THE METHODOLOGY OF FINDING LAVA TUBES WITH THE USE OF REMOTE DETECTION ON MARS, ON THE EXAMPLE OF A NEWLY FOUND CAVE

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**Introduction:** It’s not a complicated question today, if there are caves on Mars or not. Finding them entrances though is though still difficult, because doesn’t exist a definite method, using only remote detection for that. But still, because of the specialties of Mars and the technical attributes of the Martian probes it’s easier to find caves there remotely, as it is on the Earth. Most likely lava tubes can be found, because they have vertical and big entrances, which can be spotted from above. The relatively big size of these formations, the absence of flora, and the developed instruments are making that easier – for example the HiRISE can make still the most detailed civilian-used multispectral images, but THEMIS IR’s 100 m/pixel resolution is excellent too, compared to similar instruments around Earth.

By analyzing just the entrance-like pit it is possible to determine relatively sure, if the examined object is the entrance of a lava tube cave, or it’s not. The method uses the thermal infrared images, multispectral images and elevation data collected by Martian probes. Elements of the method may not be new, but using them altogether can help to get relatively exact results.

**Methods:** Because of the geological structure of Mars we know, that there are two areas where lava tubes are possible to form: these are the Tharsis region, and the Elysium Planitia. Even on these volcanic areas on only slopes steep between 0-17° are they able to form [1]. Narrowing down to these areas is possible with MOLA data.

On these areas the narrowing can be continued using the THEMIS IR instrument. The temperature of the caves on Earth, and possibly on Mars too is constant, and is equal to the yearly average temperature [2]. Accordingly thermal infrared may be used to distinguish caves from similar formations [3]: on images taken by summer daytime they will appear as cold, and on winter nighttime images they will appear as warm spots. Fortunately there are enough THEMIS IR images to do these comparisons.

After all of this, a morphological analysis is needed. For this middle or high-res, namely MOC, CTX or HiRISE images are useable.

The shape of the pit doesn’t need to be round, because it’s effected by the exact conditions of the collapse, as well by the morphology of the surface. It’s more important, that the morphological characteristics must be visible, so we can spot them on the walls and bottom of the pit. This is for example the layered structure of the basaltic material on the wall, what’s typical by a lava-flow. The evidences of collapse are also important, these are the debris on the floor, and chips around the edge of the pit.

These pits can look very similar to impact craters, so looking for further evidence that they are not, can be helpful. Unlike around impact craters, in the vicinity of vertical lava tube entrances there are no ejecta, and no crater rim is visible – these can be determined using even CTX of MOC imagery.

In case of some caves other negative forms are visible in one line, next to the cave entrance. If these aren’t showing similarities with impact craters too, and also some other attributes are indicating, that they are also collapse forms, they can be counted as further evidences, that under the examined area there is a lava tube – but in addition we can see its line.

If these attributes altogether showing, that the examined formation is a lava tube-entrance, we can say with big certainty that it really is.

The steps of the method for finding lava tube-entrances are:

1. **Finding a volcanic area, selecting an area having appropriate steepness (MOLA).**
2. **Finding relatively constant-temperature spots, by comparing the daytime and nighttime images (THEMIS IR).**
3. **Looking for evidence of lava flow and collapse around, and in the pit (MOC, CTX, HiRISE).**

In the future using more advanced probes and new knowledge this method can be expanded, so a general cave-finding procedure can be made.

The method though has its limits. Without high-resolution thermal-infrared images only the largest (in this case minimum 100m diameter) formations can be found. Also without detailed elevation data, only using complicated image-processing methods, or the using of less accurate photoclinometry is needed to get the data, to examine the exact morphology of the formations.

**Catherine:** Using this method I found a cave-entrance, displayed below (Fig. 1). It was given the name “Catherine”, on the analogy of the “Seven sisters”, the first cave-like formations found on Mars.
Using the vicinity of Arsia Mons as sample-area was an ideal choice, because it was definitely not an intact area in this topic.

After searching the IR images taken from the area, a 180x100m sized, constant temperature spot on the north-western slopes (6.8°S, 236.6°E – Fig. 2) became visible. For the morphological analysis the most detailed multispectral image, a CTX photo was taken. Even on this the evidences of collapse can be seen. On the bottom of the pit there are big debris, and on the rim there are chips. In one line next to the Catherine there are other collapse forms, probably on the top of the same cave-system.

The unusual, oval shape of the Catherine is probably because the morphology of the collapsed surface (Fig. 3-4).

So using some already proven, and analyzed fact it is possible to find even not so spectacular lava tube-entrances on the surface of Mars.

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