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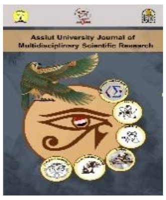

Detection of Depth and Location of Subsurface Utilities Using Smart Phone Magnetic Application: A Case Study at Assiut University, Egypt

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ABSTRACT

The present study presents the application of mobile’s magnetic sensor (Physics toolbox magnetometer) on the study area located at the Faculty of Science, Assiut University. The main objective is to investigate the efficiency and capability of the smart phone application to map the depth and location of the near surface magnetic features (e.g., utilities) at the study site. The magnetic data was collected along 27 profiles with line spacing 0.5m and station interval 0.5m and the collected data were processed using the Geosoft Oasis Montaj software. The total magnetic intensity (TMI) map was produced, then the local magnetic sources were separated using Butterworth high pass and first vertical derivative filters. Depth to shallow magnetic features (e.g., pipelines) was estimated using the radial average power spectrum technique (RAPS), source power imaging (SPI) technique and the 3D Euler deconvolution (E3D) method. The high pass and first vertical derivative maps showed high magnetic anomalies with linear shape that may represent the location of the subsurface pipelines. The RAPS technique revealed that the average depth to shallow and deep magnetic sources is 0.10 m and 0.50 m, respectively, while the SPI and E3D techniques showed that the utilities depths ranged from 0.11 m to 0.38 m. The results using the smart phone application were capable to map with a greater extent the subsurface geometry and depths of the pipelines. Mapping the studied area with a scientific magnetometer is recommended in order to compare and calibrate the smart phone application results to get better validity.

1- INTRODUCTION

One of the well-known efficient geophysical techniques is the magnetic method that have extensive applications and capable of providing very valuable information below the surface [1]. Magnetic method can be used in geological, hydrogeological mapping and hydrocarbon exploration [2], [3]. This method is based on magnetic susceptibility, as it varies with different types of pyrotechnic, metamorphic, or sedimentary rocks. Magnetic properties of sedimentary rocks are known in general to be less than the pyrotechnic and metamorphic properties [4]. Magnetic method is fast, noninvasive and can be used to map near surface magnetic features. On the other hand, the method can only be used to map ferrous materials and the image resolution deteriorates quickly with target depth.

A magnetometer is required to provide both the strength and the orientation of the earth's magnetic field. Magnetometer surveys measure small, localized variations in the Earth's magnetic field and their accuracy reaches 0.002%. The conventional instruments used for commercial applications are based upon applying proton rich fluids surrounded by an electric coil. These instruments include the gradiometer, fluxgate, proton precession and cesium vapor magnetometer systems. The available magnetometers on market nowadays vary in prices according to the accuracy and resolution of the measured magnetic data and sometimes it is difficult to purchase these instrumentations.

More recently, we have been able to find the necessary applications on smart phones to do that operation instead of scientific devices such as the global positioning system (GPS) application that is available on smart phones. The question is whether these applications could be able to make the necessary measurements with the required accuracy and resolution similar or close to scientific magnetometers. With evolution of technology, smart phones became well equipped with various innovative accessories such as GPS antenna, gravity, light detection, or magnetic sensors [5]. Although the competition between manufacturers is voracious regarding the upgrading of mobile sensors, still the efficiency of such sensors in geophysical investigation is unclear [6]. This is most likely due to the geophysical objects' complexity where the information about the physical property is encoded in the data in a complicated way.

In this work, we investigated the efficiency, accuracy and capability of a smart phone sensor, specifically magnetic sensor for geophysical exploration of near surface magnetic features (e.g., pipelines). Accordingly, we decided to go through the experiment, and we were able to easily get one of the free applications and utilized it on studying a site where there are some surface and subsurface magnetic resources.

2- MATERIALS AND METHODS

Geomagnetic investigation was performed using Physics Toolbox Magnetometer mobile application Version 1.9.4.8, app store on mobile iPhone 7 plus. Physics Toolbox Magnetometer is a smart phone application that shows the value of all the mobile sensors (magnetic sensor, proximity sensor, GPS sensor, etc.).

The explored area is located at Assiut University, Faculty of Science (Fig.1). This area is 13 meters long and 7 meters wide and is characterized by high magnetic objects such as light pillars, power cables, sewage stations and pipelines (Fig.2).

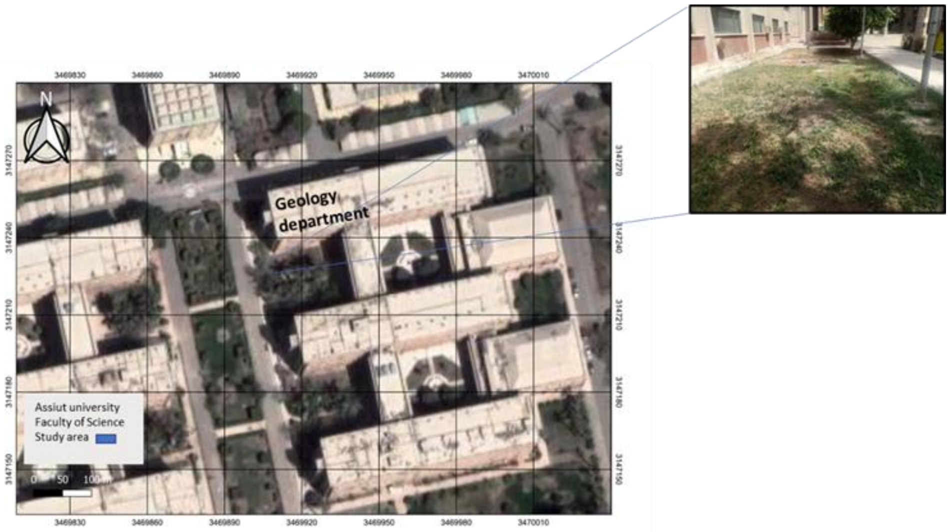

Figure 1: Location map of the study area at the backyard of Geology Department, Faculty of Science, Assiut University.

Figure 2: Surface magnetic features at the study area

We surveyed the area with 27 profiles and a total of 405 stations. The station interval was 0.5 meter and line spacing was 0.5 meter (Fig 3). The magnetic readings and time were collected and recorded manually in a notebook using the mobile phone application and then the data entered into an Excel sheet (Fig. 4). We used the Geosoft Oasis Montaj software [7] to analyze and process the data. The total magnetic intensity (TMI) map was produced; then local magnetic sources were separated using Butterworth high pass and first vertical derivative filters. Depth to near surface magnetic features (e.g., pipelines) was estimated using the radial average power spectrum (RAPS), source power imaging technique (SPI) and the Euler 3D deconvolution (E3D) methods. Brief description of the data processing and analysis are given as follows.

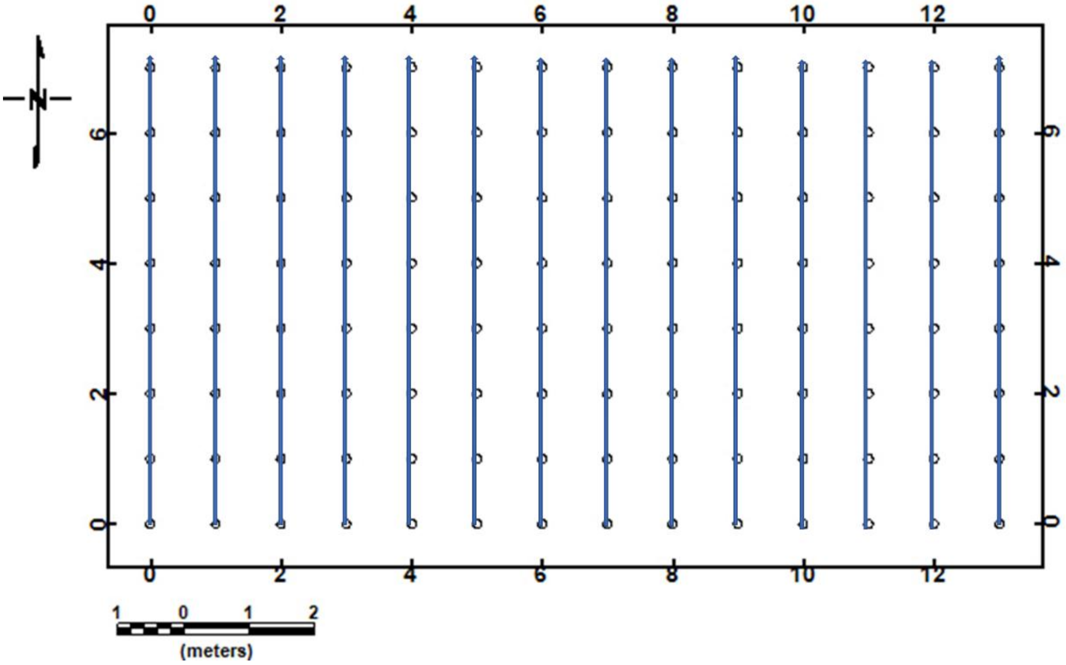

Figure 3: Layout of the magnetic survey using 0.5m line spacing and 0.5m station interval.


x = -5.86 y = -8.44 z = -79.5

Total Magnetic Field = 80.17 µT

Figure 4: Magnetic data acquisition using mobile application

2.1. Butterworth filtering techniques (high pass):

The Butterworth filter is excellent for applying straight forward high-pass and low-pass filters to data because we can easily control the degree of filter roll-off while leaving the central wavenumber fixed. If ringing is observed, the degree can be reduced until acceptable Here we applied the Butterworth high pass filter to separate the shallow magnetic anomalies which is characterized by short wavelength and high frequency. The Butterworth filter tool is applied in the frequency domain using different parameters through the Geosoft Oasis Montaj software [7]. The total magnetic data are filtered using the Butterworth filter through the method parameters, degree of filter function is 1 (default), and a wavelength of 1m.

2.2. The first vertical derivative filter (FVD):

The first derivative calculation is an important geophysical data processing technique. Derivatives tend to sharpen the edges of anomalies and enhance shallow features. The vertical derivative map is much more responsive to local influences than to broad or regional effects and therefore tends to give sharper picture than the map of the total field. In fact, the first vertical derivative is used to delineate high frequency features more clearly where they are shadowed by large amplitude, low frequency anomalies.

2.3. Radial averaged power spectrum (RAPS):

This technique was applied to the gridded magnetic data using Geosoft Oasis Montaj [7]. The 2-D radially averaged power spectrum plot of the TMI map represents the deep-seated distribution of sources was manifested by low wave numbers less than a certain cycle/km. While the contribution of shallow sources retains wave number more than a certain cycle/km. The depth of each source ensemble responsible for each segment is calculated by introducing the slope of this segment in the formula [8]:

$$h\ (\text{depth}) = -\text{slope}/4\pi$$

2.4. The source parameter imaging (SPI):

The source parameter imaging technique is a quick and easy way to calculate the depth of source bodies. Its accuracy is +/- 20% in tests on real data sets with drill hole control. Its accuracy is similar to the Euler deconvolution method. However, the image parameters image produces a full range of points of solution clear and easy to use. [9] indicated that the goal of the source parameter image method is that the image result can be interpreted easily by someone who is not familiar with magnetic interpretation. The advantages of the SPI method over Euler deconvolution or spectral depths are that in the absence of a Data window moving, and the calculation time is relatively short. On the other hand, noise errors can be reduced by carefully sorting the data before calculating the depth.

2.5. Euler 3D deconvolution techniques (E3D):

Euler Deconvolution ([10] and [11]) is a widely used tool for determining source location of potential field's anomalies. In order to deliver automatic estimates of source location and depth, it uses a structural index (SI) to characterize groups of source types. Typical values of structural indices are shown in table (1).

Table (1): Euler magnetic structural indices

Source type	SI value
Sphere or compact body at a distance	3
Line source (pipeline, narrow kimberlitic pipe, etc.,)	2
Thin sheet edge (sill, dike, etc.,)	1

Contact of considerable depth extent	0

The structural index can be interpreted as exponent in a power law expressing the falloff of the field strength versus distance from the source. For magnetic data, physically reasonable SI values range from (0) to (3). Values less than zero imply a field strength that increases with distance from the source (and it infinite at infinity), values greater than 3 imply quadruple or higher order multiple sources.

3- RESULTS and DISCUSSION

The total magnetic intensity (TMI) map shows magnetic anomalies with magnitude values range from 33.0 microT to 41.3 microT (Fig. 5). The southern and the middle spot part of the study area is characterized by high magnetic anomalies greater than 41.3 microT which may be due to the high magnetic features located at this part such as light pillars, sewage stations (Fig. 5). However, the northern part is characterized by low magnetic anomalies lower than 33.0 microT which may be due to the low magnetic features located at this part such as underground soil (Fig. 5).

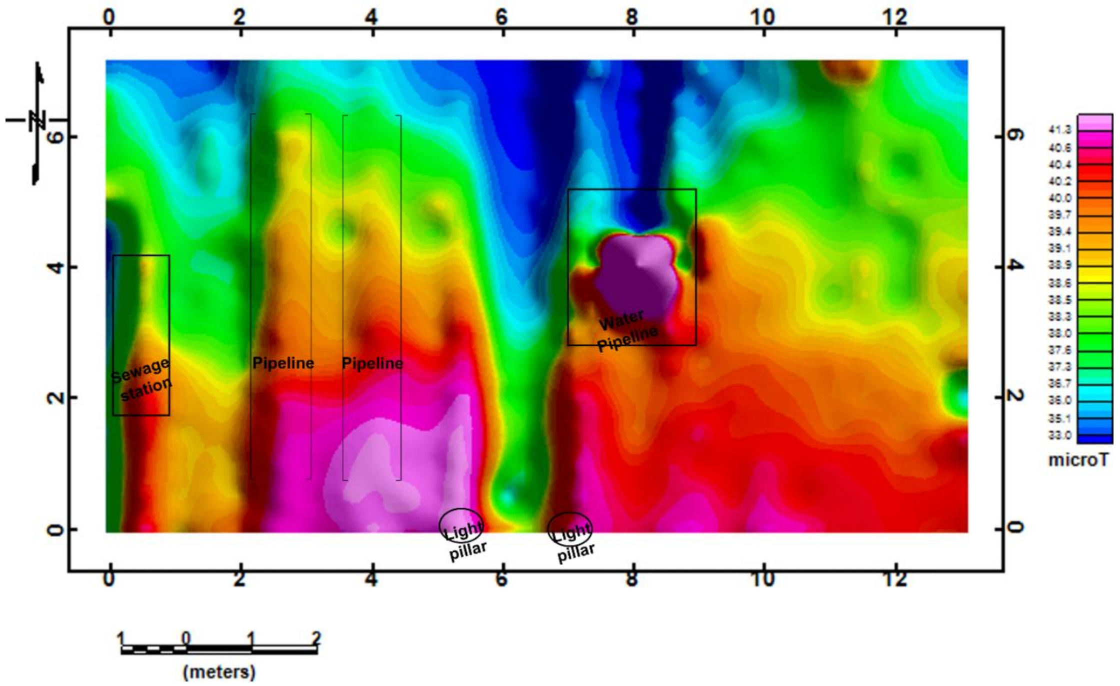

Figure 5: Total magnetic field intensity (TMI) map of the study area with surface magnetic features.

The inspection of the obtained Butterworth high pass map shows positive and negative magnetic values that takes elongated shape with short wavelength and high frequency (Fig. 6). The positive magnetic anomalies (0.01 to 0.30 microT) are characterized by high magnetic susceptibilities and may represent the shallow buried magnetic features at the study area such as the pipelines (Fig. 6). On the other hand, the negative magnetic anomalies (-0.00 to -0.63 microT) are characterized by low magnetic susceptibilities and may represent the shallow buried magnetic features at the study area such as underground soil (Fig. 6).

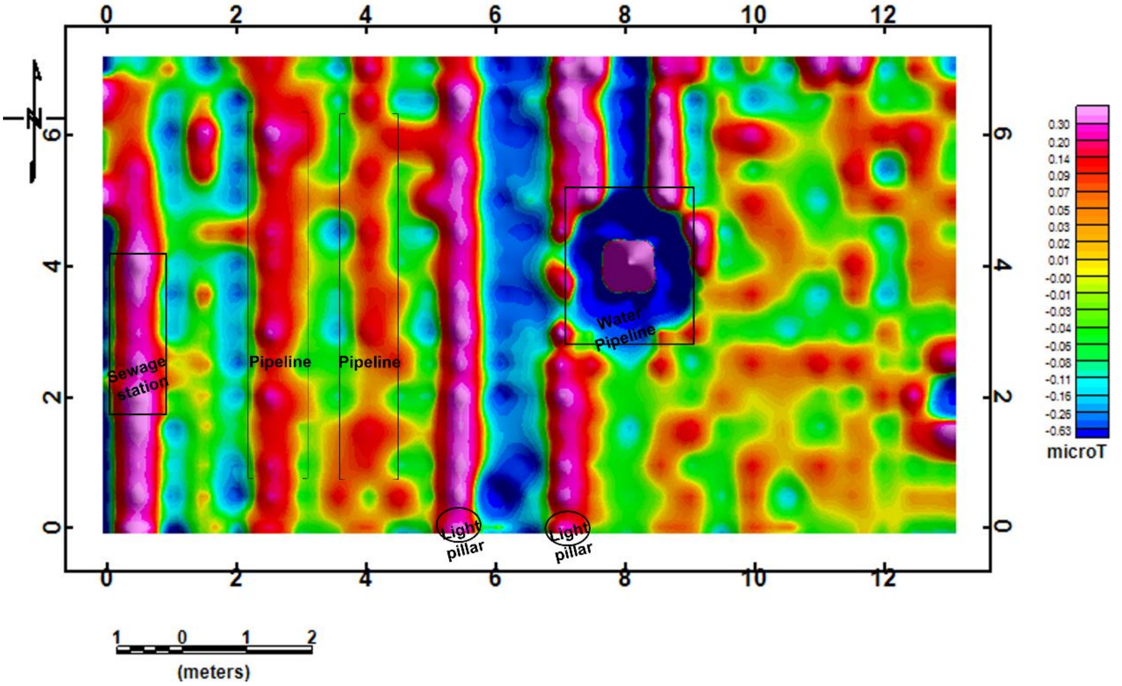

Figure 6: Butterworth high pass filtered map of the study area with interpretation.

The first vertical derivative map is similar to Butterworth high pass map showing positive and negative magnetic values that takes elongated shape with short wavelength and high frequency (Fig. 7). The positive magnetic anomalies (0.2 to 4.0 microT/m) are characterized by high magnetic susceptibilities and may represent the shallow buried magnetic features at the study area such as the pipelines (Fig. 7). On the other hand, the negative magnetic anomalies (-0.0 to -8.7 microT/m) are characterized by low magnetic susceptibilities and may represent the shallow buried magnetic features at the study area such as underground soil (Fig. 7).

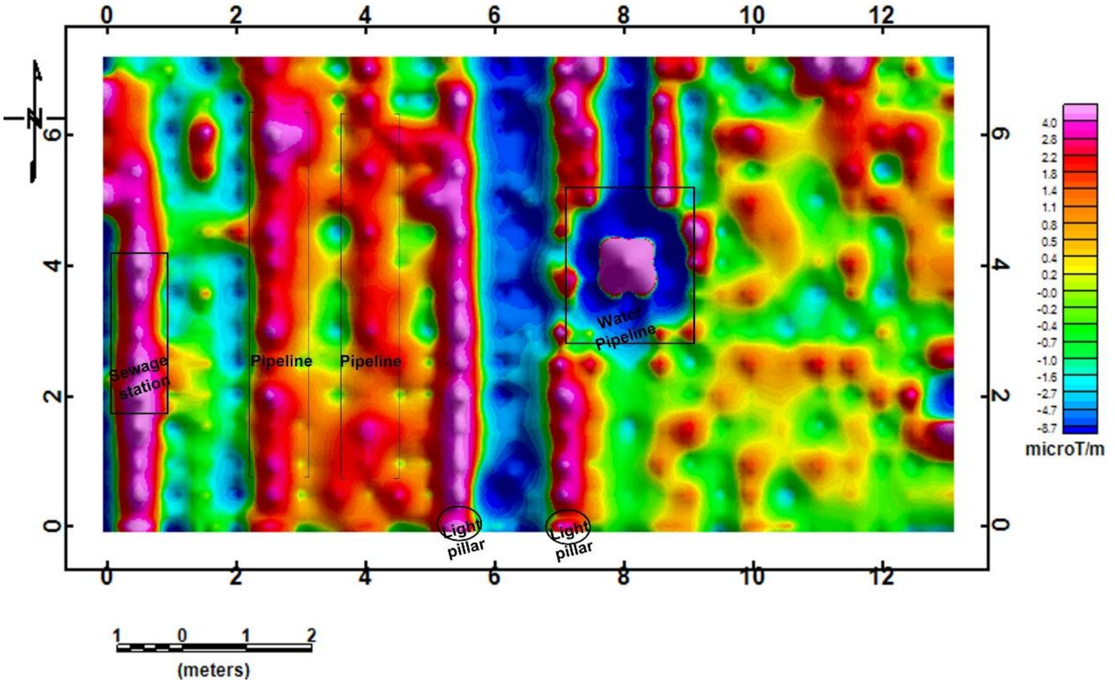

Figure 7: First vertical derivative filtered map of the study area with interpretation.

According to the radially averaged power spectrum (Fig. 8), it reveals that, there are two main average levels at depths -0.1 m and -0.5 m below the measuring level. However, these results depend on the proper choice of the slope of the different results and may be higher or lower by a small percentage.

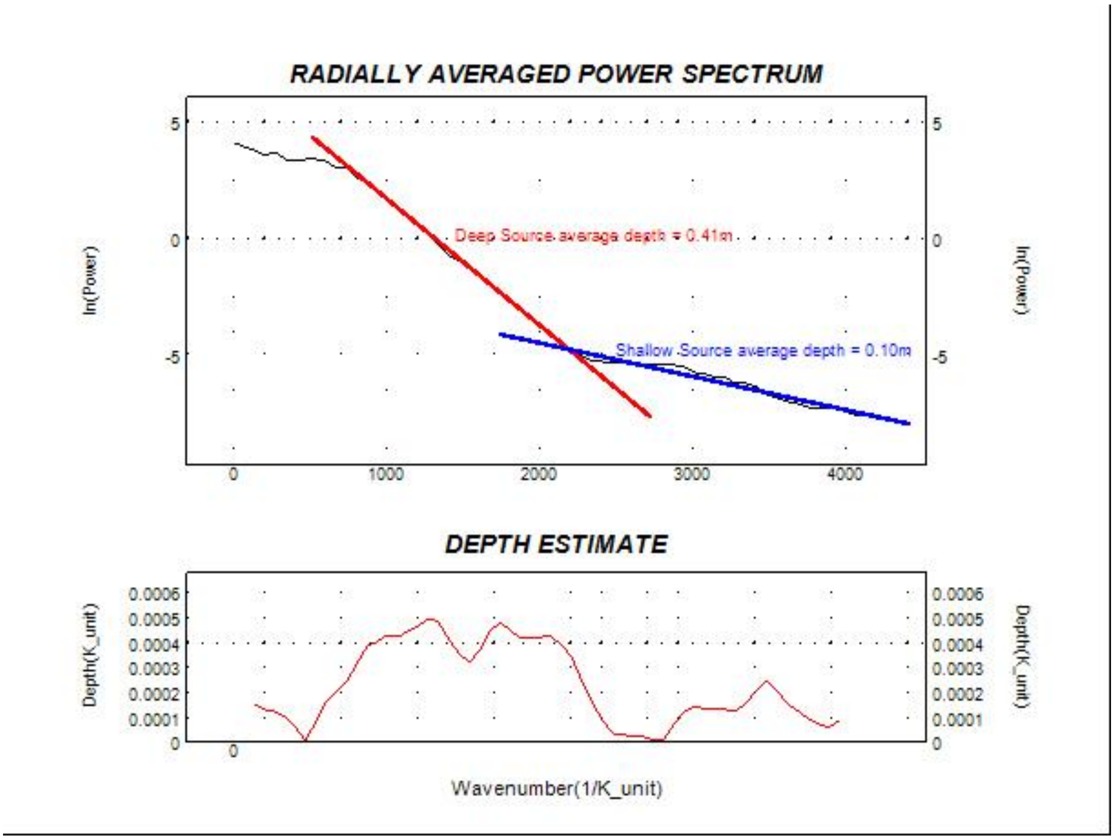

Figure 8: Average depth estimation of magnetic anomalies at the study area using radial average power spectrum technique.

Source parameter imaging (SPI) map of the study area showing that the depth of the linear anomalies varies from -0.11 to -0.26 m (Fig. 9).

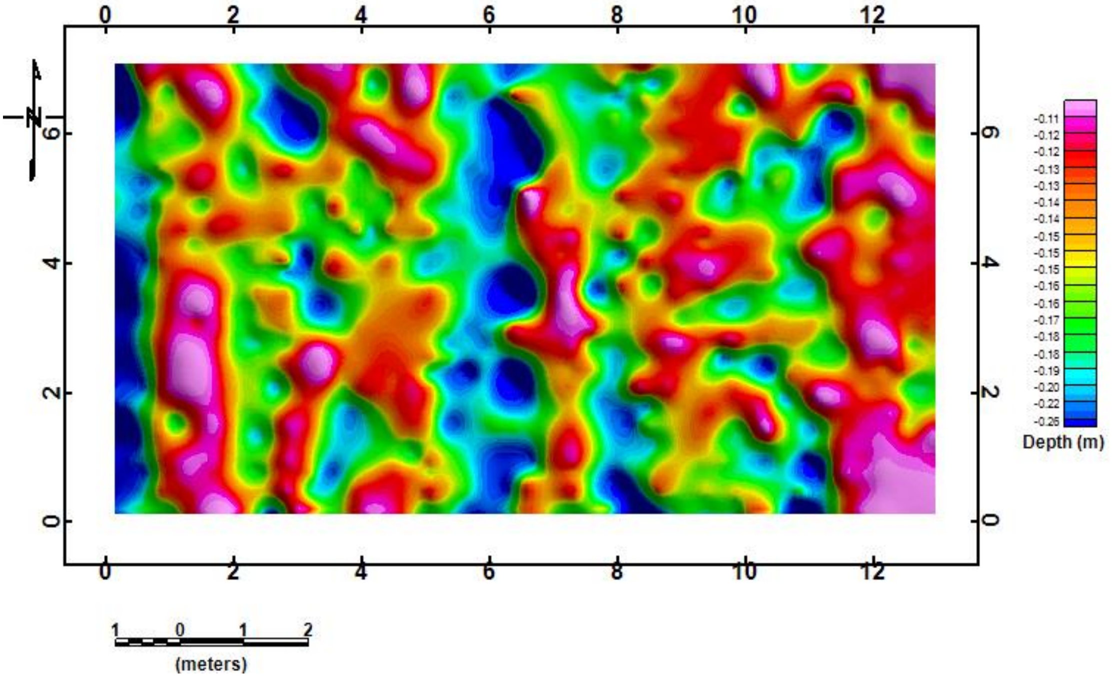

Figure 9: Depth estimation using Source parameter imaging (SPI) technique of the study area.

The estimated depth using the Euler 3D deconvolution for the high pass filtered map was determined with a structural index 2 which gives depth values more relevant to the subsurface magnetic features at the study which are considered line source (pipelines). The Euler 3D map shows that the depth values range from -0.11 m to -0.38 m which are closer to those obtained with the RAPS technique and SPI technique (Fig. 10). The high pass Butterworth filtered map was taken as a background for the results of the 3D Euler deconvolution (Fig.10). There is a complete coincidence between the Euler clusters and the boundaries of different magnetic anomalies (Fig. 10). These boundaries may represent contacts between pipelines with different magnetic susceptibilities.

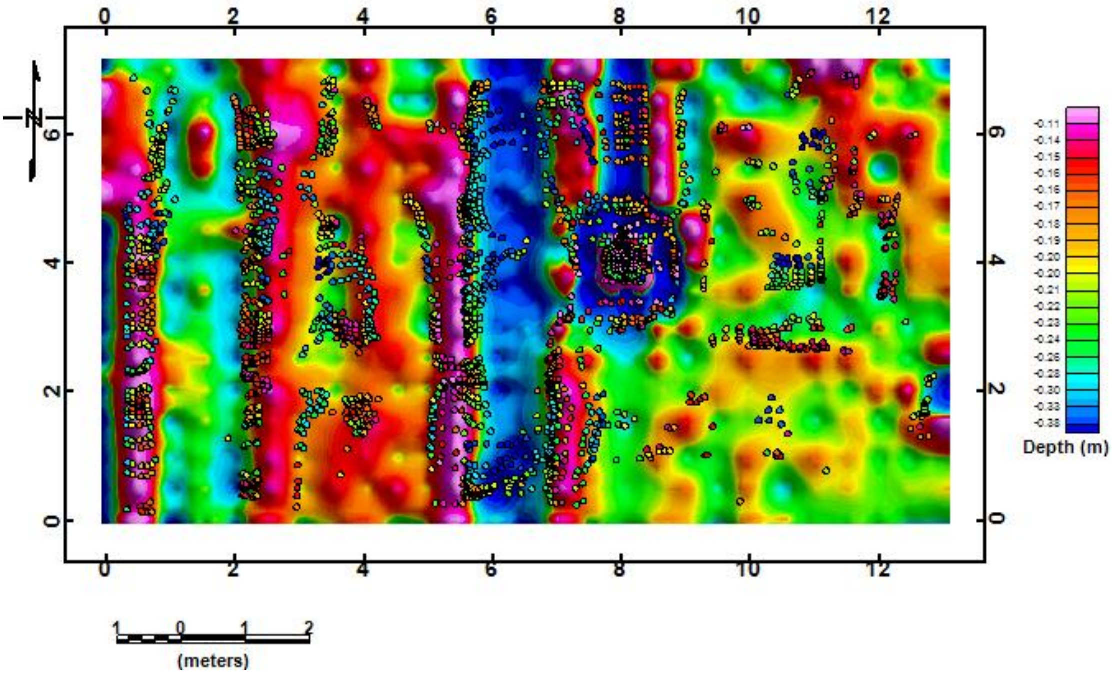

Figure 10: Depth estimation of shallow source magnetic anomalies at the study area using Euler 3D method and structure index of 2.

4- Summary and Conclusion

Accurate geometry and depth of the pipelines in the area located at Faculty of Science, Assiut University could be retrieved from the processing and interpretation of magnetic anomaly data measured using physics toolbox magnetometer through iPhone 7 plus magnetic sensor. The reliability of the results has been confirmed with existing surface and subsurface magnetic features.

It should be important to consider mapping the same area with a scientific magnetometer and comparing the results with those obtained from the smart phone application for calibration and getting better clarity, and it will be worth in the next stages to develop a unique mobile application that should process the acquired data, map the magnetic anomalies, and later attain the depth and shape of the expected magnetic bodies.

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