Grid northeastward, under the smoother, deeper part of the ice-stream bed, the sediment layer thickens to 500 meters (figure 3). A deeper layer with a wave velocity between 6.0 and 6.2 kilometers per second is also indicated by the data.

In the ice itself, the maximum wave velocity is an anomalously low 3,813±3 meters per second, more like velocities in ice shelves than in the inland ice (Robertson and Bentley 1990).

Seismic reflection experiments. The seismic reflection experiments on ice stream C and the neighboring part of ridge BC (from Upstream C to ridge BC, figure 2; Bentley, et al. 1989) were designed to map the characteristics and extent, if any, of a subglacial layer that might once have been like the deformable debris layer beneath ice stream B (Blankenship et al. 1987b; Engelhardt et al. 1990). The two profiles processed to date show that the ice-sediment interface under ice stream C is very different from that under ice stream B. The base of ice stream B is strikingly smooth, particularly parallel to flow, whereas the base of ice stream C is rough; irregularities typically have a wave length on the order of half a kilometer and amplitudes on the order of 10 meters. The ice thickness changes by as much as 200 meters over a distance of 7 kilometers (see Bentley, et al., *Antarctic Journal*, this issue, figure 2). As around Upstream B camp, however, the bed is smoother along flow than across flow.

Both vertical and wide-angle reflections show the presence of a subglacial layer that varies in thickness from 0 to 15 meters. As at Upstream B, the lower boundary of the layer appears to be at a nearly uniform depth beneath the ice in the direction of flow but to vary in depth across flow. The phases of the reflections imply that this layer has an acoustic impedance slightly less than that of the ice, as does the deformable layer beneath ice stream B. In contrast, lodged till or solid rock would have an acoustic impedance greater than in the ice. This suggests that there is still a soft layer beneath ice stream C even though the ice stream is inactive. If our analysis is correct, it implies that the shut-down of ice stream C (at least around Upstream C) cannot be attributed to removal of deformable sediments—more likely, it was loss of water pressure in the sediments that was responsible. We speculate that pressure loss was non-uniform, and that the irregularities in the ice-bed interface along flow developed while only portions of the bed were mobile.

Geophysical and Polar Research Center contribution number 512.

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Analysis of radar data

C.R. Bentley, R. Retzlaff, A.N. Novick, *and* N. Lord

Geophysical and Polar Research Center
University of Wisconsin
Madison, Wisconsin 53706

Radar fading-pattern experiment. During the 1987–1988 austral summer, a fading-pattern experiment was performed near the end of the season at Down B camp, on the ice plain of ice stream B (Bentley, Blankenship, and Moline 1988). It consisted of repeated radar reflection profiles run precisely over a 1-kilometer line of negligible ice-bottom relief at a very low vehicle speed (approximately 2 kilometers per hour) to delineate the detailed character of the bottom returns. The line was at an angle about 20° to the flow direction. The purpose of the experiment was to determine the differential movement rates between the surface and bed of the ice stream at a location on the ice plain. Eighteen transects were completed over a period of 8 days.

Figure 1 is a comparison of two radar-reflection images of a 35-meter section of the line. Of particular interest is the transition area at flag 330 where a strong return becomes abruptly weak in a distance of about a meter. Such transitions occur several times along the 1-kilometer line. There was no discernable change in the surface location of these transition zones over the duration of the experiment. Since the basal reflection pattern moves with the base of the ice, this allows us to place an upper limit on the differential motion between surface and base of the ice of 0.1 meters per day, 7 percent of the 520-meter-per-year velocity of the ice stream. This means that differential shear strain in the ice is no more than this (an expected result) and that the base of the ice is moving without change in configuration with or through a yielding bed (which could be water).

Airborne radar. During the 1988–1989 austral summer, airborne radar was flown in gridded blocks, 110 kilometers on a side, over much of the upstream portions of ice streams B and

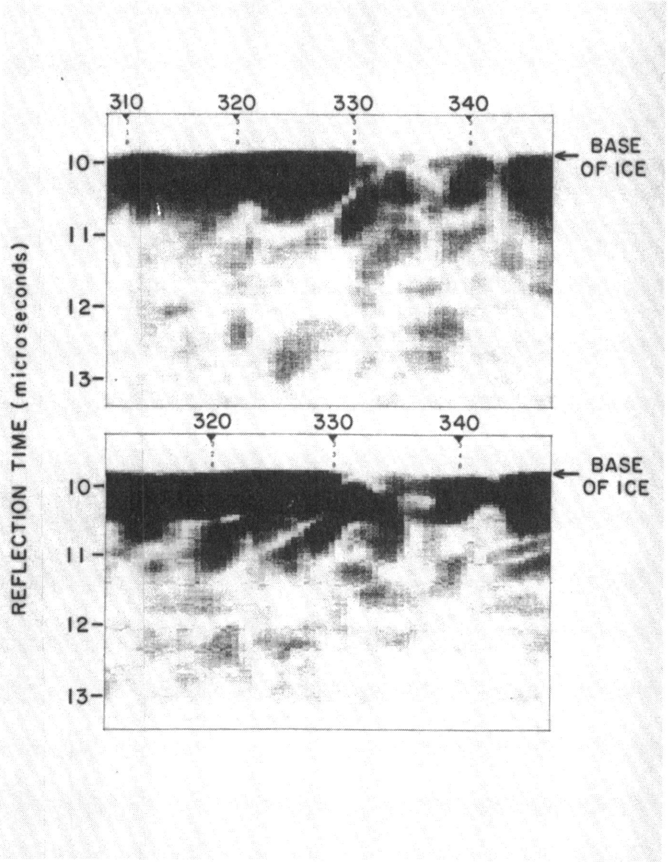

Figure 1. Two detailed reflection images of the same small section of the base of the ice on the "fading-experiment" line at Down B camp. The triangles at the top denote flag markers 10 meters apart. Recordings were 8 days apart, over which time the ice moved 11 meters to the left.

C and ridges AB and BC (Bentley et al. 1989). One transect, approximately along the main seismic line at Upstream C, is shown in figure 2. Preliminary unadjusted maps of surface elevation and ice thickness have been created for these blocks. Currently, crossover errors (discrepancies in the surface elevation and ice thickness measured on longitudinal and transverse flight lines at their crossing point) are being analyzed and corrected for. These crossover errors are caused mainly by navigational drift and changes in barometric pressure.

Crossover errors for surface elevation are treated as barometric rather than navigational (because of the small surface slope) and are minimized in a least-square sense by applying a height correction to each line. This minimization is a slightly underdetermined problem that is made solvable by constraining the sum of all height corrections to be zero. In addition to removing the large shifts due to inter-daily fluctuations in barometric pressure, this minimization also reduced the root-mean-square crossover error (in the one block examined to date) from 10 meters to 4 meters. Subsequent tying of surface elevation to known ground control points (measured by I.M. Whillans and associates at Ohio State University) will make the elevations absolute.

Crossover errors for ice thickness are treated as navigational and are minimized by applying a uniform translation to the position of each flight line while constraining the vector sum of the corrections to be zero. This minimization reduced the crossover error for ice thickness (in the same block) from 40 meters to 25 meters. Ground control points will again be used to locate the grid properly.

An automatic picker has been developed by which the computer automatically picks the ice-surface and ice-bottom reflections. The picker allows the user to select a time interval that brackets a section of an echo trace along a transect (see figure 2) and have the program automatically pick the arrivals within that interval. The program is interactive and mouse driven. A typical user can pick the transmit pulse and the ice surface and bottom echoes of a 1,000 trace file in about 5 minutes. The picker has worked well on traced with a signal-to-noise ratio as low as 2-to-1.

Short-pulse radar. The GSSI SIR-8 short-pulse radar was deployed on five profiles across the buried shear margin of ice stream C to detect the depth of the buried crevasses (see map in Bentley et al. 1989, for locations of profiles). A density-versus-depth curve obtained from a short-refraction seismic experiment was used to calculate a radio-wave velocity-versus-depth curve that was then used to convert reflection time to depth. Variations in depth to buried crevasses within individual profiles were found to increase with surface elevation slope (determined by airborne radar). This suggests that changes in surface slope affect the local accumulation rate.

After correcting the profiles for regional variations in accumulation rate along the ice stream (Whillans and Bindschadler 1988), it was found that there is no significant difference in the time of burial of crevasses for the downstream four profiles—all four indicate a shut-off time between 100 and 150 years ago. The profile farthest upstream, however, indicates an age of burial only about half that of the other profiles, which suggests a more recent shut-down for the upstream portion of ice stream C. Furthermore, open crevasses were seen from the air within 10 kilometers of the ice-stream end of the profile and at a few other nearby locations along the grid southwestern margin of the ice stream. Whether this indicates continued activity or a recent reactivation of the ice stream at its upstream end is uncertain.

Buried crevasses were detected everywhere along the tens of kilometers of lines that were profiled in the vicinity of Upstream C. Individual crevasses were correlated by profiling on a 700-meter square grid near Upstream C camp. A primary set of buried sub-parallel crevasses exists; the crevasses are aligned very nearly along the axis of the ice stream. Unfortunately, we cannot tell whether the crevasse orientation on the test grid is representative of a more extensive region.

Geophysical and Polar Research Center contribution number 513.

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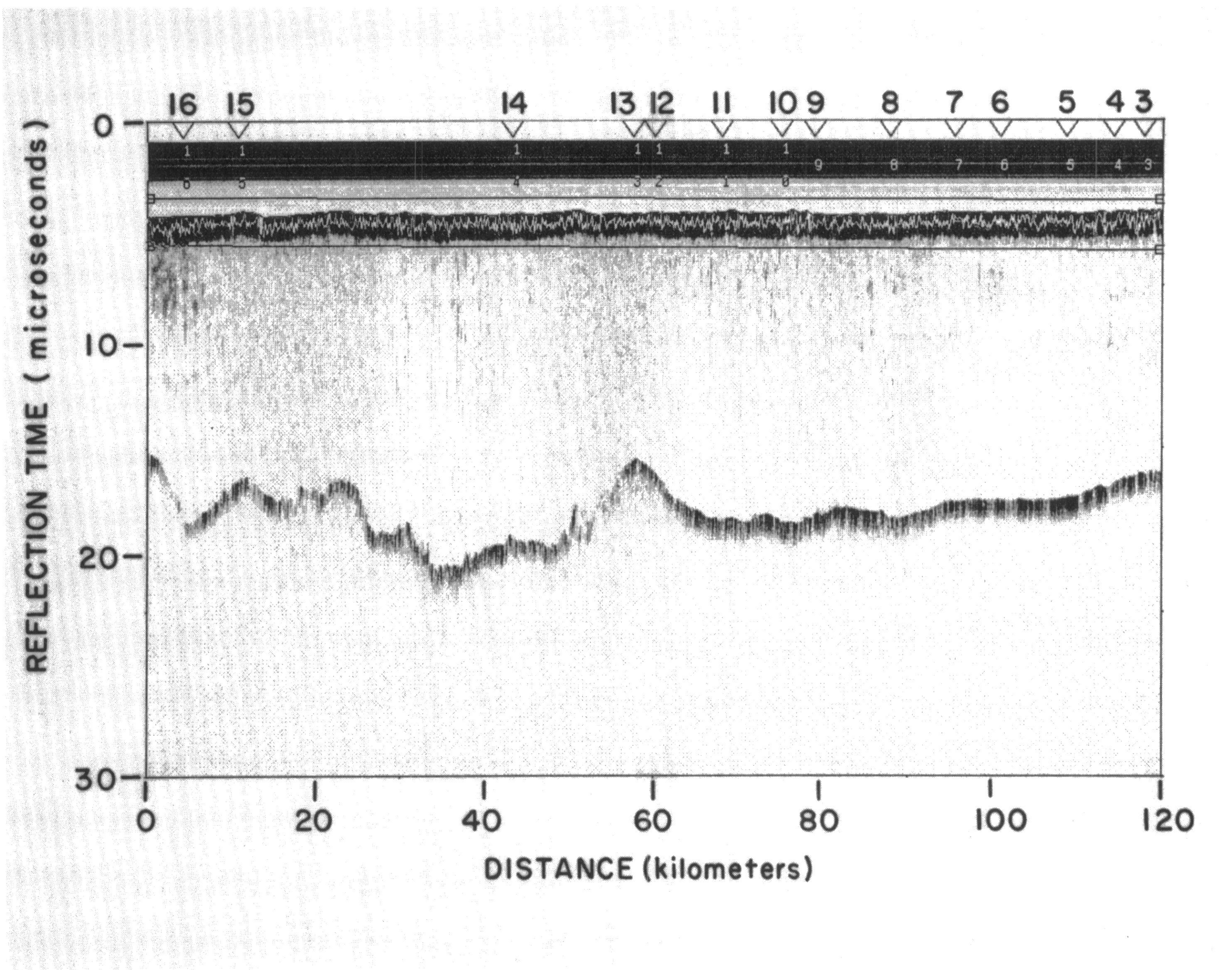

Figure 2. Airborne radar profile across ice stream C from ridge CD to ridge BC. Upstream C camp was at marker 11; the center of the seismic recording array was between markers 12 and 13 (offset a few kilometers downstream). The surface echo is at about 4 microseconds and the bed echo is between 15 and 21 microseconds. The straight lines above and below the surface echo exemplify the brackets within which the autopicker looks.

Glaciological observations on Dyer Plateau, Antarctic Peninsula

C.F. RAYMOND *and* B.R. WEERTMAN

Geophysics Program
University of Washington
Seattle, Washington 98195

The British Antarctic Survey, Byrd Polar Research Center, University of Washington, and the Polar Ice Coring Office continued a cooperative program to obtain paleoclimate data from near latitude 70°S in the Antarctic Peninsula. In 1989–1990, a field program was carried out on the crest of Dyer Plateau (70°40'S 64°50'W), which included ice coring to 235-meter depth, near-surface sampling in pits, and various geophysical measurements. This article summarizes geophysical measurements carried out by the University of Washington. Ultimately, these data will serve as input to flow models for prediction of the distributions of age and finite strain beneath the ice divide and adjacent flanks and as tests for evidence of past variations in the mass balance and dynamics of the ice sheet.

Geophysical measurements included geodetic surveying of an extensive marker network, satellite location of three markers, radio-echo sounding traverses, marking of core holes for vertical strain measurement, and snow accumulation.