

The role of Group V and VI Elements in metamorphic polymetallic melts: Parallels with magmatic sulfide systems

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Research into polymetallic melt formation during high temperature metamorphism of ore deposits has revealed that four different melt types can develop: (1) sulfide melts dominated by Pb, Fe, Cu, Zn and S; (2) sulfosalt melts involving Au, Ag, Pb, Tl, Hg, Cu and Fe complexed with Sb-S, As-S and/or Bi-S; (3) intermetallic melts developed between alloys of Au, Ag, Hg, As, Sb and Bi; and (4) telluride melts involving Au, Ag and Pb complexed with Te. The sulfide melts are comparatively unimportant for mobilizing gold, as they crystallize at high temperatures and appear to be incapable of dissolving >100 ppm Au. In contrast, As-, Sb- and/or Bi-bearing sulfosalt or intermetallic melts, can contain >50% gold, and persist to $T < 300^{\circ}\text{C}$. In some deposits, Au-rich telluride melt is associated with accumulations of sulfosalt melt, and some compositions are molten below 400°C . A concept-testing experiment, run at 850°C and 5 kbar and involving a Au, As and Bi-rich starting composition, produced coexisting Fe-Cu sulfide and Au-As-Bi-bearing sulfosalt melts. This result indicates that sulfide-sulfosalt immiscibility can develop during sulfide melt fractionation provided that high enough concentrations of the V-VI elements are reached, and also that Au partitions strongly into the sulfosalt melt. These observations can be applied to understanding controls on PGE distribution in magmatic sulfide systems since Au, Pt and Pd behave similarly in this setting. Because V-VI elements have low melting points, they will become concentrated in sulfide magma by crystallisation of MSS and ISS, although they will remain dissolved until saturation is reached. The correlation between the V-VI elements and PGE in magmatic sulfide deposits suggests that PGE may remain bound to these elements, in particular As, Bi, Sb and Te, within the sulfide melt, thereby allowing the PGE to also become concentrated during crystal fractionation. Since most V-VI element-bearing minerals found in these deposits, including many PGMs, have melting points below the crystallisation temperatures of MSS and ISS, it may be inevitable that PGE-rich sulfosalt melts will eventually exsolve. If a connected melt network remains, density differences may drive gravitational segregation of sulfosalt melt, allowing formation of PGE-enriched zones.

Metasomatic processes recorded in fibrous diamonds

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Fibrous diamonds containing both fluid and single-phase silicate inclusions provide a unique insight into metasomatic processes operating during diamond growth. Fluid-rich diamonds from the Panda kimberlite (Northwest Territories, Canada) contain peridotite-suite silicate inclusions and H₂O-carbonate fluid inclusions. The fluid is highly enriched in trace elements and has a steep negative REE pattern. The Sr isotope composition of fluids from different diamonds is highly variable (0.7049 to 0.7084). This range of values extends to more radiogenic compositions than typical convecting mantle and indicates a role for a fluid from a long-term enriched source, whereas fibrous diamonds are usually thought to originate from the MORB-source mantle.

Peridotitic clinopyroxene and garnet inclusions have high Cr contents (>7 wt% and >1.8 wt% Cr₂O₃ respectively) and olivine has high Ni (3550 ppm), indicating that the silicates have undergone depletion by melt extraction; the high Cr and Ni contents are not consistent with precipitation directly from the carbonate fluid. Therefore the silicate inclusions pre-existed the influx of H₂O-carbonate. However, the silicate inclusions have enriched trace element signatures (similar to those seen in inclusions in octahedral diamonds), recording metasomatism by the co-existing fluid. Texturally, the silicate inclusions are extremely small (<5 to 15 μm) and highly abundant. The diamond samples are also zoned with respect to silicate inclusions e.g. garnet present towards the core, and clinopyroxene towards the rim. This suggests that a process of fractional re-crystallisation may have been operating during metasomatism.