WHAT DOES THE MARTIAN MANTLE LOOK LIKE? COMPARING METASOMATIZED AND CUMULATE MANTLE XENOLITHS FROM EARTH AS ANALOGUES. A. E. Thomas[1], M. E. Schmidt[1] and C. M. Schrader[2], [1] Earth Sci, Brock Univ, St Catharines, ON L2S3A1 Canada, alicia.thomas2@brocku.ca, [2] EOS Department, Bowdoin College, Brunswick, Maine 04011.

Introduction: The compositions of Martian igneous rocks reflect their mantle source at the time of extraction, as well as later igneous processing [e.g., 1,2]. Origin of primitive alkaline and evolved alkaline (mugearite) igneous compositions identified in landed and meteorite datasets point toward partial melting followed by high-pressure fractional crystallization and/or metasomatism in the mantle source region [2-9]. Peridotite melting experiments are unable to produce liquid Na_2O contents as high as those seen in Martian mugearites (Jake M), thus is elevated relative to the parental liquid [4,9]. In order to assess these models, we compare two terrestrial suites of ultramafic xenoliths sourced from volcanic fields that have, nevertheless, produced evolved alkaline magmas very similar in composition to the Jake M class rocks examined by MSL using the Alpha Particle X-ray Spectrometer (APXS) in Gale Crater [4,8,10], but with contrasting igneous histories (Fig. 1).

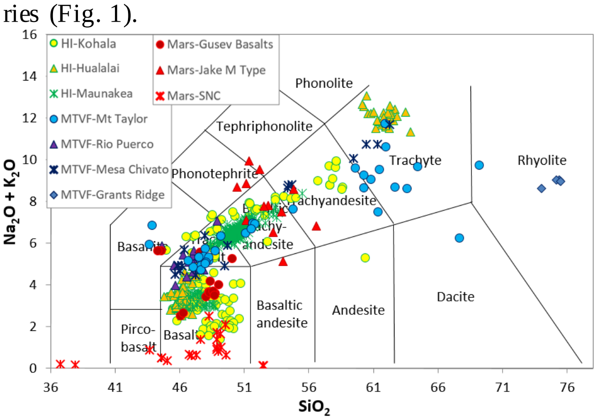

Fig 1. Total alkali versus silica rock classification diagram [2,11,12,13]. Jake M rocks, MTVF, and Hawaiian post-shield volcanoes overlap in mugearite field.

Two Field Sites: The Cenozoic Mount Taylor Volcanic Field (MTVF) is located along the Jemez Lineament at the southeastern margin of the Colorado Plateau in northwestern New Mexico. MTVF has produced a wide range of magma compositions (Fig. 1) that includes an alkaline suite with basanites and alkali basalts hosting mantle xenoliths with evidence of Si-melt and CO_2 metasomatism [14]. The Rio Puerco necks are a subfield of eroded, small-volume alkali basaltic volcanoes with a high concentration of mantle xenoliths bordering the Rio Grande Rift [15]. The lithospheric mantle beneath the MTVF has had a complex history of tectonism and metasomatism over the last 2 Ga history [15,16], that includes subduction and rifting. In addition, fluids may have been concentrated beneath the MTVF from deep seated fractures caused by the Jemez Lineament resulting in wholesale conversion of mantle peridotite [15].

Maunakea, Hualalai and Kohala are tholeiitic, intraplate hotspot volcanoes, in the post-shield stage of volcanism located on Hawaii. Each has produced alkaline magmas, but with different compositional ranges and degree of fractionation [17]. Maunakea is dominated by a thick transition zone containing interbedded tholeiitic, transitional and ankaramite basalts, overlain by hawaiite and mugearite. Kohala generated mainly hawaiite and mugearite with subordinate mafic alkali rocks. Hualalai produced a bimodal suite of alkali basalt and trachyte. All have produced lavas with cumulate ultramafic inclusions, and are consistent with models of fractional crystallization by crystal settling to generate the observed range of magma compositions [17,18].

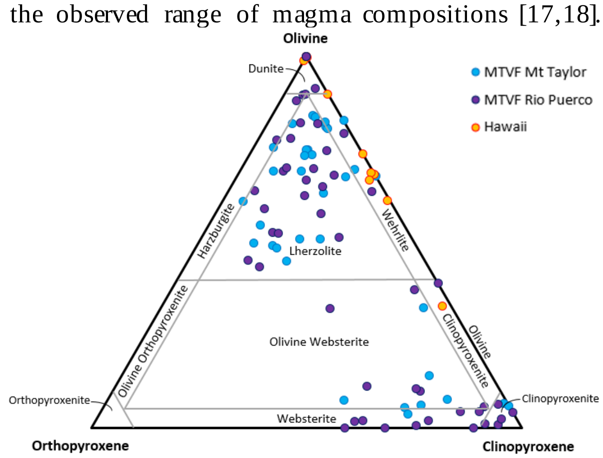

Fig 2. Olivine-orthopyroxene-clinopyroxene ternary for the classification of ultramafic rocks with modal mineralogy of ultramafic xenoliths from MTVF and Hawaii..

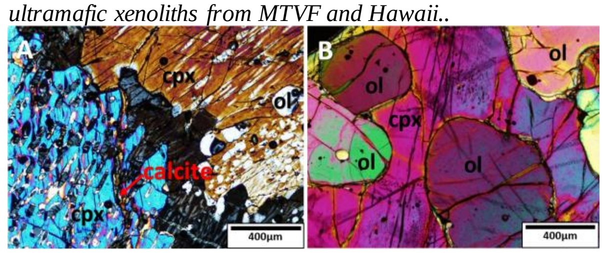

Fig 3 Micrographs of A. metasomatised MTVF xenolith MT-11-79x2 with cpx replacing olivine and calcite inclusions; and B. ultramafic cumulate xenolith from Hualalai, HI (MK-15-11) with euhedral olivine in poikilitic cpx.

Methods: Representative xenolith samples from MTVF (n=60) and Hawaii (n=13) were chosen for this study on the basis of their varied locations, large enough size for chemical analysis and composition of the xenolith. Modal mineralogy averaging 280 point counts per slide (Fig. 2) and textural characterization (Fig. 3) were conducted by petrographic analysis. Electron probe micro-analysis and Laser Ablation Inductively coupled plasma mass spectroscopy (LA ICP-MS; MTVF only) were conducted to determine major, trace and rare earth element concentrations of mineral phases. Furthermore, X-Ray Fluorescence (XRF) and ICP-MS analysis were done on 10 MTVF xenolith samples to obtain whole rock elemental compositions.

Results: A compare and contrast of the lithologic, textural, and geochemical characteristics between the two xenolith suites follows:

MTVF, New Mexico:

- Lithologically diverse and includes lherzolites, harzburgites, dunites, wehrlite, olivine websterites, and olvine clinopyroxenites
- Anhedral to subhedral grains. Consertal, lamellar and bleb-like intergrowths in pyroxenes are common. Pyroxenites contain optically continuous olivine inclusions. Sheared olivine and triple point grain boundaries are present in lherzolites.
- Olivines range from Fo57-95 in peridotites and and Fo75-85 in pyroxenites. Pyroxenes are more variable, ranging to higher Mg# 72- 93, Na_2O, and Al_2O_3 in both peridotites and pyroxenites (Fig. 4). Oxides are commonly MgAl spinels.
- Bulk xenolith analyses have higher Al_2O_3 (2.2-13.1 wt%) and SiO_2 (43.6-53.0 wt%) [13].
- Alkali basaltic lavas contain high Al_2O_3 and Na_2O. Ranging from 14.3-17.4 wt% and 2.7-4.9 wt% respectively.

Post-shield Hawaii volcanics:

- Modes include little orthopyroxene. Lithologies include dunite, werhlite, and clinopyroxenite.
- Cumulate textures with euhedral to subhedral grains. Phase layering of olvine, clinopyroxene, and chromite is present.
- Olivines range from Fo79-87. Clinopyroxenes tend to have higher Cr_2O_3 and lower Al_2O_3 (Fig. 4). Oxides are chromites.
- Bulk xenolith analyses are richer in FeO* than MTVF with a range of 10.0-26.2 wt% [13].
- Alkali basaltic lavas have lower Al_2O_3 (12.3-15.6 wt%) and higher CaO (9.8-12.2 wt%) [13].

***Discussion and Conclusions*:** Although the Martian mantle is richer in Fe and moderately volatile elements relative to Earth [19], our comparison is worthwhile because the Martian upper mantle is likely a mixture of the two endmembers (fractional crystallization and metasomatism) [1,7,8]. Xenolith textures reflect their igneous history (Fig. 3), but also have implications for models of partial melting and phase equilibria studies.

Olivine with Fo<90 in spinel peridotites is found in both xenolith suites and is not typical of the Earth's mantle. Hawaiian cumulate olivine form by fractional crystallization of mantle melts, while olivine in metasomatised xenoliths have reacted with a silicate melt.

Metasomatised xenoliths from MTVF are more varied in mineral and bulk composition than those from Hawaii. Higher Al_2O_3 and Na_2O, and generally lower TiO_2/Al_2O_3 ratios in clinopyroxenes from metasomatized xenoliths from MTVF (Fig. 4), are mirrored by the same trend in the corresponding oxide concentrations in associated basaltic lavas [4,8]. Jake M type rocks are noteably enriched in Al_2O_3 and Na_2O ranging from 14.4-17.7 wt% and 4.2-7.4 wt% respectively relative to other Martian magmas (e.g., Gusev basalts range from 8.5-15.4 wt% Al_2O_3) and are thought to derive from an alkali-rich mantle likely caused by metasomatism [4].

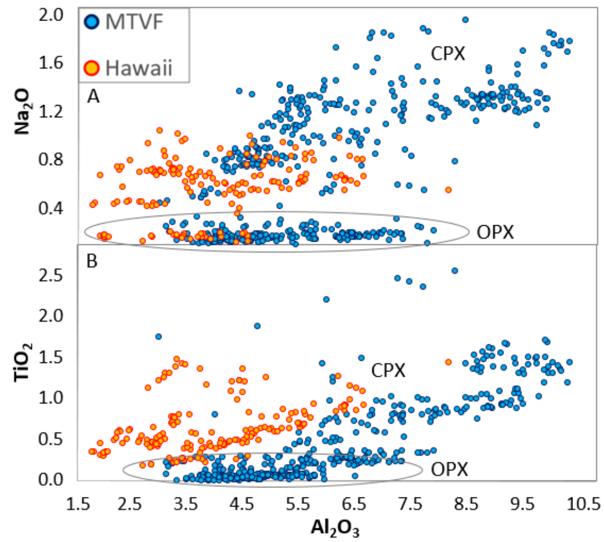

Fig. 4. Plots of A: Na_2O and B: TiO_2 versus Al_2O_3 in pyroxenes. MTVF exhibits greater variability, ranging to higher Al_2O_3 and Na_2O and lower TiO_2 relative to Hawaii.

References: [1] Symes et al. (2008) *GCA* , 72, 1696–1710; [2] Schmidt and McCoy, (2010) EPSL 296, 67–77; [3] McSween et al., (2006) JGR, 111, E09S91, pp1-15; [4] Stolper et al., (2013) Science, 341, 1239463-1-1239463-7; [5] Santos et al, (2013) MAPS; [6] Udry et al., (2014) JGR, 119, 1-18; [7] Goodrich et al., (2013) MAPS 48, Nr 12, 2371–2405; [8] Schmidt et al. (2014) JGR 119, 6481; [9]Collinet et al. (2015) EPSL 427, 83-94 [10] Schmidt et al., (2014) LPSC; [11] Le Maitre et al. (2002) Igneous Rocks, A Classification and Glossary of Terms 2nd ed. Cambridge Univ. Press; [12] Meyer (2015) The Martian Meteorite Comp.; [13] GEOROC (2015); [14] Thomas et al. (2012) *AGU abstract #* V43A-2825; [15] Porreca et al. (2006) *GSA*, 2, 7, 333-351; [16] Perry et al., (1990) JGR, 95, B12, 19,327-19,348; [17] Jackson et al. (1982) USGS; [18] Wolfe et al., (1997) *USGS*; [19] Wanke and Dreibus, (1988) Phil. Trans. R. Soc. Lond. A 325, 545-55.