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THE ROSS ICE SHELF GEOPHYSICAL AND GLACIOLOGICAL SURVEY (RIGGS): INTRODUCTION AND SUMMARY OF MEASUREMENTS PERFORMED

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Abstract. By the end of the 1960's the Ross Ice Shelf was already one of the better explored regions in Antarctica, yet glaciological and geophysical measurements had been limited largely to studies at Little America, the International Geophysical Year traverse loop around the shelf, and an L-shaped movement survey. Consequently, when plans were being made for drilling an access hole to the ocean beneath the interior of the shelf, it was decided to conduct an airlifted survey covering the entire ice shelf: the Ross Ice Shelf Geophysical and Glaciological Survey (RIGGS). Measurements of many kinds were carried out at the 200 RIGGS stations over the 5-year period 1973-1978. Quantities determined included accumulation rate, strain rate, ice thickness, subglacial water depth, and gravity at 75-95% of the sites; temperatures and movement rate at 40-50% of the sites; seismic and radio wave velocities and electrical resistivities at 10-20 sites; and radar polarization at six sites. More extensive programs, including core drilling to 50-100 m, tidal-gravity recording, and long seismic refraction profiles to investigate submarine geologic structure, were carried out at 10 primary and supplementary base camps. In addition, 13,500 km of airborne radar sounding were completed. Detailed seasonal tabulations of the types and locations of measurements are presented in this paper, along with a brief season-by-season narrative.

Introduction

The Ross Ice Shelf is a tabular mass of thick, permanent (on a human time scale) floating ice attached to the grounded Antarctic ice sheet. Lying between 160°E and 150°W longitude and 78°S and 85°S latitude and bounded on the south and west by the Transantarctic Mountains, on the north by the Ross Sea, and on the east by Marie Byrd Land (Figure 1), the shelf covers about 520,000 km^2 (slightly larger than Spain; slightly smaller than France). It has been a familiar feature of the southern continent since it was discovered by James Clark Ross, aboard *Erebus* and *Terror* in 1841. Roald Amundsen (from "Framheim" next to the Bay of Whales) and Robert F. Scott (from Ross Island) both used the Ross Ice Shelf as an access to the deeper interior of the continent, and Wright and Priestley [1922], with Scott's expedition of 1910-1913, carried out extensive studies of the ice shelf in the vicinity of Ross Island.

Pre-RIGGS Measurements

Measurements of surface heights across the ice shelf were made on both Scott's and Amundsen's 1911-1912 journeys to the south pole (Figure 2). Along Scott's route the height increased to 50 m at 79°S and then remained essentially constant to 83°S, a fact taken as a clear demonstration that the ice shelf is afloat [Wright and Priestley, 1922; Simpson, 1923; Wright, 1925]. The same flat character was found on Amundsen's route across the eastern ice shelf, along which the corresponding figure was 60 m [Mohn, 1915; Simpson, 1919]. Amundsen's eastern party under K. Prestrud also discovered the grounded ice of Roosevelt Island, measuring a maximum surface elevation of about 260 m some 65 km south of "Framheim."

Further confirmation that the ice shelf is afloat came with the first inland measurement of its movement rate. "The fortunate rediscovery of one of Scott's *Discovery* depots by members of Shackleton's *Nimrod* Expedition gives a good average value for the movement of this point in an interval of 6 1/2 years. Roughly, the annual movement off Minna Bluff was found to be about 500 yards in a north-northeasterly direction. The rate of movement is large . . . and may possibly be taken as confirmation of the fact that the Ross Barrier is generally afloat" [Wright, 1925]. That same rediscovery also led to the first measurement of accumulation rate in the interior, an average of 7 1/2 in./yr (190 mm/yr) of water over 6 1/2 years. (The nearest RIGGS measurements of velocity and accumulation rate, at a point 50 km to the south, are 660 m/yr along azimuth 030° and 160 mm/yr of water.)

The second Antarctic expedition based at the Bay of Whales was Rear Admiral Richard E. Byrd's First Antarctic Expedition, 1928-

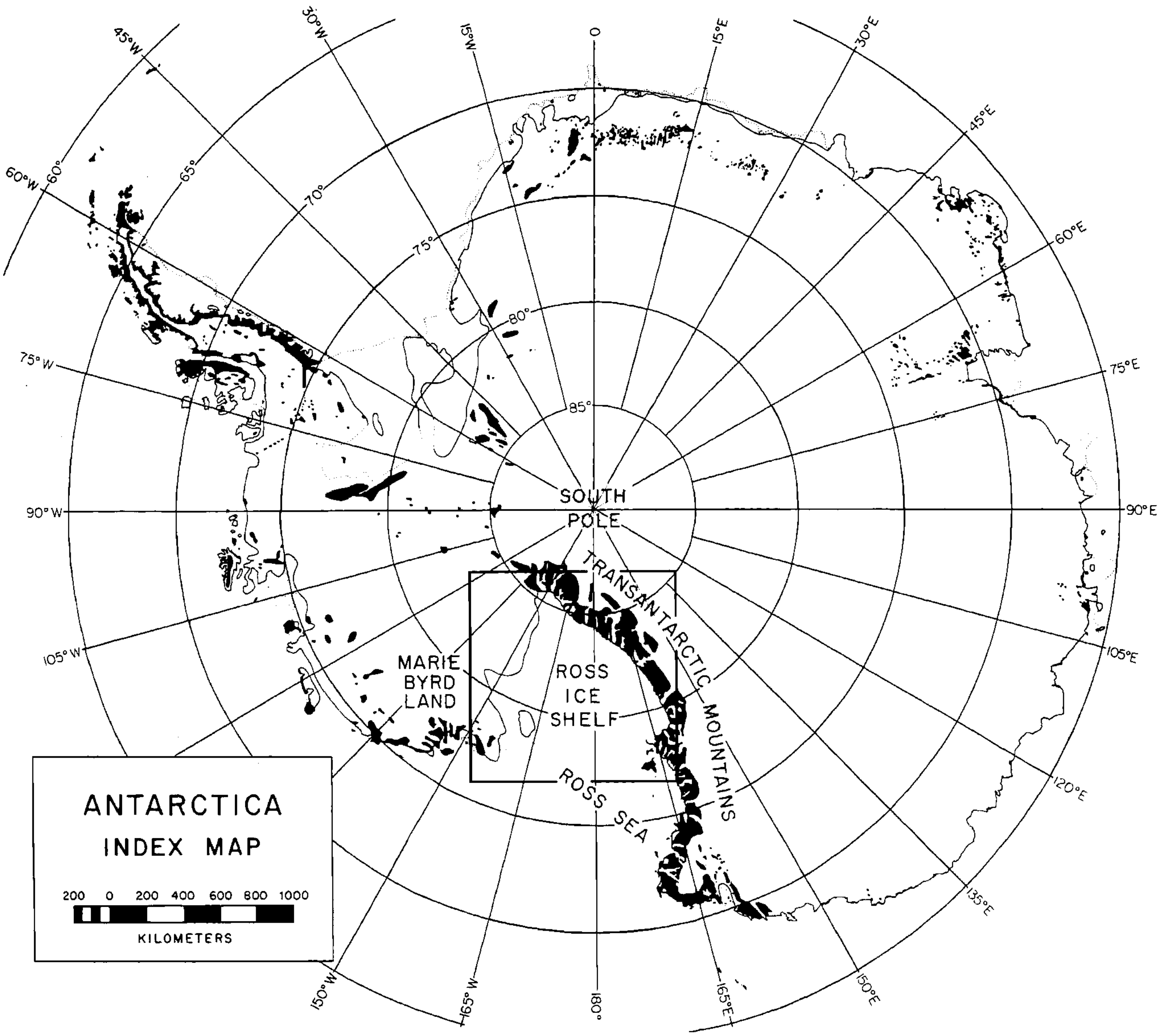

Fig. 1. Index map of Antarctica. Maps of the Ross Ice Shelf in Figures 2-4 cover the area outlined.

1930, which established "Little America" on the eastern side of the bay in January 1929. One important scientific accomplishment of that expedition was the sledging journey across the Ross Ice Shelf to the Queen Maud Mountains by a party under the direction of Byrd's chief scientist, L. M. Gould. Gould's principal contribution was in his geological studies, but he did also observe that the ice shelf itself probably moved at a rate of more than 5 ft/d (550 m/yr) and was mostly floating except where heavily crevassed [Gould, 1935].

Geophysical investigation of the shelf was inaugurated by T. C. Poulter during the Second Byrd Antarctic Expedition, 1933-1935. Using a Seismograph Service Corporation seismic system, Poulter recorded seismic shots at 122 locations around the Bay of Whales. He also successfully employed a modified McComb-Romberg seismograph containing a horizontal pendulum as a tilt meter to measure tilting of the ice at Little America in response to ocean tidal displacement. Among the scientific results of Poulter's seismic survey were direct confirmations that the ice shelf was floating to at least 10 miles (16 km) south of the barrier and that the ice rise southeast of Little America, named Roosevelt Island by

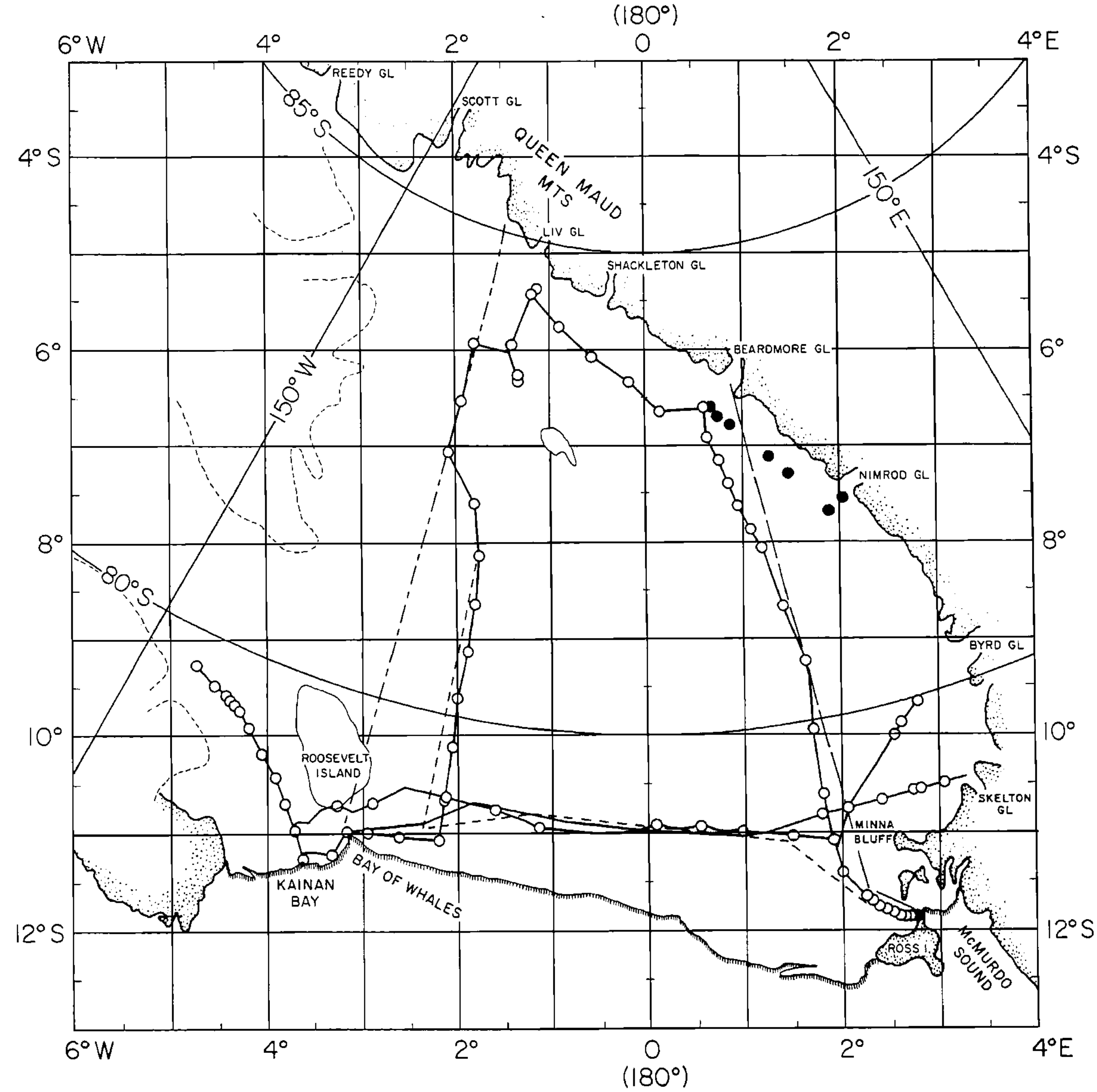

Fig. 2. Map of Ross Ice Shelf, showing stations and travel routes from which quantitative data were collected prior to RIGGS. Open circles and connecting track denote seismic traverses 1957-1960 (the circles denote seismic reflection stations). Solid circles denote movement measurements by Swithinbank [1963]. The long dashed line represents Scott's route 1911-1912; the long-and-short-dashed line, Amundsen's route 1911-1912; and the short-dashed line, Ross Ice Shelf Survey 1959-1966. The IGY "Little America V" station was at Kainan Bay.

Byrd, was grounded [Poulter, 1947a]. Poulter's actual values of ice thickness and depth to the ocean floor are in error, because in assigning a seismic wave velocity to the ice shelf he made the assumption, subsequently proven incorrect, that unfrozen seawater saturated the shelf below sea level.

Early measurements on the physical properties of the Ross Ice Shelf were made between February 1940 and January 1941 by Wade [1945]. Unfortunately, owing to the failure of Byrd's giant, wheeled, oversnow vehicle (the "Snow Cruiser"), the early termination of the Antarctic Service Expedition because of World War II, and his own commitment to the geological program, Wade's measurements were restricted to the immediate vicinity of Little America III (also located on the Bay of Whales).

Nevertheless, Wade (with L. A. Warner) was able to study densities, crystal sizes and orientation, and compaction rates in a 7-m snow pit, to measure the surface accumulation (840 mm of snow in 348 days), to determine the temperature at 15 different depths down to 41 m, and to demonstrate that the compaction rates depended upon the temperature in the firn. Wade's deep pit was studied in early 1957 by a party from the International Geophysical Year (IGY) station at Little America V on Kainan Bay (Figure 2), and data were obtained for the snow accumulation for the 17.6 elapsed years [Hoinkes, 1962].

Glaciological and geophysical investigations on the Ross Ice Shelf during the IGY years involved winter studies at the stations in 1957, 1958, and 1959 and summer and fall traverses in 1957-1958, 1958-1959, and 1959-1960.

The principal 1957 and 1958 winter studies at Little America V (LAS) involved (1) seismic measurements of ice thickness and water depth, (2) snow studies in a 20-m pit and on cores augered to a total depth of 40 m, (3) temperature observations to 11 m over a period of 20 months, (4) snow accumulation determinations from a network of over 100 stakes, from strain gauge compaction studies in the deep pit, and from oxygen isotope studies on 165 samples taken from depths between 15 and 19 m in the deep pit, (5) horizontal strain measurements from a network survey of 20 stakes through a period of 600 days, (6) oceanographic observations in Kainan Bay, including tidal current measurements coordinated with gravity meter observations at the station over a period of 31 days, and (7) a seismic refraction profile to determine sediment thickness seafloor seismic velocities [Crary, 1961a, b; Thiel et al., 1960].

In the winter of 1959 a reduced traverse crew at Scott Base carried out a glaciological program on the Ross Ice Shelf near McMurdo Sound [Stuart and Bull, 1963].

The summer and fall traverses were designed to obtain elevations by altimetry, to determine ice thickness and water depth from seismic observations, to measure gravity and magnetism, and to ascertain the annual accumulation rate of snow from pit stratigraphy over as large an area as possible. The traverses that worked all or partially on the Ross Ice Shelf (see Figure 2) included (1) the Ross Ice Shelf Traverse (RIST) from LAS counterclockwise around the ice shelf, (2) a 1958 fall traverse that extended RIST 250 km southeastward from LAS, (3) the 1958-1959 Victoria Land Traverse I, which crossed the Ross Ice Shelf from LAS to Skelton Glacier, adding traverse stations from Minna Bluff to Skelton Glacier, where a measurement was made of the volume of ice discharged into the Ross Ice Shelf using seismic sounding of ice thickness across Skelton Inlet (the embayment in front of Skelton Glacier) and the movement of stakes set out along the seismic line and resurveyed on return of the traverse 68 days later (an extension of RIST was also made on the return of this traverse from Minna Bluff to McMurdo Station), (4) the 1959-1960 Victoria Land Traverse II, which added more stations between McMurdo Station and the Skelton Inlet, and (5) a fall traverse in 1960 from McMurdo Station toward Byrd Glacier [Crary et al., 1962; Wilson and Crary, 1961; Stuart and Heine, 1961; Bennett, 1964].

In 1958-1959 an airlifted traverse studied ice thickness, subglacial rock topography, and ice movement across the 15-km-wide contact zone between the Ross Ice Shelf and the continental ice sheet near 80°S, 150°W [Thiel and Ostenso, 1961].

Deep drilling in the ice at LAS was started in October 1958 by the Snow, Ice and Permafrost Research Establishment (now the Cold Regions Research and Engineering Laboratory) of the U.S. Army. The hole at LAS was drilled to a depth of 255 m, where a crack permitted seawater to enter [Ragle et al., 1960]. Core recovery was nearly 100%, and the cores have been extensively investigated.

A special research project of IGY was undertaken to study the deformation of the Ross Ice Shelf north of Roosevelt Island in the summers of 1957-1958 and 1958-1959. The area between Roosevelt Island and the Bay of Whales contains a system of parallel crevasses and intersecting ridges and troughs; because the structural features are analogous to those of deformed sedimentary rocks, the project was designed as a model study of conventional geological structures. The observations included triangulation, topographic mapping of deformed ice layers, temperature measurements in the ice, snow accumulation, and measurements of strain [Zumberge et al., 1960; Kehle, 1964].

In 1960-1962, Swithinbank [1963] carried out ice movement rates related to the Ross Ice Shelf when he measured the velocities of seven outlet glaciers flowing through the Transantarctic Mountains. Ice thicknesses were calculated from gravity observations on the grounded glaciers and from elevation measurements on those that are floating. This work led to an estimate of the mass flux into the ice shelf [Giovinetto et al., 1966]. C. W. M. Swithinbank (personal communication, 1979) also measured ice shelf velocities at seven sites on the ice shelf between Beardmore and Nimrod Glaciers (Figure 2, solid circles).

The next important program was the Ross Ice Shelf Survey (RISS), which comprised measurements of the velocity vectors and snow accumulation rates along a trail from Ross Island nearly to Roosevelt Island, thence southward for about 300 km (Figure 2). Markers were set out for the movement measurements in the summer of 1962-1963 [Hofmann et al., 1964], and the remeasurement was carried out in 1965-1966 [Dorrer et al., 1969]. As part of the 1962-1963 survey, snow accumulation was measured at 1800 bamboo poles along the "Dawson Trail" between Little America V and McMurdo stations; the heights of the poles had previously been measured during 1959-1960 [Heap and Rundle, 1964].

Also during the 1960's, a glaciological and geophysical program was carried out on Roosevelt Island. The field program was inaugurated in 1961-1962 to determine the mass balance, strain rates, velocities, and thickness of the ice dome and to measure the physical characteristics of the ice-bedrock interface and the underlying rock. The first survey was completed in the 1962-1963 season [Clapp, 1965], and the resurvey was carried out in 1967-1968 (unpublished reports by J. L. Clapp [1970], M. P. Hochstein [1965], and C. R. Bentley [1966]; see also Thomas et al. [1980]).

During the 1960's early studies of electromagnetic wave propagation in the ice were begun. A. H. Waite continued his pioneering radar work of the IGY in 1961-1962 and the next two seasons, when he made the first airborne ice thickness sounding surveys over, among other places, the marginal parts of the Ross Ice Shelf. Detailed studies on the McMurdo Ice Shelf, Skelton Glacier, and Roosevelt Island were undertaken in 1964-1965 using Waite's equipment [Jiracek and Bentley, 1971].

In 1967-1968 there began a long and fruitful series of radar sounding flights carried out in a joint United States-United Kingdom program. Many of these sounding flights crossed the Ross Ice Shelf, leading to a much improved map of the ice shelf thickness [Robin, 1975]. Data were collected by personnel at the Scott Polar Research Institute (SPRI) using SPRI equipment mounted on a U.S. C-130 Hercules aircraft.

RISP/RIGGS

Soon after the successful completion of the borehole at Little America V there was speculation on the possibility of drilling a hole several hundred kilometers inland from the ice front. In 1969, J. W. Brodie suggested a multidisciplinary study centered around a drill hole through the Ross Ice Shelf so it would be possible to study not only the ice but also the ocean and ocean floor beneath the ice shelf. Such a hole would thus be of great interest not only to glaciologists but also to oceanographers, biologists, and geologists.

This suggestion was enthusiastically received, and planning for the Ross Ice Shelf Project (RISP) began, both nationally in the United States and internationally through the Scientific Committee for Antarctic Research in 1970 [Zumberge, 1971]. It was apparent from the outset that a survey of ice thicknesses and water depths below the ice would be necessary in order to find an optimum site for the drill hole, and it was soon recognized that the value of the survey would be greatly enhanced if it were viewed as part of a comprehensive geophysical and glaciological program for study of the whole Ross Ice Shelf and the solid earth beneath. Consequently, in 1973-1974 the Ross Ice Shelf Geophysical and Glaciological Survey (RIGGS) commenced under the direction of the Geophysical and Polar Research Center, University of Wisconsin-Madison; it continued, with a hiatus in 1975-1976, through the austral summer of 1977-1978. (The early objective of the survey, to select a site for the RISP drill hole, was attained in the first season. For reports on RISP, see Clough and Hanson [1979] and the series of papers that follow in the same issue of *Science*.)

The RIGGS program was a cooperative effort involving the Geophysical and Polar Research Center at the University of Wisconsin-Madison (radar sounding, seismic reflection and refraction measurements, resistivity soundings, and gravity surveys), the University of Maine-Orono (measurements of strain rate, 10-m temperature, and surface accumulation), the U.S. Geological Survey (absolute movement of the ice), and the University of Copenhagen (accumulation and oxygen isotope studies). Associated studies were carried out by the University of Nevada Desert Research Institute (near-surface snow studies in 1974-1975), State University of New York at Buffalo (SUNY-Buffalo; shallow core drilling in 1976-1977 and 1977-1978), and Virginia Polytechnic Institute and State University (V.P.I.; ocean tide observations beneath the shelf during all four seasons).

In the planning for RIGGS it was agreed to use a rectangular "grid" system of coordinates. Grid directions and positions refer to a transverse Mercator system that has its origin at the south pole, its equator along longitudes 90°W to 90°E, and its prime meridian along longitudes 0°-180°. Grid north is toward Greenwich. The grid system has the advantages of rectangular coordinates and uniform azimuthal directions; it maintains the familiar sense of the points of the compass, and regional maps fit without rotation into a map of Antarctica as a whole. It is used henceforth throughout this volume.

Methods and Techniques

Each season's work involved setting up one or two base camps around which detailed local surveys were conducted and from which remote stations, positioned roughly on a 55-km grid (Figure 3), were occupied by means of De Havi-

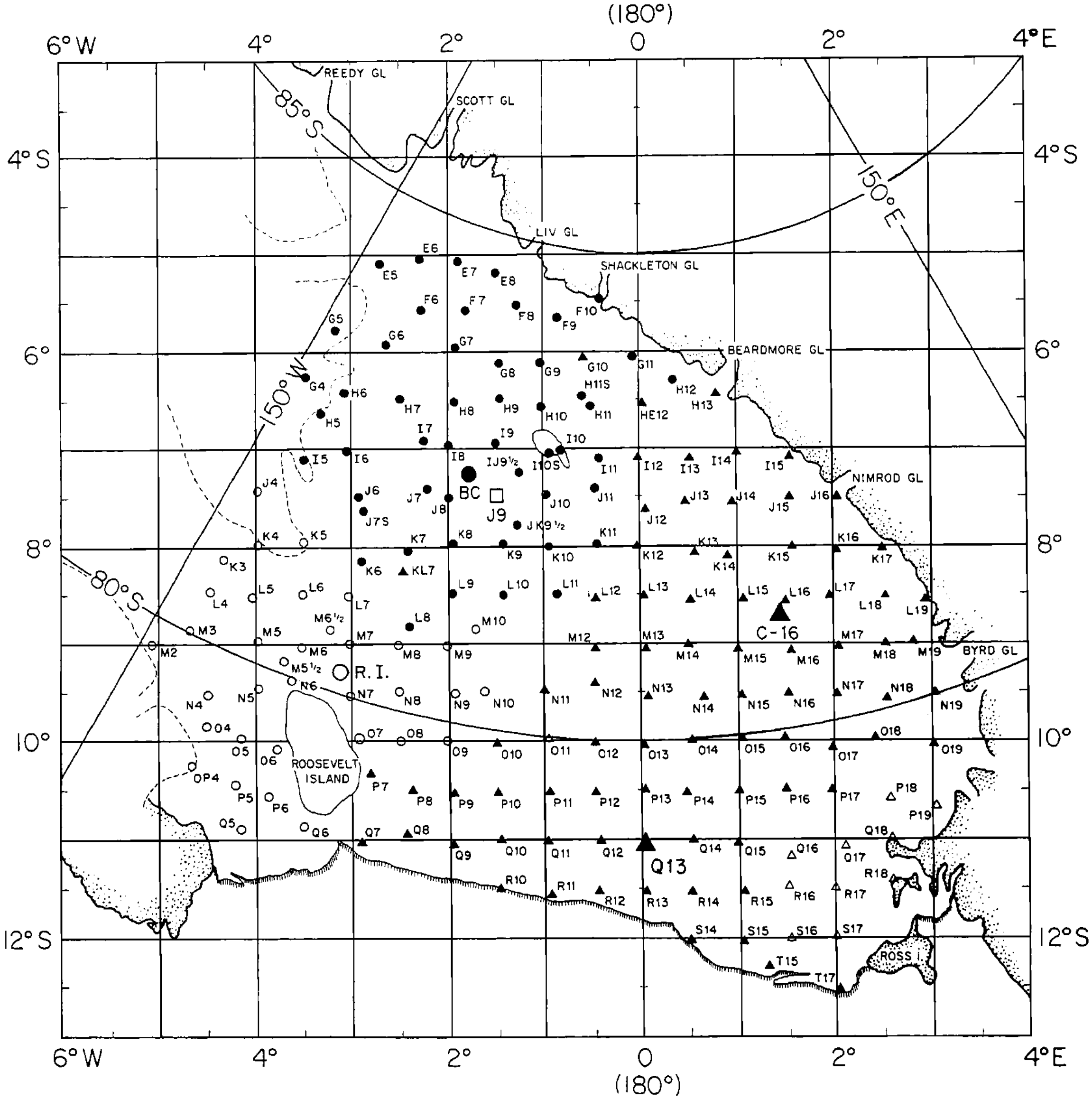

Fig. 3. Map of Ross Ice Shelf, showing RIGGS surface stations. RIGGS I (1973-1974) stations are represented by solid circles, RIGGS II (1974-1975) by open circles, RIGGS III (1976-1977) by solid triangles, and RIGGS IV (1977-1978) by open triangles. The large symbols denote base camps. The open square labeled J9 is the RISP drill site, which was the location of extensive RIGGS surface measurements.

land Twin Otter aircraft. The basic program for each site comprised the establishment (and subsequent remeasurement) of strain networks, gravity observations, and both radar and seismic sounding. Since high-frequency radio waves do not penetrate seawater, whereas seismic waves are reflected poorly from the ice-water boundary but strongly from the seafloor, the primary design of the sounding program was to combine radar measurements of ice thickness with seismic measurements of water depth. Nevertheless, seismic reflections from the ice-water interface were also recorded wherever they could be observed.

At most of the stations during RIGGS I (1973-1974) and at a dozen in the second season, the horizontal gravity gradient was determined by taking readings at the corners of the triangular strain networks. These measurements ended after RIGGS II (1974-1975) and were replaced by an emphasis during RIGGS III (1976-1977) and IV (1977-1978) on radar reflection profiling around parts of the strain networks. Radar profiling was carried out at only a quarter of the remote sites during the first two seasons.

Positioning by satellite observations was carried out at 123 sites; 80 of them were reoccupied after 1 or 2 years to determine the velocity of the ice shelf. The positions of most of the other sites were determined by sun shots; the remaining few were located either by the inertial navigation system of the aircraft or by optical resection.

Two procedures for determining surface mass balance were routinely used: (1) the heights from the snow surface to the tops of all stakes in each strain network were measured and then remeasured upon subsequent reoccupation of the site; (2) at 60% of the sites, 10-m-long cores were collected for determination of the depth to dated radioactive fallout horizons. A second purpose of the core collection was to study oxygen isotope ratios. Temperatures were usually measured in the 10-m holes.

At 14 scattered stations a more extensive geophysical program was carried out. It comprised any or all of (1) seismic short-refraction shooting to measure seismic wave velocities in the upper 100 m of the ice shelf, (2) radar variable-angle reflection determinations of average electromagnetic wave speed, hence electrical permittivity, in the solid ice, and (3) soundings yielding electrical resistivity as a function of depth within the ice shelf. Densities were calculated from the seismic velocities; the electrical resistivity measurements led to estimates of englacial temperatures. Finally, at the four RIGGS base stations and at the RISP drill camp (J9DC), seismic long-refraction shooting, to examine the thickness of submarine sediments and the upper crustal structure beneath the ice shelf, and a variety of special studies, were conducted. Upon return to J9DC in 1978-1979, sonic logging in a 155-m RISP core hole was undertaken.

All the techniques are discussed in greater detail in the succeeding papers in this volume. A complete listing of the 193 RIGGS surface stations, indicating what kinds of measurement were made at each and by which participating organization, is given in Table 1, and a season-by-season summary is presented in Table 2. Station positions in Table 1 are given in grid coordinates with precision (0.01°) sufficient for plotting or locating on a map. The accompanying paper by Thomas et al. [1984] includes a tabulation giving the most precisely known geographical and grid coordinates of most of the sites (for the exceptions, see the footnotes to Table 1).

The RIGGS program was not limited to the observations on the surface of the ice shelf. Although the initial plan was to make ice thickness measurements only at the surface stations, it became clear during the first season that ice thickness variations were too complex to be detailed with measurements only at the basic network. Consequently, antennas were fitted to the Twin Otter, and a program of radar ice thickness profiling from the air that continued through the succeeding field seasons was begun. The airborne radar measurements were carried out late in each season to permit close ties to the network of already occupied surface stations (when they could be found). This reduced navigational and closure errors and permitted many detailed variations of ice shelf thickness to be drawn with confidence. In all, 13,500 km of airborne radar sounding were completed (Figure 4).

Season-by-Season Summary

RIGGS I (1973-1974)

In mid-December, Station BC was established in the grid northwestern part of the ice shelf, and the initial occupation of the first set of remote sites was carried out. By the end of January, when the work terminated, 52 remote stations had been occupied (Figure 3). In addition to the standard program, stratigraphic studies were made in pits 3 or 4 m deep at BC, I10 (Crary Ice Rise), and G11. Strain lines that were longer than normal were emplaced at two remote stations: H5, where distances were measured and an optical leveling traverse run along a 10-km line of stakes placed across the grounding line between the inland ice sheet and the ice shelf, and G11, where stakes were emplanted along a 5-km line roughly perpendicular to the direction of ice flow in an attempt to measure shear in the ice shelf as it passes the Transantarctic Mountains.

A program around the base camp yielded 50 km of radar and gravity profiling and two electrical resistivity profiles oriented at right angles to one another. A long seismic refraction profile was attempted, but despite extension of the profile to a distance of 20 km, no energy was received along paths penetrating the ocean floor. A long seismic refraction profile that did record energy through the bedrock was completed on Crary Ice Rise (I10S). Two 40-km-long strain networks comprising double lines of stakes were established, one between BC and J9 and one on Crary Ice Rise. The latter network was intended to link the ice rise to the ice shelf; unfortunately, the ice rise was larger than expected, and the shelf was not reached. However, two ice shelf stations 15 and 25 km to the grid northeast were eventually tied into the strain network on the ice rise by tellurometer and theodolite observations. One large strain rosette with 5-km legs was established at BC.

The V.P.I. ocean tide program was begun

TABLE 1. Complete Listing of RIGGS Stations and the Measurements Made at Each

		Position			Surface Measurements			Drilling			Seismic[g]				Radar[g]					Gravity		
	Season of First Measurement	Grid Latitude, °S	Grid Longitude, °E or °W	Type of Measurement[a]	Velocity[b]	Strain and Accumulation[c]	Shallow Sample Collection[d]	10-m Core Collection[e]	Temperature in 10-m Holes[c]	50-100 m Core Drilling[f]	Short Refraction (P Wave)	Short Refraction (S Wave)	Reflection from Base of Ice	Reflection from Seafloor	Ice Thickness	Profiling	Wide-Angle Reflection	Polarization	Electrical Resistivity	Value[g]	Gradient[g]	Tidal[h]
Main base camps																						
BC	I	7.24	1.80W	1	X	X[i]	X	X	X		X	X		X	X	X	X		X	X	X	X
RI	II	9.30	3.10W	1	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X
Q13	III	11.04	0.01E	1	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	
C-16	III	8.69	1.45E	1	X	X[i]		X	X	X	X	X		X	X	X	X	X	X	X	X	X
Remote stations																						
E5	I	5.08	2.71W	1				X	X					X	X					X	X	
E6	I	5.03	2.30W	3		X								X	X					X	X	
E7	I	5.07	1.90W	2		X		X	X					X	X					X	X	
E8	I	5.19	1.51W	2		X	X	X	X				X	X	X	X				X	X	
F6	I	5.58	2.27W	2		X	X								X					X	X	
F7	I	5.59	1.81W	1	X	X	X	X	X				X	X	X	X				X	X	
F8	I	5.52	1.27W	2		X	X								X					X	X	
F9	I	5.65	0.86W	1	X	X	X	X	X				X	X	X					X	X	X
F10	I	5.50	0.40W	4		X									X					X	X	
G4	I	6.24	3.48W	1				X	X				X	X	X					X	X	
G5	I	5.78	3.17W	1	X[j]	X[j]	X	X	X						X					X	X	
G6	I	5.92	2.63W	1	X			X	X				X	X	X					X		
G7	I	5.95	1.93W	2,4											X					X	X	
G8	I	6.11	1.46W	1	X	X	X	X	X				X	X	X					X	X	
G9	I	6.10	1.02W	2		X									X					X	X	

G10	III	6.06	0.60W	1	X	X	X	X													
G11	I	6.04	0.07W	2		X									X					X	X
H5	I	6.62	3.34W	1	X[k]	X[k]	X	X	X				X	X	X	X				X	X
H6	I	6.41	3.09W	1		X	X	X	X					X	X					X	X
H7	I	6.55	2.49W	1		X		X	X		X	X	X	X	X					X	X
H8	I	6.51	1.93W	1	X	X	X	X	X					X	X					X	
H9	I	6.49	1.45W	1	X	X	X	X	X				X	X	X					X	X
H10	I	6.56	1.01W	1	X	X	X	X	X				X	X	X					X	X
H11	I	6.55	0.51W	2		X									X		X			X	X
H11S[ℓ]	I	6.46	0.61W	1				X			X	X	X	X	X					X	
HE12	III	6.54	0.03E	1	X	X	X														
H12	I	6.28	0.35E	1	X	X	X	X	X				X	X	X	X				X	X
H13	III	6.43	0.79E	1	X	X		X	X		X			X	X	X	X	X	X	X	
I5	I	7.10	3.51W	1	X[k]	X[k]	X	X	X				X	X	X	X				X	X
I6	I	7.01	3.04W	2		X		X					X	X	X					X	X
I7	I	6.91	2.26W	1		X		X	X				X	X	X					X	
I8	I	6.98	2.00W	1	X	X	X	X	X					X	X					X	X
I9	I	6.95	1.50W	2		X		X	X					X	X	X				X	X
I10	I	7.01	0.82W	2		X	X								X	X				X	X
I10S[ℓ]	I	7.05	0.95W	1	X[j]		X	X			X	X	X	X	X					X	
I11	I	7.09	0.43W	1		X		X						X	X					X	X
I12	III	7.09	0.02W	1		X		X	X				X	X						X	
I13	III	7.10	0.52E	1	X	X		X	X				X	X						X	
I14	III	7.04	0.99E	1	X	X		X	X				X	X	X	X				X	
I15	III	7.08	1.53E	1	X	X		X	X					X	X	X				X	
IJ9½[m]	I	7.24	1.24W	3										X	X					X	
J4	II	7.42	3.99W	1	X	X	X	X	X				X	X	X					X	
J6	I	7.50	2.94W	1	X[k]	X[k]	X	X	X				X	X	X					X	X
J7	I	7.41	2.23W	2		X	X	X							X					X	X
J7S[ℓ]	I	7.63	2.89W	1							X		X	X	X						
J8	I	7.50	2.00W	1		X	X	X	X					X	X					X	
J9[h]	I	7.48	1.50W	1		X		X	X					X	X					X	X
J9DS[h]	II	7.48	1.50W	1			X				X			X	X	X				X	
J9DC[h]	III	7.49	1.50W	1			X			X	X	X	X	X	X	X	X	X	X		X
J10	I	7.47	0.98W	1	X	X	X	X	X					X	X					X	X
J11	I	7.41	0.48W	2		X									X					X	X
J12	III	7.63	0.04E	2		X							X	X						X	
J13	III	7.53	0.46E	1	X	X		X	X					X	X	X				X	
J14	III	7.55	0.94E	2		X	X						X	X	X	X				X	
J15	III	7.48	1.53E	1	X	X	X	X	X				X	X	X	X				X	

TABLE 1. (continued)

		Position			Surface Measurements			Drilling			Seismic[g]				Radar[g]					Gravity		
	Season of First Measurement	Grid Latitude, °S	Grid Longitude, °E or °W	Type of Measurement[a]	Velocity[b]	Strain and Accumulation[c]	Shallow Sample Collection[d]	10-m Core Collection[e]	Temperature in 10-m Holes[c]	50-100 m Core Drilling[f]	Short Refraction (P Wave)	Short Refraction (S Wave)	Reflection from Base of Ice	Reflection from Seafloor	Ice Thickness	Profiling	Wide-Angle Reflection	Polarization	Electrical Resistivity	Value[g]	Gradient[g]	Tidal[h]
Remote stations																						
J16	III	7.50	2.04E	1				X	X				X	X	X	X	X			X		
JK9½m	I	7.77	1.26W	3									X	X	X							
K3	II	8.13	4.34W	1	X	X	X	X	X				X	X	X					X		
K4	II	7.98	3.99W	2		X								X	X					X		
K5	II	7.95	3.50W	2		X								X	X					X		
K6	I	8.15	2.90W	2		X									X					X	X	
K7	I	8.04	2.42W	1		X		X	X					X	X					X	X	
K8	I	7.97	1.96W	2		X									X					X	X	
K9	I	7.97	1.43W	1		X		X	X					X	X					X	X	
K10	I	8.00	0.95W	1	X	X		X	X				X	X	X	X				X	X	
K11	I	7.96	0.45W	1	X	X	X	X	X		X	X	X	X	X					X	X	
K12	III	8.00	0.03W	1		X		X	X					X	X	X				X		
K13	III	8.05	0.56E	1	X	X		X	X				X	X						X		
K14	III	8.09	0.90E	1	X	X		X	X					X	X	X				X		
K15	III	8.00	1.56E	2		X							X	X	X	X				X		
K16	III	8.04	2.02E	1	X	X		X	X				X	X	X	X				X		
K17	III	8.02	2.50E	1	X	X		X	X					X	X	X				X		
KL7	III	8.25	2.47W	1			X							X	X	X	X			X		
L4	II	8.45	4.48W	2		X							X	X	X	X			X	X	X	
L5	II	8.50	4.02W	2		X		X	X				X	X	X					X		

L6	II	8.48	3.51W	2		X						X	X					X	
L7	II	8.50	3.02W	2		X	X	X	X			X	X					X	
L8	I	8.81	2.41W	2		X							X					X	X
L9	I	8.49	1.96W	1		X		X				X	X					X	X
L10	I	8.49	1.43W	2		X							X					X	X
L11	I	8.48	0.88W	1		X		X				X	X					X	X
L12	III	8.53	0.48W	1	X	X		X	X		X	X						X	
L13	III	8.51	0.02E	1	X	X		X	X		X	X						X	
L14	III	8.54	0.51E	1				X	X		X	X						X	
L15	III	8.54	1.05E	2				X				X	X	X				X	
L16	III	8.56	1.49E	1		X		X	X		X	X	X	X				X	
L17	III	8.49	1.96E	1	X	X		X	X			X	X	X				X	
L18	III	8.50	2.53E	1	X	X		X	X		X	X	X	X				X	
L19	III	8.56	2.91E	1	X	X		X	X		X	X	X	X				X	
M2	II	9.00	5.07W	2		X		X	X		X	X	X	X				X	X
M3	II	8.85	4.68W	1	X	X	X	X	X		X	X	X					X	
M5	II	8.97	3.99W	2		X						X	X					X	
M5½m	II	9.18	3.71W	3									X					X	
M6	II	9.02	3.52W	2		X	X	X	X		X	X	X					X	
M6½ (ML6)	II	8.85	3.22W	2		X					X	X	X					X	
M7	II	9.00	3.01W	2		X	X	X				X	X					X	
M8	II	9.01	2.52W	2		X						X	X	X				X	
M9	II	9.02	2.01W	2		X					X	X	X	X				X	X
M10	II	8.84	1.72W	1	X	X	X	X	X			X	X	X	X			X	X
M12	III	9.05	0.47W	2		X					X	X						X	
M13	III	9.05	0.03E	1	X	X		X	X		X	X						X	
M14	III	8.99	0.49E	1						X		X	X	X	X	X	X	X	
M15	III	9.05	0.99E	1	X	X		X				X	X	X				X	
M16	III	9.06	1.53E	1				X	X		X	X						X	
M17	III	9.03	2.02E	1	X	X		X	X		X	X						X	
M18	III	9.00	2.52E	2							X	X						X	
M19	III	9.02	2.82E	1				X	X		X	X						X	
N4	II	9.51	4.50W	1	X	X	X	X			X	X	X					X	X
N5	II	9.45	3.96W	2		X					X	X	X	X				X	X
N6	II	9.38	3.64W	2		X					X	X	X	X				X	
N7	II	9.53	3.01W	2		X					X	X	X	X				X	X
N8	II	9.49	2.51W	1	X	X	X	X	X			X	X	X				X	
N9	II	9.49	1.97W	1			X	X	X			X	X					X	
N10	II	9.49	1.63W	2		X						X	X	X				X	
N11	III	9.46	1.01W	1		X		X	X			X	X					X	

TABLE 1. (continued)

	Position				Surface Measurements			Drilling			Seismic[g]				Radar[g]					Gravity		
	Season of First Measurement	Grid Latitude, °S	Grid Longitude, °E or °W	Type of Measurement[a]	Velocity[b]	Strain and Accumulation[c]	Shallow Sample Collection[d]	10-m Core Collection[e]	Temperature in 10-m Holes[c]	50-100 m Core Drilling[f]	Short Refraction (P Wave)	Short Refraction (S Wave)	Reflection from Base of Ice	Reflection from Seafloor	Ice Thickness	Profiling	Wide-Angle Reflection	Polarization	Electrical Resistivity	Value[g]	Gradient[g]	Tidal[h]
Remote stations																						
N12	III	9.40	0.51W	1	X	X		X	X				X	X	X	X				X		
N13	III	9.54	0.06E	1	X	X		X	X				X	X						X		
N14	III	9.54	0.62E	2		X							X	X						X		
N15	III	9.52	1.01E	1				X	X				X	X						X		
N16	III	9.50	1.51E	1		X		X	X				X	X						X		
N17	III	9.51	2.01E	3									X	X						X		
N18	III	9.56	2.52E	1	X	X		X	X				X	X						X		
N19	III	9.51	3.02E	1				X	X		X			X	X	X	X	X	X	X		
04	II	9.85	4.50W	2		X	X						X	X	X	X				X	X	
05	II	9.98	4.15W	1	X	X	X	X					X	X	X					X		
06	II	10.09	3.79W	2		X		X	X				X	X	X					X	X	
07	II	9.98	2.92W	2		X			X					X	X	X				X		
08	II	10.00	2.50W	2		X		X	X				X	X	X					X		
09	II	10.00	2.02W	2		X		X	X				X	X	X					X		
010	III	10.03	1.52W	3																		
011	IV	9.98	0.96W	2							X			X	X	X	X		X	X		
012	III	10.01	0.49W	1	X	X		X	X					X	X					X		
013	III	10.05	0.01E	1	X	X								X	X	X				X		
014	III	10.00	0.51E	1	X	X	X	X	X					X	X	X				X		
015	III	9.98	1.02E	1	X	X	X							X	X	X				X		

O16	III	9.96	1.46E	1	X	X		X	X			X	X						X	
O17	III	10.07	1.99E	2		X						X	X						X	
O18	III	9.95	2.41E	1				X	X			X	X						X	
O19	III	10.03	3.00E	1				X	X	X		X	X	X	X	X		X	X	
OP4	II	10.26	4.68W	2		X						X	X	X	X				X	X
P5	II	10.44	4.21W	2		X				X	X	X	X	X	X				X	X
P6	II	10.56	3.86W	1	X	X	X	X	X			X	X	X					X	
P7	III	10.31	2.82W	1	X	X	X	X	X					X					X	
P8	III	10.50	2.38W	3		X	X							X	X				X	
P9	III	10.52	1.98W	1	X	X	X	X	X			X	X	X	X				X	
P10	III	10.52	1.51W	1	X	X	X							X	X				X	
P11	III	10.52	0.96W	1	X	X	X	X					X	X					X	
P12	III	10.52	0.49W	1	X	X	X						X	X	X				X	
P13	III	10.49	0.01E	1	X	X	X						X	X					X	
P14	III	10.51	0.46E	1		X	X						X	X					X	
P15	III	10.50	0.99E	1	X	X							X	X	X				X	
P16	III	10.47	1.47E	1	X	X		X	X				X	X	X				X	
P17	III	10.50	1.96E	1	X	X		X	X				X	X	X				X	
P18^{m}	IV	10.59	2.58E	4									X	X	X				X	
P19^{m}	IV	10.66	3.03E	4								X	X	X	X				X	
Q5	II	10.90	4.15W	2		X						X	X	X					X	X
Q6	II	10.85	3.49W	1	X	X	X	X	X			X	X	X					X	
Q7	III	11.01	2.91W	1		X	X						X	X	X				X	
Q8	III	10.92	2.44W	1	X	X	X	X	X				X	X					X	
Q9	III	11.04	1.97W	1	X	X	X						X	X	X				X	
Q10	III	11.00	1.46W	1	X	X	X	X	X				X	X	X				X	
Q11	III	11.00	0.99W	1	X	X	X						X	X	X				X	
Q12	III	11.00	0.43W	1	X	X	X	X					X	X	X				X	
Q14	III	11.00	0.52E	1	X	X	X						X	X					X	
Q15	III	11.01	0.99E	1	X	X		X	X				X	X	X				X	
Q16^{m}	IV	11.16	1.51E	4								X	X	X	X				X	
Q17^{m}	IV	11.06	2.10E	4									X	X	X				X	
Q18^{m}	IV	11.02	2.58E	4										X	X				X	
R10	III	11.49	1.49W	1		X	X					X	X	X					X	
R11	III	11.54	0.95W	1	X	X	X	X	X			X	X	X	X				X	
R12	III	11.51	0.46W	1		X	X					X	X	X	X				X	
R13	III	11.52	0.03E	1	X	X	X	X	X				X	X	X				X	
R14	III	11.51	0.50E	1		X	X	X	X				X	X	X				X	
R15	III	11.51	1.02E	1	X	X	X						X	X	X				X	
R16	IV	11.48	1.50E	1				X	X	X		X	X	X	X	X	X		X	

TABLE 1. (continued)

		Position			Surface Measurements			Drilling			Seismic[g]				Radar[g]					Gravity		
	Season of First Measurement	Grid Latitude, °S	Grid Longitude, °E or °W	Type of Measurement[a]	Velocity[b]	Strain and Accumulation[c]	Shallow Sample Collection[d]	10-m Core Collection[e]	Temperature in 10-m Holes[c]	50-100 m Core Drilling[f]	Short Refraction (P Wave)	Short Refraction (S Wave)	Reflection from Base of Ice	Reflection from Seafloor	Ice Thickness	Profiling	Wide-Angle Reflection	Polarization	Electrical Resistivity	Value[g]	Gradient[g]	Tidal[h]
Remote stations																						
R17	IV	11.49	2.00E	1									X	X	X	X				X		
R18	IV	11.41	2.58E	1				X	X					X	X	X				X		
S14	III	12.01	0.49E	1	X	X								X	X					X		
S15	III	12.03	1.01E	1	X	X								X	X					X		
S16	IV	12.00	1.51E	1									X	X	X	X				X		
S17	IV	11.99	2.00E	1									X	X	X	X				X		
T15	III	12.28	1.28E	1	X	X	X	X	X					X	X	X				X		
T17	III	12.51	2.01E	1				X	X						X	X				X		
T17S[m]	III	12.53	2.01E	3										X								
Supplementary base camps																						
C-7	II	11.0	0.6W	3			X															
C-7-3	III	11.67	0.03E	3						X												
C-13	II	10.5	1.9E	3																		X
C-36	II	10.0	1.9W	3			X															X
RI dome	III	10.09	3.30W	1			X			X												

[a]Types of position measurement are (1) satellite observations (U.S. Geological Survey); (2) solar observations (University of Maine); (3) inertial navigation system on aircraft; (4) resection (University of Wisconsin).
[b]Measurements made by U.S. Geological Survey.
[c]Measurements made by University of Maine.
[d]Measurements made by University of Nevada.

[e]Measurements made by University of Copenhagen.
[f]Measurements made by University of New York at Buffalo (SUNY-Buffalo).
[g]Measurements made by University of Wisconsin.
[h]Measurements made by Virginia Polytechnic Institute.
[i]Strain measurement only.
[j]Remeasured during RIGGS III.
[k]Remeasured during RIGGS II and again during RIGGS III.
[ℓ]Precise positions for these stations were measured but are not given in the accompanying paper by Thomas et al. [1984]. Those positions are H11S: 83°30'25"S, 174°34'00"W; I10S: 82°53'26"S, 172°19'26"W; J7S: 81°53'27"S, 159°41'32"W. The position at I10S was remeasured by Doppler-satellite after 3 years; there was no measurable change.
[m]These stations are not listed in the accompanying paper by Thomas et al. [1984]; no positions more precise than those given here were measured.
[n]J9, J9DS, and J9DC are RIGGS I, II, and III designations. Camps were within 1 km of each other. Different position for J9DC reflects 3 years of ice shelf movement.

this season at BC. The experimental arrangement at BC, and at other recording sites in succeeding seasons, consisted of a LaCoste and Romberg recording gravimeter placed on a platform mounted on timbers set well into firn and housed in a 5-m-by-5-m Jamesway. The gravimeter was maintained by a technician who made frequent calibration tests and beam and level adjustments to the instrument.

Late in the season a ground party collected ice samples containing rock fragments and a few microfossils from a highly disturbed region 1/2 km to the grid south of Crary Ice Rise [Gaylord and Robertson, 1975].

Airborne radar sounding began on January 29; in the 3 days before the Twin Otter departed from the base camp, 3000 km of airborne radar profiling were completed (Figure 4).

RIGGS II (1974-1975)

The first part of the 1974-1975 season was devoted to the remeasurement of strain networks already planted in the grid northwestern part of the ice shelf. Starting in late November from base station BC, and using a Twin Otter generously provided by the British Antarctic Survey (BAS), all but six of the strain rosettes were located and successfully remeasured. The strain networks covering larger areas near stations BC, J9, H5, and G11 were also remeasured, and a leveling survey was completed along the 40-km strain line between BC and J9. The new positions of 15 stations were determined by satellite observations.

Geophysical work during the 1974-1975 season also began in late November 1974 with radar measurements, concentrating on the mapping of crevasses in the underside of the ice shelf ("bottom crevasses"), at the proposed RISP drill site (J9DS).

The "Roosevelt Island" (RI) base camp (so called because of its proximity to Roosevelt Island, even though it was on the ice shelf) was established on December 5; remote work from that camp began on December 16, continuing until January 27, 1975, when all personnel returned to McMurdo. Surveying during this period was hampered by fog and whiteouts; as a result, airborne operations were conducted only during 55% of the field season. Nevertheless, 37 remote stations were occupied during the second season's survey.

Local investigations around the Roosevelt Island camp included 50 km of radar and gravity profiling, a 40-km-long strain network along the local flow line, a 28-km seismic refraction profile that successfully recorded energy along paths through bedrock, studies of seismic velocity and of electromagnetic wave velocity in the ice, and one electrical resistivity profile. A total of 4200 km of airborne radar sounding was completed using the Twin Otter.

TABLE 2. Summary of Stations and Types of Measurement at Each

	Measuring Agency*	RIGGS Season of First Measurement I	II	III	IV	Total
Stations						
Base camps		1	4	4	0	9
Remote stations		52	37	84	11	184
Positioning						
Satellite observations	a	32	12	74	5	123
Solar observations	b	17	25	8	1	51
Aircraft navigation system		3	4	6	0	13
Resection	f	2	0	0	5	7
Surface measurements						
Ice shelf velocity	a	18	10	52	0	80
Strain	b	44	35	69	0	148
Accumulation	b	43	35	68	0	146
Shallow sample collection	c	0	22	51	0	73
Drilling						
10-m core collection	d	36	19	55	2	112
Temperature in 10-m hole	b	29	17	50	2	98
50-100 m core drilling	e	0	0	5	0	5
Seismic measurements						
Short refraction P wave	f	6	3	7	2	18
Short refraction S wave	f	5	2	3	0	10
Reflection from base of ice	f	21	24	39	6	90
Reflection from seafloor	f	38	37	79	10	164
Radar						
Ice thickness	f	53	38	60	11	162
Profiling	f	9	16	49	11	85
Wide-angle reflection	f	2	2	9	2	15
Polarization	f	0	0	5	1	6
Electrical Resistivity	f	1	2	6	1	10
Gravity						
Value	f	51	38	81	11	181
Gradient	f	44	12	2	0	58
Tidal	g	2	3	2	0	7

*Measurements were made by (a) U.S. Geological Survey; (b) University of Maine; (c) University of Nevada; (d) University of Copenhagen; (e) State University of New York at Buffalo; (f) University of Wisconsin; and (g) Virginia Polytechnic Institute.

The University of Nevada snow-sampling program, comprising season-long measurements at site C-7 (65 km from the front of the Ross Ice Shelf) and J9DS, collection of samples from shallow pits at nine RIGGS sites ranging from RI to E8, and near-surface snow sampling at 45 other RIGGS stations, was undertaken during this season.

Tidal measurements were carried out by V.P.I. at C-13, C-36, and RI.

RIGGS III (1976-1977)

The third season of RIGGS was characterized by the occupation of new remote stations using two Twin Otters operating concurrently from two new base camps, C-16 and Q13, and by early season operations at two other camps, RI and the RISP drilling camp, J9DC. During the early season all the University of Wisconsin geophysicists were at J9DC, while the resurveying

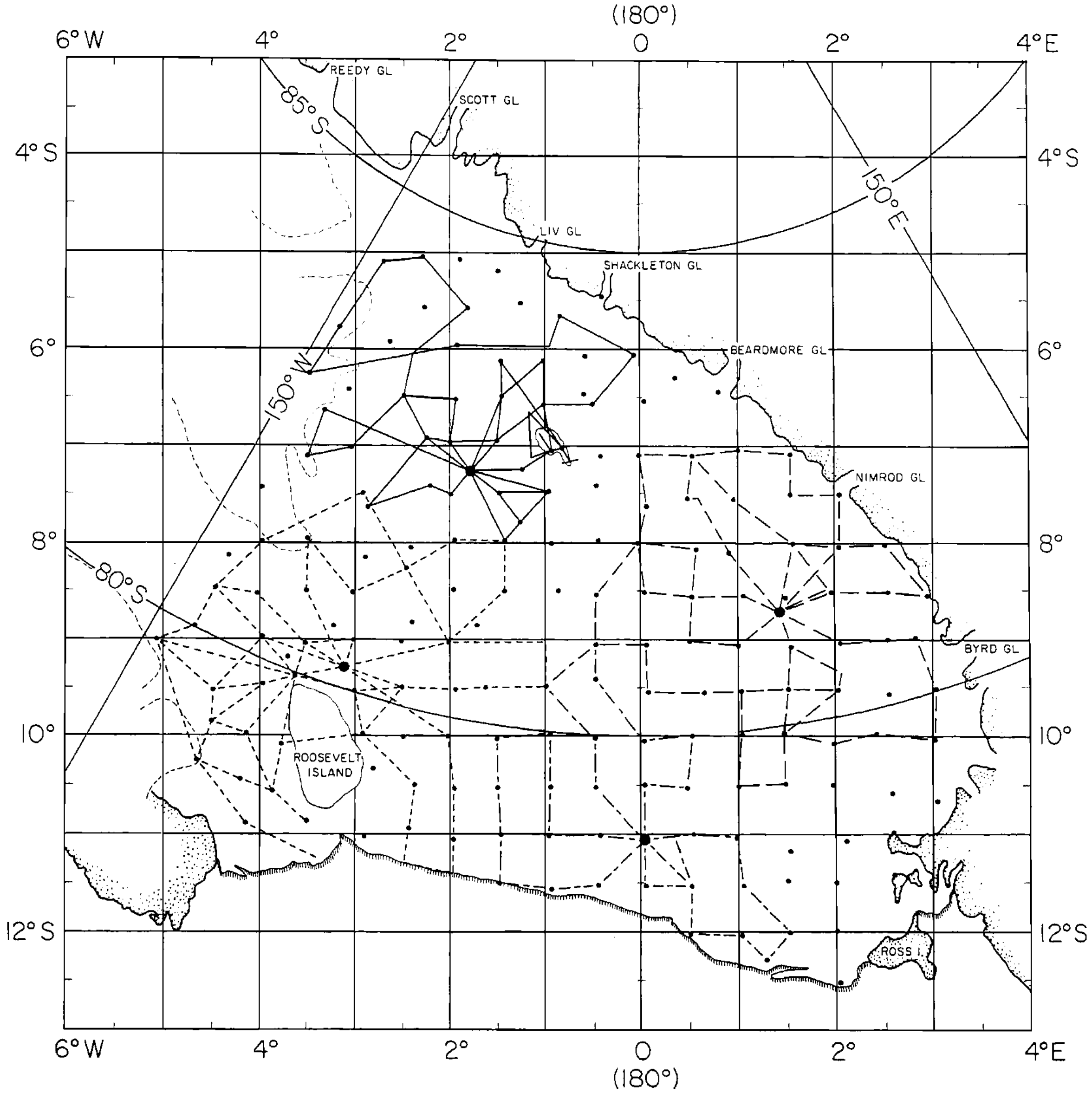

Fig. 4. Map of Ross Ice Shelf, showing RIGGS radar flight lines. RIGGS I (1973-1974) flight lines are represented by solid lines, RIGGS II (1974-1975) by short-dashed lines, RIGGS III (1976-1977) by long-dashed lines, and RIGGS IV (1977-1978) by long-and-short-dashed lines. Large circles denote base camps; small circles denote surface stations (see Figure 3).

at previously established remote sites was being conducted by University of Maine and U.S. Geological Survey parties from RI; in the later part of the season the disciplinary groups were split so that all the normal measurements could be made at each new remote site.

Part of the geophysical program at J9DC extended the mapping of the complex pattern of bottom crevasses in the area and confirmed that the location selected for the RISP access hole was satisfactorily undisturbed. Other geophysical work carried out in November included (1) ice thickness profiling of an area 3 x 5 km with a 0.5-km spacing, (2) wide-angle radar reflection profiling along two 1-km tracks perpendicular to each other, (3) experiments with collinear radar antennas, which provide a better near-surface resolution than is obtained from parallel antennas, (4) seismic P wave refraction shooting to a distance of 2 km along three azimuths differing by 60°, with closely spaced receivers at short shot-receiver distances, (5) seismic S wave refraction shooting along two mutually perpendicular lines extending to a range of 400 m with both SV and SH waves recorded, (6) determinations of ice thickness and water depth beneath the ice from shots fired in the bottom of an abandoned 150-m core hole, (7) a gravity survey along the radar-profiling network, (8) electrical resistivity profiling on two mutually perpendicular lines extending to 600 and 700 m, (9) measurement of ultrasonic wave velocities in three directions on ice core samples [Kohnen and Bentley, 1977], and (10) a complete radar polarization experiment, with each antenna being rotated stepwise in 15° increments. Early in December the geophysical party split into two groups, one going to base camp RI and the other to the new base station at C-16.

Field work at RI began in early November with the resurvey of the 40-km network of stakes near the camp. All of the remote-station strain networks that were emplanted during 1974-1975, and several from the 1973-1974 season, were located and remeasured by mid-December, again using a BAS Twin Otter. After the geophysicists arrived, occupation of new remote stations in the grid southwestern quadrant of the ice shelf began. Also, two electrical resistivity profiles at the base camp, a third 170 km upstream along the flow line, and a wide-angle radar reflection profile on grounded ice just upstream from the Steershead Crevasses (100 km grid northeast of RI) were completed. At the end of December the entire group moved to Q13 base camp (Figure 3), where the occupation of new remote stations continued until late January.

At C-16 most of the first month was spent doing geophysical and glaciological surveying near the camp, owing to late arrival of the supporting Twin Otter airplane and operational difficulties after it arrived. The following measurements were made. (1) Surface topography and ice thickness were surveyed on a network 5 x 2 km with 1/2-km spacing, revealing ice thickness waves about 25 m in amplitude and a little more than 1 km in length. An additional 11-km line with accurate leveling, emplacement of strain stakes, and radar ice thickness measurements was established normal to the "waves." (2) Strain networks were established along two 40-km lines. (3) Short seismic P wave, SV wave, and SH wave refraction profiles were completed along three azimuths at 60° angles to each other. (4) A seismic wide-angle reflection profile was completed out to a distance of 2.5 km. (5) A 400-kg seismic refraction shot was recorded at distances of 23 and 26 km. (6) Two electrical resistivity profiles at right angles to each other were completed. (7) Radar wide-angle reflection profiles were carried out along the same two lines as the electrical resistivity profiles. (8) A radar polarization study similar to that at J9DC was made. (9) Seismic reflection soundings of water depth and gravity profiling were extended 10 km from the station along each of the four cardinal points of the compass. A fifth gravity line was completed along a diagonal direction to improve the coverage over a remarkable, nearly circular, negative gravity anomaly that was revealed by the first four lines of measurements.

The station program at Q13 was similar to the one at C-16, except that more extensive radar profiling, for defining bottom-crevasse patterns and for delineation of internal layering within the ice, took the place of extensive surface topography and gravity mapping. Work completed included (1) three wide-angle radar reflection profiles, (2) one electrical resistivity profile, (3) 50 km of radar profiling (on the surface), (4) 30 km of gravity profiling, (5) 2 km of seismic profiling along the radar wide-angle lines, (6) two short seismic refraction profiles along which all three components of wave motion were recorded, (7) radar polarization experiments, (8) a seismic wide-angle profile, and (9) a 375-kg seismic refraction shot recorded at 23 and 25 km.

Despite the slow start for the airlifted program, by the completion of the season at the end of January, 84 stations had been occupied (Figure 3). In addition to the usual measurements, radar polarization studies were carried out at three remote stations (H13, M14, and N19), as well at at J9DC and C-16. Airborne radar sounding was completed along 4500 km of flight lines (Figure 4).

The 1976-1977 austral summer marked the initial field season for the SUNY-Buffalo program of core drilling on the ice shelf. A 100-m core was collected at J9DC, and 50-m cores were collected at C-7-3, approximately 20 km from the ice front, and on the ice dome of Roosevelt Island. The V.P.I. ocean tide measurements were made at three more sites: F9, J9DC, and C-16.

RIGGS IV (1977-1978)

Field work for the last season of RIGGS began at base station Q13 on December 23, 1977. During the last week of December, five new remote field sites were occupied, and early in January, airborne radar sounding was made along 1800 km of flight lines.

When not flying, the geophysical group continued detailed experiments around Q13. The new measurements included (1) a seismic surface wave experiment, carried out with shot sizes of 0.5-22 kg, shot depths of 1-5 m, and shot-detector distances of 1.5 and 10 km, (2) continuous radar-sounding profiles along the axis of, and perpendicular to, a topographical depression approximately 5 m deep and 2 km across located 10 km grid west of Q13, (3) a gravity line 45 km long, running grid east-west through Q13, and two supplementary 10-km lines along grid NW and grid SW, (4) an 800-m-long electrical resistivity profile along a line perpendicular to the 1976-1977 profile and the extension of the latter to 700 m, (5) two radar wide-angle reflection profiles, (6) a 350-kg seismic refraction-reflection shot recorded at distances of 10 and 31 km grid west of camp, (7) seismic uphole velocity experiments in a 100-m hole and in several holes of 5 m or less, and (8) radar surface wave measurements made for testing the effect of various antenna orientations.

On January 16, operations were moved to C-16, where near-camp work continued as the opportunity arose. Measurements made near C-16 included remeasurement of the strain networks along the two 40-km lines, a radar wide-angle experiment, and 30-kg and 300-kg seismic reflection shots fired in a 100-m hole. Late in the season the inertial navigation system on the Twin Otter failed, making station relocation impossible. Thereafter, the Twin Otter was flown out of McMurdo Station to establish six new stations in the McMurdo area (Figure 3). Positions were found by resection on geographical landmarks.

During this last season of RIGGS, SUNY-Buffalo obtained 100-m ice cores from sites Q13, C-16, and J9DC; downhole temperatures were measured in each hole. For surface chemical sampling and surface-to-core tie-in studies, two pits adjacent to each other were excavated 5 or 6 km from each of the drill sites. Ultraclean, detailed collections were made in one pit for further laboratory investigations of seasonal and positional variations in chemical constituents and for further characterization of the glacio-chemical regimes represented on the Ross Ice Shelf. Detailed density and stratigraphic measurements were conducted in the other pit to obtain recent rates of surface accumulation.

The V.P.I. ocean tide program on the Ross Ice Shelf finished with measurements for 39 days at site O19 and 30 days at site C-16; the latter measurements were a repetition of those obtained the previous year.

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