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HYDROLOGY OF THE ABU-AN-NIRAN GYPSUM-KARST AREA

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أظهرت دراسة رسوبيات الجبس المعروفة بتكوين بئر الغنم بمنطقة أبي النيران أن ثمة تأثيرات لعملية الاذابة بواسطة الماء الجاري على مكاشف هذا التكوين مما ينشأ عنها حفرات بالوعية ومسالك كاريستية ، وعلى ضوء دراسة مناخ المنطقة تبين أن هذه المسالك تمد بالماء لمرات عديدة على مدار السنة ، كما تبين أن حجم هذه الكهوف وكمية الماء الجاري بها تجعل من الجدير استغلال مكامن المـاء الجوفي من أجـل حـل مشكلة إمدادات الماء بالمنطقة ذات الاهتمام .

Studying the effects of solution on the outcrops of the Bir Al-Ghanam Gypsum Formation in the Vicinity of Abu-An-Niran a series of sinkholes and the subsequent underground water conduits and caves have been discovered. The study of the local climate reveals that these conduits recharged by water several times annually. Surveys indicate that the volume of the caves and the amount of annual runoff makes it worthwhile to consider the development of underground reservoirs to solve local water supply problems.

GEOMORPHOLOGY OF STUDY AREA

Driving westwards on the Al-Aziziya-Nalut highway one enters a curious landscape of beehive-leke, rounded hills shortly after leaving the village of Bir Al-Ghanam. The hills are part of the large outcrop of mostly gypseous strata which underlay the Jabal Nefusa and are exposed to weathering by the recession of the Jabal Escarpment. The sequence of strata is referred to by the latest literature/Ref. No.. 2/ as the Bir Al-Ghanem Formation. The highest and least weathered exposure of the Formation is located near the namesake town. This first exposure extends westwards to Bir Ayyad/ the Yafrin crossroads / and is bisected by the Wadi At-Tall. The Eastern part lies near to Bir Al-Ghanem its name being according to map reference /No. 3/ Zahrat Al- Ghar. The Western lower and more weathered part of the exposure is centered by the ancient ruins of Qasr Abu An Niran, which place gave the name to the Formation in former literature /Ref. No. 4, Bu Niran Form/. The Formation continues to be exposed in many outcrops from small to hundreds of km^2 line surface area, as far as the Libyan-Tunisian border. /Ref. No.1/ It is at least mapped until this extent, but literature states, that gypsum outcrops in South-East Tunisia/Mestaua Formation near Ksour Djelilett/ are equivalent to the Bir Al-Ghanem Formation. /Ref No. 4/ The Bir Al-Ghanem Formation was also referred to as the Yafrin Gypsum-Anhydrite Deposit. /Ref. No. 5/.

The mineralogy and stratigraphy of the Formation have been little studied. A series of boreholes were made in 1959 along the Al-Aziziya - Yafrin highway. The deepest hole was 95m and the highest collar elevation was 286 m above the sea level. As more, than fifty per cent of the discussed part of the area rises above that elevation, one can deduct, that little is known about the stratigraphic detailes of the higher part of the Formation.

Sporadic observations subdivide the Bir Al-Ghanem Formation to Bir Al-Ghanem, Abu An-Niran /Bu An-Niran/ and Abreghs Members, /Ref. No.2/ which cannot be clearly detected in the area of discussion. The reason for this is the shallow sea to lagunal origin of the deposits with lenses, that can not be followed for more, then a few kilometers.

In spite of the varying nature of the sub-strata the Formation is mostly composed of sulphates. As such, one of its characters is a much higher solubility than that of the adjoining formation. The landscape is formed by erosion and solution.

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RUNOFF IN BIR AL GHANEM FORMATION

The runoff is of two kinds in the Bir Al Ghanem Formation:

1. **Transit runoff** is the kind of streams, that originate on the top of the Jabal Nefusa. These have very high hydraulic gradients. In case of the wadi system Qalah-Munari-Shaykh-Tall, that bisects the Formation between Bir Al-Ghanem and Bir Ayyad it is 4 % . The effect of erosion is very strong, the exposure of the weakly resistant gypsum has completely vanished in the stream profile.

2. **The precipitation which falls on the surface of the gypsum exposures will run off two ways:**

a. *Sheet flow* of which the weathering effect is surface solution, since the primary porosity of the gypsum is almost nil.

b. *Stream flows* will concentrate the waters from sheet flow. Because of the great solubility of the rocks the streams will be deeply cut. The streams flow on the surface until they meet «planes of weaknesses» /Ref. No. 6/ and infiltrate in quantities increasing with time. As the dissolution of the rock along the «weaknesses» advances in time swallets /sinkholes/ develop. The «weaknesses» are joints and bedding planes / secondary porosity /. At favourable places the secondary porosity becomes underground conduits and later caves of big size - enough to take over the entire surface runoff in a wadi, which becomes *underground runoff*. The valley beyond the swallet becomes a «dry valley».

Underground runoff will develop only in relativeıy short streambeds, since in case of too large quantities of runoff the effect of erosion will be quicker, than infiltration-solution/ e.g. the Wadi At-Tall and others / The underground stream emerges to the surface in resurgences - karst springs. As the described phenomena are in an advanced state in the Abu An-Niran - Bir Ayyad part of the Formation, the author took the liberty to name it the Abu An-Niran Gypsum Karst. To the other - Bir Al-Ghanem part of the Formation no reference exist except a name on the map Zahrat Al-Ghar - The Hills of Holes, which is reference enough to make continued exploration be promising.

Detailed exploration of the Abu An-Niran Karst revealed the existence of a large number of swallets/Fig. 1/.The majority of these contribute to very short underground conduits at the sides of larger transit wadis. Others, much less in number swallow surface runoff to conduct it through underground hydrological systems - sizable caves of considerable lengths, which are usually independent in direction and lining from the previously functioning surface channels /wadis/ of runoff. Without going to details of the origin and development of the caves, there are two genetic types discovered in Abu An-Niran. Ones, in which solution was oriented by joints /straight, high passages/ and those in which the bedding planes were the factors of orientation/ wide, flat, meandering passages. As the underground water conduits and caves are part of the runoff system, their hydrological study is at least as important, as of channels of surface runoff.

CLIMATOLOGY

As for the climate of the area, since there is no meteorological station in Abu An-Niran data of the closest stations had to be correlated. These are the stations in Bir Al-Ghanem and in Yafrin to the North and South respectively at about the same distance of 12 km. The Bir Al-Ghanem Station is located on the Gefara Plain, the Yafrin one on the top of the Jabal Nefusa Scarp /Ref. No. 7/. Based on sporadic observations and records with great gaps the main normal climatic data are shown in table 1.

Elev. Temp. Min C° Temp mean Rainfall No. of rainy

	m		Temp. Max		mm	days
Yafrin						
Bir Al-Ghanem	680	9.1	27.5	18.5	260.8	55
	143	11.5	32.0	21.9	134.5	no information
Abu-An-Niran	340	10.0	30.0	20.0	200.0	no information

*information only in 1971-72

According to its geographic position it was considered the normal values be the averages of the two stations.

The climate of the Abu An-Niran Karst is pre desertic according to its Martonne aridity index/i $= \frac{\text{rainfall}}{\text{average temp} + = 0} = 6{,}7/$ or arid by its Emberger index/i $= \frac{2000 \times \text{rainfall}}{\text{Tmax}^2 - \text{Tmin}^2} = 34.13$. To use a more common word, the area is desert.

The fiftyfive rainy days recorded in Yafrin caused only sixteen floods in the Wadi At-Tall in the 1971-72 hydrological year, all occuring from September to May/Ref. No. 8/ As the Wadi At Tall is the recipient of a large hydrological basin it receives the runoff of usually small extent, high intensity rains and conducts a relatively large number of floods. This can not be expected

for its tributaries which may or may not contribute to any particular flood.

DETAILS OF STUDY

The author started the detailed study of the Abu An-Niran Karst in november, 1978, which was accidentally a rainy period following a completely dry one of nearly six months. In spite of the heavy rains and flood in the Wadi At-All the caves remained dry. There were pools in the deeper reaches of the caves, on the surface of which thin crusts of gypsum floated proving, that the water was of no recent origin. Weekly observation revealed that until the end of the rainy period, end of April, the caves flooded only twice, once in February and once in the beginning of April. Unfortunately no rainfall and runoff records exist in the mentioned period, thus it is not easy to correlate the hydrological factors. Also the two observed floods - once actually observed, the other time only by its effects - might be series of floods between the days of observations. In spite of all uncertainties the quantity of runoff per sq.km may be estimated. The number of rainy days registered at the Yafrin station in the rainy season of the 1971-72 hydrological year. was fiftyfive. According to observations/Ref. No. 7/ rainfalls minor to 10 mm/day have no any hydrological effect. The precipitation was less, than that in 42 of the rainy days in Yafrin, leaving only 13 days in which runoff could start in the area of the station delivering water to the Wadi At-Tall. /Other floods in the Wadi At-Tall are due to rainfalls in other parts of its hydrological basin/ The 13 rainy days supplied 74% of the total year's rainfall in Yafrin/371.8mm in 1971-72/ Expecting the same proportions in Abu An-Niran, the effective normal rainfall would be 148mm; that is 148.000m^3/km^2 of runoff. As the estimation of this number was very indirect it must be handled with care, it may be much less, but possibly not more.

Quantities of runoff - proportional to the catchment areas of each sinkhole in the gypsum karst will sink and reappear in resurgences. The waters than join one of the main recipients, to be lost to infiltration in the Gefara, leaving the area in discussion with no water resources. As a result the Abu An-Niran area is completely uninhabited, its single settlement, the Qasr Abu An-Niran completely abandoned long ago. To gain year-round water supplies construction of surface reservoires was considered, than rejected. /Ref. No.8/ There are no good dam sites, no valleys, that would pass for reservoires. Small reservoires are out of question, as the yearly potential evaporation is approximately fifteen times as much, as the rainfall.

Considering the hitherto unexplored karst phenomena in the Abu An-Niran area one may change ideas as the catchment and storage of underground runoff in the caves is a strikingly simple solution for development of reservoires. In the present stage of exploration five underground runoff systems are known with a bigger number of sinkholes, that belong to them/Fig. 2/.

RECOMMENDED STEPS FOR STORAGE POSSIBILITIES AND CAPACITIES

The neccessary steps of surveying the storage possibilities and capacities are:

1. Exploration of the underground relations: sinkholes-conduits /caves/ - resurgence. To a single resurgence one or more sinkholes belong. /e.g. to the Abu An-Niran karst system 1 spring and 8 sinkholes belong/ The knowledge of relations, which must not be and in most cases is not the same as the surface runoff system, enables one to calculate the catchment area that belong to a resurgence. Thus from the climatic data the estimated quantity of runoff in any karst system is calculable. The exploration: which sinkholes supply water to a certain resurgence, or which resurgence is the one where the swallowed water of a certain swallet reappeares - can be carried out by two ways. The more desirable way is to use the methods of speleology if the size of the conduits permits that. If the size of the conduit is not large enough to be entered and followed all the way, water tracing must be used. If none of these two methods are usable - this may happen temporarily, e.g. no water to be traced for an extended period - the solution is deduction based on tectonics, elevations, directions sediment composition, etc. This last solution must have been applied in the case of the Abu An-Niran karst system. /fig. 3/

2. Exploration is followed by survey of the sizable caves. The survey must contain enough data for the calculation of the volume of the conduits, all outlets and inlets, elevations must be shown. An example is the survey of the Spring cave in Abu An-Niran. /Fig. 4/

3. The survey finished, the cave volume and the storage capacity may be calculated. The example is the Abu An-Niran karst system.

For the Spring cave: medium with 3, 40m, medium height 1.70m, length 275 m total volume 1589.5 m^3 - 1600 m^3. Without further detailes the volume of the Abu An-Niran Main cave is 1900 m^3. The volume of the unknown, unproved passages would be calculable considering the being at least the size of the smallest passages encountered and straight in lining. The calculation yields 1000 m^3. Thus the total volume of the Abu An-Niran karst system is approximately 4500 m^3. The storage capacity is less, than that. Supposing the level of stored water rising more, than twelve meters above the spring level it will

spill through the sinkhole shown on fig. 3. This condition means, that the Spring cave and the conduits between it and the Main cave and other sinkholes will be completely filled. The Main cave because of its higher relative position will be only 50% filled. All this meaning, that the storage capacity of this single system is 3550 m^3. Comparing this with the climatological data and see, that the catchment area of the system is a rough km^2 it is easy to realise, that even if a very large mistake was committed in the calculation of yearly runoff, the system will fill to capacity in part of the rainy season.

The costs of an experimental project would be equal with the construction of a dam in a cave passage of about $2m^2$ in cross section. On the other hand the construction of any surface dam is out of question speaking in terms of money.

There are still questions which arise about the underground storage in Abu An-Niran.

-Is there any need for water in the completely abandoned area?

The area is abandoned because of the lack of water. Still there are signs, that show the struggle for water. There is a cystern, that «steals» water from a sinkhole with a collecting ditch. Another cystern was constructed nearby so recently as January 1979. The author has no knowledge who needs the water, but seemingly someone goes into much higher expenses to get much less and much worse water than it would be in a cave reservoir.

- Wouldn't the water spill through unexpected counduits?

There is little chance. It will definitely spill in the lower positioned sinkholes reversing their function, but this is a calculated risk. Other unexpected spillways are of low probability as the karst conduits are in the lowest position in the area always.

- Wouldn't the water damage the conduits by solution, being stored there all the year round?

Yes, there will be solution in the caves and sooner or later the water may find a way to escape. The most dangerous spot is the dam itself. The dam being small, still the danger is by scores smaller, than in the case of a surface dam it would be. Solution will enlarge the conduits by slow process.

- Wouldn't the solution of the gypsum produce unwanted water qualities?

The water stored in the caves will be slightly sulphatic. Only an experiment could determine how much. Still the quality would be considerably better, than in the wells of Bir Al-Ghanem, as the stored water would be completely changed more than once in a year.

As a final result the author wishes to emphasize that the proposed underground reservoirs are no answer to the great questions of water supplies in Libiya. On the other hand they would be answers to the question in a small area where people struggle for it and get it only in limited quantity and quality.

At the present state of exploration the caves are not much more, than geological curios which offer some ideas. Extended exploration of the whole area and at least one experiment might prove underground storage be a major solution of water problems in the Abu An-Niran and Bir Al-Ghanem area.

Fig. 1 . A large swallet in Abu An-Niran Karst.

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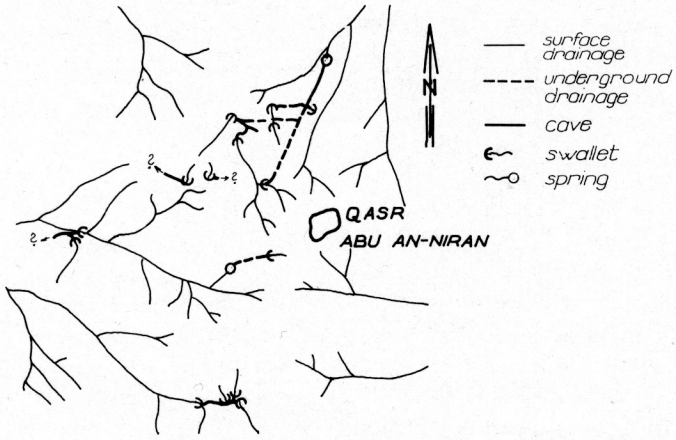
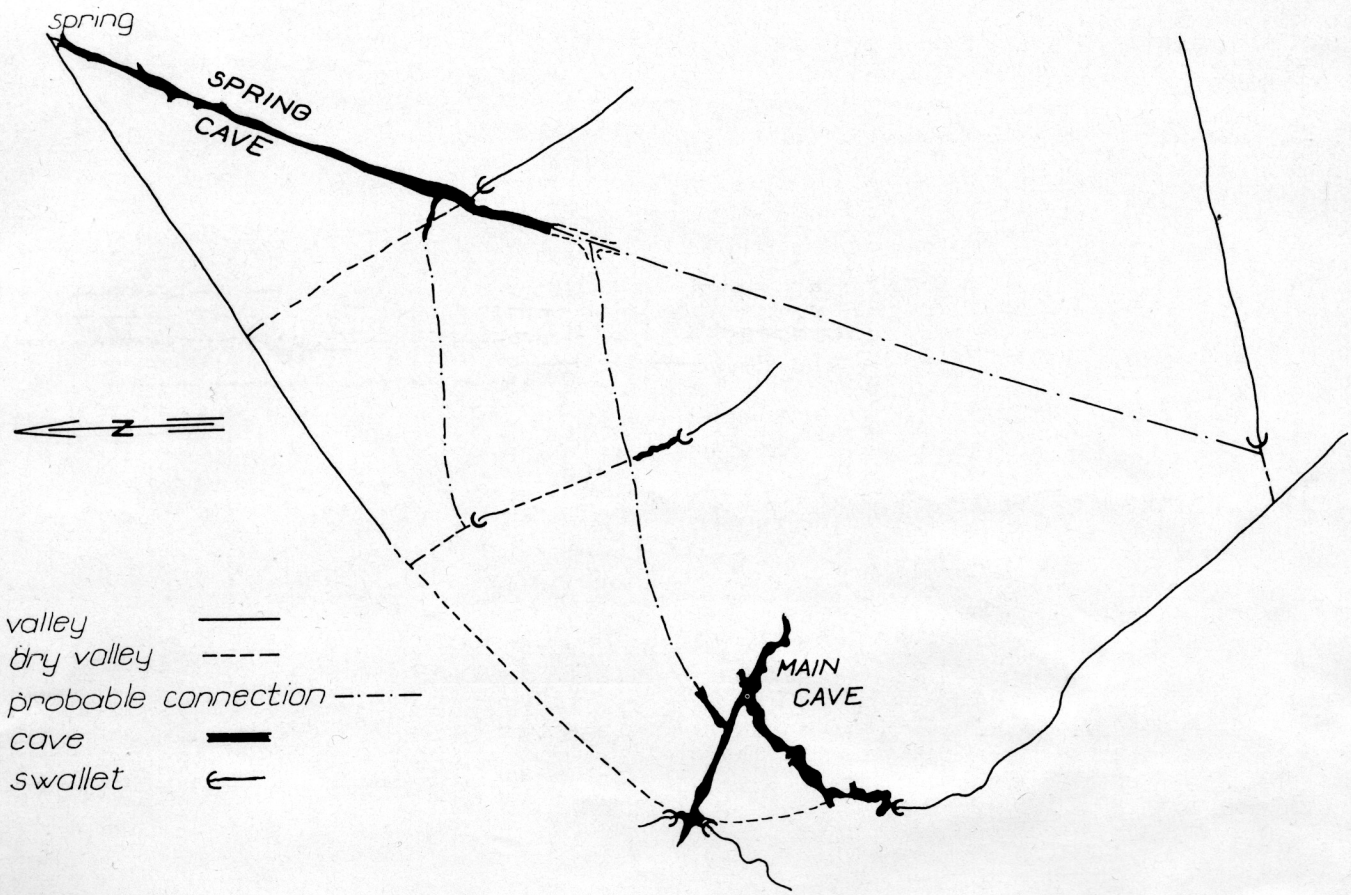


Fig. 2 Surface and Underground Drainage in Abu- An- Niran Area.



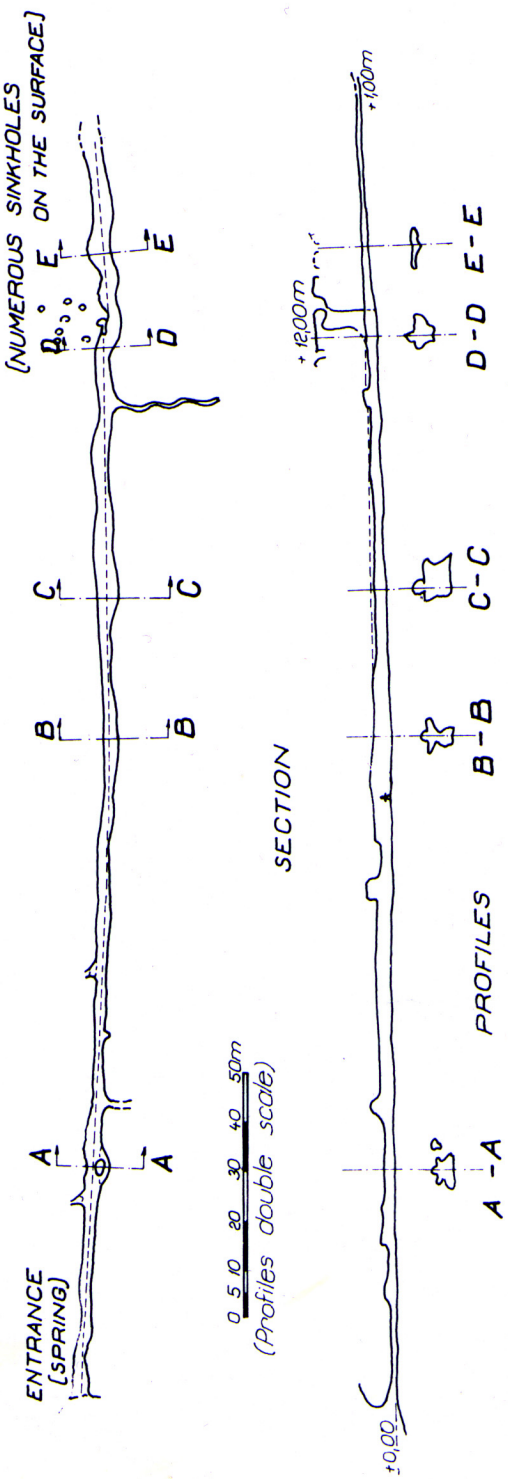


Fig. 4. Survey of the Spring Cave in Abu An-Niran area.