phosphates such as monazite and xenotime, which concentrate LREE and HREE, respectively. Thus, no significant fractionation of LREE and HREE occur during initial metamorphism.

Conclusions. Florencite from the gold-enriched black shales of the Kopylovskoe and Kavkaz deposits in the Bodaibo region belongs to Ce variety with Ce>La>Nd and Ce>Nd>La trends for the Kopylovskoe and Kavkaz deposits, respectively. Florencite is enriched in Pr and Th. Florencite from the studied deposits is optically and chemically heterogeneous. Postsedimentary formation of florencite is confirmed by euhedral crystal shape and absence of cutting of zoning. The crystallization of florencite occurred during catagenesis and initial metamorphism of sediments. The dispersed organic matter was the source of phosphorous. The catagenic transformation of clayey minerals into mica and chlorite leads to extraction of REE into porous solution and further to formation of florencite that was expressed in similar REE spectrum of florencite and host rocks.

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STRUCTURAL GEOLOGY OF THE RIO BLANCO – LOS BRONCES DISTRICT, CENTRAL CHILE: CONTROLS ON STRATIGRAPHY, MAGMATISM AND MINERALIZATION

На основе геологического картирования в масштабе 1:25000 гигантского меднопорфирового узла Рио-Бланко–Лос Брончес, локализованного в Чилийском домене Высоких Анд, представленном эоценовыми и плиоценовыми вулканитами, воссоздана история геологического развития региона, включающая эволюцию внутридугового бассейна с переходом от режима растяжения к режиму сжатия. Приводятся результаты определения относительного и абсолютного возраста интрузивных пород, тектонических разломов и ассоциирующей с ними минерализации.

Introduction

The high Andes of central Chile and Argentina (32–35°S) can be divided into two major geological domains. The eastern domain exposed close to and to the east of the international border, is composed of strongly deformed marine and continental sedimentary rocks of Jurassic to Early Cretaceous age which constitutes the Aconcagua fold and trust belt [Ramos, 1996]. The western (Chilean) domain is composed of volcanic rocks of Eocene to Pliocene age which were erupted during the evolution and inversion of an intra-arc volcano-tectonic basin. They have been grouped in the syn-extensional Abanico Formation and the syn-inversion Farellones Formation [Charrier et al., 2002 and references therein]. Our study has focused on the evolution of the western domain, with an emphasis on the district of the giant Rio Blanco-Los Bronces porphyry Cu-Mo cluster, and is based on the results of a recently finished 1:25.000 geological mapping program [Piquer, 2010], which covers the entire Rio Blanco-Los Bronces district. This new district-scale geological map was used to prepare four E-W cross-sections, with the southernmost one passing through the mineral deposits. They provide the basis for a new model of the tectonic evolution of this part of the Andes that aims to clarify the first-order controls on stratigraphic changes, magmatic activity and associated mineralization.

Tectonic evolution

Upper Eocene – Lower Miocene extension. This period is associated with the development of an intra-arc volcanotectonic basin. The main basin-margin normal faults (Pocuro and Alto del Juncal – El Fierro faults) are N-oriented, and the area within them was completely covered by the products of the Abanico Formation, but our cross-sections show strong changes in thickness (from 2 to 5 km) and volcano-sedimentary facies, both factors indicative of the presence of various sub-basins and depocenters, which are bounded by NNW and NE-oriented internal normal faults. The associated stress field was that of an E-W extension and the ascent of magma to the surface was favoured by the existence of several deep-tapping extensional structures. From 34 to 22 Ma as much as 5 km of volcanic rocks were deposited in the basin, with no coeval plutonic bodies recognized.

Tectonic inversion and plutonism since the Lower Miocene. During this period, the high angle (~60–65°) NW-NNW and N-trending faults were reactivated in reverse-sinistral and reverse mode respectively, with associated folding of the nearby Abanico and sometimes Farellones Formation. This implies that, before their movement, supra-lithostatic pressures were achieved, as evidenced by abundant dilatational, sub-horizontal sills of Miocene age cropping out in the study area. Under this compressional tectonic regime, NE-trending faults were reactivated mainly as dextral strike-slip faults, with variable although generally minor dip-slip reverse movements. This selective reactivation of pre-existing normal faults with different orientations has produced the present-day structural architecture, whereby sub-basins are bounded by high-angle faults, each one with its own thickness of local volcano-sedimentary facies, intensity of folding and exhumation level. By correlating data from the Argentinean flank of the Andes [Ramos, 1996; Giambiagi, 2003] with earthquakes hypocenters and the inferred location of Mesozoic evaporites, the existence of three main Miocene detachment levels beneath the Rio Blanco-Los Bronces district is proposed. Tectonic inversion was coeval with the deposition of the Farellones Formation, which differs markedly from the Abanico Formation in that it is restricted to specific volcanic centres and reaches a maximum thickness of only 1.5 km. The basal units of the Farellones Formation were deposited in progressive unconformities over the Abanico Formation, and have been dated at 22.7±0.4 Ma (U-Pb SHRIMP age [Piquer, 2010]). Plutonic activity was contemporaneous with Farellones Formation volcanism. The main intrusive complex in the area, the Rio Blanco-San Francisco Batholith, was emplaced between 20.1 and 4.69 Ma [Deckart et al., 2005, 2013]. The units dated between 20.1 and 8.16 Ma are coarse equigranular plutonic rocks, while those with ages between 7.12 and 4.69 Ma are subvolcanic rocks directly associated with hydrothermal activity and mineralisation. The host rocks of these subvolcanic complexes are the older equigranular plutons. This implies that in the 1 Ma period between 8.16 and 7.12 Ma this area was affected by a violent exhumation event, unroofing the older, plutonic rocks and exposing them to the subvolcanic environment, with porphyries and breccias being fed by a deeper, unexposed magma chamber. Given the characteristics and erosion level of the Rio Blanco deposit, this magma chamber is inferred to have been localized between 5–7 km below the present surface [e.g., Proffett, 2009; Sillitoe, 2010]. This depth coincides well with the uppermost of the three detachment levels and also with a notable area of low Vp/Vs in seismic tomography, which we speculate correlates with the very young (<4 Ma) crystalline rocks of the deep magma chamber that solidified after volatile exsolution and formation of the Rio Blanco-Los Bronces deposit.

Intrusive contacts, porphyry dikes, hydrothermal breccias and mineralized veins, all show clear NNW and NE preferred orientations, indicating that pre-existing normal faults inherited from the extensional period channelled the ascent and emplacement of magma and hydrothermal fluids during the compressive stage. Statistically, there is an overwhelming predominance of NE and NNW-NW fault planes; N-trending faults, parallel to the orogen, are statistically insignificant and restricted to the eastern margin of the Abanico basin. The abundance of syn-tectonic hydrothermal minerals confirms that fault inversion occurred under high fluid pressures, as it can be inferred by the slip plane infilling of minerals such as epidote, chlorite, tourmaline, quartz, calcite and Cu-Fe sulphides. Given the high dip angle of the faults (60–0°), the compressive tectonic regime and the presence of hydrothermal fluids during faulting, the required conditions for reactivating severely disoriented faults, such as supralithostatic fluid pressures, are met [Sibson, 1985].

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TWO STEP MICROBIAL FORMATION MODEL OF BLACK SHALE-HOSTED MANGANESE CARBONATE DEPOSITS – CASE STUDY OF THE URKUT DEPOSIT, HUNGARY

Рассмотрено формирование низкотемпературных карбонатно-марганцевых месторождений, приуроченных к черносланцевым толщам, в окислительных условиях на стадии биогенного восстановления Mn^{3+} и Mn^{4+} при диагенезе. Приводятся данные о геологическом строении, минералогии и геохимии гигантского неметаморфизованного месторождения карбонатных марганцевых руд Уркут юрского возраста. Изотопный состав углерода карбонатов свидетельствует о его органогенном источнике, изотопный состав кислорода – о температурах