

PLACING PUTATIVE ARABIA PATERAE ERUPTIONS IN CONTEXT WITH REGIONAL MARTIAN GEOLOGIC EVENTS

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Introduction: The Arabia Terra region is one of the oldest martian landscapes, and shows evidence of paterae eruptions similar to terrestrial supervolcanoes [1]. These potentially represent a new class of volcanism on Mars [1]. The structures could be remnants of early, explosive-style volcanism on Mars, in contrast to the effusive volcanism that dominated the landscape later in the planet's history [2]. As such, they hold great potential to link Noachian-aged explosive volcanism to several large-scale geologic events that resurfaced much of Arabia Terra. However, it is unknown if the paterae-bearing region is geochemically consistent with volcanism. Geochemical similarities between Arabia Terra, Martian meteorite samples, other Noachian-aged Martian volcanic provinces and select terrestrial volcanic sites could help identify if Arabia Terra was once subject to super-volcanic eruptions. Further analysis of the Arabia Terra region can lead to a greater understanding of the planet's geologic evolution and provide insight into the early surface conditions on Mars.

In this study, geochemistry from the two delineated areas within Arabia Terra, the broad and focus regions [3], are compared to the geochemistry of basaltic shergottites and several terrestrial volcanic areas. Using the geochronological datum [3], several volcanic provinces with similar ages were compared with the broad and focus region's geochemistry in order to assess the likeness between known volcanic provinces and the paterae region's geochemistry.

Methodology: Using chemical data (as concentrations of Al, Ca, Cl, Fe, K, stoichiometric H₂O, S, Si, and Th) derived from Gamma Ray Spectroscopy (GRS) [4], the possibility of chemical similarity between known Martian volcanic provinces and the broad and focus regions was examined. The map by Tanaka et. al [5] identified Noachian-aged volcanic provinces elsewhere on Mars, whose locations were best-fit using the Java Mission-planning and Analysis for Remote Sensing (JMARS) as the program to place rectangular boundaries around Thaumasia Planum (Site A), Malea Planum (Site B), Hesperia Planum (Site C), and Apollinaris Mons (Site D). Using the coordinates of the outlined areas, GRS data were compiled for the provinces and analyzed accordingly.

From the GRS data, the elements of key interest were K and Th, reported as PPM (shown in Fig. 1), because their trends can indicate whether or not igneous activity was present in an area [6]. In addition, the rock forming chemistries (Si, Al, Fe, Ca) from the terrestrial

volcanic sites, the Martian meteorites and the focus region, were compared (Fig. 2).

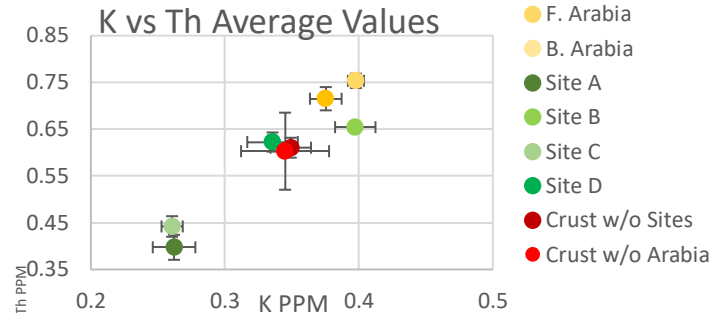


Figure 1: Average K & Th values for various sites in PPM.

Using the Martian Meteorite Compendium, meteoritic data were compiled for more evolved basaltic shergottites from enriched, intermediate and depleted suites. Those may represent a source region of mafic composition [7]. A probable cause of explosive volcanism in Arabia Terra could have been from basaltic magma rising rapidly and undergoing bubble

GRS, Terrestrial and Meteoritic Rock-Forming Chemistries

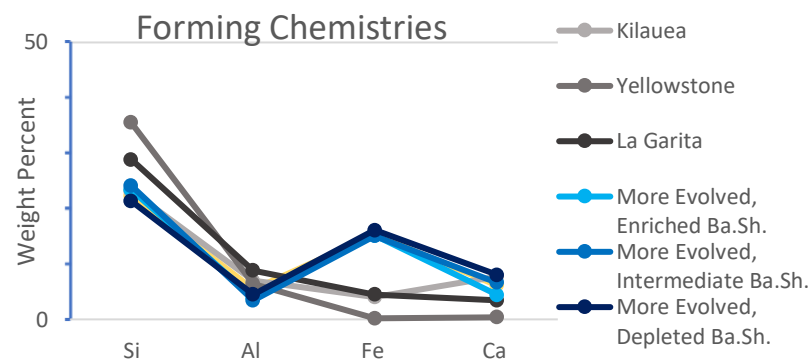


Figure 2: Major rock forming element chemistry for various sites reported as weight percent; size of point approximates error in measurement of each element.

nucleation, resulting in an explosive eruption [1]. Thus, chemical comparisons between Martian meteorites sourced from deep within Mars and the focus region could provide insight into whether or not explosive volcanism took place in Arabia Terra.

To examine the possibility of geochemical similarities between the putative paterae and known terrestrial volcanic areas, GRS data were used to create a "bulk rock" chemistry for each of the 4 Martian volcanic provinces, the broad and focus regions, and the Martian crust. Those were then compared to the derived bulk rock chemistry from 3 terrestrial volcanic sites:

Kilauea, Yellowstone, and the La Garita caldera complex. The comparisons used Si, Al, Fe and Ca, as they are most likely to indicate similarities between the styles of volcanism, i.e. more silicic or mafic.

Results: The K and Th concentrations (Fig. 1) are distinctly elevated when compared to other Martian volcanic provinces as well as the Martian crust. However, there is quite a range of K and Th values for the four volcanic sites analyzed; site C and A are both noticeably depleted in K and Th in relation to all other reported values. Site B shares similar K and Th values to that of the broad and focus regions, and site D has values similar to that of the Martian crust.

Additionally, the chemical trends shared between the Martian meteorites and the focus region, shown in Figure 2, can provide insight into possible volcanic origins. We find that the Si, Al, Fe, and Ca values from these datasets all lie within approximately 5 weight percent of each other, with the most separation of values associated with Ca and the least with Fe. These values differ greatly from the more silicic Terrestrial volcanic sites, whose Si content is much higher, and Fe content much lower. However, the Martian chemical datum shares the most similarity with that of Kilauea, the only discrepancy being Fe content.

Discussion: The K and Th abundance varies across the Martian sites analyzed, which could be due to a number of processes [6]. However, the Th and Si trends contrast with those of other volcanic sites; despite the focus region having similar values of Si to contemporaneous volcanic provinces, it exhibits significantly higher Th levels. This is unique because younger volcanism tends to have lower Si and higher Th, suggesting that there were unique igneous processes happening in the focus region [12]. The similarity between Terrestrial basaltic volcanism offers further insight into the gravity the K and Th values hold for arguing the paterae did erupt. The chemical trends between the Martian and Kilauea data match closely, although this trend is likely more indicative of the magmatic processes that formed the Martian crust [8], as the chemical signature of these processes has not been lost to crustal recycling. The K and Th content is highly variable in Martian igneous rocks, and can also be affected by surface processes such as erosion or aqueous alteration [6]. This explains the variation among the analyzed sites, and suggests that the K and Th enrichment in the broad and focus regions is the result of an abundance of unaltered igneous rocks.

Moreover, the volatile trends across the volcanic sites tend to remain below the crustal average, except for site D, which has volatile levels much higher than the crustal average [3]. One hypothesis is that these trends are a result of a massive erosional event,

triggered by meltwater runoff from a large ice sheet that covered most of the southern hemisphere of Mars [9]. This event could explain the anomalous H₂O levels found in the broad and focus regions. The melting of this ice sheet could have been facilitated by the paterae eruptions, resulting in the emplacement of igneous chemical signatures that were eroded and transported by the flow of water [10]. This hypothesis is reasonable, because the date of the paterae eruptions can be precisely inferred, based on the chemical data from the Martian meteorites. An Al enrichment is seen in sites A-D [3], but the broad and focus regions have Al values that approximate crustal values. This difference in Al concentrations could be explained by widespread Al depletion in the mantle at around 3.0 Ga [11] from which any eruptions would also be Al-deficient. However, the paterae have been dated to roughly 3.8 Ga [3], and it is unlikely that the mantle Al deficiency was present at this time. Furthermore, the meteorites and the volcanic sites all share similar Al values, suggesting that the volcanism exhibited by all Noachian volcanic sites is Al-rich. Therefore, if eruptions from the paterae did occur, they did so long before the mantle Al depletions, suggesting that the Al values in the broad and focus regions, which are approximate crustal values, could have been created through paterae eruptions. Eruptions from the paterae would have interacted with the ice sheet, resulting in meltwater emplacing unique chemical signatures as it flowed through Western Arabia Terra towards the northern lowlands [10]. Based on this geochemical and geologic evidence, the history of Northwest Arabia Terra can be explained through super-volcanic eruptions from the paterae.

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