Student Science in the Caverns: Characterizing Drip Water Chemistry at Diamond Caverns, Kentucky

Ethan Morgan, Andrew Wulff, Pat Kambesis, and Chris Groves

Department of Geography and Geology, Western Kentucky University, Bowling Green, KY

An investigation of spatial and temporal variations in the chemistry of cave drip waters was initiated at Diamond Caverns, a private show cave near Mammoth Cave National Park, Kentucky during the period May 2007 to July 2008. As part of independent student research projects, undergraduate geology-major students were central to fieldwork, data collection and in the lab analysis, in order to develop both technical experience and critical thinking skills.

Diamond Caverns, as a show cave with a management team that was very supportive of student work and cave researc made an excellent research site due to easy access, security, and the ready outreach opportunities. Because we were allowed to sample during times while the caverns were open to the public, visitors were able to watch the collections and view the collection sites as part of the tours. A goal of the study was to educate the guides in the basics of the collection process so that they could answer visitor questions. A poster showing the process and some results was made available to the management to be placed in the lobby to further the goal of building the relationship between the science and the fun and engagement of the show cave. Tourist caves such as Diamond Caverns offer exceptional locations and opportunities for high-visibility science that are accessible and interesting to visitors curious about the relationship between the natural underground that they are exploring and the overlying surface environment. Many questions they express about the relationships between human activities and water quality and the cave environments could be answered by tour guides using the sample collection points as examples.

Initially, the principal research questions involved a hydrogeochemical study of the H_2O–CO_2–Ca-Mg system in the vadose zone of Diamond Caverns. These specific data and the resulting karst water model were able to shed light on factors influencing the microclimatic and geochemical aspects of the cave. Data from this project add more broadly to the regional understanding of vadose zone geochemistry.

The main objectives of this research were: 1) Physical-chemical characterization of karst waters, and analysis in time and space of parameters such as pH, temperature, CO_2 content, and electrical conductivity; 2) Preliminary evaluation of the relationships between land use, the external atmosphere and soil cover, composition of dripwaters, and the processes of precipitation and dissolution of carbonate minerals and transfer of CO_2, and 3) Involvement of undergraduate students in field research.

Samples were collected approximately every three weeks for 13 months from fifteen sites extending approximately 0.7 km from the mouth of the cave along, or adjacent to, the tourist trail through the cave. The majority of drips came off the end of speleothems, and drip length varied from centimeters to over a meter. After training, the students collected the samples and recorded various parameters within the cave at each site, including CO_2 levels, temperature, rate of flow (drips/minute), and date and time. Water samples accumulated in fixed positions below drips until a minimum of 300 mL was collected. Total volumes of dripwater were measured to estimate rates of infiltration drip at each location. Temperature, pH and alkalinity were measure at the time of or soon after sample collection, All samples were analyzed by the students, again after appropriate training, at the Environmental Research and Training Laboratory (ERTL) at the University of Kentucky. The suite of elements analyzed included Ca, Mg, K, Na, Ba, Sr, Mn, Fe, Ni, Co, Cu, Si, Al, and Zn. These data were used to establish a base composition for dripwaters from Diamond Caverns, identify outlier compositions, and compare these data to both external (above-ground) and cave interior environmental variables. Spatial parameters included CO_2 levels and electrical conductivity, potential groundwater flow paths, and external environmental conditions (e.g. proximity to paved and agricultural areas). There were some complexities involved in establishing a baseline compositions for drip waters, even at a specific site. These included: 1) record drought conditions coupled with a wet winter; 2) complex interactions between meteoric waters and soils and bedrock; 3) variable dissolution and precipitation rates; and 4) evidence of varying source lithologies in the vadose region.

While the initial scientific questions associated with analysis of the dripwaters were of limited use to direct management of the cave, results also ended up showing relationships between surface landuse and drip water chemistry that identified sources of potential, future environmental problems. A detailed cave survey facilitated the comparison of surface features to sampled sites below. Certain elemental abundances, while not at high concentrations (e.g. Cu, Cr, Zn, Fe, Al, Na) were correlated to surface sources of anthropogenic contamination, while elemental ratios (e.g. Ca/Mg and Ca/Sr) were used in conjunction with drip rates to predict which sites were direct conduits to the surface, and which had more complicated vadose zone plumbing. Geochemical variations were compared to meteorological parameters at collected nearby.

Elemental abundances varied over the duration of sampling sometimes by a factor of four or more at a single site. These variations were compared to wet and dry periods, proximity to paved surfaces, drip rates, and lithology. For example, Na abundances and Na/Ca were strongly correlated with areas close to paved surfaces near the cave's visitor's center, roads, and parking lots, perhaps reflecting the use of salt on the roads during winter months. Strong drought conditions in 2007 introduced the possibility of sustained accumulation of heavy/base metals on surface roads and parking areas, which could be washed into the cave during sporadic showers. However, base metal (Zn, Cd, Cu and others) concentrations were a less consistent indicator of overlying paved surfaces than expected. Certain elements (e.g. Ca) did vary with precipitation, as higher Ca concentrations occurred during drier periods while lower Ca concentrations were correlated with wetter periods, particularly near the mouth and at the far end of the trail.

Various elemental ratios (Sr/Ca and Mg/Ca) were used to approximate residence time for waters in overlying lithologies. Higher Mg/Ca in samples near the mouth of the cave suggests stagnation of waters in contact with dolomitic bedrock, while higher Sr/Ca indicate proportionally more calcite water/rock interactions.

This project was designed as a model of a longitudinal study that was executed entirely by undergraduate Geology majors. The students set up a rotation for collecting the samples. They were trained by personnel at the ERTL lab at University of Kentucky and prepared and analyzed the samples under the supervision of technicians there. Each student was able to present different aspects of the research as the project progressed, gaining important experience in disseminating science at professional conferences. These types of studies are ideal for long-term projects, which are difficult to resolve during the limited time available for a graduate student. A series of undergraduates will all gain valuable experience in executing scientific procedures, while contributing to a large data base, also making the entire project more cost-effective by limiting the need for graduate assistantships. The presence of low impact sampling sites increases the value of the visitor experience by demonstrating HOW scientists learn and contribute to the information given by tour guides.

We cannot protect what we cannot understand. Often, groundwater in karst regions and more generally is hidden away and out of site. Sampling directly from caves can give direct access to this often hidden realm. In this case, the next generation of environmental scientists gets a direct insight into the relevant processes in the scientifically appropriate, yet accessible environment of a developed show cave. This setting also presents a natural opportunity public outreach and engagement into environmental science.