

## ULTRAPOTASSIC AND PERALUMINOUS MAGMA MIXING AND ORIGIN OF THE HIGH-K LATITES FROM THE EASTERN CORDILLERA OF SOUTHERN PERU.

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RESUMEN : Las latitas potásicas neógenas de la Cordillera Oriental del Sur del Peru resultan de la mezcla magmática entre magmas de composiciones riolítica peraluminosa y lamproítica respectivamente. Se presentan argumentos texturales, mineralógicos y geoquímicos que compronan este proceso magmatico.

KEY WORDS : Olivine lamproite, peraluminous monzogranite, high-K latite, magma mixing, Southern Peru.

### INTRODUCTION :

During the upper Oligocene and lower Miocene, the Eastern Cordillera of Southern Peru is the centre of an important magmatic activity characterized by peraluminous monzogranites, shoshonites and banakites [see Clark & al., 1990 and references herein]. In the Nuñoa area, lamprophyres (now classified as high-K latites) have been first reported by Audebaud & Vatin Perignon [1974]. Subsequent K/Ar datations [Bonhomme & al., 1985] indicated that these rocks are contemporaneous with the late Oligocene-lower Miocene peraluminous magmatic intrusions. Based on petrographical, mineralogical, and geochemical data, we demonstrate that the high-K latites are generated by mixing involving peraluminous and lamproitic magmas.

## MAGMA MIXING EVIDENCES IN MONZOGANITES AND HIGH-K LATITES :

The monzogranites contain quartz, oligoclase, sanidine, biotite and cordierite phenocrysts in a fine-grained groundmass made of quartz, oligoclase, biotite, apatite, zircon, sillimanite and secondary muscovite and tourmaline. They also include phlogopite xenocrysts and chromite-olivine-phlogopite-bearing mafic inclusions. The high-K latites are composed of a groundmass made of phlogopite, andesine, sanidine, hypersthene, apatite, ilmenite, graphite and sometimes osunilite microlites and colourless glass. Olivine, phlogopite, biotite, quartz, oligoclase, augite, ilmenite and rare cordierite xenocrysts are also frequent. Millimetric inclusions of chromite-olivine-phlogopite-bearing mafic inclusions have been observed in a single high-K latite.

Xenocrysts in high-K latites systematically are partially resorbed (quartz, phlogopite) or exhibit reaction textures (olivine, augite and quartz rimmed by polycrystalline orthopyroxene coronas, sieve-textured biotite and mantled oligoclase, granular intergrowths of aluminous spinel, ilmenite, orthopyroxene and osunilite or K feldspar in biotites). All these features are consistent with assimilation of solid crustal material or magma mixing processes. Nevertheless, textural evidences (ellipsoidal shape, finger-like, cusped margins...) indicate that the olivine-phlogopite-bearing mafic inclusions have been incorporated in a molten state into the magmas now represented by the monzogranites and high-K latites. Then, we conclude that magma mixing is an important process involved in the genesis of the monzogranites and the high-K latites of the Eastern Cordillera of Southern Peru. The xenocrysts of the high-K latites represent the mutual mechanical exchange of phenocrysts crystallized prior the mixing in both magmatic components.

## CHEMICAL AND MINERALOGICAL COMPOSITION OF MAGMA COMPONENTS PRIOR THE MIXING :

The absence of chemical disequilibrium evidences in phenocrysts of the monzogranites that contain phlogopite xenocrysts and mafic inclusions, suggests that the mixing process is essentially mechanical (mingling). Moreover, as xenocrysts and inclusions are scarce and do not significantly altered the whole-rock chemistry, the mineralogical and chemical characteristics of the monzogranites may be reasonably considered as representative of one of the magmatic components involved in the mixing process.

The chromite-olivine-phlogopite-bearing mafic inclusions in both monzogranites and high-K latites supply the best evidences for the identification of the other magma components involved in the mixing. Unfortunately, their small size precludes their characterization by classic procedures of whole-rock chemistry. Consequently, only the chemistry of the mineral phases provides informations on the original crystalline characteristics of this component. The crystallization order in these mafic inclusions, prior to mixing, are chromite, olivine, phlogopite and ilmenite. This sequence is unusual in potassic and ultrapotassic rocks and has been only experimentally obtained by Foley (1989) for lamproitic compositions at low oxygen fugacity and low water activity. The high Cr/Cr+Al ratio of the chromite that is liquidus phase implies a low Al content in the coexisting melts. Low oxygen fugacity conditions are supported by very low Fe<sup>3+</sup> content and probably presence

of  $\text{Cr}^{2+}$  in chromite and  $\text{Ti}^{3+}$  in ilmenite whereas the Si-Al tetrahedral deficiency and the high K/Al ratio of the phlogopite phenocrysts are indicative of both low oxygen fugacity and low water activity. All these features are consistent with a lamproitic affinity for the mafic inclusions and then for the mafic magma component involved in the mixing.

All large crystalline phases occurring in the high-K latites define incompatible mineral assemblages (quartz-olivine, aluminous biotite-phlogopite associations) and systematically are in chemical disequilibrium with the groundmass. They represent relicts of phenocrysts that have crystallized either in lamproitic or in peraluminous magmas.

All the high-K latites are ultrapotassic according to the geochemical classification proposed by Foley & al. (1987). On the element-element plots, the high-K latite and monzogranite compositions define systematic straight correlations that when extrapolated towards the mafic compositions lie on the olivine lamproite domain. From these mineralogical and geochemical data, the origin of high-K latite by mixing between peraluminous rhyolitic and olivine lamproitic magmas are deduced.

#### MAGMA COMPONENT PROPORTIONS INVOLVED IN THE HIGH-K LATITE GENESIS AND TEMPERATURE-PRESURE OF MIXING :

The relative proportions of the two magma components involved in the mixing cannot be accurately estimated in absence of precise chemical composition of these components. Nevertheless, mineral chemistry of high-K latite microphenocrysts and microlites indicates that low oxygen fugacity ( $\text{Fe}^{3+}$ -free  $\text{Ti}^{3+}$ -bearing ilmenite, graphite) and low water activity (osumilite) conditions persist in the "new" magma after mixing. Pyroxene and feldspar thermometry suggest that microphenocrysts have crystallized at nearly 1000°C. Experimental data on peraluminous and lamproitic compositions suggest that the monzogranitic and lamproitic magmas were at the time of mixing at 800-850°C and 1050-1100°C respectively. The thermal contrast between the two magmas is large (200°C) and would provoke rapid crystallization of the lamproitic component if the peraluminous magma proportion involved in the mixing is high (> 50%). At the contrary, the texture of minerals crystallising during the first stages of the mixing (phlogopite, augite) suggest low thermal contrast. We conclude that the lamproitic component involved in the magma mixing is widely predominating (>50%). Pressure at which the mixing occur is not accurately determined. Nevertheless, the absence of cordierite and sanidine xenocrysts and the occurrence of osumilite in some high-K latites suggest pressures above 4 kbar and below 11kbar.

#### CONCLUSION :

The high-K latite of the Eastern Cordillera of southern Peru originated by mixing of lamproitic and peraluminous magmas. Temperature and pressure evaluation suggests that mixing process may operate in the

lower crust. The Peruvian and Bolivian shoshonitic rocks exhibit strong mineralogical and geochemical affinity with the studied high-K latites. Magma mixing process would be an important process generating these rocks.

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