Geothermics 49 (2014) 23–30

Contents lists available at ScienceDirect

Geothermics

journal homepage: www.elsevier.com/locate/geothermics

Drilling of the well IDDP-1

B. Pálsson [a,*], S. Hólmgeirsson [a], Á. Guðmundsson [a], H.Á. Bóasson [b], K. Ingason [b], H. Sverrisson [b], S. Thórhallsson [c]

[a] Landsvirkjun, Háaleitisbrautn 68, 103 Reykjavík, Iceland
[b] Mannvit, Grensásvegur 1, 108 Reykjavík, Iceland
[c] ISOR, Iceland GeoSurvey, Grensásvegur 9, 108 Reykjavík, Iceland

ARTICLE INFO

Article history:
Received 16 July 2012
Accepted 12 August 2013
Available online 14 November 2013

Keywords:
Iceland Deep Drilling Project
Drilling
Magma
Superheat

ABSTRACT

The first well of three proposed by the Iceland Deep Drilling Project (IDDP) was drilled in the Krafla Geothermal Field in 2008–2009 by Landsvirkjun, the National Power Company of Iceland. The well was designed to reach supercritical conditions at 4500 m, temperatures above 374 °C and pressures above 22 MPa. Drilling progress was as planned down to around 2000 m when drilling became quite challenging, including becoming stuck at 2094 and 2095 m depth, followed by twist offs and subsequent side tracking. Finally, drilling came to an end at 2096 m depth in the third leg when cuttings of fresh glass indicated the presence of a magma body at the bottom. As the well had such a rigorous well design, the steering committee of the IDDP decided to complete and flow test the well, rather than abandoning it. The well was very powerful and the project has proved to be a valuable experience for drilling supercritical wells in the future and what happens when magma is encountered. Most importantly, it has been proven that it is possible to drill and complete a well in a very hot zone and produce fluid from an environment near a magma body. If sustained long term production proves possible, the drilling of well IDDP-1 will mark a new era in power production in Krafla.

1. Introduction

Since the year 2000 preparations have been ongoing within IDDP to drill 4–5 km deep wells with the aim of finding and investigating the feasibility to utilize supercritical fluid, where the temperature and the pressure are above the critical point for fresh water (374.15 °C and 22.12 MPa). The location for the first well of the Iceland Deep Drilling Project (IDDP) was chosen in the Vítismór area within the Krafla Geothermal Field (Friðleifsson et al., 2010, 2014).

Krafla is one of the most explored geothermal fields in the world, especially due to its unique history (Guðmundsson et al., 2008). It was the second high-temperature geothermal field in Iceland to be utilized for electricity generation. Following several years of surface exploration and two 1200 m deep exploration wells, drilled in 1974, the parliament of Iceland decided in spring of 1975 to build the 2×30 MW_e Krafla Power Station to meet an urgent energy demand in Northern Iceland. Three production wells were drilled in the summer of 1975; one of these, the well K-4, reached 2000 m depth in the Vítismór area (Mortensen et al., 2009). While pulling out of hole an underground blowout started, resulting in the wellhead pressure exceeding the pressure rating of the temporary wellhead valves. This lead to an uncontrollable blowout that lasted several months until the well collapsed. The fluid was acidic and the pH dropped to around 2 for a short time in February 1976. Throughout the year 1975 the Krafla area had been inflating and a series of volcanic episodes started in the Leirhnjúkur area in December that year. These lasted 9 years, with a total 21 events with 9 of them reaching the surface as volcanic eruptions. Invasion of volcanic gases into the geothermal system during the volcanic period had serious effects by causing transient increases of gases and lowering the pH, causing casing corrosion. Since 1984, the Krafla volcano has been quiet and the gas content of reference wells and steam vents has diminished. Due to the effects of the volcanic eruptions on fluid chemistry, production of usable steam for direct use in turbines proved difficult. However, the southern slopes of Krafla and Hvíthólar to south were found not to be as affected according to survey of gas sampling from natural outflow inside the Krafla caldera (Ármannsson et al., 1989). Eventually, turbine No. 1 reached full 30 MW capacity in 1985, the same year that Landsvirkjun took over the operation of the Krafla Power station from the State Electric Works (RARIK). In 1996 a decision was made to install the second 30 MW turbine and production drilling was successfully completed in 1999. Preparation for further expansion started also in 1999 and from 2006 to 2009, 8 exploration wells in addition to the IDDP well, were drilled in the area and three of them on the outskirts of the

* Corresponding author. Tel.: +354 515 9000; fax: +354 515 9004.
E-mail addresses: bjarnip@lv.is, bjarni.palsson@gmail.com (B. Pálsson).

0375-6505/$ – see front matter © 2013 Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.geothermics.2013.08.010

geothermal area. Of these, 4 wells indicated existence of low pH fluid and well K-39 intersected magma at 2500 m true depth in the southern slopes of Krafla (Mortensen et al., 2010).

2. Well design

High temperature geothermal resources in Iceland, within the volcanic rift zone, have been harnessed for decades for district heating and electricity production. Up to 200 high temperature wells have been drilled to depths of 2–3 km where temperatures above 300 °C are found. The majority of these wells drilled were of a standard design, either "regular diameter" or "large diameter" types (see Table 1). Most of the high temperature wells are designed for ANSI Class 900 although ANSI Class 1500 is occasionally used where higher temperatures are expected. Well IDDP was designed to produce from a supercritical reservoir conditions at 3500–4500 m depth, where pressure is expected to exceed 220 bar and temperature to exceed 374 °C, possibly as high as 600 °C. Therefore, the well is designed with two additional intermediate casings and according to pressure Class ANSI 2500, see Fig. 1 (Thórhallsson et al., 2010, 2014).

Table 1
Traditional program for drillbit and casing sizes for geothermal wells in Iceland.

Depth	Size	Narrow program	Wide program
70–100 m	Bit	21″	23″
	Surface casing	18-$^{5}/_{8}$″	22″
220–350 m	Bit	17-½″	21
	Anchor casing	13-$^{3}/_{8}$″*	18-$^{5}/_{8}$″
800–1400 m	Bit	12-$^{1}/_{4}$″	17-½″
	Production casing	9-$^{5}/_{8}$″	13-$^{3}/_{8}$″*2
2000–3000 m	Bit	8-½″	12-$^{1}/_{4}$″
	Slotted liner	7″	9-$^{5}/_{8}$″

The well was designed by the Drilling Technical Group of the IDDP, led by Mr. Sverrir Thórhallsson of Iceland Geosurvey, ÍSOR. Other representatives were from Mannvit Engineering,

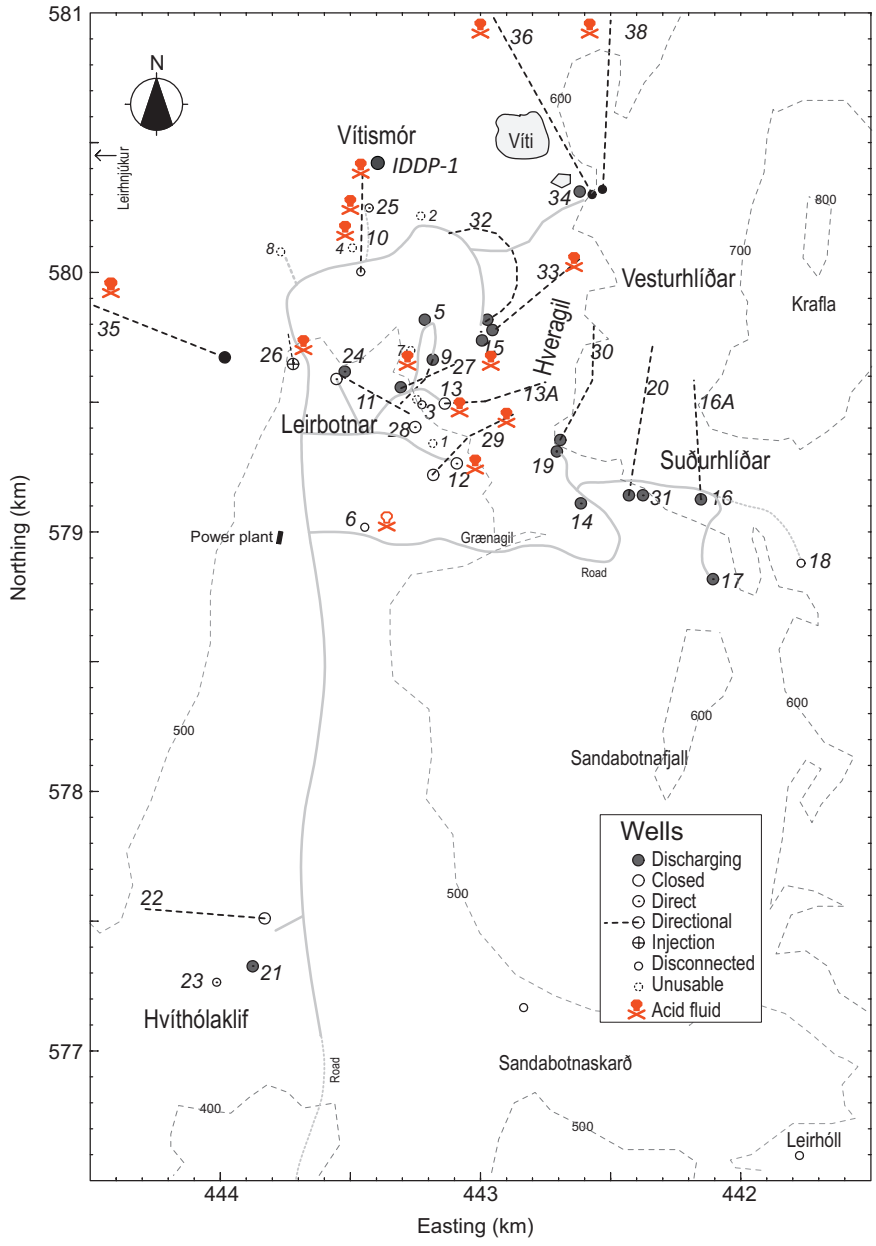

Fig. 1. Overview of the wells in the Krafla Geothermal Field.