Modeling the Construction and Evolution of Distributed Volcanic Fields on Earth and Mars

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19 February 2016

Acknowledgements

Some Collaborators

Chuck Connor	James Wilson
Laura Connor	Lis Gallant
Sylvain Charbonnier	Julia Kubanek
Judy McIlrath	Jake Bleacher
Paul Wetmore	Lori Glaze

Funding Agencies

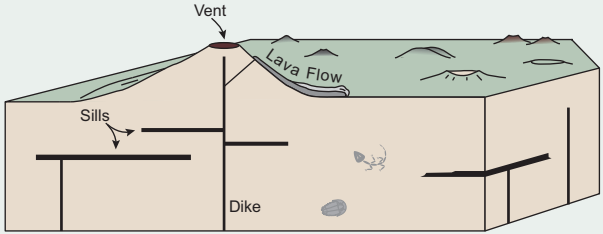
NASA Mars Data Analysis Program
NSF SSI

Introduction

Distributed-style Volcanism

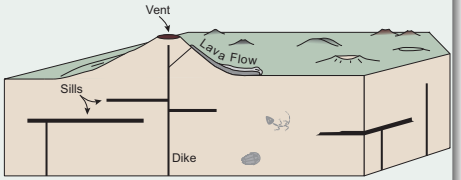
Characteristics:

- Clusters of volcanoes are formed
- Single eruptions at each location
- Isolated dikes ascend individually
- Long periods of quiescence



Outline of Talk

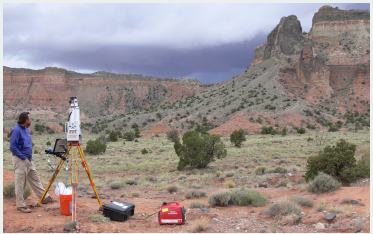
- Overview of Dissertation
  - The role of sills in the formation of volcanic fields
  - Simulating lava flows
  - The spatial organization of volcanoes in volcanic fields
  - The history of a volcanic field on Mars, Syria Planum
- Waning volcanism at Arsia Mons, Mars
  - Mapping the latest volcanism at Arsia
  - Estimating eruption timing, magnitude
  - Implications of the rate of volcanism
- Conclusions



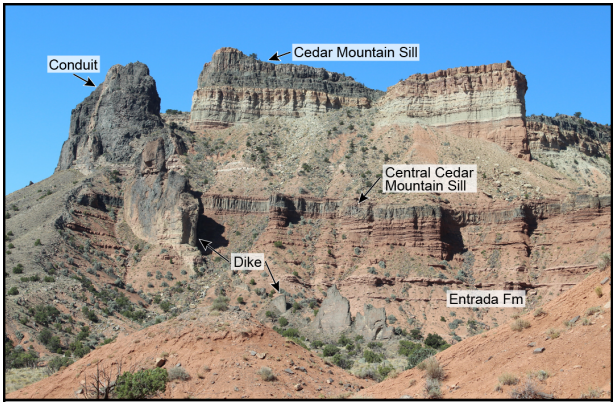
Sills in the San Rafael Swell

San Rafael Volcanic Field, Utah

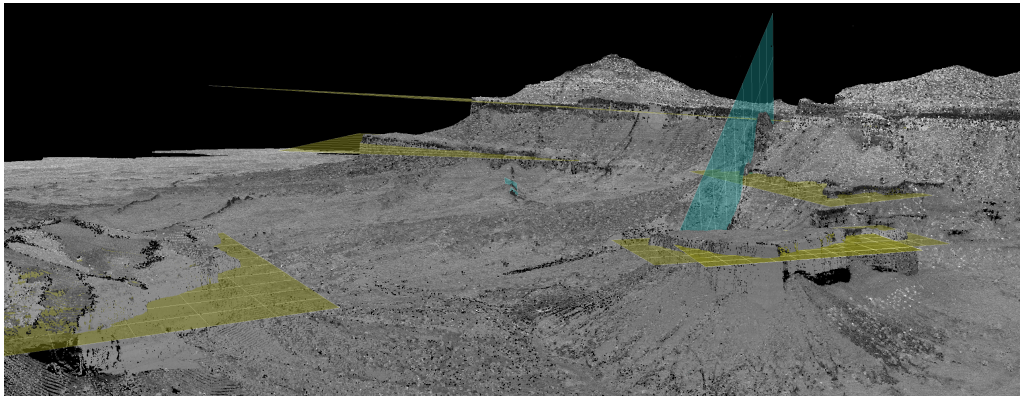
- Pliocene volcanic activity
- Now eroded to depth of $\sim$1 km
- Sills and Dikes exposed



Chuck Connor with a Terrestrial Lidar



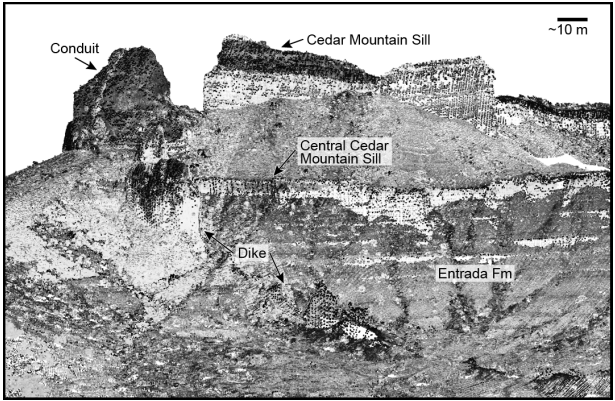
Sills in the San Rafael Swell



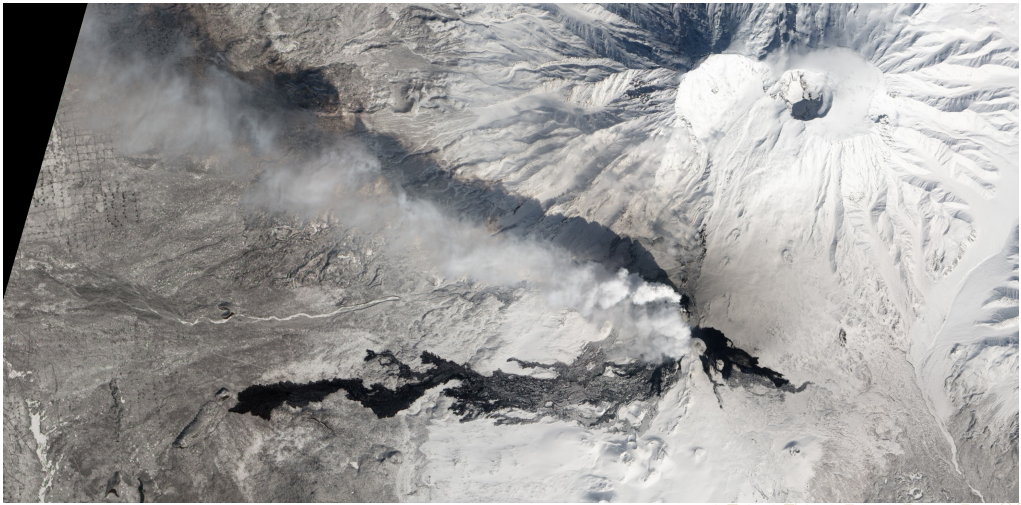
Sills in the San Rafael Swell

Results of lidar survey

- >90% of igneous rock is stored in sills
- Sill volume comparable to volume thought to have erupted at surface
- Sills had ability to modulate eruption style



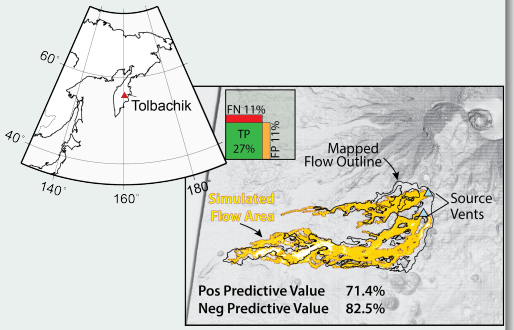
Lava Flows/Simulators



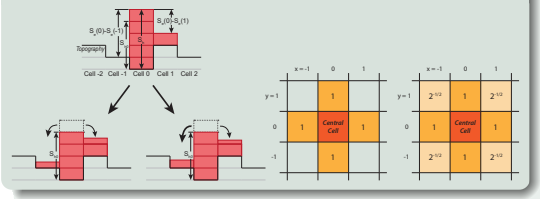
MOLASSES — Modular Lava Simulation Software

- MOLASSES developed after Connor et al. 2012
- Spreads lava over a grid according to universal rules

Using TanDEM-X satellite data, flow simulations match the 2012-3 Tolbachik flow between 70-85%.



Optional Spreading Rules

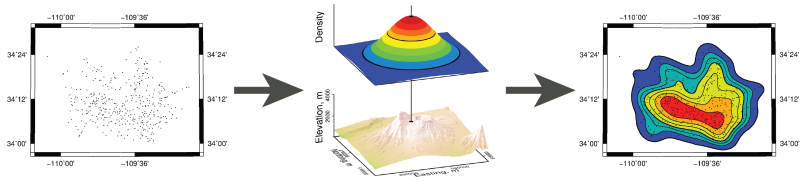


Spatial Density of Clusters

- Spatial density of volcanoes is modeled by Kernel Density Estimation
- Size of volcanic field determined by a set contour (95%)

$$\text{Average vent intensity} = \frac{\text{volcanic vents}}{\text{field area}}$$

- This is applied to fields on Earth, Mars, and Venus

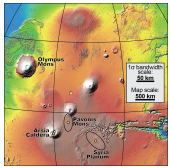


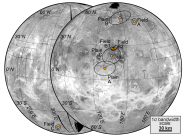
A plot of every volcanic vent location in the San Francisco Volcanic Field

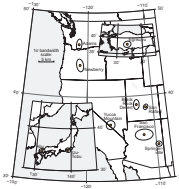
Drape a Gaussian Kernel Function over each vent

Add each function to coalesce a density model

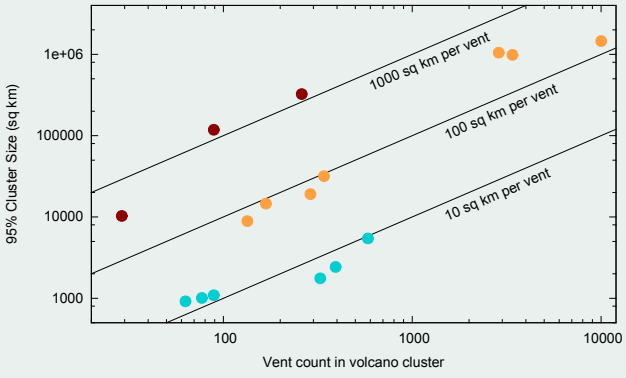
Spatial Density of Clusters



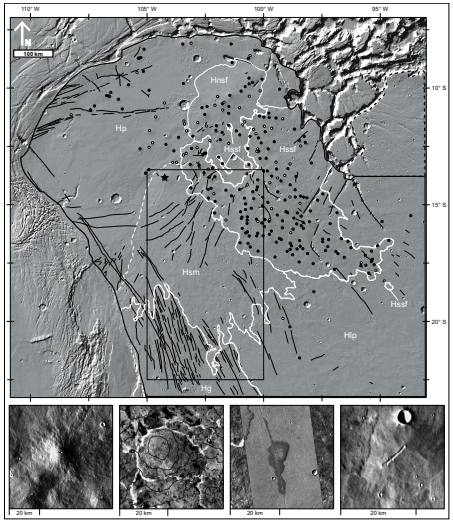




Average Vent Intensity, Colored by Planet

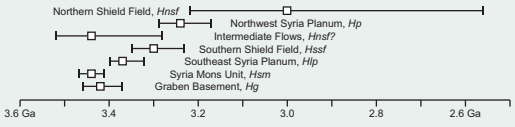


Syria Planum

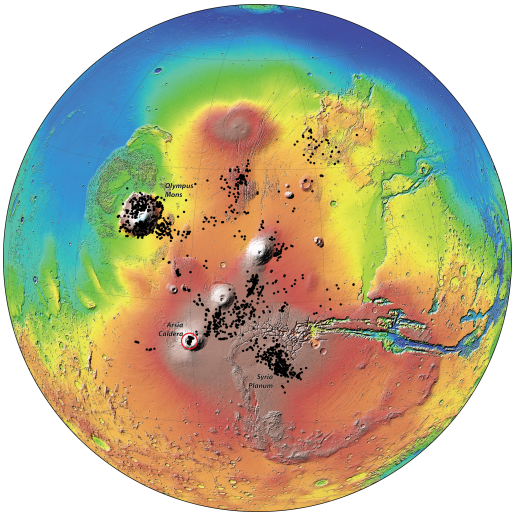


Evolution of a Martian volcano cluster

- Volcanic vents have been cataloged on Syria Planum
- Volcanic units are ID'd with geomorphology and embaying flow fronts
- Region was active for 900 Ma (3.5-2.6 Ga)
- volcanism center shifted with time



Distributed Volcanism of the Tharsis Volcanic Province



Tharsis Vent Catalog

- >1,000 small volcanic vents cataloged by J. Bleacher and others
- Vents form in different clusters

Research Questions

- How does distributed-style volcanism occur over time and space in Tharsis?
- How do volcanic fields relate to the larger volcanoes on Mars?

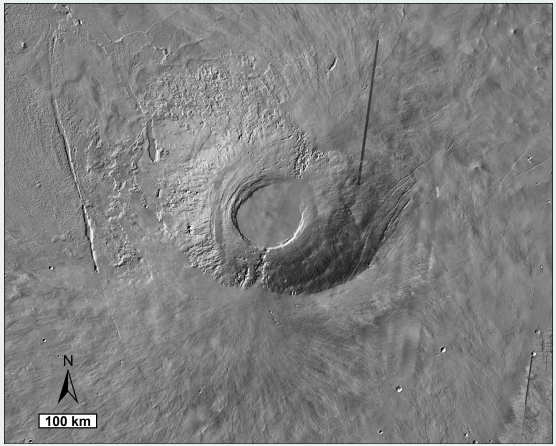
Arsia Mons Overview

Arsia Mons

- Large ($1.5{\cdot}10^6$ km^3) shield volcano with 110 km diameter caldera
- A cluster of volcanic vents lay in the caldera!

Motivation

What are the recurrence rate of volcanism and delivery rate of magma to the surface?



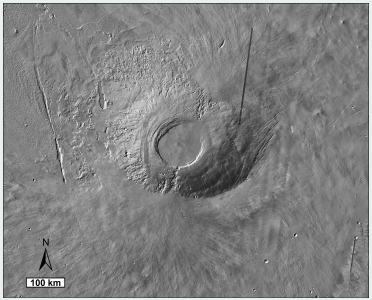
Arsia Mons Overview

Recurrence Rate and Magma Delivery Rate

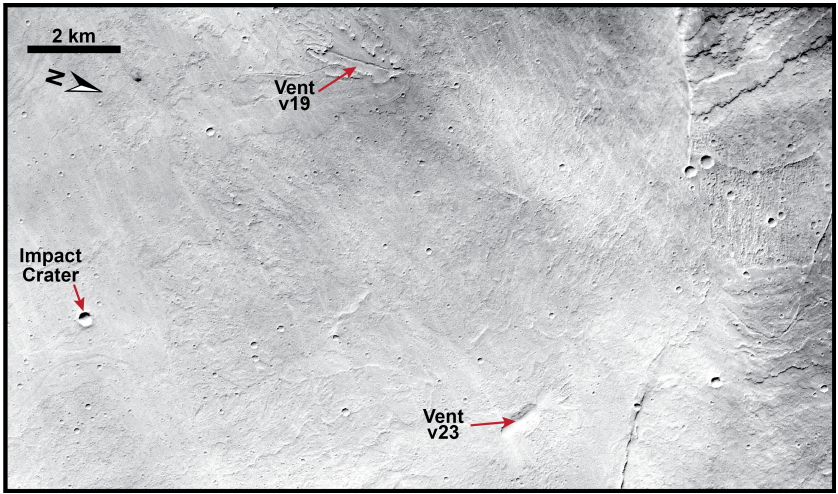
$$\text{Recurrence Rate} = \frac{\text{Number of Events - 1}}{\text{Time elapsed}}$$

$$\text{Delivery Rate} = \frac{\text{Volume per event}}{\text{Number of Events}} \cdot \text{Recurrence Rate}$$

- Lavas from these vents can be mapped to estimate volume and timing of emplacement

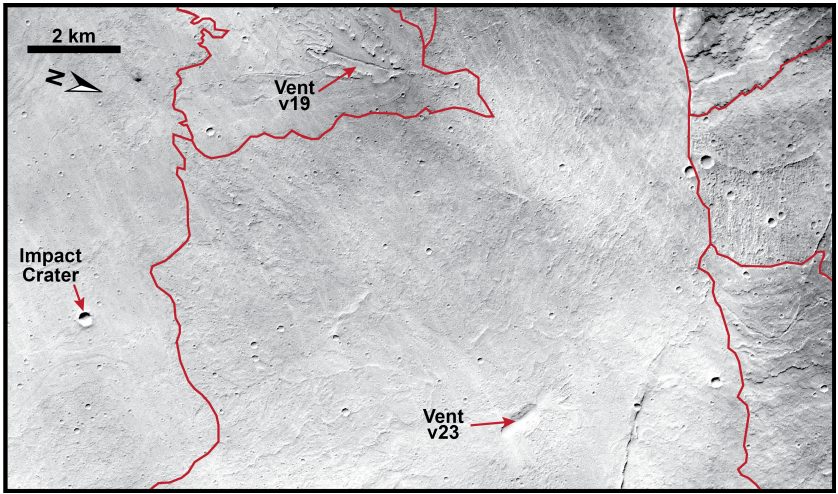


Mapping



CTX Image: G10_022160_1710_XN_09S120W (NASA/JPL-Caltech/MSSS)

Mapping



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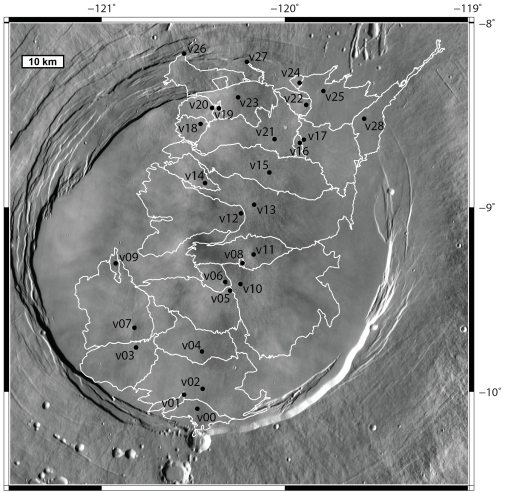
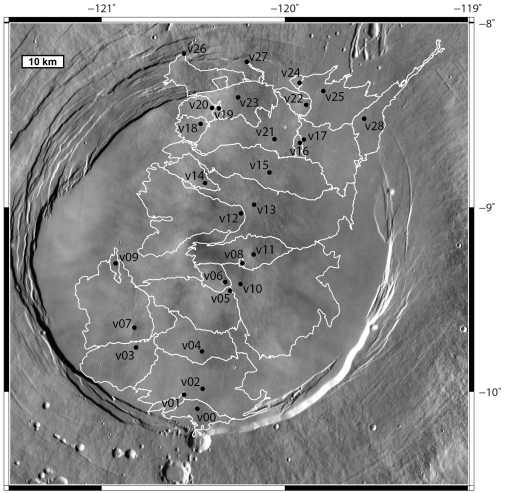
Mapping

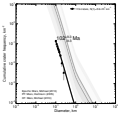


Mapping results

- 29 vents are cataloged, each with long lava flows
- Lava flow areas are 10s–100s km^2
- Flow thicknesses assumed to be 10–80 m (Mouginis-Mark & Rowland, Icarus, 2008)
- From this, volumes estimates range from 10^{-2}–70 km^3

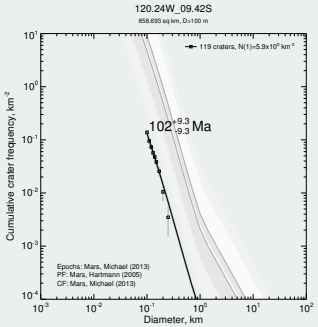
Ages: Crater Counting

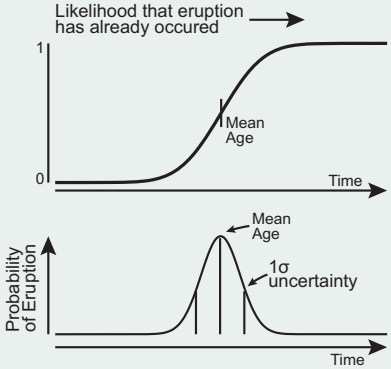




Ages: Crater Counting

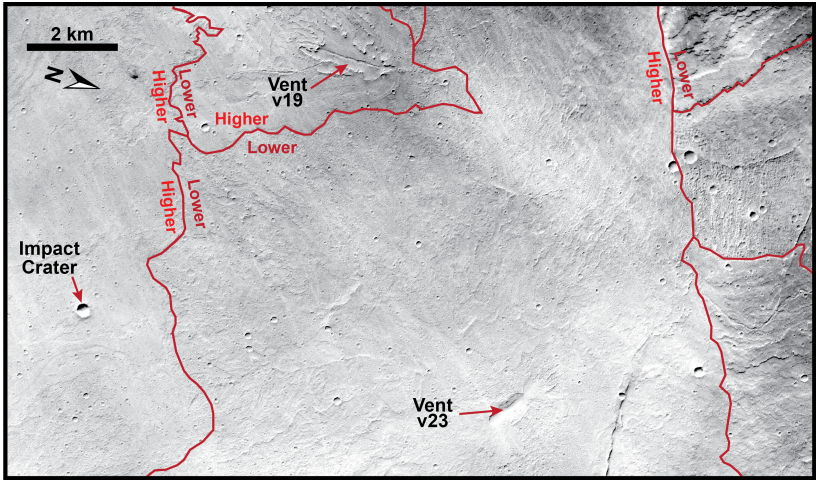
Age estimates from craterstats2 form normally distributed models of emplacement





time.

Ages: Stratigraphy



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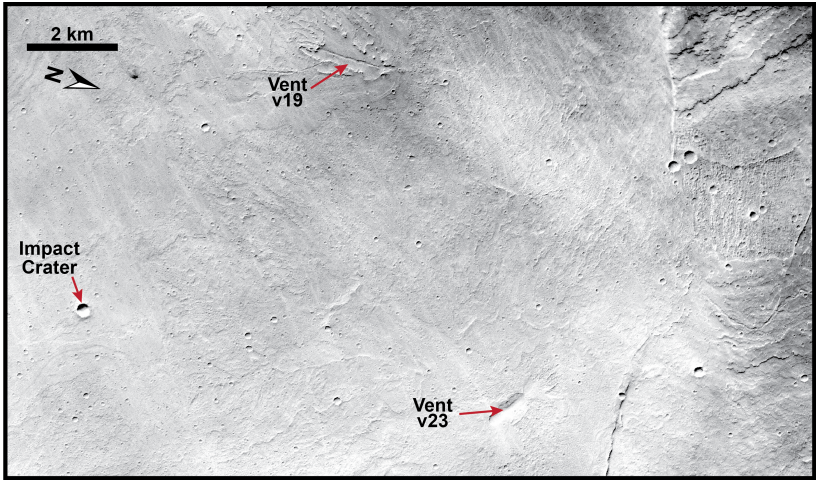
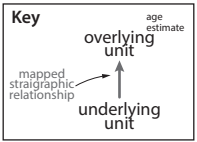
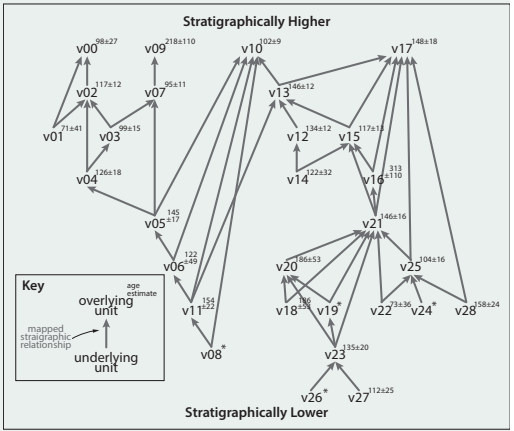
Ages: Stratigraphy

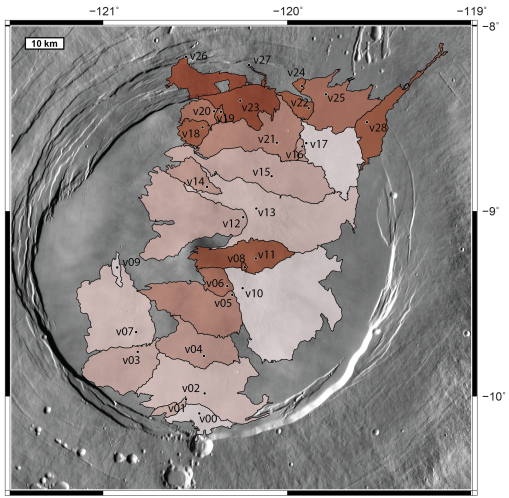




CTX Image: G10_022160_1710_XN_09S120W (NASA/JPL-Caltech/MSSS)

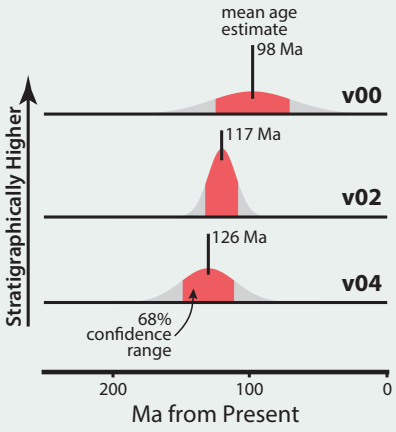
Stratigraphy "Web"

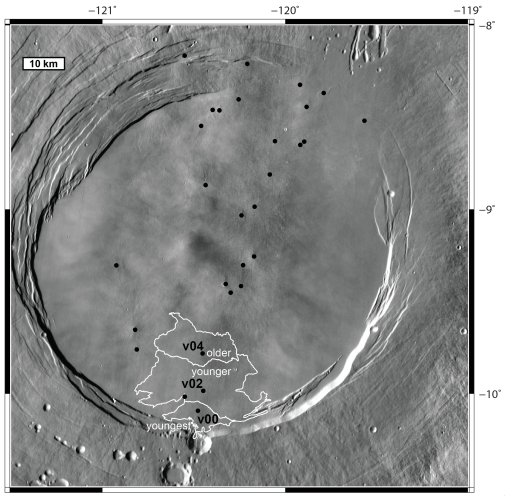




Ages: Information Conflicts

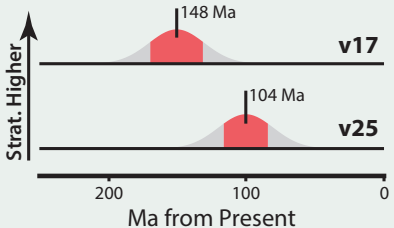
Mean crater ages can agree stratigraphy...

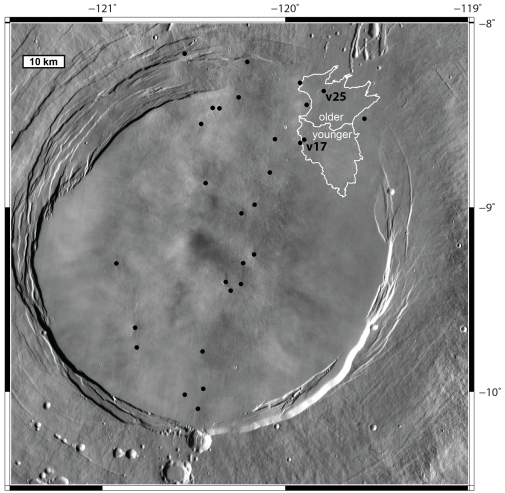




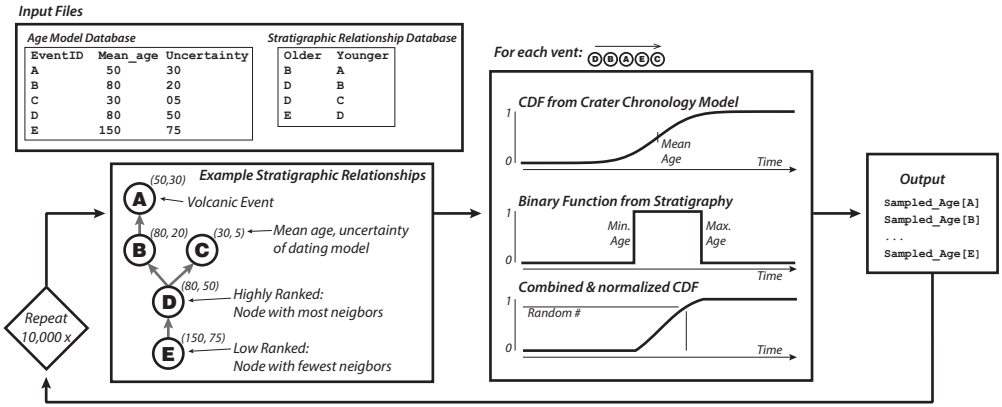
Ages: Information Conflicts

... or they can disagree



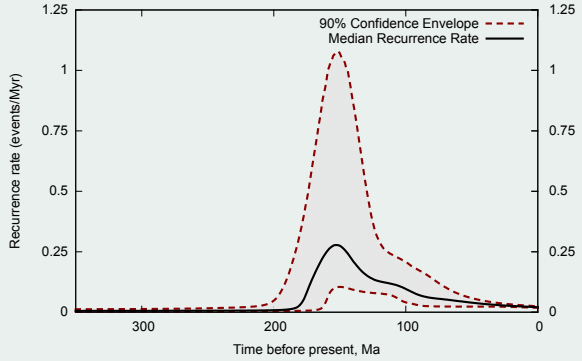


VERRM



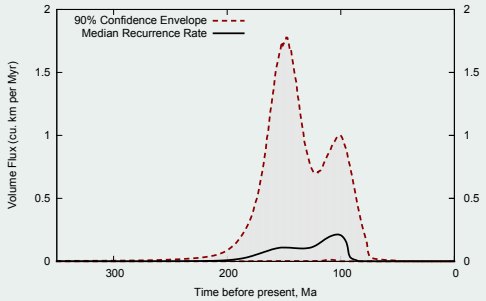
Results

Recurrence Rate

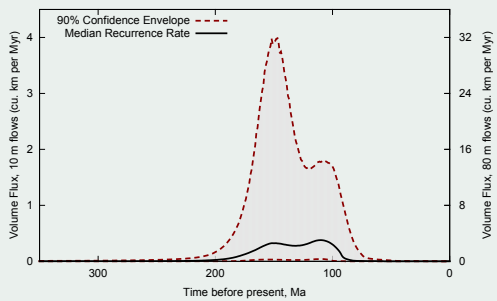


Volume Flux

Sub-surface mesh model



Thickness model



Tie in with Ashes and glaciers?

Model of waning volcanism of Arsia

Arsia Specific Conclusions

Other Conclusions

Additional Thanks

Questions?