Barometric Pumping Through Fractured Rock

A Mechanism for Venting Deep Underground Methane to Mars' Atmosphere

PRESENTER:

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GOAL To determine if **deep** (~200 m) barometric-pressure pumping can explain atmospheric methane variations on **Mars**.

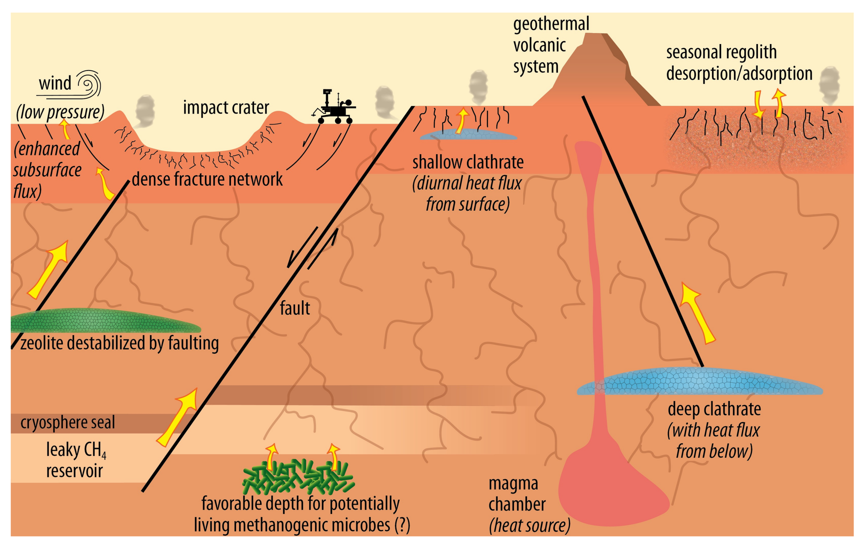

Fig. 1. *Possible sources and transport pathways of methane on Mars.*

BACKGROUND Methane on Mars is a topic of significant interest because of its potential association with **microbial life** deep underground. Atmospheric methane measurements indicate that its abundance fluctuates over **short and seasonal timescales**. We model an **advective** gas-transport mechanism (**barometric pumping**) capable of delivering methane from **habitable depths** rapidly, which could cause the observed short-term atmospheric concentration variations.

BAROMETRIC PUMPING This mechanism has been studied extensively on Earth as a driver of deeply-sourced gas transport in **fractured rock**.

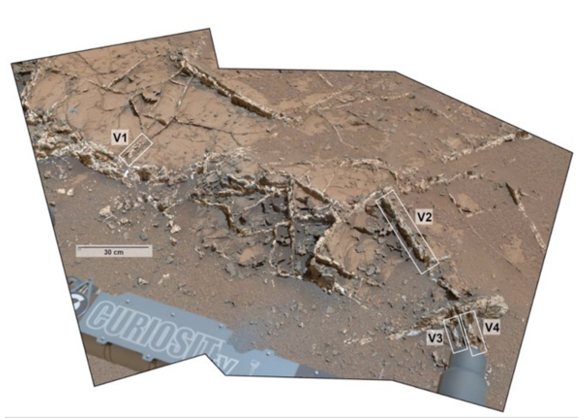

Fig. 2. *Mars' subsurface is heavily fractured. Curiosity made this mosaic of the Garden City vein complex at Gale crater (Kronyak et al., 2019).*

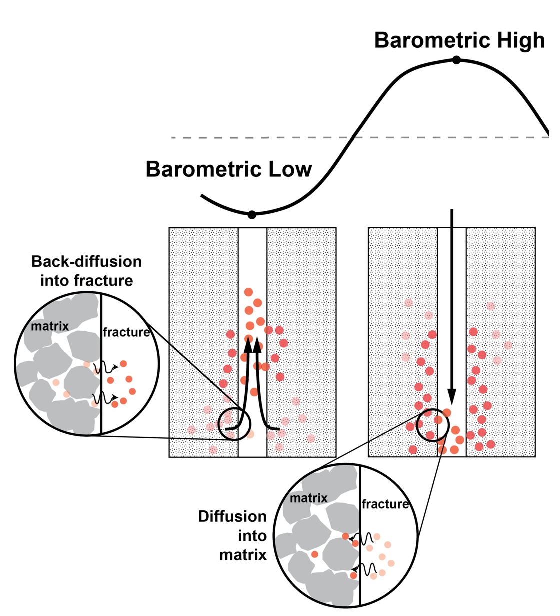

Fig. 3. *The barometric pumping ratcheting mechanism depends critically on fractures.*

FRACTURED ROCK FLOW & TRANSPORT MODEL

- FEHM simulator (Finite-Element Heat and Mass)
- Modifications to account for Mars gravity and "air" composition (~95% CO_2)
- Surface B.C. (barometric pressures) uses *Curiosity* data
- Methane source (200 m depth) consistent w/ **microbial** production rate (~0.001 µg CH_4 m^{-3} s^{-1})
- **Discrete fractures** generated using a 2-D Lévy-Lee algorithm
- Fractures embedded in the rock matrix

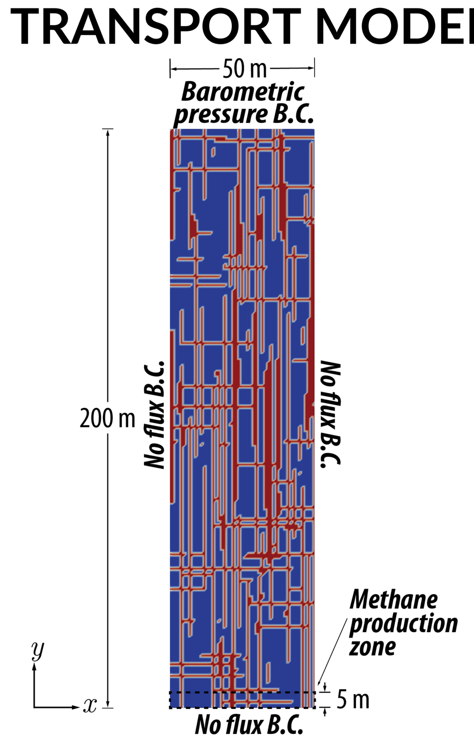

Fig. 4. *Vertical cross-section of fracture network. Fractures are red, with rock matrix in blue.*

MARTIAN ATMOSPHERIC **PRESSURE FLUCTUATIONS** CAN VENT UNDERGROUND **METHANE** FROM **HABITABLE** DEPTHS.

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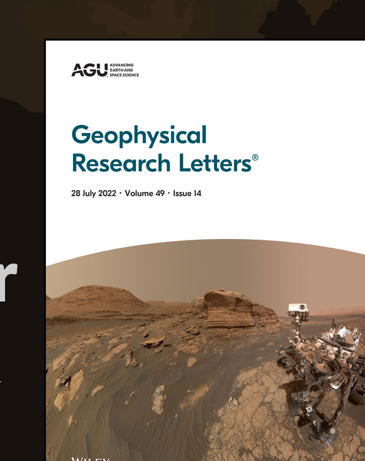

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RESULTS

Our results confirm the viability of **rapid**, **efficient** periodic methane transport from depths that are hospitable to potentially living microbial methanogens, supporting the possibility that Mars methane may be produced by extant microorganisms. **Magnitude** and **seasonality** of our simulated fluxes are consistent with previous estimates.

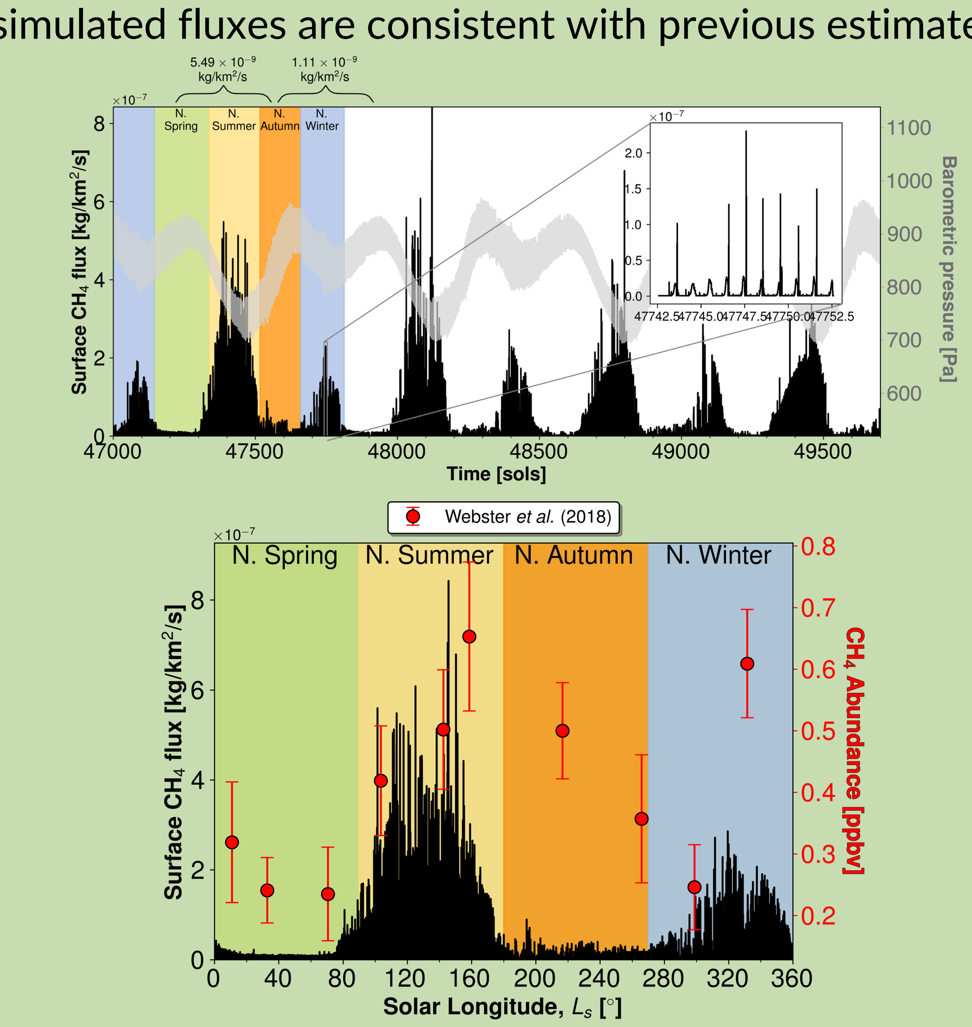

Fig. 5. *(Top) Surface methane flux (black) with barometric pressure (gray) in time. (Bottom) Fluxes plotted against solar longitude (L_s) compared to atmospheric methane abundances at Gale crater (red circles), which were collected by Curiosity.*

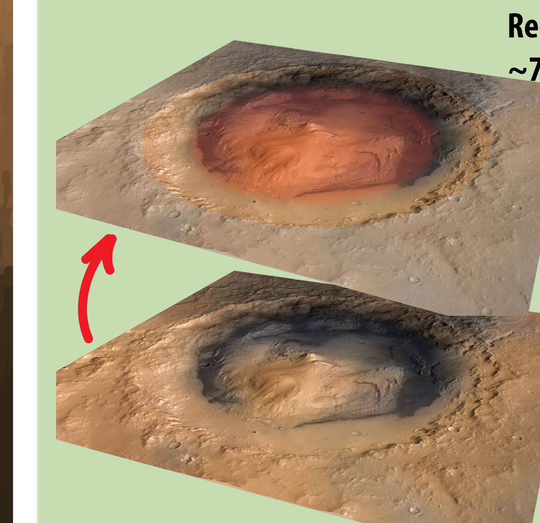

Fig. 6. *Topographical satellite view of Gale crater. Red area represents crater surface area required to supply Mars' planetwide annual methane budget based on our base case simulated surface flux. Required area is ~13,800 km² (0.01% of Mars' total surface area).*

ONGOING WORK Incorporating the effects of regolith (soil) **adsorption** controlled by temperature fluctuations. Mars daily and seasonal **temperature** fluctuations may affect both the **timing** and **magnitude** of methane fluxes.

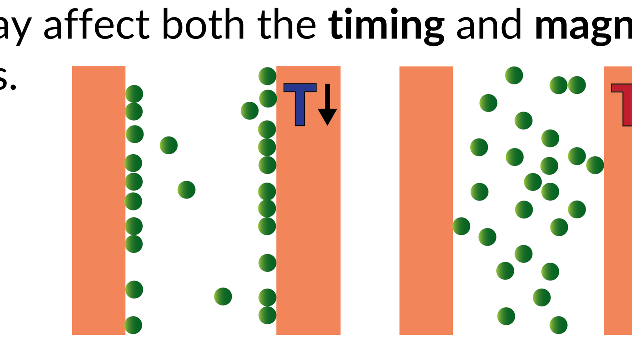

Fig. 7. *(Left) Lower temperatures promote adsorption of methane gas particles to regolith pore walls, reducing vapor-phase concentrations. (Right) Higher temperatures promote desorption.*

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