A REAPPRAISAL OF THE CENOZOIC INNER ARC MAGMATISM IN SOUTHERN PERU : CONSEQUENCES FOR THE EVOLUTION OF THE CENTRAL ANDES FOR THE PAST 50 Ma.

Gabriel CARLIER[1-2], Jean Pierre LORAND[2], Michel BONHOMME[3] and Victor CARLOTTO[4].

[1] ORSTOM, UR 13, 213, rue La Fayette, 75010 PARIS, FRANCE
[2] CNRS, URA 736, Laboratoire de Minéralogie, Muséum National d'Histoire Naturelle, 61, rue Buffon, 75005 PARIS, FRANCE
[3] CNRS, URA 69, Laboratoire de Géologie, Université Joseph Fournier, 15, rue Maurice Gignoux, 38031 GRENOBLE CEDEX, FRANCE
[4] Departamento de Geología, Universidad Nacional San Antonio Abad del Cusco, CUSCO, PERU.

KEY WORDS : Southern Peru, lamproite, shoshonite, calc-alkaline, peraluminous magmatism.

INTRODUCTION

The Altiplano, a high plateau 200 km-wide and 1500 km-long is undoubtely the major feature of the Central Andes. One of its most characteristic feature is the presence of varied magmatic events, referred to as the Inner Arc Magmatic Domain by Clark et al. (1990). This magmatism started about 48 Ma ago and shows a greater diversity compared to the Main Arc Domain of the Western Andean Cordillera. Several occurrences of phlogopite lamproites, phlogopite-diopside-sanidine lamproites and ultrapotassic minettes have recently been discovered (Carlier et al., 1996) in addition to the peraluminous magmatism of dominantly crustal origin and high-K calc-alkaline to shoshonitic volcanism previously identified (Pichavant et al., 1988; Clark et al., 1990). This led to a reappraisal of the Cenozoic Inner Arc magmatism in Southern Peru, which is presented here along with new age determinations and geochemical data on the ultrapotassic lavas, the high-K calc-alkaline to shoshonitic volcanism and the calc-alkaline plutons. These data provide important informations on the evolution of Central Andes for the past 50 Ma.

LOCATION, AGE AND NATURE OF THE ALTIPLANO CENOZOIC MAGMATISM

The South Peruvian Altiplano (SPA) constitutes the northern ending of the Bolivian Altiplano. It is progressively pinched northward and disappears in the Abancay region (Fig. 1). Like the Bolivian Altiplano, the SPA is divided into a Western Domain and an Eastern Domain separated by the Sicuani-Huancane sinistral active fault system (SHF). The Western Domain is structured by N- to NE-verging thrust fault systems, i.e. from the north to the south the Paruro-Acomayo fault (PAF), the Langui Lake fault (LF), the Calapuja fault (CF) and the Mañazo fault (MF).

The Cenozoic Inner Arc magmatism always occurs in the vicinity of the different thrust fault systems defined above. It started at about 48 Ma, in the Northernmost part of the Western Domain by gabbro-diorite plutons intruding the southern area of the Paruro-Acomayo thrust fault (Fig. 1). These are the Acomayo and Pomacanchi plutons dated at 48-34 Ma and 44-37 Ma respectively, and coeval with the large Andahuaylas-Yauri batholith which intruded the eastern margin of the Western Cordillera. All these rocks have textural and geochemical features of calc-alkaline cumulates crystallized at the bottom of

shallow magmatic chambers. The outcropping of cumulates indicates a period of uplift and erosion of the southern margin of the PAF and the eastern margin of the Western Cordillera before the intrusion of calc-alkaline dacitic and trachydacitic subvolcanic plugs dated at 34 and 32 Ma. The erosion products of this calc-alkaline magmatism filled the Cusco and Sicuani molassic basins (CMB and SMB, Fig. 1).

Magmatism becomes widespread between 30 Ma and 27 Ma, affecting both domains of the SPA. Significant changes in its composition and its location are observed in the Western Domain (Fig. 1). Sparse alkaline syenite dykes occur in the Abancay area, in the northern part of this domain. Alkaline lavas of similar ages are observed along the Calapuja thrust fault. These are the Ayaviri leucite-bearing basanite-phonotephrite-trachyte suite which coexist with high-K monzograbbroic subvolcanic intrusions. Meanwhile, a calc-alkaline magmatism (subvolcanic intrusions) still persists along the Mañazo thrust fault, to the south of the studied area (Clark et al., 1990). During the same period, the Eastern Domain was the locus of a peraluminous magmatism, the earliest cordierite-bearing peraluminous monzogranite intrusions being dated at 28 Ma (Clark et al., 1990). Numerous small peraluminous cordierite-bearing monzogranitic stocks and cordierite-muscovite-sillimanite-bearing dacitic and rhyolitic peraluminous ash-flow tuffs have been recognized over a distance of 200 km, in close association with shoshonites (Laubacher et al., 1988; Pichavant et al., 1988). The most important feature of this domain is the occurrence of potassic to ultrapotassic minettes with diagnostic features of Spanish phlogopite lamproites, i. e. orthopyroxene-bearing phenocryst assemblages, low CaO contents (<2wt%), strong enrichments in large-ion lithophile elements -LILE (Ba=1550-6550 ppm, Zr=217-779 ppm, La_N/Yb_N=17-65), Mediterranean C1-normalized REE patterns (La_N/Nd_N<1.5; Eu/Eu*<1) and negative high field strength elements -HFSE, Ba and Sr anomalies in primitive mantle-normalized multi-element patterns (Carlier et al., 1996). These minettes, dated at 24-20 Ma, are interpreted as Al-rich phlogopite lamproites contaminated to various degrees by partially crystallized peraluminous granites.

The peraluminous magmatism of the Eastern domain becomes increasingly important during the Miocene. The last peraluminous magmatic events give ages of about 4 Ma. Meanwhile, in the Western Domain, the calc-alkaline magmatism recognized along the Mañazo fault reaches its major development (Clark et al., 1990) and other evidences of calc-alkaline magmatism of similar ages are known along the Calapuja thrust fault. An important shoshonitic event dated at 5-6 Ma is also known along the Mañazo thrust fault, in the Puno department (Lefèvre, 1979).

For the past 3 Ma, the magmatic activity was focussed along the Abancay-Curahuasi-Anta, Cusco and Sicuani-Huancane fault systems which separate the Western Domain from the Eastern one and the Eastern Cordillera. Previously identified as only shoshonitic (c.f. Lefevre, 1979), the Plio-Quaternary Inner Arc Magmatism is in fact composed of shoshonites, minettes, lamproites and even peraluminous rhyolites and dacites. Shoshonites can be sub-divided into a hornblende-bearing Pliocene suite in the Abancay-Anta area, a phlogopite-bearing Quaternary shoshonitic suite in the Cusco area and a pyroxene-bearing Quaternary shoshonite suite in the Sicuani-Ayaviri area. Peraluminous rhyolites and dacites showing minettes inclusions (K_2O/Na_2O=1.5-1.7, Ba=4930-5170 ppm, Sr=2370-2700 ppm, La_N/Yb_N=36-46) are closely related to the Sicuani-Ayaviri shoshonite suite. In addition, phlogopite-diopside-sanidine-K-richterite lamproites dykes, dated at 2.3 Ma, have been identified in the Cusco and Ayaviri areas (Carlier et al., in prep.). These lavas resemble the Leucite Hill phlogopite lamproites in having very high LILE contents (Ba=4750-12400ppm, La=6.10^2 x CI-chondrites) and no negative HFSE anomaly (La/Nb=1.1-1.2) in primitive mantle-normalized multi-element patterns.

CONCLUSION

For the last 34 Ma., the Western Domain of the SPA has experienced a general N- to NE-trending compressional regime. In this domain, the Cenozoic magmatism is mainly composed of calc-alkaline suites which are related to the subduction of Nazca plate beneath the South America Plate. Alkaline and shoshonitic suites documented local extensional regimes at about 28-30 Ma and 5-6 Ma.

The lamproite occurrences provide petrologic evidence of the existence of a thick lithosphere, undoubtedly the western margin of the Brazilian Craton, beneath the Eastern Andean Cordillera and the Northern Altiplano. The westward displacement of this ultrapotassic magmatism from the Eastern Domain to the Western Domain during the last 25 Ma suggests a north-eastward thrusting of the Altiplano (and probably the Western Cordillera) above the Brazilian Craton. A consequence of the Altiplano thrusting is a local fusion of its lower crust that produces the peraluminous magmatism.

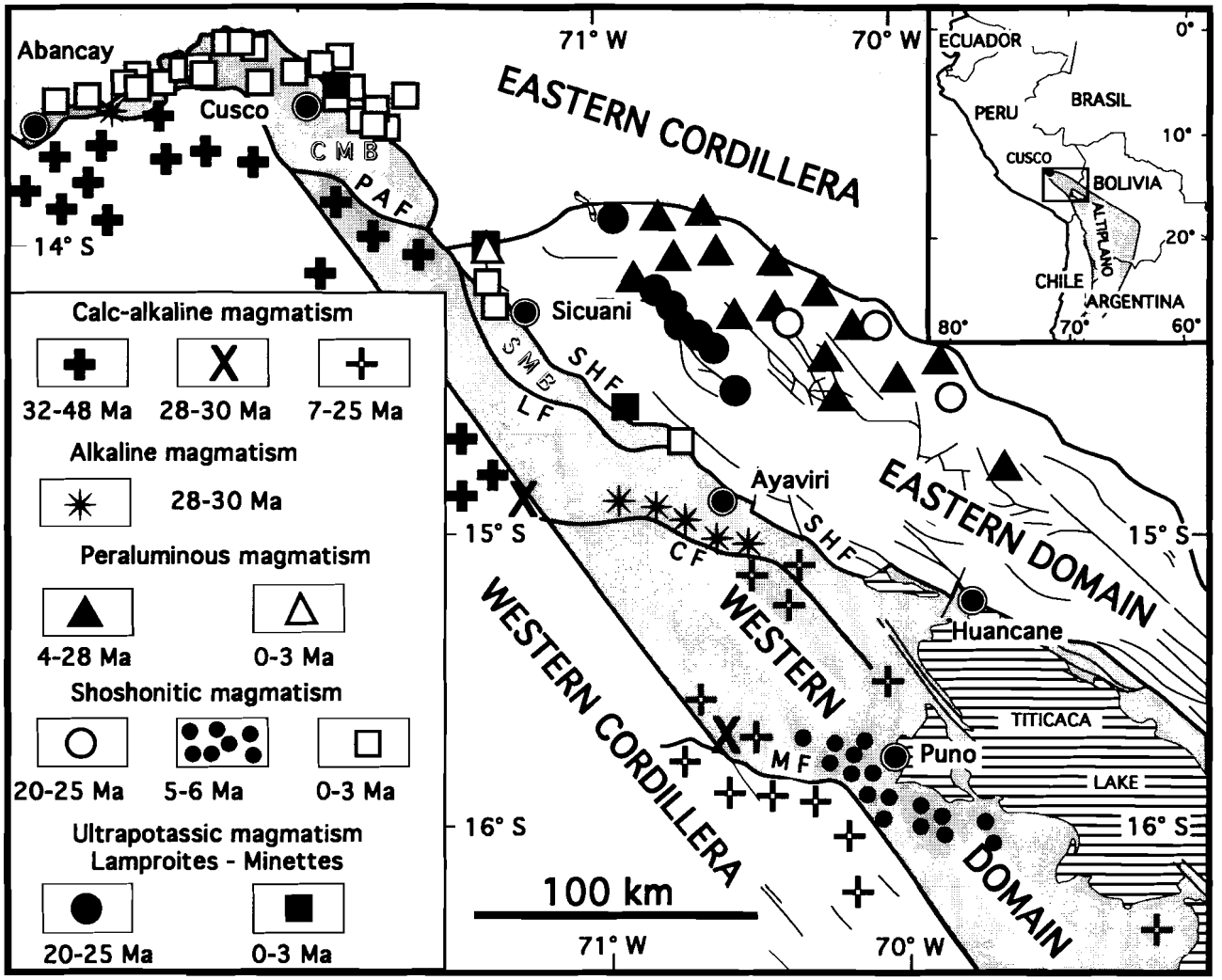

FIGURE 1 : Location, age and nature of the Southern Peruvian Altiplano Cenozoic magmatism.

Structural and magmatic features of the SPA could be explained by the progressive northward migration and counterclockwise rotation of the Western Cordillera during the Eocene-Miocene times then followed by its south-eastward displacement along the the active sinistral Abancay-Curahuasi-Anta, Cusco and Sicuani-Huancane fault systems. Such displacements of Western Cordillera and Altiplano deduced from the study of the Inner Arc Cenozoic magmatism in Southern Peru are consistent with the directions commonly assumed for the convergence between the Nazca plate and the South America Plate since the Eocene (Pardo-Casas & Molnar, 1987).

REFERENCES

Carlier, G., Lorand, J. P., Audebaud, E. & Kienast, J. R. 1996. Petrology of an unusual orthopyroxene-bearing minette suite from southeastern Peru, Eastern Andean Cordillera. Al-rich lamproites contaminated by peraluminous granites. *Journal of Volcanological and Geothermal Research*, in press.

Clark, A. H., Farrar, E., Kontak, D. J., Landgridge, R. J., Arenas, M. J., France, L. J., McBride, S. L., Woodman, P. L., Wasteneys, H. A., Sandeman, H. A. and Archibald, D. A. 1990. Geologic and geochronologic constraints on the metallogenic evolution of the Andes of Southeastern Peru. *Economic Geology*, 85, 1520-1583.

Laubacher, G., Sébrier, M., Fornari, M. & Carlier, G. 1988. Oligocene and Miocene continental sedimentation, tectonics, and S-type magmatism in the Southeastern Andes of Peru (Crucero basin) : Geodynamic implications. *Journal of South American Earth Science*, 1, 225-238.

Lefèvre, C. (1979). Un exemple de volcanisme de marge active dans les Andes du Pérou (sud) du Miocène à l'Actuel (zonation et pétrogenèse des andésites et shoshonites). *Thèse USTL*, Montpellier, 555pp.

Pardo-Casas, F. and Molnar, P. 1987. Relative motion of the Nazca (Farallon) and South America Plate since late Cretaceous times. *Tectonics*, 6, 233-248.

Pichavant, M., Kontak, D. J., Briqueu, L., Valencia Herrera, J. and Clark, A. H. 1988. The Miocene-Pliocene Macusani Volcanics, SE Peru. II Geochemistry and Origin of a felsic peraluminous magma. *Contributions to Mineralogy and Petrology*, 100, 325-338.