

# A well-preserved, ca 250 m.y. old, geothermal field in central Spain: shallowest traces of a much larger hydrothermal system

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A unique example of a barium–base-metal strata-bound deposit is located in the Permian–Triassic cover of the Linares–La Carolina Pb ore district (Upper Permian–Lower Triassic)<sup>11</sup> in central Spain (Fig. 1). The whole area was a world-class mining district between 1875 and 1920, producing a total of about 5 500 000 t lead with 500 g/t silver as by-product. The mine workings were concentrated on vein-type hydrothermal (Ba)–(Pb–Zn–Cu–[Ag]) mineralization hosted by metasediments and granitoids. No direct connection has been observed, however, between the two types of mineralization although they are spatially close.

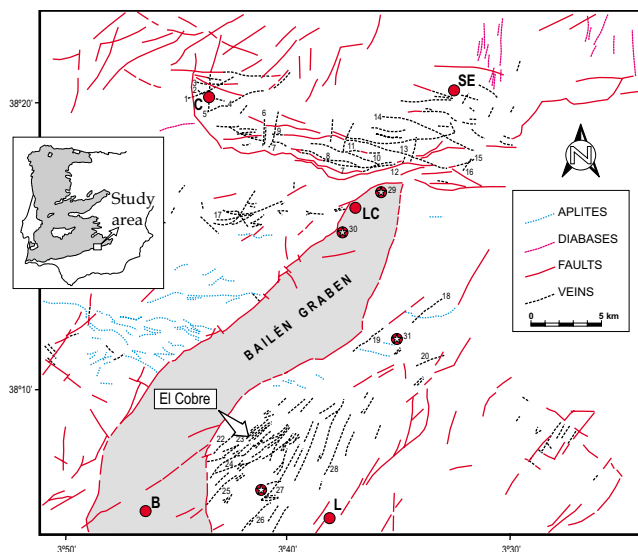


Fig. 1 Location of Linares–La Carolina Pb-ore district and spatial distribution of hydrothermal veins and strata-bound deposits (stars). S1, Cañada Incosa; S2, Los Palazuelos–Fernandina; S3, Navas de Tolosa; C, El Centenillo; LC, La Carolina; SE, Santa Elena; L, Linares; B, Bailén

The strata-bound deposits were initially interpreted as having been formed by remobilization from the Linares–La Carolina lodes,<sup>15</sup> but this interpretation was speculative as no geochemical or fluid inclusion data were available to support it. The geological, fluid inclusion and isotopic evidence reported in the present work indicate instead that the strata-bound mineralization and associated structures and facies may represent the shallowest expression (geothermal field) of a far more complex hydrothermal system that extends vertically to the structural level of the granitoids that host the

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main veins of the Linares–La Carolina district.

Las Torrecillas deposit

## General

Las Torrecillas (Fig. 1) is hosted by post-Hercynian, Permian–Triassic basal beds. Other deposits of similar characteristics in the Linares–La Carolina district include those of Navas de Tolosa and Los Palazuelos–Fernandina,<sup>15</sup> but Las Torrecillas—which was worked for barite—was the only economic mineralization. No official production figures have been published. The deposit is located about 2 km southwest from La Carolina, very close to a major fault striking between N45°E and N60°E, which defines the northwest boundary of the so-called Bailén graben.

## Mineralization and geothermal facies

The thickness of the host beds varies from 1 to 5 m and their lateral extent remains largely unknown (most of the deposit is covered by Tertiary sediments). They consist chiefly of pisolitic dolostones, dolomitic breccias and conglomerates distributed irregularly in the rock; either the three facies co-exist or only one occurs. The basal contact with the Palaeozoic rocks is gradual, showing silicified fragments of the metasediments over the first 1.5 m and a green-black jasperoid (silica sinter) in a dolomitic matrix composed of pisolites or rounded aggregates of micrite/microsparite in a microsparitic matrix. The sediments display strong silification with silica filling the voids (Fig. 2(a)). The mineralization consists of galena, barite, quartz and subordinate chalcocopyrite and sphalerite. Supergene alteration led to the formation of smithsonite and cerussite (Fig. 3). The ore appears mostly as pipe-like bodies of barite (mineralized feeder conduits—Fig. 2(b) and (c)) and/or green jasperoids (Fig. 2(d)) and disseminations in the host rock. The pipes, which are of near-circular section (Fig. 2(b) and (c)), do not always show vertical continuity, but they appear to be interconnected by thin, irregular veinlets. The average diameter of the pipes is 10 cm, with a maximum of 20 cm. The contact with the sedimentary host rock may be diffuse or sharp. The pipes are zoned, having an outer envelope (5–10 cm wide) of green jasperoid and an inner core of barite and galena (Fig. 2(b)). The dolomitic/conglomerate beds and the mineralization are sharply truncated by an erosional surface. Above this surface there is no metallic mineralization, but barite may be present locally as cement in sandstones. The erosional surface may represent an Upper Permian–Lower Triassic sedimentary hiatus.<sup>11</sup>

## Fluid inclusion data

Three types of fluid inclusions are found in barite and quartz from Las Torrecillas and Fernandina: NaCl–H<sub>2</sub>O inclusions (type Ia), NaCl–KCl–H<sub>2</sub>O inclusions (type Ib) and NaCl–KCl–CaCl<sub>2</sub>–H<sub>2</sub>O inclusions (type Ic). The data are summarized in Table 1.

Type Ia inclusions comprise two phases—H<sub>2</sub>O liquid and H<sub>2</sub>O vapour—at room temperature, the vapour phase occupying less than 30% of the apparent total volume of the inclusion (vapour-rich inclusions were not observed). The inclusions commonly occur along healed cracks and most are either secondary or pseudo-secondary. The size of the inclusions varies from 10 to 60 µm. The final melting of ice,  $T_m$  (ice), occurs from –2.3°C to –0.5°C in barite and from –1.9°C to –1.0°C in quartz, reflecting total salinities<sup>7</sup> of 3.7–0.8 and 3.1–1.6 wt% equiv. NaCl, respectively. Apparent first melting is observed at temperatures,  $T_e$ , between –6.4°C and –1.0°C (barite) and –9.7°C and –7.7°C (quartz). Temperatures of homogenization to the liquid phase,  $T_h$ , are