

HYDROTHERMAL ALTERATION ON BASALTIC MAUNA KEA VOLCANO AS A TEMPLATE FOR IDENTIFICATION OF HYDROTHERMAL ALTERATION ON BASALTIC MARS. R.V. Morris¹, T. G. Graff², D. W. Ming², S. A. Mertzman³, and J. F. Bell III⁴, ¹NASA Johnson Space Center, Houston, TX 77058

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Introduction: Certain samples of palagonitic tephra from Mauna Kea Volcano (Hawaii) are spectral analogues for bright martian surface materials at visible and near-IR wavelengths because both are characterized by a ferric absorption edge extending from ~400 to 750 nm and relatively constant reflectivity extending from ~750 nm to beyond 2000 nm [e.g., 1-10]. Palagonite is “a yellow or orange isotropic mineraloid formed by hydration and devitrification of basaltic glass [11].” For Mars-analogue palagonite, the pigment is nanometer-sized ferric oxide particles (np-Ox) dispersed throughout an allophane-like hydrated basaltic glass matrix [9,10]. Crystalline phyllosilicates are not generally detected, and the hydration state of the is not known. The poorly crystalline nature of glass alteration products implies relatively low temperature formation pathways.

The summit region of Mauna Kea Volcano also has basaltic cinder cones that underwent hydrothermal alteration (probably subareally) while the volcano was still active [12]. Since eruption ceased, the altered basaltic tephra has been leached by approximately neutral pH water (snow and rain), so that only the water-insoluble residues of the original alteration should remain. Because the Martian surface is also basaltic in composition [e.g., 13,14], characterization of the Mauna Kea alteration mineral assemblages provides a template for mineralogical assemblages expected on the surface of Mars as a result of hydrothermal alteration and subsequent leaching.

We report here x-ray diffraction, major element, Mössbauer, and VNIR data for 9 basaltic tephtras. Thermal emission spectra are reported in a separate abstract [15]. Our multidisciplinary approach both tightly constrains mineralogical interpretations and maximizes overlap with datasets available for the martian surface available now and in the future.

Samples and Methods: Tephra samples were collected as the <1 mm size fraction on Mauna Kea Volcano. All samples are described by [9,10] except for HWMK740 and HWMK742 which were collected on the summit cone Puu Poliahu. Sample analysis was performed by visible, near-IR spectroscopy (VNIR) from 0.35 to 2.10 μm , transmission Mössbauer spectroscopy, X-ray diffraction (XRD), and X-ray fluorescence (XRF) by methods described in [9].

Results and Discussion: XRF analyses are summarized in Table 1 and Mössbauer and reflectivity spectra are in Figs. 1 and 2. Variation in chemical and

spectral properties from essentially unaltered basaltic tephra (HWMK12 and HWMK513) are in accordance with the nature of the alteration product.

Table 1. Major element composition for tephra samples (<1 mm size fraction) from Mauna Kea Volcano (Hawaii).

Sample	HWMK12	HWMK513	HWMK11	HWMK600	HWMK919	JSC Mars-1	HWMK515	HWMK740	HWMK742
SiO ₂	50.19	49.61	50.68	46.38	43.47	44.38	49.54	51.07	50.97
TiO ₂	2.90	2.81	2.96	3.00	3.48	3.62	2.74	3.16	2.87
Al ₂ O ₃	16.95	17.14	17.00	19.87	23.50	21.92	16.20	26.11	20.36
Cr ₂ O ₃	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.01	0.01
Fe ₂ O ₃ T	11.81	11.85	12.17	13.80	15.28	16.03	15.25	8.83	12.33
MnO	0.20	0.22	0.19	0.26	0.31	0.28	0.17	0.11	0.18
MgO	4.29	4.17	3.21	4.29	3.46	3.75	2.52	1.21	2.65
CaO	6.72	6.63	5.98	5.94	4.88	5.88	5.56	2.16	5.36
Na ₂ O	4.00	4.39	4.84	3.88	3.04	2.28	4.68	2.48	3.14
K ₂ O	1.76	1.91	1.78	1.37	0.93	0.69	1.96	3.06	1.43
P ₂ O ₅	0.80	0.87	0.81	0.99	1.19	0.79	0.85	1.19	1.17
SO ₃	0.01	0.01	0.02	---	0.01	0.01	0.17	---	---
SrO	0.14	0.13	0.14	0.14	0.11	0.12	0.13	0.22	0.16
ZrO ₂	0.05	0.06	0.05	0.07	0.09	0.06	0.05	0.08	0.07
Total	99.71	99.67	99.85	99.88	99.74	99.80	99.62	99.69	100.70
%LOI	2.71	1.30	1.15	5.39	12.30	17.66	8.04	21.39	10.30
Fe(3+)	0.43	0.36	0.96	0.66	0.79	0.77	0.69	0.91	0.91
Fe(Tot)									

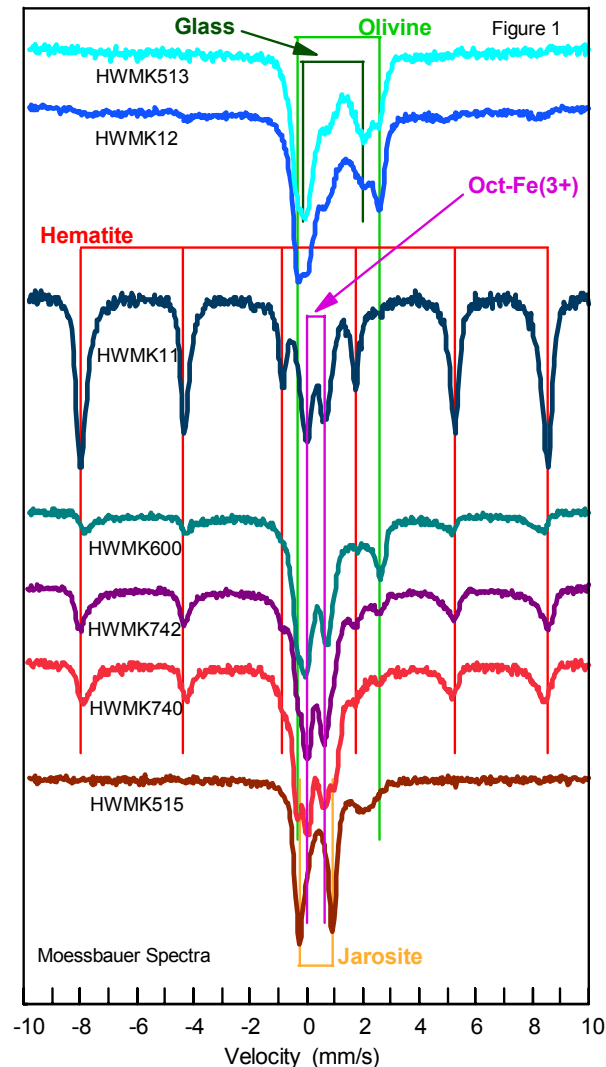
Note: Analyses for some samples reported by [9,10]. Minor differences result from averaging of repeated analyses. SO₃ is residual after LOI measurement at 950°C.

Palagonitic tephra (samples HWMK600, HWMK919, and JSC Mars-1), for which basaltic glass has undergone hydrolytic, low temperature alteration to nanophase ferric oxide particles (np-Ox) dispersed in an allophane-like hydrated glass matrix, are depleted in SiO₂ and the alkalis and enriched in other elements, including Fe, because of aqueous leaching. The Mössbauer ferric doublet and VNIR ferric absorption edge result from the np-Ox particles. Samples HWMK515 and HWMK740 are products of hydrothermal sulfatetic alteration. The former is enriched in Fe and K+Na because of the jarosite alteration product. The latter is enriched in Al and K+Na and depleted in Fe because of the alunite alteration product. Clear evidence for the sulfate alteration products are present in the VNIR spectra (Al-OH vibrations for alunite and Fe³⁺ band for

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jarosite). The jarosite doublet is present in the Mössbauer spectrum of HWMK515. Samples HWMK740 and HWMK742 have kaolinite + smectite by XRD and also distinct VNIR and Mössbauer hematite signatures. Additional analysis is necessary to show if the weak Fe^{2+} doublet assigned to olivine in these two samples is actually from smectite.

In accordance with $\text{H}_2\text{O}/\text{OH}$ -bearing alteration products, all samples except the two unaltered tephra and HWMK11 have large values of LOI (5-21%). HWMK11, however, has undergone alteration, presumably at high temperatures under dry conditions, because nearly all the iron is present as Fe^{3+} (mostly in hematite).



In summary (Table 2), the mineralogy of alteration products on Mauna Kea summit cones is dominated by three types of alteration processes: (1) hydrolytic, low temperature alteration of basaltic tephra to palagonite and nanophase Fe-oxides; (2) hydrothermal, acid sulfate alterations to sulfates (jarosite, alunite) and

phyllosilicates (kaolinite, smectite); and (3) oxidation by dry heat to form hematite.

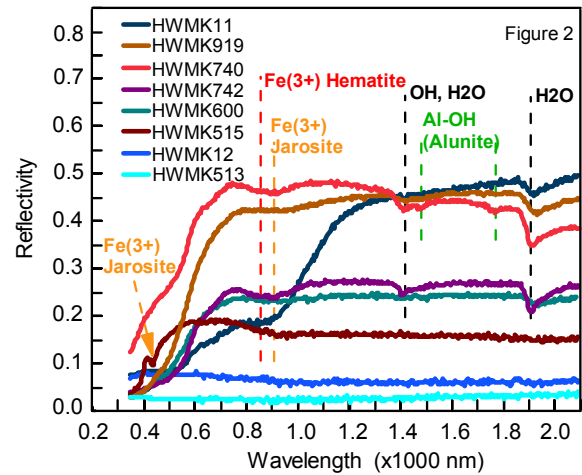


Table 2. Alteration products of basaltic materials observed on Mauna Kea Volcano.

Sample	Fe-bearing alteration products from Mössbauer	Alteration products from XRD	Type of Alteration
HWMK12	None Detected	Minor Smectite	Minor, hydrolytic (hydrothermal), oxidizing
HWMK513	None Detected	No Phyllo.	Unaltered
HWMK11	Hematite, Oct- Fe^{3+}	No Phyllo.	Pervasive, dry (high-T), oxidizing
HWMK600	Oct- Fe^{3+} as Np-Ox	Allophane, No Phyllo.	Moderate, hydrolytic (low-T), oxidizing
HWMK919	Oct- Fe^{3+} as Np-Ox	Allophane, No Phyllo.	Moderate, hydrolytic (low-T), oxidizing
JSC Mars-1	Oct- Fe^{3+} as Np-Ox	Allophane, Hisingerite, No Phyllo.	Moderate, hydrolytic (low-T), oxidizing
HWMK515	Jarosite	Jarosite, No Phyllo.	Pervasive, sulfatetic (hydrothermal), oxidizing
HWMK740	Hematite	Kaolinite, Smectite, Alunite	Pervasive, sulfatetic (hydrothermal), oxidizing, reducing
HWMK742	Hematite	Smectite, Kaolinite	Pervasive, hydrolytic (hydrothermal), oxidizing

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