

THE UNIVERSITY OF ADELAIDE

THE STRUCTURAL GEOLOGY OF THE YOHOE
CREEK TO CAPE JERVIS AREA, FLEURIEU
PENINSULA, SOUTH AUSTRALIA.

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The Structural Geology of the Yohoe Creek to Cape Jervis Area, Fleurieu Peninsula, South Australia.

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ABSTRACT

The Neoproterozoic and Cambrian Umberatana, Wilpena, Normanville and Kanmantoo Group rocks of the Yohoe Creek to Cape Jervis area underwent compressional deformation during the Cambro-Ordovician Delamerian Orogeny. This deformation prevailed as thrust faulting, and folding. In some cases the thrusts were accommodated by slip along reactivated Cambrian basin extension faults. Structural mapping of the area shows that the main structure of the area is that of two thrust faults, which are both associated with folding. Folds in the area tend to be of similar (type 2) style and manifest themselves by slip along cleavage planes. An imbricate fan in the southern part of the area is of the leading imbricate fan type. A balanced cross section through the area was based on fold analysis and measurements taken during field work, this section was then restored giving a shortening of 53% for the area. Three dimensional analysis of the structure of the area by Vulcan™ software resulted in a more easily visualised picture of the shape and extent of the folds in the area as well as showing the depth relationships of the thrusts. The method used here of tying together cross sections is a promising method for further work involving the SAFTB.

1. INTRODUCTION

1.1 Regional geology and previous investigations

The Adelaide Fold Belt has an overall sigmoidal shape extending with two axes, one from the Flinders Ranges in the central portion, to Kangaroo Island in the south (figure 1.1). It is approximately 80 kilometres at its widest and 700 kilometres in length. The southernmost portion of this Belt, the Southern Adelaide Fold Thrust Belt (SAFTB), is the area which is of interest to this study. The SAFTB is some 200 kilometres long and is defined as the area between the Mount Lofty Ranges in the north, to Kangaroo Island in the south. The SAFTB is a sequence of metamorphosed and deformed Cambrian and Precambrian sediments. In the study area shown in figure 1.1, rocks belong to the Umberatana, Wilpena, Normanville and Kanmantoo Groups (MESA 1:50000 Jervis Sheet). The sediments were deposited in an extensional basin, extension being accommodated by normal faulting during the Neoproterozoic and Early Cambrian (Jenkins and Sandiford, 1991).

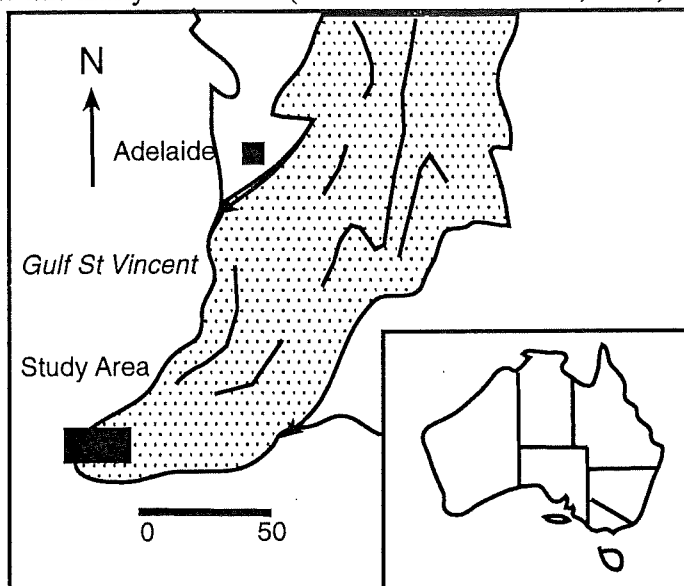


Figure 1.1: The Southern Adelaide Fold Thrust Belt, showing the location of the study area.

Deformation in the region belongs to the Delamerian orogeny (Flöttmann et al., 1994), and manifests itself in three ways, folding, thrusting and shearing. The thrusts are often the result of reactivation of the basin margin extension normal faults, and the folds are a result of accommodation and deformation associated with the thrusting of the adjacent rocks. There is an overall westerly vergence to the SAFTB structures, with this being slightly more of a northwesterly nature in this field area (Flöttmann et al., 1994).

The Adelaide Fold Belt, particularly the SAFTB has been studied and interpreted many times (Mancktelow, 1979a,1990; Jenkins, 1986, 1990; Jenkins and Sandiford 1991,1992; Clarke and Powell, 1989; Steinhardt, 1991; Flöttmann et al., 1994). Previous research in the Yohoe Creek to Cape Jervis region has been almost solely stratigraphic (Daily 1963). Previous investigations into the structure of the area, include that related to the mapping of the Jervis

sheet compiled by Campana and Wilson for the Department of Mines and Energy in 1954 (figure 1.2). This map was produced at inch to a mile scale and the results are dubious. Without the benefit of the knowledge of fold-thrust belt geometry (McClay, 1992), the structural interpretation of the area by Campana and Wilson was that of an overturned anticline with stratigraphy being repeated on the overturned western limb of the anticline. Doubt over this conclusion was raised by Daily (1963) who proposed that the structure of the area consisted of a fault, placing older Umberatana Group Rocks over Younger Kanmantoo Group rocks. The structure of the area was suspected to be much more complex than this after other work in the SAFTB including that in the Talisker area (Rogers, 1991), the Clarendon area (Kapetas, 1993) and the Rapid Bay area to the North (Barrett, 1995) as part of the work of the University of Adelaide SAFTB structure research group. The results of previous studies in this area did not have the benefit of new theories on thin skinned tectonics in other areas which have been suggested as a model for the SAFTB (Clarke & Powell, 1989). Jenkins, in his tectonic reappraisal, brought forth the notion that many of the thrust faults in the SAFTB were in fact reactivated normal faults, caused by basin extension during deposition of the Adelaidean and Kanmantoo groups. Jenkins suspicions are confirmed by Flöttmann et al.,(1994), who reports that many of thrust faults in the Talisker area have normal displacement, but kinematic indicators in the vicinity of these thrusts show reverse movement along these fault planes.

1.2 Location and physiography

The study area is situated at the southern end of the Fleurieu Peninsula, approximately 90 kilometres south of Adelaide, South Australia (figure 1.1). The study area is part of the SAFTB comprises an area of approximately forty square kilometres, extending from Yohoe Creek, 2 kilometres south of Delamere, to 2 kilometres north of Cape Jervis.

The physiography of the study area varies widely. Outcrop on the coast is excellent, with high (30m) cliffs forming along the entire length of the coastal edge of the field area. Outcrop is generally very poor inland, with grassy rolling hills, which are used predominantly for livestock grazing. Inland, outcrop was found almost solely in creeks with this varying from very good to good. Some road cuttings in the area also provided good outcrop, though a large degree of weathering on some rendered these difficult to interpret.

1.3 Aims of the study and methods of investigation

The aims of this thesis are to provide an understanding of the structure of the study area, as part of the work by the SAFTB structure research group. In providing this understanding, it is hoped that the models of thin skinned tectonics, and thrusting via reactivation of earlier basin extension faults, can be further confirmed by the structure of this area.

Aims of this study are to:

- produce a detailed structural map of the area.
- document and illustrate the structural geometry of the area.

-
- construct and restore balanced cross sections of the area.
 - use these cross sections to make a 3D model of the area.
 - determine the strain history of the area.
 - describe the microstructure of the area.
 - construct a kinematic model for the area.

The methods of investigation involve field mapping at 1:10000 scale, on a topographic map sheet, with this being prepared for entry into an arcinfo database at MESA. Strain analysis from deformed elliptical objects was undertaken using the Rf/θ method (Dunnet, 1969) and using a similar method to that used by Lacassin et. al. (1993) in SE-Asia. Thin sections were made to help identify any common fabric or kinematic indicators in the area, as well as for use in strain analysis as described above. Sub-area analysis of strain distribution and fabrics helped with the balancing of cross sections which will be made from field observations.

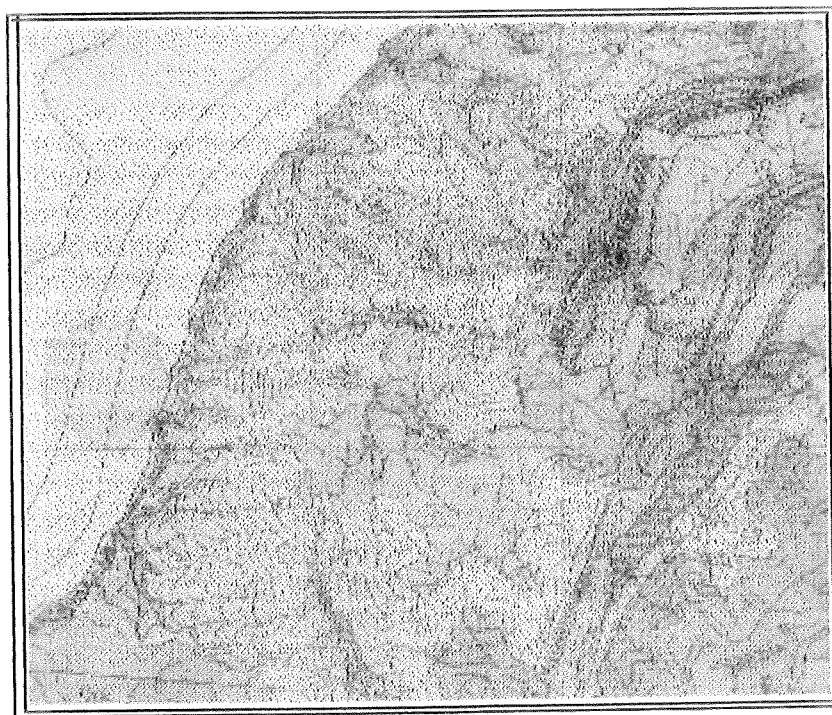


Figure 1.2 : The Yohoe Creek to Tea Tree Creek area, as mapped Campana and Wilson, 1954.

2. STRATIGRAPHY

2.1 Introduction

Previous work has established the rocks in the Cape Jervis to Yohoe Creek area as belonging to members of the Neoproterozoic, Wilpena and Umberatana Groups, and Cambrian Normanville, and Kanmantoo Groups. Previous work in this area, as outlined in chapter 1, was aimed at achieving an understanding of the stratigraphy, most notable of the previous stratigraphic studies is that of Daily (1963), who produced an excellent record of the stratigraphic succession in Yohoe (Stockyards) Creek. It is in this creek that the outcrop is best and is used in this thesis as the section from which the stratigraphy will be described. A stratigraphic table for the Yohoe Creek area, and a map showing lithology and geography are provided at the end of this chapter (Map 1).

2.2 The Umberatana Group

The Umberatana group rocks are the oldest rocks outcropping in this area, the lowermost being the Tapleys Hill Formation, which is overlain by the Brighton Limestone.

Tapleys Hill Formation

In this area the Tapleys Hill Formation is seen almost solely in Yohoe Creek, with only the topmost beds of the unit being thrust over the Cambrian Kanmantoo Group Rocks (figure 2.1). The Tapleys Hill Formation is a dark grey, fine grained, calcareous siltstone, which has undergone metamorphism to biotite grade, revealing a phyllitic appearance on its cleavage surface. Bedding is indistinct but when recognised it is as more fine grained/phyllitic layers containing biotite and sericite, and coarser layers in which quartz grains are visible in thin section. Bedding is planar in both hand specimen and thin section scale. Some thin sections taken in the Tapleys Hill Formation show ellipsoidal nodules which have been used for strain analysis (figure 2.2, chapter 4). The Tapleys Hill Formation is thirty metres thick in the Yohoe Creek section and is only observed in outcrop in the near vicinities of Yohoe Creek.

Brighton Limestone

The Brighton Limestone is like the Tapleys Hill Formation in that it is only seen adjacent to Yohoe Creek, In the field it is easily identified due to it's buff colouring when weathered, and tendency to outcrop more than the units above and below it. The lower boundary is a gradational one with the Tapleys Hill Formation, making for difficulty in thickness estimation. A combination of both the Tapleys Hill Formation and the Brighton Limestone being fifty metres thick in the Yohoe Creek section and an arbitrary boundary giving the Brighton Limestone a thickness of twenty metres. The formation varies from blue grey limestones to calcareous shales, bedding is observed as coarser and finer grained layers, no cleavage is observable in thin section.

Angepena Formation

A dark blue-grey to black calcareous siltstone lies conformably above the Brighton Limestone which Preiss (1987) suggests is a southern equivalent to the Angepena Formation, of the Munyallina Valley near Arkaroola (Preiss 1987). This lower unit is even-grained with bedding observed only as a parting in the rocks. Thirty metres from the top the Angepena Formation is an orange coloured gritty marble, overlying this is a grey siltstone which is characterised by tension gashes filled with calcite (figure 2.3 & 2.4). In this unit bedding variations are more pronounced with grain size variations being more obvious, this difference in grain size also has an effect on the distribution of strain, the angle of the tension gashes with respect to bedding being greater in the coarser grained beds than in the finer grained ones.

2.3 The Wilpena Group

Wilpena Group Rocks in this area conformably overlie the uppermost unit of the Umberatana Group, the Angepena Formation. The Wilpena Group rocks are similar to those in their type section (Daily 1963, Preiss 1987), however large differences in measured thickness is observed in this area when compared to the type section.

Brachina Formation

The Brachina Formation outcrops on Yohoe Creek and is a purple brown coloured siltstone, similar in features to that found on the shore at Hallett Cove. In the Yohoe Creek section it is most readily seen on the slopes of the south side of the creek. This purple shale has a cleavage which breaks the shale up into the familiar pencil shaped cleavage fragments (Preiss 1987). The shale is even-grained throughout with bedding taking the form of a parting, almost identical to the cleavage, little variation in colour is observed throughout the two-hundred-and-fifty metre thickness of this unit.

ABC Range Quartzite

This unit was described by Daily (1963) as an equivalent to the quartzite found at Hallett Cove, overlying the pencil slates of the Brachina Formation. This observation was confirmed by Preiss (1987). Most easily seen in a small quarry to the south side of Yohoe Creek, the ABC Range Quartzite outcrops as a pale grey flaggy quartzite, with green silty interbeds, crossbedding, and some greywacke units. The quartzite units are generally white, with iron weathering giving some a red colouring. No cleavage is visible within this unit, bedding is slabby and up to three metres thick. The ABC Range Quartzite is sixty-five metres thick in the Yohoe Creek section.

2.4 The Normanville Group

The Normanville Group are late Cambrian rocks, and have undergone numerous studies due to the abundance of fossils in some assemblages. The fossils are not treated here as the primary interest lies in the structure of the area, with the stratigraphy providing a template on which to base this work.

Mount Terrible Formation

The Mount Terrible formation in the Yohoe Creek Area outcrops as an eighty metre thick sequence of clastic sediments composed of sandstones and siltstones, the rock takes on a phyllitic appearance towards its base. The lower part of the Mount Terrible Formation is a fine grained shaly siltstone of grey colour, higher up the unit becomes coarser grained and limey. The topmost unit is a coarse grained sandstone, bedding in the Mount Terrible Formation pervades itself as coarse and fine grained units, with the coarser grained beds proving more resistant than those of a finer grained nature, cleavage is not present. Boudinage layering is found consistently throughout the beds of the Mount Terrible Formation as has been reported by Daily (1963) and seen in figure 2.5.

Wangkonda Limestone

The Wangkonda Limestone was divided up into many lithologies by Daily (1963), for this thesis two subdivisions have been used. A mottled argillaceous limestone occurs at the basal twenty metres of the unit, and various marbles above this. Outcrop of this unit is only seen in Yohoe Creek with the lower mottled member being most easily seen in a small waterfall in the creek north of the church on Yohoe Road (figure 2.6). The Wangkonda Limestone is characteristically a grey coloured marble in the Yohoe Creek section, bedding is generally quite thick, with individual slabby beds being about 1 ft thick on average. Cleavage is rarely seen within the unit, and when it is observed it is so close to bedding that measurement of it is extremely difficult. In the Yohoe Creek section the Wangkonda Limestone is approximately 50 metres thick.

Sellick Hill Formation

The boundary between the Sellick Hill Formation and the Wangkonda Limestone is visible in a road cutting in the south side of the creek and in a small quarry, just to the south of Yohoe Road. The Sellick Hill Formation is a laminated calcareous shale at its base, becoming a banded and mottled nodular limestone. The mottled limestone contains quantities of biotite, muscovite and quartz giving a distinctly phyllitic appearance. The limestone bands within these argillaceous units tend to be lenticular (figure 2.7). Nodules in the Sellick Hill Formation at Yohoe Creek are different from those seen in the type section at Sellick Hill, being flattened at Yohoe Creek due to the higher strain in this area. These nodules are phosphatic and are of a slightly grey colour when compared to the buff weathered Limestone. The planes of the phyllitic layering are the cleavage planes but their orientation is so random as to make measuring the cleavage on these planes a pointless task.

Forktree Limestone

The Forktree Limestone has two main members, the lower member is a pure banded marble, light in colour and with fairly coarse grain size. The upper unit is a dark and mottled argillaceous massive limestone and is easily seen in a quarry on the eastern side of the road, to the north side of the creek. Cleavage is not visible in either of these units, and dark and light bands, which are caused by the metamorphism, approximate the original bedding.

Heatherdale Shale

The Heatherdale Shale is a dark grey carbonaceous shale, which conformably overlies the Forktree Limestone, a transitional boundary separating the two units. In this area calcareous nodules within the shale weather out and are scattered over the ground. This proves useful for mapping in areas where the bulk of the rock seems to have weathered away. Upper units within the Heatherdale Shale are noted to contain black phosphatic nodules (Daily 1963, Rogers 1991), although none were found in the field area. Bedding surfaces in the Heatherdale Shale were poor and cleavage poorly defined. Quartz, biotite, muscovite and sericite are all present in this unit, with the presence of sericite suggesting low grade metamorphism of clays. The contact between the Carrickalinga Head Formation and the Heatherdale Shale is an unconformable one, with erosional surfaces suggested without firm evidence by Jenkins and Sandiford 1990, and observed by Jago (Jago et. al. 1995). Jago also noted large thickness differences in the Heatherdale Shale due to this erosional nature of the contact. Other thoughts with regards to this boundary are that of a thrust fault (James, pers. comms.).

2.5 The Kanmantoo Group

The Kanmantoo Group rocks are the youngest rocks outcropping in the study area, they are Cambrian in age, and consist of blue grey to brown greywackes and sandstones.

Carrickalinga Head Formation

The base of the Kanmantoo Group is an erosional surface, with erosion into the Normanville Group rocks below. This is the Carrickalinga Head Formation, a sequence of brown to blue grey massive metasandstones of low biotite grade. Most of the outcrop of this unit is observed along the coast of the field area. Lower units of the Carrickalinga Head Formation are of a brown colour and much difference in grain size is observed between layers, the top of this unit in the Yohoe Creek to Cape Jervis area is a shiny blue metallic grey quartzite. Cleavage is observed in this unit but is particularly close to bedding and most measurements of cleavage are made as intersection lineations.

Backstairs Passage Formation

The youngest rocks in the area are of the Backstairs Passage Formation, these are a series of grey and brown, cross bedded sandstones (figure 2.8). The cross bedding occurs at various scales, and some units with quite large scale cross bedding gave the only marker units within the unit. Cleavage in this rock was hardly discernible except in areas of folded bedding, where an axial planar cleavage was seen in similar style folds. Lenticular bedding, like that which occurs around the boudins in figure 3.2, and SC fabrics are seen in these rocks.

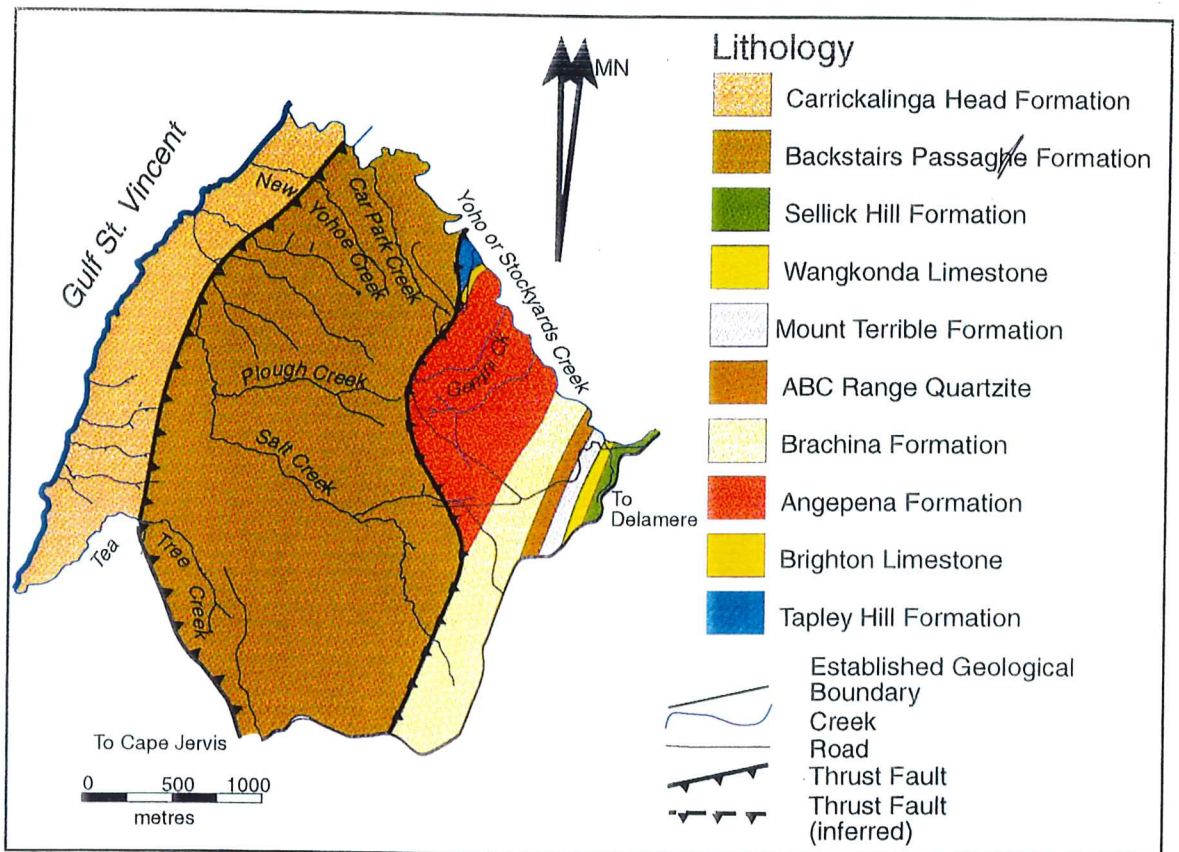


Figure 2.2 Elongate nodules in the Tapleys Hill Formation, Yohoe Creek Hangingwall.

Figure 2.3 Tension gash in a thin section of upper Angepena Formation. Section taken from sample in figure 2.4

Figure 2.4 Tension gashes in a hand specimen of Angepena Formation, in the Yohoe Hangingwall.

Figure 2.6 Wangkonda limestone in Yohoe Creek, near Yohoe Road.

Figure 2.7 Elongate nodules in the Sellick Hill Formation. The nodules are phosphatic.

Figure 2.8 Cross bedding in the Plough Creek Hangingwall, showing right way up.

Fig 2.2

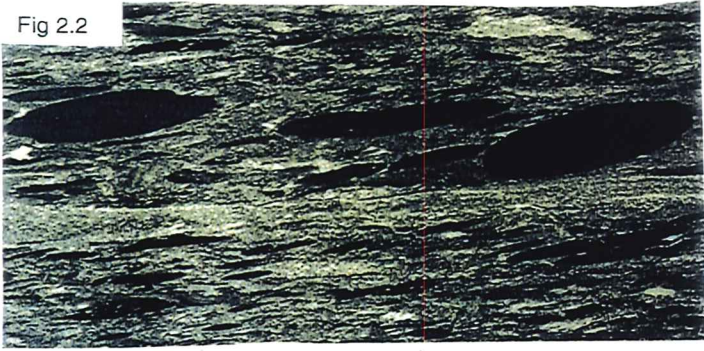


Fig 2.3



Fig 2.8



Fig 2.4

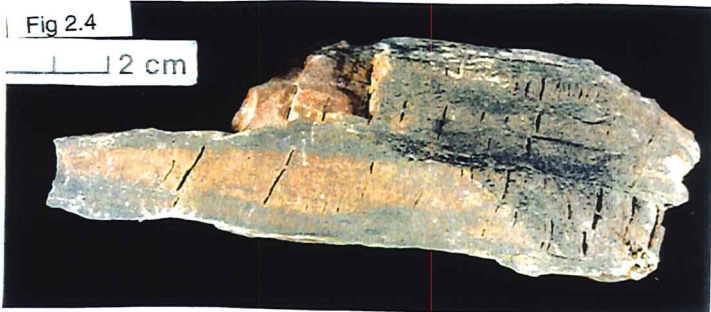


Fig 2.6



Fig 2.7



Fig 2.5



3. STRUCTURAL GEOMETRY AND MICROSTRUCTURE

3.1 Introduction

The Cape Jervis - Yohoe Creek region has been divided up into four domains, separated by major thrust faults. Maps 1, 2 and 3 represent lithological variations along with surfaces S_0 and S_1 , and lineations L_1^0 (intersection lineation) L_1 (slip lineation) and L_2^0 (Tension gash direction) and their respective stereographic projections.

3.2 Methods of structural analysis

The Cape Jervis to Yohoe Creek area was mapped in detail at 1:10000 scale using arial photographs, and contoured orthophoto base maps. Structural and geological data was collected at each locality with measurements of cleavage, bedding, elongation and intersection lineations, as well as descriptions of any structures observed at the locality. Overturned folds in the area were interpreted as such due to their bedding/cleavage vergence relationship (s/z) (figure 3.1 & 3.13).

Hand samples were collected at various locations within the field area (Appendix 3) which were cut into thin sections to allow inspection under a petrographic microscope.

3.3 Structural Zones

The four structural domains mentioned above are:

- (1) Plough Creek Footwall
- (2) Yohoe Creek Footwall
- (3) Yohoe Hangingwall
- (4) Tea Tree Creek Imbricate Zone

As can be deduced from the names given to these zones there are three main blocks which have been thrust over each other, these blocks suffering deformation due to this thrusting, giving footwall and hangingwall folds against the faults.

A brief description of each of these zones follows:-

Domain 1

This is the westernmost zone in the study area. This zone has no structural western limit, but is bound by the shoreline, which has been interpreted as the surface expression of a Tertiary Fault (Flöttmann pers comms 1995). Work by Barrett (1995) suggests an off shore shear zone as the major decollement in the area. To the east this zone is bound by the Plough Creek Thrust Fault. Veins and elongate lenticular bedding are the structures which predominate in this zone. Separating domain 1 from domain 2 is the Plough Creek Thrust Fault, this fault separates the Carrickalinga Head Formation from the Backstairs Passage Formation, with the Backstairs Passage Formation being thrust over the top of the Carrickalinga Head Formation. Although

this gives a normal sense of displacement, kinematic indicators in the overthrust zone suggest a reverse sense of movement. The Plough Creek Thrust Fault is approximately two metres wide and parallels the coast in the study area, continuation to the south has been mapped by Flöttmann (pers com, 1995) who has described it as the major decollement surface on the south coast of the Fleurieu Peninsula. The northern continuation of the PCTF has been mapped by Barrett (1995 pers com.), who concurs with my findings that this is a branch fault off the major Yohoe Creek Thrust Fault.

Domain 2

The Plough Creek Hangingwall is a sequence of east younging, right way up Backstairs Passage Formation beds, dipping at approximately 40° to the east over much of the field area. In the southern part of the area this monotony is broken by a series of folds, which may involve imbricate faulting. Some veins are seen within the Backstairs Passage Formation here, with those seen in Car Park Creek (figure 3.2) being used to determine the strain in this area.

The Plough Creek Hangingwall Anticline is a narrow but laterally extensive fold adjacent to and east of the Plough Creek Thrust Fault. Only five to fifteen metres wide, varying across the study area, this zone is an overturned anticline which abuts the Plough Creek Thrust Fault to the west, this fold has formed due to the reverse motion along the Plough Creek Fault, and is convincing evidence for reverse movement on this fault plane..

The Yohoe Creek Footwall Syncline is only recognised by the presence of overturned bedding near the Yohoe Creek Thrust Fault. This is most readily observed on the Yohoe Road, leading to the Salt Cliffs sheep station. Orange weathered sandstones show inverted cross bedding at the top of New Yohoe Creek (figure 3.3), and the overturned limb of this fold is also observable in Plough Creek. Perpendicular bedding is observed further to the south of the field area, just off the main road.

Domain 3

The Yohoe Creek Thrust Fault is the major structure within the study area, it places rocks of the Adelaidean, Umberatana and Wilpena Groups directly on top of the Cambrian, Backstairs Passage Formation. To the North of the Study area, it is the Tapley Hill Formation of the Umberatana Group thrust over the Carrickalinga Head Formation, to the South it is the Brachina Formation of the Wilpena Group. An almost complete Adelaidean succession on top of this thrust fault, continuing to the Backstairs Passage and Carrickalinga Head Formation, is ample evidence that this is definitely a fault with a reverse sense of displacement. It is proposed here that the YCTF is a link between the Talisker Fault and the Normanville Thrust, the link with the Normanville Thrust is supported by the work of Barrett (1995), and the proximity of the northern limit of the Talisker Fault (Rogers 1991), to the southern limit of YCTF is reason to suggest this relationship. Rogers (1991) has reported that the Talisker Fault is a reactivated normal fault, this may be the case for the Yohoe Creek Thrust Fault but field evidence is lacking.

Overturned bedding is observed in Gemini Creek, adjacent to YCTF, the interpretation of this is as a hangingwall anticline to the YCTF. This Anticline is not laterally extensive and appears to be present only where the Angepena Formation makes contact with the Backstairs Passage

Formation via the YCTF, as it is not seen in Yohoe Creek to the north. Here, Tapleys Hill Formation makes contact with the Backstairs Passage Formation, in the south the Brachina Formation makes contact with Backstairs Passage Formation. It is suspected that the rheology of the rocks involved are the controls on the hangingwall structure, this is discussed in more depth in chapter 6. The majority of this domain, other than the Yohoe Creek Hangingwall Anticline, is right way up eastward younging, Umberatana, Wilpena, Normanville and Kanmantoo Group Rocks. Structures in this area are all of small scale, such as boudinage bedding (figure 2.5) and veins, and elongate nodules (figure 2.2 & 2.7)

Domain 4

The Tea Tree Creek Imbricate Zone (TTCIZ) is located in the southern part of the field area, and is recognised by abrupt changes in bedding direction, which it suspected are separated by narrow thrust faults. To the north of this imbricate zone in Salt Creek and Long Walk Home Creek, the lateral extent of this imbricate zone can be observed. In Salt Creek, an overturned anticline is observed, lack of outcrop makes determining exact structure difficult, it is expected that this is followed by a syncline and another overturned anticline. In Long Walk Home Creek, bedding changes from overturned to right way up within very short distances, and it is thought that this is the beginning of the imbricate zone.

3.3 Folding

Four folded zones exist within the study area, the Tee Tree Creek imbricate zone, the Plough Creek Hangingwall Anticline, and the Yohoe Creek Footwall Syncline and Hangingwall Anticline. Some folds such as those in the Imbricate zone, and the Yohoe Creek hangingwall and footwall folds are not observable in outcrop and have been interpreted on the basis of vergence relationships.

The Plough Creek Hangingwall Anticline is observable in outcrop at a number of localities throughout the field area. The eroded state of the rocks in these areas does not allow easy description however. Samples collected in these zones commonly show similar style folding at both the hand specimen and microscopic scales (3.8a & 3.8b). Fold analysis conducted on one thin section using the dip isogon method of Ramsay and Huber 1967, displays this (figure 3.4). Analysis of this section shows that the mechanism producing these folds is that of slip along the cleavage plane, this is called shear or slip folding and can be demonstrated with a card deck model, folds of this style form via slip along discrete planes oblique to the layer being folded, these planes are consequently parallel to the fold axial plane (Hobbs et. al., 1976).

The geometry of the Yohoe Creek Hangingwall Anticline mirrors the smaller scale geometry of the Plough Creek Hangingwall Anticline, as can be seen from the dip isogon analysis in figure 3.5, the macroscopic geometry of this fold is suspected to conform to that of the microscopic scale, this fold has been interpreted on the basis of vergence, as there is no observable hinge area between the two limbs which young in opposite directions. The Yohoe Creek Footwall Syncline is the most elusive fold in the area when it comes to determining fold style, nowhere in the field area is it possible to locate a fold hinge, all that are visible are fold limbs, therefore no samples were collected for the hinges and hence fold style has not been determined. It is

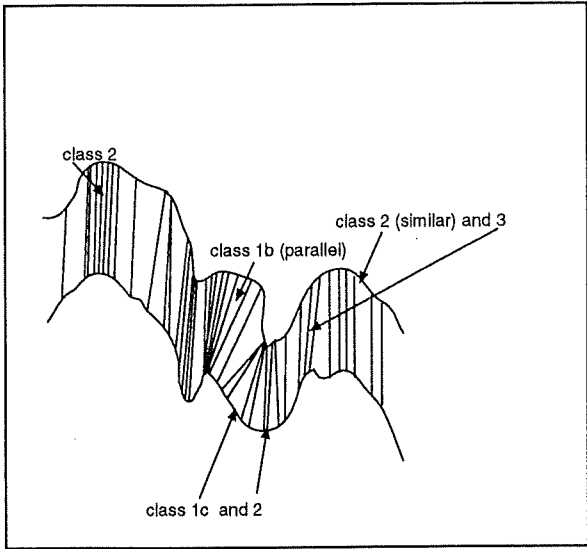


Figure 3.2: Dip isogon analysis of a folded layer in the Plough Creek Hangingwall Anticline

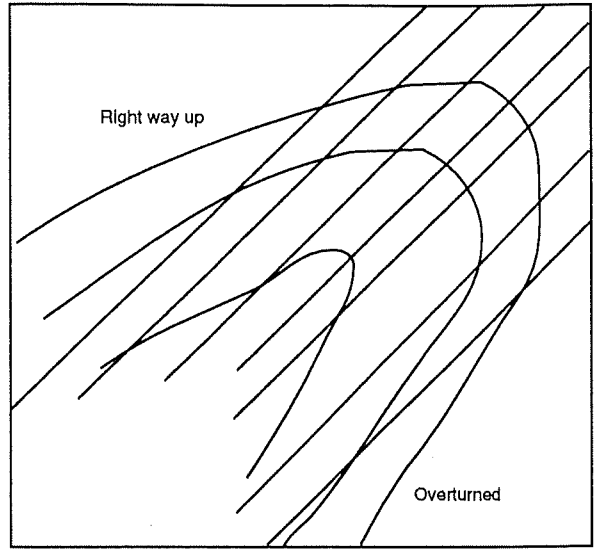


Figure 3.1: Cleavage / Bedding relationships across an overturned anticline

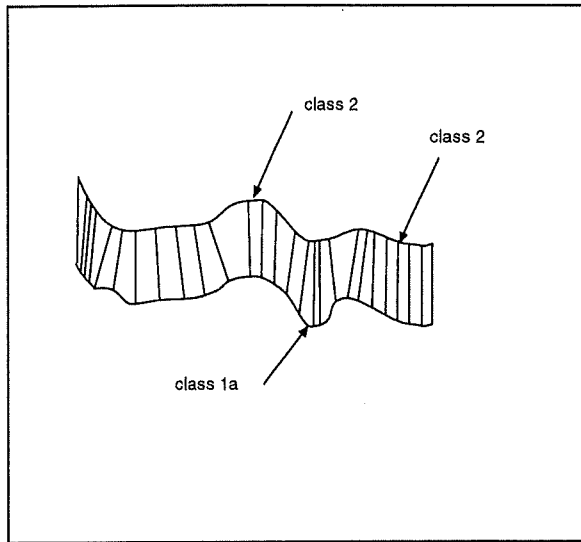


Figure 3.4: Dip isogon analysis of a folded layer in the Yohoe Creek Hangingwall Anticline

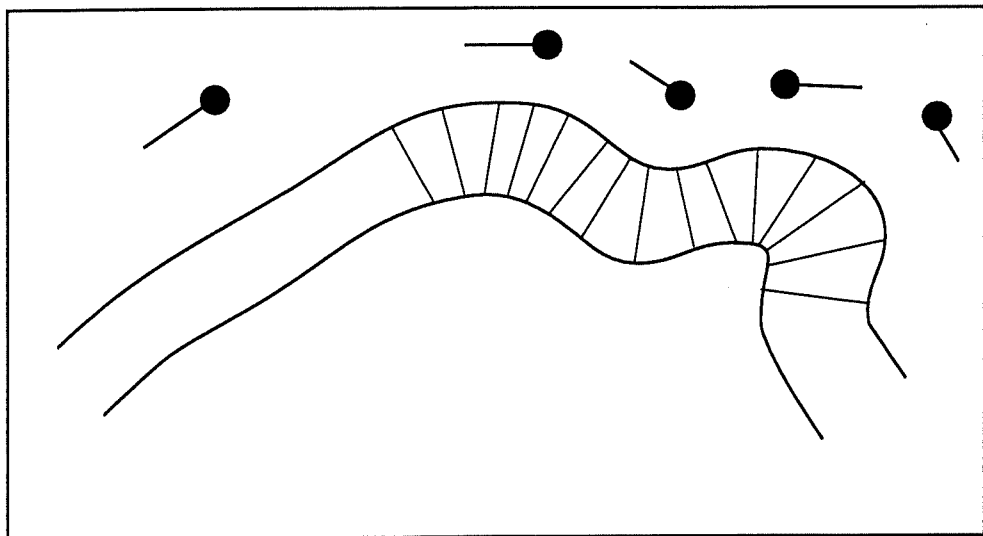


Figure 3.6: fold drawn in the profile section, taken from data collected in Salt Creek. The dip isogon analysis shows type 1 b (parallel folding)

expected that these folds are also of type 2, following the style of folding over the rest of the area.

The southern imbricate zone shows type 2 (similar) fold styles in hand specimens with slip along the cleavage plane. These folds are most likely hangingwall anticline to the thrust faults in this imbricate zone. To the north of this area more open type 1b style folding is observed, with detailed outcrop mapping producing the fold cross section as seen in figure 3.6. This more open style shows how the imbricate zone disappears laterally to the north of the field area.

3.3 Faulting

Faulting in the Yohoe Creek to Cape Jervis area is entirely of a reverse nature, evidence for this lies in the structures around the faults such as fault propagation folds. This results in footwall synclines and hangingwall anticlines, typical of faults with a reverse displacement. Both of the major fault structures cut the rocks at approximately 50°, it is suspected that these faults extend to a common basal detachment surface, perhaps the Rapid Bay Shear zone which has been reported by Barrett (1995), closer to the foreland of the SAFTB is the PCTF, which it is suspected is a growth fault, produced during basin extension during deposition of the Cambrian Kanmantoo Group rocks, and reactivated by compression, the direction of slip reversed by compression during the Cambro-Ordovician, Delamerian Orogeny. Support for this theory comes from the normal displacement on this fault which shows a reverse nature. Other faults of this type have been reported in the SAFTB, (Jenkins, 1990; Flöttmann, 1994; Rogers 1991, Mancktelow, 1990).

The YCTF is thought to be the major detachment in this area, with a large displacement of some 4.5 km observed after construction of the cross section (figure 3.11). Reverse movement along this fault is proven by a full sequence of Adelaidean and Cambrian sediments which have been thrust over younger Cambrian Backstairs Passage Formation of Domain 2.

Suspected faults in the Southern imbricate zone, are thought to be of the type created in a leading imbricate fan. These faults extend to the PCTF below them and are most likely sub-parallel to the leading PCTF. The northern extent of the folds in this zone is shown to grade towards more open style folding, it is suspected that the faults die out, allowing the folds to take on this more open style.

3.4 Fabrics

The fabric throughout the area is extremely constant, with the main deformational fabric being a cleavage which is observed in most units within the field area, with the exception of the marbles. In outcrop the cleavage is transposed with the S_0 (bedding) foliation (figure 3.7), making observation difficult on occasions. In thin section this fabric is observed as a preferred orientation of minerals, in many specimens the biotite is readily observed to follow a constant direction. This constancy of direction is useful in mapping fold structures in the area, changes in the S_0 direction while S_1 remains constant, gives a different Bedding / Cleavage relationship, allowing the structure to be recognised.

Thin sections of samples collected in the field were prepared and using a polarising microscope the fabrics of the rocks were examined. Fold axial planar cleavage is present in thin sections taken from specimens collected in the Plough Creek Hangingwall Anticline (figure 3.8), slip along these cleavage planes can be observed at the microscopic scale (3.8 a & b) as well as the hand specimen scale (3.13). Elsewhere in the Carrickalinga Head Formation the cleavage is observed to run parallel to the bedding (figure 3.8), this is the case with much of the field area, cleavage being transposed onto the bedding plane of the rocks. Sections of Sellicks Hill Formation, and other marbles in the area show a definite mineral preferred orientation, in the XZ plane but are void of any cleavage, due to the metamorphism of these rocks (figure 3.10). The Angepena Formation has been noted to contain tension gashes in its top twenty metres, in thin section it can be seen that these tension gashes are at approximately 80° to the angle of the transposed bedding and cleavage (figure 2.3 & 2.4), this is the sole evidence in this area for two separate stages of deformation in the area, but does support the D2 deformation as has been reported by Barrett (1995) for the Yohoe Creek to Rapid Bay area to the north.

3.5 Cross Section Construction

The selection of the section line (Appendix 3) was made in order to best show the structural geometry of the area. In construction of the section measurements were taken from areas close to the line of the section and projected into the plane of the section using stereoplot II (Mancktelow, 1989) for the Macintosh computers. Using these to constrain the bedding dip and the fold classification made in section 3.3 the section was drawn. The Busk method (Dahlstrom, 1969a) was used to construct the bedding planes in between the YCFS and the PCHA, and these two folds were represented as type 2 (similar) style folds according to the classification of Ramsay (1967). Restoration of this section using a stratigraphic template and curvimeter resulted in the section seen in figure 3.12 and was constructed according to Woodward (1989), constant bed thickness was used in the restoration, as the thickened limbs in the folds is tectonic and did not exist before the folding took place.

Figure 3.2 Stretched boudins in Car Park Creek, the photo is taken in approximately the XZ section

Figure 3.3 Overtaken bedding within the Backstairs Passage Formation, positive proof of a footwall syncline to the Yohoe Creek Thrust.

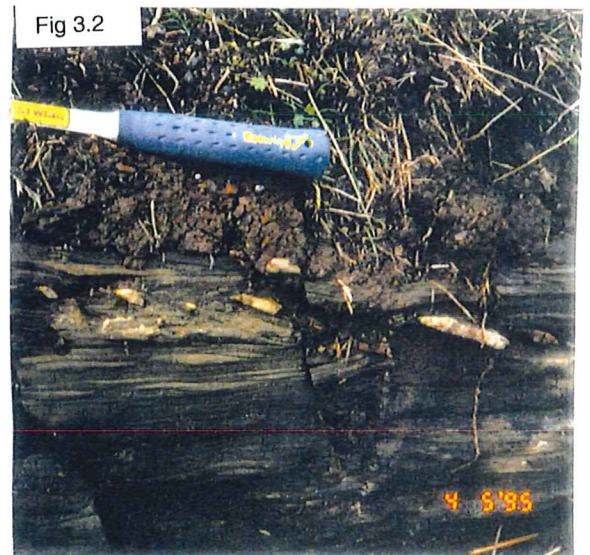
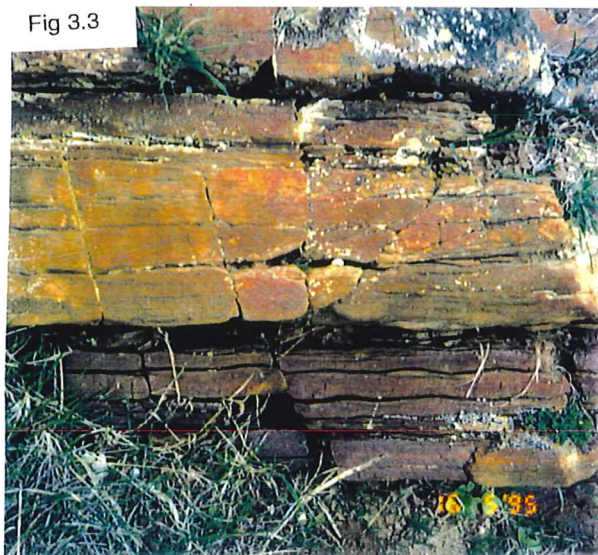
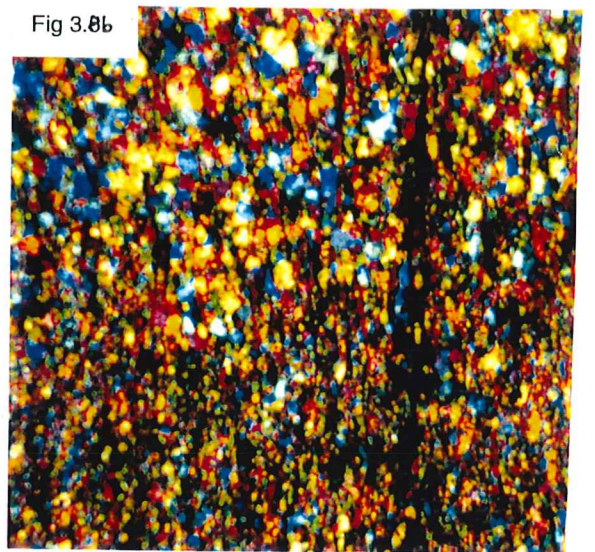
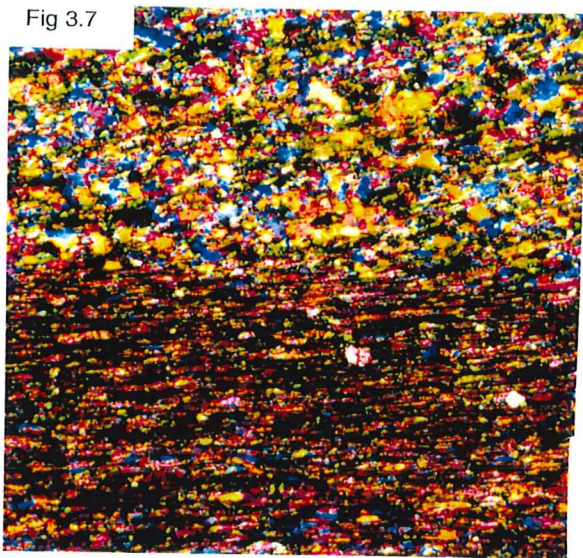
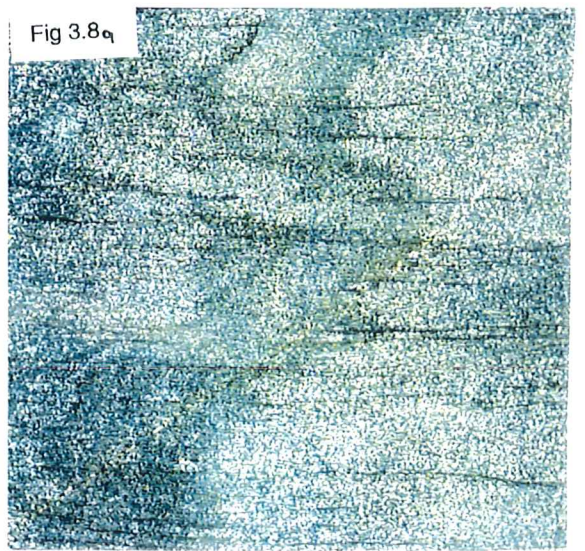
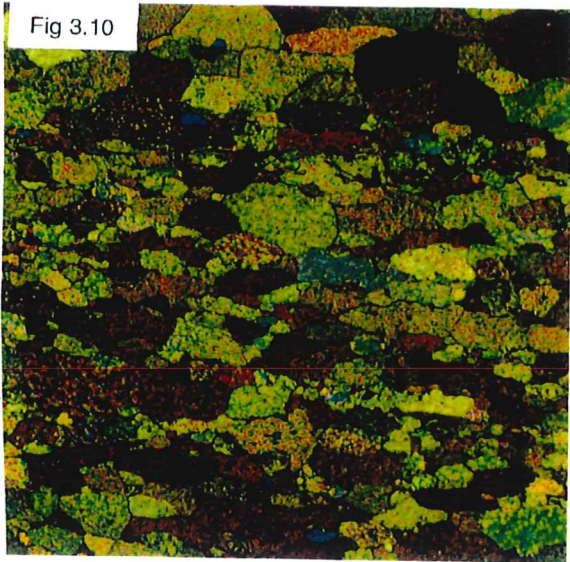
Figure 3.7 Transposed bedding in a thin section of Backstairs Passage Formation, this is a common phenomenon throughout the field area.

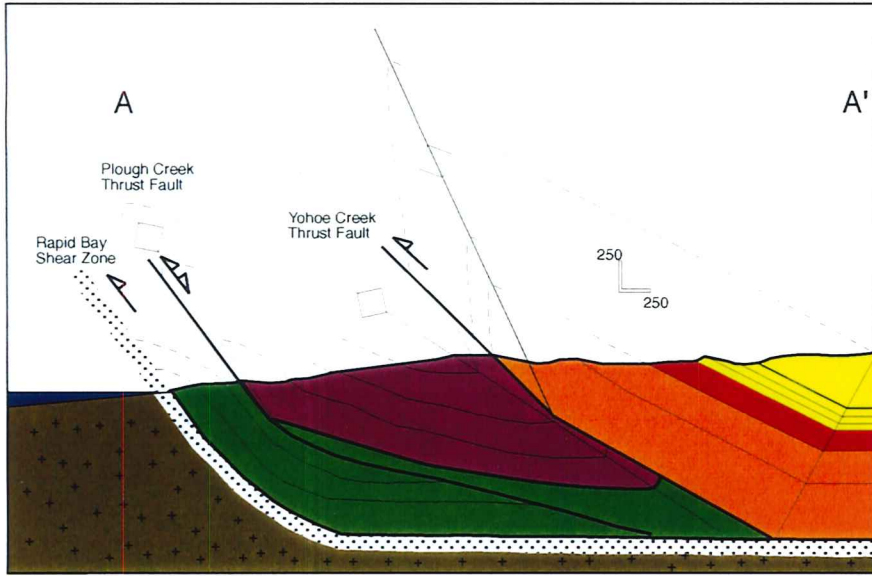
Figure 3.8a A thin section of Backstairs Passage Formation, the sample was taken from the Plough Creek Hangingwall Anticline, hence the axial planar cleavage.






Figure 3.8b Closer view of the same section as fig3.8a, this time under a microscope, the grain size delineates bedding, the fold axial planar cleavage is obvious.

Figure 3.10 Thin section of Sellick Hill Formation, this is the XZ section of the sample used for strain analysis, in chapter 4.

Figure 3.13 The hangingwall anticline in the Angepena Formation also shows similar style folding with slip along the axial planar cleavage .

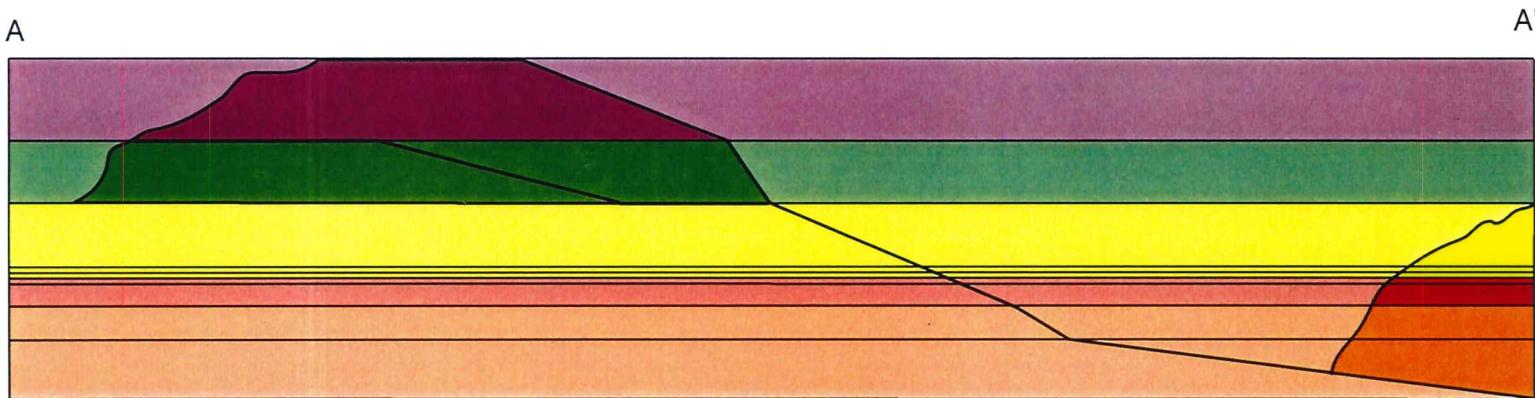




Legend	
	Backstairs Passage Formation
	Carrickalinga Head Formation
	Normanville Group
	Wilpena Group
	Umberatana Group

Cross Section From A-A' (figure 3.11)
 Restored Section From A-A' (fig 3.12)

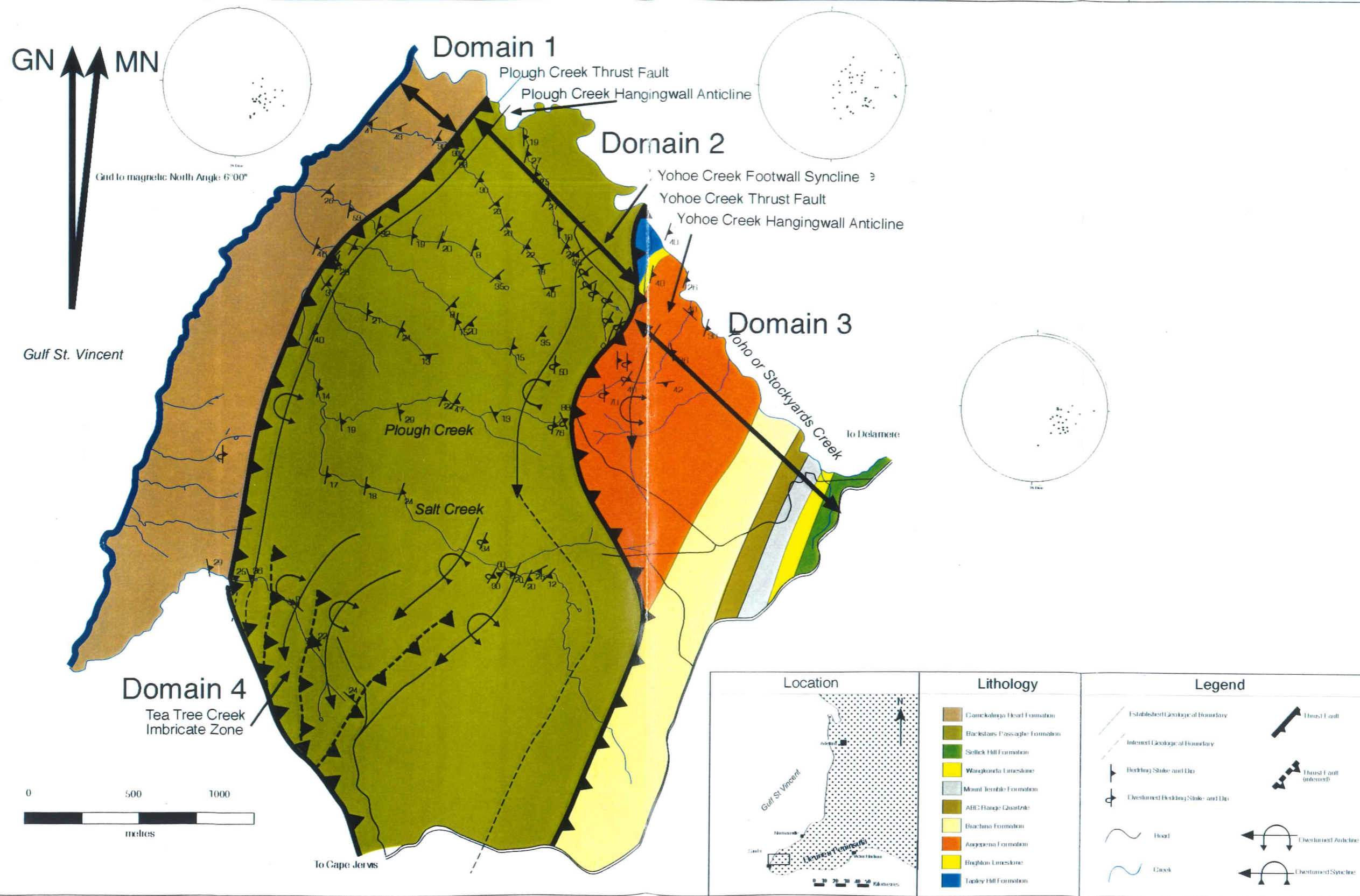
Appendix 3 shows the section line



Map #2

Geology Of the Cape Jervis to Yoho Creek Area

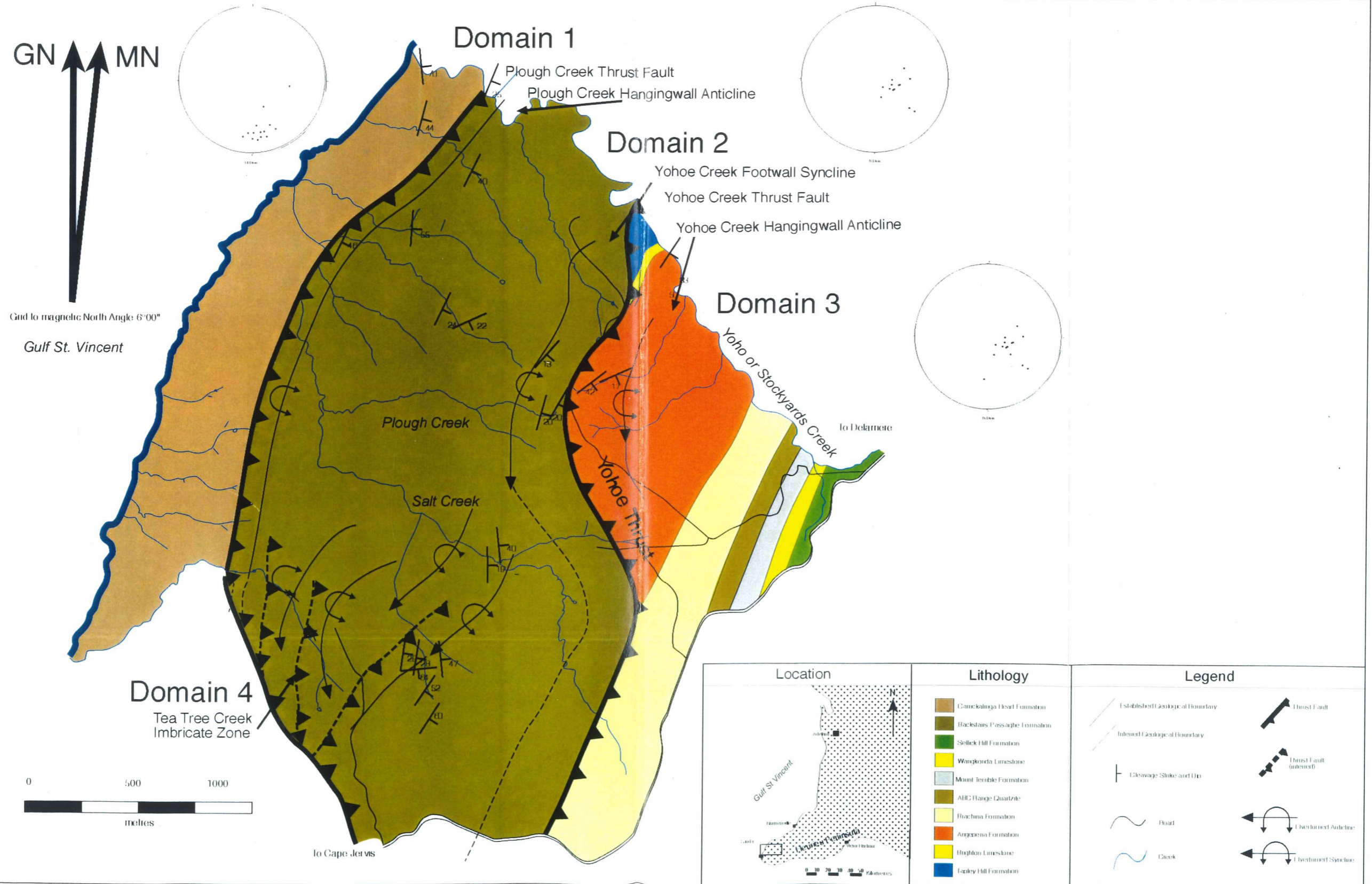
Lithology and Bedding



Map #3

Geology Of the Cape Jervis to Yoho Creek Area

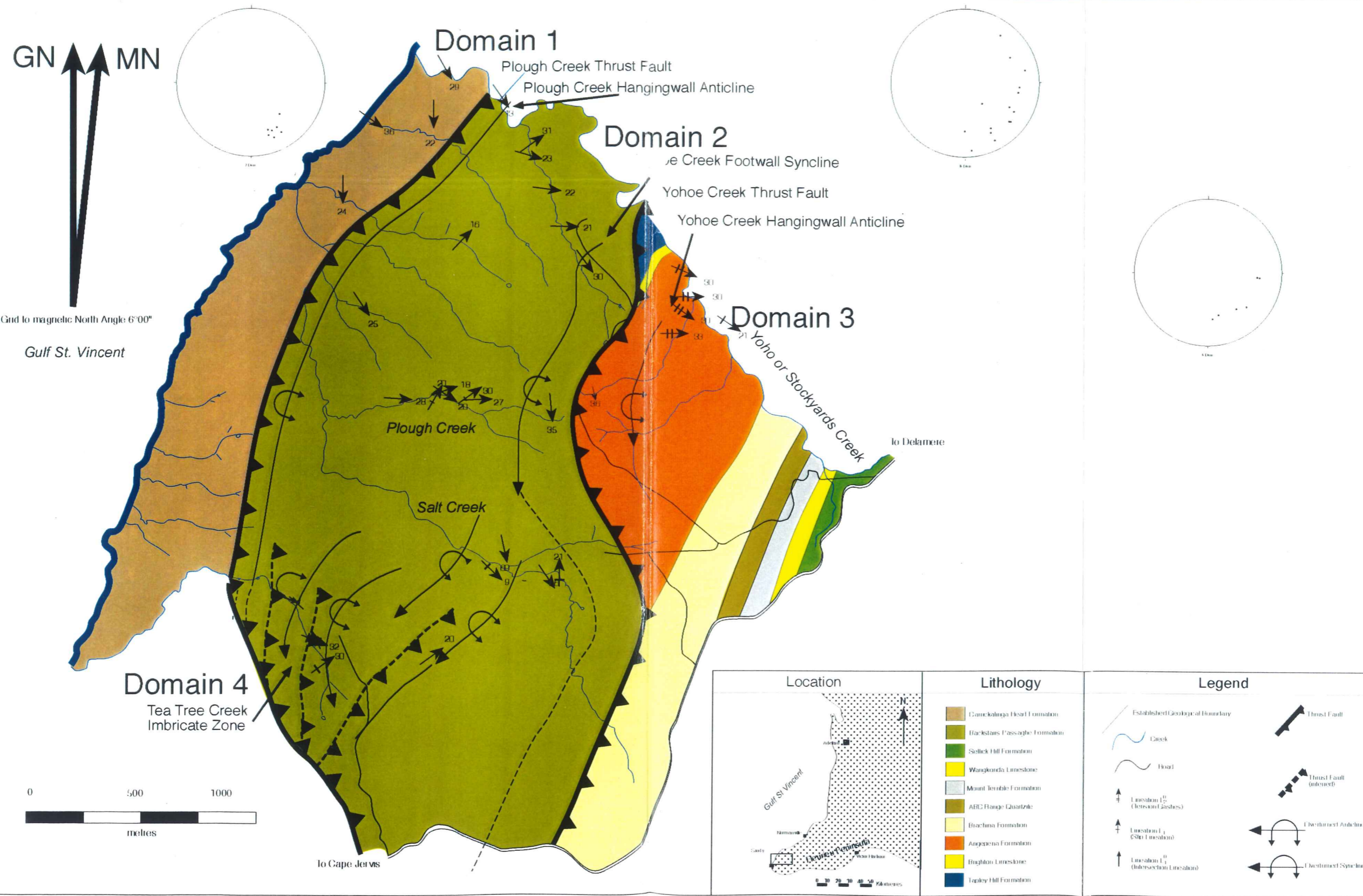
Lithology and Cleavage



Map #4

Geology Of the Cape Jervis to Yoho Creek Area

Structural Data:
Lineations



4 STRAIN ANALYSIS

4.1 Introduction

Strain analysis was conducted in the Yohoe Creek Hangingwall Anticline, the Yohoe Hangingwall and in the Plough Creek Hangingwall. Two different methods of strain analysis were used, the Rf/ϕ method (Dunnnett, 1969), the method described by Lacassin et al., 1993. These techniques were deemed the most useful techniques for determining the strain on evidence collected in the field, Fry plots (Fry, 1979) were attempted but the number of points available to be plotted gave disappointing results. Hudleston analysis on folds in the area was not considered, as this method is not intended for use on similar style folds, like those which prevail in the field area.

4.2 The Rf/ϕ technique

Strain markers in the Tapleys Hill and Sellicks Hill Formations

The Tapley Hill Formation in this area is a grey shale, its cleavage is far easier to observe than its bedding. Sectioning of this rock showed that the rock contained many elongate nodules, in some cases these made up the majority of a bed. This type of strain marker is ideal for analysis with the Rf/ϕ method and the Fry method, with these methods being designed for measuring the strain in rocks containing elongate nodules.

The Sellick Hill Formation contains elongate nodules up to 30 cm long in some beds and has been metamorphosed into a marble, having undergone recrystallization during the Delamerian Orogeny. Strain analysis was not performed on these but was conducted using the Rf/ϕ method on both XZ and YZ thin sections of the marble, as well as on photographs taken of the long nodules in the field. A comparison of the strain in both of these samples was made.

Method of Analysis

Oriented samples of the lithologies to undergo strain analysis were cut and thin sections made in both their XZ and YZ principal planes of the strain ellipsoid. The X, Y and Z axes respectively represent the major, intermediate and minor axes of the strain ellipsoid (figure 4.1). With these axes defined by the ellipsoidal objects within the Tapley Hill Formation. Close up photographs were taken of each section, and these were measured using DIGITIZE™ (McEachran, 1989), a software package for the Apple Macintosh computer, which can be used to create a two dimensional coordinate system for a series of points. Input of points was accomplished by the use of a KURTA IS/ADB digitising tablet. The shapes of the objects were input using four points which represented the long and short axes of the strain ellipse. This same technique of photography and digitising was used for the sections in the Sellick Hill Formation.

Following digitising, the numerical data was transferred to a program called INSTRAIN (Erslev 1989). This program requires its data to be input as x,y coordinates and in text only (ASCII) form, the points plotted with the digitize program are saved in this form.

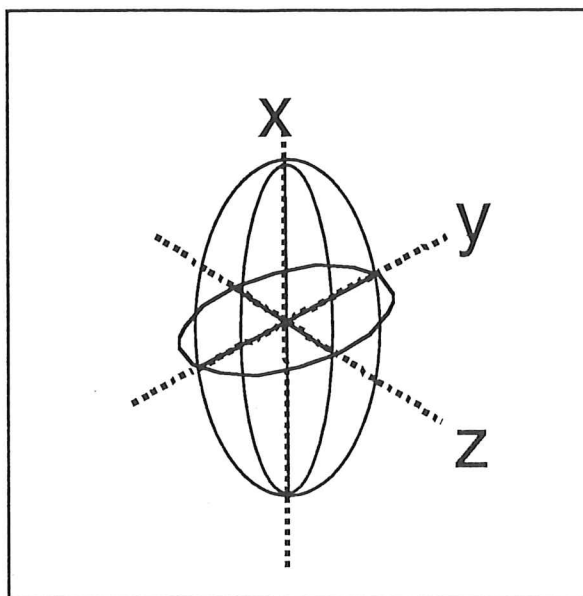


Figure 4.1: The strain ellipse showing the major (x), intermediate (y) and minor strain (z) axis.

Instrain has a number of options but is principally set up to provide Rf/ϕ and Fry Plots. In addition to Rf/ϕ plots, INSTRAIN™ gives the ellipticity Range, mean arithmetic and harmonic ellipticity of the objects, the mean object ellipse and mean phi are represented.

Results of Rf/ϕ Analysis.

Rf/ϕ plots as well as numerical data derived from the Instrain application is presented in Appendix 4 for samples 1063/10 (figure 2.2) and 1063/13 (figure 3.10) in both their XZ and YZ sections. In the Tapleys Hill sample (1063/10) the elongate nodules have their xy axis defined by the elongation lineation, and lie within the cleavage (XY) plane. The nodules within the Tapleys Hill Formation have an initially prolate form, with Ri (X:Y:Z)= 3.686:1.98:1.0, and show little alteration in the deformed state with Rs (X:Y:Z)= 3.767:2.002:1.0. Shortening was calculated using the method set out in Ramsay (1987, vol 1) for this sample and was found to be extremely high at 70%, but a result such as this is not unexpected in the vicinity of a thrust. Strain analysis on the sample from the Sellick Hill Formation (1063/13) gave Ri (X:Y:Z) values of 5.6:2.5:1.0 and Rs (X:Y:Z) = 9.7:4.2:1.0. Shortening for this sample was calculated to be 49% which appears high, but taking into account that this is probably the least competent rock in the area, the fact that it takes up so much of the strain is perfectly reasonable. Flinn plots (appendix 1) show the positions of the initial and shortened ellipsoids for sample 1063/13 and 1063/10, with both showing that the shortened ellipsoids take on more oblate shape than that of the unstrained ellipsoids, calculations of the k value according to the method set out in Ramsay and Huber (1987) also confirms this observation.

The Deformed Vein Technique

Analysis of strain on a deformed vein was performed on a quartz vein in the Carrickalinga Head Formation approximately in the middle of the Yohoe Thrust Fault and the Plough Creek Thrust Fault. The vein appears to have been boudinaged to some extent and then torn apart, the method used by Lacassin et al in Tertiary shear zones of SE Asia is a good method of strain analysis in this circumstance.

Method of analysis

The first step of the analysis was to scan in a photographed image of the veins (figure 3.2), using the software package Adobe Photoshop™, and a scanmaker plug-in colour scanner on an Apple PowerMacintosh 8100. The veins were then traced using Aldus Freehand 5.0™ (Appendix 1). Restoring the gaps between the separate boudins, caused by movement along the shear planes, was accommodated easily with this software. Surface analysis was then used with the screen image increased to 800% in size and a criss-cross fill pattern employed to estimate the area of the separate boudin elements. (results for this are displayed in Appendix 1). An estimate of the original thickness of the vein was then made, on the assumption that it was the thickness of the thickest boudin element. This assumption would underestimate the original thickness as it is unlikely that the boudin elements had increased in thickness during deformation (Laccassin., et.,al 1993). Assuming that the surface of the original vein was the same as all of the sheared components we can deduce the length of the original vein. (calculations in appendix 1). Using the restored and original length, it is possible to calculate the percentage of elongation (390%).

4.4 Field examples of strain.

Evidence that the rocks in the Yohoe Creek to Cape Jervis area had undergone strain during some point in their history, was found in many locations and within most units. SC fabrics, common to shear zones were seen in the footwall of the Yohoe Creek Thrust Fault, these fabrics suggest that the rocks have undergone some form of simple shear. Tear apart boudins were observed in the Carrickalinga Head Formation in the Yohoe Footwall , as well as in the Mount Terrible Formation. Elongate nodules seen in the Tapleys Hill and Sellicks Hill Formations, and tension gashes suggesting simple shear within the Angepena formation (figure 4.9 & 3.10). Overall the evidence in the field for the area having undergone a major period of deformation was overwhelming.

5 THREE DIMENSIONAL ANALYSIS

5.1 Introduction

Three dimensional analysis was undertaken with the aim of providing a more precise picture of the subsurface geology. A primary aim of this analysis was to use the Silicon Graphics Indigo 2 computer and Vulcan software (Maptek, 1995) to decide whether this is a useful method of mapping the 3D structure of an area in a fold and thrust belt, and provide more interpretation than standard section balancing techniques.

5.2 Method

In the three dimensional analysis of the study area it was decided that the best means of approaching the problem was to construct cross sections at intervals across the field area and tie these together using fault and bedding traces as shown (figure 5.1). To ensure reasonable sections were used in this analysis a section was balanced and restored to show that it was a viable cross section (chapter 3). Further sections were not drawn with the same accuracy, but with the same ideas as those proven acceptable through the balancing and restoring of the original cross section. These sections were scanned into an Apple Macintosh 8100 computer using a Microtek flatbed scanner and Adobe Photoshop™ Software. These sections were then converted to GIF type files by Graphic Converter, and sent to the Silicon Graphics machine via a programme called Fetch. Once in the Silicon Graphics Machine these sections could be placed in their respective positions by using them as texture on specific planes with the Vulcan™ Software (figure 5.1). A further description of the method used is given in Appendix 2.

5.3 Results

In learning the use of this complex visualisation package it was considered sufficient to present the three dimensional model with the two main thrust faults of the area and a bedding plane as a marker horizon in between this to delineate the main structures. Figures 5.2 to 5.8 show the resulting three dimensional models of the study area from a number of different perspective view angles. Of particular interest is the change in depth of the Yohoe Creek Thrust Fault over its length, in the northern area, where it is twice the depth of the Plough Creek Thrust Fault, and of similar depth to this fault in the area to the south. A "slice" option in the Vulcan™ program was used, and the results are displayed in figure 5.9. The slices are taken from south to north, looking towards the south, with section lines approximately marked on the map in figure 5.9. In analysing the results, the slices and the three dimensional model of the area enable a more clear visualisation of the structure of the area. This is particularly so of the folding where the three dimensional characteristics can be observed such as the Plough Creek Hangingwall Anticline, and Yohoe Footwall Syncline, which both dip out to the north as seen

in figure 5.3, and the Yohoe Hangingwall Anticline opens out to both the north and the south (figure 5.4).

5.4 Future Uses of This Package

The Vulcan™ three dimensional mapping program has proven itself useful in discerning the three dimensional subsurface structure of the Yohoe Creek to Cape Jervis area. Structure in the area was typical of much of the Adelaide Fold and Thrust Belt. The results obtained with the Vulcan™ software were encouraging enough to suggest that this method of analysis should become more widespread in the work of the University of Adelaide, Structural Research Group, with perhaps the ultimate aim being to map the entire Adelaide Fold and Thrust Belt in three-dimensions. Because the use of the software is not as instinctive as some two dimensional graphics packages, such as Macromedia Freehand 5.0, due to the number of options available to the user. The excellent online help documentation is particularly useful, providing step by step guides as to how to overcome problems. This along with readily available help from the distributors of the software, allow the maximum benefit to be gained from its use.

Figure 5.1 Screen image of textured triangulations. Four sections were matched with a surface map. These were later joined together with tie lines to produce the three dimensional images.

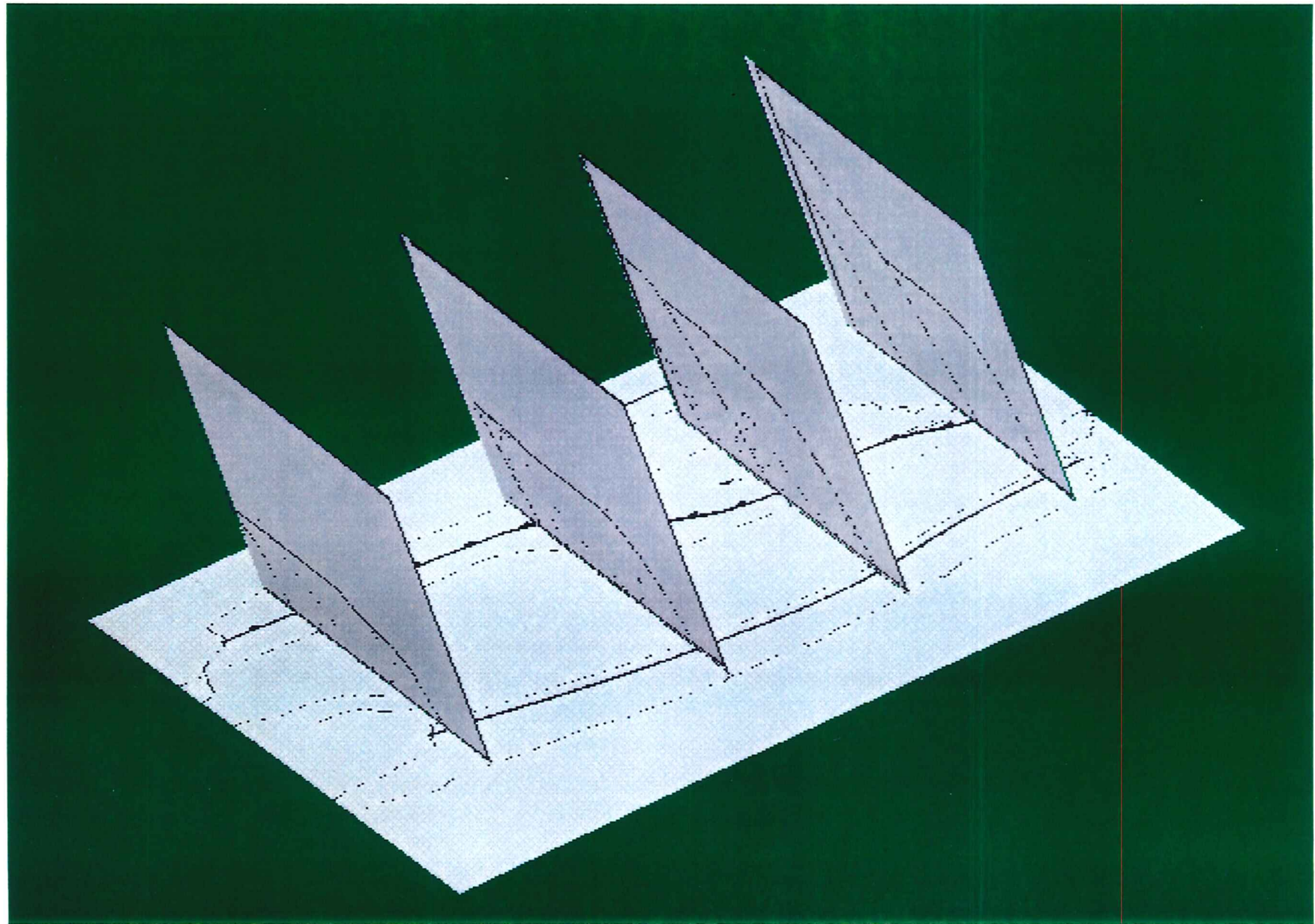


Figure 5.2 Overturned and flipped perspective of the three dimensional model. The pink surface is the PCTF, the red surface is the YCTF, the blue folded surface is a model of the Yohoe Creek Footwall, and the yellow surface is an arbitrary model of the Yohoe Creek Hangingwall.

Figure 5.3 Perspective view from the northeast to the southwest of the three dimensional model. Colours are as in figure 5.1

Figure 5.4 Perspective from the south to the north, the PCHA opens out on the far side of this view. The YCHA can be seen as present only in the central area. Colours are as in figure 5.1

Figure 5.5 An underside perspective of the model. Note the depth change of the YCTF. Colours are as in figure 5.1

Fig 5.2

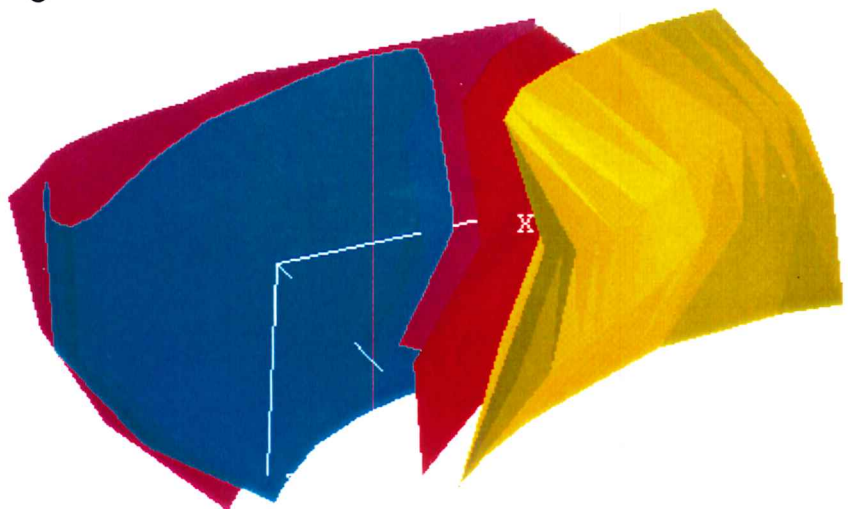


Fig 5.3



Fig 5.4

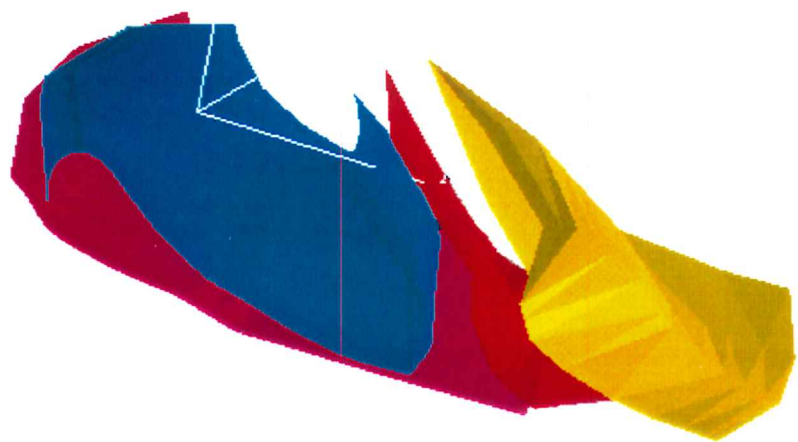


Fig 5.5



Figure 5.6 Perspective of the model from the southeast to the northwest, the folds in the Yohoe Creek Footwall can be readily observed. Colours are as in figure 5.1

Figure 5.7 The absence of folds on the blue and yellow surfaces is observed from this perspective. Depth of the YCTF (red) is also observed. Colours are as in figure 5.1

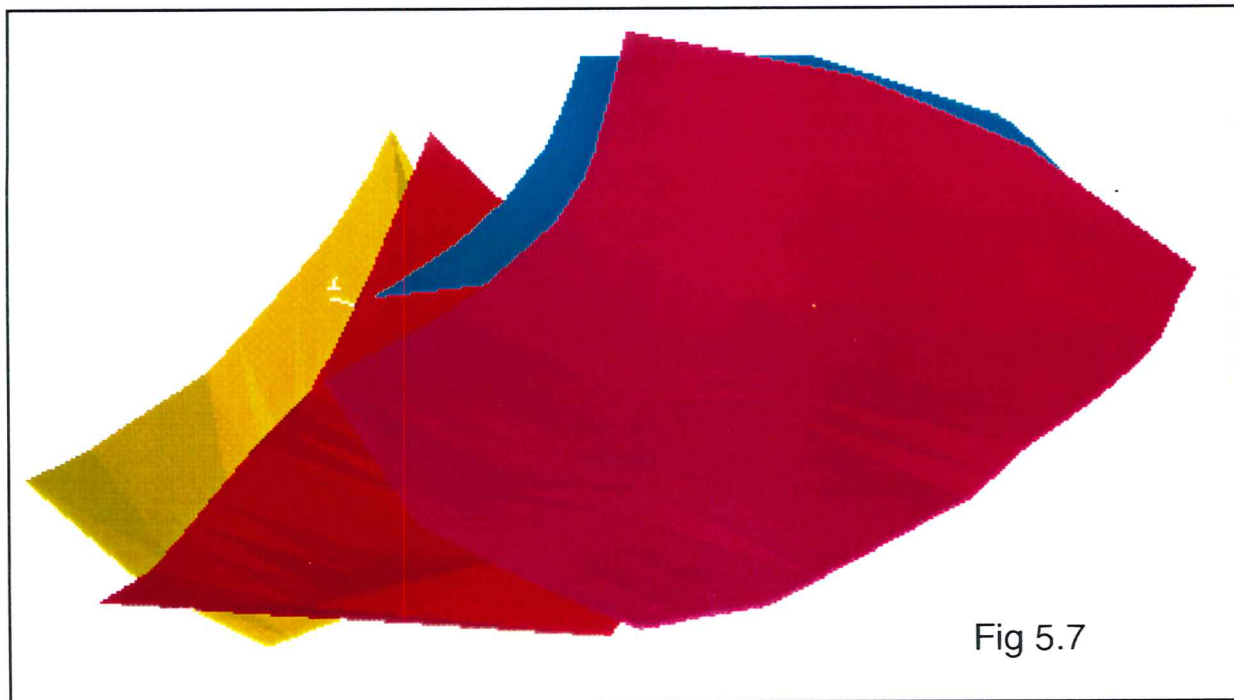


Fig 5.7

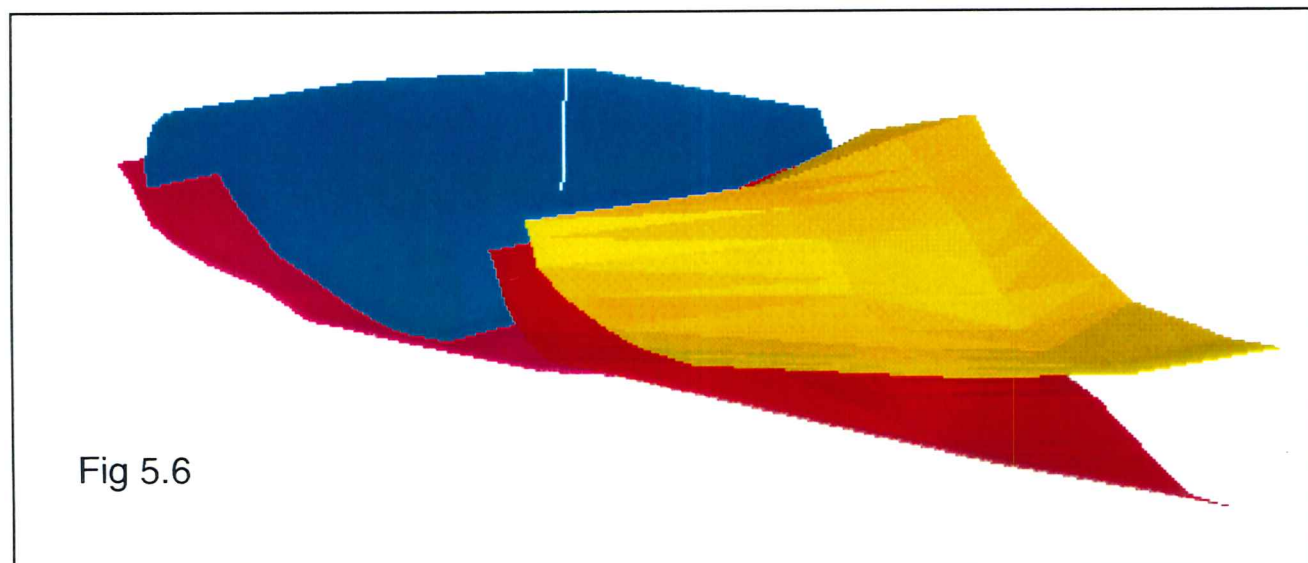
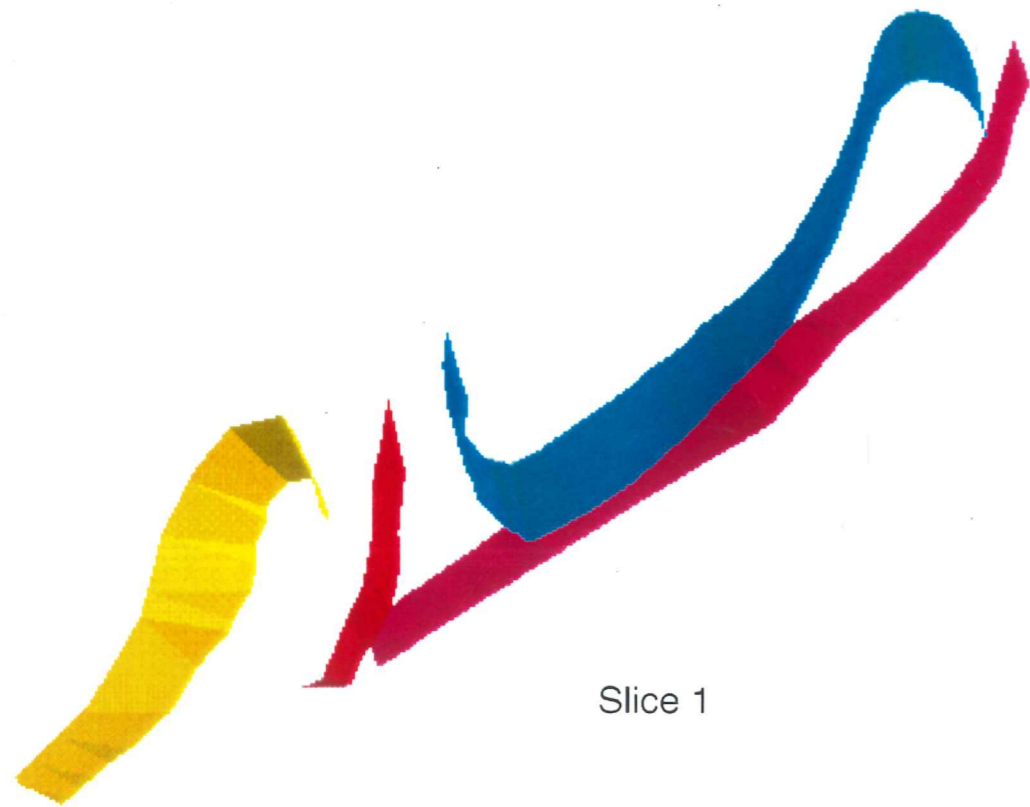
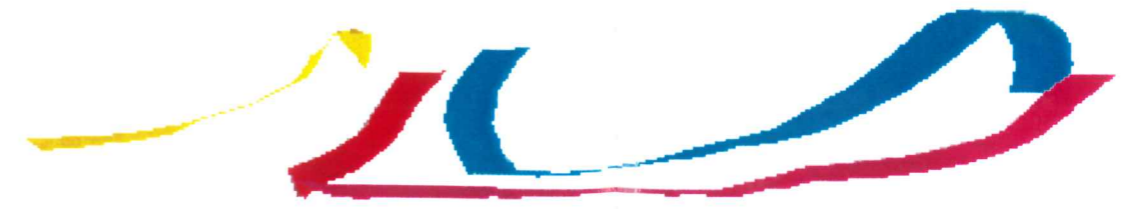


Fig 5.6



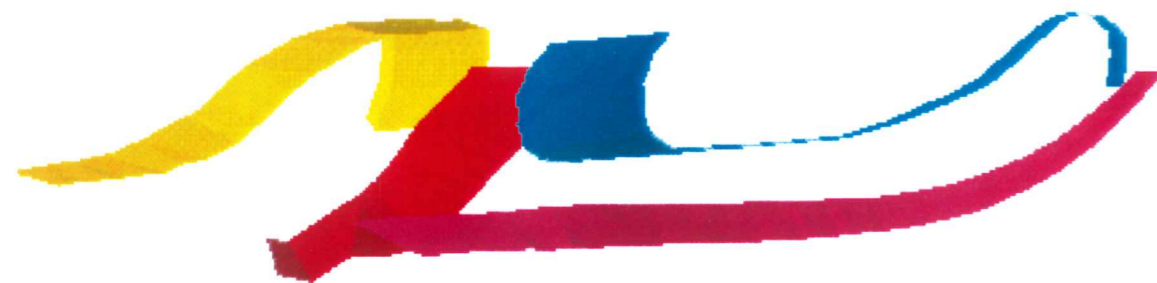
Slice 1



Slice 3



Slice 4



Slice 2



Slice 5

Figure 5.6: Slices taken through the three dimensional sections created using the Vulcan Software. Slices were taken looking South, and slicing towards the North.

6 DISCUSSION AND CONCLUSIONS

The Yohoe Creek to Cape Jervis area has not been mapped in any structural detail since Campana and Wilson produced the inch to a mile Jervis Sheet, this map was prepared without the knowledge which we now possess with regards to foreland fold and thrust belts (McClay 1992) and the new theories on thin skinned tectonics in the Adelaide Geosyncline (Clarke & Powell 1989, Jenkins 1990, Flöttmann et al., 1994).

Structure in the study area is predominantly two thrust faults. These thrusts are the Yohoe Creek Thrust Fault and the Plough Creek Thrust Fault (chapter 3), in addition to these there is the Tea Tree Creek Imbricate Zone, a series of small thrusts which branch off the Plough Creek thrust Fault (figure 6.1).

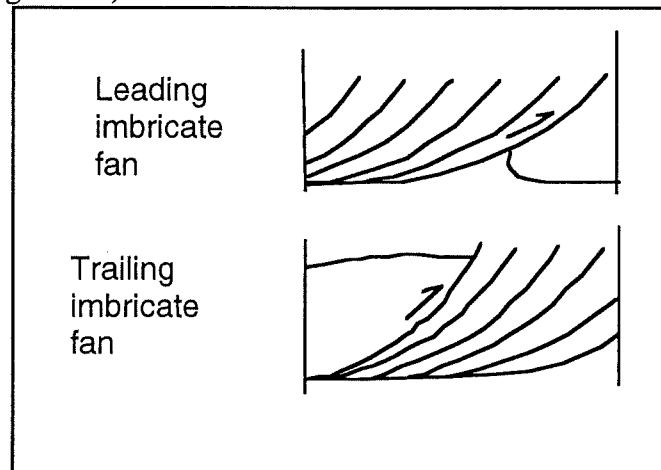


Figure 6.1: Leading and trailing imbricate fan structures named according to whether the frontal or rear plane has the highest amount of slip.

The Plough Creek Thrust Fault is a reactivated Cambrian basin margin extension fault, a normal sense of movement, and seemingly opposing westward vergence are the central points in the argument for basin extension fault reactivation. Reactivated basin extension faults have been reported elsewhere in the SAFTB (Flöttman, 1994; Rogers, 1991; Jenkins, 1990), this finding for the PCTF therefore strengthening the argument for this model of formation of many thrusts in the SAFTB.

The cross section in chapter 3 suggests that the fault with the larger offset and the larger consequent structures is the Yohoe Creek Thrust Fault, this fault was presumably present before the reactivation of the basin extension normal fault which is the Plough Creek Thrust Fault. It is possible that the YCTF is also a reactivated normal fault. Rogers (1991), reports the Talisker Fault, which is linked to the Yohoe Creek Thrust Fault, as this type of fault, citing changes in layer thickness either side of the fault as evidence. Barrett (1995) has mapped the extension of the YCTF to the north, linking it with the Normanville Thrust, emphasizing its place as a major regional structure.

The Yohoe Footwall Syncline and Hangingwall Anticline are not observed in the Yohoe Creek section, but are seen to the South where the Yohoe Thrust Fault juxtaposes Angepena Formation over the Backstairs Passage Formation. I suggest that it is the competency contrast between the formations involved in the thrusting which causes this folding. Where Tapleys Hill Formation is placed above the Backstairs Passage Formation, the much harder Backstairs

Passage Formation shows little deformation, the Tapleys Hill Formation, on the hangingwall side, shows extremely high strain (chapter 4) with elongate nodules in the near vicinity of the Yohoe Thrust Fault. A difference occurs where the Angepena Formation is placed above the Backstairs Passage Formation, here the deformation takes place in an entirely different manner. Rheological properties of the Angepena Formation and the Backstairs Passage Formation in this area are reasonably similar. Due to this the strain is not taken up by one unit as in the Yohoe Creek section. Formation of a footwall syncline in the Backstairs Passage Formation and a hangingwall anticline in the Angepena Formation is the way in which the strain is taken up in this area..

The southern imbricate zone is of the leading imbricate fan type, as opposed to a trailing imbricate fan (figure 6.1) A leading imbricate fan is described as a thrust system where the thrust with the maximum slip is at the front of the thrust system. This mirrors the larger scale where it is thought that a large offshore shear zone, the Rapid Bay Shear Zone is the surface of major slip for the fault system mapped in this area.

The overall trend of the structures in the area is approximately north south. Measurements taken in the field compare favourably with this, intersection lineations plotting approximately 40° -> 150 and slip lineations plotting approximately 50° -> 100 , as can be seen in the lineation maps which are include with chapter 3.

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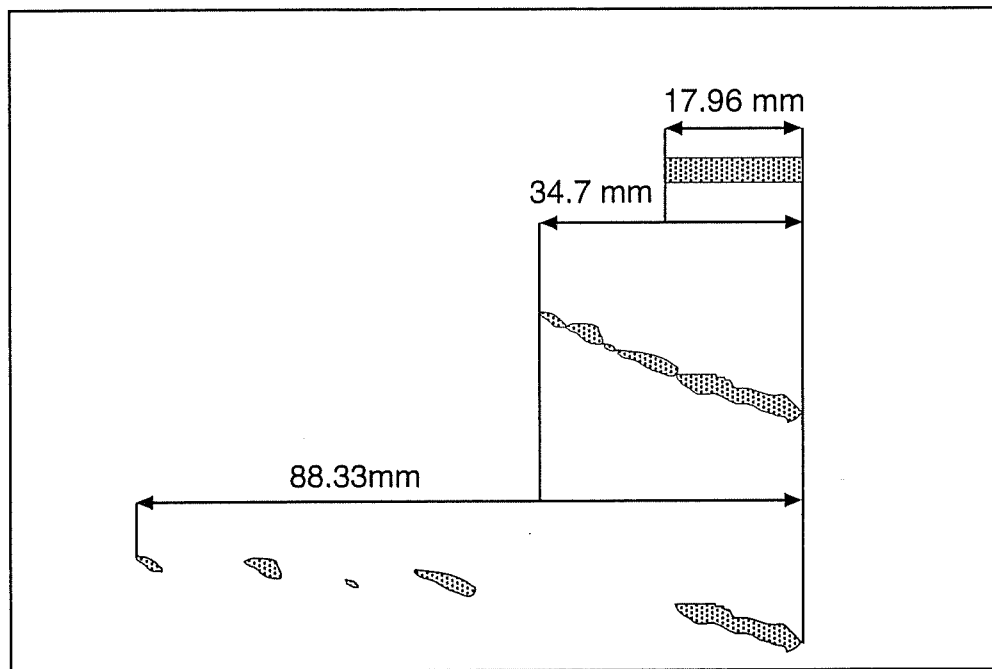
ACKNOWLEDGEMENTS

I write these acknowledgements with a feeling of regret, that the year is now over, and I am about to lose my freedom to the real world. The writing of this thesis, and indeed my whole honours year has been challenging and hellish. The freedom which comes from being responsible for your own work, and your own progress, on a project that you have chosen, is something which most people never get the chance to do. I would like to thank all the staff who were involved in the honours course, this year, John and Mike, Ross, Thomas, David, John Willo, and others who have helped me in preparation of this thesis, Geoff, Sherry, Rick, Murray, and Jacie. much thanks must also be extended to Steve at Maptek for his fruitful discussions regarding the vulcan software. To Mum, Dad, Craig, Stuart, Wendy and Greg, thanks for your support. To all my colleagues, thanks for a hellish year, with special thanks to the structure crew Rebekah, Dan, Dave and Lyon.....Lyon, thanks mate for everything over the last five years, thanks for being a great field partner, thanks for being a great mate and thanks for being a great drinking partner. Finally I would like to thank Puppa for lending Club Mac (the caravan) to Lyon and I for our accomodation in the field.

APPENDIX 1

Calculation of percent elongation of a stretched boudin in the Backstairs Passage Formation.

$$\begin{aligned}\% \text{ elongation} &= (L_0 - L_1) / L_0 * 100 \\ &= 88.33 - 17.96 / 88.33 * 100 \\ &= \underline{390\%}\end{aligned}$$



Trace of an elongate boudin as seen in figure 3.2. This was then restored and surface balanced using the method of Lacassin et al.

Calculation of percent elongation of a stretched boudin in the Backstairs Passage Formation.

$$\begin{aligned}\% \text{ elongation} &= (L_0 - L_1) / L_0 * 100 \\ &= 88.33 - 17.96 / 88.33 * 100 \\ &= \underline{390\%}\end{aligned}$$

Calculation of shortening on elliptical objects from Rf/ø plot (over page)

Sellick Hill Formation

$$\begin{aligned}&shf \ xztt \\ Rf_{min} &= 1.006 & Rf_{max} &= 13.668 \\ Rf_{min} &= R_s / R_i, & \Rightarrow R_s &= Rf_{min} * R_i \\ Rf_{max} &= Rf_{min} * (R_i)^2 \\ R_i &= 3.686 \\ R_s &= 3.767\end{aligned}$$

$$\begin{aligned}&shf \ yztt \\ R_i &= 1.98 \\ R_s &= 2.002\end{aligned}$$

$$\begin{aligned}R_i \ (X:Y:Z) &= 3.686: 1.98: 1.0 \\ R_s \ (X:Y:Z) &= 3.767: 2.002: 1.0\end{aligned}$$

$$\begin{aligned}\text{shortening } \% &= r - Z / r * 100 \\ &= 0.97 - .49 / .97 * 100 \\ &= 49\%\end{aligned}$$

Tapleys Hill Formation

$$\begin{aligned}&thf \ xztt \\ R_i &= 5.6 \\ R_s &= 9.7\end{aligned}$$

$$\begin{aligned}&thf \ yztt \\ R_i &= 2.5 \\ R_s &= 4.2\end{aligned}$$

$$\begin{aligned}R_i \ (X:Y:Z) &= 5.6: 2.5: 1.0 \\ R_s \ (X:Y:Z) &= 9.7: 4.2: 1.0\end{aligned}$$

$$\begin{aligned}\text{shortening } \% &= r - Z / r * 100 \\ &= 0.82 - 0.24 / .82 * 100 \\ &= 70\%\end{aligned}$$

Flinn Plots and Associated Calculations

Tapleys Hill Formation

For the initial ellipsoid

$$R_{xy} = 1.86$$

$$R_{yz} = 1.98$$

$$k = .87 \quad \text{OBLATE}$$

For the shortened ellipsoid

$$R_{xy} = 1.88$$

$$R_{yz} = 2.002$$

$$k = 0.88 \quad \text{OBLATE}$$

Sellick Hill Formation

For the initial ellipsoid

$$R_{xy} = 2.24$$

$$R_{yz} = 2.5$$

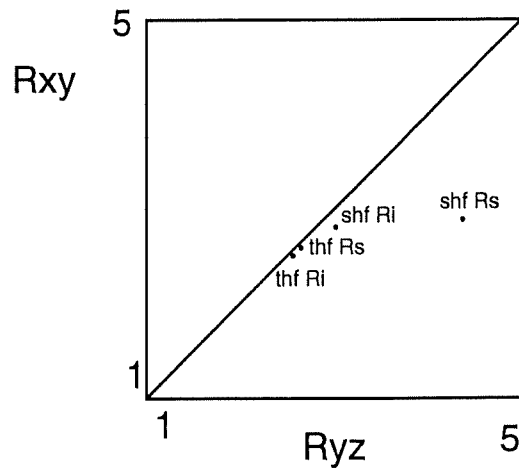
$$k = 0.83 \quad \text{OBLATE}$$

For the shortened ellipsoid

$$R_{xy} = 2.31$$

$$R_{yz} = 4.2$$

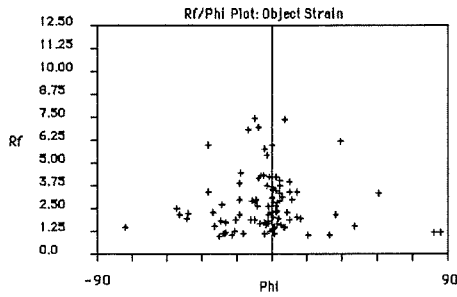
$$k = 0.41 \quad \text{OBLATE}$$



The above Flinn plot shows the positions which the strain ellipsoids plot for the Sellick Hill Formation and Tapleys Hill Formation, both the initial and shortened calculated values are shown.

INSTRAIN 2.5: INTEGRATED STRAIN ANALYSIS

Project: shf Sample ID: 1063/13
 Data File: shf.xzlt Surface Orientation: xz
 Number of Objects: 98 defined by 4 points each.



Ellipticity Range: 1.006 to 13.668

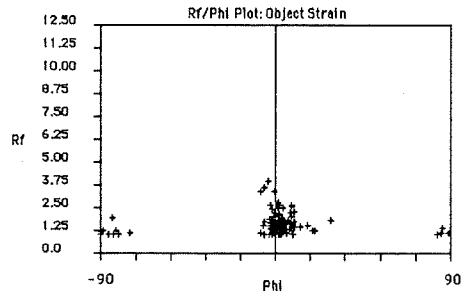
MEANS (+/- 1 STD)

Phi (degrees): -3.981 +/- 23.986
 X/Y (n = 98)
 Arithmetic 2.880 +/- 1.861
 Harmonic 2.163

Mean Object Ellipse: X/Y = 2.149 Phi = -43.68
 Average error: 38.36 %

INSTRAIN 2.5: INTEGRATED STRAIN ANALYSIS

Project: shf Sample ID: 1063/13
 Data File: shf.yzlt Surface Orientation: yz
 Number of Objects: 122 defined by 4 points each.



Ellipticity Range: 1.010 to 3.970

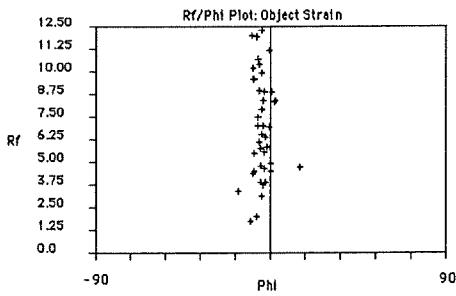
MEANS (+/- 1 STD)

Phi (degrees): -2.052 +/- 29.418
 X/Y (n = 122)
 Arithmetic 1.571 +/- 0.558
 Harmonic 1.437

Mean Object Ellipse: X/Y = 1.500 Phi = -7.32
 Average error: 11.32 %

INSTRAIN 2.5: INTEGRATED STRAIN ANALYSIS

Project: thf Sample ID: 1063/9
 Data File: thf.xzlt Surface Orientation: xz
 Number of Objects: 58 defined by 4 points each.



Ellipticity Range: 1.726 to 55.083

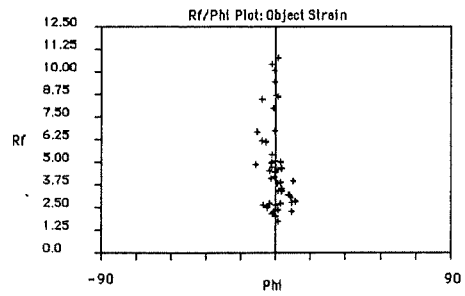
MEANS (+/- 1 STD)

Phi (degrees): -4.785 +/- 4.737
 X/Y (n = 58)
 Arithmetic 11.008 +/- 9.155
 Harmonic 6.942

Mean Object Ellipse: X/Y = 8.963 Phi = -3.43
 Average error: 38.69 %

INSTRAIN 2.5: INTEGRATED STRAIN ANALYSIS

Project: thf Sample ID: 1063/9
 Data File: thf.yzlt Surface Orientation: yz
 Number of Objects: 50 defined by 4 points each.



Ellipticity Range: 1.703 to 10.735

MEANS (+/- 1 STD)

Phi (degrees): 0.091 +/- 4.460
 X/Y (n = 50)
 Arithmetic 4.654 +/- 2.414
 Harmonic 3.705

Mean Object Ellipse: X/Y = 4.297 Phi = -4.93
 Average error: 17.48 %

APPENDIX 2

The Vulcan™ software requires much time and practice to become familiar with, the following are the basic steps which were used, and may be used again to map an area using the tying sections technique used in the analysis made in Chapter 7.

To prepare cross sections and maps the following steps must be followed.

1. Draw a geological map of the area to be studied in three dimensions.
 2. Using the same scale as the map draw cross sections across the map so as to obtain the maximum amount of information. For this study the map and the sections were drawn using Mancomedia Freehand 5.0.
 3. Using Graphic Converter the images must be trimmed such that only the essential information is present in the cross sections. This may be done by using the trim selection option in the edit men.
 4. The images must be converted into GIF files so as to be readable in the SGI computers. This may be done using the save as command.
 5. Using Fetch 2.1.2, the images may be sent to the SLABSGI computer.
 6. Once in the computer the GIF images must be converted to pexel images, which are the type required to be used as textures in the Vulcan™ Software. The instructions for this must be done in the console and entered as follows >?
`gif_to_pexel filename.GIF new filename`
-

The processes once inside the Vulcan software are more complex, and many attempts are often required to achieve the final result.

1. The first step which must be performed is to create a .dg1 file, the method for this is set out in the Vulcan manual.
2. A design database must then be created, information on how to do this is found in the online help manual.
3. In Vulcan the maps and sections are placed on triangulations of surfaces which are created with the software. These surfaces must be created in the required dimensions of the map/section and placed in the required three dimensional coordinates.
4. Triangulating a surface is most easily done by drawing two lines (parallel in the case where a rectangle is to be drawn) and then selecting the TRIANGULATE SURFACE in the MODELLING main menu.
5. By using the VIEW / CHANGE VIEW / SECTION sequence of commands enables the user to select a view in a particular plane, at any angle to the surface. The user may then trace the lines drawn in the section. By following the DESIGN / CREATE / LINE commands. (the right mouse button will stop drawing lines)
6. Using the TRIANGULATE SOLID command there are a number of options available to triangulate complicated surfaces such as the bedding planes in this study. In the case of these surfaces the user guided triangulation was selected, pressing the right mouse button three times at the SELECT BY option will allow tie lines to be drawn between points on the lines.
7. BEST OF LUCK

The processes once inside the Vulcan software are more complex, and many attempts are often required to achieve the final result.

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