PROCEEDINGS OF THE EIGHTH INTERNATIONAL CONGRESS OF SPELEOLOGY

VOLUMES I & II

A Meeting of the International Union of Speleology

Sponsored by
The National Speleological Society

Hosted by
The Department of Geography and Geology
Western Kentucky University
Bowling Green, Kentucky, U.S.A.
July 18 to 24, 1981

Edited by
Barry F. Beck
Department of Geology
Georgia Southwestern College
Americus, Georgia, 31709, U.S.A.

Desert Gypsum Karst in Bir al Ghanam, Libya

Attila Kósa
Budapest, XIV, Kover Lajos U. 46, HUNGARY

Abstract

The outcrop of the upper Triassic to middle Jurassic Bir al Ghanam Gypsum Formation lays West of its namesake town at the foot of the Jabal Nefusa escarpment. The thickness of the dolomite-intercalated formation reaches 400 meters at is main body. According to indices calculated upon meteorological data the local climate is desertic, the annual rainfall does not exceed 150 mm. Authigenic karstification is observable in the typsum hills which appeares - besides underground drainage: caves - in a landform very similar to the well known tropical "cone-karst". The karst of tropical appearence could develop in desertic conditions only due to the high solubility of gypsum. More precipitation would destroy the observed forms and develop a different landscape.

Résumé

Au pied du massif Nefusa en Libie près du village Bir al Ghanam afleure la formation de même nom gypseuse triasique superieure-a meso-jurassique.

L'épaisseur de la formation émaillée d'intercalaires dolomitiques s'élève à 400 mètres par endroit.

Selon les indices calculé des données météorologiques, le climat local est désertique; la quantité annuelle de la précipitation n'excede pas les 150 mm. Au collines gypseuses on peut observer une karstification autogène, qui apparait - en outre de l'écoulement souterrain: les cavernes - en formes très similaire au "Karst conique" bien connu dans les regions tropiques.

Le karst tropique n'est developpé parmi des conditions desertiques que grâce a la solubilité extrême du plâtre.

Une plus grande quantité de precipitation aurait résulté une érosion plus forte.

The Tripoli-Nalut /-Ghadames/ road crosses a strange landscape West of the town of Bir al Ghanam. Hills resembling beehives roll South to the foot of the Jabal Navusa escarpment. It is easy to observe in the road-cut that the rock composing the hills is gypsum. The gypsum outcrop is known as the Bir al Ghanam gypsum Formation. The age of the Formation is from upper Triassic to middle Jurassic, its thickness at its namesake town and West reaches 400 meters. The most recent parts of the outcrop are positioned between Bir al Ghanam and Bir Ayyad. These parts are the highest, 300-500 m of altitude. The rest of the Formation extends to the Tunisian border and is intensively weathered, almost level with the Jeffara Plain. /Fig. 1/

Geological knowledge is scarse about the Formation, detailed description is nonexistant. Some boreholes were drilled at its lower part along the highway, but the stratigraphy of the upper 300 m thick part of the Formation is practically unknown. According to what had been published /Ref. No. 5/ and the Author's field investigations it is known that algunal gypsum, dolomite, dolomitic-limestone and clay layers vary at the upper part with anhydrite towards the bottom. Gypsum beds are predominant, their thicknesses reach 30-40 m. Thickness of the dolomite intercalations vary from millimeter to several meters.

The climate of the area can be defined as desertic according to the data of nearby weather stations, the type of scarse vegetation and field observations. The available /discontinuous/ data correlated to the center of the gypsum outcrop /elevation 340 m above sea level/ permits to estimate the following normal data:

Minimal temperature/mean/	10.0°C
Maximal temperature	30.0°C
Mean temperature	20.0°C
Mean annual Rainfall	200 mm
Number of rainy days/annual/	30

Temperature varies between the extremes of -5°C and +55.7°C /Highest ever measured in nearby Aziziya/ Calculation of the de Martonne aridity index classifies the climate of the gypsum area desertic, according to the Emberger index it is arid.

Karstification of soluble rocks is influenced by the quantity of precipitation and runoff conditions. Observations show that in the 1971-72 hydrological year there occured 16 active runoff periods in the Wadi at Tall that bisects the discussed part of the outcrop. The Wadi at Tall collects the runoff of a large area originating on the plateau of the Jabal Nefusa meaning, that the shorter internal valleys of the gypsum area flood less frequently. Observations of the author prove that some caves flooded three times in the winter 1978-79. On of these floods was observed directly with extreme luck. The flood was preceded by a 12 houres varying intensity rain. Than a 15 minute shower of extreme intensity followed in the fifth minute of which surface runoff started instantly flooding the cave. The flood was about two houres of duration. The value of the observation is that it can be said now under what conditions and with what a duration the runoff occures in the gypsum area. Thus for any runoff extreme conditions are necessary and the valleys that originate within the gypsum hills do not flood more than several houres annually in the rainy winter season.

The relief of the Bir al Ghanam gypsum outcrop is a product of its geological position and structure as well as the prevailing hydrogeological factors. The gypsum formation is a member of the sequence of strata of the Jabal Nefusa and as such its outcropping depends on the recession of the escarpment. Active points of this recession are at the rim of the scarp where streambeds cross it. Because of the high gradient erosion is very energetic, streams cut through the outcropping gypsum beds. In the elongation of the mountain noses between the deeply cut wadis the gypsum outcrop remains intact of the intensive erosion in strips up to 20 km length. Local hydrological systems develope on the gypsum surface during the runoff of local rainfall. At first "sheet flow" starts. As the primary porosity of the gypsum rock is very small, infiltration is negligible at this phase. Sheet flow concentrates to intermittant streams which cut the surface. The corrosion effect of the water in the sheet flow forms a multitude of rounded gypsum hills. /Fig. 2./

Discussing the classification indices for tropical karst surfaces the hills in the Bir al Ghanam Gypsum Karst could be considered Sewu /Java/ type. /Morphogenetical index: diameter /height:3-8, ralative height 30-120 m, occurence 15-30/km^2/ /Ref. No. 1./ In spite of the extreme similarity the karst of Bir al Ghanam cannot be classified as Sewu type since the karstified rock itself is different /limestone in Sewu/ and forms different of the Gunung Sewu karst develope as well. Dolomite and clay beds intercalated in the gypsum mass behave differently against the weathering forces. The weathering of dolomite is slower than that of gypsum, clay weathers quicker. Accordingly dolomite surfaced plateau areas and gypsum capped clay cones develop. After the weathering of the dolomite bed the "cone karst" develops once again at a lower level. The weathering of the dolomite layer is not karstic but mechanical in nature due to the karstification of the underlaying gypsum beds.

Streams accumulated from the sheet flow deeply cut between the cone-hills, intersect "planes of weaknesses" /Ref. No. 6./ i.e. joints, bedding planes, vadose subsurface drainage develop the well know way. Considering that the deposit originally formed as anhydrite and transformed to gypsum only during weathering in the upper layers the Bir al Ghanam Karst is of vadose nature as a whole, a continuous karst water body does not exist in its depth. The Bir al Ghanam gypsum Karst is authigenic, runoff from non-karstic surfaces does not karstify but denudes it without development of karstic phenomena.

There are widely published statements about the two extremes of karst types; the desert and tropical karst such as: "Deserts are typified by the absence of karst phenomena" and "tropical karst can develop beyond the threshold of a mean annual temperature of 17 to 18°C and 1000 to 2000 mm of annual rainfall."

These statements are true concerning the dolomites and limestones in the upper Jabal Nefusa Formations /Ref. No. 7/ but are not applicable in the case of gypsum. The karstification of gypsum occures at relatively low temperatures /only in winter/ at very little rainfall.

The Bir al Ghanam gypsum Karst resembles the tropical karsts in appearance and origin. Still it is not equal with the tropical karsts as it is a desert phenomenon where unfavourable climatic conditions i.e. scarce

rainfall are balanced by a petrographic factor namely the high solubility of gypsum.

References

1. Balazs, D. /1970/: Relief Types of Tropical Karst Areas. - Symposium on Karst Morphogenesys, HUNGARY, - papers of -
2. Balazs, D. /1971/: Intensity of the Tropical Karst Development Based on Cases of Indonesia. - Karst es Barlangkutatàs, 1968-1971, p. 33-37.
3. Geological Map of Libya. /1970/: Sheet Tarabulus. - Industrial Research Center, Libya.
4. Gefli /Groupment d'Etude Francias en Libie/ /1972/: Soil and Water Resources Survey for Hydro-Agricultural Development. General Water Authority, Libya.
5. Gualtieri, J.L. /1976/: Exploration of the Jefren Gypsum-Anhydrite Deposit. - Libya, Ministry of Industry.
6. Jennings, J.N. /1971/: Karst. - MIT Press, Cambridge.
7. Kosa, A., Smykatz-Kloss, W. /1978/ Solution Phenomena in the Dolomites of North Tripolitania. - Karszt es Barlang, 1978- I.-II. p. 43-48.
8. Kosa, A. /1979/: Discoveries in Libya. - British Caving Summer Issue, 1979.
9. Kosa, A. /1980/: Gypsum Karst Discovered in Libya. - Karszt es Barlang, I. 1980. p. 23.
10. Kosa, A. /1981/: Gypsum Caves in Libya /see elsewhere in this volume/

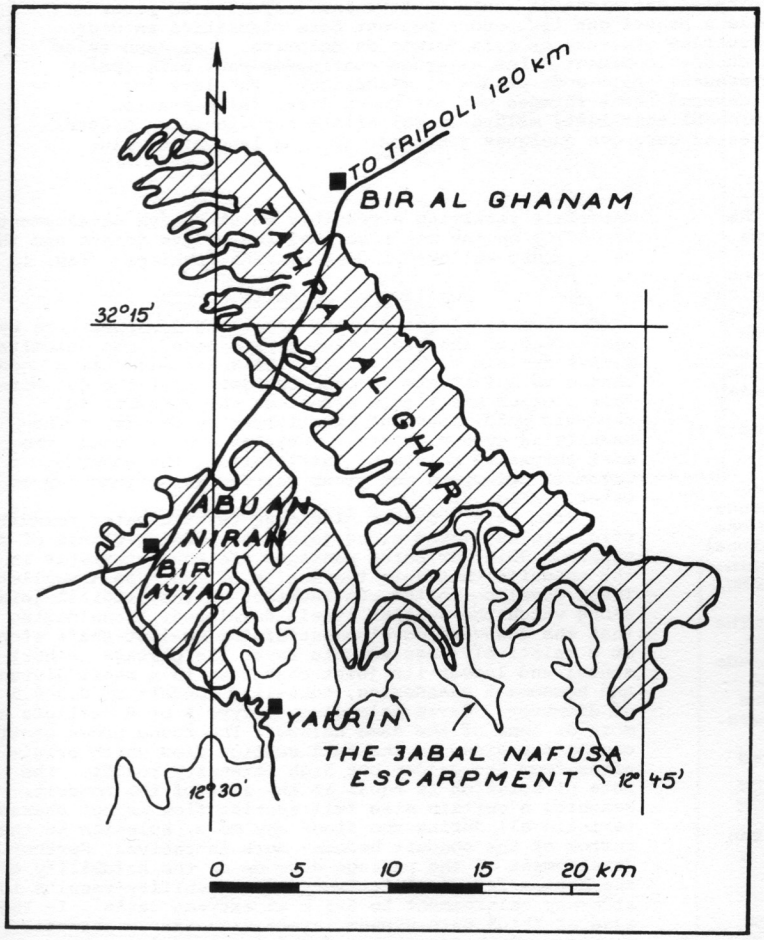

Figure 1. Map of the karstified part of the Bir al Ghanam gypsum karst

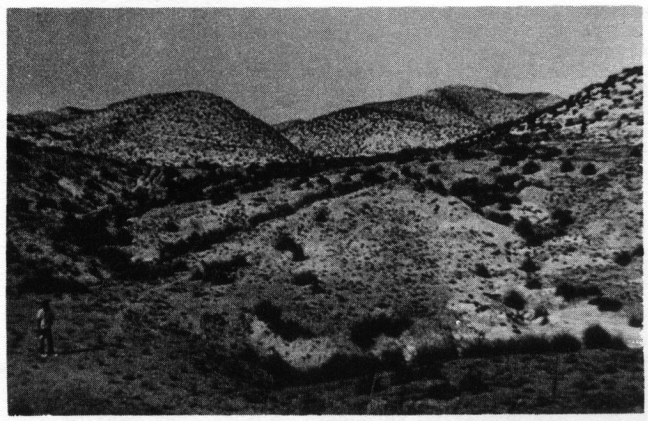

Figure 2. Typical gypsum cone-hill area with sinkhole in the foreground

Gypsum Caves in Libya

Attila Kósa
Budapest, XIV, Kover Lajos U. 46, HUNGARY

Abstract

The Bir al Ghanam gypsum karst area lies at the foothils of the Jabal Nefusa escarpment. The karst area which resembles the tropical "cone-karsts" is rich in underground drainage: sinkhole - cave - resurgence systems. Partial exploration showed that two types of sinkholes can be classified. Ones developed on gypsum and ones on dolomite surface. Both are joint oriented at the early stage of development. The continuing caves are mostly oriented by bedding planes of the gypsum beds, blat and meandering, tube-like or composite at later stages. All caves are vadose stream caves. Cave development is presumably slow in spite of the high solubility of the gypsum since the annual pluvial period of the cave systems does not exceed several houres. Length of the longest known system is more than a kilometer.

Résumé

L'aire plâtreuses-karstique de Bir al Ghanam s'étend au pied du massif Jabal Nefusa. L'aire karstique qui ressemble aux formes "cône-karstiques" tropicales est riche en cours souterrains: système de pouor - caverne - résurgence. Une exploitation partielle a prouvé que les pouors peuvent être classifiés en deux types. Notamment ceux qui sont formés sur une surface gypseuse et tels formés en dolomite. Les deux types sont orientés en faille dans la première phase du développement. Les cavernes continuées sont principalement orientées par les jonctions des couches gypseuses, elle sont planes et méandriques, tubulées our hybrides dans les phases postérieures. Toutes cavernes sont formées par des cours d'eau 'alimantation pluviales. Le développement des cavernes est probablement lent, malgré la solubilité supérieure du plâtre, comme la periode pluvieuse du systeme de cavernes ne dure que quelques jours par an. La langeur du plus long système connu est plus qu'un kilomètre.

The Bir al Ghanam Gypsum Karst is situated at the foot of the Jabal Nafusa escarpment between the towns of Bir al Ghanam and Bir Ayyad. The gypsum outcrop which is karstified in the character of tropical "cone karsts" is about 400 km^2 of surface area. Speleological research was started by the author and resulted in the discovery of a number of caves. Study of these caves which originated in various petrographic conditions and represent different stages of development, exploration of swallets and resurgences, survey of these phenomena yielded a new picture about subsurface drainage developed under unusual conditions: dry desert climate and gypsum as soluble rock. All the caves thus far discovered and explored are vadose stream-caves.

The petrographic properties of the karst may be characterised as a several hundred meter thick sequence of gypsum strata intercalated by dolomite beds from one millimeter to several meters of thickness and occasional clay lenses. The beds of the gypsum formation contain other minerals than gypsum and anhydrite. /$CaCo_3$,CaMg/$Co_3/_2$,SiO_2, clay minerals, etc./ The composition basically determines the solubility of the layers. The landscape reflects the stratigraphical conditions. Most of the area is composed of conehills the multitude of which is interrupted at places by dolomite plains which are the outcrops of the dolomite intercalations that are much less destructible than the gypsum layers. At surface conditions of both types sinkhole-cave-resurgence systems develop. The sinkholes discovered can be specified as:

A. Sinkholes /swallets/ on gypsum surface
B. Sinkholes /swallets/ on dolomite surface

The origin and development of the type A sinkholes can be described as follows.

Swallets on Gypsum Surface

A.1.a. The runoff of the rain that falls on the gypsum surface begins as sheet flow. Joints appearing on the surface swallow increasing quantities of sheet flow and due to their enlargement of size they become concentrated swallets of certain areas. The initial type of these primary swallets shows typical joint character. /Fig. 1/

A.1.b. The initial primary type swallets draw increasing quantities of runnoff during their widening and deepening as cuts develop leading to them. The resulting swallets are circular, 5-10 m deep potholes with the original joint tracable on their opposite walls. /Fig. 1/

The A.1. type swallets are classified primary because the primary runoff, the sheet flow is responsible for their development. The swallowed quantity of water is relatively small and the swallet development is possibly slow. Type A.1. swallets are usually positioned between the conical karst-hills.

A.2. Secondary swallets develop at points where joints are crossed by streambeds and by initial infiltration the development of swallets begin. During their development the swallets and continuing caves drain the surface runoff in increasing quantities until taking over the role of the surface valley. Type A.2. swallets are specified secondary because they swallow already concentrated runoff. The streamflows occur relatively oftener and the floods are richer in carried materials resulting a possibly quicker cave development. Depending on the relative position of the joints and the valleys dry valleys or deep canyons develop. /Fig. 1/

Swallets on Dolomite Surface

Dolomite plains develop after the disappearance by weathering of the overlaying gypsum beds. The dolomite plains are almost horizontal, the sheet flow has a good chance to infiltrate through the joints of the dolomite. This process has little effect on the dolomite in desertic conditions but karstification begins in the underlying gypsum layers. Cavities develop under the most intensive points of infiltration, the covering dolomite collapses and gives way for larger amounts of water. /Fig. 2/

From both types of sinkholes karstic water conduits originate developed along joints or bedding planes of the gypsum. Joint oriented passages are characteristic in the conduits that join the shafts of the type A swallets. These develope in the continuation of the original joint along which the swallet itself developed. Considering that the downward development of the swallet-shaft stops at a relatively less soluble layer the passage is horizontal and looses its joint character in a short distance and becomes a meandering, tube-like conduit of 0.3-0.5 m of diameter. Caves belonging to type A or B swallets are more or less of the same nature. The round cross section can be explained by the full section flow which originates from the seldom but high intensity runoff. The rate of solution is equal at any side of the conduit. Reaching a certain size full section flow is not characteristic all during the flood any more, solution at the bottom of the conduit becomes more intensive. Further development of the passage depends on the solubility of the bottom layer. Relatively low solubility results in a side-way enlargement to 6-8 m at extreme cases. In the case of thick pure gypsum layers high narrow passages develop. Both cases were found in clear forms but composite sections also often occur. /Fig. 3/

Caves originating from type B swallets develop more or less the same way as type A-s do. The important difference is that while development and positioning of type A caves is independent of the surface topography and the overburden can be thicker than the height of the cone hills, rock covering of type B caves is thin as they develop parallel to the dolomite surface. It is another difference that in the vicinity of the thicker dolomite layers the sequence of strata is disturbed, clayey, marly beds also occur. The nature of passages is rather flat, instead of deeper cuts development along the bedding planes is characteristic, even multiple levels develop. The thin rock covering and the wide-flat passages result in cave-ins which enlarge the cave or open it up finally resulting in the destruction of the caves and thus the dolomite plains.

According to the above description caves belonging to type A or B swallets can be specified as type A or B caves. Meaning: type A caves make systems with type A swallets where the main agent of cave development is solution while type B caves make systems with type B swallets where beside solution mechanical agents also play a significant role in cave-space enlargement and swallet development. Because of the mechanical agents caves of B type are less stabile their destruction is

relatively quicker. This fact is verified by a number of "cave-wrecks" discovered.

The foregoing speleo-genetic description is a result of the exploration and survey of a number of caves discovered in a rather small part of the gypsum karst. Information about the karstic phenomena in the rest of the area is sporadic but there does not seem to be much difference in cave types and development in the whole of the area.

The longest and most intricate known system thus far is the Abu an Niran Cave system which consists of two sizable caves with interconnecting passages that are mostly unprooved because of their flat difficult nature. Seven sinkholes belong to the system. /Fig. 4/

Continued research in 1981 will throw light on many other detailes, speleological as well as biological, archeological and others.

/See References at the end of the paper titled Desert Gypsum Karst in Bir al Ghanam, Libya by the same author in this volume./

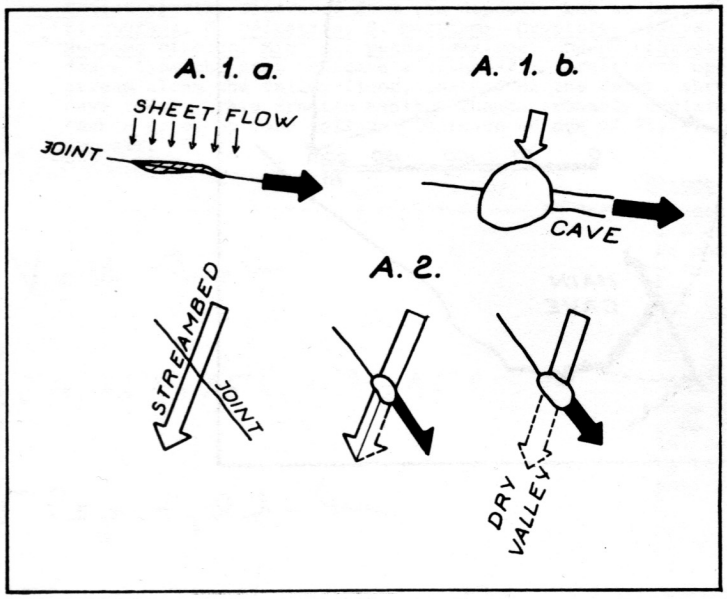

Figure 1. Development of type A sinkholes

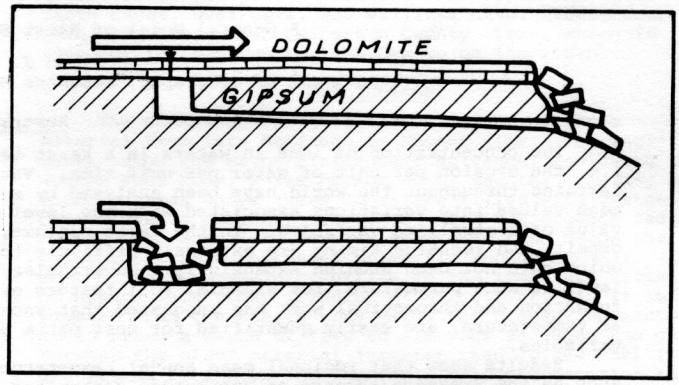

Figure 2. Development of type B sinkholes

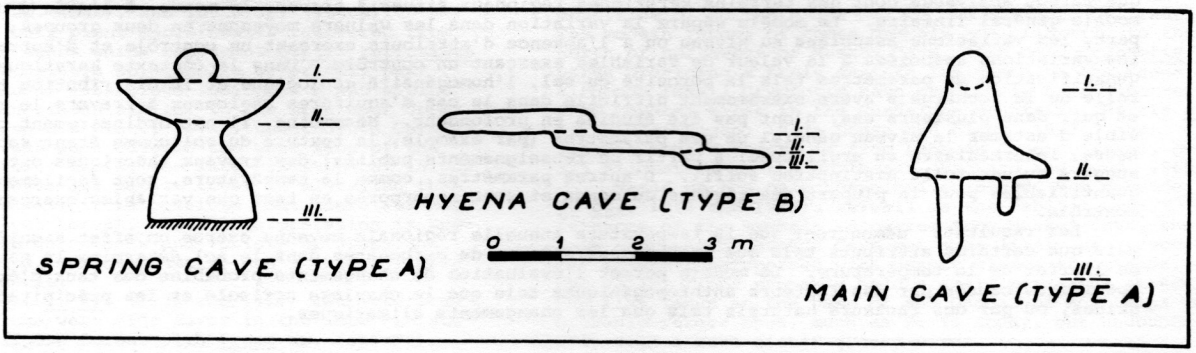

Figure 3. Various composite cave sections

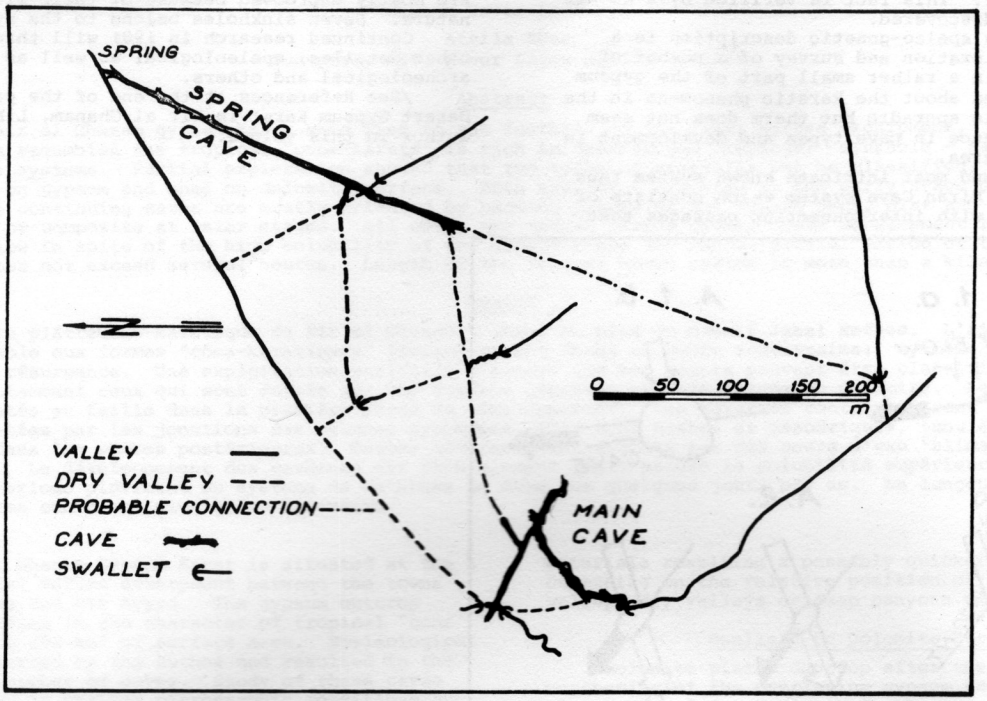

Figure 4. The Abu an Niran Cave System