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VARIACIONES GEOQUIMICAS EN ROCAS VOLCANICAS MESOCENOZOICAS DE LOS ANDES DE CHILE CENTRAL E IMPLICACIONES EN LA EVOLUCION TECTONICA

GEOCHEMICAL VARIATIONS IN MESOZOIC-TERTIARY VOLCANIC ROCKS FROM THE ANDES IN CENTRAL CHILE AND IMPLICATIONS FOR THE TECTONIC EVOLUTION

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The main geological structure in central Chile between 25°30' and 35° S is a ca. 200 km wide N-trending synclinorium comprising rocks of Jurassic to Tertiary age, resting on a pre-Andean basement. Volcanic rocks, predominating in the western flank of the synclinorium and widespread though less voluminous in its eastern flank, constitute two belts with successively younger volcanics towards the axis of the synclinorium. The belts can be explained by plate subduction, giving rise to volcanism along two parallel arcs which merge with time. Another explanation is that volcanism took place in one arc which was being split up by spreading, due to the coupled action of subduction and ensialic spreading–subsidence. Plate subduction is generally considered to produce a geochemical polarity in coeval lavas inwards from the continental margin, whereas a model involving spreading should give rise to a symmetrical pattern. Our geochemical data suggest that various combinations of tectonic processes took place at different times in several longitudinal 'segments'.

SAMPLES AND METHOD

This study is based on ca. 300 analyzed samples (about 100 for REE, and 20 for $^{87}Sr/^{86}Sr$ initial ratios) of basic to intermediate lavas from five E-W profiles in central Chile (Fig. 1). Two thirds of the samples are basalts and basaltic andesites (SiO_2 = 49-56 wt%, anhydrous), referred to as basalts; the others are andesites (SiO_2 = 56-64 %). The geochemical patterns reported here emerge from comparisons of coeval lavas within and between the profiles, using the following six age groups: Triassic, (middle–) upper Jurassic, lower Cretaceous, upper Cretaceous to Oligocene, lower Miocene and upper Miocene. Although we took special care to sample only unaltered parts of flows, almost all our samples are at least incipiently altered. Tests made on altered lavas with 'unaltered' parts from one of the profiles show that ratios between 'immobile' elements of petrogenetic interest (e.g. Zr, Y and REE) remain constant, due to coherent mobility during alteration. Ratios of 'immobile' elements were therefore used for the comparisons; AFM and other diagrams including mobile elements were also used, but only for the best preserved lavas.

Fig.1. Location map. The sampling has been carried out in five profiles; the Santiago profile is composed of two cross-sections, and the Copiapó profile of four separate areas

Fig.1. Mapa de ubicación. Las muestras provienen de cinco perfiles; el perfil de Santiago consta de dos secciones y el de Copiapó, de 4 áreas separadas.

RESULTS

(1) The basalts of each formation (or member) commonly have rather uniform compositions (geochemical 'fingerprint'), which are reflected in the chemistry of the age group the formation is included in or defines; such uniformity is also found for the andesites. Geochemically, the formations belong to different series, ranging from calc-alkaline to shoshonitic.

(2) The chemical changes of the basalts with time within each profile tend to be symmetrical, i.e. its two flanks display increasing or decreasing elemental ratios relative to the center, or have similar ratios (see examples in Figs. 2-3). A notable exception is the profile in La Serena. Andesites generally have patterns analogous to the basalts.

(3) Within each flank of the Andean synclinorium the age groups show complex geochemical patterns when compared longitudinally (N-S).

(4) The initial ^{87}Sr/^{86}Sr ratios of Triassic to upper Tertiary lavas from the Santiago profile (0.7044, SD = 0.0005; 18 basalts and 2 andesites) are consistent with a relatively homogenous subcrustal source.

CONCLUSIONS

The present tectonic situation and crustal thickness in central Chile cannot be extrapolated backwards beyond the mid-Miocene. Our geochemical data indicate that during the Jurassic and Cretaceous the degree of evolvement of the basic lavas was different than after the Miocene, and its changes with time were opposite in trend to what would be

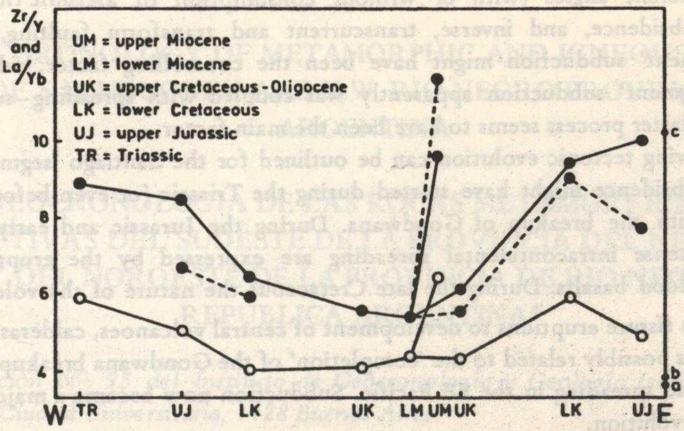

Fig.3. Zr/Y (open circles) and La/Yb (filled circles) ratios for basalts and andesites (broken line) from the Santiago profile. Points *a* and *b* are the average La/Yb and Zr/Y ratios, respectively, for three basalts from volcanoes in southern Chile (Llaima, Casablanca and Osorno), *c* is the average La/Yb ratio for two andesites from the San José volcano (SE of Santiago).

Fig.2. Razones Zr/Yb (circulos abiertos) y La/Yb (circulos llenos) para basaltos y andesitas (líneas punteadas) del perfil de Santiago. Los puntos *a* y *b* son las razones promedios La/Yb y Zr/Y, respectivamente, para 3 basaltos de los volcanes en el sur de Chile (Llaima, Casablanca y Osorno); *c* es el promedio de la razón La/Yb para dos andesitas del volcan San José (SE de Santiago).

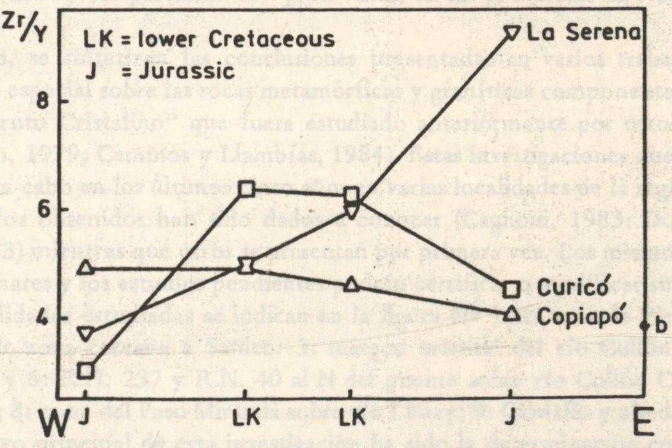

Fig.3. Zr/Y ratios in basalts from three profiles in Central Chile. Point *b* is the same as in Fig. 2.

Fig.3. Razones Zr/Y en basaltos de tres perfiles en Chile Central, el punto *b* es el mismo que en la Fig..2.

expected from the degree of evolvement of young basic lavas in the studied areas. For example, in the Santiago profile the lavas were relatively evolved during the Jurassic (an inherited Triassic character?) and became more primitive with time (Fig. 2). The only profile where a strong normal geochemical polarity can be seen is the one in La Serena (Fig. 3).

The complex geochemical patterns, the geological structure and the metallogenetic zonation can be explained by different combinations of processes in several longitudinal segments, not necessarily coinciding with those recognized now: subduction of the oceanic plate at different angles (with or without consumption of aseismic ridges), ensialic spreading–subsidence, and inverse, transcurrent and transform faulting. For the La Serena 'segment' subduction might have been the controlling factor, whereas in the Santiago 'segment' subduction apparently was coupled with spreading–subsidence. In Copiapo the latter process seems to have been the main factor.

The following tectonic evolution can be outlined for the Santiago 'segment'. Ensialic spreading–subsidence might have started during the Triassic (or even before), probably connected with the breakup of Gondwana. During the Jurassic and early Cretaceous, cycles of intense intracontinental spreading are expressed by the eruption of huge volumes of flood basalts. During the late Cretaceous the nature of the volcanic activity changed from fissure eruptions to development of central volcanoes, calderas and grabens. This change is possibly related to the 'completion' of the Gondwana breakup and the first record of rapid spreading in the SE Pacific. Subduction now became a major control for the tectonic evolution.