Iraqi Journal of Science, 2025, Vol. 66, No. 8, pp: 3244-3254
DOI: 10.24996/ijs.2025.66.8.16

ISSN: 0067-2904

2D resistivity imaging to determine the distribution of a clay layer and its thickness

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Received: 8/5/2024 Accepted: 19/8/2024 Published: 30/8/2025

Abstract

The aim of the current study is the stratigraphic detection of clay thickness in the Hasciba Al-Sharqi region, western Iraq, which is suitable for making bricks, according to the recommendation of a previous study of the same area. Three resistivity sequences were created with an interelectrode spacing of 5 m, an n factor of 6a (where the initial spacing a is 5 m), and 120 electrodes of the Wenner-Schlumberger array were used. The quality of the 2D data is excellent as shown by the likeness between the pseudosection of the measured and calculated apparent resistivity. As for the quantitative interpretation, it is an inverse model that shows the thickness of the upper part of the Injana Formation (clay layer), ranging from 8 to 17 m. The isopach map shows thickness increases in the eastern part of the study area, with a slight increase in the northwestern side. It increases in the northeastern side, and the reason for this is its proximity to the exposed area north of the study area, as the area is considered a dumping ground for erosion materials. There is also an increase in the thickness value in the center of the study area. The large amounts of sediment were being swept away to fill burying depressions or levelling the land for construction.

Keywords: Clay thickness, Resistivity method, Wenner-Schlumberger array, Bricks, Western Iraq

يحدد تصوير المقاومة ثنائي الأبعاد التوزيع لطبقة الطين وسمكها

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الخلاصة

هدف الدراسة الحالية هو الكشف الطبقي لسماكة الطين في منطقة حصيبة الشرقي غربي العراق والتي تصلح لصناعة الطوب بناء على توصية دراسة سابقة لنفس المنطقة. تم إنشاء ثلاث تسلسلات مقاومة مع تباعد بين الأقطاب الكهربائية يبلغ 5 أمتار، وعامل n قدره a6 (حيث يكون التباعد الأولي a 5 أمتار)، وتم استخدام 120 قطبًا كهربائيًا من مجموعة Wenner–Schlumberger. جودة البيانات ثنائية الأبعاد ممتازة كما يتضح من التشابه بين المقطع الكاذب للمقاومة الظاهرة المقاسة والمحسوبة. أما التفسير الكمي فهو

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نموذج معكوس يوضح سمك الطبقة الطينية الجزء الأعلى لتكوين إنجانا ويتراوح من 8 إلى 17 م. وتظهر خريطة السمك زيادة في السُمك في الجزء الشرقي من منطقة الدراسة، مع زيادة طفيفة في الجانب الشمالي الغربي. وتزداد في الجهة الشمالية الشرقية، والسبب في ذلك هو قربها من المنطقة المكشوفة شمال منطقة الدراسة، إذ تعتبر المنطقة مكباً لمواد التعرية. كما أن هناك زيادة في قيمة السُمك في وسط منطقة الدراسة. تم جرف كميات كبيرة من الرواسب لملء المنخفضات المدفونة أو تسوية الأرض للبناء.

1. Introduction

Geophysical survey techniques can provide geologists with a subsurface features map or image without destroying it. The resistivity technique is the first to gain prominence among all shallow investigation geophysical techniques. It is used to assess the electrical resistivity characteristics of subsurface materials, which are frequently used for shallow investigations [1]. Besides its application in hydrogeological mining, environmental and engineering investigations.

The 2D resistivity technique has become significant in investigating underground features due to its ease, speed, and low cost compared to other field techniques [2]. Many researchers have applied this method in various shallow-depth case studies [3; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13]. When conducting a 2D imaging survey, selecting the optimal array depends on multiple factors. These include the investigation depth, the sensitivity function related to the mapped feature, the vertical and horizontal data coverage, the array's resolution, and the resistivity meter's sensitivity and background noise level [2]. Numerous studies have examined which arrays are most effective for imaging shallow targets in various scenarios, including the research conducted by [14]. The Wenner–Schlumberger array is a better array for imaging shallow targets [5]. This technique was carried out in an array through 11 stations distributed within and out of the Abu-Jir fault zone. The 2D azimuthal results showed two types of fracture zones. The first is formed from cavities that developed from small fractures. The second fracture zone is formed with tectonic movements.

The electrical method is also characterized by the diversity of methods of measurement and dissemination, the speed of data interpretation, and the diversity of interpretation methods. Fieldwork devices and equipment are low-cost [15]. The electrical method is considered one of the good methods for providing information about the subsurface layers, as it reduces the number of wells required to be drilled to reach a better result about the clay layer thickness of the study area. This study aims to detect the thickness of clay layers in Husayba al-Sharqiya. Since most clays lie in Injana formation, this study aims to determine the contact between Fatha and Injana formations according to variation in resistivity values and evaluate the resistivity method's ability to detect that contact when convergence in resistivity values is expected.

2. Material and Methods

2.1 Location of the study area

The study area is in the Hasciba Al-Sharqi, east of the city of Ramadi, between the Euphrates River and Hbania Lake, at two latitudes (33 15¯-33 19¯) to the north and two longitudes (44 21¯-44 28¯) to the east. Figure (1).

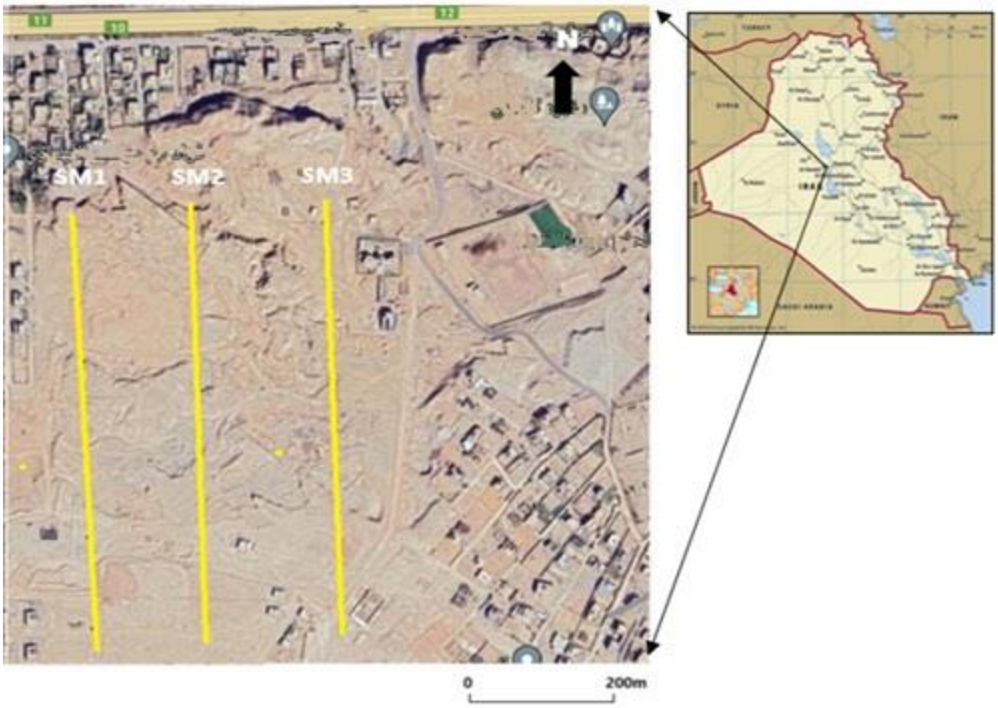

Figure 1: Location of study area

2.2 Geological setting

The discovered depth in this study is expected to penetrate two geological formations. They are from the oldest:

2.2.1 Fatha Formation (Middle Miocene)

The Fatha Formation is one of the most widespread and economically important in Iraq. The sedimentary environment for this formation is a closed lagoon environment [11] due to the high content of clay minerals [10]. The upper contact is conformable with the Injana formation, which consists of sandstone, silty clay, and claystone [12].

2.2.2Injana Formation (Upper Miocene)

The thickness of the Injana formation in the selected area is about 20 meters [16].
This clastic formation represents the transitional stage from the limited marine environment of the Fatha formation to the continental environment. It consists of different rock components, mostly red or grey clay or silty clay rocks and red or grey sands or sandstones. The deposition environments of this formation are either lagoon at the beginning, turning into marine or continental, and maybe mountainous environments. The formation in the study area consists of clay layers interbedded with silt and layers of cross-bedding sand. Injana formation is exposed in the studied area, as shown in Figure (2), consisting of solid red clay layers interbedded with silt. The thickness of the outcropped section is about 5 meters [17].

3. Data acquisition

ELECTRE pro software was used to create the sequences of measurements. This software is designed by IRIS Instruments (www.iris-instruments.com) to create a 2D, 3D sequence of measurements for the SYSCAL Pro Switch resistivity meter.
A sequence with a distance between electrodes of 5 m, n-factor of 6a (where initial a-spacing is 5m), and 120 electrodes is created for the used Wenner-Schlumberger array. We made sure that the value of n does not exceed six times a, that is, to ensure obtaining a strong signal, because whenever the value of n exceeds this limit, the signal will weaken, which affects the

quality of the measurements. The *a*-spacing reached nine times the initial *a*-spacing, which is the maximum spacing allowed by the software. Besides, six levels, representing the *n*-factor, are used for each *a*-spacing.

The requested power and measuring quality can be adjusted by this software where the requested voltage was started at 50v, the current injection time was 500ms, and the maximum standard deviation (Q) was 0%. Minimum and maximum stacking were 1 and 3, respectively.

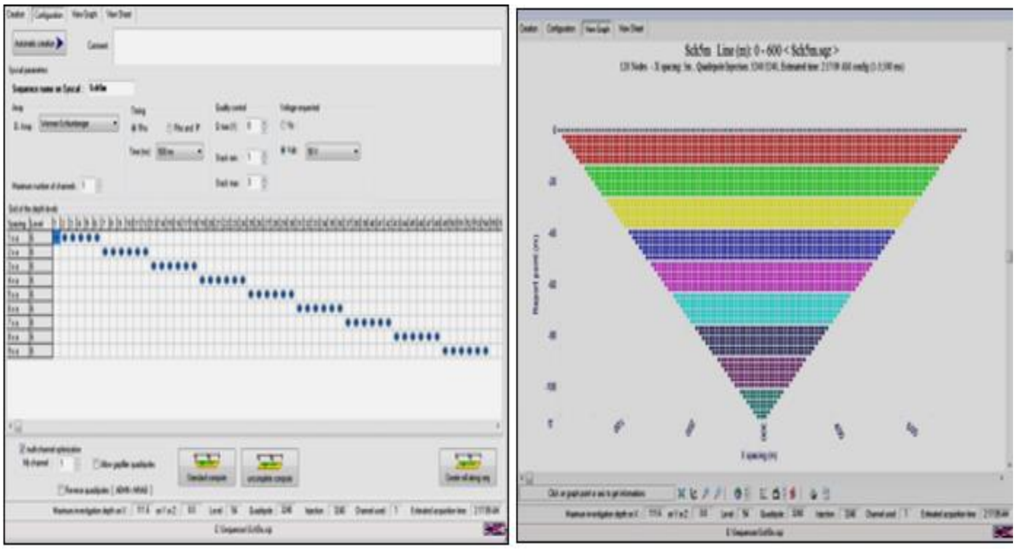

Figure 2: Selecting a-spacing, n-factor, and data levels by ElectrePro program

Due to the irregular distribution of houses in the area, finding suitable sites for sections, it took work. Besides, the Geophysics Division staff and their equipment were involved in special work, so the days allowed to work were few and insufficient to complete more than this number of lines. Therefore, only three sections, SM1, SM2, and SM3, were fulfilled.

Each 2D section consists of 120 electrodes with 5m spacing, as in Figure (3), covering the 595m along the survey line.

Figure 3: The spacing distance between electrodes is 5m.

4. Results and Discussion

After the completion of fieldwork of the 2D survey, which was carried out using a multi-electrode system, the data measurements are exported from the resistivity meter memory to the computer by PROSYS Ш software. In this software, the data are filtered by multiple filters before being exported to any interpretation software. However, the data resulting from using a resistivity meter without a multi-electrode system is not possible to export to the PROSYS Ш software because the storage systems are different in both resistivity meters, and it is also impossible to enter the data manually into the interpretation software or the PROSYS Ш software.

The 2D data of the current study have been interpreted through the RES2DINV software. This program analysed the 2D survey data through three successive stages. In the first stage, the program plots the measured and calculated apparent resistivity pseudosections [18]. The measured apparent resistivity pseudosection represents the initial model of the field data; in contrast, the calculated pseudosection represents the theoretical model plotted depending on the initial model using the finite difference forward modelling. However, the pseudosection gives elementary information to the interpreter about the lateral and vertical variations of the apparent resistivity values in the subsurface and the abnormal data, which appear as separated spots. This information can help the interpreter estimate the expected inversion model and remove the abnormal data by using the Edit option in the main menu bar until it does not affect the quality of the 2D model. The second stage includes lessening the square difference between the measured and calculated apparent resistivity pseudosections using the conventional smoothness–constrained least square method. Then, using the robust model constrains the inversion method to minimize the absolute change in the resistivity values [18]. In the third stage, the program generates the 2D model using the least square inversion method. The good quality of the inverse model depends on the quality of the field data. It is also designed automatically and robustly with minimal input from the user, [18].

4.1 2D Station (SM1)

It is located in a flat area. The quality of the 2D data is excellent as shown by the likeness between the pseudosection of the measured and calculated apparent resistivity, as shown in Figure (4). Regarding the qualitative interpretation observed in both sections, the area is divided into two parts. The first part is located between the electrodes (4 - 240). It is characterized by vertical variations in the apparent resistance values that range between the electrodes (4.83 - 23.3 Ω.m) compared to the second part, located between the electrodes (265-680), which does not include any differences and has an apparent resistance. With values ranging between (4.83 - 13.8 Ω.m). In general, the apparent resistivity values in both parts decrease with depth.

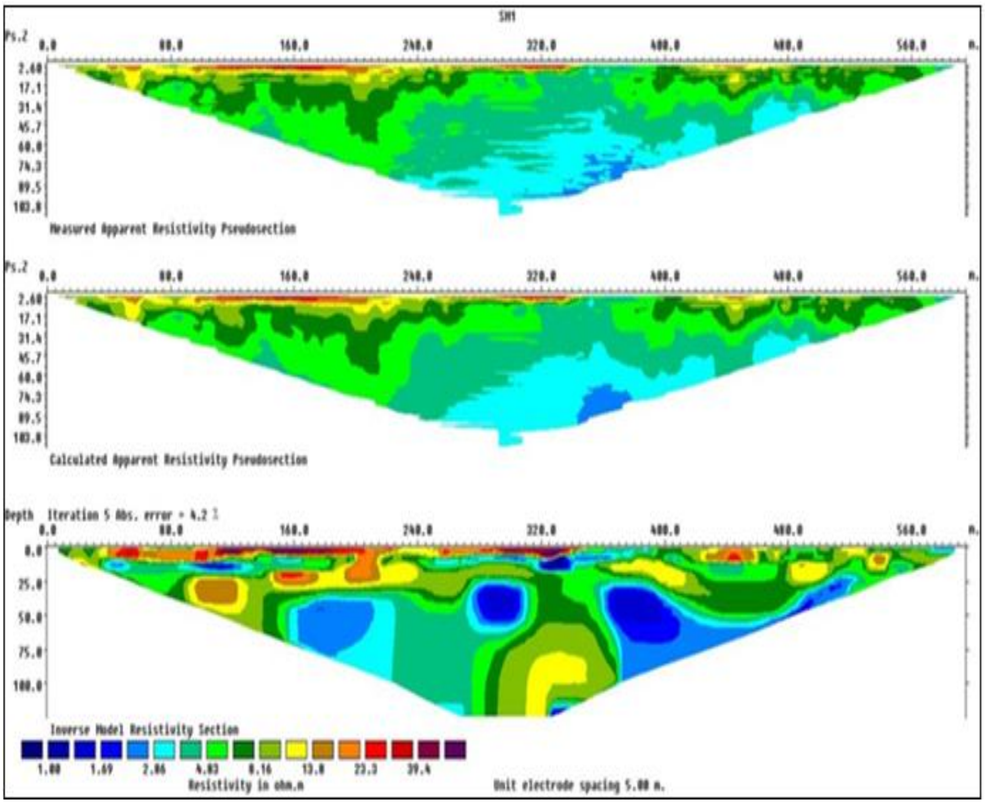

Figure 4: Measured and calculated pseudo sections and inverse model Wenner-Schlumberger resistivity section – SM1

As for the quantitative interpretation, it is an inverse model that shows the thickness of the Injana Formation, ranging from (13-24) meters Figure (5).

According to the Husaybah well **(**Well 1241**)** (Figure 6) and the formation's outcrops, it is seen that its deposits consist of two parts. The upper part is represented by reddish clays interspersed with small lenses of sand and silt deposits. This part represents clays suitable for making bricks, which were examined previously [19]. Its thickness is about 15m. Sand deposits represent the soft part, with a little clay and a thickness of about 5m.

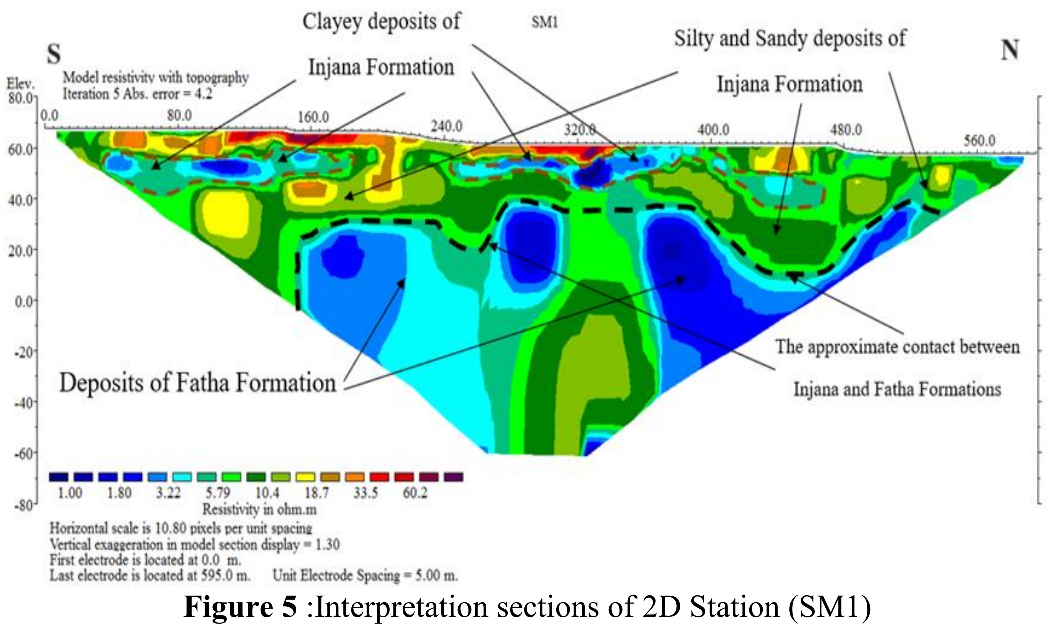

Figure 5 :Interpretation sections of 2D Station (SM1)

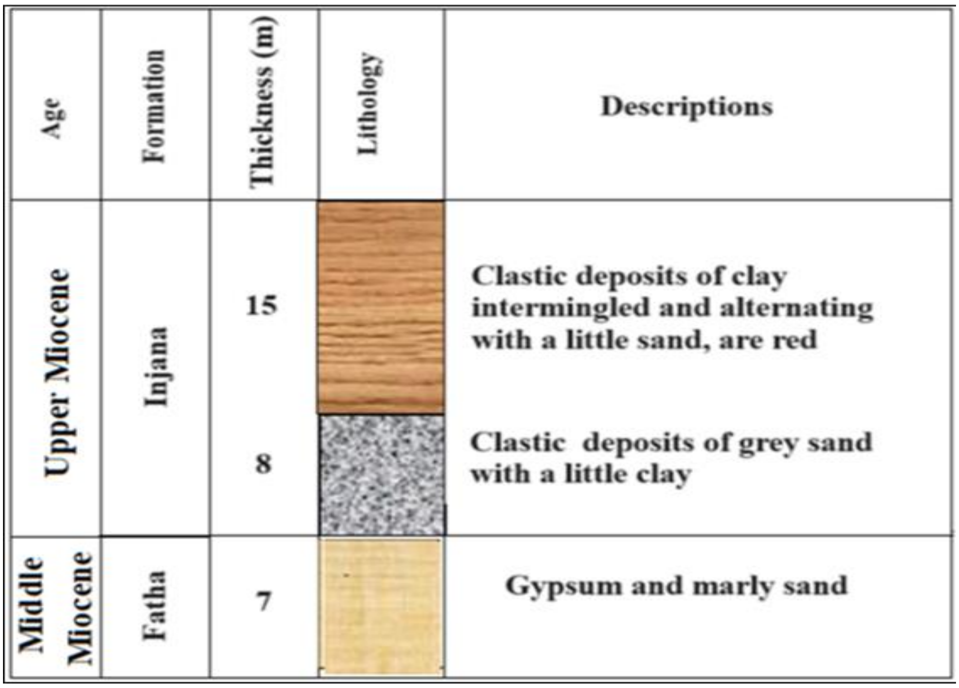

Figure 6: Stratigraphy column of Hasciba Al-Sharqi well (1241), G.C.G.W., 20012012

4.2. 2D Station (SM2)

It is located to the southeast of the second profile in a flat area; the distance separated between them is about (100m); for qualitative interpretation, that is the similarity between the measured and calculated apparent resistivity pseudosections indicating good quality of recorded data as shown in figure(7). Both pseudosections show a gradual decrease in depth of apparent resistivity values from (3.8 to 1.69 Ω.m).

As for the quantitative interpretation, the inverse model shows that the presence of Injana Formation has a thickness ranging between (m). It is located within a horizon that has high resistivity ranging between (1.88) to more than (23.3 Ω.m) Figure (8).

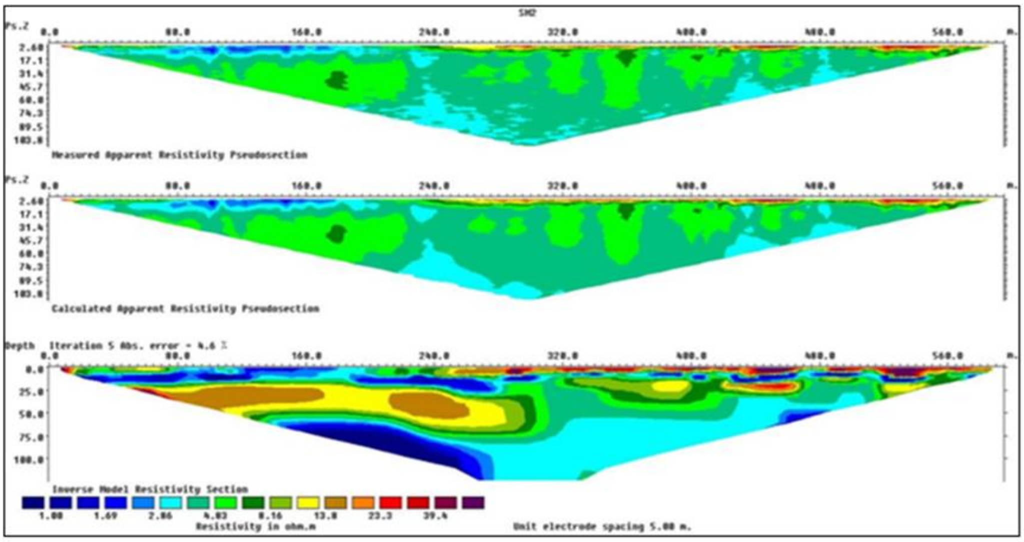

Figure 7: Measured and calculated pseudo sections and inverse model Wenner-Schlumberger resistivity section – SM2

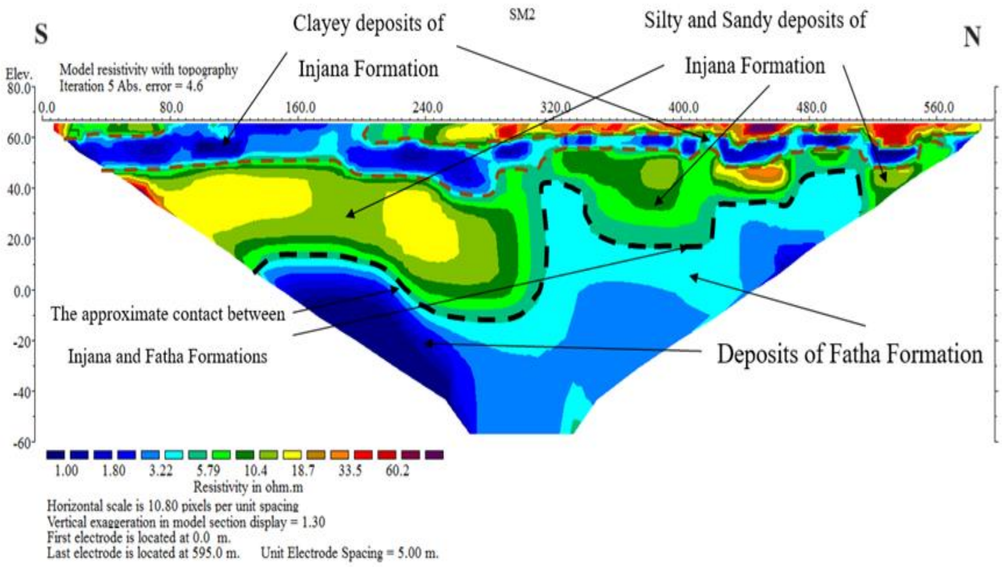

Figure 8: Interpretation sections of 2D Station (SM2)

4.3. 2D Station (SM3)

The qualitative interpretation of the measured and calculated apparent resistivity pseudosections shows some spots (blue and dark blue colours). These spots are not noise but represent oscillations in the apparent resistivity values within the lower mid-part of the Fatha Formation) as shown in Figure (9). This oscillation is caused by lateral and vertical inhomogeneities in the lithology of the formation. However, the apparent resistivity values in both sections range within the Ingana Formation (2.8- 13.8 Ω.m).
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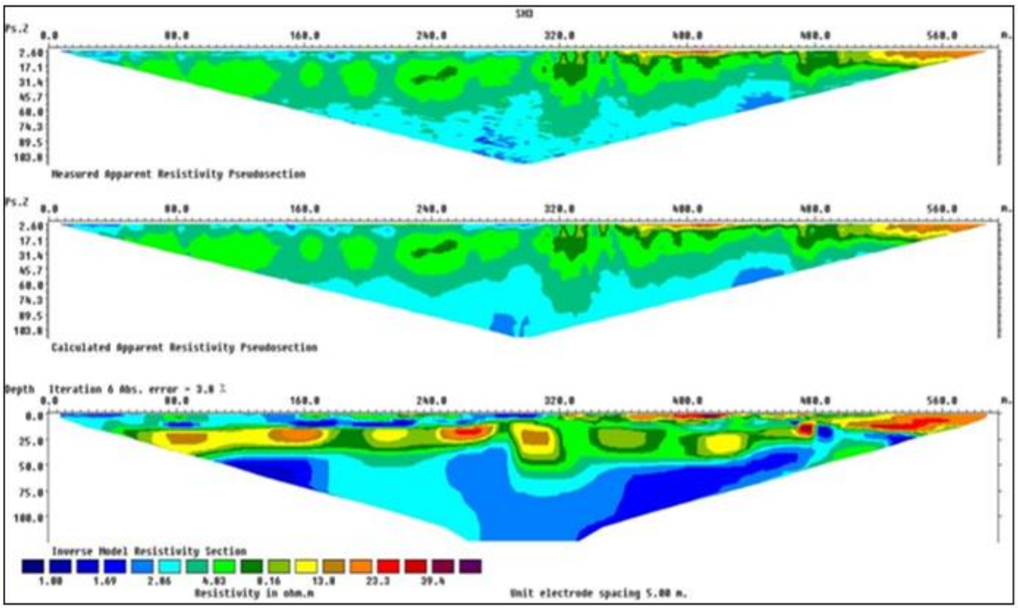

Figure 9: Measured and calculated pseudo sections and inverse model Wenner-Schlumberger resistivity section – SM3

For quantitative interpretation, the inverse model shows two prospects. The first, the youngest (the upper part), represents the Fatha Formation. It is characterized by lateral and vertical changes in resistance values, which range between (1.69 and 13.2Ω.m).

This formation was observed in the previous sounding stations with changeable thicknesses.
The second horizon represents the Injana Formation in all stations according to the lithological section of the well (1241). This Formation is characterized by lateral and vertical variations of the resistivity values that range from (26.2) to more than (38.2 Ω.m) and has changeable thicknesses
These variations caused by the presence of cavities in the gypsum of the Fatha Formation, as shown in the inverse model within Figure (10), are caused by the upper part of this formation being rich in cavities and fractures, according to [8].

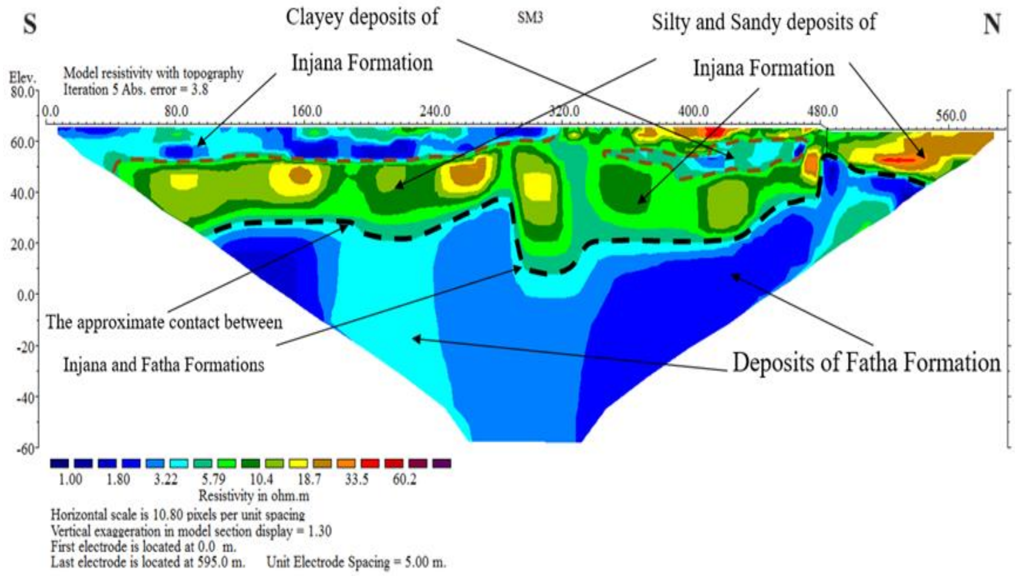

Figure 10: Interpretation sections of 2D Station (SM3)

4.4. Isopach map of Injana Formation

Figure 11 shows a thickness map of the clay layer within the Injana Formation. The thickness of the layer ranges from 8 to 16 meters. Its thickness increases in the eastern part of the study area, with a slight increase in the northwestern side. At the top of the formation, clay deposits are concentrated according to field observations in the study area and information from well 1241 (the thickness of the upper layer of the Formation consists of a pure clay layer accompanied by thin silt sand layers with a thickness of approximately 15 meters, and the lower layer is characterized by a clay silty sand layer with a thickness of 5 m), and its exposed thickness is 6 m.
During laboratory operations conducted by Mansor in 2023 on clay samples, the test results showed that the clay layer failed because it is plastic, which requires adding an amount of sand or silt to the clay mixture; this led to the success of the layers for distinctively making bricks. On this basis, we considered the upper Injana Formation to represent the mixture of clays required to manufacture bricks.
The thickness values were variable in the upper part of the Injana Formation (clay layer). They increase on the northeastern side, and this is due to proximity to the exposed area north of the study area, which is considered a dumping ground for erosion materials. There is also an increase in the thickness values in the center of the study area. Field observations showed that large amounts of sediment were being swept away to fill burying depressions or levelling the land.

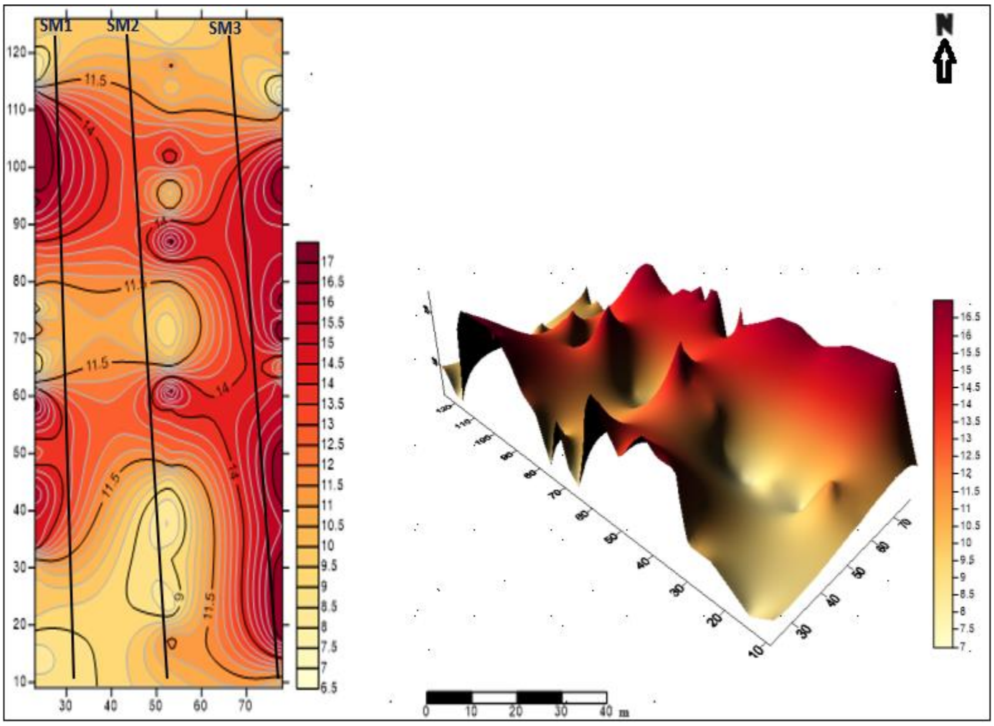

Figure 10: Isopach map of Injana Formation

5. Conclusions

The results indicate that Injana Formation thickness is approximately 14 to 25 m. and thickness increases in the eastern part of the study area, with a slight increase in the northwestern side and increases in the northeastern side. This is because of its proximity to the exposed north of the study area, which is considered a dumping ground for erosion materials. There is also an increase in the value of fish in the center of the study area. Field observations showed that large amounts of sediment were bulldozed to bury depressions or level the ground for construction.

We conclude from this study that the amount of clay present, with an area of the study area (600 x 100 m), is considered a miniature model of a good Hsiba area as a reserve material for establishing a brick factory. It is expected that the caly covers the area many times that are considered in this study.

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