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# Paleohydrologic Activity and Environmental Change on Mars

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# 화성에서의 고수문학적 활동과 환경변화

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## Abstract

Results from the most recent decade of Mars' missions to Mars highlight a liquid water and water-ice sculpted landscape. Evidence includes layered sedimentary sequences with weathered outcrops, debris flows, fluvial valleys, alluvial fans, deltas, glacial and periglacial landscapes, and geochemical/mineralogical signatures of aqueous activity, including the formation of sulfates and clays, and the leaching and deposition of elements such as potassium, thorium,and iron. Such evidence indicates weathered zones and possible paleosols in stratigraphic sequences, transport of water and rock materials to sedimentary basins, and the possible formation of extensive transient lakes and possibly transient oceans on Mars. This new evidence is consistent with Viking-era geologic investigations that reported magmatic-driven flooding, ponding to form large water bodies in the northern plains, and transient (tens of thousand of years) hydrological cycles. It may even indicate aqueous activity at present. Both endogenic (magmatic driven) and exogenic (both impact cratering and changes in orbital parameters) have influenced paleohydrologic and environmental change on Mars. Abundance of water and dynamic activity would be decisively important for the possibility of past and present life on Mars.

The identification of fluvial valley networks, which dissect the ancient cratered uplands of Mars, has pointed to past environmental conditions very different from than those prevailing today, which includes hydrological cycling (e.g., Pierri, 1976). With an atmospheric pressure, which varies with the season, ranging from 6 to 10 millibars (1 millibar is approximately one one-thousandth of the air pressure at the surface of Earth), and a temperature typically about 210 Kelvins (-63 °C or -81 °F), though the equatorial regions of Mars may occasionally reach temperatures of up to 10-20 °C (50-68 °F), while during the long polar nights, the temperatures fall to around -120 °C (-184 °F), the current atmospheric conditions will not allow the precipitation and runoff

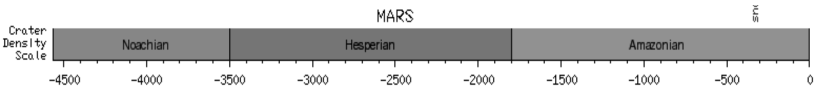


Fig. 1. Timescale of Mars based from the Wikipedia website.

necessary to produce the valley networks. Since the heavily cratered highlands of Mars mostly formed during the Noachian Period (Fig.1), prior to about 3.5 billion years ago (e.g., Fairén and Dohm, 2004), and the valley networks largely occur in the highlands (Scott et al., 1995), many researchers concluded that the age of major environmental change was also ancient, presuming that the fluvial dissection was approximately coincident (Carr and Clow, 1981).

Despite the Viking-spacecraft-based documentation of post-Noachian fluvial (Gulick and Baker, 1989; Scott et al., 1995) and glacial (e.g., Kargel and Strom, 1992) landforms, this paradigm of a "warm-wet" early Mars (Pollack *et al.,* 1987) transitioning into a cold, dry, and dead planet has continued up until recently. Newly released high-resolution image data acquired through the Mars Global Surveyor, Mars Odyssey Mars Express, and Mars Reconnaissance Orbiter spacecrafts indicate uncratered or very lightly cratered surfaces on which geologically youthful landforms pose striking anomalies in regard to the above paradigm (Baker, 2001; Dohm et al., 2008; Fig. 2). The prevailing paradigm has been further challenged by Mars Odyssey-based elemental information which shows water-enriched regions (Boynton *et al.,* 2002; Feldman et al., 2002) consistent with the geologic and geomorphic evidence on the surface of Mars (Scott *et al*., 1995; Baker, 2001).

A diverse suite of very recent, water-related, globally distributed landforms can be recognized on Mars, including landforms which are fluvial (Malin and Edgett, 2000; Ferris et al., 2002), lacustrine (Scott *et al*., 1995; Pondrelli et al., 2008), periglacial (*e.g*., Kargel, 2004), and glacial in origin (*e.g.,* Baker, 2001). In addition, there are pristine mass flows that resemble terrestrial rock glaciers (Mahaney et al., 2006). Earth counterparts are produced by processes operating under a relatively dense atmosphere along with related transport and precipitation of water.

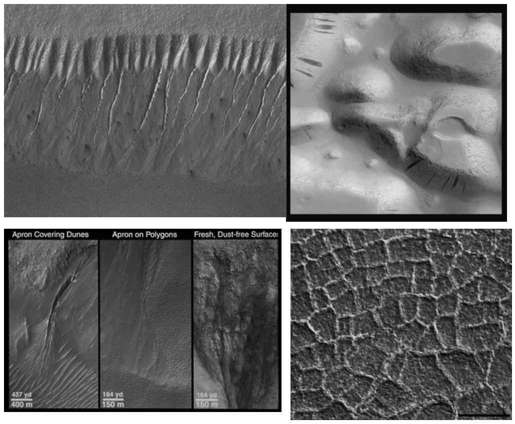


Fig.2 Mars Orbiter Camera (MOC) imagery which distinctly show gullies with associated debris aprons (top left), darks slope streaks (top right), gully and associated debris aprons, which includes related activity resulting in the modification of underlying sand dunes (bottom left), and polygonal-patterned ground typical of terrestrial periglacial environments (bottom right). Note that the width of the features generally range from tens to hundreds of meters. Courtesy of Malin Space Science Systems and NASA.

The anomalous character of these landforms in regard to the very cold, and dry present-day martian conditions may be explained by short-duration climatic perturbations (perhaps $10^3$ to $10^4$ years), triggered by locally extensive volcanism and associated outburst flooding of groundwater, ponding to form water bodies ranging from lakes to oceans in the northern plains, and landslide/mass wasting and glacial activity elsewhere (Baker et al., 1991; Baker, 2001; Dohm *et al*., 2001a,b; Fairén et al., 2003). These perturbations were transient excursions from prevailing ice-house conditions (whereas Earth is mostly clement that has transitoned into ice house and hot house conditions and Venus has prevailing hot-house conditions). In addition, though the migration of ice from the poles can not be related to the current obliquity cycle (Haberle *et al*., 2000), obliquity-related activities may have been optimal for stimulation of recent environmental change (e.g., Cabrol *et al*., 2001; Laskar et al., 2004), which includes a partial overprint of major geologic, paleohydrologic, and paleoclimatic activities of the Martian past (Fig. 3).

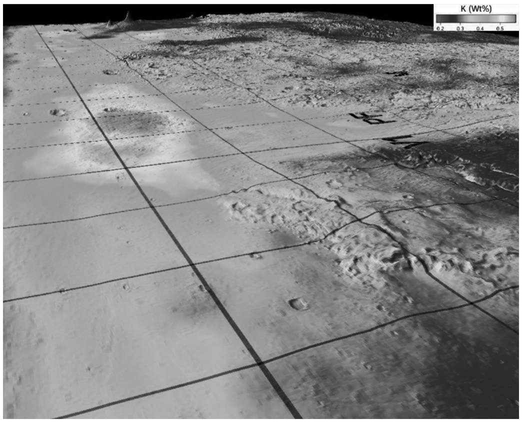


Fig. 3 3D perspective image showing the PDS released colorized Odyssey GRS potassium (K) concentration map over MOLA topography, including an extreme 25X exaggeration looking obliquely to the southeast across the highland-lowland boundary towards the Utopia Planitia basin and Elysium rise (background). Climatic perturbations resulting in hydrological cycling, which includes flooding, spring-fed activity, debris flow and alluvial fan development, is hypothesized to have resulted in the inundation of the northern plains by water bodies ranging in size from lakes to oceans. Such activity is reported to have left its elemental mark on the surface of Mars. Note that the elevated k signatures (yellow, green, and orange) are locations where floods debouched and older sediment occur and low k signatures (dark blue and violet) mostly mark materials of volcanic province (Dohm et al., 2009).

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