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Archeo-Prospecting Using Microgravity in Valley of The Golden Mummies Baharyia Oasis Western Desert Egypt

BY

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ABSTRACT

Microgravity survey was conducted in Valley of the Golden mummies (VGM) to map and detecting the archaeological features in the valley using a Scintrex CG-5 gravimeter. The Valley of the Golden mummies is located about 380 km west of Cairo. Baharyia Oasis became one of the most interesting archaeological Greco-Roman antiquities sites all over Egypt and the world.

Microgravity survey measurements covered two sites one of them about 300 m including measured points 130 about in addition to another site 70 m including measured points 30.

Microgravity data were processed to enhance data and calculate different variables. Microgravity survey successfully revealed features causes local density variations, as indicated by the acquired negative anomaly in the residual Bouguer anomalies. Final results show the presence of an anomaly represented by three oval shapes at depth 1.5 m to 11.5 m and cover an area about 2 m×2 m to 10 m×5 m. An anomaly interpreted archaeological features like tombs or corridors.

Key words: Archaeological prospecting, Bouguer, Microgravity, VGM

INTRODUCTION

Archaeological features have been found using a variety of gravity and magnetic methods. (El-Emam et al., 2014, 2021; Abdallatif et al., 2003, 2019). The microgravity method is an excellent option for locating subsurface chambers and tunnels. (Kis & Szabo, 2005; Butler, 1980; Issawy et al., 2011; Porzucek & Loj, 2021). Because of their strong density contrast with the surrounding soils and rocks, microgravity is an essential technique for cavity detection (e.g. Pašteka et al. 2020). Sensitive gravity measurements are taken at specific locations on the ground surface as part of a microgravity survey. The presence of an archaeological site, such as a tunnel or cavity, affects the physical conditions of the strata and produces a contrast between the cavity and the host stratum. If the features are large enough and the contrasts are significant enough, this contrast can be identified using appropriate geophysical techniques (McDowell, 2002).

The method is used at the Valley of the Golden Mummies ("VGM"), which is located around 380 kilometers west of Cairo at the Bahriya Oasis and is thought to be an unusual archeological phenomenon (Fig. 1). The allocation, outlining, and storing conditions are putting the valley in a dangerous scenario; as a result, a survey was carried out to find solutions.

The study area is locating in Bahariya Oasis between latitudes 28° 19 ' 51 " N and 28° 19 ' 56 " N, and between longitudes 28° 49 ' 30 " E and 28° 49 ' 41 " E. The surface of the study area is flat and composed of sandstone, sands and clay related to lower Cenomanian (Bahariya Formation) (Fig. 2). The Bahariya oasis is located in a region of the Syrian Arc anticline that runs SW–NE. It appears to extend southward to encompass the Farafra oasis and passes through the depression's main hills towards its southern portion.

Microgravity Data Acquisition

The study area had been divided into 50 m × 50 m cells (Fig. 3), with the coordinates of each cell adjusted to the base stations and indicated at each of its four corners. A Scintrex CG-5 gravimeter was used to conduct the microgravity survey (Scintrex, 2006). The standard resolution of the CG-5 is 1 microGal. The meter was first loaded from its insulated carrying case, leveled, and the base station was measured to begin the daily measuring program. At every survey, a base station for corrections to instrumental and diurnal drift was observed. The tool was leveled and its exact location was found using GPS at each measuring point. The survey had been conducted on two sites A and B spacing of approximately 1.5 m to detect small changes in the gravity values that, reflects density contrasts of the underground. Site A about 320 m^2 (20 m×16 m) includes measured points about 130 in addition to site B about 40 m^2 (3 m×12 m) including measured points about 30. Base station remeasured approximately every two hours throughout the survey and at the end of day. Trimble Differential Global Positioning System (GPS) receiver was used to estimate altitudes and station coordinates.

During measurements the various sources of error must be considered like hysteresis effect, leg lengths errors and a mechanical tare. The same operator and the same meter had been used.

Microgravity Data Processing and Interpretation

Microgravity data processing is essential step in geophysical surveys before interpretation of gravity data to improve gravity anomalies of relevance, obtain some information on source location or density contrast, and make comparisons with other data sets easier (Nabighian et al., 2005). Raw gravity measurements are generally influenced by several factors: latitude, elevation, topography of the surrounding terrain, earth tides, and rock densities. Many automatic corrections (temperature, tide, tilt, and drift) are made to the raw gravity data by the Scintrex CG-5 instrument. The drift of the instrument was figured out by taking readings over and over again at a specific base station every two hour. Oasis montaj software version 6.4 was used for the processing and analysis of the data. Latitude and terrain correction could be neglected due to the small dimension and the study areas are almost flat fig. 4.

To compensate for the reduction in gravity caused by variations in position and topography, microgravity data processing typically consists of latitude adjustment, free-air correction, and Bouguer correction (Boddice et al., 2018; Hackney, 2020; Long & Kaufmann, 2013). Following these modifications, Bouguer anomaly maps (Fig. 5) are generated from the raw gravity data.

The free air reduction is given by formula

$$\Delta g_{FA} = h\,(\text{-0.3086 mGal/m}) \qquad (1)$$

With h the height difference between a reference level (often mean sea level) and the station height.

Bouguer slab for a given gravity station

$$\Delta g = 2\pi G\rho h \qquad (2)$$

Δg is the variation in gravitational acceleration (Bouguer correction in theory), G is the gravitational constant, ρ is density, and h is height measured vertically in relation to a datum, usually sea level. When ρ is in g/cc and h is in feet, the following equation is valid (Robinson and Coruh, 1988)

$$\Delta g = 0.01278\ \rho h \qquad (3)$$

Where Δg is the Bouguer correction in mGal. A value of 2.65 g/cc, which is the specific gravity of pure quartz (Deitrich and Skinner, 1979), is sometimes used as the Bouguer density. According to Hinze, 2003.

Bouguer anomaly maps are constructed using the gravity measurements after making necessary adjustments fig. 5.

Archaeologists may find use for the Bouguer anomaly map, which shows that the long-wavelength anomalies on the map originate by deep sources, while the short-wavelength anomalies on the map are caused by shallow anomalous masses. In exploration surveys, the residual anomaly is the target of the survey. Power Spectrum method had been used to isolated a deep source (regional anomaly) component, a shallow source (residual anomaly) component and a noise component at cutoff wave no. 2.35m (Fig. 6).

Other steps are used to isolate shallower sources and deeper sources are called upward continuation. According to Jacobsen (1987) and Kebede et al. (2020), upward continuation is the transformation of a gravity anomaly that is detected at one level to a gravity anomaly that would be observed at a higher level.

Upward Continuation is a filter which calculates the potential field at heights varying from the altitude it was measured. In site A upward continuation applied to produce residual maps at different depths .5 m, 1.5 m, 2.5 m, 3.5 m, 4.5 m, 5.5 m, 6.5 m, 7.5 m, 8.5 m, 9.5 m, 10.5 m, and 11.5 m (Fig.6-7 and 8). In site A upward continuation applied to produce residual maps at different depths .5 m, 1 m, 1.5 m, and 2 m (Fig.9).

Understanding gravity data are quite easy negative anomalies indicate a difference in density, usually caused by lower density materials surrounded by higher density materials. These anomalies could show the presence of empty spaces, tunnels, or shafts. Interpretation of such anomaly aims to estimate the caves or tomb parameters such as depth, location, and geometry.

Result and discussion

In site A the bouguer map (Fig. 5A) shows that gravity anomaly values from 35.1- 33.7 mGal low gravity values 34.3-33.7 mGal concentrated in center part of the map in NS direction. High gravity values in the Bouguer anomaly map indicate the surrounding materials, whereas low gravity values inferred the existence of hidden features like caverns, tombs, and passageways.

In site B the bougure map (Fig. 5B) shows that gravity anomaly values from 35.2- 34.4 mGal low gravity values 34.6-34.4 mGal concentrated in NE and SE corners of the map. High gravity values in the Bouguer anomaly map indicate the surrounding materials, whereas low gravity values inferred the existence of hidden features including caverns, tombs, and crypts. To emphasis the result the separation of shallow sources from deep sources had been performed. A low-pass filter with cutoff 2.35 m was used to obtain regional maps (Fig. 6 A –C). Regional maps in studies areas are nearly similar to bougure maps. A high-pass filter with cutoff 2.35m was used to obtain residual maps (Fig. 6: B –D). Residual anomaly is arising from shallow sources, for example, a cave, or buried body that is the target of the survey. Residual map shows show that the low gravity anomaly in site A concentrated in center part of the map in NS direction as bougure and regional maps, while in site B the low gravity anomaly concentrated in NE corner.

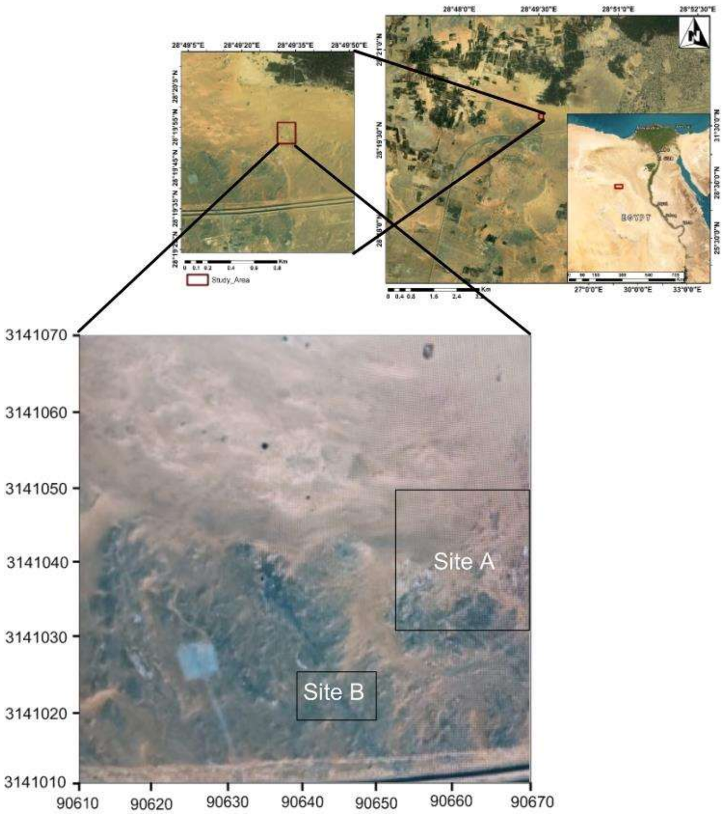

Fig.1: Sketch of the location of the study area.

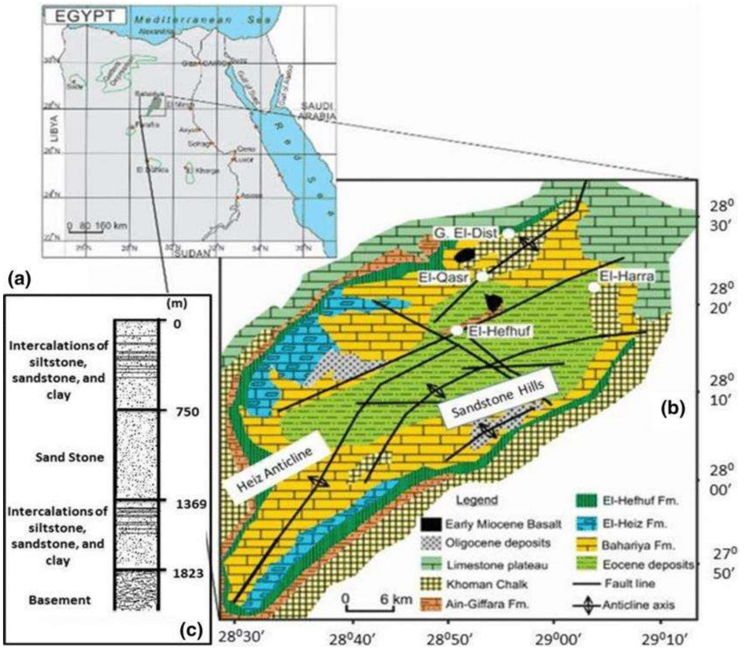

Fig.2: a) Map of Egypt showing the location of Bahariya Oasis in the Western Desert, b) the geologic map of the Bahariya oasis modified from El-Akkad and Issawi (1963), c) subsurface sequence of the BOX-1 Well (after Moustafa et al. 2003)

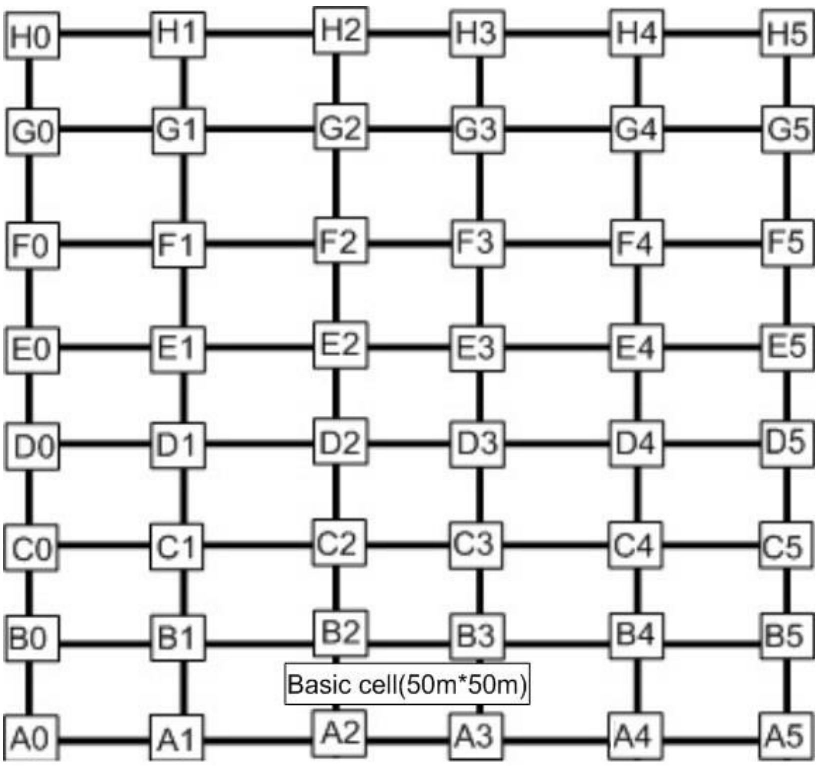

Fig.3: Allocating and land marking the measuring cells

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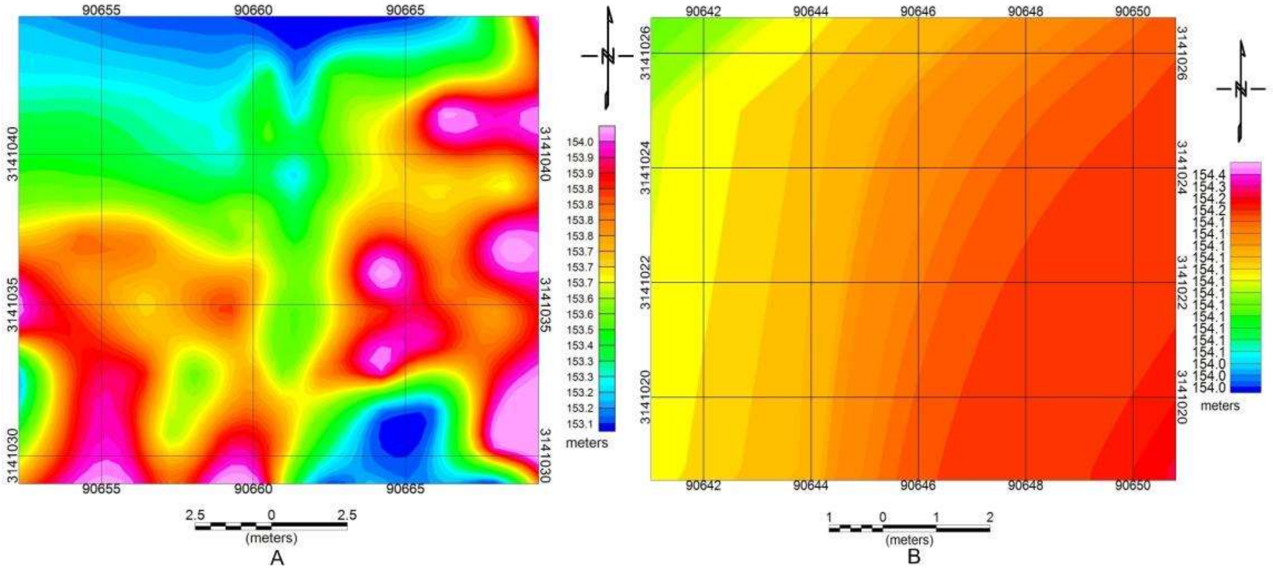

Fig. 4: A Map showing elevations at site A- B Map showing elevations at site B

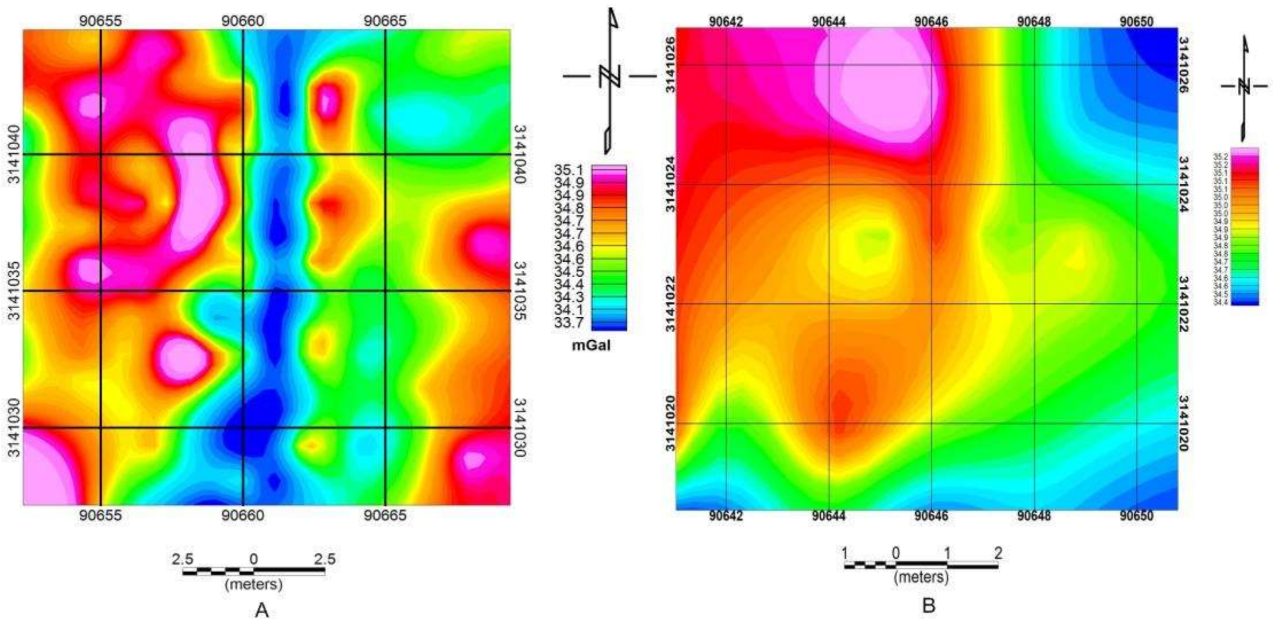

Fig. 5: A Map showing bouguer anomaly map at site A- A Map showing bouguer anomaly map at site B.

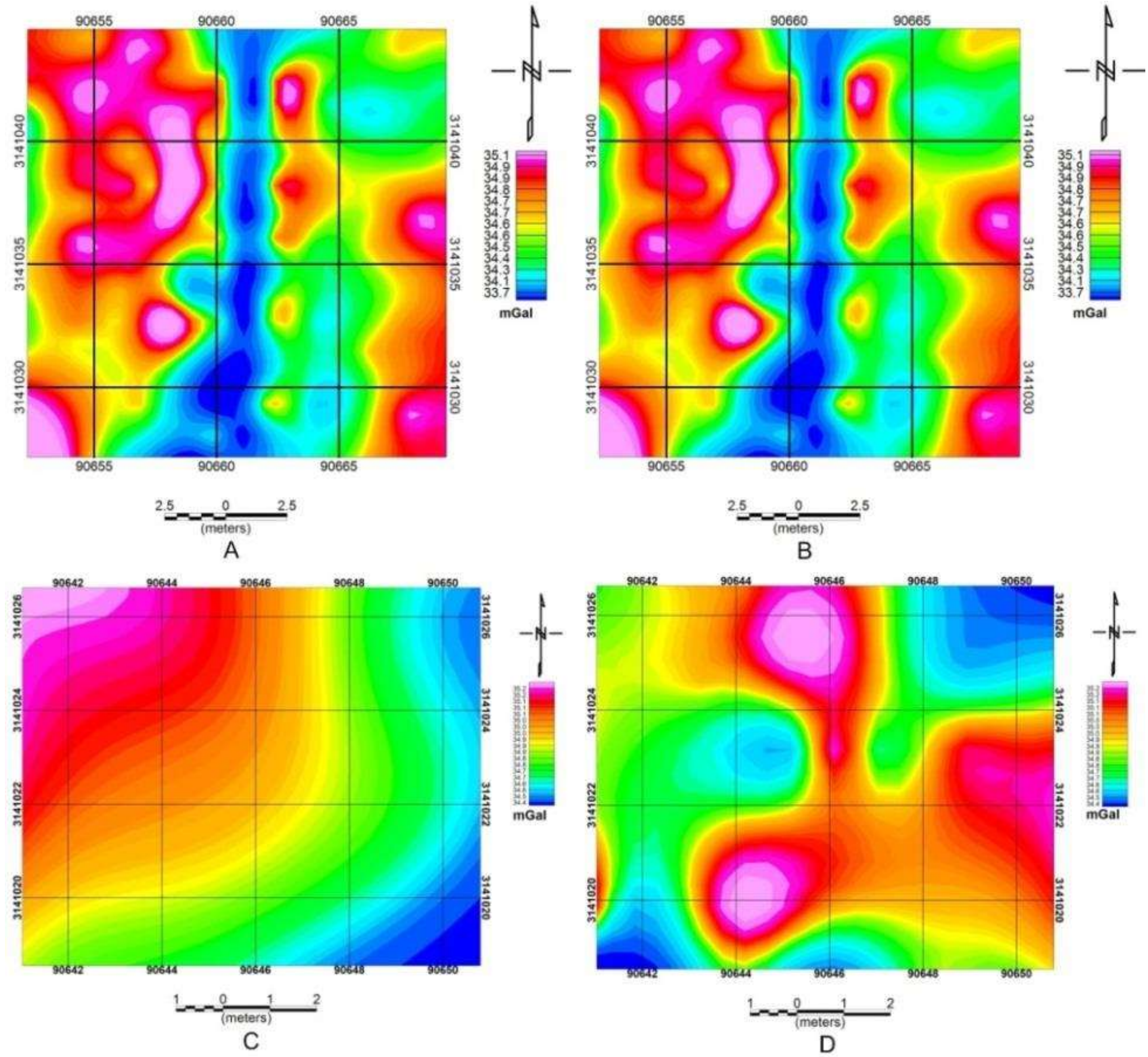

Fig. 6: (A -B)Maps showing regional and residual anomaly maps respectively at site (C -D) Maps showing regional and residual anomaly maps respectively at site B.

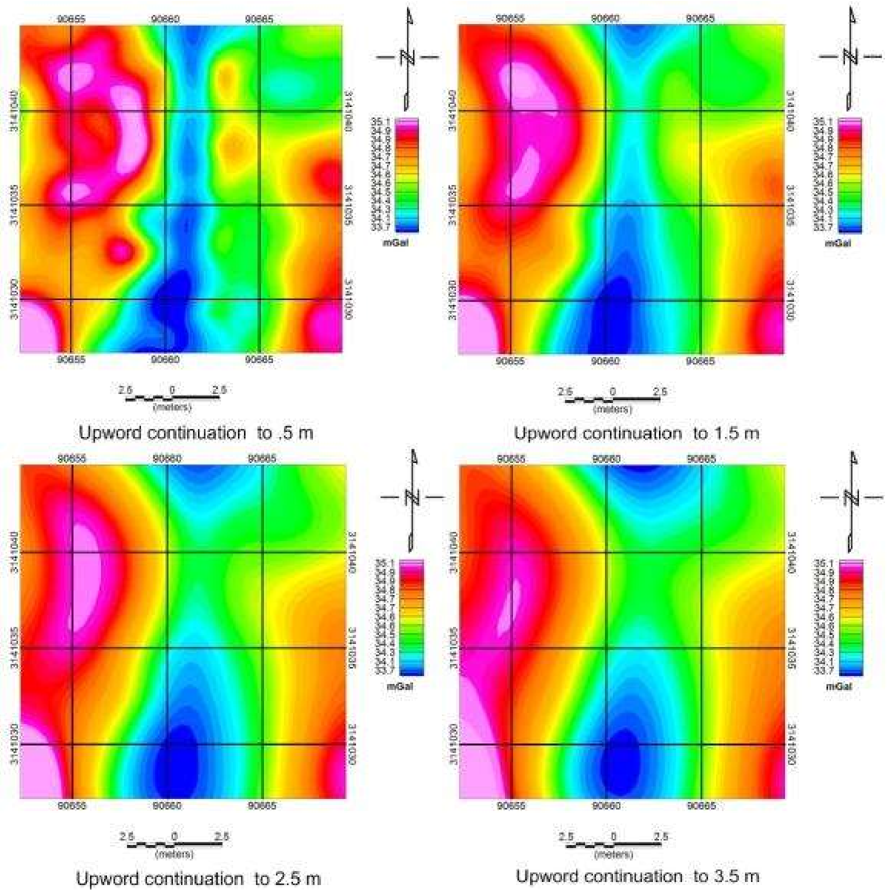

Fig. 7: shows upward contiuation maps at depths .5 m to 3. 5 m at site A

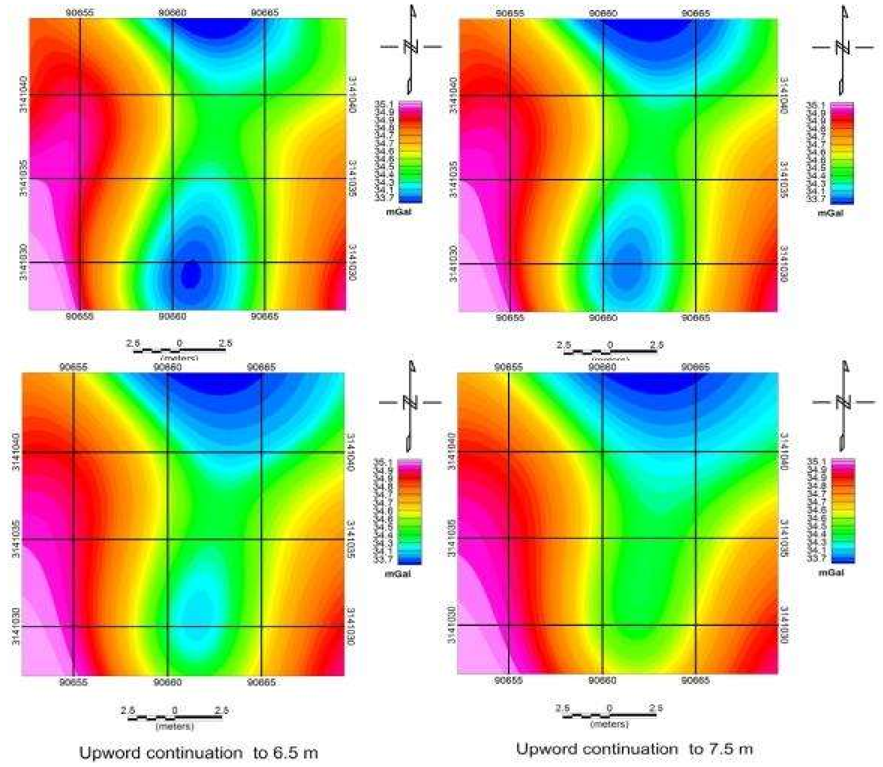

Fig. 8: shows upward contiuation maps at depths 4.5 m to 7. 5 m at site A

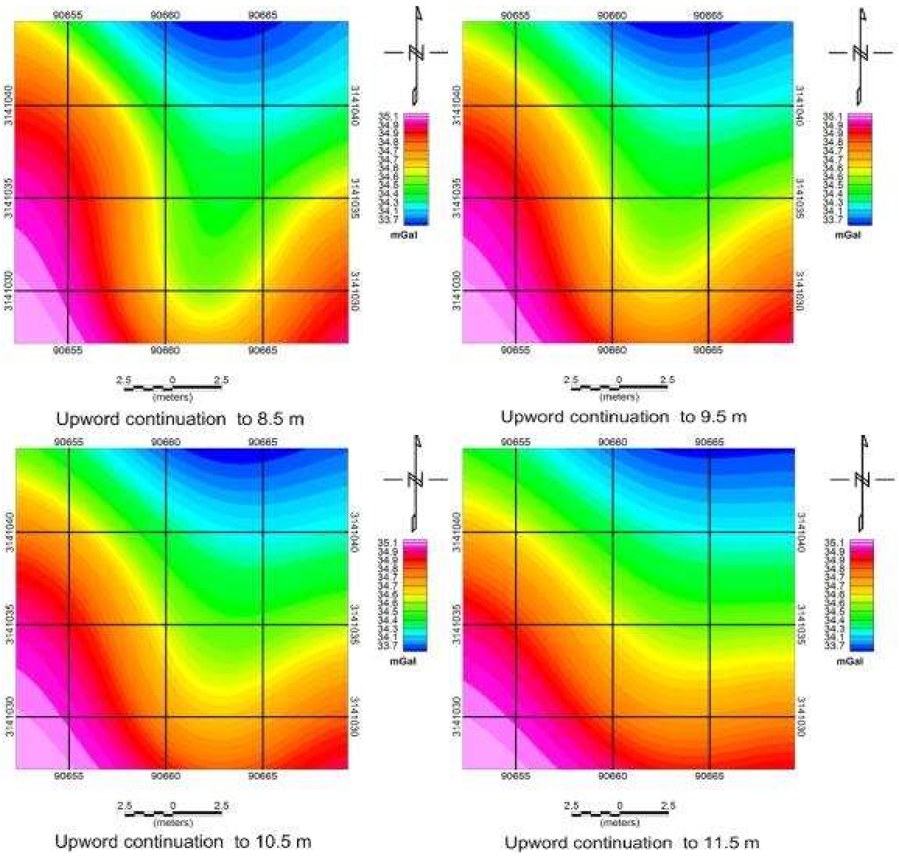

Fig. 9: shows upward contiuation maps at depths 8.5 m to 11. 5 m at site A

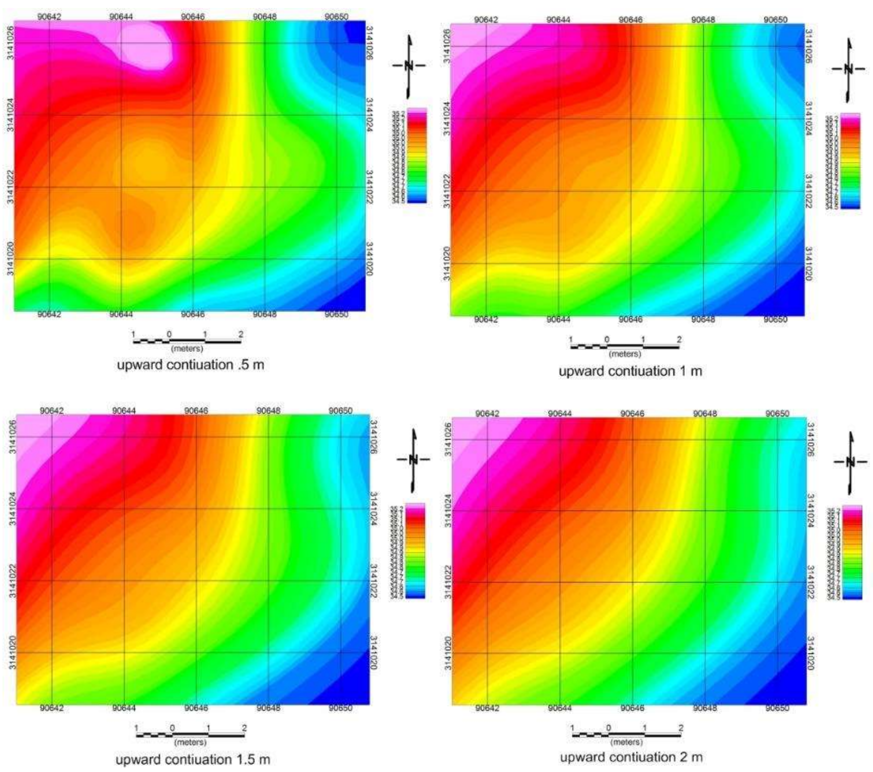

Fig. 10: shows upward contiuation maps at depths.5 m to 2 m at site B

Conclusion

The microgravity survey's findings support the theory that variations in gravity levels reflect shifts in subsurface density, revealing the presence of archaeological objects as corridor or tombs. Gravity anomaly in site A shows two oval anomaly shape in the northern and southern part of site that could be important archaeological features like tombs. Oval shapes become very clear in the continuation maps (Fig. 7-8 and 9) from depth 1.5 m to 11.5 m

The oval anomaly shape in the northern part appear at depth 1.5 m to 11.5 m and cover an area about 10 m×5 m,whiele the oval anomaly shape in the southern part of site appear at depth 1.5m to 7.5 m and cover an area about 7 m×5 m.

Gravity anomaly in site B shows one oval anomaly shape in the north eastern corner of site that could be important archaeological features like tombs. Oval shapes become very clear in the continuation maps (Fig. 10) from depth .5 m to 2 m and cover an area about 2 m×2 m.

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