Sr-Nd-Pb ISOTOPE CONSTRAINTS ON THE GENESIS OF CENOZOIC MAGMATISM ALONG A TRANSECT OF THE CENTRAL PERUVIAN ANDES

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Résumé

Les données isotopiques (Sr, Nd, Pb) suggèrent que le magmatisme calco-alcalin Cénozoïque du Pérou central est essentiellement le produit de l'évolution en base de croûte continentale, par assimilation de matériel crustal et mélange avec de nouvelles venues de magmas "primaires", de magmas provenant de la fusion d'un manteau peu déprimé, modifié par des fluides extraits de la plaque subduite. La participation crustale augmente vers l'Est et avec le temps, ce qui reflète l'hétérogénéité latérale de la croûte continentale et l'épaississement crustal au cours du Cénozoïque.

Key words: Andes, Calc-alkaline, Cenozoic, Crustal assimilation, Isotopic geochemistry, Subduction

Introduction

In order to better constraint the petrological models for the genesis of the Cenozoic calc-alkaline and alkaline magmatic rocks of the central Peruvian Andes, Sr- and Nd-isotopic compositions of nearly twenty Eocene to Pliocene plutons, stocks, and dikes from the Huacho - Oxapampa transect (~ 11° lat. S) have been determined (see Soler and Bonhomme, 1989, for a discusion of the spatial and temporal distribution of this magmatism). Preliminary Pb-isotopic composition have been determined for eight of the studied intrusive bodies. The analyses were performed at the CEA, following the analytical procedures described by Turpin et al. (1988).

Sr- and Nd-isotopic data

When the data set is sufficient, slight Sr- and Nd-isotopic heterogeneities are evidenced for individual plutons and stocks. These heterogeneities are mainly primary (heterogeneity of the source region) and/or early (crustal assimilation at deep crustal levels) and generally are not adquired during low pressure differentiation of the magmas. Whatever their petrochemical composition might be (diorite to granite), contemporaneous intrusions emplaced in similar country-rocks show very similar Sr- and Nd-isotopic compositions.

The Oligocene calc-alkaline rocks (Pativilca pluton, Acos, West Churin and Paccho Tingo stocks - the "Coast group") intruding the Albian to early Cenomanian Casma volcanics and/or the Albian and late Cretaceous Coastal Batholith have low initial Sr_i ($^{87}Sr/^{86}Sr$ ratio) (0.7040-0.7045) and high Nd_i (initial $^{143}Nd/^{144}Nd$ ratio) (0.51255 - 0.51268). These Sr-isotopic ratios are in the same range as those of most of the granitoids of the Lima segment of the Coastal Batholith (Beckinsale et al., 1985; Soler and Rotach-Toulhoat, 1989). Eastwards, contemporaneous intrusives (Huancayan and Racco stocks) of the high part of the Cordillera Occidental and the western part of the High Plateaus, show similar Sr_i but higher Nd_i (0.51270 - 0.51275), whereas Oligocene high-K calc-alkaline intrusives (Milpo-Atacocha and Mariac-Quinua stocks) of the eastern part of the High Plateaus display much higher Sr_i ($\approx$ 0.7065) and lower Nd_i ($\approx$ 0.51240).

The Miocene calc-alkaline intrusives (East Churin pluton, Mallay, Raura, Chungar and Chalhuacocha stocks) emplaced in the Mesozoic platform sedimentary series of the high part of the Cordillera Occidental have Sr_i in the range 0.7049 - 0.7053, and Nd_i in the range 0.51250 - 0.51264. Eastwards, contemporaneous calc-alkaline intrusives (Yanamate stock) of the High Plateaus tend to have higher Sr_i and lower Nd_i. Pliocene felsic calc-alkaline dikes (Rupay) and ignimbrites (Bosque de Piedra) of the high part of the Cordillera Occidental and the western part of the High Plateaus show higher Sr_i (0.7062 - 0.7069) and lower Nd_i (0.51240 - 0.51247).

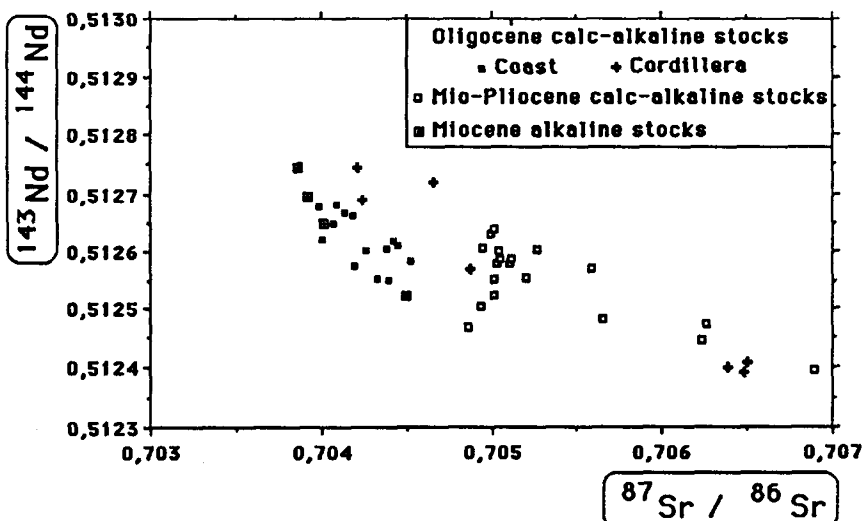

Fig. 1 - Sr-Nd isotopic data

In a Nd_i vs. Sr_i diagram (Fig. 1), the Oligo-Mio-Pliocene intrusions of the high part of the Cordillera Occidental and the High Plateaus (the "Cordillera group") as a whole define a broad hyperbolic correlation with an evolution to higher Sr_i (and lower Nd_i) both eastwards (for contemporaneous intrusions) and with time (in a single area). Sr-, and Nd-isotopic data for the Miocene alkaline stocks of the Amazonian slope of the Eastern Cordillera (Oxapampa area) define a conspicuous hyperbolic trend between Sr_i=0.7039; Nd_i =0.51275 and Sr_i=0.7045; Nd_i=0.51252. Both hyperbolic correlations are regarded as corresponding to the evolution of mantle-derived magmas through assimilation of crustal material and mixing with new batches of mantle-derived magmas at deep crustal levels and through minor AFC process during low pressure differentiation. The undepleted mantle source regions of both the Miocene alkaline stocks and the Oligo-Mio-Pliocene calc-alkaline "Cordillera group" appear to have similar Sr- and Nd-isotopic compositions. They would correspond to a slightly depleted mantle modified by fluids extracted from the basalts and the sediments of the subducted slab. The elongated cluster defined by the Oligocene "Coast group" may be viewed in the same way but with a mantle source region characterized by lower Nd_i.

Our Sr- and Nd-isotopic data show that no granulitic basement akin to the early-Proterozoic Arequipa massif participate in the genesis of the Cenozoic magmatism along the studied transect. The crustal component appears to rather be a non-granulitic or recently granulitized Proterozoic and/or Paleozoic lower crust. For the "Coast group" the crustal participation appears to be less important than for the "Cordillera group", conceivably because the coastal lower crust comprises a much greater proportion of mantle-derived component (deep equivalents of the Casma group and the Coastal Batholith) than the continental crust underlying the cordilleran area. In the Cordillera Occidental, the importance of the crustal assimilation appears to increase with time, which would reflect the progressive tectonic thickening of the continental crust during the Cenozoic.

A comparison with Sr- and Nd-isotopic compositions of modern Andean lavas shows that most of the plutons and stocks of the Oligo-Miocene "Cordillera group" have Sr-, and Nd-isotopic compositions quite similar to those of the lavas of the northern part (33-39° lat. S) of the present-day Southern Volcanic Zone (SVZ) , whereas the Sr-, and Nd-isotopic compositions of both the Pliocene dikes and ignimbrites and the Oligo-Miocene stocks of the eastern part of the High Plateaus rather resemble those of lavas from the present-day Central Volcanic Zone (CVZ). The Oligocene "Coast group" has Sr_i similar to those of modern lavas of the Northern Volcanic Zone (NVZ) and the southern part (39-42° lat. S) of the SVZ but their Nd_i are lower than those of all the modern Andean lavas (for a given Sr_i).

Preliminary Pb-isotopic data

Preliminary Pb- isotopic compositions have been obtained for 8 stocks and dikes (Fig. 2). Pb-isotopic compositions are rather homogeneous with $^{206}Pb/^{204}Pb$ (Pb6) = 18.65-18.84 (the Miocene Chungar granite has a characteristically lower Pb6 ratio of 18.56), $^{207}Pb/^{204}Pb$ (Pb7) = 15.56-15.67, and $^{208}Pb/^{204}Pb$ (Pb8) = 38.48-38.92. These values are quite similar with those obtained by Mukasa (1986) for the granitoids of the Lima segment of the Coastal Batholith (see discussion in Soler and Rotach-Toulhoat, 1989). When the data set is sufficient (e.g. East Churin pluton, Paccho Tingo and West Churin stocks), slight primary or early Pb-isotopic heterogeneities are evidenced for individual plutons and stocks.

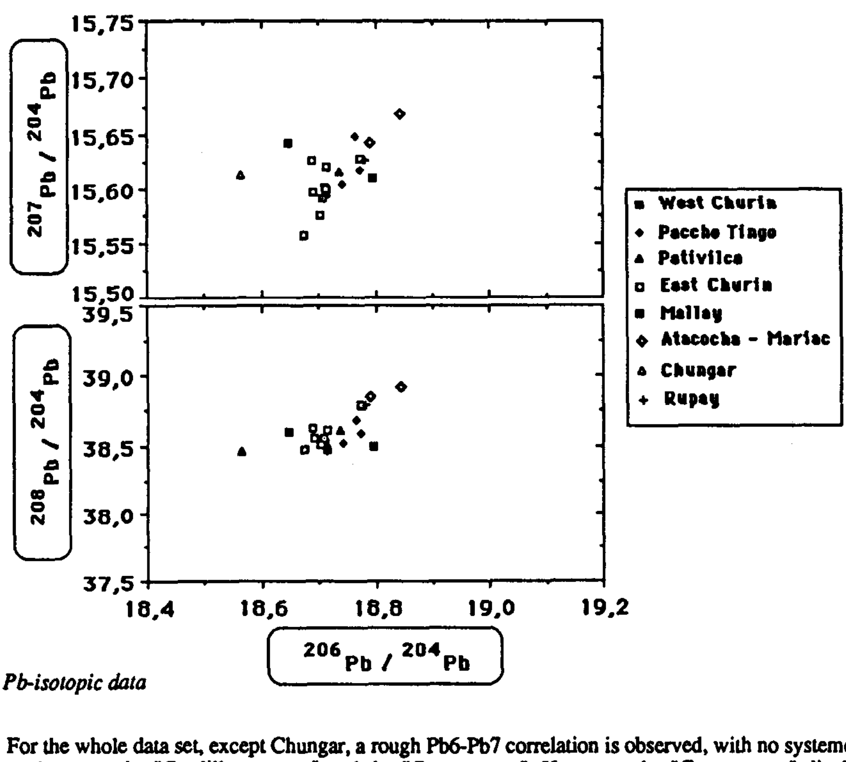

Fig. 2 - Pb-isotopic data

For the whole data set, except Chungar, a rough Pb6-Pb7 correlation is observed, with no systemetic differences between the "Cordillera group" and the "Coast group". However, the "Coast group" displays narrower ranges of Pb-isotopic ratios than the "Cordillera group" and shows a tendency to lower Pb8 ratios. In the Pb6 vs. Pb8 and Pb7 vs. Pb8 diagrams, the "Cordillera group" (except Chungar) define linear trends, whereas the "Coast group" defines a linear trend only in the Pb7 vs. Pb8 diagram. These trends are not age significant and may be considered as mixing lines. For the Atacocha-Milpo and Quinua-Mariac stocks and the Rupay dike, the high Pb-isotopic ratios correlate with high Sr_i and low Nd_i; this correlation reflecting an AFC process during low-pressure differentiation of the magmas. For the Paccho Tingo and West Churin stocks and the East Churin pluton no correlation is observed between the Sr (or Nd)-isotopic ratios and the Pb-isotopic ratios. In particuler East Churin pluton displays ranges of Pb-isotopic ratios very similar to those of the Paccho Tingo and West Churin stocks, but with much higher Sr_i than these latter.

A comparison with Pb-isotopic compositions of modern Andean lavas shows that the "Coast group" of central Peru has Pb6 ratios similar to those of the less radiogenic lavas of the CVZ (outside of the Arequipa massif) and intermediate between those of the NVZ and those of the SVZ, with similar Pb7 and Pb8 ratios. The "Cordillera group" has Pb-isotopic ratios similar to those of the lavas of the CVZ (outside of the Arequipa massif).

The Pb-isotopic data are in accordance with a slightly depleted mantle source but preclude the participation of a depleted MORB-like source. They imply the modification of the mantle source region by fluids extracted from the subducting oceanic slab. Pb-isotopic compositions preclude the participation of a granulitic basement similar to the Arequipa massif in the genesis of the Cenozoic magmatism of central Peru. The crustal component displays Pb-isotopic compositions similar to those of the present-day sediments of the Pacific Ocean.

Conclusions

For the Oligo-Mio-Pliocene magmatism of central Peru we infer a genetic model including :

- the melting of a slightly depleted (not MORB-like) sub-continental mantle source modified by fluids extracted from the basalts and the sediments of the subducting oceanic slab;
- the evolution of the magmas at deep crustal levels through a complex process of fractional crystalization, assimilation of crustal material and mixing with new batches of mantle-derived magmas. The differences between the "Cordillera group" and the "Coast group" are thinked to reflect mainly differences in the composition of the lower crust between both areas. No granulitic basement akin to the early Proterozoic Arequipa massif participate in the genesis of the Cenozoic magmatism of central Peru. The crustal component appears to be recently granutilized Proterozoic and/or Paleozoic rocks. Assimilation of crustal material develops progressively during Miocene and Pliocene times and mainly below the Cordillera Occidental, which is supposed to reflect the Neogene tectonic thickening of the Andean crust.
- minor and sporadic assimilation of crustal material during the low-pressure differentiation of the magmas.

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