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CONTENTS

An excursion guide for the Mt Lyell Mining Lease with emphasis on the Great Lyell Fault, Haulage Unconformity and North Lyell alteration

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ABSTRACT

The Devonian deformation at Mt Lyell includes early N–S trending folds, NNW trending folds (D_1), low angle north directed thrusting and high reverse faults with associated steep cleavage(D_2). The pattern of these structures is recognisable but where they interact closely as in North Lyell there is still some problems in unravelling the geometry. Many of the relationships which were used to define these phases are exposed on the Lyell leases.

The Haulage Unconformity is related to relatively shallow dips to the east and the geometry is compatible with a normal fault margin. However regional data is supports a more active tectonic setting in the late Cambrian and structure may vary very rapidly in both time and space.

The age of the North Lyell alteration is less well constrained. Both S_1 and S_2 are visible in the altered Owen Conglomerate. The alteration does penetrate into Pioneer Sandstone and possibly into Gordon Limestone but the intensity drops of sharply at the contact suggesting that either the alteration is nearly finished at "Haulage time" or two stages of alteration are required.

INTRODUCTION

Day 1 of this field meeting is designed to look at field relationships critical to the interpretation of the North Lyell ore bodies and the structure of the Lyell Mining field. Many of these relationships have been discussed in the previous report and they are only summarised here.

The field excursion concentrates on exposures relevant to the origin of the North Lyell ore bodies and the style of Devonian deformation.

SUMMARY OF PREVIOUS RESULTS

1. *Two phases of Devonian faulting* were recognised and these are consistent with the regional fault pattern of western Tasmania. The later phase (D_2) changes from upright tight folds in the Siluro-Devonian sediments to steep reverse faults in the Central V,olcanic 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 across Philosophers Ridge. elsewhere the S_2 can be recognised overprinting S_1. 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.

The early phase (D_1) is related to thrusting north and south of the Lyell alteration zone but mainly folding over the mineralised area. Major transfer zones are associated with this change in style.

Unfolding the Devonian structures, suggests there was a Late Cambrian normal fault margin to the basin of Owen Conglomerate deposition which has a complicated shape. The Haulage unconformity appears to be related to normal drag on this fault margin. The high grade oxidised ores of the North Lyell area are spatially related to the fault pattern interpreted for the late Cambrian. Field relationships suggest the vast majority of alteration associated with this mineralising event pre-dates the deposition of the Pioneer Sandstone. It certainly pre-dates both phases of Devonian cleavage. The most obvious interpretation for these bodies is that they form where reduced hot mineralised fluids are focused up along the normal faults at the margin of the Owen basin and react with cooler oxidised connate water resulting from dewatering of the Owen Conglomerate. The result is replacement deposits on or near the Owen/ volcanic contact.

2. *North Lyell Fault*

- Western segment: D_1 sinistral wrench movement, strongly reactivated as a reverse fault during D_2
- Eastern segment has split into two parts
  — northern fault trace strong D_1 sinistral wrench, weak D_2 normal movement.
  — southern fault trace strong D_2 reverse movement

3. *Great Lyell Fault (GLF)*

Defined as all conglomerate Lyell Schist contacts
Types:

- subparallel to bedding, little Devonian shearing, e.g. western side of Tharsis Ridge
  eastern side of Tharsis Trough
- low angle to bedding, strong Devonian shearing e.g. eastern side of Tharsis Ridge
  the Iron Blow
- high angle to bedding, strong Devonian faulting e.g. Razorback — both sides

4. *Cleavages*

Within the Lyell leases the S_2 cleavage is closely related to faults, refracts strongly between layers and often forms a composite diamond shaped pattern.

The very strong D_2 strain in the Lyell area has obscured S_1 in most areas but it can be found in the Owen Conglomerate at a few locations (Fig. 2).

5. *Folding*

Mesoscopic F_1 (Devonian) folds were recognised at two places within the Owen Conglomerate. The major F_1 anticline west of the mine sequence is faulted out along the Glen Lyell fault

Mesoscopic F_2 folds are widespread and can be recognised in a wide range of lithologies. Large scale F_2 folds are open to gentle in the CVC.

6. *Haulage Unconformity*

The age of the unconformity is constrained to lie near the Cambro-Ordovician boundary

All perfect exposures of the contact indicate a relatively shallow dip (~40°) to the east during deposition of Pioneer sandstone

The zone of this upturn is up to 400 m wide, and known exposures of the unconformity are limited to a zone 1.5 km long

An east dipping normal fault may have produced the Haulage Unconformity

7. *Silica sericite hematite barite alteration on the GLF* is closely associated with the North Lyell mineralisation

This style of alteration stops abruptly against the Haulage Unconformity at most outcrops

Both S_1 and S_2 cleavage is found in hematite sericite altered rocks

NEW CONSTRAINTS

1. More detailed information from the Lyell area suggests that a NE direct thrust event predates the strong S_2 cleavage. This event produces most of the tight folds which have been called Haulage folds but the folds have an ESE trend in contrast to the style of upturn associated with all the perfectly exposed Haulage contacts. This thrusting is probably younger than the Haulage unconformity.

2. Work outside the Lyell Leases has increasingly supported a major deformational event at about Haulage time. For example work to the south of Queenstown supports a pre-Pioneer Sandstone thrust at the base of the Miners Ridge Sandstone. More will be said about evidence for a Cambrian deformation event in the discussion of the Howards Road area.

3. A N–S fold event predating S_1 was recognised in the area south of Queenstown but also in Bell Shale correlates in the King River. This requires a Devonian age for this folding event.

4. Further work east of the Glen Lyell Fault supports the view that this structure lies on the boundary between the east facing mine sequence and the west facing CVC at least as far north as the intersection with the East Queen River.

THE TECTONIC SETTING OF OWEN DEPOSITION

The nature of the GLF in the Lyell area still remains enigmatic and yet is critical to the understanding of the age and nature of the North Lyell mineralisation. Owen Conglomerate style deposition is typical of syn-orogenic sedimentation. The possible range of tectonic regimes controlling deposition are:

Normal Fault Regime

This pattern was favoured in the last report and the interpreted geometry explained. For example, the Reconcavo Basin, Brazil, is an extensional basin marginal to the South Atlantic (Fig.3, Ghignone & Andrade 1970). The structure of the area has many similarities to the Dundas Trough. It is roughly the same dimensions and has old basement exposed on both sides. On the eastern margin there is a very thick basement derived conglomerate with dimensions similar to the Owen Conglomerate.

Reverse Fault Regime

An alternative model is a thrust controlled Owen deposition. This model is a slight modification of that proposed by Arnold (1985). There are many examples of foreland conglomerates (very similar in depositional style to the Owen Conglomerate) which are related to thrusting. For example the Sphinx Conglomerate in the western USA (Fig. 4). The major feature of this type of conglomerate is that the sediment is derived from the upthrust block whereas in the Mt Lyell area the major source for the Owen Conglomerate is the metamorphic basement rocks to the east which would need to be interpreted as the foreland bulge.

One advantage of this model is it explains the presence and orientation of sandstone dykes better. It also fits some of the other evidence in the belt for a latest Cambrian thrust event (e.g. the 500 Ma K/Ar date on the Arthur Lineament, the thrust geometry in the Miners Ridge area, thrusting proposed for Sorell Peninsula, evidence for early deformation on the Howards road section).

Oblique-slip mobile zones

Many major wrench faults produce rapidly deposited fanglomerates in basins of the size exposed in western Tasmania. According to Reading (1980) distinctive features of oblique slip regimes are "thick but not laterally extensive sedimentary piles ...... localized uplift and erosion giving rise to unconformities of the same age as thick sedimentary fills nearby ...... extreme lateral facies variations ...... simultaneous development of extensional and compressional tectonics within the same belt ...... little or no metamorphism". Many of these features have been reported for the Mt Read Belt. A Cainozoic area of this type and with some similarities to the Mt Read belt is North Island New Zealand (Fig. 5). The orientation of sandstone dykes in the Razorback area could be interpreted as evidence for a dextral shear sense on the GLF before consolidation of the Owen Conglomerate but this may be due to later rotation. Such information as is available for orientation of Cambrian folds might be interpreted in terms of an en echelon pattern of folding (e.g. early folding in Surprise Creek Group, Clytie Cove Group and Tyler Creek beds).

CONCLUSIONS

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

The age of the North Lyell alteration is less well constrained. Both S_1 and S_2 are visible in the altered Owen Conglomerate. The alteration does penetrate into Pioneer Sandstone and possibly into Gordon Limestone but the intensity drops of sharply at the contact suggesting that either the alteration is nearly finished at "Haulage time" or two stages of alteration are required. The significance of these two options needs further consideration. The additional work arising out of discussions at the first meeting suggest that stage B in Figure 6 must be a syn- or pre-alteration thrusting rather than early in the Tabberabberan Orogeny. Alternatives are still being considered.

EXCURSION PROGRAM

Locality 1 — Crown Lyell

Starting at a steeply plunging D_2 fold in the Owen Conglomerate (Location 1a, fig 7) walk north up the North Lyell road. Alteration initially is very sericite rich. Note the extreme refraction of the S_2 cleavage between the massive sandstones and sericite altered sandstone. (This refraction from WNW to N striking is a major hazard in recognising the S_2 cleavage). The next level of alteration is extreme silicification, them a transition to silica hematite. All these rocks are considered to be Owen Conglomerate because of ghosts of the pebble textures remaining in most of them (e.g Location 1c).

The massive altered rocks are also cut by many faults. One of the best examples of multiple fault sets is displayed on this cutting (Location 1d). The zone is dominate by moderately SW dipping faults. These faults have a series of progressive movements on them which all relate to the D_2 deformation. The earliest quartz fibre veins indicate top to the north and with time the fibres shift increasingly to more NE and finally E transport directions. The interpretation here is that the earliest fibres reflect regional D_2 stress conditions but as the strain increased the relatively flat lying beds to the east shortened by folding while the steeply dipping and very thick Owen Conglomerate to the west could not fold and reacted by a range of faults which include some transport to the east in this zone reflecting its relative uplift along the thrust faults associated with the North Lyell Fault and in the North Lyell Corridor. The whole range of striations in Fig 8 a,b,c are considered to be syn-D_2 despite the fact that 3 distinct directions can be measured on the one surface. The youngest striations are sinistral reactivation of the moderately SSW dipping fault planes.

The alteration in the Owen Conglomerate contrasts with the pyrite sericite alteration in the volcanogenic rocks to the north. A small ore pod occupied the area immediately west of this hematite alteration.

Locality 2 — North Lyell

Part of the North Lyell mineralisation was immediately south of the massive hematite/barite exposed in the North Lyell area (Fig. 9). There are pods of massive pyrite to the west of this zone. There are many minor faults across this area. To the north the intensity of S_2 cleavage increases towards the North Lyell Fault.

There are faults through the massive hematite which are D_2 in style and orientation but no cleavage is developed.

Locality 3 — North end Tharsis Ridge

The northern margin of the Tharsis Ridge exposure of Owen Conglomerate is a very enigmatic structure. There are 3 segments. The western edge is largely parallel to bedding but complicated by volcanogenic material sliced in on bedding parallel faults. Mostly these faults are in a D_2 orientation.

The north section is vertical E-W and cuts across the bedding in a very brittle fashion. In the Lyell schists the cleavage is S_2 but within the Owen Conglomerate only 10 m south S_1 can be recognised nearly parallel to bedding.

The North eastern section is related to syn-D_2 oblique faulting and produces an 'overhang' of Owen Conglomerate on structure contours of the GLF. There is also a complex fault wedge of Lyell schists which is transected by S_2 and is probably due to D_1 faulting.

Along the ridge it is possible to follow individual beds of Owen Conglomerate from relatively unaltered to strongly hematite altered. Most alteration is disseminated and the syn -D2 veins show little evidence that they transported substantial hematite. There are a few steep veins striking E–W which do carry a high proportion of hematite and these may be derived from the Lyell Tharsis area. They are steep E–W whereas the D_2 veins are largely flat lying but the distinction is not clear cut and there are some hematite bearing veins in D_2 orientations. This distinction is important because it implies the GLF on the east side of Tharsis Ridge had produced the present geometry before the hematite alteration (c.f. Fig. 6).

Locality 4 — Haulage Unconformity road to Batchelors Quarry

On the road to Batchelors Quarry there is an exposure of the Great Lyell Fault which appears to be conformable. This is only 10 m from a perfect exposure of the Haulage unconformity which has a 40° angle between Pioneer sandstone and Owen Conglomerate bedding. Alteration is very strong below the unconformity and weak above it.

Locality 5 — Batchelors Quarry and waterfall

Batchelors Quarry is the classic exposure of the Haulage unconformity.
Points of interest:

- strong alteration in the Owen Conglomerate,
- weak alteration in the Pioneer,
- exact match of the block cutoffs at the unconformity,
- ?S_1 cleavage in Owen Conglomerate
- D_2 crossfault in the NW corner of the exposure,
- weathered Gordon Limestone over very thin Pioneer,
- native copper in the unit immediately above the unconformity,
- chromite in the Pioneer Sandstone.

In the creek to the west of the quarry the contact of the Pioneer with the Owen is conformable. Alteration decreases rapidly but gradationally at the contact. This is a classic area to determine (or argue about) the origin of hematite clasts in the Owen. Originally these were considered as true clasts (e.g. Solomon 1957). Arnold (1985) argued convincingly that these 'clasts' were only found in rocks with a hematite matrix and thus were an alteration effect. At this stage the latter interpretation is highly favoured here.

Further down the creek are classic examples of diamond shaped patterns within cleavage which could be considered as a single S_2 cleavage. Alternatively the syn-D_2 stress field is highly variable in the North Lyell area as might be suggested by the striations at locality 1d.

Locality 6 — Owen Tongue west of Batchelors Quarry

A major overturned tight fold (pre-S_2) strikes E–W in the area west of Batchelors Quarry (Fig. 10). The fold here has an orientation which is inconsistent with F1 but is transected by S_2 (Fig. 11). Note the strong cleavage refraction of S_2 (similar to locality 1). There is also evidence of either north-dipping (60 to 350^0) normal faults or a steep onlap surface at the contact of the Owen Conglomerate (Fig. 12)

Locality 7 — Pre-S_2 thrusting

The cross faulting in the north Lyell zone has a complex geometry. A well exposed section east of Prince Lyell has pre-S_2 folding which has produced downward facing beds in the Owen Conglomerate (Fig.13). These folds have usually been attributed to the Haulage movement. However the fold axes are not north– south and the geometry of the faults is never reproduced on well exposed contacts of the Haulage unconformity. If time permits we will also look at a poorly exposed example of the Haulage unconformity which has been used to suggest that the thrusting represented by this structure occurred at the Cambro-Ordovician boundary.

Locality 8 — Conformable GLF contact

Due south of this contact the GLF is exposed as an apparently conformable contact with no evidence of strain.

There is no evidence for Devonian fault movement on this zone. Pebbles project from the base of the basal sandstone and are not truncated. The 5 m of volcanics immediately beneath this surface are blocky and lack distinct bedding but there is no direct evidence of faulting.

Locality 9 — Haulage Unconformity in the South

Further south, the Haulage unconformity is exposed and the Owen conglomerate wedges out to less than 5 m. The hematite veining in the Owen Conglomerate here does not continue into the Pioneer Sandstone. The Haulage unconformity has a low angle, about 20^o, and the level of strain suggests this is the result of flattening so that the original angle was more like 40^o.

Locality 10 — South end Tharsis Ridge

The southern tip of Owen Conglomerate on Tharsis Ridge is exposed on the road (Figs 14, 15). A small area at the east end of the exposure has extremely strong syn D_1 fault striations indicating oblique thrusting or that the original steeply west dipping thrust surface has been folded during D_2. Most of the fault surfaces here are syn-D_2 and there is a very clear overprinting relationship exposed in this cutting. The syn-D_2 fault striations are largely south dipping reverse faults but one steep surface has weak west side down movement early, followed by a west side up movement late in D2 reflecting the same change in conditions as recognised in the Tharsis Trough.

Locality 11 — Fault Splays west of Tharsis Ridge

D_2 crossfaults are very easily recognised in the Owen Conglomerate but in the altered volcanics they spread out to broad zones of multiple faults and then finally to ductile zones of strong S_2 cleavage. In the pavement near Western Tharsis there are numerous small faults which represent the major fault zone cutting the south end of Tharsis Ridge (Fig. 16). Individually these faults probable have small movement but together they have a very significant offset. The tracing of faults through the altered volcanics remains one of the major structural problems at Mt Lyell.

Locality 12 — Glen Lyell Fault

The Glen Lyell Fault is the most continuous of the syn-D_2 dextral wrench faults which strike NNW and define the western limit of the Mt Lyell mining field. The change in stratigraphic facing from east (to the east) to west in Conglomerate Creek occurs at or close to this fault.

Near the main Lyell access road this fault is exposed as a metre wide brittle zone in a creek. At this outcrop a dextral sense is implied by drag on cleavages but no striations were observed.

Locality 13 — Syncline on the Firewood Siding Fault

If time permits, we will inspect the thrust out D_2 syncline defined by Pioneer Sandstone in the area SE of the Lyell Mill (Fig. 17). This is the continuation of the Firewood Siding Fault. It continues towards the Glen Lyell Fault but no exact position has been found for the point at which intersects this fault.

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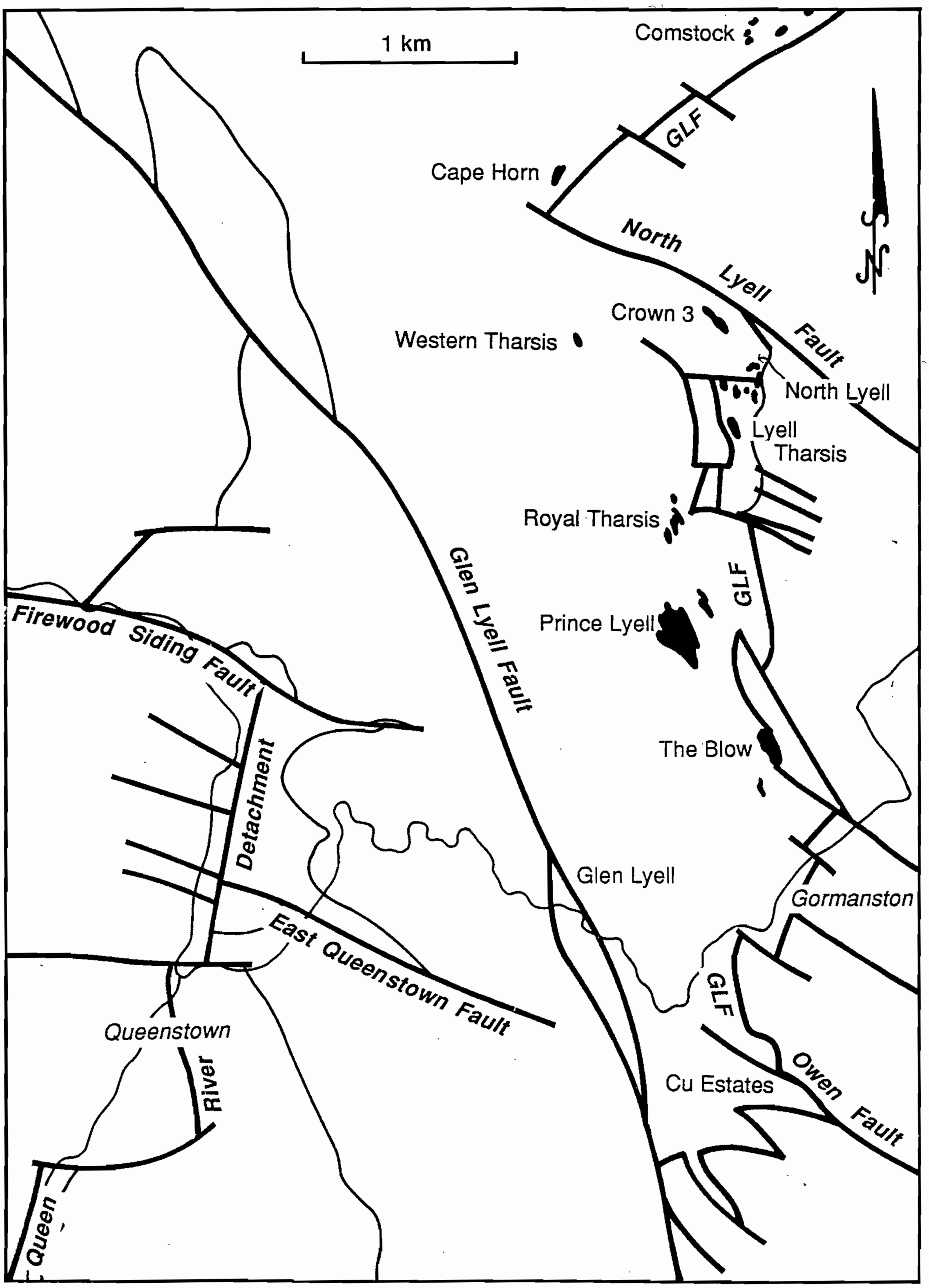


Figure 1. Locations of structural features referred to in the text.

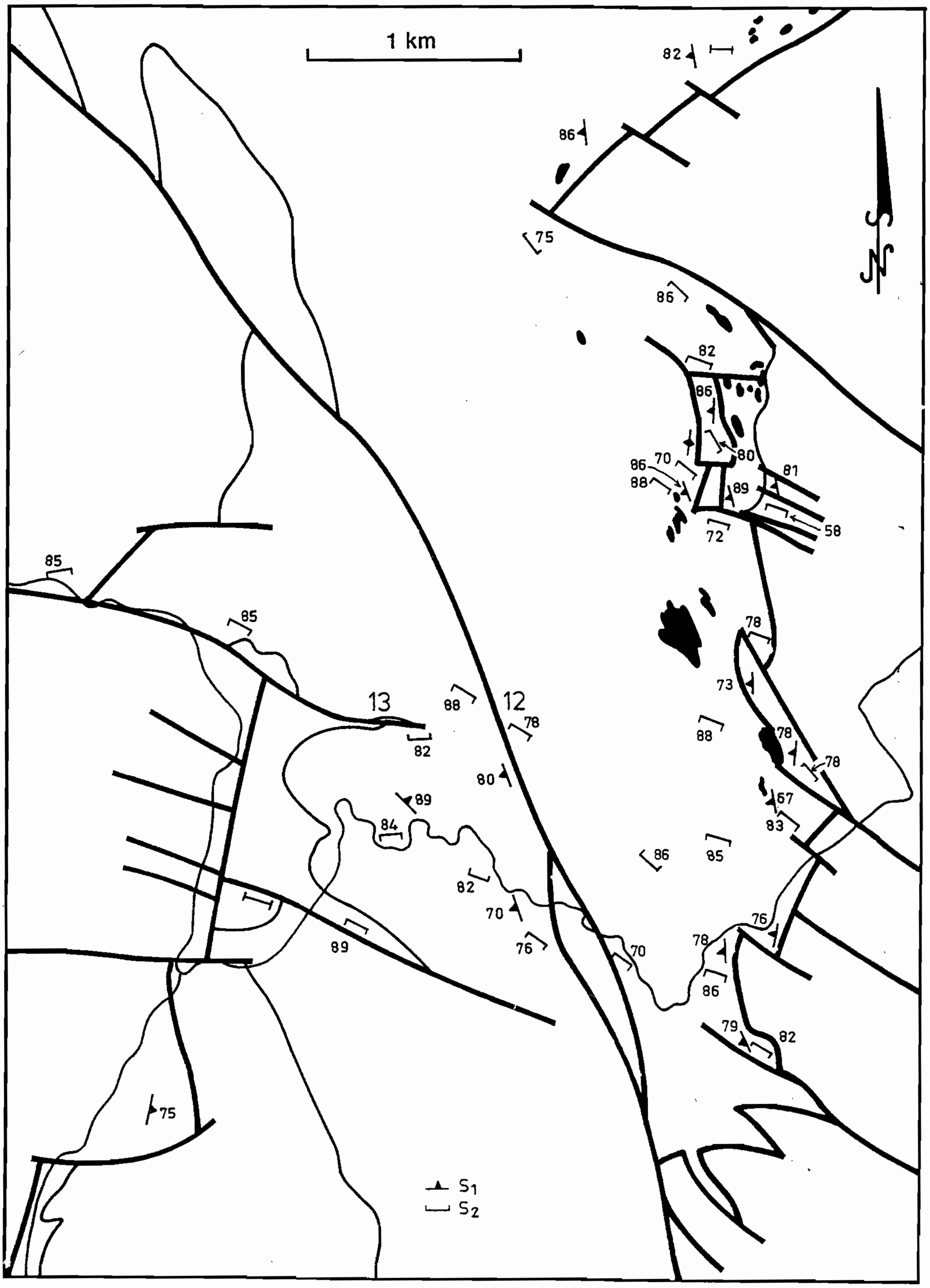
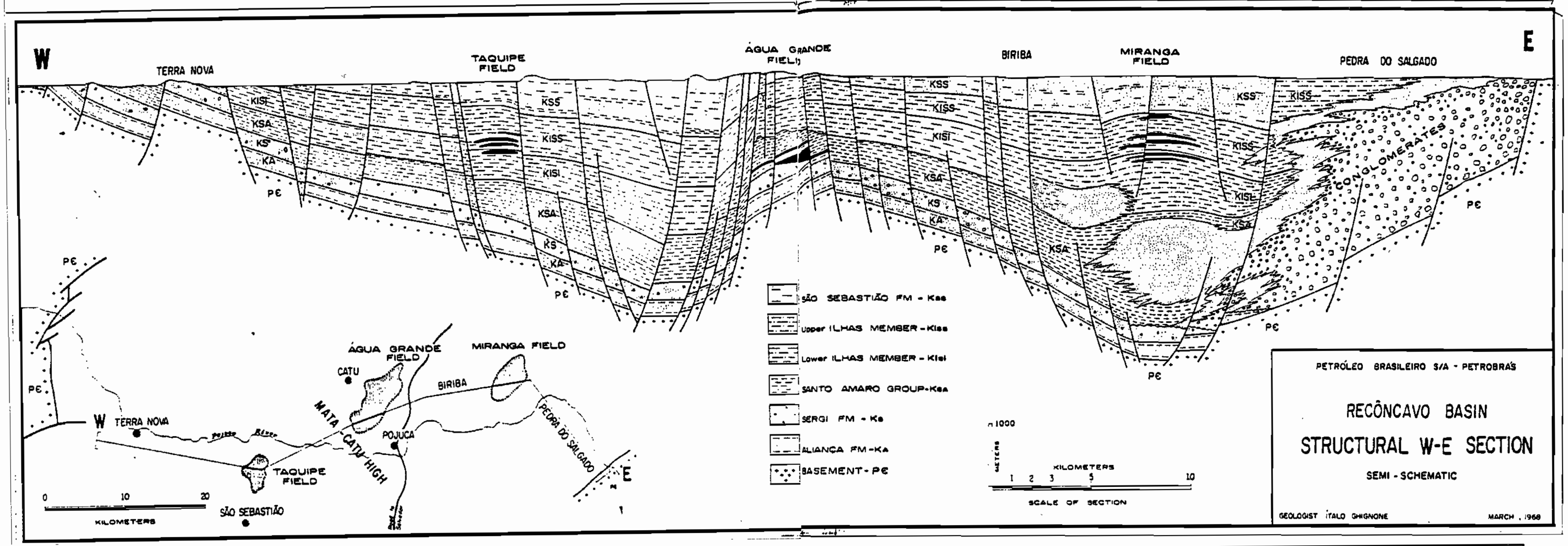


Figure 2. Representative S_1 and S_2 cleavage orientations in the Mt Lyell area.



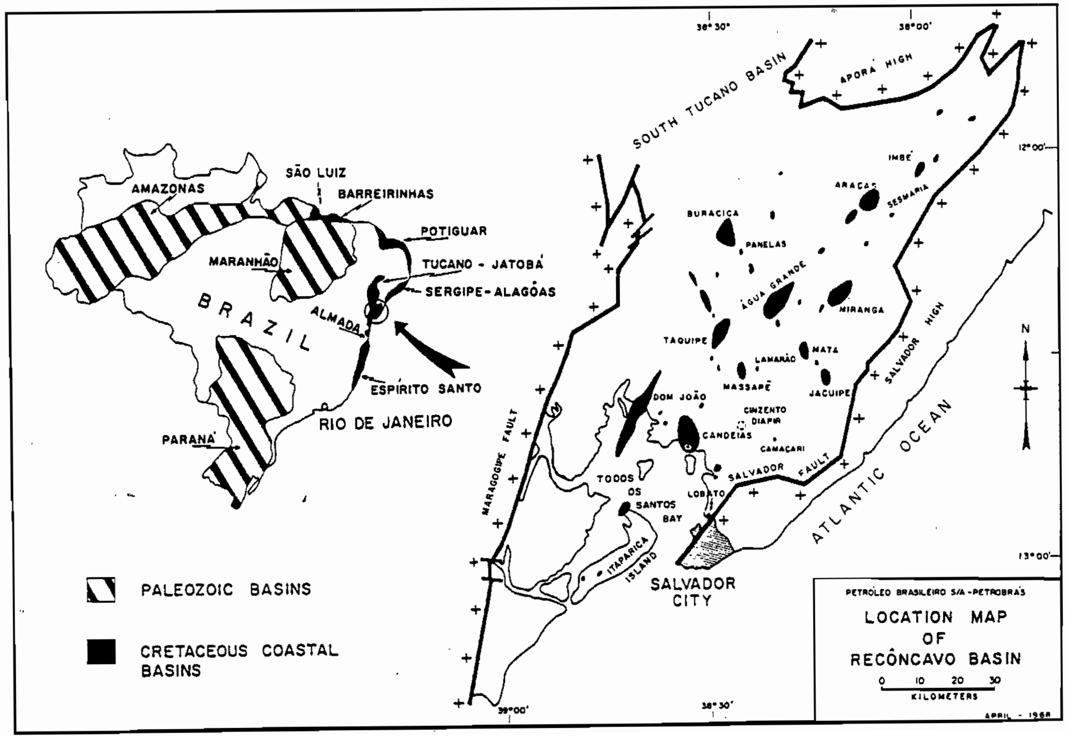


Figure 3. Crossection of the Reconcavo Basin, Brazil showing the large conglomerate wedge on the eastern margin of the basin. Section is from Ghignone J.I. & Andrade G 1970.

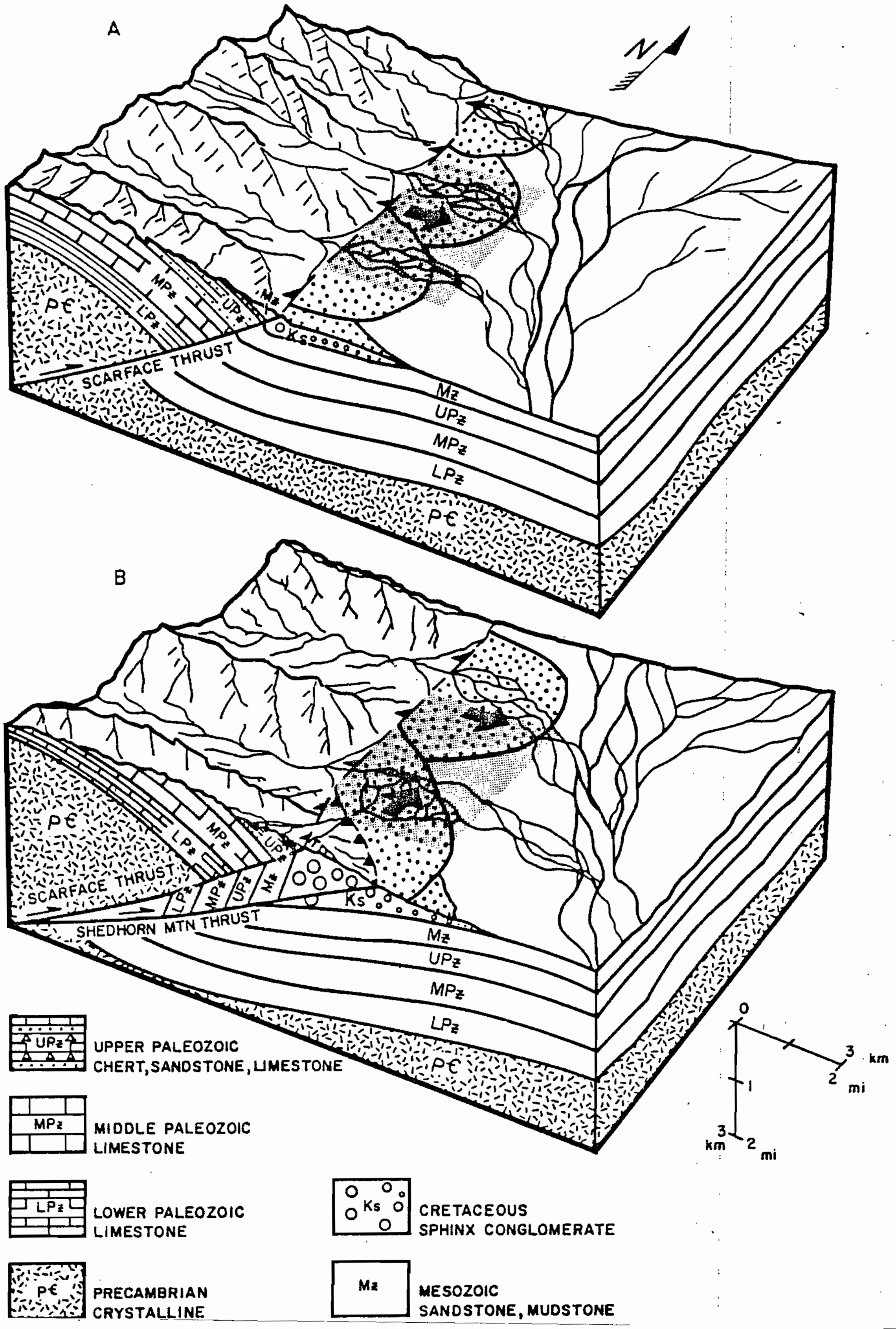
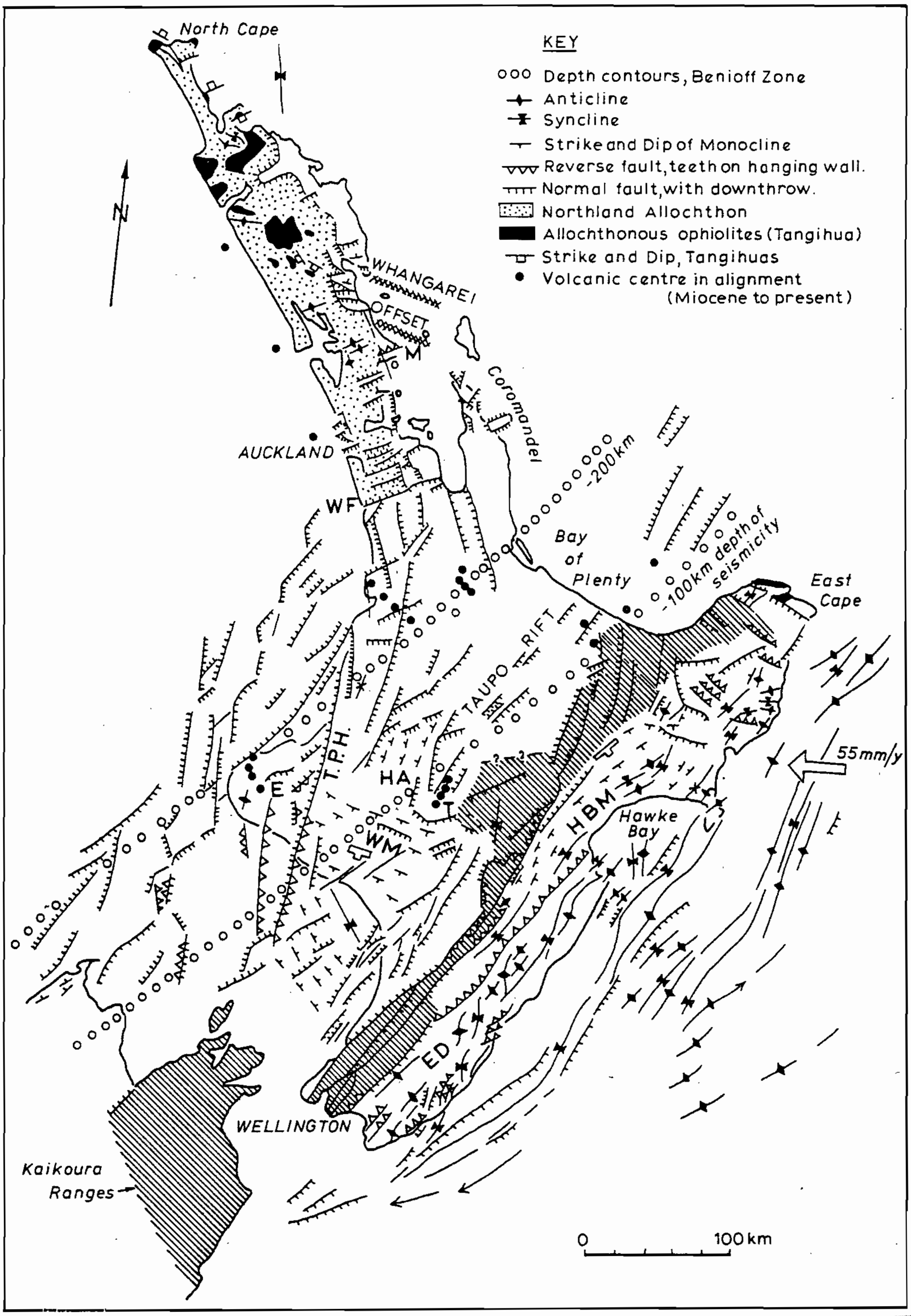


Figure 4. Schematic block diagram showing the palaeogeography during deposition of Sphinx Conglomerate. A) Lower Sphinx deposition: alluvial fans were generated by eastward movement of Scarface thrust plate. B) Middle and upper Sphinx deposition: alluvial fans were controlled by northeastward movement on Shedhorn Mountain thrust. (Decelles et al 1987).



Open arrow indicates direction of present day plate convergence. Shaded: uplifted axial basement ranges. Faults with both teeth and hachure are normal faults reactivated by reverse movement. ED: East Coast Deformed Belt. M: thrust locality, Mathesons Bay, North Auckland. WF: Waikato Fault. E: Mount Egmont. TPH: Tongapurutu–Patea High. HA: Hauhungaroa Block. T: Tongariro Volcanoes. WM: Wanganui Monocline. HBM: Hawke's Bay Monocline.

Figure 5. Cainozoic Fault pattern, North Island, NZ, from Sporli 1980.

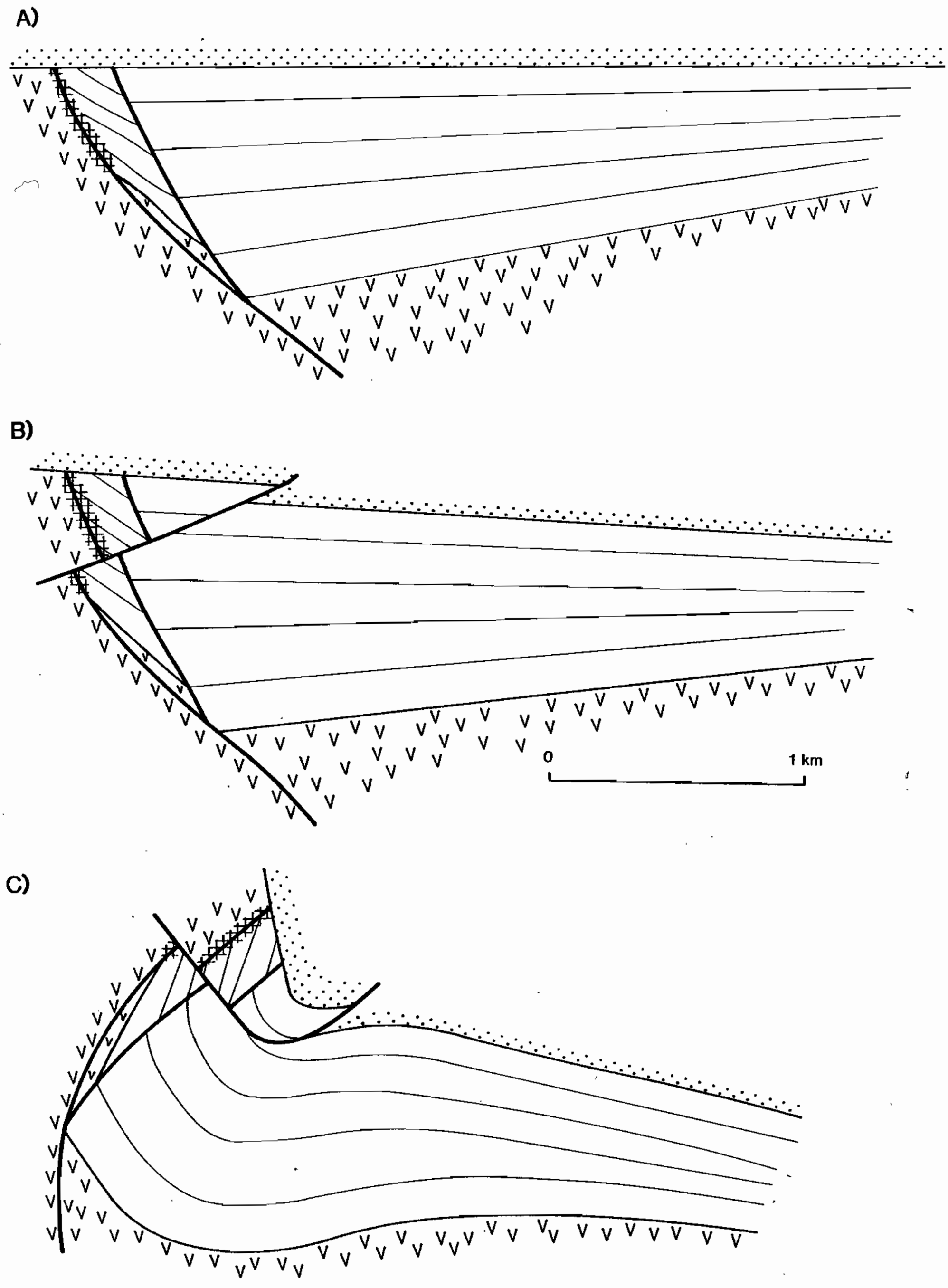


Figure 6. Model for the development of the Tharsis Ridge and Trough. a) the structure at deposition of the Pioneer Sandstone shows two normal faults with a rotated block between them forming the Haulage unconformity. Large scale thickening of Owen Conglomerate towards this structure results from the listric geometry. b) Thrusting at an early stage apparently pre-dates hematite–silica–barite alteration. c) D_1 Devonian folding produces the Tharsis Ridge and Trough structures.

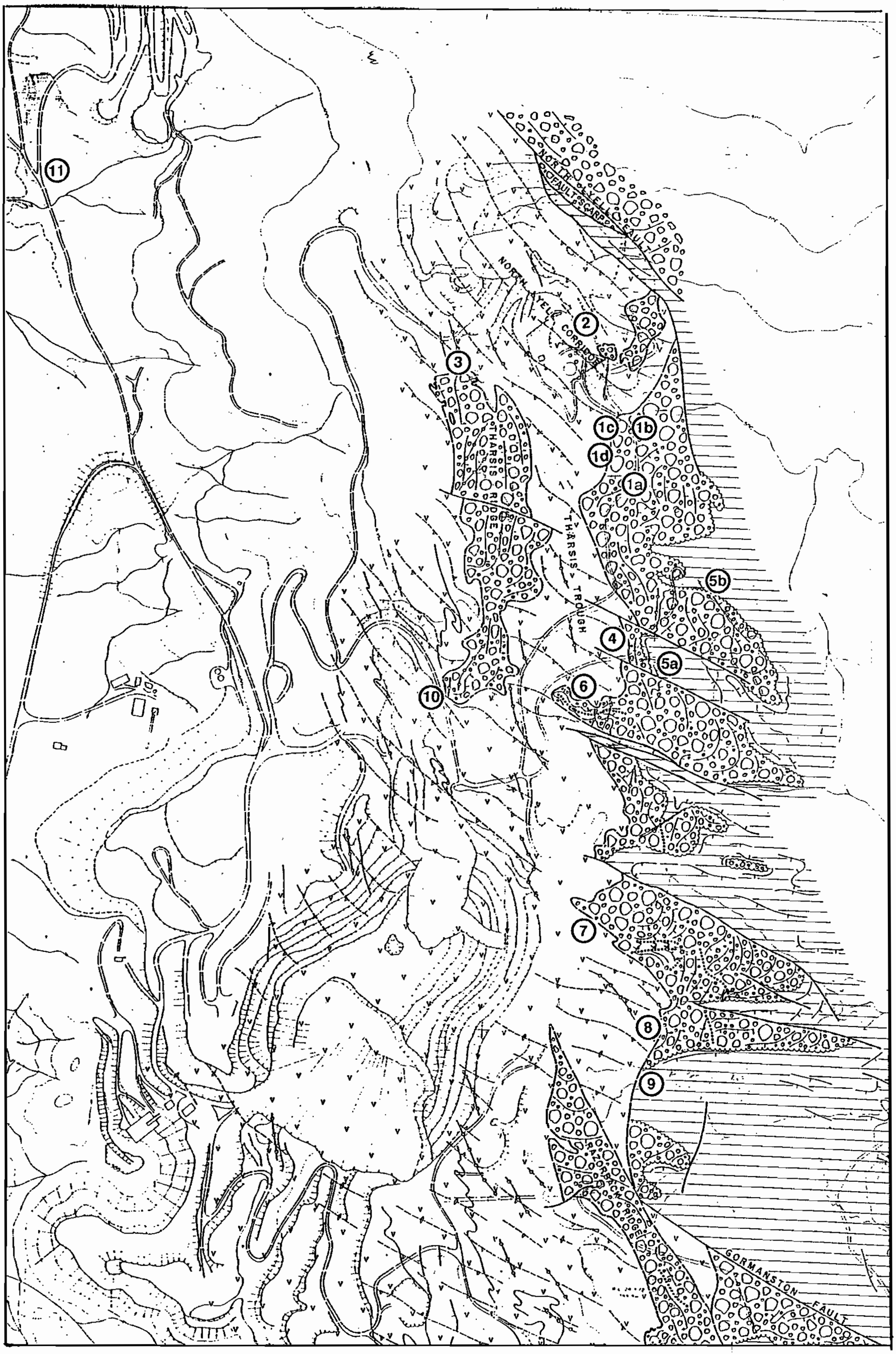


Figure 7. Location of localities 1 to 11. Geology is from Arnold 1985.

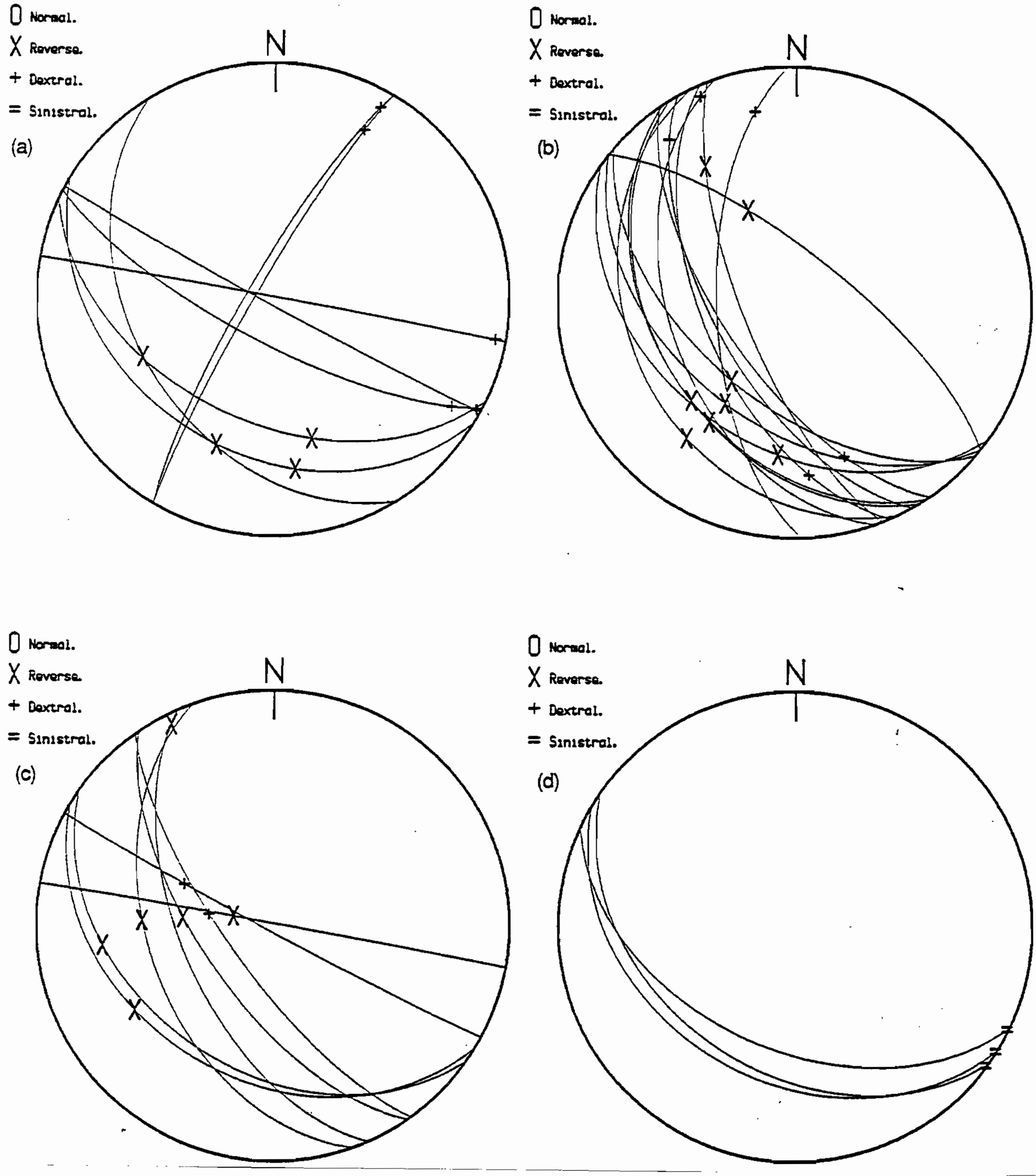


Figure 8. Fault planes and striations from the Tharsis Trough near Lyell Tharsis. (a), (b) and (c) sequential movements all within D_2. (d) post D_2 fault movements.

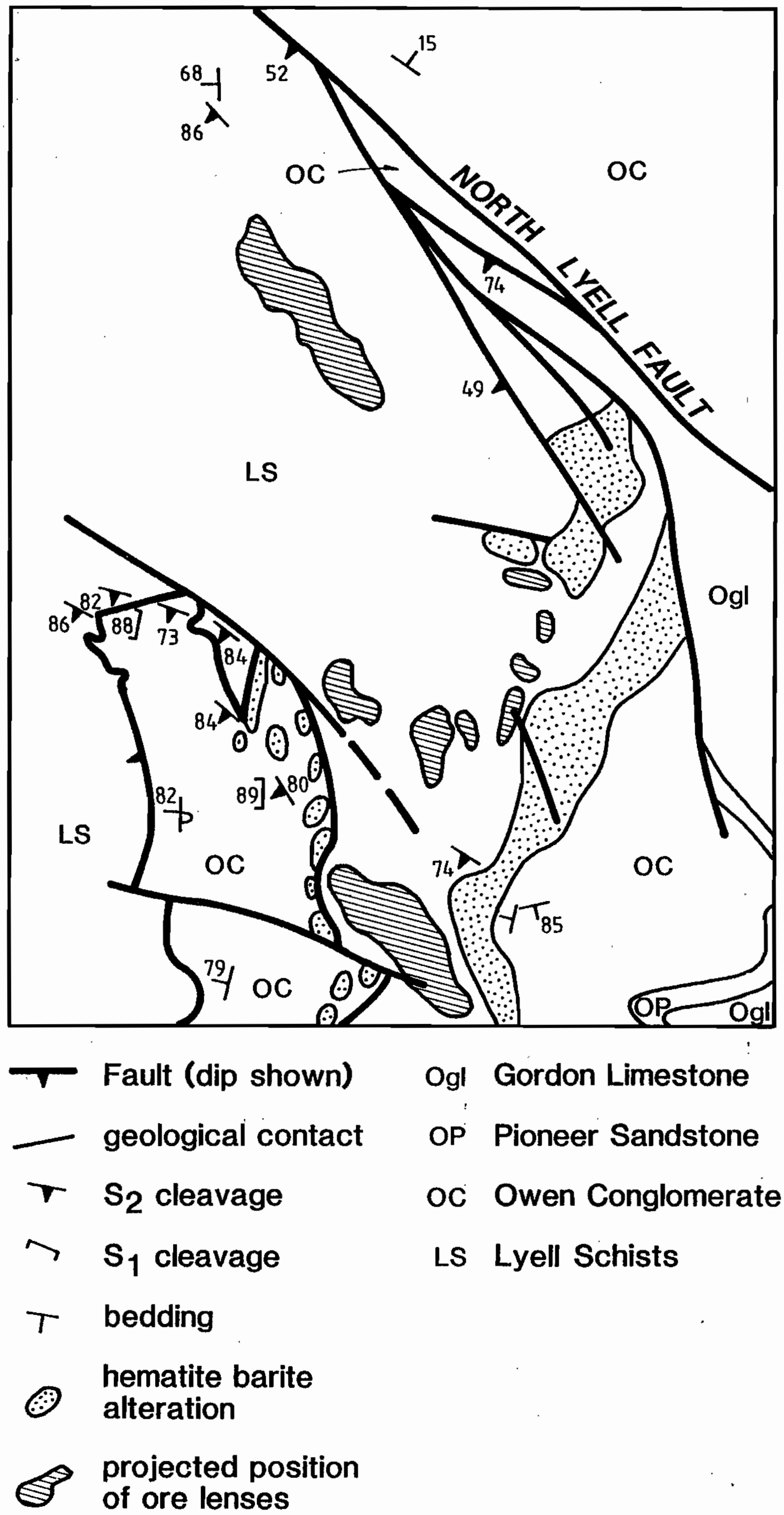


Figure 9. Detailed geology of the North Lyell area showing the relationship between hematite alteration, ore lenses and the Owen Conglomerate. Geology slightly modified from Arnold 1985.

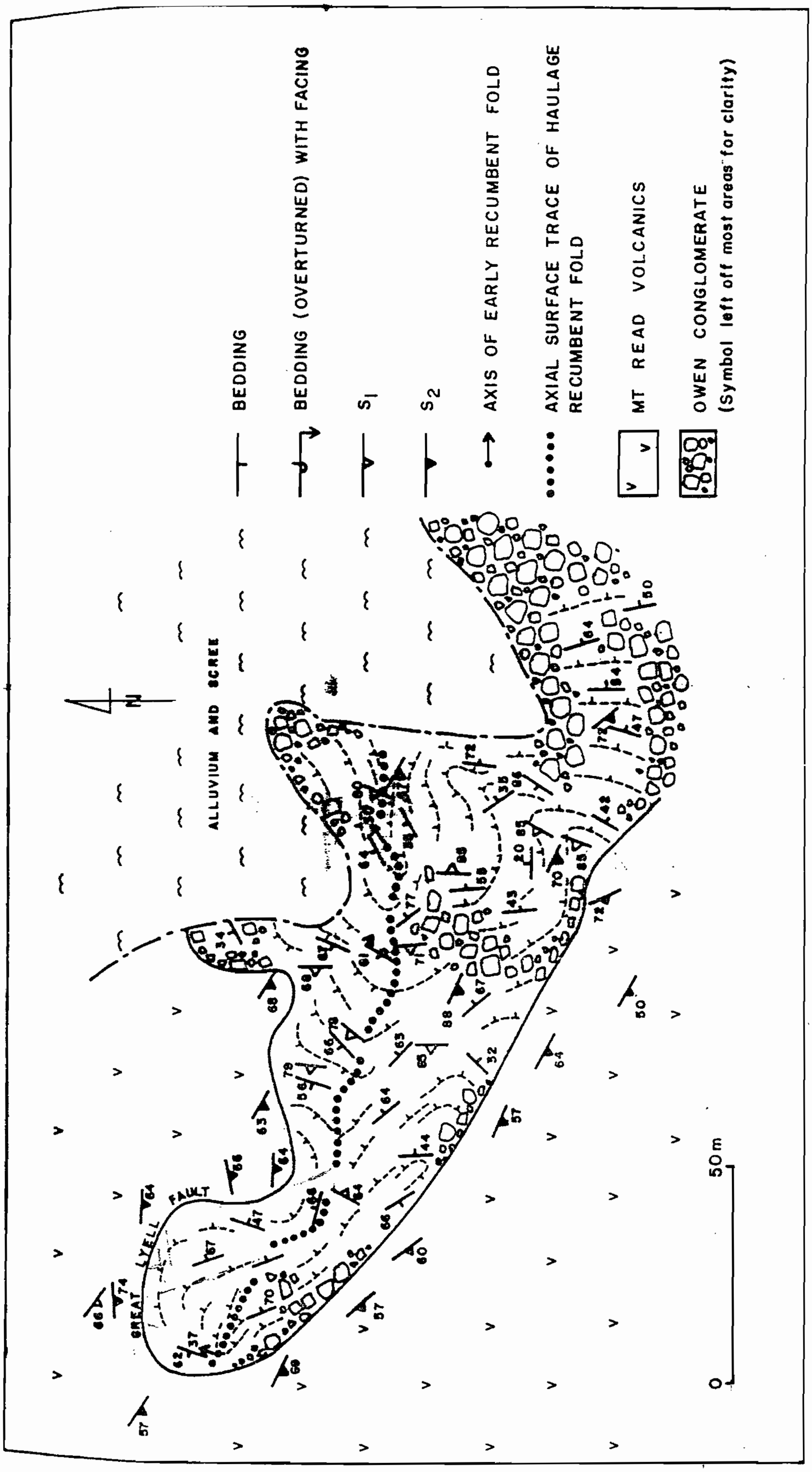
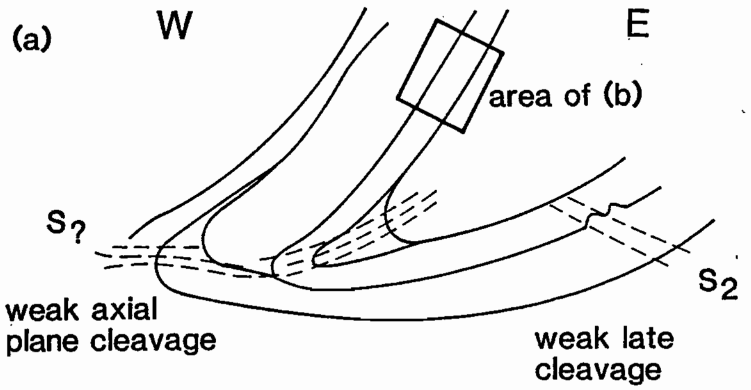


Figure 10. Sketch of complex folded Owen west of Batchelors Quarry (Fig. 5 of Arnold 1985).



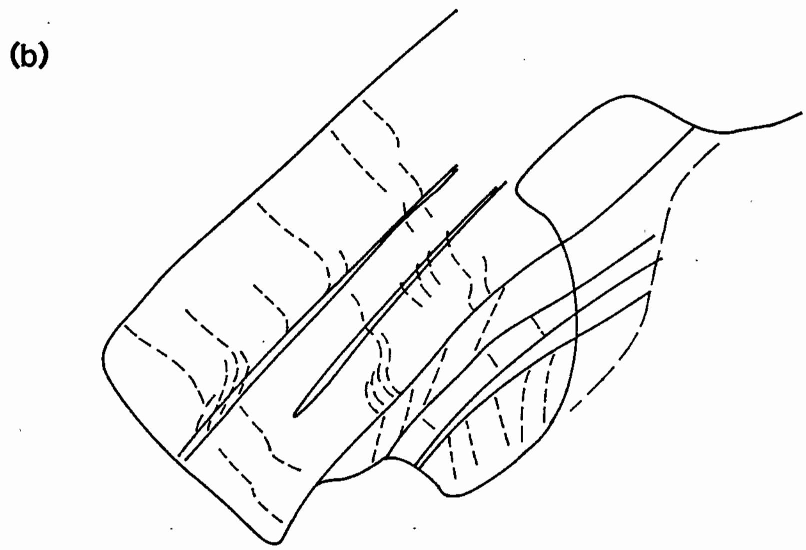


Figure 11. Sketch of early fold in the Owen Conglomerate showing the relationship to S_2. Inset shows the S_2 cleavage refracting into S_1 orientation.

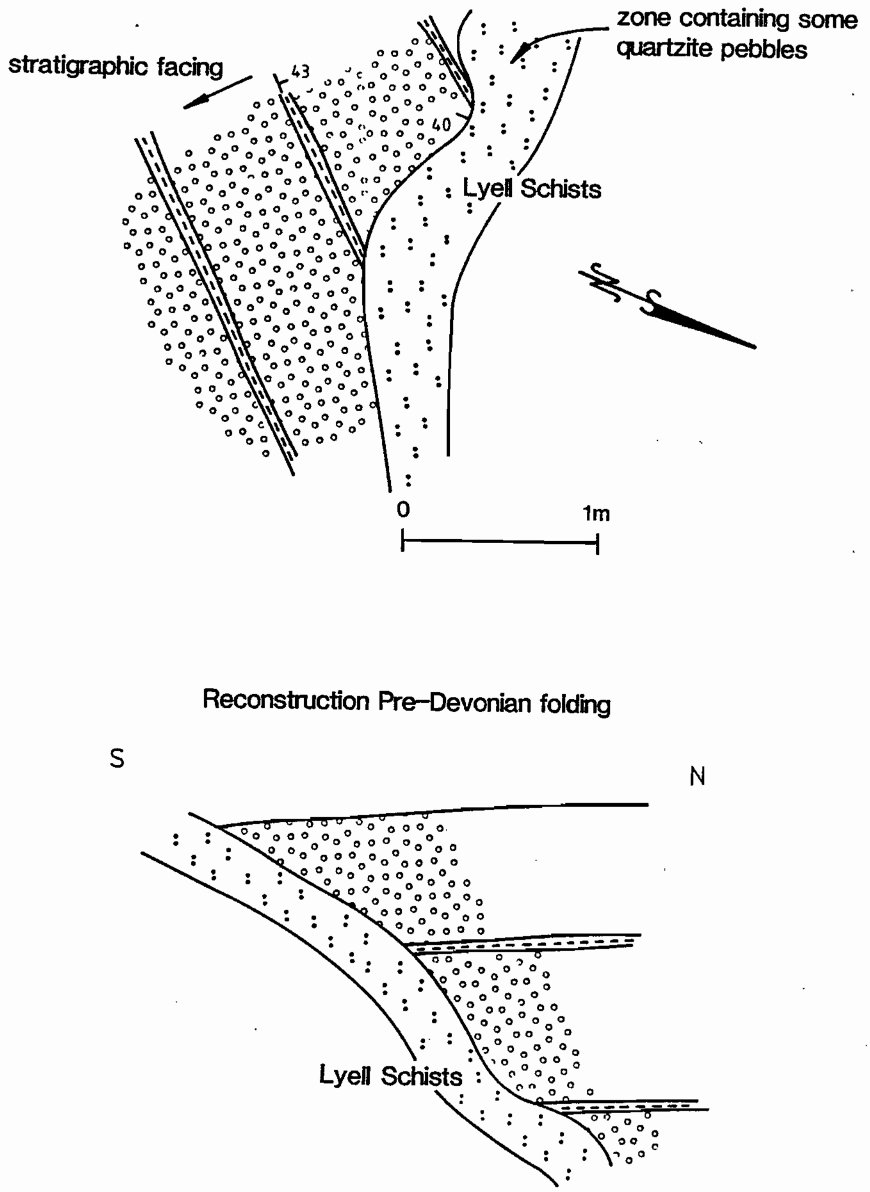


Figure 12. Sketch of complex stratigraphic relationships between Owen Conglomerate and CVC. (a) in plan view. (b) rotated to demonstrate the interpreted onlap relationship.

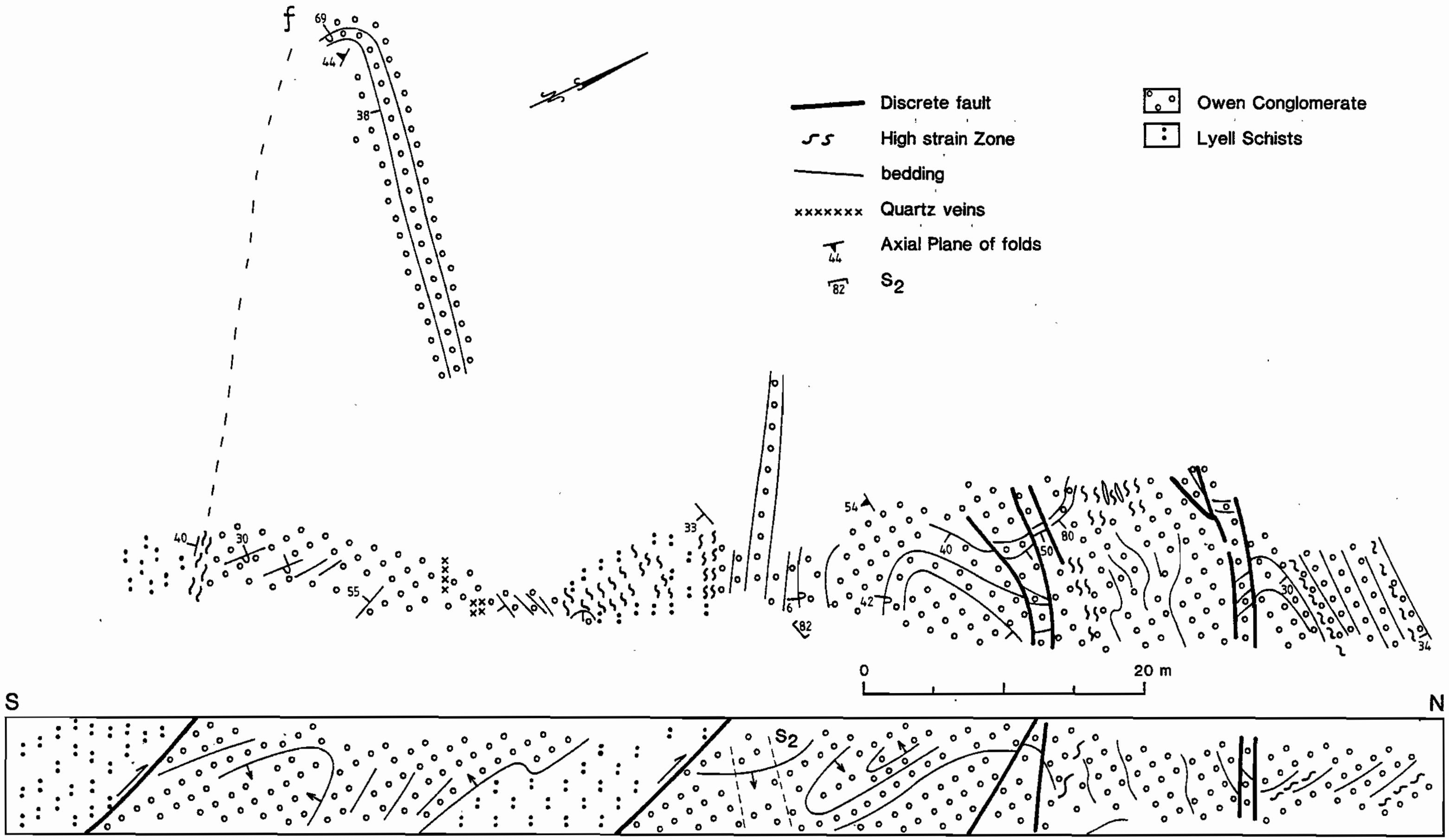


Figure 13. Sketch of gully section and associated early folds. Inset shows crossection based on this outcrop with tight pre-S_2 folding with a WSW strike. Open overturn fold at A is a classic "Haulage" fold but is inconsistent with East directed thrusts.

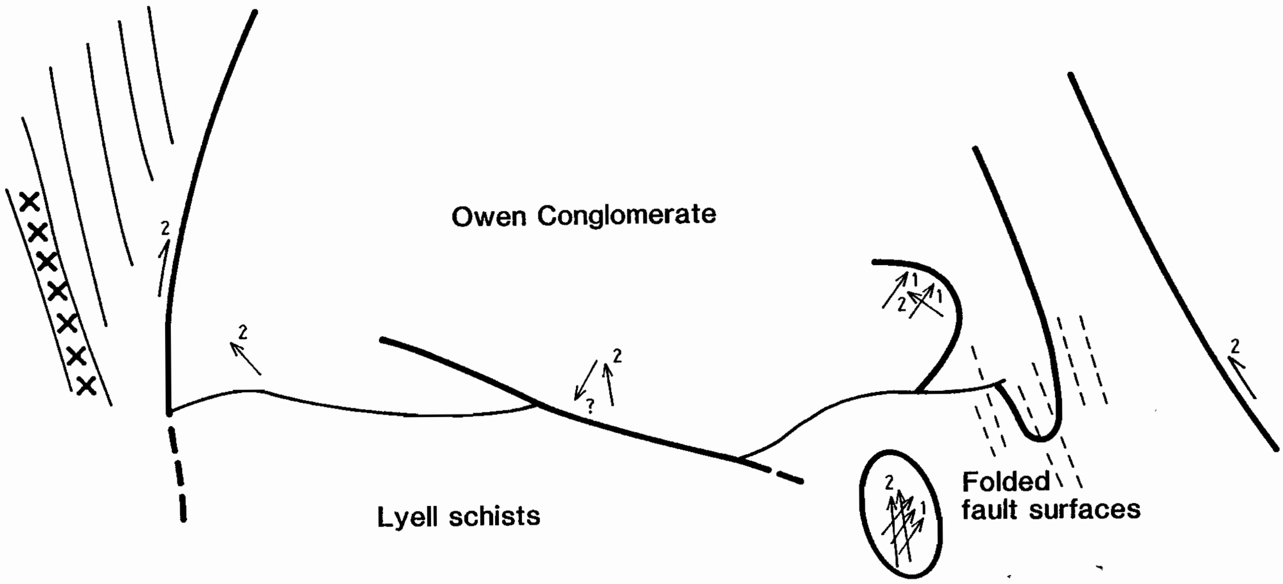


Figure 14. Sketch of faults on southern termination of Owen Conglomerate on Tharsis Ridge. Two generations of striations are visible. Neither appears to explain the distribution of the Owen Conglomerate here i.e. neither suggests a south side down movement.

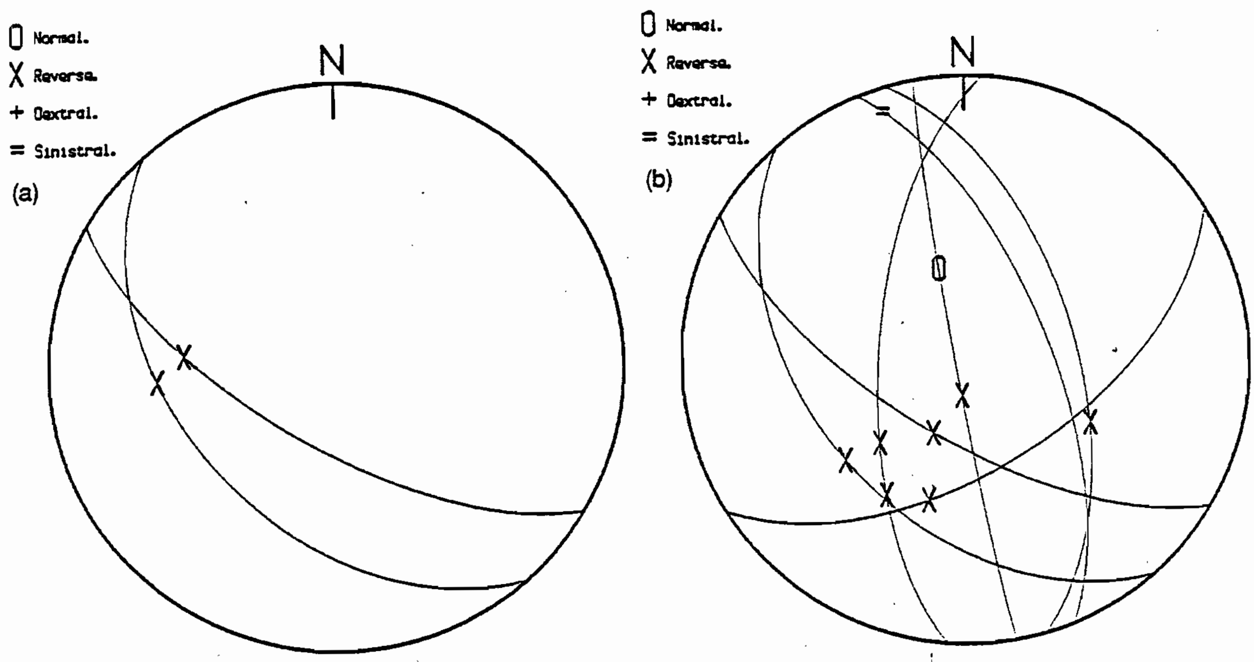


Figure 15. Fault planes and striations from the southern end of Tharsis Ridge, (a) D_1 fault movements. (b) D_2 fault movements.

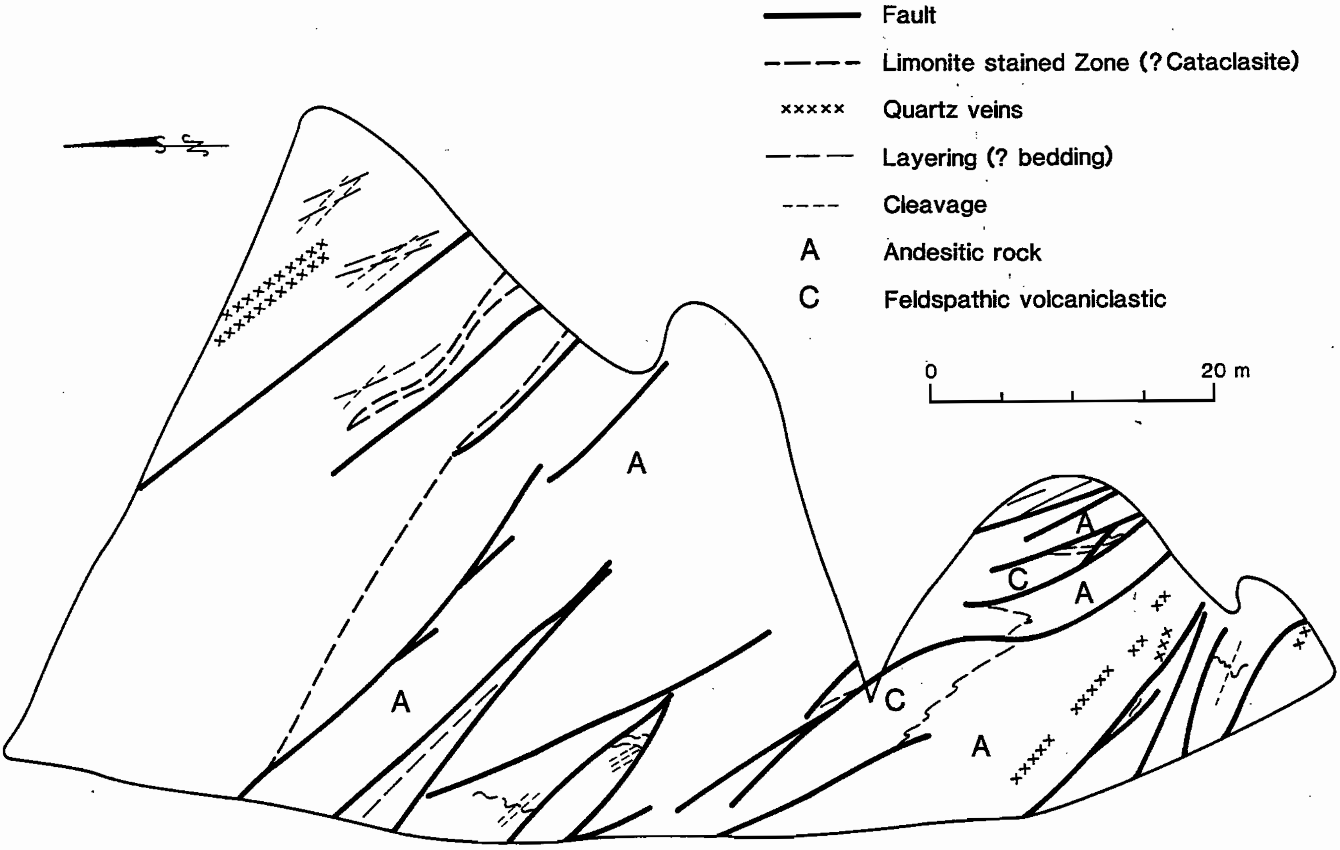


Figure 16. Sketch of multiple faults within altered volcanic rocks west of Tharsis Ridge. This is the result of the spreading of discrete faults as they emerge from the Owen Conglomerate.

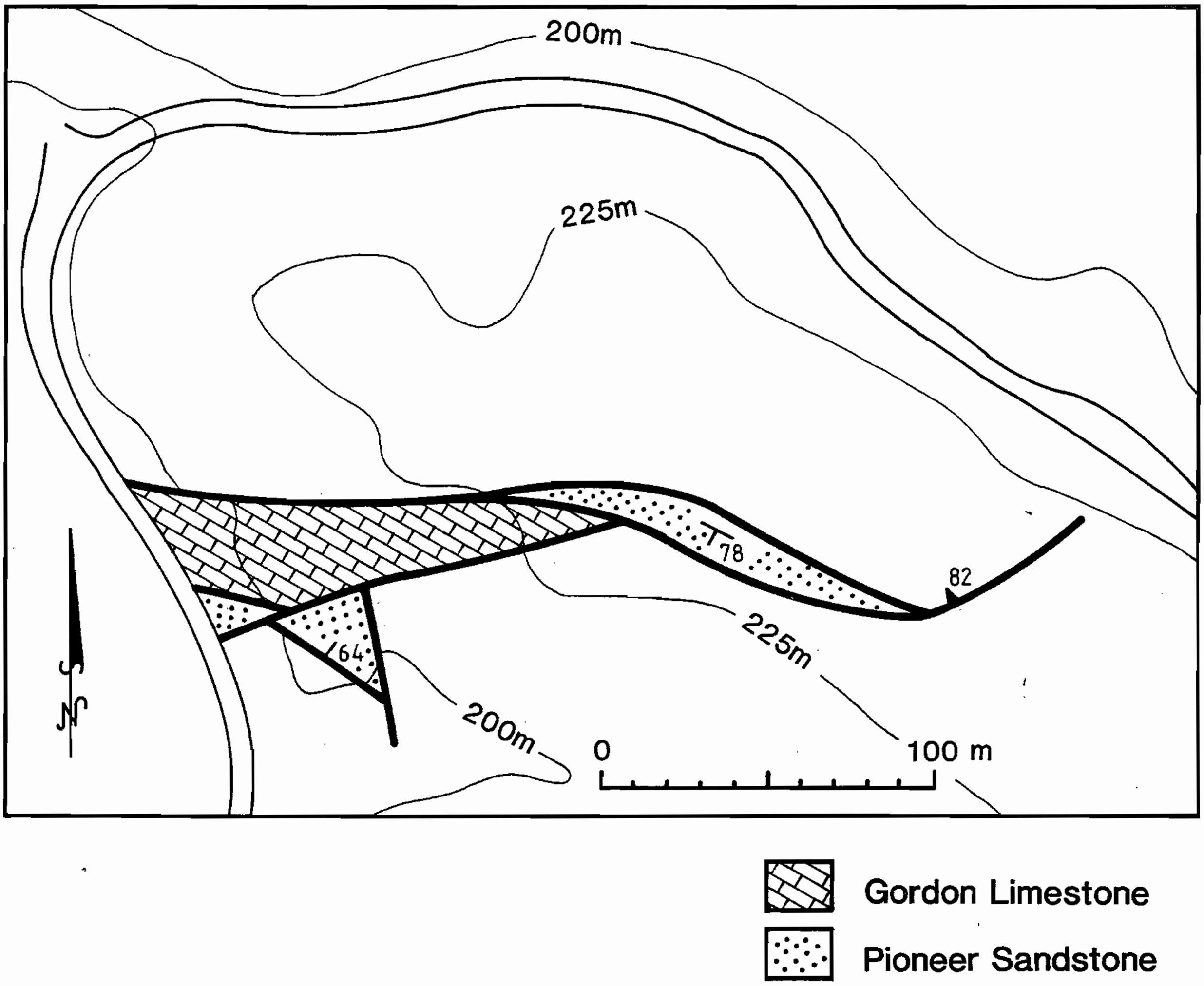


Figure 17. Map of rock distribution near the eastern termination of the Firewood Siding Fault (Location 13).

A Description of the Howards Road Traverse

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INTRODUCTION

At the western end of the traverse, the Pioneer Beds lie unconformably over the rocks of the Lower Dundas Formation (LDF). The angular unconformity is about 30°; considerable erosion is implied by the absence of the Middle and Upper Dundas Formations (equivalents of the Newton Creek Sandstone and Owen Conglomerate to the east of the Henty Fault (HF)).

The first section of the traverse (0–5 km) crosses siltstones and shales of the LDF (Fig. 1). These rocks are variably cleaved and folded into two syncline–anticline pairs. Bedding-cleavage measurements indicate that the folds are non-cylindrical and that the W-limbs of the anticlines (or E-limbs of the synclines) plunge N, whilst the E-limbs plunge S. The W-limbs of the anticlines are overturned, indicating transport is to the west. The cores of the anticlines are occupied by fine grained sandstones (Fig. 2).

The second section of the traverse (5–8 km) comprises shales, siltstones, sandstones, grits and conglomerates of the White Spur Formation (WSF). The folds in this formation are open to tight in style, the hinges are generally well preserved and opposing plunges much less marked than in the LDF. Regions of steeply to vertically plunging bedding–cleavage intersections are interspersed with the gentler plunging folds.

The third section of the traverse through to the Henty Fault (8–15 km), comprises thrusted rhyolitic and dacitic volcanics, occasional interbedded shales and mafic intrusives of the Central Volcanic Complex (CVC). The WSF appears to lie conformably over the CVC, although locally structural complications may obscure the real contact relations; further north, the boundary between the two domains is a sheared and "collapsed" anticlinal hinge.

The last and final section, beyond the HF, comprises volcanic rocks and volcaniclastic sediments of the Tyndall Group and the basal Owen which lies conformably over the latter. These rocks are folded into S-plunging folds and are affected by N-directed thrusting.

Proceed northwards from Queenstown on the Zeehan Highway, crossing the Henty Bridge and continue on for approximately 6 km to the Howards Road turn off, which is on the right-hand side of the highway. There is ample parking here.

Locality 1 — Ordovician strata

Walk the 200 m S of the turn-off to see the conglomerates, shales and limestones of the Pioneer Beds of Ordovician age on the W side of the highway. The angular difference between these beds and the nearest exposed Cambrian strata (400 m away) is 30–40°; the difference in strike of cleavage is even more marked (i.e. 90°). A weak cleavage is seen striking 300°and is consistent with the trend of the large folds in the Ord–Sil–Dev strata (OSD for short) to the W; however, it is also consistent, if fault-related, with a dextral fault that shows a 2 km offset along the westward extension of the North Henty Fault (NHF). The trend and plunge, as well as, intensity and style of folding between the rocks on either side, suggests that this is a faulted domain boundary.

No specific locality has been designated for the next 5 km; however, there are numerous road side outcrops which show the cleaved sediments of the LDF.

Locality 2 — North Henty Fault

Turn right 5.3 km along the Howards Road and proceed for 1.1 km where interbedded shales and gritty mass debris flow deposits of the WSF may be seen on the track. Bedding–cleavage intersections are steeply plunging here as a result of proximity to the NHF, and from this point on the bedding becomes progressively rotated, in an anti-clockwise sense around a vertical axis, as the fault is approached

At 1.3 km, small-scale N–S trending synthetic riedel faults with left-lateral strike-slip movement can be seen on the track.

At 1.5 km the NHF may be seen on the north side of the track. The actual fault surface is a strongly sheared, clay-rich zone of decomposed ultramafic lithologies 1–2 m wide. The serpentinites in the 100 m wide fault zone have responded brittlely and ductilely to the deformation. The following small-scale structures may be observed:

- Flat S-dipping reverse shears with asbestos fibres indicating NNW transport.
- (S)–(C) fabrics from which a left-lateral sense of movement is inferred. The (C) plane parallels the fault plane, whilst (S), the plane of flattening, strikes ENE–WSW, an unusual cleavage orientation but one that would be expected in the Henty Fault Wedge.
- Asbestiform veins that trend NNW with sub-horizontally plunging fibres.

These structures are consistent with the NHF being a splay off, or a fault termination of the main sinistral Henty Fault. (Note that there are a number of fibre directions in the brittlely deformed serpentinites which may not necessarily reflect successive generations of movement, but may rather suggest local up and down, or side to side, movements resulting from small adjustments, as a way of solving the space problems created by a moving sheet of jointed and fractured rock.) The structures of kinematic significance are shown in Figure 3.

Locality 3 — White Spur Formation

Return to the Howards Road and continue eastward for approximately 2.5 km. On the left-hand side of the road there is a large excavated area showing a coarse grained quartz–felspar wacke/tuff with laminated shale fragments up to 0.5 m across. This unit lies on top of laminated, shaley to silty graded turbiditic units which form the limb of gently S-plunging open fold, typical of the style of folding in the White Spur Formation. Note the convolute bedding at the tops of the shaley units.

Locality 4 — White Spur Dam

Continue along the road until you reach the canal proper, then follow the formed road on the S side of the canal, observing the excellent exposures of graded volcaniclastic units and structure along the way, mostly indicating reverse movements by drag folding and minor thrusting along lithological boundaries. Cross the dam wall and turn left, and sharp left again to park beside the water above the dam. In the cliff wall, a high-level thrust dipping back towards the SE at 20°, parallel to the NHF, separates darker coloured, plag-phenocrystic chloritised dacitic (?) lava in the footwall, from lighter coloured silicified plag-ser altered rhyolitic lavas in the hangingwall. This fault shows cataclastic textures along its length, but note at its top end that it becomes filled with glacial till. Such structures, if one took the time to map them out and the individual flows that they fault, would be expected to produce outcrop patterns at the CVC–WSF contact of the kind shown on the 25,000 survey map.

Locality 5 — White Spur Canal

Return to the road and continue for a short distance over the spillway and turn right down the canal road and proceed as far as the run-down to the water, between the 1.3 km and 1.4 km peg. For about 50 m along the far wall (wellies advisable here) the following structures may be observed:

1. A flat-lying thrust, with good reverse-sense quartz fibres, indicating an oblique NNW transport direction in the CVC lavas.
2. Lithological contacts, including rhyolitic and dacitic lavas and mafic units, trending NNW and showing evidence of being activated as minor reverse shears during deformation.
3. Higher strain chloritic domains with quartz veins, developed at the edges of the mafic units, which have (S)–(C) fabrics inferring dextral-reverse oblique movements parallel to the direction of thrusting. These acted as lateral ramps or transfer zones in the footwall of the thrust.
4. Late cross-cutting fault, parallel to the nearby NHF, with horizontal quartz striae/fibres.
5. Vesicles in a mafic "dyke" which lie on the western side of the intrusive suggesting that that is probably one of a suite of high-level mafic sills intruded into the CVC.

A kinematic analysis of this locality is shown in Figure 4.

Locality 6 — Henty Dam (Optional)

Proceed to the bottom of the canal road to observe the field relations of the so-called "Henty Dyke Swarm" to the CVC, beneath the dam wall. The vesicles appear to be asymmetrically distributed and preferentially, but not exclusively, developed on the W-side of the mafic units, suggesting that they may be sills rather than dykes.

Locality 7 — Newton Creek Spillway

Return to White Spur Dam, turn right and continue along the construction road past the Henty River crossing and then turn right onto the Newton Creek damsite road. Park the car and walk across the dam to the top of the spillway.

This is an excellent exposure of Tyndall Group rocks. At the top of the spillway, on the far side, a porphyry is thrusted over sandstones and clast-supported conglomerates which are folded into a SE-plunging anticline. A number of faults (numbered 1–17 by Rob Gibson) are visible on the floor of the spillway; at least two of them (1 & 14) are dextral, the latter showing a classic riedel splay.

Lower down the spillway, the conglomerates are matrix-supported showing varying degrees of alteration in both the matrix and the clasts; the clasts are altered to pink haematite-dusted plagioclase(?) set in a more ductile chloritised matrix. Spot the sulphide clast! Is it an eroded boulder derived from a nearby VMS deposit, or is it the product of replacement? The nature of the support in the conglomerate and any associated alteration should provide a clue as to the origin of these sulphides.

Locality 8 — Great Lyell Fault

Return to Howards Road, turn right and proceed to the Anthony Road junction. Park the car and walk the 100 m eastwards to locality 8.

Progressive, and successive, changes to movements on the fault zone are to be seen on the N-side of the road. The fault here is a series of 300° trending slip planes developed on the W-limb of a S-plunging anticline in sandstone, shales and silicic conglomerates of the Newton Creek Sandstone Formation. Evidence of movement is given by quartz and chlorite fibres developed on bedding surfaces.

At least three sets of fibres are to be seen. The earliest is a NE directed dip-slip reverse fibre which is overprinted by, or rotated into, an oblique-slip N directed reverse fibre. The third is a a strike-slip dextral fibre which is possibly reflecting the antithetic riedel fracture (R-prime) direction in the sinistral wrench regime on the Henty Fault.

This is a good location to observe the orientation of the quartz fibres in the flat-dipping quartz veins, which parallel the fibre directions in the nearby shear joints. This is presumed to be the extension direction during the high-angle reverse movements of Devonian age on the HF.

TOPICS FOR DISCUSSION

Structures in the Dundas — Evidence for a significant Cambro-Ordovician Deformation?

The unconformity below the Pioneer beds and the non-cylindrical, doubly plunging folds in the LDF suggest a degree of non-coaxiality to the regional deformation, which could be explained in one of three ways:

1. All the folding was Devonian in age and the patterns of structure resulted from two periods of non-coaxial folding (F1 and F2). The apparent unconformity results from dextral shearing and faulting along this boundary during the Devonian.
2. All the folding is Cambro-Ordovician; the Devonian deformation being confined to vertical movements along high-angled reverse faults and dextral to sinistral wrenching on vertical faults.
3. Folding took place during both periods (Corbett and Lees,1987), where Devonian structures (F2) were superimposed onto pre-existing folds, with or without an axial plane cleavage. Early Cambro-Ordovician folds (F1) would have been tightened, their limbs overturned and rotated along hinge faults.

The Henty Fault — A Sinistral Wrench?

Considerable evidence has been accumulated that the Henty Fault was a sinistral wrench during part of its history. The question is to what extent can the present distribution of structure and rock formations be caused by a longer period of wrenching movements, especially as the main field evidence for wrenching is that it occurred *after* the vertical movements (Berry, 1989).

One way of partly overcoming this problem is to suggest that the structures in the Howards Road area can be explained by a *Fault Termination of a sinistral wrench* or *a Restraining Bend on a right-stepping sinistral wrench.* An analogy in more recent rocks which may be of value comes from Jamaica (Mann et al., 1985), where Cretaceous sea-floor serpentinites and amphibolites have been intimately faulted in with a Tertiary volcanic arc complex on a right-stepping sinistral wrench at the boundary between the North American and Carribbean Plates (Fig. 5).

The main advantage to be gained from postulating wrenching is that deformation persists for as long as the system operates, and may produce a number of local unconformities of different ages at different localities.

CONCLUSIONS

1. The thrusting in the CVC, due to movements along the NHF, may help to explain many puzzling features on the 25,000 survey map, especially those along the contact between the WSF and the CVC. For example, the abrupt cut-off of the shales, including the "host shale", at their N and S ends is due to E–W thrusting: N directed at the southern end and S directed at the northern end. Here volcanics are thrust up over and conceal the shale beds.
2. The N–S folding in the WSF is not entirely transmitted through to the CVC, and as a consequence, E–W transfer zones have developed. The effect is noticeable where an open style anticline, traceable for several kilometres north from the Howards Road, enters the footwall volcanics where its hinge "collapses" to become a shear zone separating two opposing limbs.

REFERENCES

Berry, R.F., 1989. The history of movement on the Henty Fault Zone, western Tasmania: An analysis of fault striations. *Aust. Jour. Earth Sci.* 36: 189–205.

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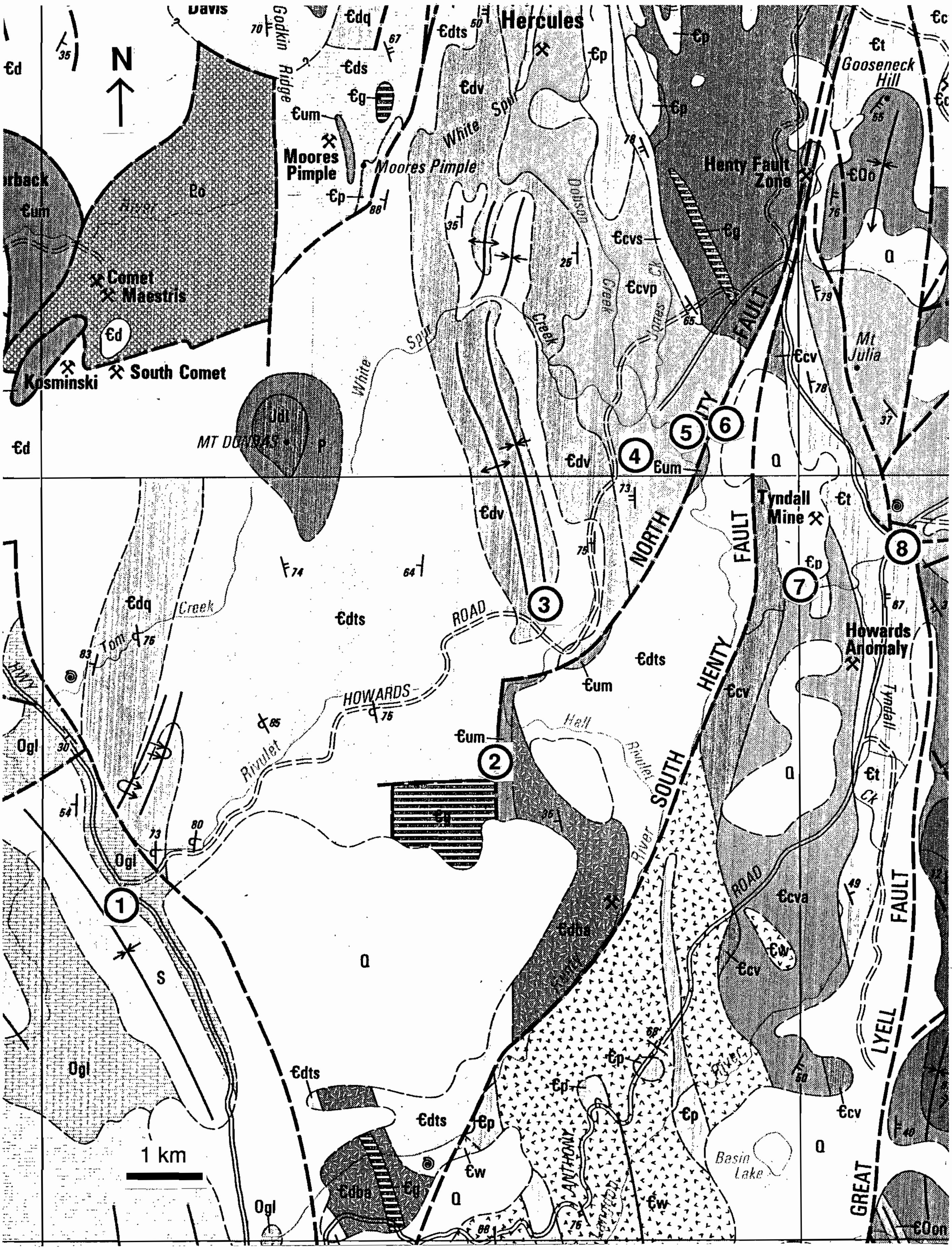


Figure 1. Howards Road traverse — locality map.

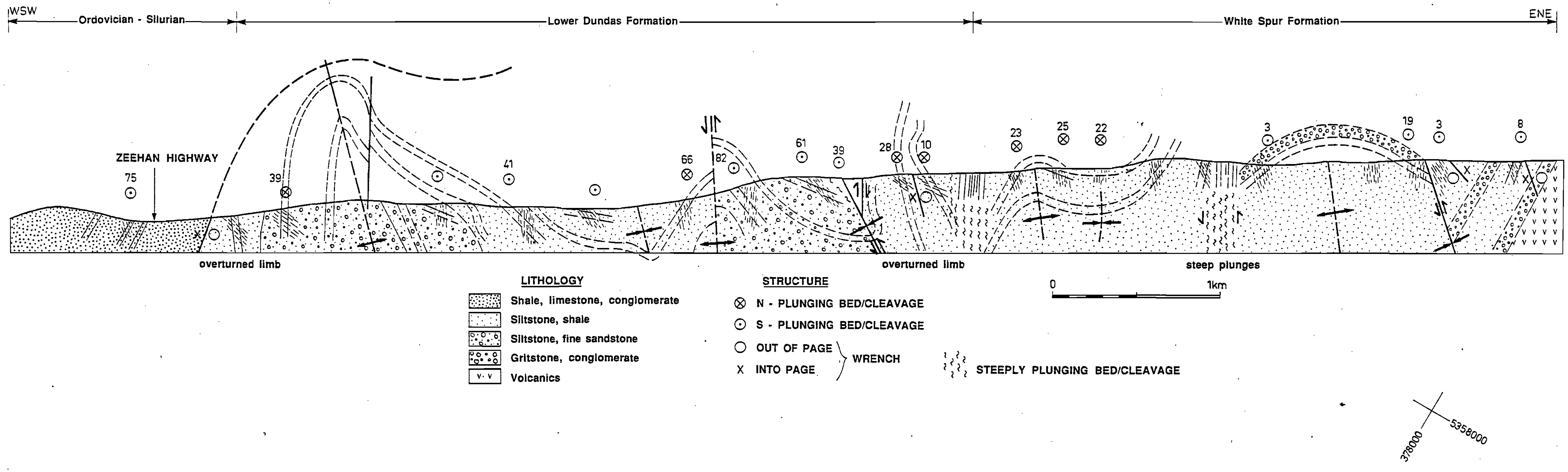
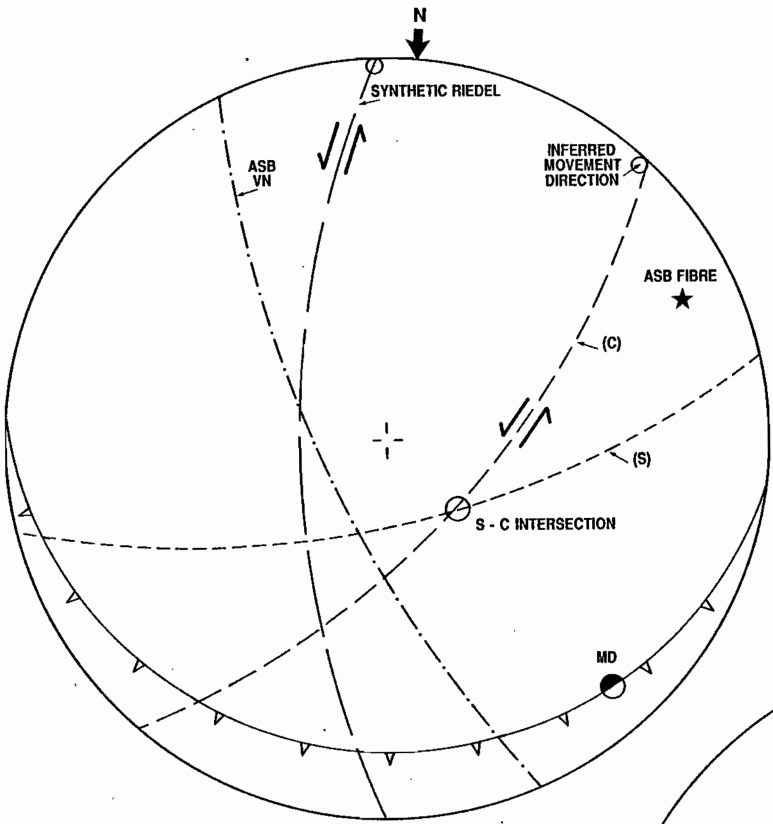


Figure 2. Howards Road cross section.



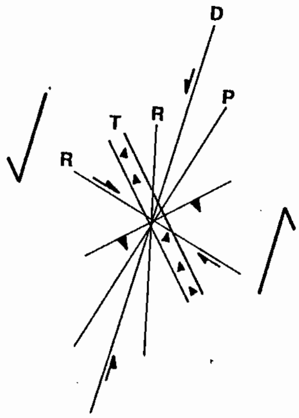


Figure 3. Structures of kinematic significance at locality 2.

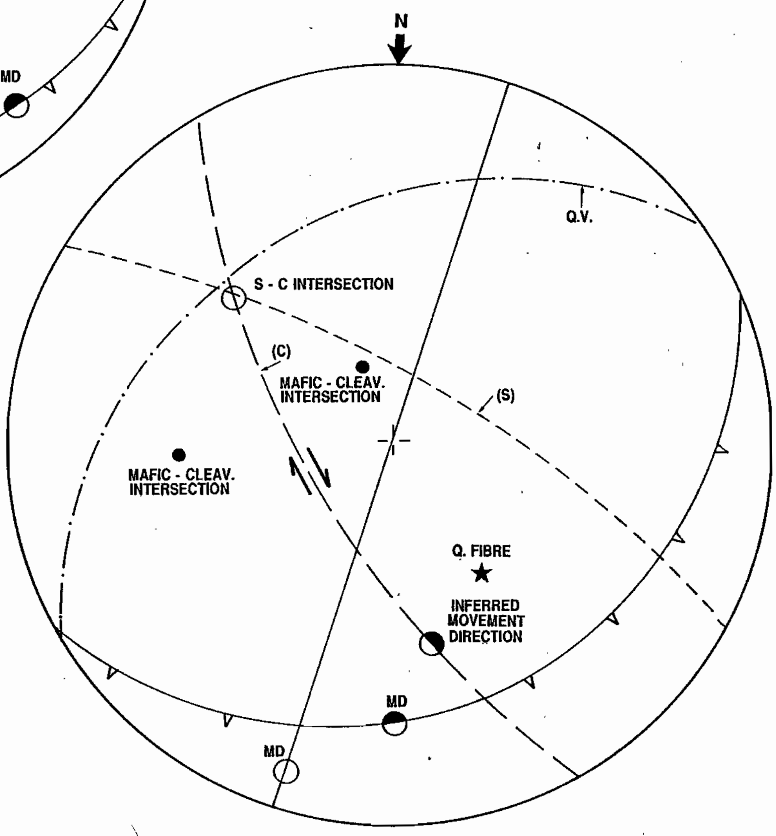


Figure 4. Structures of kinematic significance at locality 5.

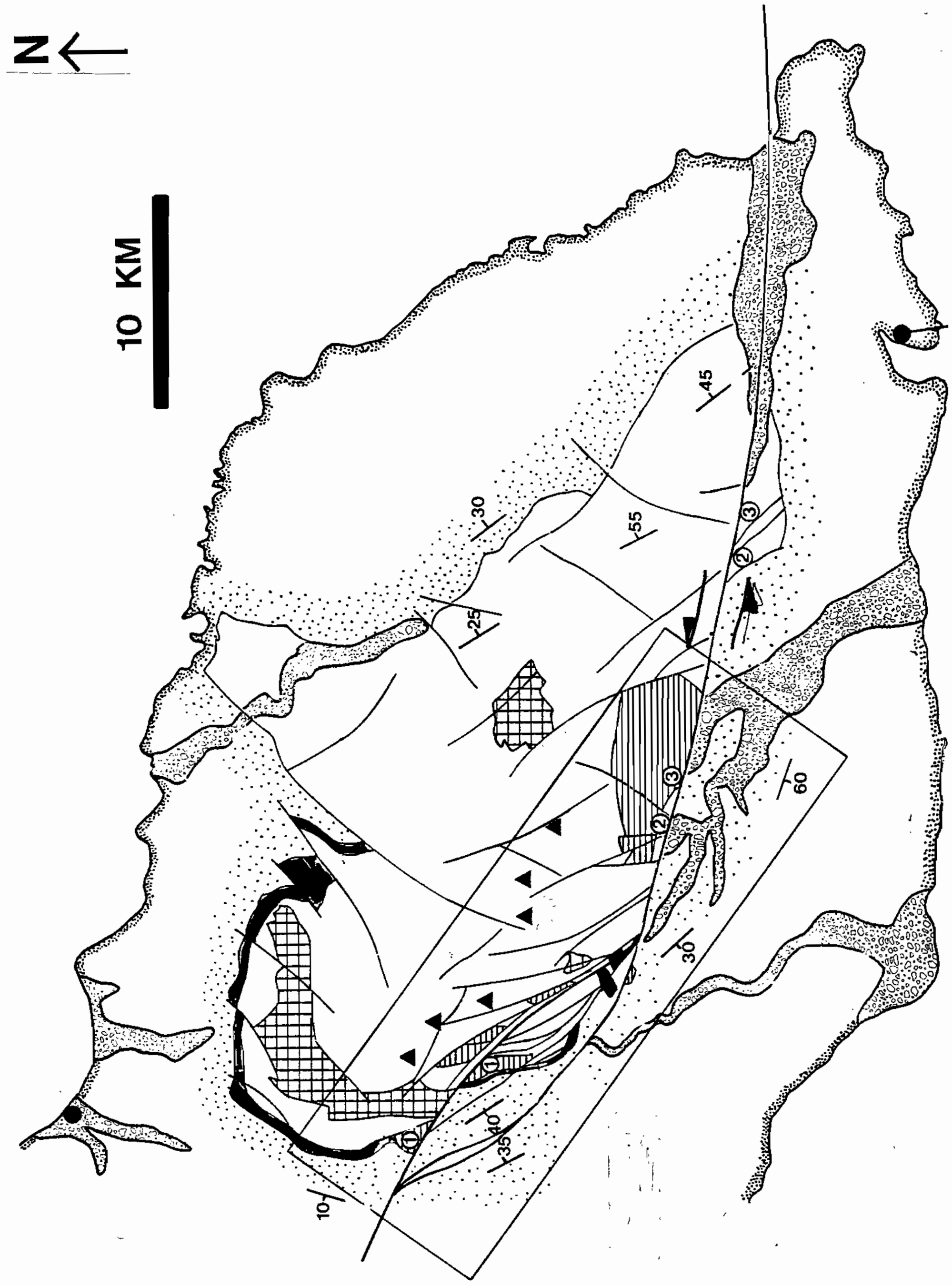


Figure 5. Geological map of restraining bend in sinistral wrench, Jamaica. White - volcaniclastics/ volcanics; chequered - Cretaceous plutons; vertical lines - greenschist/amphibolite; dotted - Palaeogene; black - serpentinite; gravel - fluvial/delta fan deposits (from Mann, Draper & Burke, 1985).