The Geothermal Research in Morocco: History of 40 Years

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ABSTRACT

The interest of geothermal research in Morocco has been increased since 1968 with studies conducted by for academic or economic purpose. So and tough temperatures were sometimes not directly determined, different authors tried to take the most of it in order to approach the real formation temperature. In any case some corrections have been operated, on measured or deducted temperature values from suitable geochemical tools

Whatever their direct or indirect link to the potential geothermal resources evaluation, these investigations endowed Morocco of an important mass of information on the geothermal gradient, the heat flow and the underground temperatures spatial distribution.

These informations constitute a considerable enrichment for our database (geothermal gradient and heat flow maps, characterization and descriptions of the warm water aquifers, geochemistry of the thermal springs, area of potential geothermal resources, etc).

Morocco counts more than 10 hot aquifers and 50 thermal springs whose emergence temperature varies between 30 and 54°C. Therefore these important hot springs and reservoirs revealed by hydrogeologic and oil wells place the country as promising target in geothermal energy and thermal waters.

Geodynamic studies linked the zones showing geothermal gradient and heat flow exceeding 50°C/Km and 100mW/m2 respectively, to Neogene - quaternary volcanic and neotectonic activities. However these thermal phenomena are still not developed and their exploitation limited to drinkable water distribution or to balneotherapy "ancient Hamam".

1. INTRODUCTION

Worldwide, the energy demand has been increasing each year and with the emergence of new economic powers of large population, this movement is not ready to stop. Morocco, as a developing country does not escape to this phenomenon. It is characterized today by important energy dependence: more than 97.3% of commercial energies are imported in 2007, which is to say 14% of the imports, corresponding to 3.02 billion dollars for a GDP of 134.6 billion dollars in 2004. Vis-à-vis this strong energy dependence, and to take up the multiple challenges and to control the energy future of the country in order to ensure a sustainable development, a new strategy based on the development of the energy potentialities has been elaborated. It consists of increasing the share of renewable energies in the energy assessment with 10% in 2012, and 19% in 2020. Renewable energies conceal in Morocco a considerable potential of development namely the wind potential, thermal solar, photovoltaic solar and geothermal.

The Moroccan subsoil has potentialities in geothermal energy still unexploited. The most promising zones are north-Eastern Morocco and the sedimentary basins of the Sahara (Rimi, 2000, Zarhloule, 1999, Rimi & Zarhloule 2007). Many warm water reservoirs place Morocco as country where average to high geothermal enthalpy could be used in several specific applications, but geothermics is still not enough developed and the interest to this energy source was up to now negligible in comparison to other renewable sources.

This paper represents the important results of geothermal activities and contraints in Morocco between 1968 and 2009.

2. GEOTHERMAL RESEARCH

2.1 Summary of geothermal activities in Morocco

In 1968 the Ministry of Energie and Mining supervised first studies to evaluate geothermal Moroccan resources (Facca 1968, Alsac et al 1969 and Cornet et al. 1974), unfortunately these studies were not positively conclusive.

In spite of the hydrogeothetmal potential of Morocco, the support of research & development in the field of geothermics remains under the yearning of the university researchers. Geothermic research undertaken so far was generally carried out by university teams since 1980 (Bahi et al. 1983, Rimi & Lucazeau 1987, Rimi et al. 1998.2008, Rimi 1990,1999,2000,2005, Ben Aabidate 1994, Lahrach 1994, Zarhloule 1994,1999,2003,2004, Zarhloule et al., 1998,1999,2001,2005,2006,2007, Boukdir 1994, Ziyadi 1993, Bellouti 1997, Lahlou Mimi and Al 1999, Bellouti, 2000, El Morabiti 2000, Benmakhlouf 2001, Cidu & Bahaj 2000, Winkel, 2002, Tassi et al., 2006). These researches carried out within the framework of Phd theses or bilateral cooperative projects between Moroccan and European universities namely, France, Italy, and Portugal and also Tunisia in order to measure and map the distribution of the underground temperatures, the heat flux density, the temperatures in the aquifers, the geochemistry of the thermal springs and hydrothermal modellings. These research tasks made it possible to highlight Moroccan hydrogeothermal potentialities and the possibilities of geothermal energy utilization.

2.2 Geothermal Resources

Situated in Northwest Africa, Morocco has been an area of a complex tectonic history resulting of continuous interactions between the main lithospheric plates, namely the American, the African and Eurasian plates. Four main structural units are defined from South to North (Fig. 1): Anti-Atlas and Saharian domain corresponds to the Precambrian basement,

Atlas belt corresponds to an Alpine intracontinental range, Mesetas corresponds to stable Paleozoic-Mesozoic basement, Rif represents the westernmost part of the Alpine belt around the Western Mediterranean.

Hydrogeothermal data come from prospecting carried out in 250 of hydrogeological wells, 410 petroleum wells and from 50 springs. The depth of the wells ranges from 50 m to 4100 m. By processing and gathering data coming from different prospecting methods (geological, geothermal, hydrogeological, geochemical and geophysical), Morocco was subdivided into six promising hydrogeothermal basins (Figure.2) that are characterized by:

2.2.1 Significant hot reservoirs (Figure.2)

Actually 50 thermal springs whose emergence temperature varies between 30 and 54°C are originating from 10 main hot aquifers. The TDS varies between 132 mg/l to 3g/l. The waters are mainly HCO3-Ca-Mg type, and rarely Na-Cl or Ca-SO4. Those hot springs characterize the discharge area of the hot carbonate aquifers in Morocco;

The temperature estimated by silica geothermometers ranges from 40°C to 100°C. The depth of the thermal aquifers was gotten by using the geothermal gradients calculated from the petroleum well that ranges from 19 to 42°C/km (Zarhloule, 1999) and the deep temperatures estimated from the geothermometers. The depth of thermal aquifers ranges from 400m to 1800m (Zarhloule, 1999).

2.2.2 High Geothermal Gradient (Figure.3)

The regional geothermal gradient ranges from 19°C/km to 36°C/km. For the the whole of Morocco the geothermal gradient is 23°C/km. The punctual geothermal gradient ranges from 16°C/km to 42°C/km. The geothermal anomalies are related to deep hydrodynamics, recent tectonics, and volcanism or to elevation of the Moho;

2.2.3 High Heat Flow (Figure.4)

The heat flow is higher in the north-eastern and south-western part of Morocco (80-140 mW.m-2).

2.2.4 Potential Geothermal Fields (Figures 5 and 6)

The synthetic approach based on the treatment and the compilation of geological, geophysical and hydro-geothermal data, allowed to identify several potential geothermal zones as following (Figure.5):

- Northern of Morocco that is characterised by geophysical anomalies (gravity, magnetism and electrical conductivity), high geothermal anomalies, neo-volcanism, neotectonics, important aquifers
- South of Morocco that is characterised by plio-quatrenary volcanism, high heat flow, geophysical anomalies,
- Midle of Morocco that is characterised by three zones, where there is a high shallow geothermal gradient, with hot springs that represent discharge from deep reservoir, and upward moving grownd water flow

These zones which present good hydrogeothermic potentialities correspond to the basins which contain hot water aquifers (zones A, B, C, D and E) giving rise to many thermal springs and boreholes. The refill of these aquifers is ensured at the level of the outcrops.

3. GEOTHERMAL UTILIZATION

In Morocco, there are many important zones where the geothermal energy could be more interesting for greenhouses, aquacultures, heat pumps etc. Unfortunatlty and currently the thermal water application is mainly limited in balneology, swimming pools and potable water bottling.

3.1 Swimming pools

Reconstruction of swimming pools has marked a small progress in the last years and the number of newly built outdoor pools has increased as well. This application is usually a part of complex thermal water utilization for domestic purposes, treatment and rehabilitation. The water is mainly Na-Cl or SO4-Cl type.

3.2 Bottling

The number of bottling companies has increased during the last five years from 2 to 5 private enterprises nowadays. Their production meets mainly the demand of the local market. Several major reasons for high development rate of bottling exist due to the:

- predominant thermal waters of low TDS (<1 g/l) and HCO3-Ca type;

- big variety of water chemical content that provides opportunity for bottling of potable water as well as of mineral water for drinking in prescribed doses.

4. DEVELOPMENTS AND CONTRAINTS OF GEOTHERMAL RESEARCH

Geothermal research in Morocco has been only ensured by university teams mainly Mohamed V-Agdal University in Rabat and Mohamed I University in Oujda. Though limited equipments and after years of research in hydrogeology, geochemistry and geophysics, these published or to be published works allowed to identify the geothermal potentialities of Morocco. Thus, to go from the phase of resources identification into the phase exploitation or development of geothermal energy, Morocco must install an adapted institutional framework to encourage the private sector to invest in this field. Also, Morocco will have to encourage geothermal research, and to mobilize more financing support to work out a development strategy which will have as objectives:

- Geothermal master project;
- Detailed geological mapping, identification of the resources area and geographically associated needs
- Tax incentives and
- Public and professionals' information.

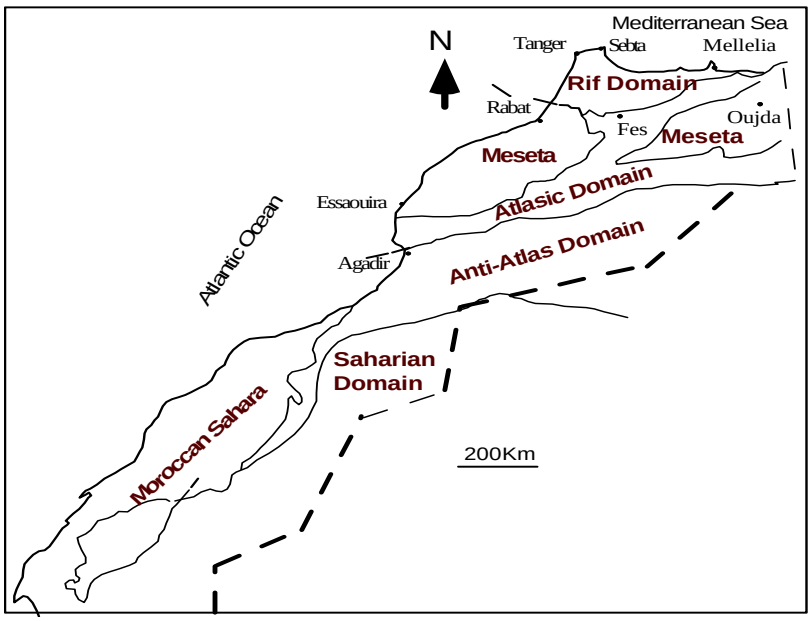
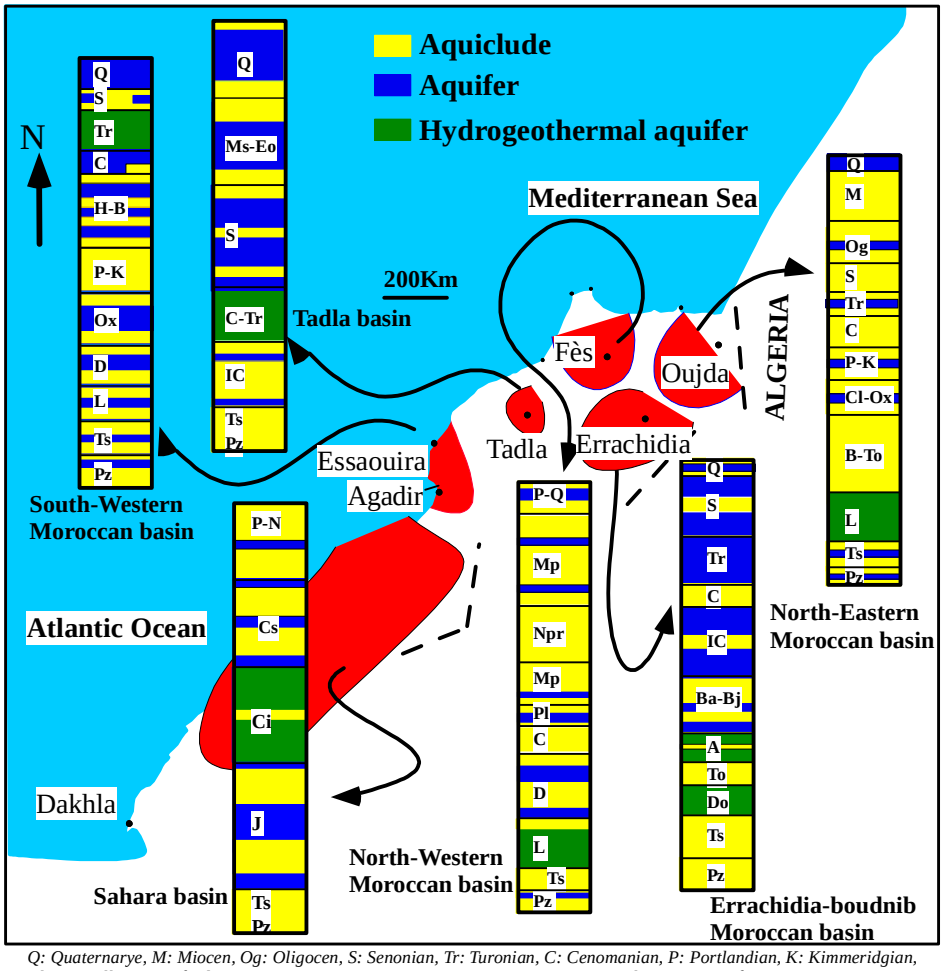


Figure.1. Main structural domains of Moroccco.



Q: Quaternarye, M: Miocen, Og: Oligocen, S: Senonian, Tr: Turonian, C: Cenomanian, P: Portlandian, K: Kimmeridgian, Cl-Ox: Callovian-Oxfordian, B-To: Batonian-Toarcian, L: Liasic, Ts: Triasic, P: Paleozoic, IC: Infra-Cenomanian, Ba-Bj: Bathonien-Bajocien, A: Aalenian, Do: Domerian, P-N: Paleogene-Neogene, Cs: Upper Cretaceous, Ci:Early Cretaceous, J: Jurassique, H-B: Hauterivian-Berriasian, D: Dogger,Ms-Eo: Maestrichtian-Eocene, , P-Q: Plio-Quaternaire, Mp: Miocene post-nappe, Npr: Nappe pré-rifaine, Pl: Pleocene, C: Cretaceous

Figure.2. Main Hydrogeothermal basins of Morocco (Zarhloule.1999)

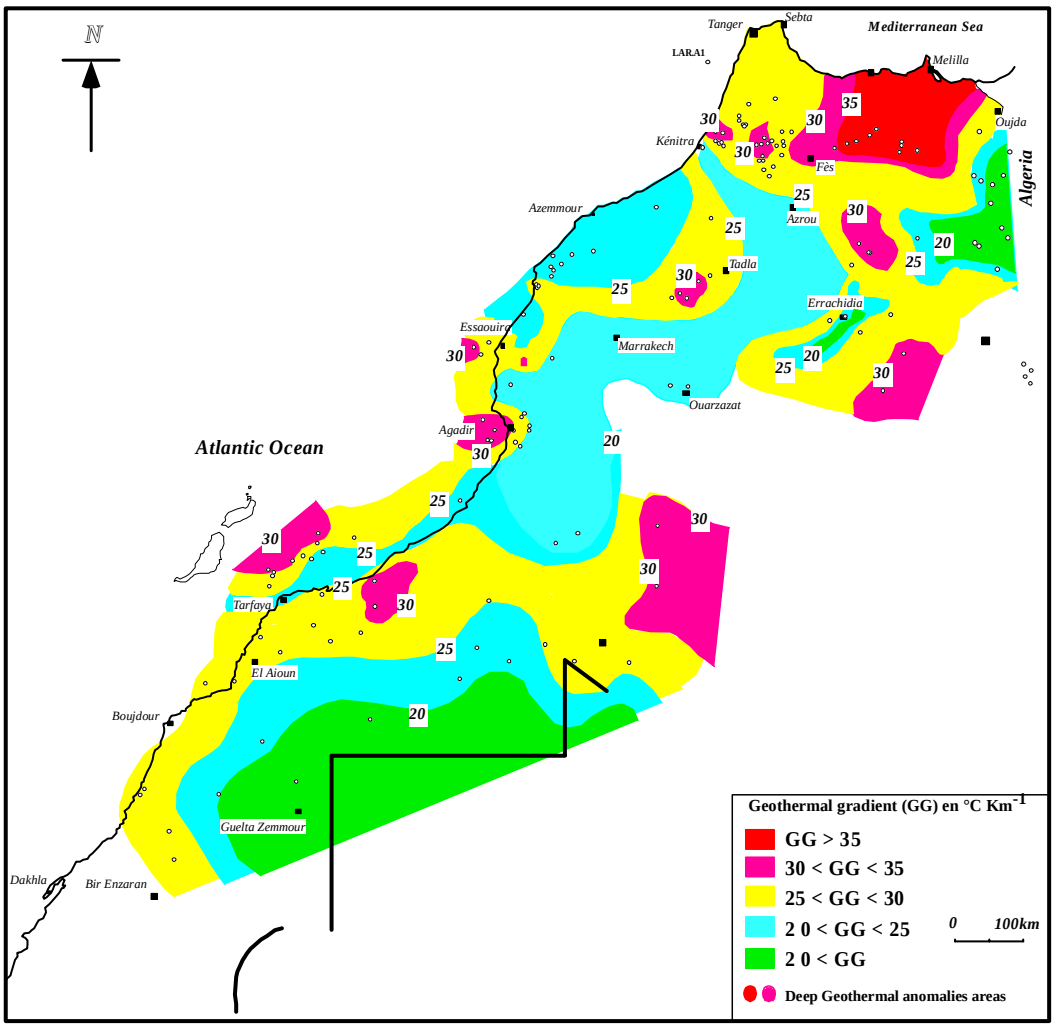


Figure.3. Geothermal gradient map of Morocco

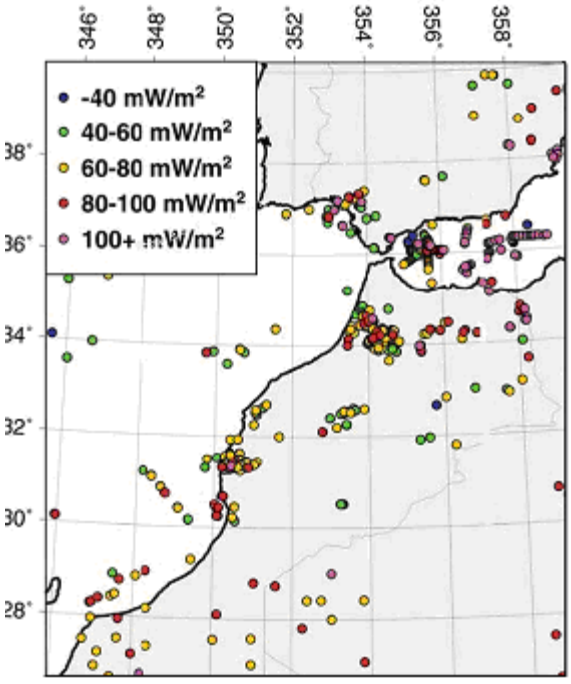


Figure.4. Heat flow Map of Morocco

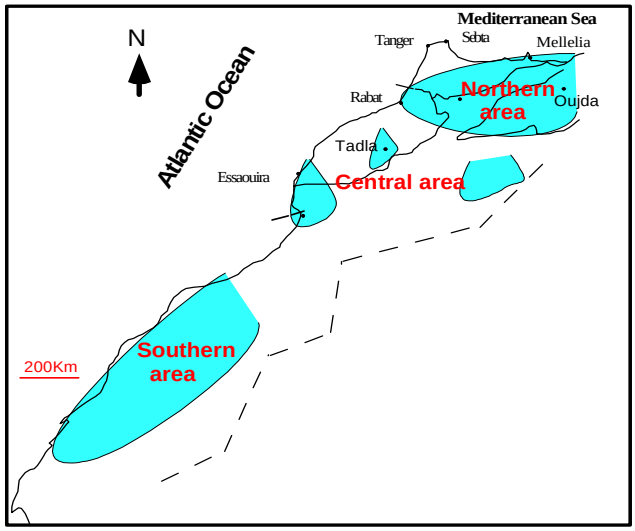


Figure 5. Potential geothermal fields in Morocco

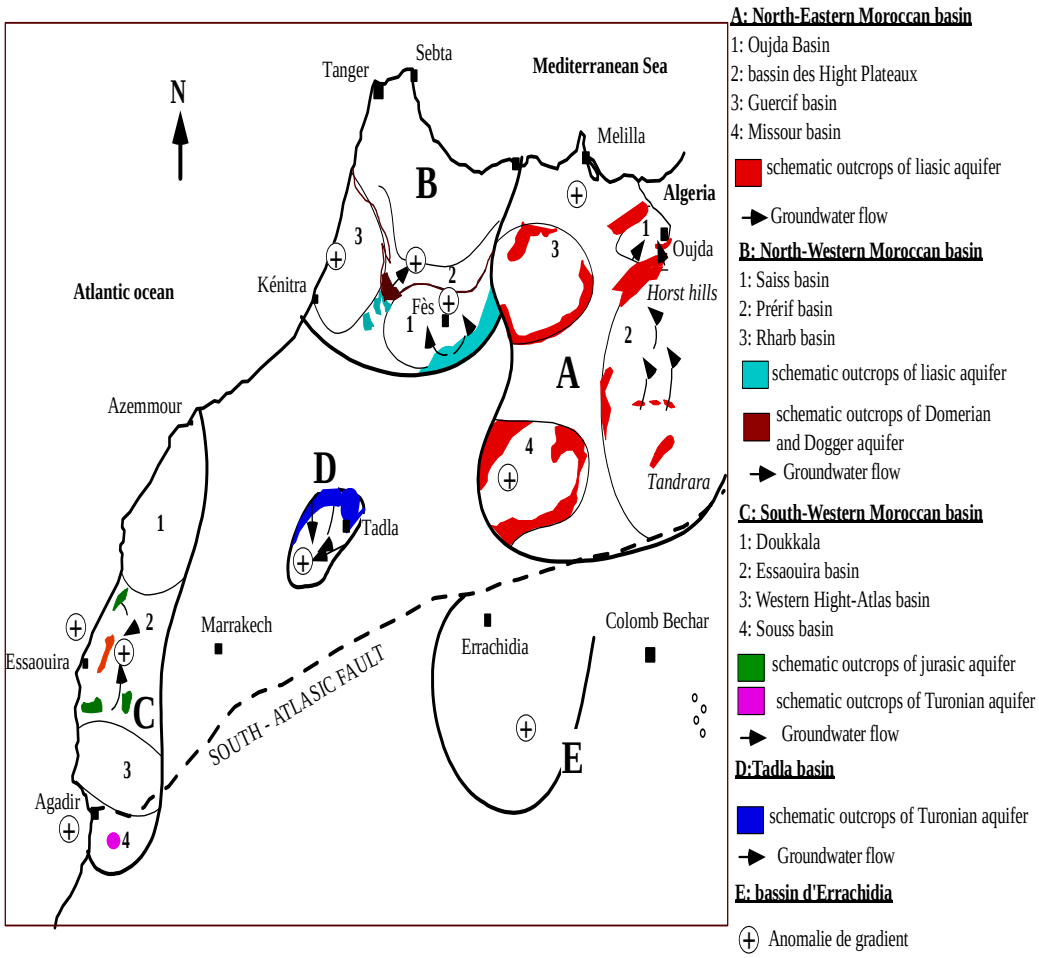


Figure.6. Outcrops of confined aquifers and relation with the flow direction and geothermal anomalies.

5. CONCLUSION

Dating the last forty years, Moroccan researchers have been making great efforts to assess and use the local hydrogeothermal potentialities. Research undertaken showed a country with real potentialities either by its important deep aquifers or by the relatively high values of geothermal gradient and heat flow. The results obtained concerning recognized the critical need for a new Moroccan strategy based on the development of the renewable energies specifically the geothermal energy and opportunities relating to hot water. Also historical data revealed that the geothermal energy could be a very promising alternative of development and that hot water resources are a primary key to the future economic progress of several regions in Morocco. Currently, in Morocco, geothermal water is used for bathing, tourism and washing with little economic return.

Thanks to a consistent database and present competences in geothermics, it is actually possible to establish a strategic route for geothermal energy whose role will be:

- to establish an exhaustive census and an inventory of the national potential;
- to set up a true policy of research in geothermics with the facilities granted to other sectors; and
- to encourage the private sector in the research and development in the geothermic field

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