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Crystal Mush Dikes as Conduits for Porphyry Copper Deposit-Forming Fluids

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Porphyry deposit formation is associated with large, long-lived magmatic systems (e.g., Cline and Bodnar, 1991; Tapster et al., 2016) where mineralising fluids are mainly derived from melt or mush reservoirs at depths of ca. 5 to 15 km (Richards, 2005; Sillitoe, 2010). How these fluids are transported upwards and focused into narrow, relatively shallow (ca. 2-5 km deep) zones of economic mineralisation is poorly understood (Dilles, 1987; Sillitoe, 2010). Although field and laboratory-based observations can offer useful insights (Pistone et al., 2020), our ability to understand whole systems is limited as in nearly all cases only small fragments of their 3D architecture are exposed (Seedorff et al., 2008).

An exception to this is the archetypal Yerington porphyry system, Nevada, which has been tilted to reveal a unique vertical section from paleosurface to a depth of ca. 8 km, through at least 4 porphyry deposits (Dilles, 1987). This provides a rare opportunity to study temporal relationships in the deeper parts of the magmatic system, important in porphyry formation, and the magmatic-hydrothermal transition (Carter et al., 2021). We show evidence for hypogene fluid exsolution and mineralisation within aplite dikes, including the presence of unidirectional solidification textures (Kirwin, 2005) and miarolitic cavities (e.g., Candela, 1997), which have not been discussed previously in the context of mineralisation (e.g., Dilles, 1987). From our detailed scanning electron microscopy and cathodoluminescence imaging, and electron microprobe and total ion beam analyses to determine trace elements in quartz, we show that the groundmass of these aplite dikes contains a wormy, interconnected generation of quartz that directly feeds mineralised miarolitic cavities. We interpret this wormy texture as marking paleopathways between earlier crystallised magmatic minerals through which mineralising fluids flowed, within what we referred to as "crystal mush dikes" (Carter et al., 2021). These acted as conduits for the upward flow of porphyry deposit-forming fluids from more evolved/water-rich internal regions of the underlying Luhr Hill granite. The textures we describe provide the first substantive petrographic evidence for the transport of fluids through crystal mush dikes, which should be considered in any new model for the formation of porphyry- and similar-type deposits and may be important in the degassing of volcanic systems.

References

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