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Tectonic models for the Patagonian orogenic curve (southernmost Andes): An appraisal based on analog experiments from the Fuegian thrust–fold belt

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ABSTRACT

Tectonic models for the evolution of the Patagonian orogenic curve were evaluated using analog experiments that considered either a rotational or a non-rotational orogenic backstop, combined with a basement promontory on the foreland cratonic margin. Five different kinematic configurations were used, aiming to evaluate the influence of the Río Chico Arc as a rigid obstacle on the evolution of the Fuegian thrust–fold belt. Rotations, strains and displacement fields obtained from each analog experiment were compared with the structural geology known from the Fuegian thrust–fold belt, in order to appraise the tectonic models that are more consistent with the natural structure. The push of a counterclockwise rotational backstop, combined with the buttressing effect of a foreland promontory, seem of major importance in controlling the final structure and map-view shape of the thrust wedge.

1. Introduction

The Fuegian thrust–fold belt constitutes the orogenic front of the southernmost Andes in Tierra del Fuego, where they form the eastern part of an orogenic curve changing strike from N–S to E–W in an arc-distance of almost 500 km (Fig. 1). The origin of this curve, named Patagonian Orocline by Carey (1958) (we use here the term Patagonian curve), has been considerably disputed. While initial studies revealed that part of the orogen has been apparently bent in a counterclockwise (CCW) motion of about 90° (Burns et al., 1980; Cunningham et al., 1991; Dalziel et al., 1973), recent ones argued that bending, if occurred, did not affect foreland strata younger than 50 Ma (Maffione et al., 2010), or only affected discrete portions of the Patagonian curve due to non-coaxial deformation (Poblete et al., 2014). These recent paleomagnetic studies appear to support a primary curve origin (cf. Marshak, 2004) for the thrust–fold belt, which contains curved thrusts as young as early Miocene in Tierra del Fuego. On the other hand, taking into account CCW rotations for the outer arc of the Patagonian curve (cf. Poblete et al., 2013), a model can be put forward where a rotating backstop of older rocks in the core of the orogen bulldoze the foreland basin sediments (Ghiglione and Cristallini, 2007; Torres Carbonell et al., 2014). Different patterns of rotations could result from such a scenario.

An additional aspect considering this latter framework is that during orogenesis the thrust–fold belt collided with the rigid foreland, especially in the Fuegian limb of the orogenic curve. It has recently been proposed that the foreland cratonic margin, with an irregular shape, may have exerted a buttressing effect on the thrust–fold belt, thus conditioning its curved configuration and its tectonic evolution (Torres Carbonell et al., 2013a). This aspect becomes even more important taking into account the Late Cretaceous to Miocene underthrusting of the cratonic slab as a fundamental part of the Fuegian Andes development (Klepeis et al., 2010; Torres Carbonell and Dimieri, 2013). This idea is also supported by seismic evidence showing the control of the foreland basement topography on the location of frontal structures of the thrust–fold belt (Torres Carbonell et al., 2013a).

The effects of a rotational vs. an originally curved backstop have been already tested with analog models, finding that both configurations can cause an arcuate sand wedge similar to the Patagonian curve. The models performed reveal diverse displacement fields, variable shortenings along the arc, and changing amounts of thrusting vs. strike-slip faulting (Ghiglione and Cristallini, 2007). However, recent work in the Tierra del Fuego has shown features of the thrust–fold belt that were not accounted for in those previous models, particularly the concave-to-the-north recess along the Fuegian thrust–fold belt (Península Mitre Recess), whose eastern termination reveals a turn

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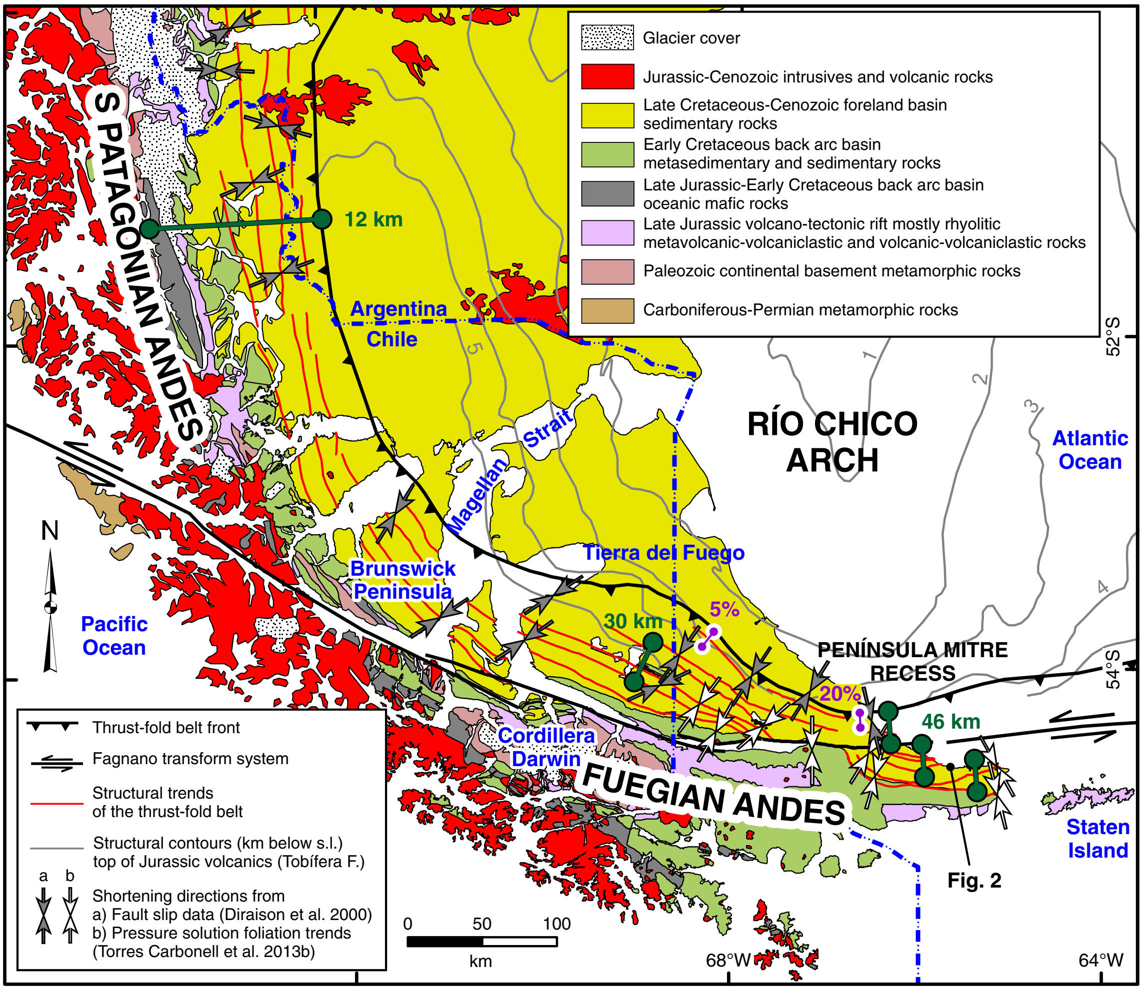

Fig. 1. Geologic map of the Patagonian curve, compiled from Olivero and Malumián (2008), Panza et al. (2002), SERNAGEOMIN (2003), and Klepeis et al. (2010). Green bars indicate location of shortening estimations for the foreland thrust–fold belt (Cretaceous–Cenozoic cover), from Fosdick et al. (2011) in the South Patagonian Andes, Alvarez-Marrón et al. (1993) in the Chilean part of Tierra del Fuego, and Torres Carbonell and Dimieri (2013) in the Península Mitre Recess. Shortening percentages for the frontal portion of the Fuegian thrust–fold belt are indicated in magenta, from Torres Carbonell et al. (2013a).

towards SW–NE structural trends (Fig. 1) (Torres Carbonell et al., 2013a). The shortening directions change along the recess, keeping perpendicularity with local structures, and are therefore NW–SE oriented at the eastern limb of the recess (Torres Carbonell et al., 2013a,b). There is also a lateral variation in shortening magnitudes obtained from structural cross-sections, which indicate significantly higher percentages of shortening in the axis of the recess (Fig. 1) (Torres Carbonell et al., 2013a).

In this work we used analogue modeling to test different structural configurations resembling alternative hypotheses for the evolution of the Patagonian curve, either with a rotational or a non-rotational orogenic backstop, considering the fundamental role of the foreland cratonic margin geometry in the evolution of the Fuegian thrust–fold belt. The results of the analog experiments contribute to the appraisal of different tectonic models for this portion of the Andes, by means of evaluating the consistence of these results with the structural data from the Fuegian thrust–fold belt.

2. Geologic background of the Fuegian Andes

The Fuegian Andes extend with a WNW–ESE regional trend from the Magellan Strait to Staten Island, forming the eastern limb (or Fuegian limb) of the Patagonian curve (Fig. 1). Since the Oligocene they constitute part of the NW Scotia Arc, and are connected to the east with the North Scotia Ridge. For our purposes, we will describe the prior history of the Fuegian Andes starting from the Late Jurassic continental stretching in SW Gondwana (South America) that led to a volcano-tectonic rift, which was associated with deposition of volcanic and volcaniclastic rocks on Paleozoic continental crust (Calderón et al., 2007; Wilson, 1991). Stretching continued until the Early Cretaceous, causing the local creation of oceanic floor in a back arc basin called Rocas Verdes Basin (Calderón et al., 2007; Mukasa and Dalziel, 1996). Marginal marine to arc-derived sediments filled this basin until the Albian (Fildani and Hessler, 2005; Olivero and Martinioni, 2001).

The Rocas Verdes Basin rimmed SW Gondwana for more than 1500 km, and was connected southeastward with the Weddell Sea (Dalziel et al., 2013a). The west-SW border of the Rocas Verdes Basin was a volcanic arc rooted on ensialic crust (Dalziel, 1986), probably connected to the south with the Antarctic Peninsula (Barker, 2001; Dalziel et al., 2013a).

As revealed by structural maps (Biddle et al., 1986; Yrigoyen, 1989), the cratonic margin of the Rocas Verdes Basin has a general SSE trend in the NW part of the basin, but toward the east this margin projects southwards for about 300 km forming the Río Chico (or Dungeness) Arch (Fig. 1). The promontory's southern tip is best defined below its 1.5 km depth structural contour. The Río Chico Arch plunges toward the south, with a topography controlled by Late Jurassic-Early Cretaceous normal faults that bound grabens and hemigrabens created during the