NANO-STRUCTURED MINERALS AS SIGNATURE OF MICROBIAL ACTIVITY. Huifang Xu and Tianhu Chen, University of Wisconsin (Department of Geology and Geophysics, 1215 West Dayton Street, Madison, WI 53706-1692, U. S. A., hfxu@geology.wisc.edu, chentianhu168@vip.sina.com)

Introduction: In general, minerals with unusual shapes, such as small spherical, rod-shaped, and filament-like calcite and amorphous silica minerals, are considered fossils of bacteria or nanobacteria. However, the internal structures of fossilized bacteria is difficult to study. As a result, morphologies and shapes are not sufficient to differentiate between goechemical and geomicrobiological mineral precipitation. Some spherical minerals may be biologically mediated, but the spheres apparently are not fossil or microbes. It was suggested that the carbonate globules in the meteorite ALH84001 contained the fossil remains of Martian microbes. Many studies have concentrated on possible mineral signatures as microbial existence, especially on crystal morphology of magnetite nanocrystals in magnetotactic bacteria and the Martian meteorites. Although a few results show possible biosignatures of magnetite in the Martian meteorite, several results show inorganic origin of magnetite and potential terrestrial contamination of the meteorite. Systematic crystallographic study of magnetite from magnetotactic bacteria and the meteorite indicated that existing crystallographic and morphological evidence is inadequate to support the inference of former life on Mars. Therefore, careful investigation is needed to identify fossils bacteria or nanobacteria. In his paper we present results showing effects of bio-generated organics on mineral morphology and textures.

Bio-generated organics and their roles: Micro-organisms can produce organics of large molecules (lipids, fatty acids, and polysaccharides) and small molecules (carboxylic acids, amino acids) in soil environment. The concentration of the organics could be high in bacterial colonies. Local environments of a bacterial colony could be suboxic even in oxic soils. Magnetite will be thermodynamically stable in such a local environment. Lipid (including fatty acid) molecules have hydrophilic heads and hydrophobic tails. Lipds may have positively charged head or negatively charged heads. The organic molecules can affect morphology, crystal structure, and texture of minerals. The organics (organic acids, lipids and proteins) that controls the assembly of the inorganic mineral may play many roles in the formation of the organized composite materials. These roles include: (1) selectively initiating the nucleation of the desired inorganic phase, (2) controlling the orientation and growth rate of the crystals, (3) controlling the size, morphology and ordering of the inorganic minerals, (4) terminating (inhibiting) the crystal growth of the mineral [1]

Results and discussions: W have studied structured materials of calcite and magnetite minerals in modern soils and ancient soils (paleosols and compare them to the synthesized minerals with controlled organic components. Both modern soils and paleosols of eolian sediments (loess) formed in arid and semi-arid environments will provide us useful information about possible bacterial activities on the Mars. We choose Chinese loess formed through continual deposition of dust during past 25 million years for this study. The loess section contains both weathered (strongly pedogenetic) palesol layers and less weathered (weakly pedogenetic) loess layers. Both modern soils and paleosols of eolian sediments (loess) formed in arid and semi-arid environments will provide us useful information about possible bacterial activities on the Mars.

Nanoporous magnetite: Based on our systematic study on magnetic extracted minerals using TEM, nanoporous structure of ferromagnetic minerals in paleosol units are more common than those in loess units. It is proposed that such kind of magnetite was induced by microbes in soil environment. Microbes could generate a locally reducing environment that can precipitate magnetite and form a composite of nano-crystalline magnetite and organic matters produced by microbes. Decomposition of the organics and oxidation of the magnetite at solid state results in the formation of nanoporous maghemite. Figure shows the texture of the nanoporous magnetite and synthetic nanoporous gamma-alumina using lipid-like surfactant.

Nano-fibrous calcite: Results from both SEM and TEM investigation show nano-fibrous calcite in semi-arid soils of loess sediments. The calcite nano-fibers with unusual elogation direction are well crystallized single crystals with smoothes edges. Such kind of calcite can not be produced in pure inorganic system. It is suggested that the intervention of organic compounds derived from microbial activity is likely in the calcite formation. Based on our laboratory experiments, we suggest that large organic molecules derived from micro-organisms control the growth of the nano-fibrous calcite in dry soil environment.

Reference: [1] Boskey, A. L. (1998) J. Cellular Biochemistry, 30/31, 83-91.

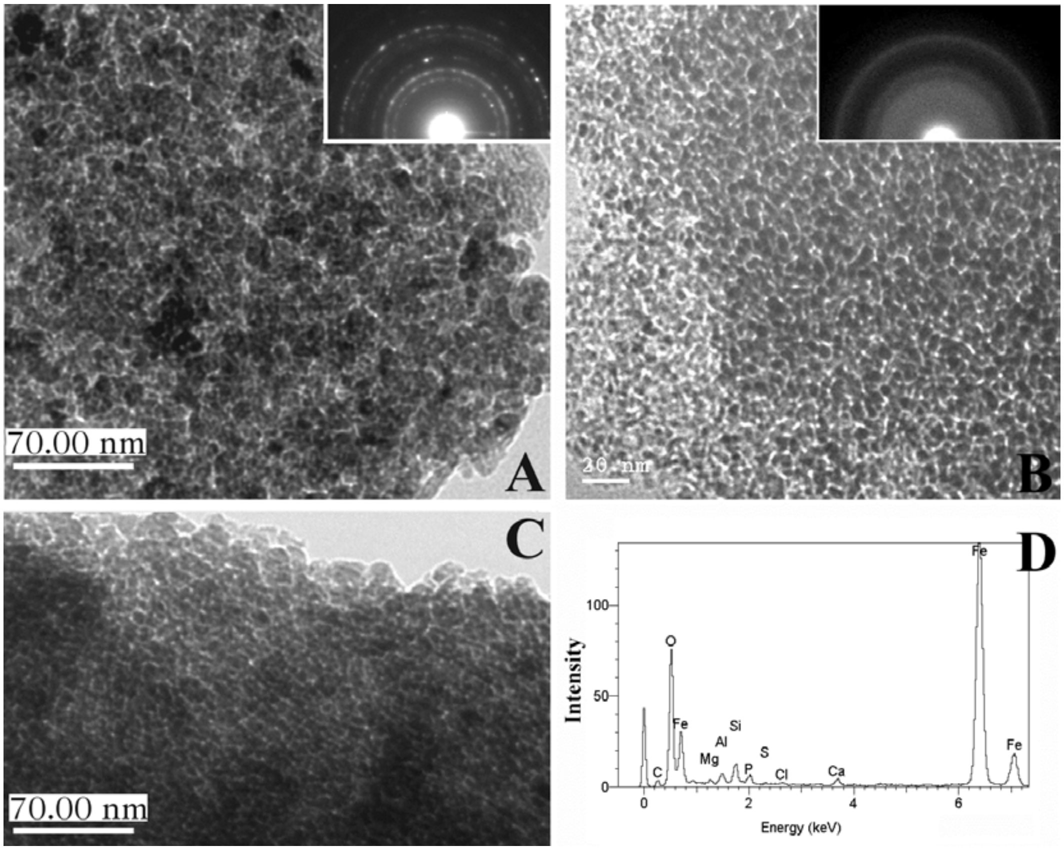

Figure 1: (A) Nanoporous magnetite from an ancient soil (a paleosol layer in Chinese loess). Inserted is a SAED pattern shows they are nanometer scale magnetite. (B) A synthetic worm-hole-like nanoporous alumina consisted of poorly crystalline gamma-alumina (see inserted SAED pattern). (C) TEM image shows a nanoporous magnetite from a modern loess in New Mexico. (D) EDS spectrum from area of Figure (C) shows Fe and oxygen with small amount of P that may be from lipids in the nanopores. All the nanopores in here are worm-hole-like nanopores. Bright areas correspond to low-electron density areas of nanopores.

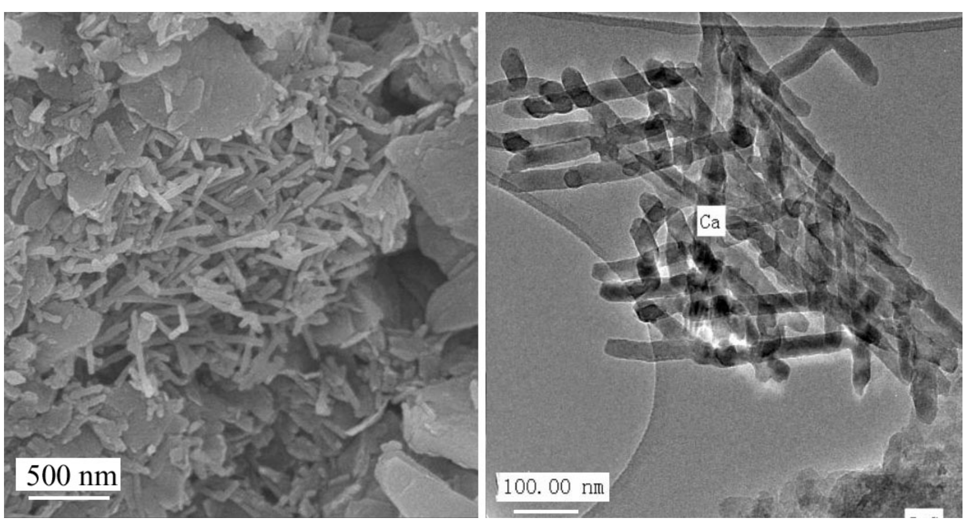

Figure 2: SEM image (left) and TEM image (right) of the nano-fiber calcite crystals from a Chinese loess in Central China. Such kind of calcite aggregates are not fossils of “nano-bacteria.” They are related to bio-generated organics.