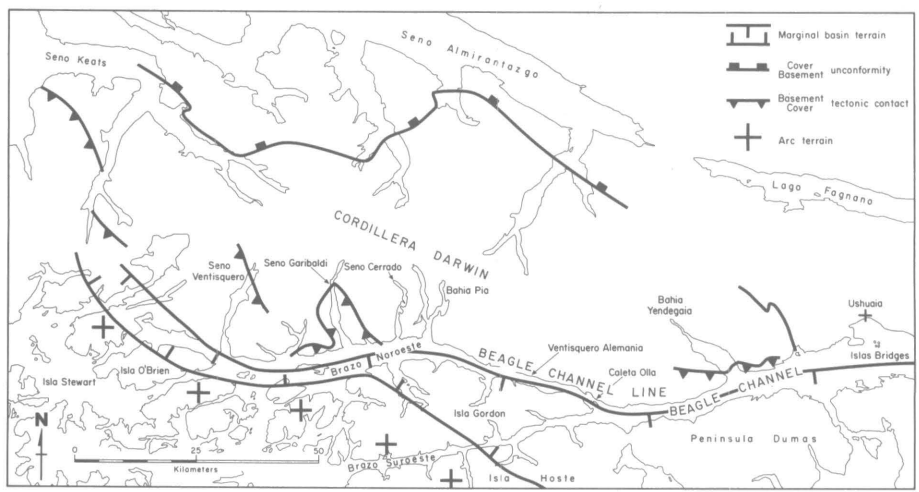
Structural and metamorphic study of the Beagle Channel lineament, Chilean Tierra del Fuego: R/V Hero cruise 84-3

The objective of R/V *Hero* cruise 84-3* was to study the geologic features of the Beagle Channel lineament. The cruise was scheduled to occur between 16 May and 5 June 1984 (see figure 1 for cruise area); it was interrupted by a 4-day search for a missing airplane near Ushuaia, Argentina.

We visited the coastlines on the north and south shores of the Beagle Channel, including both northwest and southwest arms, as well as many fjords in the southern part of Cordillera Darwin. Study of the structural and metamorphic histories, together with age constraints established by uranium-lead zircon work, will help us to better understand the kinematics of back-arc basin closure and its effect on the continental margin. Metamorphic petrology, garnet zonation, and fluid inclusion studies will be used to determine P-T (pressure-temperature) paths of the rocks collected as well as to elucidate the relationship between metamorphism and deformation. Shear-sense techniques will be applied to highly sheared rocks on both sides of the Beagle Channel (figure 2).

In southern Chile we had the unique opportunity to study the deformational

Figure 1. Areas visited on R/V *Hero* cruise 84-3.



* *Hero* cruises in Chile's 200-nautical-mile zone were conducted with the assistance and permission of the Chilean government. In June 1983 representatives of the U. S. and Chilean governments signed an agreement that outlines a cooperative plan for research conducted aboard the *Hero*. To fulfill one requirement of this agreement, NSF publishes the final reports of these cruises in the *Antarctic Journal*.

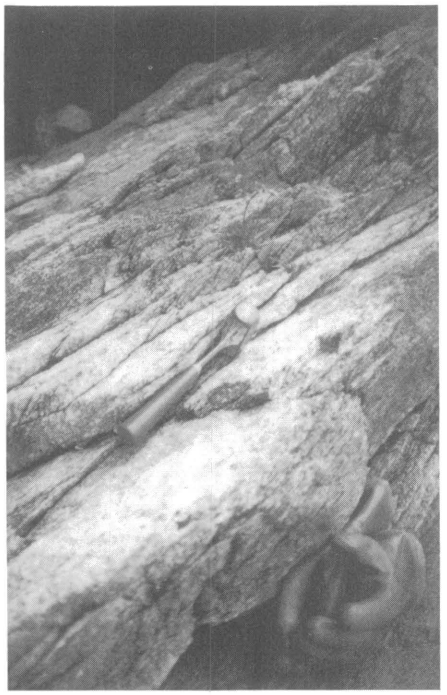


Figure 2. Pre-tectonic foliated granite (Darwin suite, Nelson et al., 1980) Bahia Pia, Cordillera Darwin.

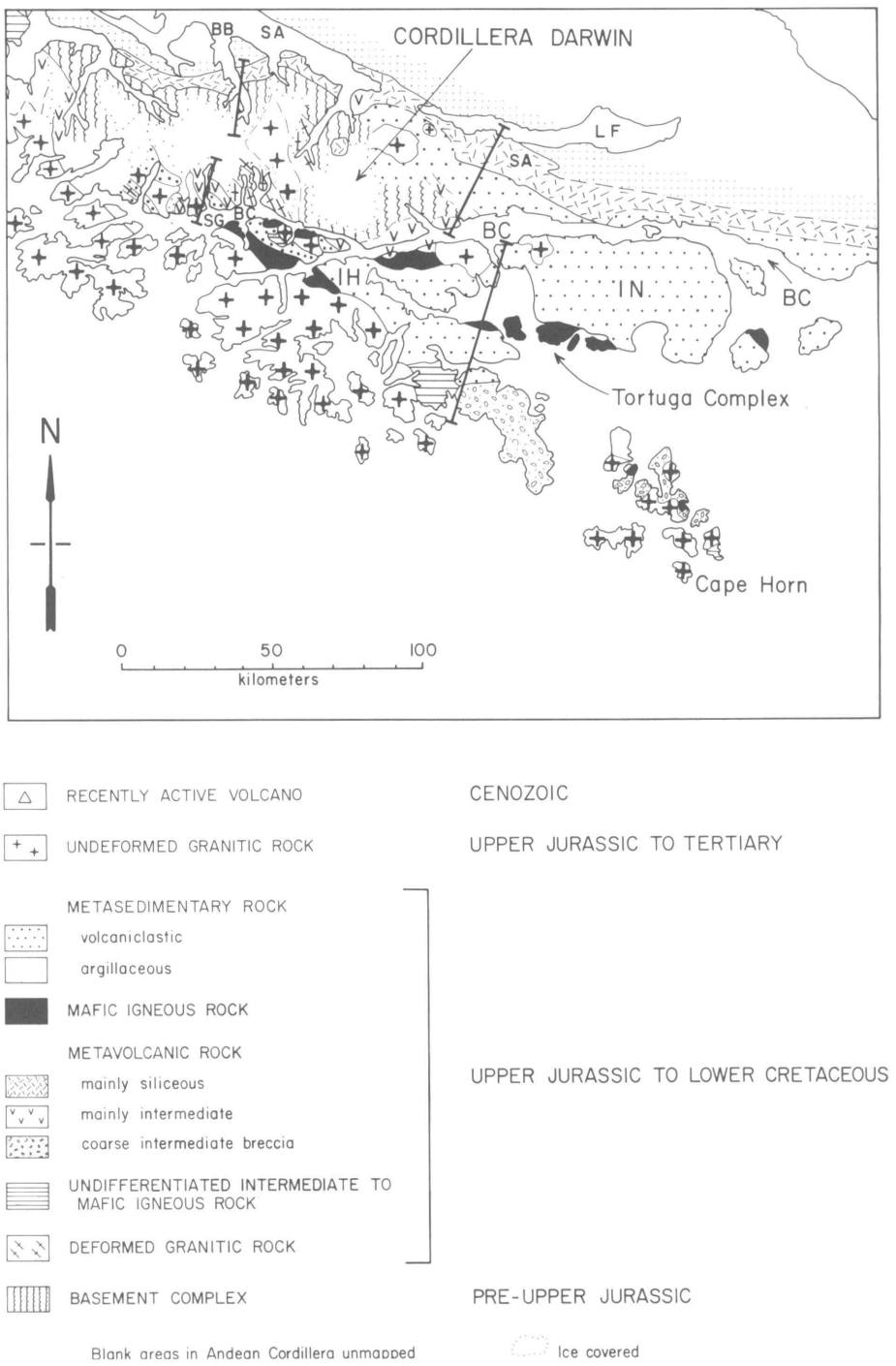
and uplift history of a tectonically well constrained arc-back-arc basin/continental margin setting (figure 3). In the mid-Cretaceous a back-arc basin, partially floored by ophiolotic crust, was closed (Dalziel, 1981). The most intense deformation took place on the continental margin, with migmatization and garnet-amphibolite facies metamorphism occurring in several areas (Nelson et al., 1980). The Beagle Channel lineament seems to represent the tectonic boundary between the ophiolitic back-arc basin terrane and the crystalline continental margin (figure 2; Bruhn and Dalziel, 1977; Nelson et al., 1980). Because the direction and location of the underthrusting during the mid-Cretaceous deformational event is uncertain, one of our objectives in this investigation is to determine these factors.

The south side of the Beagle Channel is characterized by green schist and lower grade metamorphic cover rocks, pillow lavas, gabbros, absence of pre-Late Jurassic basement, and only one main phase of structures. Garnet-amphibolite-facies rocks, including polyphase deformed mafic dikes cutting pre-Late Jurassic basement, and Upper Jurassic(?) volcanic cover occur on the north side (figure 4). Garnet, staurolite, and possibly andalusite and kyanite are present. Lower Cretaceous Yahgan metasediments (marginal basin infill) can be traced across the channel from low-grade siltstones and sandstones on Isla Gordon in the south to medium- to high-grade schists in Seno Garibaldi; this suggests that there may not have been significant strike-slip displacement along the Beagle Channel lineament since the mid-Cretaceous, despite its marked topographic expression (figure 5). The most significant field observations of R/V *Hero* cruise 84-3 are listed below.

Cordillera Darwin

We visited Seno Ventisquero, Seno Garibaldi, Seno Cerrado, Bahia Pia, and Bahia Yendegaia, as well as the shorelines of the Beagle Channel. The pre-Late Jurassic basement at Seno Ventisquero contains dolomite. This is the first carbonate rock found in Cordillera Darwin. In the other fjords, samples were collected from the basement and the Yahgan Formation for metamorphic petrology and from the silicic volcanics and granites for shear-sense studies. Near Ventisquero Alemania, the basement schists were found to contain what appears to be kyanite and fold mullions of highly garnetiferous layers (garnet coticlues?). Stau-

Figure 3. Geologic map of Tierra del Fuego. BB: Bahia Brooks; BC: Beagle Channel; IH: Isla Hoste; IN: Isla Navarino; LF: Lago Fagnano; SA: Seno Almirantazgo; SG: Seno Garibaldi. Lines indicate the location of sections in Dalziel, 1983.



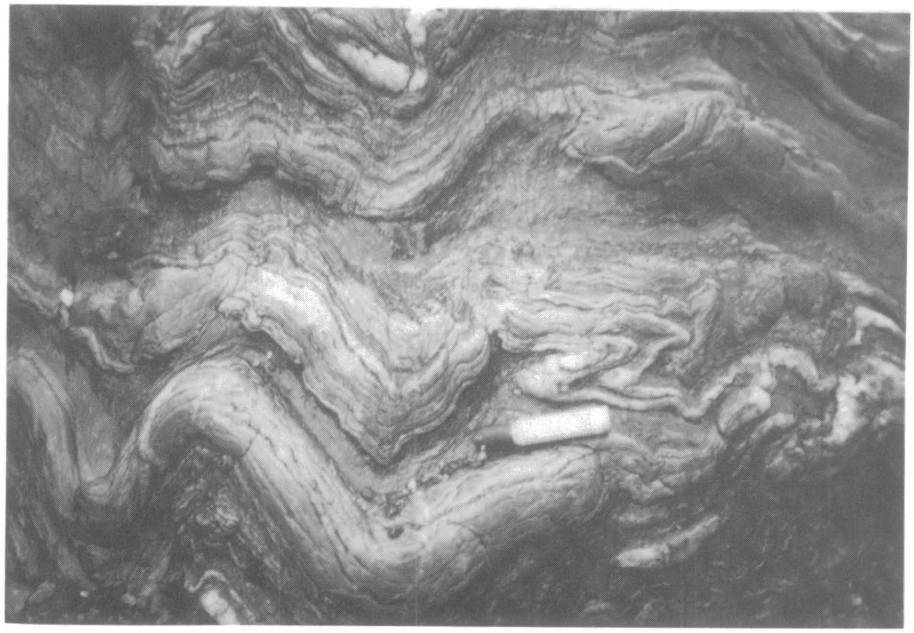


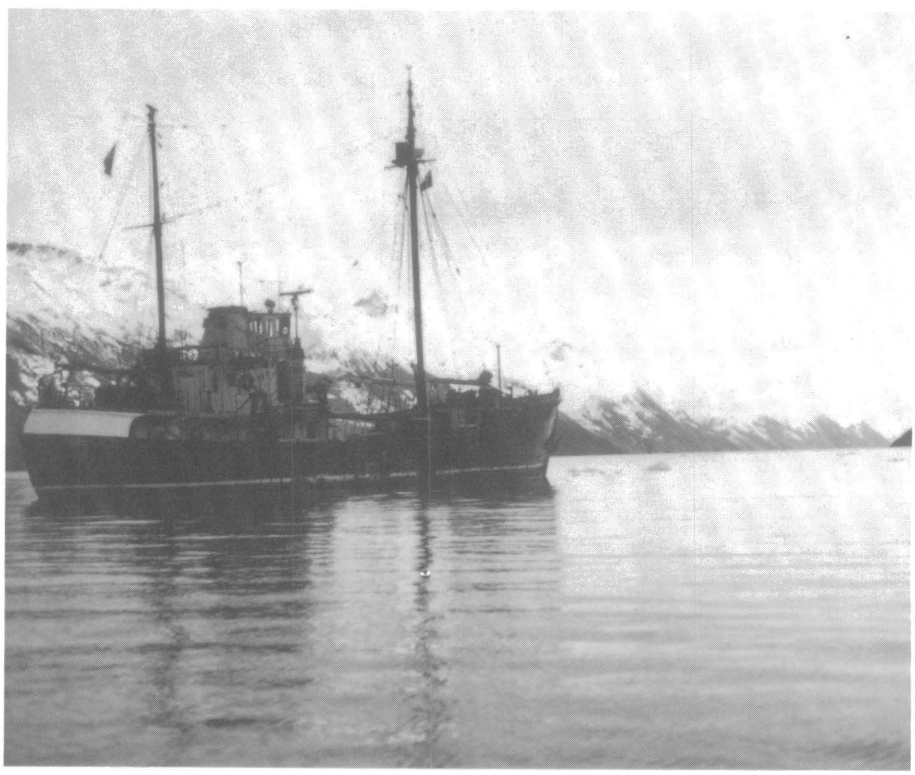
Figure 4. Polyphase folded pre-Late Jurassic "basement," near Ventisquero Alemania, Brazo Noroeste, Beagle Channel.

rolite, amphibole, and rotated garnet were found in Bahia Pia and along the Beagle Channel to Caleta Olla (figure 6). In contrast, the basement in Yendegaia Bay contained no significant porphyroblasts in the graphitic schists.

Isla Gordon

The Chilean authorities permitted landings only on the main coastlines of Isla Gordon and not along the fjords. On the northern side of the island sedimentary structures are still recognizable in the tightly folded but low-grade rocks of the Yahgan Formation. Pillow lavas that were slightly flattened, gabbros, and granite were sampled for uranium-lead studies. Xenoliths of folded garnetiferous Yahgan rocks were found in a granite body and suggest that the granite may be post-tectonic with respect to the mid-Cretaceous deformation (Herve et al., 1984). In Brazo Suroeste of the Beagle Channel, highly sheared mafic rocks contained gneissose lenses of felsic rock possibly representing highly deformed (Upper Jurassic?) silicic volcanics. Some mafic dikes and volcaniclastic rocks containing garnet were also found on the southern side of Isla Gordon.

Figure 5. R/V *Hero* in the Beagle Channel (Brazo Noroeste).



Peninsula Dumas

Flattened pillow lavas, highly foliated mafic dikes, silicic volcanics and metasediments (Yahgan Formation?) as well as unfoliated granite with foliated mafic xenoliths were found along Peninsula Dumas (figure 7). Samples were collected for shear-sense analysis, fluid inclusion studies and uranium-lead work.

Islas Bridges

In an attempt to make the best use of the lost science time in Argentina during the search mission, we studied the rocks on the Islas Bridges and in Ushuaia harbor (Yahgan Formation; Bruhn, 1979). These islands are important to this study because they extend far into the Beagle Channel from the north shore. Consequently, their structure might be expected to reflect any strike-slip or other Cretaceous-Tertiary movements.

We did not find any evidence for major fault movement on these islands. The rocks were tightly folded and cleaved shales, siltstones, and sandstones with a west-northwest structural trend, exactly along strike from those of the Yahgan Formation north of the Beagle Channel studied by Bruhn (1979) to the west of Ushuaia.

Isla O'Brien—Isla Stewart

Unfoliated granitic-dioritic rocks, gabbro, volcanic breccias, and mafic dikes were seen on these islands (figure 8). Samples

Figure 6. Rotated garnet (right side of picture), basement schist, Bahia Pia, Cordillera Darwin.

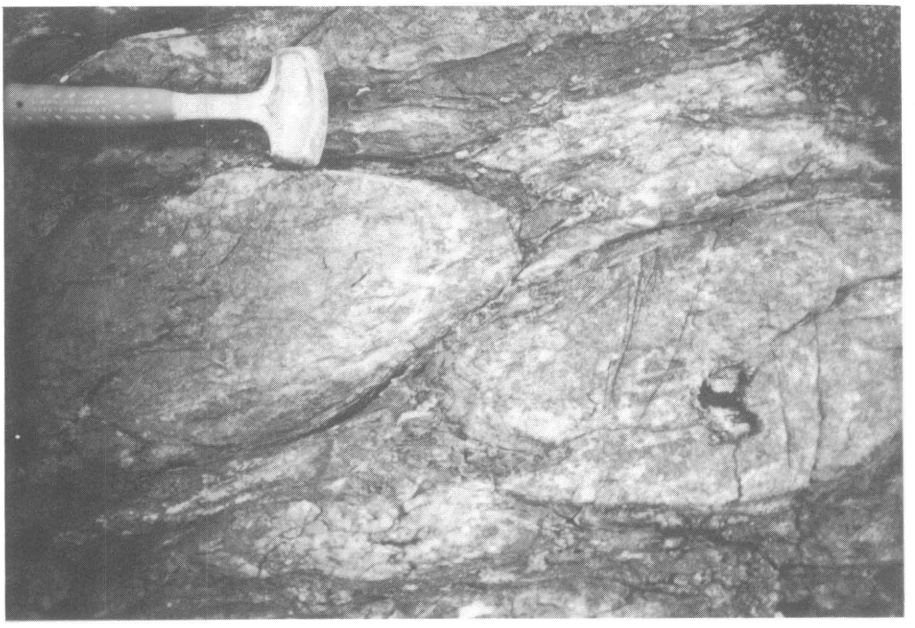


Figure 7. Flattened and foliated mafic pillow lava, Peninsula Dumas.

were collected for uranium-lead dating. The unfoliated nature of most of these rocks could imply that they are post-tectonic in age although a 25-meter wide vertical shear zone through the volcanics and metasediments does occur on Isla O'Brien.

Cruise participants

The scientists who participated on this cruise were

Anne Grunow, Lamont-Doherty Geological Observatory of Columbia University (senior scientist)

Ian W. D. Dalziel, Lamont-Doherty Geological Observatory of Columbia University (principal investigator)

Sam Mukasa, Lamont-Doherty Geological Observatory of Columbia University

Frank Spear, Massachusetts Institute of Technology

Carlos Herrero, Empresa Nacional del Petroleo, Chile

Hans Niemayer, Universidad del Norte, Chile.

Figure 8. A geologists investigates unfoliated granitic-dioritic rocks, gabbro, volcanic breccias and mafic dikes on Isla O'Brien and Isla Stewart.

We are continuing to analyze the material collected during this cruise and will published the results later.

—Anne M. Grunow and Ian W. D. Dalziel; Lamont-Doherty Geological Observatory of Columbia University; Palisades, New York 10964.

References

Bruhn, R. L. and I. W. D. Dalziel. 1977. Destruction of the early Cretaceous marginal basin in the Andes of Tierra del Fuego. In M. Talwani and W. C. Pitman, III (eds.), *Island arcs, deep sea trenches and back-arc basins*, Maurice Ewing Series, Volume 1. Washington, D. C.: American Geophysical Union.

Bruhn, R. L. 1979. Rock structures formed during back-arc basin deformation in the Andes of Tierra del Fuego. *Geological Society of America*, 90: 998-1012.

Dalziel, I. W. D. 1981. Back-arc extension in the southern Andes: a review and critical reappraisal. *Philosophical Transactions of the Royal Society of London, A*, 300: 319-335.

Dalziel, I. W. D. 1983. Geologic transect across the southernmost Chilean Andes: Report of R/V *Hero* cruise 83-4. *Antarctic Journal of the U. S.*, 18(4): 8-12.

Herve, M., M. Suarez, and A. Puig. 1984. The Patagonian batholith south of Tierra del Fuego, Chile: timing and tectonic implications. *Journal of the Geological Society*, 141: 909-918.

Nelson, E.P., I. W. D. Dalziel, and A. G. Milnes. 1980. Structural geology of the Cordillera Darwin—collisional-style orogenesis in the southernmost Chilean Andes. *Eclogae geologicae Helvetiae*, 73(3): 727-751.

Marine living resources act becomes law

On 8 November 1984 President Reagan signed Public Law 98-623, Title III of which is the Antarctic Marine Living Resources Act of 1984. The act, which is part of a bill approving how international fishery agreements with Iceland and the European Economic Community will be governed, provides the necessary legislative authority to implement the Convention on the Conservation of Antarctic Marine Living Resources (see *Antarctic Journal*, Vol. 15, no. 4 for the complete text of the convention). Introduced by Representative John Breaux (Democrat-Louisiana) in June 1983, the act was approved by Congress in October 1984.

The act directs the Department of Commerce, through the National Oceanic and