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Reconstruction of the hydrothermal history of the Cu–Ag vein-type mineralisation at Dikulushi, Kundelungu foreland, Katanga, D.R. Congo

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Abstract

The Kundelungu foreland, north of the Lufilian arc in the Democratic Republic of Congo, contains a number of various vein-type and stratiform copper mineralisations. The geodynamic context and metallogenesis of these mineral occurrences remain enigmatic. Currently, the vein-type Cu–Ag ore deposit at Dikulushi is the most significant deposit in the region. Mineralisation at Dikulushi comprises two major styles: 1) a polysulphide assemblage (Zn–Pb–Fe–Cu–As) within brecciated rocks along an anticlinal closure; and 2) a vein-hosted Cu–Ag assemblage. Petrographic and fluid inclusion studies indicate that the early Zn–Pb–Fe–Cu–As assemblage formed from a high-salinity Ca–Na–Cl fluid of modest temperature (135–172 °C). The later, economically more significant vein-related Cu–Ag mineralisation formed from intermediate salinity, lower temperature (46–82 °C) Na–Cl fluids. Weathering of the sulphide minerals resulted in a supergene enrichment with the formation of secondary Cu-minerals.

Keywords: Cu–Ag mineralisation; Democratic Republic of Congo; Kundelungu foreland; Fluid inclusions

1. Introduction

The Kundelungu foreland in the SW of the Democratic Republic of Congo (DRC) represents a triangular-shaped area to the north of the Lufilian arc. The Lufilian arc contains the “Copperbelt”, which extends from the DRC into Zambia. The “Copperbelt” forms one of the richest mineralised areas of the world, with pre- to syn-orogenic stratiform Cu–Co deposits and syn- to post-orogenic Zn–Cu–Ni–Pb–Ge–U deposits.

A number of base-metal occurrences have been identified in the Kundelungu foreland, but their geodynamic context and metallogenesis remain enigmatic. However, in the “Copperbelt” (François, 1974), a distinction can be made between two main types of mineralisation, i.e. stratiform and vein-type deposits.

This study focused on a vein-type deposit in the Kundelungu foreland, aimed to investigate its mineral

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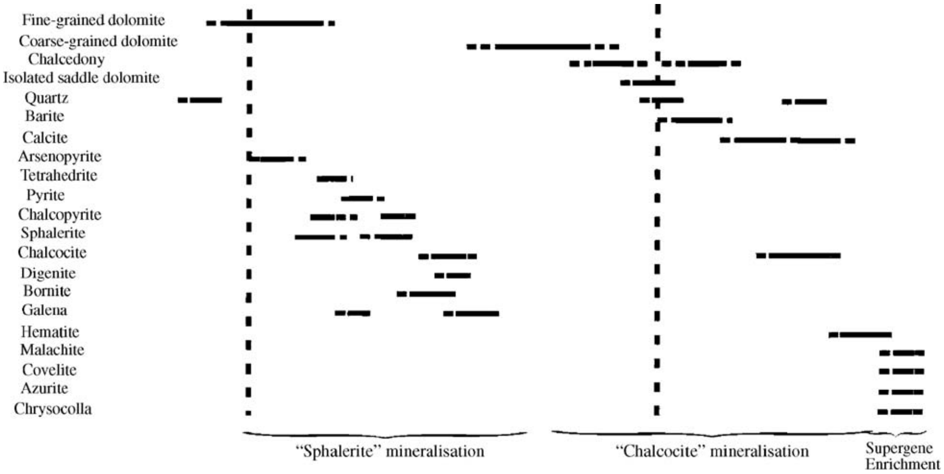

Fig. 1. Paragenesis of the Dikulushi vein-type mineralisation.

paragenesis, and to determine the chemical composition of its mineralising fluids. The Dikulushi orebody (Anvil Mining Congo) offers a unique opportunity to constrain both the geodynamics and metallogenesis of this type of ore deposit. The Dikulushi ore consists dominantly of massive chalcocite with Ag in solid solution. The orebody is hosted in a zone up to 25 m wide, with grades up to 20 wt.% Cu and 600 g/t Ag (Lemmon et al., 2003). In June, 2003, the open pit mine had a reserve of 1,138,000 tons of ore, grading an average 8.11% of copper and 238 g/t of silver.

2. Geology

The Dikulushi Cu–Ag deposit is situated west of Lake Mweru, some 300 km northeast of Lubumbashi, in the northeastern part of the Kundelungu foreland. The foreland is bounded to the west by the Mesoproterozoic (1.6–1.0 Ga) Kibaran mobile belt and to the east by the Palaeoproterozoic (2.5–1.6 Ga) Bangweulu block and extends nearly up to Lake Tanganyika.

The Kundelungu foreland consists largely of tabular metasedimentary rocks of Neoproterozoic age (1.0–0.6 Ga) belonging to the Katanga Supergroup. The Katanga Supergroup can be divided in three groups, i.e. the Roan, the Nguba and the Kundelungu groups, based on the regional occurrence of two diamictites (Cailteux, 2003). The eastern border of the Kundelungu foreland is characterised by the presence of a number of NNW–SSE-trending, open anticlines, e.g. the Kiaka and Lufukwe anticlines (Trefois and Fernandez, 2000). According to Kampunzu and Cailteux (1999), these antiforms formed during the Pan-African orogeny at the end of the Proterozoic and the beginning of the Palaeozoic era. The Dikulushi ore deposit is situated between the Kipako anticline to the south and the Kabango anticline to the north. According to Lepersonne (1974), the host-rocks of the Dikulushi deposit belong to the lower part of the Kundelungu Group, i.e. the Kalule and Kiubo subgroups.

3. Paragenesis of the Dikulushi mineralisation

Samples from the Dikulushi open pit have been described macroscopically and a number of these samples have been selected for a detailed petrographic study. A breccia consisting of large fragments of various lithologies (siliciclastic, carbonate and magmatic rocks) occurs in the quarry and is interpreted to be of tectonic origin. After brecciation of the rocks belonging to the Kalule Subgroup, quartz precipitation was followed by the precipitation of fine-grained ferroan dolomite (Fig. 1). This dolomite is associated with a first stage of sulphide precipitation that consists of Zn–Pb–Fe–Cu–As-bearing minerals (polysulphide stage). Initially, arsenopyrite formed with a first generation of sphalerite and chalcopyrite. This phase is associated with tetrahedrite–tennantite and galena. It is followed by pyrite and a second phase of sphalerite and chalcopyrite deposition. The polysulphide stage terminated with the precipitation of bornite, chalcocite–digenite and galena. This sequence is crosscut by veins with coarse-grained euhedral dolomite crystals. Subsequently, chalcedony crystallised in the breccia, together with saddle dolomite.

The second mineralisation stage starts with the precipitation of quartz, calcite and barite in veins in the eastern part of the open pit. The latter also occur as

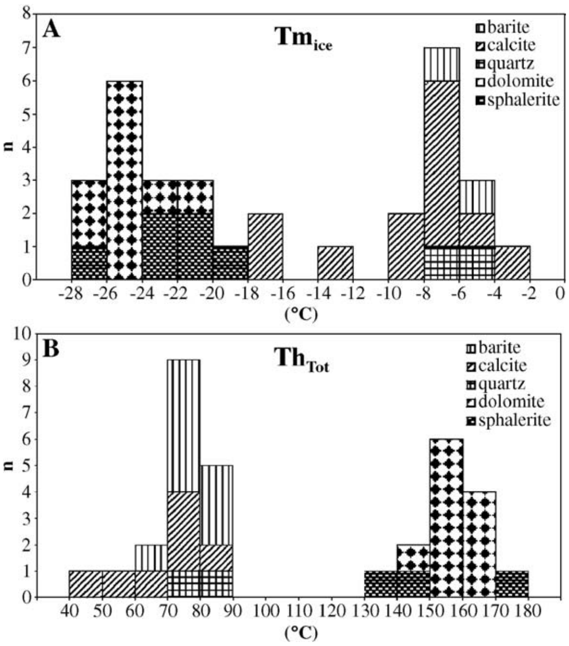

Fig. 2. Microthermometric data; A. Melting temperature of ice; B. Total homogenisation temperature. Sphalerite and dolomite belong to the polysulphide mineralisation stage, whereas barite, calcite and quartz belong to the chalcocite-dominant mineralisation stage.

small veins crosscutting both the fragments and the matrix of the breccia. A second generation of chalcedony is associated with these veins. The main massive chalcocite-dominant stage formed within these quartz–calcite–barite veins and consists dominantly of chalcocite and hematite. This second chalcocite generation can be distinguished from the earlier chalcocite in the polysulphide stage based on its orthorhombic cleavage. Finally, calcite veins with euhedral crystals crosscut the quartz–calcite–barite veins. Both original sulphide mineralisations have been intensely weathered and secondary Cu-minerals, such as malachite, azurite, chrysocolla and covellite, precipitated.

The chalcocite-dominant mineralisation is economically especially interesting due to the presence of significant amounts of Ag in the chalcocite. Electron microprobe analysis shows an average of 2500 ppm Ag in the main chalcocite generation, compared to 900 ppm in chalcocite from the polysulphide mineralisation.

The two mineralisation stages are generally spatially distinct in the Dikulushi mine. The polysulphide ore is associated with the brecciated rocks in an anticlinal structure in the western part of the mine, whereas the main chalcocite mineralisation is associated with NE-trending fracture zones. These zones crosscut and, therefore, postdate the anticlinal structures.

4. Microthermometry

300 μm-thick doubly polished sections from various minerals in the paragenesis “sphalerite, dolomite, quartz, barite and calcite” have been investigated microthermometrically. Fluid inclusion analyses were carried out on a Linkam THMSG 600 stage mounted on an Olympus BX60 microscope. Reproducibility was within 0.2 °C for the melting temperature and ≤ 5 °C for the total homogenisation temperature.

In sphalerite and coarse-grained dolomite, two-phase (L + V) fluid inclusions are present with a gas volume of 5–20% and a size <10 μm. The first melting temperature (T_{fm}) occurs below −40 °C, indicative of the presence of divalent cations (likely $CaCl_2$), in addition to NaCl (H_2O–$CaCl_2$–NaCl composition). Final ice melting temperatures ($T_{m_{ice}}$) are between −26.1 and −18.4 °C (Fig. 2A). Total homogenisation temperatures vary between 135 and 172 °C (Fig. 2B).

In quartz, calcite and barite, two-phase (L + V) and one-phase (L, only in quartz) aqueous inclusions can be observed with gas volumes of about 5% and sizes of <5 μm. First melting temperatures in these inclusions are distinctly higher than in those described above. T_{fm} occurs at ∼−25 °C, indicative of another salt in addition to NaCl (H_2O–NaCl–X composition). Ice melting temperatures vary between −9.1 and −3.9 °C (Fig. 2A). Homogenisation occurs between 46 and 82 °C (Fig. 2B). The petrographic observation of orthorhombic twinning in the chalcocite minerals that are associated with the quartz–barite–calcite veins is typical of chalcocite precipitated at temperatures below 103 °C (Ramdohr, 1964). This is in agreement with low homogenisation temperatures measured by microthermometry.

5. Discussion and conclusions

The Dikulushi mineralisation is characterised by two distinct paragenetic stages, each associated with a different fluid type. The polysulphide precipitated from fluids with a high-salinity H_2O–NaCl–$CaCl_2$ composition and a homogenisation temperature between 135 and 172 °C. This mineralisation occurs partly in a breccia and is related to an anticlinal structure, formed during the Lufilian orogeny (Kampunzu and Cailteux, 1999).

The chalcocite-dominant stage formed during the circulation of a fluid with a lower salinity and with a minimum temperature between 46 and 82 °C. This mineralisation consists dominantly of chalcocite, which occurs in NE-trending fracture zones, which cut the anticlinal structure.

The results of this investigation are in line with further systematic studies of the stratiform mineralisation in the western part of the Lufilian arc, which also indicate the involvement of various hydrothermal systems. They also emphasise the complex interplay between evolving fluid flows and geodynamic processes in the formation of economic base-metal mineralisation in Central Africa.

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