OVERVIEW OF GEOTHERMAL ACTIVITIES IN TUNISIA

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ABSTRACT

For Tunisia, the oil crises and the decrease in local energy resources, gave impetus to geothermal energy, for potential assessment, exploration and utilisation. 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. It is expected that these efforts of geothermal investigation will continue in the future.

INTRODUCTION

Tunisia is a Northafrican country of approximately 160,000 km² and 9 millions inhabitants. As a developing country the economy is mainly based on agriculture tourism and varied industrial activities. Tunisian energy supply is mainly based on domestic fossil fuel and limited quantities of imported coal and gas. Energy consumption per inhabitant has increased three times (0.2 to 0.6 TEP) between 1970 and 1986, and it can be subdivided as follows: 41% for Industry, 26% for Transport, 15% for Residential sector, 13% for Tertiary sector and 15% for Agriculture. This important increase in energetic needs is unfortunately associated with a real decrease in local ressources. Figure 1 shows the plot of Consumption/Production evolution against time, since 1970.

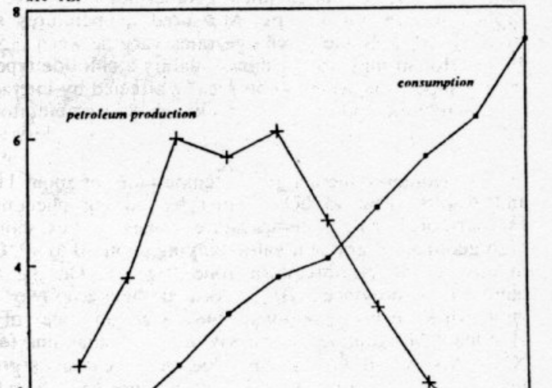

fig. 1: Plot of consumption/production evolution of energy in Tunisia

Thus 1992 is assumed to be the year to start the energetic importation products. Such a statement could explain why the development of alternative domestic energy sources has received important attention since 1980. Numerous actions have been launched to assess and also to develop the potential of geothermal energy utilisation for agricultural and industrial needs (BRGM, 1980; Ben Dhia, 1983; Khalfallh, 1985; AGIP-EATP, 1986; PGN, 1992).

Geothermal clues in Tunisia are varied and numerous. Thanks to the 70 existing hot springs, 230 hydrogeologic wells (shallow temperature values) and the 350 petroleum wells (deep temperature values) it was possible to undertake a synthetic approach of the geothermal gradient and the local geothermal possibilities. However the whole country is not equally covered by data, especially the extreme northern part of it, which did not attract petroleum exploration, despite the fact that it is considered as a promising zone of high geothermal enthalpy (Ben Dhia 1987 and 1998, Ben Dhia et al., 1992; Bouri, 1994). For thousands of years, warm springs have been used for bathing in Tunisia and in recent years, large quantities of hot water have been identified by drilling. This "discovery" is mainly a spin off from groundwater and oil exploration drilling.

Hot groundwater is mainly used for agriculture and in rare cases industrial purposes. Certain arrangements have been made to cool the water by large cooling tower, which is assumed to transfer some 70MW from the geothermal water to the atmosphere, i.e. about one tenth of the total electrical consumption in the country (Stefanson, 1986). A large program to use this energy for greenhouses growing is already launched in Southern Tunisia; results of this operation are so encouraging that the 100 hs surface greenhouses involved in 1985 will reach 3000 hs by 1995 and interest other regions.

Geothermal investigation had already identified more than 10 areas in Tunisia, where low to moderate temperature geothermal fluids (to about 150°C)) are known to occur at depths shallow enough to make them useful as alternate sources of energy. However not all the parts of the country are assessed with equal intensity: for reasons of accessibilty and limited manpower, exploration focused, in the first time, on southern and central parts of the country. For the last three years, geothermal researchs focused mainly on the northern part to estimate its geothermal potentialities.

GEOLOGIC BACKGROUND

Tunisia is located in a strategic area at the intersection of several tectonic plates (African, European and Mediterranean). The structural framework is characterized by a transition between the Saharan plateform in the Southern part of Tunisia, and the alpine folded structures (Atlas domain and Tellian Troughs) in the Northern part. The eastern region of Tunisia is subdivided into five "geothermal provinces" (fig. 2): the Northwestern province (P.I), the northeastern province (P.II), the Central province (P.III), the chotts province (P.IV) and the Southern province (P.V); the creterion used for this operation is a relative geological and structural homogeneity for each province, with the presence and regrouping of hot springs (Ben Dhia, 1983, and 1987). The Triassic and Jurassic outcrops are linked with major structural events

(Zaghouan montains, North-South Axis, Northern domain). Furthermore a relatively good correlation could be established between these outcrops and the hot springs.

Petroleum exploration and hydrologic studies have revealed that potential aquifers may occur within those five provinces (UNESCO, 1972; AGIP-ETAP, 1986; Ben Dhia, 1987).

Fig: 2 GEOTERMAL PROVINCES IN TUNISIA
(Main Triassic and Jurassic outcrops)

Province I : Geology of this Northern region is greatly affected by the overthrust of the alpine nappes, dated as upper Miocene, and the thick deposit of sandy layers "Nummidian formation". The hottest springs occur also within a discharge rate ranging between 5 and 40 l/s; there are also few granitic and volcanic rocks outcropping (10 MY of age approximately). This region is geologically related to the Toscan Italian province, and so is expected as potentially high energetic zone. This region is assessed by data and investigation programs are rather superficial; aquifers of geothermal interest may occur within Triassic and Jurassic formations (Ben Dhia, 1983) of Hairech and Ichkeul mountains, provinding most part of hot springs.

Provinces II and III : They constitute the "Atlas domain", and are separated from the province I by the "Diapirs zone". Main structural features of the region show three major directions: (a) North-South Axis, (b) SW-NE Atlas folds and (c) NW-SE Quaternary grabens. Overlying the Triassic evaporites is a thick sedimentary series with alternating limestones, shales and sandstones, from Jurassic, Creatceous and Tertiary formations with frequent lateral lithological variations. These rocks represent both marine and continental sedimentary facies and are relatively investigated either by surface or subsurface survey. Many of the layers of sands, sandstones and limestones have been defined as potential hydrothermal objectives (AGIP-EATP, 1986; Yangui et al., 1989).

Province IV : The "Chotts province" is structurally known as "Tebaga Anticline". This most important E-W structure in Tunisia, constitutes a transition between the Atlas and the Saharan domains. Sedimentary, Jurassic and Cretaceous rocks represent the most particular occuring layers, especially early Cretaceous with more than 4000m of Sands and Clays, constituting the extreme Northern part of the most important aquifer of the whole North African Sahara.

Province V : This Southern province countains the biggest sedimentary basin in Tunisia, with the thickest and widest deep aquifer system. Numerous exploration oil wells have been drilled in this region, providing quantities of indications on the underground layers. The province covers almost half of the country, with about 80,000 km² of predominately arid lands. The province is located in the Northern part of the stable Saharan platform. Tectonic features are dominated by the monoclinal trend of the present layers, diping gently from East to West.

GEOTHERMAL POTENTIALITIES OF TUNISIA

As developing country, one of the most urgent priorities of Tunisia is the discovery and development of groundwater resources. Geothermal investigation adresses both these development problems.

Several geothermal studies and projects have been carried out by different teams during the last 10 years as: (a) Office National des Mines (O.N.M), (b) Etabissements tunisiens des activités pétrolières (E.T.A.P), (c) Ecole Nationale d'Ingénieurs de Sfax (E.N.I.S) and (d) Agence de Maîtrise de l'Energie (A.M.E), with the collaboration of French, Italian, American, Belgian and Canadian experts. Geothermal indications have been obtained thanks to the numerous (350) exploration petroleum wells covering the most part of the country, the hydrogeologic wells (230) interesting mainly the Northern zones and the hot springs (70) interesting the five provinces.

Main basins in Tunisia have different geological and hydrogeological conditions. A situation that leads to a variety of cold, warm and hot water occurences. In some basins, water movement may be hindered by impermeable clay layers. In other basins, groundwater lies at great enough depths to be naturally heated, especially where geological conditions enable a natural hydrothermal convection system to become established.

For the province I, the lack of subsurface data has limited the shallow geothermal investigations to the existing hot springs (Meddeb, 1993) and hydrogeologic wells (Bouri, 1994). Several chemical geothermometers have been applied for 28 hot springs. Measured temperatures range from 21 to 73°C and discharge rates vary between 0.5 and 40 l/s. Hot springs waters shown mainly a chloride type and their composition seems to be greatly affected by interaction with evaporatic and dolomitic rocks which are ubiquitous in Tunisia.

Geothermometers give a tempertaure of about 110°C and waters seem to be affected by mixing phenomena. Furthermore, shallow temperature values studies shown a high geothermal gradient value ranging from 80 to 90°C/km mainly in the Northwestern zone (fig. 3). On the other hand, this province (I) is located between two high geothermal energy regions; the Algerian one of the Hammam Meskoutine for the SW and the Italian one for the NE. This would justify the hope that local underground temperatures could be much higher than presently found.

Province II shows also several hot springs along the Zaghouan mountains, with temperatures more than 60°C and a discharge rate ranging between 40 and 60 l/s. Regional geothermal gradient ranges from 30 to 50°C/km (fig. 4).

Heat flow is higher than 90 mWm⁻² (Ben Dhia, 1988; Lucazeau and Ben Dhia, 1989; Bouri, 1994). Potential aquifers may occur within Jurassic, Cretaceous and Tertiary formations, with significant flow rates. This province appears as one of the most promising in geothermal energy especially in the low form.

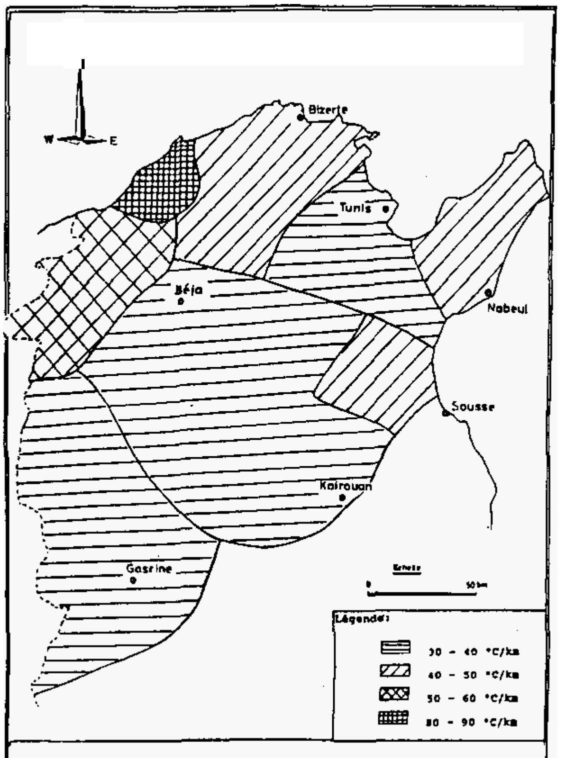

Fig. 3: Regional geothermal gradient map of Northern Tunisia

Provinces III and IV show ,also some interesting clues of geothermal potentialities, a recent (1988) shallow well in Gasrine produced, unexpectedly, water of 50°C at 50m of depth with a flow rate of 40 l/s and salinity lower than 2 g/l. Geothermal gradient ranges between 25 and 45 C/km and heat flow between 80 and 120 mWm-2 in the eastern offshore part (Lucazeau and Ben Dhia, 1989).

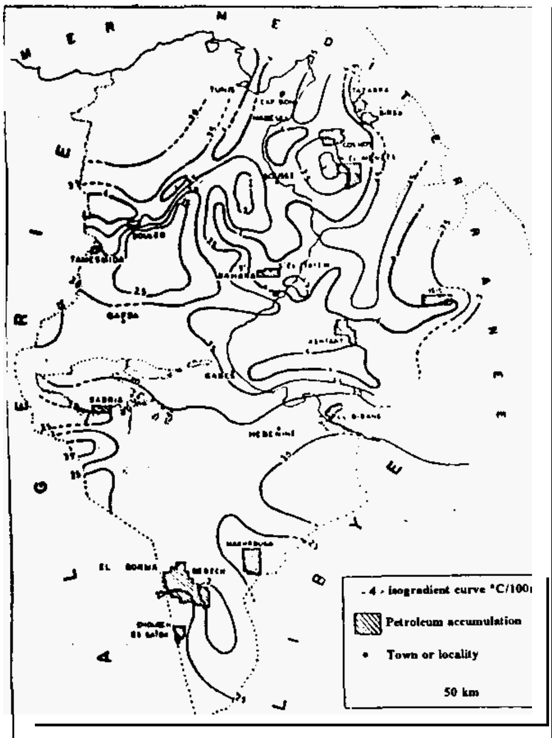

Fig. 4 DEEP GEOTHERMAL GRADIENT MAP OF TUNISIA
(Ben Dhia, 1988)

Province V shows a very interesting basin with a geothermal gradient varying between 25 and 35 °C/km and a heat flow density between 80 and 140 mWm-2. The high values have been interpreted as due to hydrodynamic effects (Ben Dhia, 1990) in the natural discharge water tables areas.

MAIN GEOTHERMAL ACTIONS CARRIED OUT IN TUNISIA

Several attempts have been made in Tunisia to assess the geothermal energy potential. Various programs of different scales and extend were made from the data compilation for the whole country (Ben Dhia, 1983; AGIP-ETAP, 1986; Lucazeau and Ben Dhia, 1989, Ben Ohia el al., 1993; Meddeb. 1993 and Bouri, 1994) down lo the small scale local studies (Yangui et al., 1989). Main actions can be summarized as follows:

- in 1979: programme to identify main geothermal areas in Tunisia, by focusing on the Southern province (Ben Dhia, 1983),
- in 1980: first attempt of the greenhouses heating, there are now handreds of them in the South,
- in 1984: - creation of the National Agency of Energy (AME)
  -programme lo assess the Central Tunisia potential users (AGIP-ETAP, 1986),
- in 1986: first project to estimate the high flow density (Lucazcau and Ren Dhia, 1989),
- in 1987: some localized studies are undertaken lo estimate few reservoirs potential (Brahim, 1989; Yangui, 1989) in Cenrral and Southern Tunisia,
- in 1988: some space heating attempts are launched by the AME for hotels as well as "fishgrowing",
- in 1990 programme to assess the Northern Tunisia potential in geothermal energy and potential users (PGN, 1992),
- in 1991: some localized studies are undertaken lo estimate the hydrogeothermic potentialities in the Northern zones of the country (Meddeb, 1993; Bouri. 1994).
- in 1992: first project to estimate the hydrogeothermic potentialities in the North of Tunisia,
- in 1994: project to estimate the hydrogeothermic and petroleum potentialities of the Eastern part of Tunisia (ETAP-ENIS, 1994)

CONCLUSION

Ddting the last decade, Tunisia researchers and authorities made real efforts lo assess and use the local geothermal potentialities. Teams working on geothermal projects know real reenforcement in fund, equipement and human supports.

Tunisia shnws a deep geothermal gradient ranging between 25 and 45°C/km and a heat flow density varying between 80 and 140 mWm-2, with occurence of numerous hot springs and important deep aquifers; thus it could be considered as a real geothermal promising country. However. the present interest is focused on the double use of hot water for both current human needs and enthalpy.

Further attention is needed toward a better knowledge and utlisation of this kind of energy, especially in the Northern Tunisia where high enthalpy is expected to be found.

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