ASSESSMENT OF KARST LANDFORM POTENTIAL ON MARS. J. G. Johnston[1], P. J. Boston[1,2], and K. W. Stafford[1] [1] Dept. of Earth and Env. Science, New Mexico Tech, 801 Leroy Place, Socorro, NM 87801 jgj@nmt.edu; [2] National Cave and Karst Research Institute, 1400 University Drive, Carlsbad, NM 88220.

Introduction: Previous studies have postulated the existence of karst features in a number of locations on the Martian surface, including Meridiani Planum (Bérczi, 2005) and chaotic terrains (Rodríguez et al, 2005). Martian cave and karst landforms could present a protected and relatively stable environment in which microbial lifeforms might exist and where they could be detected by future Mars missions (Boston et al, 2001).

Geologic Context: Observations by the OMEGA instrument on board Mars Express (Arvidson et al, 2005; Gendrin et al, 2005; Langevin et al, 2005) and by the Mars Exploration Rovers (Clark et al, 2005; Haskin et al, 2005; Ming et al, 2005), have indicated that soluble sulfate minerals are common on Mars. In addition, the MER *Opportunity* has investigated several outcrops where groundwater appears to have been an important depositional and/or diagenetic influence (Grotzinger et al, 2005; McLennan et al; 2005). It is then very likely that at some point in Martian history a portion of these deposits may have been dissolved, forming karstic terrain and possibly associated caves.

Catastrophic Speleogenesis Model: On the Earth, evaporite karst is formed by both hypogenetic (involving artesian aquifers) and epigenetic processes (involving meteoric waters). Rodríguez et al (2005) have suggested that Martian caves might develop along crater-controlled fracture systems as a result of basal warming due to volcanic intrusions, that is, hypogenetically. This mechanism would be confined to volcanically active regions such as Tharsis. Our model instead invokes the impact itself as the source of energy to melt ground ice, which then circulates along radial and concentric fractures (Stafford & Boston, 2005; Boston et al., 2006). This process may be more likely to produce cave systems similar to epigenetic systems on Earth, although deep speleogenesis is also possible (Fig. 1). Caves formed in this way would be limited only by the presence of sulfate minerals in the target rocks and thus could be widely distributed across the planet's surface.

Earth Analogs: Karst systems controlled by impact crater fracture networks exist on the Earth. A prime example is the "Ring of Cenotes" surrounding the Chicxulub structure, Yucatan, Mexico (Pope et al, 1996). Also frequently associated with terrestrial impact craters are hydrothermal systems such as those at the Haughton and Siljan impact structures (Osinski et al, 2001; Hode et al, 2003). These particular systems are located at high Earth latitudes (>61° N), and thus are especially suited for comparison with Martian environments. The mineralogy observed by OMEGA is indicative of hydrothermal alteration of basalts (Mustard et al, 2005), and so investigation of the role of hydrothermal processes in the post-cratering evolution of rocks is important to our study.

The development of caves and karst on the Earth is not precluded by cold or dry conditions (Brook & Ford, 1978), though it may be slowed by the presence of glaciers and permafrost (Ford, 1987), or occur primarily during infrequent periods of inundation (Brook & Ford, 1980). These appear to be precisely the conditions that prevail on the Martian surface. The most recent development in the ongoing study of the Martian surface by Mars Express has been the observation by MARSIS of what appears to be a subsurface ice deposit located within a buried crater (Picardi et al, 2005). On the Earth, caves located in cold regions may be partially or completely filled with ice (e.g. Schroeder, 1977; Lauriol et al, 1988). This location may represent an example of a cave originally formed by catastrophic speleogenesis and later filled with ice as the area cooled after the impact.

Future Work: The present study is an attempt to synthesize scattered information regarding impact craters, hydrothermal systems, speleogenesis and karst development in cold regions into a consistent theory of catastrophic speleogenesis which may be applied to explain certain features on the Martian surface. A primary goal is the identification of specific locations where this process may have taken place, and the interpretation of their relation to the geologic history of the planet and the search for life on Mars.

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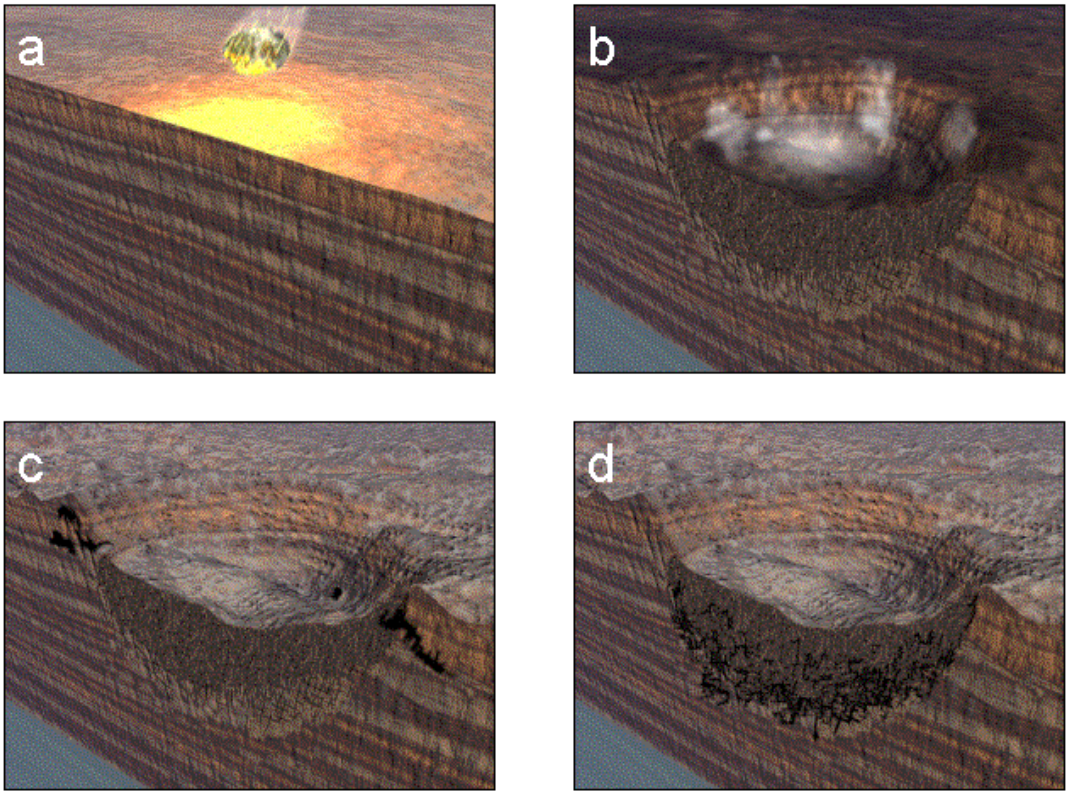

Figure 1. Proposed sequence of events in the catastrophic speleogenesis model. (a) Bolide impact into layered, ice- and sulfate-rich target rocks. (b) Release of volatile compounds from the crater area. (c) Caves dissolved along radial and/or concentric fractures. (d) Caves formed in deeper layers where impact-generated heat is retained. After Stafford & Boston, 2005. Graphics © R. D. Frederick 2005.