Sr–Nd ISOTOPE COMPOSITIONS OF CRETACEOUS TO MIOCENE VOLCANIC ROCKS IN CENTRAL CHILE: A TREND TOWARDS A MORB SIGNATURE AND A REVERSAL WITH TIME

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RESUMEN: Las razones isotópicas de Sr–Nd de las rocas volcánicas de la Cordillera de la Costa y de los Andes de Chile central entre 32°30' y 34°30'S muestran una tendencia hacia el campo del MORB desde el Cretácico inferior hasta el límite Oligoceno–Mioceno, y de ahí en adelante un alejamiento hacia los valores del volcanismo Cuaternario, mientras que en el sector entre 26° y 32°30'S el cambio sucede en el Cretácico; en ambos sectores los valores de las rocas volcánicas y plutónicas de la misma edad son similares.

KEY WORDS: Central Chile, volcanic, plutonic, Sr–Nd isotopes, Cretaceous, Tertiary

INTRODUCTION

The studies of Sr–Nd isotope compositions in the Andes of central Chile deal mainly with Quaternary volcanic rocks (e.g. Hildreth & Moorbath, 1988), Tertiary volcanics in the High Andes near the Argentinian border (e.g. Kay et al., 1991) and plutonic rocks (e.g. Brook et al., 1986). Here we present Sr–Nd isotope data for Cretaceous to mid–Miocene lavas from central Chile (46 samples; Fig. 1) with emphasis on the Santiago region (33°30'S), and describe a systematic trend towards and then away from a MORB signature with time.

GEOLOGICAL SETTING

Central Chile between 26° and 34°30'S extends across three tectonic segments: a non–volcanic zone and the end portions of the Central and Southern Volcanic Zones. Within this region Mesozoic volcanic rocks form two parallel longitudinal belts with successively younger units towards a central axis, i.e. a western belt in the Coast Range and an eastern one in the High Andes. The Mesozoic volcanism was mainly of high–K calc–alkaline to shoshonitic character except in the northernmost part of the region where less potassic types dominate (Levi et al., 1988). Oligocene to early Miocene calc-alkaline volcanics of tholeiitic affinity (Abanico Formation), overlain towards the east by mid–Miocene calc–alkaline volcanics (Farellones Formation), occur between the two Mesozoic belts in the south, while similar volcanic units show progressively older ages (up to Late Cretaceous) towards the north, where the Tertiary volcanics are found east of the Mesozoic belts. The Quaternary volcanoes are likewise situated east of (CVZ), or above (SVZ) the eastern belt.

RESULTS

In the southern part of the studied region (32°30' – 34°30'S) the initial $^{87}Sr/^{86}Sr$ ratios of the volcanic rocks decrease and the ε_{Nd} values increase with time from the Early Cretaceous to the Oligocene–Miocene boundary, constituting a trend towards MORB values, regardless of whether the samples come from the Coast Range (Fig. 1A, fields f→ e→ d) or the High Andes (g→ c/e overlap→ d); thereafter the trend reverses with eruption of successively more evolved compositions up to the present (d→ c→ b→ a). The scarce data for granitoids in this area coincide with the results for coeval volcanic rocks (Stern & Puig, 1991; Skewes, 1992). The early Miocene volcanics are slightly more primitive than the mid–Miocene ones (the lower vs. upper Farellones Formation), and the Early Cretaceous lavas in the Coast Range (Lo Prado Formation) at 33°30'S are more primitive than corresponding lavas at 32°40'S. The volcanic rocks analyzed by us from the northern part of the region plot together with granitoids of the same age (mid–Cretaceous; Fig. 1B).

DISCUSSION

A comparison of our and the published Sr–Nd isotope ratios for the region reveals trends towards and then away from MORB with time both in the south (Fig. 1A) and the north (Fig. 1B). However, the reversal took place earlier in the north (during the mid–Cretaceous; unpublished geochemical data suggest a culmination during the Late Cretaceous). The trend towards MORB in Fig. 1A coincides with the shift in geochemistry of the predominant lava types from high–K calc–alkaline/shoshonitic to calc-alkaline with tholeiitic affinity. The subsequent trend away from MORB up to the present is also in agreement with the geochemistry of the lavas. The late Oligocene to early Miocene Abanico Formation represents the point of reversal. This unit, and the younger less primitive Farellones Formation east of it, formed in a caldera–graben setting; the paleo-geothermal gradient was highest during the deposition of the former (Vergara et al., 1993).

An eastward shift of the volcanic front and a change to less primitive compositions occurred also for the late Miocene to Quaternary volcanics between 32–34°S (Stern & Puig, 1991), and north of 32°30'S during the early to late Miocene (Kay et al., 1991). Towards the north rocks of the same age plot further away from the MORB field than in the south (Kay et al., 1991; Skewes et al., 1991); however, differences in longitude might also be a contributing factor. The eastward shift has been explained by a flattening of the subduction angle leading to increased contamination in a thicker crust (Kay et al., 1991), and/or an increase in subduction erosion resulting in a larger contribution of subducted terrigenous sediments in the magmas (Stern, 1991).

The trend towards more primitive compositions from the Cretaceous to the Oligocene might be due to a combination of factors: magma generation in a progressively more depleted mantle, and a decrease in 'fertility' of the lower crust that became more refractive due to successive magmatic events (cf. Parada et al., 1992). This is consistent with upwelling of asthenospheric mantle and an extensional regimen as suggested by Levi et al. (1988) for this region. The rather primitive nature of the Abanico lavas indicates minimal crustal contribution, which is supported by the isotopic uniformity of the samples (Fig. 1A) and very similar values for ignimbrites (not treated here) and intermediate to basic lavas. We suggest therefore that the Abanico rocks formed during en episode of rapid mantle upwelling and crustal thinning.

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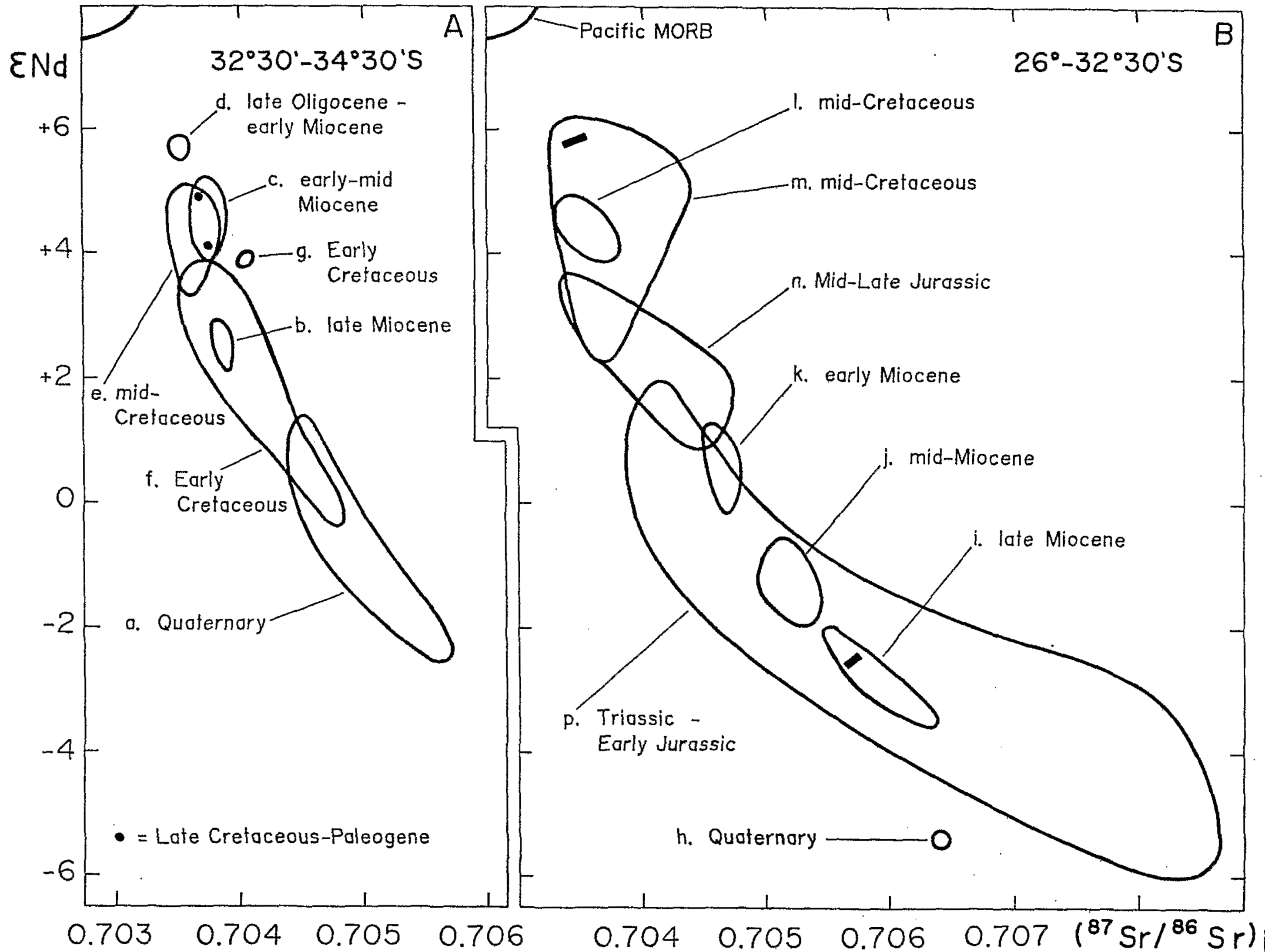
εNd
+6
+4
+2
0
-2
-4
-6
A
32°30'-34°30'S
d. late Oligocene - early Miocene
c. early-mid Miocene
g. Early Cretaceous
b. late Miocene
e. mid-Cretaceous
f. Early Cretaceous
a. Quaternary
• = Late Cretaceous-Paleogene
0.703
0.704
0.705
0.706
Pacific MORB
B
26°-32°30'S
l. mid-Cretaceous
m. mid-Cretaceous
n. Mid-Late Jurassic
k. early Miocene
j. mid-Miocene
i. late Miocene
p. Triassic - Early Jurassic
h. Quaternary
0.704
0.705
0.706
0.707
(87Sr/86Sr)i

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Fig. 1. Plot of ε_{Nd} versus $^{87}Sr/^{86}Sr$ for Triassic to Quaternary igneous rocks from central Chile showing a trend towards a MORB signature with time, up to the Oligocene–Miocene boundary in the south (= A) and to the Cretaceous in the north (= B); from there on up to the present the compositions became successively less primitive. All the fields except m, n and p in B represent lavas (m–p = granitoids); number of samples within parenthesis; fields without references = this study. Field a = Casimiro, Cerro Alto, Maipo, Marmolejo, Tupungatito (13; Hickey et al., 1986; Futa & Stern, 1988; Hildreth & Moorbath, 1988), b = El Teniente area (2; Stern & Puig, 1991), c = Farellones Formation, the High Andes of Santiago (11), d = Abanico Formation, the Andean foothills of Santiago (4), e = Cerro Morado and Ocoa Members (Veta Negra Formation), profiles in the Coast Range at 33°30' and 32°40'S (15), f = Purehue Member (Veta Negra Fm.) and Lo Prado Formation, the same two profiles as above (8), g = Lo Valdés Formation, the High Andes of Santiago (2), h = Tres Cruces (1; Walker et al., 1991), i = Copiapó, Pircas Negras, Vallecito (4; Kay et al., 1991; Walker et al., 1991), j = Cerro de las Tórtolas, Jotabeche (5; Kay et al., 1991), k = Cerro Pulido, Doña Ana, Infiernillo (5; Kay et al., 1991), l = Bandurrias Group, the Coast Range between 28°30' and 30°15'S (4), m = Inca de Oro, Sierra San Juan (5; Brook et al., 1986), n = Cavilolén, Papudo, Quintero (5; Parada et al., 1992), p = Cerros del Vetado, Chañaral, Guamanga, La Ola, (6; Brook et al., 1986). Late Cretaceous to Paleogene lavas in the High Andes of Santiago plot within the overlap of fields c and e (2 samples = dots). The extreme points of the composite of all fields in A are marked with bars in B.