CENTRE FOR ORE DEPOSIT AND EXPLORATION STUDIES

STRUCTURE AND MINERALISATION OF WESTERN TASMANIA

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CONTENTS

SUMMARY

OBJECTIVE 1
Synthesis of fault history on the west coast and its relationship to folding

The program called for a study of six regional sections which were representative of the Mount Read Volcanics and their environment. These sections have all been completed and reported separately, and an overview is included in this volume. In each section the fault history was recorded and the sections show the strong relationship between fold geometry and fault movement.

- The Mt Ramsay to Mt Cripps section was presented in Report 1 and emphasized the importance of the basin geometry in controlling the overall structure of western Tasmania. A revision of the section is included this volume.
- The Rosebery section is reported in this volume. The structures indicate a 50% shortening of the Mount Read Volcanics in the Devonian with substantial reactivation of the Cambrian normal faults.
- The section from Zeehan to Lake Selina is a composite of the four cross-sections shown in Report 3: 50, fig. 1. The section reported in this volume, has 37% shortening across the CVC.
- The Strahan to Victoria Pass section is complicated by the intense D_2 shear zone along the Linda Trend. The western segment (Report 4: 31–38) is south of the Linda Zone and is similar to the King River section. The eastern segment has been drawn over Mt Lyell (Report 3: 22–30) and emphasizes the east directed thrusting.
- The King River section was discussed in Report 4: 11–30. The outstanding features are the intensity of faulting and the complex interaction between west-directed and east-directed thrusts.

The regional sections in the Dundas Trough fall in to two classes. The three sections in the north are dominated by the Rosebery Fault. The two southern sections have more symmetric upright fold and fault patterns.

- The NW section across the Fossey Mountain Trough is reported in this volume. The Fossey Trough has an E–W to WNW–ESE strike reflecting the trend of middle to late Cambrian deformation.

The Cambrian structure has three distinct events. The first event was a middle Middle Cambrian extension associated with massive acid to intermediate marine volcanism. This event produced the major Cambrian mineralisation. Transfer faults active during the extension are spatially correlated with major ore deposits. The subsequent Delamerian orogeny produced E–W upright folds, locally overturned to the north, followed by N-trending open upright folds along the Dundas Trough during Owen Conglomerate deposition.

The Devonian orogeny caused reactivation of Cambrian folds. NNW striking cleavage transects these folds. Thrusts and high angle reverse faults in the Dundas Trough are syn- to post-kinematic with respect to the cleavage. Devonian granites and granite related mineralisation are late syn- to post- reverse faulting. The final regionally significant event produces WNW trending folds and thrusts in the south, and NW striking thrusts and associated folds in the north. Late brittle wrench faults are closely related to this event. A final phase of E–W compression was recognised locally.

OBJECTIVE 2
Determine the effect of Devonian folding and faulting on Cambrian ore bodies

Two Cambrian ore deposits were studied with the aim to see how their geometry has been modified by the Devonian deformation. At the Rosebery mine, an imbricate array of Devonian reverse faults from 0–500 m N(mine grid) have a combined displacement of 250 m. Restoration of the mine lenses allowed the recognition of a complex seafloor topography and syn-depositional fault pattern which partly controlled the ore lens geometry.

The section between the Glen Lyell Fault and the Mt Lyell ore deposit is a continuous east facing sequence. The structure is a consistent steep dip to the east cut by numerous sub-vertical west side up faults. The major disseminated ore bodies of Prince Lyell, Western Tharsis, etc. are sub-parallel to bedding. The Prince Lyell style of disseminated mineralisation is located close to the top of the CVC and just north of a Cambrian transfer fault.

The regional pattern of syn-Owen unconformities has defined a Late Cambrian NNW folding pattern where Owen depocentres occupy the synclines.

The North Lyell mineralisation is pre- to syn-Devonian F_1 folds. The high grade ore is the result of metamorphogenic remobilisation of low grade disseminated Cambrian mineralisation.

OBJECTIVE 3
Structural control on Devonian vein systems

The North Farrell and New North Farrell mines are Devonian vein style mineralisation related to granite intrusion. The veins are hosted in intensely faulted slates in the footwall to the Henty Fault. The major controls on vein geometry are fault intersections both in plan and section. The veins are late syn- to post-reverse faulting. Dilation is related to kink folds and Riedel shears.

OBJECTIVE 4
Recognition of Cambrian extensional fault patterns and their significance for exploration

A regional review of Cambrian extensional fault geometry in Dundas Trough was produced. Three type of faults were recognised: western bounding normal faults, regional scale normal faults within the Dundas Trough, and transfer faults. There is a strong spatial correlation of major Cambrian ore deposits with the transfer faults recognised in this study with three major deposits located on the northern margins of these structures. A total of 13 transfer faults have been recognised or inferred over the length of the Dundas Trough.

All the aims of the project have been met. The structural history determined has been tested over a large part of Western Tasmania and produces a workable structural synthesis. The Rosebery structural study has resolved many anomalies in the mine and produced an overview with some exploration significance. Several of the major controversies of the Mt Lyell field have been addressed and it is now possible to correlate structures with discrete events and place the mineralising events in their correct context. A study of the North Farrell mines supported earlier conclusions that this deposit is a Devonian granite-related vein system and provided additional detail on the nature of the fault controlled dilation. The geometry of the Cambrian extension which controlled VHMS formation has been defined over the Dundas Trough. This geometry has several significant features for exploration. In particular, there is a strong spatial association of economic mineralisation with transfer faults.

ROSEBERY SECTION

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ABSTRACT

A section has been construct at 537400N over the Rosebery Mine. The section was based on previous data west of the Rosebery Fault and substantial new structural information from Rosebery to the Sophia Tunnel. The structures indicate a 50% shortening of the Mount Read Volcanics in the Devonian with substantial reactivation of the Cambrian normal faults. No evidence was found that the Rosebery Fault was a normal fault in the Cambrian. It appear to be a hanging wall bypass thrust associated with the inversion. The Henty Fault has a more complex inversion history with both footwall shortcut thrusts and hangingwall bypass thrusts active although the latter are dominant.

INTRODUCTION

The Rosebery section was drawn at 537400N to pass over the south end of the mine (about 100S in mine grid terms). This northing also passes close to the main road from Rosebery to Tullah, and along the line of the Pieman River. The east end of the section is accessible from the Anthony Road and the Murchison Gorge/Sophia Tunnel Road.

There is a large amount of geological data available for this section. In the vicinity of the Rosebery fault there has been extensive drilling associated with the mine exploration. The section at 1:5000 for this area has been drawn by Lees (1987) and an unpublished section has been prepared from more recent deep drilling by Lutherborrow (1991). There has been a recent change to the interpretation of the section in this area. McPhie & Allen (1992) have suggested the hangingwall volcaniclastics of the Rosebery Mine are facies equivalents, and probable stratigraphic equivalents, of the White Spur Formation. This requires a major fault at the upper contact of the hangingwall volcaniclastics against the Mount Black Volcanics. As a result of this work, mine logs now indicate a faulted contact in this position is widespread (Lutherborrow, 1991) although some of the contacts are less deformed.

Deep drilling in the south of the mine penetrates through the Rosebery Fault into strongly deformed White Spur Formation. However, in the north, hole 120R penetrated through the Rosebery Fault into a feldspar phyric volcaniclastic which is best interpreted as a footwall sequence. While the bottom of the White Spur Formation is not constrained on section it is unlikely to be much deeper than the 114R intersection based on extrapolation from 120R, 1.4 km to the north.

To the west of the Rosebery Fault there is extensive structural data available from previous studies. Time for field work for this section was strictly limited by the deadline for the final report. Thus it was necessary to concentrate to the east of the Rosebery Fault where structural data was not available from the literature. To the west of the Rosebery Fault the structure reported here is largely based on published data (Brown, 1986; Corbett & McNeill, 1986; Lees, 1987, recent revisions of the Zeehan sheet Findlay & Brown). The section was limited in the west to the boundary of the Crimson Creek Formation. This was required because recent revision of the Zeehan sheet (Tasmania Mines Department in preparation) indicates complex out of section movement in the Success Creek further west. I interpret this to be related to deformation which predates the Mt Read Volcanics.

Also resulting from the remapping, the long standing conflict in interpretation of the Colebrook Hill region was emphasized. In the Mt Read Mapping

Project this was interpreted as Crimson Creek Formation but on the new Zeehan sheet it has been mapped as Husskisson Group, a correlate of the Dundas Group. Samples from the Colebrook Hill area have felsic volcanic clasts in them but not basaltic clasts. I have followed the new Zeehan mapping and allocated this area to the Dundas Correlate. This has important implications for the recognition of Cambrian structure in the area. The Zeehan sheet shows a boundary to the Husskison Group north of the Pieman River. The overview section (see later) includes a revised boundary of the Dundas depositional basin which has a significant correlation with the Rosebery mineralisation.

The major field work on this section was collecting data from Rosebery to the Sophia Tunnel to supplement existing data on this section. Data was collected along the Murchison Highway, on the drilling tracks north of the Highway and on the Anthony Road.

MT BLACK VOLCANICS

The Mt Black Volcanics are exposed along the Murchison Highway from the Rosebery Fault to the Henty Fault. The most common lithology is a chlorite-altered feldspar-phyric volcaniclastic rock. The most common variations are in proportions of feldspar crystals and chlorite lenses after ?pumice. Other rock types are andesite (most common in the east but compositionally very similar to the volcaniclastics although no hornblende is preserved in these) and sericite silica rocks which are usually interpreted as a dacite. The latter are feldspar phyric but vary 0–5% phenocryst contents. Several small basalt exposures have been recognised in the area.

With this range of lithologies the availability of structural information is limited. The most reliable indicators are lithological boundaries. These were recognised at a number of locations. Often variation from crystal-rich to crystal-poor lithologies could be discerned. In one location a black slate had an irregular contact with underlying volcaniclastics. There were also several intrusive contacts found on the section, especially on the boundaries of the basalt bodies. Thus the most obvious lithological boundaries were often at a high angle to all other surfaces and represent dyke margins.

Recent work by Dr R. Allen has indicated there is a diagenetic fabric in many of the volcaniclastics. These fabrics are wispy banding of indeterminate nature and preferred orientation of elongate feldspar grains. These two were difficult to distinguish from preferred orientations produced by cleavage and were only measured where they were not sub-parallel to the tectonic cleavage. Thus they could not be used to recognise steep dips. In some areas, flattened pumice fragments and elongate shale fragments form a useful primary fabric but on this section the examples measured were invariably steep and seem to represent cleavage (Fig. 2d, h). At a few locations flow banding was recognised.

In areas of cleavage development all smaller chlorite clots were aligned in the cleavage. These clots were partly pseudomorphs after glass shards but could also be replacing mafic crystals. In the andesites there is a clear transition from hornblende crystals to chlorite spots.

No substantial lithological sequence was determined. The rocks are feldspar phyric throughout. In the east the level of alteration is generally less and there appears to be less volcaniclastic rocks (about 50% lava in the east to less than 10% in the west. The last 1 km of section in the west shows a much finer scale of lithological variation and more dacite. Chlorite alteration is strong in the west with a few areas which have the pink massive texture suggestive of K-feldspar alteration. Overall the lithological variation suggests the whole section is at a similar stratigraphic level.

The structural information collected for this analysis is shown in Figs 1, 2. In the immediate hanging wall to the Mt Black Thrust, the bedding largely dips east at 50 to 80° but narrow zones of 60°W dips were found. These were less than 100 m wide. There are a number of steep fault zones in this area and these changes in dip direction are interpreted as hanging wall anticlines to the steep faults possibly indicating a ramp in the underlying thrusts. For the next 2 km east the structures are more difficult to find but those found had shallow dips indicating open folding in a uniform feldspar rich volcaniclastic with few pumice fragments. Lithologically, this zone is the best correlate for the eastern-most andesitic part of the sequence. The dips appear to steepen up against a fault zone exposed along the NNW section of the highway. In this zone are a large number of quartz veins dipping 60° to 290°. There is a strong vertical cleavage associated with brecciation. In the footwall to this zone is a number of small faults with dip slip movement on planes dipping west at 35°–45° west. I have interpreted this structure as a reverse fault dipping 45° W although it may be steeper. Immediately east of the fault the only indication of dip found was a very weak feldspar alignment so the dip here is unreliable. Further east there are several indicators suggesting a very steep dip in volcaniclastic units. The area near 837738 has several examples of flattened clasts resembling an original fabric and all subvertical. In these cases the cleavage lies within 10° of the clast alignment. However one excellent example of bedding at this locality dips 20°E and another less certain exposure has a layer folded from horizontal

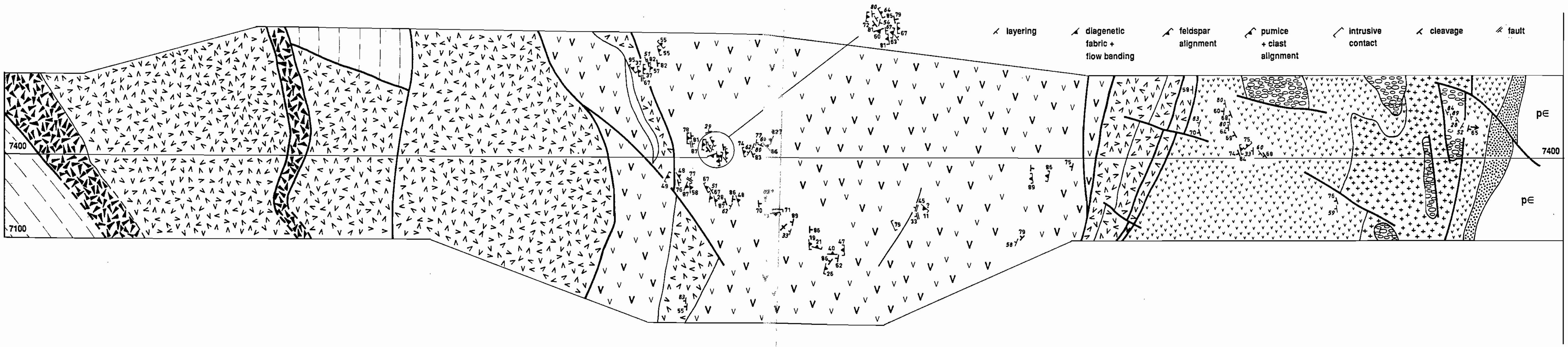

Fig. 1. Map showing locations of new structural information used in this study. Geology base is from Brown (1986), Corbett & McNeill (1986) and McNeill (1987) with minor modifications from this work.

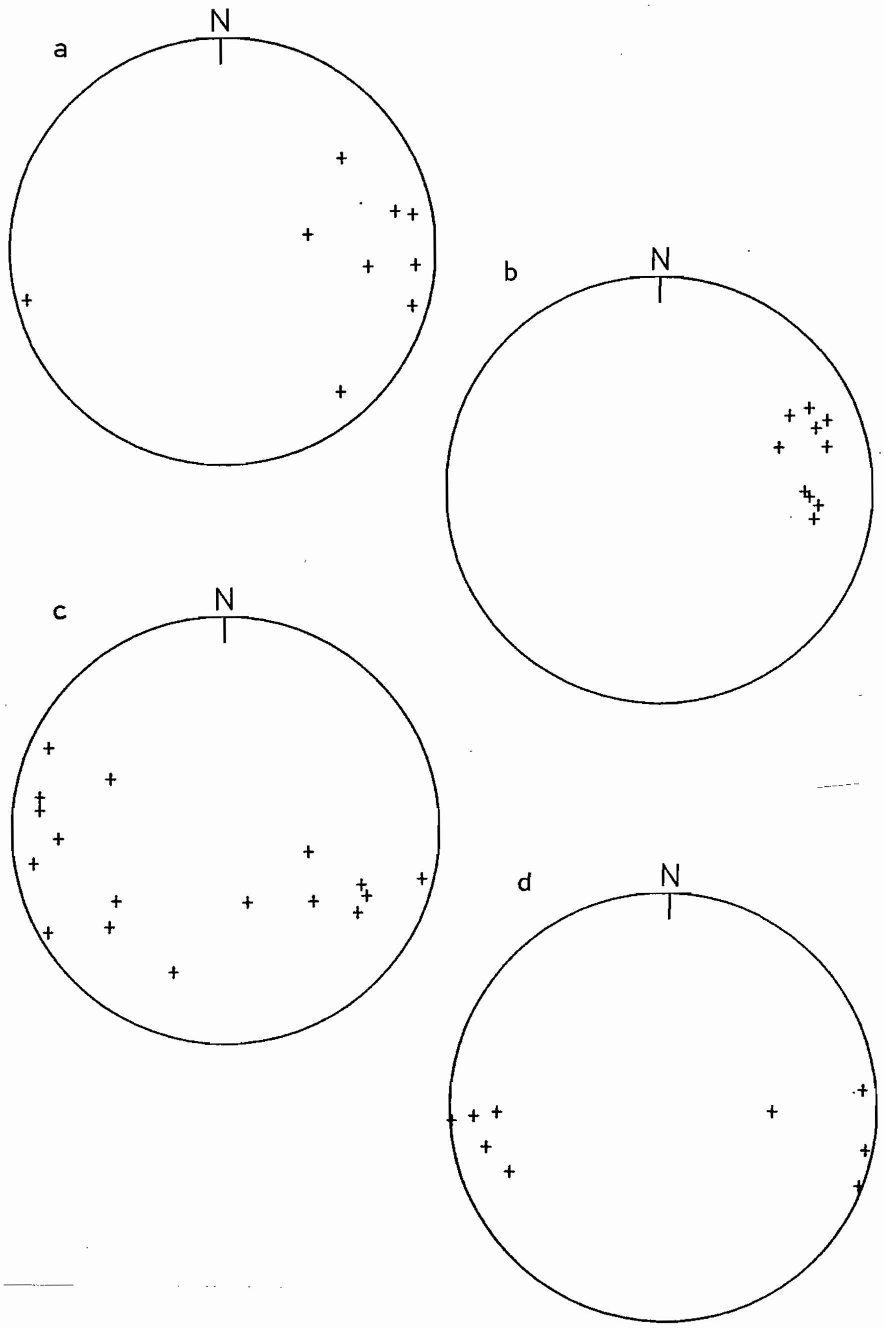

Fig. 2. Equal area stereographic projections of poles to structures collected on section 537400N, Rosebery mine: East of Henty Fault: (a) poles to bedding, (b) poles to cleavage.
Between Rosebery and Henty Faults: (c) poles to bedding , (d) poles to flattened pumice fragments and other clasts.

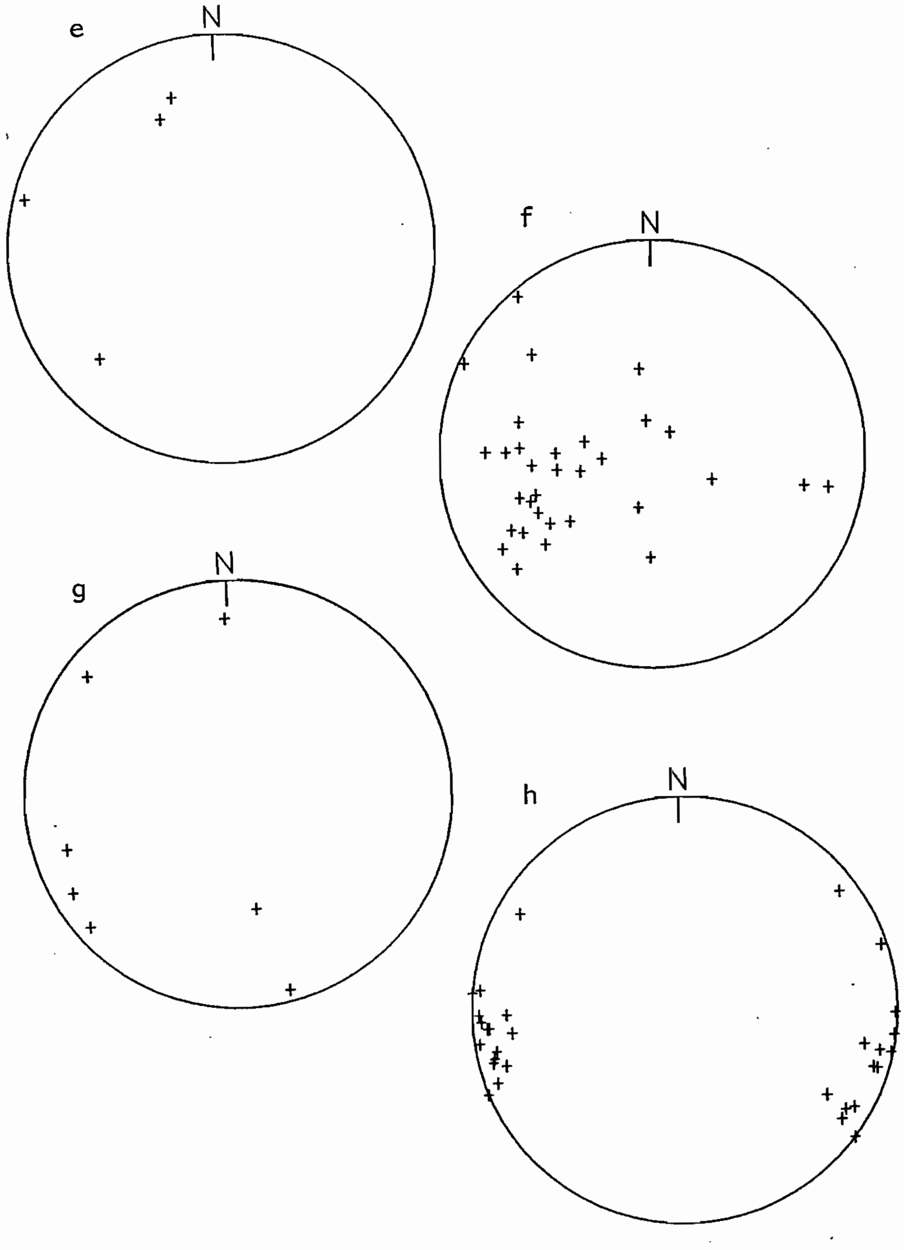

Fig. 2 cont. Equal area stereographic projections of poles to structures collected on section 537400N, Rosebery mine: Between Rosebery and Henty Faults: (e) poles to flow banding, (f) poles to diagenetic fabric, (g) poles to intrusive contacts, (h) poles to cleavage.

to steep E up against a steep W-dipping fracture. With this critical evidence, I concluded that all the clast alignment is due to folding and the section was drawn based solely on the layering in this section. The distribution of "andesite" on the shores of Lake Rosebery as shown by Corbett & McNeill (1986) suggests a west-dipping slice of CVC up against the Henty Fault which has been projected onto this section from the north.

EAST OF THE HENTY FAULT

In the Farrell Slates the bedding dips east and much previous work suggests in this southern section the slates are facing west. The strong cleavage in this zone is associated with the faulting. This zone of strong cleavage extends into the quartz-phyric volcaniclastics where moderate west dips are within 5° of cleavage and facing is difficult to determine. In the Murchison Gorge section the equivalent rocks were interpreted to face west with the Farrell Slates (Berry, 1989; Berry et al., 1990). To the east, in the Murchison Volcanics (now the "eastern quartz-porpyritic sequence" — Corbett, 1992) the layering can be recognised in a number of location along the Anthony Road. Most of this data indicates a steeply west-dipping overturned limb (Figs 1, 2). The two easternmost locations indicated the synclinal axis had been crossed and the layering dipped west. A similar dip was obtained 800 m to the east in the western abutment of the Murchison Dam.

The shape of the Murchison Granite is not well constrained here. The western boundary is assumed to be a fault. The Murchison Volcanics are missing to the east of this boundary as the Owen Conglomerate sits directly on the granite. Two slivers of Owen cross the section. The first of these is exposed on the Sophia Tunnel Road (Fig. 3) allowing the structure to be unravelled The western boundary of both slivers is an apparently disconformable contact of Owen Conglomerate on granite. In the western sliver a fault with normal fault movement forms the western boundary but strong deformation textures indicate this structure has been active as a reverse fault in the Devonian. (While these faults are normal in there present orientation it should be noted that if they are rotated to get the bedding in the Owen horizontal then they would be steep east-dipping reverse faults. The eastern sliver is visible as a faulted syncline anticline pair (Fig. 3). To the east of the Owen Conglomerate a strong cleavage is developed in volcanic sandstones There is a strong dip slip stretching lineation and a fault is required at this point to explain the stratigraphic variations.

The area of the Murchison Gorge is outstanding for the evidence of rapid variations in thickness of the Owen Conglomerate. While several possible models can be suggested for this variation the simplest is to assume original facies variations with onlap onto structural highs occupied by the Murchison Granite. The changes of thickness are so rapid that very steep slopes are required or possible growth faults.

The Farrell Slates are missing from under the Owen Conglomerate east of the Henty Fault on this section. They are best regarded as Dundas Correlates and are expected to lie above the Murchison Volcanics. The absence in this area suggests they were eroded before Owen Deposition (or not deposited). The Henty Fault has strong reverse movement but juxtaposes younger rocks over older rocks. This is a common attribute of an inverted normal fault. Thus the structural evidence is most consistent with a normal fault along this section of the Henty Fault Zone. It has often been assumed that the Henty Fault is the western limit for the Owen Conglomerate. If this is true, it requires inversion of this normal fault during Owen deposition. Unfortunately, the correct stratigraphic position is not exposed immediately west of the Henty Fault to confirm this suggestion. Further north Owen Conglomerate is found west of the Henty Fault, at Mt Pearse, while further south Owen Correlate is found on Mt Zeehan but the Owen is missing in the Dundas area (see discussion of facies distribution).

SECTION

Faults are discussed starting from the western end of the section. Fault a is a complex zone which thins the serpentinite to the south of the section line. The variation in bedding suggests a wrench movement but there is no direct evidence.

The Husskisson syncline projects to the western end of the section. This is about the southern most section which shows this structure. It changes to a more complex arrangement in the Dundas area. This appears to be the result of the crossing of a Cambrian transfer fault such that the Dundas correlates appear within the syncline. To the north the serpentinite occupies its normal stratigraphic position on both sides of the syncline but at this northing the eastern serpentinite lies within the Dundas Group. This is modeled as shear out limb with diapiric serpentine (fault b on Fig. 4). This structure suggests some out of section movement.

The next fault to the east (c on Fig. 4) is shown as an inverted normal fault. this fault is the normal fault boundary to the Dundas trough to the north (Selley 1992). In the Dundas area there is no Central Volcanic Complex under the Dundas Group west of this position which suggests the CVC stops against this boundary despite the extension of the younger parts of the Dundas Group across this structure. This is the

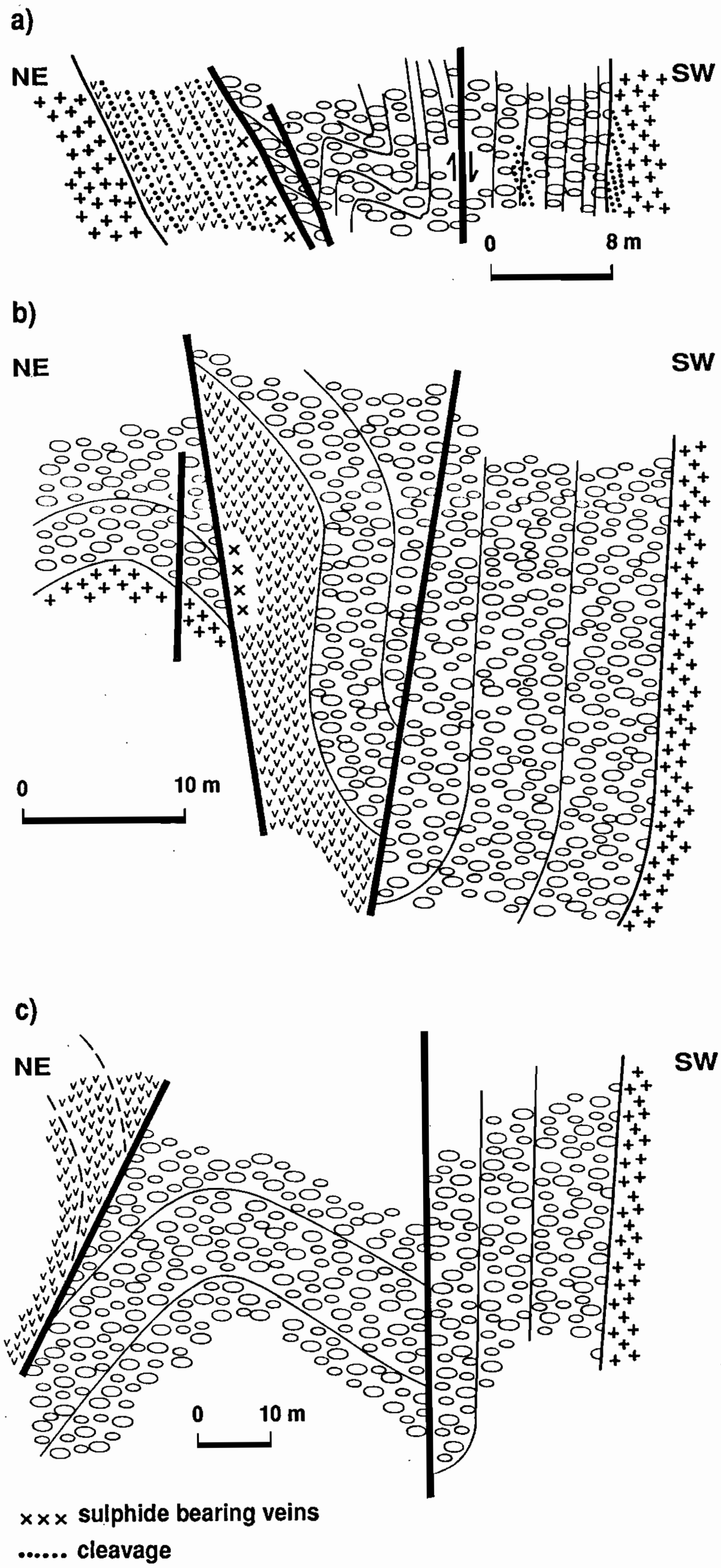

Fig. 3. (a) Sketch of structures on the Sophia Tunnel Road. (b) Sketch of structure at the Sophia Tunnel outfall, (c) cross-section of eastern margin of Owen Conglomerate against eastern quartz-phyric sequence.

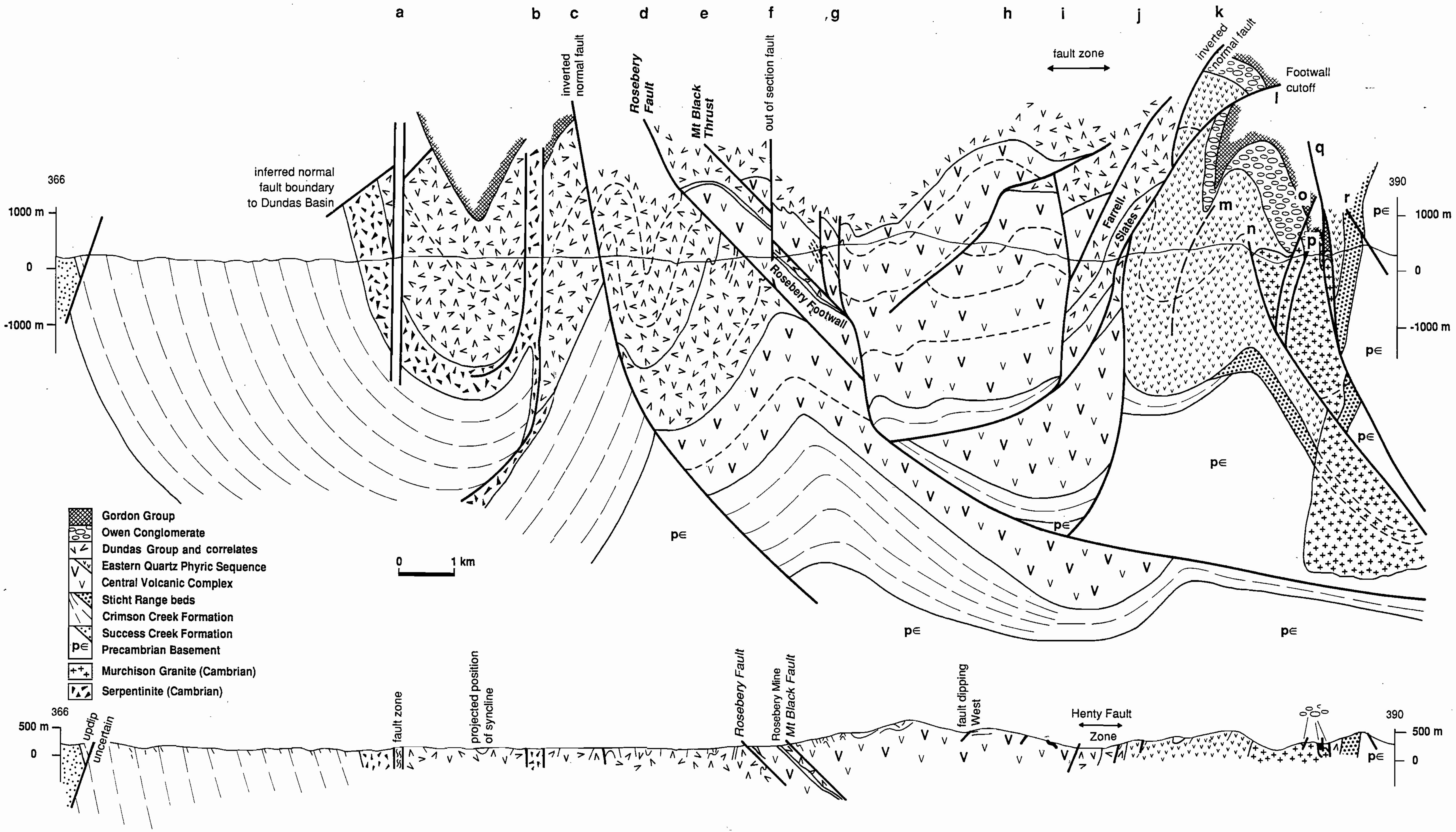

Fig. 4. Interpretive cross section at 537400 N across the Rosebery Mine. A classical section of the structure is shown below the interpretation. See text for explanation of letters.

model used here as shown in the restored section (Fig. 5).

The Rosebery Fault (d) is the next fault to the east. The geometry of this structure is very well known within 500 m of the surface. The position of the CVC upper surface west of the fault is inferred from the drilling in the north of the mine. In the preferred interpretation it is accepted that the hanging wall volcaniclastics are the lower Dundas Group. If this lithology is within the CVC the overall shortening of the belt is reduced by about 2 km which makes the balancing easier but there is no critical structural evidence that distinguishes these models (Fig. 6). The model shown in Fig. 4 is a imbricate fan complicated by the out of section fault f which is required to explain the structure to the south at Rosebery Lodes and Dalmeny (Fig. 1). The combined Rosebery/Mt Black faults define a 7 km wide sliver of thin CVC which must be balanced against a large flat through the CVC. This association is shown in the restored section (Fig. 5).

The small scale folds to the east (g) are attributed to compressional stresses associated with the ramp in the Mt Black Thrust. The position of this ramp is placed to minimise overall shortening in the belt. It is draw just below the limit of deep drilling in the mine but could easily be 1 km deeper and should not be used as a reason for limiting models for down dip extensions of the ore lenses.

Further east (h) the small thrust is shown as a complication in the surface. This structure is based on field evidence from this project. There are extensive quartz veins in this zone with a stronger cleavage development. The immediate footwall contains a number of small faults which dip 35°–45°W and have dip slip movement

The Henty Fault (i, j, k, l) is a very complex structure at this northing. At this point there is a major Cambrian normal fault (k) indicated by thrusting younger (Farrell Slates) over older (Eastern Quartz-phyric Sequence). It also explains the complex facing evidence where the major Devonian faulting occurs on the western margin of the zone but the major stratigraphic facing change occurs on the east against the older Cambrian structure. There is an imbricate fan suggested in the hangingwall. This is based on the apparent offset in lithologies to the north along the shores of Lake Rosebery. The exact geometry is not well constrained but that shown is consistent with the data. The Farrell Slates are shown as a thrust slice of lower Dundas Group which are ramping against the old normal fault on a short-cut thrust (l). The slice of Owen above this thrust is based on extrapolation from the Farrell Range (Berry, 1989).

The eastern part of the section is shown as a steep east-dipping reverse fault (q). This is influenced by the need to explain the east side up movement of the Precambrian basement. The intense LS fabric development along this zone dips steeply east on the section line. All other structures suggest a very steep fault in this position. At this point the Sticht Range Group is unconformable on the basement indicating the Success Creek Formation, Crimson Creek Formation and mafic/ultramafic complexes are missing. The overlying meta-volcanic rocks are best regarded as eastern quartz-phyric sequence. The geometry suggests these are very thin here. the balancing of the section east of the Henty Fault requires a substantial fault movement near the western margin of the granite to keep a simple shape for the margin of the granite.

In drawing a restorable section for this section the outstanding feature is the large shortening required by the top of the CVC and the equivalent Murchison Volcanics east of the Henty Fault. No other boundary is as widely exposed. The first stage was then to draw a section that minimised the length of this boundary but was consistent with the data. In carrying this out it was assumed that the fault c was a Cambrian normal fault, dipping 65°E, forming the western limit of the CVC. The base of the CVC was then draw with a gradual increase of thickness to the east reaching 3 km under the eastern edge of the Mount Black section. In order to have an west-dipping normal fault under the Henty Fault Zone, it is necessary to add an extra block of lower CVC at depth. This is also consistent with the need to have a normal offset on the base of the sequence as required by the model of a slightly inverted normal fault at this position. The boundary between CVC and Murchison Volcanics is assumed to be hidden in this block. The detachment underneath the CVC is assumed to lie in Crimson Creek Formation. This is shown as thinning to zero by the central part of the section. To the east the detachment must lie in the Precambrian.

The balance on the top of the Precambrian requires about 10 km of thrust movement. This shortening must occur down the dip of the Rosebery Fault which is shown as a listric geometry heading to the east. the depth of this detachment is at least as deep as shown but could be much deeper.

The restored section length is 37 km and the present length is 18 km indicating 19 km of shortening on this section which is consistent with structures to the south but much more than suggested for the first section across Que River to Mt Ramsay (Rattenbury, 1990). The recent review of this section (Selley, 1992) indicated strain was higher in the west than shown on the original section.

SUMMARY

The structure in the Rosebery section shows the effects of inversion of a normal fault basin. The major western normal fault is un-named but lies 2 km west of Rosebery. The eastern normal fault is part of the Henty Fault Zone. Both of these structures were reactivated in the Devonian but the major fault active at this time was the Rosebery Fault and associated splays which form as a hanging wall bypass thrust (terminology of McClay & Buchanan 1992). The reconstruction indicates a 50% shortening (19 km) across the section at this northing.

Several ambiguities remain. The exact position of the Henty Fault in the Cambrian and its dip are not well constrained. It is even possible that this structure dipped east in the Cambrian. (This is the same problem as the Great Lyell fault which is a direct correlate with the normal fault movement of the Cambrian Henty Fault. The dip of beds adjacent to the Henty Fault are such that an original west-dipping fault should now be shallow east as recorded at Buttress Hill by Berry (1989). The limiting of the Owen deposition indicates a west block up which in an extensional environment would indicate a dip to the east. But many other lines of evidence suggest the Owen Conglomerate was largely deposited in an early stage of basin inversion. Thus a west-dipping normal fault for the Middle Cambrian is inverted as a reverse fault in the Late Cambrian.) An east-dipping Cambrian normal fault is difficult to reconcile with the Farrell Slates being thrust over the Murchison Volcanics since the west block is up at all stages.

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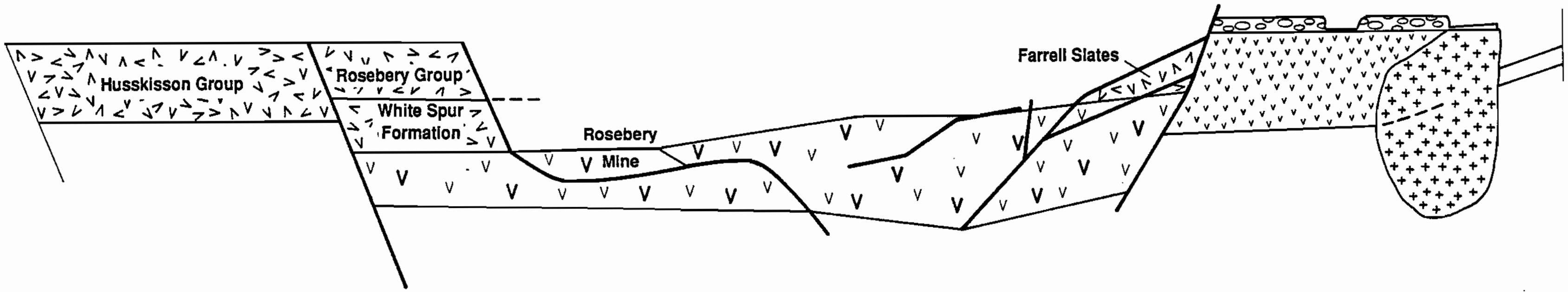

Fig. 5. Approximate restored section from the interpretation. This section was built from the west end assuming the dip of the western bounding normal fault.

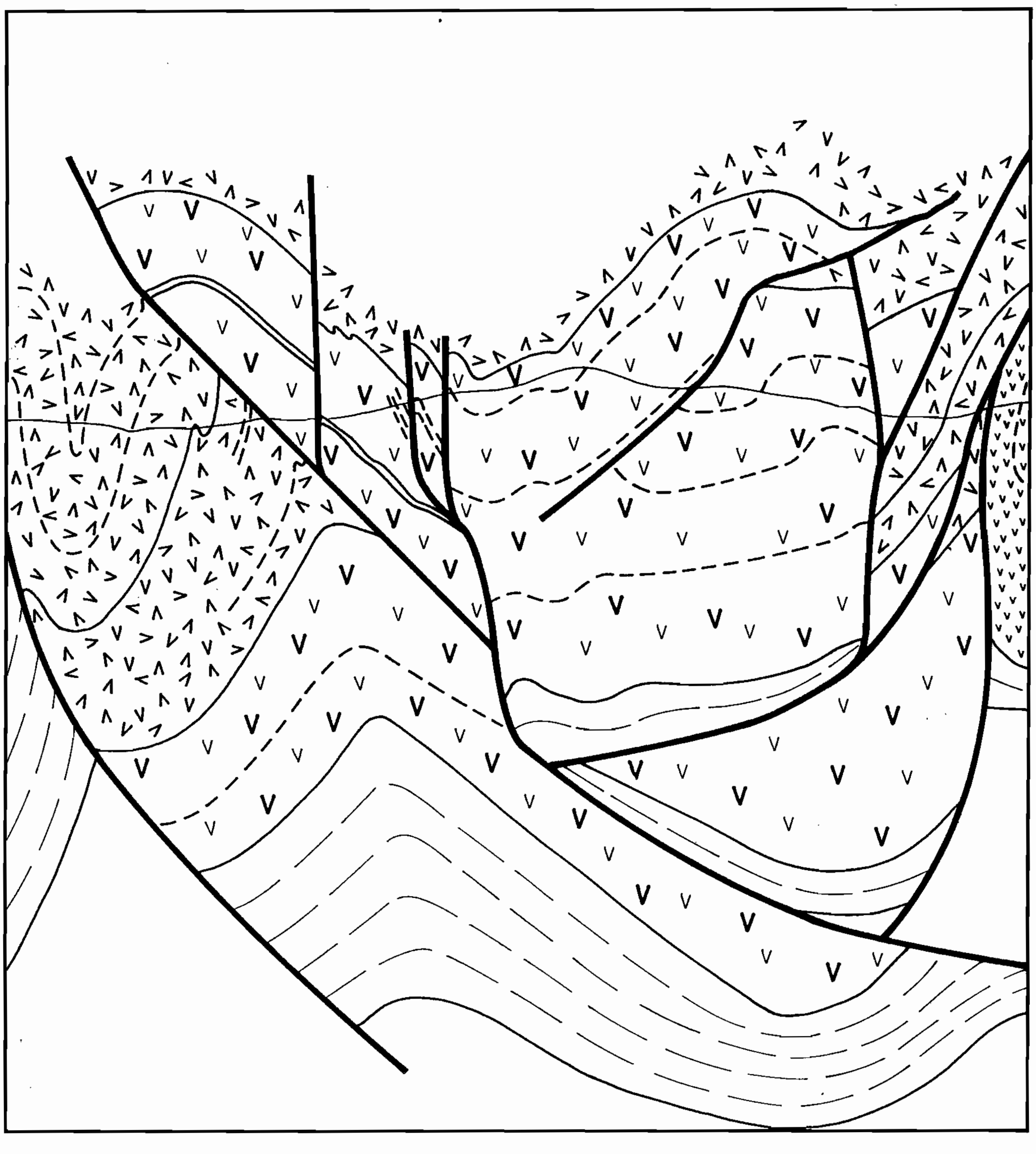

Fig. 6. Alternative interpretation with the Mt Black Thrust as a minor structure. This interpretation reduces shortening on the section by 2 km.

STRUCTURAL EVOLUTION OF NORTHWESTERN TASMANIA: with special reference to a section through the Fossey Trough

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Centre for Ore Deposit and Exploration Studies

ABSTRACT

The Fossey Trough which is estimated to be at least 5.5 km deep includes Barrington chert at the base, Lorinna Greywacke (a basal Dundas Group sandstone that underlies the whole section), thinned Beulah Formation, Gog Range Greywacke and an upper and lower Tyndall Group correlate. Its E–W to WNW–ESE strike reflects middle Cambrian extension. Although there are no known structures of this age, this early extension is reflected in the E–W trending folds that resulted from a meridional compression during a late Cambrian inversion. Cleavage transection, related to this event, shows that these folds developed, and progressively tightened, over a period of time culminating in the NE–SW compression of the Devonian orogeny. Other folds in the late middle Cambrian Tyndall correlates which show tighter profiles compared to their equivalents in the Ordovician, are also inferred to be Cambrian folds. The Nietta Fault, a major structure in the late Cambrian and Devonian that has gravity expression and forms part of the complex northern boundary to the volcanic-dominated Fossey Trough, may be the best candidate for a middle Cambrian structure. The centre of the Fossey Trough is marked on surface by a change in the sense of vergence of the Devonian thrusts from SW to NE. Total shortening across the lower Wilmot domain, or northern end of the section, is approximately 36%. Shortening across the rest of the section is impossible to estimate because of the Dalcoath Granite.

Cambrian mineralisation is of two types: the first comprises a number of the deposits and prospects related to the volcanic-dominated facies component of the northern Dundas Tough, and the second comprises prospects related directly, or indirectly, to the Beulah granite. The Preston graben, which connects the Railton–Melrose depocentre with the Black Bluff basin during the Late Cambrian, has mineralisation associated with its bounding faults. Ordovician mineralisation consists of pyritic accumulations in the Moina Sandstones and has been tentatively linked to a thermal regime caused by the extrusion of basalts at the time. Gold-bearing skarns are directly related to normal faulting around the apex of the Dalcoath granite. A unique combination of the right host being in the right place at the right time accounts for the richness of the deposits at Moina.

INTRODUCTION

The Fossey Trough, although initiated at the start of the Middle Cambrian (Burns, 1964; Jennings, 1979; Williams and Turner, 1974), contains few structures that can be directly linked with this period of crustal extension. This is due, in part, to the lesser amounts of post-orogenic uplift experienced on the northern flanks of the Tyennan nucleus, when compared to other parts of the Dundas Trough, which as a consequence has caused the trough sequences to be blanketed by younger rocks. Another cause may be the lack of rift-related volcanics, such as a CVC equivalent, in the trough. The purpose of compiling this northern section was firstly, to put constraints on the dimensions of the Fossey Trough, and secondly to compare its structural evolution with the remaining Dundas Trough. An early E–W folding event, previously recognised in northern Tasmania (Seymour, 1989; Williams and Turner, 1974), as well as the existence of pre-Owen Conglomerate folding in the Black Bluff–Mt Tor area (Pemberton et al., 1991), is compelling evidence for a Late Cambrian deformation in the Fossey Trough. The relationship between the Cambrian and Devonian deformation is much clearer here, than elsewhere, because of the younger age of the Owen Conglomerates (Banks, 1989) and the non-coaxiality of the shortening directions involved.

REGIONAL STRUCTURE

?Early Cambrian

The lowest sequences in the Dial Range–Wilmot River area are considered to be correlates of the Crimson Creek Formation. Chert and pillow basalt sequences similar to those in the Dial Range occur at Mt Bischoff (Seymour, 1989), where P.R. Williams considered the ?Early Cambrian rocks at Bischoff had suffered pre-Devonian folding. A similar inference has been made for the E–W trending isoclinal folds of the Dundas Group correlates in the lower Wilmot River, which are considered to be Late Cambrian in age.

A number of major faults parallel and define the N–S trending part of the Dial Range Trough near the coast (Burns, 1964), many of which swing into a WNW–ESE strike at the southern end of the Motton Spilites, suggesting that this edge to the volcanic part of the basin might have been sub E–W; however, there is little evidence of any fault control on these sequences (Fig. 1). The larger view of this ?Early Cambrian basin is that it trended NNE parallel to the Burnie Trough (Leaman, 1988) and presumably once covered some, or all, of the presently exposed Tyennan core.

Middle Cambrian

A series of NW to NNW trending growth faults south of the Bonds Range controls the thickness of individual units in the Back Peak and Sticht Range Beds (Pemberton et al., 1991). Although clearly originating in the Precambrian basement, these faults do not appear to have any effect on the overlying Bonds Range Porphyry and younger sequences. This suggests that after the initial pulling apart of the crust, extension either temporarily ceased or was transferred to other areas, to resume again when the Que–Hellyer volcanics were laid down. Due to poor exposure, no further middle Cambrian structures related to volcanic rocks have been recognised east and north of the Bonds Range.

The Henty Fault Zone and its extensions north of Hellyer under basalt cover (Pemberton et al., 1991), are spatially related to the andesite–basalt sequences of Que–Hellyer (Figs 1 & 2). This close association was commented on by Corbett and Komyshan (1989), who suggested that the Mount Charter Fault was a growth fault with the bulk of the volcanic material being found on the NE or down block side of the fault. Although the exact continuation of the Henty Fault has yet to be determined, it is clear from the existing data that a network of branching faults exists in the Cambrian sequences wrapping around the Tyennan nucleus, any one of which could be the extension of this fault.

Late Middle Cambrian

The extensive areas of chert, between Barrington and Lower Wilmot, would had to have been undergoing active erosion during Middle Cambrian times because of the local presence of abundant chert clasts in the Gog Range Greywacke (GRG); also, chert is seen to lie unconformably beneath the GRG, suggesting the possibility that the Alma Fault system had been a middle to late Cambrian sinistral wrench. It is to be noted that this uplift occurred close to a bend in the Alma Fault, which no doubt allowed for some convergence to take place at a restraining bend (Fig. 2).

The Tyndall Group correlates at Cethana on the south side of the Fossey Trough were, in part, controlled by the Bell Mountain and the Erriba Faults, two structures that acted as growth faults during the late Middle Cambrian (see below).

Late Cambrian Structure

A compilation of the Denison Group siliciclastic rocks, principally the Owen Conglomerate and the Roland and Duncan correlates, is presented in Figure 3. During late Cambrian times, the region covered by the northern part of the Dundas Trough and Fossey Trough consisted of three distinct, but interconnected basins or depocentres. These were: the NE to N trending Dial Range Trough (Burns, 1964), the NE trending Black Bluff basin and the broad Railton–Melrose depocentre which includes the WNW trending Fossey Mountain trough (Banks, 1989); the latter as originally defined, stretched from the Gog Range as far as Black Bluff. However, evidence presented here, indicating that the two basins were separated by the Erriba ridge, has led to the term Fossey Mountain trough being used exclusively for the thick accumulations of conglomerate along the Claude–Mt Roland axis.

Where rapid changes in thickness of conglomerate across individual faults occur, specific structures such as the Mt Tor Fault (Pemberton et al., 1991) have been inferred (Fig. 3). These features represent extremely active syn-depositional faults formed at the edges of the basins. The narrow Preston graben connects the Railton–Melrose depocentre with the Black Bluff trough, indicating that all the basins may have been connected at some stage; this is supported by a stratigraphy that is correlatable over distances up to 100 km. The source of the Dial Range conglomerates

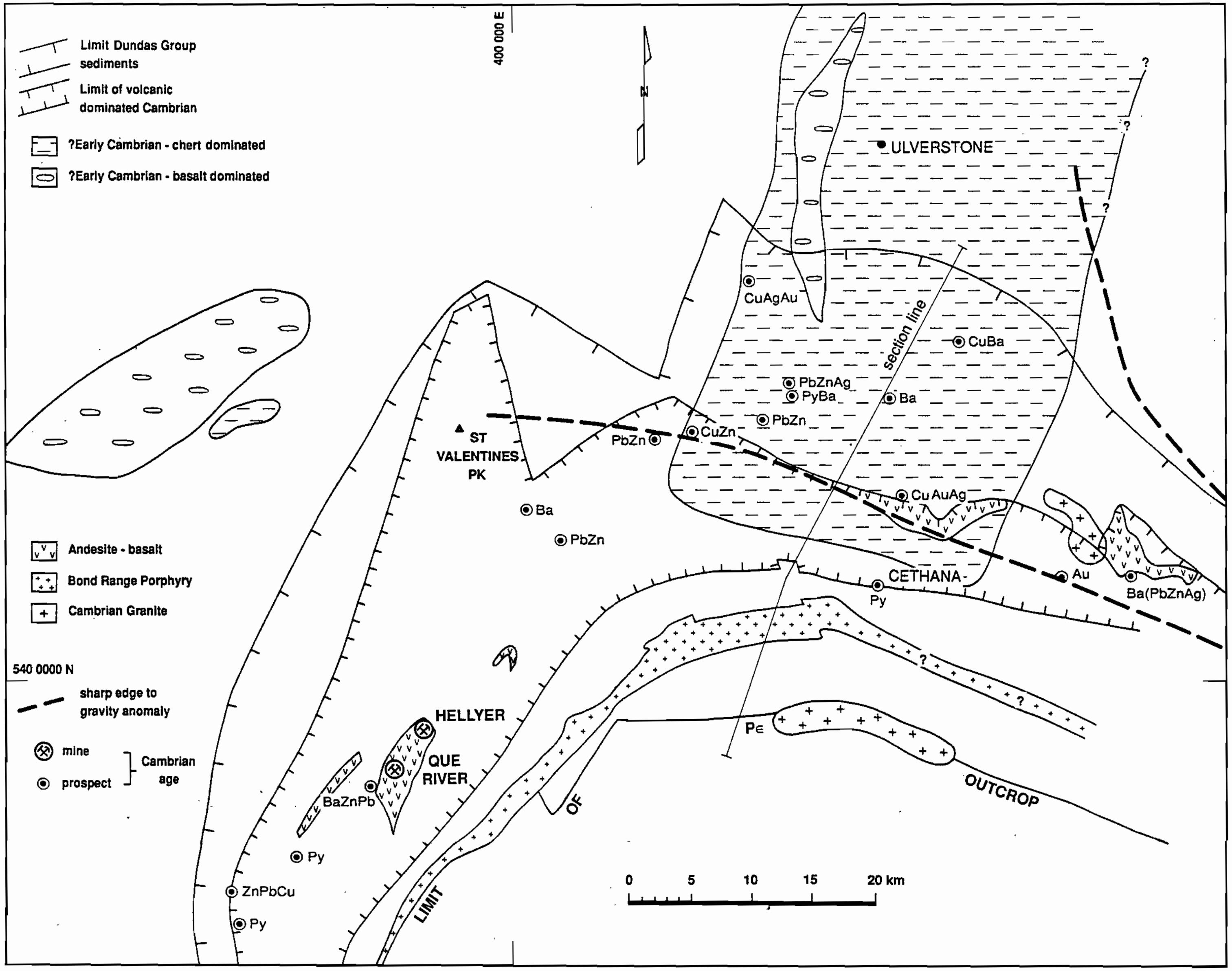


Figure 1. Facies distribution map for the Cambrian sequences in the northern Dundas Trough and Fossey Trough. The mines and prospects shown are those that are known to be Cambrian. The mineral occurrences in the northeastern part of the map, especially those with barite, are related to fluids circulating around the Beulah granite and occur in the sediment-dominated facies; all others occur in the volcanic-dominated facies.

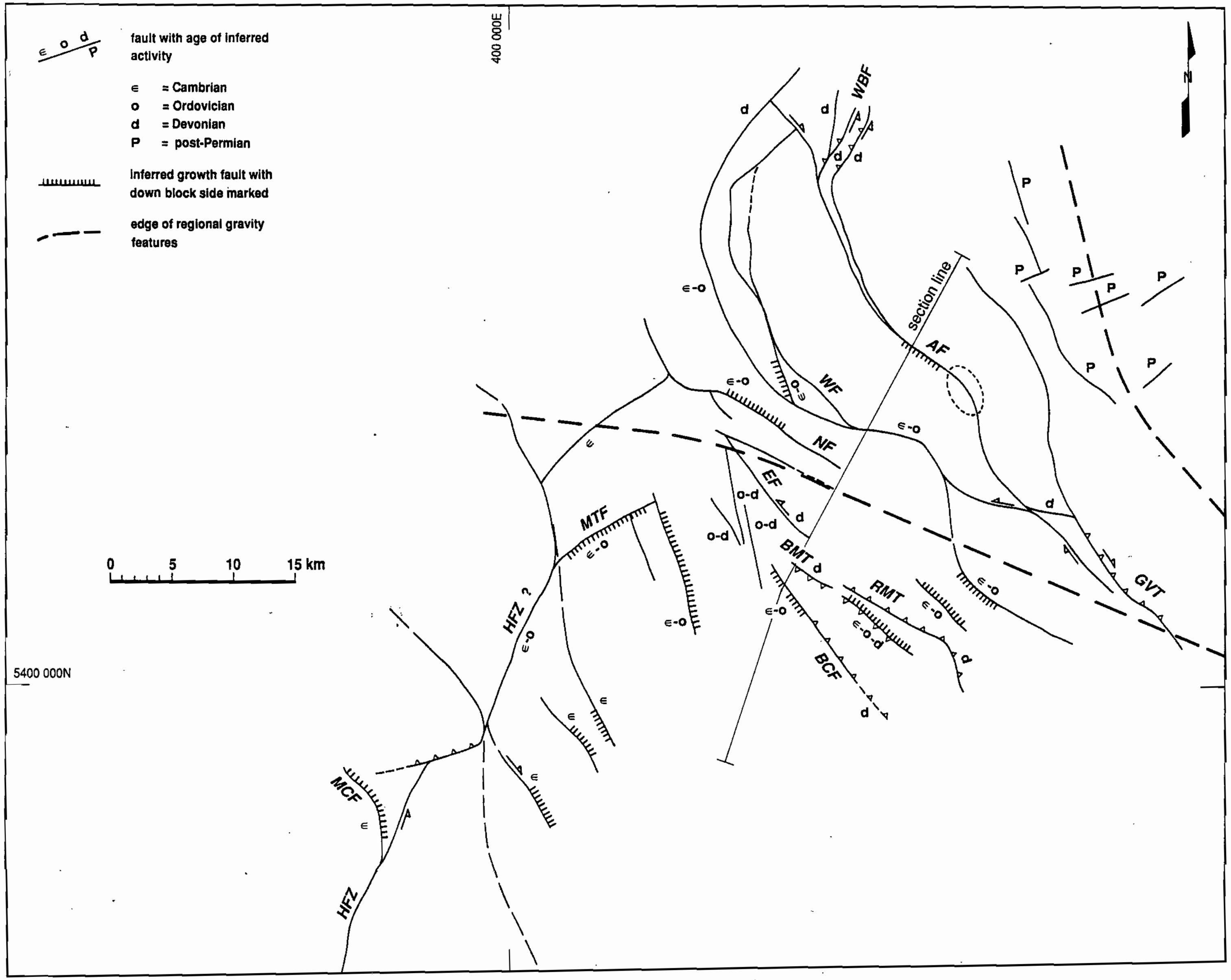


Figure 2. Interpreted fault map for the northern Dundas Trough. Where the age of activity on the fault is known with a degree of certainty it is marked on the map; where the fault is known to be a growth fault the down block side is marked with a tick. The edge to the central gravity feature marks the approximate trend of the Cambrian Fossey Trough. HFZ = Henty Fault Zone, MTF = Mount Tor Fault, BCF = Bismuth Creek Fault, AF = Alma Fault, NF = Nietta Fault RMT = Round Mountain Thrust, GVT = Golden Valley Thrust, WBF = West Bank Fault, WF = Warringa Fault. Note that the continuation of the Henty Fault could be one of a number of possible faults within a branching network of faults that wraps around the Tyennan nucleus.

was mainly from the east (Banks, 1989); whilst the Black Bluff and Fossey Mountain troughs were both sourced from the Tyennan block to the south, the Railton deposits were derived from the Forth block to the northwest.

The Erriba ridge accounts for the sharp NNE trending cut-off on the conglomerates at the eastern end of the Black Bluff range. On the southwestern flanks of this ridge, the conglomerate sequence is clearly fault-bound; however, further north it appears to lens out gradually with the Moina Sandstone showing a normal on-lapping relationship with the underlying Cambrian volcanics. An alluvial fan of significant dimensions is present in the Tiger Plains–Mt Tor area (Seymour, 1980), where the thickest conglomerates recorded in northwest Tasmania (800 m) come from. This fan probably fed much of the pebble and cobble-sized material into the Black Bluff, Railton and Dial basins via a series of interconnected rivers that drained the Precambrian hinterland to the south.

The Black Bluff trough is closely controlled on its northwestern side by the northward extension of the Henty Fault (Pemberton et al., 1991). Any section through the basin shows that the Newton Creek Sandstone and Middle Owen Conglomerate form part of a clastic wedge that thins towards the east, in much the same way as they do elsewhere. Many of the faults, particularly those trending N to NW, are located either at a bend in the trough or they lie approximately perpendicular to the trough axis, suggesting that the majority of them are syn-depositional faults related to differential extension and subsidence across the basin. Current directions in the sandstones and conglomerates are consistent with the sediments being a syn-rift fill introduced via a system of braided rivers and streams developed on the limb of a roll-over anticline.

The Fossey Mountain Trough, as conceived by Banks (1989), is the strongly fault-bound thicker sequence of Roland Conglomerate at the southern edge of the Railton–Melrose depocentre. In the vicinity of Round Mountain, the southwestern end of the Railton Basin is controlled by a growth fault located on one of Jennings' (1958) NE-directed Devonian back thrusts (the Tin Creek Fault), and not by any of the main forward thrusts (Figs 2 & 3). It is to be noted that these thrusts change into wrench faults as they exit the depocentre to the west, because of their inability to take up any NE–SW shortening across the Erriba ridge itself.

WILMOT RIVER SECTION

The structural section stretches from the Precambrian Forth Block across the Cambro-Ordovician sequences of the Fossey trough to the edge of the Tyennan nucleus, a distance of 45 km (Figs 1, 2 & 3). This section includes some of the best exposures of Cambrian sedimentary rocks in the Sheffield Quadrangle, especially in the river bed itself, although the middle Cambrian volcanic rocks themselves do not crop out. The process of compiling the section has relied on existing mapping (Jennings, 1958, 1963, 1979; Williams and Turner, 1983; Pemberton et al., 1991; Lewis, 1991) and the structural cross sections of Woodward et al. (in prep.); however, considerable amounts of new data were collected during this study, the body of which is appended to the end of this report in both tabulated form and as a map of the stations visited (see Appendices 1 & 2).

The structural cross-section has been divided into upper and lower domains on the basis of the Devonian thrusts that verge towards the centre of the section: the northern part of the section verges to the SW, whilst the southern part verges towards the NE (Fig. 4).

Upper Wilmot Domain. This domain comprises predominantly Middle to Late Cambrian rocks which are conformably and unconformably overlain by the Denison Group siliciclastics. It includes the volcanic-dominated facies of the Fossey trough (Fig. 1) and is separated from the lower Wilmot domain by the Nietta Fault. Both Cambrian (Dove) and Devonian (Dalcoath) granites are represented and significant quantities of skarn-type sulphide mineralisation are found immediately above the apex of the Dalcoath Granite; bedding parallel late diagenetic pyritic accumulations occur in the shallow marine Moina sandstones.

Lower Wilmot Domain. The lower Wilmot River section comprises ?Early Cambrian chert-mudstones and Middle Cambrian greywackes, siltstones, rare volcaniclastics and volcanics of the essentially sediment-dominated Dundas Group equivalent. It is underlain at relatively shallow depths by the broadly domal Beulah granite (Leaman, 1988; Leaman and Richardson, 1989), whose contact relations with the country rocks are observed to be both conformable and cross-cutting. Scattered Ba, Pb, Zn, Cu and Au mineralisation is related to the granite.

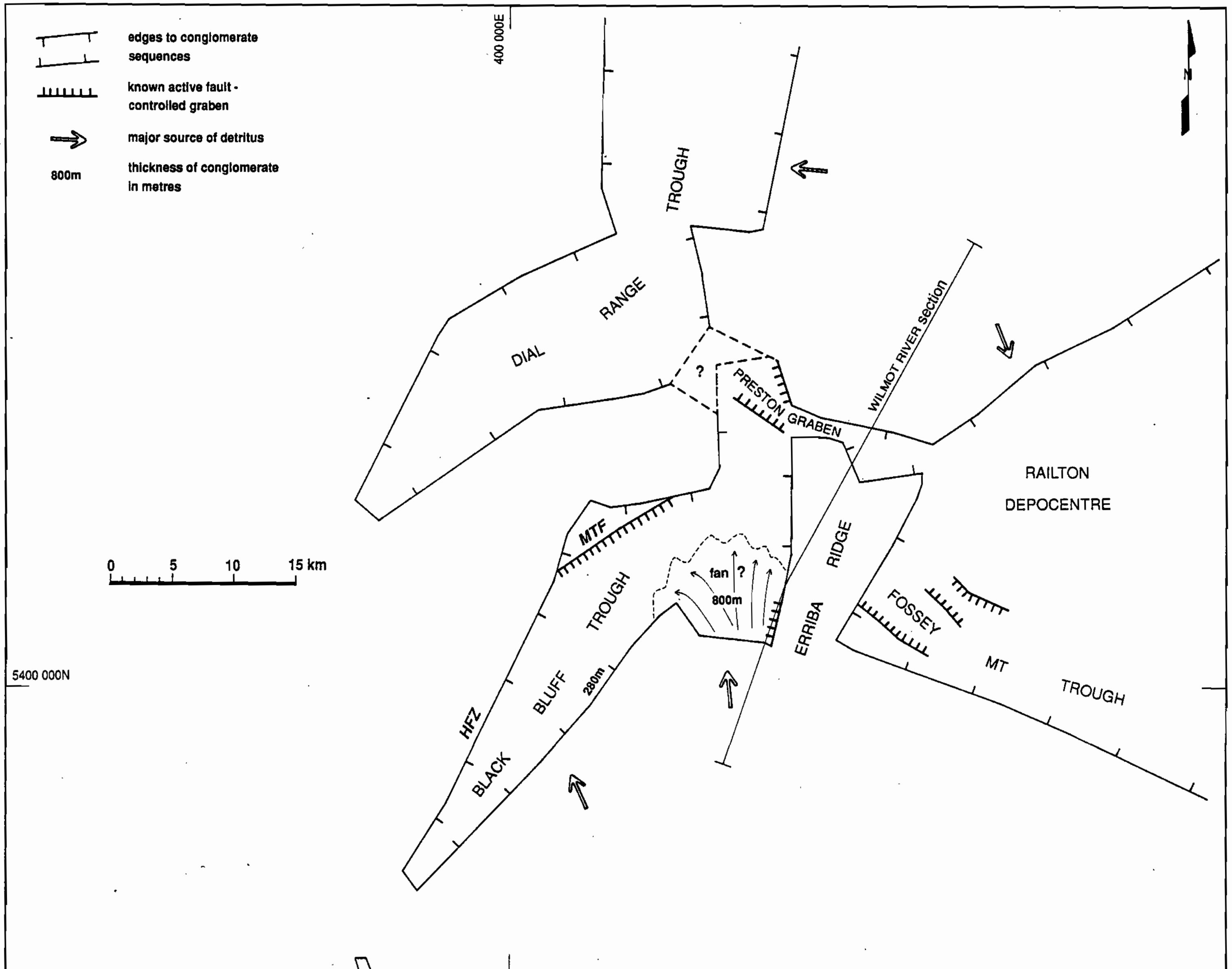
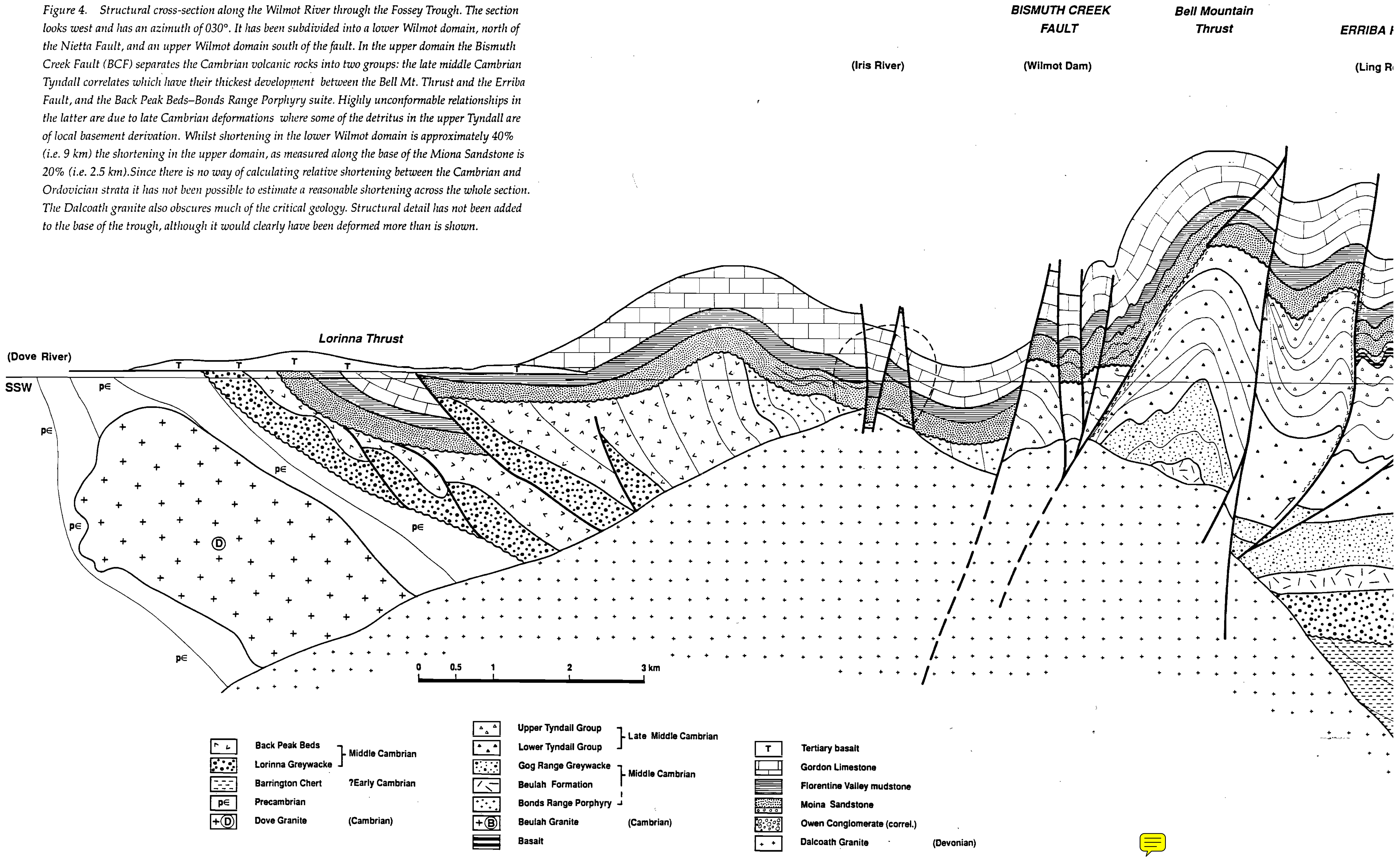
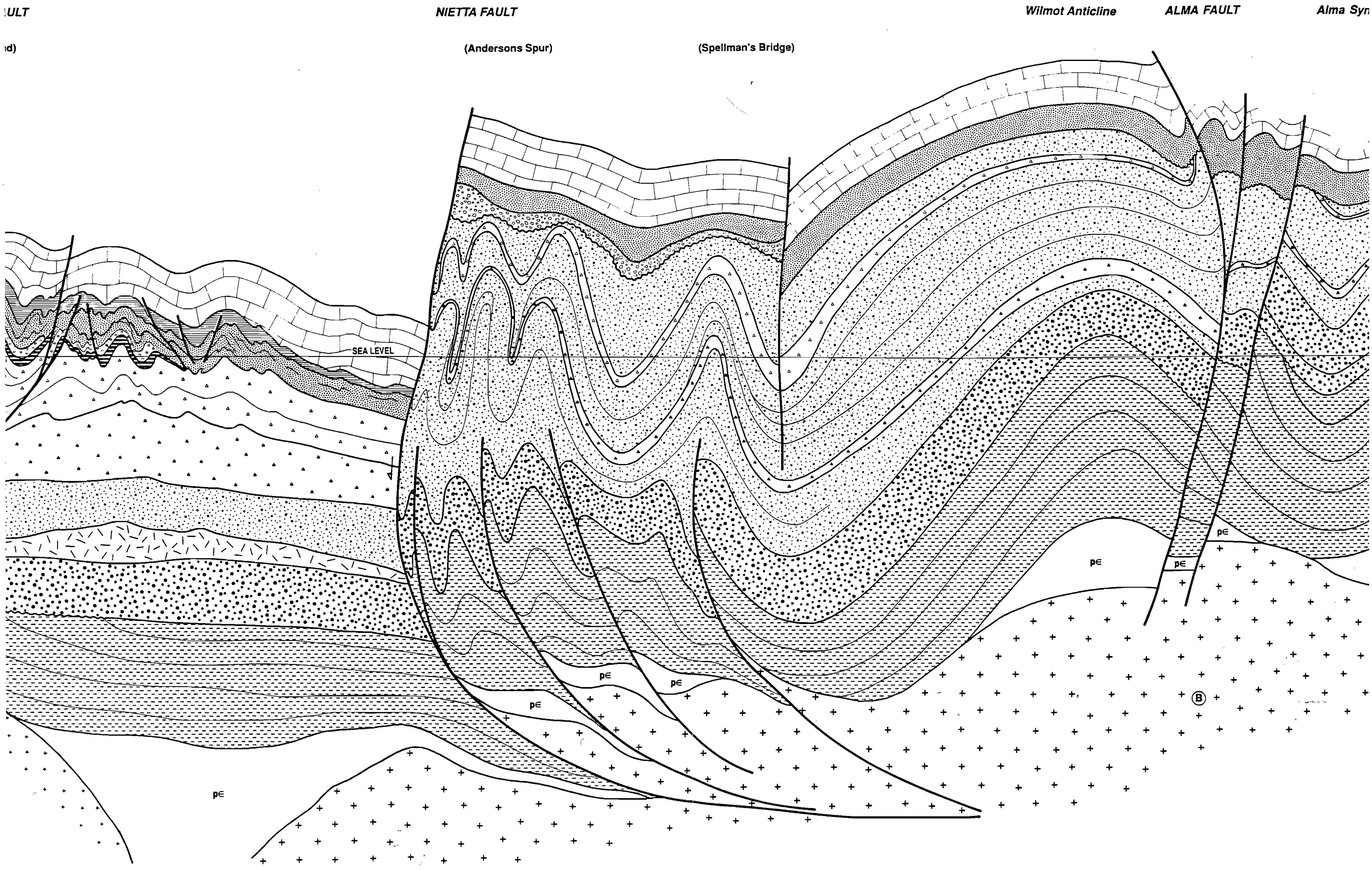


Figure 3. Late Cambrian depocentres for the Owen Conglomerates and its correlates.The Preston Graben is a narrow structure that connects the Railton-Melrose depocentre with the Black Bluff trough, and which may have also connected these to the Dial Range trough. HFZ= possible continuation of the Henty Fault; MTF=Mount Tor Fault.

Figure 4. Structural cross-section along the Wilmot River through the Fossey Trough. The section looks west and has an azimuth of 030°. It has been subdivided into a lower Wilmot domain, north of the Nietta Fault, and an upper Wilmot domain south of the fault. In the upper domain the Bismuth Creek Fault (BCF) separates the Cambrian volcanic rocks into two groups: the late middle Cambrian Tyndall correlates which have their thickest development between the Bell Mt. Thrust and the Erriba Fault, and the Back Peak Beds–Bonds Range Porphyry suite. Highly unconformable relationships in the latter are due to late Cambrian deformations where some of the detritus in the upper Tyndall are of local basement derivation. Whilst shortening in the lower Wilmot domain is approximately 40% (i.e. 9 km) the shortening in the upper domain, as measured along the base of the Miona Sandstone is 20% (i.e. 2.5 km). Since there is no way of calculating relative shortening between the Cambrian and Ordovician strata it has not been possible to estimate a reasonable shortening across the whole section. The Dalcoath granite also obscures much of the critical geology. Structural detail has not been added to the base of the trough, although it would clearly have been deformed more than is shown.





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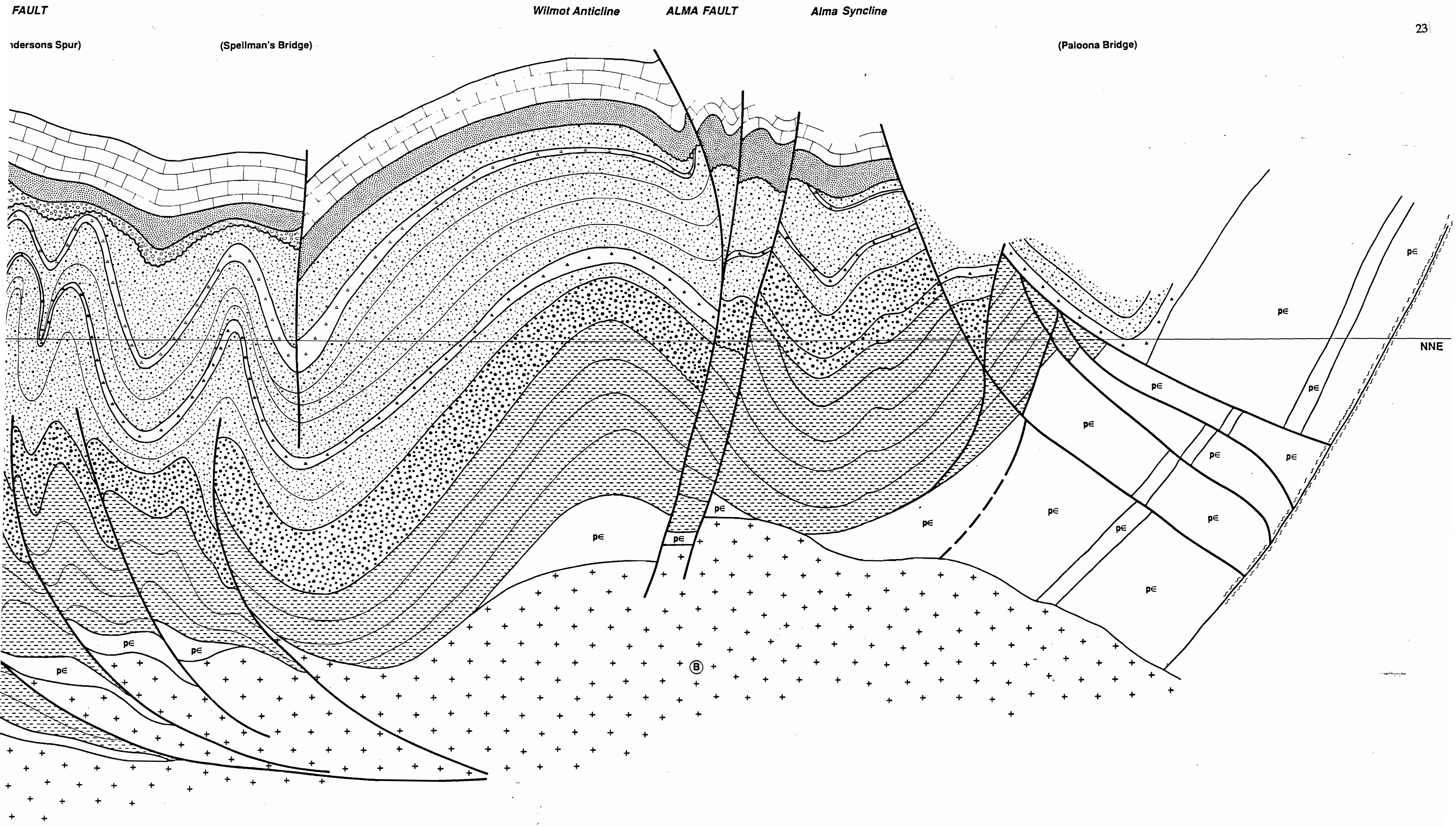
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Stratigraphy

The following stratigraphic thicknesses have been used in drawing up Wilmot structural section:

South	**North**
Gordon Limestone (600 m)	
Florentine Valley Mudstone (200 m)	
Moina Sandstone (300 m)	
Owen Conglomerate (<20 m)	
Upper Tyndall Group Correlates (1500 m)	
Lower Tyndall Group Correlates (1500 m)	
Gog Range Greywackes (1000 m)	Gog Range Greywackes (3500 m)
Beulah Formation (500 m)	
Bond Range Porphyry (1000 m)	Back Peak Beds (1600 m)
Lorrina Greywacke (350 m)	Lorrina Greywacke (600 m)
Barrington Chert (<1500 m)	Barrington Chert (2500 m)
Precambrian	Precambrian

Barrington Chert. A maximum thickness of 2.5 km has been measured for the chert on the east limb of the Alma Syncline (Fig. 4). The upper part of the Barrington chert has a mudstone band that passes conformably, via a siltstone, into the overlying Lorinna Greywacke. An answer to the question of how far the Barrington Chert extends to the south, may in part be provided by the gravity data: the exceptionally low Bouguer anomaly in the centre of the Fossey Trough, suggests that the chert may continue some distance under the Dundas Group sediments to the south. Indeed if the Crimson Creek correlates once covered the now presently exposed part of the Tyennan core, then between 1–2 km of chert is not an unreasonable thickness to invoke. The fact that the Lorinna Greywacke (see below) lies unconformably on Precambrian in the Dove River (Jennings, 1963) and that it and the Gog Range Greywacke contain chert clasts, indicates significant amount of uplift and erosion from the end of the ?Early Cambrian onwards.

Lorinna Greywacke. The similarities between the felspathic sandstone and greywacke unit in the lower Wilmot and the Lorinna Greywacke, has led to these two units being grouped into a single basal Dundas Group that underlies the whole section. It is thickest in the north (600 m) and thinnest in the south (350 m), although there is no way of knowing from the section how the thicknesses actually vary. The Sprent Formation (dominantly ?Early Cambrian chert-derived) and the Bott Conglomerate (Precambrian quartzite-derived) are considered to be coarse grained facies variants of the Lorinna Greywacke.

Bonds Range Porphyry. The unit estimated to be 2.5 km thick is a distinctive looking coarse grained biotite-bearing porphyry, of intrusive and/or extrusive origin (Vicary, pers. com., 1993). It is highly unconformable southwest of the Bismuth Creek Fault but conformable northeast of it (Fig. 2).

Beulah Formation. The stratigraphic position of the Beulah andesites, once thought to be the same age as the Motton Spilite, is now accepted as lying beneath the Gog Range Greywacke (Jennings, 1979). Here it is assumed to lie stratigraphically above the Lorinna Greywacke correlate. Since the nearest outcrop of andesite is seen disappearing under Tertiary basalt only 6 km away, a thinned sequence of andesite–basalt (250–350m) has been included as an integral part of the Fossey trough.

Gog Range Greywacke. A sequence of felspathic sandstones, greywacke, siltstone, vitric ashy siltstones, minor volcaniclastic sandstones and welded tuffs, in total 3.5 km thick, has been measured in the northern part of the section (Fig. 4). Two volcaniclastic units which have been observed in this formation have been nominated as distal facies equivalents of the upper and lower Tyndall correlates in the southern part of the section. The Gog Range Greywacke thins towards the Erriba Fault, south of which it has not been recorded; as a consequence, a modest thickness of 750 m is assumed to be present in the main axis of the Fossey trough.

Tyndall Group correlates. The Tyndall Group volcaniclastics have been divided into lower and upper units (Pemberton et al., 1991; Hicks, 1989). The only exposed contacts are faulted making it hard to estimate their true thickness. However, a 3000 m combined maximum thickness is probable.

Denison Group. A strongly altered basalt, looking to all intents and purposes like a cleaved siltstone, lies at the base of the Moina Sandstone unit (e.g. loc. WR23); since elsewhere similar basalts lie *within* the Moina Sandstone, they are considered to be part of the Denison Group and not part of the Tyndall volcanics. The regional section is remarkable for the absence of Owen Conglomerate, due mainly to the section lying along the axis of the Erriba ridge. The 10–20 m thick conglomerate which is to be found at the base of the Moina Sandstone, is usually linked to a coarse basal Moina, rather than an Owen Conglomerate, because it contains rare clasts of chert and haematitic siltstone (?basalt). Moina Sandstone passes conformably up into Gordon Limestone, via an interbedded sequence of sandstones, calcareous siltstones and mudstones called the Florentine Valley Mudstone.

Late Cambrian Structure

The upper Wilmot domain is divided into two parts by the Bismuth Creek Fault (BCF): south of fault the Back Peak Beds and the Bonds Range Porphyry (or Bull Creek Formation, Jennings, 1979) show a high-angular unconformable relationship with the overlying Ordovician rocks; whereas to the north the predominantly volcanic derived Tyndall Group correlates show a conformable, or near unconformable, relationship (Fig. 4). The Dalcoath granite coincidentally marks the boundary between these two sub-domains; however, this boundary is related more to the Cambrian fault, which had been mildly reactivated during the emplacement of the granite, than to any fundamental effect related to pluton. The Bismuth Creek Fault is assumed to be listric and dip to the southwest, in order to account for the rotation of the beds. This particular geometry would account for the fact that it had been later reactivated as a normal fault and sinistral wrench, rather than a thrust fault, because of its essentially unsuitable orientation for SW-directed transport.

Two late Cambrian growth faults in the upper Wilmot domain, namely the Bell Mountain and Erriba thrusts, form a 3 km wide zone of intense shearing, cleavage development and alteration in the folded and faulted upper and lower Tyndall correlates. The southern one of the two, the Bell Mountain Thrust (BMT), is a NE-directed reverse fault that thrusts Moina sandstone over lower Tyndall, i.e. younger over older; hence, its status as a growth fault. The lower Tyndall volcanics terminate against this fault, which must have been a site of early inversion. The second fault, or Erriba Thrust (ET), has the characteristics of a wrench fault at the structural level it now occupies in the bed of the Wilmot River. It has some normal movement on it, but principally it marks a boundary between thicker Tyndall to the south and thinner Tyndall to the north. Folding in the strongly sheared Cambrian rocks between the BMT and the ET commenced during the Late Cambrian N–S compression and continued through into the Devonian. This is recognised by the fact that the folds have been shown partly eroded away before the Moina Sandstones were laid down (Fig. 4).

The deformation is mainly ductile along the southern margin of the lower Wilmot domain where large-scale upright folds with wavelengths varying from 1 to 7 km are typical (Figs 4 & 5). A series of tight to isoclinal folds initially of late Cambrian age directly abut the less deformed sediments of the Denison Group to the south. Away from this southern edge, the amplitudes and wavelengths of the folds progressively decrease until they are quite open in style adjacent to the Precambrian block.

The internal part of the Nietta Thrust sheet is dominated by normal and wrench faults, with thrusts playing only a minor role in shaping the rocks here. The normal faults are related to the sub-surface expression of the Beulah granite. In particular, the Alma Fault system occurs at the culmination of this body at a depth of about 2.5 km (Fig. 4); this fault is inferred to be a long lived system with evidence of local uplift and erosion between the Barrington Chert and the Gog Range greywackes — there being good evidence for this off section (Jennings et al., 1959). As this section is drawn, it conveniently removes a mudstone unit above the Barrington Chert at the eastern end of the section and, in order to explain the existence of the Barrington Ridge (Jennings, 1979), it is also drawn as if it were a convergent wrench fault with local uplift at a bend in the fault. This movement is assumed to have continued right through until the end of Cambrian times. The nearby Cambrian Bott Conglomerate (Burns, 1964), derived from Precambrian quartzites would also tend to support this as an actively faulted basin margin with some early (i.e. pre-Devonian) inversion.

Devonian Structure

At the extreme south end of the section where much of the underlying geology is obscured by Tertiary basalt, and consequently exact relationships are not well known, the Lorinna Greywacke is seen to unconformably overlie the Precambrian basement and to be repeated by the Lorinna thrust. Given the probable 250–300 m thickness of the greywackes (Jennings, 1979) and their extreme dynamic hydrothermal alteration much of the space between the Dove and Dalcoath granites can be accounted for by folding and thrusting of this formation (Fig. 4).

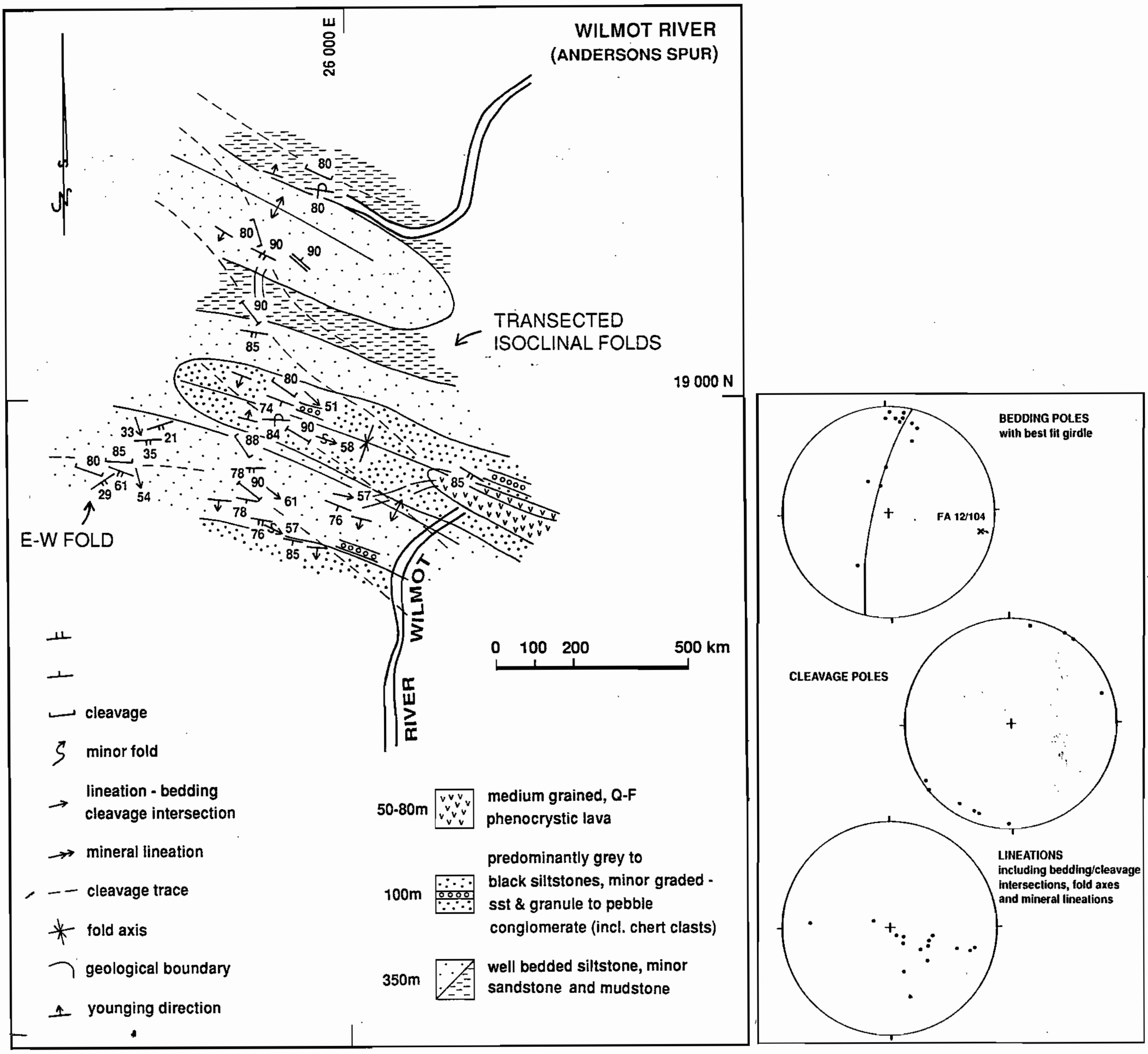

Figure 5. Geology and structure of the Andersons Spur locality, Wilmot River gorge. The transection of the late Cambrian folds clearly shows that they developed prior to the cleavage, which is Devonian in age and probably quite restricted in the time interval over which it developed. The trajectories of the cleavage implies that the package of rocks may have suffered a sinistral shear couple on axial plnar faults which have not been mapped.

A series of normal faults, with displacements of tens of metres up to a possible 100 m, directly overly the apex of the Dalcoath Granite. This occurs in a region where the granite comes to within 350 m of the surface, e.g. in the vicinity of the Iris River. The degree and intensity of development of the skarn-type sulphide alteration in the Moina sandstones is spatially related to these faults. The strongest replacement appears to be confined to the shaley calcareous beds of the Florentine Valley Mudstone unit lying at the top of the Moina Sandstone. Locally, garnetiferous skarns are abundant.

The majority of the rocks exposed in the upper Wilmot domain (between the BCF and ET) belong to the Denison Group. A series of upright, NW-trending sub-horizontal folds (Fig. 6a & b) which are open to tight in style generally have a weak or non-existent axial plane cleavage; in contrast folds in the Cambrian rocks are generally tighter and the cleavage more pervasive reflecting the greater degree of alteration and ductility associated with the volcanics. The folds are symmetrical, although local thrusting on the limbs gives both west and east senses of vergence, with the dominant sense of transport still being from SW to NE.

The thrust faults recorded in the lower Wilmot domain were very few and hardly noticeable on the section, except for a reactivated normal fault that cuts the Precambrian basement just south of Paloona Bridge. All are SW directed, in agreement with the sense of transport on the Nietta Thrust. At depth, however, the Nietta Fault is interpreted to become a thrust fault, dipping back towards the north and detaching along the lubricated Precambrian schist–granite surface. The upper parts of the folded region immediately behind the thrust is presumed to have been eroded away, with the Cambro-Ordovician unconformity surface being partly folded during the Devonian thrust/fold event. Total shortening across the lower Wilmot domain is calculated to be approximately 36%.

At the Andersons Spur locality, the transection of an earlier set of large-scale Cambrian folds by the regional cleavage and a later E–W syn-cleavage fold set confirms the progressive nature of the deformation along this part of the regional section (Fig. 5). The earlier set of folds have wavelengths measuring up 500 m and trend approximately E–W; their presence is deduced by a series of changes in stratigraphic facing within the sediments of the Gog Range Greywacke. The folds are very tight to isoclinal and are transected by a moderately developed regional cleavage which strikes WNW–ESE to NW–SE, i.e. obliquely across the limbs of the folds. The measured and calculated bedding-cleavage intersections and minor "S" folds plunge moderately or steeply towards 110°, as does the π-pole girdle on the stereonet (Fig. 5). The true Devonian folds are located on a steep track down to the river where they trend E–W and have a 25° easterly plunge; they are open in style and have a stable E–W axial plane cleavage. The cleavage, which is everywhere presumed to have formed at the same time, overprints one set of folds (Cambrian) and is contemporaneous with another (Devonian).

The local Tabberabberan fault data in the lower Wilmot domain supports a NE–SW compression followed by N–S and NW–SE compression; however, the existence of E–W folds prior to these phases of the Devonian deformation (Williams, 1978), which is most likely to be the phase associated with the strong transected cleavage, suggests that these folds range from late Cambrian to Devonian in age. The case for a Cambrian age is strengthened by the seemingly unlikely, but nonetheless quite plausible proposition that the stress field initially was N–S, then changed to NE–SW, swung back to N–S and finally ending up NW–SE. The timing of these different stress fields will be briefly discussed in a later section.

An interesting example of structural style typical in this regional section shows Cambrian beds in a near vertical attitude within the core of a Devonian anticline; the overlying Moina Sandstone beds, however, take on a very open fold profile. Clearly, the deformation in the underlying volcanics was taken up by shortening perpendicular to bedding whilst in the overlying sediments it was taken up by slip along the bedding surface. Whilst such an extreme angular difference is not common, elsewhere, where the angles of unconformability are less, i.e. north of the Bismuth Creek Fault, a combination of layer perpendicular shortening, layer parallel slip and thrusting is assumed to have taken place. The angle of unconformity is thought to be less than 25° along much of the rest of the section, and therefore the Cambrian rocks would have been folded in the much the same way as the Ordovician rocks — with the exception of the cores of the Cambrian folds where uplift allowed erosion to strip away the crests which would have been preferentially tightened during Devonian deformation.

The contacts between the Cambrian volcanics and the Moina sandstones, even in areas of low to moderate strain, always show evidence of some enhanced cleavage development; they also invariably show evidence for some kind of movement, whether strike-slip or dip-slip. The well exposed faulted contact at the Ling Road locality is a good example of a major fault (in this case the Erriba Thrust fault) which had developed at the Cambro-Ordovician boundary. Here a 20–30 m wide zone of strong sinistral shearing in the Cambrian phyllites abut directly onto vertically dipping isoclinally folded Moina Sandstone beds; away from the contact zone, within 20 m of the other side of the fault, the open style folding more characteristic of the Moina is resumed once again.

Fault Kinematics, Fault Striae and Devonian Stress Fields

The inferred Devonian stress fields, as deduced from fault striae, are relatively constant throughout the whole section. At least four stress states existed during the Devonian deformation, each corresponding to one of the four main fold trends of Williams (1978). Directions for the maximum principal stress ($\sigma 1$) are as follows: N–S, NW–SE, E–W and NE–SW. The dominant compression directions are N–S & NE–SW (Fig. 7). Although there is a subsidiary E–W compression no folding has been reported along this trend. A NW–SE directed stress field, which is best expressed through a number of post-cleavage σ_1–σ_2 extensional quartz veins is unrelated to any cleavage or fold direction and is considered to be late.

N–S Compression. A number of N and S-directed thrusts and reverse faults occur in the upper and middle Wilmot River region associated with a series of conjugate dextral and sinistral wrench faults. The E–W isoclinal folds transected by a late Devonian cleavage in the Andersons' Spur locality are Late Cambrian in age.

NE–SW Compression. This is the stress state associated with the main Devonian deformation (D_2) that controls the dominant NW-trending cleavage and fold direction. Most of the reverse faults are high-angle (e.g. the Bell Mountain Thrust at Moina) and the dominant transport direction is NE directed. A change in vergence occurs in the middle of the section where a change to SW-directed thrusting takes place.

E–W Compression. N–S thrusts and reverse faults verging towards the east have developed in both Cambrian and Ordovician rocks within the upper Wilmot River. The striae associated with this movement are steeply plunging, giving a tight cluster of points on the stereonet, particularly when the data from Fig. 7a, b & d are combined, suggesting that the direction of tectonic escape was mostly upwards during the Devonian. This vertical escape direction — giving a good estimate of the orientation of σ_3 — is typical of the Devonian orogen in western Tasmania (for example, the CVC in the central part of the King River section and the Henty/Great Lyell Fault intersection on the Anthony Road; Keele, 1991, 1992).

NW–SE compression. Evidence for this stress system can be found in the lower Wilmot River where NW–trending normal faults occur in the Cambrian sediments. This type of faulting is especially evident in the vicinity of the Precambrian Forth Complex. The reason for this stress state is due to two possible causes: firstly, extension in the back regions of the Devonian Nietta thrust and secondly, the presence of the buried WNW–trending Beulah granite. Whilst there are a limited number of conjugate wrench faults that fit this stress field (the more dominant of the two NNW-trending faults with sinistral movements), there are also a number of NW-trending extensional quartz veins. They are common in the open folds in Moina Sandstone, where they are developed in the anticlinal crests, as they are also to be seen cutting the isoclinal folds in the Cambrian sediments.

Timing of Stress Fields. Whilst the timing of the Devonian stress fields is agreed to be the N–S compression first, then a progressive anticlockwise rotation of the stress field through D_2, D_3 and finally to D_4, which is the main NE–SW compression of the Devonian (Williams, 1978; Seymour, 1989), the following unequivocal striae data obtained during this study indicate the following:

1. A N–S compression was followed by a NW–SE compression (i.e. fault truncations at locality WR96).
2. A NE–SW compression was followed by a N–S compression (i.e. overprinting of striae on same fault surface at locality WR31).
3. An E–W compression was followed by a NE–SW compression (i.e. cleavage-related faults with sinistral offset cut by faults associated with dextral kinks at WR100).

   Other observations include the following:

4. Fault movements changed from dip-slip to oblique-slip during the NE–SW compression (i.e. overprinting of striae at C1).
5. Also within the NE–SW compression a NE-directed thrust can be shown to have moved synchronously with a dextral lateral ramp (locality BM5).
6. In the NW–SE compression, a dip-slip normal fault is cut by a strike-slip sinistral fault (locality WR94).

These observations (1–3) suggest that there was an anticlockwise rotation of the stress field, which would agree with the generally held view on timing relationships in the Devonian; only one of these observations contradicts this view in any way (2), but since the later movement is associated with a polished surface as opposed to quartz fibres, this movement may be very late Devonian or Carboniferous in age, during which period it is known that a stable N–S stress field existed over most of eastern Australia. The change from dip-slip to strike-slip (4) is consistent with all observations to date on the Tabberabberan orogeny, namely that the direction of tectonic escape changed from vertical (D_1) to horizontal (D_2); (refer to

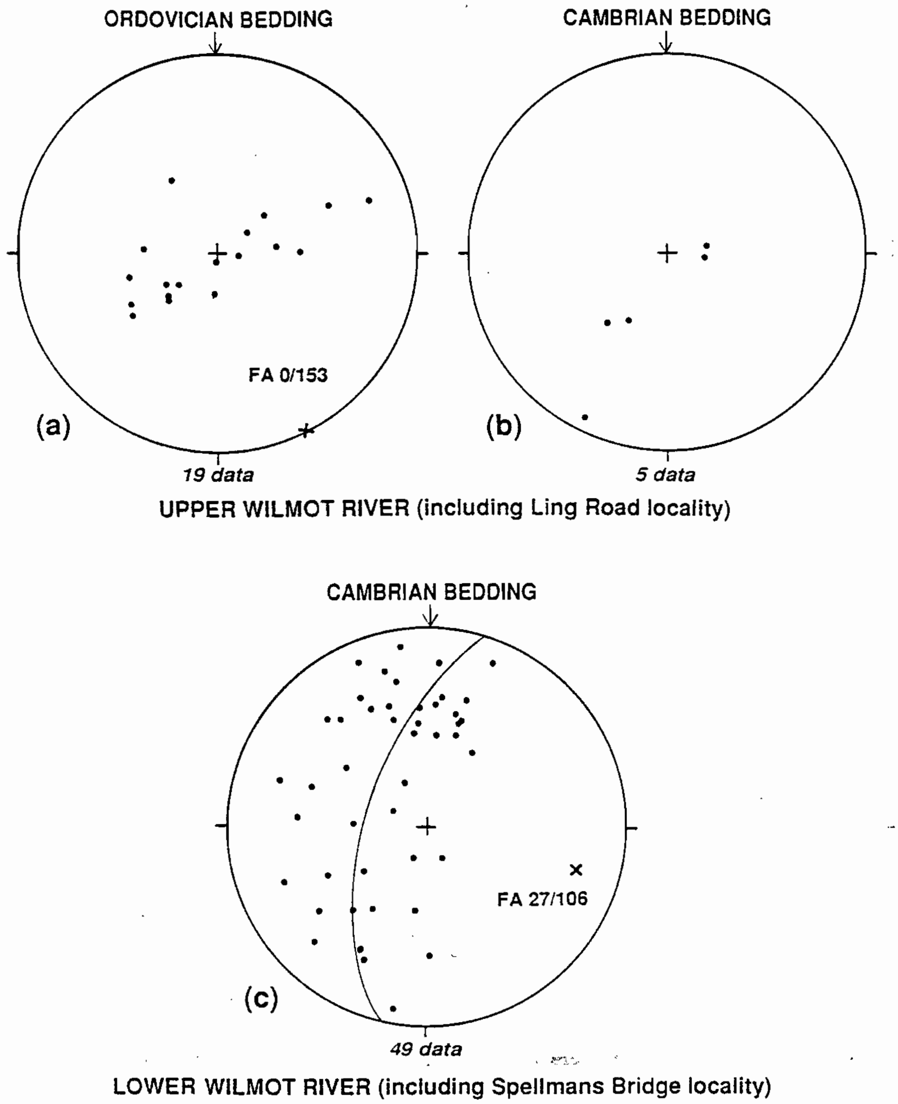

Figure 6. Bedding plane measurements for the Wilmot River traverse (except for the Andersons Road locality, see Fig. 5). In (a) and (b) poles to bedding show the sub-horizontally plunging folds related to the Devonian NE–SW compression (D_2); note that both Ordovician and Cambrian beds in the Upper Wilmot are folded around the same horizontally plunging NW–SE axis (i.e. apart from a single measurement at the Ling Road locality) indicating that the beds are locally conformable. There is a clear difference in plunge of the folds in Cambrian rocks in the Lower reaches of the Wilmot (27 → 110) when compared to the Upper Wilmot; however, whether this difference is due to unconformable relationships with the overlying rocks, or is due to a different structural domain cannot gained from this data.

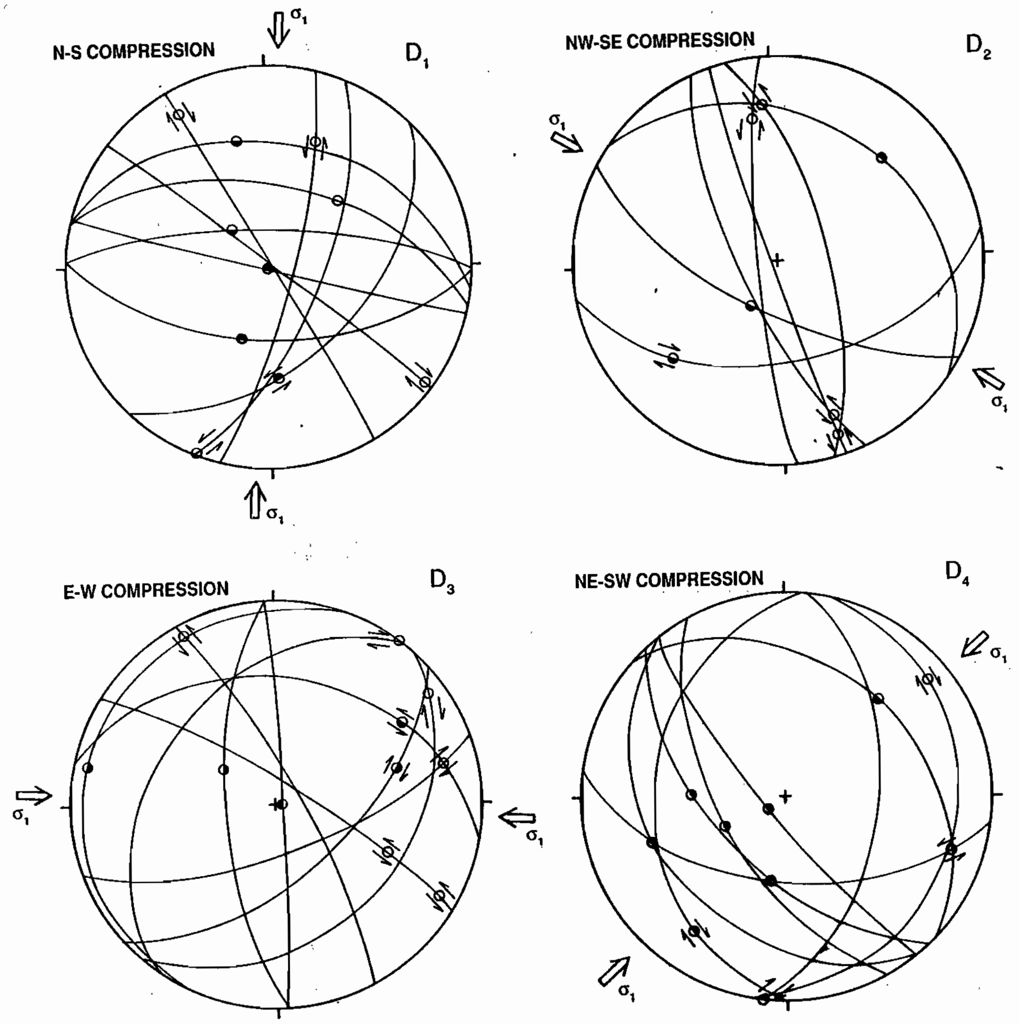

Figure 7. Fault striae, Wilmot River structural section. Although there are variations in fault type (i.e. reverse, strike-slip, etc.), the data has been broken down into compressive stress directions compatible with Williams' (1978) analysis of structural trends in western Tasmania, rather than into any structural domains. The stress fields are displayed in their order of development proposed by Seymour (1989) for the St Valentines Quadrangle. D_3 and D_4 equate with D_1 and D_2 at Mt Lyell and Rosebery. The circles indicate movement direction; the dark hemispheres of the half-filled circles indicate the down block side, whilst the open circles are used for strike-slip movements with the arrows indicating movement. For further explanations, see text.

Berry, 1989). Finally, the accompanying movement of a side ramp (5) with a thrust, is exactly the kind of relationship expected in a thrusted terrain. The sinistral wrench that cuts a normal fault (6) indicates that the NW–SE compression must have been established first, at an early stage in the deformation — perhaps during or immediately Cambrian granite emplacement — and then was re-established at a much later date, during the Permo-Carboniferous.

MINERALISATION

Mineralisation has been broadly subdivided, on the basis of age, into Cambrian, Ordovician and Devonian. The Cambrian mineralisation itself is of two types: the first comprises a number of the deposits and prospects related to the volcanic-dominated facies component of the northern Dundas Tough, and the second comprises prospects related, directly or indirectly, to the Beulah granite. The Ordovician mineralisation consists of pyritic accumulations in the Moina Sandstones and has been tentatively linked to a thermal regime caused by the extrusion of basalt at the time. The Devonian mineralisation is considered only in so far as it relates directly to the structures on the section; other Devonian granite-related mineralisation, such as Sn–W in the Dalcoath Granite, are not considered further because their structural controls have been described in the literature (Jennings, 1958).

Cambrian: Volcanic-dominated facies group

This first group occurs principally in the SW corner of the map around the Que–Hellyer volcanic centre; other deposits nearby include Boco (py), Chester (py) and Pinnacles (Zn–Pb–Cu–Au–Ag), these last two occurring right on the presumably faulted western boundary of the volcanic-dominated facies. The presence of barite at the Mt Charter prospect indicates that the mineralisation is of probable Cambrian age and its location on a Cambrian growth fault suggests that such faults were escape pathways for fluids within the volcanic pile. The isolated occurrence of barite at Two Hummocks, southeast of St Valentines Peak, is particularly interesting because it extends the known geographical range of the Cambrian volcanic-dominated facies mineralisation in the SW corner for at least another 20 km along strike. This NE structural trend is an important direction in the Cambrian (see section on domain analysis, this report).

The pyrite–sericite alteration at Cethana (the Cethana Pyrite Zone) has all the hallmarks of Cambrian mineralisation (Hicks, 1989). It is a large alteration system totalling some 3 km in length and trends E–W parallel to the strike of the Cambrian volcanics and early folds. It lies on the southern faulted boundary of the volcanic-dominated facies, the mineralisation occurring as sulphide stringer zones and as disseminated sulphides in highly altered lower Tyndall Group rhyolites. The deposit sits between the Bell Mountain Thrust and the Erriba Fault both of which are interpreted Cambrian growth faults active during Tyndall times (Fig. 4).

Cambrian granite-related (Beulah Granite)

The second major group of Cambrian prospects occurs around the Beulah granite. They occur outside the limits of the volcanic facies and are restricted to the predominantly sedimentary facies in the Dundas Group, with the single exception of the Lower Beulah prospect which occurs adjacent to the Beulah Formation andesites (Fig. 1). Those that contain barite are assumed to be Cambrian — after a study of Cambrian barite mineralisation in the Murchison granite (Abbott, 1992), from which we might conclude that barium is the best indicator we have of true Cambrian mineralisation. However, there are other prospects within this second group, which may well be Cambrian in age although there is no mention of them having barite: examples of these are the Preston Silver mine and the Crosby Creek Cu–Pb–Zn prospect in the immediate vicinity of the Castra barite prospect.

The scattered metalliferous occurrences in the Barrington area are related directly, or indirectly, to the emplacement of the Cambrian Beulah granite (Leaman and Richardson, 1989). The presence of barite at a number of localities, including the Beulah Wilmot River prospects, would tend to confirm the Cambrian age of the mineralisation The presence of copper and gold, as well as lead and zinc, would suggest a temperature zonation of the fluids circulating around granite body. Leaman and Richardson (1989) briefly discussed the possibility of such a halo around the granite body.

The following prospects have a clear relationship to structure:

1. The Preston, Castra and Crosby Creek prospects lie on the two Late Cambrian growth faults which together define the Preston graben (Fig. 3); the southernmost of the three prospects, Crosby Creek prospect, actually lies on the Nietta Fault which is a major structure with gravity expression that marks the possible northern edge of the Fossey Trough. This association suggests that the deposits may have resulted from remobilisation or escape of metalliferous fluids during the Cambrian inversion. However, further work on these prospects is required in order to determine their host rock, for if it is Moina Sandstone rather than Cambrian sediments of volcanics, then a younger Ordovician or Devonian age for the mineralisation is required.

2. The Alma Cu–Ba prospect is located on the Alma Fault system, which it has been argued is a Cambrian wrench fault system.
3. The Lake Barrington Cu–Au–Ag prospect, and at least four other prospects, are located on or very close to the northern boundary of the volcanic-dominated facies; whilst this in itself is no guarantee of a structural control, their close spatial relationship to the sharp edge of a coincident regional gravity feature and the Late Cambrian Nietta Fault, points to a structural control at deeper levels in the crust.

Ordovician

The presence of stratiform pyrite lenses in the Moina Sandstone, (for example, loc. WR10 immediately below the Wilmot Dam) testifies to the general reducing conditions that pertained during deposition of these marine sandstone beds. The issue of whether the sulphides originated as a result of diagenesis or granite emplacement, or possibly involved some combination of the two processes, is clouded (or elucidated) by the fact that the extrusive basalt flows seen at the base of the Ordovician rocks in the vicinity (e.g. loc. WR23) clearly could have provided the thermal regime required for the deposition of late diagenetic stratiform sulphides and cross-cutting sulphide veinlets (e.g. the mineralisation at loc. WR15). The circulation of oxidising fluids through a metal and sulphur enriched pile of Cambrian volcanic rocks, would meet the appropriate redox boundary conditions in the Moina sandstones beds encouraging the precipitation of metals. Such conditions could have continued and precipitation culminated with the emplacement of the Devonian granite.

Devonian (Dalcoath Granite)

Gold-bearing skarns (Taylor, 1990) are common particularly where the granite lies at a shallow depth beneath Ordovician cover (200–350 m); here, sulphide replacement, resulting directly from Au–S rich fluids originating in the granite, appears to have favoured the finer grained calcareous sediments of the Florentine Valley Mudstone sequence. The skarn halo is directly related to normal faulting around the apex of the granite (Fig. 4). The development of gold skarns in Ti Tree Creek and the Lea River is related to the unique combination of the right host, i.e. calcareous siltstones and mudstones, being in the right place, i.e. in the roof zone of the intrusion, at the right time. A second culmination of the roof of the granite is inferred to exist 2.5 km to the north where the Wilmot Ag–Pb prospect is located; however, despite the presence of favourable host rocks and normal faulting, the distances from the roof of the granite are clearly too great for this area to be well mineralised.

The gold occurrences around the Dalcoath granite cover an area 15 km by 10 km and are considerably more extensive than the more restricted Sn–W mineralisation. Alluvial occurrences are common in the Dove River, however, these workings cut out abruptly in the Precambrian terrain suggesting a connection between the gold and Cambrian rocks. Abundant Au mineralisation around the Dalcoath Granite is possibly a measure of the Au-enrichment in the Cambrian source rocks, rather than an indication of high gold contents in the Devonian granitic fluid. Highly altered volcanics generally have enhanced low level gold values (Stoltz and Large, 1988); whether these rocks could have been a source either by direct assimilation into the magma or from leaching by a fluid circulating around the granite, could be one of the foci for any future studies on this problem.

Devonian (Housetop Granite)

The Devonian-aged Housetop granite has a number of Fe deposits (including magnetite, hematite, goethite and pyrite) located around its margins which appear to have little structural control to them. Tin deposits also occur; but since they, and many other deposits like them, have been adequately described in terms of their controls elsewhere in the literature, no further space will be devoted to them here.

CONCLUSIONS

- The Fossey Trough is at least 5.5 km deep. Its contents are thought to include the Barrington chert which lies at its base, whilst the Lorinna Greywacke (a basal Dundas Group sandstone that underlies the whole section), a thinned Beulah Formation, the Gog Range Greywacke and an upper and lower Tyndall Group correlate comprise the rest.
- E–W trending folds, due to a late Cambrian meridional compression, were identified in the Gog Range Greywacke unit. Cleavage transection shows that the folds developed, and progressively tightened, over a period of time culminating in the NE–SW Devonian compression. Other folds in late middle Cambrian Tyndall correlates at the southern end of the section, which show tighter profiles than equivalent folds in the overlying Ordovician, are also inferred to be Cambrian folds.
- The centre of the Fossey Trough is marked at the surface by a change in the sense of vergence of the Devonian thrusts from SW to NE.
- Total shortening across the lower Wilmot domain, i.e. the northern end of the section in Cambrian sediments, is approximately 36%. Shortening

across the rest of the section is impossible to estimate because of the Dalcoath Granite.

- Cambrian mineralisation itself is of two types: the first comprises a number of the deposits and prospects related to the volcanic-dominated facies component of the northern Dundas Tough, and the second comprises prospects related directly, or indirectly, to the Beulah granite.
- The Preston graben, which connects the Railton–Melrose depocentre with the Black Bluff basin during the Late Cambrian, has mineralisation associated with its bounding faults: the Crosby prospect lies on the Nietta Fault a major structure with gravity expression that forms part of the complex northern boundary to the volcanic-dominated part of the Fossey Trough.
- Ordovician mineralisation consists of pyritic accumulations in the Moina Sandstones and has been tentatively linked to a thermal regime caused by the extrusion of basalts at the time.
- Gold-bearing skarns are directly related to normal faulting around the apex of the Dalcoath granite. A unique combination of the right host, i.e. calcareous siltstones and mudstones, being in the right place, i.e. in the roof zone of the intrusion, at the right time accounts for the richness of the deposits at Moina.

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NORTH MT FARRELL - NEW NORTH MT FARRELL MINES

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ABSTRACT

The North Farrell and New North Farrell mines are Devonian vein style mineralisation related to granite intrusion. They are structurally controlled and have mineralised dilatant zones 50 to 100 m into the foot-wall of the major bounding fault west of the Farrell Slates. The veins thicken at intersections between N and NNE striking subsidary faults. The best lenses are in dilatant sites over Riedel Shears. There is a close association with kink band formation. All the structural information supports mineralisation during the last part of the reverse fault movement on the Henty Fault Zone.

INTRODUCTION

The geology of the Mt Farrell and New North Mt Farrell has been summarised on a number of occasions. It is the largest of the Ag–Pb–Zn lode systems in the Farrell Field and has a historic production of 730,000 tons of Pb/Ag ore. The geology was most recently summarised by Collins et al 1981. Older summaries are by Brooks (1962) and Jensen (1959). The most recent relevant study is the Lakeside report of Taheri & Green (1990) which includes much of the isotopic work relevant to the Farrell Lodes.

All these studies conclude that the Mt Farrell mines are related to Devonian granites. This is supported by the Pb isotope data (Gulson & Porrit, 1987) and the field relations. The Pb isotope data precludes a direct remobilisation of a Cambrian massive sulphide deposit since the Pb is more radiogenic than the known VHMS deposits in western Tasmania and in the Devonian field. The high Ag and high Pb/Zn ratio confirms a relatively high temperature. The association with siderite is very common for vein style mineralisation in the Dundas field and for other vein style Ag–Pb–Zn deposits. The extremely variable Zn/(Zn + Pb) is typical of the Devonian vein systems and contrasts with VHMS deposits (Large & Huston, 1986).

The S isotopes show very high values indicating a Cambrian seawater S source (Polya et al., 1986). This appears typical of the more distal Ag–Pb deposits which occur about 3 km away from the granite (Tahari & Green, 1992) and have a high component of metamorphogenic fluid. The S value contrasts with S isotopic ratios at the Lakeside deposit which has a higher magmatic component.

The typical zonation of granite related vein systems has been the subject of a substantial amount of work with the Dundas field considered one of the classic examples. Tahari & Green (1992) have pointed out the zonation in the Farrell field. Some anomalies are the Sterling Valley prospect which is closer to the granite than expected for a Ag Pb system (depending on which model for the granite surface is accepted. This is close to the granite but has distal S isotope ratios and mainly Pb-rich mineralisation. It does have arsenopyrite suggesting it is slightly more proximal than the Farrell deposits. Murchison is anomalous in lying directly over the granite ridge but having low Cu and tin. Tullarbardine is anomalous because it is the most distal of the deposits in the field but has high Cu. There is also a high Ag–Pb vein system at this prospect. In some areas this style of vein system has associated Au–Ag veins but these have not been reported in the Farrell field.

STRUCTURE

Small scale

The Farrell lode lies 50 m into black slates and phyllites in the footwall to the major reverse fault which forms the western boundary of the Henty Fault Zone. It lies in an imbricate zone of reverse faults which interconnect in both plan and section. The region of the deposits has anomalous more intense kink band development. In some exposures and and in core siderite veins occupy the axial planes of the kinks suggesting a direct genetic link. The lode position is associated with extensive quartz siderite veining and brecciation. Veins lie in dilational sites along kink band boundaries and along faults especially near Riedels. The "lode channel" is apparently a quartz siderite stockwork along one or both sides of a cataclasite.

Quartz only veins are syn- to pre-kinematic with respect to the fault cleavage and are widespread throughout the Farrell Slates. In contrast quartz siderite veins are syn- to post-kinematic and siderite galena vein are ?syn- to largely post-kinematic. Rivers (1975) and many other authors report the galena bearing veins as deformed with a fault lineation pitching steeply south. This is consistent with mineralisation being very late syn-kinematic with respect to the reverse movement on the Henty Fault.

While alteration is not generally visible in hand specimen the slates and sandstones are very sericite rich compared to equivalent rocks away from the mineralisation (e.g. Mackintosh Spillway). This sericite alteration continues for at least 2 km north of New North Farrell, to Farrell Blocks.

A surface sample from the black slates 20 m SE of the New North Farrell deposit shows many of the features (Fig. 1). A kink has nucleated in the hanging wall to a thrust plane and where the fault ramps across the slatey cleavage. The siderite veins crosscut the very strong cleavage with only minor displacement. They also occur along brecciated margins to the kink zone and partly replace to more intensely deformed central zone of the kinks.

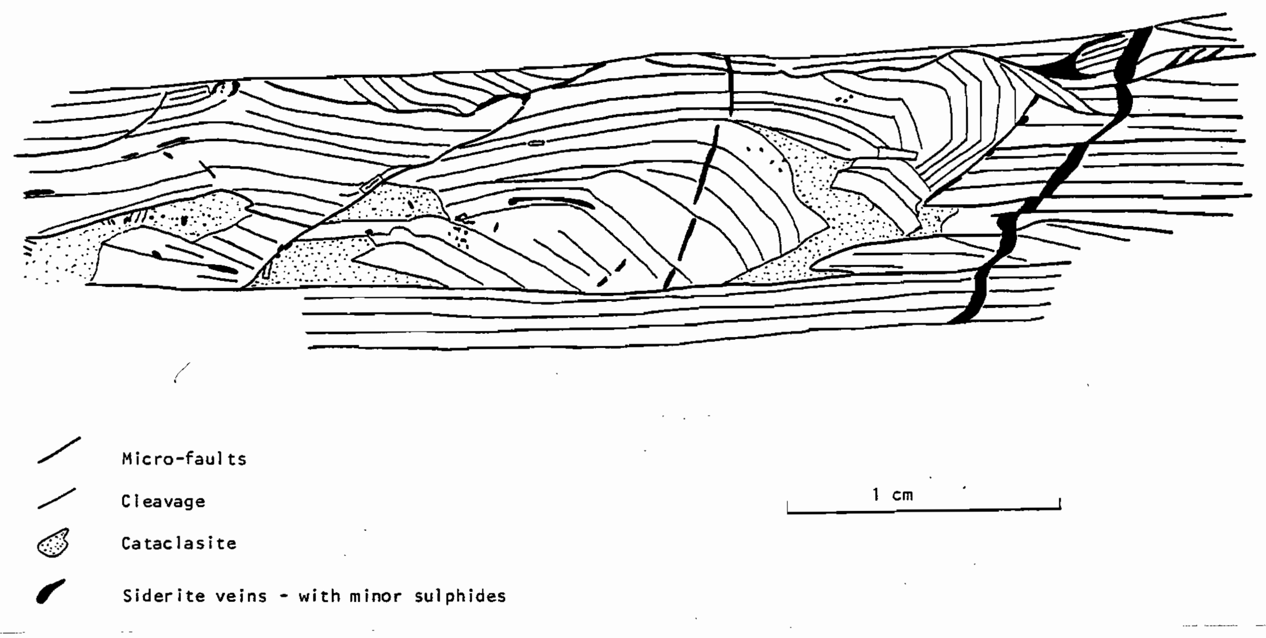


Fig. 1. Sketch of a kink structure from slates near New North Farrell Mine showing the late syn- to post-kinematic nature of siderite veining and its close association with dilational sites at kink margins.

MINE SCALE

North Farrell open cut

Exposures are very limited in the vicinity of the Farrell Mines. the most substantial outcrop is associated with the North Farrell open cut. A sketch of this exposure was made and structural readings taken from it (Fig. 2). The outcrop is entirely composed of black slates with a very strong cleavage. No bedding was recognised despite the excellent exposure. There is a strong stretching lineation visible on the cleavage and this largely pitches to the south. The dominant features are an imbricate pattern of faults largely sub-parallel to the cleavage. The position of shafts and adits suggests two and possibly three vein systems were mined at this level. The eastern vein system is still visible as a small galena bearing siderite vein along a fault dipping 60 to the west. In the footwall of this system is a small Riedel (Fig. 3) and it may be the action of this fault which lead to the dilation along the steeper fault surface. There is a close association of kink band formation and cataclasite with this minor fault.

The major fault through the centre of the pit is steeper than the cleavage (P-shear orientation). While the ore position is not visible in this area there are a number of quartz-siderite veins in the immediate hanging wall. In the footwall, a siderite vein is parallel to the kink band axis and very nearly parallel to the fault. On the western side of the open cut is a complex series of Y faults. On the north west end the fault pattern is dominated by NNE striking faults. Some folding of the cleavage is implied by the variation in cleavage orientation (Figs 2, 4).

The structure visible in the open cut is very similar to that reported at deeper levels (see below). There is a close association between siderite galena veins, and faults and kink bands.

Core

As part of this project I looked at core from five holes. A major surface hole 1F was drilled from the hanging wall side and passes through the Henty Fault at 1273 ft. (Fig. 5). There is a narrow zone of cleavage within the CVC volcaniclastics (14 ft wide) on the hanging wall of the fault. On the footwall side there is 10 ft of cataclasite in black slates and then gradually diminishing proportion of cataclasite away from this zone but some zones of cataclasite continue out to the end of the hole at 1585 ft. Throughout the Farrell Slates there are common kinks with cleavage flattening to parallel to the core axis (dips of 20°). The kink geometries are similar to those seen on surface to the north of the deposits. Siderite veins are often parallel to the kink axes and sit at the dilational sites associated with the kink band boundaries. Assuming the cleavage orientation is similar to surface exposures the kink axes are fairly shallow in plunge. Lineations on the cleavage are of two types intersection lineations and stretching lineations/striations. The stretching lineations mainly make a clockwise angle with respect to the ellipse. The interpretation of this variation depends on assumptions about the cleavage orientation. The two possible interpretation are that in this zone the stretching lineation pitches north OR that these are area where the cleavage strikes more to the NNE and is at a lower angle to the core strike. In terms of the surface information the second interpretation is more likely.

Hole 1F passes below the known mineralisation and had a poor intersection at 1546 to 1556 ft. The core tray with the intersection was missing.

Holes F24 and F25 — horizontal holes from the lode position on 8 level. F24 was drilled 66 ft into the footwall to test the possibility of footwall lenses to the lode. The first 18 feet was in breccia and the remainder was uniformily cleaved black slates. F25 was drilled into the hanging wall and indicated a barren quartz vein breccia in the middle of a sandstone. There was some kinking associated with the sandstone.

F28 was drilled from just in the footwall to the 9 level lode and drilling at 45° to the west. The ore zone was intersected at 104 to 117 feet. For a substantial proportion of the drillhole (about 20%) the cleavage is parallel to the core suggesting a moderate dipping cleavage in the ore zone in contrast to the steeper dips near to the Henty Fault west. Bedding cleavage in F28 at 60 ft has bedding dipping W shallower than cleavage supporting west facing.

F53 was drilled from a hangingwall crosscut on 9 level and intersects the ore position to the south of the mineralisation. The ore position is logged as a cataclasite zone. This hole has a much greater proportion of massive quartz veins than the other holes that were checked. This may reflect a quartz halo around the ore position. It is noteworthy that the surface mapping (Rivers 1975) indicates major quartz veins to the north and south of the North Farrell/ New North Farrell zone. There is also a high proportion of sandstone in the hanging wall position. Grading in F53 at 509 feet suggests E facing.

Level Plans

The geological information from the old mines is very scanty. From the North Farrell Mine there is little more than the long section and some level plans showing the development. No geology is shown on these sections. There is a single major ore shoot (no. 3 Lode) which pitches steeply down a fault subparallel to the major western boundary fault. Several minor

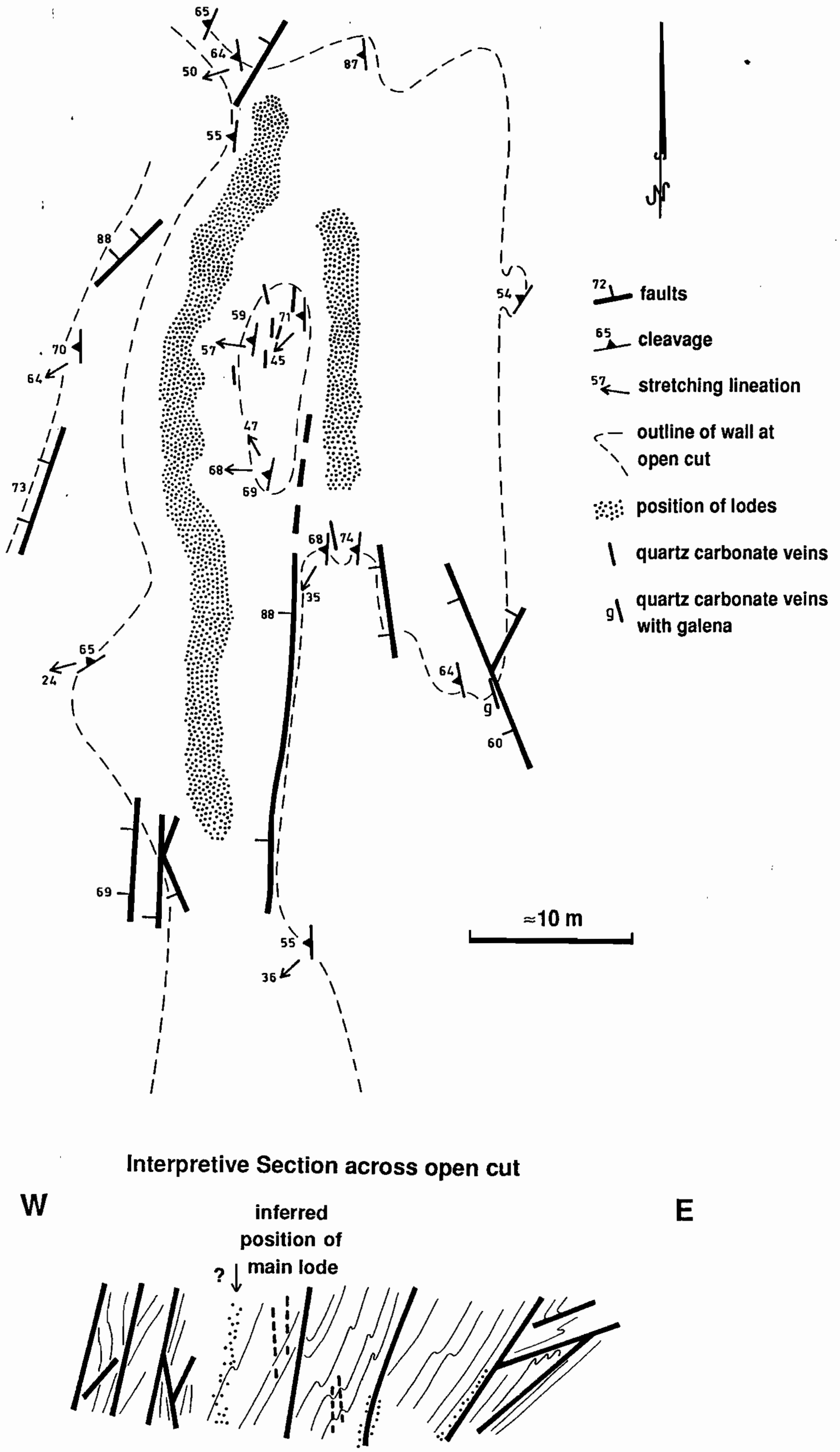


Fig. 2 Sketch of the structure in the North Farrell open cut. Position of mineralised veins (stipple) inferred from relicts of old shafts. A cross-section from the south end of the pit shows the dominant P shear orientation at the lode position and the R shear in the footwall.

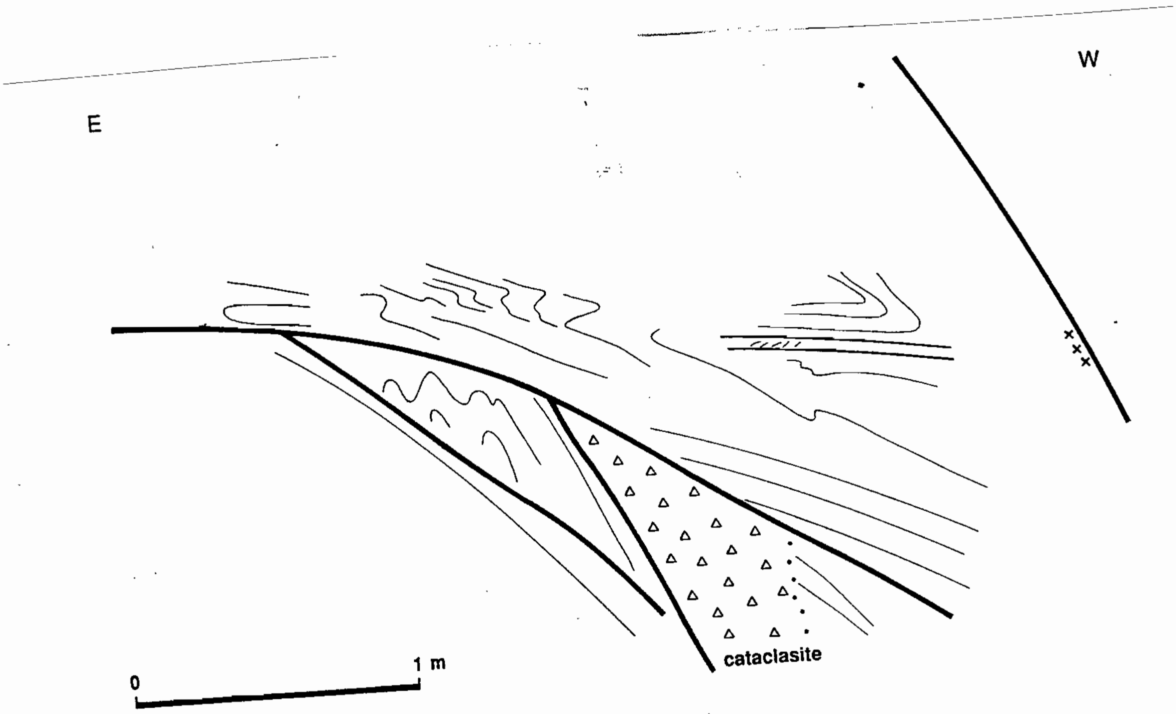


Fig. 3 Sketch of a cutting in North Farrell open cut showing the close association of kinking with a Riedel fault. Pb sulphate is common across the cutting especially below the main Riedel shear. Crosses on right hand fault indicate quartz-siderite vein with minor sphalerite.

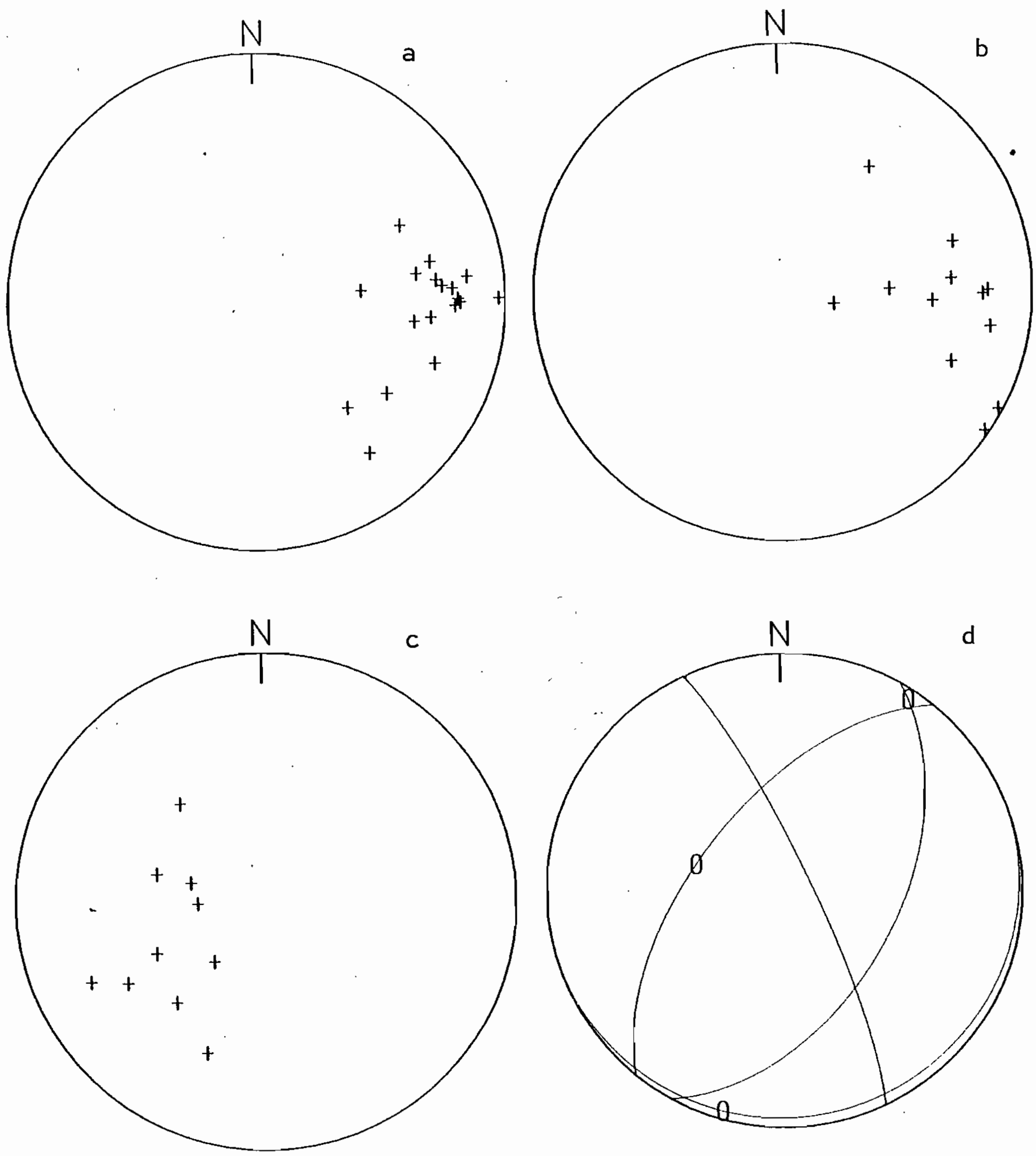


Fig. 4 Equal area stereographic projections of structural data from the North Farrell open cut. (a) Poles to cleavage, (b) poles to faults, (c) stretching lineation on cleavage planes, (d) kink band surfaces with hinges shown as circles.

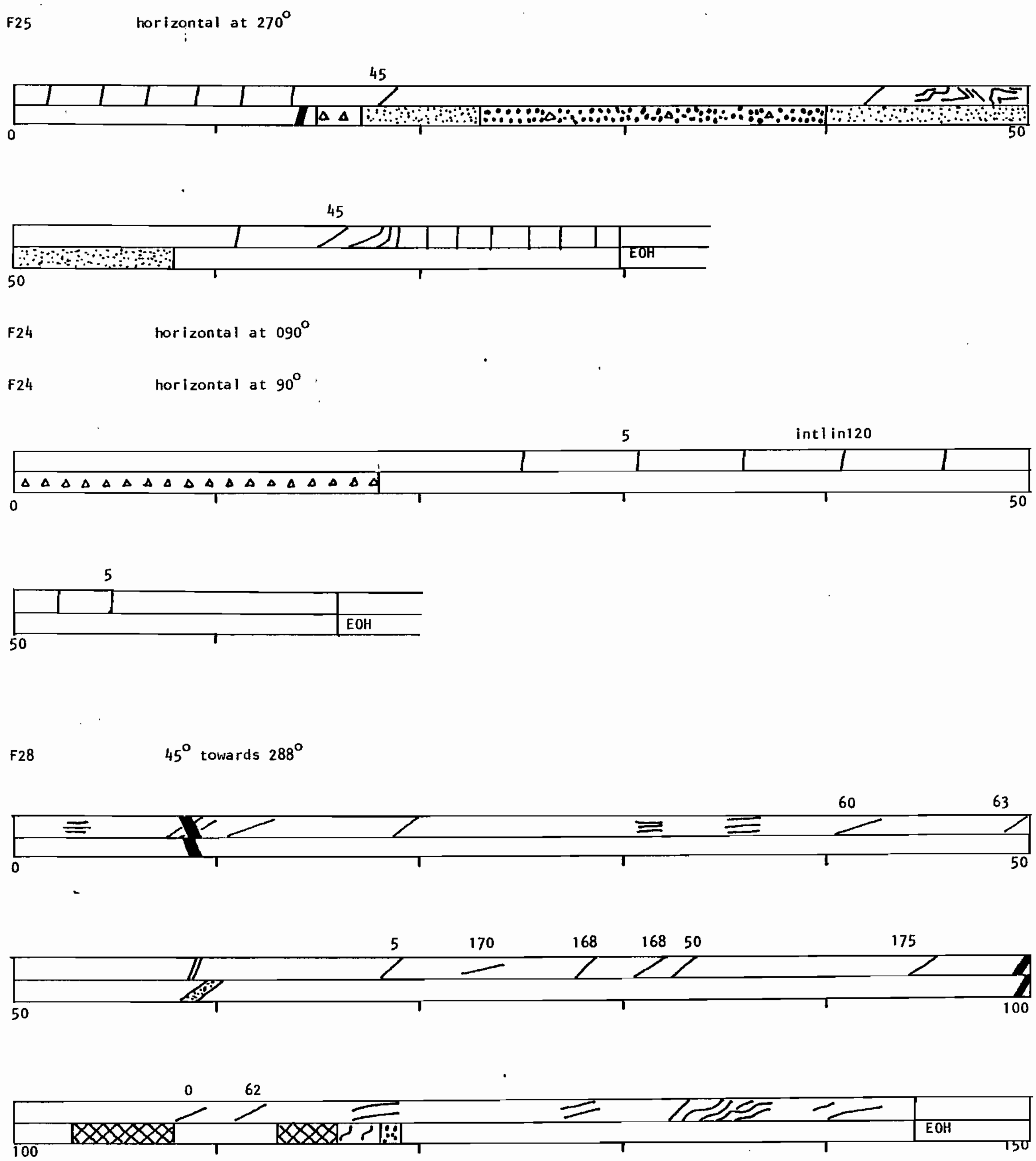
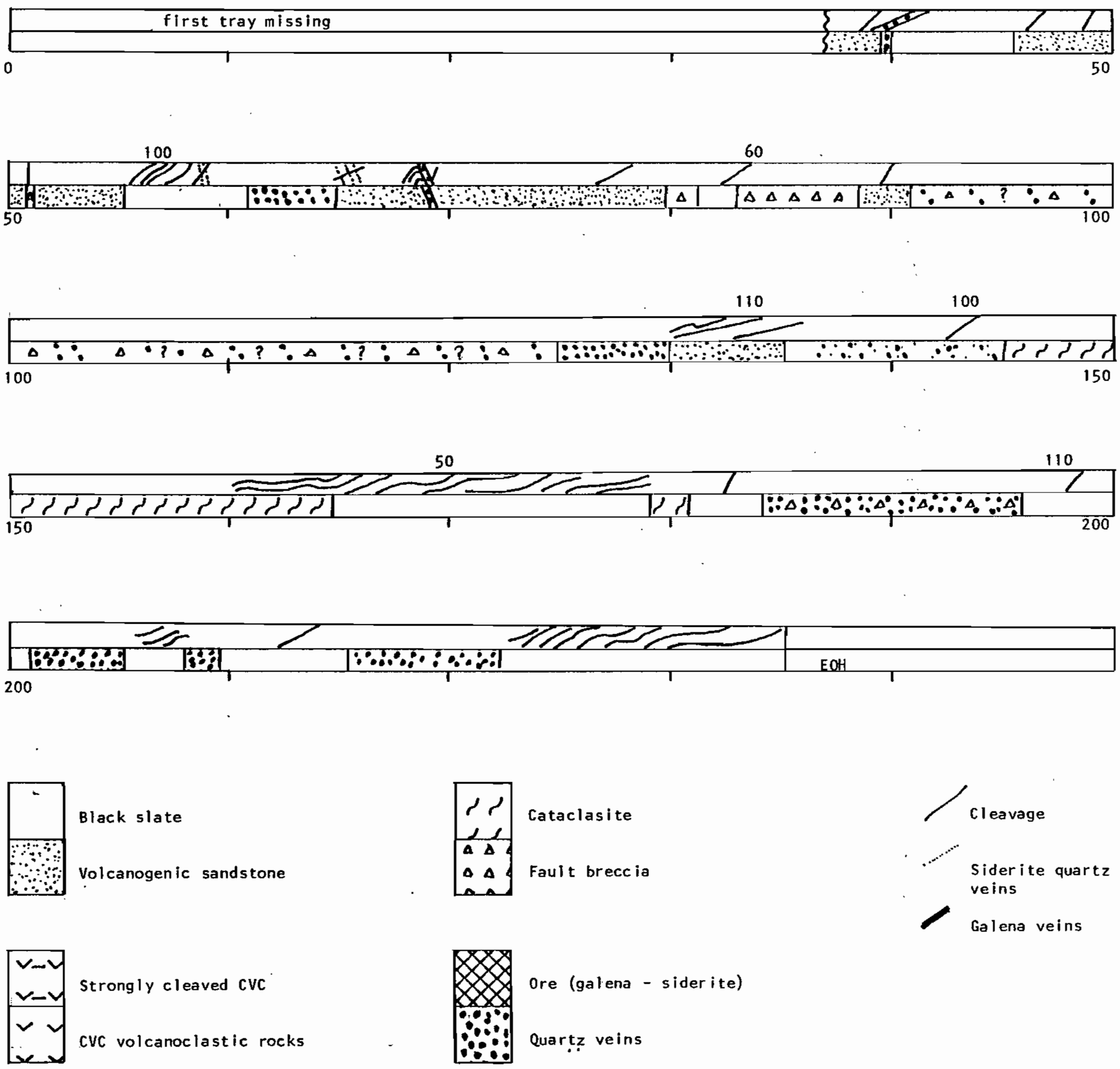


Fig. 5 Drill logs from some holes in New North Farrell showing the variation in cleavage core orientation and the position of major brecciation zones. The relationship of core to cleavage is shown with the long axis of intersection in the plane of the figure and cleavage dipping up-hole. Numbers below these figure indicate the angle clockwise of a lineation from the long axis of the core/cleavage intersection (0–180°). Measured looking down hole.


Start of Log
25 10 15 20
1250
60 170 10 50 100 30 175 8 145 55 40
1250
Henty
Fault (west)
1300
178 65 10 65 50 140 140 24 35 30 15 5 10
1300
1350
160 3 168 32 20 5 15 150 30
very broken core
1350
1400
0 0 0 10 100 55 55 52 70 48 60 45
1400
1450
55 48 40 90 82 b/c110 cren85 b/c100 55
1450
1500
130 160 120
tray missing
1500
1550
0 0 170
tray missing
EOH
1550

F53 horizontal at 122°



lodes occur on faults which intersect this fault. No. 1 and 2 lode have a much smaller depth and are less continuous. They strike at 20 to 30° different from the major No. 3 lode and have slightly shallower dips.

From the New North Farrell there are level plans which show the fault patterns in the development. These plans are unsigned They appear to be later than the mine development itself and are similar in style to the sections reported by Jensen (1959). The level plans show a complex intersecting fault pattern with ore grades very variable along individual lodes. The main lode appear to consistently be mineralised over the depth of mining but the other lodes are minor offshoots of this main stucture and are usually only mineralised for a short distance from the main lode.

Some examples of the level plans and a section from Jensen (1959) are shown on Fig. 6 (see back pocket). The outstanding feature is that the faults form a complex network in both plan and section. The major faults strike 000° magN and 020–030° magN. This style of anastomosing pattern has been predicted by Reches & Dietrich (1983) for cases where there is a three-dimensional strain. That is, there is an extensional component perpendicular to the fault movement. The faults are expected to have steep intersections. In such a system of faults a substantial amount of internal strain occurs in the blocks and there is potential for complex interconnecting dilatant sites. In section faults vary from 80° W to 45° W dips. The steeper faults are P shears while the shallower faults are R shears. Section 1200N shows the effect of the R shear (No. 4 lode) in producing dilatant sites in the overlying P and Y shears. The best ore block in the mine occurred in the upper levels, 1 and 2 Level and have been attributed to the intersection of the lodes with the sandstones. This is a classic situation for fault controlled vein systems as the fault usually refracts through the sandstone (shallowing in dip for a reverse fault) and continued displacement produces a dilatant site at the top of the sandstone. There is no evidence for such a flattening event in this or other sections produced by Jenson (1959). The 2 Level plan shows the very broad stope at 1260N, the widest reported on any of the sections, as occurring on one side of the sandstone. The sandstone dips 45° W. No Sandstone is indicated east of the ore suggesting this broad stope is related to intersecting faults at the base of the sandstone and that the sandstone itself has had little influence. This may be because of the strong sericite alteration in the sandstones in the Farrell Zone which has reduced the contrast between sandstone and siltstone (slate) rheology. Within the level plans there is an association of shallowly dipping faults (less than 55°) with areas that have been stoped. This suggests much of the dilation is controlled by Riedel shears.

The steeply pitching zones of ore in the north end of New North Farrell are related to intersection of faults striking 000° magN and 020° magN. The southern shoot has a shallow pitch to the south in the depth range of 2 Level to 7 Level (Fig. 7). This shallow pitch is consistent with dilation above a Riedel shear which would intersect the main lode at a shallow angle. From 100 to 500 N the sections of Jensen (1959) show that stoping was carried out at or just above the intersection of steep faults with the moderately dipping No. 6 Lode (Riedel orientation) confirming this origin for the shallow pitch.

Metal Zonation

There is little evidence for variation in metal content with depth in the zone. There are analyses from drilling at 6 Level and at and near 9 Level. The comparison of these analyses are shown in Fig. 8. These is a small increase in average Pb/Ag ratio towards the lower levels suggesting Ag has been enriched in the upper levels but this variation is not statistically significant at the 90% confidence level. This is consistent with mine production records listed by Collins et al (1981) which show no consistent change in Pb/Ag ratio from 1957 to 1973.

The distribution of Zn is very patchy and does not correlate with Pb. The only anomalous area reported in the assays was DDH15 on 6 level which is predominantly Zn mineralisation for 100 ft east of the main development.

REGIONAL SCALE

Tahari & Green (1990) have emphasize the zonal nature of the Farrell Field with the tin mineralisation over the top of the granite ridge from High Tor to Heemskirk. One solution for the granite geometry is shown in Fig 9. (after Leaman & Richardson 1989). A section over the New North Farrell Mine (Fig. 10) shows the distribution of the granite and indicates the Henty Fault dips subparallel to the contact and is in a perfect position to focus fluids coming from the granite and from the metamorphic aureole. This geometry apparently explains the very linear nature of the ore bodies in contrast to the more uniform distribution of the vein systems in the Zeehan and Dundas fields.

The exact location of the major bodies within the Henty Fault system is difficult to quantify. The locations are related to dilatant sites and focussing along the Henty Fault is likely to be related to more porous zones. The New North/North Farrell Mine is related to a zone of extensive kink folds. These are best developed in the region of the mines and for 1.5 km to the north. Such kinks represent a widening

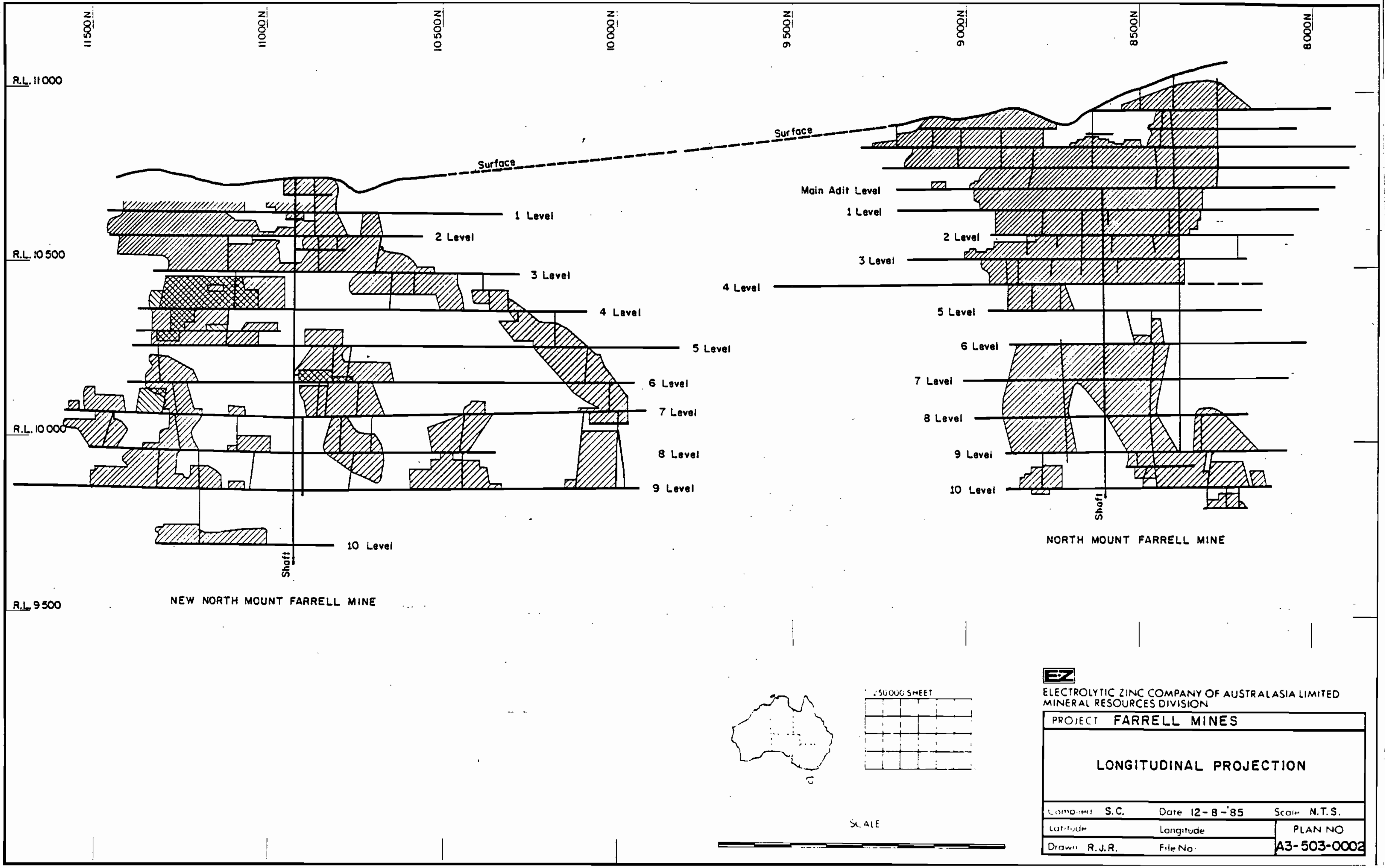


Fig. 7 Long section showing position of stopes in North Farrell and New North Farrell mines (from unpublished EZ mine plans). Note the shallow plunge of mineralisation on the south lode of New North Farrell from 2 to 7 Level.

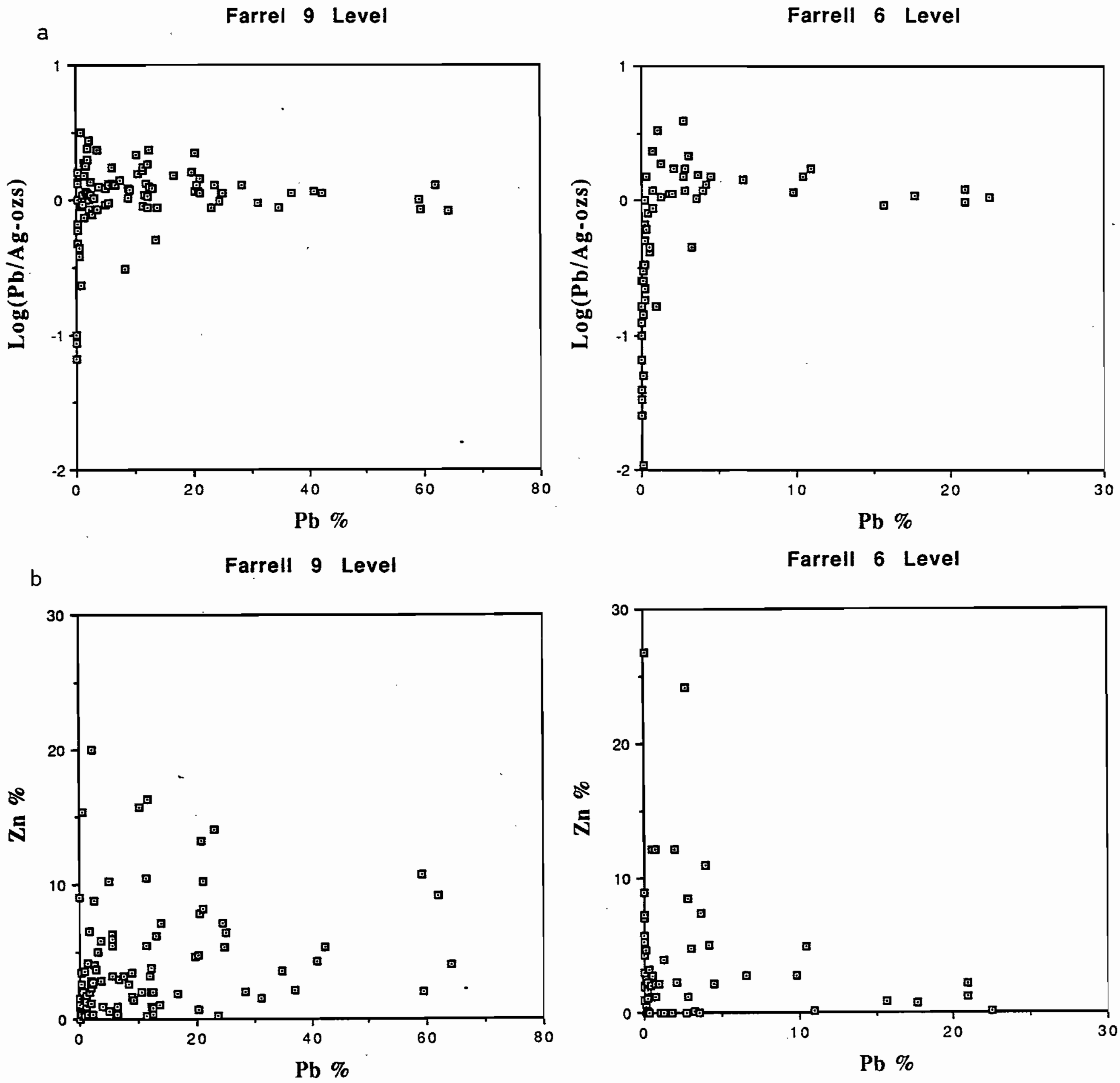
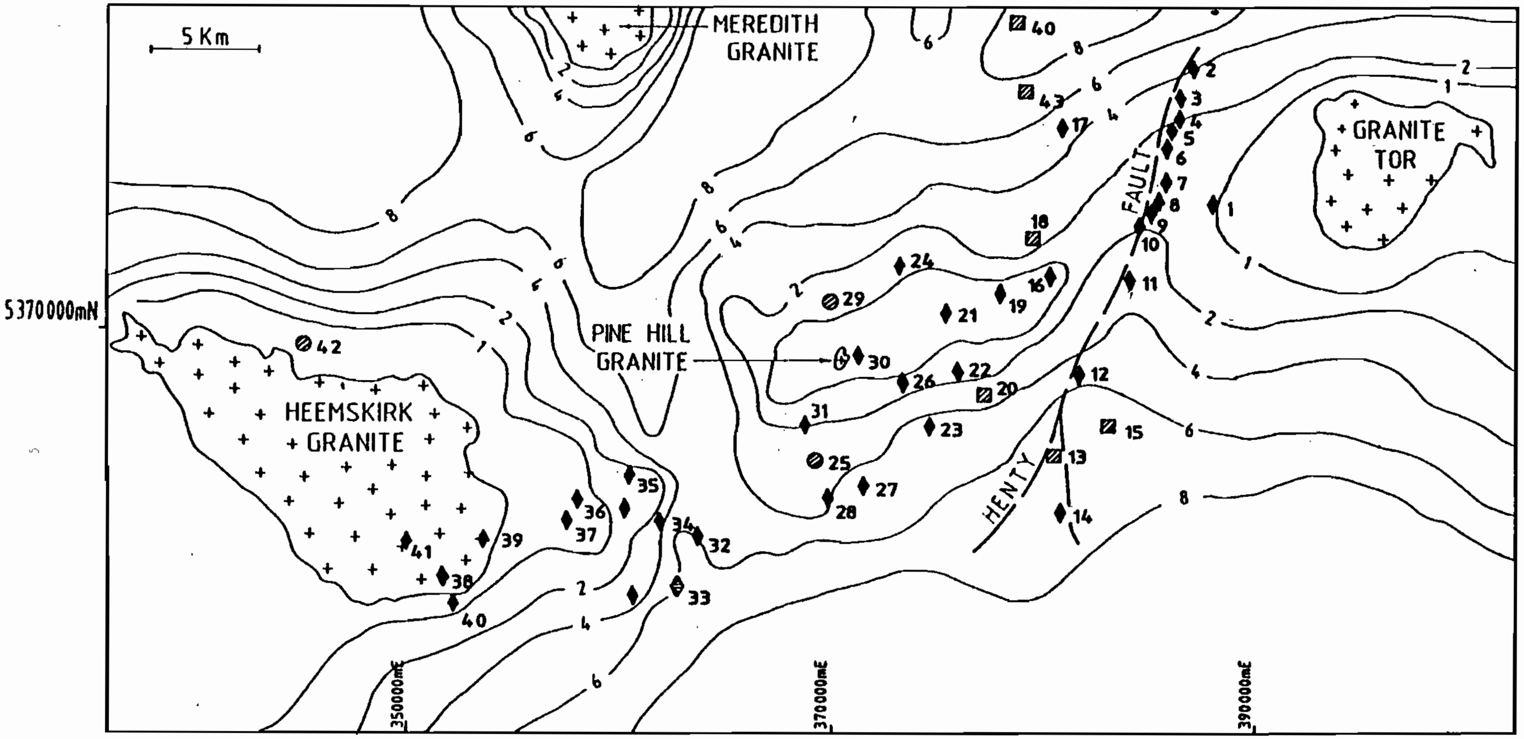


Fig. 8 Geochemical variation between 6 and 9 level based on core assays. (a) Pb/Ag ratio versus absolute Pb%, (b) Zn vs Pb content. Data from assay data on drill logs available for 6 Level and for 8–10 Level. The later assays were often more selective leading to higher absolute Pb contents but over very short intersections.



- ♦ Devonian vein
- ● Carbonate-replacement/skarn
- ▨ Volcanogenic massive sulphides
- ♦ Ordovician carbonate hosted

Fig. 9 Regional distribution of granites and the vein distribution reproduced from Taheri & Green (1990).

1 Osborne Copper (Cu, Pb, Ag)
2 Farrell Blocks (Pb, Cu)
3 Mackintosh Mine (Cu, Ag)
4 New North Mt Farrell (Pb, Ag, Zn)
5 North Mt Farrell (Pb, Ag)
6 Mt Farrell Mine (Pb, Ag, Zn)
7 Murchison River (Pb, Zn, Ag)
8 Murchison River Gold (Au, As, Pb, Zn)
9 Lakeside Prospect (As, Au, Sn, Pb, Zn)
10 Sterling Valley Tin (Sn, As, Zn)
11 Sterling Valley Mine (Pb, Ag)
12 Henty Fault Zone Copper (Cu)
13 Henty Fault Zone Gold (Zn, Pb, Au, Ag, Cu)
14 Tyndall Mine (Pb, Zn, Cu, Ag, As)
15 Red Hills (Zn, Pb, Ag, Au)
16 Great South Rosebery (Au, Cu, W)
17 Langdons Mine (Pb, Zn)
18 Rosebery (Zn, Pb, Cu, Ag, Au, Ba)
19 Chamberlain (Pb, Zn, Cu, Au)
20 Hercules (Zn, Pb, Cu, Ag, Au)
21 Olympic (Sn)
22 Hamilton Mine (Pb, Zn, Sn)
23 Moores Pimple (Ag, Cu)
24 Fenton (Sn)
25 Razorback (Sn)
26 Curtain Davis (Ag, Cu)
27 Comet (Pb, Zn, Ag)
28 Severn (Sn, Ag, Cu, Pb, Zn)
29 Renison Bell (Sn)
30 Pine Hill Tin (Sn)
31 Grand Prize (Sn, W)
32 Zeehan Bell (Pb, Ag)
33 Oceana (Pb, Ag)
34 Florence (Pb, Ag)
35 Zeehan Montana (Pb, Ag)
36 Sylvester (Pb, Zn, Ag)
37 Comstock (Pb, Zn, Ag)
38 Sweeney (Sn, Pb, Zn, Ag)
39 Globe (Pb, Zn, Sn, Ag)
40 Maynes (Sn)
41 Federation (Sn)
42 St Dizier (Sn)
43 Chester (Ba)
44 Pinnacles (Pb, Zn, Cu)

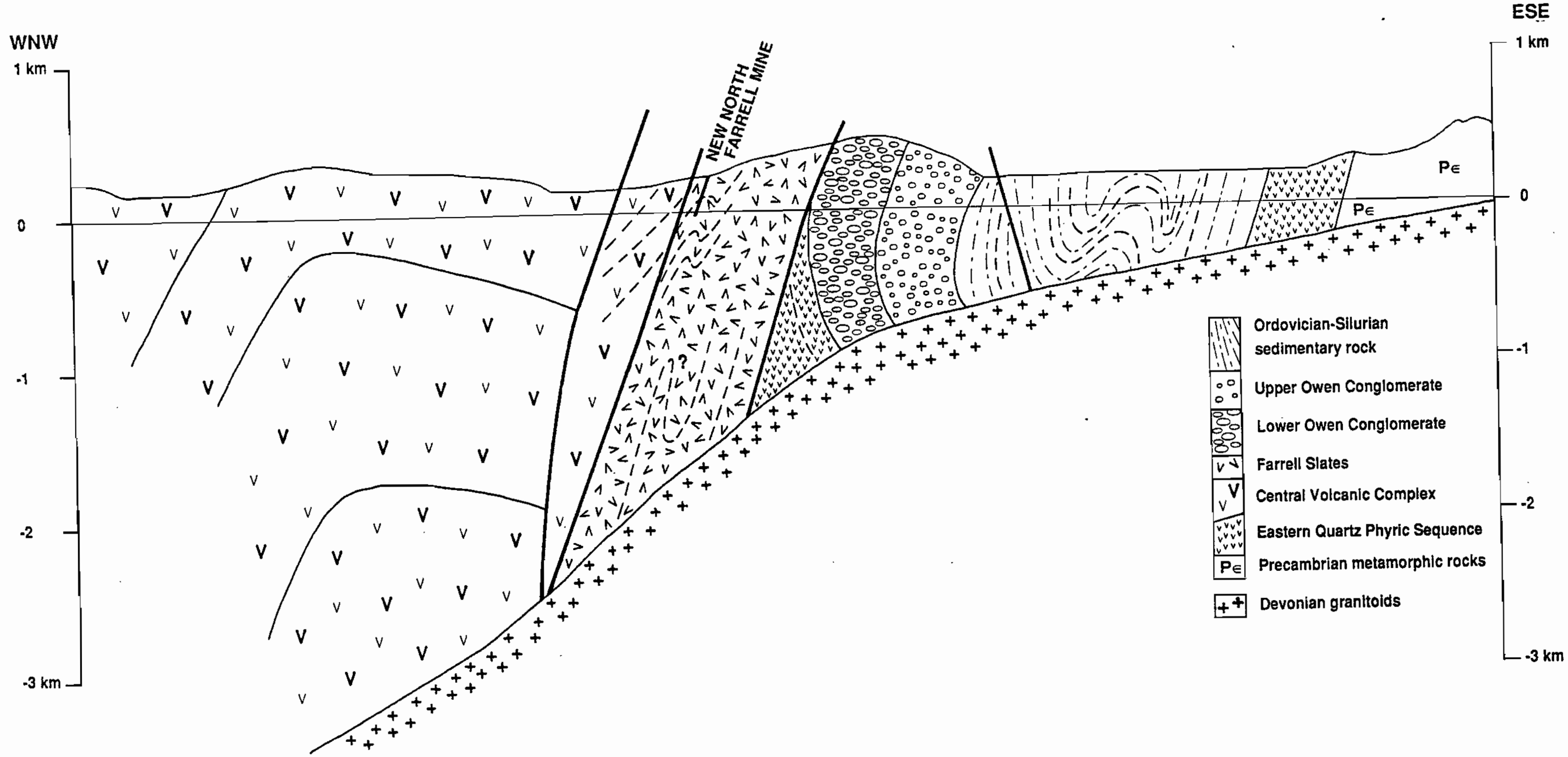


Fig. 10 Cross-section over New North Farrell Mine showing the relationship to the granite. Granite position from Archer (1989).

of the fault zone and are thus an indication of a tensional or dilatant zone within the overall fault system. There is a rapid narrowing of the Farrell Slates shown on recent maps 1 km to the north of the mine suggesting a transfer zone was operating which may define the northern limit of this dilatant zone. The kink folds continue past this boundary which weakens this argument.

It is worth noting that the major mineralised zone jumps from the western boundary to the eastern boundary of the Henty Fault Zone south of Tullah. This Murchison line of lode lies close to the boundary of west and east facing identified in the Murchison Gorge, and may be controlled by the position of the Cambrian normal fault. The Murchison Lode is interesting because of its anomalously high Zn/Pb ration for deposits of this type. The fact that it lies much closer to the granite than the Farrell Lodes is suggestive that a higher Zn content could be found down plunge from the Farrell deposits.

INTERPRETATION

North Farrell and New North Farrell are a classic Ag–Pb–Zn vein system which are widely associated with felsic magmatism. A good summary of the type is given as Model 22c base metal polymetallic veins in *USGS Bulletin* 1693: 125–129 (Cox & Singer 1986). A good description of this style is given for the Yukon territory in *Geol. Surv. Canada Bulletin* 111. In the Keno Hills– Galena Hill area the lodes are found in thick bedded quartzites and greenstones where the faults cut through them. "Principal lodes are localized in three sites: (1) at the junction of two or more vein faults, (2) at the junction of a vein fault and a subsidiary fracture, and (3) in quartzites or greenstones at or near the sites where vein faults pass upward from these rocks into schists or thin bedded quartzites." (Boyle, 1965). The zonation in this field has been the subject of recent regional isotopic studies (Lynch et al., 1990).

The structure of the Farrell Lodes is entirely consistent with this style of mineralisation. There is no direct evidence for a Cambrian mineralisation in the Farrell field. In terms of tonnage grade variation for this style of deposit listed by Cox & Singer (1986), North Farrell/New North Farrell lies on the 95 percentile for size, on the 70 percentile for Pb% but is only on the 30 percentile for silver concentration. The Zn and Cu concentration are not well constrained.

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THE STRUCTURE OF THE ROSEBERY DEPOSIT: MINOR ADDITIONS

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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) was used to identify the position and significance of reverse faults 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.

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 0–500 m 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 syn-depositional 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, 1992) the detail is subject to revision if footwall boundaries are relogged. The geochemical signature (Ti/Zr ratio) was used to distinguish footwall from host rocks.

The aim here is to report on the nature of fault boundaries interpreted using the geochemistry.

RESULTS

Section 140–190m N

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 ratio, 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 (Fig. 1). 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.

Holes 3618 and 3621 are subparallel on 190mN 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 160mN 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.

Drillhole 1500

The geochemistry from hole R1500 indicates the fault contact must lie between 861 and 881 ft. I was unable to identify any distinct lithological change in this area. There is a strong overprint of sericite pyrite alteration throughout with several zones with more chlorite.

Within this zone there are a number of faults.

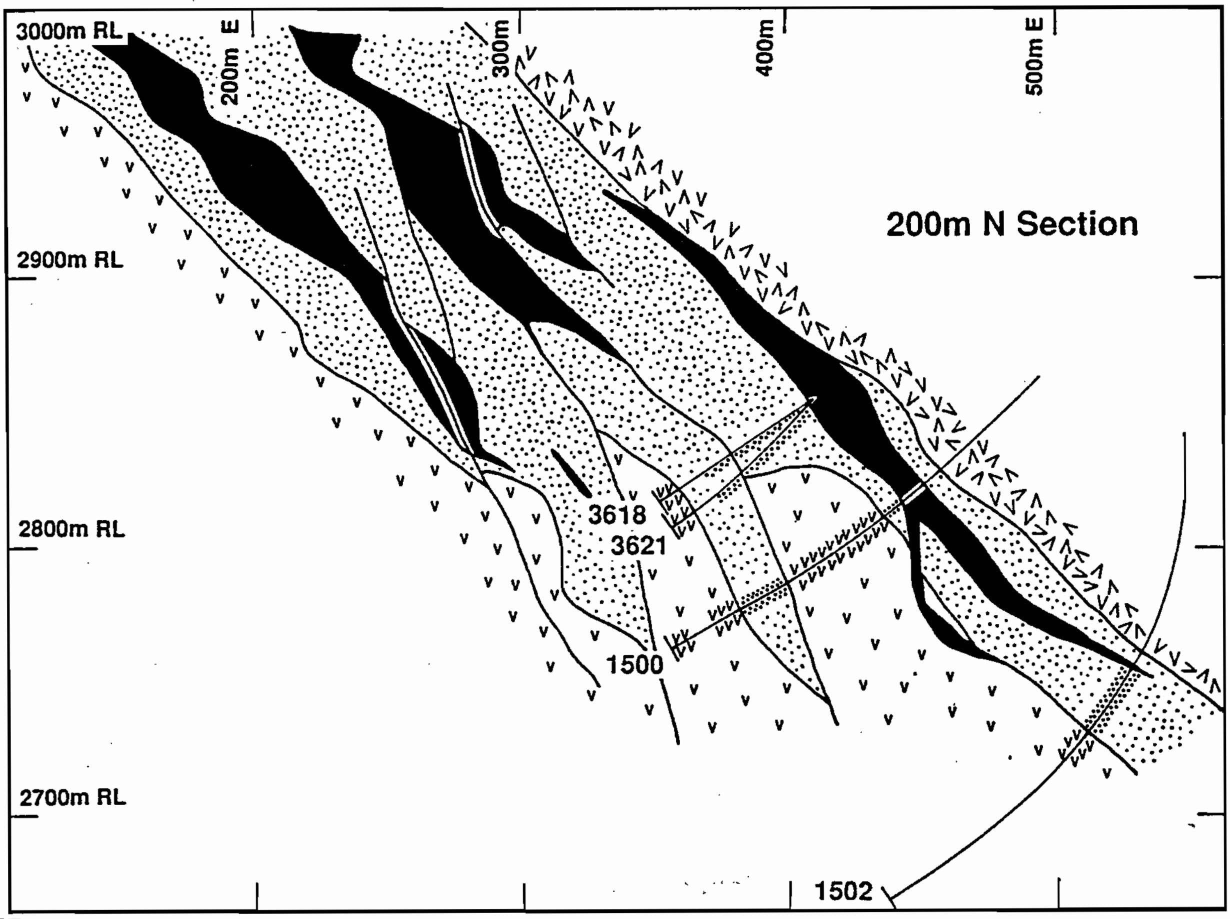

Fig. 1. Section at 200m N showing modification of the interpretation of footwall geometry arising from the geochemical study.

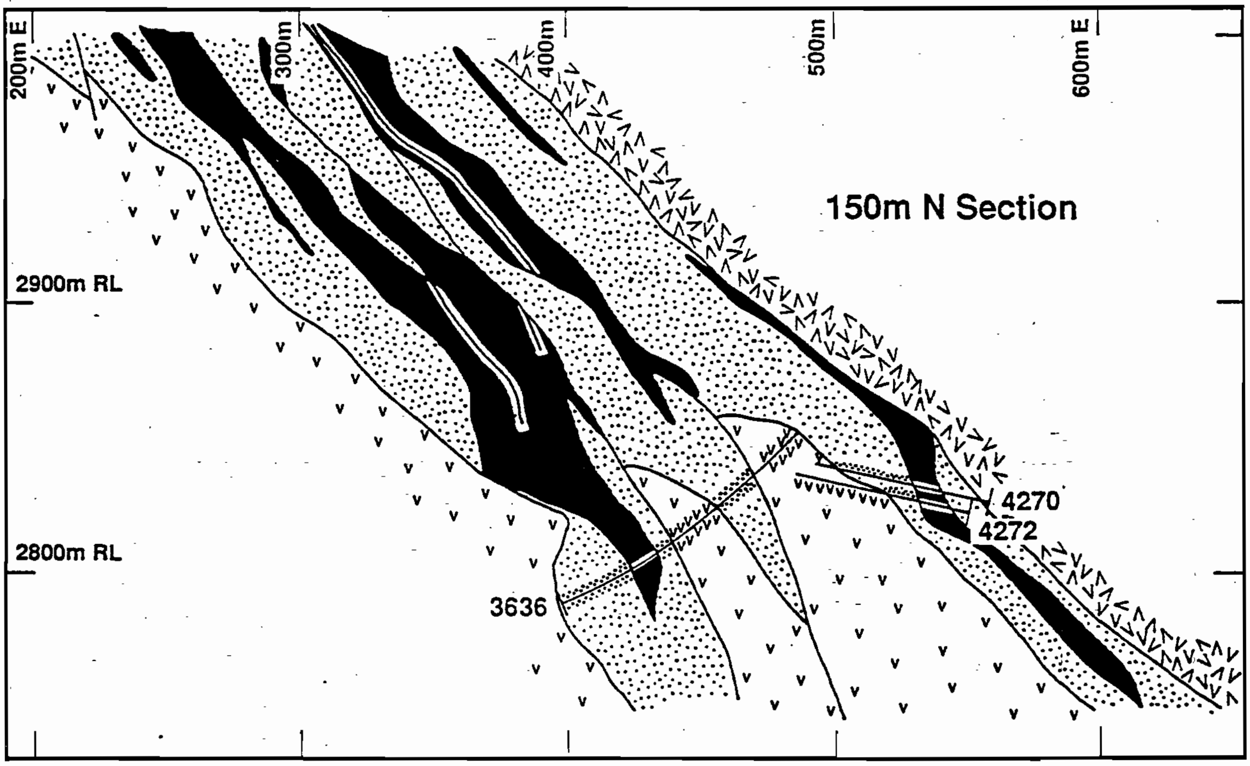

Fig. 2. Section at 150m N showing modification of the interpretation of footwall geometry arising from the geochemical study.

Chlorite seams with fault striations cutting at 45° to cleavage occur at 867.5, 868.5 and 879 ft. There is an intense cleavage zone with associated kink bands at 879 ft. Intense cleavage zones in quartz sericite and with an L/S fabric occur in four 1 cm bands between 866.5 and 868 ft. Chlorite quartz bands with minor cataclasite occur at 872 and 875.5 ft.

Considering these faults the most likely fault break occurs at 868 ft as the locus for greatest ductile strain.

Drillhole R3618

Based on the section (Fig. 6, in back pocket) a major fault must pass through hole 3618 at about 140 ft. There is a discrete break in lithology at 116 ft. Below 116 ft the core has sericite alteration while at grater depth the alteration is chloritic.

Within the relevant section there are faults in the core at

97.5 ft	2 cm quartz chlorite zone
106-107 ft	two late quartz veins (each 3 cm wide)
117-119 ft	four zones of intense cleavage development in chloritic alteration.
121ft	1 cm wide zone of intense cleavage
123 ft	small quartz vein and associated cleavage zone
125 ft	6 cm zone of intense cleavage
133 ft	very strong quartz chlorite zone with L/S fabric (4 cm wide)
147 ft	very strong quartz chlorite zone with L/S fabric (4 cm wide)
154.5	quartz chlorite zone of strong cleavage and brecciation (6 cm wide)

The cleavage development from 116-119 ft is consistent with a fault at 116 ft.

Drillhole R3621

Based on the section (Fig. 6, in back pocket) a major fault must pass through hole 3621 at about 140 ft. A major break in alteration occurs at 119 ft. Sericite pyrite alteration is dominant from 90 ft to 119 ft and chlorite alteration is dominant from 119 ft to more than 164 ft.

Within the relevant section potential faults occur at

110 ft	quartz chlorite vein at 45° to cleavage
115 ft	small quartz fibre vein
119 ft	10 cm quartz vein
122 ft	two small chloritic cleaved zones
123 ft	quartz vein at 45° to cleavage
124.5 ft	4 cm breccia with quartz and chlorite
134-138 ft	strong cleavage zone
142 ft	20 cm breccia sealed by quartz
150-151 ft	narrow cleaved zone
164.5 ft	10 cm quartz vein

From the lithological variation the boundary should be at 119 ft although the most significant looking fault structure is at 142 ft.

Drillhole 3636

From the geochemistry there are two fault repetitions of the footwall in the hole 3636. The hole drills out of footwall into host sequence between 44.5 ft and 85.5 ft. The whole section is quartz sericite pyrite altered. From 44.5 ft to 79 ft the core is massive coarse pale volcanoclastics and looks like normal footwall. From 79 ft to 84 ft the core is very strongly quartz pyrite altered and unrecognisable. From 84 ft to 84.5 ft the core is finer grained and less altered. With the supporting geochemistry this is recognised as host sequence. There is a number of quartz tourmaline veins from 73.5 ft to 79.5 ft. A close association between such veins and major faults has been widely recognised by previous workers. Faults here are visible at:

54 ft	3 mm chlorite seam with quartz vein
62 ft	pyritic stringer and breccia
75'-76 ft	two 5 cm quartz veins with associated tourmaline. Strong LS fabric in very siliceous alteration. 5 cm pyritic zone in which pyrite is deformed.
78 ft	1 cm quartz tourmaline vein
79.5 ft	three thin quartz tourmaline veins
81.5 ft	two 5 cm early quartz veins (pre- to syn-cleavage)
83.5	2 cm quartz vein, thin chlorite vein and strong cleavage
85 ft	5 mm quartz vein

Of these structures the strain features at 75 ft-76 ft mark the most obvious position to put a fault.

The second fault repetition lies between 194 ft (footwall) and 222.5 ft (host). No footwall/host boundary was recognised in terms of the pre-alteration lithology. The whole section was composed of medium to coarse volcanoclastic sandstone. Pumice and coarser clasts are visible at 200 to 205 ft and possible are more like footwall textures. The faults in this section are at:

214 ft	broken core with strong cleavage and small tourmaline vein
215.4 ft	small fault zone with kink band and narrow quartz vein
219.5–221 ft	5 cm wavelength tight fold in "augen schist" plus intense cleavage zone, two quartz veins and strong silica replacement.
222 ft	15 cm of quartz veins and broken core

The major zone at 219.5 ft to 221 ft is the most likely position for the fault break.

CONCLUSIONS

As observed underground major reverse faults in the mine do not always have a significant structure visible. Where faults crosscut the cleavage they form major quartz carbonate veins and strong cleavage drag, but where the fault lies parallel to the cleavage the faults produce a narrow zone of a few centimetres with a stronger than normal cleavage. These types of faults are very common in the mine and make the recognition of major fault structures difficult. While no detailed study was made of a representative sample of core, there is no evidence that the number of fault structures recorded in the holes listed above is unusually high for central Rosebery core. Recognition of major faults depends on finding evidence of markers which are offset by the fault surface.

SUMMARY

The position and significance of reverse faults has been confirmed in the central part of the mine partly by using Ti/Zr as a marker within less intense alteration. Even with the direct supporting evidence of the geochemistry, I was unable to recognise footwall from hanging wall in many cases through the intense alteration in the central part of the mine. In those sections where an offset has been demonstrated from the lithology it is possible to find fault like structures in the correct position for the fault surface. Unfortunately there are so many of these structures that this not a substantial test of the structural model. In part the association of tourmaline veins with larger faults in the mine was supported by this work.

ACKNOWLEDGEMENTS

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CAMBRIAN STRUCTURE IN WESTERN TASMANIA

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ABSTRACT

The detailed examination of structure on the west coast of Tasmania has concentrated on recognising the style of Devonian deformation and then trying to recognise complexities which cannot be explained by this event. These complexities are then assumed to be due to Cambrian events. No direct recognition of Cambrian structure has proved possible in this process. All cleavage development and fault plane structures could be explained by Devonian events. However the difference in stratigraphy below the Owen Conglomerate when combined with a detail knowledge of Devonian structure has allowed an interpretation of Cambrian structure to be made.

The Cambrian structure in the Mt Read Volcanics requires three tectonic events: a middle Middle Cambrian extensional phase related to the Mt Read volcanism and related complex extensional fault geometry which is synchronous with VHMS mineralisation. This early extension is overprinted by two phases of Delamerian folding. The position of Cambrian transfer faults correlates with major mineralisation.

INTRODUCTION

An aim of the project was to identify the Cambrian fault structure in western Tasmania with a view to identifying the structures which have localised the mineral deposits along the belt. This has proved more difficult than expected because of the complexity of Cambrian tectonics. It was no sufficient to identify a structure as Cambrian in age but rather to see the Cambrian as five separate structural events. The extensional faulting which has been clearly identified near VHMS deposits is a very short lived event which is restricted to part of the Middle Cambrian. The sections below review the evidence which supports the existence of three separate types of Cambrian tectonism from the middle and late Cambrian. While all of these events can be demonstrated locally the extension of each to the whole belt is model driven so some of the structures are poorly constrained. Most emphasis has been placed on the middle Cambrian extension and the two Cambrian fold generations have received less detailed attention.

RECOGNITION OF CAMBRIAN EXTENSIONAL STRUCTURES

The only unequivocal evidence of Cambrian extension recognised are syn-volcanic growth faults. The best examples of growth faults are the Mt Charter Fault and minor faults along the eastern margin of the Dundas Trough (e.g. 030900, Anio Creek and 060937, Marsden Creek on Mt Read Project Map 7; 880776, Sprent River on Mt Read Project Map 12). The detailed study at Rosebery also defined growth faults on a much smaller scale (Berry, 1992a). The remainder of the volcanic belt has a large number of facies variations which indicate fault control on deposition but it is now impossible to prove that these were normal faults or that the normal fault movement occured during middle Cambrian CVC/EQPS deposition. The widespread association of submarine volcanism emplaced on continental crust, and hydrothermal alteration suggests that strong extension has occurred. In a compressional environment the volcanics should be largely subaerial. The VHMS style mineralisation requires a combination of high heat flow, high porosity and a substantial water depth. This style of mineralisation has a strong genetic link to extensional tectonism. Thus in this report we have assumed the other growth faults associated with middle Cambrian volcanism is due to extension. This event was probably very short lived and a compressional environment returned by the middle Late Cambrian as indicated by folding described below. The geometry of the extensional event has been inferred from the growth fault patterns in Middle Cambrian rocks.

The best direct evidence for the stress system during mineralisation is the controls on the hydrothermal mineralisation itself. The geometry of the feeder system under Hellyer has been the focus of a great deal of study. Gemmell & Large (1992) report the feeder system as striking 040° (= extension to 130°). A similar elongation of the Que River deposit could be interpreted as controlled by a feeder system trending 030° (extension 120°). At Hercules the ore occupies the feeder veins themselves and the orientation of the veins implies extension towards 080°. The work at Rosebery suggests extension towards 070° ± 020°. At the Blow, near My Lyell unfolding of quartz pyrite feeders suggests extension towards 060°. At Jukes Proprietary Prospect the vein geometries suggest extension to 070 ± 20° (Doyle 1990).

The Henty Dyke swarm has a geochemistry typical of extensional environments (Crawford et al 1992). It is the correct age to be associated with the mineralising event. Thus the orientation of the dyke swarm may be a good indication of the stress field. Unfortunately the exposures of the dykes are not usually good enough to define their crosscutting relationships. Many appear to be sills rather than dykes. Thus unfolding them to Cambrian orientations is not possible. One exception is dykes described from Chester (Collins et al. 1981) which support extension towards 130°. Many of the dykes east of Rosebery recognised in the regional section are east west. The definition of the stress system during the Henty dyke swarm may be useful but is not possible on the present information.

Given the stress system from the mineralisation it is possible to interpret the Cambrian growth fault geometry in terms of normal faults and transfer faults. The faults here have been identified from a number of criteria. Mostly they have bee defined by changes beneath the Owen Conglomerate reflecting the geometry at the Middle Late Cambrian. As discussed below this adds some ambiguity since there was also a compressional event during this period but it remains the only way to generate a regional interpretation. Obvious compressional structures such as the Miners Ridge–Modder River Thrust have been shown separately.

NORMAL FAULTS

The western boundary of the Dundas Group (Fig. 1) is interpreted as a growth fault especially in the north where it abuts Precambrian basement, is sharply truncated against a fault and has Precambrian sourced clasts (Selley, 1992; Rattenbury, 1990). There are several offsets in this boundary (west of Rosebery – Berry, this volume; south of Zeehan – Berry, 1992c) which are interpreted as transfer faults (TF) (see below).

While the Dundas Group continues across the south end of the Husskisson syncline (TF 4), the CVC truncates somewhere just west of Rosebery. Thus it is assumed that the northern fault sector separates into two distinct segments at the Rosebery transfer system (4). The Precambrian block in the Dundas field has a structural position similar to the Precambrian along John Lynch Creek and it is assumed here that the eastern segment of the normal fault continues to the eastern side of this block. The uplift at this point may be due to a footwall short cut thrust during basin inversion. A second transfer fault (TF 5) is suggested as a southern boundary for the Precambrian at Dundas. South of TF 5 the western margin of the Dundas Group moves far to the west and may lie along a NNW striking surface through Strahan (covered by Tertiary). South of Macquarie Harbour the western boundary of the Dundas Group is the Modder River Thrust and any normal fault margin to the basin is missing.

The eastern margin of the Dundas Trough is limited by the erosional unconformity under the Owen Conglomerate with the Sticht Range Formation dipping west at 40° along most of the margin in the Late Cambrian. Within the trough a normal fault can be detected from Mt Farrell to Red Hills (Fig. 1) as the eastern margin of Dundas Group sedimentation. East of this fault the Owen Conglomerate sits directly on the CVC or EQPS and no Dundas or Tyndall Group sediments are preserved. This fault is interpreted as a west-dipping normal fault in the Middle Cambrian. North of TF 2 (Fig. 1) this structure is apparently replaced by the east dipping Mt Charter Fault. South of TF 6 (Tyndall Range) the fault has not been detected until a similar structure occurs south of TF 12. The west margin of the Owen Conglomerate on Mt Osmund and especially the Copper Creek Fault near TF 13, has a Dundas correlate faulted over a CVC correlate. This suggests the same relationship of an inverted normal fault to that recognised at Tullah although the level of detail available is much less. A problem in this section of the belt is that the facies relationships between sedimentary and volcanic packages is not known.

The distinctive structure of the Henty Fault at Tullah is probably due to the fact that at this position

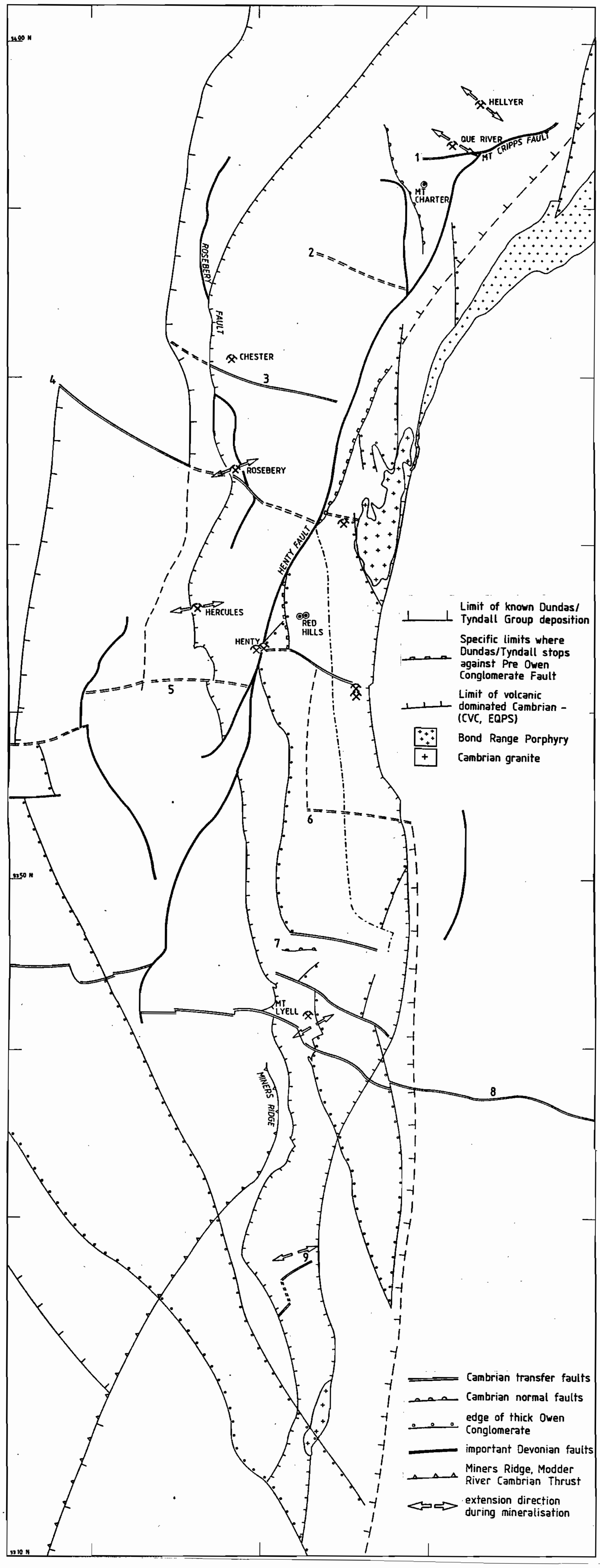

Figure 1. Cambrian fault patterns and Owen Conglomerate deposition on the Mt Read 1:100,000 summary map (Corbett & McNeill 1988).

it partly reactivates this Cambrian normal fault whereas to the south and north they are separate structures. North of TF 2 the Henty Fault has no evidence for thrusting younger units over older although this evidence may be hidden under Gordon and Eldon Groups.

The Great Lyell Fault has been defined as the margin of the Owen Conglomerate at Mt Lyell and nearby. This structure has long been tied to models of mineralisation at Mt Lyell but from the analyses reported previously (Berry, 1991, 1992) and below this structure appears to be largely related to Late Cambrian and Devonian tectonism and we have not been able to demonstrate any control on middle Cambrian sedimentation.

TRANSFER FAULTS

1. Mt Cripps Fault

Evidence: Massive change in thickness of Dundas/ Tyndall Group (under Owen Conglomerate) indicates this fault was active in Cambrian). Also a major transfer structure in the Devonian which largely truncates the Henty Fault.
Mineralisation: the extension of the Mt Cripps Fault to the west passes very close to the Que River deposit. No apparent correlation with Hellyer.

2. Tullabardine Creek

Evidence: Largely based on E–W lineation in magnetics, northern termination of intrusive quartz feldspar porphyry and general spacing of transfer faults (see below).
Mineralisation: Western termination is close to Boco pyrite zone. The eastern termination is close to Cu veins of Pearce's Copper Reward which has generally been assumed to be Devonian even though it is at the distal end of the Farrell field. Very little evidence of alteration along this structure within the CVC.

3. Lake Rosebery-Chester

Evidence: Mapping of the CVC on either side of Lake Rosebery (Corbett & McNeill, 1986) demonstrates major changes in stratigraphy not relate to any apparent Devonian structure. In addition the trend of Devonian folding changes at this boundary.
Mineralisation: The Chester mine lies on the western end of this structure. Allowing for 1.1 km of sinistral offset on the Henty Fault, the North Farrell mines lie at the eastern end of this fault but these are Devonian deposits.

4. Rosebery/Pieman River Transfer

Evidence: Truncation of Dundas group in the Pieman River against Crimson Creek Formation and onlapping Gordon Limestone. No direct evidence of extension towards Rosebery under Black P.A. but an active Devonian transfer fault occurs just south of Rosebery and runs just north of Dalmeny Prospect in the correct position assuming there is little horizontal displacement on the Rosebery. Fault. Across the Henty Fault there is no evidence for this structure except the two barite rich prospects north of Mt Murchison.
Mineralisation: the extension of this structure passes just south of Rosebery Mine. It passes just north of Rosebery Lodes and Dalmeny.

5. Zeehan–Dundas–Henty–Selina

Evidence: The Dundas Group boundary shifts west just south of Zeehan. The boundary is largely covered here and the geometry is poorly constrained. The structure is probably close to the northern boundary of thick Denison Group (Mt Zeehan Conglomerate) indicating continued activity into the Late Cambrian. The southern margin of the Precambrian block at Dundas lines up with an offset in the CVC boundary which Dugdale (1992) has shown is one of a set of growth faults on this contact. This fault position occurs at the southern termination of the Henty dyke swarm west of the Henty Fault. Just east of Henty the eastern margin of Dundas/Tyndall Group (under Owen Conglomerate) steps east requiring a Cambrian fault. This position falls directly between Henty and the Selina Prospect suggesting an association with the middle Cambrian.
Mineralisation: Minor prospects in the Dundas field are largely Devonian. Cambrian mineralisation is limited to the eastern sector (Henty and Selina) and the White Spur pyrite zone. The Oceana mine (Ordovician ?Mississippi Valley style deposit) lies very close to this structure suggesting it was an active focus for Ordovician fluids as well.

6. Tyndall Range

Evidence: North of this fault the Owen Conglomerate sits directly on the older volcanic dominated units but to the south Tyndall Group is widely found under the Owen Conglomerate suggesting a Cambrian fault. The position is only exposed at the eastern limit where Corbett (1992) identifies the contact of EQPS with Tyndall Group. The remainder of the fault is hidden under Owen Conglomerate. Possible extension to the east towards Eldon Peak.
Mineralisation: Disseminated Cu-pyrite near Lake Dora. The Basin Lake pyrite zone is correctly positioned to be on a western extension of this structure.

7. Comstock Valley

Evidence: The Comstock Valley has a long history of fault movement. The small fault at 830458 has a major effect on Tyndall Group deposition (M. White pers. comm.). The position and nature of the Great Lyell Fault change within the Linda Zone implying Late Cambrian fault movements. No direct evidence for offsets of Cambrian Normal Faults
Mineralisation: Northern termination of the Mt Lyell mineral field.

8. Firewood Siding Fault–Owen Thrust–Linda Zone.

Evidence: This major east west structure dominates the My Lyell area. There is no direct evidence that it controlled the deposition of CVC rocks but it does form the southern limit of the Mt Lyell alteration zone. It also controls the geometry of all Devonian deformation events indicating a major crustal weakness which predates the Devonian.
Mineralisation: Southern boundary of the Mt Lyell mineral field. Alteration zone from the Glen Lyell to the King River.

9. Pyramid Peak–South Jukes

Evidence: The overall pattern (see below) suggests a constant separation between transfer faults. This pattern suggests one is expected near Mt Jukes. An ENE–WSW contact between lavas and volcanoclastics is shown west of Pyramid Peak on the Lyell sheet (Calver et al., 1987). We have no direct knowledge of the status of this contact but it is in roughly the correct position.
Mineralisation: Southern margin of the Jukes mineralisation and very close to the Lake Jukes prospect.

10. Gordon River

Evidence: A major change in Devonian structure occurs at 53010N near the Gordon River (Fig. 2) where Devonian folds change there direction and wave-length and the Hardwood river/Olga River/Smith River thrust terminates. This transfer fault also correlates with a shift in locus of Owen Conglomerate deposition to the west. We cannot demonstrate a Cambrian history for this structure but is does seem probable based on analogy with the Linda Zone.
Mineralisation: a deposit possibly associated with this structure is an Ordovician disseminated Pb prospect near Kelly basin (deposit 306, Green et al., 1988). The critical section where this structure crosses the CVC is not exposed.

11. Innes Peak to Sprent River, D'Aguilar Range

Evidence: Change in thickness of Sticht Range Formation at base of Cambrian section.
Mineralisation: None reported.

12. Moores Valley

Evidence: Ten kilometres north of the Wart Hill Zone, the Tertiary basin is bounded by an ESE striking fault which is anomalous for Tertiary fault patterns and suggests there was an old fault here. The Tertiary has masked the features which might have been used to determine if this structure was active in the Middle Cambrian.
Mineralisation: None reported.

13. Wart Hill

Evidence: Area of strong east-west overprint similar in style to the Linda Zone. The stratigraphy of the base of the Owen Conglomerate changes across this zone and east-west faults in underlying Cambrian stop at unconformity (Callaghan, 1989). Extension to east based on thickness changes of units shown on Mt Read project map 10 (Elliott Bay), including the Sticht Range Formation.
Mineralisation: Voyager 19 and the Wart Hill alteration zone lies directly on this structure.

This is not an exhaustive list of transfer faults which occurred during Middle Cambrian extension. It reflects those structures which unambiguously offset lithological boundaries that can still be recognised. It is also strongly effected by the detail of investigation that has been made in an area. For the best known areas from Mt Lyell to Hellyer there are transfer faults every 10 km Thus there should be similar structures south of Mt Lyell every 10 km but only two have been recognised in 70 km. Two others (10, 12) have been inferred from later structures in this area. Transfer faults 2 and 9 are based largely on the expectation of a 10 km spacing, arising out of the pattern north of Mt Lyell.

The concept of Cambrian transfer faults provides a very useful way to explain the variation in structure along the Dundas Trough. The structures recognised represent large scale transfer faults and in modern extensional terrains there are a large number of smaller scale structures which may also control mineralising fluids. Transfer faults do not cause mineralisation but may contribute to enhanced permeability to provide a better focus for fluids. In the Mt Read Volcanics many deposits have a spatial association with transfer faults. Examples such as Rosebery, Mt Lyell and Que River have a good correlation with well constrained transfers. Rosebery is a good example of a strati-

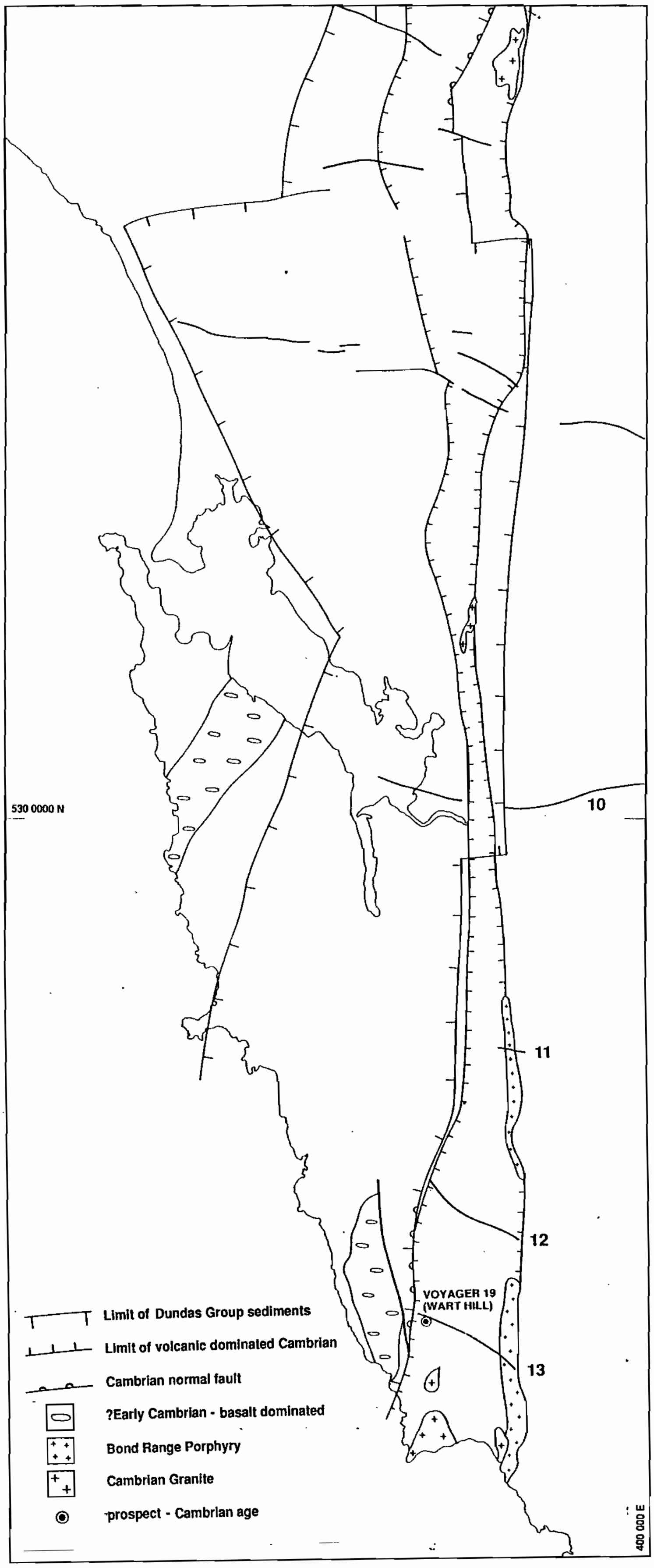

Figure 2. Cambrian fault patterns from the Dundas Trough on Queenstown and Port Davey 1:250,000 geology maps.

graphically controlled line of deposits trending NNW within which the largest deposit occurs where the transfer fault crosses this stratigraphy. In contrast no large scale transfer fault was recognised near Hellyer. The case of the Henty deposit is equivocal as the transfer was recognised 3 km to the east and the strike is so poorly constrained that the structure need not pass near the Henty prospect. It was drawn from Henty to Selina assuming there is a spatial association with mineralisation.

Where transfer faults cut through the CVC and especially at the top of the CVC there is commonly some mineralisation or at least a pyritic alteration zone.

LATE MIDDLE CAMBRIAN TO MIDDLE LATE CAMBRIAN

Dundas Trough

The nature of post-extensional Delamerian deformation can be deduced from the nature of the unconformities beneath the Owen Conglomerate. Along the Dundas Trough these are dominated by Owen Conglomerate cutting off a west dipping sequence at the base of the Cambrian including the Sticht Range Formation. This angular relationship is clear from the D'Aguilar Range through Marble Bluff and probably up to Lake Mackintosh. The Owen in this situation occupies a synclinal position on Cambrian sediments. The eastern limb of the syncline is eroded and the Precambrian basement in the anticlinal position is the major source for sediment. There is also a western anticline within the Dundas Trough. At Mt Lyell the western limb dips east at about 40° (Berry, 1992b) and is also a source of sediment so that there is a volcanic source for clasts in the west throughout the deposition of the Owen Conglomerate. A similar east dipping limb is recognisable from the unconformity at Mt Jukes where Tyndall dips 40°E. This folding finishes in the late Cambrian and the uppermost Owen Conglomerate sheet is post-folding and continuous across the area. A very similar structure has been drawn for the section at Mt Tor (Pemberton & Vicary, 1988) and this structure is a direct analogy for the Great Lyell Fault at Mt Lyell. The areas of thin Owen Conglomerate are thus interpreted as as the anticlinal positions for these Delamerian folds. The wavelength of the open NNW trending folds is 10 to 15 km. The pattern of Owen deposition in the Dundas Trough is shown on Fig. 1. The highs trend NNW and are not exactly parallel to the Cambrian extensional faults. The previous interpretations have assumed the structures defining the Owen deposition were exactly the same structures as the Cambrian structures which control mineralisation. There is little evidence that this is correct. The normal faults should be inverted during this event but if this occurred it was a very minor inversion compare to the much stronger Devonian inversion.

Table 1 Structural relationship of Middle Cambrian mineralisation

VHMS		
	Hellyer	Small scale normal fault
		Not on regional scale structures
	Que River	?normal fault control near transfer fault
	Rosebery	Extension of transfer fault
		Normal faults have second order control on mineralisation
		Top of CVC
	Hercules	Extensional veins
		Near top of CVC
Disseminated		
	Mt Lyell	Cambrian transfer fault
		Top of CVC
	Henty	Cambrian transfer fault
	Selina	Cambrian transfer fault
	Chester	Cambrian transfer fault
Granite related		
	Jukes Darwin vein systems	
		?near Cambrian transfer fault
	Anthony Tunnel Barite	
	Beulah granite	

The NNW trend is reflected in the complex pattern of Owen Conglomerate deposition in the Murchison Gorge and north end of Mt Murchison. Here the NNW trend is visible on a range of scales (Berry this volume).

In the Black Bluff area the NNW trend of basement highs can also be recognised despite the overall E-W structural grain. The Erriba Ridge (Keele this volume and Fig. 3). In this region the edges of the high are apparently faults which may reflect the strength of earlier E-W folding.

In early reports we tried to model the structures controlling Owen deposition as normal faults. This model explained intra-Owen unconformities as part of a rollover structure due to listric geometry on the extensional fault. This interpretation fails to explain the east dipping lithologies which commonly occur to the west of the depocentres (Red Hills, Lyell, High Tor, Mt Jukes). Later reports from Lyell (Berry, 1992b) supported a compressional model with folding possible associated with a west directed thrust. A wrench model was also canvassed. Critical evidence for a syn-folding compressional model is the symmetry of unconformities across the Owen depocentres and the relative consistency of the basins along strike. While there may be reverse faulting in the basement associated with this folding we have found no evidence for it. The reverse faults to the west are probably generated as apart of this stress system as the folds tightened, rather than being the cause of the folding.

There are two other lines of evidence for discarding an extensional model. To get the 40° west dips from rollover would require strong listric geometry and a west thickening wedge of sediments. It would normally produce strong uplift to the west rather than the strong source region in the east as found. Volcanism had virtually ceased by the time Owen deposition occurs suggesting the active extension has ceased.

The wrench model was abandoned for three reasons. The symmetry of the basins was incompatible with depocentres at releasing bends. The similarity of structure along the depocentres does not support a progressive shift in deposition along the belt, especially the similarity between High Tor and Mt Lyell. No wrench geometry was recognised which would explain all the basins.

A major additional structural element associated with these NNW trending folds is the Cambrian thrusts recognised south of the Linda Zone. The Miners Ridge Thrust is pre-Pioneer Sandstone. It was a shallowly west to SW dipping reverse fault within the Cambrian section. South of Macquarie Harbour the Modder River Fault forms the western boundary of the Dundas Trough. There is an unconformity in this fault (McClenaghan & Findlay, 1989) which indicates it was active before upper Owen Deposition.

Table 2 Cambro-Ordovician unconformities related to N-S trend in Dundas Trough (largely from Corbett & Turner 1989).

Sub-Owen Unconformities
Henty Bridge Cambrian bedding 70/105 Pioneer correlate bedding 60/057
unfolded — 45/145 for Cambrian bedding
Eastern end of Professor Range
Farrell rivulet southwest of Mt Dundas. Dundas overturned and tightly folded on NNE trending axis
Corbett & Lees 1987
Mt Jukes — steeply E dipping and east facing Tyndall under Owen
Red Hills — 40 E dip in CVC under Owen Conglomerate
Sorell Pa — NNE trend in Cambrian related to Modder River Thrust
Murchison Gorge — nonconformity on Murchison Granite
Owen over W dipping Sticht Range Formation
57o W dip and facing in SRF at Marble Bluff
also E-W folds in SRF not in Owen
40° W dip and facing SRB D'Aguilar Range
Within Owen
Haulage Unconformity, Mt Lyell — lower Owen dips 40° E
High Tor — east dipping lower Owen under upper Owen
Mt Jukes open fold in Owen truncated by upper Owen
Miners Ridge, Queen River west facing and dipping hanging wall

The fault strikes NNE and dips steeply west. Its present position suggests it may originally have been continuous with the Miners Ridge Thrust (Fig. 2).

A major problem remains as to whether the Henty Fault was active at this time. It does form the apparent western boundary of the Owen Conglomerate at Tullah and south to the Henty prospect. The major movement on the fault postdates regional Devonian folding but a pre-folding reverse movement was recognised by Berry (1989). The major zone of steeply plunging folds (see domain analysis) lies along this structure indicating it had an pre-cleavage phase that may have been part of the Delamerian. On the data available to us the Henty Fault was probably initiated during Delamerian folding. In contrast we have found no evidence that the Rosebery Fault was present in the Cambrian. This relationship and the similarity of orientation suggest that the Henty Fault may be genetically linked to the Modder River Thrust.

The relationship of these structures to the Arthur Lineament remains contentious. The major west side up faults which were probably active during the Late Cambrian all have the same strike as the Arthur Lineament. The Dundas Group stratigraphy in the area north of the Pinnacles is much more magnetic than normal and this is related to detrital magnetite. Thus a new source terrain is required at this stage, about halfway up the Dundas stratigraphic package. The most obvious source for this magnetite is the Arthur Metamorphic Complex. Turner et al. (1992) has dated the uplift of this material as Late Cambrian. The Arthur Lineament may be related to this stage of Late Cambrian deformation although a more probable scenario is that this structure is related to ultramafic complex emplacement and that minor reactivation lead to the appearance of a magnetite in the source region of the Dundas Group.

OTHER CAMBRIAN SEQUENCES

Outside the Dundas Trough the Delamerian structure is different in orientation. At Adamsfield there ESE–WNW trending folds in the Trial Ridge beds and in the Island Road Formation (both Middle Cambrian) which pre-date the middle Late Cambrian Singing Creek Formation. The steeply dipping limbs are overturned to the north (Brown et al., 1989). On the south coast the Tyler Creek beds contain folds overturned to the NE and major shear zones striking NE which predate the Denison Group (Late Cambrian) and are probably Middle Cambrian in age (Bischoff, 1983). The Clytie Cove Group at Port Davey is pre-Owen Conglomerate and contains two generations of folding which pre-date the Owen Deposition (Williams 1979). The earlier of these has E–W trending folds associated with thrusting while the second has NNW to N trending upright folds similar to those described in the Dundas Trough. The first of these could correlate with E–W folding at Adamsfield.

In the Black Bluff–Winterbrook area there is strong ENE folding in the volcanic sequence and the folding in the Owen Conglomerate is much more open. There are sufficient unconformities exposed to indicate these folds are Cambrian in age and have only been tightened in the Devonian (Baillie et al., 1986; Seymour, 1980). Similar unconformities are known from Cethana (Jennings, 1958). Woodward et al. (in press) have suggested these structures are related to major SW directed thrusting during the Cambrian.

The evidence from Tasmania suggests the Delamerian orogeny involved a discrete zone of N–S folding along a previous graben and a more regional E–W folding phase. Surprisingly this pattern also occurs within the near basement sector of the Adelaidean sequence in the Broken Hill–Olary Province.

The Delamerian Orogeny in South Australia has an early N to NNW trending fold phase associated with west directed thrusts and high angle reverse faults followed by a later upright E-W fold phase (Berry et al., 1978; Priess, 1987: 271–276). The structure shows strong basement control on Delamerian structures. In the south the Delamerian folds wrap around the Gawler Craton in a very similar style to that required for the folding in Cambrian of NW Tasmania. Clarke & Powell (1989) have suggested these structures are the result of compression at 110° with the E–W fold trends occurring over major dextral wrench zones. While this looks possible for the Kangaroo Island zone it does not seem to be consistent with the very broad zone of dome and basin folding in the Olary–Broken Hill Province and the Northern Flinders Ranges.

The unconformities in the Middle to Late Cambrian of Tasmania as listed above are consistent with the pattern of folding in the Delamerian of South Australia. The large areas of low angle unconformities and restricted discrete zones of steep dip is more consistent with patterns of Delamerian folding in the Willyama Complex than with the intense thrusting and folding of the Kanmantoo zone in the Mount Lofty Ranges. Many of these fold directions have been reactivated in the Devonian.

Mineralisation

Very little mineralisation is thought to be associated with this deformation. The North Lyell mineralisation is related to Owen deposition and initially we argued (Berry, 1990) that it was Late Cambrian in age but additional information on the distribution of the alteration suggests it is much later, at least middle Ordovician and probably Devonian (Berry, 1992b).

The Henty prospect occurs in Tyndall Group rocks which suggests it may be related to Delamerian structures. This correlation is strengthened by the argument above that the Henty Fault was initiated in the Late Cambrian. The existence of a west side down (Middle Cambrian normal) fault controlling Tyndall Group preservation just east of Henty prospect is strong evidence that the extensional phase continued at least through part of the Tyndall deposition and the E–W compressional phase is related to the onset of Owen deposition which post-dates Henty mineralisation (assuming it is syngenetic!).

DOMAIN ANALYSIS: IMPLICATIONS FOR CAMBRIAN STRUCTURE

An analysis of structural data pertaining to Devonian deformations derived from a number of sources (Pemberton et al.,1991; McNeill & Corbett, 1992, 1989; Seymour et al., 1989; Selley, 1992; Corbett & Komyshan, 1989) demonstrates that the effects of a Late Cambrian deformation are detectable through the pattern of Devonian folding (Fig. 3). The plunge of the Devonian folds, as calculated from the domain data, varies systematically across, as well as along, the Mt Read volcanic belt (MRV); three major domains, based on fold trends and the sense of vergence of the cleavage with respect to the underlying folds, have been delineated. The highly unconformable Cambrian sequences, indicative of Cambrian deformation, lie along a well defined northeast-trending belt (Fig. 1).

The rationale used here is that steeply plunging Devonian folds specifically developed in Cambrian rocks indicate regions of high unconformability (with the overlying Denison Group), whereas shallowly plunging folds indicate the opposite, namely regions of conformability or near conformability OR that Devonian cleavages are parallel to Cambrian fold trends. An arbitrary plunge of 45° was selected to distinguish these two groups, in other words a value greater than 45° indicates regions of high unconformability — this being especially true where folds in the overlying Denison Group have shallow or horizontal plunges, such as at Mt Murchison and Black Bluff on the eastern side of the MRV. Any value less than 45° indicates a degree of conformability, a common situation in most of the rocks of the Western Succession

Whilst steeper plunges seem to be restricted to the Cambrian and separate Cambrian structural domains into the two groups, there is one exception. In the Eldon Group rocks, within the core of the Zeehan Syncline, plunges are greater than 45° (i.e. 62°). A variability in plunge of the folds in the Gordon and Eldon Group rocks is due to the specific effects of Devonian NW–SE shortening parallel to the axis of the fold (see Report No. 3), giving a double plunge to the overall shape of the syncline, or depression. The cause for this steepening plunge is the more ductile response of the Bell Shales to the deformation when compared to the more competent Gordon Limestone and Crotty Sandstone units.

The areas of high-angular unconformity between Cambrian and Ordovician rocks, including the six domains shown in Figure 1, all lie along a NE-trending belt that stretches from the Henty Fault wedge in the south to the Erriba ridge in the north, a distance of some 100 km. This zone correlates with the Henty Fault position over the southern section but this section is also parallel to the Middle Cambrian growth fault from Tullah to Red Hills. In the northern sector the extension of the Henty Fault is generally projected west of the Black Bluff Trough (Fig. 3) and thus parallels the zone of steep plunges in this sector but is 5 km to the west. The association of direction and position is reasonable evidence of a genetic link. The NNE trending sector of the Dundas Trough could then be explained as the impingement of the deformation effects of the Henty Fault on the eastern margin of the trough. The spatial relationship to steeply plunging Devonian folds provides circumstantial evidence for a Late Cambrian fault movement on the Henty Fault.

SUMMARY

The nature of Middle and Late Cambrian deformation is complex in both time and place. The whole of the Cambrian was a period of very active tectonics in western Tasmania. This can be characterised by a number of stages

Stage 1: Rift tholeiites of the Crimson Creek Formation and the Smithton Basalt. The dyke swarms in the Rocky Cape Region indicate a period of NW– SE extension at about the Precambrian-Cambrian boundary

Stage 2: Mafic-ultramafic complexes thrust over Tasmania. This stage is dated as near the early Cambrian–Middle Cambrian boundary with field relations at Adamsfield indicating continued movement until Middle Cambrian. The transport direction is towards the west to south west based on mylonite textures (Berry & Crawford, 1989; Berry, 1989).

Stage 3: Central Volcanic Complex, Eastern Quartz Phyric sequence, lower Dundas Formation–Middle Cambrian.

Apparently deposited in a restricted graben with N–S normal faults and E–W transfer faults. The

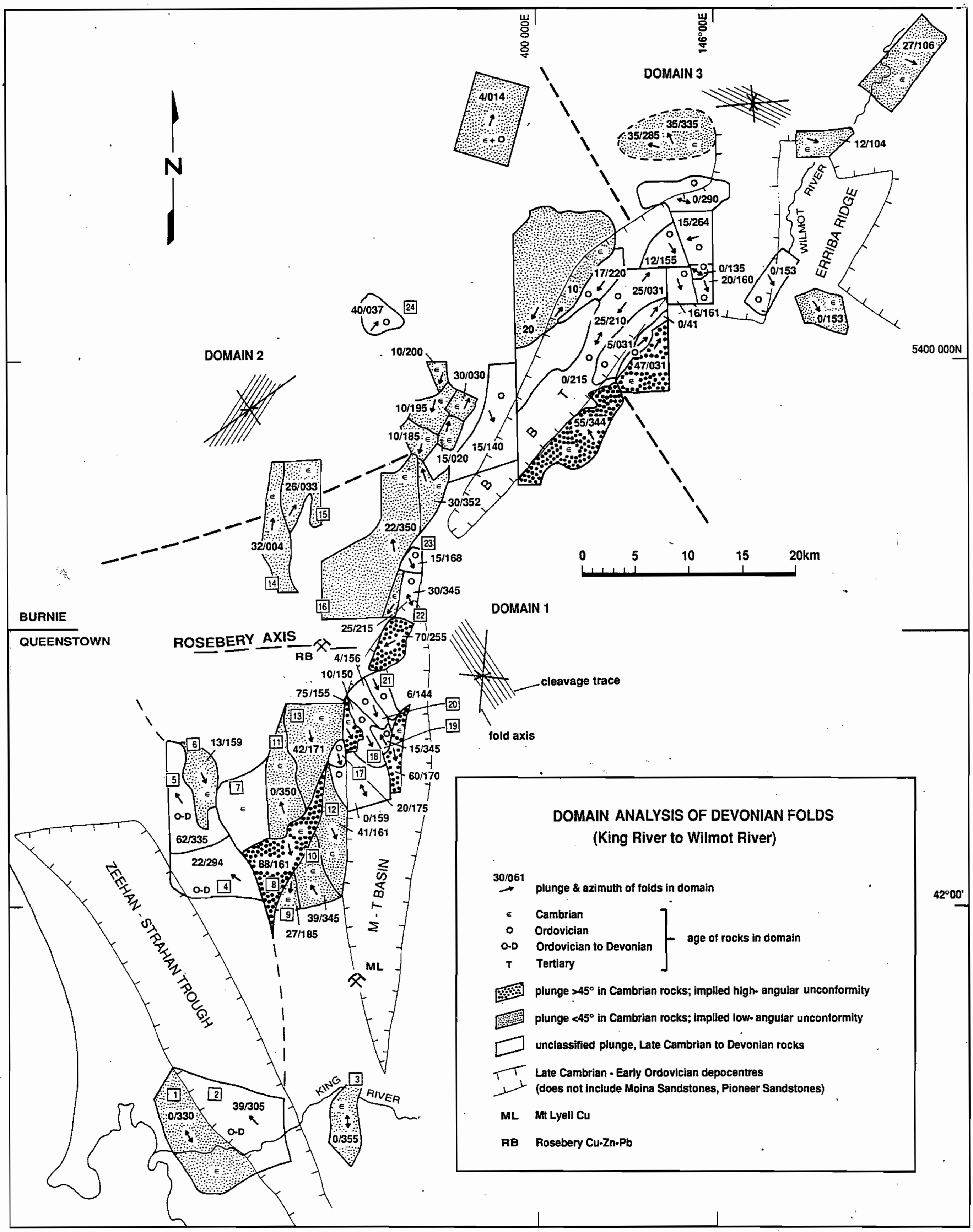

Figure 3. A domain analysis of Devonian folds in the Dundas Trough between the King and Wilmot Rivers. For explanations, see text; (from structural data by Pemberton et al.,1991; Seymour et al., 1989; McNeill & Corbett, 1989, 1992; Corbett & Komyshan, 1989; Selley,1992, Keele, 1991; and this study).

extension direction during mineralisation suggested as 080 in the south and 110 in the north.

Stage 4: E–W folding with overturning to the north and NE. Between late Middle Cambrian and middle Late Cambrian. This may be partly synchronous with the extension in the Dundas Trough.

Stage 5: N–S folding along the Great Lyell Fault continues from base of Owen until the Haulage Unconformity (middle Late and late Late Cambrian). Discrete zones of strong uplift occur at this time with NNW trends representing anticlinal axes.

The major phase on mineralisation in western Tasmania is restricted to the very brief period of extensional tectonics within the middle Middle Cambrian. Within this period there was a N–S graben produce with a complex series of transfer faults, largely striking E–W. Most massive mineralisation is restricted to the top of the massive volcanic successions, with several deposits linked to the positions of the Cambrian cross structure. Many of these faults continued to be active until the Devonian. The later compressional Cambrian events are not apparently significant in localising ore formation.

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P291
STRUCTURE AND MINERALISATION OF WESTERN TASMANIA
FINAL SUMMARY

by R.F. Berry & R.A. Keele
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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. The Devonian structural history has been determined on five regional sections. The large scale Cambrian structure has been outlined with the middle Middle Cambrian extensional fault geometry recognised from stratigraphic variations and two generations of Cambrian folds defined by unconformities under Denison Group stratigraphy. Tasmania was in an active tectonic zone through the Middle and Late Cambrian.

The VHMS mineralisation in western Tasmania has both local and regional correlations with the extensional fault geometry. The areas where Cambrian transfer faults cut the top of the volcanic package are highly prospective.

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 was to consider five 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. Every section contained evidence for a structural break during Owen Conglomerate deposition. The complexity of lithological variation has limited the sections to balancing above the Owen Conglomerate or an approximate balance between interpreted normal faults.

The identified mine geology component was the Mt 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 of 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 looked at the field relationships and some existing data of this Devonian vein style mineralisation.

REGIONAL SECTIONS

Que River Section

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 revision of the section is included here (Fig. 1) to bring it into line will the final structural model presented for this project. The new section recognises the greater complexity of Cambrian structure that needs to be included to explain the geometry of west coast geology. For example the eastern end of the section shows the Owen Conglomerate unconformable across the Bonds Range Porphyry. The Mt Cripps Fault is a major transfer structure in the Cambrian and in the Devonian. This status is now recognised in the section.

The drawing of the section across such a fault violates the assumptions for balancing sections and no balancing is attempted on this section. On the western end of the section the original version (Report 1: 1–16) failed to recognise the two faults at the margin of the section, one of which is the Rosebery fault but the other is the basin bounding fault. On our interpretation of existing mapping, the basal Dundas is onlapping Precambrian in Hay Creek. This Dundas Group sedimentary package is the Late Cambrian section (cf. Jell et al., 1991) of the stratigraphy and the CVC does not reach this far west. To the east of the Rosebery Fault is the magnetic sandstone unit of the Dundas Group. In the west, near Pinnacles, this unit is only 500 m above the top of the CVC but in the Que River there are two major porphyry bodies below this unit and the lower Dundas is much thicker. No discrete fault could be recognised for this change in thickness so it has been shown as a facies change. The shortening on this section is about 10 km. This is much less than the Rosebery section to the south. This difference partly reflects the shortening in the Husskisson syncline which is included in the Rosebery section but not in the Que River section here. It is likely that some of this difference is due to crossing the Cripps Fault. The northern sector has more shortening to the east of this structure while the southern sector has more strain between the CVC and the Henty Fault.

Rosebery Section

The Rosebery section (Fig. 2) is reported in this volume. The section was drawn at 537400 N over the Rosebery Mine. The structures indicate a 50% shortening of the Mount Read Volcanics in the Devonian with substantial reactivation of the Cambrian normal faults. No evidence was found that the Rosebery Fault was a normal fault in the Cambrian. It appears to be a hanging wall bypass thrust associated with the inversion. The Henty Fault has a more complex inversion history with both footwall shortcut thrusts and hangingwall bypass thrusts active although the latter are dominant.

Zeehan-Selina Regional Cross-section

The section from Zeehan to Lake Selina is a composite of the four cross-sections shown in Report 3: 50, fig. 1. The original report contained all the data available for drawing a restorable cross-section but we needed to confirm some regional structural aspects before attempting the final section which is provided here (Fig. 3). Some of the main geological features shown at the eastern end of the regional section are:

- The boundary between the Tyndall Group volcanics and Eastern Quartz Phyric (EQP) sequence is an interpreted normal fault that sits below Owen Conglomerate. This fault would also define the eastern limit of the Central Volcanic Complex.
- The Murchison granite intrudes the EQP sequence.
- The EQP is highly unconformable along this eastern side of the volcanic belt.
- The Newton Creek Sandstone and Middle Owen Conglomerate beds thin dramatically away from the Henty Fault.
- The Precambrian terrain is faulted up against the Cambrian sequences along a high-angle reverse fault that meets the main detachment at a depth of about 7 km.
- The Henty Fault was not the active fault during the emplacement of the CVC, but another fault to the east was, possibly the Great Lyell Fault although at Red Hills this boundary is not at the margin of Owen deposition.

The remaining part of the section which includes the full width of the Dundas Group and the remainder of the CVC is characterised by the following features:

- The Dundas Group have been affected by late Cambrian folding west of the Rosebery Fault, such that the folds have truncated by a Ordovician erosional surface and folded again during the Devonian. The effect had been to tighten the existing folds, partly by rotating their limbs giving the typical opposing plunges (a feature not possible to demonstrate on the section), but mostly decreasing their interlimb angle.
- The reason for the synclinal outlier of Gordon Group and Eldon Group west of the main Dundas Outcrop, is the direct result of the western growth fault which the CVC sits hard up against.
- The western edge to the Dundas is not known and cannot be predicted from the section, other than it is shown to be present under the Zeehan Syncline.

The shortening calculated across the CVC, i.e. from the Great Lyell Fault to the western bounding fault, is 37% or 7 km.

Strahan to Victoria Pass

The Strahan to Victoria Pass section (Fig. 4) 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 (Report 4: 31–38) is south of the Linda Zone and is similar to the King River section. The eastern segment has been drawn over Mt Lyell

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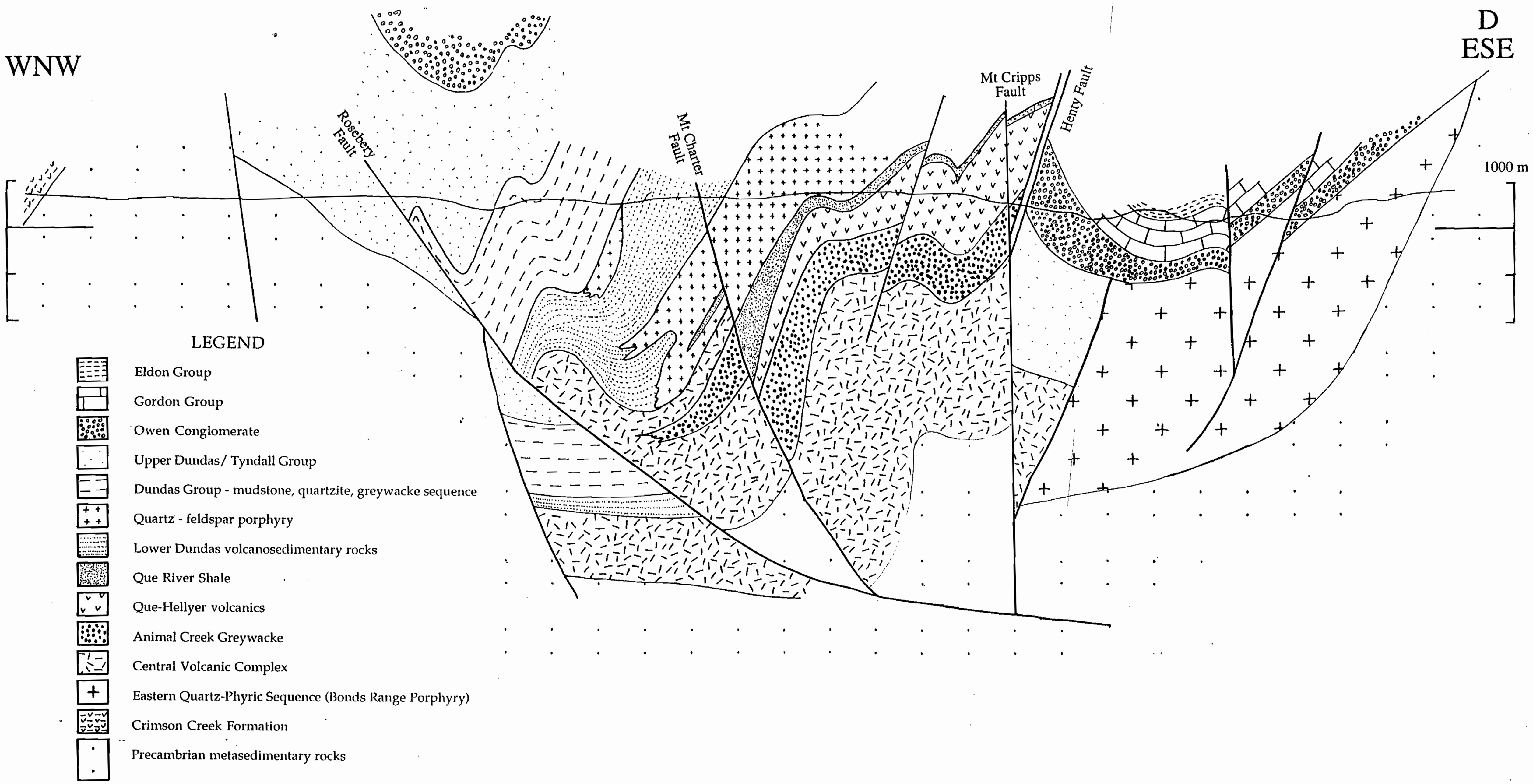


Figure 1. New version of Que River section from Hay River to Mt Remus. For exact position of section see Report 1: 3, eastern end of section CD.

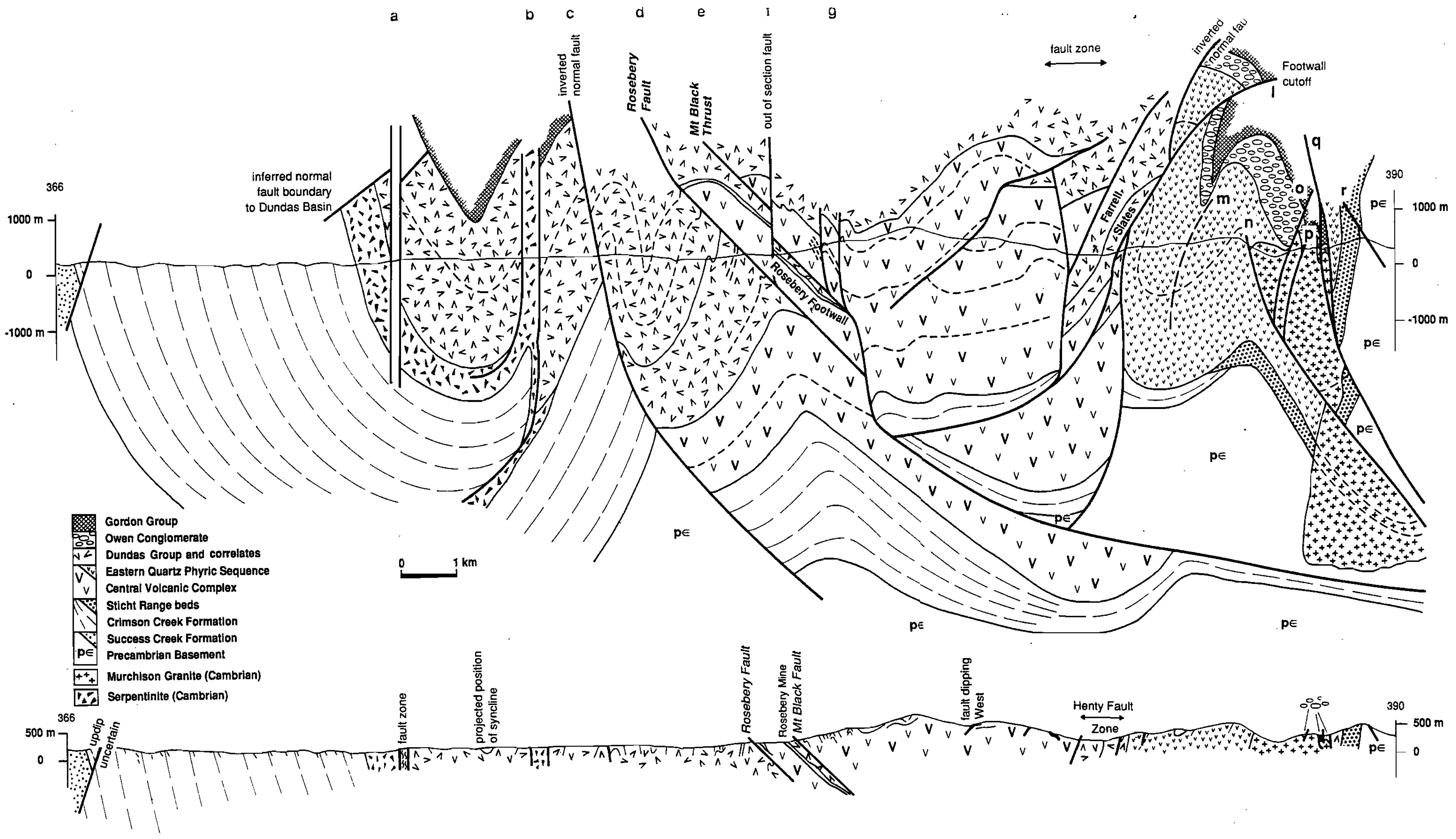


Figure 2. Interpretive cross section at 537400 N across the Rosebery Mine. Discussion of this section is provided in this report.

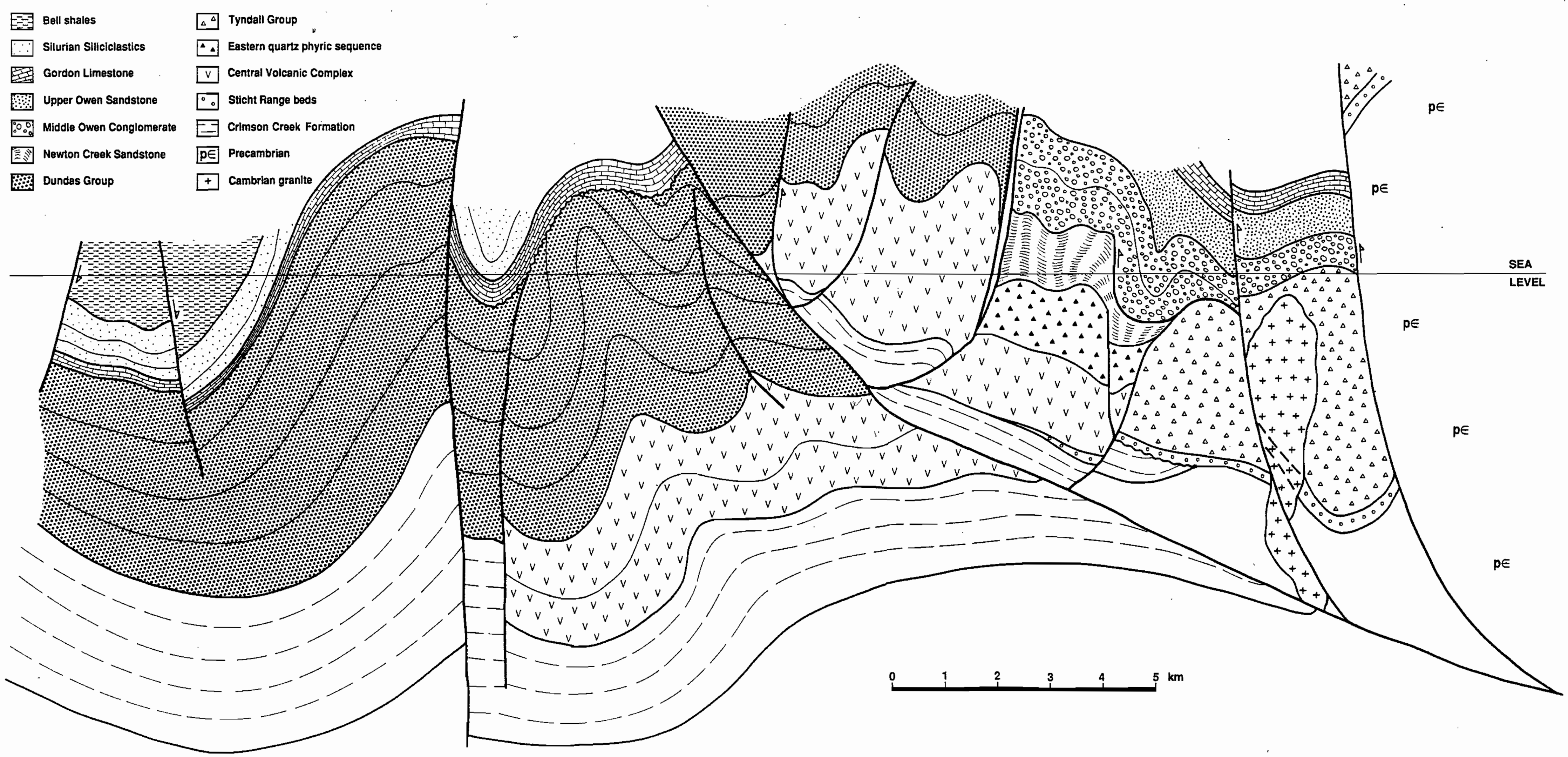


Figure 3. Interpretive cross section for Zeehan to Selina section. Database is discussed in Report 3: 40–73.

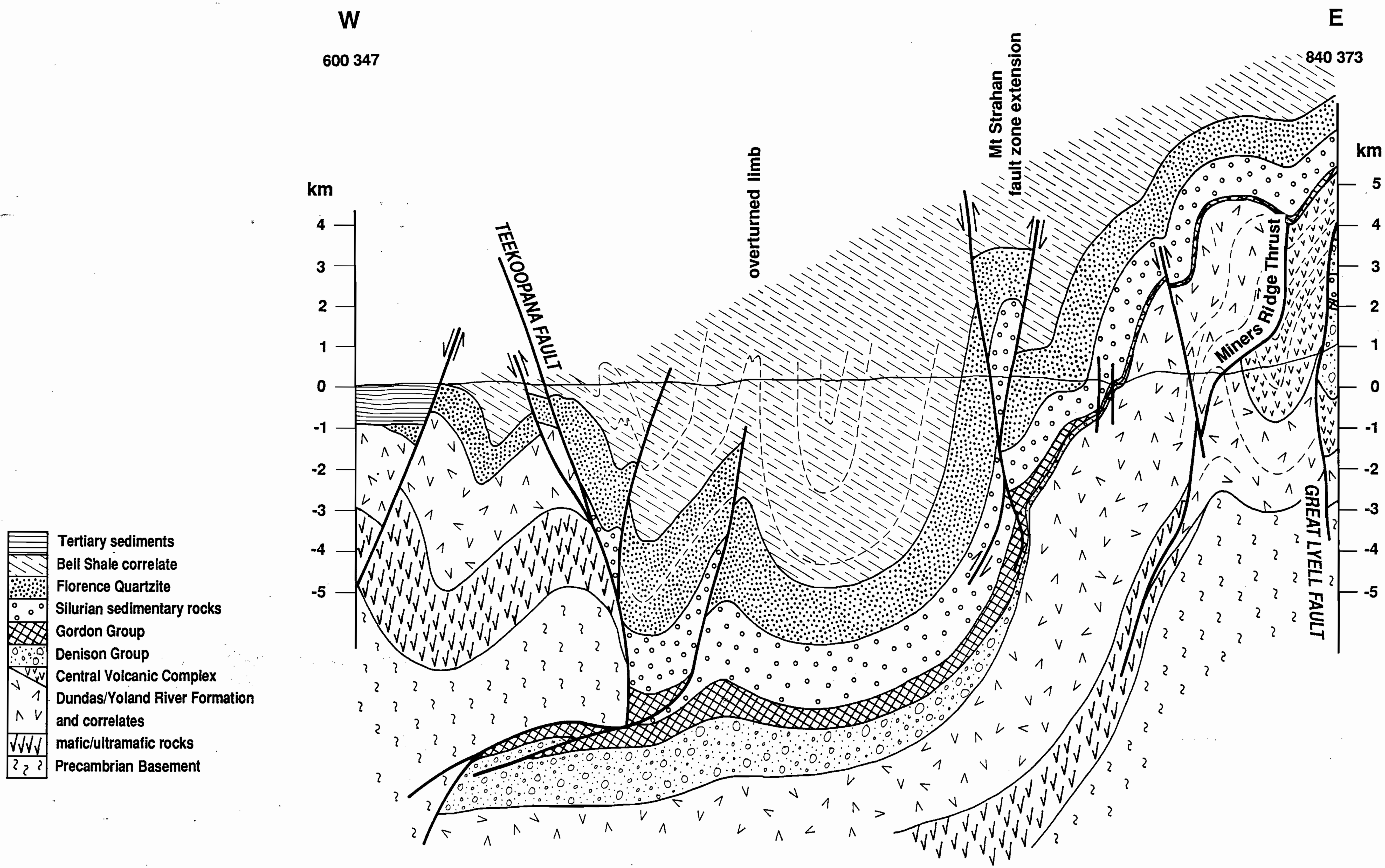
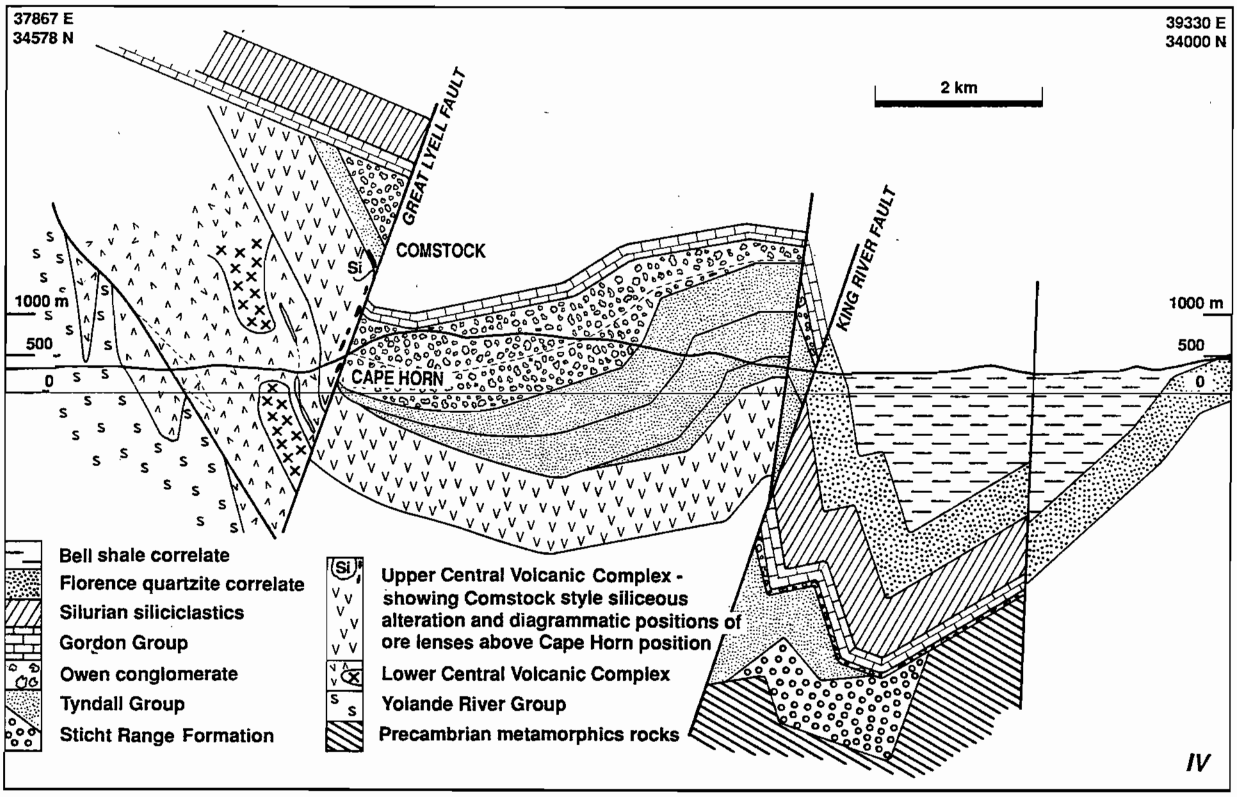


Figure 4. Victoria Pass to Strahan section from Reports 3: 22–30 and 4: 31–38. Western section (a) is south of Firewood Siding Fault, eastern section (b, following page) is from north of Owen Fault.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KING RIVER FAULT
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Bell shale correlate
Florence quartzite correlate
Silurian siliciclastics
Gordon Group
Owen conglomerate
Tyndall Group
Sticht Range Formation
Upper Central Volcanic Complex - showing Comstock style siliceous alteration and diagrammatic positions of ore lenses above Cape Horn position
Lower Central Volcanic Complex
Yolande River Group
Precambrian metamorphics rocks
IV

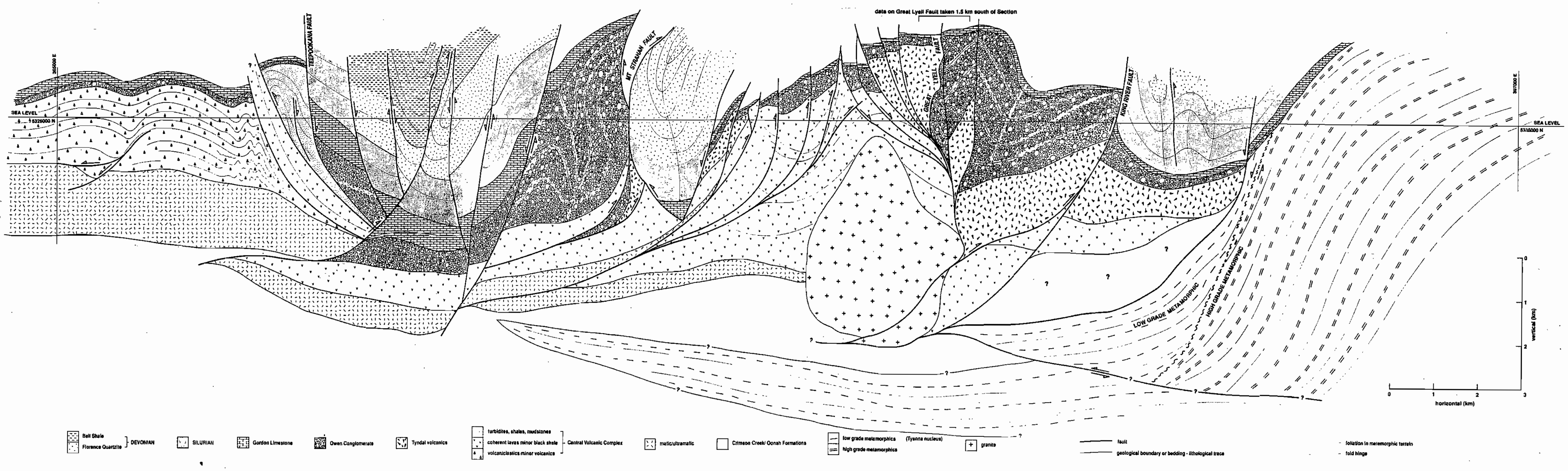

Figure 5. King River section. See Report 4: 11–30 for discussion.

(Report 3: 22–30) 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.

King River Section

The King River section was discussed in Report 4: 11–30. The outstanding features (Fig. 5) are the complexity of faulting with complex interaction between west-directed 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. The Teepookana Fault was not reactivated as a major thrust, instead inversion of the basin produced a fan of back-thrusts and a footwall shortcut thrust. Major out of section movement occurs on a dextral wrench zone just east of the Darwin Granite in this section, through the Jukes saddle.

Wilmot River Section

The NW section across the Fossey Mountain Trough is reported in this volume. The Fossey Trough has an E–W to WNW–ESE strike reflecting middle to late Cambrian deformation. This early deformation is reflected in the E–W trending folds that resulted from a meridional compression during a late Middle to early Late Cambrian inversion. Cleavage transection shows that these folds were progressively tightened by deformation phases up to and including the NE–SW compression of the Devonian orogeny. Other folds in the late middle Cambrian Tyndall correlates which show tighter profiles compared to their equivalents in the Ordovician, are also inferred to be Cambrian folds. The centre of the Fossey Trough is marked on surface by a change in the sense of vergence of the Devonian thrusts from SW to NE. Total shortening across the lower Wilmot domain, or northern end of the section, is approximately 36%. Shortening across the rest of the section is impossible to estimate because of the Dalcoath Granite.

COMPARISON OF REGIONAL SECTIONS

The regional sections in the Dundas Trough fall in to two classes. The three sections in the north are dominated by the Rosebery Fault. The section at Rosebery shows the greatest shortening (19 km, 50%) both as a percentage and as an absolute amount. This partly a result of the large amount of detail on this section. The Que River section shows many similarities but the folds appear more open and the strain lower. The amount of movement on the Rosebery Fault is poorly constrained in both this section and the Zeehan-Selina section. The slip on the Rosebery Fault is shown as a minimum value on these sections and it could be much greater.

The two southern sections lack the dominant W directed thrusting. This change in style could occur on either the Linda Zone or on the Zeehan transfer fault system. The sections have more symmetric upright folding and faulting. The shortening on these sections varies from 17 km for combined Strahan to Victoria Pass section to a lower value for the King River section (about 10 km for Cambrian units) but this difference probably reflects differences in interpretation resulting from the different stratigraphic level exposed on the section. Further work is required to integrate the data for these two sections.

While no sections were drawn south of Macquarie Harbour, the maps do not show a strong asymmetry in thrust direction within the Dundas Trough. The geology suggests a close match to the southern section. The major west directed thrust is entirely east of the Dundas trough along the Hardwood River. This structure must transfer its shortening into the Dundas Trough over a number of faults starting from transfer 10 on the Gordon River and finishing with transfer 6 (Fig. 1 in Cambrian interpretation this volume).

The section across the Fossey Mountain Trough is dominated by the Cambrian structure. The SW-directed Devonian thrusts are strongly modified by their interaction with these older structures. There is very little evidence that the structures are thin skinned as suggested by Woodward et al. (in prep.) rather the thrust involve the basement and are more consistent with a medium skinned model.

DEVONIAN STRUCTURAL HISTORY

The mesoscopic structural history of western Tasmania is very complex. A list of the recognised events during the Devonian are given under the heading "Regional Context" below. In both north and south areas there is a pre-cleavage fold event which in structural analysis terms is recognised as an earlier fold event. The work here suggests that both of these structures are Cambrian folds which were tightened during the Devonian. The regional scale fold geometry is controlled by the existing structure below the Owen Conglomerate. This relationship produces transected folds as discussed below in the domain analysis. For the Fossey Mountain Trough our assessment of the folding history is given in this volume. Detailed structural work and fault history in the Dundas Trough are included in Report 1: 27–66, Report 3: 22–30, Report 4: 11–38 (Macquarie Harbour to Queenstown), Report 3: 40–73 and this volume (Zeehan, Dundas, Rosebery).

Mega-Domains

Three very large domains, or mega-domains, comprising a number of smaller sub-domains have been outlined on the map on the basis of: Devonian fold trends, the relationship between the Devonian cleavage and the Cambrian folds, on which the former is superimposed, and the existence of the Late Cambrian depocentres. A zone of confusing fold trends in the Ordovician rocks occurs at the triple point where the three mega-domains meet.

Mega-Domain 1: NW–NNW trending folds characterise Domain 1, which extends from Macquarie Harbour to the Black Bluff trough. In this domain the cleavage always transects the regional folds, which strike more northerly than the cleavage. The folds usually, but not always, plunge towards the north; some are horizontal, such as the folds in the Dundas–White Spur region around Hercules, whereas others have opposing plunges which effectively cancel each other out, for example the two domains in the Yolande River sequence immediately south of the Henty Fault wedge (Fig. 3 in "Cambrian structure in western Tasmania", p. 66 this volume). This particular effect of opposing fold plunges, and rotation of fold limbs, is very noticeable in the Dundas Group south of Rosebery and has been commented on in an earlier report; it is due to the non-coaxiality of the strain axes developed during the progressive and continuing deformation from the late Cambrian through to the Devonian (see Reports 2 & 3).

Mega-Domain 2: NE trending folds and cleavages characterise this very large domain. The change over from 1 to 2 can be seen at Que-Hellyer and in the middle of the Black Bluff trough, where the last of the NW cleavages are observed before reaching the change in regional vergence. The plunge of the folds is variable with both N and S plunges being common. Despite a lack of field data (no work was done in this domain during the AMIRA project) it would appear that the cleavage, although symmetric with respect to the large-scale folds, in some places transects these folds, suggesting a gross clockwise rotation of mega-domain 2 with respect to 1. The sense of vergence is the same as in mega-domain 1.

Mega-Domain 3. This large domain clearly reflects the early E–W trending, late-Cambrian folds present in the Sheffield quadrangle due to the early meridional compression (Jennings, 1979; and this study). The cleavage has a northwesterly strike and transects the regional folds whose trends varying from WNW to NW. The plunge of individual domains ranges from 27° E to 35° W.

Small Domains in the Southern Sector (Mega-domain 1)

King River (domains 1-3): The domain structural data on the King River section indicate that the boundary between domains 1 & 2 (Teepookana Fault) coincides with the western edge of the Strahan-Zeehan depocentre. During mid-Devonian deformation, the normal Teepookana Fault was not reactivated as a major thrust, instead this inverted structure comprised a fan of back-thrusts (in domain 2) and a footwall shortcut thrust in domain 1. The horizontal fold plunges in the western Cambrian succession (domain 1), contrasts with the steeper, and occasionally overturned, northerly plunges in the Siluro-Devonian strata in domain 2: one of the features of the younger strata in this southern part of the MRV belt is their general, but variable, northward plunge (cf. domains 4 & 5). Domain 3 includes the volcaniclastic and volcanic rocks of the CVC. Although in an earlier report, the volcanoclastic on the Mt Jukes Road section were divided into two domains, one N-plunging and the other S-plunging, recent mapping has shown that this domain is a classic example of cleavage transection. Consequently, the regional synclinal fold is given a zero plunge here. The direction of tectonic escape in domain 3 is vertically upwards and in domain 1 it is horizontally outwards to the NW or SE, thereby indicating that the western Cambrian sequences formed part of a stable foreland region dominated by wrench faulting, whereas Domains 2 & 3 were part of the main Devonian front and were dominated by thrust faults.

Ordovician-Devonian Synclines (2, 4 & 5): Within the core of the Zeehan Syncline plunges are greater than 45° (i.e. 62° in domain 5). This variability in plunge of the folds in the Gordon & Eldon Groups is due to the specific effects of Devonian longitudinal NW-SE shortening, giving a double plunge to the overall shape of the syncline or depression (see Report 3). The cause for this steepening is the more ductile nature of the Bell Shales and hence greater shortening in response to the deformation, when compared to the more competent Gordon Limestone and Crotty Sandstone units. Therefore, this is not necessarily evidence for cross-folding and, in this respect, it is to be noted that the S-plunges of domains 12 & 13, coming off the Rosebery axis to the north, contrast with the N-plunges of domains 4 & 5.

Dundas Group west of the Rosebery Thrust (6 ,7 & 9,10,11): This group of domains, in the dominantly sedimentary White Spur Formation and Yolande River Sequence, form an intermediate group of horizontal plunges between the N-plunges to the west and the S-plunges to the east. Because of this, both boundaries are faulted: the western boundary (i.e. between domains 7 & 5, 6 and between 8 & 4) is a dextral wrench which offsets the North Henty Fault by 2.5 km, whilst the eastern boundary (i.e. between 11 &13 and 10 &12) is, in part, the southern continuation of the Rosebery Thrust zone. These two structures are perceived as playing vital roles in balancing the various discrete rock masses or units as they jostled each other for space along the length of the orogen. The boundary between 7 &11 is a splay off the Rosebery Thrust, whilst the boundary between 11 & 13 is a complex zone of D_2 thrusting, transfer movements, dextral strike-slip shearing and conformable contact relations between the CVC & WSF (Dugdale, 1992). This eastern boundary marks the trace of the plane of symmetry of the 'pop-up' structure between the Henty and Rosebery Faults, i.e. to the west of the line escape was up and out to the west, whilst to the east of it escape was up and out to the east. This style of crestal collapse may be due to the position of the "pop-up" in relation to the steep southern flank of the ENE-trending Pine Hill granite ridge (Leaman, 1988).

The Rosebery Axis (12-16): The most significant feature of the central Cambrian sequences west of the Henty and Great Lyell Faults is their shallow to moderate plunges about the approximately E-W trending Rosebery axis: four domains in the CVC and Dundas Group (including the Boco Rd and Mt Black regions, 14 & 15) have plunges that vary from 22–32°N, whilst two on either side of the fault wedge (12 & 13) plunge 42°S. This indicates a broad open-style fold with a sub E–W axis centred on the Rosebery mine, corresponding to the sub-surface Devonian granite ridge.

Internal and External parts of the mid-Devonian orogen (10-15): The line separating several domains of opposing plunge, or different fold trend, has already been referred to in respect of the eastern boundary of domains 10 & 11. North of the Rosebery axis, it corresponds to the Rosebery thrust until it hits the complex zone between domains 11 & 13 and then jumps across the Henty Fault wedge continuing between domains 10 & 12, where it forms the faulted contact between CVC andesites and the YRS on the Anthony Road. This structure, already discussed above in context of the granite ridge is clearly of Devonian age and forms a major internal boundary within the orogen; its 40 km length suggests that it is more than just a single fault and it would appear to separate the orogen into an internal and external zone.

Shallow plunges in the Denison Group east of the Henty Fault (17-23): The most striking feature of the folds in the Denison Group is their very shallow plunges. They mostly vary between 0° and 15° and trend NW to NNW. Whilst this is generally true for all the folds in the Denison Group, at least as far as the the Erriba Ridge, it is not always true for the domains out to the west, e.g. 40° plunge in domain 24 at St. Valentines Peak. The reason must be the stability given to the folds by the steeply dipping underlying Cambrian sequences in a back region of the orogen.

MINE STUDIES

Rosebery Mine

Major results for the Rosebery Mine study are in Report 3: 1–21 and Report 4: 51–66. Minor additional detail on the recognition of faults in core from Rosebery is included in this volume.

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 0–500 m N. 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 syn-depositional fault pattern which influence the ore deposition geometry.

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 (Fig. 6). 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 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.

This pattern was recognised in the original work but the association with Cambrian transfer fault orientation has only been recognised as a result of the regional geology reported in this volume. The principal orientation controlling the Rosebery orebody is sub-parallel to the transfer fault extrapolated from further west.

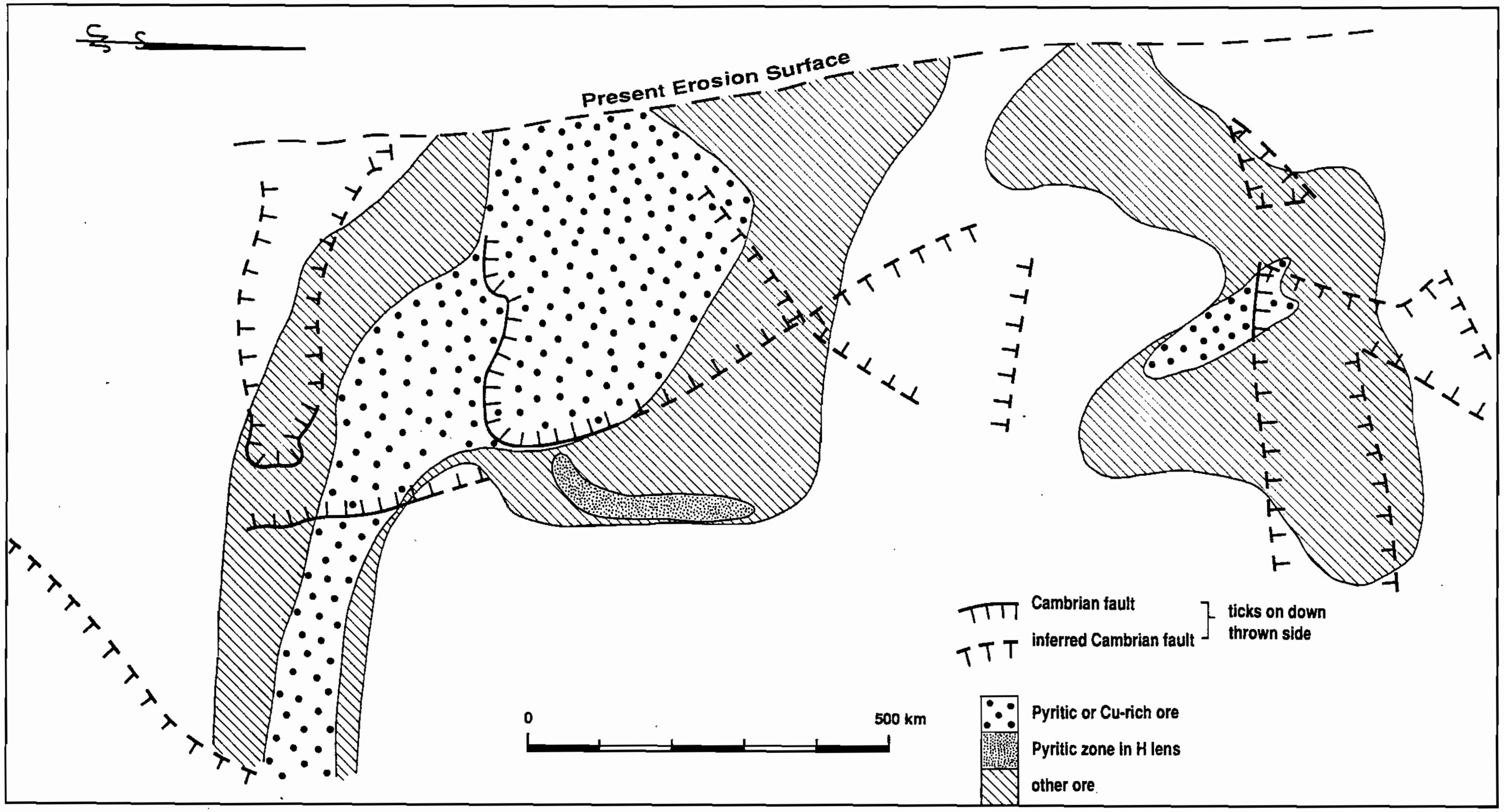

Figure 6. Reconstruction of the Rosebery deposit at the time of formation of the ore deposit in the Cambrian.

The pattern of normal faulting can be interpreted as WSW–ENE regional stretching with a N–S component. The moderate correlation with the mineralisation suggest surface fault patterns were 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 was strongly oblique to the underlying regional pattern of faults and would lead to strong dilation on the regional transfer structure.This model suggests there may be substantial continuations of mineralisation down plunge of the main Rosebery lenses. Previous reports have considered the Rosebery Fault as a reactivated Cambrian structure but the regional work near Rosebery found no evidence for a Cambrian movement on the Rosebery Fault and its present geometry essentially sub-parallel to the stratigraphy makes an early normal fault history unlikely. The reconstructed section of Rosebery (this volume) show the basin-bounding normal fault several kilometres to the west.

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 Mine Leases

The basic data on Devonian structures at Mt Lyell were presented in Report 1: 27–68. Additional structural data were reported in Report 3: 31–39. A summary and interpretation were included in Report 4: 67–76. During this period the interpretation of these data, and there application to mineralisation models has been evolving. The final interpretation is included here and varies slightly from that included in previous reports. In particular the original interpretation of the North Lyell Mineralisation was that it was Cambrian but this model has now been discarded, and the nature of the deformation event which produced the Haulage Unconformity has been a point of various interpretation, with the final analysis presented in this volume under Late Cambrian deformation superceding previous interpretations.

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. 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. 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 D2 event is the associated complex faulting. NE directed thrusts are common and at least partly pre-date 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. 7). 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. 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 (Figs 8, 9).

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. The interpretation now given for these structures is that they are Delamerian folds (Late Cambrian) which have been reactivated in the Devonian.

Delamerian deformation: 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 could not have produced the Haulage Unconformity itself. The study east of Zeehan also suggested a fold event which predated the Owen deposition. Evidence supporting a series of unconformities, in the Lyell

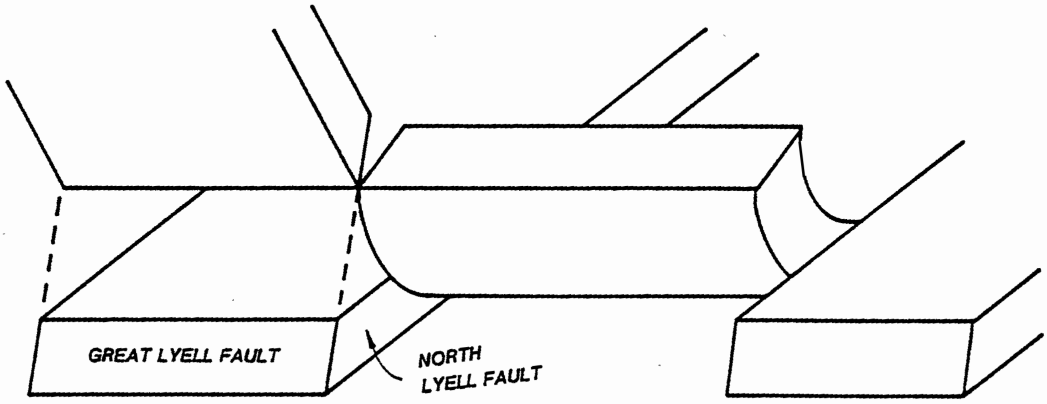

Figure 7. Cartoon of the change in D_1 style along the Great Lyell Fault

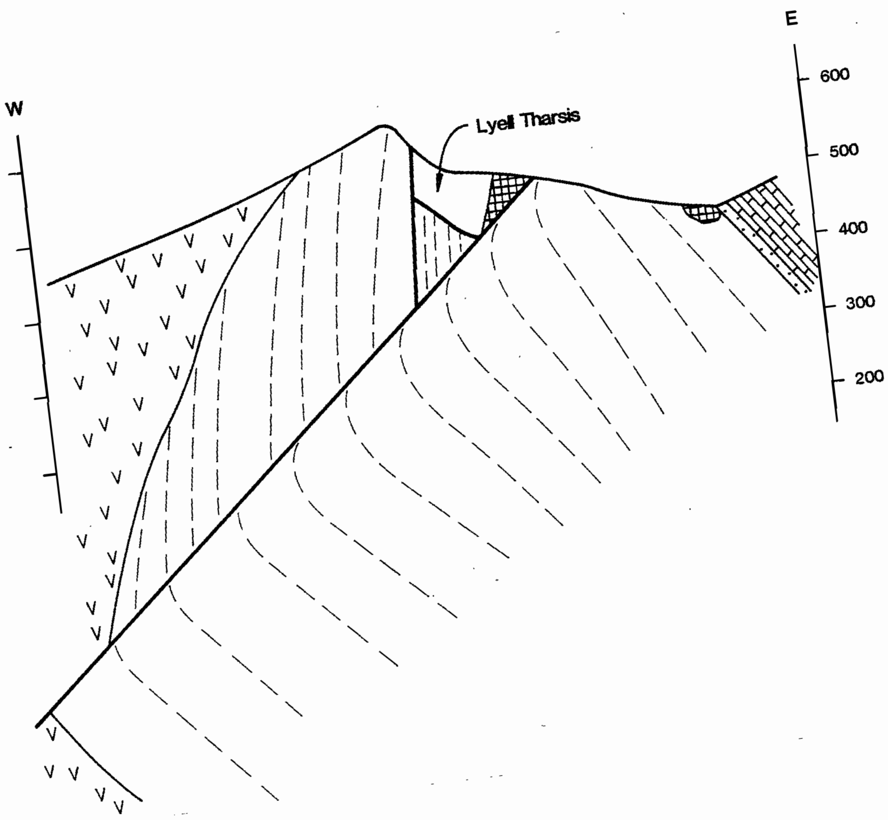

Figure 8. Section of Tharsis Trough.

area, during the Late 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 a syn-folding 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 but occupying the synclinal position with dips on the western margin being very similar to the underlying CVC. These relationships have been discussed in the section on Cambrian structure in this volume.

The Haulage Unconformity is the result of relatively shallow dips to the east at the western margin of Owen Conglomerate Deposition. Assessment of the regional pattern of syn-Owen unconformities has resulted in the recognition of a NNW folding pattern where Owen depocentres occupy the synclinal position. This produces symmetrical unconformities across the Tyndall-Owen basin. A similar structure has been reported from High Tor. Regional data supports an active tectonic setting in the late Cambrian and the structure varies very rapidly in both time and space.

North Lyell Mineralisation: It was argued in Report 1: 27–68 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 (Report 3: 31–39, 76–77) suggested 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. The evolved Sr isotope ratios of some vein style barites in the North Lyell area are consistent with a major remobilisation in the Devonian (Whitford et al. 1992) We 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 disseminated 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: The Great Lyell Fault was originally defined as all conglomerate /Lyell Schist contacts. These contacts are very variable but ȃ large number of them 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.

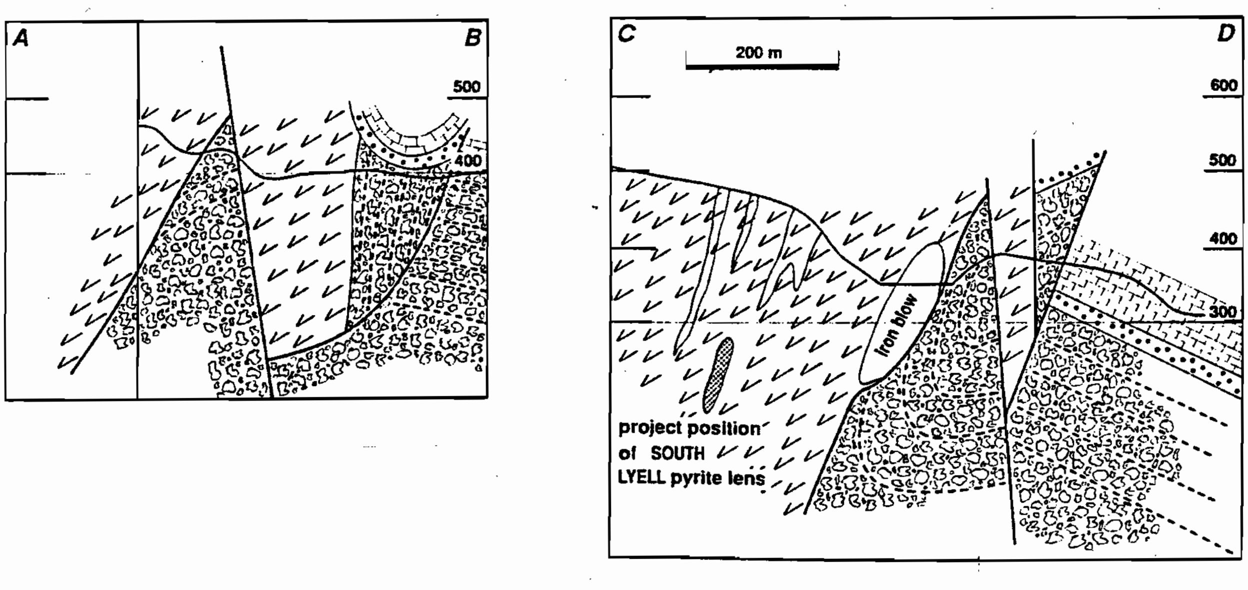

Figure 9. Sections through (a) the Razorback and (b) the Blow.

Macroscopic geometry: The section between the Glen Lyell Fault and the Mt Lyell mineralisation is a continuous east facing sequence. The structure is a consistent steep dip to the east cut by numerous sub-vertical west side up faults. The major disseminated ore bodies of Prince Lyell, Western Tharsis etc. are approximately parallel to bedding. In Conglomerate Creek, west of the fault, the stratigraphy faces west .

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 Prince Lyell style of disseminated mineralisation is located close to the top of the CVC and just north of the major Cambrian transfer fault (Firewood Siding–Mt Owen Fault).

North Mt Farrell–New North Mt Farrell Mines

A brief study was made of the structure associated with the North Farrell-New North Farrell mines. This study is reported in this volume and a summary of the results is provided below.

The North Farrell and New North Farrell mines are Devonian vein style mineralisation related to granite intrusion. They are structurally controlled and have mineralised dilatant zones 50–100 m into the footwall of the major bounding fault (Henty Fault) west of the Farrell Slates. The veins thicken at intersections between N and NNE striking subsidary faults. The best lenses are in dilatant sites over Riedel Shears. There is a close association with kink band formation. All the structural information supports mineralisation during the last part of the reverse fault movement on the Henty Fault Zone.

The combined North Farrell and New North Mt Farrell deposits are the largest of the Ag–Pb–Zn lode systems in the Farrell Field and have a historic production of 730,000 tons of Pb/Ag ore. The Farrell mines are related to Devonian granites. This is supported by the Pb isotope data (Gulson & Porritt, 1987) and the field relations. The Pb isotope data precludes a direct remobilisation of a high grade Cambrian massive sulphide deposit since the Pb is more radiogenic than the known VHMS deposits in western Tasmania and has a ratio typical of Devonian deposits. The high Ag and high Pb/Zn ratio confirms a relatively high temperature. The extremely variable Zn/(Zn + Pb) is typical of the Devonian vein systems and contrasts with VHMS deposits (Large & Huston, 1986).

The North Farrell lode lies 50 m into black slates and phyllites in the footwall to the major reverse fault which forms the western boundary of the Henty Fault Zone. It lies in an imbricate zone of reverse faults which interconnect in both plan and section. The region of the deposits has anomalous more-intense kink band development. In some exposures and in drill core siderite veins occupy the axial planes of the kinks suggesting a direct genetic link. The lode position is associated with extensive quartz siderite veining and brecciation. Veins lie in dilational sites along kink band boundaries and along faults especially near Riedel shears. The "lode channel" is apparently a quartz siderite stockwork along one or both sides of a cataclasite.

Quartz-only veins are syn- to pre-kinematic with respect to the fault cleavage and are widespread throughout the Farrell Slates. In contrast quartz siderite veins are syn- to post-kinematic and siderite galena vein are ?syn- to largely post-kinematic. Rivers (1975) and many other authors report the galena bearing veins as deformed with a fault lineation pitching steeply south. This is consistent with mineralisation being very late syn-kinematic with respect to the reverse movement on the Henty Fault.

While alteration is not generally visible in hand specimen the slates and sandstones are very sericite rich compared to equivalent rocks away from the mineralisation (e.g. Mackintosh Spillway). This sericite alteration continues for at least 2 km north of New North Farrell, to Farrell Blocks.

The level plans from New North Farrell show a complex intersecting fault pattern with ore grades very variable along individual lodes. The main lode appear to consistently be mineralised over the depth of mining but the other lodes are minor offshoots of this main structure and are usually only mineralised for a short distance from the main lode. The outstanding feature is that the faults form a complex network in both plan and section. The major faults strike 000° magN and 020-030° magN. In section faults vary from 80° W to 45° W dips. The steeper faults are P shears while the shallower faults are R shears. Section 1200N shows the effect of the R shear (No. 4 lode) in producing dilatant sites in the overlying P and Y shears. The best ore block in the mine occurred in the upper levels, 1 and 2 level and has previously been attributed to the intersection of the lodes with the sandstones. This study suggested much of the dilation is controlled by Riedel shears.

The exact location of the major bodies within the Henty Fault system is difficult to predict. The locations are related to dilatant sites and focussing along the Henty Fault is likely to be related to more porous zones. The New North/North Farrell Mine is related to a zone of extensive kink folds. These are best developed in the region of the mines and for 1.5 km to the north. Such kinks represent a widening of the fault zone and are thus an indication of a tensional or dilatant zone within the overall fault system. There is a rapid narrowing of the Farrell Slates shown on recent maps 1 km to the north of the mine suggesting a transfer zone was operating which may define the northern limit of this dilatant zone.

North Farrell and New North Farrell are a classic Ag-Pb-Zn vein system which are widely associated with felsic magmatism. The structure of the Farrell Lodes is entirely consistent with this style of mineralisation. There is no direct evidence for a Cambrian mineralisation in the Farrell field. In terms of tonnage grade variation for this style of deposit listed by Cox & Singer (1986), North Farrell/New North Farrell lies on the 95 percentile for size, on the 70 percentile for Pb% but is only on the 30 percentile for silver concentration.

REGIONAL CONTEXT

Some recently reported work in other areas has modified the context in which the Mt Read Volcanic Belt needs to be considered. This work was summarised in Report 4: 1–10. The tectonic history of Western Tasmania which we have recognised based on the published literature and the results of this project are summarised 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 Middle 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 Middle Cambrian-extensional phase
   Initiation of Dundas Trough
   Major post-collisional acid volcanism of the Mt Read Volcanics
   Henty Dyke swarm — EW extension
   VHMS mineralisation
   Part 2: Late Middle to early Late Cambrian
   E–W folds in Fossey Mountain Trough, Adamsfield, Bathurst Harbour
   Part 3: Late Cambrian
   Miners Ridge Thrust, Modder River Fault, ?Henty Fault
   Upright open folds trending 350°
   Denison Group deposition in synclinal axes
   Many local unconformities

7. Ordovician–Silurian sag phase
   Teepookana normal fault active through this stage

8. Early Devonian cycle of deposition

9. Middle Devonian orogenesis
   Reactivation of Cambrian fold trends E-W in Fossey Mountain Trough, N–S in Dundas Trough (D_1, D_2 at Wilmot (Seymour, 1980, 1989), not numbered south of Tullah)
   NNW trending folds: associated cleavage transects folds which nucleated in the Cambrian and tighten in Devonian (D_3 at Wilmot, D_1 at Mt Lyell)
   Thrusts and high angle reverse faults in Dundas Trough syn- to post-NNW folds
   Devonian granites and granite related mineralisation late syn- to post-E–W compression
   WNW trending folds and thrusts in the south, NW striking thrusts and associated folds in the north (D_4 at Wilmot, D_2 at Mt Lyell)
   Late brittle wrench faults NNW dextral and NNE sinistral
   Local return to E–W compression (e.g. Mt Lyell)

10. Permian depositional cycle

11. Late Mesozoic wrench faulting

12. Eocene extensional structures

MINERALISATION

Cambrian mineralisation is of two types: the first comprises a number of the deposits and prospects related to the volcanic-dominated facies component, and the second comprises prospects related directly, or indirectly, to the Cambrian granitoids. All the presently known economic deposits are of the VHMS type. These all occur at or very close to the top of volcanic dominated sequences. As well as the strong stratigraphic control, the results of this project have demonstrated a strong spatial relationship of economic VHMS deposits to middle Middle Cambrian transfer faults. In most cases the deposits sit just north of the position where these cross structures intersect the top of the volcanic dominated package. Examples are Mt Lyell where the alteration extends from the transfer fault for 4 km to the north, Rosebery where the deposit extends for 1.5 km north of the transfer fault, Que River where the deposit is 600 m

Table 1. Structural relationships of deposits

Middle Cambrian	
VHMS	
Hellyer	small scale normal faults
Que River	small scale basin ?normal fault control just north of transfer fault
Rosebery	extension of transfer fault small scale normal faults have second order control on mineralisation
Hercules	near top CVC — no Cambrian structural control
Disseminated	
Mt Lyell	intersection of Cambrian cross structure with top CVC
Henty	Cambrian transfer fault edge of Owen Basin
Selina	Cambrian transfer fault
Granite related	
Jukes Darwin	north of possible Cambrian transfer fault
Voyager 19	Cambrian transfer fault
Ordovician	
Oceana	Cambrian transfer fault
Devonian	
Granite related	
Renison	normal fault due to granite emplacement pre-D_2 wrench faulting
Dundas Field	late syn-D_1 reverse faulting fault controlled fluid flow
Farrell Field	late syn-D_1 reverse faulting inverted Cambrian normal fault
Skarns	no structural control
North Lyell	metamorphogenic remobilisation major Devonian reverse fault Cambrian transfer fault intersection to localise source

north of the transfer fault. There are many prospects which also occupy similar positions but alteration zones as a whole do not have a strong spatial correlation with these structures.

The basin bounding normal faults which we recognised on the western margin have no known correlation with mineralisation. We have recognised very few regional scale normal faults within the Dundas Trough. Examples are the eastern boundary of the Henty Fault zone — Tullah to Red Hills, Copper Creek Fault near Mt Osmund, and the Mt Charter Fault. All of these have nearby alteration zones but no major deposits have been found. In contrast detailed work in the major deposits either reported here or in the literature suggests very small scale normal faulting in Hellyer and Rosebery. The displacement on these structures is too small to be a reliable handrail for exploration.

The Cambrian granite-related mineralisation does not show strong correlation with the cross-structure. A possible example is the Jukes mineralised zone which does terminate on its southern margin against a suggested tranfer fault. Several barite localities north of Mt Murchison are related to the Murchison granite and have been related to a possible extension of a Cambrian transfer fault.

Several Ordovician carbonate-hosted Pb/Zn deposits are known of which the only significant producer is the Oceana deposit. This example lies very close to a Cambrian transfer fault suggesting these structures were still active during the Ordovician and were controlling fluid flow in the Ordovician.

Most Devonian mineralisation is related to granitoid emplacement. Proximal skarn type mineralisation has no regional structural control. The distal versions of Devonian vein style mineralisation are usually located in faults. In the Farrell field the structural control on the location of these deposits is especially strong with most mineralisation occurring in the footwall to the Henty Fault. In the Zeehan and Dundas fields no one fault controls the fluid flow but most mineralisation is within faults. The faults which are mineralised are often dilatant either because of the high fluid pressure or because of the effect of the granite intrusion on the regional stress field. Most vein systems are late syn- to post-D_1 in the Dundas Trough.

The other style of Devonian mineralisation that has produced economic mineralisation is the North Lyell style, where mesothermal fluids have remobilised the low grade disseminated mineralisation into high grade Cu pods along the fO_2 boundary at the base of the Owen Conglomerate.

SUMMARY

Most of the original aims of the project have been met. The structural history determined has been tested over a large part of Western Tasmania and produces a workable structural synthesis. The Devonian structure is essentially simple but complicated by many local variations. These variations have been produced by reactivation of older structures and complex interaction between folding and faulting.

The Cambrian structure has three distinct events. The first event was a middle Middle Cambrian extension associated with massive acid to intermediate marine volcanism. This event produced the major Cambrian mineralisation. Transfer faults active during the extension are spatially correlated with major ore deposits. The subsequent Delamerian orogeny produced E–W upright folds, locally overturned to the north, followed by N-trending open upright folds along the Dundas Trough during Owen Conglomerate deposition. The major cause of difficulties in recognising these events has been the strong Devonian overprinting. Only by detailed understanding of the Devonian structure was it possible to look through the late deformation to recognise enough of the earlier structure to recognise the pattern of Cambrian events.

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. Several of the major controversies of the Mt Lyell field have been addressed and it is now possible to correlate structures with discrete events and place the mineralising events in their correct context. A study of the North Farrell mines supported earlier conclusions that this deposit is a Devonian granite related vein system and provided additional detail on the nature of the fault controlled dilation.

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APPENDIX 1
STRUCTURAL DATA FOR WILMOT RIVER SECTION

Rock code:

1 Rhyolite dacite
2 Andesite
3 Ultramafic
4 Mafic
5 Mudstone/shale
6 Siltstone/fine sandstone
7 Sandstone/gritstone
8 Conglomerate
9 Quartzite
10 Limestone
11 Granite/porphyry
12 Lode
13 Chert

	A	B	C	D	E	F	G	H	I	J	K
1	UNIQ NO	FIELD NO.	ROCK	EAST	NORTH	BED-DIP	BED -DIP AZ.	CLEAV-DIP	CLEAV-DIP AZ	LIN-PLUNGE	LIN-AZ
2	1	WR1	7	422450	5408525	35	272				
3											
4											
5	2	WR2	7	422380	5408530	43	57				
6	3	WR3	6	422380	5408660	52	247				
7	4	WR4	7	422360	5408740	35	147				
8	5	WR5	7	422350	5408800	28	47	80	270		
9	6	WR6	6	422400	5408880	38	72				
10						25	234			10	
11	7	WR7	7	422500	5408900						142
12	8	WR8	7	422560	5408910						
13	9	WR9	7	422690	5408940	70	252			28	
14	10	WR10	7	422730	5408980					15	142
15										24	187
16	11	WR11	7	422820	5409050					8	147
17	12	WR12	7	422940	5409110						148
18	13	WR13	7	423075	5409150						
19	14	WR14	7	423110	5409220						
20											
21	15	WR15	7	423180	5409400	60	182				
22											
23											
24											
25	16	WR16	7	423200	5409600			80	213		
26	17	WR17	10	422480	5408560						
27	18	WR18	7	422830	5408530						
28											
29	19	WR19	1	423860	5411700						
30	20	WR20	7	424000	5412135	83	27	72	234		
31	21	WR21	7	423940	5412170						
32											
33											
34	22	WR22	7	423960	5412230			90	44		
35	23	WR23	8	423940	5412350	45	52	53	42		
36										61	
37	24	WR24	5	423910	5412300			80	45		112
38	25	WR25	5	425360	5418790	29	147	80	20		
39						50	32	85	192		
40						61	200	85	2		
41										33	
42	26	WR26	5	425460	5418885	35	177			54	164
43	27	WR27	5	425550	5418940	21	162				162
44	28	WR28	8	425615	5418950					58	
45	29	WR29	7	425830	5418940	84	182	90	211	51	110
46	30	WR30	8	425850	5419000	74	200	80	34		132
47	31	WR31	7	425760	5419170	85	190	90	52		
48											
49											
50	32	WR32	6	425760	5419400	90	27	80	252		
51	33	WR33	5	425915	5419540	80	190	80	24		
52	34	WR34	6	425730	5418800	78	180	88	57	61	
53	35	WR35	6	425740	5418760	78	186	90	37		127
54	36	WR36	6	425775	5418675	76	189			57	
55	37	WR37	6	425800	5418660						117
56	38	WR38	8	425850	5418650	85	190			57	
57	39	WR39	7	425980	5418740	76	197				102
58	40	WR40	7	426330	5418810	85	111				
59	41	WR41	1	426315	5418740						
60	42	WR42	7	429670	5421660	57	358			80	
61	43	WR43	7	429550	5421550	65	24	77	34		12
62	44	WR44	7	429400	5421390	61	27			72	
63	45	WR45	6	429340	5421240	85	10				32
64	46	WR46	5	429140	5421075						
65	47	WR47	6	429115	5421065	47	162	80	274		
66	48	WR48	7	429040	5421090	60	252				
67	49	WR49	7	428950	5421100	80	171				
68	50	WR50	6	428670	5421010	82	262				
69	51	WR51	6	428615	5420770	55	187			42	
70	52	WR52	6	429760	5421380	47	62				102
71	53	WR53	7	432360	5423770	50	176				
72	54	WR54	6	432510	5423950	43	174				
73	55	WR55	3	432560	5424125						
74	56	WR56	7	432570	5424670	55	187				
75	57	WR57	7	432770	5424800	36	212	87	68		
76	58	WR58	7	433355	5424975	20	152				
77	59	WR59	7	433890	5425330	42	32				
78	60	WR60	7	434025	5425450			87	212		
79	61	WR61	7	434215	5425705	60	302				
80	62	WR62	7	434270	5426145	68	268				
81	63	WR63	7	430000	5421680	37	8				
82											
83	64	WR64	6	434350	5426410	30	89				
84	65	WR65	6	434380	5426475	46	162				
85	66	WR66	7	434460	5426520						

	A	B	C	D	E	F	G	H	I	J	K
86	67	WR67	5	434500	5426680	33	52				
87	68	WR68	13	434490	5426860	67	67				
88						48	40				
89	69	WR69	6	434335	5427315	59	50				
90	70	WR70	6	434515	5428690	63	152				
91	71	WR71	6	434460	5429000	16	334	87	52		
92	72	WR72	6	434565	5429190	39	172				
93	73	WR73	7	434480	5429220	41	125				
94	74	WR74	5	434520	5429300	38	187				
95	75	WR75	5	434550	5429530	40	198				
96	76	WR76	13	434525	5429850	56	197				
97	77	WR77	5	434710	5430130	77	202	55	244		
98											
99	78	WR78	13	434600	5430100						
100											
101											
102	79	WR79	13	434760	5430095	45	197				
103	80	WR80	13	435470	5430160	45	197				
104	81	WR81	7	435360	5430140						
105	82	WR82	13	435650	5430160	49	194				
106											
107	83	WR83	13	436340	5430015			69	302		
108	84	WR84	13	436400	5429990	47	198				
109	85	WR85	6	436890	5430375	51	184	57	307		
110	86	WR86	13	436970	5430320	63	167	60	293		
111	87	WR87	9	436930	5436000			50	230		
112										28	
113	88	C1	8	430900	5406150	60	227	75	17		112
114											
115	89	C2	8	430525	5406610	38	162				
116	90	C3	6	431090	5406750			80	52		
117								62	228		
118	91	C4	11	427780	5408040						
119	92	C5	1	432070	5408025						
120	93	D1	7	424650	5406190	5	2	88	172		
121								77	270		
122	94	D2	6	424620	5406175			85	45		
123	95	D3	1	425400	5406120	33	335	71	35		
124	96	D4	11	425260	5405920			90	50		
125	97	D5	11	425140	5405750						
126											
127										82	
128	98	D6	7	425270	5404240	16	262				92
129						40	40				
130						33	30				
131						16	282				
132											
133	99	I1	10	421330	5406970	25	55	76	38		
134	100	I2	6	421380	5406720	25	57				
135	101	I3	7	421340	5406640						
136	102	I4	5	421390	5406540	30	92	90	102		
137	103	I5	10	421395	5406450	10	282				
138	104	I6	10	421400	5406390	18	4				
139	105	I7	5	421370	5406340	15	240				
140	106	I8	5	421295	5406100	21	47				
141	107	I9	9	421290	5405950	29	44	77	223		
142	108	WR88	6	438325	5430900	66	107				
143	109	WR89	6	438340	5431000	51	108				
144	110	WR90	7	438750	5432230	15	112				
145	111	WR91	6	437360	5430960			85	216		
146	112	WR92	7	437580	5431070						
147	113	WR93	6	437440	5430700						
148	114	WR94	6	437475	5430820	55	93				
149											
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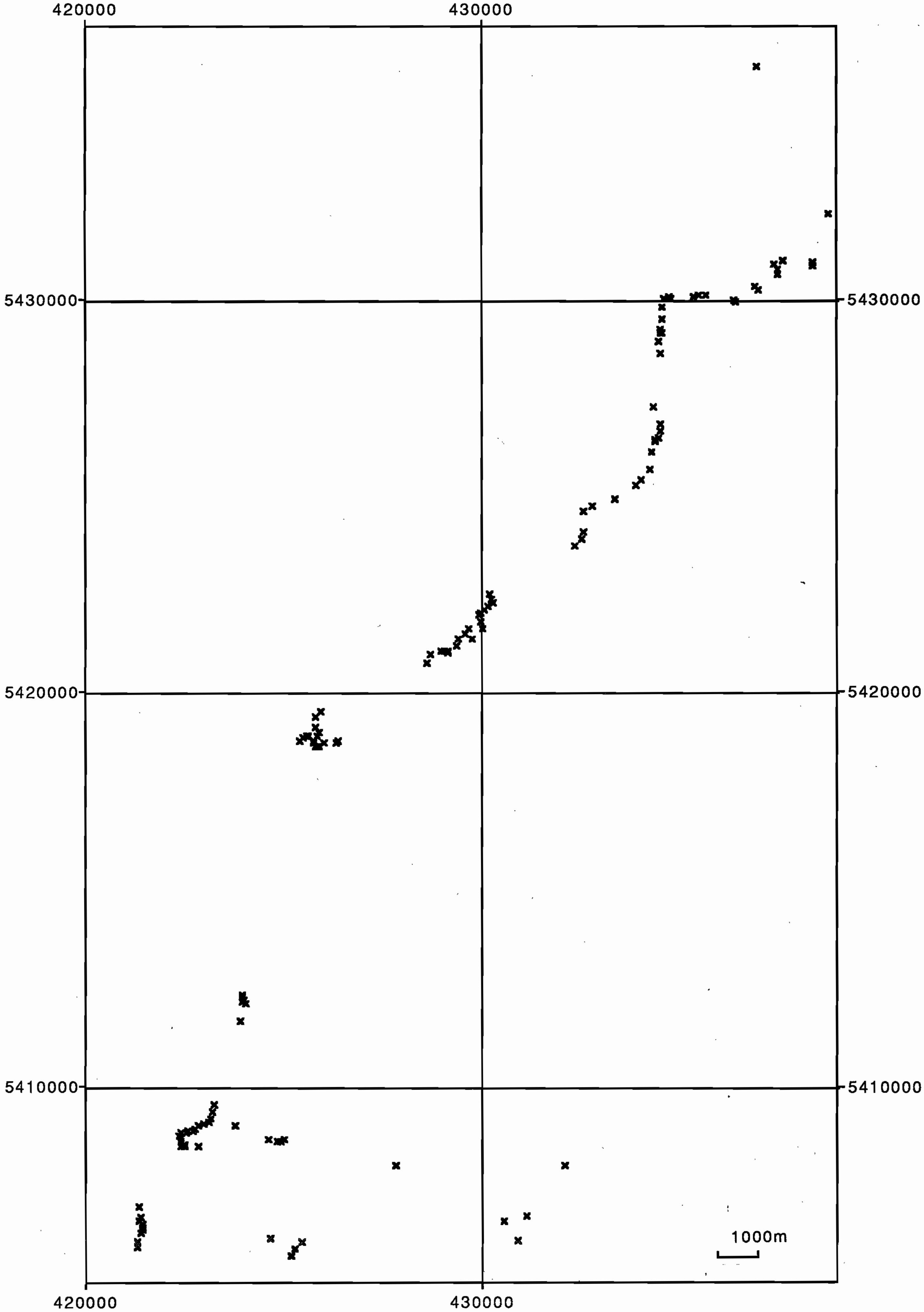
152	116	WR96	1	429960	5422050	71	43				
153											
154	117	WR97		430070	5422150						
155	118	WR98	6	430150	5422230	71	184	87	222		
156						63	137				
157	119	WR99	6	430250	5422340	70	164			40	
158	120	WR100	6	430230	5422420	78	157	81	17		109
159										56	
160	121	WR101	6	430170	5422530	55	154				120
161	122	WR102	1	429900	5422000	43	174				
162	123	BM1	7	423765	5409060	55	47	88	247		
163	124	BM2	7	424580	5408700			88	244		
164	125	BM3	7	424810	5408670			88	80		
165	126	BM4	7	424900	5408680						
166	127	BM5	7	424960	5408690						
167											

	L	M	N	O	P	Q	R	S	T
1	FAULT-STRIKE	FAULT-DIP	FAULT-DIP.AZ	FLT-PITCH	MOVE/DIR	QV-DIP	QV -DIP AZ	QTZ FIB-DIP	QFIB-DIP AZ
2	102	85	S	90	REV/N-B-D				
3	182	80	E	10	DEXT				
4	305	90		90	N-B-D				
5						57	242	40	37
6									
7									
8						50	232	15	32
9									
10									
11						63	24	36	220
12						62	232	15	52
13									
14	357	70	W	75	REV				
15	177	88	E	90	REV/W-B-D				
16									
17	12	18	E	40	REV/DEXT	78	30		
18	157	75	S	20	SIN				
19	150	76	E						
20	138	90		80	N-B-D				
21	272	75	N	75	REV				
22	342	77	W						
23	107	90		15	SIN				
24	272	60	W	80	REV				
25									
26									
27	128	90		3	DEXT				
28	308	90		65	S-B-D/DEXT				
29									
30	332	80	W		DEXT				
31	332	80	E	5	SIN				
32	152	80	E	75					
33	37	40	W	0	DEXT				
34									
35	150	90		55	N-B-D/DEXT				
36	232	12	W	0	SIN				
37									
38									
39									
40									
41									
42									
43									
44									
45									
46	127	75	E		REV				
47	102	37	N	50	REV/SIN	45	247	47	60
48	282	37	N	70	REV				
49	330	90		15	DEXT				
50									
51									
52									
53									
54	279	76	S		SIN	78	62		
55	134	35	E	90	REV				
56									
57	42	38	E	75	NOR				
58									
59	184	36	W	35	REV/DEXT	56	258	22	82
60									
61	147	79	E	25	SIN				
62									
63									
64									
65									
66									
67									
68	357	82	W	30	SIN				
69	97	55	S	20	SIN				
70									
71									
72									
73									
74									
75									
76									
77									
78									
79									
80									
81	14	80	E	35	SIN				
82	17	45	E	30	SIN				
83									
84	308	70	S						
85									

	L	M	N	O	P	Q	R	S	T
86									
87	267	60	S		NOR?				
88									
89									
90									
91									
92									
93									
94									
95									
96									
97	207	90							
98	211	90							
99	120	61	N		REV				
100	122	80	N	40	REV/SIN				
101	347	80	W						
102	207	80	E		E-B-D/NOR?				
103									
104									
105	224	51	E	50	REV/SIN				
106	320	88	S		SW-B-D				
107									
108	172	90							
109									
110	262	48	S	45	NOR/DEXT				
111	148	65	E	10	DEXT				
112									
113	137	60	S	70	REV				
114	317	60	S	65	REV				
115	202	68	E	0	SIN				
116	114	50	N	80	REV				
117	190	80	E		DEXT				
118									
119									
120						78	237		
121									
122						65	165		
123	103	56	N	70	REV				
124									
125	307	70	S		NBD	70	217		
126						70	196		
127									
128	174	80	E	0	DEXT				
129	174	80	E	40	DEXT/NOR				
130	144	90			NE-B-D				
131	123	80	E	10	SIN				
132	202	7	W	80	REV				
133	300	70	S		S-B-D				
134									
135									
136									
137									
138									
139									
140									
141									
142	348	70	E	25	SIN				
143									
144									
145									
146									
147									
148	126	30	E	80	NOR				
149	163	87	W	10	SIN				
150									
151									
152	70	70	S	20	DEXT				
153	185	53	E	0	DEXT				
154									
155	312	87	S		SIN				
156									
157									
158	87	82	S		SIN				
159	328	65	W		DEXT				
160									
161									
162	322	81	S	90	REV				
163	332	62	S	90	REV				
164	48	61	S	45	REV/DEXT				
165	285	89	S	90	REV				
166	42	35	S	15	DEXT				
167	322	33	S	75	REV				

APPENDIX 2
MAP OF STRUCTURAL STATIONS: WILMOT RIVER TRAVERSE


420000
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