The lively Aysén fjord, Chile: Records of multiple geological processes

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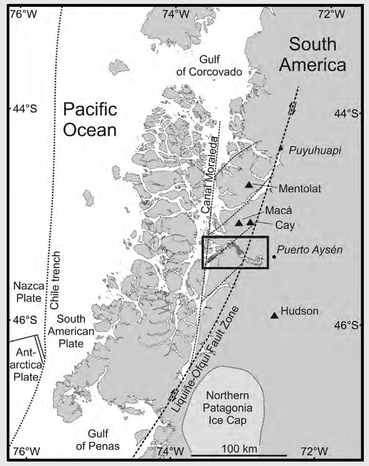
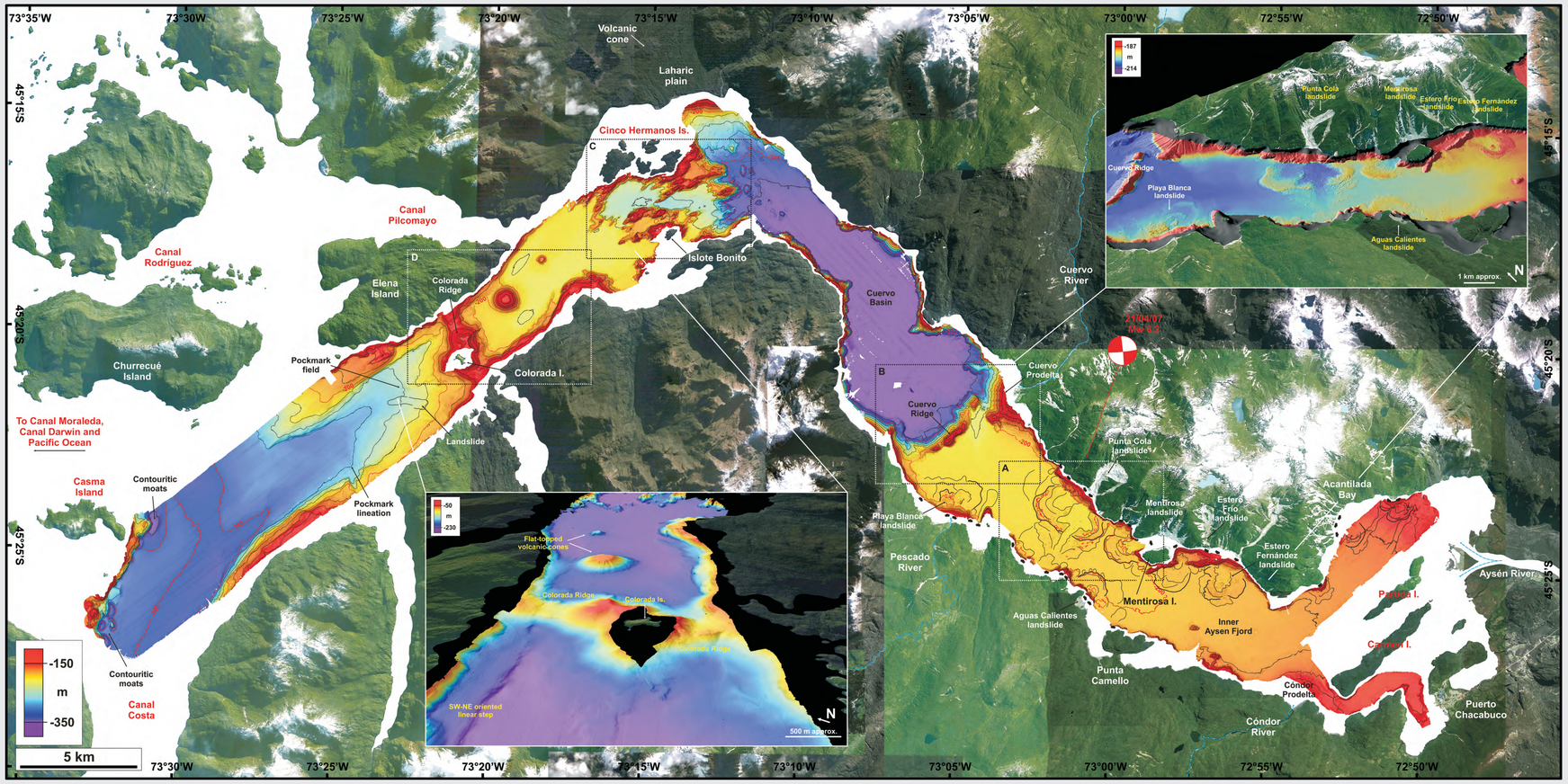
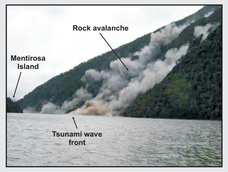
The Aysén fjord is a 65 km long, east-west oriented fjord in Chilean Patagonia, located approximately at 45º20'S and 73º10'W, with a maximum water depth of 345 m. It is the maritime access route to Puerto Chacabuco and Puerto Aysén. It hosts many salmon farms, the most important economic activity of the region. The fjord receives the riverine input of Aysén, Pescado, Condor and Cuervo rivers, which drain the surrounding up to 2000 m high Patagonian Andes, which include the Macá, Cay and Hudson volcanoes, and it opens to the west to Canal Moraleda. The fjord is crossed by a number of faults associated to the active Liquiñe-Ofqui Fault Zone, a major trench parallel intra-arc fault system. The geomorphology of the region is controled by tectonics with glacial modeling superimposed, with U-shaped valleys and steep >30º slopes covered by shallow volcanic soils mostly overlying the North Patagonian Batholith.

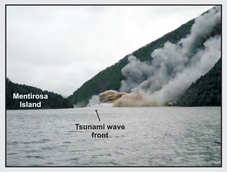


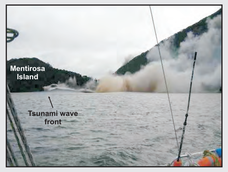
After a four-month period of moderate seismicity, an Mw 6.2 earthquake on 21 April 2007 triggered dozens of subaerial landslides along the fjord flanks. Some of the landslides reached the fjord water mass and/or involved a subaqueous component, generating a series of tsunami-like displacement waves that impacted the adjacent coastlines with 3-12 m, locally over 50 m high run-ups, causing ten fatalities and severe damage to salmon farms.

The **research cruise DETSUFA** on board BIO Hespérides in March 2013 mapped the submerged morphology of the fjord, unveiling the imprint of the landslides in the fjord floor, as well as many other features that illustrate the complex interaction between fluvial, glacial, volcanic and gravity processes in the fjord.



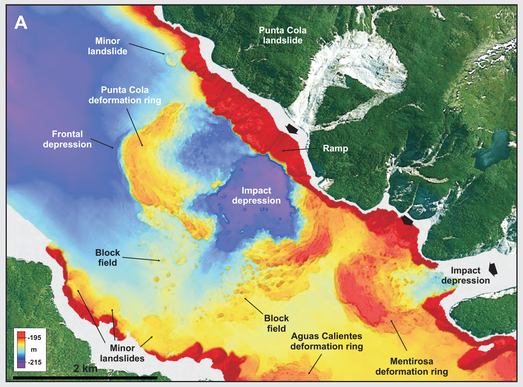




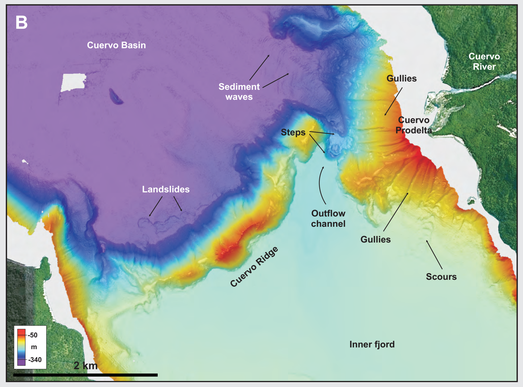


Rock avalanche and displacement wave generation nearby Mentirosa island. Wave run-up in Mentirosa Island exceeded 50 m.

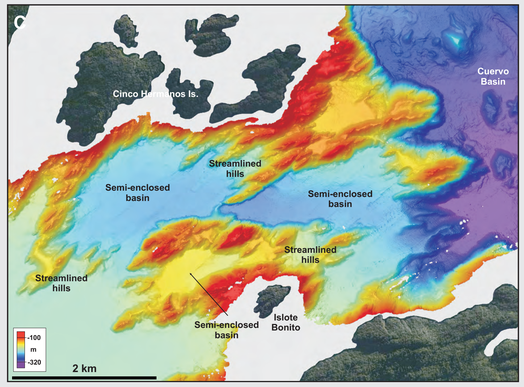
Above: Photographs taken 10, 16 and 32 seconds after the landslide (photo credit F. Olivera), and present-day view of the rock avalanche area.



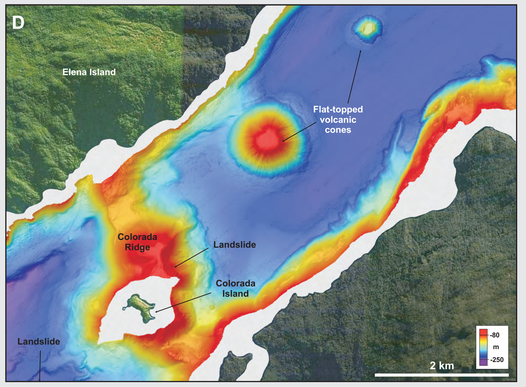
High resolution multibeam bathymetry (4 m cell size) clearly shows the deformation structures created by the earthquake-triggered landslides in the inner fjord. The landslides descended and accelerated down the submerged fjord flanks, and reached the fjord floor at approx. 200 m water depth generating large, 1 to 10 m deep impact depressions. Sediment removed from these depressions moved radially and piled up in deformation rings formed by compressional ridges 10-15 m in height, block fields and a narrow frontal depression. Up to six >1.5 km^2 of these structures can be identified in Aysén fjord, such as the Punta Cola landslide (left), as well as many landslides at the base of the fjord flanks.



Two ridges run across Aysén fjord: Cuervo (left) and Colorada (right) Ridges, located 25 and 54 km beyond the fjord-head delta. The Cuervo Ridge crosses the fjord in a NE-SW direction, reaching a minimum of 58 m water depth. It separates the 220 m-deep inner fjord and the 340 m-deep Cuervo Basin. Small landslides carve the northwestern side of the ridge. Between the Cuervo Ridge and the Cuervo Prodelta, a 350 m-wide outflow channel is present. Both ridges are volcanic structures over which recessional moraines deposited at the retreating margins of tidewater glaciers, formed during still-stands in the deglaciation of Chilean fjords after the Last Glacial Maximum.



Beyond the Cuervo Ridge, the fjord floor smoothens and deepens to more than 340 m forming the enclosed Cuervo Basin, which is also fed from the northeast by small rivulets draining a laharic plain with small volcanic edifices. There, the fjord turns southeast and abruptly shallows some 75 m to a depth of 250 m, measured in smooth semi-enclosed basins interspersed between a field of streamlined, NW-SE-oriented submerged hills. Some of these hills reach a minimum of 50-60 m water depth, although Bonito and Cinco Hermanos Islets may be the emerged tops of equivalent hills. These hills are interpreted as the result of glacial erosion, and indicate a NE-SW direction.



Two new submerged flat-topped monogenetic cones have been mapped in the outer fjord. The larger cone, to the southwest, is 1300 m in diameter, 160 m high and tops at 67 m water depth. The smaller cone, to the northwest, is 450 m in diameter, 45 m high and tops at 156 m water depth. Their flat tops are 300 m and 175 m in diameter, respectively. Seismic reflection profiles show that the smaller one cone is partially buried by recent sediment, whereas the larger one is more recent. Both cones are aligned with Colorada Island, composed of pyroclastic material. The island and the attached Colorada Ridge display evidences of instability, with large scars in both of its flanks.