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COMBINED GEOPHYSICAL TECHNIQUES FOR CAVITY DETECTION

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الكشف عن التكهفات باستخدام التقنيات الجيوفيزيقية المشتركة

الخلاصة: خلال العمل بأحد مناجم الألبستر بمحافظة بني سويف تم الكشف عن أحد الكهوف الضخمة بالمنطقة، والذي تم إعلانه كمحمية طبيعية عام ١٩٩٢ نظرا لما يتمتع به من خصائص جيولوجية فريدة. ومن أجل إعداد المنطقة كمزار سياحي تم عمل العديد من الدراسات ومنها دراسة جيوفيزيقية تشتمل علي ثلاثة قياسات للسبر الكهربي الرأسي و ثلاثة قطاعات رادارية. وأظهر تفسير هذه القياسات وجود كهف تحتسطحي جديد وتم تأكيد وجوده عن طريق قطاع جيوراداري وجسة سبر كهربي رأسي. وبذلك يتضح أنه من اللازم استخدام عدد من الطرق لتعضيد النتائج وعدم الاكتفاء بطريقة واحدة.

ABSTRACT: *During a mining work in an area near Beni Suef governorate, Upper Egypt, which is mainly characterized by alabaster formation, a huge cave was discovered. A detailed geophysical study, including Vertical Electrical Sounding (VES) and Ground Penetrating Radar (GPR), has been carried out to prepare the area around the discovered cave for touristic activities. During data acquisition another subsurface cavity is discovered. This detection is proved by a GPR profile measured along the inspected cave location. The extension and the depth to the top of the cavity was determined from both Geoelectric and GPR data interpretation. The combination of two different techniques, Geoelectric VESs and GPR profiles, is very helpful in detecting the subsurface features as well as determining their dimensions.*

INTRODUCTION

A huge cave was discovered in Beni Suef governorate, Upper Egypt (31^o 17' E and 28^o 37' N) during a mining work. The cave has a semi-circle shape with the dimensions of 300m long 4-18m wide and 24m high. The cave is characterized by the presence of stalagmites and stalactites which represent a rare phenomenon in Egypt, so the cave is announced as protected area in 1992. In order to develop the area for tourism activity, a complete geological, geophysical, and engineering study carried out in and around the cave. Our target in this research is to study the area around the cave and search for other caves. Vertical Electrical Sounding (VES) and Ground Penetrating Radar (GPR) techniques are used to achieve this target. These techniques are widely used for several purposes such as groundwater detection, engineering applications, fracture and cavity detection, as well as archaeological applications (al Hagrey and Michaelsen, 1999; Al Hagery, 1994; El-Behiry et. al., 1999, Senosy and Riad, 1989, Carrara et. al., 1994, and others). One of the main applications for GPR technique is cavity and fracture detection (Leggo and Leech, 1983, Leggo, 1982; McCann et. al., 1988; Sasahara et. al., 1995; Valle and Zanzi, 1996; El-Behiry and Hanafy, 2000; Hruska and Hubatka, 2000; Pipan et al., 2000)

A total of 3 GPR lines and 3 geoelectrical VES stations are acquired in the area (Fig. 1). A new cavity is discovered in a wadi near the huge cave. This new discovered cavity is proved by combination of the results of one VES and GPR profile.

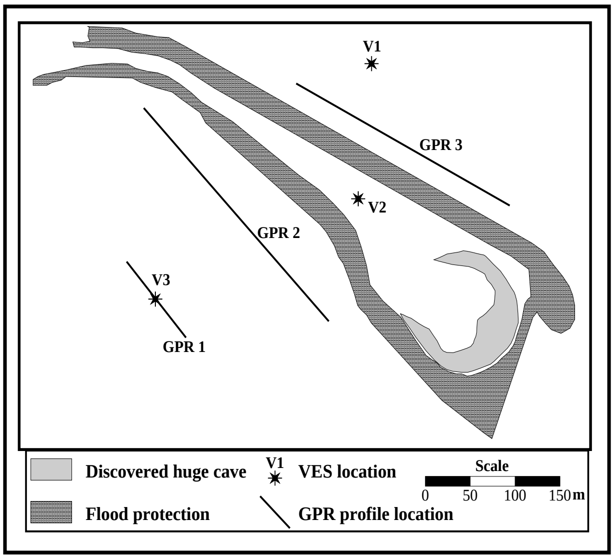

Figure 1: A location map showing the area of study and the location of acquired VES and GPR profiles.

GEOELECTRIC RESISTIVITY DATA
Acquisition and Interpretation

A total of 3 geoelectric resistivity VES's (Fig. 1) are acquired around the discovered huge cave. A Syscal R2 instrument is used for data acquisition with a maximum AB/2 of 200m The conducted data are interpreted via three steps; (a) smoothing of the field data curve during data acquisition where illogic sharp peaks are neglected. Such peaks are difficult to interpret and cause ambiguity in the interpretation results, (b) preparing an initial model depending on the geological background of the study area, (c) Introducing the initial models into Van Der Velpen (1988) software. More than one iteration were used to reach the best fit between the smoothed field curve and the calculated one. The RMS error of the resulted models ranges between 2.8-7.3%. Figure 2 shows the three acquired VES.

Interpretation of VES # 1 and # 2 shows the presence of four subsurface layers, namely. a) a surface layer of dry wadi sediments with resistivity values ranging between 1000 - 12000 ohmm, and thickness of 0.5m, b) a second layer of relatively low resistivity values ranging from 63 to 118 ohmm and thickness of about 0.9m, this layer is represented by highly weathered calcareous material, c) a very high resistivity layer (3000 – 6700 ohmm) due to alabastrine limestone with thickness more than 25m, and d) a relatively low resistivity layer (< 1000 ohmm) attributed to a saturated weathered alabaster layer.

Interpretation of VES # 3 shows the same subsurface sequence except the presence of a very high resistivity layer due to expected cavity. This layer has a resistivity of more than 100,000 ohmm and thickness of about 4.3m, located at a depth of 4m from the ground surface. This very high resistivity value is interpreted as due to the presence of air-filled cavity. The interpretation of this VES faced a serious problem because of the sharp increase and decrease of apparent resistivity due to the presence of air-filled cavity. This VES was interpreted in two phases, the first with ignoring the air-filled cavity effect (Fig.2c) and the second with taking into consideration the air-filled cavity effect (Fig.2d).

GROUNDWATER LEVEL

The groundwater potentiality in the study area can be divided into two categories, 1) the shallow groundwater level, which is represented by the fourth geoelectric subsurface layer, the saturated weathered alabaster, and is located at depth more than 25m from the ground surface, 2) the deep groundwater level, which is at depth more than 70m from the earth's surface (CEHM, 2002).

The expected main recharging source of the groundwater in the study area is the flood that occurs in the area from time to time. The two groundwater levels previously mentioned have no direct effects on the discovered huge cave. In the same time, there are no expected ground hazards on the discovered small cave. The huge cave needs to be protected from floods that occur in the area to secure its valuable importance.

GROUND PENETRATING RADAR (GPR)

In order to verify the discovered small cavity, 3 GPR profiles (Fig. 1) are acquired around and over the expected cavity location. A RAMAC2 GPR system with 100 MHz antenna is used. The acquisition parameters are; a 10-cm trace - trace distance, 16-fold stacking, and no gain is added. The acquired GPR profiles are processed and filtered to minimize the noise effects. An average velocity (13 cm/ms) of dry limestone is used to transform the GPR profile from time scale to depth scale (Daniels, 1996). We can note the presence of sinusoidal reflections due to antenna ringing at the bottom of the GPR profile # 1 & # 3 (Fig. 3 & 5).

GPR profile # 1 is acquired over the location of VES # 3 to verify the presence of the discovered small cavity. This profile shows the presence of two subsurface layers, a surface highly weathered calcareous material layer with a thickness of 4m overlaying an alabasterain limestone layer extending to the end of the profile (20 m depth). A high amplitude reflections is observed at the middle of the profile (offset 10 to 48m). These high amplitude reflection are a good indicator to the presence of a cavity at a depth of 4m from earth's surface with thickness of about 4 m and extends laterally for 38m in the profile direction.

GPR profiles # 2 and 3 (Fig. 4 & 5) shows the presence of two subsurface layer. The first is a highly weathered calcareous material with thickness ranging between 4 – 12m. This layer is highly fractured. The second layer is the alabastrine limestone layer which extends to the end of the GPR profile. There is no cavity effect on GPR profiles # 2 & 3.

CONCLUSIONS

A huge cave is discovered in Beni Suef governorate, Upper Egypt, during mining work. This cave is announced as a geological protected area in 1992. Detailed geological and geophysical studies are carried out to prepare the area for tourism development. The main target of geophysical studies is to evaluate the environmental and natural hazards such as groundwater and presence of other subsurface cavities in the study area. To achieve this target, 3 geoelectric VES's and 3 GPR profiles were acquired. The interpretation of the geoelectric VES's shows the presence of four subsurface layers, a surface layer of dry wadi sediments with resistivity ranging between 1000 - 12000 ohmm and thickness of 0.5m, a relative low resistivity layer (63 – 118 ohmm) with thickness of about 0.9m is represented by highly weathered calcareous material, a high resistivity layer (3000 – 6700 ohmm) due to alabastrine limestone with thickness more than 25m, and finally a relatively low resistivity layer (< 1000 ohmm) due to a saturated weathered alabaster layer. VES # 3 shows the presence of a layer of very high resistivity (100000 ohmm), which is interpreted as an air-filled cavity. The interpretation of the geoelectric VES shows the possibility to find groundwater at depth more than 25m which has no dangerous effects on the discovered huge cave.

A total of 3 GPR profiles are acquired over and around the discovered small cavity to assure its presence and searching for more subsurface cavities.

The discovered small subsurface cavity is shown on GPR profile # 1 as a result of interpretation of very high amplitude reflections. The other two GPR profiles did not indicate any other subsurface cavity in the study area, but reflect the highly weathered calcareous material layer which is highly fractured.The integration of geoelectric resistivity VES's and GPR technique is of valuable importance in detecting subsurface features, anomalies, and layer sequence. Integration of more than one geophysical technique leads to more accurate and assured results.

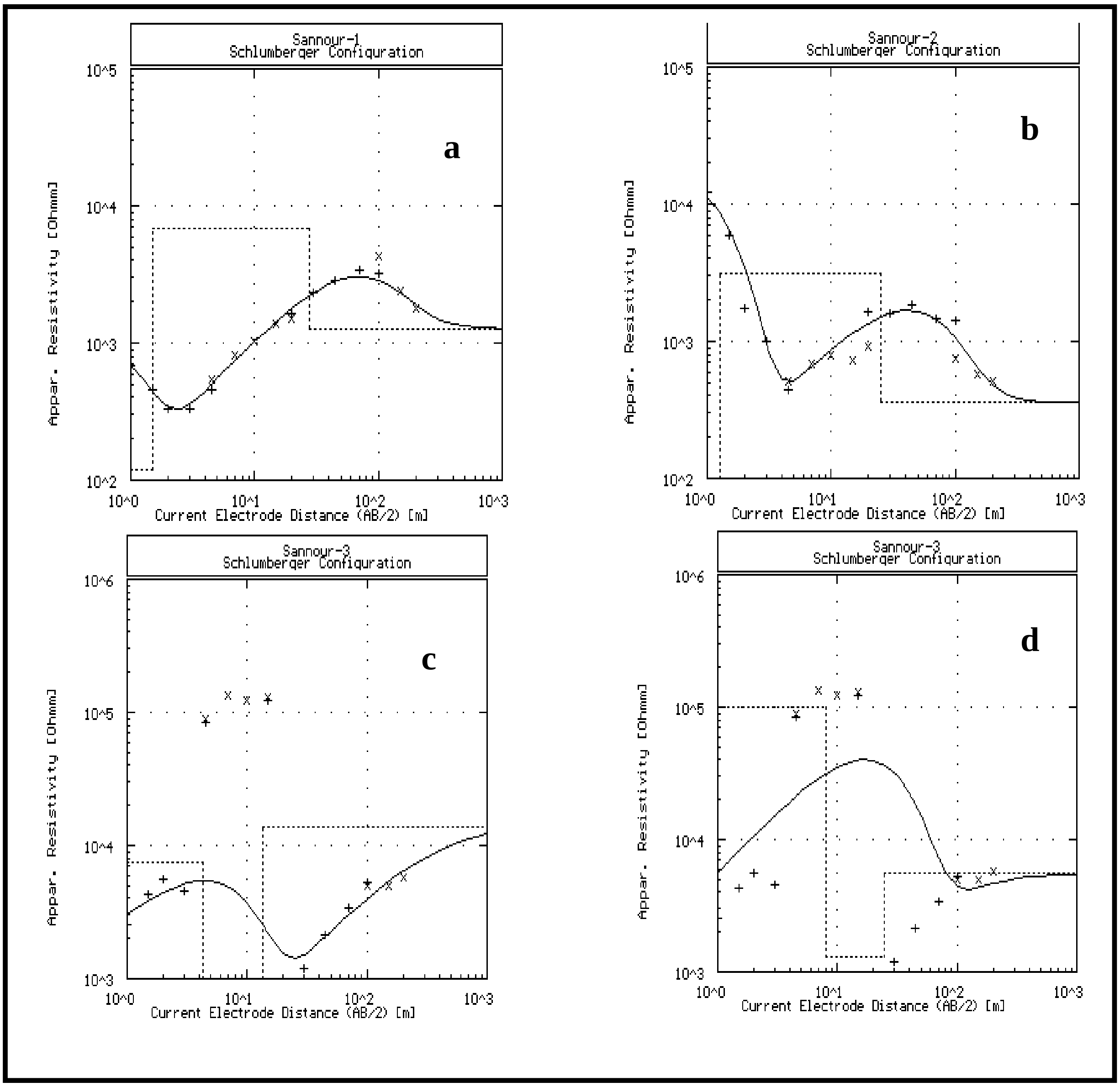

Figure 2: The interpretation of the acquired geoelectric VES's, (a) VES # 1, (b) VES # 2, (c) and (d) VES # 3.

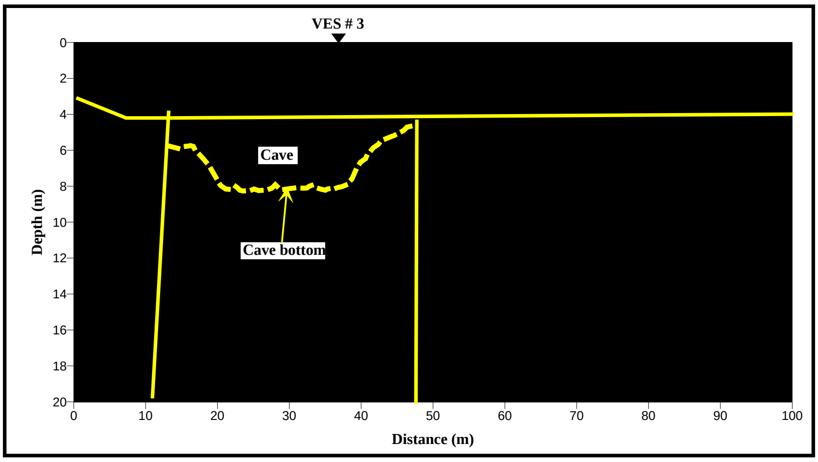

Figure 3: The acquired GPR profile # 1

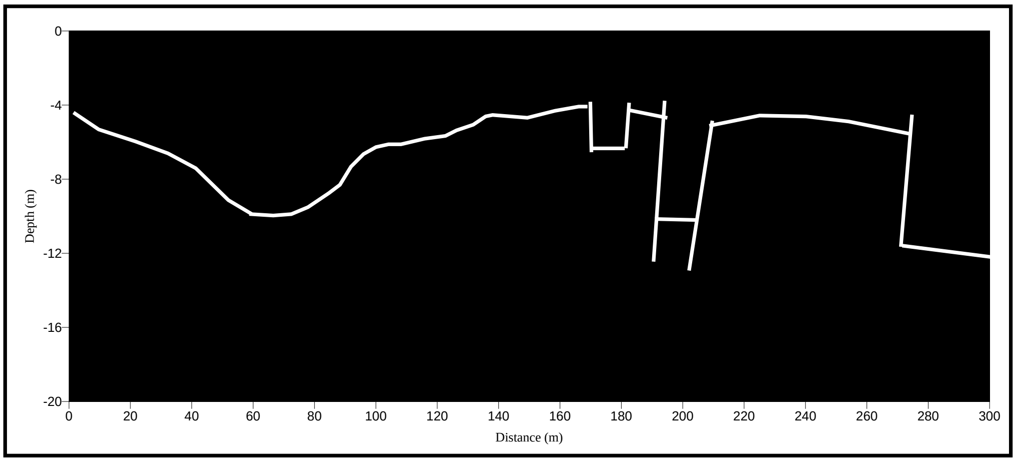

Figure 4: The acquired GPR profile # 2

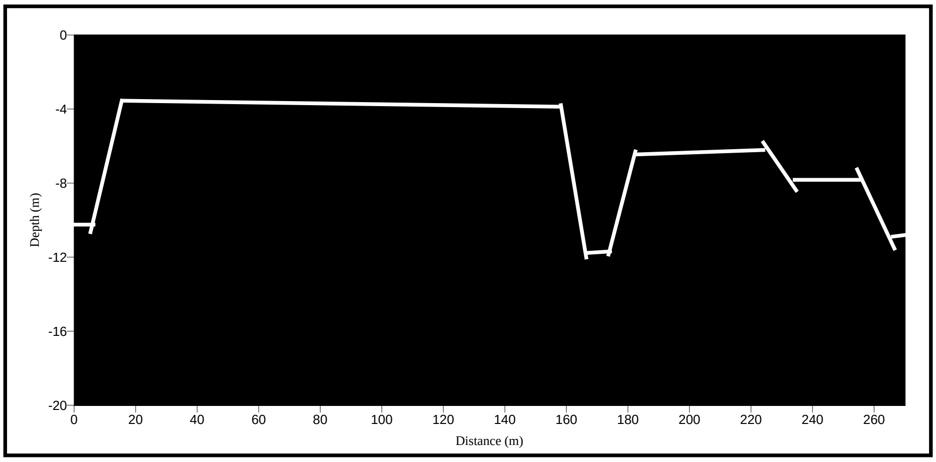

Figure 5: The acquired GPR profile # 3

REFERENCES

Al Hagrey, S. A. and Michaelsen, J., 1999, Resistivity and percolation study of preferential flow in vadose zone at Bokhorst, Germany, Geophysics, Vol. 64, No. 3, P. 746 – 753.

Al Hagrey, S. A., 1994, Electric study of fractured anisotropy at Falkenberg, Germany, Geophysics, Vol. 59, No. 6, P. 881 – 889.

Carrara, E., Pece, R., and Roberti, N., 1994, Geoelctrical and seismic prospections in hydrogeology: Model and master curves for the evaluation of porosity and water saturation. Pageoph., Vol. 143, No. 4, P. 729-751.

CEHM (Center of environmental hazard mitigation, Cairo Univ.), 2002, Integrated study for Wadi Sanour cavity protection and development, A project report.

Daniels, D. J., 1996, Surface penetrating radar: Short Run Press Ltd., England, P. 300

El-Behiry, M. G., Hanafy, Sh. M., and El-Hemamy, S. T., 1999, Electrical resistivity soundings to delineate fault trace at the southern of 15-May city, Cairo: Proc. Of 17th Ann. Meet. Of EGS, P 1-15.

El-Behiry, M.G. and Hanafy, Sh. M., 2000, Geophysical surveys to map the vertical extension of sinkhole: a comparison study.: SAGEEP-2000, 341 – 350.

Hruska, J., Hubatka, F., 2000, Landslides investigation and monitoring by a high-performance and cavities in limestone: GPR 2000 Proceedings of the 8th International Conference on Ground-Penetrating Radar, Gold Coast.

Leggo, P. J. and Leech, C., 1983, Subsurface investigations for shallow mine workings and cavities by ground impulse radar technique: Ground Engineering, 16, 20-23.

Leggo, P. J., 1982, Geological applications of ground impulse radar: Transactions of the Institute of Mining and Metallurgy; B: Applied Earth Science, 91: B1-5.

McCann, D. M., Jackson, P. D. and Fenning, P. J., 1988, Comparison of the seismic and ground probing radar methods in geological surveying: IEEE proceedings, 135 (F, 4), 380-390.

Pipan, M., Baradello, L., Forte, E., and Prizzon, A., 2000, GPR study of bedding planes, fractures and cavities in limestone: GPR 2000 Proceedings of the 8th International Conference on Ground-Penetrating Radar, Gold Coast.

Sasahara, K., Tsuchida, T., and Fenner, T. J., 1995, An investigation of cracks in rock slope using ground penetrating radar: SAGEEP’95, 149-158.

Senosy M. M. and Riad, S., 1998, An electrical resistivity study to determine characteristics of near-surface layers in the present and the new proposed sites of Hibis Temple, New Valley, Egypt. Bull. of the Faculty of Science, Assiut Univ., Assiut, Egypt, Vol. 27, No., 2, P. 73 – 94.

Valle, S. and Zanzi, L., 1996, Radar tomography for cavities detection: SAGEEP’96, 555 - 563.