Formation of Platinum-Group Minerals from an evolving sulfide liquid at Sudbury, Canada

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Chalcophile and platinum-group elements (PGE) are collected by a magmatic sulfide liquid and form PGE (± Ni-Cu) deposits. Early-crystallizing monosulfide solid solution (MSS) concentrates Os, Ir, Ru and Rh (IPGE) and the residual liquid concentrates Cu, Pt, Pd, Ag, As, Bi, Te, and Sn. It is important to determine the host phases of the PGE, which are sulfide minerals and/or platinum-group minerals (PGM), in order to understand the petrogenesis of the deposit and to improve PGE extraction. Previous work shows that PGM form by:
1) exsolution from base metal sulfides, 2) crystallization from the residual Cu-rich liquid and/or a late-stage immiscible melt and 3) remobilization during metamorphism or by hydrothermal fluids.

We have investigated the origin of PGM from Sudbury Ni-Cu-PGE deposits by combining a PGM study with whole-rock data and laser ablation-ICP-MS analysis of the sulfides. We found that a large proportion of the PGE are hosted in As-, Bi-, Te- and Sn-rich PGM, which formed over a wide range of temperatures during the evolution of the sulfide deposit. The amount of As in the initial sulfide melt, which varied according to the As content of the assimilated country rocks, was critical in determining whether As-PGM (IrAsS, RhAsS ± $PtAs_2$) crystallized early (1200-900°C) from the sulfide liquid togther with MSS. An As-rich sulfide melt crystallizes sulfarsenides so that the co-existing MSS is depleted in Ir and Rh whereas an As-poor sulfide melt does not crystallize sulfarsenides and the IPGE remain in MSS. The amount of Bi, Te and Sn increases during sulfide fractionation so that the following Pt-Pd-minerals crystallized from the residual liquid. Solitary grains of Pd_2Sn and PtSn crystallized early (1300-800°C) from the Cu-rich sulfide liquid whereas an un-named Pt(Sn,Bi)Te phase together with numerous Pt-Pd-Bi-Te-Ag minerals crystallized as composite grains from micro-droplets of an immiscible late-stage melt (1000-600°C). The small amount of Pt, Pd, Bi and Te, which partitioned into MSS, later exsolved (< 600°C) as laths of $(PtPd)(BiTe)^2$ and PdBiTe and were remobilized during greenschist metamorphism.

Probable Mars atmospheric changes by the proposed terraforming process with silicon utilizing organisms

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The silicon utilizing organisms particularly diatoms are well known to tolerate different stress as evidenced in studies on past mass extinctions on Earth and also in artificial laboratory conditions. Thus these organisms may be utilized in terraforming suitable solar system objects and such proposals have already been given for Mars and the Moon [1] and further proposals are likely to be placed for Venus, Callisto, Europa, Ganymede, Enceladus and Titan in near future. In Mars, after initiation of such a terraforming process, by application of these organisms on the surface among basalts, clays, ice etc, a target oxygen level of 150 m bar in the atmosphere may reach within 500 years, with expected significant increase in nitrogen to 300 m bar and decline of carbon dioxide to as low as 10 m bar. As most solar radiations usually reach the surface of Mars, these organisms are expected to grow even at a low temperature in a surface pressure of 6-7 m bar. High carbon dioxide levels will affect the growth, fluorescence, pigmentation and carbonic anhydrase activity of these organisms with involvement of chlorophyll a, chlorophyll c and fucoxanthin. Presence of diverse genes is essential for proper terraforming process with organisms, mainly for efficient management of C and N. Thus a set of such organisms may be chosen for initial terraforming process according to gene library matching. Iron present on Mars surface has also a pivotal role in controlling carbon uptake by these organisms and regulating atmospheric partial pressure of carbon dioxide. Finally atmospheric erosion and escape processes particularly solar wind ion or proton and magnetospheric-plasma-driven sweeping may alter the expected values to some extent.

[1] Das (2010), *Lunar settlements*, Ed Benaroya, CRC press, 679-692.