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Cooling rates and crystallization dynamics of shallow level pegmatite-aplite dikes, San Diego County, California

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ABSTRACT

Pegmatites of the Pala and Mesa Grande Pegmatite Districts, San Diego County, California are typically thin, sheet-like composite pegmatite-aplite dikes. Aplitic portions of many dikes display pronounced mineralogical layering referred to as “line rock,” characterized by fine-grained, garnet-rich bands alternating with albite- and quartz-rich bands. Thermal modeling was performed for four dikes in San Diego County including the 1 m thick Himalaya dike, the 2 m thick Mission dike, the 8 m thick George Ashley dike, and the 25 m thick Stewart dike. Calculations were based on conductive cooling equations accounting for latent heat of crystallization, a melt emplacement temperature of 650 °C into 150 °C fractured, gabbroic country rock at a depth of 5 km, and an estimated 3 wt% initial H_2O content in the melt. Cooling to <550 °C at the center of each dike occurred in ~9 years for the Stewart dike, ~340 days for the George Ashley dike, ~22 days for the Mission dike, and ~5 days for the Himalaya dike. Based on these calculations, growth rates for large pegmatitic minerals such as the 10 cm long Himalaya hanging wall tourmaline crystals may have been on the order of 10^{-5} cm/s. Crystal size distribution (CSD) studies of garnet from layered aplites suggest growth rates of about 10^{-6} cm/s. These results indicate that the dikes cooled and crystallized rapidly, with variable nucleation rates but high overall crystal-growth rates. Initial high nucleation rates coincident with emplacement and strong undercooling can account for the millimeter-size aplite grains. Lower nucleation rates coupled with high growth rates can explain the decimeter-size minerals in the hanging walls, cores, and miarolitic cavities of the pegmatites. The presence of tourmaline and/or lepidolite throughout these dikes suggests that although the melts were initially H_2O-undersaturated, high melt concentrations of incompatible (or fluxing) components such as B, F, and Li ($\pm H_2O$), aided in the development of large pegmatitic crystals that grew rapidly in the short times suggested by the conductive cooling models.