

DETERMINATION OF GEOLOGICAL AND GEOPHYSICAL (ELECTRICAL-VESMETHOD) FEATURES OF THE KARST CAVITY IN THE ESENTEPE REGION OF BATMAN PROVINCE

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Abstract:

Within the scope of this study; in order to reveal physical features of the ground pit which is considered to be the karst cavity in the Esentepe region of Batman Province, geological and geophysical researches were conducted. Within the framework of the geological studies carried out in the examination area, 4 exploratory drillings in total of 75 meters depth were performed at the locations determined with the purpose of identification of the changes in lateral and vertical directions of the geological and lithological status, the groundwater level and the engineering parameters of the ground pit which is thought to be in the karst cavity structure in Esentepe region. With the intent of detection of the physical features of the ground layers that were passed during borehole drilling, Standard Penetration Test (SPT) was carried out. Moreover, ground's natural unit bulk density, water content, sieve analysis and Atterberg limits were determined on the disturbed (SPT) and undisturbed (UD) specimens taken from the boreholes, and consolidation & Tri-axial Compression Tests were performed. Geophysical researches conducted in the examination area consist of Vertical Electrical Sounding. As geophysical study; vertical electrical sounding was performed at 2 points. Visible resistivity distance curves & ground electric sections of the Vertical Electrical Soundings and the lithology of the underground structure were evaluated by using Ipi2win program. Furthermore, in the examination area, with the multi-electrode resistivity method, resistivity area data obtained via AGI R8 device capable to measure 8-channel 84-electrode resistivity and IP were evaluated in the Earthimager 2D program which is a computer based evaluation program.

Comments were made by correlating the evaluations and the regional geology. Within the scope of the study, mechanism of the pit formations in karst cavity structure causing problems such as subsidence in the structures, construction of which is thought and as ground failure on the grounds on where these structures will be constructed, occurring at the city center of Batman Province was examined.

Key Words: Batman, Karst Cavity, Resistivity, Vertical Electric Sounding, Standart Penetration Test

1.Introduction

The main reason of the sinkhole formation can be explained by the fact that the limestone or similar soluble soil formations (dolomite, gypsum, halite etc.) can be dissolved with water having an acidic character [1, 2, 3]. In general, the most important indicators for the sinkhole formation are the emergence of fresh surfaces in the areas of contact with various sustaining walls or structures as well as bending or slipping on the sustaining walls. The speed of the melting hole, which forms the most common type of sinkholes in terms of formation mechanism, runs completely parallel with the melting rates of the limestone forming the soil. These rocks are soluble. With the dissolution of the karst rocks, only a small amount of residual material is retained. Therefore, expanding fractures and cracks do not get closer and the underground water circulation is not blocked. As a result, slowly collapsing land surfaces are formed.

The units containing sand in various regions of Batman Province and the sinkholes in the karst space structure may lead to problems such as subsidence of the constructions and soil failure in the construction space. Detection of these units prior to settlement is of great importance in terms of prevention of loss of life and property by eliminating the engineering problems that may occur during and after construction. It is known that there are many sinkholes in Batman Provincial centre. In the previous studies, especially the formation of sinkholes seen in the south of Esentepe, Gültepe district, has been investigated. During the construction of road by the Municipality personnel on October 6, 2011, a hole extending to the south of Esentepe area was found in the upper part of the road with the removal of the 30-30 cm thick soil cover. During the works on the field subsidence in two different places were found apart from other sinkholes in the same region. Each of the three subsidence are in the same direction and on about K 40-50B. The mouth size on the surface of the sinkhole is approximately 1 m x 0.75 m (Figure 1.a). The sinkhole is 8 m in depth and has a rectangular form. From this section, the sinkhole makes a 17 meters-long depth while the width is reduced to till 1.5 meters. The fault forming the northern wall of the sinkhole is covered by the newly formed sediments about 5 meters thick [4] (Figure 1.b).



Figure 1a. View of the Sinkhole found in the South of Esentepe

Figure 1b. 5m Vertical View of the Fault from the Mouth of the Sinkhole (Eren et.al. 2012)

Batman province is located in the South-eastern Anatolia, whose neighbours are Muş in the north, Diyarbakir in the west, Bitlis and Siirt in the east and Mardin in the south. The field under investigation is the Esentepe District of Batman located in the city centre (Figure 2).



Figure 2. The Site Location Map of the Investigated field

2. The Geology of the Investigated field

Batman is geologically based on the Şelmo Formation and the Quaternary units consisting of upper Miocene-Pliocene aged mudstone sandstones and conglomerates. Aside from these units, the Eocene-Oligocene units that are exposed to the West Raman Mountain in the south are the oldest units in the investigated field (Figure 3). The limestone at the surface of West Raman Mountain and the dolomitic limestones form the Hoya Formation. The age of the 228m-thick unit between Batman Hasankeyf is Lower Eocene-Lower Oligocene [5]. The unit represented by limestone, gypsum and shale on the northwest slopes of Raman Mountain forms the Germik Formation. This formation is composed of partly silty and sandy dolomite, limestone shale and white gypsum alternation. This unit is assessed to be within the Midyat Group and to correspond to the regressive evaporitic phase of the Upper Eocene Oligocene age [5].

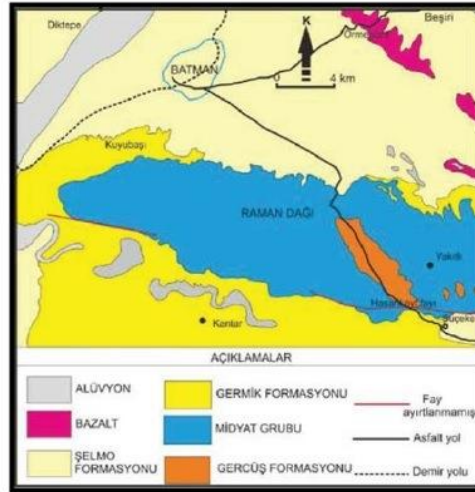


Figure 3. Geological Map of Batman City (prepared by adapting the MTA's 1 / 500,000 scale geology map)

Figure 4 shows the geological section of the investigated field. At the bottom of the formation are gypsum and salt-bedded sandstone and mudstone alternates, while at the upper parts are loosely attached conglomerate, sandstone and shale alternates. The unit is Upper Miocene-Lower Pliocene age. To the east of the city of Batman, Aydınkonak and Akça, the newly formed Pliocene sediments which are predominantly the loosely attached conglomerate and the sandstone on Şelmo Formation are considered to be the Lahti Formation defined in the Adıyaman region [5].

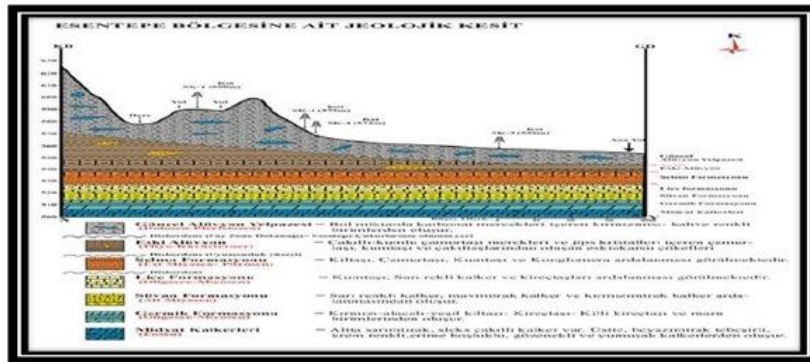


Figure 4. Geological Section of the Investigated Field

3. Findings of the research

3.1. Field Research and experiments

Within the frame of geological studies in the field of investigation, totally 75 meters long depth is drilled with 4 drills of 19.50 meters and 1 drill of 16.50 meters in the pre-chosen locations to determine the changes in the lateral and vertical directions of the geological and lithological state of the ground sinkhole, thought to be a part of karstic space in the Esentepe region, and to define engineering parameters. The index properties of the soil were determined and Standard Penetration Test (SPT) was performed in every well to determine the physical properties of the soil layers during

drilling. Figure 5 shows the general view of the sinkhole where the drilling work of SK-2 is made. It is seen that the units in SK-2 drilling wells are formed by the alternation of Clayed Sand and Sandy Clay levels where the Recent Alluviums of the Quaternary age are dominant (Figure 6).

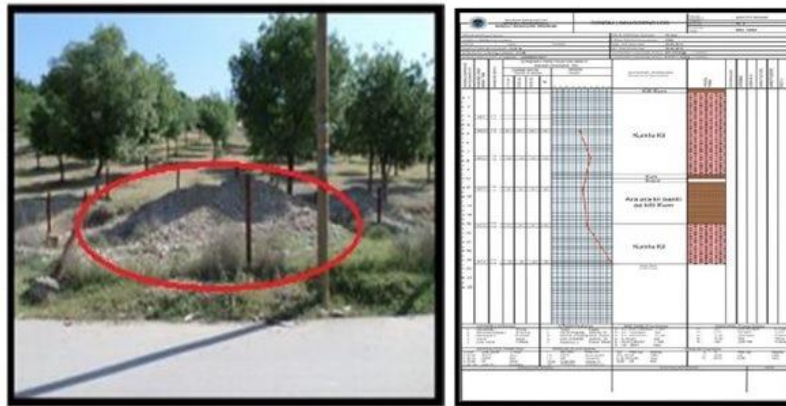


Figure 5. Overview of the drilled sinkhole Figure 6. SK-2 Log

According to the results of the SPT Tests obtained from the drillings in the field of investigation, the values in the SK-2 borehole shows that it is formed with the alternation of Clay Sand and Sandy Clays levels where the Recent Alluviums of the Quaternary age are dominant; and according to the SPT values it is in the form of solid and very solid soil. From the SPT-1 and SPT-2 values at the first 14-16 m levels of the SPT-N values obtained from the SK-3 borehole, it is understood to show a solid and very solid soil behaviour according to the soil classification (Table 1).

Table 1. SPT Experiment Results and Samples Obtained from Drills in the Field of Investigation

Drill No.	Depth (m)	SPT (N) Values
SK-1	19,50	UD-1=>2,00-2,15,SPT-1=> N=75,SPT-2=>N=81,SPT-3=> N=87
SK-2	19,50	UD-1=>3,00-3,20,SPT-1=> N=47,SPT-2=> N=63,SPT-3=>N=52,SPT-4=N=58,SPT-5=> N=50+
SK-3	19,50	SPT-1=>N=10,SPT-2=> N=20SPT-3=> N=66
SK-4	16,50	UD-1=>4,50-4,70,SPT-1=> N=18,SPT-2=> N=23,SPT-3=> N=71

3.2. Laboratory Experiments and Analyses

To define the lithological and geological states of the soil in the field as well as the engineering parameters, the Atterberg limits are determined and consolidation and triaxial compression test is made for the unit volume weight, water content, sieve analysis of the soil based on the disturbed and

undisturbed samples taken from the drilled wells. The liquid limit (PL) and plastic limit (PL), which are known as Atterberg Limits, were found in experiments on soil samples in sieve analysis and the Plasticity index (PI) was calculated. Table 2 gives the plasticity values according to the liquid limit range.

Table 2. Plasticity Values according to the Liquid Limit Range [6]

Liquid Limit Range (%)	Plasticity Degree	Description
<35	Low Plasticity	Oil-free or silty
35–50	Medium Plasticity	Medium oily
50–70	High Plasticity	Oily
70–90	Very High Plasticity	Very oily
>90	Excessive Plasticity	Excessively oily

Table 3. The index properties of obtained from drilled wells in the investigation field.

Drill no.	Sample No.	Depth (m)	Neutral density (gr/cm ³)	Water content (%)	Liquid Limit (%)	Plasticity Limit (%)	Plasticity index (%)	Class
SK2/SPT-1	SPT-2	4.50	1.86	18.7	29.5	18.5	11.0	CL
SK2/SPT-2	SPT-2	7.50-8.00	1.90	11.3	24.3	17.9	6.4	SC
SK2/SPT-3	SPT	11.00	1.93	10.3	25.2	18.5	6.7	SC
SK2/SPT-4	SPT-15	15.50	1.86	18.9	26.2	17.0	9.2	SC
SK2/SPT-5	SPT	19.50-20.00	1.87	24.1	46.3	22.8	23.5	CI
SK3/SPT-1	SPT-1	4.50	1.90	12.2	27.9	17.9	10.0	SC
SK3/SPT-2	SPT-2	12.00	1.94	8.9	25.6	17.2	8.4	SC
SK3/SPT-3	SPT	20.00	1.85	18.9	26.0	17.3	8.7	CL

According to the Atterberg (plasticity) experiments on the soil samples obtained from the drilled wells, the Liquid Limit is found to be at the range of % 46.3 and % 24.3 and the Plasticity index (PI) is found to be at the range of 23.5 and % 6.4. According to the United Soil Classification System (USCS) laboratory tests made on the samples obtained from the SK-2 and SK-3 drilled wells in the field of investigation, the soil classes of the units composing the soil are found to be as follows: Soil class CL, inorganic clay with low plasticity; Soil class SC, clayed soil; and Soil class CI, clay with medium plasticity (Table 3).

The water content is the ratio of the weight of a specific volume of water to its dry weight. The water content values of the samples obtained from the drilled wells in the investigation field are shown in Table 3 according to the geotechnical laboratory results. The water content of the floor in the study area is calculated between 12% and 25%. Natural density values range from 1.94 gr / cm³ to 1.82 gr / cm³ (Table 3).

3.3. Geophysical Electrical Method Studies in the Field of Investigation

Electric-Resistance is the method of calculating the resistivity and thickness values of the underground layers by measuring the potential of the electric field created by underground artificial current. The resistivity is the inverse of the conductivity, which is the electrical conductivity of a material and has the unit of ohm-m. The equipment used in the electrical resistivity method is a current source (battery and generator), a transmitter (controlled current transmitter unit), current and potential cabling and electrodes (Figure 7). A complex drill-profile section with various arrays of currents (A, B) and voltage (M, N) electrodes is obtained with the greatest depth of research depending on the total length of the cable. Electrode arrangements can be used in different shapes (Wenner-Schlumberger, Dipole-Dipole, etc.) [7]. In the investigation field the SUPER STING R8 IP resistivity measurement equipment was preferred (Figure 8).

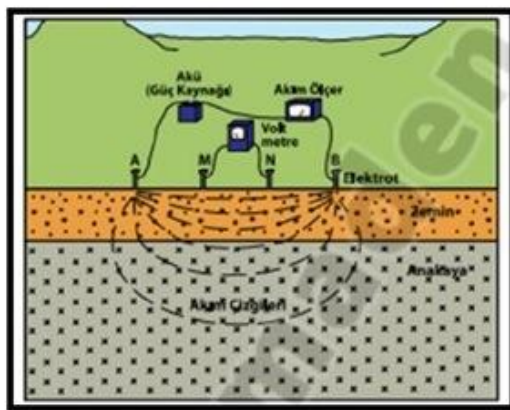


Figure 7. Typical Resistance Method's application in the Field [8]



Figure 8. SUPER STING R8 IP Resistivity Equipment

Vertical electric drilling technique (Figure 9) was used to investigate the vertical changes in the underground in the area of investigation, and directional measurements were made at separate points

(EAST-WEST). For this purpose, vertical electrical drilling measurements were made in two locations in the field of investigation. $AB / 2$ gap was applied as 30 m and electrode scheme was a schlumberger. Visible resistivity curves were plotted using the IpI2win program for apparent resistivity values obtained by the vertical electric resistivity method in the field of investigation. The electrical section of the investigation field is obtained by the electrical resistance values; and applying the measured values of Des-1 and Des-2 to the IP2win program.

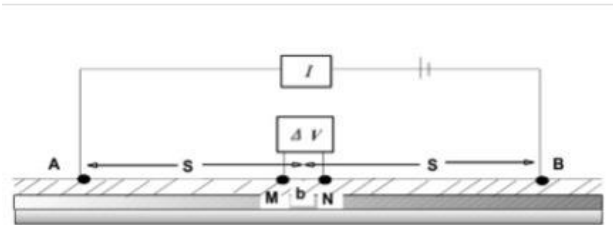


Figure 9. DES- Schlumberger Electrode Expansion [9]

It was tried to obtain resistivity values from layers up to about 36 inches deep by making an 80 m opening at the DES-1 point of the investigated field. At this point, the resistivity values at the level of 8.83 IN to 10,4 m were 1,08 ohm-m, which showed low resistivity values compared to other layers. The low clay value of 10 indicates that the ground is exposed to water (Figure 10).

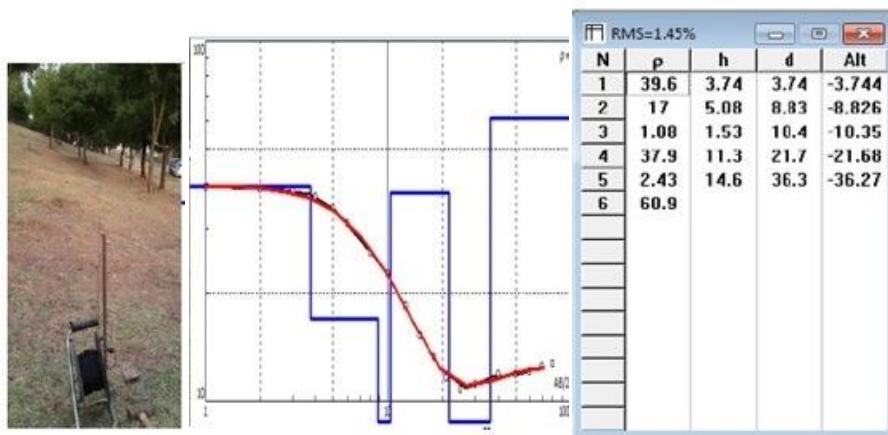


Figure 10. The measurement value of DES-1

It was tried to obtain the resistivity values from the layers up to about 30 m depth by making an 80m opening at the DES-2 point in the investigated field. At this point, the resistivity values at the level of 10.4 m to 33.2 m were 6.72 ohm-m and the resistivity values were low compared to other strata (Fig. 11).

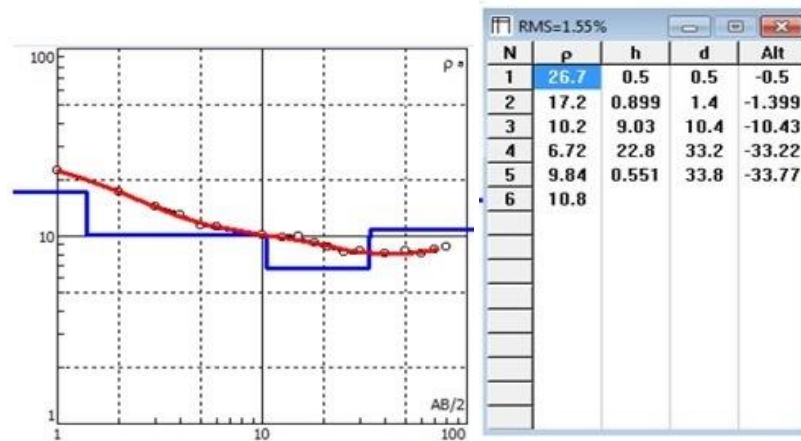


Figure 11. DES-2 Measurements

The electric section of the investigated field was created with the measurement values obtained from the Des-1 and Des -2 points by applying the IP2win program (Figure 12). According to the low electrical resistivity values of the DES (Vertical Electricity Drilling) sections obtained from DES study performed in the field, loose or potentially water-containing loose units are detected between 5.22 and 13.11 meters and water-containing units are detected between 7.94-9.81 meters. Low resistivity values between 4 m and 10 m in the DES (Vertical Electrical Drilling) sections obtained by the Vertical Electrical Drilling (DES) study made in the field of investigation show the possibility of underground water at the 4th meter (Figure 12). The most important evidence of the existence of groundwater is undoubtedly the significant resistivity reductions in regions very close to the groundwater level. The decrease in the resistivity value indicates that the grain diameter of the structure is reduced and vice versa, the growth of the resistivity value indicates the growth of the grain diameter. The gravel content of the clay at some levels lead to an increase in the resistivity, whereas the clay content of the sand at some levels lead to a decrease in the resistivity.

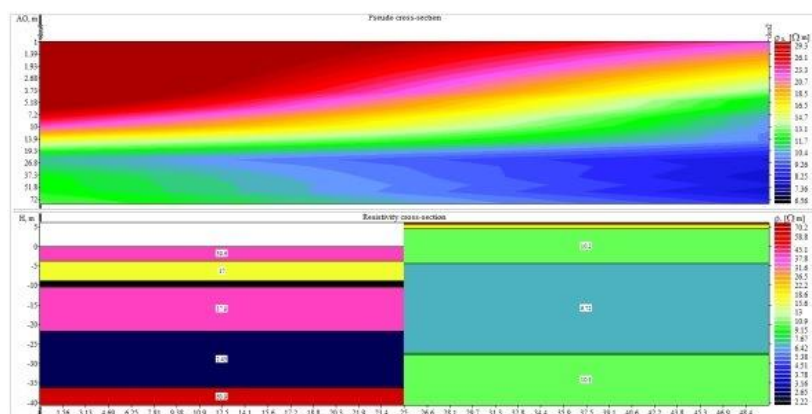


Figure 12.Des-1 Des -2 Soil Electrical Section

In recent years, rapid developments in the field of electronics and computers have enabled the development of an automatically-changeable multi-electrode resistivity measurement method (electrical resistivity imaging), which allows drilling-profile measurements to be taken along a

direction. Today, thanks to multi-electrode measuring devices, it is fast and easy to make measurements. From the data measured by this method, information about the resistivity structure in both the vertical and horizontal directions of the underground can be obtained. In the multi-electrode method, the measuring device is computer controlled. After all the electrodes are connected to the measuring device by a single cable, they are measured sequentially for the desired electrode array. As a result, this allows making measurements at certain stations (points) and for certain $AB / 2$ values and direct drilling-profile measurements. With this data, a pseudo-section is obtained. In the application of the electrical method to the multi-electrode system, the visible resistivity pseudo-section data is interpreted by an inversion algorithm to obtain resistivity depth sections along the profile for potential indicator points, showing the 2D resistivity structure for both lateral and vertical directions [10]. Also in this study, multi-electrode electrical measurements were made in the field to extend the depth of the investigation (Figure 13).



Figure 13. Measurement in the field with the multi-electrode electrical resistivity method

In the investigation field, the resistivity field data obtained with the AGI R8 device capable of measuring resistivity and IP with 84 electrodes and 8 channels by the vertical electrical drilling (DES) method was evaluated in the Earthmager 2D program, a computer evaluation program. The assessments were made in correlation with the regional geology. Dipol-Dipol-Gradient method was applied in the resistivity studies and the electrodes were placed 2-4 meters apart. 42 electrodes were placed. 2 series were made. These measurements were evaluated in the Earthmager 2D evaluation program. These evaluations were converted to a horizontal image. In order to determine the depths, thicknesses, resistivity values and water retention properties of underground units, the profile resistivity and geophysical underground structure of the profile are drawn. The data obtained from the points evaluated in the computer evaluation programs were transferred to the related sections and maps after data integration was completed. Two-dimensional sections were obtained in resistivity measurements in the investigated field and named as ERT1, ERT2 profiles (Table 4).

Table 4. The Electrode Distances and Profile Lengths of Electrical (Resistivity) Measurement Profiles

Lines	Electrode distance	Profile Length
ERT1	2 m	84 m
ERT2	4 m	168 m

With one - two-dimensional resistivity values obtained from the investigated field were tried to make a section between different electrode gaps along two profiles. Different interpretations have been developed about the approximate cover thicknesses as well as existence and the depths of groundwater in these 2 dimensional sections. The points taken for ERT locations in the survey area have been mapped in UTM 37 T Zone and ED50 6 degree coordinate system.

ERT-1, an 84-m line, is roughly North-South (K-G) directional and plotted along the average level of elevation along the line. A 2-m electrode space was chosen and arrayed accordingly (Fig. 14). Very close units are detected in this section after application of the Dipole-Dipole-Gradient method.

Because of the high level of alluvium, generally the gravel levels in the sections determine the resistive units. This profile generally corresponds to silty, sandy, clayed and gravelly levels. The units are generally very close to each other. It was examined in 5 different levels. As it is shown in the ERT-1 section in Figure 14, **clay** unit is represented by blue, **fine gravelly clay** unit is represented by green, **coarse-gravelly sandy clay** unit is represented by red, the **less sandy clay** unit is represented by light blue, and the **fine gravelly clay** unit is represented by yellow. This dominant unit is the **less sandy clay** unit. On the surface is generally the clay unit with a blue legend, followed by smooth grain-dispersed gravelly clay unit and then a coarse gravelly clay unit.

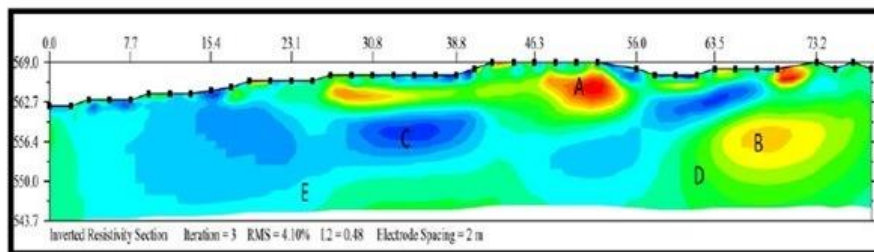


Figure 14. ERT-1 Section

As it can be seen in the conductivity model of the ERT-1 section in Figure 15, resistivity is higher in the 46.3- to 63.5-meter section than in the other units. The decrease in conductivity and the increase in resistivity is due to the decrease in the thickness of that unit and the reduction in the contact structure among the units. The clay value of less than 10 Ω indicates that the soil exposed to water. The conductivity value is high in most of the section.

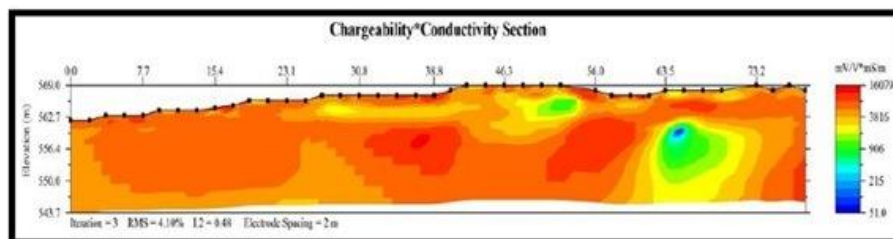


Figure 15. ERT-1 The Conductivity Model of the Section

ERT-2 is a north-south (K-G) directional in a length of 168 m and parallel to ERT-1, and average height levels along the section are plotted. The electrode gap was chosen to be 2 m and arrayed accordingly (Fig. 16). Very close units have been detected in this section with application of Dipole-Dipole-Gradient methods. The section generally consists of 4 units. But these units are very close to each other. In general, the B-C units represent clay units as it is seen in the ERT-2 section in Figure 16. The D unit yellow zone represents generally the sandy clay units. In this section, the resistivity value of the blue zone under the 101st meter is very low, probably surface waters from this area are leaking into the underground. Since the clay unit just below zone A does not pass through the water, the leaks occur southwards underground. It is thought that this area consists of hollow units containing sandy waters of about 12 meters deep at A region.

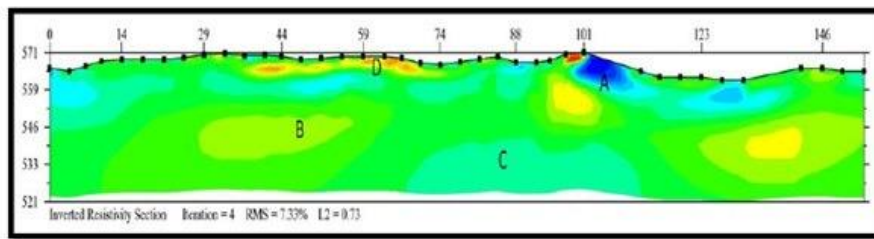


Figure 16. ERT-2 Section

As it is seen in the conductivity model of the ERT-2 section in Figure 17, the spread of the conductivity is shown in the section. Red and yellow zones, probably as a legend of excessively watery zones are highly observable.

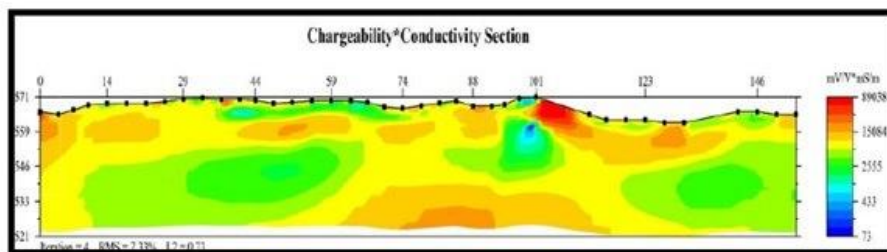


Figure 17. ERT-2 The Conductivity Model of the Section

4. Conclusion

In this study, the investigations made within the geological surveys in the Batman City Esentepe Region indicate that the investigated field is composed of quaternary aged units formed by alternation of Clayed Sand and Sandy Clay levels and behaves as a solid and very solid soil according to SPT-N values. Although the soil parameters found with the geological examinations in the Batman City Esentepe Region are suitable for settlement, it is observed that the calcium carbonate lenses in the clayed sand units form large-scale sinkholes under the effect of tectonism. In underground cavities, there are usually closures with high-value resistivity curves in accordance with the shape of the cavity. If the space is limestone and the interior is filled with ionized water, the closures are determined by low-value resistivity curves.

The low resistivity values between 4 m and 10 m in the DES (Vertical Electrical Drilling) sections obtained by the Vertical Electrical Drilling (DES) study conducted in the investigated field

indicate the possibility of underground water at the 4th meter. The most important evidence of the existence of groundwater is undoubtedly the significant resistivity reductions in regions very close to the underground water level. A decrease in the resistivity value indicates that the grain diameter of the structure is reduced and vice versa, an increase in the resistivity value indicates a growth in the grain diameter. The gravel content of the clay at some levels lead to an increase in the resistivity, whereas the clay content of the sand at some levels lead to a decrease in the resistivity. The resistivity values were found to be low in the sandy space structure between 9.50 m – 10.50 m in the resistivity model, mechanical drilling results and especially the DES-1 resistance model and SK-2 drilling. Again, in SK-2 drilling, a low resistivity value is seen at 0.50-9.50 m sandy clay level. In the obtained conductivity model, the resistivity value between 46.3 and 63.5 meters is higher than the other units; the decrease in the conductivity and the increase in resistance result from the decrease in the thickness of the units due to the decrease in contact structure among the units. The clay value of less than 10 Ω indicates that the soil is exposed to water. Considering the increase in the number of sinkhole formation in Batman city centre it is suggested that the drilling values taken from where the base of the construction will be settled in the field should not be assessed alone; rather an extensive engineering studies should be carried out in the areas to be opened for construction.

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