January 2007

Abstracts of the International Conference on Karst Hydrology and Ecosystems, Bowling Green, Kentucky, USA, 13-15 August 2007

Hoffman Environmental Research Institute

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International Conference on
Karst Hydrogeology and Ecosystems
13-15 August 2007   Bowling Green, USA
## Contents

| Welcome to Karst 2007                      | 3 |
| Conference Staff                          | 4 |
| Phone Numbers                             | 4 |
| Schedules                                 | 4 |
| Sunday, August 12                          | 4 |
| Monday, August 13                          | 5 |
| Tuesday, August 14                         | 6 |
| Wednesday, August 15                       | 7 |
| Detailed Schedule and Session Descriptions| 8 |
| Karst Information Portal                   | 8 |
| Technical Sessions: Tuesday Morning, August 14 | 9 |
| Technical Sessions: Wednesday Morning, August 15 | 10 |
| Poster Session: Wednesday Afternoon, August 15 | 11 |
| Technical Sessions: Wednesday Afternoon, August 15 | 12 |
| Field Trip                                | 13 |
| Abstracts                                  | 14 |
| Author Index                               | 31 |
| Campus Map                                 | 33 |
Welcome to Karst 2007!

The organizers and sponsors of the 2007 International Conference on Karst Hydrogeology and Ecosystems extend a warm welcome to you. With a location in the midst of one of the world’s great karst landscapes, Western Kentucky University has a rich history of karst scientific research, and has been pleased to host a series of international karst conferences over the last several decades, including the 8th International Congress of Speleology in 1981 and joint conferences of international karst commissions in 1998 and 2003. This one is to serve as a joint conference of the Karst Commissions of the International Association of Hydrogeologists and the International Geographic Union, along with the UNESCO/IUGS International Geoscience Program Project 513 (Global Study of Karst Aquifers and Water Resources) and the Union Internationale de Spéléologie Commission on Karst Hydrogeology and Speleogenesis.

Once treated as some kind of esoteric backwater by the ‘mainstream’ science community, karst science continues to emerge, with at least three events driving this over the last few decades. A wealth of direct observation has been accumulated by both cavers and scientists who have created an extensive database by exploring and surveying thousands of kilometers of cave conduits, and their contents, around the world. This accumulated information has made it clear that the nature and function of a particular karst aquifer/landscape system depend on site-specific interactions of climate, lithology, structure, and topography, and that no “one size fits all” model can adequately describe karst hydrologic phenomena in general.

Secondly, advances in technology have made new tools available for the study of karst. These include new methods of ground water tracing using fluorescent dyes and other materials, and geophysical methods that can assist in the location of conduits. The advancement of computer technology has provided important new insights into geochemical interactions within karst waters and their aquifer frameworks, as well as aquifer and flow path evolution.

Lastly, there has been a virtual explosion of interest in karst hydrology due to environmental problems associated with karst, with human and ecological dimensions. Growing populations on carbonate rock areas have increasingly had to attempt to find solutions to problems of water supply, both of water quality and quantity. Flooding has become more common with urbanization in karst regions, and sinkhole collapses present engineering challenges.

While of course research presentations form a core activity of any scientific conference, I’d make a personal observation that another aspect is also critical, and for me forms a basis of whether this meeting will ultimately be a success: that is, the potentially synergistic, informal communication and connections that take place among the participants outside of the lecture halls, during breaks and meals, and in the field. If there is a single motivation that I have for working to organize such a meeting, it is getting a group of folks together at one place, from around the world, who might otherwise never have gathered together. I know that for me such “chance” meetings have led to wonderful and productive relationships, experiences, and cooperative efforts. Do take the time to chat with your colleagues, and otherwise all of us hope that your time here in Kentucky is productive, rewarding, and fun!

Chris Groves
Karst2007 Conference Coordinator
Conference Staff

Coordinators
Chris Groves, Pat Kambesis

Staff Members
Jared Atwood
Priscilla Baker
Ted Baker
Mike Crockett
Chuck Decroix
Wendy Decroix
Scott Dobler
Chelsea Durfey
Lee Florea
Jeremy Goldsmith
Brian Ham
Bruce Hatcher
Lisa Lynn Haynes

Melissa Hendrickson
Steve Kenworthy
Laura Kreitzer
Johanna Kovarik
Jodi Lindsey
Erin Lynch
Chad Martin
James Otoo
Julie Schenk
David Spence
Nathan Talley
Rick Toomey
Amber Williams

Phone Numbers

Baymont Inn
165 Three Springs Rd
Bowling Green, KY 42104
(270) 843-3200

Hampton Inn
233 Three Springs Road
Bowling Green, KY 42104
(270) 842-4100

Bowling Green Emergency Services
Fire, Ambulance, Police (Emergency)
911

Emergency Contact
Wendy Decroix
(270) 745-4556

Schedules

See page 8 for workshop descriptions and detailed schedules of the technical sessions.

Schedule: Sunday, August 13

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00</td>
<td>Registration Open</td>
</tr>
<tr>
<td></td>
<td>Baymont Hotel Hospitality Suite</td>
</tr>
<tr>
<td>7:00</td>
<td></td>
</tr>
</tbody>
</table>
## Schedule: Monday, August 13

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00</td>
<td>Hotel Shuttles</td>
<td>Baymont Inn/Hampton Inn parking area to Mass Media &amp; Technology Hall</td>
<td></td>
</tr>
<tr>
<td>7:00</td>
<td>Registration and Info Desk Open</td>
<td>Mass Media &amp; Technology Hall, Lobby</td>
<td></td>
</tr>
<tr>
<td>8:00</td>
<td><strong>Conference Opening</strong></td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
<td></td>
</tr>
<tr>
<td>8:00</td>
<td><strong>Meeting: UNESCO’s International Geoscience Program (IGCP) Project 513: “Global Study of Karst Aquifers and Water Resources”</strong></td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
<td></td>
</tr>
<tr>
<td>9:00</td>
<td><strong>Meeting: Karst Commission of the International Association of Hydrogeology</strong></td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
<td></td>
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<tr>
<td>10:00</td>
<td><strong>Break</strong> – Mass Media &amp; Technology Hall, Lobby</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td><strong>Meeting: Karst Commission of the International Geographical Union</strong></td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
<td></td>
</tr>
<tr>
<td>12:00</td>
<td><strong>Lunch</strong></td>
<td>Mass Media &amp; Technology Hall, Lobby</td>
<td></td>
</tr>
<tr>
<td>1:00</td>
<td><strong>Meeting: Meeting of Union Internationale de Spéléologie (UIS) Commission on Karst Hydrogeology and Speleogenesis</strong></td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
<td></td>
</tr>
<tr>
<td>2:00</td>
<td><strong>Meeting: International Cave and Karst Research Institution Network (ICKRIN)</strong></td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
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</tr>
<tr>
<td>3:00</td>
<td><strong>Break</strong> – Mass Media &amp; Technology Hall Lobby</td>
<td></td>
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<tr>
<td>4:00</td>
<td><strong>KIP Panel Session: Introducing the Karst Information Portal (KIP)</strong></td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
<td></td>
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<tr>
<td>5:00</td>
<td>Hotel Shuttles</td>
<td>Baymont Inn/Hampton Inn parking area to Lost River Cave</td>
<td></td>
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<tr>
<td>6:00</td>
<td>Lost River Cave Tour, Banquet, and Dancing</td>
<td>Lost River Cave</td>
<td></td>
</tr>
<tr>
<td>7:00</td>
<td>Lost River Cave Tour, Banquet, and Dancing</td>
<td>Lost River Cave</td>
<td></td>
</tr>
<tr>
<td>8:00</td>
<td>Hotel Shuttles</td>
<td>Lost River Cave to Baymont Inn, Starting 9:00</td>
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<tr>
<td>9:00</td>
<td>Hotel Shuttles</td>
<td>Lost River Cave to Baymont Inn, Starting 9:00</td>
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</tr>
</tbody>
</table>
# Schedule: Tuesday, August 14

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:00</td>
<td><strong>Session 1</strong></td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
</tr>
<tr>
<td>9:00</td>
<td><strong>Break</strong> - Mass Media &amp; Technology Hall Lobby</td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td><strong>Session 1</strong></td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
</tr>
<tr>
<td>12:00</td>
<td><strong>Travel to Mammoth Cave Area</strong></td>
<td></td>
</tr>
<tr>
<td>1:00</td>
<td><strong>Lunch</strong></td>
<td>Hamilton Valley Field Research Station (Cave Research Foundation)</td>
</tr>
<tr>
<td>2:00</td>
<td><strong>Cave Trips</strong></td>
<td></td>
</tr>
<tr>
<td>3:00</td>
<td>Everyone must sign up for a specific trip. Please note trip limits. For those trips requiring helmet and lights, these will be provided.</td>
<td></td>
</tr>
<tr>
<td>4:00</td>
<td><strong>Option 1: Cathedral Domes (12 participants maximum)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enter via the Carmichael Entrance to Snowball Dining Room and then Cathedral Domes. Exit via Elevator. Talks on ongoing research and history. Helmets and lights will be provided</td>
<td></td>
</tr>
<tr>
<td>5:00</td>
<td><strong>Option 2: Cathedral Domes (12 participants maximum)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enter via Elevator to Snowball Dining room and then Cathedral Domes. Exit via Carmichael Entrance. Talks on ongoing research and history. Helmet and lights will be provided</td>
<td></td>
</tr>
<tr>
<td>6:00</td>
<td><strong>Option 3: Great Onyx Cave (28 participants maximum)</strong></td>
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<tr>
<td></td>
<td>Trip will focus on history and resources associated with the cave. This will be a lantern tour.</td>
<td></td>
</tr>
<tr>
<td>7:00</td>
<td><strong>Barbeque and Dinner</strong></td>
<td>Hamilton Valley Research Station</td>
</tr>
<tr>
<td></td>
<td>“Finding Big Cave: Lessons From 50 Years at Mammoth Cave” Speaker: Roger Brucker</td>
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<td>8:00</td>
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<tr>
<td>9:00</td>
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</tr>
<tr>
<td>10:00</td>
<td><strong>Return to Bowling Green</strong></td>
<td>Shuttles will leave Hamilton Valley Research Station for Baymont Hotel/Hampton Inn parking area in Bowling Green.</td>
</tr>
<tr>
<td>Time</td>
<td>Event</td>
<td>Location</td>
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</tr>
<tr>
<td>7:00</td>
<td>Session 2</td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
</tr>
<tr>
<td>8:00</td>
<td>Session 2</td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
</tr>
<tr>
<td>9:00</td>
<td>Lunch and Poster Session</td>
<td>Ivan Wilson Center for Fine Arts, Art Gallery</td>
</tr>
<tr>
<td>10:00</td>
<td>Break – Mass Media &amp; Technology Hall Lobby</td>
<td>Mass Media &amp; Technology Hall Lobby</td>
</tr>
<tr>
<td>11:00</td>
<td>Session 2</td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
</tr>
<tr>
<td>12:00</td>
<td>Break – Mass Media &amp; Technology Hall Lobby</td>
<td>Mass Media &amp; Technology Hall Lobby</td>
</tr>
<tr>
<td>1:00</td>
<td>Session 3 (continued)</td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
</tr>
<tr>
<td>2:00</td>
<td>Session 3 (continued)</td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
</tr>
<tr>
<td>3:00</td>
<td>Session 3 (continued)</td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
</tr>
<tr>
<td>4:00</td>
<td>Session 4 (continued)</td>
<td>Tate Page Hall, Room 129</td>
</tr>
<tr>
<td>5:00</td>
<td>Banquet</td>
<td>Kentucky Museum, WKU Campus</td>
</tr>
<tr>
<td>6:00</td>
<td>Hotel Shuttles</td>
<td>Baymont Inn/Hampton Inn parking area to Kentucky Muesum Every 20 minutes</td>
</tr>
<tr>
<td>7:00</td>
<td>Hotel Shuttles</td>
<td>Baymont Inn/Hampton Inn parking area to Kentucky Muesum Every 20 minutes</td>
</tr>
<tr>
<td>8:00</td>
<td>Hotel Shuttles</td>
<td>Baymont Inn/Hampton Inn parking area.</td>
</tr>
<tr>
<td>9:00</td>
<td>Hotel Shuttles</td>
<td>Baymont Inn/Hampton Inn parking area.</td>
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</tbody>
</table>
Karst Information Portal

KIP Panel Session:
Introducing the Karst Information Portal (KIP)

Penelope BOSTON (1), Robert BRINKMANN (2), Todd CHAVEZ (2), George VENI (3)
1. New Mexico Tech and the National Cave and Karst Research Institute;
2. University of South Florida, FL, USA
3. National Cave and Karst Research Institute

Karst Information Portal Workshops
Todd CHAVEZ
University of South Florida

The Karst Information Portal (KIP) Workshop builds on the introductory material communicated during the plenary session. Participants will
- register for a user account,
- navigate the site,
- conduct searches of KIP and the Google Karst customized search engine,
- contribute content, and
- explore the community, help, and contact functionality.

In addition to the hands-on activities, project partners will provide a brief overview of the content management system (CMS) and be available for questions and assistance.
## Technical Sessions: Tuesday Morning, August 14

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 1 (continued)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30</td>
<td><strong>Session 1</strong></td>
</tr>
<tr>
<td></td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
</tr>
<tr>
<td></td>
<td>Climate-driven ecological change in a highland rim karst swamp: Sinking Pond, Coffee County, Tennessee</td>
</tr>
<tr>
<td></td>
<td>William J. WOLFE</td>
</tr>
<tr>
<td>8:50</td>
<td>From the inception horizon hypothesis to a prediction tool for karstified horizons</td>
</tr>
<tr>
<td></td>
<td>M. FILIPPONI, P.-Y. JEANNIN, A. PARRIAUX</td>
</tr>
<tr>
<td>9:10</td>
<td>Use of morphometric analysis to characterize flank margin caves</td>
</tr>
<tr>
<td></td>
<td>John E. MYLROIE, Joan R. MYLROIE, Athena M. OWEN, Monica J. ROTH, Kevin W. STAFFORD, Willapa J. WATERSTRAT</td>
</tr>
<tr>
<td>9:30</td>
<td>Origin and evolution of Illinois' longest caves: An integrated approach to interpreting the geologic and paleoclimatic records</td>
</tr>
<tr>
<td></td>
<td>S.V. PANNO, B.B. CURRY, H. WANG, K.C. HACKLEY, C. LUNDSTROM, Z. ZHANG</td>
</tr>
<tr>
<td>9:50</td>
<td>Break — Mass Media &amp; Technology Hall Lobby</td>
</tr>
<tr>
<td>10:20</td>
<td><strong>Session 1 (continued)</strong></td>
</tr>
<tr>
<td></td>
<td>Mass Media &amp; Technology Hall, Room 166 (Auditorium)</td>
</tr>
<tr>
<td></td>
<td>Karst ecosystems and their ecohydrogeological features in China</td>
</tr>
<tr>
<td></td>
<td>CAO Jianhua, YUAN Daoxian, ZHANG Cheng, JIANG Zhongcheng</td>
</tr>
<tr>
<td>10:40</td>
<td>The influence of organic acids on limestone dissolution: Tongass National Forest, Alaska</td>
</tr>
<tr>
<td></td>
<td>Melissa HENDRICKSON</td>
</tr>
<tr>
<td>11:00</td>
<td>Microorganisms as speleogenetic and geological agents: Unifying themes in Fe/Mn, sulfur, and calcite case studies</td>
</tr>
<tr>
<td>11:20</td>
<td>Classification of ecosystems and their ecohydrogeological features in the main karst regions of China</td>
</tr>
<tr>
<td></td>
<td>LU Yaoru, LIU Qi, CUI Zengdi</td>
</tr>
<tr>
<td>11:40</td>
<td>Geological control of the karst underground streams in Chongqing municipality, China</td>
</tr>
<tr>
<td></td>
<td>PU Junbing, YUAN Daoxian, JIANG Yongjun, HE Qiufang</td>
</tr>
</tbody>
</table>
## Technical Sessions: Wednesday Morning, August 15

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 2</th>
<th>Location</th>
<th>Presenters</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30</td>
<td>Geochemistry of groundwater within a karstified limestone hammock of Everglades National Park</td>
<td>Auditorium</td>
<td>Lee FLOREA, Kevin CUNNINGHAM</td>
</tr>
<tr>
<td>8:50</td>
<td>Sediment transport in karst aquifers: The high end of the size scale</td>
<td>Auditorium</td>
<td>William B. WHITE, Ellen K. HERMAN, Laura TORAN</td>
</tr>
<tr>
<td>9:10</td>
<td>Hydrogeological characteristics and assessment of the water resources of Dalongdong karst system, Xiangxi, Hunan, China</td>
<td>Auditorium</td>
<td>HE Shiyi, ZHOU Jingzhong, ZENG Feiyue</td>
</tr>
<tr>
<td>9:30</td>
<td>SDSS as a management tool for karst aquifers</td>
<td>Auditorium</td>
<td>B. CENCUR CURK, S. VIDMAR, B. MAGAGNA, S. KOLLARITS, G. KUSCHNIG</td>
</tr>
<tr>
<td>9:50</td>
<td>Simulation of groundwater flow in variably saturated karst aquifers: Groundwater storage and its effect on spring hydrographs</td>
<td>Auditorium</td>
<td>Rob DE ROUJ, Pierre PERROCHET</td>
</tr>
<tr>
<td>10:10</td>
<td>Break – Mass Media &amp; Technology Hall Lobby</td>
<td>Lobby</td>
<td></td>
</tr>
<tr>
<td>10:40</td>
<td>Urban hydrogeology in karst regions of China</td>
<td>Auditorium</td>
<td>YUAN Daoxian</td>
</tr>
<tr>
<td>11:00</td>
<td>Storm response and water balance of temperate rainforest karst watersheds: Tongass National Forest, Alaska</td>
<td>Auditorium</td>
<td>Johanna KOVARIK, Chris GROVES, Stephen KENWORTHY, James F. BAICHTAL, Katherine PRUSSIAN, Albert MEIER</td>
</tr>
<tr>
<td>11:20</td>
<td>Determination of the present day hydrological connection between Box Canyon and Tygart's Creek by the examination of the hydrology and hydrochemistry of the Cascade Cave drainage basin</td>
<td>Auditorium</td>
<td>Ryan G. GARRETT</td>
</tr>
<tr>
<td>11:40</td>
<td>Buoyancy approach to analysis of Mammoth Cave air flow patterns</td>
<td>Auditorium</td>
<td>Warren CAMPBELL</td>
</tr>
</tbody>
</table>
Poster Session: Wednesday Afternoon, August 15

The poster session will be held 12:00-2:00pm in the Ivan Wilson Center for Fine Arts, Art Gallery.

US/Chinese cooperation and training in karst water resource investigation in folded carbonate strata, Qing Muguan karst groundwater basin, Chongqing, China
Brian HAM, LUO Jianyin, YANG Pingheng, YUAN Daoxian, JIANG Yongjun

Discovery of karst conduit by fluorescent dye tracer test under the downtown Taebaek, South Korea
Yongcheol KIM (1), Hyuntae HWANG (2), Byungwoo YUM (1), Khwa PARK (1)

The results of karstological researches during the planning and construction of motorways and railroads over the Slovene karst
Martin KNEZ, Tadej SLABE

Costal cave development in Puerto Rico
Michael J. LACE, Patricia N. KAMBESIS, John MYLROIE

Fluvial origin of the Cumberland River karst plain, Wayne and Pulaski counties, Kentucky
Joseph A. RAY, Robert J. BLAIR

Fractal properties of superficial karst of Middle Atlas, Morocco
Mohamed ROUAI

Soil-like systems of the Kougitangtau Caves, Turkmenistan: Mineralogy, microbiology, evolution
A. SEMIKOLENNYKH

Ostracodes, isotopes and flow paths in the karst landscape of West Virginia
Alison J. SMITH, Donald F. PALMER, Joseph DONOVAN, Dorothy VESPER, David DETTMAN, Ksenija NAMJESNIK-DEJANOVIC

Reconnaissance survey of the hydrologic distribution of trace elements in a catchment where poultry litter is used as fertilizer, northwest Arkansas
Ken STEELE

Physical-chemical characterization of karst waters involved in the vadose zone of Diamond Caverns, Kentucky
Andrew H. WULFF, Heather MONOHAN, Samantha KRAMER, Chelsea BRUNNER
# Technical Sessions: Wednesday Afternoon, August 15

<table>
<thead>
<tr>
<th>Time</th>
<th>Session 3</th>
<th>Session 4</th>
</tr>
</thead>
</table>
| 2:00  | **Transport properties of solute, particle and $^{15}$N-labeled microbial tracers under various flow conditions in a karst groundwater basin, Inner Bluegrass Region, KY**  
  J.W. WARD, A.E. FRYAR, G.M. BRION, M.COYNE | **Human impact on Heilongtang Springs, Kunming, China**  
  LIU Hong |
| 2:20  | **Geology and dynamics of underground waters in Jiu de West – Cerna Valley, Baile Herculane, Romania**  
  Gheorghe PONTA |  |
| 2:40  | **Implementation of the tracing technique in geothermal injection study**  
  ZENG Meixiang, RUAN Chuanxia, ZHAO Yuebo | **The influence of land use change on karst water quality in Shuicheng basin, Guizhou, China**  
  JIA Yanan, YUAN Daoxian |
| 3:00  | **Break – Mass Media & Technology Hall Lobby** | **Break – Mass Media & Technology Hall Lobby** |
| 3:30  | **The characters of karst evolution in China, in particular, its relationship with the developmental history of large rivers**  
  YANG Liankang, PAN Yuntang, YANG Yi | **The impact of land use covers upon karst processes: An example from Nongla fengcong depression area, Guangxi, China**  
  ZHANG Cheng, PEI Jianguo, YUAN Daoxian, CAO Jianhua |
| 3:50  | **Towards more robust dye tracing techniques: Background correction and parameter extraction**  
  Chris SMART, Ryan ADAMS, Melissa HENDRICKSON | **Collaborative efforts in karst water resource development in southwest China: The China Environmental Health Project**  
  Chris GROVES, YUAN Daoxian, JIANG Yongjun, Patricia N. KAMBESES, Priscilla BAKER |
| 4:10  | **Study of the hydraulics and water movement in Río Encantado and Vientos cave systems**  
  José MORALES | **Simulation of hydrological response of karst spring to precipitation: A case study of Shuifang Spring, Jinfo Mt., Chongqing, China**  
  WU Yuexia, JIANG Yongjun, YUAN Daoxian, LI Linli, YANG Pingheng |
| 4:30  | **A statistical strategy for determining contaminant impacts of landfills on springs in karst terranes**  
  Wanfang ZHOU, Barry F. BECK, Jie WANG, Arthur J. PETTIT | **The role of epikarstic zone for microbiological pollution retardation**  
  B. CENCUR CURK, M. BRICELJ |
Field Trip

Overview

August 16:
Tour of Jack Daniel’s Distillery  
Lunch at Mary Bobo’s, Jack Daniel’s Favorite Boarding House  
Private tour and catered dinner with cash bar at the Chattanooga Aquarium  
Presentation on the Karst of the Cumberland Plateau – Dr. Will White

August 17:
Hiking, swimming, and caving at Fall Creek Falls State Park, Tennessee  
All American Grill Out Picnic Lunch  
Private Tour of Cumberland Caverns  
Catered banquet inside the cave at Cumberland Caverns

August 18:
Shopping and sightseeing and lunch in historic downtown Chattanooga, Tennessee  
Catered banquet at the Pine Mountain State Resort Park  
Presentation on the karst of Cumberland Gap National Park – Mike Crockett, Cave Research Foundation

August 19:
Walking tour of Gap Cave  
Karst Road Rally  
Vertical Through Trip of Gap Cave (experienced cavers only, trip size limit)

Lodging Information:
Hotel style lodging with air conditioning  
All rooms have two queen beds and private bath facilities  
Free Internet (with personal laptop)  
Outdoor Swimming Pool  
Smoking/Non smoking rooms available

Caving Trips

August 17, Fall Creek Falls:

A. Lost Creek Cave
Lost Creek Cave is a horizontal, easy to moderately strenuous undeveloped cave near Sparta, Tennessee. Mainly self-guided walking with uneven ground, more difficult crawling or climbing also possible.

B. Camp’s Gulf Cave
Camp’s Gulf Cave is a horizontal, highly strenuous undeveloped Cave near Sparta, Tennessee. Caving in this cave involves climbing through tight chimneys and extremely steep breakdown piles; and squeezing through 6 inch spaces. Must be in good physical condition.
TRIP LIMIT: 30 CAVERS

August 19, Cumberland Gap National Park:

Gap Cave and Road Rally
The Karst Road Rally will tour interesting and beautiful karst sites in eastern Kentucky and northern Tennessee on the morning of August 19. Each group will ride in an air-conditioned 15 passenger van with a knowledgeable local guide.
In the afternoon, this group tours Gap Cave. Gap Cave is a developed cave managed by the National Park Service. It is a moderately strenuous trip with cement walkways, and some up/down inclined walking.
Abstracts are listed by primary author, alphabetical order. This program has been modified from that printed and distributed at the conference. † denotes abstracts which were submitted but not presented. Abstracts which were not presented and whose author(s) failed to notify the conference of their non-attendance in good time have been excluded.

ORIGIN AND DEVELOPMENT OF DAM-VALLEY LAKES AND KARST HYDROGEOLOGIC SYSTEMS, WITH REFERENCE TO THE AMTKELI RIVER (WESTERN CAUCASUS) †
G.N. AMELICHEV, B.A. VAKHRUSHEV, V.N. DUBYANSKIY
Ukrainian Institute of Speleology and Karstology, Tavrichesky National University, Simferopol, Ukraine

Dammed lakes in river valleys of mountain karst regions can be formed due to rockslides. Ancient relic cave hydrogeological systems, which had already been devoid of flow, can renew their functioning as a result. Interest in their study is due to the fact that they represent a natural model of a technogenic situation arising up while building dams in karst regions.

The Amtkel karst area is situated on the south slope of the Abkhazsky mountain range, Western Caucasus. The River Amtkel crosses the belt of Cretaceous limestone here. After an earthquake-induced rockslide in 1891, a dam-lake was formed in the middle flow of the river. Relict caves located on the slopes of the valley were flooded and began functioning as water intakes. The valley section downstream of the rockslide dam was drained, which opened former intakes at the river bed.

In order to study cave hydrogeologic systems of the area, topographic, geologic, bathymetric, hydrochemical, thermic and speleological investigations have been conducted. The large karst hydrogeologic system has been revealed, where ancient components received intense recharge by lake waters. Areas of recharge, transit and discharge have been identified in the system, with discharge occurring throughout a karst spring located 9 km away from the dammed lake. Three hydrochemical facies of waters were identified in the area: non-karstic groundwater in the Paleogene sediments, Amtkeli Lake waters with two temperature sub-facies (shallow and bottom), and river waters. Parameters of the system functioning have been established using mixing equations for low flow and high flow regimes. Speleomorphogenetic evolution of the karst hydrogeologic system of the Amtkeli Lake and river during Pliocene-Quaternary time has been reconstructed.

THE COMPARATIVE ROLE OF MICROBIAL METABOLIC ACTIVITY VERSUS INORGANIC PROCESSES IN THE PRECIPITATION OF CALCITE †
Eric D. BANKS, Hazel A. BARTON
Dept. of Biological Sciences, Northern Kentucky University, Highland Heights, KY, USA

In order to investigate whether active metabolic microbial process dominates over passive geochemistry in the formation of calcite polymorphs, we are examining calcium carbonate (CaCO₃) precipitation and dissolution by bacterial species from hypogean cave environments. Microbial species were isolated from CaCO₃ ‘popcorn’ deposits within Grayson-Gunnar Cave, Kentucky based on their ability to deposit CaCO₃ crystals on Boquet B4 media or to dissolve calcite in a CaCO₃ enriched ‘top’ agar. Current research is aimed at determining if an organic calcium salt is a possible energy source that drives such phenomenon and to identify the gene(s) responsible for this cellular function. Examination of the crystal structure produced by precipitating species using scanning electron microscopy demonstrates bacterial-like footprints in, and on, the surface of these crystals. These data have shown the same species can precipitate various mineral forms of CaCO₃, including calcite and aragonite. By correlating the structure of the CaCO₃ crystals with environmental growth conditions of individual species using powder x-ray diffraction (XRD), we hope to correlate microbial metabolic activities with CaCO₃ precipitation. By studying the conditions that similarly allow dissolution of CaCO₃, we hope to better understand the role that CaCO₃ plays on microbial growth, Ca²⁺ detoxification and metabolic adaptation to CaCO₃ rich environments.

MICROORGANISMS AS SPELEOGENETIC AND GEOLOGICAL AGENTS: UNIFYING THEMES IN FE/MN, SULFUR, AND CALCITE CASE STUDIES
1. New Mexico Institute of Mining and Technology, Socorro, NM, USA
2. National Cave and Karst Research Institute, Carlsbad, NM, USA
3. University of New Mexico, Albuquerque, NM, USA
4. Western Illinois University, Macomb, IL, USA

Caves provide habitats for countless indigenous microorganisms. Some are simply living in the subsurface without exerting much impact on their surroundings. However, some speleologically significant microbial communities appear to enhance the pace and extent of cave formation, cause secondary enlargement of primary cavities, and contribute to precipitation of a wide array of secondary minerals and speleothems. These types of communities particularly seem to occur in caves that are chemically or otherwise unusual, in other words in extreme environment caves. These organisms may be major agents of subsurface weathering but we do not yet understand the magnitude of their impact either within a given cave or at larger scales. Although the details of chemistry and specific identities of organisms differs depending upon the geological setting and geohistory of individual caves, there are significant similarities in the interaction of biofilms, organisms, and geochemistry that can provide guidance for studies in a wide variety of subsurface environments. These include widespread metal oxidation as energy sources, microbial pioneer species that move into bedrock providing conditions for subsequent species to exploit, very slow growth rates, and frequently very small cell sizes.

Cave geomicrobiology and its geological significance can be seen in our work in three chemically and microbiologically distinct types of caves. Iron and manganese deposits in Lechuguilla and Spider Caves in New Mexico show extensive microorganism involvement. They disaggregate the bedrock, mine usable materials to maintain their metabolism, and then precipitate unique mineral forms as waste products. In hydrogen sulfide caves in Tabasco, Mexico, organisms...
are involved in transformation of sulfide gas into elemental sulfur and gypsum, conduct a host of other sulfur chemical transformations and contribute to primary enlargement of the cave. In autochthonous carbonate cave deposits (e.g. moonmilk, pool fingers, etc.), we have detected significant evidence of biological activity in both living and fossilized structures and deposits. A multidisciplinary integrated approach is enabling us to study the relative importance of biological versus abiotic processes in all of these cases.

**BUOYANCY APPROACH TO ANALYSIS OF MAMMOTH CAVE AIR FLOW PATTERNS**

Warren CAMPBELL
Engineering Dept., Western Kentucky University, Bowling Green, KY, USA

This is a proposal to model air flow in the historic section of Mammoth Cave using a balance between buoyancy and friction forces. Analysis of turbulent flow is very complex. For this reason, we propose a simple and less expensive approach than a full analysis by computational fluid dynamics (CFD) which would involve solutions of the non-linear Navier Stokes equations. In discrete form, the solutions would involve solutions to millions of nonlinear algebraic equations. Rather than attacking the problem in this way, we propose a very simplified and affordable analysis supported by a moderate measurement program.

It is well known that for two entrance caves with one entrance above the other, air blows out the lower entrance in the summer and in during the winter. Many examples of this behavior are known. This behavior can be explained using a simple balance between buoyancy forces and viscous forces. The slight change in ambient temperature between a lower entrance and an upper entrance has no significant impact on the phenomenon. It can be easily shown that the important temperature difference is that between the interior of the cave and outside air temperature. If only buoyancy forces are applied, steady flow can not be achieved. However, if a flow is shut off with a barrier and then the barrier is removed, the air velocity will increase until buoyancy forces balance frictional forces. As the velocity increases, frictional forces increase. Loss coefficients for a cave system cannot be found in a handbook, but could be determined with a limited number of measurements.

Some parameters of the model can be determined by sealing off passages such as Houchens Narrows at the Bat Gate. By measuring the differential pressure between outside and inside during the winter and summer, some of the loss coefficients and other parameters of the model can be determined allowing calibration of the model. The goal of this modeling is to predict the effect of opening entrances currently sealed or of creating new entrances. The model would also allow estimation of fluxes during extreme weather events.

**KARST ECOSYSTEM OF GUANGXI ZHUANG AUTONOMOUS REGION CONSTRAINED BY GEOLOGICAL SETTING: RELATIONSHIP BETWEEN CARBONATE ROCK EXPOSURE AND VEGETATION COVERAGE**

CAO Jianhua, YUAN Daoxian, ZHANG Cheng, JIANG Zhongcheng
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Karst ecosystems are restrained by the karst environment, and especially by the karst geological setting. In karst regions, the main factors impacting plant growth are: (1) soil erosion extremely faster than soil formation, (2) suffering moisture-short in cyclicity owing to double-layer hydrogeological structure, and (3) deficiency or low availability of mineral elements in soils.

Using ArcView3.2, the percentage of exposed carbonate rocks and the arbor, bush, and grass cover were calculated for each county in Guangxi Zhuang Autonomous Region. The results show there is significant negative correlation between arbor coverage and percentage of carbonate rock by the linear relation AC = -0.34PCR + 33.75 with the correlation coefficient r=-0.75. A positive correlation can be fitted between shrub and grass coverage and percentage of carbonate rock by the linear relationship BC = 0.25PCR - 0.45, GC = 0.03PCR + 0.99 with the coefficient r=0.71 and 0.49, respectively.

**THE ROLE OF EPIKARSTIC ZONE FOR MICROBIOLOGICAL POLLUTION RETARDATION**

B. CENCUR CURK (1), M. BRICELJ (2)

1. IRGO - Institute for Mining, Geotechnology & Environment, Ljubljana, Slovenia
2. NIB - National Institute of Biology, Ljubljana, Slovenia

The purpose of the research was to study the infiltration and migration of health-hazardous human viruses, such as enteroviruses, in the unsaturated zone of fractured and karstified rock, since these rocks present important aquifers in Slovenia.

The multi-tracer experiment was performed in the frame of the common project of the Association of Tracer Hydrologists (ATH), where several tracers were used: deuterium (90%), potassium bromide, lithium chloride, zinc sulphate, sulfonic acid, pyranine, naphthionate, uranine, Sulforhodamine B, micro spheres and bacteriophages P22H5. The latter were used as a possible model for behavior of health-hazardous viruses.

The tracer experiment was performed at the research field site (RFS) Sinji Vrh in the western part of Slovenia. The experimental field site at Sinji Vrh, consists of surface set-up and a research tunnel, 15 m below the surface. Agrometeorological station and injection boreholes were installed on the surface. A special construction (1.5 m long segments) for collecting water seeping from the ceiling of the research tunnel was developed.

After injection, bacteriophages remain in the fractures (channels) and microfracture systems of the unsaturated zone and were rinsed by subsequent larger precipitation events even up to several months (years) after the injection. The field experiments have shown different flow patterns depending on the fractured rock structure. In the research area some fast conduits (large fractures or faults) exist where water runs faster than in the total conductive part of the rock. On the other hand the tracer delay in microfracture system areas was observed.

**SDSS AS A MANAGEMENT TOOL FOR KARST AQUIFERS**

B. CENCUR CURK (1), S. VIDMAR (1), B. MAGAGNA (2), S. KOLLARITS (3), G. KUSCHNIG (4)

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Karstic areas are essential for public water supply, since currently karstic aquifers contribute 25% of world-wide water supply. These areas are at the same time highly sensitive and valuable natural environments. Conversely, development of such areas is increasing. Sustainable development of karstic areas means a maximum use of the environment with simultaneous conservation of natural resources. This is difficult to achieve in practice. It requires an exceptional knowledge of natural resources and skill and knowledge of physical planners who have to optimize effects of human activities. These tasks can be supported by a spatial decision-support system (SDSS), which integrates data from various sources and helps to make decision processes more effective and transparent.

Basic work for such a SDSS has been done in the transnational and interdisciplinary project KATERI, supported by the INTERREGIIIb programme, involving cooperation between institutions from Austria, Croatia, Italy and Slovenia. With the help of an inventory all existing data about land-use, existing and potential polluters, soil and aquifer characteristics and, as far as possible, time-series of water and substance fluxes was recorded for selected pilot areas. These areas were chosen to reflect a range of land-use types and different national settings. Land-uses considered include summer and winter tourism, settlements, transport, forestry, agriculture and pasture management. Legal frameworks and socio-economic aspects with emphasis on land-use activities were also implemented in the SDSS. Also, the complex relationships between social and techno-economic variables must be taken into account in order to understand how people behave and to help them decide.

SIMULATION OF GROUNDWATER FLOW IN VARIABLY SATURATED KARST AQUIFERS: GROUNDWATER STORAGE AND ITS EFFECT ON SPRING HYDROGRAPHS

Rob DE ROOIJ, Pierre PERROCHET
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This paper presents results obtained with a newly developed numerical model for simulating groundwater flow in karst aquifers. The innovative feature of the model is the coupling of turbulent conduit flow with laminar matrix flow under variably saturated conditions. The model allows the conduits to be dry, partially filled or pressurized. The interaction between the conduits and the matrix is simulated without the need of a lumped parameter.

Since it can handle variable saturation in both the conduits and the matrix, the model is especially useful to test conceptual ideas about the storage of groundwater in karst aquifers. Simulations show that temporal storage of groundwater responsible for tailing effects on spring hydrographs can take place in the matrix as well as in the conduits. It is shown that both storage functions are related to the geometry of the conduit network.

The results confirm that storage in the matrix is only significant in aquifers with a relatively low degree of karstification. Storage in the conduit network can also result in tailing effects on spring hydrographs if certain conduit sections cannot be drained directly by the network itself.

FROM THE INCEPTION HORIZON HYPOTHESIS TO A PREDICTION TOOL FOR KARSTIFIED HORIZONS

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1. GEOLEP, Laboratoire de géologie de l’ingénieur et de l’environnement, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

The prediction of dissolution voids geometry (i.e. karst conduits; position, size and characteristics) is an important issue in civil engineering as well as in hydrogeology. In practice, dissolution voids are considered as random in most cases. However, it is obvious for karst researchers that dissolution void distribution is not random, but defined by parameters controlling the ‘speleogenesis’.

Analysis of the complex 3D geometry of 15 large cave systems around the world, respectively of more than 1500 km of conduits in relation to their geological context as well as their hydrogeological boundary condition, allowed us to get statistical evidence of the inception horizon concept. This confirms that the development of karst conduits under phreatic conditions is strongly related to a restricted number of so called inception horizons, in most cases between three and five bedding planes. An inception horizon is a part of a rock succession that can favor the earliest cave forming processes by physical, lithological or chemical deviation from the predominant carbonate facies within the sequence (Lowe 2000). The existence of inception horizons was postulated by several authors (e.g. Palmer 1989, Lowe 1992, Klimchouk & Ford 2000) but has not been demonstrated until now on the basis of well documented cases.

Furthermore, we sampled 18 inception horizons of five cave systems as well as the surrounding rock mass, at which more than 200 rock samples have been analyzed to determine parameters controlling the speleogenesis. The analysis gives first ideas of the different key properties of the inception horizons relative to the surrounding rock mass.

The presented methodology is a good tool to improve the prediction of karst conduits relevant for geological engineering problems (e.g. tunnelling, oil industry, hydrogeology) as well as for scientific understanding of the evolution of karst systems.

GEOCHEMISTRY OF GROUNDWATER WITHIN A KARSTIFIED LIMESTONE HAMMOCK OF EVERGLADES NATIONAL PARK

Lee FLOREA, Kevin CUNNINGHAM
United States Geological Survey, Florida Integrated Science Center, Ft. Lauderdale, FL, USA

Macro-porosity in the Biscayne carbonate aquifer commonly occurs as horizons of centimeter-scale-diameter, touching-vug porosity, in some instances, traceable between wells at the regional scale. The ichnofabrics generated by callianassid burrowing can dominate zones within or the entire thickness of the Marine Isotope Stage 5e part of the Miami Limestone and some or most of those of the underlying Quaternary Fort Thompson Formation. Yet, even within these highly permeable zones within the MIS 5e, we find examples of caves, particularly air-filled caves associated with transverse glades that dissect relatively high elevations along the Atlantic Coastal Ridge. A broad-spectrum monitoring program is underway at one of these caves in Everglades National Park, Palma Vista Cave, and the nearby freshwater Taylor Slough, and is providing water-level, meteorological, geochemical, microbiological, petrologic, and isotopic data over the course of one year. The goal is to provide a detailed look at the development of cavernous porosity in coastal, eogenetic carbonates.

Water levels, measured every ten minutes in Taylor Slough and Palma Vista Cave, respond rapidly to individual storms, in one case rising more than 30 cm in less than 12 hours. Present geochemical data from the slough, sampled every two weeks, reveal a shift toward lower values of pH, specific conductance, and total alkalinity at the onset of the wet season. The pH of waters from the
cave also decreases at the onset of the wet season; however, specific conductance and total alkalinity remain relatively stable. The waters of both the slough and the cave, however, remain saturated with respect to both calcite and aragonite at each sampling period up to the onset of the wet season, and soon after major rain events. These preliminary data suggest rapid saturation of recharge waters (minutes to hours). It appears that the enlargement of Palma Vista Cave does not proceed uniformly unless aided by not yet quantified microbiologic activity.

DETERMINATION OF THE PRESENT DAY HYDROLOGICAL CONNECTION BETWEEN BOX CANYON AND TYGART’S CREEK BY THE EXAMINATION OF THE HYDROLOGY AND HYDROCHEMISTRY OF THE CASCADE CAVE DRAINAGE BASIN

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Geology Dept., University of Akron, Akron, OH, USA

This study will take place in Carter Caves State Park, Carter County, Kentucky. It will involve a preliminary delineation of the Cascade Cave drainage basin, between Tygart’s Creek and James Branch. Dye tracings will be utilized in an effort to decipher what role the numerous sinkholes and the caves have in this process. Examination of groundwater flow, and chemical composition, through this karst aquifer will also yield important information that can be used to study the formation of paleoflow routes that are now abandoned cave conduits. Additional studies will be done here to determine if the sediments found in the upper-level conduits, can be correlated to the down-cutting of Tygart’s Creek, and thus to the Pleistocene-Pliocene incision of the Ohio River.

COLLABORATIVE EFFORTS IN KARST WATER RESOURCE DEVELOPMENT IN SOUTHWEST CHINA:
THE CHINA ENVIRONMENTAL HEALTH PROJECT

Chris GROVES (1), YUAN Daoxian (2), JIANG Yongjun (2), Patricia N. KAMBESIS (1), Priscilla BAKER (1)

1. Hoffman Environmental Research Institute, Western Kentucky University, Bowling Green, KY USA
2. School of Geographical Sciences, Southwest University of China, Beibei, Chongqing, P.R. China

Many rural residents of China’s southwest have yet to benefit from the nation’s explosive economic growth, so far focused in the country’s urban eastern provinces. For millions, in addition, economic and public health challenges are related to and exacerbated by the nature of the physical landscapes on which they live. This is especially the case in the region’s extensive limestone karst regions, characterized by limited surface water availability. Following extensive deforestation starting in the late 1950s, in these landscapes surface water is often limited or even absent over large areas, especially during annual dry seasons, and many residents are forced to carry water from the nearest spring or other source. Highly specialized methods are required to develop and protect groundwater resources in karst settings, technology which in some aspects is only now being introduced to the Chinese hydrogeologic scientific community. Since 1995, collaboration between Western Kentucky University (WKU), the Institute of Karst Geology (Guilin, Guangxi) and Southwest University of China (Beibei, Chongqing) has been aimed at understanding aspects of the hydrogeology of southwest China’s karst regions. Although much of this has been focused on academic research topics such as geomorphology and geochemistry, over the years our efforts have strongly evolved towards applied efforts concerning water supply and public health.

With support from the US Agency for International Development and the ENVIRON Foundation, and in collaboration with UNESCO’s International Geoscience Program Project 513, in 2006 WKU’s China Environmental Health Project was initiated to increase Chinese academic infrastructure in karst water resource studies, through a partnership with Southwest University of China, the Woodrow Wilson International Center for Scholars, and the International Institute of Rural Reconstruction. Field demonstration sites in Chongqing and Yunnan strive both to improve local conditions as well as serving as a training vehicle to build sustainability into the collaborative effort.

US/CHINESE COOPERATION AND TRAINING IN KARST WATER RESOURCE INVESTIGATION IN FOLDED CARBONATE STRATA, QING MUGUAN KARST GROUNDWATER BASIN, CHONGQING, CHINA

Brian HAM (1), LUO Jianyin (2), YANG Pingheng (2), YUAN Daoxian (2), JIANG Yongjun (2)

1. Hoffman Environmental Research Institute, Western Kentucky University, Bowling Green, KY, USA
2. School of Geographical Sciences, Southwest University of China, Beibei, Chongqing, P.R. China

The Qing Muguan groundwater basin in Chongqing China has recently been established as a demonstration field site for collaborative research and training by scientists and students at Southwest University of China in Beibei, Chongqing, and the China Environmental Health Project (CEHP) at Western Kentucky University (WKU) with major support from the US Agency for International Development. Fieldwork in summer 2007 allowed the WKU CEHP team to share experience in procedures for karst groundwater investigations, while the Southwest University students provided detailed of hydrogeologic background and previous research. The area of Qing Muguan will serve as a new study area where students from opposite sides of the world can benefit from learning new approaches to karst water resource investigations.

Qing Muguan is an 18 km long, 2 km wide karst groundwater basin with water quality impacted by agricultural land use. It consists of folded sedimentary strata, limestone and dolomite in the main valley with a coal layer and sandstones defining the boundary of the groundwater basin to the east and west. This initial field work focuses on understanding the distribution of karst features and the groundwater flow paths in the Qing Muguan karst groundwater basin. The field work was conducted between 17 July and 10 August 2007. All field work is a result of the full cooperation between the Chinese and American students and scientists. A karst hydrogeologic inventory was the initial task simultaneous with placement of background fluorescence charcoal receptors. These receptors were replaced after 10 days immediately before the dye injection. 0.8 kg of fluoresceine was used as the groundwater tracer. Charcoal dye receptors were replaced every two days initially and then on a weekly basis. Karst features and groundwater flow path are mapped by developing a Geographic Information Systems database.
HYDROGEOLOGICAL CHARACTERISTICS AND ASSESSMENT OF THE WATER RESOURCES OF DALONGDONG KARST SYSTEM, XIANGXI, HUNAN, CHINA

HE Shiyi (1)(2), ZHOU Jingzhong (3), ZENG Feiyue (4)
1. China University of Geology, Wuhan, Hubei, P.R. China
2. Institute of Karst Geology, CAGS, Guilin, Guangxi, P.R. China
3. Bureau of Hunan Geological Survey, Suzhou, Hunan, P.R. China
4. Bureau of Irrigation Works of Xiangxi State, Jishou, Hunan, P.R. China

The influence of land use and land cover on ecological environments is a focus of global change research. The industrial city of Shuicheng in Guizhou province was chosen as a study site because the karst water quality around the city is deteriorating with land use and land cover change. The natural susceptibility of karst water system is an important factor leading to karst water pollution. But the change of land use and land cover is also a main factor according to the analysis of series data of the water quality and of land use change. So it is a good way to protect karst waters through rational planning and managing land use and land cover.

THE INFLUENCE OF ORGANIC ACIDS ON LIMESTONE DISSOLUTION: TONGASS NATIONAL FOREST, ALASKA

Melissa HENDRICKSON* 
Hoffman Environmental Research Institute, Western Kentucky University, Bowling Green, KY, USA

The dissolution kinetics of limestone have been studied in depth in laboratory settings and under some situations in the field. However, little has been studied about how organic acids affect the dissolution of limestone. In accordance with the Tongass Land Management Plan, one of the research priorities for National Forest is to define a relationship between peatlands and karst development. The Tongass National Forest is underlain by extensive areas of carbonate bedrock, including extensive areas of the northern portion of Prince of Wales Island. The peatlands in the Tongass drain acidic waters into the karst. It was found that the carbonate karst system acts as a buffer for the highly acidic muskeg waters. Over the gradient of the karst system for this study, the pH increases from an average of 3.89 to 7.22 and the predicted dissolution rates drop from the insurgence to the resurgence. These rates were also correlated with a mineral weight loss experiment that was in agreement with these predicted rates. The potential for dissolution from the muskeg waters is the highest recorded for a natural karst system.

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THE INFLUENCE OF LAND USE CHANGE ON KARST WATER QUALITY IN SHUICHENG BASIN, GUIZHOU, CHINA

JIA Yanan, YUAN Daoxian
1. Institute of Karst Geology, CAGS, Karst Dynamics Laboratory, MLR, Guilin, P.R. China

The influence of land use and land cover on ecological environments is a focus of global change research. The industrial city of Shuicheng in Guizhou province was chosen as a study site because the karst water quality around the city is deteriorating with land use and land cover change. The natural susceptibility of karst water system is an important factor leading to karst water pollution. But the change of land use and land cover is also a main factor according to the analysis of series data of the water quality and of land use change. So it is a good way to protect karst waters through rational planning and managing land use and land cover.

FRAGILITY AND GEOLOGICAL BACKGROUND OF ROCKY DESERTIFICATION ENVIRONMENT IN THE KARST AREAS OF SOUTHWEST CHINA †

JIANG Zhongcheng, YUAN Daoxian, CAO Jianhua
Institute of Karst Geology, CAGS, Guilin, P.R. China

At present, rocky desertification is the most urgent ecological and environmental problem in southwest China, which has been paid attention in a high degree by Chinese governments and the relative scholars at home and abroad. The fragile karst ecosystem, which was formed by intensive karstification in southwest China, is the basement of the rocky desertification. However, the rocky desertification makes the ecological environments in karst areas of southwest China worse. There is not only a lack of water supplies and soils, but also frequent natural hazards, as well as low production capacity. So the local people have almost no conditions of production and life. About 17 million people are affected by the drinking water supply problem, and there are 88 state-grade poverty counties in Yunnan, Guizhou and Guangxi provinces.

Hard, pure and soluble carbonate rocks, uplift tectonics, tropical and subtropical karst terrains, karst water net, karst soils and double-deck space structure between surface and underground are the geological background for the formation of rock desertification. Because the chemical composition of the carbonate rocks controlled the formation speed of the soils, and distribution of the carbonate rocks influence the scope of the rocky desertification. The uplift tectonics can provide dynamic conditions for karst development and rocky desertification. The double-deck space structure between surface and underground not only lead to the leakage of the surface water, but also makes the depressions water log in the rainy season, which influences the production conditions of agriculture, forestation, and plant appearance. The shortage of soil and water supplies makes the growth rate and quantity of forest in karst areas much lower than that in non-karst areas. Moreover, some local people under high popuation pressure engage in poor land use practices, such as cultivation on steep slopes, cutting wood, and burning the grass on mountains, as well as air pollution from the factories, are important causes of rock desertification. Recent research of the international geological contrast shows that these frequent human activities under the special geological background make the rocky desertification problem situation in southwest China much graver than in any other counties. Therefore, for treatment of rock desertification, detailed researches of the geological backgrounds are primary. Then, after summing up the successful experiences of rock desertification treatment in early stage, a plan to work out the new different comprehensive treatment measures in different geological backgrounds and environmental conditions can be created. The exploitation of the karst water and the organic integration between
ecological rehabilitation and economic development should be paid particular attention.

**DISCOVERY OF KARST CONDUIT BY FLUORESCENT DYE TRACER TEST UNDER THE DOWNTOWN TAEBAEK, SOUTH KOREA**

Yongcheol KIM (1), Hyuntae HWANG (2), Byungwoo YUM (1), Kihwa PARK (1)

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The city of Taebeak is located at the middle eastern part of Korean peninsula and composed mainly of Paleozoic limestone and Mesozoic terrestrial sedimentary rock. There are geological structures such as thrust faults and unconformity that could influence on regional groundwater flow properties. There is a spring named as Hwangji in the downtown of Taebeak city, which is popular tourist site as the headwater of Nakdong river. A tracer test with fluorescent dye is performed at the middle of the city to find out hydrogeologic connectivity between Hwangji spring and three private wells which are aligned approximately to the north-west direction from the Hwangji spring. The most far well of about 956 m apart from the spring is used for tracer injection and the other two wells and Hwangji spring are used for observation points. Tracer start to be detected at the Hwangji spring 2.2 days after injection. The time taken from the start of tracer detection to peak arrival was about 1.49 days. According to the arrival time of the center of mass, the groundwater flow velocity along the karst conduit can be estimated as 259 m/day which is extremely fast compared to general groundwater velocity through porous or fractured media. This value of groundwater velocity tell us the strong possibility that groundwater outflows at the Hwangji spring after preferentially flowing through karst conduit only about 15 m below the downtown of Taebeak city. It is strongly recommended by this result that pumping activity and construction in the adjacent area around the karst conduit should be controlled to protect Taebeak people from possible disaster like sinkhole or land subsidence.

**THE ROLE OF THE BLACK SEA IN THE DEVELOPMENT OF THE DEEPEST CAVE SYSTEM IN THE ARABIKA MASSIF (KRUBERA CAVE, WESTERN CAUCASUS) †**

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Arabika is an outstanding high-mountain karst massif in the Western Caucasus composed of Lower Cretaceous and Upper Jurassic limestones continuously dipping southwest to the Black Sea shore and plunging below the modern sea level. The central sector (elevations within 2000–2700 m) is characterized by pronounced glacio-karstic landscape and hosts several deep caves including the deepest cave in the world (Krubera–Voronja Cave) recently explored to the depth of 2158 m. Dye tracing experiments conducted in 1984–1985 suggested that the Krubera Cave area is hydraulically connected with major springs at the Black Sea shore and the submarine discharge, with the flow directed across major fold structures.

The outstanding facts about the hydrogeology of Arabika are:

1. Krubera Cave has an extremely steep profile and reveals a huge thickness of the vadose zone. Its present bottom is at elevation of about 100 m, which suggests a very low overall hydraulic gradient of 0.006-0.008.
2. Reported low salinity groundwater tapped by boresholes in the shore area at depths 40-280, 500, 1750 and 2250 m, which suggests the existence of deep flow system with vigorous flow.
3. Submarine discharge up to ca. 400 m bsl.
4. Huge closed submarine depression at the sea-floor in from Arabika with a deepest point of ca. 400 m bsl.

These facts point to a possibility that the main karst system in Arabika could have originated in response to the Messinian salinity crisis (5.96–5.33 Myr) when the Black Sea could have almost dried up, similarly to the adjacent Mediterranean where the sea level drop up to 1600 m is well established. Further development of the huge vadose zone and a super-deep cave have been caused by subsequent uplifts during Pliocene-Pleistocene, highly differential between the shore sector (0.1-0.2 km of total uplift) and the central sector (2-2.5 km) of Arabika.

**HYDROGEOLOGICAL CHARACTERIZATION OF HYPOGENIC SPELEOGENESIS †**

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Karst should be viewed in the context of regional groundwater flow systems. Two major types of karst systems, hypogenic and epigenic, are regularly associated with different types, patterns and segments of flow systems, characterized by distinct hydrokinetic, chemical and thermal conditions. Epigenic karst systems are predominantly local systems, and/or parts of recharge segments of intermediate and regional systems. Hypogenic karst is associated with discharge regimes of regional or intermediate flow systems. The main characteristic of hypogenic speleogenesis is the lack of genetic relationship with groundwater recharge from the underlying or immediately adjacent surface. Hypogenic speleogenesis may not be expressed to the surface and is largely climate-independent.

Hypogenic speleogenesis is defined with reference to the source of fluid recharge to the cave-forming zone, and type of flow system. Confined settings are the principal hydrogeologic environment for hypogenic speleogenesis. While brought to the epigenic realm due to uplift and denudation, the resultant caves can be modified in subsequent unconfined settings and overprinted by epigenic processes.

Hypogenic systems evolve as a result of, and further facilitate, cross-formational hydraulic communication between common aquifers or between laterally transmissive beds in heterogeneous soluble formations, across cave-forming zones. Transverse hydraulic communication across lithological and porosity system boundaries, which commonly coincides with major contrasts in water chemistry, gas composition and temperature, is potent enough to drive various disequilibrium and reaction dissolution mechanisms. There is a specific hydrogeologic mechanism inherent in hypogenic transverse speleogenesis (restricted input/output) that suppresses the positive flow-dissolution feedback and speleogenetic competition in an initial flowpath network. Any generalization of hydrogeology of karst aquifers, as well as approaches to practical issues and resource prospecting in karst regions, should take into account the different nature and characteristics of hypogenic and epigenic karst systems. Hydraulic properties of karst aquifers, evolved in response to hypogenic speleogenesis, are characteristically different from epigenic karst aquifers. Hypogenic speleogenesis...
plays an important role in conditioning related processes such as hydrothermal mineralization, diagenesis, and hydrocarbon transport and entrapment.

THE RESULTS OF KARSTOLOGICAL RESEARCHES DURING THE PLANNING AND CONSTRUCTION OF MOTORWAYS AND RAILROADS OVER THE SLOVENE KARST

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One of major projects going on in Slovenia is aimed to connect the country with modern motorways. Almost half of Slovenia is karst and more than half of water supply comes from karst aquifers. Slovenia is country of Classical karst giving the name for this special landscape on carbonate rocks to several languages and where the science of karstology systematically started to develop. A sensitive karst landscape requires to understand it well in order to preserve it and at the same time karst makes a part of our natural and cultural heritage.

For almost 15 years karstologists take part at planning and construction of motorways over karst. The integrity of karst landscape and recommendations to avoid important superficial karst phenomena (dolines, poljes, collapse dolines, karst walls) and known caves come to the front while routing the motorway and railroad.

A special attention is paid to the impact of building and later use of motorways on karst waters. This is why motorways are supposed to be impermeable. The water flowing off the road accumulates in oil collectors and after treatment it flows into karst. We have researched pollution degree of water flowing daily from motorways.

Helped by the geo-radar method we successfully proved the extreme importance of precise definition of the contact of carbonate (permeable) and non-carbonate (impermeable) rocks as there a strong hydrological activity was stated. The contact with impermeable rock is not just a water barrier but this is the area where water really stagnates and at the same time intensively oscillates and washes and transports the material. At the contact the pressures change this is why water may shape larger channels there.

We are in charge of karstological control during the motorway building. We study newly discovered karst phenomena as an important part of our natural heritage, we advise how to protect them if this is feasible due to construction works and our new knowledge gives assistance to builders. We acquired a lot of new results related to formation and development of karst surface, epikarst and aquifer cavernosity. On 60 km of motorways built in the last years over karst more than 350 caves were discovered anew which is exceptional for this part of Europe.

This contribution presents the results of several years study and the recent cognition about karst phenomena. Some, although already known karst phenomena, were neglected in past. Without doubt these are so-called unroofed caves, a relatively frequent superficial karst feature, by all means more than we thought, visible even before the karst surface is uncovered by earth works. Unroofed caves are old caves seen on the surface due to lowering and dissection of karst surface during the geological history. The velocity of sediment transport dictates expressiveness of the superficial form of an unroofed cave from the cave compared to lowering of the nearby surface. In past the karstologists explained various indentations on the surface as different dolines or effects of lithological properties of the rock and how they are crushed. One third of newly discovered caves are unroofed caves.

Sediments filled a large part of caves. Mostly these are flood fine-grained flysch deposits interbedded by layers of gravel. We sampled the sediments for palaeomagnetic research and stated that they belong to older Olduvi. This means that the caves were filled with sediment and fossilized after Messinian crisis, before 5.2 million years ago. We find out that the oldest caves on karst are much older than it was thought by the karstologists before us.

STORM RESPONSE AND WATER BALANCE OF TEMPERATE RAINFOREST KARST WATERSHEDS: TONGASS NATIONAL FOREST, ALASKA

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The Tongass National Forest in southeast Alaska contains 2,176 km² of carbonate bedrock into which karst systems have developed. As part of the evolving Tongass Land Management Plan, research into the function of karst systems is crucial in understanding how forest management activities affect the water balance of karst areas and surrounding ecosystems. Dye trace and water balance results in two watersheds on the north end of Prince of Wales Island demonstrate the difficulty in containing the effect of management. Water can enter karst groundwater systems from unknown sources at different flow regimes and rapidly move downstream. Dye traces were conducted in Windgate and Canyon Block watersheds. Two sinking streams were traced to one resurgence spring in Canyon Block, and four sinking streams were traced to one resurgence spring in Windgate. Water balance data calculated for the entire study period and individual storm events suggest that Windgate has been sufficiently delineated. Data from the study period and storm event water balance calculations for Canyon Block suggest that at high flow groundwater contributes to Canyon Block from an adjacent karst system. High resolution monitoring in each catchment shows that there is no significant delay between the increase in discharge and the arrival of direct runoff, as evidenced by the quick increase in spring flow and decrease in specific conductance. The results of these studies demonstrate that timber management and road building in these and similar karst catchments could result in an immediate transmission of sediment and contaminants through the karst system into downstream salmon habitat.

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ANTHROPOGENIC CHANGES IN DINARIC KARST, WITH SPECIAL REGARD TO HYDROLOGY AND FOREST †

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Dinaric Karst encompasses a great part of the Balkan Peninsula and is locus typicus of karst. Although Dinaric Karst is a mountainous region and sparsely populated, the man highly changed its nature. The paper refers mostly to the changes of karst hydrology, especially on karst poljes, and changes in forest cover. The Balkan Peninsula...
was a sort of a cultural bridge between Near East and Central Europe and the first changes started since the Neolithic period. The forest was affected as the first. Originally Dinaric Karst was overgrown with forests, from Mediterranean to temperate mixed (Abies-fagetum dinaricum) deciduous-coniferous one. During the long history of exploitation large parts of it changed to “macchia”, bush, rocky pastures and even bare rock surface. The 19th century is the time when these processes had the greatest effect. Now the process is continuing. Probably the first great success of man over the karst nature was the drain of the lake Copais in the karst of Beotia (Greece), started in 13th century BC. The last achievements are hydro energy systems including accumulation lakes on the poljes and the tunnels among them and leading towards the power plants. Plans for the future are still greater — the undersea aqueduct from the sizeable Dinaric karst spring Ombra to the southern Italy.

COSTAL CAVE DEVELOPMENT IN PUERTO RICO

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The goal of this study was to provide a more comprehensive and updated inventory of the coastal caves of Puerto Rico in an effort to contribute to a better understanding of cave development in this island setting. A total of 63 coastal caves were surveyed and analyzed using detailed cartography, geometric analysis, resource inventory and photo documentation. Located along the northern, western and southern coastal areas of Puerto Rico, many of these features, due to their small size and relative obscurity, had been poorly defined in the course of previous fieldwork. Prominent sea cave (littoral) development was noted in all coastal areas examined but previously undocumented examples of flank margin speleogenesis were also identified within the Quaternary eolianite and adjacent limestone exposures along the northern coast. Spatial geometric analysis of completed maps of all caves examined also revealed that the 11 flank margin caves could be graphically segregated from the 52 sea caves by comparison of cave perimeter (ranging from 12 to 333 m²) to total cave area (ranging from 10 to 2862 m²). Furthermore, simultaneous comparison of multiple geometric parameters, including maximum entrance width and internal passage width, was sufficient to delineate intact from denuded flank margin cave examples as well as identify segments within flank margin caves that had been modified by littoral erosion and/or cliff retreat. This study revealed a surprising variety and abundance of cave resources along these dynamic and complex Atlantic and Caribbean shorelines and the detailed spatial analysis of the coastal cave morphology was able to determine speleogenic origin and quantify subsequent modification of these distinctive structures. The extensive inventory generated in this study will hopefully serve as a baseline data set for future studies with the methodology applied to the determination of speleogenic origins of coastline cave resources in other carbonate island settings.

SOIL LOSS OF PHOSPHORUS AND NITROGEN UNDER DIFFERENT PRECIPITATION AT KARST AREA IN SOUTHWEST CHINA AND ITS INFLUENCE ON SPRING HYDROCHEMISTRY: A CASE STUDY AT NONGLA, MASHAN, CHINA

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For understanding soil nutrient loss characteristics under different precipitation at karst area in Southwest China, the Nongla karst dynamic system monitoring site, situated at E 108°19', N 23°29', was studied in this paper. Because of the double-layered surface and subsurface structure at karst area, rainfall rapidly penetrates into ground and forms spring or underground water. Therefore, by monitoring the hydrochemical variation of local spring, the soil nutrient loss characteristics can be known under different precipitation. In accordance with the reason, high-resolution measurements of rainfall, K⁺ and NO₃⁻ variation of Landiantang spring were recorded by using data logger with time interval of fifteen minutes from 5 to 7 August 2003 at Nongla, Mashan county, Guangxi province, China, which is scarcely disturbed by man.

From the result, it can be seen that the contents of K⁺ and NO₃⁻ in Landiantang spring rapidly increased under different precipitation and the content of K⁺ in the spring had the positive correlation with the rainfall. According to the result, it can be known that the precipitation is the main factor that leads to the soil nutrient loss at karst area. Moreover, the content of NO₃⁻ in the spring had the different rule from K⁺ and continued increase for a long time. The reason is that because of nitrogen mainly existing as NO₃⁻N in the soil at karst area, the NO₃⁻ still can be lost for a long time undergoing eluviation, even when it stops raining.

Therefore, it can be concluded from the result that precipitation not only will bring the problem of nutrient loss at karst area, which will accelerate the process of soil erosion and rock desertification, but also can produce some environmental problems, if presents cultivate at the replenishment region of spring or underground water.

HUMAN IMPACT ON HEILONTANG SPRINGS, KUNMING, CHINA

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Heilongtang Springs, 12 km north of downtown Kunming, is composed of three springs: Pearl spring, Qingshuitang and Hunshuitang. For a long time the springs have been a famous scenic site in Kunming city and a very important water source for the local drinking water supply and agricultural irrigation. Pearl spring and Qingshuitang spring are recharged by >20 km² Carboniferous-Permian karst aquifers with discharge of 82.78 l/s in the dry season and 368.5 l/s in the wet season in 1950s. With the urbanization of Kunming and environmental change in the recharge area, the quality and quantity of Heilongtang Springs has changed tremendously. Since the early 1960s, over 11,640 m³/d of water has been exploited from the aquifer for the local water supply, which has caused the springs to run dry during the dry season and have increased turbidity during the rainy season. At present, there are still 11 pumping wells located within 1 km² of the springs. Hunshuitang is recharged by a basaltic aquifer with 3.75 l/s dry season discharge, which is getting
The purpose of this study was to determine if there was a hydrological connection between the cave systems of Río Encantado and Vientos, both located in the north-central karst region of Puerto Rico. A dye tracing test was performed, as well as discharge and water quality measurements. Twenty dye traps were installed in the last 5 access points of Río Encantado. The dye, fluorescein, was released at the last explored portion in Vientos and, 68 hours later, it was visually detected emerging through the last access point of Río Encantado system, better known as Aguas Frias; the largest natural water spring in Puerto Rico. The 20 traps were recovered a week later and processed at a photochemistry laboratory at the University of Puerto Rico. Only the two traps installed in Aguas Frias resulted positive for the fluorescein dye test. There is, then, a definitive hydrological connection between both underground rivers taking place somewhere inside the 550 m of underwater passages constituting Aguas Frias. Discharge measurements were performed indicating that Río Encantado increased from 0.015 m³/s in Yuyu cave, to 0.44 m³/s in Juan Nieves cave (first and fifth accesses to Río Encantado). But in Aguas Frias, separated from Juan Nieves cave by only 500 m, the discharge increased to 0.84 m³/s; an increment of 0.40 m³/s that the dye results indicate as coming from Vientos. The magnitude of this growth suggests a considerable cavernous size and watershed for Vientos. Finally, water samples from the last 5 accesses to Río Encantado revealed the presence of human contamination; although not enough to represent danger for explorers or researchers, it shows, never the less, the worrisome human influence on the system. From Juan Nieves cave to Aguas Frias there was, however, a significant decrease in contamination; which confirms the result of the enlarged water discharge in Aguas Frias, this, because the less contaminated tributary water from Vientos dilutes the contamination. In conclusion, the results from the dye test, discharge and water quality came to show us, with certainty, the hydrological dynamics and state of the “Encantado-Vientos” compound unit; now of some 30 km of underground rivers and tributaries, the longest in Puerto Rico.

**STUDY OF THE HYDRAULICS AND WATER MOVEMENT IN RÍO ENCANTADO AND VIENTOS CAVE SYSTEMS**

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The ecological studies of karst regions should be based on the main karst ecological conditions and karstification and related deposits, then the some typical ecosystems in main karst regions in China will be classified. The qualitative evaluation of eco-geology and rocky desertification in karst regions should be based on the main karst ecological conditions and artificial impacts.

As a result of the Himalaya movement, three stepped topographical features obviously appear in China: first stepped Qinghai-Tibet plateau, second stepped Yunnan-Guihzou plateau etc. and third stepped Guangxi basin and eastern plains and deltas. The carbonate rocks, sulphate rocks and halite rocks distributed in the three stepped topographical regions and the related karst developmental features are simply introduced. In the Qinghai-Tibet plateau, there is mainly developed the corrosion-glacial karst type and corrosion-denudation karst type; the typical broden corrosion type and limited corrosion karst type are widely developed in the second stepped regions, and the third stepped regions are represented by the peak forest, peak cluster, coastal karst etc. Obviously there are mainly developed the karst underground river system and sub-surface karst river stream in south China, and the larger karst spring systems are mostly distributed in north China. The representative karst and related karst water systems in Huanglong and Jiuzaigou located in the first stepped and its sloped land are introduced, the Caohai water system belonged to the second stepped topography in south China and the Liangziguang karst water system as the representative second stepped and sloped land is discussed. The structural movement is the important factor to the karst development, and the biological-chemical processes are also applying very important roles for karst development.

**CLASSIFICATION OF ECOSYSTEMS AND THEIR ECODYROGEOLOGICAL FEATURES IN THE MAIN KARST REGIONS OF CHINA**

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The paper presents the different ecosystems in main karst regions of both southern China and northern China. There are over 3,358 well-developed karst underground river systems with total discharge of about 420×10⁶ m³ in the main karst regions of southern China in the dry season. The exploitation rates are only 8%−15%. Over 100 larger karst spring systems in main karst regions of northern China covers the catchment area from 500 km² to over 4,000 km² each, of which the average discharge appears from about 1 m³/s to 13 m³/s, and the exploitation rates are 70%−80%. The discussion should include six aspects: water environment, ecological features, materials and structures between parent rock and soil, bio-geological processes and karstification and related deposits, then the some typical ecosystems in main karst regions in China will be classified. The qualitative evaluation of eco-geology and rocky desertification in karst regions should be based on the main karst ecological conditions and artificial impacts.

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**USE OF MORPHOMETRIC ANALYSIS TO CHARACTERIZE FLANK MARGIN CAVES**

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Flank margin caves, which develop hypogenetically as a result of mixing dissolution in the distal portion of the fresh-water lens of carbonate islands and coasts, have a unique morphology. Quantitative characterization of this morphology has allowed flank margin caves to be uniquely identified based on their shape. These shape characterizations can be discriminated from stream caves formed under epigenic conditions, and from non-karst caves, such as sea caves and tafoni caves, that also appear on carbonate coasts adjacent to flank margin caves.

The key measure of a flank margin cave is cave area, or area footprint, a better indicator of cave size than linear survey length.
that characterizes most cave databases. Creation of the cave area versus cave perimeter ratio (A/P) differentiates flank margin caves from other cave types. The A/P ratio demonstrates that as flank margin caves enlarge, their perimeters become progressively more complex, as area versus perimeter plots as a straight line. Use of the cave entrance width versus maximum cave width ratio (EW/MW) can also differentiate cave types, as well as demonstrate the degree of cave removal by denudation processes. Rank order plots of flank margin cave size display abrupt changes in slope, indicating that these caves grow from initial small voids, then jump in size as voids interconnect, and subsequently jump in size again as collections of voids interconnect. This interpretation also explains how perimeter complexity, a linear measure, keeps up with cave area, a square measure, as flank margin caves enlarge.

**ORIGIN AND EVOLUTION OF ILLINOIS’ LONGEST CAVES: AN INTEGRATED APPROACH TO INTERPRETING THE GEOLOGIC AND PALEOCLIMATIC RECORDS**

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We are currently taking a holistic approach to investigate the origin and evolution of long, branchwork-type caves and their deposits in southwestern Illinois. Fogelpole Cave and Illinois Caverns are Illinois’ longest caves (24 and 10 km, respectively) and have active streams. These caves have been affected by climate change, major floods and major earthquakes; consequently, they contain abundant fluvial sediments, flowstone, speleothems and breakdown. By systematically mapping and dating these materials (speleothems growing on them in the case of breakdown), we are beginning to see correlations among groups of deposits and relationships to specific historic and prehistoric climatic and seismic events. From this information, we are developing a conceptual model of cave initiation, development and deposition of sediments and speleothems within the caves. Such a model is also providing us with a means of identifying anomalous features within the cave; i.e., those features that we did not expect to find or do not currently understand.

To date, the results we have obtained suggest that the large caves in southwestern Illinois were initiated by glacial melting between 140,000 and 170,000 years BP (sometime near the end of the Illinois Glacial Episode and the beginning of the Sangamon Interglacial Episode). Cold, chemically aggressive glacial meltwaters probably began infiltrating into vertical fractures and flowing along bedding planes within the calcite-rich St. Louis Limestone. Once these pathways were established, subsequent infiltrating rainwater and snow melt used them as pathways to migrate through bedrock and discharge down gradient to the surface via springs and forming streams. The continuous flow of water through these developing crevices and conduits result in additional dissolution of rock and down cutting of the caves that continues today (incision rates ranged from 0.032 to 0.048 cm/yr). Remnants of flowstone near the cave ceilings and stalagmites on benches record the time of exposure of these cave levels, as well as timing of wet and dry periods. Side passages filled with fine-grained sediment record a major flood or series of floods that nearly filled the caves about 42,500 years BP. This event was also recorded in stalagmites that have been sampled, one of which recorded the period of time it took for cave streams to remove the sediment from the cave. Finally, the presence of small, white stalagmites that were initiated about 90 and 190 years ago apparently recorded major earthquakes in the region that occurred in 1917 and 1811-12, the latter being generated by the New Madrid seismic zone.

**GEOLOGY AND DYNAMICS OF UNDERGROUND WATERS IN JUL DE WEST – CERNA VALLEY, BAILE HERCULANE, ROMANIA**

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**GEOLOGICAL CONTROL OF THE KARST UNDERGROUND STREAMS IN CHONGQING MUNICIPALITY, CHINA**

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The karst rock in Chongqing municipality in southwest of China comprises about 30,100 km², approximately 37% of the total area of Chongqing. The 1:200,000 hydrogeology map of Chongqing and the relevant reports show that there are approximate 378 underground rivers with a total length of about 1,110.9 km and total mean discharge of about 115.73 m³/s.

The karst groundwater in this area could be divided into the following three types: Trough valley karst water mostly exists in the karst hilly area in the west of Chongqing. Ridge-trough mountain karst water mainly lies in the anticline core of some karst mountains in the northeast of Chongqing and southeast of Chongqing where the geologic background is mainly Permian and Triassic carbonate rocks. Buried karst water is mainly located in the interbed area where the clastic rock and the carbonate rock appears alternately, which concentrates mainly in the southeast and northeast parts of Chongqing.

The major underground streams exist mostly in the southeast and northeast of Chongqing. The flow directions of these underground streams are obviously controlled by the geological structure. The dominant flow directions of underground streams in northeast of Chongqing are NW-SE, whereas that in its southeast parts are NE-SW. The flow directions of these underground rivers are parallel to the extended direction of dominant mountains, the strike of the fault belts and the distribution direction of carbonate rock.

**FLUVIAL ORIGIN OF THE CUMBERLAND RIVER KARST PLAIN, WAYNE AND PULASKI COUNTIES, KENTUCKY**

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Ancestral Cumberland River (CR) planation of Ste. Genevieve and St. Louis limestones created a 5 to 9 km-wide floodplain corridor, mantled with up to 12 m of sandy alluvium, in Pulaski and Wayne counties of southeastern Kentucky. CR entrenchment during the Pleistocene abandoned poorly drained terraces that evolved into a broad sinkhole plain after dissection by local streams and sinkholes. The width of the primary CR corridor can be partly reconstructed from 14.5 km² of dissected terrace deposits (Qt) mapped by the United States Geological Survey. These deposits
THE USE OF FLUORESCENT TRACERS TO EVALUATE
THE ROLE OF GEOLOGIC STRUCTURE AND
STRATIGRAPHY IN CONTROLLING GROUNDWATER
FLOW IN THE EDWARDS AQUIFER OF SOUTH-
CENTRAL TEXAS †

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Seven tracer tests were performed in three phases to evaluate the role that faulting and stratigraphy play in controlling groundwater movement in the Balcones Fault Zone of the Edwards Aquifer in south-central Texas, USA. The study was centered in the contributing zone and recharge zone of the Edwards Aquifer in northern Bexar County where San Antonio is located and included portions of Camp Bullis, the Stone Oak development, and Blanco Road development. Within the study area, there are at least six mapped high angle normal faults with displacements of as much as 100 m. The Edwards Limestone is approximately 150 m thick in the area and is underlain by the Glen Rose Limestone and lies beneath the Del Rio Clay. Both the Glen Rose and Del Rio are thought to be confining units. In addition, there are more than 25 wells in the area including monitoring wells, irrigation wells, and high-capacity public water supply wells.

Tracers were injected into caves and sinkholes within the study area. Three of the tracers were injected into the Glen Rose Limestone. All of the dyes were recovered in one monitoring well (28-68-608) with groundwater velocities ranging from 25 to more than 4,300 m per day. The apparent route of the tracers crossed perpendicular to numerous faults and was not detected in any of the pumping public water supply wells. The tracer tests showed that faulting in the northern Bexar County does not act as a barrier to groundwater flow as originally perceived and may actually allow groundwater to flow between various units in the Edwards Aquifer. The tracer tests also showed that the upper 39 m of the Glen Rose Limestone in northern Bexar County provides water to the Edwards Aquifer.

SOIL-LIKE SYSTEMS OF THE KOUGITANGTAU CAVES,
TURKMENISTAN: MINERALOGY, MICROBIOLOGY,
EVOLUTION

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Red-colored soil-like systems (SLS) covering cave walls and ceilings were studied in the caves of Kugitangtau Ridge, Turkmenistan. SLS is a bio-mineral body consisting of several horizons, saturated with Ca, and has very low volumetric mass (0.1-0.2 g/cm³). Usually, eluvial horizon and some illuvial horizons (white by aluminum, yellow-red by iron) are recognized. The transformation of primary minerals constitutes the imposition of ferallitic products of weathering on the sulfide oxidizing zone at carbonate background. As the result gibbsite, dispersed quartz, hematite, goethite, yarosite and gypsum are formed. Microbial component represents by thiobacillus, coryne-like and methilotrophic bacteria, microfungi. The total quantity of microbial cells in SLS is about 10⁷ per 1 gram of dry sample. Humus-like organic matter is not formed. The possible genesis of SLS can be described by the sulfate-acid and carbon-acid
weathering models operating together or separately and everyone with the big role of microorganisms (sulfur oxidizing, carbon dioxide producing, crystallization and consolidation of SLS structure).

FEATURES OF KARST SOIL MICROBES IN DIFFERENT VEGETATION SUCCESSIONS: A CASE STUDY OF THE PEAK CLUSTER DEPRESSION IN NONGLA, MASHAN, GUANGXI, CHINA †

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In karst areas, vegetation of different successions affect the soil environment. Consequently, it influences soil microbial distribution. In the Nongla peak cluster depression karst ecosystem, microbial distribution and soil physical and chemic qualities of different succession were researched by the dilution plate counting method and soil essential analysis. The result showed bacteria was the dominant genus of soil microbes. Distribution of soil microbes varies obviously in different successions and soil depths. The number of soil microbe showed as A layer > B layer > C layer; compared microbe quantity in different successions, in A layer, the order is that tree layer > shrub layer > young tree layer > shrub and grass layer > grass layer; in B layer, the order is that shrub layer > young tree layer > tree layer > shrub and grass layer > grass layer. Meanwhile, we discussed the relationship between distribution of microbe and soil physics and chemical properties.

DESCRIPTION OF THE CONDUIT FLOW PROCESS (CFP) FOR MODFLOW-2005 †

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A Conduit Flow Process (CFP) for the modular finite-difference ground-water flow model, MODFLOW-2005 is in beta testing. The CFP is designed to simulate karst aquifers by (1) coupling the traditional ground-water flow equation with formulations for a discrete network of cylindrical pipes (CFPM1), (2) inserting a high-conductivity layer that can switch from laminar to turbulent flow (CFPM2), or (3) simultaneous coupling a discrete-pipe network while inserting a high-conductivity layer that can switch from laminar to turbulent flow (CFPM3). Pipes may represent dissolution or burrowing features, and fractures, that are fully or partially saturated under laminar or turbulent flow conditions. Conduit flow layers may represent either (1) a single secondary porosity subsurface feature, such as a well-defined laterally extensive underground cave (Woodville Karst Plain, Florida) or (2) a horizontal preferential flow layer consisting of many interconnected tubes, such as a burrowed limestone with interconnected vugs of greater than 10 mm diameter (Biscayne aquifer, Florida). In this second case, the input data are effective parameters, such as a very high hydraulic conductivity, representing multiple features.

Data preparation is more complex for CFPM1 than for CFPM2. For CFPM1, pipe locations, lengths, diameters, tortuosity, internal roughness, critical Reynolds numbers, and exchange permeability are required. CFPM1 solves the pipe network equations in a matrix independent of the porous media equation matrix, which may avoid numerical instability for some problems. However, large pipe networks sometimes result in systems of equations that are slow to converge or will not converge. For both CFPM1 and CFPM2, the Reynolds number is calculated to determine if flow is laminar or turbulent. With CFPM1, the Hagen-Poiseuille equation is used when flow is laminar, and the Darcy-Weisbach equation is used when flow is turbulent. With CFPM2, turbulent flow is approximated using the product of a turbulent conductance and head difference, rather than the product of a laminar conductance and head difference as assumed by Darcy’s law.

TOWARDS MORE ROBUST DYE TRACING TECHNIQUES: BACKGROUND CORRECTION AND PARAMETER EXTRACTION

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Filter fluorometers are increasingly used to generate tracer breakthrough curves for high-end tracing. However, background fluorescence constitutes the primary problem as it can both mask and simulate a tracer breakthrough curve and may prevent useful parameter extraction from the trace. These resulting limits in the utility and exclusivity of dye traces may compromise impact assessment and litigation. Despite these problems, there has been little progress in understanding and handling fluorescence background.

A number of background correction techniques have been tested for filter fluorometers. Standard subtraction of the premonitoring average can lead to errors. Extrapolation of premonitoring trend is better, but interpolation is more successful, providing post breakthrough background can be obtained. Serial monitoring (upstream of injection point) may identify major background fluctuations where the traced route is fairly uniform. Co-monitoring for background as well as tracer has proven the most successful strategy.

Tracer breakthrough curves not only provide compelling documentation of tracer receipt, but also permit extraction of parameters that characterize the tracer route. Travel time is widely used, but dispersion and retardation and multiple route parameters are also valuable in characterizing contaminant transport. Analytical fits are widely used, but may misrepresent typical varied systems. Statistical fits make fewer assumptions, but may be too sensitive to data quality. Simple analogues such as time to peak have been widely used as this measure is most robust. Attempts to extend the analogue approach to dispersion and retardation shows considerable promise.

OSTRACODES, ISOTOPES AND FLOW PATHS IN THE KARST LANDSCAPE OF WEST VIRGINIA

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In a study of 10 springs in the karst landscape of eastern West Virginia extending over Berkeley, Jefferson, and Morgan counties, ostracode species richness is found to increase with groundwater discharge rate (0.0025 to 0.41 m/s) and each spring has an assemblage distinct from every other. Deep aquifer species
also known from Europe are present in those springs with the greatest flow rates, including *Nannocandona faba* Ekman, 1914 and *Schelldendonia tranqueta* (Klie, 1936), with the latter being identified as a first documented occurrence in North America.

Hydrochemistry and isotopic composition are virtually identical, with water temperature in a narrow range of 12-14°C, specific conductance values between 321 and 686 uS (at 25°C) and alkalinity values ranging from 103-235 mg/l CaCO₃. An exception is the well-known Berkeley Springs, with a temperature of 23°C, and alkalinity value of 84 mg/l CaCO₃. The wide variety of species found in these ten springs is not apparently linked to the hydrochemistry or temperature values, but rather indicates long established local and separate groundwater catchments and flow paths. The isotopic signatures of the 10 springs fall on the Maryland LMWL (Kendall and Coplan, 2001), suggesting short flow paths and short residence times. Berkeley Springs and nearby Cacapon Spring (Berkeley County) show slightly more negative values in δ¹⁸O and δD (-9 per mil δ¹⁸O VSMOW and -57 per mil δD VSMOW, respectively) than the other 8 springs, which range from -8.1 to -8.4 per mil δ¹⁸O VSMOW and -50 to -53 per mil δD VSMOW.

RECONNAISSANCE SURVEY OF THE HYDROLOGIC DISTRIBUTION OF TRACE ELEMENTS IN A CATCHMENT WHERE POULTRY LITTER IS USED AS FERTILIZER, NORTHWEST ARKANSAS

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Arkansas leads the nation in poultry production with the major production in northwest Arkansas. Poultry feed contains select heavy metals and semi-metals, such as As and Se, in trace quantities as food additives. Because litter from the poultry houses is applied to pastureland as fertilizer, there is concern that these elements are contaminating groundwater and surface water. A reconnaissance survey of the distribution of these trace elements was conducted in a portion of the Savoy Experimental Watershed (SEW), northwest Arkansas. This watershed is part of a shallow mantled karst system that makes groundwater susceptible to contamination from surface sources. The SEW had poultry litter applied two of the last three years prior to this study. Three runoff, five lysimeter, four seeps, and two springs samples were collected. Ranges of concentrations were <0.001 to 0.03 mg/l for As, Cd, Co, Cr, Mo and Ti; <0.001 to 0.12 mg/l for Fe, Mn, Mo, Ni, Pb and Se; and 0.001 to 0.5 mg/l for Cu and Zn. Two selenium concentrations exceeded USEPA drinking water limits, Cu and Pb exceeded action limits, and Fe and Mn exceeded secondary MCLs. Although the lysimeter samples had a large range in concentrations, invariably the highest concentrations of all elements were from the lysimeter samples. This situation is mostly likely the result of anoxic conditions at shallow depths, which is supported by redoximorphic soil features in the area. Oxidation-reduction conditions control Fe solubility, and thus the solubility of other trace elements that are sorbed by oxyhydroxide Fe minerals.

HOW USEFUL ARE TUFAS AS ARCHIVES OF HYDROCLIMATIC HISTORY WITHIN ARID ENVIRONMENTS?: AN EXAMPLE FROM THE NAULUFT MOUNTAINS, NAMIBIA

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Within dryland environments environmental archives which record wet phases are often rare. However, in karst systems both cave deposits and tufas can provide potentially useful archives. The Naukluft Mountains in central Namibia are drained by streams forming part of the Tsondab system which drains the great escarpment and currently terminates in a vlei in the Namib sandsea. A number of very large (often < 100 m high) tufa deposits have formed within these stream systems. There is only minor tufa deposition under present conditions, with largely ephemeral streams. The tufa deposits indicate very different hydroclimatic regimes in the past, which may throw light on long-term debates over the history of aridity within the Namib Desert and its margins. We report here on preliminary investigations of the distribution, nature and facies found within the Naukluft tufas as well as initial U-series dating. The tufas are dominated by a limited range of fabrics, with moss-dominated styles particularly common. The depositional sequences reveal cycles of initiation and growth of tufas, followed by incision and the deposition of large boulders. The complexity of tufa depositional histories, and the potential for subsequent post-depositional diagenetic alteration, means that samples for dating must be very carefully selected and inferences drawn from them with great caution. However, suitable hydroclimatic conditions must have been present for very long periods over the late Quaternary for such extensive deposits to develop.

TRANSPORT PROPERTIES OF SOLUTE, PARTICLE AND ¹⁵N-LABELED MICROBIAL TRACERS UNDER VARIOUS FLOW CONDITIONS IN A KARST GROUNDWATER BASIN, INNER BLUEGRASS REGION, KENTUCKY

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From June 2006 to April 2007 a series of three groundwater traces, conducted under various flow conditions to determine transport properties of solutes, particles and microorganisms, have transpired at a karst system in the Inner Bluegrass Region of Kentucky. The area of focus is the karst conduit network between a swallet in Big Spring Park and Blue Hole Spring, ~ 500 m away. Blue Hole Spring is the headwaters of Glens Creek and drains the urban areas of the city of Versailles (~8,000 population) and outlying farmland.

On 2 June 2006, a trace was conducted under low-flow conditions using the solutes rhodamine WT (RWT) and sodium bromide (NaBr). Discharge for the trace averaged 0.079 m³/s; RWT and Br arrived at the spring ~ 6.16 hours and ~ 6.5 hours post-injection, respectively. Calculated mass recoveries were 79.15% for RWT and 84.19% for Br. A second trace consisting of solutes and particles (fluorescent labeled 1-µm diameter latex microspheres) transpired on 11 July 2006, under summer storm-flow conditions with an average discharge of 0.165 m³/s (maximum 0.262 m³/s). Breakthrough began ~ 2.33 hours post-injection for the solutes and ~ 2.5 hours for the microspheres. Another storm-flow trace occurred on 1 April 2007, consisting of solutes, microspheres and an isotopically-labeled wild strain of *E. coli* (¹⁵N-enriched) originally isolated from the research site. Results of the third trace are pending. These traces demonstrate accelerated solute movement under storm-
flow conditions in this karst basin, and show particle mobilization within the system.

SEDIMENT TRANSPORT IN KARST AQUIFERS: THE HIGH END OF THE SIZE SCALE

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Karst aquifers carry a clastic sediment load with a particle size distribution determined by the available sediment in the source region and by the hydraulics of the conduit system. Karst springs usually discharge some fine-grained sediment even during base flow with increased sediment load discharging during storms. Stream beds in caves or banks of sediment exposed in caves tell a different story. If such are available in the recharge area, clastic sediments with particles sizes ranging from pebbles to boulders are often observed. Often this material is well-winnowed producing a cobble armoring for the cave stream. Such sediments are rarely seen discharging from karst springs. Thus, the question: what flows are needed to transport cobble and larger sediments and are such conditions consistent with the known conduit hydraulics and current local climate?

Few data are available on particle size distributions that include cobble and boulder size classes. Qualitative examination of a set of Appalachian caves reveals sizes up to 30 cm in locations that could only have been reached by lateral transport. Flood flows in high gradient surface channels are observed to transport cobbles in the same size range as clastic sediments in caves. However, calculations show that needed boundary shears are relatively rare in open channels. Flood flows in caves, because of limited conduit cross-section shift from open channel flow to pipe flow and instead of a driving force generated by a fixed channel slope, the system can build up substantial hydraulic head. The needed velocities and thus boundary shear to move cobbles and boulders may be provided by temporary high hydraulic heads.

There is a single observation of cobble transport through Mystic Cave, West Virginia, by the effects of the 1985 Potomac River Flood. In other Appalachian caves such as Butler Cave in Virginia and Carpenteri’s Pit in West Virginia deep canyons have been cut through massive cobble fills. Given the low probability of storms of sufficient intensity to move massive cobble and boulder fills, there is the possibility that these deposits represent climatic conditions that no longer occur in the drainage basins.

CLIMATE-DRIVEN ECOLOGICAL CHANGE IN A HIGHLAND RIM KARST SWAMP: SINKING POND, COFFEE COUNTY, TENNESSEE

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Increased precipitation since 1970 has suppressed regeneration of overcup oak (Quercus lyrata Walt.) in Sinking Pond, a 35-hectare seasonally-flooded compound sinkhole near Manchester, Tennessee. A hydrologic accounting model, based on rainfall and temperature records covering the period January 1854 through September 2005, shows increases in ponding duration and frequency throughout Sinking Pond after 1970. This increase in ponding frequency and duration coincides with the local suppression of tree regeneration and corresponds to increases in regional streamflow and precipitation throughout the eastern United States. In a representative 2.3-hectare area of Sinking Pond, overcup oak saplings and young adults were found only in shallow (ponding depth less than 0.5 m) sites, even though overcup oak seedlings and mature trees were concentrated in deep (ponding depth greater than 1 m) sites. Analysis of tree rings from a 10% sample of mature overcup oaks in the same 2.3-hectare area shows an even distribution of tree ages across ponding-depth classes from the 1850s through 1970, abruptly followed by complete suppression of recruitment in deep and intermediate (ponding depth between 0.5 m and 1 m) areas after 1970. Trees younger than 30 years were concentrated in a small area with shallow ponding depth. The mechanism of tree suppression is seedling mortality caused by prolonged inundation during at least 2 of the first 5 years after germination.

SIMULATION OF HYDROLOGICAL RESPONSE OF KARST SPRING TO PRECIPITATION: A CASE STUDY OF SHUIFANG SPRING, JINFO MT., CHONGQING, CHINA

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This paper tried to simulate the process of hydrological response to precipitation of a typical karst spring, Shuifang spring, with SWMM (Storm Water Management Model) developed by EPA (Environmental Protection Agency).

Abstraction of the model was developed based on field survey, including geology and geomorphology, hydrology, coverage of soil and vegetation, main directions of surface and undergroundflowpaths, cave systems, depressions and swallow holes. The catchment area and connection between swallow holes and the spring were ascertained after two dye tracing tests, each with two injection points for each one with yellow-green tracer Fluorescein and purple-red Sulforhodamine B. Analysis of dye tracing results confirmed conduit flow between one of the sinkholes in the recharge area and the outlet of the drainage system – Shuifang spring. The spring catchment was divided into 7 sub-catchments with sinkholes as junctions to drainage surface water into underground, which were connected by conduits among them. Main parameters such as area, width, slope, permeable proportion, roughness of the sub-catchments, elevations of junctions, lengths, width, cross-section and roughness of conduits, porosity of aquifer, and coefficient of laminar groundwater flows into conduits through junctions and so on, are obtained under the observation, tests and analysis in ArcGIS.

SWMM gave a good report of simulated flow rate of the spring, compared with the observed data, with errors of 9.5% and 12% for calibration and validation, respectively. Results show that SWMM is applicable in simulating a karst aquifer with conduit flow system. In addition, the empirical SCS-CN (Curve Number) model was first used to evaluate infiltration and runoff in the model in domestic karst area. Infiltration tests were also done in the study area. It showed that infiltration rates are higher than that of a non-karst area. But SCS is not so sensitive to infiltration rates after it exceeds a threshold value. It gives a calculated runoff exceeding the observed, which brings a problem to develop an infiltration model exclusively suitable for karst areas in the future.
PHYSICAL-CHEMICAL CHARACTERIZATION OF KARST WATERS INVOLVED IN THE VADOSE ZONE OF DIAMOND CAVERNS, KENTUCKY

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A preliminary investigation of dripwater chemistry has been initiated at Diamond Caverns, a private show cave near Mammoth Cave National Park, Kentucky, in conjunction with the Environmental Research Training Laboratories (ERTL) at the University of Kentucky, and the Hoffman Environmental Research Institute at the Department of Geography and Geology, Western Kentucky University. The research is part of a larger effort focused on evaluating the environmental conditions in certain, specifically tourist, caves in Kentucky, Granada, and Spain, with the immediate application to devising sustainable management strategies. This phase of the research involves a hydro-geochemical study of the H2O–CO2–Ca–Mg system in the vadose zone of Diamond Caverns. It is hoped that these specific data and the resulting karst water model will contribute to the effective study and management of parameters influencing the microclimatic and geochemical aspects of Diamond Caverns. Data from this project will be incorporated into the larger data set from other caves in order to characterize the physical and chemical characteristics of the vadose zone of these show caves, and add to the regional understanding of vadose zone geochemistry.

The main objectives of this research project in Diamond Caverns are: (1) Physical-chemical characterization of karst waters, and analysis in time and space of parameters such as pH, temperature, CO2 content, and electrical conductivity; (2) Preliminary evaluation of the relationship between the external atmosphere and soil cover, composition of dripwaters, and the processes of precipitation and dissolution of carbonate minerals and transfer of CO2. This characterization of the geochemistry of the cave waters will be accomplished through analysis by OES-ICP of dripwater collected from sample sites located throughout Diamond Caverns. Sites were identified by the research team, and samples will be collected approximately every third week for a period of more than 9 months to observe seasonal variations. Sites were chosen to include a wide range of rates of drip, and a variety of types of locations.

Dripwater samples from five sampling sessions were titrated for bicarbonate and alkalinity, and analyzed by ICP-OES at the ERTL facility. Soil chemistry and geochemical characteristics of agricultural and transportation contamination are poorly known in this region, making the capacity of the ICP-OES to analyze a wide range of elements especially attractive. Elements analyzed during this initial session include: Ca, Mg, K, Na, Ba, Sr, Mn, Fe, Ni, Co, Cu, Si, Al, and Zn. Elemental ratios (e.g. Mg/Ca, Sr/Ca, Sr/Ba, etc.) will be used in conjunction with drip rates and the other chemical parameters to examine infiltration events and various phenomena of speleothem growth. The data from this portion of the study will contribute to a preliminary evaluation of the degree of influence of the external atmosphere and soil cover on drip water chemistry. The next step will be to evaluate these influences by means of the stable isotopic characterization of select speleothems.

URBAN HYDROGEOLOGY IN KARST REGIONS OF CHINA

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Urbanization has been developing rapidly along with the blooming of the economy in China. In 1980s, the number of medium size cities increased from 180 to about 400, but in 2000, it was already 666, with 32 of them having population more than a million. The course will speed up in the next decades, because the government takes urbanization as one of the strategic measures for economic development, and to reduce the difference between developed and poor regions.

China enjoys a broad expanse of karst, totalling 3,463,000 km2, i.e. about one-third of its territory. Accordingly, many cities are underlain by karstic aquifers, including some important cities, such as Jinan, the capital city of Shandong province; Taiyuan, the capital city of Shanxi province; Kunming, the capital city of Yunnan province; and Guiyang, the capital city of Guizhou province. In addition to political, cultural and economic centers, the functions of the cities in the karst regions of China are various. Some cities are local industrial centers, such as Zunyi city in the north of Guizhou province, and Liuzhou city in the central part of Guangxi province. Most of the medium and small size cities are based on
local agriculture. Some of them enjoy special products, such as sugar cane (Guigang, Guangxi), tobacco (Mengzi, Yunnan), chili peppers (Qiubei, Yunnan), grapes and wine (Mile, Yunnan), and Panax pseudo-ginseng var. notoginseng, a species of medicinal herb (Wenshan, Yunnan). Many cities are related to the development of mineral deposits, such as cassiterite (Gejiu, Yunnan; Dachang, Guanxi), lead and zinc (Siding, Guanxi), bauxite (Pingguo, Guanxi), and coal industry, such as Jiaozuo, Henan province, and Zibo, Shandong province. On the other hand, a number of cities in the karst region are related on tourism, which enjoy particular karst features, such as Stone Forest (Lunan, Yunnan), tower karst, a type of tropical karst (Gulin, Guangxi), karst springs (Jinan, Shandong).

The exploitation of natural resources (water, land, mineral deposits, coal, and touristic attractions) benefits the urbanization of karst regions. But hydrogeological and environmental problems, even geological hazards may occur when there is an ignorance of scientific management, which need a good understanding on the karst hydrological system.

In coastal area, such as Dalian city, Liaoning province in northeast China, the extraction of groundwater from the Lower Paleozoic karst aquifers brought about sea water intrusion. In the lowland of eastern China, problems following overpumping from karst aquifers include drying up of karst springs, and karst collapses. For example, the Baotu spring and more than 70 other karst springs which used to flow out around downtown Jinan city, Shandong province with a total discharge of 300,000-350,000 m³ per day stopped flowing in 1970s when the extraction from the Ordovician karst aquifer underlying the city was more than 270,000 m³ per day, and brought problems to tourism. A karst collapse 9 m in diameter, and 5 m in visible depth happened in the railway station of Tai’an city, Shandong province, January 1979, right under the major railway between Beijing and Shanghai.

For cities in the plateau karst of Shanxi province in north China, and Yunnan-Guizhou provinces in southwest China, the most serious problem is the shortage of water, even with a general annual mean precipitation more than 1000 mm. The Cenozoic uplift and the development of underground drainage system made dry valley, and doline or polje the main karst landform of the region. The underground system drains away most of the rainfall and surface water. In the karst of southwest China, land and cities are usually distributed on denudation surfaces of different altitudes, which are dozens to hundreds meters higher above the local rivers and underground streams. Finding enough water sources to support the development of cities on the karst plateau is always a challenge. On the other hand, these cities are also frequented by flood and pollution problems. Cities in polje are often inundated when the relevant underground streams are not able to drain away excess water after a heavy storm. For example, Gejiu city in southeast Yunnan province, which provided most of the tin resources in China in 1950s, is located in a polje 1600 m asl. It was flooded in the rainy season of 1954, when water from the underground stream fed back through the swallow hole which used to drain surface water. Part of the polje has become a lake since the event. The Shuicheng city in western Guizhou province is also in a polje 1800 m asl. It has developed on the bases of coal mining and steel manufactory. The industrial solid and liquid wastes have not only brought pollution problems to the polje, but also polluted the underground hydrological systems downstream.

For a sustainable development of cities in the karst regions of China, it is recommended: (1) to get a better understandings on the karst hydrological systems, and their difference in different parts of China (coastal, lowland, and plateau); (2) to take into account protecting scenic attractions, and ground stability while exploiting karst water resources; (3) to address properly the relationship between the land use planning and management and the protection of karst aquifers; (4) to carry out vulnerability assessment and mapping for karst aquifers.

THE IMPACT OF LANDUSE COVERS UPON KARST PROCESSES: AN EXAMPLE FROM NONGLA FENGCONG DEPRESSION AREA, GUANGXI, CHINA

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Previous studies of karst processes focused on karstification intensity and its variation under different geological settings, climatic and hydrologic conditions in view of macroscale, or on the contribution of carbonate rock weathering to the atmospheric CO₂ sink. Lesser attention was paid to the impact of landuse cover on karst processes.

The direction and intensity of karst processes could be deeply affected by soil physical and chemical variations which result from landuse cover. Taking Nongla fengcong depression area, Mashan county, Guangxi as an example, the authors discuss the impact of landuse cover on karst processes based on the data of field standard limestone tablet. Almost all of landuse covers occurred in a small study area, so the present study is also typical and representative.

The results showed that the corrosional ratio at varied soil depth is quite different. The corrosional ratio in woodland and orchard is mostly greater than 20 mg/a, which is much higher than that in cultivated land and shrub land. Generally, the corrosional ratio decreased from orchard, woodland, tilled land, fallow land and shrub land successively, in which soil organism and soil pH are two major controlling factors: the corrosion process is controlled remarkably by soil organism in woodland and orchard, the higher the organism content is and the lower the pH is, the higher the corrosional ratio is. Owing to lower organism content, the corrosional ratio is affected mainly by soil CO₂ in tilled land and shrub land.

The impacts of landuse cover on karst processes could be active to improve corrosional rate, such as organic fertilization in orchard resulting in soil organic matter increase; or negative to retard the corrosional rate, such as surface disturbance in tilled land resulting in increased soil porosity and CO₂ emission. Moreover, organism activities and their offspring could be the most active factor, vegetation succession can improve the three-phase condition of the karst dynamic system, thus accelerating the karst processes. Accordingly, these results have significance for the protection of fragile karst soil resources and the readjustment of landuse structures in fengcong mountainous areas.

RAINFALL-RUNOFF SIMULATION OF TYPICAL KARST FENGCONG DEPRESSION SYSTEM USING SWMM MODEL: A CASE STUDY FROM GUILIN YAJI EXPERIMENTAL SITE, GUANGXI, CHINA

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This paper presented a test study on how well the US
Environmental Protection Agency’s (EPA) Storm Water Management Model (SWMM) can simulate the flow transport in a conduit-dominated karst water system in the Guilin Yaji experimental site, Guangxi, China. The SWMM model is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity. In this study, the site was divided into six sub-catchments that correspond to the depressions in the catchment and the subsurface was simulated by using a dual, i.e., pore/fissure and conduit, media. The result showed that simulated outflow (curve) and measured discharge (Spring 31) of the catchment have similar variation, relative error of total outflow in the modeling duration is 19.1%. It proved that the SWMM model can be used to simulate surface subsurface transport of flow in karst water systems in the southwest China.

**IMPLEMENTATION OF THE TRACING TECHNIQUE IN GEOTHERMAL INJECTION STUDY**

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To study the motion patterns and spatial distribution of injection fluid in fracture karst reservoir, the injection tests of two different tracers are done in four geothermal wells in the longest exploration history and the larger exploitation Wanglanzhuang geothermal field and Shanlingzi geothermal field. The well HX-25B of Wanglanzhuang geothermal field is the only injection well for the twice tracer injection tests. The paper compares the results of two trace test with the pumping test result of traditional hydro-geological methods. The contrast result farther proves up the connected channels and seepage field characteristics among the geothermal wells.

The HX-25B trace test field consists of one injection well (HX-25B) and five exploitation wells (HX-25, HX-26, HX-14, HX-09, HX-13). The pumping test result of drilling well shows that the hydraulic conductivity (K) of injection well HX-25B is 14.62 m/d and have faint hydraulic contact with observation well HX-14. The injection rate is 100 m³/h and the temperature of injection water is about 50°C when the injection systems are circulated.

The first trace injection test was done during the heating seasons from 1998 to 1999. The chemical tracer is selected KI because of the security, no pollution and no influencing utilization for reservoirs. The injection dose is 20 kg, the period of test is 80 d, the regulation of collecting sample is 1/24 h in observation wells, the volume of collecting sample is 5 l heating water. The concentration of tracer KI is generally inspected in the laboratory and 300 groups of data are received. The results of tracing inspection test show no obvious trace response apex value. But the [I⁻] concentration of HX-14 well is 0.12–0.21 mg/l, the [I⁻] concentration change range of HX-14 well is higher than other observation wells, the [I⁻] concentration of HX-14 well is higher than original concentration (0.12 mg/l), all of this show faint hydraulic contact characteristics between HX-25B well and HX-14 well and make similar conclusion with pumping test.

The second trace test was done during the heating season from 2001 to 2002. The tracer is selected 35S(T₁/2=87 d) in order not to influence heating and living geothermal water use because of short half life, no poison for person and environment. The injection dose is 250 mCi (about 1.3 x 10¹⁰ Bq), the inspecting sensitivity is about 0.5 Bq, the period of test is 80 d, the regulation of collecting sample is 1/12 h in observation wells, the volume of collecting sample is 5 l heating water and 1 l steady dose. The samples are inspected by isotope technique application laboratory of the Atomic Energy Institute, the 340 groups of data are received. The results of inspecting data show that the trace composition of isotope 35S is the first inspected in the HX-14 well after the tracer is injected 53 d, the composition of isotope 35S reach apex value (1.229 Bq/l), the composition of isotope 35S disappears after 170 d, all of this show an obvious and whole response curve, the other observation wells have no inspected tracer. The isotope trace test makes the same conclusion with chemical trace test and pumping test shows that the HX-25B well and HX-14 well have hydraulic contact. But the maximum concentration of inspected tracer is less than the billionth of total injection quantity shows that the injection fluids in pore the huge reservoir space and only the thimbleful tracers reach the circumference of HX-14 well and are inspected. The analysis results show that the low temperature fluids of HX-25B injection don’t lead to lower the fluids temperature of exploitation well during a whole heating season (135 d in Tianjin area). In fact, the dynamic observation data show that the pumping temperature of HX-14 well keeps basic steady during the many years and has no declining phenomena. At the same time, the motion velocity of injection fluids is about 14.92 m/d from the HX-25B well to HX-14 well the distance of the two geothermal wells is 1939 m, according that the appearing time of isotope 35S apex value is 130 d. The velocity does not consider the quality of reservoir, the physical quality of fluids and other factors is the generalized velocity of injection fluids from the bottom of injection well to the bottom of exploitation well. The velocity of value is bigger than the actual seepage velocity. The hydraulic connectivity of HX-25B well is 14.62 m/d, K is seepage velocity when hydraulic gradient is 1. The generalized velocity of injection fluids by injected radioactive isotope tracer has similar value with the hydraulic connectivity of reservoir.

In summary, the results of trace test were in accordance with the traditional hydro-geological methods, e.g. pumping test. The test result of radioactive isotope tracer injection not only can judge the seepage field characteristics and the hydraulic interaction but also has the intuitionistic, obvious and quantitative advantages.

**A STATISTICAL STRATEGY FOR DETERMINING CONTAMINANT IMPACTS OF LANDFILLS ON SPRINGS IN KARST TERRANE**

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Collection of representative data in karst aquifers often requires monitoring at appropriately-located springs. Following dye tracing and geophysical investigations, one spring was selected as monitoring location for a landfill facility in southern Indiana. Nine rounds of sampling were conducted under different flow conditions. Sequential discrete water samples were collected across the hydrograph curve for each storm-pulse sampling event. The sampling frequency varied according to the flow conditions and the spring responses to the recharge events. Such sampling approaches characterized the natural variations of the water quality at the spring but complicated the development of an effective statistical evaluation plan for the landfill. A suite of water quality control charts were developed for parameters that are subject to statistical analyses to statistically determine the possible impact of the landfill on the karst system. The statistical power of the control charts was evaluated by Monte Carlo simulations.
Author Index

A
ADAMS, Ryan 12, 25
AMELICHEV, G.N. 14

B
BAICHTAL, James F. 10, 20
BAKER, Priscilla 12, 17
BANKS, Eric D. 14
BARTON, Hazel A. 14
BECK, Barry F. 12, 30
BLAIR, Robert J. 11, 23
BOSTON, P.J. 9, 14
BRICELJ, M. 12, 15
BRION, Gail M. 12, 26
BRUNNER, Chelsea 11, 28

C
CAMPBELL, Warren 10, 15
CAO Jianhua 9, 12, 15, 18, 29
CENCUR CURK, B. 10, 12, 15
COYNE, Mark 12, 26
CUI Zengdi 9, 22
CUNNINGHAM, Kevin 10, 16
CURRY, B.B. 9, 23
CURRY, M.D. 9, 14

D
DETTMAN, David 11, 25
DE ROOIJ, Rob 10, 16
DONOVAN, Joseph 11, 25
DUBLYANSKY, V.N. 14

F
FILIPPONI, M. 9, 16
FLOREA, Lee 10, 16
FRYAR, Alan E. 12, 26

G
GARRETT, Ryan G. 10, 17
GROVES, Chris 10, 12, 17, 20

H
HACKLEY, K.C. 9, 23
HAM, Brian 11, 17
HENDRICKSON, Melissa 9, 12, 18, 25
HERMAN, Ellen K. 10, 27
HE Qifuang 9, 23
HE Shuiyi 10, 18
HWANG, Hyuntae 11, 19
JEANNIN, P.Y. 9, 16

K
KAMBESESI, Patricia N. 11, 12, 17, 21
KENWORTHY, Stephen 10, 20
KIM, Yongcheol 11, 19
KLIMCHOUK, A.B. 19
KNEZ, Martin 11, 20
KOLLARITS, S. 10, 15
KOVARIK, Johanna 10, 20
KRAMER, Samantha 11
KRANJC, Andrej 20
KUNJANSKY, Eve L. 25
KUSCHNIG, G. 10, 15

L
LACE, Michael J. 11, 21
LIAN Yanqion 29
LIU Hong 12, 21
LIU Qi 9, 22
LI Linli 12, 27
LI Qiang 21
LUNDSTROM, C. 9, 23
LUO Jianyun 11, 17
LU Yaoru 9, 22

M
MAGAGNA, B. 10, 15
MEIER, Albert 10, 20
MELIM, L.A. 9, 14
MONOHAN, Heather 11, 28
MORALES, José 12, 22
MYLROIE, Joan R. 9, 22
MYLROIE, John E. 9, 11, 21, 22

N
NAMJESNIK-DEJANOVICE, Ksenija 11, 25
NORTHUP, D.E. 9, 14

O
OWEN, Athena M. 9, 22

P
PALMER, Donald F. 11, 25
PANNO, S.V. 9, 23
PAN Yuntang 12, 28
PARK, Kihwa 11, 19
PARRAUX, A. 9, 16
PEI Jianguo 12, 29
PERROCHET, Pierre 10, 16
PETITIT, Arthur J. 12, 30
PONTA, Gheorghe 12, 23
PRUSSIAN, Katherine 10, 20
PU Junbing 9, 23
RAY, Joseph A. 11, 23
ROSALAS-LAGARDE, L. 9, 14
ROTH, Monica J. 9, 22
ROUAI, Mohamed 11, 24
RUAN Chuanxia 12, 30
SCHINDEL, Geary 24
SCHNITZ, Lew 24
SEMIKOLENNYKH, A. 11, 24
SHEN, Linda 25
SHOEMAKER, W. Barclay 25
SLABE, Tadej 11, 20
SMART, Chris 12, 25
SMITH, Alison J. 11, 25
SPILDE, M.N. 9, 14
STAFFORD, Kevin W. 9, 22
STEELE, Ken 11, 26
STONE, Abi 21
SUN Hailong 21

T
THOMAS, David 26
TORAN, Laura 10, 27

V
VAKHRUSHEV, B.A. 14
VESPER, Dorothy 11, 25
VIDMAR, S. 10, 15
VILES, Heather 26
WANG, H. 9, 23
WANG, Jie 12, 30
WARD, James W. 12, 26
WATERSTRAT, Willapa J. 9, 22
WHITE, William B. 10, 27
WOLF, William J. 9, 27
WULFF, Andrew H. 11, 28
WU Yuexia 12, 27

Y
YANG Liankang 12, 28
YANG Pingheng 11, 12, 17, 27
YANG Y. 12, 28
YUAN Daxian 9, 10, 11, 12, 15, 17, 18, 23, 27, 28, 29
YUM, Byungwoo 11, 19
Z

ZENG Feiyue 10, 18
ZENG Meixiang 12, 30
ZHANG, Z. 9, 23
ZHANG Cheng 9, 12, 15, 29
ZHANG Yuebo 12, 30
ZHOU, Wanfang 12, 30
ZHOU Jingzhong 10, 18
Index

1  Mass Media & Technology Hall
2  Tate Page Hall
3  Ivan Wilson Center for Fine Arts
4  Environmental Sciences & Technology Building
5  Garrett Conference Center
6  The Kentucky Museum
7  Parking Structure