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Identification of potential areas for establishing water fodder in a base region: Particular case of the of the Mongo City (Chad)

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Abstract

Access to water in arid regions is a crucial issue in precise large-scale water management. This work studies potential areas for the installation of water boreholes in one of the most important cities in Chad, Mongo in Central Chad, which is an arid zone. To do this, a literature review presents this zone, which is a basement zone and which is affected by fractures of well-defined and specific orientations and the direction of slope allows the movement of surface water towards other regions of the country, as well as the recharge and horizontal flow of the discontinuous aquifers of the region. The implementation consists of the use of a geophysical prospecting method in order to choose suitable points for the rapid capture and good flow of groundwater which flows through the fractures. This method used is the classic Schlumberger AMNB device in which A and B are electrodes emitting the electric current and M and N are electrodes receiving the potential difference. Three sites are considered: the Mongo institute site, the Mongo pilot school site and the Mongo hospital, after which the curves giving the electrical survey are plotted and the stratigraphic column carried out at the drilling level.

Keywords: Underground water; Rock; Fracture zone; Drilling; Electrical prospecting method

1. Introduction

The assessment and identification of fodder production potential areas in Sahelian zones are very important [1]. The Sahelian zones are characterized by arid and semi-arid climate and the scarcity of rain and the access to water is very difficult, thirst is the main cause of death in these areas. Water resources are crucial environmental components as well as a key driver of social and economic Development [2]. Analyzing the groundwater potential zone is thus a fundamental first step in investigating ground water resources in arid and semi-arid regions [2]. Basement regions are areas with water tables or water circulating in shallow and discontinuous cracks; groundwater is only localized in places. Some countries in base areas have implemented rainwater harvesting systems for sustainable resource management [3].

Guèra, located in central Chad, is a basement region with a predominance of volcano-granitoid and metamorphic rocks; characterized by the outcrops of the Abtouyour division, the mount Guèra in Bitkine and the Aboutelfane, incorrectly called "the queen of Guèra" in Mongo. There are also laterites, thinned sedimentary rocks that are sometimes almost non-existent at depths barely exceeding 20 m to 30 m where water is stored. The maximum depth to unfractured rock is 85 m. Mongo, which is a crossroads, is seeing its population increase and the demand for drinking water is increasing,

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while many water boreholes were found to be non-operational. The population is concentrated all around surface watercourses and shallow drainage areas for supplying livestock and washing.

The objective of this work is to map potential areas for water drilling; to establish litho-stratigraphic series at the measurement points of the surveys carried out and if necessary; to propose solutions on the use of surface water. The application of certain methods such as: the interpretation of aerial photos, structural maps and electrical prospecting allow carrying out this work.

Thus the work is organized as follows: In section 1, the literature review is presented, following in Section 2 by the presentation of material and methods. Then in section 3, the results found are presented. Finally in Section 4, conclusion is provided.

2. Literature review

2.1. Presentation of the study area

Mongo, capital city of the Guèra division is located between latitudes 12°.18' and 13°18' North and longitudes 18°.7' and 19°7' East, at 415 ±5 m high on alluvium, with an area of 63.5 km^2 and a growing population estimated at 20,000 h (Source Mongo Town Hall) (Fig.1). The climate is Sahelian with two seasons: a rainy season from April to October and a dry season from September to March. Average extreme temperatures are around 29.36°C. The average annual rainfall is 710.07 mm (according to EGIS B., 2009 in Provisional final report 2009).

2.2. Geology of the Guéra region

The crystalline massifs of Guèra, composed mainly of granite, are separated by basins or depressions filled with arenas or more or less clayey and lateritic river sediments (Figs. 2 and 3). The arenas represent the products of on-site alterations of the first rocky scree, at the foot of the inselbergs. Below the embankments and arenas, 500 meters wide to a few kilometers, are the zone of fluvial flows, where the sands, silts and clays of heavy Berber lands (millet) dominate: These are temporary flooding zones equivalent to the low point, crossed by more or less anastomosing and poorly enclosed thalwegs; in the bed of the thalwegs the flow is very slow. The thickness of the sediments is generally low, but there may be locally ancient channels with more abundant alluvium or altered and fractured zones in the underlying rock which can give rise to a greater thickness of permeable rock (Fig. 2 and 3).

2.2.1. Sedimentary rocks

The land is made up of laterite, clay or sand, or a mixture of the three in varying proportions. A pediment zone (arena zone) in the vicinity of rock masses; ancient fluvio-lacustrine sediments in depressions; the thickness of the alluvium in the minor bed of the twelve kilometer Bam-Bam of Mongo is low and it generally appears low throughout the alluvial plain, rocky outcrops are frequent. The alluvial plains of Gorouma and Etté are interspersed between pediment zones located around the Mongo rock, arou nd the Oyo rock and to the east on the side of Mont of Aboutelfane. The valleys are made up of ancient alluvium, on which recent sandy alluvium is superimposed in the arms of the ravines.

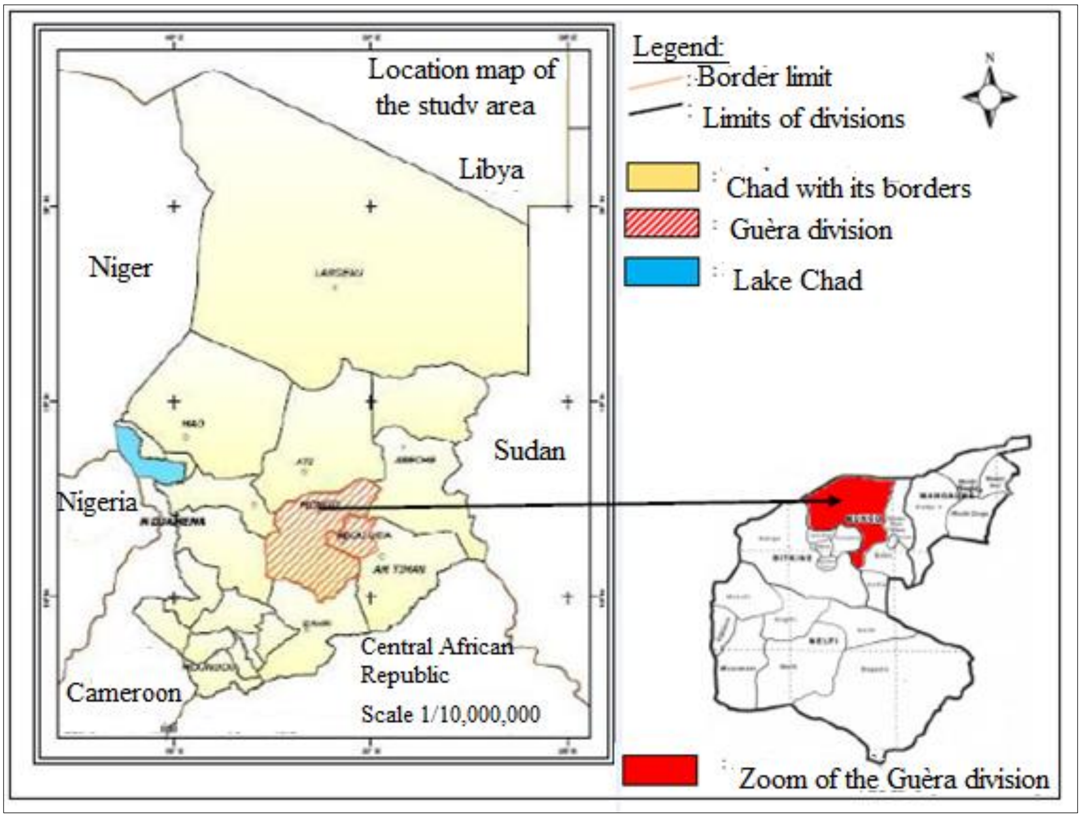

Figure 1 Presentation of the Mongo-Chad study area (according to EGIS B., 2009 in Provisional final report 2009)

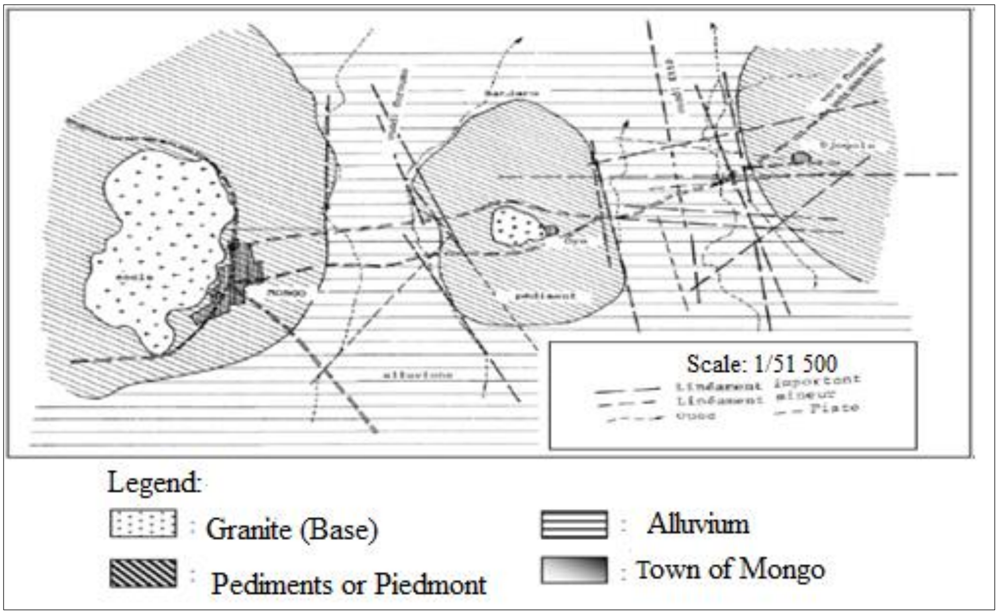

Figure 2 Lineament identified by interpretation of aerial photos of Mongo East assimilated to fractures (Mermillod J., 1960 Hydrogeological mission)

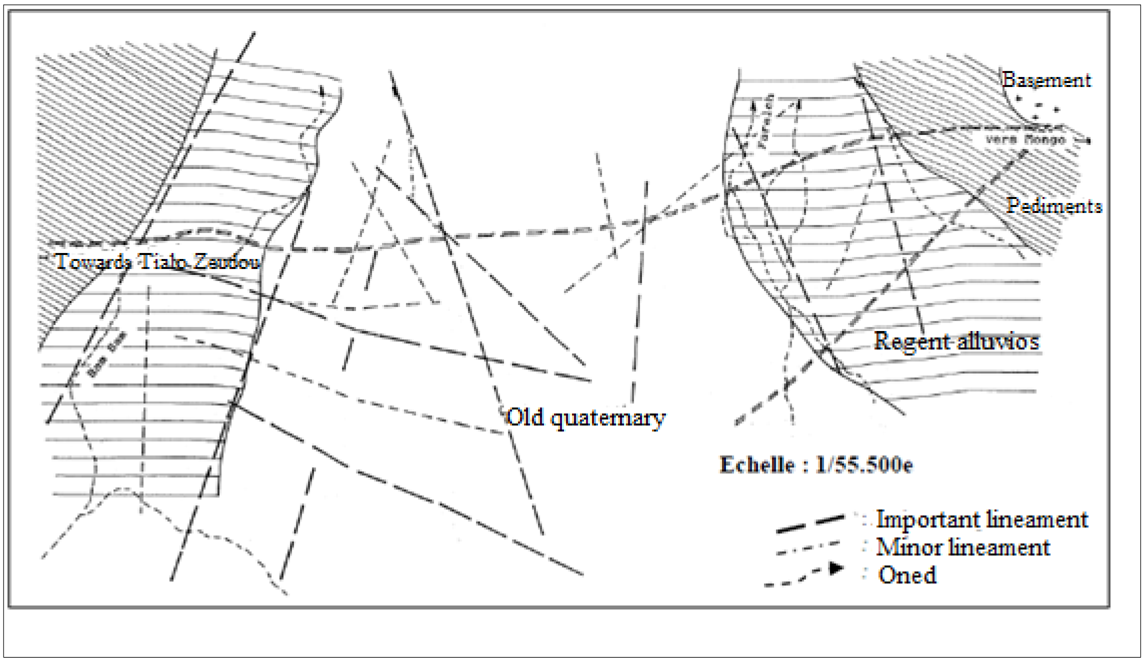

Figure 3 Lineament identified by interpretation of aerial photos of Mongo West assimilated to fractures (MERMILLOD J., 1960 Hydrogeological mission)

2.2.2. Granite chaos

These are large or medium-sized scree blocks deposited near inselbergs by weathering phenomena - erosion - transport by pure gravity (see Fig.4). Sometimes these granitoid chaos can play the role of infiltration by providing water to the caves when they constitute the mountain range (this is the case for example of the Tarro village).

Figure 4 Granite chaos of the Guèra region (Chad) (photo A. BADA, 2022)

2.3. Tectonic study

The radar image given in Fig.4 shows after interpretation the fractured zones barely visible in the photo-interpretation with two main directions NE-SW and WNW-SSE (EGIS B., 2009), which proves that these zones are therefore on average more productive than sedimentary deposits. What is necessary to know in order to position the drilling along the topo-sequence. In low glacis and shallows, fractures can be found under significant overburden, and these fractures will always be the preferred targets for water drilling. They are, however, present and remain clearly visible using radar images.

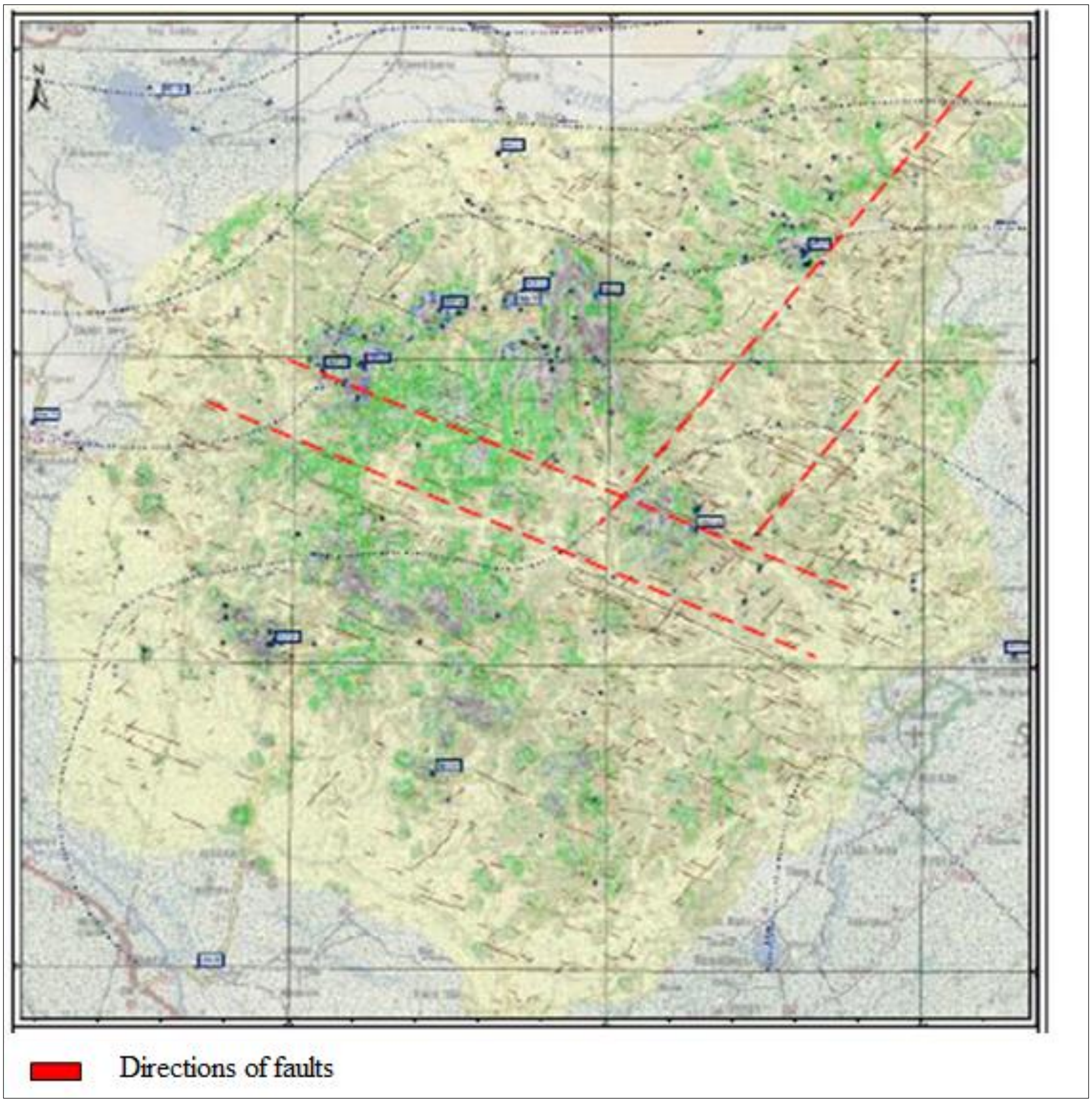

Figure 5 Radar image showing fracturing in the area (EGIS B., 2009, Interim final report 2009)

2.3.1. Structural study

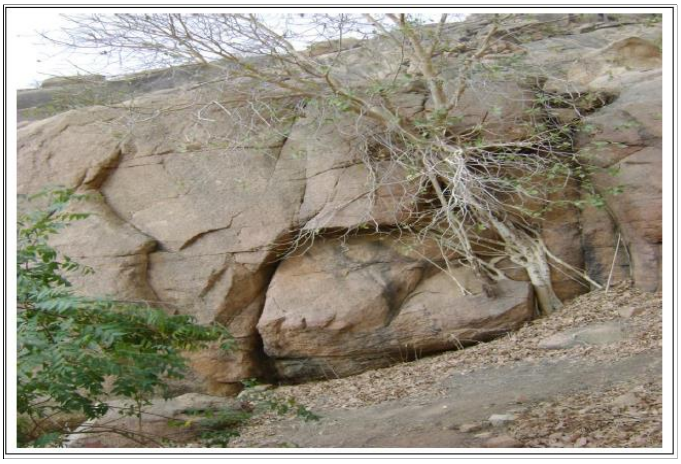

Figure 6 Base rock joints from Mongo (Chad) (photo A. BADA, 2022)

The joints affect the granitic rock (Fig.6), in addition to these fractures, these accidents seem to be delimited into three zones: A high zone near the mountain ranges, a plateau zone and a low depression zone or the base and hidden under a significant recovery of ancient Quaternary age.

2.4. Watershed and hydrographic networks

The town of Mongo is located in a watershed among many other watersheds in the Department. The hydrographic networks are numerous and very steep due to essentially steep slopes.

2.5. Geophysical prospecting

Geophysical prospecting techniques are used to resolve the various problems linked to the knowledge of the geological structures of the subsoil. The geophysical study is an essential phase for carrying out a drilling. It is through this that the location and characteristics of the drilling, including the drilling depth, which are precisely predetermined. This study is essential since the results of future drilling directly depend on its seriousness and quality.

2.6. Drilling equipment for rotary technique

The bentonite mud rotary technique is generally used depending on the nature of the terrain to be drilled and is used as shown in Fig.(7); The materials generally used are (A. BADA et al, 2022):

- The drilling tool: wheels (tricones) or blades;
- The rod masses whose main role is to provide weight and allow the upper rods not to work in compression;
- The drill string mainly subjected to tensile forces when the column is in the suspended position. The upper stems are those which are most subject to this stress. Therefore, to minimize the degree of possible deformation of the rod, it is necessary to swap them regularly;
- The injection head: it is a delicate organ which ensures the following functions: watertight hydraulic connection of the fluid circuit between the supply hose and the internal pipe of the rods, transmission to the probe line of the force of traction of the hoist, free rotation of the probe line under the fixed injection head, by means of ball bearings

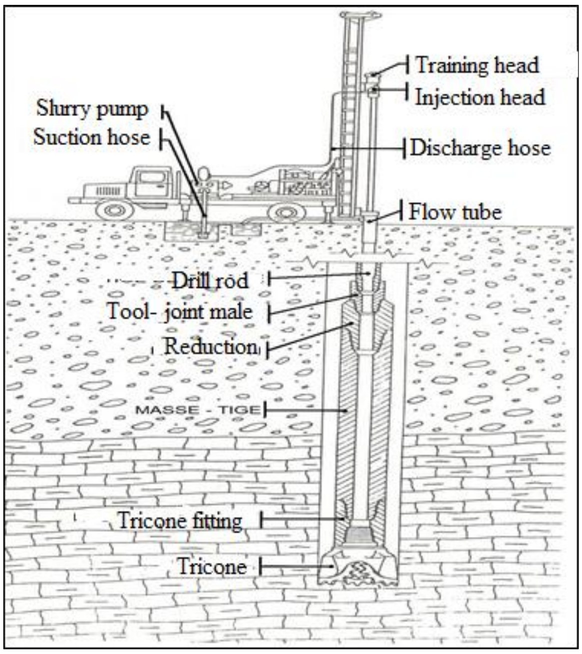

Figure 7 Device of a rotary drilling workshop (in Ketchemen, 1988)

3. Materials and methods

For a geophysical electrical prospecting campaign, the different steps necessary to successfully implement drilling are: The study of watersheds and hydrographic networks, the inventory of existing water points based on consultation of the structural map

3.1. Hydrogeological study

3.1.1. Ground reconnaissance and consultation of the structural map

The reconnaissance mission makes it possible to identify water points in the area studied and note their characteristics: GPS positioning, static level, drilled depth, equipped depth, nature of the aquifer. Structural discontinuities such as faults, fractures, joints and veins of fairly large sizes (hectometric to kilometric) which appear on the structural map are spotted and identified.

3.2. Geophysical methods used

3.2.1. Principle

For this study we used electrical prospecting, it is carried out in the town of Mongo with a view to establishing drinking water supply boreholes. The geophysical study sites and drilling location are indicated in Fig.8.

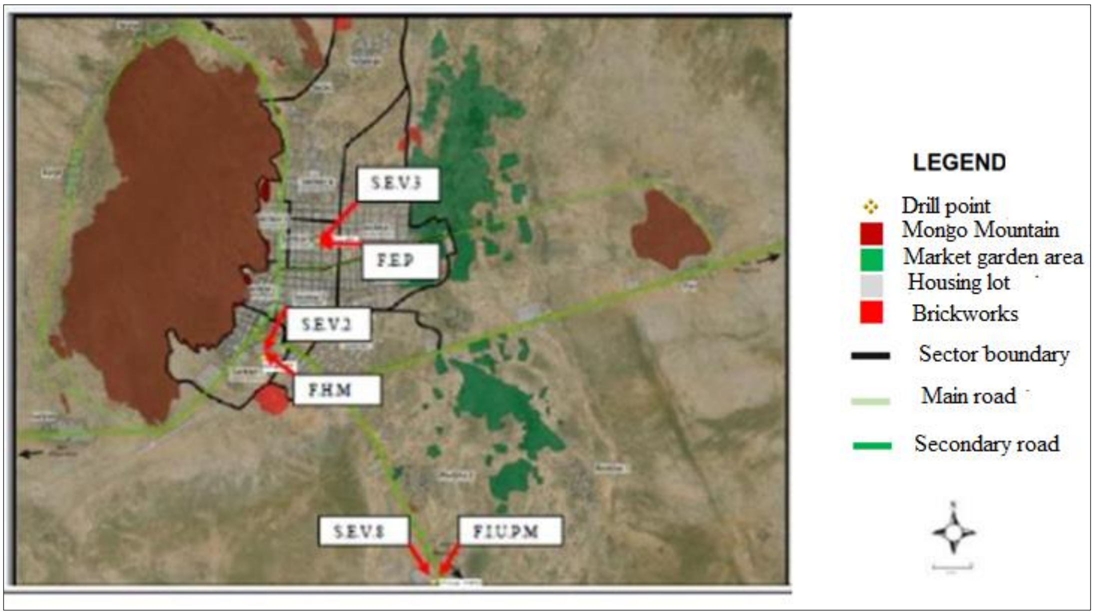

Figure 8 Locations of vertical electrical survey and drilling sites in the Mongo city sector. (S.E.V.3: vertical electric survey 3, S.E.V.2: vertical electrical survey 2, S.E.V.8: vertical electrical survey 8, F.E.P: pilot school drilling; F.H.M: Mongo hospital drilling; F.I.U.P: Mongo polytechnic university institute drilling)

3.2.2. Electrical prospecting

This method makes it possible to study variations in the apparent resistivity parameter of the subsoil vertically from the point of investigation. To carry out measurements in the field, a continuous electric current of intensity (I) is sent back into the ground via 2 electrodes A and B. Then we measure with a potentiometer the potential difference (ΔV) existing between two unpolarizable electrodes M and N. The apparent resistivity is given by the following formula:

$$\rho_a = K\frac{\Delta V}{I} \qquad \text{.........} (1)$$

where

$$K = \frac{2\pi}{\frac{1}{AM}-\frac{1}{AN}-\frac{1}{BM}+\frac{1}{BN}} \text{.........} (2)$$

is a coefficient which depends on the geometry of the device. In prospecting by the electrical method, we have two investigation processes which are trails and electrical surveys, in this study we used the two proposed: electrical and trailed surveys.

- Schlumberger method for electrical surveys

The Schlumberger electric sounding is carried out by injecting an electric current into the ground via two electrodes A and B, this current will be measured by two receiving electrodes M and N (see Fig. 9a). The measurements are carried out by increasing the distance AB of the device for increasingly deeper investigations (Fig.9b). Reporting the resistivity values as a function of the half-length AB on bi-logarithmic paper gives the electrical diagram which, after analysis, allows the thicknesses and resistivities of the underlying formations to be appreciated. The interpretation of electrical soundings makes it possible to obtain the exact thickness and resistivity of each of the layers of land directly above the center of the sounding.

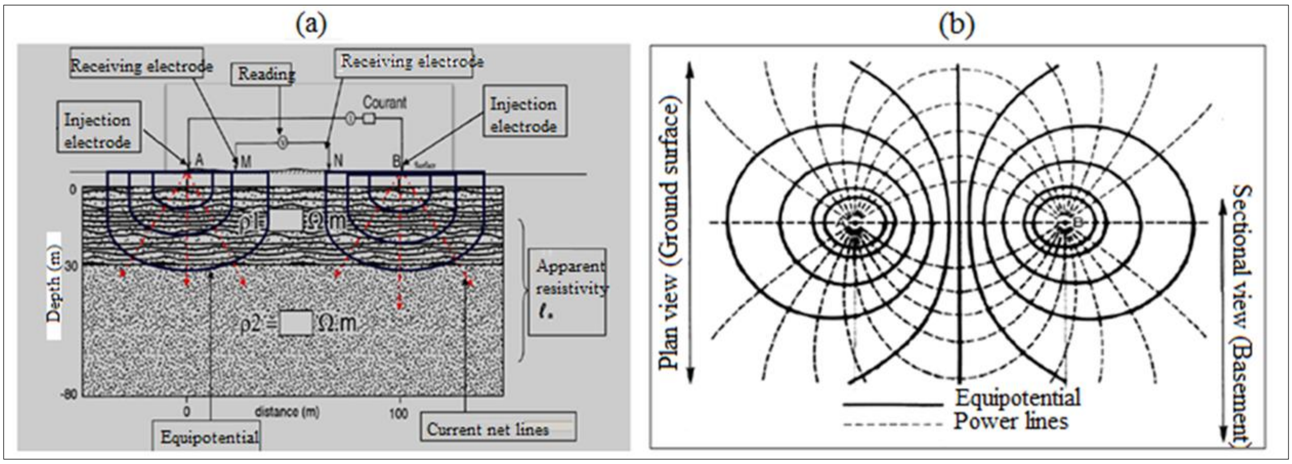

Figure 9 (a) : Diagram of the Schlumberger device. (b): Plan view and section of equipotential, current lines in a ground

- Drilling technique: Rotary method

The attack tool which has teeth or blades is rotated by the drill string. This tool, under the dual action of the rotation and the weight of the rods, perforates the rock and fragments it. This process is completed by circulating an injection fluid in the borehole, using appropriate pumps or compressors. The primary function of this fluid is to bring the drilling cuttings to the surface of the ground. The equipment used for electrical prospecting is:

- A terrameter or resistivity meter which allows the injection of current; receiving the electromagnetic field and measuring the potential difference (see Fig.10);
- Coil and stake: the coil connects the terrameter system to the stake fixed to the ground where the electric current is injected into the ground;
- A mass and a GPS (global positioning system): for locating survey sites;
- The qwseln software: for processing data in the computer;
- Survey sheets and electric trails for sampling apparent resistivity; Semi Logs sheets for determining the depths and thicknesses of layers manually.

Figure 10 ABMN terrameter for measuring electrical prospecting

4. Results

4.1. Survey area for electrical prospecting

The work is carried out at 14 vertical and 9 trailed electrical survey points in the area as indicated in Table 1.

Table 1 Surveys and electrical trails carried out in the town of Mongo. I: Mongo institute site, E: Mongo pilot school site, H: Mongo hospital site, S.E.V: vertical electrical survey

Mongo City Sights	**N° S.E.V**	**GPS coordinates**	
		Latitude	**Longitude**
	S.E.V. 8 (I)	12°11’39.9’’	18°41'022’’
	S.E.V.3 (E)	12°11’32.9’’	18°41’22.1’’
	S.E.V.2 (H)	12°10’40.8’’	18°41’01.4’’

4.2. Execution of drilling:Drilling work

The location of the boreholes was determined following an electrical geophysical study carried out and the drilling work was carried out with a view to carrying out three drinking water boreholes in the town of Mongo.

4.3. Electrical prospecting

4.3.1. Electric trainees

The qualitative study (electric trails) allows the identification of anomalies (fractures). The electric train 2 at the pilot school site gave us 2 anomaly points corresponding to the drilling points (Fig.11).

The electrical trail 1 at the Mongo hospital site gave us 3 anomaly points corresponding to the sites of the vertical electrical surveys and the drilling points (Fig.12).

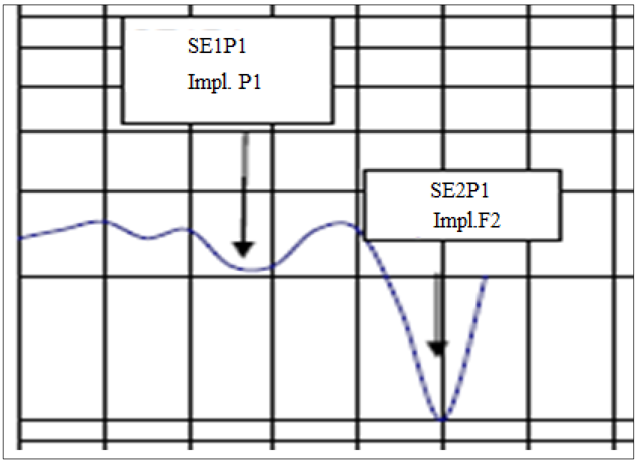

Figure 11 Electrical profile at the Mongo pilot school site

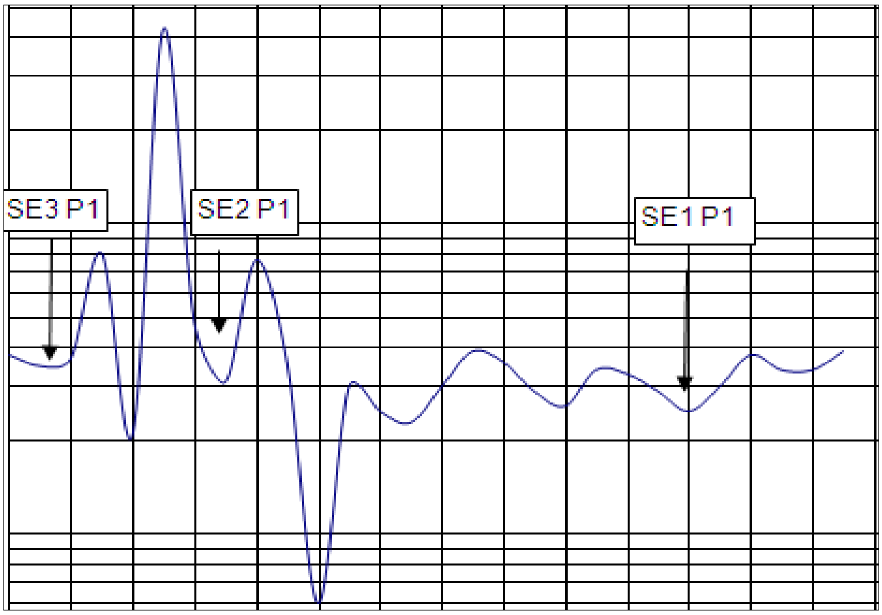

Figure 12 Profil électrique au site hôpital de Mongo

4.3.2. Electrical surveys

All the results of the quantitative study (electrical surveys) are obtained after an electrical profile drag study:

The curve in Fig.13 shows us a constant rate from AB/2= 1 to AB/2= 6 m. It should be noted that the medium begins to be continuously resistant up to AB/2 greater than 100 m; the expected depth varied between 45 m to 80 m deep, the drilling pump was located at 45 m deep with good productivity.

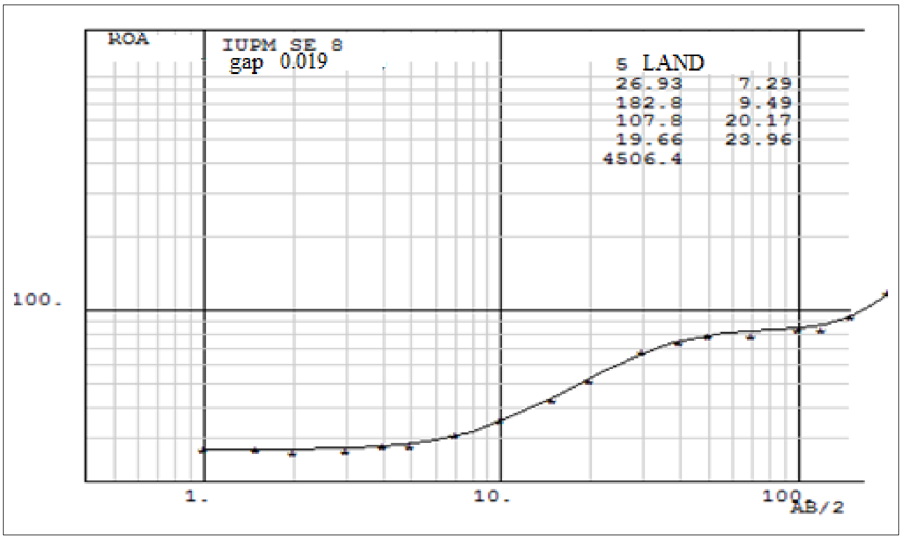

Figure 13 Electrical survey at the Mongo institute site

The curve in Fig.14 is subdivided in part: from AB/2 = 1 m to AB/2 = 10 m, the medium is conductive, and beyond AB/2 = 20 m the medium becomes resistant and at AB /2 = 100 m the medium still becomes conductive, the expected depth varied from 80 m to 100 m, the borehole pump is located at a depth of 62 m.

Fig.15 proves that the medium is conductive in the interval AB/2[1,10]; constant AB/2 [10, 25], becomes conductive again in AB/2[25, 90] the expected depth of the drilling varied from 80 m to 100 m, the drilling reached 65 m deep.

For the three electrical surveys used, the shape of the apparent resistivity curve as a function of the distance AB/2 is different; this is explained by the sedimentary nature of these sites.

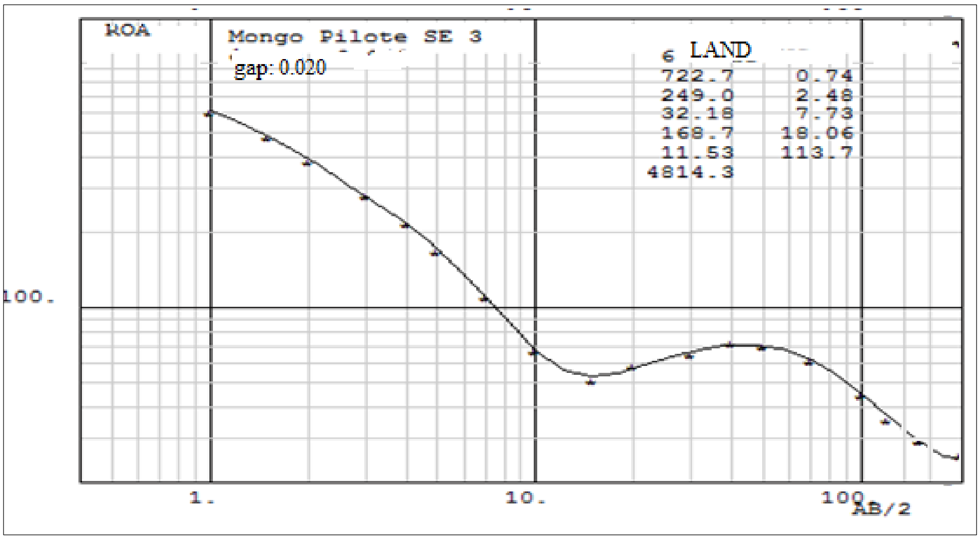

Figure 14 Electrical surveys at the Mongo pilot school site

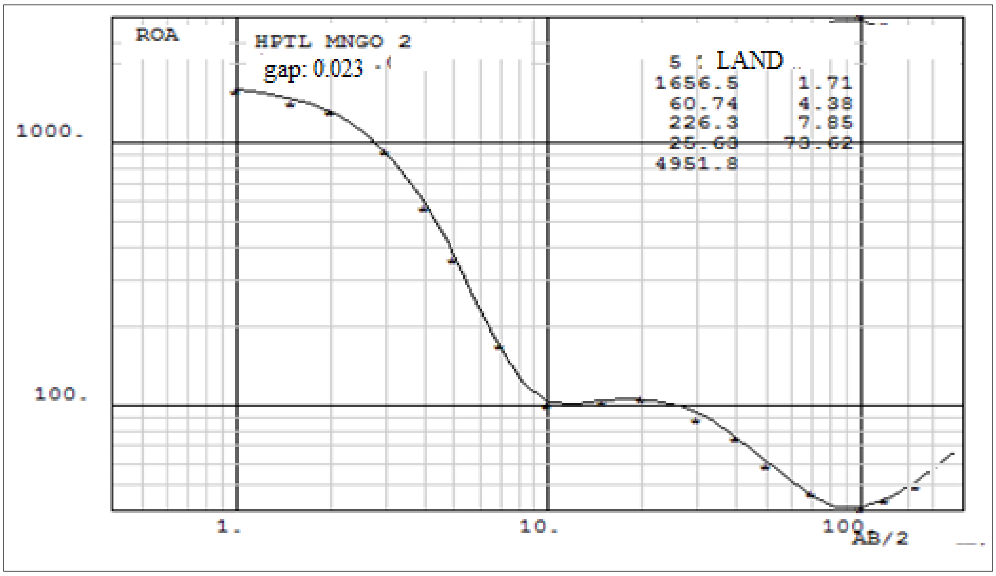

Figure 15 Electrical survey at the Mongo hospital site

4.4. Drilling

The drilling made it possible to take soil samples from the layers crossed for a succinct analysis of the lithology of these three sites, as well as the creation of stratigraphic columns at these three different study sites (Fig.16).

5. Discussion

At the end of the electrical study, some boreholes had been drilled, but unfortunately others were unproductive, which made it possible to retain one electrical borehole and one trail by site (Mongo institute, school and hospital).

The drilling reaches the fractured rock especially in specific orientation directions because these directions are interconnected from the Inselberg slope to the glacis up to distances very far from the alluvial outcrops and this by placing the pump at this location is to capture these waters located in these fractures.

The electric drag which is a qualitative research of groundwater in the base zone is recommended for a research of water resources and this is added to the study of satellite and aerial photos carried out by the 9th FED project of the Directorate of hydraulic. Preferably other methods should be added to confirm the qualitative study such as: magnetic, gravimetric method, etc.

The density of hydrographic networks is caused by strong slope slopes, which means that in the region's watersheds, these hydrographic networks are accentuated and dense.

The electric drag and the vertical electric sounding applied during this work showed us that these methods are appreciable, because they gave us two thirds (2/3) of positive results of water drilling carried out. Test pumping with a flow rate of eight cubic meters per hour ($8m^3/h$) for twenty hours (20h) time for filling a tank of fifty cubic meters ($50m^3$) at the Polytechnic University Institute of Mongo gave a level statistic of 33 m.

Therefore we recommend the following to engineers before any water drilling in Chad in general and in the Guéra area in particular:

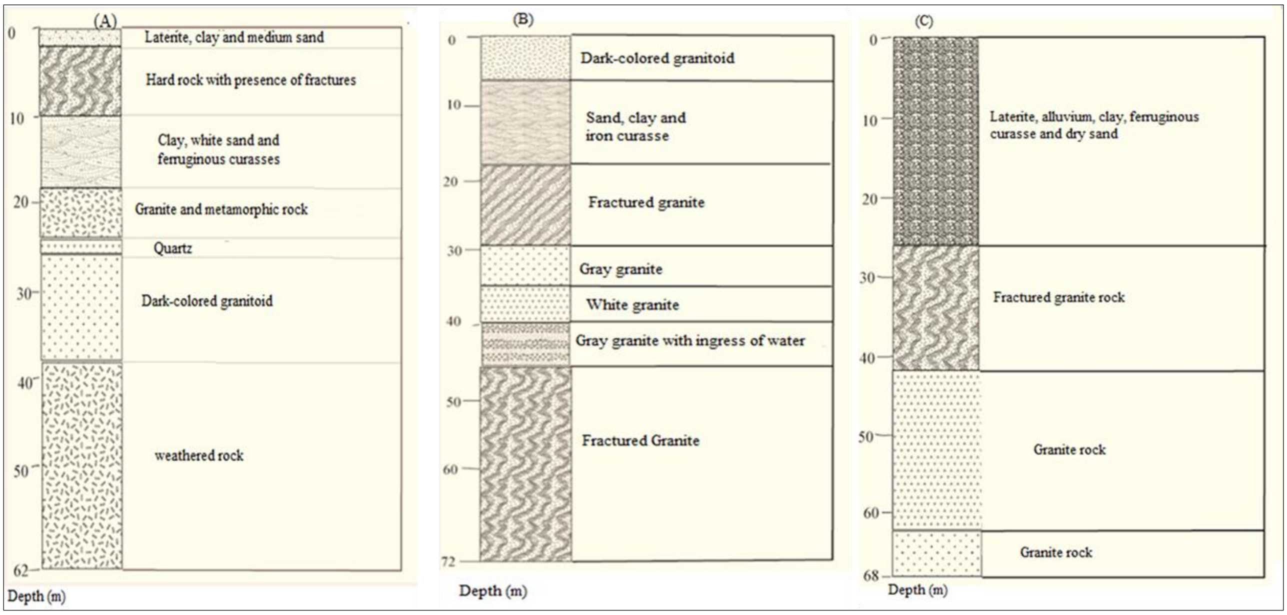

Figure 20 Stratigraphic column produced at the three drilling points after the electric drag. (A): At the Mongo pilot school, (B): At the Polytechnic University Institute of Mongo, and (C): At the Mongo hospital

- Consult the structural map of the region for a better location area (the supply of water tables and drilling productivity is linked to the intensity of the fractures);
- Carry out the geophysical study: electric dragging accompanied by electrical sounding;
- Locate the pump in the fractured rock with orientation N30° to 45° and N100 at 112° compressive stress;
- Prioritize the plateau layers which are more productive;
- Build dams and dikes along the ravine and valley path to promote infiltration and replenishment of aquifers by limiting and avoiding evaporation and evacuation of surface resources.

6. Conclusion

The potential areas for the installation of water boreholes in the Mongo city of Chad were investigated. To do this, a literature review for this zone was presented. This zone being a basement zone affected by fractures of well-defined and specific orientations, and the direction of slope allows the movement of surface water towards other regions of the country, as well as the recharge and horizontal flow of the discontinuous aquifers of the region. For the implementation, the geophysical prospecting method was used in order to choose suitable points for the rapid capture and good flow of groundwater which flows through the fractures. This method was the classic Schlumberger AMNB device in which A and B were electrodes emitting the electric current and M and N were electrodes receiving the potential difference at all chosen sites of Mongo, after which the curves giving the electrical survey were plotted and the stratigraphic column carried out at the drilling level.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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