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Mineralogy and petrology of a mullite-bearing pseudotachylyte: Constraints on the temperature of coseismic frictional fusion

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ABSTRACT

Pseudotachylyte from the Homestake Shear Zone, central Colorado, contains acicular, 5–10 × 100 μm mullite crystals, 1–5 μm octahedra of magnetite, and variably melted clasts of quartz in an originally molten matrix. Several lines of evidence support the interpretation that the pseudotachylyte represents the quenched equivalent of a molten phase derived from preferential melting of primarily biotite, microcline and plagioclase, and to a lesser extent quartz, from the gneissic protolith: the morphology of the mullite crystals, which nucleate on and radiate from relic sillimanite clasts; abundant magnetite octahedra scattered throughout the pseudotachylyte matrix and intergrown with mullite, forming plumose quench structures; partially melted relict quartz clasts; the composition of the isotropic pseudotachylyte matrix; and chemical gradients surrounding quartz clasts in pseudotachylyte matrix. Although the sample had been nearly completely molten (except for 10–100 μm relict quartz clasts), HRTEM imaging of the pseudotachylyte matrix reveals that it has devitrified. The slightly birefringent matrix consists of intergrowths of submicrometer flakes of white mica. Microprobe analysis shows that the mullite is highly enriched in Fe (8–10 wt% Fe_2O_3) compared with other natural mullites. HRTEM and SEM images reveal the presence of oriented platelets of an Fe-oxide phase, dominantly hematite that appears to have exsolved from the mullite during cooling, indicating that the limit of solid solution of Fe^{3+} in mullite decreases with temperature. The estimated melt temperature ranges from 1150 to 1200 °C; this interpretation is based on the Fe_2O_3 content of mullite, the liquidus temperature for melts corresponding to the matrix compositions, and liquidus temperatures for gneissic wall rocks, which underwent complete to very high degrees of melting.