ASTROBIOLOGICAL POTENTIAL OF MUD VOLCANISM ON MARS. G. Komatsu[1], R. Ishimaru[2], N. Miyake[2], S. Ohno[2] and T. Matsui[2], [1]International Research School of Planetary Sciences, Università d'Annunzio, Viale Pindaro 42, 65127 Pescara, Italy (goro@irsps.unich.it), [2]Planetary Exploration Research Center, Chiba Institute of Technology, 2-17-1 Tsudanuma, Narashino-shi, Chiba 275-0016, Japan.

Introduction: Future Mars exploration programs focus on detection of life or traces of life [1, 2, 3]. Asides from the question of if life ever existed on Mars, the detection of extant life or traces of past life presents a great challenge for the scientific and technological communities involved in those exploration programs. Here, we discuss astrobiological potential of mud volcanism, an important category of sedimentary volcanism/injection processes, on Mars.

Hypothesized mud volcanism on Mars and terrestrial analogs: Mound features interpreted to be mud volcanoes (MVs) occur at various locations in the northern plains of Mars, including Isidis Planitia [4, 5], Utopia Planitia [6, 7], the Utopia/Isidis overlap [8], Acidalia Planitia [9, 10], Arabia Terra [11], and Chryse Planitia [12, 13, 14]. Confirmation of the MV hypothesis on Mars has not been obtained yet but improved spacecraft data provide further support for the purported MVs. The mound feature formation ages equal or postdate the surface ages of the northern plains that are post-Noachian, but the exact ages of the mounds are not determined due to their small sizes.

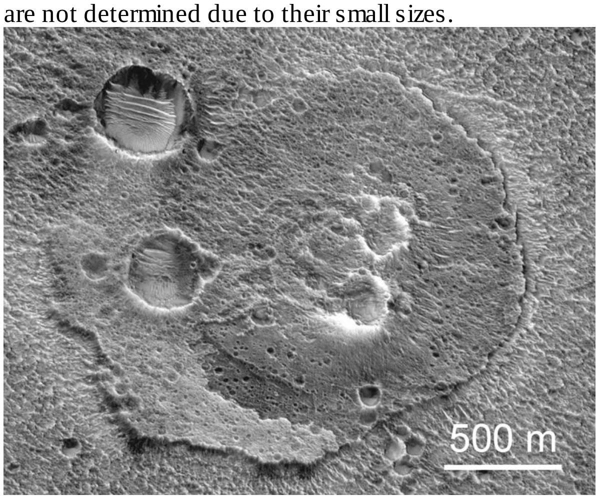

Fig. 1. An example of possible MVs on Mars. Chryse Planitia.

Mud intrusion and extrusion on Earth are well-known phenomena whereby fluid-rich, fine-grained sediments ascend within a lithologic succession mainly because of their buoyancy [15]. The buoyancy maybe given because the involved sediments are in overpressured or undercompacted conditions with abnormally high porosities for their depths due to processes such as rapid sedimentation, tectonic loading, gas hydrate dissociation, or diagenesis and mineral dehydration reactions, among others. MVs on Earth show variable geometry (up to tens of kilometers in diameter and hundreds of meters in height) and a great diversity regarding the origin of the fluid and solid phases. They typically exhibit cone- or pie-shaped (< 5º slopes) edifies and flows, which are made of a clay mineral-rich matrix and a range of clasts [15].

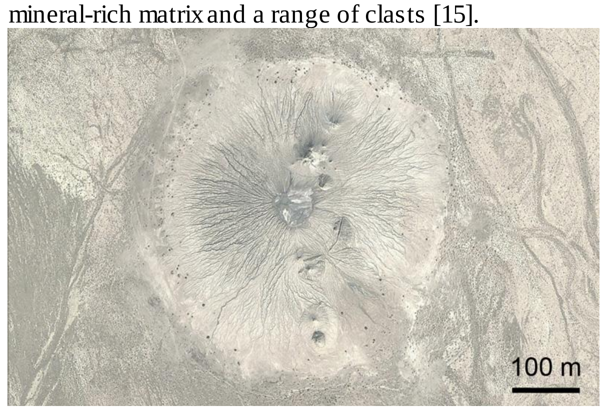

Fig. 2. An example of MVs on Earth. Pakistan.

Fig. 3. Emissions of mud and gas at a summit crater of a MV. Azerbaijan.

Astrobiological potential of mud volcanism: MVs on Earth has attracted interest for microbiology. Previous investigations, for example, have identified anaerobic methane-oxidizing archaea [e.g., 16], sulfur oxidizing and sulfate reducing guilds [17]. Such studies, together with detection of rich organic materials [18], would provide a basis for future astrobiological investigation of MVs on Mars.

The surface environment of Mars is considered to be hostile for life or organic materials due to radiation and oxidation [e.g., 19]. This does not rule out detection of life or organic materials on the surfaces. But the Martian subsurface environment may have been more suitable for biological activity [e.g., 20], and astrobiological exploration of subsurface is an approach worth consideration. The problem is that deep drilling (>10 m), particularly into consolidated rock materials is technically a great challenge on Mars. On Earth, MVs are an important "window" into the underlying strata, because both a low-competence parent bed (clay-rich layer) and some rock fragments are transported to the surface [15]. Similarly, mud volcanism on Mars would provide a window into subsurface crustal materials that were deposited earlier in geologic records. Mud volcanism on Mars, if proven, would be very important in understanding the processes of sedimentation, water saturation, and fluid and gas movement in the crust. Fluids such as water and methane are relevant to the topic of biology/astrobiology, and fine-grained sedimentary materials have the potential to preserve biosignatures or even result from biological processes [21, 22]. Thus, accumulations of subsurface materials transported upward to the surface by mud volcanism could become prime sites for future astrobiological investigations [23].

Sources of fine-grained materials for mud volcanism on Earth could reach great depths. For example, in Azerbaijan, the maximum depths of the sources are estimated to be about 3 to 4 km [24]. The whereabouts of fine-grained material sources for the purported Martian MVs is a matter of speculation. Considering that sizes of the purported Martian MVs and their terrestrial analogs are in similar ranges, it is expected that the depths to the sources could also reach ~kilometers also on Mars.

Besides water, an important fluid in terrestrial mud volcanism is gas, such as methane and carbon dioxide [25]. Terrestrial MVs derive gas, mainly methane, from organic–rich source deposits [e.g., 26], but some exceptional cases for dominance of carbon dioxide in mud volcanism are also known [27]. The gas phase is considered to play important roles for mud volcanism [28]. For example, methane through expansion in a rising mud diapir increases porosity and decreases density of the diapiric material, making it extremely buoyant. Alternatively, upward flowing methane could cause, together with fluids such as water, liquefaction/fluidization of an unconsolidated sediment pile leading to the formation of a diatreme. For both mud diapirs and diatremes, MVs are the surface manifestations of their mud rise and extrusion processes [15]. The plausibility of mud volcanism without gas phase involvement is a question not asked normally for the terrestrial analogs where gas is very rich in their environments. We currently lack information on the state of crustal gas that could have contributed to the MV formation on Mars.

Operation strategy for astrobiological investigation of mud volcanoes on Mars: Astrobiological investigation of Martian MVs should focus on localities where more recent mud eruptions occurred, such as summit craters and small mud mounds (called gryphons) where emissions of mud and gas continued even after the major eruptions. However, young fresh-looking mudflows emanating away from the summit craters are also good candidate targets for investigation. It is recommended to conduct shallow drilling into the mud in order to sample materials less exposed to the harsh surface environment. Individual mudflows of terrestrial MVs could reach nearly 10 meters in thickness [29], and the base part of such mudflows could have been well shielded from the radiation and oxidation for geologically significant time scales. Even if mud volcanism on Mars is not active today, MV sites may still preserve in their subsurface frozen ice originated from liquid water mixed with mud. Thus, drilling into mudflows in search for the water ice would be desirable.

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