# THE STRUCTURAL DEVELOPMENT OF THE KANMANTOO SCHIST BASED ON FIAS FROM SAMPLES AT PETREL COVE AND THE STRATHALBYN ANTICLINE

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Inclusions within porphyroblasts from Petrel Cove and the Strathalbyn Anticline provide evidence for metamorphic events not previously recognized in the Delamerian orogen because they contain more than five foliations defining at least two foliation intersection/inflection axes (FIAs). At Petrel Cove one FIA is preserved within cordierite. An identical FIA is preserved within staurolite in the Strathalbyn Anticline but another younger FIA is present in andalusite. The latter sequence appears to resolve the problem of apparently synchronous multiple phases of growth of staurolite and andalusite in these rocks (e.g., Adshead-Bell & Bell, 1999). Reactivation has destroyed these foliations or rotated them into parallelism with the bedding, which is why they were not distinguished until measurements of FIAs were made. The FIA succession distinguishes a progression of metamorphic events and further work of this type in the region will provide enough data for the shear senses suggested by this preliminary study to be confirmed.

## 1. Introduction

The start of orogenesis on the eastern margin of Gondwana in Australia occurred in the Precambrian (e.g., Preiss, 1987; Foden et al, 2002; Foden et al, 2006) with initiation of subduction and commencement of development of the Delamerian orogen (Talbot & Hobbs, 1968; Steinhardt, 1989; Sandiford & Alias, 2002). Although subduction is well documented, the processes associated with its initiation are poorly understood. This lack of understanding results from the problem of accessing information on what took place as deformation commenced. Multiples phases of deformation result in destruction of earlier phases through reactivation of compositional layering which both decrenulates and/or rotates developing and previously developed foliations into parallelism with the bedding (Bell, 1986; Ham & Bell, 2004). Fortunately, porphyroblasts and their inclusion trails preserve evidence for the interaction between heating and deformation during orogenesis for all deformation events after the first, even where this evidence has been entirely destroyed in the matrix because of reactivation of the bedding (Bell et al., 2003; 2004; 2005). Consequently, the measurement of FIAs provides access to both structural and metamorphic information that occurred at the commencement of subduction and which has been completely obliterated in the matrix. This paper uses this approach to access information on the early stages of orogenesis associated with the initiation of subduction on the Eastern margin of Gondwana.

## I. FIA Measurement:

A foliation intersection or inflection axis in porphyroblasts (FIA) is measured for a sample by observing the orientation of the switch in inclusion trail asymmetry within porphyroblasts (clockwise or anticlockwise) from a series of vertically oriented thin sections observed consistently in the one direction around the compass (Bell et al., 1998). For example, Fig. 1A contains a simple spiral with a clockwise curvature from core to rim in the 040˚ section but an anticlockwise curvature in the 360˚ section. This switch in asymmetry takes place across the FIA trend. The principle is expanded in Figs. 1B and 1C.

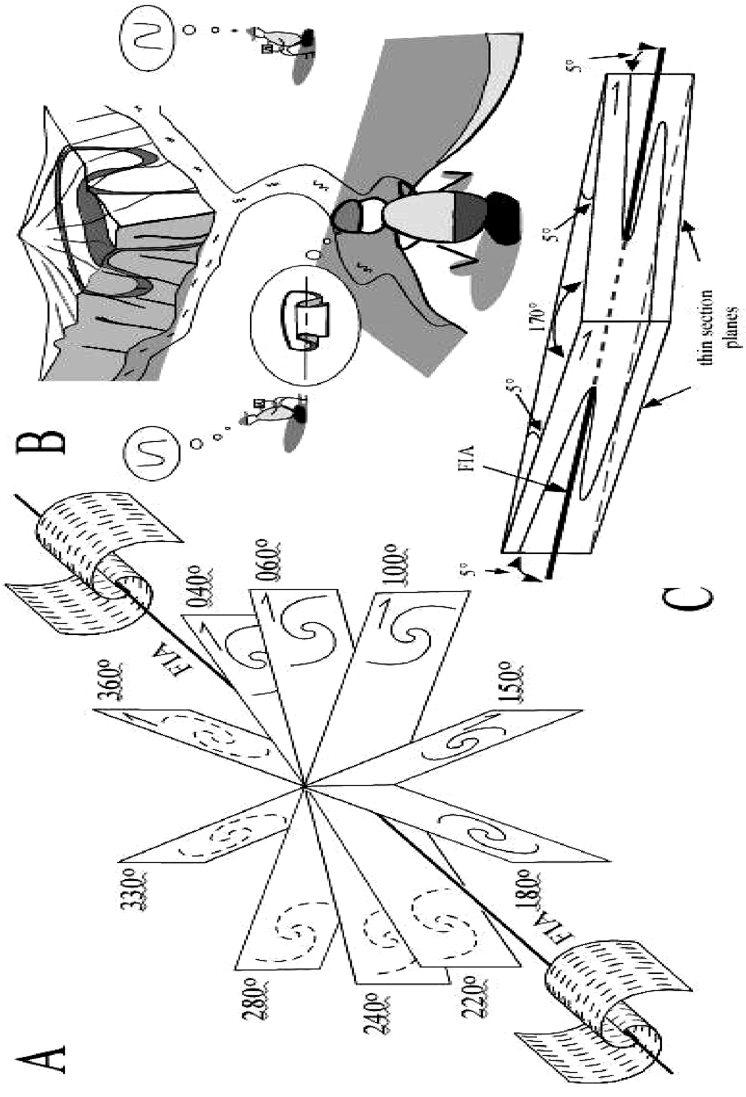


Fig. 1: A FIA trend is measured for a sample using all the porphyroblasts intersected by each vertical thin section, the principle of measurement is shown using a 3-D sketch drawn of a simple spiral. B: Sketch illustrating the principal with a fold preserved in an outcrop. The geologists to either side have no idea of the plunge direction. However the geologist in the centre does. C: Precise measurement of FIA made by cutting sections 10° apart and constraining the asymmetry switch within 10° (Modified from Bell & Newman, 2006).

## II. Regional Geology

### II. a. *Petrel cove:*

Petrel Cove is located 100 kms south of Adelaide (Fig. 2). The Rosetta Head area (Petrel Cove) in southern Australia form a part of the Kanmantoo Group of supposed Cambrian-age. There is a variety of metamorphic grades represented, from lower greenschist to amphibolite facies. The rocks of the region consist of schists with interbedded meta-sandstone which also contain well-bedded porphyroblastic biotite, andalusite, cordierite and chlorite (Steinhardt, 1989). The schists at Petrel Cove are not quite true pelites because they lack the normal percentage of potassium (Sandiford & Alias, 2002).

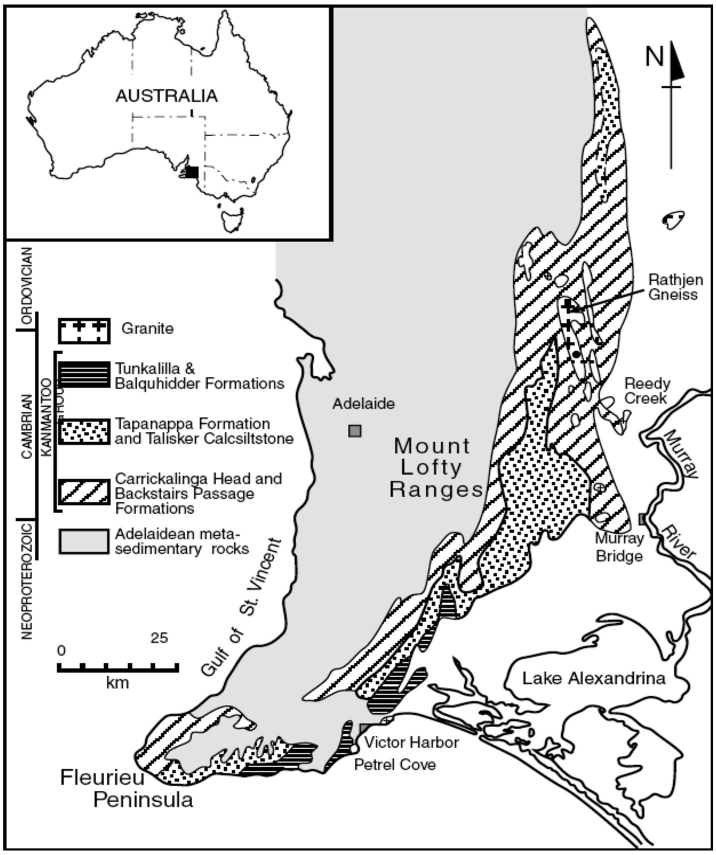


Fig. 2: Map showing location of Petrel Cove, approximately 100 km south-southwest of Adelaide (Modified from Adshead-Bell and Bell, 1999).

There has been much debate over the number of phases of deformation at Petrel Cove (e.g., Talbot & Hobbs, 1968; Steinhardt, 1989; Sandiford and Alias, 2002). The most recent workers (Sandiford & Alias, 2002) have suggested that there were three phases of deformation in these rocks. The significance of $D_1$ is uncertain because it is only preserved as a foliation parallel to compositional layering. Dolerite dikes and pegmatites were intruded prior to the development of the $S_2$ fabric. During the third deformation, megacrystic feldspar and biotite growth occurred and granite was emplaced.

The highest temperatures achieved within the Petrel Cove rocks are between 550-600°C. The following equations are chemical changes and mineralogical assemblages that have been previously described as occurring throughout the Petrel Cove sequence (Sandiford & Alias, 2002),

(1) Chl + Msc → Cord + Bt
(2) Cord + Msc → And + Bt
(3) Cord → And + Chl
(4) And + Cord → St
(5) Msc + Chl → St + Bt + Qtz + $H_2 0$

but only the first of these was found in the rocks described herein.

### II.b. *Strathalbyn anticline:*

The Strathalbyn Anticline is located approximately 45 km southeast of Adelaide (Fig. 3). These rocks were always somewhat enigmatic because their axial plane lay parallel to all the other regional folds of the Adelaide Geosyncline the north and west which had $S_1$ axial plane, yet these folds appear to have at least $S_3$ as their axial plane structure (Fleming & Offler, 1968; Offler & Fleming, 1968). This problem was addressed by Adshead-Bell & Bell (1999) and they showed that the regional folds all formed at the same time, and that the Strathalbyn Anticline was reused and modified several times during younger overprinting deformations.

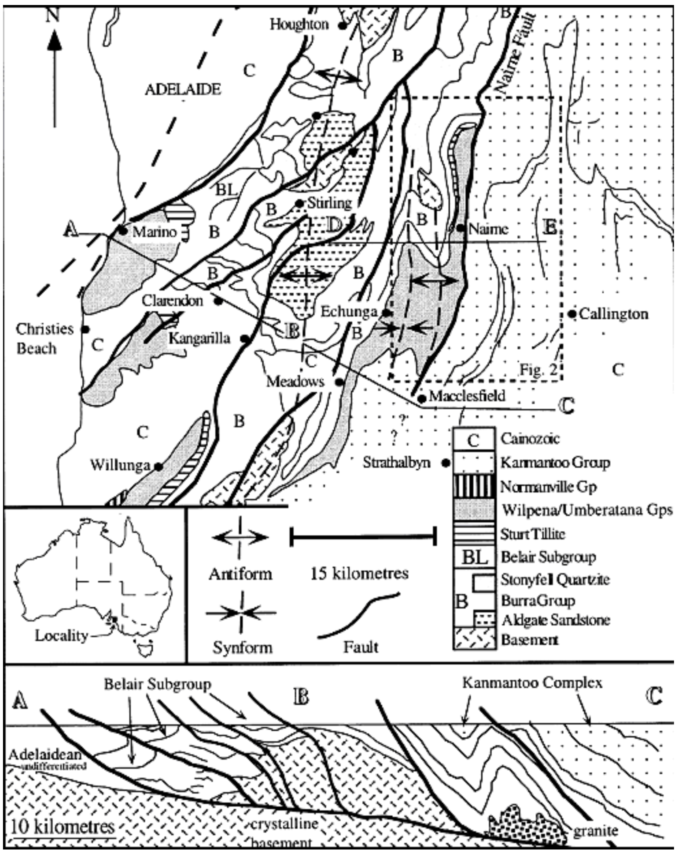


Fig. 3: Southern Australia, the Kanmantoo Group and the Strathalbyn Anticline. The Strathalbyn Anticline is approximately 40km east-southeast of Christies Beach. Two samples, K21 and K24, were examined for the purpose of this paper. The map above shows that K24 comes from just to the west of the anticlinal hinge whereas K21 comes from the east side but further away from the hinge. (Modified from Jenkins and Sandiford, 1992).

Around the Strathalbyn Anticline, the mineralogical compositions consist of namely staurolite and andalusite porphyroblasts in a matrix of quartz, biotite, and on occasion muscovite, ilmenite, sillimanite, and plagioclase. As one moves from west to east, the mineralogy changes from biotite, andalusite, and staurolite to sillimanite (fibrous and prismatic) and migmatites. The following reactions have been inferred based on previous works (e.g., Jenkins & Sandiford, 1992; Adshead-Bell & Bell, 1999).

(1) Msc + Str + Qtz → $Al_2SiO_5$ + Bt + $H_2O$
(2) Msc + Chl → $Al_2SiO_5$ + Bt + Qtz + $H_2O$
(3) Msc + Chl → Str + Bt + Qtz + $H_2O$
(4) Grt + Chl → Str + Bt + Qtz + $H_2O$
(5) Msc + Chl → Grt + Bt + $H_2O$

## III. Sample Setting

### III.a. *Petrel cove:*

Two samples, named PC2 and PC3, were collected from locations 2 and 3, respectively, at Petrel Cove (Figs. 4 & 5). Bedding, $S_0$, usually has a schistosity $S_1$ lying parallel to it. There appears to be at least two generations of cordierite porphyroblast growth within these schists but they contain the same FIA. A distinctive layering of metamorphic/deformational origin oblique to bedding occurs in phyllites, and cordierite/andalusite mica schists (e.g., Talbot & Hobbs, 1968). This layering is known as the “stripy layering” because of its distinctive appearance. The layers alternate from light to dark-gray bands, and the lighter bands are generally much thinner on the scale of mm-cm in size. It lies parallel to $S_2$ which dips shallowly SE. Bedding can be very difficult to observe within an outcrop because of the dominance of the stripy layering and many have previously mistaken this structure for bedding (T. Bell pers. comm., 2007). Bedding, $S_0$, is shown up close in Fig. 5c. The stripy layering in samples PC2 and PC3 consists dominantly of cordierite porphyroblasts and quartz. These porphyroblasts contain the same FIA as that preserved in porphyroblasts in the adjacent matrix. However, the inclusion trails in porphyroblasts within the stripy layering are commonly truncated by the dominant matrix foliation $S_2$ suggesting that they both predate this foliation and that it may have been rotated into parallelism with them by reactivation (Fig. 6, Bell et al., 2004). Fig. 7 shows detail of some folds at Petrel Cove.

### III.b. *Strathalbyn anticline:*

Two samples, K21 and K24, were examined for the purpose of this paper. Fig. 8 shows that K24 comes from just to the west of the anticlinal hinge whereas K21 comes from the east side but further away from the hinge. Sample K24 contains smoothly-curving sigmoidal-shaped inclusion trials in andalusite and staurolite porphyroblasts which are continuous into the matrix. The matrix, defined by slightly elongate quartz grains and aligned biotite grains, shows a flat foliation.

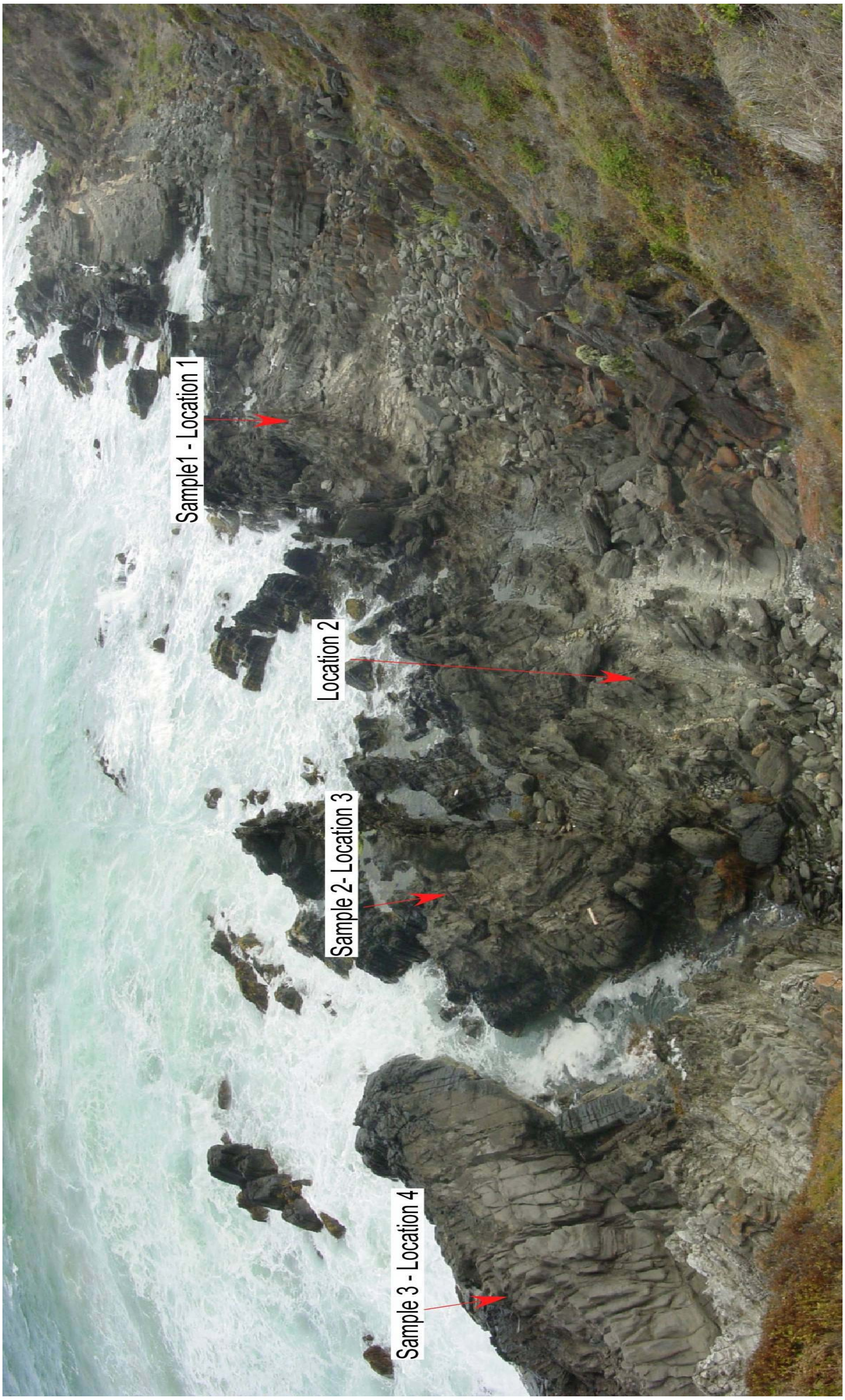


Fig. 4: Petrel Cove, sample setting looking southwest.

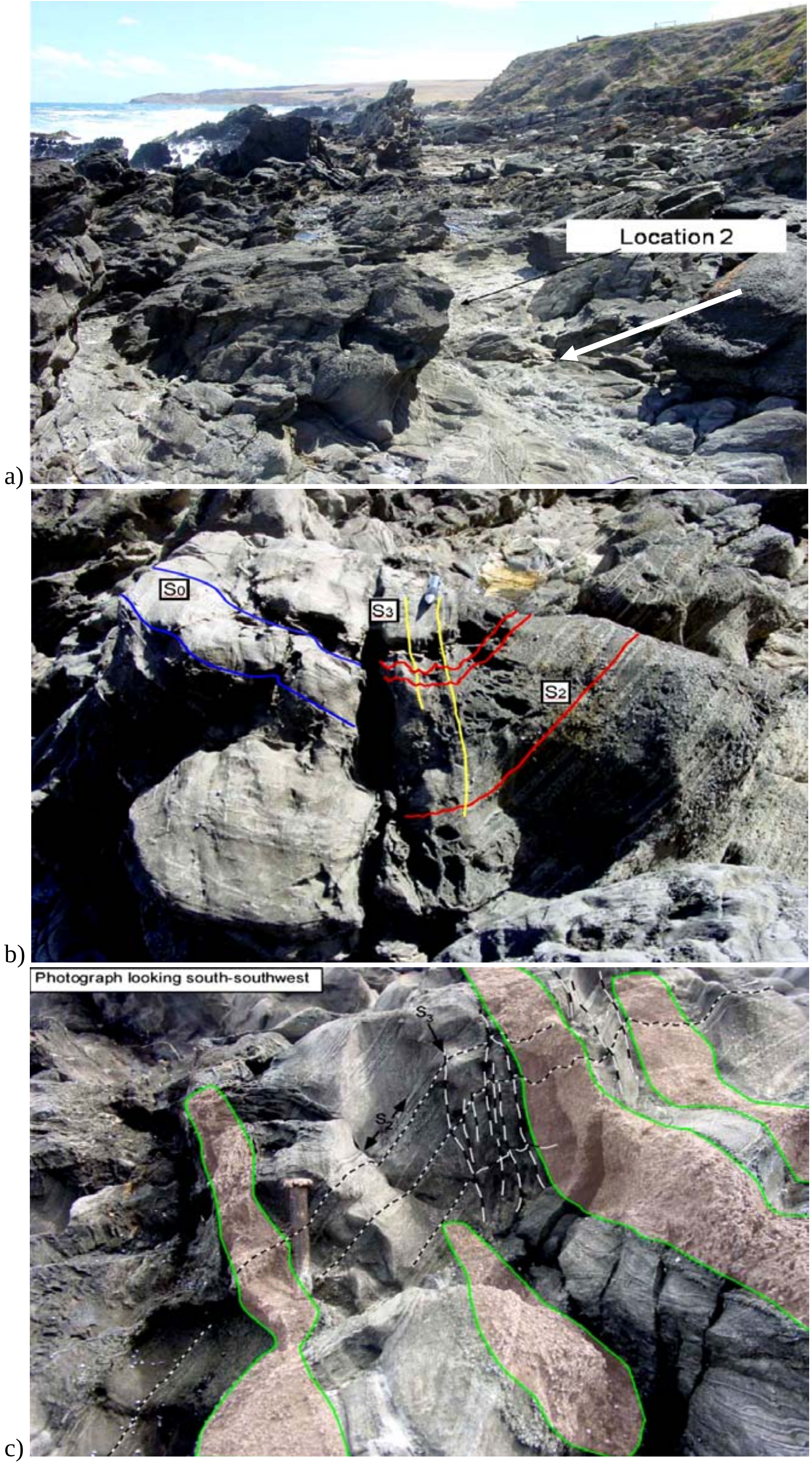


Fig. 5: a) Petrel Cove location 2, facing south. $S_0$ dips west across the outcrop and is locally outlined in blue. $S_2$ is parallel to the stripy layering (red), and $S_3$ has formed sub-vertically (yellow); b) Close up of location 2; c) Petrel Cove station PC 3, photo looking south-southwest. $S_0$ is outlined in green. $S_2$ lies perpendicular to bedding and in this outcrop is parallel to the stripy layering. $S_3$ has formed sub-parallel to bedding.

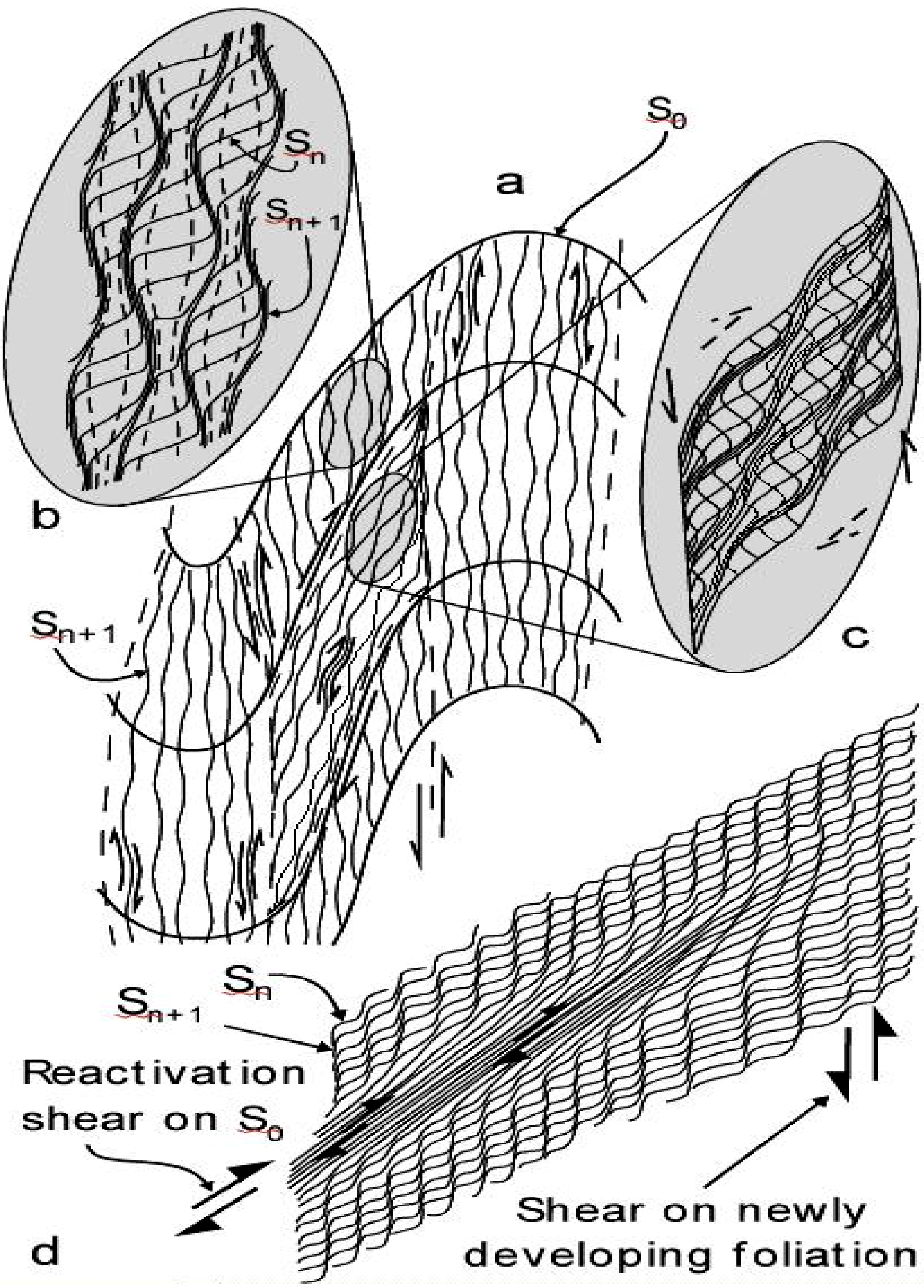


Fig. 6: Model of crenulation cleavage ($S_{n+1}$) development during folding by buckling. In this example fine-scale crenulations of $S_n$ (sub-parallel to $S_0$) form by buckling due to bulk shortening (a, b, c), cleavage development ($S_{n+1}$) occurs through "pressure solution" of long limbs (f, h), and the geometry of the cleavage orientation is a function of the competition between buckling rotation of the fold limbs $S_0$ (c, e) versus shear on the folded foliation by flexural flow (f, h). Any shear on the cleavage $S_{n+1}$ (f, h) only occurs late in the development of the fold. (Modified from Ham & Bell, 2004).

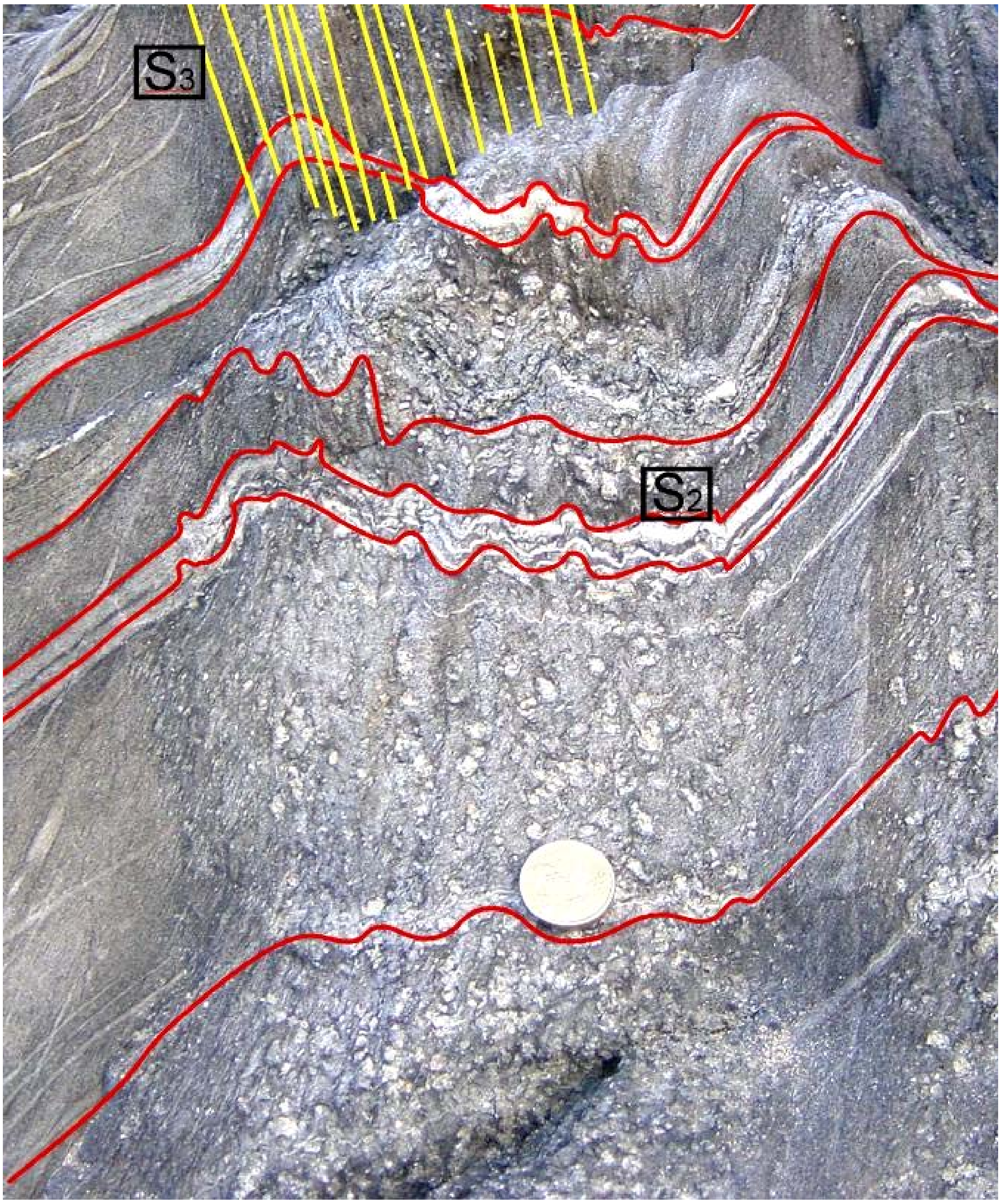


Fig. 7: Australian $2 coin for scale. Foliations seen within a Petrel Cove outcrop looking SW**.** Folded stripy layering, which lies parallel to $S_2$ (red) and andalusite layering, lies sub-parallel to sub-vertical $S_3$ (yellow). The shear sense on $S_3$ is right side up (NW side up).

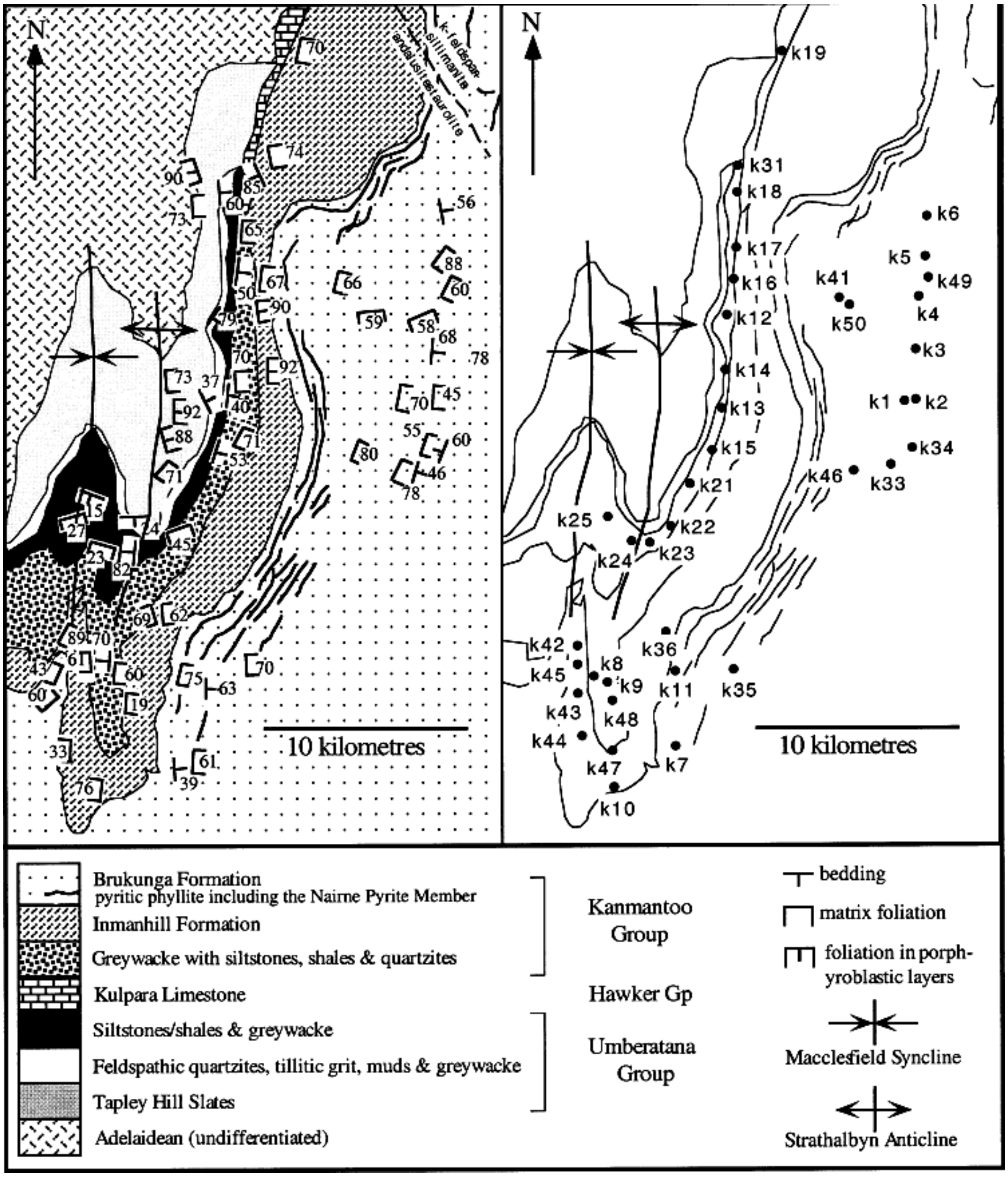


Fig. 8: Location of the Kanmantoo Group and Strathalbyn Anticline (Modified from Adshead-Bell and Bell, 1999).

## IV. Structural Setting

### IV.a. *Petrel cove:*

Petrel Cove is a region of fine-grained meta-psammites and meta-siltstone that has experienced lower greenschist to almandine amphibolite facies deformation during the Cambrian (Sandiford & Alias, 2002; Talbot & Hobbs, 1968). The $S_1$ schistosity lies parallel to $S_0$. Cordierite porphyroblast growth is mainly controlled by different composition beds (Figs. 5b, 5c, & 7), but thin section work has revealed that cordierite growth defines the stripy layers in many locations and that $S_2$ lies parallel to them as well. Biotite grains are oriented randomly inside the matrix. However, where they are more aligned, cordierite porphyroblasts can be easily found. The folded stripy layers (Fig. 7) were suggested by Talbot & Hobbs (1968) to contain andalusite/cordierite assemblages associated with intrusion of the Rosetta Head Granite**.**

At the PC2 sample site, there is an increase in the intensity of $S_2$ (Fig. 9). The number of porphyroblasts also increases within the $S_2$ fabric, to create the white striped layering. At the PC3 sample site, the $S_2$ fabric is perpendicular to bedding while $S_3$ remains parallel to bedding (Figs. 5 & 7).

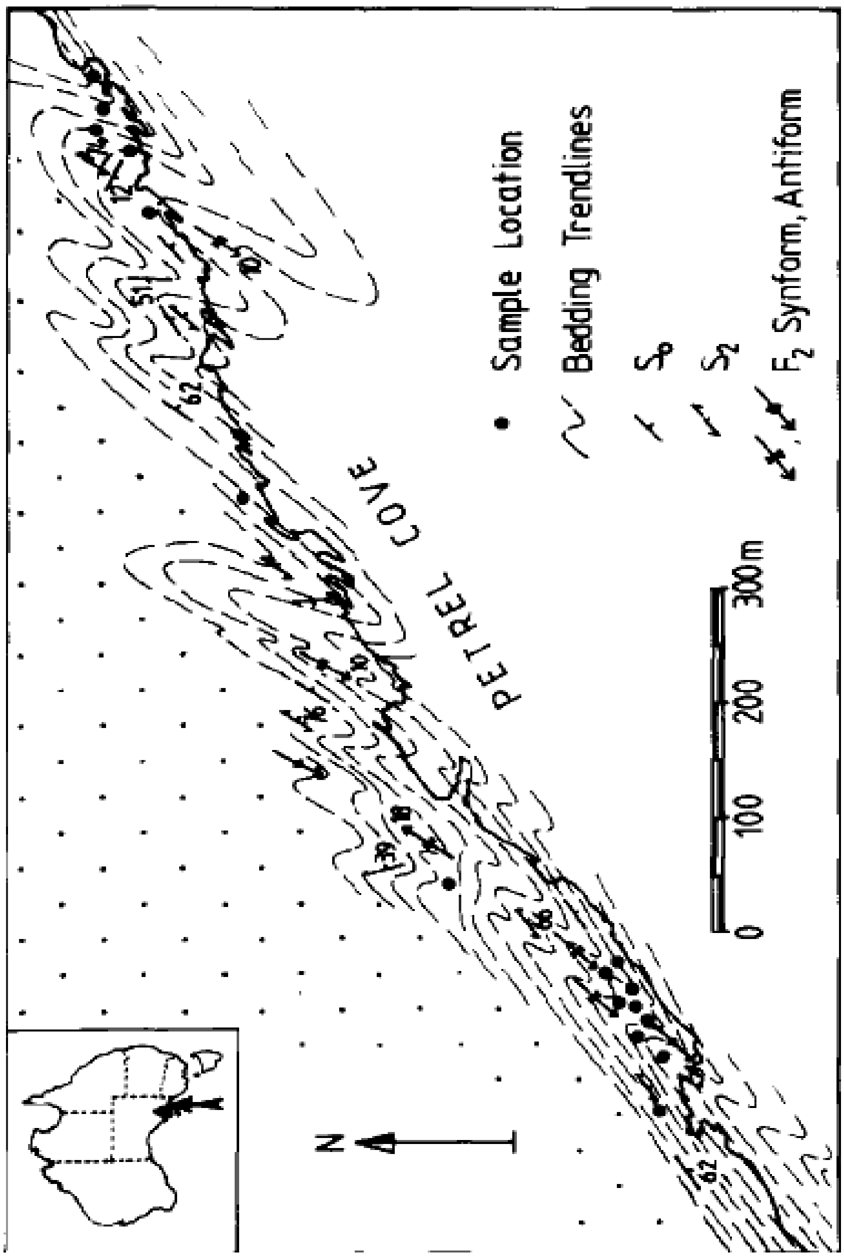


Fig. 9: Closer location of Petrel Cove, showing second deformation event at Petrel Cove (Modified from Steinhardt, 1989).

### IV.b. *Strathalbyn anticline:*

The Precambrian rocks of the Adelaide Fold Belt lie below the Cambrian Kanmantoo Group. The Strathalbyn Anticline can be described as a dextral and asymmetrical macroscopic fold which lies within the Kanmantoo group and the Adelaide Fold Belt (Adshead-Bell & Bell, 1999; Bell, 1994). This fold, formed by a thrusting tectonic setting, left the stratigraphy near the surface relatively stable and untouched. The fold is presumed by some to have formed at the same time as the spiral inclusion trails, assuming that the porphyroblasts didn't rotate (Adshead-Bell & Bell, 1999; Bell, 1994). The structure of the anticline has a near-vertical axial plane and a shallowly-plunging hinge (Adshead-Bell & Bell, 1999). The first deformation event left folds preserved which show axial-plane slaty cleavage within the Adelaide Fold Belt; the young crenulation cleavage lies parallel to the axial-plane (Adshead-Bell & Bell, 1999). At least five foliations can be seen which alternate from steep to shallow orientations, thus possibly suggesting that these folds formed as late structures because a differentiation crenulation cleavage and bedding that is parallel to schistosity exist. However, the folds formed in the early part of orogenesis (Adshead-Bell & Bell, 1999).

## V. Microstructures/FIAs

### V.a. *Petrel cove:*

Cordierite porphyroblasts generally have symmetrical strain shadows (Steinhardt, 1989). According to Talbot & Hobbs (1968), the massive Rosetta Head porphyritic granite intruded well-bedded schists, which contain well preserved bedding, ripple marks, and slump structures. The rocks are broadly folded and contain a well-developed schistosity overprinted by more than one crenulation cleavage with associated asymmetric micro-folds.

Sample locations PC2 and PC3 contain only cordierite porphyroblasts (Figs. 10, 11 & 12). The cordierite porphyroblasts are relatively fresh in PC2. The FIA in PC2 is located at 30°. The stripy layering contains cordierite porphyroblasts and quartz and lies sub-parallel to $S_2$. The compositional heterogeneity provided by the stripy layering causes it locally to behave like bedding and reactivate when suitably oriented relative to the deforming forces and shear sense (e.g. Ham & Bell, 2004). The stripy layering/$S_2$ probably formed sub-horizontal and has been rotated NW side up by the $S_3$ shear which is NW side up in both PC2 and PC3.

PC3 contains cordierite grains that are altered into muscovite and chlorite (Fig. 12). The FIA lies between 30° and 60°. Some cordierite porphyroblasts show NW side up shear indicating a similar relationship to that of location PC2. Most grew in a steep to flat event with shear sense top to SE.

### V.b. *Strathalbyn anticline:*

Although many of the matrix foliations that have developed have been subsequently destroyed by reactivation, porphyroblasts and minerals in their strain shadows are preserved. Most of inclusion trails can be traced into the matrix, especially in andalusite, but also can be seen as continuous with staurolite (Fig. 13). Those that are truncated in staurolite commonly show younger andalusite or biotite with muscovite

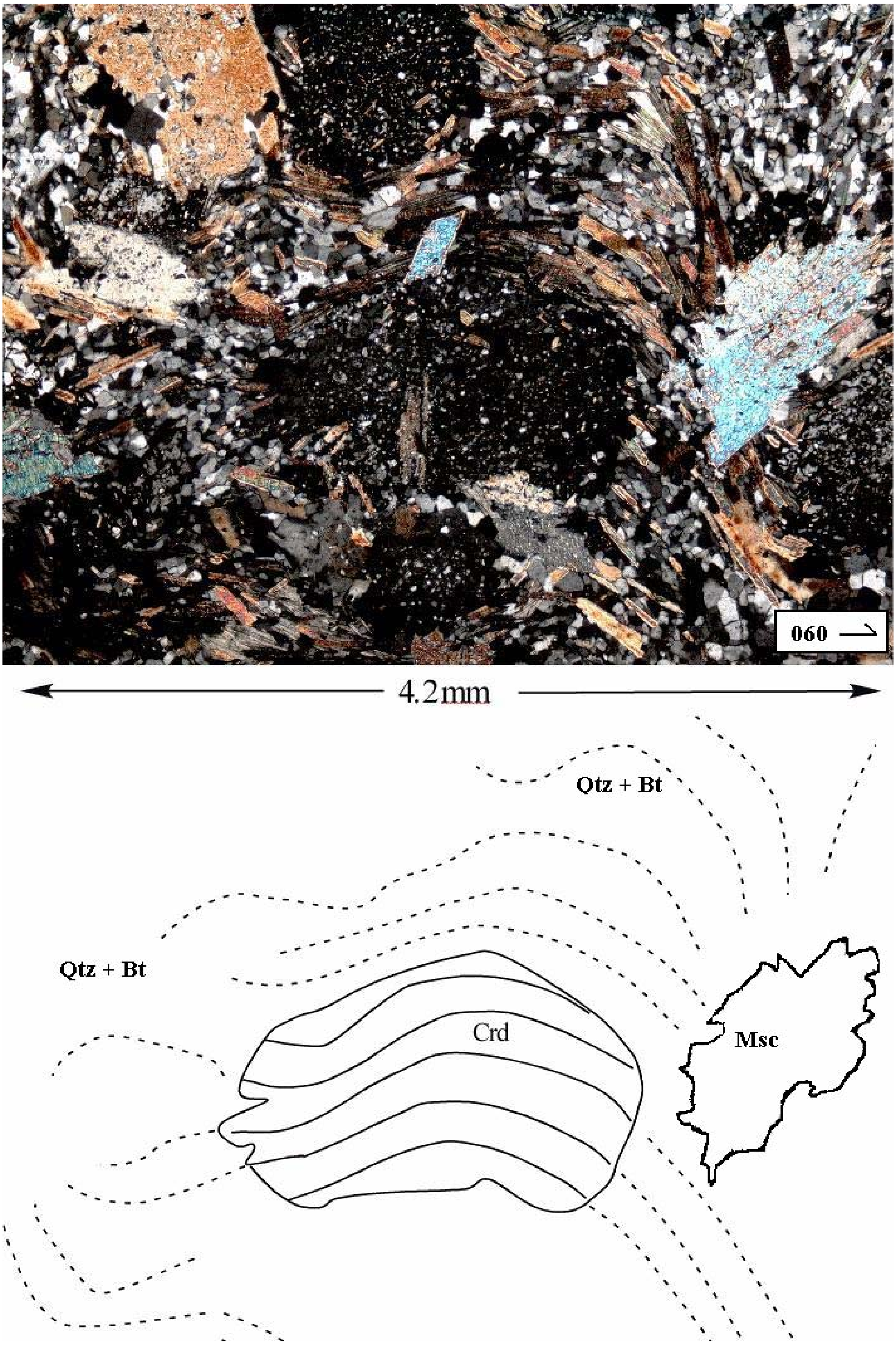


Fig. 10: Sample taken from PC2 at 30º. Sample shows a general clockwise trend in the inclusion trails which are continuous into the matrix of quartz, biotite, and muscovite.

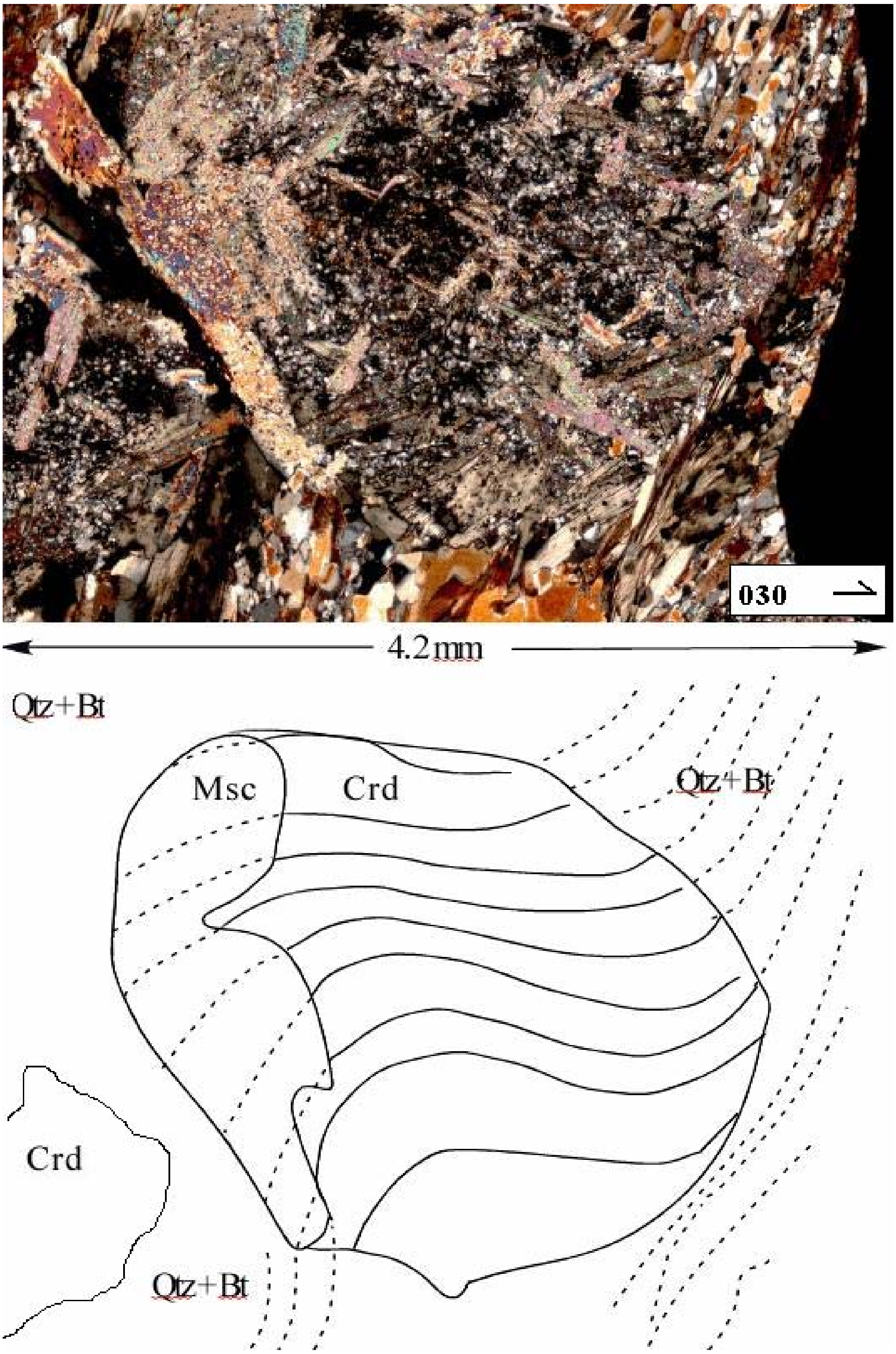


Fig. 11: Sample PC3 trending at 30º. Cordierite has been overgrown by muscovite, and the inclusion trails are continuous into the matrix. Quartz and biotite grains are aligned preferentially.

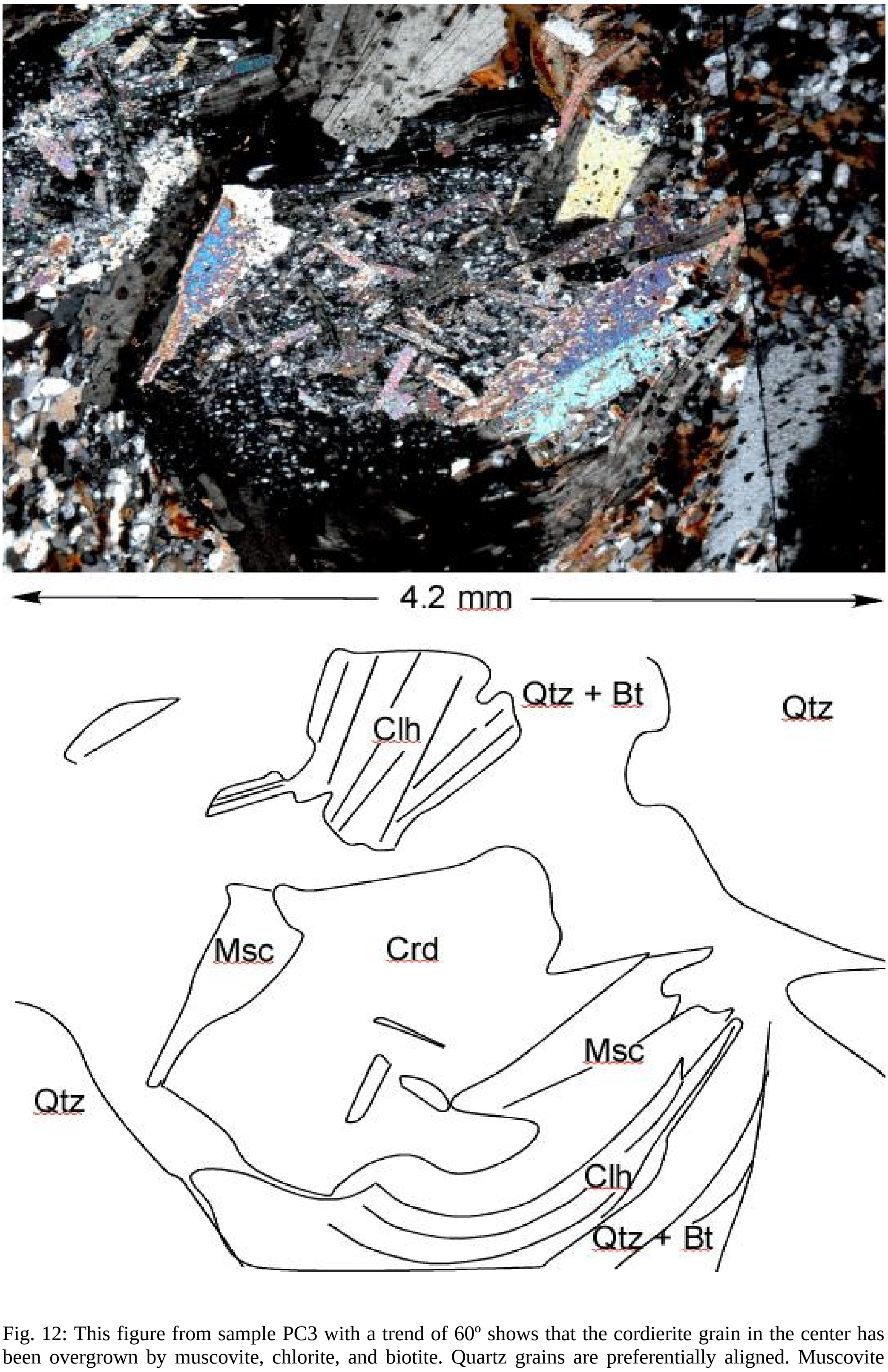


Fig. 12: This figure from sample PC3 with a trend of 60º shows that the cordierite grain in the center has been overgrown by muscovite, chlorite, and biotite. Quartz grains are preferentially aligned. Muscovite grains are randomly aligned within the cordierite suggesting that these grains are relatively older than the matrix.

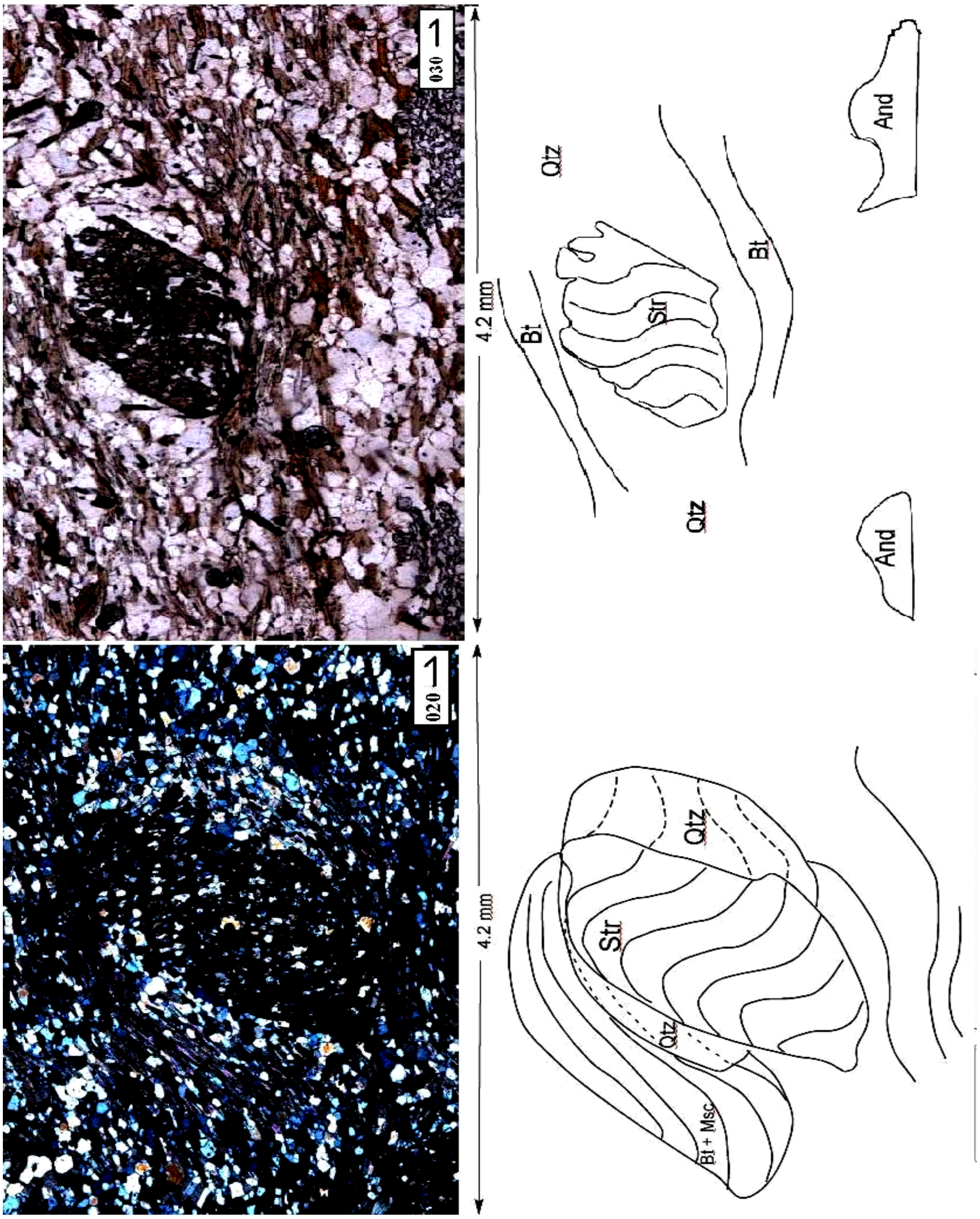


Fig 13: Sample K24 from the Strathalbyn Anticline showing staurolite grains switching from an anticlockwise pattern to a clockwise direction from the 20° to the 30° section. The FIA lies between these two sections. The inclusion trails in the LH figure could be continuous with the matrix foliation as inferred by the dashed lines. The inclusion trails in the RH figure are definitely truncated by the matrix foliation.

that has overgrown the truncational foliation and, of course, where the trails are continuous with those in the matrix. The andalusite grains are highly poikiloblastic with over 50% of their mass made of inclusions. Their trails consist of biotite, quartz, and a little illite and muscovite. The trails are mostly straight across the porphyroblast with slight curvature near the rims, but some are sigmoidal (Figs. 14 & 15).

Sample K21 contains two different FIAs (Table 1). The FIA is located at 30° ± 10° for staurolite and 55° ± 5° for andalusite. Within the 0° and 30° thin section samples, the inclusion trails within staurolite are generally straight and gently pitching with a slight curve on their edges. Inclusion trails in staurolite in sections to either side

Table 1: The data collected shows the changes between ACW and CW FIA patterns as well as similarities between the Petrel Cove samples and Stratha lbyn Anticline samples.

| | | | | |
|---|---|---|---|---|
| **Petrel Cove Samples:** | | | | CONSIDER THE FOLLOWING: |
| | | | | *Items in **red** indicate FIA location. |
| Sample | Cordierite | Andalusite | | |
| *PC 2* → | | | | **Blank boxes underneath mineral name |
| 0 | ACW | | **Presumed FIA for Cordierite is between** | indicates minerals not found in that sample |
| 30 | CW &ACW | | **0° and 30° (closer to 30°)** | |
| 60 | CW | | | ***Underlined minerals indicate that photos |
| 90 | CW | | | have been taken of that particular sample. |
| 120 | | | | |
| 150 | CW | | | |
| | | | | |
| *PC3* → | | | | |
| 0 | | | | |
| 30 | fia | | | |
| 60 | fia | | **Coridierite: BETWEEN 30° and 60°.** | |
| 90 | | | | |
| 120 | | | | |
| | | | | |
| **Strathalbyn Anticline Samples:** | | | | |
| | | | | |
| Sample | Andalusite | Staurolite | | |
| *K21* → | | | | |
| 20 | ACW | ACW | | |
| 30 | ACW | | **Andalusite FIA is 55° +/- 5°** | |
| 40 | | CW | **Staurolite FIA is 30° +/- 10°** | |
| 50 | ACW | CW | | |
| 60 | CW | | | |
| 70 | CW | | | |
| 80 | CW | CW | | |
| | | | | |
| *K24* → | | | | |
| 0 | ACW | ACW | | |
| 10 | ACW | ACW | | |
| 20 | ACW | ACW | **Andalusite FIA is 45°.** | |
| 30 | ACW | CW | **Staurolite FIA is 25°.** | |
| 35 | ACW | | | |
| 40 | ACW | CW | | |
| 50 | CW | CW | | |
| 90 | CW | | | |

are steeply pitching and tend to be sigmoidal in shape. Inclusion trails in andalusite tend to be sigmoidal and steeply pitching close to the FIA and straight and gently pitching further away.

Sample K24 also contains differently trending FIAs within staurolite versus andalusite. The staurolite FIA trends around 25° whereas the andalusite FIA trends at 45°. Both andalusite and staurolite grains contain steeply pitching sigmoidal trails. Inclusion trials in most staurolite grains are truncated while those in andalusite are continuous with the matrix. The inclusion trails show NW side up for flat to steep changes in pitch and top to the SE for steep to flat changes in pitch identical to those observed and remarked on by Adshead-Bell & Bell (1999).

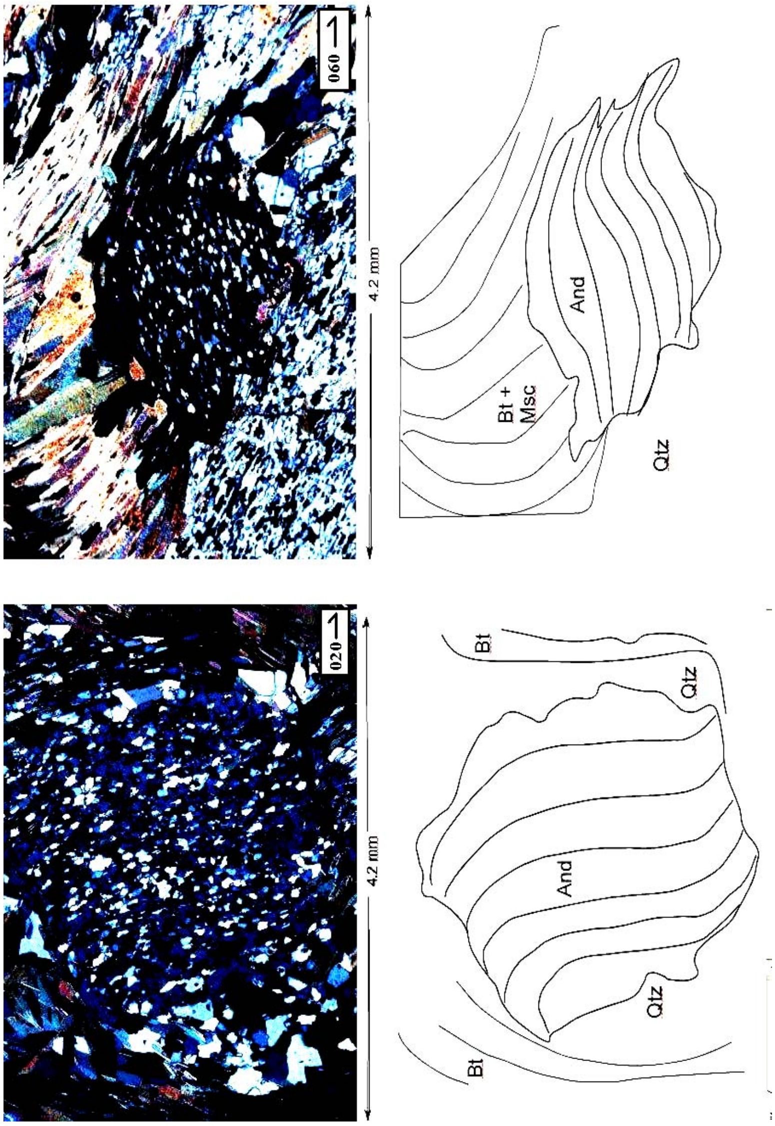


Fig. 14: ACW inclusion trails in Andalusite in the 20° section from Strathalbyn for sample K21, switch to CW in the 60° section across the FIA. The FIA trend is controlled by the sub-vertical foliation-forming event (Bell & Bruce, 2006). The strike of this sub-vertical foliation therefore lies on the FIA. Steeply pitching inclusion trails swing through the horizontal on the FIA as one crosses the strike of the vertical foliation creating them in 3D. Therefore the FIA lies close to 60°. The inclusion trails are truncated by the matrix foliation.

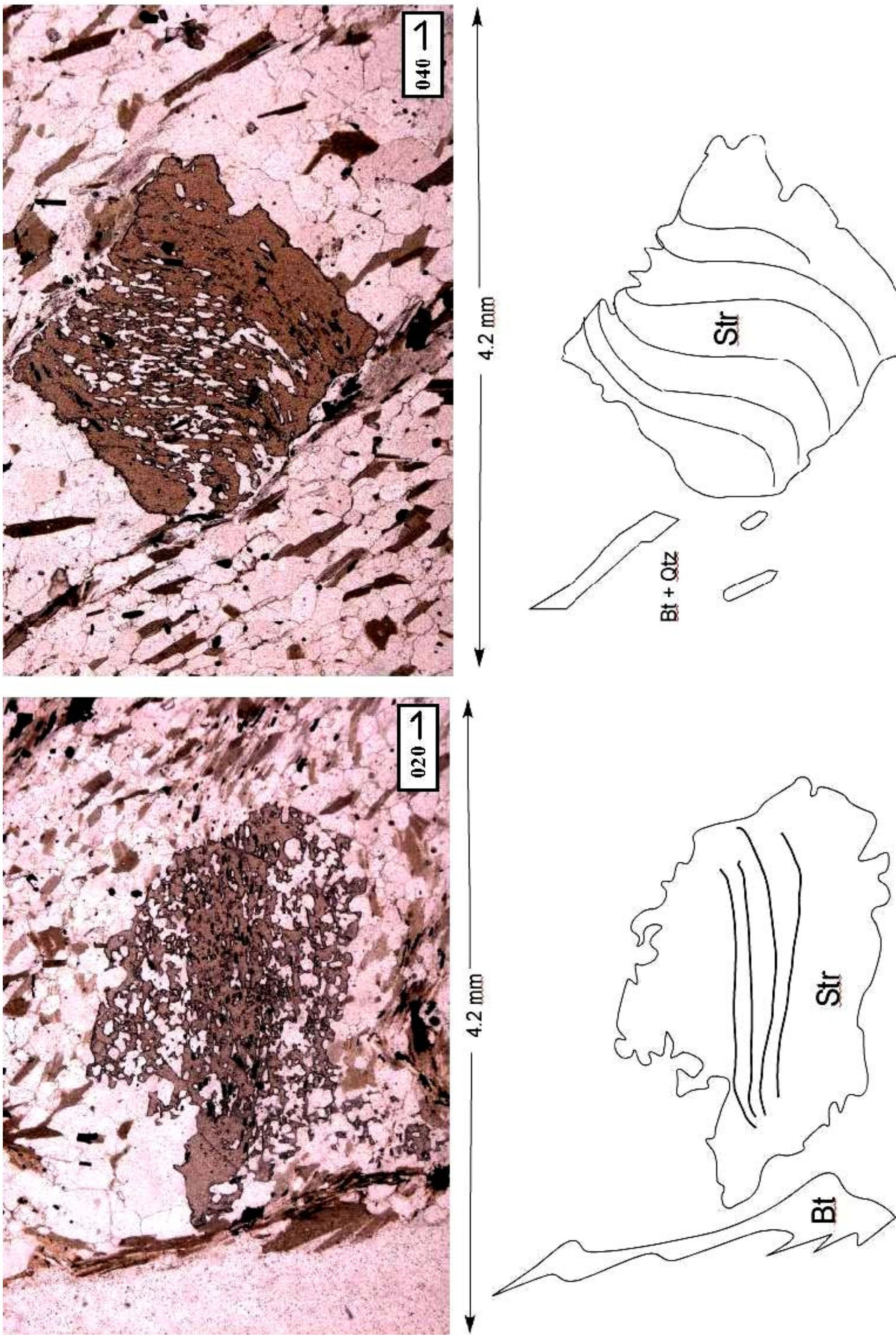


Fig. 15: Shows the switch in asymmetry in staurolite porphyroblasts from ACW in the 20° section to CW in the 40° section across the FIA trend (30°) in sample K21 from the Strathalbyn Anticline. The FIA trend is controlled by the sub-vertical foliation-forming event (Bell & Bruce, 2006). The strike of this sub-vertical foliation therefore lies on the FIA. Therefore, steeply pitching inclusion trails swing through the horizontal on the FIA as one crosses the strike of the vertical foliation crating them in 3D. This suggests the FIA trend is close to 20° than 40°. The inclusion trails in the RH staurolite are truncated. Inclusion trails commonly appear continuos in thin sections that lie sub-perpendicular to the matrix foliation because they exit he porphyroblast into strain shadows relative to that foliation (Cihan, 2004).

## VI. Interpretation

### VI.a. *Petrel cove:*

The stripy layering that dominates these rocks in outcrop, and which is commonly quite oblique to bedding, controlled where cordierite porphyroblasts grew in samples PC2 and PC3. Therefore, it is likely that in these rocks this layering formed as a result of fluids emanating from a granite that altered the margins of the fractures along which they escaped (c.f., Alias & Sandiford, 2002; Talbot & Hobbs 1968). The steeply pitching inclusion trails preserved in these cordierite porphyroblasts curve anticlockwise looking SW at the rims suggesting that the cordierites grew during top to the SE shearing. $S_2$ my have formed sub-horizontally at this time as a sub-horizontally pitching foliation in porphyroblast strain shadows merges with $S_2$ in the matrix. The sub-parallel stripy layering to $S_2$ indicates that the stripy layering developed relatively early. $S_2$ therefore may have been associated with W to E thrusting (Jenkins & Sandiford, 1992). D3 resulted in NW side up shear and the local development of a differentiated $S_3$ in both samples.

### VI.b. *Strathalbyn anticline:*

The inclusion trails preserved here show NW side up shear on the steep foliations and top the SW shear on sub-horizontal foliations suggesting uplift to the NW and thrusting to the SE.

### VI.c. *Petrel cove versus strathalbyn anticline:*

FIA 1 in the Strathalbyn Anticline is similarly oriented to with FIA 1 at Petrel Cove suggesting that they formed at the same time. FIA 2 in the Strathalbyn Anticline formed subsequently but no porphyroblast growth at this time was seen in the sample from Petrel Cove.

Furthermore, the steep to flat changes in inclusion trail geometries seen in FIA 1 at both Petrel Cove and the Strathalbyn Anticline are identical and strongly suggest top to the SW thrusting during orogenesis. Even though the FIA trends changed by some 30º during the new development of FIA 2 in the Strathalbyn Anticline, the shear sense did not change suggesting that thrusting continued to the SE. This is supported by the fact that flat to steep changes in inclusion tail geometry during the development of FIA 1 in both regions were NW side up indicating uplift to the NW and thrust the potential fold gravitational collapsed and thrusting to the SW at this time (Bell & Johnson, 1989; Bell & Newman, 2006).

## VII. Discussion

### VII.a. *Porphyroblast rotation?*

A debate over whether porphyroblasts rotate or not has been taking place ever since Bell (1985) proposed that in general they do not. All quantitative data that has been presented on FIA trends indicates that porphyroblasts do not rotate (e.g., Bell & Newman, 2006). The argument as to whether they do rotate has been entirely theoretical and model driven (Fay et al., 2008, in review). Indeed, modellers argued that porphyroblast non-rotation was impossible in a continuous medium. Fay et al (2008) have recently demonstrated that this is not the case. Indeed, they have discovered the phenomenon of gyrostasis whereby once an anastomosing or millipede geometry (a general strain developed within heterogeneous rocks) has been established by porphyroblast growth early during essentially coaxial deformation, all rotation ceases even in progressive bulk inhomogeneous simple shear (Fig. 16)! Although pressure shadows have been described in the past as being the results from rotation, they can also form as a result of gyrostasis, a process modelled in the form of a mesh-type structure which demonstrates its irregular shape as different magnitudes of strain are forced upon it (Fay et al, 2008; Cihan, 2004). Steinhardt (1989) argued that no porphyroblast rotation had occurred at Petrel Cove because the inclusion trails in all porphyroblasts that he measured were essentially sub-horizontal. Jiang & Williams (2004) inferred that non-rotation of porphyroblasts during non-coaxial deformation is mechanically impossible. However, the results presented herein disagree with his data because they suggest that many porphyroblasts overgrew a steep foliation rather than a horizontal one. One way in which his data could be reconciled with this data is if he cut a preponderance of thin sections striking within 30° of the FIA which trends at 30° in one sample and between 30° and 60° in the other.

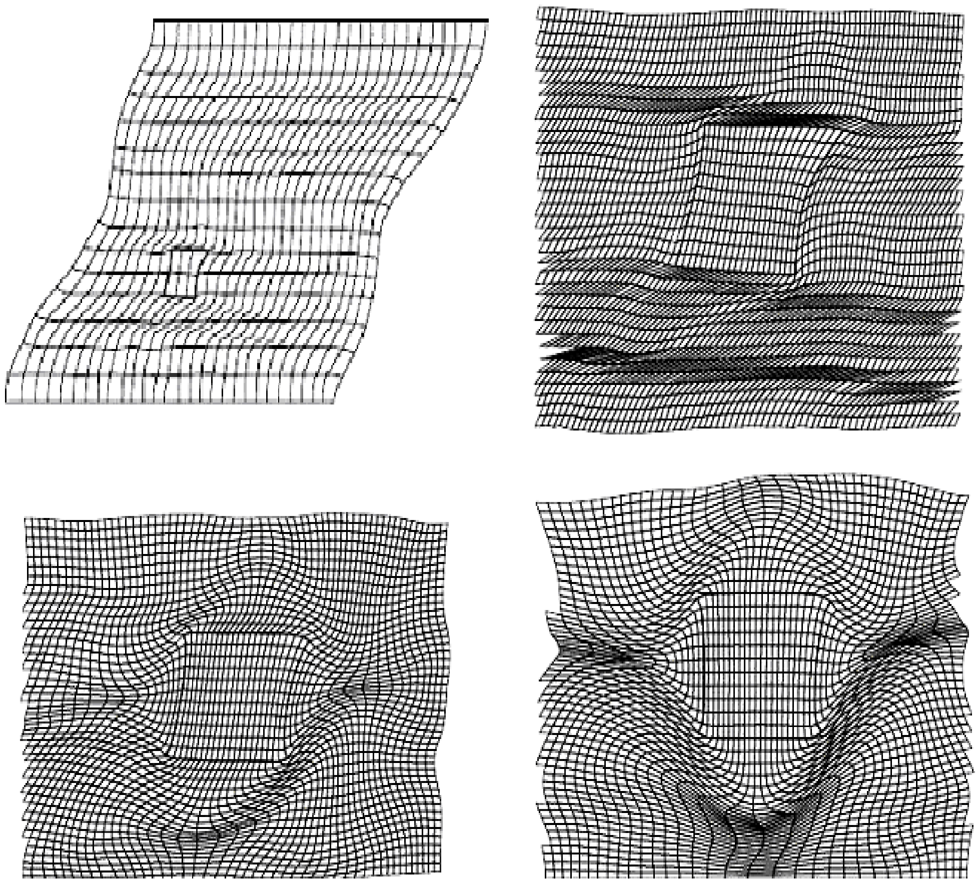

Fig 16: Figures showing the effects of shearing on porphyroblasts. The millipede geometry demonstrates that there are various levels of strain being exerted on the mesh squares, yet none of the above illustrations demonstrate rotation. Bulk shortening is the result of strain on porphyroblasts (Modified from Fay et al, 2008 in review).

The similar FIA trends determined at Petrel Cove versus FIA 1 in the Strathalbyn Anticline, which lie approximately 50 kms apart (Fig. 2), suggest that there has been no porphyroblast rotation (Bell, 1981; Fay et al, 2008) particularly knowing that at least 2 locally penetrative deformations have affected the rocks in the Strathalbyn Anticline post the development FIA 1.

### VII.b. *Stripy layering:*

The origin of the white stripes within the rock formations at Petrel Cove has been controversial. Talbot & Hobbs (1968) suggested that they formed in a non-dilatational event and represent an in situ differentiation process with some degree of chemical exchange between the host rock and a solution that may have emanated from the adjacent granite. Sandiford & Alias (2002) have suggested that this layering occurs at a shallow angle relative to schistosity and that the porphyroblasts form augen that are elongate parallel to this foliation. The results presented here provide a solution to both these observations. The stripy layers presumably formed due to fluid emanating from a granite which caused alteration to either side of the fractures in the country rock through which they passed. During subsequent deformation these altered zones were of a bulk composition such that cordierite preferentially grew within them at the prevailing PT. The deformation that accompanied cordierite growth would have caused rotation of the stripy layers towards the developing foliation. Subsequent deformations tended to cause the stripy layering to behave like bedding and thus reactivate (e.g., Fig. 6) and this further rotated any previously formed foliations and decrenulated any newly developing foliation leaving $S_2$ sub parallel to them (e.g., Ham & Bell, 2004).

### VII.c. Thrusting*:*

Previous workers (e.g., Jenkins & Sandiford, 1992) have argued that thrusting occurred from the west to east on the western side of the Mount Lofty Ranges (Fig. 2) during the Delamerian orogen. If this was the Precambrian margin of the southern Australian craton, subduction would have occurred of an oceanic plate to the east under these rocks to the west, and this accords with the direction of thrusting observed by Jenkins & Sandiford (1992). The inclusion trail asymmetry data from the FIAs accords with this both at Petrel Cove and in the Strathalbyn Anticline.

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