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Evidence for fluid circulation, overpressure and tectonic style along the Southern Chilean margin

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Abstract

The southern Chilean convergent margin, between 50° and 57° S, is shaped by the interaction of the three main plates: Antarctic, South America and Scotia. North of 53° S, the convergence between Antarctic and South America plates is close to orthogonal to the continental margin strike. Here, the deformational style of the accretionary prism is mainly characterized by seaward-verging thrusts and locally by normal faults and fractures, a very limited lateral extension of prism, a very shallow dip (~6°) décollement, and subduction of a thick and relatively undeformed trench sedimentary sequence. South of 53° S, convergence is oblique to the margin, locally, the trench sediments are proto-deformed by double vergence thrusting and the front of the prism grows through landward-verging thrusting. The décollement is sub-horizontal and deep, involving most of the sediment over the oceanic crust in the accretionary process, building a comparatively wide and thicker prism. A Bottom Simulating Reflector is present across the whole prism to the abyssal plan, suggesting the presence of gas in the sediments.

The analysis of P- and S-wave velocity reflectivity sections, derived by amplitude versus offset technique (AVO), detailed velocity information and the velocity-derived sediment porosity have been integrated with the structural analysis of the accretionary prism of two selected pre-stack depth migrated seismic lines, aiming to explain the relation between fluid circulation and tectonics.

Accretion along double vergence thrust faults may be associated with the presence of overpressured fluid, which decreases the effective shear stress coefficient along the main décollement and within the sediments, and modify the rheolgical properties of rocks. The presence of an adequate drainage network, represented by interconnected faults and fractures affecting the entire sedimentary sequence, can favour the escape of pore fluid toward the sea bottom, while, less permeable and not faulted sediments can favour fluid accumulations. Gravitational and tectonic dewatering, and stratigraphy could control the consolidation and the pore overpressure of sediments involved in subduction along the trench. The results of our analysis suggest the existence of a feedback between tectonic style and fluid circulation.

Keywords: Subduction; Accretion; Overpressure; Dewatering; Back-thrust; AVO

1. Introduction and principal structural setting

Tectonic processes (accretion and tectonic erosion) could be contemporary active along a convergent margin.

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The establishing of accretion instead of erosion may be controlled by state of stress, age of subducting plate (Uyeda, 1982), topography of subducting plate (Scholl et al., 1980; Hilde, 1983), thickness and lithology of trench sediments (Karig, 1985; von Huene, 1986), and high pore pressure (von Huene and Lee, 1983; Lallemand et al., 1994) that can depend on pore fluid content (Cobbold and Castro, 1999). High pore fluid pressure in subducting sediments strongly decreases the basal friction coefficient, modifies the thrust mechanical behaviour and causes decoupling between two converging plates (Hubbert and Rubey, 1959; Westbrook et al., 1982; Davis et al., 1983; Dahlen et al., 1984). Several authors (Kulm et al., 1986; Moore and Byrne, 1987; Le Pichon et al., 1990; Moore and Saffer, 2001) have remarked the importance of the interplay between pore fluid expulsion and sediment deformation, which plays a primary role in the development of structures and in the modification of the physical properties of rocks accreted to the overriding plate (Aoki et al., 1986; Bangs et al., 1990). Low fluid outflow is frequently associated to high pore pressure of sediments, causing under-consolidation, as observed along the Costa Rica plate boundary (Saffer, 2003), and may favour a deformational style associated to landward vergence instead of seaward vergence of thrust faulted sediments. Four main explanations have been proposed for landward vergence thrusting: (1) a seaward-dipping backstop (Byrne and Hibbard, 1987; Byrne et al., 1993), (2) a very low basal friction (Seely, 1977; McKay et al., 1992), (3) a combination of low basal friction and substantial basal dip (McKay, 1995), or (4) a combination between rheological and structural conditions along the margin (Gutscher et al., 2001).

The geodynamic setting of the southernmost Chilean margin, offshore Tierra del Fuego (50°–58° S), is characterized by the subduction of the Antarctic plate beneath Scotia and South American plates (Fig. 1). The Chilean Trench represents the limit between Antarctic and the South American plates, while the Magellan–Fagnano Fault System represents the limit between South America

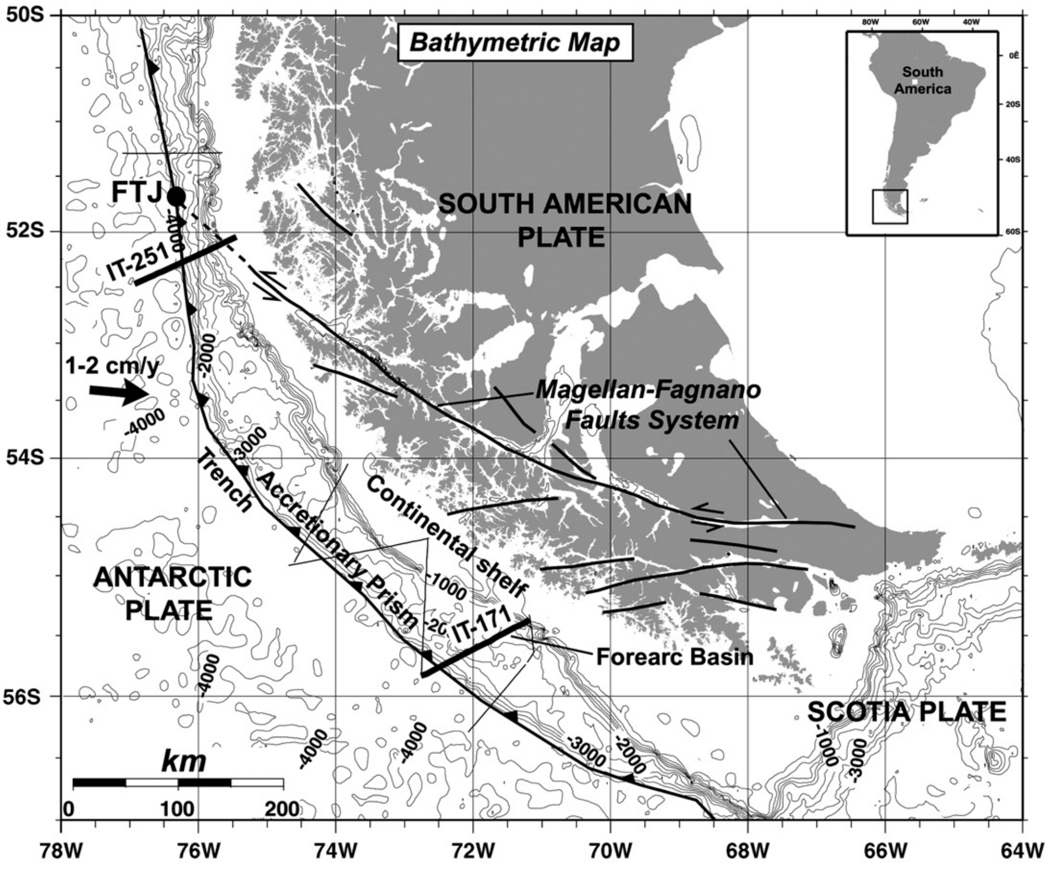

Fig. 1. Location map of acquired (thin lines) and analysed (thick lines; IT-251 and IT-171) seismic lines (bathymetry after Cunningham, 1993; Sandwell and Smith, 1997). The Fuegian Triple Junction is indicated by FTJ. The convergence vector is indicated by an arrow. The main geological structures are indicated: Magellan–Fagnano Fault System, frontal thrust, accretionary prism, forearc basin and continental shelf.