REDUCTION OF SiO_2 TO Si AND METALLURGICAL TRANSFORMATIONS IN Al BY HYPERVELOCITY IMPACT OF Al-PROJECTILES INTO QUARTZ SAND.

C.Jammes, D.Stöffler, A.Bischoff, W.U Reimold, Institute of Mineralogy, University of Münster, D-4400 Münster, Germany and D.E.Gault, Murphys Center for Planetology, Murphys, CA 95247

<u>Experiments.</u> Quartz sand targets (grain size: 0.063-0 25 mm) were impacted vertically with 0.3-0.4 g aluminum spheres at 5.9 to 6.9 km/s in the light gas gun facility of NASA Ames Research Center under an ambient air pressure of 0.5- 3 mm(1, 2). According to impedance matching solutions using measured Hugoniot curves of aluminum and quartz sand, the peak pressures achieved in the impact experiments range from 42 to 51 GPa at the point of impact (2). This magnitude of shock pressure yields sufficient post-shock heat upon pressure release to transform projectile and target material into the liquid state. The threshold pressure for shock fusion of sand is estimated to be about 20 GPa (1, 3). Silica melt agglomerates coated with aluminum were recovered from the central bottom of the craters, 32 to 33 cm in diameter,and analyzed by optical, electron optical, and microprobe methods. This is a report on preliminary results of such analyses.

<u>Results.</u> In order to understand the shock and thermal effects in both the Al-projectile and the sand target, the pre-impact properties of both materials are to be discussed. The sand is dry commercial sand of more than 99 % quartz. The Al-spheres are composed of an Al-rich alloy with an approximate bulk composition of 95.6 wt.% Al, 3.9 wt.% Cu and traces of Si, Mg, Mn and Fe (Fig.1). Reflected light microscopy reveals a heterogeneous texture which is formed by randomly distributed globules of exsolved Al-poor phases in a very Al-rich matrix (Fig.2). The globules consist of two phases which presumably represent an Al-Cu- and an Al-Mn-alloy; their exact nature and composition has not yet been established (Fig.1). The melt agglomerates (up to several cm in size) recovered from the crater bottom display distinct textural and compositional zoning which reflects a gradient of shock pressure and temperature. Four major layered zones can be distinguished in sections taken perpendicular to the surface from top to bottom (Fig. 3):

1. The top side of the melt agglomerate is coated by projectile material which forms a rugged crust of about 0.4 mmthickness. The bulk composition of this Al-crust is very similar to that of the unshocked projectile (Fig. 1). However, the microscopic texture is distinctly different (Fig. 4) and probably is due to melting and subsequent crystallization. Large subrounded Al-rich matrix areas are embedded in a thin web-like network of metal phases which show typical eutectic crystallization texture. At least 3 different phases can be identified within the eutectic areas by scanning electron microscopy.
2. At the base of the Al-crust a thin layer of material with low reflectivity forms the contact to the vesiculated silica glass underneath and predominantly consists of Al_2O_3. Very tiny spheres of silicon (?) can be found adjacent to this layer within the silica glass.
3. The Al-crust and the oxide-layer are underlain by a layer of vesiculated silica glass of variable thickness in which relic quartz grains with planar deformation structures, metal spheres and irregular bodies of metal are embedded. The metal is heterogeneous in composition and very often surrounded by a flow-structured phase of Al_2O_3-rich composition with tiny inclusions of metal spheres. The large metal bodies are composed of euhedral silicon crystals embedded in an Al-rich metal matrix which is very similar to that of the Al-crust (Fig. 5). The metal spherules consist almost entirely of silicon.
4. The lowermost layer forms a compact aggregate of quartz grains ("shock lithified sandstone") in which planar deformation structures are very rare or lacking.

<u>Interpretation.</u> Hypervelocity impact of Al-projectiles into quartz sand results in the complete melting of the projectile, partial melting of quartz sand, and chemical reactions between aluminum and silica. The liquid projectile is spread over the dense, shock lithified target sand in the center of the crater. It is remarkable that a major part of the projectile is neither mixed into the target material nor reacts with it. Only a fraction of the liquid metal which is adjacent to the fused sand, reacts with silica in a strongly exothermic reaction to form alumina and silicon. The crystallization of silicon crystals is most pronounced in metal droplets which were injected into the silica melt and relic quartz grains. Alumina is quenched from a liquid state and tends to recrystallize dendritically. This implies minimum temperatures of at least 2050°C. With respect to the volume of shock-fused target material an important conclusion is that an appreciable portion of the thermal energy for the production of impact melt is provided by the chemical reaction between projectile and target. The opposite holds for the case of natural metal projectiles (Fe-Ni), for which the corresponding reaction would be endothermic.

The results of this study bear on the understanding of regolith-forming processes on planetary surfaces. In agglutinate particles of natural regoliths (e.g. lunar, asteroidal) it should be possible to detect remnants of the meteoritic projectile material which was not mixed with the target material. The projectile should be present as fused metal (iron meteorites) or silicate melt (stony meteorites) adhering to shock fused and lithified agglutinates which originate from small scale cratering events in the regolith of all planetary bodies without atmosphere.

<u>References.</u> (1) Stöffler,D., Gault,D.E., Wedekind,J., and Polkowski,G. (1975) <u>J.Geophys.Res.</u> <u>80</u>, 4062 - 4077; (2) Stöffler,D., Gault,D.E., and Reimold,W.U. (1980) in: Papers presented to the Conf. on Multi-ring Basins, LPI Contribution No.414, 89 - 91; (3) Kieffer,S.W. (1975) <u>The Moon</u> <u>13</u>, 301 - 320 .

Fig. 1: Chemical composition of metal and oxide phases of melt agglomerates

Fig. 2: Microscopic texture of unshocked Al-projectile

Fig. 3: Generalized cross section through the layered zones of an Al-coated melt agglomerate

Fig. 4: Microscopic texture of the shock fused Al-crust on top of a melt agglomerate

Fig. 5: Microscopic cross section through the Al_2O_3-rich oxide layer and the silica glass layer with metal bodies including euhedral silicon crystals

REDUCTION OF SiO_2 TO Si

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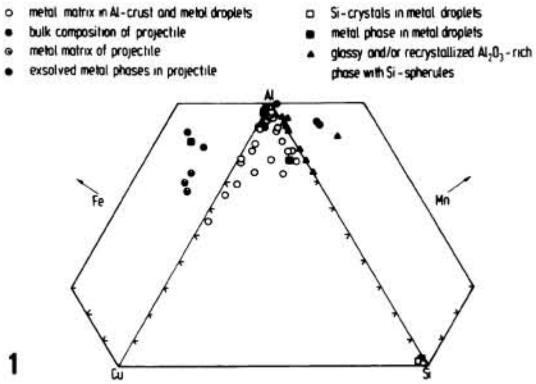

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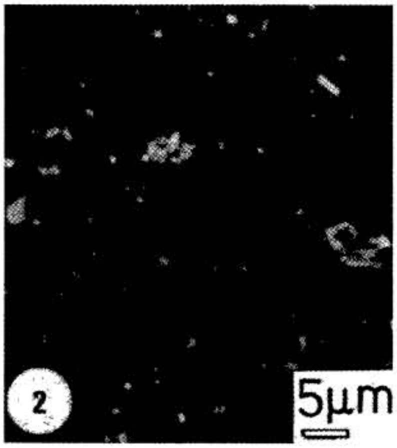

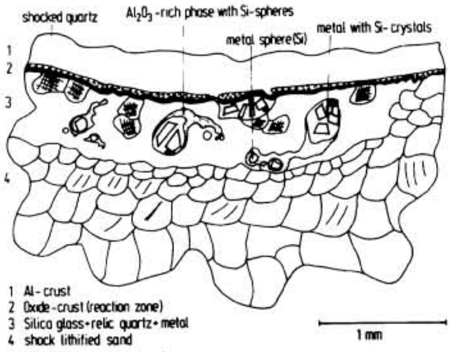

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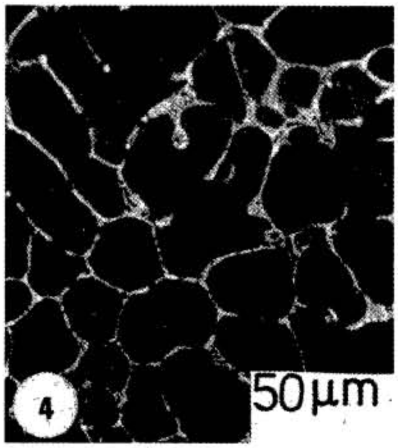

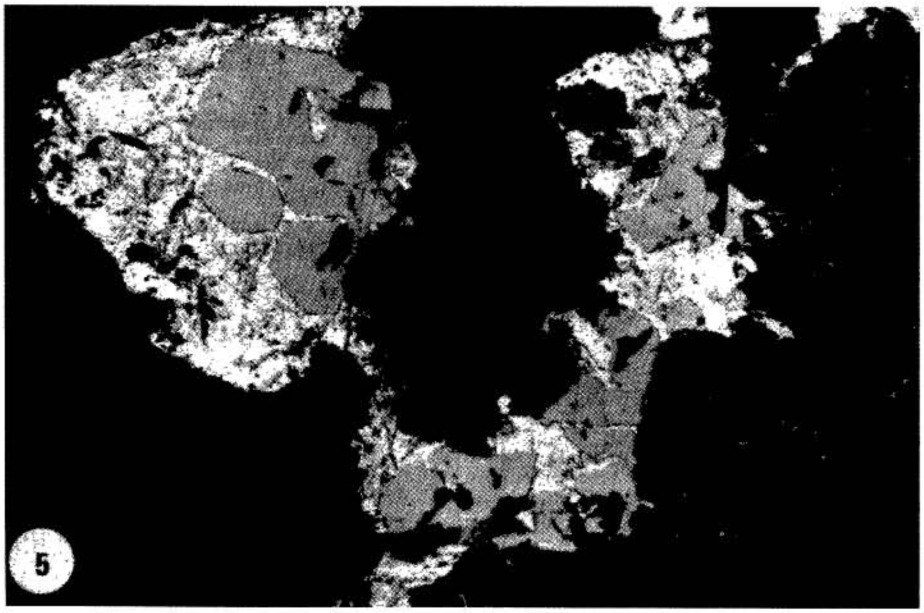

Width of field of view is ~ 2500 µm