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Magnetite solubility and trace element partitioning in carbonate-sulfate-phosphate-silicate melts: implications for recent models of iron oxide-apatite ore formation

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Molten salts have recently been invoked as agents of iron transport in iron oxide-apatite (IOA) systems. This emerging model is motivated by the widespread occurrence of melt inclusions containing carbonate, sulfate, phosphate and/or silicate phases together with magnetite and hematite[1,2,3]. However, the validity of this model remains debated and there are few quantitative experimental constraints on mineral solubility or trace element partitioning involving molten salts.

To address these knowledge gaps, experiments were conducted using a piston-cylinder apparatus at 1 GPa, 1350 ˚C and buffered by a magnetite-hematite assemblage to investigate iron oxide solubility and mineral-melt trace element partitioning. Synthetic starting materials were prepared from mixtures of $CaCO_3$-$CaSO_4$-$Ca_5(OH)(PO_4)_3$-$CaSiO_3$-SiO_2 and Fe_3O_4-Fe_2O_3, with the iron oxide mixture added to the bottom of the sample capsule in a gravitationally stable arrangement. All starting materials were sealed in platinum capsules. Run-products consist of quenched melt coexisting with magnetite and hematite.

Results indicate that iron oxide solubilities are low in both carbonate-sulfate (0.9~2.4 wt.% Fe) and carbonate-phosphate (0.5~2.4 wt.% Fe) melts, with the iron content consistently decreasing with increasing sulfate contents. In contrast, the incorporation of silicate into carbonate melts markedly enhances magnetite dissolution, with iron concentrations increasing to ~10 wt.% with 40 wt.% silicate addition. Our data therefore suggest that silicate-rich molten salts can transport significant amounts of iron, consistent with the composition of some melt inclusions reported in IOA deposits[1,2,3].

Although magnetite-melt element partitioning is largely governed by lattice strain effects, certain elements are notably sensitive to melt composition. Comparison with [4] indicates several elements exhibit distinct partitioning behaviour relative to magnetite-silicate systems and are promising as discriminators to test for the involvement of molten salts in the origin of IOA deposits.

[1] Bain, W.M., et al. (2020) *Nat. Geo.*, 13, 751–757.

[2] Bain, W.M., et al. (2021) *Geology*, 49, 1044–1048.

[3] Xu et al. (2024) *Geology*, 52, 417-422.

[4] Sievwright et al. (2020) Contrib. Mineral. Petrol., 175, 40.