EuroMoonMars, HI-SEAS 2020: Analysis of secondary mineralization and IR spectroscopy of igneous rocks in lava tubes on Mauna Loa, Hawaii; insights in extraterrestrial environments and future space exploration.

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Abstract: Lava tubes are abundant all over the Earth and even on Mars and the Moon. In lava tubes at HI-SEAS, Hawaii, there are several minerals present that appear to form from the surrounding basaltic rock by hydrological and microbial processes. The purpose of this study is to research the secondary mineralization in lava tubes to understand the characteristics and formation processes of the mineral precipitates as analogue for the presence of secondary minerals in lava tubes on other terrestrial bodies in the solar system. Furthermore, infrared spectroscopy has been applied for quick identification of the secondary minerals by analogue astronauts for future space exploration purposes in environments that are fit to host extraterrestrial life.

Introduction: One of the leading subjects within the space community is whether there is life beyond our planet. On other planetary bodies in the solar system the surface is particularly hostile. Therefore, the subsurface could be habitable for extraterrestrial life. One of these subsurface features are lava tubes, which are abundant on the Moon and Mars and provide protection for life from solar radiation. Microbial communities on Earth make use of the water and minerals present within the lava tubes, producing mineral precipitates [1]. However, the process itself and the type of mineral phases that are left behind are poorly understood. This has implications for the mineral composition of the igneous rocks within the lava tubes in terms of the original- and altered basaltic compositions. Additionally, it is often uncertain if the morphological features within caves, such as speleothems, are formed by secondary mineralization or microbial processes.

HI-SEAS: Future space exploration and the possible human colonization of the Moon and Mars in the next century could lead to the opportunity to study the subsurface of these planetary bodies in more detail. The Hawaii – Space Exploration Analog and Simulation (HI-SEAS) is a habitat that is located at the northeastern flank of the shield volcano Mauna Loa, Hawaii (Fig. 1). Since 2018 operations of simulated missions are coordinated by the International Moonbase Alliance (IMA). The region surrounding the habitat bears similarities with the surface conditions on the Moon and Mars and contains many lava tubes. Technological improvements together with simulated conditions in and surrounding the habitat will contribute to the understanding of how to properly build a Moon base on the lunar surface in the near future [2].

Figure 1: HI-SEAS habitat surrounded by basaltic lava flows that display resemblance to lunar and Martian basalts.

Research: During a two-week lunar simulation the human limitations were tested regarding scientific field research of secondary mineralization and lava tube exploration. Field research was conducted in specialized lunar analog astronaut suits together with drone operations. Multiple mineral deposits, such as thenardite, mirabilite, burkeite, calcite and gypsum, have been discovered within lava tubes that appear to be indirectly formed by biological activity and hydrological processes (Fig. 2). 28 samples were collected from three large parallel lava tube systems in different lava flows with different forming ages. The secondary minerals are sampled together with the basalt rocks from which it formed to analyse the geochemical differences. The samples were taken from within the lava tubes to mimic subsurface conditions of other planetary bodies, such as the Moon or Mars.

Mineral identification: Short Wave Infrared (SWIR) and Fourier Transform Infrared (FTIR) analysis has been done on the secondary mineral and basaltic samples at the University of Twente, Netherlands, as an easy and quick tool for mineral identification and different mineral phases (Fig. 3).

Figure 2: Mix of thenardite and mirabilite deposit within a lava tube. Hydrological and microbial processes form these precipitates on basaltic cave floors.

Further research: Further analysis in terms of XRF, SEM-EDS and ICP-OES will determine the chemical compositions of the samples and the chemical composition changes between the secondary minerals and basaltic host rocks to determine the formation processes of these secondary minerals. Furthermore, the chemical compositions of the basalt samples will be correlated with basalt from the Moon and Mars to verify the possibility that these secondary minerals can form on those planetary bodies as well.

Summary and conclusions: This study provides petrographic and geochemical data of the mineral assemblages that form from basaltic rocks within lava tubes to determine how the formation processes of these minerals work. Furthermore, the research will take into account to which extent microbial processes are involved in the formation of secondary minerals in lava tubes. Secondary mineralization together with lava tube exploration will contribute to our search for extraterrestrial life and to the understanding of secondary mineral formation processes on terrestrial bodies in the solar system.

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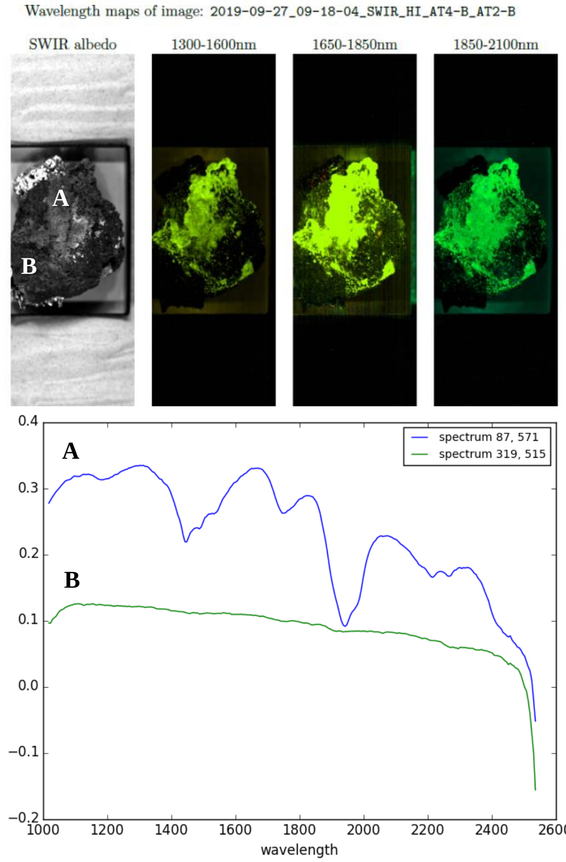

Figure 3: Different SWIR wavelength maps of a secondary mineral precipitate (A) highlighted on the surface of a basalt rock (B). The blue spectrum corresponds with gypsum and the green spectrum corresponds with basalt.

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