling exercise, Payne (1992) described the main magnetic and gravity features of the King River section. The geological interpretation that he used has since been refined, and therefore a later version, which is an natural evolution of his figures 2, 3 & 4, is reproduced here as Fig. 6. The following extract has been reproduced verbatim from his report:

> "The major features of the observed magnetic section (Figs 2, 3 & 4) are the two symmetrical spikes of about 500nT: one just to the west of the measured section and one corresponding to the Mt. Jukes area, in the east of the section. The observed gravity signature consists of a –15 mgal trough in the west at Macquarrie Harbour, with a steady decrease in gravity to the east.
>
> The magnetic high to the east is probably associated with low density, high magnetc susceptibility Cambrian granite, intruding to a high level. A north-south ridge of Cambrian granite has been previously inferred for this area (Large,1988; Payne 1991) and mineralisation seen at Jukes Proprietrary is considered to be related to Cambrian granite intrusion (Doyle, 1990).
>
> The story at the western end is not so clear. The symmetrical magnetic anomaly is best modelled by an anticlinal basalt overlying mafic-ultramafic dunite which have been thrust under the Cambrian rocks of the MRV. However, the Tertiary graben of

Macquarrie Harbour results in an offset along the axis of this structure, and the infill by Tertiary and Quarternary sediments is inferred from the gravity low in the area."

The decrease in gravity towards the east coincides with a depocentre in which at least 2–3 km of Owen Conglomerate, and possibly more, have accumated in a rapidly subsiding basin against the Teepookana and Mt Strahan Faults (Berry, this volume). A sharp drop in the gravity corresponds to the position of the Teepookana Fault; however, thickened Owen Conglomerate alone cannot explain the almost continuous drop in the gravity to the 36 km mark, which appears to be most marked over the Mt Read Volcanics.

The problem of the disparity between the calculated and observed gravity curves on the eastern part of the section (Fig. 6) is overcome by bringing in low density Tyennan quartzites beneath the MRV (Payne, 1992). This has the effect of bringing the curve down virtually as far as one needs, depending on how far west this material is taken. The drawn section takes account of this by bringing in slice of Precambrian crust as far as the western depocentre. Exactly how this is to be done is a matter of conjecture, but it could be done by a series of low-angle normal detachment faults, one of which is shown in the Precambrian rocks on the eastern part of the section; or it could be done by a series of Devonian underthrusts, one of which is shown in the regional cross section (Fig. 4). However, a discrepancy such as this could also be explained a number of other ways: by a gross overestimation of the density of the MRV, a much larger granite body, or by the three dimensional effects of a body out of the plane of the cross section.

MINERALISATION

The two styles of sulphide mineralisation at Jukes Pty, one of which is related to K-spar alteration and the other to chloritisation, are epigenetic in style (Doyle, 1990). The alteration envelope transgresses stratigraphic contacts and the Cu–Au–Ag mineralisation which is related to chlorite overprinting occurs in chalcopyrite–pyrite–magnetite veins. The veins are fracture controlled and show evidence of movement much of which is of Devonian age and post-dates the emplacement of sulphides. Tourmaline is an early mineral phase at the Jukes Pty prospect, hence it is concluded that the first phase of mineralisation is genetically related to the emplacement of the Cambrian granite. Because of the strong structural reactivation during Devonian wrenching, the second phase may be a remobilisation of Cambrian metals during metamorphism and deformation.

DISCUSSION

Correlating the Miners Ridge Basalt with the basalts in the Sorrel Peninsular

The outcrop of the Miners Ridge basalt, which is interpreted to be part of the oceanic basement onto which the CVC and/or Yolande River sediments were deposited (Corbett, 1992), lies several kilometres to the north of the section (Fig. 1). It is a tholeiitic basalt with a basal cumulate zone that lies in the core of the Miners Ridge anticline (Dower, 1991). Coming south towards the King River section, an E-directed reverse fault on the side of the anticline cuts out the west limb, then the hinge until all that is left of this structure is the overturned W limb of the adjacent syncline underneath Jukes Peak (Fig. 4).

The Miners Ridge basalt has a low TiO_2 basalt phase similar to the moderately and highly depleted Eocambrian rift tholeiites at Double Cove on the Sorell Peninsular (Crawford et al., 1992); therefore, from a structural as well as geochemical point of view the mafic-ultramafic sheet, which is interpreted to underlie the western half of the section, becomes the obvious common source for these tholeiites. The structure that brings up these Middle Cambrian rocks is interpreted to be a Devonian backthrust soleling at the base of the MRV (Fig. 4); the basalts do not crop out on the King River section because of the higher structural levels achieved here.

Cambrian Granites

The Murchison granite, which is exposed in the Anthony tunnel, has strongly deformed margins (P. Abbott, pers. comm. 1992). Having visited the exposure in the tunnel, I believe that the granite was originally emplaced as a mainly conformable body (laccolith ?) within the Tyndall volcaniclastic sequence and was reactivated during Devonian compression; this had the effect of dragging the 25° S-dipping bedded volcaniclastics into a vertical, or steep N-dipping, attitude adjacent to the granite. On the King River section the granite appears to be a forcefully emplaced stock (ignoring for the present its N and S continuations) that dragged the strata up on either side. One of the problems with the Cambrian granites is that many of them are in fact granodiorites (e.g.

Murchison granite) and their densisties insufficient for natural bouyancy to take over during emplacement (contrast this with the Devonian granites). It is suggested that these bodies initially rose as stocks through the massive CVC lavas and then spread out laterally on reaching the bedded Tyndall volcaniclastics.

The Franklin metamorphics — A classic Metamorphic Core complex?

The foliations in the Precambrian terrain form a domal structure typical of metamorphic core complexes. If the effects of mid-Paleaozoic folding on the Precambrian rocks are removed, ie. the base of the Gordon Group is restored to the horizontal (Spry & Gee, 1964), the foliations still dip away from a broad open anticline of pre-Ordovician age. Therefore, it is possible that the fault separating the two metamorphic terrains is a low-angle detachment that juxtaposed rocks which originally occupied quite different crustal levels. Recent studies (Boulter,1989; Turner,1989) have recorded two identifiable metamorphic events in the Tyennan nucleus, namely one at 780 Ma and another at 620–540 Ma respectively; movements related to the latter were clearly active in Middle Cambrian times and it may have been one of the principal structures along which extension took place during emplacement of the Mt Reads volcanics.

CONCLUSIONS

The Cambrian-aged Western Succession, comprising a 1.25 km thick sequence of volcaniclastics and lavas, together with the adjacent graben of Cambrian to Tertiary age, is underlain by a slab of mafic-ultramafic crust that dips at a shallow angle towards the east. The Western Succession acted as a stable "foreland" block during west-directed Devonian foreward thrusting which was largely been controlled by the edges of a Cambro-Ordovician basin in which a thick sequence of Owen Conglomerate had accumulated. The Teepookana and Mt Strahan Faults, which define the western and eastern limits of this basin, were initially re-activated as W-directed forward thrusts during D_1, but were later during the same event overprinted by a series of E-directed backthrusts.

The central volcanic belt, comprising coherent lavas and volcaniclastics of the CVC and Tyndall Group correlates, is uplifted with respect to its two flanking synclines which are cored by Siluro-Devonian strata. It is underlain by a granite body whose placement is asymmetric with respect to the E and W verging thrusts which overlie it. Wrench faulting on the eastern side of the granite has produced a flower structure which has both positive (compressional) and negative (extensional) characteristics; normal faulting associated with this extensional regime occurs above the tip of the pluton in the Owen Conglomerate. The Great Lyell Fault, which can be seen as a 50 m wide zone of fault brecciation and cataclasis in Owen Conglomerate, is the principal structure along which D_2 reactivation has occurred despite the fact that only limited strike–slip movements are inferred.

The Tyennan nucleus which lies to the east of the Mt Read volcanic belt has, after the effects of Middle Palaeozoic folding are removed, a residual domal structure which is suggestive of a metamorphic core complex. It is speculated that the fault separating the high-grade garnet-bearing metamorphics from the rocks of lower metamorphic grade assemblages is a normal detachment fault related to Late Cambrian extension during the emplacement of the Mount Read Volcanics.

The mineralisation related to the Cambrian granite has a clear two-stage evolution; the first phase is potassium felspar-rich and probably related to the emplacement of the granite; the second involves chlorite overprinting, which may be due to remobilisation of the metals and sulphur during D_2 wrenching and metamorphism. The edges of the Strahan–Zeehan depocentre are favoured sites for circulating basinal and metamorphic fluids, e.g. the low-grade gold mineralisation near Harveys Creek along at the northern end of the Mt Strahan Fault.

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APPENDIX
Tabulation of Structural Measurements

	A	B	C	D	E	F	G	H	I	J	K	L
1	Field No	Rock Code	Easting	Northing	Bedding-dip	Bedding-dip a	Cleavage-dip	Cleav.-dip az	Lineation-plu	Lineation-az	Q/Vein-dip	Q/vein-dip az
2	1	6	375270	5329050	50	244					78	307
3	2	6	374770	5328530	78	284	82	282				
4	3	6	374360	5328470	78	228	87	210				
5	4	6	375210	5328880	36	272						
6	5	7	375380	5329240	39	253						
7	6	1	365240	5327290			80	224				
8	7	1	365010	5327350			84	250				
9	8	1	365450	5327240			56	109				
10	9	6	365700	5327110	13	117	67	88	17	179		
11	10	7	365860	5327010			86	230				
12	11	7	366000	5326940	21	83	74	74				
13	12	7	366175	5326940								
14	13	7	366300	5326950			62	44				
15	14	5	366500	5326960	23	57						
16	15	5	366600	5326980	26	278	83	222				
17	16	6	366800	5327110	31	246	72	252				
18	17	6	366860	5327210	55	267	81	242	7	149		
19	18	6	366950	5327280	41	79	81	61	12	147		
20	19	5	367060	5327360	11	360	74	282				
21	20	6	367350	5327210			86	277				
22	21	6	367600	5327100			70	267				
23	22	7	367710	5327120			64	267			79	167
24	23	5	367820	5327150	16	102	78	263	3	157		
25	24	6	368290	5326990	30	40						
26	25	6	368500	5326890	9	82						
27	26	6	368860	5326900	28	87	56	257				
28	27	6	368960	5326950	56	72	60	242				
29	28	1	369080	5327010	49	252						
30	29	1	369250	5327010							84	342
31	30	5	369420	5327000	62	66	78	239	12	152		
32	31	1	369420	5327220	46	247						
33	32	1	369390	5327530	66	45	78	52			64	4
34	33	1	369640	5327750	67	27						
35	34	1	369760	5327830	56	53					82	166
36	35		369830	5327850			62	79				
37	36	6	369870	5327860	66	47	59	42				
38	37	6	369970	5327880	68	47	79	61	49	344		
39	38	7	370250	5327700			79	56				
40	39	7	370360	5327560			42	224				
41	40	10	370880	5327670			80	244				
42	41	7	371420	5327390	64	359						
43	42	1	379460	5331000			81	236			60	32
44	43	1	379720	5330890			75	74				
45	44		379850	5330730	24	282	78	356			12	27
46	45	1	379910	5330330			39	67				
47	46	1	379900	5330120			64	32	16	72		
48	47	8	379930	5329800	67	100	66	22	41	112		
49	48	1	380280	5329980			79	62				
50	49	6	380390	5330060	56	122	71	212	65	142		
51	50	1	380390	5330260								
52	51	1	380500	5331000								
53	52	1	380610	5331330	55	152					24	252
54	53	6	373900	5328400	79	341	86	237	78	307		
55	54	6	373620	5328330	78	192	86	214	68	136		
56	55	6	373400	5328080	73	212	64	262	64	260		
57	56	6	373400	5327710	22	308						
58	57	6	373580	5327460	85	2						
59	58	6	373060	5327600	41	52						
60	59	6	372880	5327410	63	37						
61	60	6	372700	5327270	88	57						
62	61	6	372360	5327130	40	12	87	57	32	329		
63	62	1	380920	5331410	54	178					33	132
64	63	1	381030	5331590			82	57			27	226
65	64	1	381220	5331620	50	167	61	242				
66	65	1	381380	5331710			76	78				
67	66	6	381890	5331490	70	212	86	243	20	158	33	164
68	67	1	382540	5331370								
69	68	1	382750	5331330								
70	69	1	383170	5331230								
71	70	1	383540	5331130	85	117	85	266	72	191		
72	71	1	383840	5330760			72	267				
73	72	1	383880	5330590								
74	73	1	384510	5330200			76	253				
75	74	8	384700	5330330	85	220	63	227	17	308		
76	75	8	384800	5330240	74	74						
77	76	8	384850	5329400	72	37	83	47	48	323		
78	77	8	385220	5329000	65	222					62	67
79	78	10	385850	5326340								
80	79	10	385840	5326750	48	17	38	320			64	287
81	80	8	385790	5328020								
82	81	8	385900	5328280			37	147				
83	82	8	385640	5328780								
84	83	8	385640	5328950	35	12	48	182	5	96		
85	84	7	385590	5329510	50	252						
86	85	7	385600	5330660	72	252	48	222				
87	86	8	385530	5330530	63	237	45	233			78	62
88	87	7	385860	5331230	43	162						
89	88	7	385740	5331210								
90	89	6	374170	5328300	66	252						
91	90	6	374050	5328310	55	302						
92	91		377060	5334560	62	6	65	307	61	342	65	4
93	92		377100	5334710							72	107
94	93		377130	5334650	88	36					88	36
95	94		375770	5333620	75	297	82	282	62	357		
96	95		375750	5333440	65	124						

	M	N	O	P	Q	R	S
1	Q/fib-plu	Q/fib-az	Fault-dip	Fault-az	Move-plu	Move-az	Move/sense
2			50	244	50	247	NOR
3							
4							
5							
6							
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30							
31							
32							
33							
34							
35							
36			76	15	24	99	SIN/REV
37							
38							
39			85	55	65	133	DEXT/NOR
40							
41							
42							
43	29	207					
44							
45	83	231	43	216	41	196	REV
46	10	162					
47							
48							
49							
50							
51			63	153	50	101	
52							
53							
54							
55							
56							
57							
58							
59							
60							
61							
62							
63	72	312					
64	76	351	84	222	10	311	SIN
65			64	37	6	124	SIN
66							
67			67	63	4	334	DEXT
68			47	317	32	13	SIN/REV
69			88	210	5	120	DEXT
70			56	54	53	80	REV
71			61	52	60	73	REV
72			48	77	48	78	REV
73			67	72	67	72	REV
74							
75			50	267	48	243	NOR
76			32	257	31	244	
77							
78	44	237					
79							
80	38	102					
81							
82							
83							
84			15	247	15	252	NOR
85							
86			72	252	70	222	NOR
87			63	237	63	237	NOR
88							
89			25	22	20	60	NOR
90							
91							
92	36	75	44	182			SIN/REV
93			85	65			DEXT/REV
94							DEXT
95			65	184			
96							

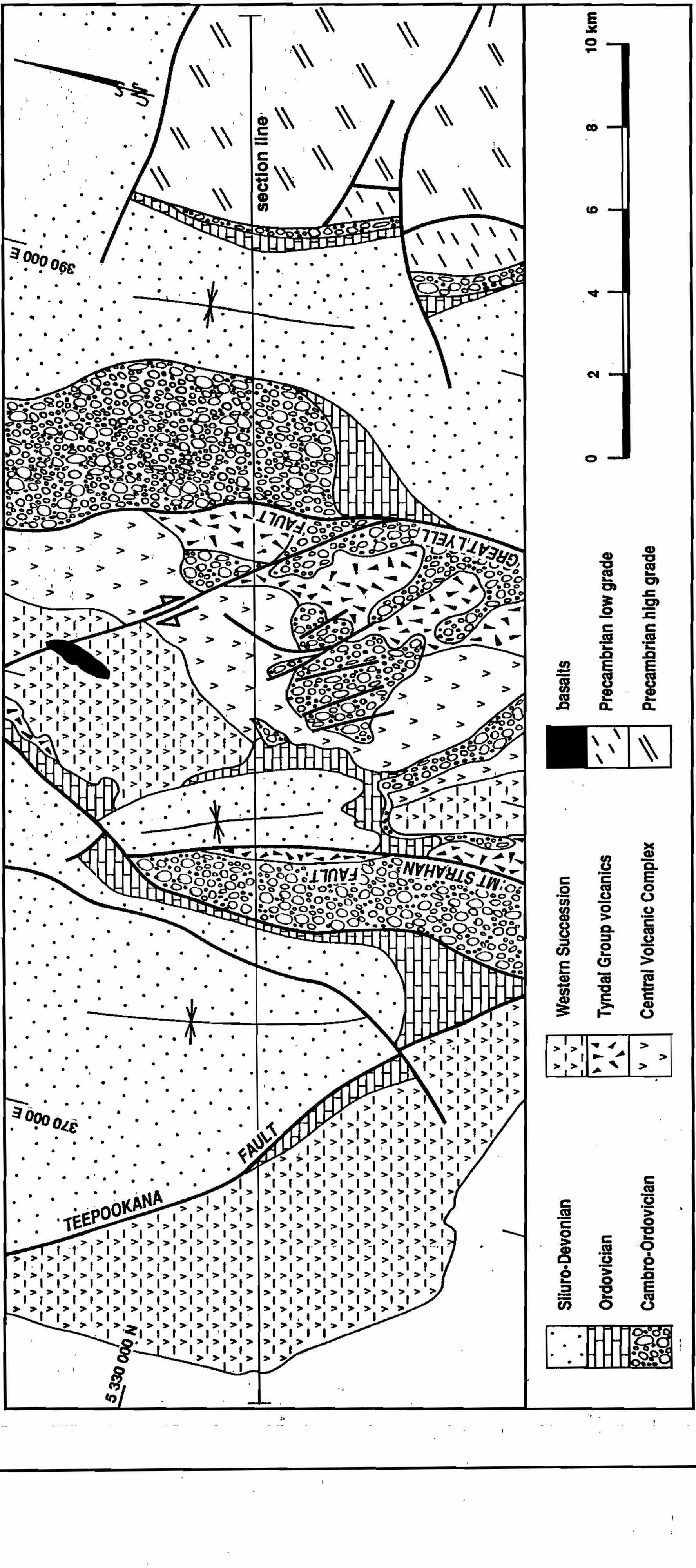


FIG. 1. Simplified map showing the position of the section line with respect to the geology and major faults (modified from Corbett & Mc Neill, 1988).

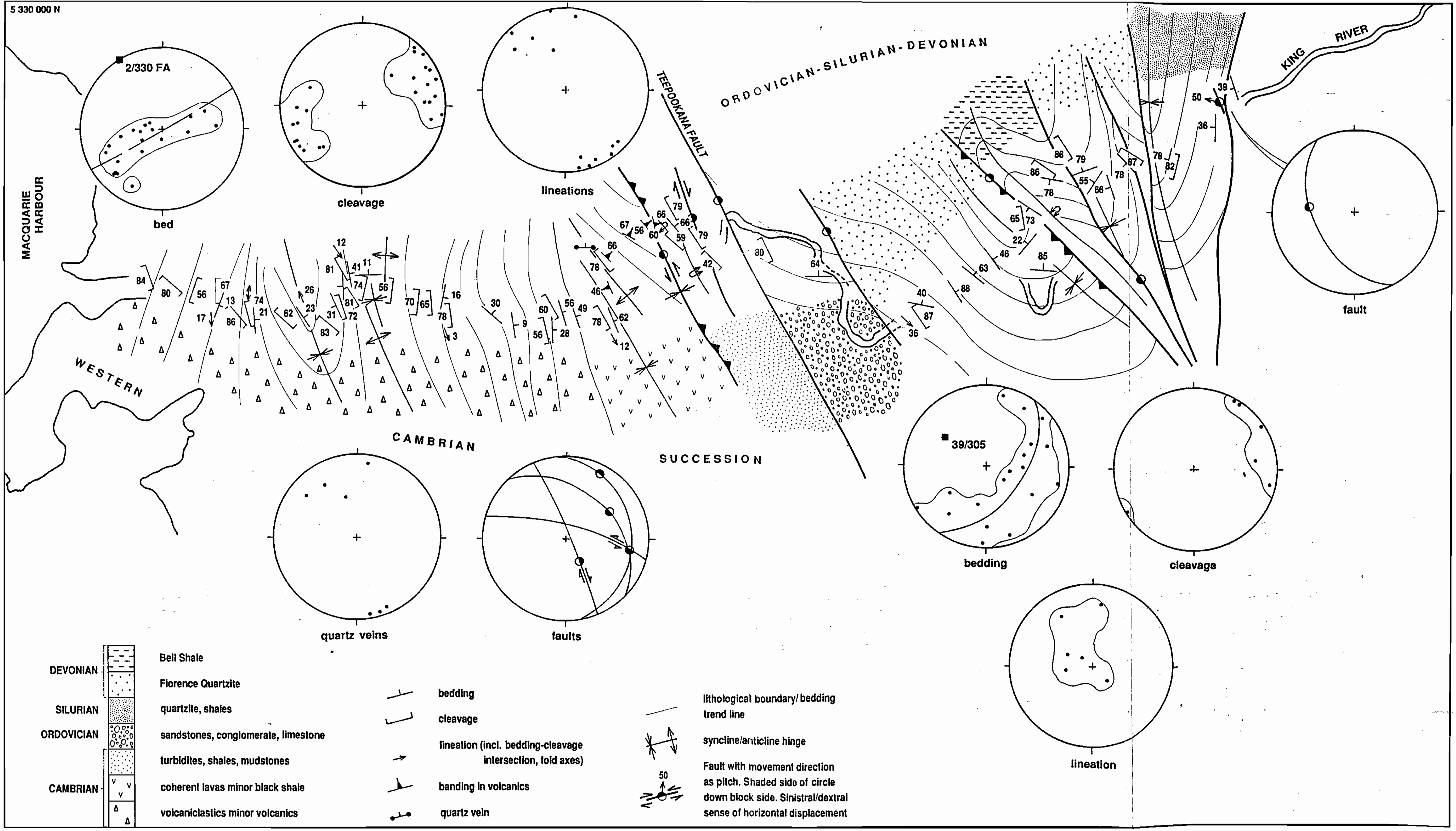


FIG. 2. Plan showing the structures recorded on the banks of the lower King River, from the western end of the regional section. The Teepookana Fault marks the western edge of the Zeehan-Strahan depocentre.

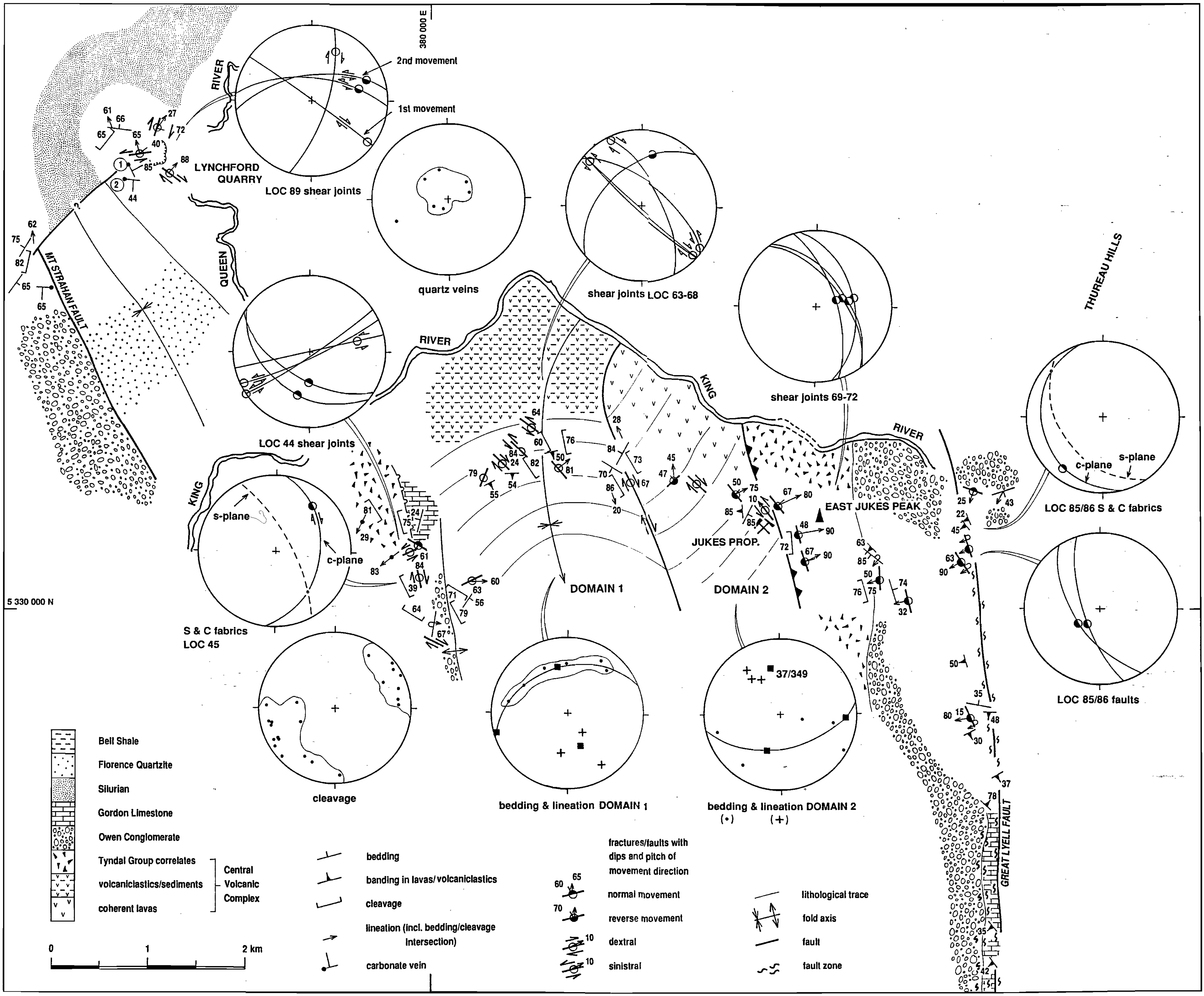
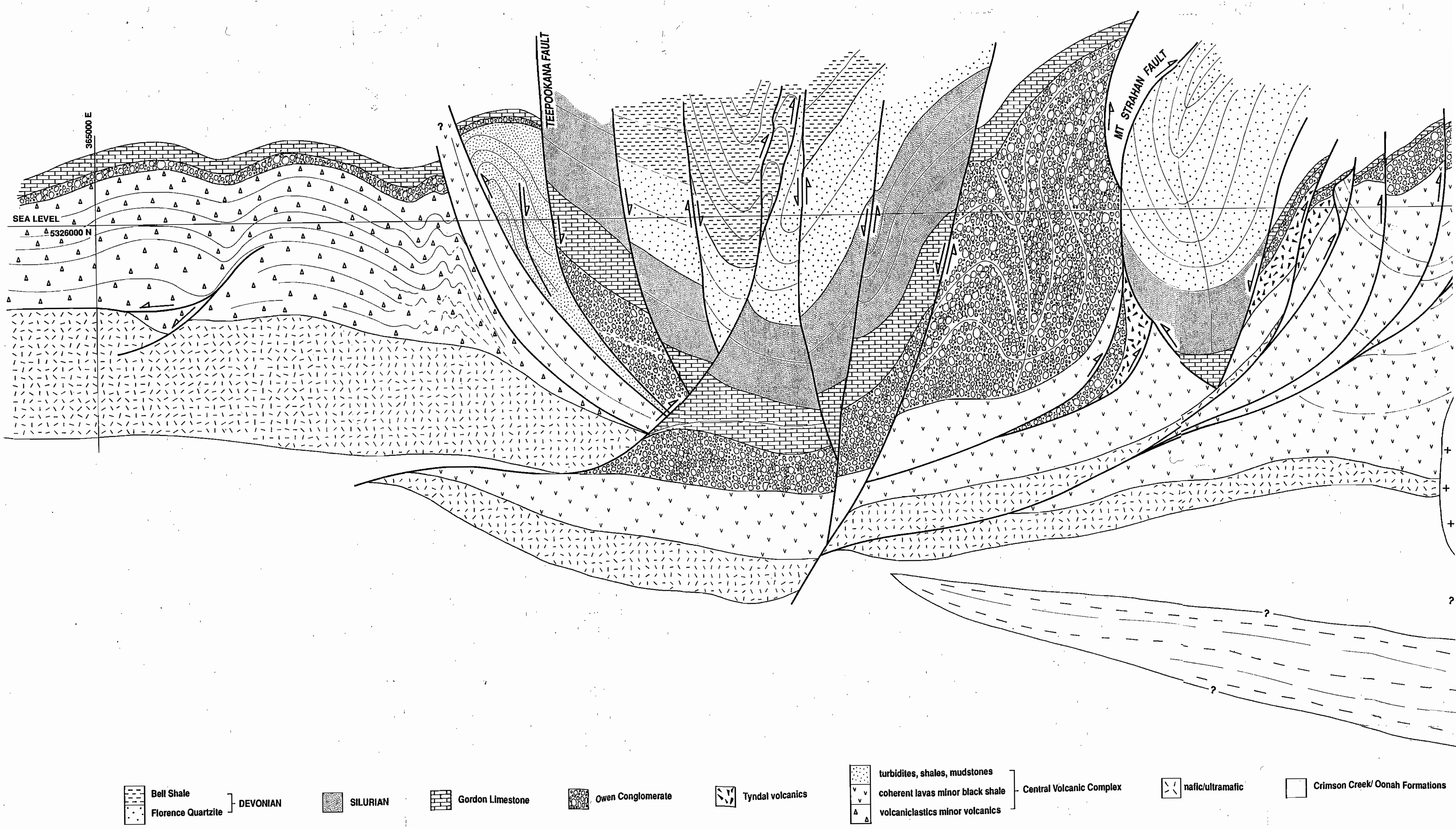
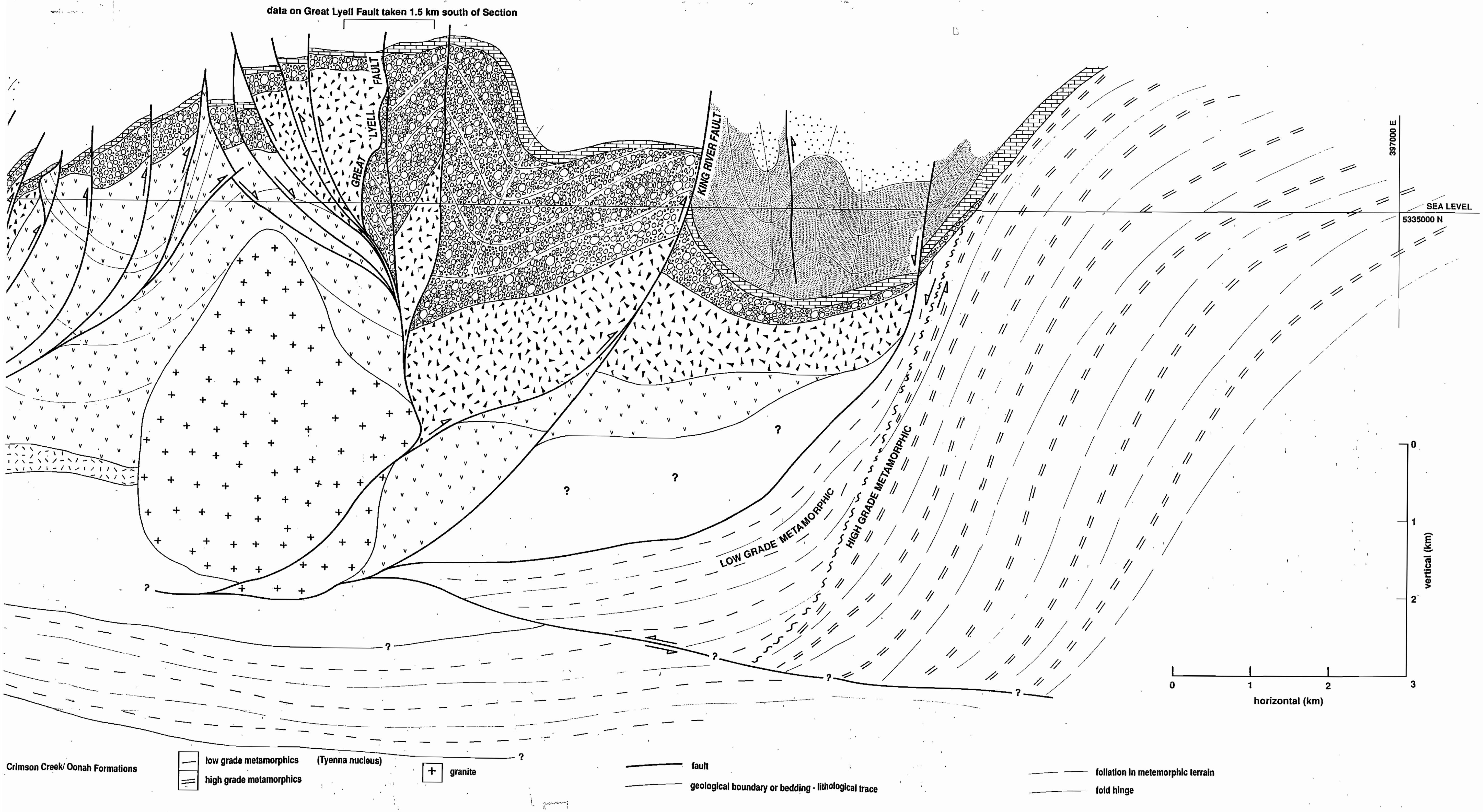


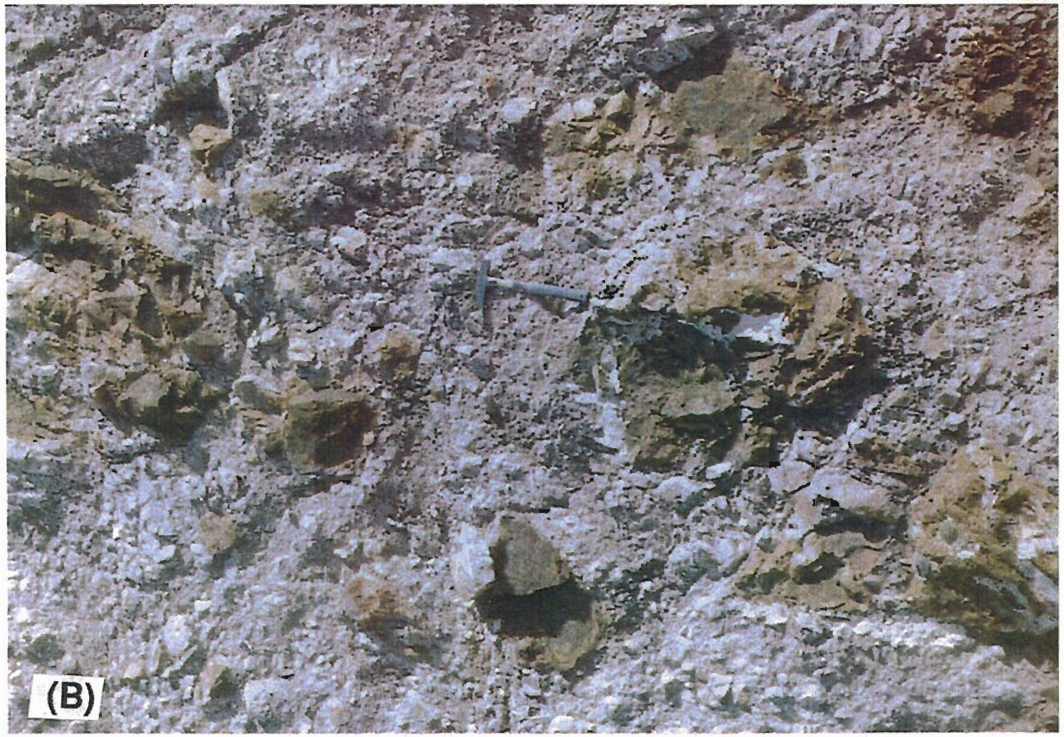
FIG. 3. Plan showing the structures recorded in the Central Volcanic Uplift, from the Mt Strahan Fault to the Great Lyell Fault. The Lynchford quarry in the NW corner shows a late-stage sinistral reactivation related to D3, an event recognised in the Cape Horn area, Mt Lyell by Cox (1981). Overturning associated with the Great Lyell Fault is demonstrated by the change in the sense of movement from reverse to normal when approaching it (the GLF) from the west. This change is due to overturning on the fault and is not due to any change in the absolute movement direction.

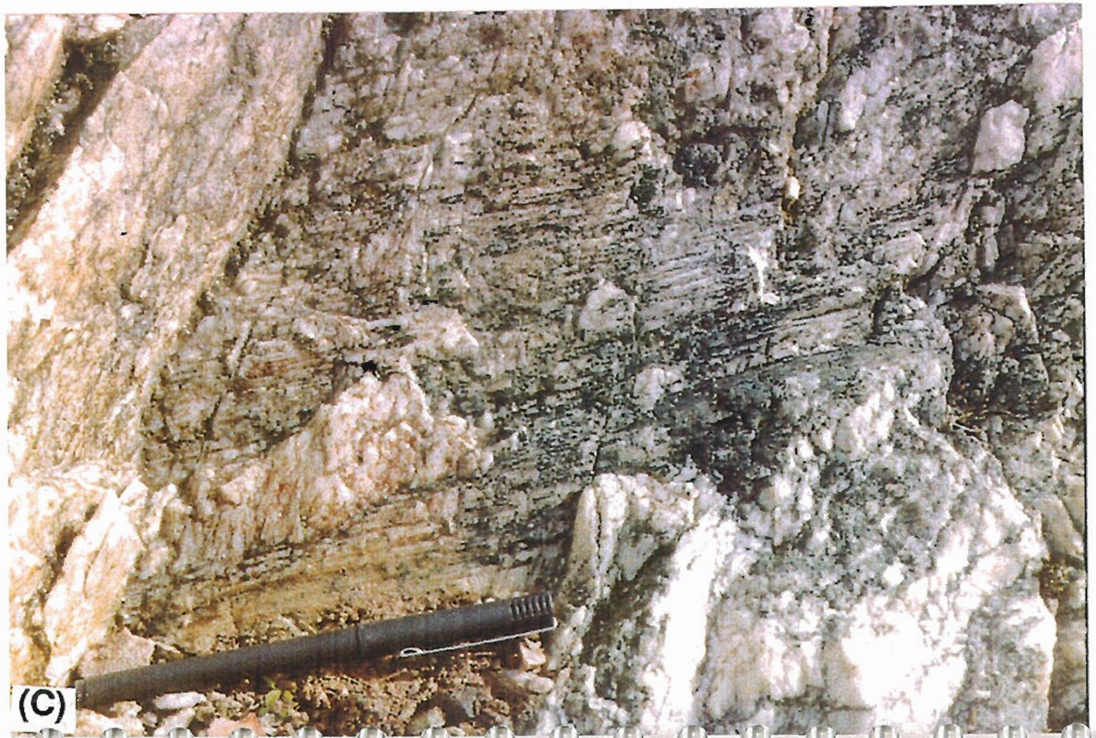
FIG. 4. *A regional cross-section through the Dundas Trough south of Queenstown. The major sub-divisions across the section are: (1) Cambrian Western Succession, (2) the Zeehan-Strahan depocentre which is bounded by the Teepookana and Mt Strahan Faults, (3) Central Volcanic Uplift, with its two flanking synclines, which is underpinned by a buried Cambrian granite and (4) the Precambrian Tyennan nucleus with its domal form due to Cambrian extension and Devonian folding. An unconformity of at least 30-40 degrees is inferred between the underlying volcanics and the Pioneer Beds above, and to the west, of the granite below implying Late Cambrian movements on the west side of the uplifted central volcanic belt. A deep seated W-directed thrust has been inferred to bring low density Precambrian rocks in beneath the CVC; this is one possible way of explaining the abnormally low gravity anomaly across the entire Central Volcanic Uplift. The majority of data needed to construct this section were collected by the author, however, certain parts of the section, eg. at Mt Jukes and east of the Great Lyell Fault, were drawn by using data from Calver et. al. (1987).*




data on Great Lyell Fault taken 1.5 km south of Section
GREAT LYELL FAULT
KING RIVER FAULT
397000 E
SEA LEVEL
5335000 N
?
LOW GRADE METAMORPHIC
HIGH GRADE METAMORPHIC
0
1
2
3
vertical (km)
horizontal (km)
Crimson Creek/ Oonah Formations
low grade metamorphics
high grade metamorphics
(Tyenna nucleus)
+ granite
fault
geological boundary or bedding - lithological trace
foliation in metemorphic terrain
fold hinge


(A)


(B)


(C)

(D)

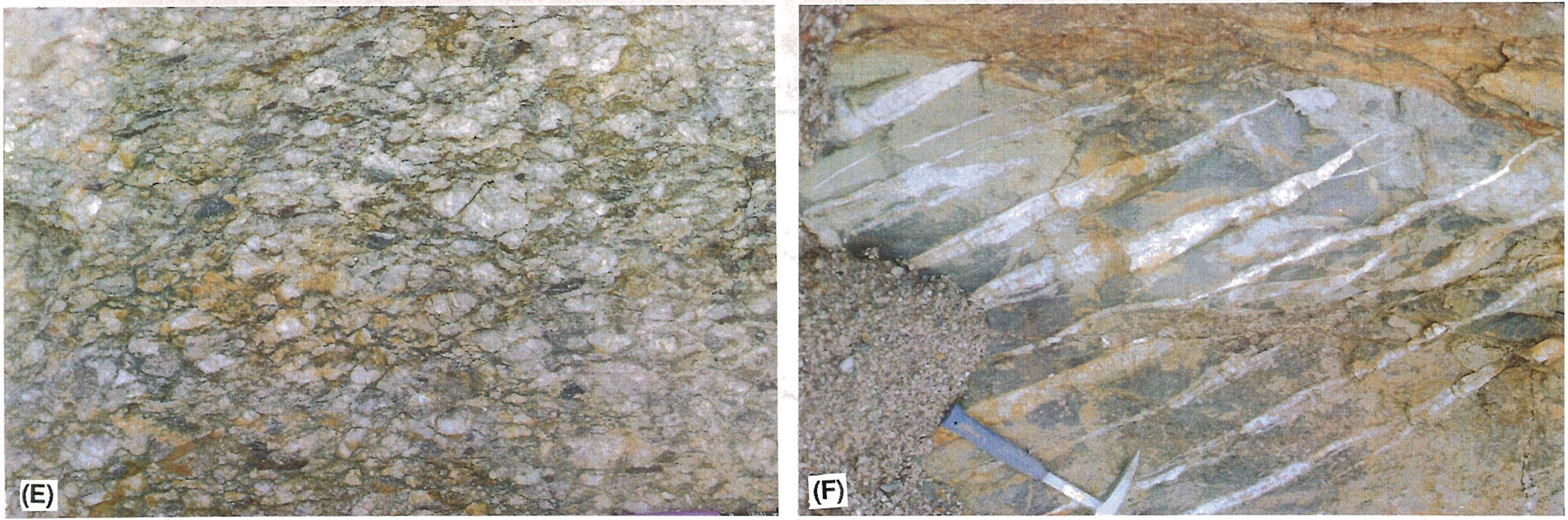


FIG. 5 Examples of Devonian reactivation on the Great Lyell Fault.

A The fault zone consists of interbedded conglomerates and green siltstones-sandstones of the middle Owen. The massive pink, heavily silicified conglomerates, in which irregular sets of quartz veins have developed sub-perpendicular bedding, are jointed and fractured on a metric scale. The green shaley beds are locally squeezed along these fractures in the early stages of boudinaging. Locality: Darwin Dam road.
B A classic fault breccia with variably sized blocks of silicified conglomerate. Sulphidic alteration of some of the larger clasts is shown by their yellow to brown staining. The matrix is a structureless cataclasite derived from conglomerate, sandstone and shale fragments. Locality: Darwin Dam road.
C Horizontal quartz striae from the main Great Lyell Fault being shown here cut by steep quartz fibres. Note that the abrupt termination of the striated surface by the coarse fibrous quartz, seen on the left-hand side of the photograph; the coarse fibres are clearly later than the striated surface. No sense of movement, however, can be discerned from these striae, meaning that these fibres represent an incipient tectonic escape event which never manifested itself as proper wrench faults. Locality: road to the Crotty Dam site.

D Overprinting quartz fibres on a bedding surface in the Newton Creek sandstones, from the Great Lyell Fault. Both sets of fibres give reverse movements — the first, clearly developed on the lower surface, is dip-slip whilst the second is oblique-slip. Although not shown in this particular photograph, but easily inspected in outcrop by the side of the Anthony road, the earlier fibres may be seen to curve in towards the overprinting fibres, indicating successive reactivations along a rotating fault. This outcrop demonstrates that the GLF was a significant backthrust in the Rosebery-Henty region but not as far south as the King River section. Locality: Anthony Road, near Henty turn off.
E Cataclastic textures in a deformed quartz pebble conglomerate which has been caught up in a higher strain zone. An elongation of the pebbles is noted as also are sets of anastomosing and intersecting fractures. Such textures are typical of in the transtion from cataclasites to mylonites. Locality: Crotty Dam road.
F En-echelon gash tension quartz veins developed in a massive sandstone layer adjacent to the fault. This photograph has been turned on its side and represent dip-slip normal movement on the bedding surface. When viewed in its correct orientation the photograph shows the base of a steeply W-dipping conglomerate layer (left) and E-dipping quartz veins. Such normal movements, which are fully supported by the quartz fibres, are used as evidence that E-directed back-thrusting did not occur on the GLF. Locality: Crotty Dam road.

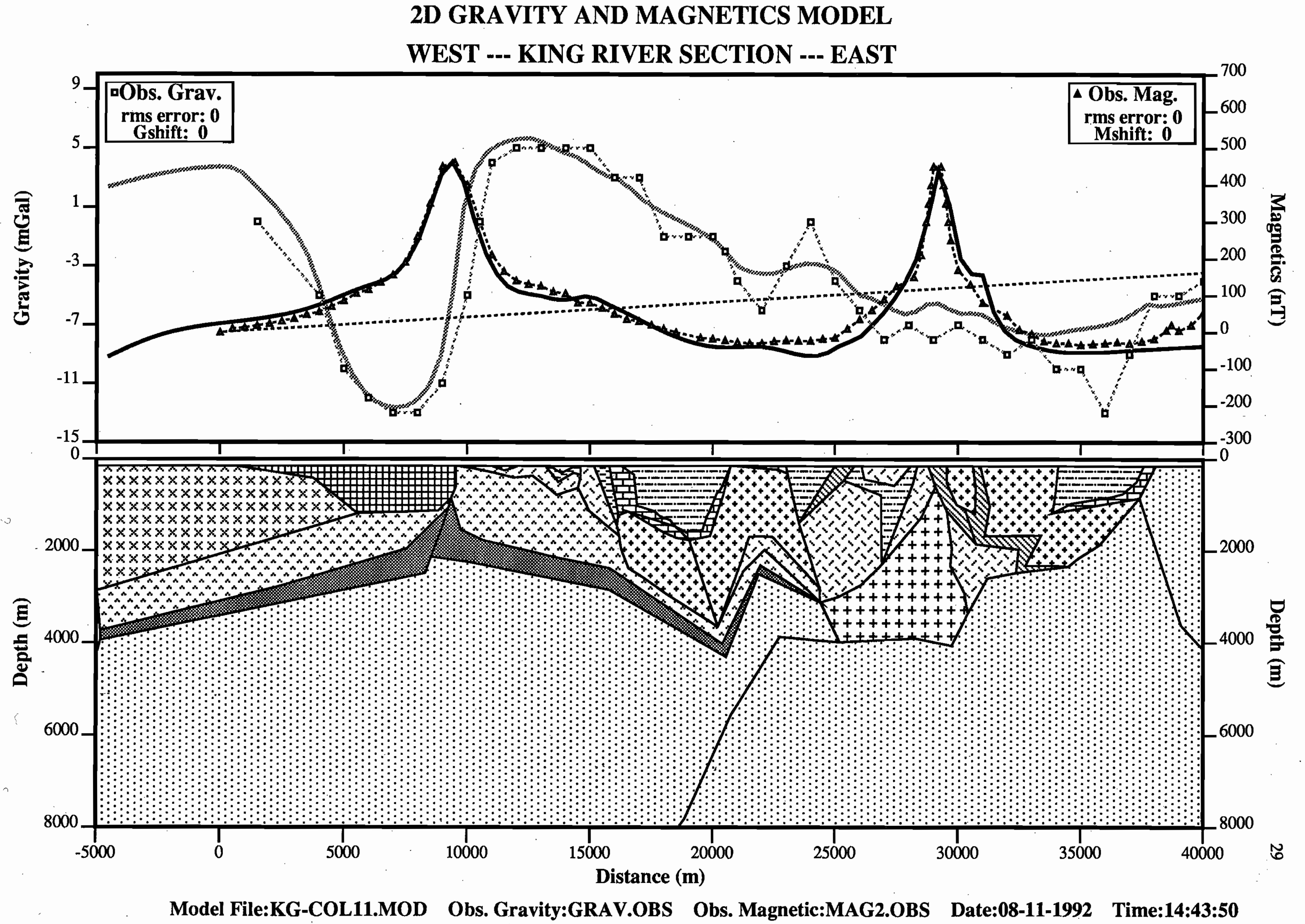


FIG. 6. Observed and calculated gravity and magnetic profiles across the King River section.

(For shading scheme details see next page.)

Shading Scheme

	Unit	Density t/m^3	Magnetic Sus cgs
▦	Unconsolidated Tertiary	-0.5	0.00001
▤	Siluro-Devonian sediments	0.02	0.00001
▦	Gordon Group	0.06	0.00001
⁘	Denison Group	-0.05	0.00001
▧	Tyndall Group	0.02	0.001
⋰	Central Volcanic Complex	0.01	0.0001
▤	Western Sequence	0.01	0.00001
^	Cambrian basalts	0.1	0.0002
▒	Dunite/serpentinite	0.01	0.01
+ + +	Cambrian granite	-0.03	0.003
⁙	Precambrian basement		
	western section (Oonah)	0.01	0.00001
	central section	-0.03	0.00001
	eastern section	-0.01	0.00001
× × ×	Unknown	0.0	0.0

FIG. 6 cont. Observed and calculated gravity and magnetic profiles across the King River section.

Strahan to Queenstown Structural Section

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ABSTRACT

The aim of this study was to complete the Strahan to Victoria Pass section by drawing a structural section from Strahan to Queenstown and describing the structural style in this western sector. There is an intense zone of E-W cleavage (S_2) for 2 km south of the Firewood Siding Fault which is dominated by south directed high angle reverse faults, transposed bedding and strongly disrupted lithologies. South of this zone the folding is superficially simple with upright folding but the F_1 fold has been strongly modified by the transecting S_2 cleavage event. The Teepookana Fault on the western margin of the syncline is interpreted as a major early Palaeozoic normal fault. The Miners Ridge Thrust is interpreted as a latest Cambrian (Delamerian) structure. The overall style of this sector differs from the northern sectors already described in that there are no major west directed thrusts in the section.

INTRODUCTION

A week was spent checking structural data along the highway from Queenstown to Strahan and three days were spent along the Queen River. The aim was to draw a structural section from Strahan to Queenstown which adequately displayed the structural style. The position of this section was a compromise based on the need to avoid the major E-W complexity of the Firewood Siding Fault and yet to tie in with the sections drawn east of Queenstown.

Based on the interpretation at Mt Lyell the section drawn from Cape Horn to the King Valley represents a zone north of the Firewood Siding Fault as it was before dextral faulting along the Glen Lyell Fault (Berry 1990, 1991). I have followed the section line in the original proposal for the AMIRA project despite this problem. Logically a section should also be drawn north of the Firewood Siding Fault but this has not yet been done.

The structural assessment is largely based on the structures measured in this program but the structural section and the distribution of lithologies depends heavily on the Strahan and Lyell 1:50 000 sheets (Baillie et al. 1977 and Calver et al. 1987).

STRUCTURAL STYLE

In order to understand the structure across this region it is necessary to subdivide it into several zones (Fig. 1). Firstly there is an intense zone of E–W cleavage (S_2) for 2 km south of the Firewood Siding Fault. This zone is dominated by south directed high angle reverse faults, transposed bedding and strongly disrupted lithologies (Fig. 2). In this zone all evidence of earlier structures has been erased by the late deformation. The significance of the Firewood Siding Fault has been discussed earlier (Berry 1990, 1991) and the main significance here is any east-west section must be drawn well south of this zone.

South of this zone the folding looks superficially simple with upright folding. However there is a great deal of variation in the structure. For example the fold plunge increases from north to south until in the King River the folds are subvertical (folds plunge steeply). Throughout, the dominant cleavage transects the major fold structure. The road follows the major subvertical eastern limb of the syncline. Within this zone there is a N striking cleavage (S_1) but the more common cleavage strikes NW and has a steeply N plunging bedding/cleavage intersection. The western limb of the syncline is partly overturned (Fig. 1) with the S_2 (NW striking cleavage) subparallel to bedding. This is a zone were the original east dipping limb has been rotated due to asymmetric tightening of the F_1 fold during D_2. This seems to be related to the effect of the Teepookana Fault Zone (informal name — see Fig. 1) on the fold profile. In the west, this zone of intense cleavage development and overturning moves away from the boundary of the Bell Shale Correlate suggesting it is being controlled by a fault a depth. This is an important point in the structural interpretation below.

Finally in the far west the structural style is simpler. The folds are upright and plunging N at 30°. The main cleavage still transects the fold but is weaker here. The anticline is visible in both the Cambrian volcanosedimentary package and in the Bell Shale. No substantial offset of this fold occurs across the Teepookana Fault Zone which appears to have a west side up movement. The fault cuts the road at 684E 297N. The exposure is poor at this locality but an intense cleavage zone dips 70° to the NE. This combination suggests a normal movement on this fault despite the overall compressional nature of the tectonics. Some of this normal movement may be post Devonian as indicated by the position of both Permian and Tertiary unconformity surfaces in this area. (At least 800 m of post-Permian displacement must occur between Victoria Pass and Strahan.) Faulting within the western zone is poorly exposed but there is evidence of dextral movement along the minor faults parallel to the Teepookana Fault.

This unusual structural relation suggests the fault zone may have an older history as well. The lithological distribution near this fault suggest it may be a reactivated normal fault. The Owen Conglomerate thins dramatically across the Lyell Fault and remains thin down the Queen River to Lynchford but then thickens dramatically to 2 km thick on Mt Strahan. A similar thickening or the Zeehan Conglomerate suggests a western depocentre for Denison Group sedimentation (Fig. 3). On this interpretation, the hinge for this thickening runs from east of the Professor Range to east of Mt Sorell (Fig. 1). Similarly the Gordon Limestone and the Silurian stratigraphy thickens dramatically up towards the Teepookana Fault. The Florence Sandstone also thickens to the south, suggesting the normal fault continued to be active until the Devonian. Unfortunately there is only circumstantial evidence that the Denison and Gordon Groups are missing west of the Teepookana Fault. Immediately NE of Strahan, and hidden by Permian stratigraphy, the Bell Shale lies directly against the Cambrian Dundas correlate. No exposures of Denison Group are known between Macquarie Harbour and the Teepookana Fault. The section through this area has been drawn assuming this fault was a growth fault throughout the early Palaeozoic based on this circumstantial evidence. Alternative interpretations require a west dipping Teepookana Fault inconsistent with the admittedly weak field evidence. The section on the King River (Keele this volume) has also been drawn with this model and is consistent with existing geophysical data.

QUEEN RIVER VALLEY

The Queen River from Lynchford to Queenstown follows along a strongly cleaved exposure of Gordon Limestone. The zone is dominated by a steep E dipping cleavage and a steep W dipping bedding. There is strong brittle overprint along this zone. For example at the Queenstown tip, strong wrench striations are visible in the Silurian. At Lynchford, there is a major limestone quarry in which three generations of fault are visible. The oldest is a rare normal fault striking EW and with down to the N movement. At a road cutting 1 km to the SE the early fault striations strike NNW and dips east with a reverse sinistral movement(Fig. 4). The second generation structures are dextral reverse faults on planes dipping steeply east and dextral faults striking ESE. These striations are consistent with the D_2 stress directions determined at Mt Lyell. The last generation are sinistral wrench faults striking 90 to 130. The first striations probably match D_1 Devonian with EW compression and are related to the cleavage. The second fit the strong dextral movement during D_2. The third generation striations indicated a return to EW compression as was also noted in the Tharsis Trough area at Mt Lyell and in the Renison area.

The area east of the Queen River has exposures of Miners Ridge basalt now considered part of the allochthonous mafic/ultramafic complexes (Dower 1991). The Miners Ridge basalt is exposed in a hanging wall anticline. The major thrust surface dips west at 30° and towards the north this surface is truncated by the Pioneer sandstone suggesting the major movement on this surface is pre-Ordovician. This interpretation has been included in the structural section. Unfortunately the exposures are sufficiently ambiguous that the major movement on this fault may be Devonian, especially if the Miners Ridge Thrust has a rotational component such that the movement is small near Queenstown and increases to the south. The brittle style of structures and lack of cleavage overprint at the exposure of this structure at 810E 373N lends some support to a Devonian origin. The unconformity at the base of the Pioneer Sandstone along the Queen River is the most convincing evidence that this fault is largely a Cambrian structure.

STRUCTURAL SECTION

The structural section (Fig. 5) has been drawn assuming the Teepookana Fault Zone is a major Palaeozoic normal fault and that the Florence Quartzite onlaps onto the uplifted block. This is supported by the changes in thickness of units noted above. The top of the Florence Quartzite has a very small net movement on the Teepookana Fault. On the section the total movement is less than 500 m, yet the displacement of the Dundas correlate is very large. The net movement of the Florence Quartzite suggests the reverse movement in the Devonian is no larger than the normal movement in the post-Permian. Again this suggests a growth fault in the Palaeozoic.

The major overturn limb suggests a large shortening in the section which is interpreted here as overlying a blind thrust. The presence of a large steep discontinuity on the Teepookana Fault and a good detachment surface (Gordon Limestone) has influenced the present interpretation. The shortening in the Florence Quartzite implied from this section is 14 km and to get a similar value for the Denison Group some major complication is required at depth. This is shown as a thrust cutting the Teepookana Fault just above the Owen Conglomerate.

The Mt Strahan Fault which is very strong in the southern section (Keele, this volume), is largely cut out by faulting up the Queen River before this section but an early part of this motion is represented by a folded pop-up (Fig. 5). The Queen River detachment has had many small movement but on this section no major offset is implied. The Miners Ridge Thrust is exposed on this section and is shown truncating the Central Volcanic Complex. The actual movement is not well constrained but as this fault brings up the Miners Ridge Basalt representing allochthonous mafic/ultramafic complexes it is shown as a pre-Ordovician detachment in the mafic/ultramafic complex and ramping through the volcanic stratigraphy to be cut of by unconformity at the Pioneer Sandstone.

SUMMARY

While the gross structure west of Queenstown looks superficially simple it is the result of a complex fold and fault history. Normal faulting was recognised along the Teepookana Fault zone. The first compressional cycle in the area was the Miners Ridge Thrust which brought exotic mafic complexes to the surface an produced steep dips in the Yolande River Group possibly as a ramp anticline. The distribution of Ordovician and Silurian units suggest the Teepookana Fault was reactivated as a normal fault after this event.

This was followed by an asymmetric F_1 fold plunging north towards a large transfer fault during D_1 Devonian. The D_2 Devonian produced and intense cleaved zone along the Firewood Siding Fault and further south the F_2 folds steepened the F_1 hinge to near vertical and further rotated the western limb of the F_1 syncline. Major east directed thrusting was probably a result of both events. There may have been early west directed thrusting as implied further south but this has been largely truncated by the later thrusts

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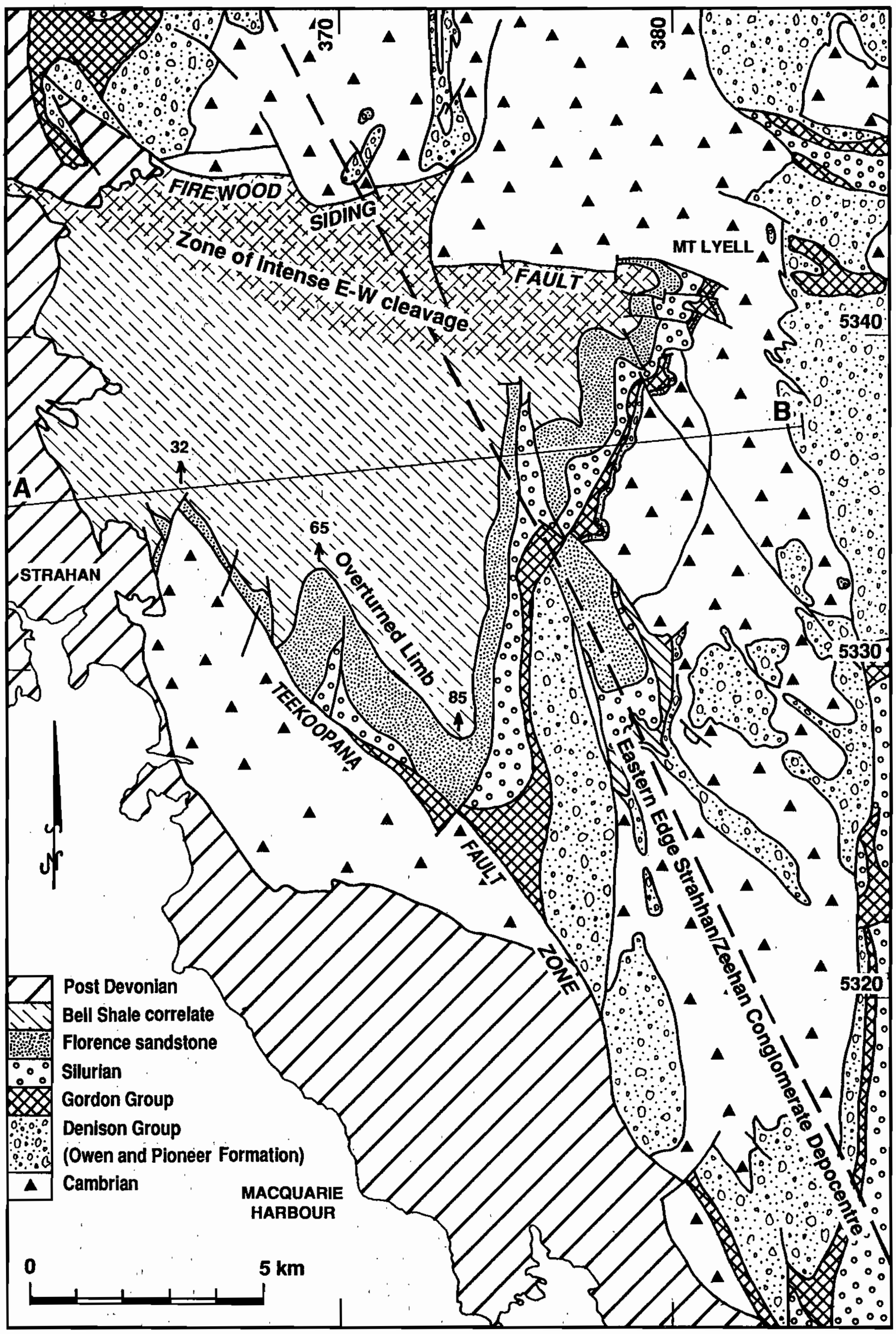

FIG. 1. Geological map of the Strahan area showing the location of the geological section AB and of other structural features discussed in the text. Geology is simplified from Corbett & McNeill (1988).

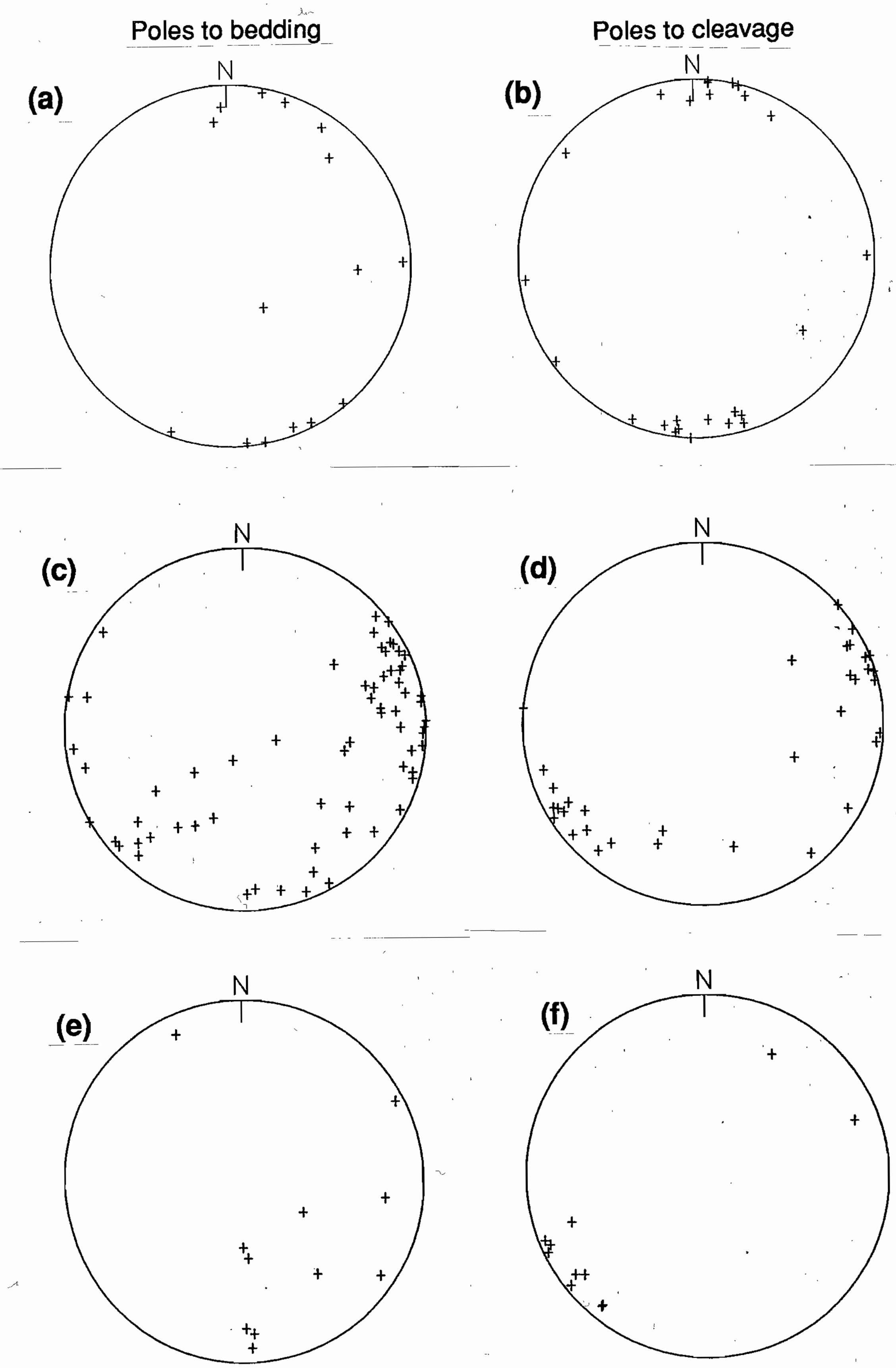

FIG. 2. Bedding and cleavage in the area west of Queenstown. Near the Firewood Siding Fault: (a) poles to bedding, (b) poles to cleavage. On the Strahan Road: (c) poles to bedding, (d) poles to cleavage. In the Queen River valley: (e) poles to bedding, (f) poles to cleavage.

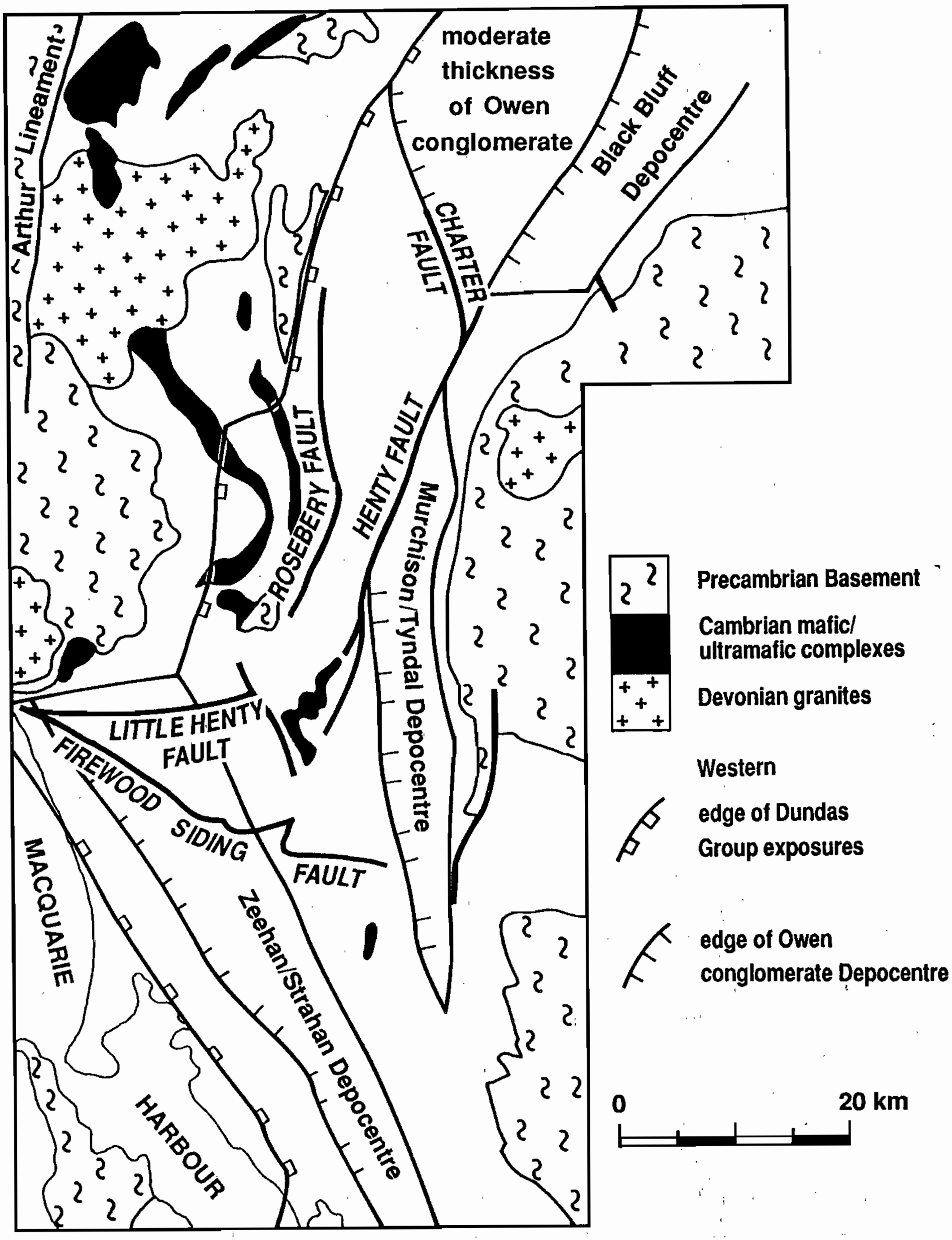

FIG. 3. Distribution of Denison Group depositional centres in western Tasmania.

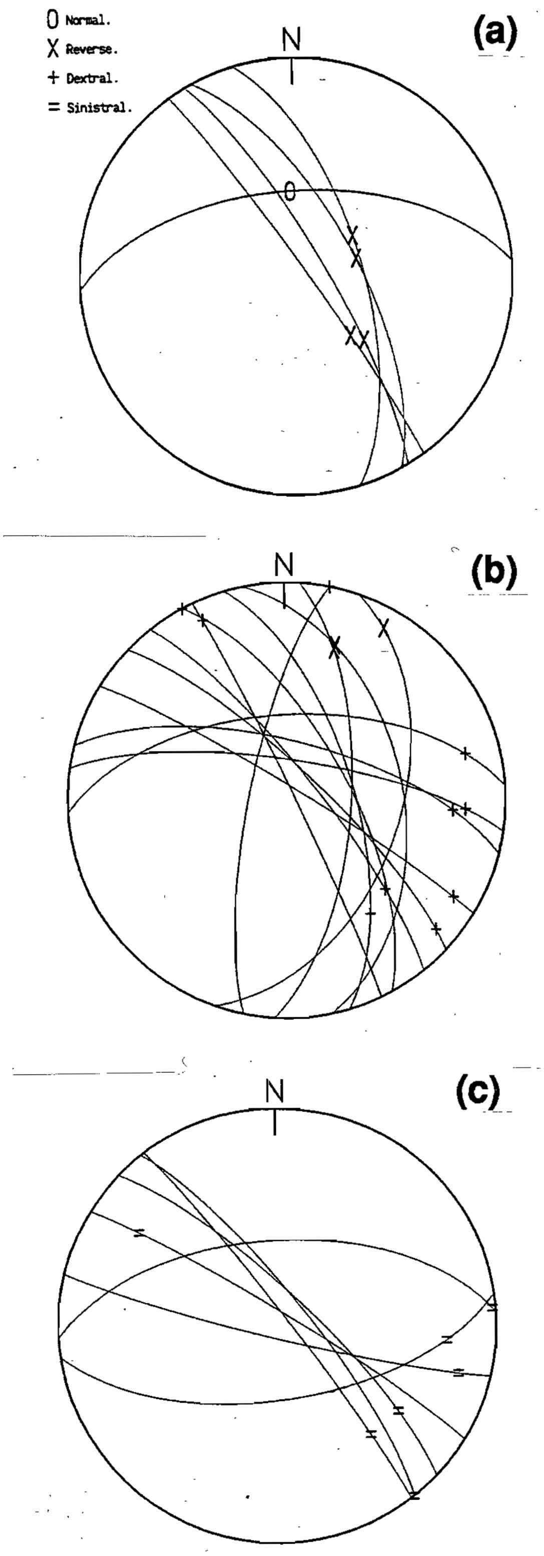

FIG. 4. Fault striation data from the Queen River valley including data from the limestone quarry at 772347 and a road cutting at 781341: (a) early (syn-D$_1$) fault movements, (b) syn-D$_2$ fault movements, (c) late sinistral fault movements.

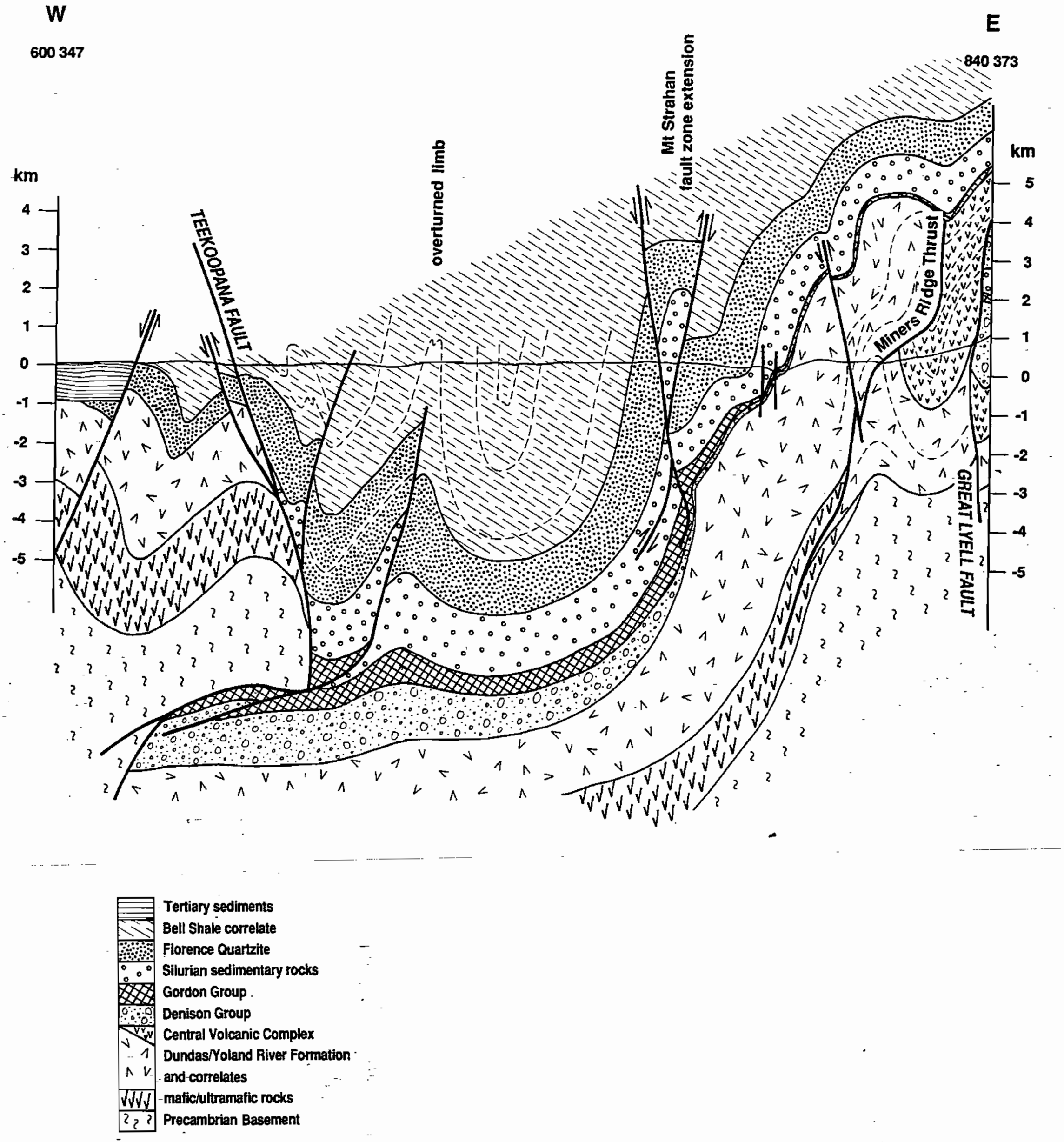

FIG. 5. Structural section from Strahan to the slopes of Mt Owen showing the structural style. Section assumes Teepookana Fault has an early normal fault movement. The section has been checked for bed length at the top of the Denison Group and the top of the Florence Quartzite. Shortening between the Teepookana Fault and the anticline at the eastern margin of the section is 14 km (47% shortening).

A Structural Cross Section through the Boco Road Area

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ABSTRACT

A westerly directed imbricate fan in the Boco Road Area is developed during Devonian compression along the Rosebery Fault. Due to the steep nature of the Rosebery Fault and competent lithologies contained within the hangingwall at this position, displacements are preferentially transferred to adjoining splays. In the footwall, this displacement is concentrated along a moderately steeply dipping frontal thrust, which cuts up through incompetent mudstones and siltstones to shear out the eastern limb of the Huskisson Syncline. The hangingwall of the Rosebery Fault is transected by oblique dextral shears, minor displacement on which results in a right-hand en echelon array of wrench folds.

The construction of an E-W balanced cross section through the region suggests 36% shortening, with 1km reverse displacement on the Rosebery Fault and 1.5km on the frontal thrust.

INTRODUCTION

The most conspicuous and well studied structural element in the Boco Road Area is the Rosebery Fault (Fig. 1). Its mapped extent has been traced in a NNE to NNW orientation from the Dundas Region in the south to Mt Pearse in the north. During Devonian compressional tectonism, it has been activated as a westerly directed thrust, with at least 1.5 km of displacement observed in the Rosebery region, where the fault surface dips at 40° to the E (Corbett and Turner, 1989). Displacement on the fault decreases rapidly towards the north, where the fault surface has steepened to 75° (Rattenbury, 1990).

This study aims to account for the northward change in geometry and kinematics of the Rosebery Fault, via the construction of an E-W structural cross section through the Boco Road Area (section line A–B). The basis for this section involves data collected from road cuttings and creeks during a two-week field period and the application of tectonic models inferred for the Dundas Region to the south (Selley, 1991). A 2-D geophysical model involving magnetic and gravity data is also presented (Section line C–D), developed largely through modification of a model by Payne (1992), which is used to constrain the geometry of structures and stratigraphic thicknesses at depth. Additional data and tectonic ideas are sourced from 1:25 000 and 1:50 000 mapping by the Tasmanian Department of Mines and work carried out by Rattenbury (op. cit.). As a result of this assimilation of data, the section presented in this report, although geometrically *viable*, lacks the stringent geological control to make it truly *balanced*. Further geological mapping is planned for the 1992/93 summer period, thus enhancing structural and stratigraphic control.

DISTRIBUTION OF LITHOLOGIES

The distribution of lithologies is shown in Fig. 1, where three broad litho-structural sub-areas are revealed:

1. An eastern domain composed entirely of mid-late Cambrian volcano-sedimentary rocks. The oldest rocks in this succession involve massive, flow banded and brecciated rhyo-dacitic lavas and interbedded sediments of the Central Volcanic Complex (CVC). Overlying this complex is the

Dundas Group, a sedimentary flysch sequence comprising coarse siliceous clastics and interbedded volcaniclastic units. Despite minor brittle disruption of beds and traces of haematitic alteration at the contact of the CVC and Dundas Group (this study), a conformable relationship is inferred (Corbett and McNeill, 1986).

2. A central fault bounded corridor dominated by late Precambrian-early Cambrian volcano-sediments of the Crimson Creek Formation. This formation is flanked to the NE and conformably underlain by a highly strained wedge of Precambrian Oonah Formation mudstones and quartzites. The latter comprise the oldest rocks in the region. The SW margin of the domain is delineated by a thin band of ultramafic rocks, dominantly serpentinite (Brown, 1986), which thickens northward to form two irregularly shaped lozenges at a bend in the bounding fault.
3. A western sub-area containing an essentially structurally conformable sequence extending from Oonah Formation to the Devonian Bell shale, the latter occupying the core of the Huskisson Syncline. It should be noted that apart from a small sliver of tuffaceous sediment to the SW of the Huskisson Syncline, the Cambrian volcano-sedimentary sequence is absent.

The entire stratigraphic package is floored by the Devonian Meredith Granite, which crops out in the NW of the study area. East of this position, the contact deepens rapidly to form a narrow trough beneath the Huskisson Syncline (Fig. 2) (Leaman, 1989).

CAMBRIAN EXTENSIONAL TECTONICS

Rattenbury (1990) suggests the development of a N-S trending graben bounded to the west by the Rosebery Fault and to the east by the Henty Fault, within which localised deposition of the mid-late Cambrian CVC and Dundas Group occurred. His evidence is based largely on stratigraphic control which suggests a dramatic thickening of the Dundas Group east of the Rosebery fault, possibly reaching 10km at Mt Pearse.

A detailed study of the movement history on the Rosebery Fault has not yet been undertaken by the author, however evidence in support of Rattenbury's model has been observed within both Dundas Group units and sedimentary horizons within the CVC. Such evidence includes ubiquitous normal microfaulting, mesoscopic synsedimentary graben development, numerous conglomerate lobes implying megascopic synsedimentary faulting, and the lack of significant thickness of the mid-late Cambrian succession in the Western Sub-area.

Although the author accepts Rattenbury's model in principle, two minor modifications are suggested. Firstly, the presence of thick units of coarse clastic material immediately to the west of the Rosebery fault implies significant synsedimentary normal movement on the structure west of the Rosebery Fault. This fault is therefore taken as the western margin of the graben. Secondly, a more conservative thickness of 7km is suggested for the Dundas Group. Any greater thickness would require an unrealistically large reverse displacement during inversion of the Rosebery Fault. Rattenbury's 10 km thickness in the north of the Huskisson-Que-Hellyer-Mackintosh Region may have been over-estimated due to stratigraphic repetition along inferred low angle structures to the east of the Rosebery Fault.

DEVONIAN COMPRESSIONAL TECTONICS

Domain Analysis

In many areas on the west coast of Tasmania, complex structural problems arise due to the juxtaposition of irregularly shaped blocks, each with its own distinct rheological properties and structural geometry. To analyse such complexities, a domain analysis approach is adopted, where domains are selected on litho-structural homogeneity. Initially, a study of the geometric relationships between structural elements is undertaken to assist with the interpretation of structural style within individual domain blocks. With an understanding of the internal kinematics of a domain, structural relationships between adjacent blocks may be determined.

A domain map and geometric data from individual blocks are presented in Fig. 3.

Domain I

This domain occurs in the south eastern corner of the study area, where it is bounded to the west by the E-dipping Rosebery Fault (dip: 75° NNE) and Domain II to the north. Lithologies involve rocks of the CVC, whose high degree of competency contrasts rocktypes in the remainder of the study area. It is therefore rheology that distinguishes Domain I from Domain II, the latter containing incompetent Dundas Group sediments.

The two dominant structural elements within Domain I include NNE trending folds, manifested in the N-propagating tongue of CVC and a NE-trending brittle-ductile shear zone, both of which are truncated to the west by the Rosebery Fault. Mesoscopic folding is rare, however planar fabrics including foliation, shear cleavage, riedel fractures, slip planes, veins and boundinage are ubiquitous, some of which are presented in a stereoplot (Fig. 3a).

The intensity of fabric development and alteration increases rapidly towards the NE-trending shear zone, which in parts approaches a width of 250 m. The geometric distribution of foliations, fractures and veins within the shear zone corresponds to that predicted by the Tchalenko Model (Tchalenko, 1970) for a strike-slip system with dextral offset and trend 045/80°E. Evidence for dextral shear sense is supported by slickenfibres on brittle slip planes and progressive clockwise rotation of veins. Moreover, the NE-trend of the shear zone coincides with the orientation of D_1 dextral features mapped in the Dundas Region (Selley, 1991).

Despite intense fabric development, however, significant offset is not recognised. It is possible therefore that the shear zone represents only the upper level expression of a deep seated pre-existing (?) basement structure. At this level a host of secondary structures would be expected, including riedel fractures, veins and en echelon folds (Harding, 1974).

The shear zone also forms the locus for migrating fluids, indeed the shear zone plays host for three of the minor mineral deposits within the area (Fig. 1). The most conspicuous alteration texture, however, is the development of ellipsoidal pods consisting of quartz and sericite. The long axis of these ellipsoids lies within the shear cleavage and they are connected by a series of oblique, synthetic fractures (possibly riedels). The existence of these opening fractures and foliation implies dilation of the shear zone at some time during its movement history.

Domain II

Domain II conformably overlies Domain I and also occurs within the hangingwall of the Rosebery Fault. It exhibits a succession involving dominant blue-grey laminated siltstone, minor volcaniclastics and coarse clastics and of the Dundas Group. This relatively incompetent, layered sequence promotes flexural slip folding as the dominant structural process, as indicated by bedding parallel slip surfaces with slickenfibres oriented perpendicular to fold hinges. Minor disruption of beds along the southern contact with Domain I may represent a detachment surface resulting from competency incompatibility during folding of the CVC-Dundas Group package.

Lithologies are folded by an open, upright syncline (F_1) which plunges moderately to the NNE (26^0 towards 033) and is truncated in the SW by the Rosebery Fault. The axial surface is steep, dipping either side of vertical, but on average to the west. Poles to S_0 are shown in Fig. 3c and exhibit a marked spread, with rotation of bedding increasing towards the eastern limb of the syncline. This spread of data reflects an asymmetric modification of the fold which appears greatest as the distance from the Rosebery fault increases. Similarly, S_1, which trends on average 029/87° W, exhibits a mild spread of pole data (Fig. 3d). The pole of rotation or *macrospin axis* for cleavage and bedding is coincident (76° towards 326) (Fig. 3e), implying that the mechanisms(s) which modified these elements was the same. Such mechanisms could include:

(i) *Refolding* ie. an unidentified post F_1 folding event. The lack of a regional post S_1 cleavage suggests that this would be a late stage, brittle event, possibly resulting in only localised modification of early structures.

(ii) *Fault Drag* associated with the NE-trending shear zone identified within Domain I, or associated structures. Pre-faulting F_1 structures would be rotated into parallelism with the dextral shear zone, causing modification to be concentrated along a narrow corridor adjacent to the fault.

(iii) *Wrench folding* ie. F_1 folds would be developed in the upper levels of a tectonic package in response to concomitant strike-slip faulting at depth.

Although none of these mechanisms are excluded, for the following reasons, wrench folding is considered to be important.

- The southwesterly abutment of folds against the Rosebery Fault in Domains I and II results in a distinctive right-hand en echelon geometry (Fig. 3). It is considered therefore, that the folds within the hangingwall of the Rosebery Fault are either generated via oblique shear on this particular structure, or by movement on oblique structures contained *within* the hangingwall itself. In no other domain in the study, however, is there evidence for oblique movement on the Rosebery Fault.
- The geometric relationship between the NNE-trending folds and the NE-trending shear zone is consistent with the model for dextral simple shear (Fig. 3g). As displacement increases on the shear,

the folds would rotate towards parallelism with the bulk shearing direction (i.e. in a clockwise fashion). In areas adjacent to the Rosebery Fault, however, structural elements may become "locked", inhibiting rotation, thus resulting in asymmetric folds where the degree of rotation increases away from the Rosebery fault.

- If the polarity of the NE-trending shear zone were to be reversed, ie. westerly dipping, the macrospin axis for S_0 and S_1 is seen to lie close to the idealised fault plane (Fig. 3e). This reversal of polarity may be permissible, as at upper levels of a strike-slip system an anastomosing network of shear zones, which may refract through layers of varying competency (i.e. CVC and Dundas Group) would replace a single principal displacement zone.
- The lack of significant offset on the NE-trending dextral shear zone within Domain I, may imply upper level strike-slip deformation, a regime in which wrench folds are ideally developed (Harding, 1974).
- An intimate association has been shown to exist between NE-trending dextral faults and NNE-trending folds in the Dundas Region (Selley, 1991).

The principal obstacle with the wrench fold model, is that it is necessary to demonstrate that growth of folds occurs as displacement is accumulating along adjacent strike-slip faults, rather at some other time (Little, 1992). Such evidence could include cleavage transection and progressive tightening of folds during clockwise rotation. Although neither features have been observed, the relatively fine grainsize of the sediments may be less prone to cleavage delay during folding than sand or conglomerate rich lithologies and consequently cleavage transection would not occur. In addition, minimal offset on the dextral structures would prevent significant frictional shear stresses to accumulate, impeding progressive fold nucleation and tightening.

It is recognised, however, that a regional D_2 phase involving N-S compression (Berry, 1989), is likely to have resulted in post-F_1 folding. Therefore, although wrench folding is preferred as a fold nucleation mechanism (based on geometric analysis), F_2 refolding cannot be excluded as a fold modification process.

Domain III

Domain III is a N–S trending corridor containing relatively coarse clastics of the Dundas group. Lithologies are not significantly different from those within Domain II except that larger volumes of grit and siliceous conglomerate are exposed. The eastern margin of this domain is delineated by the Rosebery Fault and likewise a steeply dipping fault marks the western boundary (Fig. 3). Although the western fault is poorly exposed, a tentative west-side-up sense of movement is interpreted from complex fault-related folding of mudstones in the hangingwall.

The overall structure is a close-tight, inclined syncline with an overturned E-limb. In contrast to the folds in Domains I and II, the fold axial trace parallels the Rosebery Fault and the plunge lies more than 20° anticlockwise of the former at 32° towards 004. The smaller interlimb angle and a more intensely developed axial planar cleavage suggests higher strains have been achieved in Domain III.

In accordance with Domain II, however, poles to S_0, which concentrate on the upright W-limb of the syncline, and poles to S_1 exhibit marked spreads (Fig. 3h, i). A coincident great circle defines the spread of S_0 and S_1, the pole to which pitches 69° towards 050 (Fig. 3j). Further evidence of fold modification is exhibited by the distribution of Li (Fig. 3k), which lie on a moderately steeply dipping N–S trending great circle.

An E-W trending, brittle kink generation, with only localised axial planar cleavage development is considered to represent F_2. The rotation axis for S_1 and S_0 lies close to the F_2 kink axis (Fig. 3), however more than 25^0 from the kink plunge. This removal from an ideal refolding geometry may be due a large variation in the plunge of the late stage brittle kinks.

F_1 folding is interpreted to have resulted from W-directed transport during reverse movement on the domain boundary. This sense of movement is supported by kinematic indicators from contorted black shales in the footwall of the Rosebery Fault. Unlike Domain II, folding in this domain exhibits a close geometric relationship with the Rosebery Fault, that is, a similar trend and a vergence which is consistent with the measured transport direction. Evidence of an F_2 kink generation, however, strengthens the notion that refolding played a role in the modification of F_1 structures in Domain II.

Domain IV

This domain covers the majority of the western half of the field area and contains the oldest rocks studied: Oonah and Crimson Creek Formations. Due to lack of outcrop, data collection was not sufficient to allow domain analysis.

Domain V

This domain occurs in the SW corner of the study area and comprises serpentinite after dunite-harzburgite (Brown, 1986). It forms part of an elongate belt consisting of small, isolated, lensoidal pods of sheared serpentinite, which flanks the eastern limb of the Huskisson Syncline (Fig. 1). It is suggested by previous workers (Brown (op. cit.), Corbett and Turner (1989) and Berry (1990)) that this belt of serpentinite is connected to the ultramafic body to the west beneath the Huskisson Syncline.

The northern margin of Domain V trends 294, and evidence from strike-slip duplexing, vergence of isoclinal folds and the geometric distribution of shear foliations (Fig. 3l) suggests sinistral strike-slip shear sense. This sense of shear is consistent with that characteristic of similarly oriented D_1 structures in the Dundas Region (Selley,1991). This consistency implies that the fault has not been rotated from its original orientation.

Based upon this lack of fault rotation and the huge discrepancy in serpentinite thicknesses either side of the Huskisson Syncline (W-limb: 1500 m, E-limb: <300 m) (Fig. 1), the author questions whether these two bodies comprise a single folded sheet.

Boco Road Section

The section line A-B was chosen due to its proximity to field stations in order to minimise inaccuracies due to projection. It extends eastward from the outcropping Meredith Granite to Burn's Peak (Fig. 1). The eastern half of the section is based on data collected during detailed field mapping (i.e. from Domains I–VI), whereas the western portion involving the Huskisson Syncline relies heavily on 1:25000 mapping by the Tasmanian Department of Mines. Inacuracies also result from the fact that complete, unfaulted sections of formations or groups are never encountered throughout the study area. This problem is partly alleviated via the construction of a 2-D geophysical model along an E-W section line (C–D), 7 km south of A–B (Fig. 4). In the Boco Region, the magnetic anomaly is strongly influenced by the positioning of the ultramafic sheet. If relatively uniform values for thickness (1–1.5 km, from 1:50 000 Corinna Sheet) and magnetic susceptibility (0.01 cgs, from Payne, 1992) are assumed, depth of burial of the sheet may be approximated, hence revealing the thickness of the overlying stratigraphic package. Thicknesses of individual formations and groups are then estimated from the published sections and maps which occur closest to the section line.

The geometry of major structures is based on the evaluation of structural style within each of the mapped domains, but also takes into account constraints imposed by section C–D and regional tectonic models. Moderate out-of-section faulting along NE-trending dextral structures is considered to occur east of the Rosebery Fault (based on analysis of Domains I and II), causing area balance during restoration to be questionable in this region. The sense of movement on all other major structures, however, is considered to lie close to or within the section line.

The restored section A–B is presented in Fig. 5. An overall imbricate fan geometry is revealed, where strain is concentrated internally within leading horses. The principal diversion from previously constructed cross sections in this region (e.g. Berry, 1989, p. 18), is the emplacement of the centrally positioned wedge of Oonah and Crimson Creek Formation above an easterly dipping frontal thrust, rather than a deep seated, W-dipping back thrust. Evidence in support of this interpretation includes:

- Mild westerly vergence of the Huskisson Syncline, which implies W-directed transport on the overlying thrust plane.
- Truncation of Gordon Limestone and sheared serpentinite on the eastern limb of the Huskisson Syncline, suggesting that the limb has been thrusted out.
- The magnetic anomaly over the E-limb of the Huskisson Syncline is compatible with a very thin sliver of serpentinite emplaced above an E-dipping reverse fault (Fig. 4). This body of serpentinite is therefore considered to be detached from the parent ultramafic sheet, emplaced as a thrust slice or strike-slip duplex.
- Consistency with current ideas on thrust kinematics. A moderately dipping frontal splay off the Rosebery Fault is more likely to develop than a deep seated back thrust in front of a relatively high level imbricate fan.

The Cambrian basin margin structure and the Rosebery Fault form the trailing thrusts of the imbricate fan. Their present steeply dipping geometries are considered to reflect original fault dips during early extension. Moreover, normal displacement on these structures results in juxtaposition of CVC and coarse clastics of the Dundas group with relatively incompetent lithologies contained in the Oonah and Crimson Creek Formations (Fig. 5b). During compression, therefore, steep fault dips and competency contrast will inhibit inversion of the early structures. As a result, strain will be preferentially taken up in the footwall lithologies of the basin margin fault as blind thrusts and associated tight folds, resulting in progressive rotation, steepening and probable back thrusting of the early structures.

An overall shortening of 36% is apparent, with 1.5 km reverse displacement on the frontal thrust and 1 km on the Rosebery Fault. Initial W-directed transport on the basin margin fault, followed by back thrusting due to rotation, results in negligible bulk displacement.

DEVONIAN GRANITE EMPLACEMENT

The positioning of the granite contact at depth is determined from the interpretation of gravity data by Leaman (1989). A trough is revealed beneath the Huskisson Syncline, which is defined to the west by a steep, 6 km high ridge and a 2 km rise to the east (Fig. 2). It would seem reasonable to suggest therefore, that the present geometry of the Huskisson Syncline is significantly influenced by granite emplacement. Structural thinning around the margin of the syncline, local steepening of the western limb and the doubly plunging geometry are considered to be directly related to normal faulting during development of the underlying trough.

CONCLUSION

A principal aim of this study is to better understand Devonian kinematics in the Boco Road Area. Particular emphasis is placed on understanding the way in which blocks behaved with respect to each other during reverse movement on Rosebery Fault. This aim is fulfilled via the analysis of structurally homogeneous domains and subsequent section balancing.

A dramatic thickening of the CVC and Dundas Group to the east of the Rosebery Fault implies considerable normal movement during mid-late Cambrian basin development. In the Boco Road Area, it is the geometry of Cambrian structures and the spatial relationship of stratigraphic units which controls structural style during Devonian compression. West of the Rosebery Fault, juxtaposition of rheologically incompatible blocks results in failure of incompetent footwall sequences and westward propagation of an imbricate fan. A zone of considerable lesser strain is developed east of the Rosebery Fault. In this domain, structures develop obliquely to the N–S trending thrusts and are apparently controlled by NE-trending dextral shear zones, which may connect with reverse structures at depth. A possible extensional component of shear results in dilation of the upper portions of these shear zones, promoting fluid migration, alteration and minor mineralisation.

It is not being suggested, however, that the entire length of the Rosebery Fault represents inversion of a single basin margin structure. Therefore it is stressed that this intimate relationship between Devonian thrusting and Cambrian extensional elements interpreted for the Boco Road Area should not be automatically implied to other regions of significant reverse movement.

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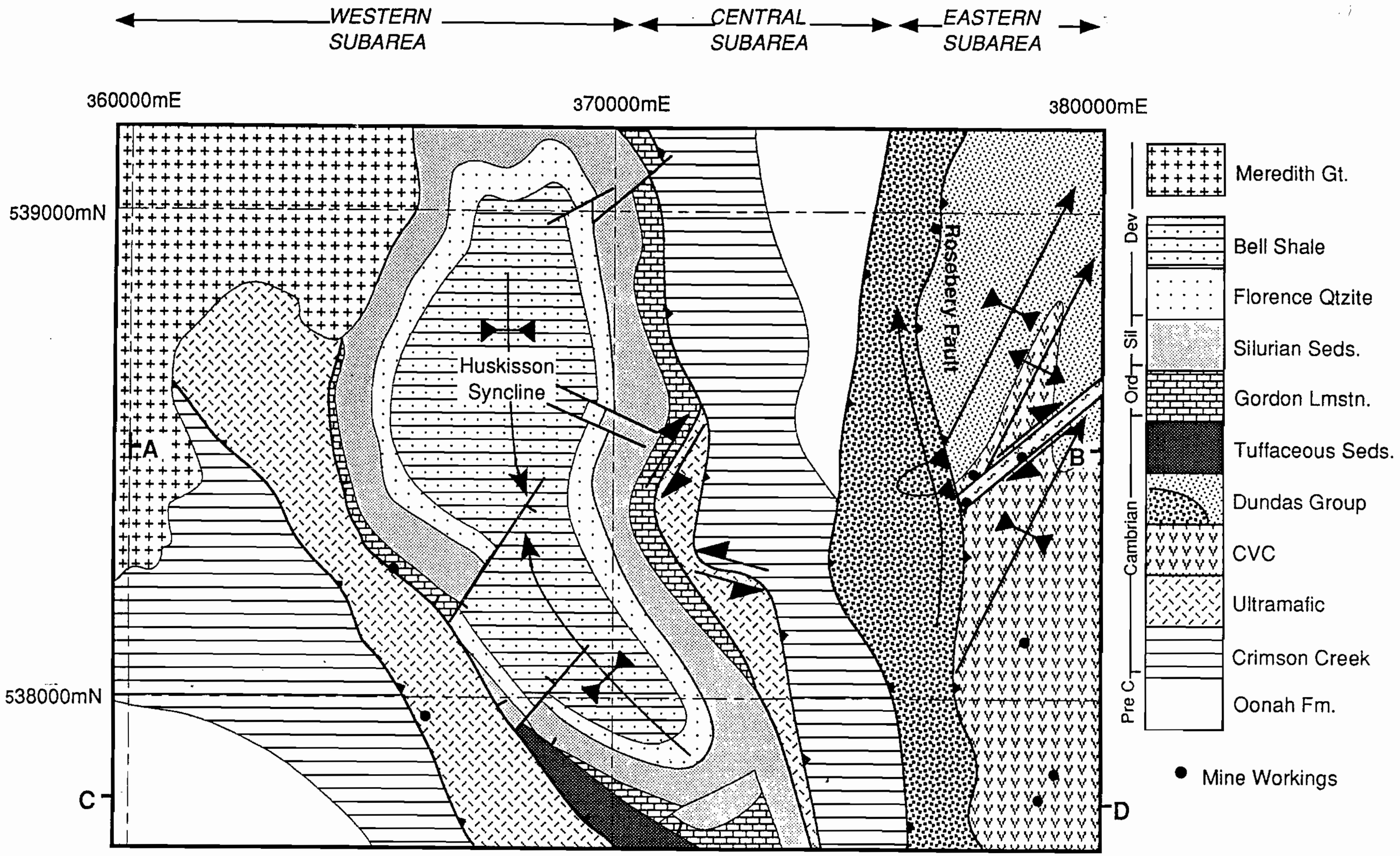


FIG.1 Geological map of the Boco Road Area. Complied using data from this study, Corbett and McNeill (1988) and Turner et. al. (1991)

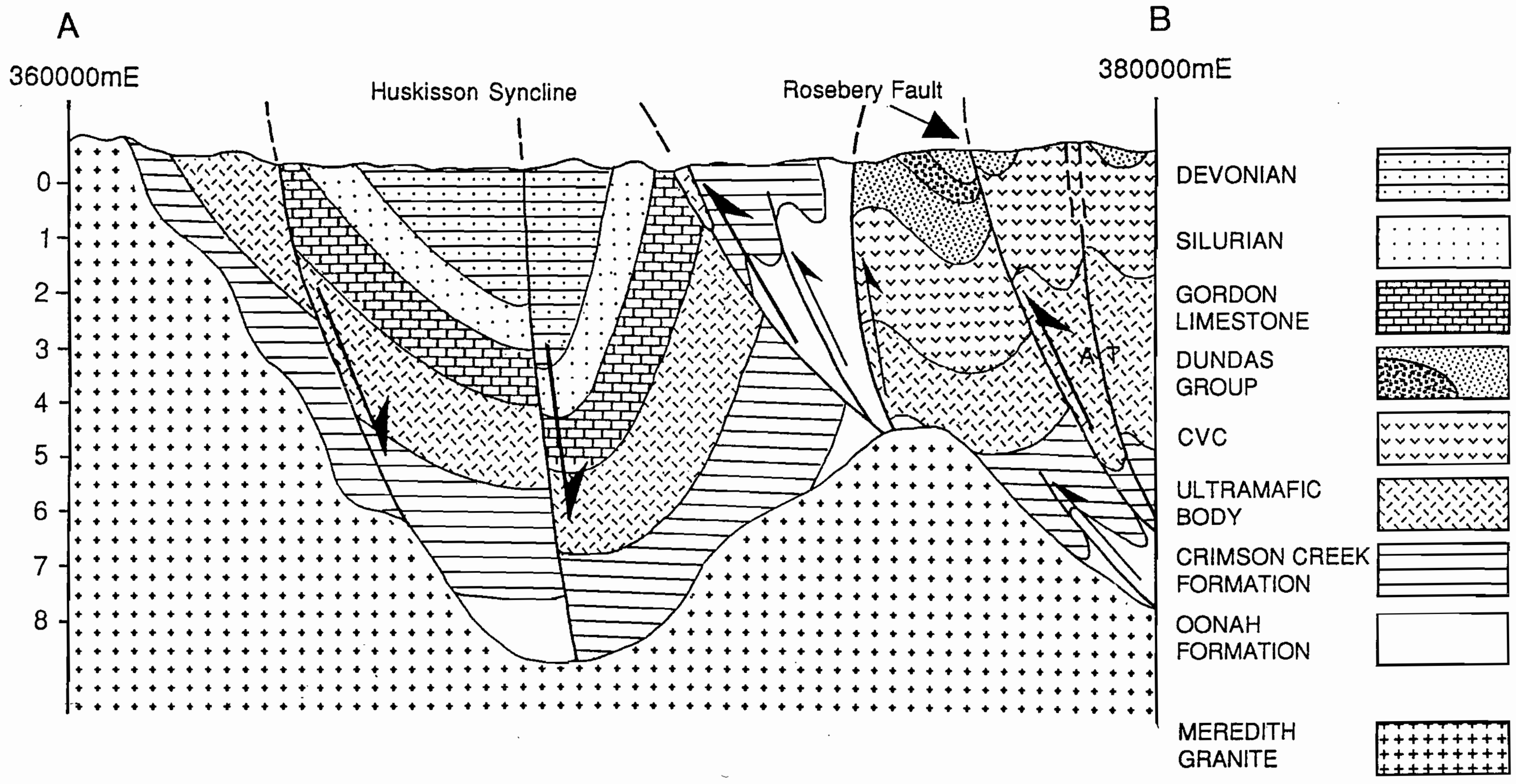
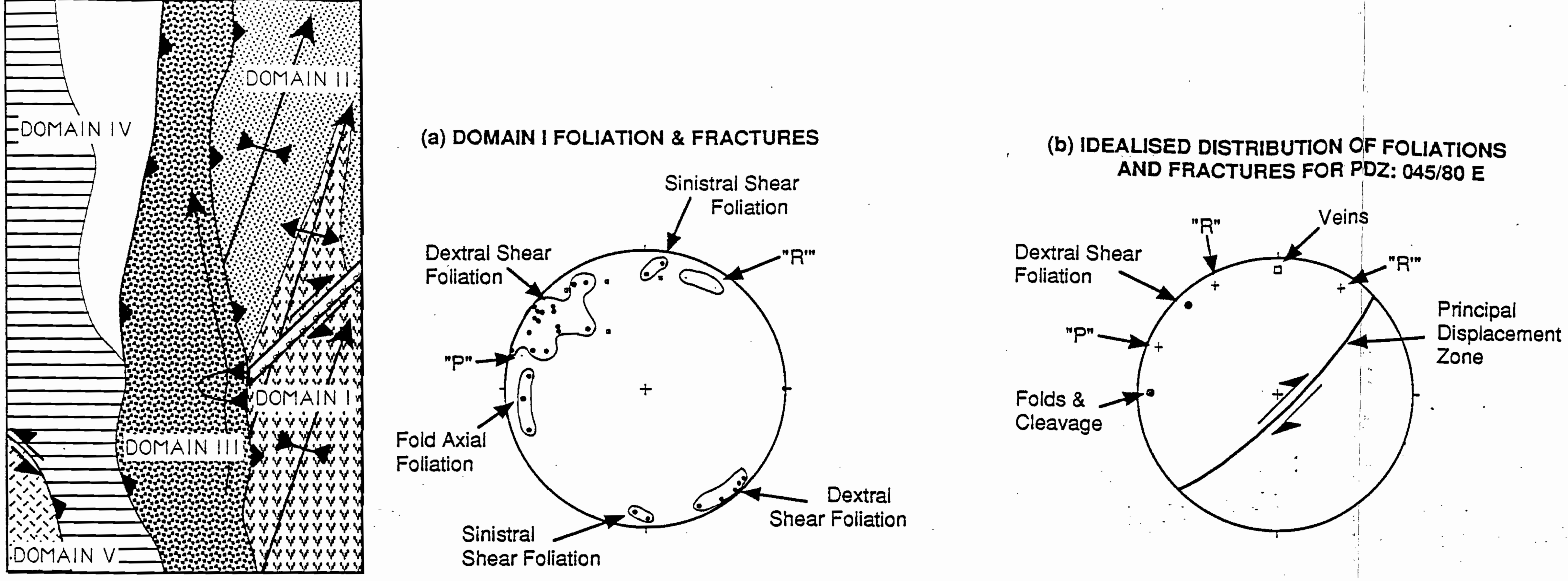
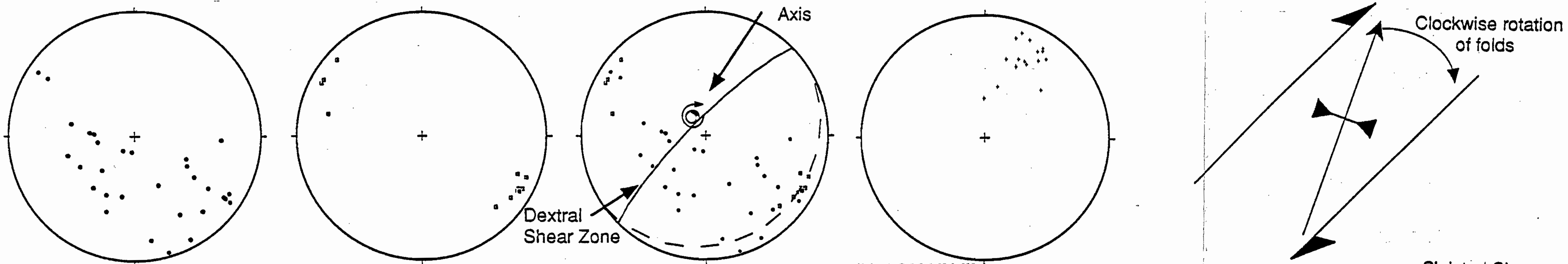


FIG. 2 Section line A - B


(a) DOMAIN I FOLIATION & FRACTURES

(b) IDEALISED DISTRIBUTION OF FOLIATIONS AND FRACTURES FOR PDZ: 045/80 E

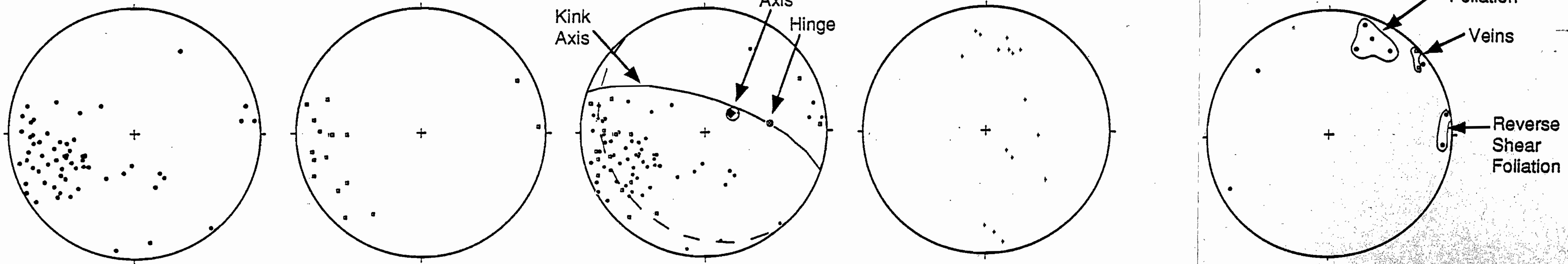

(c) DOMAIN II S_0

(d) DOMAIN II S_1

(e) DOMAIN II S_0/S_1

(f) DOMAIN II L_1

(g) SIMPLE SHEAR MODEL: DEXTRAL


(h) DOMAIN III S_0

(i) DOMAIN III S_1

(j) DOMAIN III S_0/S_1

(k) DOMAIN III L_1

(l) DOMAIN V FOLIATION

FIG. 3 Domain Analysis

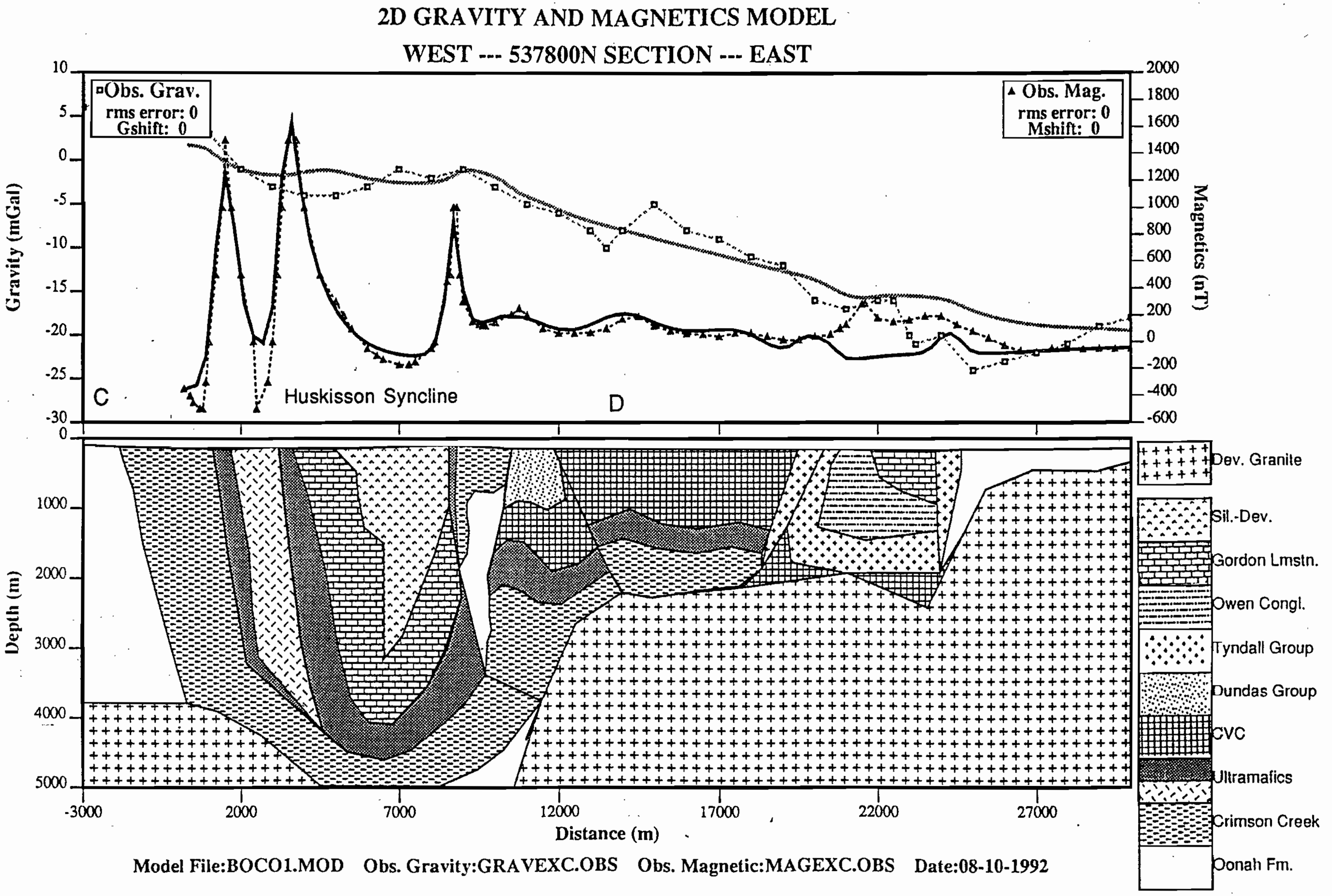
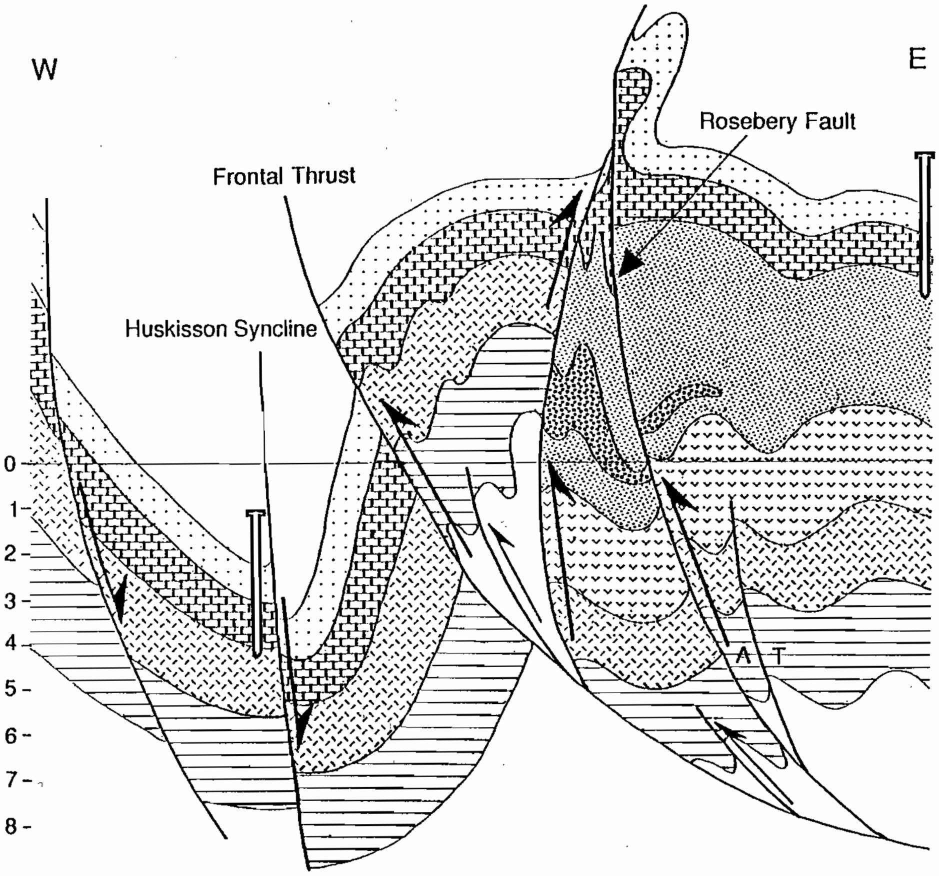


FIG. 4 Magnetic model along section line C - D. The magnetic anomaly to the east of the Huskisson Syncline requires only a thin, high level slice of highly magnetic material. The high strained wedge of ultramafics and Crimson Creek Formation at this position clearly represents a sheared out limb of the syncline.



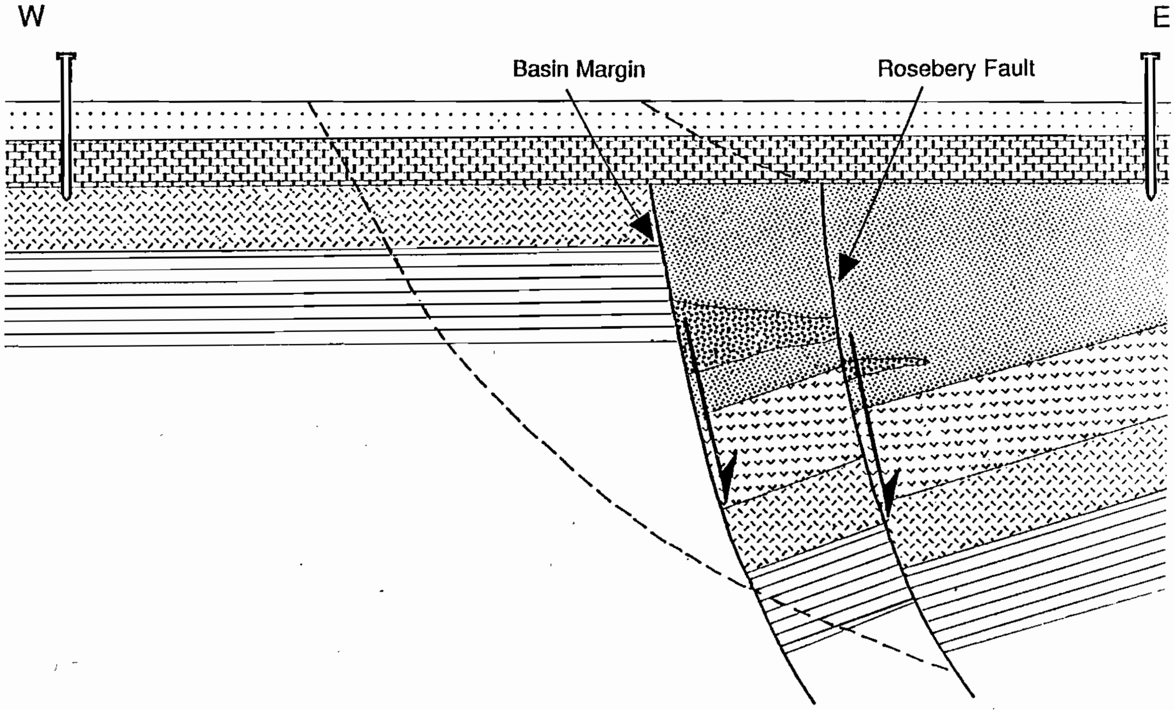


FIG. 5. (a) Balanced cross section along A–B. A distinctive imbricate fan geometry is revealed. Displacements are transferred from the steeply dipping Rosebery Fault to a frontal thrust.
(b) Restored section along A–B. The Cambrian volcano-sedimentary succession is restricted to a graben structure in the east of the section.

Geochemical Evidence for the Structure of the Rosebery Deposit

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ABSTRACT

Drill sections and level plans from 14 to 19 level support the existence of an imbricate array of high angle reverse faults in the mine from 0–500mN. The geochemical signature (Ti/Zr) is applied here to distinguish footwall from host rocks and use this additional data as a test of the thrust geometry proposed.

The position and significance of reverse faults was confirmed in the central part of the mine. The small steps in the footwall interpreted as growth faults controlling mineralisation have a distinctly different effect on the footwall boundary as defined by Ti/Zr.

The use of Ti/Zr ratio which has potential to accurately identify the boundary largely independent of alteration. In this test the Ti/Zr ratio was only affected by alteration within zones of intense silicification and provided a good marker within less intense alteration.

INTRODUCTION

The detailed assessment of drill sections and level plans from 14 to 19 level support the existence of an imbricate array of high angle reverse faults in the mine from 0–500m N (Berry 1991). These faults have a combined displacement of 250 m. Restoration of the mine lenses in this area shows G lens was originally stacked on top of E lens. H lens is completely separate but may be tied to the same Cambrian growth fault. The metal zonation and host sequence distribution support a complex seafloor topography and syndepositional fault pattern which influence the ore deposition geometry.

A major problem with detailed analysis is the ambiguity in recognising footwall boundaries for the mine. While the overwhelming weight of evidence supports the footwall distribution described by Berry (1991) the detail is subject to revision if footwall boundaries are relogged. A possible mechanism for improving this problem is to use a geochemical signature such as Ti/Zr ratio to distinguish footwall from host rocks.

The aim here is to report a geochemical study, based on core, to test the complex footwall distribution produced by hand specimen identification of the footwall boundary.

PREVIOUS WORK

In the previous report I discussed the data base from Rosebery reported by Naschwitz (1985) and Naschwitz & Van Moort (1991). The least mobile elements Al_2O_3, TiO_2, P_2O_5, Zr, Y and Nb were transformed into log ratios (Aitchison 1986) and the result was subject to discriminant analysis. The host and footwall are clearly discriminated at the 99% confidence level using these elements. In practice, it is clear from these results that the discrimination can be made at almost the same level by using the Ti/Zr ratio.

The results of this study showed that for the north end samples in the Naschwitz database, only one sample out of 86 had a log(Ti/Zr) greater than 1.0 (average of 0.9) while most host rock samples have log(Ti/Zr) greater than 1.0.

SAMPLING

In order to test the models of footwall distribution, I looked for a section with good core availability in the vicinity of (a) a thrust fault and (b) a syn-depositional offset in the footwall according to the model in Berry (1991). Difficulties with core availability meant that the thrust fault model could only be tested over a composite section from 140mN to 190mN (Figs 1, 2). With the syn-depositional fault the best availability was of a step in J lens which lies beneath the main data set reported previously. There is a wide choice of sections in this zone and I have used 180mS.

Core was sampled at about 5 m spacing through the relevant parts of the available holes. Samples of half core about 10 cm long were crushed and analysed by XRF on pressed powders for Ti, Zr, Y and Nb. In order to calculated the absorption factors a semi-quantitative major element analysis was carried out and Pb, Rb, Sr were also measured on many rocks. These analyses were not used here and are reported for reference only. For this investigation 105 samples were analysed.

RESULTS

In order to interpret the variations in Ti/Zr ratio, I first looked at the variations in some holes for which no structural complications were expected. As an example, in the south 4746 is a good example outside the most intense alteration. The first sample analysed, at 254.3 m, is from the hanging wall volcaniclastics which are similar to host sequence in Ti/Zr. The original logs identified a well bedded host sequence from 258.4 to 292 m and the subsequent thicker bedded coarse sandstones were considered to be part of the footwall. In contrast Rod Allen suggested the footwall started at 336 m, just before the end of the hole. The Ti/Zr ratios are shown in Fig. 3. The sandstones from 258 to 336 m all have high Ti/Zr indicative of the host sequence. The two low Ti/Zr in the upper part of the host sequence are from siltstones.

The Naschwitz data set contains several holes with substantial analysis across the host and footwall sequences. Good examples of variation within the footwall are shown in 1079 and 1121 (Fig. 3). In 1079, all within the footwall, the Ti/Zr is low and relatively consistent. In hole 1121 the original logs have the hole collared in host but drilling into the footwall at around 100 ft. The Ti/Zr suggests the hole was drilled entirely within the footwall. Holes 3267, 3276 and 3368 (Fig. 3) were drilled from the footwall into host sequence with a dramatic change in Ti/Zr at the boundary. Hole 3268 (Fig. 3) has the typical low Ti/Zr in the footwall and jumps to much higher values in the host sequence which contains one sample with a low ratio near the top (in shale similar to the pattern in 4746). Surface hole 46R drilled through hanging wall with low Ti/Zr into the host sequence with high Ti/Zr and then through to the footwall. In all of these holes in areas with relatively simple structure and established stratigraphy the Ti/Zr was a good marker for the footwall/host boundary.

Section 140–190mN

Samples from holes 1500, 1502, 3618, 3622, 3636, 4270, and 4272 (Figs 1, 2) were sampled in the complex area below G lens which was interpreted as a fault repetition in the last report. All these holes have been projected onto the 150mN and 200mN sections reported in Berry (1991), in order to test the footwall distribution.

Based on the Ti/Zr (Fig. 4) 1500 passes from hanging wall to footwall at 720 ft as expected from the logs but a second section of host sequence is met at 876 to 940 ft. This section is feldspathic sandstone previously logged as footwall. Alternatively, in some interpretations, the whole section has been considered as host down to 1024 ft.

The downdip hole 1502 is anomalous. The hanging wall/host contact is nominally at 725 ft in the original logs (but correlation with newer holes on the same section would suggest the hanging wall contact is at 780 ft) and the footwall/host contact at 969 or 1090 ft. The Ti/Zr values are all lower than expected suggesting the host sequence may be completely missing. Alternatively, the host sequence is represented by the area with log(Ti/Zr) near 1. The first feldspathic and bedded rocks start at 811 ft and the zone from 843 to 940 ft seems to be massive volcaniclastic sandstone with coarser fragments increasing down the hole. There is a fault zone at 880-900 ft which appears to form the host sequence boundary based on the trace elements.

Holes 3618 and 3621 are subparallel on 190m section drilling from beneath H lens through to G lens. Footwall compositions were analysed below G lens but not between H and G lenses. There is very good correlation between these holes which are close together. In contrast, 3636 is on the 160m section and has some footwall rocks between G and H lens and possibly just under G lens before going back into host sequence to the end of the hole.

Holes 4270 and 4272 were sampled to test for footwall compositions directly under H lens. 4272 on the 140mN section has a long section in the footwall while hole 4270 (170mN section) starts in footwall but changes quickly to host.

The complex footwall distribution on the 17 level at 150mN (Fig. 5) has been confirmed by Ti/Zr and indicates there are slices of footwall between G and H lens and also between G and E lens. The 150mN and 200mN sections (Figs 1, 2) have been slightly modified as a result of the Ti/Zr study and now look much more alike. The geochemistry supports a complex interfingering of host and footwall in the area under G and E lens.

Section 180mS

A step in the ore position has been identified in F/J lens at about 2750mRL during recent production logging and this is similar in character to propose syn-depositional structures reported in the last report. This structure has been added to those previously reported in Fig. 6.

In order to properly test this model the distribution of rock types at one of these steps needs to be tested using Ti/Zr and the J lens step has the advantage of readily available core. Samples were collected from holes 4313, 4388 and 4563 on section 180mS (Fig. 7).

Hole 4563 lies updip from the step hand and has been logged as host sequence. The Ti/Zr (Fig. 8) supports this interpretation except for two samples in massive silicification (~93% SiO2) which have log(Ti/Zr) near 1 and are equivocal. The hole 4313 is only 10-15 m lower in the section but has footwall Ti/Zr from 75 to 115 m. These two holes together require a footwall boundary nearly perpendicular to bedding. The intense silicification is also evident just under J lens in this hole supporting a correlation of these syn-depositional faults with the fluids pathways which produced the mineralisation.

Hole 4388 cuts through J lens just below the step. Previous logs of this hole suggested host sequence under J lens in his hole but the Ti/Zr is low over the whole interval below J lens and indicates that the footwall boundary lies very close to the base of the ore lens here.

STRUCTURAL INTERPRETATION

The results of this work indicate the separation of footwall offsets into Cambrian normal faults and Devonian thrusts is a viable model. Based on the section in Berry (1991) and in this work, I have reconstructed the geometry of Rosebery during the Cambrian (Fig. 9). First the 250 m Devonian fault offset was removed and then the whole system was inverted so that we are looking down on the Cambrian surface. This view is still distorted because no correction has been made for the 45° dip or for homogenous stretching during cleavage formation. The well defined normal faults are shown with other possible structures based on the host sequence isopachs. The limits of ore are shown, as are known areas of high pyrite or high Cu ores suggesting source areas. The pattern of mineralisation has a moderate correlation with the normal fault pattern which appears to control the local distribution of high grade ore but is imposed over a strong WNW trend in the mineralisation. The centre of mineralisation is drifting E with time as indicated by the source of H lens lying east of that for G/E lens and also higher in the stratigraphy.

The major feature of the normal fault pattern is that there is no distinctive extensional direction. This pattern is consistent with arching over a spherical intrusion. In this case the extension might be interpreted as varying from NE-SW in A/B lens to ENE-WSW in G/E lens to E-W in F/J lenses. The major centre of mineralisation would then have been eroded. This model is very discouraging for further extensions to the ore body. However it is inconsistent with the recently determined continuations down dip of both J and A/B lenses and I do not think it is the most likely scenario.

The pattern of normal faulting can be interpreted as WSW-ENE regional stretching with a N-S component. Oblique extension against a N striking normal fault (Fig. 10) is also consistent with this pattern. The moderate correlation with the mineralisation suggest surface fault patterns are not the same as those at depth. However the mineralisation is consistent with a set of NW striking normal faults separated into discrete centres by transfer faults striking NE. This model suggests there may be substantial continuations of mineralisation down plunge and to the south of J lens. It does not explain the ore grade intersections made deep under A/B lens.

SUMMARY

The position and significance of reverse faults has been confirmed in the central part of the mine. The use of Ti/Zr ratio which has potential to accurately identify the boundary independent of alteration. In this test the Ti/Zr ratio was only affected by alteration within zones of intense silicification and provided a good marker within less intense alteration.

The small steps in the footwall interpreted as growth faults controlling mineralisation have a distinctly different effect on the footwall boundary as defined by Ti/Zr. The pattern of these normal faults suggests extension in a ENE to NE direction oblique to the basin margin. A model of small normal faults separated by transfer faults at depth spreading into complex minor faults at the surface is suggested for the Cambrian structure.

ACKNOWLEDGEMENTS

I am indebted to the Pasminco Rosebery staff for the strong support they have given this project. The presentation of analyses at this stage was only possible through Phil Robinson personally pushing them through in the midst of the confusion during the installation of the new XRF in geology.

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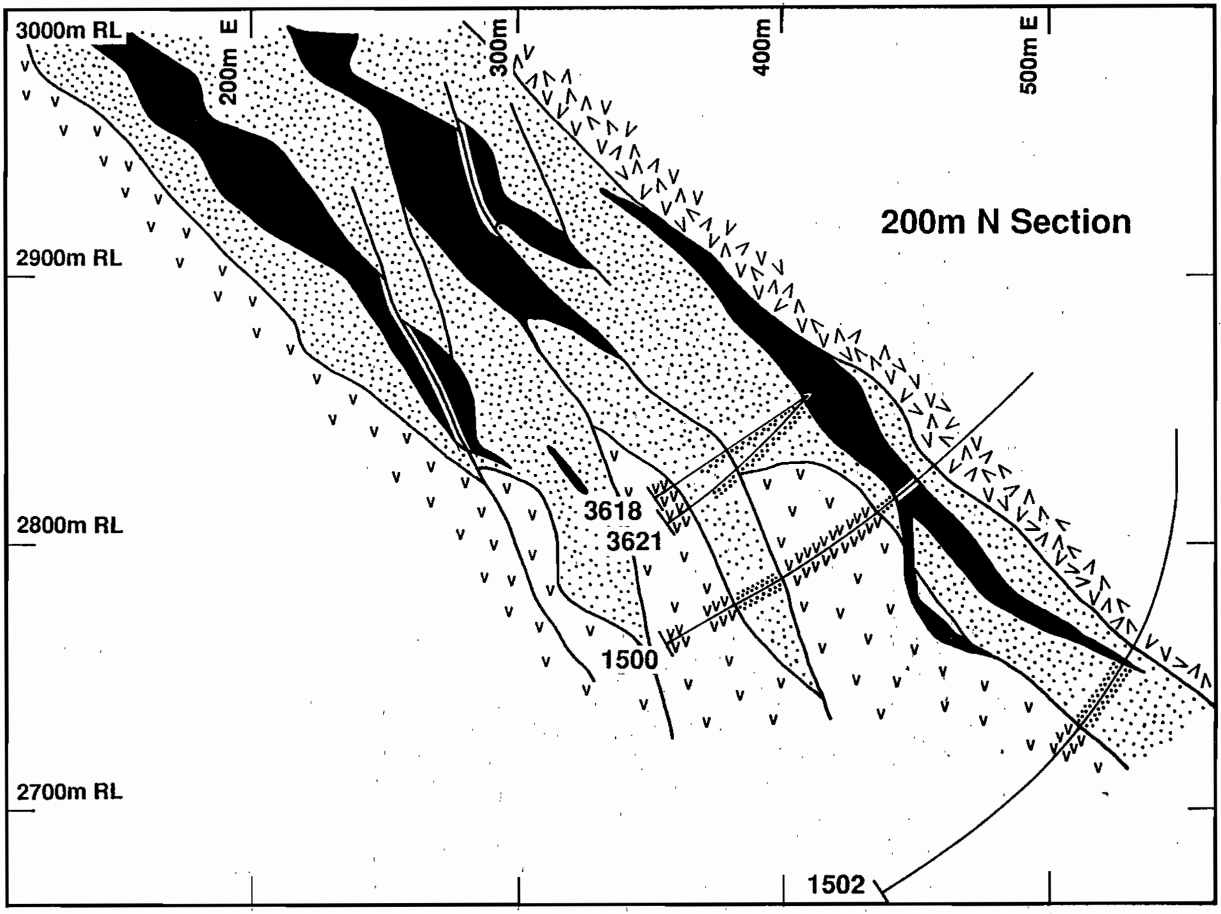


FIG. 1. Section at 200m N showing modification of the interpretation of footwall geometry arising from the geochemical study.

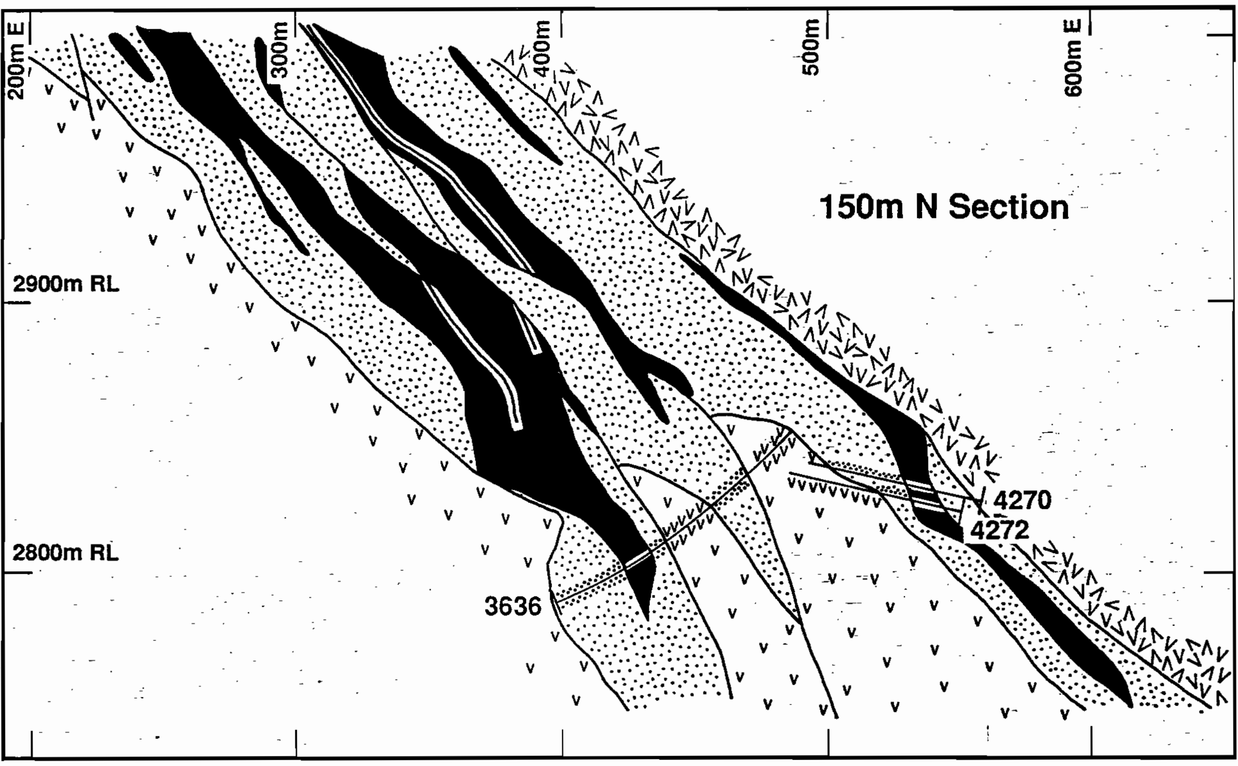


FIG. 2. Section at 150m N showing modification of the interpretation of footwall geometry arising from the geochemical study.

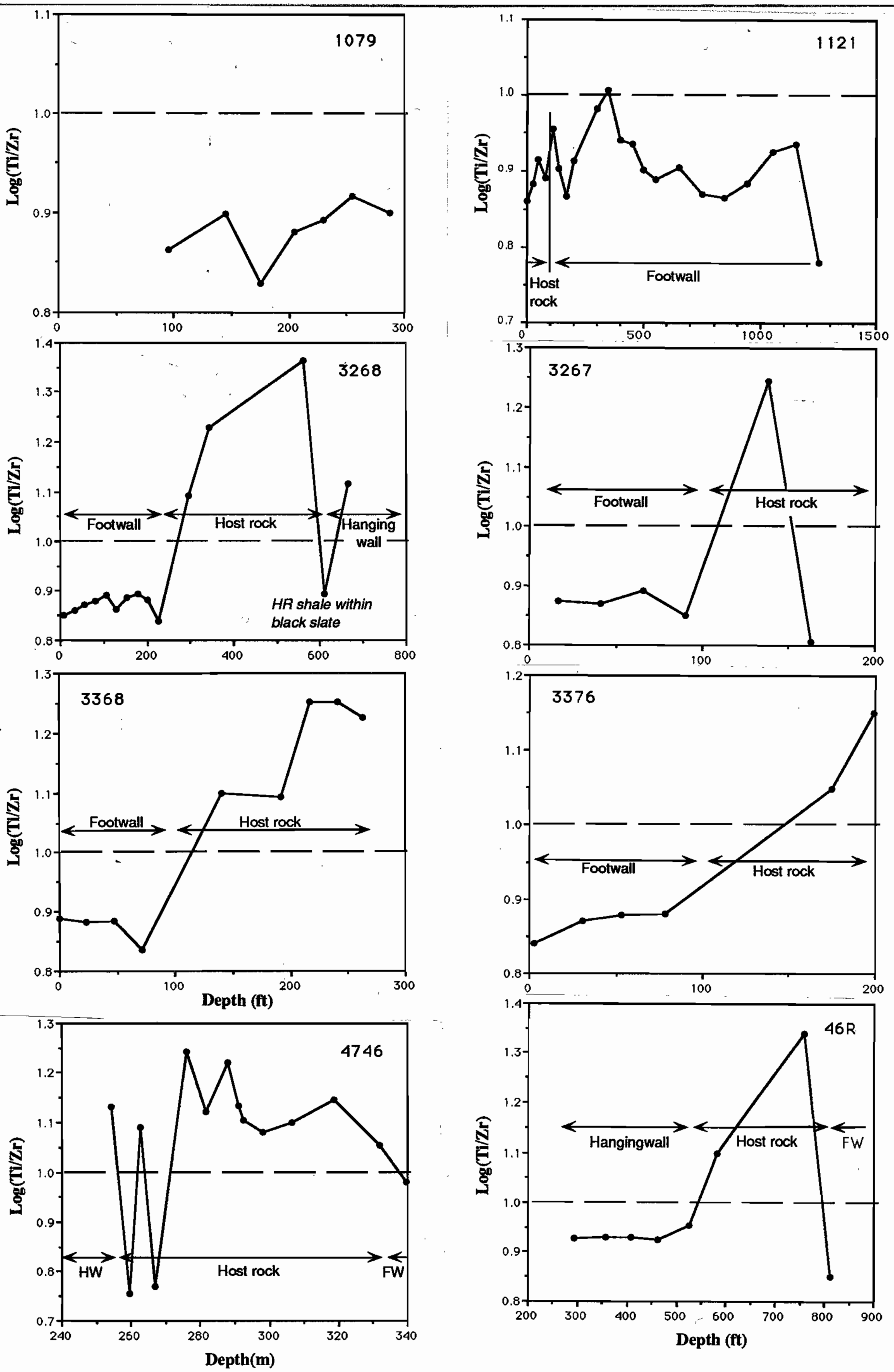


FIG. 3. Down hole variations in Ti/Zr in structurally simple areas. Hole 4746 from this study. Other holes from Naschwitz(1985).

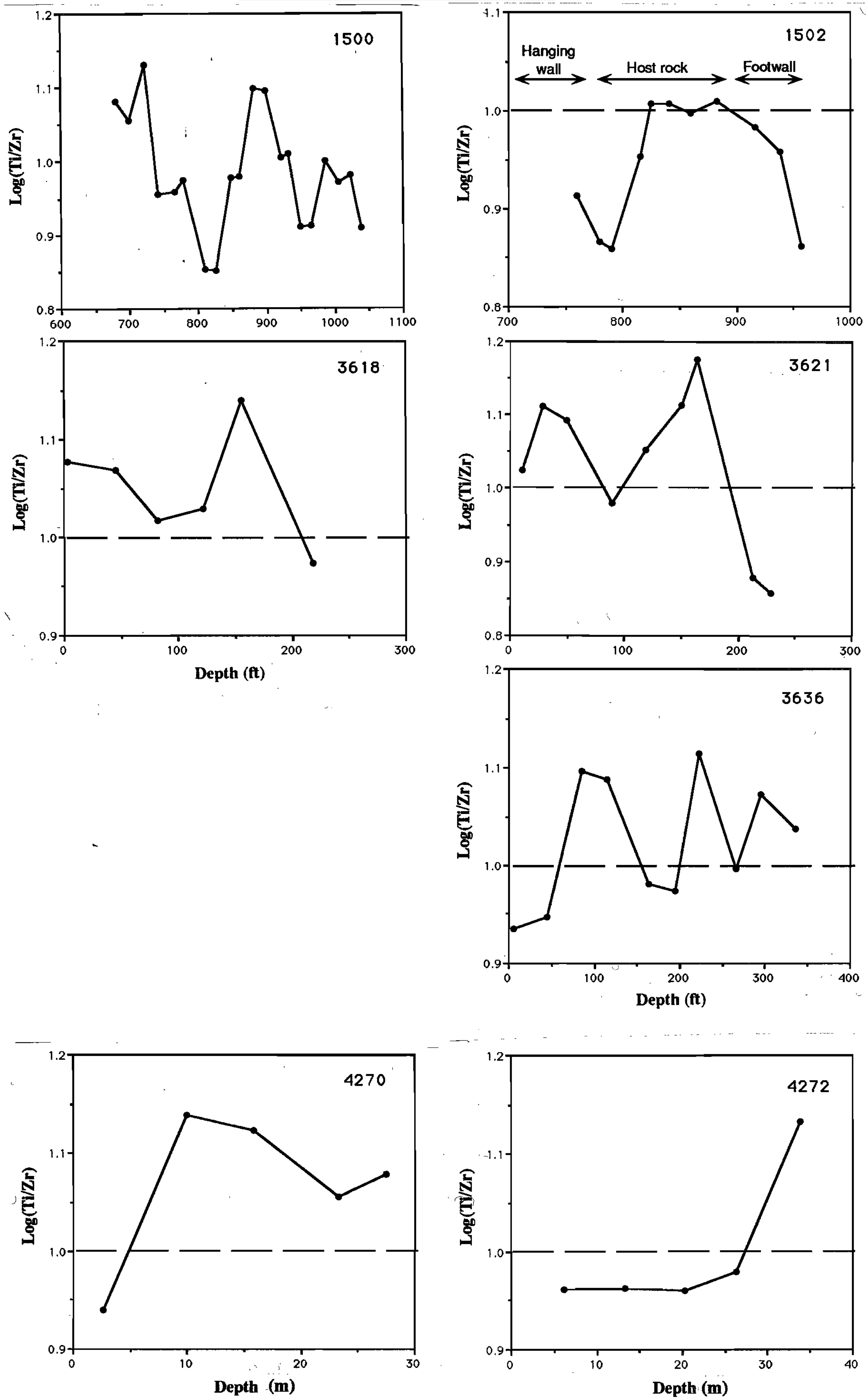


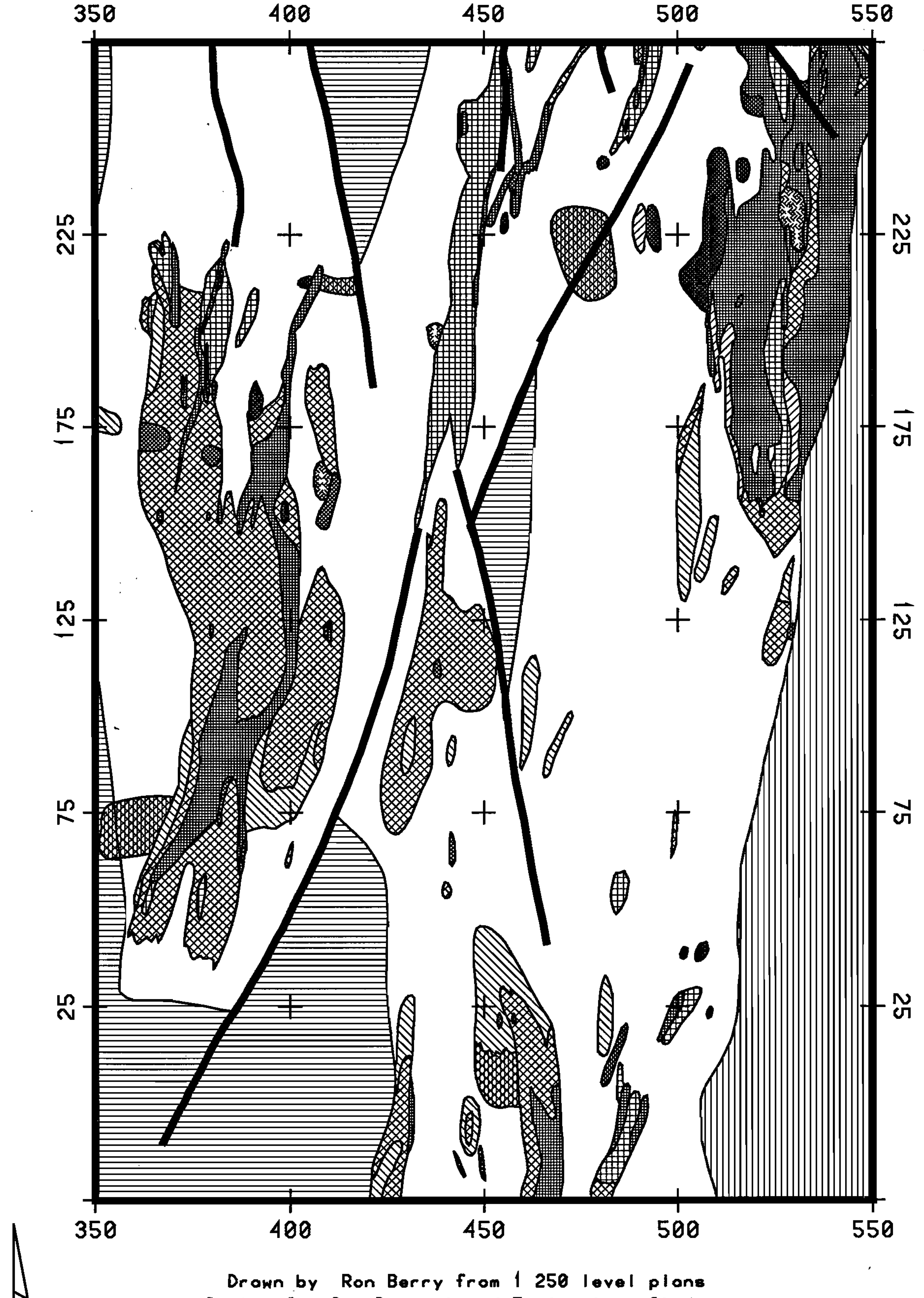
FIG. 4. Down hole variations in Ti/Zr on the 140mN to 190mN zone.

▥	Hangingwall volcaniclastic rock
▤	Black shale
□	Host sequence
▤	Footwall volcaniclastic rock
▦	Pb/Zn rich ore - high grade
▦	Pb/Zn ore - low grade
■	Cu/pyrite ore - Cu > 4%
▩	Cu/pyrite ore - Fe > 20%
▧	Cu/pyrite ore - Fe 2-20%
▨	Cu/Pb/Zn low grade ore
▒	Barite lens
■	Massive carbonate alteration
▩	Diseminated carbonate alteration
▧	Pyrrhotite replacement ore
▨	Hematite alteration

FIG. 5. 17 level plan showing slice of footwall between G and H lens.

ROSEBERY MINE

17 LEVEL - 1:1,500



Drawn by Ron Berry from 1 250 level plans
Centre for Ore Deposit and Exploration Studies
The University of Tasmania
August 1992

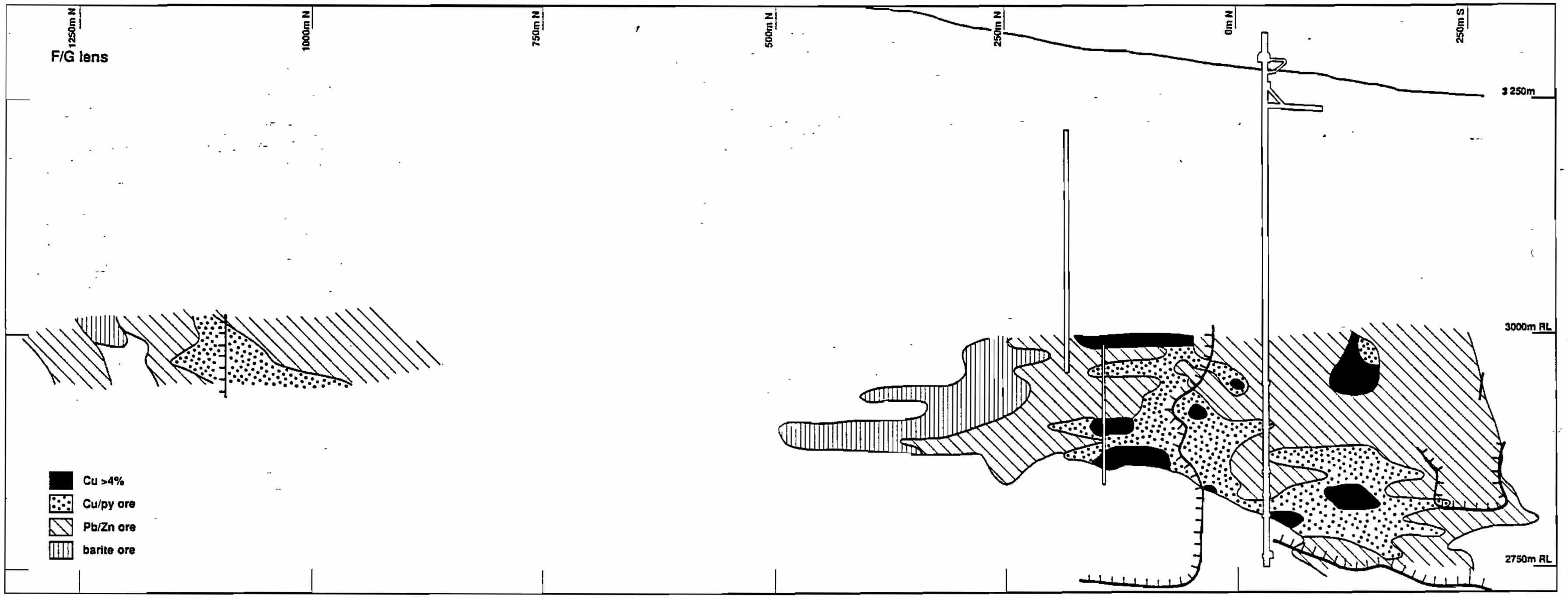


FIG. 6. Long section of A, B, H, F,J lens showing position of interpreted normal faults.

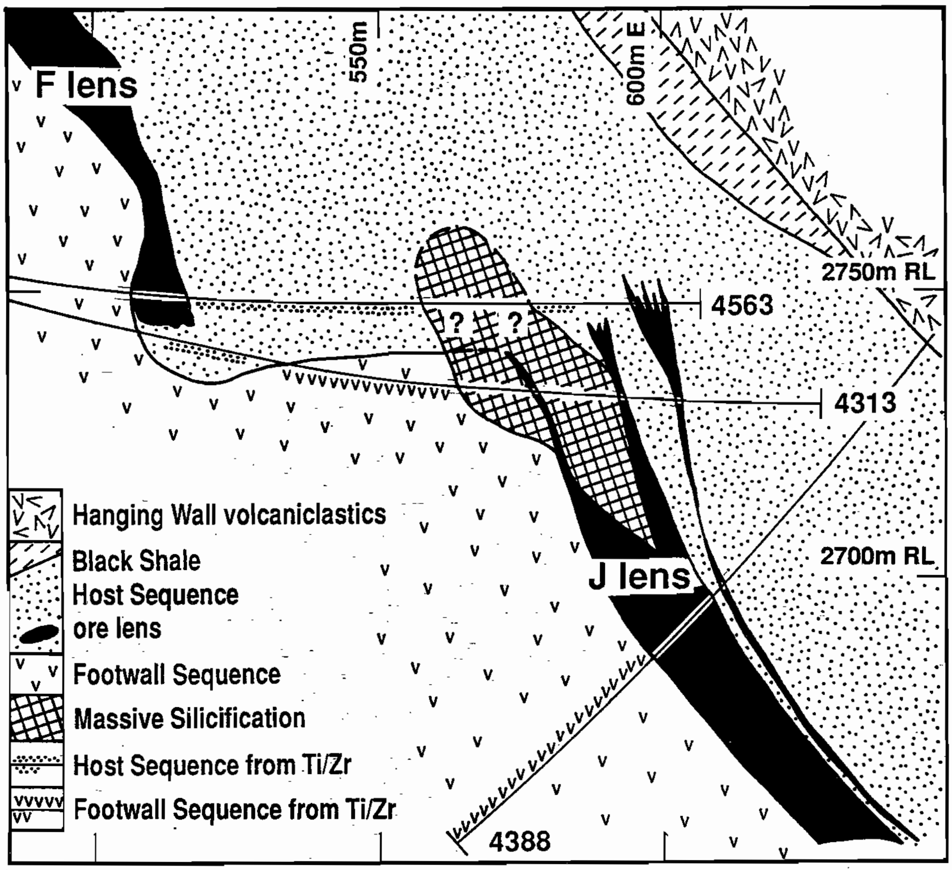


FIG. 7. Section at 180mS.

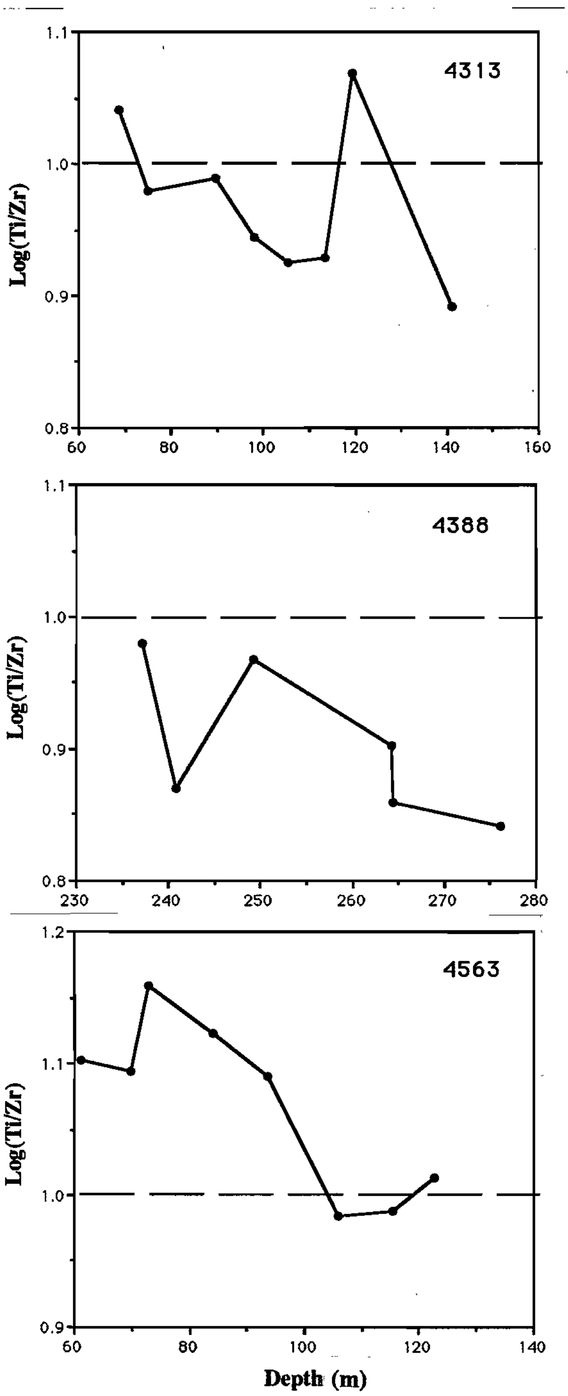


FIG. 8. Down hole variations in Ti/Zr on the 180mS section.

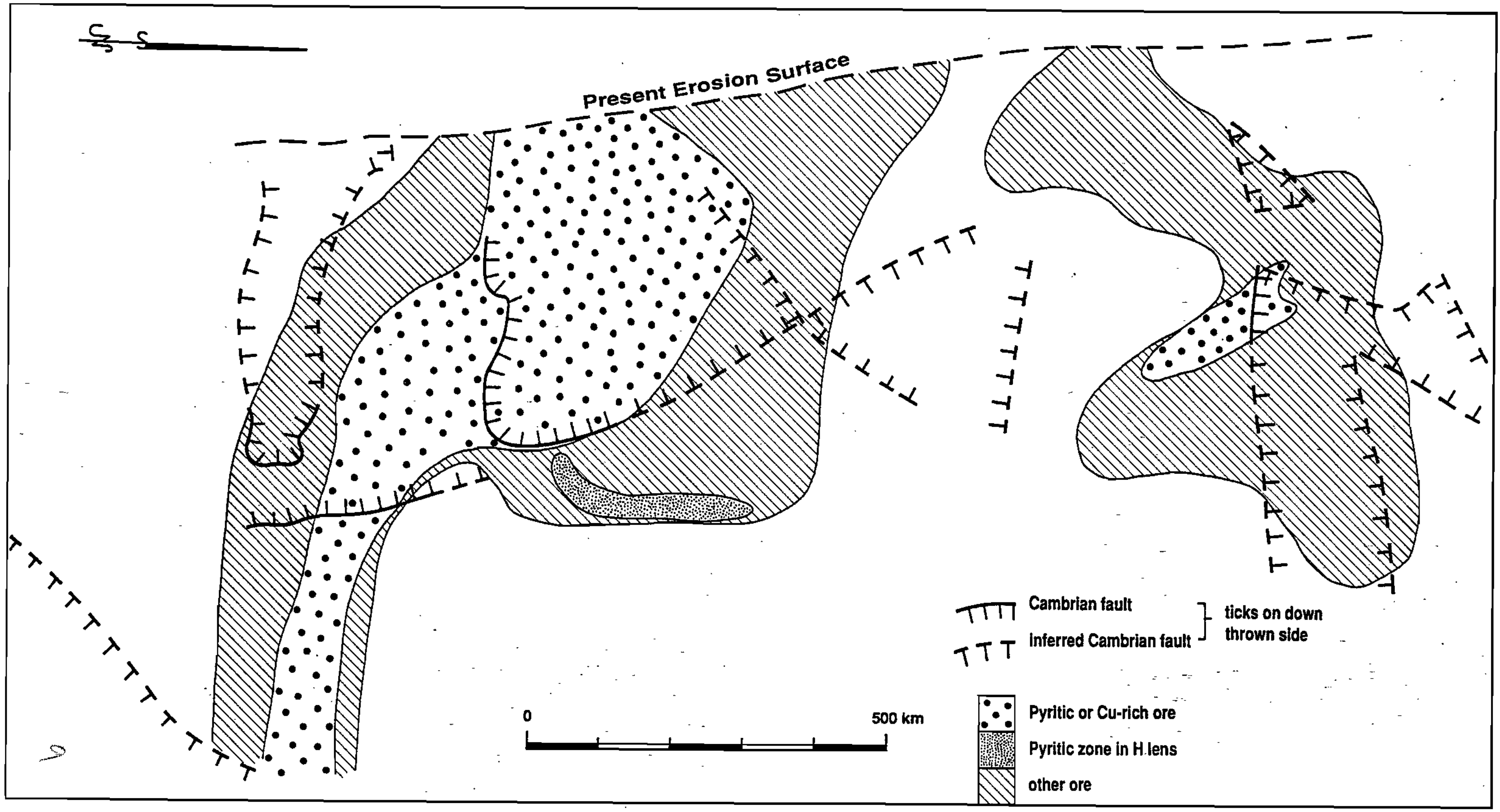


FIG. 9. Reconstruction of the Rosebery deposit at the time of formation of the ore deposit in the Cambrian.

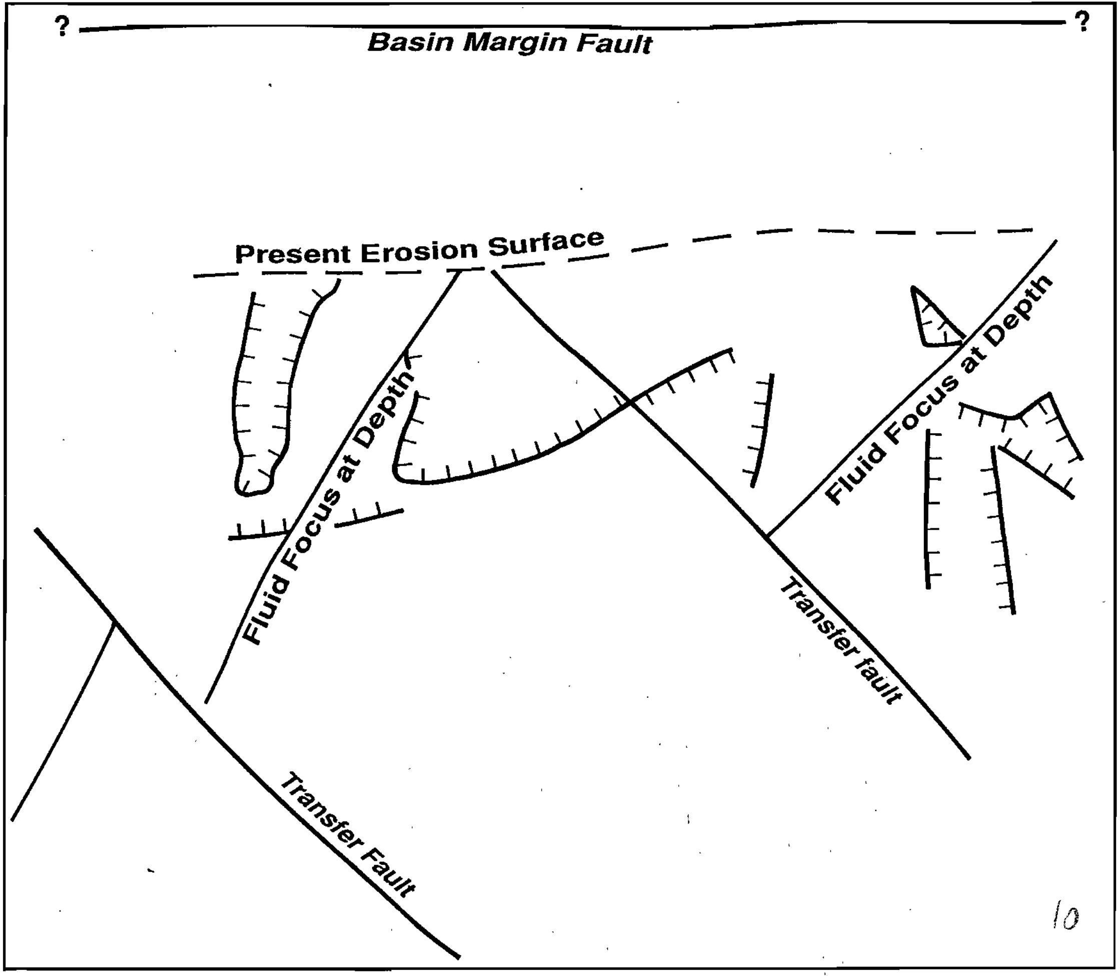


FIG. 10. *Potential fault pattern at depth under host sequence which may have acted as the fluid focus.*

TABLE 1. Chemical analysis of Rosebery core.

Hole	depth	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	Sr	Rb	Pb	Nb	Zr	Y	LogTi/Zr
1500	680.0	35.48	0.78	23.60	15.10	0.71	4.63	0.16	0.09	5.79	0.11	16	357		24	388	63	1.08
1500	699.0	56.04	0.62	23.28	6.67	0.42	4.70	0.13	0.29	5.70	0.11	21	262	93	17	327	47	1.06
1500	723.0	97.81	0.21	9.05	1.30	0.02	0.42	0.00	0.10	1.97	0.01	9	110		6	93	12	1.13
1500	741.0	73.31	0.32	18.13	4.07	0.34	1.65	0.05	0.17	4.29	0.04	9	227	688	11	212	32	0.96
1500	766.0	64.88	0.50	23.51	4.28	0.19	2.13	0.06	0.49	5.96	0.04	16	389		19	329	44	0.96
1500	778.0	85.65	0.35	17.45	2.11	0.04	0.97	0.04	0.14	4.26	0.05	11	266		13	222	26	0.98
1500	810.0	77.08	0.25	16.64	5.66	0.38	1.89	0.00	0.23	3.49	0.01	9	183	1893	14	210	28	0.85
1500	825.0	89.00	0.16	12.91	2.84	0.11	0.78	0.00	0.10	2.78	0.02	9	146		10	135	18	0.85
1500	848.0	71.13	0.39	18.00	4.87	0.23	1.56	0.05	0.13	4.52	0.05	16	250		15	246	40	0.98
1500	861.0	76.04	0.37	17.66	5.12	0.14	1.34	0.16	0.09	4.32	0.06	15	250		13	232	30	0.98
1500	881.0	41.34	0.78	25.30	20.94	1.10	3.19	0.11	0.08	5.03	0.06	16	229	56	22	373	45	1.10
1500	899.0	92.98	0.21	10.53	3.25	0.33	0.65	0.07	0.09	2.43	0.04	8	121	575	7	101	23	1.10
1500	922.0	60.33	0.47	20.41	2.14	1.61	1.82	2.04	0.64	5.65	0.05	28	291	5629	17	278	42	1.01
1500	933.0	77.79	0.35	16.40	1.18	0.90	1.36	1.60	0.36	4.31	0.04	33	196	805	12	205	32	1.01
1500	949.5	87.41	0.17	11.81	1.20	0.27	1.02	0.54	0.17	3.03	0.03	12	143	4460	8	125	20	0.91
1500	965.0	72.57	0.30	17.11	2.68	1.10	2.73	3.02	0.07	4.58	0.02	25	254		13	220	35	0.91
1500	986.5	77.05	0.39	18.32	2.15	0.90	1.40	1.12	0.09	4.79	0.06	27	237	1396	14	233	38	1.00
1500	1005.0	73.39	0.42	18.63	5.98	0.36	3.00	0.07	0.04	4.25	0.04	14	236	19	15	269	38	0.97
1500	1023.0	76.67	0.34	16.44	2.69	0.50	1.30	0.42	0.07	4.24	0.06	21	221		12	213	30	0.98
1500	1039.0	69.17	0.26	18.95	2.33	4.95	2.49	2.60	0.17	4.71	0.00	34	223	1141	15	192	38	0.91
1502	760.0	80.82	0.29	16.35	1.95	0.24	0.67	1.36	3.91	2.28	0.02	210	97		12	212	34	0.91
1502	780.0	79.25	0.25	16.32	5.20	0.47	1.29	0.10	0.07	3.68	0.02	15	225		12	204	27	0.87
1502	790.0	84.35	0.21	14.91	4.13	0.28	0.93	0.16	0.10	3.36	0.02	17	177		12	174	22	0.86
1502	815.5	62.13	0.51	24.96	5.69	0.55	2.97	0.39	0.09	6.19	0.02	28	358	415	22	341	48	0.95
1502	825.0	64.44	0.28	13.19	17.12	0.54	2.90	0.24	0.00	2.20	0.02	8	128	429	12	165	26	1.01
1502	841.0	79.04	0.29	11.96	6.73	0.42	3.21	0.05	0.06	2.27	0.04	10	157	89	10	171	28	1.01
1502	859.0	74.69	0.37	17.05	4.89	0.27	1.96	0.07	0.15	4.11	0.05	18	238		13	223	28	1.00
1502	883.0	76.46	0.38	16.67	6.89	0.56	2.89	0.05	0.15	3.43	0.04	12	192	108	13	223	41	1.01
1502	916.0	83.70	0.26	13.20	4.34	0.20	1.02	0.05	0.14	3.32	0.04	11	193		10	162	21	0.98
1502	938.0	72.78	0.28	13.03	4.65	0.40	1.80	0.14	0.24	3.16	0.06	11	176	469	12	185	27	0.96
1502	957.0	74.38	0.32	18.59	1.83	0.80	2.06	0.55	0.24	4.94		16	288		16	264	37	0.86
3618	3.0	74.47	0.54	20.90	2.16	1.12	2.35	1.14	0.16	4.87	0.06	28	249	981	15	271	37	1.08
3618	45.0	88.31	0.25	11.85	1.05	0.02	0.53	0.05	0.72	2.59	0.06	19	121		7	128	16	1.07
3618	82.3	91.23	0.25	12.94	1.87	0.10	0.69	0.08	0.14	2.97	0.02	13	159	445	7	144	30	1.02
3618	122.0	61.44	0.51	20.75	7.86	1.06	3.88	0.14	0.05	4.52	0.08	16	226	55	17	286	42	1.03
3618	155.5	56.15	0.41	12.12	14.86	1.43	6.66	0.21	0.00	1.05	0.10	6	43	515	11	178	20	1.14
3618	218.5	47.34	0.65	25.18	6.21	0.47	6.23	0.08	0.09	6.85	0.05	12	292	353	25	414	74	0.97
3621	10.0	87.76	0.33	14.12	1.55	0.45	0.84	0.44	0.22	3.31	0.03	16	169		11	187	25	1.02
3621	28.0	33.79	0.71	22.83	12.60	1.45	6.65	0.13	0.82	4.51	0.10	15	225	7900	20	329	47	1.11
3621	49.5	94.28	0.19	8.16	1.47	0.02	0.42	0.00	0.12	1.92	0.03	6	102		4	92	10	1.09
3621	89.0	83.80	0.28	14.18	2.62	0.04	0.85	0.03	0.07	3.52	0.05	10	204	890	10	176	21	0.98
3621	119.0	85.54	0.26	13.12	5.00	0.02	0.58	0.06	0.08	3.04	0.07	11	162	486	7	138	17	1.05
3621	150.0	61.62	0.54	18.87	8.28	0.63	4.30	0.10	0.06	4.05	0.08	12	209	162	15	249	46	1.11
3621	164.0	20.73	0.43	11.40	7.24	25.30	11.36	10.06	0.00	2.16	0.01	272	103	1108	11	172	27	1.18
3621	213.0	94.44	0.16	11.72	1.05	0.06	1.10	0.03	0.12	2.87	0.01	4	132	927	10	127	21	0.88
3621	228.8	53.07	0.48	26.27	4.84	0.33	3.57	0.24	0.02	7.57	0.03	16	351		26	399	44	0.86
3636	6.0	85.87	0.25	14.14	3.05	0.18	1.14	0.10	0.12	3.24	0.04	8	187		9	174	26	0.94
3636	44.5	65.25	0.47	23.81	6.36	0.17	1.53	0.18	0.13	6.23	0.05	17	388		18	318	41	0.95
3636	85.5	60.08	0.51	19.41	11.19	0.50	2.79	0.10	0.15	4.26	0.08	17	227	25	17	245	60	1.10
3636	114.0	56.50	0.37	13.98	16.24	1.08	6.92	0.16	0.00	1.69	0.08	7	75	287	11	181	42	1.09
3636	164.0	63.69	0.46	18.34	3.22	0.83	5.41	0.79	0.74	4.15	0.06	39	182	775	17	288	40	0.98
3636	194.0	52.97	0.69	24.90	3.77	0.32	4.35	0.19	0.12	7.24	0.07	23	338		25	440	60	0.97
3636	222.5	83.31	0.18	7.52	1.17	0.05	0.46	0.00	1.48	1.80	0.03	13	81	1298	5	83	12	1.11
3636	266.0	37.97	0.59	23.24	4.84	2.30	1.64	3.96	0.89	5.10	0.00	762	243	1014	22	357	39	1.00
3636	295.0	86.22	0.26	12.45	3.56	0.11	0.59	0.14	0.19	2.62	0.00	17	120	159	4	132	18	1.07
3636	335.0	53.56	0.81	31.18	3.60	0.14	1.71	0.14	0.23	7.94	0.09	49	417		25	445	60	1.04

TABLE 1 cont. Chemical analysis of Rosebery core.

Hole	depth	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	Sr	Rb	Pb	Nb	Zr	Y	LogTi/Zr
4270	2.6	66.38	0.53	22.64	4.00	0.22	1.59	0.12	0.09	6.06	0.06	14	381		22	365	42	0.94
4270	10.0	72.17	0.54	19.25	4.84	0.09	1.04	0.10	0.06	4.84	0.11	13	279	161	13	235	41	1.14
4270	15.8	84.83	0.33	13.38	3.36	0.05	0.62	0.11	0.12	3.29	0.07	12	194	487	8	149	21	1.12
4270	23.3	70.17	0.54	22.06	3.56	0.11	1.18	0.16	0.08	5.46	0.10	16	285		15	285	31	1.06
4270	27.5	59.48	0.52	18.45	10.96	0.56	3.91	0.11	0.09	3.69	0.07	12	184	81	15	260	37	1.08
4272	6.2	78.58	0.31	15.67	5.77	0.08	0.92	0.03	0.04	3.92	0.02	9	244		11	203	23	0.96
4272	13.3	69.37	0.36	15.68	5.20	0.28	2.05	0.07	0.13	3.87	0.04	10	247		13	235	27	0.96
4272	20.3	79.12	0.33	15.73	4.59	0.08	0.98	0.06	0.10	3.91	0.04	9	244	398	12	217	27	0.96
4272	26.3	83.08	0.28	13.55	4.27	0.06	0.72	0.09	0.15	3.30	0.05	13	208	972	9	176	20	0.98
4272	33.9	88.92	0.19	7.77	3.81	0.06	0.51	0.09	0.16	1.93	0.04	71	125		5	84	15	1.13
4313	68.7	52.98	0.62	23.28	9.96	0.92	4.54	0.16	0.07	5.43	0.08	29	309	14	20	338	51	1.04
4313	75.2	86.88	0.32	16.63	4.34	0.15	1.06	0.20	0.17	3.88	0.03	22	224		12	201	32	0.98
4313	89.6	93.80	0.27	13.66	2.69	0.06	0.66	0.07	0.17	2.91	0.02	16	225	75	9	166	17	0.99
4313	98.2	70.93	0.38	18.76	4.61	0.19	0.88	0.26	0.11	4.82	0.05	27	278		15	259	30	0.94
4313	105.5	63.95	0.43	20.45	8.46	0.91	3.15	0.10	0.13	4.44	0.03	27	259		18	306	30	0.93
4313	113.6	74.55	0.18	8.94	1.54	0.10	1.21	0.22	0.23	2.23	0.09	573	196		6	127	17	0.93
4313	119.6	79.91	0.32	12.49	1.89	0.12	0.60	0.15	0.09	2.97	0.13	22	193		11	164	24	1.07
4313	141.1	63.91	0.53	25.79	2.86	0.13	2.33	0.08	0.29	6.06	0.06	67	431		24	408	57	0.89
4388	237.1	73.09	0.43	18.71	4.74	0.25	1.33	0.07	0.20	4.34	0.08	20	231		15	270	35	0.98
4388	240.9	81.64	0.22	14.71	3.48	0.12	0.58	0.01	0.10	3.49	0.04	14	190		11	178	24	0.87
4388	249.3	83.64	0.33	18.24	3.84	0.18	1.21	0.02	0.08	4.16	0.04	13	230		13	213	28	0.97
4388	264.2	71.72	0.33	18.32	5.78	0.47	2.92	0.01	0.04	4.06	0.03	12	217		15	248	27	0.90
4388	264.4	75.42	0.28	18.64	3.54	0.32	2.46	0.00	0.07	4.35	0.02	13	279	367	17	232	33	0.86
4388	276.2	75.74	0.25	14.65	2.47	0.16	0.90	0.01	0.09	3.75	0.04	12	203		12	216	30	0.84
4479	5.7	32.01	0.48	17.35	18.60	0.93	4.77	0.15	0.90	3.13	0.10	99	155	5710	13	219	28	1.12
4479	15.7	44.80	0.82	26.84	7.39	0.95	7.29	0.26	0.05	6.91	0.11	15	350	1490	22	409	40	1.08
4479	21.5	91.84	0.16	8.74	0.73	0.06	0.56	0.07	0.25	2.18	0.04	17	111	4800	6	96	12	1.00
4563	61.0	67.49	0.30	12.11	9.85	1.21	5.27	0.86	0.03	1.78	0.07	13	91	50	8	142	19	1.10
4563	69.8	79.61	0.34	14.49	3.74	0.04	0.75	0.07	0.12	3.60	0.07	20	206		9	164	18	1.09
4563	73.0	60.58	0.57	19.93	3.24	2.85	5.69	3.70	0.65	4.13	0.08	78	273		14	237	42	1.16
4563	84.0	52.26	0.54	19.32	16.80	0.97	3.73	0.12	0.40	3.09	0.07	38	155	12	16	244	35	1.12
4563	93.6	51.60	0.67	27.44	9.39	0.22	1.51	0.12	0.24	6.64	0.06	58	375	59	19	326	47	1.09
4563	105.8	93.54	0.09	4.53	1.09	0.02	0.20	0.03	0.02	1.03	0.05	6	66		3	56	9	0.98
4563	115.5	100.34	0.12	5.67	0.65	0.04	0.37	0.20	0.76	0.92	0.04	30	55	292	3	74	13	0.99
4563	122.7	78.15	0.42	19.49	1.39	0.05	1.90	0.06	0.22	4.30	0.05	46	262		16	244	35	1.01
4746	254.3	72.99	0.38	15.85	5.80	0.16	0.69	0.78	1.71	4.15	0.07	89	726		9	168	24	1.13
4746	259.6	61.81	0.38	26.63	3.02	0.04	1.16	0.10	0.22	7.07	0.02	117	577		25	399	47	0.76
4746	262.6	50.13	0.86	28.13	3.58	0.16	1.51	0.33	0.18	8.30	0.12	164	863		23	419	52	1.09
4746	266.8	65.74	0.29	18.28	3.46	0.11	3.34	0.13	0.10	4.52	0.03	112	395		20	295	44	0.77
4746	276.0	71.68	0.47	19.30	2.62	0.07	1.24	0.13	0.04	4.42	0.05	66	343		20	161	29	1.24
4746	281.6	55.41	0.78	26.02	4.29	0.14	1.76	0.16	0.14	7.51	0.10	74	557		19	353	52	1.12
4746	288.0	58.74	0.95	22.83	5.06	0.17	3.06	0.21	0.15	6.41	0.12	73	636		25	342	42	1.22
4746	291.0	73.47	0.49	17.76	2.48	0.10	1.56	0.50	0.45	4.93	0.13	87	478		12	216	27	1.13
4746	292.5	57.82	0.74	25.57	3.26	0.21	1.87	0.86	0.42	7.42	0.12	115	769		19	348	44	1.11
4746	298.1	63.59	0.58	19.52	2.20	0.08	1.73	0.63	1.03	5.11	0.13	151	407		18	289	48	1.08
4746	306.6	61.42	0.66	20.08	2.40	0.10	2.73	2.25	1.55	4.81	0.15	242	445		19	314	47	1.10
4746	318.5	64.73	0.54	17.78	6.50	0.21	2.79	1.20	0.12	5.78	0.09	66	763	3	13	232	33	1.14
4746	332.0	55.09	0.91	32.70	2.92	0.03	1.17	0.14	0.02	9.13	0.09	52	520		27	482	62	1.05
4746	339.5	64.37	0.44	17.37	4.81	0.20	2.18	0.73	0.02	5.86	0.07	29	575		16	277	42	0.98

Mount Lyell Mine Leases: Summary

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ABSTRACT

The Haulage Unconformity is the result of relatively shallow dips to the east at the western margin of Owen Conglomerate Deposition. The geometry is compatible with a normal fault margin with some normal drag at the margin. Regional data supports an active tectonic setting in the Late Cambrian and the structure may vary very rapidly in both time and space.

Determining the age of the North Lyell alteration is an important aspect of the present research. Both Devonian cleavages (S_1 and S_2) are visible in the altered Owen Conglomerate. Both hematite and sericite alteration penetrates into Pioneer Sandstone. Sr isotopic evidence supports a Devonian age for the vein style barite at North Lyell. The findings here are compatible with an early metamorphogenic enrichment of the North Lyell ore bodies. This conclusion contrasts with the original observations in this project but is supported by more detailed observations on the alteration. The Devonian age for the alteration simplifies the structural interpretation since the western boundary of the Tharsis Trough can be a syn-D_1 west side up fault similar to others recognised to the west.

The Devonian deformation at Mt Lyell includes early N-S trending folds which nucleated on the Haulage upturn, NNW trending folds (D_1), and WNW trending folds associated with the Linda trend. All tight folds are due to Devonian structures as they postdate the Haulage Unconformity. Faults are very prominent in this area and are very variable in orientation reflecting the high variability in rock strength. D_1 faults include both steep west dipping reverse faults and thrusts. This variation is in part due to F_1 folding. D_2 faults show NE transport direction. Faults vary considerably along strike as they interact with a number of different lithologies and fold geometries. A late D_2 stage of dextral movement occurs on the Glen Lyell Fault. No definite Delamerian fault structures were recognised.

The Lyell Lease has a grossly simple east facing structure NE of the Glen Lyell Fault. The contrast in structure with the folding and faulting south of Queenstown strongly supports the existence of a Cambrian transfer fault along the Firewood Siding Fault and its extension to the east in about the position of the Owen Fault. The syncline recognised by Corbett et al (1989) along Whip Spur probably continues between Comstock and Mt Sedgwick. The Tyndall Group postdates the initial formation of this syncline. although it has been effect by tightening of the structure in the Devonian.

INTRODUCTION

The study of the Mt Lyell area has been reported over all three of the previous reports. As the section from Strahan to Victoria Pass is now complete and structural work on the lease is largely finished (except the geochemical modelling of the North Lyell system), a review of the results is provided here. A full restatement of the program will be made in the final report.

DEVONIAN DEFORMATION

Three phases of Devonian faulting were recognised and the first two of these are consistent with the regional fault pattern of western Tasmania. The last generation structures are relatively weak and are only found in a few localities. A weak S_3 cleavage is visible along the Great Lyell Fault from Cape Horn to Comstock. Sinistral faulting was recognised in Tharsis Trough and in the Queen River near Lynchford.

D_2 produces upright tight folds in the Siluro-Devonian sediments and steep reverse faults in the Central Volcanic Complex with a transitional zone of tight angular synclines and open anticlines in the area of the mill (Fig. 1). During D_2 the most intense cleavage development is in a zone which runs from the Victoria Pass up the Linda Valley, across Philosophers Ridge and then in a broad band south of the Firewood Siding Fault. The structural style of this zone is shown in sections across the Linda Valley (Fig. 2) and at Victoria Pass (Fig. 3). Within this zone S_1 is largely unrecognisable due to the overprinting. The major deformations within the Central Volcanic Complex during this phase are reverse faults and the major dextral fault zones through Glen Lyell, and to a lesser extent along the Great Lyell Fault. A feature of the D_2 event is the associated complex faulting. NE directed thrusts are common and at least partly predate the S_2 cleavage development. High angle reverse faults are common along the Great Lyell Fault and in the North Lyell area. Very brittle dextral wrench movements are dominant on the Glen Lyell Fault. There are very extensive vein arrays which are synchronous with S_2 indicating high fluid pressures at this time.

The early phase (D_1) is related to thrusting north and south of the Lyell alteration zone but mainly folding over the mineralised area (Fig. 4). Major transfer zones (e.g. North Lyell Fault) are associated with this change in style. Associated with the monoclinal structure at Mt Lyell are a series of subvertical west side up faults which thin the section (Fig. 5). It is the interaction of these structures with early syn-D_1 thrusts which have produced the complex geometry of the Tharsis Trough and the Razorback(Fig. 5,6). (Note that while the geometry is the same, the Razorback Fault truncates all other faults in the area, and has no alteration or folding along it suggesting this is a syn-D_2 fault.)

A N–S fold event predating S_1 was recognised in the area south of Queenstown but has also been found in Bell Shale correlates in the King River. In the former case, the folding appears to be the cause of the Ordovician unconformity along the Queen River. This ambiguous relation is typical of the problems in any complete structural interpretation of western Tasmania. The multiple reactivation of faults has lead to a large number of local effects.

DELAMERIAN OROGENY

Work outside the Lyell Leases has increasingly supported a major deformational event at about Haulage time. For example, the Haulage Unconformity is only the edge of an extensive area where the Pioneer Sandstone cuts across a large suite of rock types at high angle and cuts out the entire CVC just south of Queenstown. The Miners Ridge Thrust is in the correct position to produce some of this effect as a hangingwall anticline but this is not certain. The study east of Zeehan also suggested a fold event which predated the Owen deposition. The discussion over the significance of various unconformities within the Late Cambrian of Tasmania has a long history but as more is known the evidence continues to support active tectonism. The possible solutions to this riddle are considered in the overview of the project. At this point it is only necessary to point out that evidence supporting a series of unconformities, in the Lyell area, during the Cambrian is overwhelming. The CVC is restricted to a synclinal position cutting out underneath the Tyndall Group both near Marble Bluff in the east and near Queenstown in the west. The Tyndall Group itself thins over the CVC suggesting an onlap relationship. A similar feature occurs in the thickness on the Owen conglomerate with the thickest development of Owen Conglomerate further west than the Tyndall Group.

HAULAGE UNCONFORMITY

Unfolding the Devonian structures, suggests that all perfect exposures of the Haulage Unconformity indicate a relatively shallow dip (~40°) to the east during deposition of Pioneer sandstone. This dip cannot explain the great change in thickness of Owen and requires a structurally bound basin. The best solution is a Late Cambrian normal fault margin to the basin of Owen Conglomerate deposition. The Haulage unconformity appears to be related to normal drag on this fault margin. In making this statement there is a need to compare this with the Queen River and other evidence of folding and thrusting below the Pioneer Sandstone. An open folding event at Delamerian could produce the Haulage Unconformity provided the synclinal hinge was at the basin margin.

NORTH LYELL MINERALISATION

It was argued in Berry (1990) that the North Lyell mineralisation was pre-Pioneer based on the abrupt reduction in alteration at this boundary at a number of localities. Further work on the North Lyell alteration is suggesting that the alteration is much more extensive than realised earlier. Of the three styles of alteration in the Lyell schists (sericite; hematite; barite), two penetrate far out into the Owen Conglomerate and Pioneer Sandstone. Only barite is missing from the extensive alteration zone. Whitford et al (1992) have reported Sr isotope data from the North Lyell area. They conclude that the more evolved Sr isotope ratios of some vein style barites in this area is consistent with a major remobilisation in the Devonian. Assuming 130 Ma between the two events and the simple model of a separate extraction of Sr the values reported are consistent with a Rb/Sr ratio of 0.1 to 1.3 in the source of the fluids (Fig. 7). The highest Sr^{87}/Sr^{86} ratio comes from veins at Madam Howard Plains, in the Yolande River sequence, which is consistent with the higher Rb/Sr expected in clastic sediments. Fresh CVC lavas have a Rb/Sr ratio around 0.3 (Crawford & Corbett 1992). However the North Lyell area has extensive alteration which changes this ratio dramatically. While we do not have exact values at North Lyell, Manning (1990) reports 70 Rb and Sr analyses from Western Tharsis which average Rb/Sr = 0.2. There is a very large variation in Sr with two populations, one depleted in Sr and one enriched to about 1000 ppm. All this information is completely consistent with the interpretation put forward by Whitford that the barite was remobilised in the Devonian and Sr was extracted from the altered North Lyell rocks. As a result of all these factors, I now prefer a Devonian age for the hematite barite alteration at North Lyell and it appears a reasonable extension of this conclusion that the high grade Cu in the North Lyell field was the result of enrichment of the Cambrian diseminated deposit during prograde metamorphism. The presence of both S_1 and S_2 cleavage in the alteration indicates the alteration was pre- or syn-S_1. The geometry of the North Lyell mineralisation is much easier to explain if this part of the mineralisation predated the F1 folds (especially this obviates the need for metamorphic fluids to circulate downwards). The distribution of the alteration along the western margin of Tharsis Trough suggests that the alteration continued throughout D_1.

GREAT LYELL FAULT (GLF)

The Great Lyell Fault was defined as all conglomerate/Lyell Schist contacts. These contacts are very variable but a large number of then are subparallel to bedding with little evidence of faulting. These surfaces are interpreted here as an onlap surface. Other surfaces are at a low angle to bedding but with evidence of strong Devonian shearing, e.g. eastern side of Tharsis Ridge. The final type of boundary are faults at a high angle to bedding, The use of Great Lyell Fault in all these situation is very confusing and a redefinition is required.

MACROSCOPIC GEOMETRY

The section east of the Glen Lyell Fault as a continuous east facing sequence and contrasted this with the facing west of the fault in Conglomerate Creek. The structure is a consistent steep dip to the east cut by numerous sub-vertical west side up faults. The major diseminated ore bodies of Prince Lyell, Western Tharsis etc. are approximately parallel to bedding.

The contrast in structure with the folding and faulting south of Queenstown strongly supports the existence of a Cambrian transfer fault along the Firewood Siding Fault and its extension to the east in about the position of the Owen Fault. The syncline recognised by Corbett et al (1989) along Whip Spur probably continues between Comstock and Mt Sedgwick. The Tyndall Group postdates the initial formation of this syncline. although it has been affected by tightening of the structure in the Devonian.

CONCLUSIONS

The additional work on the Lyell area supports the previous indications that the Haulage Unconformity is related to relatively shallow dips to the east and the geometry is compatible with a normal fault margin. However regional data is supports a more active tectonic setting and the implications for the Mt Lyell area have not yet been fully tested.

The age of the North Lyell alteration has been re-evaluated. Both S_1 and S_2 are visible in the altered Owen Conglomerate. The alteration does penetrate into Pioneer Sandstone and possibly into Gordon Limestone but the intensity drops of sharply at the contact in some places. The additional work in this area combined with recently published isotopic evidence supports a syn-D_1 (Devonian) age for the North Lyell ore bodies.

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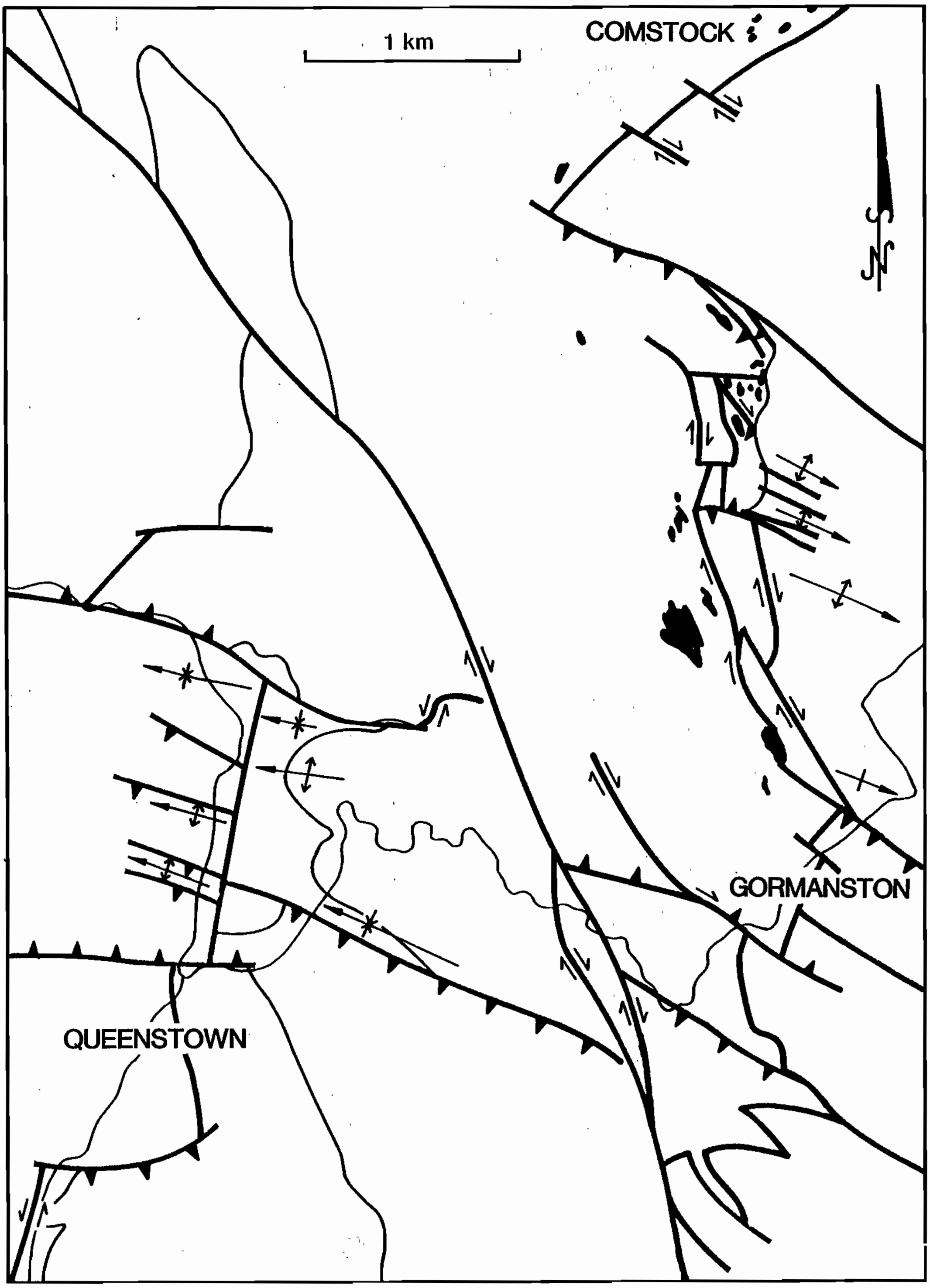

FIG. 1 Interpretation of large scale D_2 structures in the Mt Lyell area

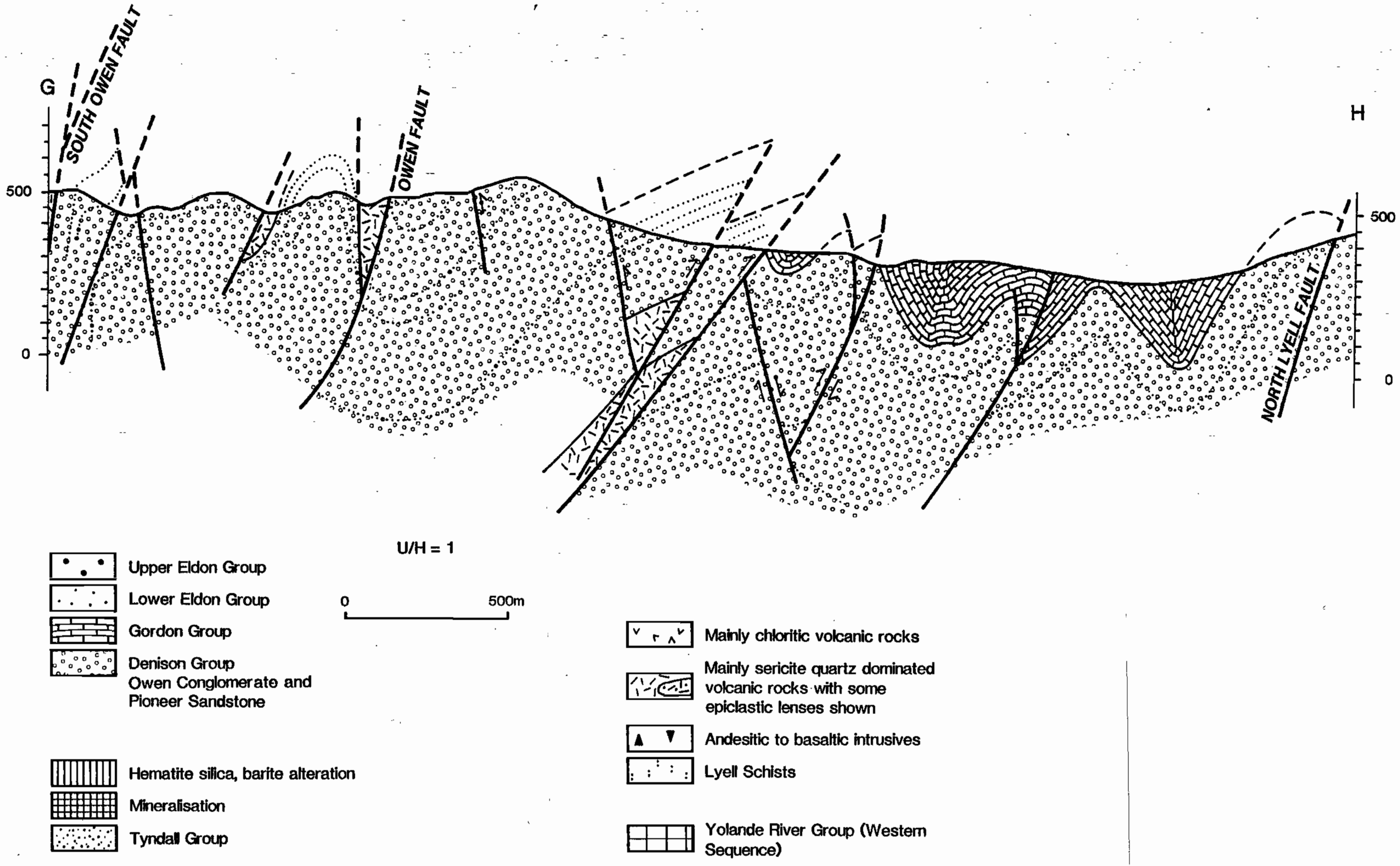

FIG. 2 Cross-section across the Linda Valley just west of Mt Lyell.

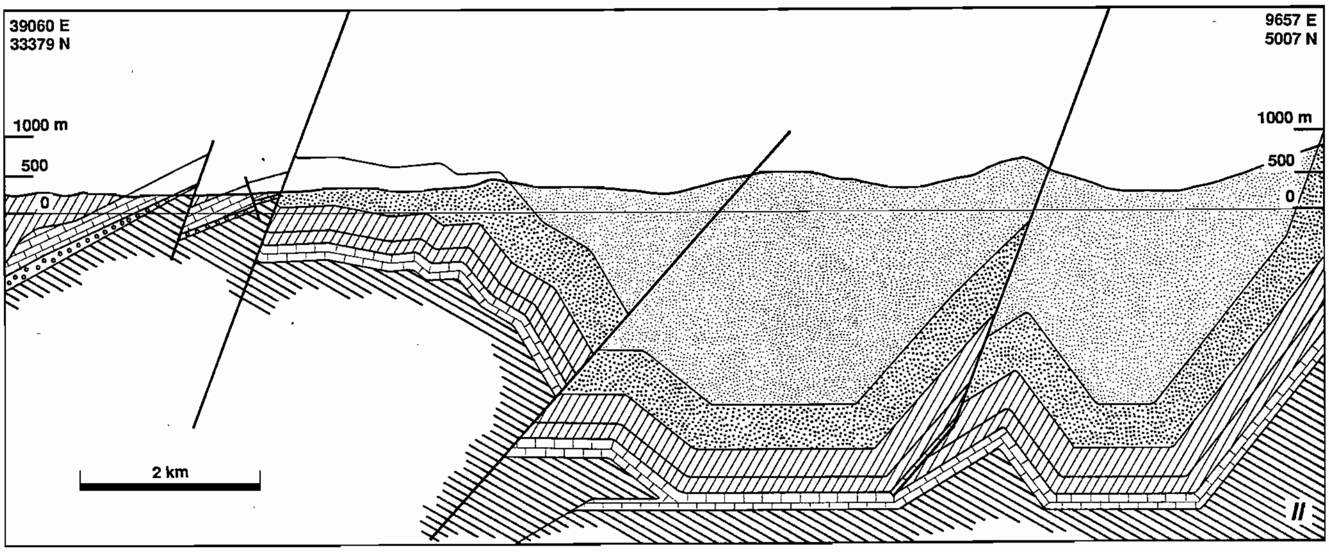

FIG. 3 NNE trending cross-section through the Linda Zone at the Princess River.

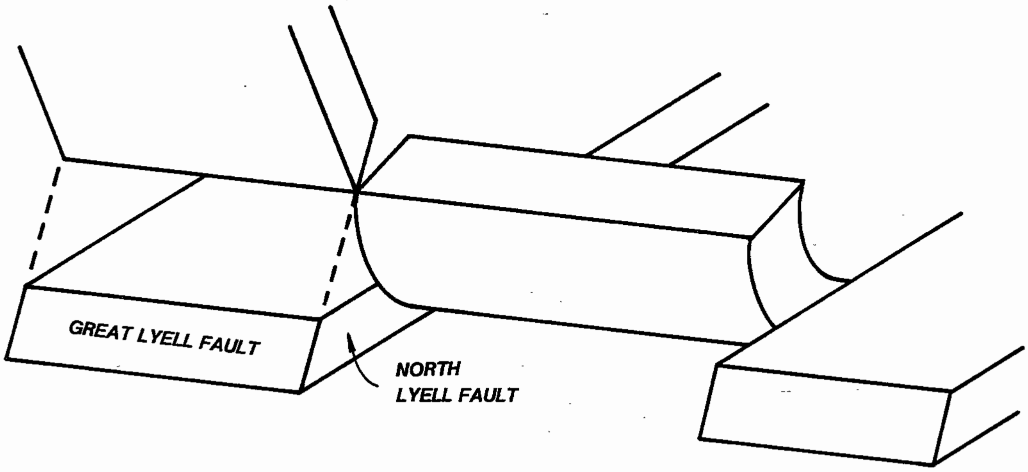

FIG. 4 Cartoon of the change in D_1 style along the Great Lyell Fault

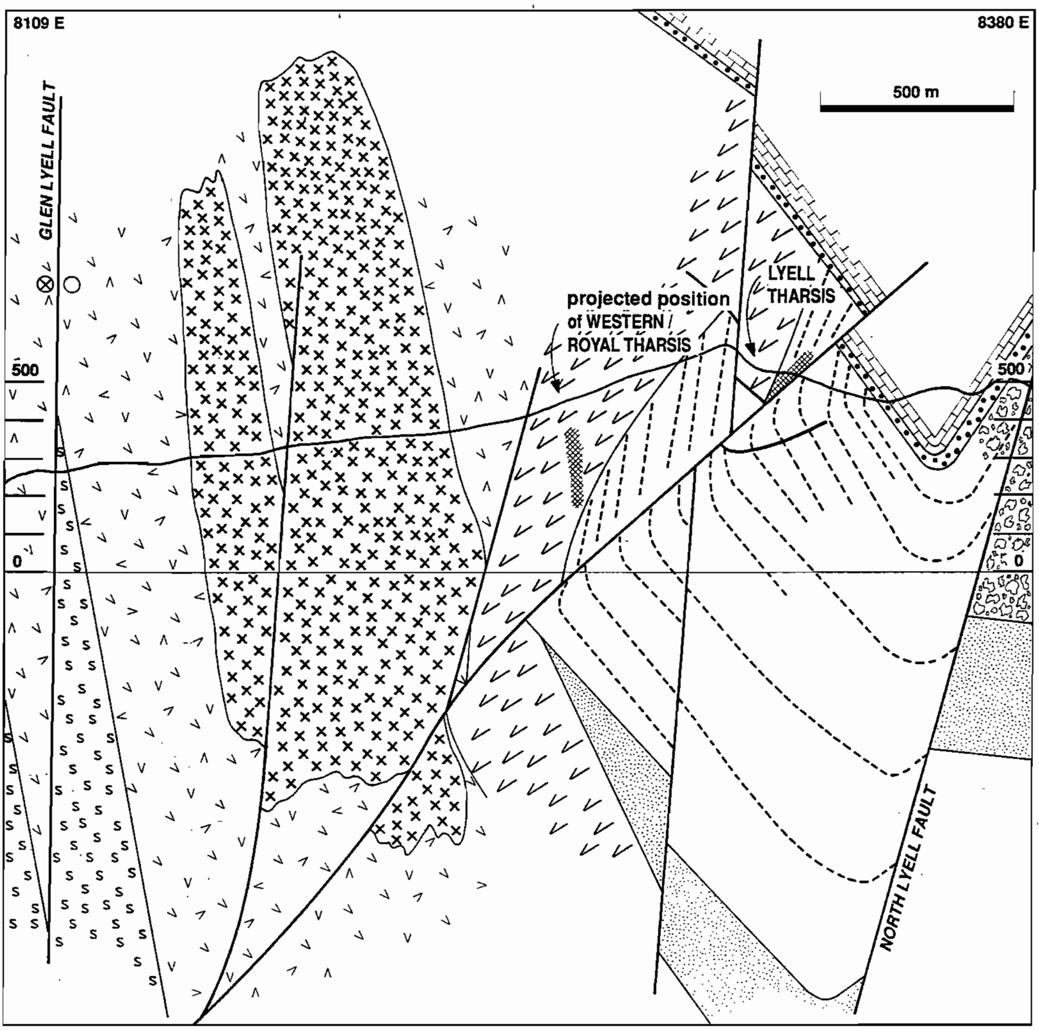

FIG. 5 Cross-section along the line 4305 N from the Glen Lyell fault to the North Lyell Fault.

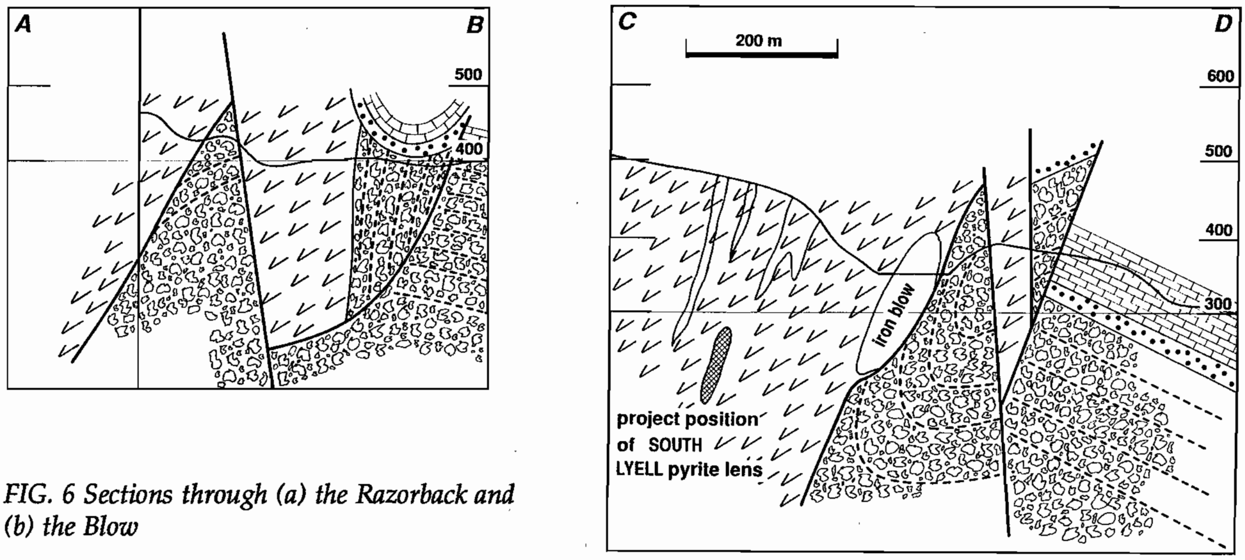

FIG. 6 Sections through (a) the Razorback and (b) the Blow

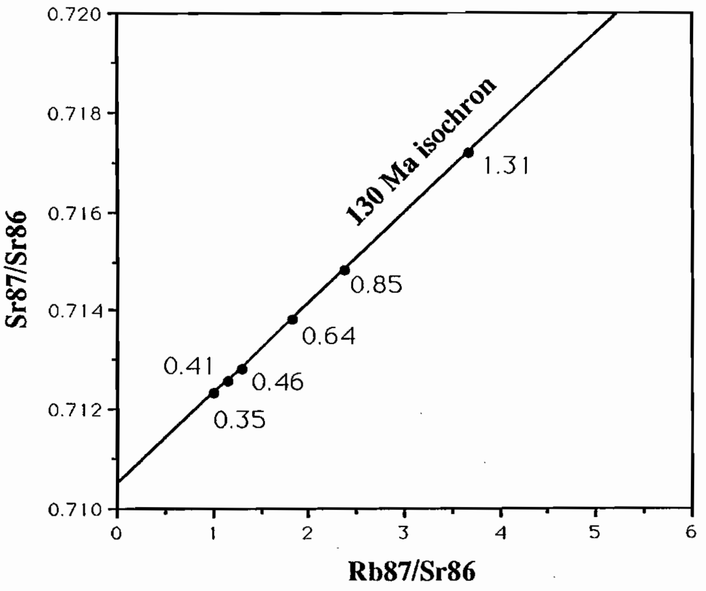

FIG. 7 Sr isotopic diagram showing barite samples from veins in the Lyell area from Whitford et al 1992. An isochron has been drawn for 130Ma with an initial ratio of 0.7105. The initial ratio is the mean value for barite in stratiform mineralisation. The Rb/Sr ratio required in the source for these samples to evolve to their present values in 130 Ma is a linear function of the Rb87/Sr87 value and is shown against the samples. The highest sample with a Rb/Sr of 1.31 is from Madam Howards Plains in the Yolande River Group and is consistent with the higher Rb/Sr expected in clastic sediments.

Quartz Veins and Cleavages: a note on the Mesocopic Structures at Mt Lyell

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INTRODUCTION

The Lyell Highway traverse, which extends from the base of the hill to the Iron Blow, provides a continuous section through the mine sequence volcanics at Mt. Lyell (Fig. 1). It crosses an F_1 fold hinge, which is an important domain boundary separating the east and west facing parts of the mine sequence (Cox, 1981); it also crosses a strongly altered section of mine sequence volcanics. This domain boundary, and the western edge of the mineralised zone associated with the alteration, is marked by a dextral strike-slip fault, called the Glen Lyell Fault. The observations included here record vein textures, cleavages, faults and shear bands, all of which have be used to refine the existing kinematic model (Berry, 1990).

SYNTAXIAL AND ANTITAXIAL QUARTZ VEINS

The abundant quartz veins related to the Devonian deformation event at Lyell show good fibre development and both *syntaxial* and *antitaxial* forms are present (Fig. 2a & b). Being able to recognise which, without the benefits of a microscopic examination, depends on whether it is possible to observe curved fibres at the centres or at the edges of the veins; for instance, in syntaxial vein growth the fibres grow from the outside towards the centre, whereas in antiaxial veins they grow from the centre towards the outside (Ramsay and Huber, 1983). The assumption made here is that the veins dilated perpendicularly to their walls at the initial stages and only later did they dilate obliquely, giving their chararcteristically curved form (Figs. 2 a, b, c & 4). If it had been the other way round, i.e. the initial dilation had been oblique, then a fault or shear joint, and not a vein, would have developed. Based on a number of observations on Philosophers Ridge, it appears that the syntaxial dominates over antitaxial by a ratio of approximately 5:1.

The reasons for the relative abundance of syntaxial over antitaxial veins may simply reflect the amount of quartz in the altered volcanics. In syntaxial fibre growth the main constituent of the vein has to be an abundant mineral phase in the wall rocks as well, so that each fibre may grow as an optically continuous grain from the walls towards the inside of the vein — hence their dominance may reflect the greater proportion of silicified volcanics that occur in the mine sequence. In the case of antitaxial veins, the grains have to nucleate on the joint surface, because there are no grains in the wall rock on which they can nucleate, and thus they continue to grow outwards from a central suture. Chlorite veins that have grown in sericite-rich volcanics have to be antitaxial; examples at Lyell usually preserve the silicified "suture" in the centre of the vein where the original crack in the rock occurred (Fig. 2c).

The syntaxial veins record any bulk rotations that the rock mass has experienced due to shearing. On Philosophers Ridge, for example, progessive movements within a shear zone have been recorded in a series of *en-echelon* quartz veins; here, the sygmoidal quartz fibres record a clockwise sense of rotation in an antitaxial vein (Figs 2c & 4). Assuming that the shear surface is known, then it should be possible to derive the sense of shear merely by plotting the orientation of the fibres on a stereonet; since the fibres rotate *towards* the movement direction, the sense of rotation will be clockwise for a dextral shear and anticlockwise for sinistral shear.

A fundamental difference between the two types of veins exists because in syntaxial veins the last material to crystallise is always at the centre of the vein, whereas in antitaxial growth it is always at the edges of the. There is always a greater opportunity for fluid-wallrock interaction, and hence deposition of metals, in antitaxial veins than there is in syntaxial veins.

RELATIONSHIP OF QUARTZ VEINS TO FAULTS AND CLEAVAGES

A common situation at Mt Lyell is the parallel development of fibres in the quartz veins and shear fibres in the faults (Fig. 6); since the vein and the shear fracture are approximately perpendicular to each other, they can therefore be demonstrated to have formed synchronously. This is part of the D_1-transitional phase of deformation at Lyell, where both sinistral oblique and strike-slip movements took place. Such quartz veins may show evidence of continued deformation and be overprinted by a metamorphic fluid that carried iron and sulphur (Fig. 2d). There is also evidence of D1 transitional movements along the Glen Lyell fault, because of a weak sinistral rotation of the boudins (Fig. 3d).

An example of the two cleavages often observed at Mt. Lyell, which here is from a position adjacent to the Glen Lyell Fault; it shows what is often assumed to be an S_1 cleavage but may be either a fabric related to the fault or a reactivated bedding/banding surface formed during D_2 wrenching (Fig. 3a). The D_2 structures are ductile because of the sericitic alteration and moderate extension that occured along the intersection of these two cleavages (Fig. 3b and 5a), a direction that is kinematically related to the dextral wrenching event, i.e. it is sub-perpendicular to the movement direction (Fig. 5 a & b). The shear bands, despite their dip-slip movements, are more in keeping with the D_2 event, because of their NW orientation and their sub-perpendicular relationship to the extension direction (Fig. 5b). Away from the most intense alteration, the antitaxial quartz veins are developed in a dextral shear regime, suggesting there was a partitioning of the deformation, with the more brittle structures forming outside and away from the ore zones (Fig. 5a).

KINEMATICS AND A METAMORPHIC FLUID

Walshe and Solomon (1981) suggested that the temperatures calculated from chlorite compositions at Prince Lyell reflected metamorphic re-equilibration during Devonian cleavage formation, which implies the flushing of a fluid through the system. The abandance of quartz veins attests to considerable amounts of metamorphic fluid having been present during D_1 and D_2 at Mt Lyell much of which is likely to have picked up and transported metal. Any attempt to establish the degree of remobilisation of ore components at Lyell has to take into account not only the presence of such a fluid and its ability to take up metals, but also the kinematics which would have necessarily controlled the movement of these fluids through the system. The kind of fabric inherited during D_2 wrenching — a horizontal movement direction and a steep extension/intersection direction — are prime pathways for a metamorphic-derived fluid (Fig. 5a & b)

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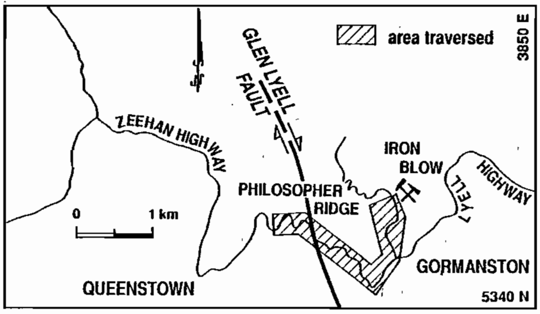


FIG. 1 Location diagram showing the traverse in relation to the Glen Lyell Fault

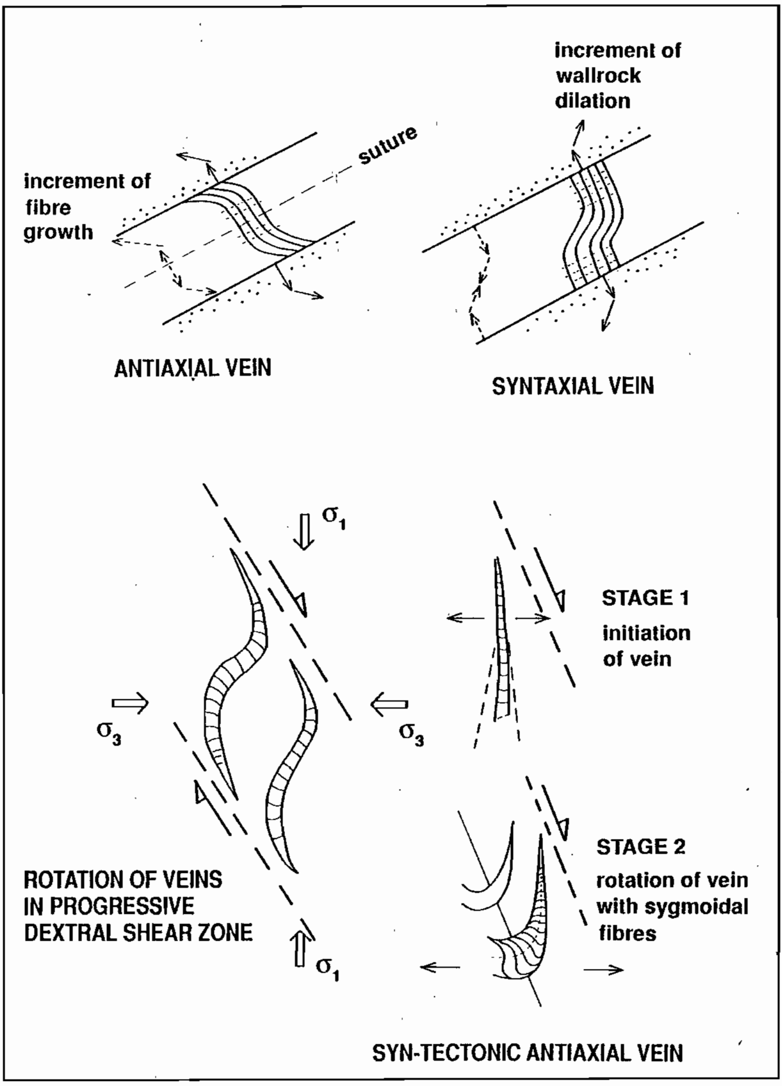


FIG. 4 Explanatory diagram showing how antitaxial and syntaxial quartz veins form (see text for explanation). Lower part of diagram shows the generalised stress orientations in a dextral shear zone. Note that when the gash vein forms the fibres grow in the direction of least principal stress (stage 1), which they continue to do so when the same vein has suffered rotation, hence the curved fibres (stage 2).

FIG. 2 Mt Lyell vein textures

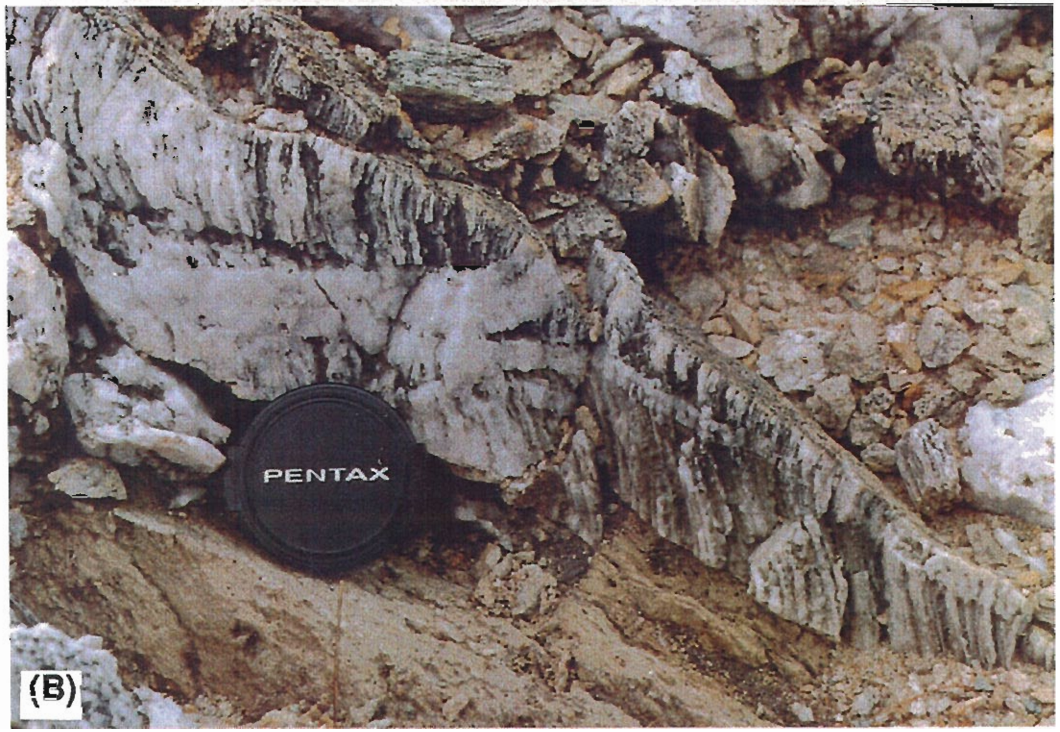
A *Syntaxial quartz vein in mine sequence volcanics. The sense of displacement across the walls of the vein is left-hand. The fibres in the quartz vein at lower left of photograph parallel the orientation of the fibres at the centre of the main vein, indicating that this smaller vein formed towards the end of the dilation event, as a result of a 90 degree rotation of the direction of extension in the rock. Locality: Philosophers Ridge.*

B *Syntaxial quartz vein in mine sequence volcanics. The growth of the vein was somewhat asymmetric with the fibres growing inwards at a faster rate from the upper wall than the lower wall. The bucky layers represent a period of rapid opening whereby fibre growth was unable to keep pace with the dilation of the walls. Locality: Philosophers Ridge.*

C *En-echelon, antitaxial quartz-chlorite veins formed within a brittle-ductile shear zone. The prominent quartz-rich central suture of the vein (bottom right) indicates that the growth was from the centre outwards; the sygmoidal fibres indicate that the vein rotated whilst it was dilating. The sense of movement is right-hand up down the vertical axis of the photograph. Whilst the vein geometry is dextral the cleavage parallel to the pencil is not, suggesting that this structure is late-stage and possibly a reactivation of a sinistral zone. Locality: Philosophers Ridge.*

D *Sub-horizontal D_1 quartz vein in altered mine sequence volcanics. Note the bleached halo around the vein at right. A second phase of alteration related to strong cleavage development, comprising sericite–pyrite ± quartz, truncates this earlier phase. As a consequence of the greater permeability and enhanced fluid flow within this structurally controlled vertical "lode", the vein and the adjacent wallrocks are deformed (i.e. where the alteration is most intense is). Such structures suggests this later fluid is produced during D_2. Locality: Lyell Hwy section.*


(A)


(B)


(C)


(D)

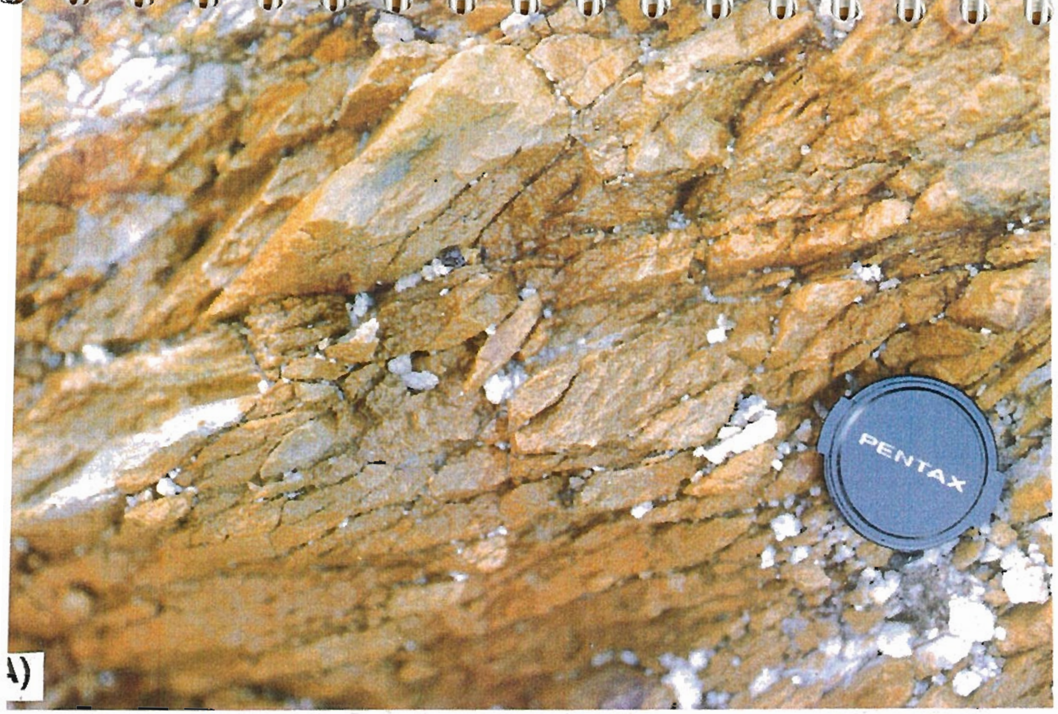
FIG. 3 Ductile fabrics at Mt. Lyell

A Strong quartz-sericite-pyrite altered mine sequence volcanic rock that shows two cleavages. The sygmoidal shape of the S_2 *cleavage and the proximity of this site to a dextral wrench fault, suggests that the spaced cleavage running across the photograph is either reactivated banding in the volcanics* (σ_0)*, or a relict* S_1 *cleavage. Locality: Lyell Hwy section.*

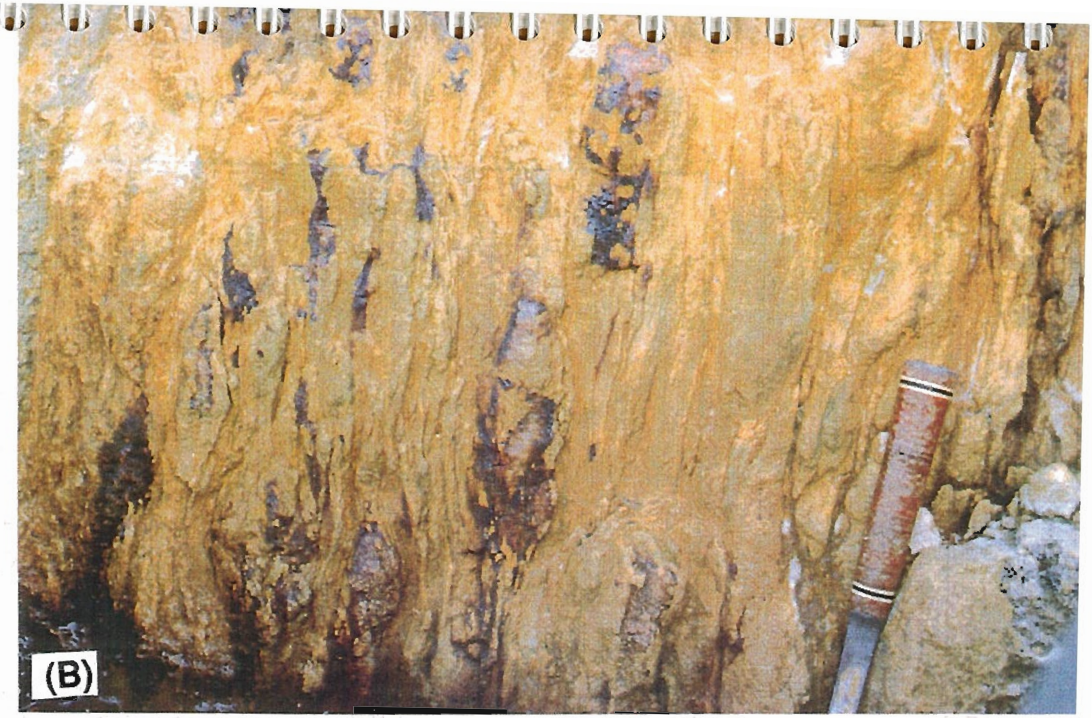
B Elongate quartz-pyrite lenses in altered mine sequence volcanics. This photograph is taken adjacent to the dextral wrench fault that divides the Lyell geology into two structural domains (Cox, 1981); the plunge of these lenses parallels the intersection of the two cleavages in the previous photograph. Locality: Lyell Hwy section.

C A shear band with reverse sense of movement in the mine sequence volcanics. The shear band is restricted to the most intensely altered domains and dies out in the adjacent chloritic volcanics (not shown in this photograph). These shear bands have SW transport and are spatially related to the sinistral phase of wrench deformation which is transitional between D_1 *and* D_2 *(see also D). Locality: Lyell Hwy section.*

D Weakly asymmetric pods of quartz-pyrite alteration which have been deformed as a result of the D_1 *transitional sinistral wrenching phase of deformation at Lyell. Locality: Lyell Hwy section.*



A)



(B)

C)

(D)

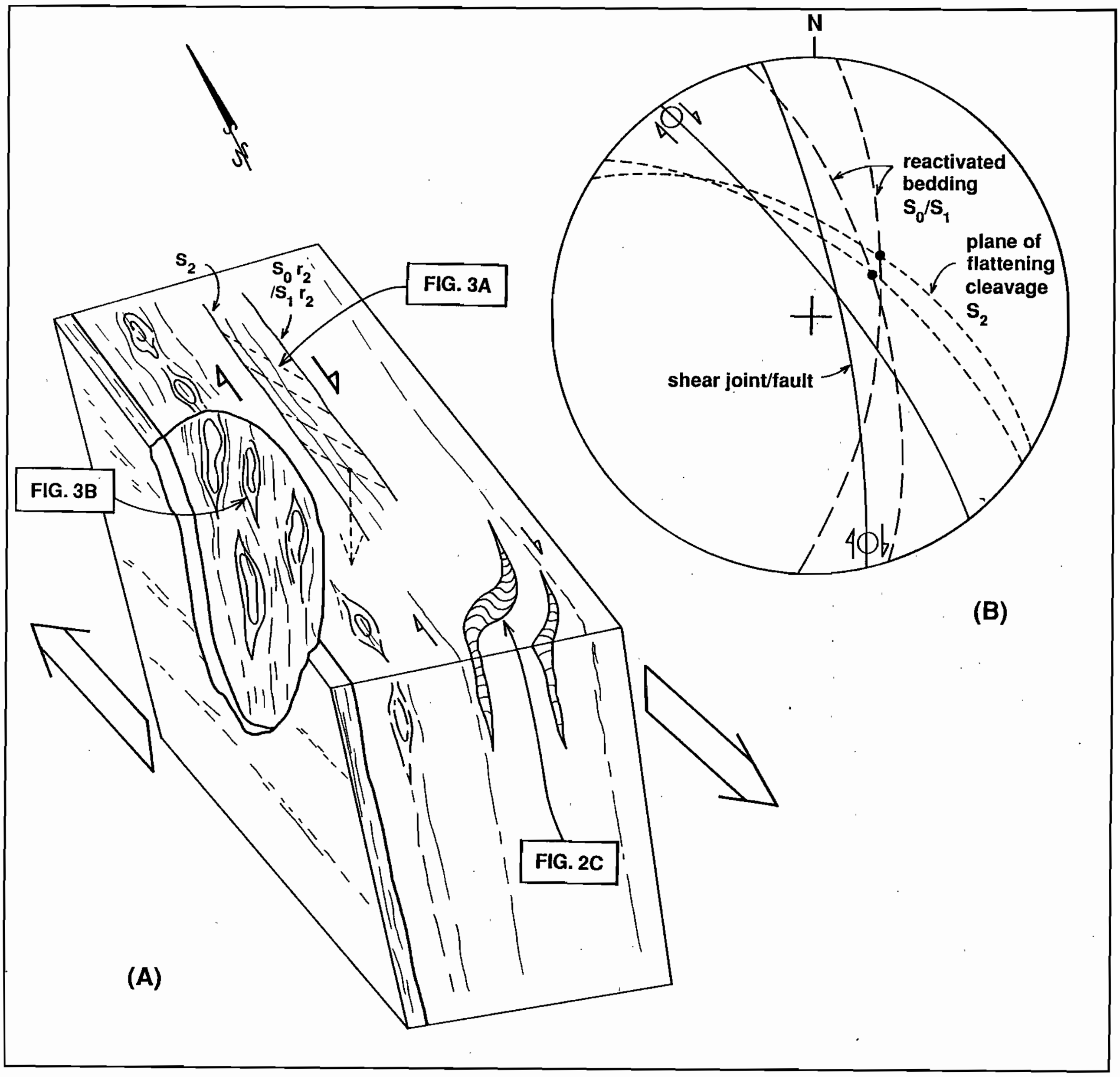


FIG. 5 Block diagram showing the mesocopic structures related to D_2 deformation. The intersecting of the cleavages and the elongation of the siliceous boudins parallel one another and the whole is related to dextral wrenching on the Glen Lyell Fault. The quartz veins with the sygmoidal fibres are assumed to have formed in a slightly more brittle deformation regime than the fault rocks (presumably the alteration was less intense?).

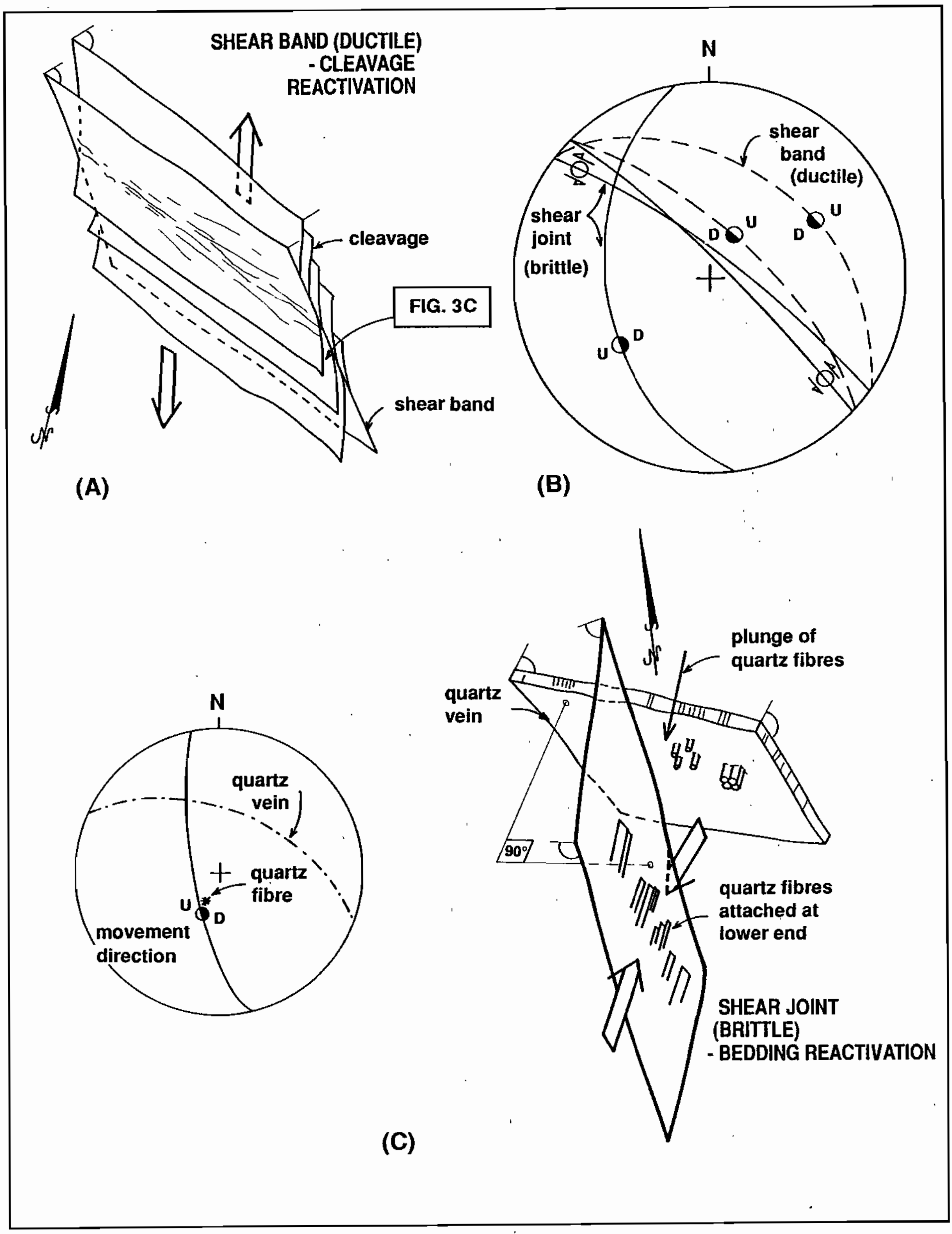


FIG. 6 Diagram showing the mesoscopic structures associated with the D_1 (transitional) deformation. The shear bands have characteristics to suggest that may belong to either D_1 or D_2; for instance, they are a reactivated cleavage and they have the S_2 orientation (D_2), however, spatially they are related to the sinistral strike-slip faults (D_1). The fault in (c) with its associated quartz veins are more typical of the orientations at Lyell and they may be related to an S_1, now largely destroyed, as much as to bedding.

An Overview of the Southern Arthur Lineament

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ABSTRACT

The Arthur Lineament is a complex fault zone which has experienced movements from the late Precambrian through to the Tertiary. A regionally stable foliation cuts through the lineament into the eastern part of the Rocky Cape Province. The eastward transport implied by the structures in the Rocky Cape association, contrasts with the west vergence of structures in the Arthur Lineament. This can be explained by dextral-oblique movements on the Arthur Lineament where the deeper parts of the fault zone are progressively uplifted causing the juxtaposition of high and low metamorphic grade rocks and structural repetitions. Such ductile deformations, normally associated with the Penguin orogeny, may belong the Delamerian Orogeny of Late Cambrian age.

The syn-D_2 (Devonian) emplacement of the Meredith and Heemskirk granites is the principal cause for the arcuate trend in the southern Arthur Lineament. Scattered alluvial gold mineralisation is spatially related to shear zones in the amphibolite grade Bowry & Nancy Formations, and faulting in the sub-greenschist facies Ahrberg Formation.

INTRODUCTION

The Arthur Lineament (Turner,1989) is a NE trending zone of brittle and ductile strain separating the Rocky Cape Province from the trough sequences of Late Precambrian to Cambrian age in central western Tasmania. It marks the western edge of the Burnie-Oonah trough, a late Precambrian platform sequence which was the precursor to the Dundas Trough (Leaman,1988); the rocks are Late-Precambrian in age and represent strongly deformed Oonah Formation, or their equivalents (Turner,1992).

In the light of recent K-Ar dates which suggest that Cambrian, as well as younger movements, had occurred on the Arthur lineament (Turner, 1992), an evalution of the structures from the recently released Corinna map sheet (Fig. 1) was considered to be a useful exercise. The lack of any direct evidence for Cambrian movements in the southern part of the Dundas Trough has shifted some of the emphasis away from the Mt Read Volcanics towards the Arthur lineament. Therefore, the purpose of this report is to present data that puts constraints on the tectonic and structural development of the western margin of the Burnie–Oonah trough as well as the evolution of the younger and more restricted Dundas Trough sequences; it takes the form of:

1. A foliation trajectory map of the western half of the Corinna sheet.
2. An assessment of all kinematic criteria.
3. A review of the gold occurrences in the southern Arthur Lineament.

The oxide and base metal mineralisation will not be discussed in this report, despite a close relationship to the structures described herein, because the mineralisation is poorly understood; and it may be volcanogenic or it may be remobilised, or or it may involve components of both.

FOLIATION TRAJECTORY MAP

A foliation trajectory map is useful for a number of reasons, the principal ones being that they may:

- highlight areas of faulting.
- point to areas of higher than normal strain, i.e. shear zones.
- confirm the sense of movement on a shear zone.
- discriminate between regions of dip-slip and strike-slip.
- outline individual structural domains.
- define areas of potential mineralisation.

Such information may be particularly useful when assessing the suitability of a region for exploration if the mineralisation has a remobilised component to it, such as the Savage River iron ore deposits (Coleman, 1975); or it may be useful if there is widespread disseminated mineralisation of the type that might be derived from a metamorphic fluid e.g. gold. On the basis of the foliation trajectory map, the region has been sub-divided into three main structural units (Figs 1, 2):

1. *The Timbs Group or the Bowry Formation Shear Zone*
2. *The Donaldson-Lefroy Ridge Fault Block*
3. *The Pieman Fault Block*

TIMBS GROUP OR BOWRY FORMATION SHEAR ZONE

The Timbs Group refers to the strongly schistose mainly metasedimentary rocks lying between the Lefroy Ridge Fault and the Oonah Formation (Turner, 1992); it comprises the main high strain zone at the southern end of the Arthur Lineament and represents a ductile shear zone typical of the kind of structure developed at mid to low crustal levels under greenschist to amphibolite facies metamorphic conditions (Evans and White, 1984). Since the shear zones themselves may be strongly influenced by the relative incompetencies of the strata involved (White, 1989), the Bowry Formation, containing as it does amphibolites, serpentinites and magnetite mineralisation, has lent its name to the high strain zone on the eastern side of the Timbs Group (Figs 1, 2).

A foliation trajectory map of the Western half of the Corinna Sheet indicates that faulting is more extensive in the BSZ than the geological map shows (Fig. 3). The thickening of the schistose metasediments (up to a maximum 10 km) was accompanied by faulting along the upper, or eastern sides, of the Nancy and Bowry Formations (Fig. 2). The latter structure swings N–S to E–W at its southern end, where it locally parallels the Devonian crenulation cleavage suggesting that the BSZ was re-activated during the Tabberabberan Orogeny. The dextral nature of the shear bands on the southern limb of the open E–W fold, to which these crenulation cleavages are undoubtedly related, supports a synthetic shear origin for the cleavage during emplacement of the Meredith and Heemskirk Devonian granites (Fig. 1).

The eastern side of the Arthur Lineament is a highly ductile shear zone some one half to one kilometre wide called the Bowry Shear Zone (BSZ). The foliation trends in the Oonah Formation to the east of the shear zone have a distinct NNW trend and merge with, or cross-cut, the more northerly trending BSZ at very low angles, with a sense that is consistent with dextral geometries (Fig. 3). Further east again, the transitional metamorphic boundary between moderate and low metamorphic grades in the Oonah Formation parallels this shear zone, whilst the foliation runs undeflected through it confirming its gradational nature. The fact that both the shear zone and metamorphic boundary are offset by the E–W shear bands in the same dextral sense, points to the structures being pre-Devonian in age.

DONALDSON-LEFROY RIDGE FAULT BLOCK

The foliation trajectory map reflects the greater amount of faulting in this block when compared to the previous domain. General foliation trends range from NNE to NNW, either running parallel with the faults, e.g. the Tunnel Race and Bernafai volcanics, or running at an obliqueangle to the faults, e.g. the Corinna and Savage dolomites. This pattern of parallel and oblique trajectories is repeated across this block, reflecting not only the structural repetitions within the lineament, but also the different rheologies of the various rock suites within it; for instance, the volcanic units have behaved as rigid slabs, whereas the sediments have tended to flow. It should be noted that the unconformity appears to have had very little effect on the foliation trajectories.

PIEMAN FAULT BLOCK

The sygmoidal foliation traces between the Donaldson and Pieman Faults is consistent with dextral and, if the SW dip of the foliation is taken into account, E block up or reverse movements between the Donaldson and Pieman Faults (Figs 2, 3). The angle between the Donaldson Fault and the foliation varies from 25° to 90°. This angle depends on how a particular rock unit responded to the stresses generated along the fault plane at the time; for instance, the buckle in the sediments at the northern end of the fault, shown here by the folded unconformity, indicates that σ_1 was oriented along the fault plane. The same stress conditions were present 10 km to the SW on the other side of the fault, a clear indication that the buckle, which is also offset, was fault related and was initiated just prior to significant dextral movement on the Donaldson Fault (Fig. 4). Elsewhere in the more homogeneous Rocky Cape sediments, the angle is a more constant 45° to the faults.

EVIDENCE FOR DEXTRAL OBLIQUE OR WRENCH FAULTING

Some of the main pieces of evidence for dextral movements on the Arthur Lineament are summarised below;

- An 8 km dextral offsets on Pieman Fault between the Interview and Pieman Granites;. a 10 km offset on the Donaldson Fault shown by the unconformity separating the Ahrberg Group from the Rocky Cape Association (Fig. 1); and an unspecified dextral displacement along the Duck Creek Fault on Ordovician strata.
- A major deflection of the fault-bound Tunnelrace Volcanics and Timbs Group sediments into a ductile high strain shear zone.
- A NNW to N trending thrust with an inferred SW transport direction that splays off the south side of the Donaldson Fault zone, an orientation that implies ENE–WSW compression (Fig. 3).
- Observations by the author of dextral S-C fabrics in the Bowry Formation amphibolites, south of Savage River deposit.
- The strong "S" sygmoidal shape of the foliations in the Pieman-Donaldson Fault block is suggestive of a brittle to mainly ductile simple shear deformation regime (Fig. 3); the moderate W to SW dip of the foliation also implies an oblique west-block down component to the movement.
- A N–S (to NE–SW) trending crenulation cleavage of uncertain age in the Ahberg and Timbs Groups.
- E-W trending Proterozoic dykes in the Rocky Cape Province indicative of an E–W compressive stress regime.

EVIDENCE FOR DIP-SLIP MOVEMENTS

The following observations support an E-block-up dip-slip movements:

- Kinematic indicators observed by the author in the Savage River pit give W-block-down movements.
- Foliation trajectories of the tunnelrace volcanics parallel their faulted margins and indicate dip-slip rather than strike-slip movements predominated in this unit.

Circumstantial evidence also suggests that dip-slip and reverse movements may have been important at the southern end of the Arthur Lineament:

- The Donaldson-Lefroy Ridge Fault Block is a convergent fault zone, in which compressive stresses were dominant;
- Considerable uplift is inferred on the BSZ structure because of the close juxtaposition between high pressure rocks formed at 7 kbar, and rocks formed at more moderate pressures (Turner, 1992).
- The geochemical correlation of the volcanics in the Crimson Creek sediments with the volcanics in the Smithton Trough requires thrust repetitions in the Arthur Lineament; the most likely place for a major structure of this kind is in the Bowry Shear Zone.

RELATIVE TIMING OF MOVEMENTS

The movements on the Pieman-Donaldson fault system post-dated the emplacement of the Late Proterozoic dykes. The evidence for this is shown by the dykes being overprinted by the foliation and offset along cleavage faults (Fig. 3). A Devonian age for the ductile deformation associated with this movement is considered unlikely, because of the stable nature of the regional foliation which persists through into the Rocky Cape Province, a region considered to be beyond the Devonian "front". These movements are believed to be Middle to Late Cambrian in age based on a new date of 510 Ma on a hornblende whose growth is synchronous with the shearing (Turner, 1992); and due to the tendency among workers on the mainland to label everything that is not Devonian in the western Tasmanian terrain, as Delamerian.

The arcuate form of the lineament is caused by the dynamic emplacement of the Heemskirk and Meredith granites which, because of their association with the E–W trending crenulation cleavage, are D_2 in age (Fig. 1). The dextral offsets along the foliation and lithological trends at the extreme southern end of the lineament is due to synthetic shearing along one of the limbs of this open fold as a result of dynamic emplacement of the granites. The lack of sinistral synthetic shears on the other limb indicates an asymmetry which cannot be readily explained; however, the dominance of the former may reflect the ENE trend of the super batholith (Leaman, 1988) which underlies much of the central west coast region, or it may reflect the dominant dextral nature of the zone.

At least 20 km of post-Devonian wrench movement is recorded by the offset of the Interview and Pieman granites and the offset between the Heemskirk and Pieman granites (Fig. 1). SE-block- down movement is implied by the preserved cover of Tertiary basalt on the coast SE of the Donaldson Fault.

UPLIFT ON THE ARTHUR LINEAMENT

The presence of higher grade metamorphic rocks abutting sub-greenschist facies rocks within the Arthur Lineament implies that a considerable amount of uplift has taken place on it during its long history. Oblique (dextral and reverse) movements are able to account for the structural repetitions and a widening of the metamorphics to the south, in much the same way as the distribution of the Alpine Schists along the Alpine Fault in New Zealand has been explained by successive phases of uplift on a dextral and reverse (i.e. oblique-slip) fault (White, 1989). One of the key features of the New Zealand experience is that augen mylonites have been juxtaposed against cataclasites, and that the the main schist belt widens towards its southern end.

GOLD MINERALISATION

Alluvial gold workings are widespread along the eastern, or upper, side of the Timbs Group Shear Zone. There are three major occurrences; the first occurs within, or immediately adjacent to, the Bowry Shear Zone; the second occurs on the sheared upper or eastern side of the Lucy Formation and the third occurs as evenly distributed group of workings between two sedimentary packages of the Ahrberg Group (Fig. 3). The alluvial deposits in the Timbs Group occur immediately to the west of the two shear zones; allowing for the general SW transport of particulate gold in the flowing rivers, the gold is clearly being sourced from the most strongly sheared parts of the sequence. In contrast, the gold in the sub-greenschist facies Ahrberg Group is related to leakage from faults that cut the more reactive carbonate-bearing sediments.

Leaman and Richardson (1989) noted that the oxide mineralisation reaches its best potential (at Savage River) where the thermal input of the Meredith granite was greatest. Since it has been argued that the bowed or arcuate trend of the southern Arthur Lineament is due entirely to squeezing by the Meredith and Heemskirk granites, it is possible that granite-related gold-bearing fluids could have permeated along shear zones reactivated during the Devonian. This is not thought to be an entirely satisfactory explanation because the gold is too widely dispersed to be spatially related to either of the plutons.

CONCLUSIONS

1. The Arthur Lineament is a complex fault zone which had experienced movements from the late Precambrian through to the Tertiary.
2. Foliation traces support a ductile phase of penetrative deformation whose geometry is consistent with a dextral wrench fault system. Such ductile deformations are normally associated with the Penguin orogeny; however, much of the movements along the fault may be Cambrian in age. The high-angle reverse movements (E block up) in the higher grade part of the Arthur Lineament, and other repetitions, are probably due to uplift arising out of the oblique nature of movements along the fault zone.
4. The Meredith and Heemskirk granites are syn-D_2 Devonian in age, their emplacement causing the arcuate trend in the southern Arthur Lineament.
5. Gold mineralisation is spatially related to the shear zones, especially the Bowry Shear Zone. Two possible sources for the fluid are considered: a granitic source, derived from Devonian granites, or a deep crustal source with the metal being transported in a metamorphic fluid.

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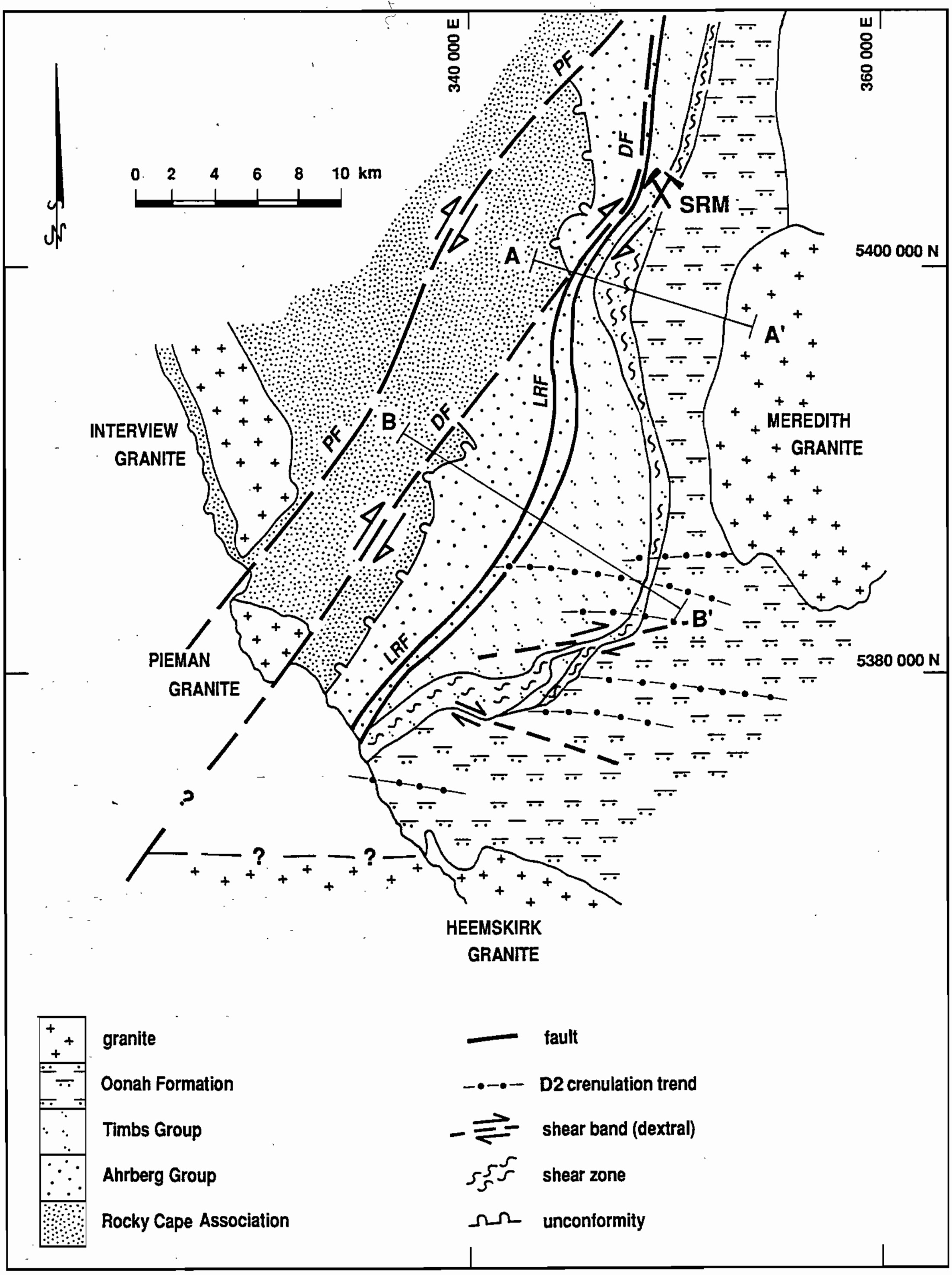

FIG. 1. Simplified geology of the southern Arthur Lineament showing the position of the cross-sections A-A' and B-B'. The Interview and Pieman granites are assumed to be part of the same granite body, both of which may join the Heemskirk granite. DF = Donaldson Fault, PF = Pieman Fault, LRF = Lefroy Ridge Fault, BSZ = Bowry Shear Zone, (after Turner, 1992).

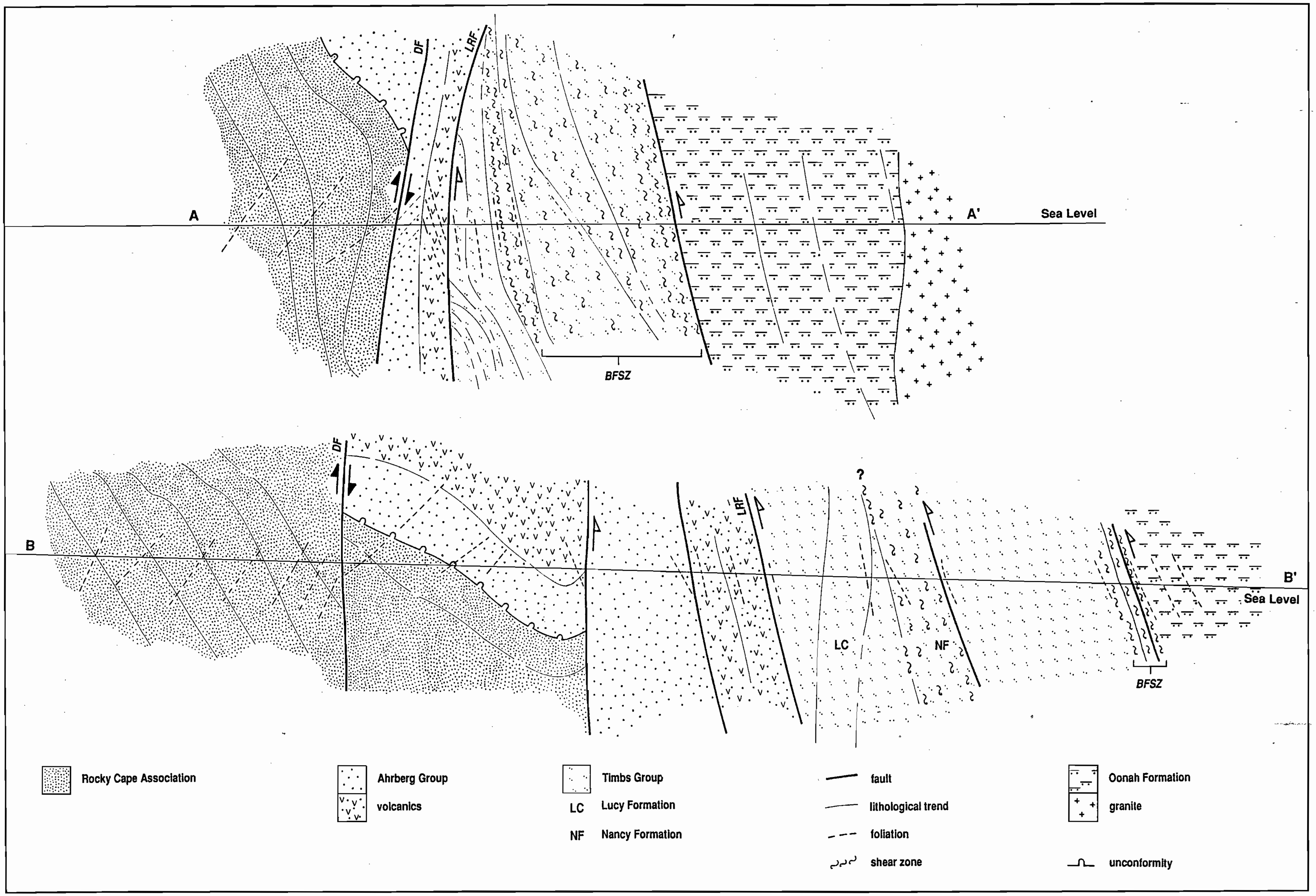

FIG. 2 Cross-sections A-A' and B-B'. The E-verging faults of the Rocky Cape Association have to be contrasted with the W-verging reverse faults east of the Donaldson fault. This can be explained by dextral-oblique movements on the Arthur Lineament that progressively uplift the deeper parts of the fault zone, causing the juxtaposition of high and low grade metamorphic rocks and structural repetitions.

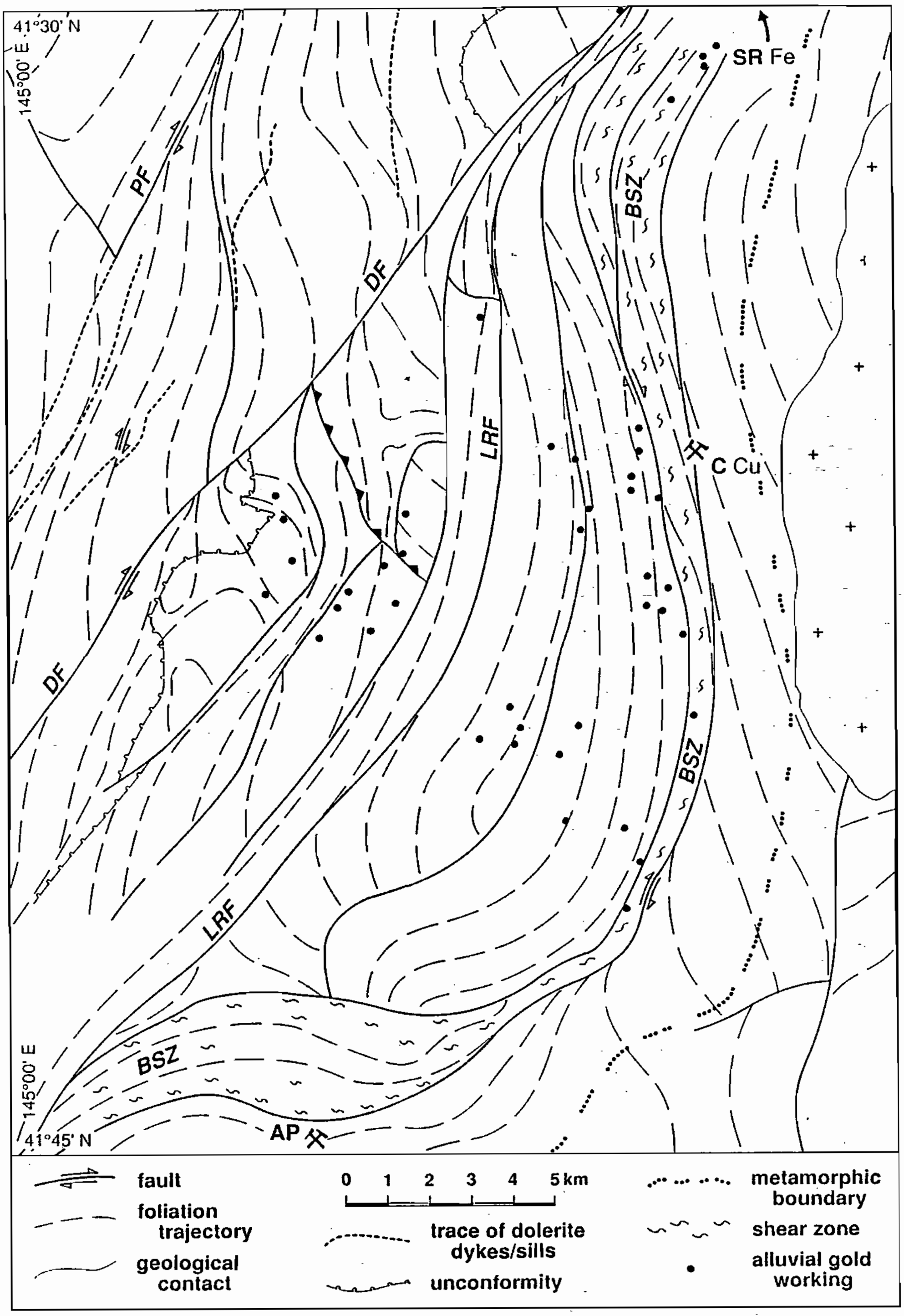

FIG. 3 Foliation trajectory map of the western half of the Corinna sheet. The stable NNW to N trending foliation traces in the flanking zones of the Arthur Lineament contrast with the mainly fault parallel traces in the central region, especially between the LRF and BSZ. In this central region the Nancy Formation can be shown to be a fault zone because of the high angle between the foliation and the formation boundary at its southern end. PF = Pieman Fault, DF = Donaldson Fault, LRF = Lefroy Ridge Fault, BSZ = Bowry (Formation) Shear Zone, AP = Alpine Prospect, C = Cape copper mine, SR = Savage River iron ore mine. (modified from Turner and Brown,1992)

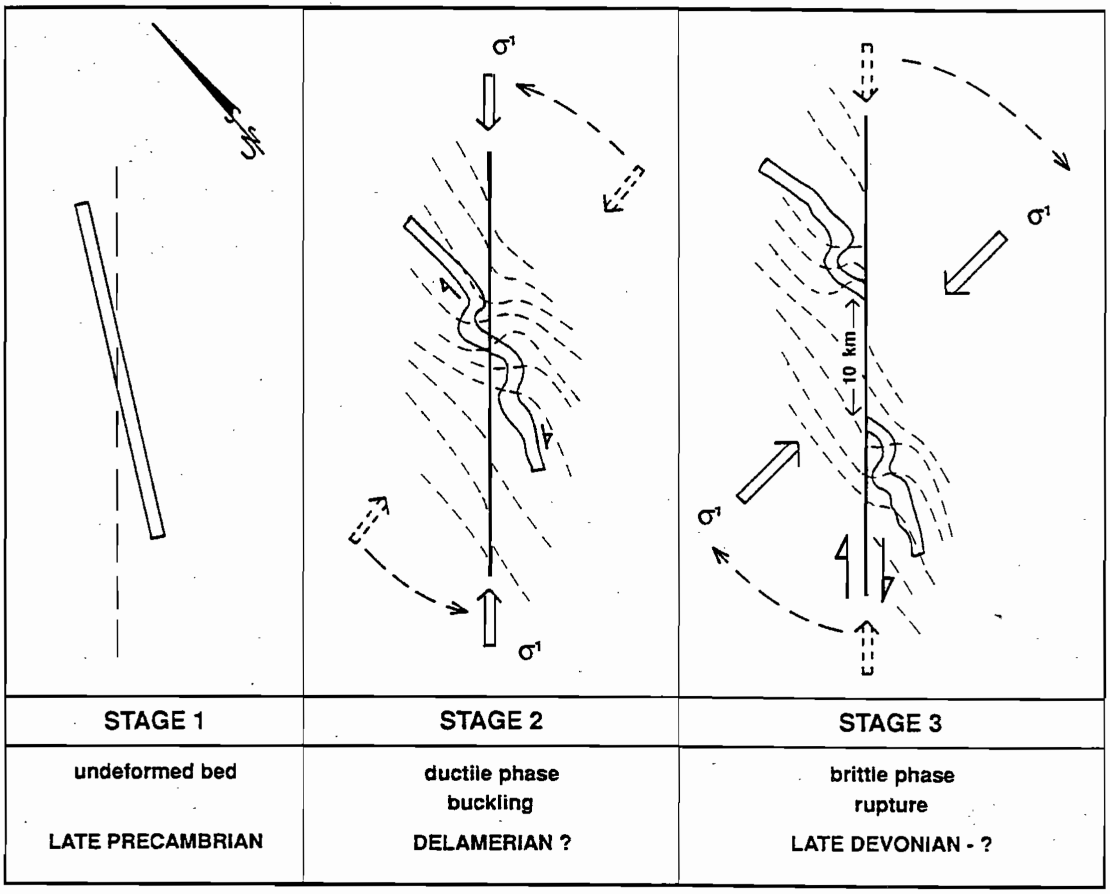

FIG.4 Diagram showing the relationship between the foliation and faulting on the Donaldson Fault. This model assumes that the foliation and buckling, are fault related.