FUSION CRUST SIMULATION AND THE SEARCH FOR MARTIAN SEDIMENTS ON EARTH.

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Approximately half of Mars may be covered by sedimentary rocks or weakly consolidated conglomerates and regolith welded by ice and evaporites [1,2]. However, the 14 martian meteorites recovered to date are all igneous rocks [3]. Furthermore, a large fraction of Mars is covered by ancient cratered uplands, whereas only one of the 14 martian meteorites is definitely older than 1.3 Ga [3]. From these two considerations, we suspect that the old martian uplands maybe under-represented in the martian meteorite collections, and investigate possible causes.

One possible cause is that many martian upland materials are too weak or too poorly consolidated to be ejected. Another possibility is that they may be sedimentary and conglomerate rocks that are not recognized during the collection process as meteorites (see discussion in [4]). The visual appearance of a meteorite is governed primarily by its fusion crust, which tends to be characteristic of that meteorite’s class. Meteorites are commonly said to have a black fusion crust. However, they vary greatly in whether the crust is shiny and highly glassy, with vesicles and conchoidal fractures (as in HED meteorites and lunar mare basalt meteorites), dull black and imperfectly glassy (as in chondrites) [5,6], or good quality, sometimes frothy, transparent olive-green crusts (as on anorthositic lunar highland meteorites) [6]. In order to determine the likely appearance of hypothetical martian sedimentary and conglomerate rocks, we subjected various rocks to an oxyacetylene flame for three minutes. The behavior of the surface was monitored during the process, and the appearance of the surface after cooling was compared to that of known meteorites.

First we examined a piece of the Kernouve H5 chondrite and several samples of terrestrial rocks thought to be analogues of the various meteorite classes. Samples include a fine grained mid-ocean ridge basalt, a coarse grained assemblage of anorthite and pyroxene, and relatively pure anorthite. The Kernouve sample produced a dull black, almost scoracious, melt crust very similar to chondrite fusion crusts, while the basalt sample and the anorthite/pyroxene assemblage both produced ample quantities of a low viscosity melt that cooled to give a shiny black crust identical in appearance to the crusts on HEDs and lunar mare meteorites. The anorthite sample produced copious amounts of melt which had an olive green color while hot but turned clear on cooling. Large amounts of degassing gave the melt a frothy appearance, similar to that reported on the lunar meteorites. It seems likely that the presence of certain impurities or a slightly thinner, translucent crust would have resulted in a crust identical to those on the lunar highland meteorites. The similarity of the surfaces produced during our experiments and the fusion crusts on the analogous meteorites suggest to us that this is a reasonable means of predicting the nature of the surfaces of rocks after passing through the Earth's atmosphere.

Other samples were examined in the same manner following this initial characterization. Samples include an iron-rich sandstone, a loosely consolidated quartz sandstone conglomerate, specular and non-specular hematite, limonite, dolomite, and limestone. Upon heating, the sandstone and quartz conglomerate had clear transparent glass coatings, although the amounts were minimal and the degree of melting was sometimes incomplete. The samples of hematite produced a smooth dull black melt that pooled in places and closely resembled the fusion crusts on iron meteorites. The limonite produced a poor quality black-brown melt, but the sample underwent considerable fragmentation upon heating. The dolomite sample also produced a pool of a brown melt, but only after considerable explosive spallation and degassing of material at the site being heated. Thus, meteorites of these compositions should have conspicuous crusts, some of which would be different from classic meteoritic fusion crust. The limestone sample readily became white hot in the flame, but there was no melting and layers tend to spall off. After the heat treatment, the surface had a white powdery appearance with no indication of melting and a considerable tendency to fragment.

The appearance of fusion crust on meteorites is clearly governed by (1) mineralogy of the meteorite and mineralogical changes that occur during atmospheric passage, (2) the melting temperature, or more precisely the range of temperatures and subsequent viscosity of the melt or partial melt on the surface of the meteorite, and (3) orientation of the surface at the time the crust solidifies (thin crusts with smooth surfaces and fine radial stringers on the front, thick crusts with scoriaous or even frothy textures on the back, and intermediate thickness crusts with lateral flow on the sides) [7]. Our experiments enabled us to assess the first two of these factors, and any rock with partial melting of its surface would be expected to produce the normal fusion crust textures, as well as excavation pits (regmaglypts) caused by the turbulent motion of air around the rock. Martian meteorites composed essentially of limonite or other iron oxides would have a dull black, smooth fusion crust much like iron meteorites, with the usual fusion textures and would be easily recognizable. Martian sandstone or sandstone conglomerate meteorites should have a thin transparent crust, again with all the usual fusion crust flow marks, although considerable degassing would make the crust appear white. Such meteorites should be recognizable in the field, if they are present. Martian meteorites composed primarily of carbonates would probably not have any recognizable fusion crust, consistent with the higher melting point of CaO compared to iron oxides and silicates (~2500 ^{o}C, c.f. ~1500 ^{o}C) and would be very difficult to recognize in the field. Thus, meteorite collectors should be alert in looking for atypical samples with clear or white fusion crust which might not otherwise be considered as meteoritic.

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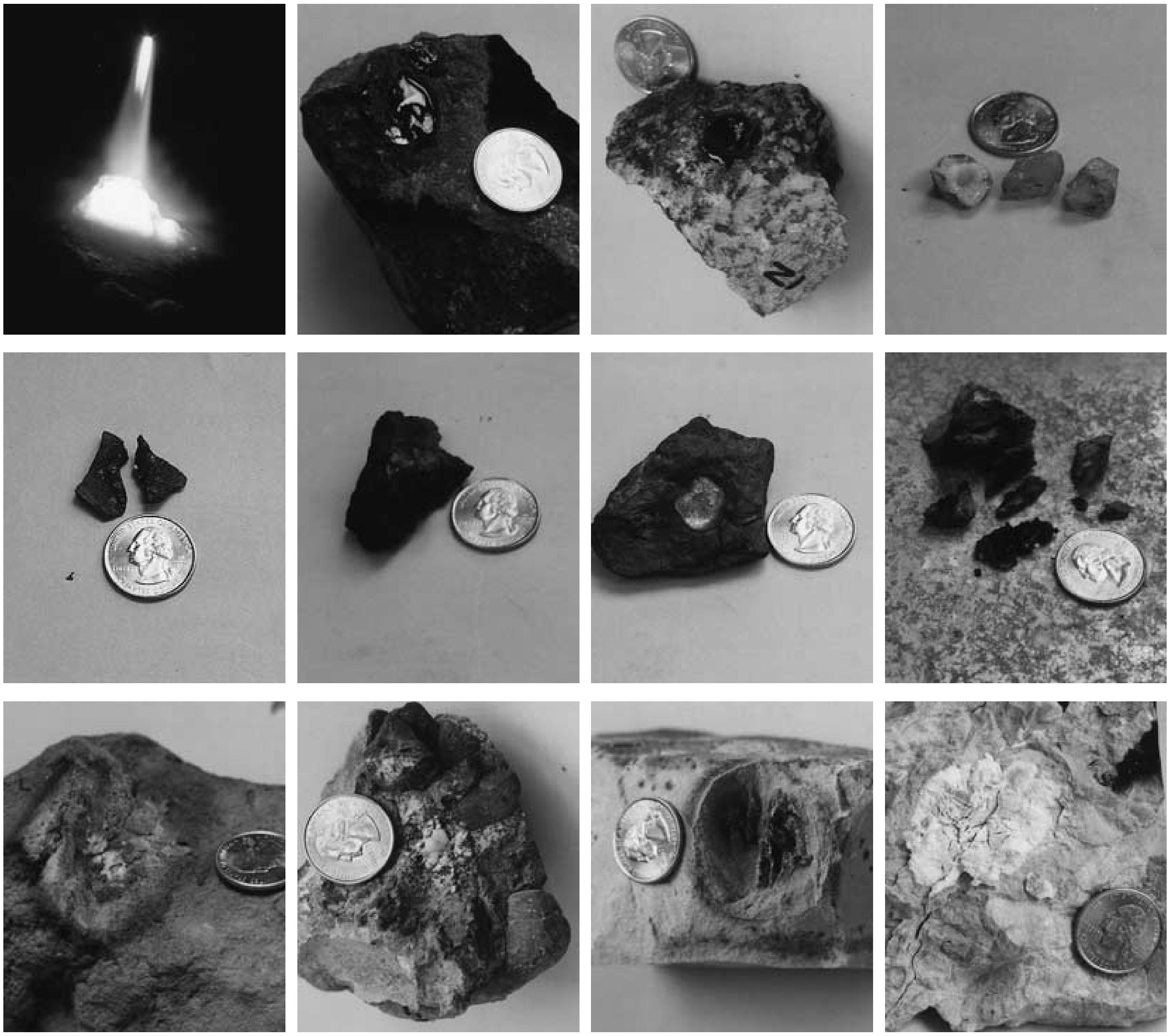

Simulated fusion crusts on meteorites. From left to right, top to bottom: (row 1) A sample being exposed to an oxyacetylene burner; basalt; coarse-grained anorthite-pyroxene; anorthite; (row 2) Kernouve H5 chondrite; hematite; specular hematite; limonite; (row 3) Fe-rich sandstone; quartz conglomerate; dolomite; limestone. The meteorite look-alikes (basalt to anorthite) and Kernouve produced melt layers very similar in appearance to the fusion crusts on the equivalent meteorites (eucrites and mare basalt meteorites, highland meteorites, chondrites), while hematite and limonite produced crusts very similar to those on iron meteorites. The sandstone and the quartz conglomerate had a clear/white crust while dolomite and limestone spalled considerably and it was impossible to produce a melt crust on limestone. A 2.5 cm diameter US coin appears in each picture for scale.