RECURRENCE RATE ESTIMATION OF DISTRIBUTED VOLCANISM IN ARSIA CALDERA, MARS

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Introduction: Volcanism is a major feature of many planetary surfaces, including the surface of Mars. Understanding the geologic history of Mars thus requires understanding of rates of volcanism, and how these rates have changed through time. Here, we use small volcanic vents to constrain the recurrence rate of volcanism for a volcano cluster within the caldera of Arsia Mons.

Over one thousand small volcanic vents have been observed on Mars with the help of recent image and altimetry data. From these observations, a detailed catalog has been developed of small vents in the Tharsis Volcanic Province, enabling vent fields to be characterized and compared [1]. These mapped small volcanic vents have likely erupted since at least the earliest Hesperian period in some regions [2] and have continued to form in other areas to the late Amazonian, as recent as several tens of millions of years ago [3]. These volcanic vents are often found in distributed volcano clusters and their edifice morphologies, either as low shields with single flow fronts or as high sloped (~6 degrees) cones [4], are indicative of "monogenetic" volcanism. Martian distributed volcanic fields are composed of tens to hundreds of small volcanic vents that each erupt lava flows, form lava flow fields, and build volcano edifices. The eruptive history of these clusters is uncertain, but by analogy to Earth monogenetic volcanic fields, each edifice likely represents a single eruptive episode, meaning that cumulatively the volcanic field provides a record of volcanism for a long period of time.

One such field, Syria Planum, produced 263 mapped volcanic vents over a time span as great as 700 million years, as estimated from crater retention rate modeling for five geologic units in the area [2]. The recurrence rate for the creation of new vents in this area might therefore be an average of one new vent every 375,000 years. However, this assumes that the volcano cluster at Syria was uniformly active for its entire history. A more accurate estimate of the rate of volcanism during a large, distributed magma generation can be gained by mapping stratigraphic relationships and modeling ages with crater counts for individual edifices in a field.

Arsia Mons: An isolated volcano cluster exists in the caldera of Arsia Mons consisting of 29 mapped volcanic vents (Fig. 1). The vents cover ~6700 sq. km (70%) of the 100 km diameter caldera with associated lava flows. Edifices constructed from lava flows have been outlined using images from the Context Imager (CTX) and gridded data from the Mars Orbiter Laser Altimeter (MOLA). Edifice perimeters are selected at the edge of the farthest lava flow that can be directly traced to its corresponding vent. Lava flows that were emplaced in the same direction but which are covered by more recent flows were not assigned to a mapped vent.

Stratigraphy: Outlined lava flows abut each other and clearly embay or are embayed by flows from other vents. A complete table of stratigraphic relationships has been created (Fig. 2) using CTX images to identify embaying features, such as lava infilling craters or grabens that cut stratigraphically lower flows. A total of 47 stratigraphic relationships connecting the 29 volcanic vents. Of the 47 mapped stratigraphic relationships, 17 are redundant (i.e. other relationships indirectly link volcanic edifices stratigraphically).

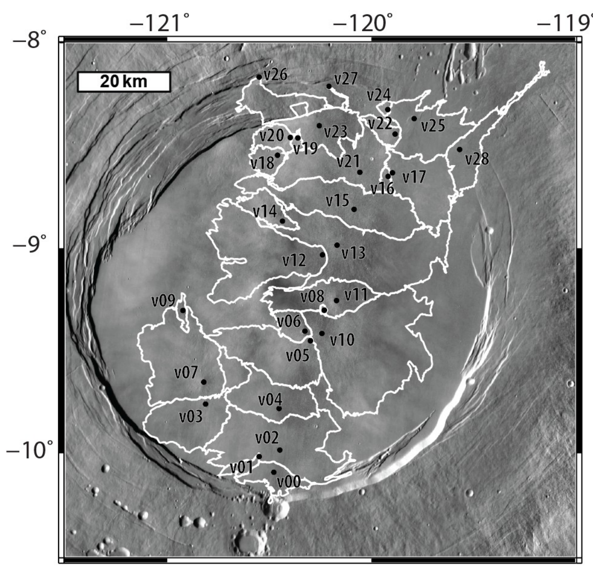

Fig. 1. Map of 29 volcanic edifices produced by volcanic vents in the Arsia Mons Caldera. Edifices are outlined in white. Vents are black dots and are labeled, corresponding to vent numbers in other figures.

Crater Age-dating: In addition to stratigraphic information, craters with diameters >60m have been counted within edifice perimeters with CTX images to provide age estimates. Craterstats2 is used to model ages based on crater counts binned by diameter [5].

Ages and uncertainty are estimated for each volcanic edifice. Our results show that the Arsia Caldera volcano cluster was likely formed over the past 500 Ma (Fig. 3).

Recurrence Rate Estimation: We have produced an algorithm to assess the recurrence interval of volcanic events in a distributed volcanic field by estimating the range of potential ages for each mapped event. Called the Volcanic Event Recurrence Rate (VERRM) model,

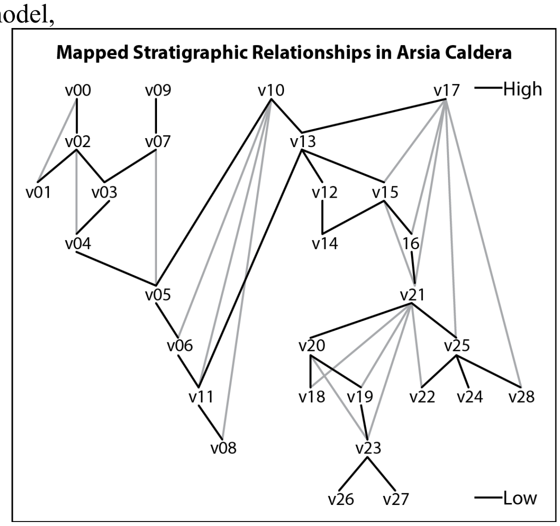

Fig. 2. Mapped stratigraphic relationships between vents are symbolized here as lines. "Redundant" lines that have been mapped are in gray. Vent numbers that are higher in the chart are stratigraphically higher than connected vents that are lower.

the code accepts stratigraphic information and other date models, in this case crater age-dating estimates, in order to create a recurrence rate estimate for eruptions in an entire volcanic field. VERRM runs in a Monte Carlo fashion, seeking to assign ages to all volcanic events in a consistent way that does not violate information gained from stratigraphic or age model data. By creating thousands of potential age models for events in an entire field, the uncertainty in the recurrence rate of volcanism, here defined as the rate of formation of a new mapped vent, is elucidated.

VERRM first identifies vents that have a high number of stratigraphic relationships with other vents, and assigns dates to these vents first, based on modeled age results. In this case ages are assigned from crater-count derived dates using a random normal distribution with 1σ being the standard uncertainty reported from craterstats2. The model then assigns dates to neighboring vents with their modeled ages, but only accepts dates that do not violate stratigraphic information. The ultimate output is a potential age for each volcanic event. By performing this thousands of times, the range of potential ages for each volcano is modeled.

The potential ages of volcanic events from the VERRM algorithm are plotted on the right of Fig. 3. We find that the modal recurrence interval of the youngest 20 events is one event per ~11 Ma. Older vents have longer intervals between eruptions, possibly due to missing vents.

Conclusions: Recent volcanism in the Arsia Mons caldera peaked between 100 and 200 Ma, as evidenced by crater retention rates. Stratigraphy can further constrain event dates. On Arsia Mons, vents have recently been created over time at a rate of ~11 Ma.

References:

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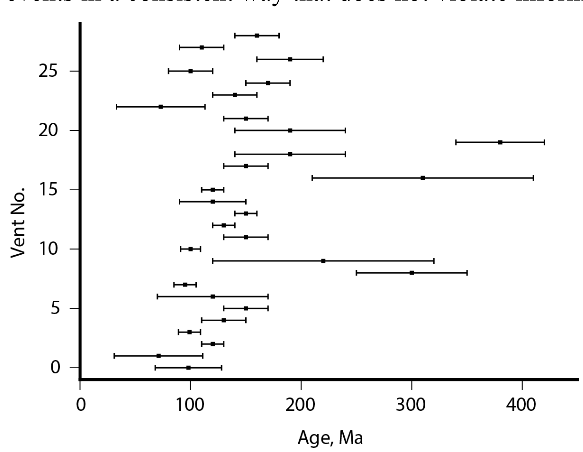

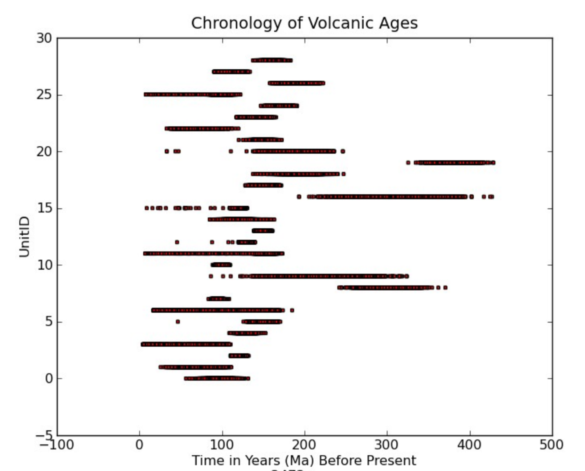

Fig 3. Age estimates for mapped Arsia Caldera vents. Left, results from age modeling using crater counts alone. Right, potential vent ages with the VERRM model, incorporating stratigraphic information to constrain crater-derived ages.