CASE HARDENING OF SURFACE FEATURES: EARTH ANALOGS TO THE MARTIAN SURFACE. James Conca, California Institute of Technology, Pasadena, CA, 91125.

Eolian processes and deposits are extremely important on the Martian surface. Analogous processes and deposits occur in the arid regions of the Earth. Case hardening is a geologic process which affects many of these desert phenomena and occurs on many types of deposits.

In the case-hardening process a hardened surficial crust is formed which results in a reduced weathering rate and friability for the exterior of the deposit relative to the interior. The deposit can be anything from an igneous rock to dune sand. The crust is usually the result of a cementing agent being introduced to the surface. The cementing agent can be derived from the host material itself or be deposited on the surface, commonly by wind or water. Porous media such as sand and sandstone can be especially affected by case hardening.

We have recently completed a study of a case-hardened sandstone (the Aztec sandstone) in southern Nevada [1]. Here, the case hardening of the sandstone has resulted in an extreme example of the morphology known as cavernous weathering, in which caves and pillars up to meters in length are formed by rapid weathering of the more friable interior. The case-hardened crust consists mainly of host rock, with a fine-grained cement and wind deposited kaolinite. The cement is usually calcite in a wide range of concentrations (0.001 to 5.0 wt% calcite), but in some cases the hydrated calcium borate, colemanite, was found to be the cementing agent (infrared spectroscopy and SEM were used to identify mineral phases in the crusts). In all cases both the presence of excess kaolinite and the presence of a cementing agent were necessary conditions for case hardening to occur. Eolian transportation of particulates containing the case-hardening components to the surface and recrystallization of the cementing agent throughout the surface is the proposed formation mechanism for the case-hardened crust at this locality.

We are presently investigating case-hardening of dunes and other sand deposits in the Salton Trough area of California [2]. Armouring of the surface of some deposits has stabilized some surfaces against eolian processes, retarding the movement of features and affecting the source of the sediment supply to eolian transport. Preliminary studies suggest that sulfates are important in the case hardening of the sand deposits in this area and may be the dominant case-hardening agent.

Case-hardening depends upon the absolute hardness of the material as well as the differential hardness between the interior and surface. If the host material is porous and friable, case hardening will be very important in altering the physical properties of the material. Surfaces are observed to be cemented by a variety of agents such as sulfates, carbonates, borates, silica, iron oxides and salts. Sometimes the agents can act in conjunction with other minerals such as clays. All of these components can be eolian transported to the surface as well as transported in solution. The fact that we have observed eolian processes to play a major role in case hardening on the Earth is especially relevant to the Martian environment.
On Mars, the conditions for case hardening to occur probably exist in many areas. Eolian processes are observed globally. Dunes and other large sediment deposits also occur in many areas. Case-hardening agents could involve iron oxides and/or sulfates and possibly inorganically derived carbonates. Favorable environments for case hardening to occur on Mars is in the canyons, polar regions and any area that combines fines, transport processes and H$_2$O in any reactive form. However, by these criteria most of the Martian surface should have some manifestation of case hardening. Duricrust, which is the most observable manifestation of the process on Mars, may in fact be globally distributed, and case hardening of dunes and even igneous rocks may occur. It has been widely accepted that the duricrust is cemented by salts, most probably sulfate salts [3], but major problems exist concerning the cation compositions of the cementing agents and formation mechanisms for the crust. Determination of formation mechanisms for terrestrial case-hardened crusts may clarify these problems.

The erosion rates of dunes and other eolian deposits on Mars is thought to be very low, suggesting that these features are ancient. As we have seen in California, the stability of these features with respect to erosion may be due in part to case hardening of their surfaces.

Another possible example of case hardening on Mars is the slumping of a fine-grained surface layer observed by the Viking I Lander [4]. The difference in cohesiveness between the surface and underlying material, which resulted in the slumping, is probably the result of a case-hardening mechanism similar to the formation of duricrust.

Characterization of case hardening and case-hardened crusts on the Earth, especially sulfate-cemented crusts, is necessary before similar Martian phenomena can be fully understood. More localities exhibiting case hardening on the Earth will be investigated, paying particular attention to their applicability to Martian environments.

REFERENCES: