THERMAL INFRARED SPECTROSCOPY OF EXPLOSIVELY ERUPTED TERRESTRIAL BASALTS: POTENTIAL ANALOGUES FOR SURFACE COMPOSITIONS ON MARS.

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Introduction: Basaltic pyroclastic ejecta from terrestrial Plinian eruptions may be analogues for Martian surface materials observed by the Thermal Emission Spectrometer (TES). We have acquired samples from the 122 B.C. Etna (Italy), 1886 Tarawera (New Zealand), and prehistoric Masaya (Nicaragua) eruptions for spectral analysis and comparison to Martian infrared surface spectra.

Explosive Basaltic Volcanism on Mars: Numerous lines of evidence suggest that explosive basaltic volcanism likely has occurred on Mars throughout the planet's history. Evidence for explosive activity includes: models of magma ascent and eruption under Martian conditions [e.g., 1], topographic similarity of Martian constructs to predicted profiles of Martian stratovolcanoes [2], edifices and units with morphologic similarities to pyroclastic materials [e.g., 3 – 8], aeolian bedforms in the vicinity of volcanic centers [e.g., 9 – 10], and globally-extensive layered units that thin with distance from Tharsis [11]. Explosive volcanism on Mars may be dominated by basaltic compositions based on strong evidence for widespread mafic volcanism on Mars from both morphologic [e.g., 4] and compositional [e.g., 12 – 15] information. Evidence for intermediate igneous [15] versus silica-rich weathered basaltic [e.g., 16] compositions remains ambiguous. There is no evidence for large abundances or the widespread distribution of considerably more silicic compositions, such as rhyolite/granite [17].

Explosive Basaltic Volcanism on Earth: Explosive (Plinian) basaltic volcanism is relatively rare on Earth. Typical terrestrial Plinian eruptions are characterized by mass eruption rates of 10^6 – 10^8 kg/s magma and eruption column heights of >20 km [18]. The best examples of such eruptions, from which we have obtained samples, are described below.

Masaya caldera complex, Nicaragua. [19] suggested the Masaya caldera complex as an analogue for explosive basaltic volcanism on Mars because it has produced large-volume, basaltic ignimbrite, Plinian ash-fall and surge deposits in the absence of significant magma-water interactions. Two specific basaltic pyroclastic deposits, the Fontana Lapilli and the San Judas Formation, have been mapped in detail at Masaya and interpreted to be the result of prehistoric, Plinian-type eruptions [20]. The Fontana Lapilli deposit covers 1200 km^2 to a depth of 1 m or more and has a bulk volume of >12 km^3. Eruption parameters derived from the deposit are: column height of 50 km and mass eruption rate of ~5 x 10^8 kg/s [20]. The San Judas Formation resulted from a smaller eruption column (18 km height) and a lower mass eruption rate (~3 x 10^7 kg/s) that deposited at least 1.2 km^3 of basaltic tephra [20]. The mechanism for Plinian eruption at Masaya is suggested by [19] to involve rapid ascent of volatile-rich basaltic magma from a deep (~100 km) source.

122 B.C. eruption of Etna, Italy. Basaltic pyroclastic deposits at Etna have formed from at least 24 sub-Plinian eruptions and one Plinian eruption in the last 13 ka [21]. Calculated eruption parameters for the 122 B.C. event are: ~25 km column height and mass eruption rate of ~7 x 10^7 kg/s [22]. The bulk volume of the deposit is > 1 km^3 and ash reached at least 400 km downwind. The inferred mechanism for the 122 B.C. Plinian eruption involves sudden decompression and vesiculation of magma stored at shallow levels, possibly within the volcanic edifice. The sudden decompression may have resulted from displacement of the eastern upper flank of the volcano by buoyancy forces associated with the ascent of a large batch of basaltic magma [22].

1886 eruption of Tarawera, New Zealand. Over the course of several hours on 10 June 1886, a 17-km long fissure explosively erupted ~2 km^3 (bulk volume) of basaltic scoria. The eruption column reached a height of ~28 km with a mass eruption rate of ~2 x 10^8 kg/s magma [23]. Ash was deposited up to 230 km away and the deposit covered at least 10,000 km^2. The intensity of the 1886 Plinian eruption at Tarawera is attributed by [23] to magma interaction with a pre-existing geothermal system. However, [24] point out that no hydrothermally altered wall rock clasts are present in the Plinian products of the eruption and they argue that external water was not necessary to drive the basaltic Plinian eruption at Tarawera.

Compositional Similarities Between Terrestrial and Martian Lithologies: Figure 1 shows the total alkali-silica (TAS) chemical classification diagram of [25]. On this diagram are plotted the chemistries of several Martian compositions measured in situ and derived from orbital mineralogical data. Also plotted are the chemistries of the terrestrial samples we are studying. Scoria from Tarawera 1886 is basalt (51 wt.% SiO_2) [26], and the 122 B.C. eruption of Etna is trachybasalt (48 – 50 wt.% SiO_2) [22]. Products from the Plinian eruptions of Masaya are basalt to basaltic andesite (51 – 52 wt.% SiO_2) [20, 27]. The chemistries of the Masaya and Tarawera samples are quite similar to those measured or estimated for Mars (Figure 1) and are expected to have the most similar spectral character. The spectra of trachybasalts from Etna will provide an interesting comparison to the spectra of those samples with lower alkali contents.

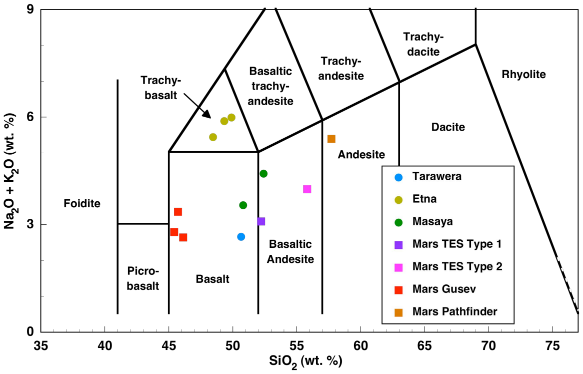

Figure 1. TAS classification diagram [25]. TES Type 1 & 2 values are the average of those in [16] and Gusev data are from [36]. Other data are from sources cited in the text.

Previous Studies: To date, thermal infrared spectral studies of relatively unaltered basaltic materials have focused on rock (not particulate) samples derived from intrusions and effusive eruptions [e.g., 28 – 29], which are the most common type of basaltic volcanism on Earth. Several studies have examined the mid-infrared spectra of the altered products of basaltic volcanism [e.g., 30 – 32]. [33] acquired visible to thermal infrared reflectance spectra of soils from the 1886 Tarawera eruption, and found that primary minerals dominated the spectra.

Samples & Data Acquisition: Bulk samples from the 122 B.C. Etna and prehistoric Masaya eruptions are being sieved to generate discrete size fractions for spectral analysis. From the 1886 Tarawera eruption, we have 14 size fractions from –2.5ϕ to 4.0ϕ, in steps of 0.5ϕ, corresponding to particle size fractions of ~5.5 cm down to <63 µm. Samples contain phenocrysts of plagioclase + olivine ± pyroxene in modal abundances of roughly 5 – 20 vol.%. The glass-rich mesostasis has a variable abundance of microlites consisting of the same mineral phases listed above ±magnetite. More detailed petrologic information can be found in [26 – 27].

We are collecting thermal infrared reflectance (~2.5 – 15 µm; ~4000 to 650 cm^{-1}) and emission (~5 –50 µm; ~2000 – 200 cm^{-1}) spectra of our samples at the new infrared spectroscopy laboratory at the Hawai'i Institute of Geophysics and Planetology (HIGP) at the University of Hawai'i [34]. These data will be compared to various Martian surface spectra measured by TES and Mini-TES. We also will look for correlated variations in the petrology and spectral character of coarse and fine fractions.

Anticipated Results: We expect to determine whether or not the products of terrestrial basaltic Plinian eruptions provide reasonable spectral analogues for spectra acquired at Mars. The glass-rich nature of these terrestrial samples may provide yet another hypothesis for the origin of silica-rich phases identified in Martian data. Petrologic and spectral variations between coarse and fine fractions may aid in the interpretation of fine particulate surfaces [35].

References: [1] Wilson, L. and Head, J.W. (1994) *Rev. Geophys., 32,* 221-263. [2] Stewart, E.M. and Head, J.W. (2001) JGR, 106, 17505-17513. [3] Greeley, R. and Spudis, P.D. (1981) *Rev. Geophys., 19,* 13-41. [4] Mouginis-Mark, P.M. et al. (1992) in *Mars,* pp.424-452. [5] Lucchitta, B.K. (1990) *Icarus, 86,* 476-509. [6] Crown, D.A. and Greeley, R. (1993) *JGR, 98,* 3431-3451. [7] Robinson, M.S. et al. (1993) *Icarus, 104,* 301-323. [8] Gregg, T.K.P. et al. (1996) USGS Map 2556, MTM-20252. [9] Edgett, K.S. (1997) *Icarus, 130,* 96-114. [10] Mouginis-Mark, P.M. (2002) *GRL, 29,* doi:10.1029/ 2002GL015296. [11] Hynek, B.M. et al. (2003) *JGR, 108,* doi:10.1029/ 2003JE002062. [12] Soderblom, L.A. (1992) in *Mars,* pp. 557-593. [13] McSween Jr., H.Y. (1985) *Rev. Geophys., 23,* 391-416. [14] Mustard, J.F. et al. (1997) *JGR, 102,* 25605-25615. [15] Bandfield, J.L. et al. (2000) *Science, 287,* 1626-1630. [16] McSween Jr., H.Y. et al. (2003) *JGR, 108,* doi:10.1029/2003JE002175. [17] Bandfield, J.L. et al. (2004) JGR, 109, doi:10.1029/2004JE002290. [18] Cioni et al. (2000) in *Encyclopedia of Volcanoes,* pp. 477-494. [19] Gregg, T.K.P. and Williams, S.N. (1996) *Icarus, 122,* 397-405. [20] Williams, S.N. (1983) *Geology, 11(4),* 211-214. [21] Coltelli M. et al. (1995) *Periodico di Mineralogia, 64,* 141-143. [22] Coltelli, M. et al. (1998) *Geology, 26,* 1095-1098. [23] Walker, G.P.L. et al. (1984) *J. Volcanol. Geotherm. Res., 21,* 61-78. [24] Houghton, B.F. et al. (2004) *J. Volcanol. Geotherm. Res., 137,* 1-14. [25] Le Bas, M.J. et al. (1986) *J. Petrol., 27,* 745-750. [26] Gamble et al. (1990) *J. Volcanol. Geotherm. Res., 43,* 253-270. [27] Walker et al. (1993) *J. Volcanol. Geotherm. Res., 56,* 379-400. [28] Hamilton, V.E. and Christensen, P.R. (2000) *JGR, 105,* 9717-9733. [29] Wyatt, M.B. et al. (2001) *JGR, 106,* 14711-14732. [30] Roush, T. and Bell III, J.F. (1995) *JGR, 100,* 5309-5317. [31] Esposito, F. et al. (2000) *JGR, 105,* 17643-17654. [32] Hamilton V.E. and Morris, R.V. (2003) *LPS XXXIV,* #1936. [33] Bishop, J.L. et al. (1998) *JGR, 103,* 31457-31476. [34] Hamilton, V.E. and Lucey, P.G. (this vol.). [35] Bandfield, J.L. and Smith, M.D. (2003) *Icarus, 161,* 47-65. [36] McSween Jr., H.Y. et al. (2004) *Science, 305,* 842-845.