THE HYPOTHESIS OF CAVES ON MARS REVISITED THROUGH MGS DATA; THEIR POTENTIAL AS TARGETS FOR THE SURVEYOR PROGRAM. E. A. Grin and N. A.Cabrol, and C. P. McKay, NASA Ames Research Center, Space Science Division, MS 245-3, Moffett Field, CA 94035-1000. Email: egrin@mail.arc.nasa.gov; ncabrol@mail.arc.nasa.gov.

Rationale: In a previous publication (Grin et al., 1998), we proposed the formation of caves at mega and microscale on Mars and emphasized their potential for the exobiology exploration. The recent MOC images have shown promising indicators that caves are actually existing on Mars. In the first section, we develop the theoretical potential formation of martian caves. Then, we show how MOC is supporting this hypothesis of their formation and the new types of environments it suggests.

The existence of caves on Mars from microscale to microscale structures can be predicted according to the Mars geological and climatic history. A first global approach is to consider caves as a result of underground water activity combined with tectonic movement. They can be formed by: (1) diversion of channel courses in underground conduits; (2) fractures of surface drainage patterns; chaotic terrain and collapsed areas in general; (4) seepage face in valley walls and/or headwaters; (5) inactive hydrothermal vents and lava tubes.

Classification of Martian Caves: Based on potential terrestrial analogs, we describe in Table I the types of caves that could be formed on Mars, by the joined action of tectonic, thermal, chemical, aeolian, and hydrological activities.

-Table 1a-

Type	Process	Morphology	Host Environment
A. *Mechanical Formation Independent of Host Environment Chemical Composition*			
Tectonic	Mass mov. Of regolith	Fossae	Cohesive with low water content
Sinking	Soil piping	Chamber	Fine-grained non-cohesive
Subsurf. erosion	Water drainage	Underground conduits	Water-rich porous
Valley and rampart talus	Piling of slope material	Interconnected holes	Coarse-grained
Channel Bank	Flow scouring	Longitudinal Excavation	Cohesive
Lake Shoreline	Wave-scouring ice-push	Leveled-shore excavation	
Aeolian	Wind Scouring	Holes	Loosely cohesive

-Table 1b-

Type	Process	Morphology	Host Environment
B. *Chemical/Thermal Formation Dependent of Host Environment Composition*			
Dissolution	Chemical	Holes, Chambers	Soluble
Lava blister	Pushed away gas	Small empty pocket	Basalt
Fracture	Mechanical pressure	Ridges	
Lava Tubes	Roof Cooling	Shallow depth conduit	Pahoehoe lava
Ice cave I	Steam from volcanic origin	Opening in dynamical equilibrium	Ice material
Ice cave II	Tension Wind Abl.	Ice cracks Grooves	Ice Ice
Glacial Potholes	Ice melt block	Isolated cavities	Ancient segregated ice environment
Pseudo-karsts	thermo-karsts	Collapsed structures	Poorly consolidated sediment

Caves. Like other depressions are favorable environment for the deposition of sediments. The process of sediment deposition can be classified (1) according to : (a) the way of transportation, and (b) the chemical deposition/erosion by the weathering of the cave structure. Entrapped sediment may keep unaltered records of their sedimentation sequence, and provide favorable environments for exobiology exploration. In Table II, we describe the most likely sediments that could be observed in Martian caves.

-Table 2-

Type	Sediment	Surface Equivalent
Clastic		
Autochtonous	Weathering detrit.	Eluvium soil
Allochtonous	Infiltrated	Colluvium
Transported	Fluvial/glacial/ aeolian	Alluvium
Chemical	Evaporites	Evaporites
Hydrothermal	Tufas Travertines	Evaporites
Ice	Ice	Ice

Martian Hydrology as a Main Trigger for the Generation of Caves. The above classification tables that water activity on Mars has to be considered as a predominant factor in cave formation. The variety of hydrothermal processes observed and/or predicted on Mars may have led to diverse cave environments that have specific relationship with the aquifer. By analogy with Earth, we propose in Table III a description of plausible cave setting on Mars. It is also predictible that the location of such environment may have been modified through time, following the subsurface aquifer through time.

-Table 3. Setting of Caves in the Aquifer-

Surface Features	Subsurface Location	Aquifer Zone	Expected Morphology
Hole	Vadose	Above perma-frost	Chamber
Collapsed Ground	Unconf. Aquifer	Above Water Table	Sink, Conduit
Channel Bank Piling	Confined Aquifer	Below Water Table	Seepage Face Hole
Depression	Vadose	Above perma-frost	Fractured Evaporites
Lake	Vadose	Above perma-frost	Shoreline Scouring

Table III point out that the channel bank piling leading to seepage face hole formation is the only case where the cave will be potentially located below the water table. In all other configuration, the caves will be between the water table and the surface. Valley walls, crater ramparts will provide exposed surface, where seepage caves may be identified at the foot of debris slopes and on terraces. Along the course of channels, the seepage caves are closely related to drainage pattern such as headwaters. The seepage face is located at the base of the drained aquifer. It is the result of the underpressure expelled water that has extracted the fine-grained material, leaving the coarser and larger blocks of the regoliths at the seepage face.

Exploration of Caves. The Mars Surveyor Spacecraft provides hight resolution images that reveal new details about the past water activity and climate of Mars. The high-resolution imagery shows indicators of subsurface water activity such as: (a) patterns of rimless pits produced by the removal of surface material on undissected watersheds of valley networks (MOC 8205), [see 1]; (b) interior of valleys wall talus slope that exibit headwater sapping morphologies, where water springed beneath the surface; (c) the interior of old impact crater ramparts, such as on the Bakhuysen Crater (MOC 10605) also displays probable sources of water confined within the crater; (d) the abrupt headwater termination of rimless valley walls show protusions of lava flow margins that resisted the retreat of the valley wall during the sapping process. These water emergences are potential candidates for the generation of caverns and alcoves protected beneath a resistant layer of volcanic rock as shown on recent MOC images.

We consider that these subsurface water constructs are promising targets for the exploration of Mars because they could provide access: (a) to the geology and stratigraphy of the subsurface down to the deepest drainage flow system; (b) to the aqueous underground activity and history of water; (c) to potential micro ecosytem for biological investigation and sample return; (d) to be investigate as potential base for future human settlement.(;e) to be investigated as deep drilling plateform as reducing the length of the boring to reach deep aquifere.