Rocks around the quartzite are much more highly deformed than rocks away from it. The carbonaceous "slates" of the Toole Creek Volcanics immediately adjacent to the quartzite are commonly intensely silicified, and in places show strong "L-S" fabrics similar to that in the quartzite. There is generally no trace of bedding in these "slates", nor in the quartz-muscovite schists and phyllites interfingered with them. Metasediments of the Staveley Formation adjacent to the quartzite are also schistose to phyllitic, and bedding is generally completely obliterated or strongly transposed (Figure 3.5e). This high strain zone contains the eastern band of ironstones in this region.

A variation on the strongly phyllitic Staveley Formation lithologies crops out in a band about 5 km to the northwest of Selwyn (around Grid. Ref. 54K VB435225). This lithology consists of strongly aligned, irregular to lenticular fragments of quartz arenite, set in a strongly foliated, phyllitic matrix (Figure 3.5f,g). These fragments (*phacoids*), range from tens of centimetres to microscopic in size. The foliation is defined by abundant, phyllosilicate-rich seams, which anastomose around the phacoids. Quartz grains within the phacoids are anhedral and equant. Away from the phacoids, within phyllosilicate-rich seams, quartz grains are reduced in size, and possess distinctly ellipsoidal shapes. These features suggest extensive dissolution of quartz in the seams. Similar foliated breccias crop out in the Limestone Creek area. A lithology of this type is believed to result from pervasive shearing of interbedded arenites and siltstones, causing initial fragmentation of the less-ductile arenites, and subsequent dissolution of the margins of the newly-formed phacoids, and also of quartz from the phyllitic matrix, to form the observed solution seams (Hammond, 1987).

The Toole Creek Volcanics and Mount Norna Quartzite are substantially thinner in the Selwyn Shear compared with their type sections. This may reflect deposition of initially thinner successions, but in combination with other evidence for high strain suggests rather tectonic thinning.

A pre-folding event may also be inferred in the Kuridala region from regional map patterns. The western margin of the Soldiers Cap Group is marked by the juxtaposition of Mount Norna Quartzite apparently concordantly against and structurally over the Staveley Formation, which is believed to be the younger unit (Blake *et al.*, 1983; Donchak *et al.*, 1983; this work). Donchak *et al.* (1983) suggested the possible existence of early recumbent nappes to explain the stratigraphic anomaly, but presented no structural evidence (such as facing changes without a fold vergence change) to support this. Extensive shear zones are reportedly present along this contact, and between the Mount Norna Quartzite and Llewellyn Creek to the east of Kuridala (Switzer, 1988; W.P. Laing, pers. commun., 1988) These are folded around the northwest-trending, open folds (Figure 3.2; see below), and interpreted to be a single shear zone folded around the Hampden Syncline (Switzer, 1988). Early thrusting was suggested by Switzer (1988) to explain the geometry, but more detailed mapping is required in the Kuridala region, particularly around these critical contacts.

Microstructural evidence

Porphyroblasts may preserve earlier stages in the development of a particular fabric, and also commonly preserve remnants of earlier structures, even where these have been totally destroyed in the external matrix (Bell and Rubenach, 1983; Bell, 1986; Bell *et al.*, 1986). Porphyroblast inclusion fabrics may therefore provide important evidence for the tectonic development of a complexly deformed and metamorphosed area.

The fabric associated with the main folding event in the Kuridala-Selwyn region is pervasive, but of variable intensity, and its development is also controlled by rock type, occurring as more intense foliations and mineral lineations in phyllosilicate-rich units. There is an overall increase in foliation (and hence strain) intensity, and a general obliteration of bedding, close to boundaries between major units (Staveley Formation, Maronan Supergroup, and Gin Creek Block). This can only partly be accounted for by the finer-grained nature of the rock types close to these contacts, and it is in these places that microstructural evidence for an earlier, intense foliation is preserved.

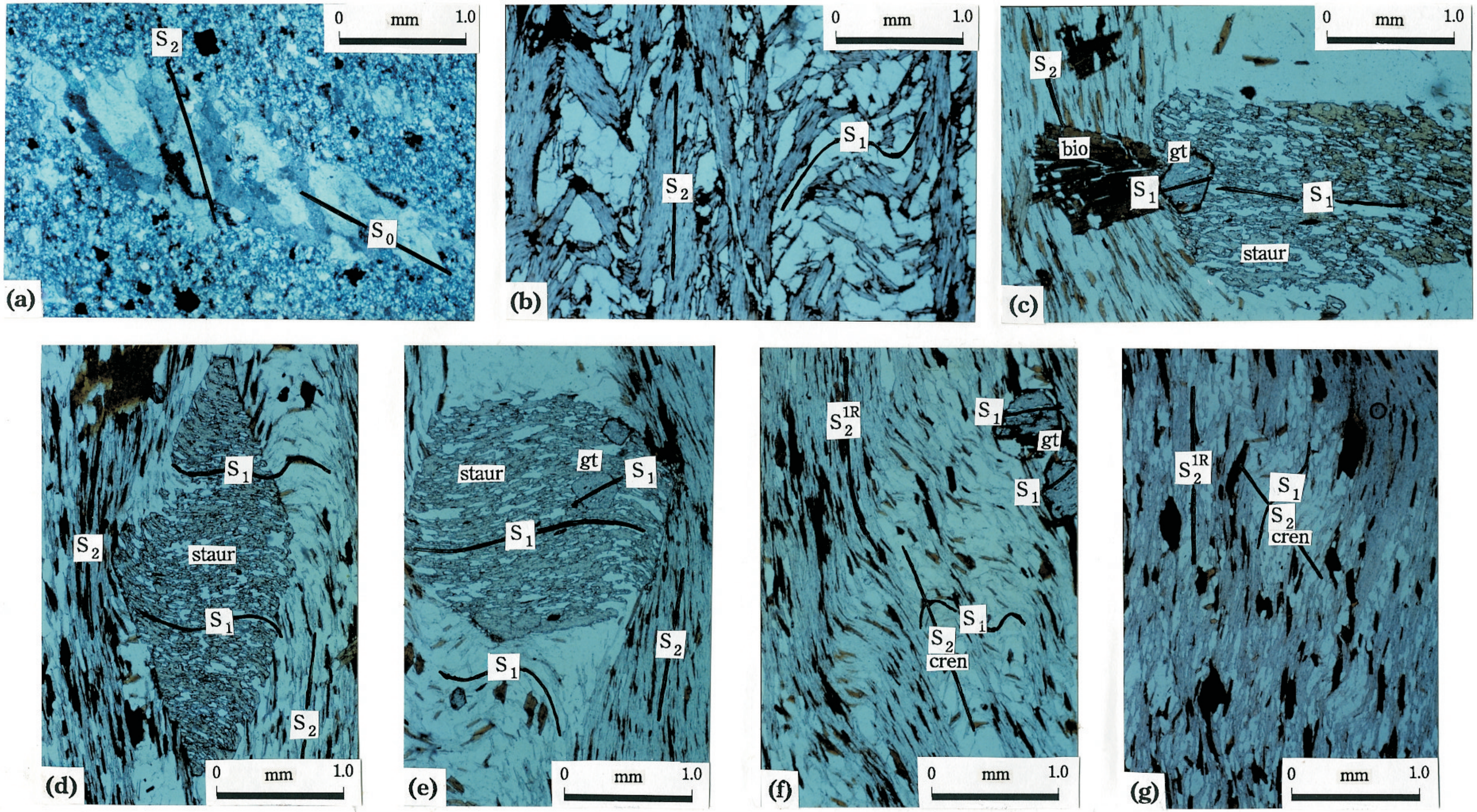
The foliation in most instances is schistose, evenly developed and generally undifferentiated. Locally, however, it is differentiated into distinct, anastomosing **Q** (quartz-rich) and **P** (phyllosilicate-rich) domains. Crenulation hinges are occasionally preserved in the Q-domains (*e.g.* Figure 3.6b). Bell and Rubenach (1983) interpret differentiated foliations to form by progressive crenulation and shearing of an earlier intense fabric (Figure 3.7).

Regional prograde metamorphism accompanied deformation, and porphyroblastic metamorphic phases grew over the fabric at various stages during its development. Switzer (1987) documented crenulated inclusion trails of muscovite in andalusite in the Starra Shear, and of fibrolite in K-feldspar, tourmaline and biotite further west in the Double Crossing Metamorphics. He also observed that the main foliation wrapping around andalusite porphyroblasts was commonly preserved as a differentiated to crenulate foliation in the strain shadows of the porphyroblasts. White (1989) observed similar evidence within the Starra Ironstones. These features were cited as evidence that the Starra Shear originally developed as a subhorizontal, layer-parallel detachment, subsequently overprinted by the main folding event.

In the Selwyn Shear west of the Mount Cobalt Mine, staurolite and garnet porphyroblasts occur in fine-grained, variably carbonaceous pelitic schists and phyllites of the Mount Norna Quartzite to the west of the Mount Cobalt Mine. Inclusion trails in, and strain shadows around porphyroblasts preserve remnants of an earlier stage of this foliation, as open crenulations of a still earlier, slaty foliation (*e.g.* Figure 3.6c,d,e). These porphyroblasts therefore nucleated and grew early during the main upright (F_2) folding event, *after* cessation of D_1 shearing. In thin sections cut parallel to the L_2^2 mineral lineation and perpendicular to S_2, the enveloping surfaces of the inclusion trail crenulations are generally consistently subhorizontal from one porphyroblast to another, and assuming porphyroblasts do not change their orientation relative to geographic coordinates during progressive shortening (as maintained by Bell, 1985), orientated thin sections indicate the earlier foliation in this zone was also initially approximately horizontal.

FIGURE 3.6: Microstructural features of the S_2 foliation: (a) weak S_2 in calcarenites of the Staveley Formation; bedding is defined by elongation of carbonate aggregates; S_2 is defined by elongation of individual crystals (as indicated); sample JCU-27308 (location: 54K VB364169); P-section (cut parallel to mineral lineation and perpendicular to S_2 foliation); XPL; (b) differentiated S_2 foliation (stage 3-4 of Bell and Rubenach, 1983) in schistose rocks in the uppermost Maronan Supergroup in the Selwyn Shear; sample JCU-27842 (location: 54K VB470182); P-section, PPL; (c,d,e) inclusion trails in staurolite and garnet preserving a foliation older than, and at high angle to S_2; all micrographs from sample JCU-27486 (location: 54K VA464932); P-sections; PPL; (f,g) examples of decrenulation of S_2 and reactivation of an earlier S_1 foliation; samples JCU-27486 and 27487 (location: 54K VA464932); P-sections; PPL.

FIGURE 3.6:


(a)
S_2
S_0
0 mm 1.0
(b)
S_2
S_1
0 mm 1.0
(c)
S_2
bio
gt
S_1
S_1
staur
0 mm 1.0
(d)
S_1
S_2
staur
S_1
S_2
0 mm 1.0
(e)
staur
gt
S_1
S_1
S_1
S_2
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S_2^{1R}
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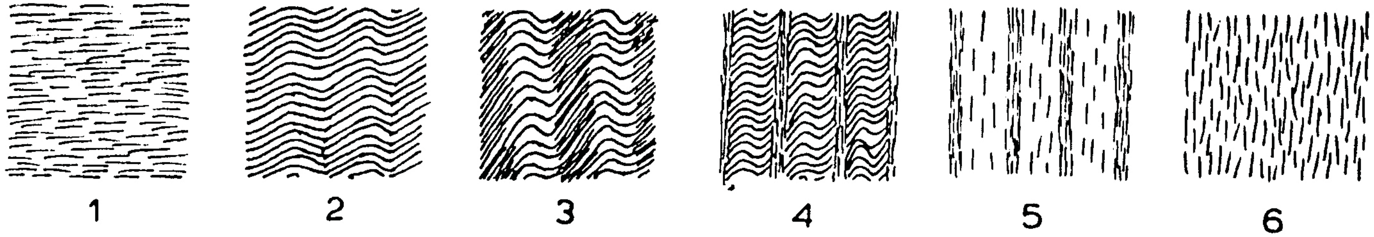


FIGURE 3.7: Six stages of development of a new schistosity via a crenulation cleavage. S_2 or incipient S_2 is orientated N-S. Stage 1 shows the original foliation S_1. Stage 2 shows crenulation of S_1. Stage 3 shows crenulation accompanied by solution transfer and consequent metamorphic differentiation. Stage 4 shows growth of new micas parallel to S_2. Stage 5 shows destruction of relic crenulations in the Q-domains. Stage 6 shows homogenized foliation S_2 (after Figure 4 of Bell and Rubenach, 1983).

Evidence for D_1 is rare, but nonetheless compelling. In general, however, there is only one foliation apparent in the high strain zones. This can be explained by reactivation of the early foliation, and decrenulation of S_2 due to shifting patterns of strain partitioning (Bell, 1986). Progressive deformation of an early S_1 begins with initial crenulation, and synthetic shear occurs parallel to fold axial planes (Figure 3.8a). At some stage in the deformation, progressive shear may become locally or regionally antithetic, causing decrenulation of the S_2 foliation and reactivation of S_1, to produce a generally undifferentiated foliation S_2^{1R} (S_1 reactivated into S_2; Figure 3.8b). Microstructures which may be interpreted as showing various stages of decrenulation are common in porphyroblast-rich layers in the Starra and Selwyn Shears (Figures 3.6f,g).

The body of evidence therefore confirms the presence before folding of early layer-parallel shear zones up to several thousand metres thick. The style of this early deformation event is considered in the Discussion.

3.3.3 D_3 - North- to north-northwest-trending folding

Steeply-dipping bedding and S_2 foliation are commonly rotated to shallow orientations around open folds, and the foliation further overprinted by a well-defined crenulation cleavage. These features are less pervasive than those associated with D_2, being most intensely developed in distinct bands less than a few kilometres wide each, scattered throughout the Kuridala-Selwyn region. These bands are interpreted as localised zones of D_3 deformation. The scale of the structures depends on the lithology in which they are developed.

F_3 folds in the Llewellyn Creek Formation have wavelengths of hundreds to thousands of metres. Macroscopic F_3 folds have not been identified in the uppermost Soldiers Cap Group or Staveley Formation in the Selwyn region, but some very large northwest-trending structures are evident in the Staveley Formation in the Kuridala Region (Figure 3.2). These fold bedding, F_2 folds and apparently the earlier D_1 shear

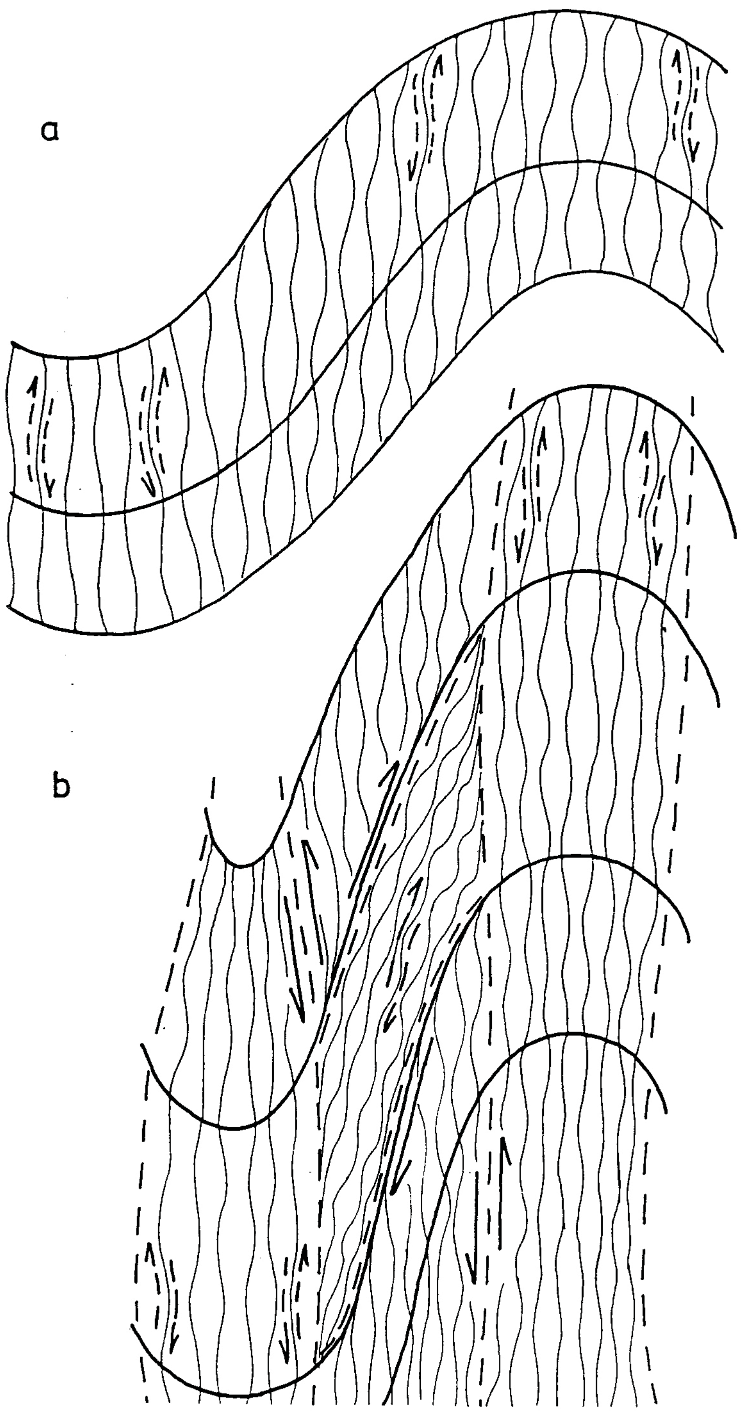


FIGURE 3.8: Schematic diagrams showing a shift in the pattern of deformation partitioning (fine- and coarse-spaced lines represent zones of shearing anastomosing around zones of shortening) during the formation of a fold limb, such that the folded foliation locally becomes reactivated. Progressive shearing (dashed arrows) is everywhere synthetic relative to the developing fold in **(a)**, but locally antithetic in the zone undergoing reactivation in **(b)**. Solid arrows in **(b)** show the sense of shearing at the coarser scale of deformation defined by the dashed lines (after Figure 1 of Bell, 1986).

inferred between the two units (Switzer, 1988). On the basis of overprinting relationships, they are interpreted as D_3 structures, although their axial plane orientation trends more to the northwest than in the Selwyn region.

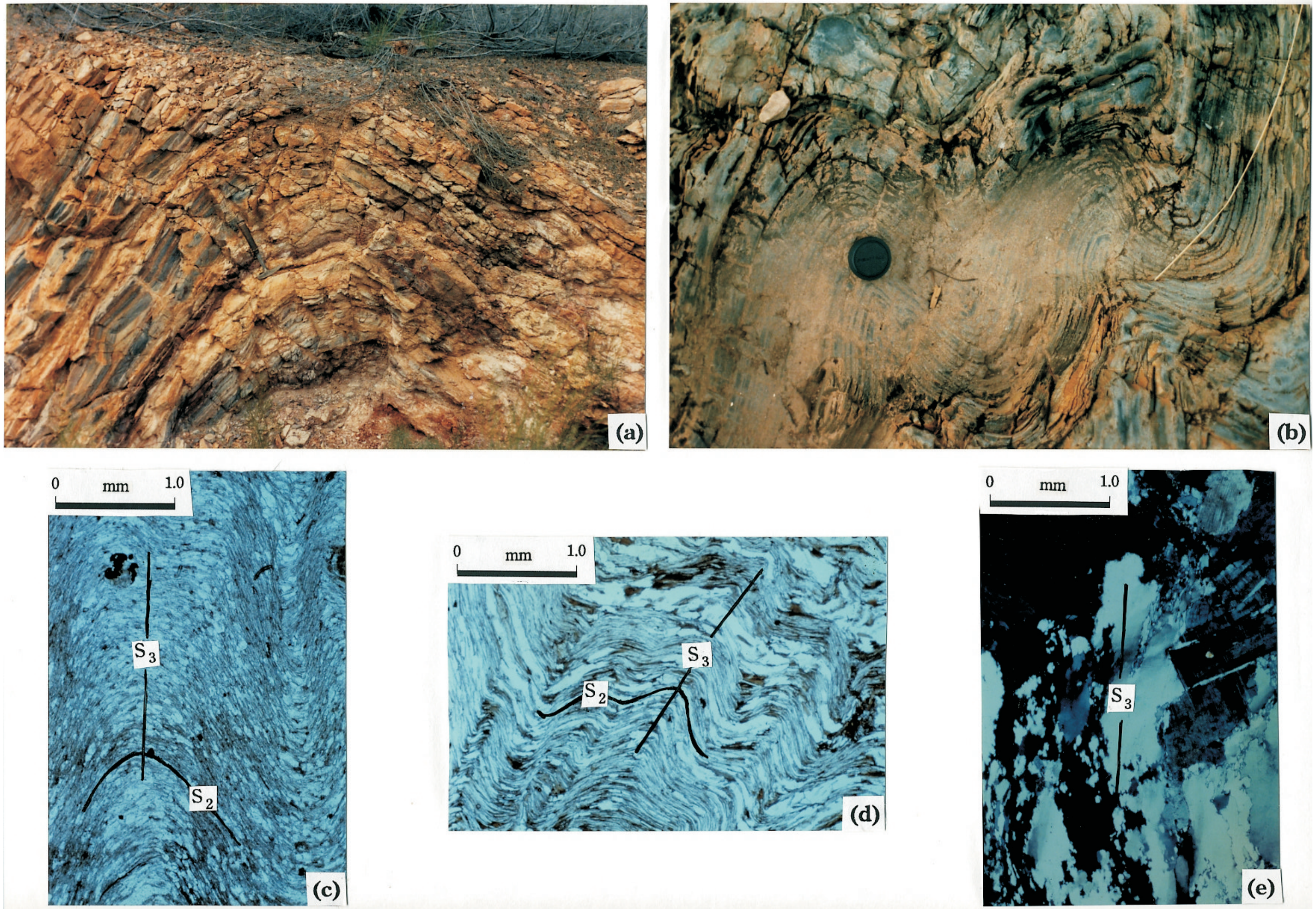
Mesoscopic F_3 folds with wavelengths ranging from tens of centimetres up to several metres are found in finer-grained, thinly-bedded or laminated lithologies, usually the Toole Creek Volcanics (Figure 3.9a,b). Such structures are rare, however, in the Llewellyn Creek and Staveley Formations, at least in the Selwyn area. Bedding in these units ranges from tens of centimetres to metres thick. Very thin (less than a few mm) laminations are apparently required for development of mesoscopic F_3 folds.

The foliation associated with F_3 folding occurs as rounded to angular crenulations in slaty to differentiated S_2 (Figure 3.9c,d). They are very well developed in the finer-grained, phyllosilicate-rich lithologies in the Selwyn region, particularly in the Starra and Mount Dore Shears. Switzer (1987) and White (1989) observed a well-developed, though localised S_3 crenulation overprinting the reactivated S_2 fabric in the extensively sheared metabasalts in the Starra Shear. S_3 crenulations may well be developed in similar lithologies in the Kuridala region, but remain undocumented. They are generally absent from the relatively thickly bedded, coarse clastic units of the Staveley Formation and lower Maronan Supergroup, probably because a schistose S_2 foliation was not developed in these rocks, due to their bulk chemistry or generally lower metamorphic grade. S_3 crenulations have wavelengths of generally 3 to 10 mm, and define a sub-vertical foliation striking roughly north (Figure 3.3e,f). Mesoscopic folds and S_2-S_3 cleavage asymmetries usually give an F_3 antiform fold vergence to the west. This is expected if a vertical S_3 overprints an east-dipping S_2 foliation. F_3 fold axes and L_3 intersection lineations have variable but largely shallow plunges to the north-northeast or south-southwest (Figure 3.4c-h).

The Mount Dore and Yellow Waterhole Granites are also affected by D_3. A weak foliation parallel to S_3 in metasediments is defined mainly by elongate quartz grains, which have deformed plastically. Feldspars have deformed by kinking and fracturing. Microstructures such as deformation lamellae, subgrains and cleavage kink

FIGURE 3.9: Field and microstructural features of D_3 structures: (a) mesoscopic F_3 fold lying to the south-southeast of the Mount Elliott Mine, developed in thinly laminated carbonaceous slates of the Toole Creek Volcanics; hammer for scale (left of centre) is 32 cm long; view looking approximately southeast; F_3 axial plane orientation is 70^o-->230^o (location: 54K VB476176); (b) mesoscopic F_3 folds developed in carbonaceous slates in Mariposa Creek; lens cap diameter is 55 mm; axial plane orientations are about 85^o-->085^o; north is upwards in photo (location: 54K VB461005); (c) photomicrograph of typical S_3 crenulations in S_2, from phyllites of the Answer Slate, near the Answer Mine (location: 54K VB340034); PPL; (d) similar to (c); S_2 is slightly differentiated in this instance; sample JCU-29838 (location: 54K VB467124); PPL; (e) photomicrograph illustrating development of vertical S_3 in the Mount Dore Granite; quartz has deformed ductilely, developing abundant subgrains, deformation lamellae, *etc.*; microcline (right) has deformed by brittle fracture; textures are not annealed, suggesting post peak-metamorphism (*i.e.* D_3); sample JCU-27230 (location: SHQ-78-38; 241.2 m); XPL.

FIGURE 3.9:



bands are preserved, suggesting that deformation occurred under waning temperature conditions, and textures were not annealed (Figure 3.9e). Regional metamorphism during D_3 was characterized by retrogression, in the most-deformed zones.

3.3.4 D_4 - Northeast-trending crenulations

Northeast-trending crenulations are locally developed to the west of the Western Ironstones, in the phyllosilicate-rich domains of the D_1 Starra Shear zone. Switzer (1987) notes they typically have wavelengths of the order of 3 cm and amplitudes of 1 to 2 cm, plunge to the southwest, and have axial planes dipping moderately to shallowly to the southeast. These crenulations are tentatively assigned to a D_4 deformation event, although overprinting criteria are lacking (other than S_2 is being folded). It is assumed to precede faulting, since it is a ductile event. In the Selwyn zone this event has not affected the regional geometry. D_4 structures have not been reported from the immediate vicinity of Kuridala.

3.3.5 Faulting

Conjugate shearing

Switzer (1987) describes a set of predominantly northeast-striking, southeast-dipping brittle-ductile shear zones in the Gin Creek Block and Starra Shear. A less well-developed set strikes northwest and dips steeply northeast. These structures for the most part cross-cut D_2 elements, but in the Starra Shear are refracted into parallelism with S_2^{1R}. They were folded, or at least crenulated, during D_3. Some of these structures are expressed as ridges of quartz-haematite vein infill, in narrow (≤ 10 metres) shears which have a strong cleavage parallel to the fault strike, and a strong down-dip mineral elongation. Blake *et al.* (1983) mapped these particular bodies as iron-formation. Amphibolites cut by the faults are retrogressed to actinolite and chlorite, indicating upper greenschist facies grade at the time. Switzer (1987) interpreted these structures as conjugate shears associated with the waning stages of D_2.

The Mount Dore Fault Zone

The youngest major structures identified in the Kuridala-Selwyn region are north-striking, moderately to steeply east-dipping faults. At surface, these faults tend to follow the regional grain of the rock, defined by the S_2 foliation, and they commonly coincide with interpreted F_2 fold hinges. The faults are scattered across the region, but are particularly common in the Selwyn region, along and to the east of the contact between the Soldiers Cap Group and Staveley Formation (Figure 3.2). This concentration of faults is essentially coincident with the Selwyn Shear, and is hereafter referred to as the Mount Dore Fault Zone. The presently recognized western boundary of the Mount Dore Fault Zone lies along the contact between the Soldiers Cap Group and Staveley Formation. The eastern margin lies just to the west of the New Hope Arkose (Figure 3.2).

The western extremities of the Mount Dore and Yellow Waterhole Granites lie close to the western margin of the Mount Dore Fault Zone, and are bounded and dissected by faults for up to a kilometre east of these boundaries. These plutons have been tectonically emplaced over metasediments subsequent to solidification by reverse slip along the Mount Dore Fault Zone.

The Mount Dore Fault Zone contains abundant buck quartz veins up to several metres thick. Brecciation is common towards the western margin of the fault zone, commonly where there an apparent coincidence of faulting and F_3 folds. Breccia petrogenesis is intimately related propagation of the MDFZ, and to Mount Dore breccia-hosted mineralization. These are touched upon briefly in the discussion below, and in more detail in Chapter Six.

A major late-tectonic fault in the Kuridala region is the Hampden Fault (Figure 3.2). This is a reverse fault apparently controlling the distribution of the Hampden copper-gold deposits (Sullivan, 1953a). On the basis of orientation and apparent style it is regarded as an equivalent to the Mount Dore Fault Zone.

3.4 DISCUSSION

3.4.1 The style of D_1

D_1 in the Kuridala-Selwyn region is represented by major, bedding-parallel, high strain ("shear") zones between the Staveley Formation and other units. They are up to several thousand metres thick, and affect units above and below the main decollément. Recent work around the Mary Kathleen and Cloncurry areas has also defined large, layer-parallel "D_1" shear zones. Such structures may form in either extensional or thrusting regimes.

Both extensional (Hill, 1987a; Holcombe *et al.*, 1987; Pearson *et al.*, 1987; Switzer, 1987; Stewart and Williams, 1988; Stewart, 1989; Oliver *et al.*, 1991) and compressional (Bell, 1983; Bettess, 1987; Hill, 1987b; Loosveld, 1987; Loosveld and Schreurs, 1987) events have been recognized around Mary Kathleen and Cloncurry. A conflict of interpretation of structures has only occurred in the region of the Deighton Klippe (Loosveld and Schreurs, 1987 versus Stewart, 1989), and it is generally accepted that there are (at least) two pre-folding events in this part of the Mount Isa Inlier. Extension in the Mary Kathleen region is interpreted to have an upper-plate-to-the-north sense of movement (Holcombe *et al.*, 1987; Pearson *et al.*, 1987; Oliver *et al.*, 1991), or to be in an east-west direction (Stewart, 1989). Thrusting and recumbent folding recognized in this area and around Cloncurry is, however, interpreted to be east-over-west (Bettess, 1987; Hill, 1987a; Loosveld, 1987; Loosveld and Schreurs, 1987).

The Starra Shear in the Selwyn region is interpreted to be extensional in origin, with the upper (Staveley) plate moving northward relative to the lower (Double Crossing) plate (Switzer, 1987; Laing *et al.*, 1988; Switzer *et al.*, 1988). This interpretation is based on the apparently subhorizontal orientation of the detachment prior to D_2, opposite shear senses developed in the limbs of the F_2 Gin Creek Antiform, the markedly lower metamorphic grade in the upper plate, the lack of superposition of older on younger rocks, and the absence, or at least immense attenuation of a large slice of the stratigraphy from between the upper and lower plates.

The style and direction of movement along the Selwyn Shear are equivocal. Shear sense indicators are rare. There is a strong mineral streaking in the mylonitic quartzite, plunging down-dip in the limbs of F_2 folds which, if an L_1^1 mineral lineation, indicates a bulk east-west transport direction during D_1. This is 90^o to the transport direction determined for the Starra Shear, suggesting the shears are different structures.

In the Kuridala region, Soldiers Cap Lithologies appear to have been juxtaposed over the Staveley Formation along the Kuridala Shear, prior to D_2 folding. The stratigraphic succession is also truncated here, with the Llewellyn Creek Formation completely removed (Figure 3.2). Extension cannot explain such a geometry, and a D_1 thrusting event is preferred. Neither the transport direction along this structure, nor its relationship to the Selwyn Shear are known. The band of rocks between Kuridala and Selwyn is poorly exposed, but the interpreted continuation of the thrust southwards passes through or close to the Mount Elliott mine, which lies to the east of the northward extension of the Selwyn Shear. Further work is required to clearly establish whether D_1 thrusting occurred, and if so how widespread it is.

3.4.2 Deformation Ages

No absolute ages have been determined for the deformation events in the Kuridala-Selwyn belt. D_2 and D_3 structures here do, however, have similar styles and orientations to D_2 and D_3 structures recognized in the Mount Isa area (Bell, 1983; Winsor, 1983, 1986; Bell *et al.*, 1988), and may (or may not!) therefore be contemporaneous. Page and Bell (1986) have dated three major deformations in the Mount Isa area, using Rb-Sr whole-rock techniques. These are 1610±13 Ma (D_1), 1544±12 Ma (D_2) and 1509±13 Ma (D_3).

The D_2 and D_3 events in the Kuridala-Selwyn region are assumed to have similar ages to those in the Mount Isa area. Supporting evidence for the age of the D_3 event comes from radiometric dating of plutons of the Williams Batholith. Rb-Sr whole-rock ages are known for the Wimberu Granite (1498 Ma: Richards, 1966) and

Mount Dore Granite (1509±22 Ma: Nisbet *et al.*, 1983). The Mount Dore Granite was deformed during D_3, and Page (1978) indicates that Rb-Sr ages can be reset by deformation. The ages rendered for the granites are comparable with that for D_3 in the Mount Isa area, suggesting a date for D_3 in the Kuridala-Selwyn belt. Such an interpretation should be regarded with caution, however, considering the limited data available.

The D_1 event in the Kuridala-Selwyn region is more difficult to date. It is an extensional event, at least in southern parts, and therefore different in character to the thrusting attributed to D_1 around Mount Isa (Bell, 1983; Winsor, 1983, 1986; Bell *et al.*, 1988). An extensional D_1 is interpreted in the Mary Kathleen area, occurring between 1780 and 1730 Ma ago, based on U-Pb zircon dating of syn-kinematic plutons of the Wonga Batholith (Holcombe *et al.*, 1987; Pearson *et al.*, 1987; Oliver *et al.*, 1991). If this is the age of extensional D_1 in the Kuridala-Selwyn region, it places constraints on the age of deposition of the Staveley Formation, since this unit was deformed during this event. It also means that a minimum of 180 Ma elapsed between extensional tectonics and the onset of compressional tectonics.

D_1 thrusting has been interpreted for D_1 in the Tommy Creek area, about 25 kilometres west of Cloncurry (Hill, 1987b, 1990). This is the closest example of thrusting to the Kuridala region, where thrusting may also have occurred. Porphyritic, apparently flow-banded rhyolites, and the so-called "Tommy Creek Microgranite", interpreted by Hill (1987) to be a recrystallised porphyritic ignimbrite, have been U-Pb zircon dated at 1603±6 Ma, and 1626±4 Ma, respectively (Page, 1983; Hill, 1990). These ages place a maximum age on subsequent thrusting. This is similar to the age determined for D_1 in the Mount Isa area (Page and Bell, 1986). In truth, however, the age of D_1 in the Kuridala-Selwyn region is unconstrained.

Late faults were clearly active after D_3, because they truncate these structures and the Mount Dore and Yellow Waterhole Granites, which were deformed during D_3. The Rb-Sr whole rock age for the Mount Dore Granite (1509±22 Ma; Nisbet *et al.*, 1983) probably places a maximum age on faulting. Mount Dore and similar breccia-hosted deposits are also contained within these faults, and a maximum age can therefore be placed on the current manifestation of mineralization.

3.4.3 Implications for tectonic modelling

Counterclockwise P-T-t paths, some demonstrably showing early isobaric cooling, have been documented in the Mary Kathleen region (Reinhardt and Hamilton, unpublished data, 1987; Oliver *et al.*, 1991). A prograde metamorphic geothermal gradient of up to 50^{o}C/km is implied (Jaques *et al.*, 1982; Loosveld, 1989a). Isobaric cooling has not been documented in the Kuridala-Selwyn region, though it cannot be precluded on the basis of existing data. Structural evidence here suggests, however, that uplift (and erosion) by late-tectonic faulting began soon after peak grades were attained, and the Maronan Supergroup may therefore have followed a different P-T-t path.

Peak thermal conditions across the entire eastern Mount Isa Inlier occurred during ductile deformation, and heating therefore cannot be directly related to crustal thickening and thermal re-equilibration during isostatic adjustment. Simple conductive thermal models cannot explain low pressure metamorphism during crustal thickening, unless significant amounts of heat are added from the mantle before or during crustal thickening (England and Richardson, 1977; Oxburgh and Turcotte, 1974). Several mechanisms for introducing this heat have been proposed:

1) Lithospheric mantle and crustal thinning by extension (*e.g.* McKenzie, 1978; Wickham and Oxburgh, 1985, 1987).

2) Emplacement of magmas at the base of or into the crust (*e.g.* Wells, 1980; Bohlen, 1987).

3) Crust-mantle detachment, with associated aesthenospheric upwelling (*e.g.* Bird, 1978, 1979; Bird and Baumgardner, 1981; Houseman *et al.*, 1981).

Extensional tectonism in the Mary Kathleen region preceded compressional tectonism by as much as or more than 150 Ma (Oliver *et al.*, 1991; Loosveld, 1989a). Numerical modelling by Loosveld (1989b) indicates that any thermal anomaly produced by this event would have decayed long before the onset of compressional tectonism. The age of extension in the Selwyn region (along the Starra Shear) is assigned a similar age to that in the Mary Kathleen region by analogy only. It could be considerably younger, and therefore a possible heat source, but further work is required.

Granitic magmas associated with the deformation event were not intruded into the crust until after the peak of metamorphism, and therefore cannot have contributed to the initial heat flux. They are, however, enriched in heat-producing elements (Wyborn *et al.*, 1988), and probably contributed to maintaining relatively elevated temperatures throughout the retrograde history. The source for the granites is interpreted to have been emplaced at the base of the crust between 1530 and 1649 Ma, or from 1630 to 1720 Ma (depending on the model used; Wyborn *et al.*, 1988). The first-mentioned range corresponds closely with D_1 and D_2 deformation in the vicinity of Mount Isa (*ca.* 1610 to 1540 Ma; Page and Bell, 1986; see Chapter Three), suggesting that underplating may have contributed to elevated heat flux.

Decoupling of the lithosphere from the crust is encouraged during orogenesis. The inherent gravitational instability caused by cold, dense lithosphere overlying hot, less dense aesthenosphere is enhanced when the lithosphere is thickened and depressed into the aesthenosphere during compression. Passive detachment of some or all of the lithosphere from the crust may occur, at which time aesthenosphere wells up to replace it (Houseman *et al.*, 1981). Alternatively, active detachment of the lithosphere could occur by convective thinning (Loosveld, 1989b). This would supply a driving force for the compression and cause emplacement of hot aesthenosphere at the base of the crust. Partial melting is also possible, through adiabatic decompression of the rising aesthenosphere.

Loosveld (1989b) modelled the P-T-t paths which would result from each of the sources considered above. On the basis of existing data from the eastern Mount Isa Inlier, he decided that convective lithospheric thinning best explained the thermal and tectonic features.

The role of the Maronan Supergroup in the tectonic history of the eastern Mount Isa Inlier requires further extensive structural and metamorphic studies. If it followed a different P-T-t path, and yet had a similar thermal peak during compressional deformation, any tectonic model must account for these characteristics. It is possible that the Maronan Supergroup was emplaced over the remainder of the eastern part of the Mount Isa Inlier (see Section 3.4.1). It would thereby have caused the underlying plate to follow a counter-clockwise P-T-t path, while itself as upper plate would have undergone relatively rapid uplift after emplacement via isostatic rebound.

3.5 CONCLUSIONS

The regional structural geometry in the Kuridala-Selwyn region results from the interplay of three major ductile events and one major brittle event. The earliest recognisable deformation (D_1) involved detachment of major lithologies from one another, and produced major shear zones up to one kilometre thick. Extension, possibly in a north-south direction, is postulated for at least some of the structures in the southern (Selwyn) part of the region (Switzer, 1987; Laing *et al.*, 1988), but regional map patterns in the northern (Kuridala) part might be better explained by early thrusting. The precise definition of style and movement direction for the D_1 event (or events) requires further work. D_1 was followed by east-west compression, which caused major folding and reactivation of earlier structures. F_2 folds are upright, tight to isoclinal, north-trending structures with wavelengths ranging from several thousand metres to millimetres. Peak prograde metamorphism occurred early during this event. Retrograde metamorphism was accompanied by development during D_3 of north- to north-northwest-trending corridors of open, upright folds, in scattered bands less than a few kilometres wide.

Ductile deformation events in the Kuridala-Selwyn region are dated mainly by analogy with dated structures having similar styles in other parts of the Mount Isa Inlier. Extensional D_1 has an age between 1780 and 1730 Ma (Oliver *et al.*, 1991). D_2 occurred 1544±12 Ma ago (Page and Bell, 1986). D_3 is dated at about 1509 Ma (Nisbet *et al.*, 1983; Page and Bell, 1986). D_3 deformation may have been broadly synchronous with intrusion and crystallization of the Williams Batholith. Late reverse faulting reactivates earlier structures, and truncates plutons of the Williams Batholith. It occurred sometime after, but probably not much later than D_3.

The P-T-t history of the Maronan Supergroup is poorly constrained, but may be different to that of the remainder of the Mount Isa Inlier. If so demonstrated by further detailed metamorphic and structural studies, this will place constraints on tectonic modelling for this part of the inlier.