12 Questions on Lunar Lavatubes

What is a "lavatube"? How are they formed?

A lavatube is a relic of a river of molten lava, self-crusted over on the top as the exposed surface cools, and then at least partially voided out as the lava spreads out eventually on the surface as a sheet as the flow ceases to advance.

Where do we find them on Earth? in what kind of terrain?

On Earth we find lavatubes in the flanks of shield volcanoes such as Mauna Loa/Mauna Kea in Hawaii and Medicine Lake in California. We also find them wherever we have had vast state-sized flood sheets of lava, as in Washington-Oregon, the Deccan flats of southern India, in northeast Siberia, and elsewhere.

Are we that similar features exist on the Moon?

The maria or "Seas" we find on the Moon are geologically analogous to the lavatube-rich lava plains found on Earth. On those grounds alone, we would have a high expectation of finding lunar tubes. But for a second higher order of evidence we also have, in the same type of terrain, long sinuous valleys on the Moon called rilles (the Latin class name is rima]. We have found hundreds of these features in orbital photographs and have visited one (Apollo 15's visit to Hadley Rille). The consensus explanation of such features is that they represent collapsed lavatubes. For a third even more convincing order of evidence, some lavatubes are clearly segmented with interrupting stretches of valley-free surface.

www.lpi.usra.edu/research/cla/images/img/D14.jpg
(below center right - crater Hyginus in the bend)

These "interruptions" can only be sections of a lavatube that have not collapsed and still remain intact. Such sections should by themselves be enough to give future lunar developers ecstatic dreams. But if there are partially intact tubes, it is inconceivable that elsewhere, if not nearby, are to be found wholly intact tubes. Lavatubes are a natural concomitant of maria formation on the Moon, and will be common.

Are they near surface objects only?

Those we have direct or indirect evidence of (from rilles) are/were near surface features. But keep in mind that the maria were filled with a series of lava floodings, and the formation of each successive sheet should have its own lavatubes. On the plus side, lavatubes in deeper layers have been more protected from collapse due to later meteorite bombardment. On the minus side, some, maybe most (a defensible guess for whatever your temperament), were filled up and plugged by later episodes of flooding. Deep tubes are unlikely to be discovered from orbit or from the surface. We could hope to find some of them serendipitously (where tubes in successive levels just happen to cross) by radar soundings taken on the floors of near surface tubes by actual explorers.

How might typical lunar lavatubes differ from typical tubes found on Earth?

(**1**) The formative episodes of lava sheet flooding on the Moon are all very ancient events on the order of 3.5-3.8 Billion years ago. Surviving lavatubes on Earth are all much much younger than that, some only thousands of years old.

(**2**) In addition to being very ancient, lunar lavatubes differ in scale. Probably because of the lower gravity in which they formed (1/6th Earth's) tube-relic rille valleys already observed, photographed and visited run an order of magnitude (ten times) typical terrestrial dimensions in width, ceiling height, and total length. Lunar tubes are BIG.

(**3**) lunar lavatubes have never been exposed to air or water (unless a comet happen to pierce the ceiling and vaporize inside with some of the volatiles freezing out on the tube's still intact inner surfaces - a real "lucky strike"!). Like tubes and caves on Earth, the temperature will be steady, but colder (Earth in general is 50°F warmer than the Moon because of the oceanic-atmospheric heat sink.)

How intact and stable would lunar lavatubes be? How prone to future collapse, total or partial?

Any lavatubes that have survived to this day wholly or partially intact are likely to continue to do so for the rest of time. The vast bulk of major asteroidal bombardment which has pocked the Moon took place in the first billion years of the Moon's history. Lunar lavatubes, not subject to any sort of active geological forces or to any kind or weathering are perhaps the safest, most stable, protected volumes to be found anywhere in the solar system. They are veritable vaults, sanctums, sanctuaries we can bank on - no bet-hedging needed.

What aspects of lunar lavatube internal environments are most attractive for human purposes and to what uses might we put them?

(**1**) "lee" vacuum protected from the micrometeorite rain, from cosmic rays, from solar ultraviolet, and from solar flares, and unlimited volumes of it, is a priceless and odds favoring handicap toward lunar outpost and settlement establishment, expansion, and maintenance. In these conditions, only simple unhardened lighter weight pressure suits need be worn, for much greater safety, comfort, and convenience. Lee vacuum is ideal as well for storage and warehousing and in-vacuum manufacturing.

(**2**) steady temperatures at all times (-4°F), protected both from dayspan heat (+250°F) and nightspan cold (-200 some °F), the "body-heat" of the subsurface Moon being much higher than the "skin" heat of the exposed surface (3) Lunar lavatubes are dust free. The moondust blanket is the result of eons of micrometeorite bombardment or gardening of the lunar surface. The unexposed surfaces of lunar lavatubes have been protected from all that and, good house-keeping measures adopted and religiously followed, will remain dust-free sanctuaries. Given the insidious invasiveness and machinery- and lung-fouling character of moondust, this asset is a clincher! For construction purposes, shielding now provided as a given and dust-control vastly easier, lavatube sites will be much simpler and easier places in which to build. We have only pressurization to provide and maintain within these natural macro-structures. As a package, lavatube assets effectively remove (squelch, eradicate, nuke) most of the common objections to the Moon as a development and settlement site, reducing worries to lack of around-the-clock sunshine (an engineering energy-storage and usage/scheduling question) and gravity one-sixth Earth normal (as if life hasn't always been able to adapt to anything!).

Are there any more special resources we might find in lunar lavatubes here and there as extras?

Mineralogically, lavatube surfaces and their host terrain will be boring, fairly homogeneous basalt. Other elements, not present in local basalt, can be mined and processed elsewhere and the products made from them brought to the site. But not to be overlooked is the possibility that we have hit the cosmic jackpot with a volatile-rich comet strike of just the right size to puncture, but not collapse, a lavatube. Frozen volatiles would be the prize. These would not be subject to most of the loss mechanisms that will surely operate in polar permashade ice fields (micro-meteorite bombardment, solar flares and solar wind, cosmic rays, splashout from other impacts). To date, the only (and it's inconclusive) teasing evidence we have is an anomalous reading over western Mare Crisium that on first interpretation would seem to indicate subsurface water-ice. This reading has been (but should not be) routinely dismissed as spurious.

What lavatube uses are near term, what uses are more challenging and likely to be realized only in the far future?

Warehousing and storage will require the least preparation. Archiving is an attractive idea: no where else in the entire solar system could the records and sample artifacts of all humankind be preserved safe and intact for billions of years. Industrial parks would find boundless pre-sheltered space within which to spread out. All of these developments can be realized within lunar lavatubes much as we find them, without wholesale modification. But the idea of pressurizing lavatubes to create more Earth-like settlements presents many daunting hurdles (sealing methods, sealant composition, pressurization stress, procuring astronomical volumes of nitrogen, in short supply on the Moon) While all considered, terraforming lavatubes would be vastly easier than wholesale terraforming of a whole surface (e.g. Mars), it is still something we may not tackle for some generations perhaps.

How much protected space are we talking about?

Let's express our back-of-envelope guesstimate range of the total available volume of intact lunar lavatubes in terms many space enthusiasts are familiar with: Dr. Gerard O'Neill Island III Sunflower space settlements. In contrast to those megastructures, lavatubes are ready-to-occuppy-and-use-NOW (without the full standard Earth-normal gravity, or sunshine, yet.) The surface area of the host terrain, the lunar maria, comprise some 17% of lunar surface = 2.5 million square miles - compare with 3 million square miles for continental U.S. Now if (we have to start the argument somewhere!) we assume that available floor and wall terrace surface of intact lavatubes compares to 1/1000th of this aggregate lunar maria surface area, we get 2,500 square miles. This is in our estimate, a very conservative estimate. Counting supposed lavatubes in lower level lava sheets, 1/100th is a fraction that could be closer to reality. That would yield 25,000 square miles, an area comparable to West Virginia. Subtracting for window strips (as we have for lavatube upper walls and ceilings), an O'Neill cylinder, if ever realized in full ambitious scale, might have 100 square miles of habitable inner surface. Argue about the figures, it won't change the overall picture. We are talking about ready to occupy network of lunar lavatubes that compares to 25 to 250 Island III units. And they have real existence outside the imagination.

Can we expect to find other similar hidden covered valleys elsewhere in solar system?

Yes, as they seem to be a standard concomitant of lava sheet flooding and of shield volcano formation, we might expect to find lavatubes on Mars, Mercury (the temperature swing refuge would make them hot property), Venus (they would be too hot, and share Venus' over-pressurization), Io (protection from Jupiter's radiation belts), and even on little Vesta.

By what Latin name are lavatubes referred?

None yet. Astronomers and cartographers, coming from many nations, have devised a neutral terminology, using Latin terms to describe various classes of features on the Moon; mare (plural maria) = the “seas” of frozen lava sheets; lacus (lake), sinus (bay) denote smaller lava flow areas. Rima is Latin for rille, etc. Cava, tubus, and ductus are available Latin words that might be used to classify lavatubes. The latter better indicates the mode of formation.

What do Lavatubes Look Like? URL
www.lunar-reclamation.org/lavatube_pix.htm