MAGMA GENESIS AND EVOLUTION OF CENTRAL ANDEAN CENOZOIC VOLCANIC ROCKS IN THE LIGHT OF REE AND ISOTOPIC DATA

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Résumé

The melts which formed the volcanic rocks of the central Andean Cenozoic "Ignimbrite"- and "Andesite"-Formations are the result of a multi-stage process: 1. Genesis in the transition zone of the upper mantle/lower continental crust. 2. "Magma-mixing" or contamination with upper crustal rocks. 3. Plagioclase- and/or pyroxene-dominant fractional crystallization and progressive segregation. Each step of this model can be evidenced by REE- and isotopic data combined with special petrographic investigations.

Key Words: Central Andes, Cenozoic volcanism, REE data, isotopic data, magma genesis.

Introduction

The central Andean Cenozoic volcanism has been investigated for more than twenty years by many scientists. Different hypotheses on the origin and evolution of the ignimbritic and "andesitic" melts exist. Systematic sampling, new petrological investigations, and REE- and isotopic data, led us to a critical review of these models.

Geological setting

The rock samples were collected by H. Pichler, W. Zeil and S. Pichowiak during several field trips which were supported by the Deutsche Forschungsgemeinschaft (DFG). The samples are located within three transverse sections across the Andean Cordillera: 1) SW-Bolivia (latitude 19°45′ to 21°S), 2) NW-Argentina (latitude 23°30′ to 24°30′S), and 3) northern Chile (latitude 18°19′ to 24°19′45″).

Petrography

The ignimbrites of the "Ignimbrite Formation" show a dacitic to alkalirhyolitic composition. The lavas of the "Andesite Formation" are of "tholeiitic" to rhyolitic composition. Mineral analyses of phenocrysts and lath-shaped groundmass minerals indicate "magma mixing" in most samples while others show a progressive plagioclase-dominant crystallization fractionation (Schmitt-Riegraf & Pichler, 1987; 1988).

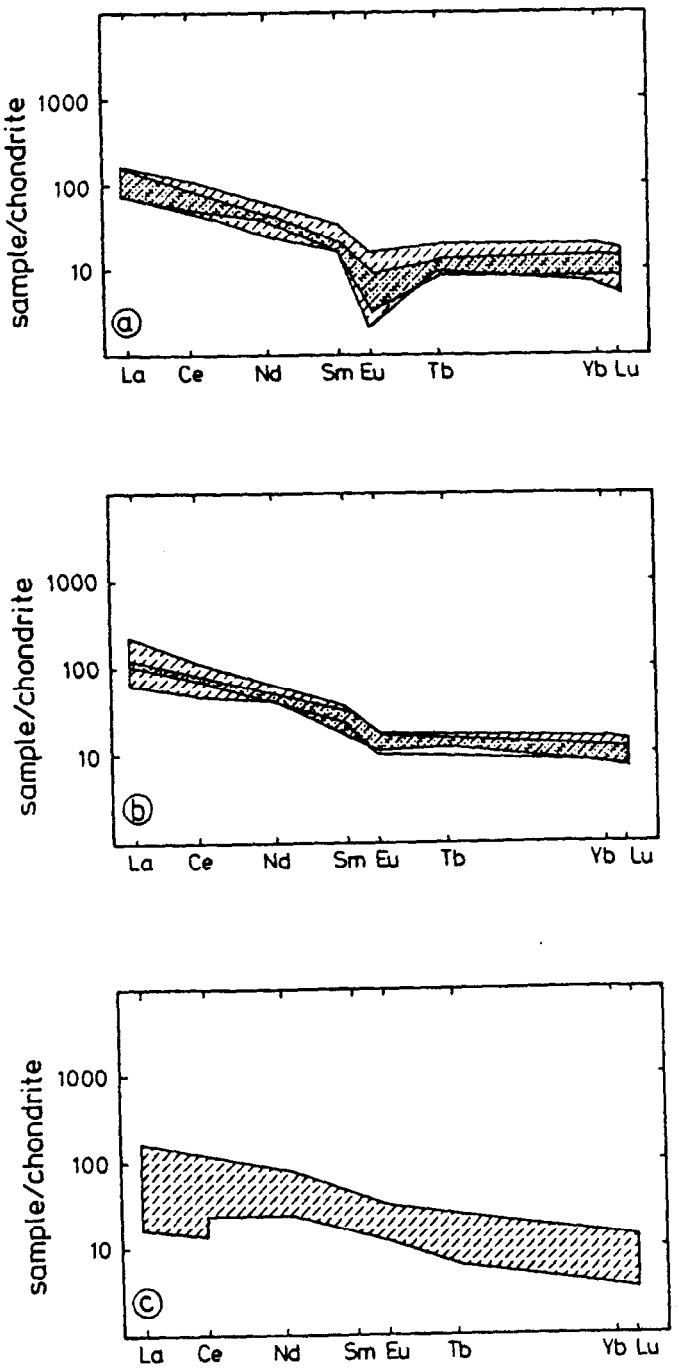

Fig. 1: Chondrite normalized REE patterns: (a) alkalirhyolitic (dashed area) and rhyolitic ignimbrites (dotted area), (b) rhyodacitic (dashed area) and dacitic (dotted area) ignimbrites, (c) undifferentiated lavas (dacites – basic andesites).

Rare earth element geochemistry

Neutron activation analysis has been applied to the samples investigated (table 1). With this procedure a part of the REE cannot be traced. The "ignimbrite" and "andesite" patterns in chondrite normalized diagrams (Fig. 1) indicate a larger enrichment in light REEs and a lower enrichment in heavy REEs. The acidic ignimbrites show a distinct negative europium anomaly which contrasts to the "more basic" ignimbrites and to the "andesitic" ones.

Andesite Formation	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu
Basic andesite	39.3	74.0	36.0	7.3	1.87	0.60	0.80	0.11
Andesite	8.2	17.8	--	3.9	1.26	0.70	2.90	0.39
Quartz-andesite	5.0	12.6	--	2.4	0.8	--	1.40	0.25
Quartz-latiandesite	39.3	76.8	35.0	6.4	1.61	0.69	2.00	0.31
Quartz-latite	43.1	77.8	33.0	6.8	1.47	0.78	1.60	0.29
Dacite	33.2	64.8	28.0	5.9	1.43	0.80	1.55	0.25
Rhyodacite	33.2	67.0	31.0	4.8	1.11	0.54	1.19	0.17
Rhyolite	33.6	60.8	22.0	4.9	0.71	1.03	1.43	0.21
Ignimbrite Formation								
Dacite	29.8	60.3	27.6	4.9	1.04	0.70	1.93	0.31
Rhyodacite	42.2	80.7	32.2	5.6	1.09	0.70	2.19	0.34
Rhyolite	32.9	61.4	21.2	3.6	0.46	0.51	0.20	0.30
Alkalirhyolite	32.3	64.7	29.6	4.8	0.62	0.69	0.26	0.37

Table 1: Average REE composition of the volcanic rock types of the "Ignimbrite" and "Andesite" Formations (own data).

Isotopic geochemistry

Isotopic data are a very helpful hint for the discussion of magma genesis. Additionally to our own data, radiogenic and stable isotope data from literature were included into table 2 (e. g. Klerkx et al., 1977; Thorpe et al., 1979; Hawkesworth et al., 1982; Francis et al., 1980, 1984; Déruelle et al., 1983, Harmon, 1986; Harmon & Hoefs, 1984).

Ignimbrite Formation	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{143}Nd/^{144}Nd$
Dacites	0.1-0.6	0.7053-0.7085	0.51252
Rhyodacites	0.3-2.2	0.7053-0.7114	--
Rhyolites	0.4-6.6	0.7069-0.7100	0.51238
Alkalirhyolites	2.8-4.4	0.7085-0.7105	--
Undifferentiated	0.1-6.6	0.7053-0.7114	0.51225-0.51256
Andesite Formation			
Basic andesite	0.1-0.5	0.7041-0.7072	0.51289
Andesite	0.2-0.6	0.7063-0.7095	--
Dacite	1.6-3.2	0.7089-0.7115	0.51222
Undifferentiated	0.1-0.6	0.7041-0.7115	0.51222-0.51289

Table 2: Variation of radiogenic isotope composition in the different Cenozoic volcanic rock types of the central Andes (own data (analyst U. Kramm) and data from literature).

Conclusions

The melts of the central Andean volcanic rocks (ignimbrites and andesites) originated from the transition zone of the upper mantle/lower continental crust, induced by the subduction of the Nazca Plate below the South American continent. A process of "magma mixing" and/or a more or less intensive upper crustal contamination followed. The "magma mixing" is indicated by mineral analyses and isotopic data ($^{87}Sr/^{86}Sr$; $^{143}Nd/^{144}Nd$; $^{208}Pb/^{204}Pb$; $^{204}Pb/^{206}Pb$). Finally, a plagioclase- and/or pyroxene-dominant fractional crystallization occurred. Minor amounts of ^{10}Be can most likely be derived from a clayey component of the Cenozoic sediments deposited on the basaltic oceanic crust.
The $^{18}O/^{16}O$-values (Harmon & Hoefs, 1984) indicate in contrast to the other isotopic data a partial anatexis of a sedimentary upper continental crust.

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