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Hydrothermal phosphate vein-type ores from the southern Central Iberian Zone, Spain: Evidence for their relationship to granites and Neoproterozoic metasedimentary rocks

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ABSTRACT

Hydrothermal quartz–apatite veins, called "Iberian-type", occur exclusively in the southern Central Iberian Zone. This study presents a multidisciplinary approach leading to the mineralogical, fluid inclusions, and geochemical characterization of these veins from two representative areas, Logrosán and Belvís–Navalmoral, in order to establish their relationship with nearby phosphorous-rich granites and apatite in Neoproterozoic metasediments. The mineral assemblage of these veins comprises quartz, apatite, minor sulfides, dolomite, Fe–Mg-carbonates and Fe–Mn-oxides. Three texturally different types of apatite have been recognized in the veins: apatite I showing prismatic habit associated with minor sulfides, apatite II occurring as white fibrous radial crystal aggregates called "dahllite", and apatite III as grayish to greenish hexagonal crystals. Hydrothermal apatite from veins (H-apatite) is enriched in Sr and depleted in Mn–Y–REE–Th–U–Pb compared to magmatic apatite (M-apatite) from the granitic plutons. However, trace element compositions of apatite from metasedimentary phosphorous-rich levels or nodules (S-apatite) of the Schist–Greywacke Complex show similar characteristics to the H-apatite, although the H-apatite stands out for its relatively high Sr-contents. This relative Sr enrichment in H-apatite is interpreted as inherited from both phosphate in Neoproterozoic metasediments (S-apatite) and carbonate levels. REE, fluid inclusion and stable isotope data are consistent with a long episode of hydrothermal activity implying cooling and dilution processes while interacting with phosphate-rich shale and carbonate beds in the SGC. Fluid inclusion study undertaken on hydrothermal apatite and quartz reveals the presence of aqueous low salinity fluids (0.2–6.7 wt.% NaCl equiv.) at moderate to low Th (125–350 °C). All available data point at a recycling event of the southern CIZ metasediments (the SGC) during post-Variscan hydrothermal fluid circulation as the more plausible origin of the phosphate vein-type mineralizations.

1. Introduction

Western-central Spain was one of the most important phosphate producer regions in Europe from the 1850s to the end of the Second World War, involving more than 50% of the Spanish production (Boixereu, 2004). At this moment the sedimentary phosphate deposits of Bucraa in Western Sahara were discovered, becoming the mean source of supply for phosphate industry. Since the discovery of the Bucraa phosphate deposits, the mines of western Spain have remained inactive, except for small operations. Two types of mineralization were exploited: (1) quartz–apatite veins of hydrothermal origin and (2) stratabound deposits related to Lower Carboniferous carbonate rocks filling karstic cavities. This study focuses on the hydrothermal veins about which there are only old and incomplete studies in the literature (Aizpurúa et al., 1982; Rambaud et al., 1983). Among the main mining districts of this type, the most productive during the first part of the 20th century was Logrosán located in the south of the studied area (Fig. 1) (Boixereu, 2003). Other small occurrences, such as Belvís de Monroy, Millanes and Navalmoral de la Mata, are situated in the north of the studied district (Fig. 1).

Hydrothermal phosphate veins occur exclusively in the southern Central Iberian Zone (CIZ), which is the innermost part of the Iberian Variscan Massif. These ore deposits are spatially related to peraluminous and perphosphorous granitic intrusions as intra or extra-batholitic veins. The phosphate veins, so-called "Iberian-type" by Aizpurúa et al. (1982),

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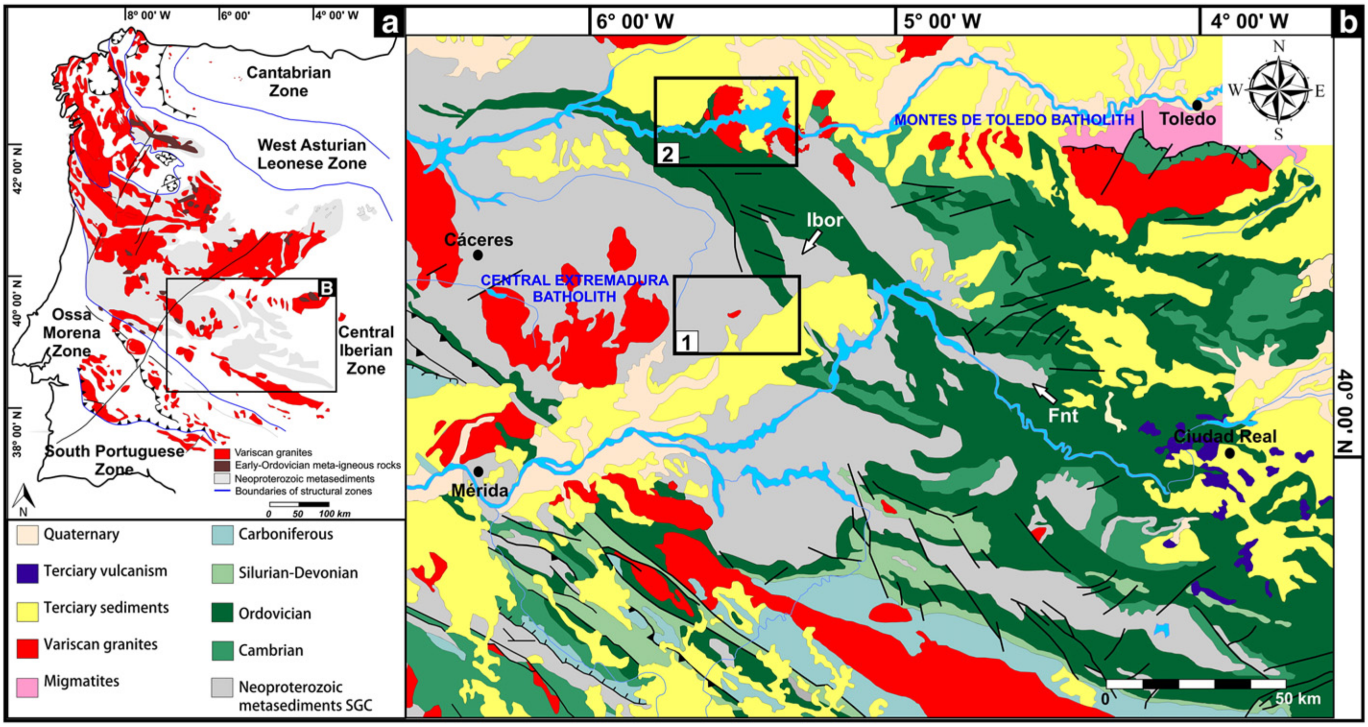

Fig. 1. (a) Location of the Central Iberian Zone (CIZ) in the Iberian Massif. (b) Regional geological sketch displaying the two studied areas: (1) Logrosán and (2) Belvís–Navalmoral. Outcrops cited in text are Ibor: carbonate unit; Fnt: Fontanarejo phosphate levels in Neoproterozoic sediments.
Modified from Rodriguez et al. (2008).

are of relevant importance since they have been recognized only in this part of the Variscan belt of Western Europe. These veins are of hydrothermal origin and their relationship with the associated granites remains unclear.

The present contribution (1) describes the main features of quartz–apatite vein deposits, (2) analyzes the apatite chemistry with REE data that are specially useful to gather information about the source of these elements, (3) compares the apatite chemistry from the veins (hydrothermal, H-apatite) with the apatite chemistry from related granites (magmatic, M-apatite) and from apatite in the Neoproterozoic metasediments (S-apatite), (4) analyzes the compositional variation of arsenopyrite in order to be used as a geothermometer, (5) characterizes the hydrothermal system through fluid inclusion analyses, and (6) deduces information on possible sources of the mineralizing fluids and protoliths involved through stable isotope analysis. Ultimately, the obtained results allow us to place the phosphate ores within the hydrothermal activity of the CIZ and to establish their relationship with phosphorous-rich granites and the Neoproterozoic metasediments.

For this purpose, this study has been focused on two representative areas, Logrosán in the South, and Belvís de Monroy (Belvís)–Navalmoral de la Mata (Navalmoral) in the North of the Cáceres province (Fig. 1). In addition, the phosphorite occurrences of sedimentary origin in the upper part of the regional Schist–Greywacke Complex (SGC) have also been analyzed for comparative purposes.

2. Geological setting

The Iberian Massif is the southwestern extension of the European Variscan Belt and one of the largest domains of the Variscan orogen. Large volumes of granitoids were emplaced during post-collisional stages of the Variscan Orogeny, mostly syn- or clearly late to the D_3 event (e.g., Dias et al., 1998). The Logrosán, Belvís and Navalmoral plutons are situated in the southern part of the CIZ (Julivert et al., 1974), in the Iberian Massif (Fig. 1). They are biotite-bearing monzogranites to two-mica peraluminous leucogranites (S-type granites) with a marked perphosphorous trend.

The Logrosán granite is one of the post-kinematic bodies of the Central Extremadura Batholith, which belongs to the epizonal domains of the CIZ (Castro, 1985). It is a small body, of no more than 4 km^2 in outcrop, which is a typical felsic cupola affected by an intense hydrothermal alteration represented by the tourmalinization, greisenization and formation of an intragranitic stockwork of Sn–(Ta)–W veins (Chicharro et al., 2013). Apatite is an accessory mineral in those granites, mostly included in plagioclase and K-feldspar. The Logrosán granite intrudes the Neoproterozoic metasedimentary sequence of the SGC which is characterized in this area by a monotonous decimetre- to centimetre-scale alternation of greywackes and slates with minor presence of sandstones and conglomerates. A Variscan low-grade regional metamorphism (Chl-Bt) has affected the Neoproterozoic country rocks while the emplacement of the granitic body has produced a contact metamorphism characterized by an inner hornfels zone and an outer zone of spotted phyllites and chlorite schists.

The Belvís and Navalmoral granites are located on the western segment of the Montes de Toledo Batholith (MTB) intruding into low-grade Neoproterozoic and Lower Paleozoic metasedimentary rocks and causing remarkable contact aureoles (Villaseca et al., 2008). The contact metamorphism induced by the Belvís intrusion suggests an epizonal level of granite emplacement with pressures of crystallization below 2 kbar (Merino et al., 2013). The later Navalmoral granite crosscuts the aplopegmatitic dyke-system associated with the Belvís pluton indicating a similar shallow level of emplacement. The Belvís massif is composed of two-mica highly fractionated leucogranites, markedly P-rich (P_2O_5: 0.63–0.85 wt.%), and involves complex accessory mineralogy (Merino et al., 2013). The Navalmoral pluton is mainly composed of biotite granite with variable amounts of K-feldspar megacrysts and lower P_2O_5 content (0.29–0.38 wt.%) than the Belvís granite (Villaseca et al., 2008). The intrusion age of the Belvís granite has been established at ca. 314 Ma, in agreement with the post-tectonic Variscan character of most granite intrusions of central Spain (Orejana et al., 2011). Recently