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Contribution of Geophysical for Studying Deep Fracturing in Connection with the Preferential Flow of Water at Tadighoust's Plain (Region of Goulmima, Morocco)

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ABSTRACT: The Alluvials formations of the plain of Tadighoust (Goulmima region) have been affected by the effects of dryness and excessive drought that led to the depletion of the particular quaternary slick surface. Increasing water demand needed to power up the population and irrigated areas require looking for water sources from deep reservoirs. Hydrogeological studies were previously conducted are mainly based on the potentiometric analysis of the works, but they have not helped to define precisely the outline of transfer of deep flows in this region. The deep circulation is distributed in a wide heterogeneity that can't be defined as from the introduction of the geophysical technique. We therefore undertook measures electrical and electromagnetic prospecting at this plain, in order to highlight the main areas of deep fracturing in connection with the preferential water circulation and favor the establishment of productive wells.

KEYWORDS: Geophysical, Deep Fracturing, Flow of Water, Tadighoust's Plain, Goulmima, Morocco.

1 INTRODUCTION

The area of Tadighoust Goulmima, belonging to the watershed Gheris, experiencing a severe drought, the flows are periodic and availability of sufficient water resources is very rare on the surface. It is therefore necessary to extract these resources from the deep circulation. This requires a great exploration of these geological formations to learn more about the functioning of aquifers in place.

The population growth up and attachment to traditional agriculture, increases water demand becomes a challenge demanding but necessary to respond to this activity. It is therefore appropriate to undertake a geophysical study to better understand the operation of flow depth of this region.

It should also be recalled that several hydrogeological exploration studies were conducted at the Tafilalt basin (RDH Report, 1988), which aims to define the potential of deep reservoirs, knowing that the alluvial layer (quaternary) of the region is exhausted long ago.

The Borehole data made between Tadighoust and Goulmima show that the rates are very low for alluvial formations on the surface of the palm of Tadighoust, while in depth, these flows are very important. In the region of Goulmima, flows are still significant for the higher levels. The polls suggest a large electric power variation limestone deep alluvium.

As part of a university project and in order to identify potential aquifers and the definition of broad lines of fracturing at this plain, we undertook a study in which we have implemented the introduction of geophysical methods of investigation, with the following techniques:

- Electrical technique
- Electromagnetic technique
- Electrical tomography

By Electric technique, we will try to best recognize the power of the different aquifers of the study area and the lateral variation.

From electromagnetic measurements, we try to highlight the alignment of the main lines of fracturing and thus confirm or refute the results previously obtained by the electrical technique.

Using the electric tomography, we want to follow the lateral continuity and spatial variation of the power of aquifers in place.

Electromagnetic prospecting, the signal of surveyed land may suffer disruption related mainly to the passage of high voltage lines (Durant, 2004), that is why it is very useful to link the results to those of the electrical prospecting order to better distinguish the response of the location of areas of deep water circulation from that attributed to other parasitic induction phenomena.

2 PRESENTATION OF THE STUDY AREA

2.1 GEOGRAPHIC LOCATION AND GEOLOGICAL SETTING

The alluvial plain of Tadighoust is located 18km north of Goulmima, it corresponds to an area bounded on the north by the Jurassic formations (High Atlas feet) and south by quaternary formations of the Anti-Atlas, and it is part of watershed Gheris. The latter belongs to the Cretaceous basin Errachidia.

Geological point of view, this region is bounded to the north by the southern flank of the High Atlas and south by the Anti-Atlas. Three morpho-structural units can be distinguished from north to south:

- The southern flank of the High Atlas formed mainly of limestone and dolomite of the Dogger Aalenian and separated by the Toarcian;
- Cretaceous basin in the centre that looks like Synclinorium asymmetrical, consisting of carbonate deposits of the Turonian, gréso sandy gypsum intercalation of infra-Cenomanian sand and clay deposits of evaporites and gypsiferous formations of Senonian;
- The plain occupied by Quaternary deposits, which sometimes outcrop of travertine and slate - greso levels Paleozoic and / or the Precambrian.

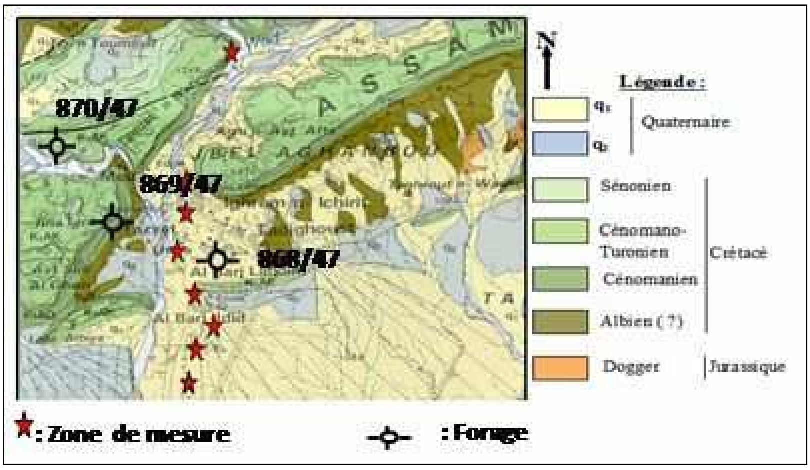

Figure 1: Location of the study area at Tadighoust
(Geological map of Morocco Goulmima sheet of 1/100.000)

The observed lithostratigraphy is characterized by a series ranging from Paleozoic to Quaternary.

The Paleozoic outcrops in the south to Erfoud and Tafilalet basin. These formations, which represent the whole series Cambrian Carboniferous, mainly detrital and match the pink sandstone of quartzite sandstone, are much consolidated conglomerates and shales. The Devonian limestone and Goniatites Clymenies (Hollard, 1974).

Mesozoic, Triassic formations outcrop north of the dam Hassan Eddakhil. They are also recognized in the basin by several drill holes some of which show that the Triassic diminishes beveled south and it no longer exists beyond Aoufous.

The Jurassic is very deep and outcrops on the northern edge of the basin. The Triassic-Lias transition is represented by a radical change of detrital sedimentation essentially carbonate sedimentation with side variations. To the South, there is gradual appearance of evaporites and red detrital sediments (Michard, 1976).

Cretaceous, Infra-Cenomanian consists essentially of red sandstone with intercalated gypsiferous marl and conglomerates at the base (Choubert, 1920-1945).

Cenomanian-Turonian outcrops in the southern Atlas furrow formed bedded limestone at the base and the summit massive (Choubert and A.Faure-Muret, 1962).

The Quaternary is represented by silts, conglomerates and alluvial deposits. The plain of Goulmima-Tadighouste is covered with these Quaternary deposits.

2.2 CLIMATOLOGICAL, HYDROLOGICAL AND HYDROGEOLOGICAL CONTEXT

The climatic regime in the study area is becoming arid Sahara to the south with strong continental influence by a micro climate in valleys and regions cultivated. The latter is responsible for the irregularity of rainfall and temperature.

At the watershed of Guir-Gheris-Ziz and Maider, we can distinguish several hydrogeological units (Figure 2). The piezometric map of the region shows two preferential flow directions: northwest to southeast and west to east (Ammary, 2007).

We must remember that many holes were drilled at the Tadighoust-Goulmima area, whose objective was to identify potential aquifers that can meet the increasing demand for drinking water and so remedy the drought experienced by the region. We would like to introduce two of these structures (Figure 3) which we also use in the interpretation of our measurements in electrical prospecting.

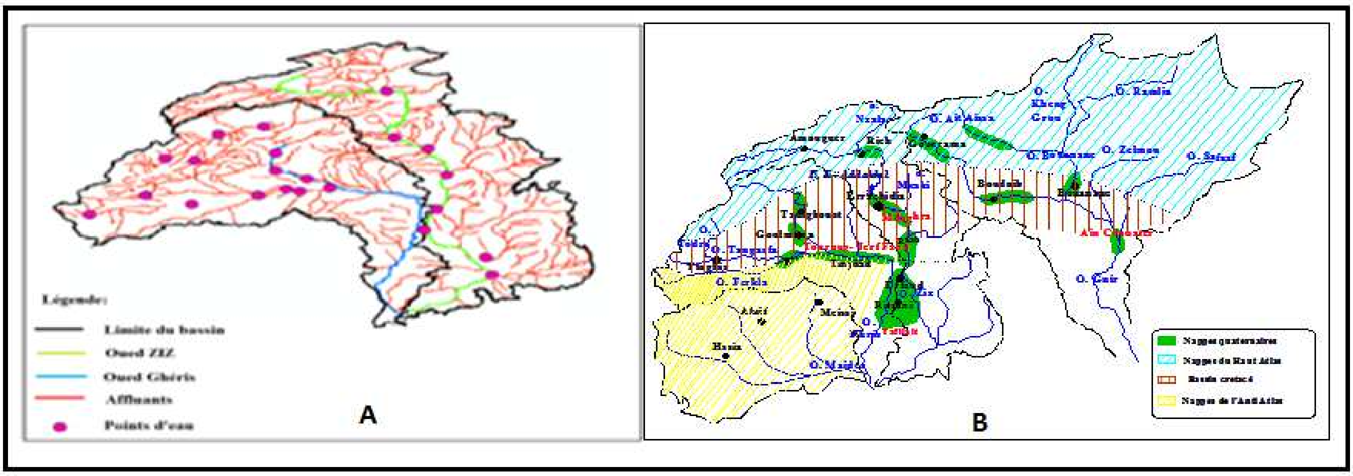

Figure 2: River system of Ziz-Gheris-basin and hydrogeological map of the different layers of the region of Errachidia (DRH Report, November 2006).

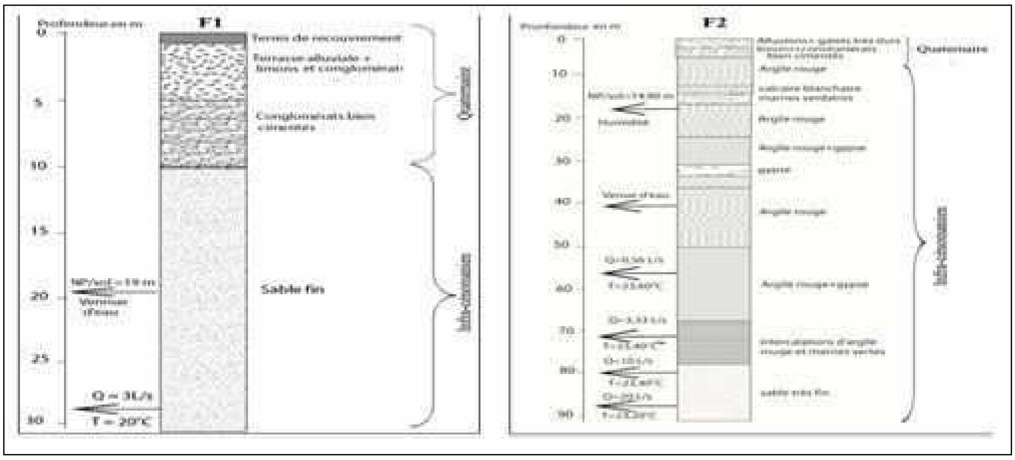

Figure 3: Drilling made by DRHE at the plain of Tadighoust. -F1 No. IRE: 868/47, X= 135.35 Y = 542.45 and Z = 1100 m. IRE -F2 No: 869/47, X = 540.25, Y = 136 and Z = 1104 m
(Map of Goulmima 1/100.000)

3 GEOPHYSICAL MEASUREMENTS AT THE STUDY AREA

To inform us properly about the quality of the geological formations in place, we borrowed the electrical and electromagnetic method. Electrical methods are used to direct currents or very low frequency making negligible the phenomena of induction. These methods to better understand the subsurface structure through the study of electrical resistivity formations that compose it. the electrical survey is obtained by performing a series of measurements with a device to four electrodes; discarding gradually two transmitting electrodes A and B on both sides of receiving electrodes M and N in the center of which is measured the potential difference (Figure 4). The electrical resistivity (ρ) is obtained from the potential difference (ΔV), the current (I) and the geometry of the electrodes (K) according to the following relationship:

$$\rho a = \frac{K\Delta V}{I}$$

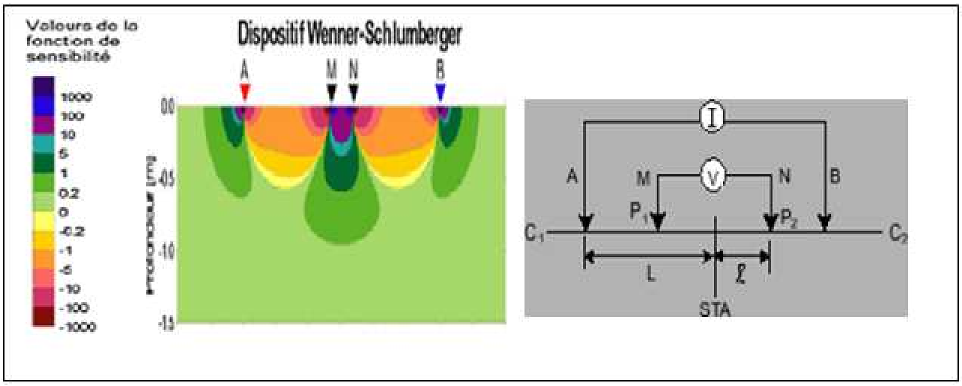

Figure 4: Representation of Schlumberger device

Trailed electrical are used in horizontal exploration and are particularly sensitive to lateral variations in the electrical quality of the subsoil. They provide qualitative information on surveyed land.

In electromagnetic prospecting, wave propagation creates an induction phenomenon therefore related to the conductivity of the body traversed by the wave of the primary field.

At the study area, measurements are carried out by the technical VLF (very low frequency method). Its principle is based on transmitting a primary electromagnetic field into the ground from a fixed transmitter to a constant frequency (below 10 MHz) and the reception of the total electromagnetic field; resulting from the primary field and secondary field generated by a conductive or resistant anomaly. It is particularly characterized by its ease use; this is why it is commonly preferred over other techniques horizontal exploration. The parameters measured are the ellipticity (b/a) which is the ratio between the small polarization axis (equivalent to the imaginary component) and the tilt angle (θ) the major axis of polarization with respect to the horizontal (equivalent to the real component).

$$\frac{b}{a} \cong \frac{H_s * \sin \alpha * \sin \varphi}{H_p} \cong \frac{I_m}{H_p}$$

$$Tan\ \theta \cong \frac{H_s * \sin \alpha * \cos \varphi}{H_p} \cong \frac{\mathrm{Re}}{H_p}$$

Hp: Horizontal primary magnetic field,
Hs: The secondary magnetic field,
The angle :α between Hp and Hs,
Le: phase shift between Hp and Hs. :
Im: the imaginary part of Hs
Re: the real part of Hs
μ0 : The magnetic permeability in vacuum = 4π.10-7,
Ex and Hy: Electric field and magnetic field in the same point.
f : Frequency

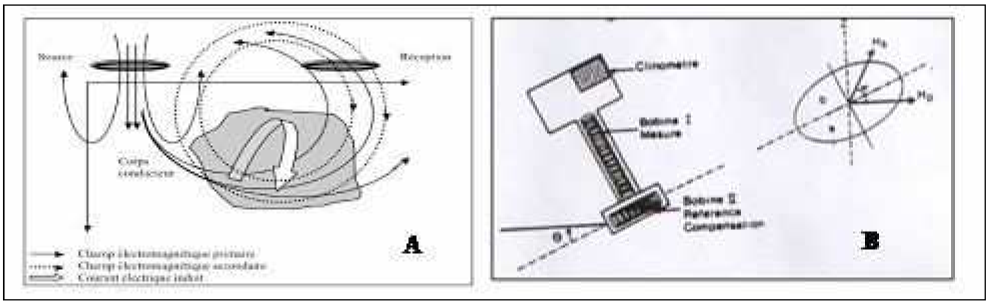

Figure 5: Schematic representation of the electromagnetic prospecting. A- Production fields and induction phenomenon, work in B- up a VLF receiver with two orthogonal coils.

This instrument is commonly used for measuring the inclination of the conductive bodies, can also be used for measuring electrical resistivity. Indeed, the primary field radiates as two components in the direction of the issuer; a vertical electric component and the other horizontal magnetic *Hy* perpendicular to the first. A close induction into the ground, another horizontal electric component *Ex* occurs along the direction of propagation. The electrical resistivity is given by the ratio *Ex/Hy* in Form magnetotelluric (also referred to as MT-VLF):

$$\rho\, a = \frac{1}{\varpi\mu}\left|\frac{E_X}{H_Y}\right|^2$$

The investigation by this technique is limited to a very shallow (about 10 m), that is why we do not often use to explore the deeper formations.

3.1 RESULTS OF MEASUREMENTS MADE AT THE ALLUVIAL PLAIN OF TADIGHOUST

At the plain of Tadighoust, geophysical measurements relate to two areas; Tazyat locality and the locality of Barj. The first seems less fissured surface, while the second was marked by a significant fracture to his level with several local subsidence observed surfaces in times of drought. The Barj the palm is in the form of a tabular plain without topographical obstacles vertically prospecting and study of its quality side.

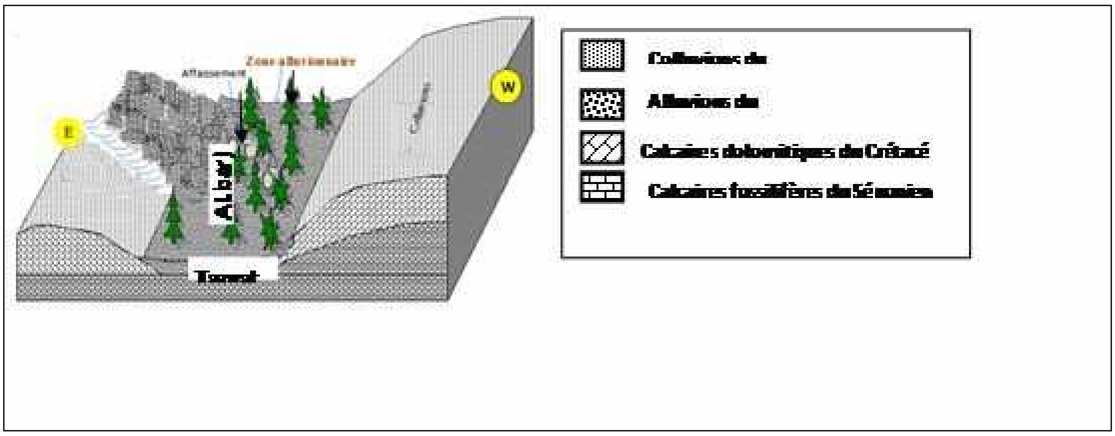

Figure 6: Schematic representation of the study area

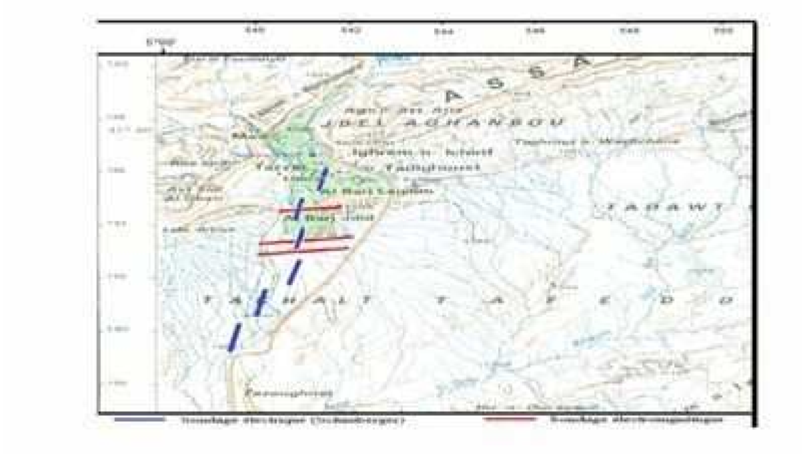

Figure 7: Location of measurements at Tadighoust (topographical map of Morocco, Goulmima sheet of 1/100000).

- The results of measures vertical exploration

Indeed, six Schlumberger type of electrical soundings were made towards NW-SE in this Tadighoust, length AB = 600 m, spaced approximately 500 m. Different surveys are conducted according to a profile from the center of the village of Tadighoust going towards Goulmima.

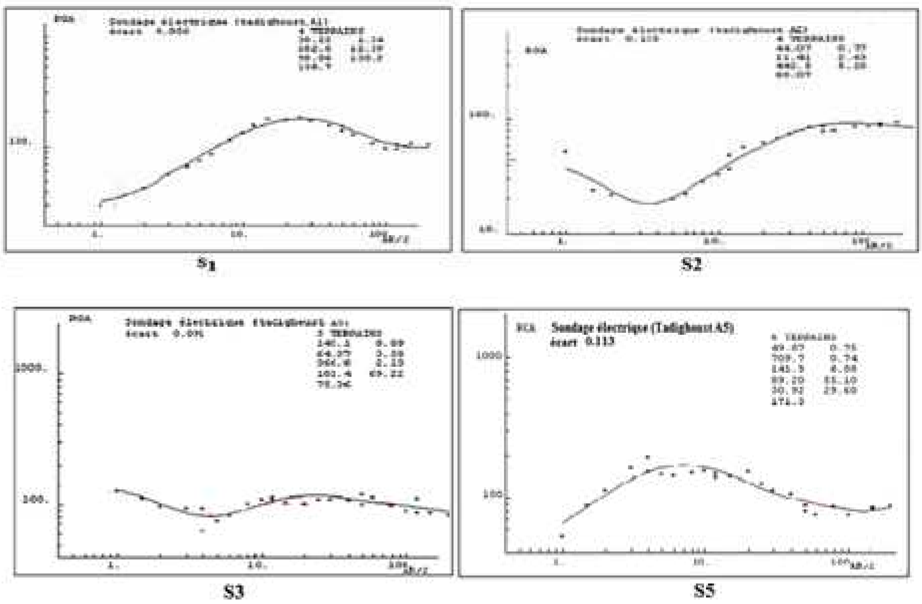

Figure 8: Electrical surveys made at the plain of Tadighoust (S1 Tazyat , S2 Barj Lakdim , S3 - Barj Jdid 500 m from S2 Rainfed Areas , S5 1km from S3 performed at the plain of Tadighoust (S5 L. C: X = 540 580.53, Y = 130 932.54 and Z = 1076m direction SW-NE).

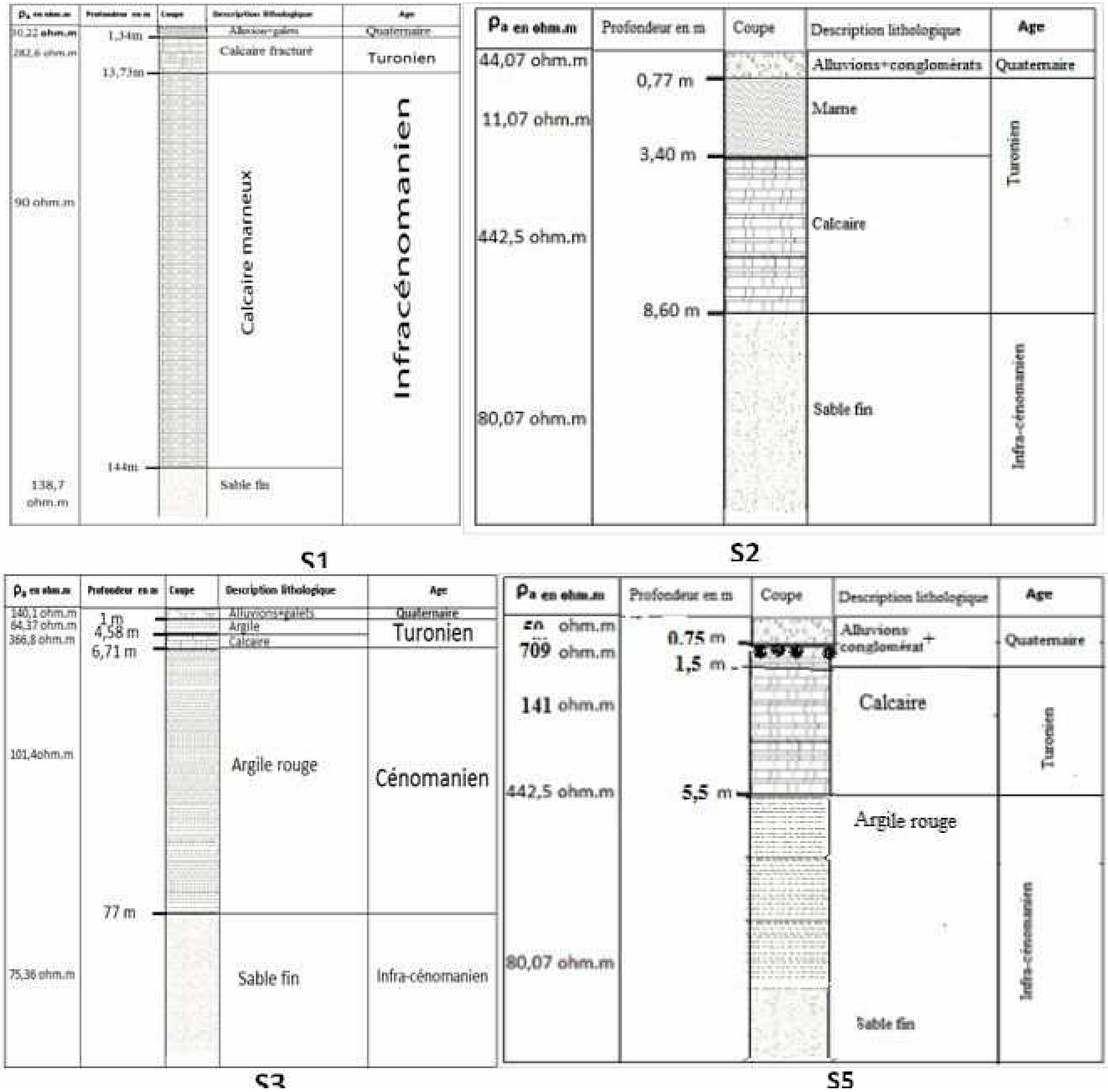

Figure 9: Lithostratigraphic logs made at the plain of Tadighoust

Below cemented conglomerates (709.70 ohm-m), the Turonian fractured limestone formation is more powerful at the Barj Lakdim and near the road Goulmima (S2 and S5) than at Tazyat and Barj Jdid (S1 and S3). In depth, all the polls meet the sands of infra-Cenomanian.

Electrical logs are correlated with data stratigraphic logs holes drilled in the nearest places their respective locations. But this correlation must be taken with great care.

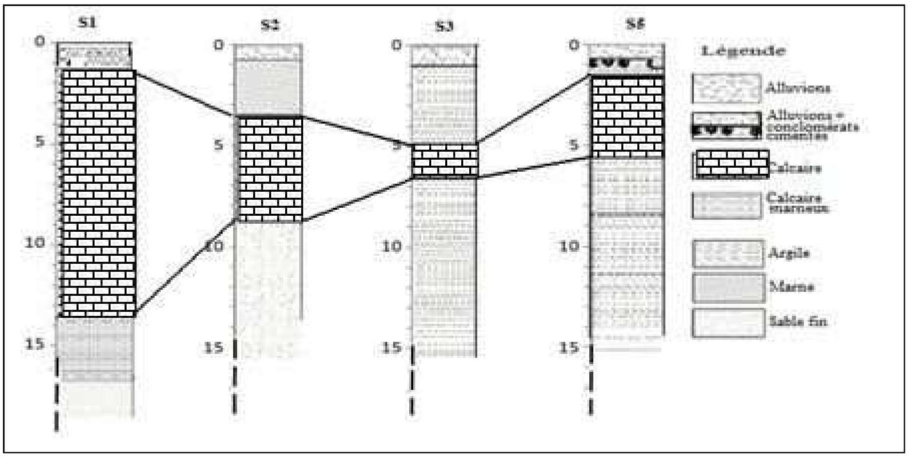

Figure 10: The stratigraphic logs of different land defined by the respective electrical soundings at the plain of Tadighoust.

Electrical surveys provide the important information on the quality and power of aquifers ground prospected. The resistivity values of the limestone formation is relatively low at the locality of Barj, thus reflecting the existence of a strong clay alteration to their level, the productivity of wells drilled in at least is low. Depth, flow rates are higher level than at the Barj Tazyat.

On the top of alluvial formation seems more conductive, thicker and more humid at the locality of Barj while it becomes thinner and dry south (site survey 3, towards Goulmima). The presence of moisture is also related to the frequent irrigation at this location.

- The results of measures horizontal exploration

- Result of electrical measurements

Indeed, four electric trailed have been made in the locality of Tazyat (Tadighoust). The result is shown by the diagram of resistivity diagram (Figure 11). This diagram shows considerable variation of the electrical resistivity, due to the existence of different contacts at the field level prospected. Indeed, the eastern part of the field appears more homogeneous and conductive and the western part seems more compact. This heterogeneity can be interpreted as follows:

- A homogeneous zone up to 100 m from the beginning of the profile;
- A stronger area that corresponds to a contact with a hard ground and located towards the western part of the land surveyed;
- The conductive anomalies areas, the first being located at a distance of 100m, the second at 150m and the third is located towards the western edge of the profiles. The latter will thus correspond to the location of rows of fracturing established;
- Conductive homogeneous area of agricultural land is much reworked.

At the Barj Lakdim four electric trailed were made by BENAMARA et al (2004) and were able to identify a large area of heterogeneity (Figure.12), observed at the surface subsidence floors, no doubt reflecting contact with the site of a major axis oriented in a fracturing NE- SW, through which are performed the flows of water depth.

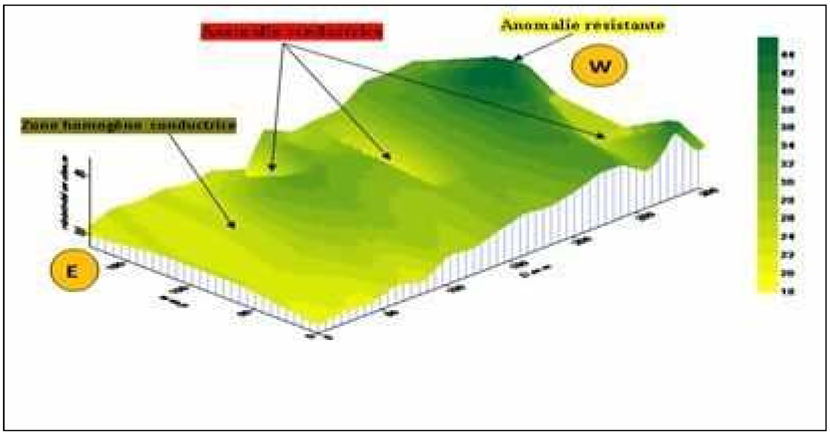

Figure 11: Isoresistivity diagram obtained by Wenner profile
(with a = 60 m, and step = 20 m at Tazyat)

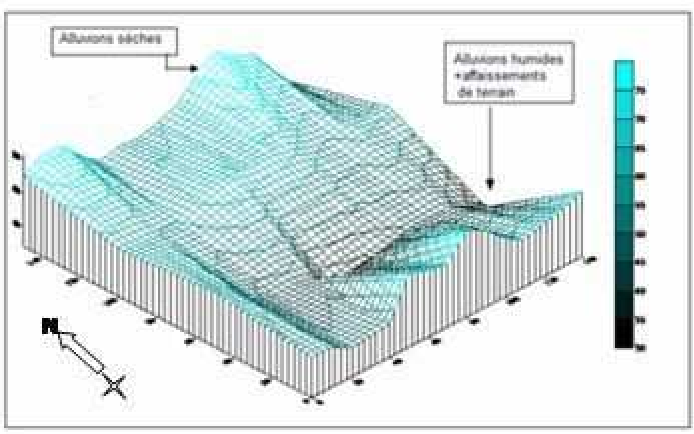

Figure 12: Isoresistivity diagram obtained by Wenner profile, with a = 60 m, and step = 10 m at Barj Lakdim (Tadighoust)

- Result of electromagnetic measurements

Four profiles have been made at this locality and are spaced 100 m going towards the direction of Barj.

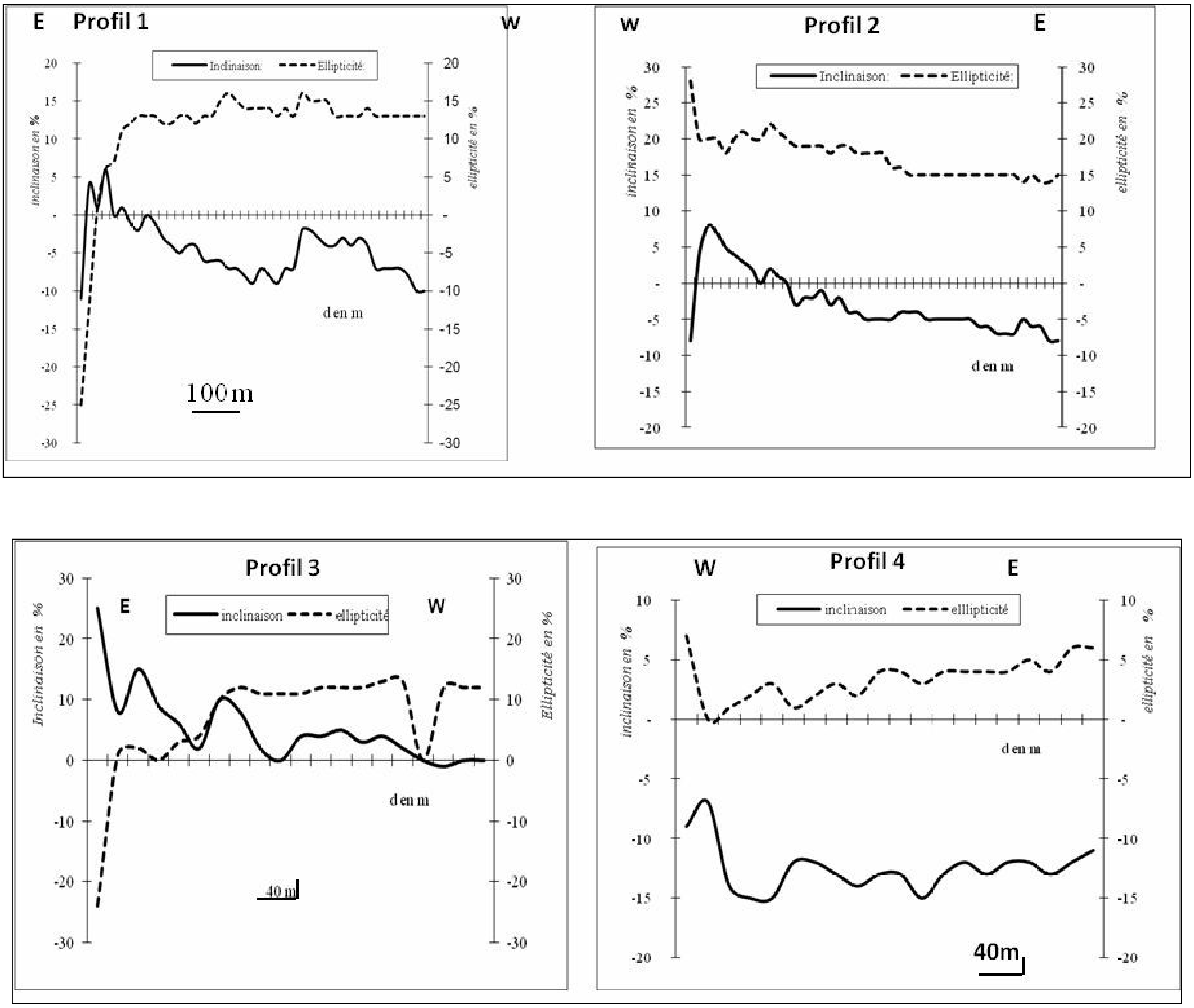

Figure 13: Variation of the inclination and ellipticity as a function of distance, with step = 20m at Tazyat (Tadighoust).

The curves in Figure 10 (Profile 1) suggest the existence of a contact between two different zones:

- An abnormality zone at the beginning of the profile and at which, for the two parameters which have mounted a substantial drop (-10% to -25 % and the inclination to the ellipticity). Presumably, this abnormality is simply related to the stability of the measuring instrument which was not achieved and not to a cracking zone.
- a conductive zone but extensive and homogeneous , in which the two components were varied in various ways , the imaginary component is positive and showed only slight variation with distance (around 14%), against the bias by underwent a significant and progressive decrease followed by an increase from a distance of 520m , its values are negative along the entire profile . This response thus reflects the quality of the land in place that corresponds to a heavily revised agricultural zone and slightly damp.

The curves of profile 2 show a progressive decrease in the value of the two components. As in the case of the previous profile, the inclination is negative and the ellipticity is positive for the entire length of the field surveyed, then we can say that we are in presence of the same terrain encountered by the first profile; slightly fractured on its west and east side of the homogeneous edge.

The figure 3 suggests that the profile is in the presence of a different lateral field quality. For the large part of the profile, the inclination showed considerable variation, while the ellipticity is almost constant from a distance of 140 from the beginning of the profile (between 10% and 12 %). Both parameters showed no negative values . Indeed, this response can be attributed to a slightly heterogeneous area, less humid and slightly fractured.

Concerning the curved of profile 4, the two parameters have relatively significant variations along the entire profile, the inclination of the lower values (between -15% and -13%), so the surveyed field seems cracked and must store high concentrations of water. It is also noted that the response of the fracturing abnormality region (to the west edge profile 2) is also shown at the beginning of this profile.

It is therefore concluded that Tazyat level, both methods (electric and dragged VLF) have contributed to distinguish two anomalies:

- A conductive zone expanded to the East, corresponds to a revamped agricultural land;
- An anomalous in zone fracturing the western border.

Finally, the results obtained by the electromagnetic technique therefore confirm the existence of this heterogeneity fracturing highlighted in electrical prospecting in the various fields prospected.

At the Barj two profiles VLF has been made at this locality in NS direction and over a length of 300 m (Figure 14). The result will learn more about the great fracturing in place and thus complement the results of electrical measurements.

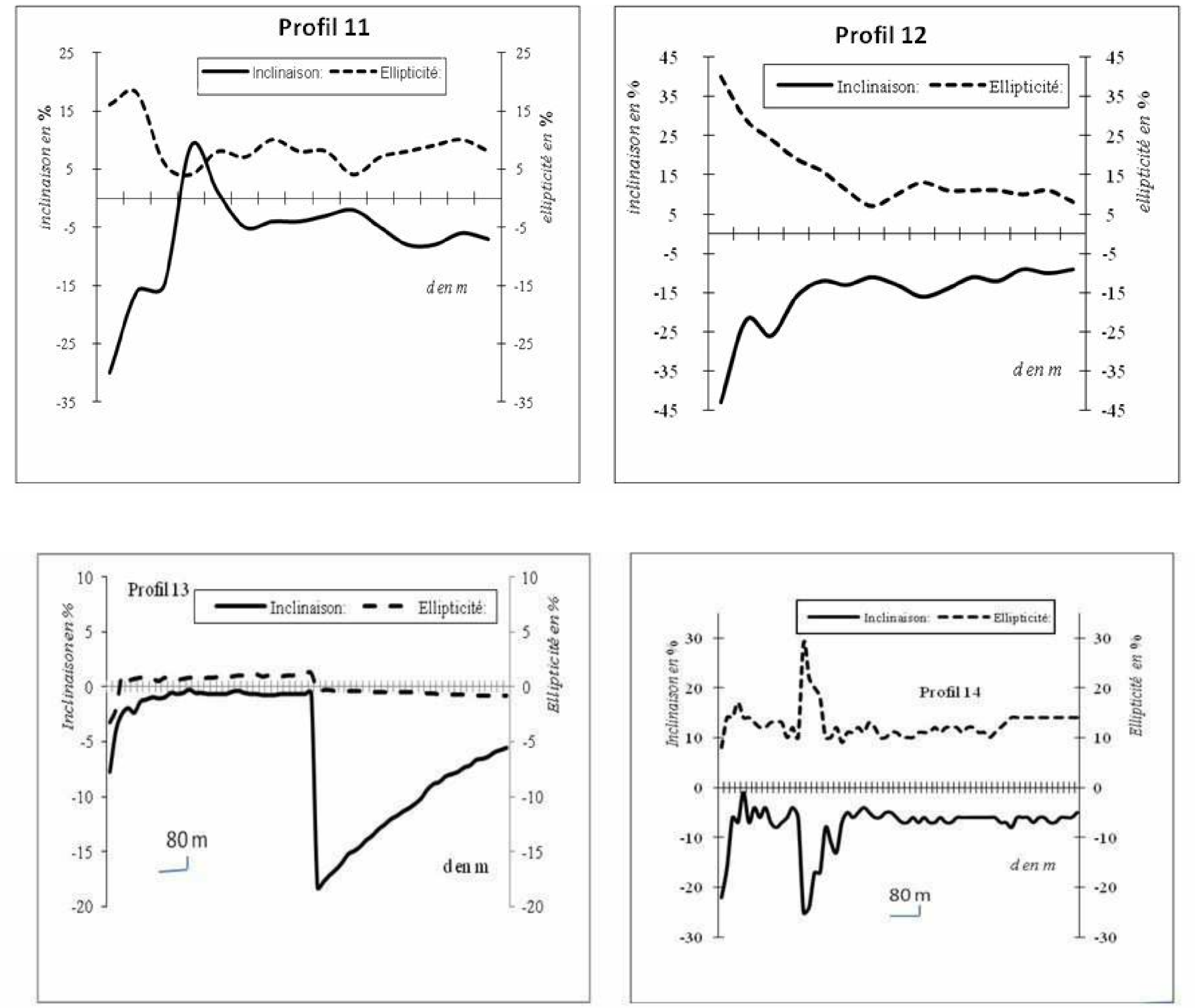

Figure 14: Variation of the inclination and ellipticity as a function of distance, with step =20m at the Barj (Tadighoust).

Indeed, for the two graphs (profile 11 and profile 12), the variation of the two components (inclination and ellipticity) first ad a heterogeneity area at the beginning of the profiles, it clearly corresponds to the passage from the area of fracturing indicated by the diagram (Figure 12). The rest of the curves suggest that we are in presence of the same type of terrain; less heterogeneous and slightly damp in her much.

Two other profiles have been made in the same area but towards west-east and slightly over a length of 1300 m (Profile 13 and Profile 14). These suggest the existence of a typical contact the location of a flaw. This site is located at a distance of 680 m from the beginning of the profile 13 and 300 m of the profile 14, at his level, the slope fell sharply (respectively, 18% and -25 %). The rest of the response of the two profiles appears to correspond to a more homogeneous field.

Near the road linking Tadighoust and Goulmima, we made three VLF profiles, in order to determine the lateral heterogeneity of the land and supplement previous work in this alluvial plain.

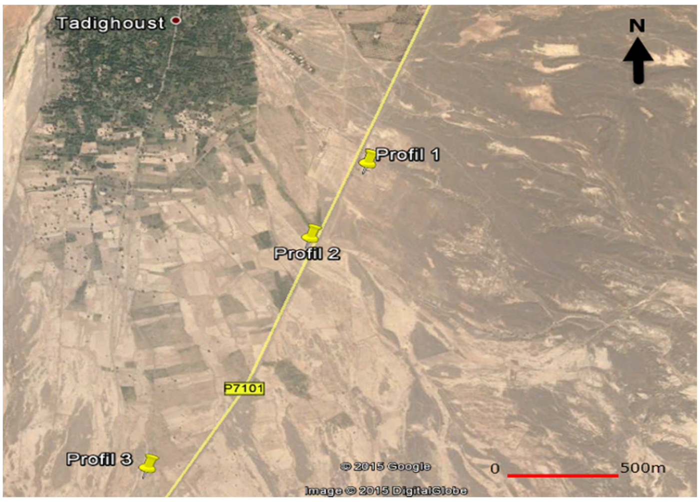

Figure 15 : Location of electromagnetic profiles made at the plain of Tadighoust (Google Earth)

Profile 1 (Fig. 16) is adjacent to the former home of the colonial operator (about 12 m) in EW direction and crossing the road to Goulmima. For this profile curves, except at the beginning of the profile, the two components show no significant variations in terrain surveyed. Their values are negative with a slight increase of the ellipticity at the end of the profile. So we can say that this is a plot more or less homogeneous and damp. The contact observed in the beginning of the profile, to which the two parameters are slightly significant (-7% and -12% to tilt and ellipticity) is probably linked to the fact that the soil in place is dry and no till (presence of gravel).

Concerning the profile 2, the two components do not show any significant variation with distance. Meaning that it is in the presence of a substantially homogeneous field on the most part. The ellipticity present negative values (lower -10 %) by tilting against shows positive values, the land is dry and less irrigated. This response of the two parameters can be also attributed to the rise of the limestone formation underlies the alluvium.

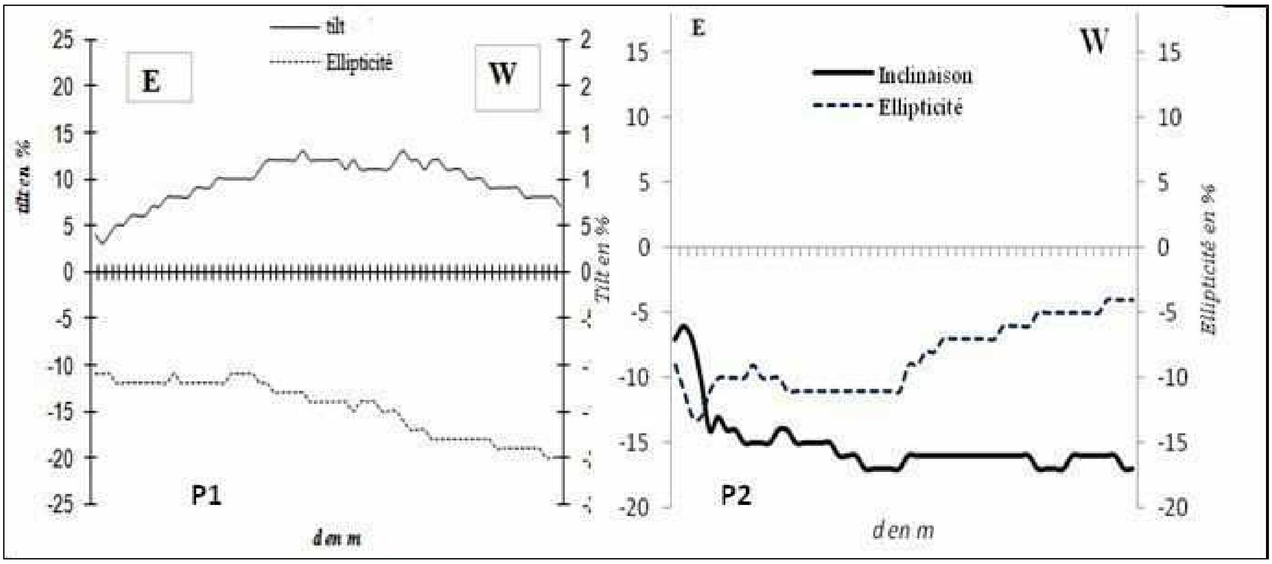

Figure 16: The inclination adjustment (tilt) and ellipticity as a function of distance, with step=20m at Tadighoust (EW, P1- c.L at the beginning of the profile X = 541 Y = 133 820.14 104 09 and Z = 1090m, c. L - P2 at the beginning of the profile. X = 563.08 541, Y = 132 673.06 and Z = 1087m).

The third profile is achieved in the direction SW-NE, at a distance of 1500 m of the second profile. The curves obtained (Figure 17) showed a contact between two different zones. This contact is located at the beginning of the profile and corresponds to the presence of a conglomerate and cracked zone at depth. The rest of the profile shows that the field is more homogeneous and slightly moist. Negative values observed for the two components are relatively higher than those obtained in the first profile, reflecting the effect of the limestone formation that is shallower than in the first case.

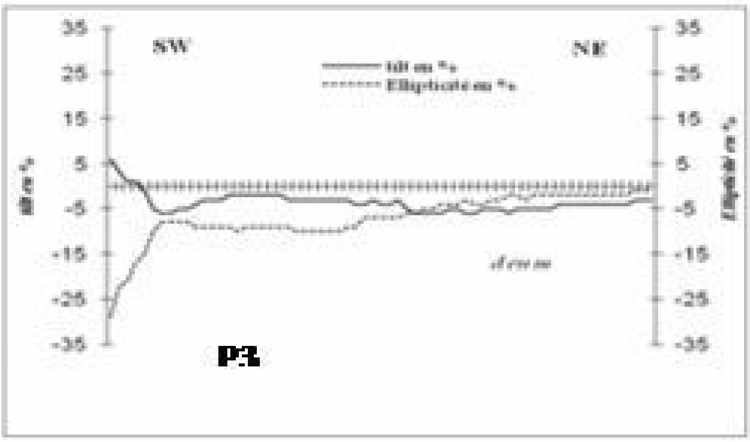

Figure 17: Variation of the inclination and ellipticity as a function of distance, with step = 20m at Tadighoust (direction SW-NE, L.C early profile X = 540 Y = 131 337.04 833.04 and Z= 1080m)

3.2 TOMOGRAPHIE ELECTRIQUE A LA PLAINE ALLUVIALE DE LA LOCALITE DE BARJ (TADIGHOUST)

Electrical tomography applied to obtain a resistivity (electric image of the basement) as a function of depth by measuring the resistivity profile for different combinations of current electrodes and potential.

The procedure involves the use of an electrical panel based on an acquisition system (ABEM) which takes care of the control measures, connected to a ABEM resistivity measuring the apparent resistivity of the medium by means of a set of 64 stainless steel electrodes and four cables for connecting the electrodes to the acquisition system. With a 12 V battery, the device injects the electric current between the electrodes A and B and measuring the electrical potential between the electrodes M and N. The datalogger allows us to choose among the following devices (Schlumberger, Wenner, dipole - dipole ...).

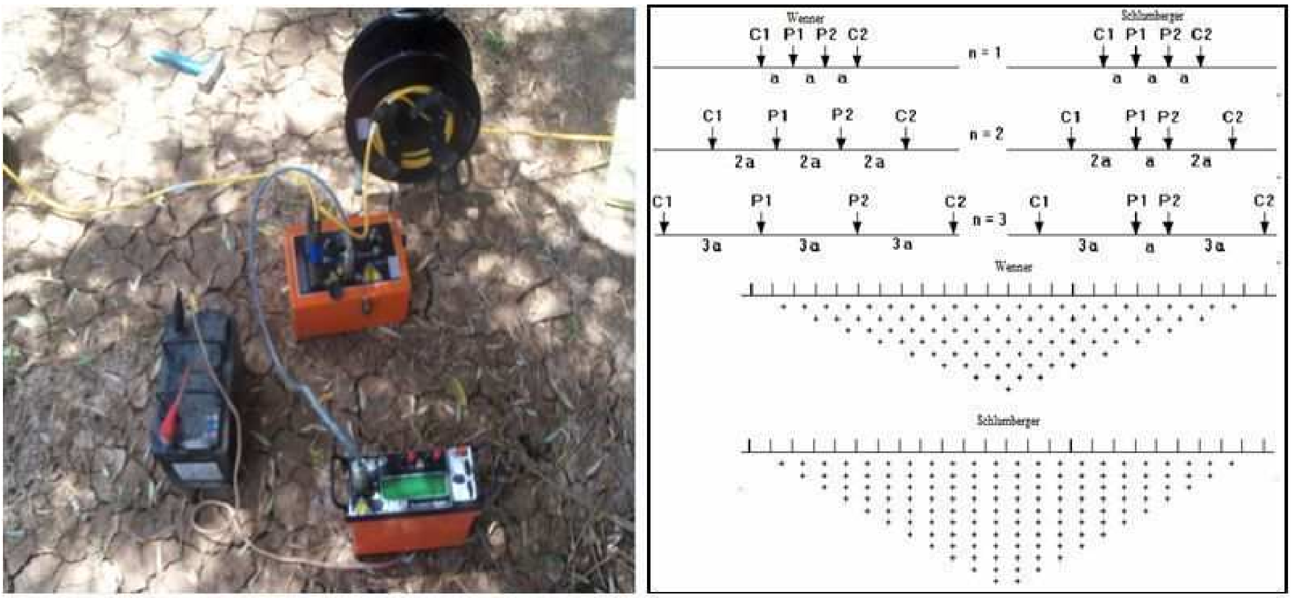

Figure 18: Investigation by the apparatus of tomography and principle of a pseudo-section

3.2.1 MEASUREMENT RESULT AT THE BARJ

To confirm the existence of this strong heterogeneity is related to the highly karstified limestone formations underlying, through which performs most of the flow of water depth, we have made steps tomography power at the Barj Lakdim and near the road to Goulmima . The result will , thereafter, to clearly delimit the extent of this mega - anisotropy limestone terrain indicated by the diagram (Figure12) which is probably the main cause of the establishment of the subsidence areas local surface observed in dry periods.

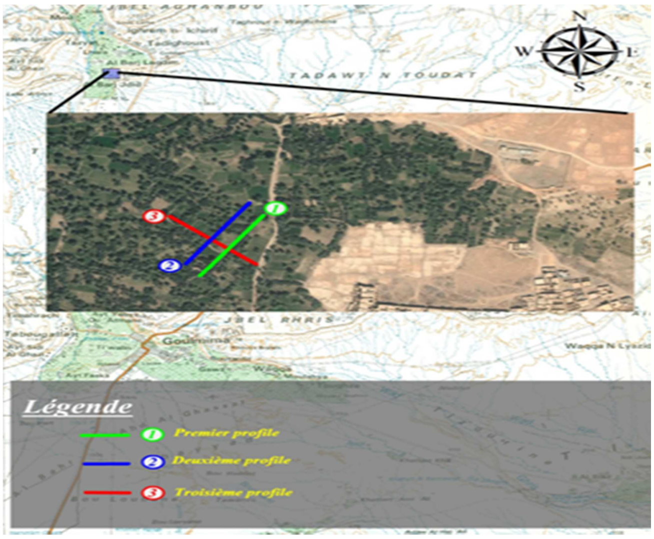

Figure 19: Location of profiles at Tadighoust (Town of Barj Lakdim , Morocco Geological Map of the one hundred thousandth , Goulmima sheet)

Indeed, three profiles were made in a collapsing zone level in the locality of Barj Lakdim. The first two are oriented towards NW-SE, the third is directed perpendicular to the two profiles in NE-SW (map at 1/100.000) (Figure 19). The training measures sought by the pseudo- section are located at a depth of about 12 m away (drilling, Figure 3) and are represented by limestones of the Turonian and Infra-Cenomanian also met by polls electrical (Figure 8).

For all established pseudo- sections, the minimum distance between the electrodes used is 5 m and the device used is of type Wenner, given its performance and adaptation to the study of heterogeneity of the land and the identification of horizontal anisotropy areas. The overall length of the coils used covers a distance of 320 m.

Profile 1 is made at a distance of 110 m from the canal. The pseudo- section obtained (Figure 20) shows that silt are almost continuous surface. They directly overcome the Turonian formation in which individualizes a conductive anomaly area heavily fractured and filled with materials from the clay alteration. This anomaly is located in the middle of the profile to a depth substantially of the order of 10 m. At his level, the value of the resistivity has undergone a considerable fall (10.5 ohm-m). In depth, we find, of course, the wetter sands and conductive of sub-Cenomanian.

It therefore notes the discontinuity of fractured land (resistivity = 143 ohm- m) which are still well developed towards the NW part of the profile, but who estampent as and as one goes towards the SE side of the profile land conductors (resistivity between 25 and 60 ohm -m).

The second profile is carried out at a distance of 50 m from the first by going to the north. The pseudo- section (Figure 21) first confirms the existence of this anomaly identified by the first profile, the Turonian limestone is cashing shows cut to his level. The conductive areas are aligned along an axis oriented NNW-SSE slightly with the same alignment of local subsidence on the surface. From the NW part of the profile, resistant formations are slightly narrowed with respect to their position illustrated by the first pseudo- section.

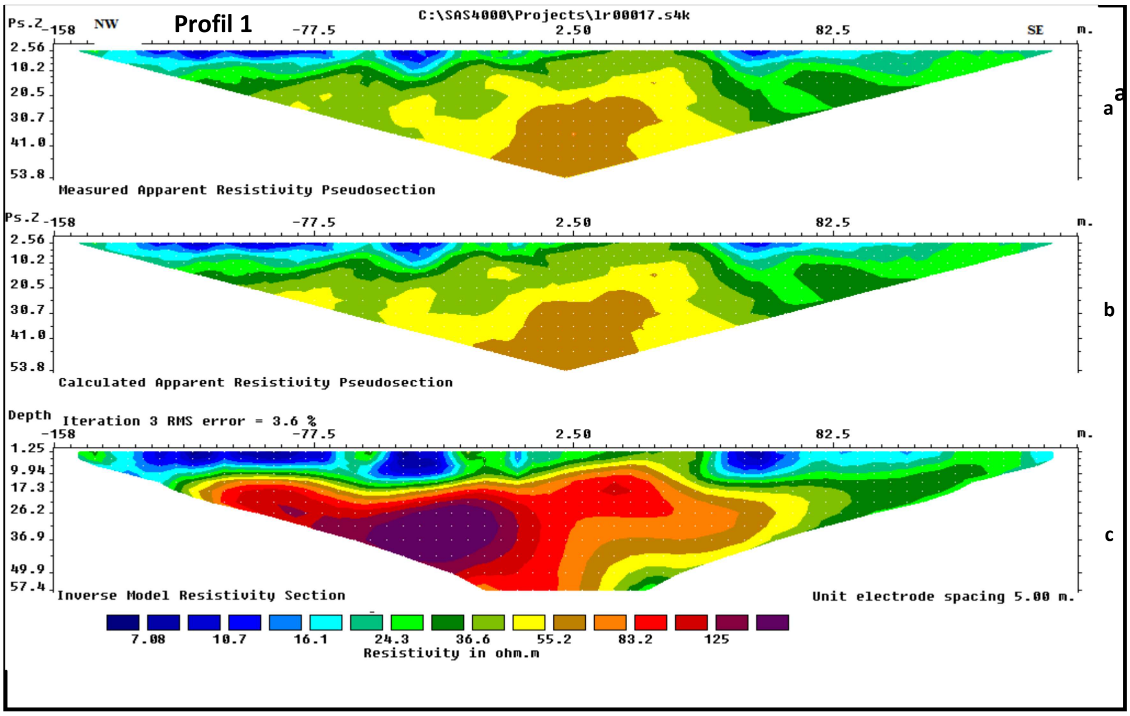

Figure 20: Pseudo- section performed in Barj Lakdim
(Wenner Profile L.C : X = 585.323, Y= 584.747 and = Z = 1337m, NW-SE direction).

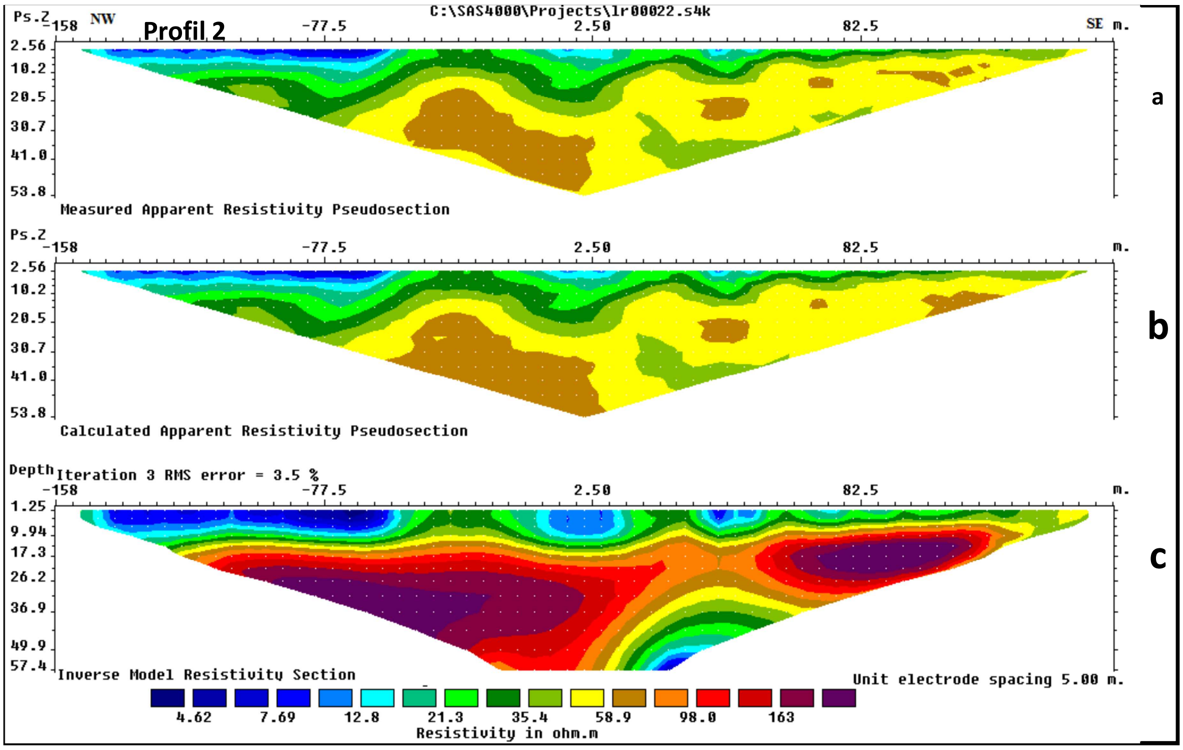

Figure 21: Pseudo- section performed in Barj Lakdim
(Wenner Profile L.C: X = 540.833, Y=134.724 and = Z = 1101m, NW-SE direction)

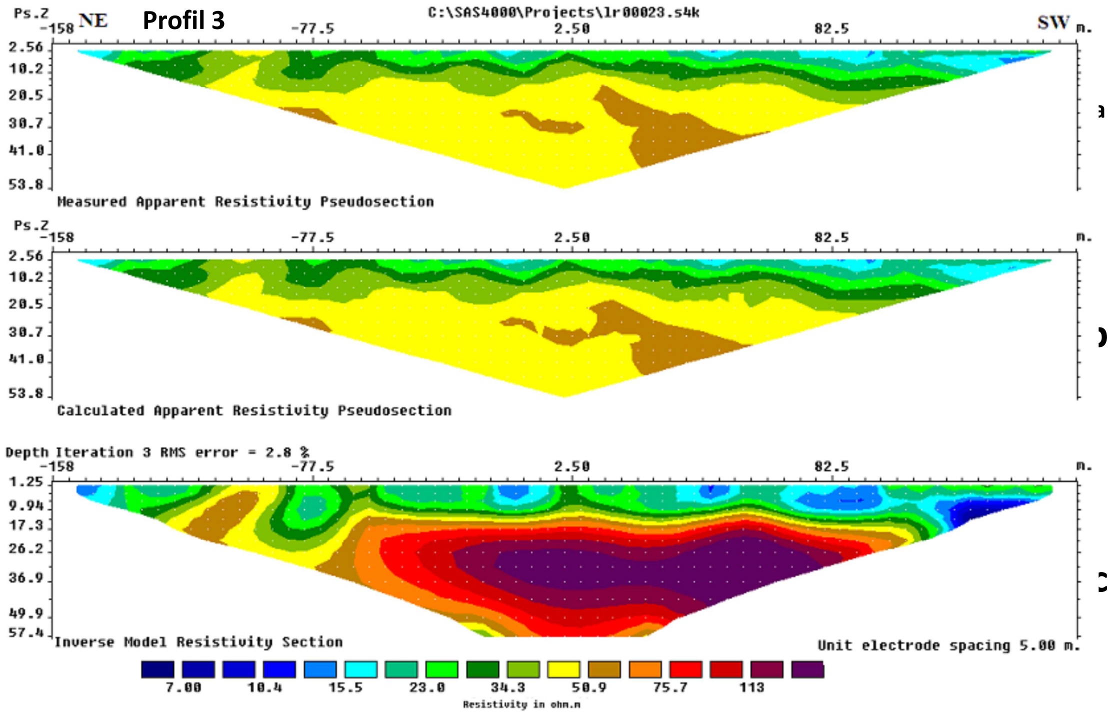

Figure 22: Pseudo- section performed in Barj Lakdim
(Wenner Profile, L.C X = 540.849, Y=134.702 and = Z = 1101 m, NE- SW)

The obtained pseudo-section of the third profile, directed perpendicularly to the first two (25 m from P1) suggests the decrease of the resistivity of calcareous soil in depth and overall response indicates that:

- In depth, the discontinuity of the limestone formation is individualized sideways.
- Values obtained are entirely resistivities lower than those measured for the preceding cases, the maximum value does not cross the 100 ohm -m, while it exceeds 200 ohm-m for the second profile. This is attributed to the fact that the orientation of this pseudo- section is relatively confused with the axis of major fracturing affecting the subsidence observed at the surface.

Finally, just by the results achieved by the VLF electromagnetic technique and those obtained by electrical prospecting, so we can highlight the different axes of fractures encountered at the Barj, indeed, Figure 23 summarizes the location of the existing lateral anisotropy within the surveyed field which represents most fracturing already identified by electrical resistivity diagram (Figure 12).

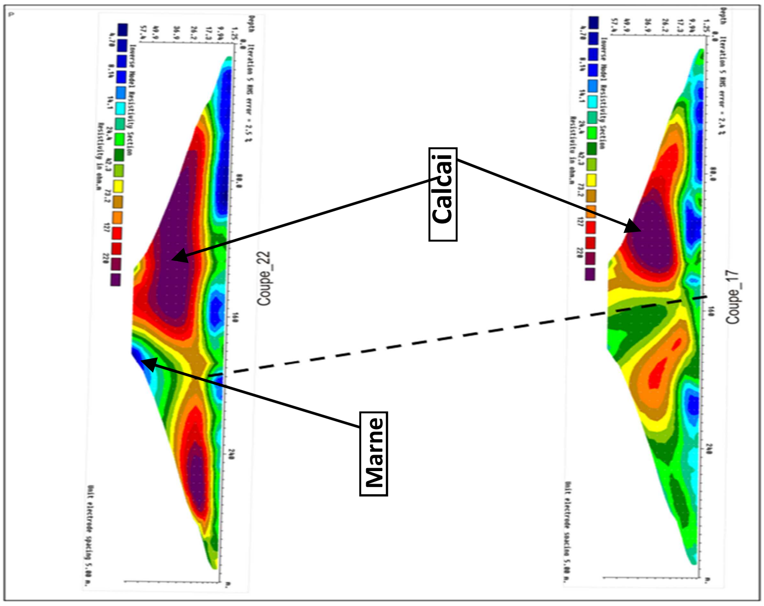

Figure 23: Corresponding pseudo- sectional representation of heterogeneous zones encountered in the collapsing zone of Barj Lakdim

3.2.2 RESULT MEASUREMENTS MADE AT THE LAND SURROUNDING THE ROAD GOULMIMA

To compare the results to those obtained at the highly altered zone at depth (Barj Lakdim), we performed measurements at the land in the absence of subsidence on the surface. The measures are carried out pseudo- section near the road between Goulmima and Tadighoust (2 km from the Barj Jdid , fig.24) in NNE-SSW direction.

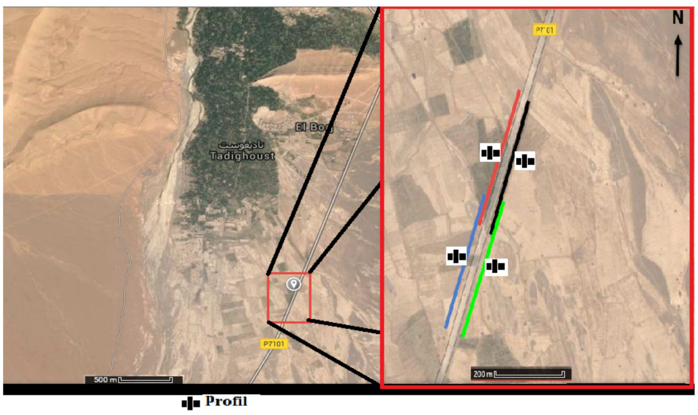

Figure 24: Location of electrical tomography profiles made at the plain of Tadighoust (Goulmima drive, Google Earth, 1:50 000) .

We also note that the interpretation of these electric profiles is made based on the data of drilling IRE No: 868/47 made by the management of the hydraulic Errachidia (Figure .3). Profile 4 (Figure 25) is performed at a distance of 200 m SSW of this drilling.

The pseudo-section obtained (Profile 4, fig. 25) shows that Quaternary alluvial formations (Silt and gravel) are conductiv , humid (30-50 Ωm) and are almost continuous to a depth of 8m order. This training is based on a considerably resistant ground (312 ohm -m) of thickness about 26m, which is cemented conglomerate encountered by the electrical survey (Fig. 8). They have a wide discontinuity observed in the middle of the profile. In depth, the profile meets the sandy deposits of the infra-Cenomanian whose resistivity is between 100 and 150 ohm-m.

The observed heterogeneity within conglomerates may correspond to an abnormal fracturing which extension also affects the Turonian limestone underlying depth. Its importance will be much cleared up by the next profiles.

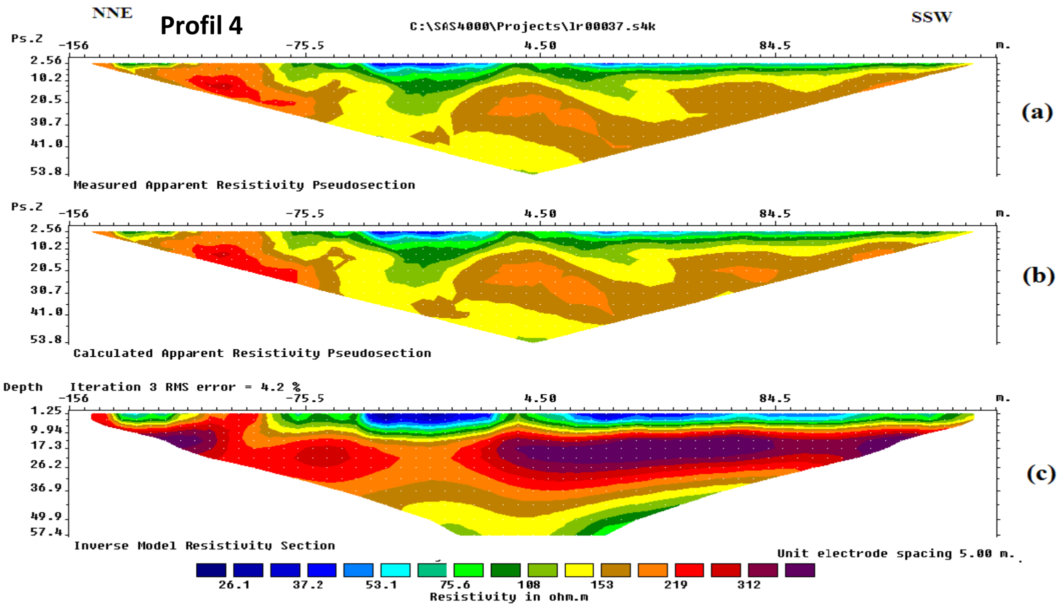

Figure 25: Pseudo-section performed in Tadighoust
(L.C: X = 541,521.08, Y = 132,465 61 and Z= 1087m)

The profile 26 is performed at a distance of 240 m from the site of the first in the same direction (NNE-SSW).

According to the pseudo-section obtained resistant surface lands (400-500 ohm- m), formed mainly conglomerates and pebbles, occupy a considerable and variable thickness (5 to 20m). This overcomes a formation layer that is sand and silt with a resistivity between 18 and 75 ohm-m, thus reflecting the presence of high humidity at the quaternary layer. All these formations appears cut in the middle of the profile thus announcing the existence of a conductive anomaly area which overlaps slightly resistant training long (about 45 m) and which represents the fractured limestone and clay sand (200 to 300 ohm-m).

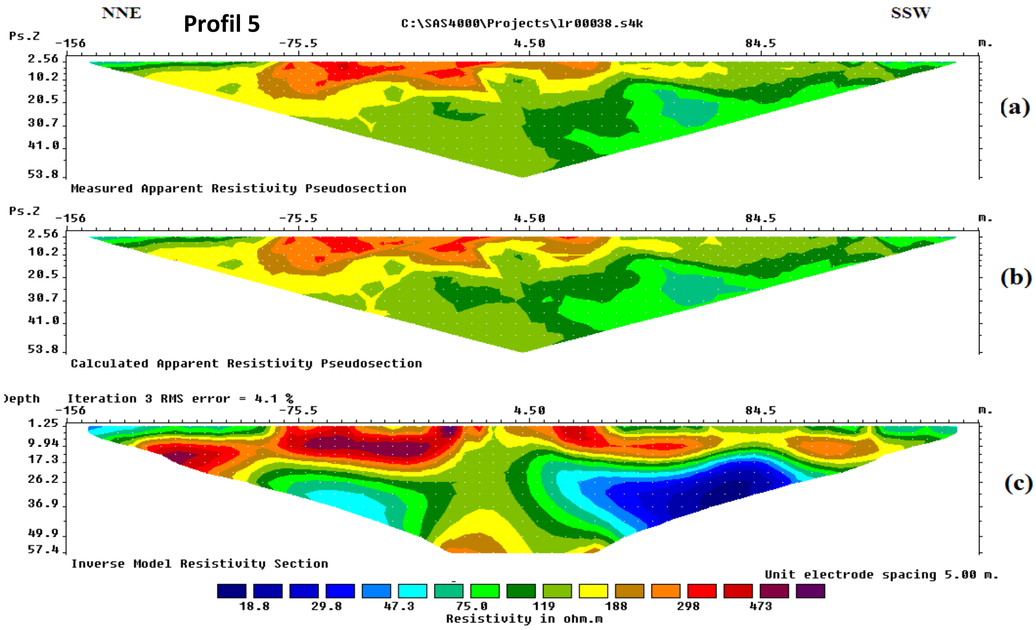

Figure 26: Pseudo-section performed in Tadighoust (c.L: X = 541 439.42, Y =132 240 13 and Z=1085m).

The profile 6 (Figure 27) is formed parallel to the first on the other side of the road. It is distant by 30 mm from the latter. The various formations encountered by this profile are almost similar to those obtained by the pseudo-section of the profile 4 (Figure 25). The observed difference lies in the fact that the resistivity values are higher compared to those of the first. This is especially related to the fact that these lands are not irrigated and are not extensively reworked and exposed to agricultural activity in the case of the other side of this road, drought is accentuated at their level. In addition, the conglomeratic areas are cut but more compact than at the first profiles.

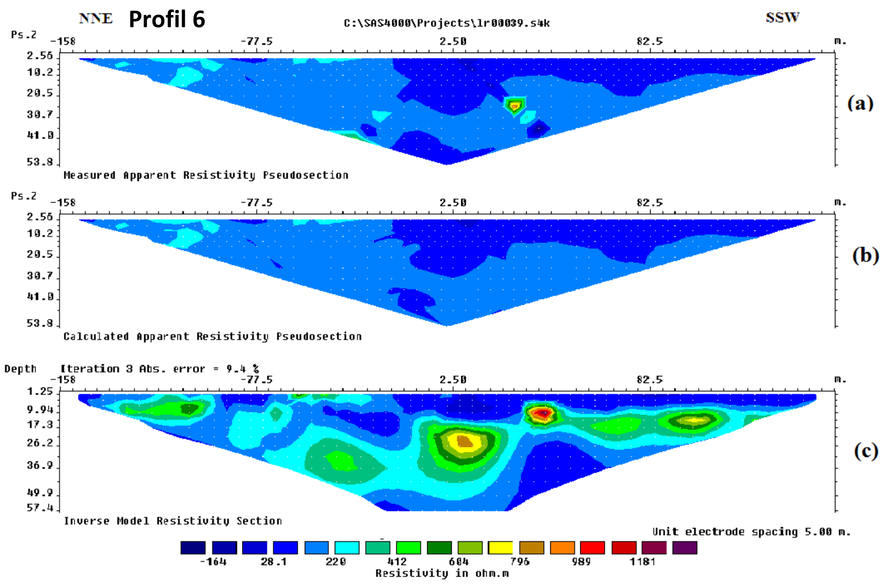

Figure 27: Pseudo- section performed in Tadighoust
(L.C: X = 540 567.42, Y = 132 458 28 and Z=1086m)

Regarding the profile of Figure 28, it is made at a distance of 240 m from the third going towards the SSW. It shows almost the same succession of formations and even heterogeneity encountered by the profile 5. Below the thin layer of vegetation cover include cemented conglomerates (248-774 ohm-m) laterally discontinuous with a thickness of about 10 m. They rely on stringers that are wetter and sometimes thicker particularly in the SW part of the profile. This training overcomes the fractured limestones of Turonian deep (250 ohm-m). In the middle of the profile, fracturing anomaly area seems much obvious compared to what is found in the pseudo-section of the second profile , in fact , it affects in a clearer way the various formations through in-depth.

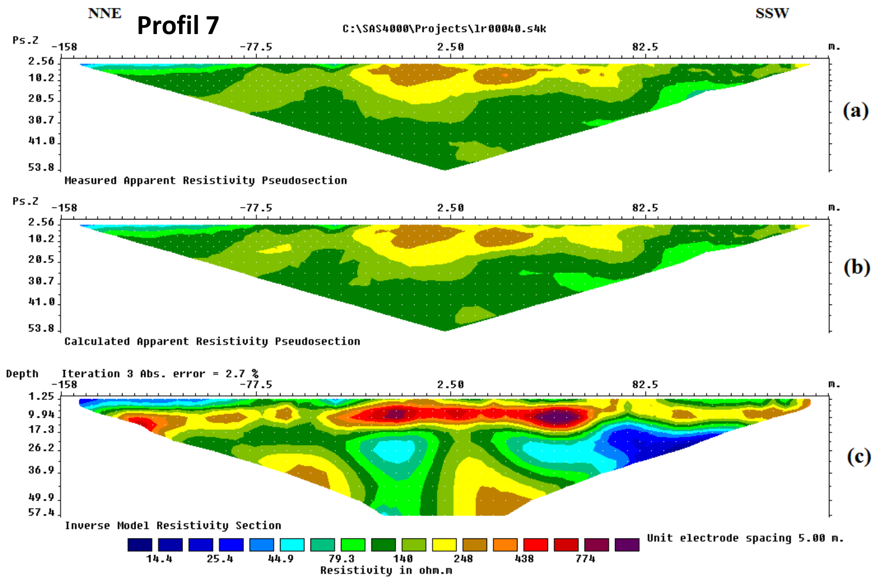

Figure 28: Pseudo-section performed inTadighoust
(L. C, X=541 449,69 Y=132 237,40 and Z=1084m)

The pseudo-sections performed at the study area allowed to monitor the quality of land vertically and laterally. They also helped locate more clearly the fortements altered zones at depth in connection with a major fracturing. The alignment of the depressions located by earlier work is directly connected to these fracturing abnormalities identified.

Note that all the obtained values of electric tomography (Fig. 25, 26, 27 and 28) and which correspond to fracturing heterogeneities is largely superior (153 ohm -m) than those measured in subsidence areas the Barj Lakdim (46 ohm- m).

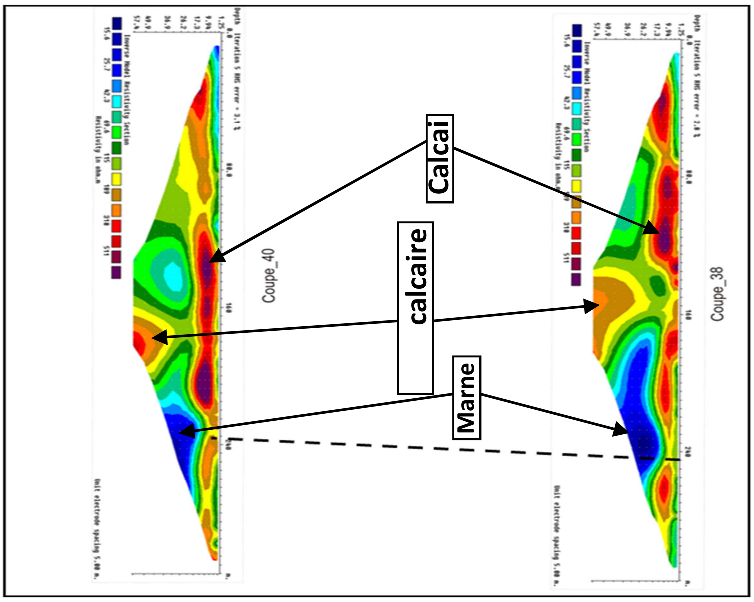

Figure 30: Correlative pseudo-section representation of heterogeneities encountered near the road to Goulmima.

4 CONCLUSION

The results of geophysical measurements at the plain of Tadighoust have provides important information about the power and quality of aquifers side up.

Indeed, vertical soundings suggest the existence of a large spatial variation of alluvial cover and limestone reservoir at depth. These courses are more developed next to the locality of Barj is why the deep holes drilled at their level are productive (20l / s). They are reduced in the direction of Goulmima. Their resistivity is particularly important to this area, which means that they are drier and less humid and limestone Turonian is less altered at that location.

The profiles of trailed electrique and electrical tomography could highlight the location of the alignment axis of a large fracturing in local subsidence. The anomaly identified along this axis translates the location of a strong karstificaion long.

Despite the impact of the current irrigation, these collapses occur due to two phenomena; the rapid infiltration of water in connection with the great fracturing of deep Turonian one hand, and the effect of evapotranspiratoire very pronounced in summer, on the other hand.

Outside the subsidence area, positron suggests the existence of a large deep fracture zone near the road to Goulmima, which should represent the continuity of the preferential flow of water from the Barj .

The electromagnetic profiles confirmed the presence of the great heterogeneity of land prospected by highlighting typical of a large fault where the slope fell sharply and oriented according to the location of the fracture zones at the location identified Barj. They also suggest the considerable variation in the power of the Turonian aquifer underlying the alluvium.

Given the importance of information provided by this geophysical investigative technique, and given its adaptation to the determination of zones of fracturing, it is appropriate to extend the measures to better define deep water flow between the locality of Tadighoust and the region of Goulmima, including the circulation zone which supplies the source of Tifounassine

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