Detachment faulting and late Paleozoic epithermal Ag-base-metal mineralization in the Spanish central system

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ABSTRACT

Hydrothermal activity during late Hercynian time resulted in epithermal silver–base-metal (Pb-Zn-Cu) vein formation in the eastern part of the Spanish central system. During the Hercynian orogeny, the central Iberian crust was thickened by compressional tectonics, heated, weakened, and subsequently overthickened by massive late Hercynian granitic intrusions. Subsequently, the central Iberian crustal welt underwent extensional collapse through lithosphere-scale, low-angle detachment faulting. The detachment systems evolved through tectonic denudation, isostatic rebound, and upward arching to define an extensional province much like the U.S. Basin and Range. Andesitic volcanism and hydrothermal activity occurred during extension, inducing epithermal-type hydrothermal convecting systems that leached, transported, and precipitated silver and base metals along fractures crosscutting the Hiendelaencina metamorphic core complex.

INTRODUCTION

The relations between detachment systems and the evolution of the Basin and Range province (southwestern United States) have been studied by many authors (e.g., Wernicke, 1981; Davis et al., 1983; Spencer, 1984; and others). Spencer and Welty (1986) have suggested that detachment systems and precious- and base-metal deposits are strongly related. Their model proposed that mineralization accompanied major detachment faulting episodes, and denudation of lower plate rocks produced unusually high geothermal gradients, which ultimately enhanced hydrothermal activity. High-angle normal faults in the upper plates of the low-angle detachment systems became suitable channels along which the solutions moved and precipitated metals. Recent studies on the tectonics of the Spanish central system (Doblas, 1987; Martinez et al., 1987) suggest a similar model to explain the late Hercynian metallogenesis. Structural evidence (Doblas, 1987) indicates that the Hercynian central Iberian crustal welt collapsed through lithosphere-scale, low-angle extensional detachment systems in the late Hercynian (late Carboniferous–Permian), and evolved toward a Basin and Range–type province. We propose that volcanism and hydrothermal activity took place during extension, resulting in the genesis of the well-known silver–base-metal district of Spain, Hiendelaencina.

MINERALIZATION

Three Ag–base-metal (Pb-Zn-Cu) vein-type deposits are recognized in the Hiendelaencina district: Congostrina, Hiendelaencina, and La Bodera (Fig. 1). Two sets of veins are observed at Hiendelaencina, occurring along high-angle faults with orientations of N70°E to N90°E and N10°W to N30°E. Kinematic indicators (e.g., slickensides, tension gashes) reveal normal and strike-slip motions for the first and the second sets, respectively. The veins are pre-Triassic in age (they are partially covered by Triassic series—e.g., Congostrina). Country rocks of the veins are low- to high-grade metamorphic rocks defining the so-called Hiendelaencina metamorphic core complex (Doblas, 1987), which includes quartzite, mica schist, augen gneiss, and orthogneiss. The wall-rock alteration types associated with the veins are phyllic and chloritic. The veins underwent several periods of filling, giving rise to breccialike textures. Ore minerals at Hiendelaencina (De Vos and Viaene, 1981; Martinez, 1987) include Ag sulfosalts (pyrargyrite, freieslebenite, stephanite, miargyrite, and freibergite); minor minerals are galena, stibnite, bournonite, sphalerite, pyrite, chalcopyrite, native silver, argentite, arsenopyrite, and hematite; the gangue consists of quartz, barite, and siderite. The veins vary in thickness from a few centimetres to about 1 m, and are up to 5 km long.

Fluid inclusions in quartz and fluorite samples from veins of the district (Sierra et al., 1987) have homogenization temperatures of 100–160 °C in fluorite and 90–120 °C in quartz, which clearly indicates mineral precipitation under epithermal conditions (Berger and Eimon, 1982).

LATE HERCYNIAN TECTONIC EVOLUTION OF CENTRAL IBERIA

The transition from the Hercynian to the Alpine cycle (late Hercynian, 310–270 Ma; Arthaud and Matté, 1975) has always been controversial. It includes a wide variety of extensional, compressional, and transcurrent features having no satisfactory global explanation within central Iberia. However, recent studies allow the subdivision of this time span into three successive deformational episodes (Doblas, 1987): an extensional event, a ductile transcurrent episode with an east-west–oriented σ_1 axis, and a brittle transcurrent event, indicating a north-south–trending compressional axis.

Only the first extensional episode is described here because it appears to be the key to explain the metallogenic features of this area. At the end of the Hercynian compressional episodes, massive alkaline and calc-alkaline granitic intrusions pervaded central Iberia (340–275 Ma; Ibarrola et al., 1986). This area was then affected by a major extensional event, which is clearly imprinted on the granitic rocks of the Spanish central system. Several east-west– to west-northwest–east-southeast–striking, north-dipping detachment faults formed during extension; they display a top-to-the-north shear sense (Doblas, 1987). These structures evolved through tectonic denudation, isostatic rebound, and upward arching of the crust toward an extensional province. The essential characteristics of the detachment systems (Figs. 1, 2) are as follows: (1) Two wide east-west– to west-northwest–east-south-east–trending extensional shear corridors crop out in the central and southern Spanish central system, dip 10° to 20° to the north, and show S-C fabrics and ultramylonites. These corridors are interpreted as the breakaway zones of the detachment systems, which display a top-to-the-north extensional motion. (2) Several east-west–oriented, listric, high-angle normal faults dip to the north or the south, with a top-to-the-north or a top-to-the-south extensional motion. These faults separated blocks with contrasting metamorphic grades, and they occasionally formed tilted half-grabens filled with Permian sediments and volcanics (as in the northeastern area). These structures are interpreted as high-angle, listric normal faults on the upper plates of the detachment systems. (3) Five major north-south–oriented ductile transcurrent shear zones (dextral or sinistral) are interpreted to be transfer faults of the detachment systems; they separate different blocks undergoing extension. (4) The evolution of these detachment systems by tec-

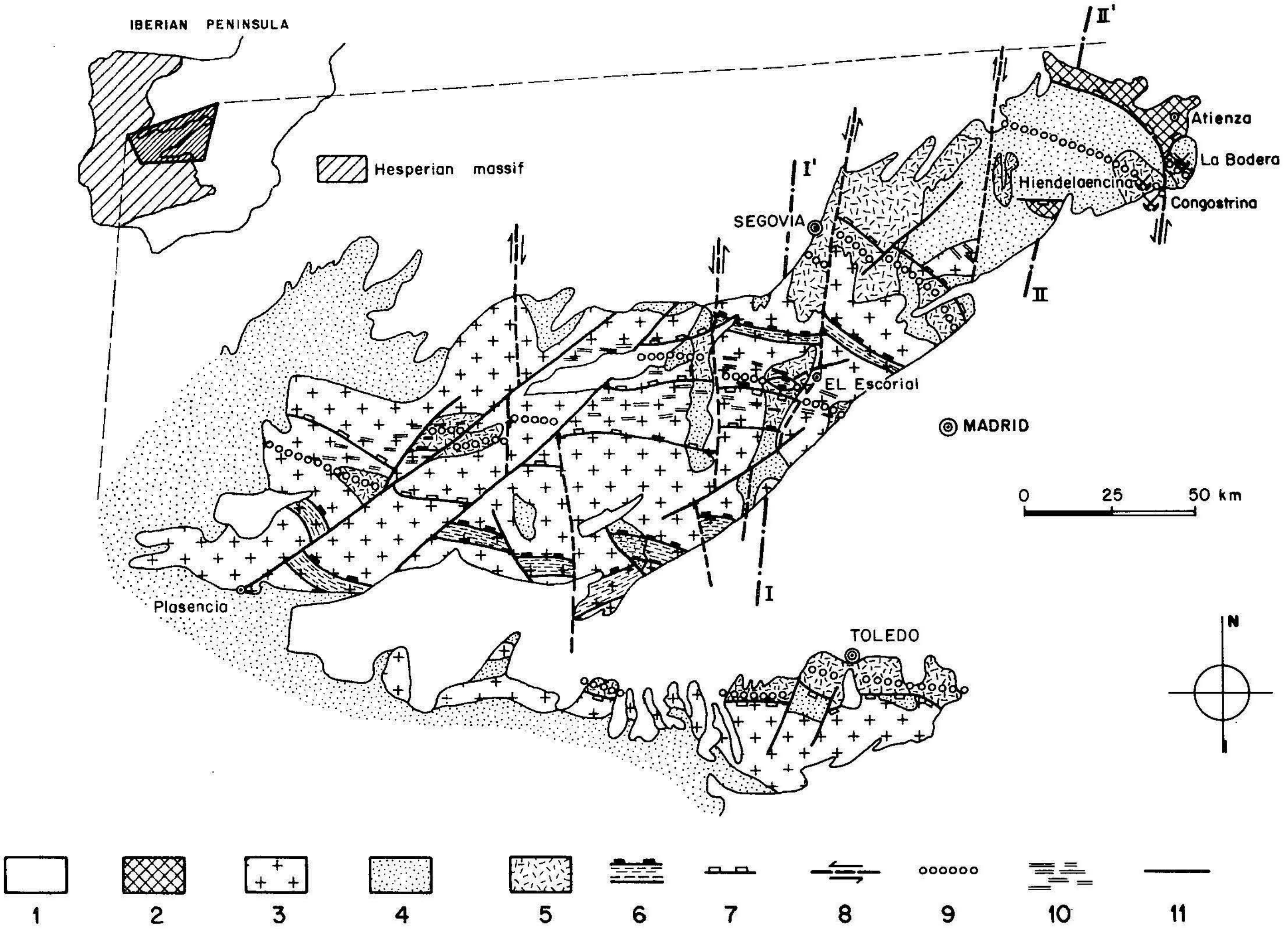

Figure 1. Simplified geologic map of central Iberia showing main structures of late Hercynian extensional detachment systems (after Instituto Geológico y Minero de España, 1980; Sopeña and Ramos, 1985; Doblas, 1987). 1: Mesozoic/Cenozoic sedimentary rocks; 2: Permian sedimentary and volcanic rocks; 3: late Hercynian granitoids; 4: low- to medium-grade metamorphic rocks; 5: orthogneisses and migmatites (metamorphic core complexes); 6: detachment surfaces; 7: high-angle normal faults; 8: north-south-trending transfer shear zones; 9: axis of dome-shaped antiform areas; 10: east-west-trending dike swarms; 11: brittle faults. I-I' and II-II' are lines of cross sections shown in Figure 2.

tonic denudation, isostatic rebound, and upward arching of the crust created synform/antiform pairs, similar to those described in the Basin and Range province by Spencer (1984). Within the synform areas, local north-south-oriented compressional stresses caused east-west-striking kink bands and crenulation cleavages. Within the antiform areas, the crustal upward arching generated east-west-oriented dome-shaped metamorphic core complexes, with local denudation of the detachment surface (El Escorial, Fig. 1). These complexes show typical overprinted brittle-on-ductile fabrics and north-south-trending slickenside striations. They are areas of higher geothermal gradients, as revealed by the intrusion of dike swarms and extrusion of Stephanian-Permian volcanic rocks.

The intrusion of east-west-trending dike swarms concentrated in the central and western parts of the Spanish central system (Fig. 1; calc-alkalic porphyry, microdioritic, and aplitic dikes; Huertas, 1985) began at the end of this extensional event (Doblas, 1987). The Stephanian-Permian volcanics extruded during this extensional episode consist mostly of andesitic lava flows, minor andesite breccias and agglomerates, and sill-type hypabyssal bodies of dacitic to andesitic composition (Hernan et al., 1981). These rocks display pervasive propylitic alteration, with chlorite and calcite. Veins and pods of calcite, barite, jasperoid silica, and base-metal sulfides occur throughout these outcrops.

Finally, the pre-Triassic mineralization of Hiendelaencina was also related to the extensional episode. Extension occurred along fractures that are parallel to the major structural trends developed during this event.

DISCUSSION AND PROPOSAL OF A MODEL

As a result of the Hercynian nappe tectonics, the central Iberian crust was thickened through intracontinental subduction and crustal telescoping (Matté, 1986; Fernandez and Doblas, 1987) and was subsequently additionally overthickened, heated, and weakened, thus lowering the crustal viscosity by massive granitic intrusions occurring in late Hercynian time. Such overthickened and overheated crust may have defined a gravitationally unstable mass with a tendency to spread under its own weight (Tapponnier and Molnar, 1977; Wernicke et al., 1987). The gravitational potential stored in this way within the crust might have provided the energy to drive the extensional collapse of central Iberia. Consequently, the area underwent deep-seated extension through lithosphere-scale detachment systems.

Much has been written during the past 10 years on precious metal epithermal-type deposits (e.g., Buchanan, 1981; Eimon, 1981; Berger and Eimon, 1982; Camus, 1986; and others), resulting in a better understanding of the ore genesis processes leading to this type of deposit. This work points to a new approach to understanding the silver metallogenesis of Hiendelaencina. Previously (Vindel, 1985), it was thought that ore genesis in the central system was related mostly to late Hercynian granitic plutonic activity. This

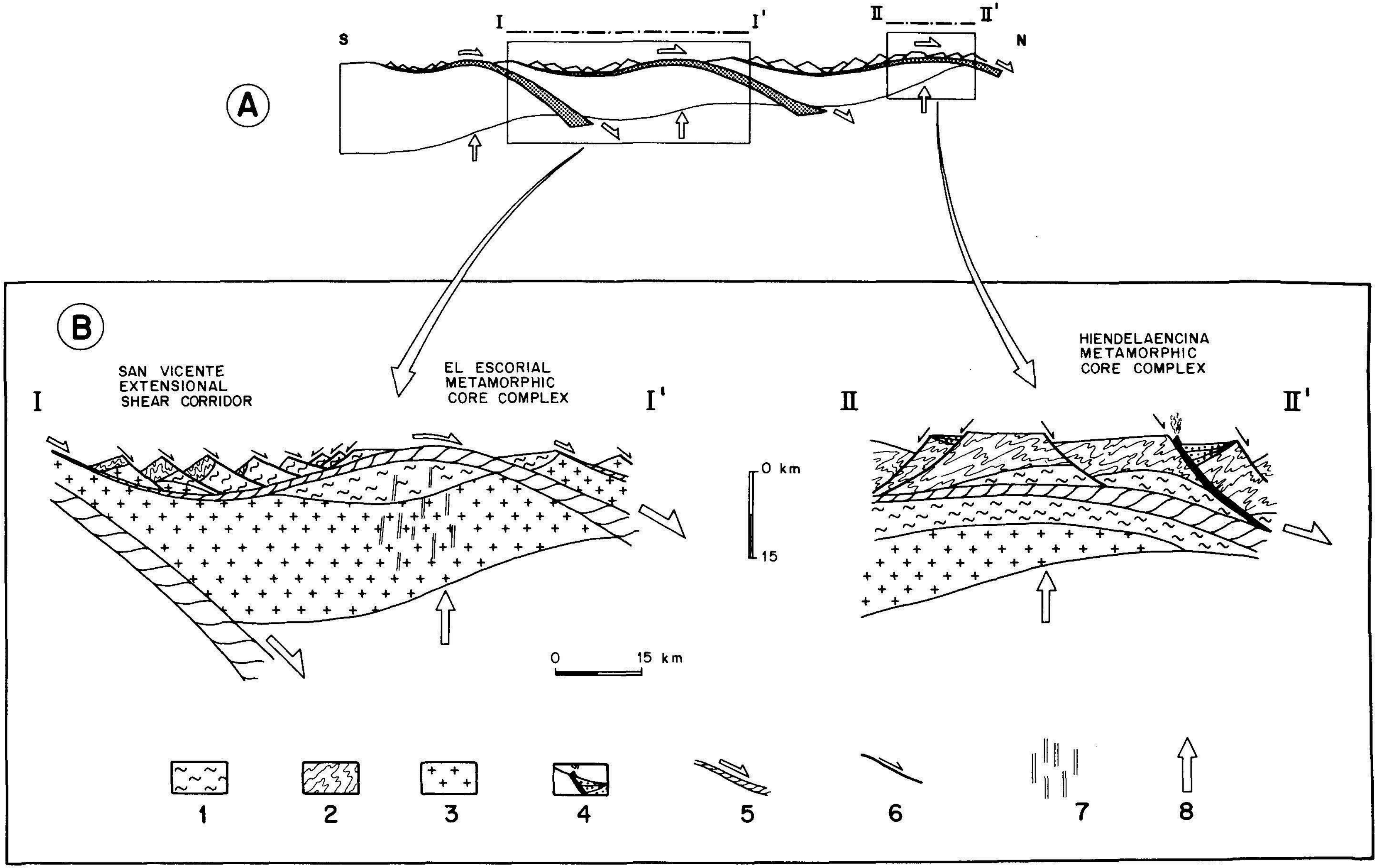

Figure 2. A: Idealized composite cross section of central Iberia during extensional episode. B: Simplified schematic cross sections of two areas in Spanish central system during same episode. 1: Orthogneisses and migmatites; 2: low- to medium-grade metamorphic rocks; 3: late Hercynian granitoids; 4: Permian sedimentary and volcanic rocks; 5: detachment surfaces; 6: upper plate high-angle normal faults; 7: dike swarms; 8: upward arching of crust. Locations of I-I′ and II-II′ shown in Figure 1.

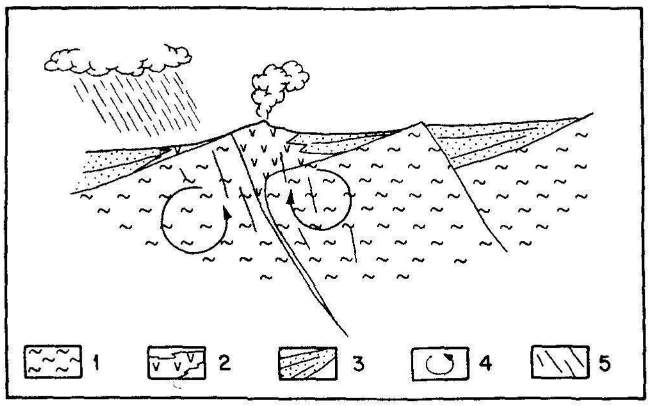

Figure 3. Idealized geologic model for Spanish central system epithermal Ag-base-metal mineralization. 1: Metamorphic core complex; 2: andesitic Permian volcanics; 3: Permian sediments; 4: hydrothermal convecting cells; 5: vein-type mineralizations.

model may be valid for certain deposits occurring close to these intrusions (Martinez et al., 1987), but it is not valid for the more distant (Fig. 1) silver-base-metal veins of the Hiendelaencina district, which are nearer to the Permian volcanics than to any other igneous outcrops. Even if we cannot totally rule out the presence and influence of hidden late Hercynian granitic bodies beneath the Hiendelaencina district, the following arguments make it very improbable. (1) There is a clear east-west polarity in plutonic and metamorphic activity within the Spanish central system (both decreasing eastward). (2) While in the central and western parts of the Spanish central system, the gneisses (the deepest stratigraphical level of the Hercynian chain in central Iberia) are enclosed and crosscut by late Hercynian granitic intrusions, this is not the situation at Hiendelaencina. (3) Most of the Spanish central system is pervaded by granitic dike swarms, except for its eastern border (Hiendelaencina), where dike swarms are totally absent.

If a genesis related to the granitic plutonic activity is not probable, a different thermal source must give rise to the hydrothermal activity that led to the genesis of the Hiendelaencina district. We propose that a plausible mechanism for the hydrothermal activity is the elevation of the geothermal gradient resulting from the uplift of lower plate rocks.

Several factors must be considered for the Hiendelaencina district in formulating a genetic model. (1) The general late Hercynian structural scheme in the Spanish central system is a direct consequence of extensional detachment tectonics. (2) The mineralized veins occur along high-angle faults whose characteristics (trends and shear senses) are typical of those belonging to the extensional event. (3) Due to their mineralogy and thermal characteristics and alteration types, the Hiendelaencina district can clearly be ascribed to an epithermal environment. (4) The late Carboniferous to Permian extensional event was associated with pre-Triassic Ag-base-metal mineralization and to extrusion of Stephanian-Permian volcanics.

On the basis of these premises, the following model can be proposed: The development of detachment systems at lithosphere scale, uplift of lower plate rocks, and consequent generation of a late Hercynian extensional province with andesitic volcanism would have produced favorable tectonic and geothermal conditions to induce epithermal-type hydrothermal activity. Silver and base metals transported by the hydrothermal solutions were precipitated as sulfosalts and sulfides along fracture systems affecting both the volcanics and the basement complex (Fig. 3).

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