

Re-interpretation of Geophysical Data for the Archaeological Hill “Malta” at Duhok City – Iraqi Kurdistan Region.



Fadhil A. Ghaib*, Sirwa Q. Gardi**

Dep. of Geology, College of Science, Salahaddin University, Kurdistan region –Iraq, e-mail: fadhil@uni-sci.org, sirwagardi@yahoo.com

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Abstract:

Two geophysical methods (gravity and resistivity) are used to investigate the Malta archaeological hill in Duhok City-Iraqi Kurdistan Region. 200 gravity observation points were occupied covering the southern half of the flat-top of the hill. Precise Bouguer anomaly map and its regional, residual and Second Vertical Derivative anomalies are constructed to show the anomalous remains. High precision altitudes and accurate positioning of the stations guaranteed reasonable reductions. Beside gravity, six resistivity traverses are executed along selected directions. A total of 84 Vertical Electrical Sounding resistivity measurements along traverses were taken to show variations with depth. A final model of the subsurface was derived by the integration of both geophysical approaches. The two geophysical methods revealed the presence of wall remains distributed in a systematic manner under the surface. Their depth ranges from 0.5m to 1.5m. They are mostly built of limestone rocks of high resistivity and positive gravity anomalies.

Keywords:Archeo-geophysics; Malta Hill; Duhok City; Iraqi Kurdistan

I. Introduction:

The application of geophysics for archaeological studies is widely used in the world. Changes in the physical or chemical properties of the soil and/or its contents are the base of such studies. Archaeological Geophysics is the non-invasive description of archaeological objects and facts by measuring the variation of their geophysical proprieties, and interpreting them. They are understood as extensive explorations made with instruments that create maps for proprieties of sub-soil to obtain information of archaeological remains. The data present for this study are taken from two earlier published studies used gravity and resistivity separately [4]and[6].

Gravity method is relatively cost effective, non-invasive, non-destructive remote sensing method, also passive as require no energy input to acquire the data; thus, the method is well suitable to be applied in populated and remote area settings. The method involves measuring the gravitational attraction exerted by the earth at a measurement station on the surface. The strength of the gravitational field is directly proportional to the mass and therefore the density of subsurface materials. Anomalies in the earth's gravitational field result from lateral variations in the density of subsurface materials and the distance to these bodies from the measuring equipment on ground surface.

The electrical resistivity method on the other hand consists of the measure of the electrical

properties of the soil. Injecting a current into the ground and measuring how this current gets altered. For every measuring point a value of apparent ground electrical resistivity is calculated. Walls and building materials tend to be more resistive than sedimentary soils as well as cavities, ashes or paved floors [7].

II. The archaeological hill ‘Malta’:

The study area is a flat-surface archaeological hill which belongs to the Assyrian civilization (2000-612 B.C.) about 5km to the west of Dohuk city center-Iraqi Kurdistan Region (Fig.1) [1]. Its Assyrian name was Mailthaya [3]. The top of the hill was well flattened for some other purposes prior to this study. The hill is elevated 30-31m above surrounding ground. The hill used to belong to an ancient village holding the same name until 1957 and inhabited by about 30 Assyrian families [3]. The hill is originally a geomorphologic isolated elevated feature. From the southwestern side clear exposures of layered claystone, siltstone and sandstone belonging to the Injana Formation (U. Miocene, previously named Upper Fars Formation) are observed. These layers dip at about 40° northwards [6], (Fig. 2).

III. Aim of the study:

The study area was earlier surveyed using gravity and resistivity methods separately [4] and [6]. It is well known that any geophysical method alone has its limitations and ambiguities. The combination of two or more geophysical methods is better to interpret a certain target in order to minimize the ambiguities.

In this research a modernization was done by using present computer packages. Qualitative and quantitative analyses were carried out for gravity and resistivity data. A

careful comparison between the two types of data were made and displayed in such a way to reach the best interpretation. The interpretation was in view of distribution of remains and their approximate depth.

IV. Field data:

A. Gravity

The task of the study is to delineate the crypt matters, which are expected to be walls, cavities or any other features by analyzing the Bouguer anomaly map. The author believes that 2mx2m grid is reliable to detect such features [4]. An arbitrary reference station (36°51'26"N 42°56'24"E) among 200 measuring points was chosen with an average time interval of about 4 minute (Fig. 1). Readings were taken during the period 3-10/6/1997 and corrected for the conventional variations of gravity field except the terrain effect, which is believed to be negligible. All readings were measured at the nearest third of the finest scale division using a LaCoste-Romberg, model G gravimeter that is used for the first time for such a purpose in Iraq [4]. However it was used by [2] and [5] in engineering projects. The area is topographically surveyed by the leveling procedure to the maximum possible precision using WildN2 level equipment.

B. Resistivity

Six resistivity traverses are selected from the original data (6) for each point of measurement being a VES test. One of these traverses is in the E-W direction along the gravity base station while the others are in the N-S direction. Wenner configuration was applied to test each of the 84 points along the six traverses (Traverse 1; 20 points, traverse 2; 10 points, traverse 3; 14 points, traverse 4; 16 points, traverse 5; 15 points, traverse 6; 14

points. The starting points of traverses 2, 3, 4, 5 and 6 are shared with points from traverse 1. At each point six values of (a) space were used by expanding the electrodes to investigate deeper; these spaces are 0.5, 1, 1.5, 2, 2.5, and 3 meters. The distance between successive points is 2 meters (Muhammad, op. cit.).

C. Densities

Microgravimetric survey deals with

measurements that covers small area and provides detailed geologic information of the near surface features. Among them, density of surface rocks and/or soil is an important factor, which its value must be known precisely because of its important role in both correction and interpretation.

The average density of the covering soil was 1.306 gm/cm^3 , which was used in Bouguer correction.

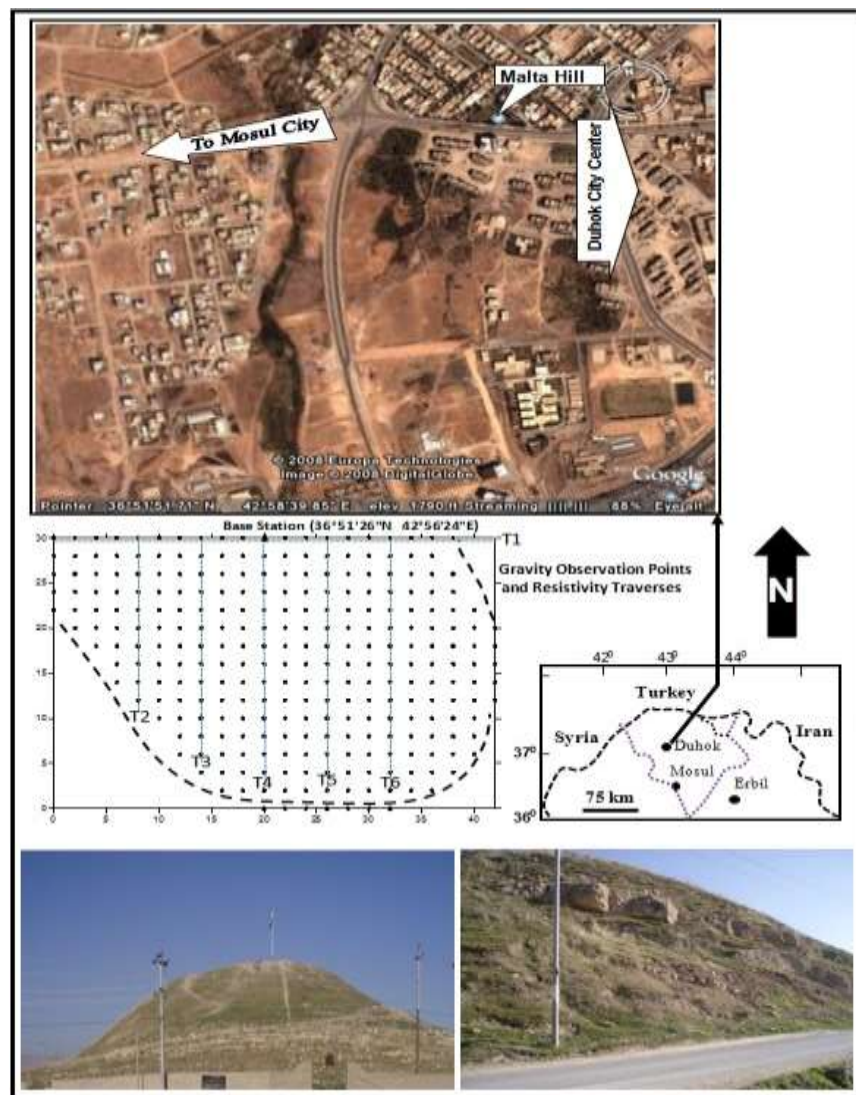


Fig. 1. Location maps and views of the Malta Hill.

V. Interpretation of geophysical data:

A. Bouguer and transferred maps

The Bouguer anomaly map (Fig. 2) shows both negative and positive anomalies. The latter group of anomalies is considered to be

the reflections of the stony walls underneath the soil surface since they are of higher density. On the extreme eastern side part of the investigated part of the hill, a small piece of the hidden walls is exposed. It is built of limestone which is coinciding a positive gravity anomaly. This emphasize that most possibly all positive anomalies should coincide the trace of hidden walls. The maximum gravity value is 0.6mGal in the northern part and more than that in a spot at the southern part while the minimum gravity value is shown in the extreme southern border, it is in the shape of linear E-W anomaly reaching a value of -0.7mGal.

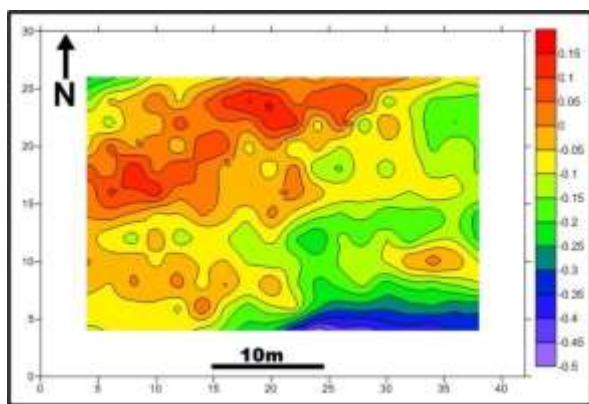


Fig. 2. Bouguer anomaly map.

Each gravity value on the Bouguer anomaly map is the summation of the effect of both deep-seated and shallow-seated anomalous bodies. Because of that these anomalies should be separated to regionals and residuals reflecting the two above mentioned groups of bodies respectively.

A simple arithmetic ring method is used to filter out the residuals and regionals. Figure 4 shows the regional anomalies of the investigated area. The anomalies in this map reflect the effect of the deeper bodies within the area which include the effect of the underneath rock layers.

The regional anomaly map (Fig. 3) is characterized by a major stripe of positive anomalies extending in the E-NE direction occupying the northwestern part of the area. These anomalies which reach a maximum value of 0.2mGal may be understood as deeper

foundations of walls or the effect of the rock layers underneath and might belong to earlier historical ages (Ghaib, 1999). A general E-W direction of contour lines however can reflect the E-W strike direction of layering of the strata.

The residual anomaly map is more important in most gravity surveys since they reflect the shallower structures which are often the target. This is shown in Figure 4. A systematic distribution of positive anomalies can be traced reaching a gravity value of more than 0.5mGal. Most of them are in the N-S and E-W direction. This gives an idea that the main skeleton of the ancient structure is constructed in these directions.

The second vertical derivative map is the reflection of shallower structures neglecting the regional background making it zero. This map was also constructed and given in Figure 5. It shows nothing more than those residual anomalies.

Positive anomalies from gravity maps were picked out to construct Figure 6. This figure is believed to show the distribution of ancient walls starting from the exposed part of the wall in the eastern side. The model shows a sort of system indicating that the structures are built mainly in the E-W and N-S directions. The thickness of the walls which exceed 5m is not real, instead the authors think about their destruction so as pieces of the walls are distributed in-between to give a broad gravity anomalies and hence broad wall thickness.

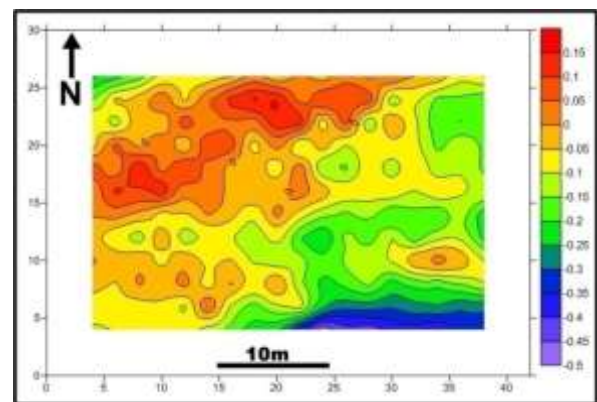


Fig. 3. Regional anomaly map.

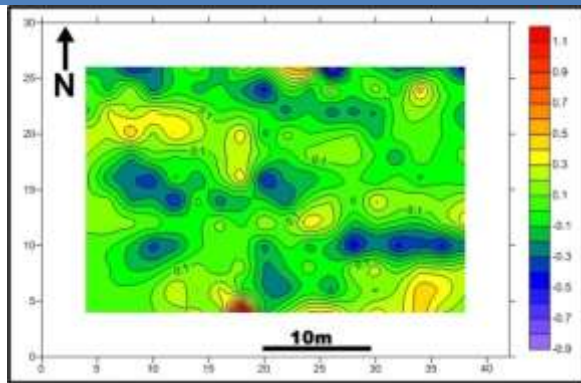


Fig. 4. Residual anomaly map.

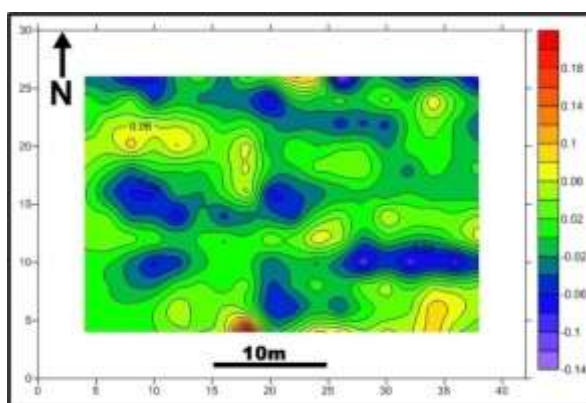


Fig. 5. Second Vertical Derivative map.

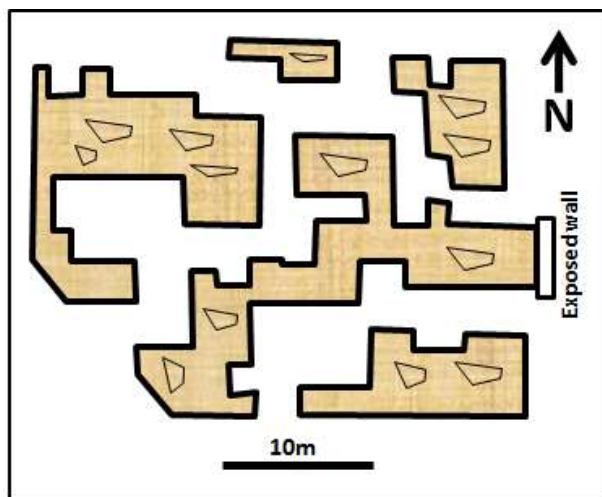


Fig. 6. Inferred structure design depending upon tracing the positive gravity anomalies.

B. Resistivity traverses and gravity profiles

The six resistivity traverses are given in Figure 7. In all traverses except 2, the effect of remains is shown at depths of about 0.5m extending down to a depth of 3m at which their effect is no more identified. There may be bodies present at depth less than 0.5m, but not identified as less than this space of electrodes was not tested. In traverse 2, on the other hand, most of the remains are deeper except at the ends of the traverse but not deeper than 3m. Since the walls are mostly built of limestone as revealed by the exposure of a small exposed part at the eastern side of the surveyed area (Fig. 6) and the higher values of resistivity such as 275, 225 and 175 $\Omega.m.$ (Fig. 7). Such values are considered to be those of limestone walls while the surroundings are less than that considerably. The apparent resistivity of the surrounding clayey materials is between 25 and 75 $\Omega.m.$ which might contain some limestone debris scattered here and there increasing resistivity value.

The Bouguer gravity anomalies along the same traverses are given in Figure 8. When correlated with resistivity curves in Figure 7, the following comments can be deduced:

- 1- In traverses 1 and 3 the Bouguer curve is perfectly comparable with the resistivity curve of $a=0.5m$ (Fig. 7) which can be related to depth of remains of 0.5m depth while traverses 4 and 6 it is partly comparable.
- 2- In traverse 2 the Bouguer anomaly profile is perfectly comparable with resistivity curve of $a=1m$ (Fig. 7), and hence depth of remains of 1m.
- 3- In traverse 5 the Bouguer anomaly profile is perfectly comparable with resistivity curve of $a=1.5m$ (Fig. 7), and hence depth of remains of 1.5m.

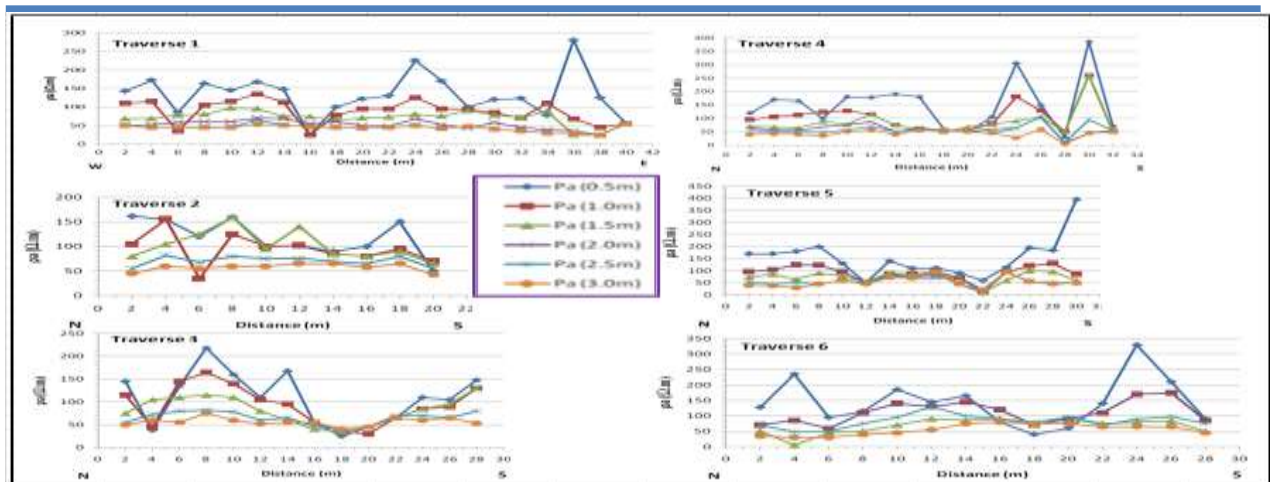


Fig. 7. Apparent resistivity curves of the six levels along the six traverses.

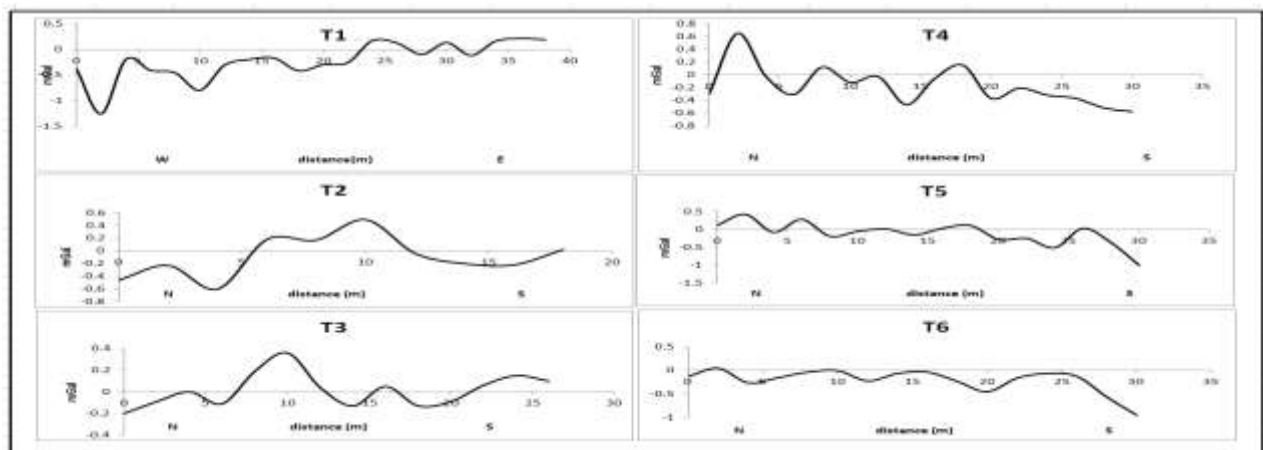


Fig. 8. Bouguer gravity anomaly profiles along the six traverses.

C- Geo-electrical sections

Vertical Electrical Sounding (VES) is generally used to determine electrical resistivity variations as a function of depth. This is the case at each resistivity point in this study since we expanded the distance of electrode space from 0.5m to 3m at the point of investigation.

The resistivity data was interpreted by the application of the commercial program IPI2WIN. Four examples for the result of points are given in Figure 9.

The errors encountered are acceptable. All sounding curves show the presence of two horizons. At each point the true resistivity of the two horizons are estimated as well as the depth to the second horizon (Table I).

By means of systematic sounding results along a traverse it is possible to construct a geo-electric section. From this section a boundary is traced between the upper and lower horizons. Geo-electric sections are constructed for all traverses and are given and used in Figures (10-15). These sections are important for inferring the subsurface model as will be shown in the next section.

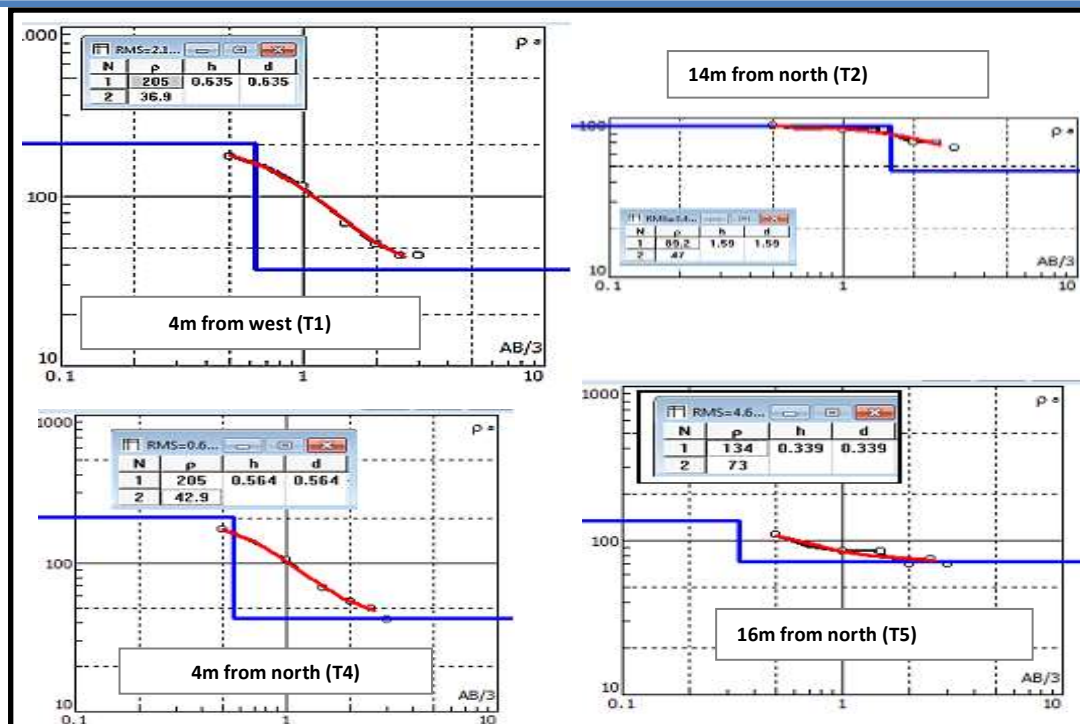


Fig. 9. Examples of some Sounding curves and their interpretation.

VI. Discussion:

Gravity, geo-electrical sections and pseudo-resistivity sections are drawn together to show a correlation data leading to infer the subsurface archaeological remains along the executed traverses. Though pseudo-sections are not reflecting true resistivity, they were plotted as a general display of vertical and horizontal apparent resistivity distribution along the traverses. The depth of remains are approximated mainly from the geo-electrical section for each traverse and approved by the agreement with the Bouguer and resistivity sections (Figs. 10-15). The interpretation is done depending on that limestone rocks have higher resistivity and density resulting in high gravity values. Ditches are those sites which have lower gravity values. In all traverses, two resistivity horizons are observed. The upper representing the upper level layer having a

resistivity value ranging from 120 to 297 $\Omega.m$ while the lower horizon or level is ranging in resistivity between 42 and 77 $\Omega.m$. It is believed that the higher resistivity values of the upper layer are attributed to the presence of limestone debris within the soil. From these figures the following points are deduced:

- 1- A vertical dashed line in all correlation figures was drawn to show better, the comparison of different anomalous areas. Most of the positive gravity anomalies are opposite to the shallow geo-electric boundary between the two horizons mentioned earlier; hence reflecting the shallower wall remains.
- 2- Except few points, all resistivity values of the upper horizon are much higher than those of the lower horizon.
- 3- The positive gravity anomalies opposite to the shallow geo-electric horizon points are considered as the subsurface wall remains.

Table 1: True resistivity of the two horizons and depth to the lower horizon.

Traverse No. / VES No.	True resistivity ($\Omega.m$)		Depth (m)	Traverse No. / VES No.	True resistivity ($\Omega.m$)		Depth (m)
	ρ_1	ρ_2			ρ_1	ρ_2	
T1/1	172	39.6	0.66	T4/2	205	42.9	0.56
T1/2	205	36.9	0.64	T4/3	203	39.4	0.61
T1/3	92.3	47.2	0.25	T4/4	123	1.7	1.59
T1/4	166	33.4	0.79	T4/5	213	49.4	0.64
T1/5	144	14.3	1.22	T4/6	162	49.5	0.96
T1/6	185	46.8	0.79	T4/7	379	53.6	0.30
T1/7	165	41	0.75	T4/8	461	54.9	0.25
T1/8	16.7	125	0.59	T4/9	70.6	52.7	0.25
T1/9	100	34.3	0.95	T4/10	43.7	56.7	0.25
T1/10	131	30.7	0.84	T4/11	96.6	11.7	1.57
T1/11	138	33.9	0.78	T4/12	397	46	0.57
T1/12	265	45.9	0.58	T4/13	164	87.3	0.63
T1/13	178	36.1	0.66	T4/14	46.5	0.28	1.24
T1/14	104	1.32	1.55	T4/15	402	44.7	0.80
T1/15	110	13.7	1.3	T4/16	95.1	49.6	0.25
T1/16	108	23.4	0.94	T5/1	226	60.5	0.42
T1/17	105	0.63	1.42	T5/2	146	1.23	1.48
T1/18	800	27.4	0.30	T5/3	207	44.5	0.70
T1/19	259	22.7	0.33	T5/4	175	1.74	1.38
T1/20	55.2	48.9	0.25	T5/5	139	61.1	0.62
T2/1	178	44.8	0.63	T5/6	47.6	51.3	0.28
T2/2	179	54.4	0.91	T5/7	252	77.1	0.25
T2/3	96.2	60.7	0.25	T5/8	134	73	0.34
T2/4	146	2.71	1.96	T5/9	128	77.3	0.41
T2/5	103	35.9	1.76	T5/10	82.4	1.31	2.13
T2/6	106	2.53	2.75	T5/11	165	10.4	0.25
T2/7	89.2	47	1.59	T5/12	173	79	0.30
T2/8	99.7	58.7	0.69	T5/13	201	42.5	0.71
T2/9	244	78.6	0.29	T5/14	200	33.7	0.78
T2/10	51.2	61.7	0.25	T5/15	1300	51.3	0.26
T3/1	169	42.4	0.69	T6/1	286	56.9	0.26
T3/2	25	127	0.46	T6/2	1522	24.2	0.27
T3/3	152	41	1.22	T6/3	166	46.2	0.30
T3/4	247	64.2	0.69	T6/4	163	63.9	0.49
T3/5	171	52.6	0.92	T6/5	277	82.9	0.43
T3/6	121	41.4	0.96	T6/6	182	104	0.38
T3/7	267	57.4	0.38	T6/7	213	93.5	0.50
T3/8	63.5	43.3	0.49	T6/8	84.4	105	0.25
T3/9	16.9	43.1	0.25	T6/9	25.8	90.6	0.25
T3/10	35.3	82.7	1.77	T6/10	42.9	104	0.25
T3/11	64.7	82.9	2.00	T6/11	170	71	0.52
T3/12	114	65.7	0.56	T6/12	618	92.4	0.37
T3/13	101	37	1.47	T6/13	295	92.9	0.5
T3/14	146	25.3	1.54	T6/14	117	62.7	0.42

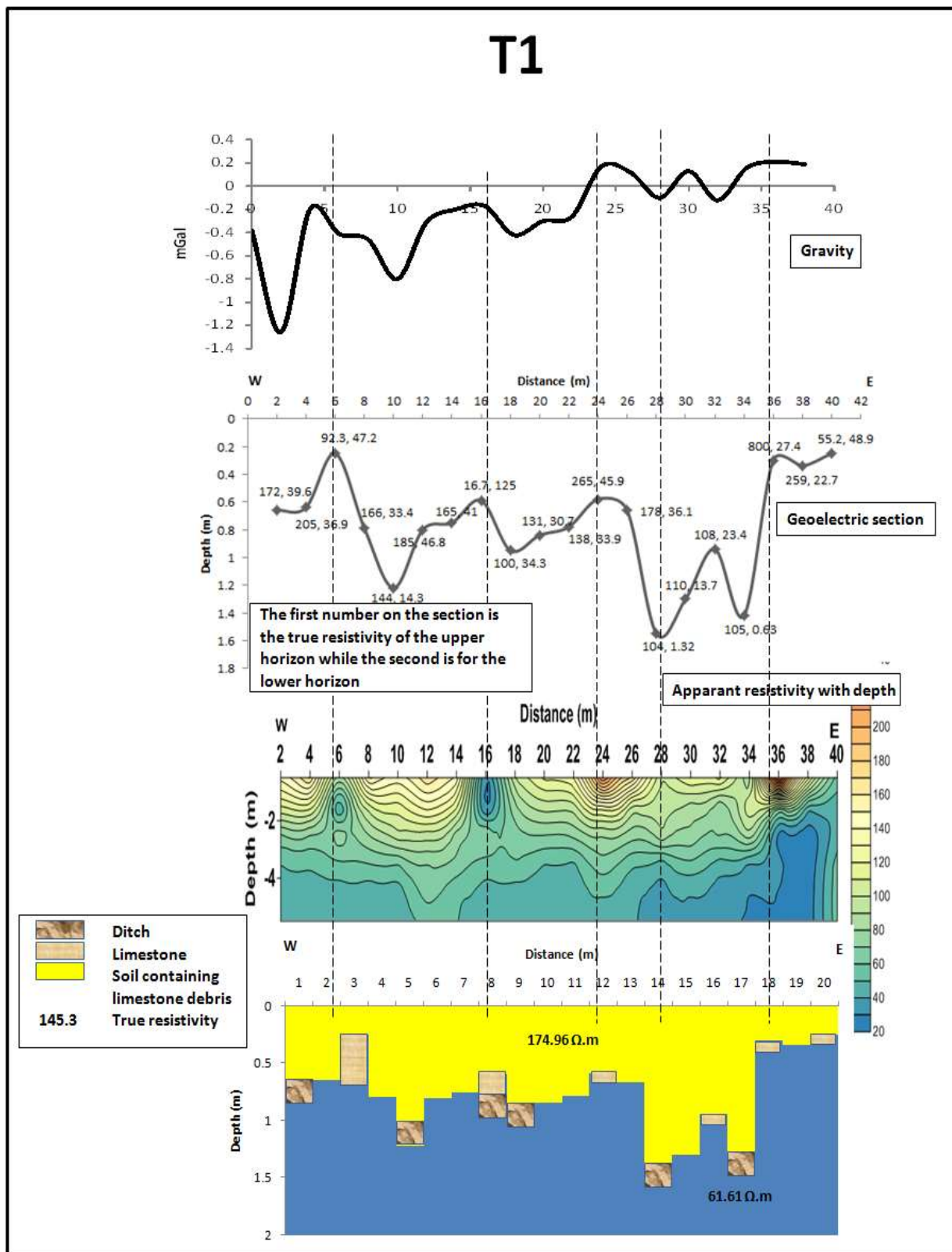


Fig. 10. Inferred structure along T1.

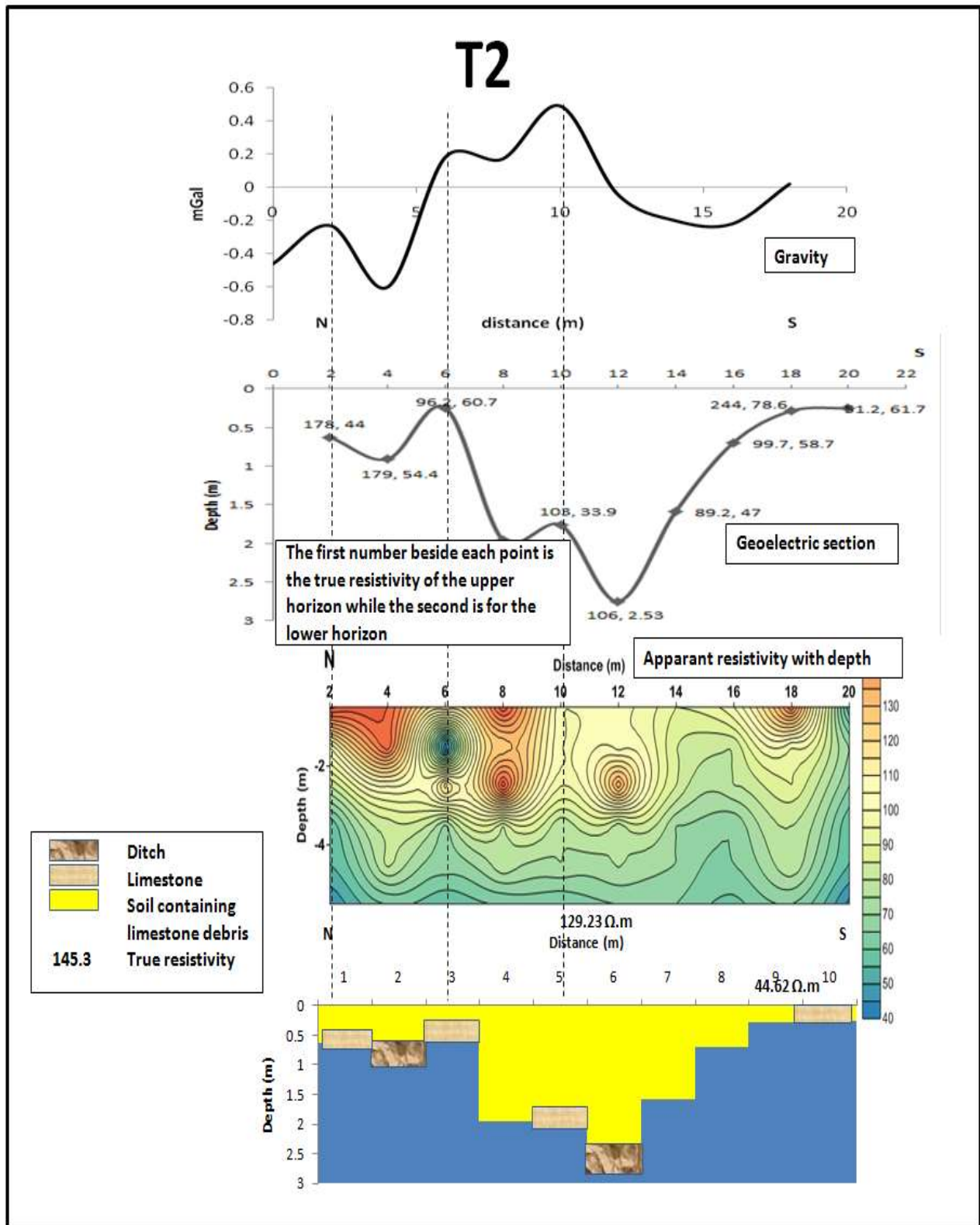


Fig. 11. Inferred structure along T2.

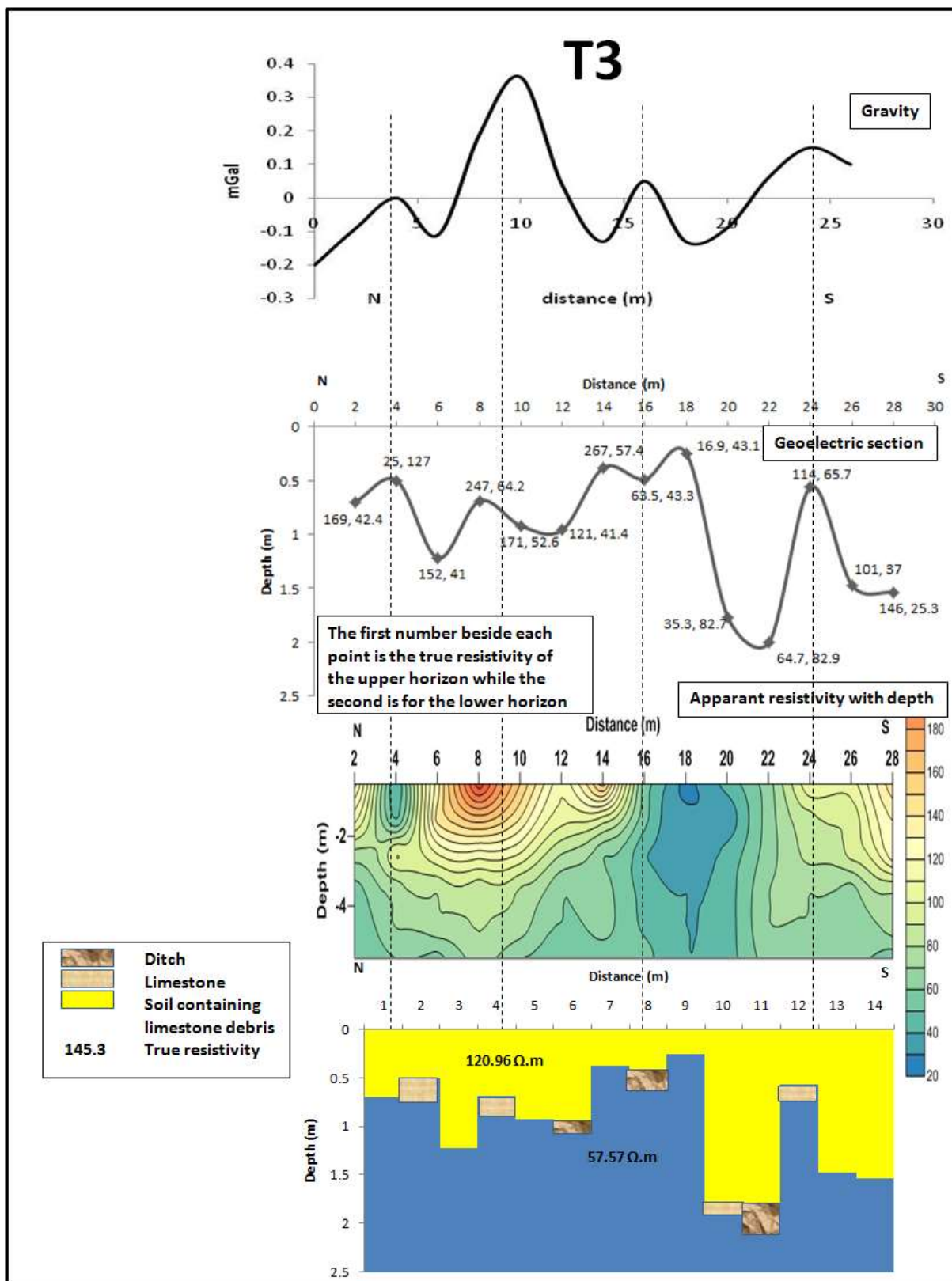


Fig. 12. Inferred structure along T3.

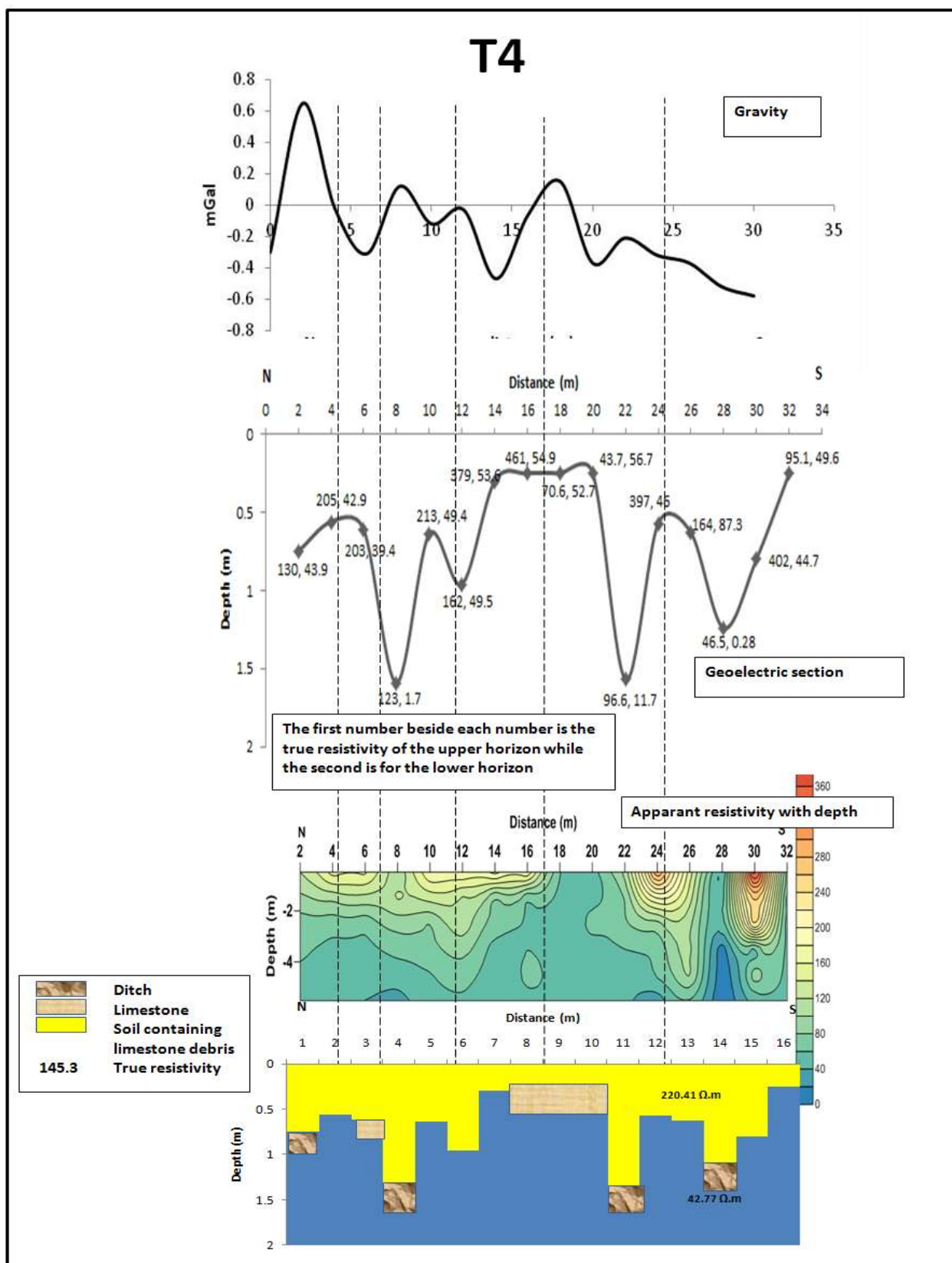


Fig. 13. Inferred structure along T4.

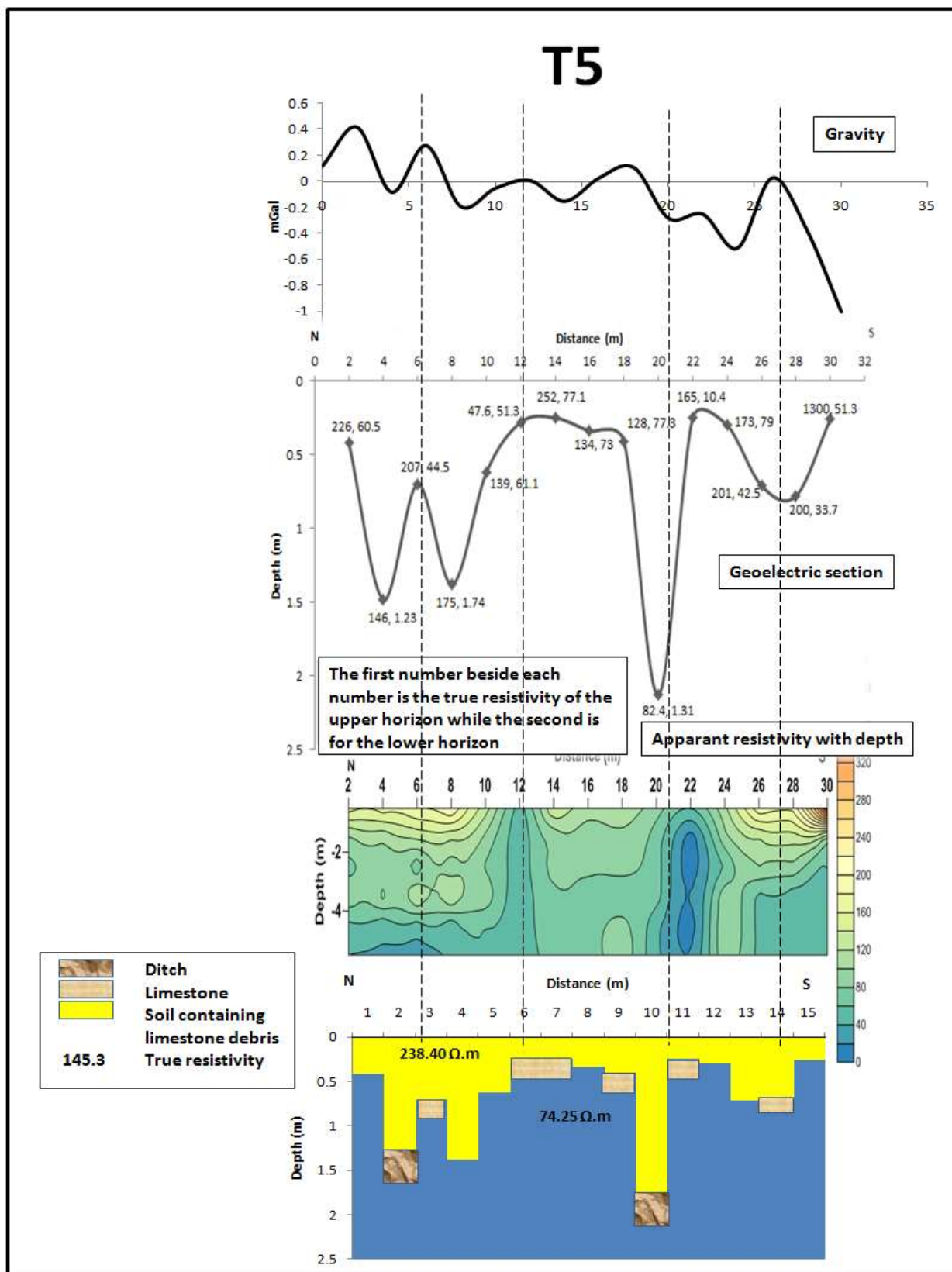


Fig. 14 Inferred structure along T5.

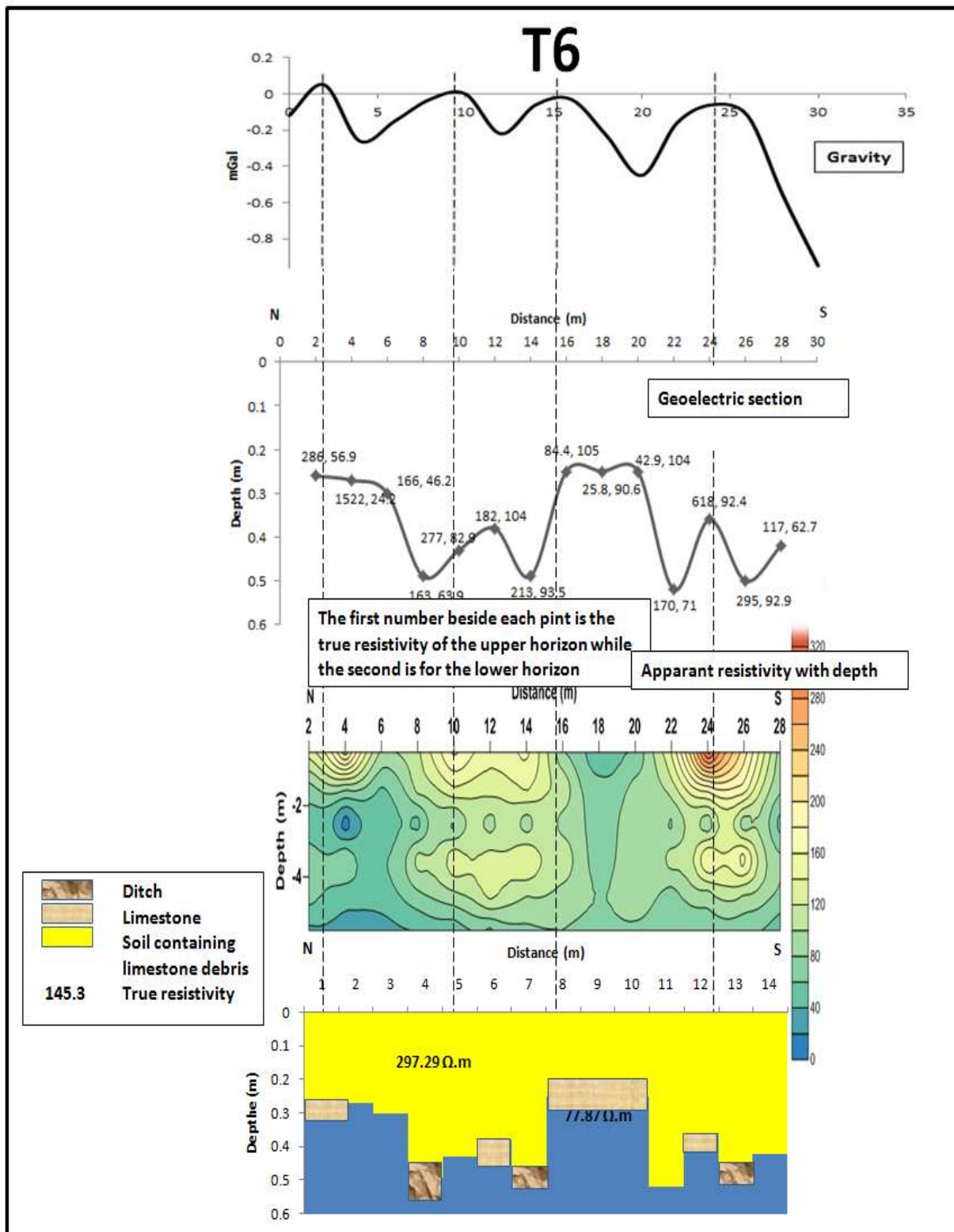


Fig. 15 Inferred structure along T6.

4- Ditches are considered below the relatively negative gravity anomalies which are opposite to deeper levels of the geo-electric section.

5- Depending upon the integration in (3) above wall remains and ditches as rectangle shapes were drawn in the box in the bottom of the figures.

6- In-between the wall rectangles there is most possibly debris of the same wall rocks are scattered to give some irregularities and some shifts between the gravity anomalies and geo-electric boundary anomalies.

7- A comparison was made between the final structure designs in the three researches carried out in Malta Hill. Figure 16 shows that there are many similarities between them with some differences also. The design given by Mohammad (2006) involves details which seem to be imagined by the author. However the design given in the present study has characteristics from both. Results which are given by a certain geophysical method may show some anomalies which are not real or ambiguous. This can be overcome by a conjunction of another geophysical method to minimize that ambiguity.

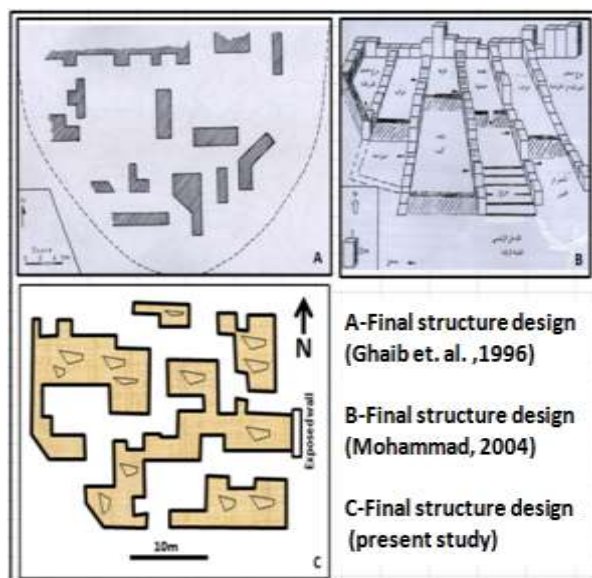


Fig. 16 Comparison between the structure designs of the present research with two other researches.

VII. Conclusions:

The analysis of both gravity and resistivity data for the Malta archaeological hill site in Duhok City showed a good consistency between the results of both types of data. The Bouguer anomaly map and its residual anomaly maps were used to show the inferred construction map of the structure underneath the soil cover. All remains are distributed systematically in N-S and E-W directions. The positive anomalies stripes were interpreted to be the limestone walls and the roofs which were destroyed inward later on.

When the Bouguer anomaly profiles were compared with the resistivity traverses along the same paths there were good coincidence between the positives and negatives in both cases (Fig. 7) and (Fig. 8). Most of the positive gravity anomalies were opposite to the positive or shallow geo-electric boundary between the two deduced horizons; hence reflecting the shallower wall remains. These two types of sections by the aid of pseudo-resistivity sections were used to draw the inferred archaeological sections in the subsurface. The geo-electrical sections were basically depended upon to estimate the depths to top of the buried objects. Ditches along the traverses were defined as having low gravity values against deep geo-electric boundary.

Depth of remains ranges between 0.5m and 3m. and are mainly composed of limestone of higher values of resistivity such as 275, 225 and 175 Ω .m. The apparent resistivity of the surrounding clayey materials is between 25 and 75 Ω .m. which might contain some limestone debris scattered here and there increasing resistivity value.

The comparison between the inferred structure designs in two researches other than the present one (Fig. 16) showed that it is better to use more than one geophysical methods to minimize ambiguities. Gravity and resistivity data gave comparable results.

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