



Resistivity Imaging: Application of 2D Resistivity Survey for Under Groundwater Prospecting in New Campus of Sulaimani University and Surrounding areas, Sulaimani City, NE Iraq

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Article info	Abstract
Original: 24 March 2019 Revised: 30 July 2019 Accepted: 11 September 2019 Published online: 20 December 2019 <i>Key words: Electrical Resistivity, Groundwater, 2D resistivity survey</i>	Groundwater, the hidden source of life, it is so important to be estimated quantitatively and qualitatively before extracting and using. New campus of university of Sulaimani locates at the west of the city, has a vast area, so that it needs to more water supplies for daily uses and irrigation. Therefore, conducting of geophysical survey was decided to ensure the existence of underground water then drilling water wells. Next, a 2D electrical tomography was carried out along seven profiles of 720m using Syscal instrument with its accessories in and out of the university. After that, the obtained data were processed then interpreted using Res2Dinv software to approach a final conclusion. Finally, the results showed in profiles 1, 2, and 3, the resistivity value was about 5-157 ohm.m and about 20-30 ohm.m in the water bearing layer with nearly 20m depth, deep well of depths ranging from 100 to 125 are recommend near the location of electrode are indicated on the resistivity sections, the expected productivity is moderate to low. At profile 4, resistivity of 2-300ohm.m was obtained and 20-100ohm.m in the water bearing layer of more than 20m depth, deep well is not recommended, the expected productivity is low. In geophysical point of view, the surveyed locations beneath the profiles 5 and 6 not suitable for drilling an artesian well, a Marley limestone of low resistivity 9-40ohm.m was detected extending 70-150m of depth. Also, profile 7, is not suitable for drilling water well because of clay layers of low resistivity ranging 18-30ohm.m in depth of 30m.

1-Introduction

The electrical resistivity method for subsurface study for practical purposes was used for the first time in France 1912, since that time this method has been proved itself to be among the most effective means for shallow subsurface investigation. It is used extensively in the search for suitable groundwater sources as well as monitoring types of ground water pollution [1]. The purpose of electrical resistivity is to determine the subsurface resistivity distribution by conducting measurements on the ground surface. From these measurements, the true resistivity of the subsurface layers can be determined. The ground resistivity is related to various geological parameters such as the mineral types and fluid content, porosity and degree of water saturation in the rock. Electrical resistivity surveys have been used for many decades in hydrogeological, mining and geotechnical investigations. More recently it can be used for environmental investigation [2]. As known, due to anisotropy of the earth materials, the resistivity will vary in x, y and z directions, so that greatest limitation of 1D resistivity sounding method does not take into account subsurface horizontal resistivity changes. In such case a more accurate model is a two dimensional 2D model which reveal the resistivity changes in both the vertical and the horizontal directions along the survey line [2]. Vertical electrical sounding (VES's) technique in hydro- geological investigations is important in identifying

the preferential groundwater flow patterns in accordance with the spatial anisotropy and depth of sub-soil [3].

Where it is difficult to locate aquifers such as water-saturated zones in hard rock, it is also difficult to select suitable sites for water drilling. The 2D resistivity technique has improved the chance of drilling successes by identifying the fractured and weathered zones in these areas [4]. The materials have different ability to conduct electricity, in some materials, they have at least one of the electrons in each atom which is loosely held and it requires only slight external influence to move or conduct some of the electrons from atom to atom through the material [5]. Use of geophysical methods provides valuable information with respect to distribution resistivity, thickness, and depth of groundwater bearing formations [6]. The application of geophysics to the successful exploration of groundwater in sedimentary terrain requires a proper understanding of its hydro-geological characteristic.

Evidence has shown that geophysical methods are the most reliable and accurate means of all surveying method for subsurface structural investigations and rock variations [7]. It is important to note that not all geophysical methods are appropriate for groundwater exploration. The principal methods used in groundwater investigations include Electrical Resistivity (ER), Electromagnetics (EM), Nuclear Magnetic resonance, Ground penetrating radar and Seismic refraction...etc. The limitations associated with these methods have prompted hydro geologists to use more than one method to collect accurate data in groundwater exploration [8]. The method of geophysical exploration happens to be the most applied method in groundwater exploration in areas where good electrical resistivity contrast exists between the water bearing formations and the underlying rocks [9]. The successful exploitation of basement terrain groundwater requires a proper understanding of its hydro geophysical characteristics. This is particularly important in view of the discontinuous nature of basement aquifers [10]. Geophysical investigations which supplement the initial geological assessment of the terrain afford wider understanding of the local hydrogeology.

In Iraqi/Kurdistan ground water prospecting by resistivity tomography has been progressed, in the past the 1D method was widely used [1], because it was rapid in data acquisition and no time consumption. Recently, 2D is available, which is more accurate than 1D, because a detailed resistivity of underground layers can be obtained both vertically and laterally. There for, the researcher was decided to use 2D model for the current study, at the new campus of Sulaimani university, which is located to the west of Sulaimani city between longitude (35° 34' to 39 18" N) and between longitude (45° 21' to 41 19" E), and other locations pointed on the map shown in figure (1).

Geologically, Sulaimani city located on the Tanjero Formation that covered by recent sediments, it consists of sand, silt, conglomerate, marle and marly limestone. According to the previous studies [1], the sandstone and marly limestone are aquifer, but clay part recorded low resistivity of about 11.3 ohm.m with high resistive of dry marle of a resistivity about 147.6 ohm.m. Structurally, the studied area is near the SE plunge of Piraagroon anticline and Sarchnar water source.

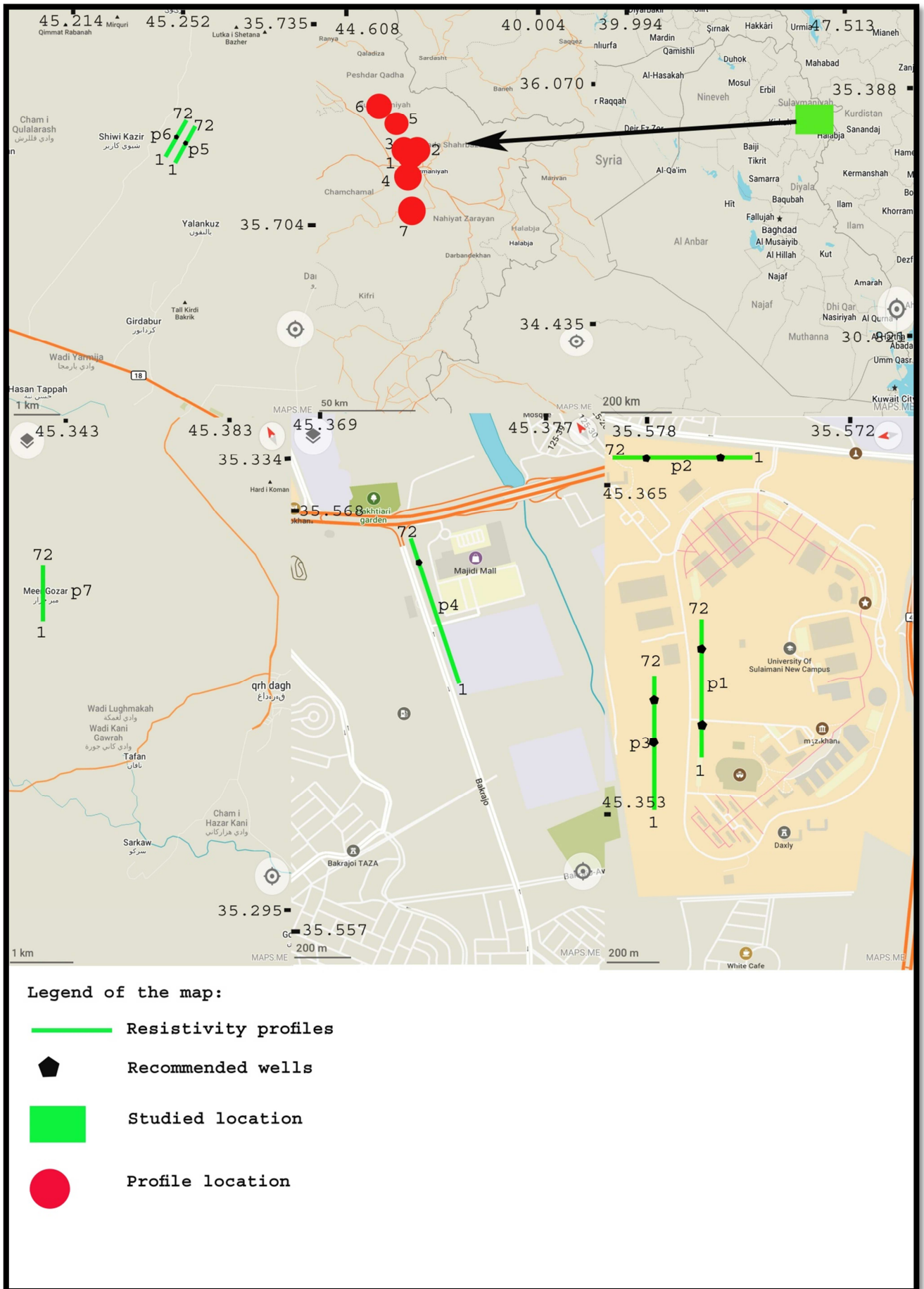


Figure.1. Showing the studied locations

2-Methodology and Field procedure:

The electrical resistivity method was used for the survey using Syscal Jr switch-72 (IRIS) resistivity meter. The entire system consists of Syscal switch-72, switching unit (link box), six reels of multi core cables, 72 electrodes with their connecting wire, car battery and chargers. The multi-core cables have take out string equal to 10m (a=10m). It is a new model that available in the markets to perform of the automatically measuring of the resistivity points. Six strings of multi core cables of 12 electrodes take out are connected together by special boxes two in each side. A number of 72 metal electrodes driven in to the ground about 10-25cm according to the soil moisture content at a fixed interval equal to 10m, therefore the total length of the spread is 72*10=720m. A number of these geophysical methods are applicable in delineating subsurface water resources [11]. A direct current was injected into the ground through two current electrodes and the variation of the current within the subsurface can be determine through the potential difference between the two other electrode [12]. If a groundwater is to be exploited, it is essential that the entire project be conducted in most efficient and cost-effective way possible [13].

Before, data acquisition a number of the devise setting can be performed using ELECTRN software as, 942 points are plotted per each sounding as shown in figure (2&3), type of the array, amount of current and voltage, no of stacks, time and quality factor.

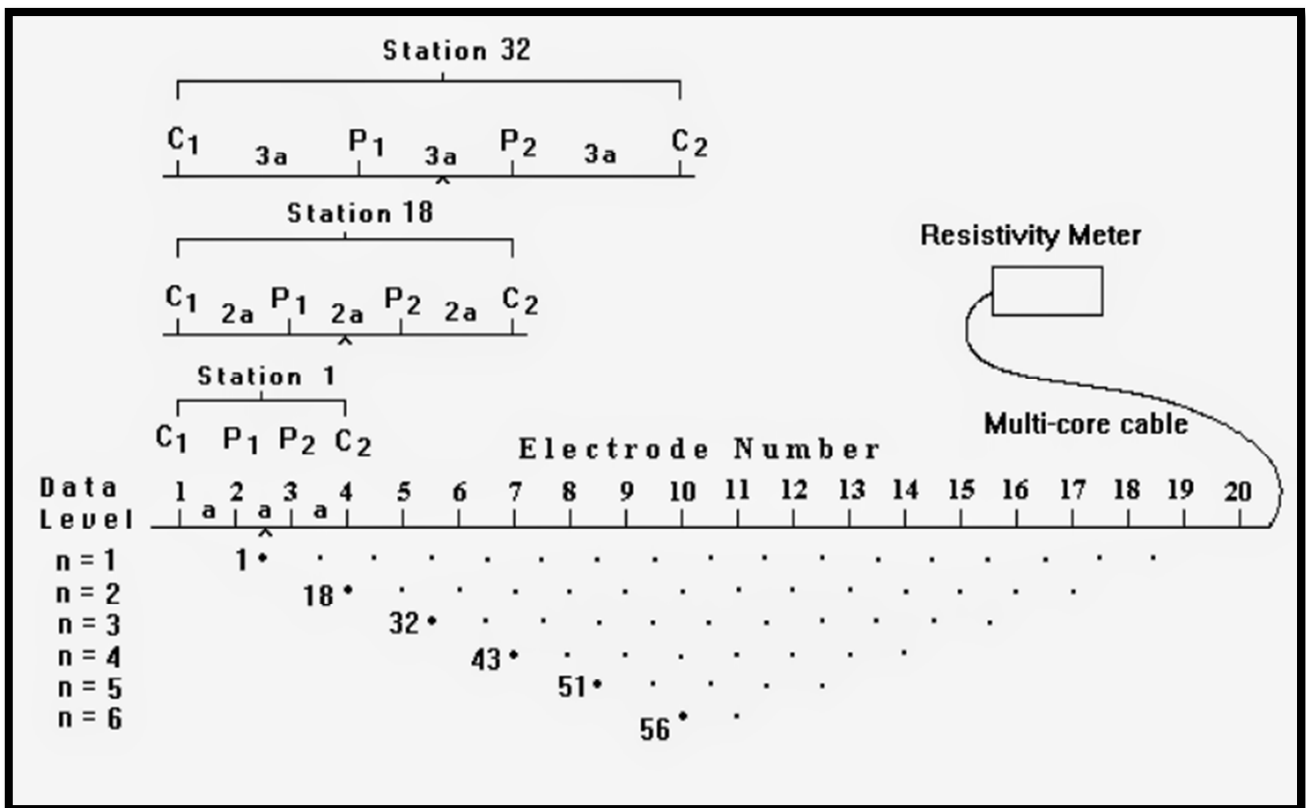


Figure.2. Showing measurement points for wenner array type (Aziz, 2005)

Finally, optimal profile lines on which the water wells should be drilled were determined for taking of underground resistivity in seven sites trending different direction according to the space for long of 720m far from metallic fence and roads. It is very important to be a best contact between the ground and the electrodes as in summer that the soil is dry in such case it should be moisturized using salted water. As well as, a prestart check should be done to ensure the best contact or disconnected wire can be detected.

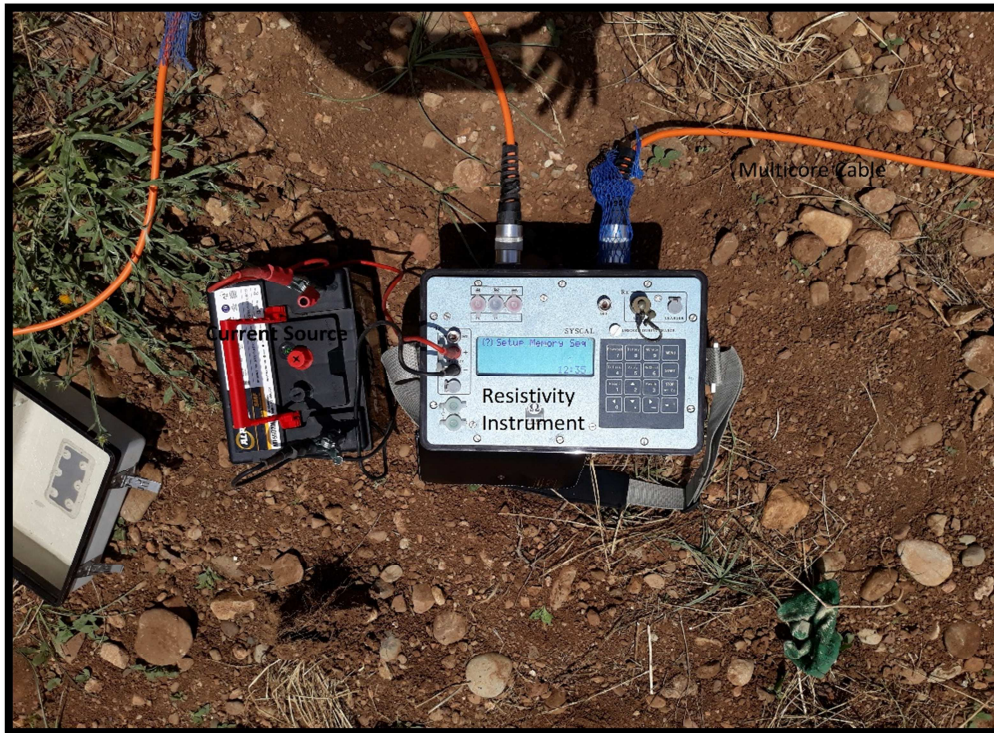


Figure.3. Resistivity instrument setting up in the field

3-Data Plotting:

After recording the data, the collected data were plotted to make pseudo section of the soundings using contouring method that gives approximate image of the true resistivity distribution that useful for further quantitative interpretation. As well as, it is useful for picking and removing of the bad apparent resistivity (2). Such bad measurement usually stands out as points (spots) with high or low values, as shown in figure (5). The horizontal location of the points that placed at the midpoint of the set of electrodes was used to make that measurement. The vertical location of the plotting point is placed at a distance, proportional to the separation between the used electrodes, Another method, has been used in the present study, is to place the vertical position of the plotting point at the median depth of investigation, or pseudo depth of the electrode array has been used Figure (2).

4-Data Inversion:

The inversion of the soundings is carried out using Res2Dinv software to make a model that is more likely reflecting a real geology with the aid of other geological information. It is software that provides a two dimensional resistivity imaging of the subsurface. The programme automatically chooses the optimum inversion parameters for a data set, it provides a 2D electrical resistivity of the subsurface depending on the resistivity values of rocks and soil in the profiles, ground water existence can be detected. The 2D model used by the inversion program consists of a number of rectangular blocks as shown in Fig (4).

The arrangement of the blocks is loosely tied to the distribution of the data points in the pseudo section. The Program automatically chooses the optimum inversion parameters for a data set. However, the inversion parameters are modified in this study depending on the geological situation of the field. Geological and structural survey of the area as well as geological column of the well are included constraining the inversion process (2).

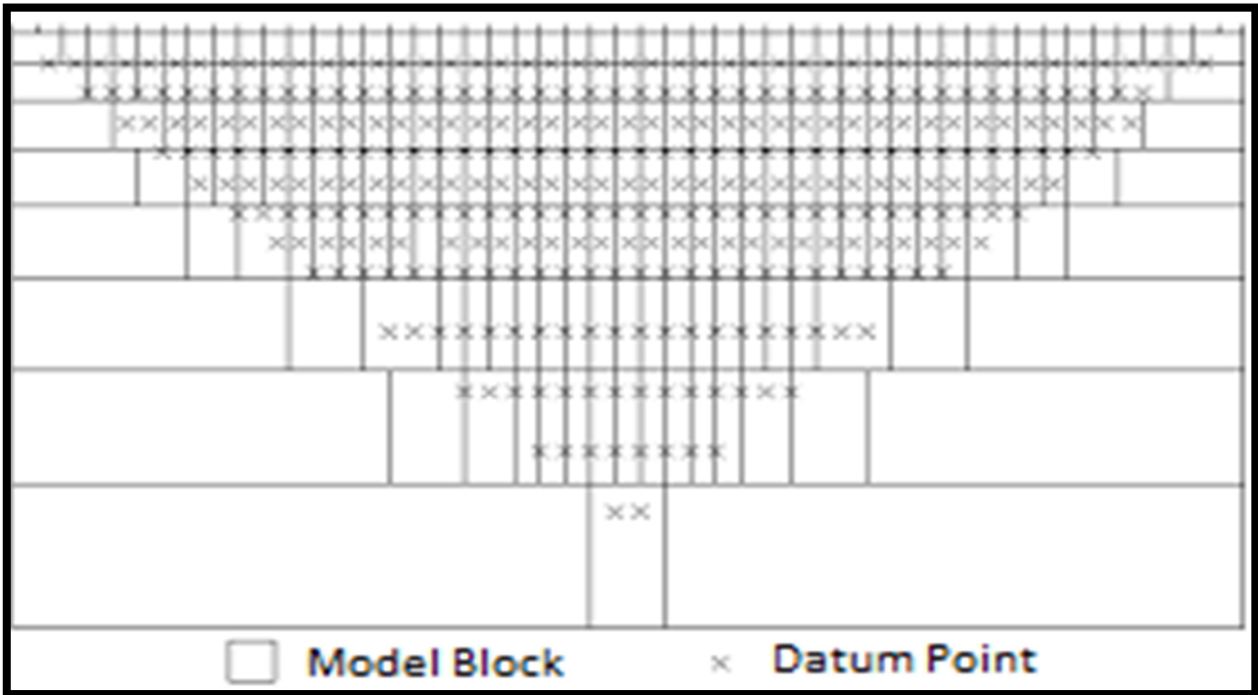


Figure.4. Subdivision of the subsurface in to the rectangular blocks (Aziz, 2005)

Another important factor is the quality of the field data; good quality data usually show a smooth variation of apparent resistivity values in the pseudo section, all the soundings give very good quality. Little appearance of irregularity and spots that show high or low resistivity than surrounding have been seen. Bad data points are removed from the data set to avoid their effect in the process of inversion. These data are exterminated by the aid of plotting the data in profile from that helps to highlight the bad datum points and remove them from the data set manually, as shown in figure Figure (5).

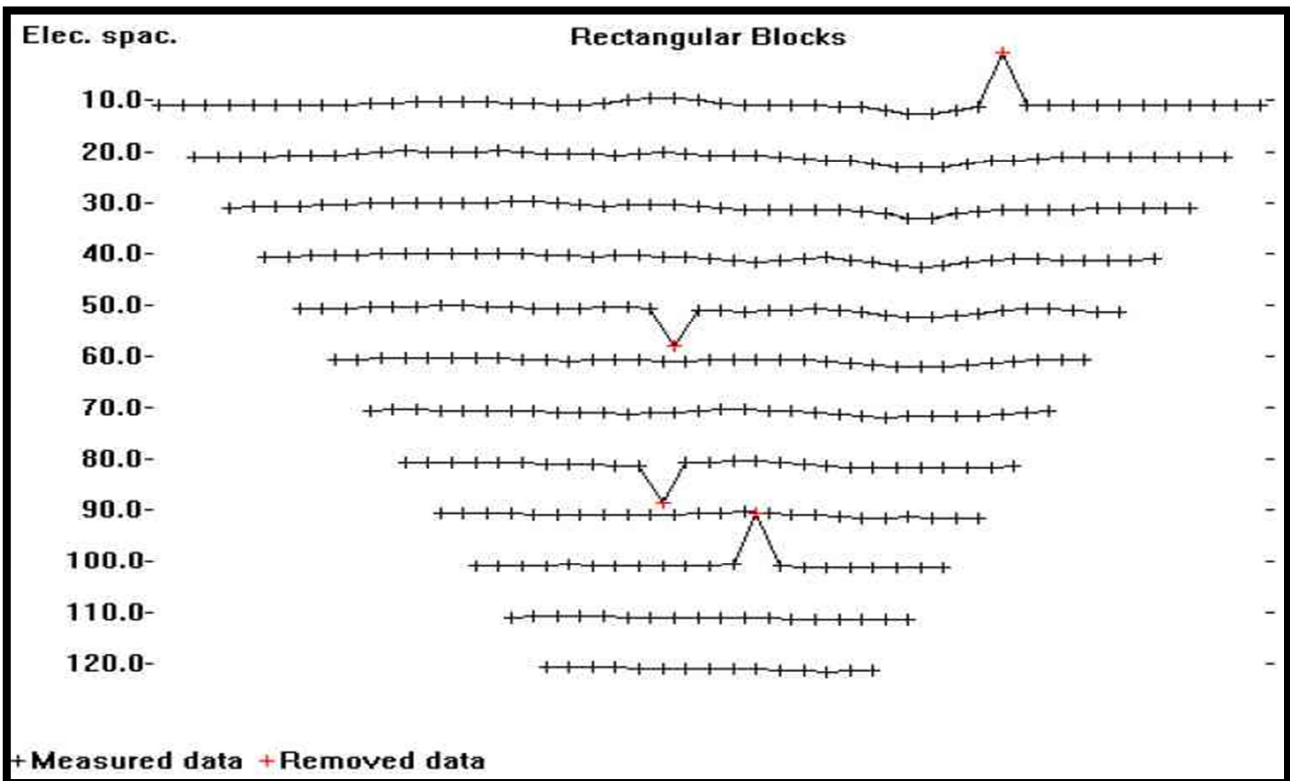


Figure.5. Exterminate of bad datum point manually (Aziz, 2005)

5-Results, Discussions:

The current study performed on seven profiles along 720m, then processed and interpreted as follow:

Profile One:

It is located in the new campus of the university, trending E-W direction. It has 720m spreading or long on the surface, the subsurface resistivity obtained in the depth of about 143m. The recorded value of resistivity in that traverse is 5-115ohm.m, as shown in figure (6). The top recent sediments show a low resistivity of about 5-8ohm.m and a thickness of nearly 20m, as previously mentioned the underlining rocks are Tanjero Formation that consists of different lithology. Marle of low resistivity about 12ohm.m, Marley limestone and sandstone of higher resistivity 19-30 were recorded with a thickness of about 120m.

Profile Two:

It is located at the new campus of the university, trending N-S direction. It was performed on the same long as in first traverse as well as the depth. As shown in the inverse model of the section the obtained resistivity was in range of 7-157 ohm.m as shown in figure (7). As a result, different lithology's were determined of different resistivity, Marley limestone which its resistivity approach to the highest of about 157 ohm.m and a thickness of 20m. Next is Marl of a minimum resistivity about 7ohm.m and Siltstone of about 20-40ohm.m with a few thickness of the top recents.

Profile Three:

It is located at the new campus of the university, trending E-W direction. As in previous profiles a resistivity profile was obtained in the third location of different resistivity value, lithology's and their thickness. So the resistivity value was in range of 7-31 ohm.m which differ according to the lithology, Marley Limestone and sandstone of a resistivity 20-31ohm.m and thickness of 40m were obtained, as well as Marl of resistivity 7-11ohm.m with a few meters of the covered soil with low resistivity value, as shown in figure (8).

Profile Four:

It is located on the Bakrajo road, trending N-S direction. The area covered by a thin high resistive topsoil layer (2-19) m. Layers of Tanjero Formation consisting of Marl, Sandstone and siltstone were detected have thickness ranging from 25 to 45 meters. The third layer is low resistive marl and siltstone of the Tanjero Formation, as shown in figure (9).

Profile Five:

It is located in the west of Sulaimani city, trending NE-SW direction. The surface of the area is covered by different lithological components, clay and rock fragments of limestone rocks is detected beneath electrodes 1 to 72 and the rest of area is covered by marly limestone and limestone of the Sinjar and Kometan Formation. The thickness of the recent sediments is around 70m meters (Red color).

The layers which are representing by blue color are layers of Marely limestone characterized by highly fractured and jointed zone. It is appearing at a depth equal to 70 m and extends to the maximum depth of investigation equal to 150 meters. This layer has a low resistivity ranging from 9 Ohm.m to 36 Ohm.m. Most of the subsurface is covered by Marely limestone rocks of the Tanjero Formation, while at a depth of about 70 meters the Marely limestone rocks are detected (Blue color), it is beneath electrodes 12 to 36, as shown in figure (10).

Profile six:

It is located at the west of Sulaimani city, trending NE-SW direction. The surface of the area is covered by different lithological components, clay and rock fragments of limestone rocks is detected beneath electrodes 1 to 72 and the rest of area is covered by Marely limestone and limestone of the Sinjar and Kometan Formation. The thickness of the recent sediments is around 75m meters (Red color).

The layers which are representing by blue color are layers of Marely limestone characterized by highly fractured and jointed zone. It is appearing at a depth equal to 75 m and extends to the maximum depth of investigation equal to 150 meters. This layer has a low resistivity ranging from 10 Ohm.m to 42 Ohm.m. Most of the subsurface is covered by Marely limestone rocks of the Tanjero Formation, while at a depth of about 75 meters the Marely limestone rocks are detected (Blue color), it is beneath electrodes 24 to 36, as shown in figure (11).

Profile Seven:

It is located at the south of Sulaimani city, trending N-S direction. The upper layer covered by a dry and high resistive layer of more than 600 ohm.m and thickness of about 30m, consists of coarse grain of gravel, sand and clay. As well as, the underlined layer is a thick layer of clay and siltstone at depth of 30m, have a very low resistivity which not suitable for drilling water well. A layer of siltstone and little sandstone appeared at depth of about 110m, may be suitable for drilling water wells, as shown in figure (12).

6-Conclusions and Recommendations:

6.1-Conclusions:

Finally, the following conclusions were obtained:

At profile one, two and three marley limestone and sandstone of a resistivity 19-40 ohm.m were detected, that suitable for drilling water well at depth of about 20m along profiles. Also, marley limestone and sandstone is detected in profile four of little more resistivity than in previous profiles, that suitable for water wells. At profiles of five and six, the area underlined by rock fragments and marley limestone of a 10-40 ohm.m that can be used for low productive water wells. At profile seven a massive clay layer was detected of very low resistivity that not suitable for water wells.

6.2-Recommendations:

The following recommendations were obtained:

Firstly, at the location of profile 1, 2 and 3, deep water well is recommended to be drilled in the studied location, in addition to that well of depths ranging from 20-80m at electrode 16 and 20-100m at electrode 48 are recommend in profile one. Also, about depth of 20-50m along profile two, and depth of 20-90m at electrodes of 35 and 46 in profile three. The expected productivity of water from wells are moderate to low that suitable for irrigation of plants in the new camp of Sulaimani university.

At location of profile four, deep well is not recommended, well of shallow depths are recommend near the location of electrode 52 of maximum depth not exceeds 75m, the expected productivity is low. At location of profile 5 and 6, in geophysical point of view the surveyed locations beneath the profiles not suitable for drilling an artesian well. The location marked by red arrows at the location of electrodes 32 and 34 may be suitable for low productivity water wells. At profile of 7, along this profile drilling water well is not suitable, but after depth of about 112m a low to moderate well may be suggested near the electrode of 35-48.

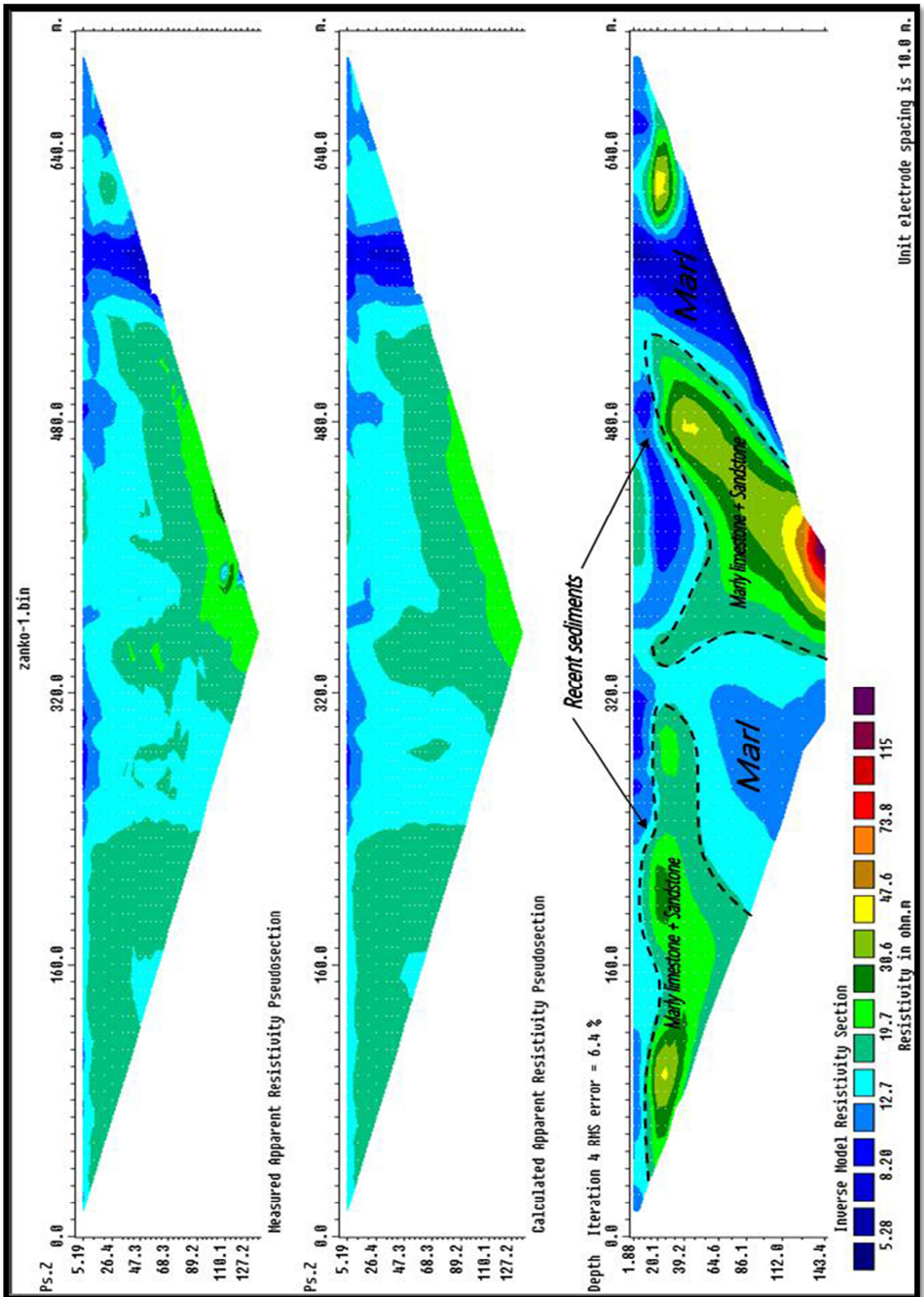


Figure.6. Showing Resistivity section at location one

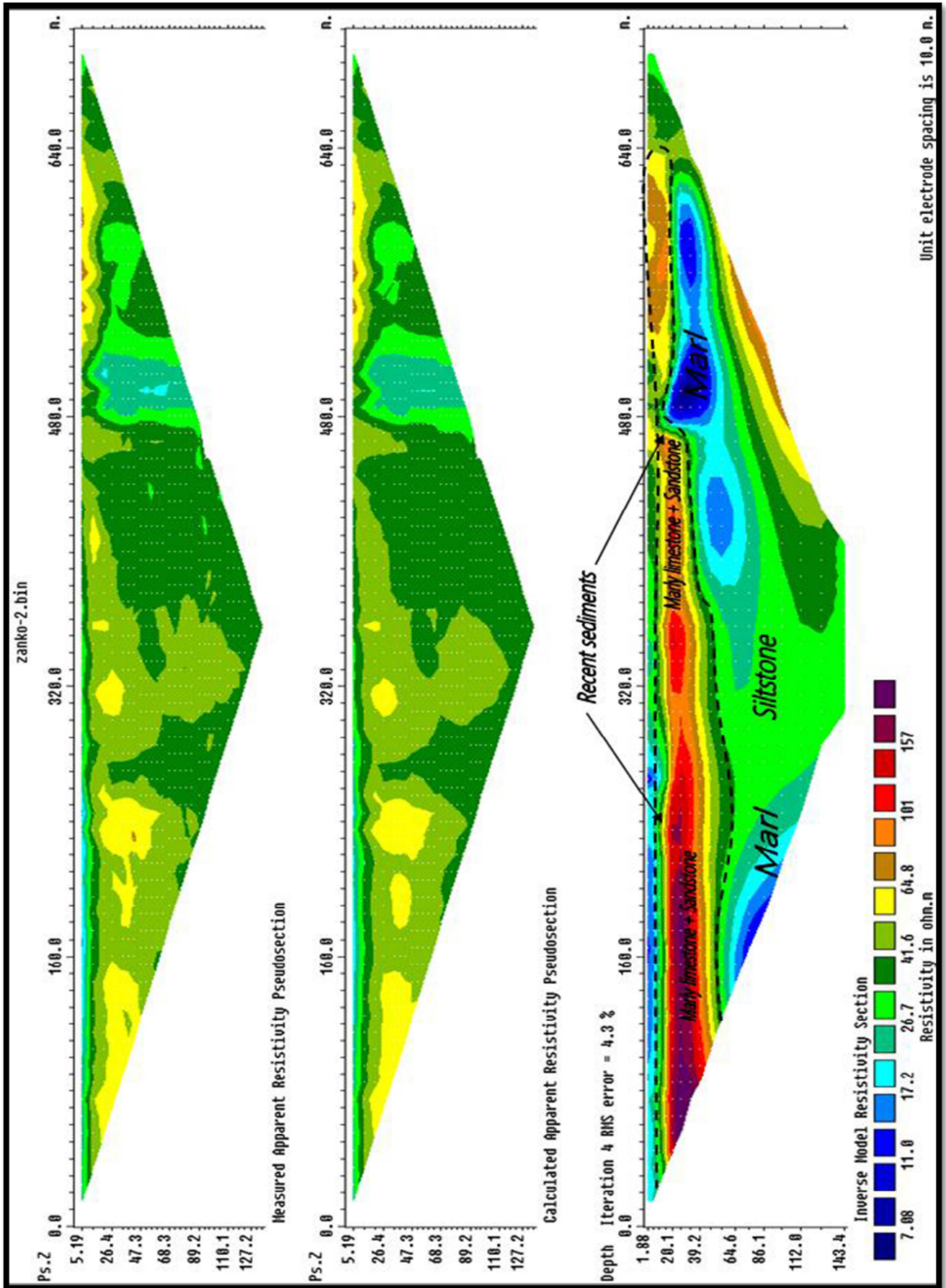


Figure.7. Showing Resistivity section at location two

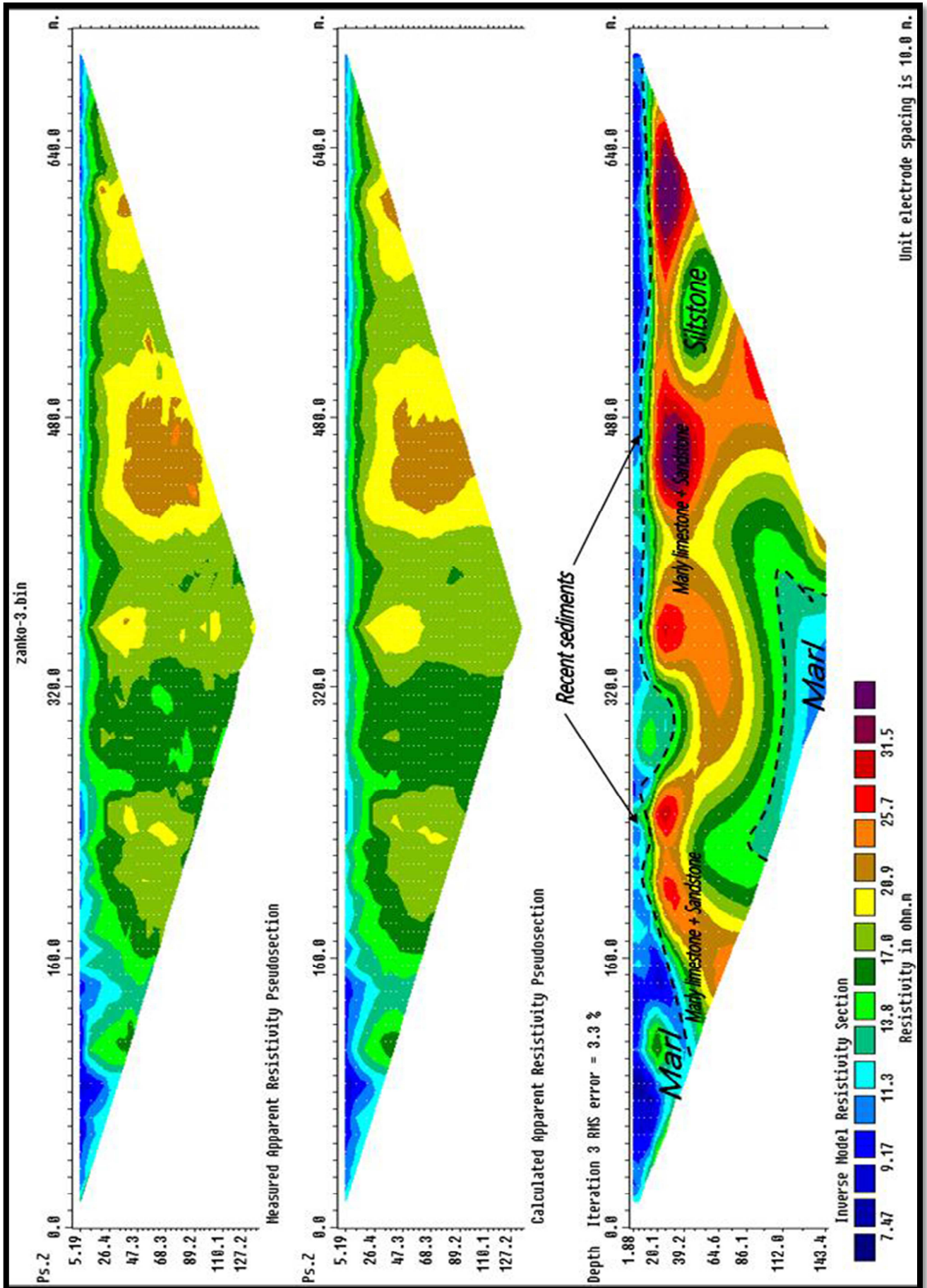


Figure.8. Showing Resistivity section at location three

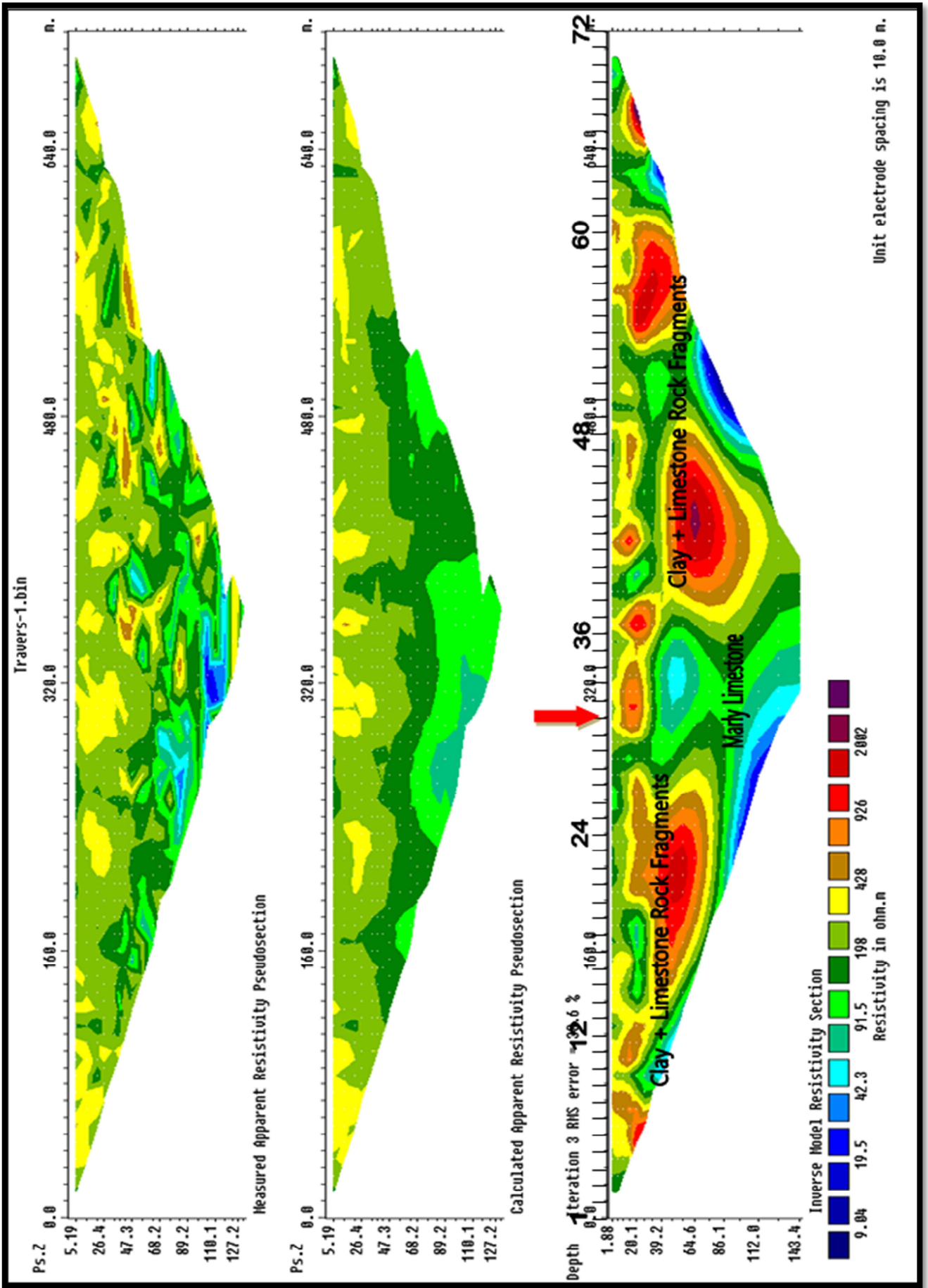


Figure.10. Showing Resistivity section at location five

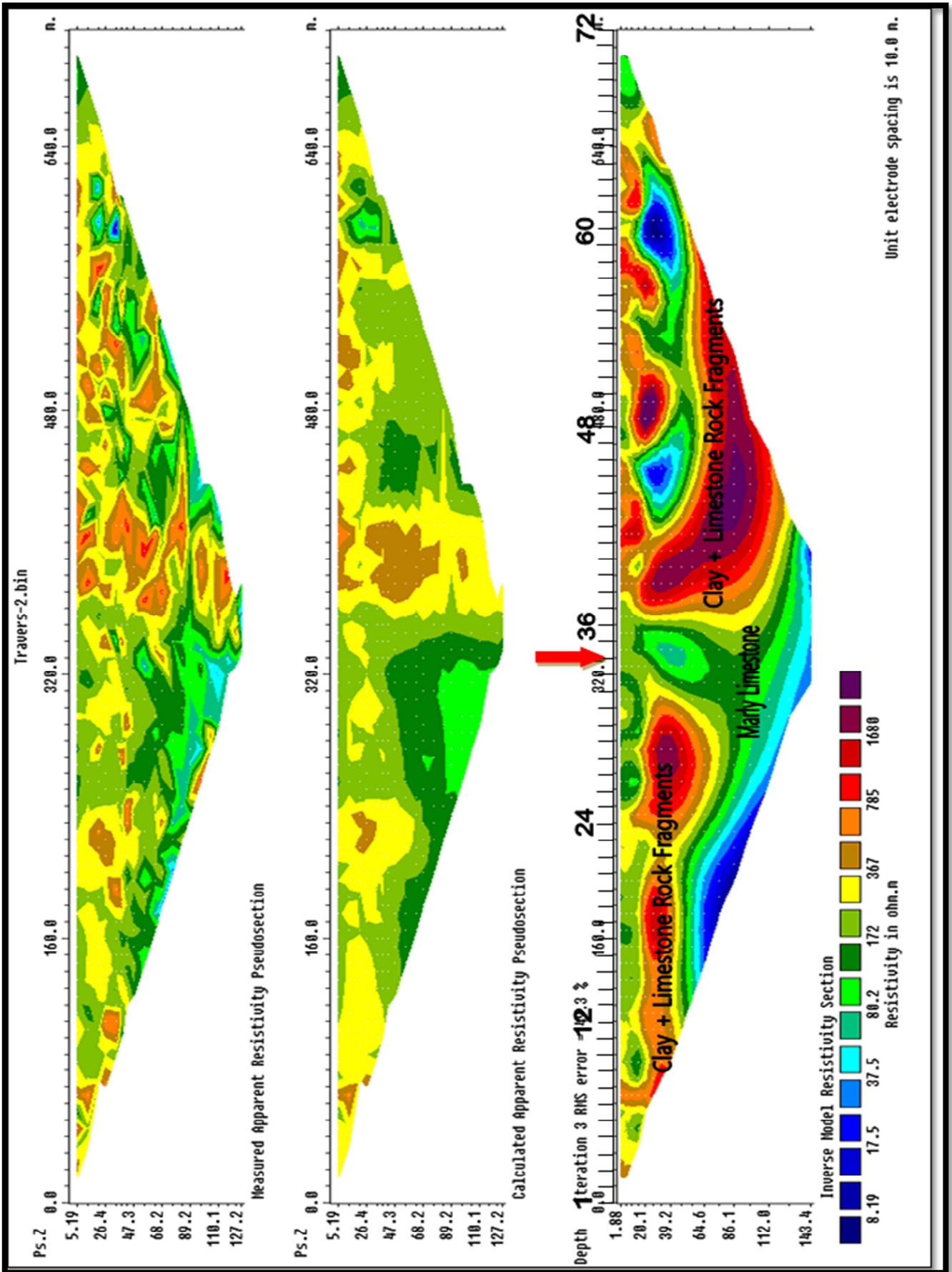


Figure.11. Showing Resistivity section at location six

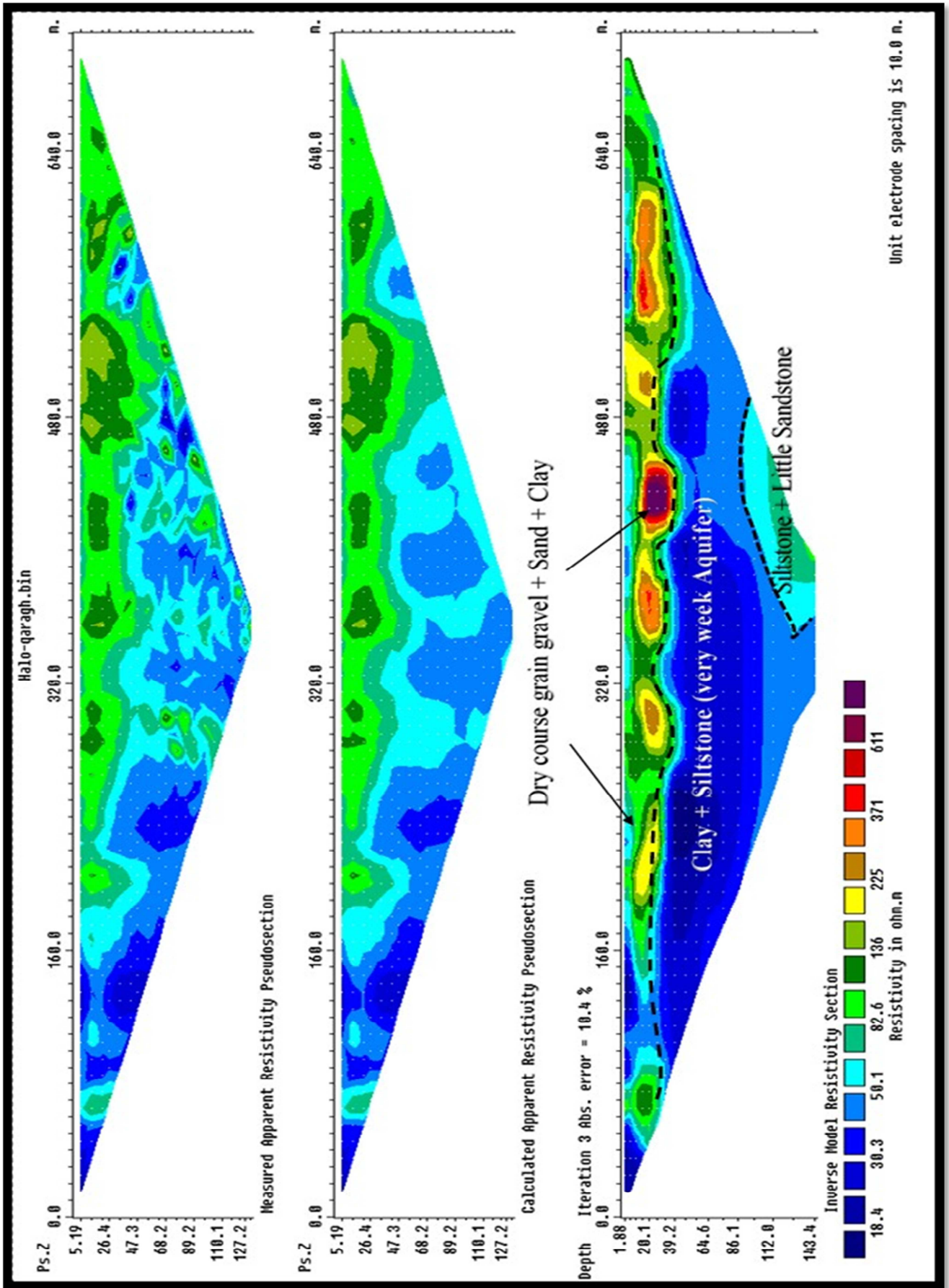


Figure.12. Showing Resistivity section at location seven

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