

Volcanic  
Fields on  
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Jacob  
Richardson

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Lava Flows

Vent Density

Mars Clusters

Arsia Mons  
Volcanic Field

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

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University of South Florida

19 February 2016

# Acknowledgements

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## Some Collaborators

Chuck Connor

Laura Connor

Sylvain Charbonnier

Judy McIlrath

Paul Wetmore

James Wilson

Lis Gallant

Julia Kubanek

Jake Bleacher

Lori Glaze

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NSF SSI

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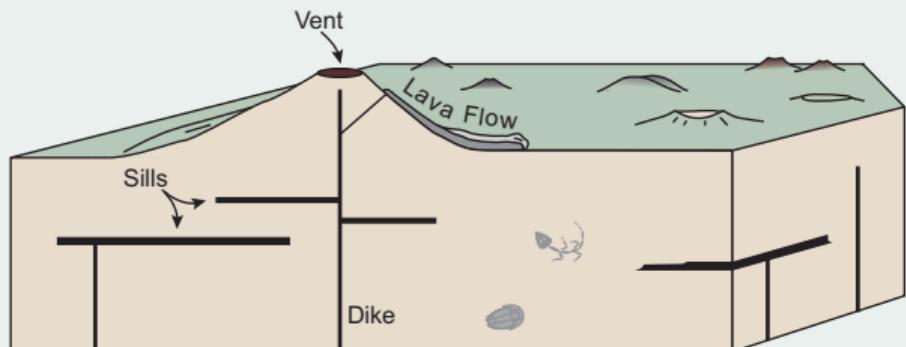
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## Distributed-style Volcanism

Characteristics:

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



# Outline of Talk

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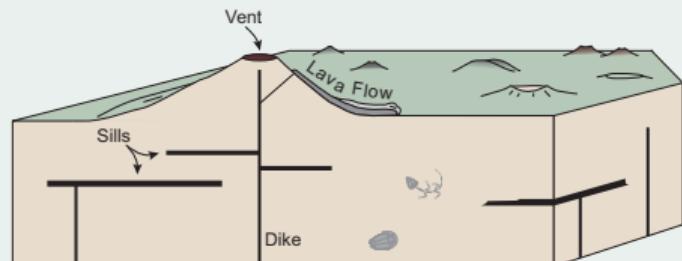
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- Overview of Dissertation
  - The role of sills in the formation of volcanic fields
  - Simulating lava flows
  - The spatial organization of volcanoes in volcanic fields
  - The history of a volcanic field on Mars, Syria Planum
- Waning volcanism 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

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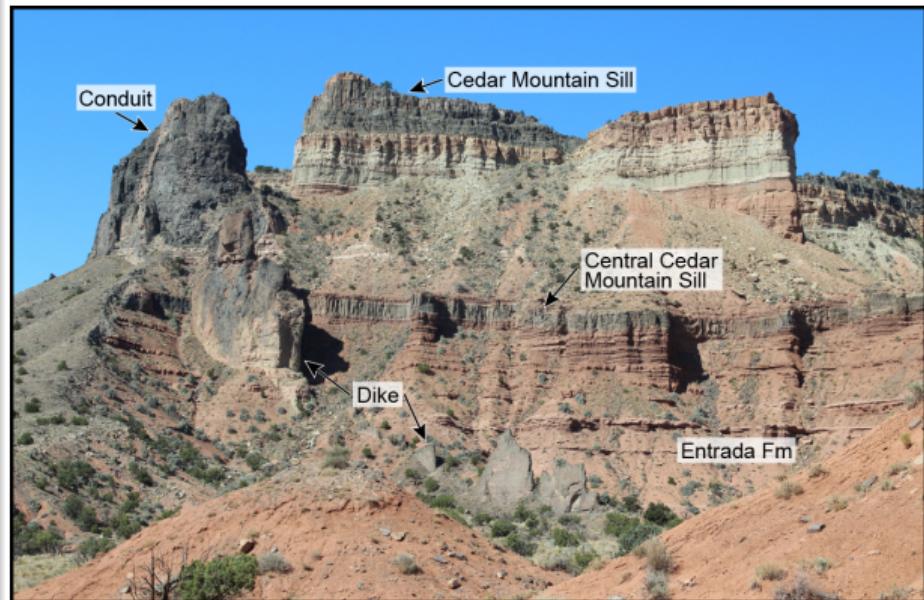
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## San Rafael Volcanic Field, Utah

- Pliocene volcanic activity
- Now eroded to depth of ~1 km
- Sills and Dikes exposed



Chuck Connor with a Terrestrial Lidar



# Sills in the San Rafael Swell

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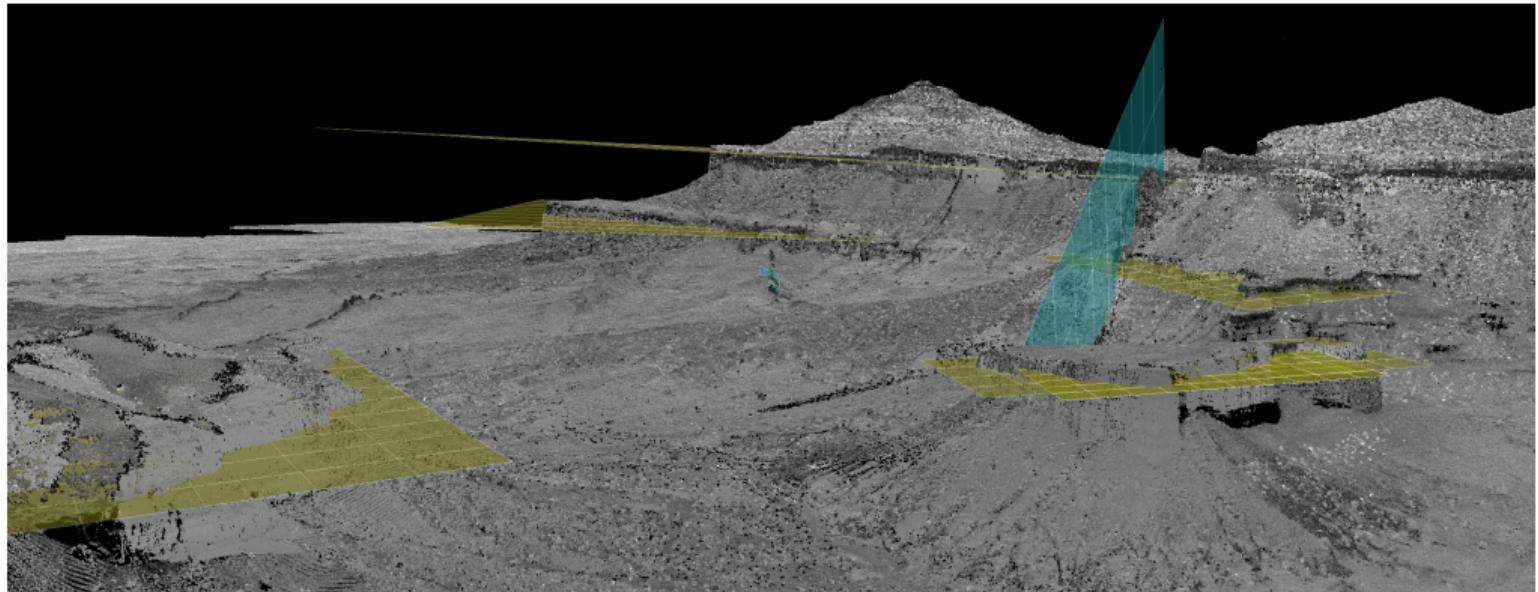
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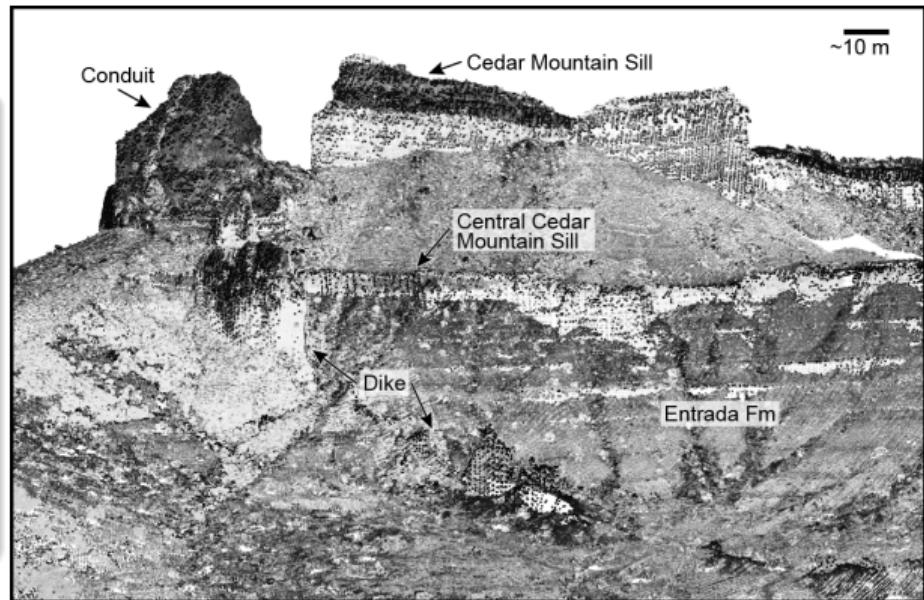
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## Results of lidar survey

- >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

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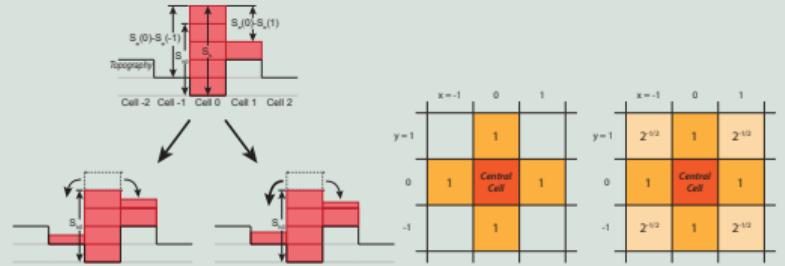
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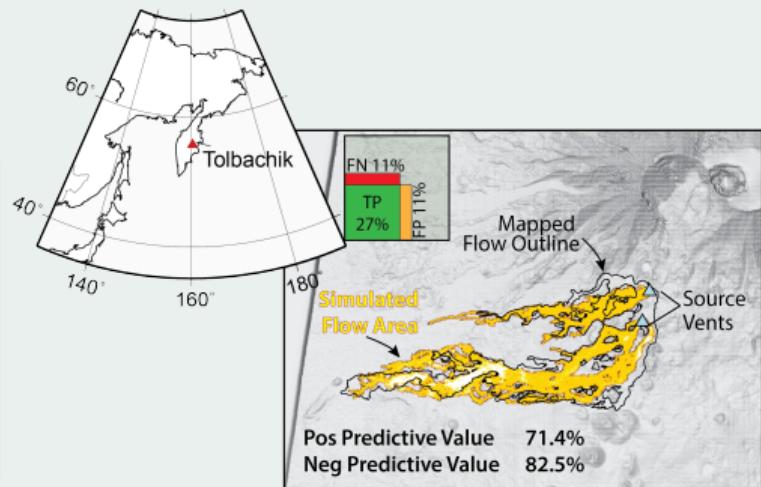
## MOLASSES — Modular Lava Simulation Software

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

### Optional Spreading Rules



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

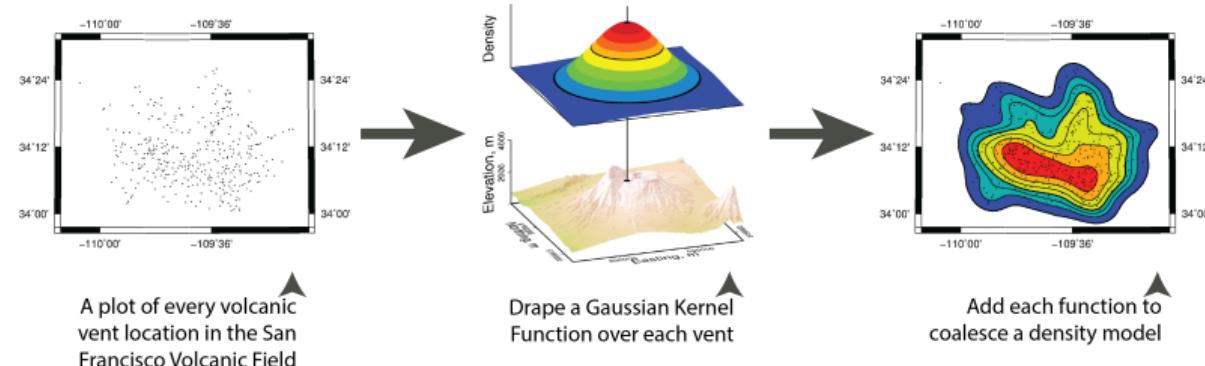


# Spatial Density of Clusters

- 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



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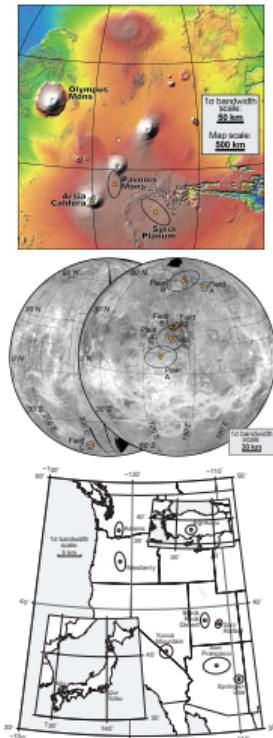
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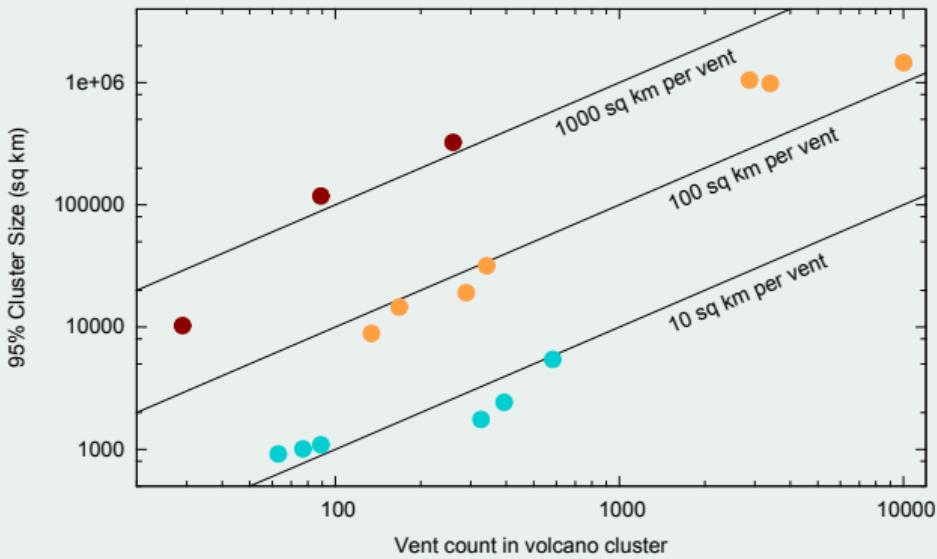
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Average Vent Intensity, Colored by Planet



# Syria Planum

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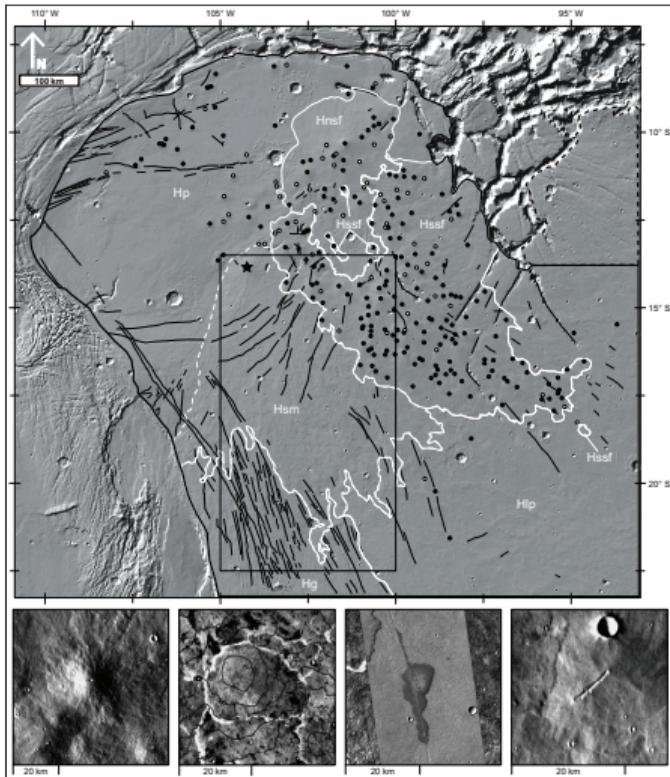
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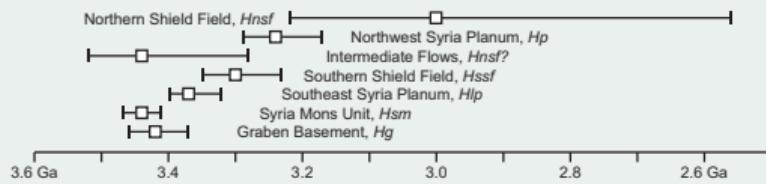
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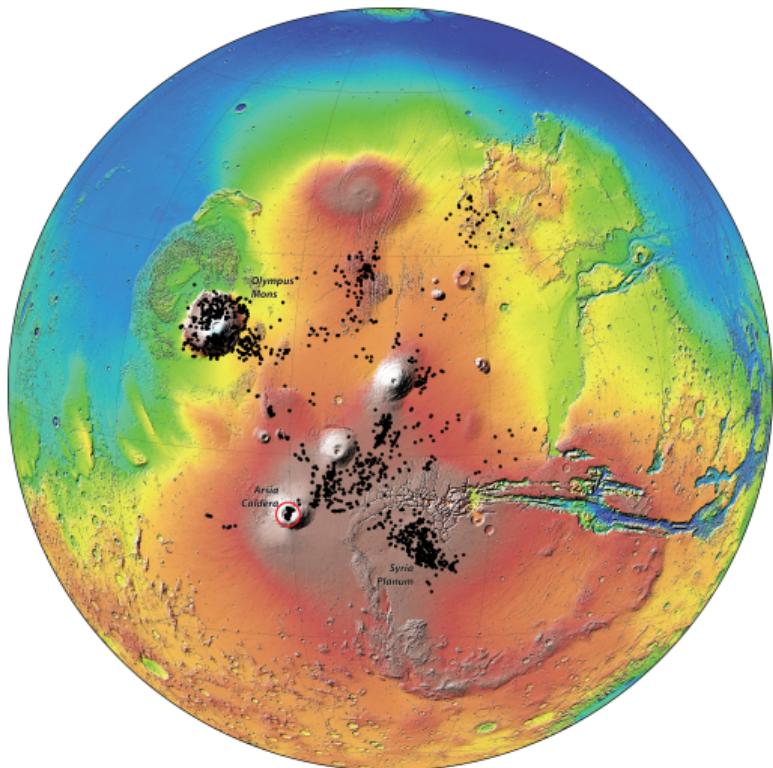


## Evolution of a Martian volcano cluster

- 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?

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## Arsia Mons

- Large ( $1.5 \cdot 10^6 \text{ km}^3$ ) 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?



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## 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

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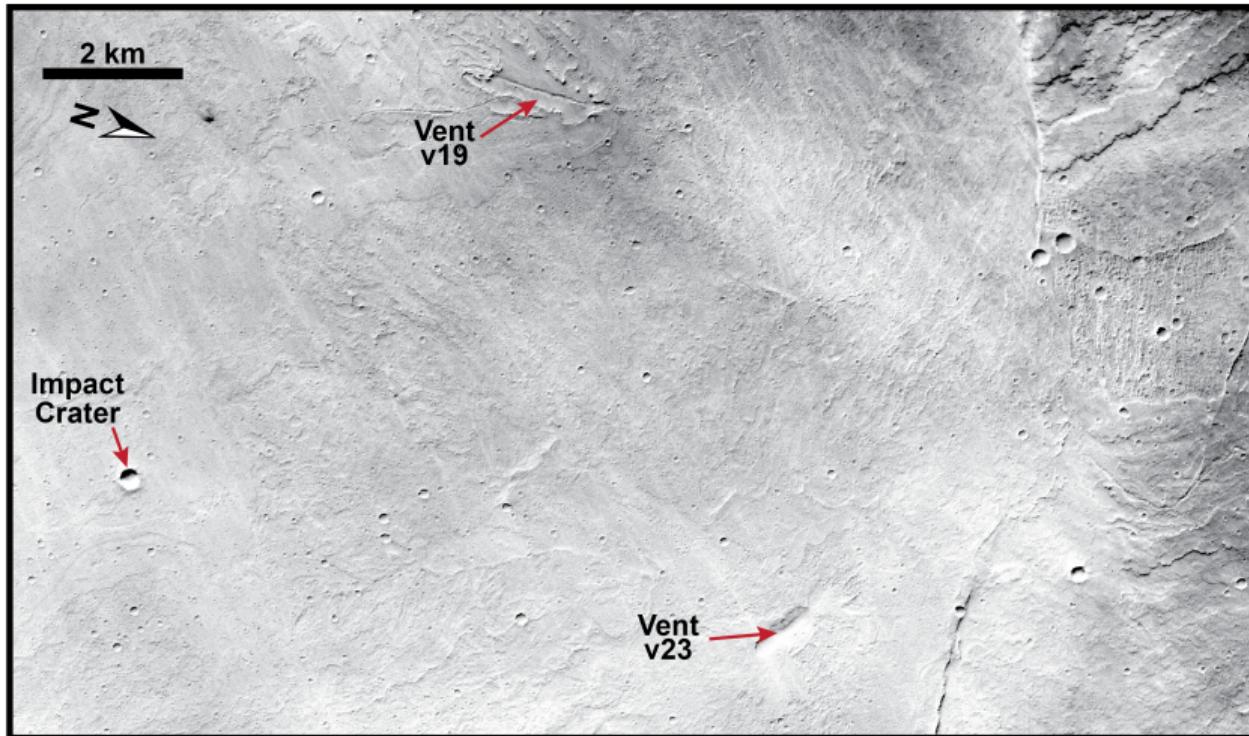
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CTX Image: G10\_022160\_1710\_XN\_09S120W (NASA/JPL-Caltech/MSSS)

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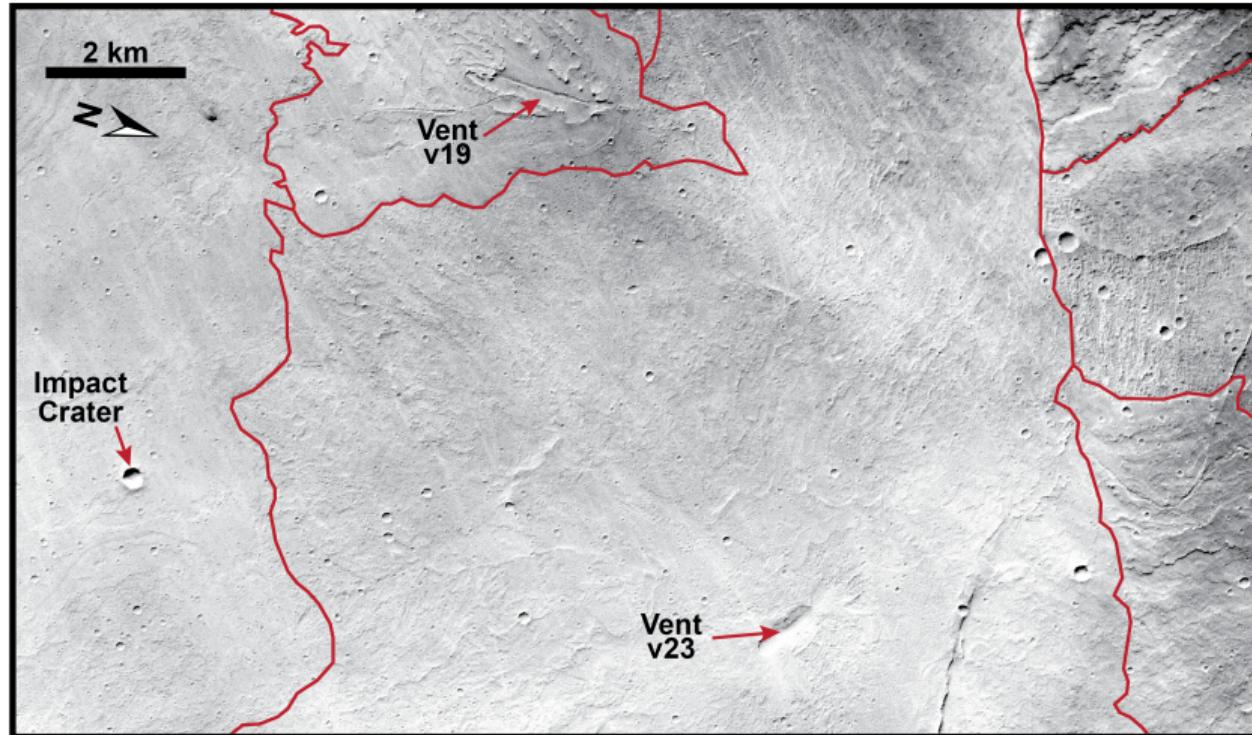
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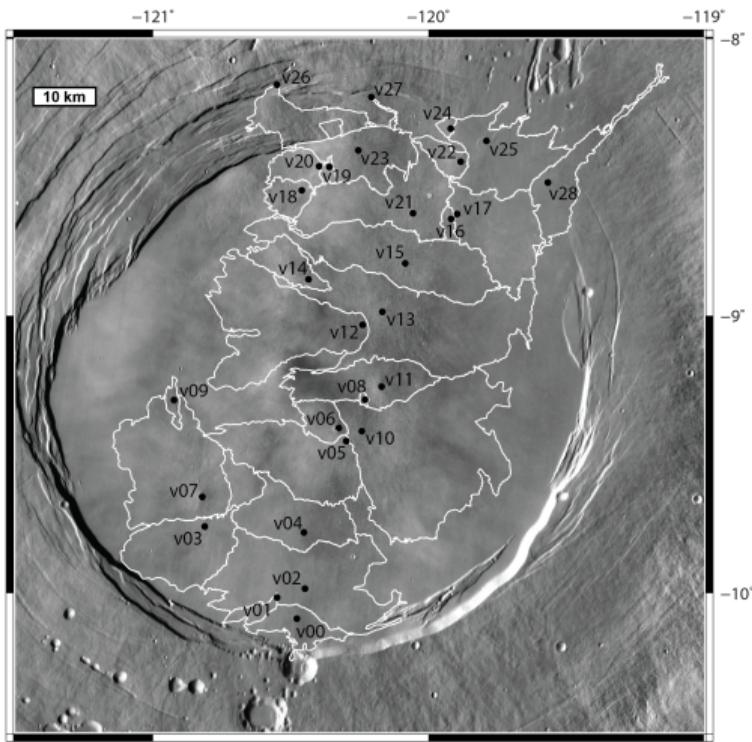
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## Mapping results

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

# Ages: Crater Counting

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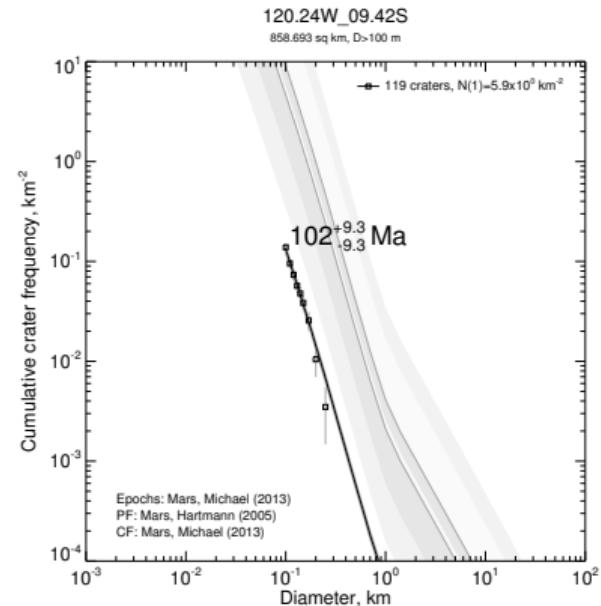
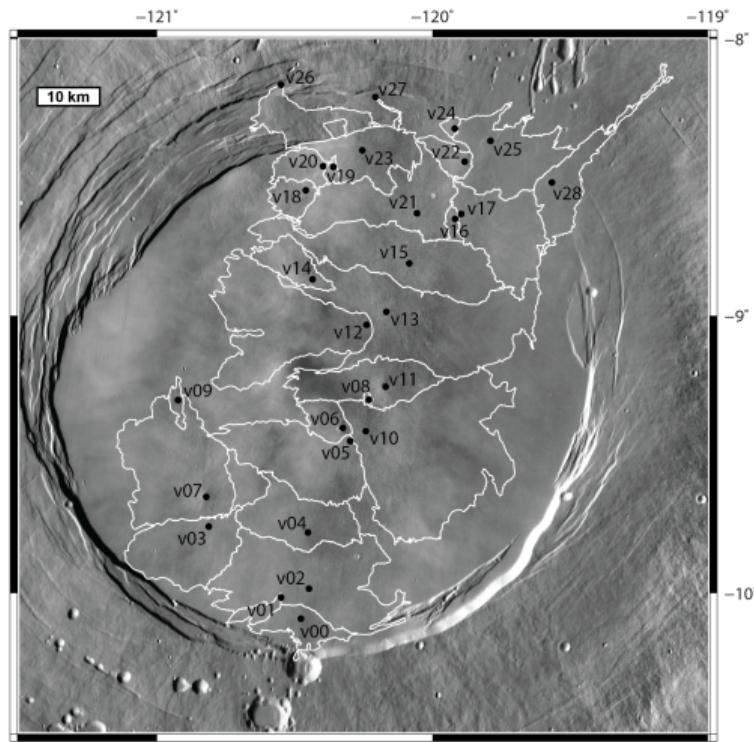
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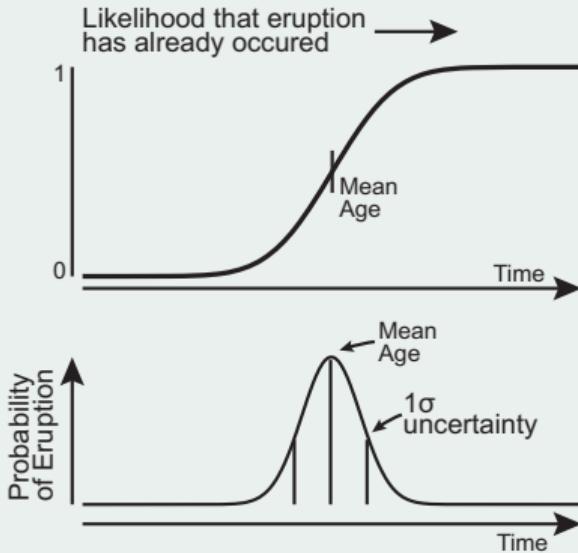
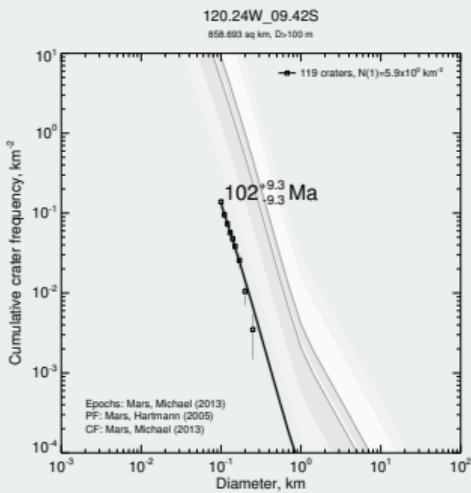
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craterstats2 results form normally distributed models of emplacement time.



# Ages: Stratigraphy

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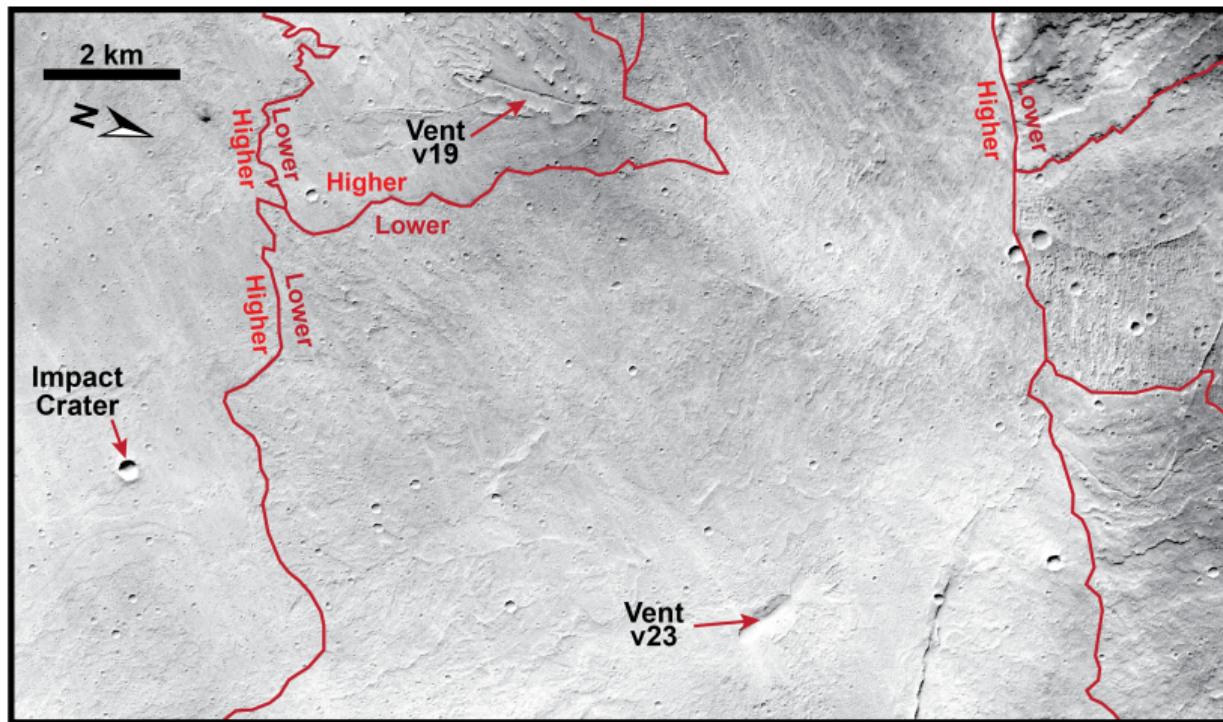
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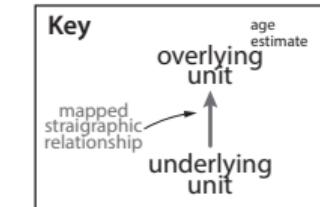
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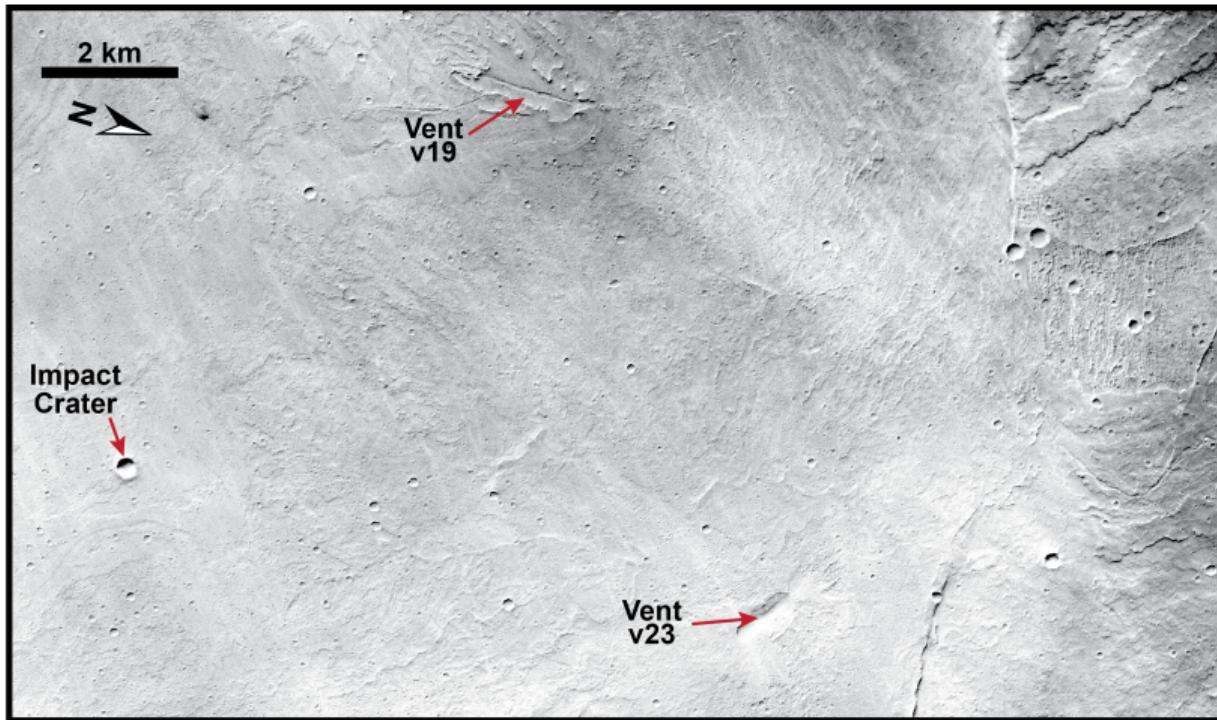
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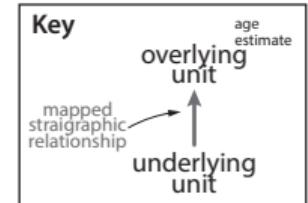
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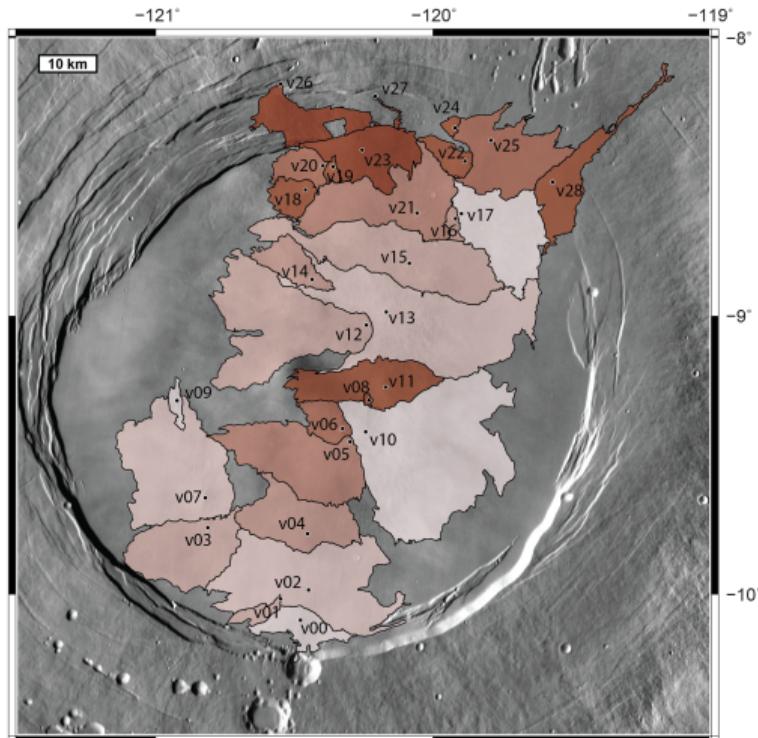
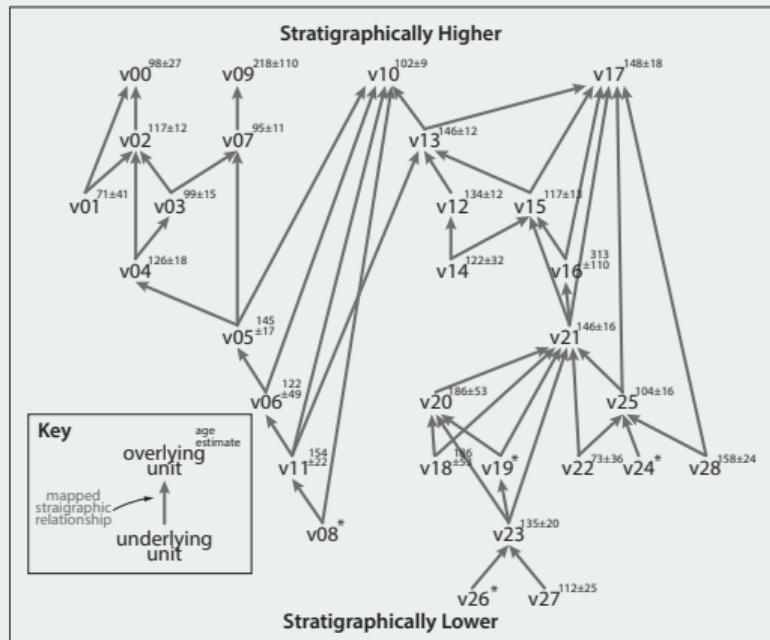
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## Stratigraphy “Web”



# Ages: Information Conflicts

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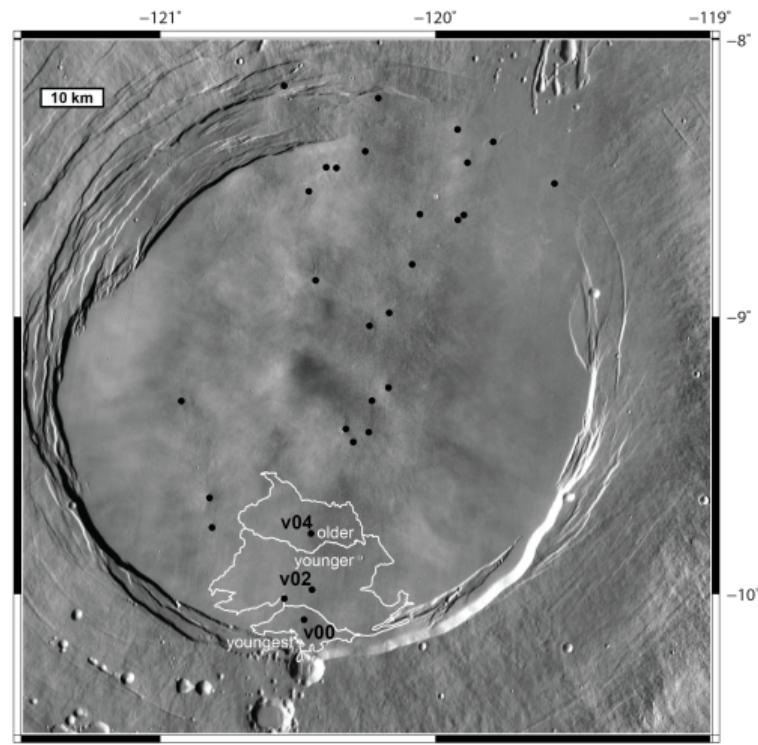
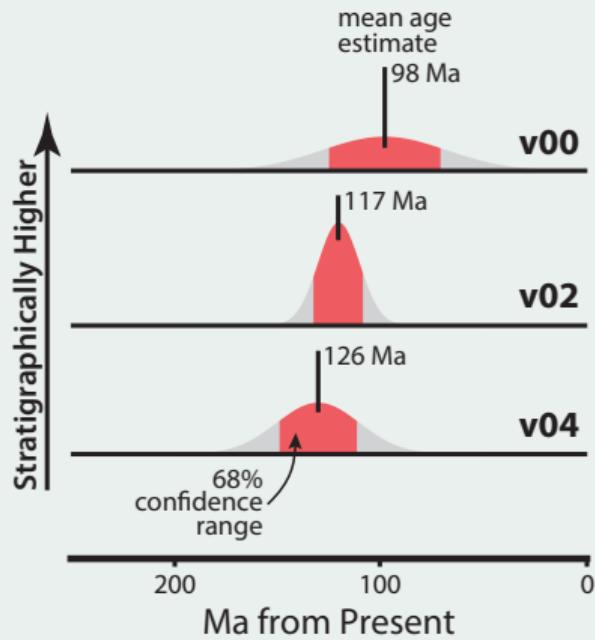
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Mean crater ages can agree stratigraphy...



# Ages: Information Conflicts

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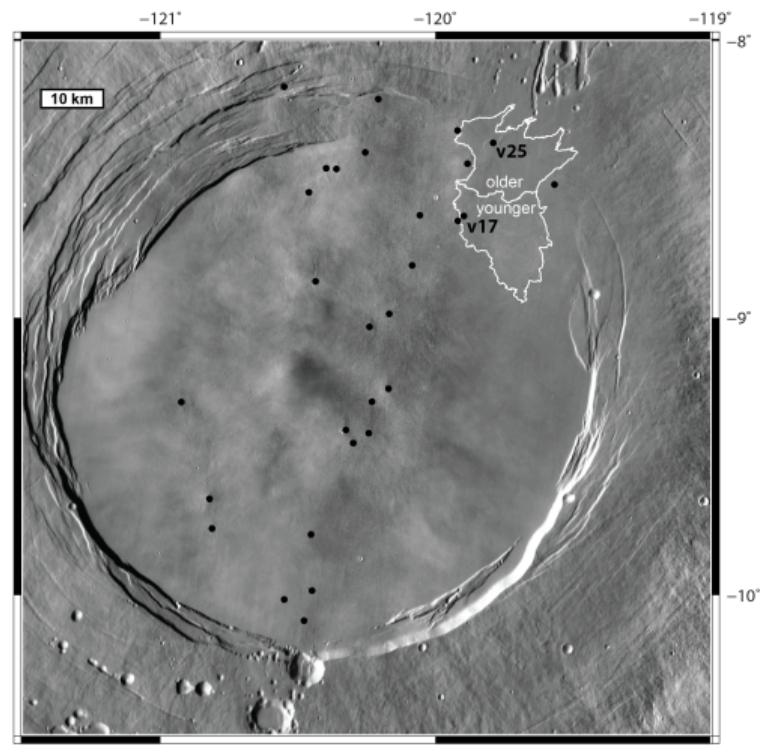
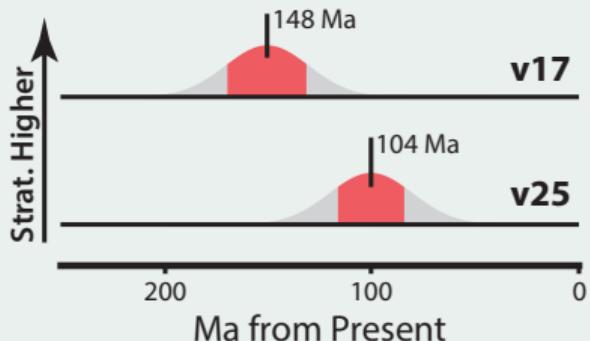
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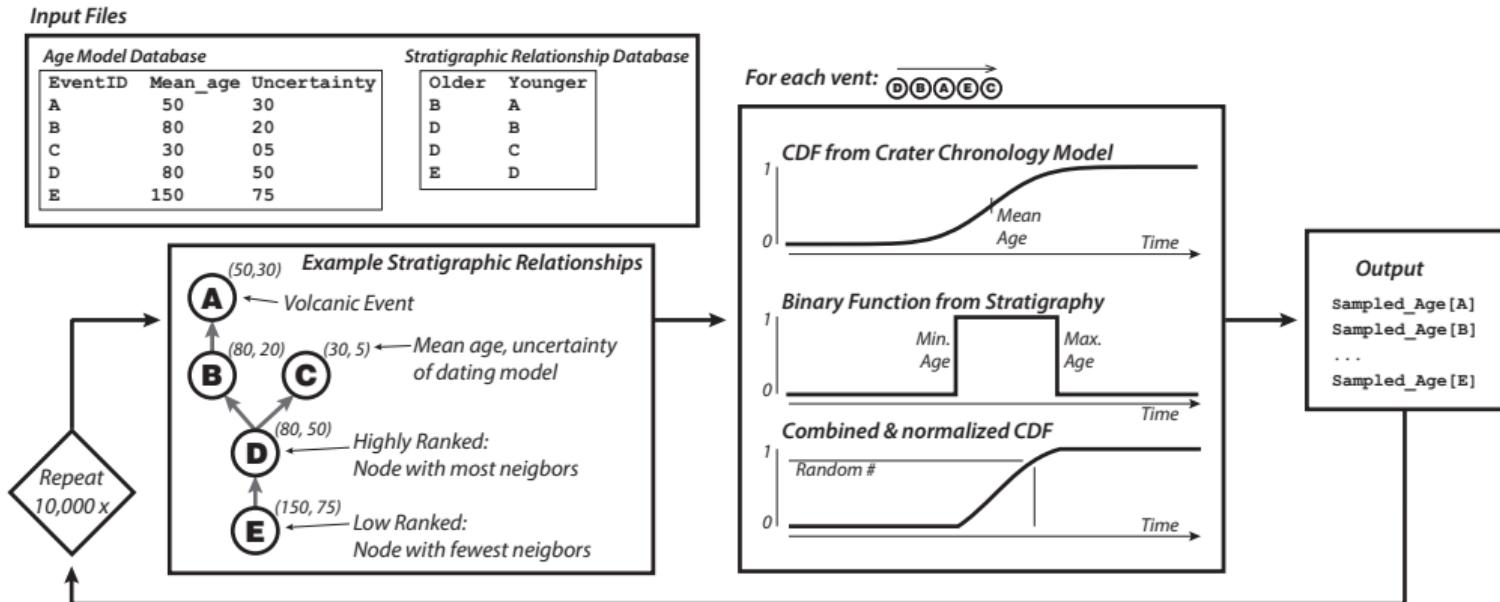
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... or they can disagree





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## Recurrence rate calculation Volume Flux Calculation

# Results

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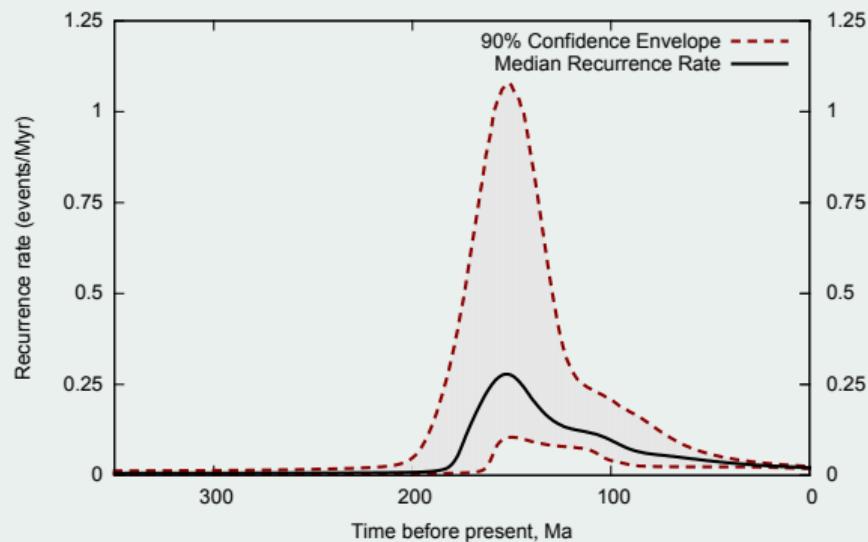
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# Volume Flux

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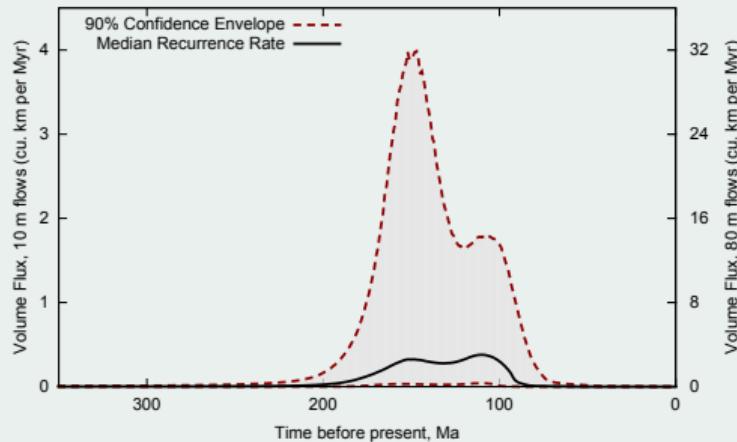
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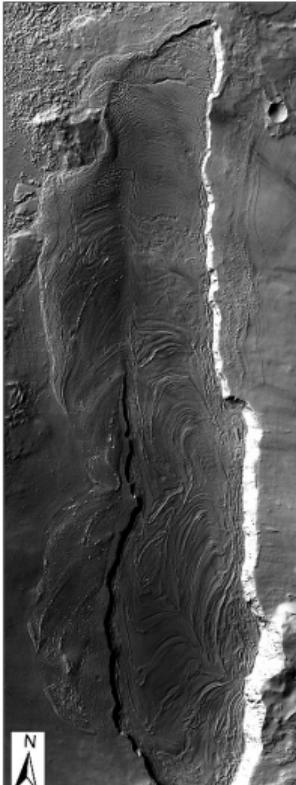
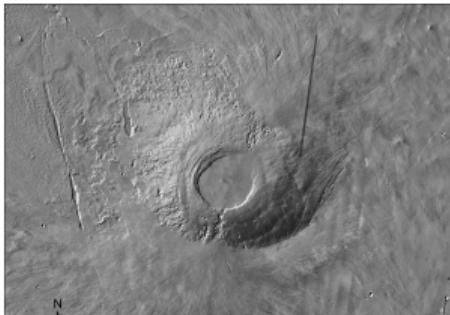
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## Discharge rate through time



# Tie in with Ashes and glaciers?



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# Model of waning volcanism of Arsia

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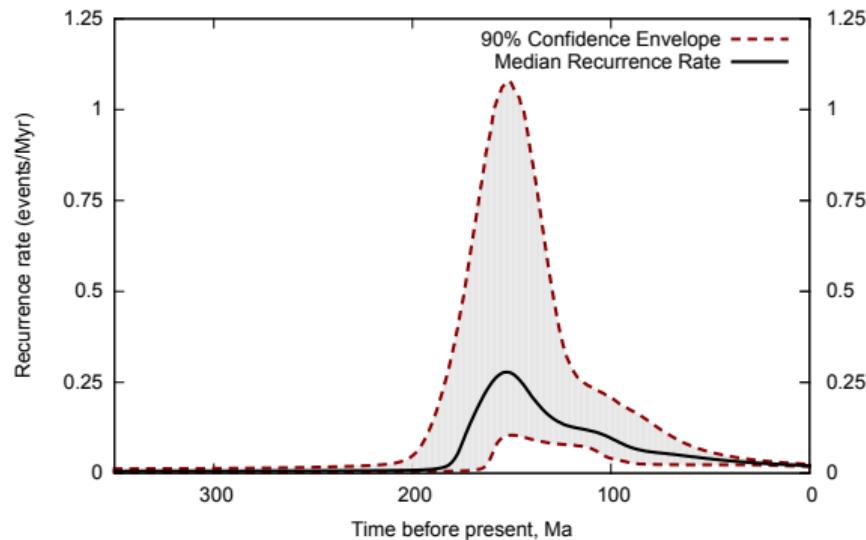
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Volcanism transitioned from explosive to effusive  
Corresponds to a waning of recurrence rate of volcanism



# Arsia Specific Conclusions

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# Additional Thanks

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