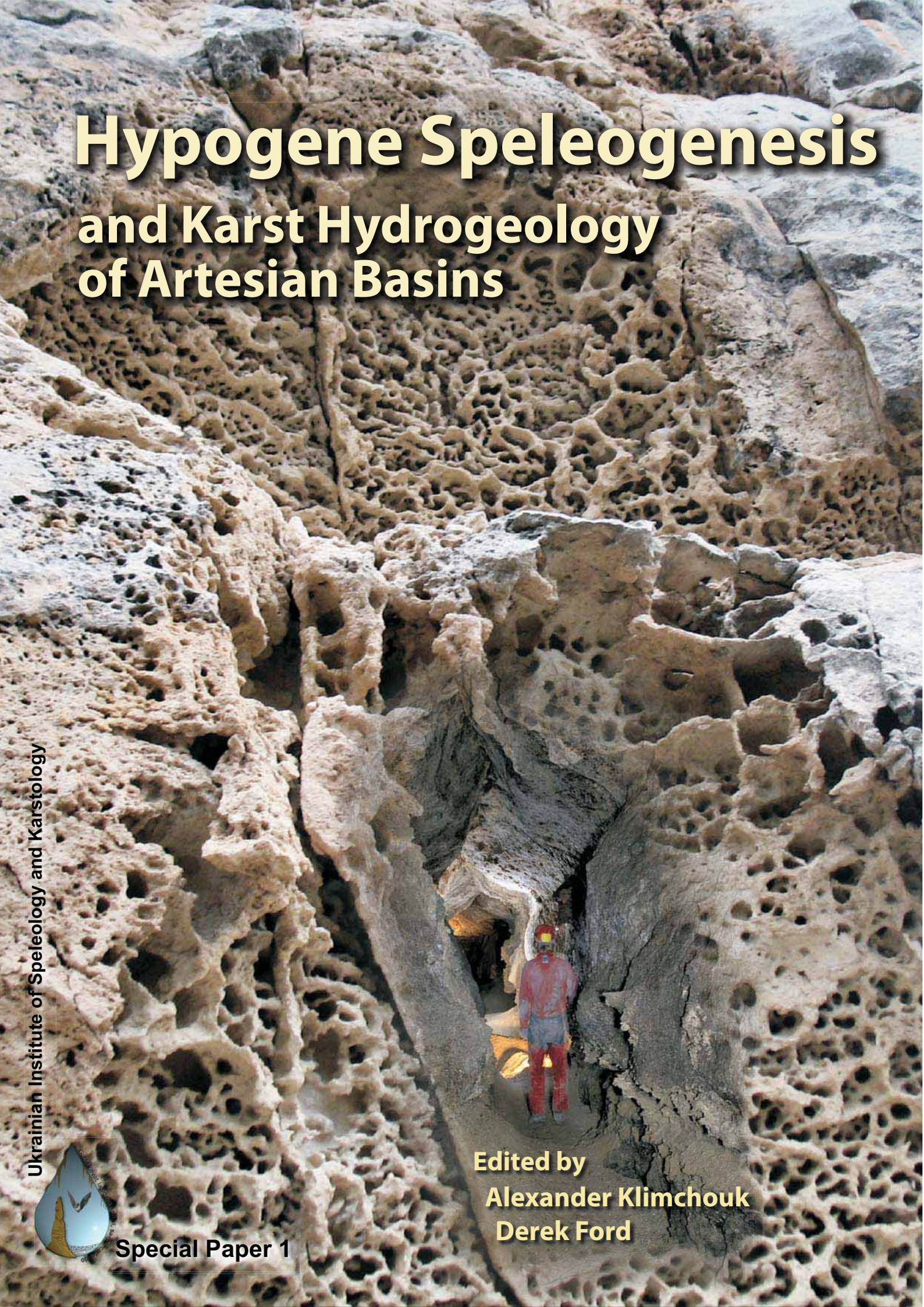
Hypogene Speleogenesis and Karst Hydrogeology of Artesian Basins



Edited by
Alexander Klimchouk
Derek Ford

Ukrainian Institute of Speleology and Karstology

Special Paper 1

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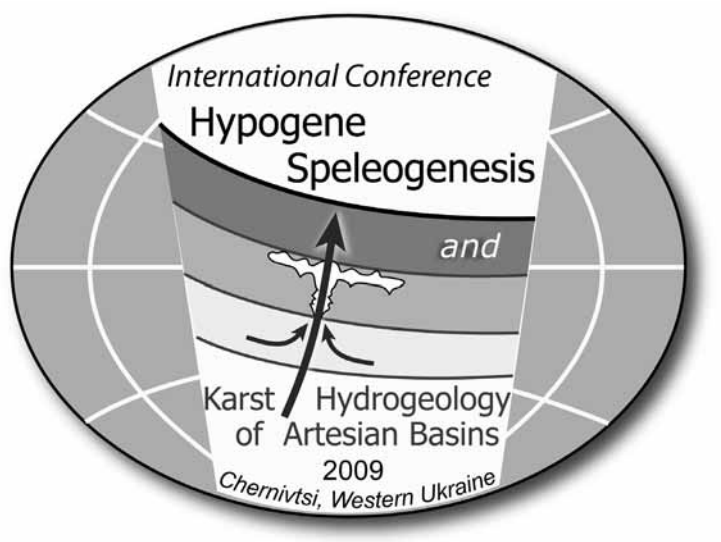

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Front cover: Tafoni on a limestone escarpment in the Crimea Piedmont (background) and a passage in Slavka Cave, Western Ukraine (inset). Photos and collage by A.Klimchouk

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

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CONTENTS

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

Stephan Kempe[1], Ahmad Al-Malabeh[2], and Horst-Volker Henschel[3]

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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, Uwaiyed 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 m^2 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 H_2S or CH_4 that reacted with oxygen carried down by sinking surface seepage water according to:

$$H_2S + 2O_2 \rightarrow 2H^+ + SO_2^{2-} \longleftrightarrow H+ + HSO_4^{2-}$$

(e.g., Hill, 2000), and

$$CH_4 + O_2 \rightarrow 4H^+ + CO_2$$ (e.g., Valentine, 2002).

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 H_2S-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

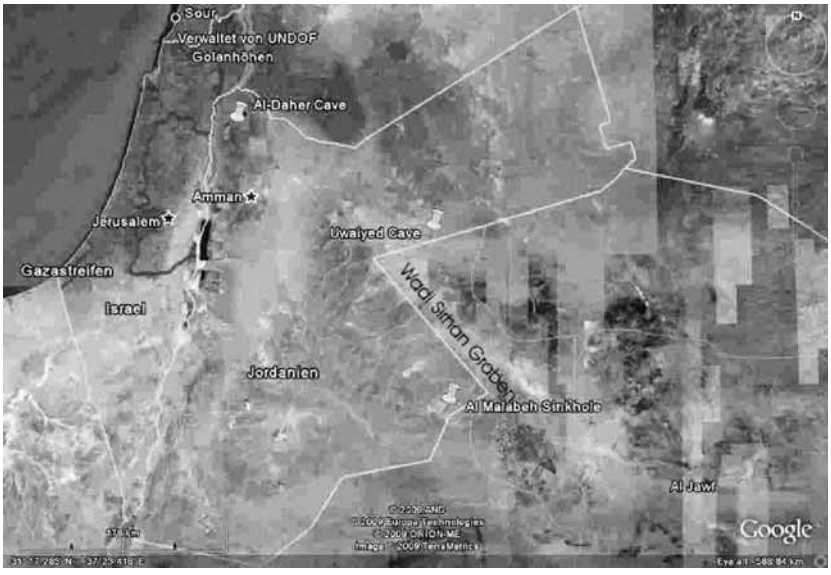

Figure 1. Google Earth View of Jordan with approximate locations of the three hypogene kartification sites.

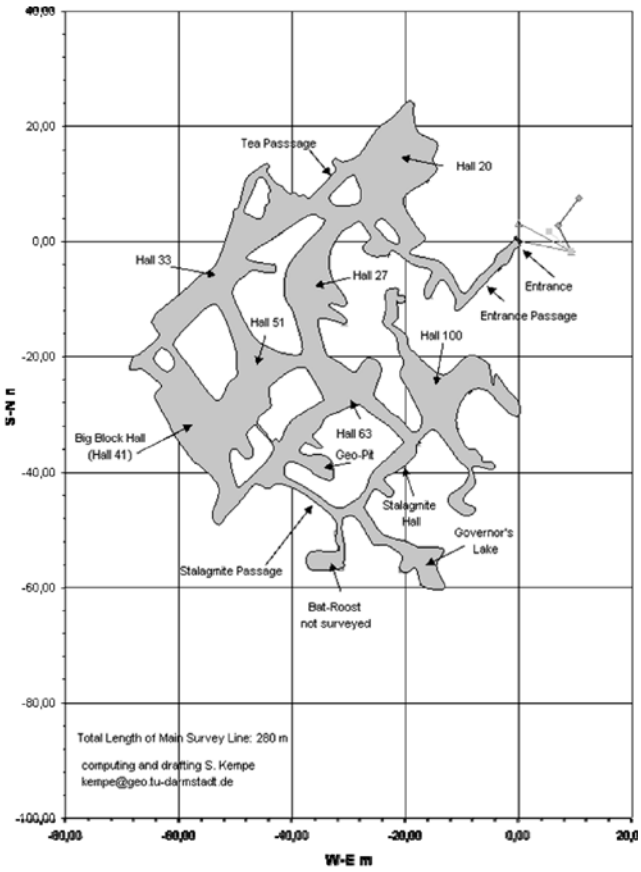

Figure 2. Map of Al-Daher Cave, a typical maze cave. Surveyed 26.-27.09.2003, 28.03.2004, S. Kempe, H.-V.Henschel, A. Al-Malabeh, A. Al-Shraideh (modified after Kempe *et al.*, 2006).

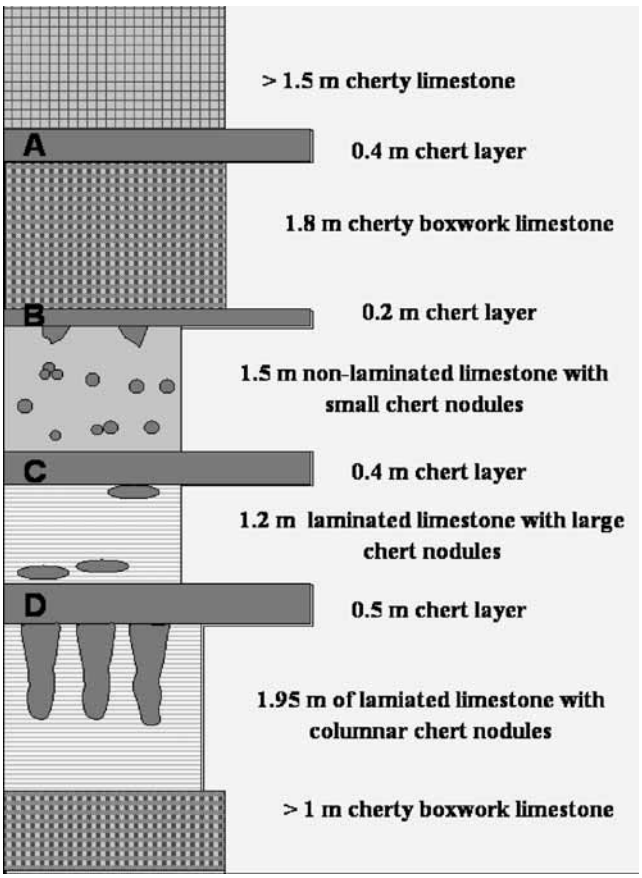

Figure 3. Stratigraphy of Al-Daher cave that developed within several limestone layers of varying texture and chert contents, separated by four distinct chert beds (modified after Kempe *et al.*, 2006).

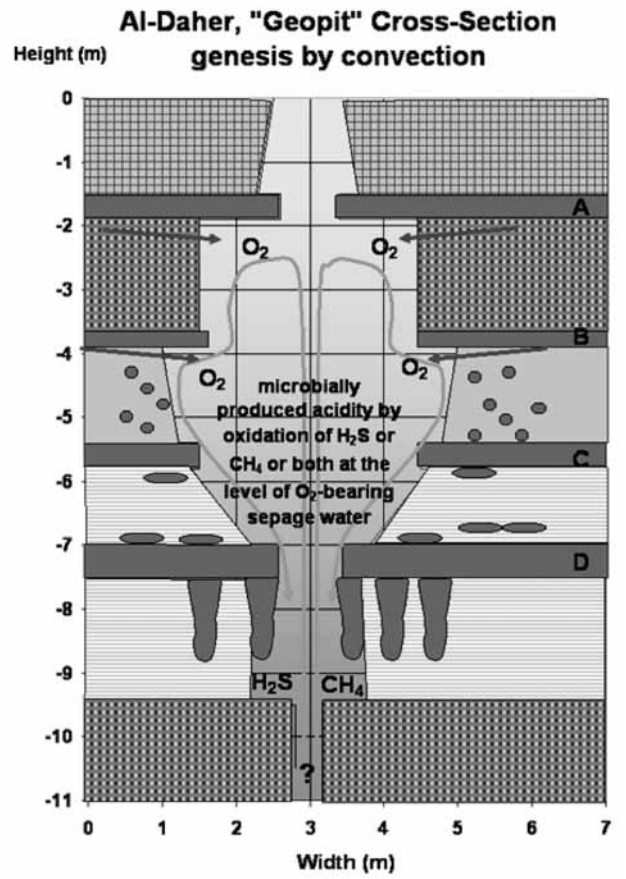

Figure 4. Model of the convection within the water-filled Geopit, part of Al-Daher Cave. Water from the deep-seated source carrying H_2S or CH_4 or both rises convectively up into the cave (driven by temperature or solution concentration or both). Seepage water, containing oxygen, that can percolate 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).

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, Uwaiyed 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 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 Sinkhole. 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 Sinkhole to the entrance ca. 20 m higher (not speleorope 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.

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