CHAPTER 4

CAVE EXPLORATION AND SURVEY

4.1 Exploration, Surface and Underground

Based on knowledge gained from the study of the aerial photographs of the outcrop of the Bir al Ghanam Formation observed features which could be considered to be karstic phenomena were located in the field and either identified as swallets, or sinkholes, or rejected as non-karstic landforms. Often field trips resulted in the discovery of karst objects that did not show on the aerial photographs. Where the identified formations were shown to be swallets or sinkholes the next problem was to locate the spring or resurgence where the waters swallowed by the swallets reappeared on the surface. As underground drainage follows the rules of surface hydrology and caves may be considered as underground valleys in a sense, springs should have appeared at the lowest level of surface erosion in the vicinity (base of erosion), somewhere in the neighboring wadis. Using this hypothesis in most cases the resurgences sought were easily found.

Knowing the location of the swallets and resurgences the task then was the exploration of the underground conduits of runoff, the caves themselves. Usually it is easier to penetrate such systems beginning at the spring as waters swallowed in the numerous sinkholes reappear here and the passage at the spring is usually the most spacious. A large number of swallets are also entrances to cave systems. Thus caves where the size of the passages allows the exploration of the system from beginning to end are known as "through caves". The relationship between impassable swallets to certain systems is deductible from surveys – surface and underground – from geological reasoning and by the exclusion of alternatives.

4.2 Topographic Survey

The scale 1:50,000 (Sheet Nos. 1789-I, 1889-I-II-III-IV) topographical map of Libya was used to find details in the study area for features such as main roads, settlements, ruins, valleys and peaks, etc., where these were not mentioned in the explanatory key for the geological map sheet. It was intended to use elevations marked on the above topographical map. However, with the exception of those marking the top of Ras Tamallilt and Qasr al Mahmal they were proved to be 6-8 meters out according to control measurements used during the road construction in the Zakhrat al Ghar area , which started from basic leveling point BM-13.

The survey was carried out using a Zeiss Dahlta 010 type diagram tachometer. A detailed survey was completed only for those areas that contained a certain density of karstic phenomena. The detailed survey is presented on scale 1:5,000 maps showing all significant features: cone hills, wadis, roads, karst springs, swallets, and sinkholes. The plans of the caves have been projected onto the surface, together with their supposed relationships if, due to the constricted nature of their passages, they were not explored. The altitudes of significant points are indicated on the maps. Detailed maps were prepared for the

- Zakhrat al Ghar area
- Abu an Niran area (two sheets)
- South Wadi Fasat area

The contours of these maps are shown on the scale 1:25,000 hydrological map. (Drawing 2-1 and 2-2: Caverniferous areas of the Bir al Ghanam Karst, topographic map (Draw0201.tif and Draw0202.tif)

Those karst phenomena which are not positioned within the detailed maps, are shown individually on the scale 1:25,000 map but those shown on the detailed maps are not shown individually, as the vast amount of information would not fit into the restricted space available.

4.3 Underground Survey

The cave passages were surveyed using the tape and compass method. The method included using a measuring tape (made of Teflon so as not to affect the compass) stretched between points in the cave which were usually as far from each other as possible. Readings were made of the compass bearing and the gradient. Dimensions of typical cross sections were measured and relevant sketches were drawn on the spot. Using the listed data, plans, extended sections and cross sections were drawn and any geometrical data relevant to the cave was calculable

with good approximation. As most of the caves have more than one entrance, the underground survey was corrected by surface linking of the entrances using a more accurate survey.

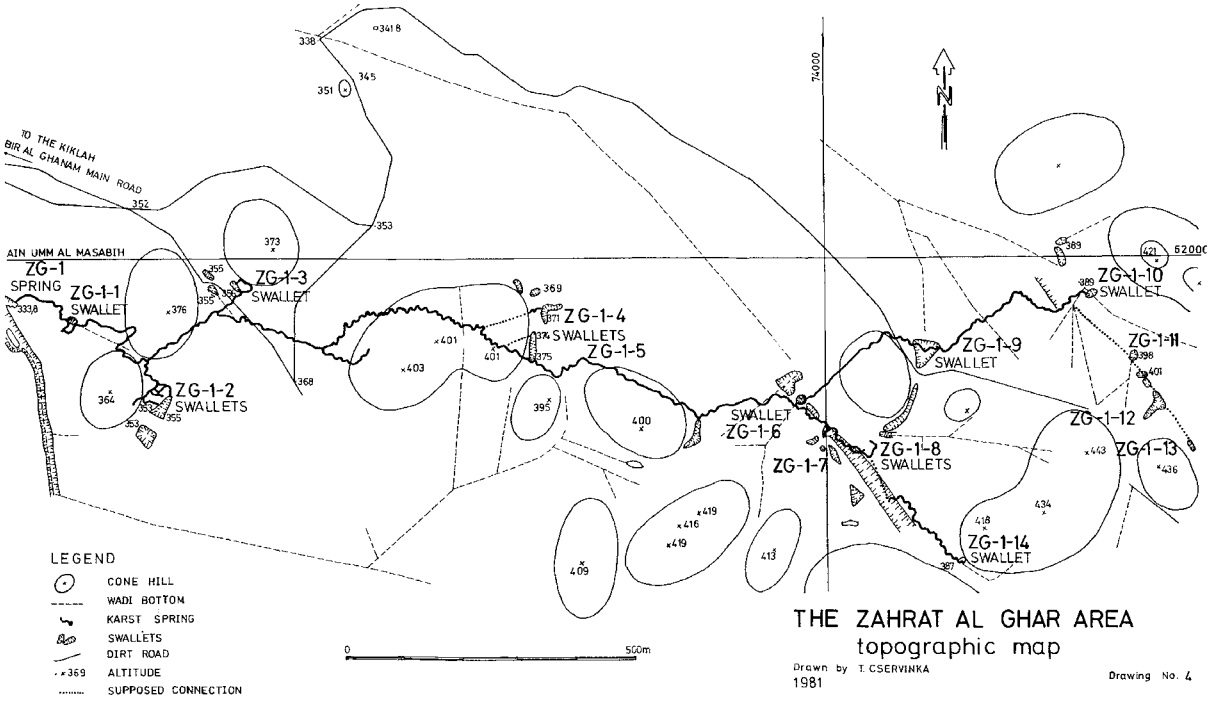
The outcome of the underground survey is the cave map showing the plan (scale 1:500) the extended section (1:500) and the cross sections (1:100). The surveyed caves are listed in the table below showing their most important data. As sources of local names were limited, code-names were given to the cave systems. Names, when available, are also mentioned in the descriptions. Names given by the explorers and published elsewhere are shown in brackets. A code indicates the name of the area to which the particular cave belongs. The following number is the serial number of the cave and also of its spring entrances. The last number in the code refers to the swallets in the order of their joining to the main cave passage upstream from the spring. A code on the map, for example WF-5-3 means Swallet No.3 upstream from the spring entrance in No.5 cave in the South Wadi Fasat area.

Area/Name of the Cave	Number of swallets	Length (m)	Volume (m^3)	Bedrock	Hydraulic head (m)
Zakhrat al Ghar (Cave Hills)				BG	
ZG-1 Ain Umm al Masabih	17	3,593	13,350	BG	55.60
ZG-2	1	-	-	BG	-
Abu an Niran					
AN –1 (Abu an Niran Cave)	8	859	4,500	BG	17.50
AN –2 (Locust Cave)	1	105	90	BG	5.80
AN –3 (Hyena Cave)	2	365	2,094	BG-BN	25.00
AN –4 (Western Cave)	5	435	805	BG	43.00
Dolomite sinkholes				BG-BN	
South Wadi Fasat				A	
WF-1 Ain Wadi Fasat	5	618	1,725	A	15.00
WF-2 (Olive Tree Cave)	3	-	-	A	25.00
WF-3 (Carpenter Cave)	1	240	425	A	6.00
WF-4 (Passageway)	1	30	525	A	0.50
WF-5 (Fig Tree Cave)	3	114	132	A	10.00
WF-6 (Ice-pit Cave)	1	88	445	A	4.00
WF-7 (Subway Cave)	3	273	1,155	A	4.00
WF-8 (Pocket Subway)	1	25	20	A	5.00
Wadi ash Shaykh					
WS-1 (Cone Cave)	1	63	79	A	0.6
Bir Ayyad					
BA-1	1	209	52	BG-BN	-
BA-2	1	-	-	BG-BN	-
BA-3	1	-	-	BG-BN	-
BA-4	1	-	-	A	-

BG – Bir al Ghanam Gypsum, BN – Bu an Niran Member, A – Abregh Gypsum

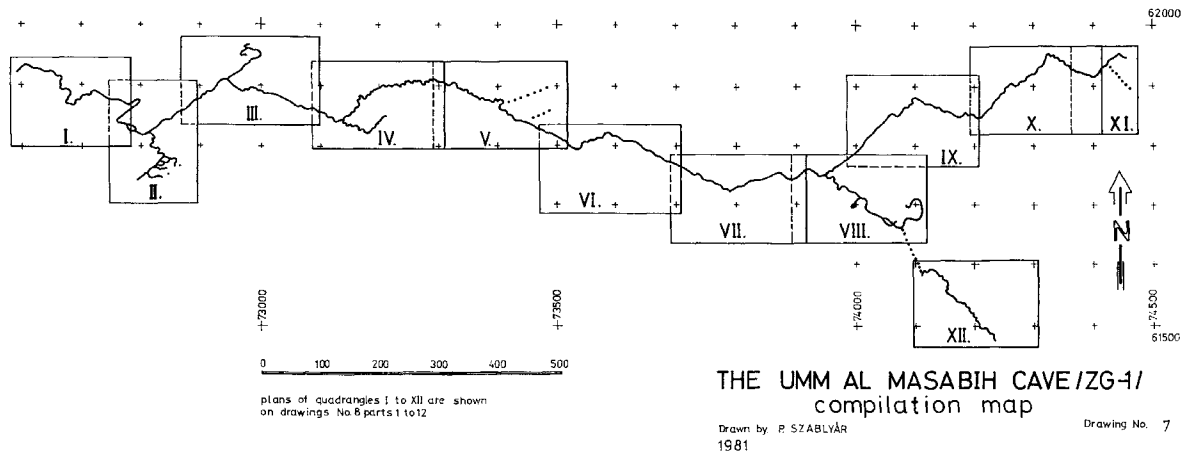
4.4 Descriptions of Caves

4.4.1 The Zakhrat al Ghar Area



Drawing 4: Topographic map with the Umm al Masabih Cave plan (Draw04.tif)

4.4.1.1 ZG-1(Umm al Masabih Cave)



Drawing 7: Compilation map of detailed plan sections (Draw07.tif)

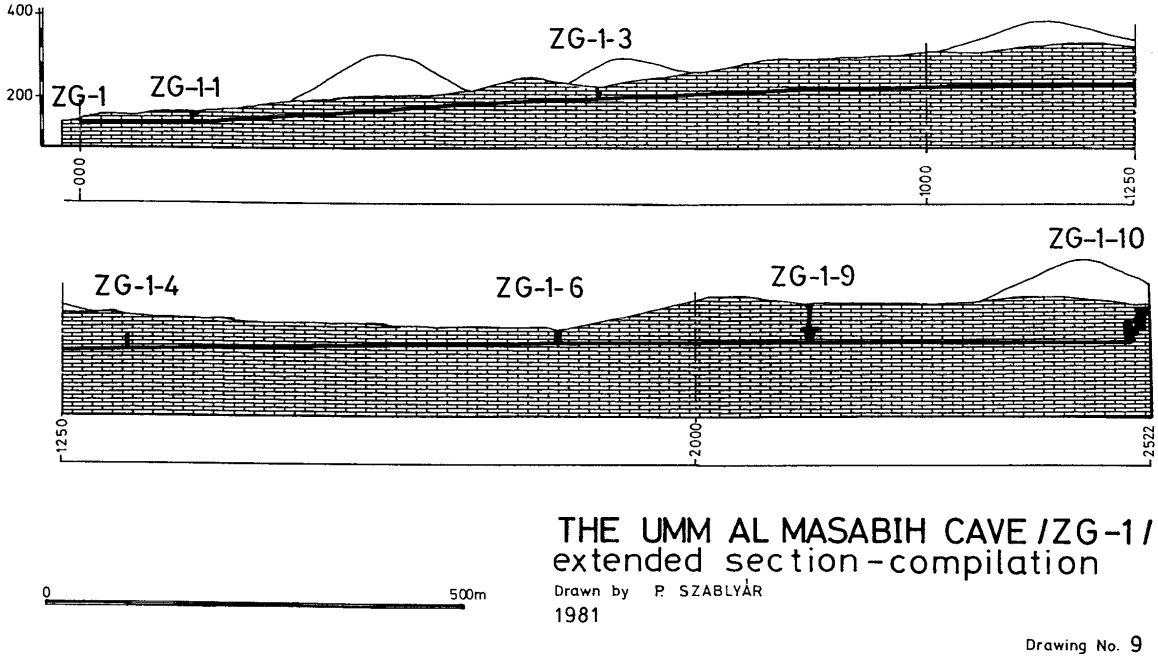
Location: East of the new road to Takbal 5 km from the al Aziziya-Nalut main road junction. Off the main road it is accessible on the dirt road shown on the detailed map of the Zakhrat al Ghar area. The dirt road is rough but passable for any kind of sturdy vehicle, 4WD is not needed.

– Bedrock: Bir al Ghanam Gypsum - Total surveyed length: 3,593 m

– Total surveyed volume: 13,350 m^3 - Number of swallets: 14

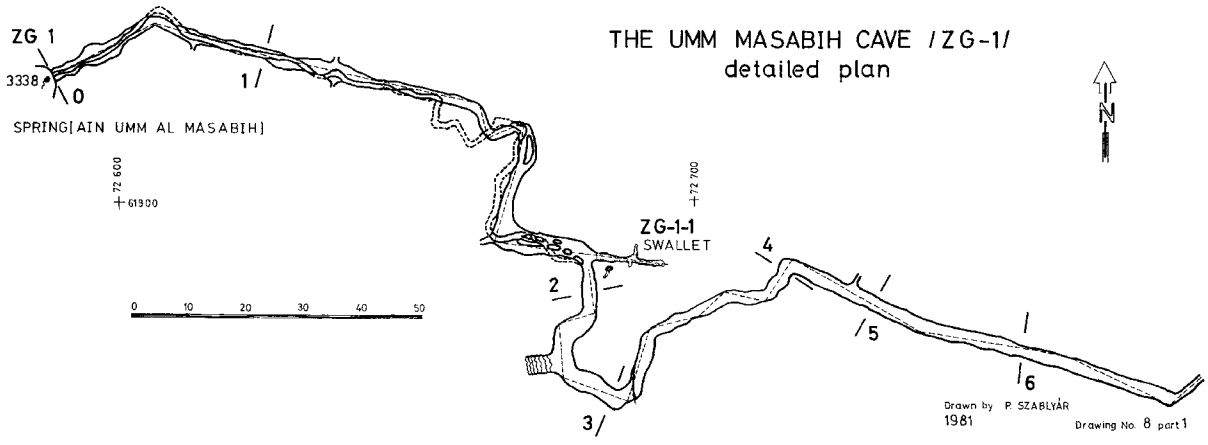
– Potential Hydraulic head: 55.60 m

– Description: Because the Umm al Masabih cave is the longest cave of the Bir al Ghanam Karst, it is therefore the most important cave in the Bir al Ghanam Karst. Its features are described in different sections between significant and easily recognizable points.



Drawing 9: Compilation profile (Draw09.tif)

Spring (ZG-1, Ayn Umm al Masabih) to the ZG1-1 swallet



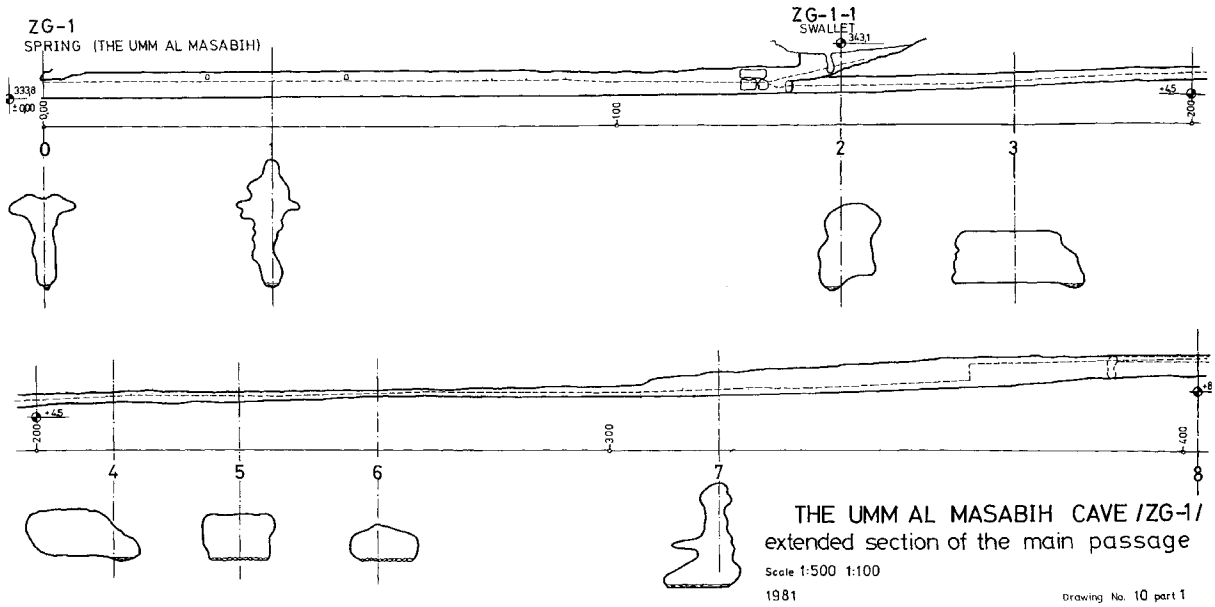
Drawing 8-1: plan, (Draw0801.tif)

The spring is located in a wadi lined by vertical gypsum cliffs in an indentation in the east cliff. The spring appears as a stream emerging from a 3 m high spacious cave entrance. The passage near the entrance is a narrow meandering actively flowing channel, which widens out as a shoulder at the top to a solution channel.

The original joint along which the initial solution took place is clearly visible at the top, and is usually filled with secondary gypsum crystals. The same joint is observable at the bottom wherever it is clear of sediments. The joint cuts through the meanders of the bottom channel. Seventy meters inside the cave the original cross section changes, the upper wide channel becomes independent as more joints cut the rock.

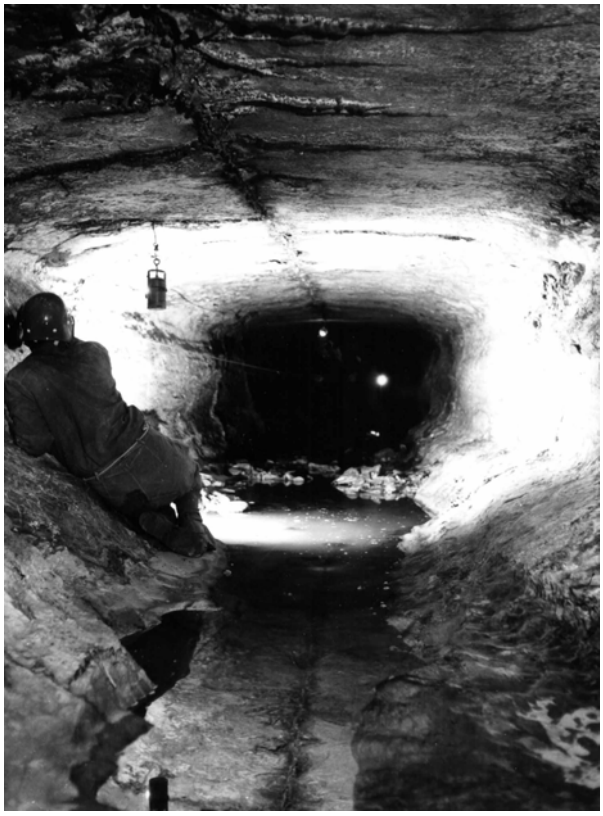
Finally all passages join a larger chamber directly under ZG-1-1 swallet. The size of the chamber is a result of massive collapses of big blocks from the sides and the roof, the breakdown being partly carried away by successive floods. The ZG1-1 swallet joins the system in this chamber from the east-southeast.

This strike is the main strike of the first section described above, and, in fact, of the whole of the Umm al Masabih Cave System. The ZG-1-1 is the most comfortable entrance to the most spacious parts of the cave system.



Drawing 10-1: sections, (Draw1001.tif)

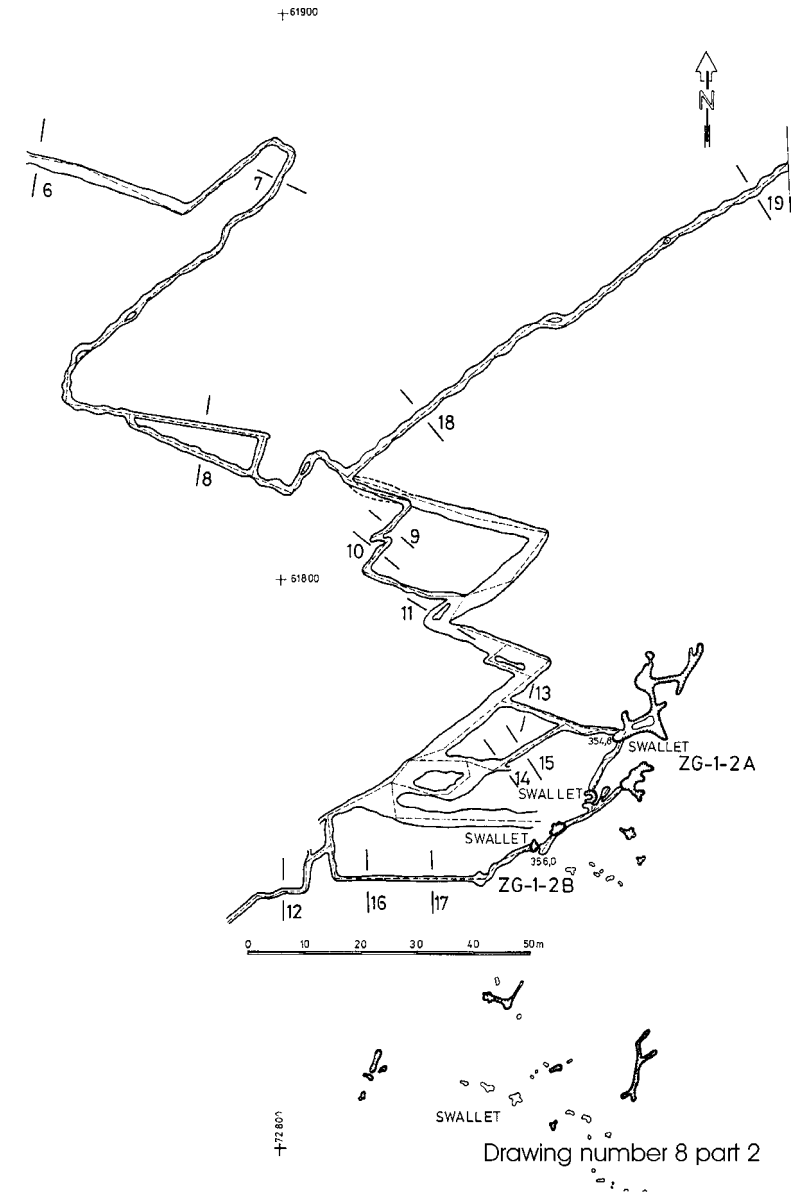
Photograph 8: The Ain Umm al Masabih spring. Lowest entrance to the Umm al Masabih cave system (pic08.jpg)



Photograph 9: The "Tube" (pic09.jpg)

ZG-1-1 swallet to the junction of the ZG-1-2 swallets

See Drawing 8-1: plan (Draw0801.tif) and Drawing 10-1: sections (Draw1001.tif) At the junction of the ZG-1-1 swallet the passage turns sharply south-southwest which is the direction of the secondary strike of the whole cave system. The large rectangular passage meanders in great bends alternating between the two main strikes of the cave system and gently rising. Twenty meters upstream of ZG-1-1 a lateral passage joins, filled by red sand. No visible swallet was found on the surface corresponding to this passage.



Drawing, 8-2: plan (Draw0802.tif)

The meandering section continues through a very typical feature of the cave. The "tube" is a 70 m long, straight, rectangular conduit with rounded edges, almost free of sediments, the initial joint shows clearly on both the ceiling and the floor, indicating active seepage at points along the joint where gypsum stalactites grow. A small impassable conduit joins the "tube" at its beginning. The cave turns sharply to the secondary strike then turns again through 180 degrees to a high typically corroded passage which meanders at its bottom but is straight at the top along the initial joint which forms an axis. The cave turns again to the main direction then deviates from it slightly at cross section No 8. At this point there is an upper tube, almost circular in shape, turning at a right angle half way along and then rejoining the main passage.

The last section before the junction of the lateral passage is a spacious conduit. Meanders, which are disected at some places, and undercut at others where the concave parts may have split down along the initial join, cut into its floor.

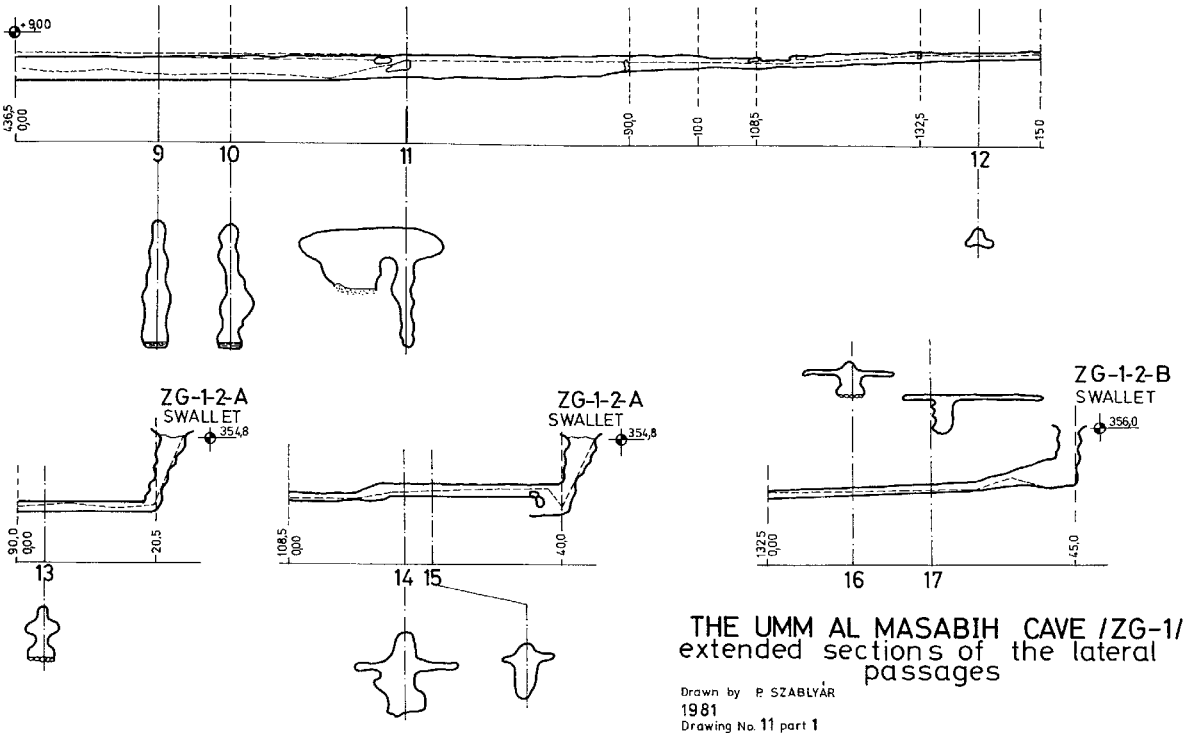
Photograph 10: Tubular passage at section 8 (pic10.jpg)

The ZG-1-2 lateral branch

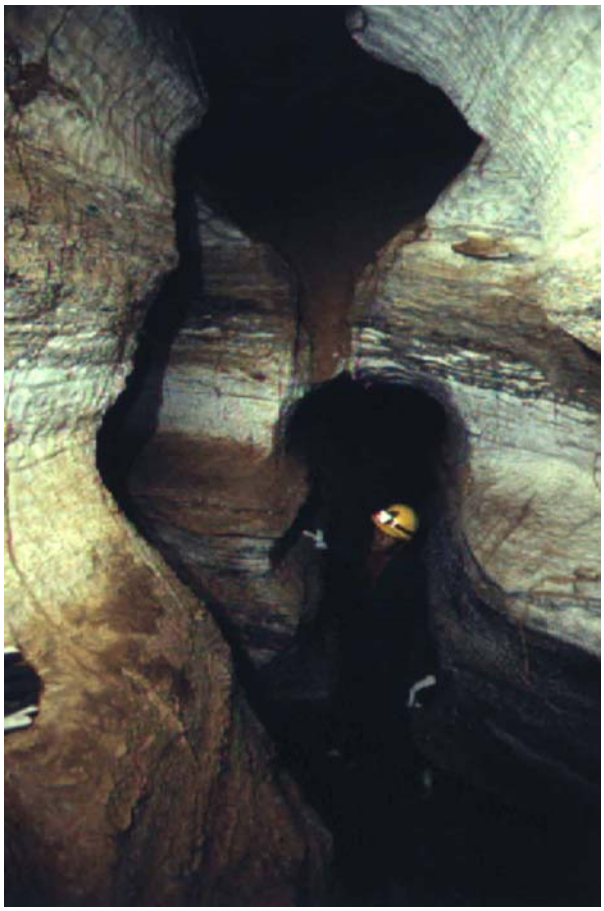
The most extensive branch joins the main passage at two levels.

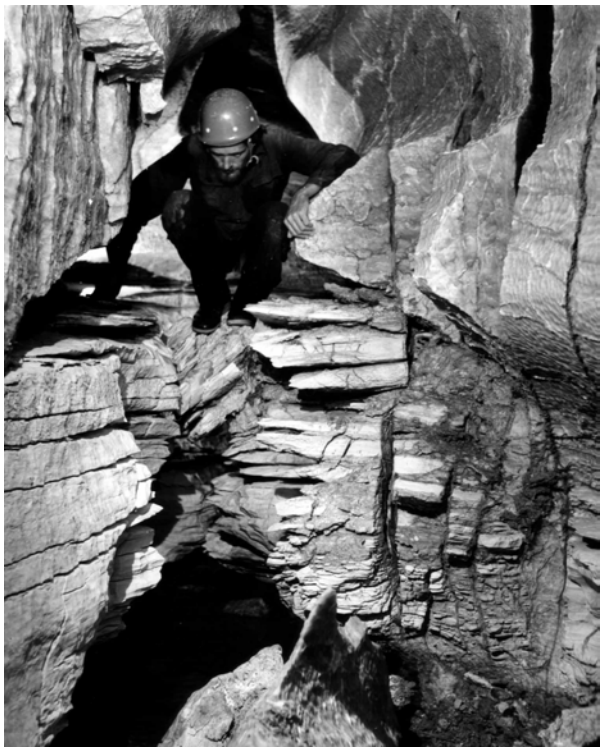
The lower passage is a 3 m high, narrow, meandering actively flowing conduit, the upper passage is wide and flat, and ellipsoid in section, its bottom filled with thick sand. First overlapping, then taking different perpendicular-parallel routes along the two main strikes of the cave system, the two passages unite in a spacious chamber forming a cross section which preserves the character of both original passages. After two sharp turns and with an elevated side passage which resembles the one at section No 8 we arrive at a passage which collects all the conduits that originate from the members in the ZG-1-2 swallet group. Five passages join this "collecting gallery" all with differing dimensions, but most of

them having developed with a typical "ghost-armed" cross section. (Nos 13 to 17). These conduits – some of them impassable – lead to the ZG-1-2 swallets through which entry to the cave is possible but difficult. See Drawing 8-2: plan (Draw0802.tif)



Drawing 11-1: sections (Draw1101.tif)



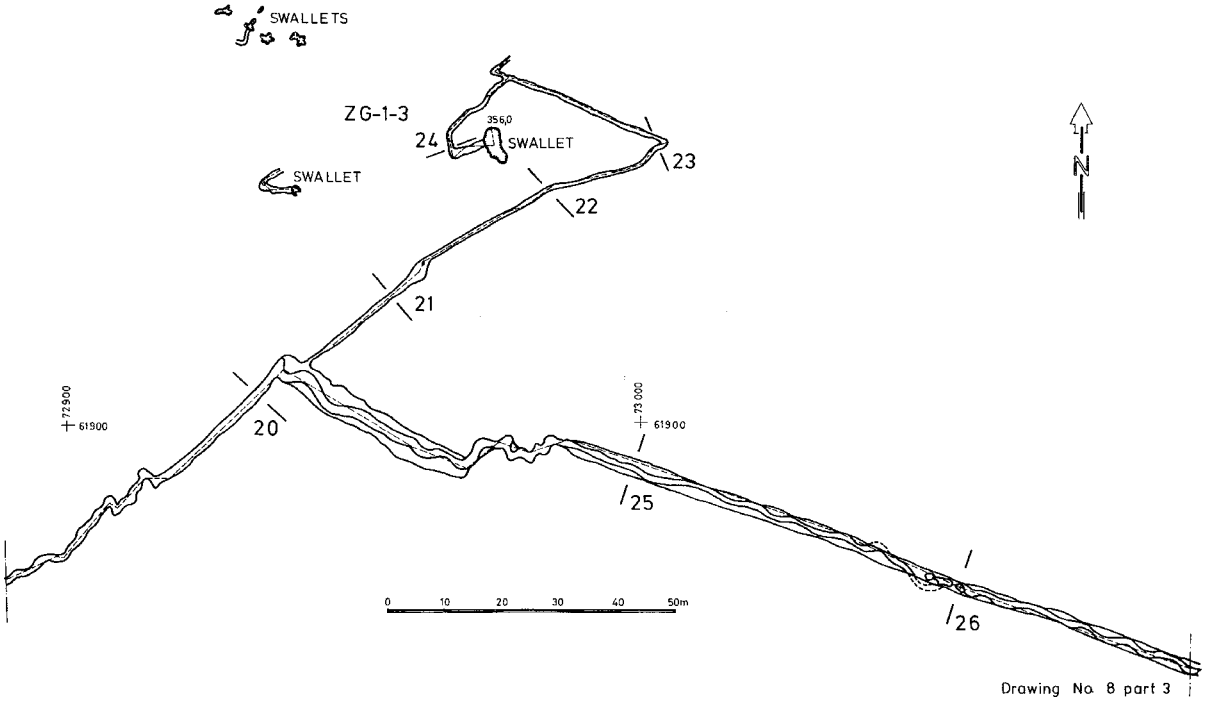


Photograph 12: The main passage cutting through an anhydrite intercalation (pic12.jpg)

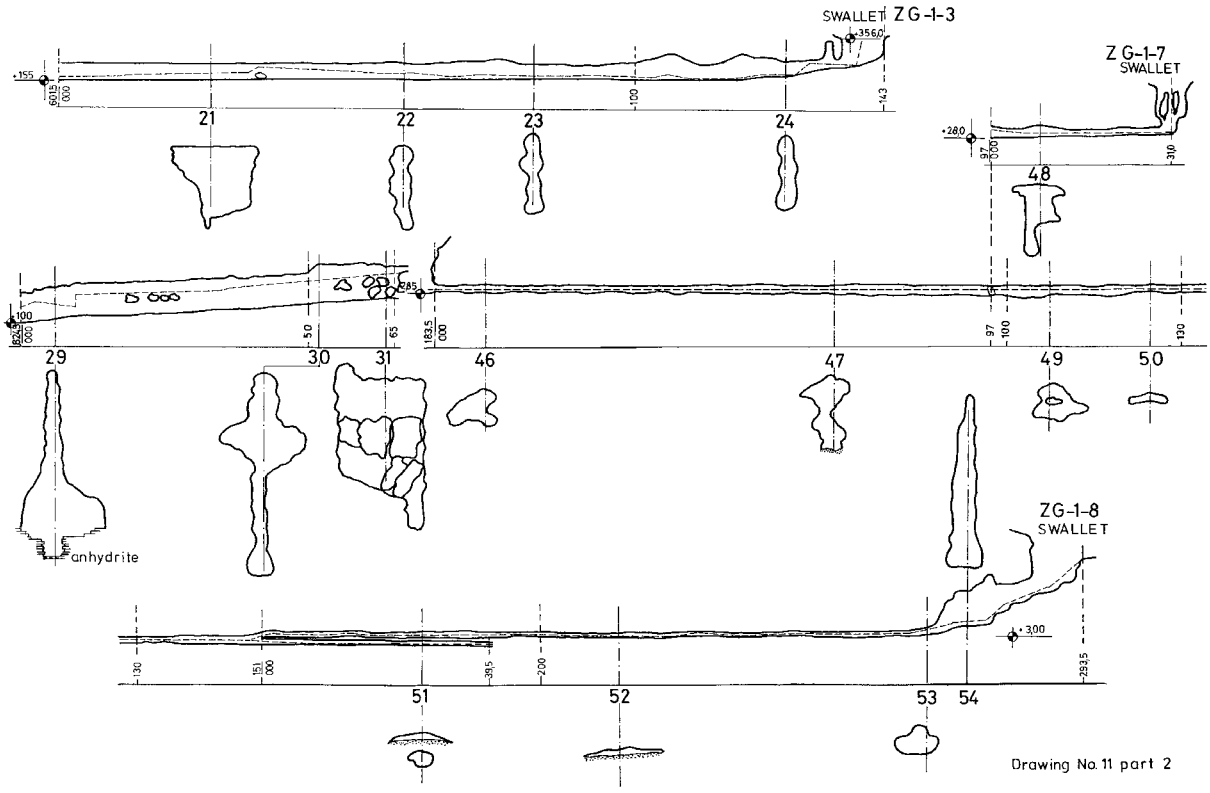
Photograph 11: The connection of the ZG-1-2 lateral branch (pic11.jpg)

Between the junction of the ZG-1-2 and -3 swallets

See Drawing 8-2(Draw0802.tif)



Drawing 8-3: plan (Draw0803.tif)



Drawing 11-2: sections (Draw1102.tif)

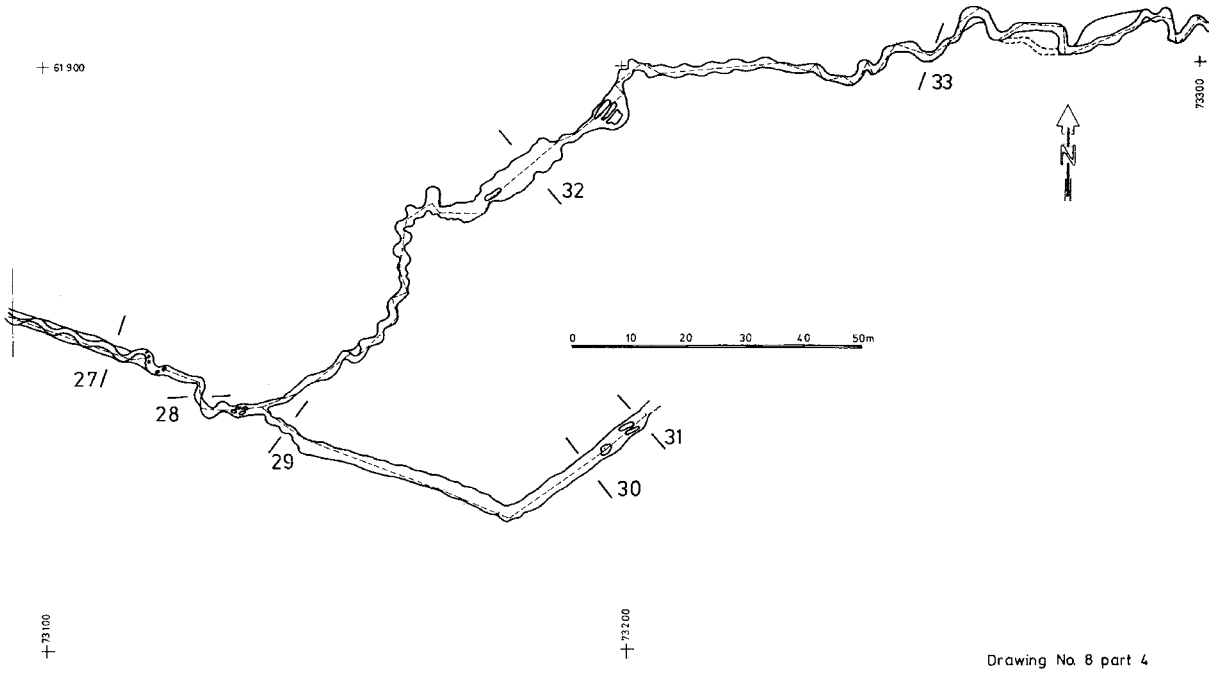
A relatively simple 150 m long very typical section of the cave. The spacious high passage makes wild meanders at the bottom whilst it is tube-like and straight at the top along an initial joint which is clearly visible. The features of this section are not easy to describe on a map, it resembles the geometry of a curtain fixed on a straight rod at the top but wavering at its lower hem.

The ZG-1-3 branch

See Drawing 8-3: plan (Draw0803.tif) and Drawing 11-2: sections (Draw1102.tif)

The ZG-1-3 group of swallets consists of three significant members of which only the easternmost, funnel-entranced one is passable. The other two become too tight after a few meters. The high, but rather narrow, passage starting at the bottom of the large funnel, receives the waters of the other swallets in the group. After making a spiral alternately paralleling both main directions it finally takes the strike of the main passage described in the foregoing paragraph. This section has the same shape as the starting spiral, high, and narrow one, except for a single chamber made as the result of a cave-in.

ZG-1-3 junction to cross sections Nos. 28 and 31



Drawing:, 8-4 (Draw0804.tif)

See Drawing: 8-3 (Draw0803.tif) and sections 11-2 (Draw1102.tif)

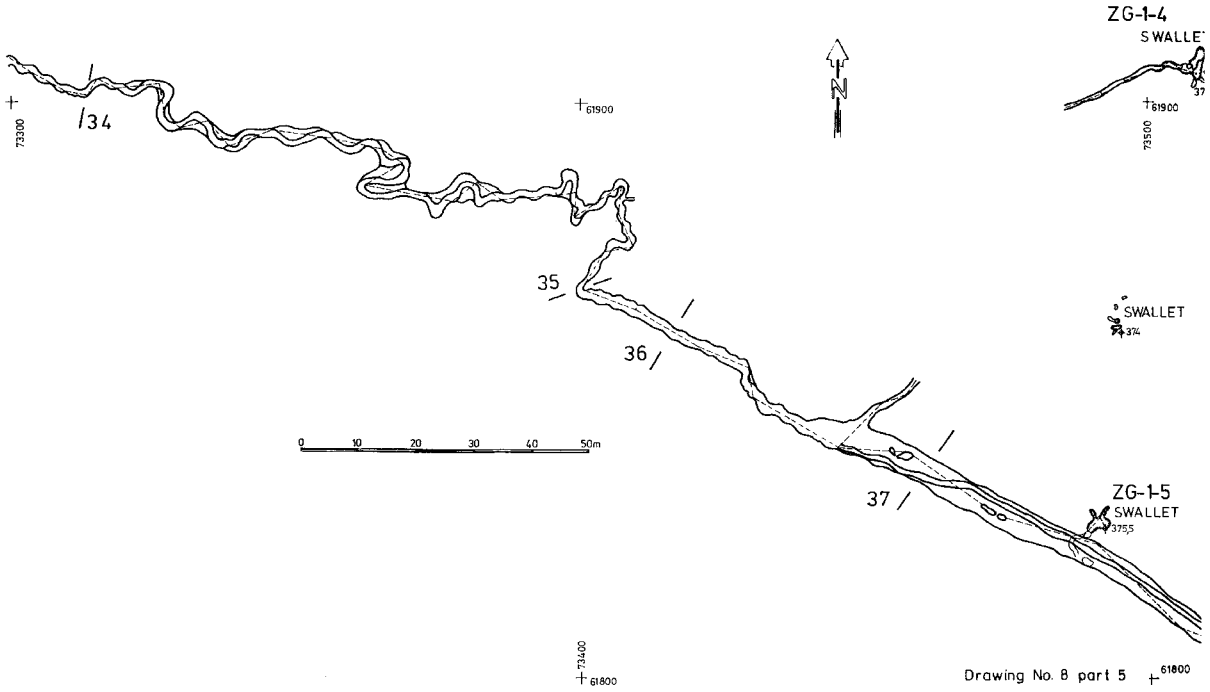
The direction of the main passage takes the main strike at the junction of the ZG-1-3 branch to form a long, straight 5-6 m high passage and consists of a spacious, straight, upper section and a meandering, narrower lower section. At the end of this section, formed in massive gypsum layers, the passage meets and cuts through an intercalated anhydrite lens and thin layers of marl.

The cross section decreases, its higher part crossing mainly dolomitic rock making this a shattered, difficult section of the cave. A side passage joins the main passage at the tectonically disturbed section. This was the "predecessor" of the now active channel having become inactive after the cut-through. This inactive part has a remarkably high and regular cross sections and is nicely decorated with gypsum stalactites. It is closed by a breakdown at its end.

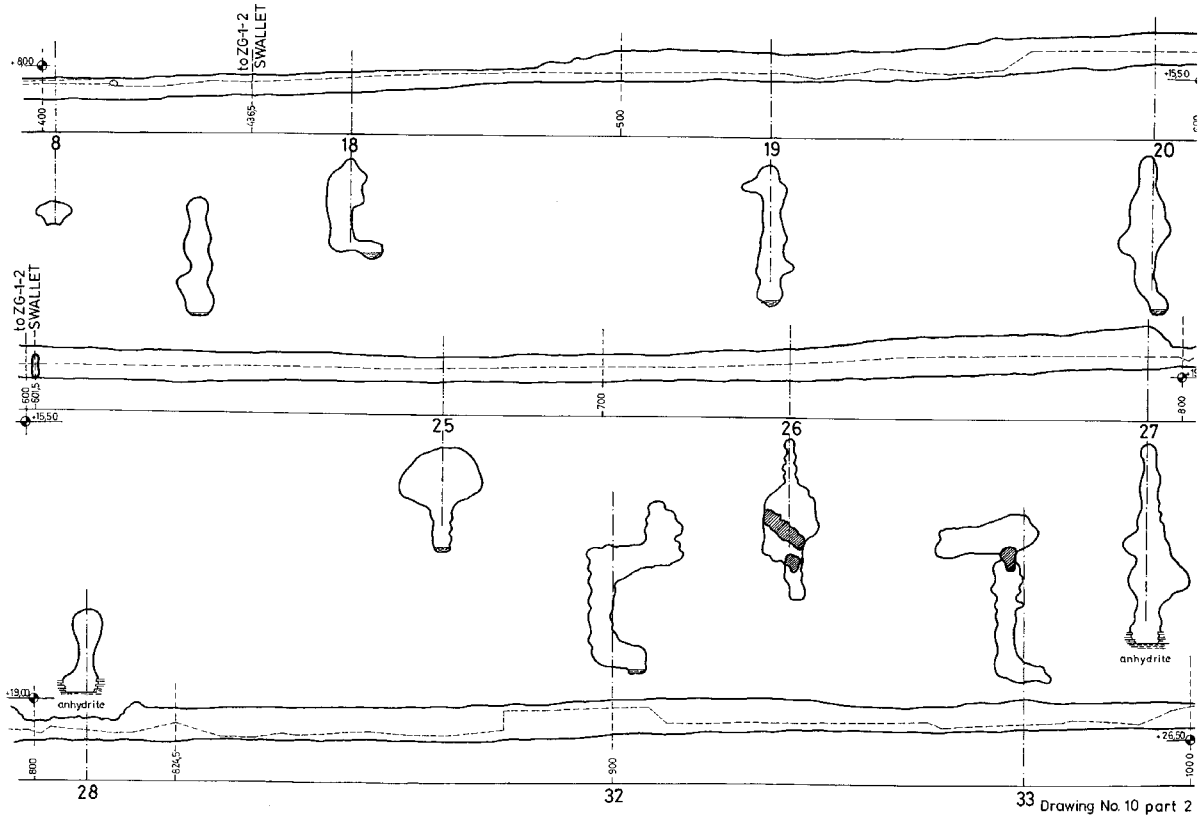
From cross sections No.28 to No.37 ("Big room")

In this wildly meandering, ledgy section of the cave it is hard to determine direction, but the trend of the passage primarily follows the main strike of the cave system. The best developed meanders are found in this part of the cave. The "amplitude" of them reaches 5-8 meters.

The walls at the extremes of the meanders deviate 30-35 degrees from vertical and in spite of the 4-6 m height of the passage one can rarely walk upright. Before cross section No. 35, an impassable branch joins the system, possibly from the ZG-1-4 swallet. Beautiful gypsum stalactite formations decorate the passage at the top and under the upper ledges in the vicinity of section No.35. See Drawing 8-4.

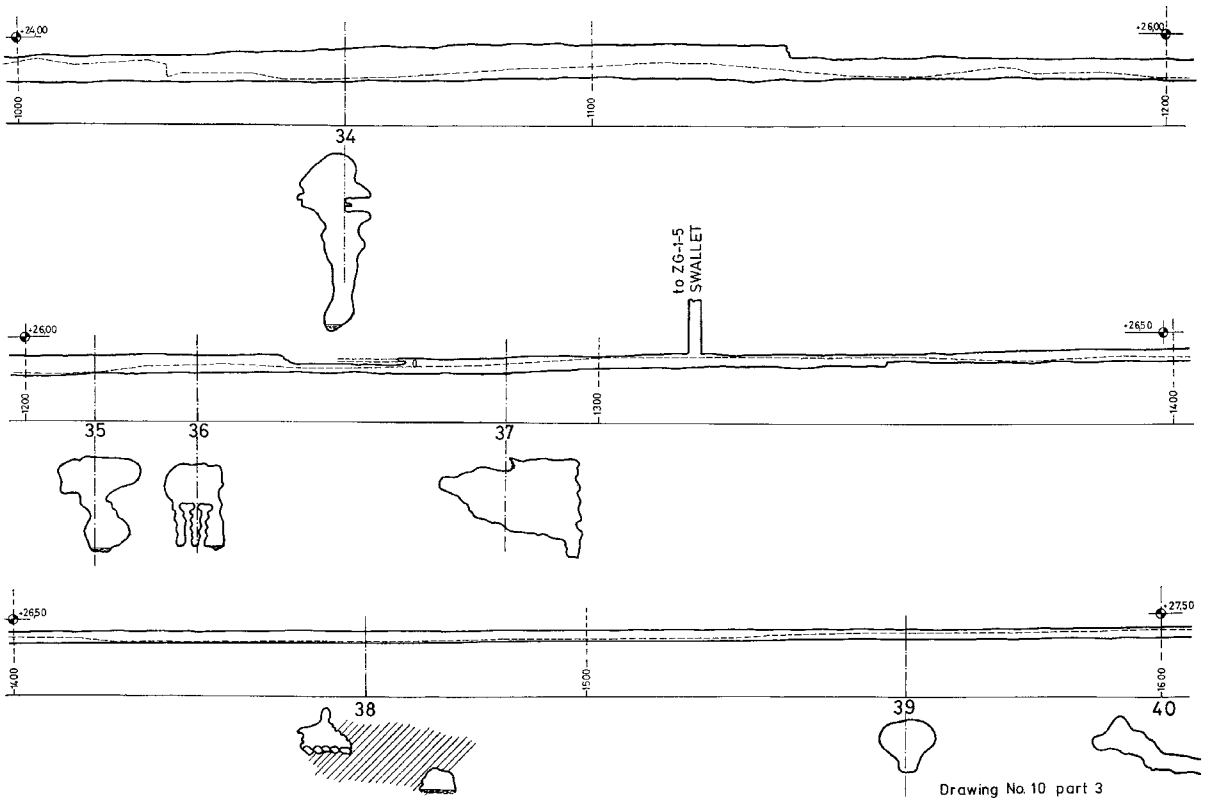


Drawing, 8-5 (Draw0805.tif)



Drawing: 10-2, sections(Draw1002.tif)

The channel stops meandering before reaching the "Big Room" where the stream cuts into a darker, seemingly relatively less soluble, gypsum. The least soluble substrata are left behind as protruding, many meters long blades.



Drawing: 10-3, sections (Draw1003.tif)

Photograph 13: Wildly meandering passage clearly showing the main tectonic line between sections 34-35 (pic13.jpg)

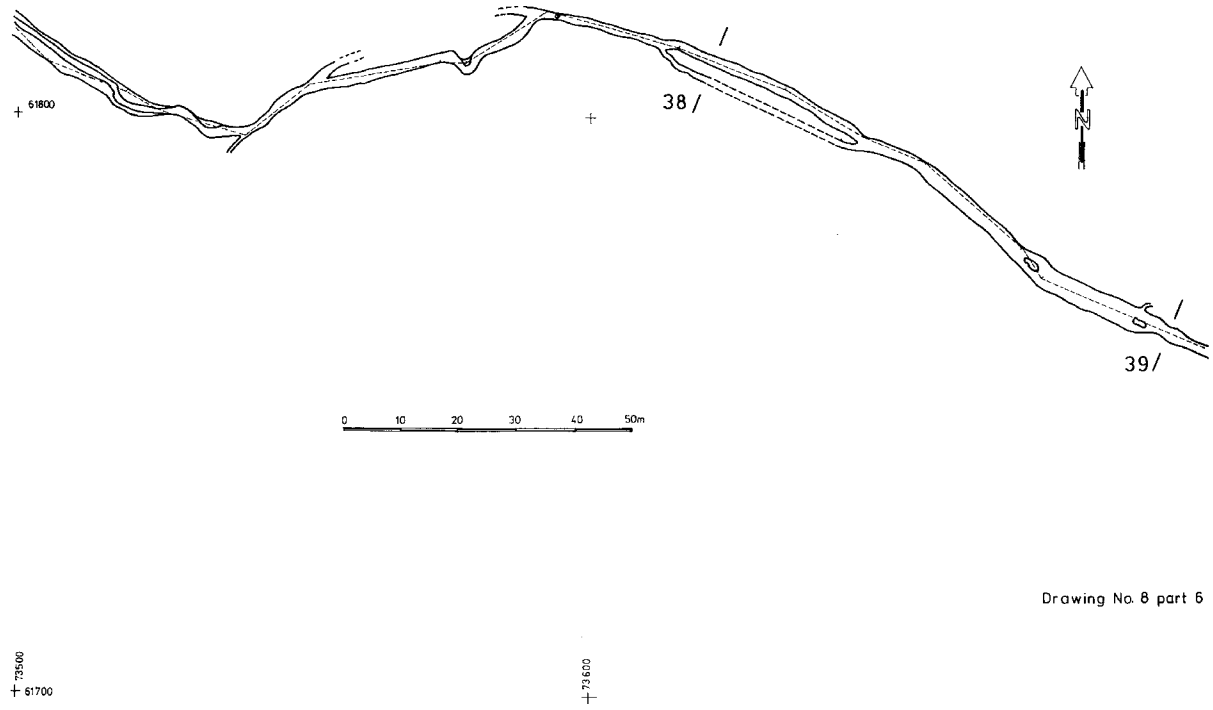
Photograph 14: Dynamic solution forms between sections 34-35 (pic14.jpg)

A small spring enters the cave in this area from between gypsum layers, depositing quantities of gypsum formations. Twenty meters after the small spring the passage enters the "Big Room".

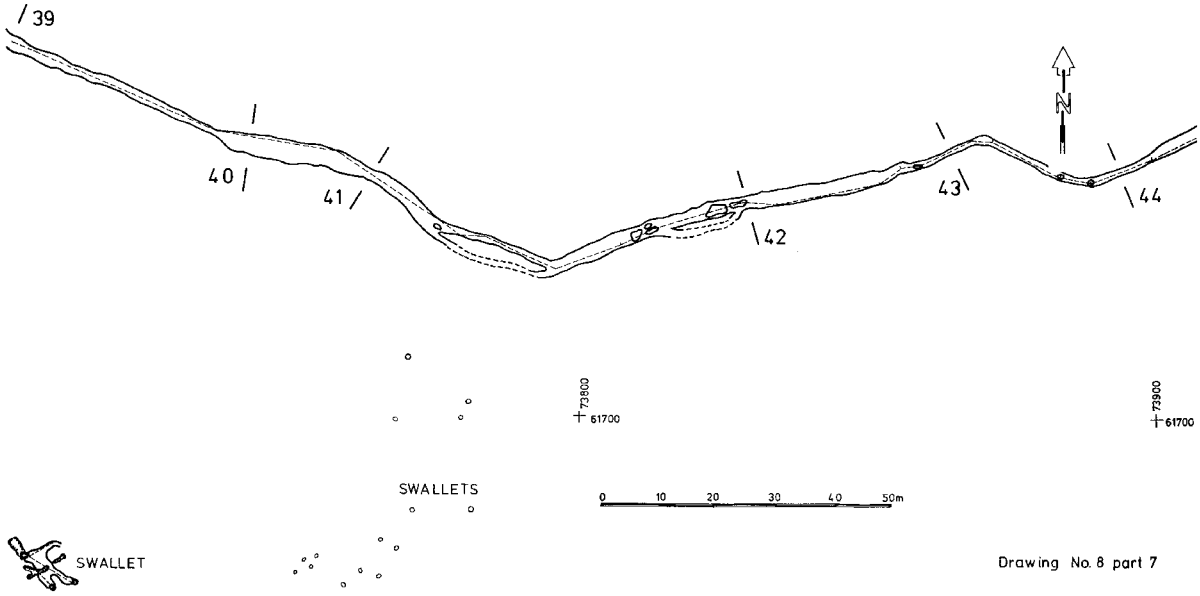
Photograph 15: Solution blades at section 36 (pic15.jpg)

The "Big Room" and-to the ZG-1-6 swallet

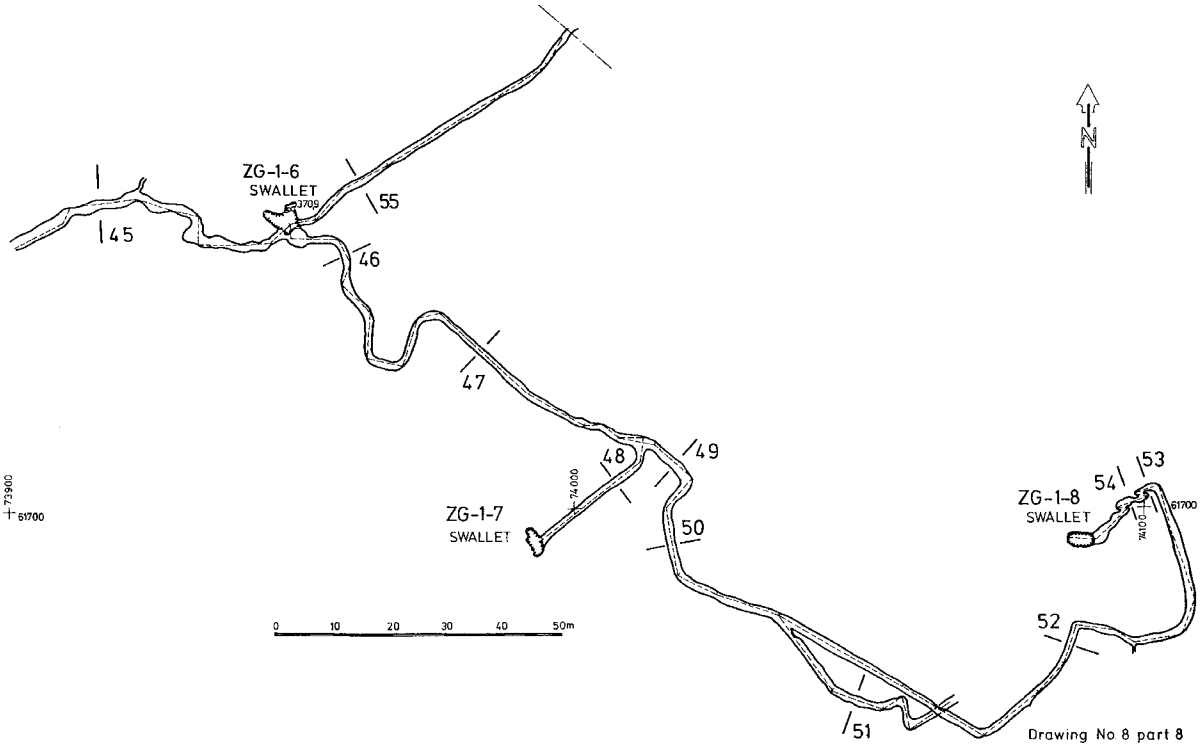
See Drawing 8-5 and



Drawing 8-6: plan (Draw0806.tif)



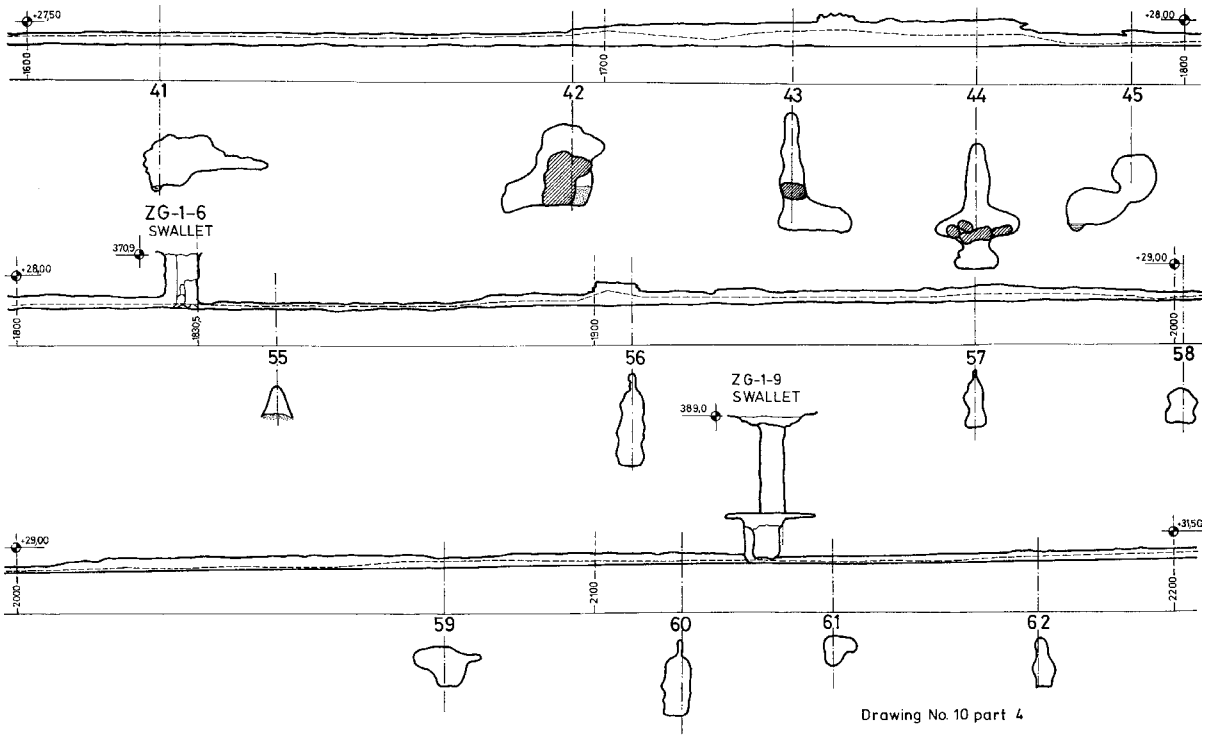
Drawing 8-7: plan (Draw0807.tif)



Drawing 8-8: plan (Draw0808.tif)

See Drawing 10-3: sections (Draw1003.tif) and Drawing 10-4: sections (Draw1004.tif)

The "Big Room" is in reality a rather spacious section of the main passage. Its large size is due to the junction of the passages from the two swallets of the ZG-1-5 group. One of them joins at the west end of the "Big Room" with an impassably tight conduit, while the other joins at the top of the center of the room and is a 3-4 m^2 cross section vertical shaft which traverses several dolomite beds. The southern member of the ZG-1-5 swallet group is almost above the top of the passage on the surface but no sign of light is visible through the narrow strongly meandering conduit which starts at the top of the shaft. The size of the 80 m long "Big Room" decreases eastwards and continues in a rather characterless passage which follows the general main strike of the cave.



Drawing 10-4: sections, (Draw1004.tif)

Photograph 16: Surveying in the "Big Room" (pic16.jpg)

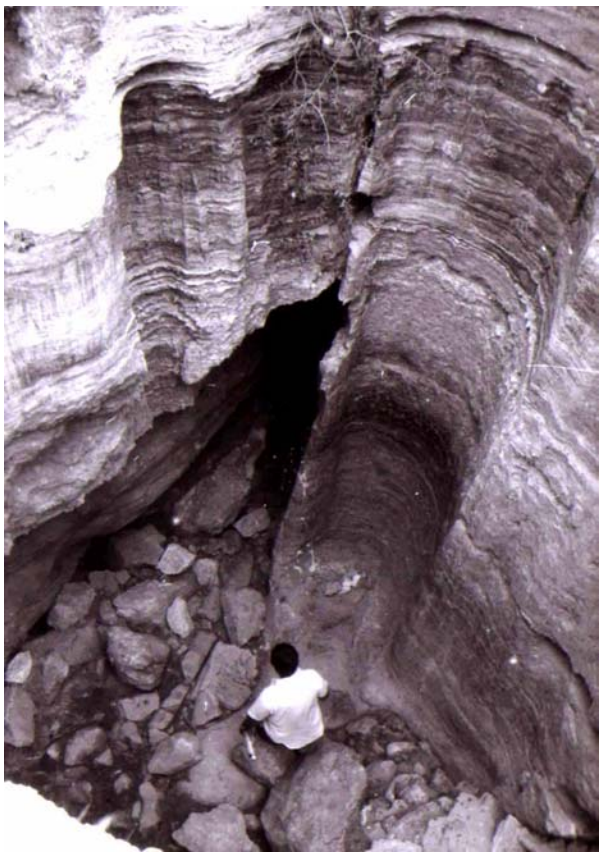
Photograph 17: The nicely decorated connecting shaft of the ZG-1-5 swallet group at the "Big Room" (pic17.jpg)

The passage becomes divided, forming a lower watery branch and an upper crumbling branch. The cave is flat in this section, its bottom filled with sandy silt. The stream channel meanders in its own deposits and possibly changes its course during every flood period. The ZG-1-6 swallet forms an important junction in the cave system. At the bottom, the upper two branches join to form the main passage of the cave system. This is a relatively easy entrance to the cave and is 1.8 km from the spring and 744 m through the cave to the next entrance.

ZG-1-6 to the ZG-1-8 swallet (south branch)

The passage follows the general strike of the cave system and encompasses several minor swallets, through two of which there are entrances to the system, (ZG-17 and 8). Others are choked by debris which has been washed in. The passages of the southern branch are rather tight, and difficult to pass. The only relatively spacious areas are those in the vicinity of the swallet-entrances.

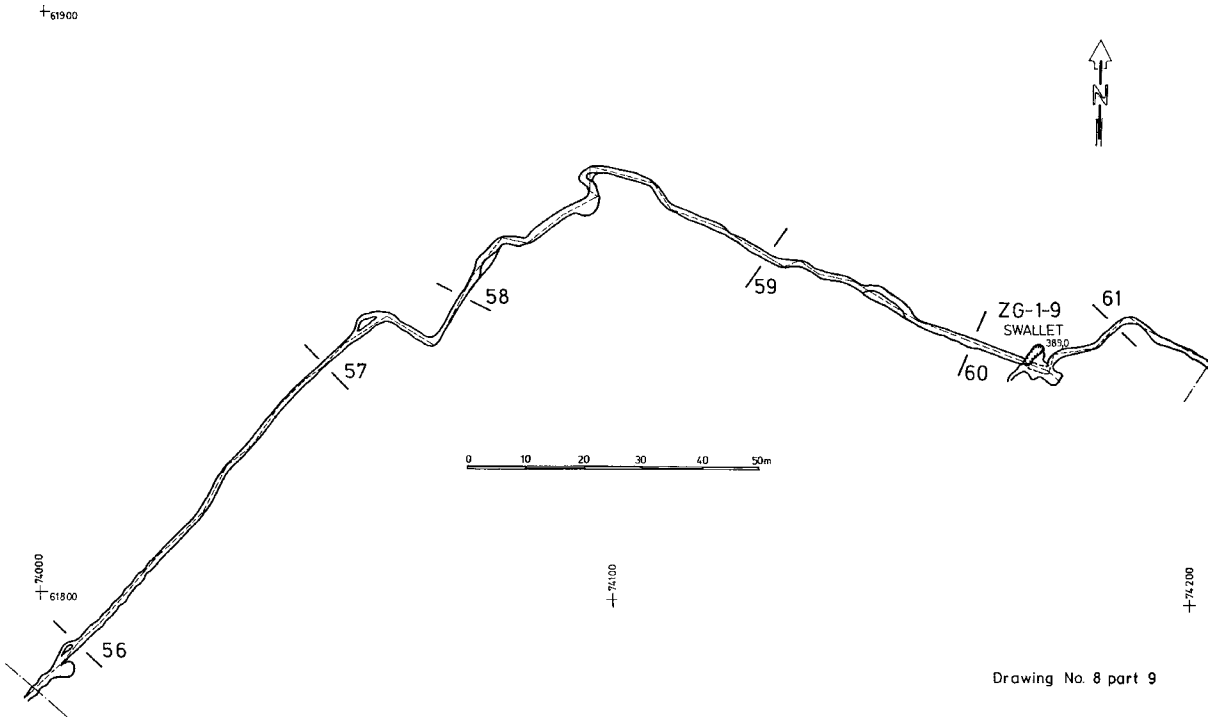
Photograph 18: The ZG-1-6 swallet (pic18.jpg)



Photograph 19: Internal view of the ZG-1-6 swallet (pic19.jpg)

See Drawing 8-8: plan (Draw0808.tif) and Drawing 11-2: sections (Draw1102.tif)

ZG-1-6 to the ZG-1-9 swallet (north branch)



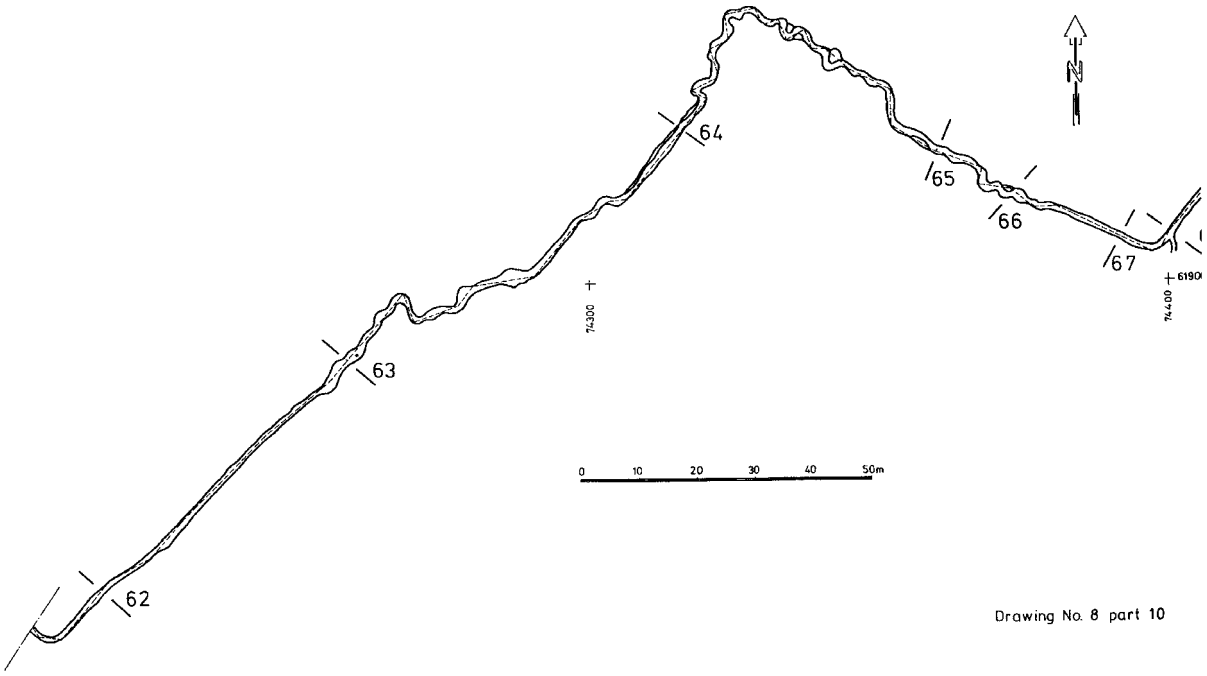
Drawing 8-9: plan (Draw0809.tif)

See Drawing 8-8: plan (Draw0808.tif, Draw0809.tif) Drawing 10-4: sections (Draw1004.tif)

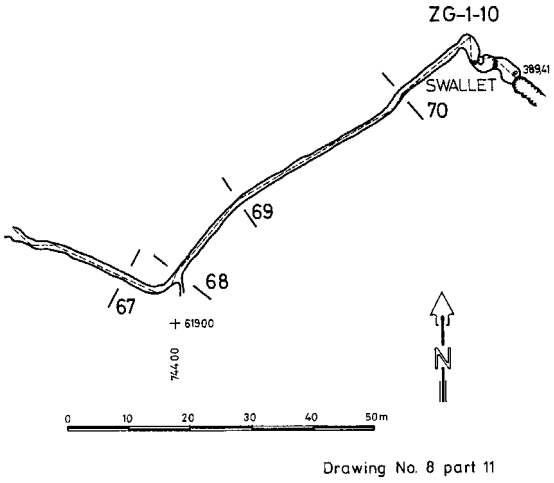
A passage starts at the northeastern corner of ZG-1-6 swallet, taking the strike of the secondary direction of the cave system. The conduit is almost impassably tight in places and is filled almost completely by stagnant water.

The passage zigzags, changing its route from one main direction to the other time and time again. The fine sandy-silty sediment at the bottom releases hydrogen sulfate gas when disturbed. This gas possibly originates from decaying sheep droppings carried in by floods.

ZG-1-9 to the ZG-1-13 swallet



Drawing 8-10: plan (Draw0810.tif)



Drawing 8-11: plan (Draw0811.tif)

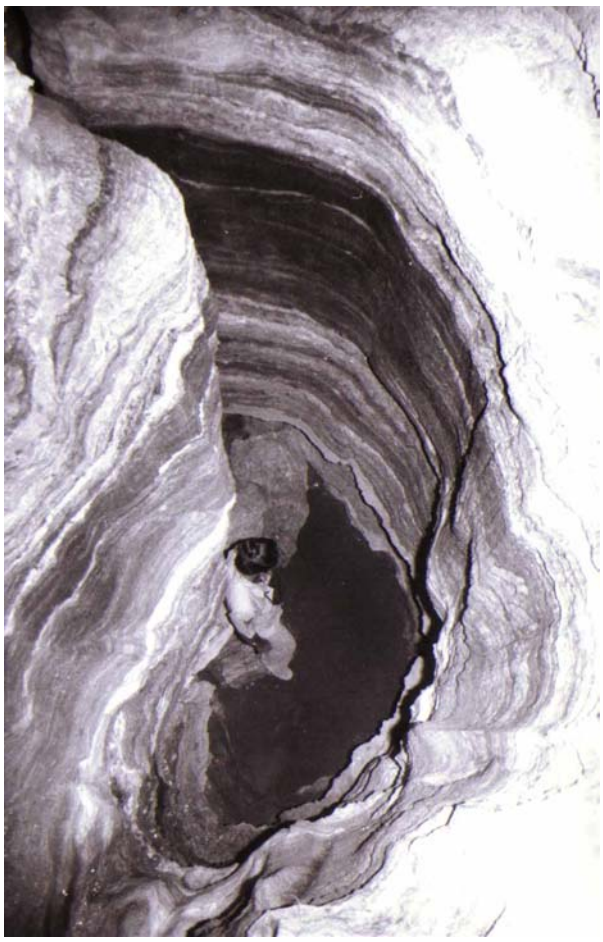
See Drawings 8-9 (Draw0809.tif), 11-2: sections (Draw1102.tif)

ZG-1-9 is the deepest and most imposing swallet of the cave system. Its shaft is divided into two sections by a horizontal ledge in its lower third. Because it has developed at the crossing of two joints, each representing one of the main strikes, it is easy to observe the geology of the cave at this point. This is an entrance to the system which requires vertical gear.

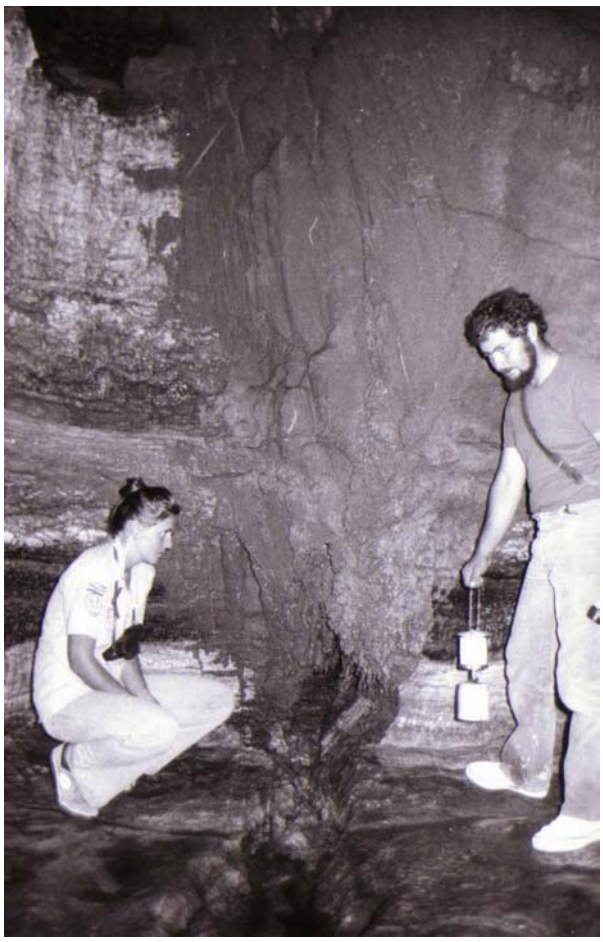
The passage between ZG-7-9 and ZG-1-10 swallets resembles that preceding ZG-1-9 but is somewhat larger and contains less stagnant water. Its route alternately takes directions parallel to the two main strikes.

Between cross sections Nos 67 and 68 a side passage enters which is impassable right from the beginning. This conduit is the collector for the ZG-1-11, -12 and -13 swallets. The latter is an impressive 10.5 m deep pothole, descent requires vertical gear but the subsequent passage is not large enough to be followed. This swallet is the furthermost karstic phenomenon that supplies water to the Umm al Masabih spring. The furthermost part of the continuous cave itself is the ZG-1-10 swallet.

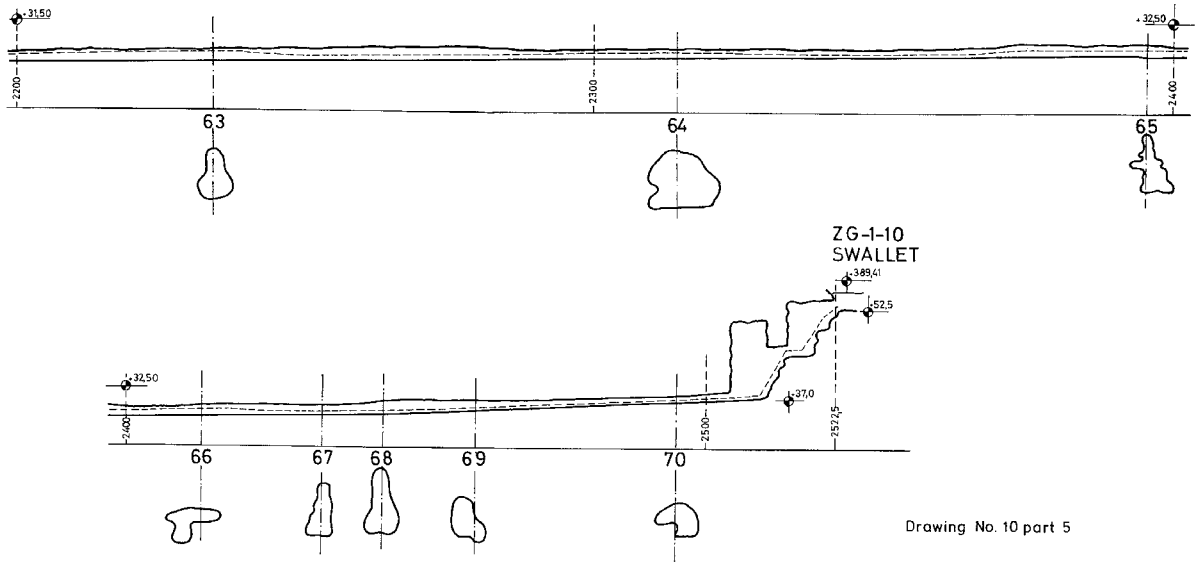
It has cut into a very impressive series of varying dark and light colored substrata, in three large steps, reaching down 20 m into a high chamber decorated with rare gypsum stalactite coating.



Photograph 20: Varying gypsum layers in the second pit of the ZG-1-10 swallet (pic20.jpg)



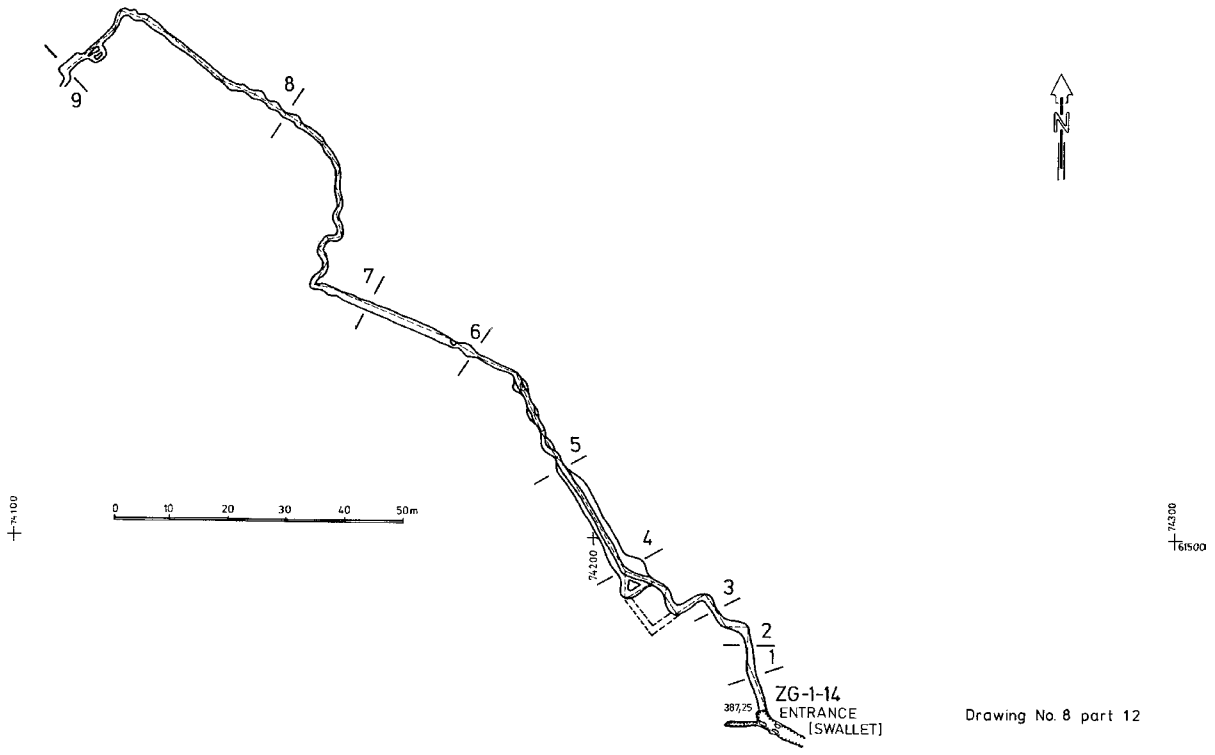
Photograph 21: Gypsum stalactite coating in the ZG-1-10 swallet (pic21.jpg)



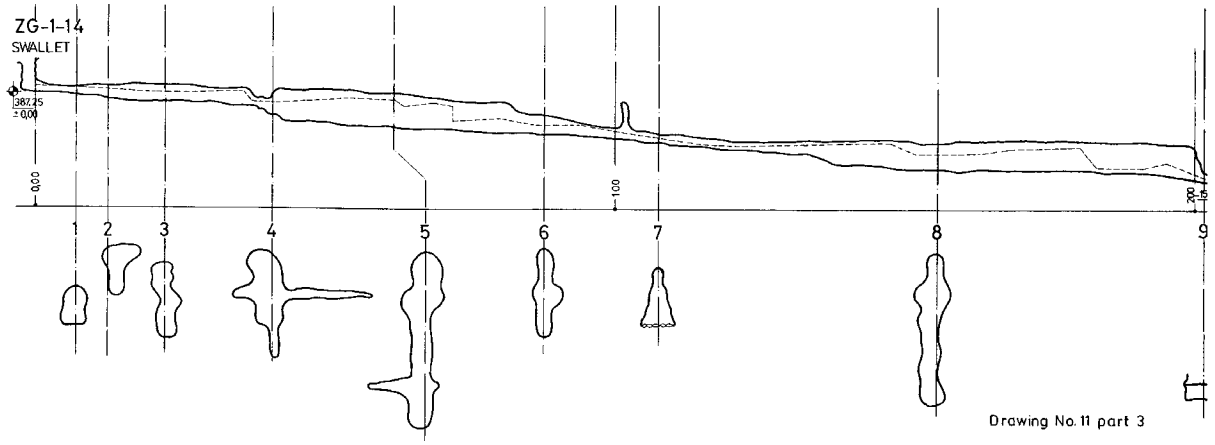
Drawing 10-5: ZG-1(Umm al Masabih), main passage, sections (Draw1005.tif)

ZG-1-14 swallet

The cave that originates in the swallet is in the extension of the southern branch of the system. Its connection to the Umm al Masabih cave is very obvious, but still not proved, as the end of the 200 m long passage which has been explored and surveyed is blocked by breakdown.



Drawing 8-12: plan (Draw0812.tif)



Drawing 11-3: sections (Draw1103.tif)

The Umm al Masabih cave is not only the longest cave in Libya at the moment, but in the year of its discovery it was the second longest cave system on the African continent. It is definitely the longest active gypsum stream cave in the world.

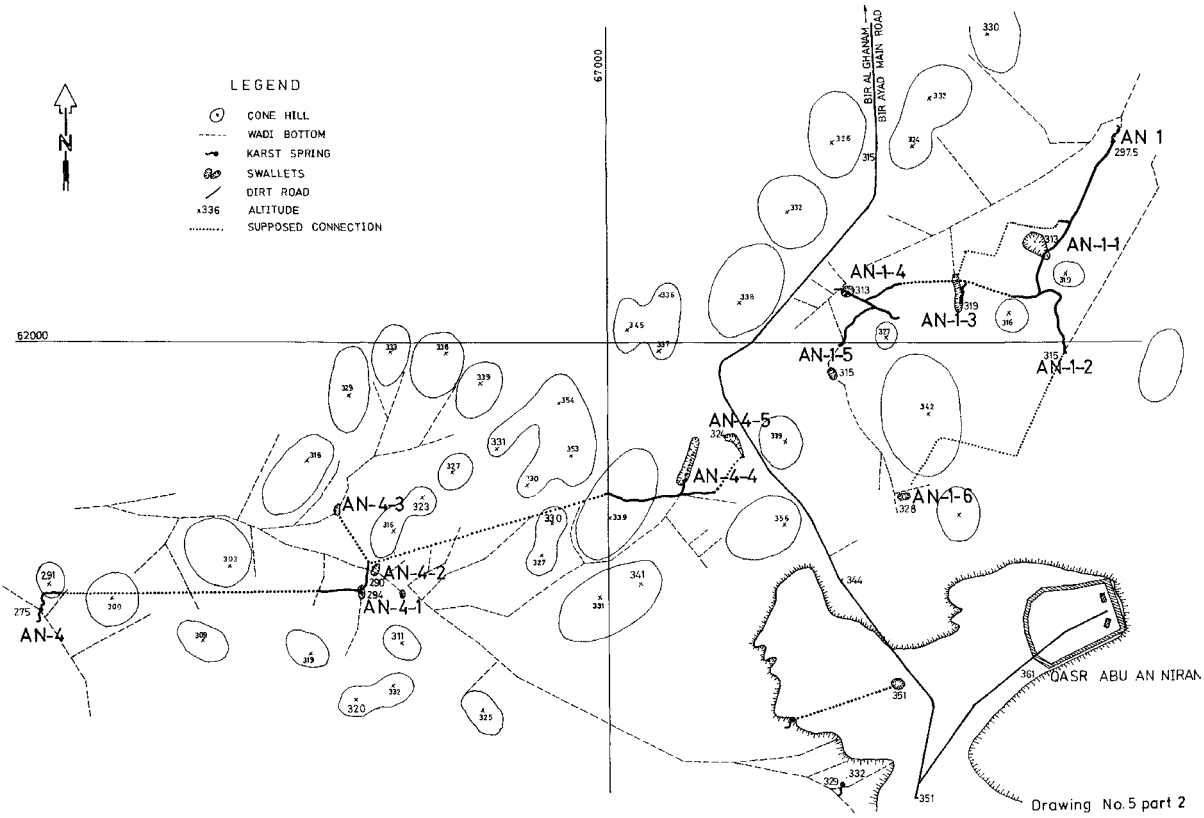
4.4.1.2 ZG-2 Cave

– Location: 2.5 km North of the Umm al Masabih spring. Accessible on a dirt road originating at the same point of the paved road leading to the Umm al Masabih cave. The swallet is located behind the first three cone hills in the wadi bank.

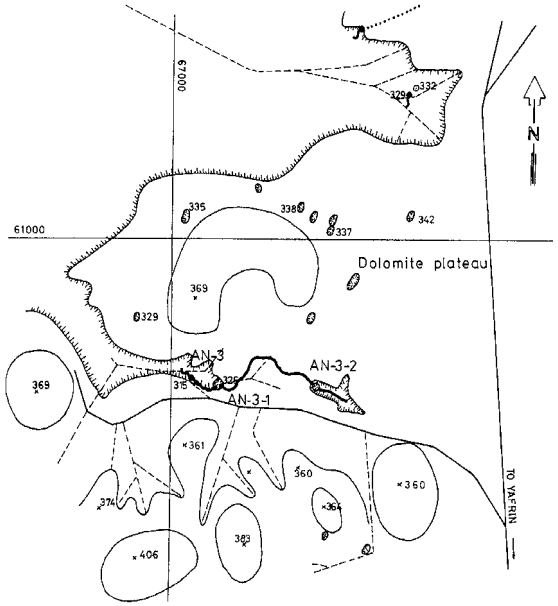
– Bedrock: Bir al Ghanam Gypsum

– Description: Swallet with impassably small 25 cm diameter round entrance. Its resurgence was searched for without success. Mentioned for the sake of completeness.

4.4.2 The Abu an Niran Area



Drawing5-2: Topographic map with caves,north part, (Draw0502.tif)



D

Drawing 5-1: Topographic map with caves, south part, (Draw0501.tif)

4.4.2.1 AN-1(Abu an Niran cave)

– Location: Northwest of the ghost town of Qasr Abu an Niran (The Castle of the Father of Lights see Photograph 3) next to the road 300 m before the last bend to Qasr. The main entrance to the swallet cave appears as a great loessy funnel.

– Bedrock: Bir al Ghanam Gypsum

– Total surveyed length; 858.00 m

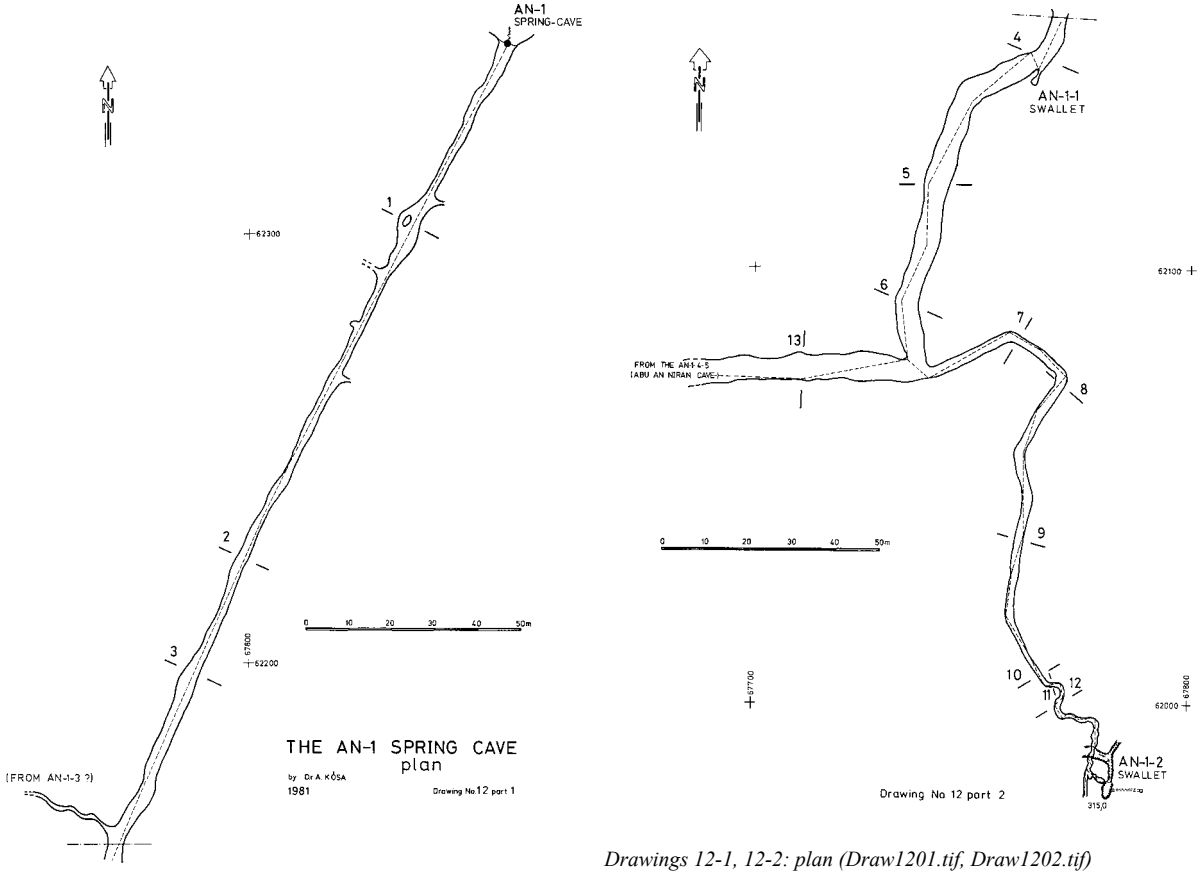
– Total surveyed volume: 4,500 m^3

– Number of sinkholes: 6

– Potential hydraulic head: 17.7 m

– Description: The cave system consists of two main components, the Spring Cave and the Swallet Cave. The two caves are connected by a very wide, and very flat, conduit that is completely filled with water in places (sumps) and thus was not passable, even by diving, during the period of exploration. The sumps probably dry up later in the summer. As the passage was explored from both ends, and shows the same character, size and direction, the two cave sections are considered to belong to the same system. The cave system occupies two main perpendicular joint systems. A large part of the system however does not follow joints but bedding planes. Thus the cave system does not show the clear tectonic pattern of the Umm al Masabih cave system.

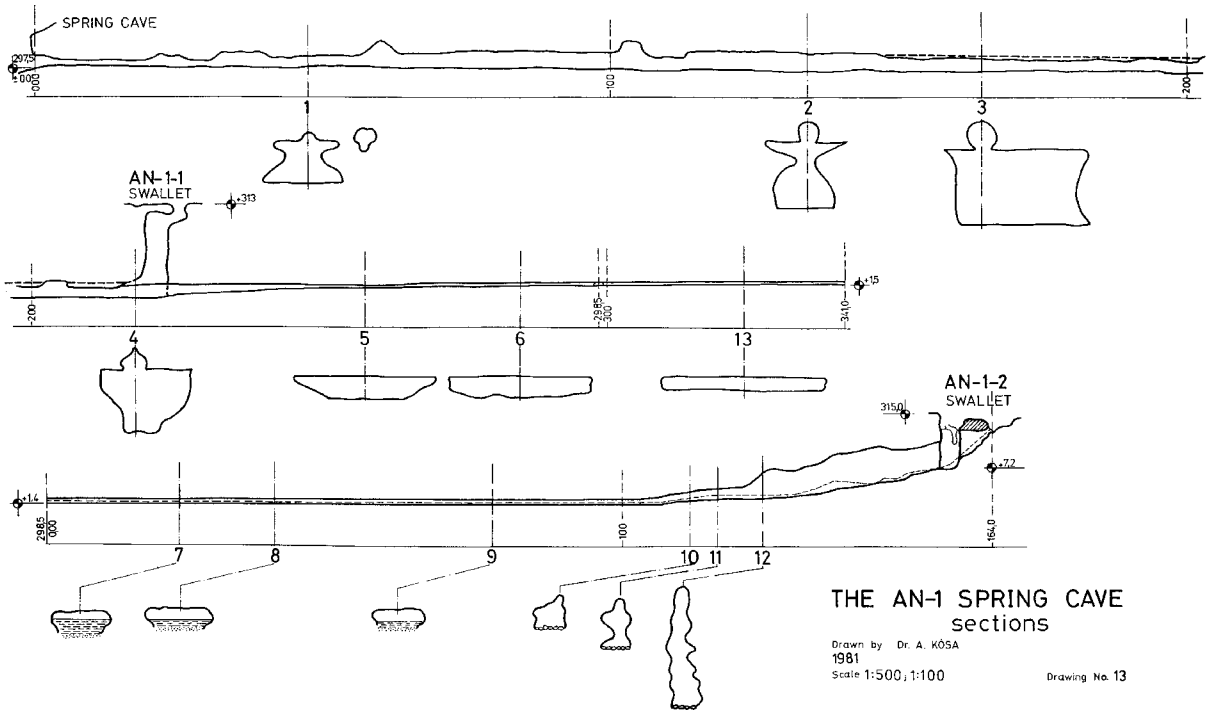
AN-1 spring to the AN-1-2 swallet



Drawings 12-1, 12-2: plan (Draw1201.tif, Draw1202.tif)

The low spring entrance opens in a cluster of bushes in the wadi that was the original route of surface runoff before the underground drainage was formed. The first 20 m is a crawlway then the next 200 m of passage is straight and spacious. The passage contains pools all year round. The curious "ghost armed" cross section prevails in this part of the cave. This shape shows very clearly the phases of development as the stream cut into strata that resisted differently. In places, blades of thin intercalated dolomite layers protrude from the walls. The direction of the passage is controlled by a joint which is orientated north-northeast. The control of the joint is observable as far as the 225 m point when the straight passage ends in an upward shaft. At the top of the shaft, feeble light is visible, coming from one of the numerous sinkholes (AN-1-1) from which the conduits are collected before they enter the shaft. Before reaching the shaft, a lateral branch joins the trunk from the right. It

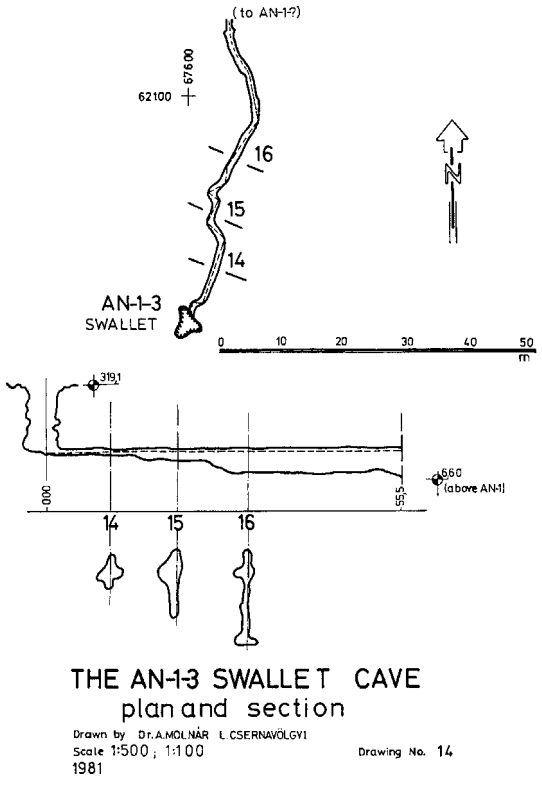
is a diminutive meandering tube, which becomes impassable after a short distance. Supposedly, this conduit is the one which starts at the AN-1-3 swallets.



Drawing: 13, sections (Draw13.tif)

Drawing 14: (Draw14.tif)

The long, straight, main passage turns right at its end, the floor rises and the passage continues as a very wide, very low, crawlway of which the ceiling is the same bedding plane which forms the top of the extended "ghost arms" of the previous section. The bottom is covered by silt in which the stream channel meanders. Three hundred and forty one meters from the entrance, the passage branches left and right. The character does not change to the right but the height decreases and also water fills the passage making access to the main cave impossible. The left branch is also bedding plane controlled, flat, and almost full of water. This passage emerges in the AN-1-2 swallet and only becomes high and narrow near to the swallet where it is controlled by a joint parallel to the main spring trunk.

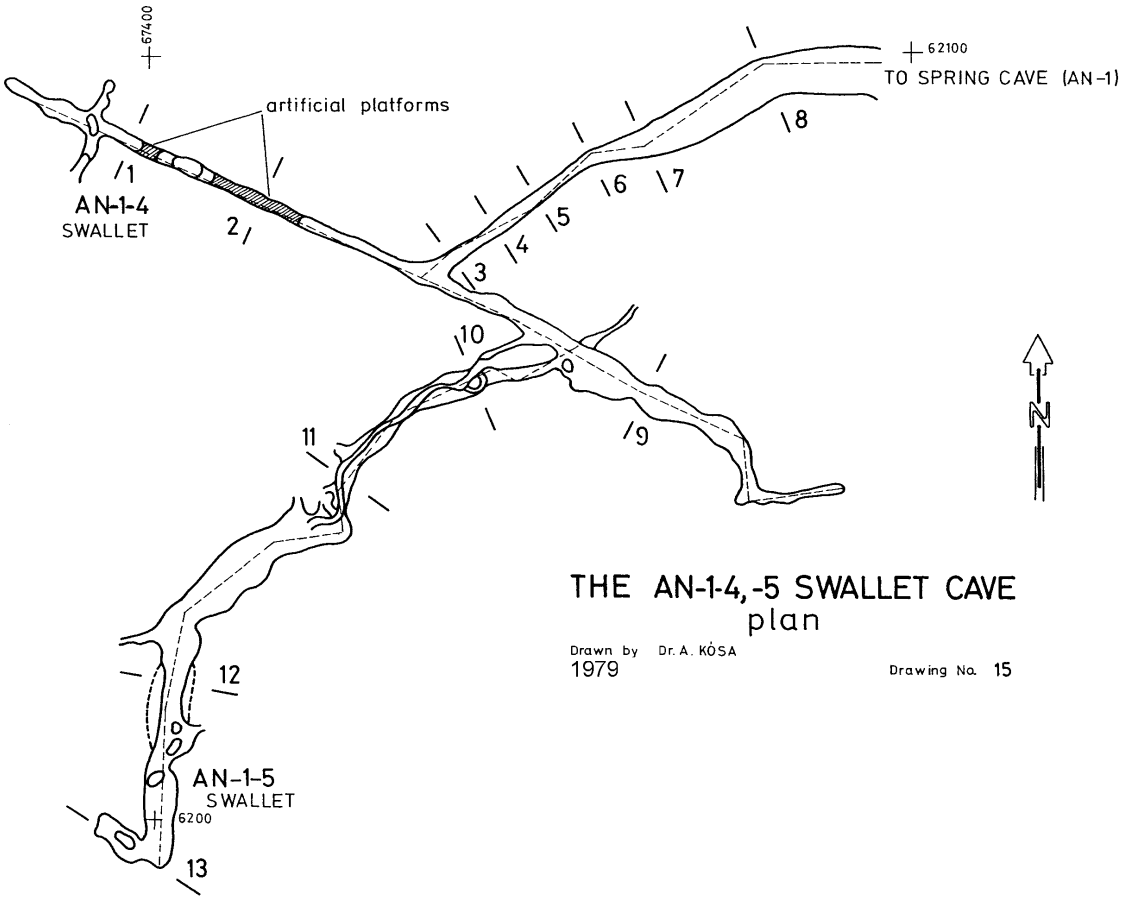


The stream from a wadi cuts into the gypsum rock, a very deep, narrow ditch that disappears underground and then again emerges after several meters only to enter again at the first spacious skylit chamber of the cave.

AN-1-4 to AN-1-5 sinkholes (Abu an Niran Cave)

From the chamber, the main passage extends east-southeast and also goes several meters backwards. The joint controlled passage represents the second main strike of the cave system. The high passage is lit from above at its commencement through a wide shaft which is an ancient swallet in the bottom of the great loessy funnel at the end of a dry valley visible from the road. In the middle of the main passage, the active streambed branches into a passage from which the water flows out parallel to a bedding plane – the same bedding plane along which the other end of this passage was developed in the Spring Cave. Soon the passage becomes impassably flat and

filled with water. A curious feature of the main passage is the two platforms built above the streambed spanning the passage. This structure possibly served as a hideaway for local people or livestock cleverly avoiding the floods that flowed underneath.

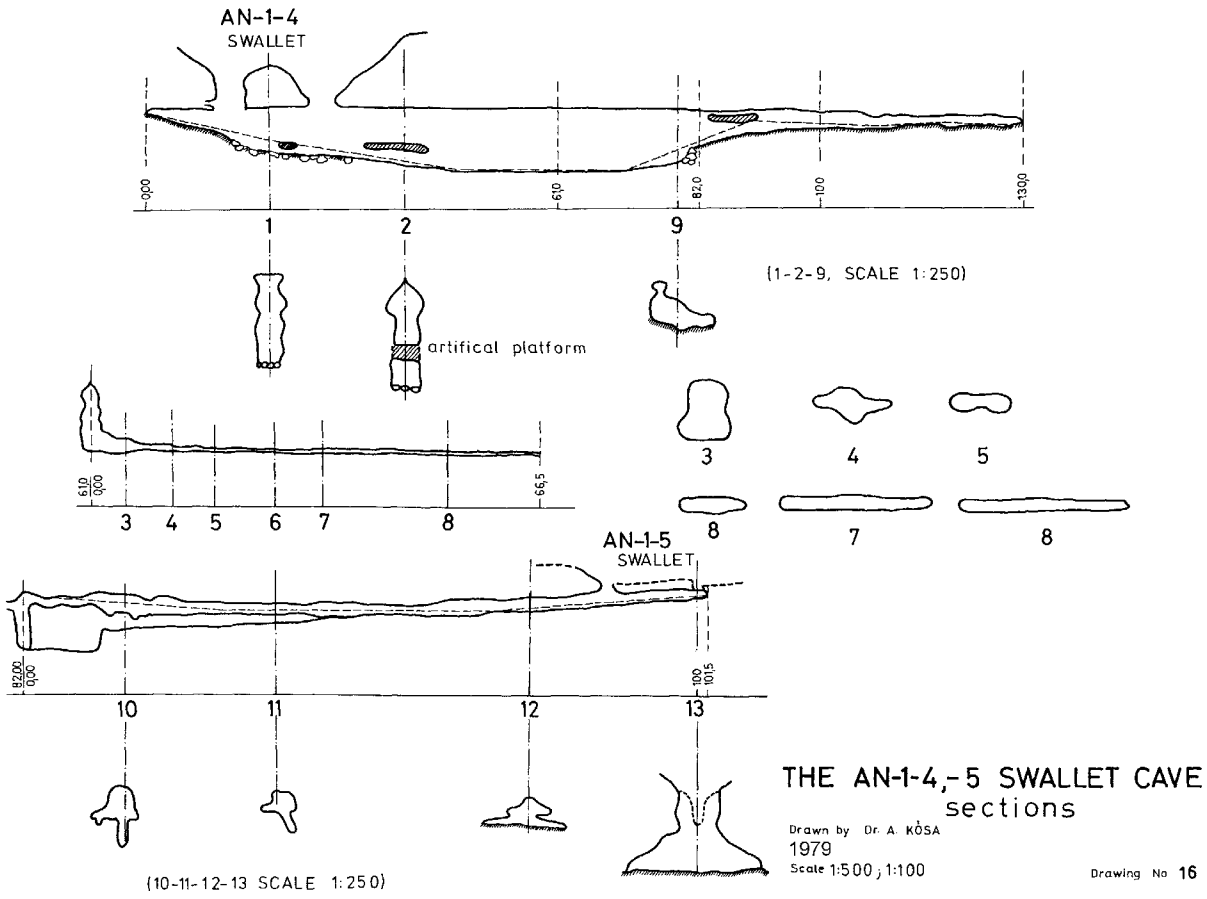


Drawing 15: plan (Draw15.tif)

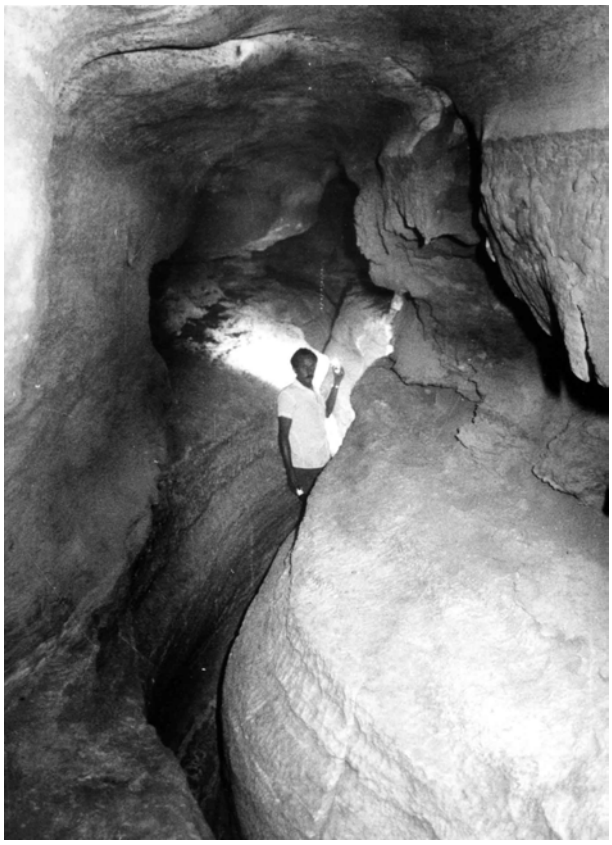
The continuation of the main passage becomes a somewhat meandering tube which narrows and becomes filled with sand. No surface swallet corresponds to this end but yet some water seepage was observed in the very rainy winter of 1980-81. The sand fill at the end is natural but it is artificially extended towards the entrance and finally supported by a stone wall. This construction, and the platforms, are the only signs of human intervention in all of the Bir al Ghanam caves. Sixty one meters from the entrance end of the main passage two side passages branch out. The one on the left is filled by sand after a few meters, while the right one leads to a branch that emerges in AN-1-5 swallet. The passage is not controlled by either of the two main joints but meanders along a bedding plane as a narrow channel at the top. The cross section widens to its maximum at a dolomitic gypsum layer. Halfway from the swallet the stream channel cuts through the harder layer and flows, in gradually deepening meanders, to the main passage.

The meander branch passes under an inactive swallet that is another entrance to the cave. The meander passage ends up at the bottom of a shaft (AN-1-5) which is the furthermost swallet of the AN-1 spring.

The meander cave is the youngest passage of the cave system. The wadi that feeds the water to AN-1-5 originally drained to the now inactive member of the AN-1-4 group and then its water started to disappear into the now dry member of AN-1-5 turning a part of the original wadi into a dry valley. In the latest phase of development the stream entered a joint parallel to the main passage and thus formed the northern dry member of AN-1-5. The two swallets of the AN-1-3 group discharge to the side passage of the spring cave with one of them entering an unexplored connecting passage. The conduits from both swallets are very high and very narrow, and impassable. Their connection to the AN-1 cave system is obvious but not proved. It is not so obvious that the AN-1-6 swallet drains to the AN-1 system but no other possibility was found. The conduit is impassable at the bottom.



Drawing 16: sections (Draw16.tif)

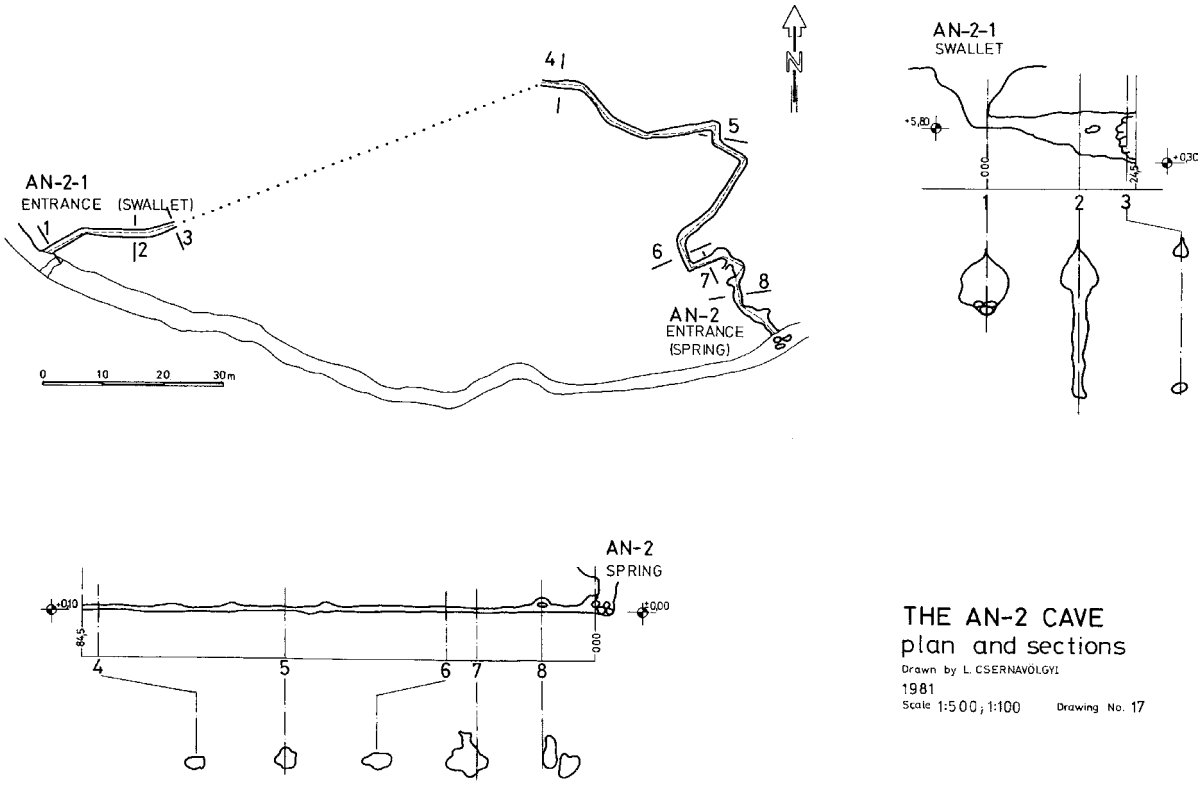


Photographs 22, 23

Photograph 22: The main passage at AN-1-4 entrance, Abu an Niran Cave (pic22.jpg)

Photograph 23: Meandering passage between sections 10 and 11 in the AN-1-5 branch (pic23.jpg)

Photograph 24: Meander between sections 10 and 11 in the AN-1-5 branch (pic24.jpg)



Drawing 17: plan and sections (Draw15.tif)

4.4.2.2 AN-2

– Location: 1700 m southeast from the shrine of Qasr Abu an Niran in the lower canyon of the wadi which originates on the south slope under Qasr.

– Bedrock: Bir al Ghanam Gypsum

– Total surveyed length: 105 m

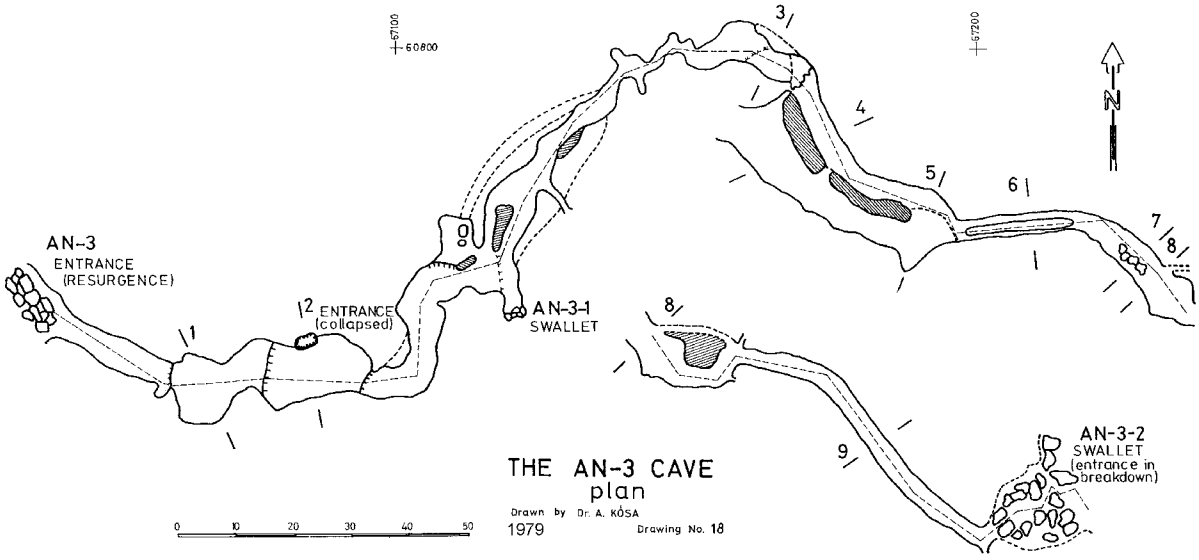
– Total surveyed volume: 90 m^3

– Number of sinkholes: 1

– Potential hydraulic head: 5.80 m

– Description: The spring entrance (AN-2) of the cave is found between boulders in the bottom of a deep canyon. The first part of the passage is crumbled. After 20 meters it becomes a small, clear solution channel which narrows to become impassable after 80 meters. The cave swallet (AN-2-1) is located 130 m upstream in the canyon. The high narrow passage is divided into a lower and an upper conduit 25 m from the entrance – both of which are impassable. The connection between AN-2 and AN-2-1 was not proved but no other possibility was found.

4.4.2.3 AN-3 (Hyena Cave)



Drawing 18: plan (Draw18.tif)

– Location: Southwest of the Qasr Abu an Niran 300 m on a dirt road on the right between two hills made of the clay of the Bu an Niran Member.

– Bedrock: Bu an Niran and Bir al Ghanam Gypsum member

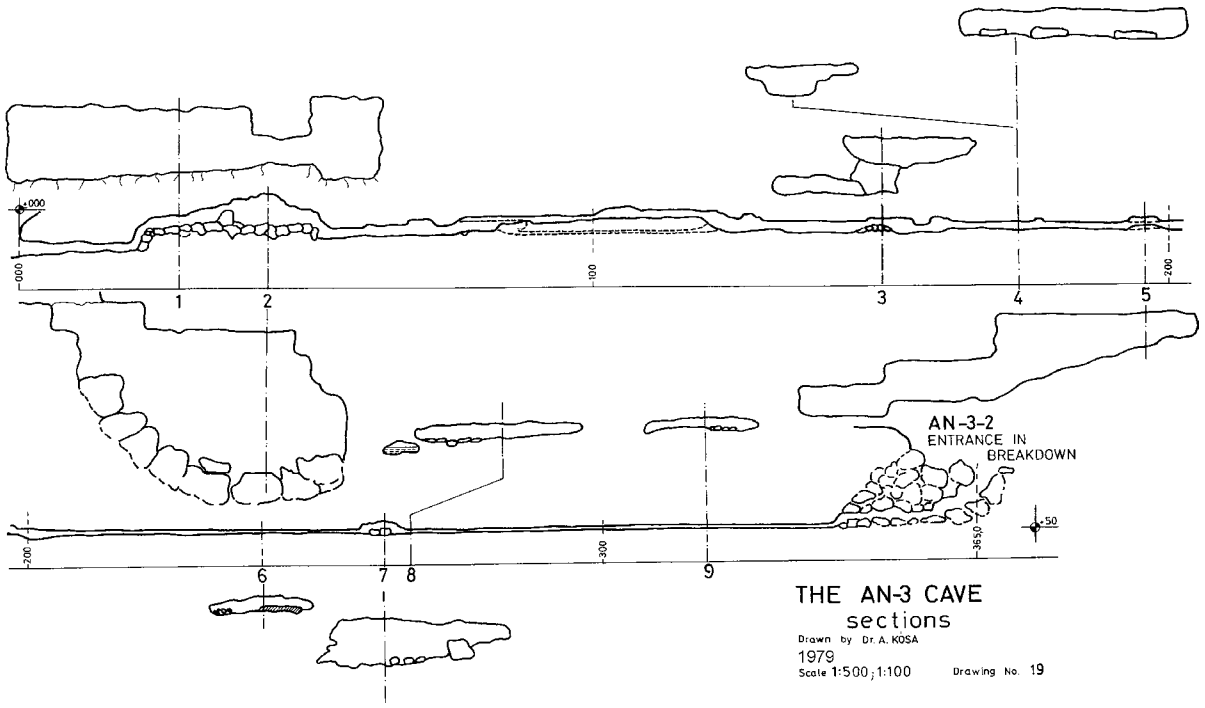
– Total length: 365 m

– Total volume: 2,094 m^3

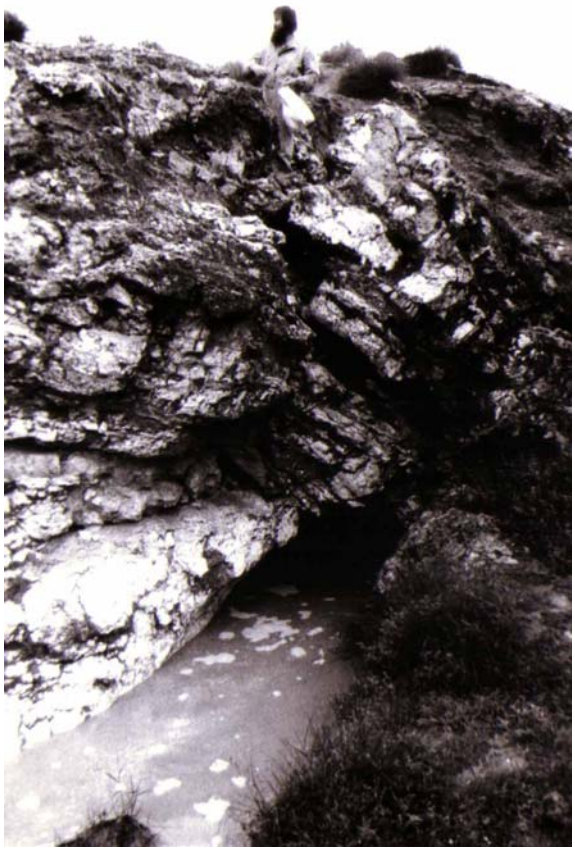
– Number of sinkholes: 2

– Potential hydraulic head: 25 m

– Description: The AN-3 cave is the most colorful phenomenon of all of the Bir al Ghanam caves. The cave passages are bedding plane orientated, joints having played practically no role in their development. Thus the cave is meandering, its cross sections are wide and flat. Due to its position where the two members meet, the mineralogy and petrology of the cave is most varied.



Drawing 19: sections (Draw19.tif)



Photograph 25: The flooding spring entrance (AN-3) to Hyena cave (pic25.jpg)

The spring entrance opens in the precipitous side of the recipient wadi among large boulders. The passage beyond the entrance is spacious, high enough to walk in, wide, with its bottom covered by rounded gypsum and dolomite gravel and sand. The spring passage ends up in a breakdown of huge boulders between which there is access to the largest cavity not only in the cave but also in the whole of the Bir al Ghanam karst. This large room was created by the cave-in of a very wide passage. The collapse is temporarily naturally stabilized, but the room shows signs of stress and the dolomite-rock covering is thin. The collapse has already opened an entrance to the surface.

Floods pass under this chamber and water never appears in the chamber itself. Dry conditions in this large chamber have allowed animals to use it as a shelter. Hyenas once made a den in the dark back part (section No.1) of the chamber where a mass of dry bones and dung is all that is left to prove the presence of the animals, not so long ago, although they are now extinct in the area. The mineralogical curio of this big chamber is the magnesium sulfate that covers the south wall of the back part in a soft, snowy mass, the origin of which is uncertain. The solution channel of the cave can be entered again at the upstream end of the large chamber. The passage is wide and low. The eastward continuation is divided, there is an actively flooding lower passage, and a dry, sandy, upper passage. The AN-3-1 swallet joins the cave in the upper passage.

Photograph 26: The large collapsed entrance chamber to Hyena cave (AN-3-1) (pic26.jpg)

Photograph 27: Stresses show on the roof of the large chamber in the Hyena Cave (pic27.jpg)

Photograph 28: Double flow channel in the Hyena (ZG-1) Cave at the 100 m section (pic28.jpg)

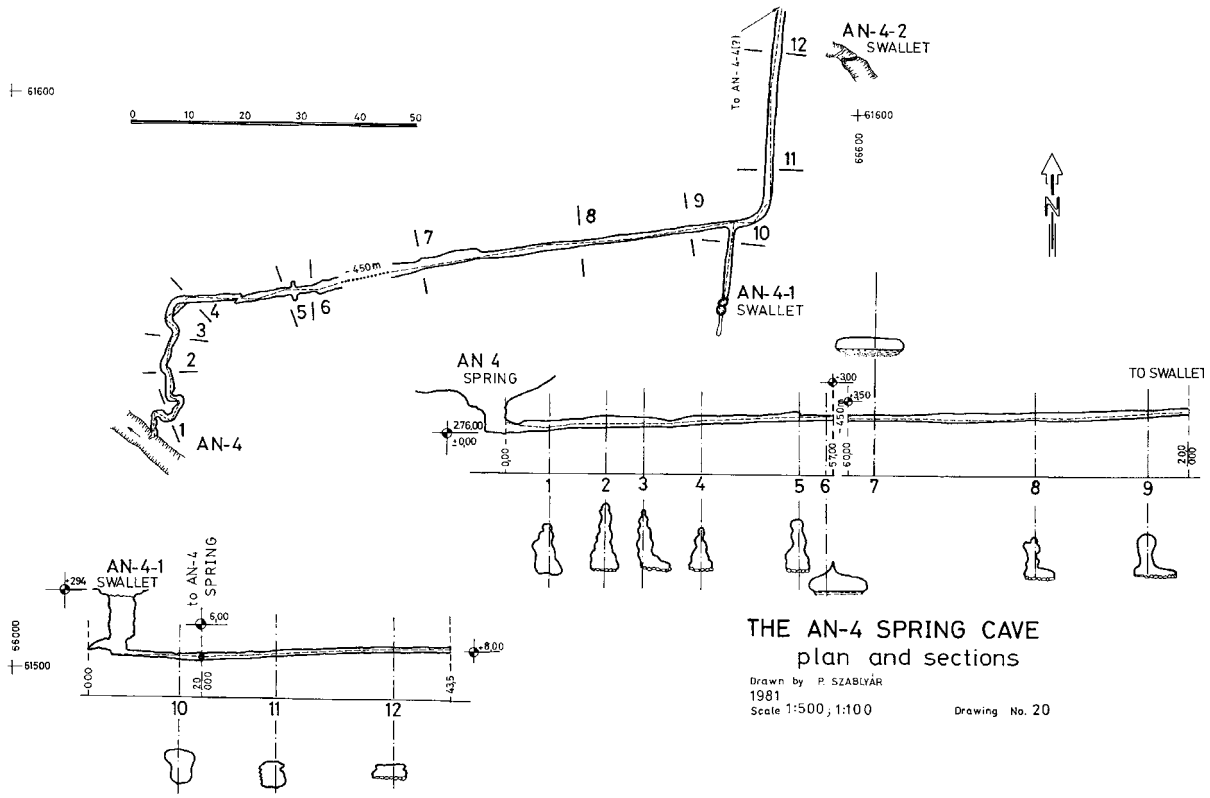
Photograph 29: Human skull in the Hyena (ZG-1) Cave (pic29.jpg)

The dry part of the upper passage is littered wih the bones of various animals. A human skull was also found. Where the two channels merge, the cross section becomes larger, the passage goes through a series of chambers with interesting solution features indicating the development of the cave, for instance the flat bedding plane roof showing the shallow mark of the initial flow channel, substrata of clay, fibrous gypsum, and stalactites. From the 200 m section the cave continues as a wide, very flat solution passage its bottom littered by debris. The cave passage ends in a breakdown. Between the boulders there is an entrance to the cave. The AN-3-1 swallet is a large sinkhole in the collapsed dolomite layer of the Bu an Niran Member.

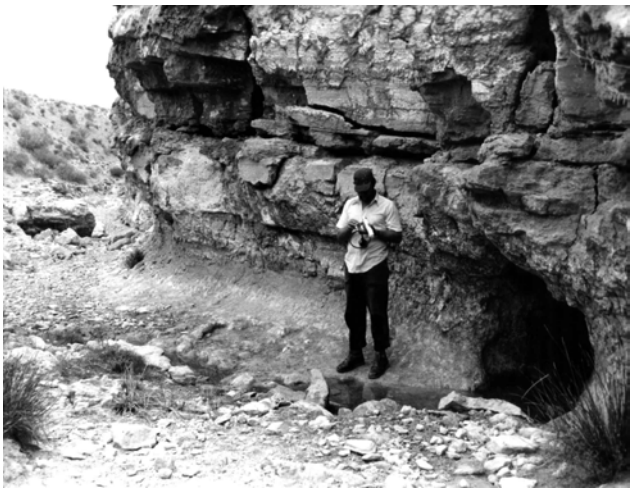
Photograph 30: The "snake", a curious solution form in the Hyena (ZG-1) Cave at section 3 (pic30.jpg)

Photograph 31: Flat bedding plain orientated passage in the Hyena (ZG-1) Cave at section 6 (pic31.jpg)

4.4.2.4 AN-4 Cave



Drawing 20: plan and sections (Draw20.tif)



Photograph 32: The AN-4 spring (pic32.jpg)

– Location: The western part of the Abu an Niran area. The uppermost group of sinkholes (AN-4-4) is located immediately right of the road after the last bend before the Qasr. The rest of the sinkholes can be found following the wadi which starts at the AN-4-4 swallets. After the AN-4-2 swallet the wadi should be followed and then the first wadi to the left taken. After 170 m upstream the spring entrance (AN-4) can be found at the foot of a cliff. The openings to the cave lie along a 12,00 m long almost straight line. No vehicle can be used in the area.

– Bedrock: Bir al Ghanam Gypsum

– Total surveyed length: 435 m

– Total surveyed volume: 805 m^3

– Number of swallets: 5

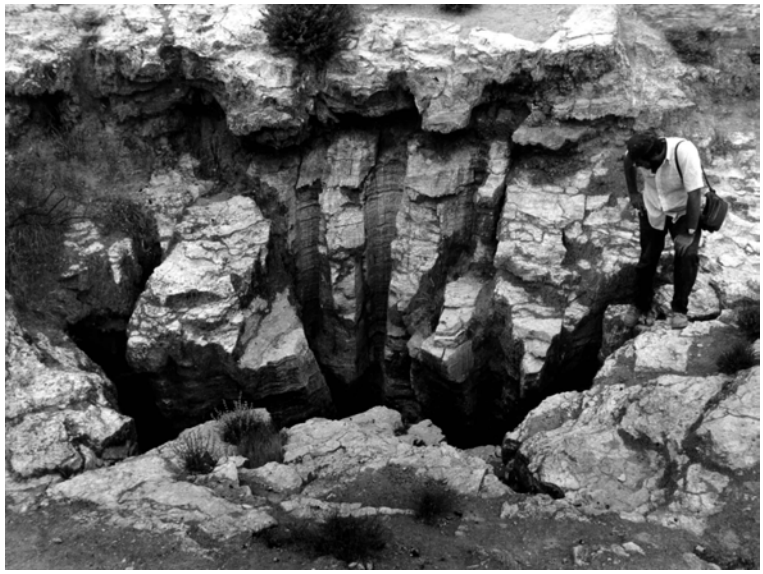
– Potential hydraulic head: 43 m

– Description: A very young cave system with only a fraction of its length passable. The continuity of the cave along its supposed line is uncertain but a thorough search did not yield any other solution. In spite of the uncertainties the known parts of the cave follow a very strong tectonic line which is visible even on the aerial photograph.

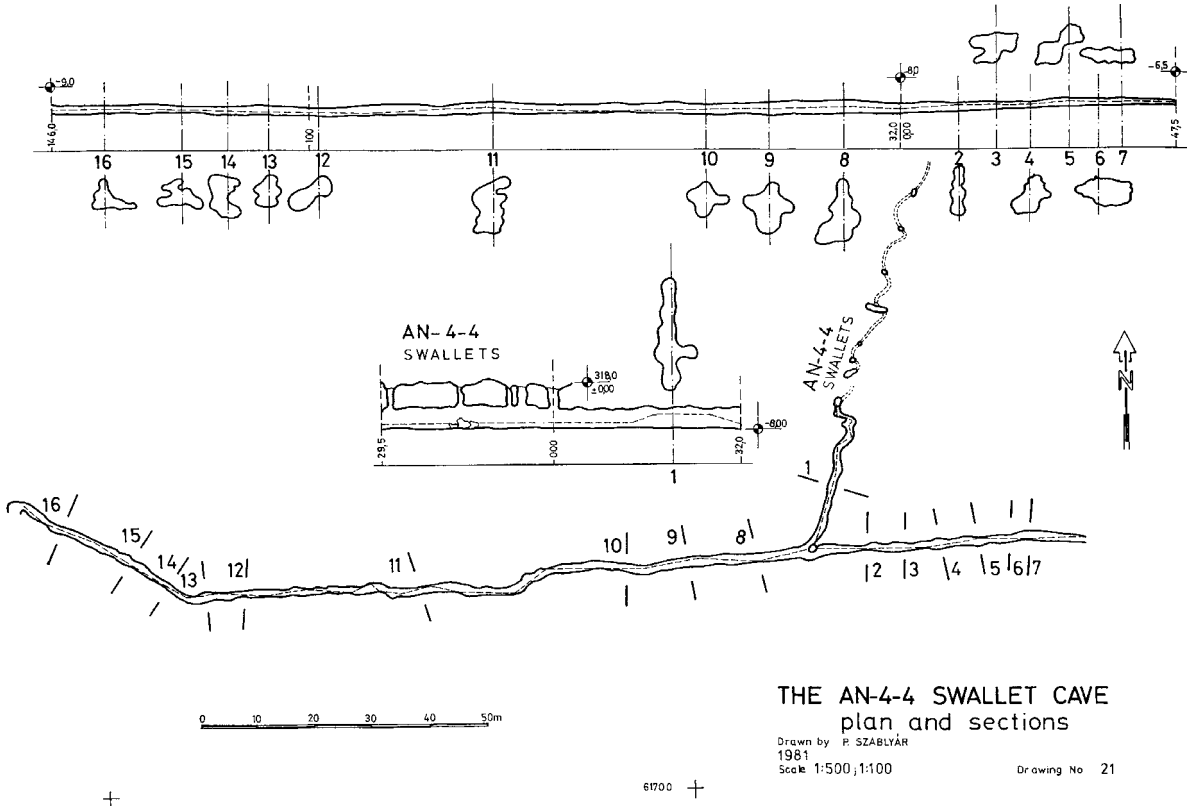
The spring cave (AN-4) can be penetrated to a distance of 57 meters. After a meandering section it takes the straight, eastern direction of the main joint. The passage is joint orientated, narrow, and filled with water at the end.

The middle part (AN-4-1, -2, -3) of the cave consists of three separate swallets, one of which has a 123 m long passage (AN-4-1).

Photograph 33: The AN-4 swallet (pic33.jpg)



This swallet is located on the top of the wadi-bank. It is large mouthed and deep, resembling the big swallet-pits of the Umm al Masabih cave. The descent to it is possible only using vertical gear. After a 20 m long passage the main passage of the cave system is reached which is orientated by the main joint on the left and points straight to the end of the spring section. The passage on the right turns north and becomes impassable after a distance, like the branch on the left, because of stagnant water that almost fills the conduit. The AN-4-2 swallet, which is located right under AN-4-1, at the bottom of the wadi, developed in the main joint of the system. It starts with a 3 m deep shaft at the bottom in which a round, small solution channel was found which possibly joins the system at an unknown point upstream of section No 12. Sixty meters upstream in the wadi a very small sinkhole was found (20 cm diameter) which probably drains to the channel at the bottom of AN-4-2. The relationship between the AN-4-3 swallet and the system is also questionable but its independent spring was not found.



Drawing 21: plan and sections (Draw 21.tif)

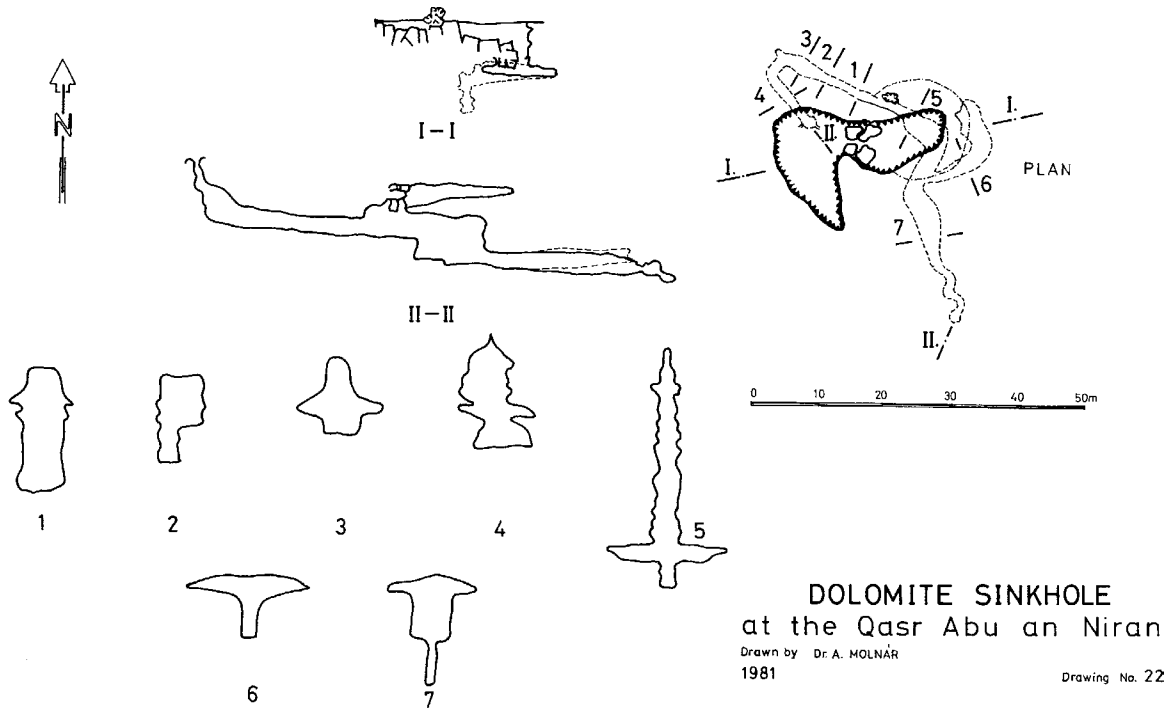
The upper part (AN-4-4, -5) can be entered via the lowest of the series of swallets, and drops to the top of a wildly meandering high, narrow passage. Thirty meters beyond the entrance the passage reaches the main conduit which is orientated by the main joint of the cave system. After a distance of 47 m, the upstream passage

is mostly filled by debris. The downstream passage can be followed for a distance of 140 meters then it is almost filled with water and disappears round a bend.

The AN-4-5 swallet opens in a big loessy, funnel-shaped depression east of the last member of the AN-4-4 group. The passage at its bottom is too small to be entered. It is probably the origin of the eastern branch of the main passage in AN-4-4.

The relationship between the upper part of the AN-4 cave system and the rest is very uncertain. The only fact that connects them is the orientation of the passages and the fact that no resurgence was found that might belong to the AN-4-4 swallet. The difference in elevation between the end of the passage of AN-4-1 and that of AN-4-4 is 25 m, which challenges the connection, as all the caves in the Bir al Ghanam karst tend to be of shallow gradient.

4.4.2.5 Dolomite Sinkholes (DS)

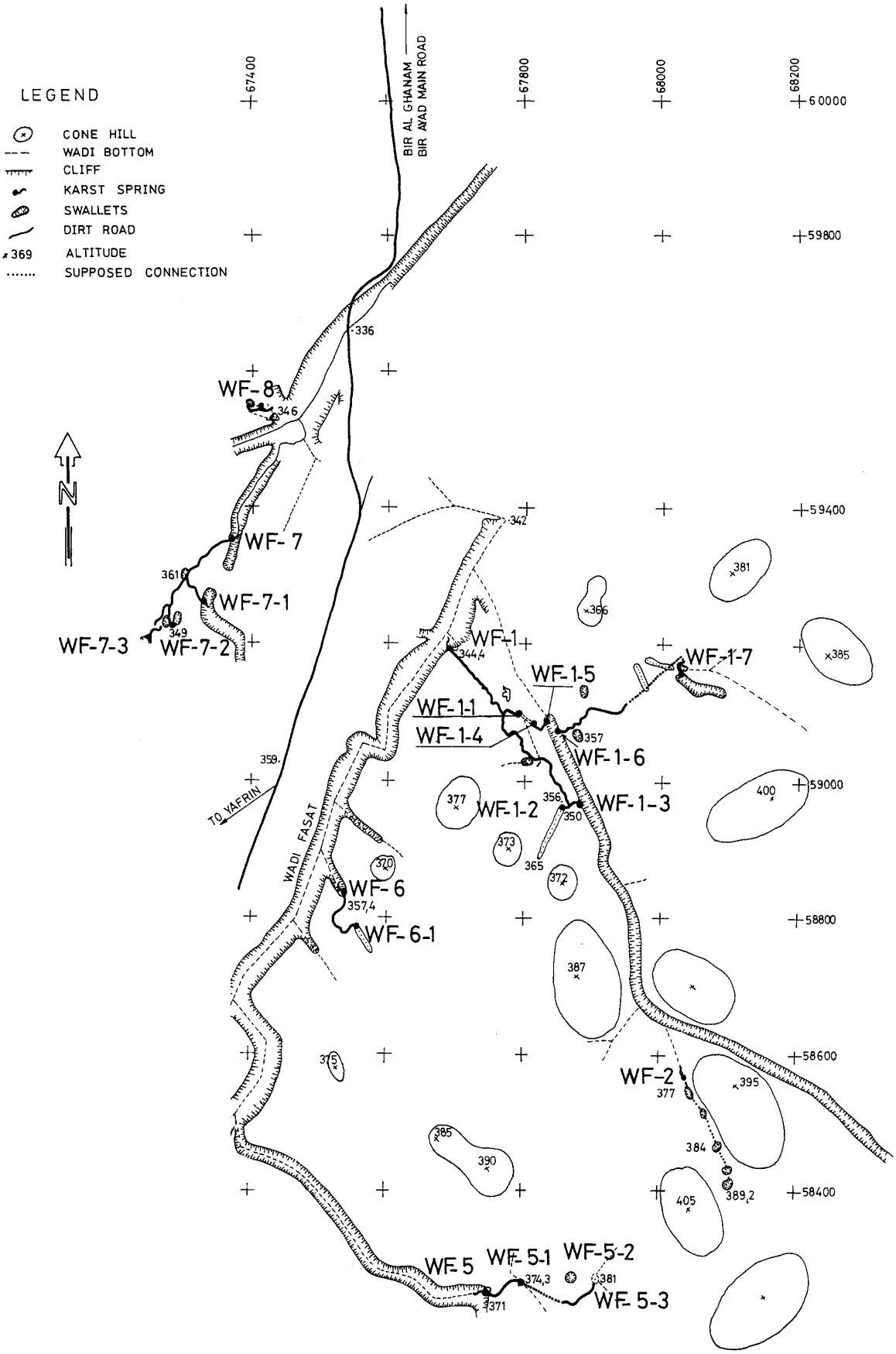


Drawing 22: plan and sections (Draw 22.tif)

A number of sinkholes dot the dolomite plateau at Abu an Niran, on the top of which Qasr was built. The plateau is the outcrop of the lower dolomite layer of the Bu an Niran Member. The dolomite is underlain by the Bir al Ghanam Gypsum. The dolomite forms both the roof of the solution chambers in the gypsum collapses and open cavities. Irregular small conduits radiate from these cavities but are of minor hydrological importance. One of the sinkholes, that at the new cistern at the Qasr (on the other side of the road) is more important than the others. The big collapsed sinkhole contains some confused passages. The collapsed ruins of a cave under the western edge of the dolomite plateau may have been its spring. Possibly the AN-3 cave is a younger version of the same phenomenon. The aforementioned dolomite sinkhole contains exceptionally nice gypsum crystal formations.

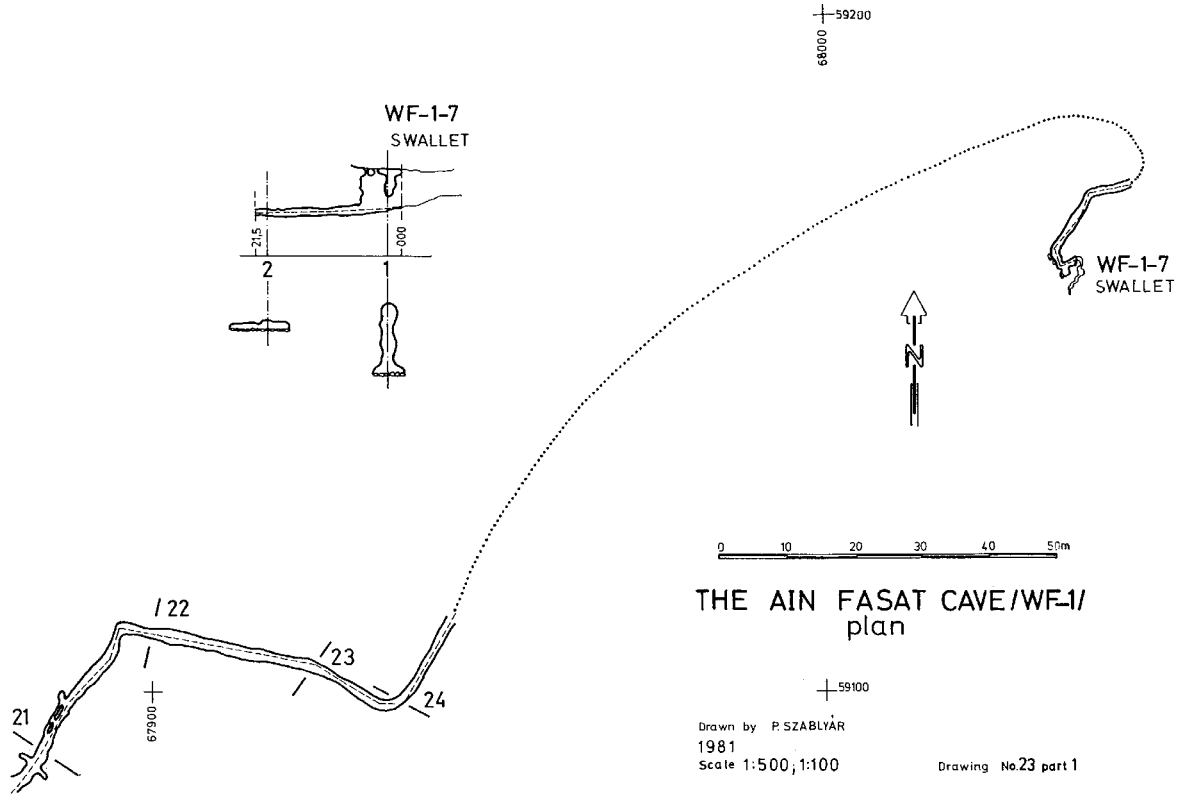
Photograph 34: Nice solution forms in layered gypsum in the largest dolomite sinkhole (pic34.jpg) (See pic. No.5 too)

4.4.3 The South Wadi Fasat Area

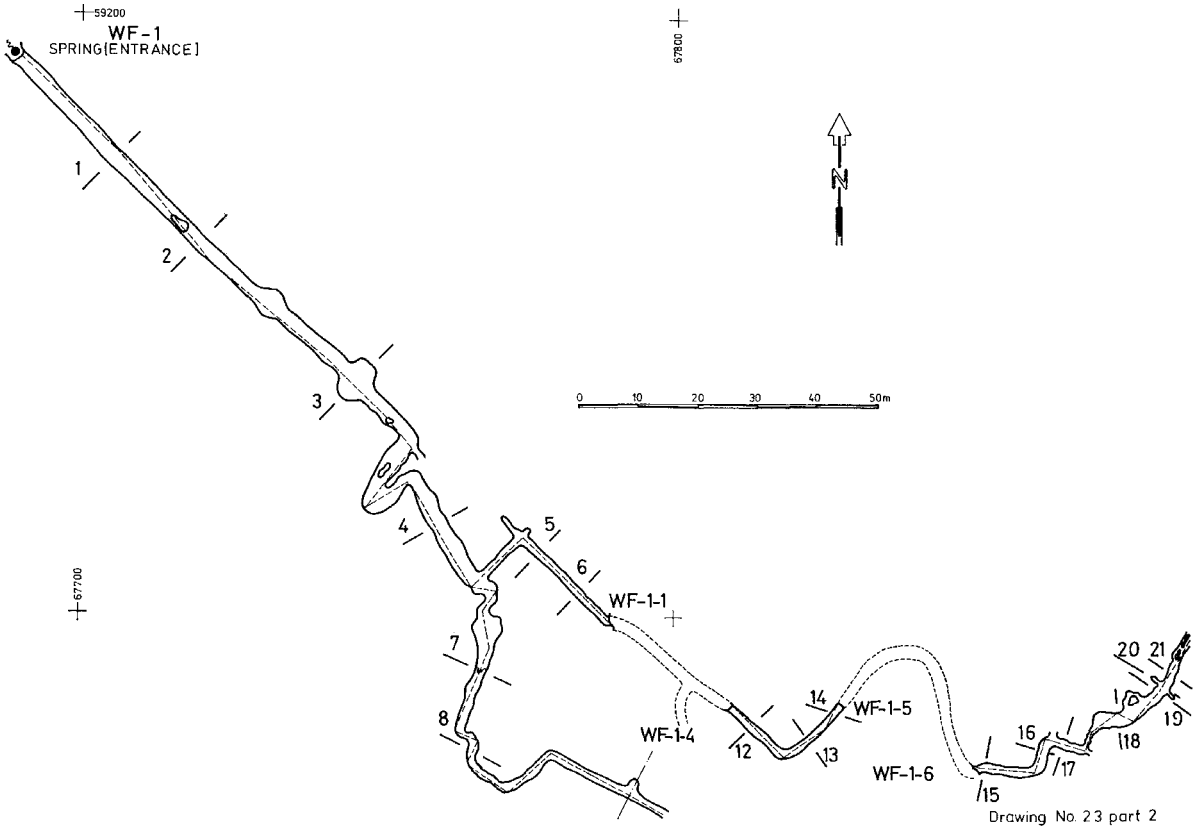


Drawing 6: topography with cave maps (Draw06.tif)

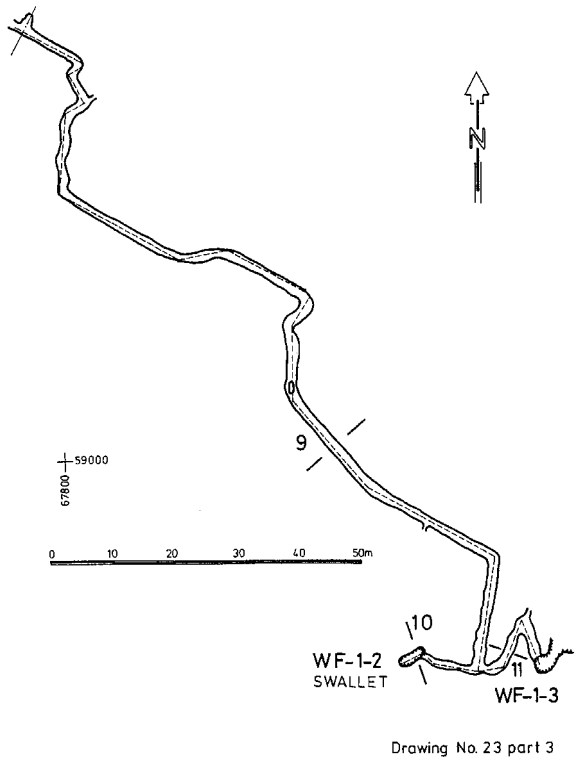
4.4.3.1 WF-1(Ain Fasat)



Drawing 23-1: plan (Draw2301.tif)



Drawing 23-2: plan (Draw2302.tif)



Photograph 35: Entrance passage of the WF-1 (Ain Fasat) Cave (pic35.jpg)

Drawing 23-3: plan (Draw2303.tif)

– Location: 2.5 km south of Qasr Abu an Niran the dirt road crosses a deep wadi with a small palm grove. The road then climbs the wadi-side and from the top another palm grove is visible at the left in the bed of another wadi. This palm grove marks the entrance to the Ain Fasat Cave.

– Bedrock: Abregh Gypsum

– Total surveyed length: 618 m

– Total surveyed volume: 1,725 m

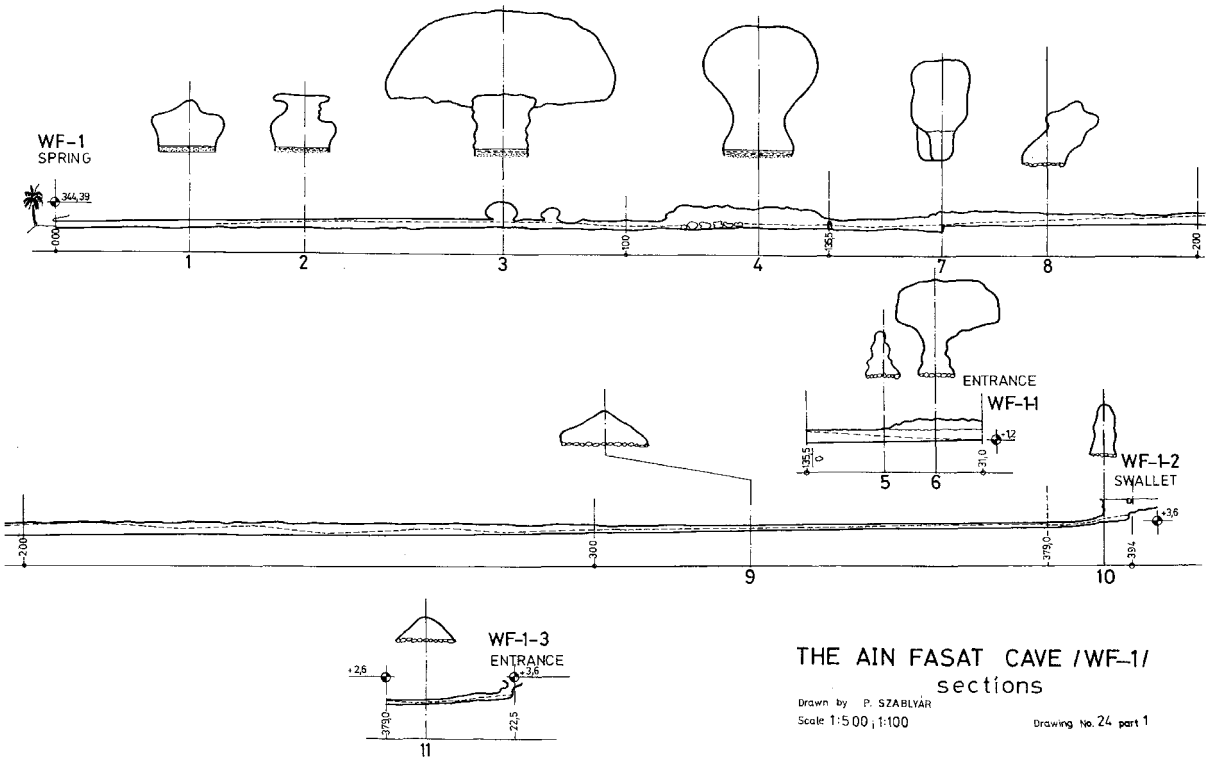
– Number of sinkholes: 5

– Potential hydraulic head: 15 m

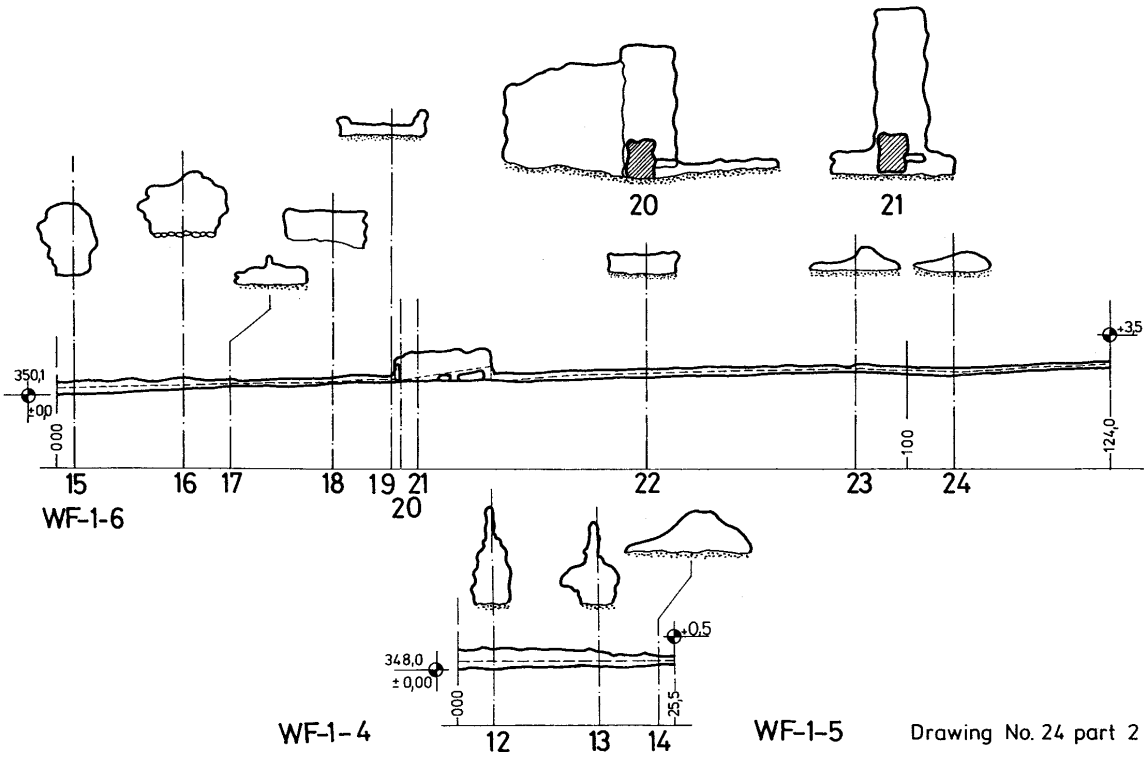
– Description: The spring entrance to the cave opens in the Wadi Fasat and is called Ain (spring) Fasat by locals. The cave developed in the top of a massive gypsum bed topped by a loessy conglomerate of uncertain origin. The section entered through the spring entrance is a joint orientated straight passage almost 100 m long, when it turns right to a meandering section, to branch off at 135 m from the entrance.

The passage is a solution channel which, at various points (sections Nos. 3-4), developed enough height to reach the loessy covering. These areas then caved-in, forming large round chambers with unstable roofs. The left branch at 135 m is the older part of the cave system. It is a high, joint orientated passage, which becomes mushroom shaped due to the cave-in of the loessy roof.

It finally opens to the surface at the bottom of a funnel shaped loessy sinkhole (WF-1-1) only to continue at the far side of the funnel (WF-1-2). The funnel itself is the very last feature of the destruction of the cave, the upper loessy conglomerate has caved-in completely. After 25 m the cave passage emerges at the end of a wadi (WF-1-5) and acts as the swallet for its runoff. (Note that WF-1-3 now takes most of the runoff from this wadi.). On the far side of the wadi another cave opening was found which we did not consider to be a spring, but merely the continuation of the now partially perished cave. In spite of the advanced age of this branch of the Ain Fasat cave, this last part is young, and small sized except for a collapsed chamber (sections Nos. 20, 21). The branch becomes impassable after a distance of 124 m. WF-1-7 swallet is the logical source of WF-1-6 even if the direction of its passage does not indicate it. This is no obstacle, however, considering the example of ZG-1-3 swallet.



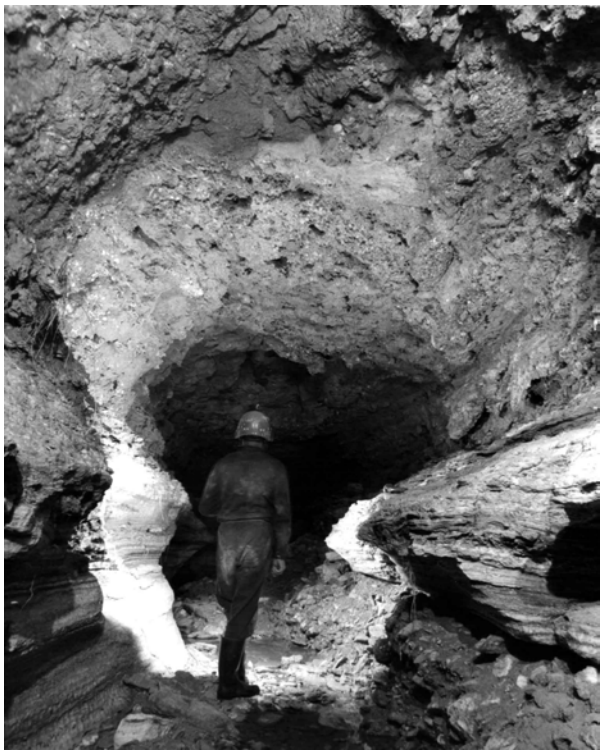
Drawing 24-1: sections (Draw2401.tif)



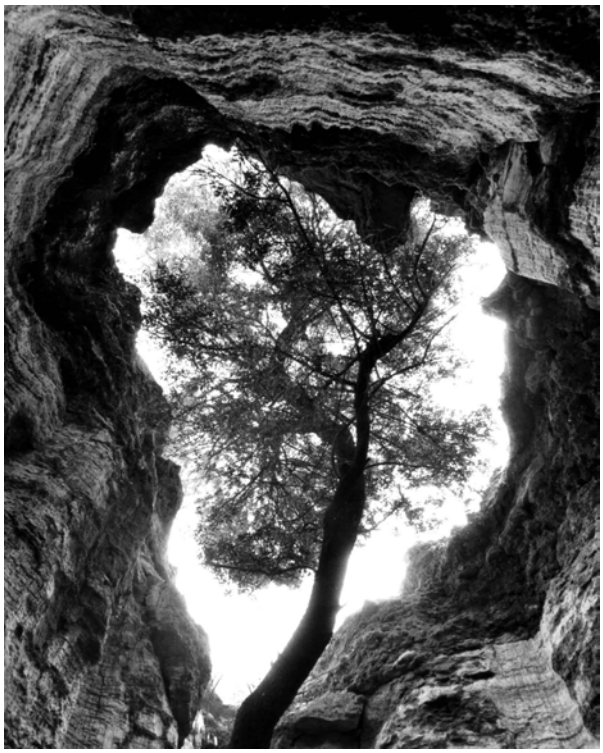
Drawing 24-2: sections (Draw2402.tif)

WF-1-7 is not a single swallet but a field of numerous sinkholes similar to the AN-1-1 group. The right branch at the 135 m point continues meandering, and comes to a waterfall topped by a darker, less soluble layer of gypsum which makes up the floor of the rest of the cave. Meandering and straight, joint orientated sections of passage alternate, the size decreases, and there is more and more sandy, gravely filling on the floor. The passage finally comes to a T junction, with both branches leading to swallets of very different types. WF-1-2 is a small

series of swallets that enter the cave system by a shaft at the end. WF-1-3 is situated at the bottom of the wadi for which the runoff used to flow to WF-1-5 but now is captured here.



Photograph 36: Cave passage with loessy roof in the WF-1 (Ain Fasat) Cave (pic36.jpg)



Photograph 37: Olive tree growing in the swallet of the WF-2 Cave (pic37.jpg)

4.4.3.2 WF-2

– Location: 1 km up the wadi of WF-1-3 always taking the right branch at forks.

– Bedrock: Abregh Gypsum

– No of swallets: 3

– Potential hydraulic head: 25 m

The spring is located in a canyon-shaped wadi. The entrance is very low and narrow, and the cave is impenetrable here. Walking up the wadi two swallets will be met at its bottom. The uppermost swallet is found at the highest end of the wadi, a large vertical opening which is completely covered by the green canopy of leaves of an olive tree which grows in the swallet. The cave cannot be entered at any of its entrances because of their small size.

4.4.3.3 WF-3

– Location: 1 km up the wadi from the spring entrance of WF-5 cave on the right side where the wadi runs between two close vertical cliffs.

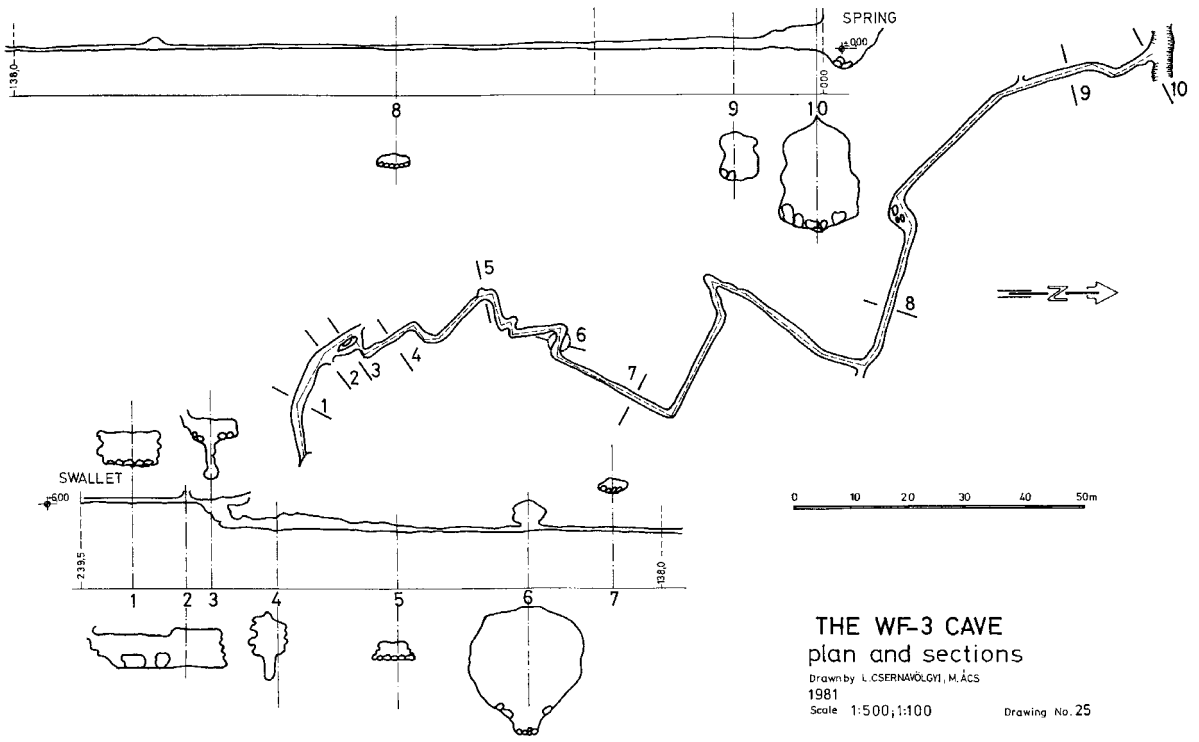
– Bedrock: Abregh Gypsum

– Total length: 240 m

– Total volume: 425 m^3

– Number of swallets: 7

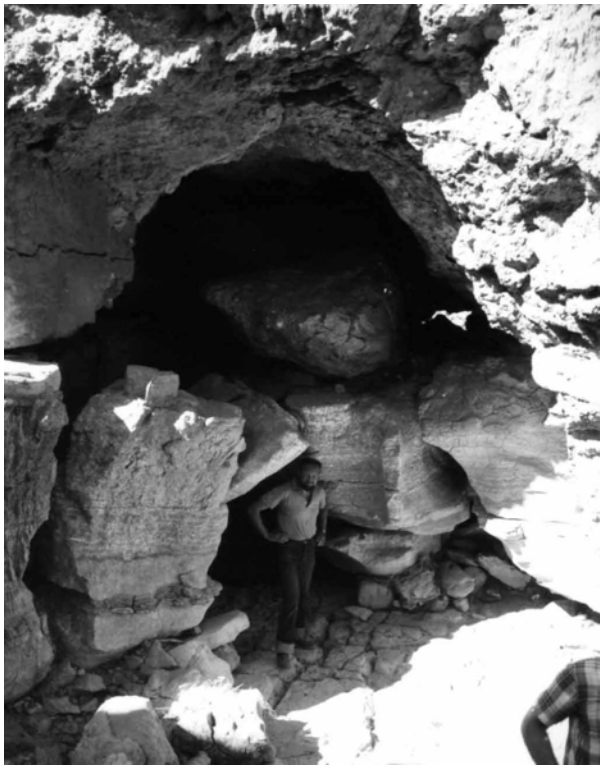
– Potential hydraulic head: 6 m



Drawing 25: plan and sections (Draw25.tif)

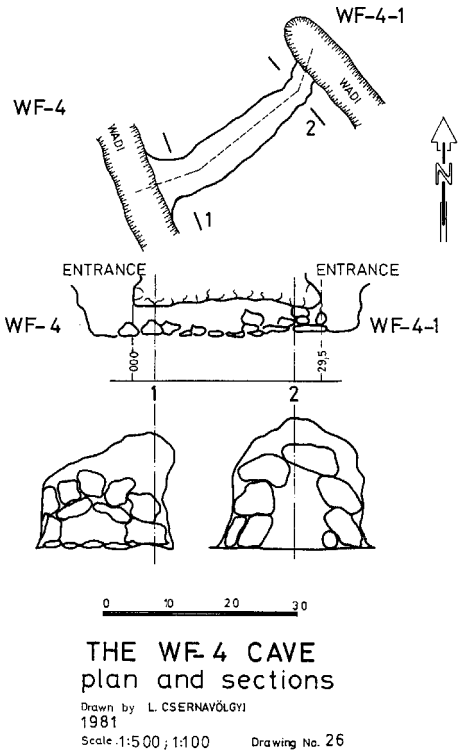
– Description: The spring entrance of the cave opens in a scenic canyon at the foot of a high vertical cliff. The entrance section is high, and spacious though soon decreases in size to a crawlway for almost the whole length of the cave. The only exception is the room at section No 6 which has developed as a result of the cave-in of the overlying loessy conglomerate in a similar fashion to the way in which the large chambers in Ain Fasat (WF-1) cave were formed. The spacious swallet-end of the cave developed on the top of a dolomite which is cut through by a narrow channel. (section No 3). The cave passages are alternately orientated by two almost perpendicular joint systems.

Photograph 38: Entrance to the WF-3 Cave (pic38.jpg)



Photograph 39: The WF-4 Cave (pic39.jpg)

4.4.3.4 WF-4



– Location: 1 km up the next wadi south of the one to WF-5.

– Bedrock: Abregh Gypsum

– Total length: 30 m

– Total volume: 525 m^3

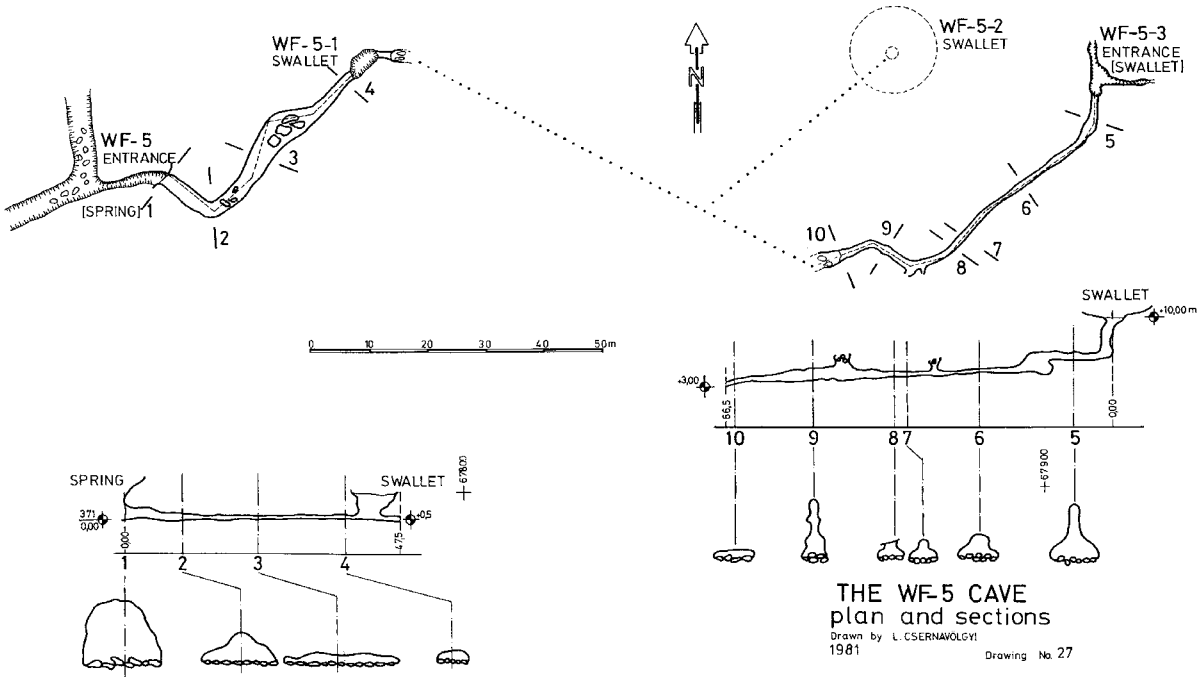
– Number of swallets: 1

– Potential hydraulic head: 1,0 m

– Description: This phenomenon is on the verge of being a cave. The swallet and the cave are in effect the continuation of the wadi. Very possibly the preceding precipitous, deep canyon is the remnant of a large cave which has been destroyed leaving only its very last section standing, although even this may not be there for much longer.

Drawing 26: plan and sections (Draw26.tif)

4.4.3.5 WF-5



Drawing 27: plan and sections (Draw27.tif)

– Location: 450 m up the wadi which merges with Wadi Fasat south of the road crossing.

– Bedrock: Abregh Gypsum

– Total surveyed length: 114 m

– Total surveyed volume: 132 m^3

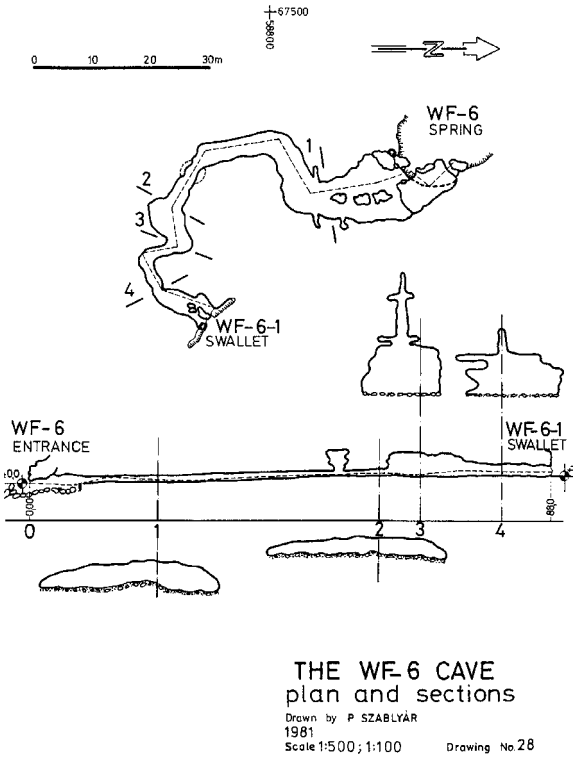
– Number of sinkholes: 3

– Potential hydraulic head: 10 m

– Description: The spring entrance of the cave shows no trace of gypsum but its whole spacious arch is composed of the loessy conglomerate typical of the area. The ceiling soon drops, and the flat, low passage continues in gypsum to emerge in the WF-5-1 swallet where a huge fig-tree grows. The cave continues at the far side of the swallet (sinkhole) but it is filled by water after a few meters.

It has not been proved, but it is obvious, that the cave originates in WF-5-3 swallet and is a part of the WF-5 system. The swallet is huge and imposing, and the largest of such phenomena in the Bir al Ghanam Karst. This large karst form soon gives way to a small passage that continues in an almost perpendicular joint system parallel to that observed in the spring section. At 66 m from the entrance the passage is filled with water. WF-5-2 swallet opens into a large loessy funnel with an impassable narrow passage. Nevertheless, it is part of the system.

4.4.3.6 WF-6



– Location: Visible from the road just before the Wadi Fasat crossing.

– Bedrock: Abregh Gypsum

– Total length: 88 m

– Total volume: 445 m^3

– Number of swallets: 1

– Potential hydraulic head: 4 m

– Description: The lower entrance section is very wide and low, and very shattered at the point of contact with a gypsum and a loessy conglomerate layer. Fifty meters inside the cave the gypsum roof is missing and the caved-in dome of a round conglomerate chamber appears, which is typical for the caves in the area. The swallet end of the cave is a high solution channel with small "ghost arms". The swallet itself is composed of gypsum boulders.

Drawing 28: plan and sections (Draw28.tif)

4.4.3.7 WF-7

Location: 2.5 km south of Qasr Abu an Niran the dirt road crosses a deep wadi with a small palm grove on the right. The wadi with the grove followed upstream becomes a canyon and comes to an end. The springs of the cave are on the right at the foot of the cliff.

– Bedrock: Abregh Gypsum

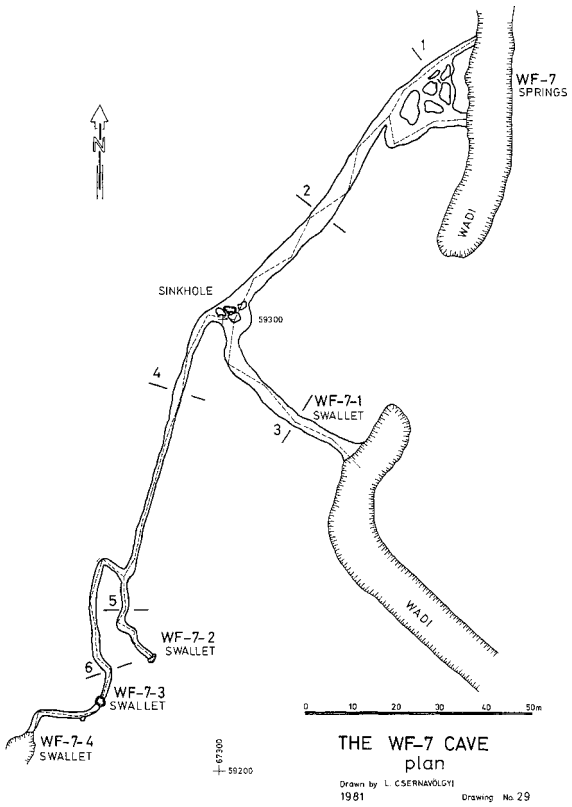
– Total length: 273 m

– Total volume: 1.155 m^3

– Number of swallets: 3

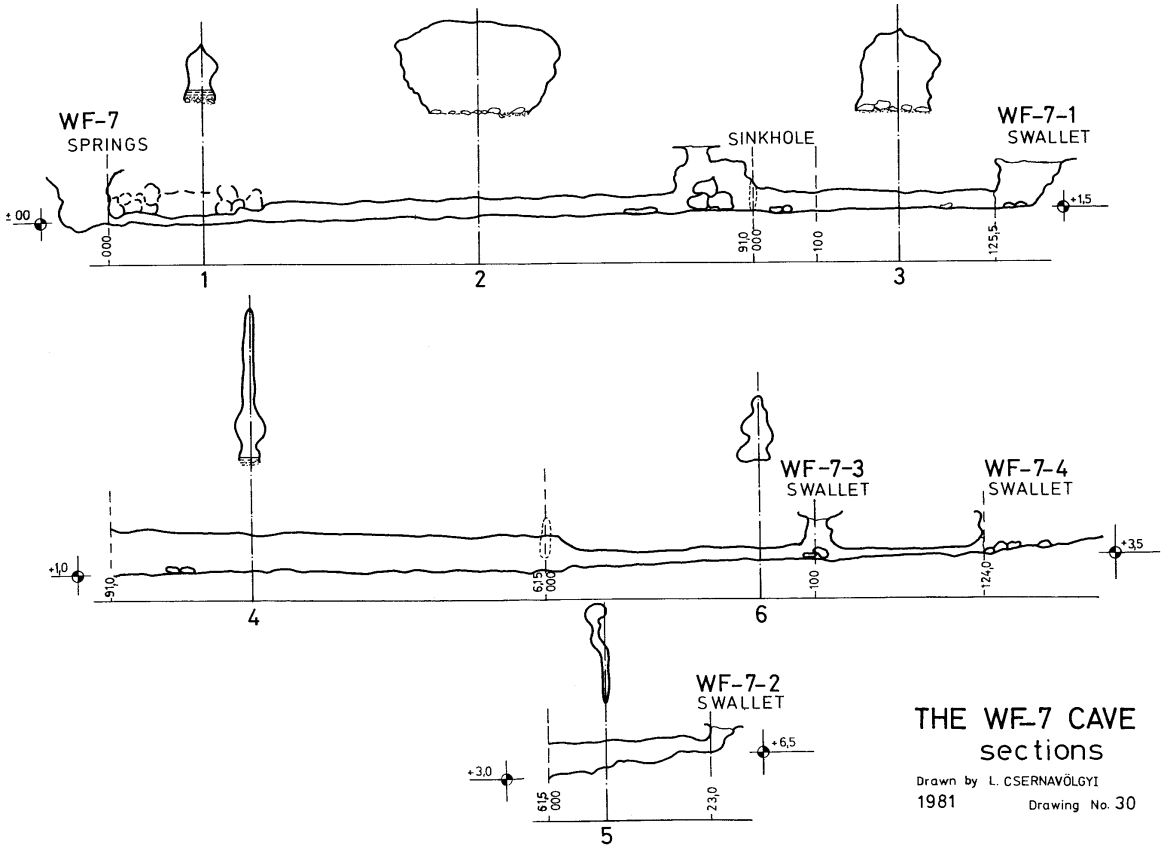
– Potential hydraulic head: 3 m

– Description: The entrance at the resurgence is a cavity enlarged by breakdown. The cave can be entered both through a solution channel (section No 1) and between the boulders. The passage starting at the end of the broken entrance section is the most spacious one in the Bir al Ghanam Karst.



Photograph 40: The main passage of the WF-7 Cave (pic40.jpg)

Drawing 29: plan (Draw29.tif)

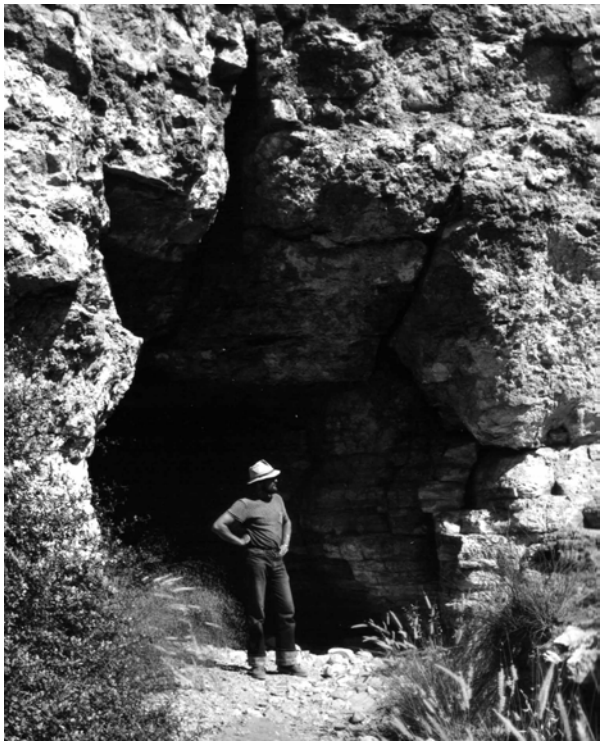


Drawing 30: sections (Draw30.tif)

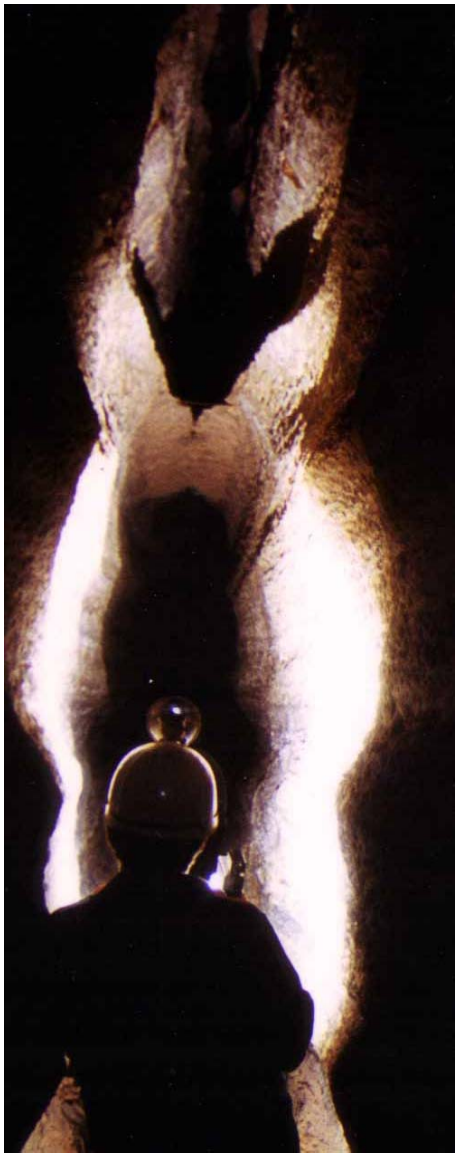
The 50 m long passage leads to a large chamber with a collapsed roof.

Photograph 41: The collapse entrance to the WF-7- Cave (pic41.jpg)

Photograph 42: The "tunnel" entrance to "Subway" cave (from WF-7-1) (pic42.jpg)



Photograph 43: The WF-7-1 entrance to the WF-7 system (pic43.jpg)

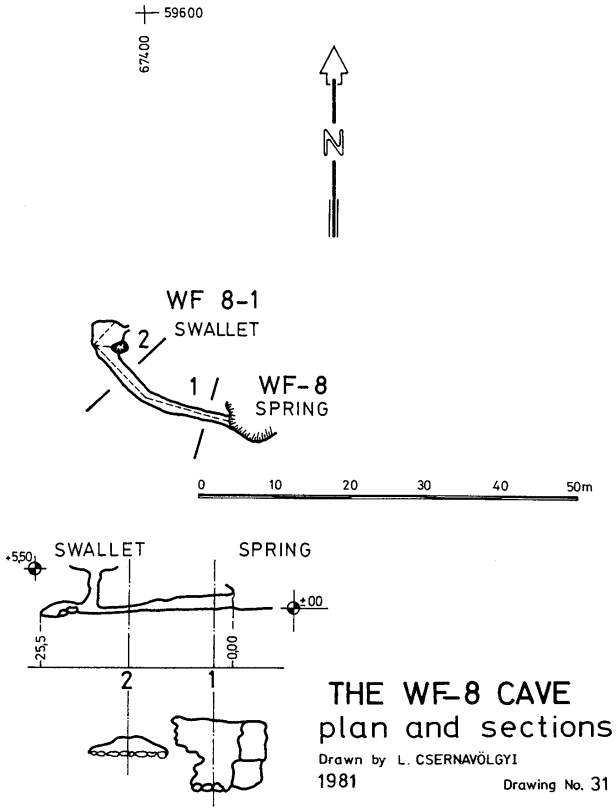


Photograph 44: Joint orientated passage in the WF-7 system at section 4 (pic44.jpg)

Light pours in through a circular shaft that does not function as a swallet. The floor of the room is composed of large boulders. The easy way out of the cave is to follow the 40 m long passage to WF-7-1 swallet. The passage is lit at both ends and is very regular and tunnel-like in shape.

WF-7-1 swallet is an opening in the side of the wadi's end much like WF-4-1. The other way from the hall follows the passage straight into the continuation of the large spring passage. The cave is very different here. The passage is joint orientated, and is high and narrow until the WF-7-2 swallet, which is an entrance to the cave, is reached.

At 60 m a smaller passage branches off to the right which leads to another swallet /WF-7-3/ which lights the passage from the top. Beyond WF-7-3 the passage is ever smaller and finally comes to WF-7-4 swallet which is at the end of a short wadi. WF-7 cave developed in two phases. In the first phase the WF-7 to WF-7-4 section developed. The wadi between WF-7 and WF-7-4, which no longer exists, was probably continuous. When the vertical canyon walls gave, raising a barrier to the runoff of the long wadi, WF-7-1 swallet (which possibly already engulfed part of the flood water) took over and became enlarged, as did the spring section leaving the WF-7-4 branch unchanged.



Drawing 31: plan and sections (Draw31.tif)

4.4.3.8 WF-8

– Location: In the first branch right of the wadi of the palm grove described at WF-7 cave.

– Bedrock: Abregh Gypsum

– Total length: 25 m

– Total volume: 20 m^3

– Number of swallets: 1

– Potential hydraulic head: 5 m

– Description: A very typical ancient swallet-spring system in a state of collapse. In all other respects the cave is unimportant. It is mentioned for the sake of completeness.

4.4.4 Bir Ayyad Area

(the area between Bir Ayyad and the Abu an Niran areas)

4.4.4.1 BA-1

– Location: On the dolomite plateau under the coffin shaped red butte well visible from the road to Bir Ayyad.

– Bedrock: Bir al Ghanam Gypsum and Bu an Niran Member

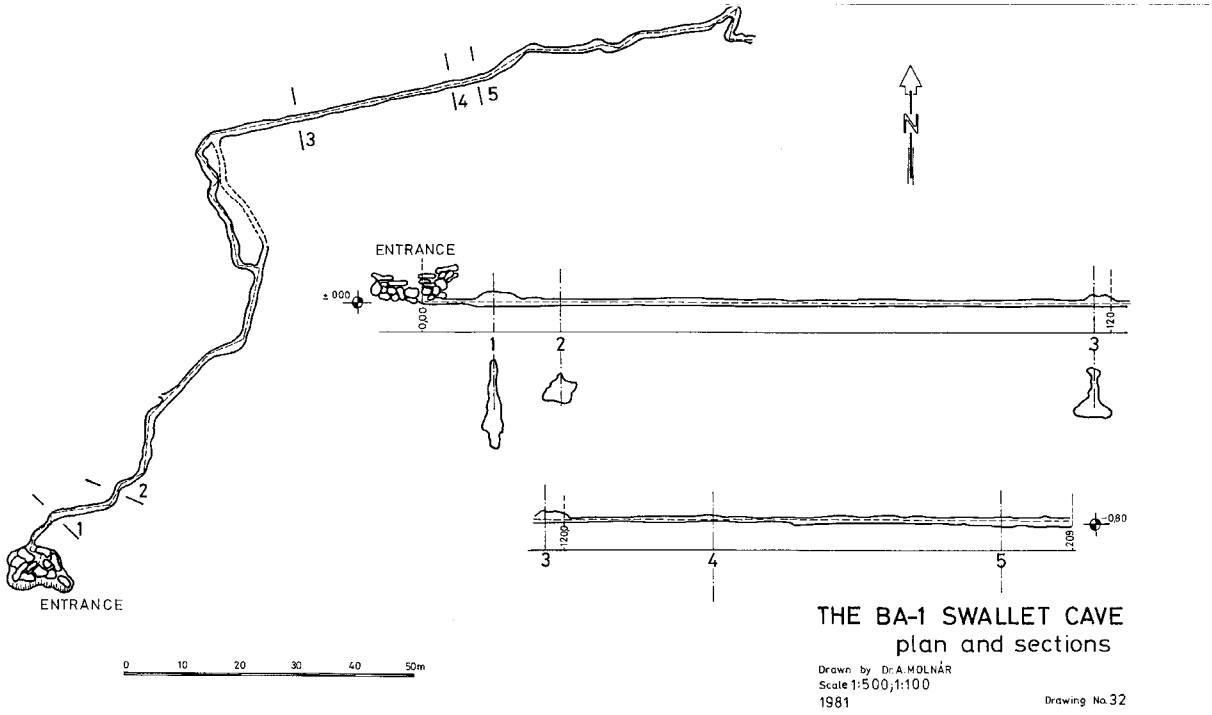
– Total surveyed length: 209 m

– Total surveyed volume: 52 m^3

– Number of swallets: 1

– Potential hydraulic head: unknown

– Description: The cave opens in a sinkhole among big, collapsed, dolomite blocks. The swallet resembles the dolomite sinkholes in the Abu an Niran area. The meandering solution channel is mainly controlled by the bedding plane of its bedrock, but the effects of joint control are also clearly visible. The cave is very young, it does not engulf concentrated wadi waters but takes in the rainfall which collects on the top of the dolomite layer of the Bu an Niran Member which forms the plateau. In spite of a thorough search all along and under the scarp of the plateau the resurgence for the cave was not found.



Drawing 32: plan and sections (Draw32.tif)

4.4.4.2 BA-2

– Location: 300 m southwest of BA-1 on the right side of the road.

– Bedrock: Bir al Ghanam Gypsum and Bu an Niran Member

– Total estimated. length: 15 m

– Description: The swallet-like entrance catches the waters of the surrounding dolomite surface, the rock being somewhat loessy. A short solution cavity ends in a mud sump. The cave may correspond to BA-1 cave or be independent, but a resurgence was not found .

4.4.3 BA-3

– Location: 1200 m southwest of BA-1 on the dirt road crossing a wadi cut into the dolomite plateau.

– Bedrock: Bu an Niran Member

– Description: The BA-3 is a bowl shaped impression on a grassy plateau, surrounded by low bushes. It shows the definite character of a swallet but in an early phase of development and has not yet opened.

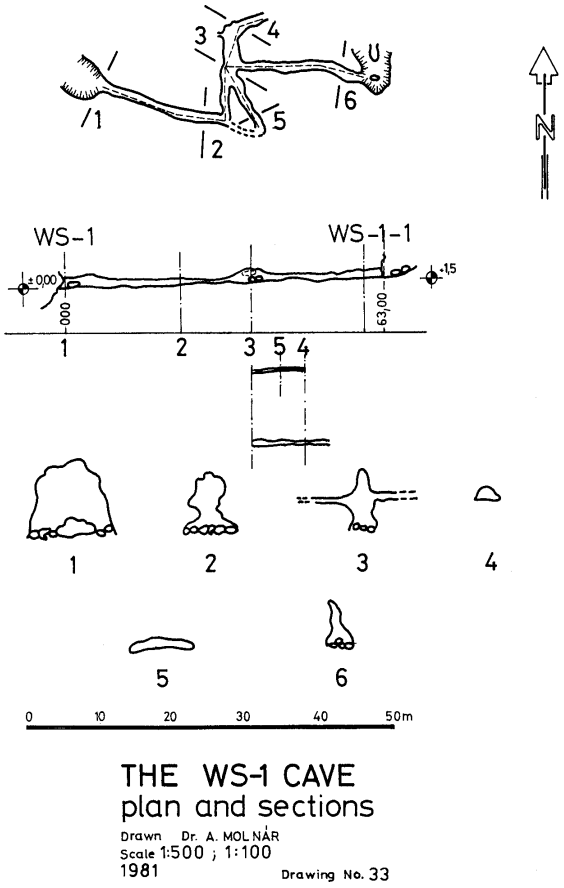
4.4.4.4 BA-4

– Location: Up in the first major wadi before Bir Ayyad station, in the saddle of the first two cone hills left on the wadi-bank.

– Bedrock: Abregh Gypsum

– Description: A typical pothole type swallet 6 m deep. A tight passage starts from its bottom. No resurgence was found in spite of a thorough search.

Photograph 45: The BA-4 sinkhole. Note Ras Tamallilt at the left top (pic45.jpg)



Drawing 33: plan and sections (Draw33.tif)

4.4.5 Wadi ash Shaykh Area

See Drawing 2-2: location (Draw0202.tif)

4.4.5.1 WS-1

See Drawing 33: plan and sections (Draw33.tif)

– Location: About 10 km from its junction to the A1 Aziziya Nalut highway the new Kiklah road makes a left bend around a pointed cone-hill, a feature seen from afar. The swallet of the cave can be found on the right side of the road in a hollow.

– Bedrock: Abregh Gypsum

– Total length: 63 m

– Total volume: 79 m^3

– Number of swallets: 1

– Potential hydr. head: 0.6 m

– Description: The spring entrance is located high in the cliff side of a deep wadi. The small size passages of the cave are joint orientated. The spring section is in a broken-down area, while the rest of the cave shows clear solution forms including some "ghost arms". The swallet is a loess funnel. The only cave of this type in the vicinity.