An overpressured fluid system associated with the giant sandstone-hosted Jinding Zn-Pb deposit, western Yunnan, China

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Abstract. The Jinding Zn-Pb deposit is hosted in continental clastic rocks in the Mesozoic Cenozoic Lanping-Simao Basin in western Yunnan. The deposit has been compared to SEDEX, MVT, and sandstone-hosted types (SST), all assuming intra-basinal origins for the ore-forming fluids. The driving forces of fluid flow and the pressure system have not been systematically investigated. This paper presents field and fluid-inclusion evidence to show that the Jinding mineralization system was strongly overpressured. The common occurrence of CO₂-rich fluid inclusions and the high fluid pressures suggest a mineralizing system marked by different from most other sediment-hosted base metal deposits including SEDEX, MVT and SST. Numerical modeling of basinal fluid flow indicates that sediment compaction alone in the Lanping-Simao Basin cannot produce any significant overpressure. Tectonic thrusting can significantly increase fluid pressure, but is not enough to cause the high fluid overpressure indicated by fluid inclusions. Input of extra-basinal fluids (e.g. deep-sourced CO₂) into the basin may have contributed to the development of the overpressured mineralizing system.

Keywords. Sandstone-hosted, Zn-Pb deposits, Jinding, sedimentary basin, overpressure, fluid inclusions, numerical modeling

1 Introduction

The Jinding Zn-Pb deposit is located in the Meso-Cenozoic Lanping-Simao Basin in western Yunnan. With a reserve of approximately 200 Mt ore grading 6.1% Zn and 1.3% Pb (i.e. a metal reserve of about 15 Mt), Jinding is one of the largest Zn-Pb deposits in the world. The nature of the mineralization at Jinding has been the subject of a number of scientific debates, focusing on whether the mineralization is syngeneic or epigenetic (see Xue et al. 2005). Most previous studies assumed the mineralizing fluids were intra-basinal (e.g. Kyle and Li 2002), although some connections with deep-seated (mantle) processes have been suspected (Yin et al. 1990; Xue et al. 2003). No studies have been carried out regarding the pressure regime of the fluid system, regardless of syngeneic or epigenetic origin.

In this paper, we propose that the fluid system associated with the Jinding deposit is strongly overpressured, based on field observations and fluid inclusion data. Using numerical modeling of basinal fluid flow, we further propose that the observed high fluid pressures were partly caused by thrusting of lithified rocks over soft sediments, and fluids external to the basin (likely deep-sourced) may have contributed to the development of the overpressures.

2 Regional geology

The Lanping-Simao basin is an intracontinental basin developed on the Changdu-Lanping-Simao micro-plate between the Yangtze Plate to the east and the Tibet-Yunnan Plate to the west, separated by the Lancangjiang and Jinshajiang-Ailaoshan faults (Fig. 1). The basin evolved from an inherited marine and marine-continental basin in Triassic period, through a continental depression basin in Jurassic-Cretaceous period, to a continental pull-apart basin in Cenozoic. The strata of the basin consist of, in ascending order, the Upper Triassic Waiqichun (T3w), Sanhedong (T3s), Wailuba (T3wl) and Maicuqing (T3m) formations, followed by a hiatus and then Middle Jurassic Huakaiziou (J2h) and Upper Jurassic Zhuluba (J3z) formations, Lower Cretaceous Jingxing (K1j), Nanxing (K1n) and Hutoushi (K1h) formations, an Upper Cretaceous hiatus, and Eocene Yunlong (E1y), Guoliang (E2g), Baoxiantshi (E2b) formations and undivided Upper Eocene sediments (E3). Except T3s that is composed of limestones and E1y that in part contains limestone fragments, all other units are composed of siliciclastic rocks with varying proportions of sandstones and shales. Cenozoic tectonic events include regional westward thrusting, local uplifting, and alkaline igneous activities of 68 to 23 Ma (see Xue et al. 2005).

3 Local geology

The Jinding deposit occurs as tabular ore bodies hosted in sandstones of the Jingxing Formation (K1j) and sandstones and carbonate breccias of the Yunlong Formation (E1y) near a NS-trending, high-angle normal fault, the Pijiang fault (Figs. 1 and 2). K1j rocks were thrust over E1y along a flat-lying fault (the F₂ fault, Fig. 2). The strata above F₂ (the Jinding nappe or allochthonous system) are overturned, whereas those below F₂ (autochthonous system) remain in normal position (Fig. 2).
Figure 1: Location and major structural features of the Lanping – Simao Basin in western Yunnan, China, with enlargement of the northern part where the Jinding deposit is located (after Xue et al. 2005).

The deposit consists of a number of ore bodies that are distributed around a doming structure called the Jinding dome. Both the strata above and below $F_3$, and the thrust fault plane itself, are folded by the dome, indicating the doming process postdated thrusting. The fact that Zn-Pb ores occur both above and below the $F_3$ fault suggests that mineralization also postdated the nappe emplacement, possibly related to the doming process. Zn-Pb mineralization similar to that around the Jinding dome, controlled by the same thrusting fault, occurs in the vicinity of the Jinding deposit, e.g., the Tuzishan occurrence, a few kilometers northeast of Jinding.

4 Indicators of high fluid pressures

4.1 Hydrofracturing

A significant portion of the Jinding ore deposit is hosted in carbonate breccias in El1y, which have been interpreted as alluvial fan or fan delta complex related to the Pijiang growth fault (Kyle and Li 2002). The matrix of the breccias is generally red-colored sandstone. Locally, limestone fragments are surrounded by an mm-wide halo characterized by a pale color indicating reduced conditions (Fig. 3A). It is possible that some of the carbonate fragments
may have been brought up by overpressured, reduced hydrothermal fluids mixed with sediments.

Angular fragments of sandstones in the matrix of sandstones in the Hutoushi Formation (K1h) (Fig. 3B), seen at the core of the Jinding dome, may be related to hydrofracturing and infilling of soft sediments. Multidirectional fractures and angular breccias of limestone cemented by calcites and sulfides (pyrite and sphalerite) (Fig. 3C) are common in the Sanhetong Formation (T3s). These features are likely related to high fluid pressures and hydrofracturing.

4.2 CO₂-rich fluid inclusions

A number of fluid inclusion studies have been carried out in the Jinding deposit (see Xue et al. 2005), most re-
porting basal brines with variable salinities (e.g. Kyle and Li 2002). CO₂-rich fluid inclusions were reported in several studies (e.g. Yin et al. 1990; Xue et al. 2002). The presence of CO₂-rich fluid inclusions is unusual for a sediment-hosted Zn-Pb deposit, and potentially indicates high fluid pressures.

Abundant CO₂-rich fluid inclusions were found in calcite closely associated with sphalerite and galena in the Tuzhishan occurrence. The fluid inclusions range from carbonic-only to aqueous-only, with variable carbonic/aqueous ratios. This is interpreted as a result of immiscibility and heterogeneous trapping. The melting temperatures of CO₂ range from -58.5°C to -57.0°C, indicating dominance of CO₂ and presence of other gases such as CH₄. The homogenization temperatures (Tₜ) of carbonic inclusions (to liquid) range from -6.6°C to 21.3°C. The Tₜ values of aqueous inclusions coexisting with the carbonic inclusions range from 110°C to 133°C. Using the Tₜ values of aqueous inclusions to approximate the trapping temperatures and isochors of carbonic inclusions, the fluid pressures are estimated to be 513 to 1364 bars (Fig. 4). The pressure variation may be related to fluctuation between hydrostatic and lithostatic or supralithostatic regimes.

5 Numerical modeling of overpressures

High fluid pressures may have been caused by sediment compaction, loading of the nappe, or input of deep-sourced fluids into the basin. We have examined the effect of sediment compaction and thrusting with numerical modeling using the Basin2 program (Bethke et al. 1993). The inputs of the modeling are lithology, thickness and duration of the strata in the Lanping-Simao Basin from T₃w to E₅, based on data from the Third Geological Team (1990). The results indicate that, considering sediment compaction alone, the maximum fluid overpressure dur-
ing the evolution history of the basin was less than 10 bars. However, if the loading of the nappe is considered, fluid overpressures increase significantly. The thickness of the Jinding nappe as is preserved is about 600 m, and it is unknown how much has been eroded. In the numerical model, we assume that the nappe was 2 km thick and thrust over the whole basin from 55.8 Ma (end of Yunlong Formation) to 50 Ma. The results indicate fluid overpressures up to 100 bars were developed throughout the basin underneath the nappe. However, this overpressure is still not enough to explain the high pressures indicated by fluid inclusions.

6 Discussion and conclusions

High fluid pressures are indicated by fluid inclusions and hydrofracturing in the Jinding deposit and nearby occurrence. The pressure regime, the occurrence of CO$_2$-rich fluid inclusions, together with Pb and noble gas isotopic data (Xue et al. 2005) all point to an origin different from other major types of sediment-hosted Zn-Pb deposits including SEDEX, MVT, and SST. The high fluid pressures can not be explained by sediment compaction, even if the loading of the nappe has been considered. Inputs of fluids from a deep-seated source may be responsible for the strongly overpressured fluid system.

Acknowledgements

This study was supported by NSERC (grants to Chi and Qing) and NSFC (grants to Xue: 40272050, 40427054).

References