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A paleomagnetic and magnetic fabric study of the Illapel Plutonic Complex, Coastal Range, central Chile: Implications for emplacement mechanism and regional tectonic evolution during the mid-Cretaceous

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A B S T R A C T

The Illapel Plutonic Complex (IPC), located in the Coastal Range of central Chile (31°–33° S), is composed of different lithologies, ranging from gabbros to trondhjemites, including diorites, tonalites and granodiorites. U/Pb geochronological data shows that the IPC was amalgamated from, at least, four different magmatic pulses between 117 and 90 Ma (Lower to mid-Cretaceous). We present new paleomagnetic results including Anisotropy of Magnetic Susceptibility (AMS) from 62 sites in the plutonic rocks, 10 sites in country rocks and 7 sites in a mafic dyke swarm intruding the plutonic rocks.

Remanent magnetizations carried by pyrrhotite in deformed country rock sediments nearby the intrusive rocks indicate that tilting of the sedimentary rocks occurred prior or during the intrusion. The paleomagnetic study shows no evidence for either a measurable tilt of the IPC or a significant rotation of the forearc at this latitude range. Moreover, new $^{40}Ar/^{39}Ar$ ages exclude any medium- to low-temperature post-magmatic recrystallization/deformation event in the studied samples. AMS data show a magnetic foliation that is often sub-vertical. Despite an apparent N–S elongated shape of the IPC, the large variations in the orientation of the AMS foliation suggests that this plutonic complex could be made of several units distributed in a N–S trend rather than N–S elongated bodies.

Previous works have suggested for this area a major shift on tectonic evolution from highly extensional during Lower Cretaceous to a period around 100 Ma, associated with exhumation and compressive deformation to conform the present day Coastal Range. The low degree of anisotropy and the lack of evidence for a tectonic fabric in the intrusive rocks indicate that the shift from extensional to compressional should postdate the emplacement of the IPC, i.e. is younger than 90Ma.

1. Introduction

An intense magmatic activity (volcanism and plutonism) dominates during the Early Cretaceous evolution in the active Pacific margin of north-central and central Chile (25°20′ to 35°40′ S) (Vergara et al., 1995, and references herein). The combination of magmatism, together with basin formation, subsidence and final exhumation in this active continental margin during the Mesozoic, conform the present day Coastal Range. Along this margin, and as a consequence of major changes in the geodynamic regime of the Aluk subducting plate under the South American plate, the continental crust went through recurrent periods of extension and compression, mainly as the consequence of a continuous convergence of oceanic and continental plates (Mpodozis and Ramos, 1989; Ramos and Aleman, 2000; Arancibia, 2004; Parada et al., 2005a).

Different authors have previously concluded that a major change in tectonic conditions took place in the mid-Cretaceous (e.g. Cobbold et al., 2007). Somoza and Zaffarana (2008) argue that the beginning of contractional events in the Andes correlates with model-predicted westward acceleration of South America indicating that this change in Andean tectonic regime is associated to

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major plate reorganization at ca 95 Ma. For that same period, Arancibia (2004) described a contractional tectonic regime in central Chile (the Sistema de Falla Silla del Gobernador reverse fault); and other authors, using fission-track analyses, have described a rapid exhumation and uplift (Gana and Zentilli, 2000; Parada et al., 2001, 2005a). To the east of the Andes, in the Neuquen area, the beginning of Andean uplift can be bracketed between 98.6 Ma and 88 Ma (Tunik et al., 2010).

High volumes of magma were emplaced and erupted in the Coastal Range of central Chile during the Lower Cretaceous. Plutonism is partially coeval with a rather primitive volcanism, basin subsidence and a burial, non deformative, very low-grade metamorphism (e.g. Fuentes et al., 2005; Parada et al., 2005a; Morata et al., 2006).

Initially defined as "Illapel Super-unit" (Rivano et al., 1985), the Illapel Plutonic Complex (IPC) is a distinctive feature of the geology between 31° and 33 °S, exposed on an area bigger than 3200 km^2 and that is emplaced mainly into Jurassic igneous rocks, and Lower Cretaceous volcanic and sedimentary sequences. Small (few km^2), lithologically diverse gabbro and diorite bodies outcrop in this plutonic complex, mostly in its western margin and at the northern part. These mafic bodies could represent the more primitive basaltic magmas present during batholith formation. U/Pb radiometric ages obtained on magmatic titanite (Morata et al., 2006) and zircons (Morata et al., 2010) show different crystallization ages of, at least, four different magmatic pulses between 117 and 90 Ma.

We have undertaken a detailed paleomagnetic and AMS study of the IPC and obtained new $^{40}Ar/^{39}Ar$ ages with three main objectives: (1) to use the magnetic fabric to better understand the type of emplacement of the different magmatic pulses, (2) to determine possible rotations on vertical or horizontal axis related to the tectonic evolution of the forearc since its emplacement, and (3) to identify (or exclude) any low- to medium-T post-plutonic emplacement processes that could modify the primary (plutonic) magnetic signal.

2. Geological setting

2.1. Regional setting

The Lower Cretaceous volcanic-sedimentary formations of the Coastal Range conforms an almost continuous 1200 km N–S long (25°20′ to 35°40′ S) and narrow (30 km average) magmatic belt, with average thickness of 3–5 km. Volcanic rocks (mostly porphyritic high-K basaltic andesites and andesites, with minor rhyolites and ignimbritic rhyolites) dominate but sedimentary shallow marine intercalations (limestones and sandstones) can be abundant in some sections (e.g. Nasi and Thiele, 1982; Vergara et al., 1995). Three major geological formations have been described for this Lower Cretaceous belt at the latitude of Santiago (33–34° S) (Fig. 1). The oldest one, Lo Prado Formation (Thomas, 1958), consists of marine and continental volcaniclastic rocks, limestones and a bimodal sequence of dacitic ignimbrites and interbedded basalts, of assumed Valanginian and Hauterivian age. Overlying the Lo Prado Formation, the Veta Negra Formation (Thomas, 1958) is composed of continental plateau-like porphyritic "flow-basalts" and basaltic andesites, accompanied by feeder dykes and sills at the bottom whereas the uppermost levels consist of continental flow-breccias of basaltic andesitic composition. These basic products have a high-K calc-alkaline to shoshonitic affinity and a mantle-type isotopic signature being remarkably homogeneous in their mineralogical and chemical composition considering the huge volumes involved. Vergara et al. (1995) estimate more than 11,000 km^3 of volcanic materials erupted during the Jurassic and Early Cretaceous in central Chile, corresponding to a minimum effusion rate of

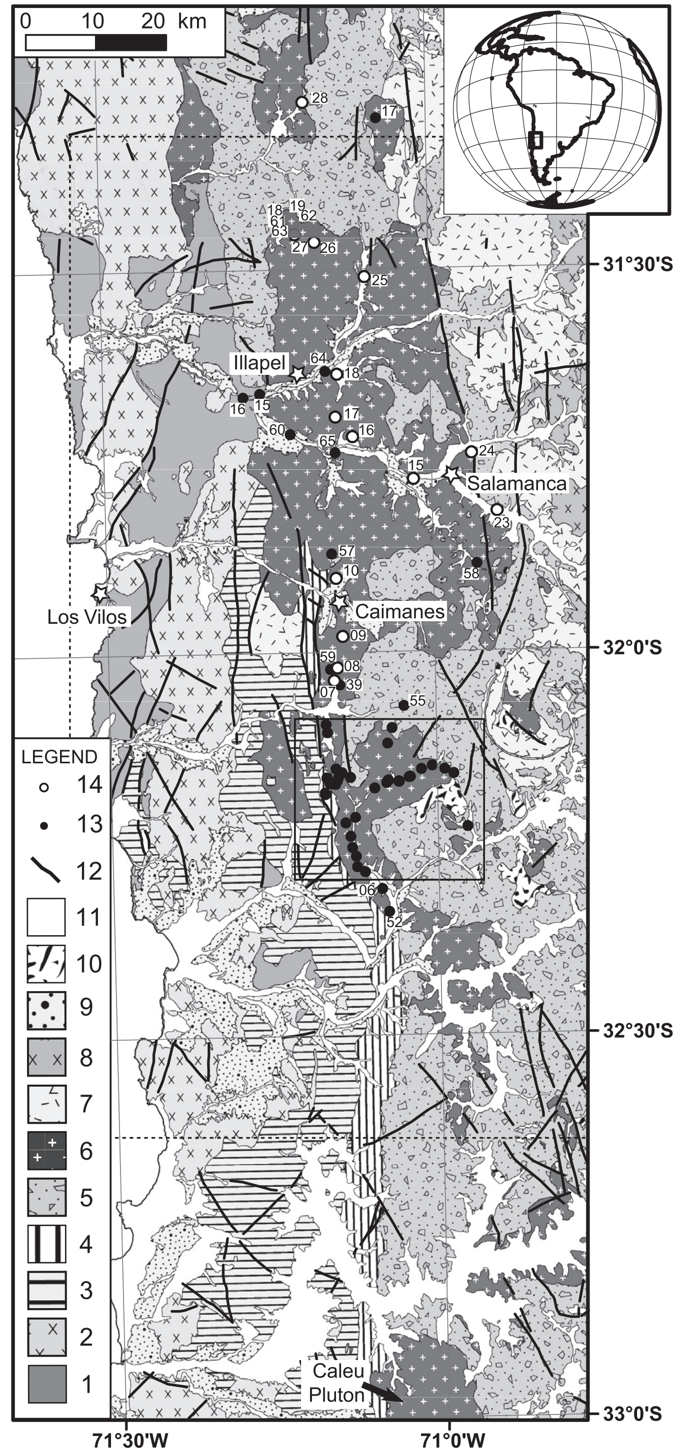

Fig. 1. Regional geological map of central Chile (31°30′-32°30′ S) modified and simplified from the 1:250,000 geological maps of Chile, Rivano and Sepúlveda (1991) and Rivano et al. (1993), showing the main units in this area. Legend: 1 = Upper Paleozoic and Triassic igneous and stratified rocks; 2 = Jurassic igneous rocks; 3 = Jurassic stratified rocks; 4 = Lo Prado Formation (Lower Createaceous); 5 = Stratified continental and volcanic rocks from Lower to middle Cretaceous; 6 = Illapel Plutonic Complex; 7 = Upper Cretaceous continental and volcanic rocks; 8 = Upper Cretaceous and K-T igneous rocks; 9 = Cenozoic volcanic and continental rocks; 10 = Rocks with strong hydrothermal alteration; 11 = Quaternary; 12 = Major tectonic lineaments; 13,14 = Paleomagnetic sites with code MR and LC respectively in data Tables. Rectangle to the south corresponds to the Las Palmas locality with more details of the sampling shown in Supplementary Fig. 1. The box delineated by dotted lines corresponds to area shown in Figs. 2 and 13.