

Developments in Fluorite (U-Th)/He Thermochronology

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We report the results of (U-Th)/He dating trials on fluorite precipitated as a secondary hydrothermal mineral within Miocene tuff (12.8 Ma) at Yucca Mountain, Nevada.

Three varieties of fluorite crystals were separated from vein specimens containing 1–3 mm thick layers of fluorite. Early fluorite adjacent to the host tuff is translucent, changing gradually to colourless and finally purple transparent varieties. Several mg of 100–300 µm, inclusion-free crystals were analysed from the three varieties. The cloudy crystal layers adjacent to the tuff have (U-Th)/He ages of 9.8 ± 0.3 Ma. The clear fluorite is slightly older (11.9–15.6 Ma), whereas the purple grains consistently yield anomalously high He contents resulting in geologically unreasonable ages.

Fluorite	U (ppm)	Th (ppm)	Age (Ma)	$\pm 2\sigma$
purple	6.5	1.4	212, 41	1.1
clear	10.6	0.22	11.9, 13.8, 15.6	0.4
cloudy	12.1	0.64	9.7, 9.9	0.3

Alpha-emission correction after Farley et al., (1996). Mean U and Th concentrations given.

He diffusion experiments were carried out at Caltech on a handpicked sample of 200–350 µm colourless fluorite. The helium closure temperature for this fluorite is 60 ± 5 °C, assuming a 10 °C/Ma cooling rate. The (U-Th)/He age of 9.8 Ma for the cloudy variety of fluorite indicates that it was precipitated within 2 myr of tuff deposition. Subsequently, only meteoric fluids cooler than 35 °C entered the site (Wilson et al., submitted). We suggest that the purple variety was in contact with late-stage U-rich fluids that implanted He in the fluorite margins and caused discoloration of the crystals.

Material properties and microstructure from Crystallisation of (PGE)AsS from sulphide melt

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Amongst Platinum-Group Minerals (PGM) there are sulpharsenides of all Platinum-Group Elements (PGE) except Pd: platarsite, PtAsS; irarsite, IrAsS; hollingworthite, RhAsS; osarsite, OsAsS; ruarsite, RuAsS. The 'ideal' composition corresponds to the end members, 'PGE'AsS, but the real ones present the intermediate members of solids solutions regarding to PGE and As-S.

PGE sulpharsenides are found in basic/ultrabasic complexes with chromite or cooper-nickel sulphide mineralization, i.e. ophiolites, layered intrusions etc. Essentially all PGE sulpharsenides occur in metamorphosed rocks and ores. But the conditions of their formation remain unknown. The (PGE)AsS bearing associations could contain other PGM and basic sulphides. Very often people find the crystal of 'PGE'AsS in close association with Ni-rich sulphides, as millerite, and heazlewoodite. For example, Shetland ophiolites contain: 1) IrAsS + RuS₂+Os, 2) IrAsS + RuS₂, and 3) IrAsS + RuS₂ + Ru-bearing pentlandite (Ni>Fe). Noril'sk Cu-Ni sulphide ores present other associations: RhAsS + CuFeS₂ + (Fe,Ni)₆S₇ (+Ni₈S₈), or RhAsS + CuFeS₂ + NiS + (Ni,Fe)₉S₈. It seems to be interesting to check the possibility of 'PGE' sulpharsenide formation directly from the sulphide melt containing Cu, Fe, Ni, and PGE.

Based on the composition of natural associations the preliminary experimental study was carried out in evacuated quartz ampoules. 100 mG charges of elements corresponded to the mixtures: 1) 'PGE'AsS + Po_m+Pn_{Ni}+Cp, 2) 'PGE'AsS + Cp + Bor + Pn_{Ni} + Mil, and 3) 'PGE'AsS + Cp + Tr +Pn_{Fe}, in different proportions. Charges were preheated in the argon flow (400 °C), then gradually heated to 1080 °C, annealed at this temperature during 76 hours, and slow cooled with the furnace. Polished sections from samples synthesized were studied with optical microscope, microprobe, and electron microscope (SEM + energy disperse analysis).

In spite of the relatively low proportion of 'PGE'AsS in the charges (~10 mol.%) some 'PGE' sulpharsenides were crystallized, i.e. RhAsS in association with Cp and Pn_{Ni}, and with Cub and Po_m, and IrAsS with Cub. The most of other PGM are dispersed in basic sulphides, but the additional study is necessary to determine the form of their occurrence: isomorphous elements in sulphide structures or tiny inclusions in sulphide matrix.

Using the composition of associated sulphides the conditions of 'PGE'AsS formation (i.e.) are discussed relative to the stability of basic sulphides. For both, RhAsS and IrAsS, $I_{g,IS2}$ is less than 10 at $T < 600$ °C that is in agreement with experimental data of one of the author on the stability field of some other PGM.