Proc. 6th NZ Geothermal Workshop 1984

GEOTHERMAL PROSPECTS IN THE DJIBOUTI REPUBLIC

Abdou Mohamed Houmed

Geothermal Institute
University of Auckland*

ABSTRACT

Four major areas with geothermal prospects have been found in the Djibouti Republic. One of the areas is the Assal Rift, an active rift associated with present-day volcanism; the rift constitutes the westward extension of the Gulf of Tadjoura Rift. The other major areas are associated with depressions bounded by active faults parallel to the Assal Rift.

The first exploratory well drilled in the Assal Rift was a discovery well (heal-1) which produced hot brine. It is likely that other brine systems also occur in the Assal Rift. Deep exploration drilling will commence soon in another geothermal area, the Hanle area, to find out whether hot water (i.e. non-brine) systems exist which might be more suitable for electric power generation.

INTRODUCTION

Djibouti Republic (23,000 km^2) is situated in the NE part of Africa on the Red Sea; it has a common border with Ethiopia and the Somali Democratic Republic. It has a population of about *0.45* million.

The country has mountainous relief, two thirds are covered by volcanic rocks and Quaternary sediments. Volcanic rocks are mainly basalts together with rhyolitic rocks, pyroclastics, and trachytes. Only in the southern part of the country, near Ali Sabieh, one finds outcrops of sedimentary rocks of Jurassic (Kimmeridgian) and probably Cretaceous age. These rocks consist of compact sandstones, which contain about 90% of quartz, massive limestones, silicified limestones and marls.

The tectonic setting of the country is affected by three major tectonic structures associated with:

1) active faulting (separation) in the Gulf of Aden,
2) active ocean spreading of the Red Sea, and
3) active faulting (separation) in the Afar Depression, an extension of the East African Rift.

*Present address: I.S.E.R.S.T.
P O Box 486,
DJIBOUTI

Tectonism, volcanism and geothermal zones in Djibouti

The Separation of the African continent and the Arabic Peninsula started in the Eocene which created both the Red Sea and the Gulf of Men and its westernmost extension, the Gulf of Tadjoura (see Fig 1). This separation can be explained in terms of a translation and an anti-clockwise rotation of the Arabic Peninsula with respect to the African continent. The direction of tectonic features caused by separation is NNW-SSE for the Red Sea and about E-W to ESE-WNW for the Gulf of Men and the Gulf of Tadjoura (see Fig 1). The tectonic features caused by the separation of the East Africa Rift Valley is about NNE-SSW. All these directions can be recognised in the tectonic map of Djibouti (see Fig 1 and Fig 2) although a general NW-SE strike direction appears to be dominant in the W part of the country where *most* of the geothermal prospects are located (see Fig 3).

Analysis of seismic data indicate that the crust beneath Djibouti is thin. Magma has intruded the crust along the axis of separation in the Gulf of Tadjoura and also. further to the vest. The most recent basaltic fissure eruption occurred at Ardoukoba (near Lake Assal) in November 1978.

There are at least 4 larger and 4 smaller areas with geothermal prospects, namely:

1. Lake Assal area, (with the separate area of Allol-Sakolol (lb) in the NW and the Goubbet area (lc) in the E),
2. Gaggade area,
3. Hanle area and
4. Lake Abbe area.

Areas with smaller geothermal manifestations are:

5. Arta,
6. Dorra
7. Tadjoura, and
8. Obock.

The four major areas are associated with depressions infilled by recent sediments and salt deposits. Common surface manifestations are hot springs and fumaroles; the intensity of visible thermal activity is indicated in Table 1. Most geothermal areas have been explored either by reconnaissance surveys or by more detailed surveys. The present state of exploration is summarised in Table 1. Geothermal exploration by the Bureau de Recherches Géologiques et Minière (BRGM, France) was started in 1970 in the Lake Assal area. A reconnaissance survey of all other thermal prospects listed in Table 1 was undertaken in 1980 by AQUATER (Italy) and the Djibouti Scientific Research Institute (I.S.E.R.S.T.).

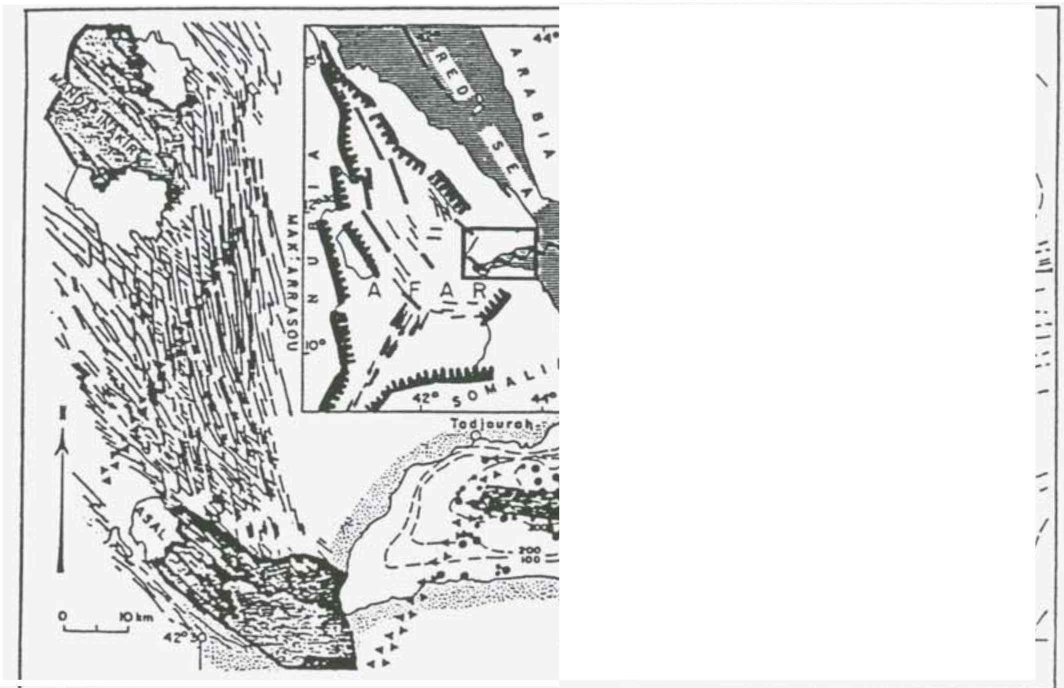

Fig 1: Tectonic structure of the Gulf of Tadjoura and surroundings

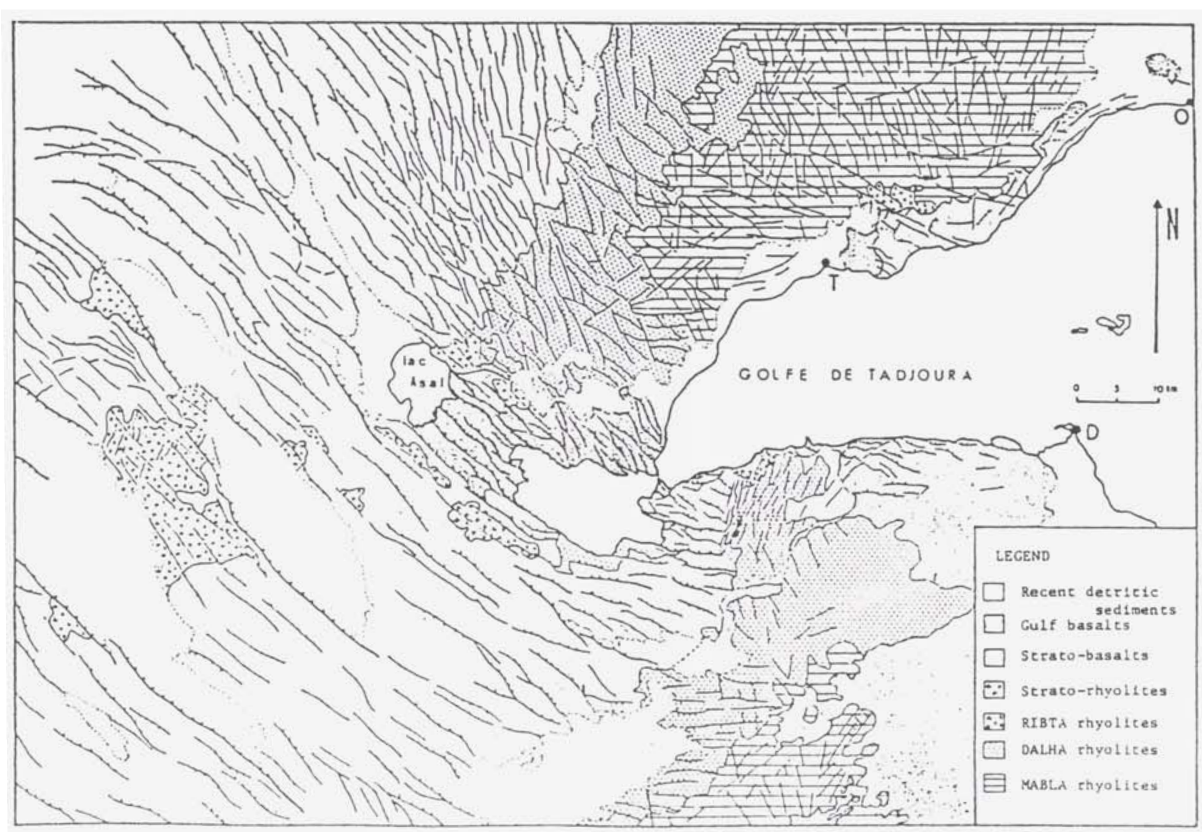

Fig. 2: Geological - tectonic map of Central Djibouti (taken from H.J. Varet (Ed.) (1975)).

Table 1: Present stage of exploration and intensity of surface manifestations of geothermal prospects in Djibouti (the degree of coverage or detail of each survey is indicated by crosses)

	EXPLORATION STAGE				SURFACE MANIFESTATIONS	
Area	Geology	Geochem.	Geophys.	Explor. Drilling	Hot Springs	Fumaroles
1a Lake Assal	++	++	+++	++	++	+
1b Allol-Sakalol	+	+			++	+
1c N Goubbet	++	++	++		+	+
2 Caggade Area	++	++			+	+++
3 Hanle	++	++	++	+		++
4 Lake Abbe	++	++			+++	
5 Arta	++	++	++			+
6 Dorra	+	+				+
7 Cadjoura	+	+			+	+
8 Obock		++			+	

In 1975 two deep exploratory wells were drilled in the Lake Assal area which will be discussed in more detail below. An exploratory hole of intermediate depth (460m) was drilled in 1981/82 in the Hanle Area where deep drilling will commence in November 1984.

The Lake Assal - N Goubbet geothermal province

As can be seen from Fig 3, the Lake Assal area, together with its NW extension, Allol-Sakolol, and its E extension, the Goubbet at Kharab Bay, forms the largest geothermal prospect area in Djibouti. The area is bisected by the Assal Rift whose axis shifted from an E-W trend in the North Goubbet area to a NW-SE trend in the Lake Assal area. The Assal Rift occurs within a thick (≃1000m) sequence of Pliocene Trapp basalts which have been cracked in the axial part of the rift which is also associated with active volcanism and with seismicity. Arching of the rift has taken place, presumably as a result of shallow magma intrusion. The Assal Rift shows similarities to features commonly observed over oceanic spreading centres.

The rift starts in the shallow, 20 km long Goubbet al Kharab Bay and swings to the NW towards Lake Assal which lies at present 155m below sea level. Lake Assal is separated from Goubbet Bay by a 12 km long silt strip with recent volcanism (Ardoukoba eruption in 1978).

Assal Lake is the lowest point of the African continent. It is now fed by sea water which moves towards the lake along fractures in the axial strip of the Assal Rift. This infiltration, balances in part the large evaporation ($6 \times 10^6 m^3$/year) taking place at Lake Assal. Some groundwater might also drain into Lake Assal; it has been postulated that most groundwater to the W of Lake Assal is supplied by infiltration from the Awash River which terminates in Lake Abbe. Recharge of most major thermal prospects might therefore be associated with this inferred regional groundwater flow from Lake Abbe to the Gulf of Tadjoura. Infiltration by meteoric waters is probably nil, although some net infiltration might occur in the mountainous areas further to the north.

The Assal Region is potentially the most important area for geothermal development since a geothermal reservoir has already been discovered here, but also because of the mineral resources represented by the [illegible]

around the lake. Lake Assal covers about 50 km², the brine making up the lake is almost saturated with respect to minerals (mainly NaCl); the maximum depth of the lake is 40m. A salt layer, about 60m thick, lies to the NW of the lake and covers an area of about 65km².

A 20 to 40m thick layer of gypsum of pure quality occurs at the margin of the salt layer and is suitable for exploitation.

Geothermal exploration of the Lake Assal area was started in 1970 by BRGM and lead to the drilling of 2 deep exploration wells in 1975. Well Assal-1 was a discovery well, the important data for both wells are summarised in Table 2.

Table 2: Summary of exploratory wells Assal-1 and Assal-2

Well Nr.	Total depth (m)	Max. temp. (°C)	Massflow (t/h)	Salinity (g/kg)
Assal-1	1146	258	135	128
Assal-2	1554		0	n.d.

Assal-1 well was tested during one week in 1975, the mass flow of 135 t/h consisted of a mixture of steam and brine; the steam flow rate was equivalent to 1.5 to 2 MW(e). Further work in the Lake Assal prospect was started again in 1980 by BRGM with some support from UNDP.

The prospect has now been outlined in great detail (Correia et al., 1983) by geophysical methods (electric, magnetotelluric, gravity and magnetic surveys). It appears that both deep wells were drilled near the edge of a geothermal reservoir with Assal-1 lying inside and Assal-2 outside the reservoir. The power potential of the field was estimated to be of the order of 300 MW(e) if thermal fluids can be produced economically. Experience in the Salton Sea Area (USA) has shown that production of hot brines with a mineralisation similar to that of Assal-1 can be maintained if proper allowance for [illegible]

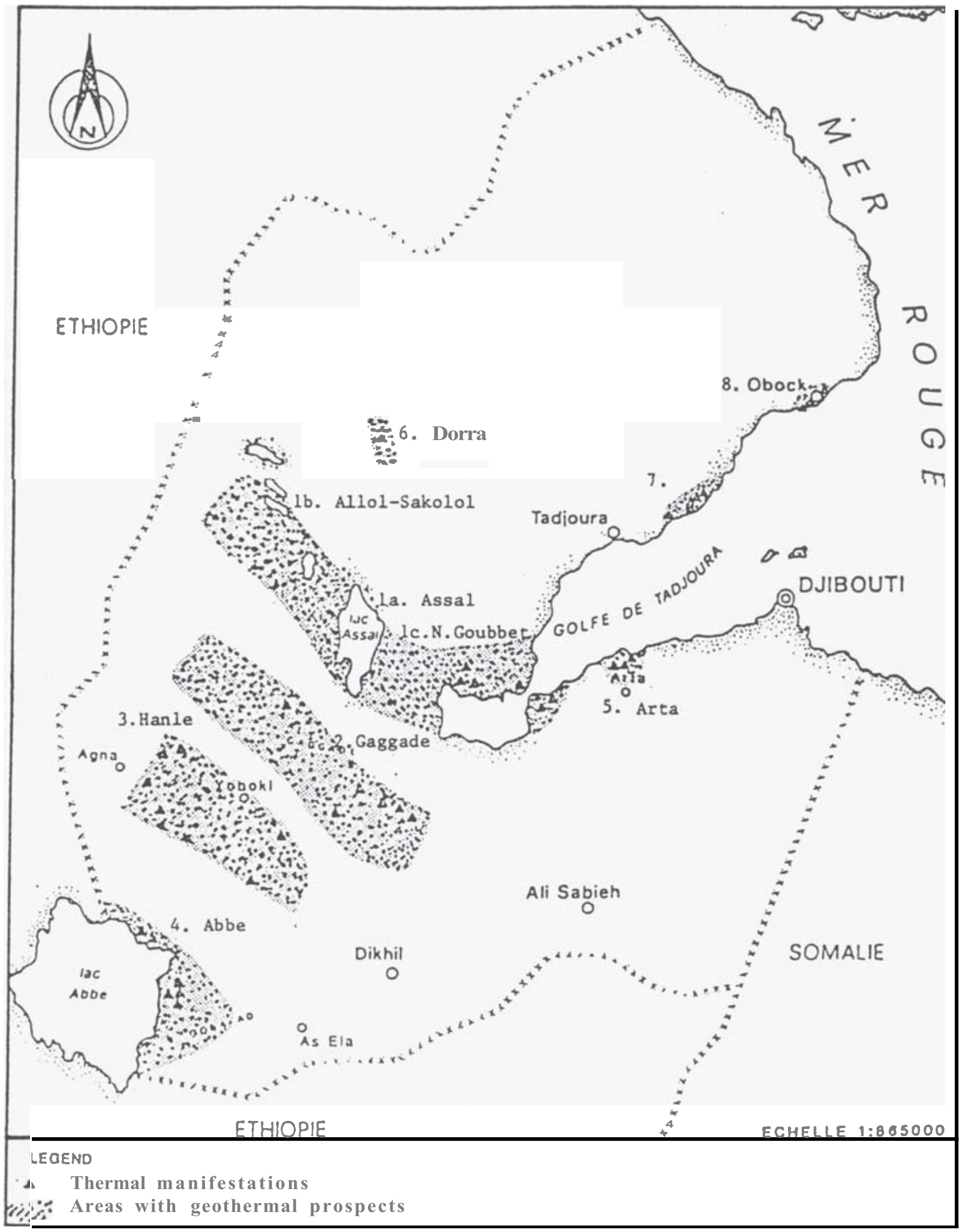

Fig 3: Areas with geothermal prospects in the Republic of Djibouti

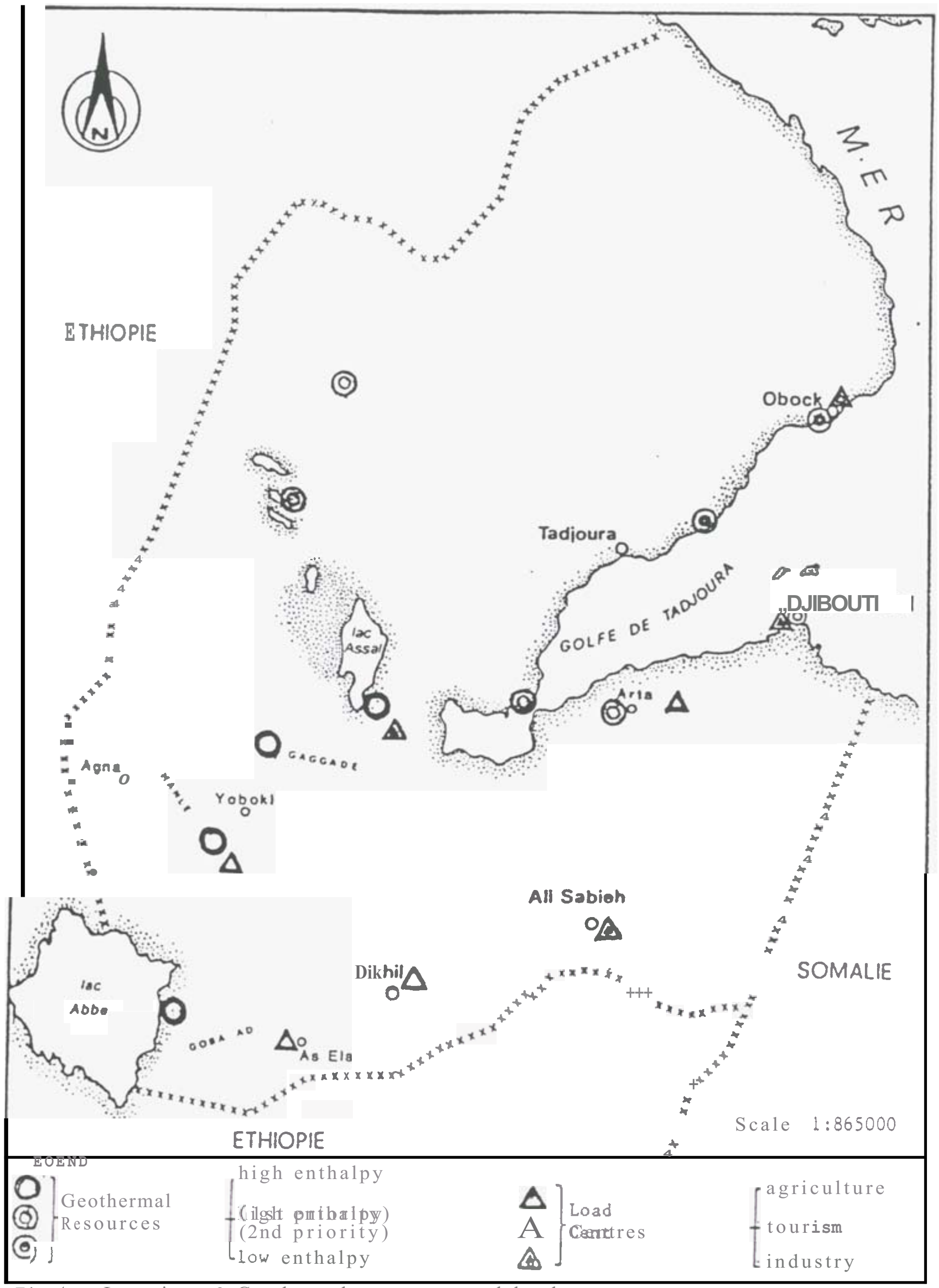

Fig 4: Location of Geothermal resources and load centres

Energy demand and possible role of geothermal energy

Electricity production in Djibouti is presently provided entirely by diesel power plants, the production was 119 GWh in 1982. The country completely depends on fuel imports to satisfy the present energy demand; the fuel bill for generating electricity was $US15 Mill. in 1982. It has been predicted that the demand for electricity will reach about 240 GWh by the year 1990, and 500 GWh by the year 2000. Cost of imported fuel will therefore increase and provide an increasing burden for the country.

In order to overcome this problem, the Government of the Republic of Djibouti has decided to diversify its energy base by promoting development of its geothermal resources. The geothermal prospects, however, are not in the vicinity of load centres (see Fig 4). If economic production of geothermal fluids will be feasible, the electricity demand of the country could be met by one or two smaller geothermal

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