Microbial Biosignature Capture and Preservation in Oncoid Microbialites of the Rio Mezquites, Cuatro Ciénegas Basin, Mexico. Valeria Routt¹ and Jack Farmer¹, ¹School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, USA (jfarmer@asu.edu)

Introduction: Microbialites are accretionary, biosedimentary structures that comprise the principal record of Earth’s biosphere during the Precambrian Eon [1]. Oncoids are spherical microbialites that form by biofilm-mediated precipitation of calcium carbonate during rolling transport. Although oncoids are common features of the geological record of shallow water carbonate environments, there have been few detailed studies of the process of oncoid accretion, or the microbial biosignatures they contain.

To gain insight into the factors that affect microbial fossilization, we studied modern oncoid microbialites that are forming today in the Rio Mezquites, Cuatro Ciénegas Basin, Coahuilla, Mexico [2, 3]. These oncoids are subspherical in shape and consist of small, branching columns having a dominantly thrombolitic microstructure. Outer surfaces of oncoids are covered by a thin greenish phototrophic biofilm, dominated by diatoms and cyanobacteria. These microbes mediate the precipitation of low-magnesium sparry calcite and micrite, which collectively accounts for a net accretion rate of ~0.8 mm/year, and which occurs during rolling transport along the streambed. Oncoids accrete up to a diameter of ~35 mm, at which point they stabilize, coalesce and accrete into small bioherms.

Study Site: The Cuatro Ciénegas Basin is a ~1200 km² extensional basin located in the State of Coahuila, north central Mexico. The basin, which lies entirely within the Chihuahuan Desert Province, along eastern edge of the Sierra Madre Oriental mountain range, hosts numerous karstic springs, spring-fed streams and pozas. These form a complex system of interconnected underground reservoirs and aqueducts that are sourced within the Pleistocene Cupido-Aurora aquifer. Spring waters are bicarbonate-rich and mildly thermal, ranging in temperature up to 25-35°C.

Methods: We sampled oncoids along a 300 meter stretch of the Rio Mezquites starting at its karst spring source. To examine trends in oncoid morphology along the stream profile, we measured the size (Length x Width x Height) of 50 specimens and population density (Oncoids/meter³) at each of three sampling sites. We also measured basic physical and chemical parameters at each site, including channel depth and width, flow velocity at the bottom, surface and 1.0 meter below the surface, pH, temperature and conductivity. Three oncoids were collected from each site for later laboratory characterization. Subsamples of biofilm-covered oncoids were fixed in the field in 2% glutaraldehyde and 4% formalin, in filtered river water. In the lab, these samples were washed and then dehydrated in a graded ethanol series to 100%. Next samples were the subdivided and one part stained for histology, then embedded in low viscosity resin for petrographic thin sections; thin sections were studied under fluorescence, dual interference, laser confocal and polarizing light microscopy. Another sample portion was critical point dried, oriented and mounted on stubs, and gold coated for examination under the Scanning Electron Microscope. A third subsample was dried and powdered for geochemical measurements (δ¹⁸O and δ¹³C ratios for both bulk oncoids and their extracted organic materials) using a continuous flow gas-ratio mass spectrometer.

Results: At the microscale, within single columns, thin section observations show that there is pervasive encrustation of biological surfaces by sparry calcite and micrite, within the upper 1-2 mm depth of the oncoid surface (Fig. 1). This mineralization is progressive and selectively entombs filamentous cyanobacteria, leading to their fossilization. Early taphonomic processing leads to the degradation of trichomes and the flattening of exopolymer sheaths. Diatom frustules apparently dissolve under the alkaline pH that prevails within the active biofilm and are only rarely preserved.

At a depth of ~2 mm, the morphologically diverse surface microbiota is replaced by a finely-filamentous (diameter ~2-3 micron), cyanobacterial community (Fig. 2). The sub-vertical, branching growth of the dominant morphotype is similar to that of species of Leptolyngbya. The appearance of this subsurface cyanobacterial community coincides spatially with pervasive mineralization of the oncoid framework, which entombs the subsurface populations, leading to their fossilization. This subsurface microbiota dominates the fossil record of the oncoids. At depths >3 mm, a dense network of filament molds becomes infilled with micrite. However, the timing of trichome degradation, in relationship to infilling of molds by micrite, varies over microspatial scales. Sheaths typically take longer to decompose than trichomes, and often do not disappear until after molds have infilled with micrite, which leaves a thin sheath mold along the margin of infilled filament molds.

The δ¹³C of organic carbon extracted from bulk oncoids ranged from -24.49 to -21.03 %o, which falls within a range typical of photosynthetically-processed carbon. In combination with the morphofossil information, this comprises a robust biosignature for the
photosynthetic community responsible for oncoid accretion.

**Conclusions:** Interactions between various taphonomic factors involved in the fossilization of biofilm communities in the Rio Mezquites oncoids leads to the preservation of a unique suite of biosignatures, indicative of a photosynthetic origin. However, the vast majority of microbial taxa making up the highly productive surface community do not leave behind a fossil record. Nearly every component of the surface biofilm community is degraded soon after death and entombment in low-magnesium calcite, leaving behind only occasional filament molds and exopolymer sheaths. Unexpectedly, the Rio Mezquites oncoids preserve abundant microfossils within their accreted framework which are derived from a subsurface (understory) cyanobacterial community dominated by a morphotype that resembles the cyanobacterial genus, *Leptolyngbya*. Pervasive micritization of the understory community facilitates the fossilization of this species, allowing it to dominate the microfossil record of the Rio Mezquites oncoids at the expense of the more diverse surface community.


Figure 1. Cyanobacterial morphotypes present in oncoid surface biofilms. Images on the left are transmitted light; images on the right are under fluorescence. a and b: Coccoid cyanobacterial morphotypes, possibly *Cyanostylon* and/or *Aphanocapsa*; c and d. *Homeothrix balearica* morphotype [see 4]

Figure 2. Degradation of cyanobacterial filaments during early diagenesis. Image on the left shows the compressed sheath of the *Homeothrix* morphotype surrounded by smaller filament molds. Image on the right shows filaments of the *Leptolyngbya* morphotype in different degrees of degradation.