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The structures of the Peninsula Ushuaia in the Beagle Channel (Tierra del Fuego, Argentina)

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ABSTRACT

New geophysical data (bathymetry, electrical resistivity tomography and seismic profiles) show the structural and morphological characteristic of the Peninsula Ushuaia structural high. The bathymetry and seismic data show that the structural high is bordered by two troughs controlled by the E-W Beagle channel strike-slip fault system and a NW-SE extensional system. Electrical resistivity tomography profiles allow us to identify similar oriented meso-scale structures onshore at the Peninsula Ushuaia. The collected evidence supports the idea that the NW-SE extensional system should be younger than the E-W system.

KEY WORDS: Southernmost Andes, Beagle Channel, transtensional faults, geophysical survey.

INTRODUCTION

Peninsula Ushuaia is located at the northern margin of Beagle Channel, south of Tierra del Fuego Island (Fig. 1). In this area the Fuegian Cordillera is traversed by E-W sinistral strike-slip faults of the Beagle Fault Zone System, with associated subsidiary normal faults. This transtensional system, superposed to Andean compressional structures, has been originated as part of a wrench tectonic regime developed in the southernmost Andes since Late Cretaceous and especially during the Cenozoic time. Geophysical surveys (seismic reflection profiles, bathymetric and electric resistivity profiles) were carried out both onshore and offshore aiming to better understand the morphology and the geometric relationship between lithologies and structures in an area, which is mostly covered by water bodies, Quaternary deposits and vegetation.

DATA SOURCES AND METHODS

In the Beagle Channel, a seismic reflection survey has been carried out using a portable acquisition system, which comprises a 10-m-long solid-state streamer and a Boomer source. The sampling rate was 0.05 ms, and the record length was 400 ms. The trace horizontal resolution was in general 1.0 m, and was achieved with a shot interval of 0.5 s, acquiring the data at an average speed of 4 knots.

The bathymetric map (fig 1) was done by compiling data from oceanographic surveys and nautical charts available on the web (GeoMapApp and GEODAS) in addition to depth-converted high resolution seismic profiles collected in previous campaigns. Data were integrated and processed using the software Surfer 10.0 to obtain an equally-spaced grid which represents the depth distribution of the channel floor.

An electrical resistivity survey has been carried out along the northern shore of the Peninsula Ushuaia. Two resistivity profiles were obtained using a Syscal R1 resistivity-meter system which operates automatically once the geometrical parameters (array type, spacing between electrodes, depth level) have been set. In this case a Wenner-Schlumberger array was selected, using 48 electrodes connected to a 470 m long multi-core cable. This configuration produces a total number of 546 quadripoles. The Roll-Along method was used to extend the original 470 m length and thus obtaining apparent-resistivity profiles (pseudosections) named "Aeropuerto Viejo" and "Peninsula Ushuaia", 1070 m and 830 m long, respectively. Resistivity pseudosections filtering and inverse-modeling were accomplished with the Res2Dinv program provided by Geotomo Software (Loke, 2002 and references therein). The inverse modeling attempts to create a model which best represents the real resistivity distribution in the subsurface, the so-called Electrical Resistivity Tomography (ERT).

EMERGED AND SUBMERGED PENINSULA USHUAIA

Deformation that affected this zone and originated the mega-structures mentioned above is also represented by meso-scale structures expressed by minor topographic features. The ERT method was used in order to characterize these structures, frequently hidden by the modern sedimentation. The ERT profiles display a variation of resistivity values, both vertically and horizontally, between 5 Ωm and 4500 Ωm, consistent with similar studies previously conducted in the area (Tassone et al., 2010). In *Aeropuerto Viejo* ERT (fig. 2a) a high-resistivity (~1000 Ωm) shallow fringe was assigned to glacial deposits outcropping in the field while low resistivity values occur at deeper levels. A low to intermediate resistivity central zone (~150 Ωm) was attributed to the subsurface expression of the Lower Cretaceous Yahgán Formation, which outcrops nearby

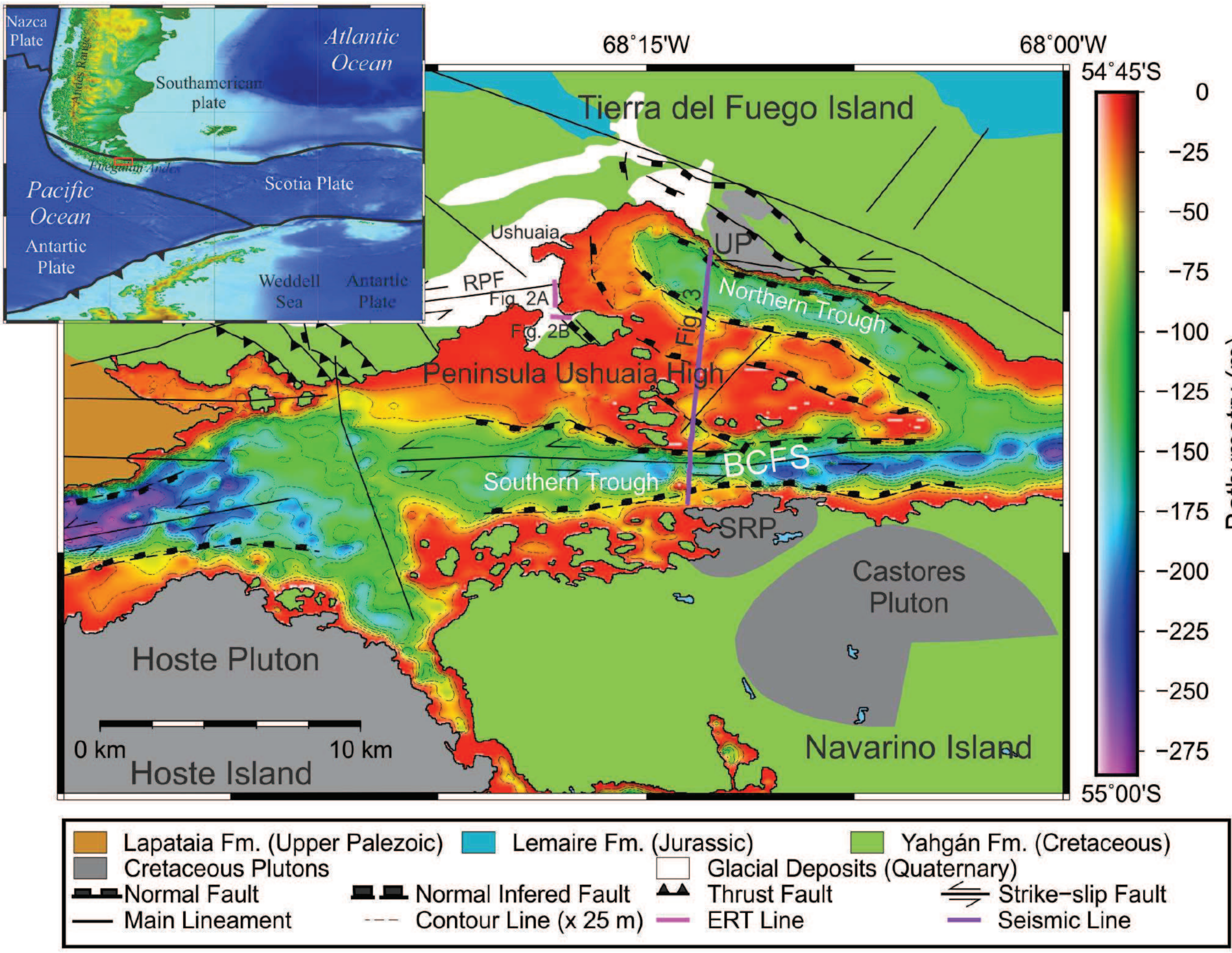

Fig. 1 – Above: General tectonic map. Below: Bathymetric map of central Beagle Channel with geology of the neighboring onshore area. BCFS: Beagle Channel Fault Zone. RPF: Rio Pipo Fault. SRP: Santa Rosa Pluton. UP: Ushuaia Pluton.

the section as silty-sandstones. Conductive zones (~20 Ωm) could represent saturated glacio-lacustrine or glacio-marine deposits. These lateral variations are separated by a series of sharp vertical contrasts that were interpreted as faults and fractures. The central zone, occupied by the Yahgán Formation (bedrock), is bounded by two of these sharp discontinuities after which the bedrock is found several meters below. Other vertical sharp boundaries appear in the tomography but do not exhibit evidence of displacement nor have been recognized as fractures. The geometry of the marine-lacustrine deposits is influenced by those faults, thickening towards the fault plane, while glacial deposits are not affected by faulting. The vertical fault system and the associated fractures may be related to the Cenozoic strike-slip faulting due to its superposition with the Río Pipo fault trace (fig. 1), which in turn is parallel to the main southern depression within the Beagle Channel (Esteban et al. 2011). These structures played a major role in basin development during a transtensional regime.

The “Peninsula Ushuaia” ERT section (fig. 2B) also displays significant lateral variations of resistivity in depth. In this case a shallow high resistivity zone (>1000Ωm) in the centre of the section is coincident with a landfill area. Low to intermediate resistivity zones (150 – 300 Ωm) are observed in sub-superficial levels and in depth, which were interpreted as pertaining to the Yahgán Formation. The high resistivity zones (>2000 Ωm) were attributed to the Ushuaia Pluton which outcrops 500 meters to the east of the beginning of the ERT profile (outcrop size can not be represented on the scale of figure 1; Peroni et al. 2009a & b). Sharp vertical displacements in resistivity fields (fig. 2B) allowed us to infer the presence of normal faults. The identified faults are younger than Late Cretaceous since they affect both the Lower Cretaceous Yahgán Fm. and the Late Cretaceous intrusive bodies; moreover, the space generated was filled by modern deposits. The faults interpreted between the 80 m and 480 m of the ERT section may be projected in prosecution with the NW-SE fault that cuts across the peninsula, which in turn is parallel to the northeastern basin identified in the bathymetry (fig. 1). Disposition of fault planes in cross-section form a negative flower structure resulting in a nearly symmetrical basin.

The bathymetric map (fig. 1) shows that Peninsula Ushuaia and some neighboring islets within the Beagle Chanel represent

an emerged part of a larger structural high extending further to the E below sea level (bsl), which here has a main depth of 40 m. This morphostructural unit is limited by two main depressions that are symmetrical in cross section and reach depths greater than 150 m bsl (fig. 3). The southern E-W oriented trough is composed of some interconnected rhomboidal depressions that follow the Beagle Channel general trend given by the transtensional faulting of the Beagle Fault Zone System (BFZS) (Cunningham, 1993; Menichetti et al., 2008; Esteban et al. 2011). The second trough is located to the NE and has a NW-SE orientation with two marked inflections in its trend; it has a remarkably continuous sharp borders. The submerged Peninsula Ushuaia increases in depth towards the northeastern basin, and it is probably controlled by the NW-SE normal faults seen in onshore areas (fig. 1). The bathymetric contours also show two NW-SE oriented narrow gorges that intersect the submerged peninsula; NW-SE aligned valleys in the channel's northeastern margin are other expressions of the same fault system

On the basis of regional correlations it is inferred that the W-E system is overprinted by the NW-SE; to the west of Ushuaia Peninsula NW-SE normal faults have been reported affecting Quaternary deposits (Bran, 2013). Similar relationships between W-E strike-slip and NW-SE normal faults have also been described in the Ushuaia Pluton area (fig. 1; Menichetti et al., 2007).

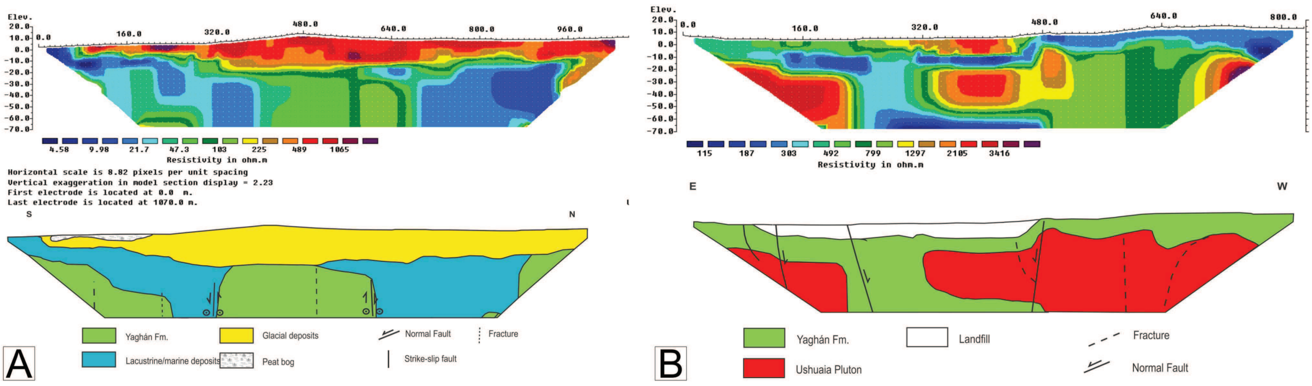

Fig. 2 – A: Above: "Aeropuerto Viejo" Electric Resistivity Tomography section. Robust inversion model. Below: Interpreted geological section from ERT. B: Above: "Aeropuerto Viejo" Electric Resistivity Tomography section. Robust inversion model. Below: Interpreted geological section from ERT. Location in fig. 1.

CONCLUSIONS

The submerged morphology of the central Beagle Channel is characterized by the presence of an asymmetrical basin that follows a W-E general trend, and which is controlled by a strike-slip fault system. It is inferred that this system is overprinted by a NW-SE oriented extensional system that form a symmetrical elongated basin. ERT profiles were useful to describe the subsurface geometry of faults that generate minor basins of similar orientation than those controlling the major Peninsula Ushuaia morpho-structure. The tomographies also aided to infer the structural origin of the main depressions. Peninsula Ushuaia resistivity section shows that modern sedimentation occupies a basin defined by a N-W oriented fault system while the glacial deposits present in the Aeropuerto Viejo ERT do not show evidence of fault activity. This reinforces the idea that the NW-SE extensional system should be younger than the E-W system.

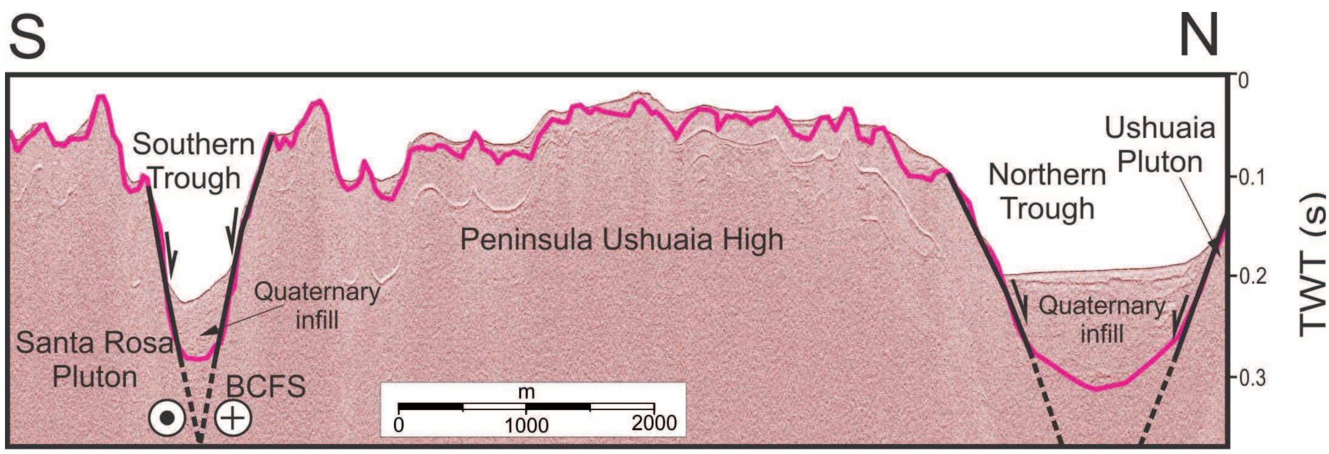

Fig. 3 – Multichannel seismic line across the Beagle channel. BCFS: Beagle Channel Fault system. Location in Fig. 1. Purple line indicates the base of the Quaternary deposits.

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