

Terrestrial Lava Tubes

Lava tubes are a type of lava cave formed when a lava flow develops a continuous and hard crust, which thickens and forms a roof above the still-flowing lava stream.

The maximum width of known terrestrial lava tubes is about 15m.

Lunar Lava Tubes?

It is not known for certain whether lava tubes have formed on the Moon.

However, [Ashley et al., 2013] point out several discontinuous rille features on the Moon, **suggestive** of lava tubes that have collapsed in some places but not in others.

In addition, photos from Lunar orbit of a large number of “pit craters” are suggestive of voids below these features, raising the **possibility** of lava tubes there.

Some of these pit craters are very large, e.g., one in Mare Tranquillitatis is over 100m in diameter [Haruyama, 2010]. This raises the intriguing possibility that **some Lunar lava tubes may be much larger in diameter than the largest terrestrial lava tubes.**

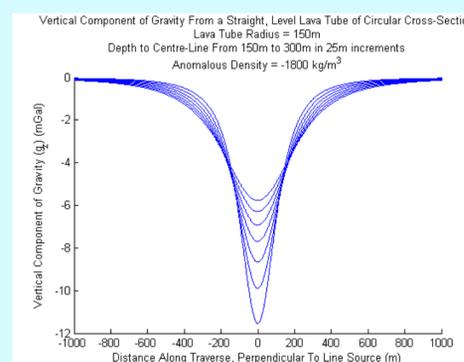
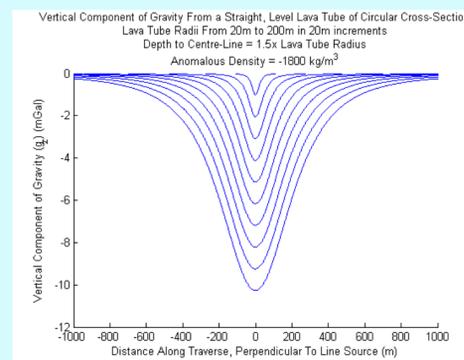
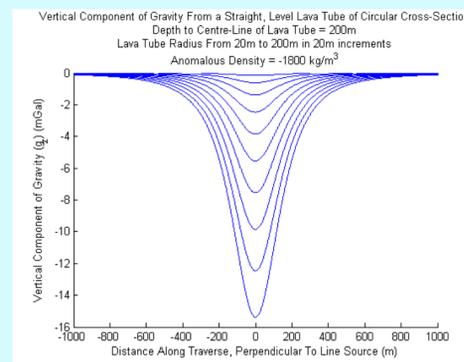
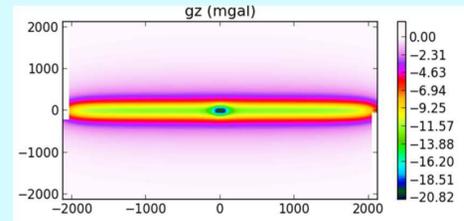
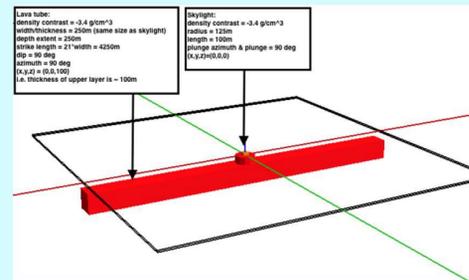
E.g., [Haruyama, 2009] discusses a 65 m diameter pit crater in the Marius Hills region of the Moon, which appears to be a skylight into a lava tube beneath it, **with an inferred lava tube of diameter > 370m.**

Is Such A Size Discrepancy Plausible?

[Hulme, 1982, Geophysical Surveys] analyzed the physical processes governing lava flows on Earth and on the Moon, with specific reference to Lunar rille formations. He found that differences in gravity, lava viscosity and flow turbulence can explain why Lunar rilles are typically much wider (from 100 m to 3 km) than terrestrial lava channels (which are typically an order of magnitude narrower).

In cases where the top surface of a Lunar lava flow solidifies, forming a roof, Lunar lava tubes having very large width — plausibly much larger than 100m wide — could potentially form.

In addition, Hulme’s model predicts erosion of lava channel floors due to melting. Erosion by melting seems apparent in some terrestrial lava tubes. Thus **Lunar lava tubes that are both very deep and very wide seem plausible.**



Gravimetric Mapping of Lunar Lava Tubes

A Lunar lava tube would generate a gravimetric signal on the surface above it, due to the density contrast between its interior (of zero density) and the surrounding rock (if basalt, density from 3000 to 3500 kg/m³). A surface traverse above such a lava tube would indicate a gravity low above the tube’s centre-line, with a magnitude dependent mainly on the tube’s diameter and depth.

As illustrated in the figures in the centre column, for large Lunar lava tubes, **the peak gravimetric signal can be much larger than 1 milliGal.**

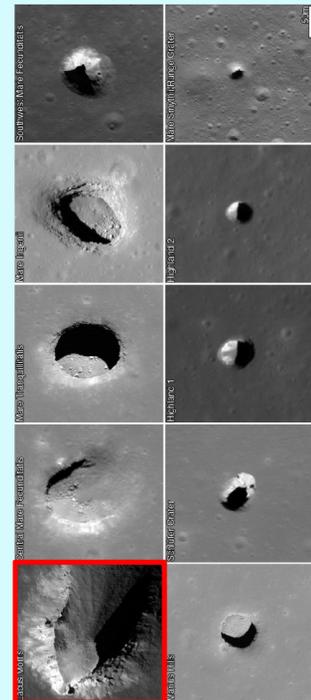
The top figure illustrates a segment of a hollow tube of 250x250m square cross-section, surrounded by rock of density 3400 kg/m³ (typical of Lunar basalt), with a 100m thick roof penetrated by a 250m diameter skylight. The plot below that shows the vertical gravity anomaly signal at locations within 2 km of either side of the tube, **showing how such a survey could map such a feature. The peak signal above the tube centre-line is about 12 mGal.**

The 3 bottom plots show vertical gravity anomaly signals for a variety of Lunar lava-tube scenarios, using the equation for the gravity field from a line source (eq. 2.54 in [Telford et al., Applied Geophysics]), from which the magnitude of the gravity low from a linear lava tube of constant depth and constant circular diameter is $2GA\rho z/(z^2 + 1)$, where A is the tube’s cross-sectional area, z is the depth to its centre-line, and ρ is the density of the surrounding rock. Each trace indicates the signal along a traverse perpendicular to a straight, level, circular-cross-section tube, with diameters ranging from 20m to 300m, and depth to the centre-line ranging from 20m to 300m. **The peak gravity anomalies range from 1 to 15 milliGal.** Also, the varying shapes of the curves demonstrate that **readings taken along such a surface traverse can be diagnostic of the depth and diameter of such features.**

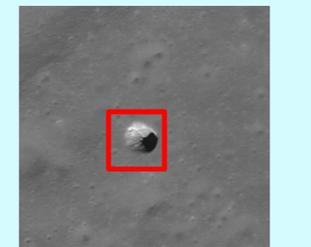
Potential Near-Term Survey Opportunity

Astrobotic Technology, Inc. is planning to fly their Griffin lander and CMU’s Andy rover to the vicinity of a Lunar pit crater in Lacus Mortis in late 2016, with the goal of winning Google’s Lunar X-Prize. That pit crater, with a diameter of 250m, may potentially be a skylight into a lava tube, or some other such subsurface void.

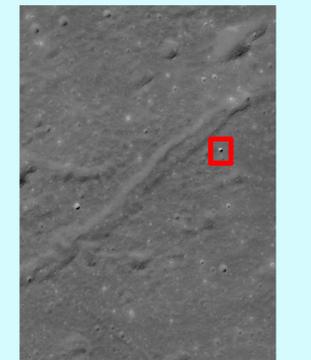
Gedex is developing a compact (10x10x15 cm) gravimeter (VEGA), with a repeatability goal on the Lunar surface of 1 milliGal. **The VEGA gravimeter, if carried on the Andy rover, could conduct a gravimetric survey around that crater, and could detect the presence of and map any such lava tube or subsurface void.**



“Distribution, Age, and Formation Mechanisms of Lunar Pits,” Wagner & Robinson, (2014), NESF.



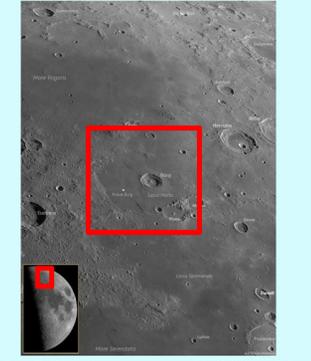
Pit crater in the Rimae Burg region of Lacus Mortis (44.96° N, 25.62° E), from LROC NAC mosaic M1105701957LR [NASA/GSFC/Arizona State University]



Rimae Burg region, west-central Lacus Mortis. LROC NAC mosaic M1105701957LR [NASA/GSFC/Arizona State University]



Lacus Mortis, from LROC [NASA/GSFC/Arizona State University]



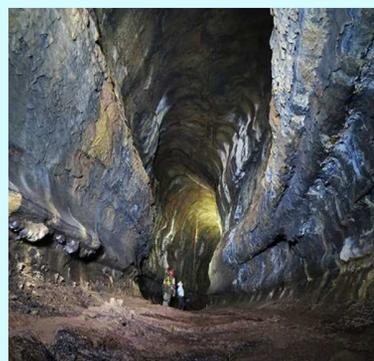
From a First Quarter Moon montage captured April 21, 2010. Photo by Yuri Goryachko, Mikhail Abgarian, Konstantin Morozov - ASTRONOMNSK, Minsk, Belarus.



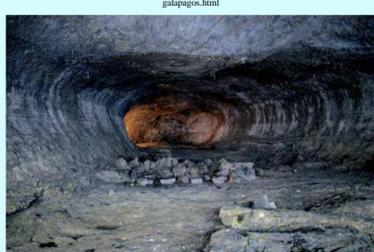
Lava tube skylight on Kilauea, Hawaii, from <http://commons.wikimedia.org/wiki/Kilauea>



Valentine Cave in Lava Beds National Monument, California, from http://en.wikipedia.org/wiki/Lava_tube



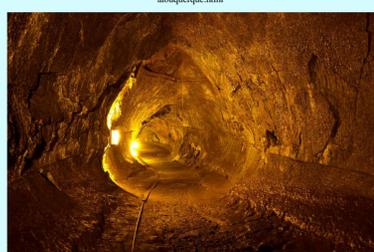
Lava tube on Santa Cruz Island, Galapagos, from <https://www.extremecolander.com/2013-04-lava-tubes-galapagos.html>



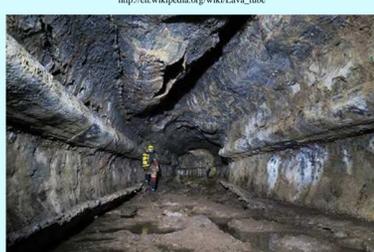
Stiefshellir lava tube, Iceland, from <https://www.extremecolander.com/2013-04-lava-tubes-galapagos.html>



Big Skylight Cave in El Malpais National Monument, New Mexico, Michael Benav photo from <http://www.nytimes.com/2014/08/31/travel/into-a-lava-lined-underworld-near-albuquerque.html>



Thurston lava tube in Hawaii Volcanoes National Park, from http://en.wikipedia.org/wiki/Lava_tube



Lava tube on Santa Cruz Island, Galapagos, from <http://phys.org/news/2013-04-lava-tubes-galapagos.html>



CMU's Andy rover, to be carried to the Lunar surface by Astrobotic's lander late 2016



Astrobotic Griffin Lunar lander mockup, ca. October 2012



Astrobotic Lunar lander approaching pit-crater, target date end of 2016



Astrobotic Lunar lander on Lunar surface near pit-crater, with rover exploring towards crater's edge