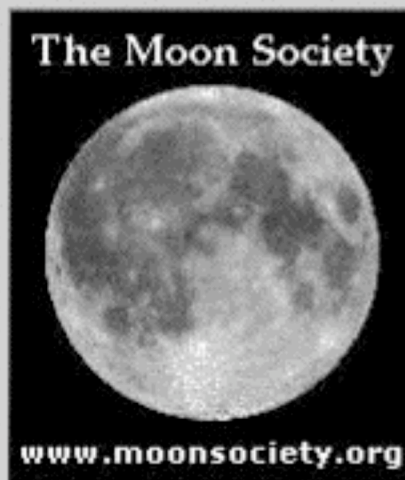


The Lavatube Skylight Explorer Design Competition

Sponsored By

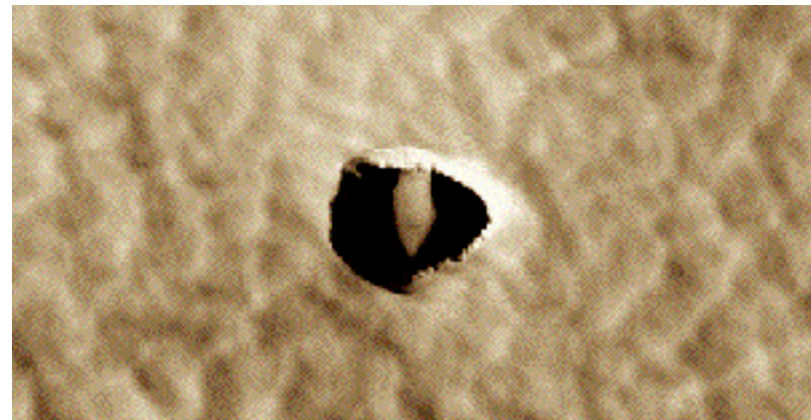
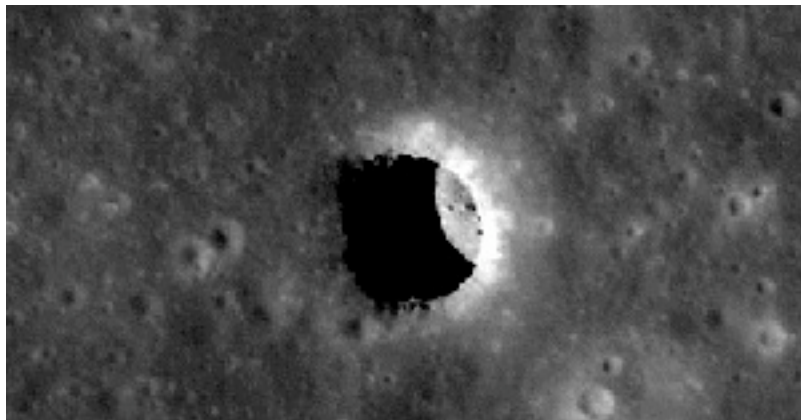
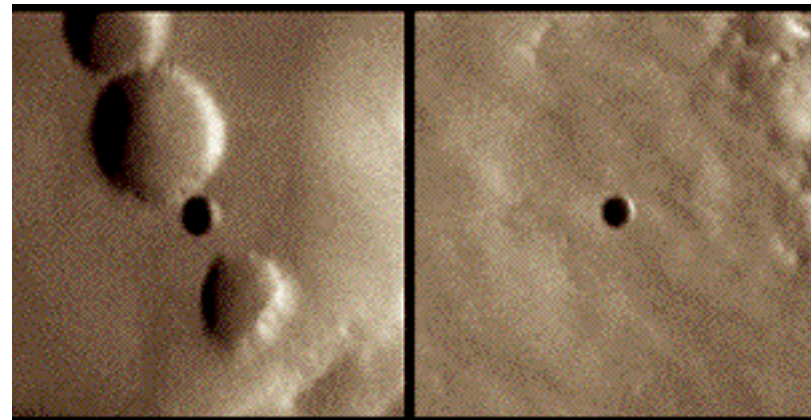
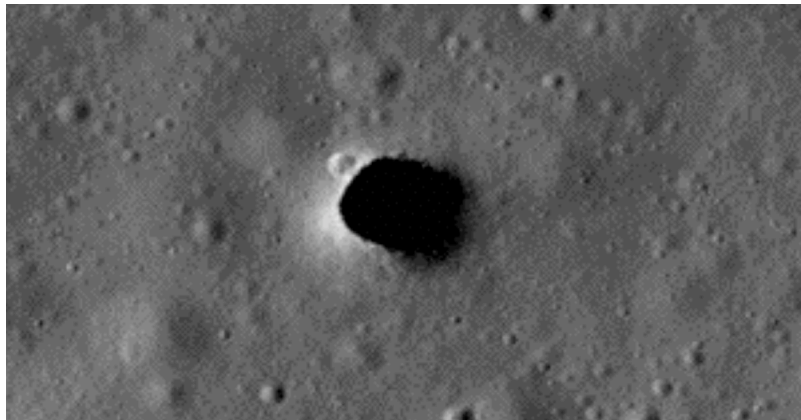
The Moon Society, Lunar Reclamation Society,
SEDS, and the OpenLuna Foundation



Additional Sponsors & Cosponsors Welcome

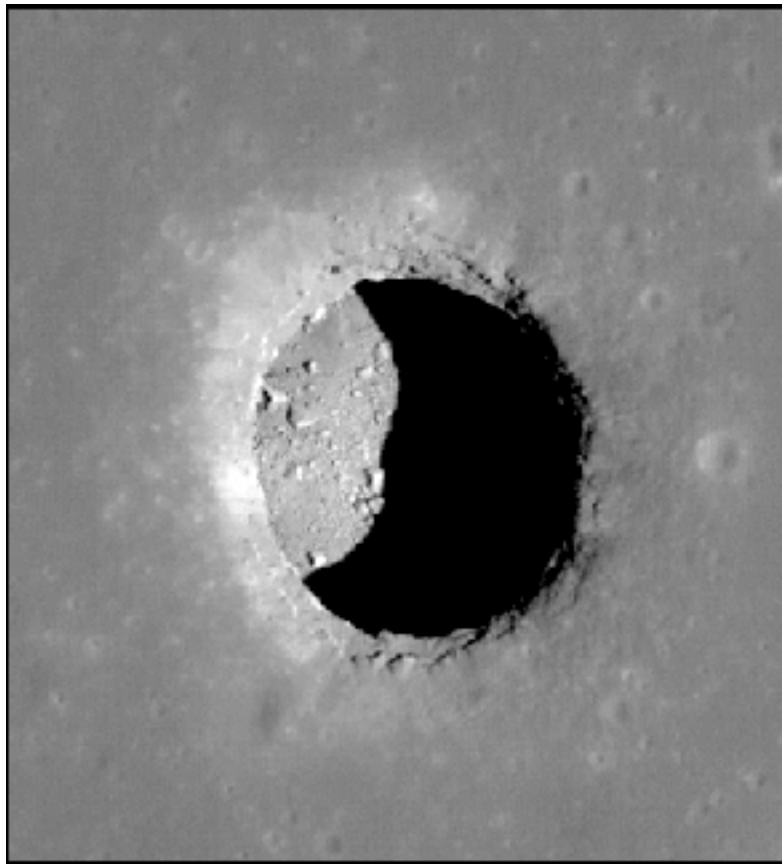
Lavatube “skylight” “pits” on Moon & Mars

Their abnormal shadow patterns stand out in high-res photos

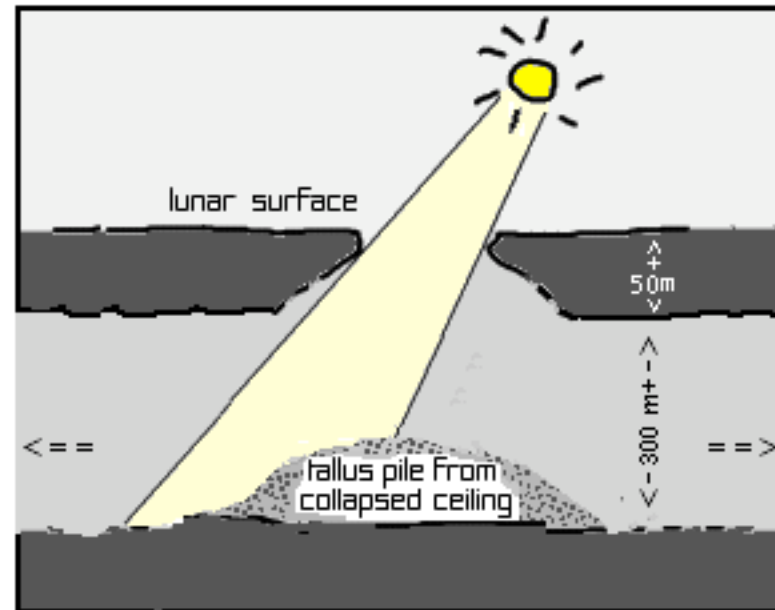


Such Skylight Pits Beg to be Explored

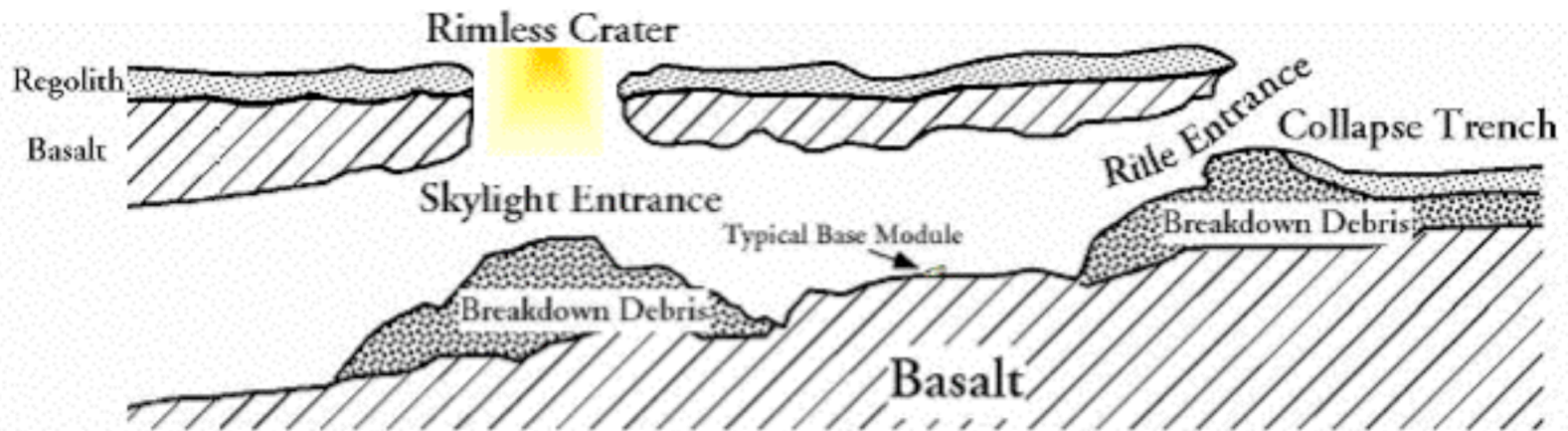
No probe has been anywhere near one



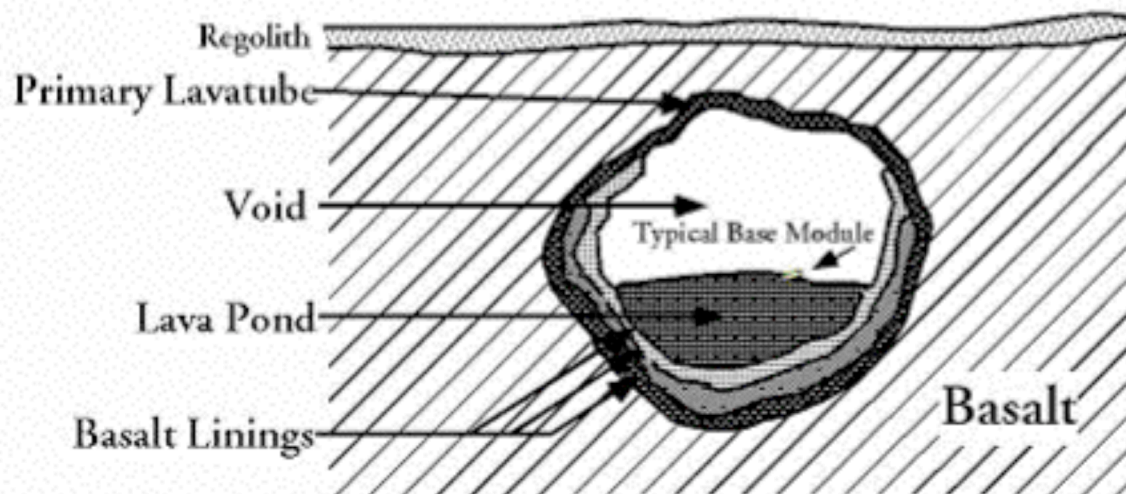
How to interpret sunlit area
Plus an idea of dimensions on the Moon



Tube sizes are in inverse proportion
to gravity levels. Mars tubes are smaller



Lavatube Longitudinal Cross-Section



Conservative Lunar Maxima

Roof Thickness \approx 50m

Width \approx 300m

Height \approx 175m

This Cave Diameter \approx 90m

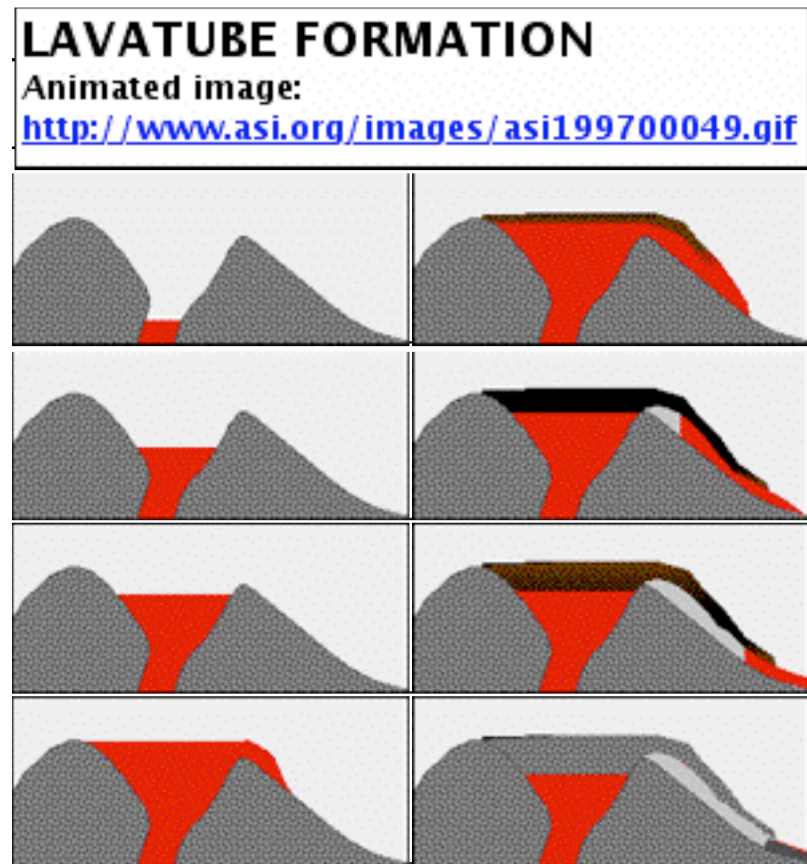


Lavatube Transverse Cross-Section

©1992 by Oregon L5 Society, Inc.
Original Drawing by P. Douglas Reeder
Chart by P. Douglas Reeder & Bryce Walden

How lavatubes are formed

- Very runny (non-viscous) lava rises to the surface and flows downhill in rivers, which gradually crust over from exposure to the cold.
- Most of the lava runs out, leaving some ponding (flat floors) in the tube and often a plug at the end
- Successive flows bury the tube.



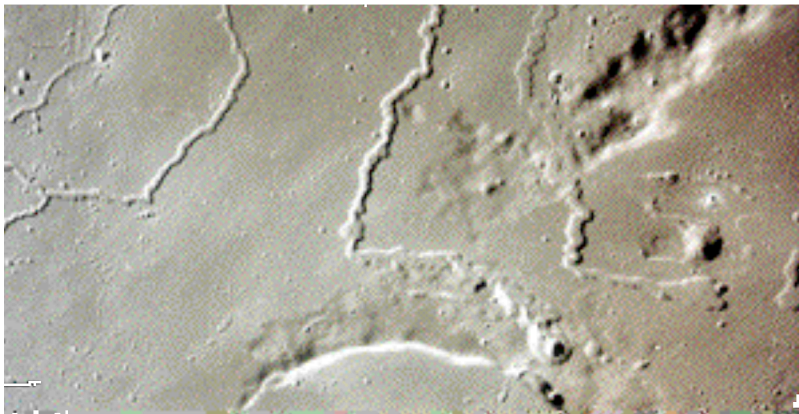
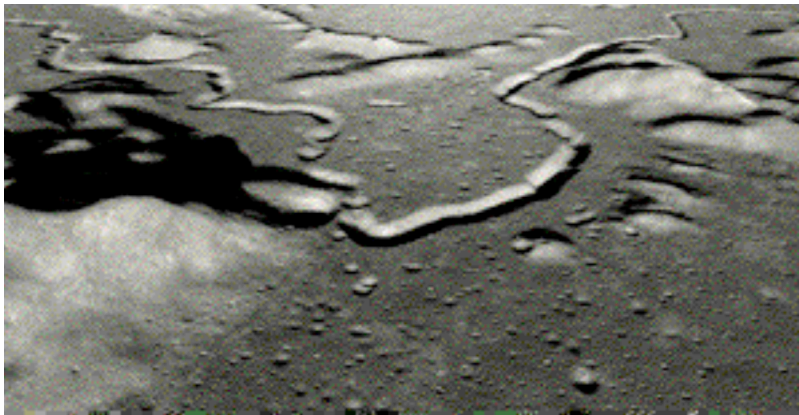
The lower the gravity, the larger the tube

Earth < 10-30 m >
Mars < 50-150 m >
Moon < 300-800 m >



Sinuuous rilles are collapsed lava flow tubes

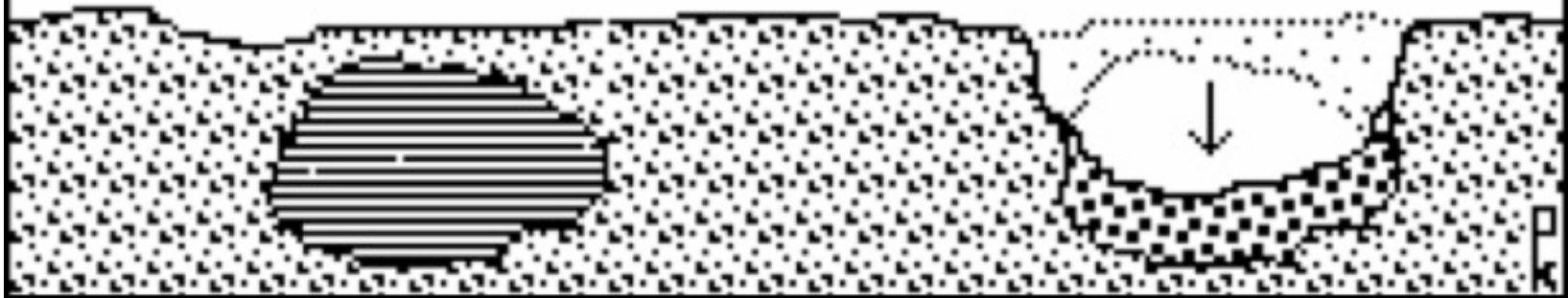
Top: Hadley from above L, from the edge R. **Bottom:** Prinz, Schroter's



From emptied lava tube to rille

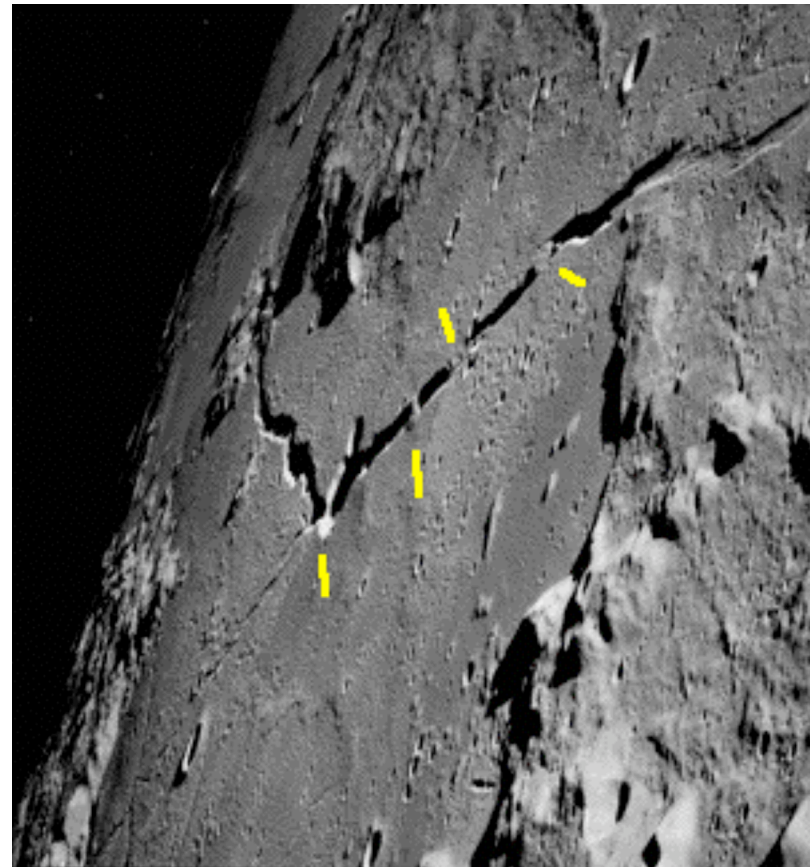
If the lavatube ceiling thickness is too thin in comparison to the lavatube width, then the ceiling may collapse of its own weight

**Collapse of ceiling of original lavatube (L)
yields present "rille" valley (R)**



Interruptions in a rille are clues

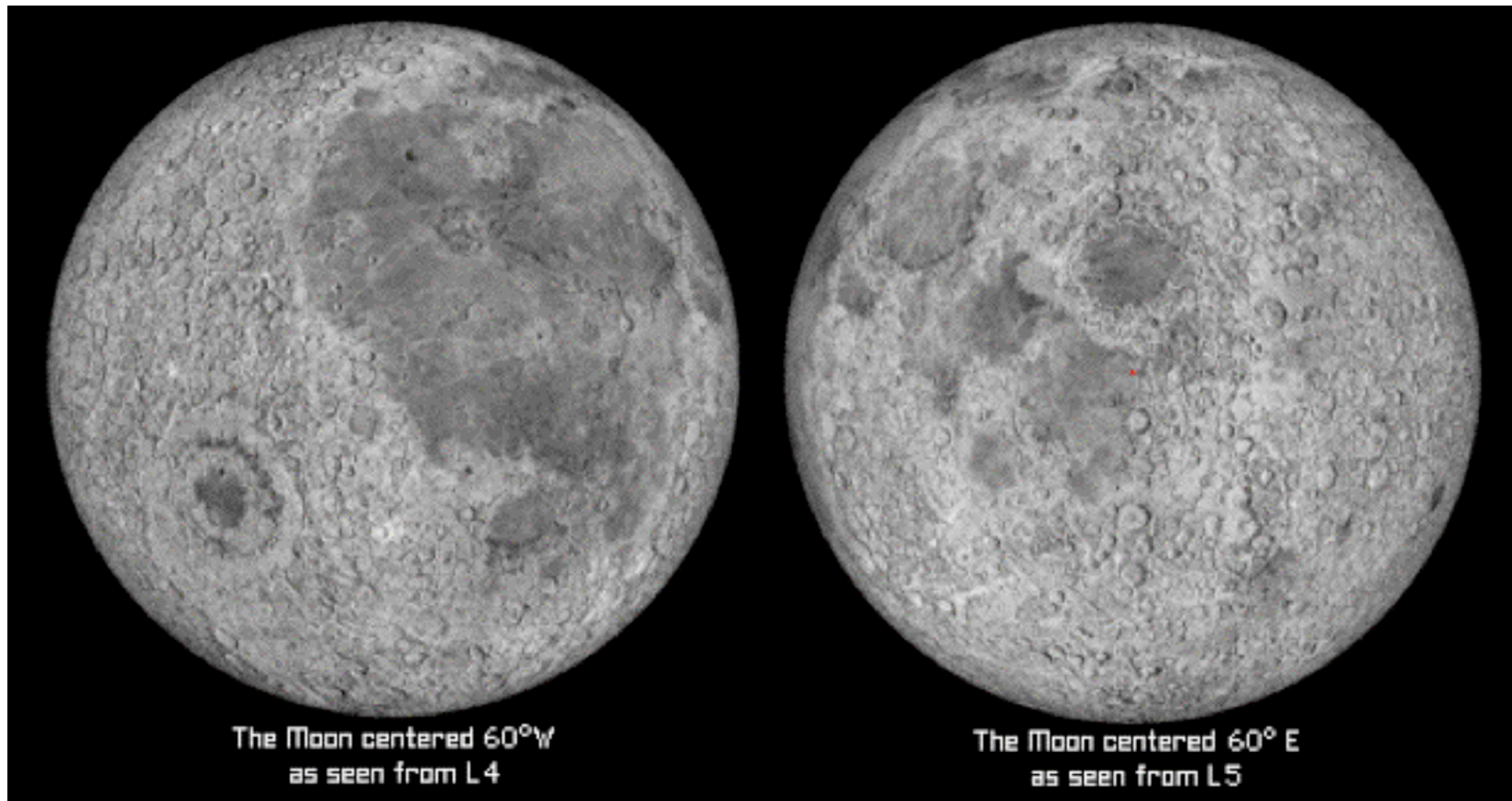
- In the image at right of Hyginus Rille in central nearside, there are 4 interruptions, places where the rille stops then starts again.
- These “bridges” are uncollapsed sections of the original lavatube



What do a few skylights and sinuous (winding) rilles prove?

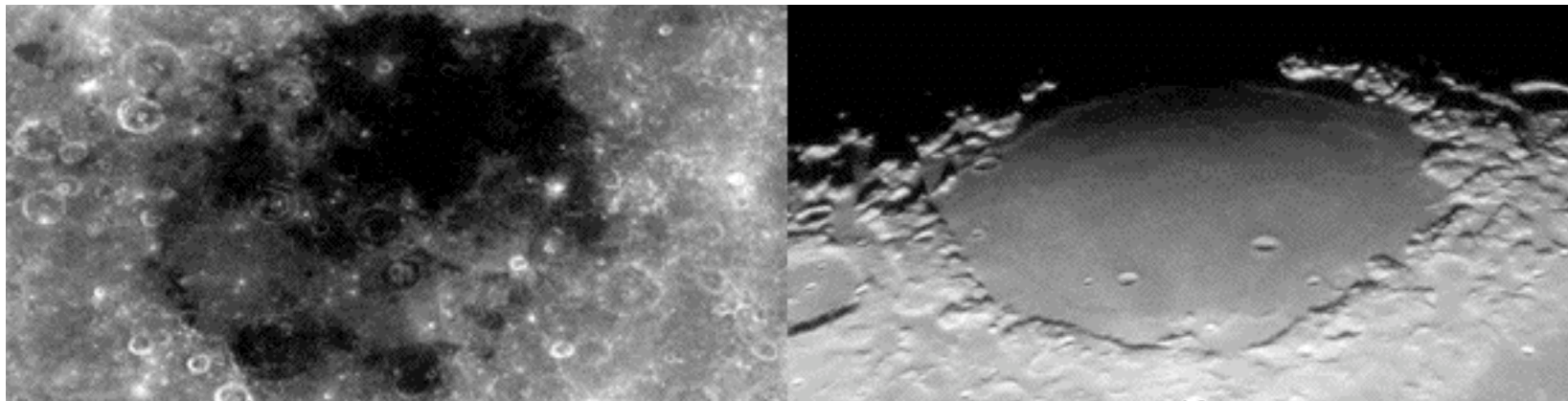
- **Where there are some, there are more.**
- Lava tubes seem to be a natural aspect of the way deep basins filled with sheets of lava
- They (and the rilles degenerated from them) run gently downhill from the high points of the lava sheets, flow radiating outwards from the points of eruption / upwelling

Lava flows formed the Moon's dark "seas"
3.5-3.8 bya! *Those still intact should stay so.*

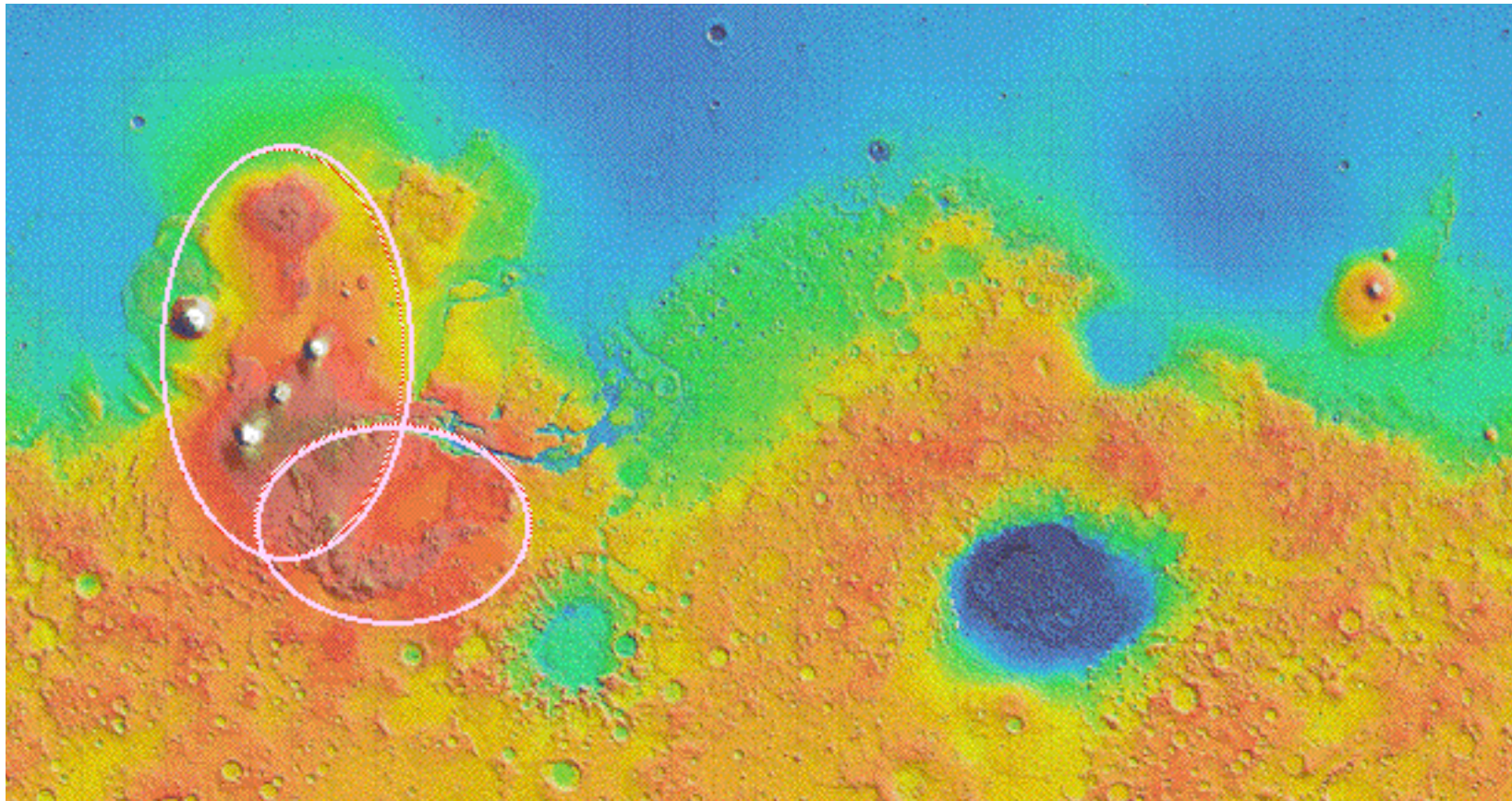


Some lunar basins appear to have several lava sheet flood layers

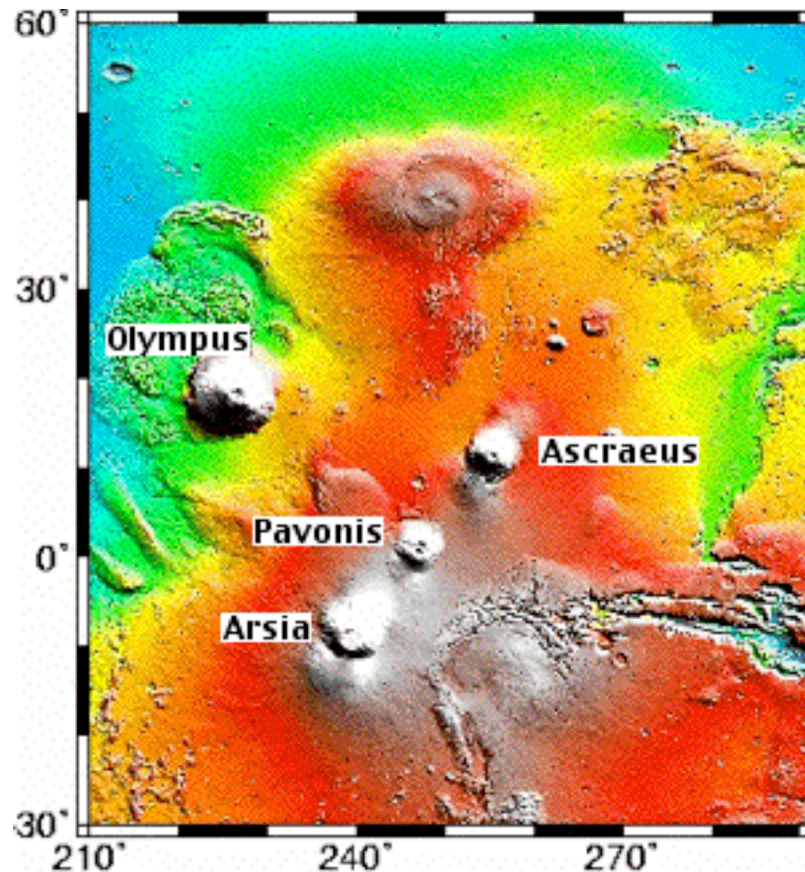
- Some lunar seas (M. Smythii) show ghost craters, and probably experienced only a single lava flood episode, thus just a one-layer lavatube network.
- Others, like M. Crisium may have many layers



Lava tube terrain on Mars: future urbanization:
The flanks of the great shield volcanoes & Tharsis plateau



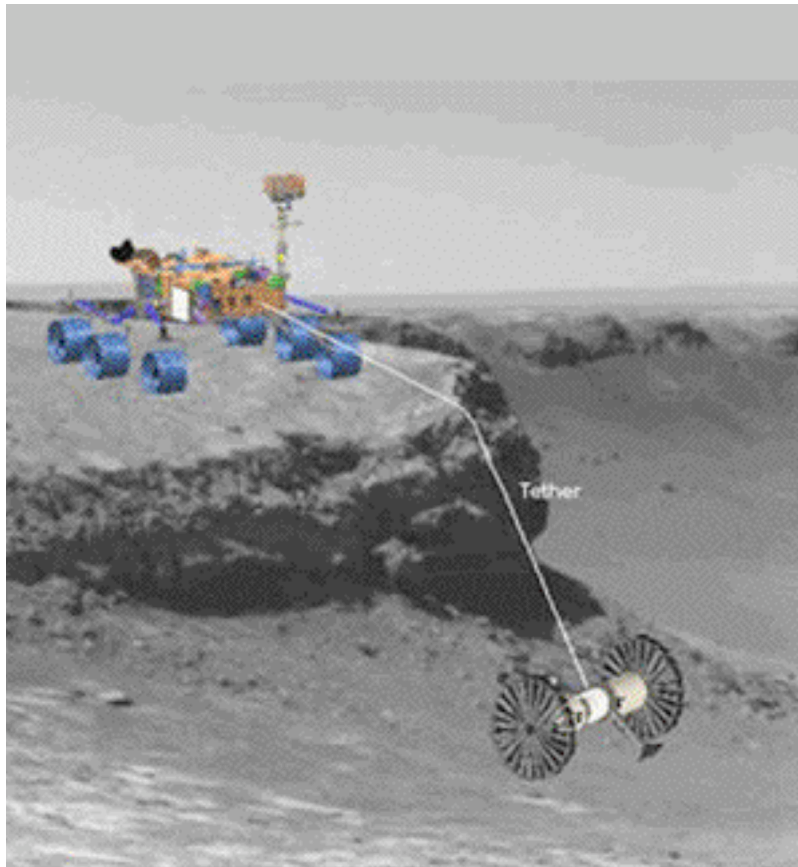
Lavatube-riddled Pavonis Mons may be the most valuable real estate on Mars



- Pavonis Mons sits astride **Mars' Equator**
- Its west flank is the ideal site for a **launch track**
- Its caldera rim is the best anchor for a **space elevator**
- Its **network of lavatubes** could house a **major metropolitan complex**

NASA-JPL's "AXEL" Rover

A concept to adapt for skylight probing?

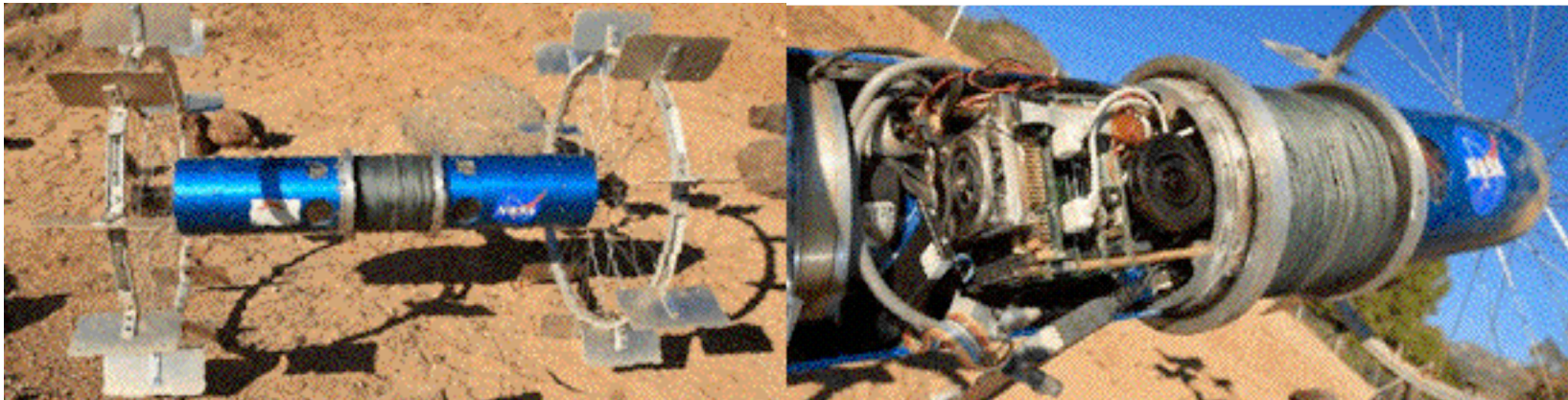


- AXEL is the 2-wheel probe on a tether that is payed out from its winch, to allow it to descend crater walls, explore, then winch itself back up to its host rover anchored on the rim

NASA-JPL's "AXEL" Rover

How it works: article & video

- <http://www-robotics.jpl.nasa.gov/systems/system.cfm?System=16>
- http://www.jpl.nasa.gov/video/index.cfm?all_videos&id=806



Axel-type Probes

and the challenges of probing a skylight pit

- **The descent length is considerably longer.** The cable will need to be thinner and lighter if the total winch assembly mass is to stay the same or less
- **The cable should carry data** to the surface anchor in case the probe is unable to climb back
- **The probe needs instruments** to measure tube dimensions and map what's in its field of view as it descends into the darkness

Axel-type Probes

and the challenges of probing a skylight pit

- **The host rover must anchor itself securely** - yet its weight and size should be minimized as well
- The host rover must be **able to send data from the probe** to scientists on Earth
- If the probe could **retrieve a tube floor sample in a secure box** to leave on the skylight rim for later retrieval, that would be a plus - note that NASA's original AXEL rover has this capacity.

Demonstrating a student-built Axel-type Skylight Explorer

- An anchor of any type and a student-built Axel-type probe's ability to winch itself down 500 ft and back is the #1 thing to be demonstrated. A site for such demonstrations has not yet been picked.
- The probe's weight and size restrictions have not been set.

NASA-Glenn's 510 ft deep "Drop Tower" is an option for Demonstrating an Axel-type student built probe's ability to winch itself down, and back up a drop of c.500 ft. or c. 150 m.



Non-Axel-type Probes

for those who want to start from scratch

- **This will be a separate competition** *with a separate prize*
- **The goal remains** to get a **probe** down into the pit depths and/or lavatube floor and retrieve data that determines dimensions, maps, and/or otherwise characterizes the surroundings
- If no cable capable of **transmitting data** is involved, then you must find some other direct or indirect line-of-sight method of doing so.
- **Weight limit restrictions** will remain the same.
- If you address the problem for a **skylight on Mars**, that may offer thin-air-assisted options

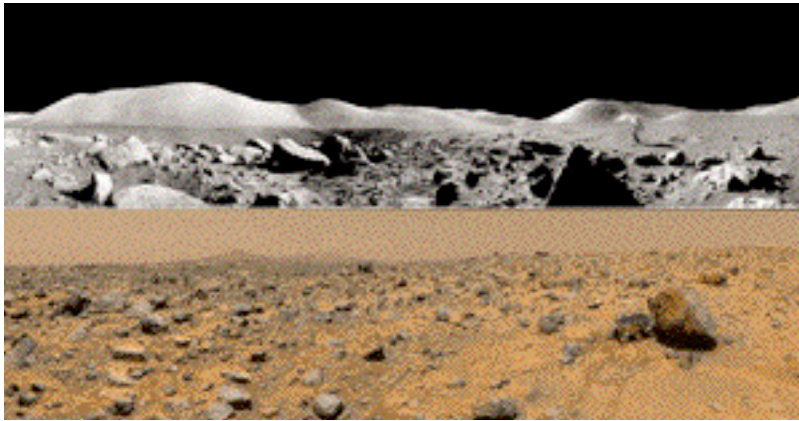
Competition *Prizes*



- The pot starts with **\$1.000** US, contributed 50-50 by the **Moon Society** and by the **Lunar Reclamation Society** (NSS-Milwaukee)
- We hope that additional sponsors and co-sponsors will join us, and contribute money and/or other attractive prizes.
- *Stay tuned.*

The stakes are high!

Changing public concepts of Moon and Mars



- From *barren dusty “rubble pile worlds”*
- To worlds with *extensive, spacious, sheltering, and livable “Hidden Valleys” ideal for human occupation and use*

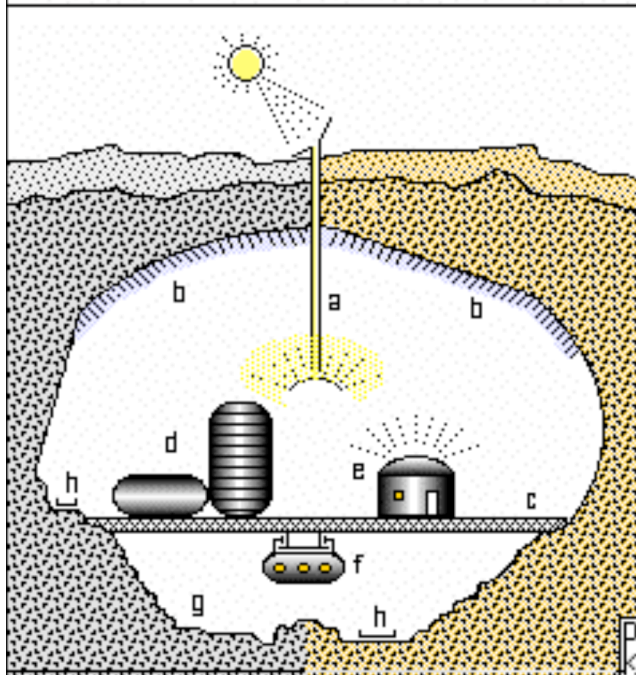
“Lee-vacuum” Lavatube Environments provide **secure shelter** from the elements for:

- Acre-hungry **industrial parks**
- Acre-hungry **warehousing operations**
- Extensive **agricultural farm areas**
- **Archives** of the **history of Earth**, and of its **life forms**, and of **mankind**, and of our **artifacts** - *safe and intact for billions of years to come*
- Acre-hungry **urban areas / settlements**

“Lee-vacuum”

Total Shelter from the Elements

- **on the Moon:** from cosmic rays, solar flares, and micrometeorite rain, as well as from the extremes of dayspan heat, nightspan cold
- **on Mars:** from cosmic rays and seasonal extreme cold



Early Unpressurized Lavatube Usage

CONCEPT KEY:

- (a) sunshine access and defuser system;
- (b) whitewashed "firmament" for sunlight reflection;
- (c) "town deck" on tube-spanning beams;
- (d) assorted structures;
- (e) "yurt/ hogan" type home with translucent dome to flood interior with firmament-reflected sunshine;
- (f) monorail transit system;
- (g) lavatube floor left natural;
- (h) nature walks.

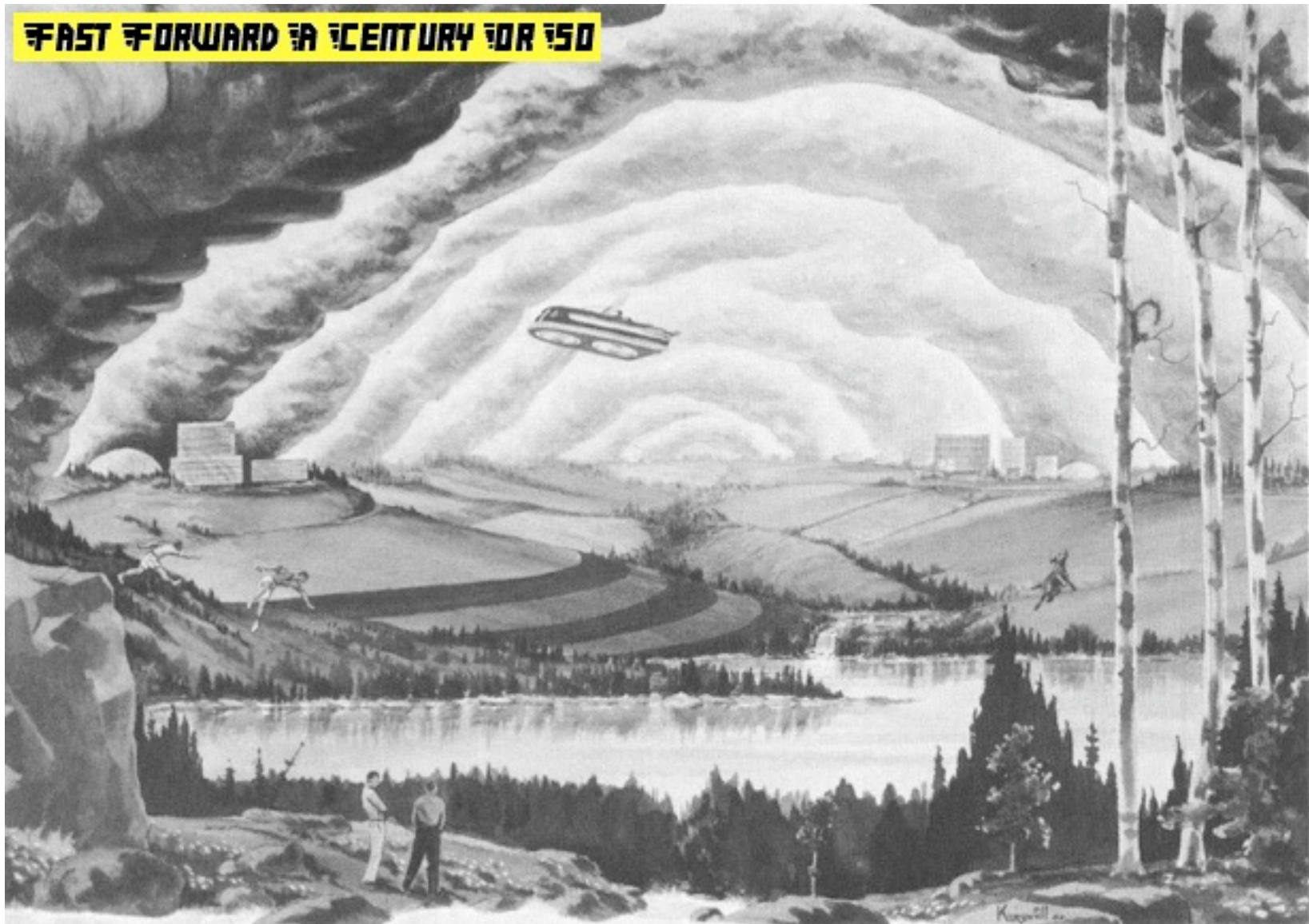
Pressurizing such vast volumes is
not a near-term option for the Moon

- The surrounding basalt rock is likely to be fractured, as well as frigid. Moisture in the air could, through freeze-thaw cycling, loosen rock from ceiling and sides, causing damage and injury.
- Any kind of sealant would be a forbidding expenditure in the amounts needed.
- The amount of Nitrogen needed to produce vast amounts of breathable air are simply unavailable on the Moon. Even reducing the Nitrogen partial pressure significantly would not help near-term.

Pressurizing proportionately smaller Mars lavatubes is *a nearer term option*

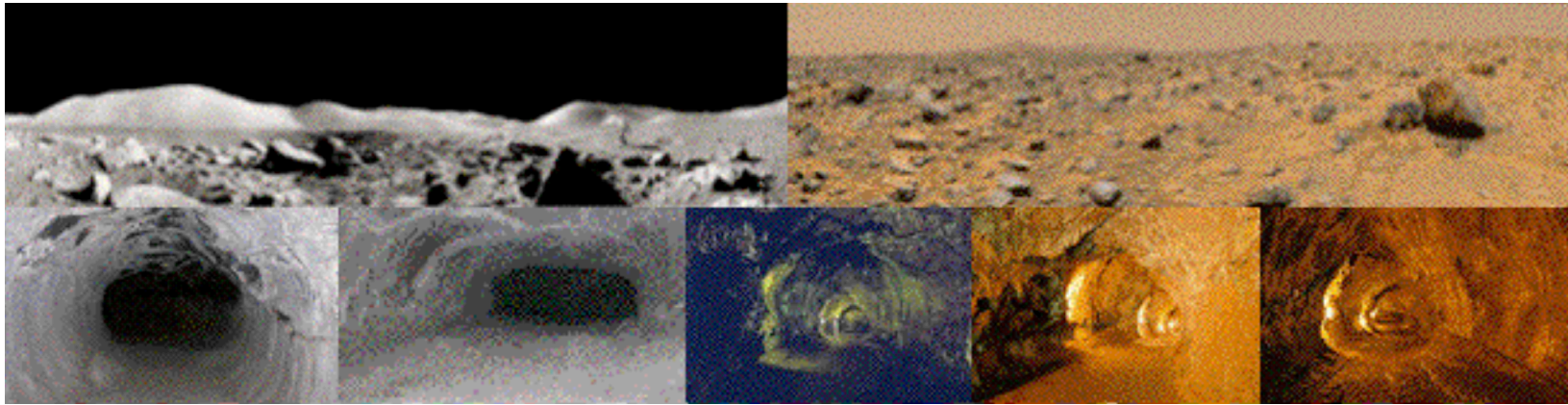
- **The challenge:** the surrounding basalt rock may be fractured, as well as frigid. Moisture in the air could, through freeze-thaw cycling, loosen rock from ceiling and sides, causing damage and injury.
- But it should be possible to produce some kind of suitable sealant from elements common on Mars.
- The amount of Nitrogen needed to produce vast amounts of breathable air are available from Mars atmosphere.

FAST FORWARD A CENTURY OR SO





Lavatube Skylight Explorer



- Considering that so much of the really exciting future possibilities on both Moon and Mars lie below the surface, the witty and “*shallow*” remark “*been there, done that!*” is as “*superficial*” as it gets!
- Why we’ve just barely “*scratched the surface!*”

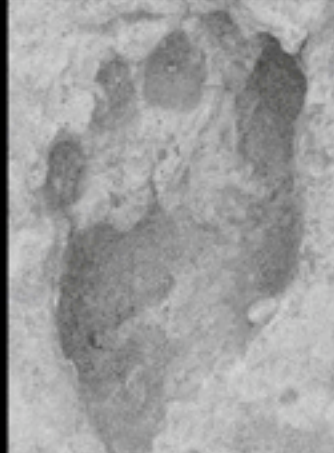
Don't judge me by my shell!
It's what's underneath that counts!



Oops!



The Moon Society - Lunar Frontier Settlement - www.moonsociety.org



From Africa to the Moon, the Human Epic told in footprints, continues to the stars!

"Towards an Earth-Moon Economy Developing Off-Planet Resources"

Moon Miners' Manifesto

& The Moon Society Journal

www.MoonMiners.Manifesto.com

Competition Contact Information

Questions about **Competition** or **Sponsorship**

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888-266-2385
one and same landline
7 am - 10 pm Central
(ask for Peter)
- **David A. Dunlop**,
Moon Soc. Director of
Project Development
- Reach both of us at:
- [Skylightexplorer@
moonsociety.org](mailto:Skylightexplorer@moonsociety.org)