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Dome C geophysical survey, 1979-80

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The geophysical survey of Dome C was continued between late November 1979 and late January 1980 (see figure 1 for survey area). Geophysical measurements included radar sounding, seismic shooting, geoelectric sounding, gravity and magnetic surveying, and magnetotelluric recording. In addition, a joint geoelectric survey and radar-sounding program was carried out with a geophysical team from the University of Münster, West Germany (see Thyssen and Shabtaie, *Antarctic Journal*, this volume).

Radar sounding. Nearly 100 kilometers of radar-sounding profiles were made around Dome C camp using a 35-megahertz system (figure 1). Accurate ice thickness measurements were made at intervals of 1 kilometer or less. The glacial bed at Dome C is a poor reflector; signals were enhanced by improving the impedance matching system of the radar antenna. A new thermal intensifier, which uses heat sensitive paper, greatly increased the quality of the records from the Honeywell Visicorder. These improvements made it possible not only to record echos from the bedrock, but sometimes to detect up to three echos from layers 30 to 100 meters above the ice-rock interface (figure 2a). Several profiles of normal internal layering were made, especially near the 900-meter borehole at Dome C; no reflectors of this type were observed below a depth of 2.4 kilometers. Detailed ice-thickness measurements carried out around the borehole site show a very rough bedrock topography (figures 2b and 2c).

At several sites the radar profiling showed abnormally strong bottom echos (figure 2d) that may represent sub-glacial water channels.

A common-reflection-point experiment to obtain electromagnetic wave velocities in the ice at 35 megahertz was

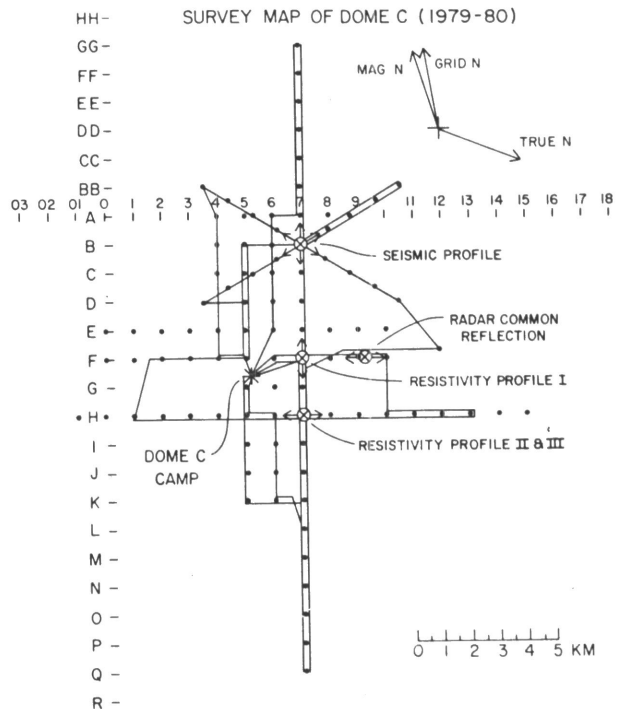


Figure 1. Geophysical survey map of Dome C. Dots (•) indicate the position of flag markers; crossed circles (⊗) show the center of a profile; lines (—) represent the surface radar sounding profiles; and arrows (→) show the direction of profiles. Dome C camp and the 900-meter borehole are located at 74°39'S 124°10'E and are at an altitude of 3,240 meters.

carried out to a maximum antenna separation of 2 kilometers (figure 1). For this experiment, the echos were recorded in four different ways: In A-display form on film, in intensity-modulated form using the Honeywell Visicorder, and in both raw and signal-averaged form on magnetic tape using the University of Münster's digital recording system (see Thyssen and Shabtaie, *Antarctic Journal*, this volume).

D.C. electrical resistivity. Before the 1978-79 season *in situ* direct current resistivity measurements had not been made on the antarctic polar plateau; measurements had been taken only on ice shelves (Bentley 1977; Hochstein 1967; Reynolds and Paren 1980; Shabtaie and Bentley 1979). During the 1978-79 season, a detailed direct current electrical resistivity profile was made at Dome C (Bentley, Jezek, Blankenship, Lovell, and Albert 1979), but the electrode spacing was limited to 1 kilometer. Earlier electrical resistivity studies on the Greenland Ice Sheet (Meyer and

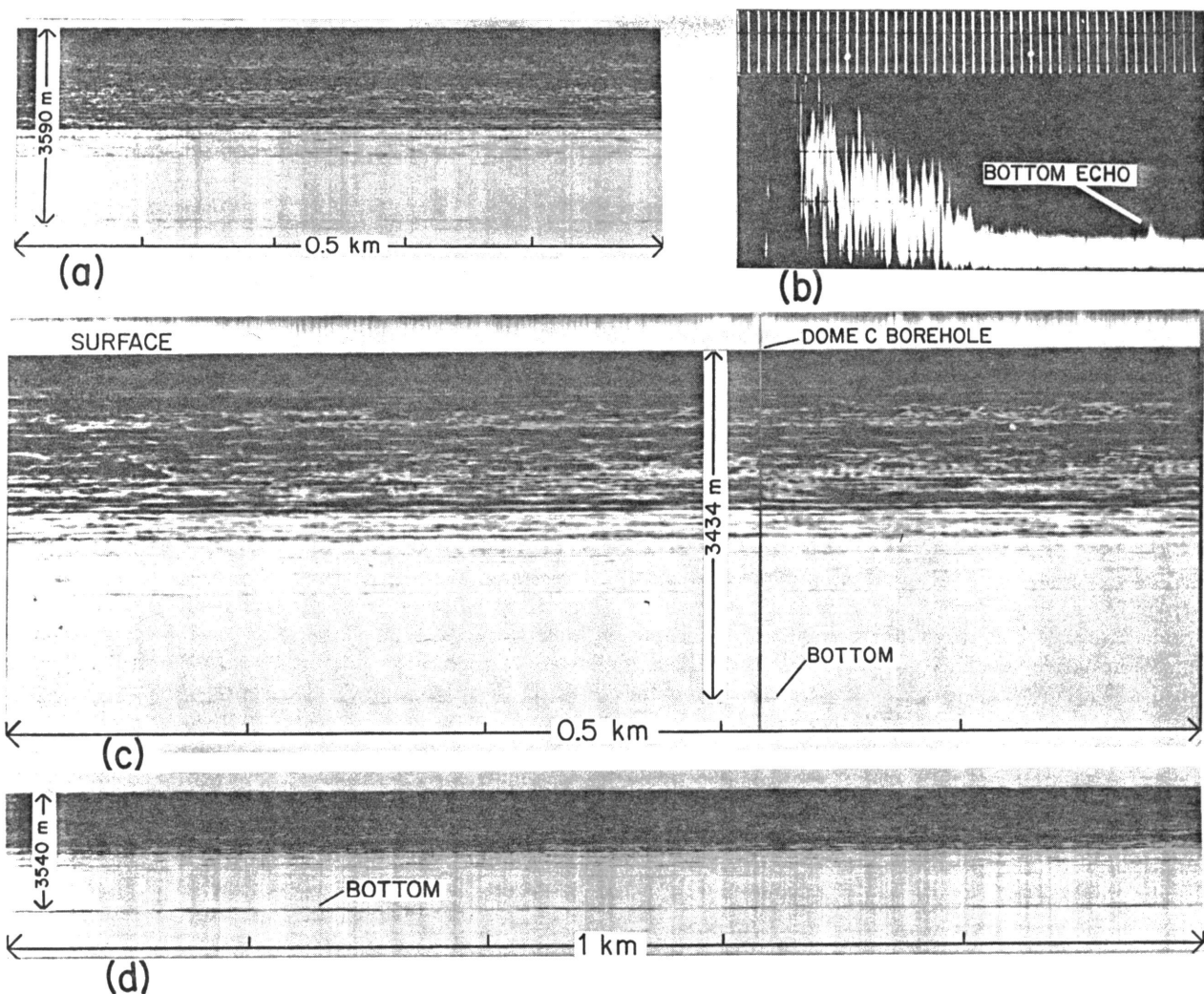


Figure 2. Examples of University of Wisconsin film records of ice thickness at Dome C using 35-megahertz radar (antenna separation, 30 meters; attenuation, zero decibels). (a) is a section showing a multi-echo pattern at the bottom. (b) is an example of an "A-scope" trace at the 900-meter borehole site; the top of the transmitted pulse is not shown, and the peak near the right side represents the bottom echo (echo strength 14 ± 2 decibels). The two-way travel time is $39.7 \pm .1$ microseconds, which corresponds to about 3,430 meters in ice thickness (using an average velocity of 173 meters per microsecond). (c) is a cross-section of the ice sheet at the Dome C borehole showing a fading bedrock echo. (d) is an area where the ice is thought to be at the pressure-melting point. At some locations the bottom echo strength is as high as 25 decibels above the receiver noise that may represent echo from subglacial water channels.

Rothlisberger 1962; Thyssen, personal communication) and on the Devon Island Ice Cap (Vögtli 1967) indicated the presence of a basal ice layer of relatively high resistivity. This phenomenon was also observed on the Ross Ice Shelf at locations associated either with major ice streams from West Antarctica or with large outlet glaciers from East Antarctica (Shabtaie and Bentley 1979). Further examination of this phenomenon was a major objective of the joint project with the University of Münster. Since the ice at Dome C is about 3,400 meters thick, resistivity profiles with electrode separations of many kilometers were needed to obtain any information about the existence of the highly resistive basal ice layer or the thermal condition of the bedrock.

Three profiles with maximum half electrode separations of 6, 8, and 2 kilometers were made, using Schlumberger

arrays (figure 1). The techniques used for the two longer profiles are discussed by Thyssen and Shabtaie elsewhere in this volume. The third profile was completed using transmitter voltages up to 4 kilovolts supplied by dry cell batteries. The contact resistance of the current electrodes was reduced considerably by employing multiple electrodes, resulting in currents of up to 4 milliamperes. On this profile, different combinations of source voltages, current and potential electrode types, and separations were tested. A new chart recorder was used to record the potential values continuously as they decayed to a steady-state value.

Magnetotellurics. Magnetotelluric experiments begun during the 1978–79 field season were completed using a new microprocessor-controlled recording system. Approximately 40 hours of data were recorded on digital tape and

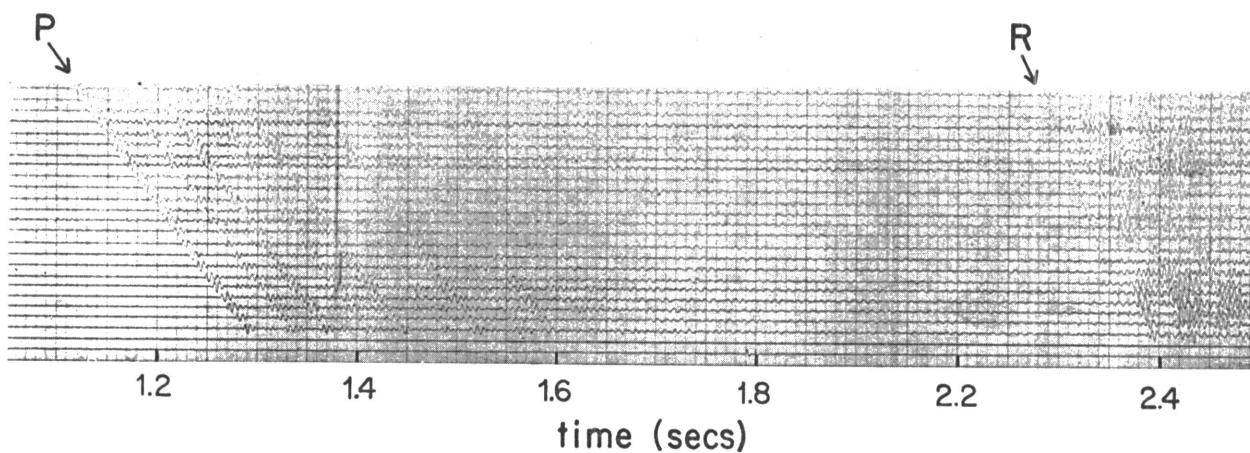


Figure 3. Seismic reflection record; the geophones have 30-meter separations, with number 1 located 4,000 meters from the shot. P is the first compressional wave arrival, and R is the reflection from the ice-rock interface. A 0.91-kilogram charge at a depth of 35 meters was used.

chart recorder for later analysis. Measurements were made at periods ranging from 0.5 to 600 seconds. Preliminary results confirm the efficacy of the magnetotelluric method on ice sheets. We hope that analysis of this year's data will yield an independent determination of the thickness of the earth's crust beneath the antarctic continent.

Gravity and magnetics. The series of gravity ties between McMurdo and South Pole Stations was continued, and a tie done during the 1978-79 season to the Ohio State University "fairy ring" approximately 1 kilometer from South Pole Station was repeated.

At Dome C, a 22-kilometer gravity survey was carried out at 1-kilometer intervals along the grid north-south seismic/resistivity line. Magnetic measurements at 50 grid points were completed at Dome C. Preliminary analysis of these data indicates that any sedimentary layer below the ice is at most no more than a few tens of meters thick.

Seismic. The 1979-80 seismic program at Dome C was provided with a number of good shooting holes by personnel from the Polar Ice Coring Office of the University of Nebraska-Lincoln. The work was carried out along a series of three lines, at 60° angles to one another and with a mutual center (figure 1). Ten- and 30-meter shot holes were drilled at approximately 1-kilometer intervals along the portions of the three lines grid south of the center, while recording was done along the grid northern portions. The primary recording system was our standard 24-channel SIE analog unit, but many of this year's shots were also recorded digitally. The digital systems included a portable 24-channel unit and a 3-channel self-triggered event recorder (developed by the Geophysical and Polar Research Center seismology group directed by R. P. Meyer), which was being tested for applicability in the Antarctic.

The experiments included a wide-angle reflection profile, a compressional wave refraction profile, two large-separation refraction shots, and extensive surface-wave

recording. The wide-angle experiment was done by the common-reflection-point technique, with 18 recording stations located along the three lines. The reflections obtained were of good quality (figure 3); together with refraction work, they will allow us to study the wave velocities throughout the ice sheet and the rock immediately beneath it. The large-separation refraction shooting was done using a pseudo-reverse technique (Cunningham 1974). Charges of 387 and 702 kilograms were used for the two shots, both of which were fired at shot-receiver separations of 30 kilometers. The apparent velocities were $5.76 \pm .06$ kilometers per second and $6.05 \pm .08$ kilometers per second, respectively. A total of 96 two- and three-component seismograms at eight stations were recorded for surface wave studies. The maximum shot-receiver separation was 10.7 kilometers.

The field party consisted of S. Shabtaie, D.D. Blankenship, J. S. Lovell, and R. Gassett from the University of Wisconsin at Madison. Some of the profiles were surveyed by W. Zick using the electro-optical distance measurement of AGA-Geodimeter 14 and Zeiss Edi 1. We would like to thank Stephen Jones for the use of his 35-megahertz radar set.

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New nonmarine fossil links in Gondwana correlations and their significance

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Africa. I explored the Cave Sandstone conchostracan-bearing beds in southern Africa (Republic of South Africa and Lesotho) from mid-May to mid-June 1979, aided by Johann Looek, University of Bloemfontein, and found new species of *Cyzicus*, *Paleolimnadia*, and *Cornia*. These genera also occur in the Angolan Phyllopod beds, indicating that these beds and their equivalents in the Cave Sandstone are time-correlates (Tasch in press).

China. Ribbed conchostracans from the Chinese Devonian (Gitou Formation, Middle Devonian, Le Chang, People's Republic of China) include *Leaia*, *Hemicycloleia* (reassigned to *Leaia*; Tasch in Tasch and Jones 1979), *Trileaia*, and *Rostraleia* (Shen 1978). As a guest of the Nanking Institute for Geology and Paleontology during July 1979, I compared these finds with my own field collections in company with Chinese colleagues. I also studied Paleozoic and Mesozoic types on deposit at the Institute.

The Chinese ribbed forms had never been reported below the Carboniferous. However, *Leaia* and/or *Leaia* (*Hemicycloleia*) is known from the Carboniferous of the USSR (Donetz Basin) (Tasch in press), western Australia (Canning Basin) (Tasch and Jones 1979), and eastern Australia (Drummond Basin) (Tasch and Jones 1979). These

occurrences clearly denote a northern and southern dispersal from eastern China by Carboniferous time, to both the USSR and Australia.

This new information puts in question the continental reconstructions for the Devonian-Carboniferous that have a sea separating Gondwana Australia from China (Scotese, Bambach, Barton, van Der Voo, and Ziegler 1979, figures 20 and 26). A nonmarine dispersal track is necessary between these two land masses sometime after Middle Devonian and by Lower Carboniferous time. The duration of such a track between the two areas is not at issue. Even if ephemeral, its existence is a prerequisite to explain the data mentioned.

The inference reported was supported independently by a presentation at the Fifth Gondwana Symposium (Wellington, New Zealand) by Harrington (in press), who hypothesized that Australia separated from Southeast Asia and Antarctica at the same time, i.e., "during opening of the Indian Ocean."

India, Antarctica, Australia. Collections of fossil conchostracans in India (Kota Formation, Jurassic; Panchet Formation, Triassic), in the western Australia Triassic, and the Transantarctic Jurassic in the past pointed to proximity of the three continents during Triassic-Jurassic time (Tasch, Sastry, Shah, Rao, Rao, and Ghosh 1975, p. 451). However, continental reassemblies at the time (1973, published in 1975) showed Gondwana India in contact either with Antarctica or Australia, but never both simultaneously—that is, until recently. Curray and Moore (1974) added area to Gondwanic India that existed prior to subduction under the Asian plate and placed India proximate to both Antarctica and Australia (figure). This reassembly meets the requirements of the nonmarine conchostracan fossil data from the three continents.

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