# Microbial Interactions with the Limestone Walls of Lechuguilla Cave, Carlsbad Caverns National Park, New Mexico, USA

Carbonate wall rock of Lechuguilla Cave, an ancient cave in near pristine condition, and Spider Cave, both in Carlsbad Caverns National Park, shows extensive corrosion that has resulted in large expanses of deposits called ``corrosion residues'' which appear to be the alteration products of several mineral types. EDS analysis of these residues and underlying wall rock reveals the presence of aluminum, silicon, manganese, iron, phosphorus, vanadium, sulfur, and rare earth elements. Wet chemical analysis of corrosion residues showed a range of manganese oxides from 0.5% to 20% and a range of 1-23% iron oxides. Insoluble residue analysis of unaltered limestone shows 2.3% insoluble residue, demonstrating that a large amount of carbonate wall rock must be corroded to produce the corrosion residues we see today.

Geologists hypothesize that Lechuguilla's extensive corrosion residue deposits are the long-term result of cells of upwelling corrosive air (Queen 1994), but the presence of a diverse community of microorganisms in the residues has caused us to examine the possibility that the residues may be at least partially biogenic.

Several lines of evidence support a biogenic origin of corrosion residues: (1) extreme pH readings from the residues; (2) microscopic and metabolic studies using redox dyes that demonstrate bacterial cells are actively respiring; (3) cultivation of putative manganese and iron bacteria from corrosion residue samples, (4) extraction and polymerase chain reaction (PCR) amplification of DNA from corrosion residues, and (5) scanning electron microscopy (SEM) studies. Sequence analyses of the extracted DNA show the presence of diverse microbial species (Northup and Barns, unpublished data) including actinomycete bacteria and low-temperature Archaea. With SEM we have noted pits on the surface of the wall rock underlying corrosion residues that contain a mesh of presumptive bacterial filaments, each approximately 200-400 nm in diameter; the presence of Hyphomicrobium sp. cells (a known iron-oxidizer) with attachment structures and nearby crater-like structures of approximately the same size as the bacterial cells on the surface of the calcite; and the presence of clusters of spherical and star-shaped iron oxide deposits associated with pitting of carbonate surfaces.

Preliminary evidence supports the presence of a community of bacteria that include iron-oxidizers and possibly bacteria that utilize manganese. These classes of bacteria are known to be actively involved in microbially-influenced corrosion. Our ongoing studies will establish the extent to which these bacteria are actually involved in the formation of the corrosion residues.