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GEOPHYSICAL PROSPECTING OF GROUNDWATER IN LAAOUAMRA, MOROCCO, USING VES METHOD AND GIS

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ABSTRACT

The bas Loukkos basin is characterized at the same time by impervious overburden materials and sub-humid climate that are two factors influencing the renewal of the groundwater resources. In this space, we found the R'Mel aquifer formation, which are one of the main water supplies in the region. It corresponding geological facies are characterized by spacio-temporal change. In this work, a Special focus was given to the aquifer systems in the R'Mel coastal area, including dune systems formed in the Quaternary epochs. By combining drilling lithological data, Geographic Information System tools, and electrical investigations results, It was possible to determine the lateral extension of the Plio-Quaternary resistant sandstone, which can constitute a potential reservoir of water supply one the one hand, on the other hand the spatial evolution of the coastal dune systems.

Keywords: pre-rifean nappe, R'Mel aquifer, vertical elecrtical sounding, bas loukkos basin, resistivity map.

INTRODUCTION

The Bas Loukkos basin (Figure-1) located in the north Gharb Plain is part of external Prerif [1]. It includes the unconfined R'Mel aquifer containing Plio-Villafranchian and Quaternary formations, and having the impervious Miocene-Pliocene blue Marl as bedrock.

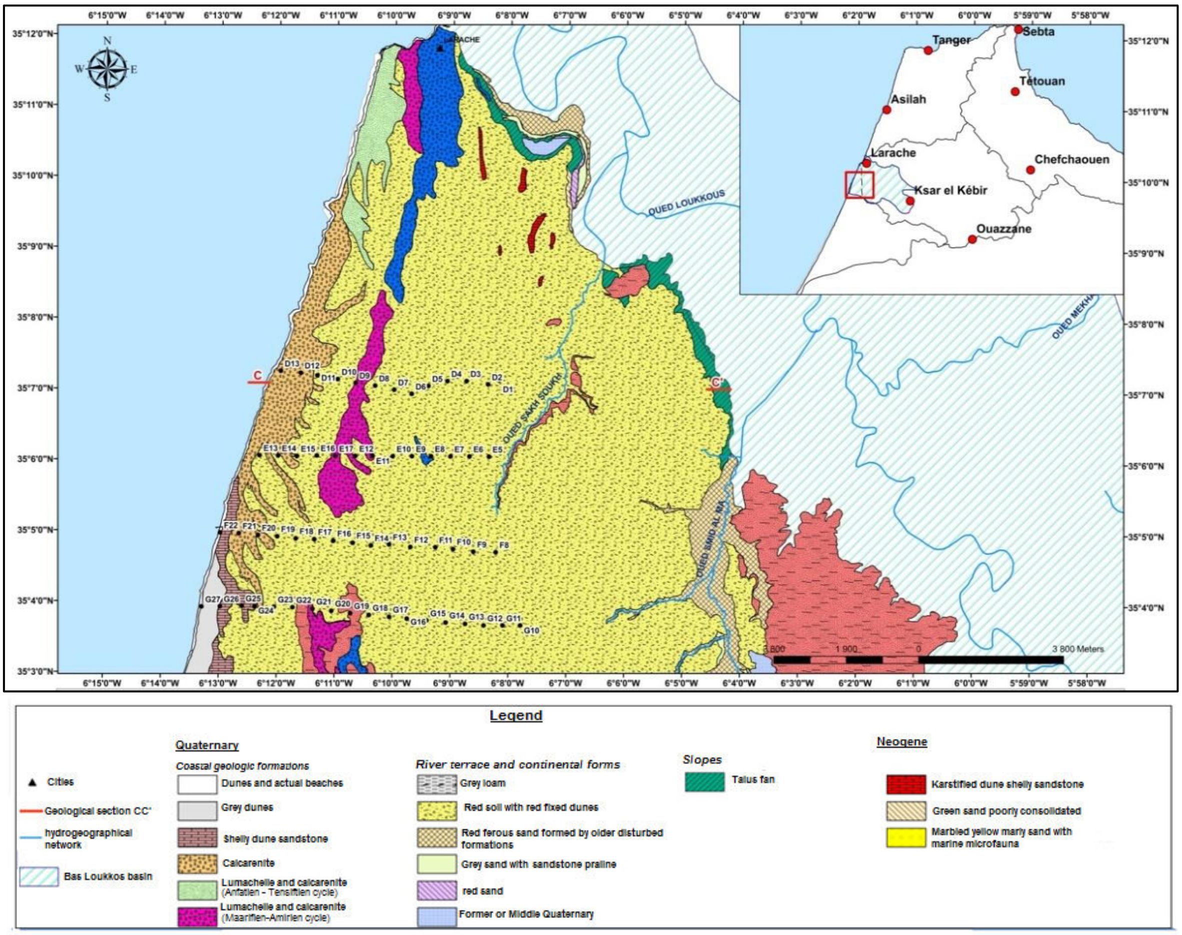

Figure-1. Geological situation of the study area extracted from geological map 1/50000 of Larache.

The Plio-Villafranchian formed by yellowish formations contain shelly sandstone, sand and sandy marl. The continental Villafranchian formations includes argillaceous cemented broken stone, and in superior lateral

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movement we have red sandy loam which in their turn keep below East Loukkos river. At continental Quaternary, we found dune sandstone facies in Rehamna area, and wide variety river deposits in the plain. These formations presenting hydrogeological interest came after the rifean thrust sheet emplacement [2].

On the West, a coastal zone is formed as parallel strip to the coast that separate the whole alluvial plain from the ocean. It's about a complex set of dune systems and interdune depressions, in which we can found at west a dune bar formed by high consolidated and continuous dune, parallel to the shoreline. By depriving upstream water of a direct outlet, it provides a barrier between Gharb plain and the ocean [3].

During it evolution, Gharb basin has undergone marine fluctuation relating to neotectonic movements, which give place to a fault in the coastal area (Figure-2), and a regular collapse resulting from isostatic rebalancing against the prerifain hills, and the ripples on the north and east, and on the south Moroccan Meseta [4], [5], [6].

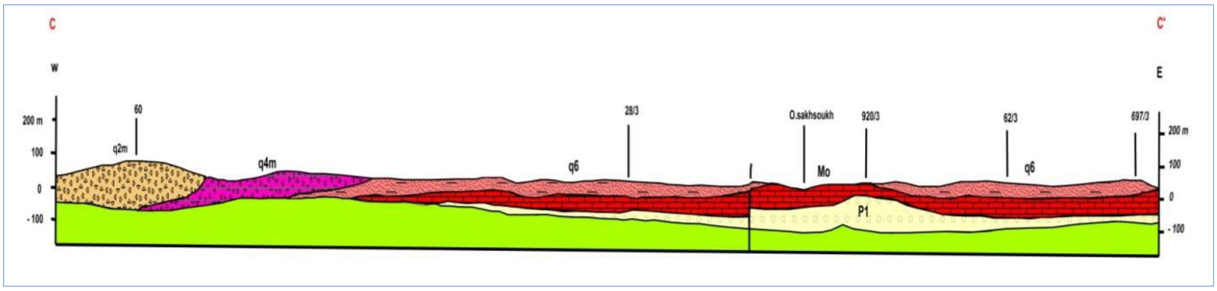

Figure-2. CC' Geological section East West in Figure-1. QUATERNARY: q2m: Rabatien-PreSoltanien cycle (calcarenites); q4m: Maarifien-Amirien cycle (lumachelle & calcarenite); q6: Villafranchien (red encrusted sand, localy with gravel); NEOGENE Mo: Moghrebien (karstified dune shelly sandstone); P1: Lower liocene (marbled yellow marly sand with marine microfauna); Ms: Late Miocene (blue marl).

In order to identify the areas where resistant formations of aquifer systems in heterogeneous Plio-Quaternary replenishment [7], [8], [9] will present sufficient thickness likely to provide a potential reservoir of water supply, and to monitor spatial sandstone dune facies evolution, a geoelectrical data investigations, supported by two geological sections has been interpreted.

METHODOLOGY

The best geophysical method that suits the intended goal is direct current geoelectrical sounding. This technique is based upon the fact that if an electrical current is introduced into the ground through a pair of electrodes it will penetrate to a depth governed by the current, the electrode separation and the resistivity of the subsurface formation. It will cause a potential difference at points between these electrodes which will be governed by the same factors. Thus, if we increase the distance between the current electrodes we will cause increasing penetration into the ground which will be expressed at the surface by changes in the potential difference as measured at the potential electrodes [10], [11].

In the case of layered bedrock the apparent resistivity (pa) obtained at the surface for a given electrode configuration is not the true resistivity of the formation but bears some relationship to it. We may think of it as a weighted average of the resistivity of all the rock layers to the maximum penetration of the current. Knowing the distribution of apparent resistivity versus the electrode separation, we can compute the distribution of true resistivity versus depth [11], [12].

In this study, we used the Schlumberger array (Figure-3) to reach a greater depth of penetration [13]. It has two potential electrodes M, N at the centre and two current electrodes A and B.

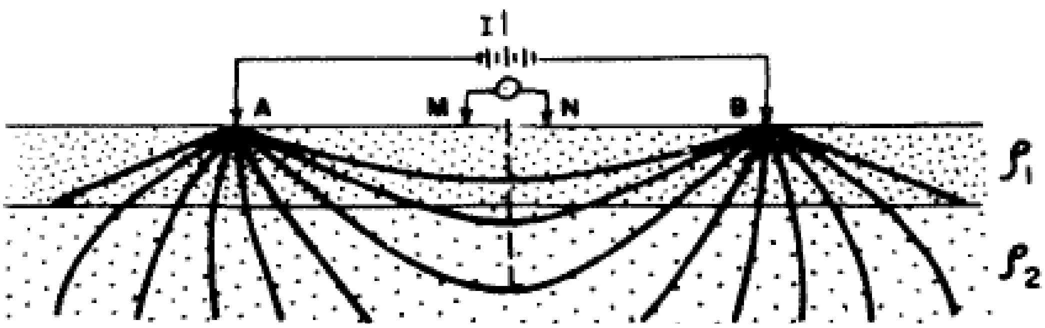

Figure-3. Schlumberger array [12].

The distance AB is much larger than the distance MN. For this configuration, the apparent resistivity of the centre of the array is:

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

Where K is the geometrical factor that depends on the electrodes arrangement [14], [15]:

$$K = \pi\frac{(L^2 - l^2)}{2l}$$

This geophysical survey covering an area of 51 km2 was performed with 57 vertical electrical sounding, and a mesh of 500 m and electrodes distance between 6 m and 1000 m (Figure-4). Resistivity maps for different lengths of lines AB were established by ordinary Kriging to deduct the aquifer systems lateral variation and extension. In parallel two geological sections oriented SW-NE et NW-SE of different water drillings existing has been made to show the deformation effects due to the Pre-Rifean Nappe advance in the Gharb basin as an accretionary wedge on Upper and Middle Miocene [16], [17], confirmed by seismic investigation data reached at its level [18].

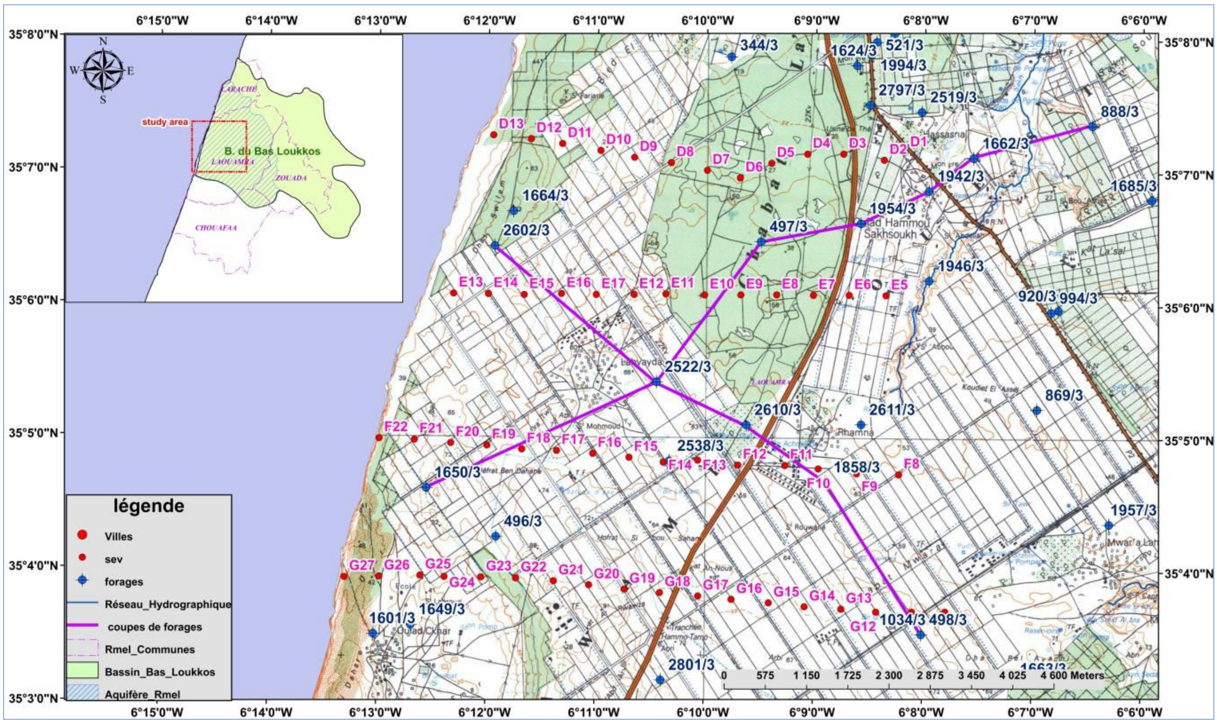

Figure-4. Location map of geoelectric soundings.

RESULTS AND DISCUSSIONS

Lithological correlation sections

Both geological drilling sections reflect spacio-temporal variation of Bas Loukkos basin Plio-Quaternary replenishment. In the NE, the correlated geological section SW-NE show that Plio-Villafranchian and Villafranchian formations represented successively by fine grained sand and Shelly sandstone, are affected by normal faults, which caused a blue Marl Miocene collapse stair-step shaped, is also seeing a good dune sandstone thickness in the coastal area, approximately 60m of depth as shown in drilling 1650/3.

In parallel, we did noticed that, in the extreme North-east, the reddish clayey or sandy-loam Villafranchian sequence present a good thickness in drilling 888/3 (Figure-5).

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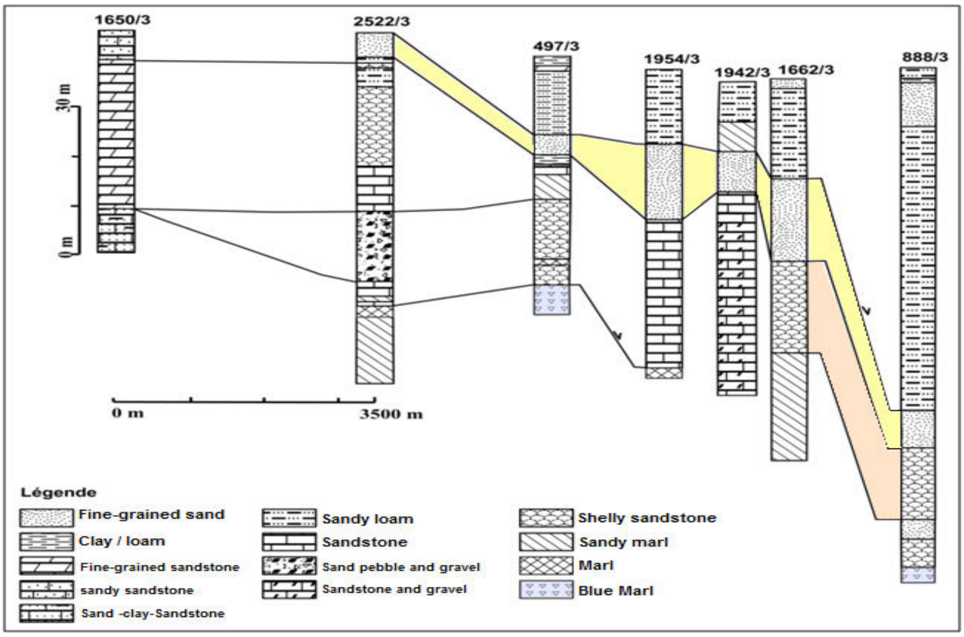

Figure-5. Lithological correlation section Southwest-Northeast

The North-east section confirmed existence of dune sandstone bar in coastal area approximately 100m of depth in drilling 2602/3 (Figure-6).

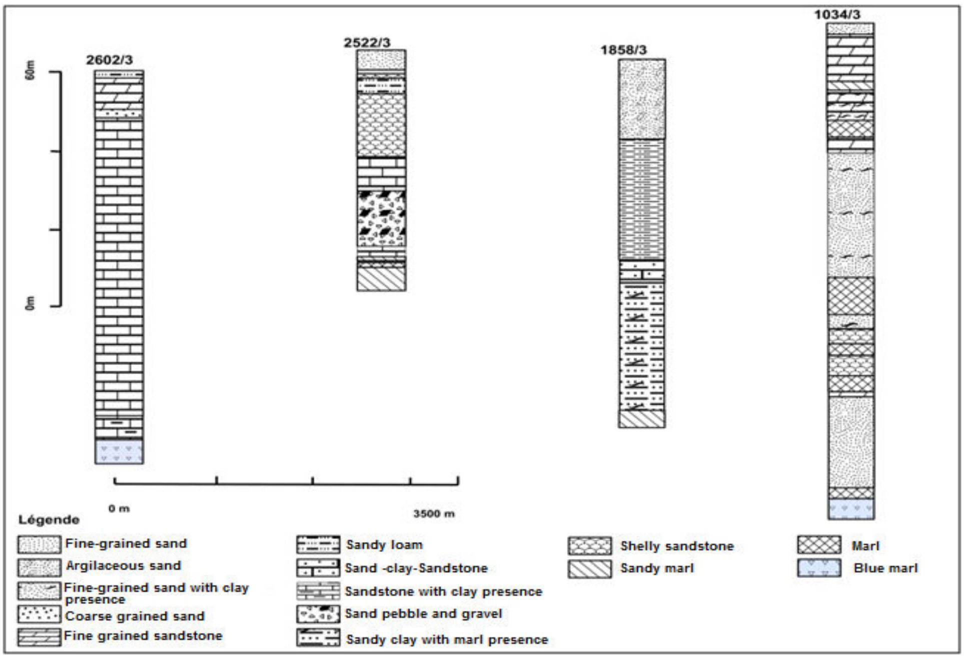

Figure-6. Geological drilling section oriented North-west South-East.

Isoresistivity maps

The kriged contour maps of electrical resistivity distribution for AB=10m (Figure-7) corresponding to the surface formations shown by the depth of 2m great values of resistivity in coastal area bellowing 720 ohm.m according to yellowish sandstone sequence of Plio-Villafranchian Period as shown in drillings 2602/3 and 1650/3.

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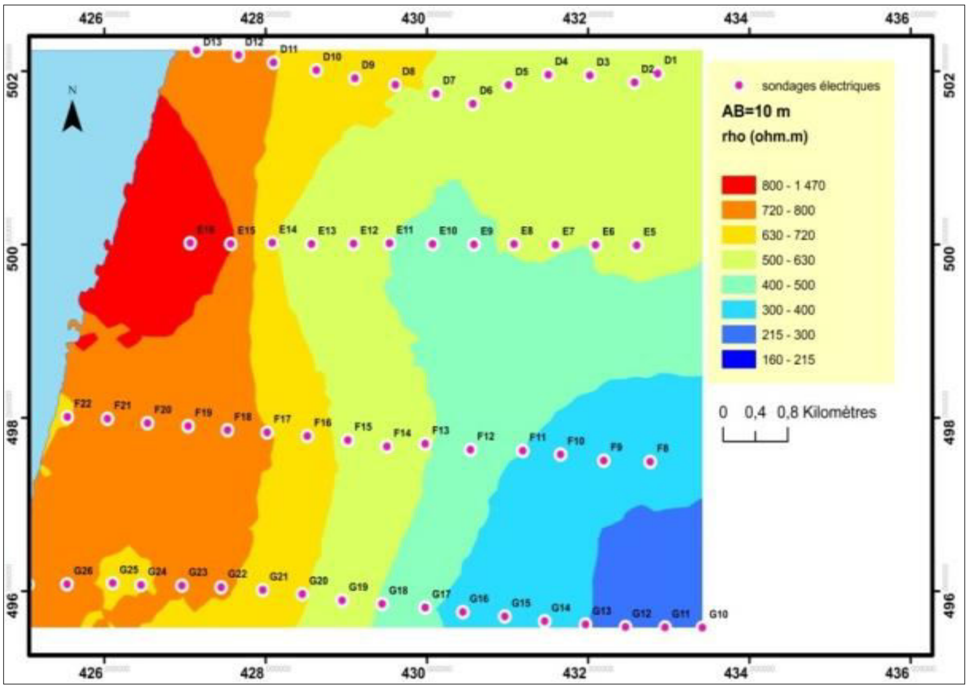

Figure-7. Isoresistivity map of AB=10m.

The kriged contour maps of electrical resistivity distribution for AB=30m (Figure-8) show two distinct regions: a high resistivity region on the West and a medium one on the East. They still exist until depth of 20m corresponding to contour map of electrical resistivity distribution for AB=100m (Figure-9). At such depth we found on medium resistivity region the Villafranchian clayey sand on South-East drilling 1858/3 with resistivity between 80 et 90 ohm.m, and in parallel marl, loamy sand, and sandy marl on North-East drillings 497/3, 1954/3 and1942/3 corresponding to resistivity between 95 and 118ohm.m. The high resistivity region (coastal area) exceeding 600 ohm.m and corresponding to dune sandstone as shown on both of drillings 2602/3 and 1650/3, expended laterally East until depth of 40m corresponding to kriged contour maps of electrical resistivity distribution for AB=200m.

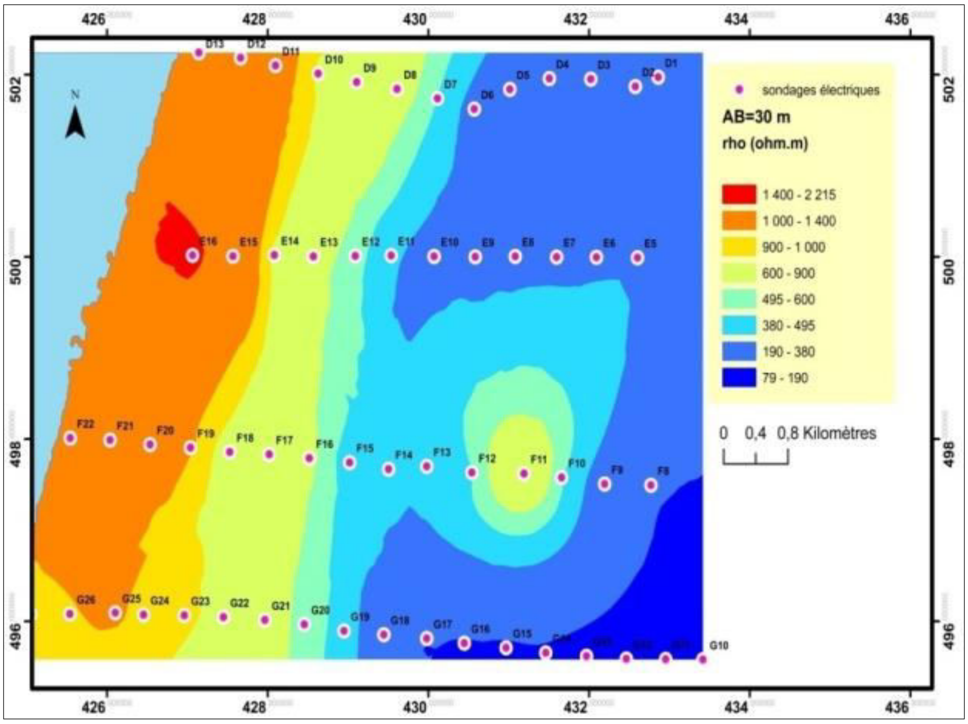

Figure-8. Isoresistivity map of AB=30m.

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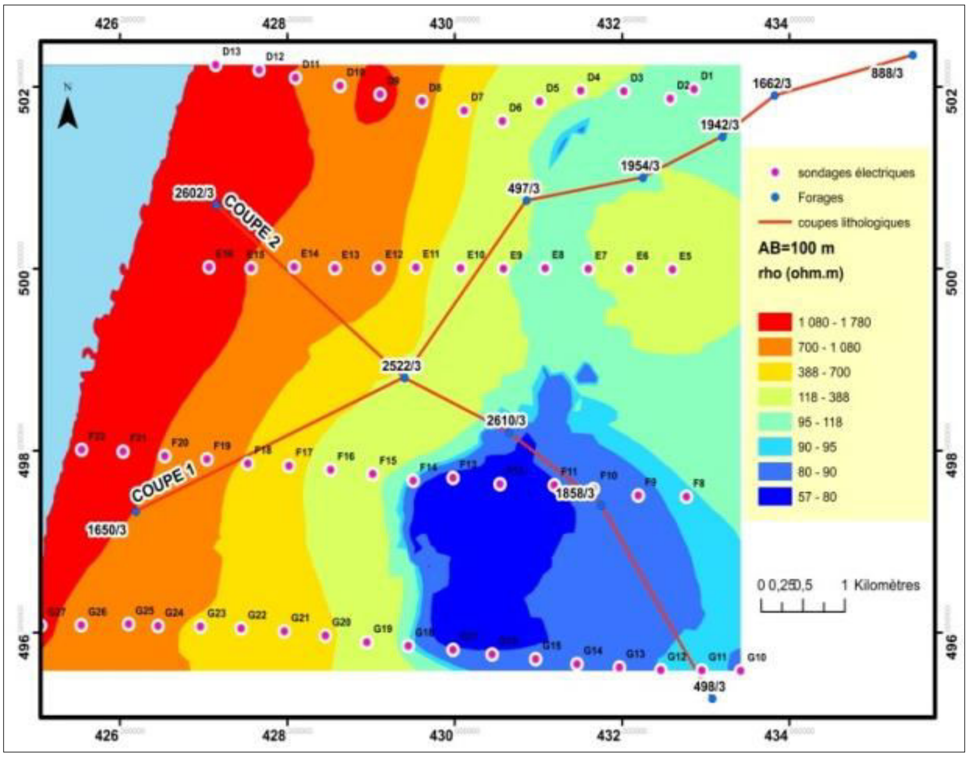

Figure-9. Isoresistivity map of AB=100m.

When moving from kriged contour maps of electrical resistivity distribution for AB=200m to AB=1000m (Figures 10 & 11), corresponding to the successive depth 40m and 200m, the conductive layers formed either by Miocene blue marl or the supernatant conductive layers, expands as a central strip whose middle has the lowest values of resistivity (< à 16 ohm.m), it separate two region of medium resistivity between 36 and 140 ohm.m for the West region, and between 36 and 50 ohm.m for the East one. This band may correspond necessarily to an elevation of impervious Miocene Marly substratum.

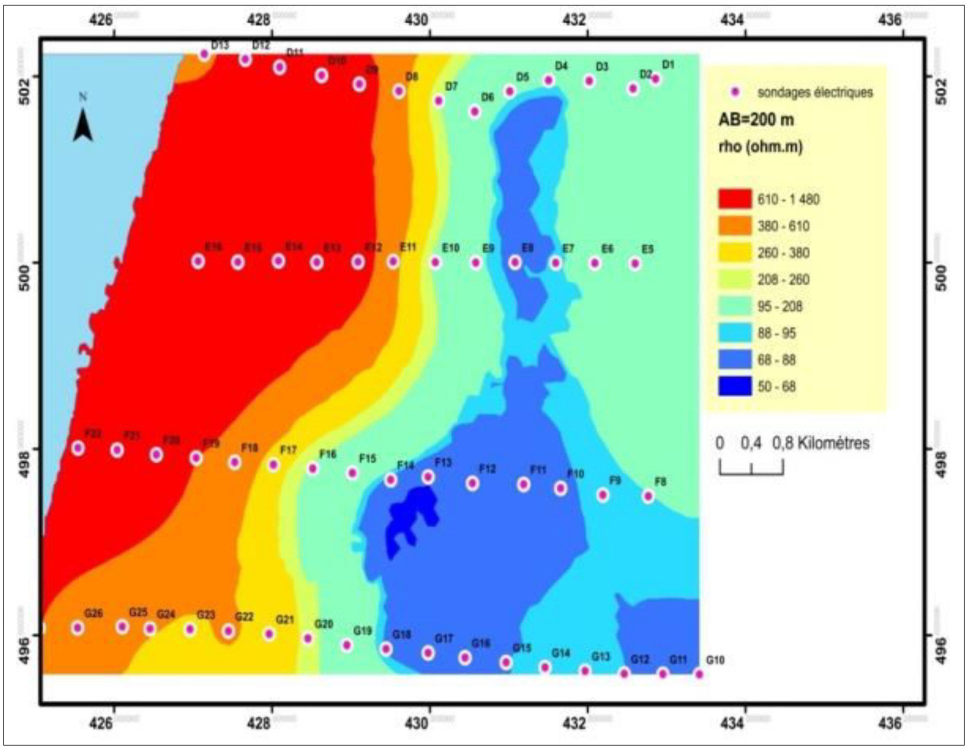

Figure-10. Isoresistivity map of AB=200m.

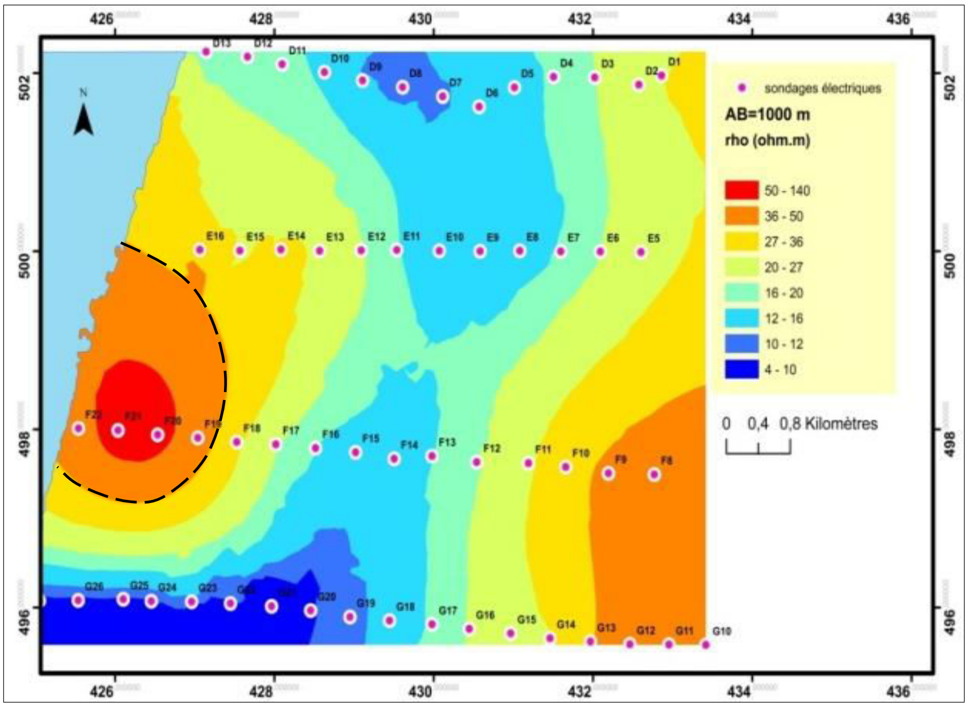

Figure-11. Isoresistivity map of AB=1000m.

CONCLUSIONS

The resistivity variation revealed in study area, reflects the spacio-temporal aquifer systems changes in Bas Loukkos Basin. In fact, tectonic movement due to Pre-Rifean nappe advance in the form of an accretionary movement was still active on upper Miocene and Plio-Quaternary Periods, which resulted as a normal fault in the East part of the Bas Looukkos Basin (Figures 2 & 6).

On the one hand geoelectrical result show spatial dune bars variation in coastal part. In fact, resistant dune sandstone appears on North-West at shallow depth corresponding to AB=10 m. As we go deeper, these formations dominate South-East region until depth of 40m, then they regress to the coastal area, until they disappears at depth of 200m. On the other hand the West caostal designated zone by the conductive band as shown on resistivity map of AB=1000m, are a potentiel drilling site which can be as deep as 200m.

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