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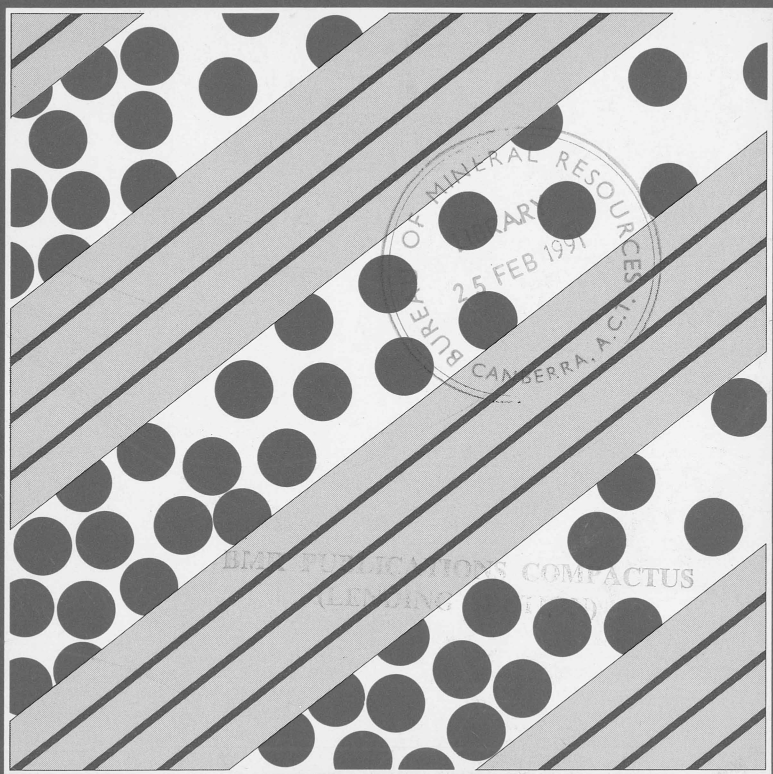
LAND SEISMIC DATA ACQUISITION PROPOSAL: GUNNEDAH BASIN, NEW SOUTH WALES

R. J. KORSCH, K. D. WAKE-DYSTER & D. M. FINLAYSON



BUREAU OF MINERAL RESOURCES GEOLOGY & GEOPHYSICS
ONSHORE SEDIMENTARY & PETROLEUM GEOLOGY PROGRAM
BMR RECORD 1990/93

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LAND SEISMIC DATA ACQUISITION PROPOSAL: GUNNEDAH BASIN, NEW SOUTH WALES

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EXECUTIVE SUMMARY

Acquisition of deep seismic reflection data and wide-angle reflection/refraction data in the sedimentary basins of eastern Australia, and particularly in the Gunnedah Basin, is needed to address several problems that cannot be solved by other means. Some of these problems are:

1. The geometry of the structural units of the Gunnedah Basin.
2. The nature of the Meandarra Gravity Ridge.
3. The geometry of the Mooki Fault.
4. Whether the Tamworth Belt is thin skinned, and overriding the Gunnedah Basin.
5. The geometry of the Peel Fault (the eastern margin of the Tamworth Belt) and its relationship to the Gunnedah Basin and Tamworth Belt.
6. The relationship between the Lachlan and New England Orogens.

Most of the above problems could be addressed by the acquisition of a single, east-west oriented, deep seismic reflection profile approximately 265 km long, at about the latitude of Boggabri in the Gunnedah Basin. Recording parameters have been selected to acquire data to 20 s record length to enable the relationships between basin geometry and crustal structure to be examined.

A program of wide-angle seismic reflection/refraction profiling in the eastern Australian basins is needed to address the nature of the Meandarra Gravity Ridge, which is a fundamental but enigmatic feature in the Bowen-Gunnedah-Sydney basin system. It is proposed to acquire data over two targets, one in the Gunnedah Basin in the vicinity of the deep seismic reflection line, and the other in the Bowen Basin in Queensland.

INTRODUCTION

This Record presents a proposal for the acquisition of deep seismic reflection data in the Gunnedah Basin in northern New South Wales and wide-angle seismic reflection/refraction data in both the Gunnedah and Bowen basins (Fig. 1). The Gunnedah Basin is an Early Permian to Early Triassic sedimentary basin that forms the link between the Bowen Basin in Queensland and the Sydney Basin farther to the south. A study of the Gunnedah Basin is an integral part of the project 112.05: Sedimentary basins of eastern Australia.

Project Rationale

The Late Palaeozoic Gunnedah and Bowen Basins, and the Mesozoic Surat Basin (Fig. 1), contain vast coal resources and are moderately prospective for hydrocarbons, being close to major markets. There is considerable uncertainty as to the geometry of the basins, the mode of formation (e.g. extension, transtension or foreland loading ?), the relation of basin development to tectonic events in the adjacent orogen, and the implications for the timing of hydrocarbon generation and accumulation. There is also considerable uncertainty as to the timing of events because of relatively poor time control on local biozones. The area of interest spans the border between Queensland and New South Wales and there is a requirement to rationalise geological concepts across the border.

Aims of the project

To undertake an integrated basin analysis with emphasis on the sedimentary, structural, tectonic and thermal histories of the Gunnedah, Bowen and Surat basin system to assess the economic potential of the basins.

To analyse and synthesise petroleum industry data supplemented with BMR deep seismic profiling, and to display the data in maps at 1:1 000 000 scale.

Strategies:

1. Determine the spatial and temporal distribution of the various sedimentary packages.

2. Determine the structural evolution and tectonic setting of the sedimentary packages.

3. Determine the maturation and burial history.

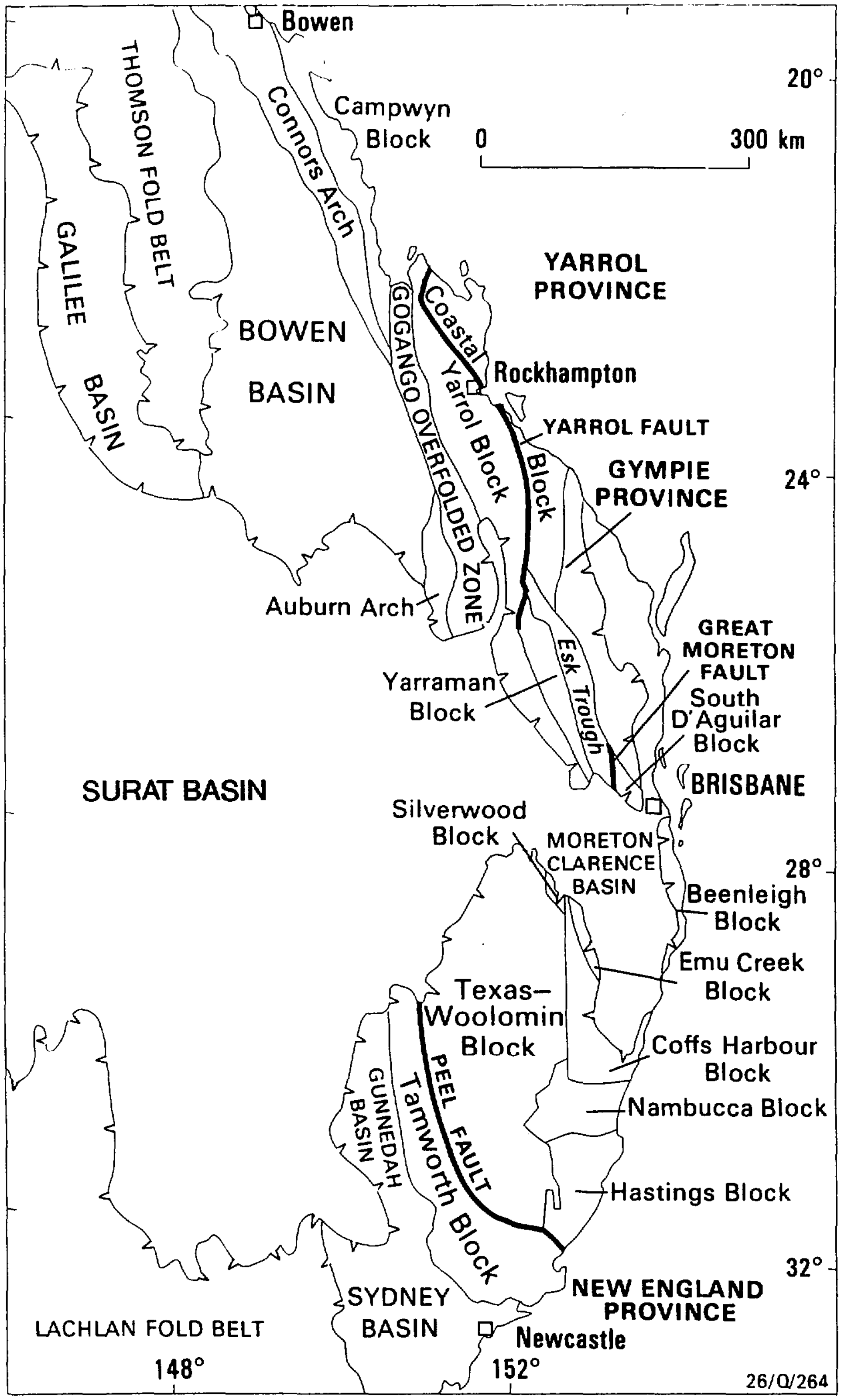


Fig. 1. general map of eastern Australia showing the present structural units adjacent to and within the new England orogen.

4. Determine the distribution and nature of economic resources.

5. Integrate into a geological history for the basin system.

Role of deep seismic studies within the project

The Project on Sedimentary Basins in eastern Australia aims to develop a tectonic model (including depositional and structural history) for the evolution of the spatially and temporally related, petroleum prospective Bowen, Gunnedah and Surat Basins. To achieve our aims, there are major scientific problems, outlined below, that can only be addressed by deep seismic reflection and refraction profiling.

BACKGROUND GEOLOGY

The Early Permian to Early Triassic Gunnedah Basin is bounded by the Lachlan Orogen in the west and by the Tamworth Belt of the New England Orogen in the east (Fig. 1). It is a structural unit separated from the Sydney Basin to the south by the Mount Coricudgy Anticline and from the Bowen Basin to the north by a structural high situated to the north of Narrabri. The eastern margin of the basin is usually taken as the Mooki Fault, but to the east of this fault is the Early Permian Werrie Basalt, which has been interpreted as the oldest unit in the basin complex by some authors (e.g. Scheibner, 1973; Korsch, 1982; Harrington, 1982; Korsch & others, 1988). The basin has been the focus of an intense sedimentological study by the Coal Geology Branch of the New South Wales Department of Minerals and Energy, focussing in particular on the coal resources, but little work on the structural, tectonic and thermal evolution of the basin has been attempted.

PREVIOUS DEEP SEISMIC STUDIES IN THE EASTERN AUSTRALIAN BASINS

Previous deep seismic studies within the area of the eastern Australian basins to be investigated by this project include:

1. A seismic reflection survey recorded mostly to 6 or 8 s in the Denison Trough of the Bowen Basin in 1978-1979 (e.g. Bauer & Dixon, 1981).

2. Deep seismic reflection data collected across the Surat Basin in 1984 and 1986 (Lines BMR84.14, BMR86.18, BMR86.19, BMR86.M01). This work has been reported in several papers including Wake-Dyster & others (1985, 1987a), Korsch & others (1988, 1990e), O'Brien & others (1990) and Finlayson & others (1990a, 1990b, 1990c)

3. A seismic refraction survey in the adjacent New England Orogen conducted in 1984; preliminary results were presented by Finlayson & others (1990c).

4. A seismic refraction survey across the Roma Shelf of the Surat Basin conducted in 1986; preliminary results were presented by Finlayson & others (1990c).

5. A deep seismic reflection survey in the Bowen Basin in 1989. The acquisition and logistics are described by Wake-Dyster & Johnstone (1990a) and preliminary results are reported in Korsch & others (1990c, 1990d).

6. A series of test surveys over selected sites in and near the Gunnedah Basin collected in 1989 (Figs 4 to 8) to examine acquisition potential and to plan parameters for the main survey (Wake-Dyster & Johnstone, 1990b).

PROPOSED DEEP SEISMIC REFLECTION PROFILE IN THE GUNNEDAH BASIN

Major geological elements in the vicinity of the proposed seismic reflection line are, from west to east (Fig. 2):

1. Lachlan Orogen
2. Surat Basin
3. Gunnedah Basin
4. Mooki Fault
5. Tamworth Belt of New England Orogen
6. Peel Fault
7. Tablelands Complex of New England Orogen

These units will be discussed individually below, specifically to outline scientific problems that will be addressed by the deep seismic data acquisition.

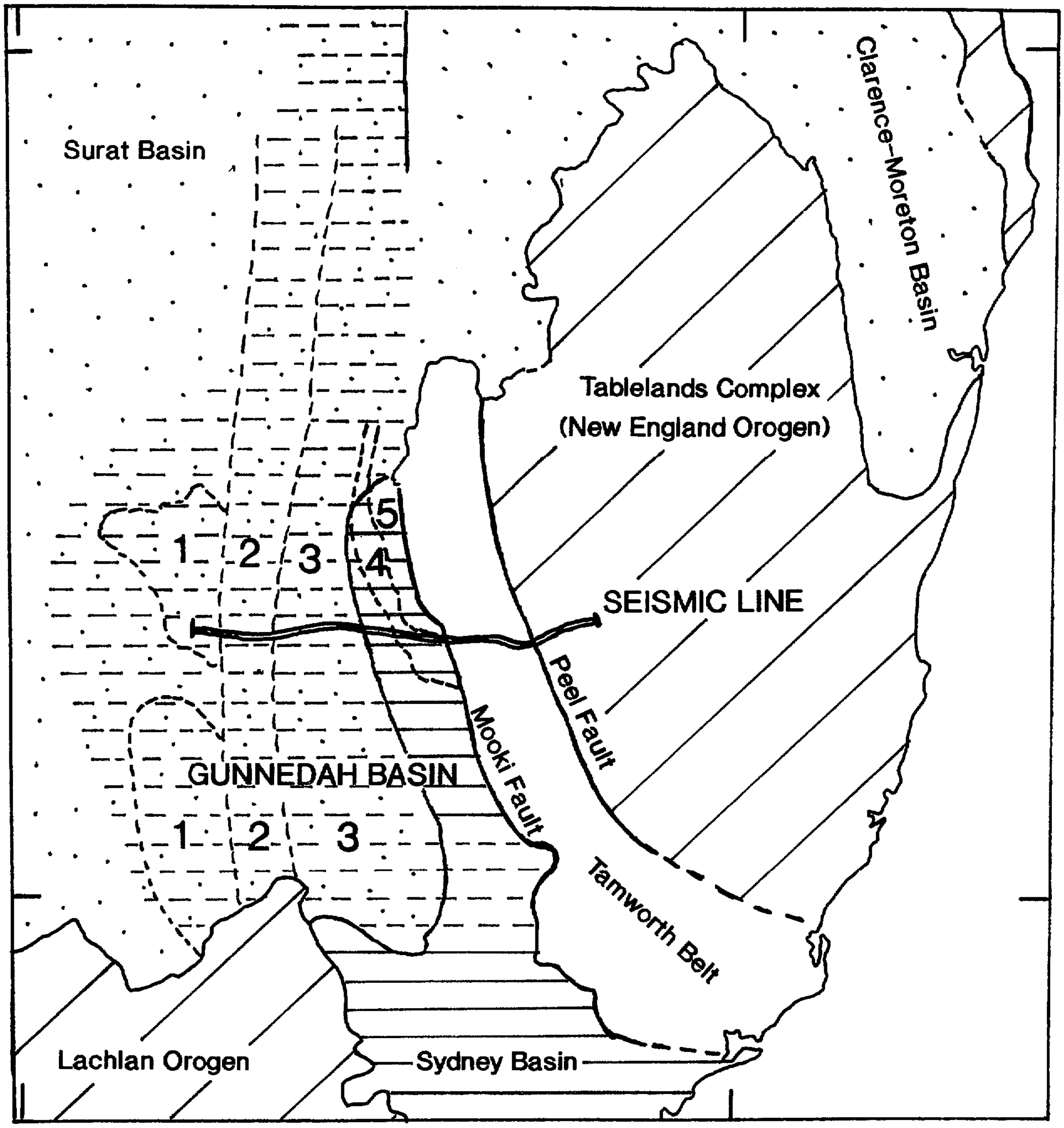
1. Lachlan Orogen

The Sydney-Gunnedah-Bowen basin system is situated between the Lachlan Orogen and the New England Orogen (Fig. 2). The boundary between the two orogens is not exposed at the surface, but must occur at depth somewhere beneath the basin system. Harrington & Korsch (1985a, 1985b) proposed that a major strike-slip fault system, the Mooki fault system *sensu lato*, occurred to the west of the New England Orogen, and hence inferred it to be the major boundary between the two orogens.

Cherry (1989) and P.G. Flood (personal communication, 1990) have suggested that there is a provenance linkage of material from the Lachlan Orogen being deposited in the Tamworth Belt in the Early to Late Carboniferous. If this is correct, it would limit the amount of strike-slip faulting that can be accommodated by the Harrington & Korsch model; an alternative possibility, which would require 500+ km of strike-slip displacement on the Mooki Fault System, is that the detritus was derived from the Drummond Basin (see Korsch & others, 1990a).

Scheibner (1985) suggested that the Lachlan Orogen could form the basement to the Tamworth Belt and that the orogen extended as far east as the Peel Fault. Rutland (1976) suggested that a lower crust of continental Precambrian material possibly extended under the New England Orogen.

Based on gravity and magnetic data, Wellman (1990) recognised several major crustal blocks in eastern Australia. In the area of interest here, he suggested that there is a major boundary based on gravity data at the approximate position of the Mooki Fault, to the west of which is crust of the Lachlan Orogen. Another boundary (based on both gravity and magnetic data) occurs at the position of the Peel Fault; to the east of this boundary is crust of the New England Orogen. Wellman referred to the



1 Gilgandra Trough
2 Rocky Glen Ridge
3 West Gunnedah Sub-basin
4 Boggabri Ridge
5 Maules Creek Sub-basin

Fig. 2. Map of the Gunnedah Basin, Tamworth Belt and Tablelands Complex showing the main structural units within the Gunnedah Basin and the position of the proposed deep seismic reflection line. Horizontal dashed lines indicate the subsurface extent of the Gunnedah-Sydney basin system.

region in between these block boundaries as a zone of "reworking". The block boundaries are both to the east of the Meandarra Gravity Ridge which forms the western margin of Wellman's zone of reworking based on gravity.

The seismic line BMR84.14 (e.g. Finlayson & others, 1990a) crosses only the northeast corner of the Lachlan Orogen and, to the east, it crosses an anomalous portion of the New England Orogen, which consists of fore-arc basin material repeated due to oroclinal bending (Korsch & Harrington, 1987; Murray & others, 1987; Korsch & others, 1990a). Thus, the proposed Gunnedah deep seismic reflection line (Fig. 3) is planned to avoid this anomalous situation, and the deep data will be used to examine the relationships between the Lachlan and New England Orogens.

2. Surat Basin

In the vicinity of the proposed seismic reflection line, the Surat Basin onlaps the Lachlan Orogen to the west and south. As shown by the seismic test survey (site 5, Fig. 8), the Surat succession is relatively thin, but in places covers a thicker section of the Gunnedah succession (e.g. site 4, Fig. 7). The data from the Surat Basin will be used to tie to industry seismic surveys to extend the coverage of the interpretation of this succession.

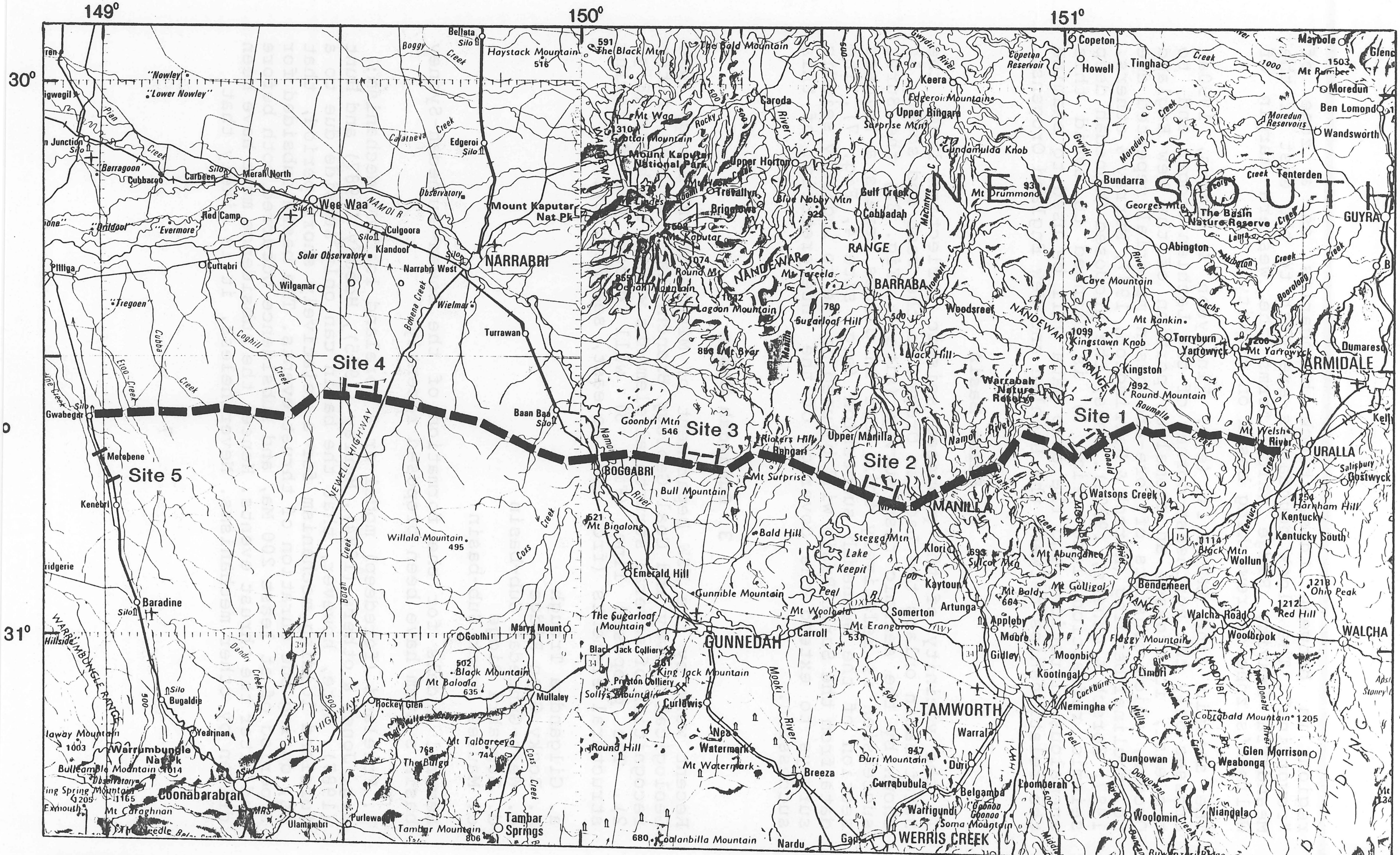
3. Gunnedah Basin

Recent work by the NSW Department of Minerals and Energy (NSW Geological Survey and Coal Geology Branch) has resulted in the recognition of several structural elements within the basin (Fig. 2). The proposed line (Fig. 3) will cross the following structural elements (from west to east, see Fig. 2):

a. Gilgandra Trough
b. Rocky Glen Ridge
c. West-Gunnedah Sub-basin
d. Boggabri Ridge
e. Maules Creek Sub-basin

Several models for the formation of the Bowen-Gunnedah-Sydney basin system have been proposed recently:

1. Foreland (foredeep) model or a foreland loading mechanism: e.g. Jones & others (1984), Murray (1985), Hobday (1987) and Hunt (1987). Note, however, that the basin can only subside due to a foreland loading mechanism for a relatively short period, that is, during the duration of thrust events. The basin subsided for a period of at least 200 Ma, and subsidence occurred both before and after the thrust events. Hence, the subsidence must have been driven by other mechanisms. Nevertheless, it is likely that



Proposed Seismic Line

|--| Seismic Test Site 1989

0 km 20

Figure 3 : Location Map

foreland loading operated as a subsidence mechanism for brief periods in the subsidence history of the basin.

2. Extensional origin: e.g. Denison Trough (Bauer & Dixon, 1981; Ziolkowski & Taylor, 1985); Surat Basin (Wake-Dyster & others, 1987b); possible early Permian extension in the Bowen-Sydney system (Hobday, 1987); Bowen Basin (Hammond, 1987; Mallett & others, 1988a); Sydney Basin (Mallett & others, 1988b); Gunnedah Basin (Tadros, 1988). These models suggest that the extensional direction was approximately east-northeast. Later compression has been invoked to invert the structures.

3. Transtensional origin: e.g. Bowen-Sydney system (Harrington, 1982); Gunnedah Basin as a strike-slip basin (Harrington & Korsch, 1985a); Taroom Trough (Korsch & others, 1988, 1990b). The transtensional origin for the Taroom Trough is related to the north-south orientation of the Mooki Fault, and is not incompatible with an extensional model for the Bowen Basin farther to the north.

4. Mixed-mode origin: This involves an early history of the basin system involving extension and/or transtension followed by a later history dominated by compression and/or transpression (e.g. Ziolkowski & Taylor 1985; Hobday, 1987; Hammond, 1987; Korsch & others, 1988, 1990b).

Previous BMR deep seismic reflection profiling has shown a marked contrast in geometries across the basins. For example, Line BMR84.14 across the Surat Basin shows that the Taroom Trough in the east is asymmetric, thinning towards the west and bounded on the east by a steeply dipping to sub-vertical fault (Korsch & others, 1988, 1990a; Finlayson & others, 1990a). There is also little evidence of deformation in the sedimentary pile away from this fault-bounded margin. The presence of three sub-basins and two intervening ridges within the Gunnedah Basin is in marked contrast to the geometry observed in line BMR84.14. In the central Bowen Basin, the seismic line BMR89.B01 shows a major detachment fault dipping shallowly to the east (e.g. Korsch & others, 1990c). This detachment forms the root zone for several thrusts which ramp to the present surface, again markedly different from line BMR84.14.

Scheibner (1973), Korsch (1982), Harrington (1982) and Korsch & others (1988) interpreted the latest Carboniferous - Early Permian volcanics (e.g. Werrie Basalt, Boggabri Volcanics) on the western margin of the Tamworth Belt and in the Gunnedah Basin as extension-related volcanics associated with transtension or extension on the Mooki Fault and formation of the Gunnedah Basin. On the other hand, McPhie (1984) considered the volcanics to be the final stages of the Devonian - Carboniferous subduction-related, continental margin volcanic arc. Leitch & others (1988) suggested that the compositions of the volcanics reflect the influence of lithosphere previously subducted during the

Carboniferous, and that the eruption of the large volume of lava was due to an extensional environment during the Early Permian. Chemical and isotopic data on volcanic centres of the Werrie Basalt indicate that the rocks are significantly different from the Late Carboniferous lavas and ignimbrites (Flood & others, 1988).

There is good evidence for shortening in the basin complex in the Bowen Basin (eg. Hobbs, 1985; Leach & others, 1986; Hammond, 1987; Mallett & others, 1988a) and in the northern Sydney Basin (Glen & Beckett, 1989; McLennan & Lohe, 1990); in both cases, the thrusting appears to be thin-skinned. In contrast, the seismic line BMR84.14 across the Taroom Trough in southern Queensland revealed almost no internal deformation of the sedimentary packages, with limited deformation being confined to the eastern margin of the trough. Korsch & others (1988, 1990b) interpreted the observed minor thrusting as positive flower structures above a deep rooted strike slip fault system. Also, there is very little evidence for thrusting in the Gunnedah Basin, except for its eastern margin, where the Mooki Fault dips moderately to the east.

The polarity of the Taroom Trough in Line BMR84.14 is the opposite to that in the Denison Trough in the Bowen Basin. Preliminary results from the 1989 BMR Bowen Basin seismic survey suggest that the sediment package on and to the east of the Comet Platform has the same asymmetry as the Taroom Trough further to the south (Korsch & others, 1990c).

Thus, the proposed deep seismic reflection profile across the Gunnedah Basin will examine the geometry of the basin and address several of the problems outlined above. This information will help constrain models for the evolution of the basin.

4. Mooki Fault

The Mooki Fault is not exposed along the proposed position of the reflection line, being covered by Quaternary alluvium. It is exposed some 8 km to the north, where it is east side up (Voisey, 1964). To the south, the Mooki Fault has a thrust geometry and usually has dips of 40° to 50° to the east (Carey, 1934). On the basis of a detailed magnetometer survey, Ramsay & Stanley (1976) suggested that, farther to the north, the fault was a complex zone, often with intrusives emplaced along it, and that it dipped to the east at about 25°.

The fault has usually been referred to as a thrust marking the boundary between the Gunnedah Basin and Tamworth Belt of the New England Orogen, and Thomson & Flood (1984) proposed that it was a Late Permian - Early Triassic thrust feature. Liang (1991) constructed a balanced cross section across the Tamworth Belt in the vicinity of the proposed seismic reflection line and inferred that the rocks of the Tamworth belt continued to the west beneath the Gunnedah Basin. On the other hand, Harrington and Korsch (1985a) proposed major strike-slip movement on the Mooki Fault in the latest Carboniferous to Early Permian.

Recently, Korsch & others (1988, 1989) have shown that Early Permian to Mesozoic sedimentary basins peripheral to the New England Orogen were initiated during transtensional events, and that the Taroom Trough (northern equivalent of Maules Creek Sub-basin) is asymmetric in shape, being bounded on one side by a very steeply dipping fault that had a strong strike-slip component to its movement during basin initiation. This fault was active, at least intermittently, throughout the depositional history of the basin. Even the youngest sediments in the vicinity of the fault have been folded or thrusted; these structures have been interpreted as a positive flower structure above a more deeply rooted strike-slip fault (Korsch & others, 1988). Thus Korsch & others (1988, 1990b) consider that the eastern margin of Gunnedah Basin, at least farther north in southernmost Queensland, is a strike-slip zone that has acted as a transtensional zone during basin initiation, and later as a transpressional zone at various times (when the positive flower structures formed).

Thus, it is possible that although the Mooki Fault in the Werrie Syncline area has a thrust geometry, it represents part of a flower structure associated with a major strike-slip fault. Seismic reflection work (including high resolution reflection profiling in conjunction with the Geological Survey of New South Wales) is required to determine the geometry of this fault and its relationship to the Gunnedah Basin.

5. Tamworth Belt of The New England Orogen

Most interpretations in the recent literature of the Middle Palaeozoic to Early Mesozoic New England Orogen prefer a convergent plate margin model associated with a west-dipping subduction zone, with refinements due to concepts of tectonostratigraphic terrane analysis (see references in Korsch & others, 1990a). In the New South Wales sector, the arc is essentially missing, but the forearc basin is represented by the Tamworth Belt and the accretionary wedge by the Tablelands Complex (Fig. 2).

In temporal terms, the subduction-related model is applicable for at least the Middle Devonian to Carboniferous or earliest Permian, but there are hints of an earlier history that extend back to at least the Cambrian, particularly seen in slivers along the Peel Fault. The Devonian to Carboniferous history of the Tamworth Belt is well documented, particularly in terms of stratigraphic and palaeogeographic aspects (see references listed by Korsch & others, 1990a). Essentially, the basin deepened towards the east and consists predominantly of terrestrial to shallow marine (shelf) clastic sediments deformed into shallow-plunging, upright regional folds and associated thrusts. The provenance of the clastic sediments is dominated by the volcanic arc which was presumably located to the west.

The inferred site of the volcanic arc is either beneath the sedimentary rocks of the Gunnedah Basin (e.g. Scheibner 1985), overthrust by the Tamworth Belt, or has been removed by strike-slip faulting on the Mooki Fault system (Harrington & Korsch, 1985a).

The Tamworth Belt has long been regarded as a fold and thrust belt (e.g. Voisey, 1959) and is bounded to the west by the Mooki Fault. If the Mooki Fault is a shallowly-dipping thrust, then the Tamworth Belt would be thin-skinned, soled by the thrust, and thrust for some distance over the eastern margin of the Gunnedah Basin. Within the Belt, the folds and thrusts might then be related to thrusts that are listric to east and might sole into a master detachment above the sediments of the Gunnedah Basin. A thin-skinned model such as this has been proposed by Liang (1991) to explain the geometry of folds immediately to the east of the Mooki Fault. In his model, Liang proposes only a very limited amount of overthrusting of the Tamworth Belt onto the Gunnedah Basin. On the other hand, if the Mooki Fault represents the thrust portion of a flower structure above a strike slip fault, then the Tamworth Belt would not be thrust over the Gunnedah Basin to any marked extent. In this case, the folds and thrusts in the belt might possibly represent a wide braided strike-slip fault zone. This zone would be required to detach at some level in the crust, but presumably at a greater depth than if the Mooki Fault became a subhorizontal detachment to the east.

In southern New England, thrust sheets, interpreted as gravity glides by Roberts & Engel (1987) and Engel & Morris (1987), resulted in overthrusting over Permian sediments of the northern Sydney Basin by structural blocks in the southern Tamworth Belt, that is, a north over south movement. Bounding faults for these thrust sheets would most likely have a strike-slip character, with opposite senses of movement on the eastern and western sides of the thrust sheets.

Thus, the seismic reflection line is needed to determine if the Tamworth Belt is thin skinned and thrust over the Gunnedah Basin.

6. Peel Fault

The Peel Fault marks the present boundary between the Tamworth Belt and Tablelands Complex of the New England Orogen. Voisey (1959) showed that, in the vicinity of Nundle, the fault dips 60° to the east, and Scheibner & Glen (1972) considered the fault to be a listric thrust flattening towards the east. Runnegar (1974) extended this idea in suggesting that the fault was a spoon-shaped thrust extending under the whole of the Tablelands Complex to re-emerge in the east at the Baryulgil Serpentinite. In contrast, a magnetometer survey across the fault by Ramsay & Stanley (1976) showed it to dip at about 65° and to continue at this angle to a depth of 5 km, and possibly to at least 7.5 km.

It is likely that the Peel Fault has also behaved as a strike-slip fault, at least for a part of its history. There is controversy over movement directions on the Peel Fault, particularly in the Permian. Evidence for sinistral strike-slip presented by Corbett (1976) and Offler & Williams (1985) conflicts with dextral transtension determined by Katz (1986). An even more complicated movement history for the Peel Fault is starting to emerge (Blake & Murchey, 1988a, 1988b; Offler & others, 1989).

In a block diagram interpretation of the orocline in the New England Orogen, Harrington & Korsch (1987) showed the Peel Fault dipping steeply to the east at the surface, and postulated that the fault would detach onto a shallowly-dipping detachment at depth. They implied considerable strike-slip movement on this fault.

Because there is little consensus on the nature of the Peel Fault, its relationship to the Tamworth Belt is also uncertain. Could it be the root zone for thin-skinned imbricate thrusts in the Tamworth Belt, or could it be the fault zone that forms the backstop to the accretionary wedge ? Seismic reflection profiling is needed to examine the subsurface geometry of this structure.

7. Tablelands Complex of the New England Orogen

There is now a general consensus that, during the Devonian and Carboniferous, the southern New England Orogen developed at a convergent plate margin related to a west dipping subduction zone (see references in Korsch & others, 1990a). The Tablelands Complex in New England is interpreted as an accretionary wedge that grew oceanwards by accreting trench-fill volcaniclastic turbidites (derived from a magmatic arc) and minor amounts of oceanic crust (basalt, chert, pelagic mudstone).

Immediately east of the Peel Fault in the accretionary wedge, Blake & Murchey (1988a, 1988b) recognised a series of imbricate, east-directed, west-dipping nappes. There is some support for these structures in the seismic test section 1 (Fig. 4). This section was recorded on outcrops of the Bundarra Plutonic Suite, but shows west-dipping reflections in a zone between 1 and 3 s two-way time.

The accretionary wedge in the orogen is intensely deformed, both as a result of accretion processes and later oroclinal bending which also thickened it. The orocline cannot be expected to continue to an indefinite depth. Harrington & Korsch (1987) postulated that the lower crust under the oroclinally-bent accretionary wedge consists of a "frozen" part of the subducted slab of oceanic crust, with or without pelagic or trench-fill sediments; the top of this slab would represent a major detachment in the middle part of the crust. To the north, lines BMR84.14 and BMR84.16 show the existence a subhorizontal, mid-crustal detachment (see Korsch & others, 1990a, fig. 8). As discussed above, these seismic lines cross an anomalous part of the orogen; hence a deep seismic reflection line cutting the western part of the accretionary wedge is required to examine its structure and its relationship to the Peel Fault and Tamworth Belt.

In summary, a deep seismic reflection profile is needed to:

1. Determine the geometry of the components of the Gunnedah Basin.
2. Determine the geometry of the Mooki Fault at depth.
3. Determine if the Tamworth Belt is thin skinned, and overriding the Gunnedah Basin.
4. Image the Peel Fault (the eastern margin of the Tamworth Belt) and determine its relationship to the Gunnedah Basin and Tamworth Belt.
5. Determine the relationship between the Lachlan and New England Orogens.

All of the above could be examined a single seismic profile approximately 265 km long.

LOGISTICS FOR THE PROPOSED LAND SEISMIC DATA ACQUISITION

1. Background Information

Originally, a deep seismic reflection profile across the Peel and Mookie Fault systems was proposed by Erwin Scheibner and other members of the NSW ACORP Committee, as a major priority, to test models proposed for the structure of the fault systems and their relationship to the Gunnedah Basin (Scheibner, 1985).

The NSW ACORP Committee proposed several alternative locations for the positioning of the deep seismic profile. A brief examination of the proposed traverse positions was made by David Johnstone (BMR) in November 1988, to examine the logistic feasibility of the traverse locations. At that stage, the first choice proposal from Premer to Dongowan, appeared logistically a better choice than the second choice proposal from Boggabri through Manilla to Uralla.

In February 1989, a second more detailed reconnaissance of the seismic traverse location proposals was made by Kevin Wake-Dyster and David Johnstone, to make a final decision on the location of the seismic traverse. Prior to the reconnaissance trip, aeromagnetic and geological maps were studied in greater detail, to highlight areas of surface volcanics, and to examine the possibility of extending the seismic line farther west to examine the Gunnedah Basin as a whole. The extension of the seismic line farther west was a suggestion made both by geologists from petroleum companies with petroleum exploration leases in the area and from geologists in the NSW Coal Geology Branch. Based on the additional objectives of the seismic survey and the distribution of surface volcanics, if the route from Boggabri through Manilla to Uralla proved logistically feasible, it would be the preferred seismic line location. Detailed reconnaissance of the Boggabri-Manilla-Uralla route highlighted some very difficult areas to record seismic data, especially in the very hilly and rugged areas between Manilla and Uralla. A seismic survey following shire roads, although very crooked and bendy, from Boggabri-Manilla-Uralla was technically feasible, but data quality may be reduced.

The extension of the seismic survey line further westward involved problems with recording seismic in the Pilliga Sandstone (Formation), regarded by companies and the NSW Geological Survey as a poor quality seismic data area. In addition, a major proportion of the outcropping Pilliga Sandstone is covered by native forests, and administered by the Forestry Commission of NSW, restricting access to existing forest trails and roads.

As a result of the planned westward extension of the seismic line, and uncertainty of seismic data quality in different areas, a seismic test survey was planned at short notice in May 1989, to better define acquisition parameters before executing a major survey in the region.

The proposed seismic survey line position is shown in Figure 3 (dashed line), with seismic test line locations positioned along its route.

2. BMR Seismic Test Survey, May 1989

To test the feasibility of recording good quality deep seismic data along the proposed route, from south of Narribri to Boggabri and eastward to Uralla, the BMR carried out a test seismic survey in May 1989. Test seismic survey lines were 5.7 km in length (96 channels, 60m geophone group interval, 360m shotpoint interval), and were made at five locations along the proposed route in the region of the Gunnedah Basin and margins (Fig. 3). Results from the seismic test survey are shown as seismic sections (to 4 secs) for Sites 1 through to Site 5 in Figures 4 to 8 respectively. Results from the test survey were encouraging, with good data recorded in areas with outcropping granites (Fig. 4), floaters of volcanic basalts (Figs 5 & 6), in the Pilliga Sandstone (water saturated from recent heavy rainfall) (Fig. 7), and west of the Rocky Glen Ridge (Fig. 8). Based on the results of the test seismic survey, the proposed seismic survey line from south of Narrabri to Uralla is recommended as the route for the deep seismic reflection profile across the Gunnedah Basin and the eastern bounding fault systems.

The seismic survey was planned to be carried out during October and November 1989, but due to additional seismic work proposals and a major review of the BMR, the Gunnedah Basin Survey is now scheduled for early 1991.

3. Deep Reflection Seismic Data Acquisition

The following specifications and information for the deep seismic reflection data acquisition across the Gunnedah Basin relate directly to previous methods and specifications as used on earlier BMR deep seismic surveys.

The seismic survey will utilise explosives as an energy source (as in previous years), with acquisition parameters similar to the BMR Sercel SN368 seismic acquisition system.

SITE 1

Seismic Test Section

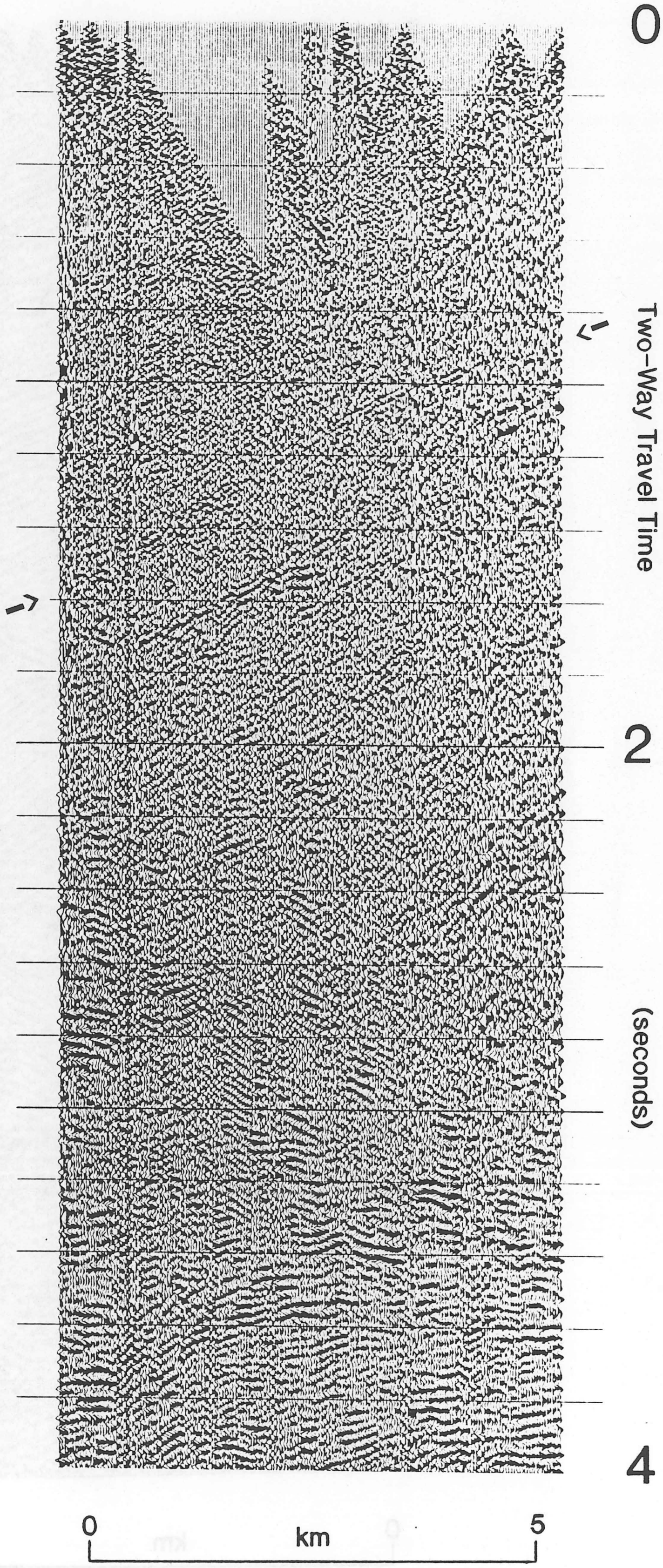


Figure 4: East of Peel Fault on outcrops of granitoids

SITE 2

Seismic Test Section

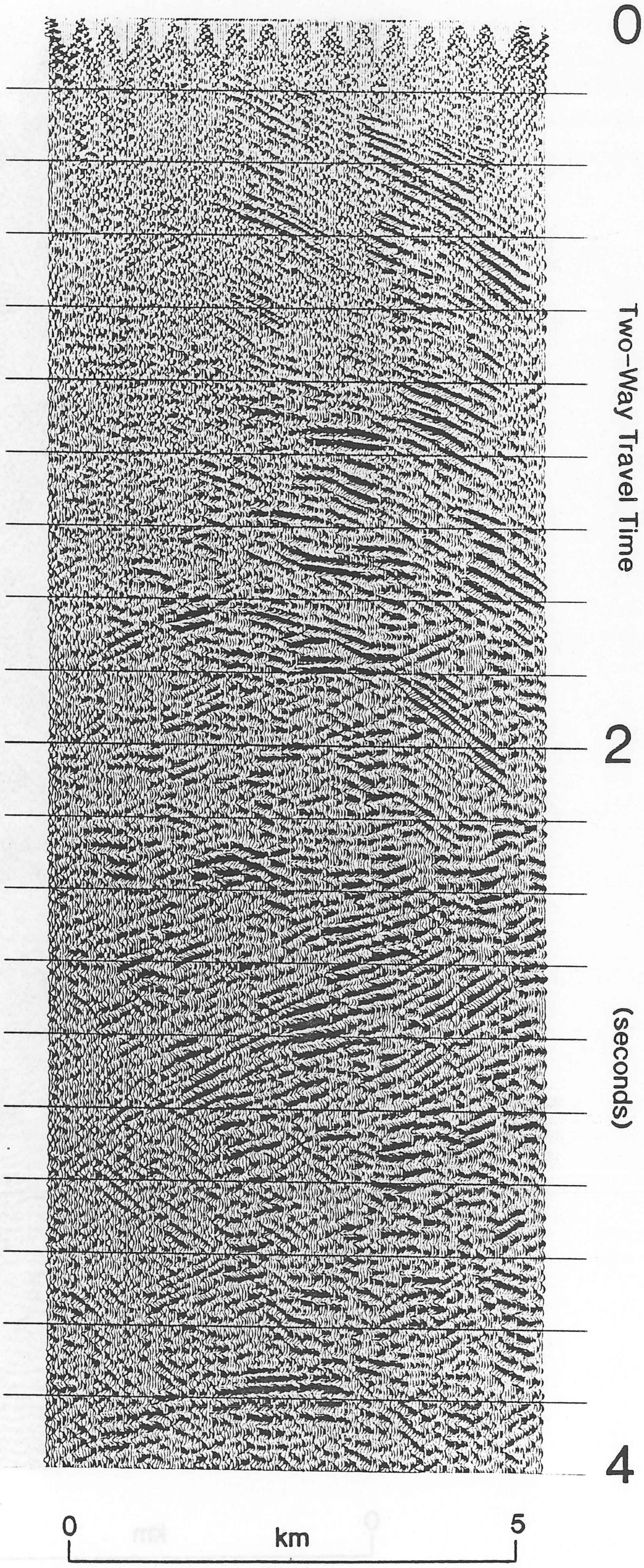


Figure 5 : Between the Mooki and Peel Faults.

SITE 3

Seismic Test Section

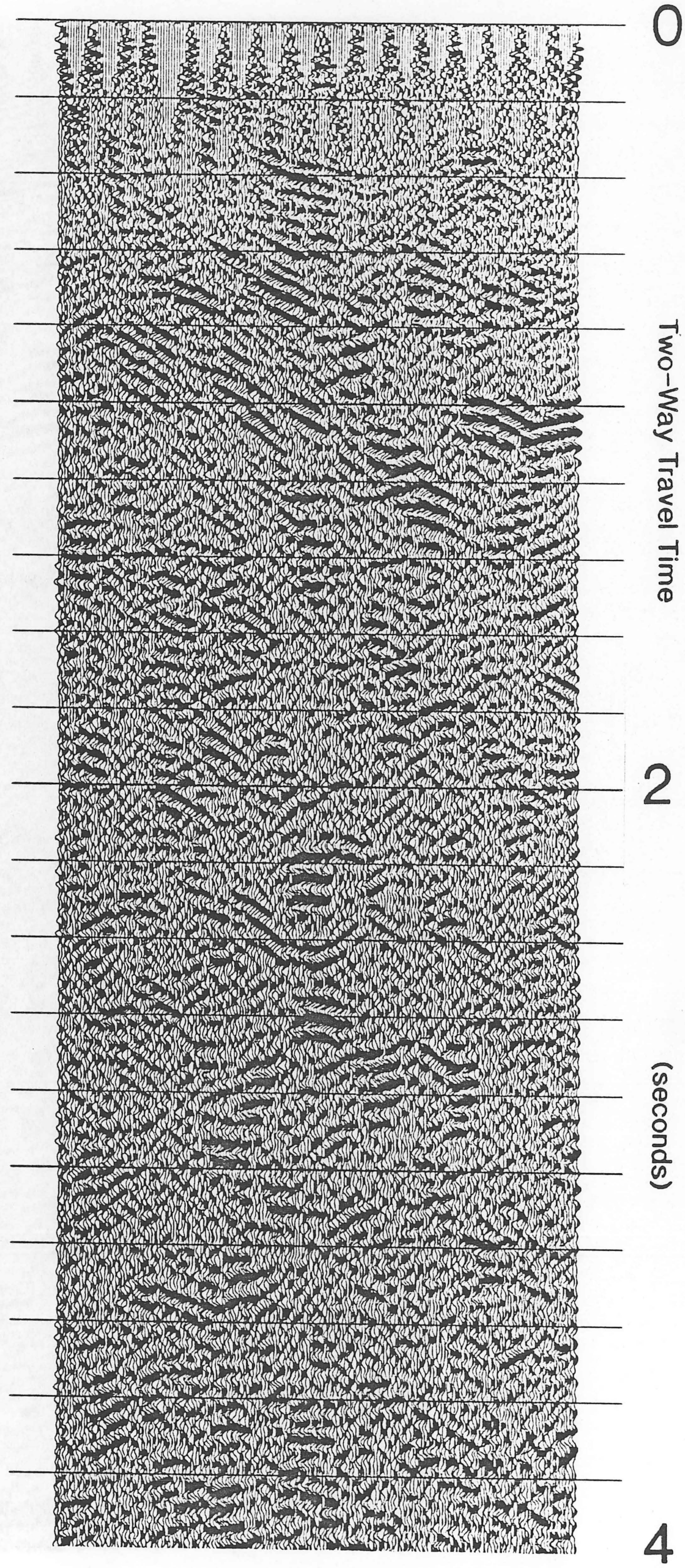


Figure 6 : Across the Mooki Fault.

SITE 4

Seismic Test Section

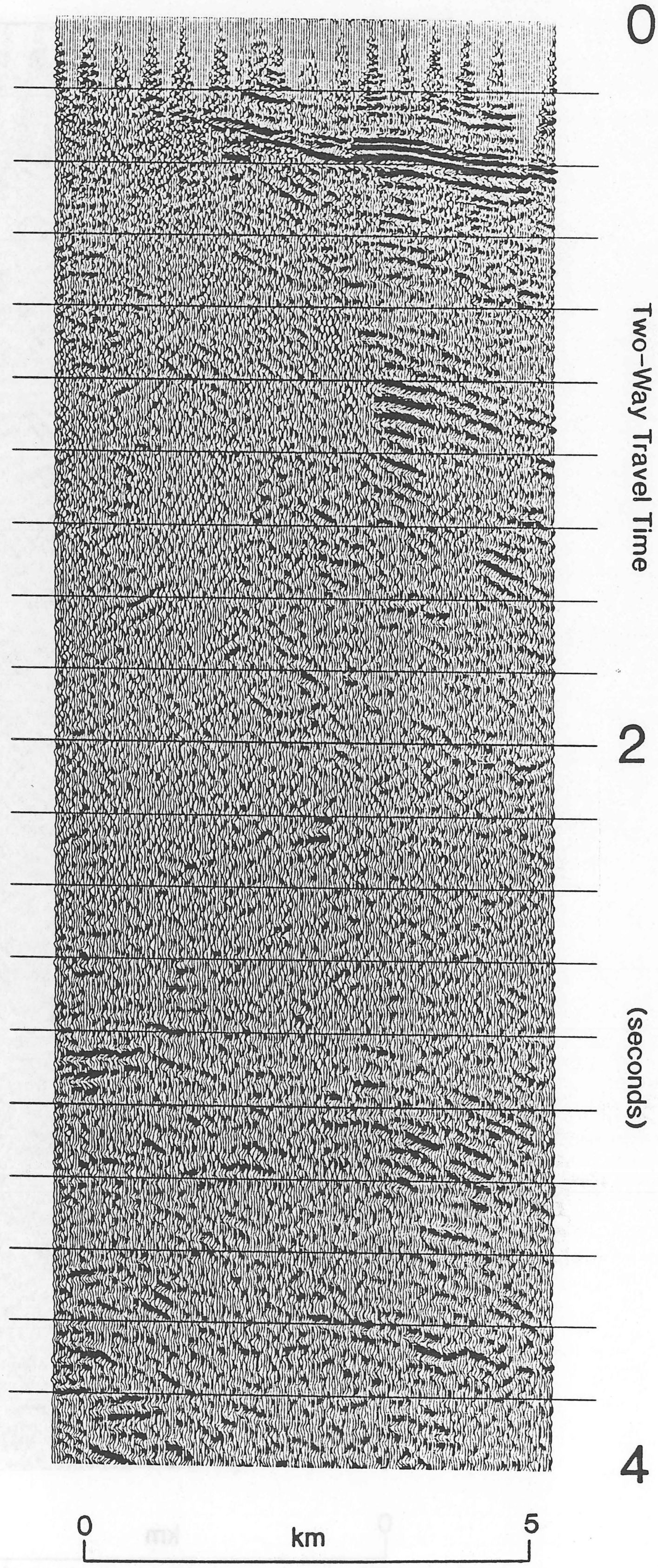


Figure 7 : Area of outcropping Pilliga Sandstone, western margin of the Gunnedah Basin.

SITE 5

Seismic Test Section

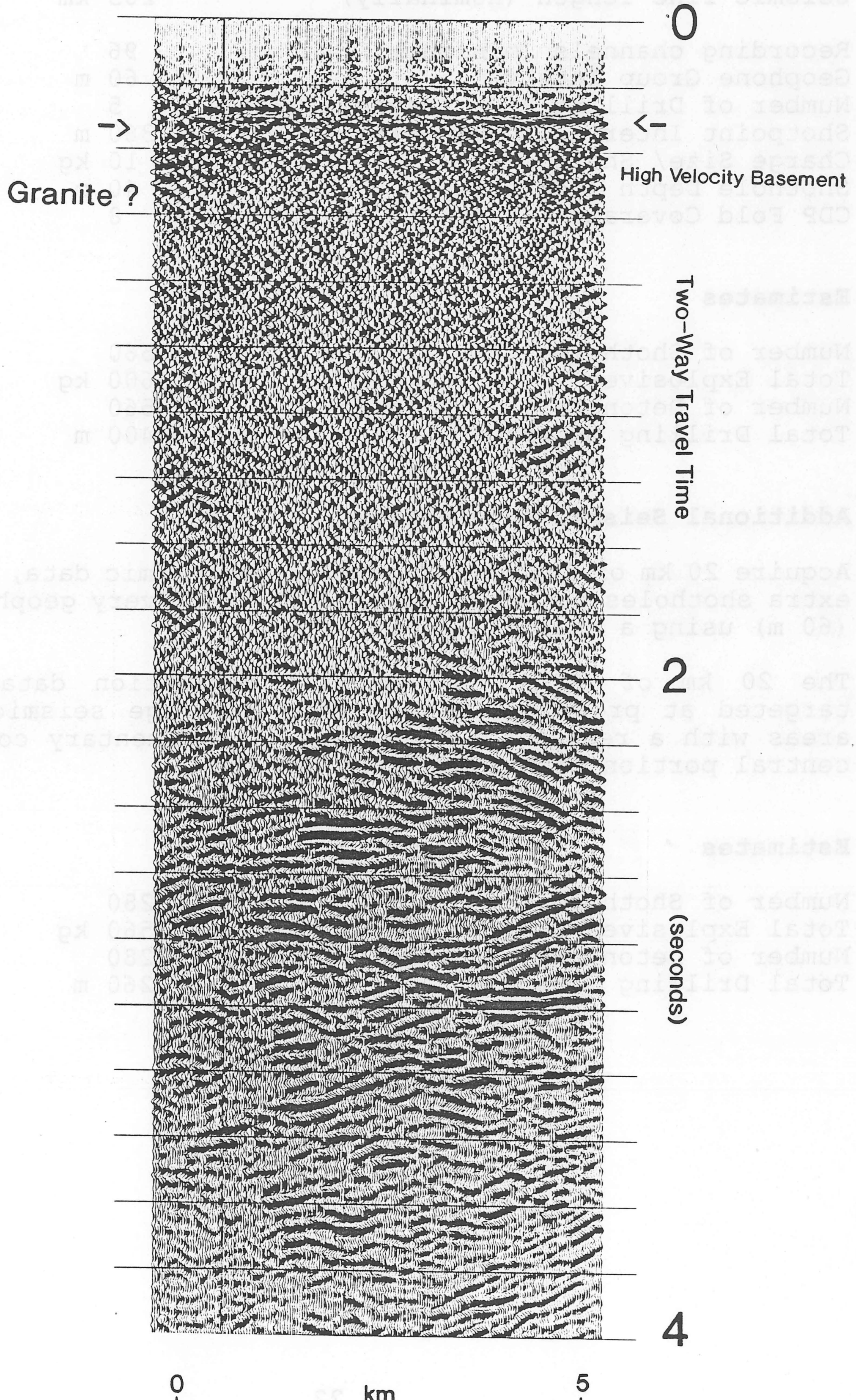


Figure 8: West of the Rocky Glen Ridge, across a postulated Permo-Triassic sub-basin. (Gilgandra Trough).

Proposed Acquisition Parameters

Seismic Acquisition Survey Duration (based on a 5 day working week)	8 weeks
Seismic line length (nominally)	265 km
Recording channels (minimum)	96
Geophone Group Interval	60 m
Number of Drilling Rigs (Mayhew 1000)	5
Shotpoint Interval (nominally)	360 m
Charge Size/ Shotpoint	10 kg
Shothole Depth (nominally)	40 m
CDP Fold Coverage	8

Estimates

Number of Shotholes	560
Total Explosives	5600 kg
Number of Detonators (45m leads)	560
Total Drilling Meterage	22400 m

Additional Seismic Acquisition

Acquire 20 km of integrated additional seismic data, by drilling extra shotholes to kelly depth (4.5 m) at every geophone station (60 m) using a charge size of 2 kg.

The 20 km of additional seismic reflection data, would be targeted at providing higher fold coverage seismic data over areas with a reasonable thickness of sedimentary coverage (eg. central portion of the Gunnedah Basin).

Estimates

Number of Shotholes	280
Total Explosives	560 kg
Number of Detonators (6 m leads)	280
Total Drilling Meterage	1260 m

4. Seismic Survey Line Clearing

Seismic line clearing has been minimised, by using existing roads and tracks where possible.

Reasons:
- scientific objectives maintained without the additional cost of bulldozer line clearing.
- avoids cultivated paddocks and crops which may result in heavy compensation claims.
- areas requiring bulldozing would also require archaeological site clearance, hence minimises the cost of employing an archaeologist ($100/km).
- allows better access to the seismic line, as existing tracks and roads are usually in a better state of repair than a bulldozed seismic line.
- no other choice. eg. Must use existing tracks in State Forests.

It should be noted, that by following existing roads and tracks where possible, savings occur in bulldozing costs, but some cost is usually incurred either regrading the road verges and table drains or slashing grass and weed growth on the road verges to enable a clear path for planting geophones. The regrading is often done to clear build-ups of cuttings from shothole drilling, and smooth out corrugations made by rigs and trucks along gravel roads.

The following summarises the estimate of clearing requirements for the Gunnedah Basin seismic survey.

The proposed seismic survey line position has been subdivided in four sections, to localise clearing requirements in specific areas.

Section 1

Commencing in the west, 10 km east of Gwagbegar and extending east to the Newell Highway, 30 km south of Narrabri. (This section is entirely in the Pilliga State Forest.)

Bulldozing:	0 km
Grading :	55 km
Slashing :	0 km

Section 2

Newell Highway 30 km south of Narrabri, to 4 km north of Boggabri. (Partly in the Pilliga State Forest, remainder along shire roads and through private properties.)

Bulldozing:	35	km
Grading :	12	km
Slashing :	0	km

Section 3

4 km north of Boggabri, east to Manilla. (Following existing shire roads.)

Bulldozing:	0	km
Grading :	35	km
Slashing :	35	km

Section 4

Manilla east to Macdonald River (turnoff to Bendemeer). (Following existing shire roads, with short-cuts to straighten the seismic line, across private properties.)

Bulldozing:	5	km
Grading :	40	km
Slashing :	10	km

In addition to clearing requirements, some grading restoration maybe required, and low-loader transport hire for mobilising and demobilising bulldozers, graders and tractor/slashers will be needed.

Summary	Estimates		
Total Bulldozing:	40 km	Clearing Rate	0.5 km/hr
Total Grading :	142 km	Clearing Rate	2.0 km/hr
Total Slashing :	45 km	Clearing Rate	2.0 km/hr
Total Line Length	227 km		

5. Seismic Survey Line Surveying

Surveying requirements and guidelines

- Geophone station and shotpoint positions, positioned by use of a surveying chain.

- Geophone Station Interval = 60 m
  (White pin marker or wooden peg every 60 m)

- Shotpoint Interval = 360 m
  NB. Shotpoints to be located midway between geophone stations, but at 360 m intervals. Shotpoints numbered by the lowest value geophone station nearest the shotpoint.
  (Red pin marker or wooden peg every 360m)

e.g.:

```
      <--------------------360m--------------------->
   +   *   +     +     +     +     +     +   *   +
      SP               <--60m-->             SP
```

(+ Geophone station, * Shotpoint)

- Permanent Markers every 5 km. Permanent markers consist of a steel star picket, 40 cm in length, for a dumpy hammered flush with the ground surface (and is the actual survey location point), and a 165 cm steel star picket as a finder, tagged with a 2mm thick aluminium tag, punched with the seismic line number and geophone station (and offset if not on a integer value geophone station).
  eg. BMR 1990 L1 SP 1052+32m

- Bends in the seismic survey line are to be kept as small as practicable.

- Elevations to be measured using staff and auto-levels, with double face readings at change points only. Elevations for both geophone stations and shotpoints are required.

- AMG coordinates (Easting and Northings, Map Grid Zone) are required for bendpoints in the line, and the AMG coordinates of the geophone stations either side of the bendpoints.
  If bendpoints have an offset to a geophone station, the bend-point is to be numbered with the geophone station number of lowest value either side of the bendpoint, with the offset being measured as a positive value from the geophone station of lowest number.

- Normally, geophone station and shotpoint numbering increases from west to east, or from south to north.

6. Seismic Survey Personnel

(Based on the presumption that the BMR seismic acquisition system and drilling capabilities will be used.)

Bureau of Mineral Resources:

Seismic survey Party Leader	Science 3
Drilling Supervisor	1
Party Clerk	ASO 4
Geophysicist	Science 1/2
Technical Officer (Engineering)	TO2/STO1
Technical Officer (Science)	TO2
Drillers	Grade 2
	Grade 1
Mechanics	TA2
	TA2
Field Assistants (Explosives)	FA
	FA

Temporary Personnel (Contract):

Assistant Drillers	5
Cooks	2
Assistant Cooks	2
Field Hands	10
Field Assistant	1
Drillers	3

7. Seismic Survey Vehicle Requirements

Recording:

Recording truck	Mercedes 911 4tonne 4X4	ZBE-748
Workshop truck	Mercedes 911 4tonne 4X4	ZBE-689
Water truck	Mercedes 911 4tonne 4X4	ZBE-781
Cable truck	Mercedes 911 4tonne 4X4	ZBE-633
Stores truck	Mercedes 911 4tonne 4X4	ZBE-169
Computer truck	International 1830C 8 tonne	ZUE-121
Geophone carrier	Toyota tray top 4X4	ZBE-791
Geophone carrier	Toyota tray top 4X4	ZBE-792
Geophone carrier	Toyota tray top 4X4	ZBE-793
Geophone carrier	Toyota tray top 4X4	ZBE-794
Shooting truck	Toyota tray top 4X4	ZBE-734
Personnel carrier	Toyota troop carrier 4X4	ZBE-796
Personnel carrier	Toyota troop carrier 4X4	ZBE-
Reconnaisance	Nissan Patrol S/W 4X4	ZBE-862
Kitchen	4 wheel trailer	ZTL-914

Ablutions	4 wheel trailer	ZTI-344
Generator	4 wheel trailer	ZTV-021
Stores	4 wheel trailer	ZTV-020
Workshop spares	4 wheel trailer	ZTL-674
Water	2 wheel trailer	ZTV-018

Drilling:

Drilling rig	Mayhew 1000/Mack R600 6X8	ZSU-606
Drilling rig	Mayhew 1000/Mack R600 6X8	ZSU-471
Drilling rig	Mayhew 1000/Mack R600 6X8	ZSU-472
Drilling rig	Mayhew 1000/Mack R600 6X8	ZSU-473
Drilling rig	Mayhew 1000/Mack R600 6X8	ZSU-529
Drill W/Tankers	Mack R875 6X6 8645 litres	ZSU-863
Drill W/Tankers	Mack R875 6X6 8645 litres	ZSU-864
Drill W/Tankers	Mack R875 6X6 8645 litres	ZSU-865
Drill W/Tankers	Mack R875 6X6 8645 litres	ZSU-866
Drill W/Tankers	Mack R875 6X6 8645 litres	ZSU-911
Water tanker	Mercedes 911 4tonne 4X4	ZBE-782
Workshop	Mercedes 911 4tonne 4X4	ZBE-647
Explosives truck	International 1830C 8tonne	ZUE-136
Stores truck	Mercedes 911 4tonne 4X4	ZBE-645
Preloading truck	Toyota tray top 4X4	ZBE-735
Personnel carrier	Toyota troop carrier 4X4	ZBE-
Personnel carrier	Toyota troop carrier 4X4	ZBE-
Office	4 wheel trailer	ZTL-739
Drilling spares	4 wheel trailer	ZTL-514
Kitchen	4 wheel trailer	ZTL-917
Ablutions	4 wheel trailer	ZTI-343
Workshop spares	4 wheel trailer	ZTV-023
Stores	4 wheel trailer	ZTL-916
Generator	2 wheel trailer	ZTL-984
Welding	2 wheel trailer	ZTL-501
Water	2 wheel trailer	ZTL-016

PROPOSED WIDE-ANGLE SEISMIC REFLECTION/REFRACTION PROFILING IN THE EASTERN AUSTRALIAN BASINS

In Australia as a whole, investigations of major geological terranes on a crustal scale have involved regional seismic profiles, complemented by regional gravity and aeromagnetic mapping. The regional gravity and magnetic mapping provides a good indication of the lateral extent of structures but only provides limited information on the depths, extent and geometry of the geology causing the anomalies. Regional seismic profiles (both near-vertical and wide-angle recordings) give good resolution of structures/compositional boundaries at depth on scales comparable with geological units seen at the surface.

In eastern Australia to date, the wide-angle reflection-refraction techniques applied should be regarded as only reconnaissance in nature, that is, they provide relatively simple models of the velocity (composition?) at depth throughout the crust. The techniques required to produce more refined models, however, are well understood and have been applied extensively in Europe and North America.

Within the Bowen-Gunnedah-Sydney Basin system, there are only a few 1970s reconnaissance data available in the northern part which give an indication of velocity structures throughout the crust (Collins, 1978, 1980). These data were collected along lines which crossed major terrane boundaries and it is, therefore, difficult to determine with any certainty, the differences, for instance, between the velocity structure under the major depocentres and the intervening structural highs.

On the flanks of the Bowen-Gunnedah-Sydney Basin system, there are a few reconnaissance surveys which have established some basic velocity information within the crust. These are across the New England Province and in the Roma-Mitchell Shelf area. The interpretation of these data has not been finalised, but they have provided important preliminary information in conjunction with the 1984-86 BMR reflection profile across southern Queensland (Finlayson & others, 1990c).

Geological Problems

There are major features of the Bowen-Gunnedah-Sydney Basin system which are of fundamental importance to any geological history of the system, but the interpretation of which is very speculative, because of a lack of appropriate data. A complete discussion of the main problems is given above, and the following is a summmary of the main questions that would be addressed by wide-angle seismic reflection/refraction work:

1. What is the nature and significance of the geological

processes which have produced the Meandarra Gravity Ridge?

2. Where is the "arc" which produced the detritus in the forearc basin and accretionary wedge sequences in the southern part of the New England Orogen? Is there any evidence for this arc west of the Mookie Fault? Does it underlie the Gunnedah Basin or Tamworth Trough?

3. Is the Tamworth Trough allochthonous and thrust over the eastern part of the Gunnedah Basin ? Can the detachment be identified? If so, is crustal loading a factor in basin subsidence?

4. Can the Auburn Arch be used as a crustal analogue for the whole of the early New England Orogen?

It is considered that velocity information within the crust will provide the answers to at least some of these questions. As part of the overall strategy of investigating the tectonic framework of the Bowen-Gunnedah-Sydney Basin system, it is proposed that wide-angle reflection/refraction be undertaken to define the major velocity structures within the system. Targets are proposed which are closely associated with existing and proposed BMR near-vertical seismic reflection profiling.

TARGETS

Targets suitable for wide-angle reflection/refraction studies to assist in the study of the Gunnedah Basin and margins are described below.It is not necessary for each line to be collected in the same field season, but these targets should be investigated within a 3 year period (from 1 July 1990) to fit in with the overall schedule for the Sedimentary Basins of eastern Australia project.

Target A: Meandarra Gravity Ridge

One fundamental problem in the Bowen-Gunnedah-Sydney basins system is the interpretation of the Meandarra Gravity Ridge (Fig. 9). This 1200 km long, nearly linear structure is up to only 50 km wide and extends from the southern Sydney Basin to the southern Bowen Basin. It parallels, but is located to the west of, the eastern margin of the basin for its entire length.

The gravity ridge has been described by Lonsdale (1965), Darby (1969) and Fraser & others (1977). Various interpretations have been published. Qureshi (1984, 1989) and Qureshi & others (1990) has attributed the gravity feature to an upper crustal mafic body below the basin fill and this interpretation seems to withstand

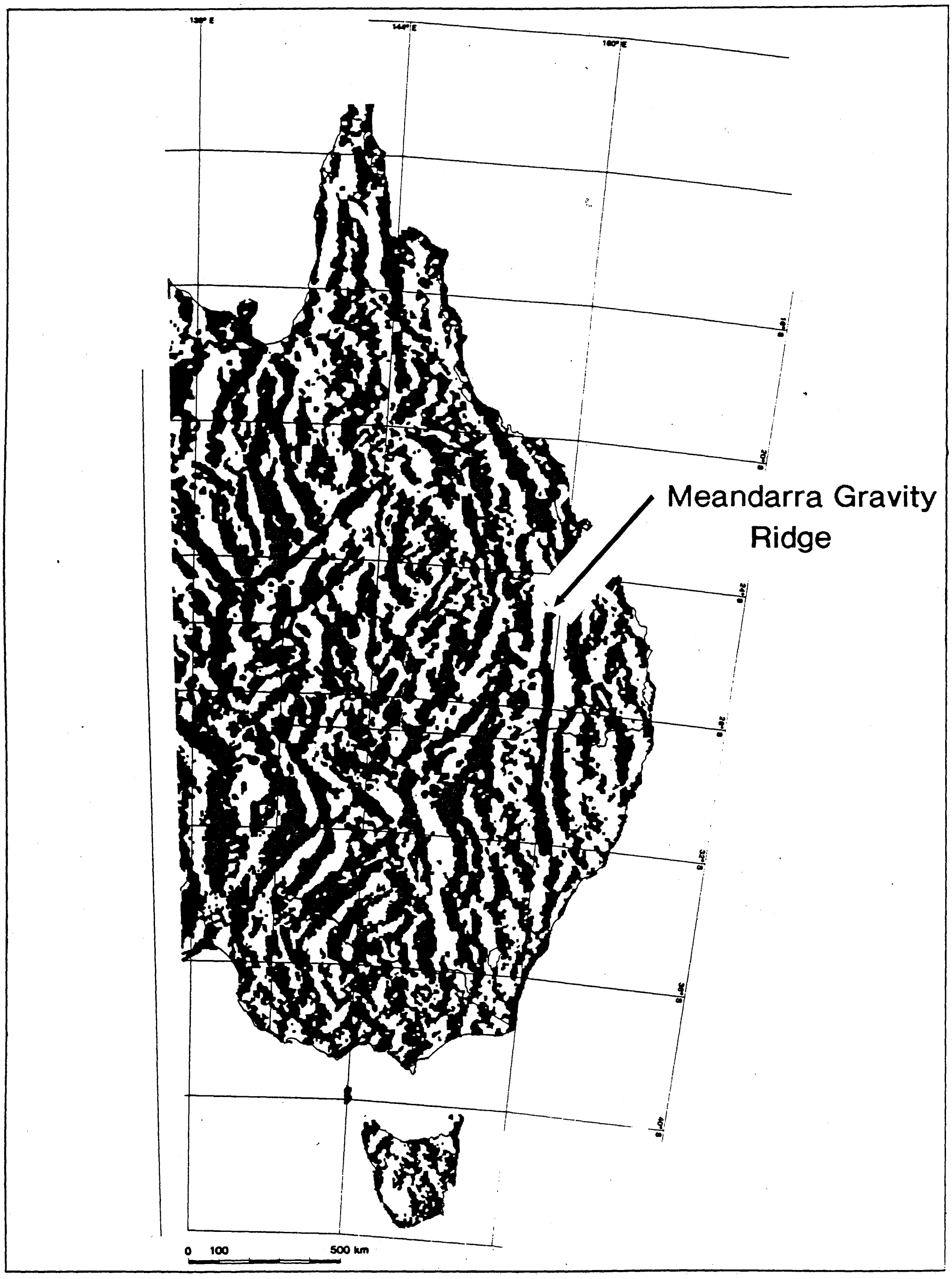


Fig. 9. Map of residual Bouguer gravity of eastern Australia east of longitude 138°E showing relatively positive (shaded) and negative domains. Note the pronounced linearity of the Meandarra Gravity Ridge (after Murray & others, 1989).

the reservations of Leaman (1990). It is probable that significant volumes of mafic material occur at depths of greater than 20 km beneath the Sydney Basin (O'Reilly, 1990). Murray & others (1989) described the gravity ridge as a "gravity paradox which appears to be related to rifting and basin formation." They suggested that the anomaly is the result of a combination of mafic volcanics in basement and mafic intrusives deeper in the crust.

Thus at present, there is no consensus on the interpretation of this gravity ridge.

Geological problems that require answers are:

1. The ridge is obviously related to the formation and development of the Sydney-Gunnedah-Bowen basin system, but the precise relationship is unknown. In determining the basin-forming mechanisms, any model must be able to explain the existence and nature of the ridge.

2. If this anomaly is due to mafic volcanics and/or mafic intrusives, why is it so extensive, so linear and so narrow ? What are the implications for the thermal history of the basin, particularly the early history of the basin ?

The deep reflection seismic line BMR84.14 crossed this feature in southern Queensland but there was no obvious reflection seismic expression of it. Nevertheless, because it is an important gravity feature, it must have a density signature and hence a velocity signature. The Meandarra Gravity Ridge is obviously related to the formation of the Bowen-Gunnedah-Sydney Basin system, and a better model of its velocity structure is highly desirable so that basin formation models and thermal history can be more tighlty constrained. Thus the main technique to solve the problem would need to be a deep seismic refraction experiment over this feature.

To solve this problem, it is proposed to acquire wide-angle reflection/refraction data along four lines (Fig. 10). Line 1 is a north-south line along the ridge. Lines 2 and 3 are subparallel lines to the east and west of Line 1. These are essential for comparative purposes and to control the velocity structure for Line 1. [As discussed below, they will also contribute data to other important scientific problems.] Line 4 is an east-west line which is required to link the three data sets collected along the three north-south lines.

Line 2 (Western Margin of the Gunnedah Basin)

It is clear from the gravity and magnetic anomaly maps that the Meandarra Gravity Ridge separates the main depocentre from the Lachlan Orogen to the west (Fig. 10) and that the nature of this

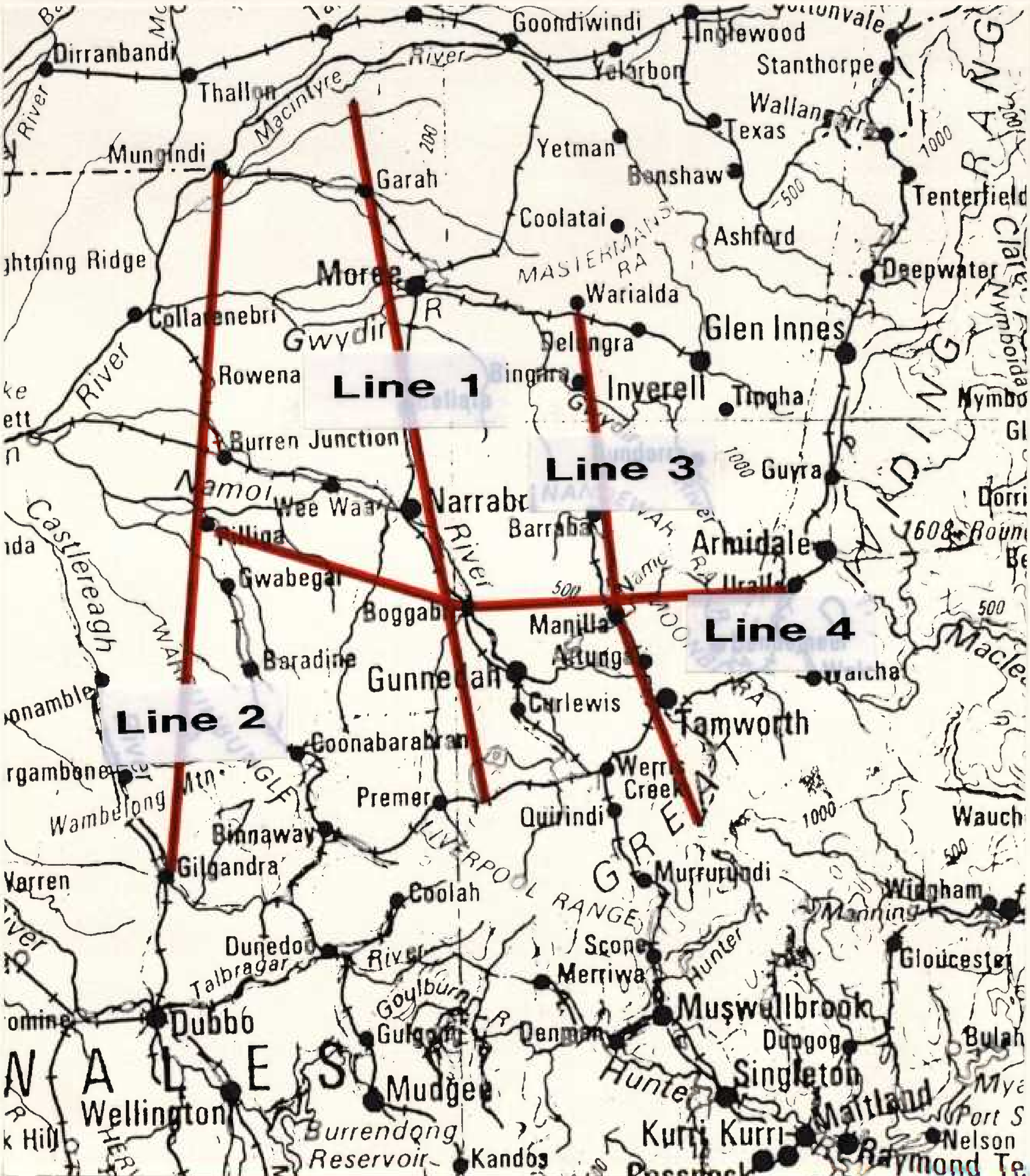


Fig. 10 Location of proposed Line 1 to 4.

western margin is not clear. One possible mechanism for the formation of this part of the Bowen-Gunnedah-Sydney Basin system is that it formed on thinned and extended Lachlan crust. At present there is no crustal model for this part of the Lachlan Orogen, yet the crust in this area probably represents one end-member of the process which led to the formation of the Gunnedah Basin.

Line 3 (Tamworth Belt) and Line 4

Is the Tamworth Belt allochthonous and thrust westwards over the Gunnedah Basin ? If so, did crustal loading influence the formation of the Gunnedah Basin ? The Tamworth Belt is a fore-arc basin, but the volcanic arc is not exposed to any extent in the New South Wales sector. Where is the arc? Is it beneath the Gunnedah Basin or beneath the Tamworth Belt, or has it been removed, possibly by strike-slip faulting ?

In the northern New England Orogen the magmatic arc is identified as the Auburn Arch (see references in Korsch & others, 1990a). The gravity feature associated with that arch continues south to the Tamworth Belt (Fig. 9). If there is an underlying arc, then its presence should be detectable as a characteristic velocity profile.

For Lines 3 and 4, the wide-angle reflection/refraction work to examine the crustal velocity profiles would be centred on Manilla, with Line 3 along the axis of the Tamworth Belt (Warialda-Manilla-Nundle) and Line 4 along the proposed BMR near-vertical reflection profile through Uralla-Manilla-Boggabri-Pilliga (Fig. 10). Near Uralla, Line 4 would tie with the 1984 refraction profile across the New England Block. Near Boggabri it would tie with the wide-angle reflection/refraction profile along the axis of the Meandarra Gravity Ridge (Line 1), and near Pilliga it would tie with the north-south profile at the western margin of the Gunnedah Basin on the Lachlan Orogen (Line 2).

Methodology:

Line 1

The axis of the Meandarra Gravity Ridge in NSW lies approximately between Boomi (near the Queensland border between Goondiwindi and Mungindi) and Tamarang (on the railway between Werris Creek and Coonabarabran). The proposed BMR east-west reflection profile crosses the gravity ridge just west of Boggabri.

Based on experience in Queensland, a seismic refraction profile at least 300 km long is required to adequately determine the total crustal velocity structure down to the Moho. Short-cuts attempted in Queensland during 1984-86 were shown to produce inadequate results. A recording distance of 300 km is achieved between Boomi and Tamarang. The profile is well served by roads. It is assumed that 40 BMR data-loggers would be available (if necessary using older BMR analogue recorders as well as digital loggers. Recorders would be deployed along two sections of the whole profile: Boomi-Edgeroi and Edgeroi-Tamarang. The maximum recorder spacing would be 5 km to enable correlation of seismic phases along the profile.

Shot points would be located at Boomi (1.0t and 2.5t), Ashley (0.5t), Edgeroi (1.0t and 1.0t) Boggabri (0.5t), and Tamarang (1.0t and 2.5t). The total explosive requirement is 10t. Experience in recent years suggests that ICI Powergel 2841 or 2851 was the cheepest suitable explosive (about $3500 per tonne), however others may now be available.

Approximately 4000m of drilling would be required (100 holes with 100kg/hole to 40 m depth). It is estimated that shot firing and recording could be completed in 14 days by a party of 4 persons in 4 vehicles.

Recording of Hunter Valley coal shots would extend the maximum recording distance by at least 100 km, and this is highly desirable, as experience in New England has shown.

Line 2

The shooting geometry and mode of operation would be much the same as that along the Boomi-Tamarang profile discussed above, i.e., a total explosive requirement of 10 tonne, 4000m of drilling, and 14 days recording with a party of 4 persons. The proposed profile would extend approximately from Gilgandra to Mungindi through Pilliga, the western end of proposed BMR east-west near-vertical reflection profiling.

Lines 3 and 4

The shot requirements would be as follows. The maximum recording distance would be about 240 km at 5 km recorder spacing, but off-end recording should also be attempted to extend the maximum travel path to about 300 km at wider recorder spacing. On both the profile within the Tamworth Belt and on the Uralla-Pilliga profile, end shots of 2 tonne and 1 tonne would be required plus two centre profile shots of 1 tonne each. Thus 8 tonnes of explosive would be required on each profile making a total explosive requirement of 16 tonnes.

A total of about 6400 m of drilling would be required (assuming 100 kg/hole to 40 m depth). This may vary according to the drilling conditions in hard-rock areas.

In addition to recording BMR shots, there should be recording of Hunter Valley coal shots. This would extend the maximum recording distance to at least 350 km and give a fan shoot at about 200 km. A total recording period of 3 weeks would probably be required.

Target B: Bowen Basin (including Comet Ridge and Auburn Arch)

The mode of formation of the northern (exposed) Bowen Basin is thought to be intimately related to the processes affecting the formation of the Meandarra Gravity Ridge/Gunnedah Basin system. The strike of the Taroom Trough in the Bowen Basin changes markedly to the northwest in the northern part of the basin system (Figs 1 & 9). This probably reflects a change in the basin-forming mechanism compared with that under the Surat Basin, possibly from transtension in the south to pure extension in the north. It is likely that there would be differences in crustal velocity structure between the main depocentres of the Gunnedah and Bowen Basins, the structure of the Gunnedah/Tamworth system being related to processes east of the Meandarra Gravity Ridge, and the northern Bowen Basin being related to processes west of the ridge.

In the northern Bowen Basin, it is proposed to examine the crustal velocity structure with the aim of identifying elements of pre-Permian crust and elements related to "reworked" crust and late Palaeozoic - Mesozoic basin forming episodes. The three targets are (a) the main Bowen Basin (Taroom Trough) depocentre, (b) the Comet Ridge, and (c) the Auburn Arch of the New England Orogen (Fig. 11).

Line 5 (Taroom Trough)

The crustal velocities along the northwestern and southern arms of the Taroom Trough can be investigated using wide-angle reflection/refraction lines northwest and south of Moura respectively. It is possible to use the Moura mine as a shot source along the two arms, assuming that the effects of distributed coal shots can be eliminated. Recording would be conducted on two profiles; one between Moura and Nebo and the other between Moura and Meandarra, east of the Meandarra Gravity Ridge (Fig. 11). It would be necessary to reverse the profiles with BMR shots. The amount of explosive involved would be about 10 tonne. About 4000 m of drilling would be required. Recording could probably be completed in a 3 week period provided the mines are firing regularly.

The recording profiles would intersect the 1984 BMR near-vertical reflection profile across the Taroom Trough in southern Queensland and the 1989 BMR reflection profile across the northern Bowen Basin in the region of the Duaringa Basin/Folded Zone.

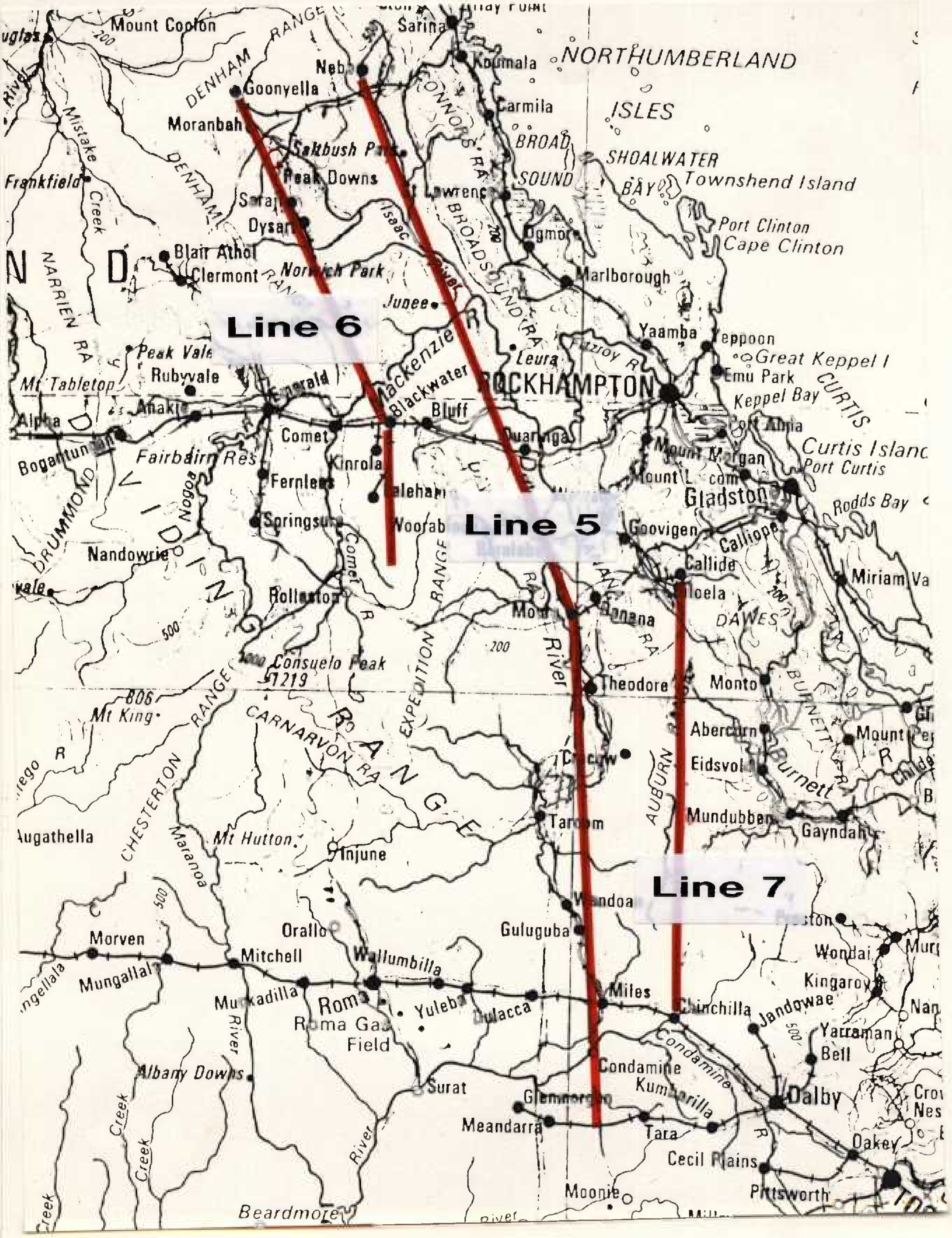


Fig. 11 Location of proposed Lines 5, 6 and 7.

Line 6 (Comet Ridge)

The Comet Ridge has always remained a structural high during the formation of the Bowen Basin. It seems possible that the ridge is a distinct structural feature with a velocity structure akin to that of older basement to the west. In any modelling of the Bowen Basin system, it is important to know what is likely to have remained relatively undeformed and what crust has been involved in any extensional/transtensional process.

The north to north-northwest trend of the Comet Ridge is markedly different from the northeast trends associated with the Thomson Orogen (Fig. 9). Wellman (1990) concluded that the terranes east of the Thomson Orogen were younger or had accreted at a later stage. How did such terranes develop? By strike-slip? By accretion from a distant source? One of the first problems is to demonstrate just how different the terranes are from their neighbours and from the Gunnedah Basin system. Could there really be 500 km of southerly relative movement by the New England system? If so, the Tamworth Belt would have been adjacent to the Comet Ridge in earlier times. Some of these questions can be addressed by determining the velocity profiles of the various terranes.

Method:

The velocity structure of the ridge can be relatively easily determined using coal blasts as shot sources (again assuming that the effects of distributed charges can be eliminated). Recording distances of 300 km and more can be achieved using the Goonyella, Peak Downs, Norwich Park, German Creek, and Blackwater mines (Fig. 11). Recording would be done at 5 km recorder spacing and the quality of the interpretation should be a considerable improvement on the early 1970s data from the same area. The data would complement the BMR near-vertical reflection profile recorded across the basin in 1989 from Comet No. 1 well to the New England Orogen.

It is estimated that data could be collected in a 3 week period, assuming that mines are working regularly.

Line 7 (Auburn Arch)

The Auburn Arch is interpreted as the location of the magmatic arc associated with the northern part of the New England Orogen (Day & others, 1978; Murray & others, 1987; Korsch & others, 1990a). It is reasonable to assume that the crustal velocity structure of the arch can be taken as a model for any magmatic arc structures located farther south in the orogen. Such a velocity structure may well be detected under the Tamworth Belt or Gunnedah Basin if the arc has been buried or overridden. If not, serious consideration must be given to the possibility of substantial movements between terranes to restore them to a realistic Palaeozoic palaeogeography.

Method:

It is therefore proposed that the velocity structure of the crust under the arch be determined by wide-angle reflection/refraction methods. It is probable that this can be done using Bowen Basin coal mine blasts for most of the shot sources. The Moura and Callide mines are conveniently located at the northern end of the arch and can probably be used as convenient sources (Fig. 11). To adequately determine the crustal velocity structure a recording profile of about 300 km should be used. The distance from Callide to Chinchilla is about 270 km, (possibly adequate).

Using a recorder spacing of 5 km, it would probably require a recording period of 3 weeks to obtain the data. To reverse the profile it is desirable to fire a 2.5 tonne shot in the Chinchilla area. This would require about 1000 m of drilling in one location.

Estimated requirements for recording: Equipment, vehicles, and manpower

The general requirement is for wide-angle reflection/refraction lines to be recorded along line segments 150 km long, two such lines being required to meet the specification of the maximum recording distance of 300 km. Recording is reversed along each line, that is, shots are recorded from both ends of the line. The recorder spacing is 5 km maximum, except where off-end recorders are used at larger spacing.

The existing BMR analogue recorders (36 sets) must be regarded as antiquated and wasteful in terms of field use and subsequent digital file recovery. Submissions have been made for the purchase of 40 digital recorders of modern design and it is assumed that these will be delivered over two financial years, 20 in calander year 1991 and 20 in calander year 1992. It is assumed that during the first year of recording there will only be 20 digital recorders and in that case the shortfall will have to be made up from existing analogue recorders.

It is estimated that 10 digital recorders can be managed by one person from a Toyota Landcruiser station wagon, assuming that he/she will also have a setup computer, shot firing equipment, and general equipment to carry. From past experience a 1-tonne utility (6-wheel Land Rover/Jeep) is necessary to carry 10 analogue recorders and their batteries. It may be possible to get away with 1-2 tonne covered Toyota flattop trucks (2-wheel drive) as an alternative if they are accompanied by Landcruisers for vehicle recovery if necessary. Most recorder deployments are in farmland/forest where tracks can be used.

With these provisos in mind, it is estimated that the recording of one 150 km line should not take more than 5 days for 4 skilled persons in 4 vehicles, 10 recorders in each; 3 days for site location, owner location, and equipment setup; 1 day for shooting; and 1 day for equipment recovery.

The recording party of 4 persons would comprise a party leader plus 3 geoscientists/technical officers, depending on availability at the time of the survey. The vehicle requirements would be two Toyota Landcruiser station wagons plus two 1-2 tonne Toyota flattop covered trucks (or equivalents) if analogue recorders are needed. If the recorders are all digital then four Toyota Landcruiser station wagons would be required. The man-day requirements below are estimated using the above assumptions and that deployment from and to Canberra will take a total of 4 days.

Line	Recorder Deployments	Days	Deployment	Total	Man-days
1	2	10	4	14	56
2	2	10	4	14	56
3+4	4	20	4	24	96
5	4	recording of coal shots		24	96
6	2	recording of coal shots		24	96
7	2	recording of coal shots		24	96

Estimated drilling and explosive handling manpower and vehicles

It is assumed that BMR staff will be conducting all drilling and shot loading operations. Explosive handling manpower and drilling manpower are required concurrently. The drilling conditions at each individual shot site largely determine the time taken to load shots; this is difficult to foresee prior to a reconnaissance. However, if the drilling rates on the 1989 Cobar survey are taken as a guide, it is estimated that one drilling rig can drill 5 holes/day to 40 m depth. It can also be assumed that one day will be spent travelling between sites in the survey area and a minimum of 2 days spent deploying from and returning to Canberra. It is assumed that a two-man explosives crew and a two-man drilling crew will be used. Using these guidelines the following estimates can be made of manpower requirements.

Line	Drilling	Days	Travel	Deployment	Total	Man Days
1	4000 m	20	5	4	29	116
2	4000 m	20	5	4	29	116
3+4	6400 m	32	8	4	44	176
5	4000 m	20	5	4	29	116
6	-	-	-	-	-	-
7	1000 m	5	-	4	9	36

The minimum requirement for vehicles will be: 1 drilling rig, 1 water tanker, 1 explosives truck, and 1 preloading vehicle (Toyota traytop). Depending on regulations and shot site security, it may be necessary to have drilling/shot loading concurrent with recording because of preloading restrictions. Detailed reconnaissance investigation at each shot site by the field part leader will be required.

Summary of Refraction Field Work Requirements

	Explosives (cost)	Drilling	Recording
Line 1: Meandarra Gravity Ridge	10 t ($35K)	4000 m (5 sites)	56 man days
Line 2: W. Margin of Gunnedah Basin	10 t ($35K)	4000 m (5 sites)	56 man days
Lines 3 & 4: Tamworth Trough-Gunnedah Basin	16 t ($56K)	6400 m (6-8 sites)	96 man days
Line 5: Taroom Trough	10 t ($35K)	4000 m (4-5 sites)	96 man days
Line 6: Comet Ridge	-	-	96 man days
Line 7: Auburn Arch	2.5 t ($8.75K)	1000 m (1 site)	96 man days

PROSPECTS FOR COST RECOVERY/SHARING

There has been an increase recently in the interest shown by petroleum companies in deep seismic reflection data acquired by BMR in eastern Australia, particularly in the Surat and Bowen basins. It is envisaged that the petroleum industry will also show interest in the deep seismic reflection profile across the Gunnedah Basin which will lead to sales of the data sets.

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