

Project Skippy Explores the Lithosphere and Mantle Beneath Australia

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A new project is probing the seismic structure of the lithosphere and mantle beneath Australia. The Skippy Project, named after the bush kangaroo, exploits Australia's regional seismicity and makes use of recent advances in digital recording technology to collect three-component broadband seismic data from over 60 sites across the continent (Figure 1).

The main goal of the Skippy Project, which is run by Australian National University's Research School of Earth Sciences (RSES), is to delineate the three-dimensional seismic structure of the lithosphere and mantle beneath the continent.

Operating 60 stations simultaneously would be expensive and technically demanding. Instead, restricted arrays of up to twelve portable seismic recording systems with a spacing of around 400 km will be used.

Because of the high level of seismic activity in the Australasian region, excellent data coverage can be achieved in 5 months. The Skippy array will be deployed at different locations in Australia, and plans call for covering the continent by mid-1997.

The data acquired will be used along with broadband data available from permanent seismic observatories in the region (Figure 1). The information gained during the first 5 years of the project can be used to identify regions of particular interest or complexity that need to be studied in detail.

Research Directions

The basement of the Australian continent can be divided according to age into three tectonic super provinces that correspond to major stages of crustal evolution: the Archean, Late Archean-Middle Proterozoic, and Phanerozoic (Figure 2). Despite major advances [see *Drummond, 1991*], knowledge about basement structure and crustal evolution is fragmented, often because the boundaries between the super provinces are obscured by younger platform cover.

Although the investigations will concentrate on the Australian region, the research will be relevant for general topics, such as the structure of Precambrian shields. It will

help answer such questions as, how thick are continents? Can we detect the boundaries between the Archean, Proterozoic, and Phanerozoic provinces?, and if yes, to what depth?

The data should also help answer questions about the seismic expression and dynamics of hot spots and mantle plumes, including, what is the evidence from seismic imaging for hot spots below eastern Australia?

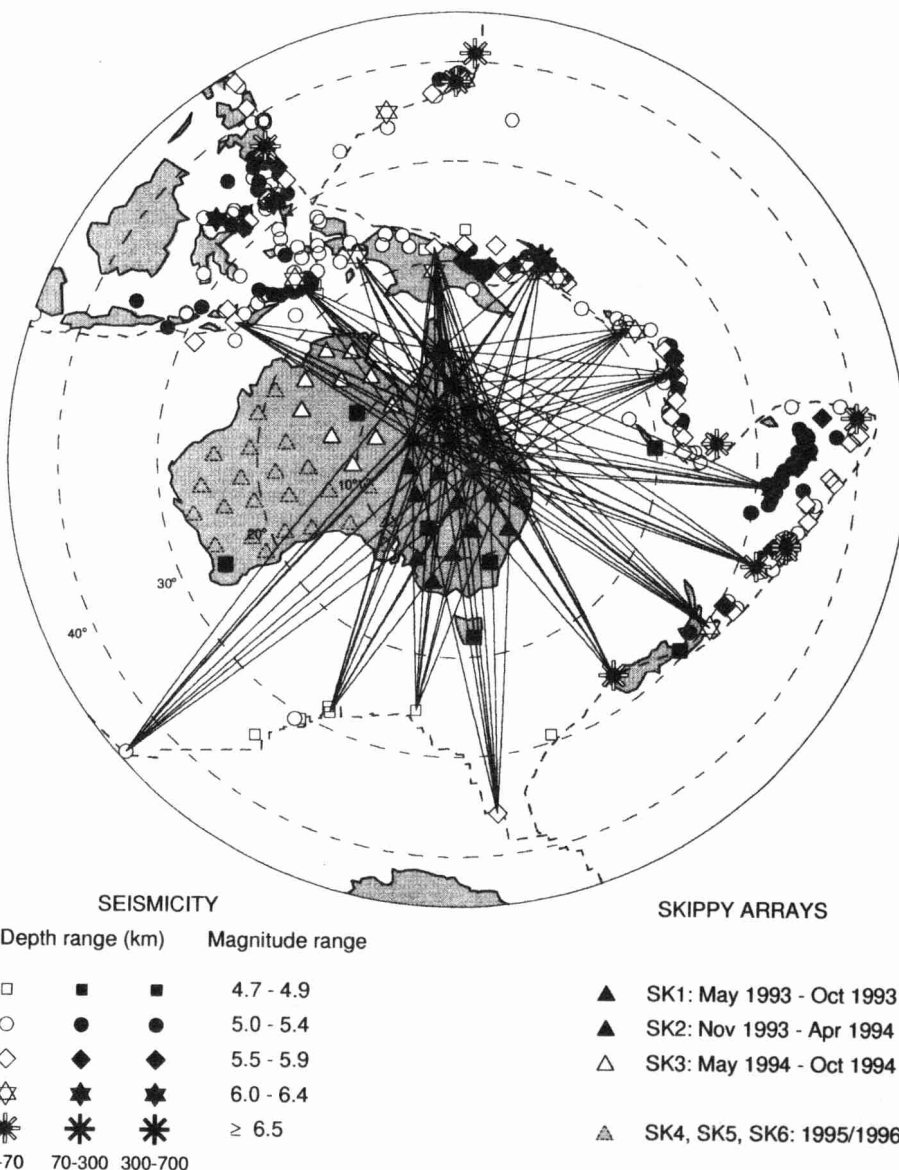


Fig. 1. Seismicity map and locations of the Skippy stations and permanent seismic observatories in the region. Epicenters are given of earthquakes selected from the PDE weekly listing for the operation period of the first Skippy array. Wave paths (great circle paths) are drawn for a relatively small subset of the recorded earthquakes to illustrate the potential wave path coverage. Solid black squares mark the location of permanent seismological observatories: CTAO (Charters Towers-IRIS), WRA (Warramunga-RSES), NWA0 (Narrogin-IRIS), STK (Stephens Creek- Australian Geological Survey Organisation), CAN (Canberra-GEOSCOPE), and TAU (Tasmania University-IRIS).

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lia and the Tasman Sea?, and can we infer a spatial relationship between these hot spots and the presumed plume below the Coral Sea?

At RSES, the broadband data will be used for a wide range of studies. A major research project involves inverting seismic waveforms for shear wave structure of the lithosphere and upper mantle. It is based on a nonlinear optimization technique developed by Nolet [1990] and previously applied to map the European lithosphere and upper mantle [Zielhuis and Nolet, 1994]. With the dense wave path coverage (Figure 1), we expect to resolve variations in seismic properties of length scales larger than about 250 km.

A three-dimensional model of P-wave speed will be constructed by inverting travel time information of compressional waves (P, pP, PP, etc.) and perhaps by waveform techniques. Another study will investigate seismic anisotropy and its relation to the macro-scale structural fabric of the Australian crust and the stress/strain orientation associated with plate motion.

Research will also focus on the major seismic discontinuities beneath the continent associated with, for instance, the mantle-crust interface (Moho), the phase transition from olivine to spinel structure at a depth of about 410 km, and the core-mantle boundary.

These studies will build on reconnaissance work in northern Australia, which produced P and S wave velocity and attenuation profiles through the mantle and indications of shear-wave splitting for refracted waves in the upper mantle [Kennett et al., 1994].

Portable Seismograph Stations

The portable stations used in the Skippy Project consist of a sensor that measures ground motion over a wide frequency range, a recorder that digitizes the analogue output signal of the sensor and writes the data to a storage medium, a clock, and a power supply.

The signal is recorded by a refraction technology system featuring a 24-bit analog to digital converter, an internal clock, a Global Positioning System (GPS) clock, and a digital audio tape (DAT) drive.

The internal clock is reset every hour by the GPS, which keeps the timing error less than 0.1 m/s. The ground motion signal is recorded continuously and digitized at a rate of twenty-five samples per second. Power is supplied by a 12-V automotive battery that is recharged through a solar panel. With our specific recording parameters, the recording unit can run autonomously for about 70 days.

The field setup of the instruments is simple but efficient for Australian soil and climate conditions. The seismometer is placed on a concrete tile and buried in a 1-m deep hole; the recording unit is wrapped in plastic and covered with 30–40 cm of soil, which protects the instruments from cattle and cockatoos who do not respect seismological

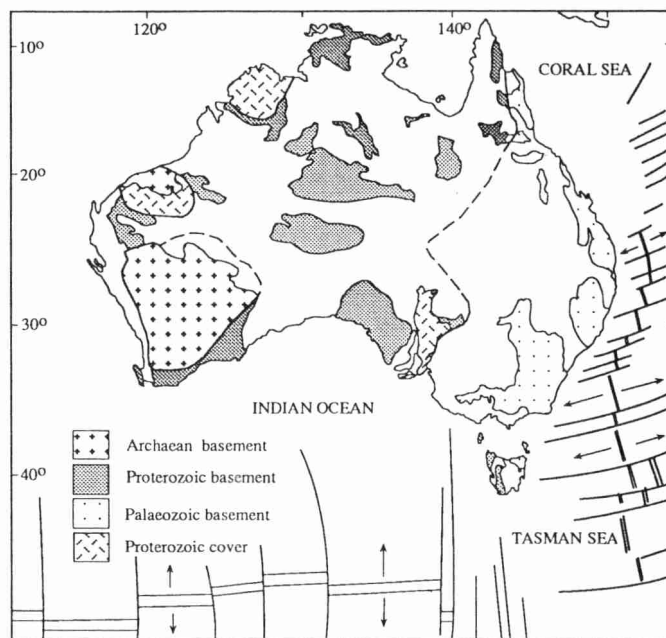


Fig. 2. Schematic map showing principal orogenic domains of Australia, grouped according to age [Rutland et al., 1990].

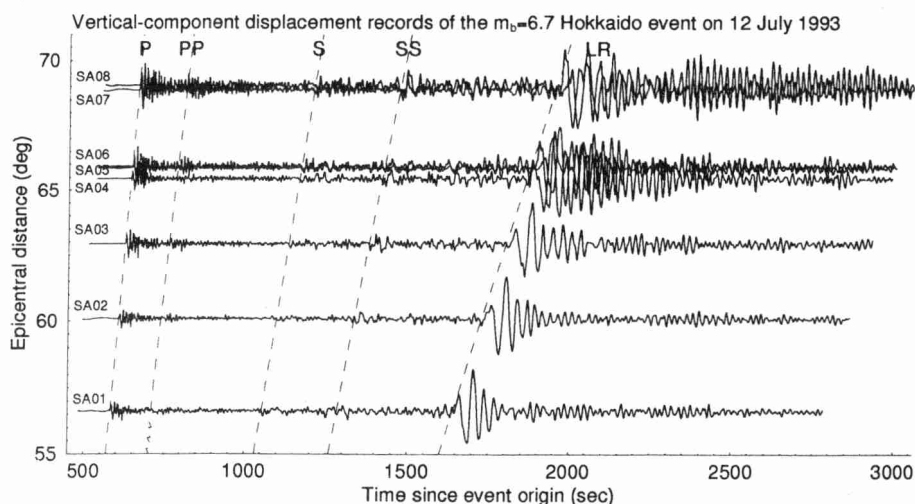


Fig. 3. Records corrected for instrument response of the M7.8 earthquake that struck Hokkaido, Japan, on July 12, 1993. This earthquake produced one of the largest tsunamis in Japan's history and caused many fatalities.

research and keeps the DAT drive's temperature below the advised maximum of 45°C. The solar panel with the GPS antenna is placed on a pole about 10 m away from the sensor.

The Project's First Phase

Eight field stations operated in Queensland between May and October (Figure 1). In addition to the deployment and pull-out of the array, two field trips were made to change the DAT tapes. Initially, 1.3-gigabyte tapes were used, but for the third tape we successfully used the longer 2.0-gigabyte tape at each station. The recorders operated for a total of 1064 days; with a maximum total tape capacity of 1160 days, this means a success rate of more than 90%.

During this operation period, the level of seismic activity in the Australasian region was high, and a large number of earthquakes were recorded. Figure 1 shows the epicenters of selected earthquakes in the region. As expected, seismicity is substantially lower near the ocean ridges to the south of Australia.

Figure 1 demonstrates the promising coverage of surface wave paths in a wide area around the first Skippy array. The availability of waveform data from the permanent observatories (black squares in Figure 1) makes the wave path coverage even better. For many of the larger events, focal mechanisms are already available from the Harvard seismology group and the U.S. Geological Survey, and matching of the observed data with synthetic seismograms has begun.

Figure 3 shows a record section for the vertical-component displacement records of the earthquake that caused major damage to Hokkaido, Japan, on July 12, 1993.

In November, the second Skippy array was installed. The twelve stations in New South Wales, Victoria, South Australia and Queensland will operate until mid-April 1994. From May to October, ten stations will be deployed in the northern territories (Figure 1).

Data Management and Availability

At RSES, the field tapes are copied to backup tapes. Earthquakes for which data are extracted are selected using a simple magnitude-distance criterion and the Preliminary Determinations of Epicenters (PDE), published by the USGS and obtained through the Incorporated Research Institutions for Seismology (IRIS). During the first Skippy deployment, more than 350 earthquakes were selected.

The extracted waveform data are converted to the standard format for the Exchange of Earthquake Data (SEED) and ar-

chived as network-day-volumes, which means that all daily data from selected events recorded at the Skippy stations are combined into a single file.

Software tools such as Orfeus' cdlook and IRIS' rdseed can then be used to view and extract data from the archives. Software for event selection and data extraction will be released through IRIS. If required, time data not initially selected can be extracted from the backup tapes.

Two years after the conclusion of each experiment, the waveform data for the selected events will be published on CD-ROM through the ORFEUS Data Center in De Bilt, The Netherlands.

Acknowledgments

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