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Newly discovered lava tunnels of the Al-Shaam plateau basalts, Jordan

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The north eastern part of Jordan is covered by alkali olivine basaltic flows: the Harrat Al-Jabban volcanics. These are part of the large intra-continental Harrat Al-Shaam volcanic field (45 000 km^2), which is the largest lava field of about eleven basaltic plateaus on the Arabian Plate. These lavas may be derived from asthenospheric and lithospheric partial melting of the mantle. Based on K-Ar dating three major volcanic phases can be discerned: 26-22 Ma, 13-8 Ma and 7 to less than 0.5 Ma old (Tarawneh *et al.*, 2000; Ilani et al., 2001).

In these lavas we explored, surveyed and studied four natural lava tunnels (Abu Al-Kursi, Beer Al-Hamam, Al-Howa, and Al-Dabié) and two other lava caves (Azzam and Dahdal) in September 2003 and March 2004 (Table 1). All caves occur in the youngest eruptive phase, nevertheless they belong to the oldest lava conduits yet reported world-wide. The two smaller caves (Azzam and Dahdal) are most probably pressure ridge caves formed by the buckling-up of the upper layers of pahoehoe flowing down from nearby Al-Qu'ays volcano, while they were still hot and plastic. Abu Al-Kursi and Beer Al-Hamam are large lava tunnels, up to 15 m wide and 8 m high. Al-Howa is a section of a medium-sized lava tunnel, while Al-Dabié is the smallest of these conduits, less than 4*2 m in cross-section. Similar tunnels have been recorded in the Syrian part of Harrat Al-Shaam (e.g., Arika and Sulkhad) and in two of the Saudi Arabian lava plateaus (Pint, 2003).

These tunnels served to transport lava subterraneously over long distances, i.e. in case of the large caves possibly over several tens of kilometres. Now, they are accessible through ceiling collapse holes that expose the structure of the tunnel roofs. These

consist of a stack of up to twelve several decimetre thick and laterally uninterrupted lava sheets. This structure reveals that these natural tunnels did not form by crusting-over of lava channels (as suggested by most textbooks) but by repeated inflation of initial lava deltas. In this way, lava flows build forward only at the tip, while the rest of the flow is stationary apart from the lava flowing inside the conduit. The underground lava flow quickly cuts down, until flowing in an underground canyon with an open surface. These processes have been studied in Hawaii, where back-cutting of lava falls also add to the down-cutting (e.g., Kempe, 2002); lava falls have, however, not been noticed in Jordan as yet.

Table 1: Data of Jordan lava caves (locations WGS 84).

Name of Cave	**Latitude**	**Longitude**	**Length**	**Depth**	**Direction**	**Type**
Abu Al-Kursi W	32˚15.401’	36˚39.442’	77.1 m	8.1 m	N-S	Tunnel
Abu Al-Kursi E	32˚15.401’	36˚39.442’	153.7 m	12.2 m	W-E	Tunnel
Azzam Cave	32˚17.104’	36˚36.594’	44.1 m	4.2 m	NWN-SES	Ridge
Beer Al-Hamam	32˚07.91’	36˚49.42’	445.0 m	17.2 m	NW-SE	Tunnel
Dahdal Cave	32˚17.344’	36˚35.718’	28.9 m	0.0 m	SW-NE	Ridge
Al-Howa	32˚18.536’	36˚37,240’	100 m	11.0 m	NW-SE	Tunnel
Al-Dabié	n.d.	n.d.	197 m	1 m	N –S	Tunnel

The existence of these tunnels shows that the basaltic plateau flows of at least the last eruptive period are tube-fed. Thus, it was possible to transport the lava over long distances (i.e., several tens of kilometres) from the eruptive centres in the north and across terrain at slopes of, or less than 2˚, comparable to the distal slopes of Hawaiian volcanoes. Most probably many sub-parallel “tunnels” exist in all of the Harrat Al-Shaam flows.

Because of the (compared, e.g., to Hawaiian caves) old age of the Jordanian flows it came as a surprise that the tunnels are still accessible, at least partially. Dahdal, Abu Al-Kursi, Beer Al-Hamam, and Al-Dabié contain thick sediment deposits. In case of the three latter caves this sediment fill prevents any further exploration of the tubes beyond the distances given in Table 1. Torrential rains can cause a small wadi stream to cascade into the entrance sink of Beer Al-Hamam carrying surface sediment into the cave. During such rains the lower part of the cave fills with water and becomes a large underground reservoir. Signs of rapidly flowing water (e.g., ripple marks) are seen on the sediment surface in the upper part of the cave. The sediments were sampled at a profile. They are mostly silts with some fine sand. Quartz, calcite, plagioclase, illite

and kaolinite (in decreasing order of amounts) compose most of the sediment, indicating that it is of wind-blown origin, possibly representing glacial loess, and not derived from an autochthonous soil. In the upper centimetres, the sediment also contains large concentrations of ammonium nitrate. This is derived from pigeon droppings. In both sections of Abu Al-Kursi, the floor is smooth and covered with a thin layer of fines, laid down by occasional floods that pond at the end of the cave. No sign of flowing water is seen.

All these caves were known to a few locals only. Until recently, Azzam Cave was used as a sheep pen. Its entrance was excavated recently, and a nearby sediment pile contains pot shards. Black drippings caused by the use of plastic irrigation pipes as makeshift torches reveal visits by adventurous explorers in Abu Al-Kursi. Visiting Beer Al-Hamam requires climbing down an overhanging pit, 5 m deep, but it must have been visited in the past because we found stone cairns inside. Dahdal Cave contains a stone wall; therefore, it was visited in the past too. Some of these visits, however, may have been prehistoric: numerous flint tools (possibly neolithic) were found in the neighbourhood of Dahdal and in two digs in the entrance of Abu Al-Kursi. Dahdal, both sections of Abu-Al-Kursi, and Al-Dabié contain camel bones and were used as dens by hyenas. Shallow circular pits are seen throughout Abu Al-Kursi. They do not appear to be anthropogenic since no excavated material is present. Possibly, they are hyena or wolf sleeping pits. The mandible of a wolf or jackal was collected in this cave. A mummified hyena was found in Al-Dabié. Considering the age of these caves, they could contain very valuable deposits of faunal fossils covering a large section of the Pleistocene.

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