Report as of FY2010 for 2009TX335G: "The Role of Epikarst in Controlling Recharge, Water Quality and Biodiversity in Karst Aquifers: A Comparative Study between Virginia and Texas"

Publications

Project 2009TX335G has resulted in no reported publications as of FY2010.

Report Follows

Title: The Role of Epikarst in Controlling Recharge, Water Quality and Biodiversity in Karst Aquifers: A Comparative Study between Virginia and Texas

Project Number: 2009TX335G

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Principle Investigator: Benjamin F. Schwartz, Texas State University

Co-PIs: Madeline E. Schreiber, Virginia Polytechnic Institute and State University; and Daniel H. Doctor, U.S. Geological Survey.

Annual report for June 2010 – May 2011

Progress Summary:

Progress at the Texas site continues to be very good. Weather data collection and precipitation sampling have been ongoing at the surface above all three in-cave sites in TX, and geochemical parameters continue to be measured in the caves at a variety of sites, including numerous drip sites with variable precipitation response times, an in-cave stream, and a nearby well. Since the end of the drought in October 2009, a rainy period caused sufficient infiltration and recharge for samples to be collected at all monitoring sites on a regular basis. Since September 2010, we have again been in a drying period, during which no significant recharge or infiltration has occurred. This has allowed us to sample continuously through a complete wet-dry cycle, and into what is not a period of extreme drought. This is the type of information that the project was designed to collect, so we could investigate how the epikarst functions to control infiltration and recharge in a semi-arid setting with thin soils. Two graduate students defended their theses on this project in Fall 2010, and work is underway to publish their findings. One new graduate student started on this project in Fall 2010, and another was recruited for Fall 2011. Both are expected to defend their theses ~2.5 years after beginning studies, and both will also be publishing their results in peer-reviewed journals.

At the Virginia site, progress also continues to be very good, with a fourth year of data collected during 2010-2011. This year has been wetter than average, which provides information about how the VA site responds under these conditions. To summarize, this funding allowed us to continue monitoring and sampling activities for a fourth year at the James Cave site where a stream, three drip sites, and precipitation are being monitored and sampled. Additionally, lysimeters that were installed in soils above the in-cave sites and water samples are routinely being sampled. One graduate student successfully completed his thesis and we are in the process of preparing two manuscripts from his work, which will be submitted for publication in peer-reviewed journals.

We are in the process of applying for a one-year no-cost extension for the project. Because the transfer of funds was significantly delayed beyond the start-date, we expect the project completion date to be 7-31-2012 rather than 7-31-2011.

Work Summary:

Over the past 12 months, numerous visits have been made to maintain equipment installed both on the surface and underground. In Texas, since the end of the 2009 drought, frequent visits are being made to maintain equipment, download data and collect samples. In Virginia, trips to the surface site and into the cave are limited to once or twice each month due to logistics. One graduate student defended his thesis on the VA work, two graduate students defended their theses on work at the TX sites, and two additional graduate students were recruited to work on the TX sites. Several other students (both graduate and undergraduate) have helped with work on the projects.

Detailed Summary of Preliminary Results:

Texas

In Headquarters Cave, McCarty Cave, and Cave Without A Name, drip rates slowed or nearly stopped during 2009, recovered after the rains in the fall season of 2009, and have steadily declined since rainfall decreased in September 2010. We are again in a period of extreme drought in TX, and geochemical and drip data are revealing how the epikarst responds to an extended period of depletion by drainage and ET on the surface.

Preliminary analysis of the time-series drip rate data has resulted in several interesting findings. These can be summarized as follows:

1) Drip rates appear to be controlled by variable amounts of storage in bedrock matrix, as well as some rapid flow during wet periods, which is allowing us to investigate what we believe to be a representative range of the flow systems in the epikarst. For example,

some sites respond only briefly to large rain events and completely dry up, while others drip continuously and appear to have very slight responses to large rain events, but with a ~4-month lag time.

2) At all sites (VA and TX), close investigation of 'noise' in drip rates has revealed that the drip rate responds inversely to changes in barometric pressure. Although this work is in its very preliminary stages, we are investigating the use of these signals to model epikarst hydraulic properties such as storage and hydraulic conductivity.

3) Long term drip records at some of the sites in TX show that there is a perched aquifer system which drains through a fracture leading to the monitoring site. The perched aquifer has different storage and hydraulic conductivity properties. Once depleted, the drip rate drops sharply to a new baseflow level. A certain amount of precipitation is then required to reach a recharge/infiltration threshold where drainage from the perched aquifer is re-activated.

At the TX sites, storage in the matrix supports baseflows at drip sites for long periods of time and (for some sites) attenuates signals from precipitation events. In contrast, matrix storage appears to be much less important at the Virginia site and precipitation signals at drip sites are dominated by seasonality of ET.

<u>Virginia</u>

With this funding, we have extended our collection of long term records of hydrologic and geochemical data in James Cave. We continue to examine the role of epikarst in controlling the quantity and geochemical evolution of recharge water as it passes through the epikarst.

Data collected from September 2007 to present are being used to identify trends in the temporal and spatial distribution of recharge to underlying aquifer. Results show that water-rock interactions and anthropogenic inputs (e.g., manure, fertilizer, and road salt) have significant impacts on the water quality of recharge (e.g, levels of Nitrate well above the drinking water standard at one drip site). However, samples from the main stream in the cave rarely show elevated Nitrate levels, indicating that they may be attenuated by microbial processes, or that our drip sites do not represent the larger baseflow contributions to the stream (and high levels are being diluted), or that we have simply not sampled the main stream at a time when large pulses of Nitrate are being flushed through the system.

Geochemical signatures of different water types (precipitation, soil water, epikarst drips, cave stream) are still being used to estimate the degree of evolution and residence time of recharge and infiltration through the epikarst. As is typical with karst systems, heterogeneity exists in the epikarst; however all sites share similar hydrologic and geochemical responses to recharge events. Drip rate patterns conclusively indicate that recharge through the epikarst occurs during late winter/spring, and is almost negligible during the summer due to high evapotranspiration. Recharge may continue from late spring and into the early summer during exceptionally wet years. Analysis of water stable isotopes is being used to estimate retention time of water in epikarst.

By assessing the timing and quality of recharge, both during base flow conditions and in response to multiple recharge events of varying magnitudes, we are able to use the results from James Cave as an analog for watersheds in the greater Shenandoah Valley region. This was one of our primary objectives of the research, and it allows managers to better understand and characterize the role of epikarst in controlling recharge and water quality in similar karst aquifers.

Student involvement:

Five graduate students and three undergraduate students are or have been involved with various aspects of the TX portion of this research, including thesis work related to the project for three of the graduate students. An additional graduate student will begin work on the project in Fall 2011.

In Virginia, one graduate student completed his thesis in 2010, and several graduate and undergraduate students have supported the continuing sampling and data collection at the site.

Publications:

To date, several abstract has been published during this project, including the three listed below. Additional publications are expected to result from this work – in the form of journal articles, theses, and abstracts.

SPATIAL AND TEMPORAL PATTERNS OF TEMPERATURE AT JAMES CAVE, VIRGINIA

Southeastern Section - 60th Annual Meeting (23–25 March 2011)

SCOTT, Heather[1], SCHREIBER, Madeline E.[1], SCHWARTZ, Benjamin[2], and ORNDORFF, William D.[3], (1) Department of Geosciences, Virginia Tech, 4044 Derring Hall, Blacksburg, VA 24061, heath88@vt.edu, (2) Department of Biology, Texas State University- San Marcos, 206 FAB, Freeman Aquatic Station, 601 University Drive, San Marcos, TX 78666, (3) Virginia Department of Conservation and Recreation Natural Heritage Program, 8 Radford St, Christiansburg, VA 24073

Temperature data provide information that may be used to quantify patterns of air and water movement within karst systems and to examine how the in-cave temperature signals are related to environmental drivers at the surface. In this study, we collected nearly continuous (10 min intervals) measurements of air and water temperature at three epikarstic drip sites in

James Cave, Virginia, in addition to temperature measurements at the surface and within a cave stream, over a three year period. Data show pronounced seasonal variations in temperature at the drip sites that contain a temporal lag when compared with surface temperature. Data also show between-site variations in temperature within the cave. These temporal and spatial patterns are being analyzed to clarify the relationship between cave air and water temperature and surface air temperature, and to elucidate the relative influences of the dominantly conductive heat transfer through the overlying epikarst (soil and weathered bedrock) and convective heat transfer associated with movements of air in response to changes in barometric pressure and external temperature.

HYDROLOGIC RESPONSES IN EPIKARST: A COMPARATIVE STUDY BETWEEN VIRGINIA AND TEXAS

2010 GSA Denver Annual Meeting (31 October –3 November 2010)

SCHWARTZ, Benjamin F.[1], GERST, Jonathan[2], SCHREIBER, Madeline[3], TOBIN, Benjamin W.[4], ORNDORFF, William D.[5], DOCTOR, Daniel H.[6], and SCHWINNING, Susan[1], (1) Department of Biology, Texas State University - San Marcos, 601 University Drive, San Marcos, TX 78666, bs37@txstate.edu, (2) Geosciences, Virginia Tech, 4044 Derring Hall, Blacksburg, VA 24061, (3) Department of Geosciences, Virginia Polytechnic Institute and State University, Derring Hall 4044, Blacksburg, VA 24061-0420, (4) Sequoia and Kings Canyon National Parks, National Park Service, 47050 Generals Hwy, Three Rivers, CA 93271, (5) Natural Heritage Karst Coordinator, Virginia Department of Conservation and Recreation, 6245 University Park Drive, Ste. B, Radford, VA 24060, (6) U.S. Geological Survey, MS 926A, Reston, VA 20192

The epikarst regulates both the quantity and quality of recharge to karst aquifers and, as a result, is a “critical zone” in karst systems. Over the past three years, we have collected continuous hydrologic data from two caves in different hydrogeologic regimes to examine relationships between precipitation, drip response, climate, vegetation, and epikarst properties. At James Cave (VA), bedrock has low matrix storage and epikarst is covered by 1-2m of residuum. Permeability and storage are primarily in solutionally enlarged fractures and bedding planes, with soils and residuum contributing to baseflow. At Cave Without A Name (CWAN; TX), bedrock is covered by thin or no soil, and permeability and storage are primarily found in matrix porosity and enlarged fractures and bedding planes.

Discharge data from drip sites in each cave reveal differences and similarities in the hydrologic functioning of epikarst. In James Cave, drips at three sites respond to precipitation events only after sufficient precipitation during late winter and early spring, with subsequent rapid responses in quickflow (peaking at 5 to 30 L/hr), and corresponding increases in baseflow (~0 to 1 L/hr). Baseflow recession analyses indicate that epikarst contributions support baseflow in the nearby cave stream during the summer months. Baseflow levels depend on receiving sufficient precipitation during the previous fall and winter. At CWAN, however, drip responses at five sites are primarily related to periods with above average precipitation, with less connection to season and more dependence on El Nino and La Nina climate patterns. Three

drip sites responded quickly to repeated rain events after a 2-year drought when most drip sites were essentially dry. After a large rain event and rapid drip initiation, two of these (>10 L/hr) cease to drip after 2-4 weeks, while the third site increased from ~80 ml/hr to ~1500 ml/hr and now maintains this drip rate. The other two sites showed no response to precipitation and continue to drip at essentially the same rate (~5-10 ml/hr). Results thus far support a complex conceptual model of flow and storage in the epikarst where physical and hydrologic properties, in combination with climatic conditions, determine how epikarst regulates recharge to the underlying aquifer.

EPIKARST ROLE IN CONTROLLING THE QUALITY OF KARST AQUIFER RECHARGE

2009 Portland GSA Annual Meeting (18-21 October 2009)

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Abstract

Epikarst, or the region of vegetation, soil, and weathered bedrock lying between the land surface and soluble bedrock, offers water retention capacity that does not exist in deeper, more mature sections of karst aquifers. Thus, the epikarst can act as a temporary reservoir for surface-applied contaminants and naturally-occurring chemical species. Long-term multi-parameter records of precipitation, soil water, epikarst drip water, and in-cave stream-water at James Cave in Dublin, VA, allow us to examine the role of epikarst in controlling the quality and geochemical evolution of recharge water as it passes through the epikarst.

Data collected since September 2007 are being used to identify trends in the temporal and spatial distribution of recharge to the karst aquifer. Drip rates indicate that recharge occurs during late winter/spring, but is minimized by evapotranspiration in summer. Precipitation over James Cave passes through the epikarst where its composition is modified by water-rock interactions. Chemical species such as Na, K, Cl, NO3, SO4, and DOC can serve as tracers to assess the timing and mechanisms of recharge. Geochemical differences between sites indicate that hydrologic and geochemical processes in the epikarst are spatially heterogeneous. However, temporal variations in major ion concentrations can be correlated between sites as a function of recharge.

Specific conductance, pH, alkalinity, and major ion concentrations in epikarst drip water increase during low flow due to increased water-rock interaction. During high flow, however, younger recharge pushes older geochemically saturated water through the epikarst. High flow also inhibits the potential for natural attenuation of contaminants. The structural orientation of the epikarst, the presence of microbial activity, climate, and amount and timing of recharge are

all factors in determining the extent to which epikarst controls the quality of recharge to the karst aquifer.