FUMAROLES ON MARS: LESSONS LEARNED FROM THE VALLEY OF TEN THOUSAND SMOKES, ALASKA.

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INTRODUCTION: During June 6-8, 1912, a new vent (Novarupta) near Katmai in the Aleutian Range of Alaska released the largest volcanic eruption of the century and the largest rhyolitic eruption in 20 centuries. The volcanic tephra includes rhyolitic, dacitic, and basaltic compositional types. Spectacular fumaroles developed in the ash-flow sheet prompting Robert F. Griggs to name it the Valley of Ten Thousand Smokes (VTTS). For a brief review and references see Papike, 1992 [1]. We have analyzed a cross-sectional suite of samples outward from a fumarolic vent conduit into unaltered dacitic tuff [See Spilde et al., 1993 [2] for details]. The ash-flow deposit in VTTS ranges from a few meters in the lower valley 20 km from the vent to ~200 km near the vent. The hot ash fell into the valley that contained rivers, snow and ice. The flash vaporized H_2O sources mixed with the volcanic gases derived from the degassing tephra. This vapor streaming formed a variety of “rootless” fumaroles in the valley. Rootless refers to the fact that the fumaroles are not sited over the volcanic source. We feel strongly that this same process has, almost certainly, occurred on Mars over time with hot basaltic pyroclastics falling on martian H_2O and CO_2 ice. We suggest that this process formed some of the sulfates, sheet silicates, and amorphous SiO_2 deposits found on Mars.

RESULTS AND DISCUSSION: Samples J-O were taken sequentially outward from the vent wall toward less altered tuff (Figure 1). The phase identifications were conducted using XRD, EMP, and analytical TEM methods [2]. Original fumarole temperatures were as high as 645 °C but most fumaroles died out in 30 years. In this abstract we emphasize the fumarolic alteration of plagioclase and pyroxene (Figures 2a, 2b, 3a, and 3b). In slightly altered tephra, plagioclase compositions >An_{73} are not observed, the more calcic portions of the phenocrysts having been replaced by amorphous silica. With increasing proximity to the fumarole conduit, progressively more sodic parts of the phenocrysts have disappeared. Adjacent to the fumarole, plagioclase >An_{44} has been removed because of the increased solubility of albitic feldspar in chloride-rich fluids as a function of increasing temperature. On a submicrometer scale, a zonal sequence of replacement phases has developed at the interface between unaltered and altered feldspar. A thin leached surface layer (<500 Å), depleted in Al, Na, and Ca but highly enriched in Si and Cl is always present. In altered phenocrysts away from the vent, a zone <5000 Å thick of amorphous Al-bearing silica is present, locally containing secondary Al-rich smectite crystals. Closer to the fumarole, smectite is absent, and a zone of impure amorphous silica occurs. Extensive alteration of pyroxene phenocrysts only occurs close to the fumarole conduit, where replacement develops along fractures parallel to (100). A narrow leached zone (200-300 Å), depleted in Mg and Ca, is present at the alteration interface, and halloysite is present locally as a secondary precipitate. The alteration of both plagioclase and pyroxene occurred when the fumarolic system cooled significantly (<300 °C) and was dominated by Si-rich, Cl bearing fluids with pH <2.5.

IMPLICATIONS FOR MARS: Certainly the sulfates, sheet silicates, and silica-enriched amorphous phases on Mars formed by a variety of processes. However, we predict with confidence, that some of these phases formed by processes described in this abstract. We will probably know soon, roughly by 2010, the significance of sheet silicates occurring at the MSL landing site. One possibility is that most are hydrothermal, fumarolic.

REFERENCES: [1] Papike (1992) GCA, 56, 1429-1449. [2] Spilde et al. (1993) Am. Min., 78, 1066-1081.

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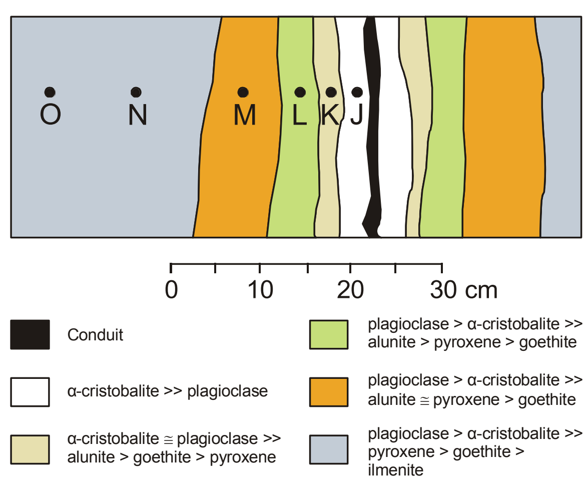
Figure 1. Schematic map showing the locations of samples J-O in dacite rich ash-flow tuff in the region of the fossil fumarole conduit. The relative abundance of crystalline phases in the alteration zones are noted in the legend.



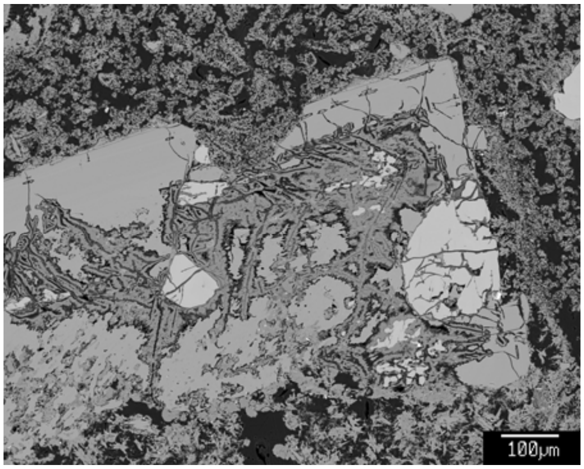


Figure 2a. BSE image of partially altered plagioclase (light gray) in which the calcic core has been replaced by amorphous SiO_2 (dark gray).

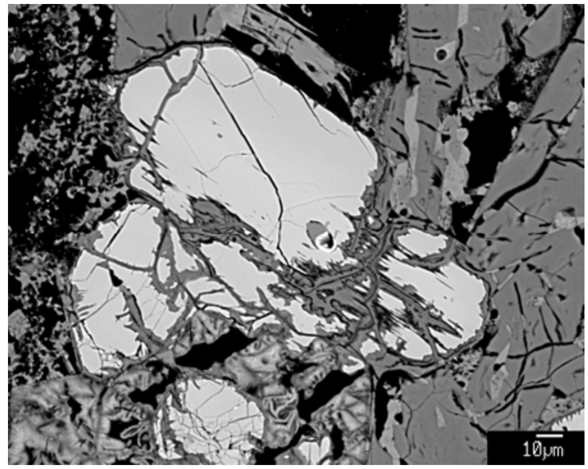


Figure 3a. BSE image of partially altered hypersthene (upper light gray grain) and augite (lower light gray grain). The hypersthene grain shows crystallographic control of the alteration.

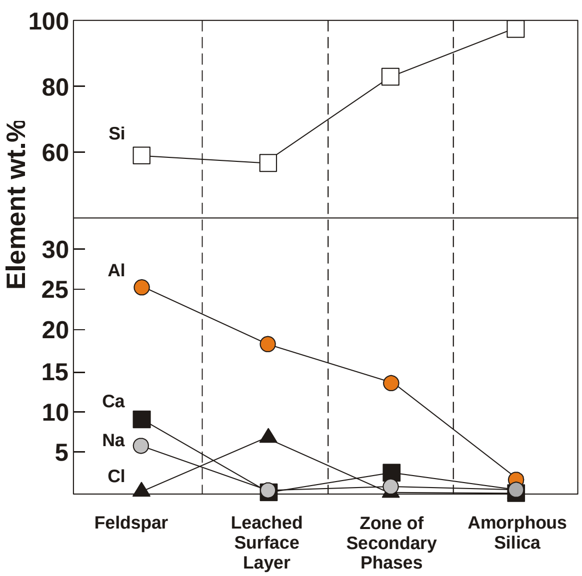


Figure 2b. Normalized element concentrations illustrating the compositional variations that occur in a traverse from plagioclase into the leached surface layer and subsequent layers of amorphous Al-bearing silica and pure silica (TEM analytical data).

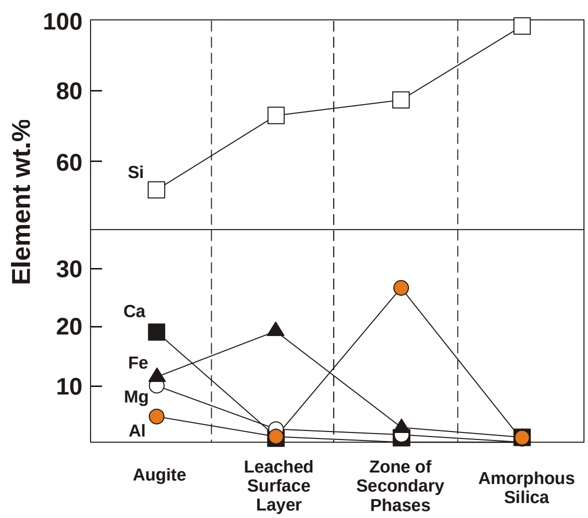


Figure 3b. Normalized element concentrations illustrating the compositional variations that occur in a traverse from unaltered augite into the alteration zone, which consists of three distinct layers (TEM analytical data). The leached layer adjacent to the augite is depleted in Ca and Mg. The second layer consists of secondary phases that have precipitated from the fluid phase, and the outer zone is composed of amorphous silica.