ENGINE- G*eothermal lighthouse projects in Europe*

Information gathered during the ENGINE co-ordination action (ENhanced Geothermal Innovative Network for Europe)
http://engine.brgm.fr/
Last update April 2008

Project Name: The Iceland Deep Drilling Project (IDDP)
Project Leader [Companies]: Iceland Energy Consortium: Hitaveita Sudurnesja, Landsvirkjun, Orkuveita Reykjavíkur, Orkustofnun
Contact Person: Gudmundur Ó. Fridleifsson, gof@isor.is, ÍSOR, Iceland Geosurvey
Web-site: www.iddp.is
Country: Iceland
Location: Iceland (Reykjanes, Krafla, Hengill)

Types of resource [High/Low Enthalpy / EGS etc.]: High Enthalpy
Main on-site operators [Drilling, Simulation, Monitoring, Power plant etc.]: Landsvirkjun
Number of wells [w. Total Depth pr. well]: 34 (~2200 m)
Type of wells [Exploration, Production, Injection]: Production
Well configuration [Single well, Doublet, Triplet]: Single well
Distance between well at Depth [Horiz. Dist at Depth]:-
Temperature at Total Depth [Single well, Doublet, Triplet]: 340°C
Combination with other energy sources [Biomass, Biogas plants etc.]:-
Geothermal co-operation [Heat, Electricity etc.]: Electricity

Geothermal potential [MW at Date]: at least 100 MWe proven, upper limit not known.
Installed capacity [MW/*time* at Date]: 60 MWe 2006
Running capacity [MW/*time* at Date]: 60 MWe 2006

Short description of ***Exploration History*** ***(Limit this section; no more than 200 words):***

Possible keywords:

Objective of project: To improve the efficiency and economics of geothermal energy production by exploring for supercritical hydrothermal fluids as a possible energy source.

Important dates: Deep drilling in 2008

Main geological context [stratigraphy, sedimentary fms, volcanism, granite intrusions, faults, graben etc..]: Hyaloclastites and basaltic lava sequences down to ~1 km and intrusive complex below that to >2 km. Cooling magma chamber below 4-5 km.

Project funding : Iceland Energy Consortium, ICDP, US-NSF.

Distribution network: ICDP, http://www.icdp-online.de/contenido/icdp/front_content.php

Reservoir Characteristics ***(Limit this section; no more than 200 words):***

Possible keywords:

- **Type of reservoir [fractured, porous or both] :** fractured
- **Hosted lithology/rock/mineralogy/fluids [composition]:** Intrusive complex, amphibolite facies and basaltic skarn, dilute fluids of meteoric origin and possibly with magmatic affinity.
- **Fracture system:** Spreading plate boundary within central volcanic complex.
- **Stress field:** Mixture of extension and magma camber.
- **Temperature range or temperature profile:** Supercritical conditions.
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- **Simulation types [hydraulic, thermal, chemical]:** ?
- **Main reservoir characteristics [porosity, (natural) permeability etc.]** ?
- **Connectivity between wells** ?
- **Occurrence of natural brines** ?
- **Flow rate** ?

- **Storage capacity** ?

Exploitation ***(Limit this section; no more than 200 words):***

Possible keywords:

- Type of exploitation/power plant [ORG, Kalina cycle, single flush etc.]: Heat exchange cycle?
- Type of secondary fluid [ammoniac etc.]: H2O
- Production quail ability [day/year] : ?
- Cooling system [water, air]: to be decided
- Injection fluid [water, salty water etc.]: ?

- Need for special tools [pumps, turbine etc.]: yes
- Development/improvement of methods (chemical frac. etc..): chemical?
- Monitoring and optimising of field/area using computer models: -
- Assessment of environmental impact: -

On-going or future works planes ***(Limit this section; no more than 200 words):***

Possible keywords:

- Next important event [major hydraulic test, new geophysical measurements etc.]: Workshop in April 2007, Drillsiting and predrilling 2007
- Future plans ? e.g.:
    - New wells : 2008
    - Optimizing of existing. or building new power plants: after pilot and production tests
    - Implementation of new tools: yes, HITI project
    - Implementation of new methods: yes, during pilot and production tests?
    - .. new exploration phase: -

ENGINE partners involved in the Project:

- Use list of partners (No.1–31) from ENGINE Web-site http://engine.brgm.fr/partners.asp

1. BRGM, France, http://www.brgm.fr
2. GFZ, Germany, http://www.gfz-potsdam.de
3. ISOR, Iceland, http://www.isor.is
7. IGG, Italia, http://www.igg.cnr.it
11. CNRS, France, http://eost.u-strasbg.fr

Main References *(no more than 5 references):*

Albertsson, A., Bjarnason, J.Ö., Gunnarsson, T., Ballzus C. and Ingason, K., 2003. Part III : Fluid Handling and Evaluation, 33 p. In: Iceland Deep Drilling Project, Feasibility Report, ed. G.O.Fridleifsson. Orkustofnun Report OS-2003-007.

Fridleifsson, GO, Albertsson, A (2000). Deep geothermal drilling at Reykjanes Ridge: opportunity for an international collaboration. In: *Proceedings of the World Geothermal Congress, Japan,* pp.3701-3706.

Fridleifsson, G. O., Ármannsson, H., Árnason, K., Bjarnason, I.,Th., and Gíslason, G., 2003 a. *Part I : Geosciences and Site Selection. In: Iceland Deep Drilling Project, Feasibility Report, ed. G.O.Fridleifsson.* Orkustofnun Report OS-2003-007.

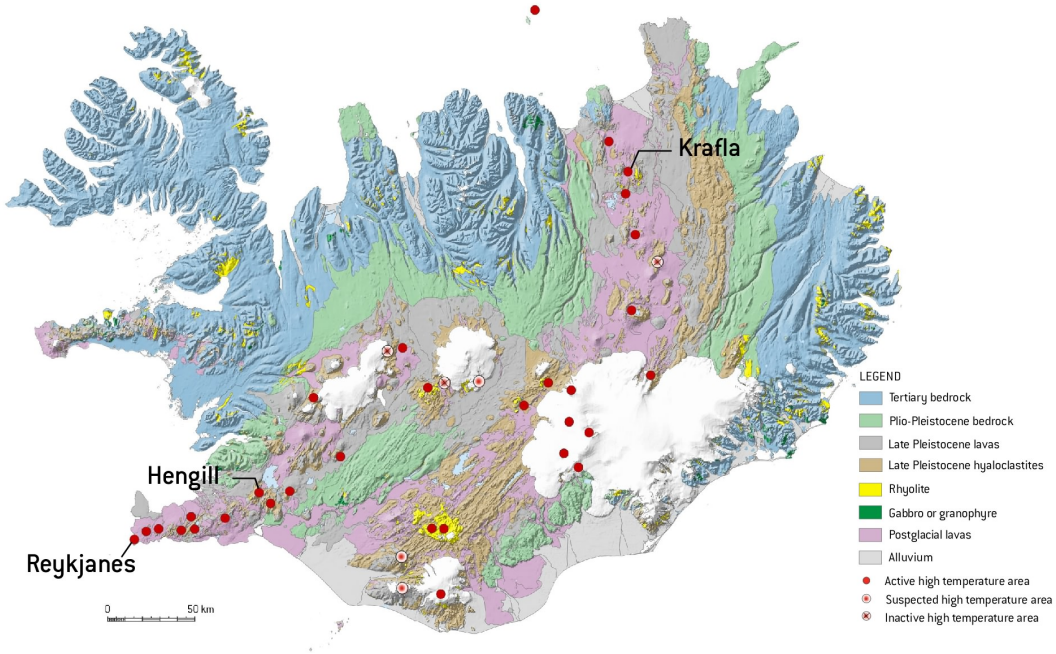
Fridleifsson, G. O. and Elders, W.A., 2005. The Iceland Deep Drilling Project: a search for deep unconventional geothermal resources. *Geothermics, 34, 269-285.*

Thórhallsson, S., Matthíasson, M., Gíslason Th., Ingason, K., Pálsson B., and Fridleifsson G.O., 2003. Part II : Drilling Technology, 75 p. & appendix (45 p). In: Iceland Deep Drilling Project, Feasibility Report, ed. G.Ó.Fridleifsson. Orkustofnun Report OS-2003-007. Prepared for Hitaveita Sudurnesja Ltd., Landsvirkjun and Orkuveita Reykjavikur.

NB: Please provide a site picture, - and if possible, a few relevant figures would be appreciated

The Iceland Deep Drilling Project (IDDP)

The IDDP is a project of "Deep Vision", a consortium of the government and three leading energy companies in Iceland. It aims to improve the economics of geothermal energy production by exploring for supercritical hydrothermal fluids as a possible energy source. This will require drilling to depths of 4 to 5 km in order to reach temperatures of 400-600°C. From the outset, the guiding principle was that the incremental costs of drilling and sampling for the science program, and their subsequent study, should be met by the scientific community. Two planning workshops, funded by the ICDP, were held in 2002 and a two year-long feasibility study, funded by Deep Vision, was concluded in 2003 (Fridleifsson et al., 2003). Three high-temperature geothermal fields, at Reykjanes, Hengill, and Krafla, were selected as sites for deep drilling.



Basemap: Geological map of Iceland by Haukur Jóhannesson and Kristján Sæmundsson 1999. Iceland. 1:1.000.000. Icelandic Institute of Natural History.

A geological map of Iceland showing the location of the three high-temperature hydrothermal systems being considered as sites for deep boreholes by the IDDP.

In late 2003 a member of the consortium offered one of its planned exploratory wells located on the Reykjanes peninsula for deepening by the IDDP. It was completed at 3.1 km depth in February 2005. However, this well of opportunity became blocked during a flow test in November 2005. After subsequent attempts at reconditioning failed, this hole was abandoned in February 2006. This required a change in the IDDP work plan.

In June 2006 Deep Vision decided to move operations to Krafla, the northernmost of the high-temperature areas, as the site for the first deep IDDP borehole. The IDDP plan is to rotary drill and spot core this hole to 3.5 km depth, and subsequently deepen it to 4-5 km, using continuous wireline coring for scientific purposes, and then attempt a flow test from the deepest portion of the well. This

plan is a compromise between the desire to obtain as much drillcore as possible and technical and budgetary limitations.

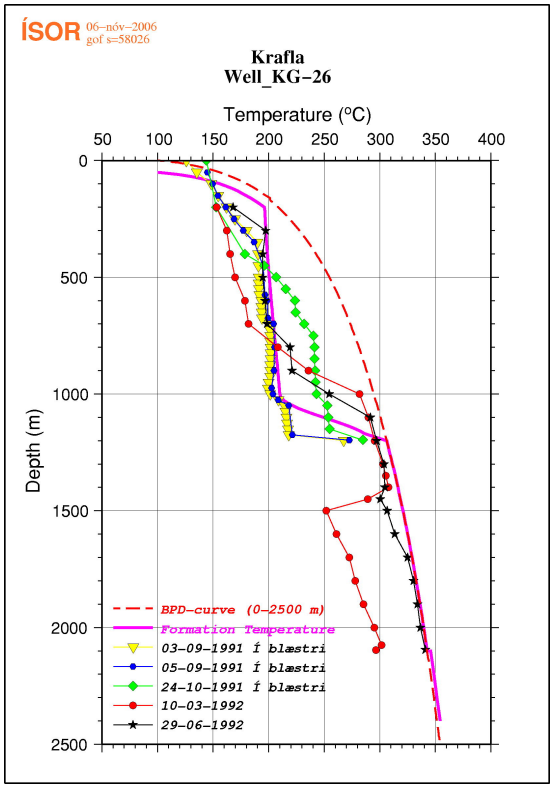
A view to the Krafla Central Volcano. A 60 MW power plant is seen in the foreground. The red circle denotes the potential IDDP drillsite.

The features of paramount importance in relation to the drilling of the IDDP well are

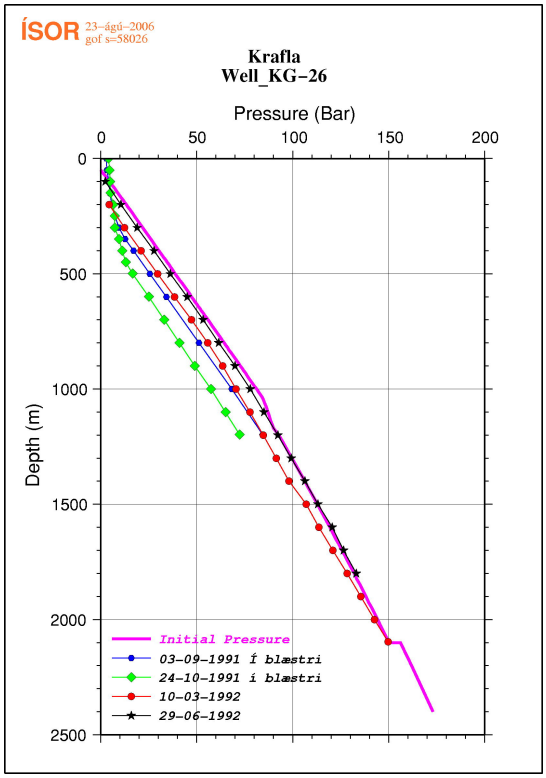
(1) the presence, size and specific location of a magma chamber previously interpreted to exist beneath the Krafla caldera
(2) the pressure temperature conditions within the geothermal field
(3) the nature of permeability likely at depth at the drill site

The magma chamber in Krafla was inferred from S-wave attenuation during the volcanic eruptions at Krafla in 1975-1984, and interpreted to be at 4–8 km depth below the drill field (Einarsson 1978, Björnson 1985). The thermal conditions within this body at present are not known. One of the aims of the IDDP at Krafla is to drill into the seismogenic zone at 4 to 5 km depth to determine if the formation of natural fractures at high temperatures generates permeability and test the hypothesis that the base of the seismogenic zone marks the transition from brittle to ductile behaviour.

Well KG-26 is at about 300 m distance from the site selected for the IDDP well and we expect P-T conditions to be similar.



Temperature profiles during ("í blæstri") and after flow tests in well KG-26 in 1991 and 1992.



Pressure curves corresponding to the temperature logs in well KG-26. The initial pressure curve corresponds to the initial pressure within the formation.

The P-T data from well KG-26 show that conditions should follow the boiling point with depth curve (BPD-curve) in the IDDP well from 1100m depth downwards. For pure water the critical point would be reached at about 3.5 km depth. The plan is to cement the third and last intermediate casing to ~3.5 km depth in the first phase of the IDDP well. Thus supercritical conditions should be reached soon after drilling out of the 3.5 km deep casing (see up-date in Fridleifsson et.al. 2006).

For further information http://www.iddp.is/

Selected references:

Björnsson, A., 1985. Dynamics of crustal rifting in NE- Iceland. Geophysics, 90, pp. 151-162.

Einarsson, P., 1978. S-wave shadows in the Krafla caldera in NE-Iceland, evidence for a magma chamber in the crust. Bull. Volcanol. 41, pp 1-9.

Fridleifsson, G. O., Ármannsson, H., Árnason, K., Bjarnason, I.,Th., and Gíslason, G., 2003. Part I : Geosciences and Site Selection. In: Iceland Deep Drilling Project, Feasibility Report, ed. G.O.Fridleifsson. Orkustofnun Report OS-2003-007.

Fridleifsson, G. O., Ármannsson, H, Mortensen A. K. 2006: Geothermal conditions in the Krafla caldera with focus on well KG-26. A review in relation to the Iceland Deep Drilling. Íslenskar orkurannsóknir. Report ÍSOR-2006/030, 37 p. http://www.iddp.is/news/2006/11/teneder_documents.php