

VULCANOSPELEOLOGY IN SAUDI ARABIA

VULKANOSPELEOLOGIJA V SAVDSKI ARABIJI

John J. PINT¹

Abstract

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John J. Pint: Vulcanospeleology in Saudi Arabia

Saudi Arabia has over 80,000 km² of lava fields, locally known as harrats. However, only a few studies of lava caves in Saudi Arabia have been published internationally. This article summarizes the published and unpublished findings of all known expeditions to lava caves in the kingdom. Prior to 2001, reports of such caves were mostly limited to sightings of collapse holes by vulcanologists surveying the lava fields. Few caves were entered and no cave maps were produced. In 2001 and 2002, expeditions were organized to Harrat Kishb, located northeast of Makkah (Mecca). Three lava caves measuring 22 m, 150 m and 320 m in length were surveyed and the collapse features of a fourth cave—possibly over 3 km long—were studied. Two throwing sticks, a plant-fiber rope and the remains of stone walls were found in some of these caves. In 2003, lava tubes measuring 530 m and 208 m were surveyed in Harrat Ithnayn and Harrat Khaybar, respectively. Animal bones and coprolites were found in both caves. In 2003 and 2004, studies were carried out in Hibashi Cave, located in Harrat Nawasif/Al Buqum, 245 km southeast of Makkah. The cave was surveyed (length: 689.5 m) and found to contain two layers of burnt bat guano overlying a bed of redeposited loess up to 1.5 meters deep and up to 5800 years old. At least 19 different minerals were found, three being extremely rare organic compounds related to the guano combustion. Bones, horns, coprolites, ruins of a wall and a human skull ca. 425 years old were also found. There is evidence of many more lava caves in Saudi Arabia, particularly in Harrat Khaybar. Formal archeological and biological studies have not yet been carried out in Saudi lava caves but may produce interesting results.

Key words: lava tubes, lava caves, Saudi Arabia, vulcanospeleology, speleology.

Izveček

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John J. Pint: Vulkanospeleologija v Savdski Arabiji

V Savdski Arabiji je preko 80.000 km² lavinih polj, lokalno poznanih pod imenom harrat. O njih je bilo do sedaj v mednarodni literaturi objavljenih le malo študij. Članek povzema objavljena in neobjavljena odkritja vseh znanih odprav v lavine cevi. Pred letom 2001 so vulkanologi poročali o udorih, ki so jih opazili med raziskovanji polj v lavi, obiskali pa so le malo jam, jamskih načrtov ni bilo. V letih 2001-2002 so organizirali več odprav na območje Harrat Hishb, nedaleč od Meke. Raziskali in izmerili so tri jame, dolge 22, 150 in 300 m. Poleg tega so raziskovali tudi podobne oblike četrte jame, verjetno dolge preko 3 km. V jamah so našli dve sulici, vrv iz rastlinskih vlaken in ostanke kamnitega zidu. Leta 2003 so na območju polj v lavi Harrat Ithnavn in Harrat Khaybar raziskali in izmerili 530 in 208 metrov dolgi jami. V njih so našli živalske kosti in koprolite. V letih 2003-2004 so raziskovali v jami Hibashi na območju polja Harrat Nawasif/Al Buqum, 246 km jugovzhodno od Meke. Jama je bila izmerjena v dolžini 690 m, v njej pa so našli dve plasti izgorelega netopirskega gvana, ki pokriva plast presedimentirane naplavine, debele 1.5 m in stare do 5800 let. V jami je bilo najdenih vsaj 19 različnih mineralov, od tega so trije izredno redke organske spojine, nastale kot posledica izgorevanja gvana. Našli so bile tudi kosti, rogove, koprolite, ostanke zidov in človeško lobanjo staro 425 let. V Savdski Arabiji je še veliko neraziskanih cevi v lavi, predvsem na območju Harrat Khaybar. Pravih arheoloških in bioloških raziskav še ni bilo, si pa lahko od njih veliko obetamo.

Ključne besede: cevi v lavi, jame v lavi, Savdska Arabija, vulkanospeleologija, speleologija.

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INTRODUCTION

This article presents a brief history of Vulcanospeleology in the Kingdom of Saudi Arabia and summarizes the known studies carried out in Saudi lava caves. Some of these studies have been published internationally (Forti *et al.*, 2004; Forti, 2005; Pint and Pint, 2005) or locally in Saudi Arabia (Roobol *et al.*, 2002; Pint *et al.*, 2005). Others are alluded to in non-scientific field trip reports on the Saudicaves web site (www.saudicaves.com). Many other details still remain in the field notes of the speleologists who visited the caves. It is hoped that this article will assist researchers and authorities in ascertaining what is

presently known about lava caves in Saudi Arabia and in determining the nature and direction of future vulcanospeleological studies on the Arabian Peninsula.

Fig. 1 shows the location of most of the lava fields (Harrats) of Saudi Arabia, which cover an area of at least 80,000 km². Cave locations are given in the text below, but seconds of latitude and longitude have been omitted, in order to help protect these caves from accidental damage or deliberate vandalism. The exact locations of these caves can be found in Pint, 2002.

MAJOR LAVA FLOWS (HARRATS) OF SAUDI ARABIA

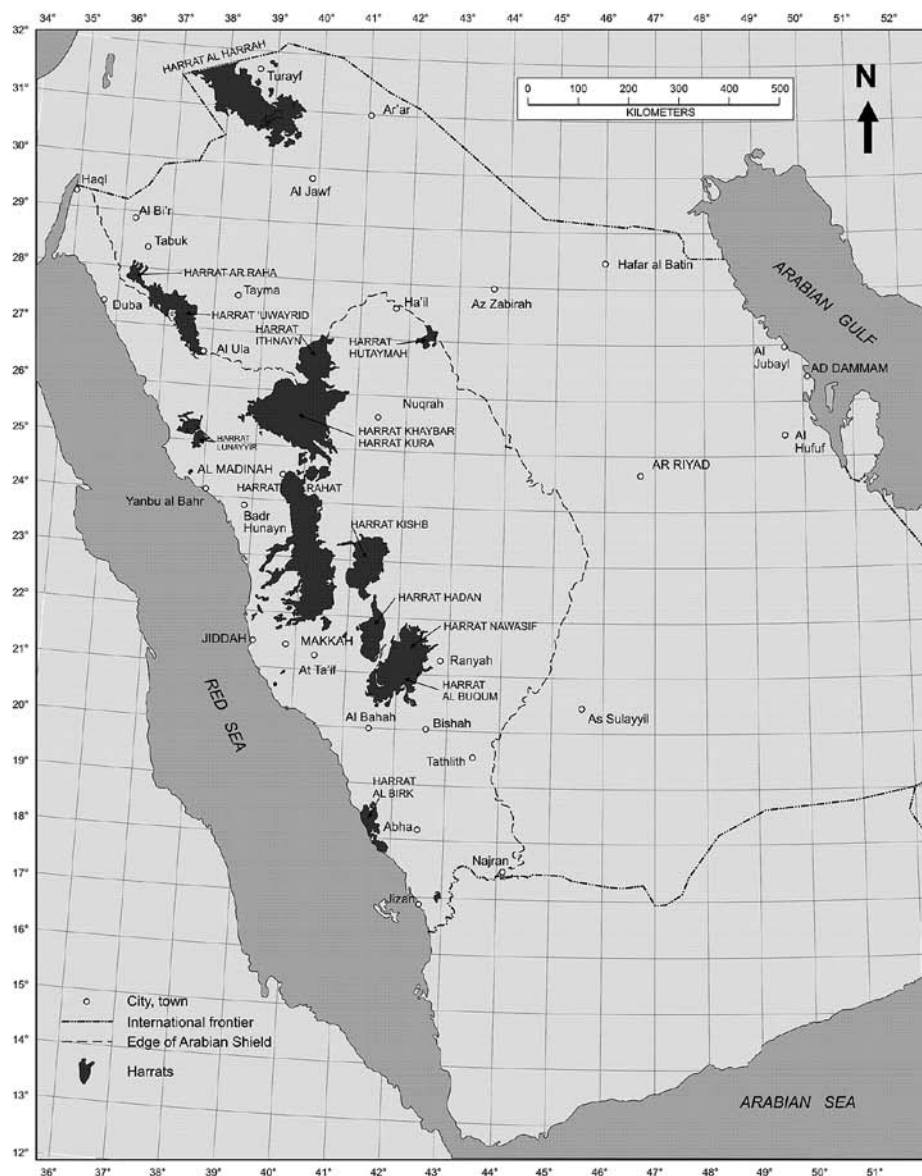


Fig.1: Map showing the major Cenozoic lava fields of Saudi Arabia.

EARLY STUDIES

Roobol and Camp (1991a) reported the existence of lava-tube caves up to 10 m high on Harrat Khaybar, a large lava field north of Medina. In one of these caves—located in a flow from Jebel Qidr Volcano—delicate lava stalactites were observed. A 100-meter-long lava tube in southern Harrat Khaybar was found to contain a fumarole at its deepest point. In another publication, Roobol and Camp (1991b) describe lava tubes on Harrat Kishb, which is located northeast of Mecca. In particular, they mention seeing the collapse holes of a lava tube which might be 3 km long.

REPORT ON THERMAL ACTIVITY IN A LAVA TUBE

Geologist Mahmoud Al-Shanti reports that his father, Dr. Ahmed Al-Shanti, one of Saudi Arabia's most eminent geologists, once investigated reports that an individual had suffered severe leg burns inside a cave probably located in Harrat Khaybar. Because the cave appeared to be inside a lava field and might indicate renewed thermal activity in the area, the government requested Dr. Al-Shanti to investigate. A visit to the cave in question proved that the source of heat was a smoldering fire beneath the surface of a large bed of dry guano (Al-Shanti, 2003). The only other cave in Saudi Arabia where guano fires have been documented is Ghar Al Hibashi (see below).

EARLY MEASUREMENT OF KAHF AL SHUWAYMIS

Perhaps the first attempt to accurately map a lava tube in Saudi Arabia was made by Mamdoah Al-Rashid, headmaster of the Shuwaymis school system, who used a 50 m-long tape to measure the length of Kahf Al Shuwaymis, located in Harrat Ithnayn and described below. The date of this event is not recorded, nor is there any reference to the use of a company, but Mr. Rashid's calculation of the cave's length (500 m) comes very close to the length of 530 m measured in a recent survey using a compass and a Disto laser measuring device (Fig. 7). If the length of side passages (30 m) is removed from the total, Mr. Rashid's results are exactly on the mark (Rashid, 2002).

While the above reports and incidents indicate that Saudi Arabia does indeed have lava caves, they did not result in the production of lava-cave maps or studies of the genesis, nature or content of such caves. This situation changed in November of 2001 when Dr. John Roobol led an expedition to the vicinity of Jebel Hil Volcano in Harrat Kishb. The explicit purpose of the expedition was to locate and survey lava caves, as well as to describe them accurately.

RECENT STUDIES

THE KISHB SURVEYS

The first expedition to Harrat Kishb took place November 10-14, 2001, led by Dr. J. Roobol, J. Pint and M. Al-Shanti. The project took place at the urging of Dr. William Halliday, member and founder of the Commission on Volcanic Caves of the International Union of Speleology (UIS). By coincidence, Dr. Roobol had received, from geologist Faisal Allam, several photographs of cave entrances found some 6 km east of Jebel Hil in Harrat Kishb. Accordingly, the goals of the expedition were to locate the caves shown in the photographs as well as to precisely locate the collapse holes west of Jebel Hil which were observed by Roobol and Camp (1991b) and thought to be entrances to a lava tube.

After much searching, the photographed caves were located and one of them, Mut'eb Cave, was surveyed. In addition, the GPS locations of twelve collapse entrances of the Jebel Hil Lava Tube were taken, a difficult undertaking since 12 km of mostly a'a lava had to be traversed on foot.

A second visit to Harrat Kishb was made from February 2-5, 2002, again led by J. Roobol, J. Pint and M. Al-Shanti. Ghostly Cave was surveyed and a new cave, Dahl Faisal, was located and surveyed. The results of the Kishb Surveys were published in Roobol *et al.*, 2002.

GEOLOGY OF THE HIL BASALT

All the surveyed caves found in Harrat Kishb are located in the Hil Basalt, which is a basaltic lava field younger than one million years, with an area of 5,892 km², centered about 270 km northeast of Jeddah. These deposits comprise both scoria cones and lava flows which were probably formed during a moist climatic period or pluvial interval and which are distinguished from overlying subunits because they are significantly eroded (Roobol *et al.*, 2002).

MUT'EB CAVE

Mut'eb Cave, or Kahf Al Mut'eb is registered as number 124 in Pint, 2002 and is located at 22°55'N, 41°24'E.

Geological setting

The cave is found in a sinuous ridge of smooth, hard pahoehoe lava curving around an older, obstructing scoria cone in the volcanic deposits of the Hil Basalt.

Description

The cave is 150 m long. The entrance to the cave measures 3 x 7 m and is found on the eastern side of a collapse 20 m in diameter. There are remains of an ancient, man-made wall across the front of the cave. A single passage trends east, sometimes reaching a width of 20 m. The passage height varies from 3 to 5 m. Sand or clay-rich sediment cover the floor to an undetermined depth. The cave contains abandoned wasps' nests, mounds of rock-dove guano, animal bones, and bat urine stains on the walls and ceiling. A 40-cm-long cord composed of long plant fibers, with one knot in it, was hidden beneath a flat rock at the eastern end of the cave (Roobol *et al.*, 2002; Pint and Pint, 2005).

Comments

To the author's knowledge, Mut'eb was the first lava cave in Saudi Arabia to be accurately surveyed (Grade 5D in the survey classification system used by the British Cave Research Association. This requires a magnetic survey with horizontal and vertical angles measured to $\pm 1^\circ$; distances recorded to the nearest centimeter, station positions identified to less than 10 cm and measurement of

significant changes in passage dimensions at survey stations and wherever needed.) See Fig. 2.

Because a man-made structure is found at the entrance to this cave and because an apparently ancient artifact was found deep inside, it is suggested that the cave be investigated by archeologists. Note that Mut'eb Cave, in Harrat Kishb, is located approximately 55 km east of the celebrated Darb Zubaydah, a well-marked trail complete with shelters, water wells and reservoirs one day's march apart (See Fig. 12). The trail led from Baghdad to Mecca and was built by Queen Zubaydah, the enterprising wife of Caliph Harun al-Rashid around the beginning of the ninth century A.D.

GHOSTLY CAVE

Ghostly Cave or Kahf Al Ashbaah is registered as number 123 in Pint, 2002 and is located at 22°55'N, 41°25'E.

Geological setting

The cave is found in a flat area of basaltic pahoehoe lava in the volcanic deposits of the Hil Basalt.

Description

The cave is 320 m long. The entrance is a collapse 10 m in diameter with a 7 m drop to a flat floor below. The passage leads off east and west. Up to 50 stalagmite-like mounds of rock-dove guano are found just inside the entrance to the western passage along with the remains of a stone wall partly buried beneath bird guano. The cave passages

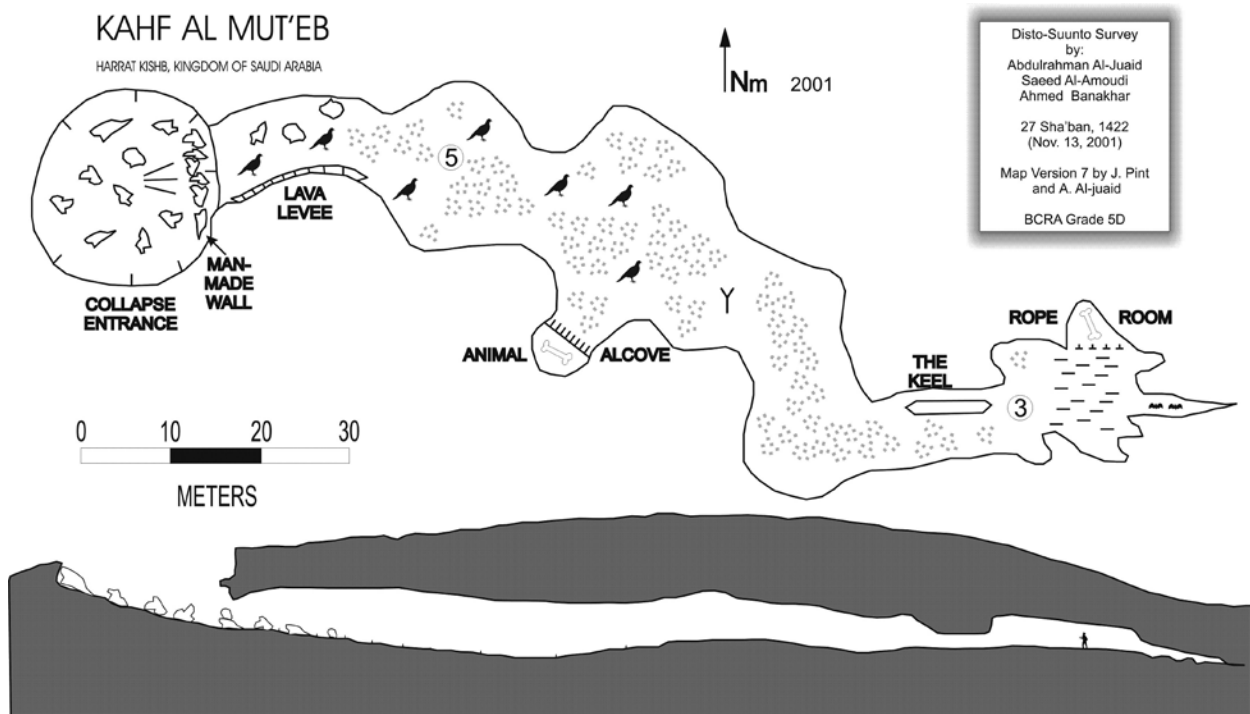


Fig. 2: map of Mut'eb Cave.

KAHF AL ASHBAAH (GHOSTLY CAVE) HARRAT KISHB, KINGDOM OF SAUDI ARABIA

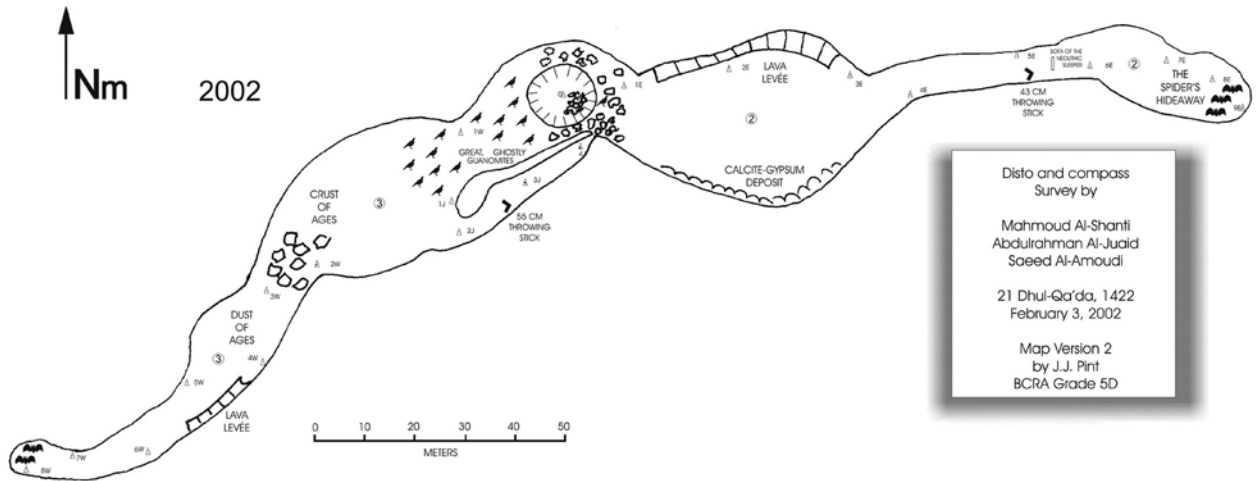


Fig. 3: map of Ghostly Cave.



Fig. 4: Throwing sticks found in Ghostly Cave are flat on the bottom and curved on top to provide aerodynamic lift.

have a maximum width of 30 m and vary in height from 1 to 3 m. Both passages have white, calcareous patches on the ceiling and a thick layer of powdery dust on the floor. Analysis of the dust showed high concentrations of calcium, phosphate and potassium salts. Bats are found at both extremes of the cave. Two flat, L-shaped wooden throwing sticks were found in dark areas of the two passages, resembling similar instruments depicted in Neolithic rock art found in Saudi Arabia. See Fig. 3 and 4 (Roobol *et al.*, 2002; Pint and Pint, 2005).

Comments

Man-made constructions and two ancient throwing sticks were found in this isolated and difficult-to-enter cave. Digging in the sediment which completely covers the cave floor may produce historically or archeologically important finds. As noted in the comments on Mut'eb

Cave, Ghostly Cave is located approximately 55 km east of the celebrated Darb Zubaydah (see Fig. 12).

DAHL FAISAL

Dahl Faisal is registered as number 162 in Pint, 2002 and is located at 23°11'N, 41°27'E.

Geological setting

The cave is found in a nearly flat-lying "whale-back" lava flow of the Jabal Zuwayr volcano. The flows of this volcano consist mainly of basanite and alkali olivine basalt with small volumes of hawaiite, phonotephrite and phonolite and are located in the northern portion of the Hil Basalt.

Description

Dahl Faisal is 22 m long. The cave is entered through a smooth, 3-m-long pipe, 80 cm diameter at its narrowest

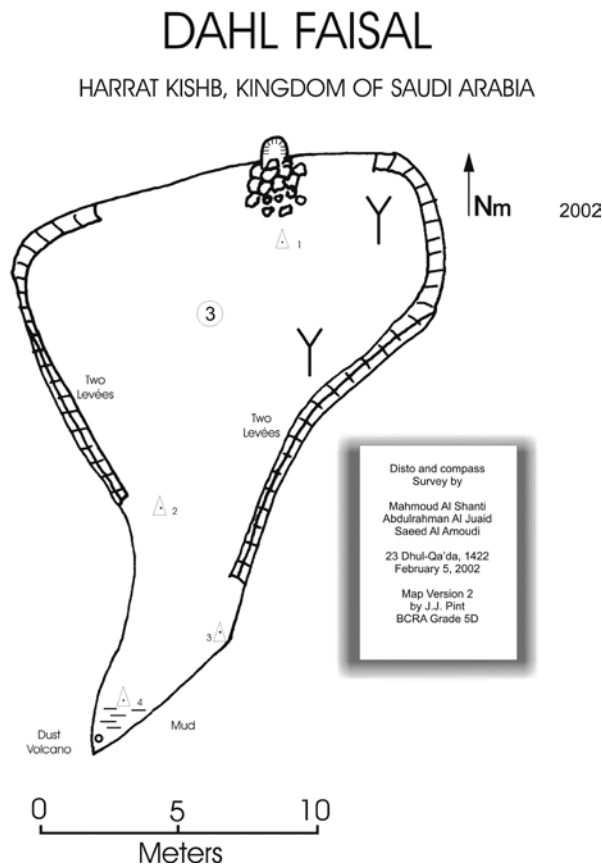


Fig. 5: Map of Dahl Faisal.

point, oriented at a 60° angle. This appears to have formed when the cave was created. Below the entrance tube lies a heap of rocks apparently piled up by people using the cave in the past. Dahl Faisal consists of one room, 17 x 22 m, with a maximum ceiling height of 3 m. Sediment of unknown depth covers the original floor. The cave contains basaltic stalactites, stalagmites and lava levées. Desiccated animal scat apparently from wolves, hyenas and foxes was also found. See Fig. 5 (Roobol *et al.*, 2002; Pint and Pint, 2005).

Comments

Dahl Faisal is located 60 km east of Darb Zubaydah and about 70 km southeast of Mahad adh Dhahab, an operating gold mine and reputedly the site of one of King Solomon's Mines. See Fig. 12. Carbon-14 dating of wood from fires used for smelting suggests that the mines are 3,000 years old. This information, together with historical studies, indicate that gold, silver and copper were indeed recovered from this region during the period considered by some to be the reign of King Solomon: 961-922 B.C. (Kirkemo *et al.*, 1997, Levy *et al.*, 2004). Evidence of human use and the proximity of

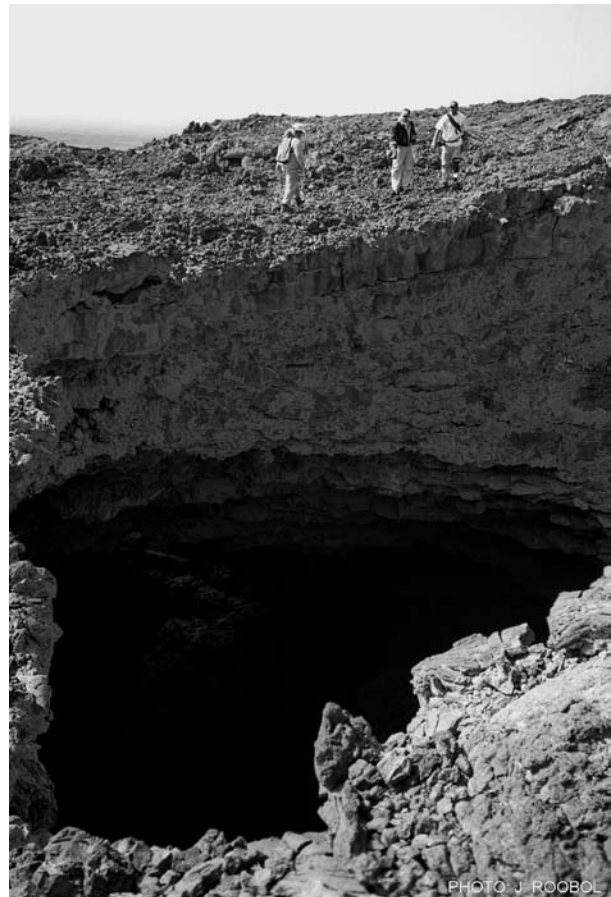


Fig. 6: Collapse Structure 6 of the Jebel Hil lava tube, looking west, showing the upper part of the lava tube with geologists standing on the roof.

the cave to known historical sites, suggest that it could contain artifacts.

JEBEL HIL LAVA TUBE

This lava tube extends westwards from Jebel Hil. Along its length are aligned small rootless shields, collapse holes, subsided areas and one area of local updoming. Twelve such features were located, one of which is shown in Fig. 6. The lava tube is up to 20 m high and the depth of its floor beneath the surface varies from 28.5 to 42.5 m, measured by Disto Laser Measuring Device at each hole. The surface features of this lava tube were mapped and described, and they suggest that the tube is at least 3 km long. However, the cave itself was not entered. A detailed map and description of these features are given in Roobol *et al.*, 2002.

OTHER CAVES LOCATED ON HARRAT KISHB

Two other lava caves, First Cave and Bushy Cave were also located during the Kishb surveys. The entrance to First Cave is a collapse 20 m deep in what appeared to be

a lava tube. It was not entered due to apparent instability of the entrance walls. Bushy Cave is a nearly round room 12 x 13 m, possibly formed by a gas bubble. It was sketched, but not surveyed.

THE SHUWAYMIS EXPLORATIONS

A reconnaissance for caves in Harrat Ithnayn and northern Harrat Khaybar was undertaken by J. and S. Pint, November 6 to 10, 2002. The head of the local school district, Mamdoah Al-Rashid showed them Dahl Rumahah in northern Harrat Khaybar and Kahf Al Shuwaymis in Harrat Ithnayn. Both caves were briefly entered and photographed. April 14-17, 2003, J. Pint and M. Al-Shanti led a trip to this area. Kahf Al Shuwaymis was surveyed as well as collapses and other features between the cave and the source volcano, Hazim al Khadra. Sept. 14-17, 2003, the same team returned to the Shuwaymis area to map Dahl Rumahah. No geological report on the Shuwaymis explorations was published by Saudi Geological Survey due to the cutting of funding in 2005.

KAHF AL SHUWAYMIS

Kahf Al Shuwaymis or Shuwaymis Cave is registered as number 177 in Pint, 2002 and is located at 26°14'N, 40°07'E.

Geological setting

This cave is located at the foot of Hazim Al Khadra Volcano in Harrat Ithnayn, which is a lava field centered 240 km north-northeast of Medina. This lava is mildly alkaline with low Na and K contents and its age ranges from ~3 million years to present. The cave is entered through one of at least seven collapses located in a roughly straight line 2.5 km long with a bearing of 164° from the center of the volcano.

Thermal activity, manifested in fumaroles emanating from shelter caves, was noted along this line, at a distance of 560 m from the lip of the volcano and 2.1 km from Kahf Al Shuwaymis.

Description

The cave is 530 m long. The entrance is a collapse hole 15 m in diameter overlooking the floor of a horizontal passage 5 m below. A steep breakdown slope leads to a mostly south-trending passage varying in width from 4 to 15 m, with a typical height of about 10 m. Speleothems are limited to lava stalactites under 5 cm in length. There are at least four caches of animal bones, presumably carried into the cave by hyenas. A narrow channel of sand runs almost the entire length of the cave, indicating water flow in the past. Air currents entering the cave were noted from the east wall near station 12 and from the floor near station 17. There is a small, parallel upper passage between stations 8 and 9. Evidence of present-day, small-

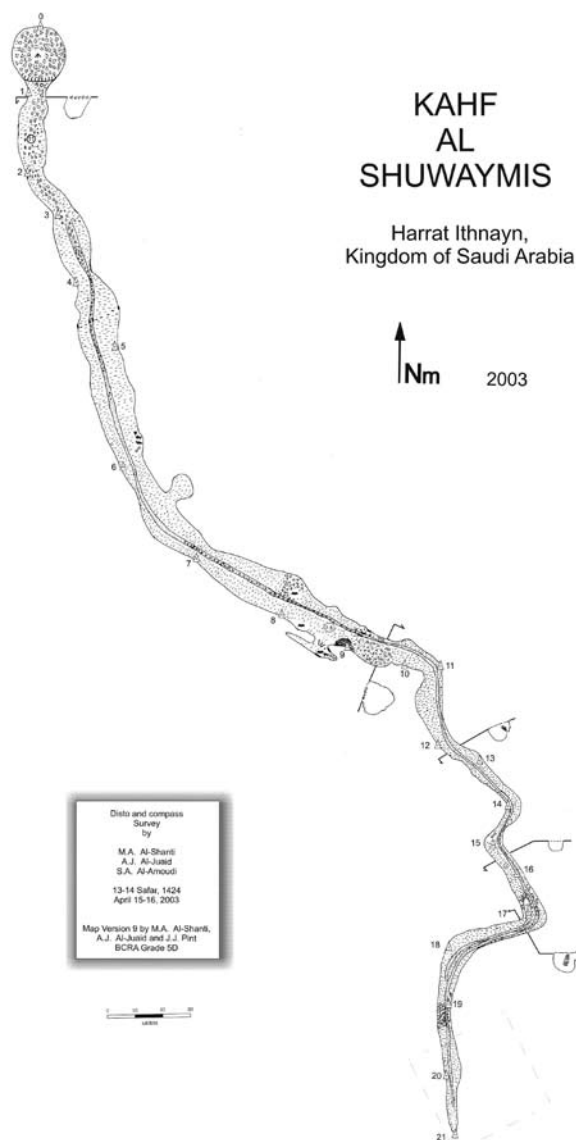


Fig. 7: Map of Kahf al Shuwaymis.

animal activity was noted in this passage. Radon gas levels of 17.4 Pci/L and 10.2 Pci/L were measured inside this cave. The cave map is shown in Fig. 7 (Pint, 2004).

Comments

Archeologist Marian Bukhari briefly visited this cave in 2005. She states that the cave was used as a dwelling and may contain burial pits (Bukhari, 2006). It should be noted that this cave lies only 26 km northeast of a major Neolithic rock-art site. Petroglyphs from the site are shown in Fig. 8.

DAHL RUMAHAH

Dahl Rumahah (also spelled Romahah) is registered as number 176 in Pint, 2002 and is located at 25°56'N, 39°54'E.



Fig. 8: Ostriches, camels and Nabatean script on a sandstone cliff located 26 km from Kahf Al Shuwaymis.

Geological setting

This cave is located 169 km NNE of Medina in the northern part of Harrat Khaybar, part of an area comprising 20,560 km² of lava flows. The lavas and volcanoes in Harrat Khaybar are mildly alkaline with low Na and K

low wall outside the entrance channels rainwater into the cave, which local people say was used as a reservoir. Most of the cave is a single, nearly flat, northwest-trending passage from 1.5 to 7 m wide and 2.5 m high. Rooms north of station 7 and south of station 11 terminate in very low crawls which may be connected. In September of 2003, it was found that dry sediment covered the floor of the southeast part of the cave while mud floored the northwest portion and occurred along part of the eastern wall. Water droplets and cave slime cover the ceiling at the far northwestern end of the cave. A natural bridge 1.5 m thick crosses the passage near its western end. Calcium-and-carbonate-rich percolation water leaked through ceiling cracks, producing white stalactites, curtains and flowstone. There is a large area of bones, including hedgehog and porcupine quills, mixed with desiccated hyena, wolf and fox coprolites. The highest radon level noted in Saudi caves was found in Ruma-hah: 119 Pci/l. The cave's temperature was measured at 25°C. Within a period of four hours the relative humidity rose from 68% to 74% at one point in the cave. The cave map is shown in Fig. 9 (Pint, 2004).

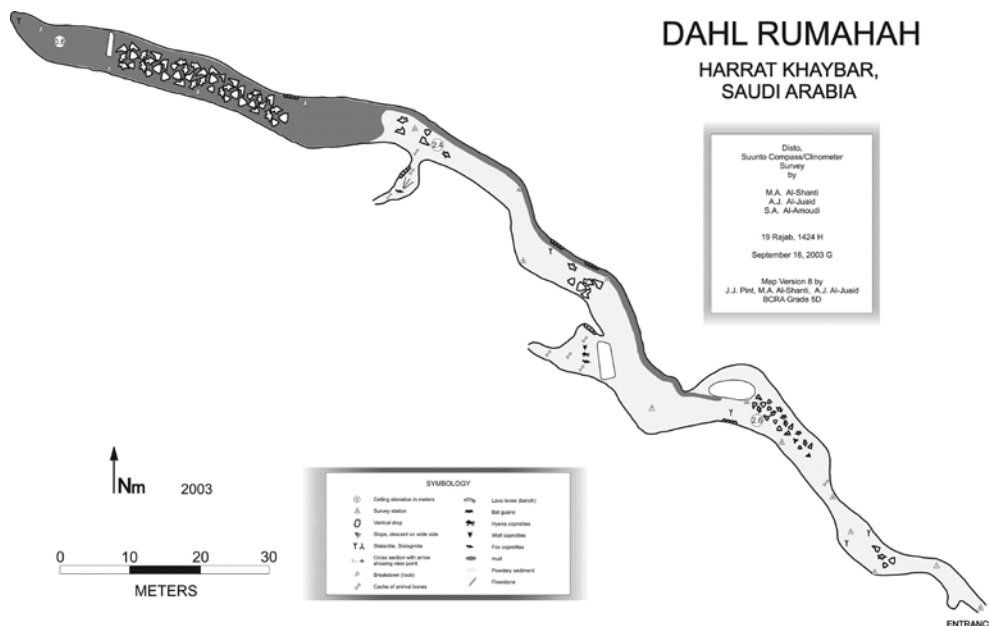


Fig. 9: Map of Rumahah Cave.

content and include alkali olivine basalt (AOB), hawaiite, mugearite, benmoreite, trachyte and comendite. The age of the Khaybar lavas ranges from ~5 million years old (orangish flow field) to post-Neolithic (reddish-orange lava flows), to historic (black lava flows). Rumahah Cave is found in a black flow.

Description

The cave is 208 m long and has a horizontal entrance 1 m high by 1.5 m wide, set in a small depression. A long,

Comments

The radon level found in this cave seems high for a lava tube. It is possible that radon gas is entering the cave through cracks in the floor. The complete skeleton of an unknown animal is found in this cave, cemented to the floor by calcitic speleothems. There is evidence (including construction of a water-retaining wall) that this cave has long been used as a water reservoir. It should be noted that this cave lies only 22 km south of a major Neolithic rock-art site and is located roughly 126 km east of the old Nabatean Incense

Trail between Yemen and Petra. A paleontological and archaeological survey of the cave should be undertaken.

THE HIBASHI STUDIES

Six field trips to Hibashi Cave in Harrat Nawasif/Al Buqum took place between January 2003 and June 2004, led by J. Pint and/or M. Al-Shanti. Samples of cave formations and debris were collected and sent to cave mineralogist Prof. Paolo Forti for analysis. Due to the many unusual and some rare secondary minerals found in the cave, Ghar Al Hibashi was added to the list of the ten mineralogically most important lava caves in the world (Forti *et al.*, 2004; Forti, 2005).

Dr. Peter Vincent and Fayek Kattan participated in a visit to the cave on August 31, 2003 to take samples of the sediment overlying the original cave floor, for age-dating by Optically Stimulated Luminescence (OSL). A sample from the human skull found lying on the surface, deep inside the cave, was sent out for carbon-dating.

Redeposited loess (10 micron mean particle size) covers most of the cave floor. Researchers planning for the exploration of Martian lava tubes are using photographs and maps of Hibashi cave to produce robotic motion simulations for testing the capabilities of microrobotic designs to navigate inside the caves of Mars (Pint *et al.*, 2005).

HIBASHI CAVE

Hibashi Cave or Ghar Al Hibashi (also spelled Hebashi) is registered as number 180 in Pint, 2002, and is located at 21°08'N, 42°08'E.

Geological setting

Ghar Al Hibashi lies near the center of Harrat Nawasif/Al Buqum, a group of lava flows located east of Makkah (Mecca). These titaniferous, olivine basalts are described as gray to dark gray, vesicular, medium-grained and porphyritic (Ziab and Ramsay, 1986). Pint *et al.*, 2005, speculate that Ghar Al Hibashi may lie in basalt dated at ca. 1.1 million years by Hötzel *et al.*, 1978.

Description

The cave is 689.5 m long. The cave entrance is a collapse 14 m in diameter located in a slightly elevated area of a major basaltic flow emanating from a large crater to the southeast. A steep slope leads down to a gallery which intersects the east-west-oriented main passage of the cave. This passage is typically 12 m wide, increasing to 33 m at its eastern end. The height ranges from <1 m to >9 m. The cave map is shown in Fig. 10.

The floor of Hibashi Cave is mostly covered with as much as 1.5 m of loess (having lain up to ca. 5800

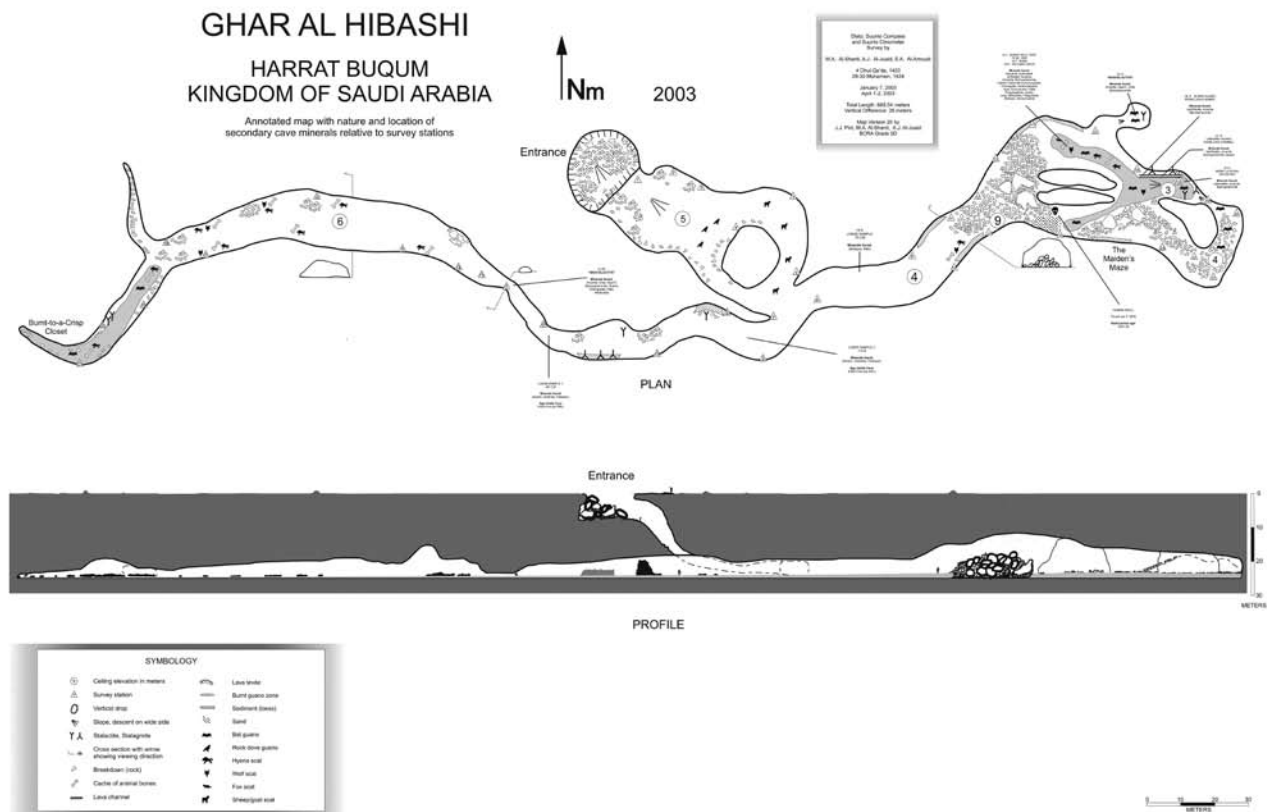


Fig. 10: Map of Hibashi Cave.

years inside the cave, according to OSL dating), underlying beds of burnt bat guano at the extreme ends of the main passage. Volcanic levees, stalactites and stalagmites are common. At least 19 different minerals were found in the cave, three of them being extremely rare organic compounds related to the guano combustion. Bats and small animals live in the cave. Bones, desiccated animal scat and a human skull ca. 425 years old (Fig. 11) were also found in the cave (Forti *et al.*, 2004; Forti, 2005; Pint *et al.*, 2005; Pint, 2005).



Fig. 11: Part of a human skull found inside Hibashi Cave and carbon dated at 425 ± 30 years BP.

Comments

The well-preserved scat of hyenas, wolves and foxes is found throughout the cave. Studies of plant material and other substances contained in these coprolites could be rewarding. Phytoliths preserved in the plant material may be used for identifying the plants and may shed light on the process of desertification which has taken place on the Arabian Peninsula. A wall built inside the cave indicates that it was used by humans at some point. Archaeologists, paleontologists and historians may wish to explore what may be hidden in the thick bed of loess covering the cave floor.

OTHER INVESTIGATIONS

On May 29 and 30, 2001, J. Pint flew over parts of Northern Harrat Rahat by helicopter. Pint noted areas of Pahoehe lava at $24^{\circ} 15' \text{ N}, 39^{\circ} 40' \text{ E}$; $22^{\circ} 34' \text{ N}, 39^{\circ} 20' \text{ E}$ and $24^{\circ} 28' \text{ N}, 39^{\circ} 44' \text{ E}$ and noted what appeared to be collapse entrances to lava caves at $24^{\circ} 17' \text{ N}, 39^{\circ} 41' \text{ E}$ and $24^{\circ} 21' \text{ N}, 39^{\circ} 42' \text{ E}$. Most of these locations may be difficult to access by vehicle or on foot. None of the sites observed from the air during this field trip have yet been visited.

In February of 2003, an attempt was made to survey Dahl Um Quradi, a lava tube located in southern Harrat Khaybar. J. Pint and M. Al-Shanti led this field trip with J. Shawali acting as guide. Just outside the cave entrance, SGS geologist Saeed Al-Amoudi was seriously injured and had to be rescued by helicopter, resulting in the cancellation of the survey. However, it was noted that the cave has a walk-in entrance measuring $2 \times 3 \text{ m}$ and a vertical (collapse) entrance 4 m in diameter and ca. 5 m deep. This lava tube may be $100\text{--}200 \text{ m}$ long. Jamal Shawali stated that there is another lava tube in the area, but this could not be visited.

In January, 2004, J. Pint, S. Pint and A. Gregory travelled to the center of Harrat Khaybar. The entrances to several lava tubes on the flanks of the basaltic strato-volcano Jebel Qidr were observed and photographed. According to Roobol *et al.* (2002) this volcano may have last erupted in 1800 A.D., suggesting that lava caves in this flow may be among the youngest and most pristine in Saudi Arabia.

In May of 2004, a search for lava caves in Harrat Harrah, in the extreme northwestern corner of Saudi Arabia, was undertaken by an SGS team led by Mahmoud Al-Shanti. This same lava flow extends across the border into Jordan, where several lava tubes have been found and studied (Kempe *et al.*, 2004; Kempe and Al-Malabeh, 2005). It was therefore hoped that lava caves would also be found on the Saudi side. Although no noteworthy caves were encountered, a well 13 m wide and $24\text{--}25 \text{ m}$ deep was found on a small basalt hill. Ancient script – apparently Thamudic – covers many rocks near the cave entrance suggesting that this well may have been in use at least 2,000 years ago. Due to the instability of the well's walls, it was not entered. The location of the well is given in Pint, 2002.

FUTURE POSSIBILITIES

POTENTIAL FOR THE FURTHER DISCOVERY
AND TOPOGRAPHY OF LAVA CAVES

Saudi Arabia has at least 80,000 km² of lava fields, roughly divided into twelve major *harrats*. During a short period of four years, six of these *harrats* were visited and in each of them some feature of interest to vulcanospeleologists was observed. The core team which located and/or entered these cavities consisted of only five individuals

(J. Pint, M. Al-Shanti, S. Al-Amoudi, A. Al-Juaid and S. Pint). It can only be concluded that with more time and/or more personnel, many more lava caves will be found in Saudi Arabia. This assertion, in the case of Harrat Khaybar, is backed up by the many references to lava-tube collapse holes in Roobol and Camp (1991a), including descriptions of numerous collapses on whale-back formations up to 25 km long, situated up to 25 km from

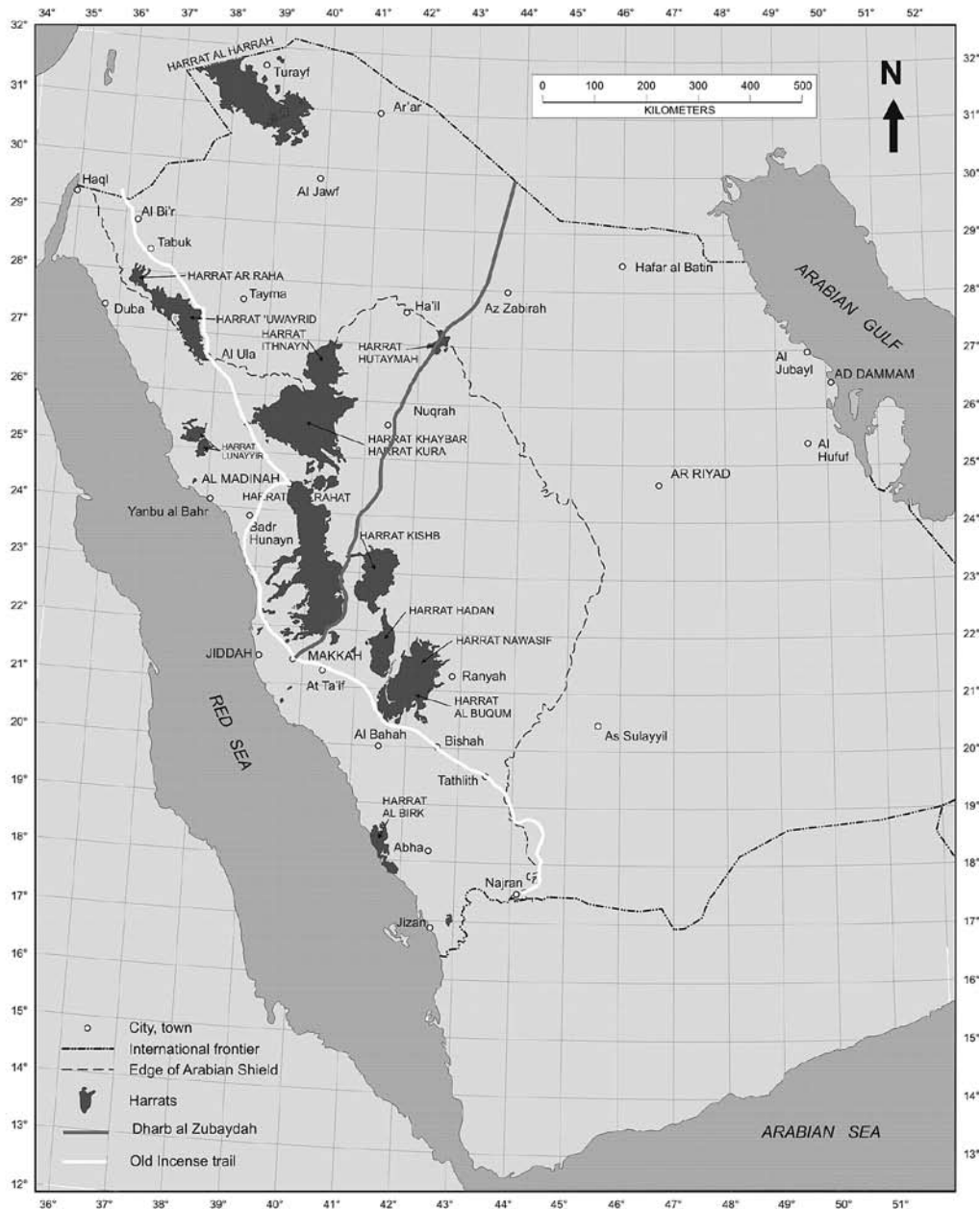
MAJOR LAVA FLOWS (HARRATS) AND CARAVAN TRAILS
OF SAUDI ARABIA

Fig. 12: Map of two ancient caravan trails in Saudi Arabia, showing lava fields. After Hussein Sabir, 1991.

the source volcanoes, indicating a potential for lava tubes up to 50 km long in Saudi Arabia. To these collapses may be added the lava tubes observed in southern and central Harrat Khaybar (mentioned above under Other Investigations) but not yet explored. At present the record for longest mapped lava cave in the Middle East is held by Al-Fahda Cave, 923.50 m long, in Jordan (Kempe and Malabeh, 2005).

POTENTIAL FOR NEW SPELEOLOGICAL STUDIES

- **Mineralogy:** Significant and unusual cave minerals were found in Hibashi Cave (Forti *et al.*, 2004; Forti, 2005) but such studies have yet to be undertaken in other Saudi lava caves.

- **Archeology:** Saudi lava caves lie near ancient sites of human habitation as well as adjacent to several ancient caravan trails (Fig. 12). All mapped lava caves contain structures or artifacts indicating use or visits by humans in the past. The only recorded visit to a Saudi lava cave by an archeologist (Bukhari, 2006) revealed indications that the cave may have been used as a dwelling and may contain burial sites. A search of archeological journals in February of 2006 suggests that few if any formal archeological studies have ever taken place in Saudi lava caves.

- **Biology:** Many lava caves were formed a million or more years ago and are located in remote areas of difficult access. Speleologists have found numerous indications that a variety of living creatures inhabit or inhabited the Saudi lava caves thus far explored (Roobol *et al.*, 2002; Pint *et al.*, 2005). A February 2006 search of biol-

ogy journals suggests that no biological studies have ever been carried out in any Saudi lava cave.

PROBLEMS RELATED TO LAVA-CAVE STUDIES

In some parts of the world, the scientific study of caves has a long history and over the years, organizations dedicated to speleology were founded in the private sector, the public sector or both. In Saudi Arabia, however, public realization of the nature, extent and resource value of the Kingdom's caves (limestone, lava and others) is a very recent phenomenon. Saudi Arabia has no laws specifically related to caves and no private or government organization specifically concerned with speleology. Many of the speleological studies carried out in Saudi Arabia were done by foreigners living in the country for only a few years. For the most part, the results of these studies were not properly recorded.

Recent speleological work by a semi-government organization (the Saudi Geological Survey) has laid an excellent foundation for speleology in Saudi Arabia. However, its work has been somewhat limited to the field of geology, which is only one of the several sciences included under the umbrella of speleology. Speleo-archeology and biospeleology, for example, have been neglected. The formation of a Kingdom-wide speleological organization, whether academic, governmental or recreational, might provide the coherence and stability that the Kingdom of Saudi Arabia needs for a sustained study of its caves.

CONCLUSIONS

It is likely that Saudi Arabia's lava fields contain a great many caves and possibly some of the longest lava tubes in the world. It is also likely that archeological, mineralogical and biological cave studies (among others) will yield important discoveries. Reconnaissance for caves in the lava fields of Saudi Arabia should, therefore, be resumed.

The establishment of a Kingdom-wide organization dedicated to speleology may foster studies in all branches of cave science and facilitate the preservation and dissemination of the resultant findings.

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