ANALYZING SEMI-CIRCULAR DEPRESSIONS IN NORTHWESTERN ARABIA TERRA, MARS, WITH SEDIMENTARY BASINS. E. A. Pesar[1], S. Karunatillake[2], D. A. Susko[2], D. R. Hood[2], G. Rewerts[2], L. K. Carnes[3], B. Yi[4], [1]Queens College, The City University of New York, School of Earth and Environmental Sciences 65-30 Kissena Blvd. Queens, NY 11367-1597 (elizabeth.pesar98@qmail.cuny.edu), [2]Louisiana State University, Department of Geology and Geophysics, E235 Howe Russell Kniffen, Baton Rouge, LA 70803, [3]Lehigh University Earth and Environmental Science Department, 1 West Packer Ave, Bethlehem, PA 18015, [4]China University of Geosciences, 388 Lumo Road, Wuhan, Hubei P.R. China.

Introduction: Arabia Terra is a region in northern Mars whose origins could help shed light on the planet's geologic evolution, as well as elucidate its past and future habitability. Several otherwise nondescript semi-circular, possible volcanic depressions near its NW boundary show a plausibly distinctive geochemical signature. The area that encompasses these depressions was previously delineated by Carnes in recent work [1]. It consists of a smaller region and an encompassing larger one optimized for geochemical characterization at region scales: Focus Arabia Region (FAR) and Broad Arabia Region (BAR).

Three putative paterae, irregularly shaped volcanic craters, Eden, Ismenia, and Siloe, are contained within the smaller FAR region [2]. Their origin can be evaluated based on the contrasting chemical signatures of an explosive volcanic environment versus that of a hydrated sedimentary basin. If these paterae are confirmed to have a volcanic origin, it could be indicative of an entirely new class of volcanism [2]. On the other hand, an equally plausible explanation is that of a hydrated sedimentary basin as suggested by Dohm due to the presence of phyllosilicates [3] and supported by evidence of episodic flooding events [4]. To explore the basin possibility, Arabia was studied in reference to three known sedimentary basins using the most recent derived publicly available chemical data from the Mars Odyssey Gamma Ray Spectrometer (GRS), archived at the NASA PDS and as used in recent work [5] [6].

Geochemistry: Available data were in the form of chemical maps with Al, Ca, Cl, Fe, H_2O, K, S, and Si abundances reported as percentage mass fractions, and Th in mg/kg, which covered the entire surface of Mars as a longitude-latitude pixel grid at 5° × 5° resolution from 57.5° S to 57.5° N. The mass fraction of each element was reported at the centroid of each pixel. BAR and FAR were geochemically delineated in ArcGIS 10.3.1 [1].

Argyre, Hellas, and Eridania sedimentary basins were used as references, using GRS-reported chemistry at individual pixels of the GIS chemical maps using Microsoft Excel. The pixels over Hellas basin were determined according to the work of Tanaka [7], Argyre according to Dohm [8], and Eridania according to Michalski [9].

Crustal Mg cannot be measured directly, but since it can be useful in characterizing igneous versus aqueous chemistry, Baratoux's method for calculating Mg concentration was applied [9]. This method is useful for determining Mg content in igneous regions; higher Mg generally correlates with mafic igneous activity. The final step of this method was to find the Mg# (obtained by calculating Fe/(Fe+Mg) molar ratio) for each pixel, and constrain it within the 40-70 range typical of a region of igneous provenance. Since Baratoux's method applies only for igneous crustal material, it was repurposed as a proxy discriminant of igneous chemistry. Finding similar Mg# trends in Arabia that would be observed in a confirmed basin would bolster the case against an igneous origin for Arabia.

Boxplots: Seven box plots were constructed from the GRS chemical data showing depletion or enrichment of a given element in a target region versus a reference region [10]. The top bound of each box is the 75th percentile of the upper (target) region divided by the 25th of the reference region, the dividing line within each box is the 50th of the target region divided by the 50th of the reference region, and the lower bound of each box is the 25th of the target region divided by the 75th of the reference region. When the dividing line of a box is located at 1 (unity), the regions have equal amounts of the given element. When the dividing line is above unity, the target region is enriched in that element; when it is below unity, it is depleted [10]. The error bars indicate the uncertainty of the ratio of the medians as calculated by the median absolute deviation (MAD). The box plots show noticeable enrichment in H_2O, and Al, and depletion in Mg and the K/Th and Cl/H_2O ratios for both FAR

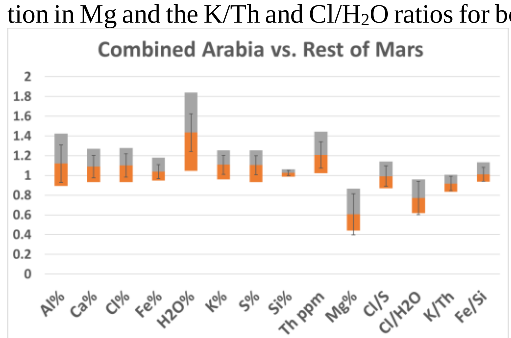

Figure 1: Modified box plot comparing the geochemistry of the combined FAR and BAR regions to the rest of Mars.

and BAR compared to the rest of Mars. FAR shows significant depletion in Mg and enrichment in Th and H_2O compared to Hellas.

Morphology: FAR and BAR were examined in JMARS using MOLA data for paterae candidates that resembled the morphology of Eden, Ismenia, and Siloe paterae. A sampling of nine depressions was used to get a preliminary presentation of the range of depression morphology that exists on Mars. We take two transects per depression that measured distance, slope, and elevation of the three putative paterae, three known Martian volcanic depressions, and three of nearby impact craters (one an infilled impact crater) along the major and minor axes. Michalski and Bleacher suggest that a putative ancient volcanic crater may exhibit the following characteristics: low topographical relief, lack of a central peak, and lack of a raised outer rim. In contrast, an impact crater may include layered ejecta, elevated crater rims, and raised central peaks [2] [11].

Ternary diagrams: Three chemical molar ratio ternary diagrams were constructed using a ternary plot approach model [12]. Using the constrained data for BAR, FAR, and Eridania, Hellas, and Argyre basins, element weight percents were stoichiometrically converted to oxides, then to moles to obtain molar fractions. The molar data points were plotted on a ternary diagram and the points for each basin identified within a color-coded cloud. These clouds illustrate the elemental range within a specific region. The preestablished mole percent ranges of Martian meteorites, Meridiani outcrops, and altered and unaltered rocks as determined by Karunatillake are provided for comparative reference [12]. Figure 2 shows the ranges of both FAR and BAR overlap with Hellas basin.

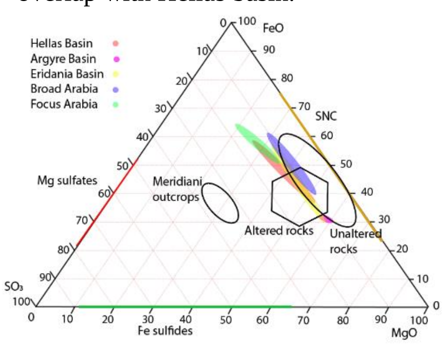

Figure 2: Chemical molar ratio ternary diagram that uses MgO, SO_3, and FeO as its vertices to evaluate altered and unaltered rock within selected regions.

Discussion: Evolved magmatism could explain the enrichment of Si in Arabia relative to the rest of Mars shown in the box plots. Alternatively, the depleted BAR and FAR K/Th ratios also shown in the box plots is consistent with aqueous alteration [13]. The reference basins and Arabia ranges seen in the ternary plot overlap with the previously established altered and unaltered ranges from Karunatillake, consistent with varying degrees of past aqueous activity. Nevertheless, explosive volcanism also can yield the relatively high amounts of volatiles shown. Both the ternary diagrams and modified box plots suggest that BAR is most similar to Hellas basin.

The putative paterae appear morphologically consistent with features indicating possible past volcanism [2]. In addition, these depressions have high depth to diameter ratios and are devoid of ejecta, both of which are uncharacteristic of an impact crater. Furthermore, they exhibit faulting consistent with caldera complexes [2]. With the exception of the infilled impact crater, the other six depressions were consistent with the morphological characteristics of impact craters.

While 98% of the fractional area in Argyre basin and 87% of the fractional area in Eridania yield Mg numbers in the 40-70 range, only 28% in Hellas had values in this range. Consequently, Argyre and Eridania sedimentary basins are indistinguishable from an igneous provenance with respect to their Mg#. While the Mg# of a sedimentary basin can fall within the range Baratoux considered igneous, going outside that range may decrease the likelihood that it has an igneous origin. In contrast, Hellas shows more characteristically non-igneous Mg numbers. The FAR and BAR fractional area Mg numbers that fall into the 40-70 Mg# range are 0% and 22% respectively, suggesting a non-volcanic origin. Hellas may be worth considering as a basin analog for this region.

Conclusion: While Arabia Terra has previously been considered as a volcanic region, there is ample evidence to justify examining it as a putative sedimentary basin. High H_2O content, low K/Th ratio, and very low Mg content and Mg numbers relative to the rest of Mars make a basin origin plausible. Significant geochemical overlap with known sedimentary basins add more weight to this possibility. If Arabia is confirmed to be a hydrated sedimentary basin, it may hold promise in the search of biosignatures on Mars, as well as the past conditions of environments life once may have flourished in. Further inquiry is needed to better explore this possible origin.

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