LAVA-ICE INTERACTIONS ON MARS; D. E. Wilhelms, U.S. Geological Survey (MS-946), Menlo Park, CA 94025

Diverse phenomena that are consistent with origins by the interaction of basaltic lava with ice-rich sediment characterize ten geologic provinces in a large area of Mars between lat 30° N.-30° S. and long 115°-225° W.

Aeolis province (MC-15 SW, MC-23 NW): An intricately textured deposit near Aeolis Mensae has provided some of the most definitive clues to lava-ice interaction [1]. Narrow ridges are probably moberg dikes formed by intrusion of basalt sills into ice-rich ground and subsequently exhumed by erosion. Volcanic debris created during the interaction apparently has been mobilized by meltwater and flowed as lahars.

Elysium-Hecates province (MC-7 SW, SC; MC-15 NW): Channeled, thick, irregularly textured deposits originating near Elysium Mons and Hecates Tholus have been interpreted as megalahars created by the intrusion of lava into an ice-rich substrate [2]. Several of the moberg tablemountains and ridges in the province [3] were formed by intrusions into the lahars, showing that the lahars retained interstitial ice for some time after their deposition. The exhumation of the resistant tablemountains and a distinctive etched texture of the lahars shows that the lahars, unlike martian lavas, were subject to erosion. Fluid lahars (jökulhlaups) are thought to have been generated by lava flowing over ice-rich ground [4]. These flows have eroded exposed parts of the thicker lahars.

Phlegra-Orcus province (MC-15 NE): The thick, distinctively etched, viscous lahars and the smoother, fluid, erosive flows are also evident near Phlegra Montes, Orcus Patera, and other dense concentrations of knobby terrain. Lavas apparently dominate other parts of northern Elysium Planitia. These spatial associations indicate that the knobby terrain was the source of the meltwater in the lahars and jökulhlaups.

Apollinaris (MC-8 SW, MC-15 SE, MC-16 NW, MC-23 NE): Much of the upland-lowland front (ULF) is characterized by soft-textured, easily erodable deposits called the Medusae Fossae Formation (MFF) [5], which has been variously interpreted as silicic ignimbrite [5,6], stranded former polar deposits [7], aeolian deposits [8], or palagonitic mudflows (lahars) [9]. Thickening of the MFF toward the volcano Apollinaris Patera suggests that at least this part of the MFF is volcanic in origin, although partly eroded and redistributed by the wind. Partly degraded and partly resistant materials like those of the Elysium-Hecates lahars form the contact between the soft material and the Elysium plains, and also form islands in the plains. Thus, basaltic lavas from Apollinaris could have interacted with ice-rich material along the ULF, thereby forming the lahars and creating abundant palagonitic tuff that constitutes the soft material of the MFF. Jökulhlaups created by meltwater from these interactions apparently swept over southern Elysium Planitia, eroding the lahars and crater rims, and depositing extensive (though thin) sediments relatively recently in martian history.

Amazonis Planitia (MC-8 NW, NE, SW): Some of the probable jökulhlaups that originated near Apollinaris and elsewhere flowed NW along a broad braided channel into Amazonis Planitia [10], where they deposited sediment over a large area. This sediment is eroded into distinctive, irregular, cell-like textures whose hollows probably represent concentrations of less-resistant debris than that which forms the "cell walls" and plateaus.

Nicholson province (MC-8 SW, MC-16 NW): The soft MFF terrain is replaced along the ULF between the crater Nicholson (0°, 164° W.) and long. 172° W. by dark-and-light stratified mesas surrounding knobby terrain. The overall map pattern of degraded terrain and resistant mesas, many of which are sinuous, is like that of the Elysium-Hecates lahars, except that more material has been removed here. Small pedestal craters with extensive but partly eroded ejecta blankets show that the wind has removed some of the MFF. More severely eroded pedestal craters occupy broad valleys whose geometry suggests fluid-flow origin. Erosive jökulhlaups originating from the lahars or the original zones of lava-ice interaction probably formed these valleys and removed most of the MFF. The redeposited MFF sediment merges with the cell-textured sediments of northern Amazonis.

Medusae Fossae-Gordii Dorsum province (MC-8 SW, SE; MC-16 NW, NE): This most complex and also best-photographed province has provided good insights into the process of lava-ice interaction. It contains thick, extensive, stratified deposits of the soft facies of the MFF, whose stratigraphic relations with resistant ledges of probable lava suggest an origin as palagonitic tuff. The MFF has been eroded into yardangs [9], whose orientations differ in the various layers, and has been redistributed locally as eolian dune fields. Windows eroded in these soft deposits reveal lahars, probable lava sills, fluid-flow lineations emanating from beneath the sills, channels eroded by fluid flow, sediments deposited from the flows, tablemountains, and possible moberg ridges.

Mangala Valles (MC-16 NE): Based on the relations reported above, I interpret the complex, braided outflow-channel system Mangala Valles [11] as another product of lava-ice interaction. Dark, coherent plains that are probably composed of lava occupy many crater floors, a large trough between massifs of the >2,000-km-diameter "Daedalia" basin, and belts of upland parallel to Mangala and the Daedalia rings. The same material also forms a sinuous intrachannel ridge (7.5° S., 151.5° W.), which apparently formed by the flow of lava in an earlier, smaller channel and was exhumed by erosion of weaker material of its former banks. Episodic lava intrusions may have melted ice contained in the upland deposits, and the resulting meltwater may have cut the channel system.

Fluid flows emanating from the mouth of Mangala (4° S., 150.5° W.) and from parallel channels have eroded a broad path through the MFF and crater ejecta as far as 9° N., 153.5° W. This erosion is like that of the Nicholson province, and its sediment adds to the Amazonis deposit.

Olympus-Biblis province (MC-8 NE, SE; MC-9 NW, SW): Etched, channeled flows resembling the lahars of the Elysium-Hecates province occur NE of Olympus Mons. The much-studied, controversial Olympus Mons aureole has been interpreted as another manifestation of lava-ice interaction [12]. This interpretation is supported by the similarity of short, irregular ridges of the northern Medusae Fossae-Gordii province to the ridges that characterize the aureole. The ridges of the NW-most aureole lobe have a gridlike pattern lacking evident pull-apart gaps, suggesting that this lobe formed nearly in place. Most of the aureole, however, is partly allochthonous, having slid outward along decollement surfaces from an origin closer to the mountain [13,14]. This relation is particularly evident where the SE aureole lobe has overthrust older terrain NW of Biblis Patera. Meltwater from the lava-ice interaction could have lubricated the flow. Furthermore, flow patterns of some of the weblike sediments of Amazonis suggest sources in the aureole.

Uplands (MC-16; MC-23): The history of the lava-ice interactions in the above "lowland" provinces is consistent with one or more episodes of recycling of ice originally contained in deposits of the uplands. Loss of some of this ice converted the upland deposit into knobby terrain along much of the ULF and in northern-plains outcrops, such as those of the Phlegra-Orcus and Nicholson provinces. However, sufficient ice remained to interact with the lava to form lahars and the MFF, and the uplands retained still more of the ice in relatively cohesive deposits.

Much of the evolution of the landscape of Mars can be ascribed to this process, highly diverse in detail but basically originating from the inevitable interaction of two of the most common martian geologic materials, ice and basalt.

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