6th International Symposium on Andean Geodynamics (ISAG 2005, Barcelona), Extended Abstracts: 413-416

Magmatism in the Huarina fold and thrust belt, Bolivia, and its geotectonic implications

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KEYWORDS: Cordillera Oriental, back arc, alkaline, high-K calcalkaline, shoshonitic, rift, delamination

INTRODUCTION

The Huarina "fold and thrust" belt, which extends along the western side of the Cordillera Oriental up to the southern Altiplano – Puna region (fig. 1) is a tecto-stratigraphic unit with distinctive geological features. One of these peculiarities is its metallogeny; most of the polymetallic ore deposits of Bolivia, including the tin ores, are located into this belt. For this reason it is also named the *Bolivian tin belt.* However, small gold-antimony ore deposits and mesothermal quartz-gold veins are also exclusive of this belt. A second distinctive characteristic is the igneous activity. Since the Paleozoic, most of the magmatism of the back arc region of the Bolivian Andes occurred in this belt. This activity increased gradually through Mesozoic up to Miocene when the voluminous pyroclastic eruptions formed extend ignimbrite plateaux as well as other small centers and intrusives.

The origin of this magmatism was a theme of debate since a close relationship between magmas and mineralization was recognized. Then, different models were proposed trying to explain it. In this contribution, we summarize the present knowledge of the back arc magmatism of the Bolivian Andes and, on these basis, we propose a model of geologic evolution of the Cordillera Oriental.

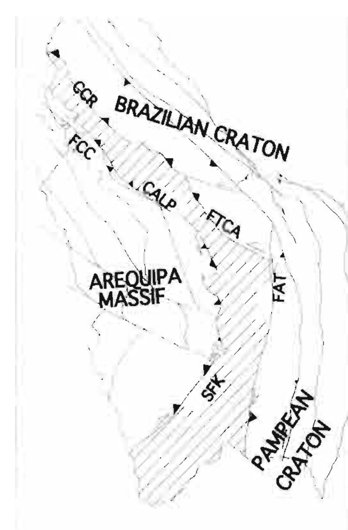


Fig.1: The Huarina fold and thrust belt.

GEOLOGIC SETTING

Both geophysical and isotopic data (Dorbath et al., 1993; Aitcheson et al., 1993; Myers et al., 1998) as well as geologic evidence suggest that three cratonic blocks are underlying the Bolivian Andes (fig. 1). Two of these blocks, the Arequipa Massif and Pampean Craton, are relatively well known because they crop out locally. On the contrary, the nature of the third block, which is thought to be an extension of the Brazilian craton underthrusted below the Cordillera Oriental, is unknown. Between these blocks, the Huarina belt is a weakness zone probably inherited from the Proterozoic (Diaz-Martinez et al., 2000). During the Paleozoic, this belt was a part of an intracratonic marine basin receiving sediments predominantly from the Arequipa Massif and hosting the scarce contemporaneous magmatism. Also exclusive paleontological communities developed at this time in the Huarina belt. In the Mesozoic, the whole Bolivian Andes emerged but along the Huarina belt a continental diachronic rift formed coevally to the break up of Pangea (Sempere et al., 2002). In relation to this structure both igneous rocks and continental basins, sporadically invaded by the sea, were formed. In the Cenozoic two major events occurred in the Huarina belt. In the Eocene the belt was uplifted forming a proto-cordillera and disengaging the Altiplano basin from the rest of the continent (Lamb et al., 1997). Between Late Oligocene to Medium Miocene the Huarina belt and the whole Cordillera Oriental were strongly folded and uplifted.

MAGMATISM

Paleozoic igneous rocks are very scarce in the Bolivian Andes and are exclusively located into the Huarina belt. They are cropping out locally near the Titikaka Lake and in the southernmost of the belt, close to the Bolivia-Argentina border. These ones are considered to be a northern extension of the abundant Paleozoic magmatism of the NW Argentina (Rapela et al., 1992). Although different interpretations have been made about the origin of this magmatism, the scarce data suggest a within plate character for these magmas (Jiménez and López, 2003).

The rift related Mesozoic magmatism developed in the Huarina belt is better studied (see Jiménez and López, 2003 and reference there in). Alkaline magmas (ultrabasic breccias, melanefelinite, carbonatite and melilitite intrusives, basaltic lavas and sills, sienite and phonolite small intrusives) mainly of Cretaceous age, are cropping out usually in the southern part of the belt, while in the northern one Triassic high-K calcalkaline granitoids form relatively voluminous plutonic centers.

The complex Cenozoic igneous activity extended along the western side of the Cordillera Oriental embracing also the southern Altiplano - Puna region. In the northern part of the belt, the two parallel regional structures which are the limits of this belt with the Altiplano and the Eastern part of the Cordillera Oriental are controlling the magmatism (Coniri fault system and Cordillera Real fault system, respectively). In the last one, Eocene to Lower Miocene ages are commonly found; so, near the Bolivian – Peruvian border (15°S), rhyolitic lavas of 47 to 56.8 Ma were reported. Near the La Paz city (16°30'), the Illimani pluton and Cohoni volcanics gave K-Ar ages of some 28 to 26 Ma, and the Quimsa Cruz granitoid was dated between 34 and 22 Ma. On the contrary, in the Coniri fault system, the small intrusives and volcanic centers were formed in the Medium to Late Miocene, mainly between 15 and 5 Ma. The igneous activity of the segment comprised between 18°S and 20°S (Oruro - Potosí region) started at the Late Oligocene (Kumurana granitoid, 25.2 Ma) and continued up to Holocene (Nuevo Mundo volcanic complex, a potentially active volcano). Several small volcanic and intrusive centers, with related polymetallic ores, developed between Early and Late Miocene (San Pablo – Japo stock, 24.8 to 20.2 Ma; Llallagua - Salvadora stock, 21.6 to 20.6 Ma; San José, 16.3 Ma; Cerro Rico de Potosí, 13.8 Ma; Tihua – Carguaycollo, 10.4 Ma). The coeval voluminous pyroclastic volcanism gave origin to the Morococala (7.8 to 5.8 Ma) and Kari Kari – Los Frailes (23.6 to 1.2 Ma) volcanic fields. South of 20°S, the pyroclastic magmatism is also common but mainly restricted to the Medium and Late Miocene. In the Lipez region (southern Altiplano) some of the biggest calderas of the world (Pastos Grandes, Guacha, Panizos, Vilama – Coruto, etc.) formed the extend volcanic field where the arc and back arc magmatism occurred together.

The composition of the Cenozoic magmas of the Huarina belt reflects the complexity of the high mountain building. Most of these magmas are high-k calcalkaline to shoshonitic with $K2O/Na2O>1$ and some alkaline affinities (fig. 2b). They are also mainly peraluminous with the ASI >1. Although there is a wide spectrum of compositions, the intermediate rocks (andesite – dacite and their plutonic equivalents) predominate. Tectonic discrimination diagrams, like the Rb vs Y+Nb, fail to classify these rocks (fig. 2c). When a comparison is done with magmas of the central Andean arc, the igneous rocks of the Huarina belt clearly are richer in REE, Nb, Rb, Cs, and P2O5 (fig. 2d). On the contrary, Ba/Ta, Ba/La, and Ba/Be are lower in the Huarina belt magmas than in the the volcanic arc ones. In the prolongation of the Huarina belt toward Peruvian territory Carlier et al. (1997) and Carlier and Lorand (2003) have found "Mediterranean" type lamproites and lamprophyres.

GEOTECTONIC IMPLICATIONS

The nearly continuous occurrence of magmatism in the Huarina belt since the Paleozoic to the Neogene suggests the presence of a persistent weakness zone where within plate magmas generated independently of the processes related to oceanic plate subduction (fig. 3). In the Paleozoic and, specially, in the Mesozoic the predominantly extensive regime of the continental lithosphere lead to the lithospheric thinning and opening of basins. The magmas can arrive to the upper crust without major contamination. In the Cenozoic, the prevailed compressive conditions lead to a gradual thickened of the lithosphere and the building of the high plateau. The thermal instabilities in the mantle lithosphere induced the delamination of this one taking advantage of the old lithospheric weaknesses. The mantle - generated magmas interplayed widely with crustal melts giving origin to the dominantly peraluminous magmatism of the Huarina belt.

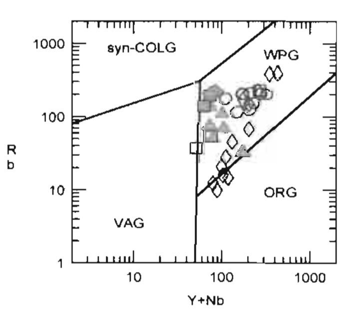


Fig. 2a: Discrimination diagram for Mesozoic magmas

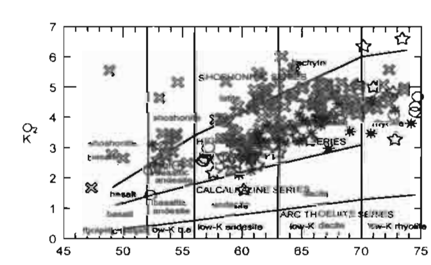


Fig. 2b: Peccerillo & Taylor diagram comparing the arc (,) and back arc (x fill & open) rocks of the Bolivian Andes

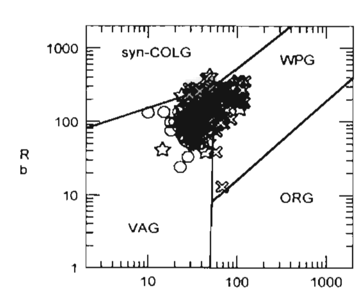


Fig. 2c: Discrimination diagram for arc and back arc Cenozoic magmas.

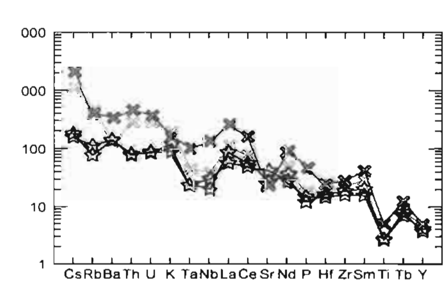
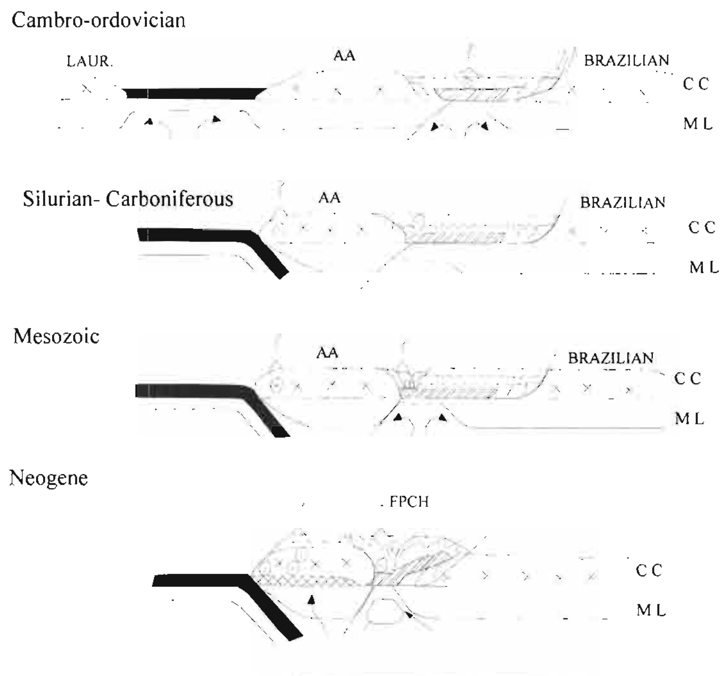


Fig.2d: Spider diagram normalized to primitive mantle of the arc and back arc Cenozoic magmas. Same symbols as 2b.



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