

Magnetite-apatite deposits at El Laco, Chile, formed by eruption of Fe-rich immiscible melt

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Magnetite-apatite deposits are important sources of iron and other strategically important metals. A prominent example is the 'magnetite lava flows' at El Laco, a ~3 Myr old andesitic arc volcano in the Central Volcanic Zone, Northern Chile. The deposits are well known for their striking structures and textures that suggest effusive to mildly explosive extrusion of a highly Fe-enriched lava on the flanks of the volcano. The genetic processes leading to their formation remain hotly debated. We propose that an Fe-rich melt separated from silicate magma by spontaneous liquid immiscibility in a subvolcanic reservoir and extruded along volcano collapse faults. We use the thermodynamic model alphaMELTS to show that Fe-Si liquid immiscibility evident in melt inclusions at El Laco aligns with recent experimental results documenting the geochemistry and micro-textural characteristics of such systems in great detail. Using a numerical model of rock deformation, we demonstrate that volcano collapse can form faults extending from the base of a mildly deflating reservoir towards the edifice flanks. If squeezed into these fractured pathways following a collapse event, vapour bubble exsolution may drive the low-viscosity ore liquid towards extrusion despite its high density. Our results present a process-based, internally consistent genetic model for intrusive to extrusive magnetite-apatite deposits, which may apply to other related deposits worldwide. Our work highlights the role of liquid immiscibility in the formation of magmatic ore deposits and demonstrates the effectiveness of combining geological field work and geochemical analyses with thermodynamic and mechanical modelling.