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FIELD EXCURSION GUIDE, TUMUT TROUGH, NSW

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SIESMIC PROBING OF CONTINENTS & THEIR MARGINS

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Tumut Trough Excursion Guide

for the International Workshop and Symposium on

Seismic Probing of Continents and their Margins

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by

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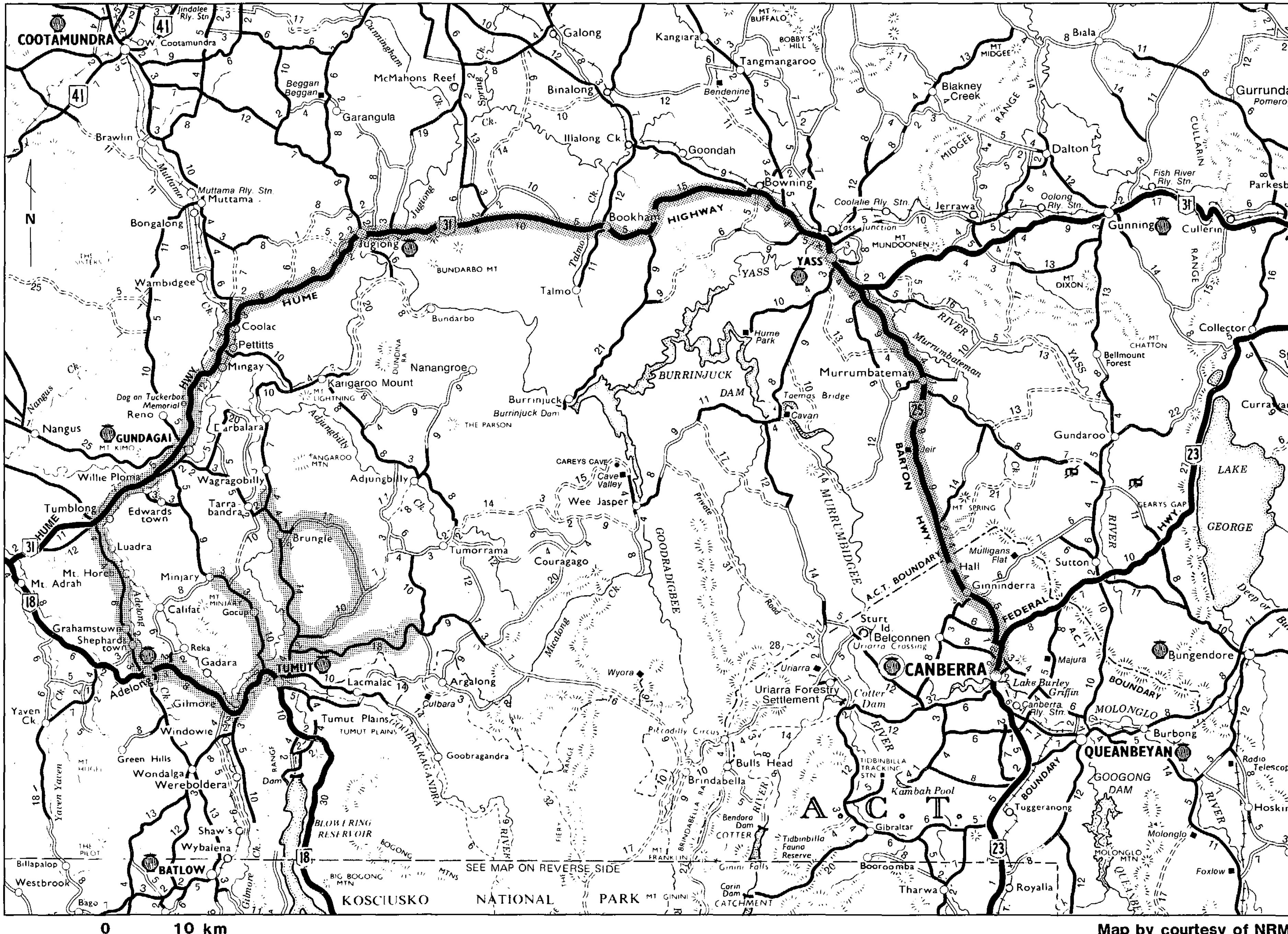
PLATES

(in pocket)

Plate 1. Geology of the Tumut Seismic Traverse
Plate 2. Tumut Trough Seismic Section

EXCURSION ITINERARY

Depart Canberra	07:30 am
Arrive Snake Gully (rest stop)	09:15
Depart Snake Gully	09:45
Tumblong turnoff	10:00
Arrive Adelong Falls (STOP 1)	10:15
Depart Adelong Falls	11:00
Arrive Gilmore Creek (STOP 2) Remain in the bus for this stop	11:15
Depart Gilmore Creek	11:25
Tumut	11:30
Arrive Gocup (STOP 3)	11:45
Depart Gocup	12:05
Arrive Tumut for lunch	12:20
Depart Tumut	1:00 pm
Arrive Bumbolee Creek (STOP 4 & 5)	1:15
Depart Bumbolee Creek	3:15
Arrive Holt's (STOP 6)	4:00
Depart Holt's	4:45
Brungle Creek Road (LOCALITY 7)	
Wee Jasper Road (LOCALITY 8)	
Arrive Tumut RSL	5:45
Dinner PINETUM's Restaurant	6:00
Depart Tumut	8:00
Arrive Canberra	10:30 pm



Map by courtesy of NRMA

Fig. 1 Bus route for Tumut Trough excursion.

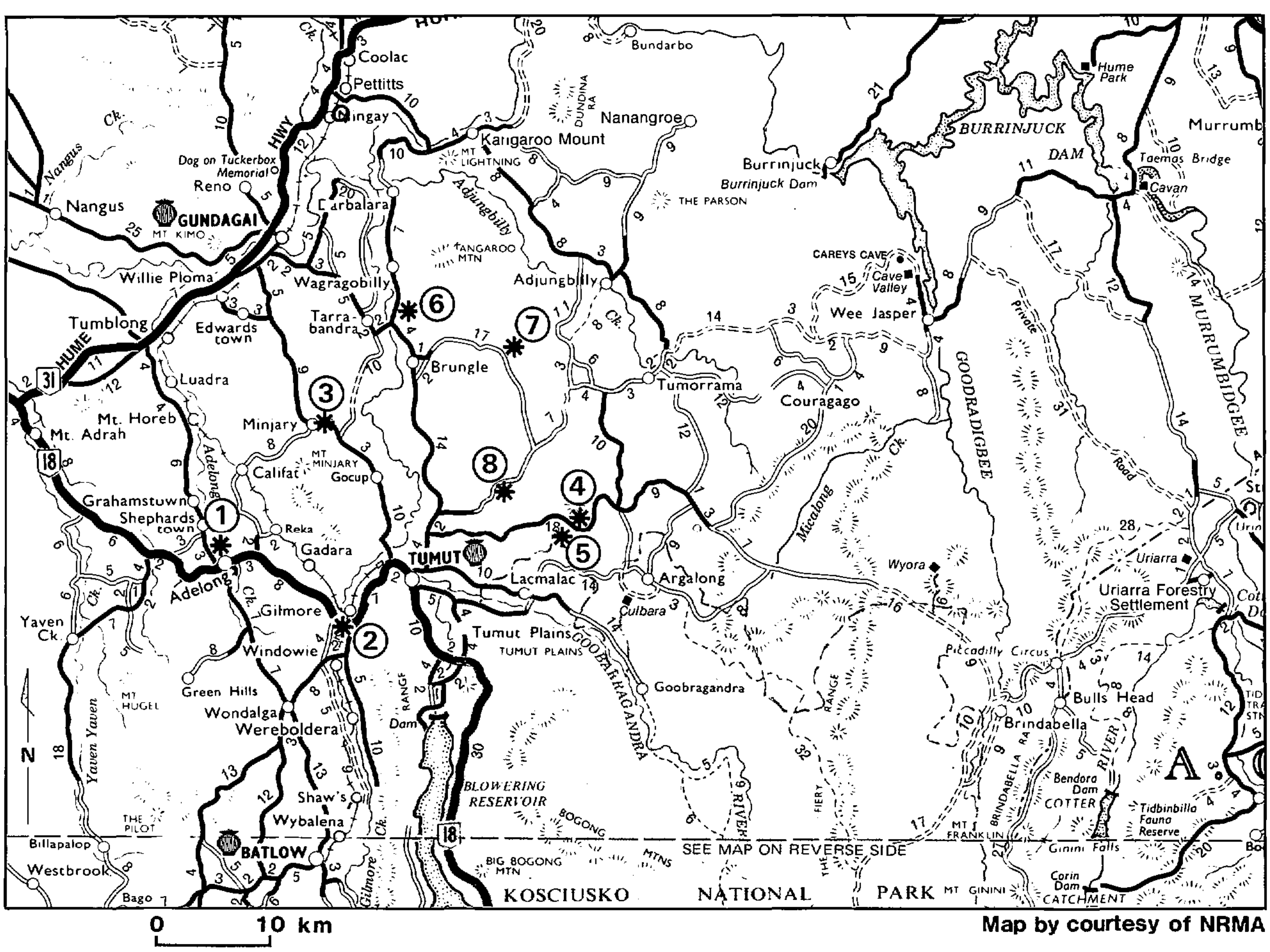


Fig. 2 Location of the excursion stops.

REGIONAL GEOLOGY

2.1 The Tumut Trough within the Lachlan Foldbelt

The Lachlan Foldbelt is a complex Cambrian through Devonian tract that forms the southern part of the Palaeozoic Tasman Foldbelt of eastern Australia (Fig. 3). It is characterised by widespread turbidites, mafic and felsic volcanics, local limestones and associated shallow marine clastic sediments, and extensive granitoid batholiths.

The place of the Tumut Trough within the Lachlan Foldbelt can best be appreciated in the context of the Ordovician and Silurian history of south eastern Australia, as discussed by Powell (1983) (Fig. 4). During the Ordovician, the region was a site of widespread deep marine sedimentation associated with a convergent plate margin close to the present east coast (Figs. 5, 6). By the early Silurian, subduction at this margin had ceased (Fig. 7). The region west of the site of the Tumut Trough was deformed and metamorphosed, becoming a site of widespread granitoid magmatism (Fig. 8a). Subsequently, a dextral trans-tensive regime was established (Figs. 8b, 9), during which the Tumut Trough developed as an ocean-floored pull-apart basin concomitantly with other basins to the northeast (Fig. 8b).

In the Early Devonian the sedimentary and volcanic fill of the Tumut Trough was deformed, apparently concomitant with extensional events to the northwest, including the opening of the Cobar Trough (Crook 1980). Paralic redbeds and associated felsic volcanics overlie the deformed Ordovician and Silurian rocks of the Tumut Trough with profound angular unconformity. This facies association, which became widespread in the Lachlan Foldbelt by the end of the Devonian, represents a tectonic regime transitional in space and time between the pre-cratonic mobile stage and the succeeding stage of cratonic stability which was established during the Carboniferous. This history is summarised in Figure 10.

Although there is general agreement about the origin of the Tumut Trough as a Silurian extensional feature, there is considerable dispute about details of its evolution and its mode of closure. Crook (1980) suggested that closure occurred by eastwards-directed subduction along the eastern margin of the Trough, implying a much more extensive area of oceanic crust that that shown in Figure 8b. Other authors (e.g. Powell, 1983) consider that the maximum width of the Tumut Trough was never large, so that closure could have been achieved without invoking subduction. One of the aims of the seismic reflection profile was the acquisition of data to test these alternative scenarios.

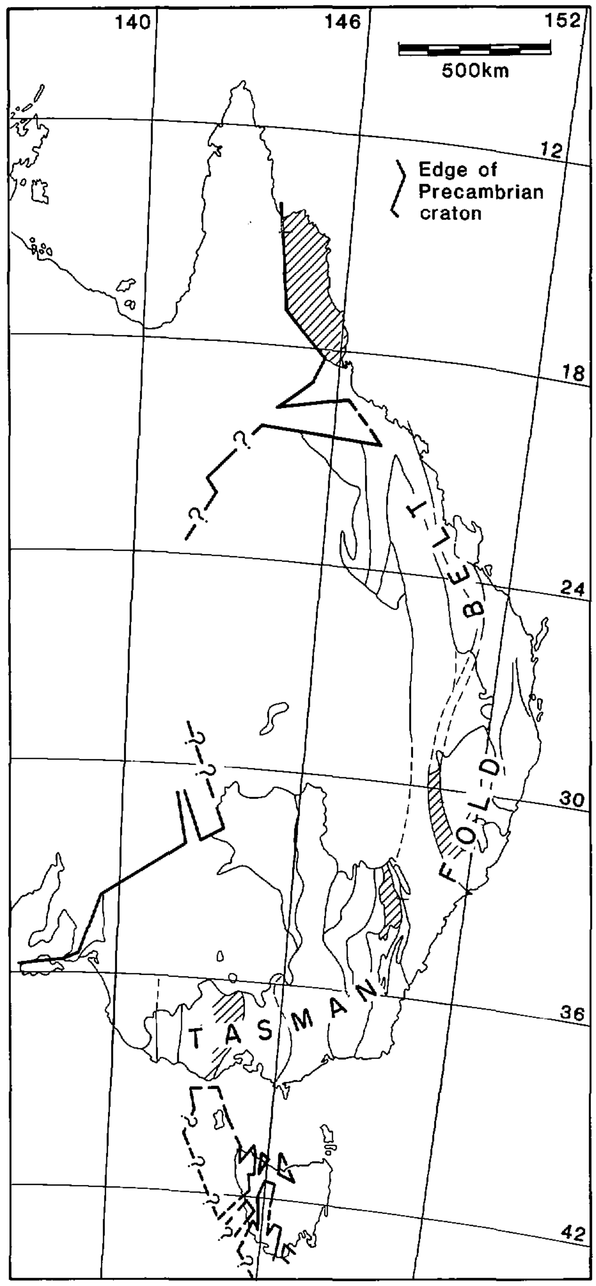


Fig. 3 Map of the Tasman Foldbelt (after Crook, 1986).

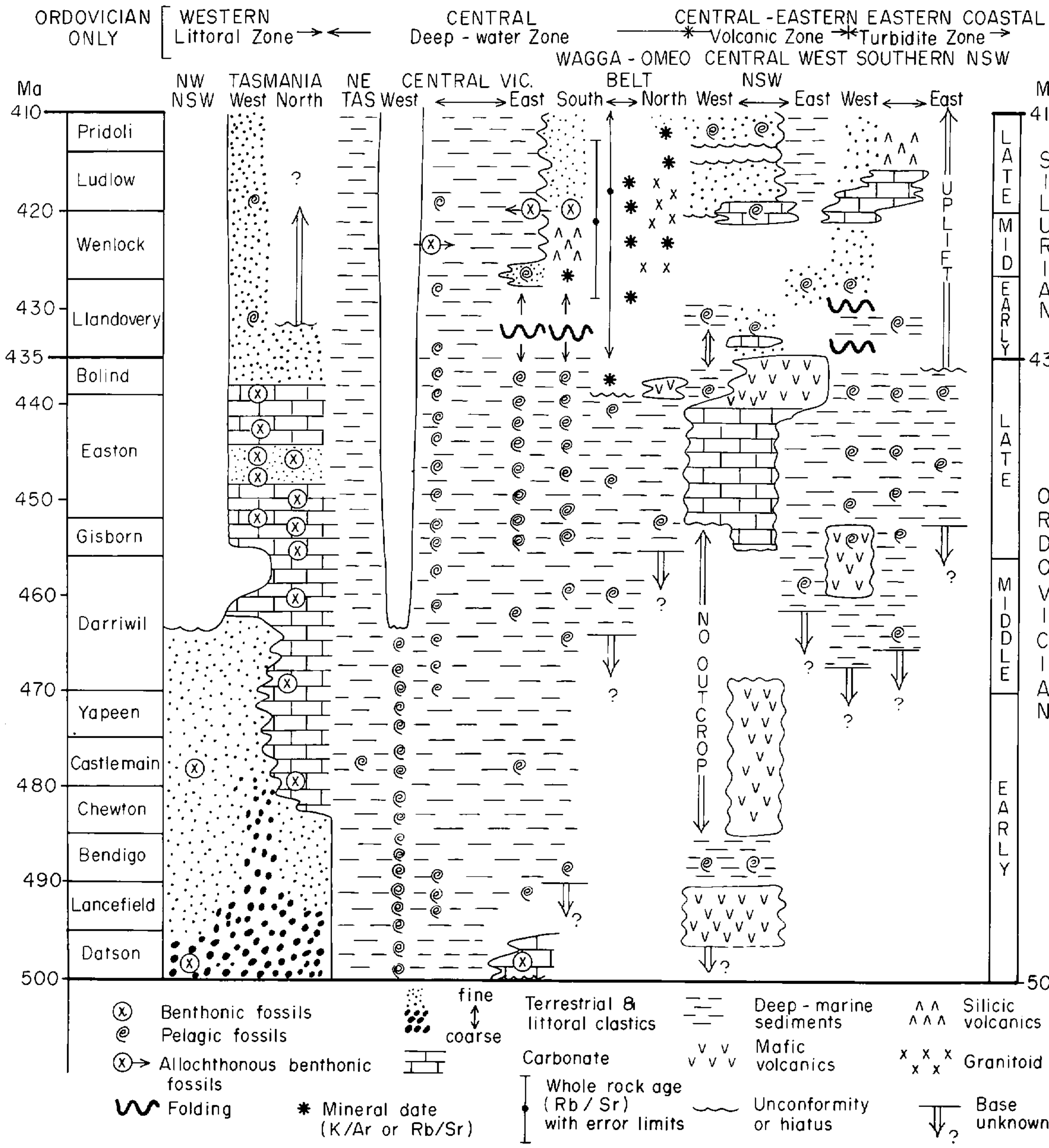


Fig. 4 Ordovician and Silurian time-space chart west to east across southeastern Australia (after Powell, 1983).

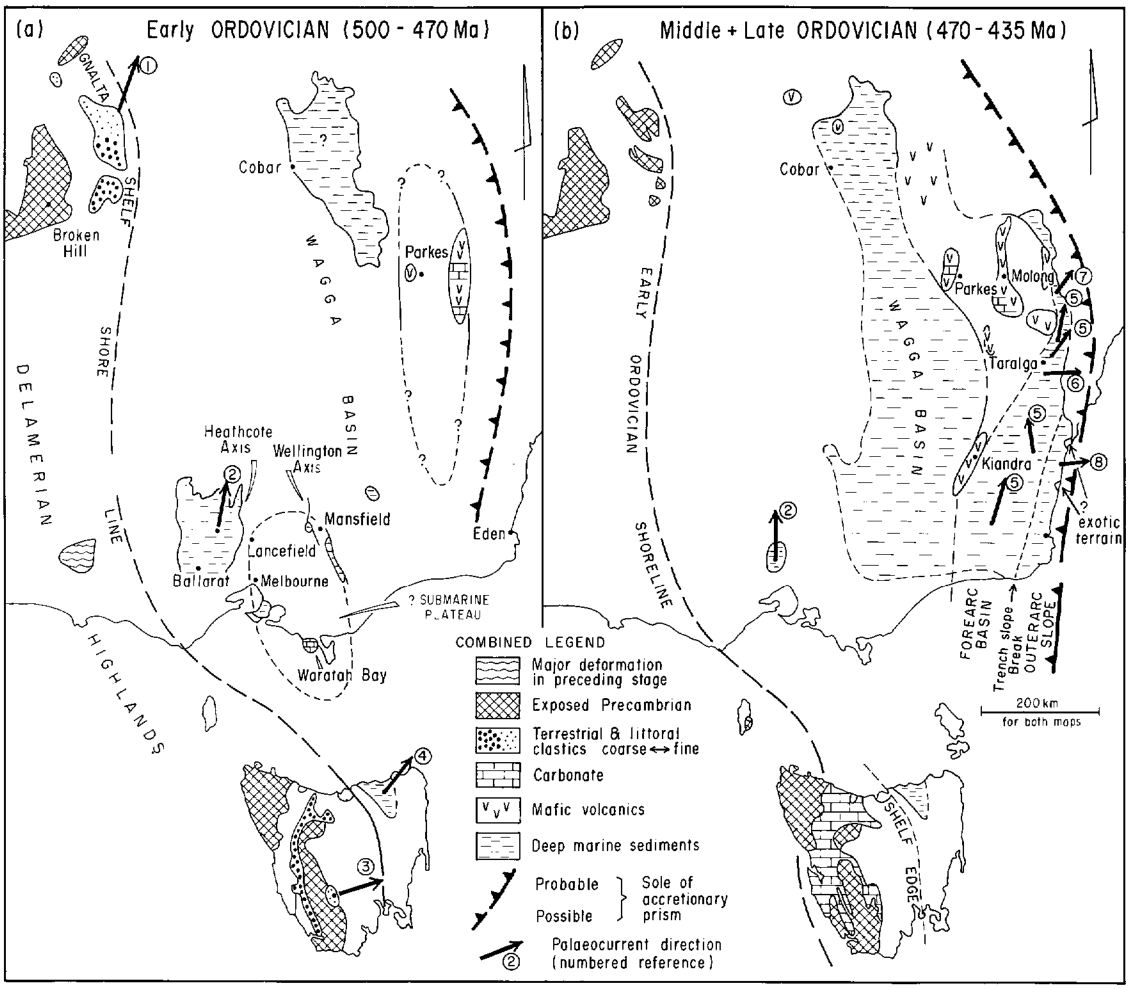


Fig. 5 Distribution of Ordovician rocks in southeastern Australia. (a) Early Ordovician, (b) Middle and Late Ordovician (after Powell (1983), which includes references to numbered palaeocurrent sources).

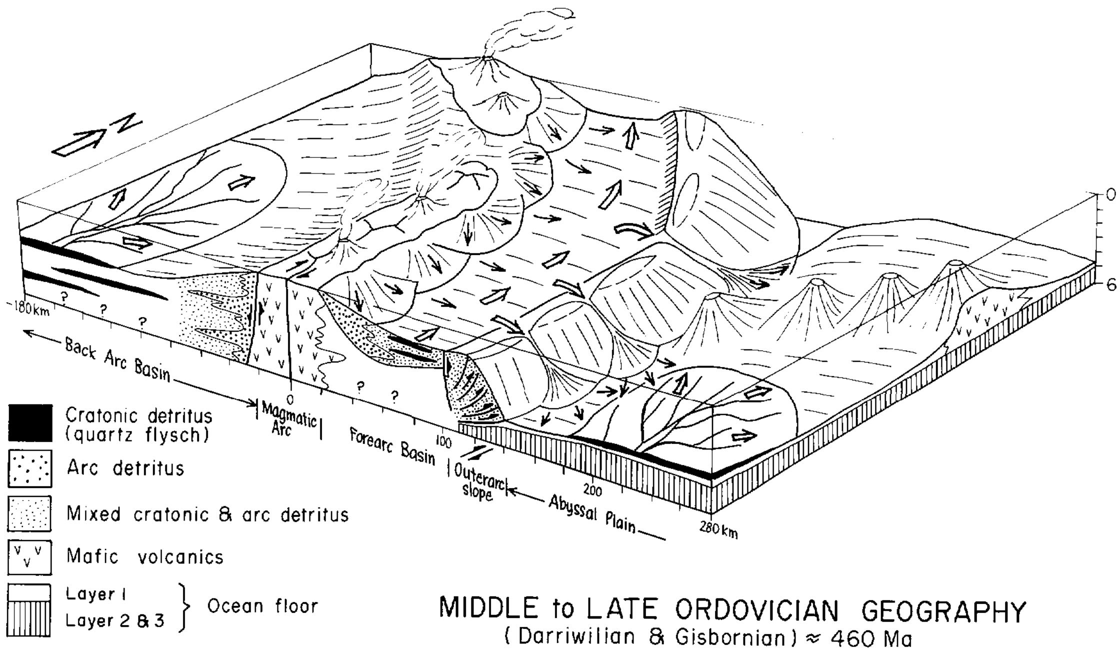


Fig. 6 Scaled block diagram of Middle to Late Ordovician palaeogeography (after Powell, 1983). Arrows indicate palaeoflow directions.

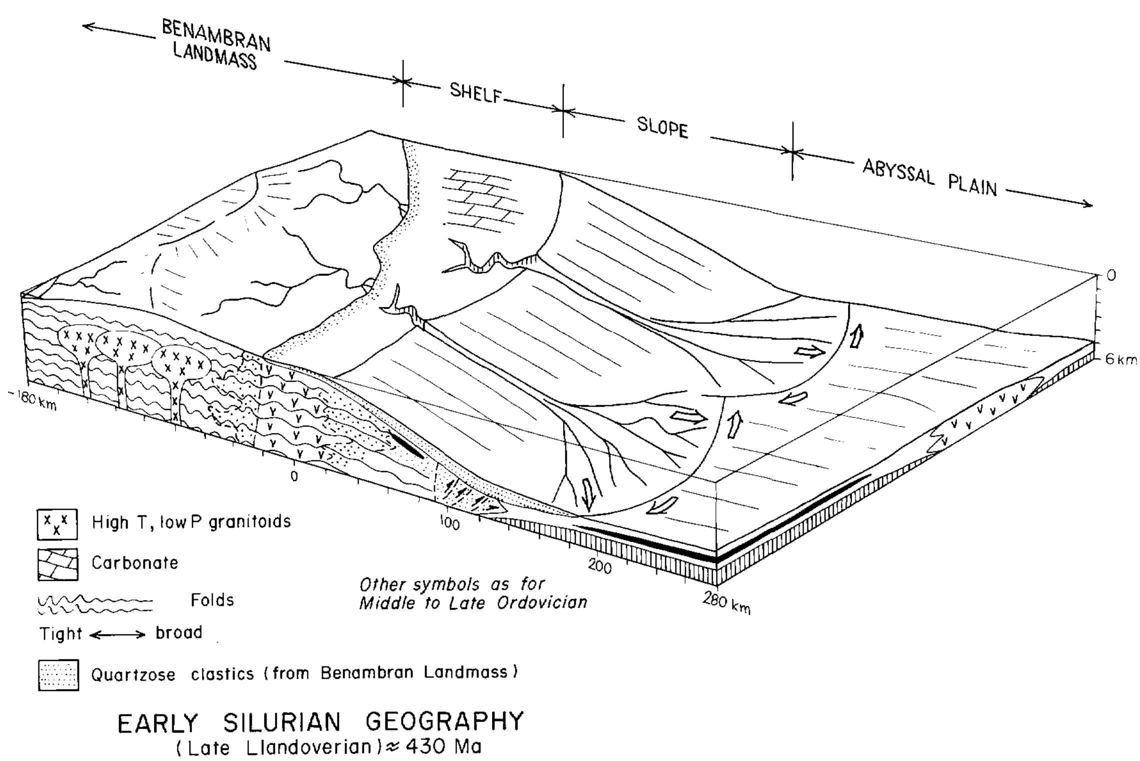


Fig. 7 Scaled block diagram of Early Silurian palaeogeography (after Powell, 1983).

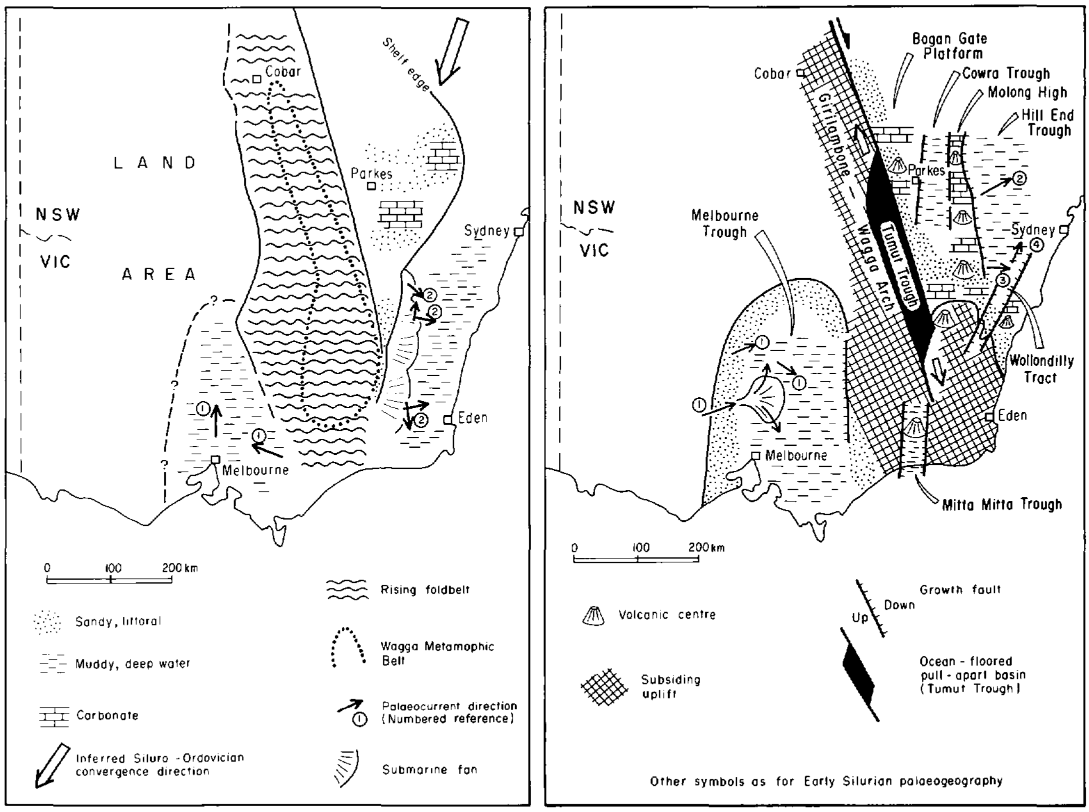


Fig. 8 Distribution of Silurian rocks in southeastern Australia. (a) Early Silurian, (b) Late Silurian (after Powell (1983), which includes references to numbered palaeocurrent sources).

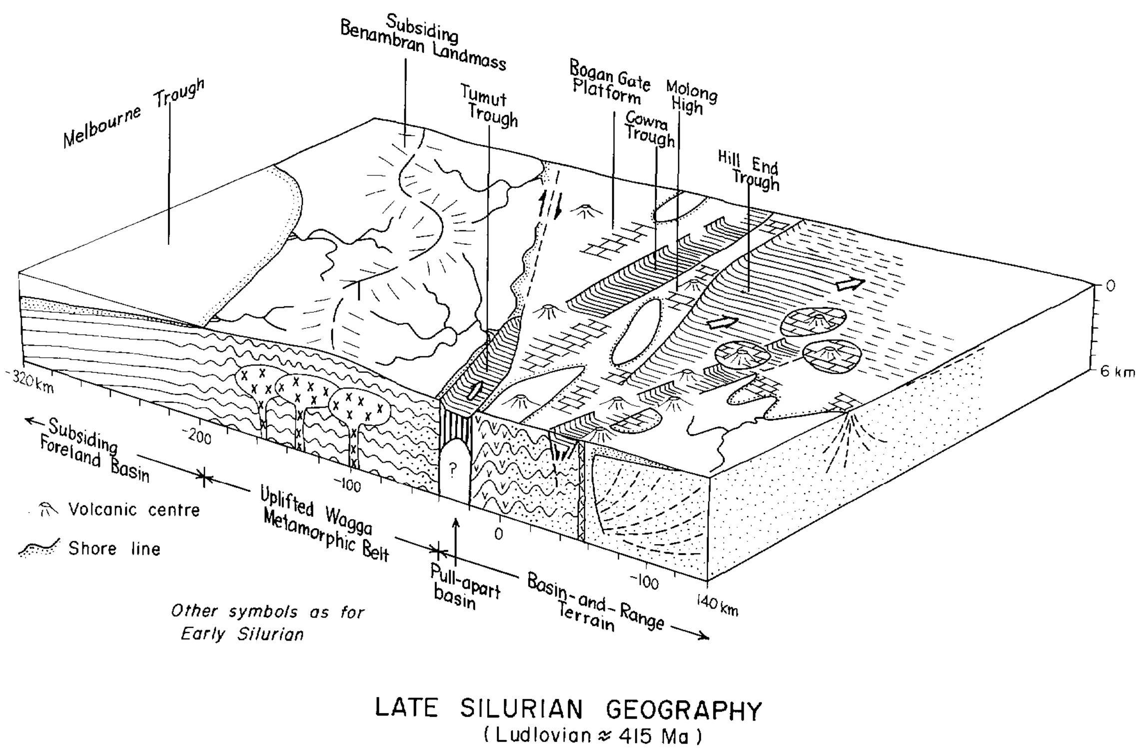


Fig. 9 Scaled block diagram of Late Silurian palaeogeography (after Powell, 1983).

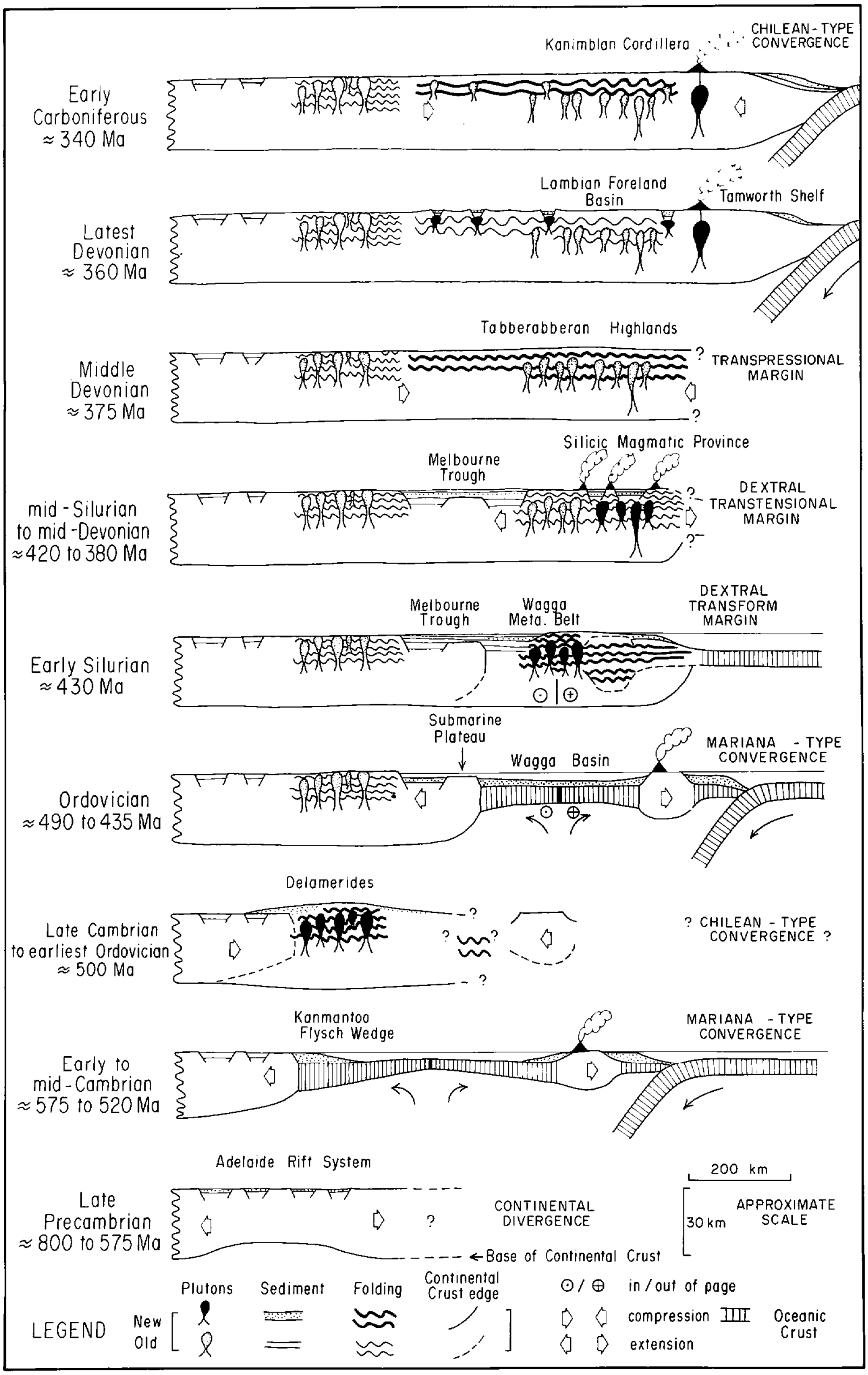


Fig. 10 Cartoon showing plate-tectonic interpretation of the development and ultimate stabilization of the Lachlan Foldbelt (after Powell, 1983). E-W sections are drawn at a latitude about 36° S, with some elements projected on to profiles along tectonic strike. Scale is very approximate.

2.2 Geology of the Tumut Trough

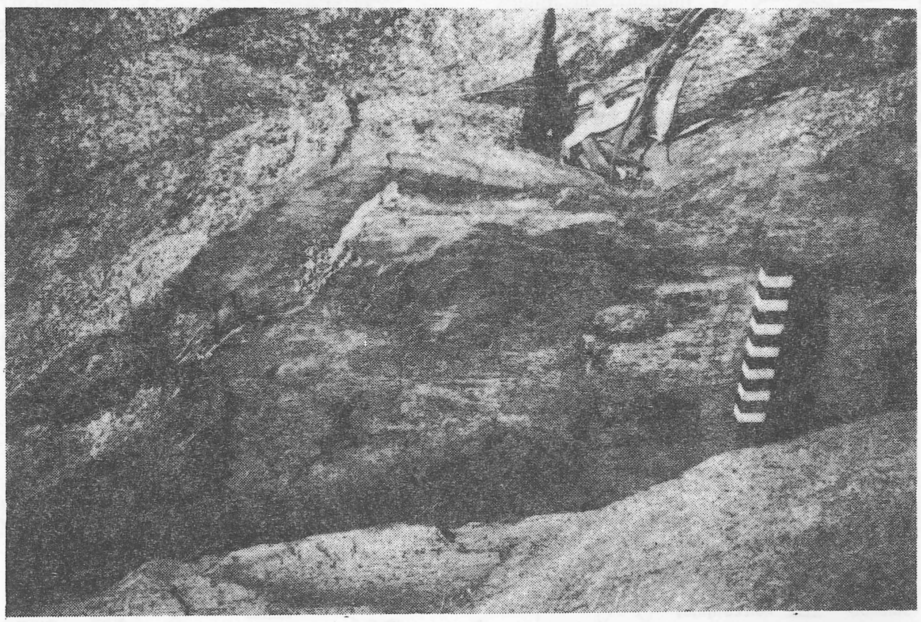
The Tumut Trough is an Early Palaeozoic tectonic and palaeogeographic feature striking NNW-SSE within the Lachlan Fold Belt. It is bounded to the east by the Mooney Mooney Fault System, and to the west by the Gilmore Fault, both of which have been interpreted as terrane boundaries. Interest in the Tumut Trough stems from the occurrence of ultramafic rocks and Silurian flysch in association not found elsewhere in the Lachlan Fold Belt. The presence of ultramafics along the bounding faults of the trough indicates deep penetration and involvement of mantle material. Within the trough a basement anticline of mafic schists of possible Ordovician age is flanked by basaltic and dacitic volcanics. The trough is bordered to the east and west by the dominantly granitic rocks of the Lachlan Fold Belt: to the east - the Late Silurian Young Granodiorite; and to the west - the Ordovician Wagga Metamorphic Belt.

The association of ultramafics, gabbros, pillow basalts, cherts and turbidites with felsic volcanics has led to a variety of scenarios for the formation of the trough - marginal sea, continental rift, trans-tensional pull-apart basin - and for its closure by transpression or eastward directed subduction of the trough floor.

The stratigraphic sequence is set out in Plate 1. The earliest deposits were basic volcanics now highly deformed into nappe-like slices of actinolitic schists (Bullawyarra Schist). These represent a possible Ordovician Island Arc deposit distinctly different from the quartz-rich flysch found elsewhere in the Lachlan Fold Belt. Subsequent Silurian development of the trough involved different facies; with metabasalts and quartz-poor flysch in the east, and felsic and basic volcanics followed by quartz-intermediate to quartz-rich flysch and shales in the west. Both sequences were covered by extensive sheets of felsic S-type volcanics in the Middle Silurian (Blowering Volcanics). Volcanic activity continued with the Devonian I-type felsic volcanics and local granites and molasse sediments. Thus only in pre-Blowering times was the palaeogeography different from elsewhere in the Lachlan Fold Belt.

Deformation is variably mild to intense with strong folding and intense shearing along the major fault zones. Detailed geological mapping of the structure along the seismic traverse is described by Stuart-Smith (1988).

(a)



(b)

Fig. 11 Stop 1: Adelong Falls. (a) Ultramylonitic zones within the Wondalga Granodiorite showing the displacement of dolerite dykes (left). The main metamorphic foliation in the granodiorite is indicated by the pencil. In this photo the sinistral mylonite zone offsets a dextral set, however, in the same outcrop the reverse also occurs. (b) Subhorizontal lineations in a mylonitic zone within the Wondalga Granodiorite.

3. EXCURSION STOP DESCRIPTIONS

3.1 STOP 1. Adelong Falls

At Adelong Falls, about 7 km south of the planned seismic traverse, excellent exposures of the Wondalga Granodiorite crop out in a gorge along Adelong Creek. The medium- to coarse-grained biotite granodiorite is one of a number of ?Lower to Upper Silurian granitoids which intrude deformed Ordovician metasediments and together make up the Wagga Metamorphic Belt. Although the seismic survey did not extend into this belt, reflections from the bordering Gilmore Fault (about 4 km northeast of Adelong Falls) were recorded.

Exposures in the gorge lie within a broad zone of deformation flanking the Gilmore Fault. 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 west and a sinistral subvertical set trending NNW (Fig. 11a). Both mylonitic sets, interpreted to represent a conjugate pair, have a prominent lineation which respectively plunges gently to the NNE and subhorizontally (Fig. 11b). Widespread dolerite dykes within the granodiorite at this locality are also foliated and displaced by the mylonite zones.

The NNW-trending mylonites at Adelong Falls parallel the Gilmore Fault which, in this area, also shows mainly sinistral strike-slip displacement. The formation of the mylonite zones and the sinistral movement on the Gilmore Fault were possibly synchronous with upright folding of the Tumut Trough Silurian sequence during the Early Devonian.

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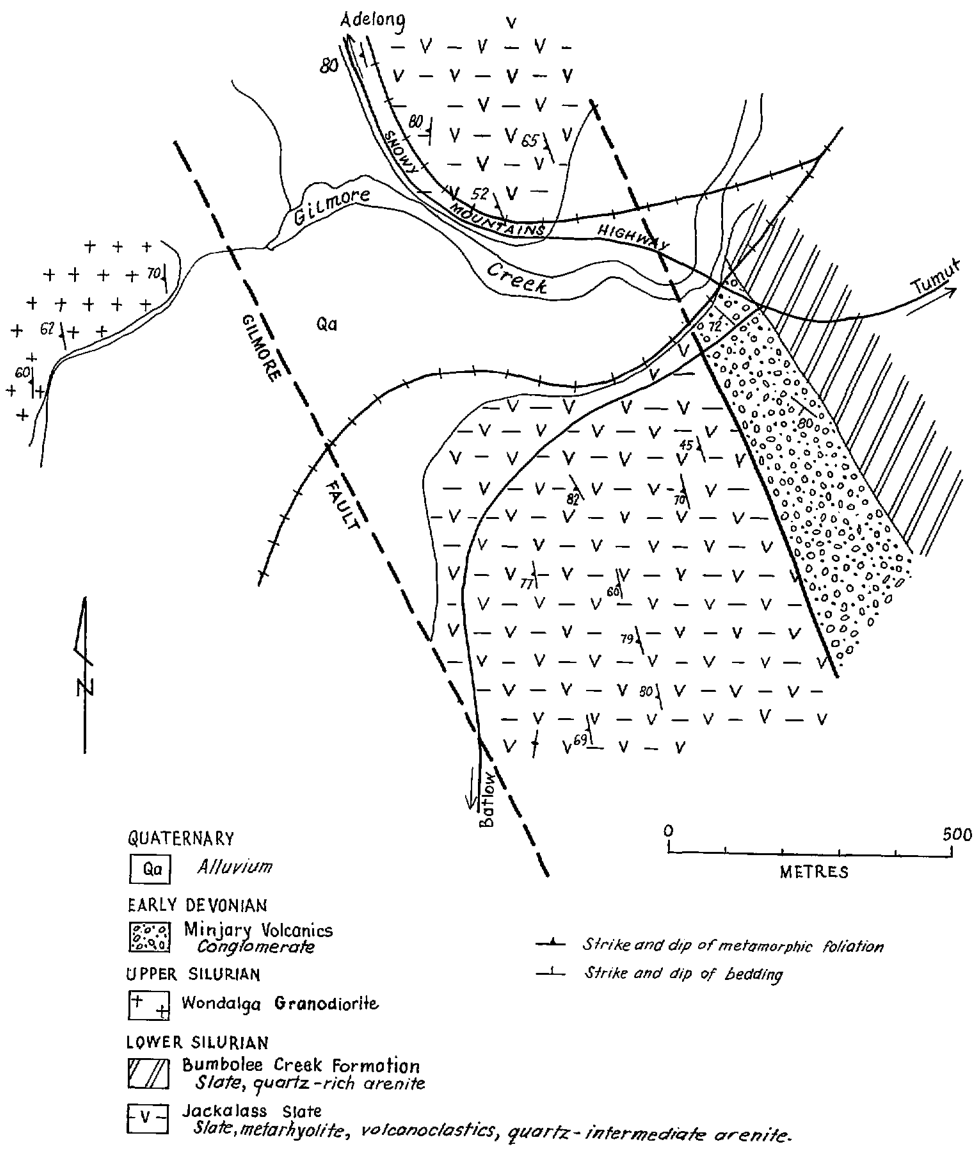

Fig. 12 STOP 2: Gilmore Creek (geology modified from Ferguson, 1982 unpublished data)

3.2 STOP 2. Gilmore Creek

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 Silurian metasediments and volcanics immediately east of the fault (Fig. 12).

Mylonitic granodiorite of the Wondalga Granodiorite crops out in the creek about 1 km west of the Batlow turnoff. As at Adelong Falls, and along the seismic traverse, the foliation parallels the fault, trending NNW and dipping steeply to the west. However, mineral lineations in the granodiorite pitch 25^{o} - 55^{o} NNW indicating oblique-slip displacement. Microfabrics indicate that movement was reverse (ie sinistral horizontal component).

Metasediments, felsic volcanics and volcaniclastics of the Jackalass Slate abut the Gilmore Fault. As in the granodiorite a steep west-dipping penetrative foliation is present. This foliation decreases in intensity away from the fault and is present as a spaced fracture or crenulation cleavage in metasediments of the Bumbolee Creek Formation (exposed in the eastern portion of road cutting at the Batlow turnoff). Here and farther to the east two deformations pre-date 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 down-faulted against the Jackalass Slate to the west. The contact with the underlying Bumbolee Creek Formation is probably unconformable with some localised faulting. The conglomerate contains abundant phyllite and vein quartz clasts and is interpreted to be part of the Early Devonian Minjary Volcanics.

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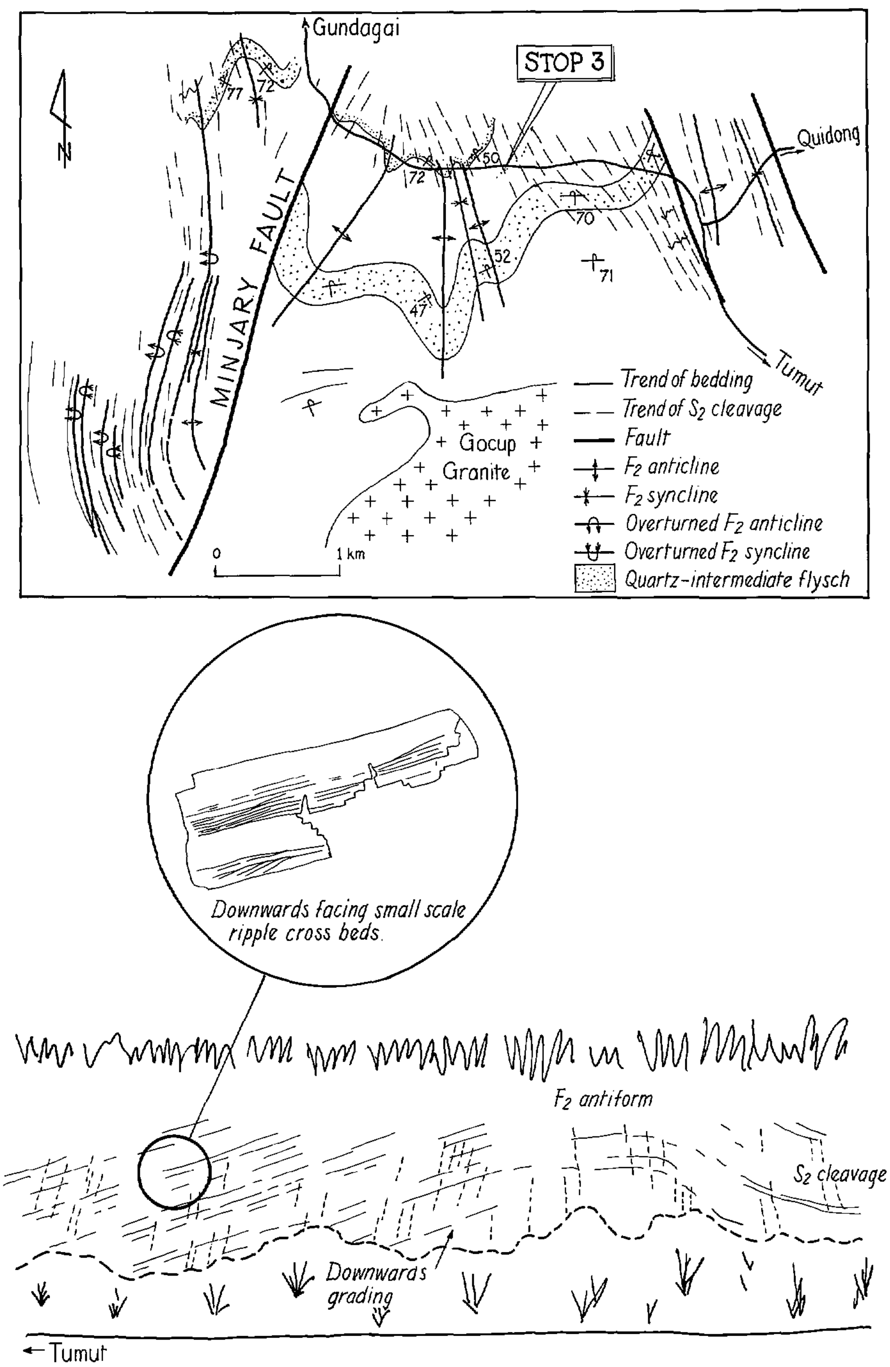

Fig. 13 Stop 3: Gocup road cutting, locality map and sketch.

3.3 STOP 3. Gocup road cutting

An antiform and subsidiary folds in flysch of the Bumbolee Creek Formation are exposed in a low road cutting on the South Gundagai road 15 km northwest of Tumut. Rock types present include quartz-intermediate arenite, mudstone and polymictic rudite. Quartz-rich arenite predominates in the unit elsewhere in the Tumut Trough but is not present at this locality.

Graded bedding in the rudite and small-scale ripple cross beds in arenite at this locality indicate that the folds are downward-facing (Fig. 13). The folds plunge ca. $30^{\circ}/150^{\circ}$, with an axial-surface subvertical crenulation cleavage striking 330°. The folds are open, a style restricted in this area north of the Gocup Granite (Duff & others, 1979). On the western and eastern margins of the granite they become tight to isoclinal with a penetrative axial cleavage and associated flattening. This relationship and overprinting of contact metamorphic minerals on a bedding-parallel cleavage indicate that the granite was emplaced prior to the main N-S trending folds but after an earlier phase of recumbent folding (Crook, 1978).

The structural history outlined at this stop is present throughout the Silurian metasediments encounted by the seismic traverse west of the Killimicat Fault (Bumbolee Creek Formation and Jackalass Slate). Basement to the Silurian sequence is not exposed in this part of the Tumut Trough.

NOTES

3.4 STOPS 4 & 5. Bumbolee Creek road and creek sections

Dismembered sections of the Coolac Ophiolitic Suite form the eastern margin of the Tumut Trough within a meridionly-trending intensely faulted belt extending for over 50 kms. This belt known as the Mooney Mooney Fault System (Basden, 1986) interpreted as a terrane boundary (Basden & others, 1987), throws the Upper Silurian Young Granodiorite to the east against the ophiolitic suite. Spectacular exposures of deformed granodiorite, serpentinite and the Honeysuckle Metabasic Igneous Complex occur along the Bumbolee Creek road and in the adjacent creek bed where the road traverses the Honeysuckle Range 12 to 13 km east of the junction with the Brungle road (Fig. 14).

Road Cutting (STOP 4)

The Young Granodiorite is a coarse, relatively homogeneous, "S" type granitoid, the bulk of which is massive to slightly more foliated approaching the fault contact where the rock grades into an ultramylonite. The stop commences with a walk down the road through granodioritic mylonite to the tectonic contact with the serpentinite.

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 later brittle deformation associated with minor thrusting of the granodiorite to the west. 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 (see Fig. 14).

The contact between the mylonite and serpentinite is sharp and dips steeply to the east (60-75^{o}/090^{o}) parallel to the main foliation in the mylonite and shear planes in the adjacent serpentinite. A vertical to steep SE-dipping foliation is also present in the serpentinite. Shear movement vectors determined in the serpentinite in this area indicate oblique-slip with a dominantly sinistral strike-slip motion except where the dextral shear zone transgresses the belt south of the creek. The serpentinite, a metasomatised harzburgite (Ashley & others, 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.

Creek section (STOP 5)

In Bumbolee Creek, directly below the road section, tectonic slivers of the Honeysuckle metabasic Igneous Complex and the Coolac serpentinite are exposed. The section represents a tectonic melange of the crustal section of a dismembered ophiolitic suite.

Walking upstream: a series of variably deformed basalts, sometimes separated by serpentinite bands, extends for about 250 m. This is followed by a massive dark green basalt cut by widely spaced shear zones. About 20 m further upstream is a pyritic basalt with small vesiculated pillows (diameter about 15 cm) and cherty interpillow matrix, cut by steep E-dipping shears. Bedding dips 50^{o} E but stratigraphic facing cannot be determined. Quartz-feldspar vein networks, present within all of the basalts, may be associated with hydraulic fracturing prior to faulting.

Further upstream, massive gabbros, with a foliation defined by elongate pyroxenes and amphiboles, are intruded by oceanic plagiogranites (the low-K products of residual liquids) and mafic hornblende pegmatites. These rocks are cut by a number of basalt dykes which dip steeply towards the south (65-90°/175°).

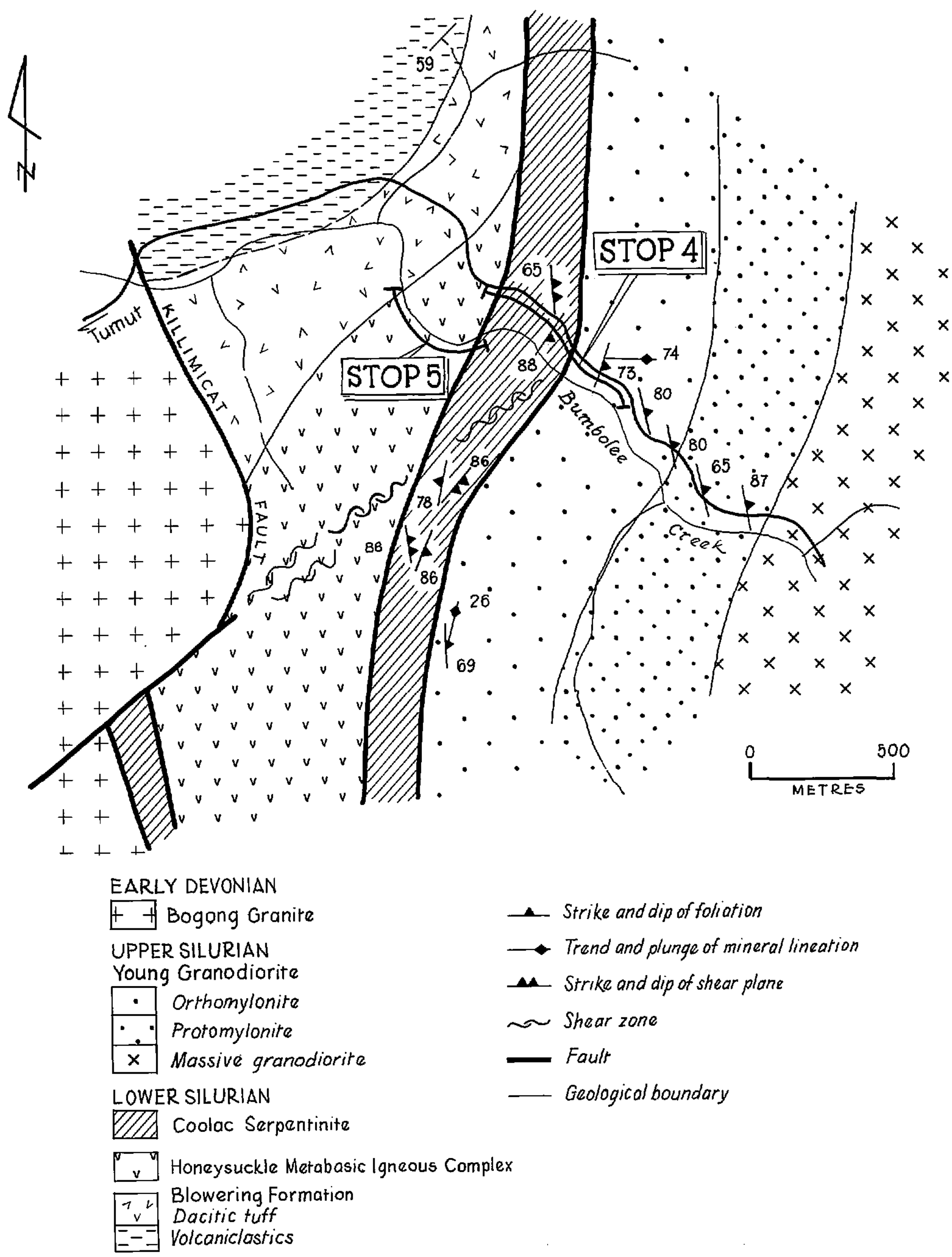

Fig. 14 Stops 4 & 5: Bumbolee Creek locality map.

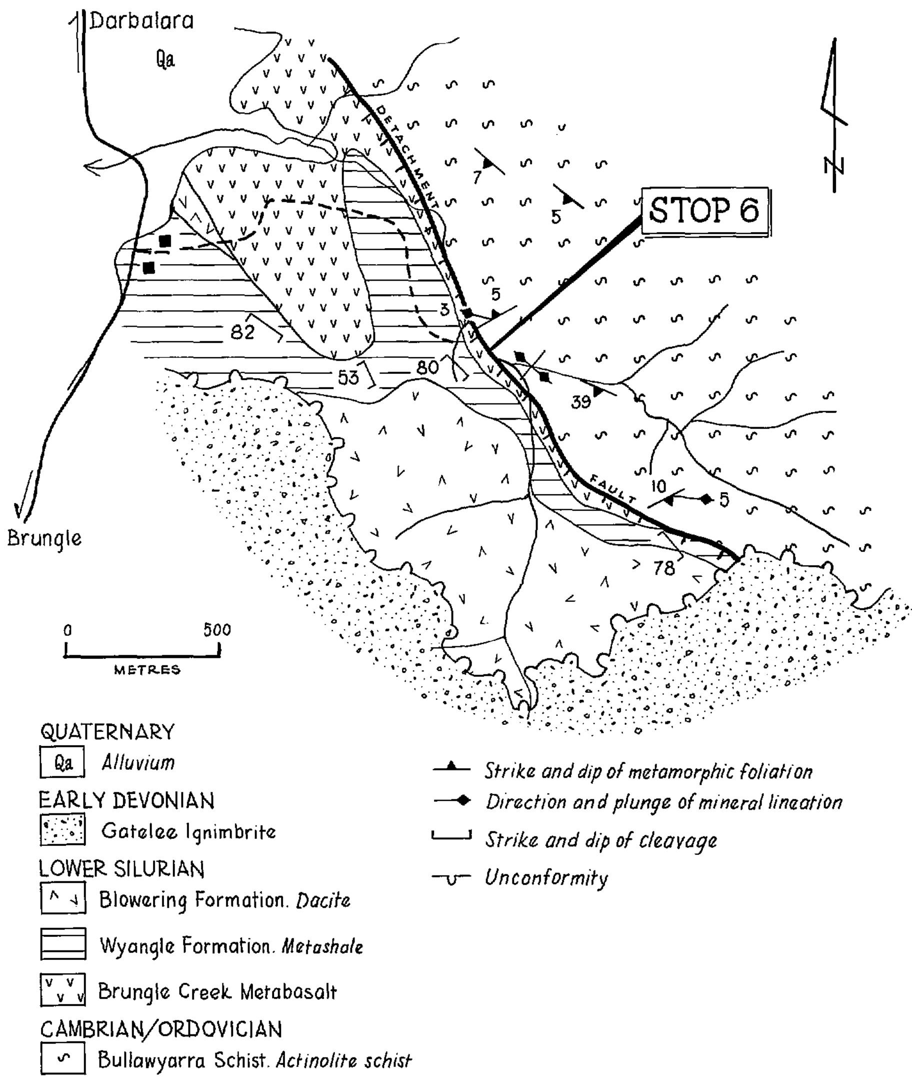

Fig. 15 Stop 6: Holt's Property locality map.

3.6 STOP 6. Holt's property

Metabasaltic rocks and minor metasediments of the Bullawyarra Schist crop out in two inliers in the Brungle-Darbalara area of the Tumut Trough. The rocks are thought to be Cambrian/ Ordovician in age Basden, 1986, 1988) and form structural basement to the Silurian trough sedimentary-volcanic sequence. Although the Bullawyarra Schist did not outcrop on the seismic traverse, which crossed between the two inliers, it is interpreted to be continuous in the subsurface.

The Bullawyarra Schist is separated from the overlying rocks by a sharp discontinuity marking an abrupt change in rock type, structure and metamorphic grade. Cover sequences have undergone only one major deformation during the Early Devonian involving lower greenschist facies metamorphism and upright folding as a result of E-W compression. 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, in prep).

The structural and metamorphic discontinuity separating the schist from the Silurian cover is characterised by widespread cataclasis and alteration. It is interpreted as a major detachment fault associated with extension and development of the Tumut Trough during the Lower Silurian (Stuart-Smith, in prep).

The detachment fault is not exposed at this locality (Fig. 15), but adjacent outcrops of the basement and cover can be viewed. Exposures of Bullawyarra Schist in the creek bed exhibit a 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.

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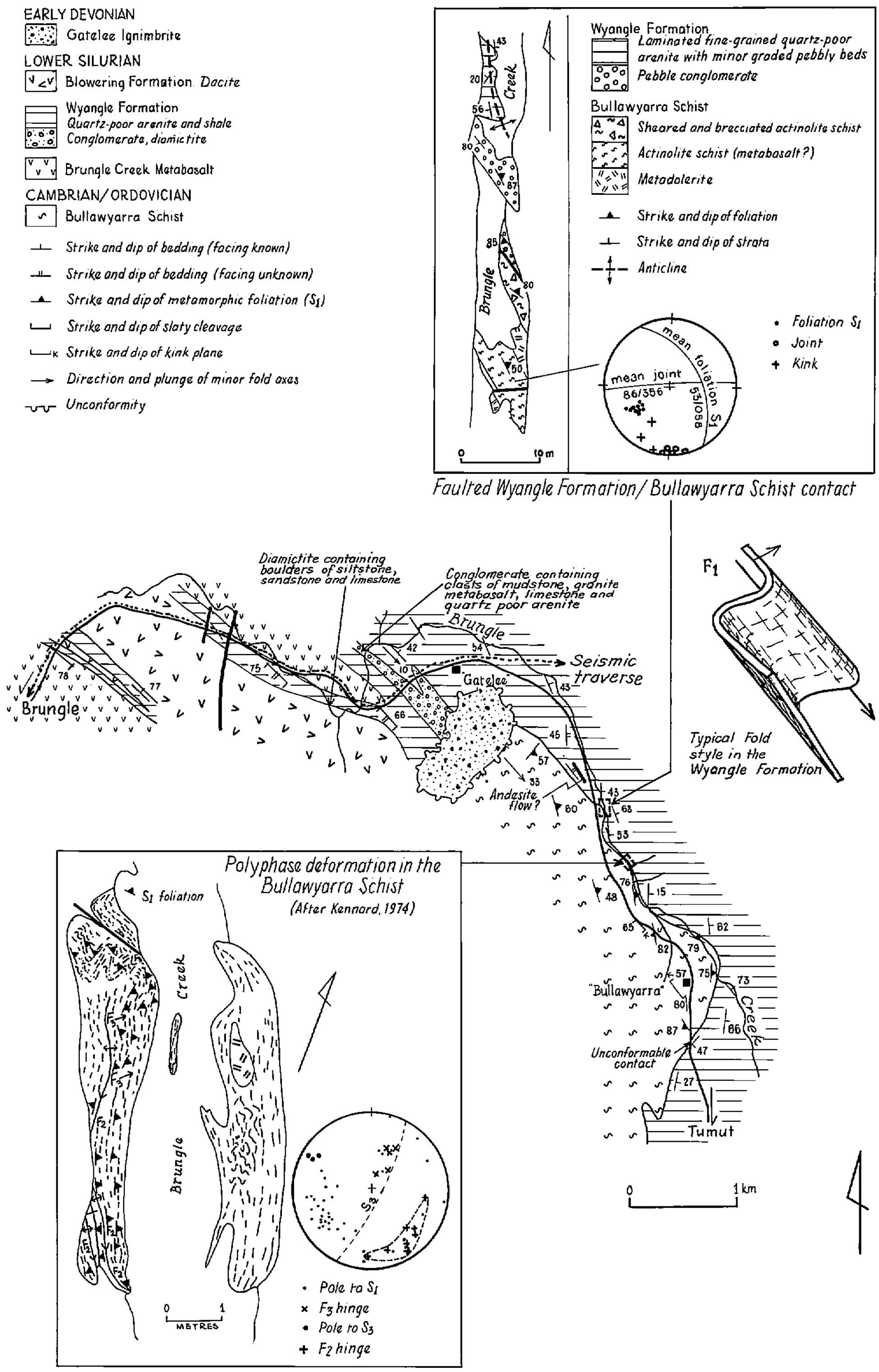

Fig. 16 Location 7: Brungle Creek Road, locality map and sketches.

3.7 LOCATION 7. Brungle Creek Road

The drive along Brungle Creek road (Fig. 16) follows the seismic traverse eastwards from Brungle to Gatelee homestead and then continues south past Bullawyarra homestead. Exposures of the Lower Silurian Brungle Creek Metabasalt, Wyangle Formation, Blowering Formation and the Cambrian/Ordovician Bullawyarra Schist can be seen on the 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) which unconformably overlies older rocks. The Coolac Serpentinite forms the Honeysuckle Range running the length of Brungle Creek to the east.

The Wyangle Formation is much thicker (500 m) in this area than at STOP 6. Here the formation is a flysch sequence comprising interbedded quartz-poor and quartz-intermediate arenite, volcanilithic pebble and boulder conglomerate, diamictite, shale, mudstone, tuff and minor andesite ?flows. Allochthonous limestone blocks contain conodonts of probable late Landoverian to early Wenlockian age (Lightner, 1977). The conglomerate and diamictite, which are well exposed in Brungle Creek between Hillside and Gatelee homesteads, are interpreted to represent debris-flow deposits (Kennard, 1974; Crook & Powell, 1976) which intertongue with subaerial volcanics of the overlying Blowering Formation. In other places the Blowering Formation appears to conformably overlie or intrude into the Wyangle Formation. The contact with the underlying Bullawyarra Schist is both faulted and unconformable (Fig. 16).

Two distinct deformations have affected rocks in the area. The first, at upper greenschist facies involved only the Bullawyarra Schist and may be late Ordovician/early Silurian in age. The second involved retrograde metamorphism of the Bullawyarra Schist and upright folding of both the schist and the Silurian rocks. The Early Devonian Gatelee Ignimbrite post-dates both deformations. Good examples of polyphase deformation in the schist are found in Brungle Creek between Gatelee and Bullawyarra homesteads (Fig. 16). In the same area folds in the Wyangle Formation are upright, open and plunge gently to the SE (Fig. 16). A close-spaced fracture cleavage associated with the folds is only developed in pelitic units.

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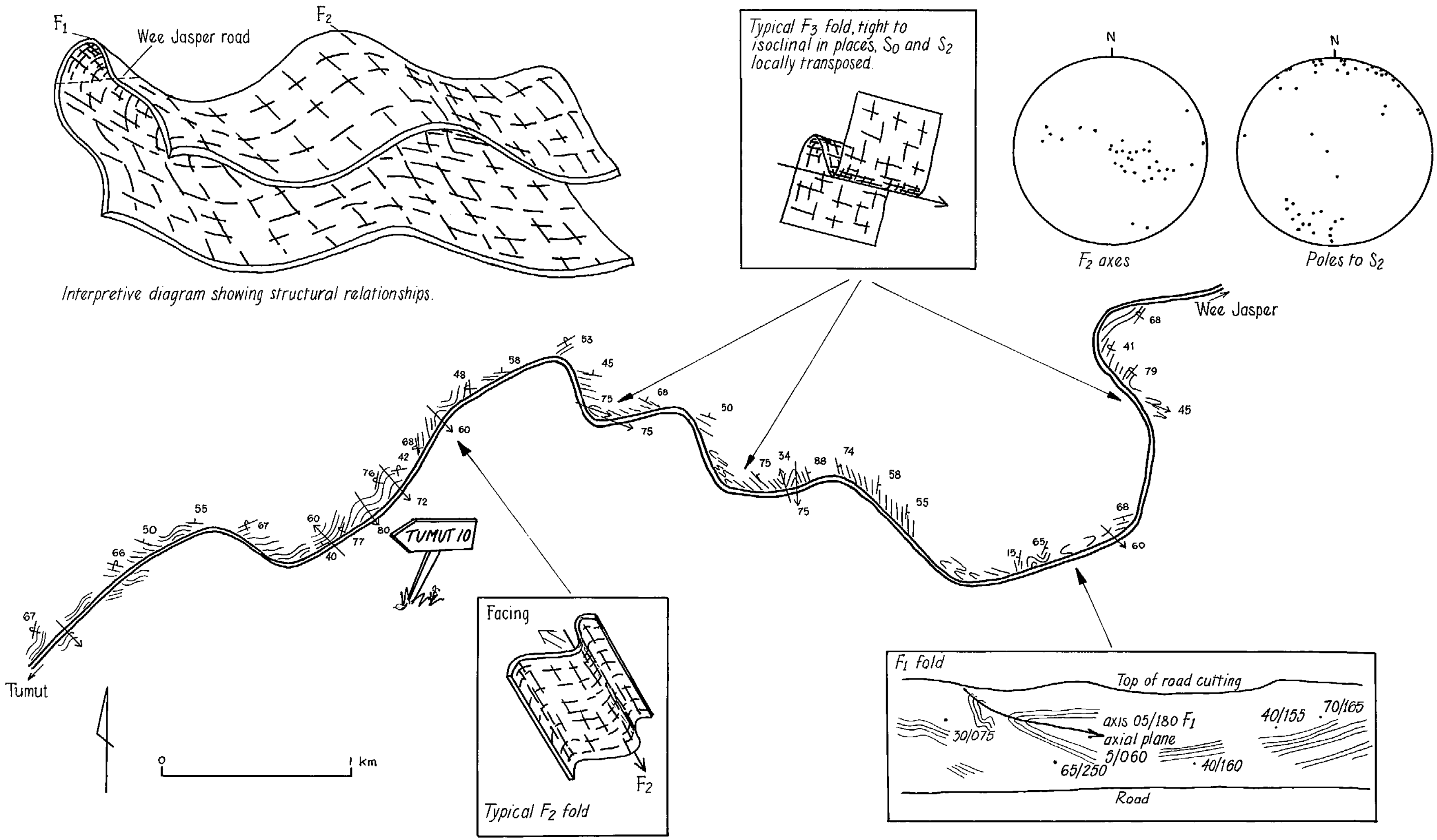


Fig. 17 Location 8: Wee Jasper Road, locality map and sketches, (geology after Killick, 1982).

3.8 LOCATION 8. Wee Jasper road

The drive back to Tumut along the Wee Jasper road provides an opportunity to view the southern part of the Tumut Trough as the road winds down into the Tumut valley. An Early Devonian pluton, the Bogong Granite, forms the prominent mountain about 10 km to the southeast. Road cuttings at this location expose deformed quartz-rich flysch of the Bumbolee Creek Formation (Fig. 17).

The road cuttings were mapped in detail by Killick (1982). As at STOP 3, F_2 folds dominate outcrop-scale structures. These folds are symmetrical and open, plunging steeply to the southeast. Facing is consistently to the northwest and most beds are overturned, dipping steeply to the southeast. A subvertical slaty cleavage (S_2) is axial plane to the folds. Locally this cleavage is folded by tight to isoclinal folds (F_3) in disrupted zones trending more easterly. Minor recumbent folds (F_1) trend ESE and face north. Killick (1982) interpreted the exposures to lie near the hinge of a regional recumbent fold (Fig. 17). Thus a similar structural history is observed here to that in the Gocup area (STOP 3).

NOTES

SEISMIC SURVEY OVERVIEW

4.1 Introduction

A joint project between the Geology Department of the Australian National University and the Geophysics Division of the Bureau of Mineral Resources, Geology and Geophysics was conducted to investigate the crustal structure underlying the Tumut Trough, NSW. The objective of this survey was to image the bounding faults of the Tumut Trough, in order to test various geological models which have been proposed for its formation.

Forty five kilometres of nominal 8-fold common mid-point (CMP) seismic reflection data were collected in the two week recording period of the ANU vacation, from the 4-16 May. The traverse was chosen to cross the trough perpendicular to strike given the constraint of using existing roads and tracks. The seismic traverse started 8 km NNE of Adjungbilly and finished 3 km SW of Midway.

There is no evidence in the seismic data of the listric bounding faults which were envisaged prior to the survey. A particularly strong reflection event was observed in the vicinity of Adjungbilly beneath the Young Granodiorite at 7.2 seconds two-way reflection time (twt) dipping to the west. Other reflection events beneath the trough are generally weak and dip to the east.

4.2 Aims and Objectives

The primary aim of this survey was to use the seismic reflection method to image the bounding faults of the Tumut Trough, and thereby test the various models which had been proposed its formation.

Expected seismic targets were:

1) the major fault shear zones which were presumed to flatten eastwards at depth.
2) the Bullawyarra Schist should act as a local basement to the trough, since equivalent rocks crop out to the west as the Nacka Nacka amphibolite zone (Duff and others, 1985)
3) the large Young Batholith at the eastern margin was expected to show a floor in the 5-10 km depth zone.

4.3 Location and Maps

The location of the survey was severely constrained by the sensitive rural environment of the Tumut Valley. Three survey routes which transected the trough roughly perpendicular to its strike were suggested on the basis of existing roads and tracks, the route from Adjungbilly through Brungle, along the Westview-Califat Road to the Bandang Road was selected. The survey area is covered by the Tumut 1:100,000 map sheet (8527, 1976). Four map sheets of the 1:25,000 series covered the area, and were generally used for operations: Adjungbilly, Tumorrama, Brungle, and Tumut. Figure 18 shows the location of the seismic line in relation to the boundaries of the trough.

4.5 Associated Geophysical Surveys

Gravity measurements were made along the whole length of the survey traverse at a nominal spacing of 360 metres. Five shot holes were logged using the BMR logging facility to obtain some measurement of the seismic velocity and density of the serpentinite and granite.

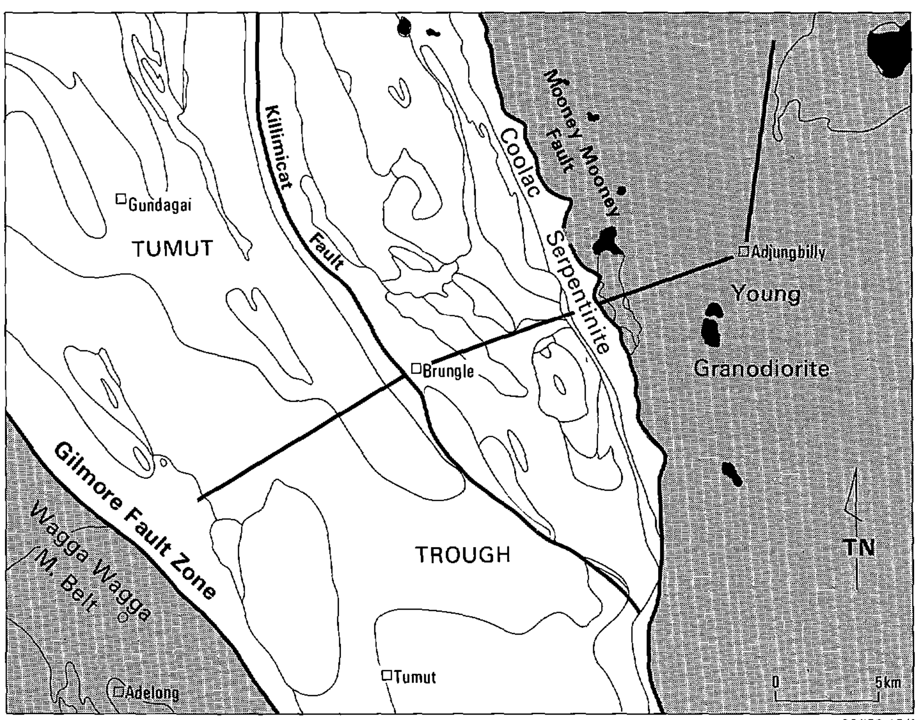


Fig. 18 Location of the seismic traverse.

SEISMIC SURVEY FIELD OPERATIONS

5.1 General

A single nominal 8 fold traverse was planned to cross the Tumut Trough with a length of 58.3 km. This line was geographically biased towards the the east and recording commenced at the eastern end as it was thought to be most likely that the bounding faults dipped eastwards at depth. Forty five of the planned fifty eight kilometres were recorded in the 2 week period.

5.2 Drilling and explosives

Drilling commenced on the 27 April one week ahead of the seismic recording and finished on the 14 May. Three Mayhew rigs and associated tankers were used. Drilling conditions varied significantly along the traverse. Shotholes were drilled to a depth such that the hole had one rod length into "hard rock", and the average depth of shotholes was 18 metres. This allowed reasonable drilling progress, while still achieving the aim of detonating shots below the weathering layer.

Charge sizes were either 8.2 or 12.3 kg of ANZITE blue. Larger charge sizes were used around the Honeysuckle Range to increase the distance at which these shots would be recorded by the portable seismic recorders used for the tomography experiment.

5.3 Seismic recording

The recording parameters used for this survey are detailed in Appendix 2. Field operations conformed closely to standard BMR practice, except that the spacing of shotpoints was irregular along the line. No shots could be detonated in close proximity to houses or concrete water tanks, and this together with the need to concentrate shotpoints around bends in the traverse led to the irregular shotpoint distribution. Shotpoints were also concentrated near the Honeysuckle Range for the tomography experiment.

Radio firing of shots remote from the line was successfully used, both for undershooting the Honeysuckle Range and for the offline tomography shots. The off-line shots were fired over distances of up to 10 kilometres.

5.4 Tomographic experiment

An experiment designed to image the Coolac Serpentinite using a tomographic technique was piggy-backed onto the reflection seismic recording experiment. The production shots of the reflection survey were recorded by an array of portable seismic recorders installed within a circle of radius 15 km centred on the point where the reflection traverse crossed the Honeysuckle Range.

5.5 3-Component experiment

An auxiliary experiment to investigate the utility of recording 3-component data from a reflection survey was also piggy-backed, again using the production shots as sources. Sets of three portable seismic recorders were connected to 3-component geophones to record vertical, transverse and radial components.

PROCESSING AND RESULTS OF SEISMIC SURVEY.

6.1 Data processing

Data from the reflection survey has been processed at the BMR using the Disco seismic processing package, and standard deep seismic processing techniques. The lack of strong continuous reflectors and troublesome statics problems associated with the steeply dipping near-surface geology has inhibited this processing.

6.2 Processing of tomography data

Although the charge size of the production shots was increased for this tomography experiment, the recording of the production shots beyond about 5 kilometres was not successful. Wind-generated noise caused by relatively high winds during the three days shooting period near the Honeysuckle Range resulted in poor signal-to-noise ratio of the refracted arrivals.

6.3 Stack section and results

Figure 19 shows a line diagram of sub-coherent reflection segments which have been manually digitized from the brute stack seismic section (Plate 2), with some surface geology also plotted to aid interpretation.

The target of this survey was the bounding faults which were thought to dip to the east and have a listric form. The occurrence of serpentinite along these major faults was expected to provide a marked seismic impedance contrast with the surrounding rocks, and produce relatively strong reflection signals. However, the stacked section of the Tumut Trough seismic data shows no indication of these listric bounding faults, even though strong reflectors at 7.2 seconds two-way time (TWT) indicate the penetration of seismic energy to depths of 20 km, and the capacity of the technique to image such features. This suggests that the bounding faults do not have a listric form and are probably near-vertical.

Relatively strong reflected refractions can be seen from both the eastern and western edges of the trough. Towards the eastern side of the trough, the structure within the ?Ordovician basement is imaged by the fabric of the sub-coherent seismic reflection segments.

Beneath the Young Granodiorite there is a non-reflective zone to 3 seconds TWT, interpreted to be the batholith extending to a depth of around 9 km. Beneath this zone reflections extend down to a strong sub-horizontal reflector at 7.2 seconds TWT. Within the Tumut Trough there are two regions which display coherent reflections. The mapped fold structure of the Bullawyarra Schist is reflected in the short segments of coherent energy east of Brungle. Near Minjary, a set of strong sub-horizontal reflectors at 1 second TWT is interpreted to be either structural basement or the Gocup Granite contact.

The deeper seismic data shows no coherent energy beneath 10 seconds TWT, but the depth of the Moho is undetermined. Between 3 and 9 seconds TWT, sub-coherent reflections dip eastward suggesting imbricate structures beneath the trough.

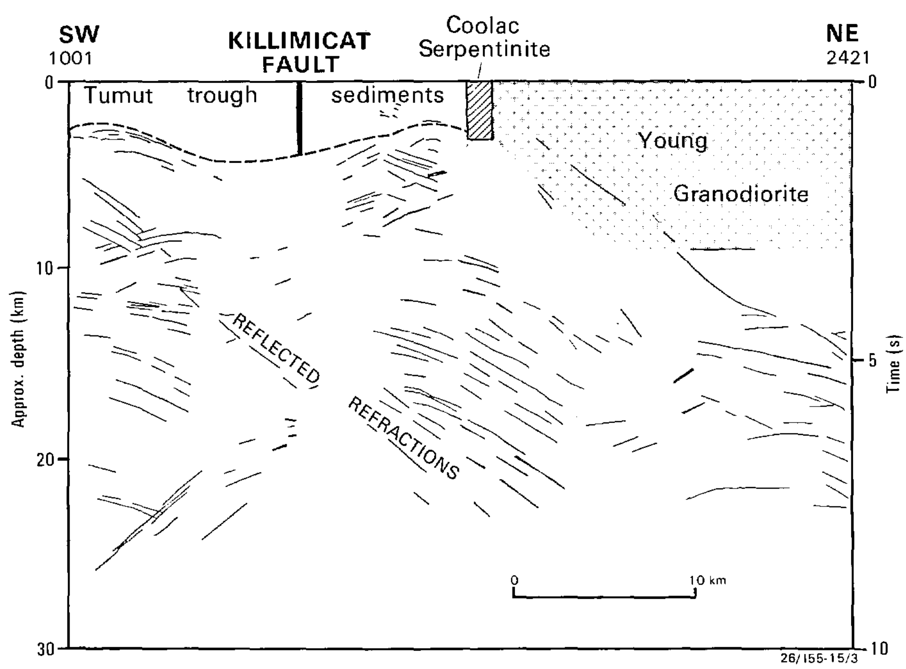


Fig. 19 Line diagram from brute stack.

REFERENCES

ASHLEY, P.M., CHENHALL, B.E., CREMER, P.L., & IRVING, A.J., 1972. The geology of the Coolac Serpentinite and adjacent rocks east of Tumut, New South Wales. Journal and Proceedings of the Royal Society of New South Wales, 104, 11-2

ASHLEY, P.M., BROWN,P.F., FRANKLIN, B.J., RAY, A.S. & SCHEIBNER E., 1979. Field and geochemical characteristics of the Coolac Ophiolite Suite and its possible origin in a marginal sea. Journal of the Geological Society of Australia, 26: 45-60.

BASDEN, H., 1986. Tectonostratigraphic and geochemical development of the Tumut area. New South Wales Institute of Technology M.App.Sc. Thesis (unpublished)

BASDEN, H., 1988. Tumut 1:100 000 Geological Sheet 8527. New South Wales Geological Survey, Sydney

BASDEN, H., FRANKLIN, B.J., MARSHAL, B., & WALTHO, A.E., 1987. Terranes of the Tumut district, southeastern New South Wales, Australia. In TERRANES, ACCRETION AND OROGENIC BELTS, Geodynamic Series, 19, American Geophysical Union

CHOPRA P. & SPENCE A., 1988. A field and laboratory study of the acoustic impedance of rocks from Tumut, NSW. Bureau of Mineral Resources, Australia, Record, in preparation.

CROOK, K.A.W., 1978. Implications of a downward-facing fold in the Bathurst Granite contact aureole, Hill End Synclinorial Zone, New South Wales. Journal of the Geological Society of Australia 25, 467-471

CROOK, K.A.W., 1980. Forearc evolution in the Tasman Geosyncline: the origin of southeast Australian continental crust. Journal of the Geological Society of Australia 27: 215-232.

CROOK, K.A.W. 1986. Terranes vs Dewey-Grams PP or how best to understand the geological evolution of foldbelts. Geology Today, Jan-Feb 1986, 9-10.

CROOK, K.A.W., & POWELL, C.McA., 1976. The evolution of the southeastern part of the Tasman Geosyncline. Field guide for Excursion 17A, 25th International Geological Congress, Australia, 1976

DUFF, B.A., CROOK, K.A.W., RICKARD, M.J., & OWEN, M., 1979. Tasman Orogen profile 5 - field excursion, Wagga Wagga - Batemans Bay. International Geodynamics Project WG 9, field guide (unpublished)

DUFF, B.A., WARD, P., CROOK, K.A.W. & RICKARD, M.J., 1985. Tasman Orogenic Profile - Wagga Wagga - Batemans Bay, New South Wales Geological Survey, Department of Mineral Resources, Sydney.

FERGUSON, I., 1981. Telluric current investigation near Tumut. Australian National University, B.Sc. (Hons) thesis (unpublished)

JOHNSTONE, D.W., SEXTON, M.J., & TAYLOR F.J., 1987. Sercel SN368 Equipment tests, Millmerran, Qld 1986. Bureau of Mineral Resources, Australia, Record, 1987/16.

KENNARD, J.M., 1974. Geology of the Brungle district. Australian National University, B.Sc. (Hons) thesis (unpublished)

KILLICK, C.L.A., 1982. Geology of the Bumbolee Creek Formation, Tumut Trough. Australian National University, B.Sc. (Hons) thesis (unpublished)

LIGHTNER, J.D., 1977. The stratigraphy, structure and depositional history of the Tumut region, NSW. Australian National University, M.Sc. thesis (unpublished)

MOSS, J. & GOLEBY, B. 1986. Abstracts: ACORP deep seismic Reflection Profiling Workshop. Bureau of Mineral Resources, Australia, Record 1985/7.

POWELL, C. McA., 1983. Tectonic relationship between the Late Ordovician and Late Silurian Palaeogeographies of southeastern Australia. Journal of the Geological Society of Australia, 30: 353-373.

STUART-SMITH, P.G., 1988. Surface geology and structure of the Tumut seismic traverse, Lachlan Fold Belt, NSW. Bureau of Mineral Resources, Australia, Record, 1988/27.

STUART-SMITH, P.G., in prep. Evidence for extension tectonics in the Tumut Trough, Lachlan Fold Belt, N.S.W.

WAKE-DYSTER, K.D., & BARTON, T.J., in prep. Southeast Queensland Seismic Survey 1986 Operational Report.

APPENDIX 1

OPERATIONAL STATISTICS

Surveying Commenced	7 April 1987
Surveying Completed	11 May 1987
Drilling Commenced	27 April 1987
Drilling Completed	14 May 1987
Recording Commenced	4 May 1987
Recording Completed	16 May 1987
Total Sub-surface coverage	45 km
Number of recording days worked	11 days
Number of recording days lost due to weather	1 day
Total number of shots	156
Average # production shots/recording day	14.2
Average surface coverage/recording day	4.1 km
Max. Number of shots in one day	22
Explosives used	1476 kg
Number of detonators used	159
Average charge / production shot	9.5 kg
Total number of rig days worked	41
Rig days lost due to : breakdown	1
: travel	3

APPENDIX 2

RECORDING PARAMETERS

Spread length		varied 4.26 to 5.7 km
Geophone station interval		60 metres
Number of data channels		72 - 96
Nominal fold		8
Geophones per trace		16 inline, 4m apart
Recording format		SEGD
Number of recorded channels		96 + 4 aux
Tape		9 track GCR 6250bpi
Record length		20 seconds
Sample rate		2 milliseconds
Filters	Low-cut	8 Hz 18dB/octave
	Hi-cut	178 Hz 18dB/octave
Pre-amp gain factor		128
Notch filter		50 Hz IN

PLATE 1

GEOLOGY OF THE TUMUT SEISMIC TRAVERSE

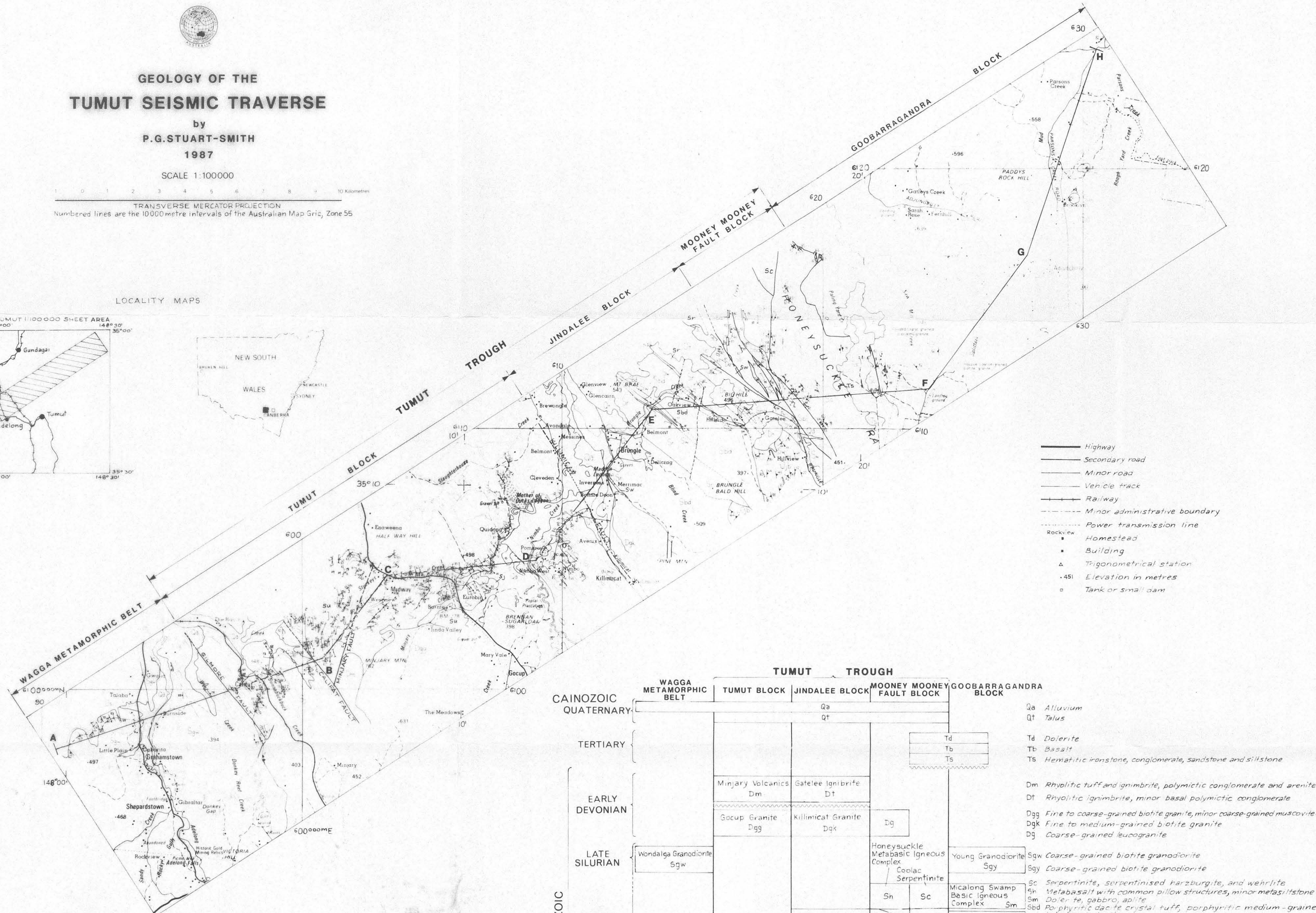
by

P.G.STUART-SMITH

1987

SCALE 1:100000

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



LOCALITY MAPS

TUMUT 1:100000 SHEET AREA
Gundagai
Adelong
Tumut
NEW SOUTH WALES

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

TUMUT TROUGH
WAGGA METAMORPHIC BELT
TUMUT BLOCK
JINDALEE BLOCK
MOONEY MOONEY FAULT BLOCK
GOOBARRAGANDRA BLOCK
CAINOZOIC
QUATERNARY
TERTIARY
PALAEOZOIC
EARLY DEVONIAN
LATE SILURIAN
MIDDLE SILURIAN
EARLY SILURIAN
ORDOVICIAN
Qa
Qt
Td
Tb
Ts
Minjary Volcanics Dm
Gatelee Ignibrite Dt
Gocup Granite Dgg
Killimicat Granite Dgk
Dg
Wondalga Granodiorite Sgw
Honeysuckle Metabasic Igneous Complex
Coolac Serpentinite
Young Granodiorite Sgy
Sh
Sc
Micalong Swamp Basic Igneous Complex Sm
Blowering Formation Sbd
Sbl
Sbd
Blowering Formation
Goobarragandra Volcanics So
Sw
Wyangle Formation
Bumbolee Creek Formation
Su
Sj
Jackalass Slate
Brungle Creek Metabasalt Sr
Os
Bullawyarra Schist Ojb
Unconformity
Facies boundary

- Qa Alluvium
- Qt Talus
- Td Dolerite
- Tb Basalt
- Ts Hematitic ironstone, conglomerate, sandstone and siltstone
- Dm Rhyolitic tuff and ignimbrite, polymictic conglomerate and arenite
- Dt Rhyolitic ignimbrite, minor basal polymictic conglomerate
- Dgg Fine to coarse-grained biotite granite, minor coarse-grained muscovite-biotite granite
- Dgk Fine to medium-grained biotite granite
- Dg Coarse-grained leucogranite
- Sgw Coarse-grained biotite granodiorite
- Sgy Coarse-grained biotite granodiorite
- Sc Serpentinite, serpentinised harzburgite, and wehrlite
- Sh Metabasalt with common pillow structures, minor metasiltstone and slate
- Sm Dolerite, gabbro, aplite
- Sbd Porphyritic dacite crystal tuff, porphyritic medium-grained intrusive dacite
- Sbl Slate, siltstone, quartz intermediate arenite, porphyritic dacite crystal tuff
- Sc Porphyritic dacite
- Sw Slate, fine to coarse-grained, quartz-poor to quartz-intermediate arenite, polymictic conglomerate, diamictite, rare hornblende-andesite
- Su Slate fine-grained metaquartzite, fine to coarse-grained or pebbly quartz intermediate arenite, minor polymictic conglomerate
- Sj Slate, fine to coarse-grained quartz intermediate arenite, polymictic conglomerate, rare marble and meta-andesite
- Sr Metabasalt, minor chert
- Os Undivided metasediment hornfels
- Ojb Actinolite schist (metabasalt and metadolerite), minor chert

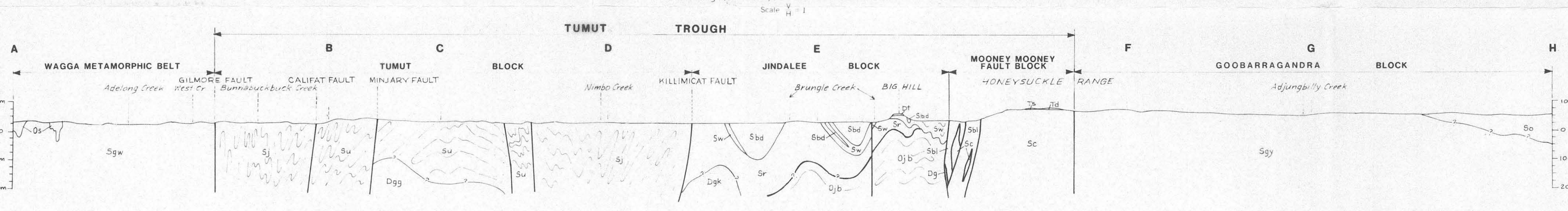
- Geological boundary, accurate, approximate
- Fault, accurate, approximate
- Dyke or vein; p- porphyry, q- quartz
- Plunge of minor fold
- Plunge of minor fold showing 'S' vergences
- Plunge of minor fold showing 'Z' vergences
- Plunge of minor fold showing 'M' vergences

F1, F2, F3 refers to fold generation

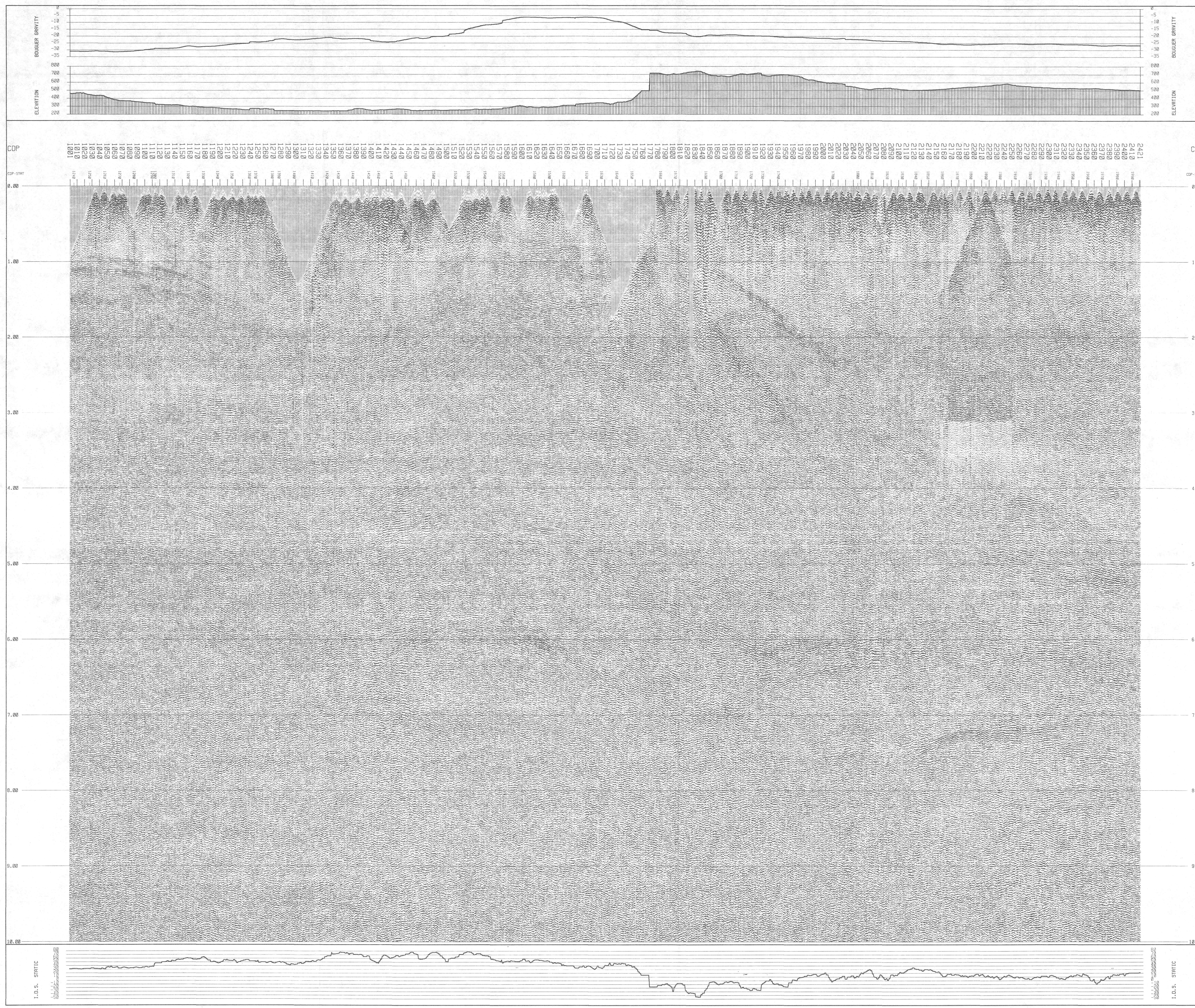
- Strike and dip of stata
- Vertical strata, dot indicates facing
- Strike and dip of overturned strata
- Strike and dip of strata, facing not known
- Trend-line / Lineament — airphoto interpretation
- Strike and dip of foliation
- Vertical foliation
- Strike and dip of shear planes
- Trend and plunge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

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

SCHEMATIC SECTION
Quaternary sediments omitted
Section along approximate position of seismic traverse
Scale V/H = 1



GEOLOGY OF THE
TUMUT SEISMIC TRAVERSE
1987



BUREAU OF MINERAL RESOURCES

SURVEY : TUMUT TROUGH 1987

LINE : 1

STATIONS: 1218 - 1998

STACK

NORTH-EAST

RECORDING PARAMETERS

SHOT BY : BMR

DATE : MAY 1987

SYSTEM TYPE : SERCEL SN368

TAPE FORMAT : SEGD
DENSITY : 6250BPI

RECORD LENGTH: 20 SECONDS

SAMPLE RATE : 2 MSEC

FILTERS : LCF 8HZ, 18DB/OCT
: HCF 178HZ, 18DB/OCT
: NOTCH IN

SOURCE TYPE : DYNAMITE
CHARGE : 8-12 KG
DEPTH : 18M

SP INTERVAL : VARIABLE
OF CHANNELS: 72 TO 96
SPREAD PATTERN: VARIABLE
SHOT ON TRACE : VARIABLE
GROUP PATTERN : 16 IN-LINE, 4M SPACING
GROUP INTERVAL: 60.0M
COVERAGE : 800% NOMINAL

PROCESSING SEQUENCE

[1] DEMULTIPLEX: SEGD TO DISCO INTERNAL FORMAT
[2] GEOMETRY DEFINITION
[3] QUALITY CONTROL DISPLAYS AND TRACE EDITS
[4] SPHERICAL DIVERGENCE CORRECTION
[5] STATICS COMPUTATION (FIELD)
DATUM USED: SP: 700M
[6] CDP SORT (TO CROOKED LINE) AND BRUTE STACK
[7] VELOCITY ANALYSES
[8] REFRACTION STATICS COMPUTATION
[9] NORMAL MOVEOUT CORRECTION
[10] PRE-STACK NMO MUTE
[11] INTERGRATED DIFFERENTIAL STATICS
CALCULATION AND APPLICATION
[12] TRACE EQUALIZATION
[13] TIME VARING FILTER
[14] COMMON-MID-POINT STACK
[15] TIME VARYING EQUALIZATION
(AGC GATE LENGTH 1000MS)
[16] DISPLAY WITH SURFACE GRAVITY AND ELEVATION

PROCESSED BY:

BUREAU OF
MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

DIVISION OF
PETROLOGY & GEOCHEMISTRY

CANBERRA, A.C.T.

QUALITY CONTROL CHECK

GEOPHYSICIST : JIM LEVEN

DATE : JUNE 1988

HORIZONTAL SCALE: 1:50.000
: 42.3 TRACES/INCH
: (2 CM = 1000. METRES)

VERTICAL SCALE : 6.0 CM/SEC
: 2.3622 IN/SEC
: (V:H = 1:1 AT VEL=6000M/S)

POLARITY : -VE ON TAPE = UPWARD GROUND DISPLACEMENT
= TROUGH
(I.E. NORMAL SEG CONVENTION)