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Update of the Most Important Algerian Geothermal Provinces

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ABSTRACT

Algerian geothermal prospective remains unexplored, thus the Algerian government aims to support research to implement a new strategy for renewable energy. Geothermal resources maps drawn in the framework of several projects will a solid basis for future development of this strategy. Geochemistry, Geology, Geophysics were used to delineate six geothermal provinces. These provinces have been classified by their geothermal potential as from low to medium enthalpy: North Western Province; North Central Province; North Eastern Province; Saharian Platform Province; Hoggar Province; South Western Province. The maximum thermal springs temperature at the surface reaches T=98°C in North Eastern province, most geothermal reservoir temperature does not exceed 130°C based on chemical Geothermometers. A global map of Main Geothermal provinces in Algeria was drawn recently updating hydrochemistry data and we calculated the geothermal potential and the flow rate.

1. INTRODUCTION

The study area is located in the north-western part of Africa (Fig. 1). This area comprises the most Algerian geothermal provinces characterized by the presence of several thermal hot springs known since Roman times and mainly used as baths. This area is known to be of a semi-arid climate with 500 mm/yr average precipitations. Geothermal reservoirs discharge its fluids along fault systems loaded with chemical elements, crossing Jurassic and Triassic diapers. The geothermal exploration in Algeria started in 1967 with investigations made by the national oil company (SONATRACH). More efforts should be made to make a balance between renewable energy and fossil-fuel resources which represents nowadays more than 96 percent of Algeria's electricity generation.

Since the 80’s, the geothermal exploration studies in Algeria have been taken in charge by the Renewable Energies Research Center of Algeria (CDER). Several studies address the geothermal potential over the Algerian territory by Fekraoui (1988); Issaadi (1992); Kedaid and Mesbah (1996); Lahlou Mimi et al. (1998); Kedaid (2007); Saibi (2009); Bouchareb-Haouchine (2012) Saibi (2015); Bahri et al. (2011) Chenaker et al., (2018) and Ait Ouali et al (2019). Recently Algerian government approved a renewable energy national plan to rise a new era for electricity production using renewable energy sources. The present paper focuses on the geology, hydrogeochemical, thermal potential and rate flow from recent field works (2014 to 2019). A new global map of Algerian geothermal areas was updated.

2. GEOLOGY BACKGROUND

The geology of the North Algeria is underlined by Figure 1 and shows the different geological domains in the study area (Durand-Delga et al., 1980, Wildi 1983, Bouillin 1986 and Bracène 2002). The main geological districts is the Tell Atlas of Algeria is represented by folds, thrust belt and quaternary basins such those of Cheliff, Mitidja, Hodna, Constantine and Guelma (Caire 1960, Villa 1980 and Meghraoui 1988). The Tell south Atlas faults system, which is an uplifted geological structure under tectonic process during the collision between the African and the Eurasian plates. The north part of the study area belongs to the Alpine structural domain with important seismic activity. From lithological point of view the area is characterized by carbonates and marls.

To the South the Sahara basins occupies the large surface compared with the Tell Atlas. The southern study area considered a stable tectonic district categorized mostly by sedimentary basins, hold the Albian geothermal waters. The main geothermal reservoirs are found in Mesozoic calcareous rocks and sandstones.

In the northern part of Algeria the geothermal reservoirs are encountered in Triassic sandstones, Liassic Carbonates and lower Cretaceous formations (most of them are composed of sandstones in the western part and carbonate rocks in the eastern part).

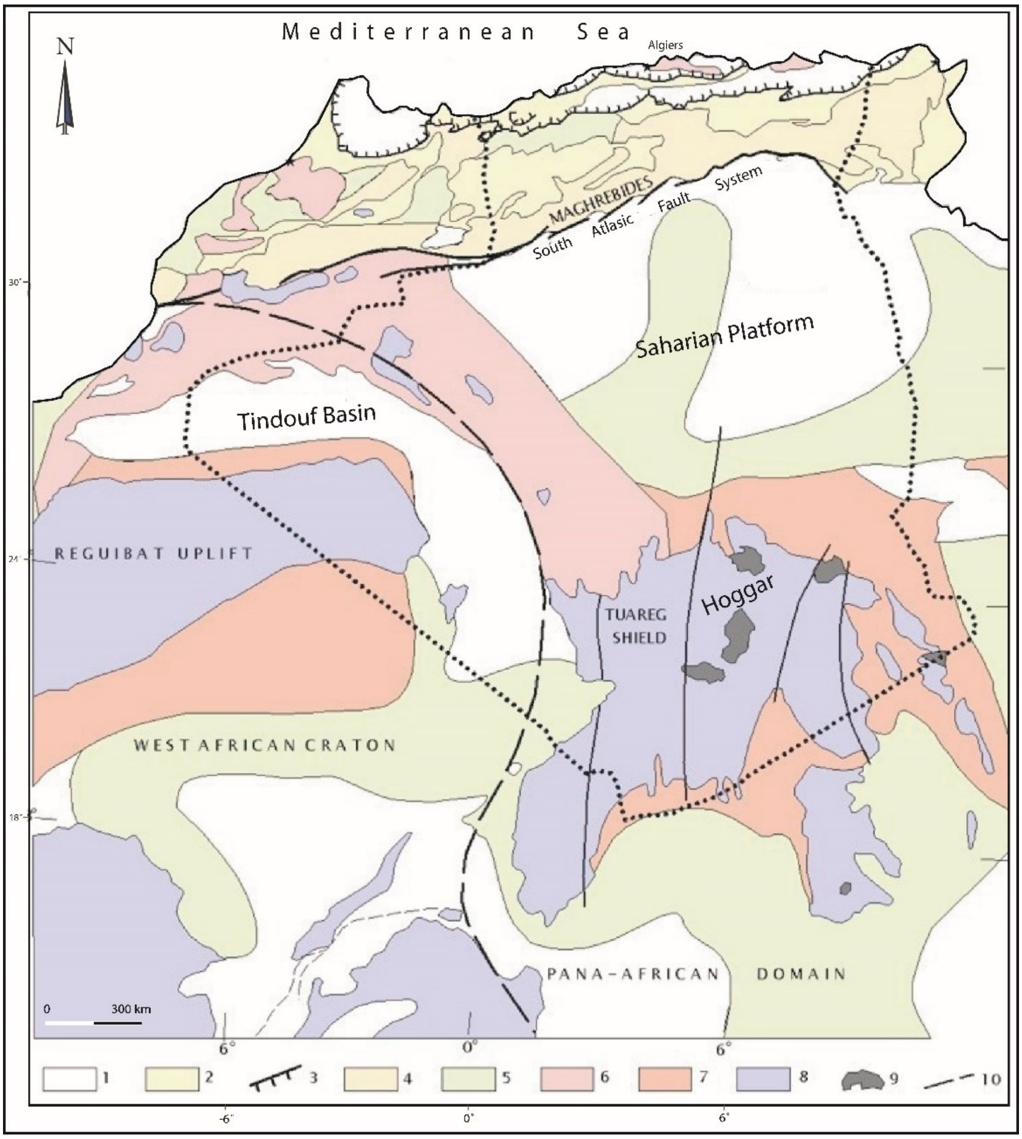

Figure 1: The major geotectonic unites of West Africa (Fabre, 1976) 1: Tertiary and Quaternary; 2: Alpine molasses; 3: Tertiary thrust sheet; 4: Secondary tabular; 5: Secondary plicative; 6: Primary plicative; 7: Primary tabular; 8: Precambrian and Precorce Cambrian of Sahara; 9: Cenozoic magma; 10: Megafault.

3. MAIN ALGERIAN GEOTHERMAL PROVINCES

3.1 North Western Geothermal Province

In the North western geothermal area, many thermal springs discharge through faults system, their temperature varies from 25 to 65° C. The measured geothermal gradient is higher than 4°C /100m. The main sedimentary reservoir at depths is ranging between 600-1200m. Most important geothermal springs in this area are Hammam Bouhadjar and Sidi Ayad. The recharge area of this reservoir comes from Jurassic limestone located in Saida mounts. In the Mostaganem zone the geothermal gradient is between 4.4°C /100 m and 5.1°C /100m. Thermal waters chemistry analyses show a dominant chlorinated-sodium water types. After geothermometry calculation, the reservoir temperature does not exceed 110°C.

3.2 North Center Geothermal Province

In the central geothermal area, the geothermal reservoir is constituted by the limestone and dolomite, with an average thermal spring's temperature ranging between 80°C and 90°C. The thermal waters during their flow from the deep reservoir (2,000 to 3,000m) have underground exchanges of elements without modifying their original chemical compositions. In the Biban region several springs are located along the abnormal contact separating two very important tectonic units and deeply affecting the formations up to the basement. The waters in this region are too mineralized from Jurassic limestone crossing Triassic formations. The geothermal potential recently calculated varies from 70 to 80 mW/m^2.

3.3 North Eastern Geothermal Province

The Eastern geothermal area is characterized by a plenty of springs and high heat flow values that vary between (45 and 99 mW/m^2). The thermal waters appear principally controlled by tectonics; most thermo-mineral springs are located on geological faults. Most important springs in this area are: Hammam Debbagh (98°C), Hammam Ouled Ali (80°C). An important heat flow anomaly was found near Guelema (85 mW/m^2). This region is also characterized by the occurrence of magmatic helium signals and an important seismic activity Rezig (1991). Another anomaly was located in the eastern most part of the province close to Tunisia border (Fig 2).

3.4 Saharian Platform Geothermal Province

This area covers the Algerian Sahara basins characterized by high heat flow (80-120mW/m^2) as reported by Takherist (1988) and (Nyblad et al. 1996). This area is a wide zone of sedimentary basins with few hot springs such Hammam Zelfana (42°C). The exploration of oil-wells by National Oil Company (Sonatrach) revealed the existence of a large thermal anomaly under the Sahara basins (Takherist (1989). The Sahara geothermal area is characterized by a geothermal reservoir in sandstone covering an area of 600,000 km^2. The Sahara geothermal area aquifer is mostly used for domestic and agricultural purposes. Thermal springs are infrequent in this area (Conrad, 1983). Main reservoir lithology presented by calcareous, with chloride chemistry water type dominant and 1.5 g/L mean TDS value (Ait Ouali et al., 2018).

3.5 Hoggar Geothermal Province

The Hoggar shield is considered as a wide uplifted area probably due to the past activity of a hot spot. The region experienced several intraplate magmatic episodes during Mio-Plio-Quaternary era. An average heat flow was found to be 90-110 mW/m^2. Over the Hoggar area seven sources were reported and the maximum temperature measured is 29°C at the surface.

3.6 South Western Province

In the south-westernmost part of Algeria, the Tindouf Paleozoic sedimentary basin with average heat flow (80-90 mW/m^2). The area experienced a Mesozoic magmatism over a surface of 240,000 km^2 and appears with few geothermal springs three thermal sources are present on the area and the maximum temperature measured is 26°C.

4. GEOTHERMAL UTILIZATION

The main use of the geothermal waters in Algeria are in domestic heating, Spas and agriculture. Several projects were launched for geothermal direct applications in domestic heating and in agriculture fields (green houses heating and aquaculture farming). A pilot project for geothermal power plant is planned to be implemented in the Eastern geothermal area In Hammam Debagh, Guelma province. A successful project of fish farming product in the Sahara geothermal area (Ouargla and Touggourt) is a good example of the geothermal water use with hot waters temperature is 60°C as reported by Bellache et al. (1984). Eighteen greenhouses covering a total surface of 7,200 m^2 are heated by the 57°C Sahara geothermal waters. The source temperature combined to a flow rate of 1 L/s is used to assure a minimum temperature of 12°C inside every greenhouse (Saibi, 2015). An important geothermal potential was found in the Sahara geothermal area sufficient to heat 9,000 greenhouses and the total energy use for geothermal is about 1,778.65 TJ/yr as reported by Bellache et al. (1995).

5. CONCLUSIONS

Algeria has high potential of geothermal energy enough to be used in domestic heating, agriculture and fish farming. Up to now all the geothermal capacities are not completely used. The Algerian government has now a new strategy to support projects for renewable energy use and has recently approved new laws and provided significant financial resources for investors to help them exploring and exploiting renewable energies for power production and other usage. The most important geothermal areas are inventoried in new global map (Fig. 2) for all the country, a very high heat flow found in the Sahara geothermal area (90-110 mW/m^2). The second highest geothermal potential was in the Eastern geothermal area in Hammam Debagh thermal spring with T=98°C. The Hammam Debagh locality was chosen for pilot project to implement a power plant. A good EGS (Enhanced geothermal System) is also possible in the Hoggar Shield. The government is currently investing in the protection of the environment by exploring green energy such geothermal waters as a substitution to fossil-oil resources.

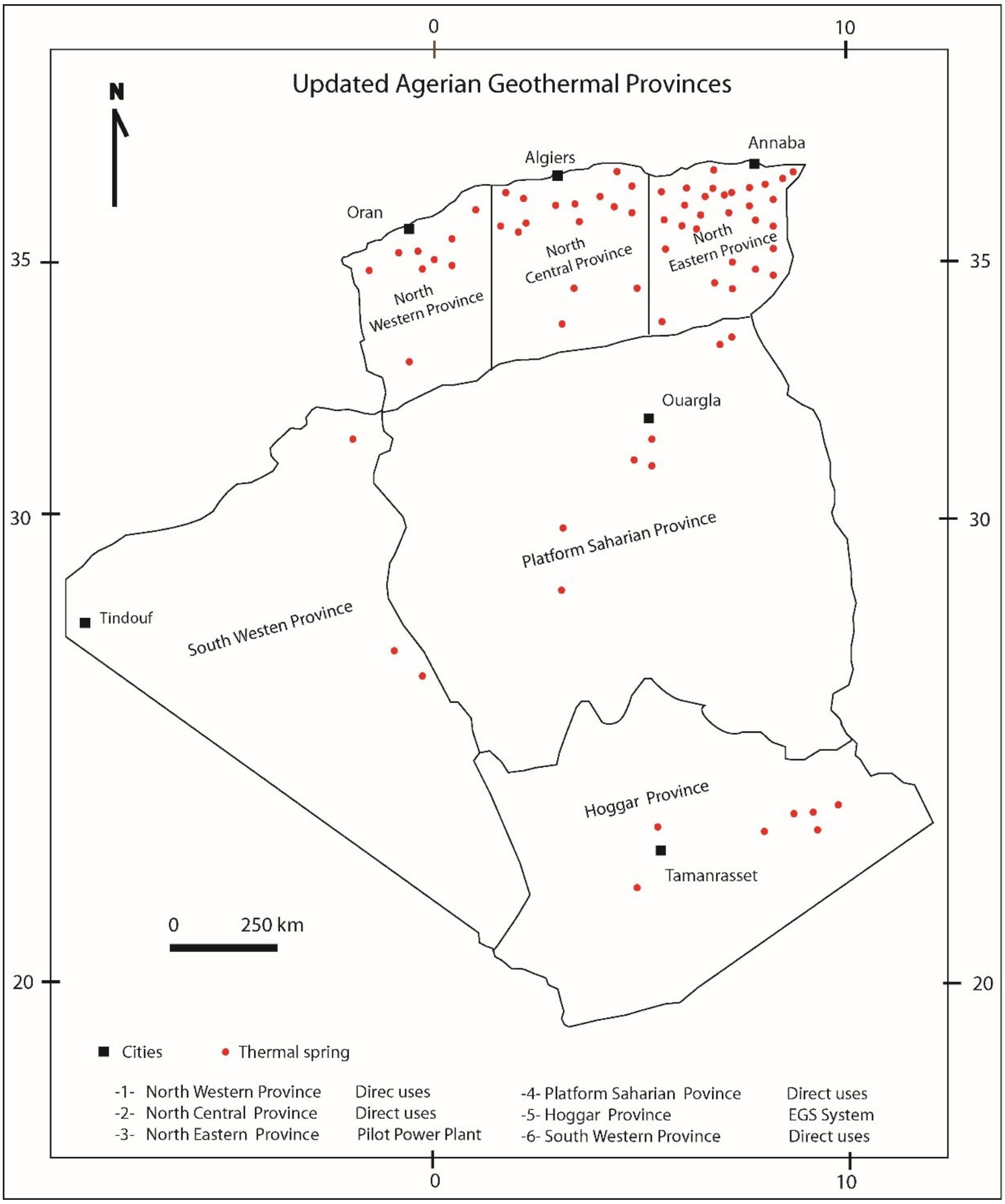

Figure 2: Main Algerian geothermal provinces

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Table 3 : Utilization of geothermal energy for direct heat as of 31 December 2019 (other that heat pumps)

1) I = Industrial process heat; H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling); D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables); B = Bathing and swimming (including balneology)
F = Fish farming; G = Greenhouse and soil heating
K = Animal farming; O = Other (please specify by footnote)
S = Snow melting

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (oC) - outlet temp. (oC)] x 0.004184 (MW = 10^6W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (oC) - outlet temp. (oC)] x 0.1319 (TJ = 10^{12}J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% of capacity all year.
Note: please report all numbers to three significant figures.

Capacity3)		Maximum Utilization		Annual Utilization	
Locality	Type1)	Flow Rate / Temperature (oC)	Enthalpy2)(kJ/kg) / Ave. Flow	Energy4)	Capacity
(kg/s)	Inlet / Outlet	Inlet	Outlet / (MWt)	(kg/s) / (TJ/yr)	Factor5)
Meskhoutine	B	80	90	30	635
Oulad Ali	B	83	50	20	329
Ain Berda	B	100	28	20	85
Soukhna	B	83	50	30	320
F, Mohammadia	B	12	47	25	27
Teleghma	B	10	48	48	26
Bougharara	B	7	37	20	15
Bouhanifia	B, D	9	68	35	40
Chiguer	B	5	35	25	30
Bouhadjar	B	5	65	30	250
Rabi	B	6	48	20	18
El biban	B	2	80	30	300
Essalihine	B	65	43	25	200
Beni Guechat	G	4	55	20	20
Dehamecha	B	2	29	20	15
Boutaleb	B	6	52	30	150
Ennakhla	B	4	33	25	30
Sidi-Mansour	G	4	55	30	20
Ouled Yeles	B,G	4	47	30	28
Guergour	B	25	43	25	25
Ibainan	B,G	5	55	30	210
Kiria	B	5	40	20	25
Silal	B	12	46	20	23
Sidi-Yahia L'Aidli	B,G	30	50	30	230
Mansourah	B	3	38	20	70
Delaâ	B	3	42	25	30
Kséna	B,G	10	61	30	250
Salihine	B	3	36	20	15
Melouane	B	4	39	20	30
Righa	B,H	2	67	30	260
Boutrigue	B	3	39	25	20
Serguine	B	3	40	25	16
TOTAL		599	1556	833	3742

Table 5 : Summary table of geothermal direct heat uses as of 31 December 2019

1)Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (oC) - outlet temp. (oC)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001
2)Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (oC) - outlet temp. (oC)] x 0.1319 (TJ = 10^{12}J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154
3)Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

Use	Installed Capacity1)	Annual Energy Use2)	Capacity Factor3)
(MWt)		(TJ/yr = 1012J/yr)	
Individual Space Heating4)		2	26
District Heating 4)			
Air Conditioning (Cooling)	0,5	3,2	
Greenhouse Heating	1,2	5	
Fish Farming	15	300,5	
Animal Farming			
Agricultural Drying5)			
Industrial Process Heat6)			
Snow Melting			
Bathing and Swimming7)	58,3	1955,4	
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps	0,7	85	
TOTAL			

Table 6 : Wells drilled for electrical, direct and combined use of geothermal resources from January 1, 2015 to December 31, 2019 (excluding heat pumps)

1)		Include thermal gradient wells, but not ones less than 100 m deep	
Purpose	Wellhead Temperature	Number of Wells Drilled	Total Depth (km)
Electric Power	Direct Use	Combined	Other (specify)
Exploration1)		(all)	
>150o C		Production	
150-100oC			
<100oC	6	>2	
Injection		(all)	
Total		6	

Table 7 : Allocation of professional personnel to geothermal activities (restricted to personnel with university degrees)

(1) Government			(4) Paid Foreign Consultants		
(2) Public Utilities			(5) Contributed Through Foreign Aid Programs		
(3) Universities			(6) Private Industry		
Year			Professional Person-Years of Effort		
(1)	(2)	(3)	(4)	(5)	(6)
3		4		2015	
5		6		2016	

2	3	2017
3	4	2018
6	7	2019
19	24	Total