Integrated Geophysical tools for Hydrocarbon exploration in Nile delta area, Egypt

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SUMMARY

The Nile Delta Basin offshore Egypt has long been known as a significant source of gas and oil. The study area is located on the Middle Eastern part of the Nile Delta near to Mansoura city. Electromagnetic methods have emerged as promising tools for oil exploration than any other geophysical technique. Hydrocarbon reservoirs typically exhibit higher electromagnetic resistivity than their surroundings. In this study both time-domains electromagnetic (TEM) and Magnetotullurics technologies (MT) have been used to measure subsurface resistivity related to hydrocarbon exploration and integrated with seismic data that performed in the same area. A good coherence was found between the electromagnetic and seismic profiles and show that the Hydrocarbon is exiting in the Abu-Madi and Qawasim channel which represent the main gas containing layers in the Nile delta. The depth and extension of these layers were estimated and imaged and the maximum thickness was 4000 m at profile 1 in the northwestern part of the study area.

Keywords: Hydrocarbon exploration, TEM, MT, Nile Delta, Egypt

INTRODUCTION

The Nile Delta is considered as the most important gas producing province in Egypt. It is an emerging giant gas producing province with proven reserves of approximately 42 Trillion Cubic Feet (TCF). The area of study is located in the Middle Eastern part of the Nile Delta of Egypt around Mansoura city, It lies between latitudes 30^0 57' 30" & 31^0 10' 00" N and longitudes 31^0 20' 00" & 31^0 36' 00"E with an area of 566480km$^{2.}$ As shown in Figure 1.

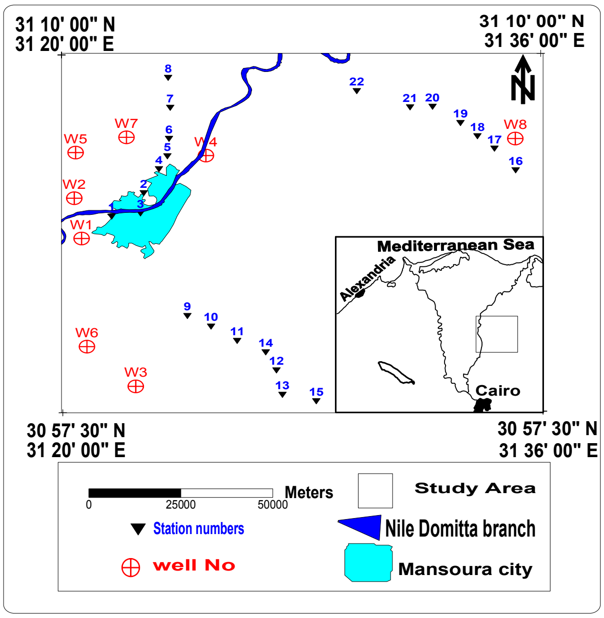

Figure 1. Location map of the study area showing the distribution of the drilled boreholes

Detecting and assessing hydrocarbon reservoirs without need to drill test wells is of the major importance to the petroleum industry. In the present work, both Electromagnetic techniques Time-domains electromagnetic (TEM) and Magnetotullurics (MT) technologies have been used to measure subsurface resistivity related to hydrocarbon exploration and integrated with seismic data that performed in the same area. The aim of my study is using the Electromagnetic method to delineate the subsurface stratigraphy and structural features of the area distinguished according to resistivity values of the geological units of the study area. Recently the Electromagnetic methods have a wide range of deep investigation especially in hydrocarbon to treat the defect of traditionally seismic methods that have problems in salt domes and fractured rocks added its high expenses in application.

Electromagnetic method considers the most commonly geoelectrical method which is used in the prospection of good electrical conductors. Hydrocarbon reservoirs typically exhibit higher electrical resistivity than their surroundings. A good coherence was found between the electromagnetic and seismic profiles and show that the Hydrocarbon exits in the Abu-Madi and Qawasim channel which represent the main gas containing layers in the Nile delta. Thus

TEM AND MT DATA ACQUISITION

In this study, 154 TEM sounding at 22 stations (fig.1) were measured using a SIROTEM MK-3 time-domain system of simple coincident loop configuration, in which the same loop transmits and receives signals, was employed (Fitterman and Stewart, 1986). The loop side length was 25 m in all sites, the measurements were repeated four or five times. The best signal-to-noise data sets were chosen for further processing and interpretation.

Twenty -two of MT stations were measured in the study area as shown in fig (1) divide in to three profiles throw the studied area, above the two major seismic lines, using Stratagem EH4 Hybrid-Source Magnetotullurics. Fig (2) illustrates the author during data acquisition in the study area.

Figure 2. The stratagem and the site.

The Stratagem represents a unique MT system that records both natural and manmade electromagnetic signals to obtain a continuous electric sounding of the earth beneath the measurement site. First, we recorded low frequency natural MT waves using AMT only, and we then repeated the measurement using an artificial signal source for CSAMT. Electrode stakes were used to measure electric fields, and highly sensitive magnetic coils were used to measure magnetic fields. Before going to process MT data, some of the noisiest sites were excluded from the database.

TEM DATA PROCESSING AND MODELING

There are many ways, in which TEM data can be processed and these are largely dependent upon which instrument is used to acquire the original data. Most of the TEM systems record the transient voltage at a number of discrete intervals during the voltage decay, after the applied current is switched-off. In each time, the current is applied and then stopped, measurements are taken; when the current is applied again and switched-off, and a repeat set of measurements is taken. This process may be repeated many tens of times at a given location, where all the data are being logged automatically. Consequently, these many data can be processed to improve the signal-to-noise ratio. At the same time, the field data are checked for repeatability. Commonly, the data are normalized with respect to the transmitter current or other system parameters, and the effects of the time decay may be amplified in compensation by normalizing the observed field at each point with the respective primary field value at the same point (Soliman, 2005; Shaban, 2009; Metwaly et al., 2010, and Masoud et al, 2010)

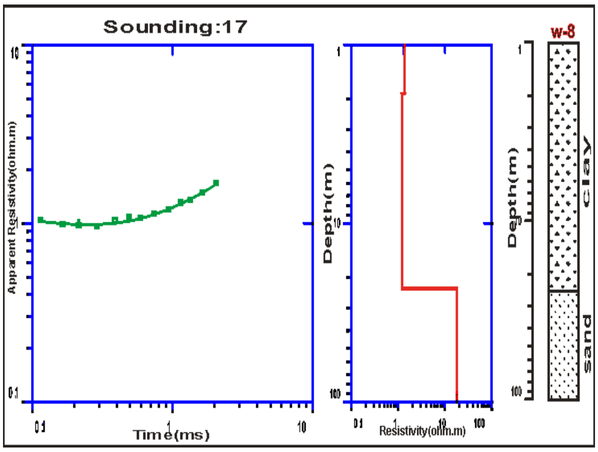

Figure 3. Calibration of the TEM station17 with the liithology of well 8

TEMIX XL (2000) and 1X1D (2007) programs were used in the processing.
The obtained 1-D models were used as initial models for 1-D inversion of the TEM data, according to the well information in the study area, as the station is taken beside the well to compare the model of the TEM station to the lithology of the well (El Hadad, 2002 and Mansoura Petroleum Company) as shown fig (3). Finally, a trial and error modeling was applied to the comparable data sets to give a single model.

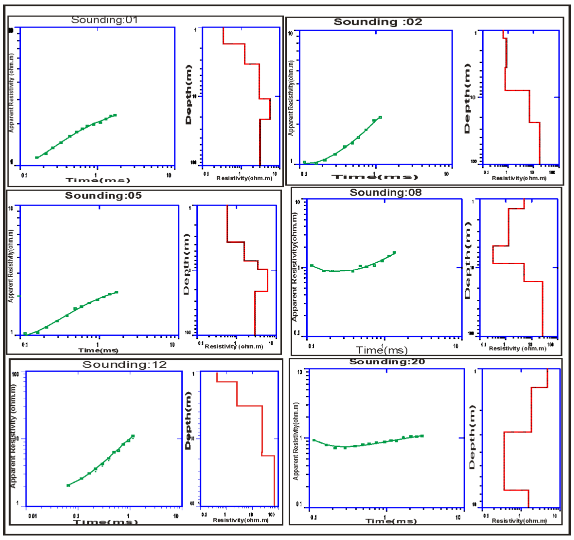

Figure 4. Examples of interpreted models for TEM curves measured in this study

MT DATA PROCESSING AND MODELING

Data processing and interpretation were conducted on the MT data by using WinGLink software

(GEOSYSTEM SRI). As a result some of the noisiest sites were excluded from the dataset. The MT data consists of two kinds of modes; high frequency (0.01-100 kHz) and low frequency (0.01 – 10 Hz). At the beginning of data processing, MT data at different frequencies for the same MT site were merged. Then these combined data were used to estimate the elements of the MT impedance tensor which finally used for determining the apparent resistivities and phases for both transverse electric (TE) and Transverse magnetic (TM) modes.
Figure 5 shows the apparent resistivity curves as well as their corresponding phase curves for station No 10. Almost at all frequencies, the apparent resistivity are congruent for the XY- and YX- components with a small offset which indicating a small static shift.

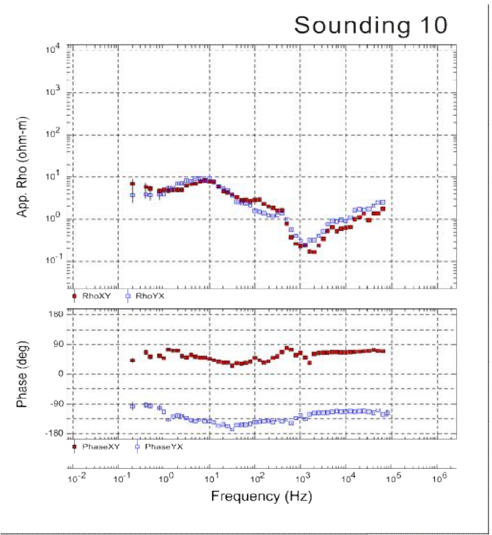

Figure 5. The apparent resistivity and phase recorded at site no. 10 for both TE and TM modes.

The apparent resistivities at all MT sites increase in low frequencies that reflect increasing resistivity with depth. The oscillations in the apparent resistivity and phase above 0.1 Hz are due to the existence of layered resistivity structure in the upper strata. The MT phase is also exhibits these changes. The scattering of the phase of MT data with frequencies can be due to the structure that is not truly 2-D as mentioned before.
In profile 1, the sounding can be classified into two groups on the basis of similarity of apparent resistivity curves. The first group includes soundings 1, 4, 8 and 9 which show small variation of resistivity at all frequencies. These sites indicate the homogeneity of the subsurface rock strata. Only at site 4 the resistivity curve locate in a very low conductivity ranges that reflect the existence of a very high resistive body below this site. The other group includes soundings 2, 3, 5, 6, 7 which show a wide range of resistivity values. In these sites the resistivity increases with frequency decrease and reached to the maximum at site 7. In profile 2, all soundings curves have same conductivity structure where the resistivity decreases at higher frequencies and then below 1000 Hertz the resistivity increase. Highest resistivities were detected at sites 12, 13, 15, 16 which reflect high resistive layers below them.

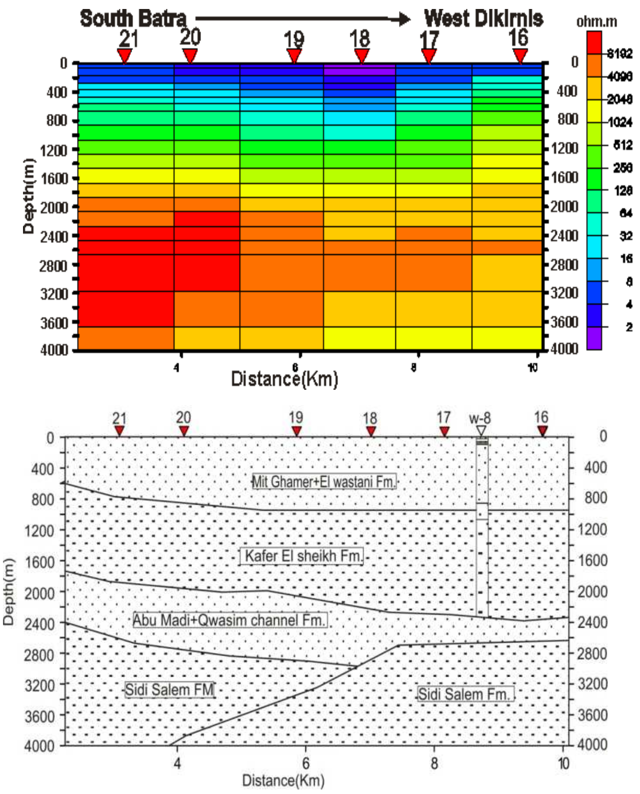

Figure 6. 2D inversion resistivity model along profile extended from South Battra to West Dikirnis and its geological cross section

A good coherence was found between the electromagnetic and seismic profiles and show that the Hydrocarbon is exiting in the Abu-Madi and Qawasim channel which represent the main gas containing layers in the Nile delta. The depth and extension of these layers were estimated and imaged and the maximum thickness was 4000 m at profile 1 in the northwestern part of the study area.

CONCLUSION

the Electromagnetic methods both TEM and MT is consider as one of the best techniques that used for hydrocarbon exploration that is due to the Cheap and easy to use compared to the traditionally seismic methods and to detected the salted and fractured rocks that can't be distinguished by the seismic methods, So the using of Electromagnetic methods is importance in hydrocarbon industry all over the world. Also the depth and extension of the layers containing hydrocarbons were estimated and imaged and the maximum thickness was 4000 m at profile from Mansoura to South Battra in the northwestern part of the study area.

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REFERENCES

EL Haddad, M.I., 2002, Hydrogeological studies and their environmental impact on future management and sustainable development of the new communities and their surroundings, east of The Nile Delta, Egypt .Ph. D. Thesis, Faculty of Science, Mansoura University, Egypt. 435p.

Fitterman, D.V., and Stewart, M.T., 1986, Transient electromagnetic sounding for groundwater, Geophysics **51**, 995-1005.

Metwaly, M, El-Qady, G, Massoud, U, El-Kenawy, A and Matsushimi, J., 2010, Integrated geoelectrical survey for ground water and shallow subsurface evaluation: Case study at Siliyin spring, El-Fayoum, Egypt. Int J Earth Sci**. 99**, 1427-1436.

Shaaban H.,M, 2009, Applications of the Geophysical Survey for Environmental and Archeological Purposes, Central Western Part of the Nile Delta, EGYPT. Ms. Thesis, Faculty of Science, Mansoura University, Egypt,153p.

Soliman, M. M., 2005, Environmental and geophysical assessment of the ground and subsurface water resources of Ras El-Hekma area, northwestern coast of Egypt. Ph. D. Thesis, Faculty of Science, Ain Shams University, Cairo, Egypt, 148p.

Massoud, U, Santos, F, El Qady, G, Atya, M and Soliman, M., 2010, Identification of the shallow subsurface succession and investigation of the seawater invasion to the Quaternary aquifer at the northern part of El Qaa plain, Southern Sinai, Egypt by transient electromagnetic data Geophysical Prospecting **58**, 267–277.