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The genetic link between Jurassic-Cretaceous mafic dyke swarms and coeval plutons and volcanic units, Coastal Ranges of central Chile (33°-33°45'S)

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1. Introduction

Large exposures of dyke swarms are recognized along the coast of central Chile (33°-33°45' S, figure 1). In most cases, these rocks intrude pervasively deformed Upper Paleozoic and Lower Jurassic granitoids. The main objective of the study of these dyke swarms is to recognize its probable genetic links with the Jurassic and Lower Cretaceous mafic magmatism documented along the Coastal Ranges of central Chile. We present new geochronological, geochemical and isotopic data on mafic dyke swarms of central Chile. These results are compared with existent data on Jurassic and Cretaceous magmatic products.

2. Geologic setting

In central Chile (30-34° S), the development of an extensional arc setting during the Middle Jurassic – Lower Cretaceous has been proposed by several authors (e.g. Mpodozis & Ramos, 1989). This exceptional period in the evolution of the central Andes is characterized by emplacement of abundant mantle-derived magmas in the form of lavas and intrusive rocks that show a progressive depletion in their source signature with time (Parada et al., 1999; Morata & Aguirre., 2003). Lower Cretaceous volcanism, grouped into the Ocoite Group, represents an important volume of mantelic magmas added to the crust in a short period of time (Aguirre et al., 1999).

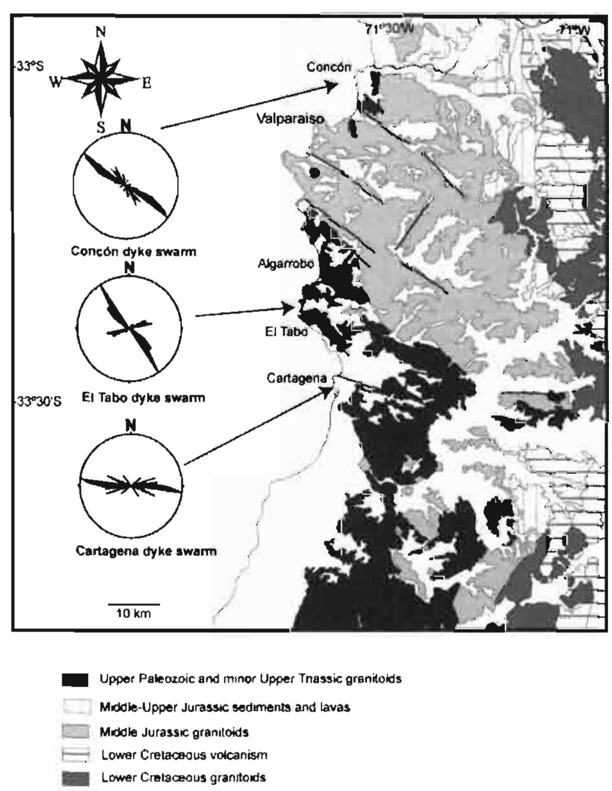

Figure 1: Geological map of the study area. Rose diagrams for dyke swarms are included

Mafic dyke swarms, outcropping along the coast between 33° and 33°45' S, are assembled into three groups:

a) Concón Dyke Swarm: foliated NW-trending basaltic dykes (figure 1), mainly composed of Mg-hornblende and calcic plagioclase, with minor biotite, magnetite and quartz. They are outcropping between localities of Concón and Viña del Mar (33° S), intruding deformed Upper Paleozoic granitoids.

b) El Tabo Dyke Swarm: composed of two groups of unfoliated dykes; the older one are NE-trending basaltic dykes characterized by the presence of pink pyroxene and biotite. These dykes are cut by younger NW-trending dykes, characterized by occurrence of clinopyroxene and plagioclase in a groundmass of brown amphibole. This unit is recognized between localities of Algarrobo and El Tabo, but locally at Cartagena (figure 1).

c) Cartagena Dyke Swarm: corresponds to WNW to E-W-trending mafic dykes (figure 1), whose petrography is similar to those of the Concón Swarm. These rocks are recognized mainly in the coastal outcrops of Cartagena town, where they are intruding into deformed Paleozoic and Upper Triassic intrusions.

3. Geochronology

We performed four new $^{40}Ar/^{39}Ar$ age determinations in amphibole grains of representative mafic dykes. Gas extraction was performed using step heating procedure with a CO_2 laser beam on hornblende grain populations (<15 grains) in the Geochronology Laboratory of Sernageomin.

For the Concón Dyke Swarm, two plateau ages of 161±3 Ma and 164±3 Ma was obtained. For the first one, a considerable component of excess ^{40}Ar was indicated by inverse isochron, and the corrected age assumed for this sample is 157±4 Ma. For the second sample the plateau age agree with inverse isochron age ($^{40}Ar/^{36}Ar$ intercepting near the atmospheric ratio). These two age determinations represent cooling contemporaneous with emplacement and deformation events. For the Cartagena swarm, a plateau age of 157+3 Ma was obtained and no important Ar excess was detected. For El Tabo Dyke Swarm, an Ar-Ar age in a NW-trending dyke gives a spectra with perturbed pattern, with a plateau age of 175+4 Ma at high temperature steps and a pseudo plateau age of ca. 135 Ma at lower temperature, considering ~40% ^{39}Ar released. Despite the complex pattern showed by this sample, we interpret that the high temperature step results from interaction of gas extracted from amphibole with gas coming from plagioclase inclusions present in the sample. Following field and structural observations in the whole area (the dykes of this swarm are unfoliated), we think that the age of this unfoliated dyke is ca. 135 Ma.

4 Compositional features

The coastal mafic dykes show a marked primitive nature in the light of major and trace elements. The low SiO_2 contents (<55 wt%) and generally high #mg (50-80) indicates that magmas were poorly differentiated, and probably, derived from mantle melts. Samples from the Concón Dyke Swarm have SiO_2 between 50.10 and 55.03 wt% and relatively low (3-7.2%) MgO contents. Trace element patterns reflect similarity with the plutonic and volcanic rocks of the Middle Jurassic arc, including a Ta-Nb depletion. Isotopic composition of both samples reflects also this affinity (figure 2), with low $(^{87}Sr/^{86}Sr)_0$ (0.7036 – 0.7034) and positive εNd (1.29 and 2.01), plotting on the field defined for samples of the Middle Jurassic batholith (Parada et al., 1999). One sample for the Cartagena Dyke Swarm indicates a strong primitive signature, with low SiO2 (44.29wt%) and high #mg (80) and Cr (900 ppm) values. Trace elements composition show LILE enrichment, but similarity in HFSE and other elements respect to N-MORB. Bimodal distribution is present in El Tabo Swarm, where NE-trending dykes (sample CC-03-38) are rich in TiO2 (2.01 wt%), Zr (573 ppm) and Nb (22 ppm), without Ta-Nb depletion meanwhile NW-trending dykes (e.g. CC-03-27) are poorer in Ti, Zr and Nb and rich in Cr. Isotopic composition of these samples is markedly different from the rest of the Middle Jurassic –Lower Cretaceous magmatism (figure 2). Both samples are similar between them in terms of εNd (-1.52 and -1.58 for NW and NE trending dykes, calculated at 135 Ma), but are clearly different in terms of $^{87}Sr/^{86}Sr$ initial ratios (0.7059 and 0.7035). Sample from a NW-trending dyke (CC-03-27) is isotopically similar to mafic enclaves of the Upper Paleozoic batholith (Parada et al., 1999).

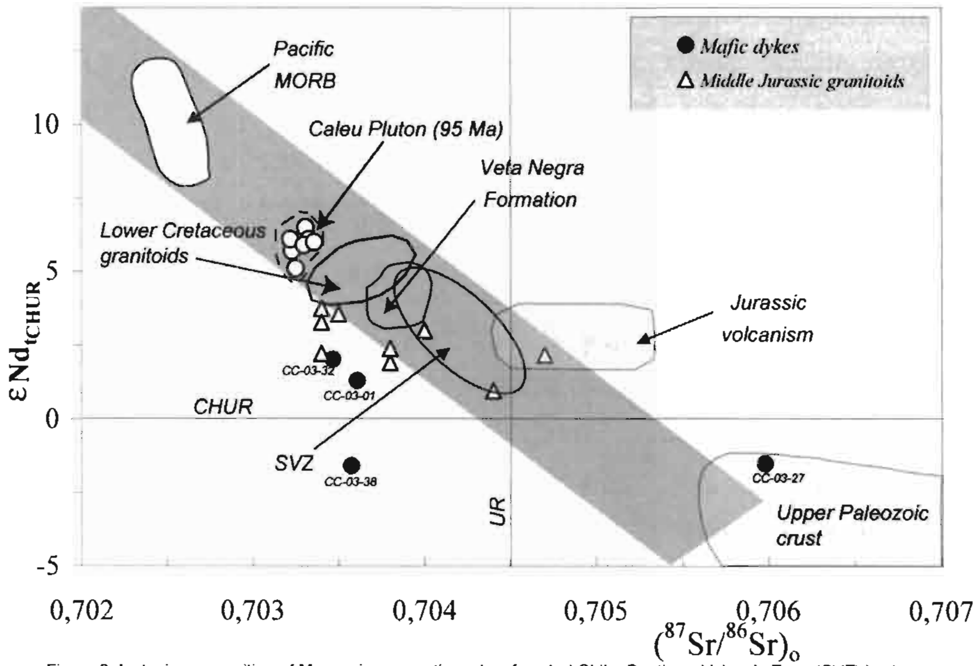

Figure 2: Isotopic composition of Mesozoic magmatic rocks of central Chile. Southern Volcanic Zone (SVZ) is also included. References in Morata & Aguirre (2003), with exception of Caleu Pluton (Parada et al., 2002) and Middle Jurassic and Lower Cretaceous granitoids (Parada et al., 1999).

5. Discussion

Geochronology and compositional features of the Concón and Cartagena Dyke swarms indicates that both untis are related to the activity of the Jurassic arc in the area. Our new Ar-Ar ages are similar to the U-Pb, Rb-Sr and Ar-Ar ages obtained in Jurassic plutonic rocks of the area (Irwin et al., 1987; Hervé et al., 1988; Godoy & Loske, 1988; Gana & Tosdal, 1996). Those data indicate that the activity of the Jurassic arc was in great part concentrated in a short time span (164-157 Ma) and was, in part, related to tectonic activity along NW-trending structures (Godoy & Loske, 1988; Creixell et al., 2004). Our isotopic results are also similar to values of plutonic rocks from the same age in the area, reflecting homogeneity in the source of this magmatism. The genetic relation between the Concón and Cartagena swarms and the Middle-Upper Jurassic volcanism (Horqueta Formation) remains unclear, because the lack of geochronological data in the volcanic rocks and differences in terms of Sr initial ratios in respect to mafic dykes (figure 2). Field, structural, geobarometric data and magnetic fabric observations in the Concón Dyke Swarm (Creixell et al., 2004 and unpublished) suggest that the dykes were injected from plutonic reservoirs located southeastward from the swarm. On the other hand, current results in El tabo Dyke Swarm marks a sharp break in the evolutionary tendency of the Mesozoic magmatism (e.g. Parada et al., 1999). Trace element composition of these rocks do not reflect clear affinity with arc magmatism and differences between NE and NW-trending dykes suggest that both conforms bimodal series of low-Ti and high-Ti basalts, documented widely in extensional settings related to rifting and continental fragmentation (e.g.

Storey et al., 1999). Isotopic composition indicates that these rocks were derived from lithospheric rather than asthenospheric sources as suggested for the rest of the Mesozoic magmatic rocks (Parada et al., 1999; Morata y Aguirre, 2003). Geochronology in El Tabo Dyke Swarm need more precise data but indicates that this anomalous magmatism occurs during the Lower Cretaceous, previous to the extrusion of the voluminous Veta Negra Formation (ca. 119 Ma, Aguirre et al., 1999) and nearly coeval with acid lavas of Lo Prado Formation.

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