

Study of Geothermal Sources and Potential Using GIS in Adrar site, Algeria

A.Benatiallah and B.Nasri,

Laboratory energy, environement and information system, Faculté des sciences et science de l'ingénieur,
University of Adrar Street, 11 December 1960 Adrar, Algeria

benatiallah.ali@gmail.com, benatiallah@univadrar.org

Keywords: temperature, Adrar, GIS, Geothermal Potential

ABSTRACT

The region of Adrar is located in south - western Algeria, covers a total area of 443.800 km² and is occupied by a population of 432,193 inhabitants. The main activity of the population is agriculture, mainly date palm cultivation occupying a total area of 23,532 ha. The climate of Adrar region is continental desert characterized by a high variation in temperatures exceeding 48°C between July to August and 16°C between December to January. The rainfall is very limited in frequency and volume with an aridity index of 4.6 to 5.0 which corresponds to a typical arid climate.

Geologically Adrar region, located on the edge North West and is characterized by a Precambrian basement covering stolen sedimentary deposit of Phanerozoic age transgressively. The depression is filled by Touat site Paleozoic deposits (Cambrian to Namurian) of a vast sedimentary basin extending secondary age of the Saharan Atlas to the North of hamada Tinhirt Tademaït, the plateau to the South, Touat Gourarato the West and Gulf of Gabes in the Northeast.

This work outlines a study of the geothermal potential of Adrar region from the borehole

data in various sites across the area of 400,000 km². From the data we developed distribution plots of the data of the various points and boreholes in the region specifying information on available geothermal potential at various depths.

1. INTRODUCTION

The Algerian Sahara is part of the great Sahara. A few millennia ago, this region's flora and fauna were rich and varied. This was the time when prehistoric man scored on cliffs or on the Tassili rock walls of the Saura and Tidikelt, the testimony of the prolific nature. Changes in climate towards desertification were increasingly intense leading man who lived in the Sahara to adapt to new living conditions. Life and survival were related to water. This water essentially was caught in the web of the Continental

Intercalary and has been exploited through the system of foggaras.

Algeria, with its geographical location (area of high tectonic activity) is considered among the rich countries of thermo mineral waters. While the potential of geothermal resources in Northern Algeria are well known , no detailed study has yet been conducted in Southern Algeria. The area of study lays in the Algerian South, in the South-western Algeria in the central part of the Algerian Sahara. The main purpose of this work was the realization of a geothermal database in GIS, and the assessment of geothermal potential in the Adrar region (Southern Algeria).

The Adrar state is located in South-western Algeria, and extends between the geographical coordinates: longitudes 0°30' E and 0°30'W, latitudes between 26° and 28°30'N and average altitude of 222m. Geothermal energy is one of the largest sources of renewable energy worldwide. The uses of this energy are numerous. They have direct uses such as fish farming, greenhouse heating and spa and industrial uses such as electricity generation. There are three types of geothermal fields:

- The geothermal fields of recent volcanic areas: This type of deposit is characterized by the existence of a deep magma chamber very hot (1300°C) [06] which is the natural heat source. This magma chamber gives up its heat to the surface geological layers. In this case, the waters are very warm and are more suitable for power generation [1]. Among the countries with this type of deposits are New Zealand and Iceland
- Deposits areas of stable continental platform, covered with sedimentary deposits: With this type of deposit there is no heat source in particular depth, but the heat is solely due to the geothermal gradient. In this case the reserves are generally very deep and their exploitation requires the completion of drilling. Such deposits are encountered in France (Paris and Aquitaine basins) and Algeria (the basin of the northern Sahara.)[5]
- The geothermal fields of active continental areas: In this third case, the water resulting from the thermal water flow through cracks and geological discontinuities and arrives at the surface as springs.

We find this type of deposits in Algeria, through the various hot springs that flow north.

2. GEOTHERMAL DATA

The geothermal data was characterized by two attributes: descriptive attributes or tabular alphanumeric, incorporating information on temperature, depth, physico-chemical characteristic, geology, water points and boreholes; and spatial attributes related to the geometry of aquifers and the location of boreholes and resources [2].

Data was collected from various primary and secondary sources. The National Hydraulic Agency (ANRH) provided data on the chemical composition of water, topographic and geological maps. Geothermal data on temperature, depth, physical and chemical characteristic, coordinates for the location, geology, water points and boreholes was collected from the field [3]. The database allowed us to perform the following tasks:

- View information from any geothermal point (depth,

Désignation	Forage A.E.P	Forage Irrigation	Forage Industrie	Forage Pétrolier	Forage Minier	Puits traditionnel	Foggara
Totaux	277	539	37	46	21	3355	1400

temperature, RS, physio-chemical characteristics).

- Compose as raster maps overlaid on topographic map, geologic map or satellite map.

2.1 Database creation

To enhance the information collected, in a first step, the data was entered into a Microsoft Excel table. This database is organized in a tabular table contains information on water points, namely: the coordinates, locality, chemistry, and sampling date, Fig 1.

Aj343	B	C	D	E	F	G	H	V	Z1		
	No	De	Uruguay	Ville/lieu	Date	Commune	Lieu_dit	IB	Préférable	Total	Temps/heure
1	W004-00005	ASB48	TIJUANA	TIJUANA	08/06/2017	OLDEO SAID	OLDEO SAID	T-IB-NDJOU	150	50	
2	Z005-00007	ASB48	ASOLEUR	ASOLEUR	10/06/2017	ADOUF	ADOUF	AHDY-T (10)	150	25	
3	W004-00007	ASB48	ASOLEUR	ASOLEUR	10/06/2017	ADOUF	ADOUF	AHDY-T (10)	150	25	
4	W004-00007	ASB48	ASOLEUR	ASOLEUR	10/06/2017	RSGUA-JNE	RSGUA-JNE	REGO-NA-C01 (17)	150	30	
5	L005-00023	ASB48	TIJUANA	TIJUANA	10/06/2017	TAJAS	TAJAS	T-IB-TAS (0)	150	29,5	
6	W004-00007	ASB48	ASOLEUR	ASOLEUR	10/06/2017	RSGUA-JNE	RSGUA-JNE	REGO-NA-C01 (17)	150	30	
7	W004-00050	ASB48	RSGUA-JNE	RSGUA-JNE	10/06/2017	SALE	EL AKEL	REGO-NA-C01 (17)	150	29,5	
8	W004-00057	ASB48	TSABIT	TSABIT	10/06/2017	SAUA	BDU AGRO (0-1 et ej 01)	SBAA 48	150	28	
9	L004-00004	ASB48	TIJUANA	TIJUANA	10/06/2017	STL	STL 44-65000	SB11-AR-B001	120	20	
10	W004-00007	ASB48	ASOLEUR	ASOLEUR	10/06/2017	FEKOUH	FEKOUH	FEKOUH	150	28,7	
11	W004-00032	ASB48	ASRAS	ASRAS	10/06/2017	CAKS	05-51,2	AEROCORTE 07	150	28,7	
12	W004-00004	ASB48	ASOLEUR	ASOLEUR	10/06/2017	TIT	TIT	TEIT 01	150	28,8	
13	W004-00004	ASB48	ASOLEUR	ASOLEUR	10/06/2017	TIJUANA	TIJUANA	TIJUANA 1	150	28,8	
14	W004-00051	ASB48	TSABIT	TSABIT	10/06/2017	SAUA	HSASSI 02 (0418)	SBAA 64	150	28,8	
15	W004-00043	ASB48	FEKOUH	FEKOUH	10/06/2017	OUJOUHA	OUJOUHA	OUJOUHA 01	150	28,8	
16	W004-00004	ASB48	FEKOUH	FEKOUH	10/06/2017	FEKOUH	FEKOUH	FEKOUH 01	150	28,8	
17	W004-00028	ASB48	TSABIT	TSABIT	10/06/2017	FEKOUH	FEKOUH	FEKOUH 01	150	28,8	
18	W004-00028	ASB48	TSABIT	TSABIT	10/06/2017	Ksar Kadour	Ksar Kadour	Teghette 1	6,52		
19	W004-00048	ASB48	DUET KOU	DUET KOU	10/06/2017	OUJA	OUJA 01-001	TLIOLLOUE 03	150	27,2	
20	W004-00048	ASB48	DUET KOU	DUET KOU	10/06/2017	OUJA	OUJA 01-001	TLIOLLOUE 03	150	27,2	
21	W004-00049	ASB48	DUET KOU	DUET KOU	10/06/2017	CHEDD ARDOUS-OUJAH	CHEDD ARDOUS-OUJAH	BAJOUR 07-07-09	150	38	
22	L005-00029	ASB48	TIJUANA	TIJUANA	10/06/2017	FATIS	FATIS	FATIS 01	60	25	
23	W004-00013	ASB48	DUET KOU	DUET KOU	10/06/2017	EL OUJAS-OUJANA	EL OUJAS-OUJANA	EL OUJAS-OUJANA 01	125	30	
24	W004-00048	ASB48	DUET KOU	DUET KOU	10/06/2017	OUJOUHA	OUJOUHA	OUJOUHA 01	150	28	
25	W004-00058	ASB48	DUET KOU	DUET KOU	10/06/2017	MOLAY TATE (ben zine)	MOLAY TATE (ben zine)	AZIZ 29	150	28	
26	W004-00065	ASB48	ASARE	ASARE	10/06/2017	TIL-JANE	TIL-JANE	TIL-JANE 01	120	28	
27	W004-00058	ASB48	DUET KOU	DUET KOU	10/06/2017	FEKOUH	FEKOUH	FEKOUH 01	150	28	
28	W004-00092	ASB48	DUET KOU	DUET KOU	10/06/2017	SOUTDAB-JOUDEBBIA	SOUTDAB-JOUDEBBIA	BAJOUR 07-01	150	27,5	
29	W004-00016	ASB48	TIJUANA	TIJUANA	10/06/2017	ZEDKOUR	ZEDKOUR	ZEDKOUR 01	120	28,5	
30	W004-00048	ASB48	DUET KOU	DUET KOU	10/06/2017	FEKOUH	FEKOUH	FEKOUH 01	150	28	
31	W004-00079	ASB48	FEKOUH	FEKOUH	10/06/2017	FEKOUH	FEKOUH	FEKOUH 01	150	28,5	
32	W004-00093	ASB48	DUET KOU	DUET KOU	10/06/2017	KHALI ALI	KHALI ALI	BAJOUR 07-02	150	28,5	

Fig 1: Geothermal database

2.2 Analyzing of geothermal data

The software used to display data is ArcGIS 9.2. This software allows the combination of GIS layers, digitizing, editing and visualization of raster images Fig 2. ArcGIS data are exported in PDF or jpeg format [5].

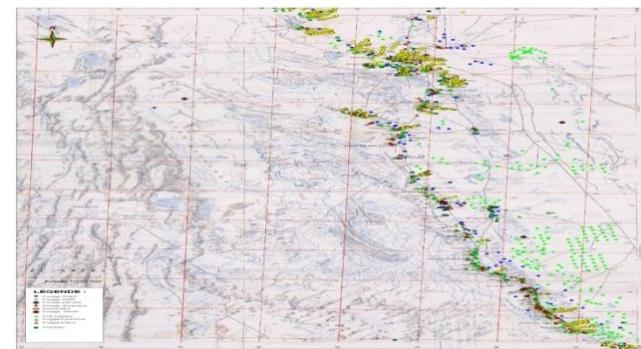


Fig 2: Geothermal points in Adar

The geothermal data for Adrar region was collected at water points from continental in fill systems which are operated by traditional harvesting methods (foggaras, Traditional well) with a flow rate of 2 to 35 l/s is drilling a flow rate of 3-60 l/s Tab 1.

Table 1: Water source point in Adrar

3. MAPPING OF GEOTHERMAL RESOURCES

Mapping of data points in the study area was done in Arc GIS. Geographical representation of waterholes in the area of study is shown in the following figure.

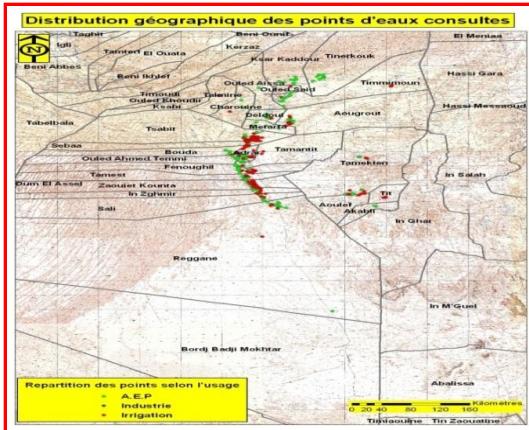


Fig 3: Geological distribution of water points

3.1 Geothermal potential characteristics

In this study, the aquifer continental intercalary is the largest supply of ground water. This water is the single source in Adrar region and is contained in the sandy horizons sandstone of continental interlayer. The latter is formed by Post-Paleozoic sediments ranging from Triassic to the Albian source and represented by alternating layers of sandstone and Sandy-Clayey levels where permeability is predominant. The substratum of the aquifer is composed of clay formations, Sandy Clay or Carbonate. In the South and Southwest, are unconformable land Paleozoic (Devonian) [6]. Coverage of the aquifer of the Continental infill consists mainly of clay formations with evaporates and the Cinemania Sands of Ergs. To the West and South, the spacer is flush Continental widely in the Touat, and Gourara Tidikelt.

The hydrodynamic characteristics of the reservoir are good. The average porosity is 26% and transitivity range from 1 to $6 \times 10^{-3} \text{ m}^2 / \text{s}$, where the drawdown is a few meters to tens of meters [7]. In the Touat site and Tidikelt Western Continental infill of water is drained by lines of depression that identify outcrops of the tank. The natural outlet of the aquifer is the foggaras part of which flows not captured evaporates at the salt flats, the other party escapes to the Taoudenni basin Fig 4.

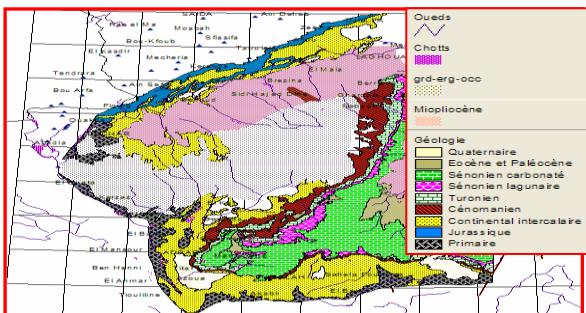


Fig 4: Map of geological affluent for reservoir

3.2 Temperature map of geothermal fluid

The data collected from different holes are shown on the map (Fig 5). The temperature varies with depth; the deepest waters that are influenced by the geothermal gradient are the hottest as shown in the temperature map. Temperatures of the ground water increase from West to East. The minimum temperature is located on the Western outskirts which correspond to areas of outcrop water or the temperature is *below 28°C.

Temperature data from a total of 145 boreholes in the study area was collected. The maximum temperature value was 32.5°C in the region of Meguiden, while the minimum value was 24.5°C in the region of Charouine. The measured temperatures are classified as follows: 115 wells whose waters are mesothermal $24^{\circ}\text{C} < T < 30^{\circ}\text{C}$, 30 wells whose waters are orthothermal $30^{\circ}\text{C} < T < 40^{\circ}\text{C}$.

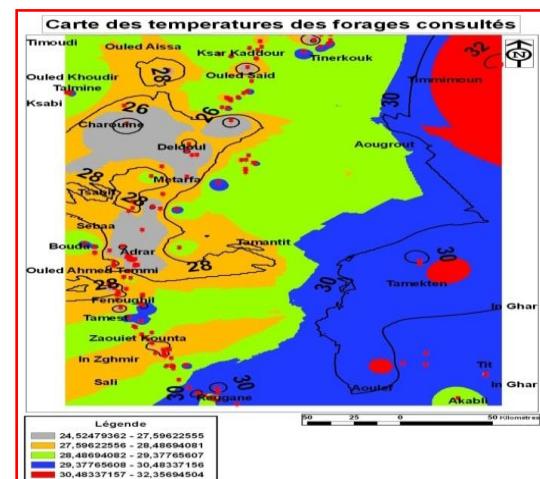


Fig 5: Temperature geothermal map

The hydrodynamic characteristics of the reservoir are good. The average porosity is 26% and transitivity range from 1 to $6 \times 10^{-3} \text{ m}^2 / \text{s}$, where the drawdown is a few meters to tens of meters (100m). The Adrar area is end of Albania reservoir and depth of water is not far from surface, and traditional methods (foggers) are used for water pumping

- First it flows in the direction NE-SE from the green plateau Tademaït (center of the study area).
- The second it flows through the NE-SW direction from a plateau green Tademaït depression Touat and erg Cheche.
- The third that flows in the direction NE-NW from the plateau region Tademaït green city of Adrar.

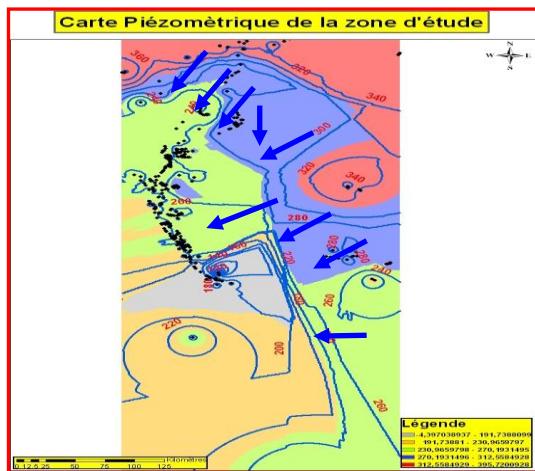


Fig 6. The piezometric map

The analysis results show that the dry residue salinity geothermal fluid in the Adrar region varies between 400 and 5200 mg / l and that 15% of water is highly mineralized [8].

The temperature map shows that temperature of geothermal fluid varies with depth, the deepest waters are warmer. We also note that temperatures are rising from west to east of water circulation [9] [10]. The geothermal fluid in the Adrar region has a neutral pH ranging from 7 to 9 and a geochemical facies sodium chloride to sodium sulfate

4. CONCLUSION

The aim of our work was to study geothermal sources and potential in South Algeria and specifically in Adrar state. We developed a GIS geothermal database of water sources and temperature distribution in the area. The lap of Continental Intercalary is a freshwater tank; most of the water of this resource has been filled during the rainy periods of the Quaternary. The waters of the Continental Intercalary are characterized by a temperature which exceeds 60°C except where the aquifer is close to the ground surface. In addition to the many hot springs in the North as there are in Southern Algeria and the development of a GIS database will help in managing, updating, analyzing and displaying the available information. The spatial analysis conducted in ArcGIS allowed us to publish thematic maps characterizing the geothermal resources of Adrar state.

The temperature of geothermal fluid in the study area increases towards East of the water source, the minimum temperature is located on Western outskirts which corresponds to areas of outcrop of the aquifer. Thus, the water temperature varies with depth; deepest waters that are influenced by the geothermal gradient are the hottest. Given the temperature of reservoir waters of Albion, the same application of geothermal energy in the Northern Algeria can be realized, particularly in the field of agriculture and the building heating or cooling in summer as the temperature air exceeds 40°C. With the exception of a few experimental applications, geothermal energy has been reserved until now for balneology. The temperature map can be used as a guide for communities to promote applications of geothermal energy such as heating or cooling of urban areas, agriculture and fish farming.

REFERENCES

- ANRH D'ADRAR (2004), Exploitation des eaux dans les zones arides L'évolution. L'exploitation Des Eaux Souterraines Dans La Daïra D'Adrar, Fenoughil Et Zaouit Kounta. Rapport Interne
- BESBES M, LARBES A, BABASY M, MERZOUGUI B. (2005), Modélisation Du Système Aquifère Du Bassin Occidental Du Sahara Septentrional, Première Phase : Hydrogéologie Et Modèle Conceptuel .rapport final d'OSS
- FABRE J. (2005), Géologie Du Sahara Occidental Et central, vol 8 édition Terrene Africain Géosciences collection Belgique.
- F.Z. Kedaid. (2006), Développement de la base de données géothermique de l'Algérie par un système d'information géographique, Revue des énergies renouvelables Vo.9N°4 P. 253-256
- OULD BABA SY M. (2005), Recharge et Paleorecharge Du Système Aquifère Du Sahara Septentrional; Thèse Doc, université de Tunis EL MAN
- OUALI S, (2006) Etude géothermique du Sud de l'Algérie, Mémoire de fin d'étude pour l'obtention du diplôme de Magister, Université de Boumerdes
- H.ASKRI, et All. (2001), Géologie De L'Algérie vol 1 édition SCHLUMBERGER WECCONATRACH
- KHADRAOUI A. (2006), Gestion des ressources en eau souterraines au Sahara Algérien. WWW. ABHS.DZ
- KHADRAOUI A. (2007), Eau Et Impact Environnemental Dans Le Sahara Algérien Définition Et Perspectives De Développement. WWW. ABHS.DZ
- OSS (2008), Le Système Aquifère du Sahara Septentrional, Rapport final, www.oss-online.org