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A Fluid Inclusion Study of Au-Bearing Quartz Vein Systems in the Central and North Deborah Deposits of the Bendigo Gold Field, Central Victoria, Australia

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Abstract

The Central and North Deborah gold deposits, with a production of about 7 tons Au, are located in one of 15 domes in the Bendigo gold field, central Victoria, Australia, an important mesothermal lode gold province. The gold-bearing quartz vein systems are hosted predominantly by reverse faults in Lower Ordovician turbidites, which underwent lower greenschist facies metamorphism. In the Central and North Deborah mines, there are six stages of quartz veins that developed in the following sequence: (1) laminated veins, with a metal association of Au-As-Sb-Pb-Zn-Ni; (2) spurs (Au); (3) massive barren veins (main dilation stage); (4) brecciated veins, with Au-As; (5) quartz-ankerite veinlets; and (6) late, pure quartz or calcite veinlets. Of the three mineralized vein stages (1, 2, and 4), only the first one predated or was coeval with the main deformation event, whereas stages 2 and 4 postdated the main deformation. The vein structures indicate that vein development was controlled by repeated fluctuations of fluid pressure inducing hydraulic fracturing.

Fluid inclusions in vein quartz contain C-O-H fluids of variable compositions. Three main types of fluid inclusions are recognized at room temperature: type I, two-phase, primary $(CH_4)_V + (H_2O)_L$ fluid inclusions; type II, two- or three-phase, primarypseudosecondary $(CO_2)_{V\text{ or }L} + (CH_4)_{V\text{ or }L} + (H_2O)_L$ fluid inclusions, including IIa, CH_4-CO_2-H_2O, and IIb, CO_2-H_2O fluid inclusions; and type III, $(H_2O)_V + (H_2O)_L$ fluid inclusions. Type III fluid inclusions are further divided into three groups: IIIa, primary pseudosecondary, vapor-rich; IIIb, primary-pseudosecondary, liquid-rich; and IIIc, secondary, liquid-rich.

Data from fluid inclusion distribution, microthermometry, and Raman spectroscopy indicate that fluids associated with Au mineralized quartz veins (stages 1, 2, and 4) have moderate salinity ranging from 0 to 12 wt percent NaCl equiv (modeled salinities around 7–8 wt % NaCl equiv). These veins formatted at temperatures from 325° to 375°C, and pressures of 200 to 300 MPa, with emplacement depths of about 8 to 12 km. Fluids associated with barren quartz veins (stages 3, 5, and 6) have a low salinity of about 0 to 3 wt percent NaCl equiv (modeled salinities about 2–3 wt % NaCl equiv) and lower temperatures. There is evidence of fluid immiscibility in all vein stages and mixing between fluids of the same souce, but differing f_{O_2} may also have influenced gold deposition (Cox et al., 1995).

Hydrothermal ore-forming fluids responsible for gold mineralization are in the CH_2-CO_2-H_2O-NaCl system, whereas those of massive barren veins (stage 3) and veinlets (stages 5 and 6) are in the CO_2-H_2O-NaCl and H_2O-NaCl systems, respectively. The carbonic phases of type I and II fluid inclusions range from pure CH_4, through mixed CH_4 and CO_2, to pure CO_2. Gold ore-forming fluids were weakly acidic, with f_{O_2} estimated to have been 10–25 to 10–37 bars, and generally above the CO_2/CH_4 and below the SO_2/H_2S buffer boundaries throughout gold mineralization. The relatively reduced mineralizing fluids are similar to those of other turbidite-hosted lode gold deposits and counterparts in volcanic-plutonic terranes.