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DETECTION OF SUBSURFACE CAVITIES BY THE ELECTROMAGNETIC METHOD
(Case Study at Haditha Area)

Mohammad S. Zaynal
Iraqi Natural History Research Center and Museum. University of Baghdad.
Baghdad, Iraq.

ABSTRACT

Two EM techniques, terrain conductivity and VLF-Radiohm resistivity (using two different instruments of Geonics EM 34-3 and EMI6R respectively) have been applied to evaluate their ability in delineation and measuring the depth of shallow subsurface cavities near Haditha city.

Thirty one survey traverses were achieved to distinguish the subsurface cavities in the investigated area. Both EM techniques are found to be successfiul tools in study area.

INTRODUCTION

The development in Iraq has necessitated a new vast areas for housing, construction and agriculture. Most of the new land is characterized by high gypsum content and various geotechnical problems. So the obtaining of the required subsurface geotechnical informations prior to the erection of any large engineering construction are very important from both economic and safety point of view. For this reason. geophysical methods play an increasingly important role in the providing of this informations (such as assessment of the top layers; location, trend and depth of the shallow subsurface anomalies features).

Of the many different surface geophysical methods; the one which has been used in the present study is the electromagnetic method. It falls in two categories: the fixed- source technique and moving source-receiver technique. These techniques have several advantages over other geophysical surveys. The most important of these do not require the use of potential field and current electrodes as in the gravity survey and resistivity sounding. Therefore; field measurements are very rapid and data acquisition includes low cost, easy operation, speed and accuracy. Also the instruments give readings directly in mappable units.

The most of successful applications of these two EM techniques were published in different parts of the world including different studies such as:

Stewart (1982), Ritsema (1983), Baker and Zaynal (1985,1986 & 1987), Baker and Abdul Razzak (1985,1986 a&b), Stewart and Bretnall (1986), Zaynal and Tobia (1989), Al-Naib et al (1989), Al-Omari et al (1989).

This work has investigated location and depth of the subsurface cavities (filled with water) in Haditha area within the skin depth through using the electromagnetic method.

<u>The electrornainetic method and the measuring instruments</u>

Electromagnetic induction methods utilize current flow induced in the subsurface material by a surface transmitter. An alternating electric current produced in a transmitter coil generates an alternating magnetic field, which in turn induces current flow through the earth material. The secondary magnetic field generated by the induced current is sensed by a receiver coil. The secondary field sensed at the coil depends on the strength of the primary field, current frequency, distance between the transmitting and receiving coils and on the ground conductivity. In general, the secondary field which is picked up by a suitable receiver coil, will differ from the primary field in intensity, phase and direction and can reveal the presence of conductors. However, the detailed discussions of the electromagnetic methods and their theories of operation are given in many text books such as Telford et al (1976), Griffiths and king (1981), and Parasins (1983).

Two different electromagnetic techniques have been used in this study: namely the EM terrain conductivity and the VLF-Radiohrn EM resistivity measurements. The former is the moving source-receiver method and the latter is the fixed-source method.

The instrument used with the EM terrain conductivity measurements is the Geonics EM34-3. It consists of two portable coils: one to transmit a magnetic field and the other is to receive this field and the magnetic filed is excited by conductors in the earth. The EM34-3 instrument is entirely portable, requiring only two persons for field operation.

A direct reading of conductivity in mmhos/m is obtained while the transmitting and receiving coils are held in a coplaner orientation (either horizontal or vertical plane) at one of three possible coil separations: l0m, 20m, or 40m for which cables are supplied by the manufacture.

The transmitter operates at a fixed frequency for each of the three coil separations (6400HZ; 1600HZ and 400HZ respectively). The effective depth of penetration increases with increasing coil separation. Depth of penetration, as well as current distribution, can also be varied by alternating between the horizontal and vertical coil orientations. More detailed descriptions of terrain conductivity and principles of operation are given in McNeill (1980) and Stewart (1982).

In the second EM technique; the selected instrument is the Geonics EMI6R because of its low weight and simplicity of operation. The instrument was described by Collett and Beker (1968). It requires only one operator. it uses very low frequency (VLF) radio waves (10-30 KHZ) transmitted from distant stations as the primary magnetic filed. The EM16R is mainly a radio receiver, measuring the ratio and the phase angle between the horizontal electric and magnetic fields. When the instrument is well oriented with respect to the VLF radio station, the apparent resistivity of the earth can be derived from the ratio between the horizontal electric field in the direction of the radio station and the horizontal magnetic field perpendicular to that direction using a magneto-telluric relation given by Cagniard (1953).

The measurement of the phase angle between the horizontal electrical and magnetic fields of the wave that radiates from these radiostations gives information about the vertical variation of resistivity. A homogeneous earth produces a (45°) phase angle, while a two layer case produces phase angles greater or Less than (45°). A high conductivity lower layer produces a phase angle more than (45°), whereas a phase angle less than (45°) is interpreted as indication for high resistivity lower layer. (Arcone. 1979).

The exploration depth with this method is source limited because the depth of penetration depends on the frequency of the signal and the resistivity of the top layer. Therefore. the depth will be equal to the skin depth. (Grant and West. 1965).

<u>Location and field work procedure</u>

The survey area was located at about (26 km) NW of Haditha city (fig.l). The marker point for the area is located on lat. (34° 11′ 22″) and long. (42° 7′ 30″). The cavity of interest runs in the Euphrates limestone formation (Early Miocene) fig(2). The geology of the area and the formation of cavities are not to he discussed in this paper.

The EM survey covered (651) stations over an area of (200 x600) meters. The survey has been executed with EM terrain conductivity and VLF-Radiohm EM resistivity measurements respectively. They have been carried out along (31) traverses with (20m) separation and (l0m) grid interval.

In the first EM technique. the coils of the (EM 34-3) instrument were set at (20) meters spacing and held in a horizontal plane while in the second EM technique (using EM 16R instrument) and at the start of the field work the transmitting station was chosen to be the British Rugby station (GBR) with frequency (16KHZ).

Field results and interpretation:

The results obtained during the EM survey are presented as contoured maps, (fig.3&4). The EM apparent conductivity measurement map (fig.3) clearly shows three zones of high conductivity values (240 mmhos/m) that lie in the left and central part of the study area.. These conductivity values are coincident in position with that of low resistivity data obtained from the second EM technique (i.e. high conductivity values reflect low resistivity values 40 ohm.m, flg.4). The observed phase angle over these zones is greater than (45°) as shown in (fig.5); indicating a resistive layer over a conductive layer. This means that resistivity decreases with depth at these zones. These anomalies could possibly be considered as water filled cavities as revealed by the drilling in this area. The depth to top of these cavities was calculated by using the observed resistivity profiles (fig.5) and the Geonics standard curves (1979) and found to be a round (20) meters.

Conclusions

The two techniques used in this study have proved to have the potential of becoming an effective and efficient diagnostic tool for field geophysical prospecting. They offer a rapid means for delineating area of subsurface anomalously high electrical conductivities. However; result that can be obtained with these techniques depend mainly on the conductivity contrast, i.e., in this case contrast between the water filling the cavity and the surroundings. Also, the size depth relation will have a direct effect on the results.

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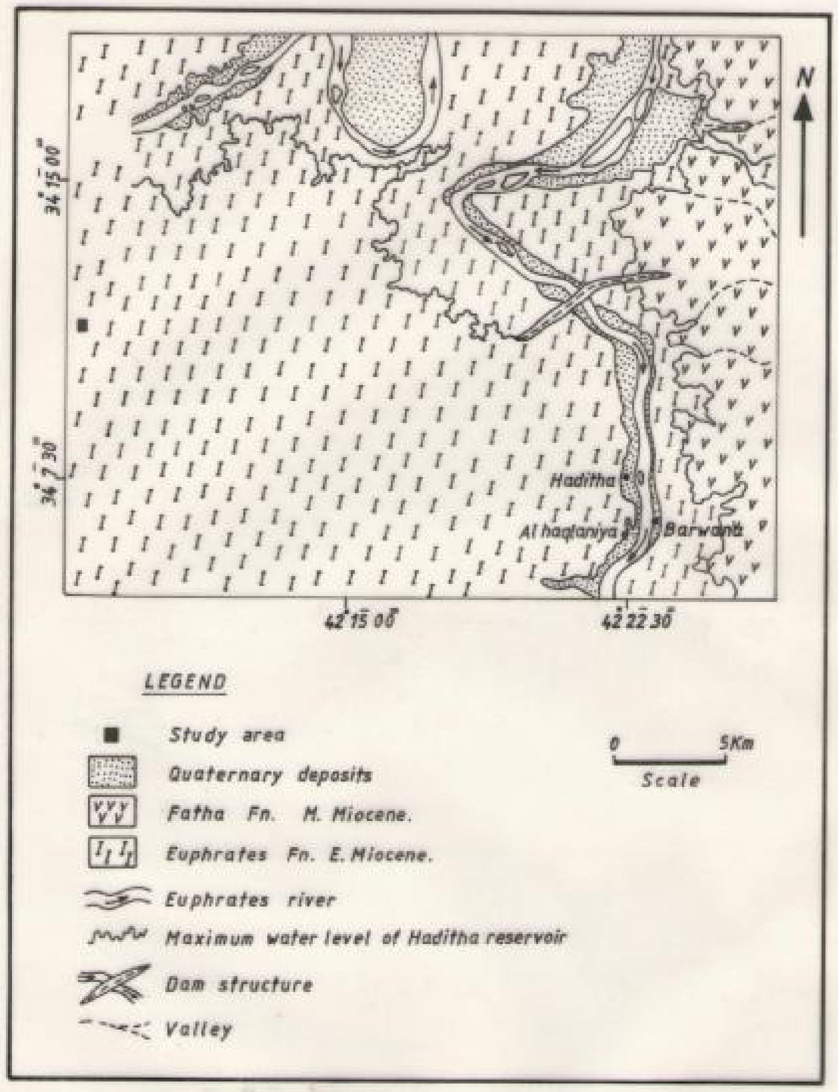

Fig. (1) A map showing the location and geology of study area.

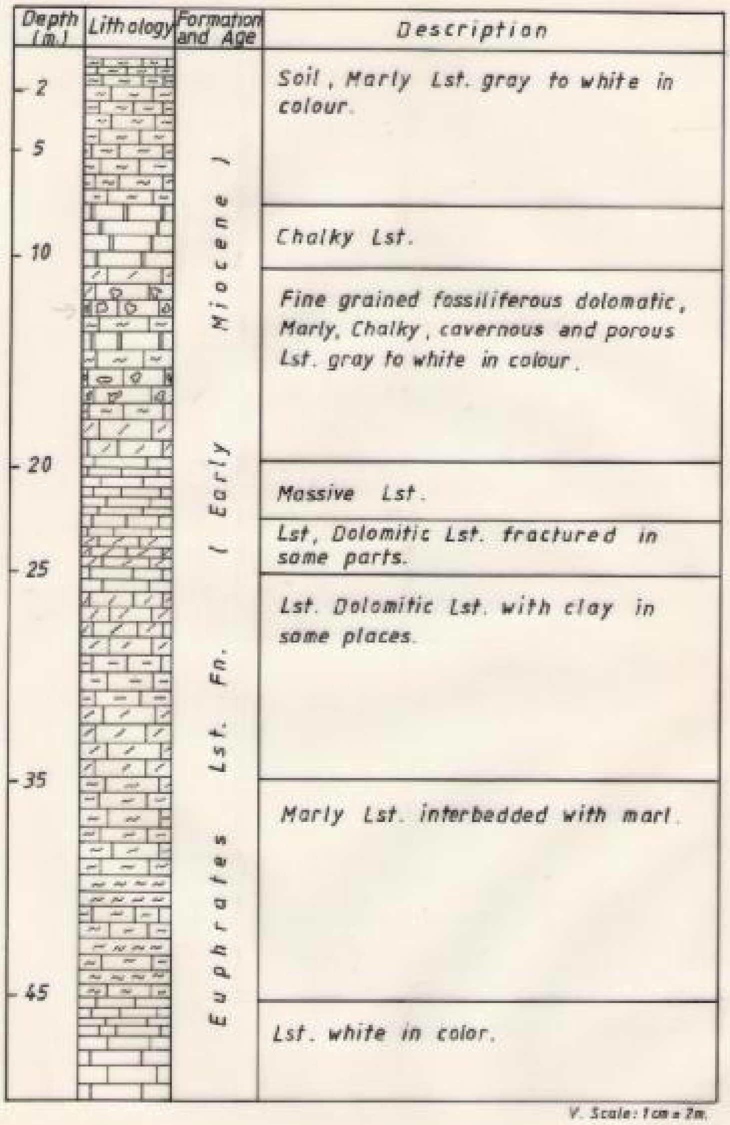

Fig.(2). Stratigraphic columnar section in borehole-A .

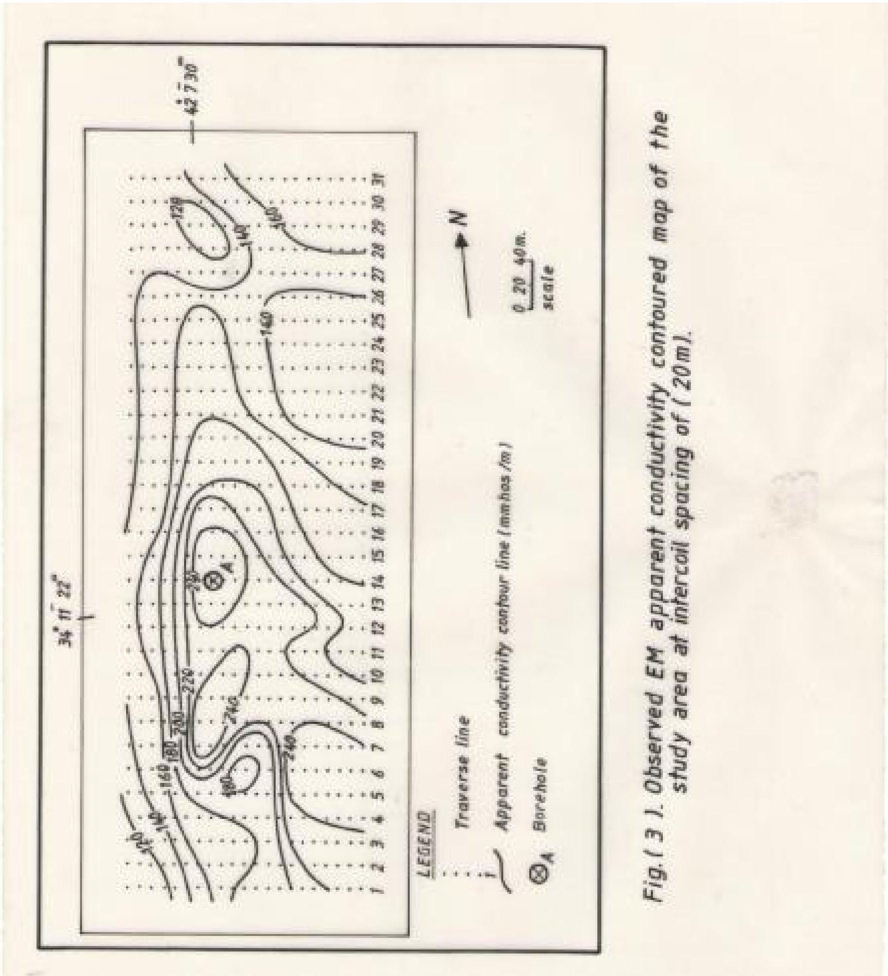

Fig.(3). Observed EM apparent conductivity contoured map of the study area at intercoil spacing of (20m).

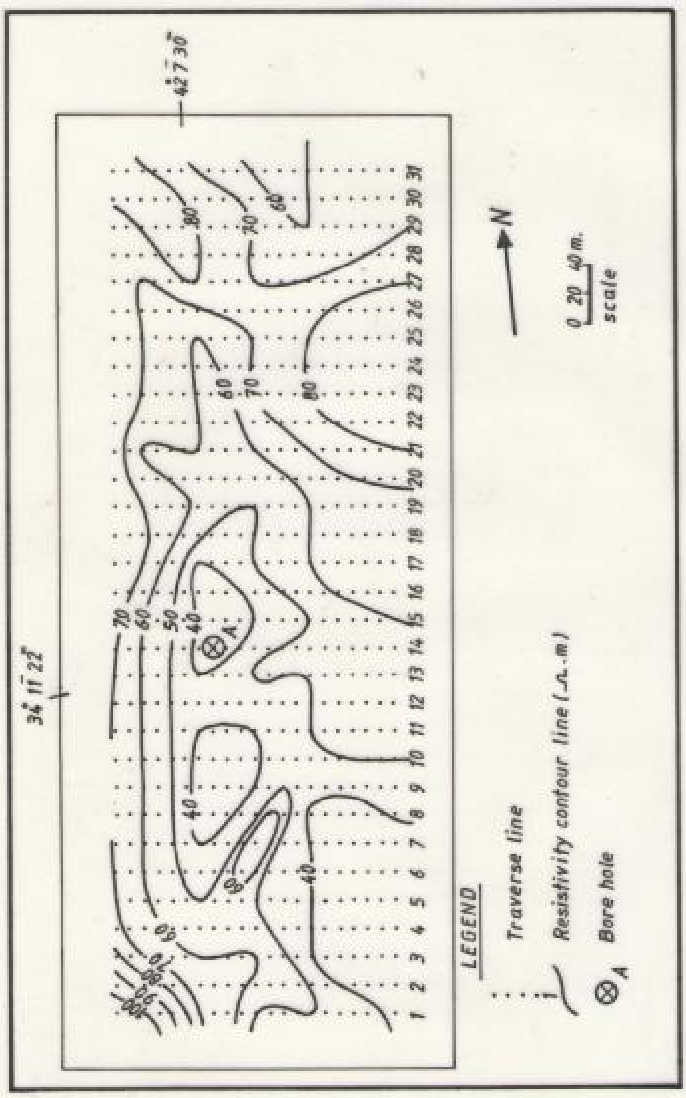

Fig. (4). Observed VLF-Radiohm EM resistivity contoured map of the study area.

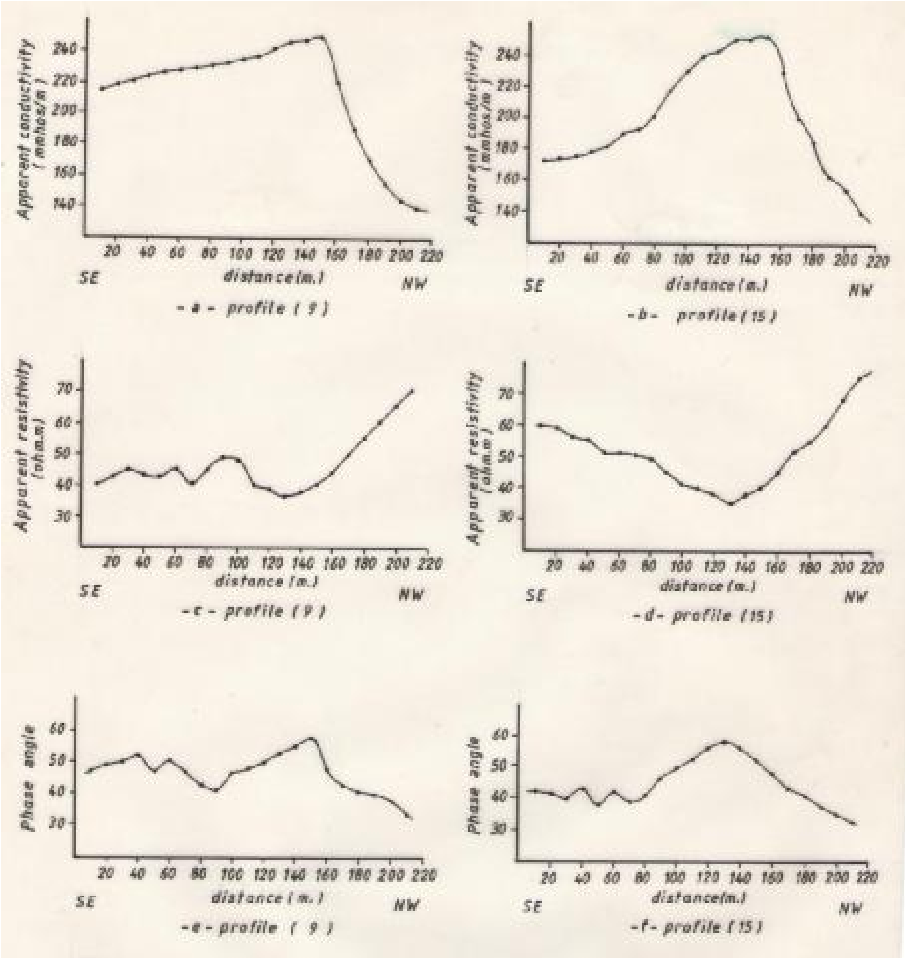

Fig. (5)

a & b - observed conductivity values (σ_a) for coil separation (20) along profiles (9&15) respectively.

c & d - observed radiohm resistivity values (ρ_a) along profiles (9 &15) respectively.

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د يلحه تفهك تلك اتيجطه تح تالسيط اغمرهكلا ة يرطلا ملختسا بة
(لحة مينطة ديثة راسة)

م حمد شكري زينل
العراق — بغداد — جامعة بغداد — مركز بحوث التآكل الخارجي

الخلاصة

ا تلويصق ليالبس أ دلمو حلب ك نمضه ا لأول ب أسلوب نيلدت لخلمح تلطريقة الكاهرو نا طيبية
ب تسا خلمام (القاومة الهريبائية و الذي كان ادلم ب قياس EM 34-3) با تسا دلم جهاز (الكاهربائي
ا لا يربة لمزلتكهفي تلتحي دق ا سعا ق ا لأسلوب نيذلا كغرض يمي مذ ني (EM 16R ا زجهي
ع قت ة ط مفي حسلا ا ثيلحة م رقلا ب.
م نظقة ا دراسة أ خاتء تضع المكلاهك بغناط سيو ل د ثؤ مين لدمار اً مؤزع اع جيع
د يد ا التكافيت حي ا لأسلوب نيحاج كفاءة ذين علی قيقهة مهلط رن ةتائج أ ثبتتوقد
ال تحطيجة.