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4: Transpressional tectonics, lower crust decoupling and intrusion of deep mafic sills: A model for the unusual metallogenesis of SW Iberia

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Abstract

SW Iberia is interpreted as an accretionary magmatic belt resulting from the collision between the South Portuguese Zone and the autochthonous Iberian terrane in Variscan times (350 to 330 Ma). In the South Portuguese Zone, pull-apart basins were filled with a thick sequence of siliciclastic sediments and bimodal volcanic rocks that host the giant massive sulphides of the Iberian Pyrite Belt. Massive sulphides precipitated in highly efficient geochemical traps where metal-rich but sulphur-depleted fluids of dominant basinal derivation mixed with sulphide-rich modified seawater. Massive sulphides formed either in porous/reactive volcanic rocks by sub-seafloor replacement, or in dark shale by replacement of mud or by exhalation within confined basins with high biogenic activity. Crustal thinning and magma intrusion were responsible for thermal maturation and dehydration of sedimentary rocks, while magmatic fluids probably had a minor influence on the observed geochemical signatures.

The Ossa Morena Zone was a coeval calc-alkaline magmatic arc. It was the site for unusual mineralization, particularly magmatic Ni–(Cu) and hydrothermal Fe-oxide–Cu–Au ores (IOCG). Most magmatism and mineralization took place at local extensional zones along first-order strike-slip faults and thrusts. The source of magmas and IOCG and Ni–(Cu) deposits probably lay in a large mafic–ultramafic layered complex intruded along a detachment at the boundary between the upper and lower crust. Here, juvenile melts extensively interacted with low-grade metamorphic rocks, inducing widespread anatexis, magma contamination and further exsolution of hydrothermal fluids. Hypersaline fluids ($\delta^{18}O_{fluid}>5.4‰$ to 12‰) were focused upward into thrusts and faults, leading to early magnetite mineralization associated with a high-temperature (>500 °C) albite–actinolite–salite alteration and subsequent copper–gold-bearing vein mineralization at somewhat lower temperatures. Assimilation of sediments by magmas led in turn to the formation of immiscible sulphide and silicate melts that accumulated in the footwall of the layered igneous complex. Further injection of both basic and sulphide-rich magmas into the upper crust led to the formation of Ni–(Cu)-rich breccia pipes.

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Younger (330 to 280 Ma?) peraluminous granitoids probably reflect the slow ascent of relatively dry and viscous magmas formed by contact anatexis. These granitoids have W–(Sn)- and Pb–Zn-related mineralization that also shows geochemical evidence of major mantle–crust interaction. Late epithermal Hg–(Cu–Sb) and Pb–Zn–(Ag) mineralization was driven by convective hydrothermal cells resulting from the high geothermal gradients that were set up in the zone by intrusion of the layered igneous complex. In all cases, most of the sulphur seems to have been derived from leaching of the host sedimentary rocks ($\delta^{34}S = 7‰$ to 20‰) with only limited mixing with sulphur of magmatic derivation.

The metallogenic characteristics of the two terranes are quite different. In the Ossa Morena Zone, juvenile magmatism played a major role as the source of metals, and controlled the styles of mineralization. In the South Portuguese Zone, magmas only acted as heat sources but seem to have had no major influence as sources of metals and fluids, which are dominated by crustal signatures. Most of the magmatic and tectonic features related to the Variscan subduction and collision seem to be masked by those resulting from transpressional deformation and deep mafic intrusion, which led to the development of a metallogenic belt with little resemblance to other accretionary magmatic arcs.

Keywords: Iberian Pyrite Belt; Ossa Morena Zone; IOCG mineralization; Ni–(Cu) mineralization; Layered mafic–ultramafic intrusion; Crustal detachment

1. Introduction

Subduction-related orogens and accretionary plate margins are ore-forming environments of prime importance. Tectonic, magmatic and hydrothermal processes related to the subduction of an oceanic slab under an active margin and subsequent arc–continent or continent–continent collision are responsible for the formation of a wide variety of ore deposits, commonly related to the extrusion of large volumes of subaerial calc-alkaline andesite in the overriding plate. Such processes are well known in the Late Phanerozoic accretionary orogenic belts of the Pacific Ocean, Asia or eastern Europe (e.g., Mitchell, 1992; Camus and Dilles, 2001; Heinrich and Neubauer, 2002; Zengqian et al., 2003). Localized extensional zones were the preferred loci of ore deposits, including a wide spectrum of porphyry-related and epithermal systems, replacements (including skarns), veins and volcanogenic massive sulphides. However, not all collisional margins behave in the same way and less common ore-forming processes can prevail that depart from the well-known simple subduction/collision model.

Recent geological, geochronological and geophysical results in both the Ossa Morena (OMZ) and South Portuguese (SPZ) zones of SW Iberia show that the contrasting styles of mineralization found on both sides of the Variscan suture were broadly synchronous and formed in response to a unique tectonic evolution. In this paper, we examine the unusual features of this accretionary magmatic belt in which transpressional deformation and related magma emplacement controlled the tectonic, magmatic and hydrothermal evolution, masking other geological features typically related to subduction/collision and obduction.

2. The geological evolution of SW Iberia: tectonic framework

The Ossa Morena Zone is a continental Proterozoic terrane (Nd T_{DM} ages 1.4 to 2.0 Ga; Nägler, 1990) that was perhaps accreted to the autochthonous Iberian terrane during the Cadomian Orogeny at the Neoproterozoic to Cambrian transition (Abalos et al., 1991; Ochsner, 1993). During Variscan times, oblique collision of Gondwana with an exotic terrane, probably Laurentia (Silva et al., 1990; Quesada et al., 1991; Eguíluz et al., 2000; Matte, 2001), led to the amalgamation of the Iberian Variscan massif. The more currently accepted models propose that north-dipping subduction of an intervening ocean was followed by ophiolite obduction and continental collision. Subduction and obduction were apparently proceeding in Early to Middle Devonian times, coming to an end in the Late Devonian to Late Visean (Silva et al., 1990; Oliveira and Quesada, 1998; Eguíluz et al., 2000). This old suture between the two continental terranes, the OMZ and SPZ, is now defined by the oceanic Pulo de Lobo terrane, the Acebuches-Beja ophiolite and the South Iberian