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The 10th Legion Thrust, Zeehan District:

Distribution, interpretation, and regional and economic significance

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Abstract

The 10th Legion Thrust (to the west of Zeehan) is an extensive fault which juxtaposes units of the Precambrian Oonah Formation over rocks of probable Cambrian to Devonian age. The fault commonly dips shallowly in the south although dips vary because of subsequent folding. Kinematic indicators suggest southward-directed transport. The implications of interpreting the Oonah Formation of the Zeehan area as a thrust sheet are presented.

INTRODUCTION

This report stems from fieldwork by RHF during the 1989–90 and 1990–91 field seasons as part of the revision of the 1:63 360 Zeehan geological map sheet, and extensive work by AVB to the west of the 10th Legion–South Comstock Mine region (fig. 1).

The discovery of a thrust sheet of Precambrian rocks overlying Cambrian beds in the Sorell Peninsula (McClenaghan and Findlay, 1989) has raised the possibility of low-angle thrust relationships between Precambrian and Lower Palaeozoic rocks occurring elsewhere in western Tasmania. This report identifies, for the first time, regional thrust relations between the Precambrian Oonah Formation and younger rock sequences in the Zeehan area, and extends the previous implications discussed in Brown *et al.* (1991) for interpreting the three-dimensional rock distribution in the west Tasmanian mineral belt.

THE 10th LEGION THRUST

Distribution and outcrop data

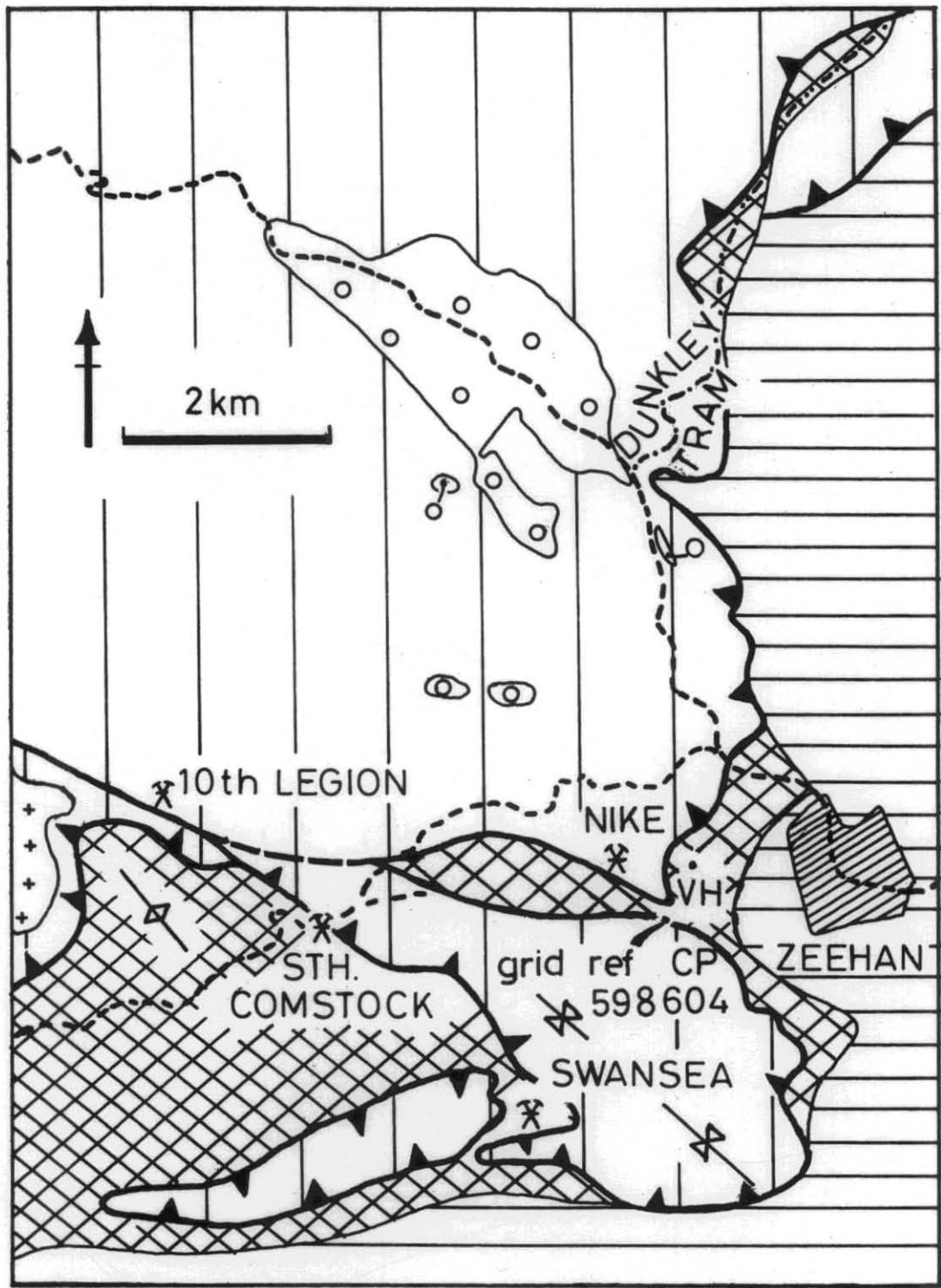
The 10th Legion Thrust has been mapped in considerable detail between the 10th Legion and Swansea Mines and north along the Dunkley Tram valley (figs 1 and 2). In the region between the 10th Legion and Swansea Mines the mapped outcrop trace of the fault is based on the numerous closely-spaced road cuts, quarries, disused adits and old costeans common throughout this area (fig. 2). In every

instance here, the Precambrian rocks form the higher ground overlooking the fault, whereas rocks of probable Cambrian age form the lower ground.

Between the South Comstock and Swansea Mines (fig. 2) the sinuous outcrop trace of the fault follows the topographic contours, indicating that here the 10th Legion Fault is of very low angle. At the South Comstock Mine and to the northwest, the dip steepens to about 45°. West of the Swansea Mine Blissett and Gulline (1962) and co-workers mapped a large fault-bound packet of Precambrian rocks (fig. 1). Here, remapping by AVB shows that, as to the east, the Precambrian rocks occupy the high ground whereas the probably Cambrian units form the low ground, and that the contact between the two sequences follows the topographic contours. Therefore, it is interpreted here that these Precambrian rocks form a klippe underlain by the western extension of the 10th Legion Thrust.

The 10th Legion Thrust is also interpreted as extending along the eastern side of the Precambrian outcrop between the Swansea Mine and Zeehan (fig. 1). Here, the Precambrian rocks are faulted against Cambrian and Ordovician rocks (Blissett and Gulline, 1962). In this area too the contact between the Precambrian and Cambrian sequences tends to follow the topographic contours, and the fault here must therefore be of shallow dip. In addition, company drill-hole data demonstrate that in the region of the Nubeena and Swansea Mines (fig. 2) the Oonah Formation overlies a volcano-sedimentary sequence containing mafic rocks closely resembling mafic volcanic rocks of known Cambrian age elsewhere. That is, in this region, the Oonah Formation can be interpreted as a 200–300 m thick thrust sheet.

North of Zeehan, the fault contact between the Oonah Formation and the Cambrian rocks follows the valley of the Dunkley Tram (fig. 1). Rather sparse outcrops, including spherulitic acid volcanic rocks, indicate that this valley is floored by rocks of probable Cambrian and Ordovician age. Again the Precambrian rocks form the high ground and the fault follows the topographic contours; that is, the fault is likely to dip at a shallow angle.



- | | | | |
|---|---|--|---------------------|
|  | Permian tillite |  | Cambrian rocks |
|  | Devonian granite |  | Oonah Formation |
|  | Ordovician – Devonian sedimentary rocks |  | inferred thrust |
| | |  | fault |
| | |  | geological boundary |

5 cm

Figure 1.

Regional geological summary map showing mapped extent of 10th Legion Thrust.
 VH = Vanoaness Hill.

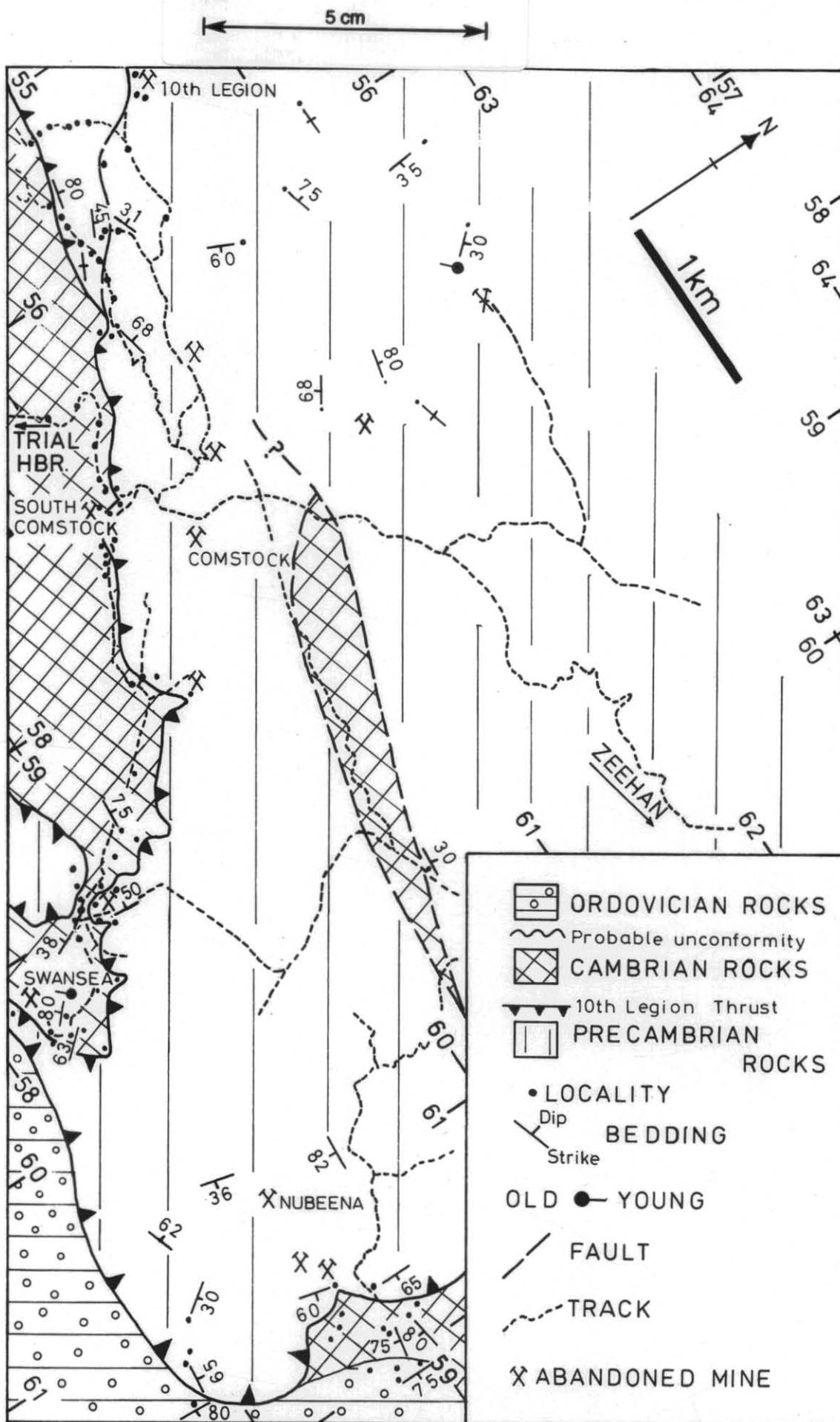


Figure 2.

Geological map summarising geological information along outcrop of 10th Legion Thrust between the 10th Legion Mine and Zeehan.

These data, summarised in Figure 1, indicate that the 10th Legion Fault as mapped by Blissett and Gulline (1962) is better interpreted as part of a regional thrust, and that the Oonah Formation rocks of the Zeehan district may be interpreted as forming part of a regional thrust sheet; the regional implications of this interpretation are discussed later.

Kinematics and structural history of the 10th Legion Thrust

The contact between the upper and lower plates is marked by a fault rock formed of the cataclastically deformed and sheared derivatives of the overlying and underlying units.

Although the distribution of the fault can be mapped readily and with accuracy, there are very few localities where this fault rock is exposed in its entire thickness and where the upper and lower plates can be seen in a continuous exposure. The best continuous exposure occurs at the recently re-excavated South Comstock Mine (figs 2, 3), and the data bearing on the kinematics of the fault are drawn principally from this exposure and are summarised in Figure 3.

SOUTH COMSTOCK MINE

The fault rock is about 15–20 m thick and forms a black to grey finely comminuted schistose unit containing phacoids of various sizes of the overlying and underlying units. The latter include locally tectonised, probably boninitic pillow lavas; these rocks form the mafic volcanic units in the bird's-eye sketch of the exposure at the South Comstock Mine (fig. 3).

The Oonah Formation rocks overlying the fault rock are complexly folded (Findlay, in prep. *a*) and faulted; the faulting, as exemplified by the N-S sketch section in Figure 3, dies out in intensity northwards away from the fault rock. Structures resembling a dextral C-S fabric occur at and within the upper margin of the fault rock (fig. 3, inset 1). Although it could be argued that these structures are part of the lower limb of a southward-closing recumbent fold, and folded transposed isoclinal-like folds have been

identified here (fig. 3, inset 2), the style of deformation given in inset 1 has not been recognised further north in the rocks forming the upper plate; that is, this style of deformation is regarded as restricted locally to the 10th Legion Thrust. Secondly, a dextral C-S fabric of similar geometry and of millimetre to centimetre scale has been recognised by RHF and colleagues in the fault rock near Adit 'b' at the South Comstock Mine (fig. 3). The geometry of this fabric is identical to that which occurs on a larger scale in inset 1, Figure 3. The C-planes dip variably but generally shallowly north, and the dextral geometry of the C-S fabric indicates southeastward transport.

In Figure 3, stereonet A shows the distribution of poles to the C planes; two possible great circle distributions may be discerned, one whose pole (βA) plunges shallowly north, and another whose pole (βB) plunges shallowly northwest. These data suggest folding of the C-S fabric about recognised fold directions within the Oonah Formation (Findlay in prep. *a, b*) and elsewhere in the younger rocks of the Zeehan area (Blissett and Gulline, 1962). Five bedding readings from folded chert beds below the fault rock (inset 3, fig. 3) follow the great circle B in Stereonet A and form part of a fold plunging 45° to 320° parallel to βB , thus supporting the contention that the C-S fabric could be folded.

Stereonet B in Figure 3 gives bedding measurements within the Oonah Formation of the upper plate along the Road between the South Comstock Mine and the Trial Harbour road (see N-S sketch cross-section, fig. 3). Again, northwest and north-plunging fold trends are discernible; the distribution of the five crenulation lineations measured may indicate folding of the northwest-trending folds by the northerly trend.

Stereonet C (fig. 3) gives all fault orientations measured between the South Comstock Mine and the Trial Harbour road. Although the majority of these faults are from the upper plate, there is no obvious distinction in orientation between faults within the upper and lower plates. These measurements confirm a wide range of dips for the faults, between $40\text{--}80^\circ$ west to $20\text{--}60^\circ$ east. Within this range there is no obvious principal single orientation, although a

Figure 3.

Top sketch: Bird's-eye view of South Comstock Mine area (see legend for rock types).

Bottom sketch: Summary of structures exposed in road north of South Comstock Mine, showing faulting in upper plate immediately overlying the fault rock. Section 40 m long.

Inset 1: C-S structures in rocks of upper plate immediately overlying fault rock.

Inset 2: Transposed isoclinal fold at margin of upper plate and fault rock; the age of this structure relative to thrusting is uncertain; bedding is transposed along a penetrative fabric generally parallel to the S-fabric of the fault rock and the structure is folded by a northward-trending fold.

Inset 3: NW-trending fold in lower plate within layered chert-siltstone-mafic volcanic sequence.

Stereonet A: Poles to C-planes (solid circles) and bedding (open circles) of fold in inset 3. Likely statistical fold axes shown.

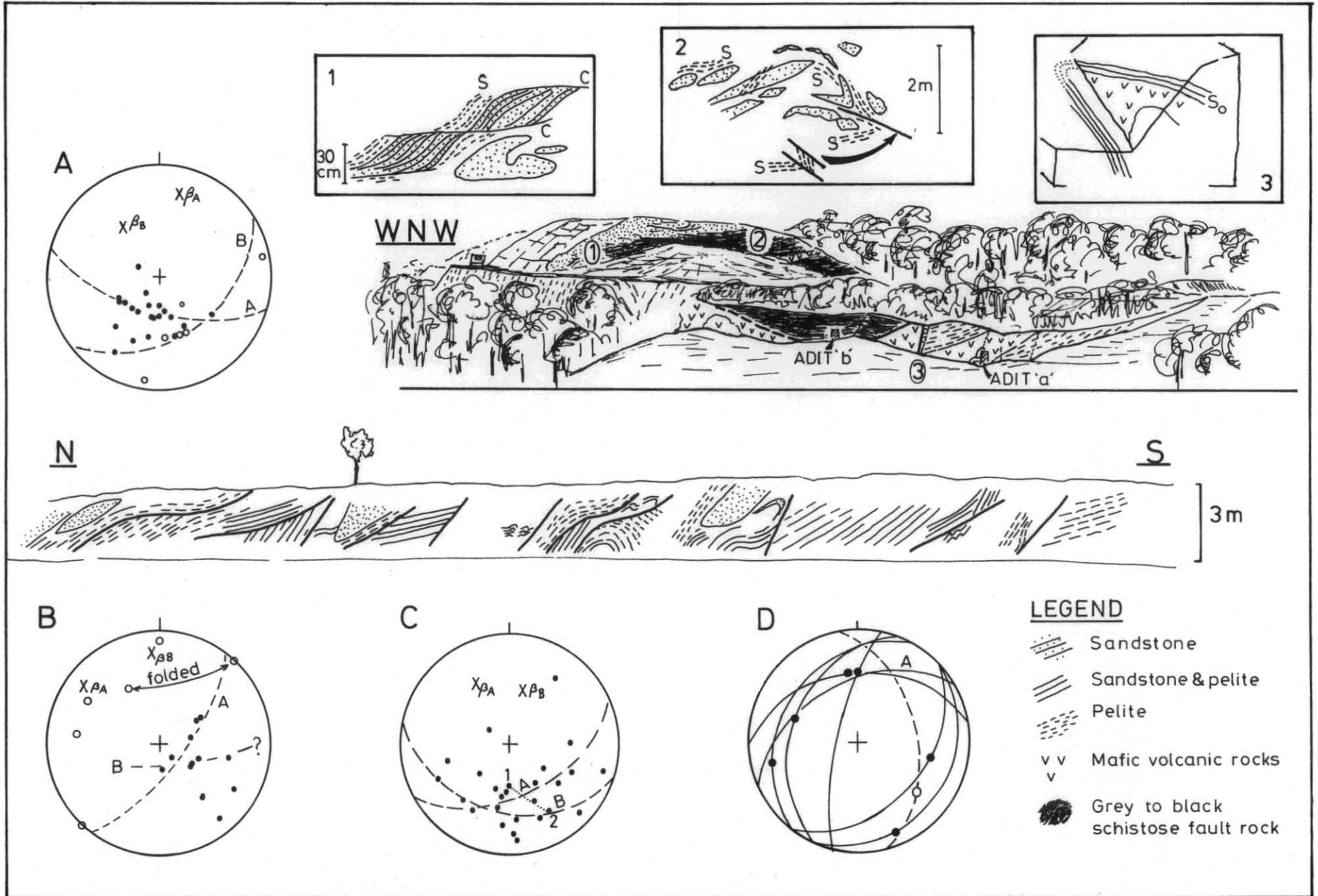
Stereonet B: Poles to schistosity (solid circles), commonly parallel to bedding, in the pelitic units in lower sketch section (upper plate rocks). Open circles are crenulation lineations possibly associated with folding on north and northwest trends; note one crenulation lineation is folded, as shown.

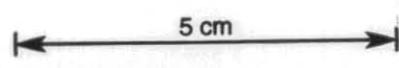
Stereonet C: Poles to all faults. Faults 1 and 2 (linked by dotted line) form a fault splay with an interfault angle of 36° .

Stereonet D: Solid great circles with solid circles are faults carrying quartz-fibre striations. The broken great circle represents a tension gash array thought related to slip on fault A, with open circle showing orientation of compression axis.

All stereonet projections are equal-area southern-hemisphere projections.

Figure 3.





northerly-dipping group is dominant. Rather, even given the likelihood of complex fault arrays in this tectonic environment, it is reasonable to propose distribution of fault orientations along two great circle girdles (A and B, stereonet C). This raises the possibility that the faults have been folded by the north and northwest-trending folding discussed above.

Stereonet D (fig. 3) presents the orientations of minor faults bearing quartz-fibre striations and one fault with spatially-related tension gashes; these structures occur within the upper and lower margins of the fault rock. Minor faults, carrying striations on which the sense of slip is known, have long been recognised as useful in identifying the regional stress tensor (Bott, 1959; Angelier and Mechler, 1977; Findlay, 1980; Etchecopar *et al.*, 1981; Angelier, 1984). Although the slip sense on the observed striations could not be determined, and the data in stereonet D are too few for adequate statistical analysis, these faults do suggest a dip-slip regime, given their present orientation. The fault-tension gash system is indicative of a NW-SE directed stress system. Combining the two sets of data leads to the interpretation that these faults formed in a reverse fault system with a NW-SE directed stress tensor. It is emphasised strongly that this interpretation rests on simplistic assumptions concerning the mechanics of faulting and that it does not take into account the previously described multiple folding.

NIKE MINE AREA

Blissett and Gulline (1962) mapped a sliver of Cambrian rocks striking west from Vanoaness Hill (fig. 1) to the Trial Harbour Road. The southern contact between these rocks and the Oonah Formation to the south is exposed in a track cutting at grid reference CP598604, due south of the Nike Mine (fig. 1). Here the fault contact dips steeply south, and the fault rock is relatively thin. At the contact, quartz-fibre striations on three minor faults indicate reverse dip slip (fig. 4), as does the geometry of the C-S fabric within the fault rock.

This fault was mapped initially as an inferred splay off the Balstrup Fault (Blissett and Gulline, 1962). However, given our conclusions that the 10th Legion Thrust controls the outcrop of the south-trending "tongue" of Oonah Formation in the Zeehan area (fig. 1), it is reasonable to regard the exposure at CP598604 as displaying part of the thrust, here tilted to a steep southerly dip. Note that simple rotation of the C-plane in Figure 4 to shallow or zero dips would produce a shallowly-dipping C-S fabric with the same movement sense (dextral) as that seen at the South Comstock Mine.

Age of 10th Legion Thrust

The 10th Legion Thrust cuts across units ranging in age from Cambrian to Lower Devonian, and appears to be folded on both a small and regional (fig. 1) scale by the same north and northwest-trending folds which occur in these units (Blissett and Gulline, 1962) and which are attributed by Williams (1978) to the late Early to middle Middle Devonian Tabberabberan Orogeny. The Oonah Formation is intruded by the Heemskirk Granite, which is likely to extend under and east of the thrust sheet to meet with the Housetop Granite some 60 km east (Richardson

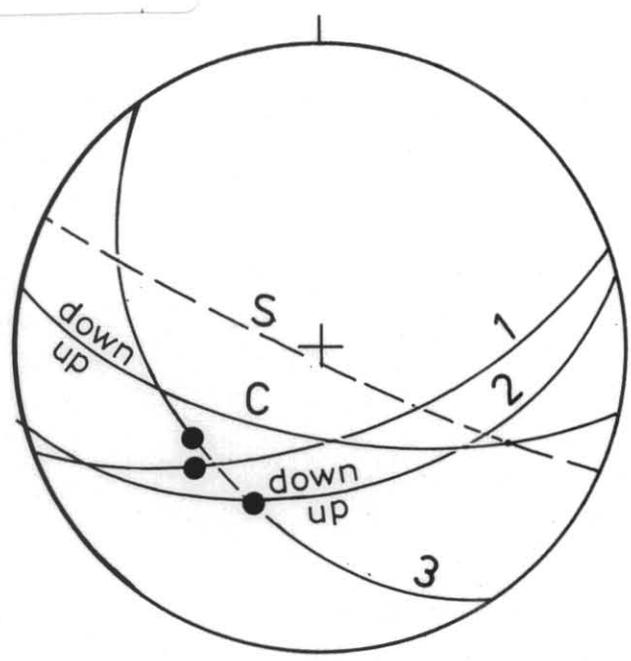


Figure 4.

Equal area lower-hemisphere stereographic plot of S and C-planes and faults (1, 2, 3) with quartz-fibre striations (solid circles) on faults at grid reference CP598604.

and Leaman, 1987). These two granitic bodies therefore "pin" the thrust and as their ages range between 330 and 380 Ma, with the overlap in respective ages spanning the range 345-360 Ma (McClenaghan *et al.*, 1989), thrusting occurred before Late Devonian/ Carboniferous times.

In the Zeehan district the extensive Sn-Pb-Ag-Zn mineralisation is associated with the Heemskirk Granite (Blissett, 1962). Many of the orebodies strike between NNW and NNE and follow zones of faulting, shearing and fracture resulting from the Tabberabberan deformation (Blissett, 1962); however Blissett also states that the orebodies have been dislocated by post-Permian faults and thrusts. As the relationship between the faults described by Blissett (1962) and the 10th Legion Thrust has not been determined, it is the relationship between the north and northwest-trending folding and the 10th Legion Thrust that is critical; our present view is that as the thrust precedes these folds it represents an early phase of Tabberabberan deformation.

REGIONAL IMPLICATIONS

The recognition that the southern outcrop trace of the Oonah Formation is controlled by thrusting of probably Early to Middle Devonian age has major implications for the interpretation of the Precambrian to Upper Palaeozoic geology of western Tasmania. These implications include the following:

1. If the Oonah Formation is a thin thrust sheet, does it override Cambrian and Ordovician beds of economic importance? Note that:
 - (1) acid volcanic rocks of probable Cambrian age and carbonate-bearing Ordovician units are known in the Dunkley Tram valley;

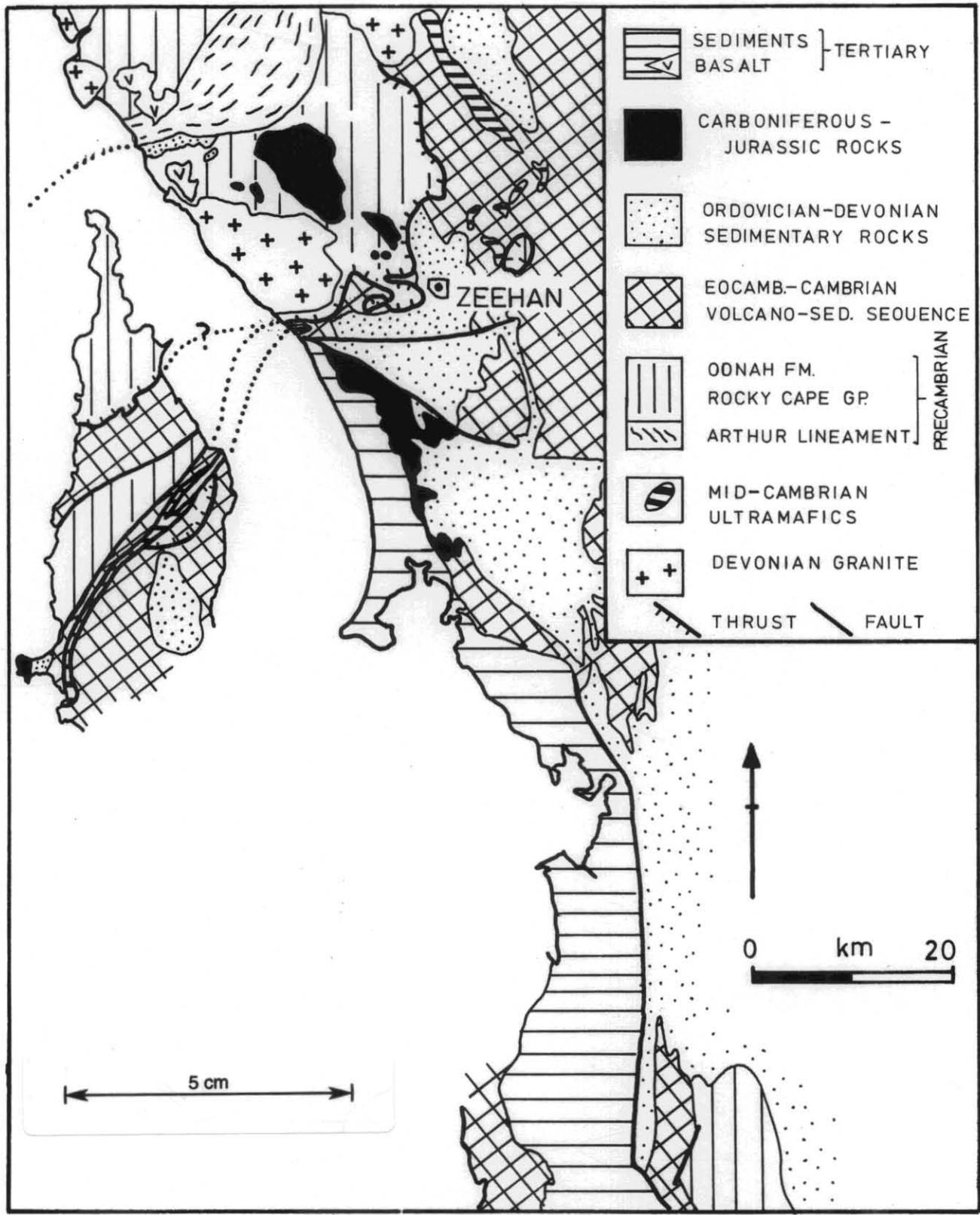


Figure 5.

Interpretation of probable pre-Carboniferous configuration of rocks assuming correlation of the serpentinite belt of the Sorell Peninsula with that at Trial Harbour, and that the Precambrian thrust sheet in the Sorell Peninsula forms part of the Oonah thrust sheet. Post-Carboniferous units marked for geographical reference purposes.

- (2) carbonate-bearing Ordovician units are known from the Zeehan area, where they appear to be overthrust by the Oonah Formation.
- If the Oonah Formation is a thin thrust sheet, then the isolated outcrops of Precambrian rocks within the Cambrian volcano-sedimentary sequence of the Dundas trough, such as the Concert Schist (Turner, 1979), may be klippen derived from this thrust sheet.
 - Do the thrust Precambrian rocks of the Sorell Peninsula region form part of this thrust system? If so there could well be a major sinistral strike-slip fault intervening between the Zeehan and Sorell Peninsula regions (fig. 5), and the thrust event has involved at least two sedimentologically distinct Precambrian units, such as are recognised in the Sorell Peninsula (McClenaghan and Findlay, 1989).
 - The internal structure of the Oonah Formation has not been resolved completely and nor has its sedimentology. Could this unit be formed of several thrust slices and could it incorporate units of the Rocky Cape Group (see above and fig. 5)?
 - Burns (1964) described thrusting in Lower Palaeozoic rocks of northern Tasmania. This occurred during the earliest phase of the Tabberabberan Orogeny, and minor thrusts were also formed during the last phase of this event. If this early thrusting, the thrusting described herein, and that seen in the Sorell Peninsula are contemporaneous, then this thrust event must be regarded as a regional, early feature of the Tabberabberan Orogeny; this has important implications for minerals exploration programmes.
 - Extending the idea to its full limits, do our data confirm the geophysical interpretations of Richardson and Leaman (1987) that the Precambrian rocks forming both the Rocky Cape and Tyennan Regions are thin thrust sheets, but of a younger age than supposed by these workers?

CONCLUSIONS

The Oonah Formation of the Zeehan area is interpreted as forming a thin thrust sheet overlying the Early Palaeozoic sequence. This sequence may include Cambrian acid/andesitic volcanic rocks which elsewhere host extensive gold and copper mineralisation, and also includes Ordovician carbonate beds which could well act as hosts for Devonian Sn-Pb-Ag-Zn mineralisation. In the Swansea-Nubeena Mine area, the thrust sheet is thought to be about 200–300 m thick; if this is representative of the thrust sheet as a whole then the entire area covered by Oonah Formation rocks must be regarded as prospective.

As outlined in the preceding section, the interpretation that the Oonah Formation is a Tabberabberan thrust sheet has profound implications for the interpretation of the 3-dimensional distribution of the Lower Palaeozoic sequences of western Tasmania. Similar thrusting is possible at any stratigraphic level; the subsequent folding and faulting could well have brought any of the mineralised units of western Tasmania into near-surface regions.

Finally the recognition that intra-Devonian thrusting occurs as far afield as Devonport, Zeehan and the Sorell

Peninsula, and that this thrusting involves Precambrian rocks, means that extensive thrusting of other Precambrian units is a distinct possibility. Thus areas previously thought unprospective for minerals require rigorous studies of the regional structural geology as part of future exploration programmes.

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