SGTSG FIELD EXCURSION GUIDE: KOSCIUSKO TO WAGGA WAGGA

by
P G Stuart-Smith

RECORD 1994/5

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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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P.G. Stuart-Smith

Record 1994/5
Australian Geological Survey Organisation

R9400501

Australian Geological Survey Organisation, Record 1994/5

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Resources: Hon. David Beddall, MP
Secretary: Greg Taylor

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Harvey Jacka

ISSN: 1039-0073
ISBN: 0 642 20119 6

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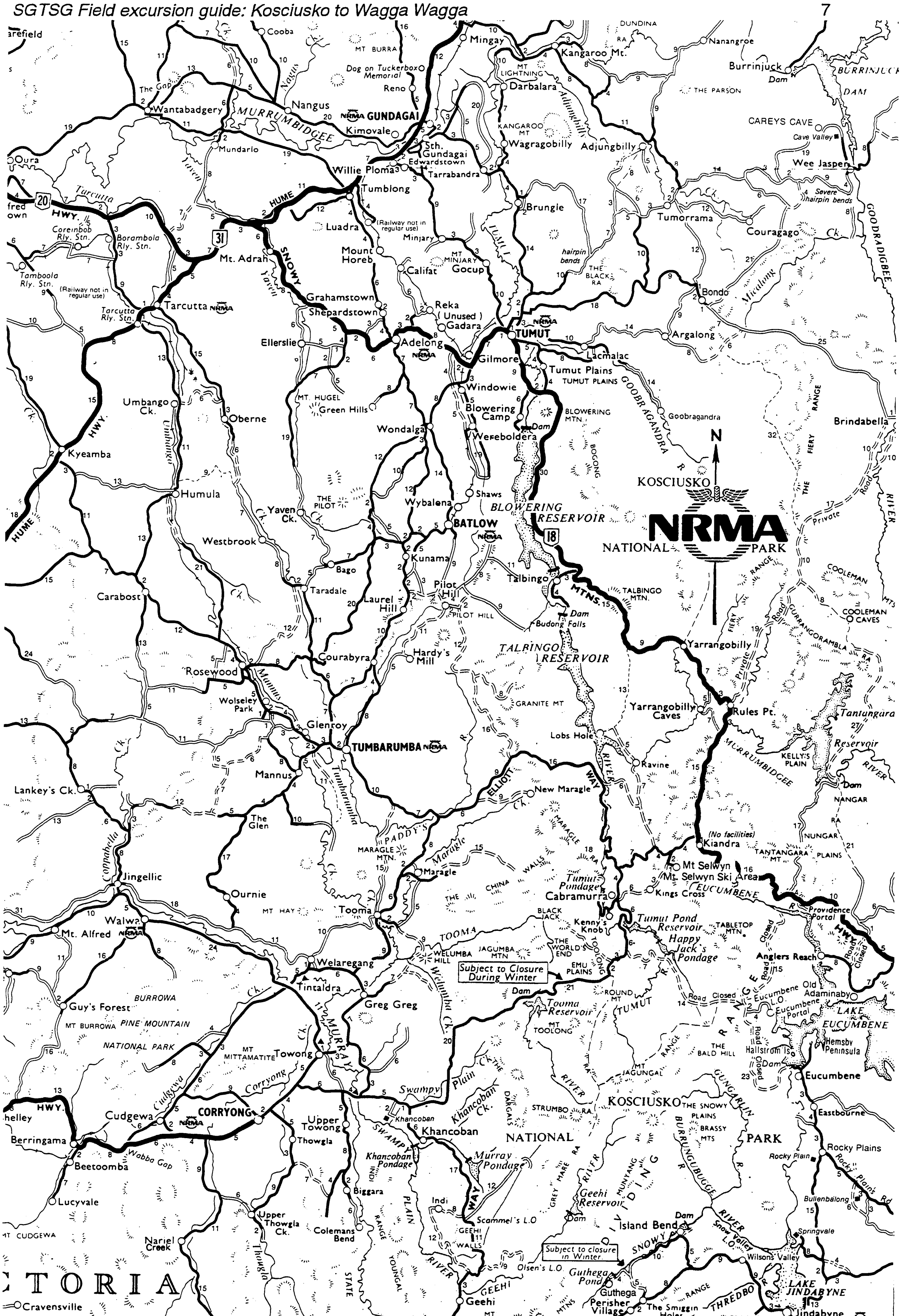

Figure 1. Excursion route map (map courtesy of the NRMA - 1994)

INTRODUCTION

The Kosciusko to Wagga Wagga excursion (Fig. 1) traverses three main tectono-stratigraphic provinces (Fig 2): the Goobarragandra/Tantangara Blocks, Tumut Synclinorial Zone and the Wagga Metamorphic Belt (WMB). These regions, lying within the southeastern part of the Lachlan Fold Belt (LFB), are separated by major tectonic zones of the Mooney Mooney and Gilmore Fault Zones, respectively. The aim of the excursion is to compare and contrast the structural and tectonic histories of these provinces and the nature of the bounding fault zones. In particular the excursion will focus on the Silurian history of the Tumut region, within the southern part of Tumut Synclinorial Zone (Scheibner 1985), which has been a focus for geological investigations in the LFB over the past 25 years with mineral exploration concentrated on prospecting principally for base and precious metals.

Understanding the tectonic history of the Tumut region is important in any account of the development of the LFB within the Tasman Fold Belt. The main reason for this is the presence of an ophiolitic rocks in association with Silurian flysch which is unique to this part of the LFB. Considerable interest has also centred on the Gilmore Fault Zone, which is a major crustal feature forming the eastern margin of the WMB. The zone extends for 100's of km and is the locus of gold mineralisation in a variety of geological settings.

The stratigraphy and structural history of the Tumut region has been recently shown (Stuart-Smith et al., 1992) to be little different to that of other areas of the Lachlan Fold Belt where Silurian deposition was characterised by bimodal volcanic sequences in basins separated by shallow-marine sediments and subaerial volcanics on intervening highs (Cas 1983, Powell 1983). However, the presence of interpreted Cambrian to Ordovician basement and the oceanic affinity of mafic volcanics and tholeiitic intrusions suggests a tectonic environment not replicated elsewhere in the fold belt. An intracratonic pull-apart basin model for Early Silurian extension in the region is compatible with these features (Stuart-Smith et al. 1992). Similar transtensional tectonic settings may apply to other Early Silurian basins in the LFB where extension was insufficient to enable crustal thinning and extrusion and/or intrusion of uncontaminated mantle melts.

GEOLOGICAL SETTING AND STRATIGRAPHY

The geological setting of the Tumut region is shown in Figure 2. The region covers the southern part of the Tumut Synclinorial Zone which consists of two

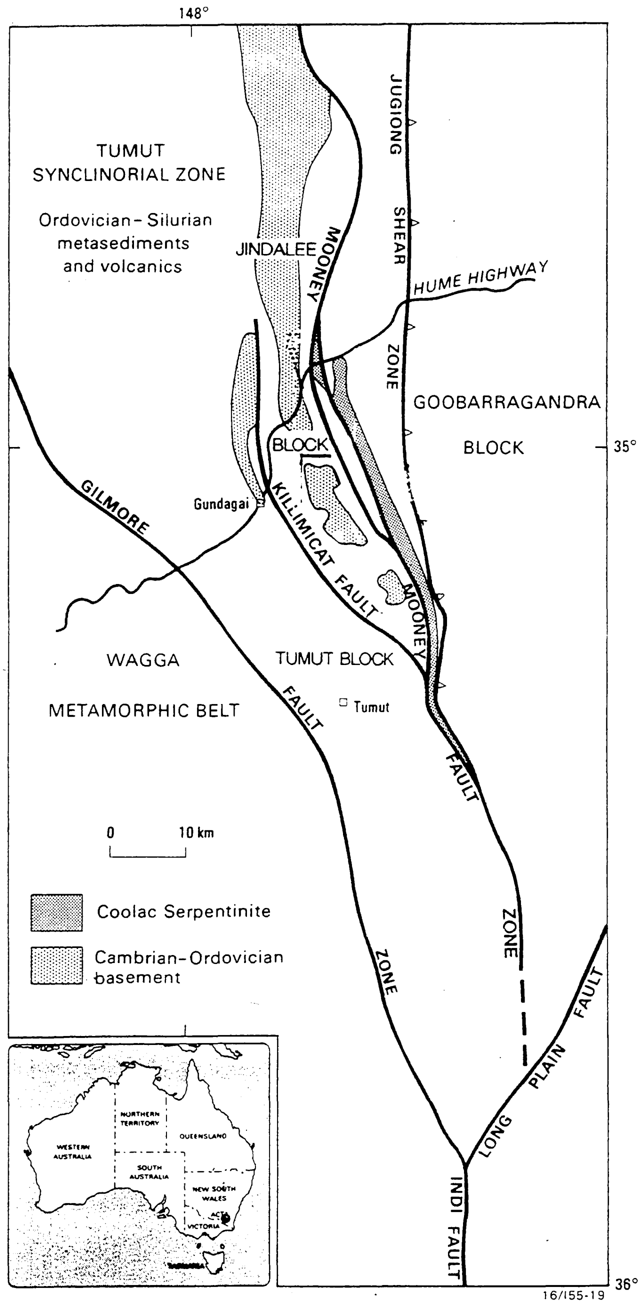

Figure 2. Location of the Tumut region within the Lachlan Fold Belt.

blocks, the Jindalee and Tumut Blocks[1], separated by the Killimicat Fault. These blocks are bounded by the NW-trending Mooney Mooney and Gilmore Fault

[1] The Jindalee and Tumut Blocks correspond to, respectively, the Jindalee and Gocup Blocks of Basden (1990a) and the, respectively, Jindalee and Tumut Terranes of Basden & others (1987).

Zones which separate the Synclinorial Zone from, respectively, the Goobarragandra Block to the east and the WMB to the west. The Goobarragandra Block comprises mainly Silurian granitoids and their coeval waterlain to subaerial volcanics, and Silurian shallow-marine sediments and mafic intrusions. The WMB consists of Ordovician flyschoid metasediments and volcanics, and Silurian granitoid felsic and mafic intrusions (Basden 1982, 1986, 1990a).

The geology of the region, described by Moye et al. (1969a, b & c), Ashley et al. (1971), Basden (1982, 1986, 1990a), Basden et al. (1978), Owen & Wyborn (1979a), Wyborn (1977), and Degeling (1975, 1977) is shown in Figure 3. A summary of stratigraphic units of the southern part of the Tumut Synclinorial Zone and adjacent areas is given in Table 1. Unit relationships (Fig. 4), distribution and nomenclature follow that of Stuart-Smith (1990a)[2].

The oldest unit in the area is the **Cambrian-Ordovician Jindalee Group**, comprising mainly greenschist facies mafic and ultramafic rocks (Bullawyarra Schist, Gundagai Serpentinite). These rocks crop out either as inliers within the Jindalee Block, northeast of Tumut, or as fault-bounded allochthonous blocks elsewhere in the region. Extensive ultramafic belts within the Mooney Mooney Fault and Gilmore Fault Zones, respectively, the Coolac and Tumut Ponds Serpentinites, may also be part of this basement or may represent Early Silurian intrusions.

Ordovician to Late Silurian flyschoid metasediments and felsic and mafic volcanics form two tectonostratigraphic sequences which are either structurally emplaced over or unconformably overlying basement rocks. The older of these two sequences consists largely of undated **quartz-rich to quartz-intermediate flyschoid metasediments and mafic and minor felsic volcanics**. These rocks, deposited in deep to shallow-water environments, comprise in part, the southern portion of the Ordovician-Early Silurian Molong Volcanic Arc. Units included here in this sequence are: the Nacka Nacka Metabasic Igneous Complex; Brungle Creek Metabasalt; Wermatong Metabasalt; Snowball Metabasic Igneous Complex; Gooandra Volcanics; Frampton Volcanics; Jackalass Slate; Kiandra Group[3]; Bumbolee Creek Formation and the Tumut Ponds Beds. These strata, deformed and metamorphosed during the Early Silurian **Benambran Orogeny**, are overlain by dated **Early/Late Silurian S-type felsic volcanics, mafic volcanics, and minor fossiliferous quartz-poor to quartz-intermediate flysch** (Wyangle Formation, Blowering Formation, Honeysuckle Beds, Ravine Beds). The latter volcanics and sediments, excluding the Ravine Beds, form the *Tumut Basin*, an interpreted Silurian pull-apart basin. Locally **tholeiitic dyke complexes** (North Mooney Complex, Micalong Swamp Mafic Igneous Complex) intruded during an extension event, which accompanied this later period of volcanism.

During the Siluro-Devonian **Bowning Orogeny** the Early/Late Silurian and older strata were meridionally folded and metamorphosed to lower greenschist facies following intrusion of **S- & I-type granitoids** (Wondalga, Green Hills and Young Granodiorites, Rough Creek Tonalite and Gocup Granite). These granitoids, forming only a minor constituent of the Tumut Synclinorial Zone, are the dominant rock types in the adjacent WMB and the Goobarragandra Block.

Early Devonian post-kinematic I-type granitoids (the Bogong and Killimicat Granites, Lobs Hole Adamellite and several minor unnamed granite bodies) intrude older units and are associated with coeval **shallow-water to subaerial ignimbrite and minor sediments** (Minjary Volcanics, Gatelee Ignimbrite, Boraig Group, Byron Range Group). These volcanic sequences form remnant subhorizontal sheets unconformably overlying older strata and granitoids. Minor outliers of flat-lying **Tertiary basalt and minor sediments** also unconformably overlie older rocks, commonly forming hill-top cappings in the region.

Extensive Quaternary alluvial and colluvial deposits of sand, gravel and clay form the floodplain of the Tumut River and its tributaries in the north of the region.

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[2] Significant differences in the description, stratigraphic position and relationships of some units from that interpreted by Basden (1990a & b) and other previous workers was indicated by Stuart-Smith (1990a). Units affected by these changes included: the Coolac Serpentinite, North Mooney Complex, Mooney Mooney Serpentinite, Honeysuckle Beds, Blowering Formation, Goobarragandra Volcanics and the Gooandra Volcanics.

[3] includes the Nine Mile Volcanics and Temperance Formation.

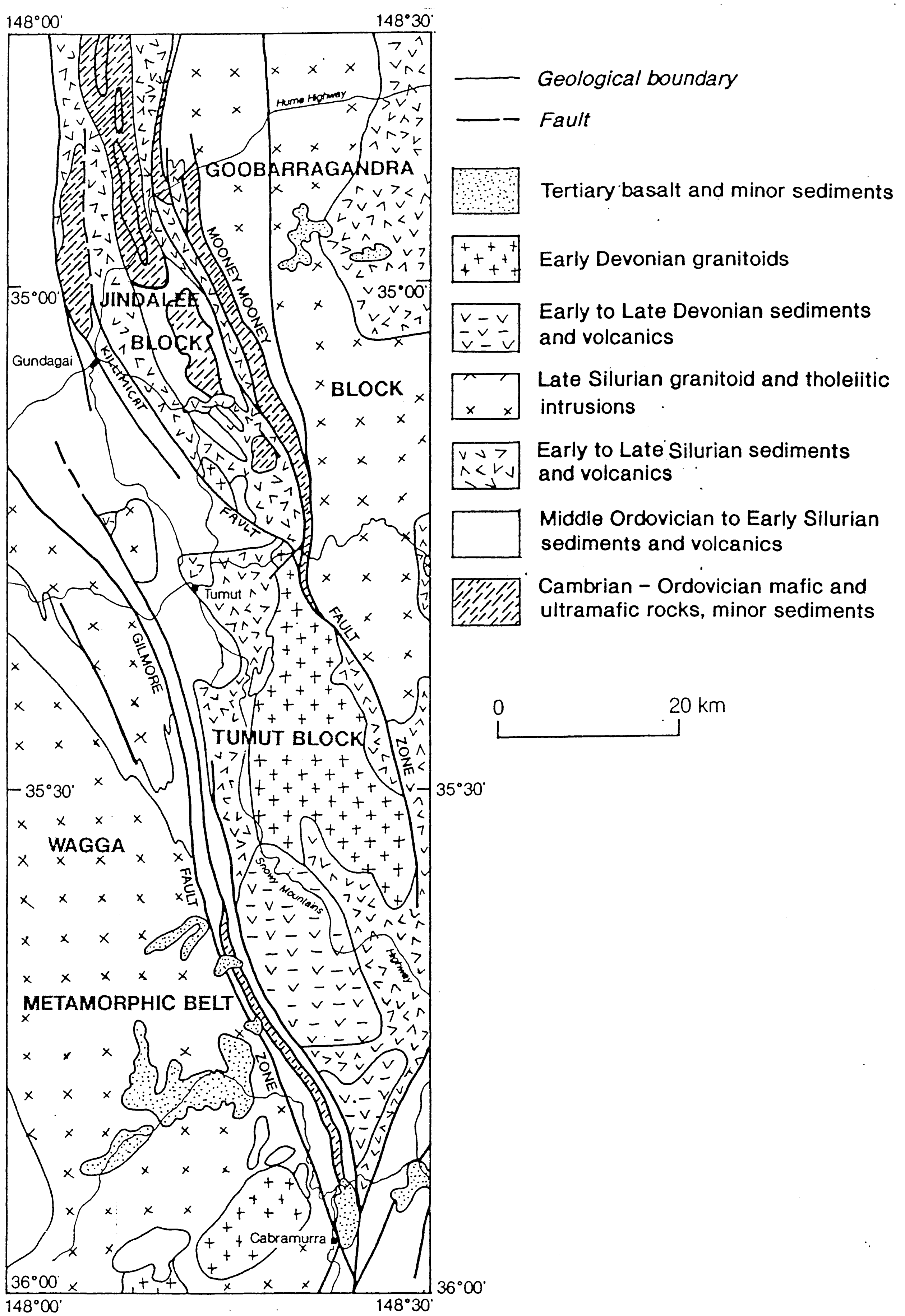


Figure 3. Generalised geology of the Tumut region.

Table 1. Summary of Palaeozoic stratigraphy of the Tumut region.

	Unit	*Description*	*Field relationships*	*Thickness (m)*	*Remarks*
CAIN-OZOIC	T	Basalt, minor limonitic pebble conglomerate, hematitic ironstone, sandstone, siltstone and sandy clay at base.	Unconformably overlies older units	<40	Forms flat-lying caps.
			UNCONFORMITY		
EARLY DEVONIAN	(Dg)	Fine-grained biotite granite; coarse-grained leucogranite.	Intrudes Oub and Ovg. Faulted against older units.		Forms minor intrusive bodies and tectonic slices within the Mooney Mooney Fault Zone. Part of Dgb?
	Killimicat Granite (Dgk)	Fine- to medium-grained equigranular granite.	Intrudes Or, Sw and Sbd.		Similar chemically to Dgb (Basden, 1986).
	Bogong Granite (Dgb)	Massive fine to medium-grained leucogranite, medium to coarse-grained equigranular biotite granite. Metasediment hornfels rafts.	Intrudes Sbd, Sbl, Oub, COc and Ow		I-type granite. Age 410±16 Ma (K-Ar on biotite; Ashley *et al* 1971).
	Benwerrin Diorite (Sdw)	Medium-grained diorite and quartz-diorite.	Intrudes Ow and intruded by Dgb (Willcock 1982).		Part of I-type Boggy Plain Supersuite (Basden 1986). Coeval with Dgb.
	Lobs Hole Adamellite (Dgl)	Porphyritic granophyric leucogranite.	Intrudes Dlv.		Subvolcanic intrusion comagmatic with Dlv (Barkas 1976).
	Byron Range Group (Dls)	Shale, limestone and arenite.	Unconformably overlies Ssr and basal part of Dlv. Faulted against Oub.	625	Shallow-marine (Moye *et al* 1969).
	Boraig Group (Dlv)	Rhyolite, rhyolitic tuff, siltstone, shale, volcanilithic arenite, and cobble conglomerate.	Unconformably overlies Ssr and Sbd. Unconformably overlain by Dls (Moye *et al* 1969). Faulted against Oub.	2400	Shield volcanic complex (Owen *et al* 1982).
	Minjary Volcanics (Dvm)	Rhyolitic tuff and ignimbrite, polymictic conglomerate and arenite.	Unconformably overlies Sgc and Oub. Faulted against Ovg and Oub.	350+	Late Early Devonian (early to mid. Siegenian) fossils (Barkas 1976). Shallow-marine to subaerial environment (Basden 1986).
	Gatelee Ignimbrite (Dt r)	Rhyolitic ignimbrite, minor basal polymictic conglomerate.	Unconformably overlies older units.	100	Forms remnants of a subhorizontal ignimbrite sheet (Ashley *et al* 1971; Kennard 1974).
			UNCONFORMITY		
EARLY/LATE SILURIAN	Gocup Granite (Sgc)	Fine to coarse-grained biotite granite; minor coarse-grained muscovite-biotite granite.	Intrudes Oub. Unconformably overlain by Dvm (Barkas 1976). Faulted against Ovg.		S-type granite (Wyborn pers comm) Age 409±2 Ma (K-Ar on biotite; Richards *et al* 1977).
	Rough Creek Tonalite (Sgr)	Coarse-grained equigranular chloritised biotite tonalite.	Allochthonous fault slices. Intrudes Ovg.		Late synkynematic S-Type granitoid (Wyborn 1977).
	Wondalga Granodiorite (Sgw)	Medium-to coarse-grained biotite granodiorite.	Intrudes On and Os.		Late synkynematic I-type granitoid (Basden 1986).
	Green Hills Granodiorite (Sgg)	Coarse-grained equigranular muscovite-biotite granodiorite.	Intrudes On and Os.		Late synkynematic S-type granitoid (Wyborn 1977; Basden 1986). Ages 406±6 Ma, 419±6 Ma, 422±6 Ma (K-Ar on biotite; Webb 1980).
	Young Granodiorite (Sgy)	Massive coarse-grained equigranular granodiorite. Minor net-vein complexes with fine to medium-grained quartz diorite. Mylonitic within the Jugiong Shear Zone.	Intrudes €Oc, Shm. Gradational with Sbd.		S-type granite. Age 417±6 Ma (K-Ar on biotite; Evernden & Richards, 1962). Coeval with Sbd.
	Micalong Swamp Basic Igneous Complex (Sm)	Dolerite, gabbro and aplite.	Intrudes So; intruded by Sgy.		Dyke complex. Age 430±9 Ma. (K-Ar on hornblende, Owen & Wyborn 1979).
	North Mooney Complex (Shm)	Gabbro and dolerite. Minor diorite, trondjhemite and albitite.	Intrudes €Oc, Sbd, Sbl, and Sh. Tectonic inclusions in €Oc.		Sheeted-dyke complex (Brown 1979) Age 426±6 Ma. (K-Ar on hornblende; Webb 1980).

Table 1 continued.

	Unit	*Description*	*Field relationships*	*Thickness (m)*	*Remarks*
EARLY/LATE SILURIAN	Honeysuckle Beds (Sh)	Massive dark green fractured altered metabasalt. Foliated near fault contacts. Pillow structures common. Minor interbedded meta-shale, silty slate, argillite, graded mafic tuff and rare fine- to coarse-grained quartz-poor arenite. Polymictic sedimentary breccia (basalt and dacite clasts) common at base.	Intruded by Shm and Sgy Conformably overlies Sbl; local basal breccia . Intertongues with and overlies Sbd.	500	Subaqueous basalt flows and minor intercalated sediments. Water depth < 1000 m (Basden 1986).
	Blowering Formation (Sbd)	Porphyritic dacite crystal tuff; porphyritic medium-grained intrusive dacite.	Conformable upright sequence, overlies Sw and intertongues with Sbl and Sh. Intrudes structurally underlying Ow. Unconformably overlies Oub.	1000	Flows and subvolcanic intrusions. Coeval with Sgy and correlative of 429±16Ma Goobarragandra Volcanics (Owen & Wyborn (1979).
	(Sbl)	Brown meta-shale and slate with silty laminae and graded very fine to coarse-grained quartz-intermediate arenite. Minor dacite flows, mafic and felsic tuff,and meta-basalt	Conformable upright sequence overlying and intertongueing with Sbd. Underlies Sh and intruded by Shm in north. Unconformably overlies Oub.	750	Proximal sedimentary volcaniclastic sequence. Early Middle Ludlovian conodonts in allochthonous limestone clasts (Lightner 1977).
	Wyangle Formation (Sw)	Shale, mudstone, fine to coarse-grained quartz-poor to quartz-intermediate arenite, polymictic conglomerate, diamictite and rare hornblende andesite .	Unconformably overlies and faulted against Ojb. Underlies, intertongues with and intruded by Sbd.	500	Allochthonous limestone blocks in diamictite contain conodonts of probable late Llandoverian to early Wenlockian age (Lightner 1977).
	Ravine Beds (Ssr)	Shale, slate, chert, graded coarse-grained volcanilithic arenite and conglomerate.	Unconformably overlain by Dlv and Dls. Faulted against Oub.	1000	Late Wenlockian to early Ludlovian (Labutis 1969).
	Goobarragandra Volcanics (So)	Dacite, volcanic breccia, tuff, volcaniclastic sediments.	Intruded by Sgy and Sm.	1000+	Subaerial and ignimbritic fissure eruptions. Age 429±16 Ma. (Rb-Sr whole-rock; Owen & Wyborn 1979)
			UNCONFORMITY		
ORDOVICIAN-EARLY SILURIAN	(Od)	Medium-grained leuco-quartz-diorite.	Intrudes Ovg,		Minor intrusion associated with Ovg
	Blacks Flat Diorite (Odb)	Medium- to coarse-grained biotite-hornblende diorite.	Intrudes COjb.		?Thermal event 417±6 Ma (K-Ar on hornblende, Webb 1980).
	Tumut Ponds Beds (Out)	Graded thickly bedded fine-to coarse-grained quartz-intermediate arenite, slate and minor quartz-rich arenite.	Lateral equivalent of Oub. ?Conformably overlies Ovg.	1000+	Deep-marine turbidite sequence.
	Bumbolee Creek Formation (Oub)	Slate and phyllite with laminae and thin beds of fine-grained quartz-rich arenite; medium- to coarse-grained quartz-intermediate arenite. Rare volcanilithic and quartz pebble conglomerate and laminated black and grey chert.	Conformably overlies and intertongues with Ouj and Ovg. Intruded by Dg and Sgc. Lateral equivalent of Out.	2000+	Deep-marine turbidite sequence. Trace fossils of indeterminate age (Atkins 1974).
	Jackalass Slate (Ouj)	Dark grey slate with silty laminae. Rare fine-grained quartz-rich and quartz-intermediate arenite.	Conformably overlies Ovg and underlies Oub. Intertongues with Ovg and Oub.	1000	Distal facies of deep-marine turbidite sequence.
	Frampton Volcanics (Ovf)	Meta-rhyolite, meta-rhyodacite, and siliceous slate.	Intertongues with Ovg.	100	Subaerial to shallow-water environment (Basden 1986). Age 425± Ma (U-Pb zircon).
	Brungle Creek Metabasalt (Or)	Meta-basalt, minor chert and meta-dolerite.	Unconformably overlain by Sw.	<1000	Flows and subvolcanic intrusions.
	Wermatong Metabasalt (Ow)	Metabasalt, chert, chert-basalt breccia; minor dolerite (Basden 1986).	Intruded by Dgb (Goldsmith 1973), Sdw (Willcock 1982) and Sbd. Structurally overlain by Sbd.	~800	Low-K tholeiite (Basden 1986). ?Correlative of Ovs and Or.
	Snowball Metabasic Igneous Complex (Ovs)	Metabasalt; minor meta-micro-gabbro, chert, siltstone and volcanilithic arenite (Basden 1986).	Intertongues with Oub and Ovg. Intruded by Dg.	~1000	Low-K tholeiite (Basden 1986). ?Correlative of Ow and Or. Forms lenses within probable deep-marine turbidite sequence.

Table 1 continued.

	Unit	*Description*	*Field relationships*	*Thickness (m)*	*Remarks*
ORDOVICIAN-EARLY SILURIAN	Gooandra Volcanics (Ovg)	Meta-andesitic lapilli and crystal lithic tuff, meta-andesite, meta-basalt, meta-rhyolite, meta-rhyolitic tuff, meta-dacite, polymictic conglomerate, silty slate, fine to coarse-grained quartz-intermediate and fine-grained quartz-rich arenite; rare jasper, laminated black chert and marble.	Conformably overain by Oub, Out and Ouj. Intertongues with Ovf, Ouj, Ovs and Oub. Intruded by Dg, and Sgr. Faulted against Oub. ?Lateral equivalent of On.	700+	Forms discontinuous volcanic aprons within probable deep-marine turbidite sequence. ?Late Darriwilian to ?early Gisbornian (Owen & Wyborn 1979).
ORDOVICIAN	Kiandra Group (Ovk)	Fine- to coarse-grained and pebbly mafic volcaniclastic metasediments, silty slate.	Faulted against Ovg.	<5000	Deep- to shallow-marine, locally subaerial. Late Darriwilian to ?late Gisbornian (Owen & Wyborn, 1979).
ORDOVICIAN	Nacka Nacka Metabasic Igneous Complex (On)	Amphibolite, metagabbro.	Intruded by Sgw and Sgg. Lateral equivalent of Ovg.		Ages 465±6 Ma and 467±6 Ma (K-Ar on hornblende, Webb 1980).
ORDOVICIAN	(Os)	Phyllite, biotite hornfels, banded quartz-albite-hornblende-biotite hornfels, chlorite schist, albite-biotite-muscovite hornfels.	Intruded by Sgw and Sgg. Interdigitates with On.		Metamorphosed quartz-rich flysch. Gisbornian fossils in same sequence to west (Sherwin 1968).
CAMBRIAN-ORDOVICIAN	Tumut Ponds Serpentinite (COs)	Serpentinite, talc schist, serpentinised harzburgite, metabasalt and amphibolite inclusions.	Faulted against other units.		Age unknown. Forms allochthonous tectonic slices within the Gilmore Fault Zone. ?Part of the Jindalee Group.
CAMBRIAN-ORDOVICIAN	Coolac Serpentinite (COc)	Massive well-jointed harzburgite with rare primary layering, schistose serpentinite, minor talc schist and rodingite dykes. Minor wherlite, pyroxenite and lherzolite in north. Common tectonic inclusions of gabbro, dolerite and diorite (Shm); meta-basalt (Sh); fine-grained quartzite ; biotite schist ; and granite. Anthophyllite hornfels adjacent to Dgb.	Intruded by Sgy, Shm and Dgb. Faulted against Sbl, Sbd, Sh, Dgb, Sgy and Shm.		Forms tectonic slices within the Mooney Mooney Fault Zone. ?Part of Jindalee Group.
CAMBRIAN-ORDOVICIAN; JINDALEE GROUP	Gundagai Serpentinite (COg)	Massive and schistose serpentinite, meta-pyroxenite, carbonate-talc schist.	Tectonic slivers within thrust faults. Faulted against Oub, Ouj, Ovg and Ovf.		Forms allochthonous bodies derived from basement Jindalee Group.
CAMBRIAN-ORDOVICIAN; JINDALEE GROUP	Bullawyarra Schist (Ojb)	Actinolite schist (meta-basalt and meta-dolerite)	Faulted against other units. Intruded by Odb.		Forms metamorphic core complexes and faulted allochthonous slices.

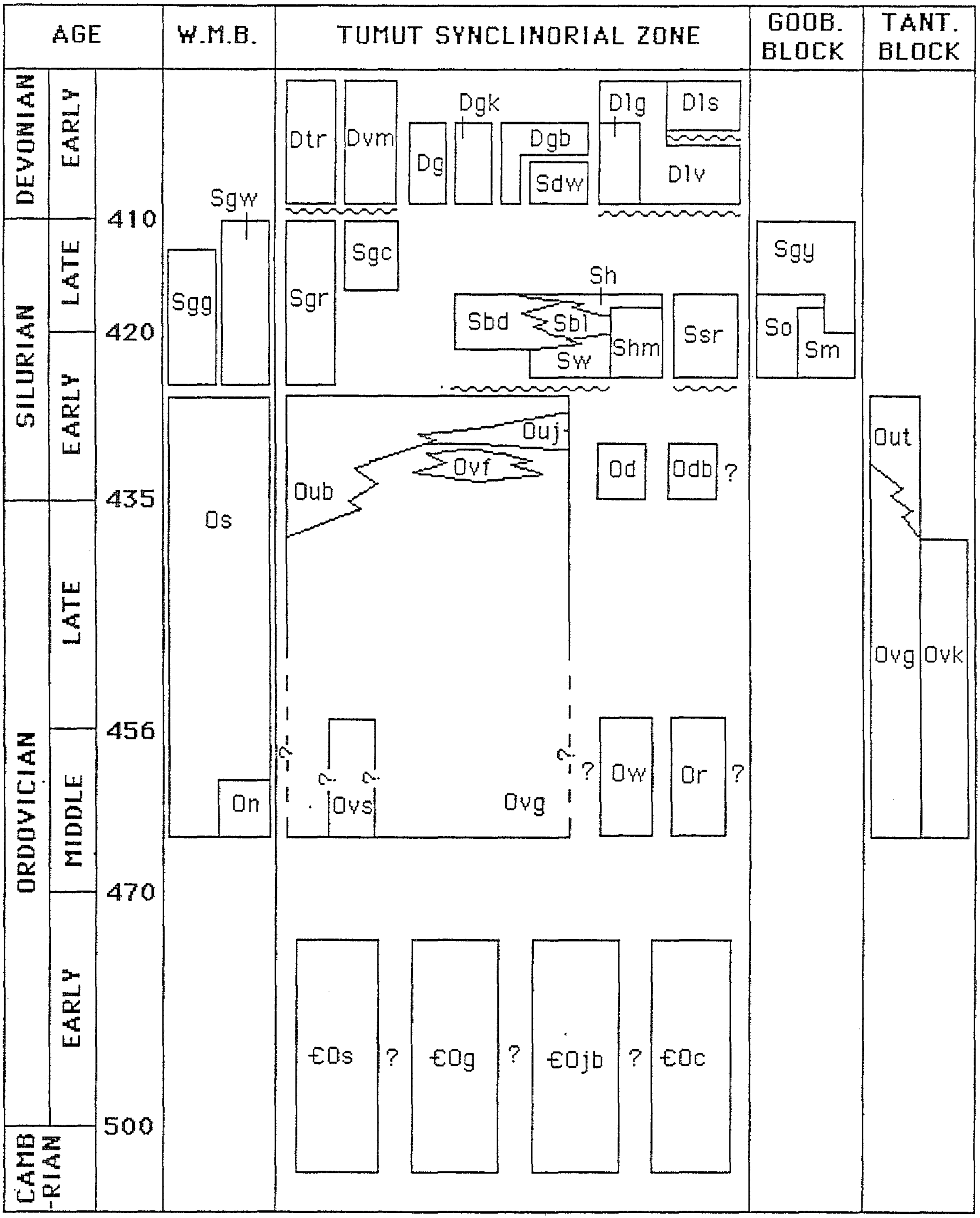


Figure 4. Diagrammatic Palaeozoic stratigraphy of the southern part of the Tumut Synclinorial Zone and adjacent parts of the Wagga Metamorphic Belt, and the Goobarragandra and Tantangara Blocks in the Tumut region. Note: unit symbols correspond to those in Table 1.

PALAEOZOIC GEOLOGICAL HISTORY OF THE TUMUT REGION

Cambrian to Ordovician basement

Although actinolite schist and ultramafics of assumed Cambrian to Ordovician age are the oldest rocks in the region, little can be ascertained about their origin, as they occur as either faulted inliers or thrust slices. The rocks, forming structural basement to Ordovician to Early Silurian and younger strata, possibly represent an Early Palaeozoic ophiolitic suite accreted to a late Proterozoic crust in the Early Ordovician (Basden 1986).

Ordovician to Early Silurian deposition

The Late Ordovician of southeastern Australia is characterised by extensive quartz-rich flysch deposits interfingering with volcanic piles and associated volcaniclastic aprons (eg. Cas 1983, Degeling et al. 1986). These volcanics are thought to be part of a palaeo-volcanic arc: the Molong Volcanic Belt formed on thin Late Proterozoic basement at the Gondwanaland margin above a westward-dipping subduction zone (eg. Degeling et al. 1986, Packham 1987) or a migrating delaminated crust (Wyborn, 1988).

In the Tumut region, deep-water (below wave-base) proximal and distal quartz-rich and quartz-intermediate turbidites form part of this sequence, interfingering with mafic and felsic volcanics and associated volcaniclastic deposits. These deposits include the Nacka Nacka and Snowball Metabasic Igneous Complexes, the Kiandra Group, Brungle Creek Metabasalt, Wermatong Metabasalt, Gooandra Volcanics, Jackalass Slate, Bumbolee Creek Formation, Tumut Ponds Beds, and the Frampton Volcanics. The Ordovician and Early Silurian stratigraphy of the region has been substantially revised. Previously, most of the above units were regarded as part of the Early Silurian *Tumut Trough* sequence. However, they are separated by a major structural discontinuity, interpreted as an unconformity, from overlying dated Early/Late Silurian volcanics and fossiliferous (late Llandoverian to early Wenlockian) quartz-poor flysch (Stuart-Smith, 1990a). These two tectonostratigraphic units are distinguished by distinct differences in arenite composition and differences in clinopyroxene-phenocryst compositions from mafic volcanics which reflect differing tectonic environments of formation. Mafic volcanics in the lower unit are interpreted as subduction-related whereas those in the upper unit (ie. Early/Late strata) have both intraplate and subduction-related characteristics. A rhyolite flow within the Frampton Volcanics yields a U-Pb age of about 425 Ma (Stuart-Smith et al., 1992) placing an Early Silurian upper limit to the volcanic arc-related environment which characterised the Late Ordovician.

Early Silurian deformation

Deposition of deep-water turbidites and mafic to felsic volcanics was terminated in the Early Silurian by a deformation, characterised by lower to sub-greenschist facies metamorphism, thrust faulting, E-W recumbent folding and later local coaxial upright folding. The deformation is comparable to the Benambran Orogeny described in Ordovician metamorphics of the adjacent WMB and is tightly constrained in the Tumut region to about 425 Ma. Fold characteristics of this deformation are indicative of thin-skinned intraplate dextral transpressional deformation rather than classical collisional tectonics, as envisaged by some workers for the Benambran Orogeny here and elsewhere in the LFB.

The structural and metamorphic history of the Cambrian to Ordovician basement in the Jindalee Block involved at least two distinct deformations at greenschist facies in addition to Siluro-Devonian sub-greenschist facies metamorphism and upright folding. The earliest deformation, of unknown age, predates diorite intrusion and the formation of high-strain zones and associated recumbent folding during the Early Silurian. As continuous prograde greenschist facies metamorphism is indicated for the two earlier deformations it is probable that both occurred during the Benambran Orogeny. High-T low-P conditions indicated for the metamorphism are comparable to those in the WMB. Apart from remobilisation of serpentinite locally into the thrusts, Cambrian-Ordovician basement rocks in the Tumut Block were largely detached from this deformation.

Early Silurian extension and basin formation

Crustal extension on the western margin of the Molong Volcanic Arc, mostly confined to the Jindalee Block in the Tumut region, immediately followed the Benambran Orogeny and resulted in the formation of the *Tumut Basin*. Evidence for this extension is preserved in inliers of Cambrian-Ordovician basement rocks and in the nature of the structural and metamorphic discontinuity separating basement and cover units (Stuart-Smith, 1990b). This discontinuity is a major, originally subhorizontal, fault zone characterised by massive breccias and cataclasites, and extensive chlorite and carbonate alteration. The zone is interpreted as the major detachment associated with attenuation of Ordovician-Early Silurian strata and associated basement uplift in a manner similar to that described for metamorphic core complexes. High-strain zones, subconcordant to this detachment, are present in the basement and are characterised by a ubiquitous mineral-elongation lineation. These zones record a discontinuous history of ductile followed by brittle behaviour, consistent with an extensional origin. They probably represent reactivated thrust faults formed during the preceding deformation.

The indicated south-southeast to southerly extension direction, subparallels the Mooney Mooney Fault Zone consistent with the basin forming a narrow pull-apart basin, as a result of dextral transtension between a jog in the Mooney Mooney Fault Zone and the Killimicat Fault (Fig. 5). The detachment fault probably linked into both strike-slip faults at depth, dipping southwards beneath the Goobarragandra Block. Unlike typical extension terranes, such as those associated with the Cordilleran metamorphic core complexes and back-arc terranes, the *Tumut Basin* grew in length rather than width.

Major movement on the detachment took place prior to deposition of late Llandoverian to early Wenlockian (Early Silurian) quartz-poor to quartz-intermediate flysch (Wyangle Formation), which unconformably overlies both the basement and Ordovician to Early Silurian strata. These sediments, deposited in shallow-marine conditions, exhibit rapid facies changes, filled interpreted steep-sided fault-bounded troughs and onlapped the underlying basement and attenuated cover. Basal flysch deposits were sourced from both older mafic volcanics and penecontemporaneous felsic volcanics. Later felsic and mafic volcanics were extruded filling the narrow basin formed within the Jindalee Block and covering parts of the adjacent Tumut Block. About 2500 m of strata are preserved in the basin, which extended for at least 80 km along the western margin of the Mooney Mooney Fault Zone, and was linked *en echelon* to a similar basin (the *Yarrangobilly Basin*) to the south (Fig. 6).

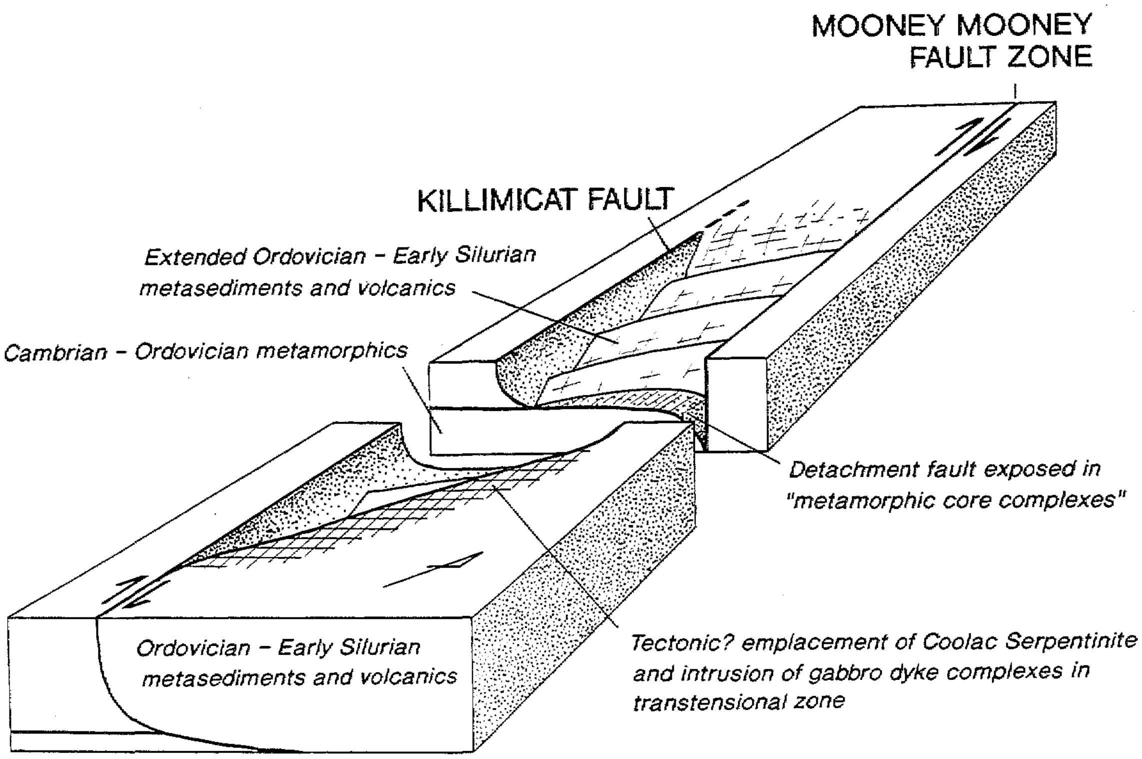


Figure 5. Schematic block diagram showing Early Silurian pull-apart model for formation of the Tumut Basin (after Stuart-Smith et al., 1992).

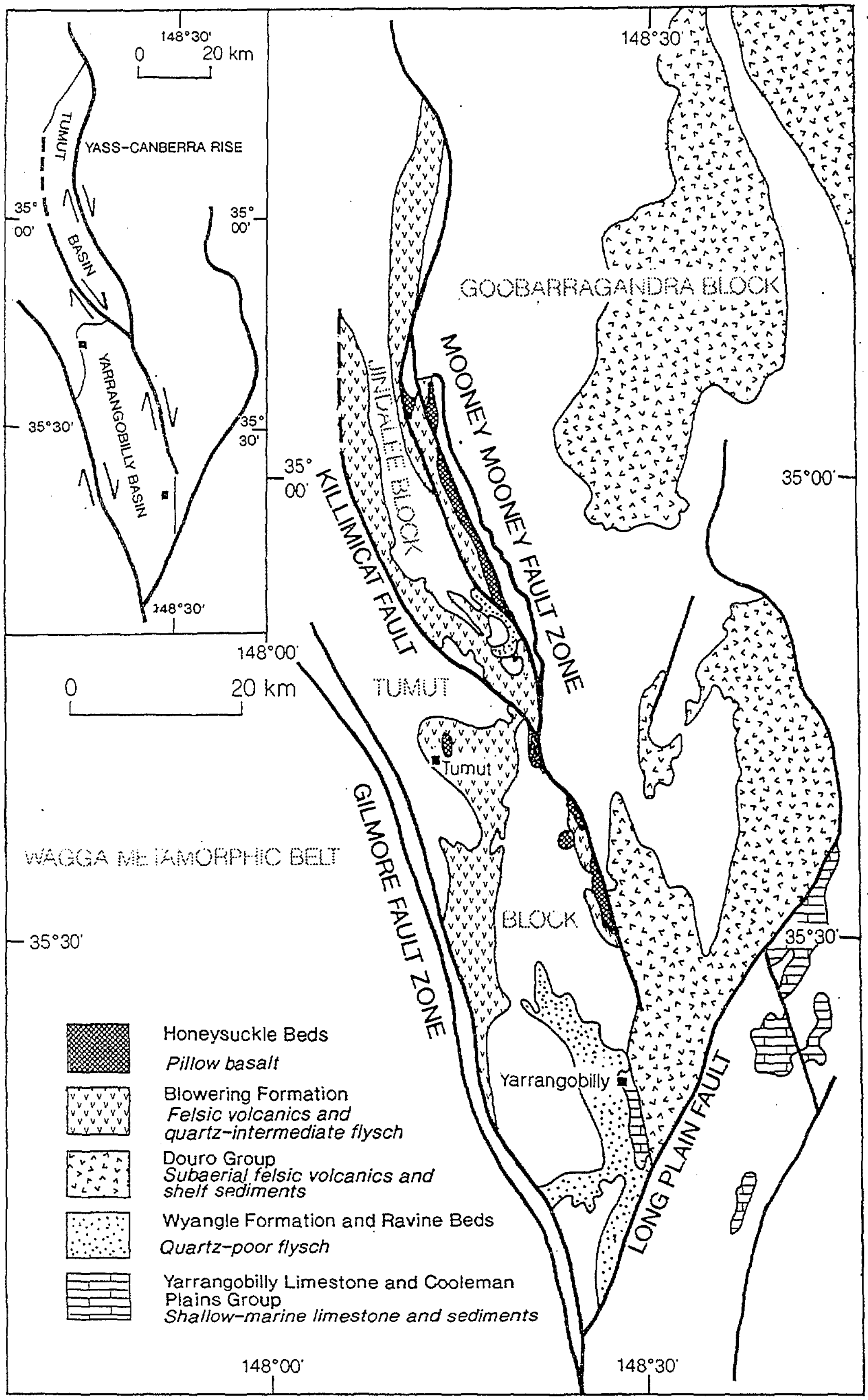


Figure 6. Distribution of post-Benambran Silurian facies in the Tumut region, showing en echelon arrangement of interpreted Silurian basins and inferred direction of Early Silurian strike-slip fault movement. Note: Mid-Devonian sinistral strike-slip movement of several kilometres occurred on the NW-trending faults displacing the Yarrangobilly Basin farther south relative to the Tumut Basin, from its originally position (from Stuart-Smith et al., 1992).

Emplacement of the Coolac Serpentinite

Intrusive relationships and the structural history of the Coolac Serpentinite (Stuart-Smith, 1990c) indicate that it was emplaced into the Mooney Mooney Fault Zone during this Early Silurian extension event and not during the Siluro-Devonian Bowning Orogeny as previously interpreted (eg. Ashley et al. 1979). Although the serpentinite may have originated as part of an ophiolitic suite, it is more appropriately interpreted as an Alpine-type body occupying a crustal suture. The serpentinite possibly represents either an Early Silurian ultramafic intrusion, or most likely, a tectonic slice derived from the underlying Cambrian-Ordovician Jindalee Group.

Gabbro and granitoid intrusion

Mantle upwellings responsible for the Early Silurian deformation and subsequent extension resulted in the generation of bimodal felsic S-type and tholeiitic magmas. Extrusion of these melts into the *Tumut Basin* and adjoining blocks was followed by widespread intrusion of granitoid plutons and gabbroic dyke complexes. The Mooney Mooney Fault Zone was the locus of the tholeiitic flows and gabbro intrusions, distinguished from their regional counterparts by lack of iron enrichment and other geochemical characteristics typical of ocean-floor basalts (Basden, 1986). This difference, used to support the inclusion of these rocks in a Silurian ophiolitic suite (Ashley et al., 1979), can be explained by their location on a major active strike-slip crustal fracture zone. Crustal thinning, associated with extension localised on the fault zone, was sufficient to allow the passage of uncontaminated mantle-derived melts in a situation analogous to the leaky Dead Sea transform.

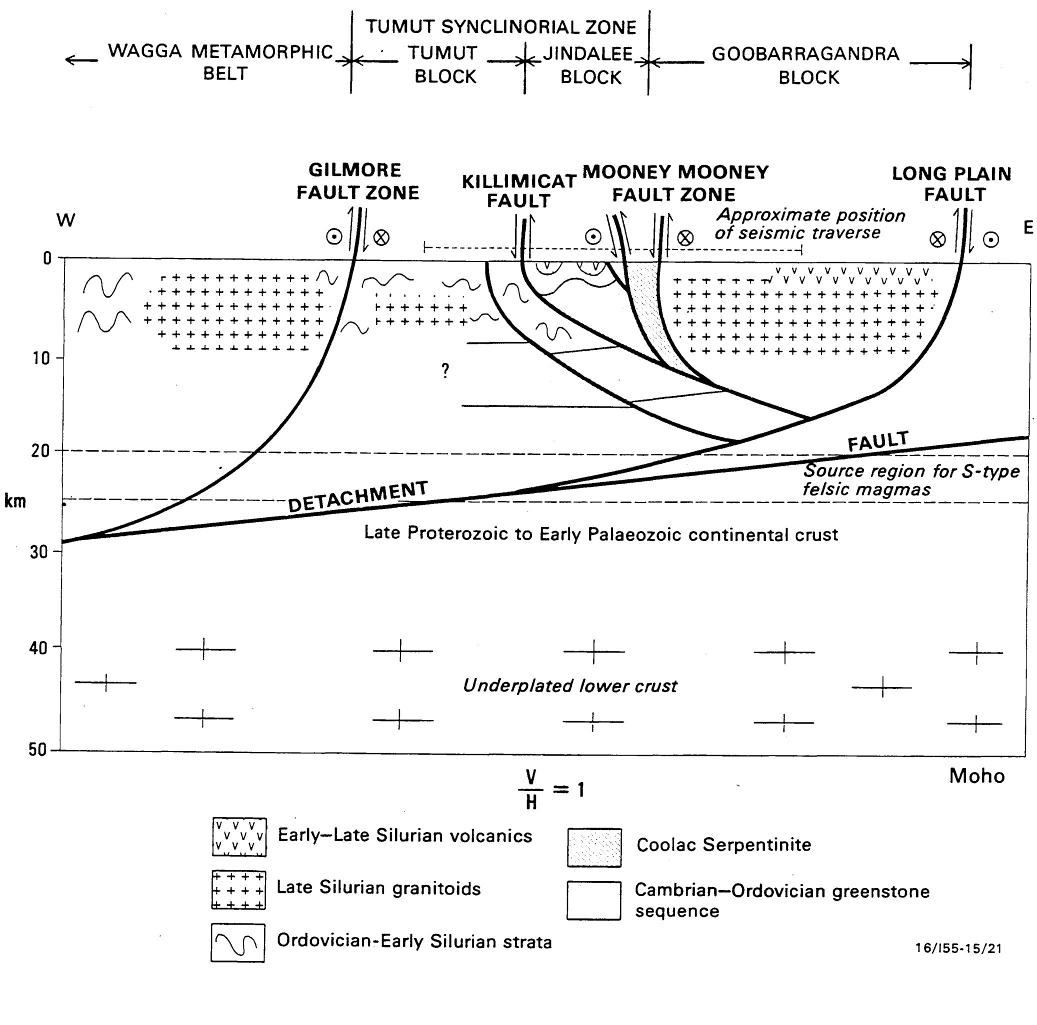


Figure 7. Schematic crustal profile for the Tumut region, showing relationship of major faults to interpreted mid-crustal detachment, based on the Tumut seismic traverse (from Stuart-Smith, 1991)

Siluro-Devonian deformation

During the Late Silurian/Early Devonian, in response to lateral compression, the WMB and the Goobarragandra Block were thrust towards one another over the Tumut Synclinorial Zone, resulting in meridional folding of older strata. Thermal gradients were still high following intrusion of the Gocup Granite and other granitoids, and in the Tumut region, regional greenschist facies metamorphism accompanied the deformation.

The Mooney Mooney and Gilmore Fault Zones, trending northwesterly, oblique to the principal-compression direction, were active imbricate sinistral strike-slip systems during the deformation. Mylonitic rocks with common *S-C* fabrics and minor structures typical of Riedel shear geometry formed in the fault zones (Stuart-Smith, 1990c, 1991). Although older structures are not preserved, the faults were probably active strike-slip zones during the Early Silurian Benambran Orogeny and subsequent extension event.

The fault zones, which share a common, complex, history of deformation since the Siluro-Devonian, are interpreted to be linked to a mid-crustal detachment together with the other major faults in the region such as the Long Plain Fault (Fig. 7). Dominantly-reverse movements occurred on the Jugiong Shear Zone and the Indi Fault, both of which were orientated orthogonally to the principal-compression direction. The latter fault is continuous with the Gilmore Fault Zone.

Devonian felsic magmatism and strike-slip faulting

Extensive flat-lying ignimbrite sheets and associated fossiliferous Early Devonian subaerial to shallow-water volcaniclastic sediments were deposited in the now cratonised Tumut Synclinorial Zone. The volcanics, forming shield volcanic complexes in places (Owen et al. 1982), were intruded by comagmatic I-type granitoid plutons of the Boggy Plain Supersuite (Wyborn et al. 1987). These felsic magmas were interpreted to be derived from a gabbroic source, underplated at the base of the crust during the Ordovician (Wyborn et al., 1987).

During the mid-Devonian and/or Carboniferous, renewed lateral compression resulted in reactivation of the Killimicat Fault and the Gilmore and Mooney Mooney Fault Zones. In the latter two zones, sinistral strike-slip faulting was locally associated with development of both chloritic cataclasite in granitic mylonite and extensive schistose serpentinite margins to contained ultramafics (the Coolac and Tumut Ponds Serpentinites) characterised by *S-C* fabrics. Within the fault zones, Early Devonian strata were openly folded, with an axial-spaced cleavage commonly developed. A total of 28 km horizontal displacement is interpreted for the Mooney Mooney Fault Zone during the mid Devonian and/or Carboniferous movement(s). The amount of displacement on the Gilmore Fault Zone, Killimicat Fault as well as earlier movements on the Mooney Mooney Fault Zone is unknown. During the waning stages of sinistral strike-slip movement conjugate NE-trending dextral strike-slip faults formed in localised transpressional zones within the Mooney Mooney Fault Zone.

EXCURSION STOPS

DAY 1

In the southern part of the Tumut region, the Tumut Block abuts the Long Plain Fault, juxtaposing Early to Late Silurian volcanic and sediments of the *Yarrangobilly Basin* against Ordovician mafic volcanics and quartz-rich flysch of the Tantangara Block.

The first day of the excursion provides a rapid transect across the Tantangara Block and briefly examines units within the *Yarrangobilly Basin* as well as examining the southern part of the Gilmore Fault Zone. Although there are some gaps in detailed structural accounts of the areas to be visited the stops will provide an insight into the stratigraphy, metamorphism and structural styles within the area, thus providing an important comparison with areas of the Tumut Block and WMB to be visited later on in the excursion. After leaving Jindabyne, the route follows the Happy Jacks road from Eucumbene Dam, joining the Khancoban-Kiandra road near Tumut Ponds Dam, and then proceeds onto Tumut via the Snowy Mountains Highway (Fig. 8).

Stop 1.1 Boltons Beds. Happy Jacks Road

(stop description modified from BMR excursion to Tantangara-Brindabella, Stop 1.4; Owen, Wyborn & Wyborn, 1976).

The Ordovician Boltons Beds, a flysch sequence of fine-grained clastic rocks with minor bands of thin-bedded chert, impure quartzite, dark slate and shale, comprise the oldest sediments in the Tantangara Block (Moye, 1953; Moye et al., 1969). The rocks grade into the overlying Temperance Formation.

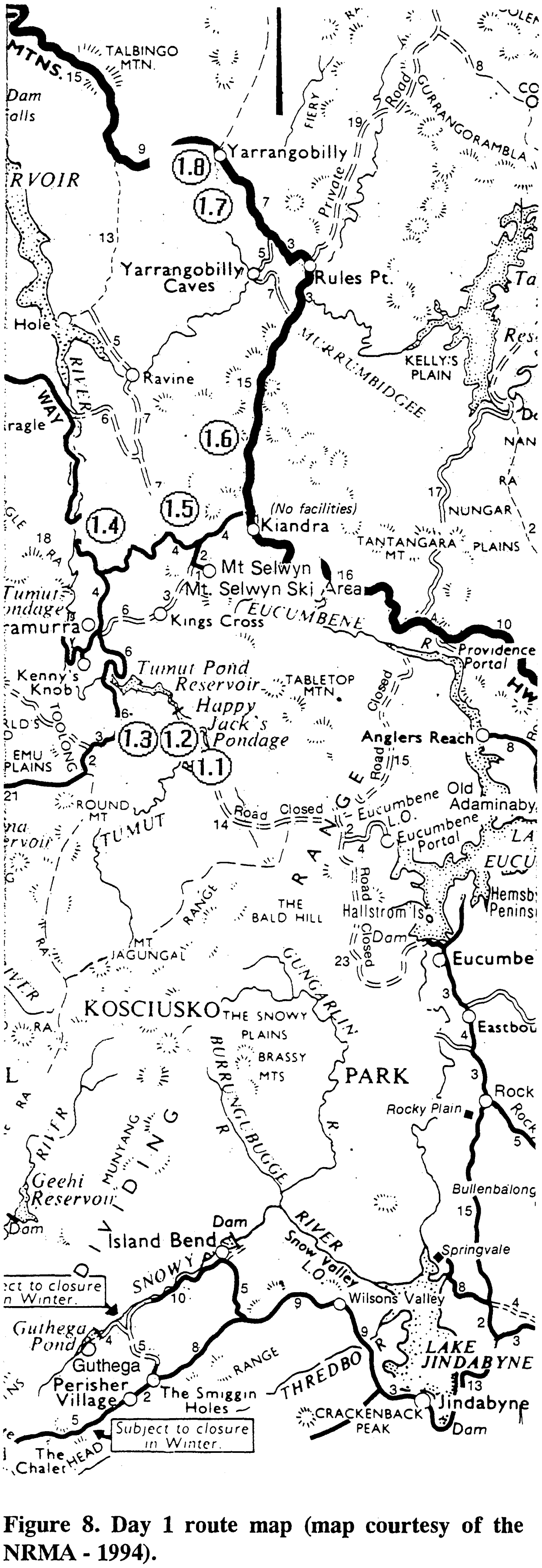


Figure 8. Day 1 route map (map courtesy of the NRMA - 1994).

At this locality the unit is contact metamorphosed by the Early Devonian Dodger Diorite (Boggy Plains Supersuite); however, sedimentary structures, including parallel lamination, convolute lamination and ripple cross lamination are well preserved in the quartz-rich distal flysch sequence. The presence of minor interbedded chert beds indicates that this locality is within the upper part of the unit.

Stop 1.2 Temperance Formation

(stop description modified from BMR excursion to Tantangara-Brindabella, Stop 1.7; Owen, Wyborn & Wyborn, 1976).

In the Tantangara Block the oldest deformation preceded deposition of the Early Silurian Tantangara Formation. as the unit unconformably overlies the Ordovician Nugar Beds (correlative of the Boltons Beds). However, the nature of this deformation is not well known owing to the intensity of meridional folding during the middle Llandoverian (Early Silurian), which preceded deposition of the Upper Llandoverian-?Lower Ludlovian Peppercorn Formation (Owen & Wyborn, 1979a). The timing of this second phase is similar to the ~425 Ma old (Benambran) recumbent folding within the Ordovician - Early Silurian flysch in the Tumut Block. The effects of the Siluro-Devonian Bowning Orogeny in the Tantangara Block appears to vary considerably from meridional to local latitudinal folding.

An isoclinal fold within the Temperance Formation is exposed at this stop. The fold, within an axial-plane dipping 60° to 230°, has been interpreted by Williams (mentioned in Owen et al., 1976) as an early fold lying on the southwestern limb of a younger NW-trending anticline, formed during the second phase of folding. More folds can also be seen along the roadside, for 350 m (and across the bridge), in the well-bedded chert and tuffaceous sedimentary sequence .

Stop 1.3 Nine Mile Volcanics

(stop description modified from BMR excursion to Tantangara-Brindabella, Stop 1.8; Owen, Wyborn & Wyborn, 1976).

The Nine Mile Volcanics, part of the Ordovician Molong Volcanic Arc, comprise high-K phyric basalt and basaltic tuff interbedded with shales, chert, tuffaceous siltstone and feldspathic volcaniclastics (Owen & Wyborn, 1979a). The volcanics, deposited in deep to shallow-marine and locally subaerial environments, pass laterally into the Temperance Formation; the boundary being defined by the predominance of lavas and tuffs in the volcanics. Minor hornblendite and monzonite dykes are associated with the volcanics.

The Nine Mile Volcanics at this stop form a steeply dipping exposed section of mostly of shales, chert, tuffaceous siltstone and feldspathic volcaniclastics. Graded beds indicate the strata are upwards facing. A subvertical penetrative slaty cleavage is also present. The volcaniclastics are composed mainly of a metamorphic assemblage of calcite + chlorite + albite ± quartz ± muscovite.

The volcanics are unconformably overlain by columnar-jointed Tertiary basalt flows at the top of the hill. Fallen columns of the basalt and imported (dumped) blocks of the Dodger Diorite can also be seen at this locality.

Stop 1.4 Gilmore Fault Zone, Section Creek

The Gilmore Fault Zone is a long-lived imbricate fault system separating the WMB from the Tumut Synclinorial Zone. The geology of the southern part of the zone is shown in Figure 9. Structures within the fault zone indicate dominantly sinistral transpressional movements during regional deformation in the Siluro-Devonian and mid-Devonian and/or Carboniferous (Stuart-Smith, 1991). The movements, in response to lateral compression, resulted in the WMB being thrust over the Tumut Block. In addition, strike-slip movement may be inferred during Early Silurian regional deformation and Early Silurian extension. Common structural and metamorphic histories, and lithological correlation of rock units straddling the fault zone indicate that the Gilmore Fault Zone does not represent a terrane boundary in either the Late Ordovician or Silurian, as suggested by some previous workers. Differences in geophysical expression and crustal composition across the zone can be explained by the zone being a reactivated basement fault linked to a mid-crustal detachment.

The Section Creek aqueduct provides an excellent 2000 m section through the western portion of the southern part of the Gilmore Fault Zone. The section includes the deformed eastern margin of the Green Hills Granodiorite (WMB) and highly deformed and faulted slivers of Gooandra Volcanics, Rough Creek Tonalite and Tumut Ponds Serpentinite (Figs 10 & 11).

The aqueduct access road traverse commences at the Tumbarumba road turnoff in massive to weakly foliated granodiorite of the Green Hills Granodiorite and passes eastwards through a progressively more deformed zone about 500 m wide. At vent 8100, about 1.6 km from the turnoff, the granodiorite is mylonitic with a foliation dipping about 80° ESE. A mineral elongation lineation pitches 45° to 50° S and *S-C* fabrics indicate west-side up movement. Over the next 50 m section ultramylonite zones and tectonised slivers of carbonate-chlorite schist (probably altered Gooandra Volcanics) are common. The mylonitic foliation in this zone is, in places, deformed by later closely spaced NE-dipping shear planes.

A faulted slice of Rough Creek Tonalite, about 100 m wide, separates the mylonite margin of the Green Hills Granodiorite from highly deformed Gooandra Volcanics farther to the east. A deformed, intrusive contact between the tonalite and the Gooandra Volcanics has been observed at this locality in 1975 by D. Wyborn (personal communication, 1993) but is not evident in the present exposure. The tonalite is weakly foliated, extensively silicified, fractured and brecciated with cataclasite zones present in places. Fractures in the tonalite subparallel the foliation in the adjacent granodiorite and highly deformed and altered mafic rocks of the Gooandra Volcanics, dipping steeply to the east with slickenlines pitching about 40° S.

The remainder of the section is mostly interbedded phyllite and fine-grained quartz-rich arenite with lesser quartz-intermediate arenite. Bedding and cleavage are mainly parallel, trending north, and graded bedding is preserved in places. Boudinaged quartz veins (Fig. 12) indicate down-dip extension.

The traverse ends in a 200 m section through the Tumut Ponds Serpentinite. Here, the unit is mainly a massive breccia with interspersed zones of foliated altered (talc, dolomite) serpentinite. The breccia contains a mixture of mafic and ultramafic clasts including foliated gabbro and metapyroxenite.

Stop 1.5 Long Plain Fault, Kiandra - Khancoban road

The Kiandra - Cabramurra road crosses the NNE-trending Long Plain Fault about 5 km west of Kiandra. The fault, separating meridional-trending Silurian and Early Devonian rocks of the Tumut and Goobarragandra Blocks to the north from tightly folded NNE-trending Ordovician-Silurian volcanic and flysch sequences of the Tantangara Block (Owen & Wyborn, 1979a) to the south, has been described as a W-dipping reverse fault farther to the north where its strike is more northerly (Wyborn, 1977, Owen & Wyborn, 1979b). Farther to the south, the Long Plain Fault is truncated by the Gilmore Fault Zone, which becomes continuous with the Indi Fault (Stuart-Smith, 1991).

At this locality (Fig. 13), the fault contact is not exposed; however, tightly folded strata in the Tumut Ponds Beds, east of the fault, young westwards and

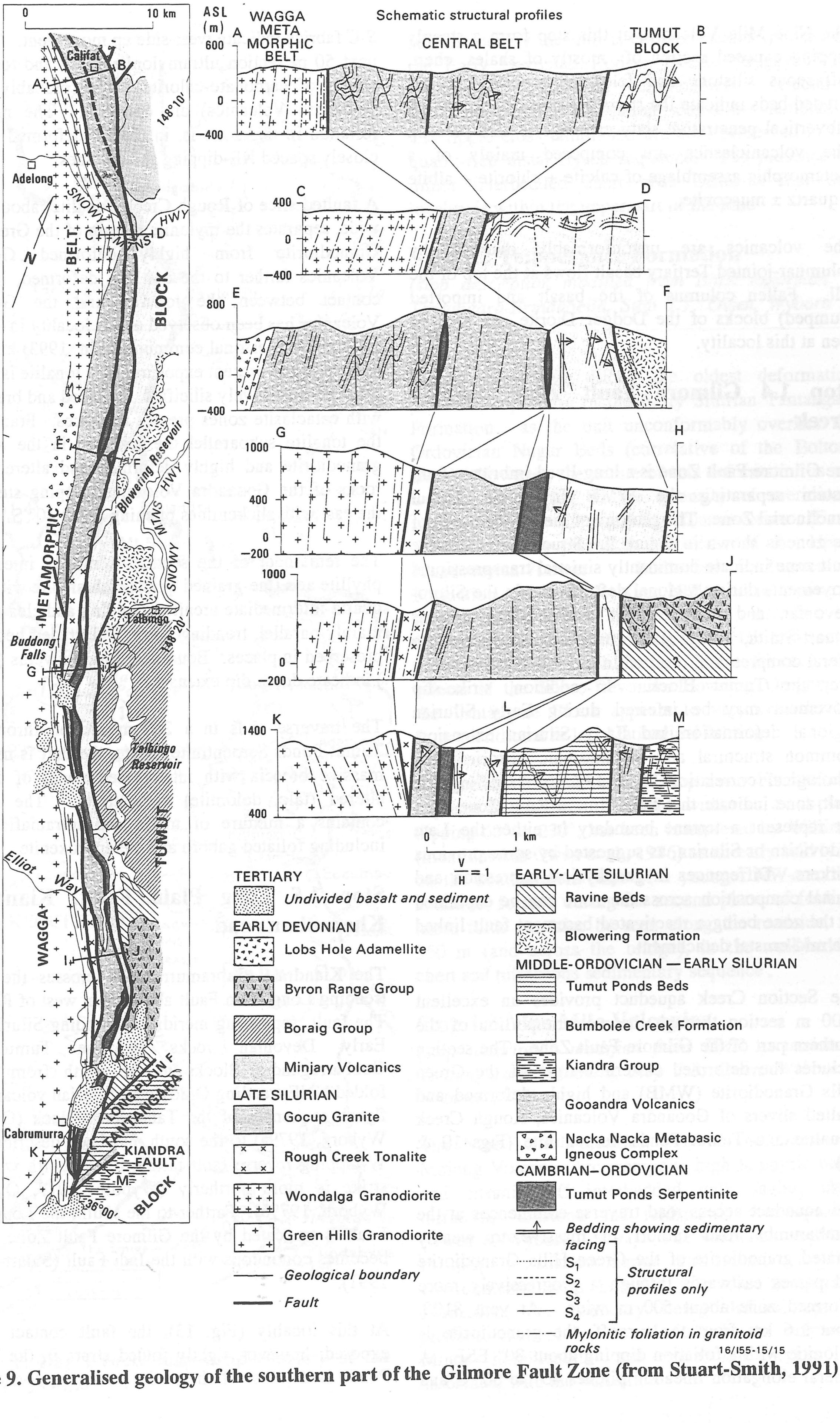


Figure 9. Generalised geology of the southern part of the Gilmore Fault Zone (from Stuart-Smith, 1991)

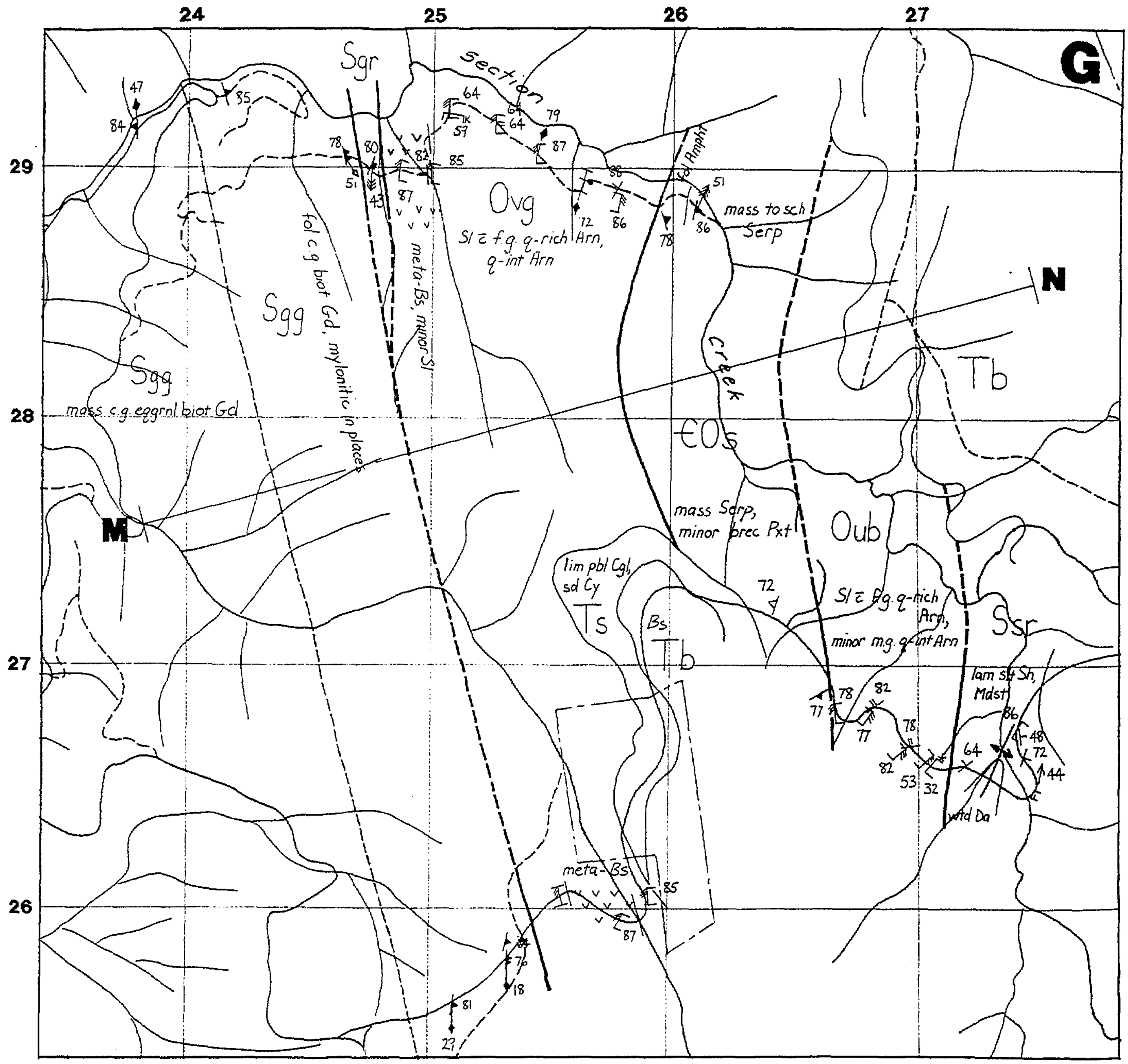
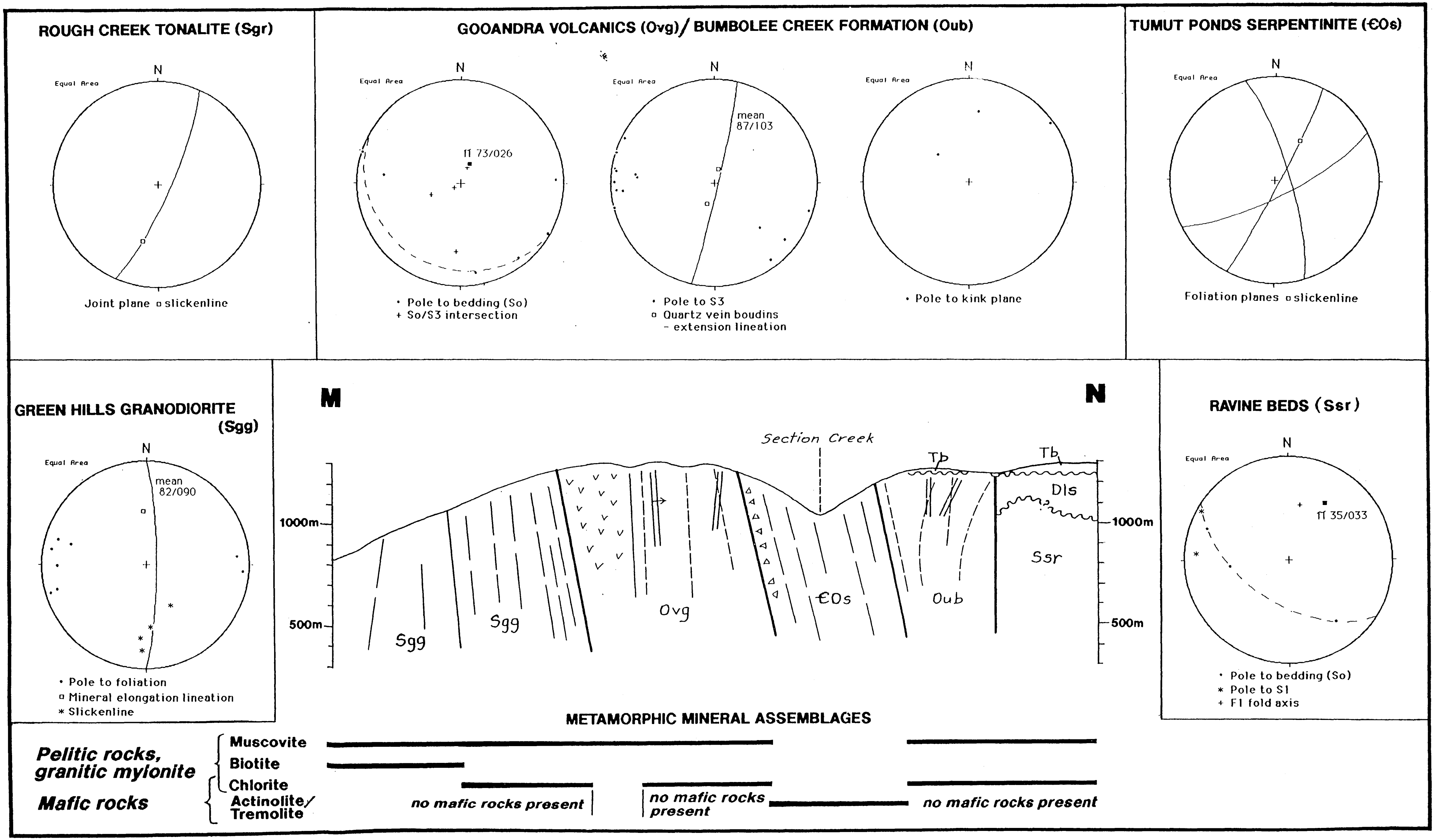


Figure 10. Geology of the Section Creek area (from Stuart-Smith, 1990d).

Figure 11. Structural profile of the Section Creek traverse (from Stuart-Smith, 1990d).

become progressively overturned approaching the fault. Within 250 m of the fault, bedding, dipping 70° SE, parallels a penetrative cleavage and the inferred fault contact. Northwest of the fault the cleavage in slate of the Ravine Beds is rotated clockwise from a near vertical N-trending orientation into parallelism with the fault at the fault contact. Minor boundinaged quartz veins are extended down-dip and are associated with rare steeply pitching slickenlines and rare quartz-fibre lineations pitching about 60°NE. The above structures are all consistent with reverse (and minor dextral) movement on the Long Plain Fault.



ROUGH CREEK TONALITE (Sgr)
Equal Area
N
Joint plane ▫ slickenline
GOOANDRA VOLCANICS (Ovg)/ BUMBOLEE CREEK FORMATION (Oub)
Equal Area
N
π 73/026
• Pole to bedding (So)
+ So/S3 intersection
mean 87/103
• Pole to S3
▫ Quartz vein boudins - extension lineation
• Pole to kink plane
TUMUT PONDS SERPENTINITE (€Os)
Foliation planes ▫ slickenline
GREEN HILLS GRANODIORITE (Sgg)
mean 82/090
• Pole to foliation
▫ Mineral elongation lineation
* Slickenline
M
N
Section Creek
Tb
Tb
Dls
1000m
500m
Sgg
Sgg
Ovg
€Os
Oub
Ssr
RAVINE BEDS (Ssr)
π 35/033
• Pole to bedding (So)
* Pole to S1
+ F1 fold axis
METAMORPHIC MINERAL ASSEMBLAGES
Pelitic rocks, granitic mylonite
Mafic rocks
Muscovite
Biotite
Chlorite
Actinolite/ Tremolite
no mafic rocks present
no mafic rocks present
no mafic rocks present

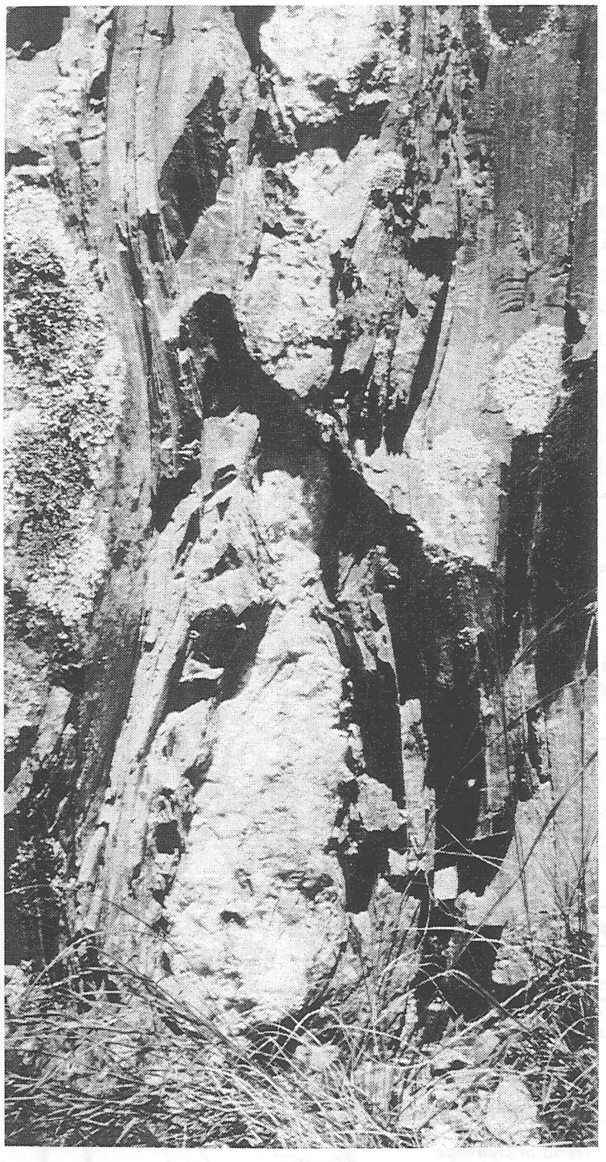


Figure 12. Boudinaged quartz veins in quartz-rich flysch of the Gooandra Volcanics, Section Creek.

Stop 1.6 Nine Mile Volcanics, Snowy Mountains Highway

(stop description modified from BMR excursion to Tantangara-Brindabella, Stop 1.12; Owen et al., 1976).

Pillows are rarely preserved within the basaltic lavas of the Nine Mile Volcanics, but can be seen at this locality. The rocks have been metamorphosed to lower greenschist facies with actinolite and albite common in the pillow cores and epidote and calcite concentrated in the pillow selvedges.

Stop 1.7 Goobarragandra Volcanics, Yarrangobilly

(stop description modified from BMR excursion to Tantangara-Brindabella, Stop 1.13; Owen et al., 1976).

The Goobarragandra Volcanics form a thick sequence of dacitic subaerial ash flow tuffs exposed along the length of the Goobarragandra Block. The volcanics, together with the correlative Blowering Formation in the adjacent Tumut Block, are chemically similar to and coeval with the Young Granodiorite, which intrudes the volcanics. The volcanics have been dated at 438±16 Ma (Rb/Sr whole rock) and 429±12 Ma (Rb/Sr biotite).

At this stop porphyritic blue and green dacite is exposed in the road cutting and passes upward into interbedded weathered acid tuff and purple shale which dip 65° to 250°. The shale is probably overlain or faulted against the Late Silurian Yarrangobilly Limestone, which crops out about 50 m to the west. Owen et al. (1976) suggested the shale may be part of the Kings Cross Shale (which overlie the Tumut Ponds Beds in the Cabramurra area).

Stop 1.8 Ravine Beds, Yarrangobilly

(stop description modified from BMR excursion to Tantangara-Brindabella, Stop 1.14; Owen et al., 1976).

The Late Silurian Ravine Beds, comprising quartz-intermediate proximal flysch, form the bulk of the Silurian *Yarrangobilly Basin* in the southern part of the Tumut Block. It conformably overlies the Yarrangobilly Limestone and is itself unconformably overlain by the Lower to Middle Devonian Boraig Group. The unit was possibly continuous with the correlative Blowering/Mundongo Formations farther to the north in the *Tumut Basin* sequence.

The quarry at Yarrangobilly exposes arenite typical of the unit. The coarse-grained arenites are composed of quartz, mafic volcanic rock fragments, chert, plagioclase and metamorphic calcite and chlorite. Rare quartz-rich arenites occur within the unit west of Yarrangobilly Caves.

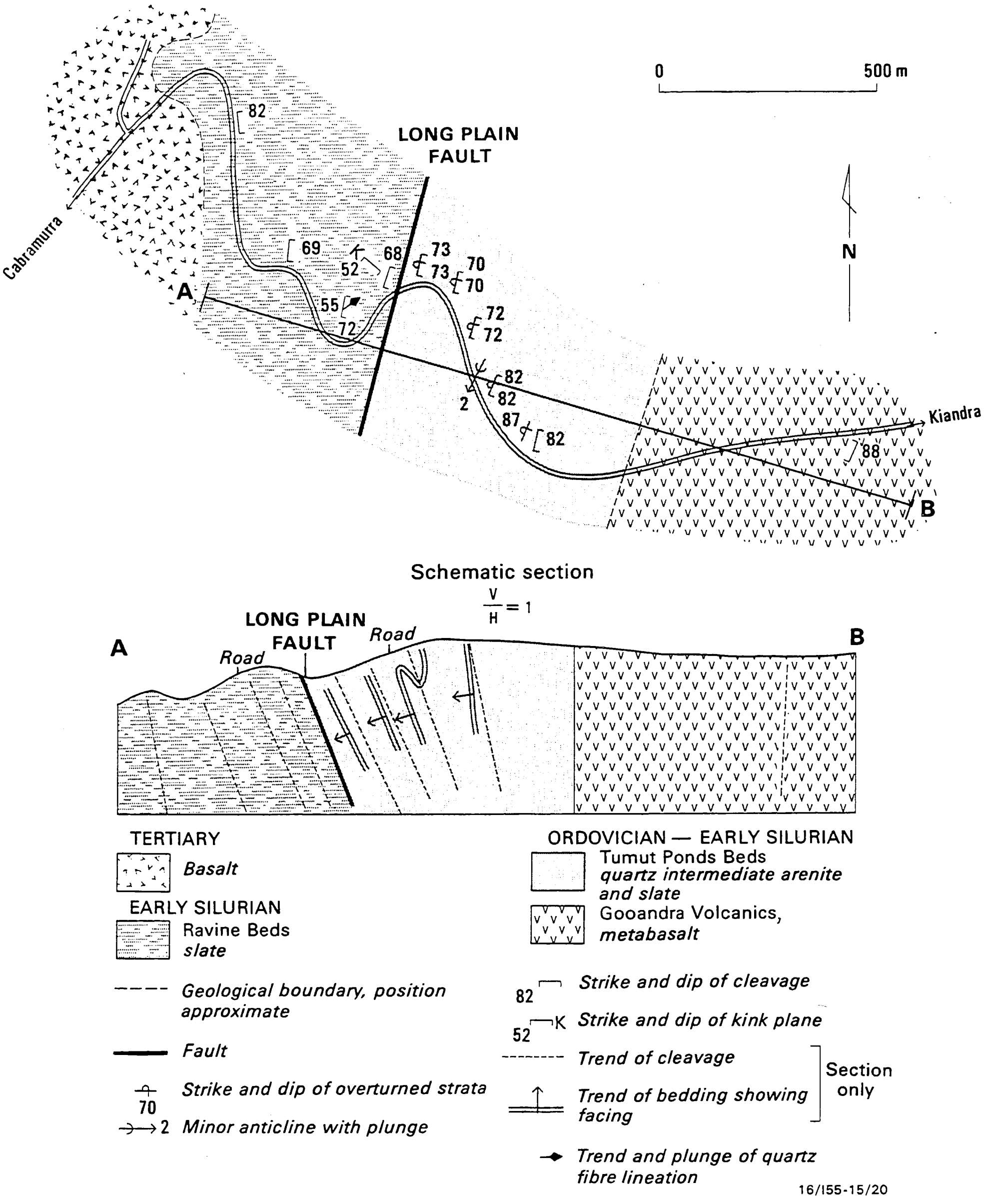


Figure 13. Geological sketch map and section across the Long Plain Fault, Cabramurra-Kiandra road (after Stuart-Smith, 1991)

DAY 2

The Gilmore Fault Zone continues to be of interest during Day 2 with two stops in the morning on the fault zone near Talbingo. However, most of the day will focus on the stratigraphy and structural history of the Tumut Block with two stops also on sections of the Mooney Mooney Fault Zone. Figure 14 shows the route for Day 2.

The Tumut Block forms the southern part of the Tumut Synclinorial Zone in the southeastern part of the LFB. The block contains two major tectonostratigraphic sequences: Ordovician-Early Silurian quartz-rich to quartz-intermediate flysch and volcanics; and an overlying fossiliferous Early-Late Silurian volcanic sequence (Stuart-Smith 1990a, Stuart-Smith et al., 1992). The former sequence will be seen at Stop 2.3, the latter at Stops 2.4 and 2.5. Rhyolite within the older sequence yields a U-Pb zircon age of about 425 Ma. Arenites from the two sequences are compositionally distinct and differences in clinopyroxene phenocryst compositions from mafic volcanics in both sequences reflect differing tectonic environments. Both tectonostratigraphic sequences were meridionally folded during the Siluro-Devonian Bowning Orogeny. An earlier deformation, characterised by thrust faulting, E-W recumbent folding and later local coaxial upright folding, is present only in the older flysch sequence. This earlier deformation (seen at Stop 2.3) is comparable to the Benambran Orogeny described in Ordovician metamorphics of the WMB and is tightly constrained to about 425 Ma. Fold characteristics of this deformation are indicative of thin-skinned intraplate transpressional deformation (Stuart-Smith et al., 1992).

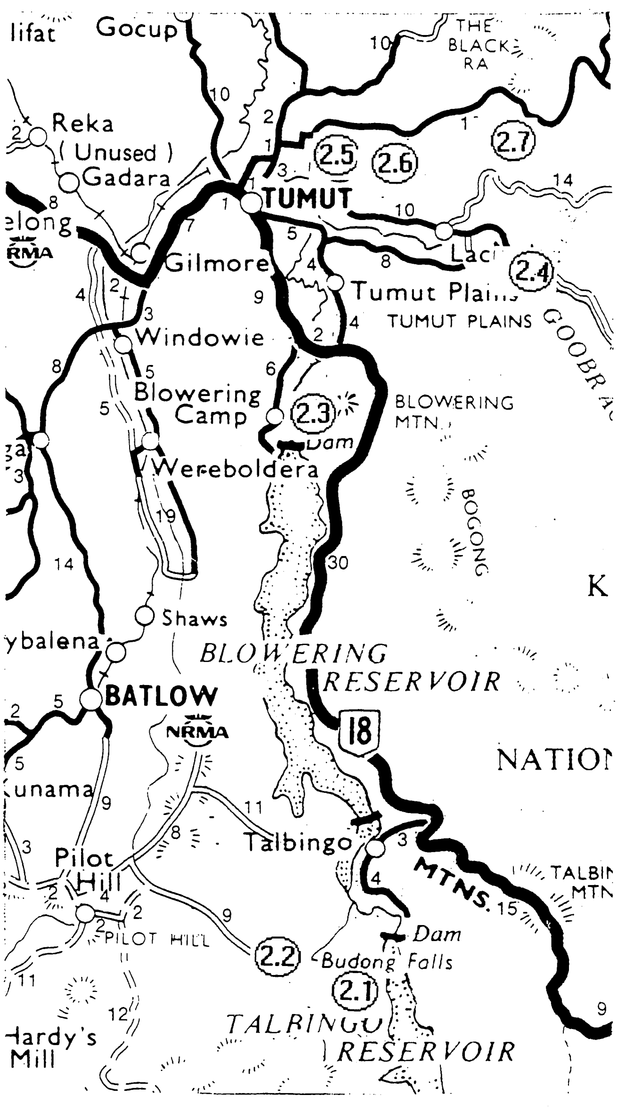


Figure 14. Day 2 route map (map courtesy of the NRMA - 1994)

Stop 2.1 Tumut Ponds Serpentinite, Gilmore Fault Zone

The road from Talbingo Dam to Buddong Falls traverses almost the entire width of the Gilmore Fault Zone with semicontinuous exposure provided by the incised road. The bulk of the zone is taken up by deformed flysch of the Bumbolee Creek Formation and metabasalts of the Gooandra Volcanics (Fig. 15). Between these two units are tectonic slivers of Tumut Ponds Serpentinite, which show a consistent structural fabric. One such exposure is examined at this stop where blocks of Gooandra Volcanics metabasalt alternate between serpentinite exposures.

The Tumut Ponds Serpentinite, together with the Rough Creek Tonalite (seen at Stop 1.4), occur as allochthonous slivers up to 600 m wide, within the central part of the Gilmore Fault Zone, extending over 25 km form Tumut Ponds Dam in the south to north of Buddong Falls. This central zone is bordered to the west by the deformed eastern margin of the WMB, and to the east by the folded and faulted western margin of the Tumut Block: the latter comprising Ordovician, Silurian and Early Devonian rocks.

The serpentinite bodies include mostly massive to schistose serpentinite, and minor metapyroxenite, serpentinised harzburgite, talc schist, metabasalt and amphibolite. Typically the margins of the bodies are schistose serpentinite with a well developed *S-C* fabric (Fig. 16). This fabric comprises a subvertical *C* plane which parallels the major faults and the main foliation in adjacent rocks (Fig. 17). A subhorizontal mineral elongation lineation is present on the *C* plane orthogonal to the intersection of the plane and a vertical N-trending flattening foliation (*S* plane). The orientation of the fabric indicates mostly sinistral strike-slip movement with minor reverse component, the C planes forming synthetic shears to the main faults (Stuart-Smith, 1990d). These structures are consistent with the youngest (post-Early Devonian) structures found in the Ordovician and Silurian units and testimony to the relative ease at which older fabrics are obliterated by successive deformations.

The metamorphic grade of the mafic and ultramafic rocks is lower greenschist facies, similar to the tonalite, metasediments and volcanics within the central belt. Pyroxenites are altered to actinolite/tremolite, and mafic rocks to chlorite + epidote assemblages.

The Tumut Ponds Serpentinite, like the Coolac Serpentinite may represent tectonic slices derived from the Cambrian-Ordovician basement, which is exposed elsewhere in the region (Stuart-Smith, 1990a, 1991).

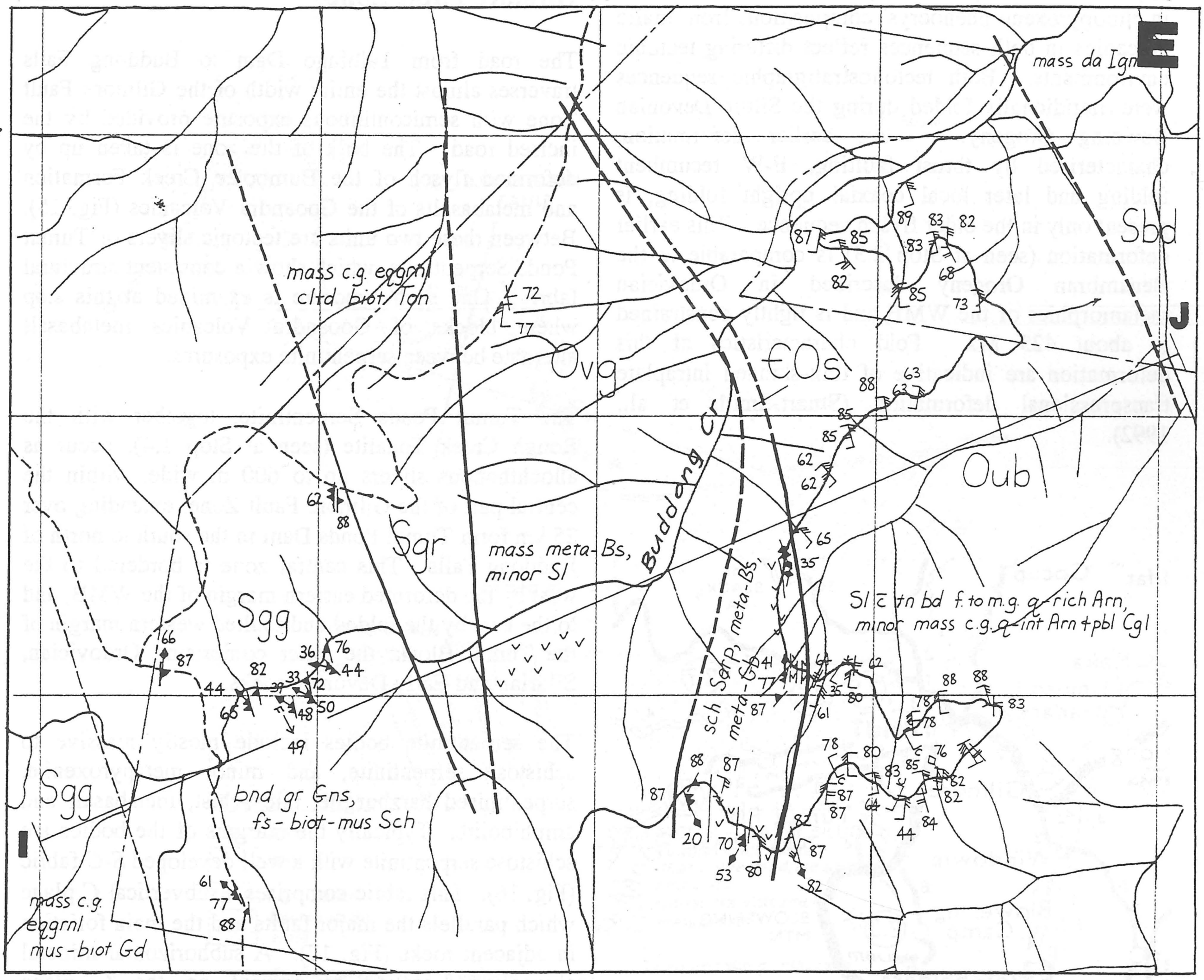


Figure 15. Geological sketch of the Buddong Falls area (after Stuart-Smith, 1990d). See Table 1 for unit symbol reference. Scale = 1:25 000.

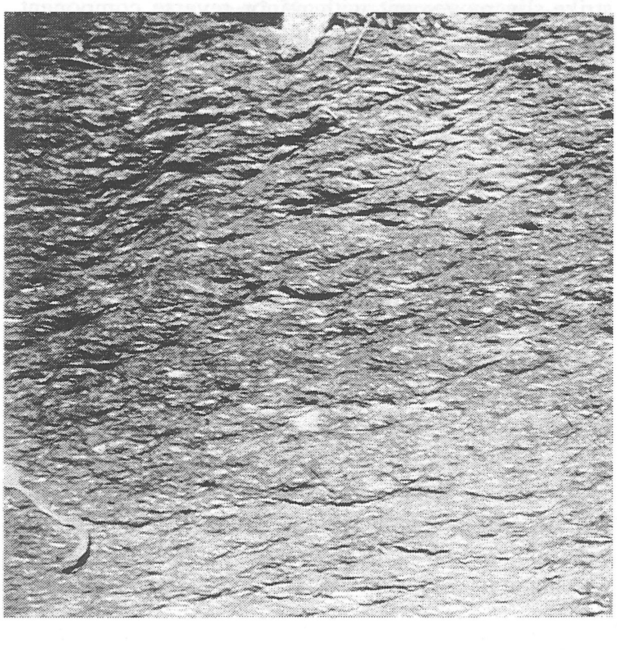


Figure 16. Typical S-C fabric developed in the Tumut ponds Serpentinite at Stop 2.1.

Stop 2.2 Gilmore Fault Zone, Buddong Falls

The deformed eastern margin of the WMB, consisting of the Wondalga and Green Hills Granodiorites and minor metasedimentary and volcanic rocks, is marked by a deformed zone up to 1300 m wide (Stuart-Smith, 1991). Both the metasediments and the normally massive granodiorites are typified in the zone by a variably developed foliation, which dips steeply to the west in the north and subvertical in the south. The intensity of deformation in the granodiorites progressively increases towards the faulted contact with the central belt, from moderately foliated to strongly foliated with ultramylonite at the contact.

The foliation is defined by aligned muscovite, biotite, ribbon-quartz mosaic and polygonised quartz lenses.

At Buddong Falls (Fig. 18), the deformed margin of the Green Hills Granodiorite, with enclaves of banded gneiss (Fig. 19), is exposed along the falls track. Deformed zones alternate with areas of more massive granodiorite and gneiss; however, overall the rocks become progressively more schistose to the east. *S-C* fabrics are well developed in places, comprising a subvertical *S* plane (83°/259°), a moderately SW-dipping *C* plane (57°/249°) with a mineral elongation pitching 43° NW. The intersection of these planes is orthogonal to the mineral lineation, in keeping with a true S-C fabric. The shear planes parallel the main fault trend (Fig. 15 & 17), thus representing synthetic shears, whereas the foliation is slightly oblique to the main fault trend and parallels the Siluro-Devonian cleavage (S3) in the adjacent metasediments.

The development of S-C fabric within the granodiorite probably occurred during the waning stages of Siluro-Devonian meridional folding of the Ordovician and Silurian rocks when the WMB was thrust over the Tumut and Tantangara Blocks (Stuart-Smith, 1991).

Stop 2.3 Bumbolee Creek Formation, Blowering Dam quarry

The complex and multiple folding history of the Ordovician to early Silurian sedimentary-volcanic sequence in the Tumut Block is spectacularly illustrated in exposures of the Bumbolee Creek Formation at the Blowering Dam quarry. The structures and sedimentary facies were described in detail by Killick (1982).

The sediments comprise a quartz-rich turbidite sequence of very thick to thinly bedded fine- to coarse-grained arenite and lesser siltstone. Sedimentary structures, including graded bedding, laminated and small-scale lenticular cross laminated tops are common and well preserved (Fig. 20).

BUDDONG FALLS TRAVERSE

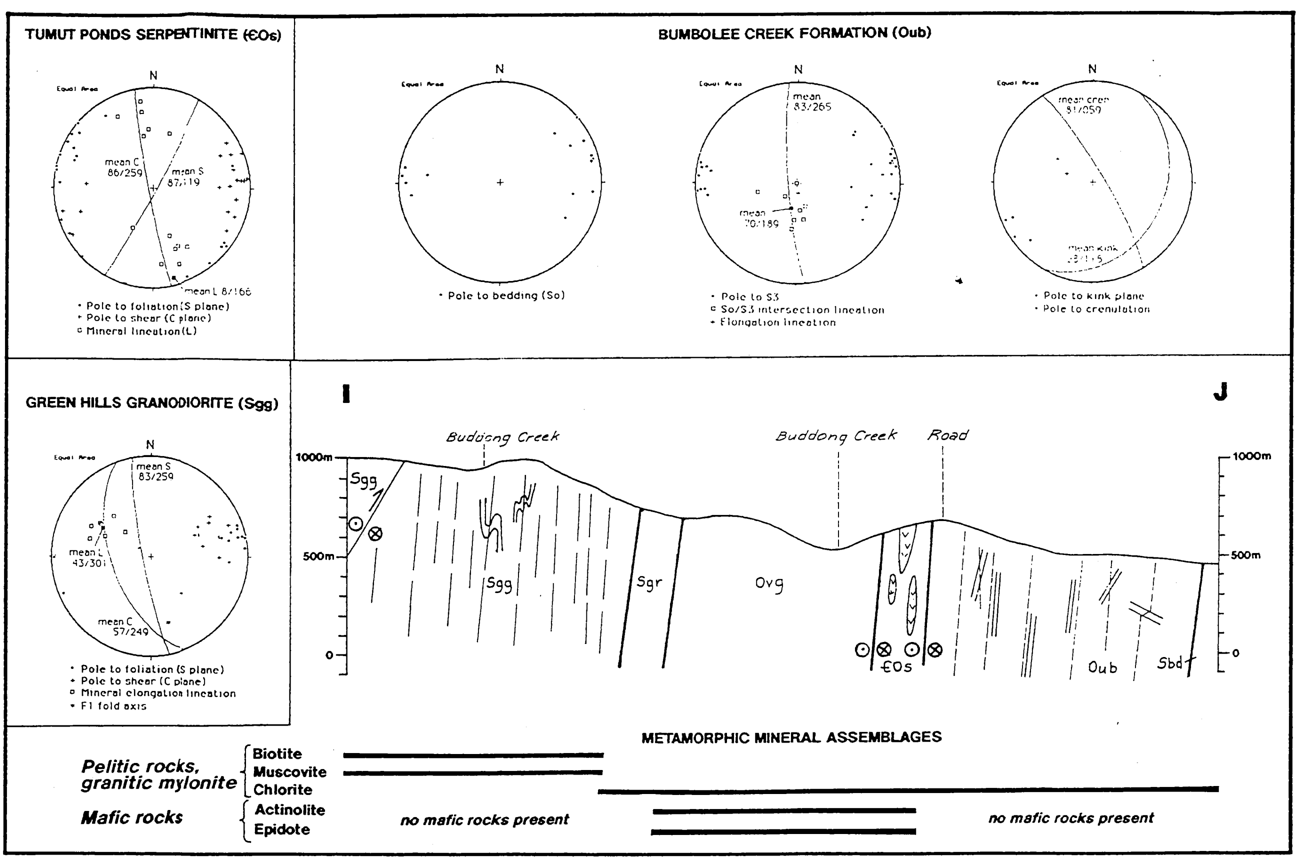


Figure 17. Schematic section and structural elements of the Buddong Falls area (after Stuart-Smith, 1990d). Note reduced scale to Figure 15.

Figure 18. The picturesque Buddong Falls, located within the deformed margin of the Wagga Metamorphic Belt, have formed owing to the more rapid incision of adjacent metasediments within the Tumut Block. For most of its length the Tumut Valley follows the Gilmore Fault Zone.

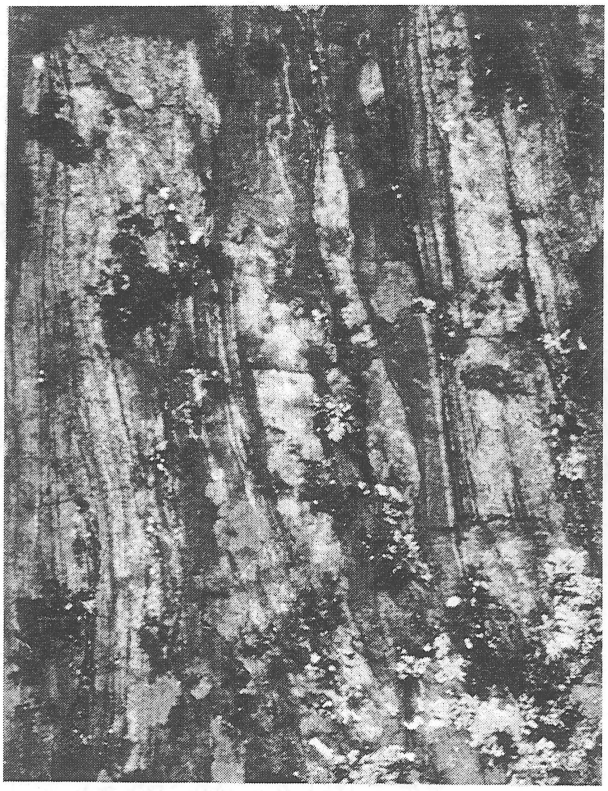


Figure 19. Banded gneiss occurs as minor enclaves within the deformed margin of the Green Hills Granodiorite at Buddong Falls.

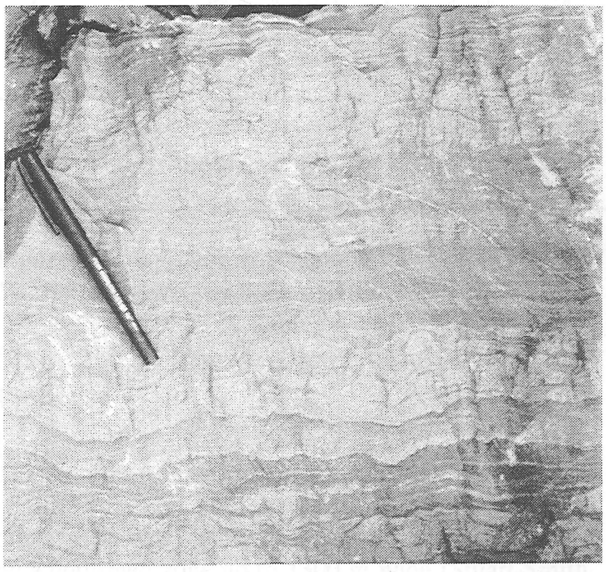


Figure 20. Graded quartz-rich arenite beds with laminated tops typical of flysch within the Bumbolee Creek Formation, Blowering Dam quarry.

The three phases of folding, present throughout the Tumut Block, are well expressed in the quarry exposures. Bedding is predominantly and shallow-dipping, forming the lower limbs of large N-facing recumbent folds. These limbs are best exposed along the eastern face of the middle bench where they are broken by a series of thrust faults (Fig. 21). Unfortunately recent quarrying operations have removed the hinge of a major recumbent fold, although remnants of the hinge are still preserved at the very top of the face. A penetrative slaty or segregation cleavage is associated with the F_1 recumbent folds. Locally the limbs are refolded by coaxial E-W trending upright open F_2 folds with and axial crenulation. Both the F_1 and F_2 folds probably developed in the regionally deformed zone adjacent to the Gilmore Fault Zone during the Benambran Orogeny at about 425 Ma (Stuart-Smith et al., 1992).

Later, upright, downward facing F3 folds formed during the Siluro-Devonian Bowning Orogeny, are exposed in faces at the northern end of the quarry. Here the folds are subhorizontal, trending SSW, locally with an associated axial crenulation and quartz veins. This fold phase corresponds to the only folds present in the overlying *Tumut Basin* sequence and forms the dominant regional map-scale structures in the region.

Figure 21. Graded arenite beds within the Bumbolee Creek Formation forming the lower limbs of F_1 recumbent folds are disrupted by thrust faults, Blowering Dam quarry.

Stop 2.4 Mooney Mooney Fault Zone - Bogong Granite/Coolac Serpentinite contact, Goobarragandra

The Early to Late Silurian volcanics and flysch of the Tumut region are interpreted to have been deposited in an elongate pull-apart basin (the *Tumut Basin*), about 80 km long, flanking the Mooney Mooney Fault Zone (Stuart-Smith et al., 1992). This fault zone, active during basin extension, separated basinal shallow-marine deposition of the Wyangle, Blowering, and Mundongo Formations and Honeysuckle Beds to the west from subaerial deposition of the Goobarragandra Volcanics, and coeval granite intrusion (Young Granodiorite) to the east. The fault zone contains an ultramafic belt - the Coolac Serpentinite (Fig. 22). This belt and adjacent volcanics are intruded by Early Silurian gabbro dyke complexes and syn-kinematic Late Silurian granodiorite. These intrusive relationships indicate that the ultramafic rocks were present in approximately their present structural position prior to the Siluro-Devonian deformation. The ultramafics probably represent either Early Silurian or Cambrian-Ordovician mantle-derived material which was emplaced within the fault zone during Early Silurian oblique extension (Stuart-Smith, 1990b).

The generalised geology of the fault zone is given in Figure 22 and Figure 23 shows the main structural elements. A complex reactivation history for the imbricate fault zone is interpreted with four phases of movement interpreted (Stuart-Smith, 1990c). These are:

(1) dextral strike-slip movement during early Silurian extension,

(2) reverse (east-side-up) movement during the Siluro-Devonian Bowning Orogeny - formation of the Jugiong Shear Zone,

(3) mid -Devonian sinistral strike-slip movement - formation of the schistose serpentinite margin,

(4) conjugate NE-trending dextral strike-slip faulting in localised transpressional zones during waning stages of sinistral strike-slip movement.

This excursion will inspect the Mooney Mooney Fault Zone at three localities (Stops 2.4, 2.7 & 3.4) where different aspects of this structural history are evident.

At this stop in the Goobarragandra River Valley near 'Federal Park', a cutting on the main road passes through the Coolac Serpentinite exposing the western contact. Here the southern extension of the Coolac Serpentinite is about 50 m wide and separates the Early Devonian Bogong Granite to the southwest from the Late Silurian Young Granodiorite to the northeast. Near the contact the Bogong Granite, a medium, equigranular biotite granite, is extensively chloritised and cut by ultracataclasite veinlets. Within 1 m of the serpentinite contact the granite is entirely converted to ultacataclasite. This style of deformation (ie chloritic cataclasites) is typical of the third phase and contrasts sharply with the mylonite developed in the Young Granodiorite exposed 200m to the southeast along the road. The mylonitic foliation (70°/055°) with a mineral elongation pitching about 65° SE formed earlier during Siluro-Devonian reverse (east-side-up) movement (second phase). The serpentinite is schistose melange with a consistent fabric in places (such as in the quarry) consisting of a steep NE-dipping shear plane (80°/035°) and a steep SW-dipping foliation (80°/230°). This fabric is consistent with *S-C* fabrics developed elsewhere in the belt, indicating mainly sinistral strike-slip movement (third phase).

Stop 2.5 Mundongo formation, Bumbolee Creek road

Early to Late Silurian volcanic rocks and associated sediments in the Tumut region comprise predominantly crystal-rich dacitic volcaniclastic rocks (Blowering Formation, Goobarragandra Volcanics) and less abundant fine-grained, volcanogenic sedimentary rocks (Mundongo formation) locally overlain by pillow basalt (Honeysuckle Beds) and overlying basal quartz-poor flysch of the Wyangle Formation. The dacitic rocks have been interpreted as ash flow and air fall tuffs (Owen & Wyborn, 1979; Basden, 1990a). The Wyangle Formation, Mundongo formation and sedimentary rocks in the northern Goobarragandra Volcanics were probably deposited in a marine environment below wave base, dominantly by mass flow processes (Lightner, 1977, Stuart-Smith & Dadd, 1993).

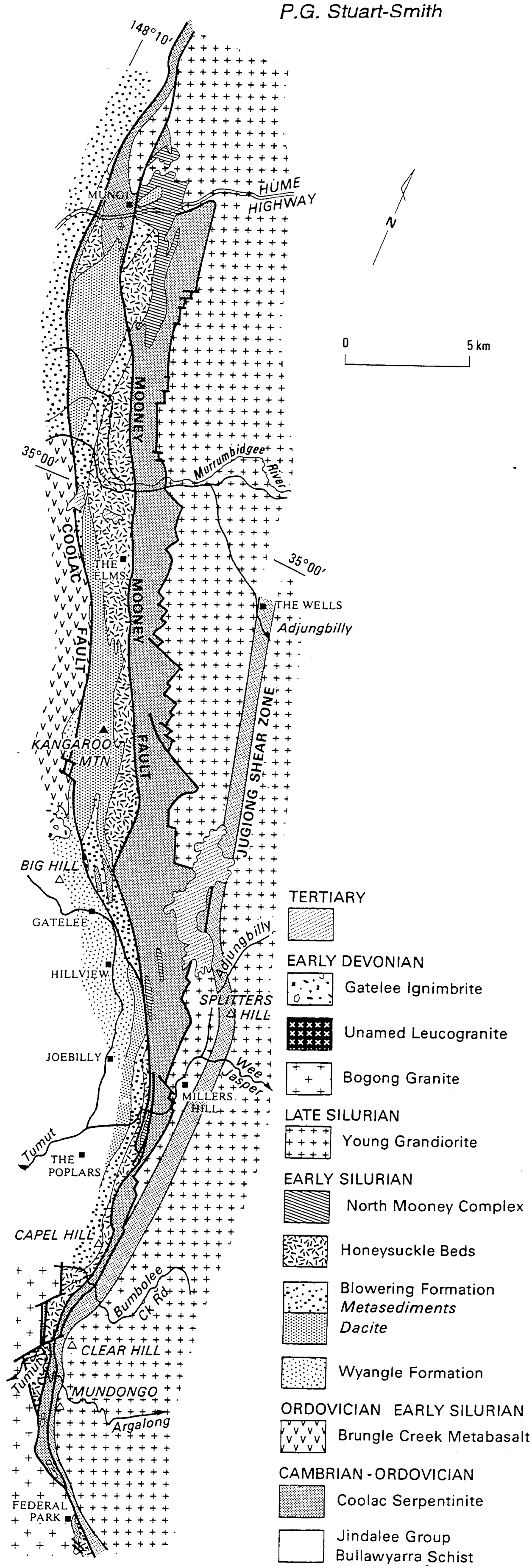


Figure 22. Generalised geology of the Mooney Mooney Fault Zone (after Stuart-Smith, 1990c).

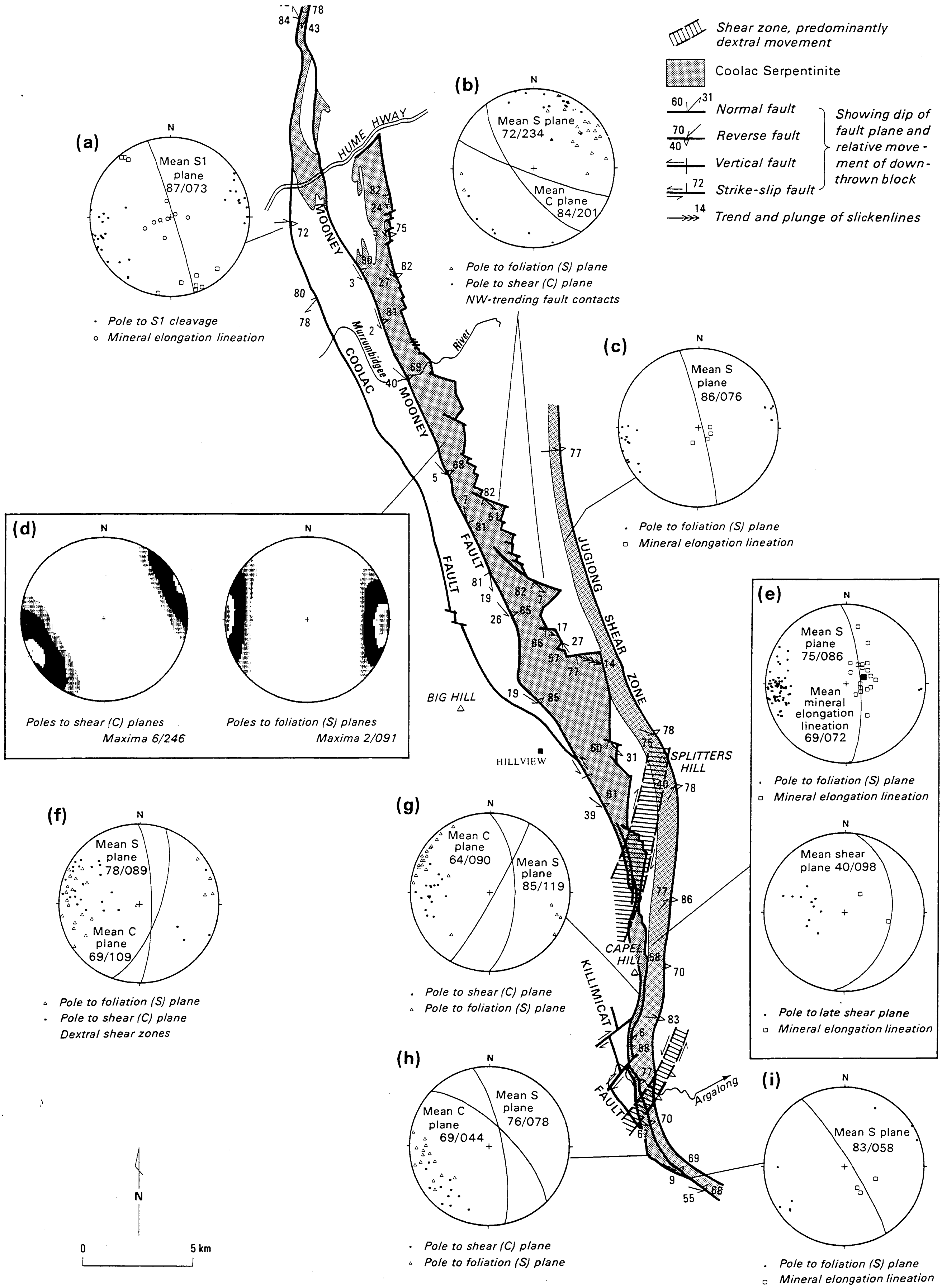


Figure 23. Structural sketch map of the Mooney Mooney Fault Zone showing interpreted fault style and kinematics (obtained from S-C relationships, mineral elongation lineations and slickenlines), after Stuart-Smith (1990a).

The Mundongo formation consists of epiclastic rocks ranging from mudstone to conglomerate. The dominant lithologies are quartz-intermediate arenite and siltstone (Stuart-Smith & Dadd, 1993). Grains comprise plagioclase, quartz, lithic fragments, biotite, minor chlorite aggregates after magmatic mafic minerals and rare zircon. The lithic clasts include dacitic volcaniclastics, basalt and chert. The coarser-grained sedimentary rocks will not be examined during this trip. They are of variable character and range from pebble conglomerate to coarse breccia. Both matrix and clast supported varieties are present.

Medium to thickly bedded fine- to coarse-grained quartz-intermediate arenite, typical of the formation are well- exposed in the road cutting at this stop, about 2.2 km west of the Lowther's Lane turnoff on the Bumbolee Creek Road. The thick arenite beds are well-graded and interbedded with minor thinly bedded laminated shale.

Figure 24. Typical graded quartz-intermediate arenite beds within the Mundongo formation. Note a weak spaced subvertical fracture is present and is axial planar to the F_1 anticline.

Only one phase of folding affects the Early to Late Silurian units and is illustrated in this exposure (Fig. 24) which reveals the open hinge of a upright subhorizontal, northerly-trending anticline near the base of the formation. (Fig. 25). A weak-spaced fracture is axial-planar to the fold. Folding occurred during the Siluro-Devonian Bowning Orogeny and is synchronous with both lower greenschist facies metamorphism and the third phase of folding present in the Bumbolee Creek Formation rocks at Blowering Dam (Stop 2.3).

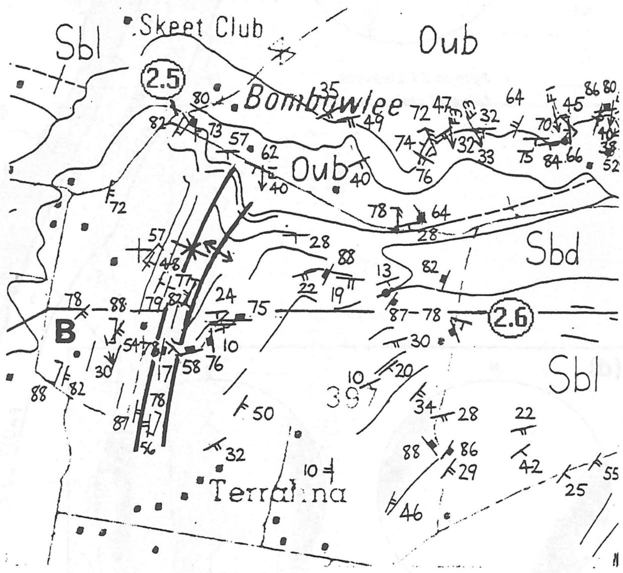


Figure 25. Stop 2.5 and 2.6 locality map. Geology after Stuart-Smith (1990a).

Stop 2.6 Mundongo formation, Lowther's Lane

(stop description modified from IAVCEI Tumut Region excursion, Stop 6; Stuart-Smith & Dadd, 1993)

Stop 2.6 is located in Lowther's Lane within the Mundongo formation (Fig. 25). Figure 26 is a measured section of the sequence in the cutting on the western side of the lane. The section comprises interbedded medium and fine-grained arenite and siltstone with laminated siltstone to fine arenite making up about 80 %. The siltstone alternates from purple to buff in colour. The coarser arenite beds consist of a hard grey arenite. They typically have sharp tops, erosional bases and are ungraded. The arenite and siltstone form discrete beds with no apparent grading. Several thick beds of laminated siltstone with intraformational folding are exposed in a more recent road cutting on the eastern side of the lane (Fig. 27).

The coarser-grained arenite in the cutting is a lithic arenite. Framework grains include siliceous rock fragments (20-25%), volcanic quartz (10-20%), plagioclase (10-20%), siltstone (10-15%), quartz aggregates (~5%), epidotised fragments (~2%), basalt

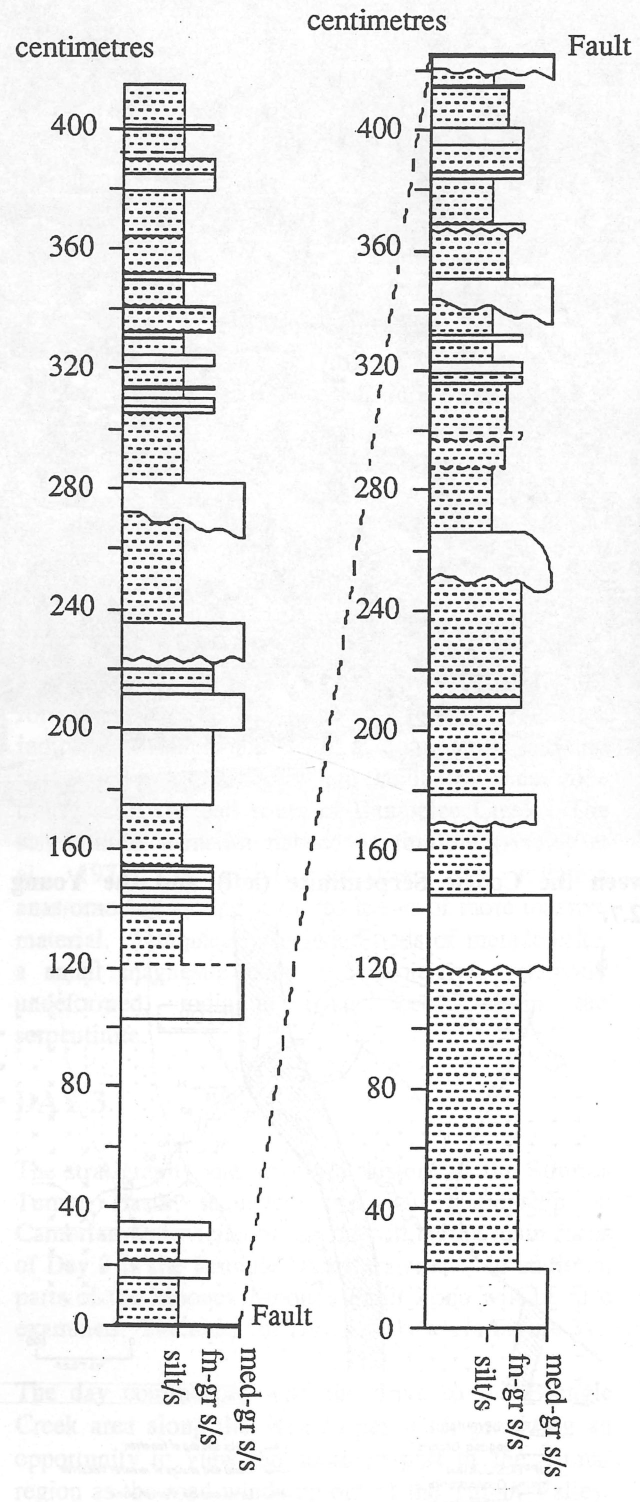


Figure 26. Measured section through the Mundongo formation in Lowther's Lane (from Stuart-Smith & Dadd, 1993). The section comprises interbedded medium and fine-grained arenite and siltstone. The coarser arenite beds typically have sharp tops and erosional bases and most are ungraded. The arenite and siltstone form discrete beds with no apparent grading.

(1-2%), and minor opaque minerals and biotite (Fig. 28). The matrix generally comprises <15%. The arenite is immature with angular grain-shapes and relatively fresh plagioclase.

The sequence in Lowther's Lane does not contain graded Bouma sequences, as seen elsewhere in much of the Mundongo formation. Sedimentary structures in this section suggest deposition below wave base, possibly as a series of channel levee deposits and crevasse splays.

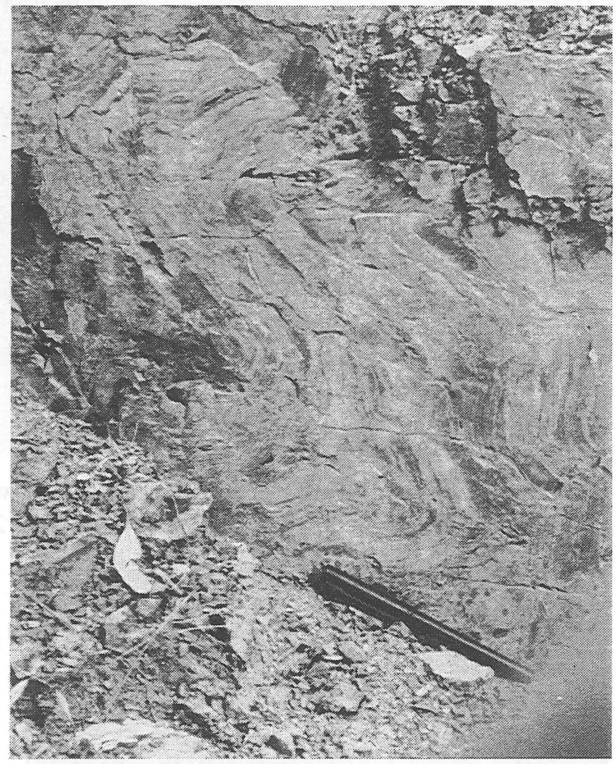


Figure 27. Intraformational folds within thinly bedded silty arenite, Mundongo formation. The folds are most probably soft sediment slumps.

Stop 2.7 Mooney Mooney Fault Zone - Faulted Coolac Serpentinite/Young Granodiorite contact, Bumbolee Creek road.

(stop description modified from IAVCEI Tumut Region excursion, Stop 4; Stuart-Smith & Dadd, 1993)

Spectacular exposures of deformed granodiorite and serpentinite within the Mooney Mooney Fault Zone occur along the Bumbolee Creek road where it traverses the Honeysuckle Range east of Tumut (Fig. 28). The stop commences with a walk down the road through granodioritic mylonite to the tectonic contact with the serpentinite.

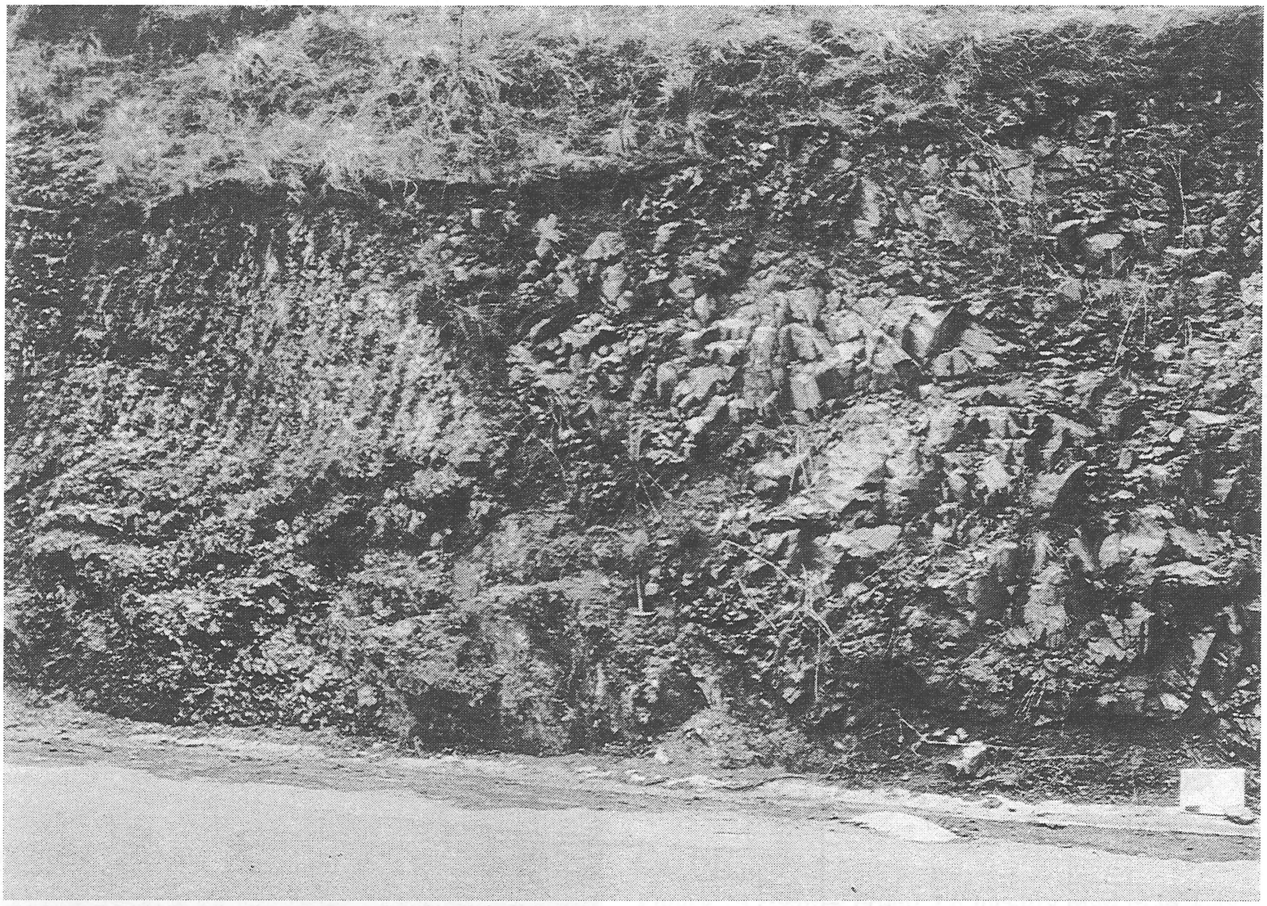


Figure 28. Steeply dipping faulted contact between the Coolac Serpentinite (left) and the Young Granodiorite (right) exposed in road cutting at Stop 2.7.

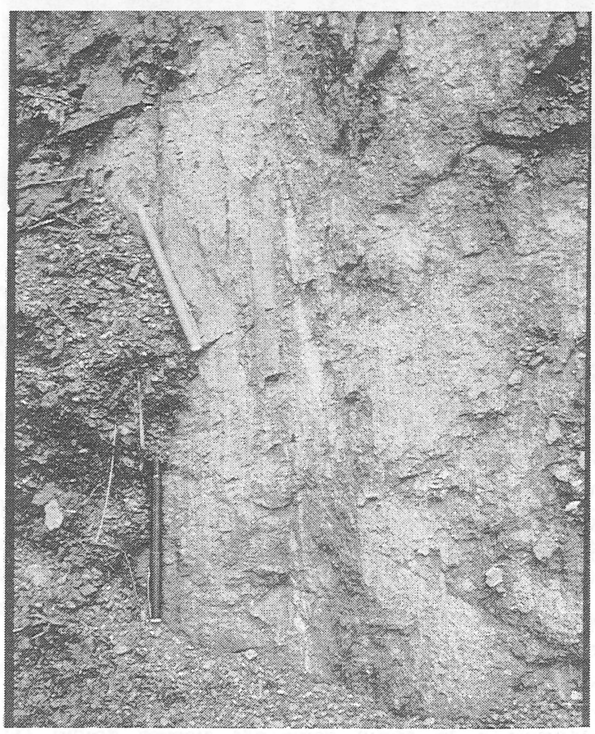


Figure 29. Ultramylonite developed in the Young Granodiorite adjacent to the contact with the Coolac Serpentinite, Stop 2.7.

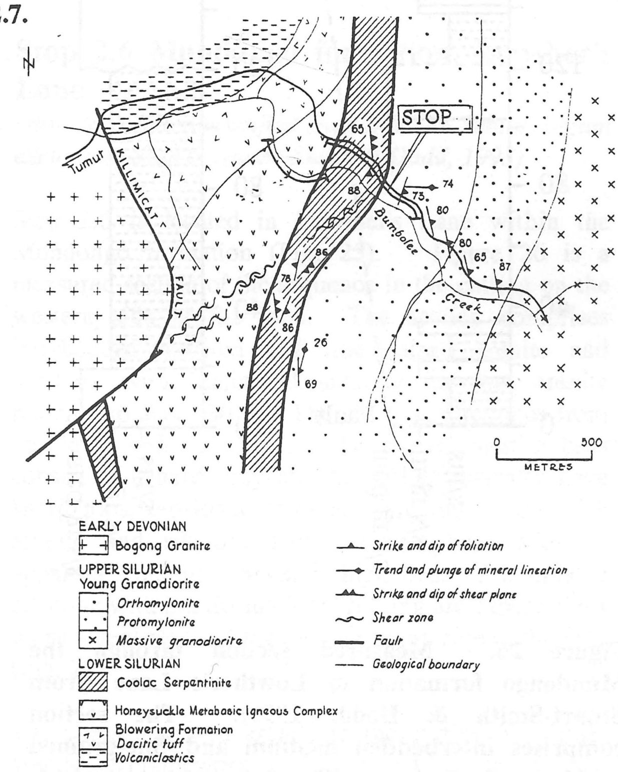


Figure 30. Stop 2.7. Geology, Coolac Serpentinite/Young Granodiorite contact, Bumbolee Creek (after Stuart-Smith et al., 1988).

The Young Granodiorite is a coarse, relatively homogeneous, S-type granite, the bulk of which is massive to slightly more foliated approaching the fault contact where the rock grades into an ultramylonite (Fig. 29). Fabrics within the mylonite reflect three discrete phases of deformation with different movement directions. The dominant fabric is a steep east-dipping foliation with a steeply pitching weak to strong mineral elongation lineation reflecting reverse movement. This fabric is deformed by spaced moderately east-dipping shear bands, which formed during latter brittle deformation associated with minor thrusting of the granodiorite to the west during the Siluro-Devonian Bowning Orogeny. Near the contact with the serpentinite, fabrics within a narrow band of ultramylonite show a dextral strike-slip motion. This zone forms part of a dextral shear zone, which passes through the serpentinite and displaces the Killimicat Fault by about 1 km (Fig. 30).

The contact between the mylonite and serpentinite is sharp and dips steeply to the east parallel to the main foliation in the mylonite and shear planes within the adjacent serpentinite. A vertical to steep SE-dipping foliation is also present in the serpentinite in this area, indicating oblique-slip with a dominantly sinistral strike-slip motion except where the dextral shear zone transgresses the belt south of Bumbolee Creek. The serpentinite, a metasomatised harzburgite (Ashley et al., 1971), is mainly schistose, the foliation anastomosing around scattered lenses of more massive material. Tectonically included pods of metadolerite, a small magnesite body and a narrow, relatively undeformed, rodingite dyke occur within the serpentinite.

DAY 3

The stratigraphy and structural history of the Silurian Tumut Basin sequence and its relationship to Cambrian-Ordovician basement will be the main focus of Day 3 in the Brungle-Darbalara area. In addition, parts of the Mooney Mooney Fault Zone will be also examined. The route for Day 3 is shown in Figure 31.

The day commences with the drive to the Brungle Creek area along the Wee Jasper road, providing an opportunity to view the southern part of the Tumut region as the road winds up out of the Tumut Valley. The Early Devonian Bogong Granite forms a prominent mountain about 10 km to the southeast. Road cuttings at this location expose deformed quartz-rich flysch of the Bumbolee Creek Formation (Fig. 32).

The road cuttings were mapped in detail by Killick (1982). Steeply SE-plunging, open and symmetrical F_2 folds dominate outcrop-scale structures. Facing is consistently to the northwest and most beds are overturned, dipping steeply to the southeast. A subvertical slaty cleavage (S_2), axial plane to the folds, is locally folded by tight to isoclinal F_3 folds in disrupted easterly trending zones. Minor recumbent F_1 folds trend ESE and face north. Killick (1982) interpreted the exposures to lie near the hinge of a regional recumbent fold (Fig. 32). It is likely that S_2 at this locality corresponds to the Early Devonian S_3 present at the Blowering Dam quarry (Stop 2.3).

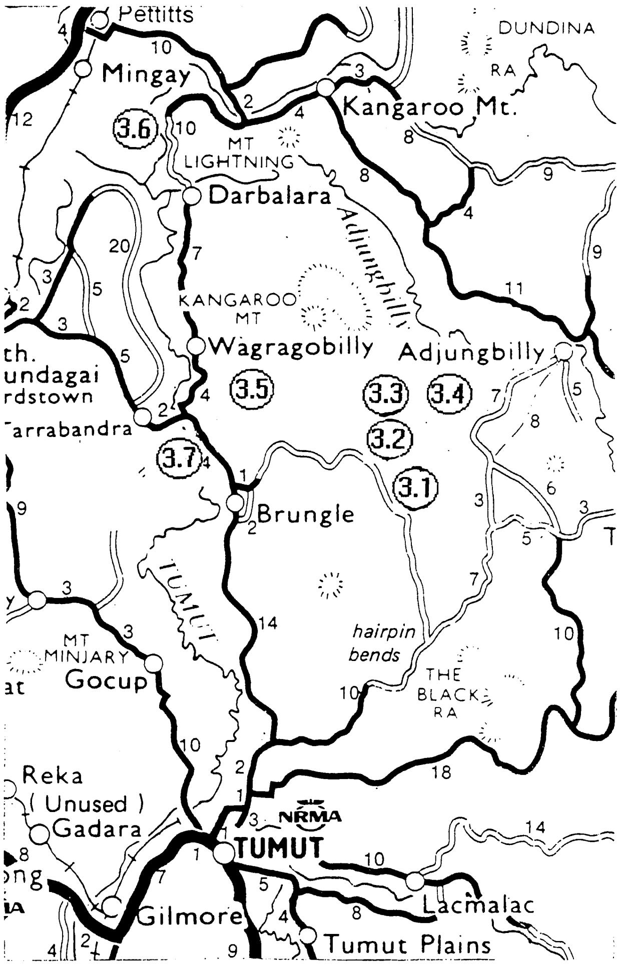


Figure 31. Day 3 route map (map courtesy of the NRMA - 1994)

Stop 3.1 Bullawyarra Schist/Wyangle Formation contact, Brungle Creek

(stop description modified from the International Workshop and Symposium on Seismic Probing of Continents and their Margins, Tumut Trough excursion, Stop 7; Stuart-Smith et al., 1988)

In the Brungle Creek area, exposures of the Ordovician-Early Silurian Brungle Creek Metabasalt, Early Silurian Wyangle and Blowering Formations and

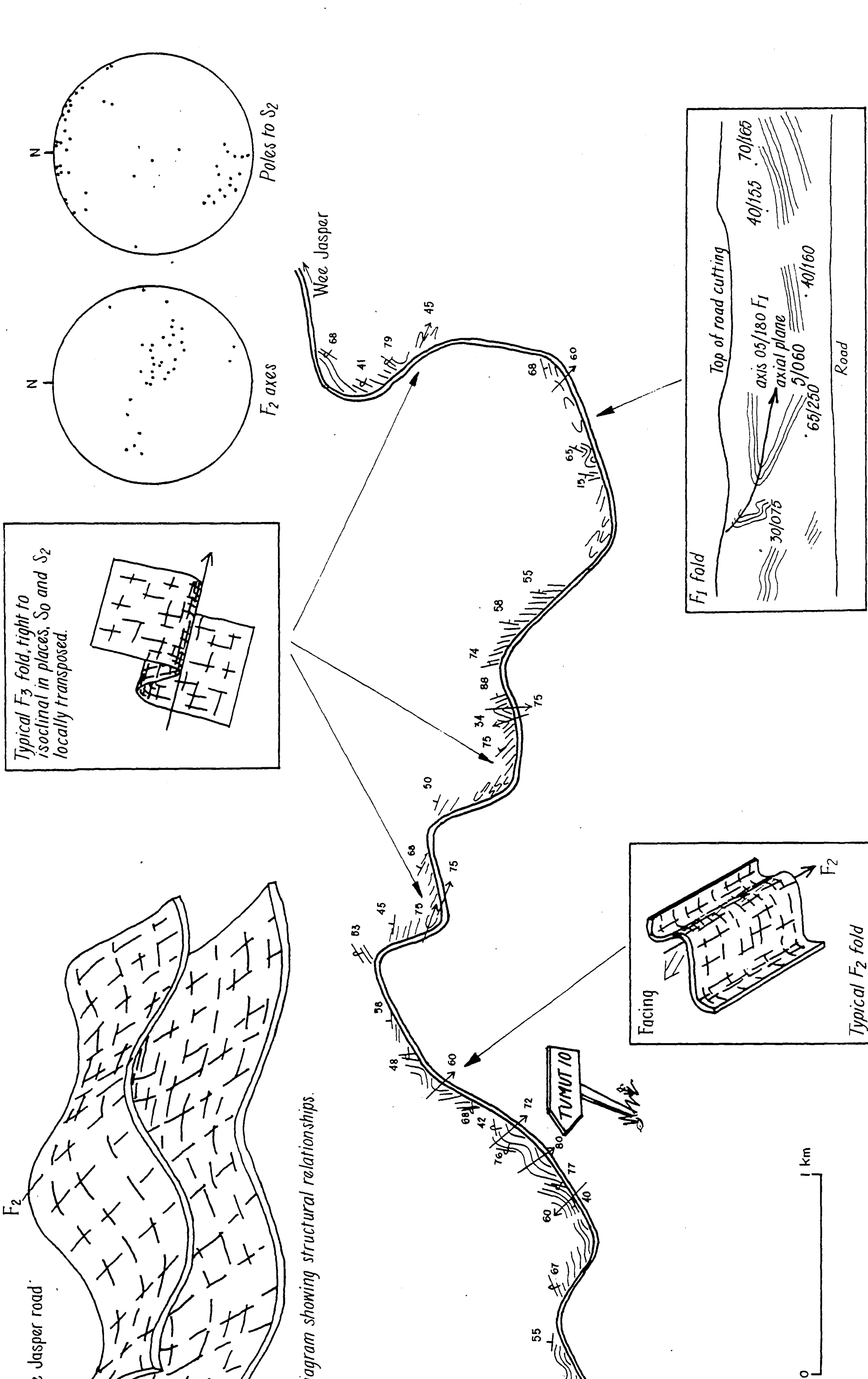


Figure 32. Wee Jasper Road, locality map and sketches (from Stuart-Smith et al., 1988: geology after Killick, 1982).

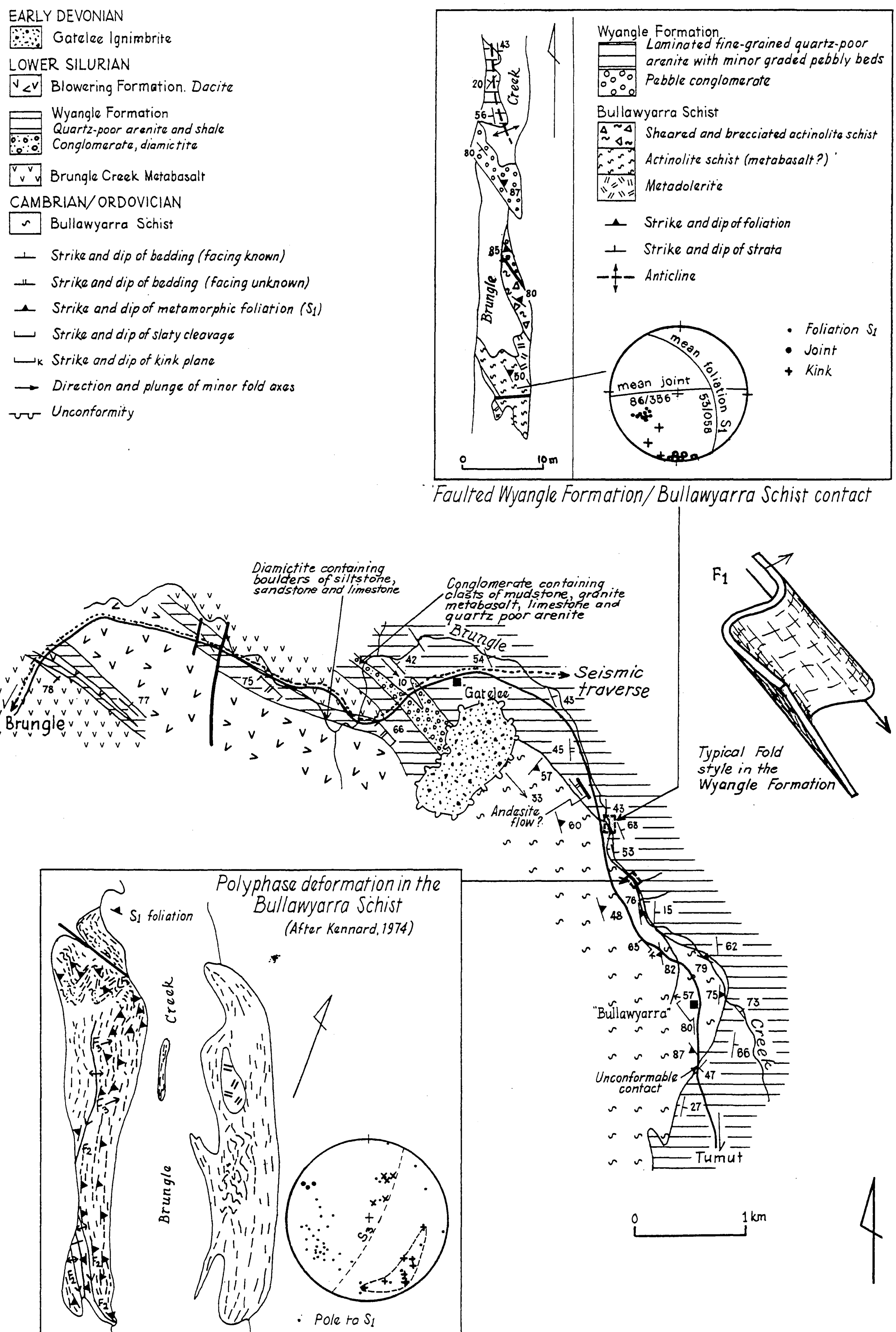


Figure 33. Stop 3.1 Brungle Creek road, locality map and sketches (after Stuart-Smith et al., 1988).

the Cambrian-Ordovician Bullawyarra Schist can be seen on hill slopes and in Brungle Creek. The two hills immediately north and south of Gatelee homestead are capped by remnants of a relatively flat-lying Early Devonian ignimbrite sheet (the Gatelee Ignimbrite: see description Stop 3.7) which unconformably overlies older rocks. The Coolac Serpentinite forms the Honeysuckle Range running the length of Brungle Creek to the east.

The Bullawyarra Schist locally forms basement to the Silurian Tumut Basinal sequence in the Brungle area. The structural and metamorphic discontinuity separating the schist from overlying rocks of the Wyangle Formation is both faulted and unconformable (Fig. 33). At this locality the schist comprises actinolite schist with boudinaged pods of fine- to medium-grained greenschist facies metadolerite. Common elongate lenses, up to 10 mm across, of recrystallised quartz and epidote aggregates in the schist may be deformed amygdales. The prominent schistosity, representing the oldest deformation in the region, is at least as old as the Early Silurian Benambran deformation and is deformed by upright northerly trending open folds (Fig. 34) and easterly trending kink zones. Retrogressive sub- to lower greenschist facies conditions prevailed during the latter two deformations.

Quartz-poor flysch deposits of the Wyangle Formation form the base of the Tumut basin sequence and unconformably overlie or are faulted against Cambrian-Ordovician basement and Ordovician-Early Silurian Brungle Creek Metabasalt. Where not faulted, the lower contact reflects an unconformable onlapping relationship. In places the overlying Blowering Formation oversteps the unit to rest directly on older rocks (Stuart-Smith, 1990b). The formation is conformably overlain, intruded by or intertongues with the Blowering Formation.

The Wyangle Formation is thickest (600 m) in the Brungle Creek area where it comprises interbedded quartz-poor and quartz-intermediate arenite, volcanilithic pebble and boulder conglomerate, diamictite , shale, mudstone, tuff and minor andesite? flows. Although poorly exposed relative to the coarser clastics, weakly cleaved shale and mudstone probably account for over 50% of the unit. The conglomerate and diamictite are interpreted to represent debris-flow deposits (Kennard, 1974; Crook & Powell, 1976). Allochthonous fossiliferous limestone clasts within diamictite contain conodonts of probable late Llandoverian - early Wenlockian age (Lightner, 1977), indicating a maximum age for the unit. However, the formation is probably considerably younger as other clasts contain ?Late Silurian *Tryplasma* and ?*Mazaphyllum* (Crook & Powell, 1976) and conformably overlying and intertonguing Blowering Formation strata contain early to middle Ludlovian allochthonous clasts (Lightner, 1977).

Conglomerate and diamictite, well-exposed in Brungle Creek below Gatelee Homestead, are interpreted to represent debris-flow deposits (Kennard, 1974; Crook & Powell, 1976) which intertongue with the overlying Blowering Formation. In other places, the Blowering Formation appears to conformably overlie or intrude into the Wyangle Formation. The Silurian sediments were folded about N to NW-trending axes during the Siluro-Devonian Bowning Orogeny. Locally folds in the Wyangle Formation are upright, open and plunge gently SE (Fig. 33) A closely spaced fracture-cleavage associated with the folds is only developed in pelitic units.

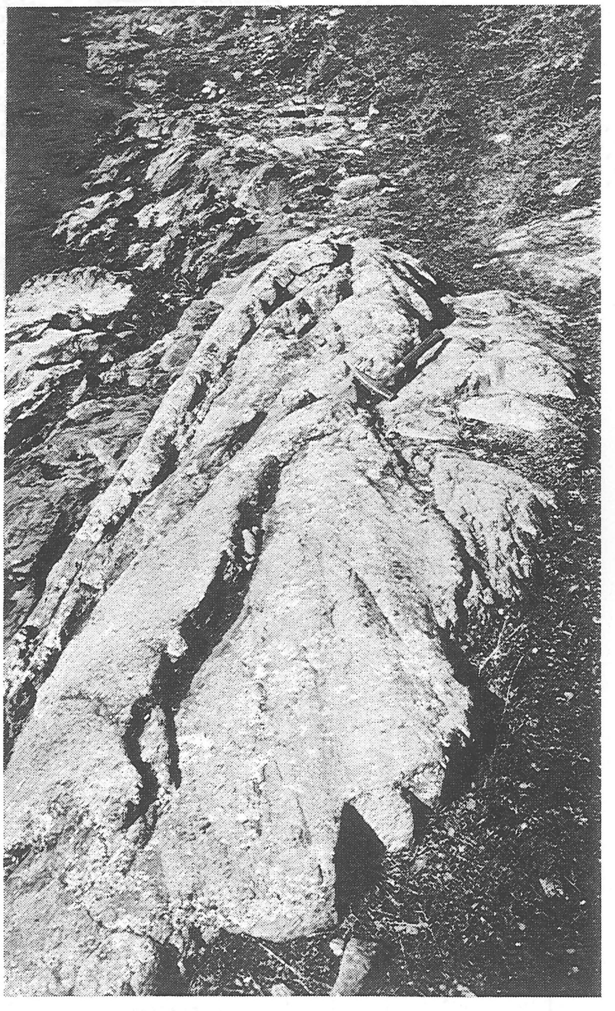


Figure 34. Upright north-trending Siluro-Devonian fold in the Bullawyarra Schist, Stop 3.1.

Stop 3.2 Wyangle Formation, Brungle Creek

(stop description modified from IAVCEI Tumut Region excursion, Stop 4; Stuart-Smith & Dadd, 1993)

This stop provides an opportunity to examine another part of the Wyangle Formation where a sequence of very thickly-bedded to laminated, pebbly to very fine-grained quartz-poor arenites are well exposed along Brungle Creek (Fig. 33). The beds are commonly graded with rounded clasts of dacite (Blowering Formation) and intraformational arenite (Fig. 35).

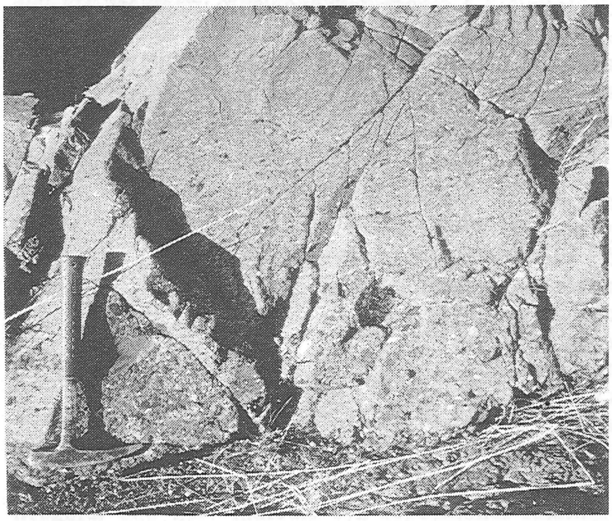


Figure 35. Typical graded quartz-poor volcanilithic pebble conglomerate, Wyangle Formation.

The quartz-poor arenites consist predominantly of plagioclase and mafic and dacitic volcanic rock fragments. Detrital quartz grains constitute less than 2% with plagioclase 40-45%, amphibole up to 8%, and pyroxene less than 4% (Basden, 1990). The composition of the detrital clinopyroxene grains, and phenocrysts in mafic clasts, is similar to those in underlying Ordovician-Early Silurian mafic rocks (Stuart-Smith et al., 1992), indicating a probable local source for the flysch. Dacitic volcanics of the Blowering Formation also contributed, with dacitic clasts and mineral grains becoming more common in the upper parts of the unit.

Stop 3.3 Blowering Formation/Honeysuckle Beds contact

(stop description modified from IAVCEI Tumut Region excursion, Stop 5; Stuart-Smith & Dadd, 1993)

The Honeysuckle Beds, a sequence of pillow basalt and fine-grained sedimentary rocks, occur to the east of the Blowering Formation. They were included by Ashley and others (1979) within a disrupted ophiolite sequence which included the Coolac Serpentinite to the east and the North Mooney Complex, and were thought by Ashley and others (1983) to represent the upper part of layer 2 and layer 1 of oceanic crust. Recent field mapping (Stuart-Smith, 1990a; Warner et al., 1992) within the Honeysuckle Beds and Blowering Formation, to the west, demonstrated that the Honeysuckle Beds are largely east-facing and dipping, and are interbedded with the uppermost Blowering Formation, thus placing them at the top of the Tumut Basin sequence, a position which is incompatible with them forming part of the disrupted ophiolite as previously interpreted.

Four main facies have been recognised within the Honeysuckle Beds including pillow basalt, massive to vesicular basalt, basaltic breccia and a chert-siltstone-arenite association (Stuart-Smith & Dadd, 1993). Pillow basalts are the dominant lithology with the chert-siltstone-arenite facies the second most abundant, typically overlying or interbedded with pillow basalt. The mafic rocks are characteristically tholeiitic basalt to andesite in composition. REE profiles resemble those for basalt and basaltic andesite erupted in back-arc basin environments.

The nature of the Blowering Formation - Honeysuckle Beds contact varies along its length. In the south, basalt is adjacent to coarse dacitic rocks of the Blowering Formation and the two do not interfinger. The contact is not exposed and could be either conformable or faulted. Here the contact is complicated by mafic intrusions included within the Micalong Swamp Basic Intrusive Complex (Owen and Wyborn, 1979a) and possibly related to those in a similar position to the north (eg. North Mooney Complex). Further north, the contact zone is moderately well exposed. The contact varies from a simple conformable relationship to zones of complex interfingering and occasional sections in which there is a poorly-sorted, matrix-supported, sedimentary breccia containing both basalt and dacitic clasts in a siliceous siltstone matrix such as at this stop where it is well exposed in a small creek. At this locality the sequence youngs and dips to the east. Further to the east, the Honeysuckle Beds are in fault contact with the Coolac Serpentinite. The serpentinite forming the sharp ridge to the east with a characteristic flora, including grass trees, honeysuckle heath and she-oaks.

A detailed section across the contact is shown in Figure 36. The base of the section is within the massive dacitic volcaniclastic facies of the Blowering Formation. This outcrop is typical of the facies but also has a series of epidote and calcite alteration veins. At approximately 25 m above the base of the section there is a breccia with irregular dacite clasts up to 25 cm in a matrix of fine arenite to siliceous mudstone.

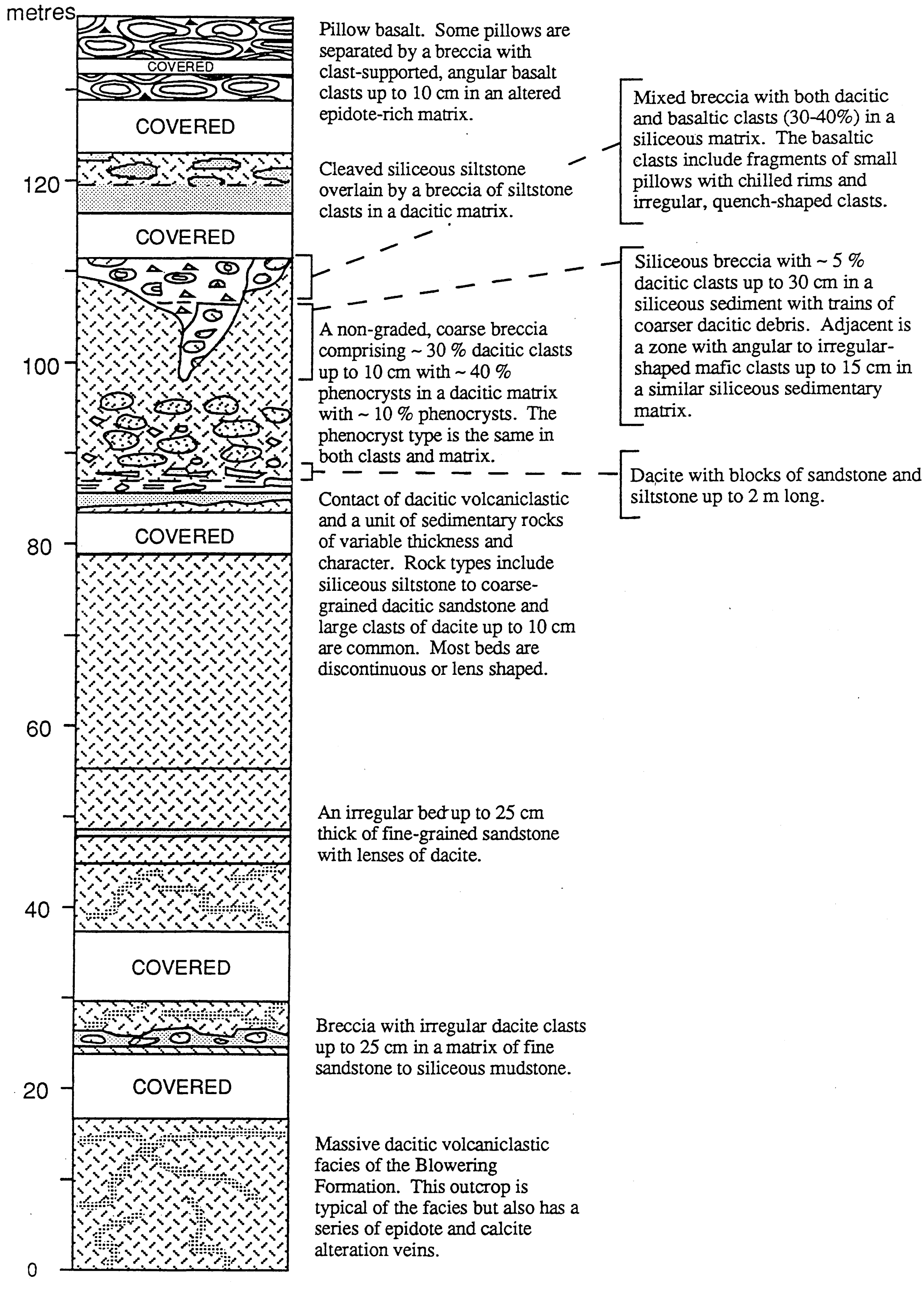


Figure 36. Measured section through dacitic volcaniclastic rocks, sedimentary rocks, mixed mafic and felsic breccia and pillow basalt at the contact of the Blowering Formation and the Honeysuckle Beds. The presence of the mixed breccia indicates that mafic and felsic volcanic activity were contemporaneous. The irregular bed contacts suggest that the area was unstable and subject to disruption by faulting (after Stuart-Smith & Dadd, 1993).

At 50 m is an irregular bed up to 25 cm thick of fine-grained arenite with lenses of dacite.

At approximately 85 m up the profile, near a small waterfall, the contact between the massive dacitic volcaniclastic and overlying arenite is exposed. This unit of sedimentary rock is of variable thickness and character. Rock types include a range from siliceous siltstone to coarse-grained dacitic arenite and large clasts of dacite up to 10 cm are common. Most beds are discontinuous. Sedimentary structures that indicate an easterly younging direction include scours and graded beds. The arenite unit has a gradational contact with the overlying coarse dacitic volcaniclastic. At the base of this bed, the dacite contains blocks of arenite and siltstone up to 2 m long. These clasts are poorly graded in number upwards. Overlying this zone, the dacitic volcaniclastic is a non-graded, coarse breccia comprising about 30 % dacitic clasts up to 10 cm and with approximately 40 % crystals in a dacitic matrix with approximately 10 % crystals. The crystal type is the same in both clasts and matrix.

Above the dacitic breccia, the stratigraphy is difficult to establish and bed contacts appear to cross-cut the previous strike direction. The contact of the dacitic breccia and a breccia with a siliceous matrix is very irregular and may indicate syn-depositional faulting within the sequence. The siliceous breccia is shown as a tongue into the dacitic breccia on Figure 36. This breccia comprises about 5 % dacitic clasts up to 30 cm but averaging 1-2 cm in a siliceous sediment with trains of coarser dacitic debris. Adjacent to this breccia is a zone with angular to irregular-shaped mafic clasts up to 15 cm in a similar siliceous sedimentary matrix. To the east of this breccia is a mixed breccia with both dacitic and basaltic clasts (30-40%) in a siliceous matrix. The basaltic clasts include fragments of small pillows with chilled rims and irregular, quench-shaped clasts.

At about 115 m above the base of the section is a bed of well-cleaved siliceous siltstone approximately 3 m thick. The siltstone is overlain by a breccia of siltstone clasts in a dacitic matrix similar to that just above the waterfall. This is the uppermost dacitic unit in the section and can be traced to the south around the hillside indicating a change in strike from the sedimentary beds at the waterfall. The dacitic breccia is overlain by pillow basalt of the Honeysuckle Beds. The outcrops in the creek have well-preserved pillow forms that unfortunately give ambiguous younging directions. Some pillows are separated by a breccia with clast-supported, angular basalt clasts up to 10 cm in an altered epidote-rich matrix.

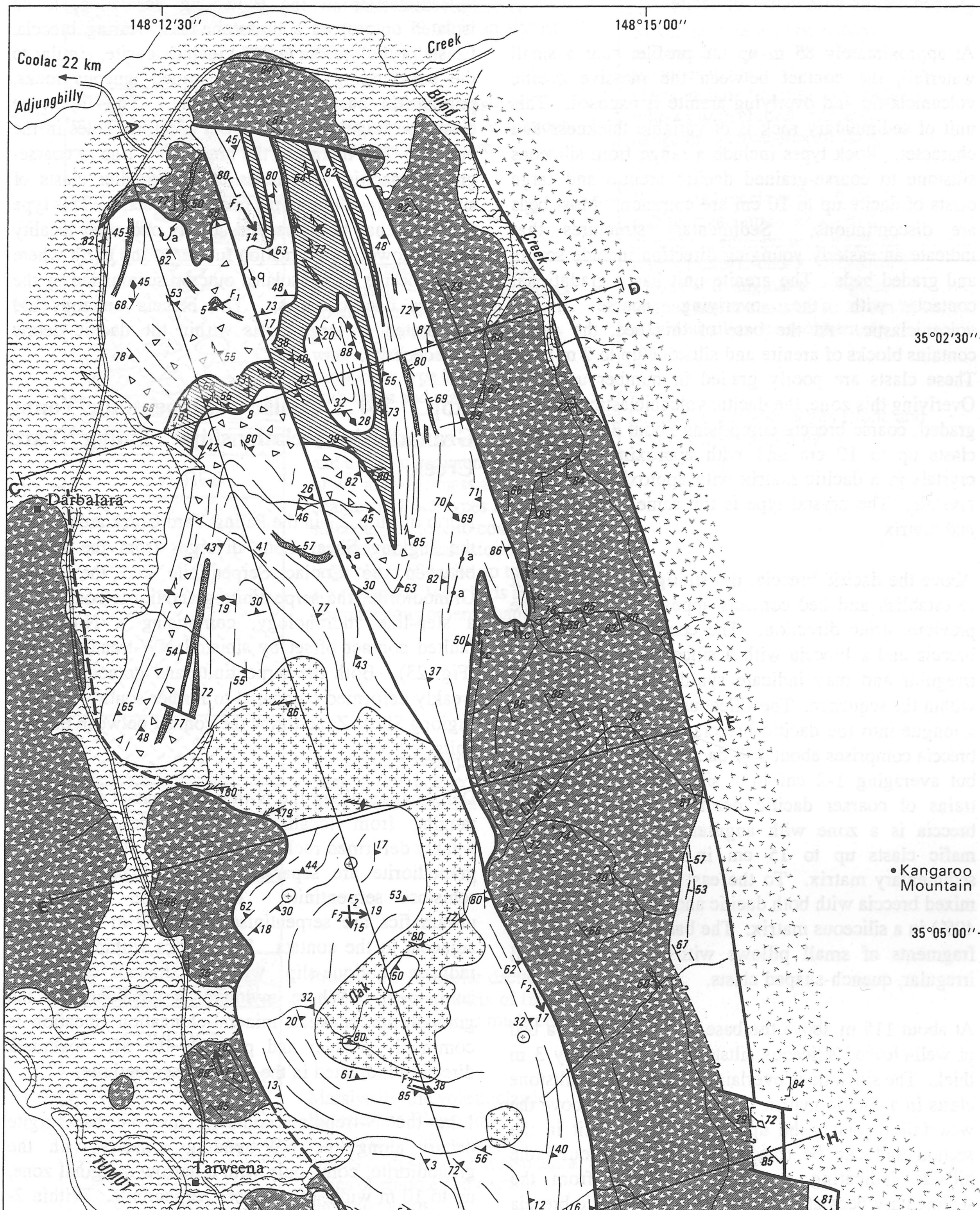
To the south of the creek section, within the dacitic volcaniclastics of the Blowering Formation, is an isolated outcrop of a limestone-clast bearing breccia. Clasts in the breccia (~50%) include dacite, similar to the surrounding MDV, fine-grained igneous rocks, porphyritic basalt, and limestone. The limestone clasts are largely weathered out and form holes in the outcrop. The matrix of the breccia is a fine to coarse-grained dacitic volcaniclastic with smaller clasts of similar composition to the framework clasts. This type of breccia has been mapped at only one other locality in the Blowering Formation further to the north where it also occurs as an isolated outcrop surrounded by the massive dacitic rocks. The breccia outcrops are interpreted as large clasts within the dacitic debris flow deposits.

Stop 3.4 Coolac Serpentinite/Young Granodiorite relationships, Paling Yard Creek

North of Stop 2.7 in the Paling Yard Creek area, where the Jugiong Shear Zone diverges from the contact between the Coolac Serpentinite and the Young Granodiorite, the serpentinite-granodiorite contact has a step-like morphology, comprising a N-trending faulted contact offset by sinistral NW-trending faults (Fig. 23). Both the serpentinite and granodiorite are weakly deformed compared to farther south where the Jugiong Shear Zone forms the contact between the two units.

Deformation along the N-trending contact is variable, ranging from localised mylonite development to weakly deformed rocks where massive ultramafics and granodiorite are separated by less than 50 cm of schistose serpentinite. However, in general the ultramafics are serpentinised in a 10 m wide zone adjacent to the contact. S-C fabrics within this zone indicate oblique-slip with a sinistral strike-slip component. Where mylonite is developed in the granodiorite, a weak mineral-elongation lineation is commonly present and parallels the SE movement direction indicated in the adjacent serpentinite.

Like the N-trending contacts, massive harzburgite occurs along the NW-trending contacts with the granodiorite, commonly with a narrow marginal zone, up to 10 m wide, of schistose serpentinite. Within 2-10 m of the contact, massive granodiorite is silicified, fractured and cut by subvertical quartz-albite-epidote veins and chloritic cataclasite zones up to a few cm wide. The cataclasite zones in the granodiorite are parallel to the contact and shear (*C* planes) within the serpentinite. A foliation, present in the serpentinised zones, trends NW and dips steeply to the SW. *S-C*


148°12'30''
148°15'00''
Coolac 22 km
Adjungbilly
Creek
Blind
Creek
35°02'30''
Darbalara
Kangaroo Mountain
35°05'00''
Oak
Creek
Tarweena
TUMUT
RIVER
Tumut 25 km
0
1 km
16/155-15/3

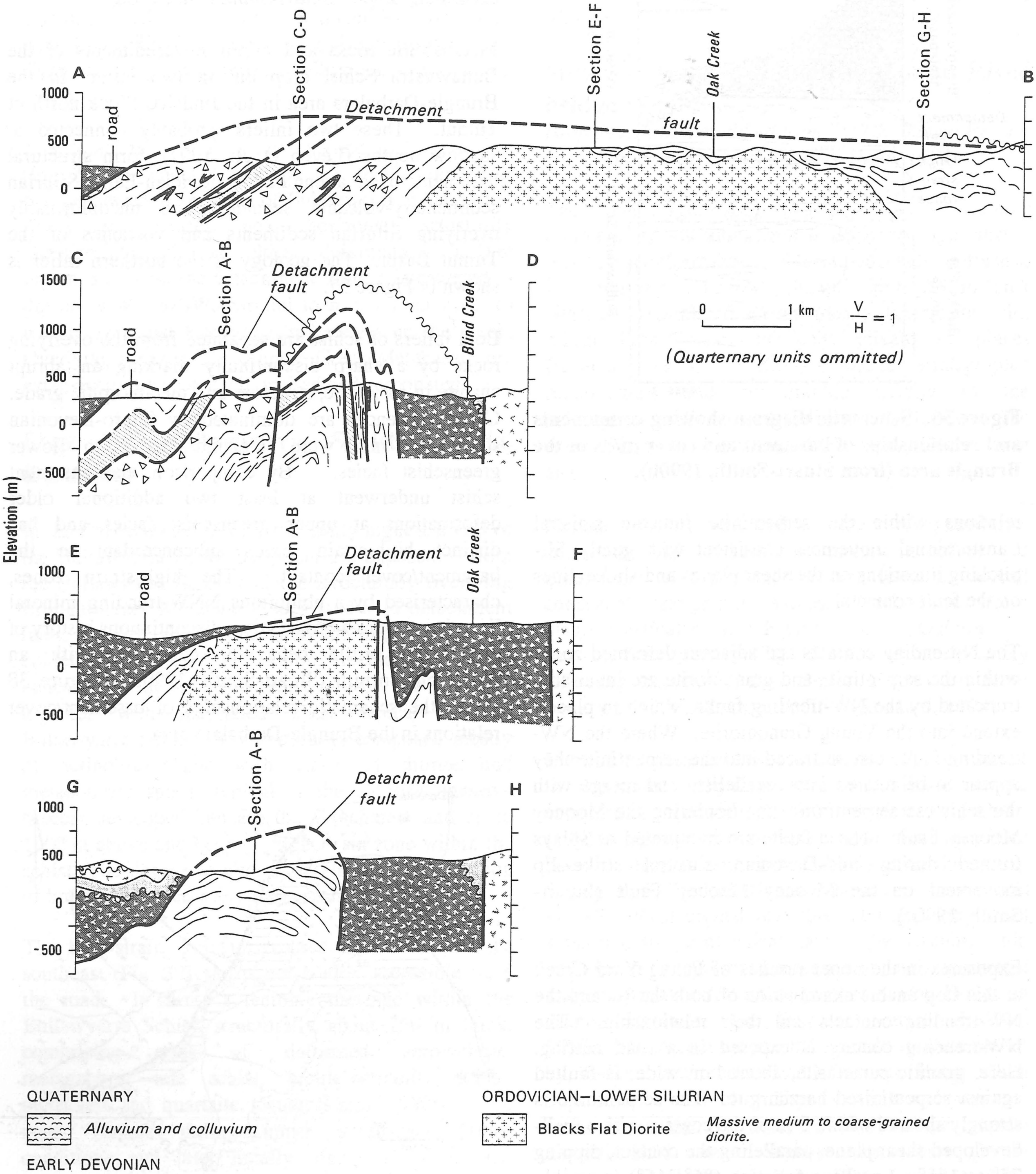


Figure 37. Geological map and sections of the northern basement inlier (after Stuart-Smith, 1990b).

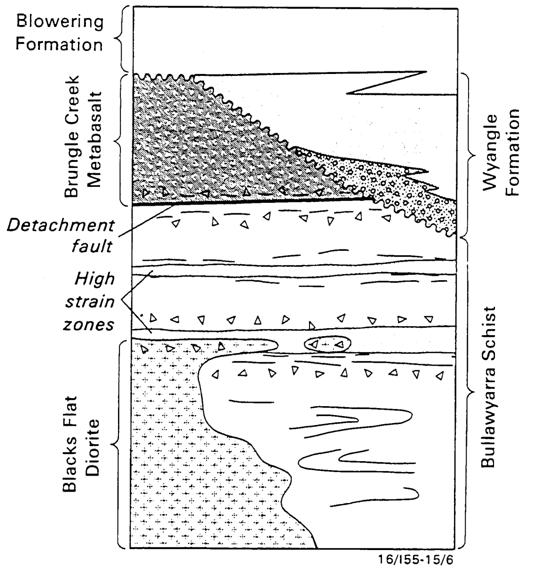


Figure 38. Schematic diagram showing components and relationships of basement and cover units in the Brungle area (from Stuart-Smith, 1990b).

relations within the serpentinite indicate sinistral transtensional movement consistent with gently SE-pitching lineations on the shear planes and slickenlines on the fault contacts.

The N-trending contacts and adjacent deformed zones within the serpentinite and granodiorite are invariably truncated by the NW-trending faults, which in places, extend into the Young Granodiorite. Where the NW-trending faults can be traced into the serpentinite they appear to be rotated into parallelism and merge with the schistose serpentinite zone bordering the Mooney Mooney Fault. These faults are interpreted as splays formed during mid-Devonian sinistral strike-slip movement on the Mooney Mooney Fault (Stuart-Smith, 1990c).

Exposures in the upper reaches of Paling Yard Creek at this stop enable examination of both the N- and the NW-trending contacts and their relationship. The NW-trending contact is exposed in a road cutting. Here, granitic cataclasite, about 1 m wide, is faulted against serpentinised harzburgite. The serpentinite is strongly sheared within 3 m of the contact with a well-developed shear plane, paralleling the contact, dipping 75° to 185°. Locally a foliation (85°/215°) is weakly developed. In the creek bed, the contact is again exposed where it truncates foliated granodiorite (foliation 70°/260°) along a N-trending contact zone.

Stop 3.5 Bullawyarra Schist/Brungle Creek Metabasalt relationships, Holts property

(stop description modified from the International Workshop and Symposium on Seismic Probing of Continents and their Margins, Tumut Trough excursion, Stop 6; Stuart-Smith et al., 1988)

Metabasaltic rocks and minor metasediments of the Bullawyarra Schist crop out in two inliers in the Brungle-Darbalara area in the Jindalee Block north of Tumut. These two inliers, probably connected at shallow depths (Leven et al., 1992), form structural basement to an attenuated Ordovician-Early Silurian sedimentary-volcanic sequence and unconformably overlying Silurian sediments and volcanics of the Tumut Basin. The geology of the northern inlier is shown in Figure 37.

Both inliers of schist are separated from the overlying rocks by a sharp discontinuity marking an abrupt change in rock type, structure and metamorphic grade. Cover sequences are dominated by Siluro-Devonian structures and were metamorphosed to lower greenschist facies. By comparison, the basement schist underwent at least two additional older deformations at upper greenschist facies and has distinct high-strain zones subconcordant to the basement/cover contact. The high-strain zones, characterised by a ubiquitous NNW-trending mineral lineation, record a progressive, discontinuous history of ductile to brittle behaviour consistent with an extensional origin (Stuart-Smith, 1990b). Figure 38 shows the schematic relationships of basement/cover relations in the Brungle-Darbalara area.

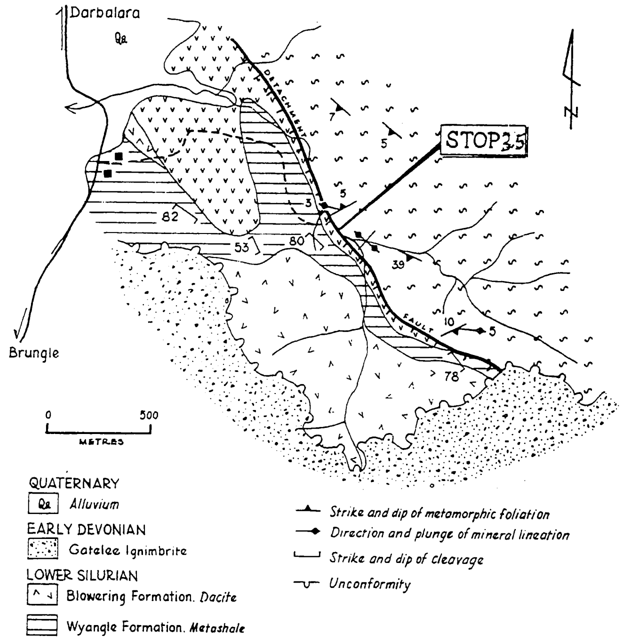


Figure 39. Geology of the basement/cover contact, Holt's property, Stop 3.5.

The structural and metamorphic discontinuity separating the schist from the cover units is characterised by widespread cataclasis and alteration. It is interpreted as a major detachment fault associated with Early Silurian extension and formation of the Tumut Basin (Stuart-Smith, 1990b; Stuart-Smith et al., 1992).

The detachment fault is not exposed at this locality (Fig 39), but adjacent outcrops of basement and cover can be viewed. exposures of Bullawyarra Schist in the Creek bed exhibit near horizontal schistosity characteristic of the oldest deformation in the basement. Here, the detachment fault is interpreted to dip about 40° WSW, parallel to minor fault breccias within the schist a few hundred metres up the creek. Overlying rocks of the Brungle Creek Metabasalt, are extensively brecciated, chloritised and carbonated.

Stop 3.6 Bullawyarra Schist breccia, Darbalara

In the Darbalara area, the structurally highest levels of the Bullawyarra Schist basement are exposed. Both the Bullawyarra Schist and the structurally overlying Brungle Creek Metabasalt, separated by a detachment fault, are extensively brecciated and altered (chlorite-epidote-carbonate). At this stop, breccia immediately beneath the detachment crops out by the roadside together with laminated chert typical of the Bullawyarra Schist. The breccia is composed mostly of actinolite schist with clasts of diorite and metadolerite and is typical of the chloritic massive breccia developed beneath the detachment and up to 1000 m above and below a high-strain zone within the schist. The degree of alteration, strain and proportion of brecciation decreasing away from the zone.

The high-strain zone is exposed 2 to 3 km to the southeast (Fig. 37) and is not readily accessible from the road. It forms a tectonic mélange within the Bullawyarra Schist, structurally about 250 m thick, comprising pods of deformed serpentinite, metagabbro, talc schist, biotite-actinolite schist, metachert and quartzite (Stuart-Smith, 1990b). The zone, formed during upper greenschist facies conditions and later locally highly disrupted and brecciated, is characterised by the presence of L- and S-tectonite fabrics.

The cataclasis of both the high-strain zone and adjacent rocks predates Siluro-Devonian meridional folding of the cover sequences and postdates intrusion of the Blacks Flat Diorite into the Bullawyarra Schist. The development of the high-strain zone, later cataclasis and detachment faulting probably represent a continuum of deformation associated with reactivation and incisement of basement high-strain zones during lithospheric extension, which resulted in formation of the *Tumut Basin* during the Early Silurian.

Stop 3.7 Gatelee Ignimbrite, Tumut River bridge

(stop description modified from IAVCEI Tumut Region excursion, Stop 2; Stuart-Smith & Dadd, 1993)

The Gatelee Ignimbrite (Ashley et al., 1971) forms remnants of a subhorizontal sheet of ignimbrite, resting unconformably on Silurian and older deformed volcanics and sediments. The unit, up to 200 m thick (Basden, 1990a), comprises mostly ignimbrite with minor basal polymictic conglomerate in places (Kennard, 1974). Based on similar stratigraphic relationships and petrographic affinity to the palaeontologically dated Minjary Volcanics, the Gatelee Ignimbrite is assumed to be Early Devonian in age.

Kennard (1974) described a variety of ignimbrites within the unit. These vary mainly in colour, are gradational with one another, and form an overall consistent stratigraphic succession which is shown diagrammatically in Figure 40. Outcrop is characterised by alternating cliffs and benches possibly reflecting successive flow sheets in part or zonal variations within the one ash-flow (Kennard, 1974).

Limited geochemical data indicates that the ignimbrite is dominantly rhyolitic with subordinate dacitic compositions (Basden, 1990a). Ashley and others, (1971) suggested that the Gatelee Ignimbrite may have been contemporaneous with, and related to, the nearby Devonian Killimicat Granite, however, Crook and Powell (1976) argued that this interpretation is not supported by geochemical data. The volcanic unit, however, may represent a more mafic, less fractionated magma, possibly related to another nearby Devonian granite intrusion, the Bogong Granite (Basden, 1990a). Both granites and the ignimbrite were placed by Wyborn and others (1987) into the Boggy Plain Supersuite, a belt of I-Type granitic and volcanic rocks extending for over 500 km in the central Lachlan Fold Belt. Wyborn and others (1987) suggested that the suite was derived from basaltic sources at high temperatures with compositional variation of the resultant magmas due to fractional crystallisation.

At this stop, purple flow-banded ignimbrite near the base of the Gatelee Ignimbrite is well exposed in the road cutting along the eastern bank of the Tumut River. A eutaxitic fabric with possible flattened pumice fragments is evident. This rock together with

a blue grey variety, more common higher in the sequence, are typified by complex flow-banding and intensely compacted and welded textures (Kennard, 1974). Both ignimbrites, together account for over 90% of the unit and are described by Basden (1990a) as "..... *weakly (10% or less) porphyritic in plagioclase and lesser quartz and K-feldspar to 2 mm in size. The phenocrysts are cracked and veined with sericite; the feldspars show heavy alteration to sericite, carbonate and limonite.*
Plagioclase is zoned. The groundmass comprises a <0.05 mm - 0.2 mm mosaic of recrystallised grains. Banding has been preserved. Occasional sub-arcuate areas represent shards, and possible pumice fragments were observed."

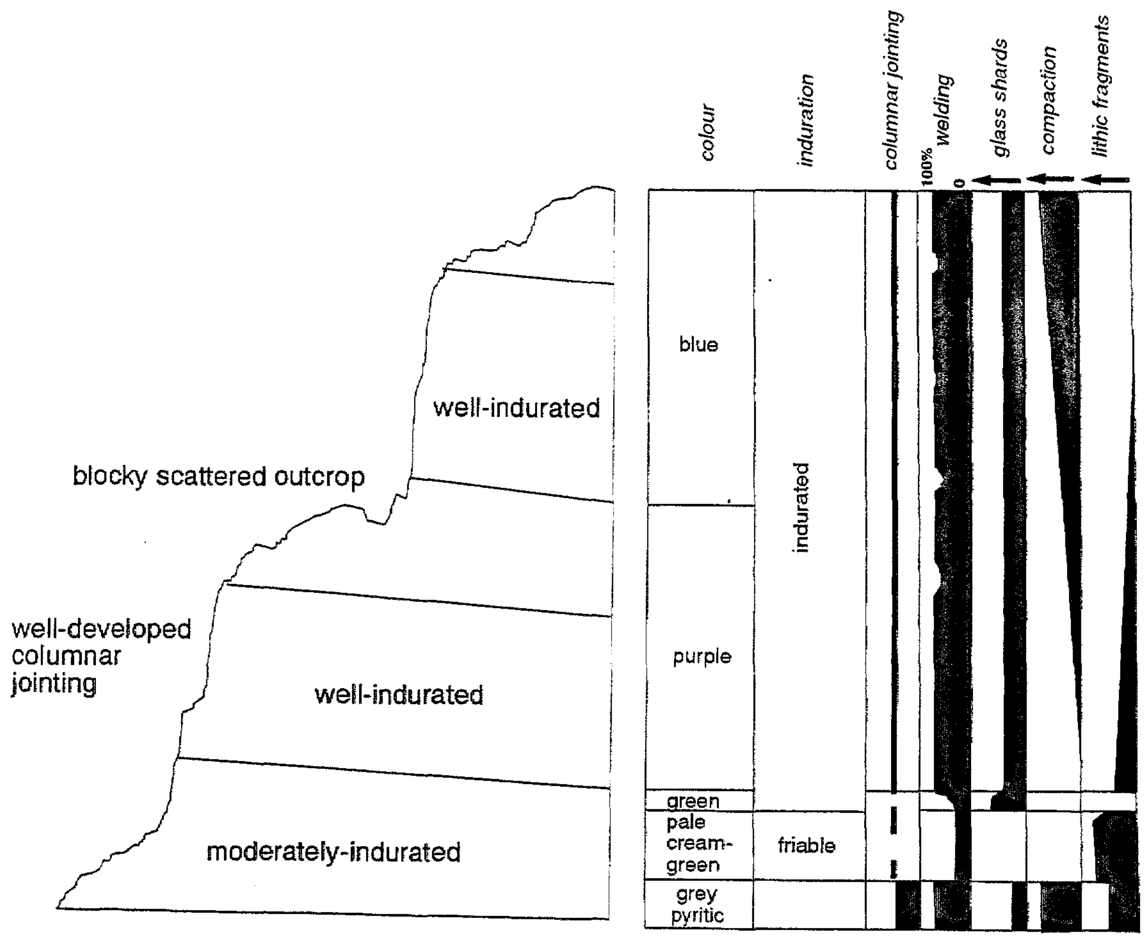


Figure 40. Diagrammatic cross-section and log of the Gatelee Ignimbrite (modified from Kennard, 1974).

DAY 4

The structural history and stratigraphy of the Ordovician WMB will be the main focus of Day 4. The route is shown in Figure 41. Commencing with a brief stop at Gilmore Creek on the Snowy Mountains Highway, two stops are then made within the deformed margin of the belt, which flanks the Gilmore Fault Zone. In addition to the presence of abundant mylonitic rocks, the stop at Adelong Falls (Stop 4.3) is of considerable interest as the ruins of a historic gold treatment plant have been preserved within a reserve and give an insight into bygone practices. The remaining stops will examine exposures along the Hume Highway, providing a transect across a range of metamorphic and deformation zones present within the metamorphic belt. The geology of the northern part of the WMB is shown in Figure 42.

Stop 4.1 Gilmore Fault Zone, Gilmore Creek

(stop description modified from the International Workshop and Symposium on Seismic Probing of Continents and their Margins, Tumut Trough excursion, Stop 2; Stuart-Smith et al., 1988)

Exposure of the Gilmore Fault is poor; however, road cuttings along the Snowy mountains Highway in the Gilmore creek area expose a 1 km wide zone of highly deformed Ordovician-Silurian and ?Early Devonian

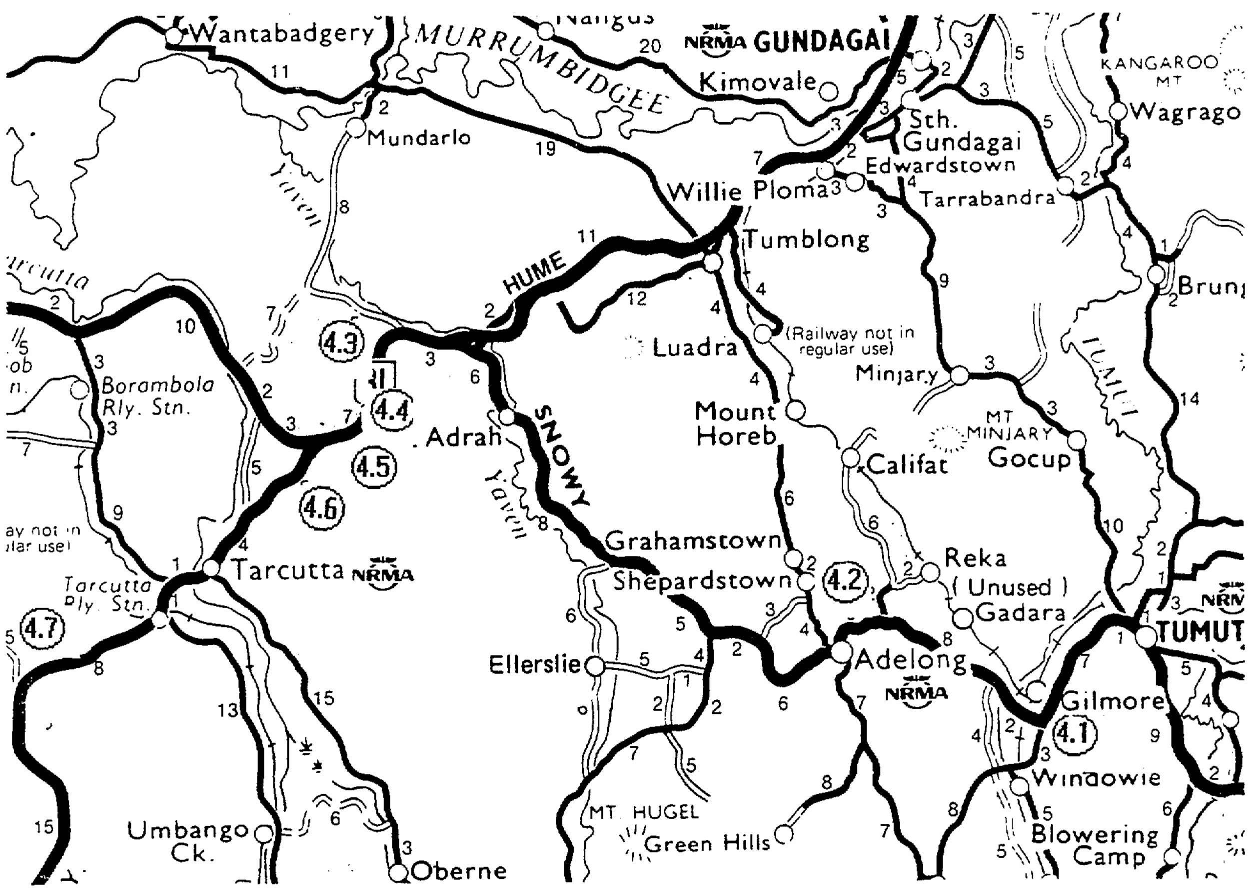


Figure 41. Day 4 route map (map courtesy of the NRMA - 1994)

metasediments and volcanics immediately east of the fault (Fig 43).

Mylonitic granodiorite of the Wondalga granodiorite crops out in the creek about 1 km west of the Batlow turnoff. As at Adelong Falls (Stop 4.2), the foliation parallels the fault, trending NNW and dipping steeply to the west. However, mineral lineations in the granodiorite pitch 25° - 55° NNW indicating oblique-slip displacement. Microfabrics indicate that movement was reverse (ie. with a sinistral component).

Metasediments, felsic volcanics and volcaniclastics of the Gooandra Volcanics (Jackalass Slate on Fig 43) abut the Gilmore Fault. A steep west-dipping foliation is present and decreases in intensity away from the fault to the east where eventually it grades into a spaced-fracture or crenulation in metasediments of the Bumbolee Creek Formation (exposed in the eastern portion of the road cutting at the Batlow turnoff. Here and farther to the east, two deformations predate the NNW-trending cleavage: recumbent folds and later upright folds are preserved.

At the Batlow turnoff, a narrow band of west-dipping conglomerate and minor shale is downfaulted against the Gooandra Volcanics to the west. The contact with the underlying Bumbolee Creek Formation is probably unconformable with some localised faulting. The conglomerate, containing abundant phyllite and vein quartz clasts, is interpreted to be part of the Early Devonian Minjary Volcanics.

Stop 4.2 Gilmore Fault Zone, Adelong Falls

(stop description modified from the International Workshop and Symposium on Seismic Probing of Continents and their Margins, Tumut Trough excursion, Stop 1; Stuart-Smith et al., 1988)

Excellent exposures of the Wondalga Granodiorite crop out along Adelong Creek at Adelong Falls (Fig. 44). The medium- to coarse-grained biotite granodiorite is one of a number of Late Silurian granitoids which intrude deformed Ordovician metasediments and together make up much of the WMB. The geology of the area is shown in Figure 45.

Exposures within the gorge lie within the Wondalga Shear Zone, part of the broad zone of deformation flanking the Gilmore Fault Zone. A weakly to strongly-developed foliation, dipping steeply to the west, is present in the granodiorite. Common mylonitic zones within the granodiorite include a dextral set, trending NNE and dipping steeply to the

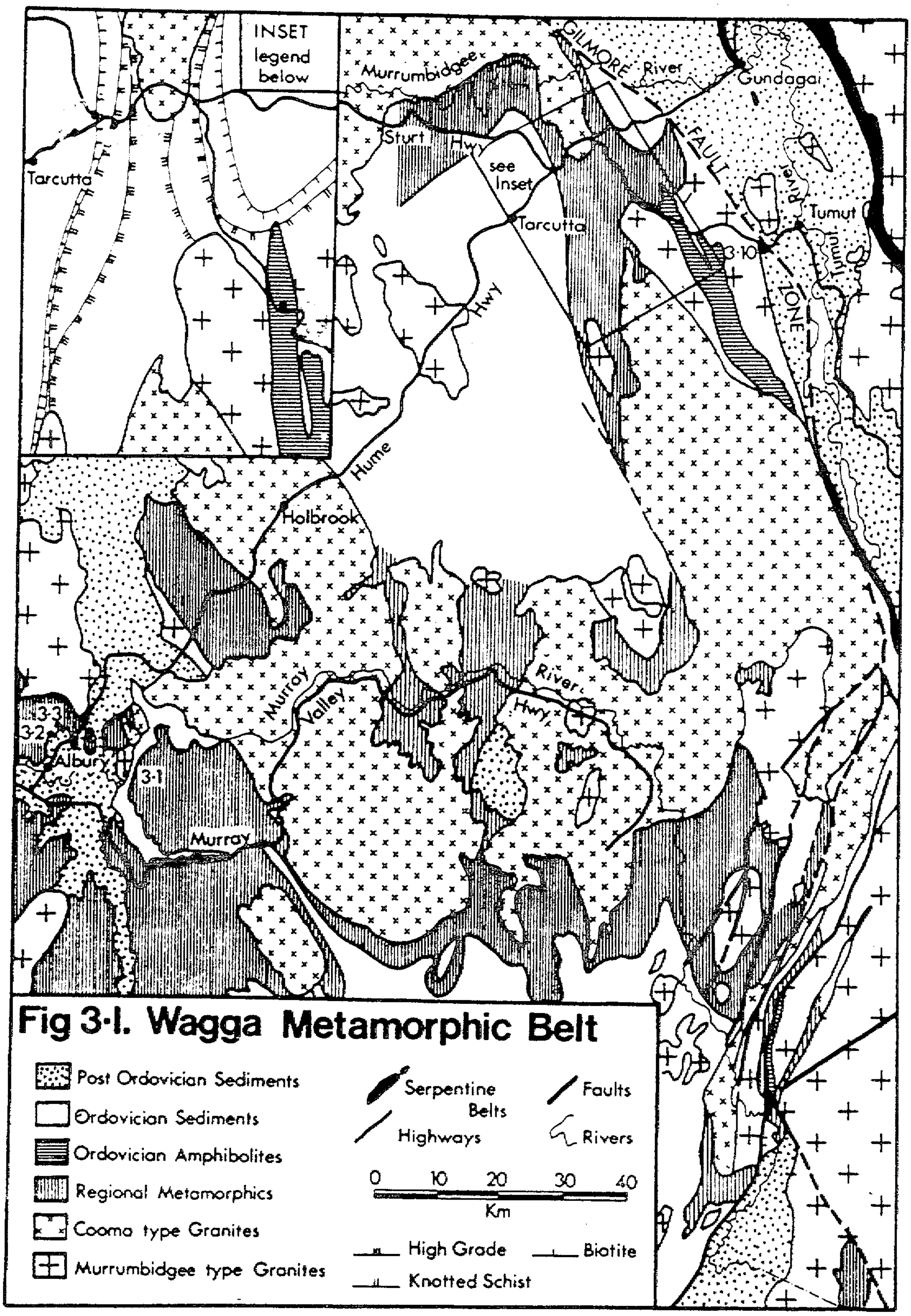


Figure 42. Geology of the northern part of the Wagga Metamorphic Belt (after Crook & Powell, 1976).

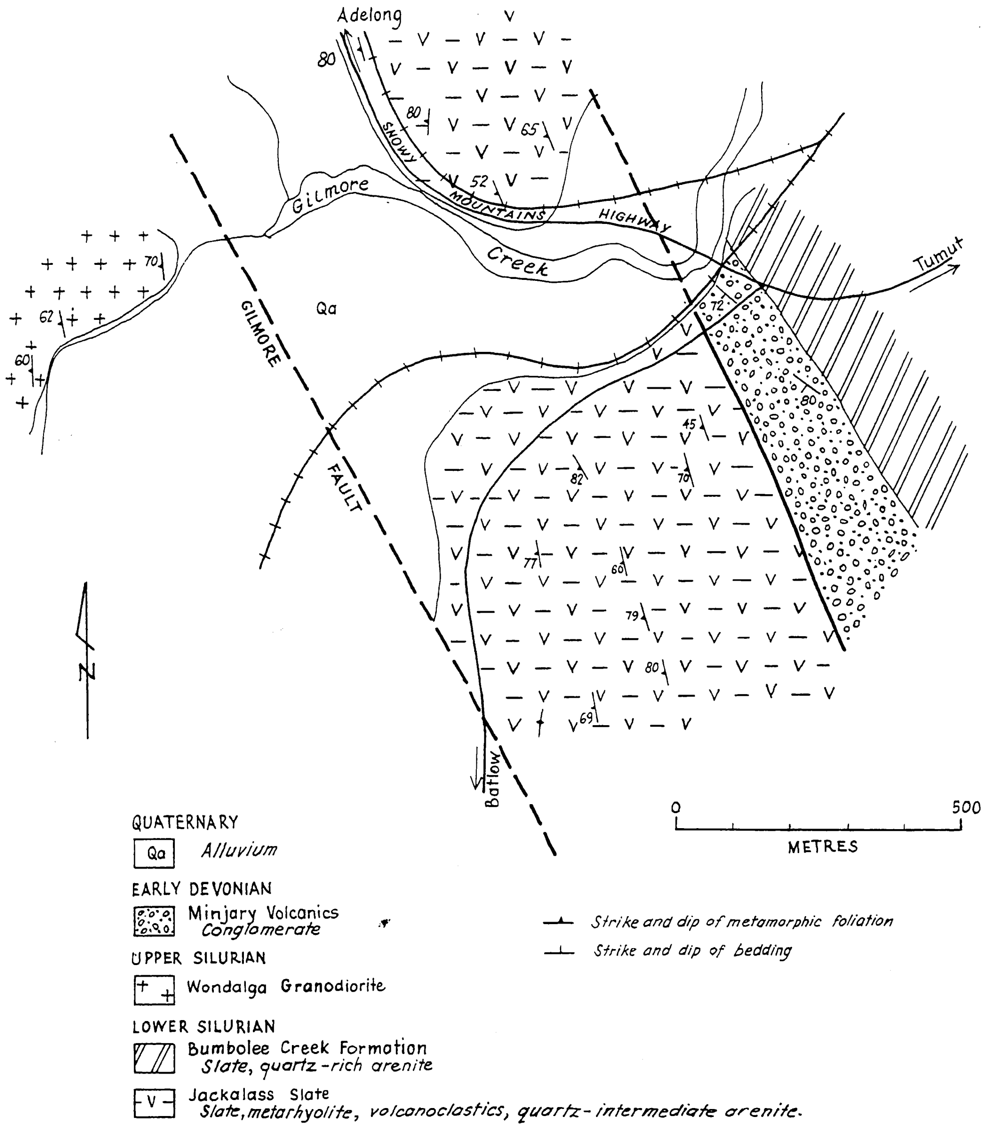


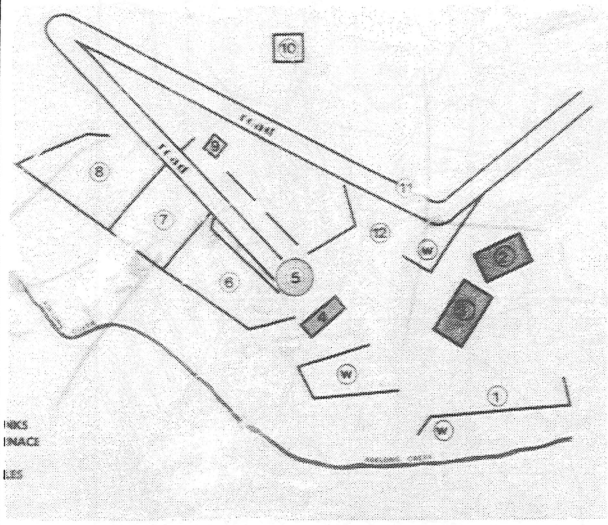
Figure 43. Gilmore Creek (after Stuart-Smith et al., 1988: geology modified from Ferguson, 1982 unpublished data).

west and a sinistral subvertical set trending NNW. Both mylonitic sets, interpreted to represent a conjugate pair, have a prominent lineation which respectively plunge gently to the NNE and subhorizontally (Fig. 46) Widespread dolerite dykes within the granodiorite at this locality are also foliated and displaced by the mylonite zones (Fig. 47)

The mylonites zones show similar orientations and relationships to other post-Early Devonian structures developed throughout the region and already examined in the Gilmore and Mooney Mooney Fault Zones. Either a mid-Devonian or Carboniferous age is probable (Stuart-Smith, 1991).

Adelong Falls is a historic reserve containing the ruins of an extensive gold treatment plant. The plant, operating until 1914, treated ore from nearby lode gold deposits. Recent exploration in the area, including underground development, has defined a resource of 410 000 t at 3.2 g/t gold (Morrison & Nenke, 1990). The primary deposits occur within shear zones in the Wondalga Granodiorite and to a lesser extent in the Avenall Basic Intrusive Complex (Fig. 45). The gold occurs in pyritic quartz veins and stockworks associated with both the NNE- and NNW-trending zones. A mantle origin for the gold is indicated by the association of mineralisation with lamprophyres, high heat flow regime, noritic intrusives, I-type granite and its location within a regional tectonic zone (Morrison & Nenke, 1990).

THE ADELONG FALLS TREATMENT PLANT



1. Holding tanks
2. Caretaker's cottage & store
3. Water wheel housing
4. Water wheel in place
5. Buddle
6,7,8 Holding tanks
9. Reverberatory furnace
10. Chimney
11. weighbridge scales
12. Ore processing machinery

Gold was discovered in the Adelong area in 1857 and within a few years the district had a population of 20,000.
Numerous mines were opened up in the surrounding hills and rich gold-bearing ore was processed using water powered stamper batteries on the Adelong Creek. These gold workings were once described as being one of the best, if not the very best, on the New South Wales goldfields.
The batteries continued in operation until 1914.
All the machinery at the site was worked by two large water wheels (3) and (4) supplied with water from Adelong Creek and carried down by races either cut into the hillside or on wooden trestles.
To separate the gold from the quartz the ore was either crushed with a heavy iron wheel, rotating in an iron pan or with heavy iron stampers or rollers (120.
To recover the gold, the crushed ore was bought into contact with mercury. As the ore passed over the mercury, the gold combined with it to form an amalgum and was retained. The final process to recover any residual gold was at the buddle (5) which resembled a huge gold panning dish.
The furnace (9) with its underground flue and tall brick chimney (10) was used to treat ore with impurities and to separate the gold from the mercury amalgum.
The process was far from perfect and processed ore was often held in tanks (6, 7, & 8) to be worked again.

(modified extract from the notice at Adelong Falls Reserve)

Stop 4.3 Deformed Ordovician Turbidites: Mt. Adrah road cut, Hume Highway

The highly deformed margin of the WMB extends up to 10 km west of the Gilmore Fault Zone as far as the Wantabadgery Granite and includes the Wondalga Shear Zone. Ordovician metasediments within this deformed zone show a similar polyphase structural and metamorphic history to that interpreted for Ordovician - Early Silurian strata in the Tumut Block east of the Gilmore Fault Zone (eg. the Bumbolee Creek Formation at Blowering Dam; Stop 2.3) (see Table 2).

A good example of the deformed margin is at Stop 4.3 where multiply deformed Ordovician flysch is exposed in a cutting on the Hume Highway near Mt. Adrah. The flysch comprises interbedded graded thin to medium-bedded fine to coarse-grained quartz arenite and phyllite. Several pyroxene phyric basalt dykes intrude the metasediments crosscutting all structures (Fig. 48).

A penetrative bedding parallel foliation is present in both the arenites and pelites and is axial planar to isoclinal folds. Both the foliation and bedding are tightly folded about southeasterly trending F_2 folds with a well developed vertical axial crenulation (Fig. 49) The F_2 folds at this locality probably correlate with the main upright folds (F_1) present in the Ordovician flysch west of the Wantabadgery Granite (eg. Stops 4.6 and 4.7).

Late conjugate kinks present trending 040° and 095° reflect a subhorizontal, southeast (158°) directed principal-compression direction, the same as that interpreted for conjugate kinks in the Tumut Block (Stuart-Smith et al., 1992). This direction parallels that of some of the mid-Carboniferous regional megakinks described by Powell (1984) and Powell et al. (1985) in the southeastern part of the Lachlan Fold Belt. On the basis of their post "Bowning Orogeny" age and their similar orientation to the regional megakinks, the kinks in the Tumut region were interpreted by Stuart-Smith et al. (1992) to be also mid-Carboniferous.

Quartz veining is common with at least two generations evident (Figs 50 & 51). The oldest veins, perpendicular to bedding, are localised within sandy beds. The veins are mostly deformed and rotated into parallelism with the S_1 foliation and a second generation of narrower and more continuous veins which are syn S_1.

Figure 44. Excellent exposures of the Wondalga Granodiorite at Adelong Falls, the site of an old gold treatment plant for the Adelong goldfield.

Stop 4.4 High-grade zone Ordovician turbidites, Hume Highway

(stop description modified from 25th International Geological Congress, Excursion 17A Field Guide, Stop 3.7; Crook & Powell, 1976

West of the Wantabadgery Granite, newly formed road cuttings along the Hume Highway expose a sequence of Ordovician turbidites metamorphically zoned from sillimanite bearing pelitic schist adjacent to the granite, through biotite zone metasediments, to low grade chlorite zone rocks west of the Wagga Wagga turnoff.

At this stop the metamorphic rocks comprise high grade quartz-rich metasediments with the mineral assemblage quartz + biotite + muscovite + fibrolite + retrogressed ?cordierite ± K-feldspar.

A prominent foliation in the schists dips 60° W and contains a strong mineral lineation pitching 70° S. The same foliation and mineral elongation lineation can be traced into the adjacent Wantabadgery Granite which is exposed in the road cutting some 200 m to the east. Minor quartz-mica-tourmaline pegmatite veins are present in places.

The structural and metamorphic history of the rocks appears to have been one of isoclinal folding with axial-surface slaty cleavage and progressive medium to high grade metamorphism largely of the thermal type. Deformation probably commenced late in the metamorphism and continued as temperatures declined (Crook & Powell, 1976). This relatively simple history contrasts with complex deformation history of rocks east of the Wantabadgery Granite, such as those seen in the previous stop (Stop 4.3), where at least two groups of tight folds and associated crenulation cleavages postdate peak metamorphism (Barnes, 1972).

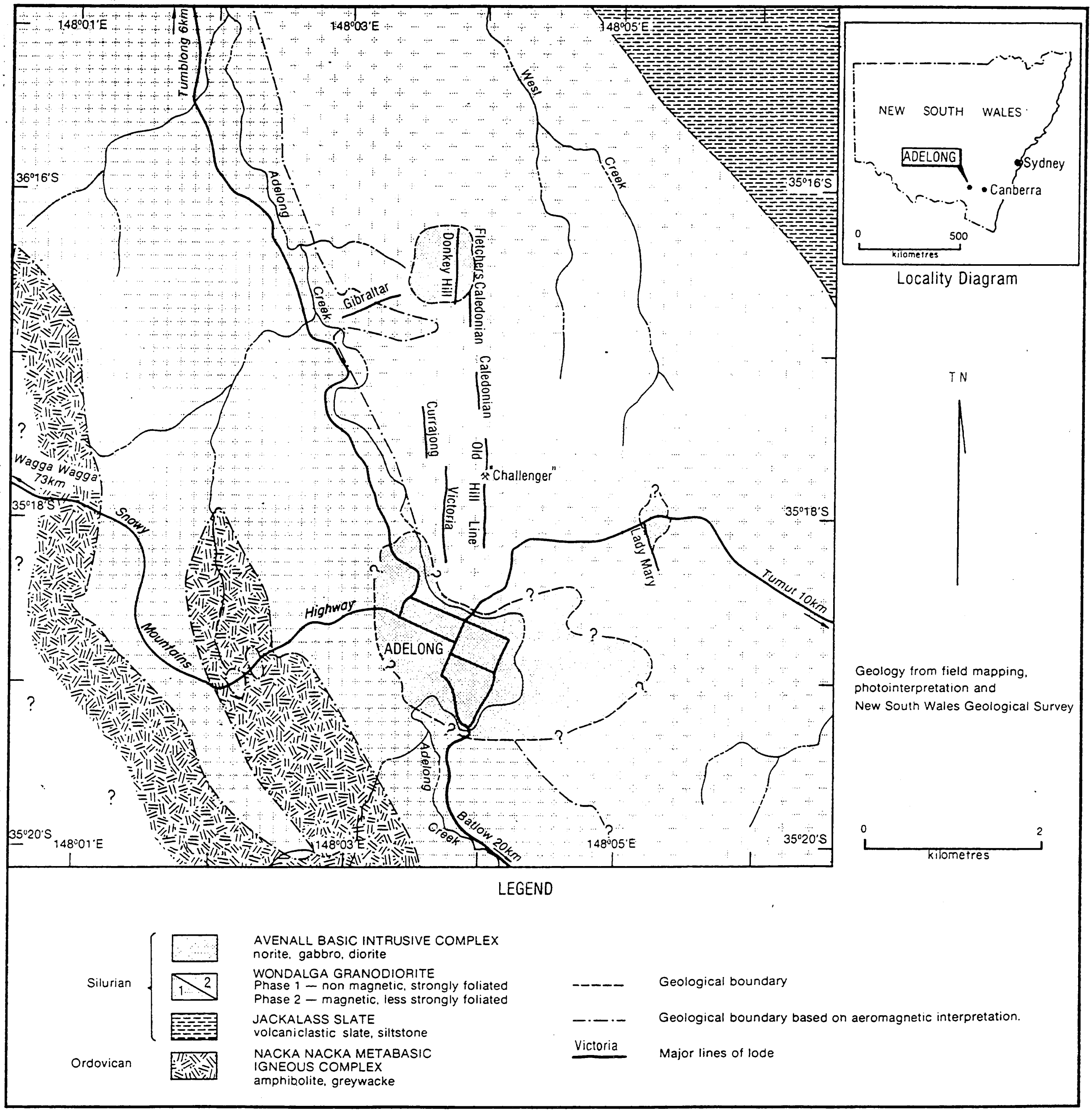


Figure 45. Simplified geology of the Adelong gold field, after Morrison and Nenke (1990)

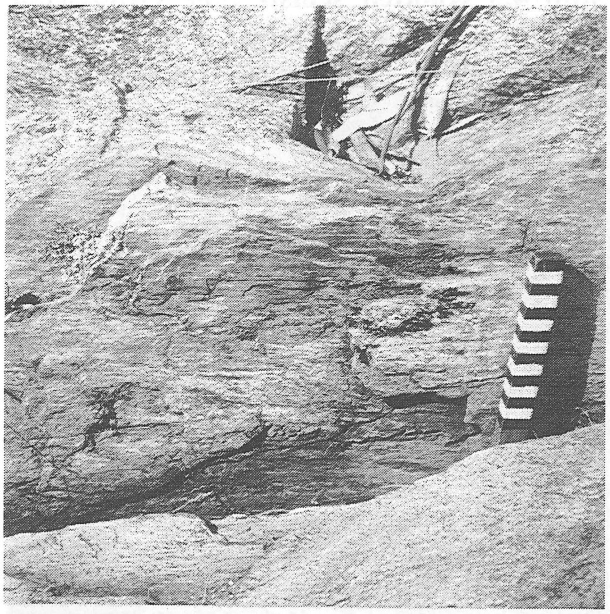


Figure 46. Subhorizontal lineations in a mylonitic zone within the Wondalga Granodiorite at Adelong Falls.

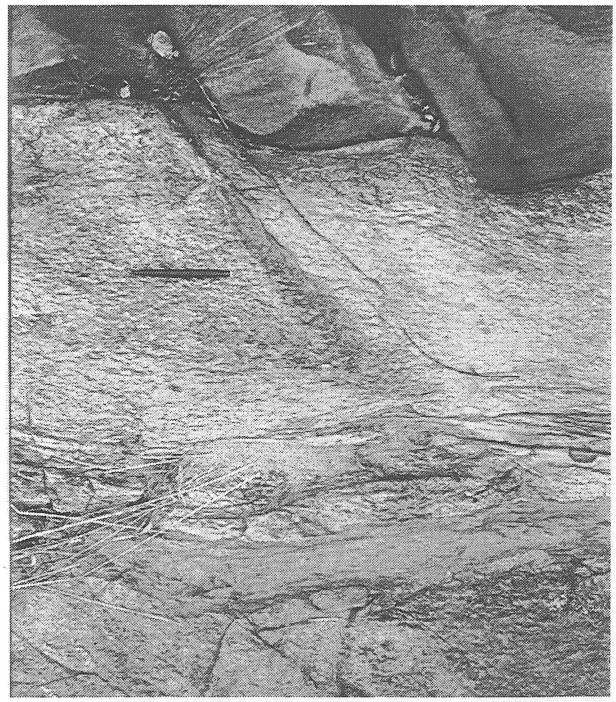


Figure 47. Ultramylonite zones displacing dolerite dykes within the Wondalga Granodiorite, Adelong Falls.

Deformation	Age	Structural elements: Tumut Block	Structural elements: Wagga Metamorphic Belt
D_3	Mid-Devonian	F_4: open to tight, E-verging S_4: crenulation, fracture, mean 82/061	F_3: chevron, E-verging, mean: 35/360[3], 16/330[1], 14/340[2] S_3: crenulation, mean: 78/055′
D_2 Bowning Orogeny	Siluro-Devonian (~ 410 Ma.)	F_3: open to isoclinal, upright variable fold plunge S_3: crenulation, fracture, foliation, mean: 89/245 N of Gocup Gr., 86/099 S of Gocup Gr. Associated flattening and steep NW-plunging elongation lineation, mean: 79/290	F_2: tight to isoclinal, upright, mean 15/310[1], trend 150[4] S_2: crenulation, foliation mean: 86/230[2] Associated flattening and steep NW-plunging elongation lineation
D_1 Benambran Orogeny	Early Silurian (~ 425 Ma.)	F_2: open, upright, mean: 7/084 S_2: crenulation, mean: 89/174 F_1: recumbent, mean: 43/093 S_1: bedding-parallel slaty cleavage	F_1: rare isoclinal in E[1], in S upright tight to isoclinal trending 080°[4] S_1: bedding-parallel foliation in E[1,2]

[1] Barnes (1972), [2] Dobos (1971), [3] Langely (1972), [4] Rogerson (1976).
Note: all F- and S-orientations shown as plunge/plunge azimuth and dip/dip azimuth, respectively.

Table 2. Summary of structural history of the Tumut Block and Wagga Metamorphic Belt (from Stuart-Smith et al., 1992)

Stop 4.5 Knotted schist- zone Ordovician turbidites, Hume Highway

(stop description modified from 25th International Geological Congress, Excursion 17A Field Guide, Stop 3.6; Crook & Powell, 1976)

Muscovite-biotite schists with prominent staurolite and cordierite porphyroblasts are exposed in the road cutting at the hill crest. The schists lie within the "knotted schist zone" (Crook & Powell, 1976) of regionally metamorphosed Ordovician quartz-rich flysch. The porphyroblasts were mostly altered to muscovite and chlorite by retrogression which continued with deformation after peak metamorphism. The schistosity, marked by foliated biotite, dips about 60° W, with a mineral elongation lineation pitching 64° S (Crook & Powell, 1976).

Interbedded foliated biotite-bearing metachert and black carbonaceous slate are also present. The latter, containing graptolites (Packham & Crook, 1954 - referred to in Crook & Powell, 1976), occurs in highly disrupted and faulted zones.

Figure 48. Basalt dyke intruding deformed Ordovician metasediments, Stop 4.3.

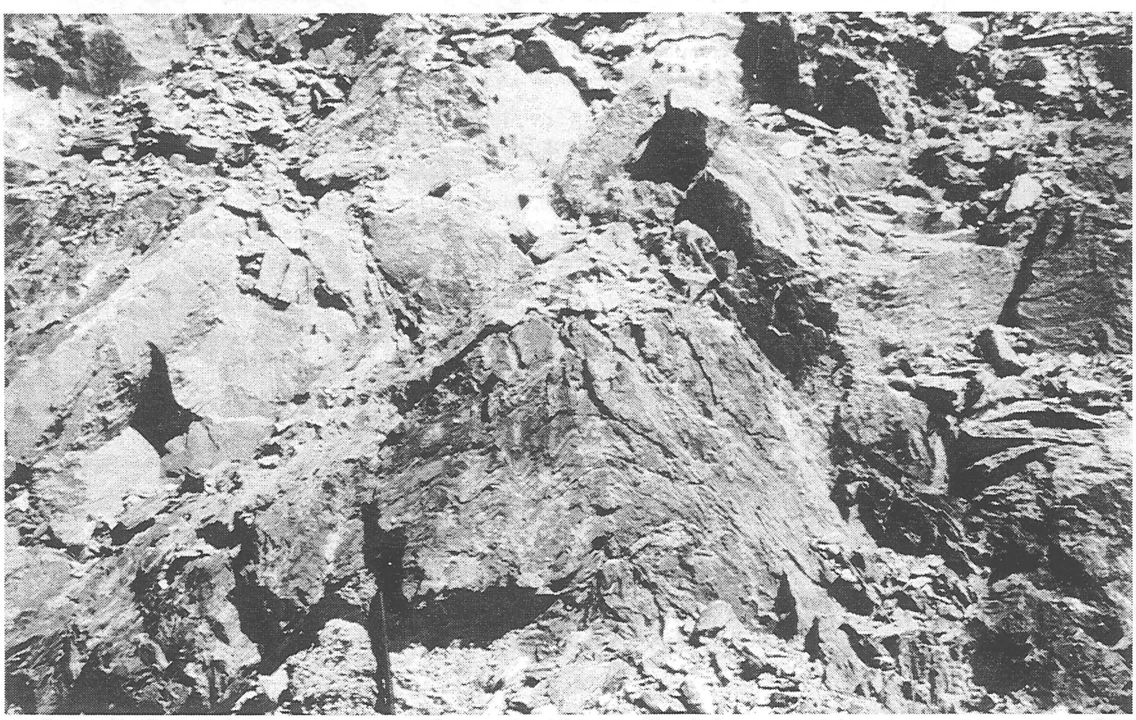


Figure 49. F_1 isoclinal fold hinge refolded by open F_2 folds associated with a vertical axial crenulation.

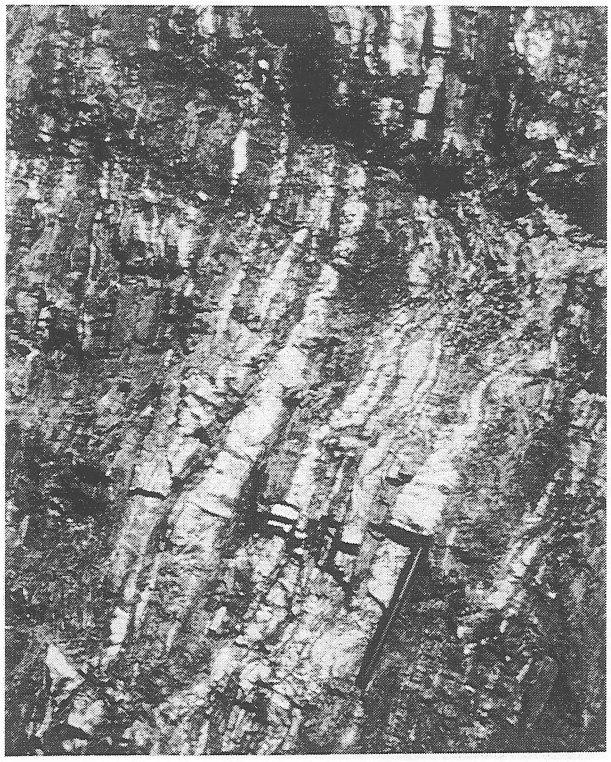


Figure 50. Extensive quartz veining is common within the deformed metasediments.

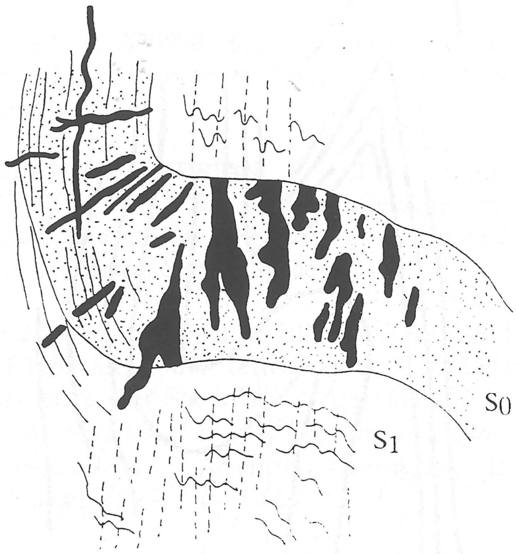


Figure 51. Sketch showing pre- and syn-S_1 quartz vein relationships.

Stop 4.6 Low-grade zone Ordovician turbidites, Hume Highway

(stop description modified from 25th International Geological Congress, Excursion 17A Field Guide, Stop 3.4; Crook & Powell, 1976)

The road cutting on the Hume Highway about 1.7 km south of the Highway 20 (Wagga Wagga) turnoff exposes a mostly westward younging sequence of deformed low grade Ordovician quartz-rich flysch. This outcrop, within the lowest metamorphic zone (chlorite-muscovite slate) is typical of much of the WMB and the Ordovician throughout southeastern Australia (Crook & Powell, 1976).

The exposed sequence comprises mostly interbedded slate and graded fine to coarse grained medium to thickly bedded quartz-rich arenite. Minor thinly bedded carbonaceous slate with very fine grained sandy laminae are also present (Fig. 52). A sequence of laminated to very thinly bedded chert is in fault contact with the flysch facies at the western end of the road cutting.

Only one major deformation is evident. Folds are upright, tight and overturned with an axial, slaty cleavage dipping steeply to the west. Fold hinges are subhorizontal (Fig. 53)

Figure 52. Thinly bedded carbonaceous slate with fine grained sandy laminae form minor interbeds in fine to coarse-grained quartz-rich flysch at Stop 4.6.

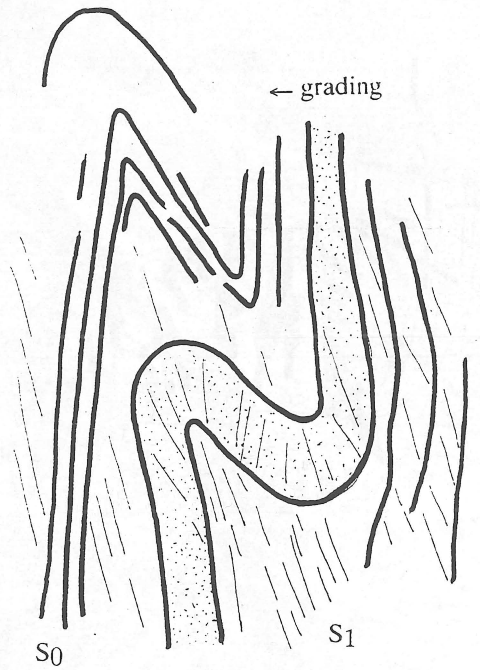


Figure 53. Sketch of fold hinge and structural elements, Stop 4.6.

Stop 4.7 Low-grade zone Ordovician turbidites; 'Alloomba' cutting, Hume Highway

The Ordovician flysch changes very little in either its composition or deformation history across the WMB from Stop 4.6 to west of Wagga Wagga. Some of the best exposures of the rocks occur in road cuttings along the Hume Highway. One such example is on the south side of the Sydney-bound lane near Alloomba homestead, about x km west of Tarcutta.

At this stop low-grade medium to thickly bedded coarse-grained quartz arenites (Fig. 54) are interbedded with slate which is carbonaceous in part. The sandy beds are well-graded and contain shale rip-up clasts in places. Very minor quartz veins, mostly sub-perpendicular to bedding, are also present in the sandy beds.

Only one major deformation is evident. Folds are upward-facing, tight and overturned with gently southeast-plunging axes (Fig. 55). A steeply WSW-dipping (80°/245°) slaty cleavage is axial planar to the folds.

Figure 54. Typical medium to thickly bedded Ordovician quartz rich flysch in the low-grade zone of the Wagga Metamorphic Belt. Pelitic rocks, typically carbonaceous in part, are interbedded with the medium to coarse-grained quartz-rich sandy facies.

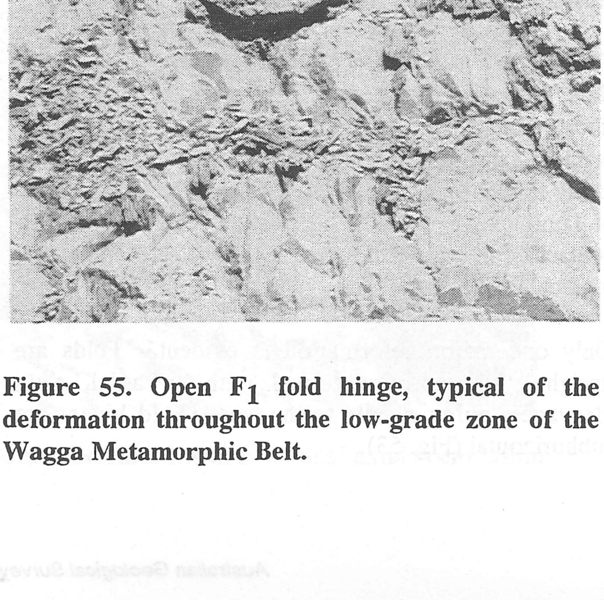


Figure 55. Open F_1 fold hinge, typical of the deformation throughout the low-grade zone of the Wagga Metamorphic Belt.

ACKNOWLEDGEMENTS

Some of the excursion stop descriptions and related figures have been modified from previous published excursion guides on the Tumut area. These publications have been duly acknowledged where appropriate in the text. In this regard, I especially thank Dr. Kelsie Dadd for her detailed work on the Blowering Formation and Honeysuckle Beds for the IAVCEI 1993 excursion guide, some of which has been reproduced in this guide. Drs. D. & L. Wyborn organised some of the stops for Day 1. Drs. D. Wyborn and R. Shaw (AGSO) are thanked for their helpful criticism of the guide. I am very grateful to NSW National Parks & Wildlife staff who assisted with acess into the Kosciusko National Park.

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