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Mineral Deposits: From Their Origin to Their Environmental Impacts

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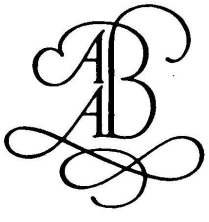

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The nature of the fluids associated with scheelite (± gold) mineralization, Metaggitsi-Pravita Area, Central Chalkidiki Peninsula, N. Greece

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ABSTRACT: Fluid inclusion, and O- and C-isotope, studies have provided evidence on the nature of the fluids associated with Alpine scheelite(±gold) mineralization, Metaggitsi and Pravita Areas, central Chalkidiki peninsula, N. Greece. The most abundant inclusions in quartz (and scheelite in Metaggitsi) contain a low salinity aqueous fluid (about 2 to 6 equivalent weight % NaCl), variable volume percentages of a CO_2 phase, and minor CH_4. Inclusions containing an aqueous brine also occur, especially at Pravita. Scheelite(±gold) was deposited either from heterogeneous (Metaggitsi Area), or homogeneous (Pravita Area), CO_2-rich fluids, at P-T conditions of 1-2.5 kb and 250°-310 °C, and, minimum P-T conditions of 1.9-3.0 kb and 250°-380 °C, respectively. Fluid densities and P-T characteristics, coupled by $\delta^{18}O_{fluid}$ values of 3-6 ‰(SMOW)and $\delta^{13}C$ CO_2-fluid values of -1.2 to +4.3 ‰(PDB) for Metaggitsi, and geologic data, suggest generation of mineralizing fluids by metamorphic devolatilization reactions.

1 INTRODUCTION

Exploration for tungsten in the Chalkidiki peninsula, N. Greece, has been carried out by BPMC (Bauxite Parnass Mining Company, Athens, Greece)during the years 1963-1983 and between 1985-1991 by the Institute of Geology and Mineral Exploration (IGME) of Greece. Mineralization was discovered in 1965 by BPMC in the Metaggitsi area (Fig. 1), when UV lamp prospecting, trenching and gallery excavating delineated a mineralized zone approximately 1X3 km in extent containing some major scheelite-bearing quartz veins and minor stratabound scheelite dissemination. Additionally, stratabound scheelite(±gold) mineralization, associated with a small base metal sulfide body, occurs in the Pravita area (Fig. 1)(Frei 1986; Veranis and Bitzios 1989).

Fluid inclusion, and oxygen and carbon isotope, data were evaluated in an attempt to decipher the nature of mineralizing fluids, and the physicochemical conditions of scheelite(±gold) deposition in central Chalkidiki peninsula.

2 GEOLOGIC SETTING

The scheelite mineralization of the Metaggitsi area occurs in the Vertiskos Formation(VF) that constitutes the western part of the Paleozoic or older Servo-Macedonian Massif(SMM) (Fig. 1)(Kockel et al. 1977). East of the Vertiskos Formation lies the tectonically underlying Kerdilia Formation (Fig. 1). Scheelite mineralization in Metaggitsi, occurs in quartz vein systems, and minor stratabound dissemination, hosted by mafic metavolcanics (Salonikio and Kalogrias Livadi locations) (Fig. 2). Chemical assays from the veins at Salonikio indicate grades up to 0.5 % WO_3. Minor mineralization also occurs in veinlets found in silicified marble of the Svoula Group(SG) which in the Metaggitsi area constitutes the upper part of the Mesozoic Circum Rhodope Belt (CRB)(Fig. 1)(Kaufmann et al. 1976; Schunemann 1986) bordering the SMM to the west (Fig. 1).

The scheelite mineralization in the Pravita area occurs in stratabound silicate-carbonate-sulphide-oxide-facies "iron formation", and conformable

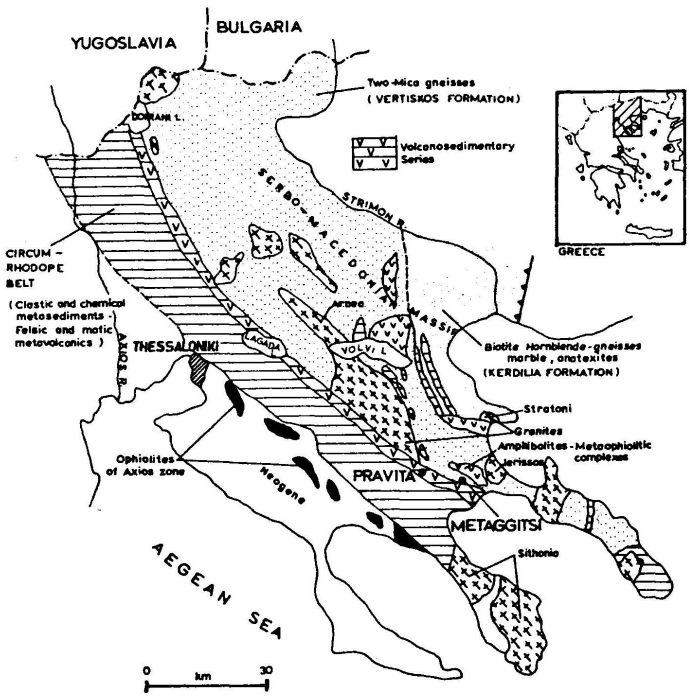

Figure 1 Geotectonic map of the Servo-Macedonian Massif and Circum Rhodope Belt (modified after Kockel et al. 1977).

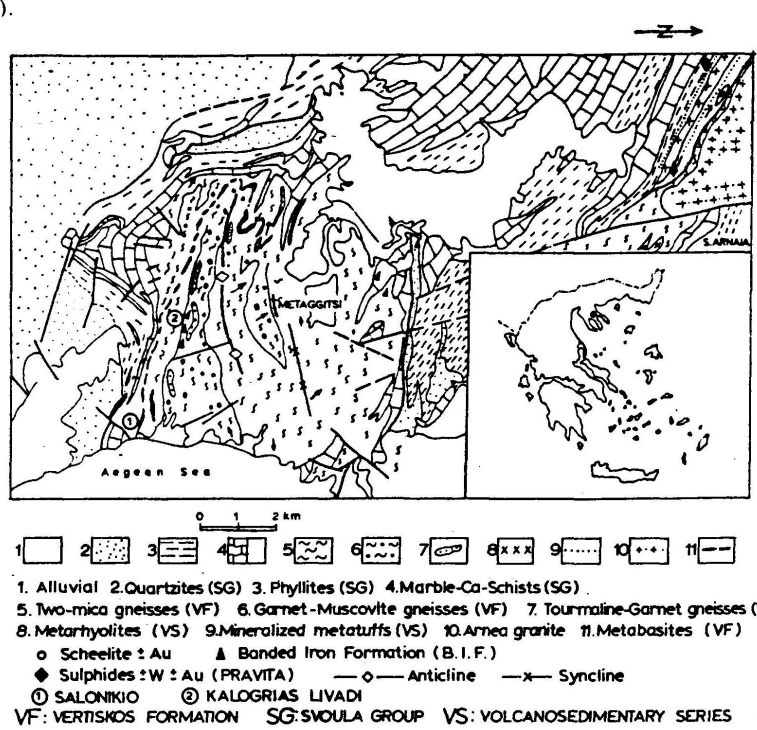

Figure 2 Geological map of the Metaggitsi-Pravita Area, central Chalkidiki peninsula, N. Greece (Veranis and Bitzios 1984, modified after Kockel et al. 1977).

gold-bearing quartz lenses or veins. Mineralization is hosted by meta-volcanosedimentary strata consisting of felsic to intermediate metatuffites mixed with meta-clastic and meta-chemical precipitates, belonging to the Permo-Triassic (240 Ma, Frei 1986) "Volcanosedimentary Series"(VS) which is the stratigraphically lower part of CRB in the area. Chemical assays from the mineralization indicate grades up to 0.2 % WO_3. The scheelite-bearing "iron formation" is laterally associated with stratabound Fe-Zn-Pb-Cu sulfide mineralization that has been explored extensively by BPMC. The estimated ore reserves of the Pravita deposit are about 5 Mt with an average grade of 5 % Pb+Zn and 2 g/t Au.

The rocks of the VF have suffered the Alpidic (Late Jurassic to Early Cretaceous) deformation and regional metamorphic event reaching amphibolite facies conditions (P:5-8 kb, T:600-700°C) (Kockel et al. 1977; Dixon and Dimitriadis 1984; Sakellariou 1988). This main tectonometamorphic event was followed by retrogression to the greenschist facies (Upper P:4-5 kb., T:500-550 °C, and Middle-Lower P:2-3 kb, T:350-450 °C)(Sakellariou 1988) and Tertiary calc-alkaline magmatism (Fig. 1). The older (212 Ma, Frei 1992) Arnea granitic intrusion (Figs. 1 and 2) is thought to have been tectonically emplaced (Kockel et al. 1977). The rocks of the VS in the Pravita area have been metamorphosed to the greenschist-amphibolite facies transition and retrograded to lower facies conditions (Frei 1986). Metamorphic grade in the SG reached upper greenschist facies conditions in the range of 420° to 520 °C and 1-5 kb (Kockel et al. 1977).

3 FLUID INCLUSIONS

3.1 Metaggitsi area

Three types of primary fluid inclusions coexist in quartz and scheelite (Kilias and Konnerup-Madsen 1994): Type 1, the most abundant type, consists of mixed H_2O-CO_2 inclusions with highly variable (20-90 volume %) CO_2 content, low salinities (3.9±2 equivalent weight % NaCl) and bulk densities ranging from 0.79 to 0.99 g/cc; Type 1 inclusions also contain traces (<2 mole %) of CH_4.. Type 2 is nearly 100 volume % CO_2 with traces of CH_4, and densities between 0.75 and 0.88 g/cc. Type 3 inclusions, the least abundant type, is an aqueous liquid of low salinity (0.5 to 8.5 equivalent weight % NaCl) with 10-30 volume % H_2O gas containing also small amounts of CO_2 (<2 mole %); densities range from 0.72 to 0.99 g/cc. Type 1 inclusions homogenize between 250° and 310° producing different phases, and appear to have trapped immiscible fluids along the solvus in the CO_2-H_2O-CH_4-NaCl system at the above temperature range and pressures of 1 to 2.5 kb. The wide range of coexisting fluid inclusion compositions is interpreted as a result of fluid immiscibility during entrapment. It is indicated that scheelite was deposited from a fluid undergoing CO_2(+CH_4) and H_2O(+NaCl) phase separation at temperatures of 280±30 °C and fluctuating pressures of 1 to 2.5 kb. Oxygen fugacities during mineralization varied from 10^{-35} to 10^{-31} bars and were above the Ni-NiO buffer values. These data combined with $\ddot{a}O_{fluid}$ values of 3 to 6 per mil (SMOW) and $\ddot{a}^{13}C$ CO_2-fluid values of -1.2 to +4.3 per mil (PDB)(Kilias and Konnerup Madsen 1994), and geologic data, suggest generation of mineralizing fluids by late-metamorphic devolatilization reactions.

3.2 Pravita area

Two main types of fluid inclusions are found in quartz cogenetic with scheelite, and gold: Type 1, consists of a low-salinity (3.2±1.6 equivalent weight % NaCl) aqueous fluid, and a CO_2 phase occupying 20 to 60 % (usually less than 40 %) of the inclusion volume, with minor CH_4. Bulk densities range from 0.77 to 0.97 g/cc. Total homogenization of type 1 inclusions occurs in the liquid phase at temperatures between 245° and 377 °C, and most values lying between 280° and 300 °C. Type 2, a less common type, consist of an aqueous liquid of low salinity (1.8 to 9.5 equivalent weight % NaCl) with 10-50 volume % H_2O gas, and no evidence of CO_2; densities range from 0.51 to 0.90 g/cc. Type 2 inclusions homogenize in the liquid phase at temperatures ranging from 150° to 370 °C, but mostly between 180° and 280 °C. There is a moderate positive correlation between salinity and homogenization temperatures of type 2 inclusions. The mutual relationships of the two types of inclusions are not clear. Type 1 CO_2-rich fluid is interpreted as representative of the scheelite-associated fluids, and type 2 aqueous fluid as an influx in the system of progressively cooling and diluting fluid. No evidence for phase

separation was shown by fluid inclusion data. It is concluded that scheelite was deposited from a homogeneous CO_2-rich fluid at minimum P-T conditions of 1.9 to 3.0 kb, and 250° to 380 °C, respectively. Mineralizing fluid densities and minimum trapping P-T conditions suggest generation of mineralizing fluids by metamorphic devolatilization reactions.

4 CONCLUSIONS

Fluid inclusion data, coupled by isotopic data, are consistent with mineralizing fluids of metamorphic nature associated with scheelite(±gold) mineralization in central Chalkidiki peninsula, northern Greece

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