BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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SURFACE GEOLOGY AND STRUCTURE OF THE TUMUT SEISMIC TRAVERSE, LACHLAN FOLD BELT, N.S.W.

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ABSTRACT

The Tumut Trough is a Palaeozoic terrane comprising a fault-bounded Silurian volcanic-sedimentary sequence flanking the eastern margin of the Wagga Metamorphic Belt in the southern part of the Lachlan Fold Belt.

This record presents results of structural and stratigraphic work carried out along a seismic traverse in May 1987. The trough is divided into three Blocks; the Tumut, Jindalee and Mooney Mooney Fault Blocks. Silurian units traversed in the trough include the Brungle Creek Metabasalt, Jackalass Slate, Bumbolee Creek Formation, Blowering Formation, Wyangle Formation, Coolac Serpentinite and the Honeysuckle Metabasic Igneous Complex. A Lower Silurian detachment fault is inferred to separate some of these units from a metamorphic basement comprising the ?Ordovician Bullawyarra Schist. The stratigraphic position of the Honeysuckle Metabasic Igneous Complex is changed and the validity of the Coolac Ophiolite Suite is questioned.

The Silurian rocks underwent two periods of compressive deformation accompanied by lower to upper greenschist facies metamorphism: Lower Silurian recumbent folding and Early Devonian upright folding. Granitoids, intruded at about 409 Ma, separated these two events. The younger period of deformation was accompanied by strike-slip faulting of the Coolac Serpentinite along the eastern margin of the trough.

INTRODUCTION

The Tumut Trough is a Palaeozoic terrane flanking the eastern margin of the Wagga Metamorphic Belt in the southern part of the Lachlan Fold Belt (Fig. 1). The trough is fault-bounded and contains tectonically emplaced mafic and ultramafic rocks thought to represent remnants of Ordovician oceanic crust or to be coeval with the trough sequence (Wyborn & others, 1979).

The tectonic setting of the trough has been regarded as either: a zone of fore-arc collision with a continental margin (Crook, 1980a, b); or a subsequently closed small ocean-floored rift (Ashley & others, 1979; Powell, 1983); or an intracratonic rift (Wyborn, 1977).

In May 1987 a seismic survey was conducted by BMR and the Australian National University across the trough from 3 km west of Grahamstown to 8 km north-northeast of Adjungbilly. The survey failed to complete the westernmost 9 km of the 54 km long traverse falling about 4 km short of the Gilmore Fault; the western margin of the trough. The survey was primarily designed to determine the attitude of the bounding faults and the crustal structure beneath the trough. In the fore-arc collision model these faults were thought to dip to the east and be listric in form, whereas in the pull-apart basin model of Powell (1983) they would probably be vertical. It was thought that the common occurrence of serpentinite along these faults would provide a marked seismic impedance contrast with the surrounding rocks and thereby assist in producing relatively strong reflection signals from the faults.

In conjunction with the seismic survey structural studies were carried out along the traverse and adjacent areas in order to determine: the nature of the major faults, in particular their orientation and movement history; and the stratigraphy and structure of the Silurian trough sequence. The results of these studies would assist interpretation of the seismic results and would also contribute to a continuing broader study on the structure and tectonics of the Tumut Trough.

This record presents the results of the structural and stratigraphic work only. Operational details of the seismic survey are given by Leven and others (1987) and a preliminary interpretation of the survey results is presented by Leven and others (1988). A more detailed account of the seismic survey and interpretation of the crustal structure of the Tumut Trough is in preparation.

The geology and structural elements of the traverse are presented in Plates 1 and 2 respectively. Six figure grid references used throughout the text are Australian Metric Grid coordinates, corresponding to the grid used on both plates.

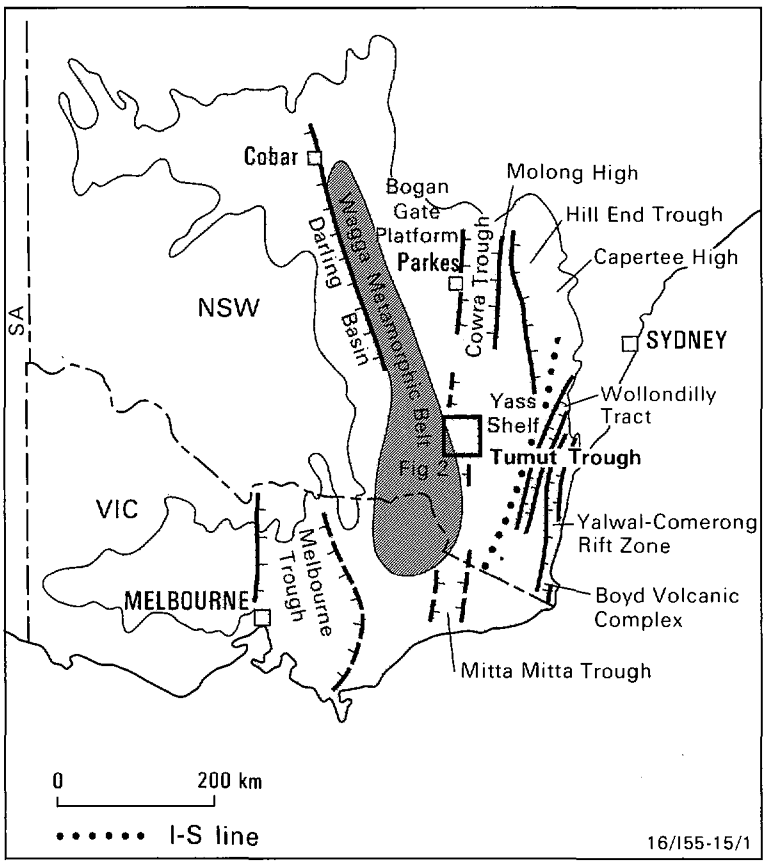

Fig. 1. Location of the Tumut Trough and mid-Silurian to mid-Devonian tectonic elements of the Lachlan Fold Belt (modified from Powell, 1983; Veevers, 1986).

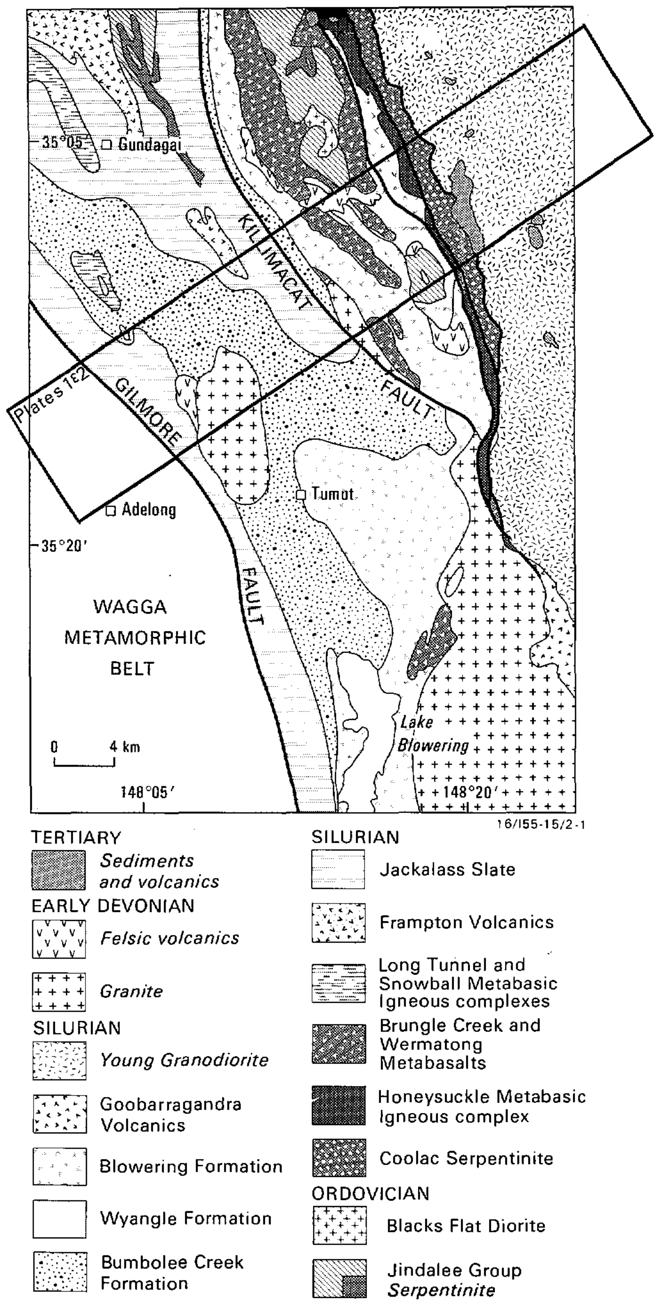

Fig. 2. Generalised geology of the southern part of the Tumut Trough (modified from Basden, 1982).

Rock terminology and classification

Sedimentary rock classification follows that by Crook (1960) and limestone classification by Folk (1959). Granitoid and pyroclastic rock nomenclature follow that recommended by the IUGS Subcommission on the Systematics of Igneous Rocks (Streckeisen, 1973 and Schmid, 1981 respectively). Terminology of fault-related rocks (eg. cataclasite, mylonite) follows that suggested by Wise and others (1983).

All the Silurian and older rocks are metamorphosed to lower or upper greenschist facies, and the prefix meta- is used for all rock types where the original protolith can be identified. Mineral prefixes in metamorphic and igneous rock terms are in order of increasing abundance.

Acknowledgements

Some of the figures were drawn by L. Emerton and D. Pillinger assisted with compilation of Plates 1 and 2.

REGIONAL SETTING

The Tumut Trough is located in the southeastern part of the Lachlan Fold Belt along a southern extension of the Cowra Trough (Fig. 1). Major fault boundaries separate the trough from the Goobarragandra Block to the east and the Wagga Metamorphic Belt to the west; the former comprising mainly Silurian granitoids (Young Granodiorite) and their coeval volcanics (Goobarragandra Volcanics), and Silurian mafic intrusions; the latter, comprising Ordovician flyschoid metasediments and volcanics, and Silurian granitoid and mafic intrusions.

The trough comprises three main blocks; the Tumut Block, the Jindalee Block, and the Mooney Mooney Fault Block. These correspond to the similarly named terranes defined by Basden and others (1987). However, lithostratigraphic differences between these terranes are insufficient to warrant designation as separate terranes and the term Block is preferred. Where appropriate these blocks have been divided into structural domains (domains 1 - X111, Plate 2) on the basis of orientation of major structural elements and/or direction of sedimentary facing. Boundaries between the domains correspond to either mapped or inferred faults, or possibly early recumbent fold hinges.

The geology of the region is described in detail by Basden (1982, 1986). The generalised geology of the southern part of the Tumut Trough is shown in Figure 2. The oldest unit in the region is the ?Ordovician Jindalee Group, which comprises mainly upper greenschist facies mafic volcanics (Bullawyarra Schist) intruded by the Blacks Flat Diorite. These rocks crop out in two inliers in the Jindalee Block northeast of Tumut and are overlain by a Silurian sequence of metabasalt (Brungle Creek

Metabasalt), quartz-poor flysch (Wyangle Formation) and dacitic volcanics (Blowering Formation). To the east, the Silurian sedimentary - volcanic sequence is terminated against the fault-bounded Coolac Serpentinite and Honeysuckle Metabasic Igneous Complex, which together are thought to represent upthrust Silurian oceanic crust (Ashley & others, 1979).

The main Silurian trough sequence occurs in the Tumut Block between the Gilmore and Killimicat Faults west of Brungle. Here the sequence consists of basal mafic (Long Tunnel and Snowball Mafic Igneous Complexes) and felsic volcanics (Frampton Volcanics) overlain by flyschoid sediments (Jackalass Slate and Bumbolee Creek Formation) and felsic volcanics (Blowering Formation). The sediments were most probably derived from both the Wagga Metamorphic Belt to the west and Silurian volcanism to the east on the Yass Shelf (Crook, 1980a; Duff & others, 1979).

The Silurian sedimentary - volcanic sequences were deformed and metamorphosed to lower to upper greenschist facies following Early Devonian granite intrusion and prior to erosion and deposition of shallow-water to subaerial ignimbrite and minor sediments. The ignimbrite and associated sediment form remnant subhorizontal sheets unconformably overlying older rocks. Minor outliers of Tertiary terrestial sediments and basalt flows cap the Coolac Serpentinite and Young Granodiorite to the east.

WAGGA METAMORPHIC BELT

The Wagga Metamorphic Belt, comprising Ordovician metasediments and mafic igneous rocks, was deformed in the Lower Silurian* and later intruded by Lower to Upper Silurian granitoids. The belt, forming the western margin of the Tumut Trough, was thought to have been a provenance area for much of the Silurian trough sediments (Crook & Powell, 1976).

The traverse terminated in the belt about 7 km west of the Gilmore Fault. Rocks in the mapped section included undivided metasediments, the Wondalga Granodiorite and a metadolerite tentatively placed in the Nacka Nacka Metabasic Igneous Complex.

STRATIGRAPHY AND STRUCTURE

Nacka Nacka Metabasic Igneous Complex

Minor outcrops of fine-grained epidote-albite-actinolite-biotite hornfels crop out at GR 950010 within the Wondalga Granodiorite; contacts are not exposed. The rock, a metadolerite, is probably part of the Nacka Nacka Metabasic Igneous Complex (Basden, 1982) which is the only mafic unit in the area predating the granodiorite. K-Ar isotopic age determinations on the complex give ages of 465 ± 6 Ma and 467 ± 6 Ma (Webb, 1980).

Undivided Ordovician metasediments

Stratigraphic and stuctural observations of the metasediments were severely limited by poor exposure on the traverse section. The metasediments, which are best exposed around the northwestern margin of the Wondalga Granodiorite, include phyllite, biotite hornfels, and banded quartz-albite-hornblende-biotite hornfels. Intrusive contacts are exposed at GR 909975 where numerous granite veins intrude the hornfels. The contact with the granodiorite is highly irregular owing to later tectonism and transposition.

Low outcrops of chlorite schist and albite-biotite-muscovite hornfels occur within the Wondalga Granodiorite around GR 954999 and may form a roof pendant or a raft within the granodiorite.

A prominent NNW-trending cleavage in the metasediments dips 80° SW and parallels the main foliation in the granodiorite. The cleavage post-dates metamorphic compositional banding and isoclinal folds.

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* The Silurian time scale used in this report follows that adopted by BMR (Strusz & Young, 1988)

Wondalga Granodiorite

Medium to coarse-grained biotite granodiorite, minor aplite and fine-grained granodiorite of the Wondalga Granodiorite crop out as bouldery hills in the Grahamstown area. The granodiorite intrudes and contact metamorphoses undivided Ordovician metasediments and is thrown against the Jackalass Slate by the Gilmore Fault. The intrusive contact is highly irregular and marginal phases of the granodiorite contain numerous biotite-rich metasedimentary xenoliths.

A variably-developed flattening foliation is present in the granodiorite and parallels the Gilmore Fault and a late cleavage developed in the Ordovician metasediments. The foliation dips steeply to the WSW and is more intensely developed within 700 m of the Gilmore Fault where it also becomes subvertical. In this zone a mineral elongation lineation is present (eg. GR 983980, 985979, 986973) and plunges shallowly (7^{o}-18^{o}) to the NNW. Asymmetrical tails of fine-grained polygonal quartz on deformed coarse quartz grains indicate sinistral displacement. West of Gramhamstown a steeply SW-plunging extensional mineral elongation lineation is rarely present.

At Adelong Falls, about 4 km southeast of Grahamstown, excellent exposures of the granodiorite crop out in a gorge along Adelong Creek. The granodiorite contains a weak to strongly developed foliation which dips steeply to the west and is cut by numerous pre-foliation dolerite dykes up to 1 m wide, and a conjugate set of ultramylonite zones (Fig. 3). The mylonitic zones include a dextral set trending NNE and dipping steeply to the W and a sinistral subvertical set trending NNW (locality 1, Plate 2). Both mylonitic sets have a prominent lineation which respectively plunges shallowly to the NNE and subhorizontally (Fig. 4).

Unstrained fabrics (fine-grained polygonal quartz mosaics with aligned biotite and muscovite) indicate that both the foliation in the granodiorite and the mylonitic zones formed during greenschist facies metamorphism, possibly contemporaneously (Fig. 5).

Fig. 3. Ultramylonitic zones within the Wondalga Granodiorite at Adelong Falls (locality 1, Plate 2) showing displacement of dolerite dyke. The main metamorphic foliation in the granodiorite is indicated by the pencil. In this photo the sinistral mylonite zone offsets a dextral set, however, in the same outcrop the reverse also occurs.

Fig. 4. Subhorizontal lineations in a mylonitic zone within the Wondalga Granodiorite, Adelong Falls (Locality 1, Plate 2).

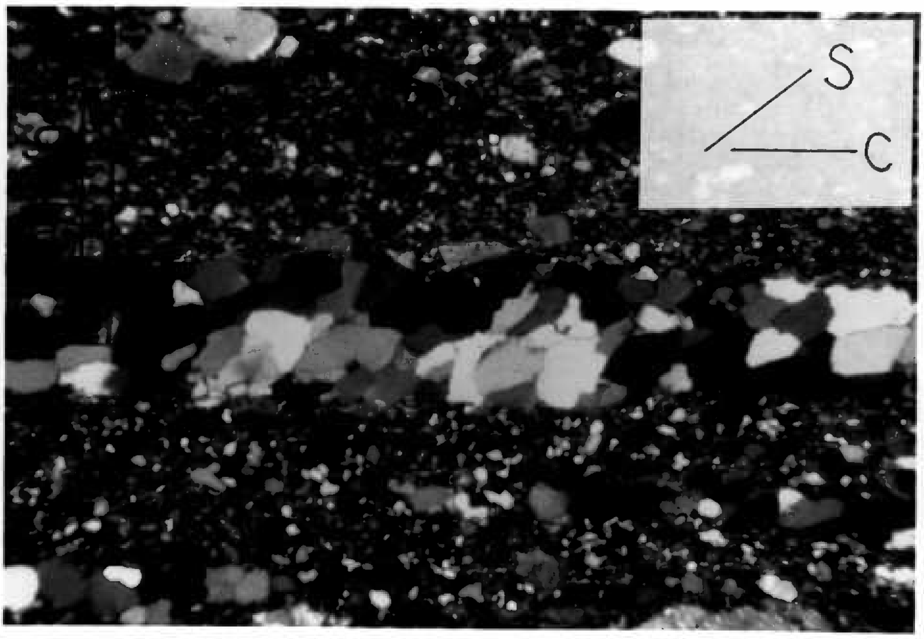

Fig. 5. Photomicrograph of ultramylonite in the Wondalga Granodiorite. An S-C fabric is evident: quartz grains are elongate parallel to the S plane, Adelong Falls (Locality 1, Plate 2).

Fig. 6. Rounded boulder (30 cm across) of metaquartzite within conglomerate, Jackalass Slate (GR 001027). Note the S_2 cleavage present in the matrix passes through the boulder.

TUMUT BLOCK

The Tumut Block, bounded by the Gilmore and Killimicat Faults, contains Silurian metasediments and minor volcanics both of which are intruded by Lower Devonian granite and porphyritic felsic dykes. Silurian units included in the traverse section are the Jackalass Slate and the Bumbolee Creek Formation. Deformation of these units is more intense than in the adjoining Jindalee Block, with at least two fold generations present.

At Mount Minjary a gently-dipping outlier of the Lower Devonian Minjary Volcanics unconformably overlies the Gocup Granite and the Silurian rocks.

STRATIGRAPHY

Jackalass Slate

Metasediments and volcanics comprising the Jackalass Slate (Basden, 1982) are poorly exposed along the traverse being largely covered by Quaternary alluvium of the Tumut River and Califat Creek. The formation is fault-bounded by the Gilmore Fault in the west, where it is thrown against the Wondalga Granodiorite, and by the Killimicat Fault in the east where it is in contact with the Killimicat Granite and possibly the Brungle Creek Metabasalt. In this area the Killimicat Fault is obscured by alluvium and talus.

About 2 km northwest of Mount Minjary the Jackalass Slate structurally overlies the Bumbolee Creek Formation. Both units are downward-facing and represent a conformable sequence with both the quartz-rich and quartz intermediate arenite facies present in both units. The Jackalass Slate is distinguished from the Bumbolee Creek Formation by the presence of volcanics and marble and the larger size of clasts in conglomerate. Southwest and northeast of the Gocup Granite the contact with the Bumbolee Creek Formation is inferred to be faulted. In the Mount Minjary area the formation is also faulted against the Minjary Volcanics and is intruded by porphyritic felsic dykes. An aplite dyke also intrudes the unit at GR 977006 where it is thrown against the Wondalga Granodiorite by the Gilmore Fault.

The Jackalass Slate comprises mostly slate with silty laminae or thin beds (<2 cm thick) of graded very fine-grained quartz-rich arenite and lesser graded fine- to coarse-grained quartz-intermediate arenite, the latter forming beds up to 30 cm thick. Minor polymictic pebble and cobble conglomerate and rare marble (GR 995023, 076073), meta-rhyolite (GR 986005), and meta-basalt (GR 995027) are also present in places. Pebbles and cobbles, up to 30 cm across, in the conglomerate are well-rounded and include fine-grained meta-quartzite (Fig. 6), felsic and mafic volcanics, and marble.

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The thickness of the Jackalass Slate is indeterminate in the area owing to poor exposure and structural complexity. Basden (1986) estimated a maximum thickness of 2500 to 3000 m for the unit in the Tumut region.

The age of the Jackalass Slate is poorly constrained. Crinoid stems and trace fossils are non-age specific (Thompson, 1970; Atkins, 1974; Stevens, 1975; Basden, 1986). On the basis of a correlation with the Wyangle Formation Basden (1986) suggested a late Landoverian to early Wenlockian (Lower Silurian) age.

Bumbolee Creek Formation

A thick downward-facing sequence of flysch metasediments of the Bumbolee Creek Formation (Ashley & others, 1972) is exposed in creek beds around the northern margin of the Gocup Granite between Califat homestead and the Tumut River. The granite intrudes the metasediments and has an associated contact metamorphic aureole up to 1 km wide. Within the aureole arenites are recrystallised and pelitic rocks form cordierite hornfels. Minor NE-trending porphyritic felsic dykes also intrude the formation north of the Gocup Granite.

East of Califat homestead the formation is structurally overlain by the older Jackalass Slate. The contact is conformable and graded bedding indicates both units are downward-facing. West of Mount Minjary and near Eurobin homestead the contact between the two units is inferred to be faulted because of converging structural trends and reversals of recumbent fold vergences. The Bumbolee Creek Formation is the youngest of the Silurian trough units exposed along the traverse in the Tumut Block. Farther to the south, however, it is conformably overlain by the Blowering Formation (Basden, 1985).

The stratigraphy of the unit is shown diagrammatically in Figure 7. In the area the unit comprises about 2000 m of alternating pelitic-rich sequences of brown or grey slate and minor quartz-rich arenite with quartz-intermediate arenite-rich sequences containing lesser slate and quartz-rich arenite. Quartz-rich arenite in both sequences is typically graded, lenticular cross-bedded, very fine- to fine-grained and forms laminae or beds up to 10 cm thick. Rarely it is medium-grained occuring as beds up to 50 cm thick. Quartz-intermediate arenite is generally massive, fine- to very coarse-grained and pebbly in places. Beds are commonly graded and range from 10 cm to 7 m thick. Locally (eg. GR 044040, 042033) the arenite contains minor pebble conglomerate horizons containing clasts identical in composition but smaller in size to those in conglomerate of the Jackalass Slate. The quartz intermediate arenite sequences were differentiated as Stuckeys Creek Formation by Stevens (1974), Atkins (1974) and Crook (1980) which was thought to overlie the Bumbolee Creek Formation. However, this subdivision is not valid as both varieties of arenite are interbedded throughout the sequence (Fig. 7).

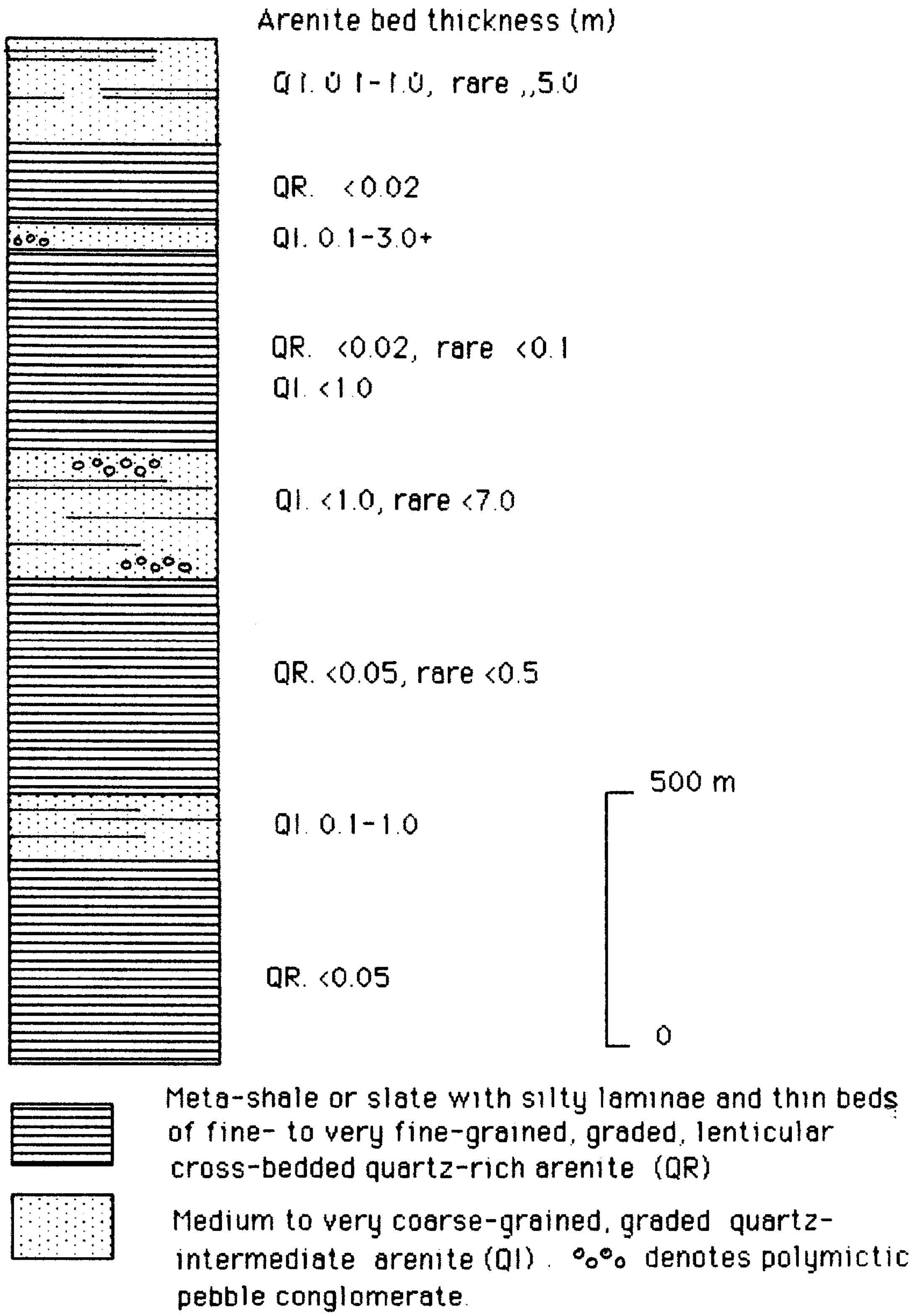

Fig. 7. Stratigraphy of part of the Bumbolee Creek Formation, Minjary area.

The age of the Bumbolee Creek Formation is probably Lower/Upper Silurian as the formation conformably overlies the Lower Silurian Jackalass Slate and underlies the Upper Silurian Blowering Formation. Trace fossils are non-age specific however correlation (Atkins, 1974) with part of the Tumut Ponds Group indicates a late Wenlockian - Ludlovian age (Labutis, 1969).

Gocup Granite

The Gocup Granite (Barkas, 1976) crops out south of the Gundagai - Tumut road in rugged wooded hills extending southeast of Mount Minjary. The granite intrudes the Bumbolee Creek Formation and is unconformably overlain by the Minjary Volcanics. Extensive induration and fine cordierite spotting in metasediments up to 2 km north of the granite indicate shallow-dipping contacts in that area. About 2 km northeast of Mount Minjary, granite is exposed at the base of a ridge capped by metasediment and a subhorizontal contact is indicated. Northeast-trending porphyritic felsic dykes, up to 50 m wide, intrude the granite and the adjacent metasediments.

The granite, a pink coarse muscovite - biotite granite, is similar petrographically to the Killimicat Granite (Basden, 1982) and has the major element characteristics of A-type granites but not the trace element characteristics (B.W. Chappell, personal communication in Basden, 1982). K-Ar dates on muscovite from the granite yeild a crystallisation age of 409 ± 2 Ma (Richards & others, 1977). A Rb-Sr whole rock age of 402 ± 2 Ma probably records a deformation event (Richards & others, 1977).

Unnamed porphyritic felsic dykes

Unnamed porphyritic felsic dykes, up to 50 m wide and 1 km long, intrude the Gocup Granite and the Bumbolee Creek Formation north and east of Mount Minjary. The dykes post-date F_1 recumbent folds and pre-date the upright F_2 folds. The axial plane cleavage (S_2) to the latter folds is present in the dykes as a foliation (defined by aligned metamorphic muscovite, biotite and chlorite) which is particularly well-developed on dyke margins.

Minjary Volcanics

The Minjary Volcanics (Barkas, 1976), a sequence of shallow-marine to subaerial (Duff & others, 1979) rhyolitic ignimbrite, tuff and minor polymictic conglomerate and arenite over 450 m thick, unconformably overlies the Bumbolee Creek Formation and the Gocup Granite (Atkins, 1974). The sequence dips between 40^{o} and 50^{o} to the southwest and is faulted off against the Jackalass Slate by the Califat Fault. The sediments contain brachiopods and corals of an early to middle Seigenian (mid Early Devonian) age (Barkas, 1976; Richards & others, 1977).

STRUCTURE AND METAMORPHISM

Silurian rocks in the Tumut Block have undergone two major periods of folding (early recumbent folding and later upright folding) separated by intrusion of the Gocup Granite. Locally kinks and a crenulation cleavage are also present in areas adjacent to the Gilmore and Killimicat Faults.

The earliest structures present are quartz fibre veins, less than 2 mm thick and regularly spaced about 2 cm apart. They are folded by F_1 (Fig. 8). The veins, occupying tensile fractures, trend 275^{o} orthogonal to bedding and the Early Silurian extension direction observed in the Brungle-Darbalara area (Stuart-Smith, in prep). This geometric relationship and their early formation suggests that they may have formed during extensional deformation of the Tumut Trough.

Recumbent folding

Evidence for large-scale early recumbent folding in the Tumut Block is based on widespread downward-facing structures and locally the presence of recumbent fold hinges (F_1) and a bedding parallel cleavage (S_1). Downward-facing beds predominate in Domains 1V, V, and V111. These domains are separated from upward-facing beds in domains 111, V1 and V11 by NW-trending faults or possibly F_1 fold hinges. Bedding facing could not be determined in Domain 11 owing to the dominance of the S_2 fabric and a higher degree of metamorphic recrystallisation.

Recumbent structures are best preserved in Domain V and V1 around the northern margin of the Gocup Granite where F_2 folds are open and S_2 is poorly developed. Recumbent F_1 fold closures are exposed in a road cutting at GR 053042 (Fig. 8). Here an axial plane S_1 slaty cleavage is present which elsewhere is bedding-parallel. Within the contact aureole the foliation, defined by aligned muscovite and chlorite, is overprinted by round chloritised cordierite porphyroblasts (Fig. 9), and is cross-cut by porphyritic felsic dykes. The folding therefore pre-dates granite intrusion at about 409 Ma (Richards & others, 1977). Minor epidote-carbonate-chlorite-quartz veins parallel the S_1 cleavage and are folded by F_2. They may have developed during S_1 formation or during contact metamorphism.

The enveloping surface of beds within Domain V dips moderately to the south and faces north (ie. downward-facing). The beds therefore represent the lower limb of a large-scale recumbent structure, the hinge (or fault) of which must lie farther to the north as the Bumbolee Creek Formation passes into the older Jackalass Slate about 3 km north of the traverse.

The presence of minor 'F_1' folds showing normal vergences on the downward-facing beds in Domain V is consistent with the downward-facing beds representing the lower limb of a large recumbent fold. The S_1

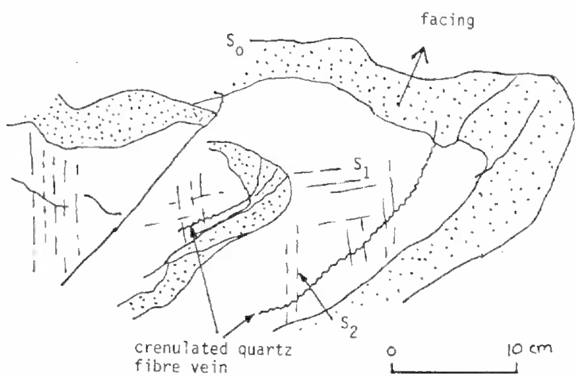

Fig. 8. Recumbent F_1 fold hinge in Bumbolee Creek Formation (GR 058041). An axial plane cleavage (S_1) is present in the hinge and is crenulated by S_2. Note fine quartz veins pre-date F_1 fold.

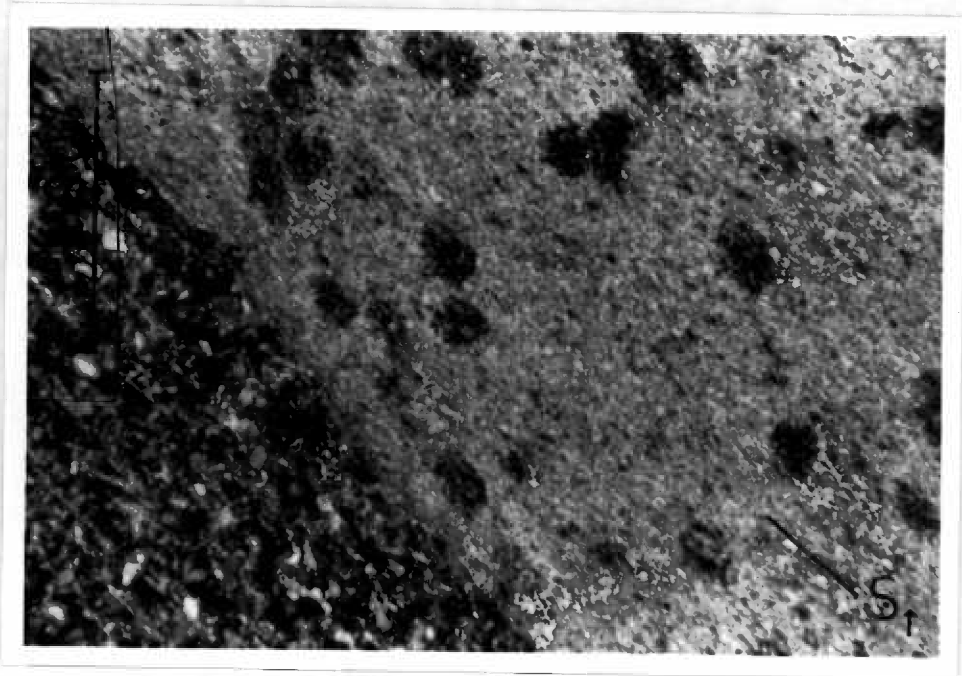

Fig. 9. Round chloritised cordierite porphyroblasts overprinting foliated S_1 micas in meta-sandy shale, Jackalass Slate (GR 047037).

Fig. 10. Strongly banded marble within the Jackalass Slate, Quidong marble Quarry (locality 13, Plate 2).

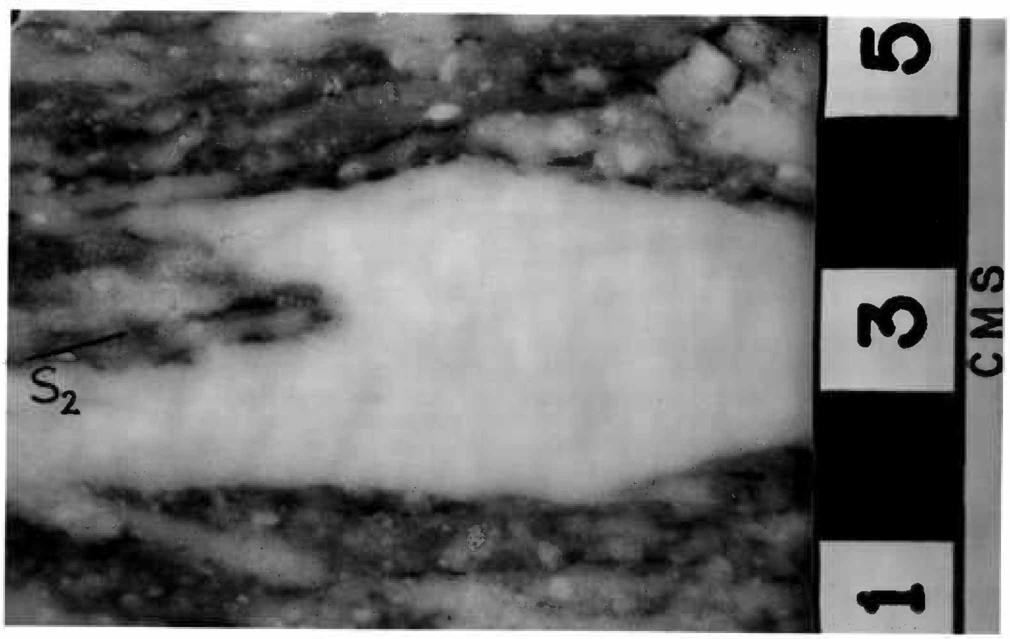

Fig. 11. Rootless isoclinal F_1 fold hinge in highly strained marble, Quidong marble Quarry (locality 13, Plate 2). F_1 fold axes parallel S_o/S_2 intersection and a prominent elongation lineation associated with S_2.

Fig. 12. Open F_2 folds in the Bumbolee Creek Formation north of the Gocup Granite (GR 043045).

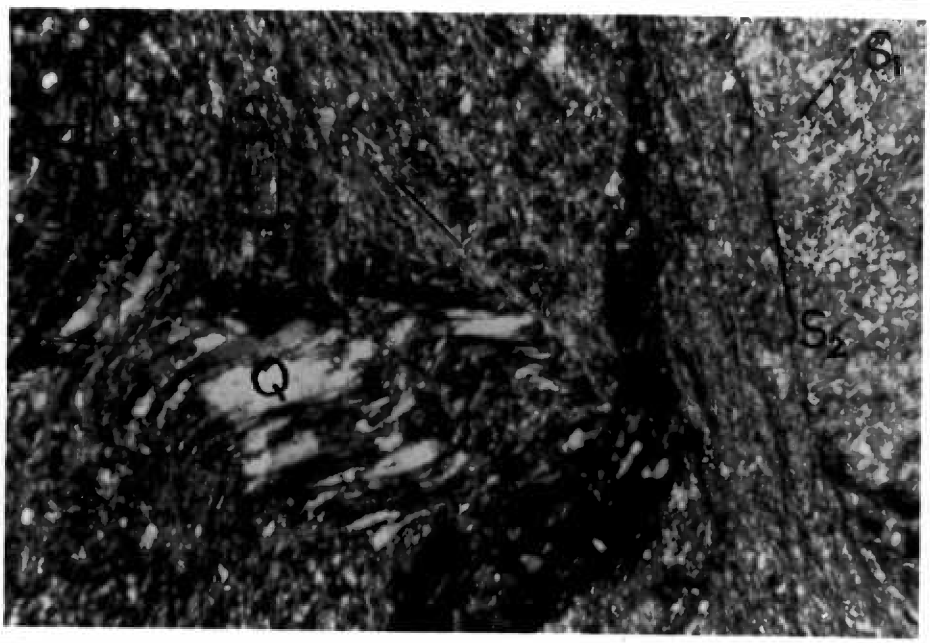

Fig. 13. A weakly developed S_2 crenulation cleavage, associated with minor quartz and chlorite remobilisation, is axial plane to open F_2 folds in the Gocup area. Foliated S_1 micas and quartz fibre vein (Q) are deformed with no new mineral growth, Bumbolee Creek Formation (GR 046044).

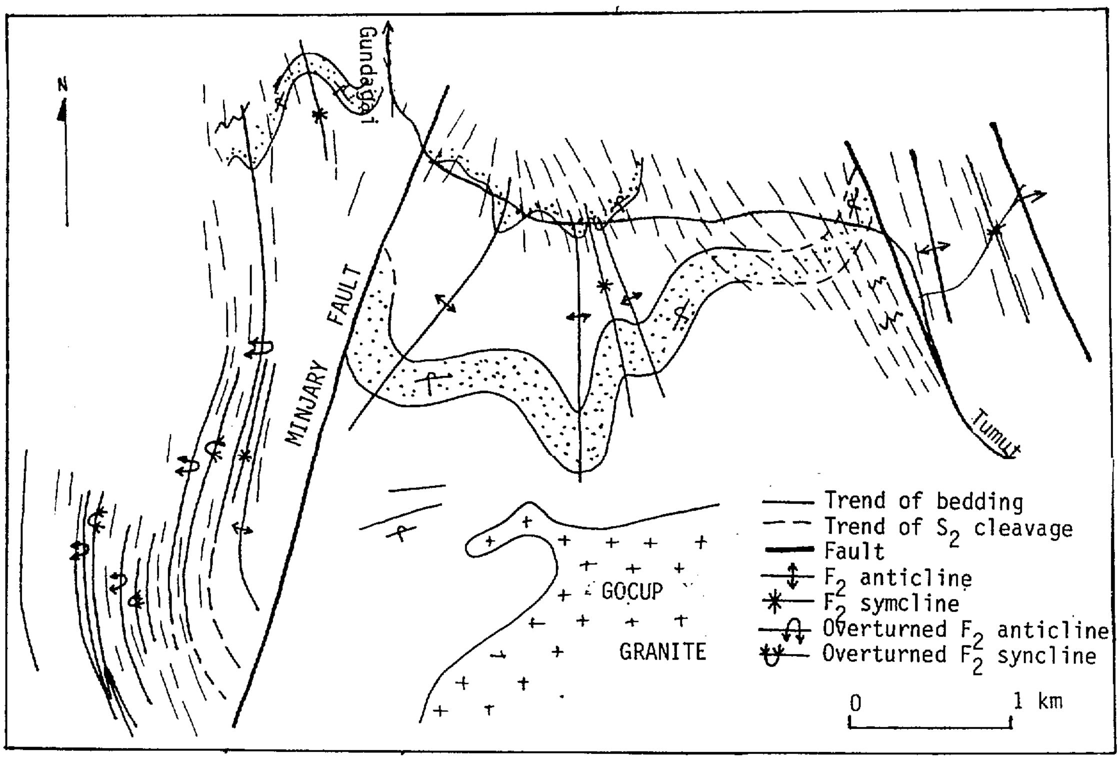

Fig. 14. Structural patterns around the northern end of the Gocup Granite.

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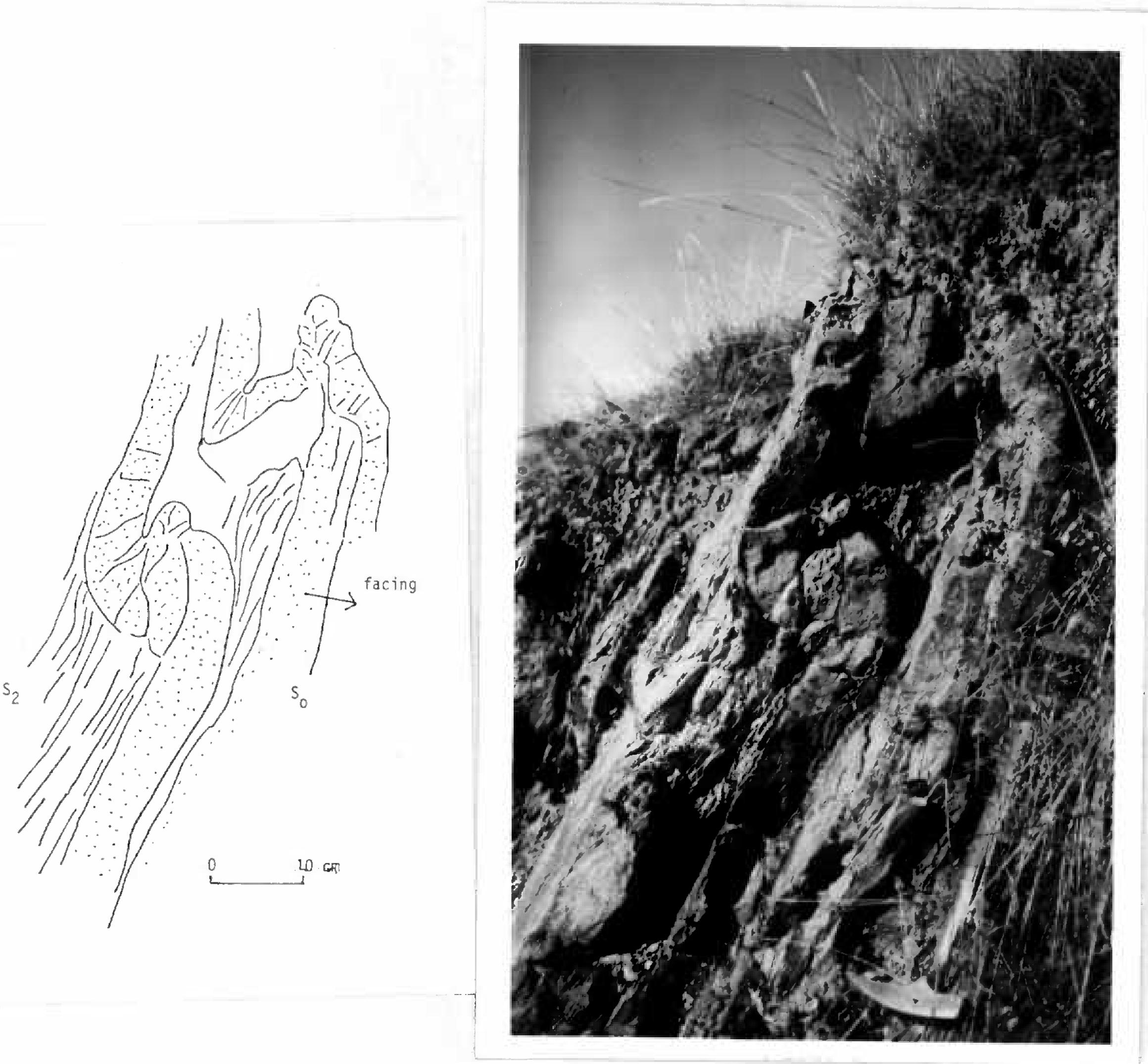

Fig. 15. Tight F_2 folds in the Bumbolee Creek Formation (GR 059040).

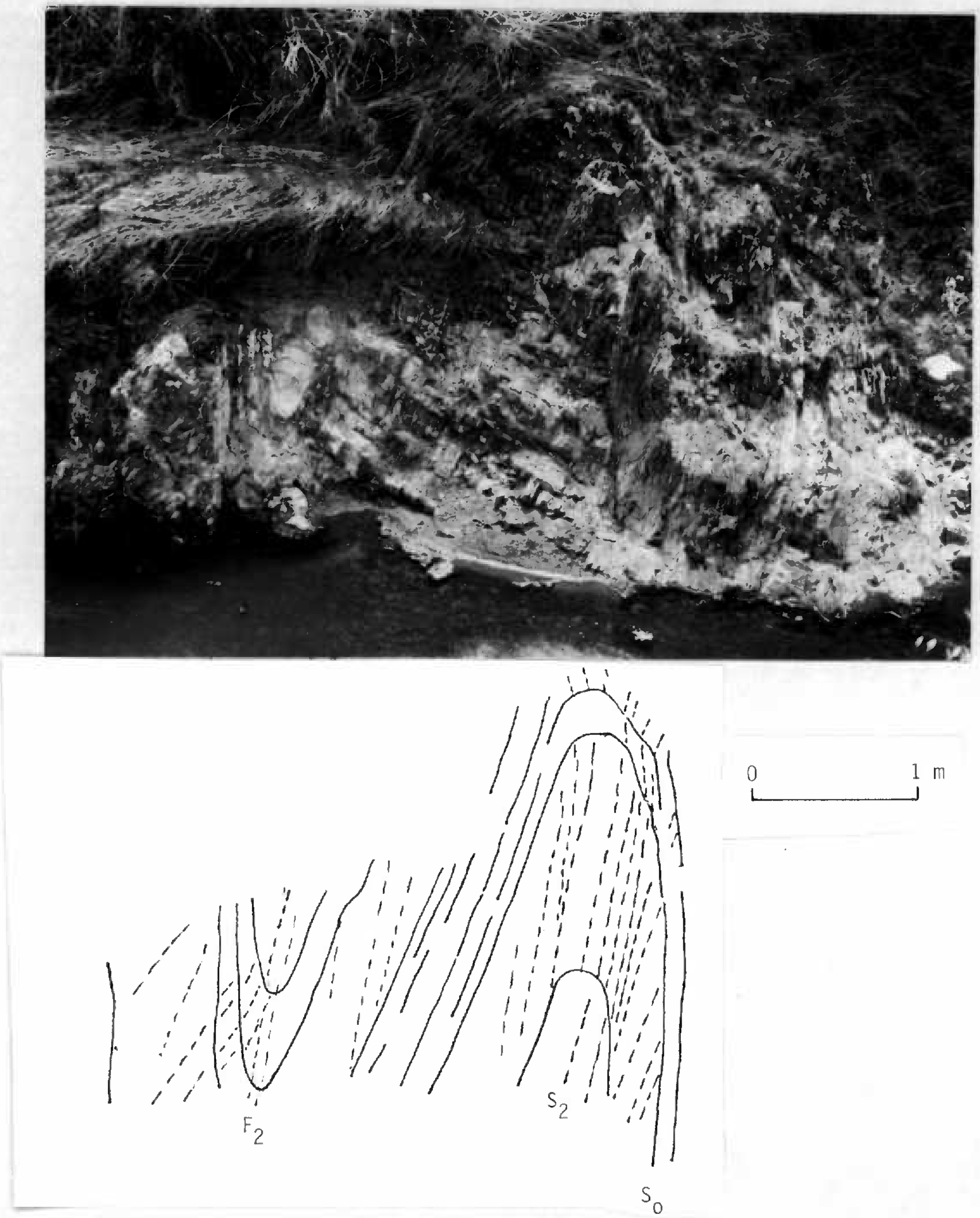

Fig. 16. Tight inclined asymmetric F_2 folds in arenite and slate of the Jackalass Slate, (locality 4, Plate 2; GR 987007).

cleavage is best developed on the downward-facing beds. Noticeably the minor folds are open (eg. locality 9, Plate 2), contrasting with the isoclinal F_1 closures observered elswhere. The minor folds on the lower limb may therefore have undergone minor unfolding during progressive nappe development.

In Domain V11, where bedding is upwards-facing, F_2 folds show considerable variation in plunge mainly to the SE. At GR 068047 (locality 10, Plate 2) this variation is demonstrably caused by an ENE-trending F_1 fold closure. The enveloping surface of beds in the domain therefore represent mainly the upper limbs of S-facing recumbent folds. The direction of F_1 facing is opposite that in Domains V1 and V indicating the presence of an accomodation structure, such as a tear fault, between Domains V1 and V11.

Apart from the downward-facing of beds and the local presence of a bedding-parallel S_1 cleavage in Domain V111 there is no evidence of F_1 folds except in a lens of marble presently being mined near Quidong homestead. Here rootless isoclinal F_1 fold hinges occur within a strongly banded marble (Fig. 10) which is truncated by a S_2 cleavage (Fig. 11; Locality 13, Plate 2). The F_1 closures parallel the S_0/S_2 intersection and a prominent elongation lineation associated with S_2.

Upright folding

The early recumbent structures are refolded by upright tight to isoclinal F_2 folds which have a penetrative N to NW - trending axial plane cleavage (S_2). The intensity of this deformation increases east and west of the Gocup Granite and is greatest in Domains II, III, VII and VIII where accompanying regional metamorphic grades reached upper greenschist facies. Elsewhere the metamorphic grade was lower greenschist facies.

Around the northern margin of the Gocup Granite (Domain V) F_2 folds are open and the S_2 cleavage is present as a closely spaced crenulation cleavage (Figs. 12 & 13). The latter dips away from the granite and fans around the granite contact (Fig. 14). This pattern reflects the post-granite age of the deformation. The northern end of the granite pluton formed a strain shadow during SW-NE compression. The post-intrusion age of the deformation is also evident by the presence of the S_2 cleavage in post-granite porphyritic felsic dykes.

East and west of the Gocup Granite folds become progressively tight to isoclinal with subvertical to steep W-dipping axial surfaces (Figs. 15 & 16). Approaching the Killimicat Fault (Domain V111) the S_2 cleavage shallows progressively to less than 60° and trends more northerly. This may be a result of deflection around the NW margin of the adjacent Killimicat Granite in a similar manner to that around the Gocup Granite. If this is the case then major movement on the Killimicat Fault was prior

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to or possibly syn-F_2 folding.

The amount of strain associated with S_2 increases away from the Gocup Granite. Conglomerate pebbles which are undeformed in Domain V, V1 and V11 become flattened and stretched within the S_2 surface forming a prominent elongation lineation which pitches consistently 70° NW in Domains 111, 1V and V111 (Fig. 17, 18a & b). In domain 11, adjacent to the Gilmore Fault, the lineation is subhorizontal and parallels F_2 isoclinal fold axes. In the same area the S_2 cleavage, now a schistosity formed by aligned muscovite and biotite, is subvertical and is rotated from a NNW trend into parallelism (trend 130°) with the Gilmore Fault. The increase in strain and rotation of structures adjacent to the Gilmore Fault is consistent with significant sinistral strike-slip movement of the fault during F_2 folding. A similar relationship between F_2 folding and the Killimicat Fault is probable as strain is higher throughout Domain V111 and F_2 axes parallel the elongation lineation.

The style of F_2 folds changes from cylindrical in Domains 1V, V, V1 and V11 to non-cylindrical in areas of higher strain adjacent to the bounding Gilmore and Killimicat Faults. In the latter areas variation in fold plunge is caused, at least in part, by heterogenities in the strain rather than F_1 folds as in the former areas.

Kinking

A widely to closely-spaced, steep N-dipping, kink cleavage is present throughout Domains 11 and 111. The kink bands rotate the penetrative S_2 cleavage with a consistent dextral sense of shear. The lack of a conjugate set indicates that the kinks were not a result of layer-parallel shortening but rather may have been the result of sinistral shear. In such a case the kinks would have developed as P' shear bands with P the most active shear (Harris & Cobbold, 1984) paralleling the S_2 foliation (Fig. 19).

No cross-cutting relationships were found between the kink bands and the S_3 cleavage. However, in view of the similar nature of movement indicated by the Kink bands and the S-C fabrics in the foliation in the adjacent Wondalga Granodiorite the kinks probably formed during the latter stages of the main sinistral strike-slip movement on the Gilmore Fault.

A conjugate set of kinks is widespread in the eastern part of the Tumut Block throughout Domain V111 (Fig. 20). The kinks reflect layer-parallel shortening with a shallow SE-plunging principal stress. Kinks with a dextral sense of shear, subparallel those in domains 11 and 111, and are less common than those with a sinistral sense of shear. Thus a similar relationship to the adjacent Killimicat Fault may be envoked where the kinks have formed in response to sinistral strike-slip movement on the fault.

S_3 Crenulation

A steep ENE-dipping crenulation cleavage is present in domain 11 within 2 km of the Gilmore Fault (Fig. 21). Adjacent to the fault, where development of the cleavage is more intense, F_2 folds are rotated into recumbent orientations by open F_3 folds with an axial plane S_3 crenulation cleavage (Fig. 22; locality 2, Plate 2). The spatial association of the cleavage and its parallelism with the Gilmore Fault suggests that the cleavage is probably a result of late movements (ie. Early Devonian or younger) on the fault. The S-vergences displayed by minor SSE-plunging F_3 folds (Fig. 23; locality 3, Plate 2) would be consistent with reverse movement on the Gilmore Fault whereby the Domain 1 (Wagga Metamorphic Belt) was displaced over Domain 11.

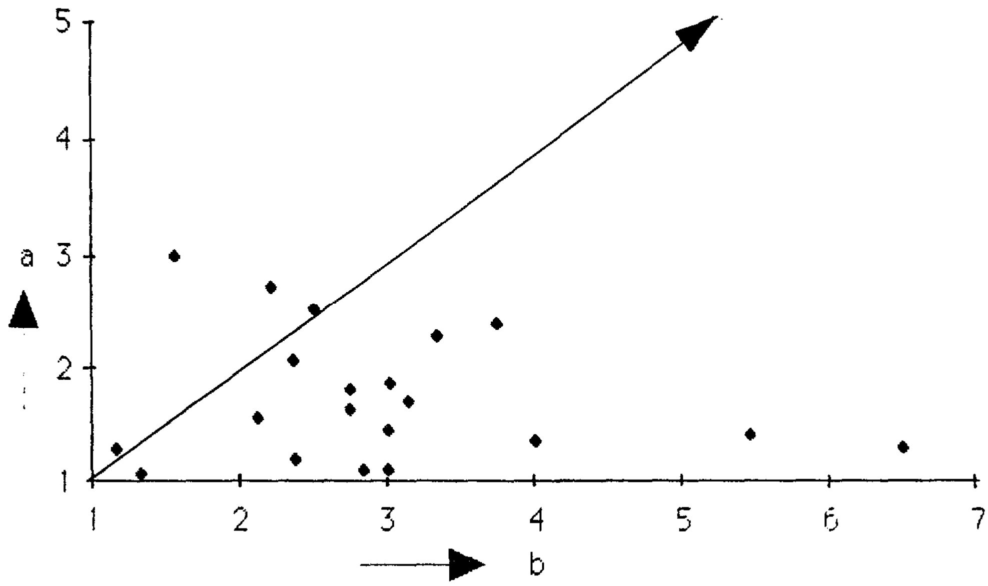
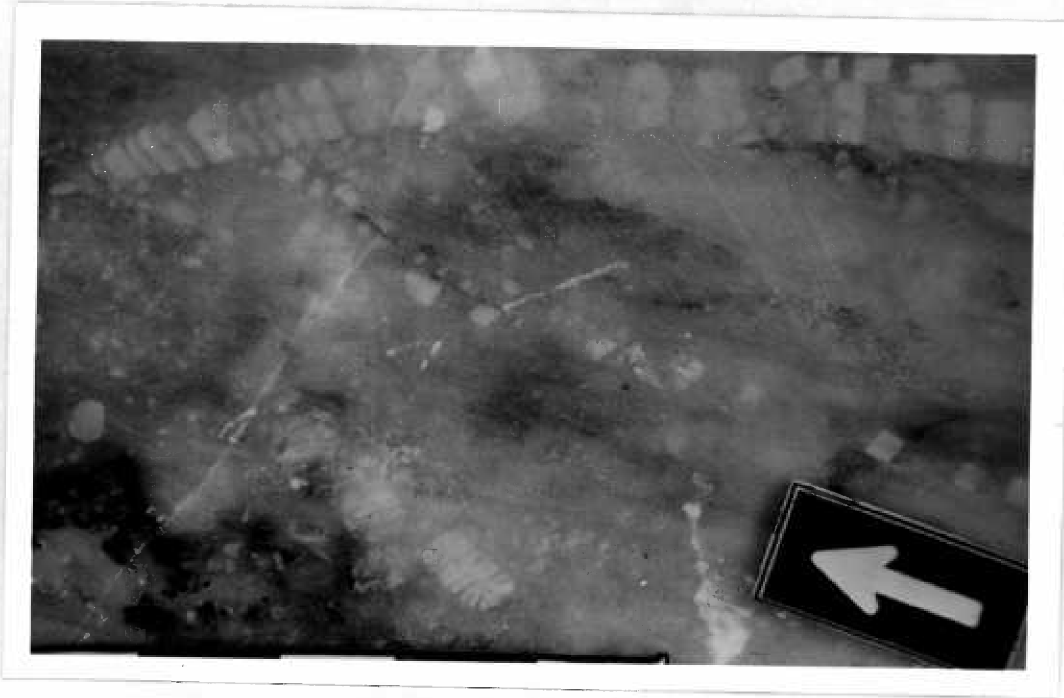
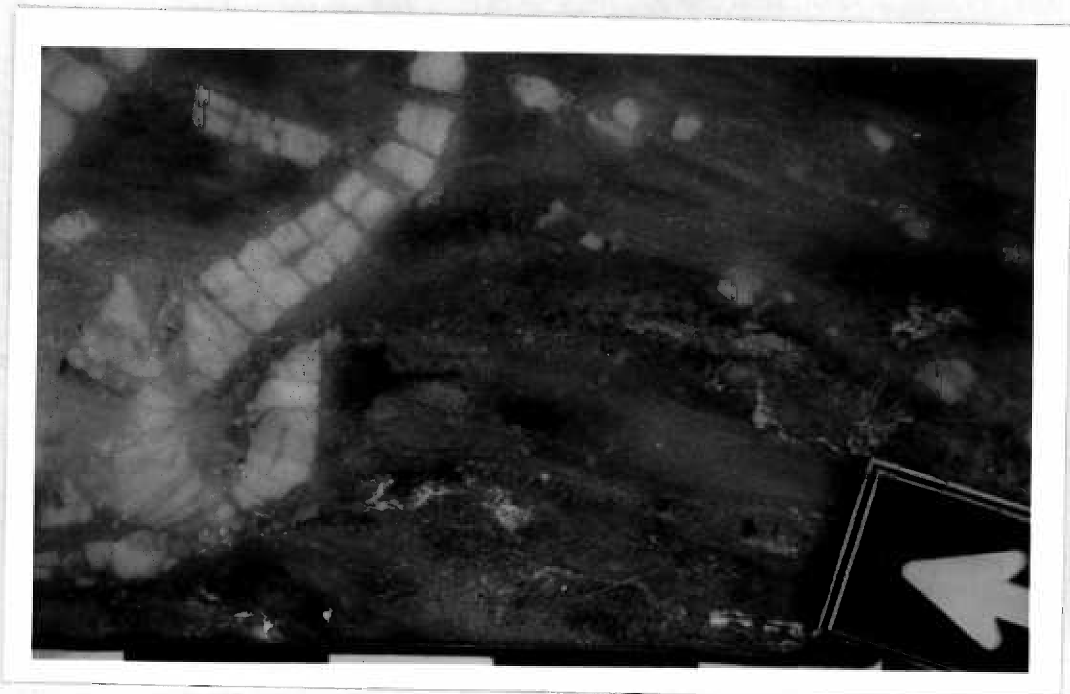


Fig. 17. Flynn diagram of quartzite pebbles in conglomerate, Jackalass Slate (GR 988017).



(a)



(b)

Fig. 18. Deformed crinoid stems in marble, Jackalass Slate, Quidong marble quarry (locality 13, Plate 2). Arrow indicates elongation lineation: note the heterogeneity of extension indicated by widely differing spaces between crinoid segments. In this area $S_o/S_1/S_2$ intersections are coincident: the lineation plunging about 70^{o} NW. Scale - arrowhead is 0.5 cm across.

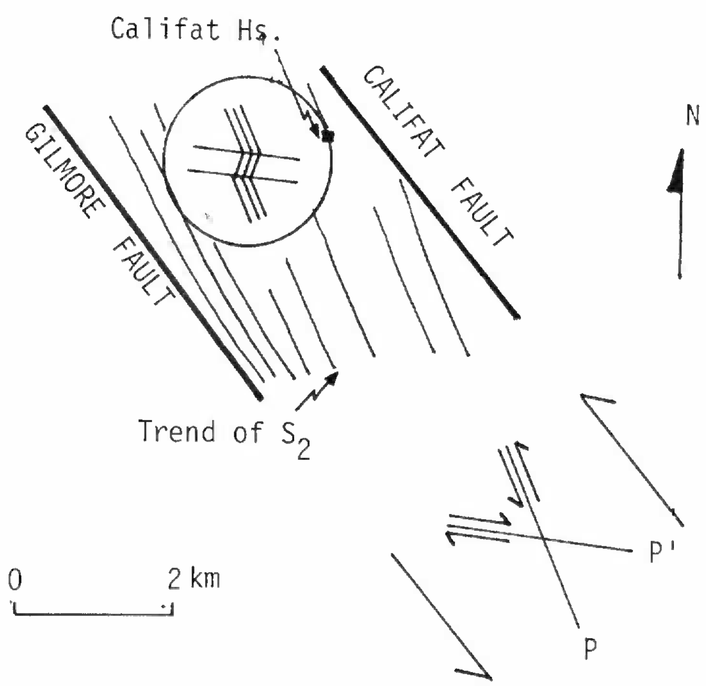


Fig. 19. The relationship of kinks in Domain II to sinistral shear along the Gilmore and Califat Faults.

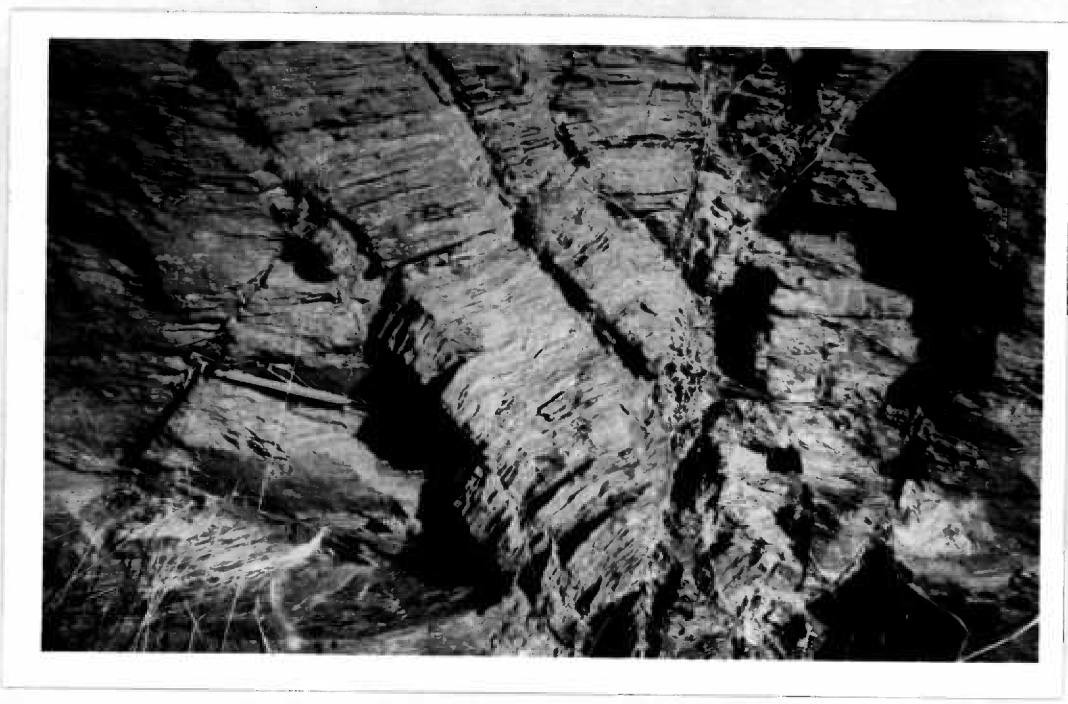


Fig. 20. Conjugate kinks in the Jackalass Slate (GR 079072).

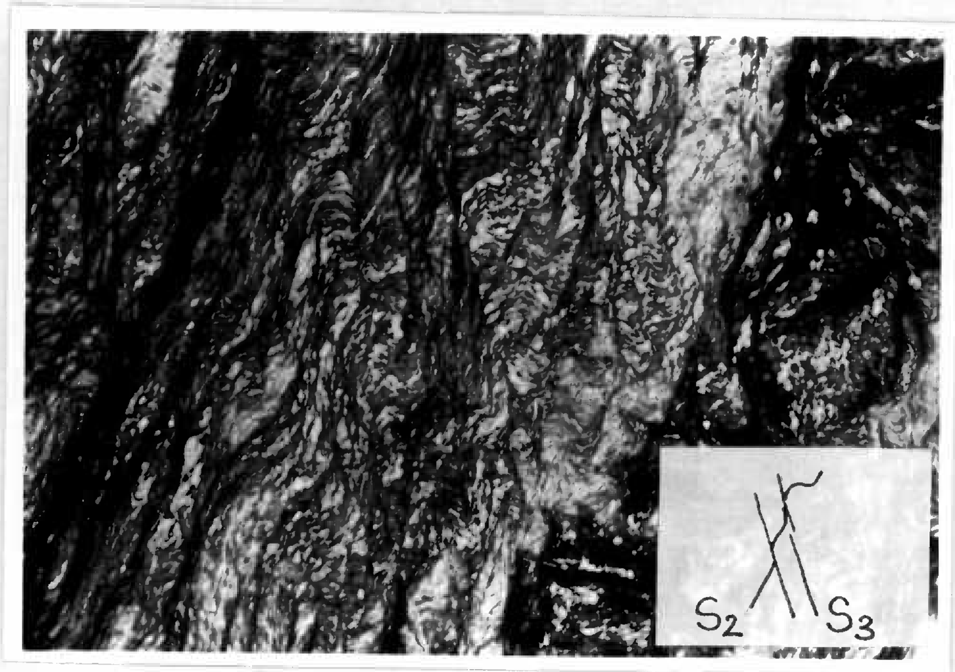


Fig. 21. Strongly differentiated S_2 cleavage (biotite, muscovite and quartz) crenulated by S_3, Jackalass Slate (GR 976005). At this locality the S_3 cleavage dips 80^{o} NE and may be related to late vertical movements on the Gilmore Fault.

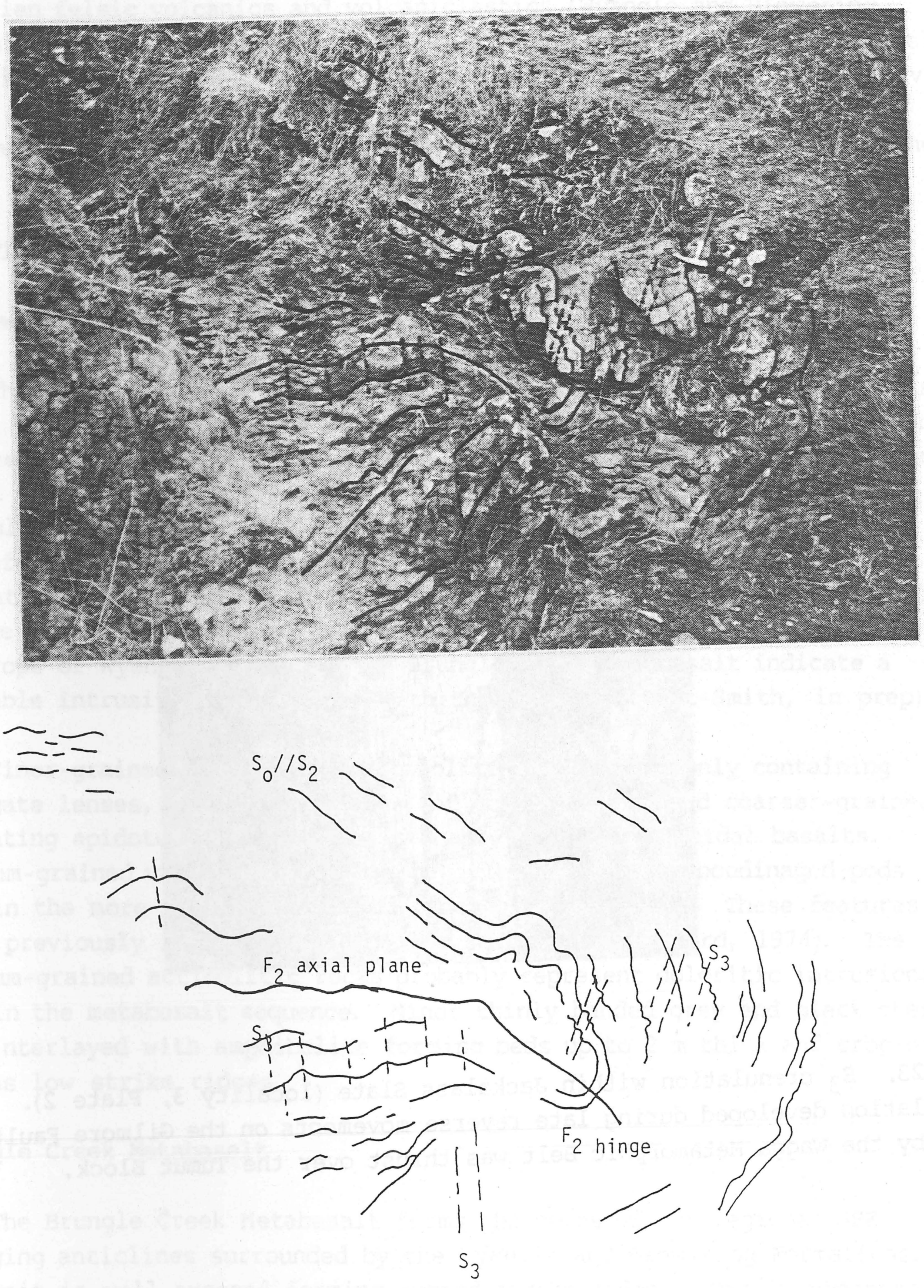


Fig. 22. Recumbent F_2 fold in Jackalass Slate adjacent to the Gilmore Fault (locality 2, Plate 2). A steeply NE-dipping S_3 crenulation cleavage present is axial plane to to open F_3 folds.

Fig. 23. S_3 crenulation within Jackalass Slate (locality 3, Plate 2). The crenulation developed during late reverse movements on the Gilmore Fault whereby the Wagga Metamorphic Belt was thrust over the Tumut Block.

JINDALEE BLOCK

The Jindalee Block consists of Ordovician basement inliers of Bullawyarra Schist surrounded by a 2000 m thick sequence of Lower Silurian mafic volcanics (Brungle Creek Metabasalt) overlain by Lower to Upper Silurian felsic volcanics and volcaniclastics (Wyangle and Blowering Formations). The Silurian rocks have only undergone one major deformation typified by tight NNW-trending folds and a poorly developed axial cleavage.

Outliers of subhorizontal Devonian Gatelee Ignimbrite (Ashley & others, 1972) unconformably overlie older units in the Brungle Creek area.

STRATIGRAPHY

Bullawyarra Schist

The Bullawyarra Schist, consisting of mainly foliated and minor massive fine- to medium-grained actinolite schist is well exposed as boulders and pavements on low hills south of Gatelee homestead. It also crops out in a small fault-bounded lens, about 1 km long and 120 m wide, within the Wyangle Formation in Oaky Creek north of Big Hill. The unit is unconformably overlain by, and in places faulted against, the Wyangle Formation. Along the western margin of the inlier the contact with dacite of the Blowering Formation is not exposed but hornfelsing of nearby outcrops of Wyangle Formation and Brungle Creek Metabasalt indicate a probable intrusive relationship with the schist (Stuart-Smith, in prep).

Finer-grained varieties of actinolite schist, commonly containing elongate lenses, up to 1 cm across, of quartz mozaic and coarser-grained radiating epidote aggregates are probably meta-amygdaloidal basalts. Medium-grained varieties are more massive and occur as boudinaged pods within the more strongly foliated finer-grained schist. These features were previously interpreted as pillow structures (Kennard, 1974). The medium-grained actinolitic rocks probably represent doleritic intrusions within the metabasalt sequence. Minor thinly banded grey and black chert are interlayed with amphibolite forming beds up to 2 m thick and croping out as low strike ridges.

Brungle Creek Metabasalt

The Brungle Creek Metabasalt forms the cores of two regional SSE-plunging anticlines surrounded by the Wyangle and Blowering Formations. The unit is well exposed forming rugged strike ridges. Deeply weathered mafic volcanics, probably of the Brungle Creek Metabasalt, are exposed in road cuttings near Bonnie Doon homestead on the Tumut-Brungle road and are interpreted to form the core of a third anticline extending NNW of the Killimicat Granite.

The metabasalt structurally overlies the Bullawyarra Schist, however, contacts with the schist are not exposed on the traverse. Elsewhere in the region the contact, where exposed, forms a cataclastic zone which represents a major metamorphic and structural discontinuity, interpreted as a detachment fault (Stuart-Smith, in prep).

The Wyangle and Blowering Formations overlie the metabasalt with an unconformable onlapping relationship (GR 153138). There is no evidence of tectonism near the contact with these units, nor of older stuctures in the metabasalt. The only penetrative structural surface in the metabasalt is coincident with that in the younger units: metamorphic grades are comparable. In places, such as near Bald Hill, an intrusive relationship with the Blowering Formation is indicated by contact metamorphism of the metabasalt to actinolite-epidote hornfels.

On the traverse section the unit consists mostly of interlayered massive and fractured metabasalt and minor metadolerite, meta-devitrified vitric tuff and thinly bedded grey and black chert beds up to 1.5 m thick. Possible pillow structures in metabasalt occur at GR 158106 and in Brungle Creek near Hillside homestead (Crook & Powell, 1976). Mafic and felsic tuffs found in the formation elsewhere (Stuart-Smith, in prep) are not present. The thickness of the unit in the area is probably less than 500 m.

Wyangle Formation

Quartz-poor to quartz-intermediate proximal flysch deposits of the Wyangle Formation unconformably overlie or are faulted against the Bullawyarra Schist and the Brungle Creek Metabasalt. The formation is conformably overlain by, intertongues with, or is intruded by the Blowering Formation. The unit crops out mostly to the north and east of the Bullawyarra Schist inlier where it is about 500 m thick. The unit thins westwards to less than 200 m near Hillside homestead and finally pinches out near Bald Hill. Magnetite-biotite-cordierite-quartz hornfels, cropping out over 50 m near Bonnie Doon homestead, here interpreted as Wyangle Formation, separates weathered mafic volcanics (correlated with the Brungle Creek Metabasalt) and the Blowering Formation and is intruded by the Killimicat Granite.

The contact with the underlying rocks, where not faulted (eg. 4 km south of Kangaroo Mountain), reflects an unconformable onlapping relationship. At these localities the overlying Blowering Formation oversteps the unit to rest directly on the older rocks. Four kilometres south of Kangaroo Mountain (Plate 1; GR 154138) conglomerate beds within the Wyangle Formation thicken from less than 2 m near the contact to over 5 m 500 m southwards away from the contact.

Fig. 24. Graded fine-grained quartz-poor arenite, Wyangle formation (GR 159122).

Fig. 25. Graded volcanilithic pebble conglomerate, Wyangle Formation (GR 181109).

Where the Wyangle Formation thins or pinches out north of Bald Hill it intertongues with felsic tuffs of the overlying Blowering Formation. Near Gatelee homestead the contact of the Wyangle and Blowering Formations is either faulted or intrusive. A small "dacitic" sill, intrudes a shale bed 700 m east of Gatelee homestead (Plate 1; GR 185106) where intrusive contacts are exposed; contact effects are limited to local reduction (green colouration rather than the usual red). Farther to the south diopside-bearing hornfels is described in the Wyangle Formation adjacent to the Blowering Formation (Stuart-Smith, in prep).

The formation comprises a sequence of interbedded quartz-poor and quartz-intermediate arenite (Fig. 24), volcanilithic pebble and boulder conglomerate (Fig. 25), diamictite, shale, mudstone, tuff and minor andesite flows (GR 172115). Allochthonous limestone blocks contain conodonts of probable late Llandoverian to early Wenlockian age (Lightner, 1977). Although poorly exposed relative to the coarser clastics, weakly cleaved shale and mudstone probably form over 50% of the unit.

Blowering Formation

Dacitic volcanics and intrusives of the Blowering Formation form an extensive sheet, less than 1000 m thick, conformably overlying the Wyangle Formation and unconformably onlapping onto the Brungle Creek Metabasalt. The unit crops out as boulders on lower undulating hills south of Brungle Creek. Dacitic ignimbrite, containing bipyramidal quartz, plagioclase, and minor biotite, apatite and garnet crystals up to 1 cm across, is the predominant rock type. Volcaniclastics and pelitic metasediments found within the formation in the adjacent Mooney Mooney Fault Block are not present in the area.

Where the underlying Wyangle Formation pinches out north of Bald Hill it intertongues with dacite of the Blowering Formation. Farther to the south massive dacite intrudes and contact metamorphoses adjacent Brungle Creek Metabasalt and Bullawyarra Schist. One kilometre southeast of Big Hill dacite clasts predominate in debris-flow diamictite within the Wyangle Formation.

Killimicat Granite

The Killimicat Granite, an elliptical-shaped pluton about 2 km across, intrudes and contact metamorphoses the Brungle Creek Metabasalt and the Wyangle and Blowering Formations south of Brungle. The western margin of the granite is obscured by talus and alluvium. However, south of the traverse, granitic cataclasite occurs along this margin where it is thrown against the Bumbolee Creek Formation by the Killimicat Fault.

The granite is similar petrologically and chemically to the Bogong and Gocup Granites which have major element characteristics of A-type granites but not the trace element characteristics (B.W. Chappell personal communication in Basden, 1982). An Early Devonian age for the granite is inferred for the Killimicat Granite as indicated by K-Ar dates of 410±16 Ma and 409±2 Ma on the Bogong and Gocup Granites respectively (J.R. Richards, personal communication in, Basden, 1982).

Gatelee Ignimbrite

The Gatelee Ignimbrite (Ashley & others, 1972) forms remnants of a subhorizontal sheet of ignimbrite which unconformably rests on older rocks in the Jindalee Block. The unit, up to 100 m thick, comprises mainly welded tuffs with minor basal polymictic conglomerate in places (Kennard, 1974). Ashley and others (1972) suggested that the ignimbrite may have been contemporaneous with, and related to, the nearby Killimicat Granite, however, trace element data (Kennard, 1974) does not support a common genesis (Crook & Powell, 1976).

STRUCTURE AND METAMORPHISM

Two distinct deformations have affected rocks in the Jindalee Block. The first, at upper greenschist facies, involved only the Bullawyarra Schist and may be Late Ordovician/Early Silurian in age. The second, involved retrograde metamorphism of the Bullawyarra Schist and upright folding of both the schist and the Silurian trough sequence. The Early Devonian Gatelee Ignimbrite is undeformed and clearly postdates all major structures in the block including NNW- and NNE-trending faults.

Upper greenschist facies metamorphism

The oldest deformation and metamorphic event is only recognised in the Bullawyarra Schist. Rocks are characterised by a penetrative metamorphic foliation (S_1) which is the dominant planar structural element present. Epidote and quartz nodules (amygdales), where present, are commonly flattened and stretched in the foliation plane forming a prominent mineral elongation. The foliation, marked by mostly unstrained, aligned, fibrous to prismatic actinolite, parallels compositional banding (epidote-quartz rich bands) which are mostly <2 mm thick. Boudins of coarser-grained actinolitic rock (metadolerite), where present, are extended in the S_1 foliation plane.

Folds associated with the S_1 surface have not been identified in this area, however, isoclinal fold closures do occur farther to the north (Stuart-Smith, 1988). In this area recumbent folds (F_2), associated with high strain zones (LS-tectonite fabrics) were probably contiguous with the formation of the S_1 fabric as metamorphic conditions remained at upper greenschist facies and only rocks in the structurally higher parts of the basement were involved (ie. northern part of the northern inlier). There is no evidence of recumbent fold closures or high strain zones within the

Fig. 26. Open F_3 fold in Bullawyarra Schist (GR 197084).

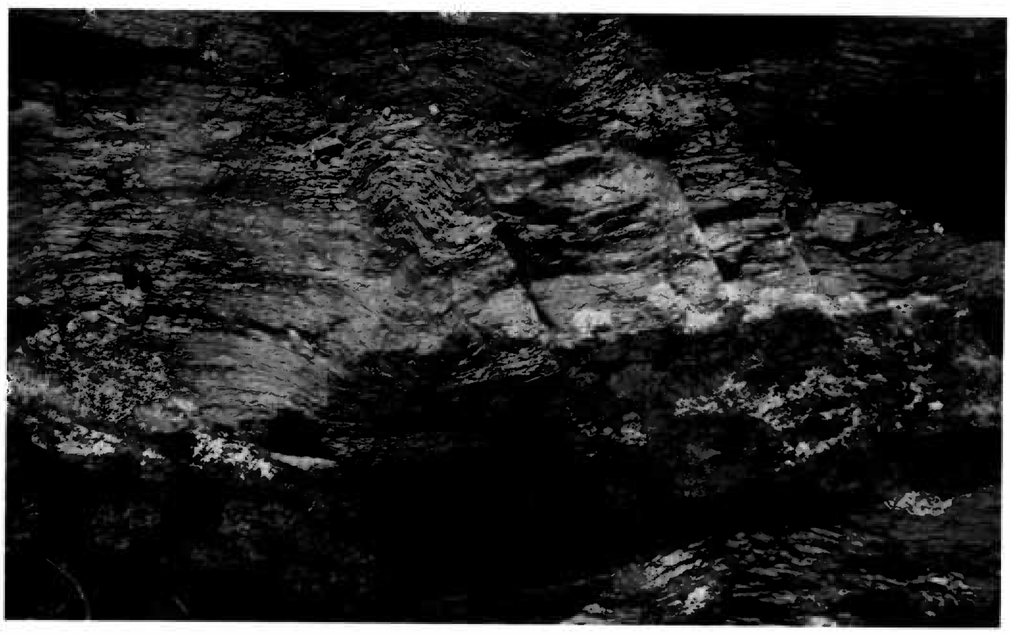


Fig. 27. Conjugate kinks in the Bullawyarra Schist (GR 191062).

Fig. 28. Meta-shale with thin graded quartz intermediate arenite bed showing closely spaced subvertical S_1 fracture cleavage, Wyangle Formation (GR 187105).

southern inlier on the traverse section possibly reflecting a stucturally lower position. However, the S_1 foliation is broadly conformable with the overlying cover sediments indicating a subhorizontal disposition prior to Silurian sedimentation.

Detachment faulting

The Bullawyarra Schist and the Silurian cover sequence are separated by a sharp discontinuity marking an abrupt change in rock type, metamorphic grade and deformational style. North of the traverse this discontinuity probably represents a detachment fault along which major extension took place during Lower Silurian formation of the Tumut Trough (Stuart-Smith, in prep). The fault post-dates regional upper greenschist metamorphism and pre-dates folding of the Silurian units. In this area, rocks of the Wyangle Formation (which are stucturally higher in the sequence to the north) either unconformably overlie or are faulted against the Bullawyarra Schist. However, a detachment fault may well exist in the area in the subsurface between interpreted lateral extension of the schist and the overlying Brungle Creek Metabasalt (see section DF on Plate 1).

Upright folding and lower greenschist facies metamorphism

The Silurian cover sequence underwent one major deformation which produced the dominant regional NW-trending F_1 folds and associated axial cleavage (S_1). In the local area lower greenschist facies metamorphism accompanied the deformation. The orientation, style and timing of this deformation indicates that it was contiguous with retrograde metamorphism and F_3 folds in the Bullawyarra Schist.

The S_1 foliation in the schist and the basement/cover contact are open to tightly folded about subhorizontal to gently SSE-plunging axes (F_3) (Fig. 26). A subvertical axial plane surface (S_3) associated with the folds is present as either a spaced fracture, kink, or crenulation cleavage and trends 152°. Both S_1 and S_2 actinolite crystals are strained and fractured with chlorite, epidote and minor carbonate filling fractures and partly replacing adjacent folia.

Locally F_3 folds in the Bullawyarra Schist are deformed by conjugate kink sets, reflecting a principal compression directions of either $\sim 140^{\circ}$ or 050° (Fig. 27). Kinks with the former orientation, which parallels the compression direction during the main period of upright folding, most likely represent late deformation during that event. However, the relationship of kinks with the latter orientation to other structures is unknown. Both kink sets are not developed in the cover, possibly owing to the lack of a penetrative fabric.

Mafic volcanics of the Brungle Creek Metabasalt are extensively altered to chlorite and carbonate with no primary mafic minerals, except for rare augite and biotite, preserved. Plagioclase phenocrysts, where present are mostly replaced by carbonate. Carbonate$\pm$ chlorite veins are ubiquitous and either pre-date (boudinaged in S_1), are synchronous with, or postdate an S_1 foliation marked by anastomosing zones of weakly to strongly foliated chlorite, carbonate and minor sericite.

In contrast to the Brungle Creek Metabasalt, rocks in the Wyangle Formation are less altered and have a variably developed S_1 foliation. Clinopyroxene and hornblende, showing only minor marginal chloritic alteration, are common both as detrital minerals and as phenocrysts in mafic volcanic clasts. Chlorite, epidote, carbonate and albite are common metamorphic minerals in both volcanics and clastic rocks of the Wyangle Formation. An S_1 foliation is only developed in pelitic units where it is present as a closely spaced fracture cleavage (2 - 10 mm) (Fig. 28).

The S_1 foliation, heterogeneously developed throughout the cover sequence, is subvertical and trends NW. Within the Brungle Creek Metabasalt, bedding planes, rarely observed, are near vertical and strike mostly parallel to S_1. Facing is indeterminate in the metabasalt but readily distinguished in the Wyangle Formation by common grading and scours in arenite beds. The S_1 foliation is axial plane to the regional anticlines and synclines and upright, open F_1 folds plunging shallowly to the SE. Minor overturned limbs (locality 19, Plate 2) occur adjacent to the bounding fault with the Mooney Mooney Fault Block which is marked by siliceous cataclasite development up to 10 m wide.

MOONEY MOONEY FAULT BLOCK

The Mooney Mooney Fault Block forms a highly faulted NNW-trending zone comprising dismembered Silurian sequences of the Blowering Formation, Honeysuckle Metabasic Igneous Complex the Coolac Serpentinite and an unnamed leucogranite. The zone represents a terrane boundary separating the Tumut Trough from the Goobarragandra Block to the east.

STRATIGRAPHY

Blowering Formation

Faulted slices of Blowering Formation form the western margin of the Mooney Mooney Block and include lenses of tectonically emplaced Coolac Serpentinite and medium-grained muscovite leucogranite. The formation is conformably overlain by metabasalt of the Honeysuckle Metabasic Igneous Complex in the north and is fault-bounded against the Wyangle Formation to the west and the Coolac Serpentinite to the east. Along these faulted contacts rocks are brecciated, fractured and silicified within a 20 m wide zone and chlorite-carbonate-epidote veins are common.

Massive dacite (differentiated as Sbd on Plates 1 and 2), containing minor thinly to thickly bedded quartz-intermediate arenite, slate and intraformational breccia, crops out extensively in the north. It intertongues laterally to the south with flyschoid sediments (Sbl) comprising dark grey silty slate, graded fine to coarse-grained quartz-intermediate arenite and reworked dacitic volcaniclastics. The latter rock type forming graded beds up to 2 m thick with basal scours. The maximum thickness of the formation in the Block is about 700 m, but is probably considerably less owing repetition by faults which are poorly exposed in the area.

Honeysuckle Metabasic Igneous Complex

Poorly exposed metabasalt and metasediments of the Honeysuckle Metabasic Igneous Complex (Basden, 1982 modified from Ashley & others, 1972) crop out at the foot of the Honeysuckle Range about 3 km north of Big Hill. The unit is described in detail by Ashley (1973) and Ashley and others (1979, 1983). In the traverse the unit conformably overlies the Blowering Formation and is faulted against the Coolac Serpentinite. Within 20 m of the latter contact, the metabasalt is sheared, fractured and extensively silicified and epidotised (eg. GR 179136, 180130). Shears and fractures in this zone parallel those in the adjacent serpentinite; dipping steeply to the west. In places (GR 180130) massive quartz veins occupy the fault contact.

There is no evidence of a faulted contact between the Honeysuckle Metabasic Igneous Complex and the Blowering Formation in the traverse as portrayed on maps of the area (Basden, 1986). The conformable contact between the units is exposed at GR 171135 where the base of the complex consists of a breccia, up to 2 m thick, comprising clasts of dacite and metabasalt in a green chloritic shaley matrix (Fig. 29). Stratigraphic facing cannot be determined at this locality, however, the contact dips to the east, conformable with upwards graded silty laminae in slate horizons within both formations in the vicinity. The Honeysuckle Metabasic Igneous Complex therefore represents the youngest Silurian unit in the Mooney Mooney Fault Block rather than the oldest (Basden, 1986).

In the area the complex is about 1000 m thick and comprises mainly metabasalt, with common pillow structures (Fig. 30), and minor interbeds of chloritic green silty slate, siliceous grey tuffaceous metasiltstone, meta-pitchstone and rare graded coarse-grained quartz-intermediate arenite (GR 154206).

Coolac Serpentinite

The Coolac Serpentinite forms the eastern margin of the Mooney Mooney Fault Block, cropping out as the rugged Honeysuckle Range which rises up to 300 m above the Brungle Creek valley to the west. The serpentinite also occurs as two lenses, up to 2 km long and 200 m wide, within the Blowering Formation along the western margin of the Block.

The main body of serpentinite, up to 3.5 km wide, is fault-bounded between the Blowering Formation and Honeysuckle Metabasic Igneous Complex to the west and the Young Granodiorite to the east. The western margin of the body is strongly foliated and serpentinised up to 500 m from the contact with the Silurian units where it is also locally silicified and brecciated within 20 m of the contact. Elsewhere the main mass of the Coolac Serpentinite consists of massive harzburgite with minor serpentinised zones and pods of meta-dolerite and meta-gabbro.

A narrow (<50 m) serpentinised zone, typically containing blocks of massive harzburgite (GR 222114, 218139) and pods, up to 5 m long and 1 m wide, of silicified granite cataclasite (GR 222114, 221122, 198167) occurs along the eastern margin where it is in contact with granitic mylonite of the Young Granodiorite. This contact is poorly exposed on the traverse and is mostly covered by a veneer of Tertiary sediments, basalt and dolerite.

Unnamed granite

Two pods, up to 600 m long, of sheared coarse-grained leucogranite occur along the faulted contact with the Jindalee Block about 1 km north of Big Hill. The age of the leucogranite bodies is unknown. They are inferred to be Early Devonian in view of their felsic nature and lack of a metamorphic fabric.

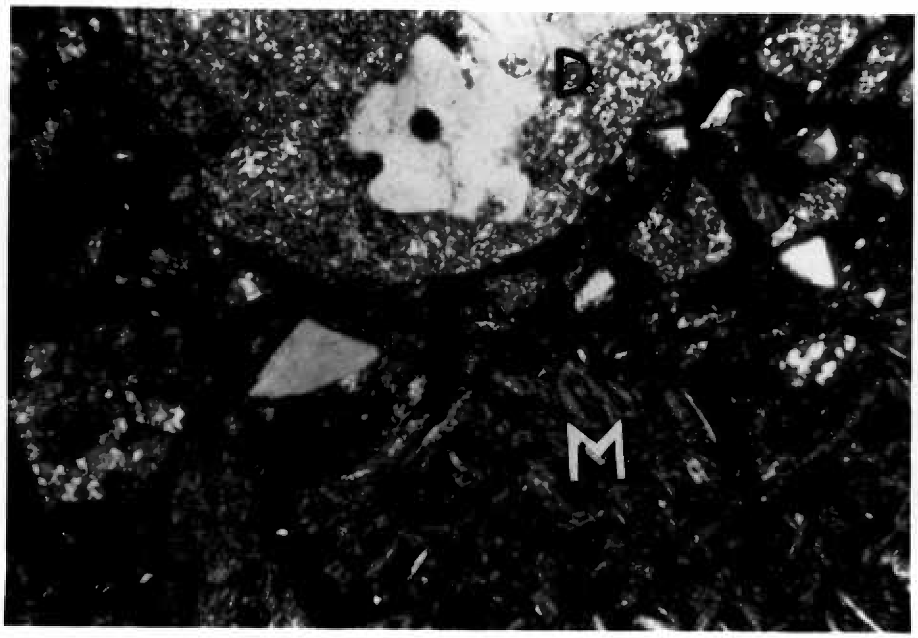


Fig. 29. Photomicrograph of basal breccia consisting of undeformed clasts of dacite (D) and metabasalt (M), Honeysuckle Metabasic Igneous Complex (GR 171135)

Fig. 30. Massive metabasalt with pillow structures, Honeysuckle Metabasic Igneous Complex (GR 171135).

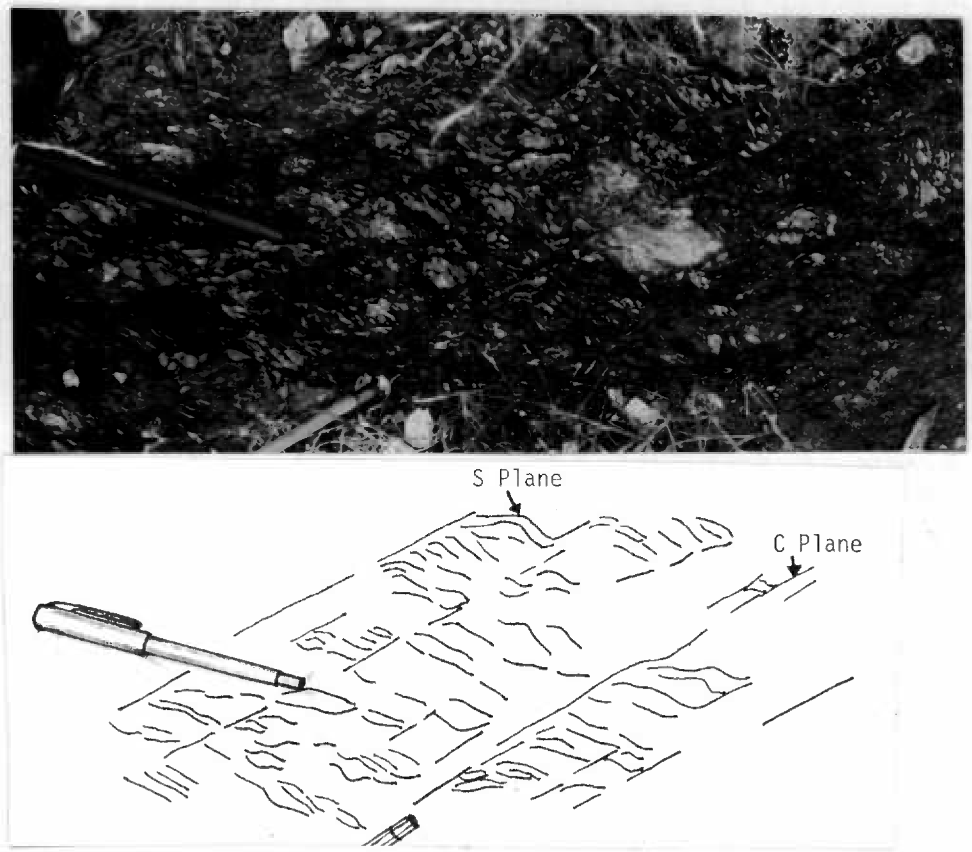


Fig. 31. S-C relationships in the Coolac Serpentinite (locality 21, Plate 2)

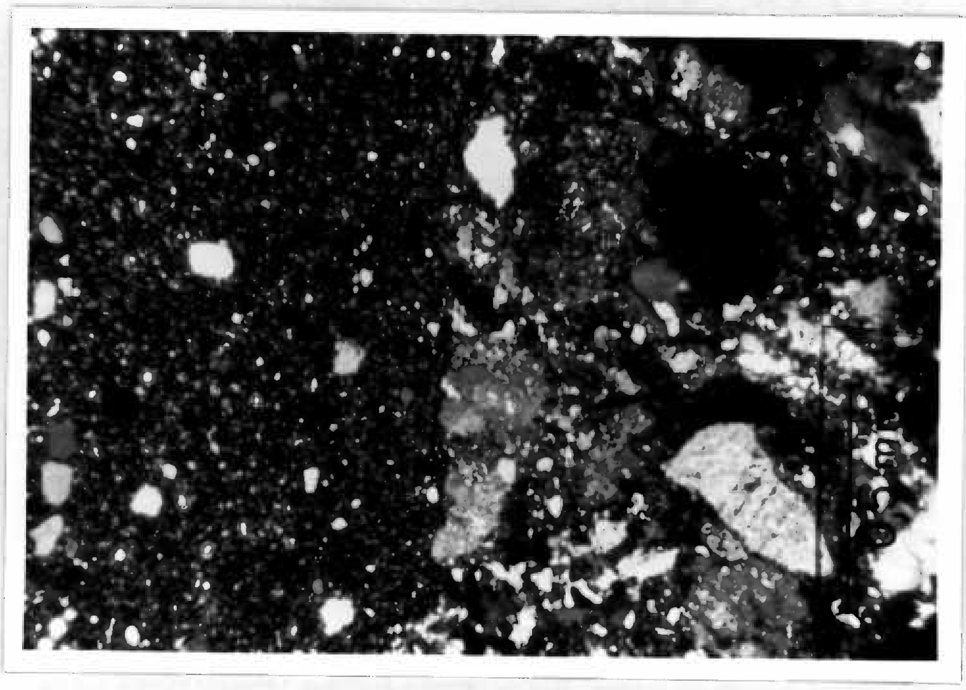


Fig. 32. Photomicrograph of typical cataclasite, consisting of deformed quartz, minor plagioclase and chlorite, developed in the Young Granodiorite along WNW-trending contacts with the Coolac Serpentinite (GR 195018).

STRUCTURE AND METAMORPHISM

The Mooney Mooney Fault Block represents a major imbricate strike-slip fault zone. Coherent fault-bounded lenses of the Blowering Formation and Honeysuckle Metabasic Igneous Complex show a similar structural and metamorphic history to Silurian units in the adjacent Jindalee Block. The Coolac Serpentinite, however, exhibits structures consistent with several periods of fault emplacement including a significant sinistral strike-slip movement.

Rocks are metamorphosed to lower greenschist facies. Pelitic rocks comprise weakly foliated sericite and chlorite, and detrital biotite in arenite is altered to chlorite and epidote. Mafic rocks in the Honeysuckle Metabasic Igneous Complex are mostly altered to carbonate, chlorite, epidote and sphene with minor albitised plagioclase phenocrysts and microlites, and rare primary augite crystals present.

Within 200 m of the faulted contact with the Coolac Serpentinite rocks of both the Blowering Formation and the Honeysuckle Metabasic Igneous Complex are fractured, strained with common quartz-albite, prehnite, and epidote veining. Within this zone metamorphic biotite is present and actinolite replaces primary mafic minerals in metabasalt.

Within the Coolac Serpentinite mafic rocks contain common primary augite and metamorphic tremolite, chlorite, epidote and talc. Ultramafic rocks comprise mostly antigorite with minor tremolite, carbonate and crysotile. In less deformed rocks remnant olivine and bastite are also present.

Common grading and scours in arenites and volcaniclastics of the Blowering Formation and Honeysuckle Metabasic Igneous Complex indicate that both units are upright and dip mainly to the east. A near-vertical, N-trending, slaty cleavage (S_1), present only in pelitic rocks, is axial plane to minor open folds with Z-vergence which plunge gently to the south (eg. Locality 20, Plate 2).

The Coolac Serpentinite has a massive core bordered by strongly foliated margins. Foliated zones along the western margin and the eastern margin, where the latter trends northerly, are characterised by a ubiquitous foliation which dips steeply mainly to the WSW, slightly oblique to the sepentinite margins. This foliation is cut by spaced (<10 cm) subvertical NW-trending shear planes. S-C relationships (Fig. 31; locality 21, plate 2) between these two surfaces are consistent with sinistral strike-slip shear movement along the western and eastern margins.

Where the contact between the serpentinite and the Young Granodiorite trends ESE both units are less deformed than elsewhere. Massive harzburgite occurs at the contact commonly with a narrow marginal serpentinite zone up to 10 m wide. Within 2 m of the contact massive undeformed granodiorite is silicified, fractured and cut by subvertical chlorite cataclasite zones up to a few cms wide (Fig. 32). This zone within the granodiorite crops out as a low strike ridge and is shown as a dyke on the Tumut 1:100 000 - scale geological map (Basden, 1986). The cataclastic zones in the granodiorite parallel the contact and shear planes in the serpentinite. A flattening foliation, present in serpentinised zones, trends more NW and dips steeply to the SW. S-C relationships between the foliation and shear planes in the serpentinite indicate sinistral strike-slip shearing, consistent with a shallow-plunging lineation on the shear plane (Locality 22, Plate 2).

North to NW-trending contacts and corresponding deformed zones within the granodiorite are truncated by the WNW-trending faulted contacts which in turn appear to be rotated into parallelism with the western margin of the serpentinite. The WNW faults are therefore interpreted as splays formed during sinistral strike-slip movement along the western serpentinite contact.

Dissected uplands east of the Honeysuckle Range form the western edge of the Goobarragandra Block, which was thought to be a shelf or in part a landmass bordering the Tumut Trough during Silurian deposition (Lightner, 1977; Owen & Wyborn, 1979; Basden, 1986). The traverse included mostly the Young Granodiorite and its volcanic equivalent the Goobarragandra Volcanics (Owen & Wyborn, 1979). Minor bodies of Micalong Swamp Basic Igneous Complex intrude the volcanics in the far northeast. Remnants of a Tertiary capping, up to 40 m thick, of basalt, dolerite and minor sediments crop out on the western margin of the block and partly obscure the faulted contact with the adjacent Mooney Mooney Fault Block.

STRATIGRAPHY

Goobarragandra Volcanics

Massive dacite, containing quartz and zoned plagioclase phenocrysts, up to 1 cm across, in a fine-grained groundmass of graphically intergrown quartz and K-feldspar, forms bouldery hills east and north of Adjungbilly. The dacite, included in the Goobarragandra Volcanics (Owen & Wyborn, 1979), appears to cap the Young Granodiorite. North of Brooklyn homestead the volcanics are intruded by small bodies of the Micalong Swamp Basic Igneous Complex. The thickness of the unit is indeterminate in the area owing to the lack of bedding structures.

The volcanics dated at 429$\pm$16 Ma (Rb-Sr whole rock, Owen & Wyborn, 1979) are chemically similar to and probably comagmatic with the Young Granodiorite (Owen & Wyborn, 1979; Basden, 1986).

Micalong Swamp Basic Igneous Complex

Two roughly circular bodies, about 500 m across, of Micalong Swamp Basic Igneous Complex, comprising dolerite, hornblende gabbro and aplite, intrude the Goobarragandra Volcanics north of Adjungbilly. Intrusive contacts of the southernmost body are exposed in a gravel pit near Brooklyn homestead. Here aplite is the youngest phase present intruding both the mafic rocks and the volcanics. In the other body aplite forms net-vein complexes (Blake, 1981) with the mafic rocks.

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Determined on the Broken Cart Granodiorite which is part of the Young Batholith (Owen & Wyborn, 1979) referred to as Young Granodiorite in the Tumut area (Basden, 1982; 1986).

The complex was probably intruded over a considerable period at about 430±9 Ma (Owen & Wyborn, 1979). It typically occurs as stocks and dyke swarms and elsewhere is intruded by the Young Granodiorite (Owen & Wyborn, 1979; Basden, 1986).

Young Granodiorite

Massive coarse-grained equigranular biotite granodiorite of the Young Granodiorite (Ashley & Basden, 1973) crops out between the Honeysuckle Range and Adjungbilly. The granodiorite abuts the Coolac Serpentinite to the west and is capped by the Goobarragandra Volcanics in the northeast. The contact with the volcanics is not exposed in the traverse but elsewhere the granodiorite intrudes the volcanics (Ashley & others, 1972; Basden & others, 1978). Beneath remnant Tertiary cappings, and over much of the area corresponding to the Tertiary erosional surface, the granodiorite is deeply weathered and locally silicified.

The granodiorite, thought to be comagmatic with the Goobarragandra Volcanics, is probably Upper Silurian (Basden, 1986). Ages of 417±6 Ma* (Evernden & Richards, 1962) and 405±16 Ma (Basden & others, 1978) determined by K-Ar dating of biotite reflect younger thermal or deformational events (Basden, 1982; 1986).

STRUCTURE

Apart from deformed zones in the Young Granodiorite, particularly along the contact with the Coolac Serpentinite, the Goobarragandra Block shows only minor evidence of tectonism. The Goobarragandra Volcanics and the Micalong Swamp Basic Igneous Complex contain widespread minor cataclastic zones and quartz-chlorite-epidote veins. Both the zones and veins parallel photo lineaments and foliation and joint orientations within the Young Granodiorite. Biotite in the volcanics shows either marginal or complete replacement by chlorite and epidote, and augite in mafic rocks of the Micalong Swamp Basic Igneous Complex is largely replaced by fibrous actinolite.

Deformation of the granodiorite adjacent to the Coolac Serpentinite ranges from narrow cataclasite zones along WNW-trending contacts to extensive mylonitic and foliated zones bordering N-trending contacts.

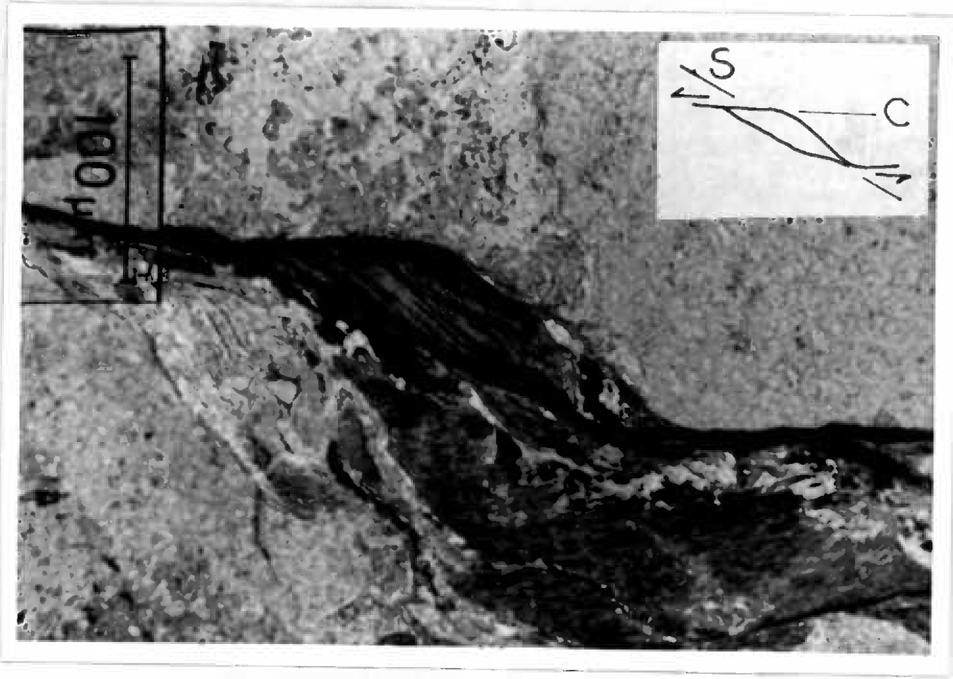
Where the contact with the serpentinite trends northerly, such as 800 m southeast of the repeater tower (GR 221122), granitic mylonite (orthomylonite) up to a few metres wide crops out discontinuosly along the contact and grades eastwards into a 500 m wide strongly foliated zone (protomylonite) then into a 2 km wide weakly foliated zone (protomylonite). The foliation is steep W-dipping to near vertical and parallels the contact. In places a mineral-elongation-lineation is present in the orthomylonite zone, pitching 75°S at GR 221122 and 45°N at GR 197165.

Within this zone primary minerals are deformed and fractured with most quartz and some K-feldspar recrystallised to fine-grained unstrained polygonal mosaic. Deformed assymetrical biotite 'fish' (Lister & Snoke, 1984), commonly replaced by unstrained chlorite and white mica aggregates, form S-C fabrics indicating east side up displacement (ie. the granodiorite has been displaced upwards relative to the serpentinite).

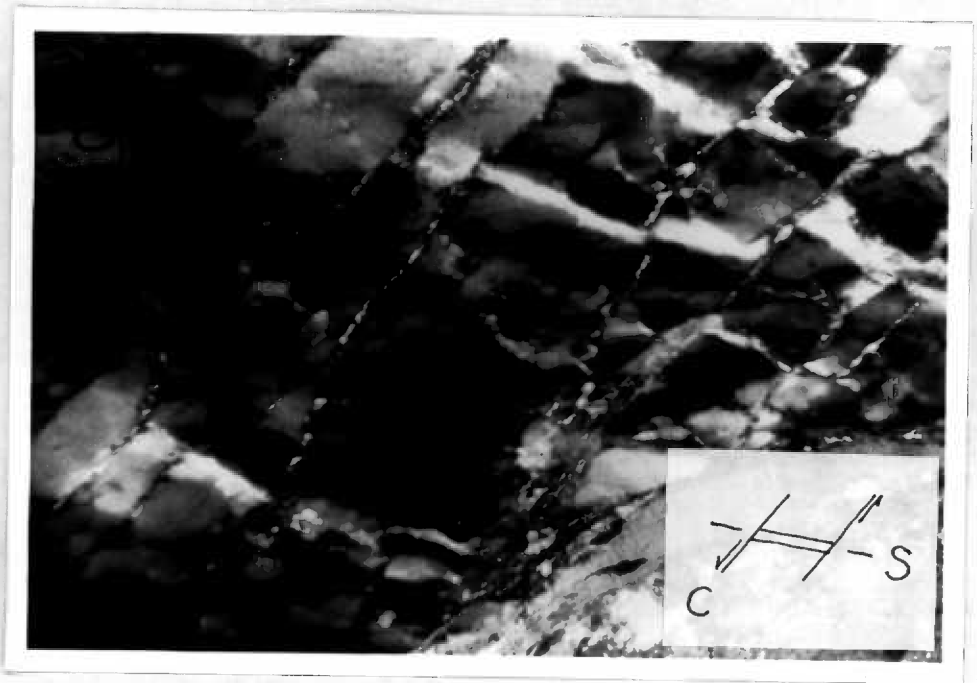
The sense of movement indicated in the orthomylonite zone is, however, not universal throughout the protomylonite zone. About three hundred metres east of the serpentinite contact, at GR 224124, a mineral-elongation-lineation is present and pitches about 75°S on the foliation plane. At this locality mica 'fish' and rectilinear fracture and dislocation patterns in quartz grains indicate a steep reverse movement (ie. west side up) (Fig. 33). Elsewhere S-C fabrics are not developed and the main foliation present in the granodiorite reflects a flattening strain history.

Differing senses of vertical movement within the foliated margin of the Young Granodiorite could be explained by transpression during strike-slip faulting of the Coolac Serpentinite. The WNW-trending cataclasite zones (discussed under previous section on structure of the Mooney Mooney Fault Block), which truncate the N-trending foliation, and are interpreted to have formed accommodation structures during transpressive deformation.

Numerous air-photo lineaments throughout the Young Granodiorite parallel the foliation and indicate a NE swing to the north of Adjungbilly.



(a)



(b)

Fig. 33. Biotite fish (a) and fracture and dislocation patterns in quartz (b) indicating S-C relationships in protomylonite of the Young Granodiorite about 300 m east of the contact with the Coolac Serpentinite (GR 224124). At this locality a near vertical west-side-up movement is indicated, however, along the contact with the serpentinite similar fabrics in orthomylonite indicate east-side-up.

450	440	430	420	410	400	390

LATE ORDOVICIAN			SILURIAN				EARLY DEVONIAN
			LOWER		UPPER		
Gisbornian	Eastonian	Bolindian	Landoverian	Wenlockian	Ludlovian	Pridolian	

Wagga Metamorphic Belt,
Graptolites,
(Sherwin, pers. comm. in,
Basden & others, 1987)

Micalong Swamp Basic Igneous Complex,
K-Ar on hornblende
(Owen & Wyborn, 1979)

Gocup Granite,
K-Ar on muscovite,
(Richards & others,
1977)

Minjary Volcanics,
Brachiopods and corals
(Barkas, 1976)

Wyangle Formation,
Conodonts,
(Lightner, 1977)

Blowering Formation,
Conodonts,
(Lightner, 1977)

Goobarragandra Volcanics,
Fossils in Limestone pod,
(Basden & others, 1978)

Honeysuckle Metabasic Igneous Complex,
K-Ar on hornblende,
(Webb, 1980)

Goobarragandra Volcanics,
Rb-Sr whole rock,
(Owen & Wyborn, 1979)

TABLE 1. IGNEOUS CRYSTALLISATION AND FOSSIL AGES

450	440	430	420	410	400	390

LATE ORDOVICIAN			SILURIAN				EARLY DEVONIAN
			LOWER		UPPER		
Gisbornian	Eastonian	Bolindian	Landoverian	Wenlockian	Ludlovian	Pridolian	

Avernall Basic Igneous Complex	414±6 Ma K-Ar on biotite (Webb, 1981)	401±6 Ma K-Ar on biotite
Blacks Flat Diorite	417±6 Ma K-Ar on hornblende (Webb, 1980)	
Ellerslie Granodiorite	404±6 Ma K-Ar on biotite (Webb, 1980)	
Gocup Granite	402±3 Ma Rb-Sr whole rock (Richards & others, 1977)	
Goobarragandra Volcanics	417±8 Ma RB-Sr whole rock & biotite (Owen & Wyborn, 1979)	
Green Hills Granodiorite	419±6 Ma K-Ar on biotite (Webb, 1980)	406±6 Ma K-Ar on biotite (Webb, 1980)
	422±6 Ma K-Ar on biotite (Webb, 1980)	
Young Granodiorite	405±16 Ma K-Ar on biotite (basden & others, 1978)	
	417 6 Ma K-Ar on biotite (Evernden & Richards, 1979)	

TABLE 2. RADIOMETRIC AGE DATES - SILURIAN AND EARLY DEVONIAN DEFORMATIONAL AND THERMAL EVENTS OF ROCKS IN THE TUMUT AREA

SUMMARY AND DISCUSSION

Structural studies along the seismic traverse have outlined significant changes in the nature and timing of deformation and faulting of the Silurian trough sequence as previously understood. In addition a change in the stratigraphic position of the Honeysuckle Metabasic Igneous Complex is indicated. This has implications regarding the tectonic development of the trough and the validity of the Coolac Ophiolite Suite as a lithostratigraphic entity.

The structural history as outlined below is a preliminary assessment based only on the traverse section. The conclusions reached here have a wider application to other areas of the Tumut Trough, however, variation in orientation and style of structural features would be expected.

NATURE AND TIMING OF DEFORMATION OF THE SILURIAN TROUGH SEQUENCE

The relative timing, style, and correlation of structural elements is shown in the reference on Plate 2. Age constraints provided by igneous crystallisation and fossil ages are given in Table 1.

The Lower Silurian trough sequence, deposited during active extensional faulting, underwent two periods of deformation (Lower Silurian and Early Devonian) separated by granite intrusion. A 404 Ma. age for the younger deformation is reflected in radiometric age determinations of igneous rocks in the Tumut area (Table 2). The Mooney Mooney Fault Block and the Jindalee Block only show evidence of the second deformation which is correlated with the Bowning Orogeny in the region.

Deformation and accompanying upper greenschist facies metamorphism of the Bullawyarra Schist probably took place during Lower Silurian deformation of the Wagga Metamorphic Belt and preceded extension in the trough (Stuart-Smith, in prep).

Detachment faulting

Although not exposed on the traverse a detachment fault is interpreted in the subsurface beneath the Brungle Creek Metabasalt in the Jindalee Block, separating the underlying Bullawyarra Schist. The fault, exposed farther north (Stuart-Smith, in prep), pre-dates deformation of the Silurian sedimentary-volcanic sequence and is interpreted to have been active during extension of the Tumut Trough in the Lower Silurian. Quartz-fibre veins, pre-dating recumbent folds in the Tumut Block, may be the only evidence for early extensional deformation outside the Jindalee Block.

Recumbent folding

Large-scale (several kms) recumbent folds, first noted in the Gocup area by Atkins (1974) and Crook (1978) represent the earliest compressional deformation of the trough sequence and are widespread throughout the Tumut Block. The fold axes are at a high angle to the meridonal trend of the trough and to the SSE to SSW extension direction indicated by a basal detachment fault and in high strain zones within the Bullawyarra Schist (Stuart-Smith, in prep). The folds face both north and south indicating that accommodation structures such as tear faults must have been present. These faults, most likely located on transfer faults active during the earlier extensional phase, were also the major strike-slip faults active during later deformation.

Not all the trough was affected by recumbent folding: the Jindalee Block and the Mooney Mooney Fault Block only exhibit one deformation which corresponds in nature and timing to the second deformation in the Tumut Block. As considerable horizontal movement probably took place on the major NNW-trending faults during the second deformation the blocks were probably more spatially separated along the length of the trough rather than their present juxtaposition. In such a strike-slip system continued fault movements following the cessation of major extension could result in localised areas of transpression. The recumbent folds may well have developed in such an environment.

The timing of recumbent folding*, as first suggested by Crook (1978), is constrained between deposition of the Bumbolee Creek Formation (Lower Silurian) and intrusion of the Gocup Ganite (409 ± 2 Ma., Richards and others, 1977).

Upright folding and regional metamorphism

The main deformation of the Silurian sequence produced upright (locally overturned), open to isoclinal, NNW-trending folds and was accompanied by lower to upper greenschist facies metamorphism and strike-slip faulting. This deformation also effected the Bullawyarra Schist, the adjoining Wagga Metamorphic Belt and Silurian granitoids in the region. Deformation was most intense in the Tumut Block particularly adjacent to the Gilmore and Killimicat Faults.

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* Preliminary results of work in progress east and south of Tumut indicate that this deformation pre-dates deposition of the Blowering Formation and therefore must be a least early Lower Silurian in age. As known fossils are non age-specific and there are no radiometric ages for the Bumbolee Creek Formation an Ordovician age for this formation, and underlying units in the Jindalee Block, is therefore a possibility.

Folds formed during this deformation dominate the regional as well as outcrop-scale structures and have a NNW-trending penetrative axial plane cleavage which mostly dips steeply to the WSW. This axial surface is variably developed as: a crenulation or schistosity in the Tumut Block; a fracture or slaty cleavage in the Jindalee Block and Mooney Mooney Fault Block; and as a foliation in granitoids of the Wagga Metamorphic Belt and Goobarragandra Block.

Radiometric age dates on the Blacks Flat Diorite*, Young Granodiorite, A vernall Basic Intrusive Complex# and the Green Hills Granodiorite# indicate an Upper Silurian thermal or deformation event at about 417 Ma (Table 2). This event has previously been correlated with the main period of upright folding and regional metamorphism in the trough and was thought to date the Bowning Orogeny (Basden, 1982, 1986). However, this study has shown that the deformation is Early Devonian in age as it postdates the 409 Ma. Gocup Granite and predates Early Devonian felsic volcanics. Potassium-argon age determinations (Table 2) on biotite from the Gocup Granite, Young Granodiorite, Ellerslie Granodiorite#, Avernall Basic Intrusive Complex, and Green Hills Granodiorite reflect a thermal or deformational event at about 404 Ma. (Table 2) probably correlating with this deformation.

Strike-slip faulting

Major faults in the region, including the Gilmore and Killimicat Faults and the Mooney Mooney Fault System trend NNW and are subvertical to steep west-dipping. S-C fabrics, kinks and lineations in the fault zones and adjacent rocks indicate major sinistral strike-slip movement during the main Early Devonian deformation of the trough sediments. Later minor vertical movement is indicated for the Gilmore Fault. It is likely that the faults were in existence during the extensional phase of trough formation and Upper Silurian deformation although this cannot be established. Basden (1986) interpreted syn-depositional normal fault movements to account for stratigraphic differences between the blocks, however, these differences could equally be explained by post-depositional strike-slip displacement.

Minor NNE-trending faults occur within the blocks. They appear to be Early Devonian in age, post-dating the Killimicat Granite and upright folding of the Silurian metasediments, and pre-dating Early Devonian felsic volcanics. No movement directions could be determined, however, they show a component of dextral displacement. The faults mostly abut the NNW-

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* The Blacks Flat Diorite is a small intrusion within the Bullawyarra Schist 7 km north of Brungle.
# The Avernall Basic Intrusive Complex, Green Hills Granodiorite and the Ellerslie Granodiorite intrude the Wagga Metamorphic Belt south of the traverse.

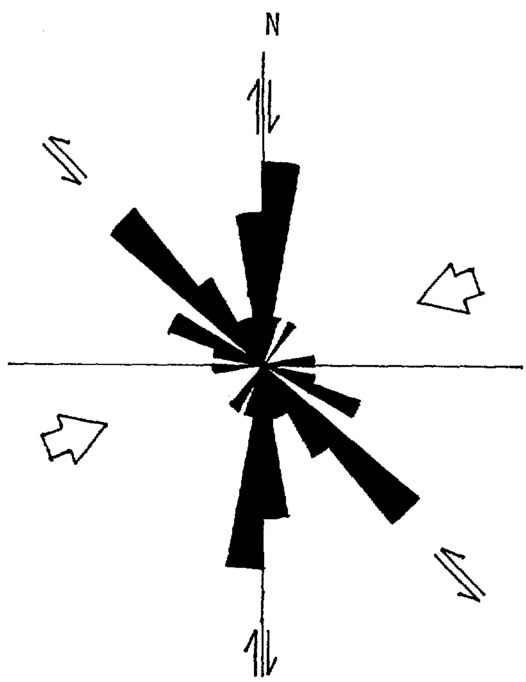

Fig. 34. Rose diagram of faults in the traverse section showing conjugate relationship and position of principal compression direction. n = 21.

trending faults except 3km south of Califat homestead where one such fault displaces the Gilmore Fault. Thus the NNE-trending faults probably developed during the late stages of movement on the NNW-trending faults. Together the faults form a conjugate set with a subhorizontal ENE-trending principal compression direction (Fig. 34). This pattern is also well expressed on an outcrop-scale by mylonitic zones within the Wondalga Granodiorite at Adelong Falls, and conjugate kinks sets in the Bullawyarra Schist.

Significant displacement (10's of km) on the NW-trending faults is likely considering the differences in stratigraphy and structure between the blocks and the width of highly strained rocks adjacent to the fault zones. As sinistral displacements were involved then the Jindalee Block and Mooney Mooney Fault Block were originally located farther south of their present position relative to the Tumut Block. The Killimicat Granite and faulted lenses of leucogranite in the Mooney Mooney Fault Block may well be slices of the Bogong Granite which crops out respectively 10 and 16 km to the south. Such a location would also place the Brungle Creek Metabasalt closer to its correlative, the Wermatong Metabasalt.

EMPLACEMENT OF THE COOLAC SERPENTINITE

The Coolac Serpentinite is fault-bounded within the Mooney Mooney Fault System between the Young Granodiorite to the east and the Silurian trough sequence to the west. Contacts are subvertical to steep W-dipping. S-C fabrics in the serpentinite indicate sinistral strike-slip displacement along both contacts. Most movement was probably along the western margin which has a much wider (500 m) deformed zone.

The eastern margin is displaced up to 1.5 km in several places by WNW-trending sinistral strike-slip faults associated with localised cataclasis of the granodiorite. These faults, interpreted to be splays off the western margin, formed accommodation structures in areas of transpression during progressive strike-slip movement.

Structures in the Young Granodiorite indicate a different history. A steeply-plunging elongation lineation, present within granitic orthomylonite near the serpentinite contact, indicates vertical rather than strike-slip movement. Basden and others (1987) noted that the lineation plunges 50^{o}-70^{o} NW and that kinematic indicators required east side up motion with a right-lateral component. Thus they interpreted the Goobarragandra Block to be thrust in a WSW direction over the Mooney Mooney Fault Block.

The different structural history evident in the granodiorite from the serpentinite is here interpreted to reflect transpressional deformation associated with the major sinistral stike-slip movement in the sepentinite.

This deformation took place in the Early Devonian (ie. 404 Ma) and was probably synchronous with upright folding of the trough sequence.

STRATIGRAPHIC POSITION OF THE HONEYSUCKLE METABASIC IGNEOUS COMPLEX

The Honeysuckle Metabasic Igneous Complex has previously been considered one of the oldest units in the Silurian trough sequence (Basden, 1986). Ashley and others (1979) included the complex (referred to as 'Honeysuckle Beds') together with the North Mooney Complex (Franklin, 1976) and the Coolac Serpentinite in the Coolac Ophiolite Suite. The suite, thought to represent early Palaeozoic oceanic crust (Scheibner, 1972, 1973, Ashley, 1973, 1974), was dismembered and obducted into its present position during the closure of the Tumut Trough (Upper Silurian).

Although eastward-facing beds in the Honeysuckle Metabasic Igneous Complex had been noted by D.P. Thrum (personal communication in Crook and Felton, 1975) the suite was thought to be overall west-facing. Contacts between the suite and the adjacent Silurian units to the west are shown as faulted on published maps of the region (Basden, 1986). The discovery, during this survey, of a conformable contact between the Honeysuckle Metabasic Igneous Complex and the Blowering Formation (GR 171135) and that both units verge eastwards and are upright (no downward-facing beds have been found) in the Mooney Mooney Fault Block indicates that the complex is the youngest unit in the Silurian trough sequence directly overlying felsic volcanics. The concept of an ophiolite suite as defined is therefore untenable. Metabasalt, overlying Blowering Formation dacite, also occurs in the Tumut Block south of the traverse about 3 km northeast of Tumut (Lightner, 1977). The metabasalt, presently unnamed and not shown on published geological maps of the area, may well be a correlative of the Honeysuckle Metabasic Igneous Complex.

Contacts between other members of the ophiolite suite are well established: the North Mooney Complex intrudes the Honeysuckle Metabasic Igneous Complex (Franklin, 1975) and the Coolac Serpentinite is faulted against the two complexes (Ashley & others, 1979). Similar differentiated tholeiitic intrusions to the North Mooney Complex occur in the Micalong Swamp Basic Igneous Complex east of the Tumut Trough (Owen & Wyborn, 1979). Both complexes have sheeted dykes (Wyborn, 1977) and similar ages. Wyborn (1977) suggested that the intrusions were related to a period of crustal extension accompanying upwelling crustal melts which produced the Silurian felsic volcanics and batholiths. Thus the Honeysuckle Metabasic Igneous and North Mooney Complexes did not form part of an oceanic substrate to the Tumut Trough, however, the Coolac Serpentinite may well represent part of the oceanic lithosphere and its formation could still be linked to extrusion and intrusion of mafic rocks of the two complexes. Major and trace element data for the units indicate a marginal sea or back-arc setting (Ashley and others, 1979) consistent with presence of a thinned continental crust beneath the trough. Basden (1986) also interpreted depths of less than 1000 m for the extrusion of mafic volcanics in the Honeysuckle Metabasic Igneous Complex.

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PLATE 1

GEOLOGY OF THE TUMUT SEISMIC TRAVERSE

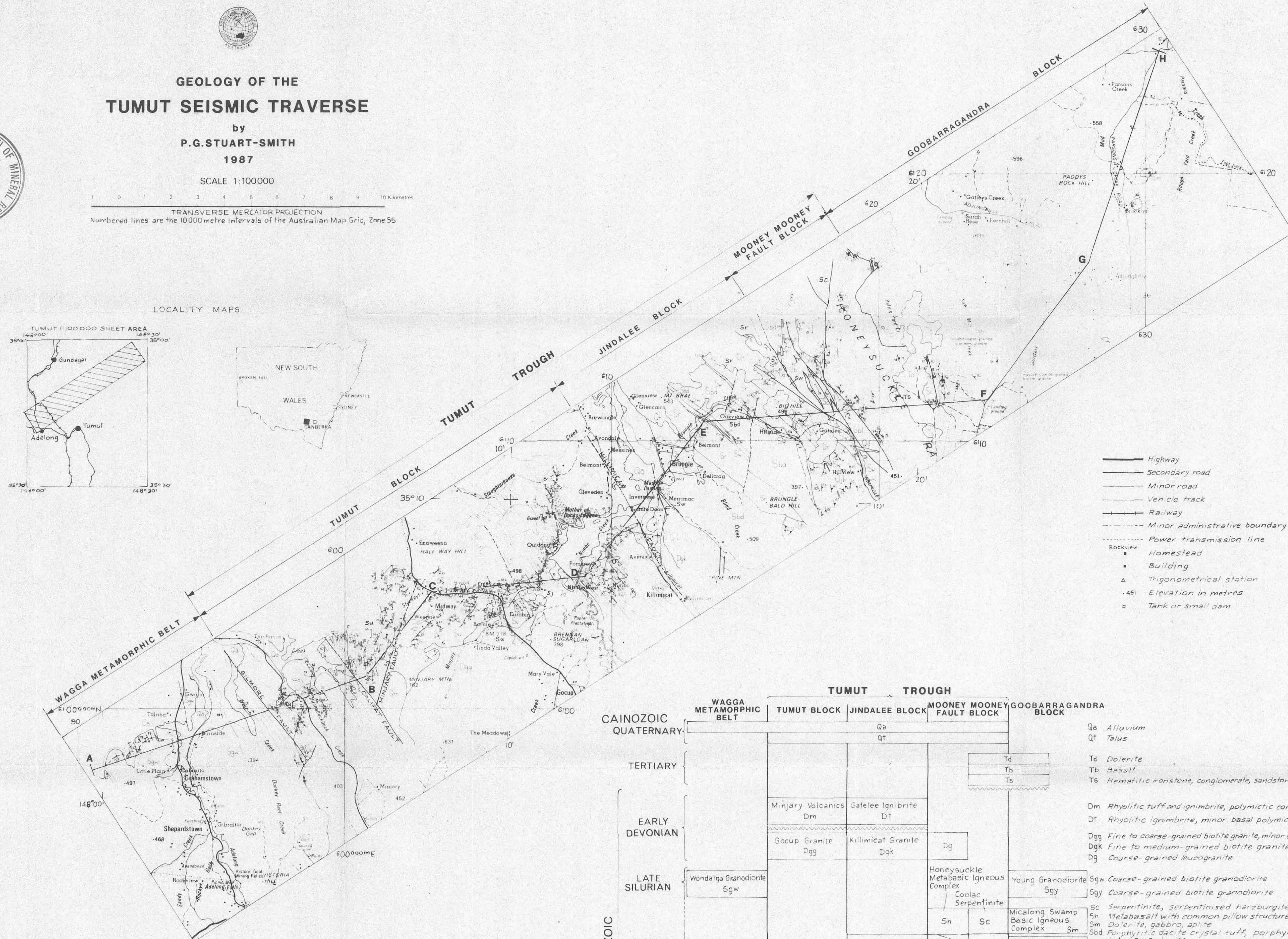
by

P.G. STUART-SMITH

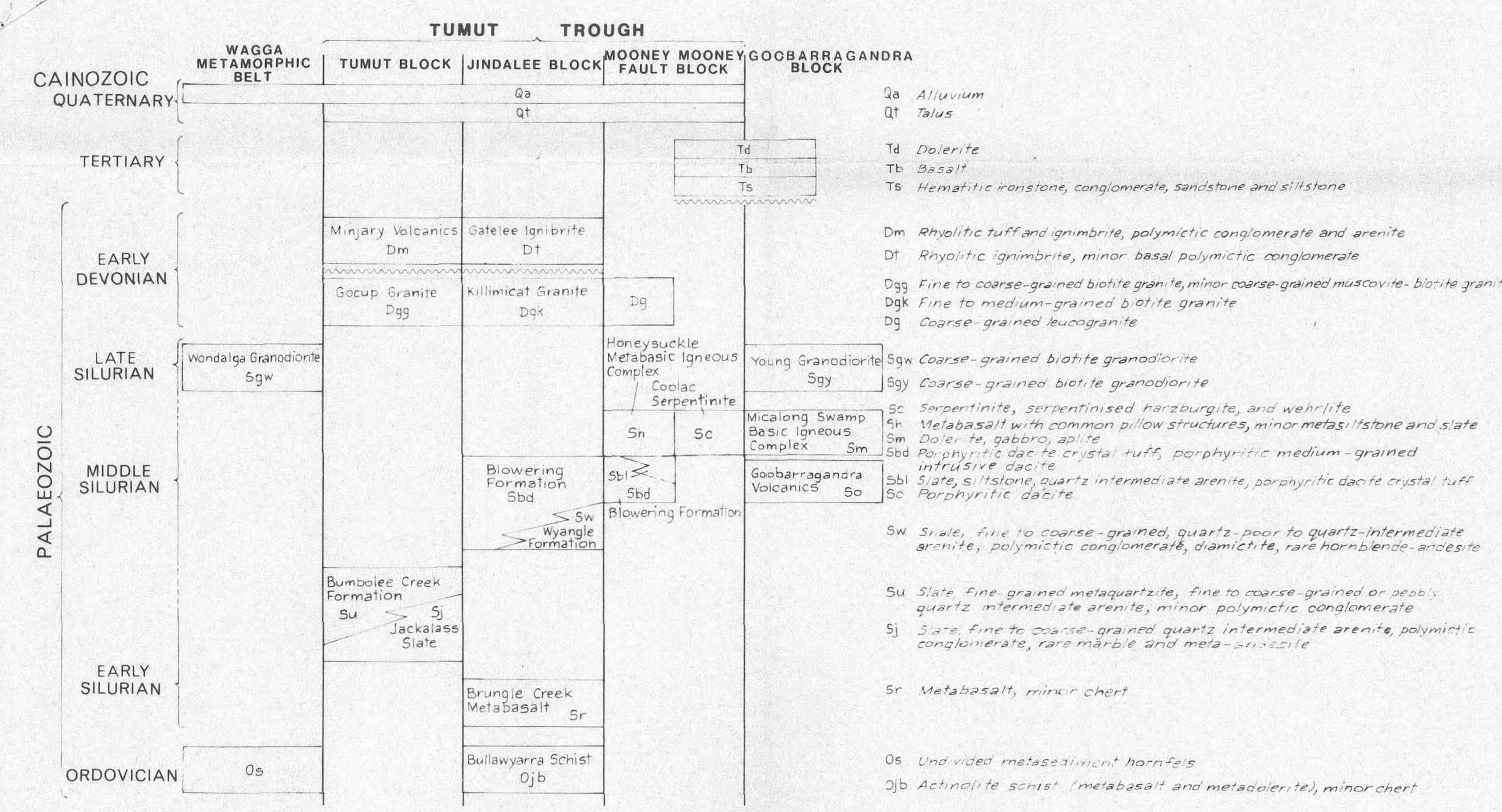
1987

SCALE 1:100000

TRANSVERSE MERCATOR PROJECTION
Numbered lines are the 10000 metre intervals of the Australian Map Grid, Zone 55



- Highway
- Secondary road
- Minor road
- Vehicle track
- Railway
- Minor administrative boundary
- Power transmission line
- Rockview • Homestead
- Building
- Trigonometrical station
- ·451 Elevation in metres
- Tank or small dam



- Geological boundary, accurate, approximate
- Fault, accurate, approximate
- Dyke or vein; p- porphyry, q- quartz
- Plunge of minor fold
- F1 Plunge of minor fold showing 'S' vergences
- F2 Plunge of minor fold showing 'Z' vergences
- F3 Plunge of minor fold showing 'M' vergences

(F1, F2, F3 refers to fold generation)

- Strike and dip of stata
- Vertical strata, dot indicates facing
- Strike and dip of overturned strata
- Strike and dip of strata, facing not known
- Trend-line (airphoto interpretation)
- Lineament (airphoto interpretation)
- Strike and dip of foliation
- Vertical foliation
- Strike and dip of shear planes
- Trend and plunge of mineral elongation
- Trend and plunge of bedding-cleavage intersection
- Strike and dip of cleavage
- Vertical cleavage
- Strike and dip of kink plane
- Strike and dip of crenulation cleavage
- Strike and dip of joint

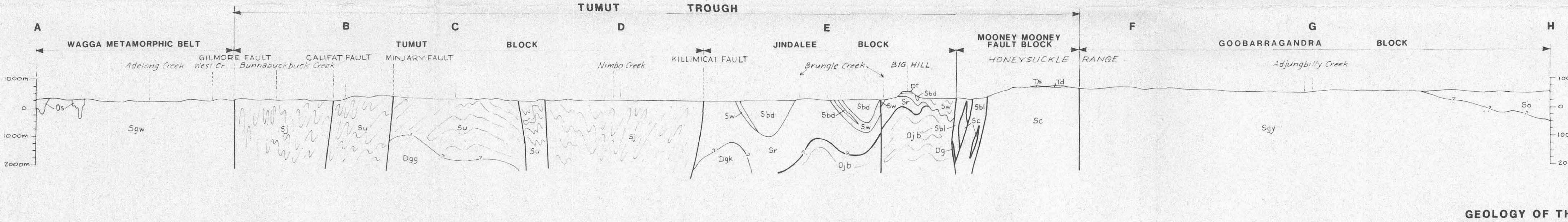
Some structural elements observed at a single locality are combined on the map

SCHEMATIC SECTION

Quaternary sediments omitted

Section along approximate position of seismic traverse

Scale $\frac{V}{H} = 1$



GEOLOGY OF THE
TUMUT SEISMIC TRAVERSE
1987

16/N/41

STRUCTURAL ELEMENTS,

TUMUT SEISMIC TRAVERSE

by

P.G. STUART-SMITH

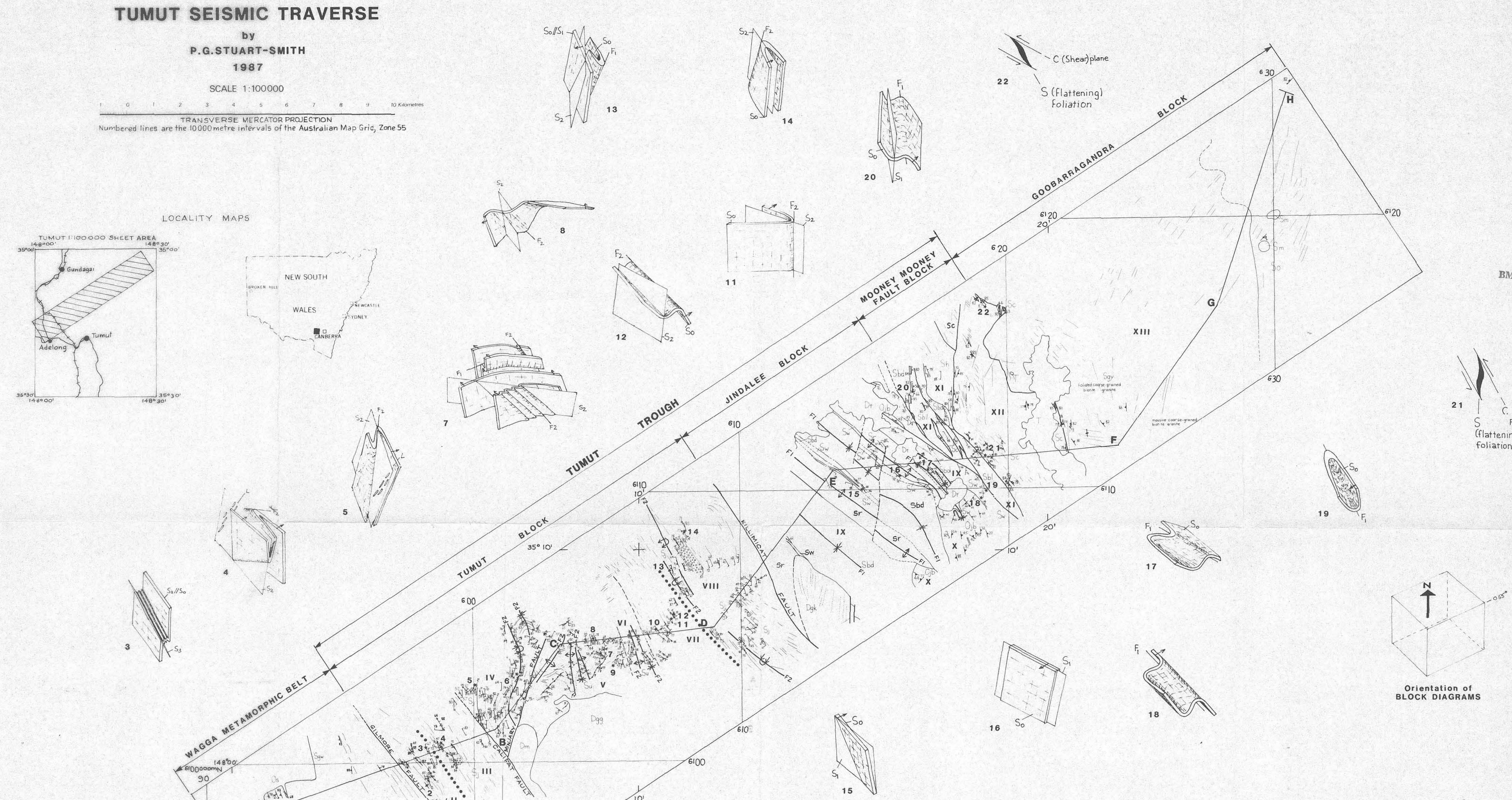
1987

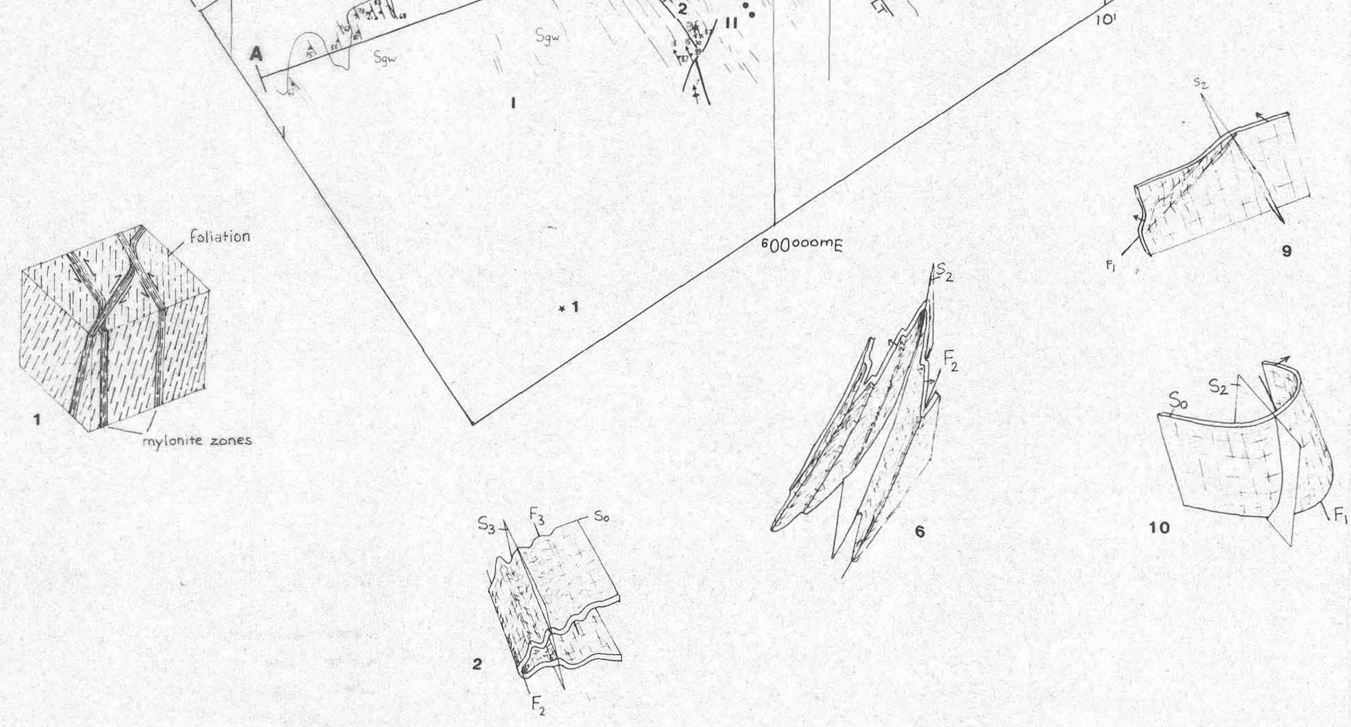
SCALE 1:100000

TRANSVERSE MERCATOR PROJECTION

Numbered lines are the 10000 metre intervals of the Australian Map Grid, Zone 55

PLATE 2





Geological boundary, accurate, approximate

Fault, accurate, approximate

Dyke or vein; p- porphyry, q- quartz

Anticline

Syncline

Overturned anticline

Overturned syncline

Plunge of minor fold

Plunge of minor fold showing 'S' vergences

Plunge of minor fold showing 'Z' vergences

Plunge of minor fold showing 'M' vergences

F1, F2, F3 refers to fold generation

Strike and dip of stata

Vertical strata, dot indicates facing

Strike and dip of overturned strata

Strike and dip of strata, facing not known

Trend-line – airphoto interpretation

Lineament – airphoto interpretation

Strike and dip of foliation

Vertical foliation

Strike and dip of shear planes

Trend and plunge of mineral elongation

Trend and plunge of bedding – cleavage intersection

Strike and dip of cleavage

Vertical cleavage

Strike and dip of kink plane

Strike and dip of crenulation cleavage

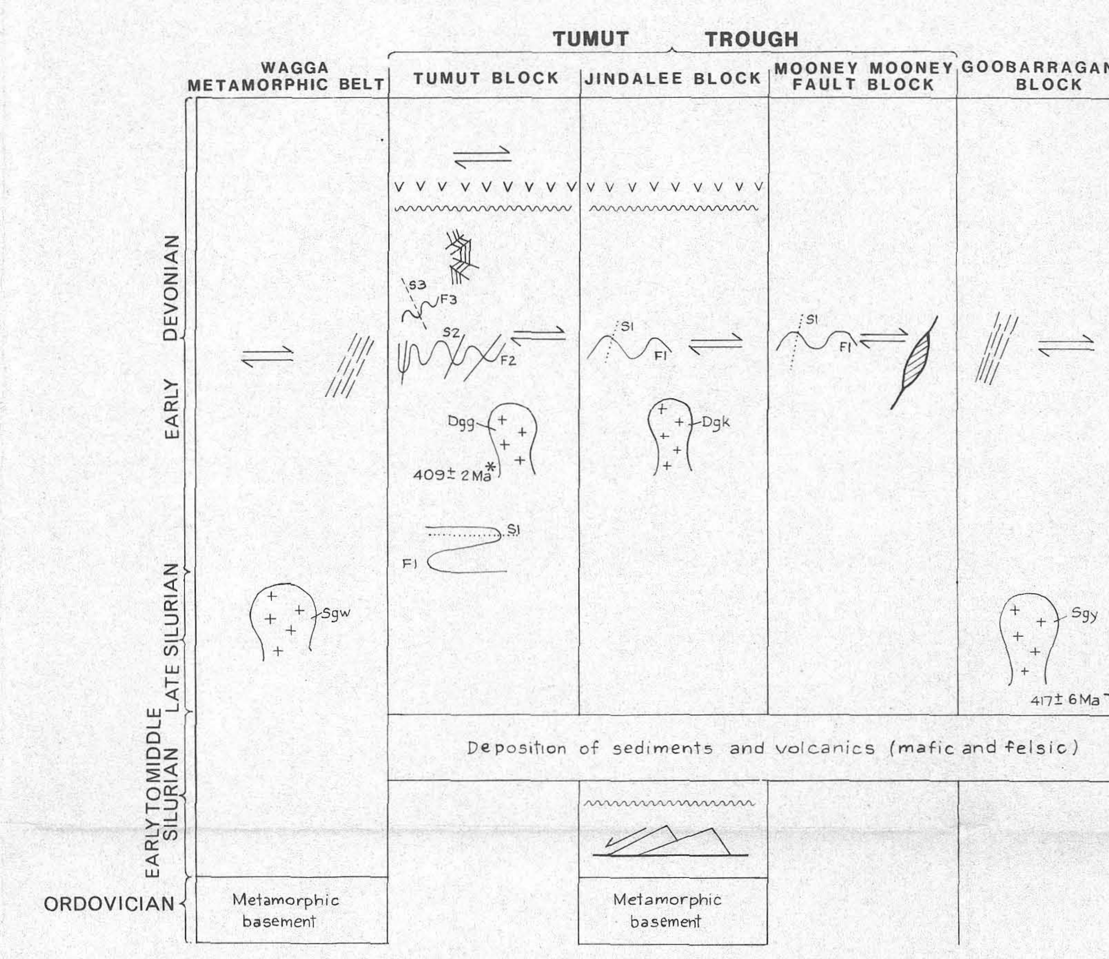
Strike and dip of joint

Some structural elements observed at a single locality are combined on the map

XIII Structural Domain

•••••••• Structural Domain boundary

•23 Structural sketch locality



TERTIARY

T	*Undivided volcanics and sediments*

EARLY DEVONIAN

Dm	Minjary Volcanics
Dt	Gatelee Ignimbrite
Dgg	Gocup Granite
Dgk	Killimicat Granite
Dg	*Undivided granite*

LATE SILURIAN

Sgw	Wondalga Granodiorite
Sgy	Young Granodiorite

EARLY TO MIDDLE SILURIAN

Sh	Honeysuckle Metabasic Igneous Complex
Sc	Coolac Serpentinite
Sm	Micalong Swamp Basic Igneous Complex
Sbd	Blowering Formation *(volcanics)*
Sbl	Blowering Formation *(sediments)*
So	Goobarragandra Volcanics
Sw	Wyangle Formation
Su	Bumbolee Creek Formation
Sj	Jackalass Slate
Sr	Brungle Creek Metabasalt

ORDOVICIAN

Os	*Undivided metasediments*
Ojb	Bullawyarra Schist

Wrench faulting

Detachment faulting

Serpentinite emplacement

Granitoid intrusion

Felsic volcanism

Unconformity

Open, Tight, Isoclinal, Recumbent – folding

S1, S2, S3 – Cleavage

Kinking

Foliation in igneous rocks

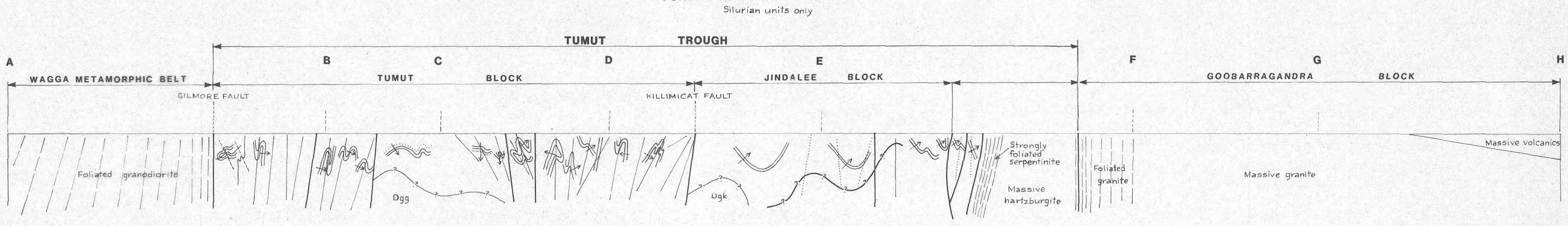
Sedimentary facing. Structural profile only

* K-Ar on muscovite (Richards and others, 1977)

\+ K-Ar on biotite (Evernden and Richards, 1962)

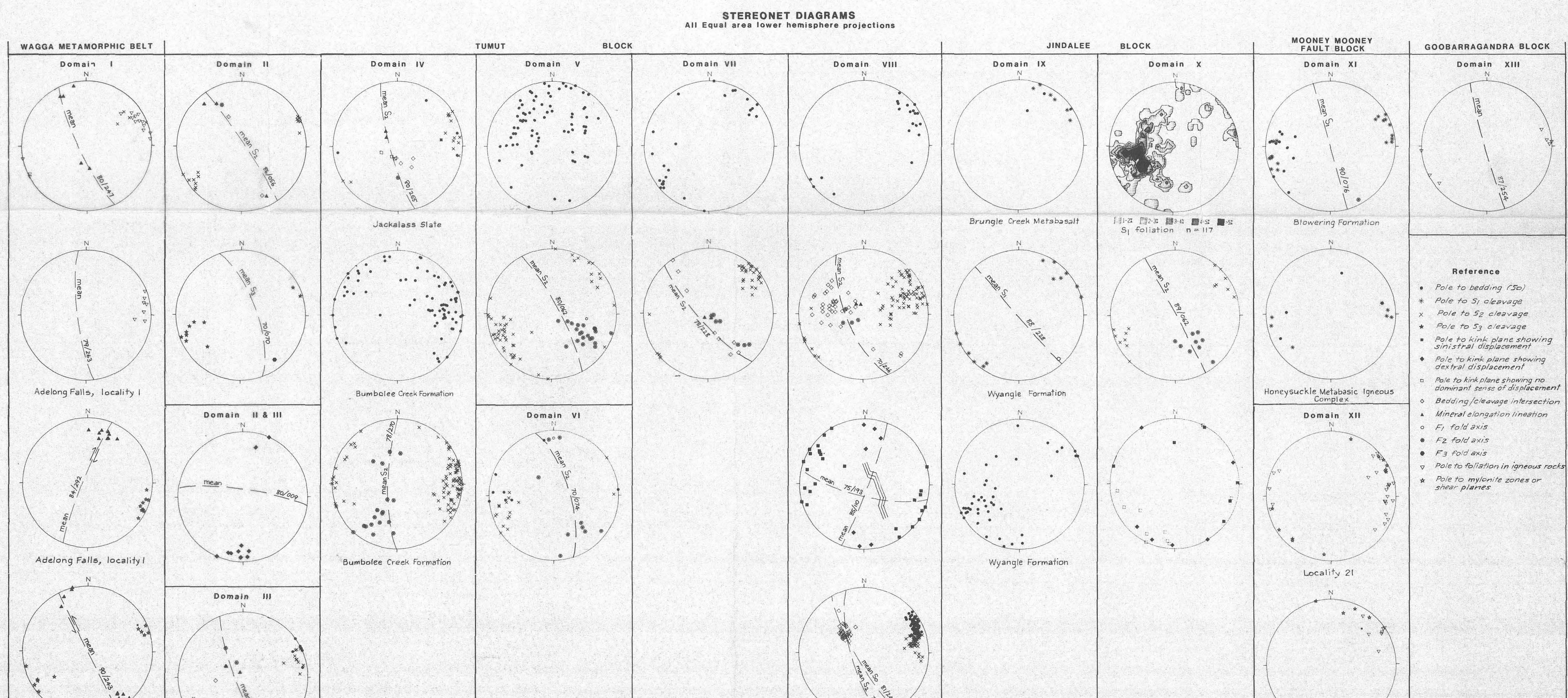
SCHEMATIC STRUCTURAL PROFILE

Silurian units only



STEREONET DIAGRAMS

All Equal area lower hemisphere projections



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STRUCTURAL ELEMENTS,

TUMUT SEISMIC TRAVERSE

1987