IRON OXIDE-COPPER-GOLD-STYLE DEPOSITS IN NORTHERN FINLAND, IS THERE ANY? AN FLUID INCLUSION APPROACH.

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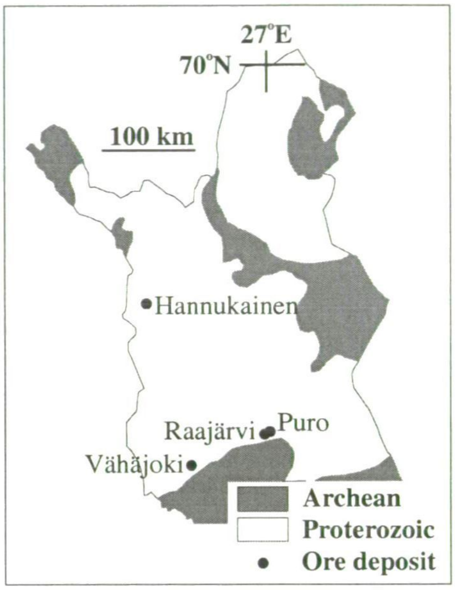
Introduction

Iron Oxide-Copper-Gold deposits (IOCG), concept first introduced by Hitzmann et al., 1992, probably occur in several areas in northern Finland. The most obvious ones, Hannukainen and Vähäjoki, were selected for this study. Both deposits contain variable amounts of Au and Cu in addition to abundant iron oxides. Raajärvi and its satellite Puro iron oxide deposits share numerous features typical for IOCG deposits, although they contain only trace amounts of Co, Cu, and Au. These two deposits were also selected for the study. Here we compare the results of the fluid-inclusion work with the data on known IOCG deposits.

General description of the selected deposits

The Hannukainen deposit consists of four different ore bodies, which are situated in a contact zone of a large, synorogenic monzonite intrusion. The ore was mined 1982-1992, the total production being 4.5 Mt of ore with 43% Fe, 0.88% Cu and 0.95g/t Au. Main ore minerals are magnetite, chalcopyrite, pyrite, and pyrrhotite. Diopside and hornblende comprises the gangue. The ore is hosted by skarnoids within diorite and mafic meta-volcanic lava unit. Other wall rocks are monzonite, meta-quartzite, quartz-albite rock and mica-gneiss. Multistage alteration is characteristic: regional albitisation and scapolisation, local Na-K-Ca-Fe±CO_2 alteration. Metal association in the Hannukainen deposit is Au-Cu-Fe-Te±Ag, Bi, Co, Co, Mo, LREE. The age of the mineralisation is 1.86-1.75 Ga. Possible fluid and metal source for the Hannukainen deposit is the synorogenic monzonite intrusion. (Hiltunen, 1982, Eilu & Niiranen, 2002).



The Vähäjoki deposit consists of 14 different magnetite lenses within N-S trending area of 1.5 km wide and 3.5 km long. Magnetite occurs as breccia matrix, veins and blobs in skarnoids within dolomite. Other wall rocks are mica-schists, mafic tuffs and tuffites, and minor graphite bearing schists. Total inferred amount of ore is 10.5 Mt. Best sections contain up to 1.9 g/t Au, 1.1% Cu and 0.12% Co. Fe content of the ore is generally ca. 30-40%. The main opaques are magnetite, pyrite, chalcopyrite, pyrrhotite, cobaltite and hematite. The gangue minerals are tremolite, actinolite, biotite, chlorite, cummingtonite, carbonates and hornblende. Metal association in Vähäjoki deposit is As-Au-Cu-Co-Fe. Local Ca-Fe±CO_2-alteration (formation of skarnoids and magnetite) and weak Na±Cl-alteration (albitisation and scapolisation) is characteristic. No extensive regional albitisation has been noted in the area. The age of the mineralisation is 2.2-1.8 Ga. (Huhma et al. 1990, Liipo & Laajoki, 1991, Eilu & Niiranen, 2002).

The Raajärvi and Puro magnetite ores occur as lens- and pipe-shaped bodies and are hosted by skarnoids within a sequence of dolomite marbles, meta-quartzites, albite rocks and minor mica-schists. The ores were mined during 1960-1975 with the total production of 5.66 Mt and 0.06 Mt of magnetite ore for Raajärvi and Puro satellite deposits respectively. Average grades were 47% Fe, 0.11% S for Raajärvi and 53% Fe, 0.3% S for Puro. Both deposits contain also small amounts of V and P, and trace amounts of Cu, Co, and Au. Main ore minerals are magnetite and hematite with small amounts of pyrite and chalcopyrite. The gangue minerals are lizardite, tremolite, actinolite, chlorite, talc, biotite and carbonates. Regional alteration is characterized by extensive albitisation and scapolisation. Local intense albitisation and Ca-Mg-Fe±CO_2 (formation of magnetite and skarnoids) is typical in association with ores. The age of the mineralisation is 2.1-1.9 Ga. (Nuutilainen, 1968, Eilu & Niiranen, 2002, Niiranen et al., submitted).

Fluid-inclusion study

Several samples of quartz±carbonate±scapolite±magnetite±hematite±sulphide veins were prepared from each deposit for petrographic and microthermometric analysis mainly from drill core specimens. Six types of fluid inclusions were identified, most of which are less than 30 microns in diameter: (1) H_2O-halite±hematite±solids, (2) H_2O-CO_2±CH_4±halite±solids, (3) H_2O-CH_4-halite±solids, (4) H_2O-CH_4, (5) H_2O, and (6) CO_2±CH_4. Halite, carbonate, nahcolite and hematite were identified by their optical properties. Type 1-3 inclusions represent the earliest fluids observed in the studied samples and are related to Fe-mineralisation stages. Type 4-5 inclusions represent later fluids related to postmineralisation stages. Type 6 inclusions are monophase CO_2 inclusions, which occur together with the type 2 inclusions.

At Puro, Raajärvi and Hannukainen, type 1-3 hypersaline inclusions show very low first ice-melting temperatures between -75 and -40°C. This requires other dissolved salt components besides NaCl (i.e. $CaCl_2$, $MgCl_2$ and $FeCl_2$). When these inclusions are heated, the vapour bubble typically disappears (78 to 325°C) prior to halite dissolution (149 to 486°C), which is commonly the last mineral to homogenise. However, some inclusions exhibit homogenisation behaviour where vapour bubble and halite crystal both disappear approximately at the same temperature (270 to 330°C). The halite-dissolution temperatures for the type 1-3 inclusions indicate salinities between 29 and 58 wt.%.

At Vähäjoki, the earliest fluid is represented by the type 2 H_2O-CO_2 inclusions without a cube of halite. Instead, nahcolite is a common daughter mineral. Dissolution of nahcolite occurs at temperatures 180 to 210°C. Clathrate melting temperatures for the inclusions varies from 4 to 8°C indicating salinities between ca. 3 and 10 eq. wt.% NaCl. Total homogenisation to liquid occurs at temperatures between 232 and 339 °C.

Type 4 H_2O-CH_4 inclusions, which only occur at Puro, show a narrow range of extremely low first-melting temperatures of ice from -80 to -75°C. Melting temperatures of ice in the range -20 to -4°C indicate salinities between ca. 6 and 22 eq. wt.% NaCl. Total homogenisation to liquid takes place at temperatures from 84 to 162°C. Type 5 H_2O inclusions are encountered at every deposit. They have first-melting temperatures of ice between -60 and -30°C, indicating a complex aqueous-salt system. The salinity of the inclusions determined from the ice-melting temperatures (-20 to 0°C) varies from ca. 0 to 22 eq. wt.% NaCl. Temperatures of homogenisation of the inclusions to liquid range from 104 to 226°C. Type 6 CO_2 inclusions contain practically pure CO_2 ($TmCO_2$ = -56.6 to -57.2°C). These inclusions are present in all deposits except Raajärvi.

Conclusions

Fluid-inclusion studies of IOCG deposits typically indicate the presence of coexisting hypersaline and CO_2-rich fluid inclusions (e.g. Pollard, 2000). This seems to be also the case for the studied Finnish deposits. This is especially valid for the Hannukainen, Raajärvi and Puro deposits. Only exception to this is the Vähäjoki deposit, where low to moderate salinity H_2O-rich inclusions coexist with CO_2-rich inclusions. However, locally occurring marialitic scapolite and local weak to moderate albitisation suggest that Na±Cl-rich fluids may have circulated in the area.

The fluid-inclusion data together with alteration styles, petrological and geochemical data clearly shows that the Hannukainen deposit at Kolari belongs to the IOCG class. Evidence from the Vähäjoki deposit suggests, that the sulphides and gold have been precipitated from H_2O-CO_2 fluids, as it is generally the case with the IOCG deposits. Fluids, alteration styles, petrography and geochemistry of the Raajärvi and Puro deposits strongly suggest IOCG type mineralisation, although the deposits are barren in relation to Cu and Au.

Acknowledgements

Outokumpu Oyj Foundation has financed the work of the first author.

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