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Hydrothermal pipes in eight granitic plutons in California: Evidence for evolution and migration of a magmatic volatile phase in epizonal silicic intrusions

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Hydrothermal pipes occurring in granitic intrusions provide significant insights into the genesis and migration of a magmatic volatile phase which evolves at late stages of crystallization of silicic plutons. At this point, we have located more than 600 pipes in plutons in California. We have carried out our most detailed investigations on the Tuolumne Intrusive Suite in the Sierra Nevada Batholith and have located more than 400 pipes within the three most silicic members of this nested intrusive suite. Although our mapping is not complete, the preliminary distribution pattern of pipes is as follows: Half Dome Granodiorite (366 pipes), Cathedral Peak Granodiorite (44 pipes) and Johnson Granite Porphyry (6 pipes). The majority of pipes ($\sim$70%) occur either directly centered on, or within one meter of a pegmatite or pegmatite-aplite dike.

Most pipes display concentric zoning with an outer rind enriched in quartz, potassium feldspar and muscovite, and a core composed primarily of internally nucleated albite and epidote, with intercrystalline spaces partially filled with fine-grained chlorite displaying a radial to spherulitic habit. Evidence that a fluid phase has streamed through the pipes is suggested by the presence in the pipe core of a finely-milled microbreccia of epidote, quartz and plagioclase enclosed in a matrix of spherulitic chlorite. The abundance of hydrothermal pipes in the shallowly emplaced Tuolumne Intrusive Suite suggests to us that such conduits are a common feature of epizonal silicic plutons, and have originated in large part by upward migration of a magmatic volatile phase released from the associated pegmatites. This hydrothermal fluid has subsequently streamed upward through a partially solidified host, leaving a charac-

teristic pipe-shaped track. This inference has been partially confirmed by the close association of pipes and pegmatite dikes in the petrologically similar and shallowly-emplaced Paradise-Whitney Intrusive Suite, located 120 km south-east of the better known Tuolumne Suite.

The zonal mineralogy frequently leads to differential weathering of the pipes producing a recessed core and a protruding rind. The resultant similarity of surface expression to potholes, weathering pans and miarolitic cavities, may explain why hydrothermal pipes in granitic intrusions have apparently been overlooked by previous workers.