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Online Publication of Conference Abstracts

2007 International Conference on Karst Hydrogeology and
Ecosystems

Bowling Green, Kentucky, USA

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A Note on the Spatio temporal Variations in the temperature and relative humidity over Akure, Ondo State, Nigeria

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This study was carried out in one of the Administrative State Capitals in the southwestern part of Nigeria. Its aim is to serve as a baseline data for highlighting the effect of spatial distribution of settlements, population, and socio-economic activities on urban air temperature and relative humidity. The main objective of the study is to assess the impact of urban growth on the microclimate of the administrative city. Temperature and relative humidity data from 1992 to 2001 were obtained from the three existing meteorological stations in Akure, the Administrative Capital of Ondo State, Nigeria, namely the Federal Ministry of Aviation, Akure Airport station (FMA), Federal University of Technology, Akure (FUTA) and the Federal School of Agriculture (SOA). Air temperature and relative humidity measurements along primary roads and in the built up areas were obtained

from seventeen stations, using sling psychrometer. The data were subsequently analysed for spatial and temporal variations. The results obtained indicated that while the maximum, average and minimum temperatures showed significant annual variations, the spatial variations among the existing meteorological stations were not significant. The city is characterized by increasing annual mean temperatures whose maximum was significantly higher than that of Ondo town - another important town within the state. The annual mean temperatures ranged between 26.20C and 30.40C. Minimum and maximum temperatures varied from 12.30C to 26.0C and 22.50C to 39.60C, respectively while the relative humidity ranged between 27.5% and 98.2%. Urban 'heat island' intensity was exhibited around central business district of the Oba market.

Origin and development of the dam-valley lakes and karst hydrogeologic systems, with reference to the Amtkeli River (Western Caucasus)

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Dammed lakes in river valleys of mountain karst regions can be formed due to rockslides. Ancient relict cave hydrogeological systems, which had already been devoid of flow, can renew their functioning as a result. Interest to 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 river. Relict caves located on the slopes of 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. Their results are presented in the paper. The large karst hydrogeologic system has been revealed, which 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 groundwaters 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 Verses Inorganic Processes in the Precipitation of Calcite.

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In order to investigate whether active metabolic microbial process dominates over passive geochemistry in the formation of calcite polymorphs, we are examining calcium carbonate (CaCO_3) precipitation and dissolution by bacterial species from hypogean cave environments. Microbial species were isolated from CaCO_3 'popcorn' deposits within Grayson-Gunnar Cave, Kentucky based on their ability to deposit CaCO_3 crystals on Boquet B4 media or to dissolve calcite in a CaCO_3 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 CaCO_3 , including calcite and aragonite. By correlating the structure of the CaCO_3 crystals with environmental growth conditions of individual species using powder x-ray diffraction (XRD), we hope to correlate microbial metabolic activities with CaCO_3 precipitation. By studying the conditions that similarly allow dissolution of CaCO_3 , we hope to better understand the role that CaCO_3 plays on microbial growth, Ca^{2+} detoxification and metabolic adaptation to CaCO_3 rich environments.

Structural controls on the hydrogeology of semi-karstic dam foundations in the southwest of Iran

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The hydrogeological study of some dam foundations and their karstification in the eastern part of Khuzestan Province, south west of Iran shows that they are fairly related to the basement structures. Although the area, named Seydoon, is located in the Zagros Simply Folded Belt, the geological structure is complicated and different basement trends caused clear deflections and displacements in the axes of the existing anticlines together with a few number of fracture systems. High variations in the thickness of the overburden, occurrence of Artesian wells, and nearly straight river courses are all coincident with the observed or inferred lineaments and basement trends. The morphology of the river courses confirms it, as well. The complexity of the local structures is increased by occurrence of plastic Miocene Gachsaran Formation. The other formations in the valley, named Chavil, are very karstifiable Asmari Limestones of Oligo-Miocene and naturally impervious Pabdeh Marlstones of Eocene. However, the marls and marly limestones of Pabdeh are almost permeable and semi-karstic according to the geotechnical investigations. Due to unsuitability of the geological maps, and lack of detailed structural or seismic profiles, it is necessary to review the studies and do some more detailed structural analysis in the area. The recent field studies show that they should be revised and updated. As a final conclusion it could be said that the key role of the geological structures on the hydrogeology of dam sites specially is very significant so that it caused to change the primary selected dam axes several times.

Karst Denudation Cycles In Bulgaria

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We studied annual variations of the karst denudation in 5 Bulgarian karst regions. For two

of them we obtained monthly variations of the karst denudation in the last 34 years. The last two time series allow us to study the cycles of the karst denudation. We found that the carbonate karst denudation exhibit tremendous variations from month to month. In Iskrec karst region, Bulgaria it varies over 81 times in the last 34 years from 53.9 to 4380.7 tons/month. Karst denudation in this region exhibits strong annual variation with strongest cycles of 12 and 6 months. It exhibits also several longer cycles with duration of about 4 years (46.5 months), 64-73 months and 128- 170 months. These cycles suggest precipitation source of these karst waters. Carbonate karst denudation in Devnya karst region exhibits different pattern of variations from 3334 to 6076 tons/month in the last 32 years. In this region karst denudation do not exhibit strong annual variation, but have a great number of other cycles, strongest of which is of 4.5 months. It exhibits also several longer cycles with duration of 5.4, 7.3, 12.5, 16.9, 23, 51 and 85-102 months. These cycles suggest deep source of these karst waters. Observed range of variation of the karst denudation suggest that common techniques for calculation of the average karst denudation rate can produce unreliable results if use averaging of the recharge for periods shorter than 30 years.

Buoyancy Approach to Analysis of Mammoth Cave Air Flow Patterns

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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.

The role of epikarstic zone for microbiological pollution retardation

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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 behaviour 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

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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 KATERII, supported by the INTERREGIIIb programme, involving co-operation 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

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 6 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.

Classification of ecosystems and their ecohydrogeological features in main karst regions of China

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The paper presents the different ecosystems in main karst regions of both areas Southern China and Northern China. There are over 3,358 karst ground river systems well developed with total discharges about $420 \times 10^8 \text{ m}^3$ in the main karst regions in the Southern China in the dry season. The exploiting rates are only 8%~15%. Over 100 larger karst spring systems in main karst regions of the 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 exploiting rates are 70%~80%. The discussion should be included of six aspects as 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. Resulted by the Ximzlaya movement, the three stepped topographical features are obviously appearing in China, which are: first stepped Qinghai-Tibet Plateau, second stepped Yunnan-Guizhou 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 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 broad 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 the Huanglong and the Jiuzhaigou 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.

Urban Hydrogeology in Karst Regions of China

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Urbanization has been developing rapidly along with the blooming of 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, which makes 3,463,000km², 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), chile pepper (Qiubei, Yunnan), grape and wine (Mile, Yunnan), and panax pseudo-ginseng var. notoginseng, a species of herb medicines(Wenshan, Yunnan). Many cities are related to the development of mineral deposits, such as cassiterite (Gejiu, Yunnan; Dachang, Guangxi), lead and zinc(Siding, Guangxi), bauxite (Pingguo, Guangxi), 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 (Guilin, 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 happen 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 underlain the City was more than 270,000 m³ per day, and brought problems to tourism. A karst collapse 9m 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 1000mm. 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. How to find 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 1800m asl. It has developed on the bases of coal mining and steel manufactory. The industrial solid and liquid wastes have not only brought about environmental 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.

Combating Flood Crisis with Geographic Information System (GIS): An Example from Akure, Southwest Nigeria

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Flood is a natural environmental disaster which could be aggravated by man's unguided development. It may subsequently cause destruction of properties and loss of life. Therefore it needs to be controlled and human influences controlled. This study attempts to

describe an application of GIS as decision support to flooding problems in an urban area in Nigeria. The objective of the study is to describe the efficacy of GIS in monitoring of development on floodplains in an urban area in Nigeria. Topographic features were digitised from an existing 1:5,000 topographic map of Akure, with some position data collected and map updated using a handheld GPS. A database was created using both cartographic and attributes data collected from these and other sources. Spatial analyses were carried out using a PC based Integrated Land and Water Information System (ILWIS), version 3.2. The results obtained implicated dumpsites within the river channel as well as structural development within the River Ala floodplain as the major causes of inundation in this section of the city, especially, in the wet season. The study concluded that GIS could provide adequate decision support information to policy makers.

A Hierarchical Approach for Groundwater Modeling

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In Egypt, there has been a major effort to improve the water supply and also sanitation services although there are still major deficits in rural areas. Remaining a major challenge on the national level, rural drinking water supply is projected to become increasing inadequate with population growth. A part of the water supply comes from the Nile system and the other part comes from groundwater sources mainly by using wells. Typical applications of numerical models to field scale problems generally require large grids that can seldom accommodate cells as small as the actual well diameter. Several methods have been used to simulate a more accurate head at the well scale. The three primary methods are local grid refinement, local analytical correction and local numerical correction. However, all these methods have limitations, especially for applications that involve the development of numerical models for large scale hydrogeologic systems with multiple pumping wells. The paper presents a hierarchical approach for groundwater modeling and especially for predicting head at the well scale. The hierarchical approach enables converting a large, complex problem into a network of hierarchically nested and dynamically coupled models that can be easily solved. The main objective of this paper is to study the groundwater model of potable water system for a small rural community. Based on the hierarchical approach of groundwater modeling, the study with an optimization of number of wells and locations of them aimed to recommend a schedule for

running the wells to minimize the interaction between them.

From the inception horizon hypothesis to a prediction tool for karstified horizons

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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 voids distribution is not random, but defined by parameters controlling the "speleogenesis". The 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 favour 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 5 cave systems as well as the surrounding rock mass, at which more than 200 rock samples have been analysed 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.

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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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.

Water Resource of Telaga (Small Lake) in Gununsewu Karst: The Environmental Problems and the Rehabilitation Options

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A telaga is a small lake formed in the dolines as a result of ponor plugging. A total number of 443 telaga are randomly distributed within Gunungsewu Karst (3200 km²). Telaga used to provide approximately 90% of the local people's water supply needs (before 1990s). However, most telaga are currently drying up, only 30 telaga remain perennial. The

environmental problems of the telaga can be grouped into three categories, namely a) diminishing storage, b) rapid water loss, and c) water quality deterioration. Diminishing storage has resulted from rapid sedimentation (caused by extensive agriculture in the karst hills) and the increase of infiltration (caused by the loss of karst hill soil cover). Rapid water loss is due to basal leaking (caused by removal of bottom soil during telaga deepening practices or concrete levy construction) and higher evaporation (caused by higher wind velocity and warmer local temperatures). Water quality deterioration has resulted from multiple usages (human bathing, wash ing, animal bathing, animal drinking, fishery) inside the telaga, thus waste is retained in the telaga water body. Major contaminants of telaga water are phosphate, COD, nitrate, detergent, collie bacteria, and suspended solid. Proposed rehabilitation options which may be easily applied among others are, a) leaving the upper slope of karst hills for perennial crops, b) sealing the base with asphalt soaked sacks buried in clay, c) replacing concrete levy with a sandwich of stone pile and clay, d) planting readily consumed perennial crops along telaga sides, and e) establishing simple bathrooms outside telaga so that waste will not remain in the telaga water body.

Human impact on Heilongtang Springs, Kunming, China

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Heilongtang springs, 12km north of Kunming downtown, are composed by three springs- Pearl spring, Qingshuitang and Hunshuitang. For a longtime it has been a famous scenic site of Kunming city and very important water sources for the local drinking water supply and agricultural irrigation. Pearl spring and Qingshuitang spring are recharged by more than 20km² Carboniferous- Permian karst aquifers with the discharges 82.78l/s in dry season and 368.5l/s in wet season in 1950s. With the urbanization of Kunming and environmental change of recharge area, the quality and quantity of Heilongtang Springs have been tremendous changed. From early of 1960s over 11640m³/d water has been exploited from the aquifer for local water supplying, which has caused the springs drying during dry season and the turbidity increases during raining season. At present, there are still 11 pumping wells distribute within 1km² near the springs. Hunshuitang is recharged by basaltic aquifer with 3.75l/s dry season discharge, which is getting dry during dry season with the water pumping for the park water supply. During October-December of

2000, Heilongtang Springs suffered a paroxysmal water pollution event and caused the death of *Sinocyclocheilus grahami*, a kind of indigene fish. Two temporary landfill sites in recharge area were suspectable. Based on the analysis of water samples from 1983 to 2005 (twice a year, dry and raining season respectively) and hydrogeological characteristics, the possible pathways of pollutants were studied and a conservation strategy was established.

The Nature Conservancy's Global Karst Initiative

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Karst ecosystems are significant global land types, covering about 10% of the Earth's land surface. Species dependent on karst ecosystems are among the world's most rare and endangered fauna, and they dominate the IUCN Red List. In the US, karst occurs in 48 of 50 States, covering 20% of the land surface. Cave and groundwater-limited fauna represent over half of the imperiled (G1-G2) species in the US, yet less than 4% have federal protection status. The Nature Conservancy (TNC) has established the goal to protect 10% of each of the world's major habitat types by 2015. Despite importance of karst to humans and species, the TNC 2015 goal does not address karst as a major habitat type. Karst landscapes occur in at least 26 of 29 countries where TNC works. In 1999, TNC in Arkansas established the Ozark Karst Program (OKP) with the goal of protecting this ecoregion's rare, endangered, and diverse karst species. Since its inception, OKP and its partners have developed, refined, and implemented a variety of strategies specifically for conservation and protection of karst water resources, habitats, and species. OKP is now developing tools that will help TNC to address karst conservation at a global scale. Global karst GIS layers are being compiled from existing research and literature to help TNC prioritize its karst conservation efforts across the globe. The Karst Conservation Toolbox is also being assembled from existing research and knowledge. The Toolbox will be a centralized source of methods for karst science and conservation practitioners.

The role of the Black Sea in the development of the deepest cave system in the Arabika Massif (Kruber 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 (Kruber-Voronja Cave) recently explored to the depth of -2158 m. Dye tracing experiments conducted in 1984-1985 suggested that the Kruber 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) Kruber 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 boreholes 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 front of Arabika with the 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

A.B. Klimchouk

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 overlying 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 Olduvai. 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.

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 (*Abio-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 reversed: due to nature helped by human impact the forest is again gaining the territory. Although the first successful attempts to change karst hydrology are very old, the maximum changes occurred during the 20th century. The process is continuing now with slower pace maybe out of respect for nature. 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 B.C. 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 Ombla to the Southern Italy.

The characters of Karst evolution in China, in particular, its relationship with the developmental history of large rivers

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Following more than 50 years of investigation, the author drew conclusions which differed greatly from traditional views of karst evolution----- Since Miocene, the rapid uplift of Mt. Himalaya caused the formations of three geomorphic stages---the world's highest Tibet-Qinghai plateau, the intermediate plateau--basins and eastern plains in China. As a result the Yellow, the Yangtze, the Zhu (Pearl) river rushed down from plateaus to plains. The karst evolution is astonishing in conformity with the developmental history of the geomorphology and large rivers. Horizontal karst is found on the surface of geomorphic stages at Lunan "Stone Forest", Yunnan, and at Guilin, Guangxi. Vertical karst may be found on the transition belt of adjacent geomorphic stages (At Guizhou, the Baishui river which Huangguoshu waterfall is situated on, is only 64 km long, but with 718 m drop and many types of karst). The deepest shafts at Wulong (552 m) and Xiaozhai (662 m) (Chongqing), are separately situated near to the world's highest terraces with gravels of the Three Gorges of the Yangtze which had been discovered by author, and their depth are in conformity with the relative height of terraces (1250 m)... The rapid uplift of the Himalaya and Tibet-Qinghai plateau also effected the Chinese climate. The fact that there are a few karst formations in Northern China, typical karst in the Yangtze basin and extremely developmental at the Pearl river basin, are a direct result of this. At the latter site, not only are there many of world-famous karst landscape, but have also caused mass loss of the surface runoff and have led to form the region with serious deficiency of water. At this region, it will be necessary to adopt a new available way to find karst water. According to my surveying of the entire courses of the Yellow, the Yangtze, the Pearl on foot for 1200 days, including all of hundreds of caves, hidden rivers and other kind of karst along rivers I have come to the conclusion that finding karst water along recent river systems is very important for China. This way differed from traditional geologic structure approach. Nevertheless, we believe that utilizing the amount of precipitation (800 mm) of the region could prove invaluable in solving the water deficiency problem facing the area of 1 million km² in south-west China.

Superficial drain from takirs of Ustyurt Plateau as a source for storage of drinking water

Gani Mavlyanov

One of the characteristic elements of natural landscape of deserts is TAKIRS. Takirs are described as open, deprived the maximum vegetation, strongly leveled flat surfaces combined in the top part by densely connected clay materials. Takirs of Ustyurt are formed at combination of some factors. The main following from them: arid conditions of the climate; the certain orientation of the geological processes, preparing a cover from poorly nontight breeds; deep bedding of underground waters, excluding secondary desalination of soil; small surfaces inclination and obligatory stoppage of superficial waters; absence of the maximum vegetation and presence of the lowest - communities of blue-green seaweed and lichens. Average of takirs area (1-3 km²) are dated for karstic forms on wings of positive structures, 3-5 km² and more than 5 km² develop on the bottoms of karstic valleys. The characteristic of takir reservoirs of the Karakalpak Ustyurt on the area, km² In total 1736,42 , the number of takirs 5861 The general physic-geographical conditions of a plateau is the distribution of deposits on seasons of year (including flow making), binding of them to the periods described in rather low temperatures of air and small boiling process, strong humidity of the top layer of takir adjournment and presence of communities of lowering losses, - all this promotes the formation of non permanent superficial drain on takirs, natural reservoirs of stony desert Ustyurt. The only one way for saving the fresh water is storage it in the karst For this we need to remove the densely connected clay materials. By this way we can storage more than 3 millions tons of fresh water annually and then this water can be used for drinking.

The implementation of the tracing technique in geothermal injection study

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To Study the motion patterns and spacial 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 trace 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° 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 20kg, the period of test is 80d, the regulation of collecting sample is 1/24h in observation wells, the volume of collecting sample is 5l heating water. The concentration of tracer [I-] 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 0.12~0.21mg/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 (0.12mg/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(T_{1/2}=87d) 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 350mCi(about 1.3×10¹⁰Bq), the inspecting sensitivity is about 0.5 Bq, the period of test is 80d, the regulation of collecting sample is 1/12h in observation wells, the volume of collecting sample is 5l heating water and 1l 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 53d, the composition of isotope ³⁵S reach apex value (1.229Bq/l), the composition of isotope ³⁵S disappears after 170d., all of this show an obvious and whole response curve, the other observation wells have no inspected tracer. The i isotope trace test makes the same conclusion with chemical trace test and pumping test shows that the HX-25B well and HX-14well 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 pour 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 (135d 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 1939m, according that the appearing time of isotope ^{35}S apex value is 130d . 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 14.62m/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 a word, 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.

Key words: Trace test, Chemical tracer, Radioactive isotope tracer, Response curve, Seepage field characteristics, Wanglanzhuang geothermal field

Study of the Hydraulics and Water Movement in Río Encantado and Vientos Cave Systems

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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 Frías; 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 Frías resulted positive for the fluorescein dye test. There is, then, a definitive hydrological

connection between both underground rivers taking place somewhere inside the 1,800 feet of underwater passages constituting Aguas Frías. Discharge measurements were performed indicating that Río Encantado increased from 0.015 m³/s in Yuyú cave, to 0.44 m³/s in Juan Nieves cave (first and fifth accesses to Río Encantado). But in Aguas Frías, separated from Juan Nieves cave by only 500 meters, 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 Frías there was, however, a significant decrease in contamination; which confirms the result of the enlarged water discharge in Aguas Frías, this, because the less contaminated tributing waters 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 the state of the "Encantado-Vientos" compound unit; now of some 30 kilometers of underground rivers and tributaries, the longest in Puerto Rico.

Use of Morphometric Analysis to Characterize Flank Margin Caves

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Flank margin caves, which develop hypogenically 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 areal 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.

How did that get there? - Migration and degradation of halogenated hydrocarbons at depth through limited fractured limestone

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Since 1975, facility operators manufactured drilling equipment and assembled utility trucks. Several Environmental Site Assessments (ESA) were completed from 1990 to 2004 and subsequently a fuel UST removed, shallow wells installed, and halogenated hydrocarbon contaminated soils removed. The site is underlain by a Cambrian age formation consisting mainly of interbedded limestone and calcareous shale with an estimated thickness of 1,100 to 1,900 feet. The setting has been interpreted from subsurface data from prior investigations and data from corehole drilling and construction of 24 wells. Double cased monitoring wells were constructed to prevent interconnection of the water-bearing zones and downward migration of contaminant. Ground-water movement occurs along fractures of limited size (5-15 cm) and bedding or very limited shallow karst. The beds strike N 250 E to N 300 E, and dip 230 southeast. Interpretation of ground-water elevations indicate the direction of ground-water movement is generally towards the southeast. Ground-water quality data, from multiple and iterative rounds of sampling, indicate that the migration of halogenated hydrocarbons has occurred down strike. The contaminated ground water encompasses most of the property and has migrated downward to at least 225 feet BLS.

Study on the karstic conduits of Koohrang Third Tunnel Project using dye tracing

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Koohrang III tunnel with a length of 23390 m and an altitude ranging between 2180-2200 masl is being constructed to transfer 17 m³/s of water from Karun river basin to Zayandehrud river basin. Under appropriate condition, numerous karstic features such as sinkholes, shafts and a polje which is called Lagharak plain have been formed in the area. The karstic formations are extensively outcropped in route of the tunnel. A considerable amount of water emerged from a karstic conduit during the excavation of the Nasirabad adit. Besides, water with a pressure of about 10 atm and a flow rate of about 20 l/s emerged from a karstic channel during the excavation of the main tunnel. Twenty kilograms of dissolved Uranine were injected into the main sinkhole of the southern rim of Lagharak plain and sampled at all the emerging points. It was concluded that: 1) Most of the water in the Lagharak plain does not flow in the vicinity of the tunnel. 2) Karstic channels connect the injection sinkholes and most of the springs emerging from both sides of the main tunnel. 3) High amount of recovered dye flowed over Eocene and Oligocene formations through Naleshkanan River. Parts of this water infiltrate into these formations and head toward the karstic channels, emerging from the main tunnel faces and the springs. The tunnel is located at least 200 m below the karstic springs; therefore an extensive karstic system is unlikely. However, small conduits with high water pressure may be found during excavation. The flow model in the study area is proposed.

The role of the exchange coefficient and hydraulic conductivity in karst aquifers

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Karst regions are characterised by surface features such as sinkholes and losing streams. These features provide direct connections between the ground surface and karst aquifers. Because of these bypass features karst aquifers are vulnerable to any surface activities that may cause contamination. The potential for contamination of karst groundwater from human impact sources is likely to be great if the recharge area is experiencing increased land use, particularly through urbanisation and agricultural activity. The objective of the study was to simulate a hypothetical karst aquifer system to understand the sensitivity of changing the values of the exchange coefficient between matrix and surrounding pipe-like conduits and the values of the hydraulic conductivity of the matrix on the particle movements within the aquifer. The physically-based model (SHETRAN), which is developed to model karstic aquifers, was applied in this study. The results of the simulation scenarios showed that any increase in the exchange coefficient or hydraulic conductivity of the matrix will enhance the chance that more particles will reach the outlet.

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 range from 250 to 318 m amsl, extending up to 138 m above the Cumberland River elevation. The corridor's maximum width is 65 times greater than the depth of river incision. In addition to the distinctive terrace deposits, yazoo-type tributaries help to identify the northern limit of the ancestral corridor. Courses

of these northern tributaries were apparently altered to the southwest by dominant CR channels or sloughs. Also, high-gradient tributaries, draining the Cumberland Plateau Escarpment, have re-worked broad areas of the southern periphery of the CR corridor. These stream flats, up to three km wide, are mapped with recent alluvium (Qal). Within a 500 km² study area, the delineated CR corridor encompasses 195 km², 46% of which is a core zone occupied by the entrenched Cumberland River and mapped terrace deposits. The remaining 54% of the corridor surface has apparently been reworked by tributaries and dissected by sinkholes, thus removing or altering most deposits. Since mapped depressions occupy less than 5% of the corridor area, most of this deposit removal was by local streams and tributaries. Even without diagnostic CR sediments on the outer flanks of the corridor, a fluvial planation origin is persuasive. Although karst is well-developed in Ste. Genevieve and St. Louis limestones, varied evidence supports the interpretation that entrenchment of the CR planation corridor has produced a modified fluvial landscape, where extensive karst development is a secondary, subordinate element.

Simulation of groundwater flow in variably saturated karst aquifers: groundwater storage and its effect on spring hydrographs

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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.

Fractal properties of superficial karst of Middle Atlas (Morocco)

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The karst structure of Middle Atlas (Morocco) is investigated by fractal analysis using a 1:100,000 scaled geomorphological maps obtained from aerial photographs at scale 1:40,000. Six karstic surfaces were selected to test the fractal character of karst, and to perform frequency-size distribution analysis. Using the popular box-counting algorithm, the fractal dimension D_b in the region ranges from 1.11 to 1.44. These results show that karst spatial distribution is fractal, and D_b tends to increase with density of karsts. Fractal dimension thus provides a tool for quantifying spatial clustering of karsts. The area-perimeter plots of digitised data from the six karst surfaces show that perimeters appear to be fractal with contour fractal dimension D_c ranging from 1.06 to 1.29, which may reflect a karst evolution degree. The size-number distributions of karst areas and perimeters exhibit power-law behaviour with characteristic exponents for this region. The Mandelbrot-Korçak law for karst areas distribution is: $N(>a) \propto a^{-0.92}$. This work supports that karstification process is a self-similar phenomenon; it is well known that many geological processes like fracturing and fragmentation are fractals. A fractal driving processes with combination of rainfall and other fractal climatic factors will lead to the fractal structure of karst. Fractal or scaling properties characterize the hierarchical and spatial organization of karsts. It may be encouraging that the fractal analysis can be used to compare structural variations in karstic areas and to follow the maturity level of karstification.

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 meters. The Edwards Limestone is approximately 150 meters 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 meters 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 meters of the Glen Rose Limestone in northern Bexar County provides water to the Edwards Aquifer.

The psychrophilic fungal biofilms from the Djupvik Cave of Geta Island (Alands, Finland).

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Fungal biofilms were investigated on walls and ceiling in the Djupvik Cave which is located on Geta Island of Alands Islands (Finland) in granite bedrock. White-colored biofilms cover a granite with thickness of several millimeters. Three species of microfungi were isolated and studied from the samples. The dominant species is *Geomyces pannorum* which is developed in association with dark-colored sterile mycelium. Secondary species is *Acremonium strictum* which started to grow after the beginning of development of first two species. Both species of microfungi have demonstrated ability to growth at temperature nearby zero degrees of Celsius. The studying of the samples by scanning electron microscopy shown that a granite is not weathered. The zones of biofilms localization are mainly connected with deepenings in a bedrock and also with interblock micro cracks, that allows to assume, that the consumed organic matter penetrates in water-soluble form.

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 (Turkmentistan). 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, jarosite 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).

Assessment on the Karst Water Resources of Dalongdong Underground River Catchment, Xiangxi, Hunan

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We calculate the natural reserves and recoverable reserves by the methods of infiltration and runoff coefficient which enables us to give different coefficients according to the hydrogeological conditions and makes the results more suitable to the actual situation. The natural runoff resources and natural reserves under the different frequency of precipitation are also calculated by the method of hydrological analysis, the results show that 2003 is the second low-water year. By methods of the statistic and hydrological dynamic analysis, the recoverable reserves under the condition of natural and factitious regulation, and the natural adjustment capacity of the system is calculated respectively, the results indicate that the natural adjustment capacity is still smaller than capability of the estimated underground space. These results calculated by different methods, especially the recoverable reserves, have high reliability and comparability and provided the scientific data to the design of the planning reservoir.

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 millimeter 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

Reconstructions of Past Annual Variations of the Karst Denudation

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We used the quantitative theory of solubility of karst rocks to reconstruct past carbonate denudation rates. It produced equations assessing the carbonate denudation rates in dependence on the temperature or on the precipitation. We used an estimate of the averaged denudation rate in Kananaskis karst region, Alberta, Canada based on integrated data of the carbonate hardness of the waters and average precipitation rate from meteorological data. Obtained denudation rate is 38 t/km² per year. We used this as starting point and substituting our proxy records of the annual temperature and the annual precipitation for the last 1250 years in dependence on the temperature. Both reconstructions produce quite reasonable estimate of the variations of carbonate denudation, which is within observed variation of 8- 20 mm/ kyr (86% variation). Temperature dependence of carbonate denudation produce only 9.3 % variation in the denudation rate. Precipitation dependence of carbonate denudation produce 79 % variation in the denudation rate. We measured a very high resolution luminescence record covering the last 2028 ±100 years from Savi Cave, Trieste, Italy. It consists of 40106 data points compiled of 16 overlapping scans. Its time step varies from 15.6 days to 19.9 days. We made a reconstruction of the annual growth rate variations for the last 2028 years, which represents annual precipitation for the region of the cave. We found that the strongest cycle of the annual rainfall in the region is with duration of about 300 years. It should produce variations of the karst denudation rates with the same duration.

Origin of the Sub- Annual Paleoluminescence Cycles

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We used a new real- space periodogramme analysis algorithm to calculate and compare the real intensity of the cycles in speleothem luminescence time series. We studied speleothems from Cold Water Cave, Iowa. Obtained power spectra demonstrates that speleothems recorded many short cycles of the soil temperature in the region. In addition to the annual cycle produced by the Earth's rotation we found a number sub- annual cycles in extremely high- resolution luminescent records (with resolution of 2- 4 measurements per day). Cosmic rays influence on the atmospheric transparency provides a mechanism of

strong nonlinear multiplication of the solar variations in the insolation at the Earth's surface. Cosmic rays have strong modulation by the solar wind, which roles their concentration at the Earth's atmosphere. Observed cycles with duration of 32, 30, 28.5, 27 and 14 days can be produced by the period of rotation of the Sun, which produces similar variations in the solar wind modulating cosmic rays flux. This period produces periodical appearance of the active zones on the Sun, which are major emitters of solar wind so produce strong variations of its density. The duration of the cycles of 30 and 27 days is close to the tidal cycles of 29.5, 27.55 and 27.32 days. We discuss both hypothesis of the origin of these cycles in the paleoluminescence record.

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 (40 to 6500 gpm), 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 *Schellencandona triquetra* (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 d18O and d2H (-9 per mil d18O VSMOW and -57 per mil d2H VSMOW, respectively) than the other 8 springs, which range from -8.1 to -8.4 per mil d18O VSMOW and -50 to -53 per mil d2H 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 less than 0.001 to 0.03 mg/L for As, Cd, Co, Cr, Mo and Ti; less than 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 Naukluft 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 hydroclimate 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 Glenss Creek and drains the urban areas of the city of Versailles (~ 8,000 population) and outlying farmland. On June 2, 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- μ m diameter latex microspheres) transpired on July 11, 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 April 1, 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.

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 meter) sites, even though overcup oak seedlings and mature trees were concentrated in deep (ponding depth greater than 1 meter) sites. Analysis of tree rings from a 10-percent 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 meter and 1 meter) 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.

Fragility and Geological Background of Rocky Desertification Environment in the Karst Areas of Southwest China

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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 eco-system, which formed by the intensive karstification in the 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 are not only lacks of water supply and soils, but also frequent natural hazards, as well as low capacity of production. So the local people almost have no conditions of production and life. About 17 million people exit 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 rocky 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 the leakage of the surface water, but also makes the depressions water log in rainy season, which influence the production conditions of agriculture and forestation and plant appearance. The short of soil and water supplies makes the grown speed and storage quantity of forest in karst areas much lower than that in non-karst areas. Mover, some malpractices of local people in land use under high population pressure, such as cultivation in a steep hill slope, wood cut, burn the grass on mountain and the air pollution from the factories, are also the important causes of rock desertification. Recent researches of the international geological contrast show that, the frequent mankind activities under the special geological background makes the rocky desertification problem situation in southwest China much graver than any other counties. Therefore, for treatment of rock desertification, detailed researches of the geological backgrounds are firstly. then, after summing up the successful experiences of rock desertification treatment in early stage, to work out the new different comprehensive treatment measures in different geological backgrounds and environmental conditions. The exploitation of the karst water and the organic integration between ecological rehabilitation and economic development should be particularly paid to attention.

A statistical strategy for determining contaminant impacts of landfills on spring in karst terranes

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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.
