

2.1 Submarine topography in the Chilean North Patagonian channels

Cristián Rodrigo

Departamento Científico. Instituto Antártico Chileno.
E-mail: crodrigo@inach.cl

Prior characterization of the submarine topography in North Patagonia was based on complementary, single-beam echo-sounder records carried out during oceanographic studies (e.g. Pickard, 1971; Silva *et al.*, 1995; Silva & Calvete, 1997), and low-frequency echo sounders or seismic profiler records (Araya-Vergara, 1997, 1998; Da Silva *et al.*, 1997). These methods are only able to describe the seismic facies below the seafloor along the transects of the vessel's navigation trajectory and cannot characterize the submarine geomorphology of areas adjacent to the profile.

However, in 1995, the first multibeam sonar survey of the Chilean channel and fjord region was carried out. This cruise, CIMAR 1 Fjordos, took place between Puerto Montt and Laguna San Rafael, North Patagonia, and used a Sea Beam multibeam echo-sounder installed onboard the AGOR Vidal Gormaz of the Chilean Navy. The sonar, which emits at a frequency of 12 kHz, projects 16 sound beams (similar to an acoustic fan) to the side of the navigation route, resulting in a bathymetric survey with a lateral coverage of 0.75 times the vertical depth below the vessel. Rodrigo (1996) used the bathymetry obtained during this cruise for the first time, but lateral bathymetric coverage was not wide enough to allow a more detailed spatial study due to the system design for deep water surveys, in spite of the available bathymetry of current navigational charts. Moreover, some navigational charts provided no datum, exhibiting distortions and no sounder information. In 2000, the multibeam sonar systems Hydrosweep (320 sound beams emitted at 50 kHz) and Fansweep (maximum capacity: 1440 sound beams emitted at 200 kHz) were installed on board the Chilean Naval vessel PSH Cabrales in order to carry out precise, high-resolution bathymetric surveys in shallow and intermediate waters (up to 700 m depth). The

spatial coverage of these sonar systems was about 6 times the depth below the vessel. Furthermore, differential satellite positioning, speed of sound, and ship's movement real-time corrections helped to exceed international quality standards for the data used in navigational charts. Rodrigo (2002) presented the preliminary underwater geomorphology results from the multibeam bathymetry study of interior waters from 41° 30'S to 46° 30'S providing detailed geomorphology for Fiordo Aysén, Canal Moraleda, Canal Chacao, Seno Reloncaví, and Golfo Corcovado.

This paper presents a compilation of the bathymetric data obtained up to 2004 with the equipment on board the AGOR Vidal Gormaz and PSH Cabrales as well as with portable echo sounders installed on Zodiac-type boats that navigated between Puerto Montt and Canal Moraleda. These data were provided by the Centro Nacional de Datos Hidrográficos y Oceanográficos de Chile (CENDHOC). The bathymetry was corrected for the tides (except for the Sea Beam data), adjusting the data to the lowest tide level (NRS) according to standard hydrographic procedures. Due to the large amount of bathymetric data, the sounder data were automatically selected based on their lowest value in an average radius of about 140 m. Then, two digital 400 x 400 m grids were created for each area (Puerto Montt-Laguna San Rafael, Canal Moraleda) by using the "nearest neighbor" interpolation algorithm (<http://gmt.soest.hawaii.edu>).

Figure 1 shows the submarine topography from Puerto Montt to Golfo Corcovado. The image uses simulated illumination from the NW at an elevation of 30°. The terrestrial area (gray) is merely referential because it originally has another datum with regard to the submarine topography (in WGS-84) and, therefore, is displaced in latitude and longitude. The deepest areas (> 300 m; blue) are

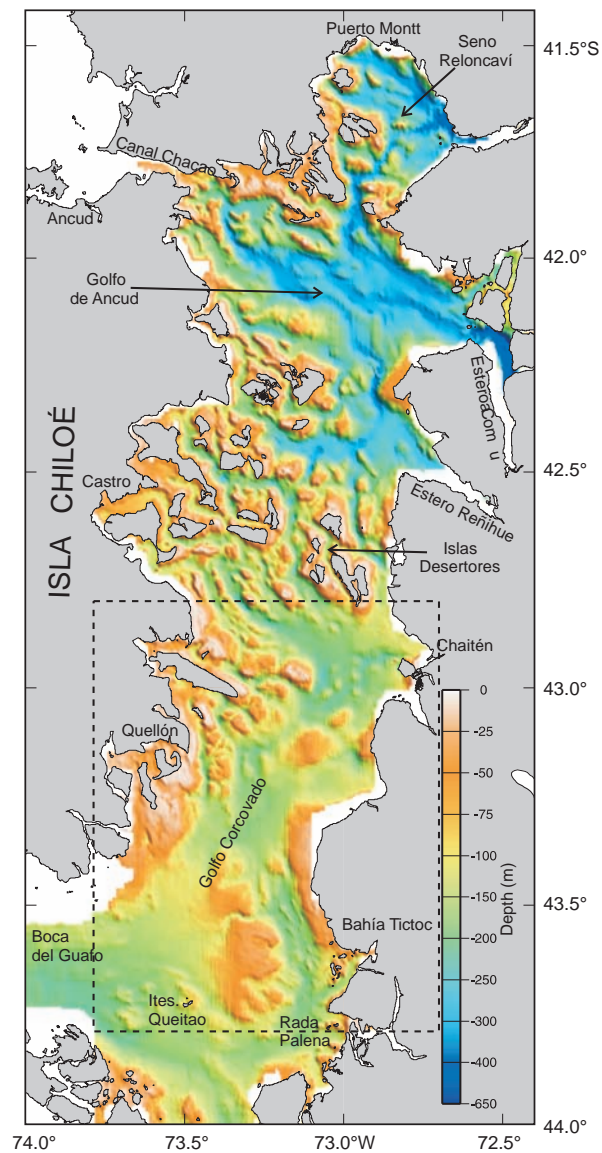


Figure 1: Submarine topography between Puerto Montt and Golfo Corcovado based on single and multibeam bathymetric information from 1995 to 2004. The topographic image is illuminated from the NW and its elevation is 30°. The coastal and terrestrial zones are only referential because of a spatial displacement due to differences in datum. The area outlined with dotted lines indicates the area shown in the 3D topographic representation of Figure 3.

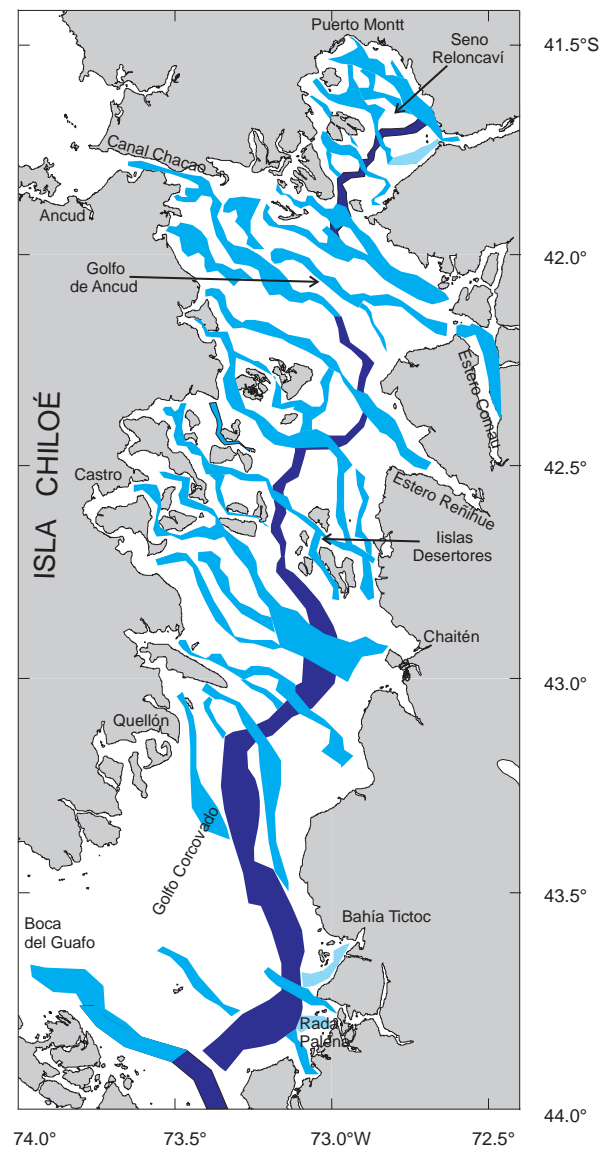


Figure 2: Map of the region between Puerto Montt and Golfo Corcovado indicating the main areas of submarine depressions (dark blue: longitudinal depression, light blue: oblique depressions).

located in Seno Reloncaví and Golfo Ancud to the latitude of Río Reñihue (Fig. 1). These areas tend to form channels or narrow depressions, approximately NW-SE in direction (Fig. 2). Other smaller submarine features and islands also tend toward elongated NW-SE extensions, with steeper walls in the direction of the tendency. These features are probably manifestations of the advance-retreat movements of glaciers in the past (Heusser, 1990) and/or the influence of secondary faults associated with the Liquiñe-Ofqui fault (Delgado, 2004). The semicircular shape of the deepest part of the Golfo Ancud, on the eastern coast of Isla Chiloé, indicates where the influence of the glacial advance ended in this area. Structural lineaments with a NW-SE direction can also be seen around the Islas Desertores (Fig. 1 and 2). To

the south of these islands (Golfo Corcovado), the longitudinal depression (Fig. 2, dark blue), which has an approximate N-S direction, seems to dominate the deep sectors of the area (Araya-Vergara, 1997). Here, the shallow areas (orange-brown) are not as elongated as in the north, but are more rounded like submarine plateaus. The largest plateau is located between the Islotes Queitao and Rada Palena. Smaller elongated features, very similar to drumlins, are found mostly between this plateau and Bahía Tictoc, south of the Islas Desertores, and demonstrate the mechanical action of past glaciers. Given the disposition and shape of the shallow areas (100-150 m deep, round), moraine debris is likely to be found between Chaitén and Isla Chiloé.

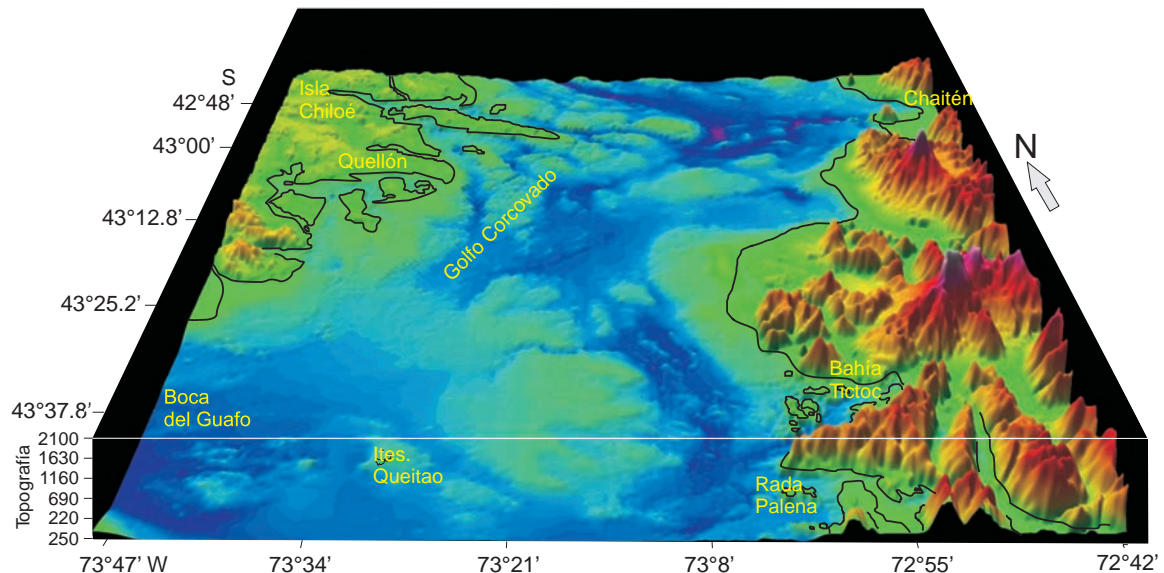


Figure 3: 3D representation of the Topography of the Golfo Corcovado area.

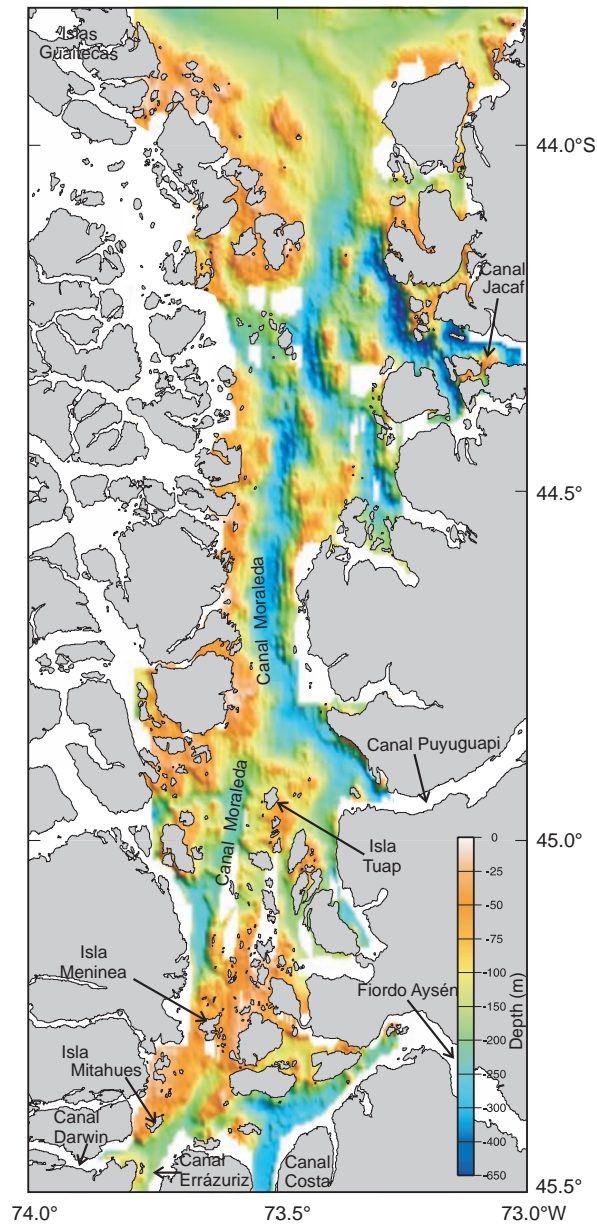


Figure 4: Submarine topography in the area of Canal Moraleda based on single and multibeam bathymetric information from 1995 to 2004. The topographic image is illuminated from the NW and its elevation is 30°.

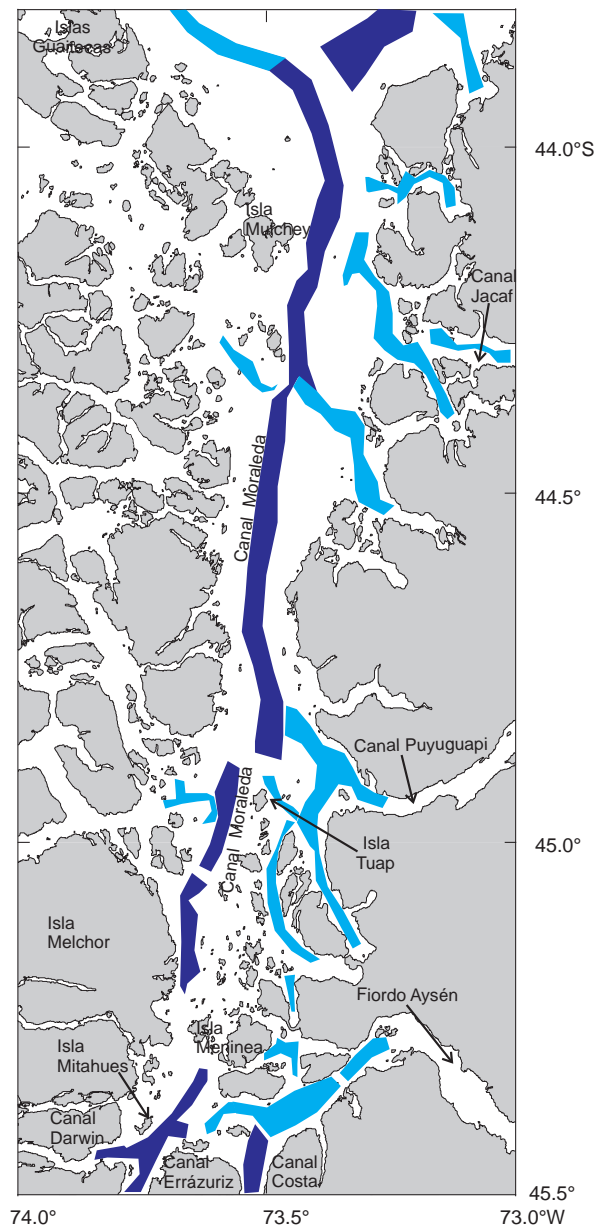


Figure 5: Map of the Canal Moraleda area indicating the main areas of submarine depressions (dark blue: longitudinal depression, light blue: oblique depressions).

A 3D view of the submarine topography in the area of Golfo Corcovado is presented in Figure 3 (area outlined with dotted lines in Fig. 1). In this case, the digital grid was created by incorporating the altitude values from the terrestrial topography, which were determined through the restoration of aerial photographs taken in 1996 by the Servicio Aerofotogramétrico de la Fuerza Aérea de Chile (SAF). The vertical exaggeration of this image is six times and its elevation is 20° N-S. A black line indicates the topographic level 0m (coastline). The longitudinal depression, plateaus, and smaller submarine topographic features are more visible in this image, as are the deepest areas (dark blue) located in front of Rada Palena, south of Boca del Guafo, and off Chaitén.

Figure 4 is a map of the submarine topography in the sector of Canal Moraleda between the Guaitecas and Mitahues islands. Again, the coast and terrestrial areas are only referential due to a spatial displacement from differences in datum. In general, the depth range in this sector is similar to that of the northern zone (Fig. 1). The deeper areas are located at the mouths of the main continental fjords or channels (e.g., Jacaf, Puyuguapi, Aysén) and the center of Canal Moraleda. The longitudinal depression (dark blue, Fig. 5) is fairly straight, except in the north where it appears to curve toward Boca del Guafo. The remaining depressions (light blue) tend to be similar to those in the northern zone (NE-SW). In some cases such as the mouth of Canal Jacaf, near and to the south of Isla Tuap, and in Fiordo Aysén, the continuity of the depressions is interrupted by shallower zones, probably moraine deposits given their semi-curved shape. Fjords between 150 and 300 m depth can be seen in the continental sector between Tuap and Meninea islands; the mouths of these fjords have the typical shape of terminal moraines, indicating that the direction of the glacial advance here was probably to the S or SE. As pointed out by Delgado (2004), in this zone, the influence of the fault systems could be an important factor in the geomorphology of the channels and fjords.

References

- Araya-Vergara, J. F. 1997. Perfiles geomorfológicos de los fiordos y depresión longitudinal de Norpatagonia. *Cienc. Tecnol. Mar*, 20: 3-22.
- Araya-Vergara, J. F. 1998. El problema genético de los fondos de fiordos norpatagónicos. *Invest. Mar., Valparaíso*, 26: 3-29.
- Da Silva, J. L., J. B. Anderson & J. Stravers. 1997. Seismic facies changes along a nearly continuous 24° latitudinal transect the fjords of Chile and Northern Antarctic Peninsula. *Mar. Geol.*, 143: 103-123.
- Delgado, S. 2004. Relación entre el perfil del basamento en fiordos y canales y la morfoestructura regional en Norpatagonia. Tesis de Magíster en Geografía con mención en Evaluación Territorial, Escuela de Geografía, Universidad de Chile, 93 pp.
- Heusser, C. J. 1990. Chilotan piedmont glacier in the southern Andes during the last glacial maximum. *Rev. Geol. Chile*, 17: 3-18.
- Pickard, G. 1971. Some physical oceanographic features of inlets of Chile. *J. Fish. Bd. Can.*, 28: 1077-1106.
- Rodrigo, C. 1996. Morfología submarina de canales y fiordos: principales morrenas y umbrales (resultados preliminares). Resultados Crucero CIMAR-Fiordo 1. Resúmenes ampliados. Comité Oceanográfico Nacional, Valparaíso, pp. 11-14.
- Rodrigo, C. 2002. El sistema de sonar de multihaz y la nueva cartografía náutica y geomorfología submarina de las regiones X-XI. VII Congreso Internacional de Ciencias de la Tierra, Resúmenes ampliados en CD-ROM, Instituto Geográfico Militar, Santiago.
- Silva, N. & C. Calvete. 1997. Características oceanográficas físicas y químicas de canales australes chilenos entre Puerto Montt y laguna San Rafael (Crucero CIMAR-Fiordo 1). *Cienc. Tecnol. Mar*, 20: 23-106.
- Silva, N., H. A. Sievers & R. Prado. 1995. Características oceanográficas y una proposición de circulación para algunos canales australes de Chile entre 41° 20' S y 46° 40' S. *Rev. Biol. Mar.*, 30(2): 207-254.