CHAPTER IV
MAGNETIC ANALYSIS

IV. 1. Introduction of geophysical methods:

Geophysics essentially is the measurements of contrasts in the physical properties of material beneath the surface of the earth and the attempt to deduce the nature and distribution of the material responsible for these observations. Variations in elastic moduli and density cause seismic waves to travel at different speeds through different materials. By timing the arrivals of these waves at surface observation points, we can deduce a great deal about the nature and distribution of subsurface bodies. Variations in electrical conductivity of rocks and sediments produce varying values of apparent resistivities as the distance between measuring probes is increased or as the position of the probes is changed on the surface.

Density variations in the subsurface lead to variations in gravitational acceleration at surface instrument stations, and variations in magnetic susceptibilities produce measurable differences in the magnetic field at field observation sites. These variations in physical properties must be sufficiently large so that their effects can be determined by our instruments.

A frequent problem is that insufficient contracts exist to detect the subsurface target of interest. Other times presence of nearby bodies of great contrasts creates effects that mask those created by our target. (Rebort Burger, 1992). Different geophysical tools such as gravity, magnetic, resistivity, self potential, induced polarization and seismic are used as separate or integrated for oil, groundwater exploration and ore deposits exploration.

Seismic refraction method has a wide application in technical and engineering problems as underground constructions to be placed in rock. Among these can be mentioned machine halls for power stations, tunnels and there entrances, oil and petrol storage deposits, air raid shelters, military installations factories, mines and sewage treatment plants. Seismic surveys are used in such cases to determine the depth of solid bedrock to obtain an estimate of the rock cover available for the construction. Seismic refraction also can be used for the constructions to be founded on rock or on other solid layer as bridges, dam sites, heavy industrial buildings and nuclear power plants. It is important here to obtain the depth to the bedrock or other solid layer, on which the construction can be founded.

The present-day applications of the seismic refraction are used in landslides and erosional problems, often in combination with geotechnical methods. The thicknesses and velocities of the soil layers and the overall picture of the subsurface aid the evaluation of the rocks for landslides or soil erosion, geotechnical data, such as the strength of a material and its composition, can be extended over a greater area with the help of the associated seismic velocities (Sjogren, 1984).

Because an object on the earth's surface is attracted by the mass of the earth, the gravity exploration method detects variations in the densities of the subsurface materials by measuring gravity at the surface and analyzing the differences in the recorded values (Burger, 1992). Different rock densities produce small changes in the gravity field and can be measured using portable instrument known as gravimeters (Milsom, 1989). The end product of a gravity field survey (after applying the necessary corrections) is usually a contoured anomaly map, the so-called Bouguer gravity anomaly map. The aim of geophysicists is to determine the various characters from the study of the shape, amplitude, sharpness and frequency of the residual anomaly.

The magnetic method, as used in geological exploration, is possibly the method versatile of the methods of geophysics, as it can be applied to both deep and shallow structures, and relative to other methods, measurements can be relatively cheaply obtained for both local and regional studies (Burger, 1992). Magnetic method is based on the measurements of small variations in the magnetic field, which may be caused by inhomogeneities in the composition of the basement rocks or by structural or topographic relief of the basement surface. These variations may be measured at the surface or more commonly by suitable instruments carried in an air craft. The measured variations are, then, interpreted to determine the depths to the basement rocks and, thus, defining the thickness of the sedimentary cover (Nettleton, 1976). The shape of the magnetic anomaly varies dramatically with the dip of the earth's field, as well as with the changes in the shape of the source body and its direction of magnetization (Milsom, 1989).

The electrical methods deal with the electrical state of the earth and include conclusions about the electrical properties of rocks and minerals under different geological environments, as well as their influences upon various geològical phenomena. Electrical exploration is a major branch of exploration geophysics. It uses principles of geoelectricity for geologic mapping of concealed structures, for the exploration and prospecting of ores, minerals, oil and in the solution of many hydrological and engineering problems. Geoelectric exploration consists of exceeding diverse principles and techniques, and utilizes both stationary and variable currents either artificial or by natural processes. One of the most widely used methods of geoelectric exploration is known as the resistivity method. In this method, a current (a direct or very low frequency alternating current) is introduced into the ground by two or more electrodes and the potential difference is measured between two points (probes) suitably chosen with respect to the current electrodes. The potential difference for a unit current sent through the ground is a measure of electrical resistance of the ground between the probes (Battacharya and Patra, 1968).

IV. 2. Introduction of magnetic methods:

The magnetic method involves the measurement of the earth's magnetic field intensity. Typically the total magnetic field and/or vertical magnetic gradient is measured. Anomalies in the earth's magnetic field are caused by induced or remanent magnetism. Induced magnetic anomalies are the result of secondary magnetization induced in a ferrous body by the earth's magnetic field. When a ferrous material is placed within a magnetic field such as the earths, it develops an induced magnetic field. The induced field is superimposed on the earth's field at that location creating a magnetic anomaly.

The Earth's magnetic field is described by seven parameters which are represented in the (Fig. 24), these components include declination (D) , inclination (I), horizontal intensity (H), the north (X) and east (Y) components of the horizontal intensity, vertical intensity (Z), and total intensity (F). To measure the Earth's magnetism in any place, we must measure the direction and intensity of the field. The parameters describing the direction of the magnetic field are declination (D) and inclination (I). D and I are measured in units of degrees, positive east for D and positive down for I.

The intensity of the total field (F) is described by the horizontal component (H), vertical component (Z), and the north (X) and east (Y) components of the horizontal intensity. These components may be measured in units of Oersted (1 oersted=gauss) but are generally reported in nanoTesla (1nT * 100,000 = 1 Oersted). The Earth's magnetic field intensity is roughly between 25,000 - 65,000 nT (.25 - .65 Oersted). Magnetic declination is the angle between magnetic north and true north. D is considered positive when the angle measured is east of true north and negative when west. Magnetic inclination is the angle between the horizontal plane and the total field vector, measured positive into Earth. In older literature, the term magnetic elements often referred to D, H, and I.

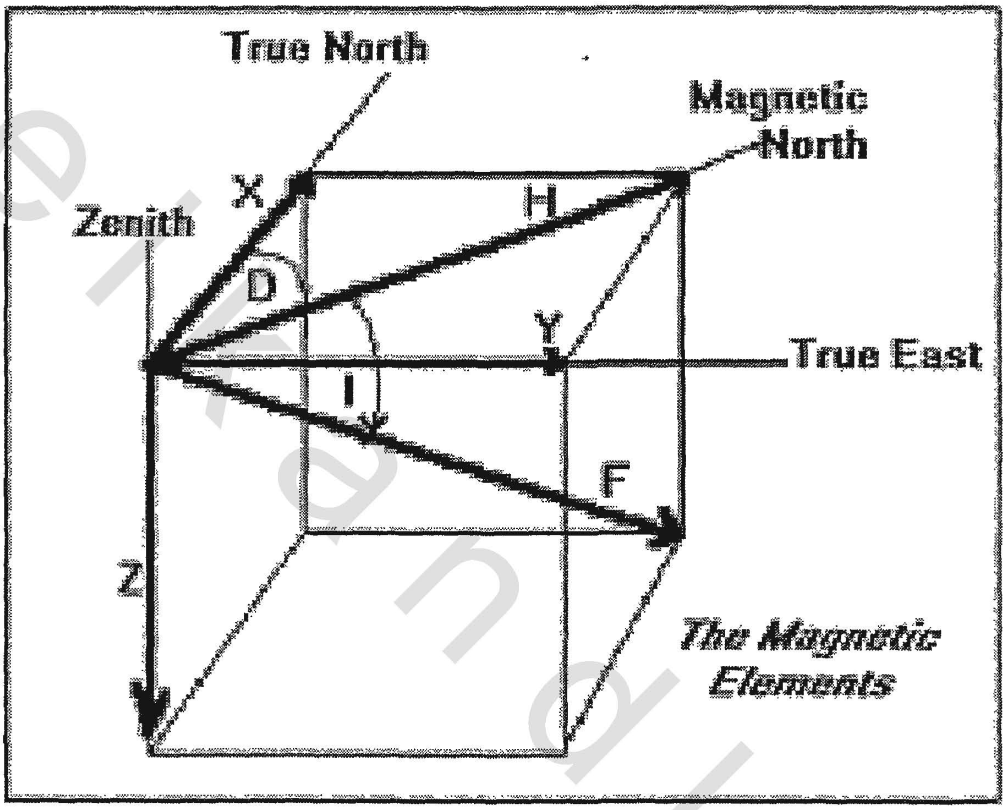

Figure (24): Parameters of the earth magnetic field.

IV. 3. Magnetic Data
IV. 3.1. Data acquisition

The area under study is surveyed by (Aero-Service 1984). The measurements of the aeromagnetic surveying is probably the most common airborne survey type conducted for both mineral and hydrocarbon exploration. Because total magnetic intensity and vertical magnetic gradient surveys are intimately related (total intensity data is always collected simultaneously with vertical gradient data). The type of aeromagnetic survey specifications, instrumentation, and interpretation procedures, will depend on the objective of the survey. Generally, the aeromagnetic surveys divide into two classes: regional and detailed surveys. The study area measured with the regional one where, usually have a relatively wide traverse line spacing, 500 meters or more, and cover an area of at least 5,000 square kilometers.

This class of survey is usually done for one of the following purposes:

1-Geological mapping to aid in mapping lithology and structure in both hard rock environments and for mapping basement lithology and structure in sedimentary basins or for regional tectonic studies.

2-Depth to basement mapping for applications to petroleum, coal and other non metallic exploration in sedimentary basins or mineralization associated with the basement surface such as strata bound Pb-Zn deposits or U-bearing basal pebble conglomerates. The reduced to the magnetic pole map are separated into residual and regional anomalies. Finally, the reduced to the pole magnetic map is used to determine the depth of the basement surface by using specialized software (Geosoft programs, 1994).

IV. 4. Reduction To The Magnetic Pole:

IV. 4. 1. Concept of the reduction to the Pole.

The resulting magnetic anomalies have characteristics shapes, which depend on some factors as the strike and dip of the bodies, their depth of burial and inclination and declination of the inducing field. In most cases, the produced anomaly consists of positive and negative parts and their parts must be dominant. The causative body in such cases is centered at a point between the two counter parts of the anomaly. The exact location is a function of the ratio of the magnitude of the two parts and the depth of burial to the top of the body.

The magnetic fields created by geological bodies are distorted by the inclination and declination of the earth's field. This can be attributed to the fact that, at low or moderate angles of inclination of the geomagnetic field, the peak of the anomalies have to be shifted a way from over the centers of the magnetized bodies, making it difficult to determine correctly the shapes and locations of these magnetized bodies.

In order to overcome this distortion in the appearance of an anomaly that depends on its magnetic latitude and the corresponding variation of the dip angle of the magnetization vector in the body a mathematical procedure is adopted on a grid of values of the contour map of the total magnetic intensity.

This mathematical procedure was first described by Baranov (1957), Baranov and Naudy (1964), Battacharya (1965 and 1967) and Baranov (1975). The magnetic data are calculated and covert the total intensity magnetic data into reduced to the magnetic pole by aero-service company and the values of the reduced to the pole data (RTP) are replotted on a base maps and contoured with contour interval 10 gammas (nano tesla). The resulting picture represents a preliminary total intensity magnetic map reduced to the pole (Fig. 25).

IV. 4. 2. Description of the reduced to the magnetic pole map:

The high magnetic anomaly occupying the northeastern, northwestern and eastern parts of the study area, while the low magnetic anomaly occupying the southwestern part. Also, there are several high and low magnetic anomalies, which directed N-E trend, which are respectively for the common structural trend in the study area. The map reveals different magnetic gradients at the eastern and southern parts of NE- SW trend and at the northeastern part of NW-SE trend.

IV. 5. Data Interpretation

IV. 5. 1. Magnetic separation:

Any magnetic effect the sum of all effects from gross roots down. Accordingly, a magnetic map is seldom a simple picture of a single isolated disturbance, but almost always a combination of relatively sharp anomalies which must be of shallow origin, of anomalies with intermediate dimensions which may be indicative of geologically interesting sources, and of very broad anomalies of regional nature which may have their origin far below the section within which the geological interest lies. By this way, an important step in magnetic interpretation is to separate the anomalies that result from shallow sources (residual anomalies) from other affects that result from relatively deeper sources (regional anomalies).

Moreover, there are several analytical techniques by which the regional, as well as the residual effects can be estimated. In this study, the author utilized special program (Geosoft programs, 1994). The author used high and low pass filter technique to separate the two components. The FFTIN program as apart of the Geosoft programs, which can read grid, file and calculated 2-D Fourier transform using FFT algorithm to give power spectrum file (Fig. 25) the depth to the top of the deep, shallow and noises can be determined using the relationship:

$$\text{LogE}(r) = 4\pi hr$$

The depth (hr) of an ensemble of sources is easily determined by measuring the slope of the energy (power) spectrum and dividing by 4π. (Fig. 24) is a typical energy spectrum for magnetic data, which exhibit three parts to the spectrum: a deep source component, a shallow component, and a noise component. The separation was carried out at wave number 0.0000287 (1/km).

However, in such a work, this technique of separation is carried out on the magnetic map reduced to the pole (Fig. 25). Two maps are produced representing the two separated pattern features (regional and residual) of the magnetic map reduced to the pole (Figs. 27 and 28).

IV. 5. 2. Regional anomalies in relation to the deep-seated interferences

The regional total intensity magnetic map reduced to the pole (Fig. 20) reveal the smoothing of the contours of the principle high and low magnetic anomalies, that surrounded by high and moderate magnetic gradients. Also, the minor anomalies, as well as the small undulations in the inherited magnetic contours are mostly disappeared, giving rise to the larger anomalies of deep-seated occurrence and regional nature in the subsurface.

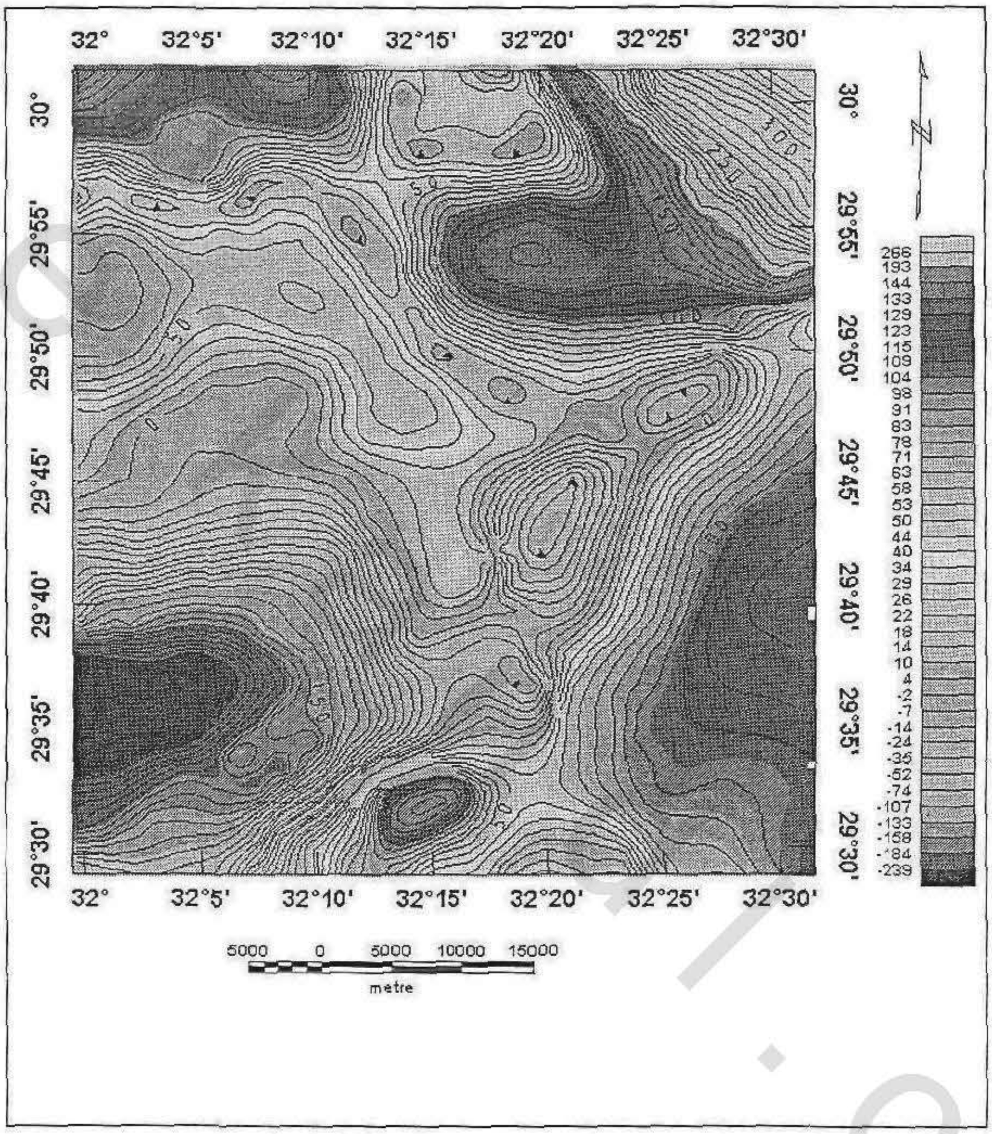

Figure (25): Total intensity magnetic map reduced to the pole in the study area.

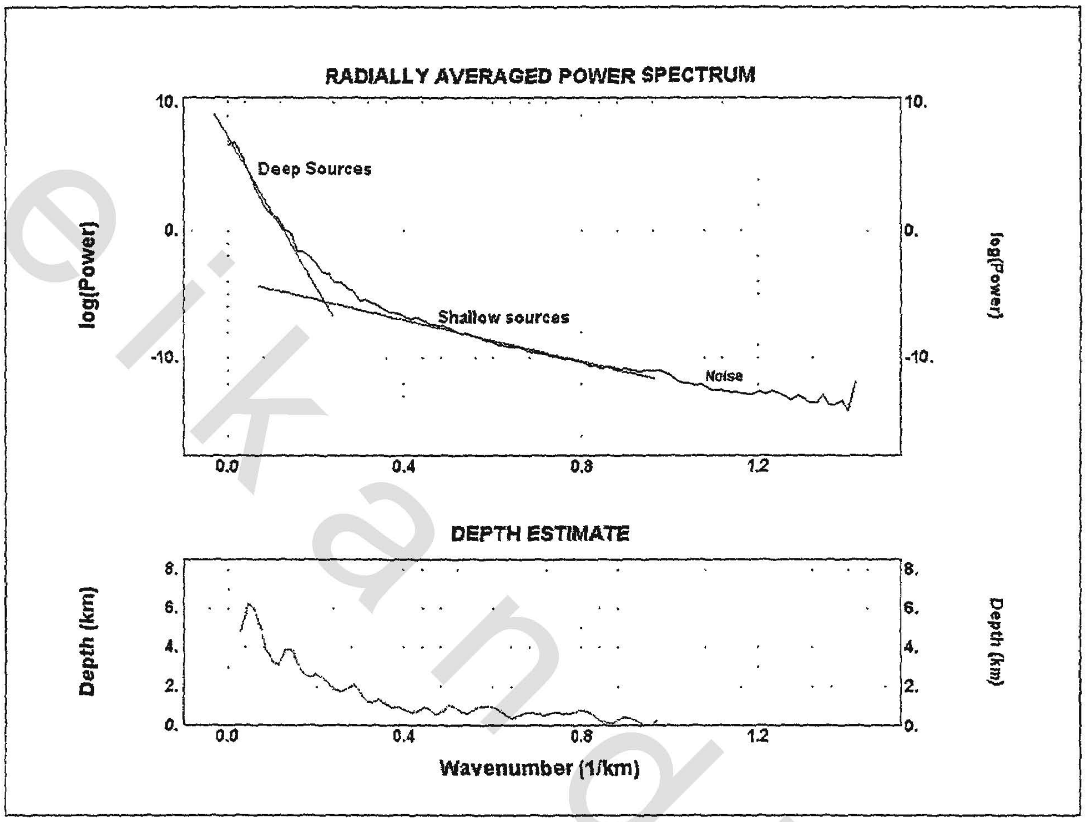

Figure (26): Power spectrum used for magnetic filtering.

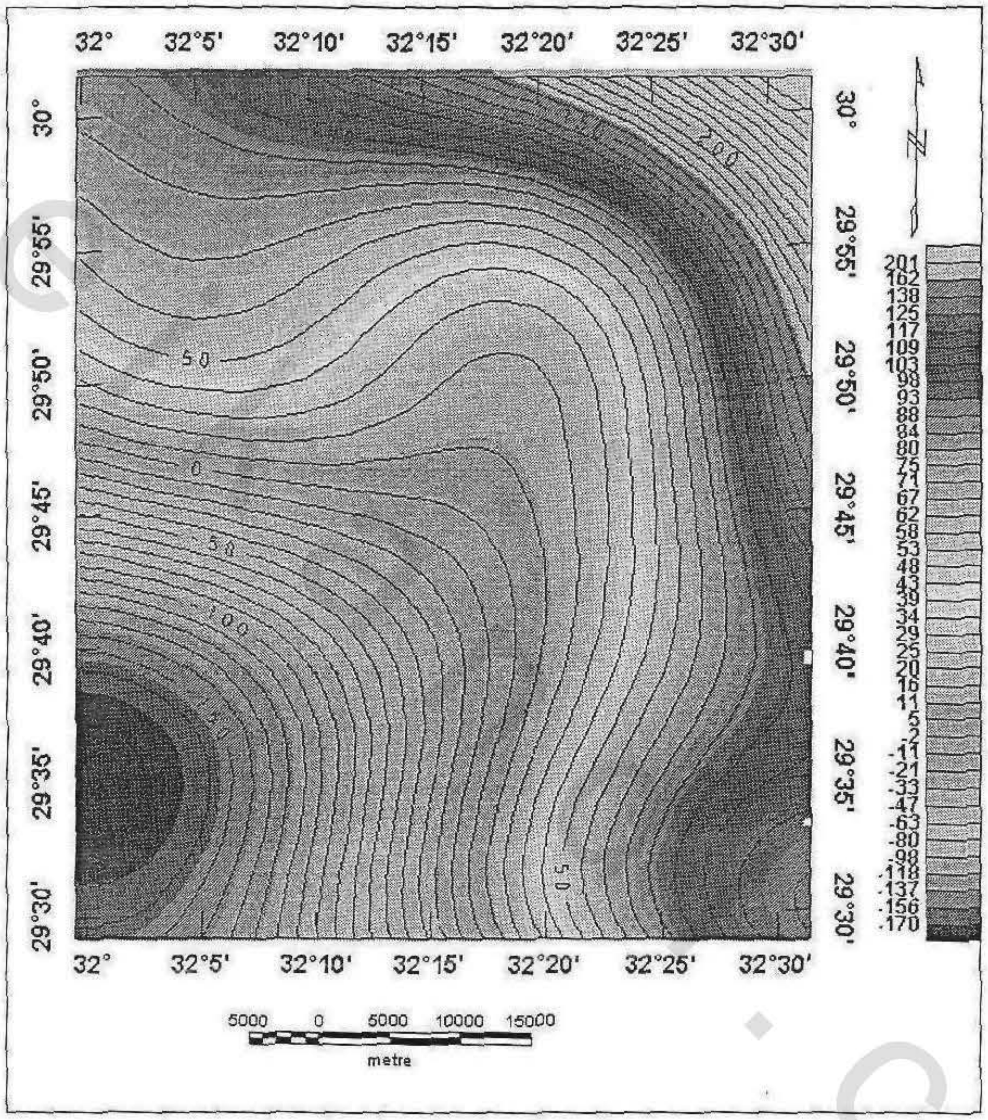

Figure (27): Regional total intensity magnetic map reduced to the pole in the study area.

However, the southwestern part of the area is defined by very low magnetic anomaly of –180 nano-tesla, this low magnetic anomaly extended to the central part of the study area to become a moderate magnetic anomaly of (-10-10 nano-tesla). The southeastern, eastern and northeastern parts occupying by high magnetic anomaly to give the maximum value at the northeastern part of 280 nano-tesla. Added, the northeastern part of the area is occupied by a steep magnetic gradient of NWW-SEE trend.

Also, the regional anomalies of the total intensity magnetic map reduced to the pole (Fig. 27) shows clearly a comparable distribution for the high and low magnetic anomalies according to the distribution of the magnetic sources, where the northeastern and eastern parts are shallow sources and the southwestern part of deep sources.

IV. 5. 3. Residual Anomalies In Relation To The Shallow-seated Features

The residual total intensity magnetic map reduced to the pole (Fig. 28) reveals the smoothing of the contours of the principle high and low magnetic anomalies, that surrounded by high and moderate magnetic gradients added to the appearance of some local anomalies through the most parts of the area. Most of the local anomalies arranged in NE-SW trend and some of them represented by NW-SE and E-W trends.

The residual anomalies of the residual total intensity magnetic map (Fig. 28) shows of varying frequency and relief for the most local anomalies, such a change in the frequency content can be interpreted in terms of basement bodies of varying nature (suprabasement and intrabasement).

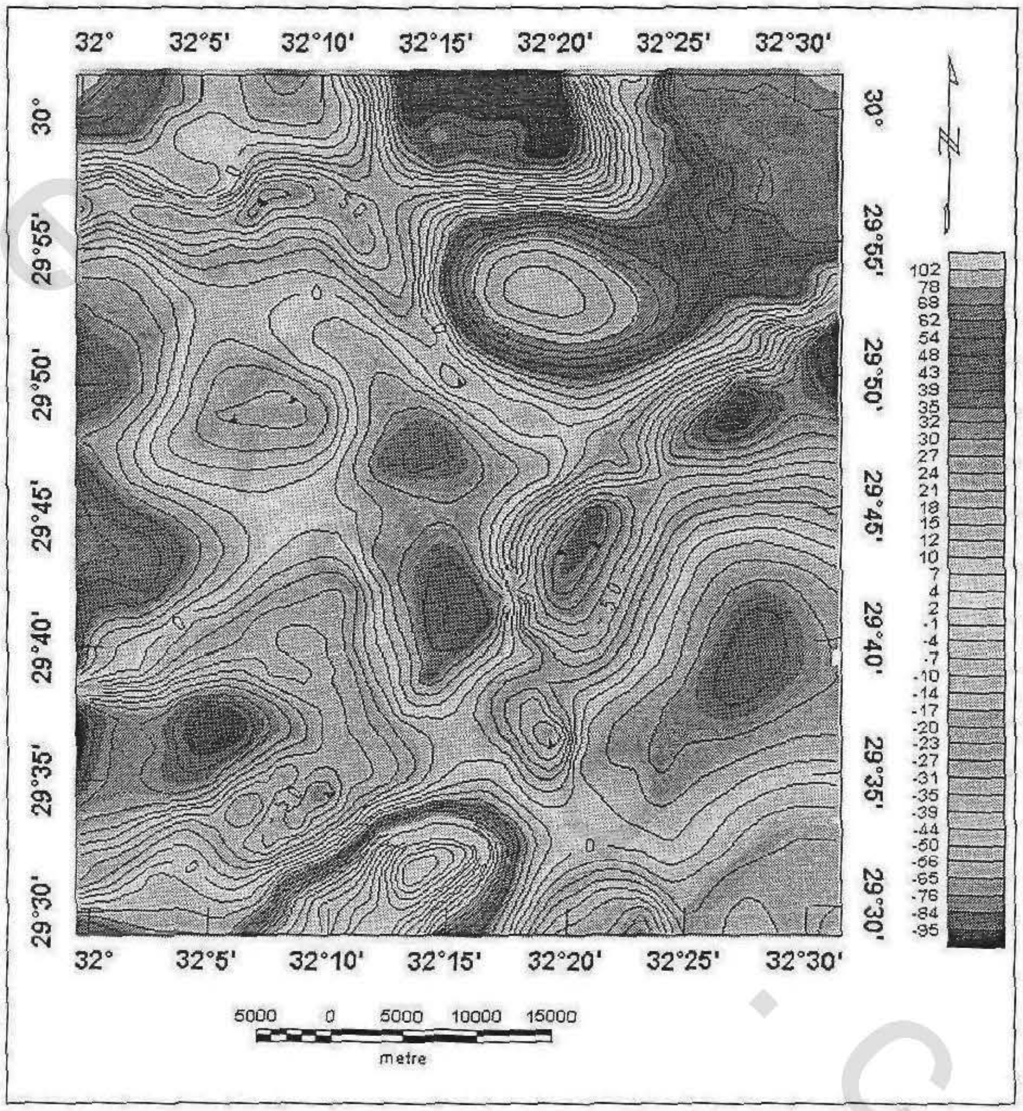

Figure (28): Residual total intensity magnetic map reduced to the pole in the study area.

Also, the residual anomalies of the total intensity magnetic map reduced to pole reflect mostly identical configuration for the implied high and low anomalies.

IV. 6. Magnetic Depth Determination

The principal application of magnetic data is to determine the depth to the top of the geologic sources that produce observed anomalies. For mineral exploration, the depth estimation is often used to determine the depth and location of geologic units or structures that produce a magnetic anomaly.

The author used Mag Mode interactive software (Geosoft programs, 1994) to determine the depth source parameters such as depth, half width and magnetic susceptibilities on twenty selected profiles distributed through out the consider area (Fig. 29) as shown in the Figures (30, 31, 32, 33, 34, 35 and 36). The results of magnetic depth determination are tabulated in (Table 3).

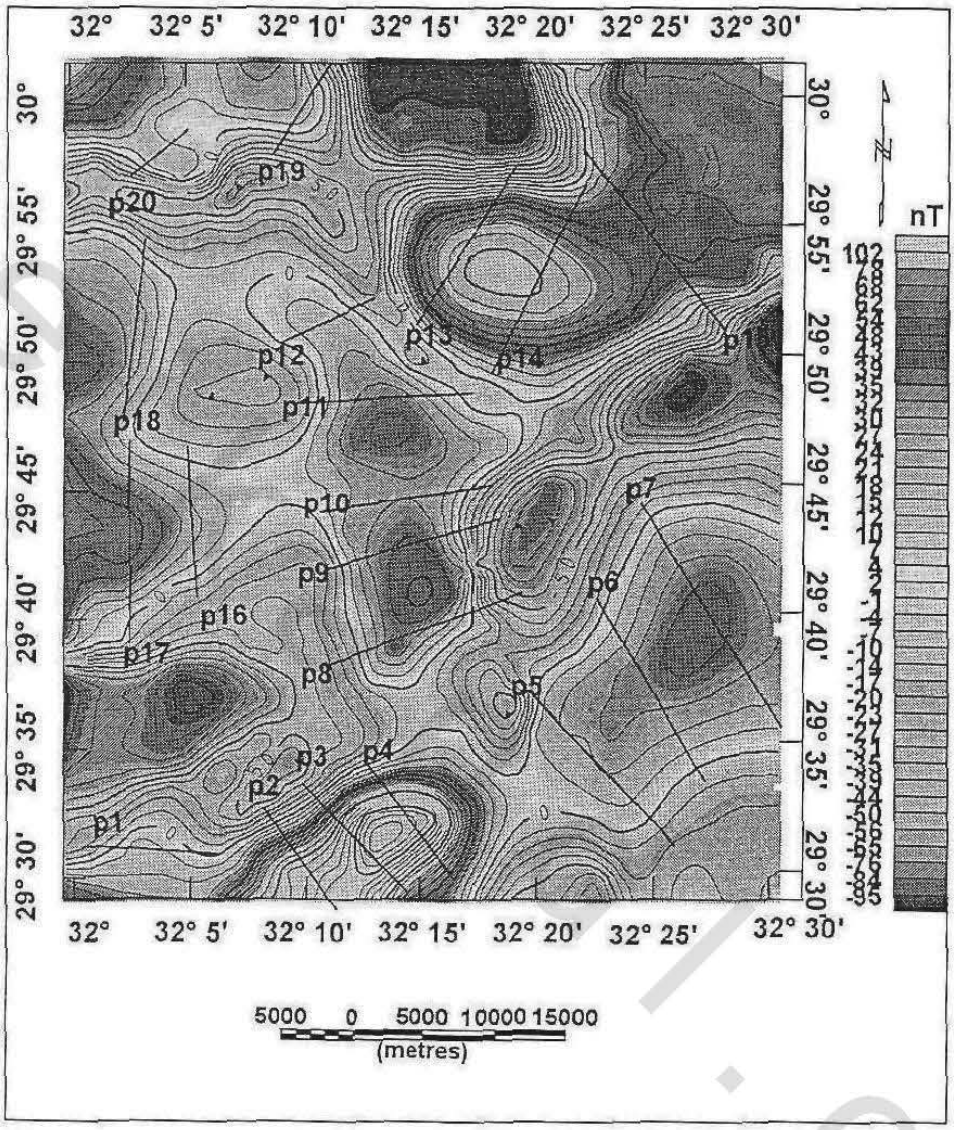

Figure (29): Location map of magnetic profile depth in the study area.

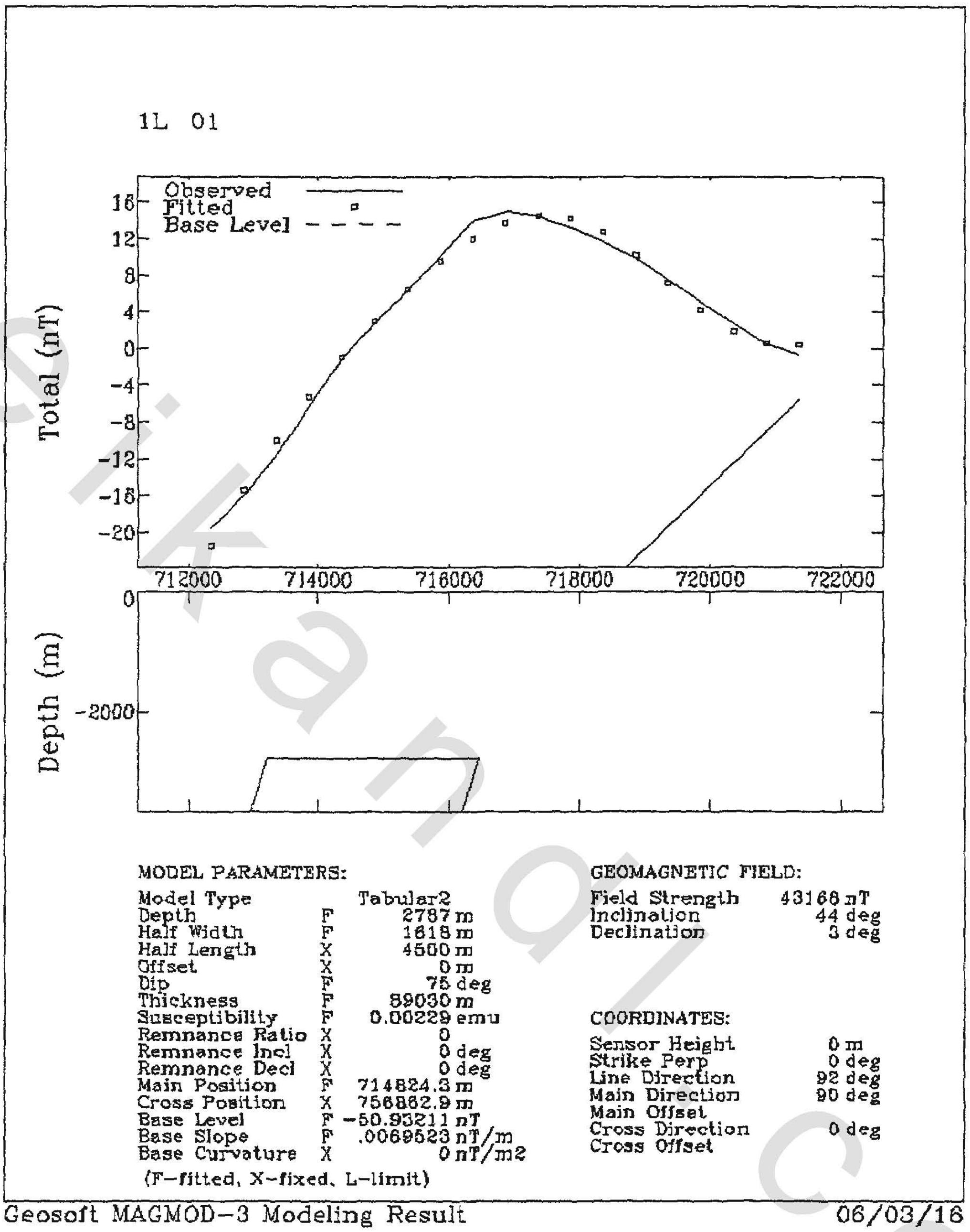

Figure (30): Interpretation for geometry determination of the magnetic bodies along Profile 1 (Using MagMode software).

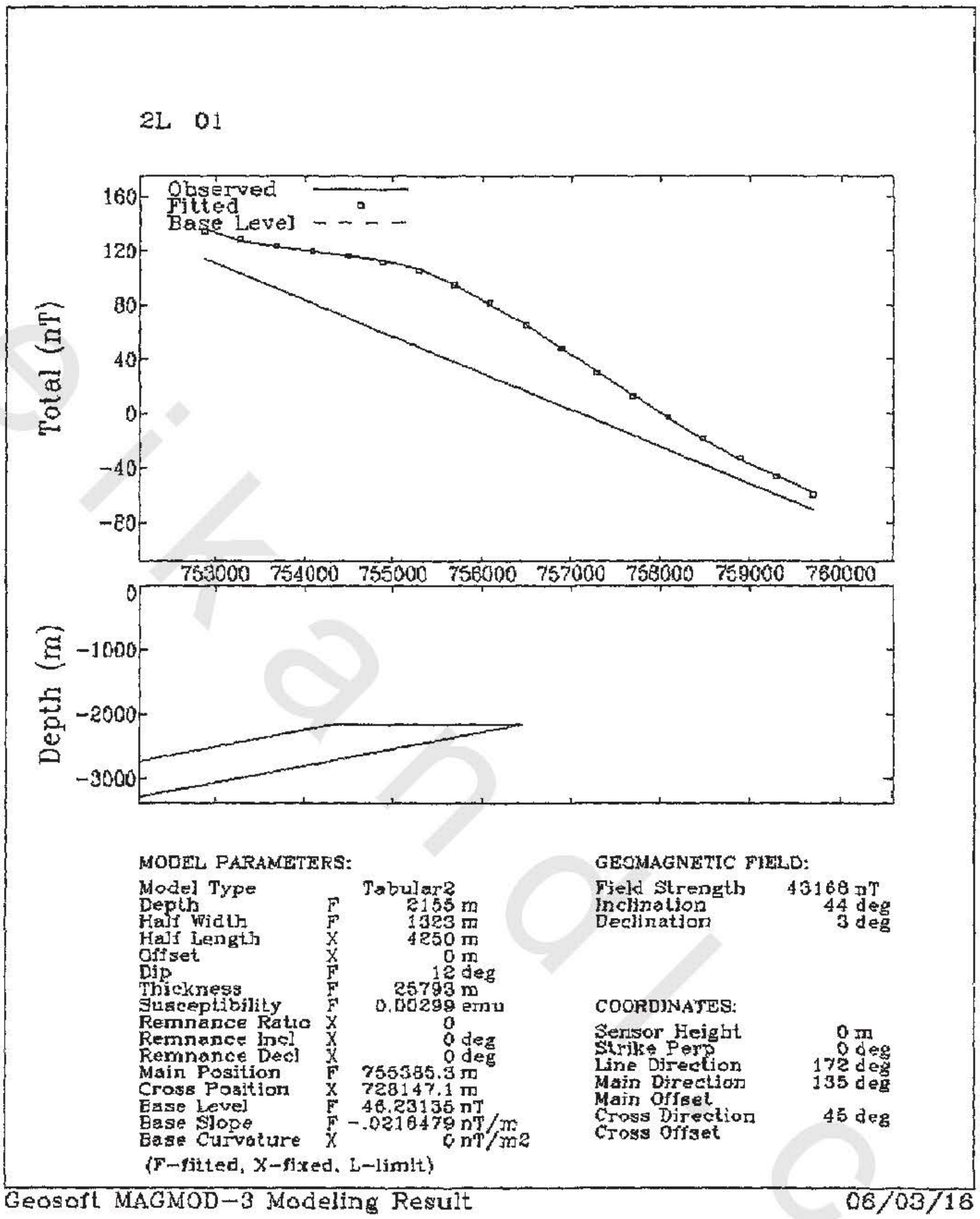

Figure (31): Interpretation for geometry determination of the magnetic bodies along Profile 2 (Using MagMode software).

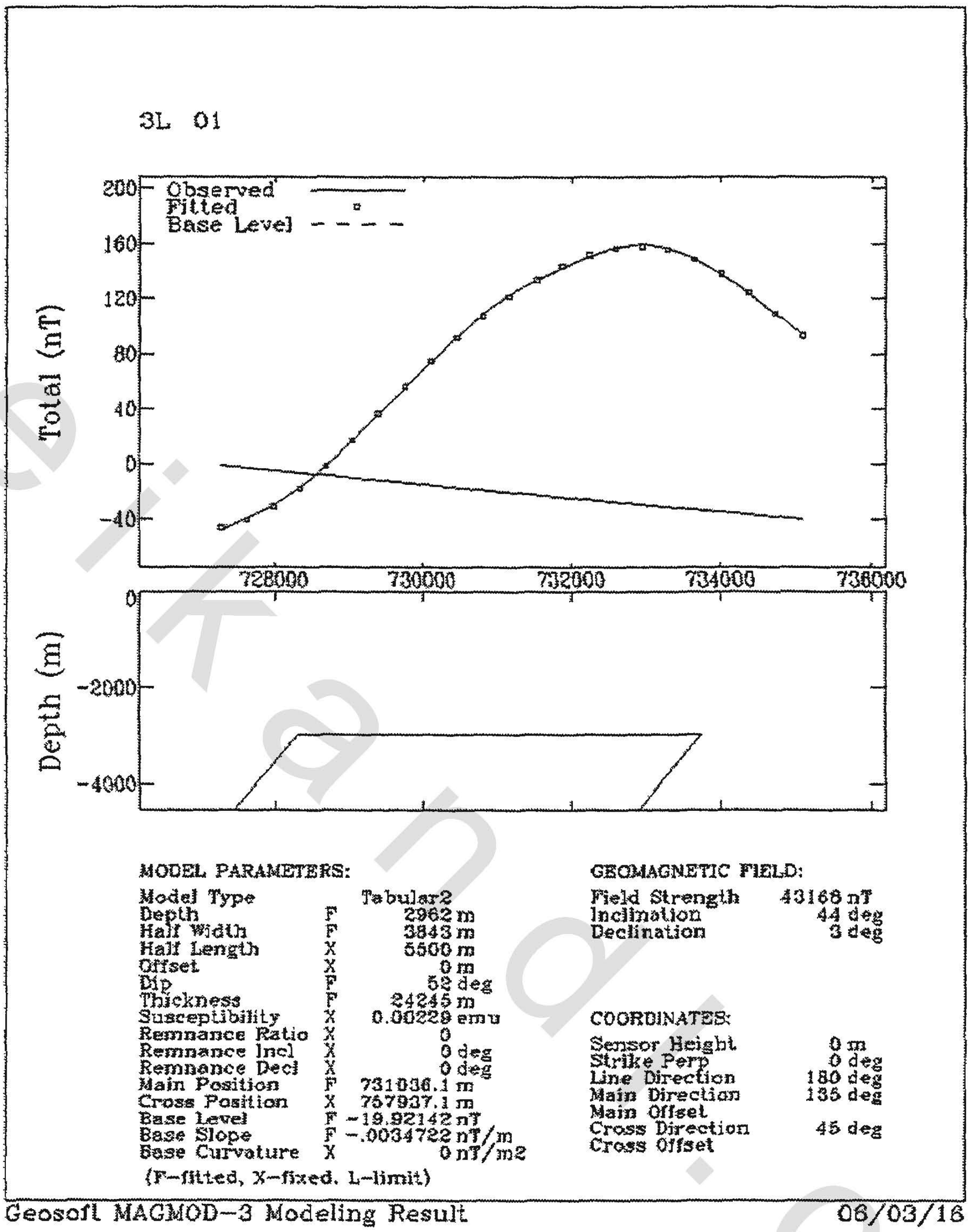

Figure (32): Interpretation for geometry determination of the magnetic bodies along Profile 3 (Using MagMode software).

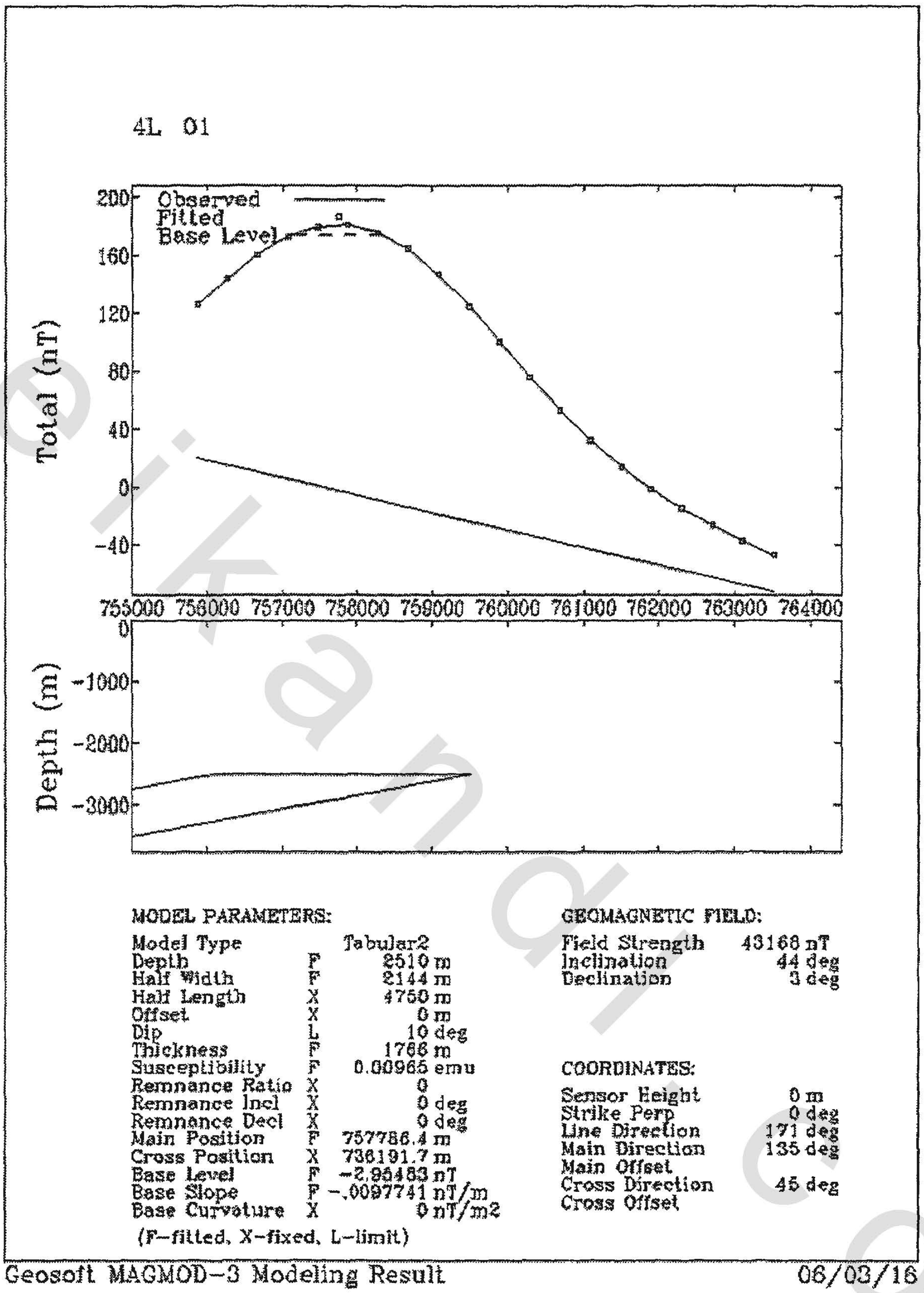

Figure (33): Interpretation for geometry determination of the magnetic bodies along Profile 4 (Using MagMode software).

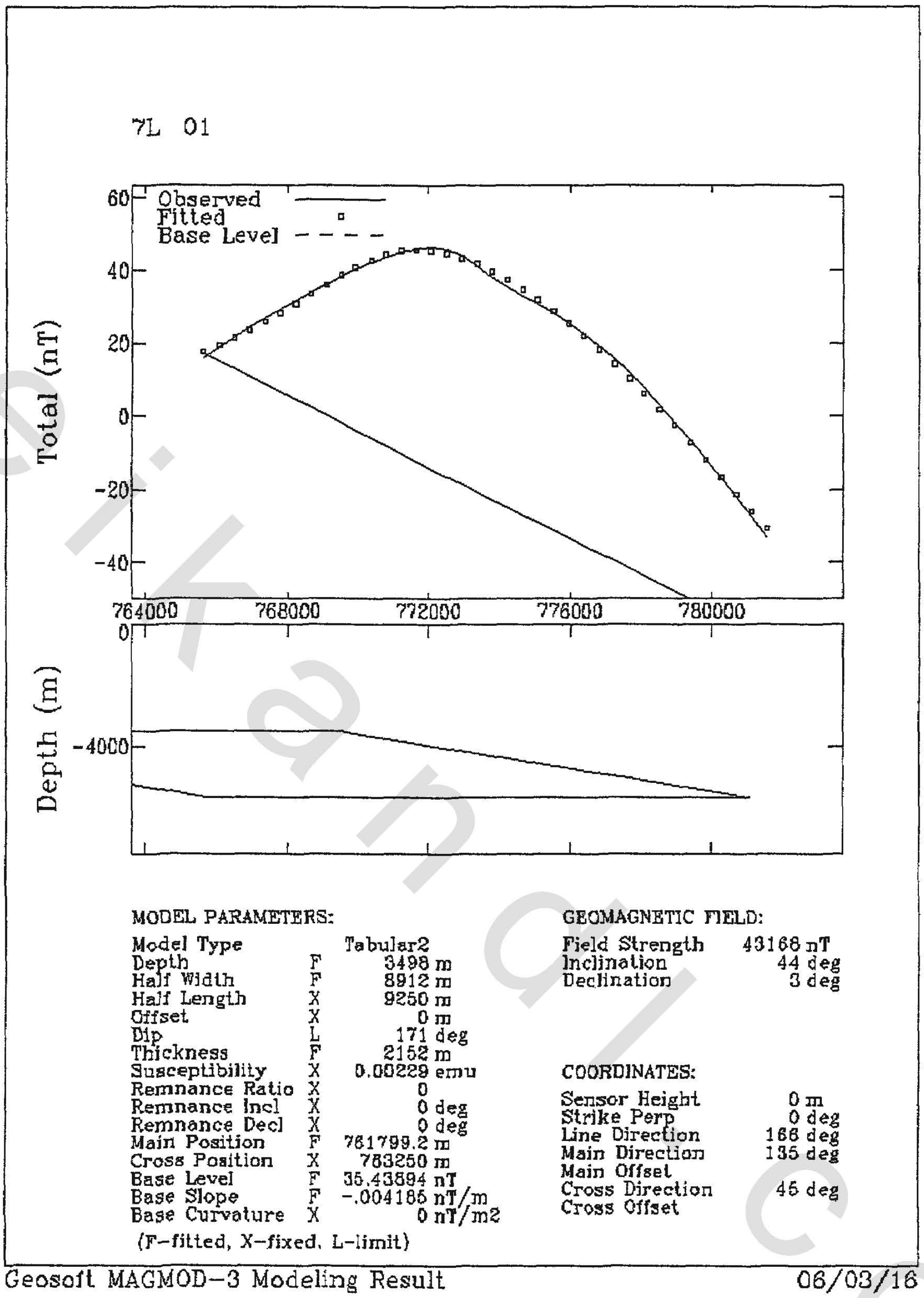

Figure (34) Interpretation for geometry determination of the magnetic bodies along Profile 7 (Using MagMode software).

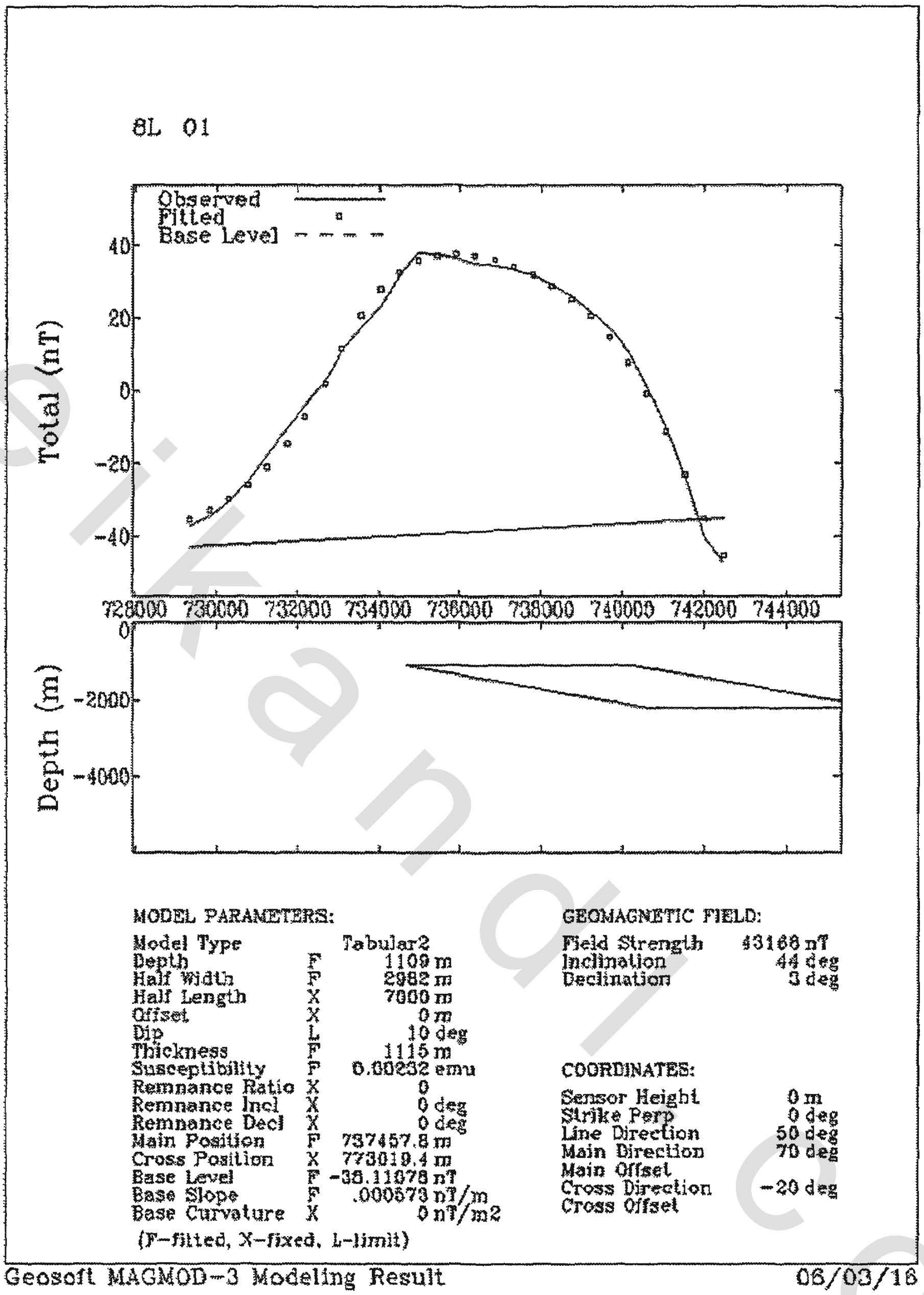

Figure (35): Interpretation for geometry determination of the magnetic bodies along Profile 8 (Using MagMode software).

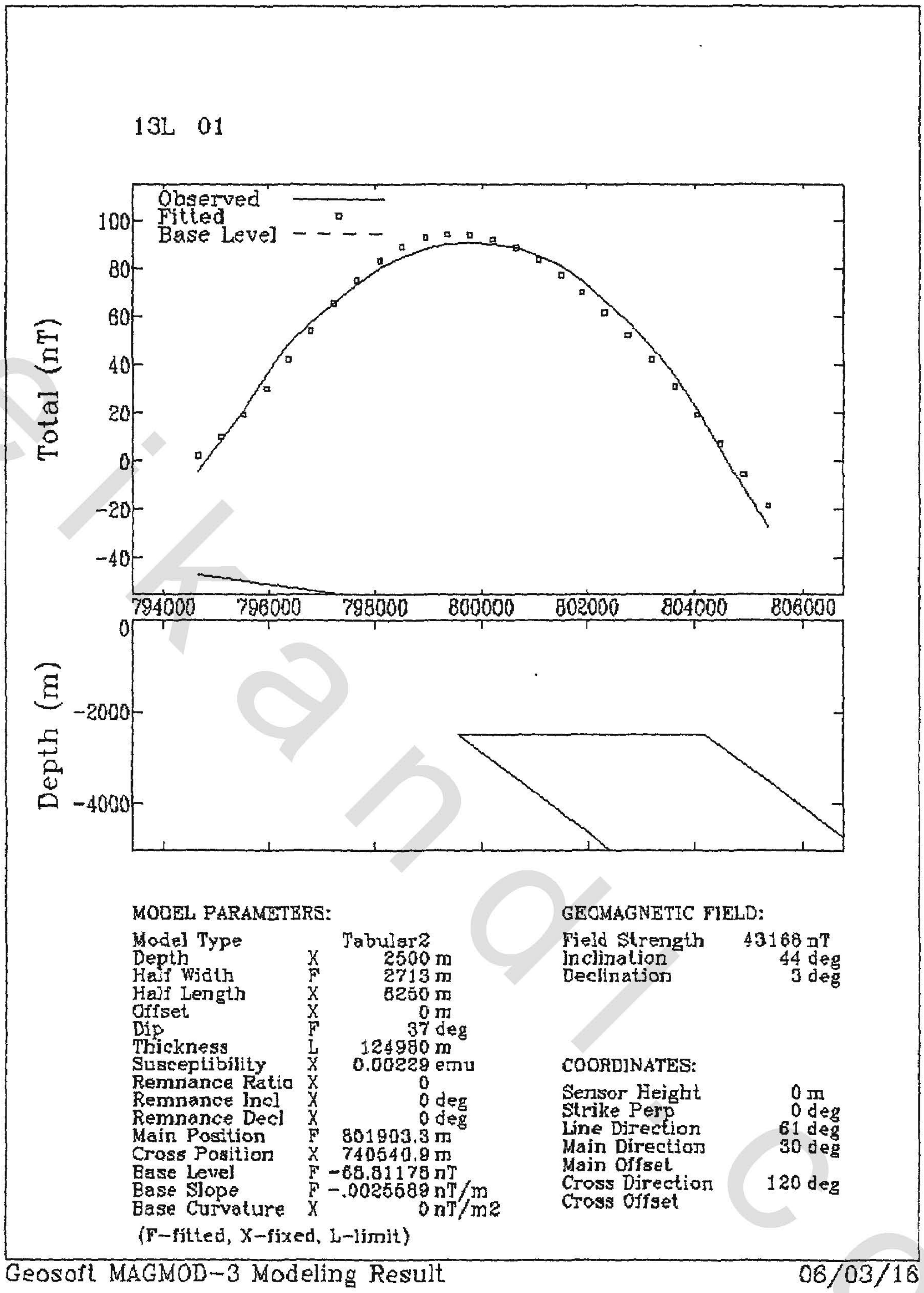

Figure (36): Interpretation for geometry determination of the magnetic bodies along Profile 13 (Using MagMode software)

Table: (3): Shows the results of magmod software, which include depth, half width and magnetic susceptibilities for each profile.

Profile no.	Depth (m)	Half-Width	Magnetic susceptibilities	Remarks
1	2787	1618	0.00229	
2	2155	1323	0.00299	
3	2962	3843	0.00229	
4	2510	2144	0.00965	
5	2732	2822	0.00229	
6	2800	4672	0.00229	
7	3498	8912	0.00229	
8	1109	2982	0.00232	
9	2200	2795	0.00229	
10	2043	670	0.00542	
11	2300	971	0.00277	
12	2059	2604	0.00160	
13	2500	2713	0/00229	
14	3024	3384	0.00229	
15	1986	5158	0.00214	
16	2500	3738	0.00229	
17	2061	3935	0.00162	
18	2986	5963	0.00229	
19	2600	4565	0.00229	
20	2046	1296	0.00229	

IV. 6. 1. Depth map

The results of the depth determination are used for the depth map construction using Oasis Montaj software. The depth map of the upper surface for the basement complex (Fig 37) reveals that the depth of the basement surface is deeper at the southern part where the depth reach to 3500 m, and represented the main basin in area which may be included oil and ground water accumulation, also the depth of the basement surface is deeper at the northwestern part where the depth reaches to 3200 m. The central part of the study area is occupying by shallow depths of the basement surface where the depth is 1200 m and represents the uplift in the study area.

IV. 7. Magnetic Modeling:

There are several computer programs available to calculate the magnetic response of the subsurface geologic sections. In the present study, the GM-sys program produced by the Northwest Geophysical Associates Inc. USA (1999) was used. The five magnetic profiles crossing the magnetic anomalies and covering the study area, P1, P2, P3, P4 and P5 of W-E trend using magnetic susceptibility of 0.00229 cgs units for the basement rocks (Fig. 38).

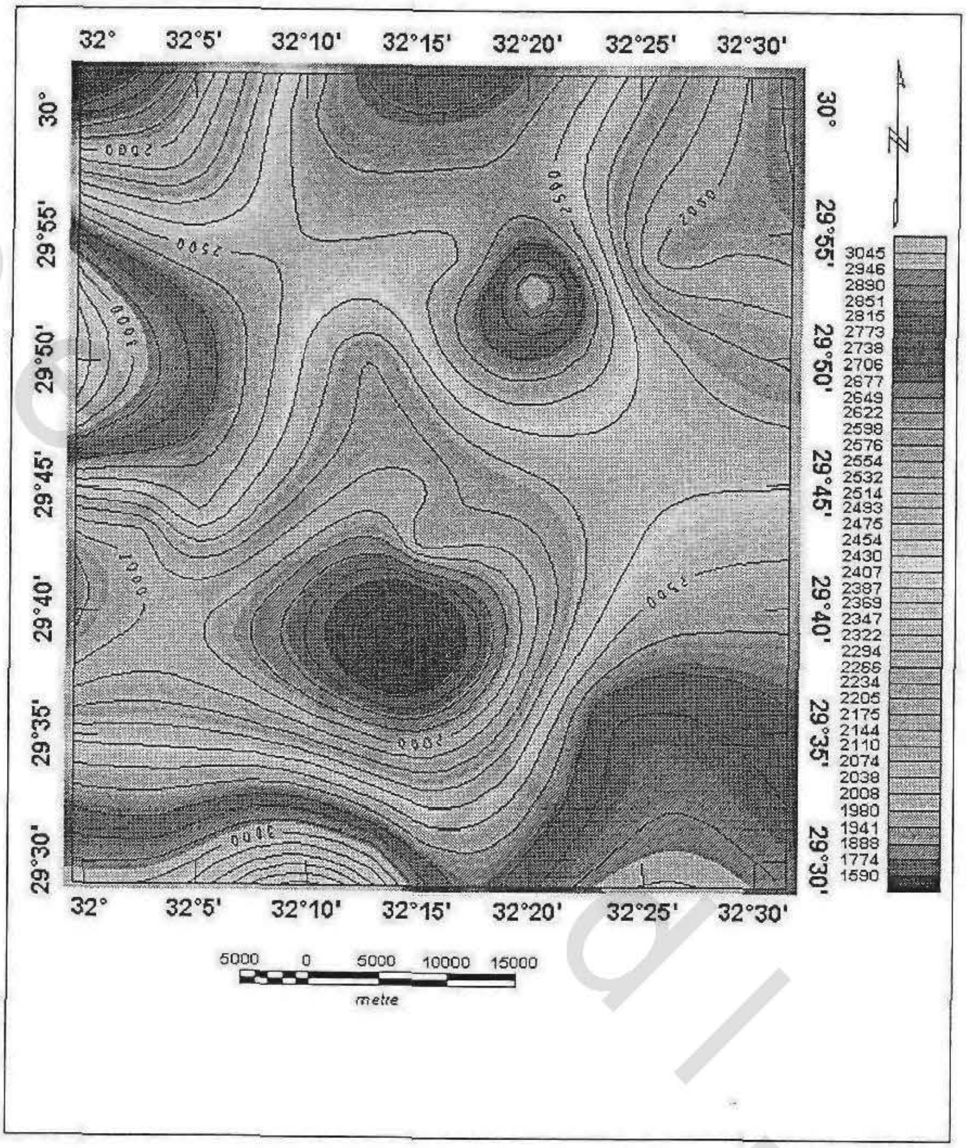

Figure (37): Shows the depth of the basement in the study area.

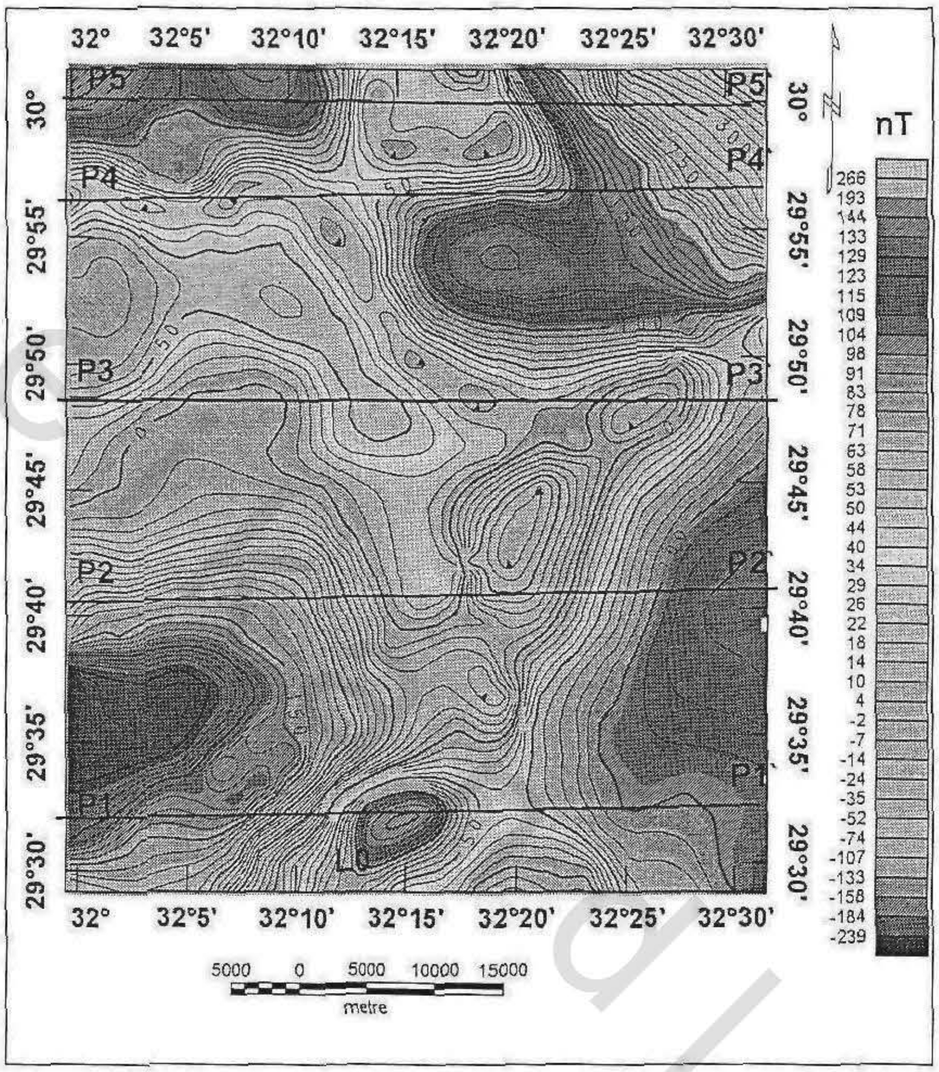

Figure (38): Location map of the magnetic modeling profiles for the study area.

IV. 7. 1. Magnetic modeling along profile P1

The magnetic modeling along profile P1(Fig. 39) shows variation in the basement surface, the first part of the profile exhibits deeper values for the basement surface of about 3500 m but the depth of the basement surface become shallower at the end part of the profile of 1100 m.

IV. 7. 2. Magnetic modeling along profile P2

The magnetic modeling along profile P2 (Fig. 40) shows deeper values for the basement surface at the central part of the profile of 3900 m and exhibits moderates depth values at the first part of 2800 but the end part of the profile shows shallow values for the basement surface of 2000 m.

IV. 7. 3. Magnetic modeling along profile P3

The magnetic modeling along profile P3 (Fig. 41) reveals large variation in the basement surface, the first and the end part parts of the profile exhibit shallow values for the basement surface of about 1800-2000 m but the depth of the basement surface become more deeper at the central part of the profile of 3500-3800 m.

IV. 7. 4. Magnetic modeling along profile P4

The magnetic modeling along profile P4 (Fig. 42) reveals shallower for the basement surface at the end part of the profile reach to 1100 m but the basement surface is more deeper at the central and first part of the profiles of 3900 m.

IV. 7. 5. Magnetic modeling along profile P5

The magnetic modeling along profile P5 (Fig. 43) reveals more shallower for the basement surface at the first and end parts of the profile reach to 1100 m but the basement surface is more deeper at the central and first part of the profiles of 4800 m.

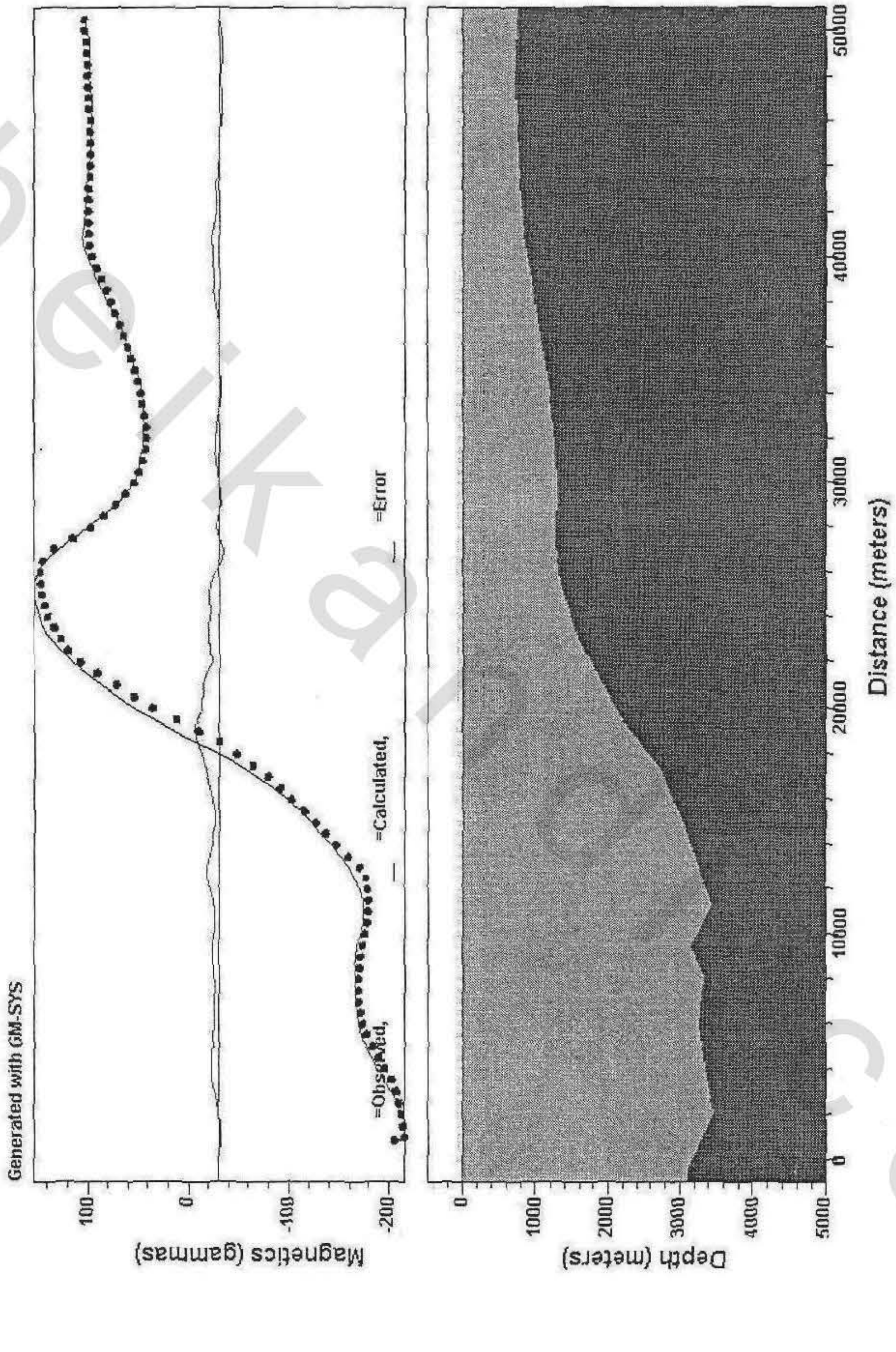

Figure (39): Magnetic modeling along profile P1 in the study area.

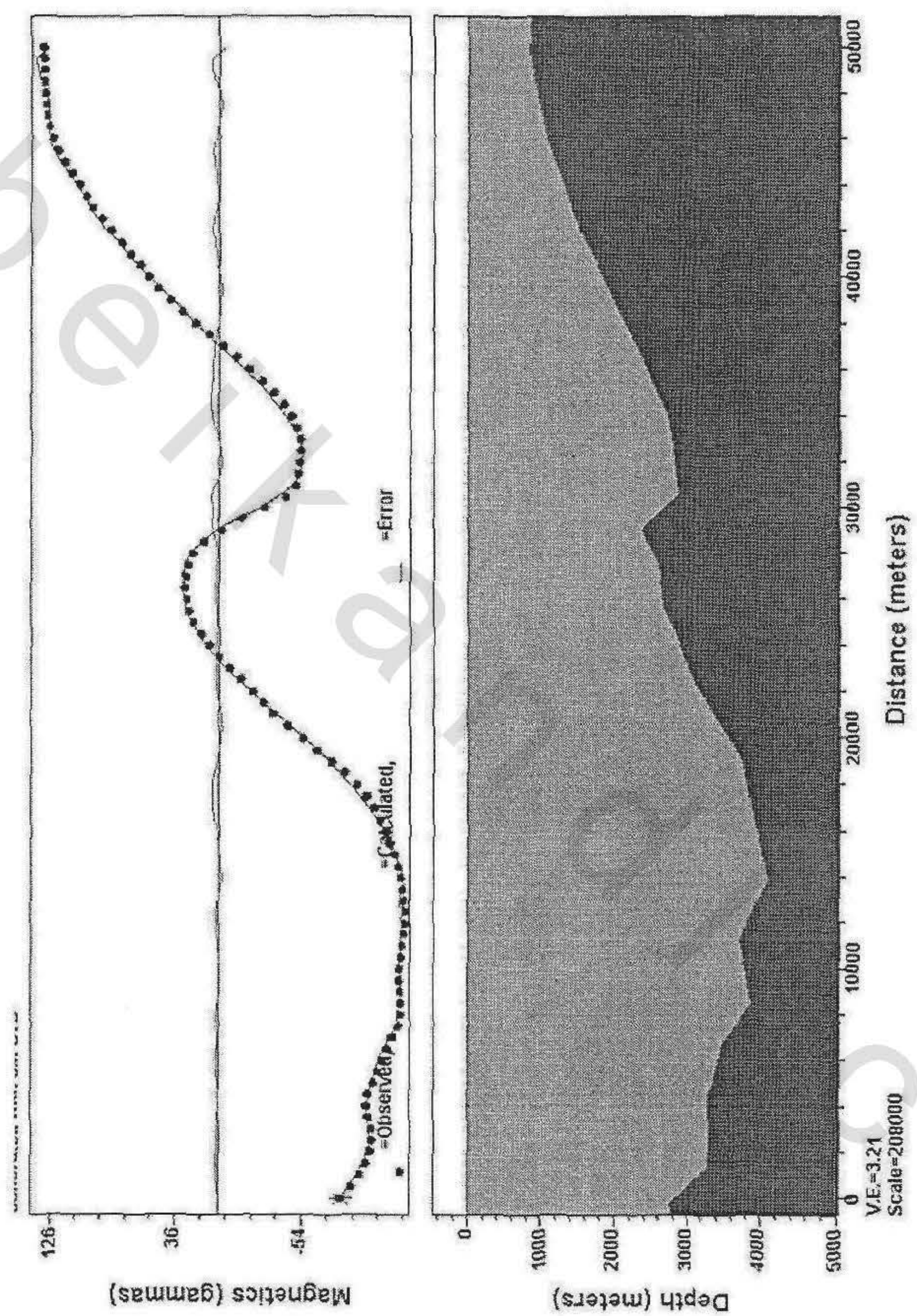

Figure (40): Magnetic modeling along profile P2 in the study area.

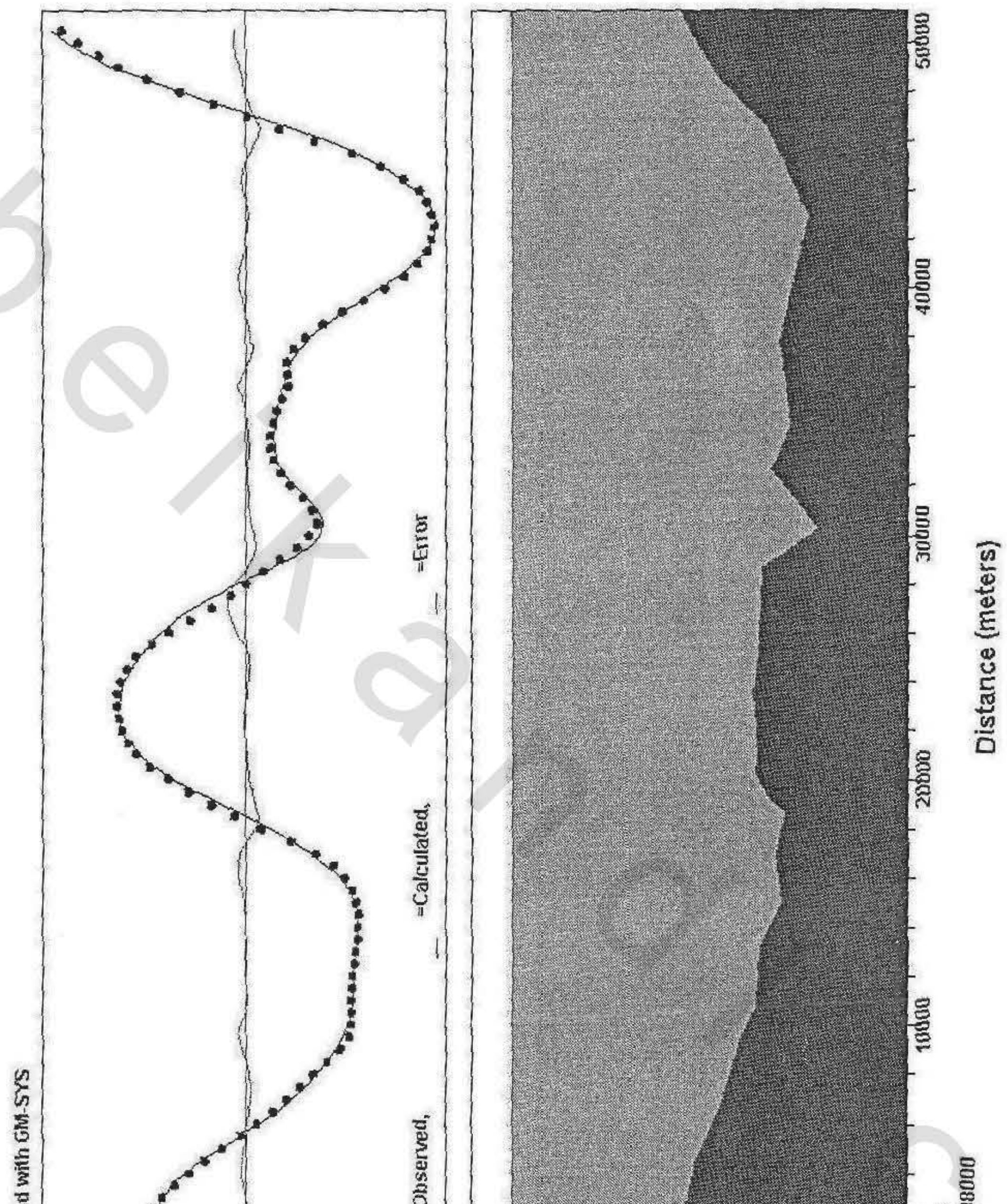

Figure (41): Magnetic modeling along profile P3 in the study area.

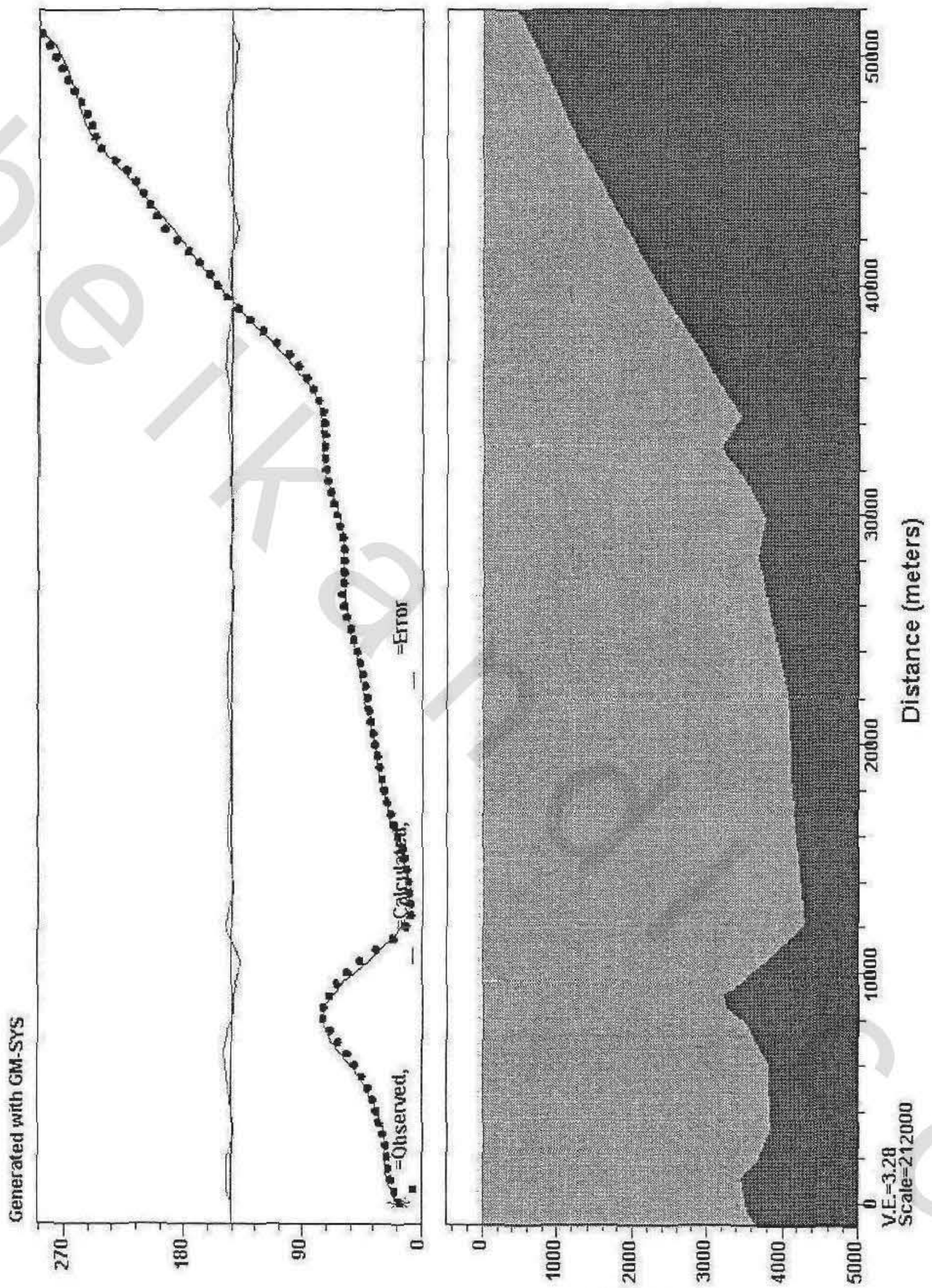

Figure (42): Magnetic modeling along profile P4 in the study area.

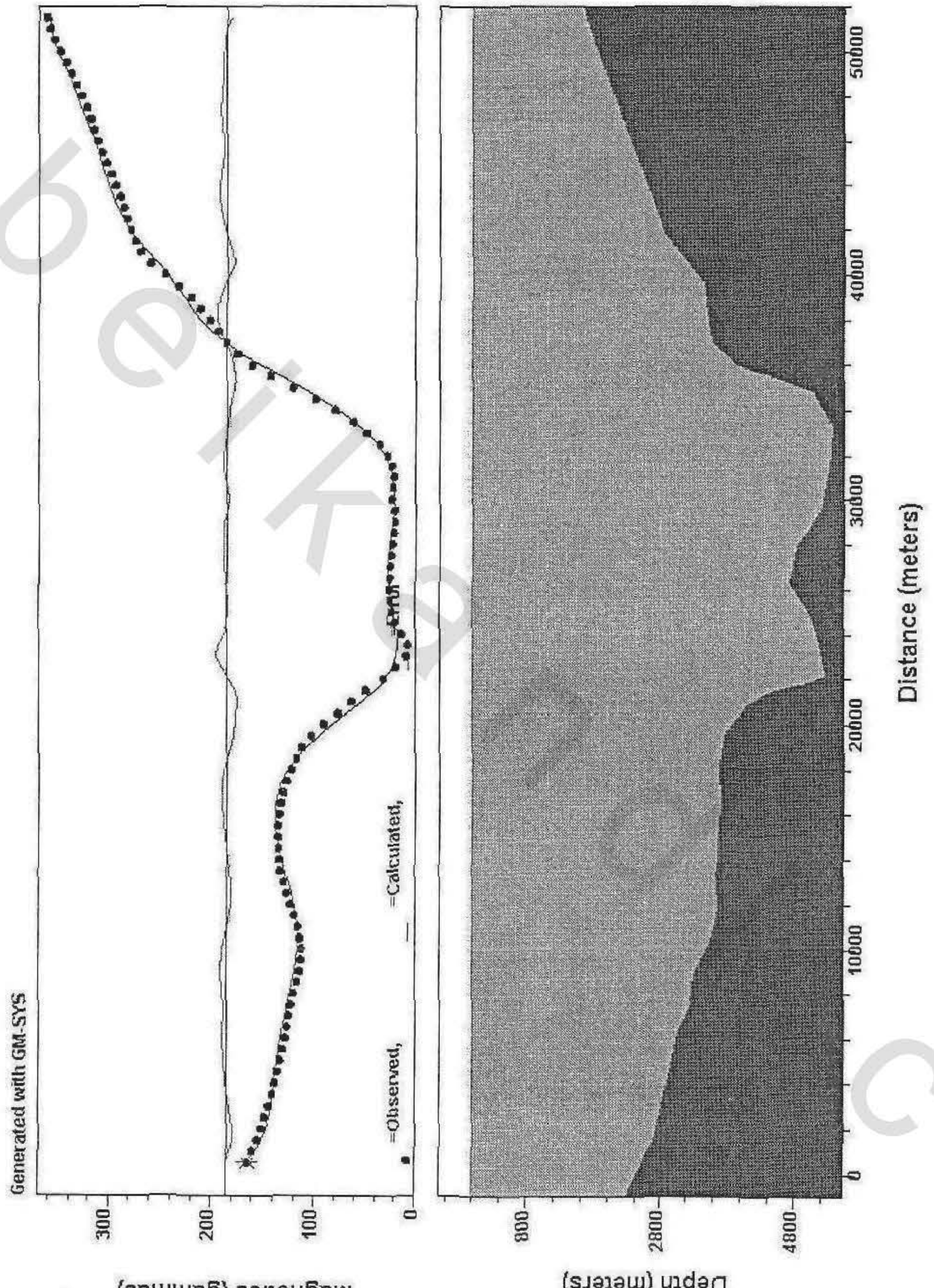

Figure (43): Magnetic modeling along profile P5 in the study area.