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

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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 successful 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
different surface geophysical methods; the one which has been used in the
geotechnical problems. So the obtaining of the required subsurface geotechnical information
in the present study is the electromagnetic method. It falls in two categories: the fixed- source
prior to the erection of any large engineering construction are very important from both
technique and moving source-receiver technique. These techniques have several advantages
economic and safety point of view. For this reason, geophysical methods play an increasingly
over other geophysical surveys. The most important of these do not require the use of
important role in the providing of this informations (such as assessment of the top layers;
potential field and current electrodes as in the gravity survey and resistivity sounding.
location, trend and depth of the shallow subsurface anomalies features).
Therefore; field measurements are very rapid and data acquisition includes low cost, easy
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in the electromagnetic method.

The electromagnetic method and the measuring instruments
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
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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 Paraisins (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: 10m, 20m, or 40m for which cables are supplied by the
manufacturer.

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).

Location and field work procedure

The survey area was located at about (26 km) NW of Haditha city (fig.1). 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 be 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-Radiohrn EM resistivity measurements
respectively. They have been carried out along (31) traverses with (20m) separation and (10m) 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, fig.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 standared 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.

REFERENCES


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Fig. (1) A map showing the location and geology of study area.
<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Lithology</th>
<th>Formation and Age</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Soil</td>
<td></td>
<td>Marly Lst. gray to white in colour.</td>
</tr>
<tr>
<td>5</td>
<td>Chalky Lst.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Fine grained fossiliferous dolomitic, Marly, Chalky, cavernous and porous Lst. gray to white in colour.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Massive Lst.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Lst. Dolomitic Lst. fractured in some parts.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Lst. Dolomitic Lst. with clay in some places.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Marly Lst. interbedded with marl.</td>
<td></td>
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**Fig. (2). Stratigraphic columnar section in borehole-A.**
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Fig. 14: Observed VLF-Radiohmm EM resistivity contoured map of the study area.

Legend:
- Traverse line
- Resistivity contour lines (a.m.)
- Bore hole

Scale: 1 cm = 20.4 m
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Fig. (5)  
a & b - observed conductivity values (6a) for coil separation (20) along profiles (9 & 15) respectively. 
c & d - observed radium resistivity values (Pu) along profiles (9 & 15) respectively.
تعداد تكثيفات المجففية مع أجهزة الاستشعار EM16R وEM34-3، وتثبت قدراً من تشددي التلاحم الميكانيكي.

مع ذلك، تؤثر الجراثيم على المجففية عند أجهزة الاستشعار EM16R وEM34-3، وتثبت قدراً من تشددي التلاحم الميكانيكي.