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Geothermal Exploration Under Geology and Geophysics Methods in North Algeria

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ABSTRACT

The study area in north Algeria appears as a slightly waved landscape, extending between the Saharien Atlas from South and the Mediterranean Sea to the North. The High Plain average altitude is 900 meters. We have in the northern border isolated reliefs: Djurdjura Montaigne (1200 meters), DjebelTnoutit (1193 meters), and DjebelTella (1055 meters). SebkhetBazer, Sebkhet El Hamiet, the Chott El Fraïn, sebkha Oran are located in some closed depressions.

In this paper we focused on geological, geophysical and hydrogeochemistry investigations of geothermal reservoirs to develop its lithology. The hydrogeology study allowed us to identify the main aquifers in the region, which are the Mio-plio-quaternaire aquifer near the surface and the deep carbonated aquifer (Jurassic and Cretaceous).

The electric soundings supplied invaluable geological information for the exploration of the groundwater. We have some limestone outcrop in (DjebelsYoussef), although affected by numerous faults. In the overlapping zones (DjebelTnoutit) the outcrops are reduced. The calcareous formations constitute good aquifers. The geophysics study had just confirmed some geological work fields where interpreted the same cross section and geological maps.

Finally, to optimize geothermal reservoir exploitation in regards to hydrodynamics as water quality, it's better to exploit the limestone aquifer of the lower Cretaceous (Aptien. Barrémien). Results show that the geological structure of the region would be one of a graben weaknesses faults and the waters of study area have a chemical type of sodium chloride.

1. INTRODUCTION

The natural boundaries of Algeria are the Mediterranean Sea to the north (1200 km of shoreline), Morocco to the west, Tunisia and Libya to the east, Mauritania and Western Sahara to the south-west and finally Mali and Niger to the south (Figure. 1). The prime meridian (Greenwich) goes through the city of Mostaganem. From the standpoint of its area (2,381,741 km2), Algeria is the largest country in Africa and the Arab world (Figure 1).

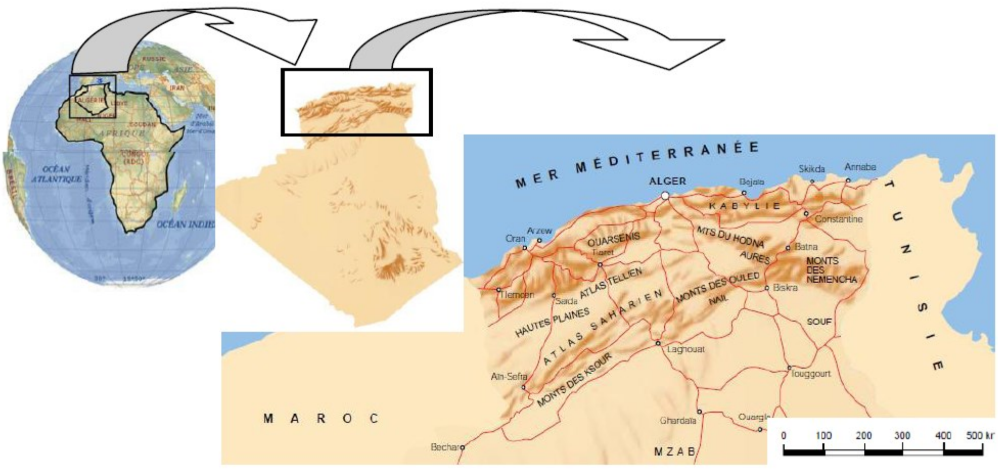

Figure 1: The study area.

The history of thermal baths begins in antiquity with the Greeks and Romans. In Algeria, in spite of the availability of significant resources, the thermal potential remains little or badly exploited. Thermal tourism nowadays can play a driving role with the development of an area. The modern exploitation of a thermal spring is required in this objective.

The main target for this paper is the geothermal reservoir study to show the natural aspects of the hydrothermal system, the hydrodynamic and physiochemical conditions of emergences, mineralogical quality and the curative properties of water. This study is entirely based on indirect investigation methods, such as geology, geochemistry and geophysics, which are coupled with the methods of direct approaches, to work out assumptions on the nature and reservoir characteristics. The data analysis collected from field works allows us to have the first results concerning the major geological structure of the aquifer formations, the physiochemical characteristics of water, the hydrodynamic characteristics of the reservoir and the inventory of the water points.

2. METHODOLOGY

Field works carried out during this period consisted of locating hot springs emergences and geological outcrops, carrying out water samplings and measuring the physiochemical parameters. We will present in this paper only some results; the measurements and chemical analyses will be interpreted and presented like maps and tables. The collected data are as follow:

- Geological investigations;

- Hydrogeology studies;

- Hydrochemistry studies and analyses;

- Geophysical Studies.

In our study we had taken a huge interest to geophysical electric method like individual to the group. This latest needs a good geological fieldwork investigation in the study area.

3. GEOMORPHOLOGICAL CHARACTERISTICS

3.1. Climatic characteristics:

By their altitude, the North Algeria region is subjected to a semi-arid mountain climate: heat during the day and cold in the night. The rainy period is spread out from September to April (according to Dar El Baida stations). Irregular snowfalls are recorded between April and November. The annual average temperature calculated for the period ranging between (1970 and 2010) and for the Blida station is 14°C. August and July record the highest temperatures, and it is in January that the average temperature is lowest.

3.2. Morphology characteristics:

The country is divided from north to south into four zones:

- The Tellian Atlas (or the Tell) is made up of the northernmost steep relief, flanked by rich coastal plains such as the Mitidja in the centre, the Chelif to the west and the Seybouse plains in the east;

- The High Plateaus;

- The Saharan Atlas as a succession of NE-SW oriented reliefs spreading from the Moroccan border to Tunisia;

- The Sahara desert south of the Atlas, which contains most of Algeria's hydrocarbon resources.

The North Algeria is the vast wide ones leveled. It contains several mountains with different altitudes such as DjebelZdim (1160m), Djebel Youssef (1442m), DjebelBraou (1263m), Djebel or KoudiatTella (1018m) and DjebelTnoutit (1192m).

The Plio-Quaternary formations, which consist primarily of red clays, conglomerates, friable white limestone and a surface calcareous crust, would correspond to successive periods of large rains and dryness.

The average rainfall in the study area is weak. Under the basin of Mitidja, there is a (600 mm approximately) rain deficit, as well as a strong evapotranspiration that enormously reduces the rate of infiltration to the aquifer system.

3.3. Geological aspect

The North Algeria can be divided into three structural zones such as:

The Tellian Atlas;

The high plateaus;

The Saharian Atlas.

The Tellian Atlas is orogenetic chains made from superposition layers which derive from three major paleogeographic fields: The Interns Domain which is part of the Alboran plate, consists of a cristallophyllien bottom and a paleozoic sedimentary cover with tertiary sector. This cover can be disunited from its base and form over thrust folds whose carbonated levels (From Trias to Eocene) constitute the Limestone ChainsFabre (1976).

- The FlyschsDomaine: these sedimentary formations (Cretaceous to Oligo-Miocène) constitute the mauretanienesnappe, massyliennes and the numidienne layer, which comprises a pelitic formation with alternation of burdigaliens likings and clays (Figure 2).

- The External Domain: pelitic series and sandstone - pelitic with pelites of Trais, dolomites and limestones of Lias and Dogger lower and marno-limestones than ammonites.

Units of the Internal Domain overlap the Flysch, which they also overlap towards the South, of the units in External Field.

- This last phase of orogenesis alpine was followed by volcanic activitiy along the littoral during the Miocene period.

The High plateaus represent a zone which we know from Trias and during all Mésozoïque, a subsidence and a more or less significant sedimentation. Their tectonic style is tabular, with convexities and depressions with a large radius of curvature. This area would have been prone to vertical accidents, giving formation to horsts and grabens.

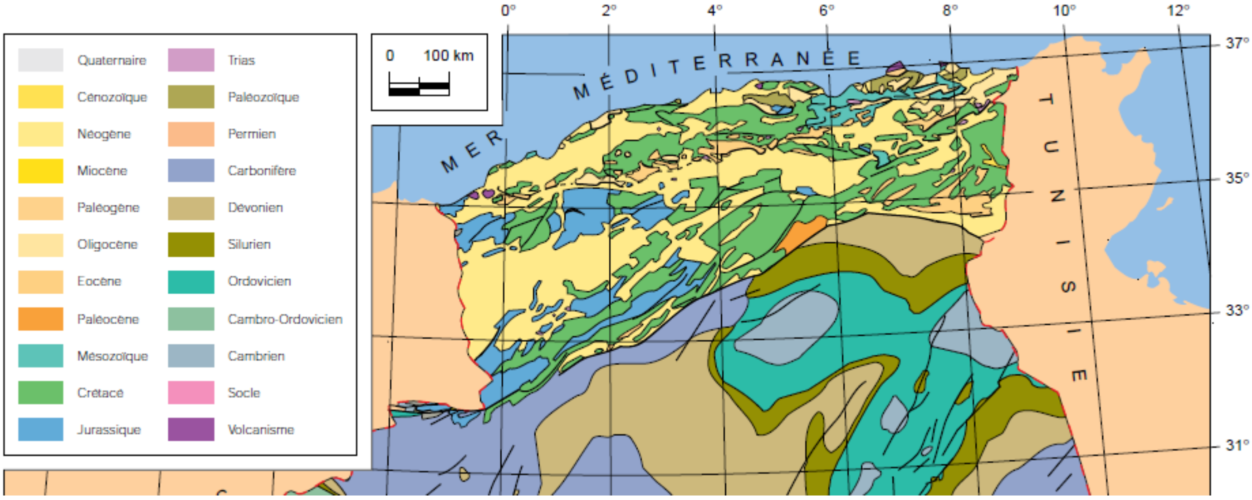

Figure 2: Geological aspects of the study area.

The High plateaus are limited to the south by the Saharian Atlas, which are assembly lines folded in SW orientation. These assembly lines are bordered by a major accident, the southern accident or flexure-atlasic. The nappe chains are bordered in the South by stable tectonic forelands such as the high plateaus; the folded tectonic forelands autochtones, thick mesozoïc series, such as the Saharian Atlas and the Mounts of Hodna and Aurès; and rigid units parautochtones overlapping.

Points of considering structural, the solid masses constituting the series North Houdna, present three types of relation: in the South they abnormally cover the formations folded with the atlasic basement at the level of the high plains, they present tangential accidents intern marked out Trias and correspondent to the nappe overlapping towards the South; in North, the formations of DjebelsAnini and Guergour appear in window under the nappe of DjemilaLesquerand Bourmatte (1988).

3.4. Geophysics characteristics

The geophysics prospection, through the use of various methods, became inescapable for the determination of the deep geological structures and the location of the faults and the splits. At the level of the High Plains, geological formations rarely appear and it is sometimes difficult for the geologist to establish correlations or to guess the structures below the recent sedimentary deposits. In this case, the geophysics prospecting becomes an essential tool Issaadi (1992).

Many geophysics methods exist. But the choice of the reliable method depends on the studied target. So, the electric prospecting is often used in the hydrogeological research, the seismic and magneto telluric methods are used in the oil exploration and the localization of the deep horizons; the gravimetric and magnetic methods are generally used in the research for the mining deposits. The combination of two or several methods (seismic and geo electric) is sometimes necessary to highlight certain structures or confirm certain hypotheses.

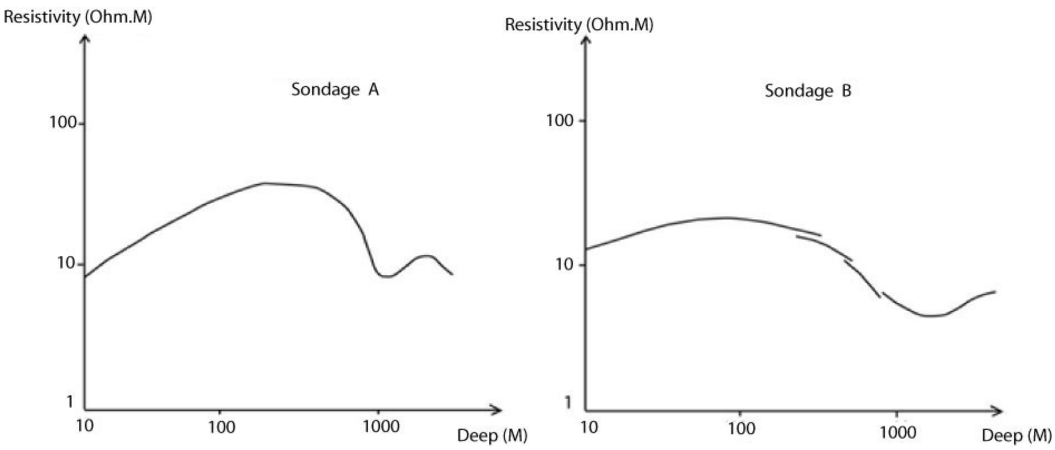

Figure 3: Electric soundings (A) and (B) in study area

Below we have a localization both sondage (A) and (B) in a map see **figure (3.b)**

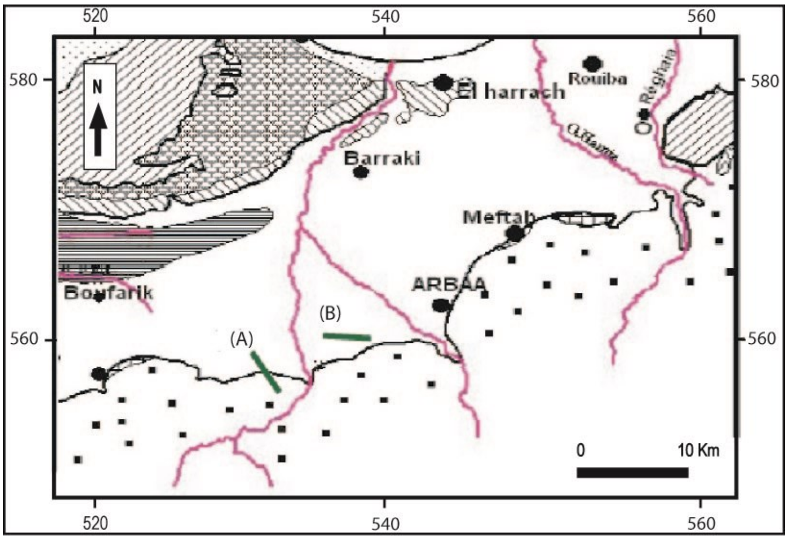

Figure (3.b): Localization for (A) and (B) sondage in study area

The High Plains were the object of several operations of prospective geophysical exploration for the localization of the geothermal reservoirs for mining and oil research.

So, in 1973, the General Company of Geophysics (CGG) led a vast prospecting operation in the study area at the request of local authorities. Another operation of electric prospecting was led in the same region by the engineering consulting and our time; the objective being the localization of the geothermal formations Verdeil (1982).

The use of the geophysics methods in the geothermal research and in the determination of the deep geological and tectonic structures was unquestionably a big utility for the localization of the interest formations. The interpretation of the geoelectric profiles obtained, was, in a sense, influenced by the theory of the overlapping geological formations southward. So, all the faults and the abnormal contacts are oblique northward. All the realized profiles are directed N-S who cannot detect that the accidents E-O. The execution of profiles E-O would certainly have brought many more details and revealed the existence.

Figure 3 shows electric soundings on the study area. We postponed only the profiles having a direct interest for the study zone.

We drew the position of the geoelectric profiles covering the study area and realized by our team. The electric profiles will be the only ones considered to study the deep geologic structure.

The geoelectric cross section represents resistant structures and conductive levels which can correspond to rises of salt Trias. The accidents and the abnormal contacts are tilted northward. The profile N1 shows one huge fault at the level of the electric soundings, giving a structure horst and graben and bounding in the South (Figure 4).

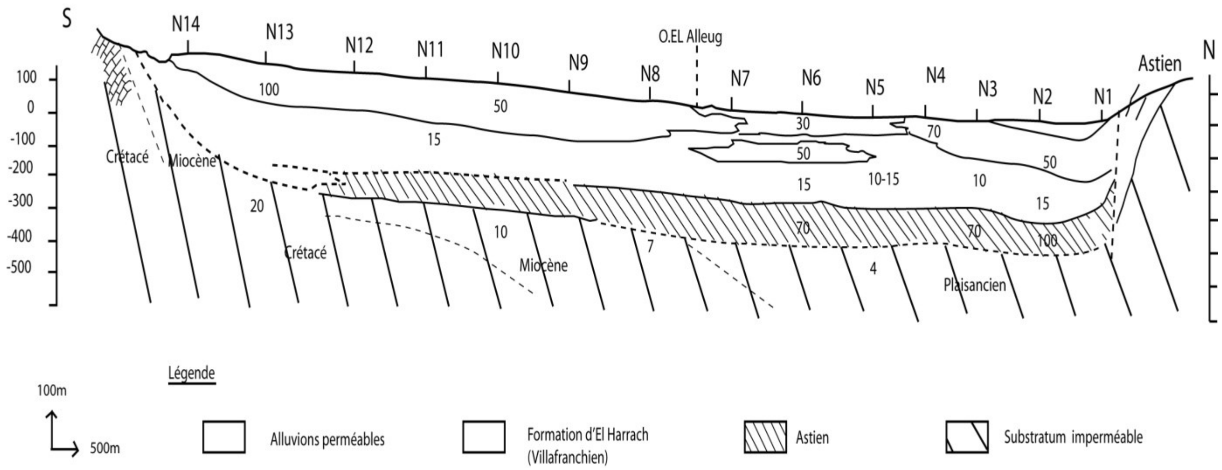

Figure 4: Geo electric cross section A

The study of these electric profiles generally confirms the existence of accidents revealed through the electric prospecting, but shows an orientation different from these accidents Fekraoui andAbouriche (1995).

The electric cross section can be compared with the seismic profile. Both tectonic accidents revealed by the electric method are confirmed by the seismic survey reflection. The geologic structure is the one of a graben (Figure 5).

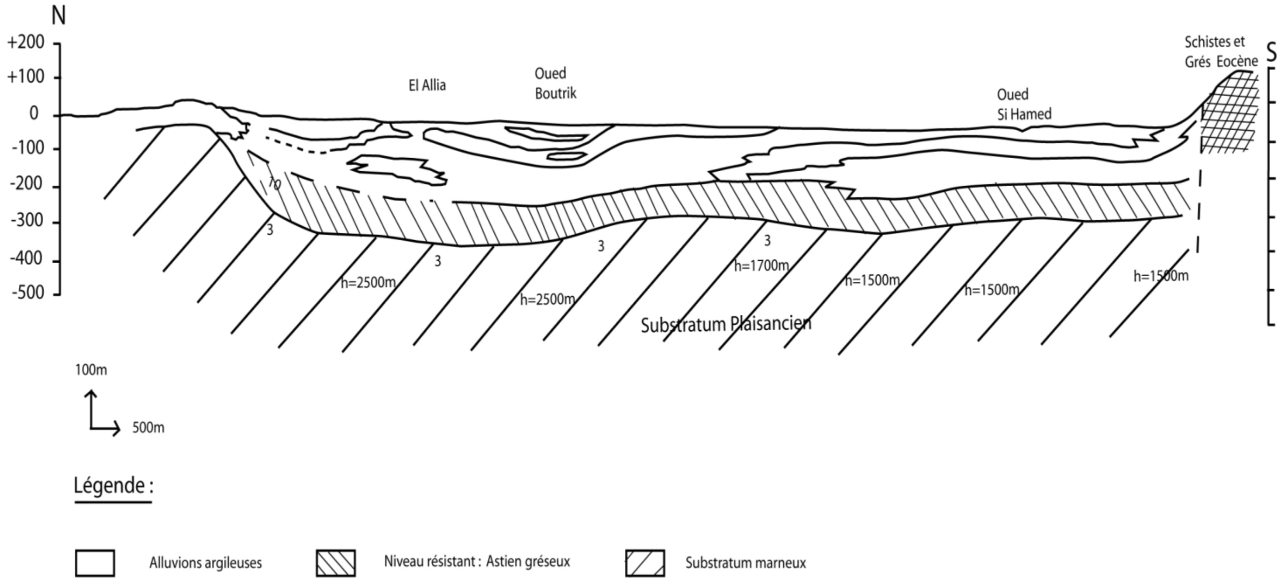

Figure 5: Seismic profile in the study area

The relationship of the water resources map for the North Algeria established by the ANRH in 2007 mentions five aquifer formations in the study area:

The quaternary aquifer encloses sands, gravels and clays. The average thickness is between 15 and 20 m; this aquifer occupies the major part of the study area and is exploited by wells with generally small flow rates (0.3 - 1.0 l/s).

Mio-Pliocene aquifer (limestone, silt and conglomerates); this aquifer limits varies 10 in 35m Sonalgaz(1983).

The lower Eocene aquifer gives a flow rate that varies between 15 and 30 l/s. The upper Cretaceous limestone aquifer debits which vary between 30 and 80 l/s. In the end the lower Cretaceous and Jurassic carbonated aquifer.

Some hydrodynamics data for all the aquifer of the study area are shown in the table below (Table 1).

Table 1: Hydrodynamics data for all the aquifer of the study area

Aquifer	Permeability K (m/s)	TransmissivityT(m^2/s)	Q (l/s)
Aquifer 1	10^{-4}	3 to 8.10^{-2}	0,3 to 1
Aquifer 2	5.10^{-5}	5.10^{-3}	57
Aquifer 3	3.10^{-3}	3 $.10^{-3}$	15 to 30
Aquifer 4	6.10^{-4}	7.10^{-3}	40 to 100
Aquifer 5	2.10^{-3}	4 to 6.10^{-4}	20 to 200

3.5 Geochemistry aspect

The physio-chemical characteristics of waters are connected to their underground path, temperature depth, the nature of the crossed rocks and the time residence. The dissolved elements are the major elements in significant quantity, which are anions (bicarbonates, sulphides, chlorides); the alkaline cation (Na, K); alkaline-earthy (Mg); silica; and minor elements or in tracks, absentees in commonplace waters, which are: halogenates (Br, I, F); trace elements (Li, Sr, Ba, Be) and elements tracks (Fe, Cu, Mn) Conrad (1983).

Water chemical classification is established by the presence of remarkable chemical elements, either by its nature or by its proportion with regard to the other elements. Waters of the study area are the object of several chemical analyses made by various authors. We grouped some chemical analyses and composition of these waters through several years Kedaid (2005).

The temperature varies between 30 to 50°C, pH between 6 to 6.90 the conductivity average 3000 ms/cm, which presents a stable water type of the sodium chlorinated. This chemical composition is influenced by the presence of the Trias formations in the region (Issaadi,1992).

Bellache and all (1995) had suggested that a better reservoir temperature estimation could be obtained by considering simultaneously the state of balance between water and several hydrothermal minerals, according to the temperature. The constants of balance are dependent on the temperature and pressure. The dissolution of minerals is very close in the temperature. The convergence of several minerals towards a point of balance to a certain temperature can mean that this temperature corresponds to that of the reservoir. This approach was used by certain researchers who obtained temperatures which agree with those obtained by the empirical geothermometer (Figure 6).

The solution is supersaturated or under saturated towards a mineral, as IF is positive (> 0) or negative. The temperature of balance is of 90°C approximately for the most part of minerals. This value can indicate that waters of the study area reached at least a temperature of 90°C in depth. According to the ternary diagram Cl-SO_4-HCO_3 of Giggenbach, (Figure. 5) we postponed the water. This water is in a volcanic water zone, meadows of the pole SO_4. (Table 2).

Table 2:Summary of the chemical analyses

Year	**1970**	**1980**	**2002**
Elements	North Hodna	North Hodna	North Hodna
Ca	180.33	248	174
Mg	49.87	14	52
Na	200.35	259	430
K	5.67	14	10
Cl	220	415	775
SO4	400.16	518	370
HCO3	100	178	207
SiO2	50	50.4	29.5
pH	6.60	6.81	7.55
T°C	40	46.5	52
Cond (µS/cm)	1599	2018	2400

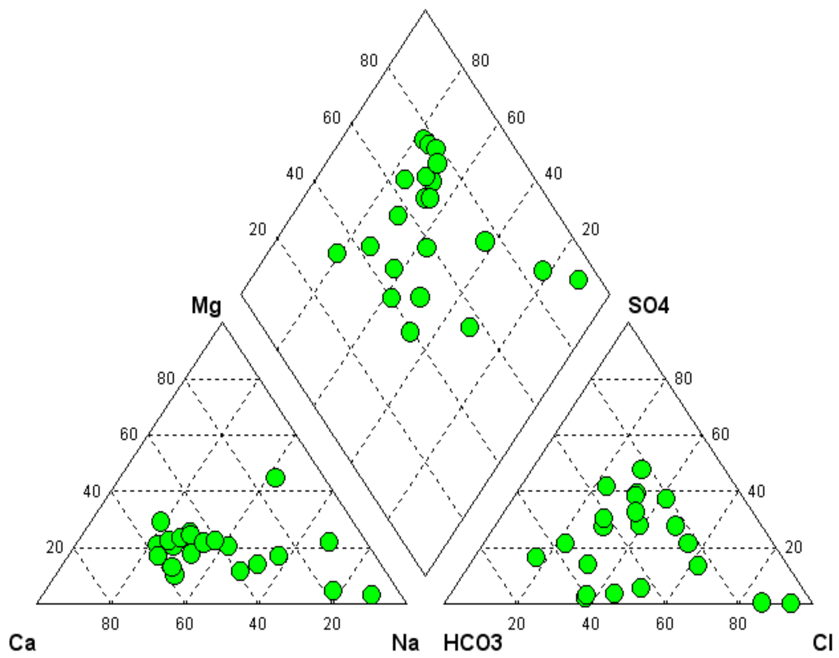

Figure 6: The water chemistry type.

4. CONCLUSION

The numerous studies which were led in the concerned region did not provide, to our knowledge, a precise geologic and structural plan to bound the deep geothermal reservoir. The contribution of prospecting geophysics (electric and seismic method) was unquestionably essential in the location of the faults and the levels of various resistivities, but without data of deep drillings, any geologic correlation between these levels would be difficult. The seismic survey reflection brought new elements into the deep geologic structure. The synthesis and the analysis of all the meditative data ended in preliminary results, which we presented in the present study.

The first results can be briefly summarized:

- The geologic structure of the region would be one of graben weaknesses faults.

- The geothermal water emerged through a fault of direction NW-SE. This water no longer reaches the surface; it is reached through drilling at 450 meters depth.

- Waters of study area have a chemical type of the sodium chloride. The temperature of the water varies of 30°C in 48°C.

- The temperature in the reservoir would be at least 90°C.

The zone of the emerging fault can be transformed into a zone of pollution (infiltration of polluting products stressed by the pumping well). We hope in the future to add some perspective as to why another study using geophysics MT methods should be conducted to allow further exploration.

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