

# Hero cruise 84-5: geology and geophysics in the Patagonian Andes

*Editor's note:* 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*. *Hero* was the National Science Foundation's antarctic research ship from 1968 through 1984. During the austral winters, when ice prevented work in the far south, *Hero* operated in the Subantarctic and along the southern coasts of South America.

The *Hero* was used from 14 July to 7 August 1984 to conduct geologic and geophysical investigations in the southernmost Andes. Our objectives were to define the nature of Cenozoic tectonic movements in the southern Andes and investigate the geologic and geochemical evolution of the Patagonian batholith (a more than 2,000-kilometer-long linear outcrop of igneous rock) along the Pacific margin of southern South America.

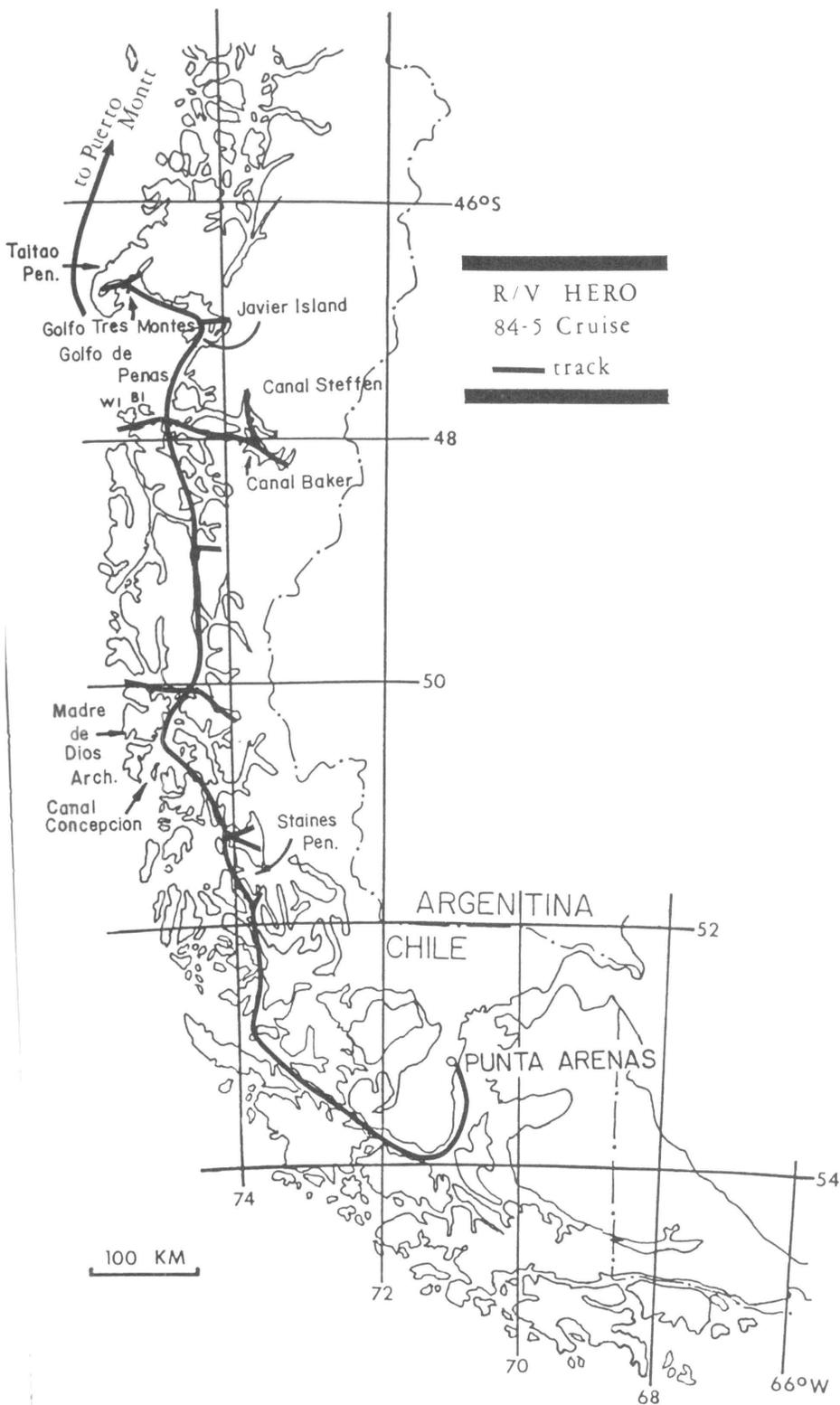
In addition to the author, scientific personnel included Bob Bruce from the Colorado School of Mines, Lisa Chisholm and Margaret Kaeding from Rutgers University, Carlos Johnson of the Empresa Nacional del Petroleo of Chile and Jose Manuel Sofia from the Universidad de Chile, Santiago. The official Chilean observer was Teniente Segundo Patricio Banados F. of the Chilean Navy. The cruise track for the 84-5 cruise is shown in the figure.

## Project description

To accomplish the cruise objectives, we divided our project into two parts. From 14 to 28 July we collected rock samples, fault and fracture data, and gravity readings along traverses made from the region of Peninsula Staines north to Canal Baker. Over 100 samples collected principally from the Patagonian batholith were obtained for fission track and geochemical work. We measured nearly 80 brittle and semi-brittle fault and shear zones along the traverses. Gravity readings were made every 2 nautical miles along east-west traverses and every 4 to 6 miles along north-south traverses.

Although final scientific results must await laboratory studies that are underway, a few preliminary findings are clear. Distribution of brittle faults and fractures is highly irregular, but they have reasonably consistent orientations over fairly large areas (greater than 100 square kilometers). Because these regionally consistent fault sets affect Late Cretaceous and early Tertiary intrusives, they are mostly of Cenozoic age. We interpret this as reflecting regionally prevalent tectonic patterns of brittle deformation that followed the main phase of Andean orogenesis (mountain-formation processes) in the mid-Cretaceous (Dalziel, 1981).

Gravity data was reduced onboard on a microprocessor to yield preliminary Bouguer anomaly values. Bouguer anomalies are derived by correcting the observed gravity for latitude, variations in elevation, and the mass of material between the observation site and sea level. A strong positive Bouguer anomaly appears over the north-west extent of the Sarmiento Complex on the north side of the Staines Peninsula. Also, we found very steep gradients in the Bouguer field along two traverses—one across Canal Concepcion and Canal Ancho, located east of the Madre de Dios Archipelago, and the other, a north-south profile, along Canal Steffen into Canal Baker. Both likely reflect deep-seated discontinuities in the Andean crustal structure. The northern discontinuity trends east-west across the Andes and correlates with the southern boundary to the Golfo de Penas



Ship track of *Hero* cruise, Punta Arenas to Puerto Montt, 14 July to 7 August 1984. Symbols WI and BI are for Wager Island and Byron Island, respectively.

and the southern limit of the North Patagonian ice cap.

During the second part of the cruise, 28 July to 7 August, we mapped and sampled geologic units within the regions surrounding the Golfo de Penas. Three areas were investigated. The first area was Wager

and Byron islands, which are the southwesternmost islands that border the Golfo de Penas. Then we took time to study Javier Island marine and glacial deposits, which were discovered the previous year on *Hero* cruise 83-5. The third area of study was the inner coast of the Taitao Peninsula.

### Observations near Golfo de Penas

*Wager and Byron Islands:* We mapped four geologic units in this area. Wager Island appears to be entirely formed by intrusions of the Patagonian batholith. Byron Island has four major units exposed from east to west along its north shore. To the east, in apparent continuity with units of Wager Island, are exposures of calc-alkaline plutonic rocks that are mapped as part of the Patagonian batholith. To the west there are three additional units that had not been previously mapped. Adjacent to the plutonic units, appears a sequence of silicic and intermediate volcanic rocks. To the west of the volcanic strata, there is an indurated sequence (rock material hardened by heat, pressure, or cementing material) of plant-bearing dark siltstone, sandstone, and conglomerate. The contact with the volcanic sequence was unexposed. Preliminary work on foraminifera from the sedimentary strata (R. K. Olsson, personal communication) suggests Middle Eocene ages. Finally, west of the sedimentary strata, there is an outer belt of tight-to-isoclinally folded metasedimentary strata that most likely correlate with the pre-Late Jurassic basement complexes mapped along the outer fringes of the Patagonian Archipelago both to the north and south (Herve et al., 1981; Forsythe and Mpodozis, 1979).

*Javier Island:* Additional sampling was done on the sequence of poorly consolidated marine and glacial strata that were discovered the previous year along the southeast side of Javier Island. The sequence is at least 70 meters thick and has a shell bearing marine diamict unit near the base, which is overlain by a marine unit of interbedded silt and sand that contains shell fragments. The top 30 meters is composed of coarse gravel, sand, and till with approximately 1 meter of peat at the top of the section.

*Taitao Peninsula:* Here, our investigation concentrated on obtaining a better definition of the distribution of cenozoic marine sedimentary strata and igneous units. Within the region, three separate marine sedimentary sequences can be distinguished on the basis of their lithofacies, age, and degree of induration. The oldest and most indurated sequence is formed of interbedded plant-bearing, dark sandstone, siltstone, and conglomerate. These strata have identical lithofacies and induration as those strata mapped on Wager Island and are likely to be of a similar age (Middle Eocene). This sequence is principally exposed along the northeast shores of the Tres Montes Peninsula.

The next younger sequence is composed of a moderately indurated sequence of principally buff to grey siltstones and sandstones, with less frequent conglomerate, and calcarenite beds. This sequence has

yielded Late Miocene foraminifera (R. K. Olsson, personal communication). It is principally exposed on islands to the east of the Taitao Peninsula.

The third and youngest sequence was discovered along the southeast shores of the Taitao Peninsula where an indurated sequence of thin-to-moderately bedded marine sandstone and siltstone is interbedded with marine volcanic and volcanoclastic units of basalt-andesite to rhyolite composition. Some sedimentary strata preserve turbidite structures. Preliminary work on foraminifera indicates a Pliocene to Pliestocene age for portions of this sequence.

Cenozoic igneous units of the area include a series of isolated intrusions as well as a coherent complex of igneous rocks that is referred here to as the Taitao ophiolite. Some of the isolated intrusive bodies intrude the latest Miocene marine strata; others have been dated by potassium-argon methods at the Chilean geological survey (Servicio Nacional de Geología y Minería, M. Herve, personal communication) and are of Pliocene ages.

In the outer western portions of the Taitao Peninsula a reasonably coherent complex of ultramafic rocks, gabbro, diabase and interbedded volcanic and marine sedimentary strata forms the Taitao ophiolite. The complex has its plutonic units principally exposed along its southwest limit, and the volcanic units to the northeast. It covers approximately 210 square kilometers. Based on both potassium-argon dating (Servicio Nacional de Geología y Minería, M. Herve, personal communication) and a study of foraminifera in the marine strata (R. K. Olsson, personal communication) our assumption is that the complex is Pliocene to Pliestocene in age. Initially, it appears to be a reasonably complete ophiolite; it is the most complete ophiolite discovered thus far in southern South America and may be one of the world's youngest. Further work is needed to better define the nature and origin of the Taitao ophiolite.

Samples and field data from the 84-5 cruise are located either at Rutgers University or at the Colorado School of Mines. Representative sample suites also have been retained by the participating Chilean geologic organizations. Support for this work comes from National Science Foundation grants EAR 82-06646 and EAR 83-07604 to Eric Nelson (Colorado School of Mines) and EAR 82-06100 to R. Forsythe. We also thank Captain P. Lenie and the entire crew of *Hero* for their efforts.

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## Sightings of toothed whales along the antarctic coast and in the South Atlantic Ocean

From 21 January to 7 March 1983 we survey marine mammal populations as the Coast Guard icebreaker *Polar Star* traversed westward from McMurdo Station, Antarctica, to Palmer Station, Antarctica (Erickson et al., 1983). During the transit (figure), the ship traveled in open water next to the ice edge or in the ice pack. This cruise, which covered a large area in a relatively short time, provided us with a unique opportunity to record observations of cetaceans. Many of the areas surveyed were regions of the continent rarely visited by research ships.

Sightings also were made as the ship transited from Palmer Station to Punta Arenas, Chile, between 7 and 10 March 1983 and then on to Rio de Janeiro, Brazil, between 10 and 18 March 1983. During this part of the trip, we observed marine mammals in temperate and tropical waters of the South Atlantic Ocean.

We observed several hundred whales and dolphins during the cruise. Although baleen whales represented the majority of sightings, these observations will be reported in a separate publication. The observations reported below are preliminary. Funding for this project was provided by National Science Foundation grant DPP 80-10588.

### Observation methods and data analysis

Transect surveys for marine mammals were conducted during daylight hours

\* A Beaufort 4 or higher sea state exists when waves exceed 4 feet in height, numerous whitecaps exist, and winds exceed 11 knots. Sea states exceeding Beaufort 4 rating create conditions that are minimally effective for surveys.

when sea states did not exceed a Beaufort 4 rating.\* We made our observations from the loft con (elevation 105 feet) during the transit from McMurdo Station to Palmer Station and from the flying bridge (elevation 72 feet) during the Palmer Station to Punta Arenas and Rio de Janeiro transits.

For data analysis, survey observations and supporting data were recorded in 20-minute time blocks. When a sighting was made, we recorded the following data: the side of the ship, estimated distance from the ship (at the nearest point), species, and number of individuals, as well as any significant behavior. Position, sea temperature and water depth were later interpolated from the ships log.

### Results and discussion

We conducted surveys over 5,385 nautical miles of the total 10,414 nautical miles of the westward traverse between McMurdo Station and Palmer Station (figure). Of the 3,218 nautical miles traveled from Palmer Station to Punta Arenas, to Rio de Janeiro, 836 nautical miles were surveyed.

During the McMurdo-Palmer transit, we observed 162 odontocetes (toothed) whales representing four genera and four species (table 1). The Palmer-Rio de Janeiro trip yielded sightings of 64 odontocetes of which 49 were dolphins (table 2).

### Sperm whales

In all, we observed 10 sperm whales (*Physeter macrocephalus*). Of this total, only one, a large bull, was seen in antarctic waters. This animal was observed 0.75 mile off the ice edge near Vincennes Bay at 65°09'S, 111° 12'E. According to Ber-