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The Central Australian seismic experiment, 1985: preliminary results

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Summary. The major objective of the Central Australian seismic experiment is to investigate the structural evolution of the Arunta Block and the Ngalia and Amadeus Basins. A regional north-south reflection line of 420 km length from the Northern Arunta Province to the southern part of the Amadeus Basin was recorded in 1985. The most significant basement features are prominent bands of reflectors from beneath the Northern Arunta Province and the Ngalia Basin at times of between 4 and 10 s that dip towards the north. Deep crustal features south of the Ngalia Basin are less clear except in the Redbank Zone. Bands of deep reflectors similar to those observed in the north occur at times of between 5 and 10 s beneath the southern part of the Amadeus Basin. Additional seismic profiling included a reflection line of 40 km length recorded across the northern margin of the Redbank Zone, three expanding spread reflection profiles and a tomographic experiment. An east-west seismic refraction profile of 400 km length was recorded within the Arunta Block, and suggests an average crustal thickness of 55 km.

1. Introduction

The Wiso, Ngalia, Amadeus and Officer Basins are separated by regions of exposed Proterozoic crust (Fig. 1). Large differences in gravity anomalies exist between the basins and adjacent blocks. The interpretation of these anomalies in conjunction with the results of seismic profiling will have important bearing on ideas concerning the formation of these intracontinental basins. An account of the objectives of the Central Australian seismic experiment and the field procedures has been given by Goleby *et al.* (1986). Gravity was measured at 333 m intervals along all reflection traverses, and airborne magnetics were recorded along line 1 (Fig. 1). The purpose of this paper is to provide a brief summary of the tectonic problems that have been highlighted by earlier geological and geophysical studies, to give a few significant preliminary results and to indicate the problems of interpretation that require new avenues of research.

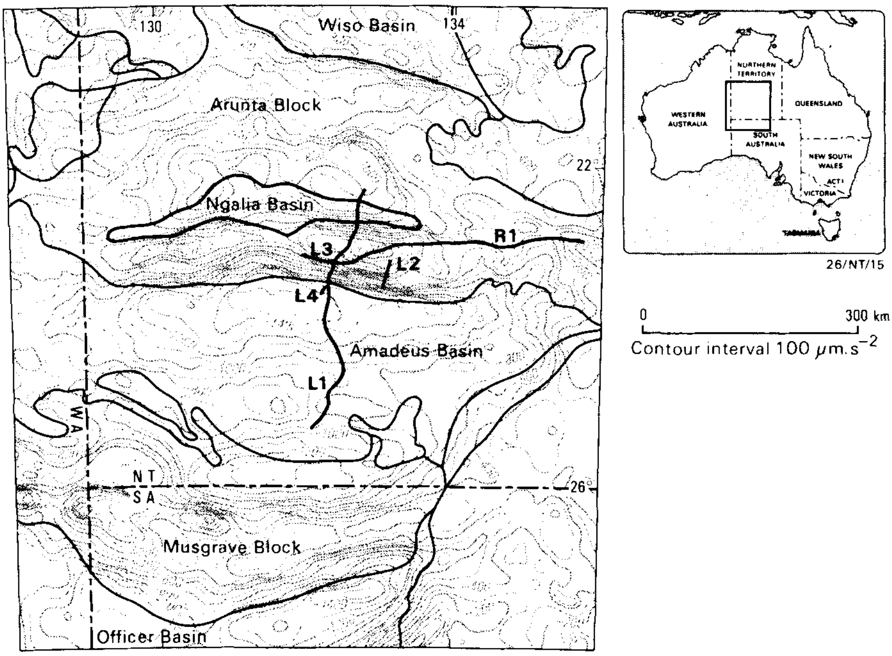

Figure 1. Map of the central Australian region showing the gravity anomalies, and the location of the seismic profiling undertaken in 1985. L1 denotes the main north-south reflection profile. L2, L3 and L4 denote shorter supplementary profiles. Line R1 defines the refraction profile within the Arunta Block.

2. The geological and tectonic evolution of the Arunta Block and the Ngalia and Amadeus Basins

The Arunta Block consists mainly of Precambrian metamorphosed sedimentary and igneous rocks, and has been interpreted as a Proterozoic mobile belt underlain by continental crust (Shaw *et al.* 1984; Stewart *et al.* 1984). It consists of three tectonic provinces with separate histories of deformation and metamorphism (Fig. 2). The tectonic evolution of the Arunta Complex resulted from six cycles of crustal extension and compression that commenced prior to 1800 Ma and ended with the Alice Springs Orogeny between 400 and 300 Ma.

The Ngalia Basin covers much of the southern part of the Northern Province of the Arunta Block (Fig. 2), and contains late Proterozoic and Palaeozoic sediments of maximum thickness of about 6 km that can be correlated with those of the Amadeus Basin (Wells *et al.* 1972; Wells & Moss 1983). The basin has been a structural entity since the Alice Springs Orogeny, when the thrusting of the Arunta rocks from the north over the northern margin of the basin probably took place.

The Amadeus Basin is an east-west trending intracratonic depression of about 800 km length, bounded on the north and south by the Arunta and Musgrave Blocks respectively. The maximum thickness of sediments (14 km) occurs near the northern margin of the basin. The late Proterozoic and Palaeozoic sedimentation was interrupted by tectonic episodes at 1050-900 Ma and at about 600 Ma (Wells *et al.* 1970; Schroder & Gorter 1984). Subsequent Palaeozoic sedimentation was more restricted and the Alice Springs Orogeny was the last major diastrophism to influence the structure and petrological nature of the basin.

Models of the central Australian crust to explain the features of the gravity field have been provided by Anfiloff and Shaw (1974), Mathur (1976) and Wellman (1978), but none of

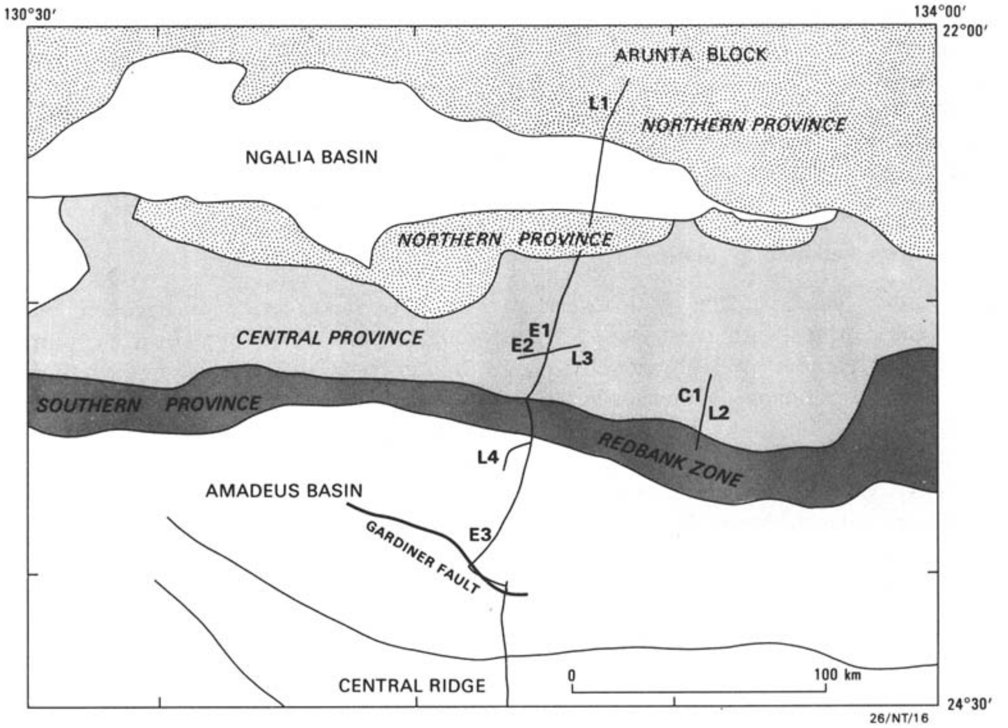

Figure 2. Map of the Arunta Block and northern Amadeus Basin showing the locations of expanding spreads and other experimental profiles. L1-L4 are as in Fig. 1. E1, E3 and E2 define the locations of expanding spreads on lines 1 and 3. C1 shows the location of eight 80 kg shots recorded at offsets of 21 - 25 km.

these authors have attempted to explain the tectonic processes that could have resulted in the proposed models. It is evident that the formation of the Ngalia and Amadeus Basin is not satisfactorily explained by models involving thermal or stretching mechanisms, and a mechanical model for the evolution of these basins has been developed by Lambeck (1983, 1984), assuming that the central Australian crust has been predominantly in compression for the last 1000 million years.

3. Near-vertical incidence reflection profiling

The near-vertical incidence profiling was recorded 6 or 12 fold with 24 s record lengths; explosive charges of 8 or 12 kg were used in shot holes usually of 40 m depth. The main basement features have been inferred from examination of both the single shot records and brute stacks, and are shown schematically in Fig. 3. We recognise that statics problems in central Australia are particularly severe due to very deep weathering. The single shot records were therefore used to determine if the stacking was removing important reflection information. We find that the stacking preserves the more prominent reflection features but degrades some of the bands of high frequency energy. Preliminary results indicate that strong reflectors within the deep basement occur below the Northern Arunta Province, Ngalia Basin and Redbank Zone. The most remarkable feature of Fig. 3 is the band of northerly dipping reflections in the north at times of between 4 and 10 s. These reflections die out near the Reynolds Ranges and are replaced by shallower, relatively flat reflections. The pattern of reflections suggests that the thrusting of the northern part of the Arunta Block towards the Ngalia Basin involved the entire crust. The frequency characteristics of the deep reflectors observed beneath the Arunta present some interesting problems in interpretation (Goleby *et al.* 1986b).

Strong reflections similar to those observed beneath the Arunta are observed at times of between 5 and 10 s below the southern part of the Amadeus basin (Fig. 3), but are relatively flat with a small apparent dip to the south.

4. Other seismic profiling

Two orthogonal expanding spreads (Musgrave 1962) of 36 km length were recorded above the Central Arunta Province. During the recording of each expanding spread, 16 portable refraction recorders were deployed to give three-dimensional coverage and so enable tomographic techniques to be used to image the underlying structure (Goleby *et al.* 1986a). Preliminary results from this refraction tomographic survey suggest lateral heterogeneity or anisotropy with P wave velocities in upper basement in the range 5.6 to 6.2 km s^{-1}, and S wave velocities of about 3.3 km s^{-1} on average. In addition to the near-vertical incidence profiling across the Redbank Zone (Shaw *et al.* 1984), five 80 kg shots were detonated near the northern end of line 2 and recorded at offsets of 21-25 km to assist in velocity determination and in the mapping of steeply-dipping fault structures (Fig. 2). Eight portable refraction instruments were also deployed near the northern end of the line to provide further information on velocity changes (Goleby *et al.* 1986a).

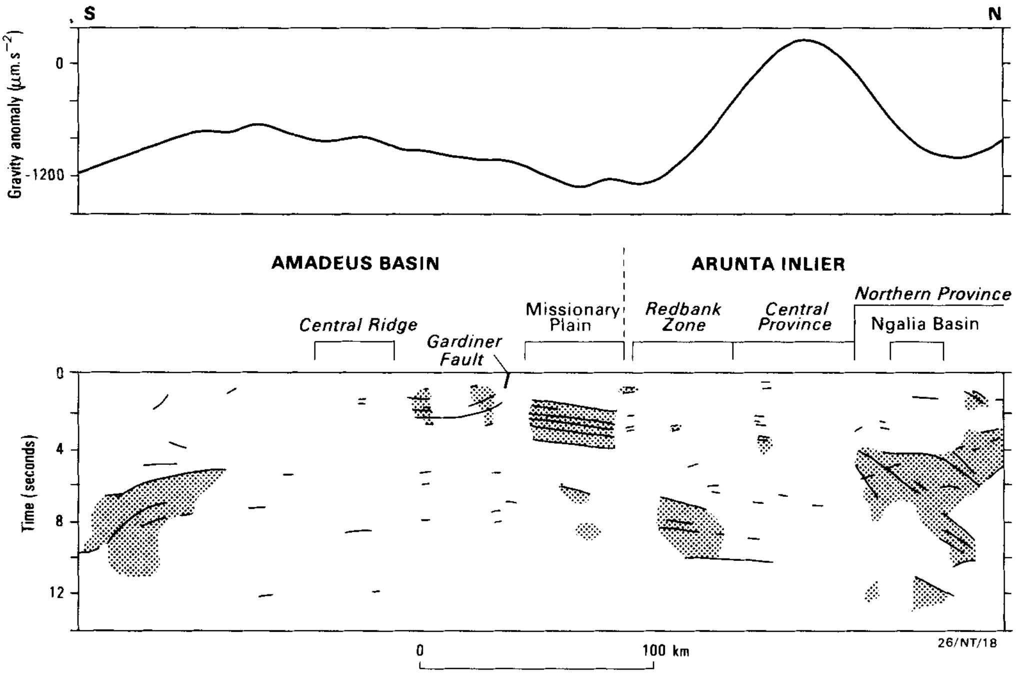

Figure 3. Line diagram showing the main deep crustal features observed along reflection line 1 of the central Australian seismic experiment (Fig. 1) with the observed gravity profile. In the line diagram only the most prominent features have been shown, and the shading denotes regions of strong bands of reflected energy. Vertical exaggeration is 2.8:1. We note that the term Arunta Inlier has been used by Shaw *et al.* (1984) and Stewart *et al.* (1984).

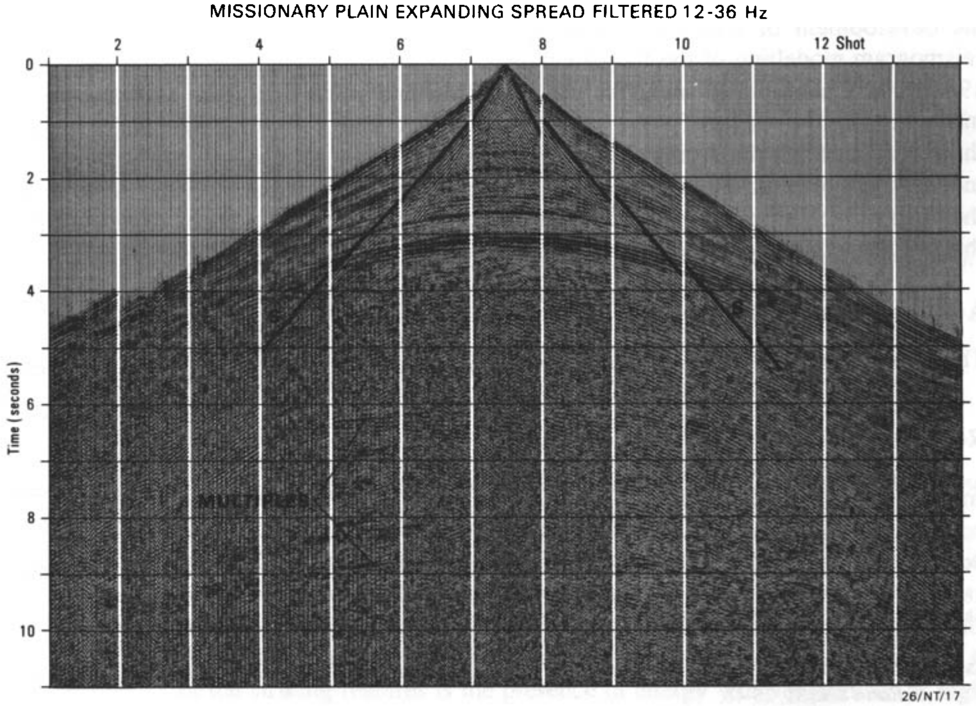

Figure 4. Missionary Plain expanding spread plotted with adjacent shot side by side, and not in the alternating manner proposed by Musgrave (1962). Field receiver and least squares shot statics have been applied using the method of Wright and Taylor (1986). The most northerly shot on the left appears offset because the recording spread could not be placed at the correct location.

An expanding spread of 25 km length was recorded over the Missionary Plain in the northern part of the Amadeus Basin (Fig. 4). High quality reflectors are observed in the sedimentary section but there are no clear deep crustal reflectors. Clear S wave signals are observed, noting that we are labelling as S a wave that has travelled for the major part of its propagation path as a shear wave, but some P to S or S to P conversion is involved (Wright & Finlayson 1986).

The seismic refraction survey yields P wave velocities near the surface that vary between 4.0 and 5.5 km s^{-1}, and increase rapidly to about 6.2 km s^{-1} at a depth of about 1 km. A weak refracted arrival with an apparent velocity of 7.2 km s^{-1} occurs at offsets greater than 220 km, and is attributed to a velocity boundary at a depth of about 31 km. This boundary probably corresponds to the base of the reflecting zone that ends at times of about 10 s below parts of the Arunta Block (Fig. 3). No arrivals with velocities greater than 8 km s^{-1} are observed. Later arrivals at offset between 200 and 240 km may be wide-angle reflections from the crust-mantle boundary at about 55 km depth. Good S wave arrivals are observed from most shots and yield apparent velocities of between 3.4 and 3.9 km s^{-1}.

5. Conclusions

The seismic reflection profiling across the central Australian region has yielded strong deep crustal reflections below the Northern Arunta Province and Ngalia Basins, the Redbank Zone and the southern part of the Amadeus Basin, but large sections of the profiles show few prominent reflections. The areas of research that need to be pursued before the reflection data can be properly evaluated and used to develop models of the evolution of the region include the development of alternative methods of determining statics corrections, synthetic seismogram modelling of the frequency dependence of the deep reflectors (Goleby *et al.* 1986b), and attempts to integrate the reflection and refraction data with the gravity, magnetics and the results of teleseismic travel time studies. The refraction results suggest a thick crust beneath the Arunta Block, and this is not easy to reconcile with the physical model for the evolution of the central Australian region of Lambeck (1983, 1984) or with the observed teleseismic travel time anomalies and gravity data (Lambeck & Penney 1984) that suggest a thin crust beneath the Arunta Block.

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