Bureau of Mineral Resources, Geology & Geophysics

R E C O R D

BMR RECORD 1991/63

SEISMIC DATA ACQUISITION PROPOSAL

CENTRAL OFFICER BASIN SOUTH AUSTRALIA

J. Lindsay[1], J. Leven[1], G. Krieg[2]

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1. Onshore Sedimentary and Petroleum Geology Program
   Bureau of Mineral Resources
2. South Australian Department of Mines and Energy

TABLE OF CONTENTS

SUMMARY

The Officer Basin Project is a five year basin study program developed co-operatively between the Bureau of Mineral Resources and the South Australian Department of Mines and Energy as part of the National Geoscience Mapping Accord. The main BMR objective is to collect regional seismic data in order to develop a depositional and post-depositional model of the poorly exposed eastern Officer Basin and to compare the basin with other Australian intracratonic basins. Concurrently and in conjunction with the BMR program, the South Australian Department of Mines and Energy will carry out a regional field mapping programme and an extensive drilling and coring project along the BMR seismic line. It is hoped that the new insights into basin evolution gained from the programme will aid in the search for hydrocarbons and encourage economic activity in the basin in general.

Seismic reflection profiling offers the best and in most cases the only means for resolving many of the questions posed by the Officer Basin. Consequently, in this record we outline two proposals for seismic profiling across the central Officer Basin that take into consideration the scientific requirements of the program. These two surveys would involve 650 km and 950 km of data acquisition respectively. Proposal 2 involves a considerable increase in line kilometres because it involves a strike line to link the unknown stratigraphy in the vicinity of the Birksgate #1 well to the better known stratigraphy farther east around the Munta #1 and Giles #1 wells. Additional funding will be sought for this option.

INTRODUCTION

The Officer Basin is perhaps the least studied of all Australian intracratonic basins. It is remote, and very poorly exposed due largely to a widespread Pleistocene sand-dune cover (Fig. 1). As is the case in many intracratonic basins in Australia, hydrocarbon prospectivity is perceived to be relatively limited and in combination with access and logistical problems the basin has been seen as a high risk prospect. As a consequence only 30 wells have been drilled to depths greater than 500 m in the South Australian part of the basin. Most are to the extreme east with only one well drilled close to Western Australian border (Birksgate #1). Only 7200 km of seismic data are available, mostly farther east, much of it gathered more than 10 years ago (Fig. 2). In light of these problems, the Officer Basin Project was developed co-operatively between the Bureau of Mineral Resources and the South Australian Department of Mines and Energy as part of the National Geoscience Mapping Accord to broaden our understanding of the basin and encourage economic activity in the area.

GEOLOGY OF THE OFFICER BASIN

The Officer Basin occurs in one of the most arid and inaccessible regions of the Australian continent and for that reason is perhaps the most poorly understood of the continent's intracratonic basins (Fig. 1). It extends west to east from longitude 135° E in Western Australia to longitude 132° 30' E in South Australia, a distance of more than 1100 km. From north to south it extends from latitudes 27° S to 32° S, a distance of 550 km, and covers an area of 375,000 km^2 (Palfreyman, 1981). To the north the basin terminates against the older (Early to Middle Proterozoic) Musgrave Block whereas to the south it is onlapped by the younger sediments (Cretaceous to Tertiary) of the Eucla Basin. The Archaean to Middle Proterozoic Gawler Block forms the basin margin to the southeast.

The Officer Basin can be subdivided into several distinct morphological features. Magnetic (Gerdes, 1982) and gravity data indicate major sub-basins along the northern margin of the basin (Birksgate Sub-basin and Munyarai Trough) which are separated from each other by ridges (Nurrai Ridge) (Figs 3, 4). The sub-basins are in turn separated from a much larger platform area (beneath the Nullarbor Platform of the Eucla Basin) to the south by a shallow ramp or a low ridge which is apparently extensively faulted. The basin contains a complex Late Proterozoic to Cretaceous depositional succession much of which is either shallow marine or subaerial (Fig. 5) (Pitt et al., 1980; Brewer, et al., 1987). The stratigraphy of the eastern Officer Basin (Fig. 5) is summarized by Pitt & others (1980) and Brewer & others (1987) and more recently Gravestock and Hibburt (1991) have looked at sequence stratigraphic models for the Cambrian succession.

Regional setting

The Officer Basin is one of a number of early intracratonic basins that developed on the older Australian craton (including, for example, the Amadeus, Ngalia, Georgina, Warburton and Wiso Basins) (Fig. 1 inset). All have similar subsidence histories and many features in common in their morphology and sediment fill.

Preliminary studies by Lindsay & others (1987) suggest that these basins are complex polyphase, stacked basins formed in response to major extensional tectonic events that occurred during the breakup of a supercontinent in the late Proterozoic and early Palaeozoic. At least two major extensional events have been identified, one occurring at about 900 Ma and another at approximately 600 Ma.

Because of the common regional tectonic controls and superimposed effects of eustacy, the sedimentary fills of these intracratonic basins all have similar stratigraphy and facies distributions (Lindsay and Korsch, 1989; Lindsay et al., 1987), a factor of considerable value in understanding the poorly exposed Officer Basin. The fact that hydrocarbons are being produced in one of these basins (the Amadeus Basin), and that shows have been reported in other basins, suggests a similar hydrocarbon potential in the Officer Basin.

Project Rationale

The objective of the Officer Basin Project is to develop a regional depositional and post-depositional model of the poorly exposed eastern Officer Basin and to compare the basin with other Australian intracratonic basins. The project has been developed as part of the National Geoscience Mapping accord in conjunction with the South Australian Department of Mines and Energy.

Aims of the Project

The aim of the project is to undertake an integrated basin analysis of the eastern Officer Basin. The program will emphasize the basin's evolution through an evaluation of its sedimentary fill, structure, morphology, tectonic and thermal history. The programme will consist of two major components (1) synthesis of existing well and seismic data and (2) acquisition of seismic reflection data in the central Officer Basin which will be used to investigate specific problems. As part of the program, the South Australian Department of Mines and Energy will carry out a regional field mapping program (Fig. 6) and an extensive drilling and coring project along the BMR seismic line.

Analytical Elements of the Program

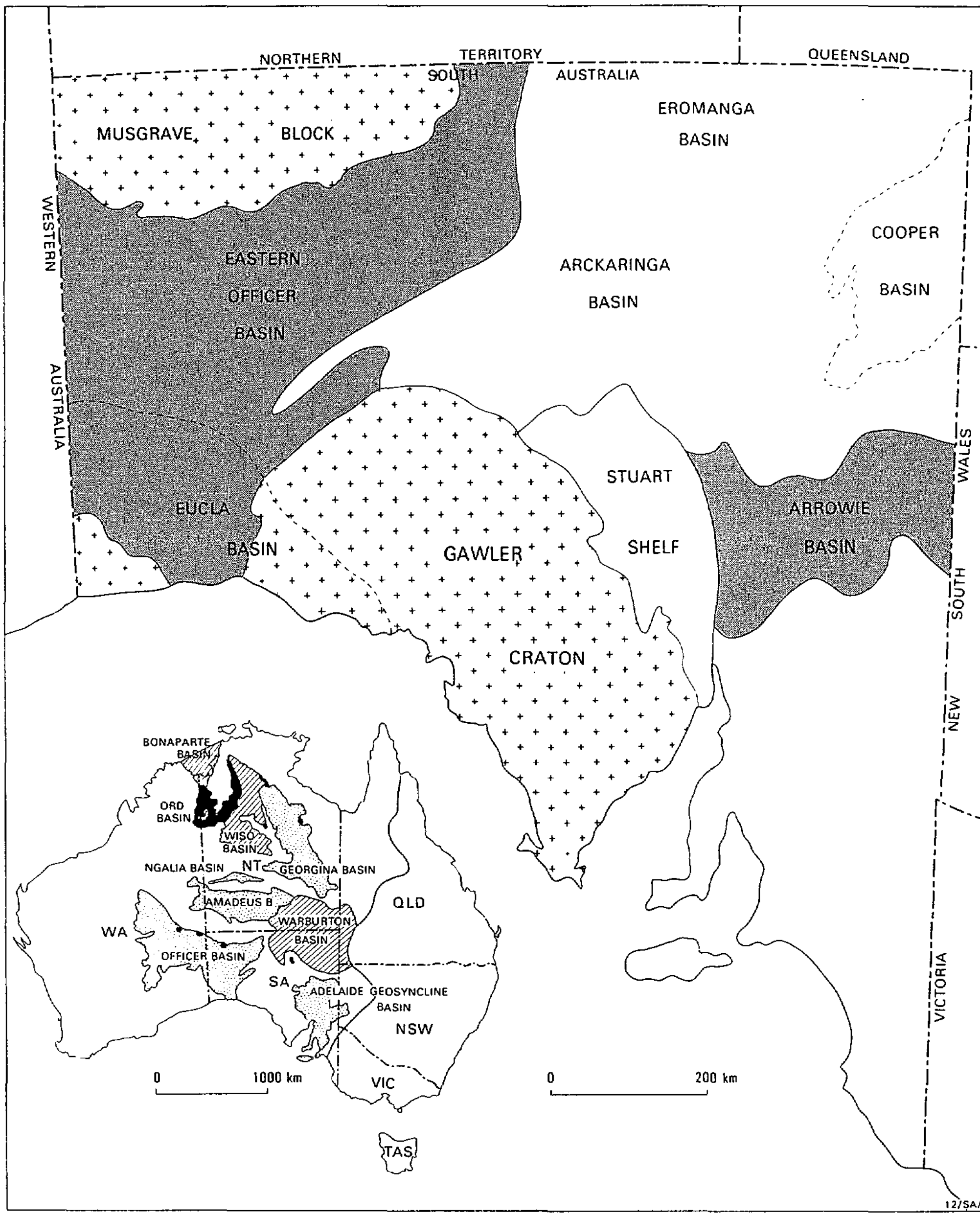

Figure 1. Location map of the Officer Basin and the study area. The inset map shows related intracratonic basins. Stippled basins were initiated about 900 Ma; the cross hatched basins were initiated about 600 Ma (see Lindsay and Korsch, 1989).

1. Develop a sequence stratigraphic model for the basin by integrating well and seismic data.

2. Evaluate basin morphology and develop models for basin subsidence history and subsequent tectonism.

3. Evaluate the basin's maturation and burial history.

4. Compare the Officer Basin with other similar basins (especially the Amadeus Basin) to improve the understanding of this poorly exposed basin.

5. Develop an integrated basin history, oriented towards hydrocarbon exploration.

PREVIOUS GEOPHYSICAL STUDIES IN THE OFFICER BASIN

Potential Field Data

The intracratonic basins of Australia share many similarities, not only from the view point of their stratigraphy but also in terms of their overall morphology. Most are asymmetric in cross section such that they have deep sub-basins connected by troughs along one margin and a broad shallow platformal regional along the opposite margin. For example, recent studies in the Amadeus Basin have shown that it has deep sub-basins along its northern margin which are linked by troughs with a broad platformal region to the south (Lindsay, 1987; Lindsay and Korsch, 1989) whilst the Georgina is almost a mirror image of the Amadeus Basin (Lodwick and Lindsay, 1990).

The Officer Basin shows this same general morphology which is reflected in the imaging of the potential field data (Fig. 4). Deep sub-basins terminate against the steep northern basin margin. To the south the sub-basins shallow more gradually, eventually merging with a broad platformal region. Significant and detailed structural information can be extracted from the potential field data already available.

Gravity

The western portion of South Australia is covered by the BMR National gravity grid. This dataset has a denser station coverage than the 11 km national grid, with an average station spacing of around 6 km, and even denser coverage over the Coompana Block and over petroleum exploration leases south of the Munyarai Trough. The relative precision of the data is 10 $\mu m\ s^{-2}$.

The Bouguer gravity data provide a good picture of the Officer Basin's regional structure. Strong negative anomalies indicate an arcuate geometry of deep troughs which border the southern edge of the Musgrave Block. Within one of these, the Munyarai Trough, the minimum Bouguer anomaly value is below -1400 $\mu m\ s^{-2}$. The gravity gradient between the Musgrave Block and the Munyarai Trough is comparable with those observed in the Amadeus Basin. The Officer Basin is generally represented by negative Bouguer anomaly values, although these become less negative in the platform region south of the Birksgate Sub-basin and Munyarai Troughs. The edge of the Gawler Craton to the southeast is marked by a ridge of positive anomalies and the Coompana Block to the south is also characterised by higher Bouguer anomaly values. Bouguer gravity data have been used to divide the basin into provinces (Fig. 3) having a similar anomaly character (Stainton & others, 1988).

Aeromagnetics

Regional aeromagnetic data have been acquired over most of the Officer Basin by the BMR surveys from 1969 to 1982. The only areas not covered are within the Tallaringa and Maurice 1:250 000 map sheets. In general, those surveys over the Musgrave and Gawler Cratons (where the magnetic signature has a higher spatial wavenumber) were flown with a line spacing of 1.6 km, whereas those surveys over the basin had a line spacing of 3.0 km. All surveys were flown at 150 m AGL, and the digital acquisition of 1982 used a sampling interval along the line of 60 m. The relative precision of this data exceeds 2 nT.

The total magnetic intensity data has been levelled and gridded into a TMI image which covers the western portion of South Australia. This image has been displayed and processed on the I^{2}S image processing system to enhance information on the structure within basement (Fig. 4). Strong east-west lineations in the Musgrave Block correspond to both mapped and un-mapped faults. The TMI image shows mapped granite batholiths within the Musgrave Block correspond to the lighter anomalies. Comparable anomalies in the Officer Basin can be interpreted as batholiths covered by sediment. Along the northern margin of the basin the bounding faults vary in character quite markedly, suggesting several fault segments which may be separated by transfer faults.

Previous Seismic Surveys

A number of relatively small-scale seismic surveys have been carried out over prospective areas of the basin beginning in 1966. A total of 7200 line kilometres are available (Fig. 2) although data quality is poor to fair in the earlier surveys. The Serpentine Lakes seismic survey was an early vibroseis survey conducted by Continental in 1966. The BMR conducted a reconnaissance seismic survey in the western Officer Basin in Western Australia in 1972. More recent industry activity in the eastern Officer Basin, includes SADME i 1974 and 1978, Comalco (Stainton and others, 1988) and Amoco in 1987.

Comalco Aluminium Limited carried out a seismic survey in PEL 20 and 30 between 1984 and 1986, shooting 2613 km of data and drilling 5 cored wells (Cucuzza and Akerman 1984; Cucuzza et al., 1984, Hibburt, 1990; Thomas, 1990). Amoco (1987) gathered a further 120 km of seismic data in PEL 29.

PROPOSED BMR SEISMIC REFLECTION PROFILES IN THE OFFICER BASIN

The aim of the Officer Basin Project is to study basin morphology, tectonics and subsidence history. To accomplish this a major seismic reflection survey will be carried out in near the South Australian-Western Australian border with the primary objective of developing a regional north-south cross section of the central region of the basin. The seismic survey would, by necessity, extend from the Musgrave Block on the basin's northern margin across the main depocentre of the Officer Basin (Birksgate and Munyarai Sub-basin) onto the platformal region (beneath the Nullarbor Platform) now onlapped by the Eucla Basin and the associated Nullarbor Limestone (a platform carbonate unit). The central region of the basin has received little scientific scrutiny and many of the scientific objectives outlined below can only be addressed by a seismic reflection profile.

Scientific Objectives and Constraints for the Proposed Seismic Line

A regional seismic traverse of the central Officer Basin will solve a number of problems which cannot be addressed by means other than seismic. The scientific objectives

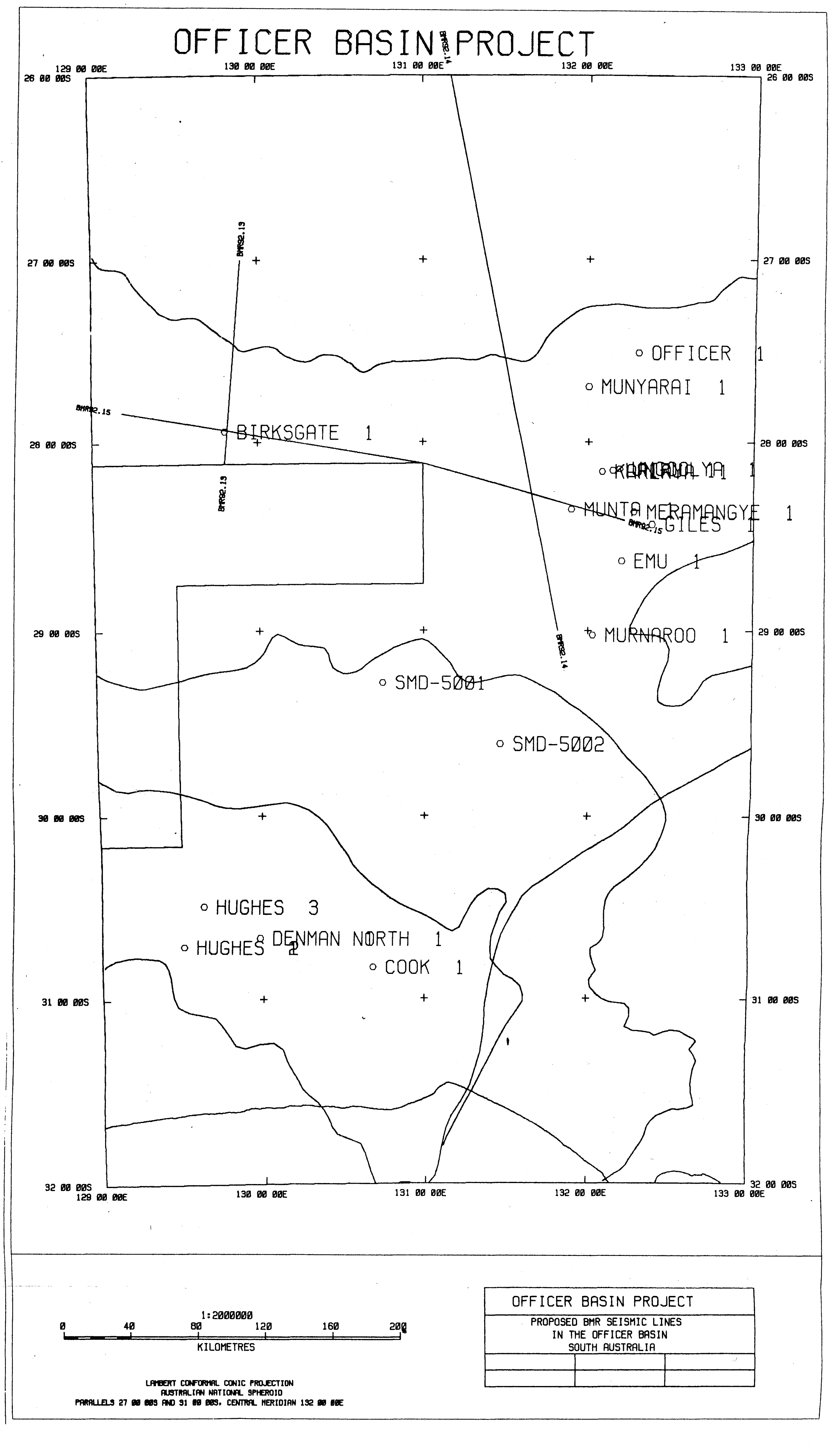

Figure 2. Map of the eastern Officer Basin showing the location of the proposed BMR seismic lines.

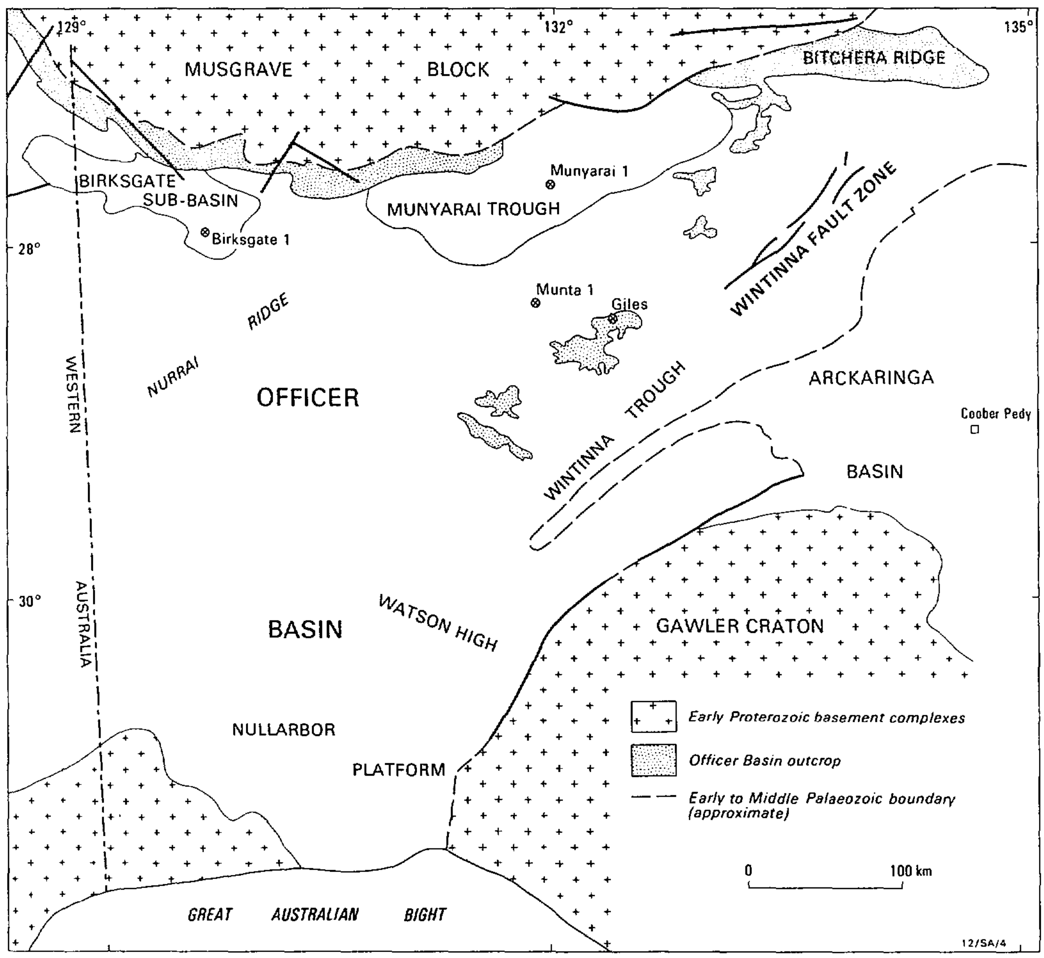

Figure 3. Map of the eastern Officer Basin showing the main morphologic and tectonic features as currently understood.

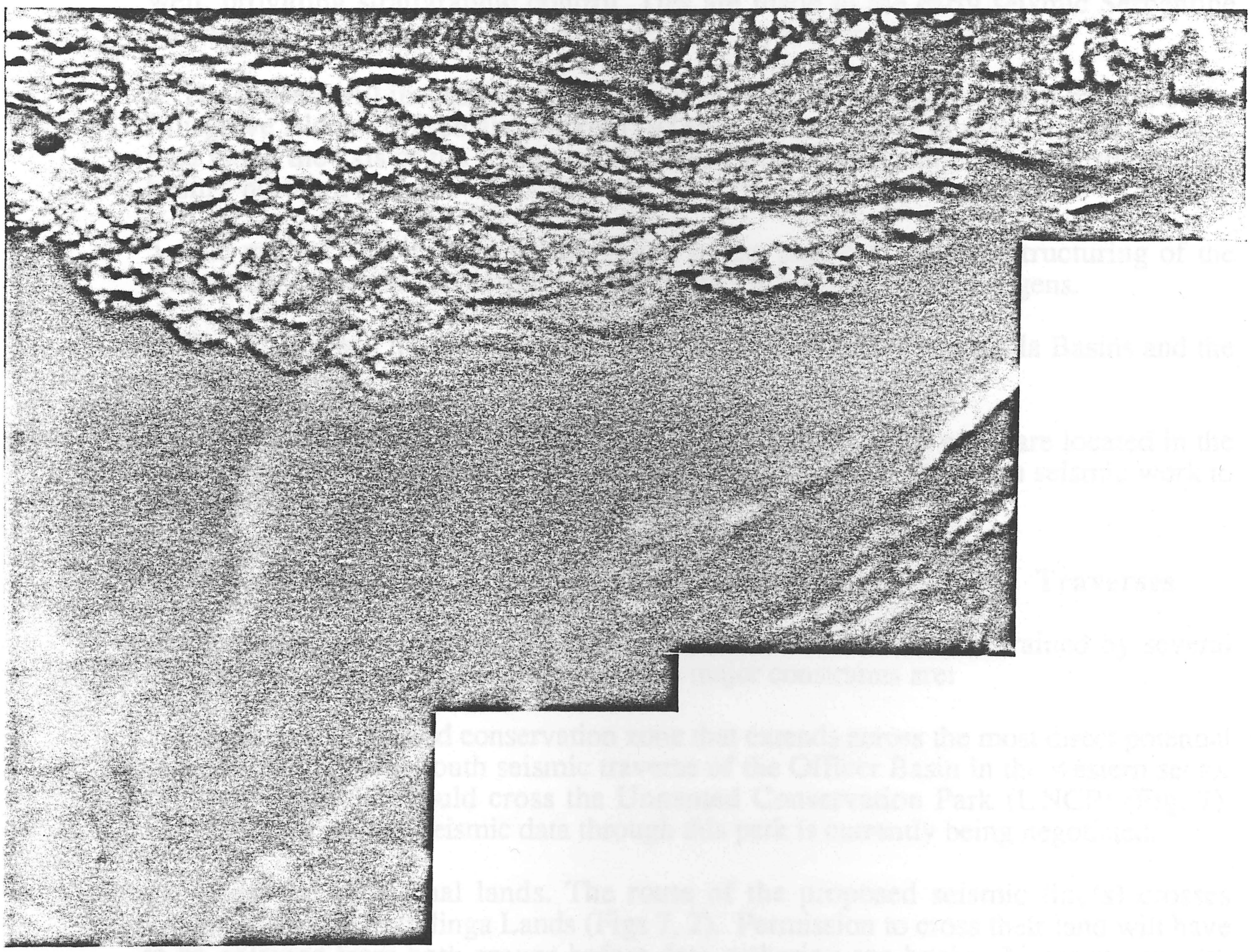

Figure 4. Total magnetic intensity image of the eastern Officer Basin. Note the faulted northern margin.

determine the siting and nature of the survey. Some of the objectives and constraints are outlined below:

1. A seismic profile of good quality (high fold) seismic data is required to develop a cross section to evaluate basin morphology. Thus emphasis will be on the upper 5 seconds of the section.

2. A seismic reflection survey is required to investigate the basin's subsidence history.

3. The stratigraphy of the central Officer Basin needs to be defined in terms of the concepts of modern sequence stratigraphy. A section of the traverse ties to Birksgate #1 well, providing stratigraphic control. Ties are made to the early seismic Serpentine Lakes lines 1 and 2 and (in the case of proposal 2) to Munta #1 well.

4. The project will investigate the nature of the thrusting of the southern margin of the Musgrave Block. Milton and Parker (1973) noted anomalies in magnetic and seismic data along the axis of the Birksgate Sub-basin that suggest major overthrusting of the basin's northern margin.

5. The project will investigate the nature of the post-depositional structuring of the Officer Basin and the relationship of this to the Central Australian Orogens.

6. The project will investigate the relationship of the Officer and Eucla Basins and the Coompana Block.

A somewhat more detailed seismic exploration grid and more wells are located in the eastern Officer Basin, and it would be desirable to tie BMR reflection seismic work to this control (Fig. 2).

Field and Logistical Constraints on Positioning of Seismic Traverses

The gathering of seismic data across this part of the basin is constrained by several factors other than scientific objectives. The major constraints are:

1. Access to an unnamed conservation zone that extends across the most direct potential seismic line. A north-south seismic traverse of the Officer Basin in the western sector of South Australia would cross the Unnamed Conservation Park (UNCP) (Fig. 7). Permission to acquire seismic data through this park is currently being negotiated.

2. Access to Aboriginal lands. The route of the proposed seismic line(s) crosses Pitjantjatjara and Maralinga Lands (Figs 7, 2). Permission to cross their land will have to be obtained from both groups before data gathering can begin. Negotiations with both groups are currently under way.

3. Logistical problems. The Officer is a remote basin in one of the most inaccessible parts of Australia and logistic problems are considerable[1]. There is almost a complete lack of infra-structure in the area and water supplies are limited. It will be necessary to cross large east-west trending dune systems which will create considerable difficulties for the movement of vehicles.

4. Tying the new seismic line(s) to existing seismic surveys and well sites.

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[1]Operations in the Officer Basin (Great Victoria Desert) are further complicated by the fact that they must be restricted to the cooler months of the year.

5. Seismic data acquisition is complicated by a cover of thin platformal carbonates in the south (Nullarbor Limestone) and an extensive Pleistocene dune cover in the north (see Appendix 1). Early discussions between the two participating organizations (BMR and SADME) considered an extension of the seismic network onto the basin's southern margin. This aspect of the program has been set aside until a test program can be carried out in the Cook area in July/August 1991 (see Appendix 2).

With these constraints in mind the proposed seismic program has been viewed as a two stage process:

1. Acquisition of data across the Birksgate Sub-basin. There are three important reasons of gathering data in this area:

i. To develop an understanding of the sub-basins and establish a cross section.

ii. To understand the northern margin of the basin and its relationship to the Musgrave Block to the north (nature and timing of the faulting).

iii. To understand the southern margin of the sub-basins and how they relate to the platform region and the Eucla Basin to the south. Experience in the Amadeus basin suggests that the region of greatest petroleum potential lies along the southern margin of the trough (sub-basin) where the trough merges with the platform.

2. Acquisition of data along the axis of the Birksgate Sub-basin (additional to the original proposal). This seismic line would link the Birksgate #1 and Munta #1 (or Giles #1) wells and cross the Nurrai Ridge between these two main troughs. This is important because it would clarify the relationship of these two troughs and the sediments contained within them. It would provide a link, allowing a seismic tie between the stratigraphy of the better studied regions farther east and the central region of the basin. At present the Birksgate #1 well is isolated from all the major seismic grids farther east.

ALTERNATIVE PROPOSALS[2]

Based upon the scientific and logistical constraints we have developed two proposals for the gathering of seismic data in the region (Fig. 2). First, we are suggesting two seismic lines extending across the Birksgate Sub-basin from the Musgrave Block in the north to the edge of the carbonates associated with the Eucla Basin to the south. The distance to which the seismic grid extends onto the Nullarbor Plain will be determined by the results of a series of seismic tests to be carried out in the Cook area in July/August 1991 (see Appendix 1).

We are further suggesting, as discussed above, that a strike line at right angles to the main seismic line through Birksgate #1 well be extended to Munta #1 well farther east. The Birksgate #1 well, to which the main survey will be tied, is isolated by a considerable distance from the more comprehensive and modern seismic networks farther east. The problems are complicated by the fact that the stratigraphy of the Birksgate #1 well has more in common with wells drilled to the west in Western

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[2] Line length estimates given here are minimum estimates; as the actual seismic lines will not be as straight due to the sand-dune terrain, and possible avoidance of Aboriginal sites, etc.

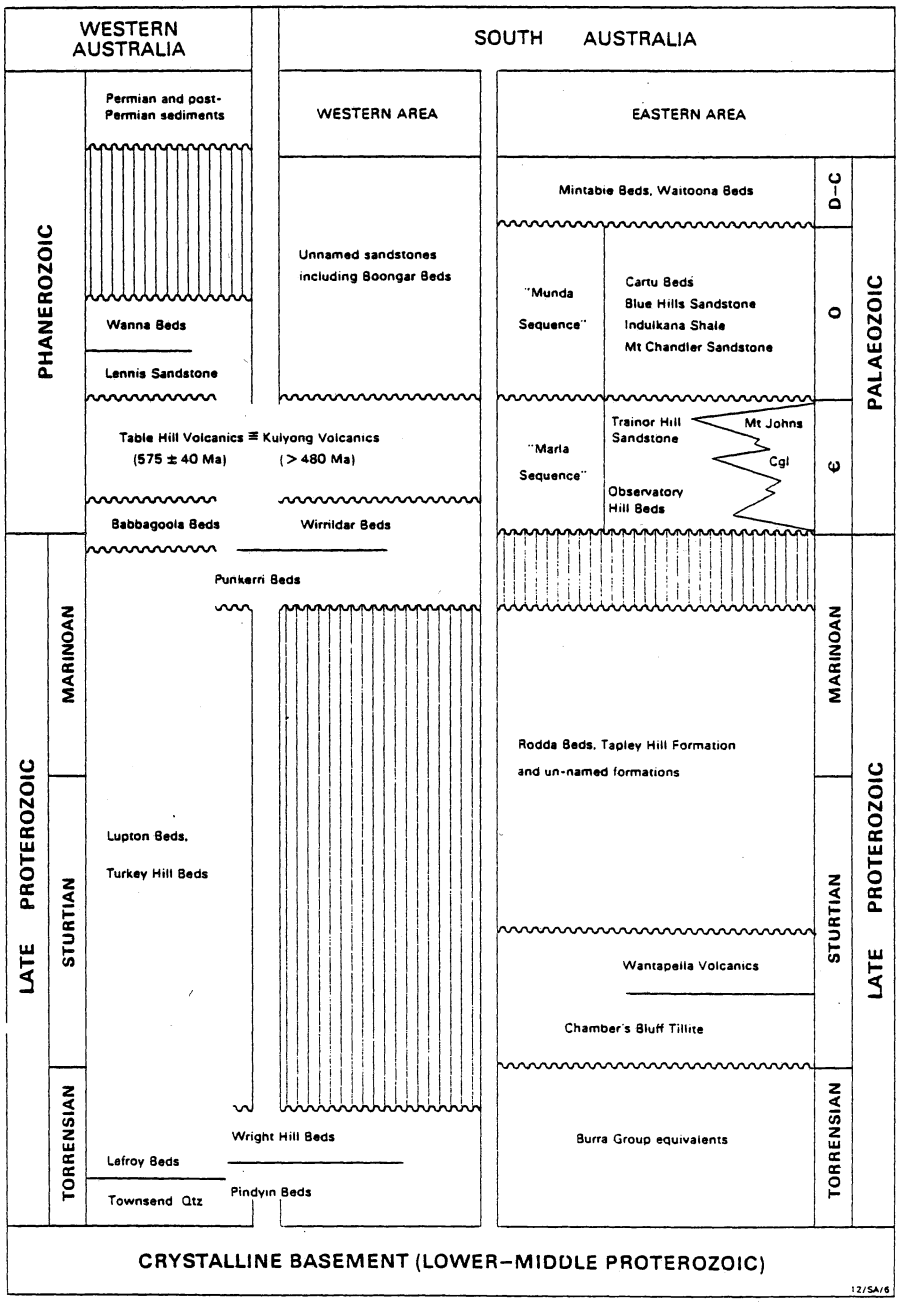

Figure 5. Correlation chart showing the stratigraphy of the Officer Basin (After Pitt & others, 1980). Note that the stratigraphy of western area (Birksgate #1 well) is closer to the Western Australian stratigraphy than that of the eastern Officer Basin.

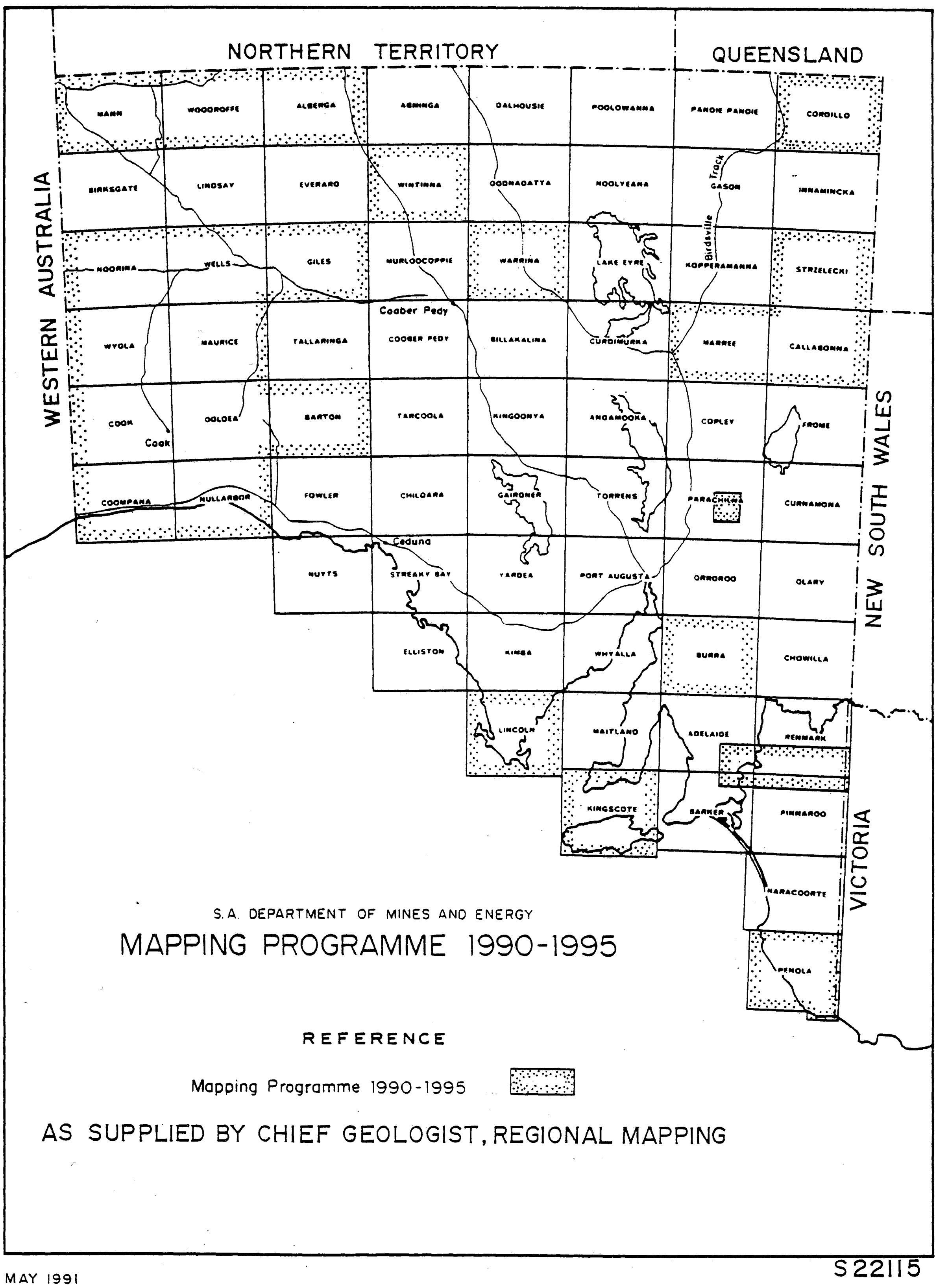

Figure 6. Proposed South Australian Department of Mines and Energy mapping programme for 1990-1995.

Australia than those in South Australia. The two proposals are outlined briefly in the following section.

Proposal 1

Consists of two lines:

BMR92.01	340 km	dip line thorough Birksgate #1 well
BMR92.02	310 km	dip line roughly parallel to line 1 but
	160 km further east	

Total around 650 km

These data will be supplemented by reprocessing of the Serpentine Lakes seismic data.

Proposal 2[3]

Consists of three lines:

BMR92.01	340 km	dip line thorough Birksgate #1 well
BMR92.02	310 km	dip line roughly parallel to line 1 but
	160 km	further east
BMR92.03	300 km	strike line close to the sub-basin axis and connecting Birksgate #1 and Munta #1 (or Giles #1) wells.

Ties to the seismic network in the eastern Officer Basin

Total around 950 km

COST SHARING

The programme was developed as part of the National Geoscience Mapping Accord and costs will be shared by the Bureau of Mineral Resources and the South Australian Department of Mines and Energy. The main contributions are as follows:

BMR Contribution

1. Shoot, process and interpret a major seismic survey across the central Officer Basin.

2. Reprocess and reinterpret existing seismic where necessary.

3. Interpret seismic data and integrate with well data to develop basin models.

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[3] Proposal 2 requires the acquisition of more than 650 km of seismic reflection data, which represents more than could be achieved in one winter field season. Additional funds will be sought through industry involvement.

SADME Contribution

1. An extensive drilling and coring project along the BMR seismic line for the development of the basinal cross section.

2. A regional field mapping program involving the mapping a number of 1:250 000 sheets (Fig. 6).

3. Survey the BMR seismic line(s).

4. Negotiating access to conservation zones and Aboriginal lands and obtaining necessary permits and clearance to operate from the traditional owners.

5. Locating adequate groundwater supplies for seismic operations.

BMR and SADME will be jointly involved in the regional interpretation of seismic data and the integration of field and seismic data.

EXPECTED PRODUCTS AND COST RECOVERY

Products will include:

a. A folio of geological maps and sections of the Eastern Officer Basin. This will be the main product to come from the project and will be specifically oriented towards the search for petroleum resources.

b. A geophysical dataset consisting of interpreted seismic sections and a well-log database in a digital format. This will include both existing industry data and data to be gathered during the present programme.

c. A refined basin model to aid in the prediction of petroleum source and reservoir rocks.

d. Specialised papers and publications concerning the evolution of the basin and the nature of the basin's sediment fill.

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APPENDIX 1: RECONNAISSANCE OF THE SOUTHERN CENTRAL OFFICER BASIN, MAY 1991

The reconnaissance of the southern part of the proposed seismic study area of the central Officer Basin was carried out between May 6 and 18, 1991. The reconnaissance party consisted of eight people from both participating institutions:

BMR: John Lindsay, Jim Leven, Dave Gregg, Christian Thun

SADME: John Parker, Graham Krieg, Mark Benbow, Tony Hayball

The objective of the reconnaissance was to assess the area from the viewpoint of logistics and accessibility prior to the shooting of the proposed seismic lines and to meet with members of the Maralinga Aboriginal community and the National Parks and Wildlife Service to discuss access to lands. Original plans included a meeting with Pitjatjantjara community leaders to the north but this meeting was delayed pending a Pitjatjantjara council meeting in Alice Springs in June.

Initially the party met at Ceduna to visit the Maralinga and National Parks and Wildlife Service offices for preliminary discussion on May 8 and 9. The subsequent reconnaissance of the study area was divided into two stages. First, between May 10 and 12 the party surveyed the Nullarbor Plain in the southern part of the study area to assess potential problems associated with the Nullarbor Limestones (Fig. 8) and to evaluate logistical problems. Second, the party visited the Maralinga Community encampment at Oak Valley on May 13 and 14 before reconnoitering the dune country north of the Nullarbor Plain between May 14 and 17.

Itinerary:	Adelaide	7 May
	Ceduna	8
	Ceduna	9
	SW of Nullarbor	10
	Cook	11
	Lake Ifould	12
	Oak Valley	13
	York's Camp	14
	Beadell Highway	15
	Coober Pedy	16
	Adelaide	17

Access to Lands

In Ceduna the party met Ross Allen of the National Parks and Wildlife Service to discuss access to park lands and conservation zones (Fig. 7). He expressed concern about bulldozing in the Conservation Park and advocated the use of tracked vehicles (e.g. Wallis rigs) so that minimal damage would be done to the dune systems.

We also visited the Maralinga Tjarutja offices in Ceduna and arranged permits to cross their lands (Fig. 7). At the Maralinga encampment south of Oak Valley, we talked with Allan Dodd and Mervin Dey, who indicated that there would be no problems working in the area south of the parallel 29°30'S. North of this region, the area would have to be cleared, with elders walking the line. Alan Dodd requested that we avoid creating obvious tracks that would allow access to their lands from the Eyre Highway.

Water

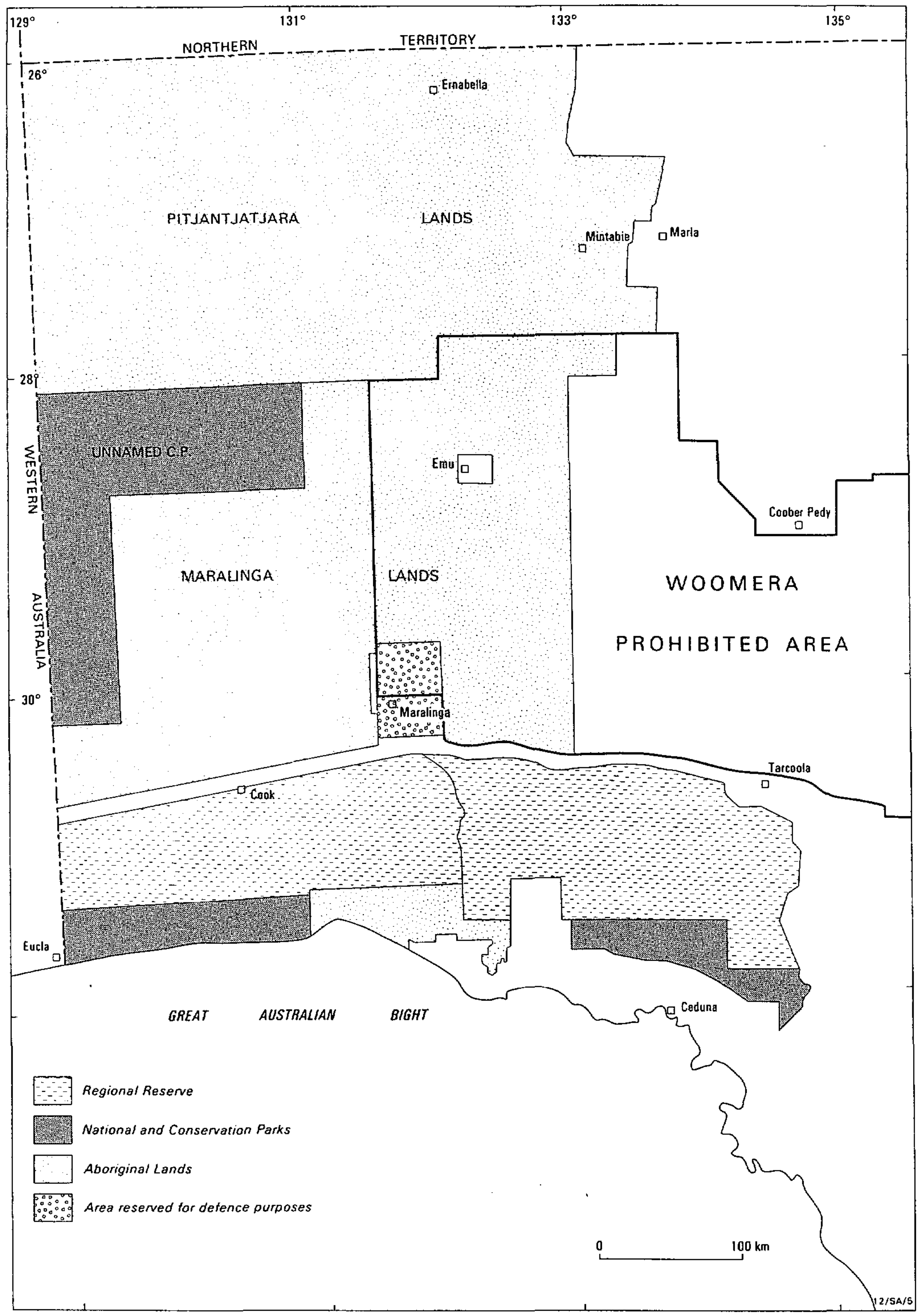

Figure 7. Map of Aboriginal lands and conservation zones in the central Officer Basin.

Water would be the major logistic problem for the seismic operations. No free standing water was seen in our travels in the region (with the exception of the Tallaringra well farther to the east). SADME will initiate an exploratory water drilling program along existing tracks near the proposed seismic line. The Maralinga representatives expressed considerable interest in locating groundwater. Any sub-surface water found by the drilling program would benefit the Aboriginal communities in the long term.

Access

Nullarbor Plain

The southern margin of the Officer Basin lies beneath younger platform carbonates of the Eucla Basin and as a consequence is not readily studied (Fig. 8). A proposal to extend the seismic grid on to the platform area is under consideration but because of the problems associated with seismic acquisition in limestone country it was considered desirable to carry out a preliminary test program before making a commitment to shoot seismic over the area (see Appendix 2).

A brief reconnaissance of the Nullarbor Plain was carried out in preparation for the July/August test shooting. If the results of these tests are satisfactory the seismic profiles may be extended onto the Nullarbor Plain.

The platform carbonates of the Eucla Basin consist of three units, the Wilsons Bluff Limestone, the Abrakurrie Limestone and the Nullarbor Limestone (see James and Bone, 1991 for summary). The three units have a combined thickness of approximately 150 m near the Great Australian Bight but gradually thin inland as they onlap the Officer Basin sediments. In coastal cliffs at the head of the Bight the Nullarbor Limestone was found to be well cemented and probably high velocity. However, large open cavities 10-15 cm in diameter occur throughout the unit. Inland from the coast exposures of the unit are limited; at Koonalda Cave the Nullarbor Limestone was found to be a little more massive but open cavities were visible. In contrast, in quarries at Cook and Watson along the Trans-Australian Railway, the unit was seen to be massive. The units beneath the Nullarbor Limestone, although free of cavities, were less well consolidated. Consequently, there is likely to be a strong velocity contrast within the platform carbonates as well as between the carbonates and the underlying Officer Basin sedimentary rocks.

The onshore portion of the Eucla Platform extends inland for as far as 300 km (Fig. 8). The region, which is known as the Nullarbor Plain, has been exposed subaerially since Middle Miocene and consequently is a remarkably flat karst surface (Lowry and Jennings, 1974). The plain is covered by very low scrubby vegetation, but in spite of this, hard limestone boulders at the surface make cross country travel slow and uncomfortable. Two possible approaches could be taken to road construction. The first is to undertake no road making, and to let the vehicles avoid the worst limestone outcrop, and create their own path. This would save the cost of earth-works over this portion of the seismic line and produce minimal environmental disturbance, but would only ever give a poor road. Alternatively, the traverse could be dozed and graded to produce a higher quality track. Dongas (sub-surface cavity collapses) and rabbit warrens would have to be avoided and pose a risk to travel off existing roads. There is some danger of cavity collapse beneath vehicles, but discussion on this point suggested that this danger was minimal. The road from Watson to the Maralinga Test Site is sealed although only a single lane road.

Dune Country

Vehicle access over the sand dunes to the north of the Nullarbor Plain was better than expected. The dunes of the Ooldea Range would pose a problem, but the seismic line could run to the west of this obstacle. Elsewhere, the dunes were less severe, and with a bulldozer cut of several metres off the top, should be trafficable. Nowhere did the 4WD Toyotas and Nissans have any problems negotiating the dunes.

How the track will stand up to the vehicle traffic is a more difficult question to answer. Those tracks which had stood for many years and had regular use had a good firm base, whereas the recent tracks cut by BHP exploration 12 months ago were still unconsolidated and quite "cut-up" by use. Any winter rainfall would help to consolidate the road surfaces and dunes.

In general, the 4WD vehicle speed on the tracks was around 30 - 40 km/h, with the exception of the Eyre Hwy to Cook road and the eastern end of the Anne Beadell Highway near Mabel Creek, both of which were 80 km/h roads. The Anne Beadell Highway was narrow, with the Toyotas scraping brush either side. For truck use the Ann Beadell Highway may have to be re-bulldozed to widen it and remove a few washouts. Such road work may not be acceptable to National Parks and Wildlife Service.

Supply

Supplies for the proposed Officer Basin seismic operations can only come in via four routes (Fig. 9):

1. Supply trips from Nullarbor (roadhouse, motel and pub), Eyre (roadhouse, motel) or Ceduna (town) would be possible while operating near the Eyre Hwy.

2. Supplies can be delivered by rail to any of the sidings. Cook has a hospital, small store, good air strip, with fuel and water for sale. The "tea and sugar" supply train operates every Thursday.

3. Within and north of the Conservation Park, it may be more efficient to obtain supplies from Coober Pedy along the Ann Beadell Hwy.

4. In northern SA, supplies may have to be trucked from Alice Springs.

The complete lack of firewood will be a problem on the Nullarbor Plain.

Nuclear Test Sites

A number of nuclear tests were carried out by the British Government at two sites in the area in the 1950s. The Emu Site to the north lies on the main route to Coober Pedy along the Ann Beadell Highway and it will be necessary to pass through the area on supply runs. Only two atmospheric tests were carried out at this site in 1953 as part of the Totem tests. The site is open access. However, there are low levels of radiation around the ground zero sites and it is recommended that whilst it is safe to visit it is unwise to camp in the area.

The Maralinga site further south was used much more extensively than Emu and is still a closed site. Roads into the site are blocked by locked boom gates with guards employed by the Commonwealth. The tests series carried out here were complex and involved blowing up plutonium weapons with chemical explosives as part of safety tests. Some area are still contaminated with plutonium which, if breathed as a fine

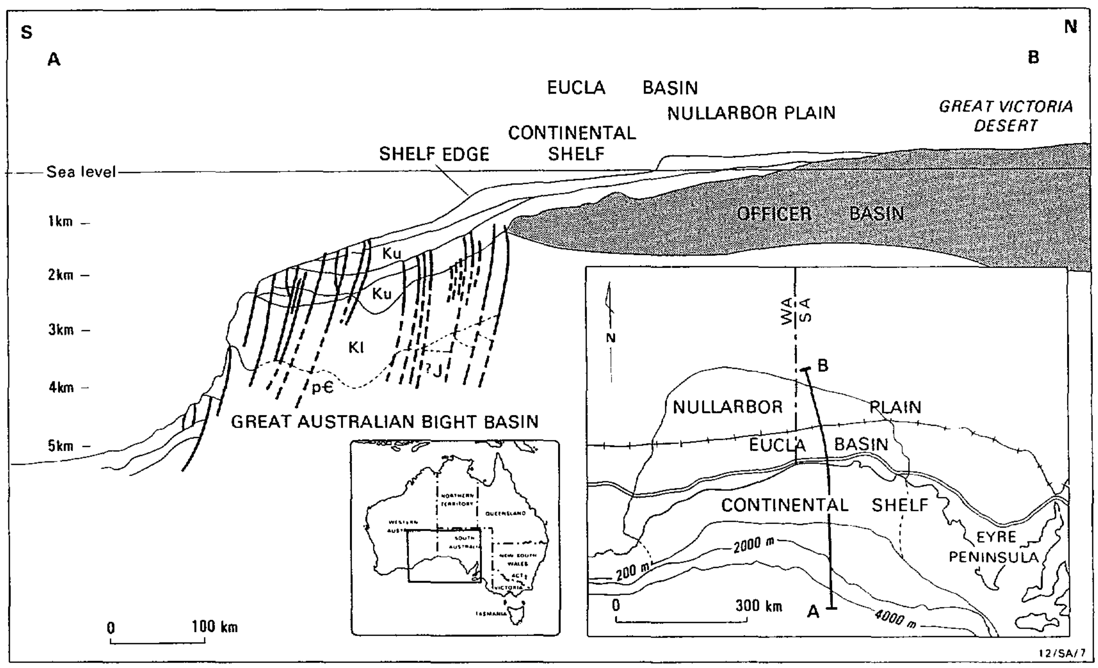

Figure 8. Simplified geological cross-section of the Nullarbor Plain showing its relationship to the Eucla and Officer Basins (modified from James & Bone, 1991).

dust, can cause serious health problems[4]. The area is safe to pass through on the road, if it is necessary, but requires prior approval. To obtain approval contact should be made with Karen Powell, DPIE on (06) 272-4202 well before access is required and specific times given as guards need to travel some distance to the boom gates.

Conclusions

1. Water will pose major problems for the seismic crew.

2. Roads whilst slow are trafficable. Distances are large (Fig. 9).

3. Supplies are available through Cook and Coober Pedy.

4. Atomic test sites should be treated with caution.

5. The Nullarbor Limestone is a potential technical problem for seismic acquisition and needs closer scrutiny before shooting begins (Fig. 8).

6. Discussions with Aboriginal Communities and National Parks and Wildlife Service regarding land access are continuing.

Accommodation and Other Contacts

Accommodation in Adelaide near SADME:

Adelaide Hilton Motor Inn	(08) 271 0444
Powell's Court	(08) 271-7033

Accommodation in Ceduna:

East West Motel	(086) 25 2102 Fax (086) 25 2829

Port Augusta Flying Doctor Service VNZ

Tel (086) 422 044
Fax (086) 410 461

Shell Truck Stop Ceduna — (086) 252 501

Cook Community

Station Supervisor, Cook	Merv Gould (086) 422611
Store Manager, Cook	Andrew Spackman

Trains to/from Adelaide

Depart Cook	7 pm	arrive Adelaide	2 pm
Depart Adelaide	10-30 am	arrive Cook	4-45 pm

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[4] For additional information see,
Symonds, J.L., ed., 1985, A History of British Atomic Tests in Australia. Australian Government Publishing Service, 593p.
McLelland, Justice J.R., 1985, Royal Commission into British Nuclear Tests in Australia. Parliamentary Paper No. 482/1985, Australian Government Publishing Service, 2 Vols. and Summary volume.

Maralinga Tjarutja

Archie Barton	administrator	(086) 252946
Darcy O'Shea	lawyer	
Dickie Le Bois	supply driver	
Allan Dodd	manager CEDA	
Mervin Dey	elder	

NPWS

Ross Allen	Manager, western SA Fax (086) 25 3123	(086) 25 3144

Nuclear Test Sites

Karen Powell, DPIE on (06) 272-4202

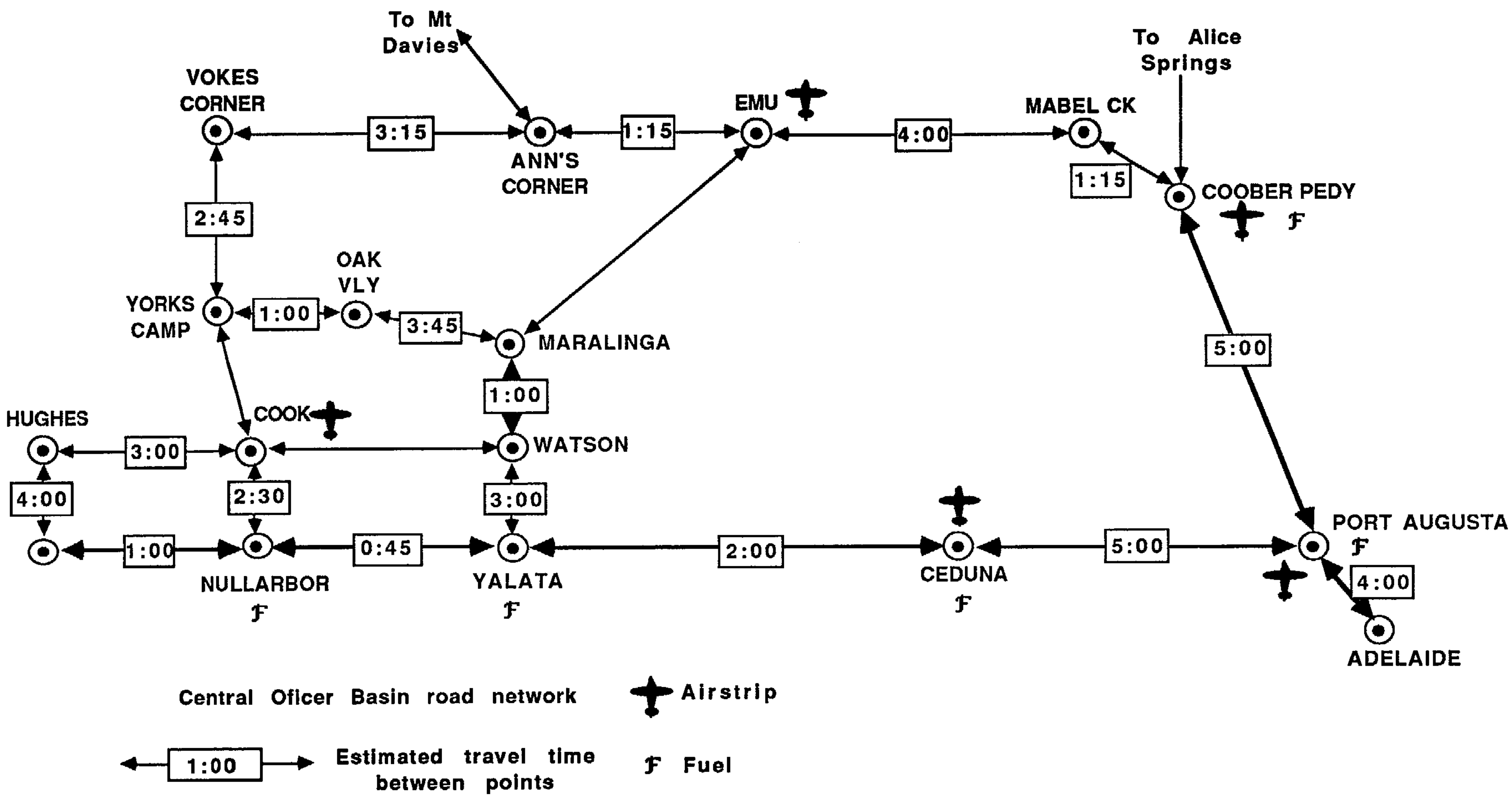

Figure 9. Diagrammatic representation of the road network across the central Officer Basin showing travel times (Hours:Minutes) between main centres.

APPENDIX 2: PROPOSED BMR SEISMIC REFLECTION TESTS IN THE OFFICER BASIN

SEISMIC TEST OBJECTIVES

Tests on road between Eyre Highway and Cook, 1991

1. Drilling shot holes - penetration rates in the Nullarbor Limestone
2. Noise tests - look at the ground roll characteristics and optimum group interval
3. Uphole test - optimum shot depth (undoubtedly below the Nullarbor Limestone)
4. Charge size test
5. Kelly depth shots - seismic quality comparison with deeper shot, penetration
6. Expanded spread or walk-away test - optimum recording window and velocity analysis
7. Processing: Test for the enhancement of reflection from the Officer Basin sequence in the Mallabie Depression beneath the Nullarbor Limestone, by a variety of processing techniques. Comparison of the high fold data from the kelly depth shots with the lower fold data from the deeper shotholes.

Outline of the proposed tests

1. Uphole in 70 m hole, solid tamped with 3 - 4 m of cuttings

   spread: 96 channel split spread with bunched geophones at 10 m intervals.

70 m	4 kg	65 m	4 kg
60 m	3 kg	55 m	3 kg
50 m	2 kg	45 m	2 kg
40 m	2 kg	35 m	2 kg
30 m	1 kg	20 m	1 kg
15 m	1 kg	10 m	0.5 kg
4 m	0.5 kg		

   Total: 26 kg explosive 70 m drilling

2. Noise test, bunched geophones @ 10 m, 96 channels, i.e. 960 m length

```
Shot       Shot       Shot  Uphole  Shot       Shot       Shot
*----------*----------*xxxxxUxxxxx*----------*----------*
12         10         8  Geophones  8        10         12
```

   Six holes at 50 m, or optimum depth, 8, 10, 12 kg on each side.

   60 kg, 300 m

3. Expanding Spread or walk-away (if time permits at southern test site)

   50 m group interval 96 channel

   4 holes each with 8 to 15 kg at 50 m or optimum depth

   45 kg, 200 m

4. Charge size comparison

   3 holes close to the near offset expanding spread

   4, 12 and 25 kg at 50 m or optimum depth

   41 kg, 150 m

5. Kelly depth shotholes (30 fold)

30 kelly depth holes at 40 m shot interval with 2 kg charges into 96 channel at 40 m group interval

60 kg, 70 m

6. Normal depth shotholes (6 fold) (at one site only)
   6 holes to 50 m (or optimum depth) at 320 m shot interval with 10 kg charge into 96 channel 40 m group interval

   60 kg, 300 m

7. Pattern shooting (at one site only)
   Four holes to 20 m with 5 kg in each hole into 96 channel 40 m group interval

   20 kg, 80 m

TOTAL EXPLOSIVES 500 kg for the two tests
TOTAL DRILLING 1800 m for the two tests

Requirements:
- 3 drilling rigs
- 3 water tankers
- recording crew with 6 juggies
- 500 kg explosive
- 75 detonators

Test site

From the Nullarbor Roadhouse drive 42 km west on the Eyre Hwy to the Cook turnoff. The test sites are 28 and 66 km north of this turnoff. The camp site will be located between the two test sites.

Schedule

Estimate of time:

Drilling rigs and tankers
- 0.5 days camp set-up
- 2 days drilling southern test shotholes
- 2 days drilling northern test shotholes
- 0.5 days camp pack-up

Seismic crew
- 1 day camp set-up
- 0.5 days surveying
- 1.5 days recording tests at the southern site
- 1.5 days recording tests at the northern site
- 0.5 days camp packup

APPENDIX 3: LOGISTICS OF PREVIOUS SEISMIC SURVEYS IN THE OFFICER BASIN

BMR Officer Basin Seismic Survey, 1972

Tests[5]

Uphole and noise tests
Experimentation with different:

i. Geophone and shot hole patterns
ii. Shot depths
iii. Geophone intervals

Expanded Spreads for velocity control
Geoflex comparison (which was inconclusive)

Results of the tests

Reflection quality was variable and depended greatly on the surface conditions. Quality was good to fair over dry salt lakes, fair to poor over lateritized Cretaceous outcrop, and very poor over sand dunes and sandy country.

It is clear from the shot records and the drilling information that the depth of weathering may extend to greater than 100 m. In such cases, it is not feasible to detonate the shot below the weathering layer. Serious coherent noise was observed in the noise test shots detonated within the weathered layer. A geophone array was designed to minimise the coherent noise: this array had 48 geophones per trace in three rows of 16 spaced 6 m apart inline and with 14 m between rows. (Such a line geometry would slow field operations.)

Shot patterns were also used to minimise the ground roll. In places a pattern of 25 kelly depth (4.5 m) holes with 20 m spacing was optimal, whereas in other areas 3 to 5 holes to 30 m were used, or a single shothole.

Large variations in the thickness of weathering over short distances and the lack of reliable weathering information reduced the effectiveness of CMP stacking. Difficulty was encountered in recording the first break arrivals, due to the presence of near-surface stringers and the severe attenuation in the near-surface layers.

A basalt layer associated with the Table Hill Volcanics reduced energy transmission, and multiple coverage was not attempted over the areas of basalt subcrop.

Weathering velocity	1100 - 1700 ms^{-1}
Sub-weathering velocity	2000 - 3200 ms^{-1}

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[5] Notes:

Used ammonium nitrate as well as Anzite blue explosive.
Group interval 45 m.
36 km of reflection and 71 km of refraction in 4 months.
All camps located close to "rock holes"

Field Monitor Records

The field monitor records of the 1972 BMR Survey, and particularly the experimental tests, have been inspected. The shots at greater depth have substantially less ground roll than shallow shots, but unfortunately there are no obvious deeper reflectors on which to judge the relative benefit of shot depth. Analysis of the uphole times suggests 20 m as an optimum shot hole depth around Station 300.

Serpentine Lakes Reconnaissance Survey 1966

This Vibroseis survey in the Officer Basin S.A is of particular relevance as the proposed BMR line lies between the Serpentine Lakes regional reconnaissance Lines 1 and 2. The terrain consists of scrub covered sandy desert overlain with numerous high stationary sand ridges.

The average production was 3.7 km per recording day (for Vibroseis).

The two north-south reconnaissance lines outline a broad asymmetric basin, with the axis of the trough located 32 km south of the limit of the outcrops which form the Musgrave Block. The maximum thickness of sediment in the axis of the trough interpreted from Line 2 is 5180 m. The seismic results show low structural relief and marked conformity of the reflecting horizons.

Operational considerations

Dunes are typically 6 to 25 m high, and are asymmetric, with the steeper side facing north. It is therefore easier to traverse from south to north. In the south the dunes occur at a frequency of 2 to 3 per kilometre, and this frequency increases in the north to about 4 per kilometre. In the north, the sand cover becomes continuous. Clay pans are scattered throughout the area. Some laterite occurs in the area.

Two D7 bulldozers were used to clear the line and cut a road through the sand dunes. Progress of the bulldozing team was 1.6 to 8 km per day, depending on the amount of sand dune cutting needed. The east-west lines were generally quicker to cut, as they extended parallel to the dunes.

Logistics

Access was either from the east via Coober Pedy and Mabel Creek Station, or northwards from Cook along the Cook-Vokes Hill Junction track. The east-west track offered fewer sand dune obstructions. The supply run from Cook traversed soft sand dunes, tree roots, boulder strewn stony tracks, and occasionally mud. Consequently the wear on vehicle suspensions, transmission systems and tyres was severe.

A twice weekly plane schedule (five seat) was operated between Adelaide and the camp. Five airstrips were constructed (four to five days construction time each).

The survey was conducted as a continuous operation on the basis of 300 hours per month, so that 1/5 of the crew were on leave at a time. Personnel worked four weeks with a week's leave in Adelaide.

All drinking water was brought from Cook to the camp by tanker. Additional water was obtained from the Waldana rock hole.

Climate was pleasant during the winter months, with temperature ranging from 0 to 26°C and with clear skies and light winds. Rainfall was spasmodic, usually in the form of thunder showers. Summer conditions were arduous, with shade temperatures exceeding 48°C.

Bulldozers were essential for towing the caravans over the sand dunes during most camp moves.

Recording

A Techno 20 channel recording system was used with three 10000 lb thrust phase compensated hydraulic vibrators, and 14 Hz geophones.

Refractor velocities	3500 m s^{-1} 5500 m s^{-1}
Ground roll	1500 m s^{-1}
Geophone array	300 geophones per trace 300 x 61 m array area
Station Interval	61 m

Sand dunes adversely affected the reflection quality. Tests were done to see if the difference in elevation was responsible for the reduction in quality, and these tests proved inconclusive. The low velocity of the sand dunes created problems for datum corrections. Weathering depth was not simply related to the elevation, and calculated values ranged from 2 to 60 metres. The near-surface layer velocity of 610 m s^{-1} is considered to be that of unconsolidated sand.

For the refraction recording, charge sizes of 5 to 500 kg were used in the offset range of 2 to 16 km. Ammonium nitrate was used for the refraction shots.

Drilling

A Mayhew 1000 drill rig was used for uphole shots and to look for water. Holes to 61 m were drilled with air, or air with water injection. Drilling was generally easy, the major problem being the supply of water.

No sign of artesian water was found, including in one hole drilled to 200 m depth.

Water is likely to be the major logistic problem for operations in the Officer Basin.

Processing

Stacking velocities used in the interval 0 to 1 second: 3048 + 1219 * T m s^{-1} (where T is in seconds)
Below 1 second, a stacking velocity of 4267 m s^{-1} was used.

Refraction velocities:

Depth metres	Velocity m s^{-1}	
640	4420	Line 1 V.P. 123-147
2103	5440	
2682	6000	
1188	5470	Line 1 V.P. 296-310

381	5330	Line 2 V.P. 98-118
2087	5715	

Comalco Test Work

In 1983 Comalco evaluated the relative cost effectiveness of four seismic sources: Thumper, Vibroseis, downhole dynamite and detonating cord (Cucuzza and Akerman, 1984). Comalco decided to use a weight drop source in their reconnaissance survey in PEL 23, mainly on grounds of cost effectiveness (see Cucuzza and Akerman, 1984; Cucuzza, Akerman and Gatti, 1984; Stainton, Weste and Cucuzza, 1988). The data quality is fair to poor, especially in comparison with the vibroseis work of Amoco in PEL 29 (Amoco, 1987; Thomas, 1990).

Comalco's experience with explosive sources was negative: "Downhole dynamite produced inferior results characterised by very low S/N." They used single shots, 1 to 8 kg charges at 15 to 30 m depth. Ground roll was a significant problem; velocities in the range 650 to 850 m s^{-1} and wavelengths from 50 to 102 m[6]. Ground roll is minimised with downhole detonations.

Aspects of field monitors:

1. Continuous reflection energy is not usually visible.

2. Reflection energy is predominantly on the far offset traces.

3. Good quality first breaks are usual, and necessary for static corrections.

BMR Seismic Acquisition

Implications for the BMR Tests

The total energy of a typical weight drop (3000 kg over 3 m) is around 88 kJ, whereas the total energy of a 1 kg shot is around 5 MJ. Therefore roughly 56 weight drops would be required to achieve equal energy.

The total energy for a vibratory source is typically in the range 0.6 to 2.0 MJ. The limitation with a vibratory source is the length of vibrating time required for deeper seismic data, and the impact that this has on the production rates.

The BMR land seismic acquisition program is set up to use explosive sources. The project requires good quality seismic data from the sedimentary section (upper 2.5 seconds).

A Possible Compromise

Kelly depth shotholes with 2 kg charges at each geophone station can be used to obtain 48 fold data (96 channels). Drilling for these holes would be comparatively rapid operation. This would provide high-fold shallow (1-2 s) data.

[6] Note that this minimum wavelength of 50 m would require a maximum group interval of 25 metres to avoid aliasing especially for subsequent FK filtering.

Deeper seismic data could be obtained at lower fold. Shotholes drilled to 40 m and loaded with 25 kg of explosive could be used to provide either single-fold or 3-fold data. The advantage of 3-fold data is that a median stack could be used. The following table outlines the proposal for a 40 m group interval:

	Units		Shallow	Deep	Shallow	Deep
Fold	---	12	48	1	48	3
Explosives	kg/hole	12	2	25	2	25
Interval	m	160	40	1920	40	640
Shothole Depth	m	250	121		163	
Explosives	kg/km	75	63		90	
Detonators[7]	/km	7	27		27	
Drilling	m/km	40	4	40	4	40

[7] The increased costs associated with the detonators may be offset by the decrease in the required drilling and the increased drilling production rate of kelly-depth holes.