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Application of electrical prospecting to lithological facies mapping in the Tselfat ridge, Morocco

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ABSTRACT: An electrical survey was carried out in the TSELFAT zone (SIDI KACEM - MOROCCO). The objective of the prospection was to trace the top of sandy limestone and limestone formations from the Miocene age. These materials could be used as raw material for cement manufacture if they were present in sufficient quantities. The results of the geophysical soundings show the succession of layers with resistivity ranging from 50 to 1300 Ω.m and thickness from 0.5 to 80 m. Considering the geological context, the sandy limestone and limestone layers at the study site are very interesting because they can establish a reserve of raw material.

KEYWORDS: Tselfat, raw material, electrical geophysics, sandy limestone and limestone, Miocene, reserve.

1 INTRODUCTION

This work is part of collaboration with the Project leader to build a cement factory in order to answer questions related to the quantity and quality of the deposit. We proposed a geophysical study to demonstrate the continuity of Miocene geomaterials (limestone and sandy-limestone) in depth, and to determine the possible thicknesses for each formation and discontinuities and abnormal contacts.

2 GEOGRAPHICAL AND GEOLOGICAL CONTEXT

2.1 GEOGRAPHICAL LOCATION

The study area is located in the commune of Zegotta, Province of Sidi Kacem, which is part of the region of Gharb Chrarda-BeniHssen. It is accessible by the national road N°4 connecting Kénitra to Fes through Sidi Kacem. (Fig.1).

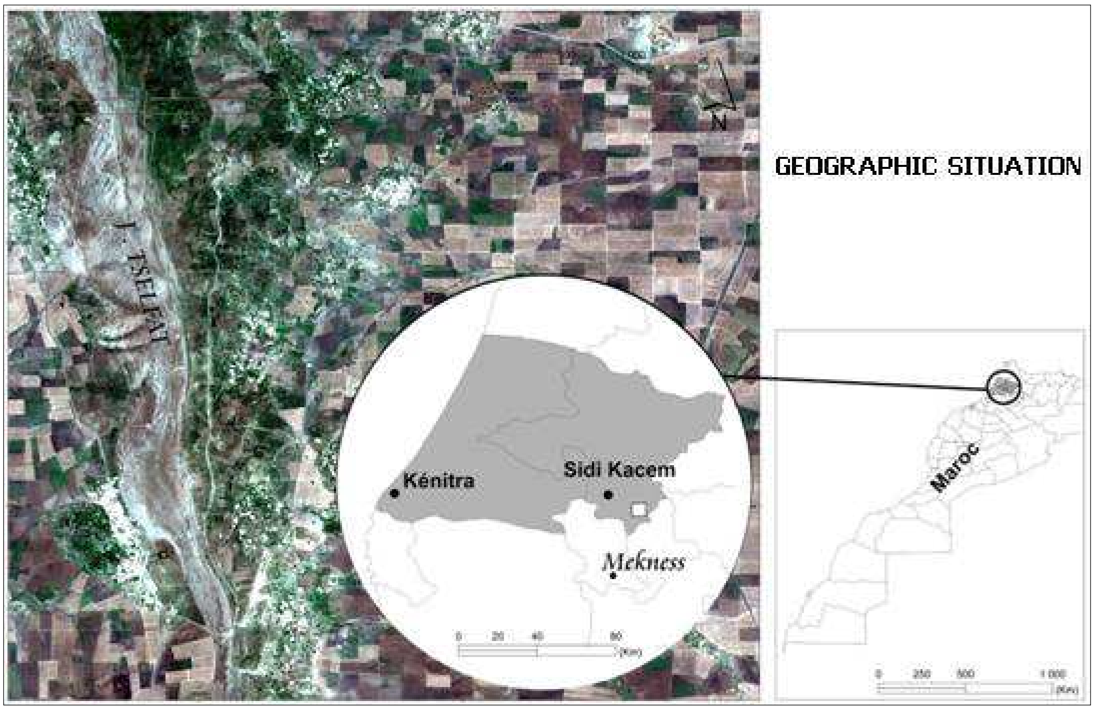


Figure 1: location of the study area

2.2 GEOLOGICAL SETTING

The studied area is located at the “Tselfat ridge”, one of the “sud-rifaines Ridges”. The latter are located at the southern edge of the Rifian chain and are known for their particular geological history. They are bounded by the Sebou River to the east, the plain of Gharb and Zemmour region to the west, and the Saïs basin to the south (FAUGERES 1978). The “Tselfat ridge” corresponds to one of the two lines of the northern branch of the southeastern Rif arc. It includes the Tselfat mountain in the North and the BouKanfoud mountain in the South, which are separated by the Zagotta pass through which the National Road N° 4 (fig. 2).

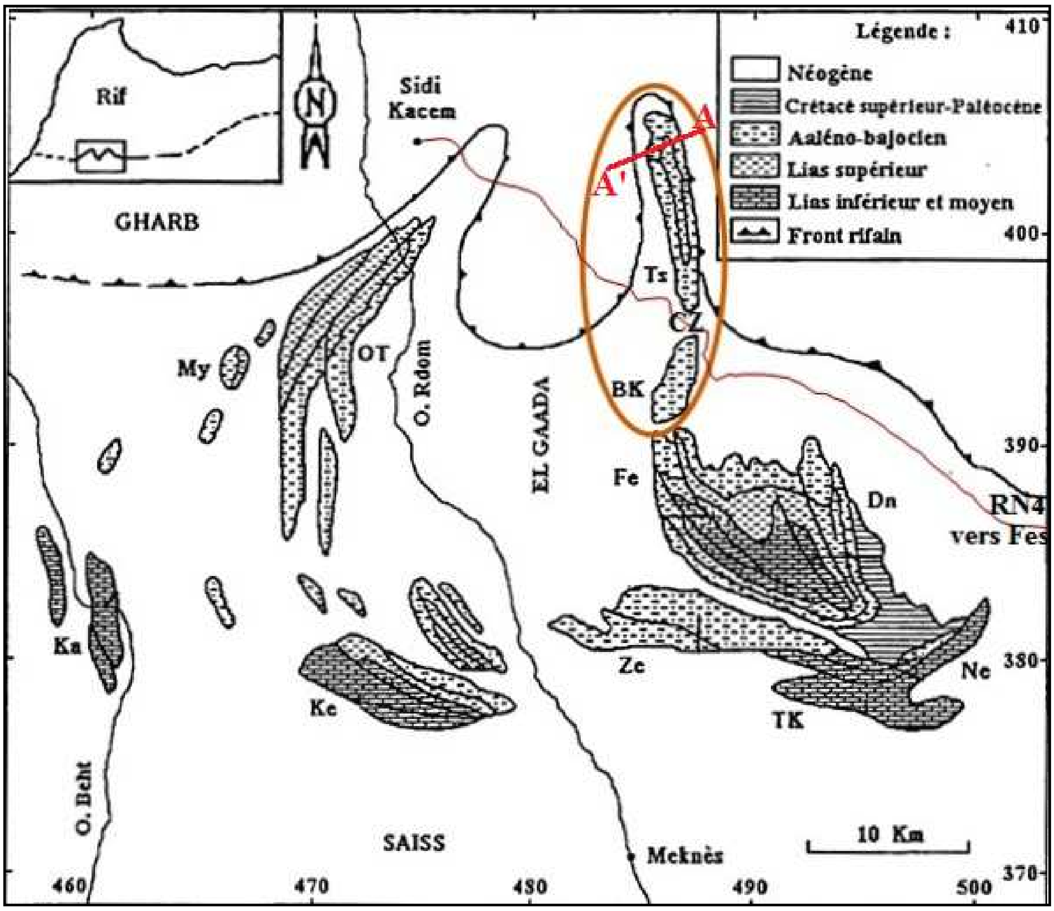


Figure 2: Geological location of the "Tselfat ride" (HADDAOUI, 2000)

Easternsouth-riffian lines: CZ : ZegotaPass, BK : Bou Kanfoud, Dn : Dehar En-Nsour, Fe : Fert El Bir, Ne : Nesrani, TK : Tekerma-Kannoufa, Ts ; Tselfat, Ze : Zerhoun. AA' : geological section. **Western south-Riffian lines:** Ba : JbelBalaas, Bz : Koudia Bou Azzouf, Ka : El Kansera, Ke : Kefs, My : Moulay Yacoub El Hamma, No : Nouillat, Ot : Outita.

The age of the Tselfat mountain formations extends from Jurassic to Late Miocene (fig.3).

The Jurassic series includes four different formations (from bottom to top):

- Marls and gray limestone-marl (EarlyToarcien, 100 m),), (Formation 1)
- Sandy limestone-marl (Toarcien -Aalenien, 80 m), (Formation 2)
- Sandy limestone-marl with Cancellophycus (Early Bajocien, 30 m) (Formation 3)
- Marls and white limestone-marl (Bajocien, 100 m). (Formation 4) (FAUGERES, 1978; EL-MOURABET, 1996; HADDAOUI 2000; Notes and memories N°431, 2004)

The Miocene series is transgressive and slightly discordant on the Jurassic deposits. It consists of (from bottom to top):

- The lower calcareous (or Limestone) sandstone (Lower Molasse).
- The sandstone or/and brecciated red clay (continental Miocene).
- The upper Calcareous (or limestone) sandstone (Upper Molasse).
- The pelagics white marl. HADDAOUI 2000 and FAUGERES 1978.

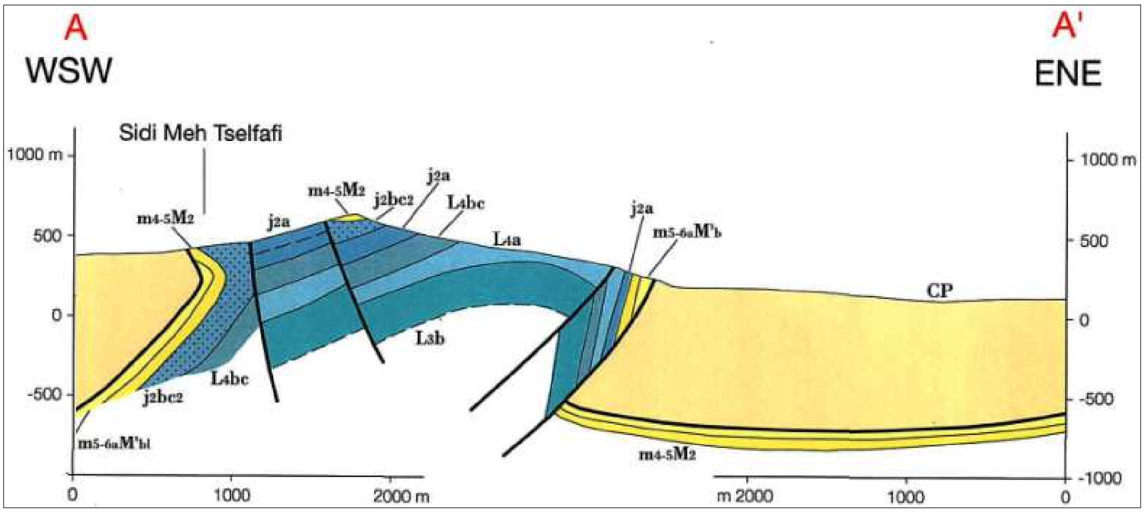


Figure 3: geological section AA'. (Geological services of Morocco, geologic map of SIDI KACEM 1/5000, Edition 2004)

Cp: pre-riffain complex, m4-5M2: Bioclastic Limestone slightly sandy (Late Miocene). m5-6aM' bl : Marls and white limestone-marl with sandy intercalations (Late Tortonian, late Messinian). j2bc2: Marls and white limestone-marl (Early Bajocian). j2a: Irregular alternation of sandy limestones benches and gray micaceous marl (Early Bajocian). L4bc: Marl slightly sandy with thin marly limestone intercalations (Toarcian and late Toarcian). L4a: Marls (Early Toarcian). L3b: dolomite and limestone (Early Domerian)

The lower calcareous sandstones are related to the beginning of Miocene transgression during which a clastic platform had settled down and was observed in the lines of Dhar-En-N'Sour, Tselfat and MoulayYacoub El Hamma which collect less and less terrigenous contributions. However, upper calcareous sandstone and white marls are generally uniform and they are spread throughout the entire region. They bear witness to a lake environment, which is the seat of the Miocene continental sedimentation. HADDAOUI, 2000; BARGACH, 2011

From the structural point of view, the zone of the south Riffian lines was the object of several interpretations:

- It is the result of structures under compression taken between two systems of combined slips NE-SW to the right and also to the left WNW-ESE, associated with diapiric movements (FAUGÈRES, 1978).
- It is the result of the unsticking of the meso-cenozoic sedimentary prism towards the SW during the late Miocene under compressive tectonic pressures in the general direction ENE-WSW, in relation to Mediterranean convergence. (HADDAOUI, 2000).
- The Tselfat line corresponds to a developing structure shooting upwards between two important overlapping faults and towards opposite vergencies: the principal overlap verging towards the west and the Tselfat retro-overlap verging towards the east. (FAUGÈRES, 1978; EL-MOURABET, 1996).
- The geometry of the general structure of the Tselfat Line reflects a propagation fold that became complicated as it evolved into a rupture fold. The structuring is assured by the combined action of the operation of a main detachment towards the west at the Trias level and a retro-overlap with vergence towards the east. This combined, complex, and antagonistic action is essentially favored by the influence of Jurassic accident geometry of Tselfat-BouKanfoud and by the dejective tectonic style of the general structure of the TselfatLine. (FAUGÈRES, 1978; EL-MOURABET, 1996).

3 ACQUISITION AND INTERPRETATION OF THE RESULTS

We used the geo-electric prospection, in particular vertical electrical sounding (VES) with the Wenner-Schlumberger device. This device includes two circuits: an emission circuit between points A and B and a reception circuit between points M and N close to the center of the device. We carried out in the same point a series of measures by increasing gradually the length of the quadripole. We exploring this place an increasingly thick slice of basement and thus we used as evidence the geological changes following the vertical line.

Visible resistivity measures were acquired using a resistivimeter GTR-2 of GEOTRADE-INSTRUMENTS. To cover the site study area, twenty-one soundings, directed N-S, were performed (fig. 4).

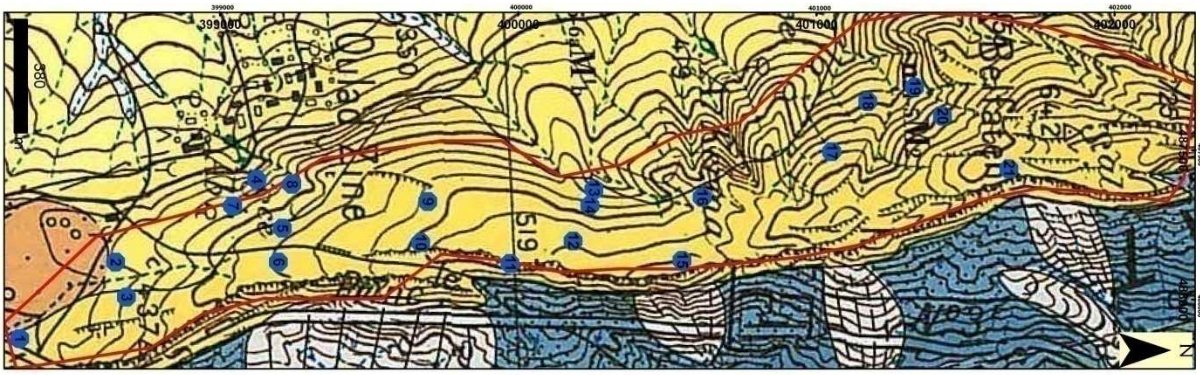


Fig 4: localization of the electric soundings on the site of study

Measurement results are presented as fact sheets, including information related to the sounding (Fig.5)

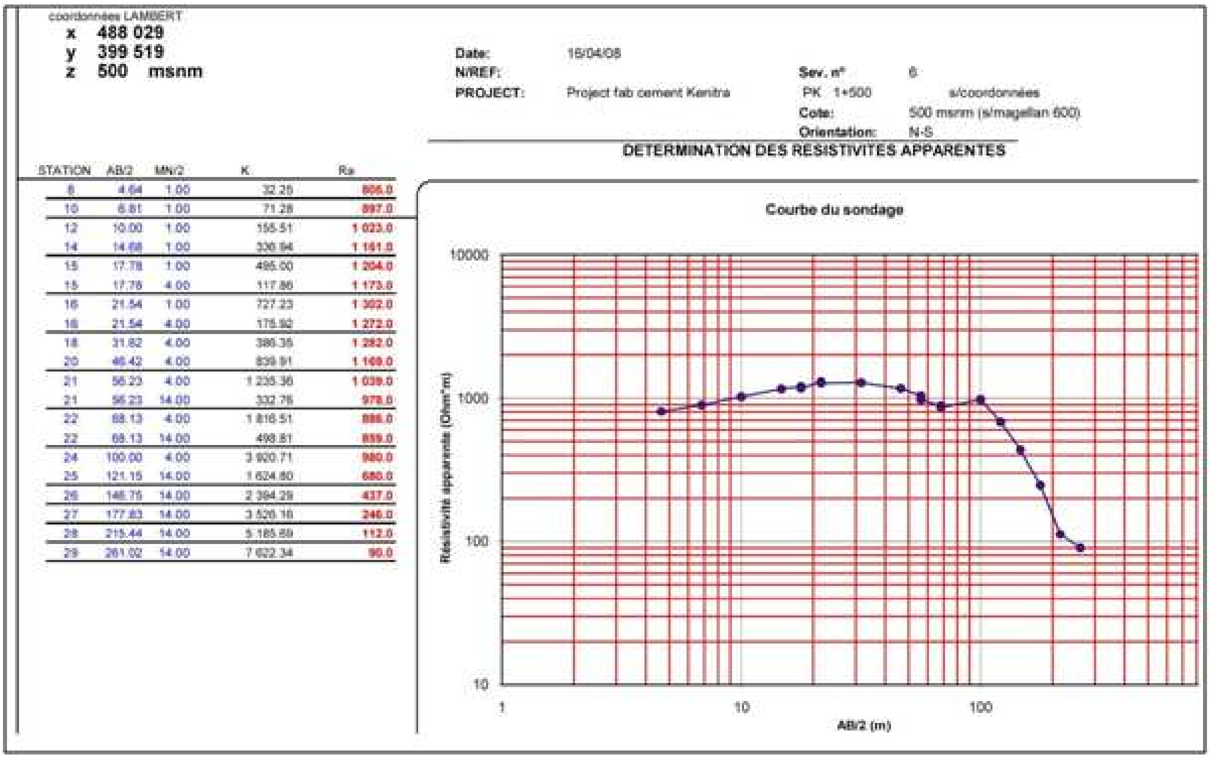


Fig. 5: Example of sounding sheet

The soundings interpretation was undertaken manually using charts and automatically using the software WinSev-6. Thus, inversion allows building a theoretical terrain Model explaining the resistivity values measured at the surface. This model is characterized by the number of layers, the thickness and the "true" resistivity of each layer (table 1).

Table 1: Substratum depth at realized soundings

VES	depth. Substratum (m)
VES1	60
VES2	110
VES3	80
VES4	88
VES5	50
VES6	41
VES7	90
VES8	85
VES9	100
VES10	40
VES11	50
VES12	65
VES13	80
VES14	85
VES15	80
VES16	+110
VES17	90
VES18	80
VES19	80
VES20	70
VES21	50

In general, the soundings end with a relatively conductive substratum (55 to 90 ohm.m) probably corresponding to the Bajocian marno-calcaires. The top of this conductive substratum is deep in the western part of the ridge where it could reach 110m deep (VES 2 and 16), whereas its depth progressively decreases toward the eastern limit of the studied area.

This thick substratum (>100m) is overlain by a less resistant group. Its variable thickness increases from the eastern part to the western part of the studied area. The analysis of this group shows that it is made by two different levels:

- The first level, overlaying directly the Bajocian formation, is very resistant and slightly thick (400 Ohm*m< R, 15m< Ep < 30m) and could correspond to the Upper Miocene massive limestone.
- The second level, slightly resistant and thick (150 Ohm*m< Ra < 200 Ohm*m, 8m< Ep < 80m) correspond to the Upper Miocene sandy limestone.

The thickness lateral differences between layers as observed in the majority of the soundings (Table 1) is due to the conjugated effects of tectonics and erosion experienced by the “rides sud-rifaines” since the Upper Miocene. Thus, the layers are oriented NNE-SSO with a westward dip ranging from 15 to 25°. The erosion effects are more important toward the eastern part (Fig. 6 and table 1).

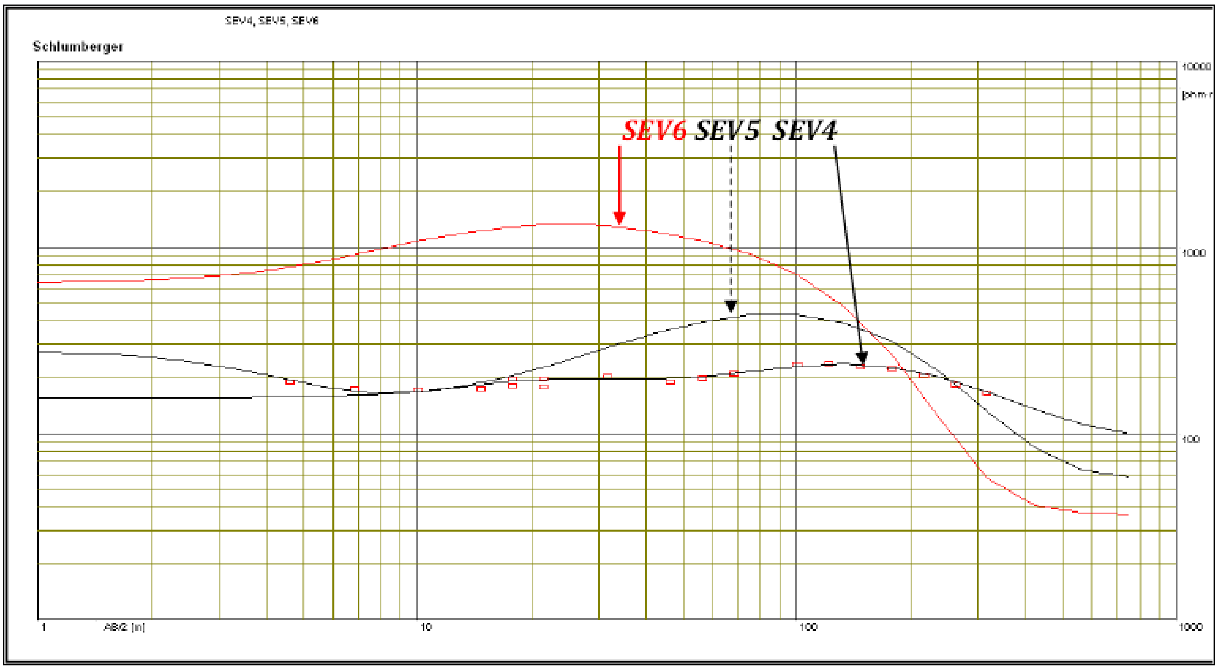


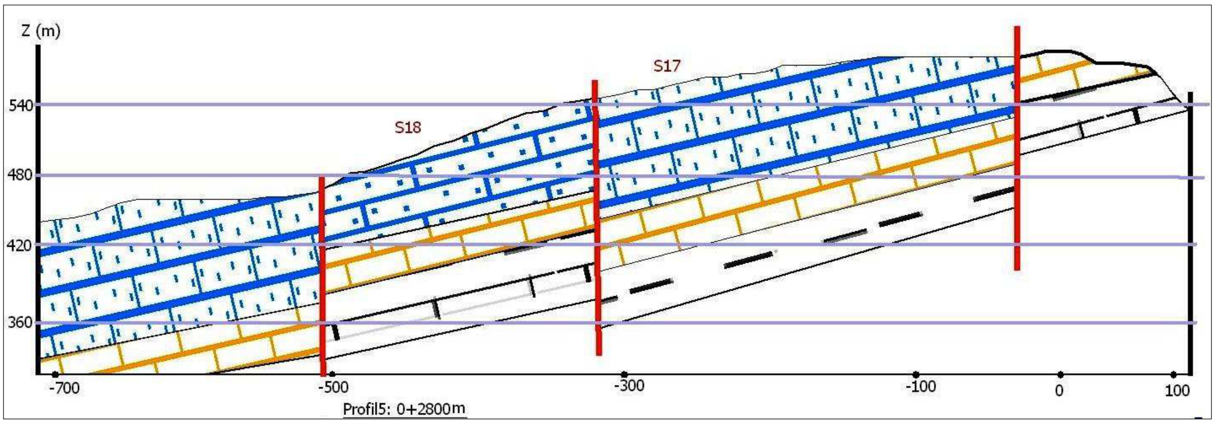
Fig. 6: Curves of the soundings 4, 5 and 6

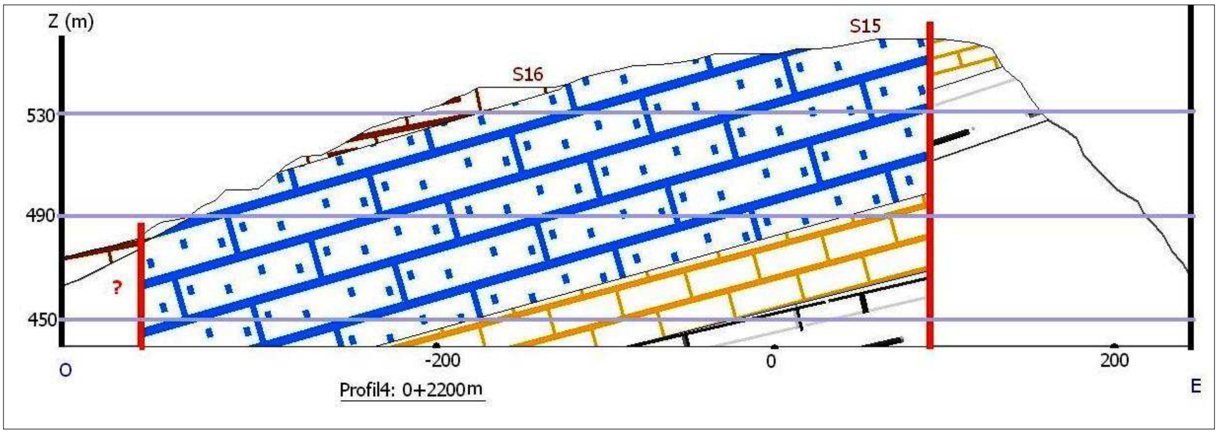
Table 1 : Comparaison between aligned soundings

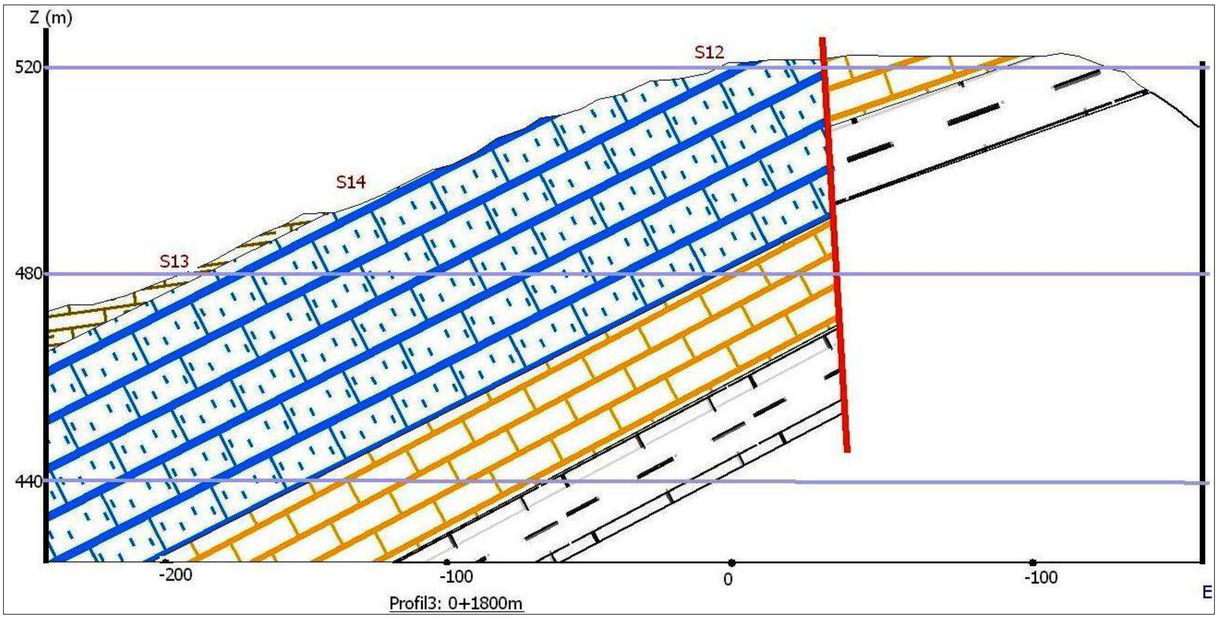
VES	depth. Substratum m	depth. resistant principal m	thickness m	Resistivity Ωm
VES4	88	28	60	433
VES5	50	13	37	1100
VES6	41	6	35	1335-2050

The fact that the litho-stratigraphic succession is E-W oriented (monocline structure) and the important faults affecting the Jbel Tselfat are N-S oriented, we undertook a correlation between soundings aligned along the E-W direction.

The result is presented as an E-W cross section or transverse profiles showing simultaneously the vertical and lateral variability of material. (Fig.7)


Z (m)
540
480
420
360
S17
S18
-700
-500
-300
-100
0
100
Profil5: 0+2800m


Z (m)
530
490
450
S15
S16
?
-200
0
200
O
E
Profil4: 0+2200m


Z (m)
520
480
440
S12
S14
S13
-200
-100
0
-100
E
Profil3: 0+1800m

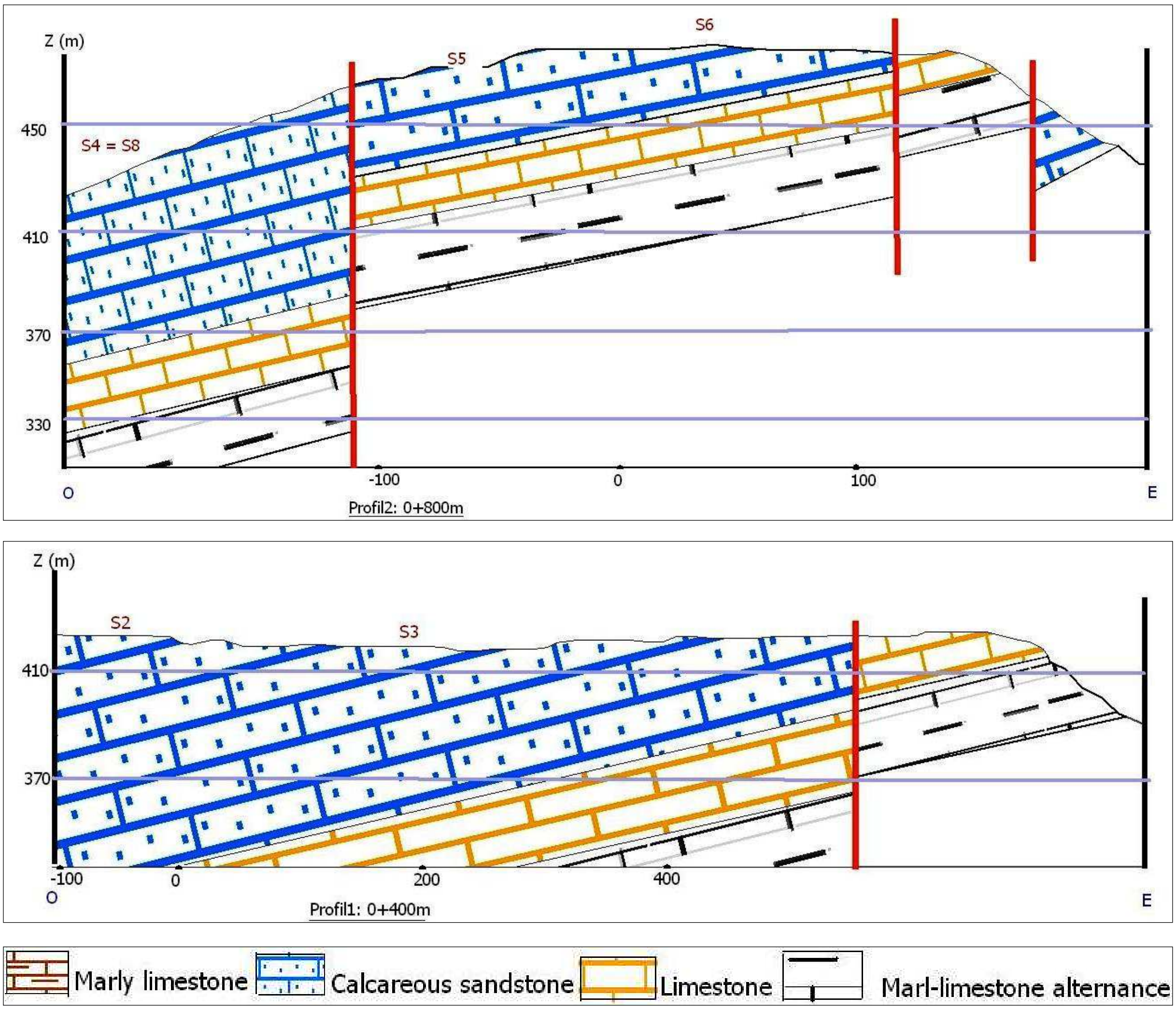


Fig. 7: Cross sections after correlation.

Associated to the previous works on the “rides sud-rifaines”, the obtained geoelectrical results allowed us to construct a lithological facies map of the studied area (fig. 8).

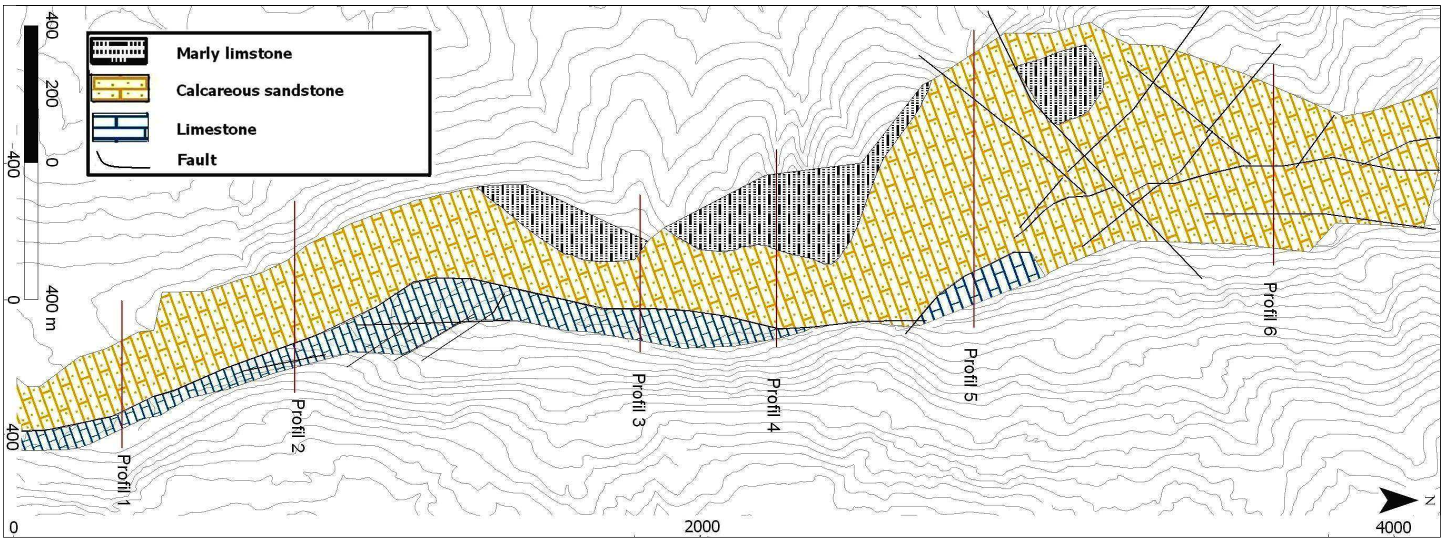


Fig. 8: Lithological facies map of the deposit

4 CONCLUSION

This study allowed us to highlight the role of the brittle tectonic that affected the Tselfat serie and brought up limestones and sandy limestones inside an overlapping serie made by marls (Olistolites marls and Pre-rifain Complex). The calculated thicknesses of these deposits emphasize their continuation in depth and make them a good geo-materials deposit with sufficient quantities to be exploited.

A next paper will deal with the geochemical patterns of this deposit.

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