SIMULATION OF EFFECT OF IMPACT MELTING ON OPTICAL PROPERTIES OF MARTIAN SOIL

A.T.Basilevsky, O.I.Yakovlev, A.V.Fisenko, L.F.Semjonova, L.V.Moroz*, C.M.Pieters, T.Hiroi**, N.G.Zinovieva***, H.U.Keller****, A.S.Semenova, L.D.Barsukova, I.A.Roshchina, A.Kh.Galuzinskaya, I.A.Stroganov**

Vernadsky Institute, Moscow, Russia

* DLR Institute for Space Sensor Technology and Planetary Exploration, Berlin, Germany

** Geological Department, Brown University, Providence, RI, USA

*** Geological Department, Moscow State University, Russia

**** Max-Plank Institut fur Aeronomie, Katlenburg-Lindau, Germany

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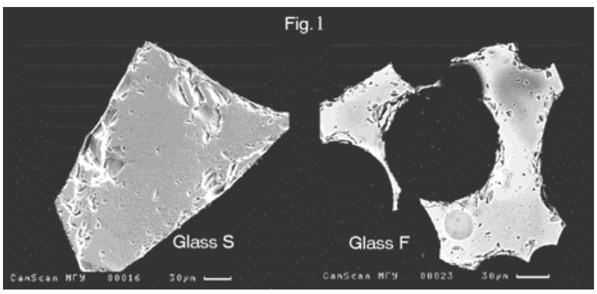
Introduction: This work appeared as a result of analysis of the characteristics at the Mars Polar Lander landing site [1,2]. The latter was planned to be within polar layered deposits (PLD) composed of mixtures of ice and airborn dust [3]. Darker, less red (than PLD) material was observed there in topographic depressions and interpreted to be eolian deposit caught in the saltation traps [4]. Saltation implies sand size particles so the question arised how these particles could appear in the dust-and-ice environment. It was suggested by [1,2] that meteorite bombardment of PLD could partially transform their silicate dust component into the impact melt sand-sized particles, which became a source of the eolian deposits. To explore this possibility we simulated the impact melting of the Mars soil analog and measured reflectance spectra of the melting products. The failure of the Mars Polar Lander did not close the problem of contribution of the impact melt to the composition of Martian soils. Moreover it is evident that because meteorite bombardment affects Mars globally, the results of this study are applicable to much broader analysis of spectra of this planet.

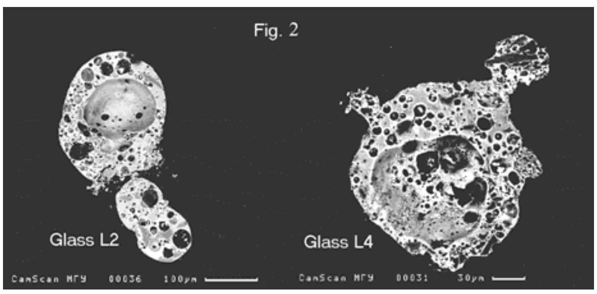
Martian soil analog: For our experiments we used JSC Mars-1 simulant (palagonite soil) [5]. The sub-sample studied by us is close in its chemistry to that described by [5] except LOI which is higher (21.8 wt %) in their and lower (15.88%) in our sub-sample. Our analysis showed that the dominant part of LOI is CO_2 (11.12%), H_2O is second in abundance (5.40%). S is <0.3%. N_2 is 0.058%.

Experiments: Melting associated with impacts reworking of regolith is fast and occurs with superheating of significant part of the melt [6,7]. Its products are typically dispersed and hence cool very fast. We simulated impact melting of palagonite simulant at Vernadsky Institute producing glasses by: 1) fast melting in the resistance furnace at ~1650°C and fast (seconds, glass F) and more slow (10's sec, glass S) cooling at vacuum ~10^{-1} mm Hg; and 2) by laser shots thus melting very fast small pieces of the target which cooled also very fast (<1sec), vacuum ~10^{-2} (glass L2) and ~10^{-4} mm Hg, (glass L4). Vacuum ~10^{-1} to ~10^{-2} mm Hg has oxygen fugacity close to that in Mars atmosphere [8].

Grains of fractions +200-380 μm of samples F, S, L2, L4, and P were sealed in epoxy, polished and then studied at the Moscow State University Camscan 4 DV + Link AN10000. For most components the microprobe analyses did not show systematic compositional differences between the produced glasses and the palagonite sample and among the produced glasses except some depletion of L2 and L4 in Na and K.

The SEM study showed that glass S (Fig. 1, left) is compositionally homogeneous and looks massive with no gas bubbles. Glasse F (Fig. 1, right) shows compositional inhomogeneities seen as variations in the brightness on BSE images and sometimes has gas bubbles larger than 10-15 μm across. Sometimes clusters of very small (~1 μm) bright (on BSE images) grains of Fe-Ti oxides and skeletal crystals of plagioclase, olivine and ilmenite are seen included in the F glass.





Glasses L2 and L4 (Fig. 2) are represented by spheroidal droplets and irregular fragments with numerous gas bubbles of 1-2 to 30-50 μm across. The glass in between bubbles frequently shows compositional inhomogeneities with typical size from a few microns to a few tens of microns. In rare cases inclusions of minerals such as plagioclase are observed.

Spectral measurements: The reflectance spectra of several size fractions of the samples were recorded between 0.3 and 25 μm at Brown University using spectrometers RELABbds and Nicolet 740 FTIR, and at DLR, Berlin, using spectrometer Bruker IFS88. Although the glasses show spectral variability depending on the method of production and the cooling rate [9] all of them are darker and less red in the visible relative to palagonite (P). Below is an example of the preliminary results: the 0.59/0.45 μm ratios:

Size, μm	P	S	F	L2	L4
200-380	2.33	~1.05	~1.05	1.73	~1.7
<40	3.06	1.58	1.42	2.02	2.11

Discussion and conclusions: It was found by [4] that dust mantling PLD has 0.59/0.45 μm ratios to be 3.2-3.7 while darker, less red material in topographic depressions has the ratios to be 1.8-2.1. It was suggested in [4] that the dark material consists of sand-sized particles which could form from the local dust, e.g., through aggregation of dust particles in a process of sublimation of the dusty ice [10,11]. However the latter authors noted that color and brightness of the aggregates do not differ significantly from those of the dust. This is why [1,2] suggested that meteorite impacts into the layered deposits could produce the glass particles then involved in saltation and forming the darker and less red deposits in local lows. Spectral studies of our experimental glasses showed that they are indeed darker and less rede than the Martian soil simulant. This agrees well with the suggestion of [1,2]. We expect that future missions to Mars will identify impact melt glasses in the regolith of polar regions and in other areas of Mars and confirm their importance in forming the lithology of the surface layer of this planet.

Unexpected implications: Among other features detected in spectra of the experimental glasses, the 4.27-μm absorption was found [9]. Similar (4.25-μm) feature was recently described in NIMS spectra of Callisto and Ganymede and interpreted as signature of CO_2 trapped in interstitial spaces or fluid inclusions in water ice [12]. In our studies the 4.27-μm absorption was found only in spectra of the L2 and L4 glasses [9]. The latter differ obviously from the F and S glasses in presence of numerous gas bubbles (Figs 1 and 2). So one may suggest that this feature is a signature of CO_2 trapped in the observed bubbles and/or in some other form. This is supported by the fact that the dominant part of LOI of the used palagonite is CO_2. Laser shots are good simulation of high-velocity micrometeorite impacts. This implies that micrometeorite bombardment of targets, which release on their melting gas CO_2, may produce glass with CO_2 gas bubbles. Good candidates for such targets are 1) surface materials of the DPC asteroids and 2) compositionally close to them dark non-icy lag material on the surfaces of Callisto and Ganymede. If so: 1) we may suggest that the 4.25-μm absorption in spectra of these satellites is, at least partly, due to CO_2 trapped in the silicate glass produced by the micrometeorite bombardment; and 2) we may expect the 4.25-μm feature in spectra of DPC asteroids also related to the gas release in micrometeorite bombardment of their regoliths.

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