UPPER CRUSTAL STRUCTURE OF THE PRINCE OLAV COAST, EAST ANTARCTICA

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***Abstract*:** The *P*-wave velocity structure of a part of the Prince Olav Coast, East Antarctica was revealed by a seismic refraction experiment conducted by the 21st Japanese Antarctic Research Expedition in July 1980. Ten seismic stations were set along a line with a length of about 10 km at intervals of about 1 km. The station consists of a seismometer and a direct analogue data-recorder with an electric panel-heater in an insulated box. The observed travel times of the first and later arrivals from two explosions at both ends of the line were analyzed. The *P*-wave velocity of the basement complex is 6.02 km/s which is a typical value in East Antarctica. This basement complex is covered by the ice sheet with the thickness of about 700–1000 m. No layer with a velocity less than 6 km/s is detected between the ice sheet and the basement complex.

1. Introduction

The 21st Japanese Antarctic Research Expedition (JARE-21) carried out an explosion seismic experiment in July 1980 at around 69.0°S, 40.4°E along the glaciological traverse route (S-route) on the Prince Olav Coast in East Antarctica. The purposes of the experiment were to test an ice-drilling machine and seismographs, and to reveal the relationship between the seismic wave amplitude and the yield so as to know the nature of the noises and seismic waves on the ice sheet, in preparation for the large-scale experiment to be conducted in November 1980 (IKAMI *et al.*, 1983). The experiment also aimed at a seismic survey of the upper crust.

The details of the field operation are given in ITO *et al.* (1983). This paper represents the results of the refraction survey for the *P*-wave velocity structure of the upper crust. Other results are described in separate papers of this volume (ITO and IKAMI, 1984; IKAMI and ITO, 1984).

2. Description of Experiment

A 10-km long profile line was set up between station S22 and station S27-3 along the glaciological traverse route on the ice sheet of the Prince Olav Coast. Shot and observation points are shown in Fig. 1. Six shots (Shots 10–15) with charge sizes of

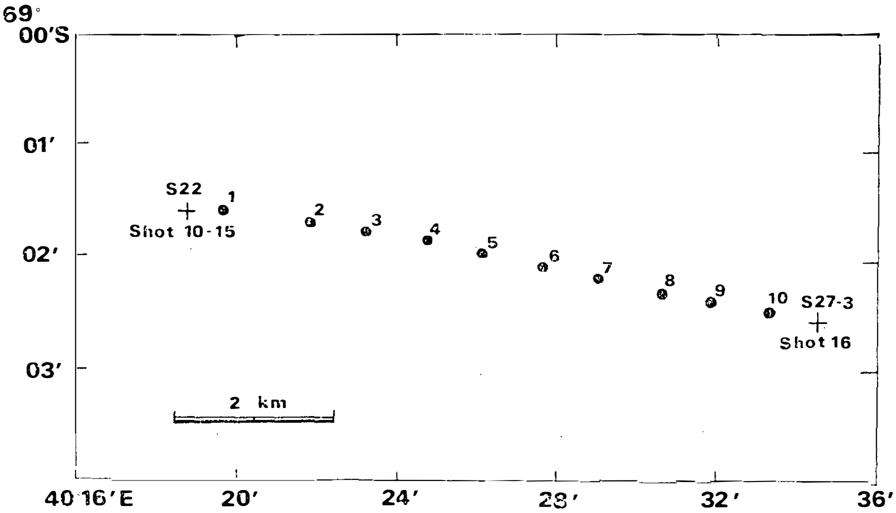

Fig. 1. Locations of shot and observation points for Shots 10–16.

10 to 100 kg were fired at S22 at the depths of 5 to 30 m. The largest explosion of 100 kg was used to derive the upper crustal structure. The same amount of explosive (Shot 16) was fired at S27-3 as a reverse shot. Charge sizes, shot depths and shot times for Shots 10–16 are given in Table A-1 of Appendix.

The positioning of the shot and observation points was planned to be made by satellite surveying. The position, however, had to be determined by distance-meters of over-snow vehicles and hand-bearing compasses in July, because of a trouble of the satellite surveying receiver (JMR). The two shot points were fixed in November by the satellite receiver and observation points were calculated from the results of November and the results of the survey in July. The error in the location is about 100 m.

The observation stations were installed on the ice-sheet surface at intervals of about 1 km. At each station a vertical component seismometer with a natural frequency of 2 Hz was set in the ice sheet at a depth of 30–50 cm. To keep the seismometer vertical, it was attached on the top of a 1-m long rod which was buried vertically in the ice sheet. The signal from the seismometer was recorded with a four-channel magnetic tape recorder of direct analogue type with an electric panel-heater in an insulated box. At stations No. 2 and No. 5, seismometers were set at the depths of 3, 5 and 10 m in drill holes as well as on the surface of the ice sheet. The recording and reproducing systems are the same as those of the explosion seismic experiment conducted in the vicinity of Ongul Islands in May 1980 (ITO *et al.*, 1984).

The time signal from each crystal clock set in the recorder was calibrated by a master clock to keep time accuracy within 0.01 s. As some clocks were disordered by intense static-electricity caused by blizzard (IKAMI and ITO, 1984), the calibration was made within ten hours before and after each shot.

The experiment was conducted by K. SHIRAISHI, K. SHIBUYA, K. KATAOKA, R. KATO, H. OHMORI, S. KOMAGATA, K. MATSUHARA, Y. NAKAMURA and the present authors during a period from July 15 to 31, 1980 during which period the air temperature was −30°C.

3. Upper Crustal Structure

The seismograms of Shots 12 and 16 are shown in the form of record section in Figs. 2 and 3 respectively. The explosives of 100 kg gave arrivals large enough to pick up the first arrivals at 10 km from the shot point. Direct wave through the ice sheet, refracted and reflected waves from the basement rock are seen in the record sections (Figs. 2 and 3). The later arrivals as well as the first arrivals were picked up and are shown in Figs. 4 and 5 in the form of reduced travel-time graph with a reduction velocity of 6 km/s to emphasize a velocity around 6 km/s.

We first estimate the general trend of the boundary between the ice sheet and the basement on the assumption of a homogeneous layered structure using a conventional method of analysis. Two linear lines are fit to the observed travel times corresponding to the direct (t_1) and the refracted (t_2) waves by a method of least squares for Shots 12 and 16. The obtained travel times for Shot 12 are as follows:

$t_1 = D/3.9,$

$t_2 = D/5.81 + 0.208,$

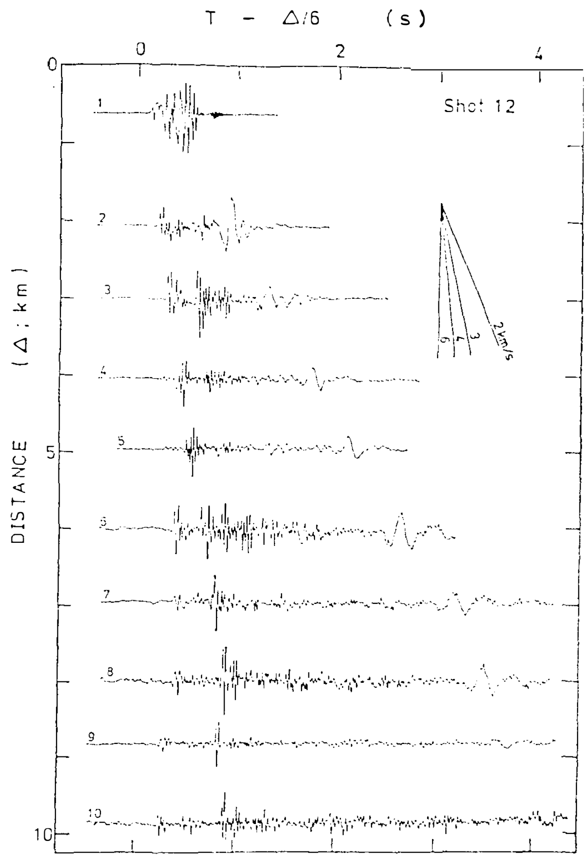

Fig. 2. Record section for Shot 12. Numerals are station numbers shown in Fig. 1.

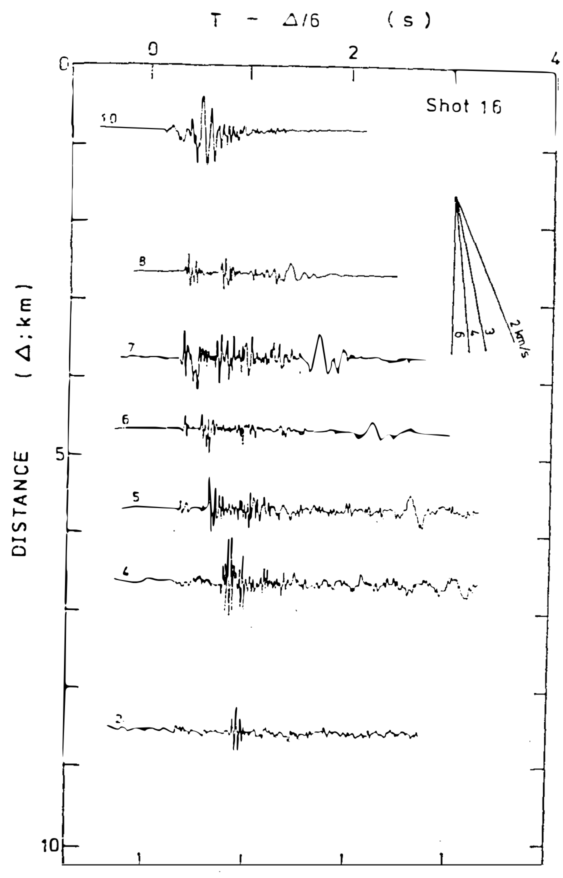

Fig. 3. Record section for Shot 16.

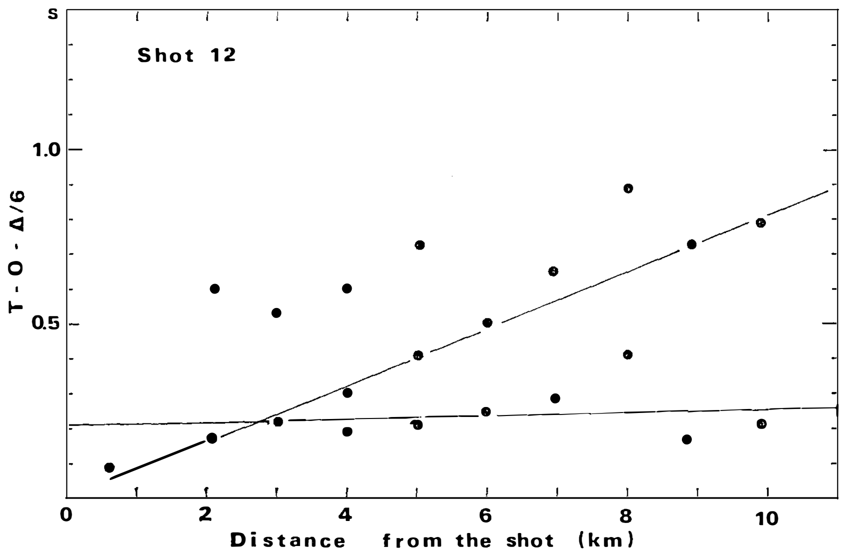

Fig. 4. Reduced travel-time plots for Shot 12.

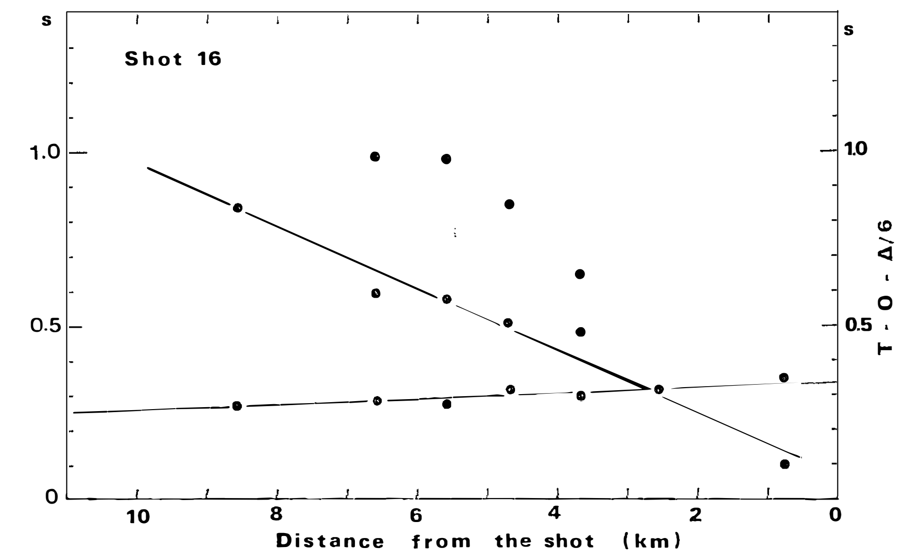

Fig. 5. Reduced travel-time plots for Shot 16.

where D is a shot-detector distance in km, and for Shot 16,

$$t_1 = D/3.9,$$

$$t_2 = D/6.25 + 0.333.$$

From the resultant travel times the inclined boundary between the ice sheet and the basement is calculated and shown in Fig. 6 by a broken straight line. The basement velocity is also obtained as 6.02 km/s from the analysis. Then the bedrock topography is derived by using the basement velocity and the observed travel times, calculating the time-term at each station and converting the time-term into the thickness of the ice sheet. The result is illustrated in Fig. 6 by solid circles and a solid line.

In Fig. 7 travel-time curves calculated for the obtained structure with a straight dipping boundary (dashed line in Fig. 6) are inserted in the record section for Shot

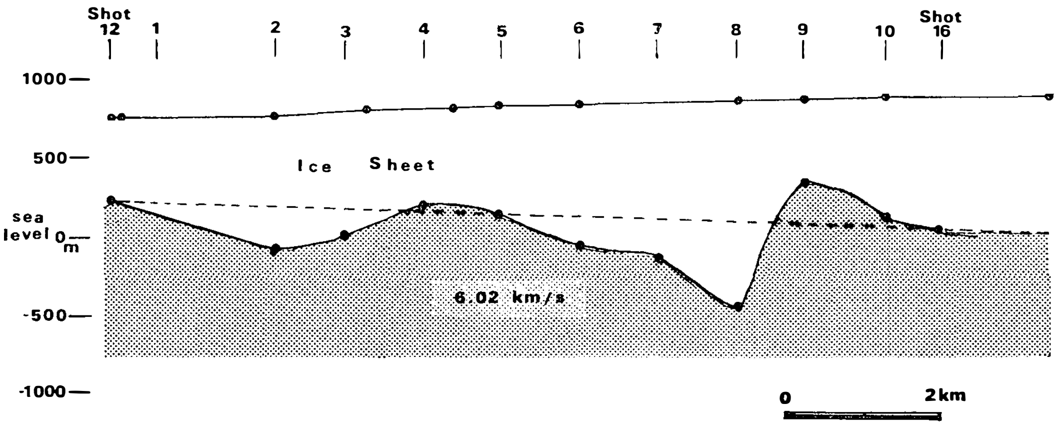

Fig. 6. Upper crustal structure revealed in the experiment. Surface elevation is after NARUSE *and* YOKOYAMA *(1975).*

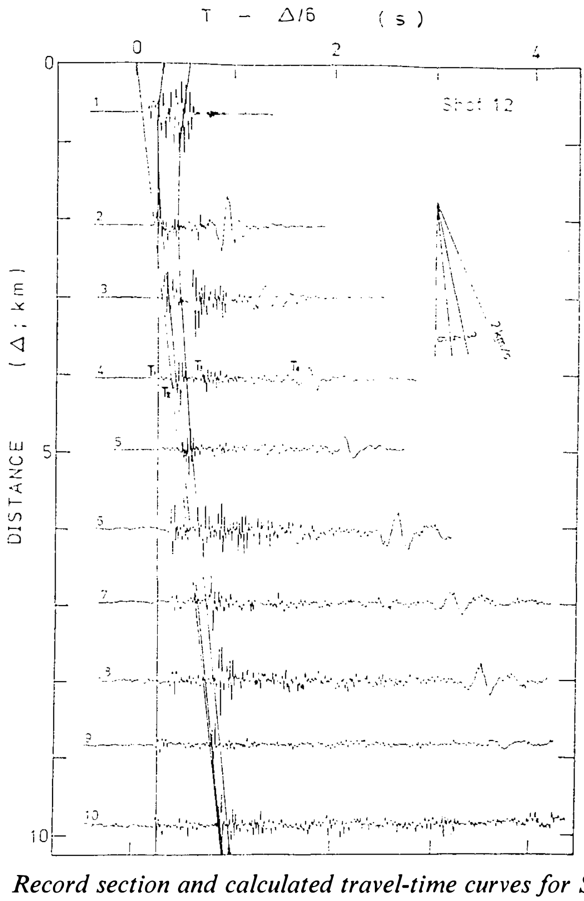

Fig. 7. Record section and calculated travel-time curves for Shot 12.

12. Similar result was obtained for Shot 16. Several remarkable phases are seen in the record section. Phase T_1 is a refracted wave from the basement complex, T_2 is a direct wave through the ice sheet or a reflected wave from the basement, T_3, though not obvious, seems to be a double-reflected wave from the basement, and T_4 is a surface wave propagating through the ice sheet. The calculated travel-time curves for T_1 and T_2 agree well with the observed phase. The agreement is not good for T_3, because

the travel time of double-reflected wave is very sensitive to the depth of the basement rock. If the depth of the reflected point is varied by 200 m, it easily varies by 0.1 s. For T_4 an analysis of the surface wave is made by IKAMI and KAMINUMA (1984) to deduce the structure of the ice sheet, considering phase T_4 as a Rayleigh wave propagating through the ice sheet.

As travel times T_1 and T_2 agree with those calculated for the model shown in Fig. 6, there is no reason to assume a layer with a velocity less than 6 km/s between the ice sheet and the basement in the surveyed area. If a layer with a velocity less than 6.0 km/s exists at the boundary, it must be very thin. This supports the results that the basement velocity of 6.0 km/s is typical and that the layer overlying the basement is no more than 0.5 km thick in East Antarctica (BENTLEY, 1973).

The bedrock topography under the ice sheet along the profile was previously measured by radio-echo soundings in 1969–1971 (SHIMIZU *et al.*, 1972), in 1973–1974 (NARUSE and YOKOYAMA, 1975) and in 1979 (WADA *et al.*, 1981). The data are now being reanalyzed together with the data of 1982 by JARE-23. According to the preliminary result, the bedrock is nearly at the sea level and its slope is gentle in the surveyed area of this study (NISHIO, personal communication). The irregularity of the bedrock topography obtained in the experiment (Fig. 6) may indicate a layer between the ice sheet and the basement. When the accurate bedrock topography is available, the layer overlying the 6 km/s one may be clarified.

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