



## Along-strike segmentation of the Abanico Basin, central Chile: New chronological, geochemical and structural constraints



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### ABSTRACT

The Andes of central Chile are composed mostly of Cenozoic volcanic rocks, erupted during the opening and subsequent inversion of the intra-arc volcano-tectonic Abanico Basin. Until recently, the internal segmentation of this inverted basin was poorly understood. Based on a combination of U-Pb geochronology, (U-Th)/He thermochronology, whole rock geochemistry and structural data, we propose that the Abanico Basin can be divided into two main segments, separated by the NW-striking Piuquencillo fault and conjugate, NE-striking faults. Stratigraphic units defined in the northern segment (Abanico and Farellones formations) cannot be correlated with the rocks of the southern segment (Coya-Machali Formation and Teniente Volcanic Complex) in terms of lithofacies, depositional ages and geochemistry. The northern and southern segments also show temporal differences in their tectonic evolution. An early deformation event beginning at ~22 Ma affected only the northern segment and is associated with the formation of progressive unconformities between the Abanico and Farellones formations, and also with crustal thickening as reflected in the geochemistry of the Farellones Formation. A second stage of crustal thickening and exhumation began at ~12 Ma, as suggested by a sharp increase of the La/Yb ratios in the northern segment. In the southern segment, this event is reflected by only a moderate increase of La/Yb ratios, and by the transition between the Coya-Machali Formation and the Teniente Volcanic Complex. Finally, a third stage of exhumation and crustal thickening beginning at ~7 Ma affected both the northern and southern segments. This last stage was the main exhumation event affecting the rocks of the Andes of central Chile, and is recorded in the geochemistry of igneous rocks by a sharp increase in the La/Yb ratios in the southern segment.

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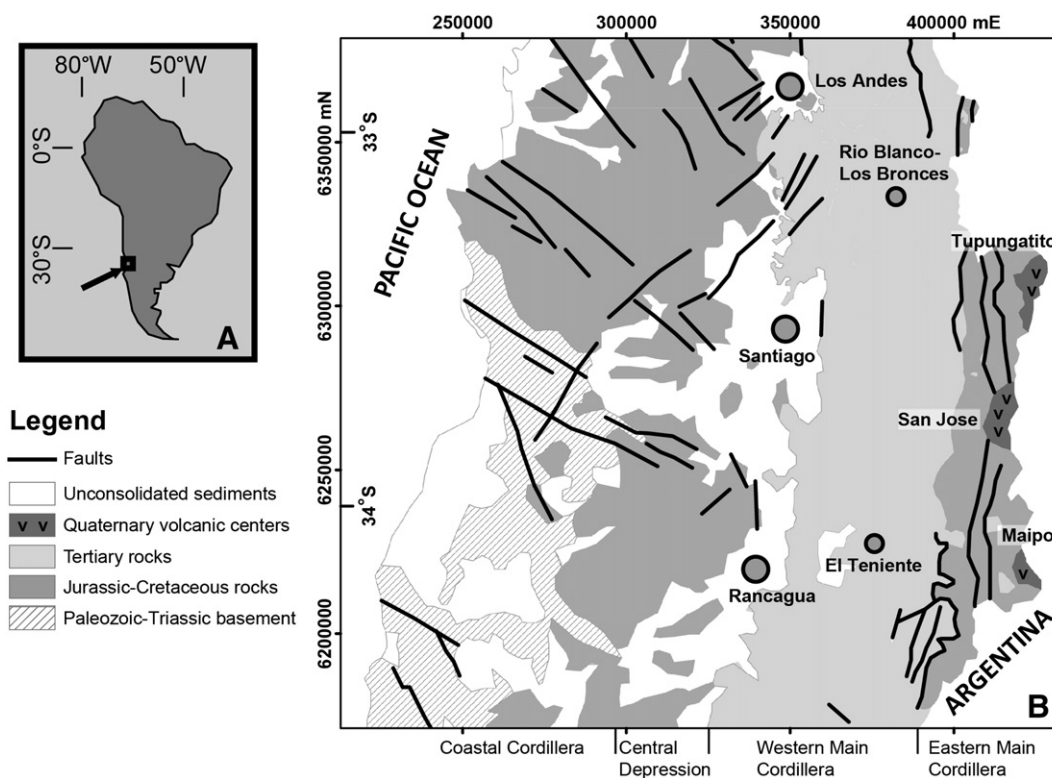
### 1. Introduction

Most of the Main Andean Cordillera of central Chile (~33–35°S) is composed of arc-related Cenozoic volcanic and intrusive rocks (Fig. 1; Charrier et al., 2002, 2007; SERNAGEOMIN, 2002). Due to the lack of appropriate chronostratigraphical data, this sequence was originally interpreted to be Late Cretaceous-early Paleogene in age (Aguirre, 1960; Klohn, 1960), but more recent studies have demonstrated a late Paleogene-Neogene age based on mammal fossils, K-Ar and <sup>40</sup>Ar/<sup>39</sup>Ar geochronology (late Eocene to early Pliocene; Charrier et al., 1990, 2002; Flynn et al., 1995, 2003; Fock et al., 2005; Kay et al., 2005). The lower part of this Cenozoic volcanic sequence was deposited under

extensional conditions within an intra-arc volcano-tectonic basin, the Abanico Basin (Charrier et al., 2002, 2007). Similar mid-Cenozoic, intra-arc extensional basins formed to the north and south of the Abanico Basin along the strike of the Andean orogen. Examples of this are the syn-extensional deposits of the Cura-Mallín Formation to the south (36–39°S; Jordan et al., 2001; Suarez and Emparan, 1995) and of the Doña Ana Group and Valle del Cura Formation to the north (29–30°S; Winocur et al., 2015). Syn-extensional rocks in central Chile have been grouped into the Abanico Formation (Aguirre, 1960; Thomas, 1953) in the area to the east of the cities of Santiago and Los Andes, and into the Coya-Machali Formation (Klohn, 1960) in the Main Cordillera to the east of the city of Rancagua (Fig. 1). More recent studies have considered these two units as stratigraphic equivalents, and the name Abanico Formation has been preferred (e.g., Charrier et al., 2002). The younger part of the Cenozoic sequence was deposited during tectonic inversion of the basin, which resulted in strong folding of the syn-extensional units and reactivation in reverse mode of the basin-margin faults (Charrier et al., 2002). Syn-inversion volcanic rocks of Miocene age have been grouped into the Farellones Formation,

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**Fig. 1.** A. Location of the study area in South America. B. Simplified regional geology of Central Chile, showing the location of the porphyry copper deposits (Rio Blanco-Los Bronces and El Teniente) and the main geomorphological units (Coastal Cordillera, Central Depression, Western Main Cordillera and Eastern Main Cordillera). Modified from [SERNAGEOMIN \(2002\)](#).

first defined by [Klohn \(1960\)](#) in the Main Cordillera to the east of the city of Santiago ([Fig. 1](#)). Flat-lying or gently folded Cenozoic volcanic rocks have been correlated with the Farellones Formation both to the south and to the north of its original type locality, in the Andes to the east of Los Andes and Rancagua ([Fig. 1](#)), and also further to the south and north (e.g., [Charrier et al., 2002](#); [Godoy et al., 1999](#); [Jara and Charrier, 2014](#)). A different nomenclature, the Teniente Volcanic Complex, has been proposed for Miocene volcanic rocks at around 34°S ([Godoy, 1993](#); [Kay et al., 2005](#)). However, this volcanic complex has been considered a lateral equivalent to the Farellones Formation (e.g., [Godoy et al., 1999](#)).

Different segments of the inverted basin-margin faults of the Abanico Basin have been recognized (e.g., [Armijo et al., 2010](#); [Charrier et al., 2002](#); [Farías et al., 2010](#); [Fock, 2005](#); [Piquer et al., 2010](#)). They define the boundaries of the Western Main Cordillera with the Coastal Cordillera and the Central Depression to the west and the Eastern Main Cordillera to the east ([Fig. 1](#)). However, only a few studies ([Piquer et al., 2015, 2016](#); [Rivera and Falcon, 2000](#)) have focused on the internal architecture of the inverted basin. All these previous studies concluded that the main internal fault systems are oblique to the N-striking inverted basin-margin faults, showing NW and NE strikes. The internal faults have been interpreted to have been inherited from the architecture of the Palaeozoic-Triassic Andean basement ([Piquer et al., 2015, 2016](#)). They were reactivated as normal faults during the opening of the Abanico Basin, and subsequently reactivated as strike-slip  $\pm$  reverse faults during Mio-Pliocene tectonic inversion under E-directed compression ([Piquer et al., 2016](#)). They controlled the ascent and emplacement of magma and hydrothermal fluids, and in particular, the location of the porphyry Cu-Mo deposits of the area ([Piquer et al., 2015, 2016](#); [Rivera and Falcon, 2000](#)). However, it is unclear if any of these arc-oblique faults acted as regional-scale boundaries between different segments of the basin.

This contribution investigates the existence of a regional-scale segmentation along the axis of the intra-arc Abanico Basin, and how this segmentation influenced the deformation history during tectonic inversion. It discusses the similarities and differences in the tectonic evolution of different segments of the basin, placing them in the context of the broader Andean evolution of central Chile, and debating the implications for the stratigraphic definitions currently in use. This study is based on new geochronological, thermochronological and geochemical data from Cenozoic volcanic and intrusive rocks of central Chile, combined with regional-scale stratigraphic and structural observations.

## 2. Geological framework

The Andes of central Chile can be divided into three parallel, N-trending morpho-tectonic units. From west to east, they are the Coastal Cordillera, the Western Main Cordillera and the Eastern Main Cordillera ([Fig. 1](#)).

The Mesozoic magmatic arc was located in the Coastal Cordillera ([Mpodozis and Ramos, 1989](#)), and contains a complex array of Jurassic and Cretaceous intrusive, volcanic and sedimentary rocks. In the southern part of central Chile (~34°S; [Fig. 1](#)), these rocks intruded and overlie Carboniferous to Triassic metamorphic and intrusive units, commonly referred to as the “basement” of the Andes (e.g., [Herve et al., 2007](#); [Fig. 1](#)).

The Central Depression is a broadly N-S, discontinuous longitudinal valley filled with up to 500 m of Oligocene to Holocene unconsolidated sedimentary and pyroclastic deposits ([Aranceda et al., 2000](#)) which partially separates the Coastal and Main Cordilleras ([Fig. 1](#)). Early hypotheses regarding the origin of this depression favored an extensional graben ([Aubouin et al., 1973](#)), but more recent studies describe it as a foreland basin bounded by the Main Cordillera to the east along west-vergent thrusts ([Armijo et al., 2010](#); [Cembrano et al., 2007](#); [Fock et al., 2005](#)). Ridges that are not covered by these upper Cenozoic deposits

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