AGGREGATION IN PARTICULATE CLOUDS IN ASTROPHYSICAL AND PLANETARY SETTINGS: PRELIMINARY RESULTS FROM USML-2; J.R. Marshall and F. Freund, SETI Institute/NASA Ames Res. Ctr., MS 239-12, Moffett Field, CA 94035

Particle aggregation experiments were conducted in the 2nd U.S. Microgravity Laboratory (USML-2) to determine how particulate materials aggregate in response to cloud density, dielectric properties of the grains, and grain shape. Results confirm earlier findings from USML-1 that aggregation in particulate clouds is predominantly controlled by long-range electrostatic forces. They also confirm the universal occurrence of filamental aggregates, structures that implicate dipoles as the primary coulombic force leading to aggregation. USML-2 experiments led to the discovery of this filamental aggregation in metallic particles where dipole interactions would seem to be ruled out. The work is supported by NASA’s Exobiology Program.

Aggregation occurs in volcanic eruptions, in dust palls raised by wind on Earth and Mars, in global debris palls raised by bolide impact on planetary surfaces, in planetary rings, and in interstellar and protostellar/protoplanetary nebulae. The mode and rate of aggregation may influence, if not completely control, the behavior and longevity of these dust and debris clouds. We believe that electrostatic forces may be extremely important in controlling aggregation: van der Waals, covalent, ionic, and metallic attractions are not effective at distances greater than nanometers. The only practical way such forces can be effective is for turbulence or Brownian motion to move particles together (neither mechanism is effective in space). With the exception of limited cases involving ferromagnetic or paramagnetic attractions, electrostatic forces are required to drive aggregation (gravitational forces between cloud particles are many orders of magnitude weaker than coulombic forces). We note also that, for many reasons, virtually all natural materials have static charge.

Static forces have been studied in USML-1 & 2 where the absence of gravity has enabled aggregates to form without precipitation to the chamber floor, and without weight-induced collapse of fractal aggregate structures. The experiment device flown in the USML-2 Glovebox Facility consisted of a hand-operated pump and eight test chambers each of 125 cm³. Test particles contained in each chamber were dispersed throughout the chamber volume by a momentary pulse of compressed air injected by the pump unit. Once dispersed, the particles were allowed to aggregate for several minutes while being filmed on video. Limited high-magnification data were also obtained with the Glovebox microscope.

USML-2 test materials included volcanic ash, quartz, copper, and a mixture of copper and quartz, all particles of 400 microns diameter. All materials produced filamental aggregates within seconds to minutes after dispersion. The modules with higher density clouds produced the largest aggregates. Particle shape had no unique influence on the aggregation process. In some cases (with the quartz), aggregates were several centimeters long while remaining (apparently) in a single chain. Dipole-dipole interactions are believed to be the cause of both grain-to-grain attraction and grain-to-grain adhesion after contact. Copper and copper/quartz populations also produced similar chain structures. For metals, chains are a surprising result. Chains imply alignment of forces co-axially with the grains. We postulate that when oppositely-charged metal grains come into contact, they only partially discharge at the junction. The residual charges are concentrated (and paired) near the contact and supply both a force of adhesion and an aligned dipole effect.

USML-1 and USML-2 results strongly suggest that any relatively dense particle cloud, regardless of composition, will undergo rapid aggregation owing to electrostatic forces inherent in the cloud-particle system. There is no circumstance that we have tested that has not produced almost instantaneous aggregation. Ironically, it is implied from the data that denser clouds might be shorter-lived than dilute ones because there is sufficient material to cause aggregate interactions. Aggregation is probably important in determining the longevity of volcanic eruption clouds, global dust palls, and it might contribute to the demise of interstellar nebulae which are known to collapse at rates in excess of that implied from gravitational considerations alone.