TIN-BEARING GRANITES FROM BOLIVIA: TECTONIC SETTING AND GEOCHEMICAL PARAMETERS

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RESUMEN
Se establecen las características geoquímicas de los granitos estannífe-ros bolivianos y se discute su ambiente tectónico.Así, los granitos triá-sicos del norte de la Cordillera Real (La Paz) ostentan una tipología "S-like" y se ubican tanto en el campo de los granitos sincolisionales como en los de arco volcánico.Mientras que los granitoides del sur de la misma cadena montañosa tienen edad Oligocena y se relacionan a un arco magmático vinculado a la subducción temprana de la placa de Nazca.
En contraste, los granitos proterozoicos del Escudo Precámbrico Bolivia-no (Santa Cruz) poseen rasgos del tipo "I" y ambiente intraplacas. Adi-cionalmente,los granitoides alcalinos y sienitas del Complejo alcalino de Velasco conforman plutones anulares de edad Jurásica Superior-Cretácica Inferior y ambiente de rift ensiálico.

KEY WORDS: Bolivia; tin-bearing granites; geochemical parameters.

INTRODUCTION

The petrological and geochemical research of the granitoid rocks is par-tially devoted to establish the sources of the magmas,the depth of its emplacement and the features of their tectonic settings. In this context the tin-bearing granites from Bolivia will be examined in terms of its petrochemical nature and geochemical constraints determined by the usage of certain discriminant diagrams,such as: Rb/ Sr versus DI; Rb (ppm) vs Nb + Y (ppm); Rb-Sr-Ba,etc.
The Bolivian tin-bearing granites correspond to three main magmatic pro-vinces. These are: a) tne Cordillera Real of the eastern Andes (CR); b) the Bolivian Precambrian Shield (PS); and c) the Velasco Alkaline Com-plex (VC).

GEOLOGICAL SETTING

The Cordillera Real is a high mountainous range conformed by Paleozoic sediments that were intruded by six small granitoid batholiths in its axis. Among them,the northern intrusive bodies have been consolidated during the Triassic (230-200 Ma.ca.),whereas the southern plutons were dated by K-Ar in an Upper Oligocene-Lower Miocene range (28-23 Ma.ca.)
The granitoid batholiths of CR are mostly composed by the granite-grano-diorite association with minor quartz-monzonite,tonalite,quartz-diorite, leucogranite and monzogabbro seggregations. These calc-alkaline pluto-nics are commonlly enriched in potassium and they encompassed a wide si-lica range for variable alumina contents.
The geotectonic situation of northern Triassic plutons of CR is still enigmatic but probably is tenously related to a paleo-subduction event rather than rifting (Avila-Salinas,1990). Whilst the southern Oligocene granitoids are linked to the uplift of the Quechua phase.

b) The tin-bearing granitic plutons of the Bolivian Precambrian Shield have been consolidated during the Middle Proterozoic San Ignacio Orogenic Cycle (1400-1280 Ma.ca.),as well as, during the next Sunsas Orogeny (1280-950 Ma.ca.)
The syn-kinematic stannogenic plutons associated to the Pensamiento granitic Complex (Litherland et all,1986) have a scattered distribution. Among them, the Florida granite (1244 Ma.ca.) and the granophyric complexes of Bella Vista and Cerro Grande are peculiar examples. In contrast, the post-kinematic intrusions of significant tin content belong to the "I" type granitoids,such as: the Diamantina and Orobayaya "allochthonous" plutons. Examples of tin-bearing granites related to the Sunsas Orogenic Cycle are provided by the Cerro Talcoso and Casa de Piedra plutons.
The tin content of the Bolivian Precambrian granites ranges from 3 to 15 ppm Sn.
c) The Velasco Alkaline Province (Fletcher and Litherland,1981) consists of a suite of 15 ring-type plutons and associated alkaline volcanics that are mainly composed by granitoid and s yenitic rocks of a Late Jurassic-Lower Cretaceous age (142-120 Ma.ca.). These alkaline plutonics overlie a Proterozoic gneissic basement and their intrusions result from cauldron subsidence of volcanic edifices.
The tin-bearing rocks from the Velasco Complex are aegirine-bearing granites (i.e; Cabeza de Toro and Tirari plutons,with 2-7 ppm Sn), as well as, quartz-syenites,nordmarkites and melasyenite dikes.

PETROCHEMICAL FEATURES
The granitoid rocks of CR are both peraluminous to moderately metaluminous plutonics displaying a characteristic "S-like" signature (Avila-Salinas, 1990),that resulted from fractional crystallization of the magmatic melts originated at the upper mantle,followed by variable assimilation of crustal rocks (such as the tin-bearing Precambrian granites of the Basement). In a such way, the tin-bearing granites of CR exhibit a wide silica range, moderate alumina surplus and MgO and CaO depletions into their most acidic terms (leucogranites).
The Triassic plutons consist predominantly of granites (leucogranites, syenogranites,monzogranites) with lesser granodiorite and tonalite seggregations,while the Oligocene intrusives are mainly composed by granodiorite and quartz-monzonite.
Furthermore, the tin-bearing granitoid rocks of the PS are both syenogranites and/ or monzogranites belonging to an "I" type. Whereas other areas of the Bolivian Shield present certain syn-kinematic "authoctonous" granites associated to granitization or migmatization of the late stages of the San Ignacio Orogeny. These are barren granites (with lack of tin),that are distinguished by a "S" type,with common gneissoid banding,restite minerals and sedimentary xenoliths.
Among the tin-bearing granites of the PS,the composite Orobayaya pluton show an ellipsoidal shape,displaying an external envelope of biotite-bearing monzogranite followed by inner pulses of syenogranite and syenogranite porphyry (in the core).
The Velasco Complex (Santa Cruz department) conform several ring-type plutons,some of them with nepheline syenite in their cores and external rings consisting of pulses of nordmarkite,pulaskite,aegirine-bearing granite, quartz-syenite and biotite-bearing calc-alkaline granite.
A magmatic differentiation process from a parental magma of pulaskitic composition has been invoked for the origin of these alkaline rocks.

The tin content of the VC alkaline granitoids is probably related to fenitization rather than greisenization or albitization of those ring-complexes.

GEOCHEMICAL CONSTRAINTS

The geotectonic settings of the Bolivian tin-bearing granites have been examined in the light of discriminant geochemical diagrams. Thus, the Rb/ Sr versus DI variation diagram was applied for the three magmatic provinces selected here. In this context, the high Rb/ Sr ratios combined with high DI values distinguished the alkaline rocks from VC, and similarly, high values were observed in samples of the Proterozoic granites of the Bolivian Shield. These rocks lie on the field of the "I" type granites. Likewise, the population of granodiorites from the southern CR show features of volcanic arc granitoids. Whilst the Triassic granitoids of the northern CR lie alternatively in the field of the "S" and "I" types, and particularly, on the experimental boundary line established with comparative samples of Malasian tin-bearing granites.

With the usage of the Rb (ppm) versus Nb + Y (ppm) variation diagram several populations of Bolivian granitoids were plotted. Thus, the PS granites and alkaline rocks of VC fall on the field of the within-plate granites (WPG), that are characterized by high Nb and Y contents.

The field of the Volcanic Arc Granites (VAG) is mostly occupied by samples of southern CR and from the Triassic Sorata batholith. Other granitoids of the northern CR lie alternatively, in the area of syn-collisional granites and in the VAG field. Consequently, the enigmatic nature of those "S-like" cordilleran granitoids is still underlined in this diagram. Nevertheless, a plotting of granitoids from CR in the Log CaO% / Na_2O + K_2O % versus SiO_2 % variation diagram emphasizes the increase in arc maturity for samples of southern CR (that are subduction-related rocks), and also for granitoids of Sorata batholith .Assuming the origin of the former as the result of the Nazca plate subduction is inferred, consequently, a paleo-subduction as explanation of the emplacement of the northern Sorata pluton, whose population lies in the same place.

CONCLUSIONS

a) The northern Triassic granitoids of the Cordillera Real of the eastern Andes of Bolivia (which is an important mining district) form part of an enigmatic igneous arc, that is tenously related to a paleo-subduction process (of the PaleoPacific lithospheric plate ?). These rocks have a "S-like" status, considered formerly.

b) The tin-bearing granitoids of the southern CR correspond mostly to "I" type granitoids, consolidated in a volcanic arc linked to the Nazca plate subduction (circa 25 Ma.)

c) The tin-bearing granitoids of the Bolivian Precambrian Shield consist of isolated intrusions within the huge gneissic basement. These rocks have a within-plate setting and "I" type status.

d) The alkaline granitoids and syenitic rocks of the Velasco Complex are classed as "A" type granitoids, resulting from the rift-controlled emplacement of a suite of 15 ring-type plutons of Late Jurassic-Lower Cretaceoua age.

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