Al-Fahda Cave (Jordan): The Longest Lava Cave Yet Reported from the Arabian Plate

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The northeastern region of Jordan is volcanic terrain, part of a vast intercontinental lava plateau called the Harrat Al-Shaam. The centre is formed by young alkali olivine basaltic lava flows, the Harrat Al-Jabban volcanics or Jordanian Harrat (Al-Malabeh, 2005). The top most and therefore youngest flows are ca. 400 000 years old (Tarawneh et al., 2000). There we explored, surveyed and studied a total of twelve lava caves since September 2003, among them six lava tunnels (one has two caves) and five pressure ridges caves. A total of 2,525 m of passages have been surveyed until September 2005. This includes the 923.5 m long Al-Fahda Cave (Lioness Cave) that lies about 85 km east of Al-Mafraq, and 18 km northeast of Al-Safawi (Fig. 1). It was surveyed September 16th and 19th 2005 by the authors (Figs. 2 to 5). It is currently the longest reported from the Arabian Plate (J. Pint, pers. comm.). Table 1 gives the pertinent topographic data of the lava tunnel.

Al-Fahda Cave was found by the first author (Al-Malabeh) on a field trip in the Harrat by following an anthropogenic line along which stones had been cleared away. It led from a wadi Rajil (830 m a.m.s.l) in the north downslope to the main entrance of the cave (730 m a.m.s.l). It appears to have been a channel, designed to fill the cave with water during winter rains and used as a reservoir throughout the year (Fig.6). If this ever was very successful must be doubted, but mud cracks in the floor sediments and some rough "retention" walls indicate that water does enter the cave occasionally and that its management was attempted.

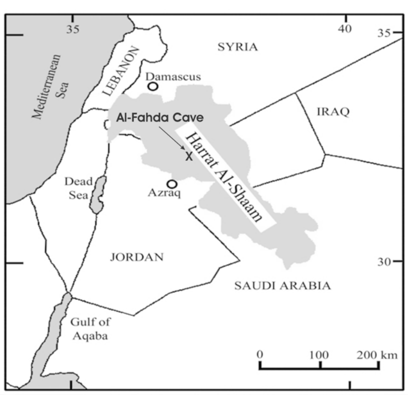

Figure 1. Location map of Al-Fahda cave and the extent of Harrat Al-Shaam (altered after Al-Malabeh, 1994).

Two entrances exist (Fig. 3). The main entrance (Fig. 7) gives access to the cave stretching for almost 490 m downslope (makai) and almost 190 m upslope (mauka). The tunnel is on the one hand amazingly wide (7.5 m) but also very low (average 1.2 m). The surveyed slope, with little guaranty to its accuracy, apparently is less than one degree (8.6 m altitude change on 755 m). This is very low, even when compared to the lower reaches of Hawaiian lava tunnels, and an important observation since it shows why the Harrat lava could spread so far: they were tube-fed pahoehoe lavas.

The cave shows, compared to Hawaiian tunnels (see data in Kempe, 2002; Kazumura, Keala and Huehue, some of the longest caves on Hawaii have sinuosities of 1.30, 1.25 and 1.2), a rather low sinuosity (1.13), in spite of the fact that it has a lower slope than the mentioned Hawaiian caves (1.51°, 1.51°, 4.58° resp.). The intuition that there should be a reverse relation between slope and sinuosity can therefore not be proven. The winding of the cave should have provided for a "Thalweg", i.e. a path along which the lava flow was maximal with slip-off and undercut slopes to the sides depending on curvature.

The main entrance (to which the surface channel was directed) is a "cold puka", i.e. a roof collapse at the apex of a 15 m wide hall, dating much later than the activity of the cave. Breakdown blocks allow easy access to the highest section of the cave.

The second, much smaller entrance, 60 m to the NE of the main puka, poses a riddle: it is situated to the side of the cave.(Fig. 8). It was certainly opened by humans, who removed blocks from a natural hole. A low crawl descents to the NW, gradually enlarging and joining the main tunnel after 15 m. This passage appears not to be a lava tube, but a wide and low separation between two lava sheets. Where the passage descents to the main tunnel we noticed remains of ceiling linings. Also benches composed of stranded and welded thin plates are found on both sides of the lower passage. This bench can be followed into the main tube, mostly makai. The next larger deposit is at St. 32 (niche or cove) and at St. 33. Each niche is smaller than the one before. These benches occur mostly on the southern wall, but also on the northern wall at Station 15. These lava benches mark a lava high-stand, when small solidified lava plates floated on the surface of the lava and stranded on the walls opposite to the main flow velocity (slip-side of flow). On the benches between stations 15 and 14 we find stalagmites, composed of lava blisters (Fig. 9), pressed out of the ceiling, a rather interesting formation, suggesting that the degassing and solidifying of the primary roof was still going on at the time when the lava subsided in flow to below the platy benches. Both the lining and the existence of the benches prove that the passage existed when the lava was still actively flowing. It therefore appears that the 2nd entrance passage resulted from the upward bending of the top flow sheet in an axis more or less perpendicular to the flow.(Fig. 10). It opened early on in the formation of the tube, when the surface sheets were still partly plastic. This mechanism explains also the niches found at St. 32 and 33. This interpretation could be tied together with the observation that the cave is widest at the 1st entrance where the cave makes a notable 90° turn (Fig. 3). This turn could be caused by the lava flowing against a pre-existing surface obstacle, such as the side of a previous flow, a pressure ridge or any other form of lava tumulus. It could then have been deflected to the north, causing the partings of the sheet due to the shear caused by the top lava sheet pressing against the obstacle. The hot lava immediately intruded these niches and since flow in them was slow, deposited floating lava plates. Only the 2nd entrance passage, which rose upward was not clogged. Evidence on the floor of the passage clearly shows, that this branch of the cave does not have anything to do with the a'a flooring.

The cave does not have much breakdown, indicating a very stable roof. The entrance puka reveals that the primary roof is composed of two pahoehoe sheet only, the upper one being 2.5 m thick and the lower one being 1.2 m thick. This may explain the long-term stability of the roof, which caved in geologically recently only at one of its widest spots.

Surface loess has been washed into the cave through cracks and through the entrance, covering the original floor in the upper stretches and for some part in the lower stretches, but leaving some of the original floor uncovered. Were it is visible (between St. 14 and 50), we find the floor astonishingly to be composed of small a‘a rubble, wall to wall (Fig. 11). Only at the lower end, where the cave branches, crude pahoehoe ropes are found with their flow lobes pointing makai (Fig. 12). The a‘a ends mauka of this junction (St. 50) in a sort of terminal wall. It is conceivable that this a‘a forms the final flow event in the tunnel, shortly before is became too cool to keep lava flowing. It may also represent a later event that invaded the cave after it was

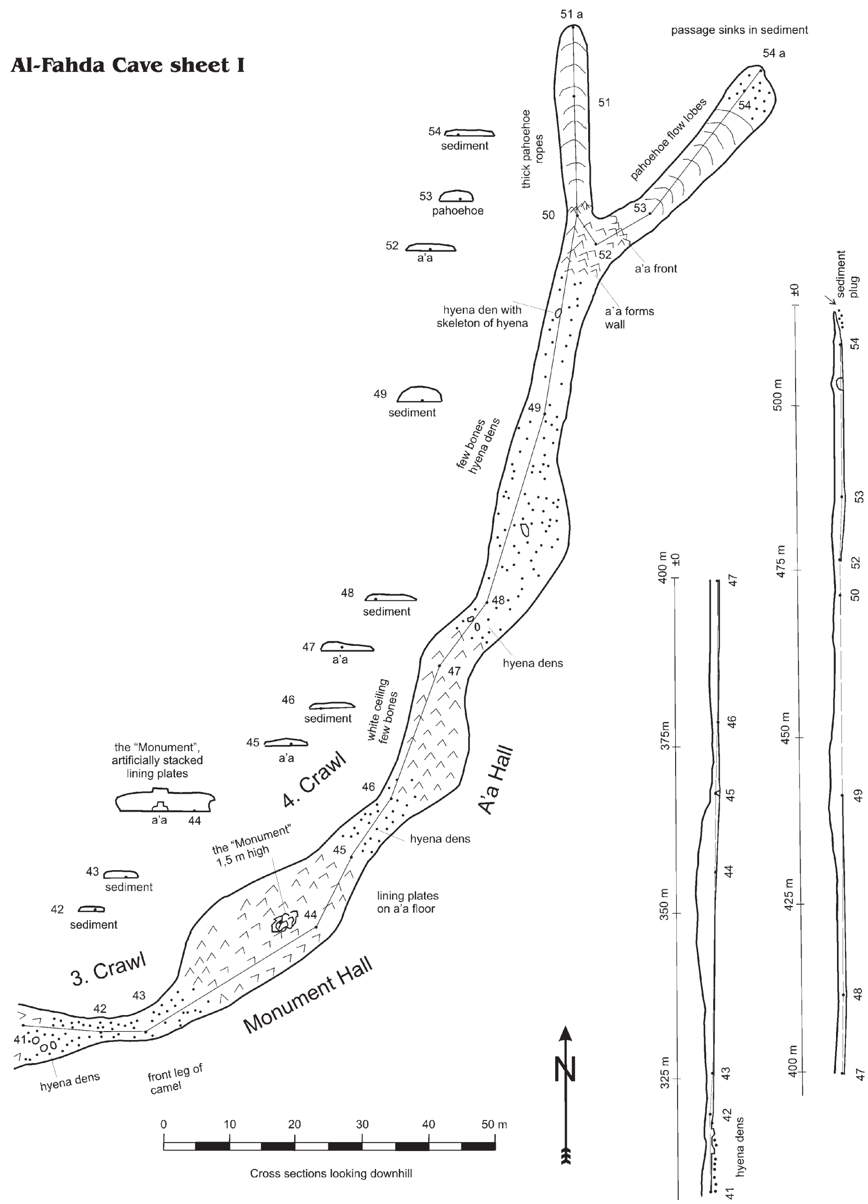

Figure 2. Map of Al-Fahda Cave (by the authors), sheet 1. The uphill and Mahmoud´s passages. Larger versions of map figures 2–5 are in the supplementary material on the CD.

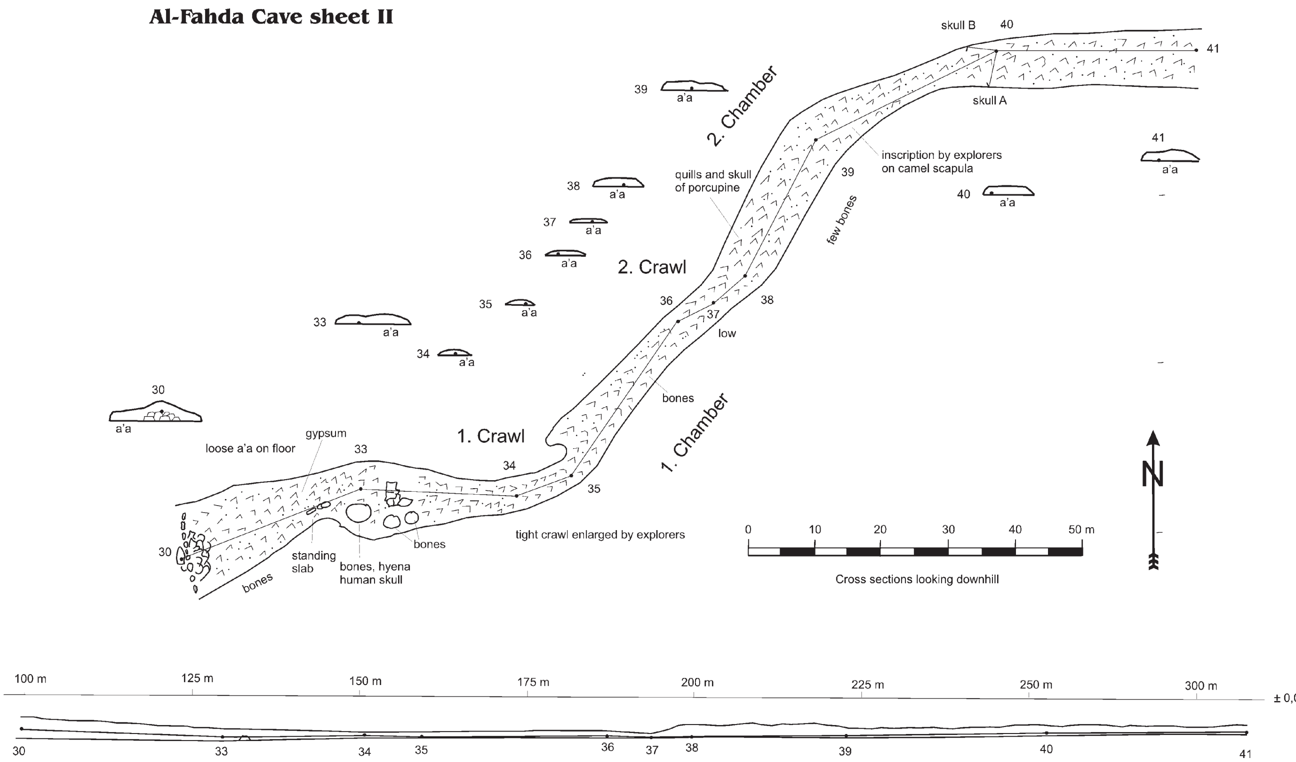

Figure 3. Map of Al-Fahda Cave (by the authors), sheet 2. The Mud, Large and A'a Halls. Also the both entrances.

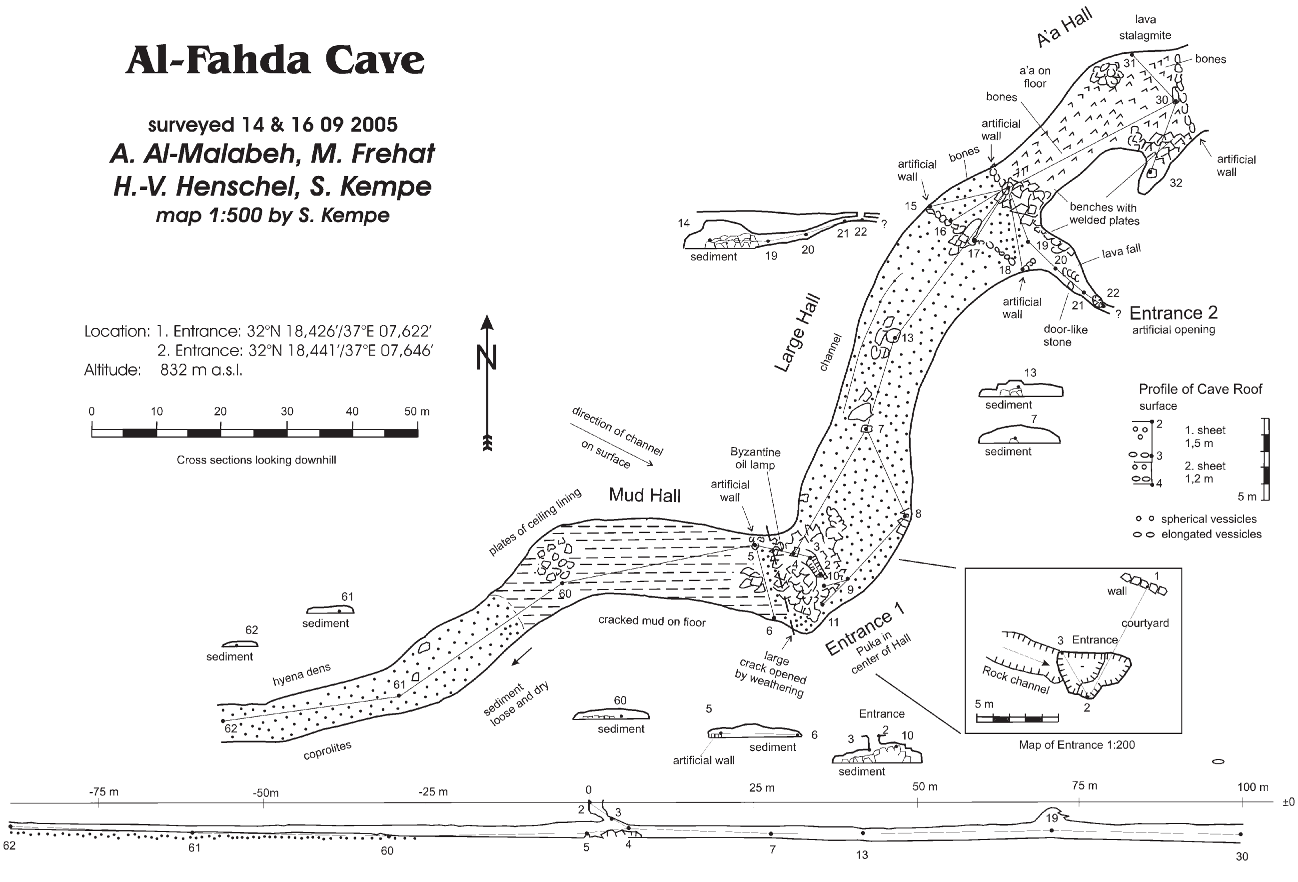

Figure 4. Map of Al-Fahda Cave (by the authors), sheet 3. The Crawl Halls.

Al-Fahde Cave sheet III

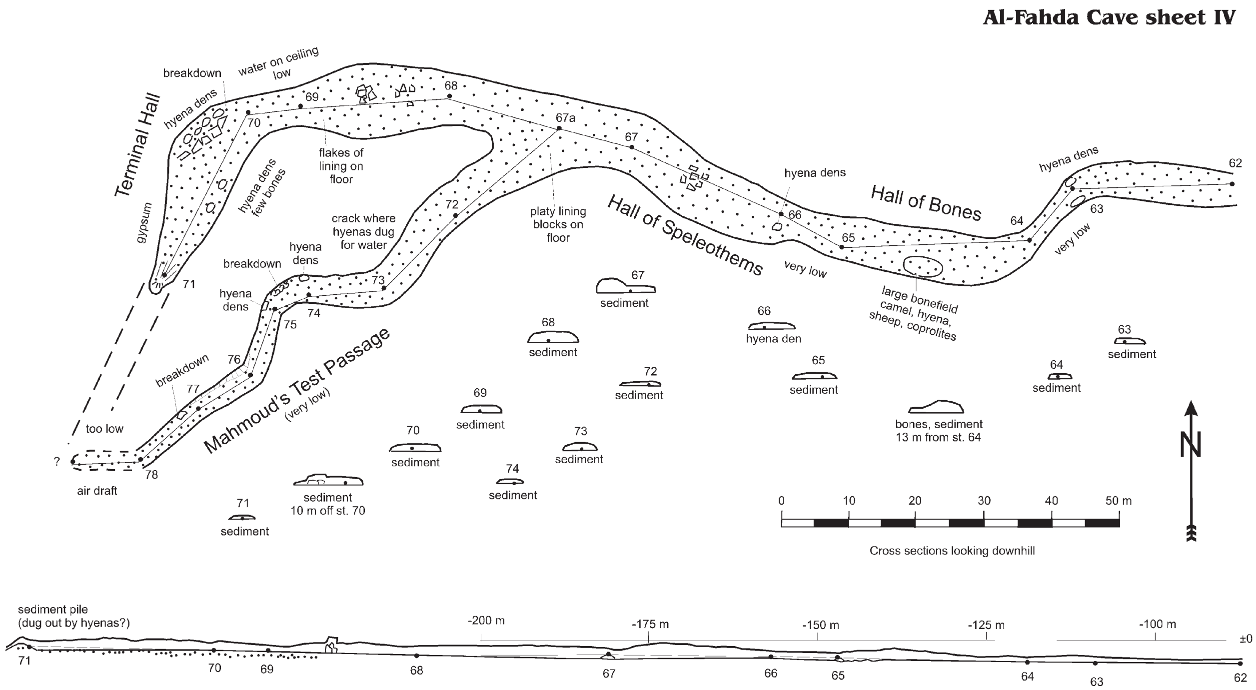

Figure 5. Map of Al-Fahda Cave (by the authors), sheet 4. Monument and, Pahoehoe and terminal Halls.

Figure 6. Anthropogenic channel consists of unworked stones led from Wadi Rajil in the north down slope to the main entrance.

Table 1. Survey results of Al-Fahda Cave.

Stations	**Horizontal**	**Length m**
2-54a	Main survey makai	488.60
8-11	Back of entrance	18.68
19-22	To second entrance	14.46
50-51a	W-passage of terminal split	28.45
4-5	Connection makai mauka	6.05
5-71	Mauka passage	266.21
67a-79	Mahmoud's Test Passage.	101.07
Total		**=SUM(ABOVE) 923.52**
	Main Passage length	
4-54a	Makai Passage	482.86
4-67a	Mauka Passage	187.10
67a-79	Mahmoud's Test Passage	101.07
Total		**771.03**
	End-to-end (as the crow flies)	**684.00**
	Sinuosity (771.03/684)	**1.13**
2-54a	**Vertical (entrance to deepest point)**	**-6.74**
71-54a	**Vertical extent of Main Passage**	**-8.41**
71-54a	**Horizontal length**	**755.12**
Slope 1	**slope (°) ($\tan^{-1}$ (8.41/755.12)***	**0.64°**
Slope 2	**slope (°) ($\tan^{-1}$ (8.41/684)**	**0.70°**
Width	**Maximal at St. 8**	**17.5**
	Minimal at St. 64	**3.55**
	Mean width main passage (39 stations)	**7.51**
Height	**Maximal St. 14**	**4.67**
	Mean height main passage (39 stations)	**1.21**

* This is the slope of the path the primary flow followed over the terrain.

evacuated by the original lava flow. This interpretation appears however less likely since invasion into a cold tube should stop very quickly due to fast cooling of the low volume of the invasion. Intrusive flows are known in Hawaiian caves, such as the Kazumura lava which intruded the mauka end of the Keala Cave and can be followed for 190 m with the characteristics of a surface pahoehoe flow (Kempe, pers. observ.). The a'a fill seems to explain the very low height of the tunnel compared to its large width and its level floor. It would also explain why we only found a few benches and other flow indicators: they were simply buried by the late lava event. How far mauka of st. 14 the a'a extends, is difficult to say, but the low nature of the mauka tunnel seems to suggest, that it extents all the way to the present end. Digs through the sediment may help to solve this question.

The cave is also remarkable for its paleontological and biological value: It was (is?) visited by hyenas (stripped hyena, *Hyena hyena*) all the way to both ends (Fig. 13). According to a search of the literature (D. Döppes, Darmstadt, pers. comm.) this is so far the furthest distance of hyenas penetrating caves on record. Since the cave is so low, the hyenas must have been crawling through some of the low spots, just as the modern cave explorer does. The hyenas also dragged in an appreciable amount of bones, among them at least three human skull caps (Fig. 14). Most of the bones appear though to be camel bones. But remains of sheep, gazelle,

Figure 7 (above). Main Entrance of Al-Fahda Cave.

Figure 8 (right). The second entrance, 60 m NE of the main entrance.

Figure 9 (below). Stalagmites composed of lava blisters.

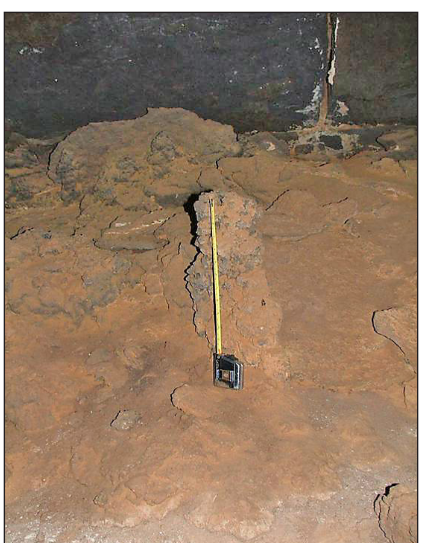

Figure 10. The second entrance passage resulted from the upward bending of the sheet in an axis more or less perpendicular to the flow.

porcupine, and hyenas were also noticed. The hyenas also left plenty of coprolites, which might be interesting objects to study, possibly revealing much about the ecology of these animals throughout thousands of years and possibly even longer time periods. In the sediment-covered section (Fig. 15) we find many hyena dens, mostly along the walls, that the animals seem to prefer. Sometimes the sediment appears to form a ridge in the center of the passage due to the digging activity of the carnivores along the sides. In one instance we even think that they were digging for water along a crack. Parts of the ceiling were still wet in mid-September, suggesting that the hyenas may have been going into the caves not only for shelter, to consume bones, give birth or die, but also in search of water.

Human presence is seen also in the cave. Low walls (Fig. 16) or retaining dams have been erected at stations 5, 15-18, 14 and 30. Actually, the makai part near the entrance up to St. 30 could house comfortably a large number of people. However, the cave appears to be rather clean and has not been used for sheep shelter as have some of the other caves in the area. Two very intriguing findings were made. First of all we found a pile of lining plates stacked by people on a large breakdown block near station 44, i.e. 330 m from the entrance. To get there, we had to move rocks in one of the crawl ways. Whoever stacked the stones must have been an ardent caver. So far we do not see any possibility to date this "Monument"

Figure 11. A´a small rubble stones cover the downhill section from wall to wall.

Figure 14. Human skull cap (St. 40) one of three skulls found in the downhill section.

Figure 12. Pahoehoe ropes found at the lower end of the terminal Hall.

Figure 13. A dead hyena in its den nearby the end of the terminal Hall.

Figure 15. Sediment covers the floor of the uphill section, Mud Hall, west of the main entrance.

Figure 16. Panorama view of the man-made artificial wall (St. 30).

Figure 17. Monument formed of stacked stones (man-made) in the Monument Hall.

(Fig. 17). Next we found (S. Kempe) a well preserved Byzantine oil lamp (Fig. 18), forgotten in a ceiling pocket near the entrance ca. 1500 years ago. It is now at the Hashemite University to be studied. At the surface we found a series of walls and crescent-shaped shelter walls along with pottery shards and a few (Neolithic?) flint flakes. All this suggests that both paleontological and archeological investigations in the cave might give valuable data on the history of the Jordanian desert.

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Figure 18. A well preserved Byzantine oil lamp discovered in a ceiling pocket near the main entrance.