

SEARCHING FOR LIFE ON MARS AND EUROPA...

...IN OZARK REGION CAVES

by David J. Thomas, Ph.D.

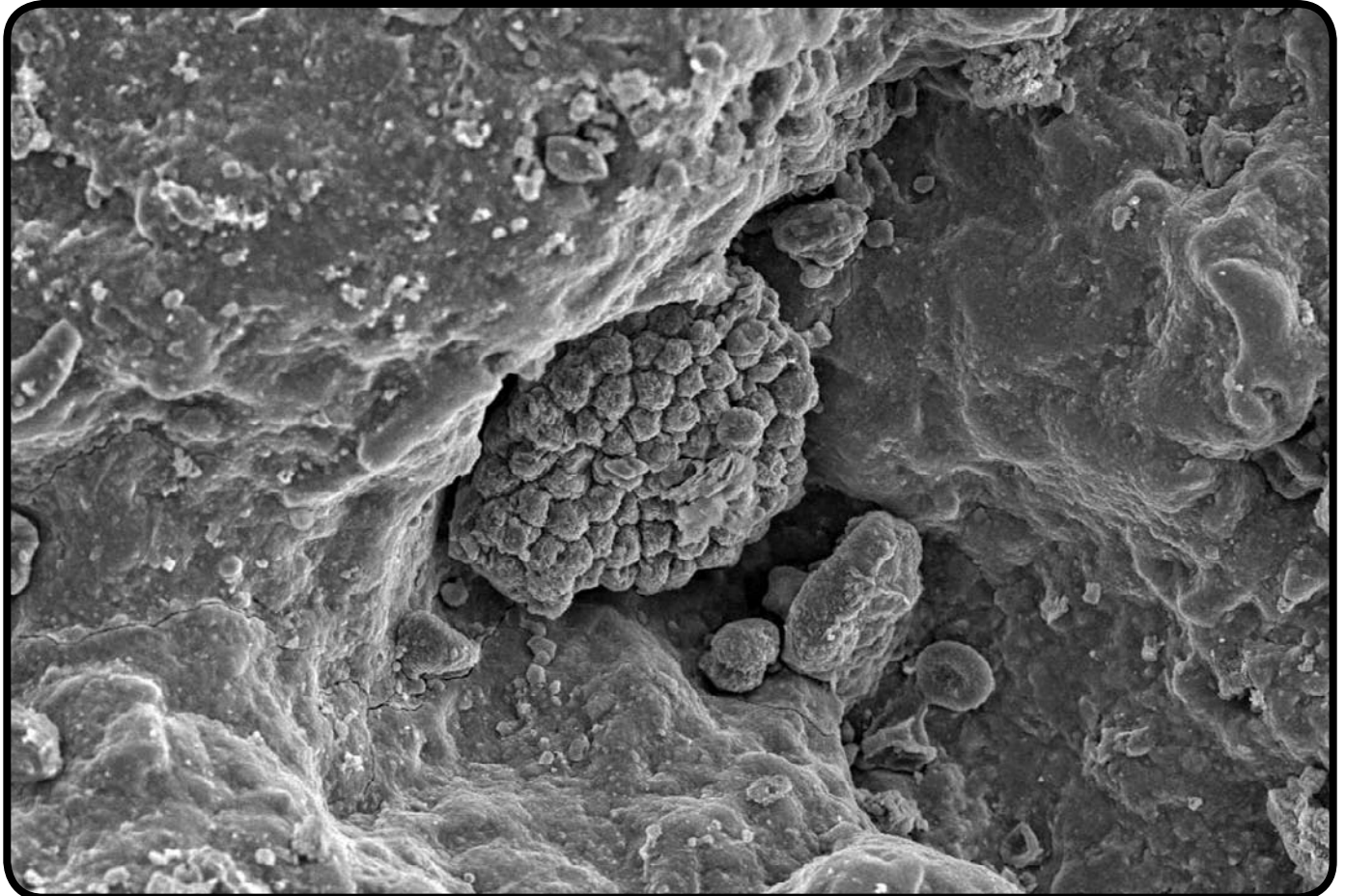
The vast majority of life on Earth gets its energy from the Sun. Plants and green microbes use photosynthesis to convert light energy into chemical energy (food). Other organisms gain energy by eating the plants or by eating the organisms that eat the plants. Even in Earth's dark places – caves and the ocean depths – the food chain starts in lighted areas. Thus, most life is solar powered – either directly or indirectly.

However, exceptions exist. Some microorganisms pro-

duce energy by oxidizing metallic minerals, and produce their own food through the process of chemosynthesis. Chemosynthetic organisms live in abundance around certain deep-sea hydrothermal vents. During the last fifteen years or so, they have also been found in caves such as Lechuguilla and Villa Luz.

In these caves, the chemosynthetic microbes are associated with grey-black and orange-brown formations that contain oxidized forms of manganese and iron (Figure 1). The scientists who have studied these formations – Penny Boston and Diana Northup among others – suggest that the microbes actually helped to produce the formations. These scientists also believe that microbes are responsible for oxidized metal mineral crusts in most caves (Figures 2 & 3), and on some surface formations.

Currently, my students and I are searching for similar microbes in Ozark area caves. Our research has two main goals: to catalog the abundance of chemosynthetic and other microbes in these caves, and to use cave microbes as models for life on other worlds such as Mars and Europa (one of Jupiter's moons). Both of



these worlds possess the necessary chemicals for life, but their surfaces are inhospitable to life. Their sub-surfaces, though, may contain abodes for life similar to what we find in caves and deep-sea vents on Earth.

Aside from Earth, Mars (Figure 4) is the most studied planet in the solar system. Mars possesses a very thin atmosphere that mainly consists of carbon dioxide. The average surface temperature on Mars is far below freezing. The combination of low pressure and low temperature means that liquid water is unstable at the surface. In addition, Mars receives much more ultraviolet and cosmic radiation than Earth does. This adds up to a surface environment that would kill any life as we know it. However, geological evidence on Mars suggests that early in its history (around four billion years ago), Mars had an environment similar to that of primordial Earth when life appeared. Perhaps life also evolved on Mars at this time. If any presumptive martian life survived to the present, its most likely abode would be in the subsurface.

At present, five robotic probes are orbiting Mars or exploring its surface. These and previous missions have



Page 10, Fig. 1. This is a scanning electron micrograph of microorganisms associated with iron and manganese deposits. A cluster of microbes is visible in the center of the image. These microbes were found in a dark crust similar to that seen in Figure 3.

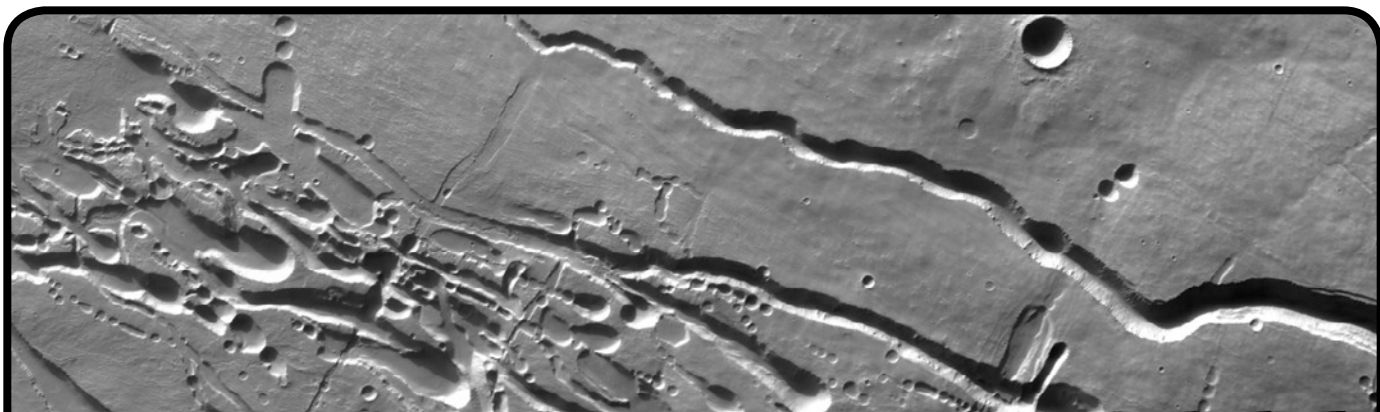


Top Right, Fig. 2. The orange coloration on this formation in Bat Cave is due to oxidized iron-containing minerals. In some caves, bacteria oxidize the iron in order to generate energy. My students and I are trying to find out whether the same types of bacteria are found in Ozark region caves.

Right, Fig. 3. Some cave formations and soils in Blanchard Spring Caverns are covered by black crust. The crust contains oxidized manganese-containing minerals. As with iron, some bacteria oxidize the manganese in order to generate energy. My students and I are trying to determine whether the same types of bacteria are found in Ozark region caves.

Bottom Right, Fig. 4. Although Mars is the most Earth-like planet in the solar system, it's still very inhospitable. The combination of low atmospheric pressure, low temperature, and high cosmic and ultraviolet radiation makes the surface unfit for life as we know it. However, microbial life could still exist in the subsurface.





returned huge amounts of data about Mars' surface, and they have provided glimpses into Mars' subsurface. Some images from orbit show "pit chains" that planetary scientists think are collapsed lava tubes (Figure 5). Although these particular features are open to the surface, and are thus probably uninhabitable, other lava tubes may remain sealed, and provide a more hospitable environment for microbial life.

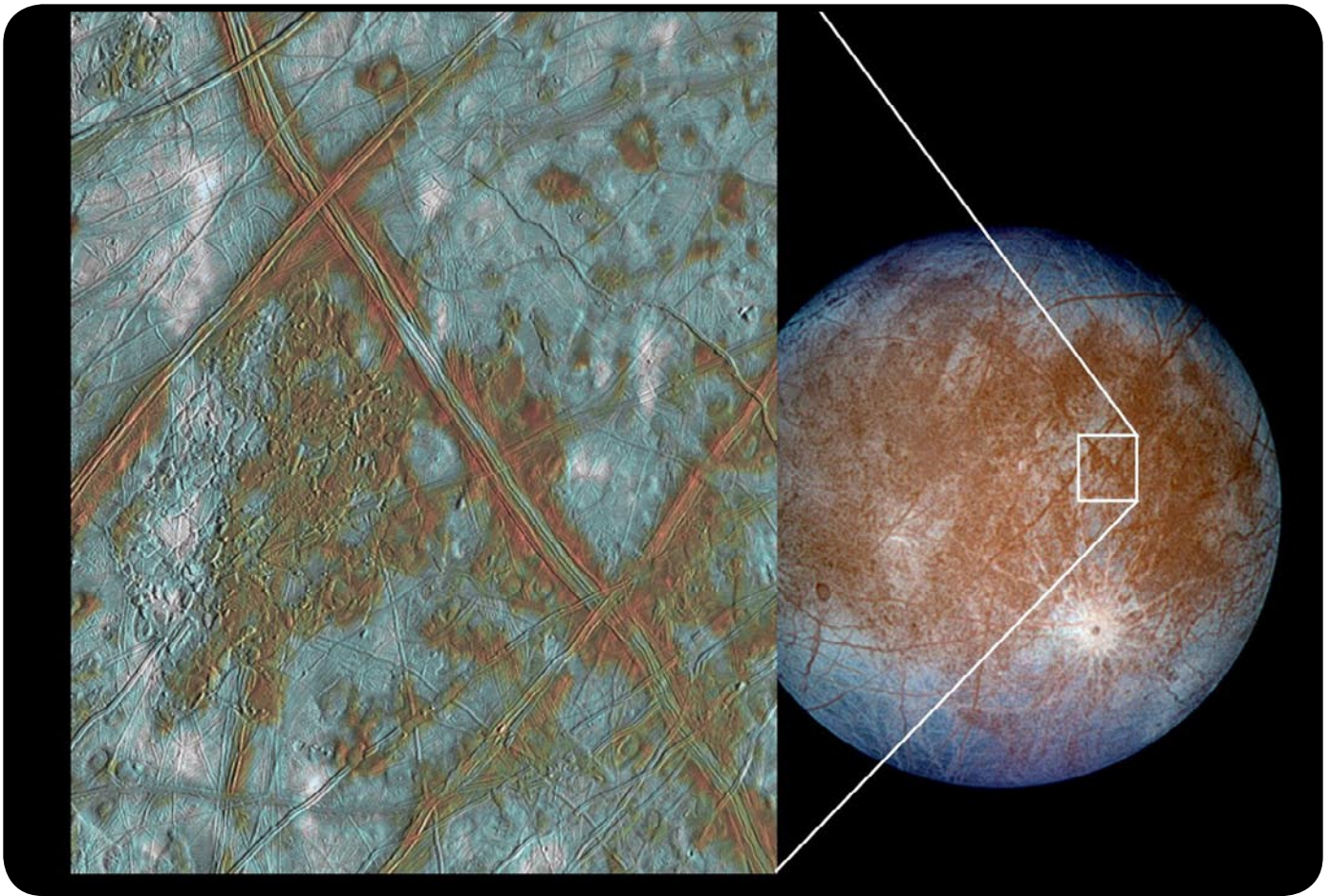
Other images indicate large, circular pits of unknown depth (Figure 6). If such pits are extremely deep (several kilometers or more), they may provide micro-environments that could just barely support life as we know it. Very recently, Mars probes have detected carbonate minerals on Mars. Calcium carbonate is the primary mineral found in most solutional cave formations. However, at present, the extent of the carbonate deposits is unknown, and scientists don't know whether solutional caves ever formed on Mars.

Jupiter's moon, Europa, is an icy water-world that may be the most likely abode for extraterrestrial life in the solar system. The combination of telescopic observations and visits by several robotic probes indicates the

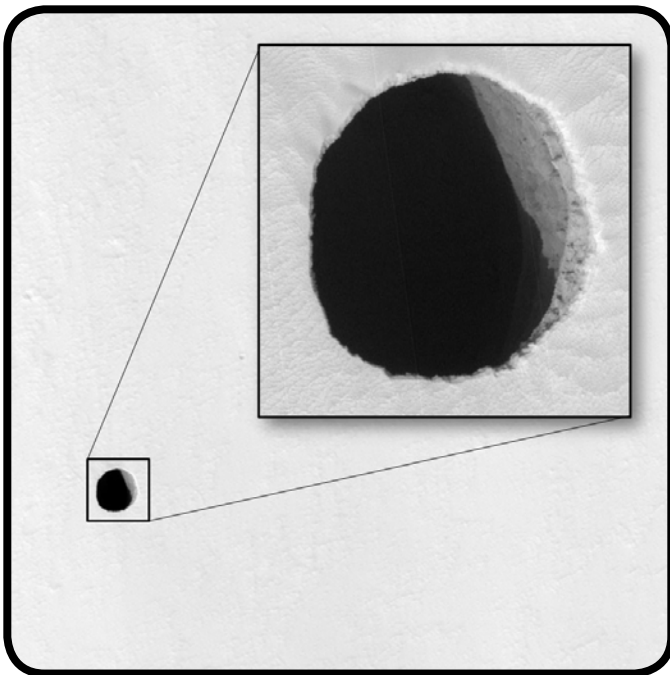
likely existence of a subsurface ocean beneath an icy crust. Jupiter's enormous gravitational field squeezes and distorts Europa as it orbits, which causes heating of Europa's interior. Europa's surface is crisscrossed with crevices and ice floes (Figure 7). The bottom of its subsurface ocean probably has hydrothermal vents like those of Earth. If the same chemistry occurs around Europa's vents, then perhaps chemosynthetic life evolved there as well. In addition, if life exists in Europa's oceans, then there might also be photosynthesis.

In 2002, planetary scientist Richard Greenberg hypothesized that when crevasses opened in Europa's surface, light could penetrate to a depth of several meters with enough intensity to support photosynthesis. Assuming that the crevasses opened and closed with some regularity as Europa orbited Jupiter, putative European plant-like organisms would have to endure long periods of darkness between periods of light. Photosynthetic organisms in caves experience similar light deprivation.

At cave openings, the combination of moisture and light determines the types of photosynthetic organisms that live there. "Higher" plants can make a living at the



Page 12, Fig. 5. The pits and channels in these images of Mars are thought to be due to the collapse of lava tube caves. Since these features are exposed to Mars' sterilizing surface environment, they would not be good areas in which to search for life. However, sealed caves could harbor chemosynthetic microbial life.



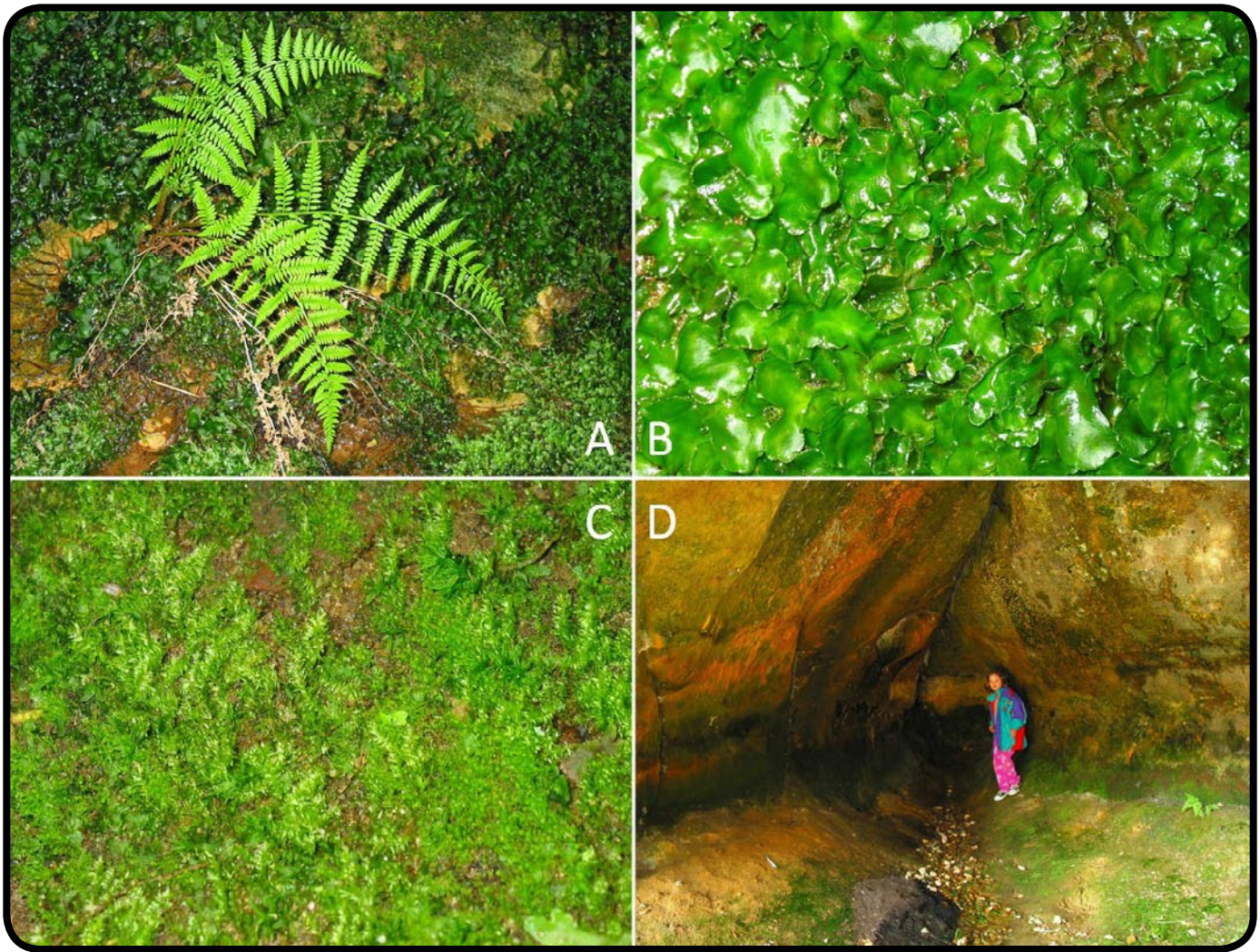
Left, Fig. 6. Several large, deep openings like this one have been found on Mars' surface. This particular pit is approximately 150 meters in diameter; it's depth is unknown. A very deep pit (many kilometers) could have high enough atmospheric pressure and temperature at the bottom to allow liquid water (and possibly life) to exist.

Above, Fig. 7. Europa, one of Jupiter's larger moons, probably hides a vast ocean beneath its cracked and chaotic icy surface. If the same processes that occur in Earth's oceans also occur in Europa's ocean, then Europa might harbor life.

cave mouth where sunshine is most intense. Farther into the cave, ferns, mosses and other "lower plants" grow in dimmer light. At the farthest reaches of light, only lichens, algae and cyanobacteria can photosynthesize (Figure 8). This situation is analogous to the en-

vironment that hypothetical European "plants" would experience with increasing depth from the surface.

Photosynthetic microbes have been found inside the dark regions of caves as well. Presumably, cyanobacte-



rial and algal cells are carried by water as it percolates down from the surface. Under natural conditions, when the cells arrive inside a cave, they must either become dormant or utilize organic materials inside the cave, since no light is available for photosynthesis.

The time required for microbes to be transported from the surface to a cave is not well understood. Nor do biologists know exactly how long these microbes can survive in the dark. Obviously, some do survive the trip from the surface to the subsurface; owners of show caves consider cyanobacteria and algae to be nuisance organisms because they grow on formations in the presence of artificial light (Figure 9).

Depending on the show cave's tour schedule, lampenflora (as these microbes are called), may experience many short periods of light every day during the tourist season, or they may spend months in darkness during the "off" season. On Europa, the hypothetical plant-like organisms in the ocean would experience similar

light-dark regimes as crevasses opened and closed.

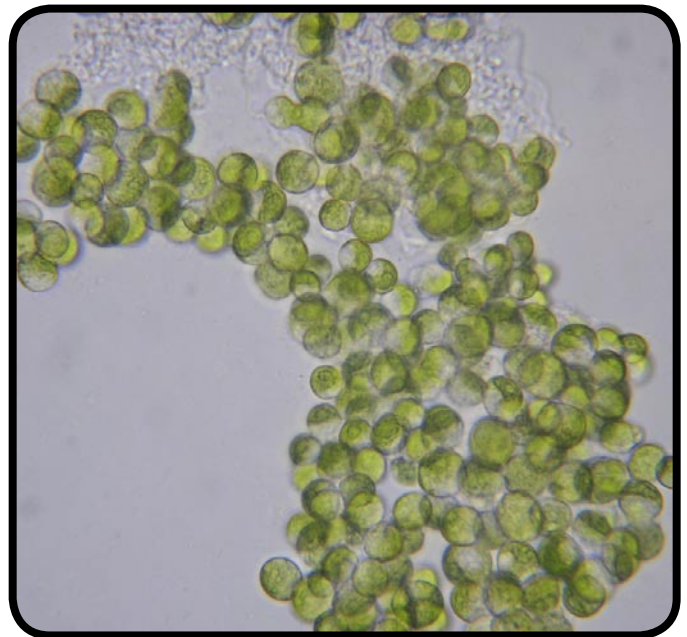
Back on Earth, my students and I have been working on this project for about a year. Chemosynthetic organisms take a very long time to grow, and so far, we haven't isolated any in the lab. However, we have isolated a large number of photosynthetic microbes as well as some of the more common soil and water bacteria. Our first study site was Blowing Cave, near Cushman, AR. Lyon College students Melissa Kuehl and Michael McQueen (Figure 10) have worked on this project since its inception. In addition, Little Rock Grotto members Jeff Bartlett and Michael Patton brought me samples from the deepest known parts of the cave.

Of note was the relatively high concentration of bacteria known as fecal coliforms. These are bacteria that normally inhabit the intestines of animals. Water testing laboratories use fecal coliform detection as a sign of sewage contamination. At present, our results are preliminary, but the samples from the deepest regions of



Page 14, Fig. 8. As long as moisture is available, light intensity is the single most important factor in the distribution of photosynthetic organisms in caves. Under natural conditions, plants are usually limited to just inside of cave mouths. In the Indian Rock Cave system, ferns (A), liverworts (B) and mosses (C) grow throughout the main shelter cave since it is a relatively large, yet shallow cave. Some of the smaller caves exhibit steeper light gradients. Image D shows plants in the foreground at the cave mouth, and lichens and algae on the walls deeper inside this small cave. The little girl is one of my daughters, Hannah.

Above, Fig. 9. In show caves, algae and cyanobacteria grow in the presence of artificial lighting. These microbes in Gardner Cave may only receive a total of one or two hours of light per day during tourist season, and even less during the “off season.”



Top Right, Fig. 10. Rachael Thomas, Melissa Khuel and Michael McQueen emerge from Blowing Cave muddy, but happy.

Bottom Right, Fig. 11. This is a micrograph of a strain of algae isolated from Blanchard Spring Cavern.

the cave had some of the highest fecal coliform levels, but no animals were observed.

An overlay of the cave map on a topographic map (see following page) shows that Blowing Cave extends back toward the town of Cushman. It’s possible that septic system drain fields may be leaching into the groundwater that feeds the stream in the cave.

Other research sites include Blanchard Springs Caverns, Indian Rock Caves, and Bat Cave. We have isolated a variety of photosynthetic microbes from these caves (Figure 11), and we are in the process of identifying them. With time, we expect to be able to identify chemosynthetic microbes in our collection as well. We plan to increase our sampling range as more caves become available to us. Eventually, we should have a large catalog of microbes from all over the Ozark region. We’ll also have a better understanding of how all of these different microbes contribute to the ecology of caves – on Earth and beyond.