Journal of Applied Geophysics 204 (2022) 104678

Contents lists available at ScienceDirect

Journal of Applied Geophysics

journal homepage: www.elsevier.com/locate/jappgeo

Environmental geophysical study for ideal locations of landfill within Iraqi Southern Desert

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A R T I C L E I N F O

Keywords:
Al-Khersan
Ameen
Gravity and magnetic
Iraqi Southern Desert
Basrah University for Oil and Gas
Landfill

A B S T R A C T

Solid wastes and toxic chemicals are the main contributors, which influence the environment and quality of life. Demographic population, economic and building structures considered as major factors that are controlling such pollution. Therefore, it is very important to find proper areas to dispose of these pollutants. The current study aims to find best locations for wastes disposal areas that comply with the national and international standards. The study area, the Iraqi Southern Desert had been subjected to comprehensive study for geology, gravity and magnetic investigations. The existence of impermeable beds, tectonic, seismology and structural features show that the area understudy is located in the stable shelf that has no folding and faulting complexity; however, the saline groundwater lies at about 150 m depth. The gravity field data were analyzed using three methods: Trend Surface Analysis, Average Smooth Matrix and the First Vertical Derivative. Negative and positive gravity anomalies were noticed and interpreted. Remote sensing is also carried out in order to locate linear features, drainage patterns and watersheds within the Southern Desert depending on the interpretation of satellite images of the study area. Finally, a comparison of natural and environmental factors with remote sensing and both gravity and magnetic analyses gives thirteen locations of different coordinates. Only sites 1, 2, 3,10 and 13 yield good environment satisfaction agreement that permits us to choose them as a good locations for future landfill waste purposes.

1. Introduction

Landfill solids (disposal of solid wastes) are the solid waste residues of all sources or undesirable materials resulted from several human activities. Arab countries including Iraq use exposed landfills with less cost and easier to implement. Since the methods used in this type of projects are almost to bury pollutants by earth soils inside uncased landfill, which leads to cause leakage of toxic fluids infiltrate and transport to groundwater and rivers, however the emission of gases and bad odors (resulting from the decomposition of organic matters) will surely increase the danger of these wastes (Keller, 1985).

Generally, the Iraqi Southern Desert represents the extension of the northern part of the regional plateau of the Arabian Peninsula covered by Tertiary marine carbonate and younger continental clastic deposits. It is dissected by systems of N—S and NE–SW wadies. The desert is built up mainly by carbonate facies, clastics and evaporites sequences; while, most of its parts, still not well explored or mapped to allow a fair understanding of its geology and mineral resources, their ages range from Paleocene to Recent. The desert, which occupies about 76,000 Km^2 is located between longitudes 48°- 42°30′ E and latitudes 32°- 29° N. Administratively, four governorates share the area of the Southern Desert; they are Najaf, Samawa, Nasiriya and Basrah Provinces. Because of its harmful climate and deficiency of water, the majority of the Southern Desert is not populated. Therefore, most of the present towns are located either along the Euphrates River or as small towns far away from these cities as shown in (Fig. 1). It has relatively flat terrain, sloping gently towards NE. The elevated part (300–400) meters (a.s.l.) exists along the Iraqi–Saudi Arabian borders; while the apparently depressed part (20–150) meters (a.s.l.) is developed along the western side of Euphrates River. The depressed area comprises morphologic features, such as Bahr Al-Najaf, Sawa Saline Lake depressions (Ma'ala, 2009).

Unfortunately, there are few studies in Iraq deal with this type of researches. Al-Halbusy, (2008) performed a geological-geophysical-environmental study in order to locate the right sites for getting grid of polluted wastes within northwestern Iraq using remote sensing, magnetic and gravity information. The aim of this research is to explore the suitable locations within the Iraqi Southern Desert used to get quite of the industrial pollution and/or contamination such as solid waste and

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https://doi.org/10.1016/j.jappgeo.2022.104678
Received 20 January 2020; Received in revised form 24 November 2021; Accepted 12 May 2022
Available online 28 May 2022

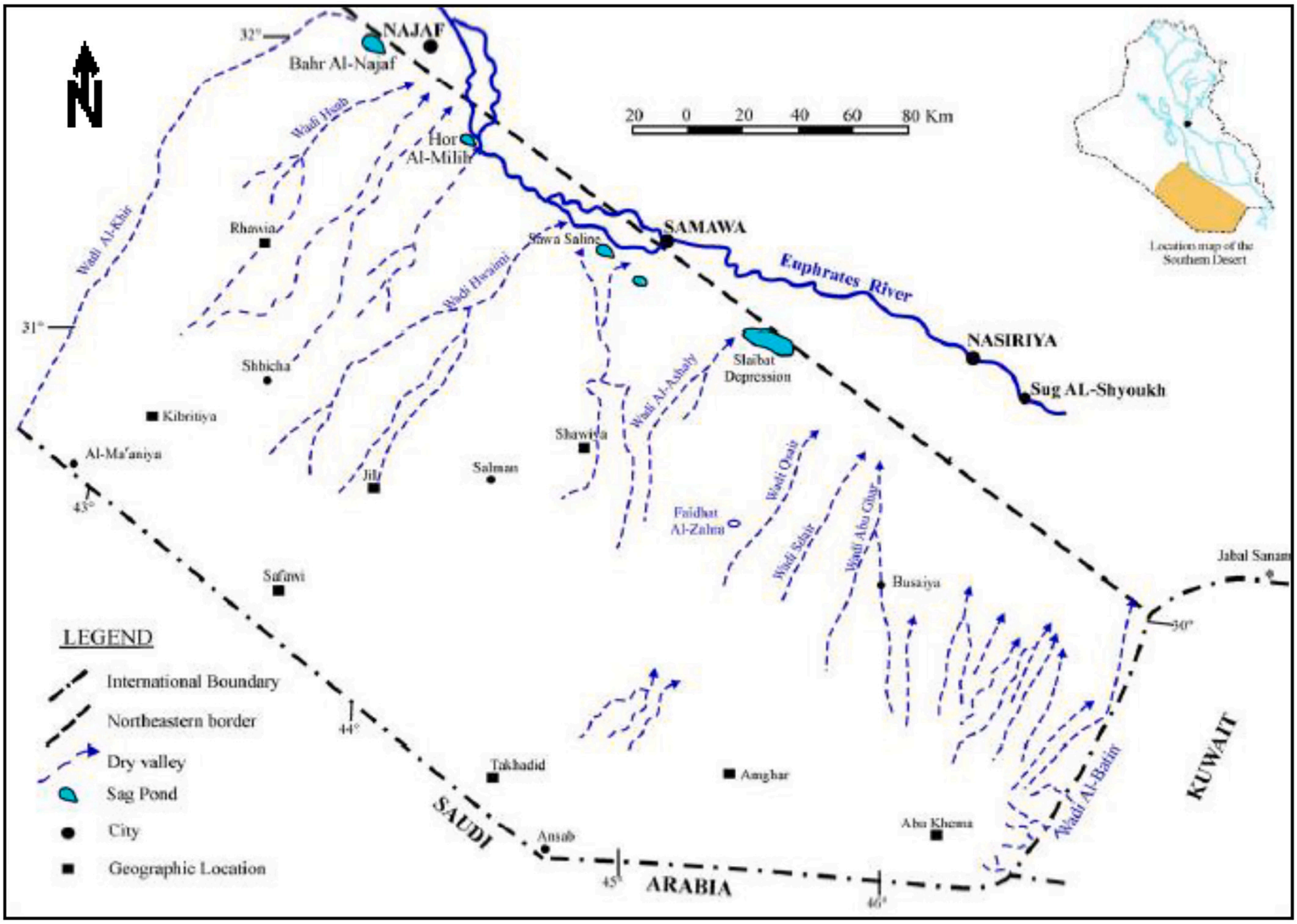

Fig. 1. Location map of the area understudy shows the drainage patterns.

toxic chemicals that occurred inside the nearby cities; i.e., Basrah, Nasiriya, Samawa and Najaf using the gravity, magnetic and remote sensing data with the assistance of the available geological information; taking into consideration the minimum environmental requirements in these cities; their villages and districts.

2. Tectonic and geologic settings

Tectonically, the Arabian Plate is divided (from southwest to the northeast) into Arabian Shield, Arabian Platform (with its stable and unstable parts), and the Zagros Thrust Belt (Fouad, 2007). The Iraqi Southern Desert lies within the stable one, where Cenozoic rock units are exposed and slopping gently east and southern east towards the unstable part of the Arabian Platform. Basement outcrops are completely absent in Iraqi territory, as well as, no boreholes were penetrated it. Therefore, the basement characteristics and depths were determined from previous geophysical studies. The estimated depth of the basement within the Southern Desert based on Compani General De Geophysique (CGG), (1974) ranges from 5 to 8 km; mainly 6 to 7 km towards east. Seismically, the region is quiet with no seismic risk areas, but in the last four years, many aftershocks earthquakes with few magnitudes were occurred in Basrah and Nasiriya Provinces come from the east (Zagros seismic activity).

Geologically, the denudation processes have exposed a sequence of marine and continental sediments, which range in age from Paleocene to Pleistocene as shown in the geological map of the area (Fig. 2). The Mesozoic section is not exposed in the desert, but penetrated by boreholes. Boreholes were drilled until the Jurassic rocks. Abu Khema borehole penetrates the Late Jurassic rocks; therefore, the data concerning the stratigraphy of the Southern Desert is limited to this age onwards. The geologic succession of Abu Khema borehole (2680 m total depth) is represented by twenty two formations. They are assigned to the Late Jurassic Najmah to Miocene-Pleistocene Dibdibba Formations as shown in (Fig. 3) (Roychoudhury and Nahar, 1980).

The Tertiary sequence exhibits two sedimentary cycles, each cycle starts by sea transgression and terminates by sea regression. The latter represents a beginning of the continental phase. Therefore, the stratigraphic sequence of the Tertiary includes two periods of continental phases: (Jassim and Goff, 2006).

- The first continental phase, which occupied the whole gap between the Eocene rock unit (Dammam Formation) and the Early Miocene rock units (Euphrates and Ghar Formations) which were formed owing to the sea regression.
- The second continental phase is marked by a period of the last sea regression in the Late Miocene to Recent.

3. Climate, hydrology and hydrogeology

The climate in the Southern Desert is arid. It is called desert due to low precipitation, the mean annual rainfall is 100–150 mm. Many weather forecasting stations are available in the concerned area. According to the meteorological information of Iraq for the period 1971–2000; mean annual rainfall was >112 mm, mean annual temperature was 24.5 °C, mean annual relative humidity was approximately 41%, mean annual evaporation was 3352 mm and mean annual dryness

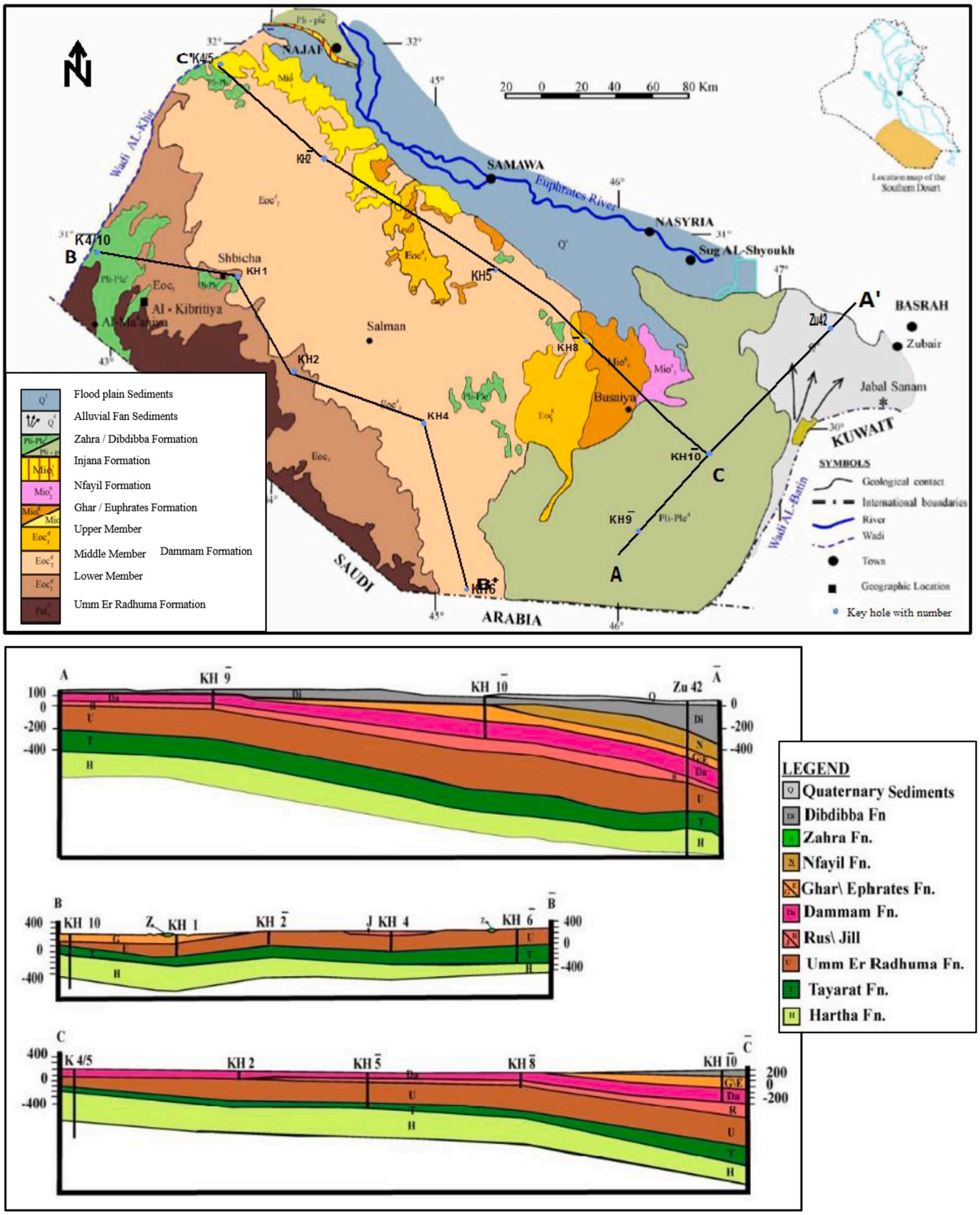

Fig. 2. Geological map and stratigraphic sections of the study area (after Sissakian, (2000)).

index was about 37 as illustrated in (Table 1) (General Iraqi Institute of Meteorological Information, 2000).

The groundwater in the area originates mainly from the atmosphere. Rainfall partly infiltrates through soil and rocks and saturates voids, fissures, cracks, joints and faults. Run-off in wadis and along their courses partly percolates through bedrocks. In addition, leakage from deeper aquifers occurring in the eastern part of the area is also important in groundwater replenishment. In recharge regions, water movement is generally from above to down, and the quantities of percolated water depend mainly on lithology and permeability of the rocks and the amounts of rainfall and surface run-off. While in discharge regions, water movement is upwards within spring's zone to the west of Euphrates River at the extreme northeastern part of the Southern Desert, and laterally towards the Mesopotamian Plain (Fig. 4), (General Iraqi Institute of Meteorological Information, 2012).

From this figure, groundwater movement in the Southern Desert is from southwest to northeast direction, towards discharge zone along Euphrates River and Hor Al-Hammar Marsh near Basrah City. Locally, deviation from the main groundwater direction may occur due to geological, structural and topographic nature, which effect on the groundwater flow. The source of water recharge is mainly from direct rain fall and infiltration from intermittent wadis within the area and

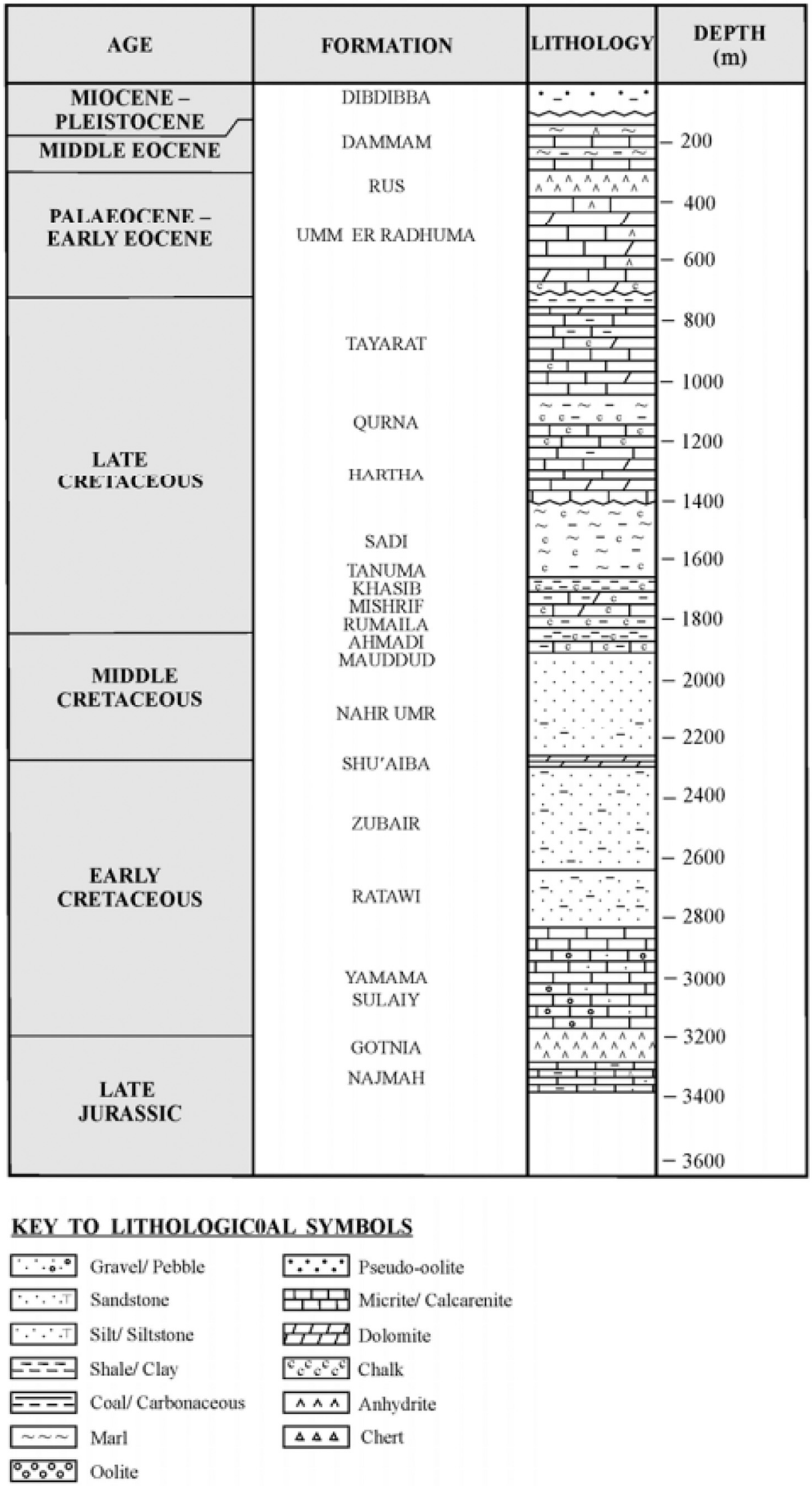

Fig. 3. Stratigraphic column as shown in Abu Khema borehole.

Table 1
Climatic factors of the Iraqi Southern Desert for the period (1971–2000).

Station	Mean annual Rainfall (mm)	Mean annual Temp. (C∘)	Temperature (C∘)		Mean annual Relative Humidity (%)	Mean annual Evaporation (mm)	Mean annual Dryness Index
			Min.	Max.			
Samawa	100	24.2	16.8	31.8	40	3380	34
Nasiriya	130	24.5	17.2	31.8	42	3320	30
Salman	<100	24.2	16.2	32.1	<36	3490	44
Busalya	100	24.7	16.6	32.1	39	3350	38
Basrah	130	24.9	17.8	32.2	>47	3220	28

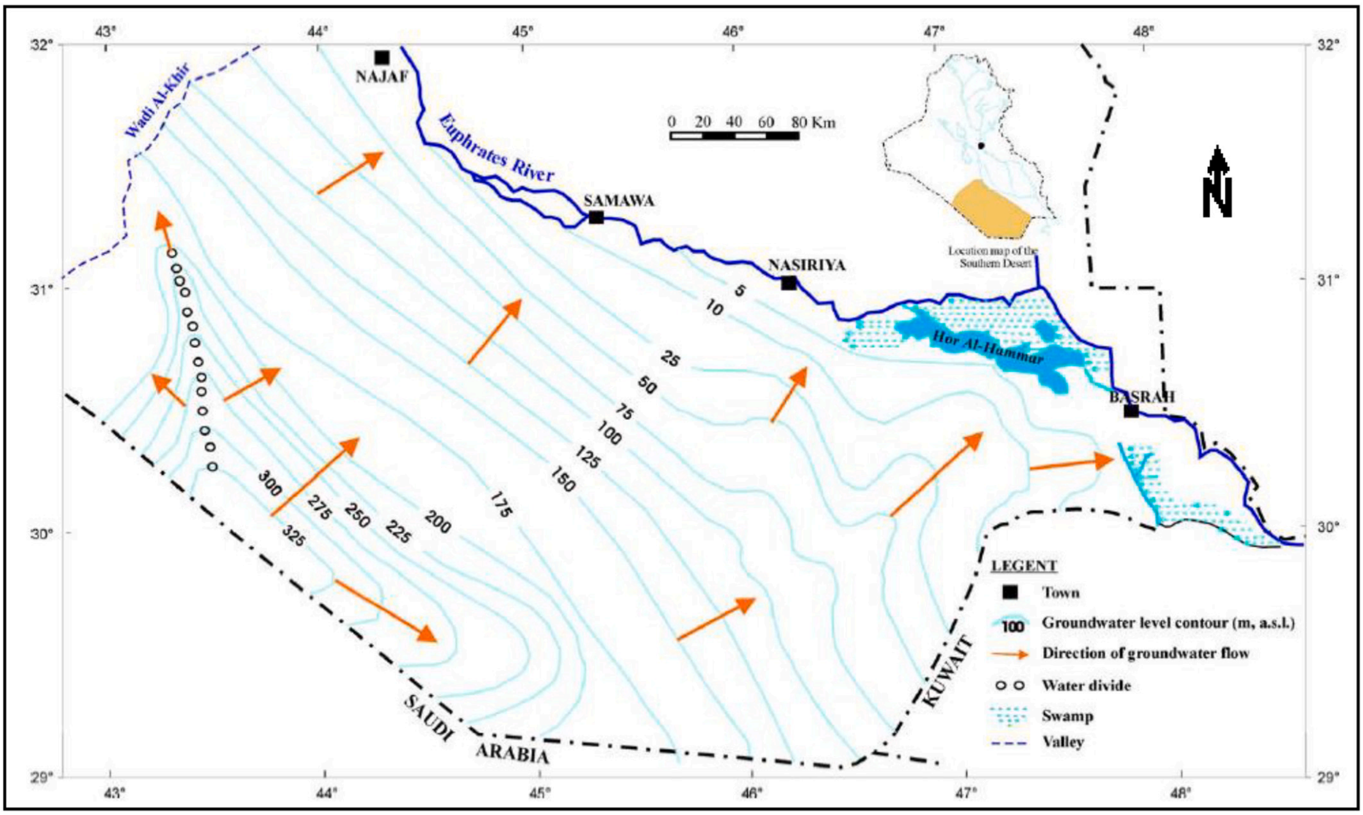

Fig. 4. Hydrogeological map of the Iraqi Southern Desert showing static water level and direction of groundwater flow.

adjacent regions outside Iraqi borders in Saudi Arabia, so underground leakage from groundwater basins in Saudi Arabia is also possible. Generally, Dammam Formation represents the main regional aquifer within the Southern Desert.

4. Results and discussion

4.1. Analysis of linear structures and lineaments using Remote Sensing Technique

Remote sensitivity data are considered as a useful and effective method in studying and analyzing the elements of the land surface shapes and in monitoring the changes occurring in the areas of settlement expansion represented by the urban, industrial and agricultural activities. The population growth at the present time has become one of the modern problems that in turn increase human consumption and thus increase the amount of waste and this is what increases the severity of environmental pollution, so that the need to reduce its severity, so the importance of these data is in a state of continuous increase in the world especially Third World Countries, considering that these countries need information resources that help to employ them in the right direction, especially in the field of future urban planning (Mahavir and Galema, 1991).

The Iraqi Southern Desert was examined using remote sensing technique depended on several satellite raw data of the Enhanced Thematic Mapper-ETM sensor and Land Sat-7; which form a satellite image that covered large scale out of the study area with 2GBs size and Tif files extension. The image is characterized by its good quality and the ability of discrimination ground (ground resolution) equals 57 m. The corresponding image consists of three geometrically corrected bands (Red3, Green2 and Blue1) were constructed as shown in (Plate 1).

Erdas Imagine 8.4 and ArcView 3.1 softwares were used to achieve this step. According to El-etr, (1974) classification, 222 lineaments and 264 linear structures have been deduced from the interpretation of the satellite image of the study area depending on the several visual surface features, such as the regular topography, drainage patterns, outcrops, streams deviations, dry valleys and rims crack. The directions of the observed phenomena can be classified into three types: 282 of it (59% of the total) have N*E*-SW trends, 145 (30% of total) trending NW-SE direction; and 59 of the rest (1% of total) trends to E-W and N-S directions. Table 2 illustrates the detailed linear structures that picked from the satellite image of the study area. The effect of these phenomena (linears

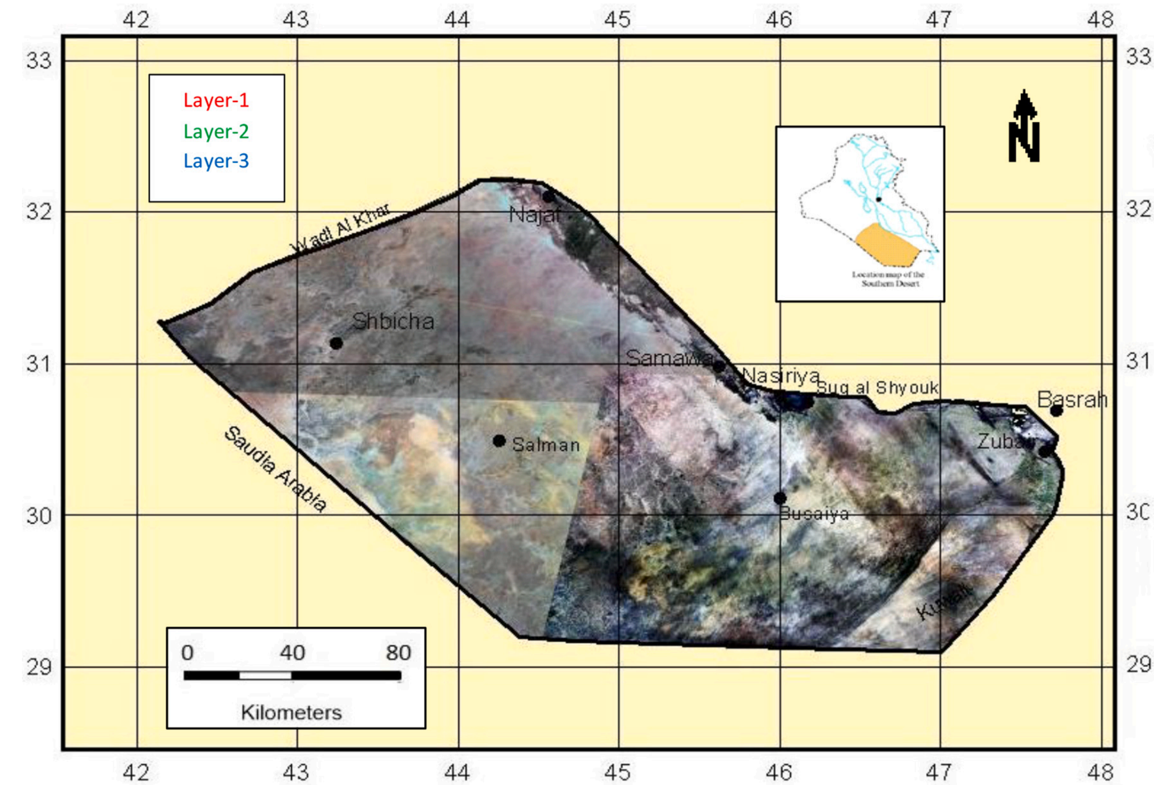

Plate 1. Satellite image of the study area consists of three spectral bands.

Table 2
Lengths and directions of both lineaments and linear structures related to the study area.

No.	Direction	Length of lineaments (km)		Length of linear structures (km)		Fold and fault name
		(10–100)	Large (>100)	Short (<2)	Large (2–100)	
1	NE-SW	131	3	33	115	Al-Batin Fault
2	NW-SE	61	2	31	51	Euphrates fault zone
3	E-W	20	–	–	21	–
4	N-S	5	–	–	13	Safawi region near Iraqi-Saudi border
Total		217	5	64	200	486

and lineaments) on the selection of future landfill sites will discussed later.

The results of this analysis showed a diagnosis of the north-eastern and north-western directions of the linear and rectilinearities, and it is believed that the north-eastern linear phenomena are associated with regional tectonic influences, which make their concentration within the stable zone is possible. The dominance of the northwest directions may reflects the deformations resulted from the horizontal compressional stresses (produced from Zagros), which formed folds and faults in the unstable zone. In addition, the linear phenomena with a N-S direction, they are of special importance due to their connection with an ancient fault system inherited from the Hejaz movement named Abu-Gir Fault (Buday, 1980).

4.2. Gravity data interpretation

Bouguer gravity anomaly map of Iraq which prepared by Al-Kadhimi et al., (1984); with the available scale of 1:1000 000, and contour interval equals to (1) mgal was used for future gravity interpretation. The gravity contour lines within the borders of the Iraqi Southern Desert have been digitized from the original gravitational map of Iraq and re-drawn again using the Surfer program (Ver.16) with similar contour interval and (1 × 1) cm spacing (equals to 10 × 10 km on the ground surface (Fig. 5).

Generally, it is noticed that the gravity values are ranged between (−20) mgal to (−76) mgal at the NW and (NE and SE) parts of the study area respectively; which means that the gravity gradient values are decreasing to the NE and SE directions. This result briefly clarifies the increasing of the sedimentary overburden towards these directions; as well as, the lateral and vertical differences, may occur in the rock density distribution or even between the underlying structures. Also, N-S and *E*-W grid lines with (1 × 1) cm spacing (equals to 10 × 10 km on the ground surface) were done for the current Bouguer anomaly map, and therefore, the gravity readings of the study area were extremely subjected to several quantitative interpretation procedures to isolate the regional from residual gravity anomalies and the density reduction that occurred in the rocks, as follows:

4.2.1. Trend surface analysis

Trend surface technique was applied on the Bouguer anomaly map of the area, and first order for both regional and residual anomaly maps were constructed as follow:

The first order of the regional anomaly map using Trend Surface Analysis shows parallel straight contour lines trending NW-SE direction with values range between (−46) mgal at the eastern parts of the desert to about (−25) mgal at the western parts (Fig. 6). The regional slopes of the underlying layers in study area is from west and southwest towards east and southeast directions Thus, it means that the depth of the basement rocks was increased and the advanced geometry of the underlying layers during deposition was developed at these directions.

From this map, there are wide areas locates at the western and central parts of the region have no features, and characterized by their

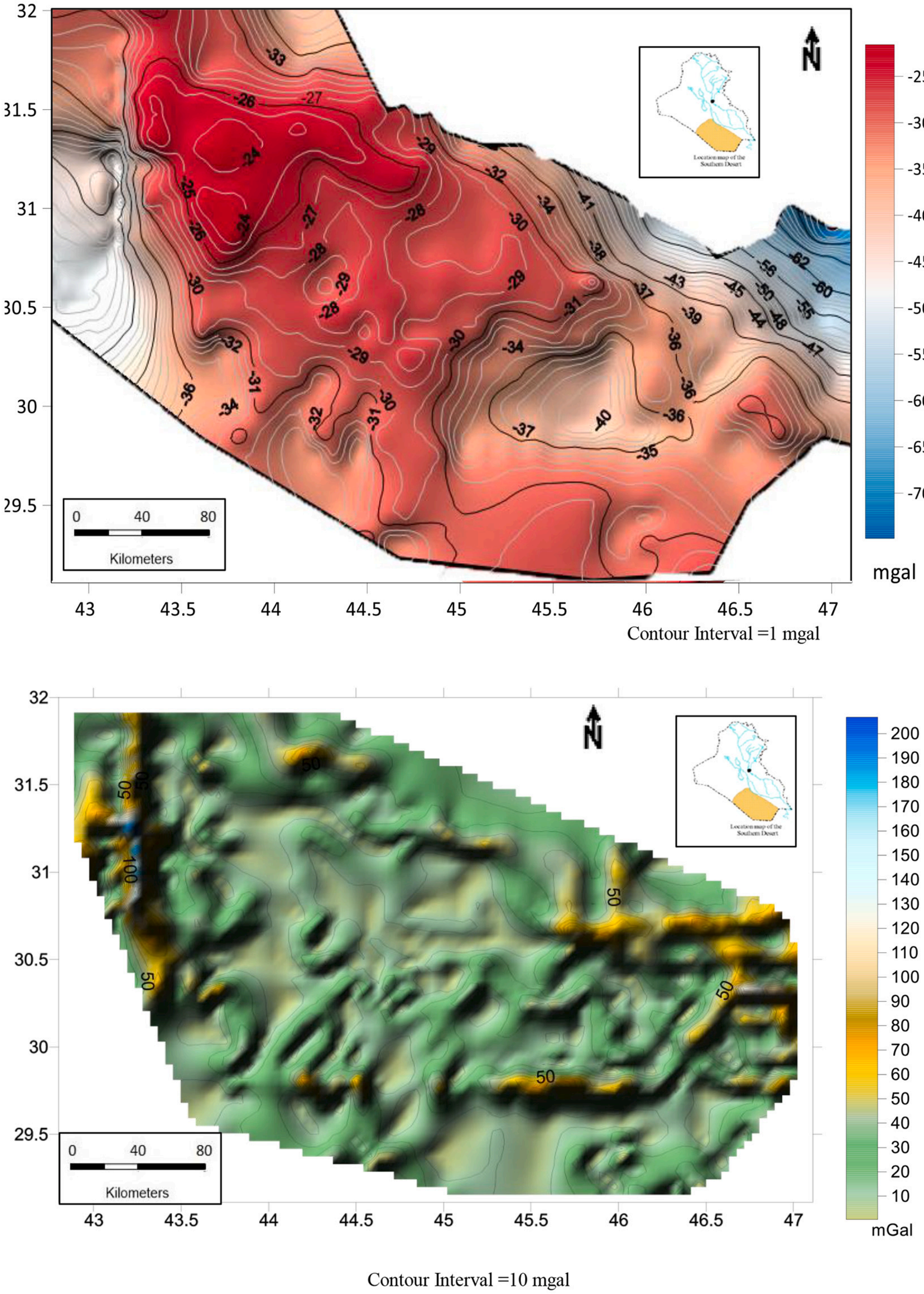

Fig. 5. Bouguer anomaly map of the study area.

gravity values (−26 to −34 mgal), however, it may reflects the existence of hard rock layers far away from the influence (deformation) coming from the east (Zagros Mountain Belt). According to this fact, these parts of the desert were suggested to be one of the suitable site/sites probably used for future landfill development.

Also, the 1st order residual map of the Trend Surface technique was drawn for the study area. This map declares the existence of the positive (red) and negative (blue) values (anomalies) that depend on the nature of the subsurface lithology. Relatively, highly dense rocks yield positive anomalies, whereas the weak zones, such as faults, joints, fissures, voids and cavities surely represent the low dense rocks (negative values), and therefore it is considered as invalid areas for landfill purposes. In addition, it is observed that the positive anomalies are positioned and distributed along NW-SE trends, especially at the central parts of the studied area which have highly dense rocks as shown in Fig. 7.

Moreover, high values of Bouguer anomaly correlates with carbonates shown in blue on Fig. 8. It could be reflect from a forebulge on the western edge of foreland basin, but tectonic map suggests that it is much more to the east. With that and geological map, cross-sections and surface rock types, it is thought that these values were most-likely reflects

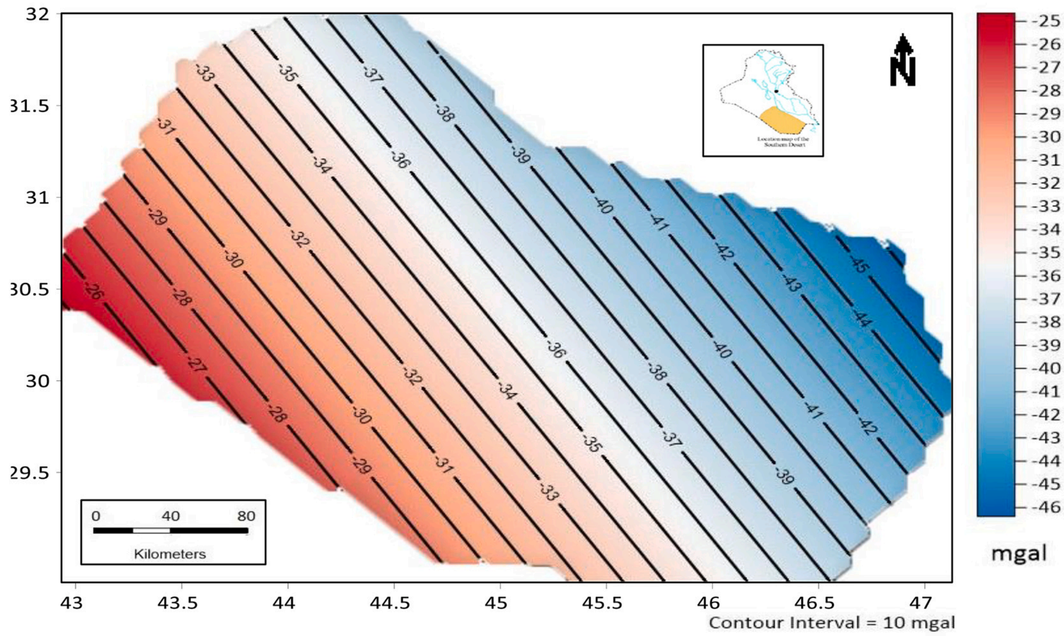

Fig. 6. First order of the regional Trend Surface anomaly map for the study area.

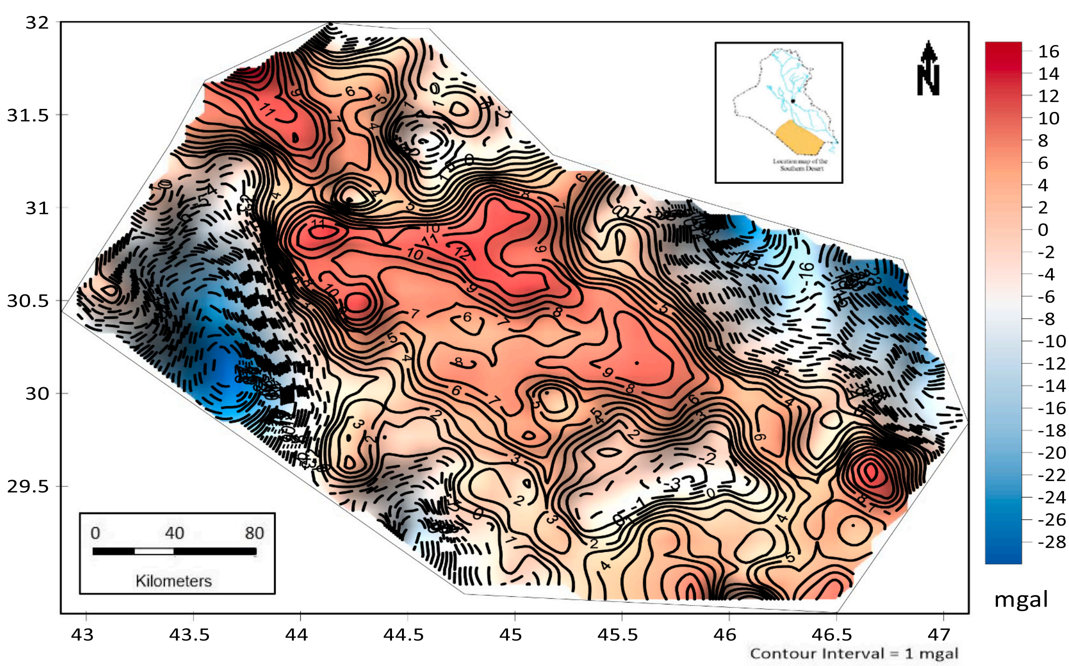

Fig. 7. First order of the residual Trend Surface anomaly map for the study area.

density or thickness variations within the shallow section. Therefore, thirteen possible landfill sites had been suggested within the area according to the fact that says "the landfill sites must be far away from the weak zones". These sites were chosen directly over the positive residual gravity anomalies related to the first order Trend Surface map.

4.2.2. Average smooth matrix analysis

This analysis was applied on the original Bouguer anomaly map of the Iraqi Southern Desert to isolate both regional and residual anomalies by plotting the second spacing map for each type of anomaly. As shown in Fig. 9, the regional 2nd spacing map gives similar behavior to the Bouguer map and almost they have the same values. Also, it is noticed that the largest values of the gravity anomaly throughout the region occupies a large area (northern and central parts) which indicates the probability of the presence of high dense deep or/and intermediate rocks or even uplift in basement rocks.

This map is characterized by the existence of two main anomalies with values between (−22) and (−37) mgal that are observed at the north-center and south-east of the study area respectively. The possessed anomalies which represent the second value may reflect the presence of low-dense rocks belong to the sedimentary overburden, and therefore, the area can probably be excluded from future landfill selection.

In the 2nd spacing of the residual gravitational anomaly map (Fig. 10), it seems that, it has positive and negative anomalies that

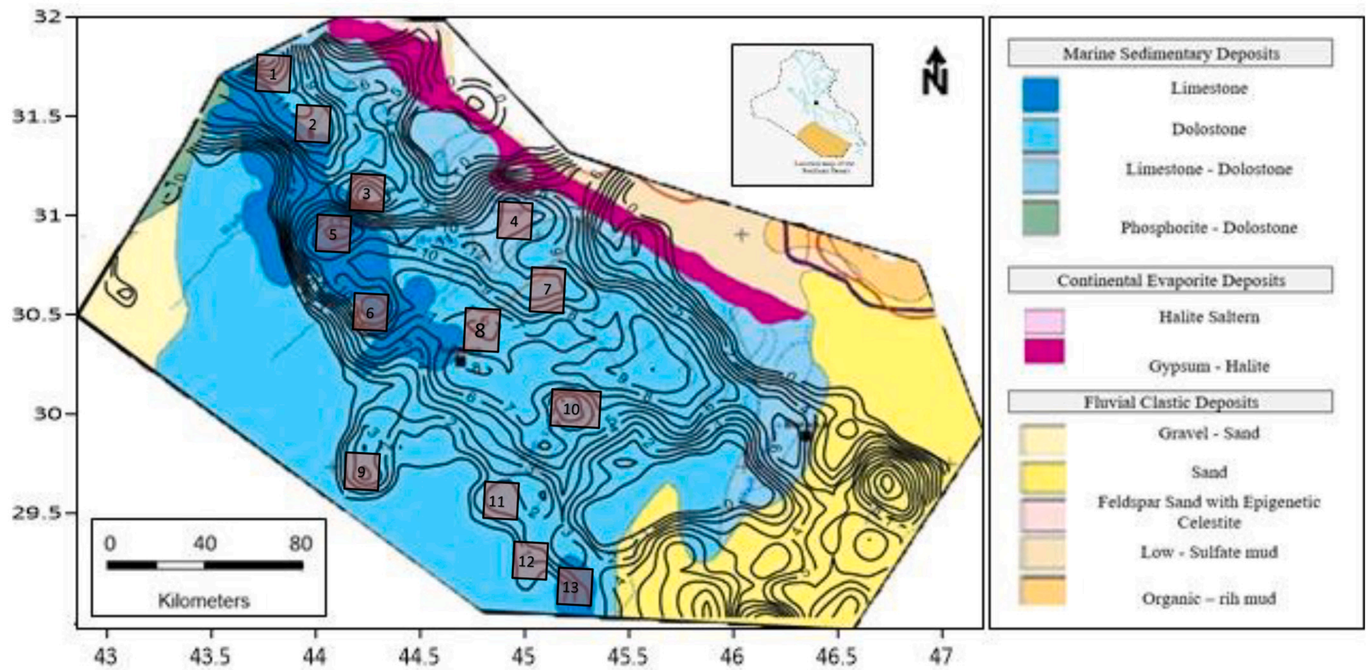

Fig. 8. First order positive residual Trend Surface map superimposed on the mineral assemblages map of the study area.

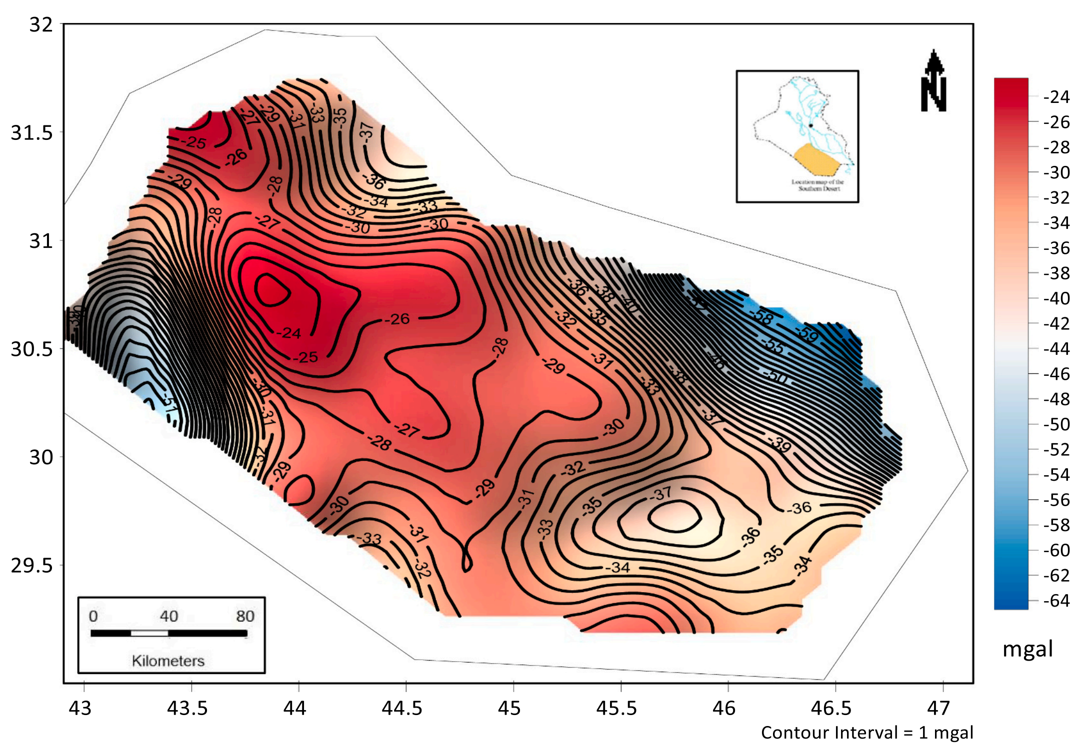

Fig. 9. Regional anomaly 2nd spacing map of the study area using Average Smooth Matrix.

occupy all the area understudy. On the other hand, the positive anomalies which located at the central and northern parts of the area probably indicate the existence of dense rocks represented by Dammam and Ghar Formations; however, it indicates the occurrence of dolomitization referred to Dammam Formation. The reality of the geological and structural settings of these parts have no caves, sinkholes and weak fractured rocks, thus, it can be strongly selected for landfill future purposes. While, the negative anomalies show the presence of sedimentary rocks which could have the cavities and sinkholes.

4.2.3. *First vertical derivative (FVD) analysis*

This method is considered as one of the important techniques in the appointment of the detection of the shallower small structures sited close to each other. However, the plotted map clearly contains different anomalies and having various sizes, shapes and extensions as shown in (Fig. 11). It reflects the presence of a set of shallower and small

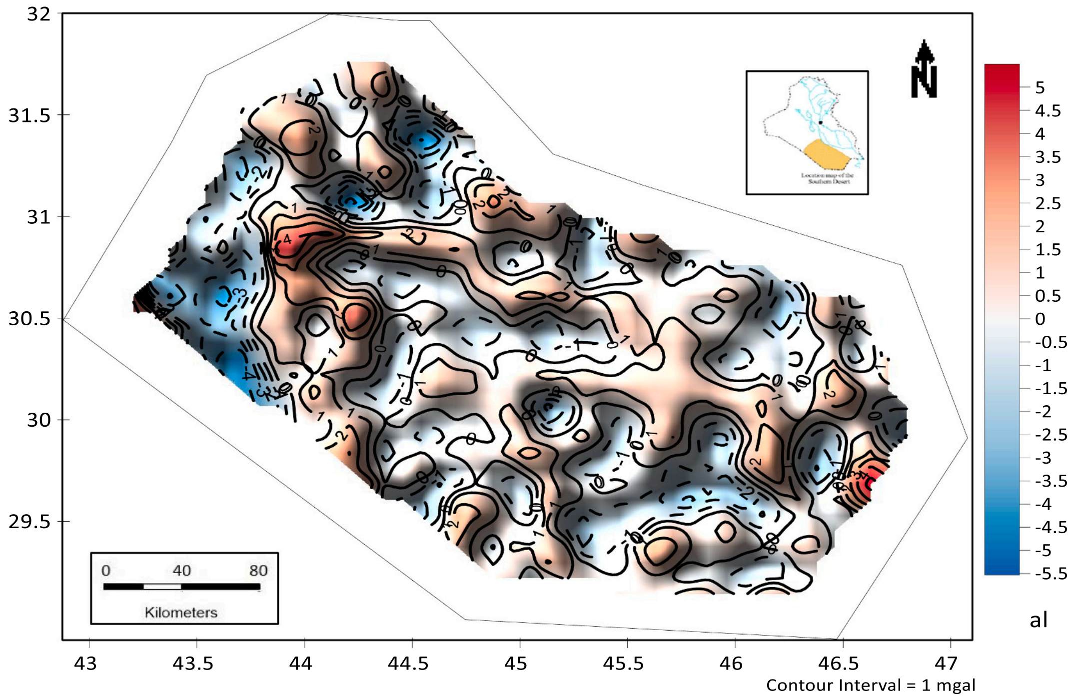

Fig. 10. 2nd spacing of the residual Average Smooth Matrix anomaly map for the study area.

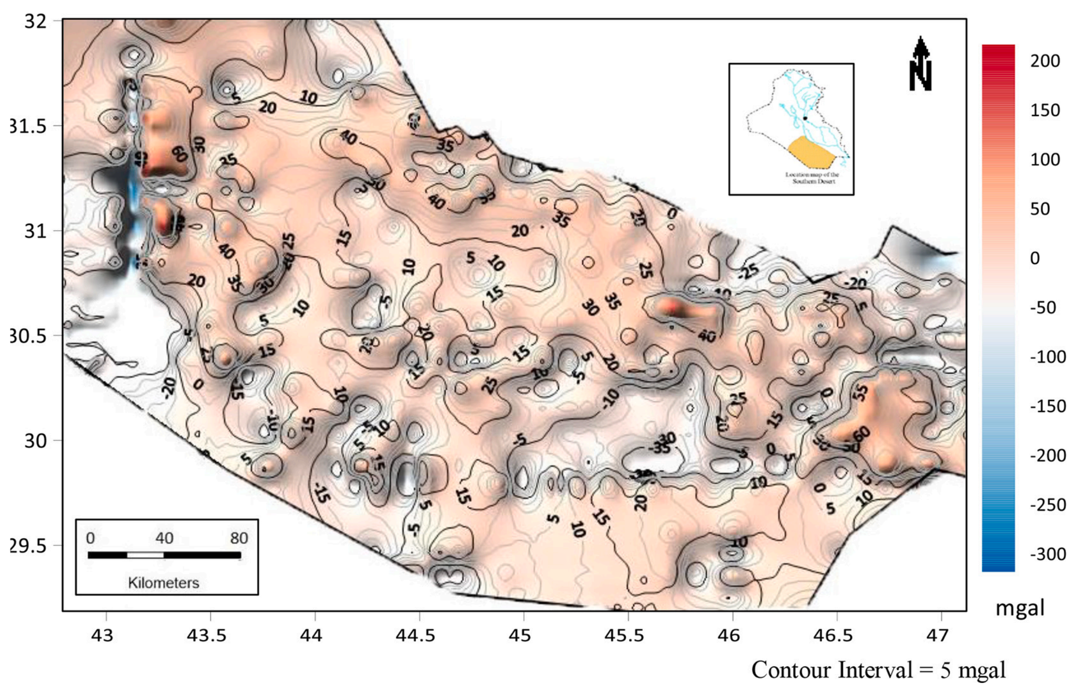

Fig. 11. First Vertical Derivative Analysis of the study area.

structures. Moreover, the positive and negative residual anomalies in this map are the same as that related to the 2nd spacing residual anomaly of the Average Smooth Matrix method. FVD map gives many of the anomalies counterfeit, which have nothing to do with the reality existence of the geological features. The residual positive anomalies represent areas with good (high dense) lithological specifications, which made it one of the areas extremely selected as sites for the future landfill wastes. On the contrary, the region marked by color (negative residual anomalies) is consider as weakness zones including fractures and cavities. FVD was overlain on the hydrogeological and map of the area; and thirteen sites are indicated on this map, and probably considered as a good locations for landfill waste purposes, (Fig. 12).

4.3. *Magnetic data interpretation*

4.3.1. *Total magnetic intensity (TMI) data*

The magnetic data used in this study were obtained from the magnetic data from space (aeromagnetic) that are available by EMAG2: EARTH MAGNETIC ANOMALY GRID (2-ARC-MINUTE RESOLUTION) (http://www.ngdc.noaa.gov/geomag/emag2-download.html, n.d.;

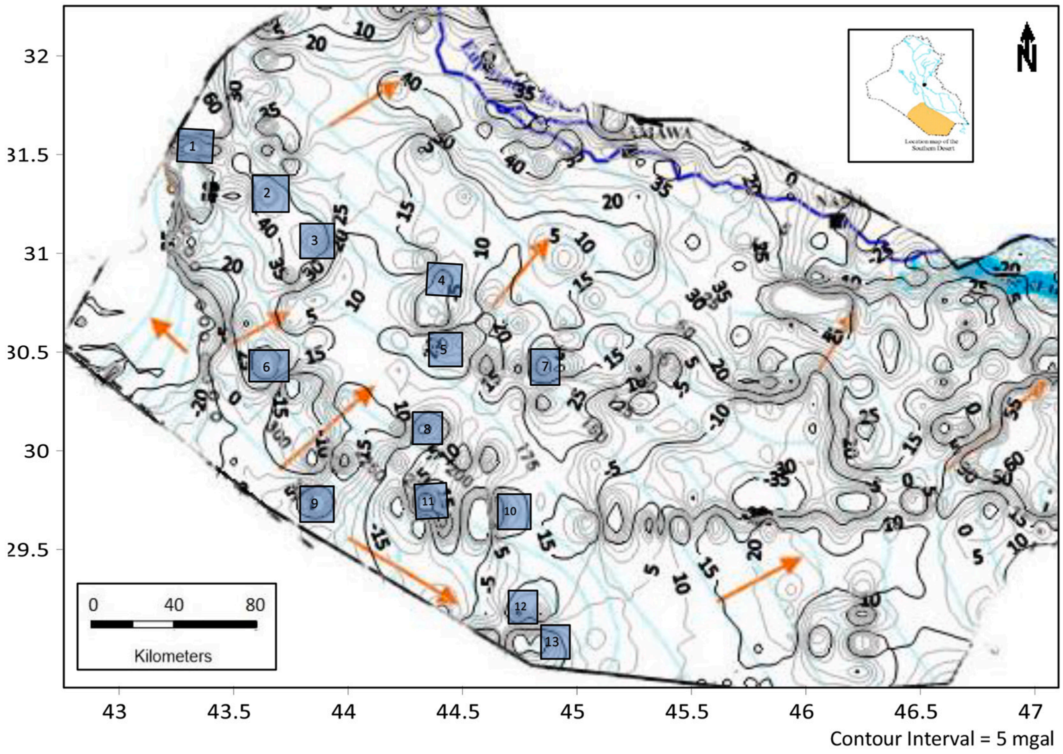

Fig. 12. FVD map overlain on the hydrogeological map of the studied area showing the suitable sites.

Maus et al., 2009; Al-Saady, 2018). These data are the only recent available magnetic data referred to the study area. Geosoft DAP is also excellent website to download magnetic data from space. The Geosoft DAP is a server technology for publishing, distributing and discovering exploration data. With DAP, data are secure, organized, easily accessed and shared among all the people that need exploration data to make decisions.

4.3.2. Reduction to pole Map (RTP) Data

Shapes of any magnetic anomaly depend on the inclination and declination angles of the main magnetic field of the Earth comparative to magnetization of the source. The same magnetic body will yield an altered anomaly depending on where it happens to be in the Earth's field, so the major anomalies forming a dipole. The study area has inclined magnetic Earth as a dipole. In contrast, in the area of vertical Earth dipole, they will simply shown by the high magnetic amplitude of

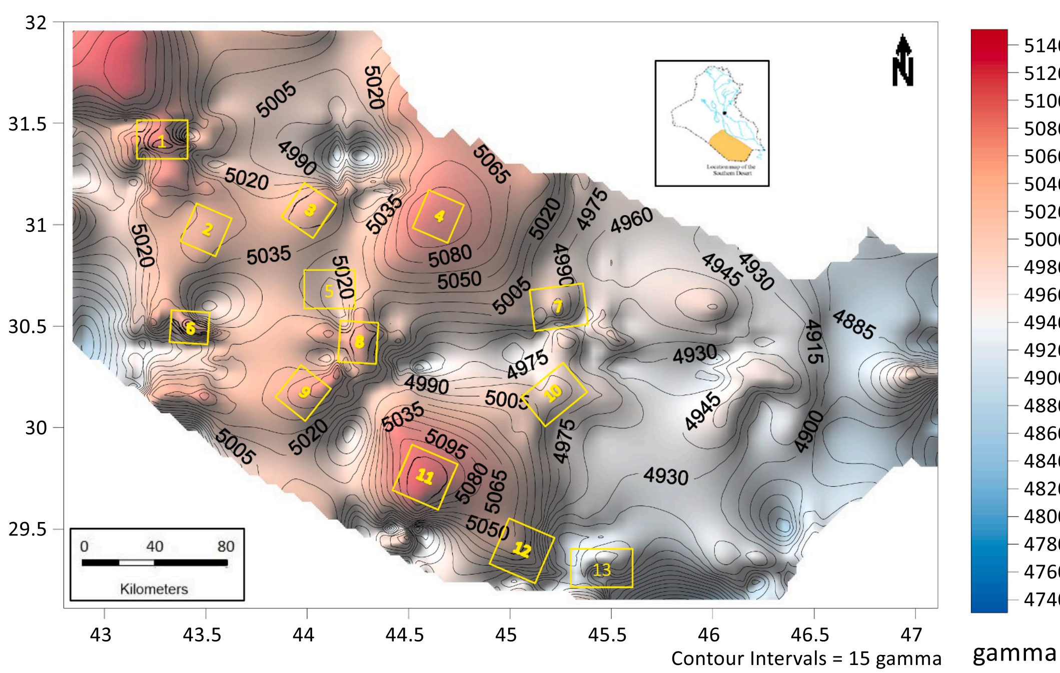

Fig. 13. RTP magnetic map illustrating the possible thirteen sites inside the study area from the total magnetic intensity map of the same area indicates the locations of suitable landfill sites.

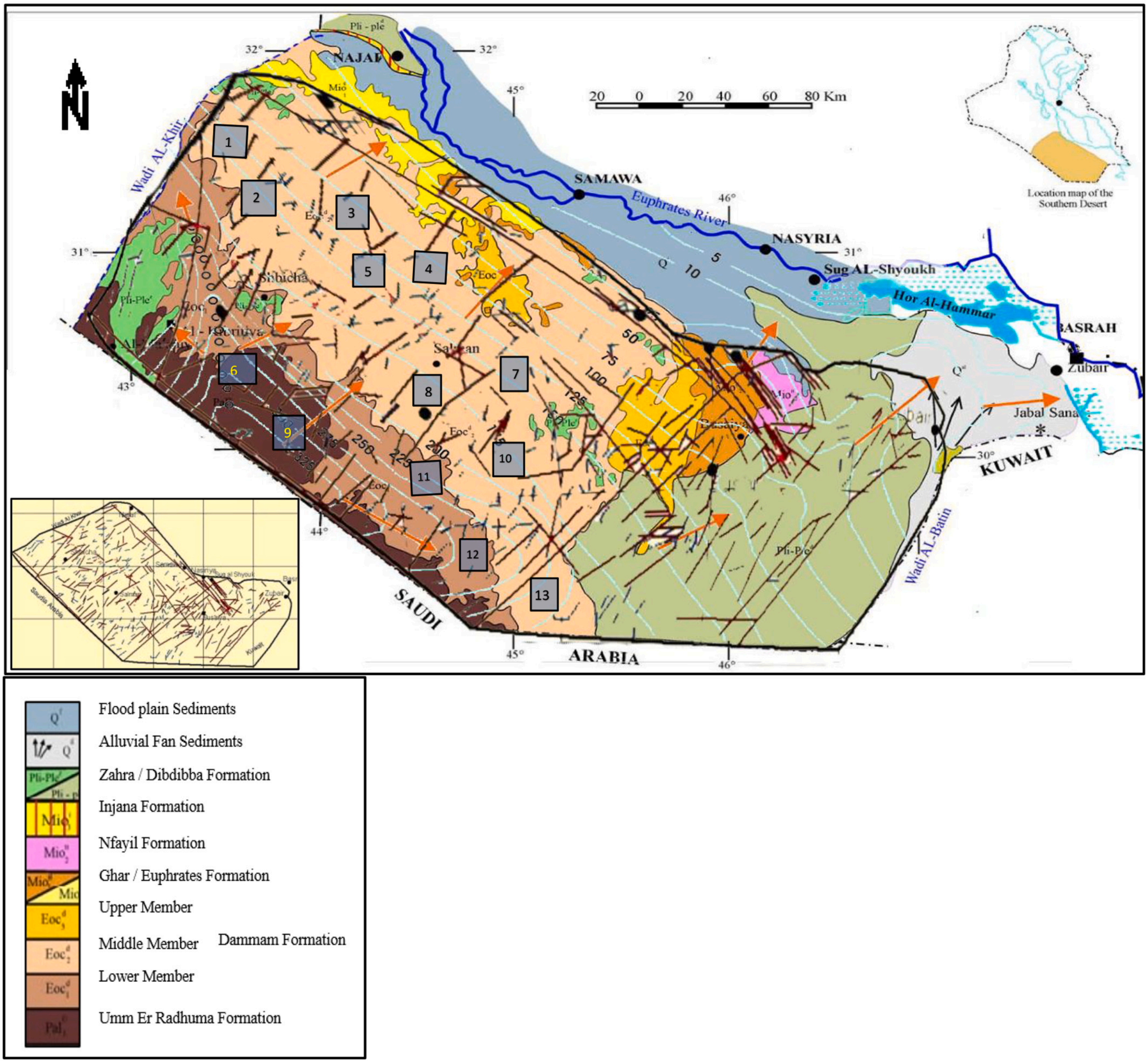

Fig. 14. Candidate sites were projected on the geological and hydrogeological map of the area.

the vertical bodies. As a result, reduce to the Pole (RTP) significantly simplifies the interpretation of magnetic data. In this way, the interpretation of the data is made easier than what the raw data maps show (www.geosoft.com/products/dap-server/overview, n.d.).

4.3.3. Similarity between gravity and magnetic data interpretation

In order to compare the magnetic data of the study area with the gravity data of the same area, the total magnetic intensity map has been reduced to the pole. If the magnetic anomalies are mainly caused by induced magnetization, the reduced to the pole will produce symmetrical anomalies located above their causal bodies. Then, the RTP magnetic map can be directly compared with the gravity anomaly map, since anomalies from the same sources will have the same locations and nearly similar shapes. There is nearly moderate-good similarity between the RTP and the gravity anomaly maps in the locations and shapes of the negative and positive anomalies of the study area. This may indicate that the anomalies on both maps are resulted by the same causative bodies.

Economic Model Vision Program was used to model the subsurface bodies that cause the positive anomalies on the RTP map of the study area. The positive magnetic anomalies are chosen for modelling because they are thought to be the best locations that should be selected as a suitable landfill sites, because they are more stable, with high-density subsurface rocks and have more suitable standard factors for site selection by gravity interpretation. Thirteen clearly positive anomalies are chosen for modelling as preferable landfill sites depending on the high magnetic values they have, as shown in (Fig. 13).

From the comparison between the sites that chosen by gravity and magnetic methods, it is clear that there is a general similarity among them. The little differences present in the locations of some of them may be due to the remnant magnetization in the subsurface rocks. The similarity between the interpretation of gravity and magnetic data (especially the FVD) gives more confidence in the results and the interpretation in determining the suitable landfill sites.

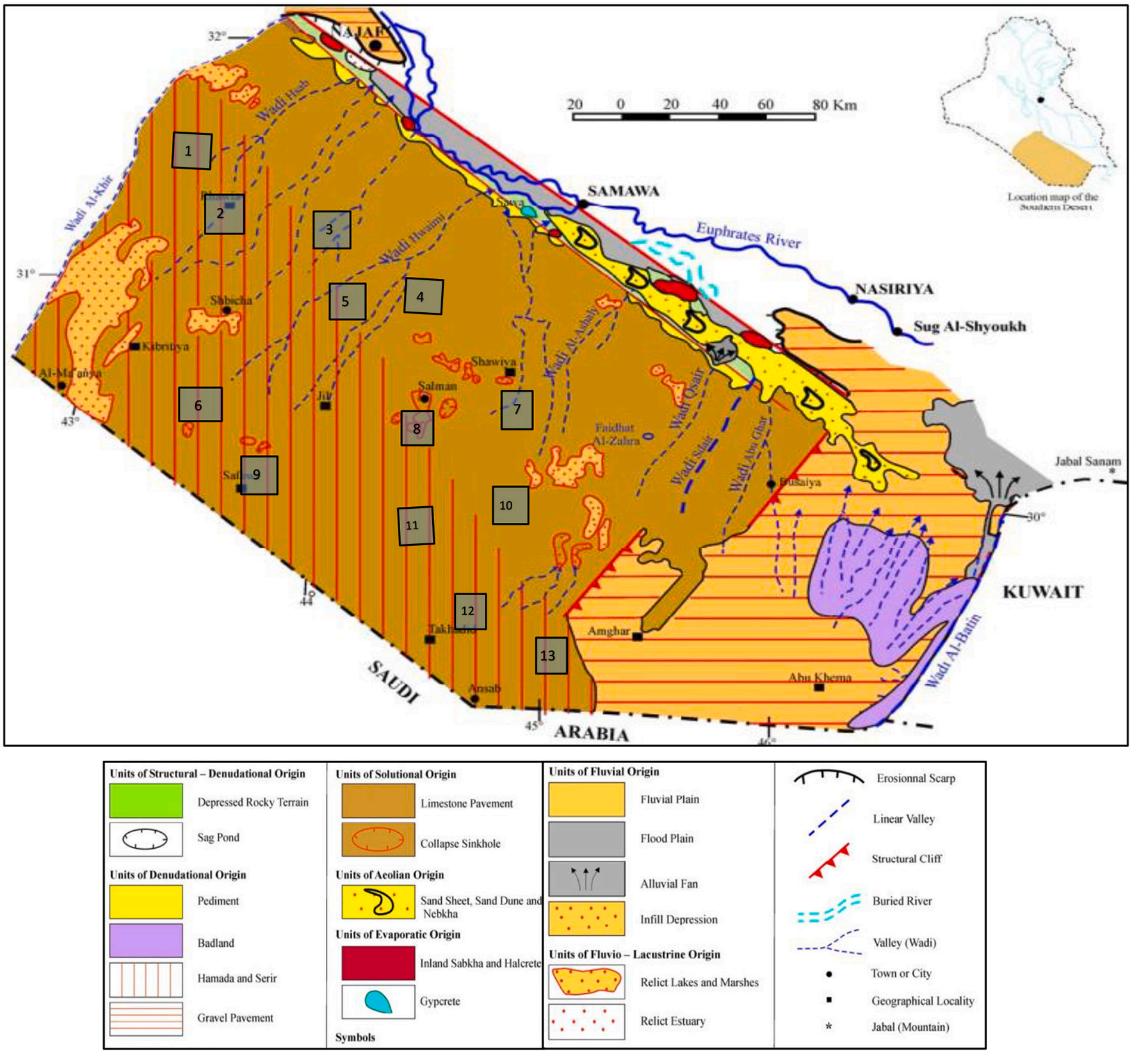

Fig. 15. Geomorphological map of the study area showing the candidate sites.

4.4. *Identifying the sites candidate to landfill wastes*

Depending on the analysis of the previous gravity and magnetic anomaly maps, as well as the interpretation of remote sensing data, the following points can be estimated in order to identify the proper locations for landfill purposes with the assist of the geological information of the Iraqi Southern Desert:

- It appears that the positive and negative residual gravity anomalies occupy the same sites in almost all the methods of analysis, which indicates that these anomalies are reflected from the same original subsurface sources.
- The lower gravity and magnetic areas show the presence of sedimentary rocks which have the cavities and sinkholes.
- A match between the lineaments linear (linears and lineaments) features and negative gravity anomaly locations is recognized; however, the negative anomaly that reflects the subsurface weak zone coincides with the locations of the these features in the study area except in some parts. In addition, the interpretation of some negative anomalies gives an indication about the lithofacies variation occurred in the area.

4.4.1. *Standard factors for sites selection*

By studying and analyzing the results of gravitational, magnetic and remote sensing data of the Iraqi Southern Desert, with the assistance of the geological information, the final proper locations were suggested and considered as the best and suitable locations for landfill purposes in the area understudy The effected standard factors are:

4.4.2. *Geological factor*

The proposed sites within the area were superimposed on the outcropping geological map as shown in (Fig. 14). Geologically, these outcrops (layers) are denser and thick, impermeable, and extend on wide shallow depths above the water table. Moreover, these layers are empty from cavitations, sinkholes, subsidence and sand dunes.

4.4.3. *Tectonic, structural, hydrological and hydrogeological factors*

The selected sites are located within the area of the stable shelf of Iraqi tectonic setting. Seismically, it is considered as one of the calm areas in spite of the existence of both deep linear structures and lineaments. In addition, these sites have no folding and faulting features. It is believed that the lineaments does not provide any value, because they represent surface expressions of drainage pattern or the existence of possible faults. Therefore, the selected future landfills should stay away from known drainage/wadis in the area, in order to prevent contaminants against leaching towards out-side. The water level depth decreases according to the groundwater flow direction in the recharge areas; it reaches more than 200 m below ground surface, while at the discharge zone the water level becomes of less depth near ground surface or may

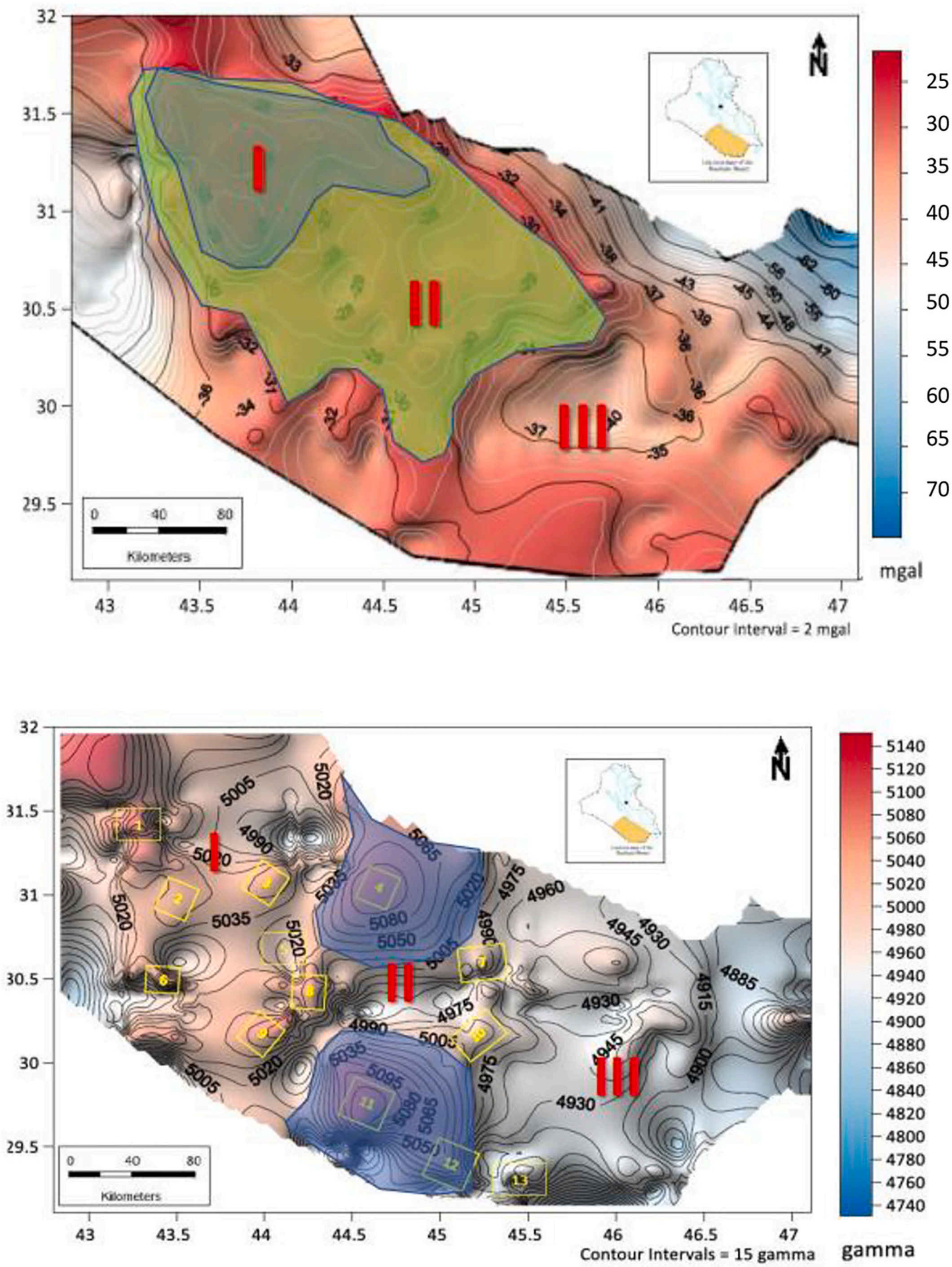

Fig. 16. Gravity (above) and magnetic (below) maps of the area understudy represent the model of selecting the landfill sites.

be self-flowing (artesian) within upper formations. The thirteen sites were selected according to the criteria that the surface and subsurface water are far from pollutants. Euphrates River and fluids aquatic valleys are located far away from these sites especially those sites that located at the north-western parts of the area, since the direction of flood in the valleys is trending NE towards Euphrates River. On the other hand, the aquifers are deep reaching between 5 and 325 m relative to ground level, and the groundwater is more saline and sulphureous which make it unsuitable for drink and agriculture.

4.4.4. Proximity to the waste sources

This important factor was used during this step of selection, and it may serve the General Company of Fertilization, General Company of Petrochemicals and Refineries to get rid of the chemical waste near Governorates. However, this factor may strongly progressively apply ~~to~~ on most of the selected suitable sites (1, 2, 3, 4 and 5), while the rest sites (6, 7, 8, 9, 10, 11, 12 and 13) are located far away from their governorate centers despite of the fact that they are seem to be suitable sites for landfill as they can be utilized in the future for Al-Batin, Salman and Shbicha regions respectively.

4.4.5. Geomorphological and natural resources factors

The proposed sites are considered as flat plateau areas having gentle slopping towards NE, including few valleys with U-shape. They are

Table 3
Remote sensing, potential anomalies, comparison factors and the extent of compliance with all the candidate sites in the study area (green cells means inappropriate sites).

No.	Comparison factors / Remote sensing and potential anomalies	Selected sites												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Geological factor	√	√	√	√	√	√	√	√	√	√	√	√	√
2	Tectonic and structural factors	√	√	√	√	√	√	√	√	√	√	√	√	√
3	Proximity to sources of waste	√	√	√	√	√	×	×	×	√	×	×	×	×
4	Hydrological and hydrogeological factors	√	√	√	√	√	√	√	√	√	√	√	√	√
5	Geomorphological factor	√	×	×	√	√	√	√	×	√	√	√	√	√
6	Climatic factor *	√	√	×	×	×	×	×	×	×	×	×	√	√
7	Seismic factor	√	√	√	√	√	√	√	√	√	√	√	√	√
8	Agricultural factor *	√	√	√	×	×	×	×	×	×	×	×	×	×
9	Land and water uses factors	√	√	√	×	×	×	×	×	×	×	×	×	×
10	Proximity to roads and public sources of energy and water factors	√	√	√	×	×	×	×	×	×	×	×	×	×
11	Natural Resources factor	√	√	√	×	×	×	×	×	×	×	×	×	×
12	Distance from the international border factor	×	×	×	×	×	√	×	×	√	√	√	√	√
13	Remote sensing analysis	√	√	√	√	√	√	√	√	√	√	√	√	√
14	Positive gravity anomalies	√	√	√	√	√	√	√	√	√	√	√	√	√
15	RTP (Positive anomalies)	√	√	√	√	√	√	√	√	√	√	√	√	√
Final convenient sites (%) (compliance)		92	85	85	69	69	69	69	54	62	77	69	69	77

*not extremely active factor (neglected from compliance calculation).

located away from the areas of Euphrates flood plain and sand dunes and collapsed areas. In addition, no sites locate in a depression of gypsum soil. The candidate sites and the surrounding areas have no significance as hydrocarbon regions, however, the outcropping limestone and dolomite are not useful for quarry purposes because the sites are located far away from governorates centers, (Fig. 15). (See Fig. 16.)

4.5. Comparison and differentiation between the candidate sites

From the foregoing results, we can achieve to some facts about the selection of the candidate sites for the landfill solid waste and toxic chemicals in the study area and try to make personal efforts to match the studied factors of the area with the international standard factors as illustrated in (Table 3) below. Mark (√) means sites that possess appropriate factors while mark (×) site is tend to have inappropriate factors (less than 70% compliance).

According to this table, it is clear that the sites 1,2,3, 10 and 13 are suitable for landfill and toxic chemicals. It can also be noted that these sites have satisfied specifications and discriminate a good matching with the international standards with some careful concern to sites 4, 5, 6, 7, 11 and 12 (exceed 69% compliance), (Table 4). From these thirteen proposed sites, two of them namely (sites 8 and 9) must be neglected because they have fewer standard properties as mentioned above.

5. Conclusions

Depending upon the findings of the present study, the following conclusions are deduced:

1. The Iraqi Southern Desert is found to be a good region for future landfill purposes, because it is nearly empty from forbidden environments with the standard and economic factors were applied and taken into consideration.
2. A set of linear features including faults (weak zones) and linear structures in the area understudy were determined depending on the satellite image analysis. These features are located outside the proposed sites, therefore; it is necessary to avoid them as locations for landfill operations.
3. The analyses of gravity and magnetic maps show positive anomalies and the locations of these are nearly the same on their maps, this may indicate that they are coming from the same causative bodies. In addition, the negative gravity anomalies may reflect the presence of weak zones including fault zones and low density subsurface rocks.
4. Integrating gravity, magnetic and satellite image data in site selection process can greatly improve waste management in the study area. This can done by establishing a landfill facility to serve the Iraqi teams and their environs.

Table 4
Coordinates of the centers of the best candidate sites for the landfill in the study area.

The important site according to their potential anomalies and standard factors	Coordinates (degree)		Reasons
	Latitude	Longitude	
1	31°55′	43°30′	No factors negatively affected except distance from the international border.
2	31°35′	43°58′	No factors negatively affected except distance from the international border and the geomorphological (relict lakes and marshes) factors.
3	31°17′	44°17′	Distance from the international border and the geomorphological factors.
13	27°46′	45°10′	1. Poor in proximity to sources of waste. 2. Poor in land and water uses. 3. Poor in proximity to roads and public sources of energy and water factors. 4. poor in natural Resources.
10	28°25′	44°52′	1. Poor in proximity to sources of waste 2. Poor in land and water uses. 3. Poor in proximity to roads and public sources of energy and water factors. 4. poor in natural Resources.

5. The positive gravity anomalies and the RTP magnetic anomalies occupy the central and northern parts of the study area, and this similarity gives more confidence in the goodness of the selected landfill sites.
6. There are little differences occurred in the locations of some of sites deduced by RTP in comparison with those sites of positive gravity maps may be due to the remnant magnetization in the subsurface rocks. Thus, the chooses of the candidate sites among the studied area faced some difficulties due to this fact.
7. No sites were chosen close to the Euphrates River, the matter which certainly prevent the adjacent governorates from solid waste and toxic chemicals inertance.
8. Through studying all the factors of the study area to select suitable landfill sites, in addition to the results of gravity, magnetic and remote sensing interpretations, they give suitable situations to apply thirteen convenient factors. Therefore, and during the application of all standard factors, only five useful sites were chosen for future landfill applications, there are sites 1, 2, 3, 10 and 13.

6. Recommendations

1. Key factors necessary in suitable landfill siting should be well considered to avoid the problems from neglecting these important factors.
2. The findings from this study can be followed as significant bases for replication such studies in other Iraqi areas as a step into an efficient and effective practice of waste management and disposal. To prepare desert for future landfill purposes, it is recommended to do detailed studied for each site individually using other techniques to detect caves, solution cavities, hidden weak zones …. etc. to avoid them during the choosing of other new sites.
3. The current study is considered an incomplete part of the basic research, especially the field work, due to the difficulty of accessing it during the research period owing to security reasons. Therefore, its recommend to conduct geological and geophysical (gravity, magnetic, seismic reflection and electrical resistivity) studies for the seven selected sites, in order to detect detailed shapes, sizes and depths of the underlying caves and weak zones.

Declaration of Competing Interest

No.

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