A Self-Perpetuating Catalyst for the Production of Complex Organic Molecules in Protostellar Nebulae. J. A. Nuth[1] and N. M. Johnson[1], [1]NASA Goddard Space Flight Center, Code 691, Greenbelt MD 20771 (Joseph.A.Nuth@NASA.gov).

The formation of abundant carbonaceous material in meteorites is a long standing problem (1) and an important factor in the debate on the potential for the origin of life in other stellar systems (2). Many mechanisms may contribute to the total organic content in protostellar nebulae, ranging from organics formed via ion-molecule and atom-molecule reactions in the cold dark clouds from which such nebulae collapse (3), to similar ion-molecule and atom-molecule reactions in the dark regions of the nebula far from the proto star (4), to gas phase reactions in sub-nebulae around growing giant planets (5) and in the nebulae themselves (6). The Fischer-Tropsch-type (FTT) catalytic reduction of CO by hydrogen was once the preferred model for production of organic materials in the primitive solar nebula (1, 7, 8). The Haber-Bosch (HB) catalytic reduction of N_2 by hydrogen was thought to produce the reduced nitrogen found in meteorites. However, the clean iron metal surfaces that catalyze these reactions are easily poisoned via reaction with any number of molecules, including the very same complex organics that they produce (9) and both reactions work more efficiently in the hot regions of the nebula. Both of these problems may now be moot.

We have demonstrated that many grain surfaces can catalyze both FTT and HB-type reactions, including amorphous iron and magnesium silicates, pure silica smokes as well as several minerals (10). Although none work as well as pure iron grains, and all produce a wide range of organic products rather than just pure methane, these materials are not truly catalysts. The properties of these surfaces change during the course of reaction and become more efficient as the reaction proceeds to build up a macromolecular grain coating that would usually serve to shut down such activity (12). Indeed amorphous iron silicate smokes that had accumulated a coating comprising 10% by mass carbon and 0.2% by mass nitrogen based on the total mass of the sample, remained an active and very efficient surface for production of nitrogen-bearing organic materials from a mixture of CO, N_2 and H_2. More recent work may provide a simple explanation for these observations: the carbonaceous grain coating is itself an efficient surface for the reduction of CO and N_2 by hydrogen to form a variety of organic materials. Even graphite can serve as a substrate to promote these reactions.

Such coatings could have been incorporated into growing planetesimals and would then be modified by heating, hydration and other lithification processes to produce asteroids and meteorites. More work is required to understand the metamorphism of these initial organic materials, and the analogs produced in these experiments are intended for such experiments. However, finding an organic coating that will naturally form under conditions in protostellar nebulae, and that will continue to grow as long as it is exposed to a CO, N_2 and H_2 rich gas at moderately high temperatures, adds an entirely new dimension to the chemistry of these nebulae: One must now account for abundant organic material produced in the innermost regions of these nebulae and transported outward, possibly to the Kuiper Belt and beyond, by the same mechanisms that brought crystalline grains and fragments of chondrules and CAIs to Comet Wild2.

References:

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