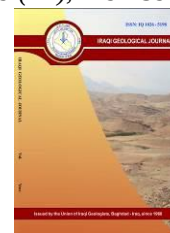




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Detection of Shallow Subsurface Utility Using Magnetic Method at the Campus of the University of Baghdad, Jadriya, Iraq

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Abstract

Ground magnetic surveying was used to identify shallow subsurface engineering utilities at the University of Baghdad campus in Jadriya, Iraq. The site area was surveyed with a proton magnetometer G816 along closely spaced profiles to obtain the Total Magnetic Intensity (TMI) data. Twelve profiles trending east-west, and six others trending north-south, were surveyed. The length of profiles ranges between 31 and 39 m, and the spacing between the measured stations was 1 m. Standard corrections were applied, followed by Reduction To Pole and regional- residual separation to enhance shallow magnetic responses. The Total Magnetic Intensity, Reduction To Pole, regional, and residual profiles and maps show a main magnetic negative anomaly, whereas the residual anomaly showed linear characteristics suggestive of near-surface sources. The interpreted anomalies exhibit clear linear trends that correlate spatially with subsurface utility layouts provided by the engineering department, suggesting that the detected responses are mainly associated with buried reinforced concrete rooms (Shelters) and electrical cables. However, noticeable discrepancies between mapped utility paths and the detected anomaly locations indicate that the existing engineering maps require updating. This study indicates that ground magnetic surveying offers a dependable, non-destructive means for identifying and delineating shallow engineering utilities, thus safer excavation planning in urban sites.

Keywords: Magnetic survey; Engineering subsurface utilities; Reinforced concrete buildings; Electrical cables; Shallow geophysical investigation

1. Introduction

The geophysical magnetic method, which is rapid and low- cost, is used to investigate the anomalies within the Earth's magnetic field in certain locations. The magnetic anomalies are usually related to the subsurface variation in the distribution of magnetic susceptibilities or the presence of electromagnetic sources (Nettleton, 1971; Blakely, 1995; Milsom and Eriksen, 2011; Hinze et al., 2013; Nabighian and Li, 2015). Several processing techniques are usually used on the magnetic data to enhance the field data. These include diurnal correction, unifying the different day surveys according to the base station, and then using many analytical techniques to clarify and isolate magnetic anomalies. The interpretation includes detecting the location of the subsurface source extension and depth (Hinze et al., 2013; Li et al., 2021). The magnetic method is widely used in mineral exploration, geological mapping, deep faults detection, structures of basements, and tectonic studies (Akintayo et al., 2014; Joshua et al., 2017; Al-Garni, 2010; Reynolds, 2011; Feumoe et al., 2012; Oyeniyi et al., 2016; Mbang

et al.,2018; Al-Banna and Daham, 2019). This method is also used in environmental studies, near-surface engineering investigations, and archaeological prospection (Marchetti et al., 2002; Itembo et al., 2020; Thomposon et al., 1980; Sharma, 2012; Al-Bahadily et al., 2015; Keumala et al., 2020; Mendoza et al., 2023). The magnetic method, in recent years, has been used to identify shallow subsurface engineering and environmental targets containing ferromagnetic materials or electromagnetic sources (Alao et al. 2024; Omolaiye et al. 2024; Adebisi et al. 2026).

This study aims to use a ground magnetic survey to delineate shallow subsurface engineering utilities at the Campus of the University of Baghdad, Jadriya, Baghdad, Iraq. This study attempts to detect the path of electrical cables in the study site (at a depth not exceeding 5 m) as an application of magnetic survey to detect the shallow subsurface objects or engineering utilities in urban areas.

2. Location of the Studied Area

The study site is a park located in front of the Computer Department at the Campus of the University of Baghdad. The site is located in zone 38 N of UTM coordinates: 3681792 m – 3681759 m Northing and 442395 m – 442417 m Easting (Fig. 1). It is worth noting that the study site is covered by alluvial sediments of the Tigris River with a thickness of more than 30 m (NCCI, 2002), and the groundwater depth in the University of Baghdad Campus ranges from 5 to 8 m (Thabit et al., 2016).

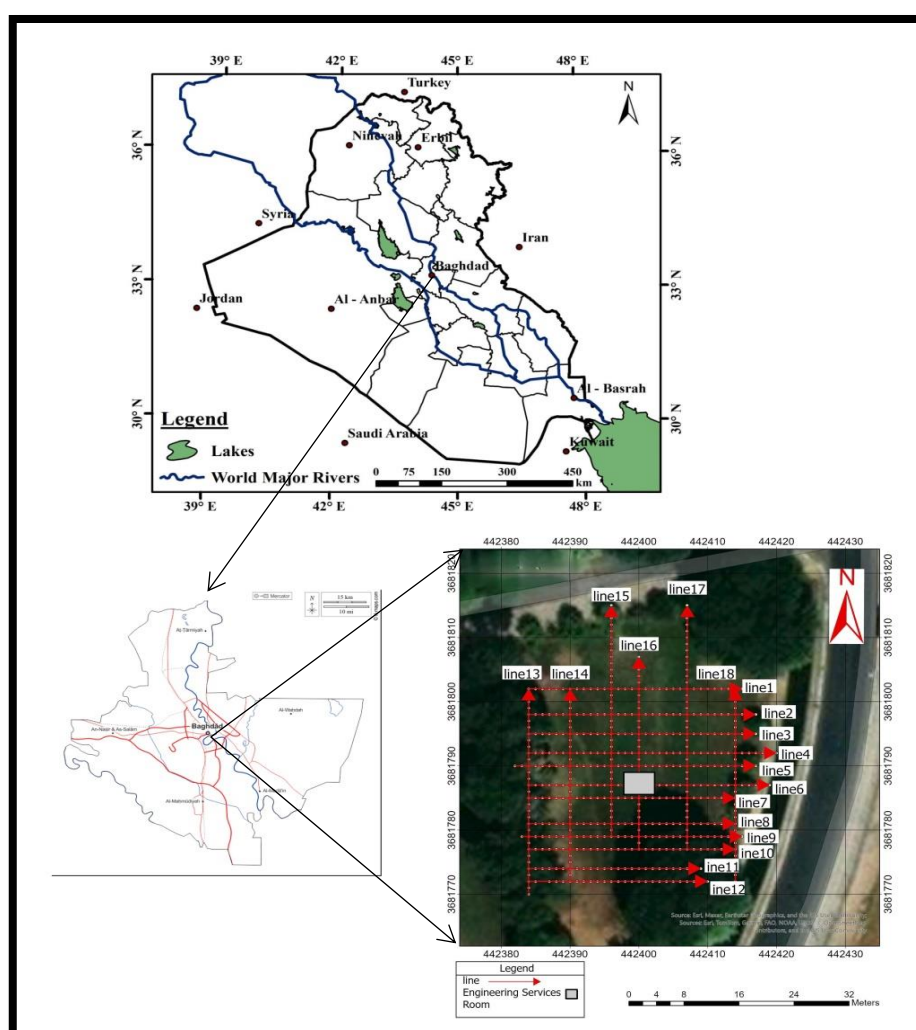


Fig. 1. Location of the study site at the University of Baghdad (Jadriyah)

3. Materials and Methods

3.1. Data Acquisition and Processing

Eighteen Total Magnetic Intensity (TMI) lines were acquired in the study site, twelve lines oriented east-west and six lines running from north to south. The magnetic values of the base station are measured twice or more during the magnetic measurement along each line. These lines cover the area surrounding the subsurface engineering utility room (Fig. 1). The spacing between adjacent stations was 1 m, the line lengths range from 31 to 39 m, and the spacing between profiles range from 2 to 5 m (Fig. 1). The height of the sensor of the instrument during the measurements was 1.24 m (Fig. 2a). A G816 proton magnetometer with an accuracy of ± 1 nanotesla was used (Fig. 2b). The diurnal correction was applied to the raw data to remove daily variations in the measured data, depending on base station reoccupation. The resulting data were expected to be complex due to interference from different magnetic field sources. The reduction to pole technique was used in most magnetic studies to transform the magnetic data to be as it is measured at the pole (Qiang et al., 2025). The TMI field data are used to determine the magnetic anomaly relative to the base station to eliminate the Earth's magnetic field. The obtained magnetic anomaly data are subjected to the algorithm process proposed and developed by Baranov and Noddy (1964) to obtain the RTP profiles. The magnetic field parameters used to convert the TMI to RTP, in the study site, are inclination 49° , declination $+4.7^\circ$, and magnetic field strength 46960.5 nT.

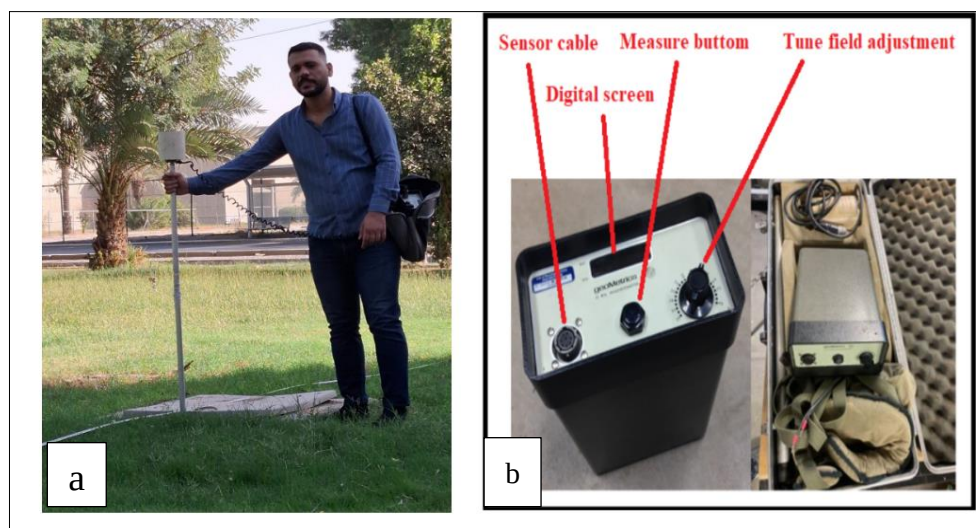


Fig. 2. a) Magnetic measurements in the field, and b) Proton Magnetometer G816

3.2. Regional- Residual Separation

The regional and residual magnetic anomaly profiles' contribution to the total magnetic field anomaly is simply determined quantitatively using Geosoft Oasis Montaj, and the magnetic anomaly map is also displayed using Surfer 13. The magnetic data consist of regional components related to deep sources, while the residual anomalies are associated with shallow subsurface targets (Nettleton, 1971). The regional field was estimated using the upward technique up to 8 m, which shows good regional results. The residual magnetic field was calculated by subtracting the regional magnetic anomaly from the RTP magnetic data deduced from the corrected total magnetic intensity data.

$$RTP (residual) = RTP (determined from TMI) - RTP (regional) \quad (1)$$

All corrections, filtering, reduction to the pole (RTP), and separation procedures were performed using specialized geophysical processing software.

4. Results

4.1. Magnetic Profiles

The magnetic profiles provide a representation of the subsurface variations across the study site. These profiles were processed using Geosoft Oasis Montaj (Version 8.4).

4.1.1. Magnetic lines 1-6

The magnetic lines 1-6 are located in the northern sector of the study site, relative to line number Six (which is passing through the center of the study site). These lines are oriented in an east-west direction. These lines were analyzed to investigate the subsurface magnetic objects and structural framework. The regional magnetic profiles of the six lines mainly show negative anomalies extended from 16 to 18 m in length along the profiles. The main negative anomaly is located at a distance of 11 to 28 m (from the starting point of the measuring station of each line) on most lines, except line four, where the anomaly seems to be positive in the wide negative anomaly.

Line 4 shows relatively high magnetic values in the central part of the regional and residual profiles; this may be due to the presence of a reinforced concrete wall. The residual magnetic profiles of the six lines show many positive magnetic anomalies. Generally, two positive residual magnetic anomalies are detected at each line. The locations of the positive anomalies in each line for the six lines are as follows: (13, 16) m, (14, 17) m, (14, 18) m, (14, 21) m, (19, 24) m, and (13, 20) m, respectively (Fig. 3).

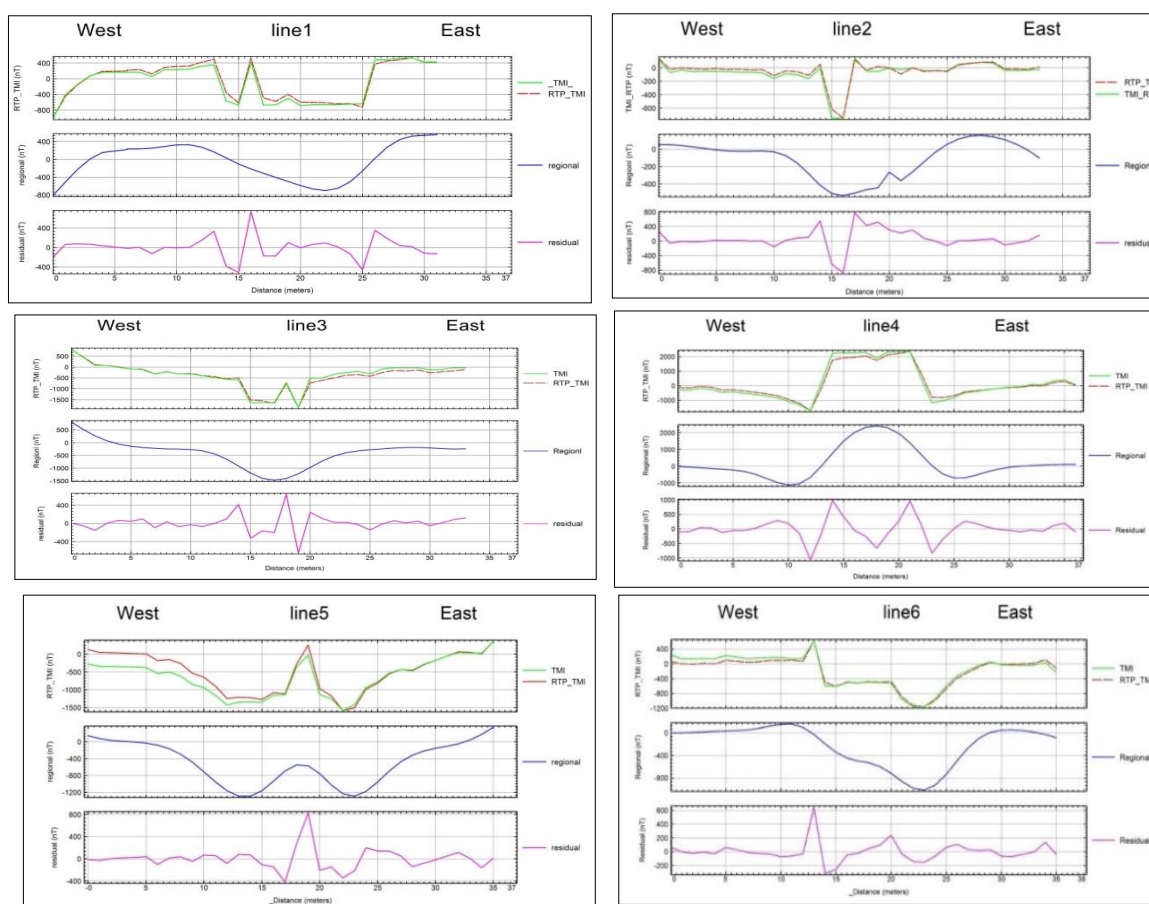


Fig. 3. The TMI, RTP, regional and residual magnetic anomaly profiles of lines 1-6 (Trending E-W) in the study site

4.1.2. Magnetic lines 7-12

The magnetic lines 7 to 12 cover the southern sector of the study site. These lines are trending east-west. These data from these lines were analyzed by upward continuation, to determine the regional magnetic anomaly, and then the residual magnetic anomaly is obtained, in order to detect the subsurface magnetic targets and associated civil engineering structures. The regional magnetic profiles of the six lines mainly show a central negative anomaly, with an extended width range of 9-14 m. The main negative anomaly is located at a distance of 9 to 23 m (from the starting point of the measuring station of each line) on most lines. This negative regional magnetic anomaly seems to be related to the presence of a subsurface reinforced concrete utilities room. The residual magnetic profiles of the six lines show many positive magnetic anomalies. Generally, three positive residual magnetic anomaly peaks are detected at each line. The positive anomalies in each line, for the lines 7 to 12, are located from the point of the start station at distances as follows: (12, 17, 22) m, (13, 16, 19) m, (12, 17, 22) m, (13, 16, 20) m, (11, 14, 16) m, and (12, 14, 16) m, respectively. These positive magnetic anomalies are related to the presence of electrical cables (Fig. 4).

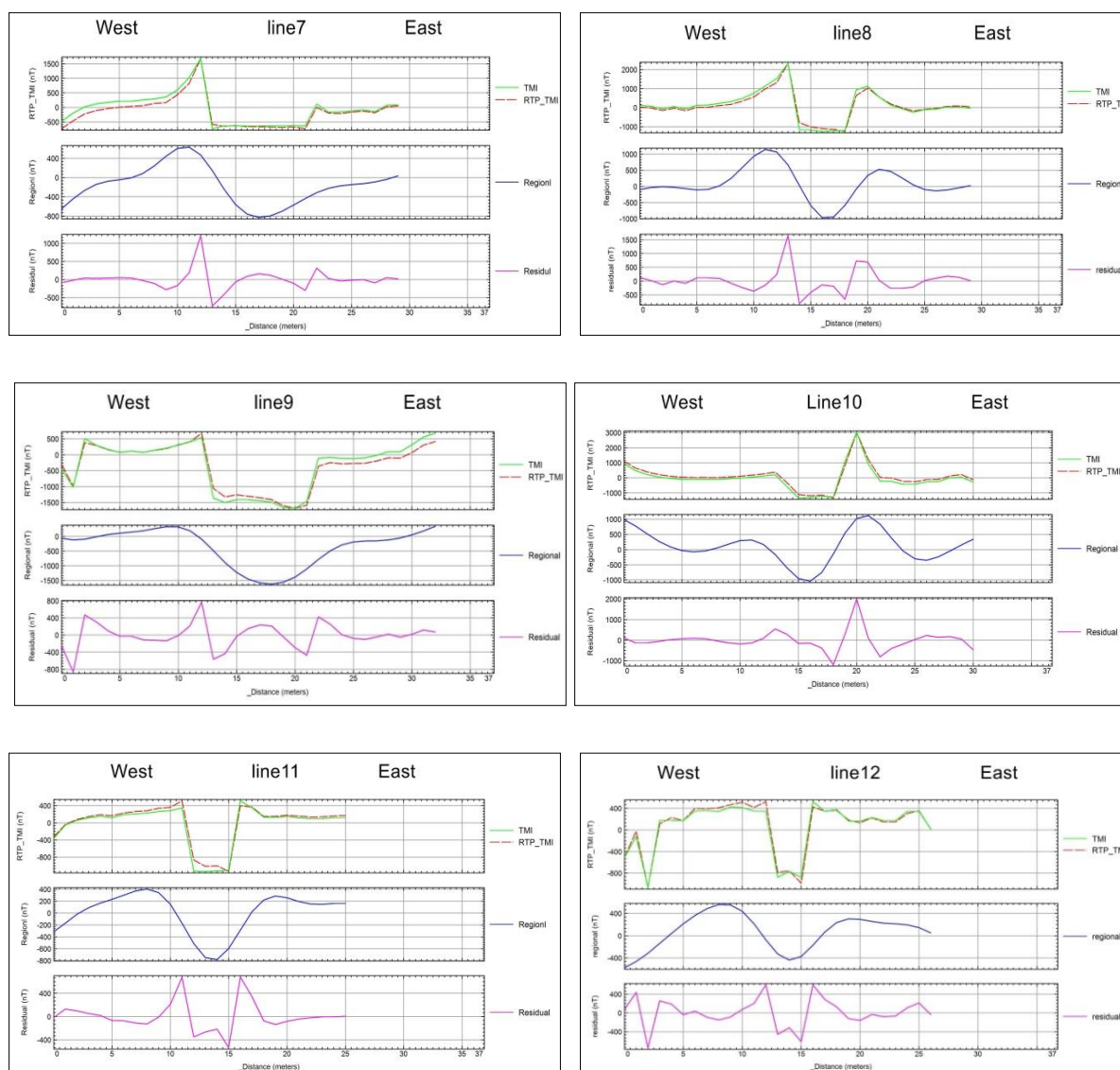


Fig. 4. The RTP, regional, and residual magnetic anomaly profiles of lines 7-12 (Trending E-W) in the study site

4.1.3. Magnetic lines 13-18

The magnetic lines 13 to 18 cover the entire study site. These lines are oriented north-south. These lines were analyzed to detect the E-W magnetic sources. Generally, the regional magnetic profiles of lines 13-18 are characterized by high magnetic anomaly, located at distances 9, 10, 9, 5, 12, and 7 m from the starting point of each line, respectively. The regional anomaly of profiles 17 and 18 are characterized by high magnetic values, which decrease gradually toward the north by a magnetic value that not exceed 1000 nT. The residual magnetic profiles of lines 13-18 include many positive residual anomalies with low magnetic values not exceeding 200 nT. Most of these positive anomalies are located on the southern side of the survey lines, at distances ranging from 2 to 20 m. Line 13 shows a positive residual anomaly at the northern side at a distance of 27 m (Fig. 5).

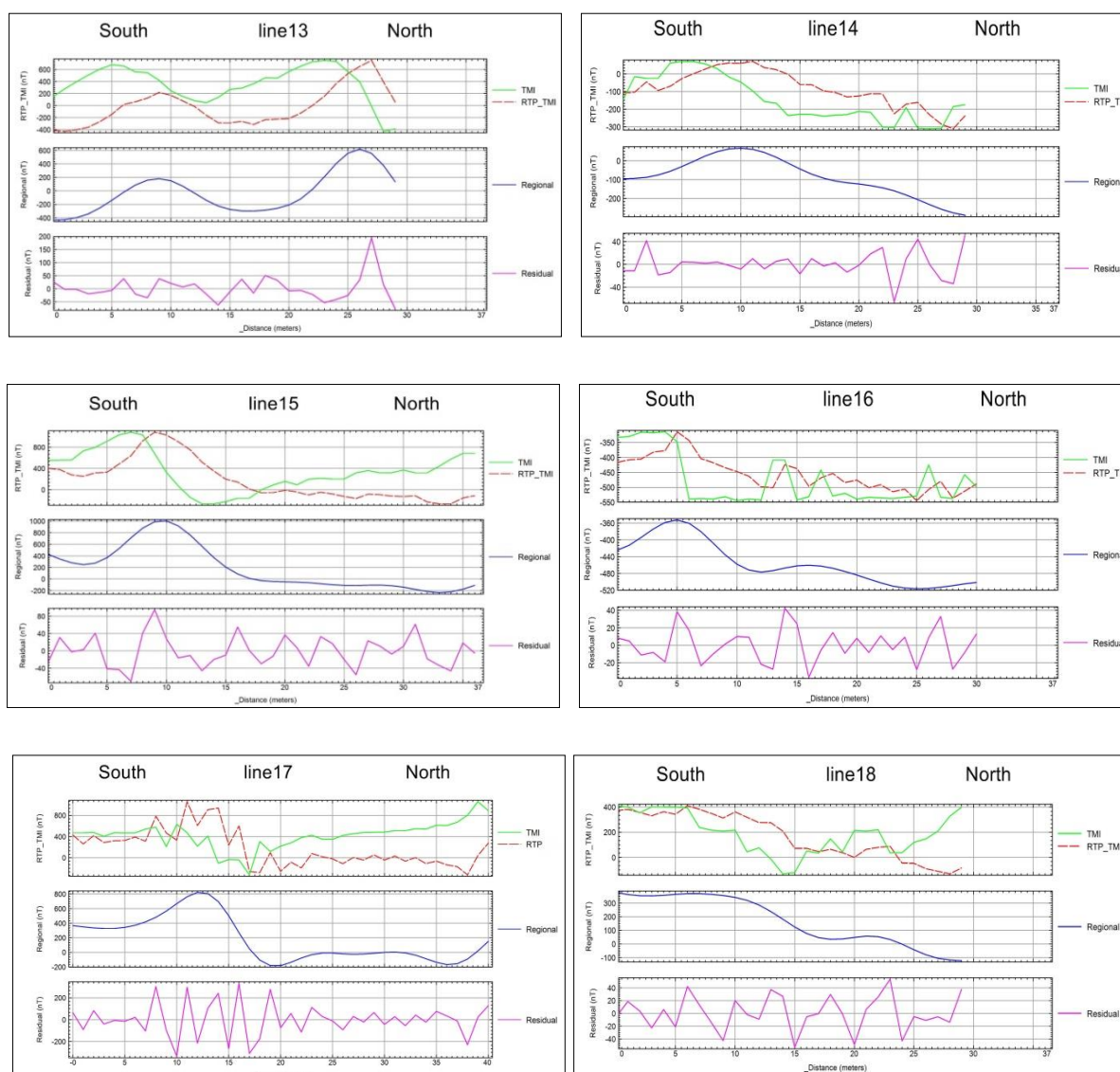


Fig. 5. The RTP, regional, and residual magnetic anomaly profiles of lines 13-18 (Trending N-S) in the study site

4.2. Magnetic Anomaly Maps

Magnetic anomaly maps were generated to investigate the spatial distribution of magnetic anomalies, which are related to the subsurface magnetic sources in the study site. The analysis includes TMI, RTP, regional, and residual magnetic maps (Fig. 6). The TMI map represents the primary

magnetic dataset and reflects the combined effects of both shallow subsurface sources and deeper geological structures.

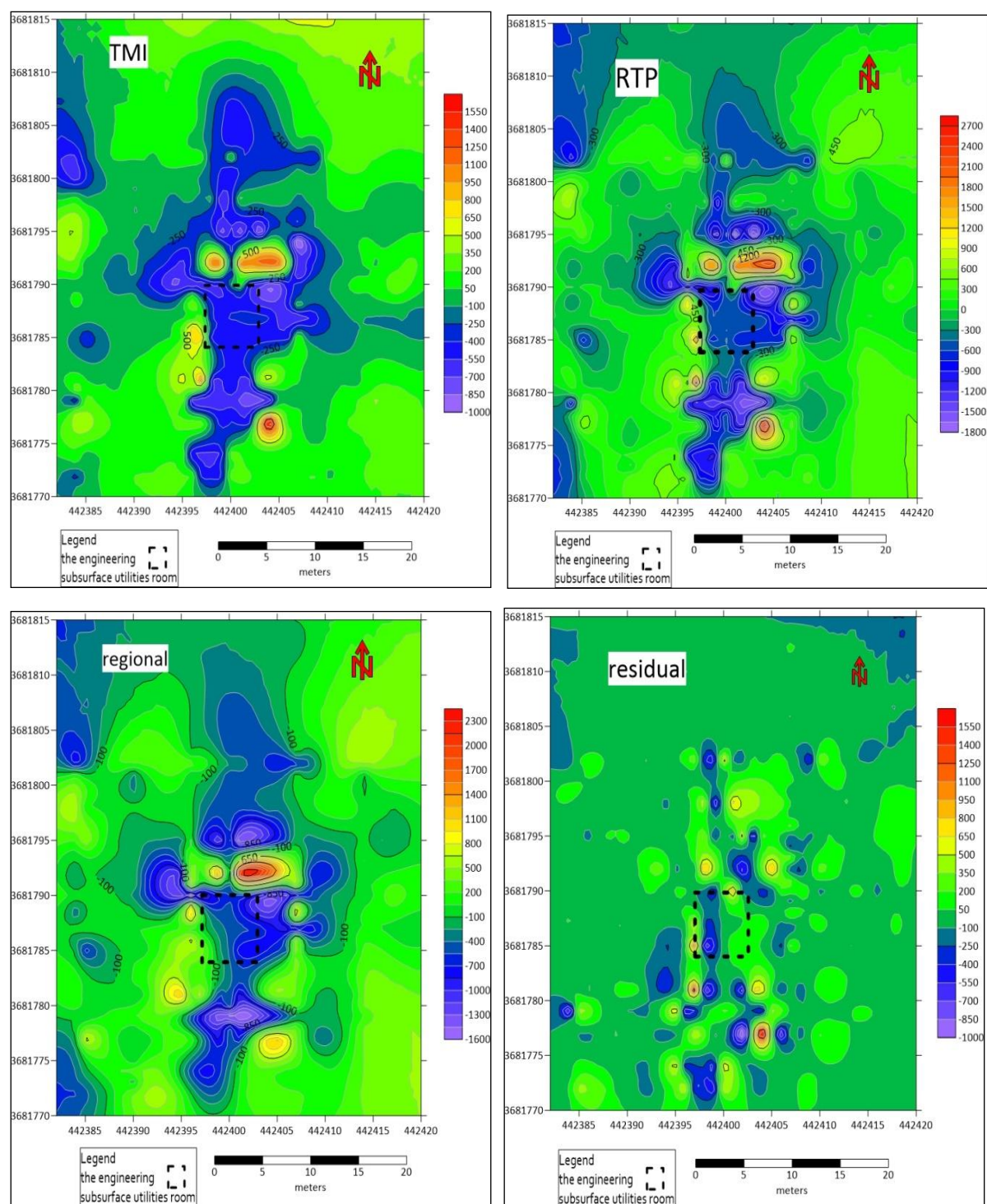


Fig. 6. The TMI, RTP, Regional, and Residual magnetic anomaly maps of the study site

The TMI map shows a main low magnetic value in the center of the study site, extending in N-S direction, with some local high magnetic anomalies (2500-2600nT) within the low magnetic anomaly. The RTP magnetic anomaly map shows the same anomalies that appear in the TMI map, with more enhancements in the shape of the magnetic anomalies. The RTP map was produced to reduce the effects of magnetic inclination and declination, thereby centering the magnetic anomalies over their causative

sources. This transformation enhances the symmetry of the anomaly and facilitates more direct spatial correlation between magnetic responses and buried magnetic bodies.

To distinguish shallow magnetic sources from deeper geological contributions, regional-residual separation was applied. The N-S negative (low) regional anomalies appear in the magnetic anomaly, RTP, and regional anomaly maps, which are characterized by a width that ranges between 10 and 12 m, and amplitude reached a range of 1200-1500nT. This negative anomaly is related with the subsurface reinforced utilities room. The residual anomalies map shows many positive and negative anomalies (Fig. 6). The positive and negative residual anomalies seem to be located along a path that can be used to determine the route of the electrical cables. Two paths were drawn, passing through the positive magnetic anomalies (Fig. 7). The two paths were compared with the cable on the site's engineering map, and a good match was observed (Fig. 7).

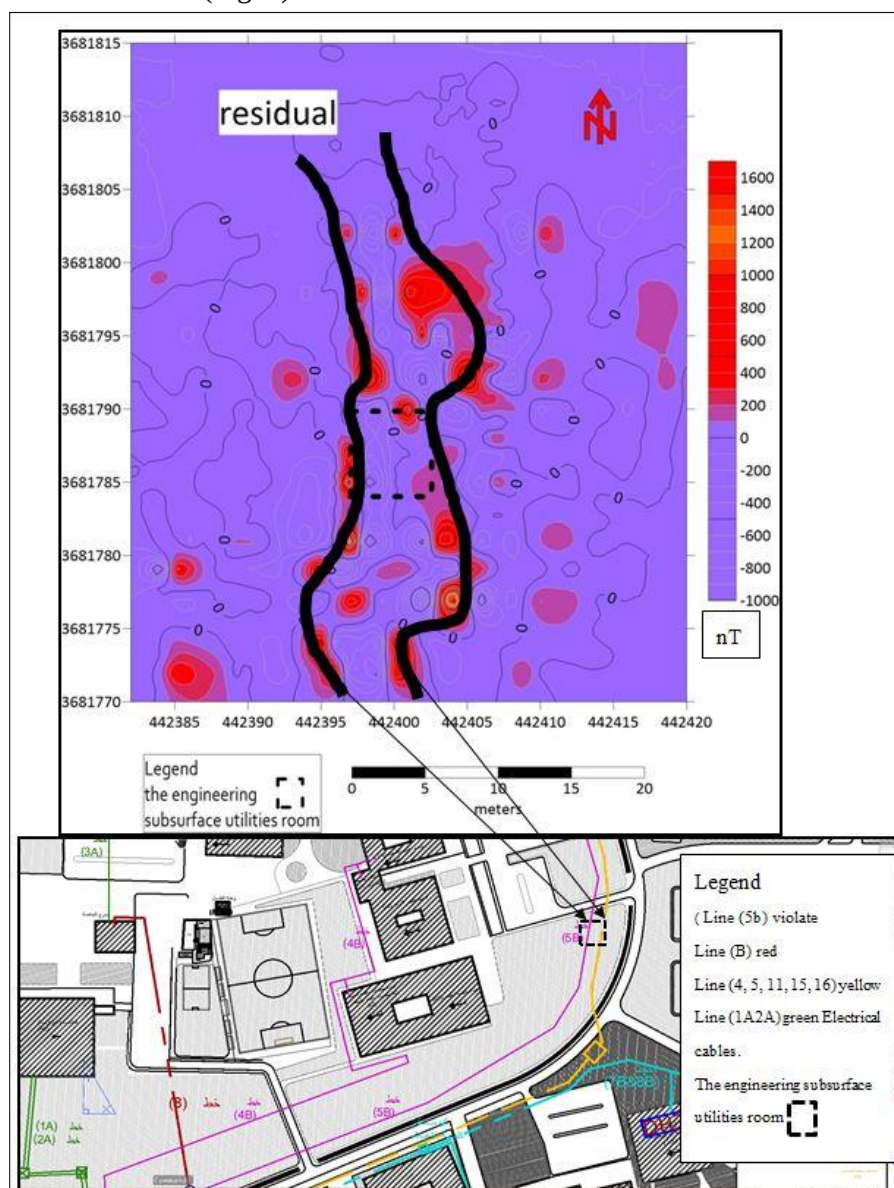


Fig. 7. The residual magnetic anomaly map and the AutoCAD subsurface utility layout of the electrical cables provided by the Engineering Consulting Office

5. Discussion

The study site is located within the mid-latitude magnetic region, which is characterized by moderate magnetic inclination and a relatively low declination value. The causative magnetic sources

are interpreted to predominantly extend in the N-S direction. Accordingly, most magnetic profiles were oriented E-W, i.e., approximately perpendicular to the expected source trend, to enhance anomaly resolution. Consequently, both TMI and RTP magnetic data provide reliable results.

For survey lines trending N-S, the RTP magnetic values are observed to be shifted approximately 2 m northward, relative to the corresponding TMI anomalies. This shift is likely related to the shallow depth and geometry of the magnetic source, as well as limitations in the RTP transformation at mid-latitude.

The regional magnetic field shows amplitudes ranging from 1000 to 3500 nT along the E-W profiles, whereas along N-S profiles the amplitudes range from 200-1000 nT. The values of the residual magnetic anomalies along the E-W lines range from 1200 to 2000 nT, while those along N-S lines range from 90 to 150 nT. These differences further support the interpretation that the dominant structural trend of the magnetic anomalies is N-S.

The main subsurface reinforced concrete utility room is expressed in the magnetic data as a negative anomaly extending in the N-S direction. The negative anomaly reaches its maximum width in the central part of the study site and gradually narrows toward both the northern and southern parts. This pattern suggests that the subsurface structure is laterally confined to the central portion of the site.

The residual magnetic anomaly map reveals a cluster of high-amplitude and short-wavelength linear anomalies in the central study site, which reflect the presence of highly magnetic subsurface sources (Fig. 7). Their linear orientation closely corresponds to the utilities alignments, as shown in the engineering plans and supports their interpretation as buried electrical cables. The confinement of these anomalies to narrow zones suggests shallow burial depths and limited lateral continuity.

These findings indicate that the existing engineering map may require a revision, as the documented cables' positions show spatial discrepancies relative to the detected magnetic anomalies, despite confirming their presence within the surveyed site.

6. Conclusions

The RTP processing and regional-residual separation, used in this study, improved the anomalies related to the relatively deep and shallow magnetic sources. The deeper magnetic source at the study site is found to be related to the presence of a subsurface reinforced concrete room, while the residual magnetic anomalies detect the route of the subsurface electrical cables at the study site. The obtained results revealed the path of the electrical cables at the study site. The good result of the magnetic method application in this study confirms the ability of geophysical methods to detect shallow subsurface features in urban environments.

Declaration of Competing Interest

The author declares no conflicts of interest.

Data Availability

Data will be made available on request.

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