Preliminary Atlas of Geothermal Resources of Algeria

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Abstract. Many geothermal reservoirs have been identified in Algeria. The most important one is the Albian geothermal reservoir which extends on 600 000 km2 in the Sahara region. Large part of this reservoir is confined. Considerable amount of water which temperature ranges from 40°C to 80°C is obtained by exploiting wells. The total heat discharge is estimated to 800 MWt.
The gathered data from oil and water drillings were used to draw different maps as the geothermal gradient, the pH, and the reservoir depth.
In the North, the geology is more complex and reservoirs boundaries are not defined.
Hydrothermal reservoirs are located in sedimentary rocks as limestone and dolomite, at 600m to 1000m depth. Many hot springs emerge trough deep faults generating a total heat discharge of about 188 MWt. The calculated subsurface temperature does not exceed 123°C.
In this region, data coverage is limited; maps of geothermal gradient and the main water characteristics have been drawn as well.

Introduction

Few geothermal projects have been conducted in Algeria. The most recent one was a subregional exploration where the Algerian SONELGAZ and the Italian ENEL electric companies were involved (SONELGAZ, 1982). The project carried out in the North East of Algeria was aimed to identify eventual high temperature geothermal reservoirs for electricity production. Deep geothermal reservoirs of medium temperature were expected at more than 2500m depth. More detailed studies are required to confirm these assumptions.
Many geothermal reservoirs of low temperature exist in the Northern Algeria. The main geothermal indicators are the numerous hot springs, and recent volcanic activities. Nevertheless, these reservoirs are not well defined because of the scarcity of data and the complex geology.
The large sedimentary basin of the Sahara constitutes the Albian geothermal reservoir which extends on more than 600 000 km2.
Gathering of surface and subsurface data is required for the assessment of geothermal resources and for drawing atlas maps. In our case, data were scattered throughout different companies of oil prospecting, hydraulics, mining and tourism. Oil drillings data have been used to calculate geothermal gradient. Water chemistry data were collected from theses, publications and internal reports. To update geochemical data, some hot waters have been sampled and analysed in the mining company laboratories in 2003.
The atlas includes geothermal gradient maps for selected areas, an inventory of the main hot springs in the North, temperature and depth maps of the Albian reservoir of the South, and a summary of the main geological and geothermal features.

Main geological features

The mountains belt called the Saharan Atlas separates the country into two major zones: the northern zone which is still tectonically active and the stable Saharan platform in the South.
The first zone comprises the Tellian Atlas in the North and High Plains in the South.

The Tellian Atlas is an orogenic belt constituted with superimposed nappes which derive from three major paleo-geographic domains (Wildi, 1976): the "Domaine Interne" which consists of a crystalline crust with a Palaeozoic to Tertiary cover and the calcareous belt which constitutes the "chaine calcaire" and the "nappes telliennes" (Mesozoic to Lower Miocene), the domain of the "Nappes de Flyshs"and the "Domaine Externe" constituted with Mesozoic to Tertiary evaporates and carbonates.
Units of the "Domaine Interne" are overlaying the "Nappe de flyshs", whereas the Nappe de Flyshs" is overlaying units of the"Domaine Externe".

This last alpine orogenic phase has been followed by magmatic activities along the coastal area during the Miocene.
The High Plains constitute the foreland (autochthonous) of the Alpine belt in Algeria. They are characterized by tabular structures. The main geological formations are limestone, marls and dolomites. These formations of Jurassic and Cetaceous become more detritic at the Lower Miocene (G. Duée, 1973).
The Saharan Atlas belt is made with a series of very thick and folded geological structures where Jurassic and Cretaceous formations such as dolomites, limestone and marls are dominating.
The Sahara platform is a tectonically stable zone. Large sedimentary basins constitute hot water and hydrocarbon reservoirs.

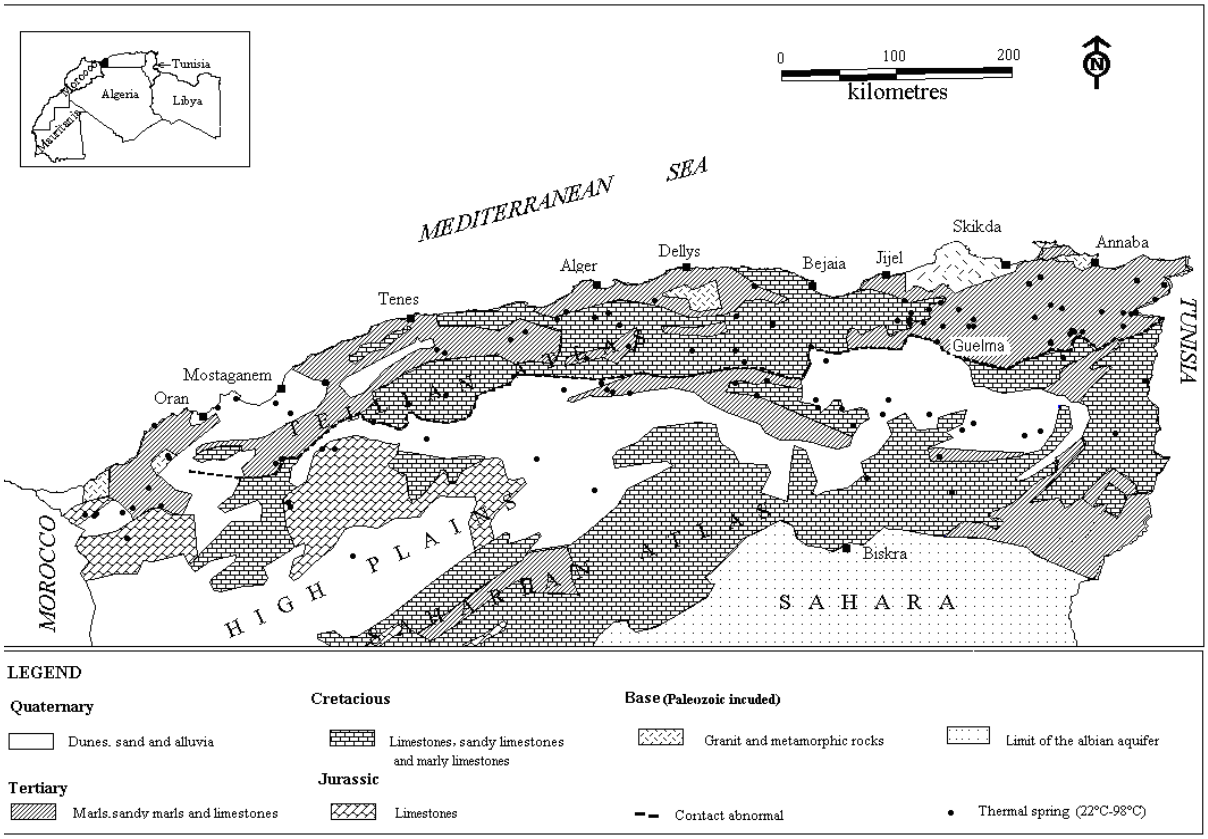

Figure 1: Geological sketch map and hot springs location.

Geothermal reservoirs and resources

Units of the "Chaine Calcaire", the calcareous layers of "nappes telliennes" and limestone and dolomites of Tlemcen and Saida, are the main geothermal reservoirs of the northern region. These reservoirs are generally located at 500 to 1000m depth in the West and are deeper in the Eastern region (1000m to 2600m). These geothermal reservoirs are generating many hot springs (Fig. 1). The temperature of hot springs and wells ranges from 30°C to 98°C.
The total heat discharge is estimated to 188 MWth. This heat discharge is concerning the western region and part of the eastern one.
Geothermal reservoirs of the North are not well defined. More exhaustive and detailed assessment is necessary to characterize these reservoirs and to have a more precise idea on the geothermal reserves and possibilities.
In the Sahara, the Albian geothermal reservoir has been more studied. The availability of data has allowed drawing up different maps such as temperature map, reservoir depths map, thickness map, pH map and TDS map.
This reservoir is confined in its northern part where it deepens to about 2600m. The water temperature mean value is about 60°C. The maximum water temperature is 80°C. The total flow rate from exploiting

wells is over 10m3/s which is equivalent to a heat discharge of 800 MWth (Fekraoui A. and Kedaid F.Z, 2005).

Chemical characteristics

About 100 water samples have been analysed. Sample location maps and facies maps have been drawn separately for the central, the eastern and the western regions.
The eastern region waters can be divided into three chemical groups: Chloride waters, sulphate waters and bicarbonate waters.
In the central zone, three types of water are dominating: Na-HCO3 waters; NaCl - CaCl waters and Na-SO4 types.
Geothermal waters in the western zone are of primary type i.e. including three facies:
Sodium-Potassium –Magnesium bicarbonate waters; Na-(Cl, SO4) and Na-HCO^3 waters.
The subsurface temperature has been calculated using classical geothermometers. The quartz geothermometer which is the most adequate gives a maximum temperature of 123°C.

Geothermal gradient maps

Geothermal gradient maps have been drawn for selected areas in the northern zone. The petroleum company SONATRACH has drilled many holes for hydrocarbon prospecting in some sedimentary basins. Measured Bottom-hole temperature (BHT) of 127 drillings has been used to draw the gradient maps. BHT data have not been corrected. Measured gradient values in Guelma - Souk Ahras region (East) have been used too. Positive gradient anomalies are observed at Guelma region (Hammam Meskhoutine spring, 98°C, is located in this region). The geothermal gradient can reach 60°C/Km.
Gradient maps of the Central and Western zones show also positive anomalies where gradient values are two; tree or four times greater than the normal value.
According to the relationship between water temperature and depth, the geothermal gradient for the Albian reservoir is about 3°C/100m.

Heat flow map

A heat flow map has been established and published by Takhrist D. and Lesquer A. in 1989. Different oil wells data, such as BHT, temperature of fluids in drill stem test and rock porosity have been used to evaluate the heat flow. High heat flow values are associated with the Sahara basins (average of 82 mW/m^2). The Hoggar region is characterized by a very high heat flow values (90-130 mW/m2). High values are also registered in the northern basins.

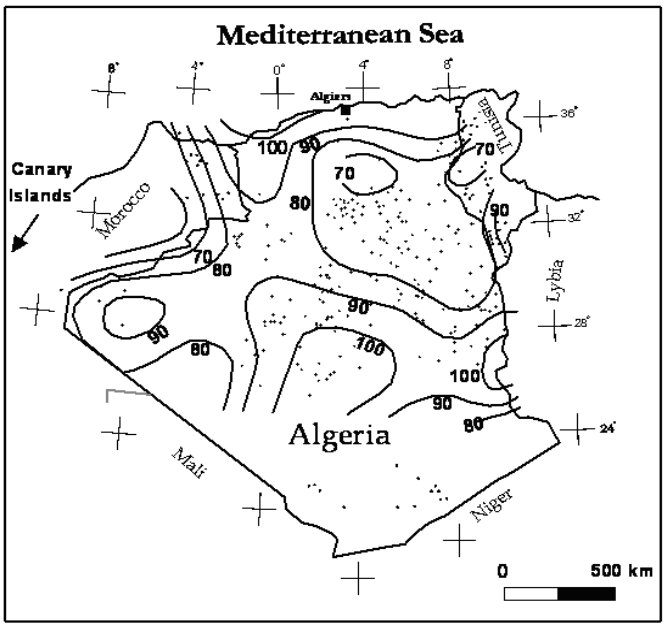

Figure 2: Heat flow map of Algeria. Units are in mW/m2.
230 oil wells with depth 500m to 5,500m

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