

Hypogene Speleogenesis and Karst Hydrogeology of Artesian Basins

Ukrainian Institute of Speleology and Karstology

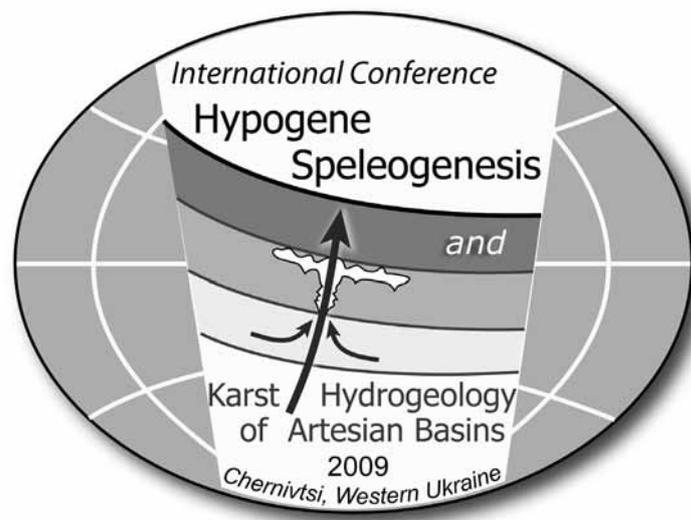


Special Paper 1

Edited by
Alexander Klimchouk
Derek Ford

Hypogene Speleogenesis and Karst Hydrogeology of Artesian Basins

Proceedings of the conference held May 13 through 17, 2009 in Chernivtsi, Ukraine



**Edited by
Alexander B. Klimchouk and Derek C. Ford**

**Ukrainian Institute of Speleology and Karstology
Special Paper 1**

**Simferopol
2009**

УДК 556
ББК 26.22
Г 505

Recommended citation for this volume:

Klimchouk, A.B. and Ford, D.C. (eds.). 2009. Hypogene Speleogenesis and Karst Hydrogeology of Artesian Basins. Ukrainian Institute of Speleology and Karstology, Special Paper 1, Simferopol, 280 pp.

ISBN 978-966-2178-38-8

The volume contains papers presented during the International Conference held May 13 through 17, 2009 in Chernivtsi, Ukraine.

Published by:
Ukrainian Institute of Speleology and Karstology,
4 Vernadsky Prospect, Simferopol 95007, Ukraine
<http://institute.speleoukraine.net>
institute@speleoukraine.net

Дизайн обкладинки: О.Б.Климчук
Cover design: A.B.Klimchouk
Оригінал-макет: О.Б.Климчук, А.М.Гребнев
Master copy: A.B.Klimchouk, A.N.Grebnev
Комп'ютерна верстка: А.М.Гребнев
Computer layout: A.N.Grebnev

Надруковано в типографії СПД Харітонов О.О., Сімферополь, АР Крим, Україна
Printed by SPD Kharitonov A.A., Simferopol, AR Crimea, Ukraine

Front cover: Tafoni on a limestone escarpment in the Crimea Piedmont (background) and a passage in Slavka Cave, Western Ukraine (inset). Photos and collage by A.Klimchouk

Back cover: Hypogenic morphology in gypsum caves of the Western Ukraine. Photos and collage by A.Klimchouk

©2009 by Ukrainian Institute of Speleology and Karstology (the book)
©2009 by authors (individual contributions)

ISBN 978-966-2178-38-8

Ukrainian Institute of Speleology and Karstology, Ukraine
Vernadsky Tavrichesky National University, Ukraine
Fed'kovich Chernivtsy National University, Ukraine
Institute of Geological Sciences, Ukraine
National Cave and Karst Research Institute, USA
Karst Water Institute, USA
Silesian University, Poland
Katowice Section of the Polish Geographic Society, Poland
Ukrainian Speleological Association, Ukraine

With support of:

Union International of Speleology (UIS),
UIS Commission on Karst Hydrogeology and Speleogenesis
International Geoscience Program 513
"Global Study of Karst Aquifers and Water Resources" (UNESCO)
International Year of Planet Earth (UNESCO-IUGS)

Patronage Committee

Bagrov N.V. – Rector of the Vernadsky Tavrichesky National University, corresponding member of the NASU
Gozhik P.F. – Director of the Institute of Geological Sciences of NASU, corresponding member of NASU
Mel'nichuk S.V. – Rector of the Fed'kovich Chernivtsi National University, corresponding member of NASU
Shelepnitsky I.O. – Head of the Chernivtsi Province Council
Shestopalov V.M. – Academician-Secretary of the Department of Earth Sciences of NASU, academician of NASU

Organizing Committee

Klimchouk A.B. – UISK, Ukraine – Chairman
Andrash V.V. – Ternopil' Speleo-Club "Podillya"
Andreychuk V.N. – University of Silesia, Poland – UISK, Ukraine
Apostoljuk V.A. – UISK – Ternopil' Speleo-Club "Podillya"
Koptchinsky A. – Vienna University, Austria
Rudenko V.P. – Fed'kovich Chernivtsy National University
Ridush B.T. – UISK - Fed'kovich Chernivtsy National University
Sokhatsky M.P. – UISK – Borshchiv Regional Museum
Vakhrushev B.A. – UISK – Vernadsky Tavrichesky National University
Zimel's J.L. – UISK – Ternopil' Speleo-Club "Podillya"

Scientific Committee

Shestopalov V. (NAS Ukraine) – Chairman
Audra Ph. (University of Nice, France)
Auler A. (Brazilian Institute for Karst and Caves, Brazil)
Andrejchuk V. (University of Silesia, Poland – UISK, Ukraine)
Dublyansky Yu. (Institut für Geologie und Paläontologie, Leopold-Franzens-Universität Innsbruck, Austria)
Ford D. (McMaster University, Canada)
Forti P. (University of Bologna, Italy)
Frumkin A. (Jerusalem University, Israel)
Kempe S. (University of Darmstadt, Germany)
Klimchouk A. (UISK, Ukraine)
Lowe D. (British Geological Survey, Nottingham, UK)
Osborne A. (University of Sidney, Australia)
Palmer A. (University of Oneonta, USA)
Veni G. (National Cave and Karst Research Institute, USA)
White W. (Pennsylvania State University)

CONTENTS

PRINCIPAL FEATURES OF HYPOGENE SPELEOGENESIS <i>Alexander Klimchouk</i>	7
HYPOGENE CAVE PATTERNS <i>Philippe Audra, Ludovic Mocochain, Jean-Yves Bigot, and Jean-Claude Nobécourt</i>	17
MORPHOLOGICAL INDICATORS OF SPELEOGENESIS: HYPOGENIC SPELEOGENS <i>Philippe Audra, Ludovic Mocochain, Jean-Yves Bigot, and Jean-Claude Nobécourt</i>	23
HYPOGENE CAVES IN DEFORMED (FOLD BELT) STRATA: OBSERVATIONS FROM EASTERN AUSTRALIA AND CENTRAL EUROPE <i>R.A.L. Osborne</i>	33
IDENTIFYING PALEO WATER-ROCK INTERACTION DURING HYDROTHERMAL KARSTIFICATION: A STABLE ISOTOPE APPROACH <i>Yuri Dublyansky and Christoph Spötl</i>	45
MICROORGANISMS AS SPELEOGENETIC AGENTS: GEOCHEMICAL DIVERSITY BUT GEOMICROBIAL UNITY <i>P.J.Boston, M.N. Spilde, D.E. Northup, M.D. Curry, L.A. Melim, and L. Rosales-Lagarde</i>	51
SIDERITE WEATHERING AS A REACTION CAUSING HYPOGENE SPELEOGENESIS: THE EXAMPLE OF THE IBERG/HARZ/GERMANY <i>Stephan Kempe</i>	59
SIMULATING THE DEVELOPMENT OF SOLUTION CONDUITS IN HYPOGENE SETTINGS <i>C. Rehr, S. Birk, and A. B. Klimchouk</i>	61
EVOLUTION OF CAVES IN POROUS LIMESTONE BY MIXING CORROSION: A MODEL APPROACH <i>Wolfgang Dreybrodt, Douchko Romanov, and Georg Kaufmann</i>	67
SPELEOGENESIS OF MEDITERRANEAN KARSTS: A MODELLING APPROACH BASED ON REALISTIC FRACTURE NETWORKS <i>Antoine Lafare, Hervé Jourde, Véronique Leonardí, Séverin Pistre, and Nathalie Dörfliger</i>	75
GIANT COLLAPSE STRUCTURES FORMED BY HYPOGENIC KARSTIFICATION: THE OBRUKS OF THE CENTRAL ANATOLIA, TURKEY <i>C. Serdar Bayari, N. Nur Ozyurt, and Emrah Pekkans</i>	83
ON THE ROLE OF HYPOGENE SPELEOGENESIS IN SHAPING THE COASTAL ENDOKARST OF SOUTHERN MALLORCA (WESTERN MEDITERRANEAN) <i>Joaquín Ginés, Angel Ginés, Joan J. Fornós, Antoni Merino and Francesc Gràcia</i>	91
HYPOGENE CAVES IN THE APENNINES (ITALY) <i>Sandro Galdenzi</i>	101
STEGBACHGRABEN, A MINERALIZED HYPOGENE CAVE IN THE GROSSARL VALLEY, AUSTRIA <i>Yuri Dublyansky, Christoph Spötl, and Christoph Steinbauer</i>	117
HYPOGENE CAVES IN AUSTRIA <i>Lukas Plan, Christoph Spötl, Rudolf Pavuza, Yuri Dublyansky</i>	121
KRAUSHÖHLE: THE FIRST SULPHURIC ACID CAVE IN THE EASTERN ALPS (STYRIA, AUSTRIA) <i>Lukas Plan, Jo De Waele, Philippe Audra, Antonio Rossi, and Christoph Spötl</i>	129
HYDROTHERMAL ORIGIN OF ZADLAŠKA JAMA, AN ANCIENT ALPINE CAVE IN THE JULIAN ALPS, SLOVENIA <i>Martin Knez and Tadej Slabe</i>	131
ACTIVE HYPOGENE SPELEOGENESIS AND THE GROUNDWATER SYSTEMS AROUND THE EDGES OF ANTICLINAL RIDGES <i>Amos Frumkin</i>	137
SEISMIC-SAG STRUCTURAL SYSTEMS IN TERTIARY CARBONATE ROCKS BENEATH SOUTHEASTERN FLORIDA, USA: EVIDENCE FOR HYPOGENIC SPELEOGENESIS? <i>Kevin J. Cunningham and Cameron Walker</i>	151
HYPOGENE SPELEOGENESIS IN THE PIEDMONT CRIMEA RANGE <i>A.B. Klimchouk, E.I. Tymokhina and G.N. Amelichev</i>	159

STYLES OF HYPOGENE CAVE DEVELOPMENT IN ANCIENT CARBONATE AREAS OVERLYING NON-PERMEABLE ROCKS IN BRAZIL AND THE INFLUENCE OF COMPETING MECHANISMS AND LATER MODIFYING PROCESSES <i>Augusto S. Auler</i>	173
MORPHOLOGY AND GENESIS OF THE MAIN ORE BODY AT NANISIVIK ZINC/LEAD MINE, BAFFIN ISLAND, CANADA: AN OUTSTANDING EXAMPLE OF PARAGENETIC DISSOLUTION OF CARBONATE BEDROCKS WITH PENE-CONTEMPORANEOUS PRECIPITATION OF SULFIDES AND GANGUE MINERALS IN A HYPOGENE SETTING <i>Derek Ford</i>	181
THE INFLUENCE OF HYPOGENE AND EPIGENE SPELEOGENESIS IN THE EVOLUTION OF THE VAZANTE KARST MINAS GERAIS STATE, BRAZIL <i>Cristian Bittencourt, Augusto Sarreiro Auler, José Manoel dos Reis Neto, Vanio de Bessa and Marcus Vinícios Andrade Silva</i>	193
HYPOGENIC ASCENDING SPELEOGENESIS IN THE KRAKÓW-CZĘSTOCHOWA UPLAND (POLAND) – EVIDENCE IN CAVE MORPHOLOGY AND SURFACE RELIEF <i>Andrzej Tyc</i>	201
EVIDENCE FROM CERNA VALLEY CAVES (SW ROMANIA) FOR SULFURIC ACID SPELEOGENESIS: A MINERALOGICAL AND STABLE ISOTOPE STUDY <i>Bogdan P. Onac, Jonathan Sumrall, Jonathan Wynn, Tudor Tamas, Veronica Dărmiceanu and Cristina Cizmaş</i>	209
THE POSSIBILITY OF REVERSE FLOW PIRACY IN CAVES OF THE APPALACHIAN MOUNTAIN BELT <i>Ira D. Sasowsky</i>	211
KARSTOGENESIS AT THE PRUT RIVER VALLEY (WESTERN UKRAINE, PRUT AREA) <i>Viacheslav Andreychouk and Bogdan Ridush</i>	213
ZOLOUSHKA CAVE: HYPOGENE SPELEOGENESIS OR REVERSE WATER THROUGHFLOW? <i>V. Korzhyk</i>	221
EPIGENE AND HYPOGENE CAVES IN THE NEOGENE GYPSUM OF THE PONIDZIE AREA (NIECKA NIDZIAŃSKA REGION), POLAND <i>Jan Urban, Viacheslav Andreychouk, and Andrzej Kasza</i>	223
PETRALONA CAVE: MORPHOLOGICAL ANALYSIS AND A NEW PERSPECTIVE ON ITS SPELEOGENESIS <i>Georgios Lazaridis</i>	233
HYPOGENE SPELEOGENESIS IN MAINLAND NORWAY AND SVALBARD? <i>Stein-Erik Lauritzen</i>	241
VILLA LUZ PARK CAVES: SPELEOGENESIS BASED ON CURRENT STRATIGRAPHIC AND MORPHOLOGIC EVIDENCE <i>Laura Rosales-Lagarde, Penelope J. Boston, Andrew Campbell, and Mike Pullin</i>	245
HYPOGENE KARSTIFICATION IN SAUDI ARABIA (LAYLA LAKE SINKHOLES, AIN HEETH CAVE) <i>Stephan Kempe, Heiko Dirks, and Ingo Bauer</i>	247
HYPOGENE KARSTIFICATION IN JORDAN (BERGISH/AL-DAHER CAVE, UWAIYED CAVE, BEER AL-MALABEH SINKHOLE) <i>Stephan Kempe, Ahmad Al-Malabeh, and Horst-Volker Henschel</i>	253
ASSESSING THE RELIABILITY OF 2D RESISTIVITY IMAGING TO MAP A DEEP AQUIFER IN CARBONATE ROCKS IN THE IRAQI KURDISTAN REGION <i>Bakhtiar K. Aziz and Ezzaden N. Baban</i>	257
FEATURES OF GEOLOGICAL CONDITIONS OF THE ORDINSKAYA UNDERWATER CAVE, FORE-URALS, RUSSIA <i>Pavel Sivinskih</i>	267
ОСОБЕННОСТИ ГИПОГЕННОГО СПЕЛЕОГЕНЕЗА ГОРНО-СКЛАДЧАТОЙ ОБЛАСТИ ЗАПАДНОГО КАВКАЗА <i>Б.А.Вахрушев</i>	271
ГЛУБИННОЕ СТРОЕНИЕ ГИДРОГЕОСФЕРЫ: МОДЕЛЬ ВЕРТИКАЛЬНОЙ ЗОНАЛЬНОСТИ <i>В.Н. Катаев</i>	277
РОЛЬ КАРСТА В ФОРМИРОВАНИИ СОЛЕННЫХ ВОД И РАССОЛОВ ОЛЕНЁКСКОГО БАССЕЙНА <i>Александр Кононов, Сергей Алексеев, и Сергей Сухов</i>	287

HYPOGENE KARSTIFICATION IN JORDAN (BERGISH/AL-DAHER CAVE, UWAYYED CAVE, BEER AL-MALABEH SINKHOLE)

Stephan Kempe¹, Ahmad Al-Malabeh², and Horst-Volker Henschel³

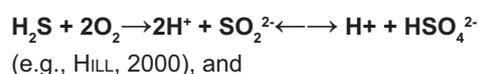
¹ University of Technology, Institute of Applied Geosciences, Schnittpahnstr. 9, D-64287 Darmstadt, Germany, kempe@geo.tu-darmstadt.de,

² Hashemite University, Department of Earth and Environmental Sciences, P.O. Box 150459, Zarka 13115, Jordan, a_malabeh@yahoo.com,

³ P.O. Box 110661, D-64221 Darmstadt, Germany, h-v.henschel@henschel-ropertz.de

Large parts of Jordan are underlain by Cretaceous and Tertiary limestone but no larger cave were known there until Bergish/Al-Daher Cave was discovered in 1995. Since then a few other caves have been investigated, mostly lava caves within the vast Jordanian Harrat (KEMPE *et al.*, 2008). Here we report about three caves that are indicative of hypogene karstification (*sensu* KLIMCHOUK, 2007): Al-Daher Cave, Uwayyed Cave and the Beer Al-Malabeh Sinkhole, situated in different parts of the country (Figure 1).

Bergish/Al-Daher Cave (KEMPE *et al.*, 2006) is located E of the Natural Reserve of Zubya in the mountains of Bergish at an altitude of 830 m above sea level. The cave occurs in the Upper Cretaceous Wadi As Sir Limestone Formation. It is a maze developed along NW-SE and NE-SW striking joints owing their existence to the Dead Sea Transform Fault west of the cave. The cave occupies a total area of 1750 m² within a square of 70x70 m (Figure 1). It developed in a series of laminated and non-laminated limestone beds, divided by four distinctive chert layers (labelled A to D; Figure 3). These can be followed throughout the cave as marker beds. Chert nodules occur also within the limestone layers. The morphology is that of a cave formed by convective circulation within a phreatic groundwater body, i.e. it is wide at the top and narrows down into pits at the floor that are choked with chert blocks. There are no signs of epigene cave evolution such as scallops, external sediment, canyons, etc. The solution capacity that etched out the cave must have come from upwelling, deeper waters that rose either thermally or by natural convection (density driven). These waters must have carried either H₂S or CH₄ that reacted with oxygen carried down by sinking surface seepage water according to:



Thus, Al-Daher Cave may have formed by hypogene processes similar to those which formed the Guadalupe Mountain caves, New Mexico, among them Carlsbad Cavern. If gypsum ever has precipitated in the cave (like the gypsum found in the Guadalupe Mountain caves and indicative of an H₂S-genesis), then it has been dissolved by drip water a long time ago. The altitude of the cave suggests that it may be as old as upper Miocene. The cave contains several relict generations of speleothems but also active forms.

Al-Daher appears to be the only such cave in northern Jordan. However, two more caves may have been caused

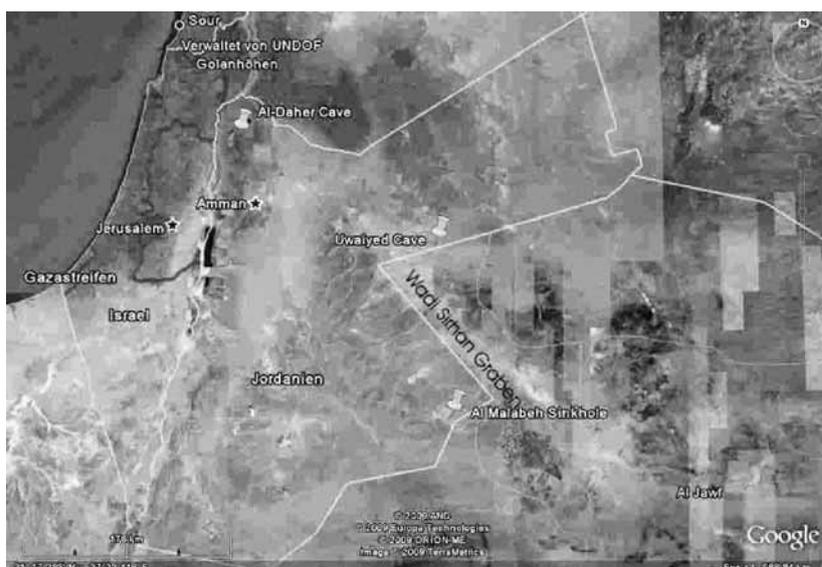


Figure 1. Google Earth View of Jordan with approximate locations of the three hypogene karstification sites.

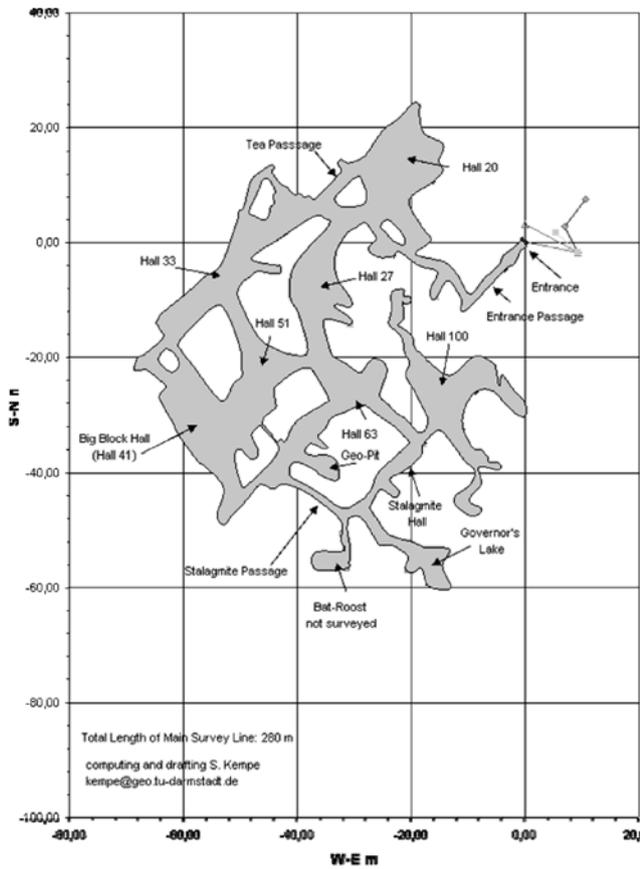


Figure 2. Map of Al-Daher Cave, a typical maze cave. Surveyed 26.-27.09.2003, 28.03.2004, S. Kempe, H.-V.Henschel, A. Al-Malabeh, A. Al-Shraideh (modified after KEMPE *et al.*, 2006).

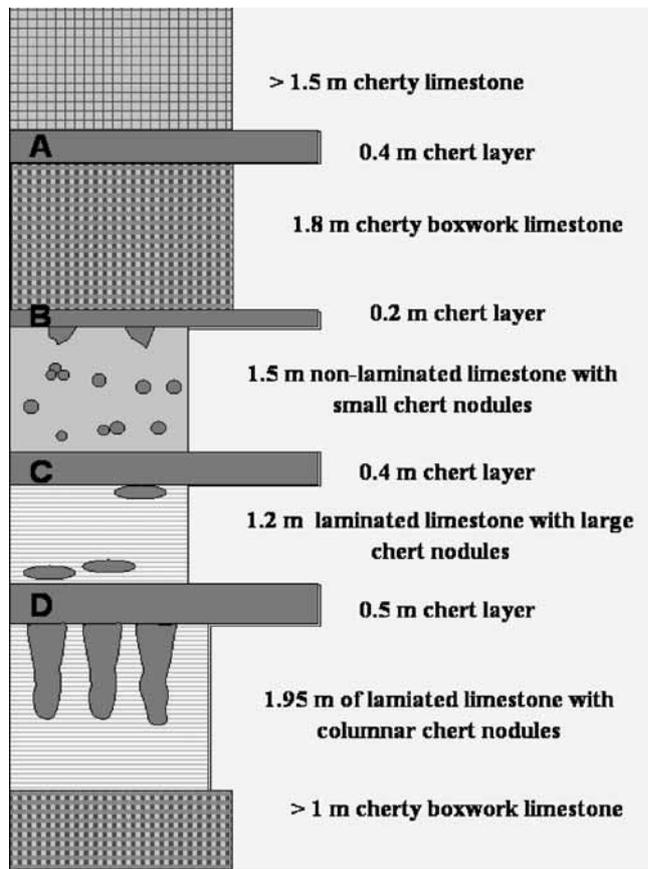
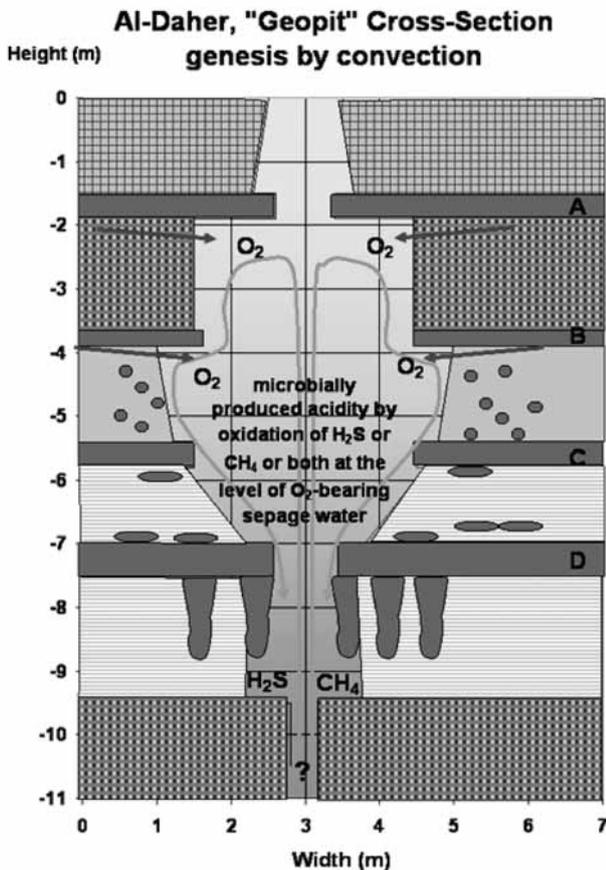


Figure 3. Stratigraphy of Al-Daher cave that developed within several limestone layers of varying texture and chert contents, separated by four distinct chert beds (modified after KEMPE *et al.*, 2006).



by hypogene karstification as well (KEMPE *et al.*, submitted). These are situated along the Wadi Sirhan Graben in SE Jordan (Figure 1). Both appear to have formed by upward stoping of collapsed, deep-seated hypogene cavities along breccia pipes. The first one, Uwayyed Cave, is a 11 m wide breakdown-dominated chamber in basalt of the Naslet Al-Dhirwa volcano (Figure 5); the second, Beer Al-Malabeh, is a large, bell-shaped, 23 m deep sinkhole that has opened up to the surface in the recent geological past (Figures 6 and 7). Several hypogene processes may have led to their formation, such as salt or gypsum dissolution or rising formation waters containing H_2S and or CH_4 . The review of the existing stratigraphy as obtained by oil well drilling suggests, however, that no salt layers occur below the caves. Gypsum layers seem to be limited to 4 m in thickness, probably not enough to form the observed features. The remaining process is again dissolution caused by ascending gas (H_2S or CH_4) -rich waters from the underlying oil and oil-shale fields. When these plumes

Figure 4. Model of the convection within the water-filled Geopit, part of Al-Daher Cave. Water from the deep-seated source carrying H_2S or CH_4 or both rises convectively up into the cave (driven by temperature or solution concentration or both). Seepage water, containing oxygen, that can percolate through the fractured chert layers is mixed into the cave water. There it is consumed by bacterial oxidation of the advected gases, liberating acids that generate the cave locally above the rising deep water plume (modified after KEMPE *et al.*, 2006).



Figure 5. Panorama view of the single-chambered Uwaiyed Cave looking from the entrance into the interior (Foto S.Kempe).



Figure 6. View of the opening of the Beer Al-Malabeh Sink-hole. Wall in the back has been bulldozed around the hole to prevent accidents (Foto S.Kempe).

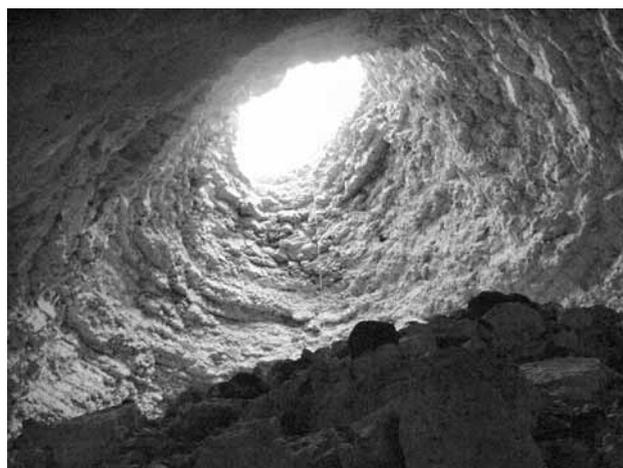


Figure 7. View from the bottom of the Beer Al-Malabeh Sink-hole to the entrance ca. 20 m higher (not speleoscope for scale) (Foto S.Kempe).

reach the water table, bacterial oxidation may create enough dissolutional power to form localized, large cavities within the Cretaceous or Tertiary limestones. Their collapse could lead to the observed cavities and would explain the paucity of other cave structures throughout southeastern Jordan.

REFERENCES

- Hill, C. A. 2000. Sulfuric acid, hypogene karst in the Guadalupe Mountains of New Mexico and West Texas, U.S.A. In *Speleogenesis, Evolution of Karst Aquifers*, Klimchouk, A.B., Ford, D.C., Palmer, A.N., & Dreybrodt, W., (Eds.), National Speleological Society, Huntsville, Alabama, pp. 309-316.
- Kempe, S., Al-Malabeh, A., Al-Shreideh, A., and Henschel, H.-V. 2006. Al-Daher Cave (Bergish), Jordan, the first extensive Jordanian limestone cave: A convective Carlsbad-type cave? *Journal of Cave and Karst Studies* **68:3**, 107-114.
- Kempe, S., Al-Malabeh, A., Frehat, M., and Henschel, H.-V., 2008. State of lava cave research in Jordan. Proc. 12th Intern. Symp. on Vulcanospeleology, Tepoztlán, Mexico, 2-7 July, 2006, Assoc. for Mexican Cave Studies, Bull., **19** and Societed Mexicana de Exploraciones Subterráneas Bol., **7**, 209-218.
- Kempe, S., Al-Malabeh, A., Frehat, M., and Henschel, H.-V. 2008. Hypogene Point Karstification along Wadi Sirhan Graben (Jordan): A Sign of Oilfield Degassing? Submitted to *Acta Carsologica*.
- Klimchouk, A. 2007. Hypogene Speleogenesis: Hydrogeological and Morphogenetic Perspective. – National Cave and Karst Research Institute, Special Paper **1**, 106 pp.
- Valentine, D. L. 2002. Biogeochemistry and microbial ecology of methane oxidation in anoxic environments: a review: *Antonie van Leeuwenhoek*, **81**, 271-282.

