DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1974/2

EAST CANNING BASIN EARTHQUAKE MARCH 1970

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ABSTRACT

On 24 March 1970 an earthquake of magnitude ML 6.7 took place in the eastern Canning Basin. The earthquake was unusual because it occurred in a region where no previous earthquake had been reported and where there was no evidence of recent tectonic activity. First motion results indicate a thrusting type focal mechanism with the pressure axis approximately northeast-southwest and dipping about 24° to the southwest. The main shock was followed, over the next two years, by many earthquakes in a zone covering 140 km by 20 km. The longitudinal axis of this zone is approximately parallel to the north-northwest striking nodal plane determined from the first motion results, and to the trend of intrabasin faulting.

It is suggested that continental crust may be sensitive to small changes in stress pattern and consequently seismic activity may be interrelated over large distances.

Introduction

Until recently little has been known about the earthquake patterns and consequent current tectonic activity in the Australian continent. This results from the low level of seismic activity and the few seismograph stations suitable for monitoring local and regional earthquakes. Up to 1958 only, at most, six seismographs were operating in Australia (ADE, BRS, MEL, PER, RIV and SYD). However, with the development of the regional networks in Western Australia by the Bureau of Mineral Resources (Gregson, 1971), South Australia by the University of Adelaide (Sutton & White, 1968), and Victoria and New South Wales by the Australian National University (Doyle & Underwood, 1965), it has become possible to locate many more earthquakes, and patterns of earthquake activity are beginning to emerge.

In Western Australia one of the first active regions to be identified was the Southwest Seismic Zone, which is known to extend for at least 400 km (Everingham 1968). The 1968 Meckering earthquake (Everingham et al., 1969) and the 1970 Calingiri earthquake (Everingham & Parkes, 1971) were situated in this zone.

On 24 March 1970 a new zone (the East Canning Basin Seismic Zone) was revealed when a large earthquake and subsequent aftershocks took place in the eastern Canning Basin. This earthquake series was unusual because it occurred in a region where no previous earthquakes had been reported and where there was no known evidence of recent tectonic activity. The main shock was followed during the next two years by many aftershocks, of which about 200 were large enough for their magnitudes to be determined. Over 90 of these were recorded by enough seismic stations for accurate epicentres to be determined*.

This earthquake sequence provides important evidence relating to the tectonic processes taking place within the Australian continent and to proposals that there are intra-plate boundaries in this region defined by zones of earthquake activity (Cleary & Simpson, 1971; Stewart & Mount, 1972).

Epicentres and Magnitudes

Figures 1 and 2 show the epicentres of the 1970 eastern Canning Basin sequence and of all the Australian earthquakes with body wave magnitudes 4 or greater that are known to have occurred since 1900. The main earthquake, on 24 March 1970, was well recorded by seismographs in Australia and overseas. The US Coast and Geodetic Survey (CGS) epicentre, computed from 138 stations, was 21.98°S, 126.68°E. Our epicentre, determined by a computer program

* A list can be obtained on request to the Director, BMR.

based on that originally written by Bolt (1960) was using travel-times based on recordings from the Ord River explosions (Denham et al., 1972), is 22.05°S, 126.61°E. These epicentres are not significantly different and both solutions give depths which indicate a crustal focus. However, depth control was poor owing to the absence of close stations and of identifiable pP phases.

The epicentres of the earthquakes which followed the main earthquake are shown in Figures 2 & 3. These were determined from the Ord River travel-times and arrival times from the Australian stations ASP, CLV, DAR, HTT, ILN, KLG, MEK, UMB, and WRA. Times from other regional stations were discarded since they gave consistently high residuals and were only available for the larger aftershocks. All depths were restrained to zero in order to obtain a consistent set of solutions. The relative accuracy of the epicentres is probably better than 0.1°, and the values given by CGS for the 7 largest earthquakes in the sequence are within 0.1° of our solutions.

All the well located epicentres lie in a clearly defined north-northwesterly zone about 140 km long and at most 25 km wide; and almost 90 percent of them lay in a zone 45 km x 20 km, trending north-northwest, and presumably related to the fault plane of the principal earthquake.

The main earthquake had a magnitude of MB(CGS) = 6.2 (E.D.R. 73-70). The Gutenberg & Richter (1956) body wave magnitude of 6.9 may be found from the approximate relation MB = MB(CGS) + 0.7, given by Båth (1966). This equals a Richter magnitude ML of about 7.1 (using Gutenberg & Richter's formulas). Gibowicz (1972), using shallow New Zealand earthquakes, determined the following relation:

$$ML = 1.17\ MB(CGS) - 0.43$$

If this result applies to Australia the CGS estimate may be converted to give ML = 6.8.

A surface wave magnitude MS = 5.9 was determined by CGS. This converts to an ML value of 6.1 if the relations in Gutenberg & Richter are used. These three derived values show a large scatter from the arithmetic mean of ML = 6.7, which is adopted for the main earthquake.

Effects from the main earthquake were not reported from the uninhabited epicentral region, and the highest reported feld intensity was MM5 at Fitzroy Crossing, about 500 km from the epicentre. At Perth, 1500 km from the epicentre, the earthquake was felt clearly in tall buildings (MM intensity 2). These felt effects were similar to those

observed at distances of 500 km and more from the 1941 Meeberrie and the 1968 Meckering earthquakes (Everingham & Parkes, 1971) and suggest that a magnitude of at least ML = 6.7 for the main 1970 earthquake is reasonable.

Focal Mechanism

First motion data from the main earthquake are shown in Figure 4. The nodal planes are well determined with the first arrivals at Australian stations ASP and WRA defining nodal plane n1 and the Antarctic stations MAW, MIR, SBA, and SPA providing close control over the nodal plane n2. The solution, similar to that obtained by Fitch et al. (1973), suggests a NE-SW compressional stress at the earthquake focus, resulting in overthrust faulting with the fault plane either dipping steeply to the southwest (n2) or shallowly to the northeast (n1).

The north-northwest trend of the aftershock zone is consistent with the solution but does not indicate which nodal plane was the fault plane.

If the stress shown by the solution represents the regional stress then the results are at variance with the predictions of Cleary & Simpson (1971) who suggested a tensional regime in the region, and those of Stewart & Mount (1972) who postulated right-lateral strike-slip faulting.

Tectonic Implications

The entire earthquake sequence is situated in the eastern Canning Basin, which trends northwesterly from the central Australian Arunta Block between the elevated basement of the Precambrian Kimberley Basin in the north and the Pilbara Block in the south (Geological Society of Australia, 1971) (Fig. 2). To the south the Canning Basin appears to be continuous with the Officer Basin. The two thickest parts of the Canning Basin are separated by the Broome Platform, which is a regional axial high separating the Fitzroy Trough to the north from a series of sub-basins in the south.

The Fitzroy Trough is a fault-bounded structure containing up to 8 km of mainly Permian and Carboniferous sediments. Over the Broome Platform the sedimentary thickness is reduced to about 2 km. South of the Platform there are several deep sub-basins; the largest is the Kidson Sub-basin, which contains up to 7 km of sediments. The aftershock epicentres are on the Broome Platform slightly north of, but close to, the northeastern edge of this sub-basin, and the aftershock area trends north-northwest, roughly parallel to the intra-basin faulting.

It has not yet been possible to associate the earthquake with any particular structure because Quaternary sands cover the epicentral region. Furthermore, the low levels of seismicity in central Australia prevent any definite links being made with other earthquakes. However, although there is no continuous line of epicentres across the northwest part of the continent, it would appear that the evidence supports the existence of a general compressive province here (Fitch et al., 1973). Additional support for this interpretation comes from the March 1964 Broome earthquake (17.71°S, 123.16°E). First arrivals from ADE, BRS, DAR, KOU, MUN, and TAU for this event give the same directions of first motion as those observed from the East Canning Basin earthquake, and although these data are insufficient to determine any focal parameters they are consistent with a compressional stress field whose pressure axis lies NE-SW.

Whether the active zone near Broome extends to the southeast to join the central Australian zone of activity (around 26°S 137°E), as has been postulated by some authors (Cleary & Simpson, 1971; Stewart & Mount, 1972), cannot be ascertained from current evidence. During the period June-September 1968 weak seismic activity listed in the Table between the area around Broome and central Australia led to a suggestion (Everingham & Gregson, 1971) that the two areas were tectonically linked. The East Canning Basin Seismic Zone might be included in this extended zone of weak activity if it does exist.

Focal mechanism studies of all large recent earthquakes in the Australian Continent indicate that most of this region is in compression (Fitch et al, 1973). Apparently in central and western Australia the compression results not in long continuous transcontinental seismic zones but in small, separate, and usually elongated zones of seismic activity, e.g. the East Canning Basin Zone discussed here, the Southwest Seismic Zone, and the zones in South Australia and the Simpson Desert (Stewart & Denham, 1974).

The levels of activity in the seismic zones that have been recognized have been spasmodic, and new zones will probably emerge in the future. The comparatively long zone of aftershocks associated with some large earthquakes (140 km from East Canning Basin, 1970, and 120 km for the Simpson Desert, 1972), indicates that stress changes resulting from the main earthquakes can affect areas far from the initial rupture.

In the Southwest Seismic Zone the 1968 Meckering earthquake sequence, which was contained in a 15 km x 40 km area, probably caused changes in the regional stress pattern; these changes probably triggered the 1970 Calingiri earthquake - 80 km from Meckering. Similar changes in stress pattern probably took place in the Simpson Desert, where two magnitude 6 earthquakes in 1937 were followed by 3 earthquakes of similar size in 1941 (Burke-Gaffney, 1951).

These observations lead to speculation on the extent of effects of large earthquakes and how activity in one seismic zone relates to activity in another and to the activity at the Indian-Australian plate margins. At present the numbers of continental earthquakes are too small to permit meaningful statistical analyses on the space-time relations in these regions. However, the large rise in seismic activity throughout the whole of Western Australia in the period 1968-1970 and the weak activity in 1968 (see Table 1) suggest that continental seismic activity may be interrelated over distances as large as a few thousand km.

TABLE - SOME AUSTRALIAN EARTHQUAKES, 1968

dy	mo	yr	hr	min	sec	Lat (^{o}S)	Long (^{o}E)	*MB(MUN)
13	06	68	06	44	19.8	20.97	131.18	4.5
19	06	68	05	55	42.7	19.40	125.10	5.1
25	06	68	08	53	43.1	25.97	137.47	5.0
30	06	68	19	21	22.6	16.60	121.60	5.1
02	08	68	20	45	48.5	22.89	133.09	5.3
06	08	68	19	08	52.0	18.50	123.20	5.3
10	09	68	12	46	35.0	16.80	117.40	5.0

*MB(MUN) - body wave magnitude determined by Mundaring Geophysical Observatory

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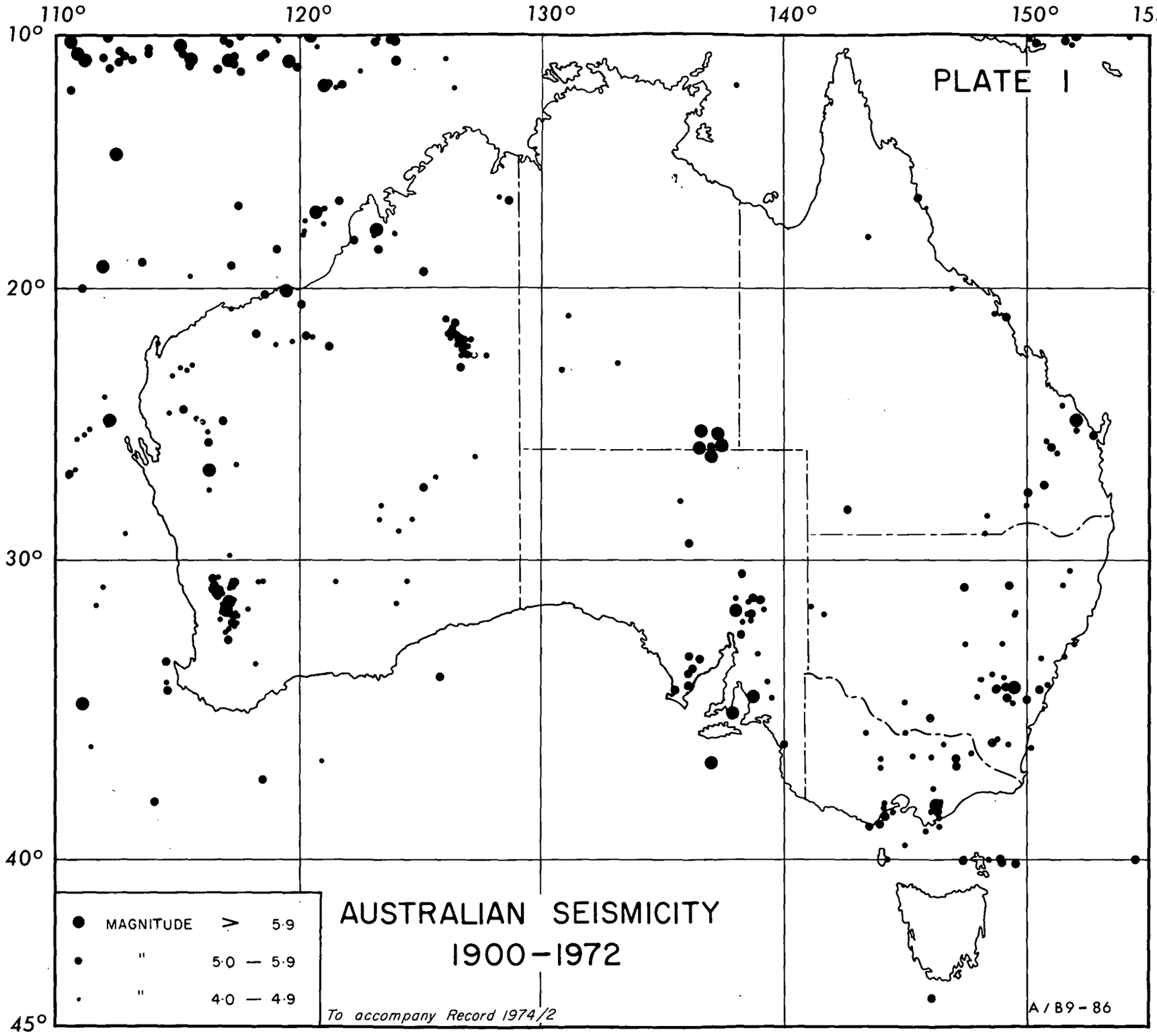
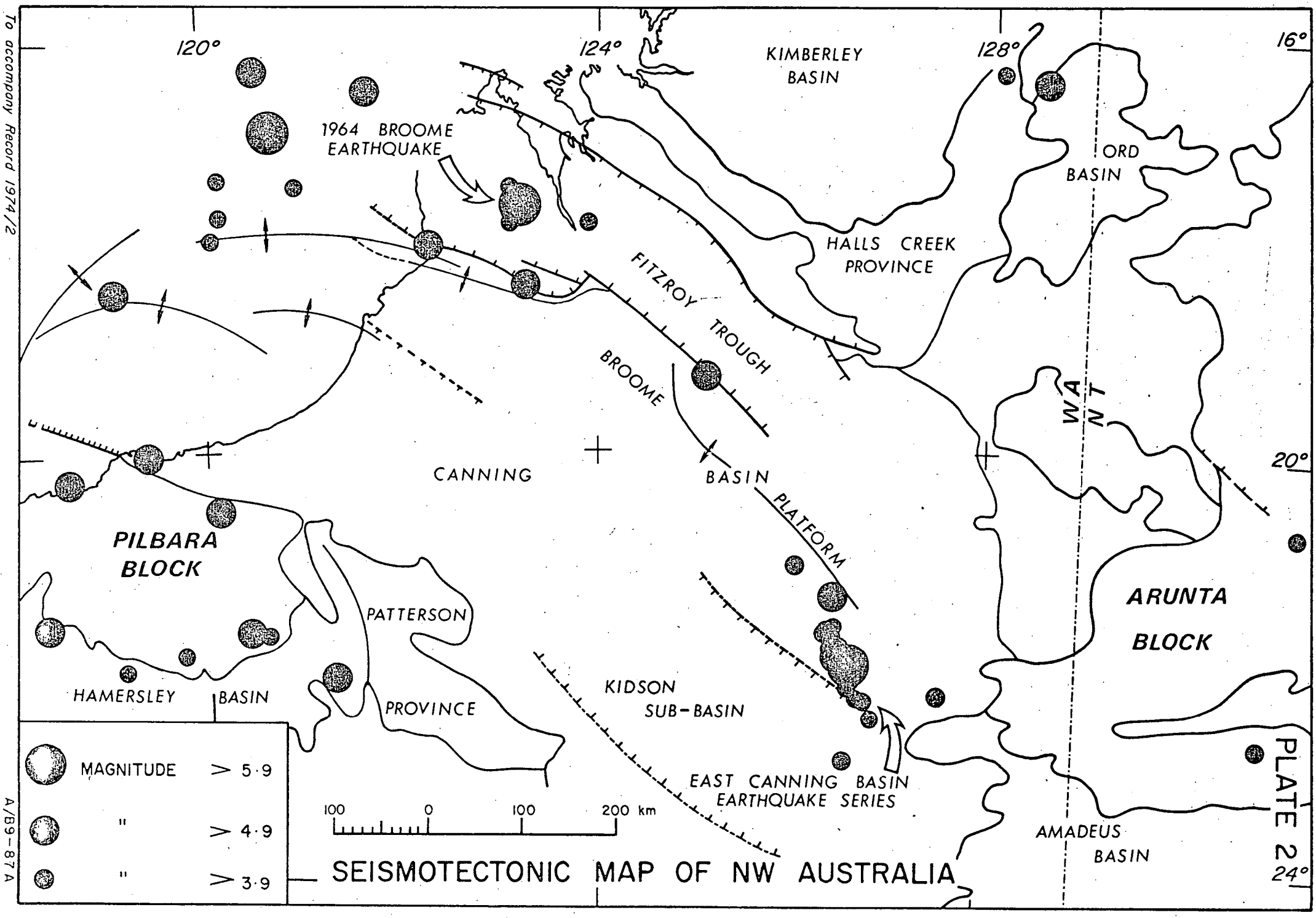


PLATE 1
110°
120°
130°
140°
150°
155°
10°
20°
30°
40°
45°
MAGNITUDE > 5·9
" 5·0 — 5·9
" 4·0 — 4·9
AUSTRALIAN SEISMICITY
1900–1972
To accompany Record 1974/2
A/B9-86

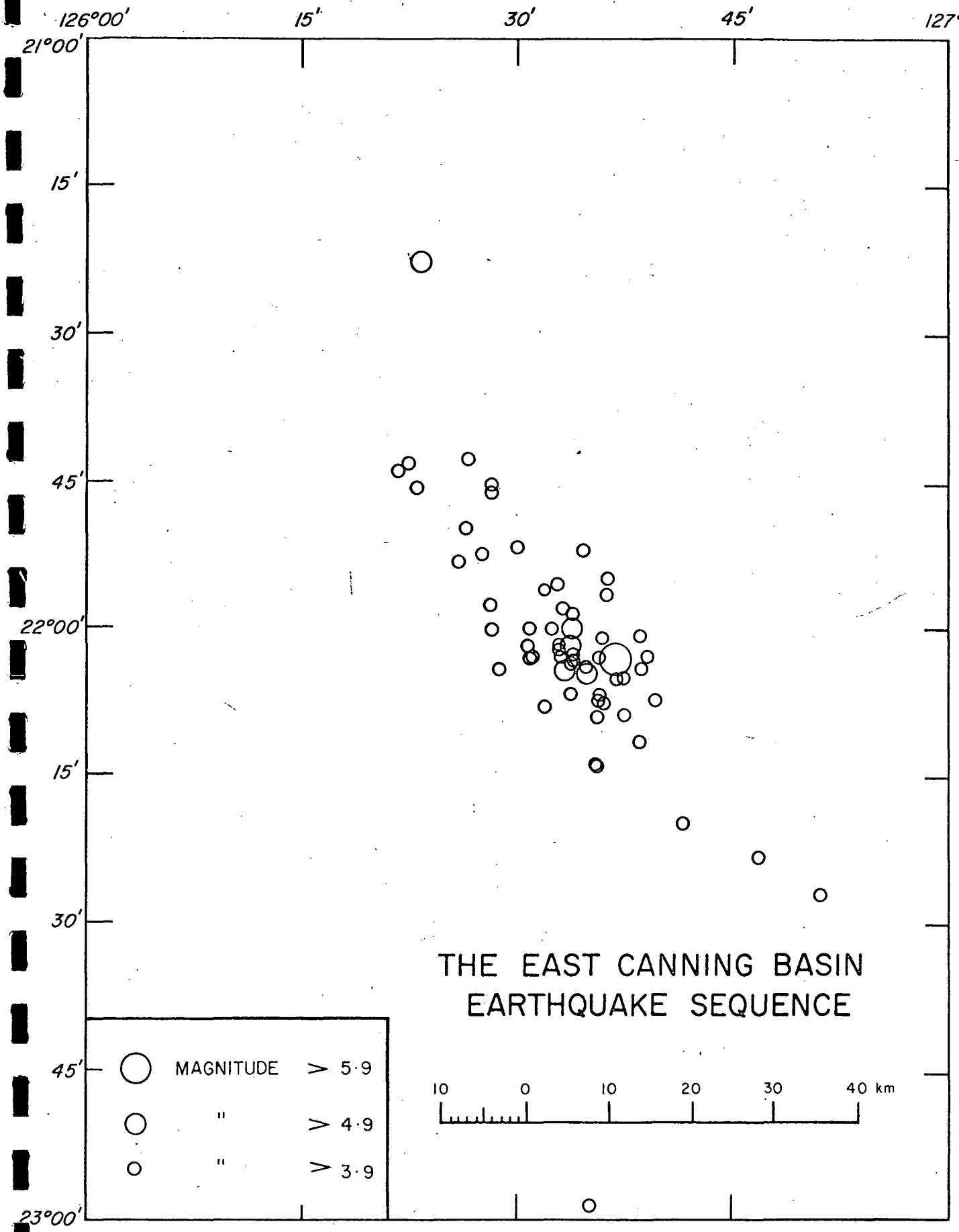
To accompany Record 1974/2



SEISMOTECTONIC MAP OF NW AUSTRALIA

A/B9-87A

PLATE 3



THE EAST CANNING BASIN EARTHQUAKE SEQUENCE

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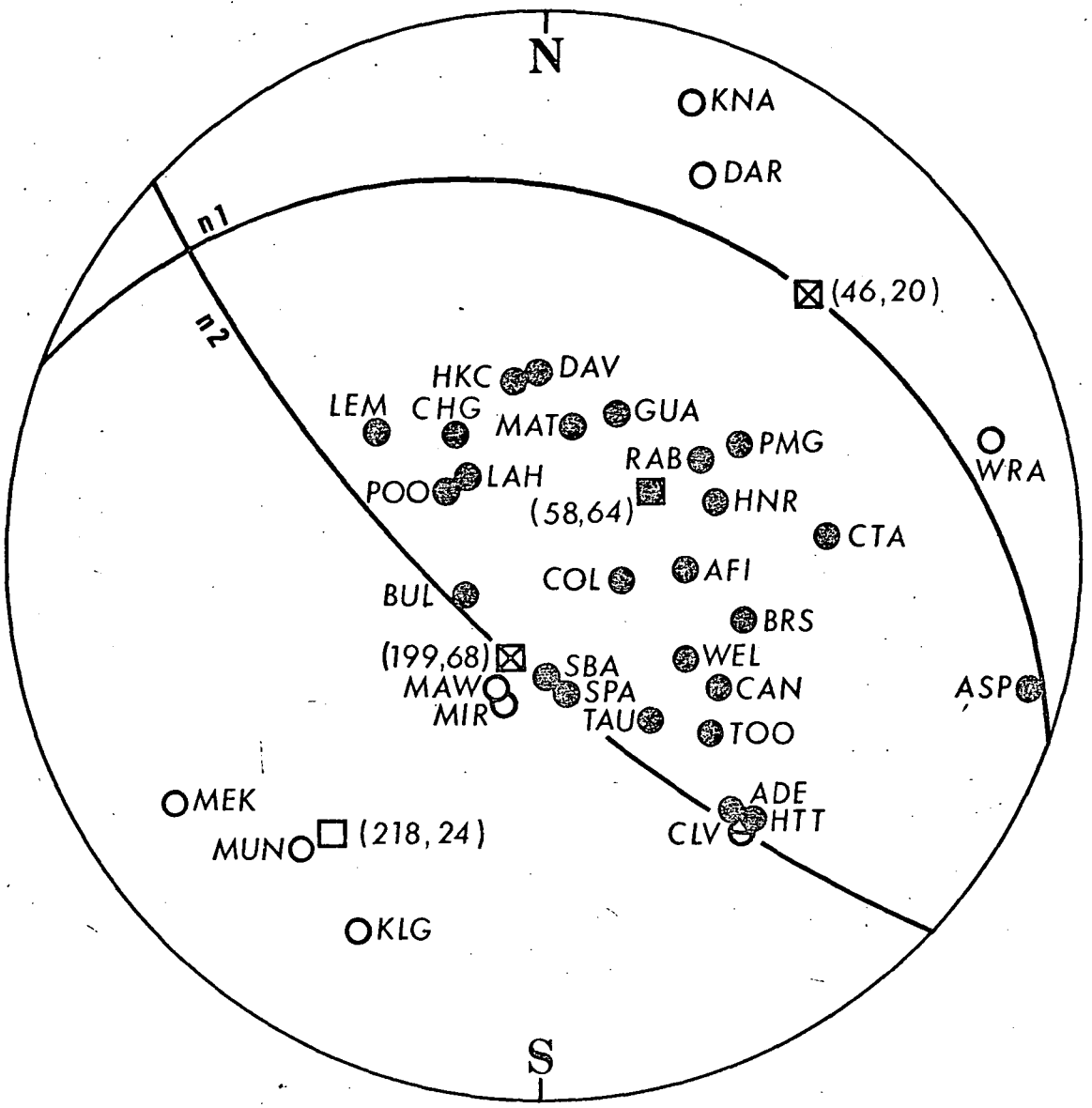
F52/B9-2A

PLATE 4



●	COMPRESSION
○	DILATATION
⊖	EMERGENT
□	PRESSURE AXIS
■	TENSION AXIS
⊠	NODAL POLE

EAST CANNING BASIN EARTHQUAKE

24 MARCH 1970

To accompany Record 1974/2

A/B9-84A