

Appendix A

Mineral paragenesis

The Nayongzhi carbonate-hosted Zn-Pb deposit has experienced diagenetic, hydrothermal and oxidized periods (Table 1), of which the hydrothermal period can be further subdivided into sulfide + (quartz + calcite/dolomite) and quartz + calcite/dolomite + (barite) stages (Figs. 7-10). There are two principal types of sulfide ore formed during the sulfide stage: sphalerite-dominated + pyrite + galena + quartz + calcite/dolomite, and sphalerite- and galena-dominated + pyrite + quartz + calcite/dolomite. The spatial distribution of sulfide ore (Fig. 7) shows the formation sequence is from sphalerite-dominated massive (Fig. 8D, I) or dense disseminated ore (Fig. 8A-C, L), and sphalerite- and galena-dominated massive (Fig. 8E-F) or sparse disseminated ore (Fig. 8G), to metasomatic, filled or cemented ore vein (Fig. 8H, J, L-P). Therefore, sulfide minerals have two generations. Sphalerite-I is fine- to medium-grained (0.02-0.6) mm, coexisting with pyrite-I (Figs. 8D, 9A, C, G-H, 10C, E, J) or galena-I (Figs. 8C, 10C), and is enclosed by pyrite-II (Figs. 9B, 10D) or galena-II (Figs. 9O, 10A), as well as is replaced by galena-II (Fig. 9H); Sphalerite-II is medium to coarse granular crystal (0.5-10 mm) that coexists with pyrite-II (Figs. 9B, F, 10D, H-I) or galena-II (Figs. 9D, F, J-K, N-O, 10B, G-H, L-O), and is enclosed by calcite-II (Fig. 9E, 10G-I, N-O) and also replaces pyrite-I (Figs. 9M, 10F). Galena-I is fine- to medium-grained (0.05-0.2 mm), coexisting with pyrite-I or sphalerite-I (Figs. 8C, 10C), and is enclosed by sphalerite-II (Figs. 9I, 10L), pyrite-II (Fig. 10I) or calcite-II (Fig. 10K); Galena-II is medium to coarse granular crystal (0.1-0.6 mm) that coexists with sphalerite-II (Figs. 9D, F, J-K, N-O, 10B, G-H, L-

O) or pyrite-II (Fig. 10H), and is enclosed by calcite-II (Fig. 10G, N), as well as replaces sphalerite-I (Fig. 9H). Pyrite-I coexists with sphalerite-I (Figs. 8D, 9A, C, G-H, 10C, E, J) or pyrite-I (Fig. 10C), and is enclosed by galena-II (Fig. 10A) or sphalerite-II (Fig. 10P), and also is replaced by sphalerite-II (Figs. 9M, 10F); Pyrite-II coexists with sphalerite-II (Figs. 9B, F, 10D, H-I) or galena-II (Fig. 10H), and encloses sphalerite-I (Fig. 9B). In addition, calcite/dolomite-I is rare (Figs. 9A, H-I, 10E, J-K); Calcite/dolomite-II fills or cements sphalerite-I, galena-I or pyrite-I (Figs. 9A-C, G, 10C, E, J-K), and coexists with pyrite-II, sphalerite-II or galena-II (Figs. 9D-E, J-K, N-O, 10B, D, L-M); Calcite/dolomite-III occurs as crumb, veinlet or stockwork that fills into fractures of sulfide ore (Figs. 7B-C, 8G, 9C) or cements carbonate breccia (Fig. 7C, F, H).

Appendix B

Analytical methods

(I) Bulk C and O isotope analyses

Bulk C and O isotope analyses were completed by using a Finnigan MAT-253 mass spectrometer at the State Key Laboratory of Ore Deposit Geochemistry (SKLOGD), Institute of Geochemistry (IG), Chinese Academy Sciences (CAS). Calcite and whole-rock limestone reacted with 100% phosphoric acid (H_3PO_4) to produce CO_2 . The analytical precision calculated from replicate analyses of unknown samples is better than 0.2‰ (2σ) for $\delta^{13}\text{C}$ and 1‰ (2σ) for $\delta^{18}\text{O}$. The C and O isotopic ratios are reported relative to Vienna Pee Dee Belemnite (V-PDB).

(II) Bulk S isotope analysis

Bulk S isotopic composition was analyzed by using a Finnigan MAT-253 mass spectrometer at the SKLOG, IGCAS. Powder of sulfide separate finer than 200 mesh was mixed with CuO powder, and then heated to extract SO₂ gas. The ³⁴S/³²S ratios are expressed by the conventional $\delta^{34}\text{S}$ value in per mil relative to the Vienna Canyon Diablo Troilite (V-CDT) standard. The analytical error is better than 0.1‰ (1 σ) calculated from replicate analyses of the IAEA international standards: IAEA S1 (-0.3‰), IAEA S2 (+22.62‰) and IAEA S3 (-32.49‰). The precision calculated from replicate analyses of unknown samples is better than 0.2‰ (2 σ).