Journal of Glaciology, Vol. 40, No. 134, 1994

Observations of a rift in the Ronne Ice Shelf, Antarctica

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ABSTRACT. During seismic profiling on the northwest Ronne Ice Shelf, Antarctica, a rift in the ice shelf was encountered. The rift trends southeast to northwest and is located approximately 30 km inland from the present-day ice front. The rift is 340 m wide and the surface elevation of the ice shelf drops by 14.65 m over the axis of the rift. The rift has an asymmetrical base with a near-vertical ice–water interface on its northeast flank and a more gently dipping ice–water interface forming its southeastern flank. The ice shelf thins from a thickness of 350 m away from the rift to a thickness of 225 m at the rift axis. The rift is the probable location of a future major calving event on this section of the Ronne Ice Shelf, an event which would release an iceberg of up to 30 km by 180 km into the Weddell Sea.

INTRODUCTION

The ice-shelf rift described here lies in the northwest corner of the Ronne Ice Shelf, Antarctica (Fig. 1), and shows up clearly on satellite images of the region (Swithinbank and others, 1987). During a seismic investigation of the sub-sea-bed structure in the area, the rift was encountered crossing the planned track of the second of our two seismic lines. The observations presented here will be of interest to those studying the calving behaviour of large ice shelves and to those interested in locating thinned ice shelf for easier drilling down to the ocean beneath the ice shelf.

SURFACE AND BASE PROFILES

Figure 2 shows an oblique cross-section of the rift. The surface profile, determined using a Geotronics 220 electronic distance meter, has sides sloping gently to a low point 14.65 m below the surrounding ice-shelf surface. The corresponding bottom profile was derived from the seismic reflection data (Fig. 3). To maintain maximum clarity of the base of ice return, only the near-offset traces are plotted. No gain control has been applied except that the amplitudes of the traces were balanced for the display to remove the effects of small differences in the power of the source explosions. The shots used were 2 kg of ammonium nitrate/fuel-oil explosive in 15 m deep holes. Note the nature of the base of ice return as a double pulse comprising the direct reflection followed after 16 s by the surface ghost.

In order to convert the time of reflection returns to depth, average velocities of 3500 m s^{-1} outside the rift and 3400 m s^{-1} inside the rift were used. These average P-wave seismic velocities were computed from short-offset seismic refraction records and from the refracted first arrivals which appear on the reflection data. The average velocity is lower than the P-wave velocity in ice (3860 m s^{-1}),

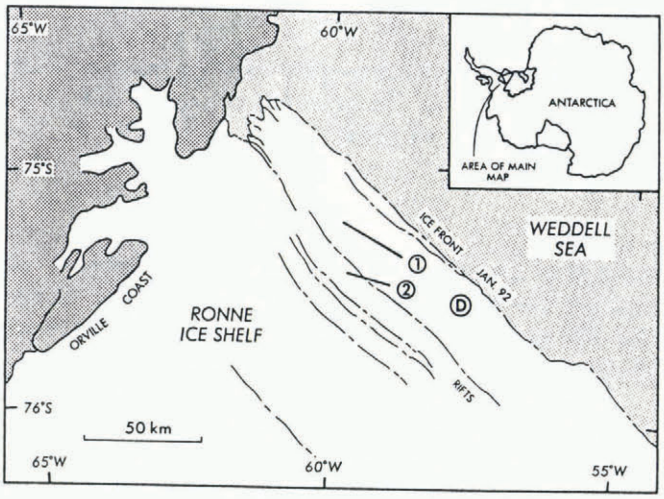

Fig. 1. Location map showing the northwest corner of the Ronne Ice Shelf, adjacent to the Orville Coast. The form of the ice front and rifts is taken from Swithinbank and others (1987). The positions of these features in January and February 1992 at the time of the work described were determined using GPS satellite positioning. 1, seismic line 1; 2, seismic line 2; D, Druzhhnaya II station (abandoned).

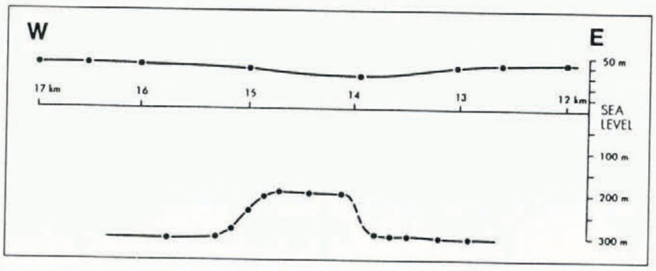

Fig. 2. Profile of the ice-shelf rift as determined along seismic line 2 marked in Figure 1. Surface heights were measured using an electronic distance meter. The base of ice profile is derived from the seismic reflection results.

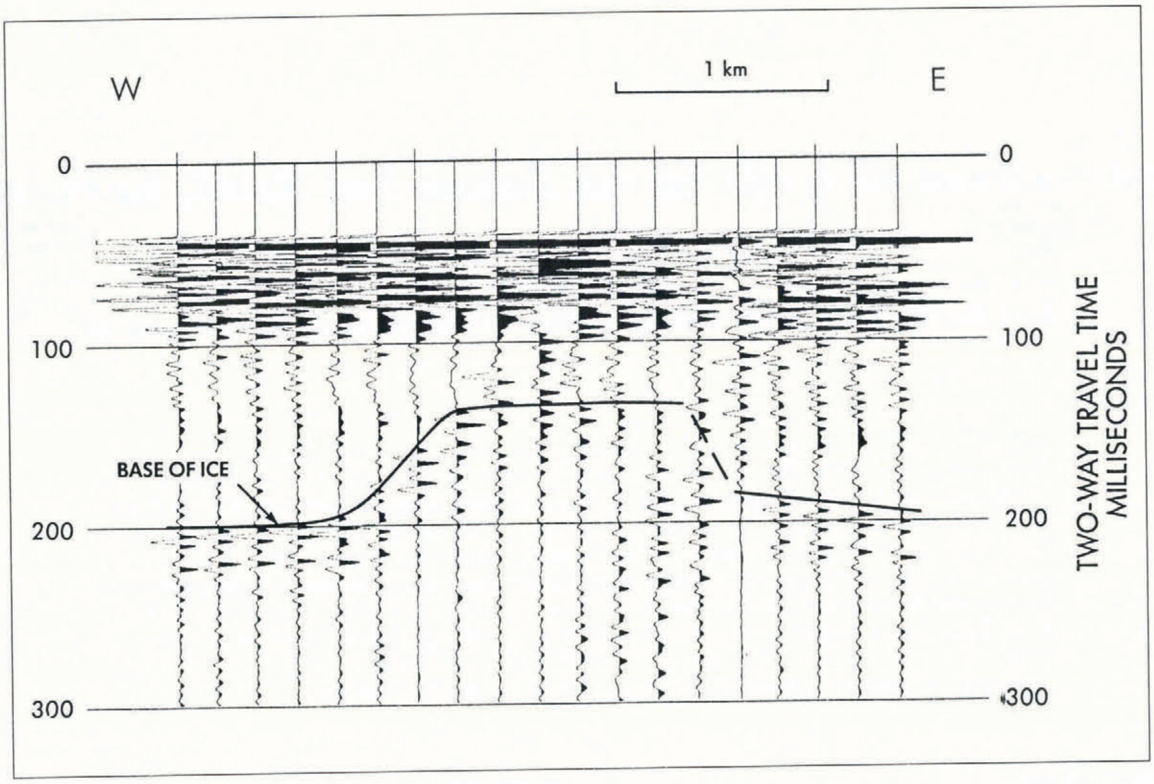

Fig. 3. Display of near-offset seismic traces over the ice-shelf rift. Trace spacing is 150 m. No filtering or gain adjustment has been applied. The source was 2 kg explosives in 15 m deep holes. Receiver array was a drag cable with 50 m groups and 24 geophones per group.

because of the influence of the low-velocity firn near the surface. The lower average value for the velocity within the rift arises, because a larger proportion of the total thickness at this point is composed of firn.

The thickness of the ice shelf away from the rift is about 350 m, whereas within the rift the thickness is 225–230 m. The profile crosses the rift at an oblique angle, hence the apparent width of 1 km represents a true width of about 340 m (using the base profile to define the width rather than the surface profile).

Average densities for the ice shelf can be derived from the refraction velocity profiles. The densities are 0.872 Mg m^{-3} outside the rift and 0.865 Mg m^{-3} inside it. The first figure implies a freeboard of 45 m for this general area of the ice shelf. The density of 0.865 Mg m^{-3} implies a freeboard of 31 m inside the rift. This gives a theoretical elevation change of 14 m, which compares favourably with the measured difference of 14.65 m. The rift structure is therefore in approximate hydrostatic equilibrium. However, the density of topographic and seismic data points is insufficient to say whether hydrostatic equilibrium is maintained all the way across the structure.

ASYMMETRY IN RIFT STRUCTURE

Figures 2 and 3 show that the gradient of the bottom of the ice shelf is steeper on the eastern than the western side, indicating a degree of asymmetry in the rift. This observation is emphasized when the full reflection record is examined (Fig. 4). It is important to note that Figure 4 shows a time section, not a depth section. The return from the sea bed beneath the rift occurs later than elsewhere and is an artifact produced by the thinner ice. This occurs because there is less high-velocity material (ice) and more low-velocity material (water) at this point. The result is a lower mean velocity and therefore greater travel time, even though the sea bed is at approximately the same depth all the way across the section. The apparent delay was used to confirm the interpretation of the base of ice reflection in Figure 3, given the assumptions that the sea bed was flat and that the velocity of sound in sea water at this location is 1445 m s^{-1}.

There is a group of returns dipping across the record from east to west in Figure 4. This is the only point on the two seismic profiles where such events were observed. The dipping returns have the form of hyperbolic diffractions with an origin coincident with the steepest part of the bottom profile. The diffractions are the result of a near-vertical ice–water interface with a high acoustic impedance contrast (i.e. a large change in either sonic velocity or density) at the base of the ice shelf. The near-vertical interface forms the eastern wall of the rift on the underside of the ice shelf and has acted as a point-scatterer of near-vertically travelling seismic waves (Fig. 3).

EVIDENCE OF DECOUPLING ACROSS THE RIFT

As part of the geophysical survey, gravity-meter readings were made along the line crossing the rift. The readings made on the ice shelf to the seaward side of the rift were

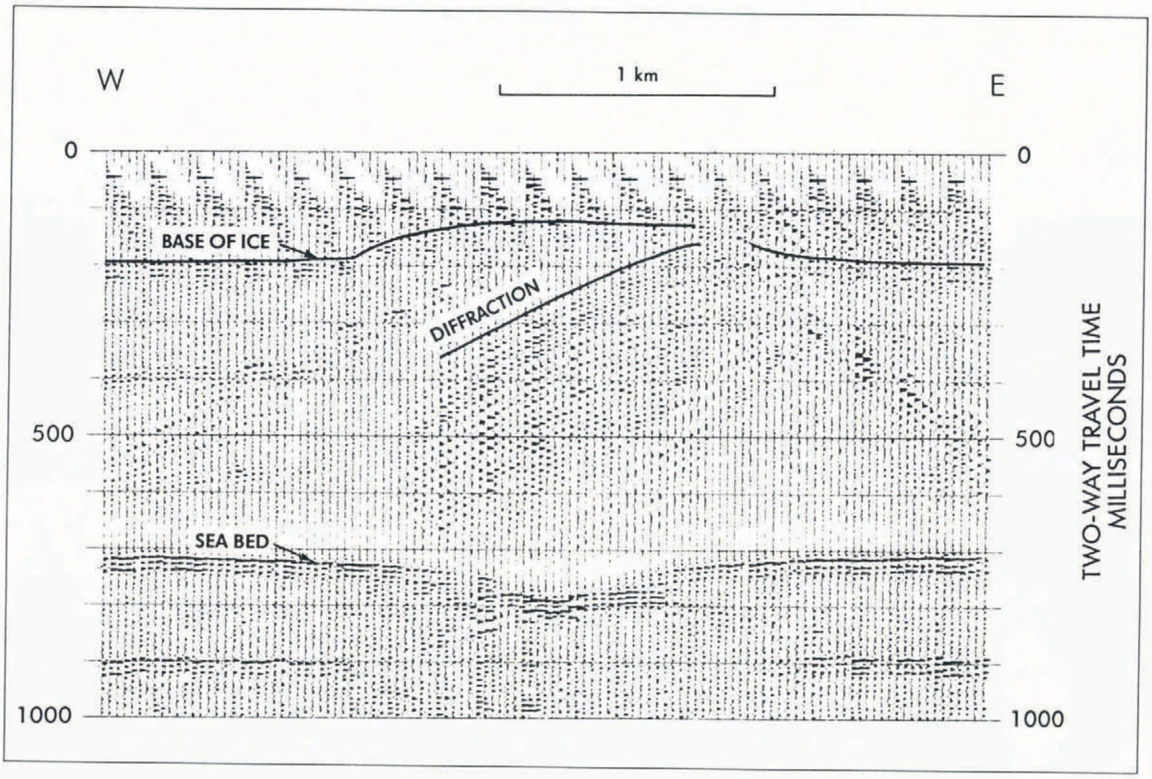

Fig. 4. Single-channel profile across the rift. Trace spacing is 25 m. Band-pass filtering and automatic gain control have been applied. The base of the ice shelf is the weak reflection at 200 ms two-way travel time. The sea-bed reflection is the strong event at between 700 and 800 ms. Apparent structure on the sea bed and the diffraction events are discussed in the text.

strongly affected by an ocean-swell component, causing the gravity-meter reading line to oscillate. The readings made on the opposite side of the rift were much less affected by the swell motion. This suggests that the sections of ice shelf on either side of the rift were moving with some degree of independence, although no evidence of surface crevassing indicative of differential movement was observed. However, when shooting the seismic line across the rift, one shot resulted in a strong secondary event. A narrow crack (~2 mm wide) opened up through the shot hole and parallel to the axis of the rift. This may have been either a partial bridge collapse into a crevasse or the collapse of a near-surface hoar-frost layer.

DISCUSSION

There are two reasons why these observations may be of interest. First, this rift is the most likely line along which the next major calving event for this section of the Ronne Ice Shelf will take place. If this were the case, an iceberg of dimensions 30 km by 180 km could result, which would include the abandoned Druzhnaya II station. Secondly, such rifts may provide suitable access points for drilling through the ice shelf for the purpose of oceanographic sampling or instrument placement where the drilling effort would be reduced.

ACKNOWLEDGEMENTS

These field observations were made with the able assistance of A. Bell, T. Bird, B. Hull and D. Routledge. E. Jarvis assisted with preparation of the manuscript.

REFERENCES

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The accuracy of references in the text and in this list is the responsbility of the author, to whom queries should be addressed.

MS received 15 January 1993 and in revised form 24 June 1993