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Reykjanes high-temperature field

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REYKJANES HIGH-TEMPERATURE FIELD

INTRODUCTION

The Reykjanes geothermal field is one of several high-temperature areas found on the Reykjanes peninsula. Wells there have the highest temperature (295°C), wellhead pressure (30-40 bar) and output (8-16 kg/s of high press. steam) and are thus one of the best sources of geothermal steam in Iceland. The scientific exploration of Reykjanes started over fourty years ago and the area has been of considerable geological interest in the past. Some 184 scientific papers and reports have focused on this area and the geothermal effort there. The field has been in more or less continuous exploitation for 20 years and the cumulative production has been 40 million tonnes of fluid without measurable draw-down in the reservoir. All indications are that the field can sustain substantial production but a reservoir study to has not yet been carried out for estimation of the reservoir yield. At present there is only one production well and additional wells will have to be drilled to supply new users.

GEOLOGICAL OUTLINE

The Reykjanes high-temperature system is located on the westernmost tip of the Reykjanes peninsula in Southwest Iceland, where the Mid-Atlantic Ridge emerges above sealevel (fig.1) Along the sub-aerial extension of the spreading axis there is a narrow east-west trending micro-seismic zone below about 2 km depth, which is interpreted as the plate boundary. The plate boundary in the upper 2 km of the crust is represented by NE-SW en echelon fissure swarms, which are arranged approximately at right angle to the spreading direction. The Reykjanes high-temperature field is located within the Reykjanes fissure swarm.

The main surface geological features and well locations are shown in figure 2. Most of the rocks on surface are glacial hyalocalstites and postglacial lava flows of basaltic composition. Active surface thermal manifestations on surface cover some 0.5 sq. km but about 2 sq. km if fossil alteration is included.

Resistivity survey indicates that the upflow zone covers an area of about 1 sq. km down to a few hundred meters depth but becoming more extensive at deeper levels (fig.3).

A total of 9 wells have been drilled and the location of these are shown in figures 2 and 3. A geological cross-section along line A-B (fig.2) is shown in figure 4. The succession consists mainly of interglacial lava series intercalated by hyaloclastite formations and sediments (mostly reworked tuffs). Evidence from well no. 9 suggests that basaltic intrusions appear below about 900 m depth.

A detailed study on the relation between aquifers and geological features encountered in the reservoir has not been undertaken, but it is assumed that permeability is related mostly to sub-vertical tectonic fractures and fractures along intrusive boundaries.

A comparison between hydrothermal alteration and probable formation temperature indicates a general conformity in the reservoir except in the southwest part of the field (around well 6) where measured temperatures are notably lower than indicated by the hydrothermal alteration and thus suggesting an incursion of cooler seawater into the upper part of the reservoir (<600 m depth).

GEOTHERMAL BRINE

The reservoir water in the Reykjanes high-temperature geothermal field (table 1) has practically the same salinity as seawater and is assumed to have originated from seawater. The reservoir water appears to be stratified as the salinity varies somewhat from one aquifer to another. The range in chloride concentration of deep-water is from about 18100-19200 mg/l, which is about the same as in the cold saline groundwater below the Reykjanes peninsula. The chemical characteristics of the brine indicate an origin from seawater which has reacted with basaltic rocks at 100-300°C. Magnesium and sulfate are extremely depleted relative to seawater concentrations whereas calcium, potassium, silica, manganese and iron are enriched relative to seawater. Aluminum, chromium, copper, zink, arsen, silver, cadmium, antimony, mercury and lead have been analysed in a few samples although not shown in table 1. The concentration of these elements is low compared to geothermal brines elsewhere in the world and in emanations from seafloor geothermal vents at ocean ridges.

The geothermal water from the production well RN-09 has been monitored regularly since 1983 when it was drilled and no significant changes in chemical composition or production characteristics have been observed (table 1). The properties of steam from well RN-09 are described in a separate report.

GEOTHERMAL WELLS

To date nine wells have been drilled for exploration of the geothermal field, two of which have served as producton wells (table 2). The early wells suffered damage due to drilling problems and lack of a liner or they were drilled outside the main geothermal area. Well Rn-8 drilled in 1969 was the first well to have a liner and was at the time the most productive geothermal well in the country having an output of 45-82 kg/s in spite of its medium size production casing of 9 5/8". Well Rn-9 was drilled as a production well for the pilot salt plant at Reykjanes. It has a production casing og 13 3/8". Figure 5 shows the initial well output curve (solid line) and the points indicate the operating output vs. wellhead pressure at different times during its 10 years of operation. There has been some loss of output due to scaling in the well and lately due to a broken liner. The output was partially recovered when the well was cleaned in 1993. Figures 6 shows the mass flow of well Rn-9 from the beginning to the present and fig.7 the well head pressure.

Down-hole surveys show a reservoir temperature in the range of 270-295°C (fig.8). The reservoir is in single phase condition (water) below 900 m depth but follows the boiling point with depth curve above 900 m. Through 25 years of mass production no pressure draw-down or temperature changes have been observed. The reservoir porosity and permeability appear to be high, resulting in highly productive wells.

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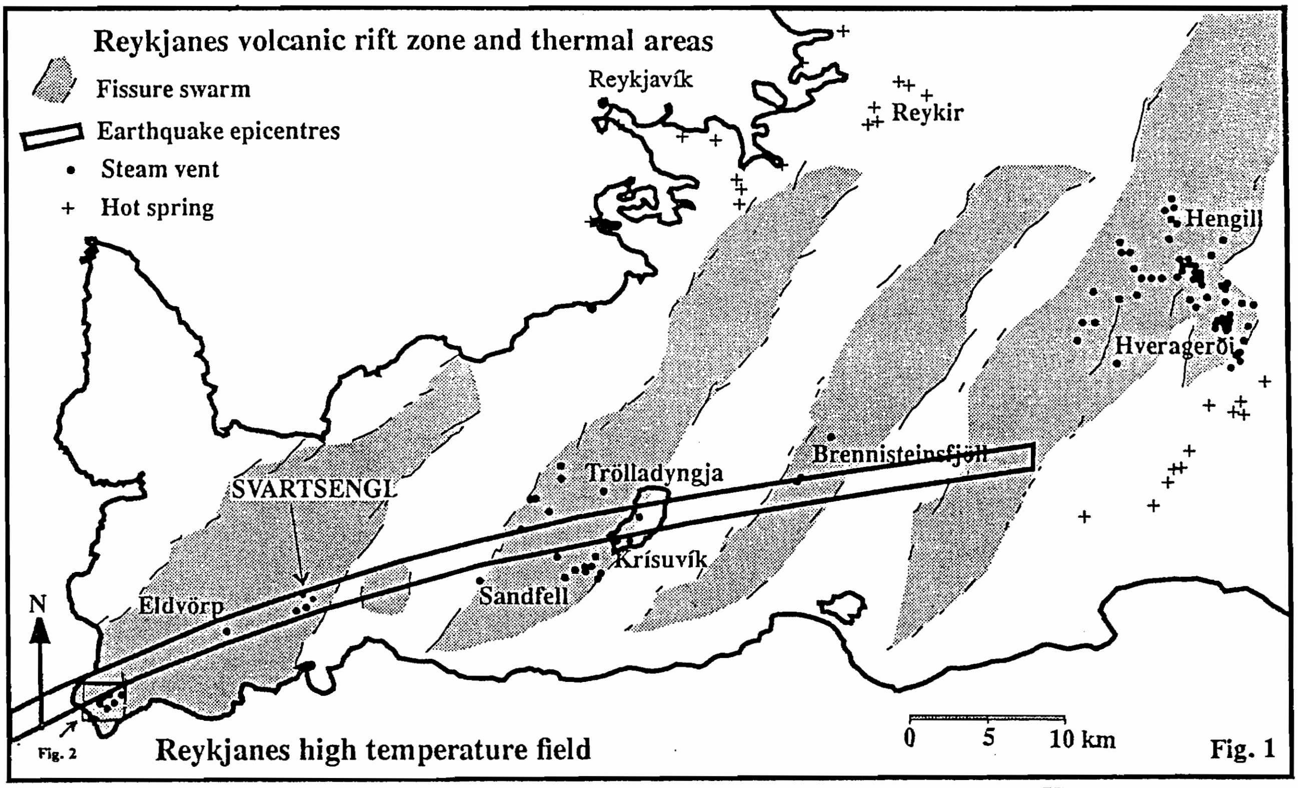

Reykjanes volcanic rift zone and thermal areas
Fissure swarm
Earthquake epicentres
Steam vent
Hot spring
Reykjavík
Reykir
Hengill
Hveragerði
Brennisteinsfjöll
Trölladyngja
SVARTSENGI
Krísuvík
Sandfell
Eldvörp
N
Fig. 2
Reykjanes high temperature field
0
5
10 km
Fig. 1

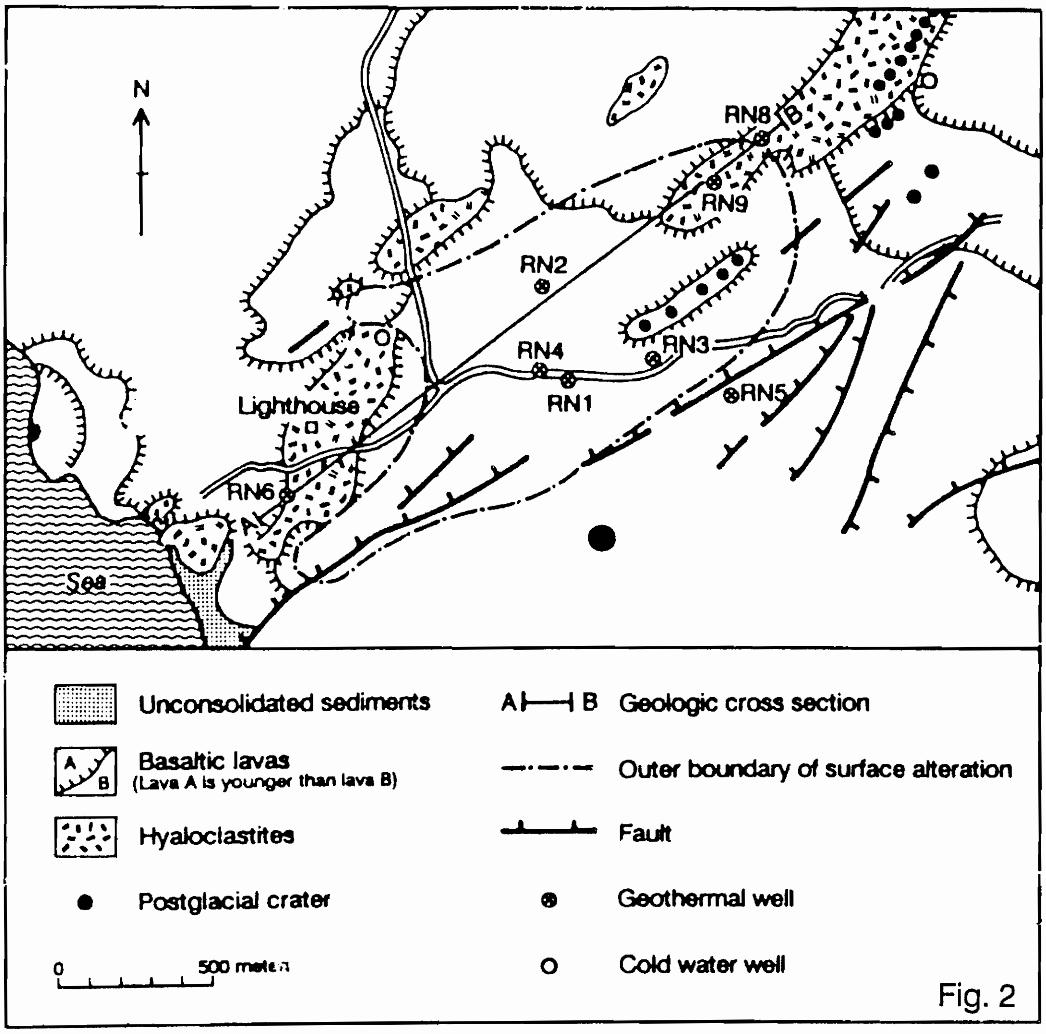


FIGURE 2: Surface geology of the Reykjanes geothermal field (Lonker et al., 1993)

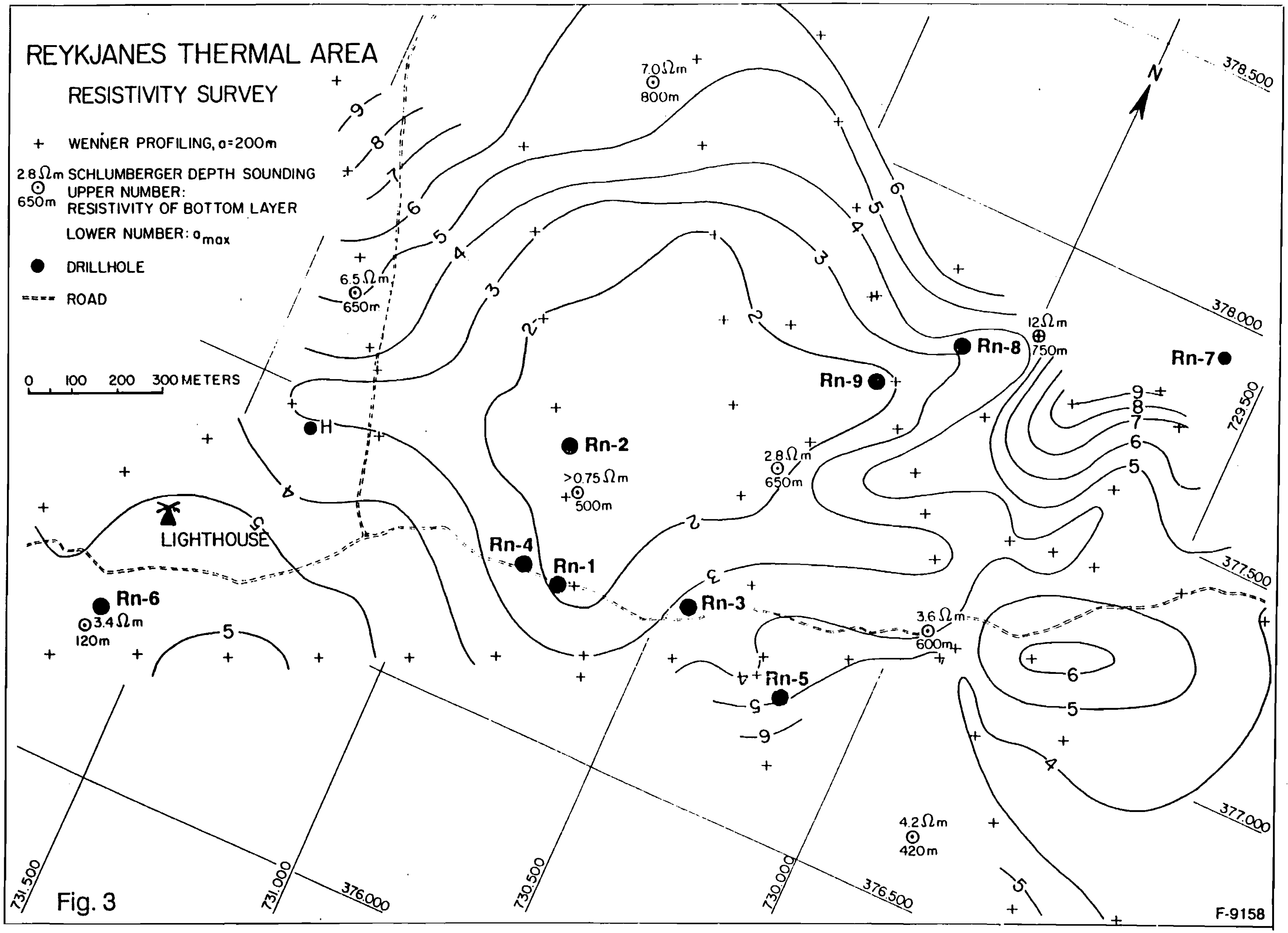


FIGURE 3: Resistivity map of the Reykjanes high-temperature field (mod. after Björnsson et al., 1970)

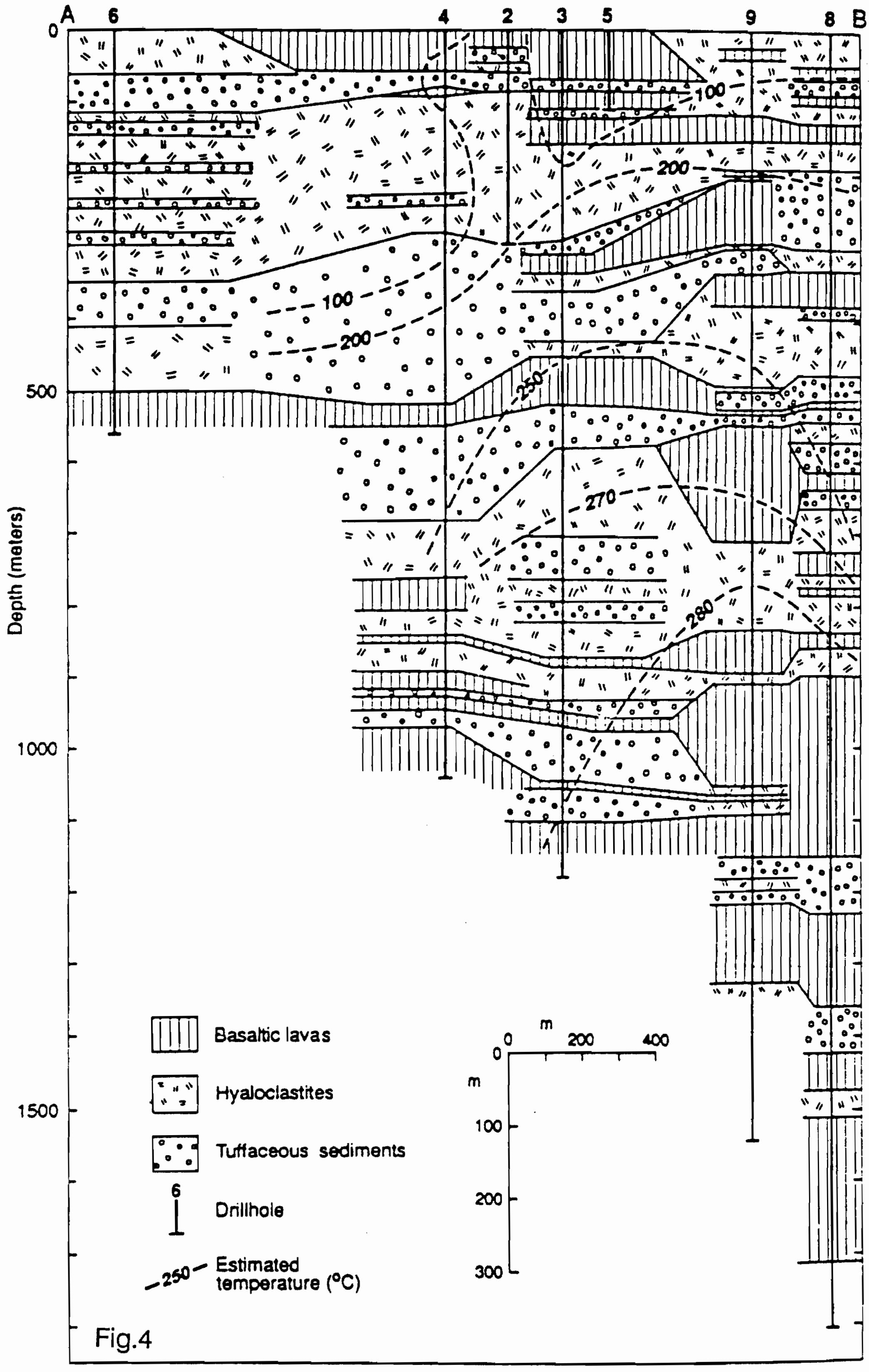
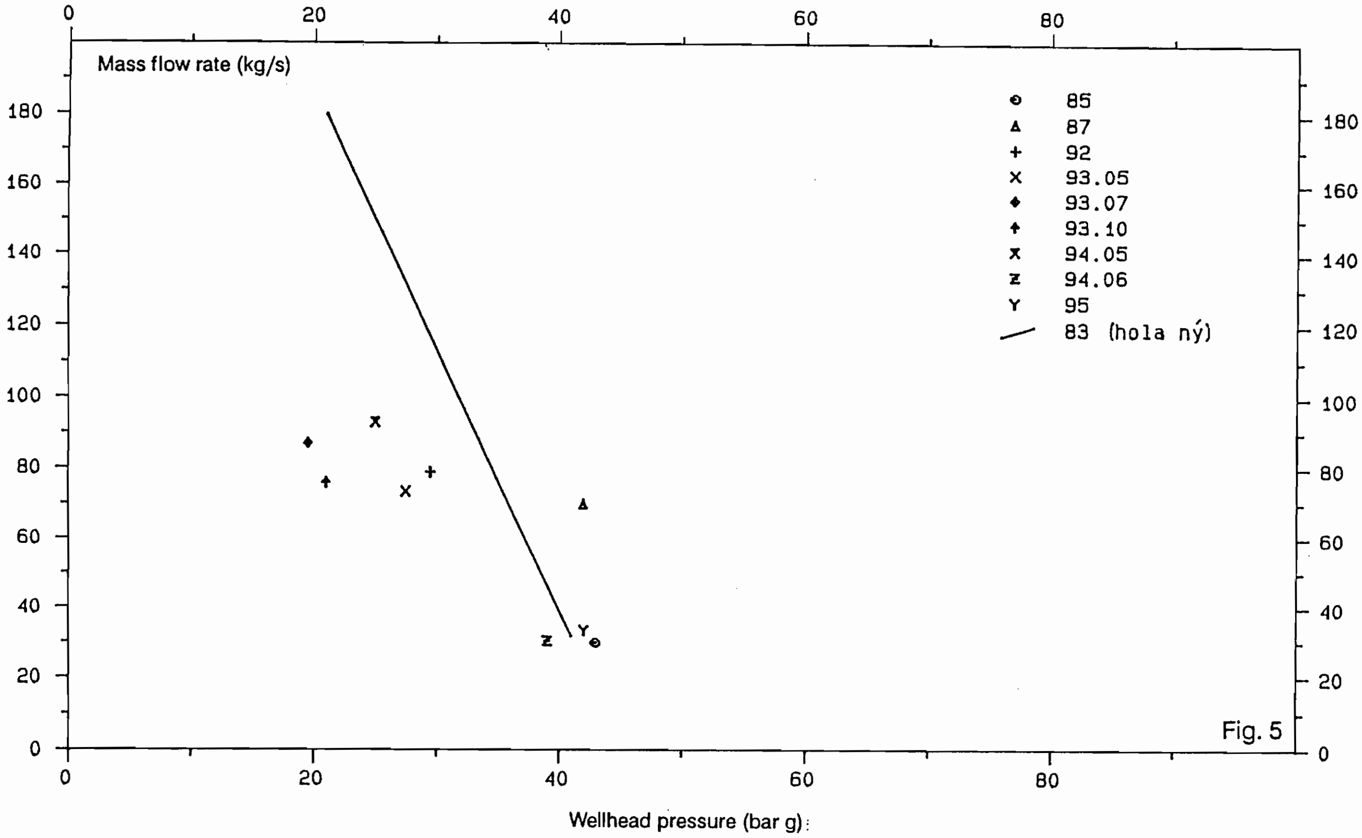
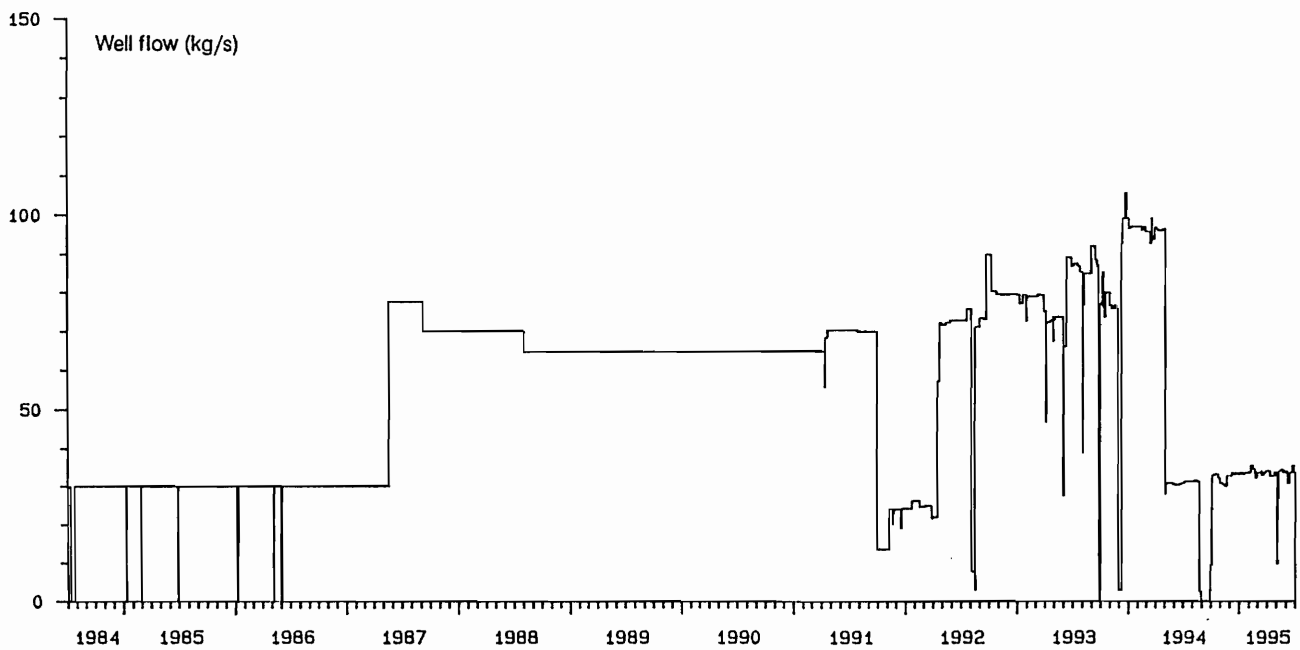


FIGURE 4 : Cross section of lithological correlation and temperature isotherms in Reykjanes (Lonker et al., 1993)


Mass flow rate (kg/s)
85
87
92
93.05
93.07
93.10
94.05
94.06
95
83 (hola ný)
Wellhead pressure (bar g)
Fig. 5


Well flow (kg/s)
1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995
Fig. 6

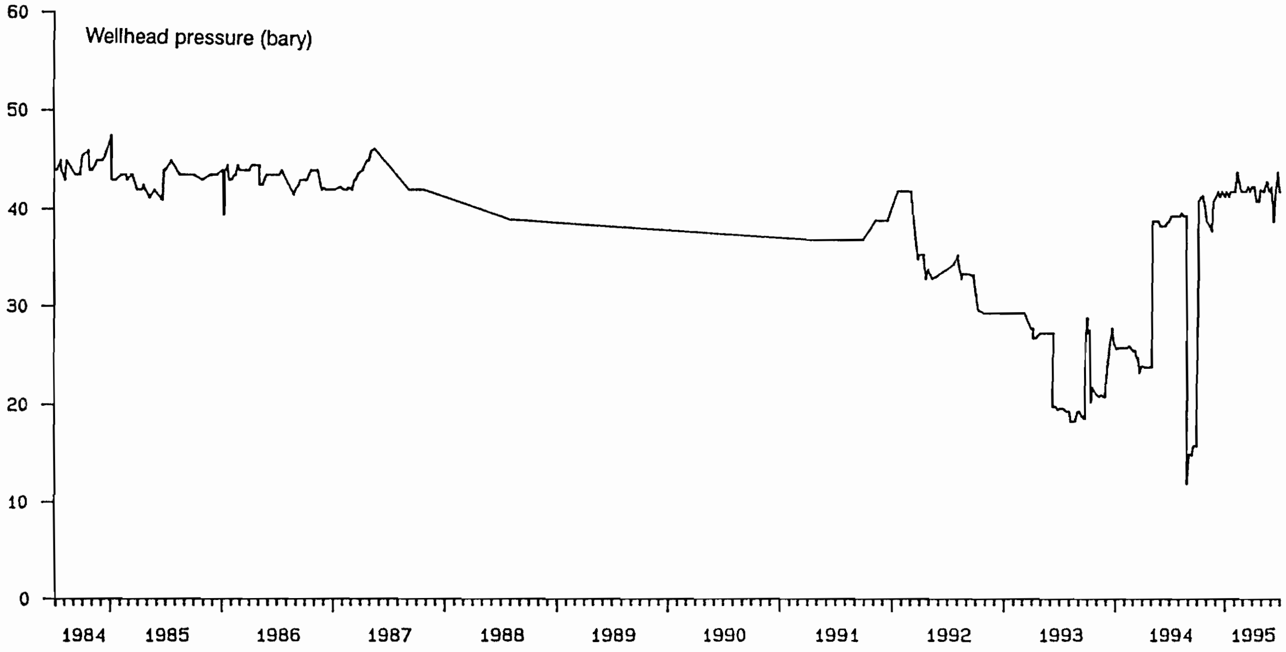
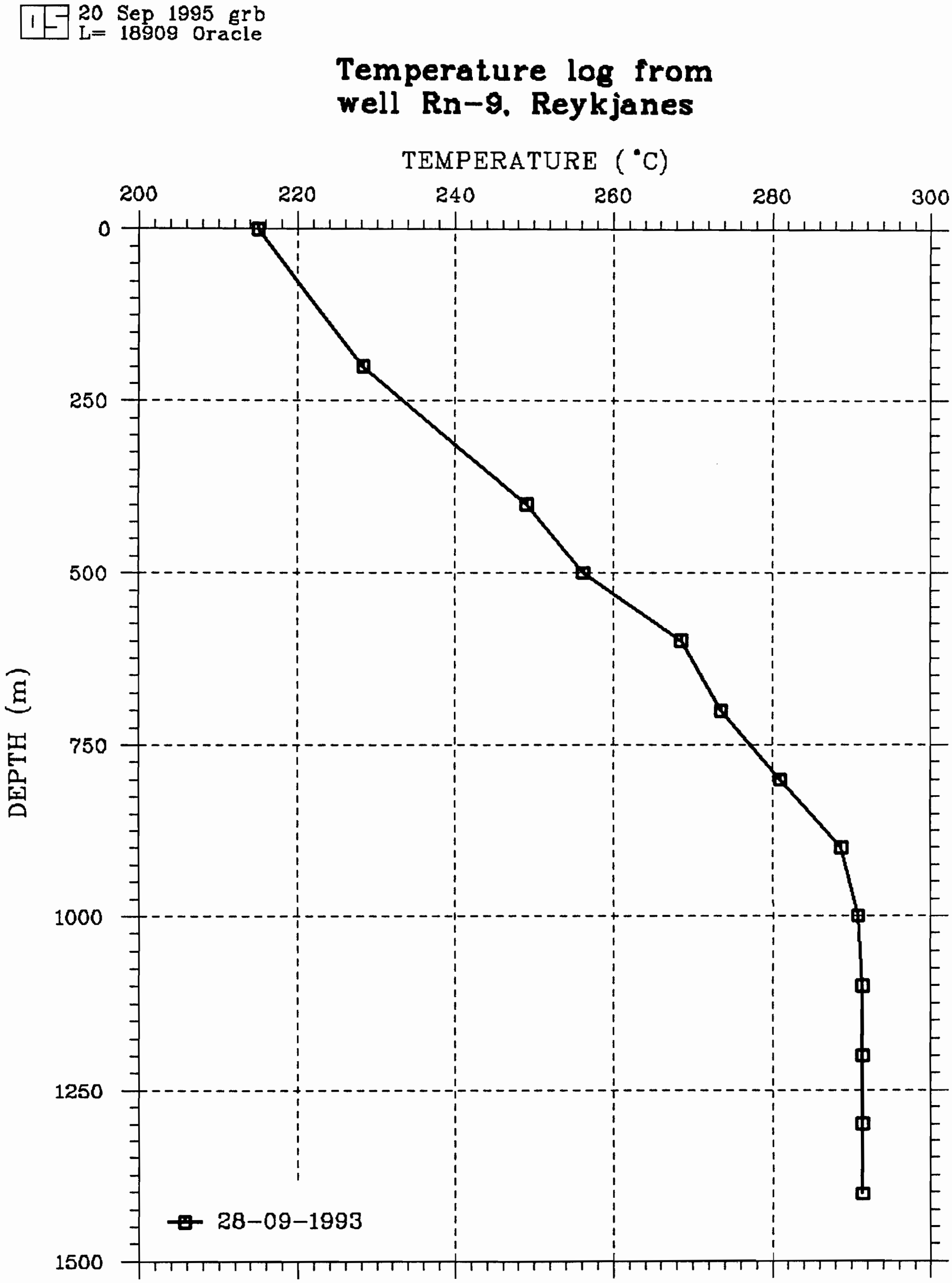

Wellhead pressure (bary)
60
50
40
30
20
10
0
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995

Fig. 7



20 Sep 1995 grb
L= 18909 Oracle
Temperature log from
well Rn-9, Reykjanes
TEMPERATURE (°C)
200
220
240
260
280
300
0
250
500
750
1000
1250
1500
DEPTH (m)
28-09-1993

Figure 8.

Table 1. Chemical composition of deep water from geothermal well RN-09 REYKJANES Field

Well Nr.	Sample Number	Date	Po bar abs.	Ho kJ / kg	SiO2 mg/kg	Na mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg	Fe mg/kg	Mn mg/kg	SO4 mg/kg	Cl mg/kg	F mg/kg	B mg/kg	Diss. solids mg/kg	CO2 mg/kg	H2S mg/kg	CH4 mg/kg	H2 mg/kg	N2 mg/kg
Rn-09	830234	Sept '83	41,5	1317	555,2	9761	1410,5	1447,1	0,897			16,6	17989	0,15		30720	1740	54,2	0,15	0,18	10,5
Rn-09	870006	Jan '87	44,5	1317	662,1	9339	1388,9	1447,3	0,899	0,12		9,7	18227	0,17		32359	1297	46,7	0	0,04	3,6
Rn-09	940057	May '94	41	1317	626	9476	1356,3	1565	0,974	0,23	3,7	19,7	18953	0,17	7,5	32499	1421	45,2	0,06	0,08	2,7

Table 2. Geothermal wells at Reykjanes.

Well number	Year drilled	Depth (m)	Casing (m)	Temp. max.°C	Tot. flow kg/s	Remarks
1	1956	162	12			*Collapsed*
2	1968	300	43	225	26	
3	1968	1166	242			*Collapsed*
4	1968	1036	245	250	19	*Out of order*
5	1969	112	41			*Drilling abandoned*
6	1969	572	222			*Cold*
7	1969	70	38			*Cold*
8	1969	1754	297	298	67	*Connected to plant*
9	1983	1445	529	295	180	*Connected to plant*