ALTERED VESICULAR BASALTIC TUFFS AS POTENTIAL HABITABLE ENVIRONMENTS: IMPLICATIONS FOR MARS. M.P.C. Nikitczuk[1], M.E. Schmidt[1], and R.L. Flemming[2]. [1]Dept. Earth Sci., Brock University, (St. Catharines, ON L2T 3V8 Canada, mn09ye@brocku.ca, mschmidt2@brocku.ca), [2]Dept. Earth Sci., University of Western Ontario (London, ON N6A 5B7 Canada, rflemmin@uwo.ca)

Introduction: The Fort Rock Volcanic Field (FRVF) in now arid Central Oregon erupted ~40 hydrovolcanoes in the Pliocene-Pleistocene through a pluvial lake. We consider it a Mars analog because hydrovolcanism has been identified by the Spirit rover at Home Plate [1] and from orbit by HiRISE [e.g., Athabasca Valles, 2]. Also, basaltic glass and its devitrification products, including phyllosilicates, zeolites, and amorphous palagonite have been identified on Mars from the ground and from orbit, [e.g., 1, 3]. CRISM orbital observations suggest that layers at the base of Mt. Sharp in Gale Crater contain phyllosilicates [4], which may be the products of hydrothermal alteration of basaltic pyroclastic material and are known to promote biosignature preservation [5]. The habitability of such a deposit for (micro)-organisms depends on the primary volcanic textures (i.e., vesicularity and grain size) because they influence hydrologic properties [6]. We here present textural and mineralogical properties of basaltic tuffs from FRVF focusing on vesicles, which can account for a high proportion of the primary porosity of these tuffs and may represent a good micro-environment to support life on Mars.

Methods: We sampled from two adjacent tuff rings, Reed Rock and South Reed Rock. The analytical techniques utilized are analogous to, but a step up from instruments on board the Mars Curiosity rover. The petrographic microscope and true hand lens mirror the use of the MAHLI instrument capable of imaging rock textures at the hand lens scale. The Bruker D8 Discover Diffractometer is analogous to the CheMin instrument to determine mineralogical diversity [5]. Using µXRD with a normal beam diameter of 100 µm permits *in situ* analysis of minerals in rock samples at the microscopic scale and allows correlation between crystal structural data and other microscopic data such as from the polarizing microscope [7].

Textures and Mineralogy: All samples contained glass with amorphous palagonite and/or brown clay associated with vesicular basaltic glass. Some samples contained endolithic microborings/tubular bioalteration with the most abundant microtubules in glasses surrounding vesicles with palagonitic alteration rims and in fills of matrix material.

Vesicle Features. Vesicle shapes are most commonly circular to oblong with less common fluidized morphologies. Sizes range from 30 µm-6 mm with the most common sizes ranging from 0.2 - 1.5 mm and the largest sizes and most abundant numbers in lapilli. Pyroclast grain sizes range from lapilli (>64 mm) to fine ash (<1/16 mm). Yellow palagonite and phyllosilicate coatings from 5-25 µm thicknesses with both distinct and diffuse glass-clay/palagonite interfaces initiated along fractures, glass edges, pores and vesicles (Fig.1) are present. Vesicles with brown coatings have visible clay lamellae structures (Fig.-1A), and clay, with post-hydrothermal secondary calcite and zeolite in fills are frequent (Fig.1). Fractures interconnect vesicles (Fig.-2C) for increased permeability.

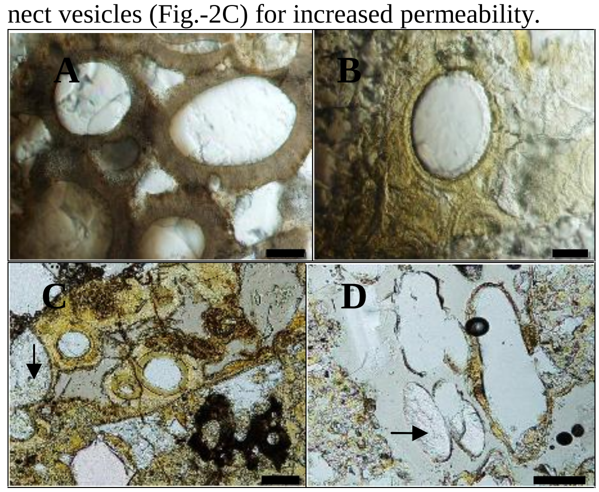

Fig.1. A-Brown coating around clay filled vesicle vesicle (FR-12-94B). B-Palagonite coating around clay filled vesicle (FR-12-94A). C-Palagonite rimmed and zeolite filled (left-arrow) vesicles (FR-12-90-1). D-Palagonite rimmed and calcite filled (bottom center-arrow) vesicles (FR-12-97C). (Scale bar-A and B 20 µm, C and D 100 µm).

Tubular Bioalteration: Several samples contained small channels inferred to be tubular bioalteration features originating from clast margins, along fractures (asymmetrically distributed) (Fig.-2C), and most abundantly from glass-clay/palagonite interfaces along vesicle walls (Fig.-2A, B, D). Features originate from cracks, vesicles and matrix material containing altered coarse and fine ash. Microtubule dimensions range from 1-5 µm widths and 20-100 µm lengths. Biogenic forms [8] include corrugated bores on straight tubes, spiraling "cork screw", simple to complex bifurcating (same diameter) (Fig.-2A), linear to curvilinear, tapered ends, apical cells and segmented shapes (Fig.2). These features post date clay/palagonite glass alteration and secondary calcite/zeolite formation.

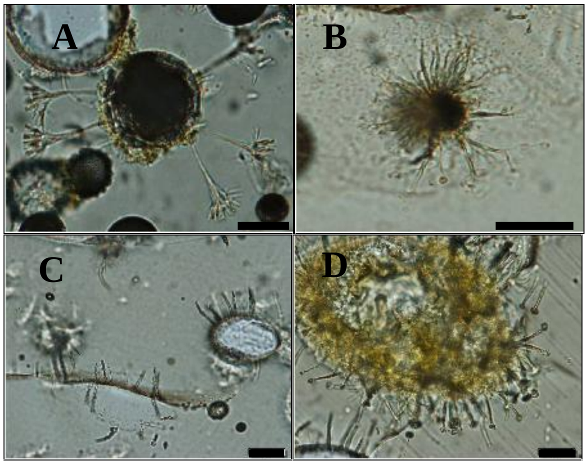

Fig.2. A-Bifurcating microtubules from palagonite rimmed and matrix filled vesicle (FR-12-94B). B-Radiating microtubules from matrix filled vesicle (FR-12-97A). C-Microtubules originating from fracture and connected vesicle (FR12-97E). D-Microtubules originating from altered matrix filled vesicle (FR-12-97E). All scale bars on lower right corners are 20 µm.

Mineralogy. Primary juvenile minerals identified in all samples were olivine and plagioclase consistent with the basaltic composition. Abundant primary basaltic glass is reflected in broad hump in XRD pattern centered on 30˚ 2θ. The most abundant secondary minerals include calcite, chabazite (zeolite), and nontronite (phyllosilicate) (Fig.3). Other minor alteration minerals include saponite, cookeite, phillipsite, and stilbite.

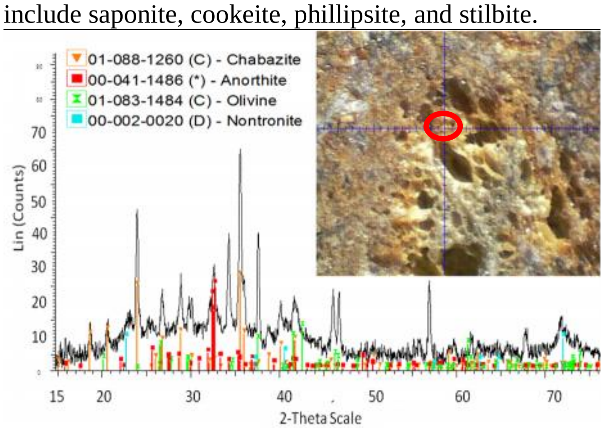

Fig.3. µXRD pattern of 100 µm spot (red circle) shown on inset.

Discussion: Vesicles make a large contribution to the primary porosity and surface area. Hydraulic conductivity/permeability is enhanced by interconnecting fractures. Circulating fluids and rock matrix containing essential nutrients [9] and microorganisms can penetrate deeper to the interior of rocks with vesicles acting as traps. Alteration upon contacting unstable glass surfaces in the form of palagonite and smectite coatings can be initiated within vesicles. Amorphous material has already been identified by Curiosity in soils at Gale Crater [10]. Smectite/clay formation can potentially make some nutrients more available to organisms than in solid glass [11]. Furthermore within vesicles higher moisture contents may be maintained for longer periods of time [12] increasing the likelihood of a habitable environment.

Tubular alteration (microtubules) in these rocks is most abundant in glasses surrounding vesicles implying that vesicles may host larger populations of microorganisms than elsewhere in the rock. The vesicles from which these microtubules originate are often linked by fractures, filled with matrix material and have a palagonitic alteration rim. Vesicles are found on the interior of rocks and thus are protective against erratic external environmental conditions [13] including UV radiation, temperature fluctuations, and moisture contents.

Basaltic glass is a high quality substrate for microbial growth [14] that can provide a growth medium chemical reservoir with nutrients and energy to microorganisms [13, 15]. Upon tunneling into glass, the microbes can obtain nutrients, protection from predation, and traction to oppose desiccation and bodily erosion [8]. The basaltic glass can also act as a medium in which traces of life may be preserved. Lastly, vesicles filled with secondary minerals such as zeolites and calcite precipitated from groundwater may implant signs of the elemental and isotopic changes connected to geochemical and biogeochemical processes [5].

Conclusion: Textural and mineralogical observations provide evidence that vesicles in basaltic pyroclastic material can be potentially habitable environments. Factors such as protection from external environments, prolonged interaction with circulating fluids, formation of secondary phases, and nutrient availability support this possibility. Microtubules found on lapilli interiors suggest that coarse grained substrates may be conducive to habitable conditions in addition to fine grained material. In considering potential habitable environments on Mars, coarse-grained vesicular basaltic materials may deserve more attention.

References: [1] Squyres, S.W. et al. (2007) *Science*, 316, 738-742 [2] Keszthelyi, L.P. et al. (2010) Icarus, 205, 211-229 [3] Ehlmann, B.L. et al. (2008) NG, 1, 355-358 [4] Milliken, J.P. et al. (2010) GRL 37 [5] Grotzinger, J.P. et al. (2012) SSR, 170, 5-56 [6] Schmidt, M.E. et al. (2012) LPSC 43 [7] Flemming, R.L. (2007) CJES, 44, 1333-1346 [8] Staudigel, H. et al. (2008) ESR, 89:3-4, 156-176 [9] McLoughlin, M. et al. (2007) Astrobiology, 7, 10-26 [10] Bish, D. et al. (2013) this meeting [11] Cockell, C.S. et al. (2012) GJ, 26:7, 491-507 [12] Bagshaw, E.A. et al. (2010) Astrobiology, 11:7, 651-664 [13] Cavalazzi, B. et al. (2012) LEOPB, 24, 27-33 [14] Edwards, K.J. et al. (2005) TM, 13, 449-456 [15] Izawa, M.R.M et al. (2010) PSP, 58, 583-591