

THE SIMULTANEOUS USE OF EM CONDUCTIVITY AND RADIOHM RESISTIVITY TECHNIQUES IN SOLUTION CHANNEL DETECTION

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ABSTRACT

The chalky limestone and marley limestone are the main lithological unit of Euphrates Formation which can be existed and appeared in the area under investigation "north west Haditha area". When the groundwater passing through these types of rocks, a part of their may suffer from dissolution by means of dissolving process. Hence, the main task of the present survey is to locate and delineate the buried channels caused by this type of process in the area located in western part of Iraq by applying two EM techniques namely, electromagnetic conductivity and VLF-Radiohm electromagnetic resistivity methods.

The Geonics EM34-3 together with the EM16R instruments were used in the field survey. More than ten predetermined traverses were pegged out in the area at which the EM measurements along these traverses were carried out.

The results come from both surveys in correlation with available geological information have obviously showed a trend of clear and identity feature described as a single buried dissolved channel.

Keywords: Em conductivity, Radiom Resisyivity, Haditha, Iraq

INTRODUCTION

It is well known that all methods fall underneath the wide title of electromagnetic prospecting are almost the most commonly used in mineral exploration. It depends on detecting electrical conductivity contrast with different types of lithology.

Thirty years ago, the geophysical methods as DC electric current and seismic methods were successfully used for investigation of ground flow system in many projects in the world. Recently, the EM techniques as a geophysical method are also proved as a successful tool in hydrogeological investigation and aiding in some cavity detection as well (Collett and Beker, 1968; Mullern and Eriksson, 1981; Ritsima, 1983; and Monterio Santos *et al.*, 2001). With the availability of new equipment further applications for cavity delineation and studies involving groundwater quality problems in sedimentary formations were carried out, (palacky *et al.*, 1981; Dirka *et al.*, 1983; Baker and Abdul-Razzak, 1985, Baker and Zaynal, 1987; Stewart 1990, Monteiro Santos *et al.*, 2006; and Ahmed and Carpenter, 2003).

However, and in order to achieve the main purpose of this study, two different EM techniques were used namely, the EM conductivity and VLF-Radiohm EM resistivity measurements. These EM methods have several advantages over some other geophysical ones which are used in this type of work. Among them are its portability, low cost, ease of operation, rapid data acquisition and it gives direct reading in mappable units.

PRINCIPLES OF THE EM METHODS AND INSTRUMENTS

The electromagnetic method is based on the existence of different electric properties of the objects under investigation and the surrounding rocks. The electric inhomogeneities cause disturbances within the distribution of the electromagnetic field. When a conducting body lies between the transmitter and the receiver; an area of increase in the attenuation of the electromagnetic field is observed, i.e. the methods are based on the measurements of magnetic field associated with alternating currents induced in subsurface conductors by primary magnetic field (Jardani *et al.*, 2007).

Detail descriptions of the electromagnetic method can be found in many text books and studies such as Keller and Frischknecht (1977), Spies and Frischknecht (1987), McNeill (1980) and Monteiro Santos *et al.* (2002).

However, the operation of instruments used in this study can give some brief idea about electromagnetic prospecting which only differ from one to another in minor details, basically fall in to two types: the first one is the moving source-receiver method

and the second is the fixed-source method. The first type is called Geonics EM34-3. Such instrument consists of two coils: the first one is the transmitter, which is energized with an alternating current at a specific frequency, the second one located at a short distance away from the transmitter is the receiver. The variable magnetic field created by the transmitter (the primary field) induces electrical currents in the subsurface. These currents generate a secondary magnetic field which is detected together with the primary field by the receiver coil. The instrument can be operated at transmitter-receiver spacings of (10, 20 and 40 m) with fixed frequency for each of the three coil separations (6400, 1600 and 400 HZ, respectively). The depth investigation depends on the frequency of the energizing field, on the electrical structure of the earth and further on the inter coil spacing and coil configuration (vertical dipole or horizontal dipole mode). In the vertical dipole mode (VDM) the transmitter and receiver coils are located horizontally while in the horizontal dipole mode (HDM) they are placed vertically on the ground surface. These modes have different effective penetration depth which is approximately 0.75 and 1.5 times the inter coil spacing for the horizontal and vertical dipole respectively (McNeill, 1980). The uses of different inter coil spacing and operating modes allow us to construct an image of the subsurface electrical conductivity distribution. In the second electromagnetic method which is called fixed-source method, the instrument used during the field work is the Geonics EMI6R in which it was described by Collett and Beker (1968). It uses very low frequency (VLF) radio waves 10 – 30 KHZ transmitted from distant stations as the primary magnetic field. This instrument is mainly a radio receiver measuring apparent resistivity and the phase angle between the horizontal electric and magnetic field. When the instrument is well oriented with respect to the direction of the VLF transmission station and by the rising magneto-telluric relation given by Cagniard (1953), the apparent resistivity of the earth can be determined from the ratio between the horizontal electric field in the direction of propagation and the horizontal magnetic field perpendicular to that direction. The phase angle between electric and magnetic fields provides information on the conductivity structure of the sampled zone.

A uniformly conductive earth produces a phase angle of 45° . If high conductivity materials overlie low conductivities, the phase angle will be less than 45° . On the other hand if low conductivity overlies high conductivity materials the phase angle will exceed 45° .

GEOLOGY OF THE STUDY AREA

The geology of the area is characterized by the carbonate rocks of the Euphrates Formation (Early Miocene) and underlined by carbonate rocks of Anah Formation (Late Oligocene) according to the borehole drilled in the investigated area (Fig. 1), (Haditha dam project, 1978). In general the carbonate rocks in the area are made up of interceded layers of limestone and dolomites, exhibit a considerable lithological heterogeneity in both direction. The rocks contain lenses and breccia, conglomerate-breccia, marl and clays. The limestone in this area is fissured, cavernous and karestied.

Mahdi *et al.* (1985) mentioned that the exposed geological unit in the study area is Ezqhaden, represents the upper member of Euphrates Formation (Fig. 2). The facies belongs to this unit is called Ezqhaden facies, consists of intercalation of green marl, marly dolostone and white dolostone.

Age	Formation	Lithology	Description	Depth (m.)	Thickness (m.)	Elevation of depth above S.L (m.)
Early Miocene	Euphrates Fn.		Chalky Lst.		20	128
			Fine grained, dolomitic, marly, chalky fractured and cavernous Lst.	20	15	113
			massive Lst.	35	5	108
Late Oligocene	Anah Fn.		Very hard, splintary, massive and cavernous Lst.	40	20	88
				60		

Fig. 1: Stratigraphic columnar section in bore hole (224). (after Haditha Dam project, 1978) V. Scale 1 cm = 4 m

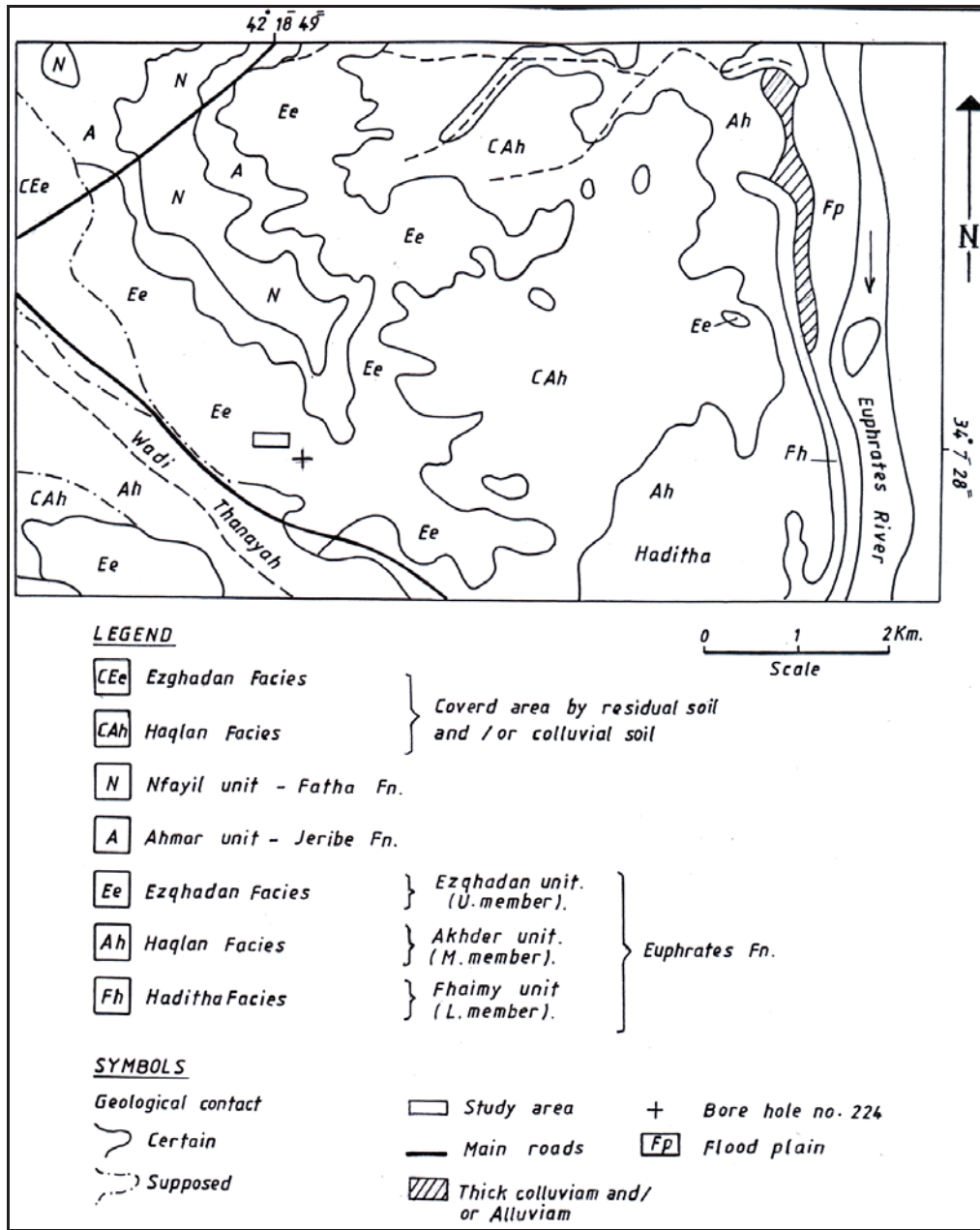


Fig. 2: Geological map of the study area surroundings. (after Mahdi *et al.*, 1985)

LOCATION AND FIELD WORK PROCEDURE

The study area lies at 5 km NW of Haditha city at latitude 34° 7' 28" and longitude 42° 18' 49" (Fig. 3).

The electromagnetic survey represented by EM conductivity and VLF-Radiom EM resistivity measurements has been carried out along eleven traverses in (NW – SE) direction, each one is of 260 m length with sampling interval of 10 m. The distance between traverses is chosen to be 10 m. Therefore, the studied area has dimension of 260 × 100 m.

The first EM technique uses the EM34-3 instrument in which it positioned in vertical dipole mode (VDM) with coil separation of (20 m), while in the second EM technique is represented by EM16R instrument with transmitting station of British Rugby (GBR), frequency (16 KHZ), is chosen to be carried out in the field. This station among other optional station was found to be appropriate for the survey.

Conductivity (mmhos/m) is the main measurement given by EM34-3 technique used while the resistivity (ohm.m) and the phase angle (degree) measurement were given by EM16R technique.

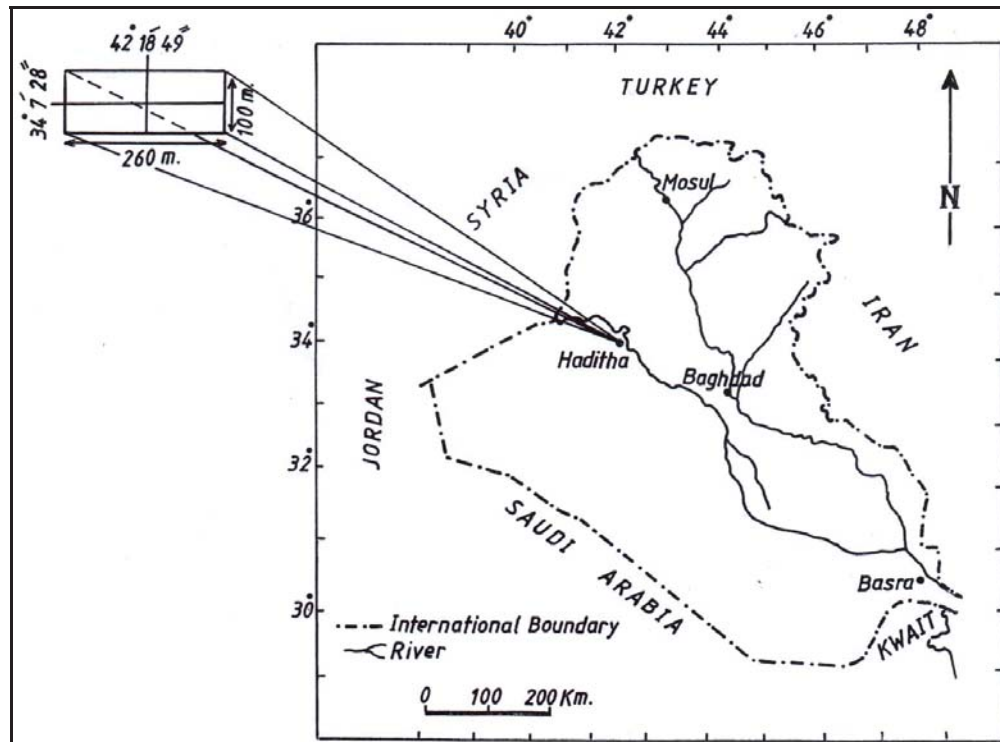


Fig. 3: Location map of the study area

RESULTS, DISCUSSION AND CONCLUSIONS

The results obtained during the EM survey are presented as profiles (Fig. 4 and 5) and contour maps (Fig. 6, 7 and 8). The radiohm resistivity profiles clearly show a single high resistivity zone which related to each other in somewhat we call the same place with slight shift in their locations. Figure 4 correspondingly this feature agrees well with that result obtained by EM34-3 conductivity measurements in their location with reversible physical property i.e. low conductive zone. On the other hand, Figures (5 and 6) show a contour map of apparent resistivity obtained on the grid lines. This resistivity map clearly shows a single high resistivity zone delineating (NE – SW) with some deviation towards southeast direction. The maximum resistivity values of this anomalous zone reached 290 ohm.m. The conductivity measurement map also reflects the same contour behavior with low conductivity values (Fig. 7) that coincide in position with the resistivity high. Figure (8) shows clearly the trend of the phase angle contour line which is well coincide with the both former maps in their location and delineation. This phenomenon indicates that the subsurface feature is represented by channel filled with air reflected by their phase angle values as less than 45° which confirmed the result above. The single anomalous zone suggests the possible existing buried channels filled with air as a result of dissolving process in which the behavior of the contour lines in both methods may indicate the continuity of the dissolving process.

The depth to this channel was calculated using the standard curves of Geonics (1979) and it is found to be at the range of (17 – 23) m.

The given result was confirmed by the preliminary geologic information which available from the near borehole drilled at a distance of about 85 m away from the survey area where the trend of the anomalous zone was in the same direction of the borehole.

Now, it is concluded that in applying these two techniques together, an efficient and valid results can be obtained and confirmed with the geological information available in the area under investigation. Finally, the rapidity with such result may be obtained, gives these two methods particular attraction over other geophysical techniques (conventional electrical resistivity techniques and seismic method).

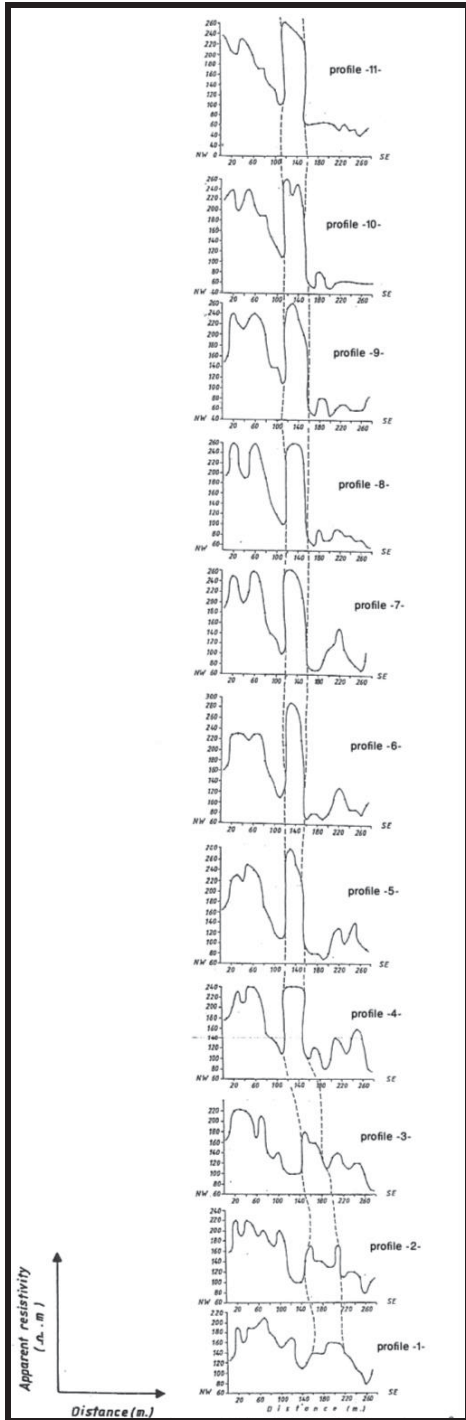


Fig. 4: Observed EM radiohm resistivity values (ρ_a) along profiles (1 to 11) respectively

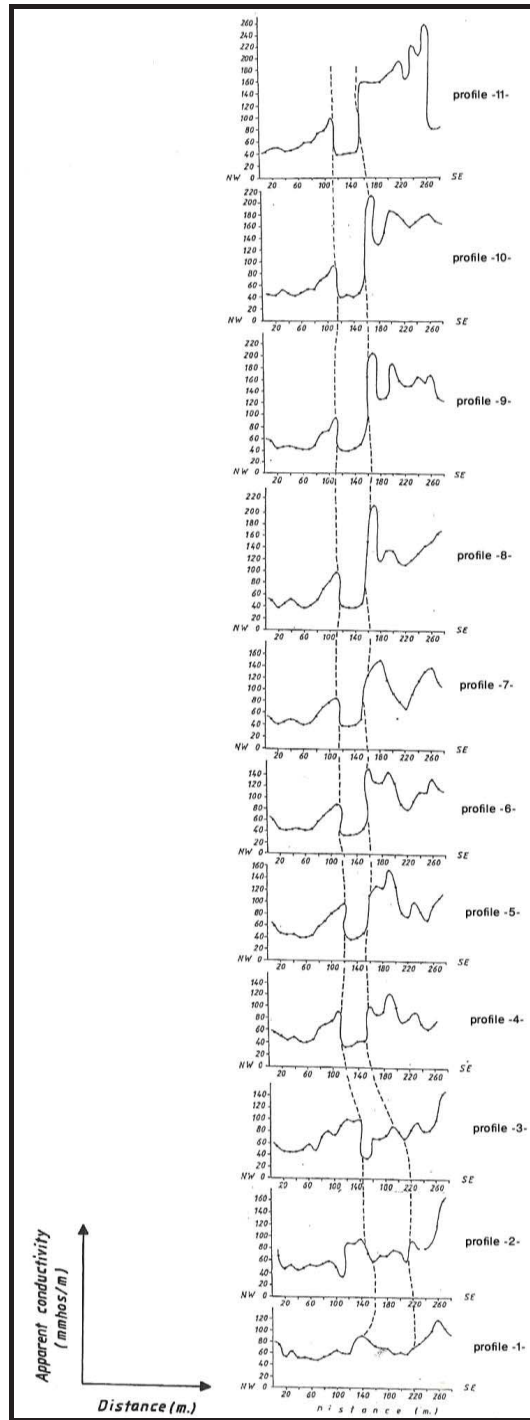


Fig. 5: Observed EM conductivity values (σ_a) for coil separation (20 m) along profiles (1 to 11) respectively

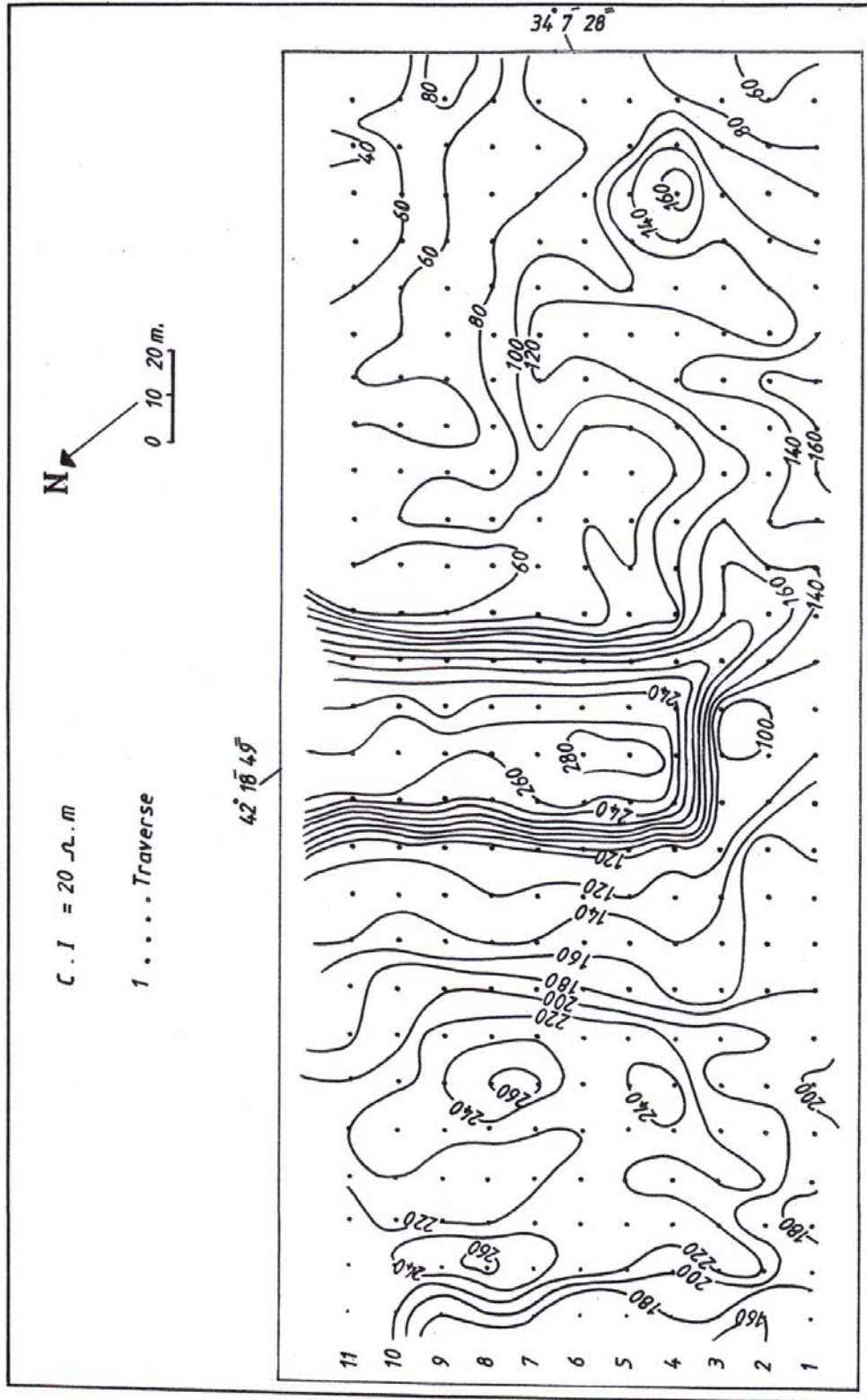


Fig. 6: Observed VLF-radiohm EM resistivity contour map of the study area

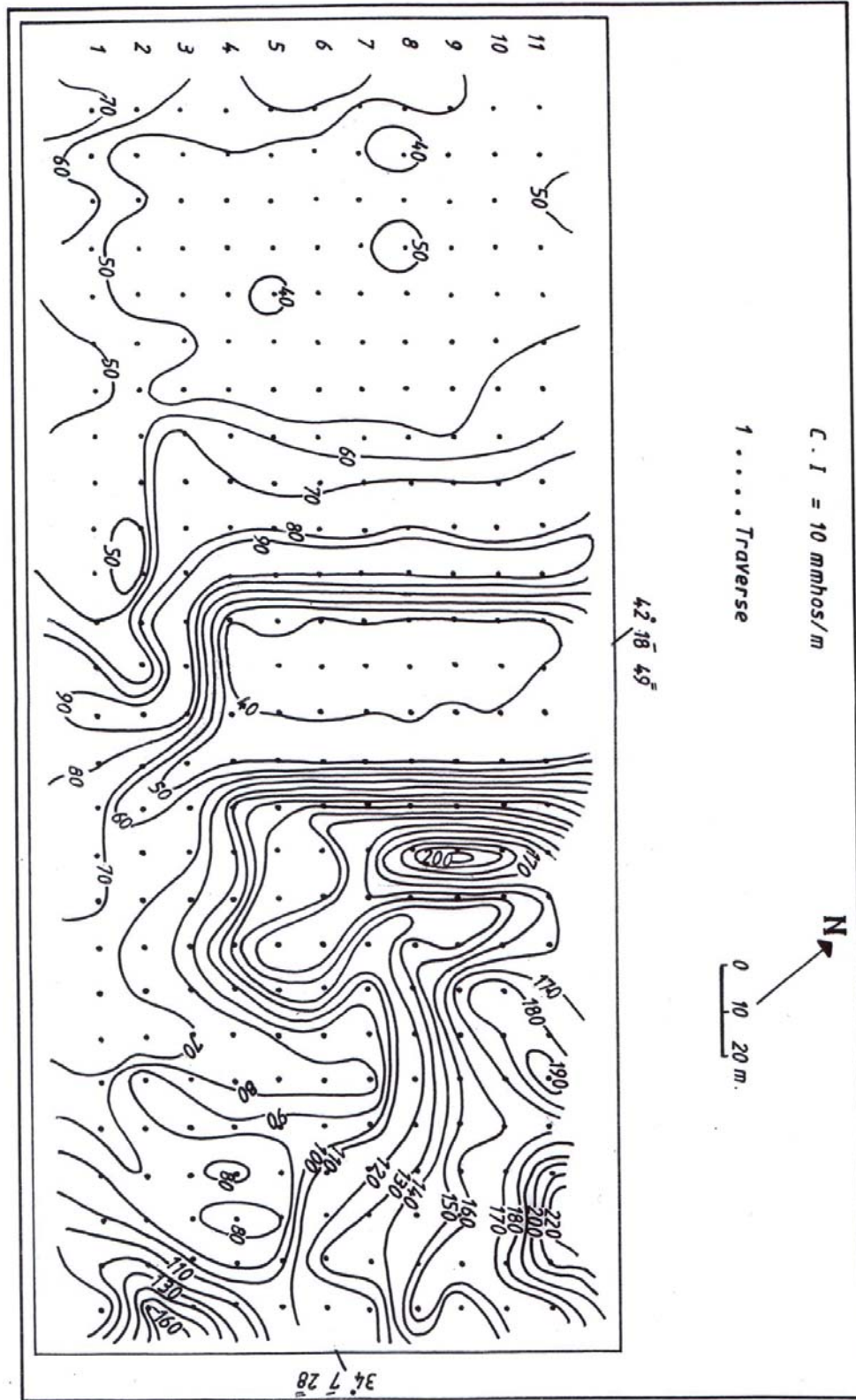


Fig. 7: Observed EM apparent conductivity contour map of the study area (coil separation 20 m)

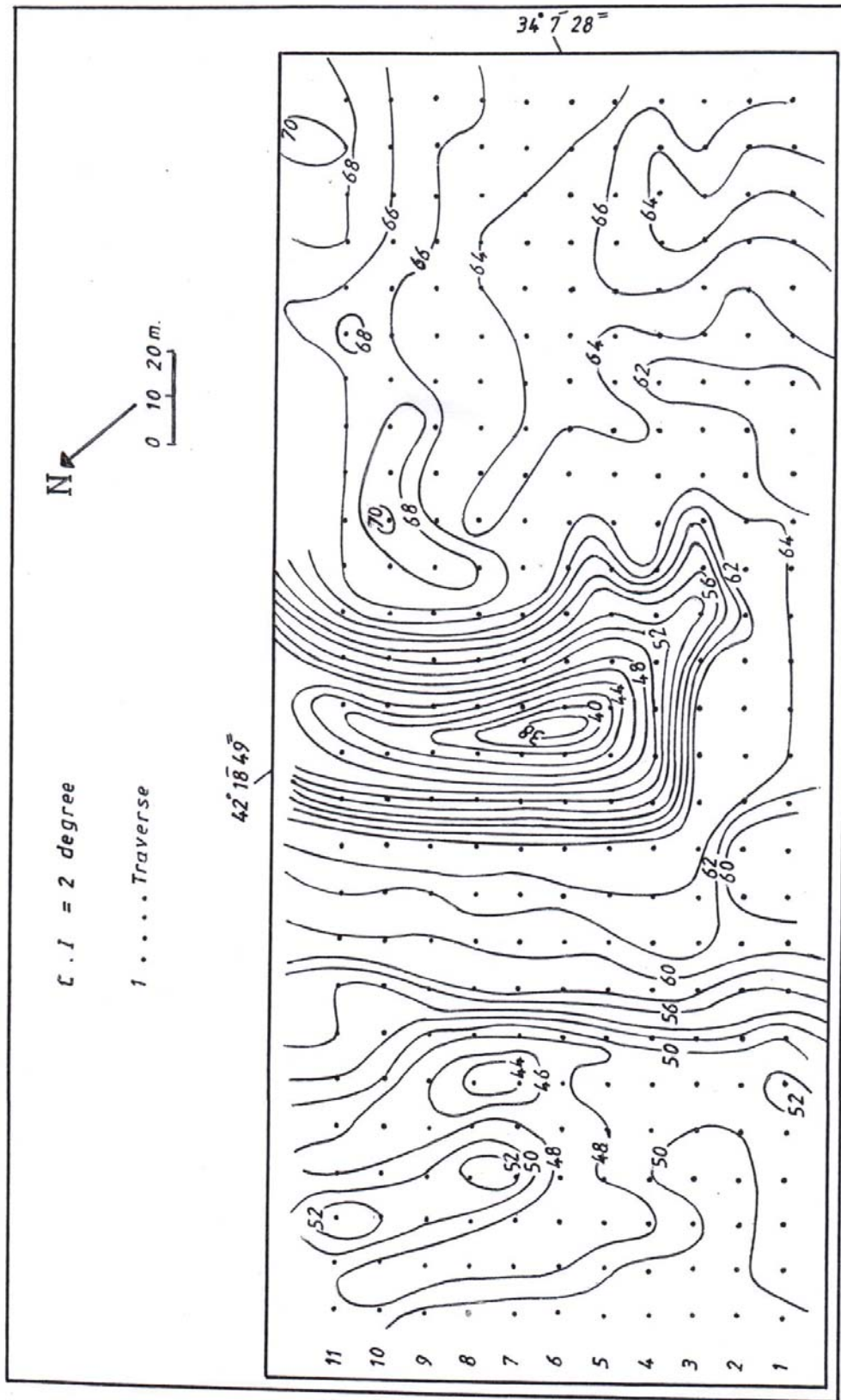


Fig. 8: VLF-radiohm phase angle contour map of the study area

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