Geologic transect across the southernmost Chilean Andes: report of R/V *Hero* Cruise 83-4

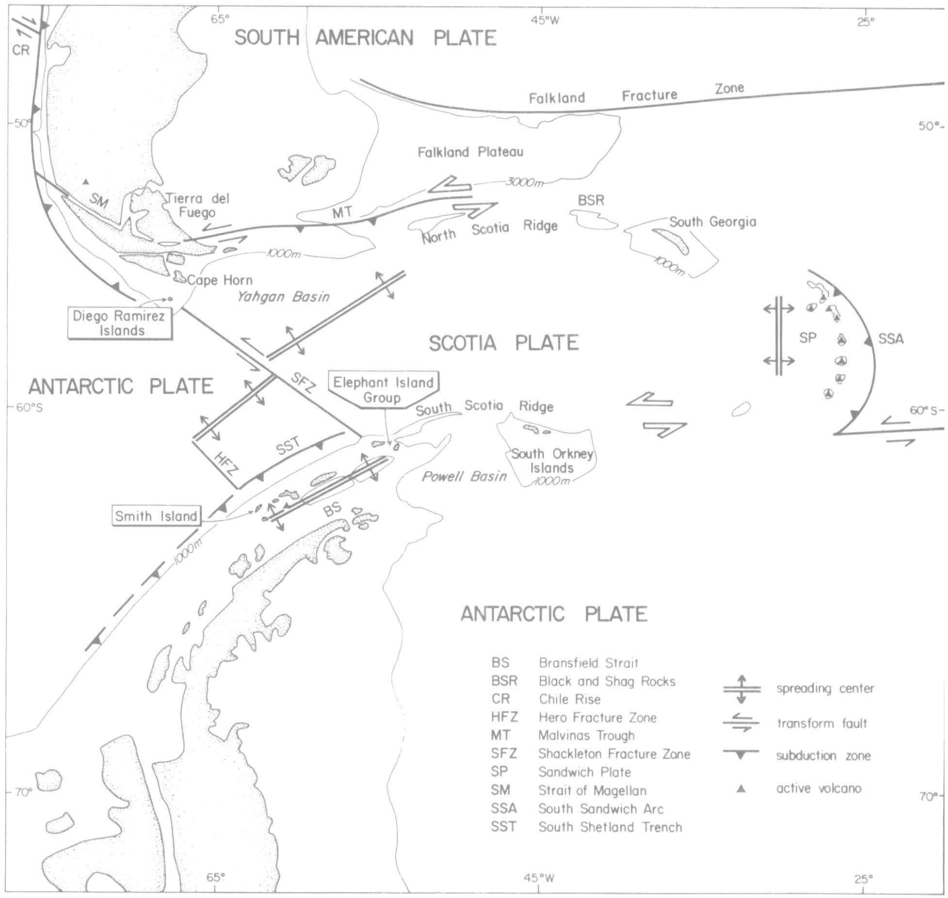
Cruise 83-4 of R/V *Hero*, which began in Punta Arenas, Chile, on 1 June 1983 and ended at the same port on 29 June 1983, involved a geologic transect of the Andean Cordillera in Chilean Tierra del Fuego from Seno Almirantazgo to the Diego Ramirez Islands, approximately 100 kilometers southwest of Cape Horn (figure 1). The objective was to further scientific understanding of the tectonic evolution of the southernmost part of the cordillera in relation to the rest of the Scotia Arc. We made geologic observations, collected samples for geochemical analysis and fission track dating, and made a gravimetric survey.

The participating scientists were:

- Ian Dalziel, Lamont-Doherty Geological Observatory of Columbia University (senior scientist)
- Randall Forsythe, Rutgers University
- Bryan Storey, British Antarctic Survey
- Manuel Suarez, Servicio Nacional de Geologia y Mineria, Chile
- Juan-Carlos Parra, Servicio Nacional de Geologia y Mineria, Chile
- Anne Grunow, Lamont-Doherty Geological Observatory of Columbia University.

The cruise track and principal landing sites are shown on a geologic map of southern Tierra del Fuego (figure 2); geologic sections through the Cordillera are presented in figure 3. U.S., Chilean, and British investigators are still analyzing much of the material and data collected and will present the results of laboratory studies and data reduction at later dates. This report includes observations made during the cruise and comments on their significance.

Figure 1. Tectonic sketch map of the Scotia arc showing locations of cruise area (hatched), the Diego Ramirez Islands, the Elephant Island group, and Smith Island.



Cordillera Darwin

Because Bryan Storey (British Antarctic Survey), who has worked extensively

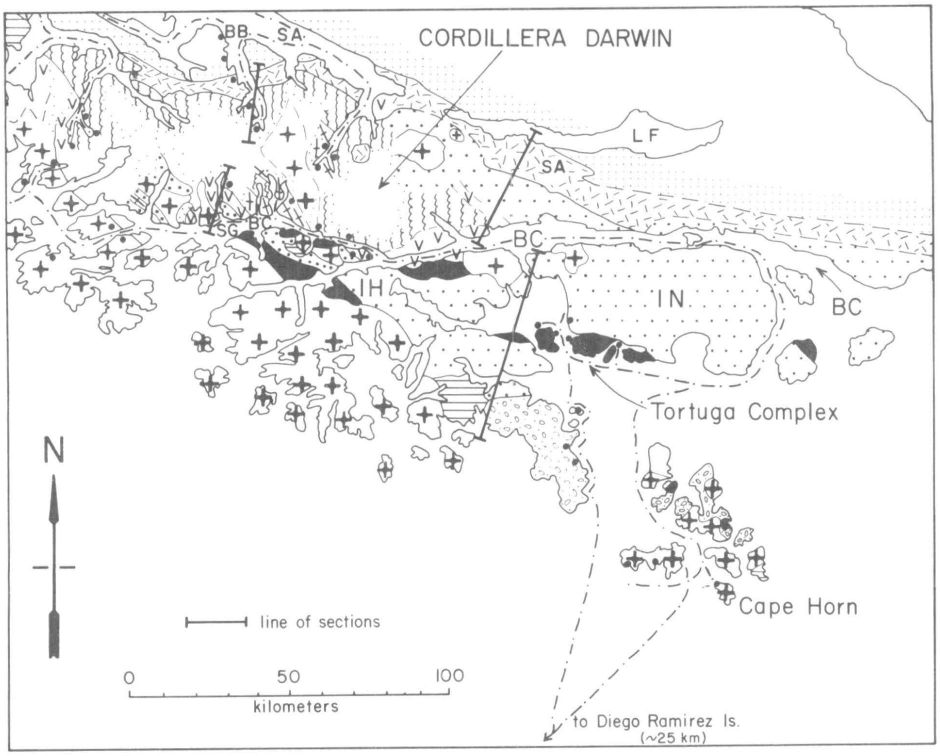


Figure 2. Geologic map of southern Tierra del Fuego showing track (dashed lines) and principal landing sites (dots) of R/V *Hero* Cruise 83-4. For explanation see Table. Solid lines show location of sections. BB-Bahia Brookes, BC-Beagle Channel, IN-Isla Navarino, SA-Seno Almirantazgo, SA1-Sierra Alvear, SG-Seno Garibaldi, IH-Isla Hoste.

RECENTLY ACTIVE VOLCANO	CENOZOIC
UNDEFORMED GRANITIC ROCK	UPPER JURASSIC TO TERTIARY
METASEDIMENTARY ROCK	UPPER JURASSIC TO LOWER CRETACEOUS
volcaniclastic	
argillaceous	
MAFIC IGNEOUS ROCK	
METAVOLCANIC ROCK	
mainly siliceous	
mainly intermediate	
coarse intermediate breccia	
UNDIFFERENTIATED INTERMEDIATE TO MAFIC IGNEOUS ROCK	
DEFORMED GRANITIC ROCK	
BASEMENT COMPLEX	PRE-UPPER JURASSIC
Blank areas in Andean Cordillera unmapped	Ice covered

Table. Principal geologic units of southern Tierra del Fuego.

on South Georgia, participated in this investigation, we were able to compare the geology of Tierra del Fuego and of South Georgia island while we were in the field (figure 1). Previous general correlations were confirmed as a result of these discussions (Katz and Watters, 1966; Dalziel *et al.*, 1974; Tanner, 1982). A major difference lies in the extent of the Andean (middle to Late Cretaceous) deformation. In Cordillera Darwin the pre-Late Jurassic basement has been extensively re-tectonized, and the basement (Gondwanide) structures almost entirely obliterated (Nelson *et al.*, 1980). By contrast South Georgia's Drygalski Fjord complex, although intruded by mafic dikes, is virtually unaffected by Andean tectonism (Storey *et al.*, 1977).

Another significant observation emerged from our work in Cordillera Darwin. Volcaniclastic sedimentary rocks (figure 6) mapped as belonging to the Tobifera Formation (Upper Jurassic) in Bahia Brookes are remarkably similar to the rocks of the Sandebugten Formation (Upper Jurassic or Lower Cretaceous) in South Georgia (Dalziel *et al.*, 1974; Tanner, 1982). Geologists have recognized for a long time that the Sandebugten sedimentary strata was derived from a siliceous volcanic source, probably the Tobifera Formation (Dalziel *et al.*, 1974). Therefore, it is logical that part of what has been mapped in South America as the Tobifera Formation may represent the Sandebugten Formation of South Georgia.

Two outstanding structural problems in Cordillera Darwin must be considered: how well can pre-Andean deformation still be recognized in the pre-Tobifera basement and how much of the volcanic rock in the basement may represent the Tobifera cover rocks emplaced as tectonic slices or fold cores.

Canal Beagle

For some years now geologists have pointed out that field evidence and radiometric data from the southernmost Andes indicate that the main deformation in the Cordillera itself took place during the mid-Cretaceous. Subsequent folding would have been confined to the foothills on the Atlantic side (Dalziel and Palmer, 1979; Winslow, 1982). Recently, however, Manuel Suarez discovered evidence suggesting that deformation in the Cordillera continued into the Late Cretaceous.

During the cruise we observed considerable evidence for this hypothesis. The evidence included not only deformed granitic rocks (figure 5) but also highly foliated contacts with the country rocks.

Horn Island

The most significant observation was that the rocks on the west coast of Horn Island, previously mapped on a reconnaissance basis as gneisses (Suarez, 1979), are flow-banded rhyolites. Presumably, they are part of the Hardy Formation (Lower Cretaceous) of Suarez and Pettigrew (1976).

Diego Ramirez Islands

Before R/V *Hero* cruise 83-4, geologic observations of the Diego Ramirez Islands, located approximately 100 kilometers southwest of Cape Horn, had been limited to the small area around a Chilean navy observation post. These observations, which have not been published, were made by Chilean geologists on their way to Antarctica. During the *Hero* cruise, we were able to land throughout the islands and to study the rocks in some detail. Most of the islands

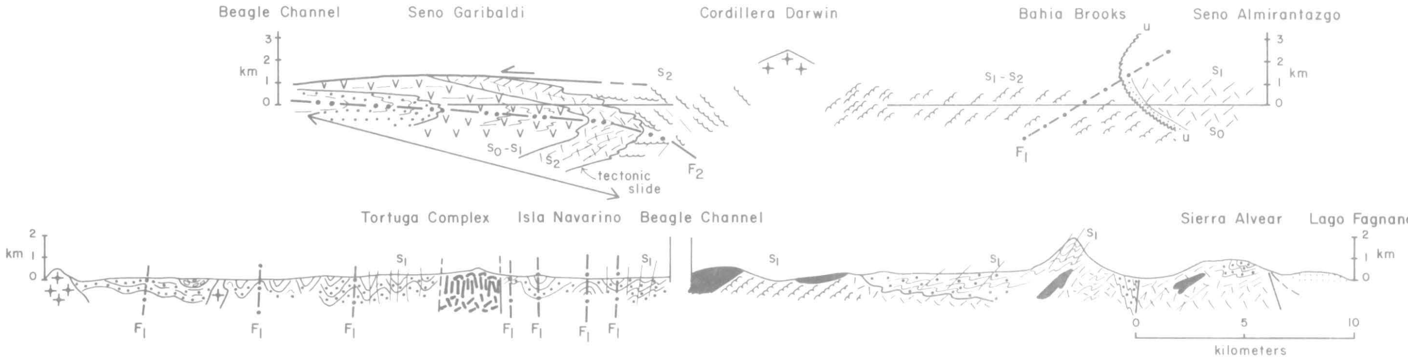


Figure 3. Geologic cross-sections through the Andean Cordillera in Tierra del Fuego. For locations see figure 2; for explanation, see Table.

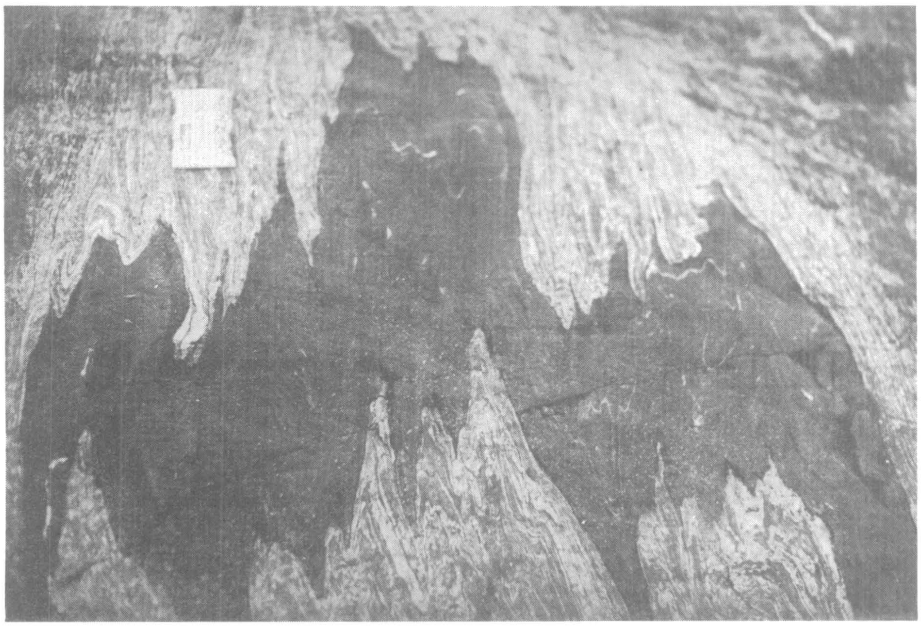


Figure 4. Tightly folded mafic dike, north shore of Beagle Channel, Tierra del Fuego.

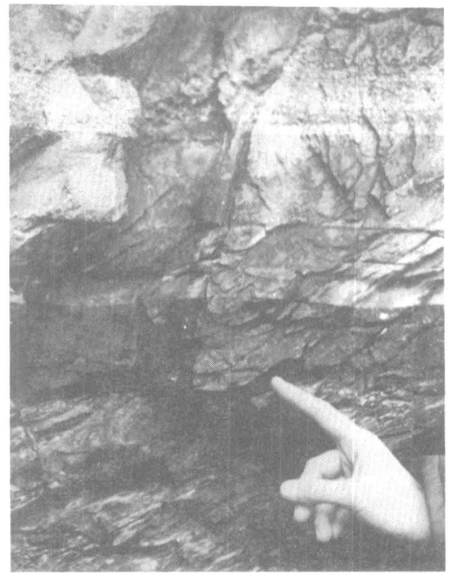


Figure 5. Cleaved volcaniclastic strata of the Tobifera Formation, Bahia Brookes, Cordillera Darwin.

consist of undeformed mafic pillow lavas tilted gently to the northeast (figure 7). There are local intercalations of chert and black argillite; numerous small faults are present.

On the southwesternmost island black phyllites and highly deformed silicic volcanics occur near the Chilean observation post. These rocks (figure 8) have suffered multiple-phase folding and, in the field at least, are virtually identical to the rocks forming the southwestern point of Clarence Island in the South Shetland Islands (figure 1).

The presence of these rocks presents two interesting and potentially important points. First, the Diego Ramirez Islands and Clarence Island are at opposite ends of the same transform fault—the Shackleton fracture zone, which forms the boundary between the Scotia and Antarctic plates (figure 1). This may have no more significance than to indicate a similar tectonic setting at opposite ends of the transform

Figure 6. Two generations of granitic intrusions in the basement rocks of Cordillera Darwin.

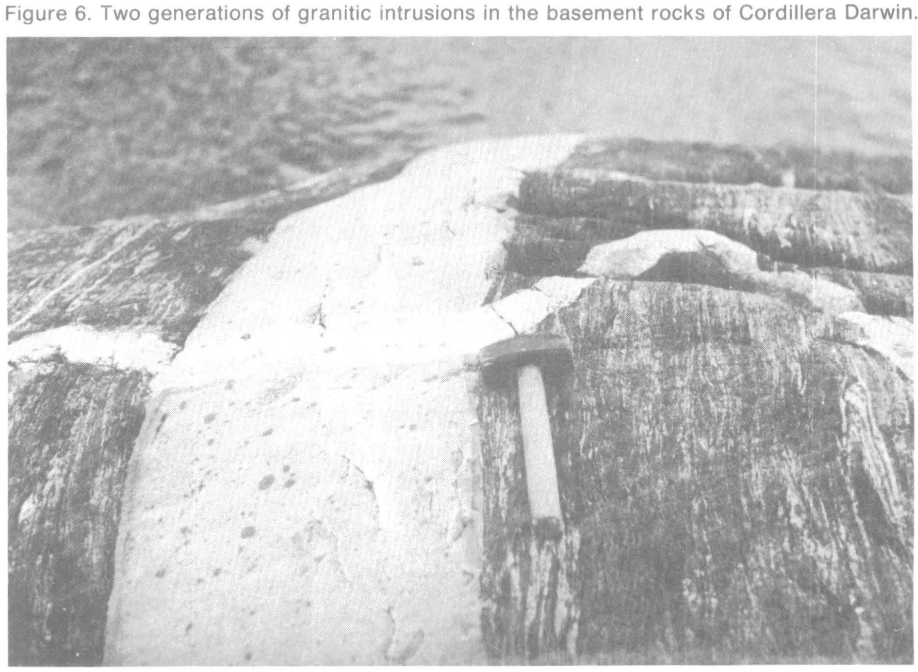


Figure 7. Pillow lava, Diego Ramirez Islands.

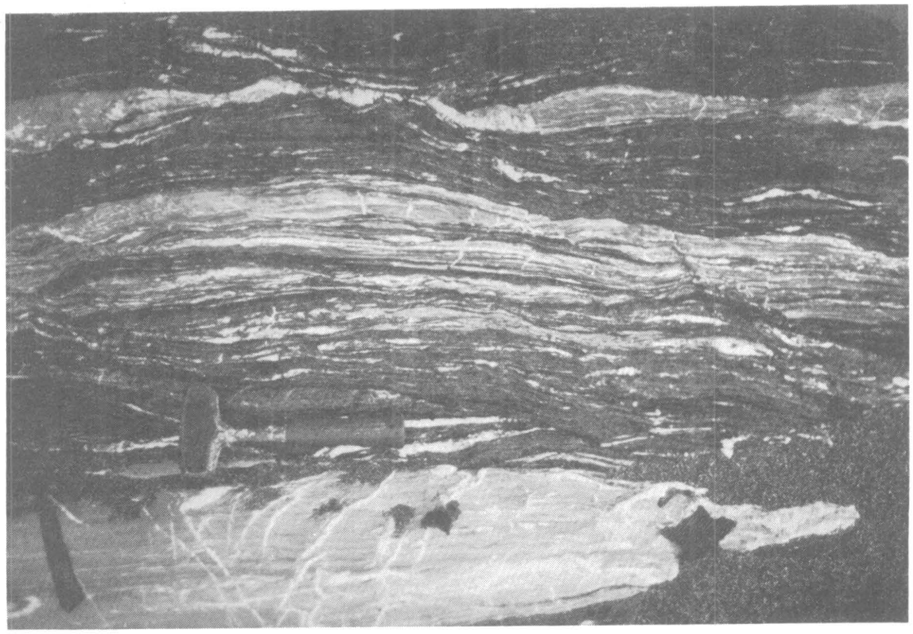


Figure 8. Black phyllite and white deformed volcanic rock, Diego Ramirez Islands.

Figure 9. Pyroclastic rocks, Hardy Formation, Isla Hoste.

fault. However, the second point appears to be more important. At the three places where the terminations of the Shackleton and Hero fracture zones intersect, the convergent margins of South America and the Antarctic Peninsula have experienced significant uplift. For the Diego Ramirez Islands this may not be substantial, because the rocks do not appear to have been highly metamorphosed. The rocks of the northern Elephant Island group (including Clarence Island) and of Smith Island (figure 1), however, reflect uplift of at least 20 kilometers along the Antarctic Peninsula margin (Dalziel, 1982; Tanner *et al*, 1982). To the best of my knowledge, this relationship between fracture zones and convergent margins has not yet been pointed out in other parts of the world and remains unexplained.

Peninsula Hardy and western Isla Navarino

The facies relationships of volcanic and sedimentary rocks of the Hardy and Yahgan Formations along Peninsula Hardy and western Isla Navarino (figures 9 and 10) are exceedingly complex and have led to long debates about their paleogeographic significance. Clearly proximal (debris flow) facies are present (figure 10), but there seems to be no simple geometry for the Pacific edge of the Early Cretaceous "Rocas Verdes" marginal basin (Suarez and Pettigrew, 1976). Indeed the widespread extent of near-shore proximal facies such as those shown in figure 10 calls to question the unique significance of the so-called Tekenika Beds (Dott *et al.*, 1977).

Isla Packsaddle

We collected from the young columnar-jointed alkali-basalt flow on this island. The flow appears to represent the southernmost exposure of the Patagonian basalt field that extends northwards past the eastern end of the Strait of Magellan, eventually to southern Bolivia.

—Ian W. D. Dalziel, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York.

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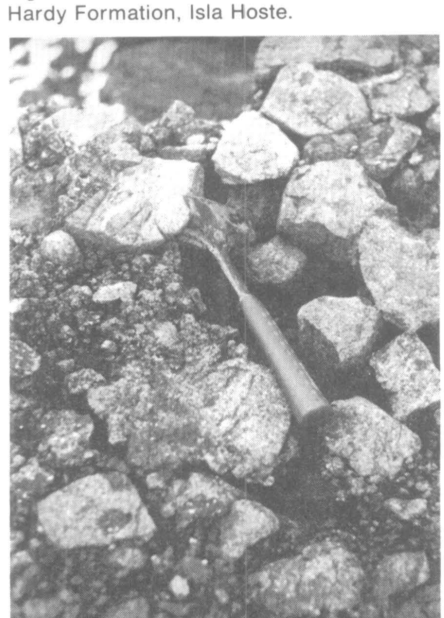
Figure 10. Proximal volcaniclastic breccias, Hardy Formation, Isla Hoste.



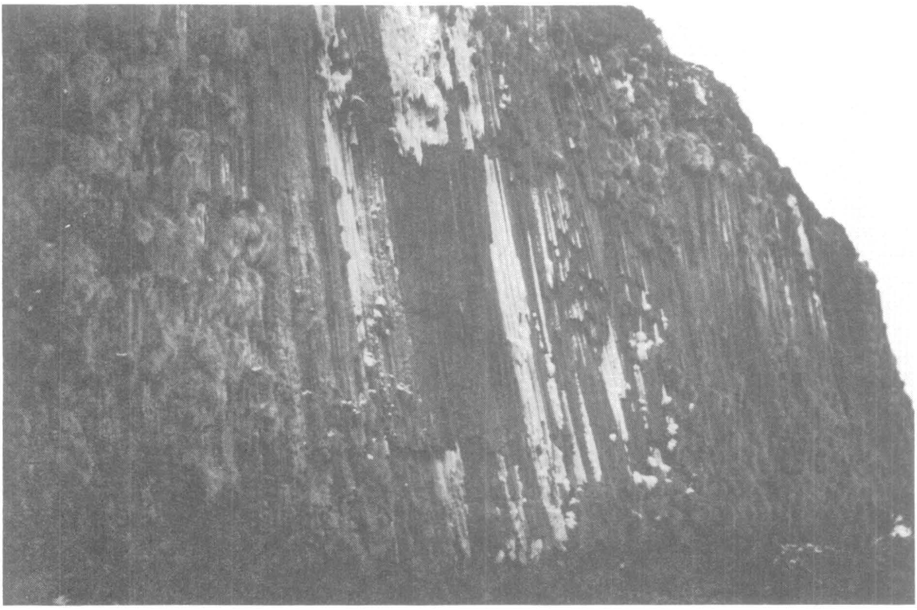


Figure 11. Columnar jointed alkali basalt, Packsaddle Island.

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Maintenance of an observation hole through the McMurdo Ice Shelf for winter oceanography

At the northwest end of White Island (78°10'S 167°30'E) we maintained a 1.2-meter-diameter and 16-meter-deep hole through the McMurdo Ice Shelf (78°S 110°31'E) from February to December 1981 as part of a Weddell seal study. This site enabled us not only to observe the seals' winter activities but also to lower traps and bottom grabs, photograph the benthos with a deep submersible camera, measure water temperatures, collect water samples to a depth of 80 meters, and directly observe ice conditions beneath the shelf using diving equipment. To protect us from the harsh winter environment, we positioned a portable hut with a trap door over the hole. Because this procedure has great potential for studies of seasonal changes in the ice and marine environment beneath the ice shelf, we describe below how we drilled and maintained the observation hole for one year.

White Island, located 26 kilometers south of Ross Island, is bounded on the south and east by the Ross Ice Shelf and on the west by the McMurdo Ice Shelf. We selected a site for the oceanographic hole at the northwest end of the island near an area where Weddell seals regularly haul out along the tidal cracks and pup in November. We knew the ice could be penetrated here because a New Zealand scientific team had maintained an oceanographic hole in this area during the 1978-1979 austral summer.