Iceland Deep Drilling Project: Deep vision and future plans

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Abstract

The IDDP was founded in 2000 by an Icelandic energy consortium, Hitaveita Sudurnesja Ltd., Landsvirkjun, Orkuveita Reykjavikur and Orkustofnun. The steering committee of IDDP is composed of representatives from these companies and called DeepVision. The principal aim of DeepVision is to enhance the economics of high temperature geothermal resources. IDDP expects to drill and test a series of more than 4-5 km deep boreholes that are expected to produce supercritical fluids from the Krafla, Nesjavellir and Reykjanes fields in Iceland. The expected outcome is whether more efficient utilization of heat will cause increased productivity of single wells at a competitive cost.

Keywords: *deep drilling, supercritical steam, deep resources*

1 Introduction

Over the next several years the Iceland Deep Drilling Project, IDDP, expects to drill and test a series of boreholes that will penetrate supercritical zones believed to be present beneath three currently exploited geothermal systems in Iceland, Krafla, Nesjavellir and Reykjanes. This requires drilling to depths greater than 4 to 5 km, in order to produce hydrothermal fluids at temperatures of 400 to 600°C.

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An international advisory group SAGA has assisted DeepVision in science and engineering planning of IDDP (see Elders et al., 2003, this volume). SAGA was established in 2001, after a financial support form the International Continental Scientific Drilling Program (ICDP) had been granted. The financial support has been used to organize and discuss in detail both drilling and scientific issues linked to IDDP. An IDDP/ICDP start-up meeting was held in Reykjavík in June 2001. This was followed by a workshop on drilling technique in March 2002, and a science workshop in October 2002. Altogether some 160 participants from 12 nations participated in the workshops. The essence of these workshops and recommendations to IDDP are described in SAGA reports 1, 2 and 3, respectively, all of which are available on the IDDP website (http://www.os.is/iddp/) and appended to the IDDP Feasibility Report (op.cit.). The IDDP/ICDP workshops and SAGA influenced the feasibility report considerably, and focussed its approach in many aspects.

2 The main purpose of the IDDP project and its potential benefits

The main purpose of the IDDP project is to find out if it is economically feasible to extract energy and chemicals from a hydrothermal system at supercritical conditions, at temperatures of 400-600°C and pressures above 230 bar. At pressures and temperatures greater than the critical point, the difference between water and steam disappears and only a single fluid exists, that has high enthalpy and low viscosity. The critical point of pure water occurs at a temperature of 374.15°C and a pressure of 221.2 bar. In systems where fluid pressures are hydrostatic, the critical pressure would be reached at 3.5 km depth. For geothermal fluids containing dissolved chemical components, the critical point is elevated.

Hitherto, supercritical natural fluids have not been accessible for geothermal utilization. The basic idea of the Iceland Deep Drilling Project (IDDP) can thus be shown schematically by using a McKelvey diagram. The chief purpose is to find out if the ***accessible*** part of the geothermal ***resource base*** can be enlarged significantly at the expense of the ***inaccessible*** part – evidently in order to increase ***useful*** *and* ***economic*** exploitation of geothermal energy.

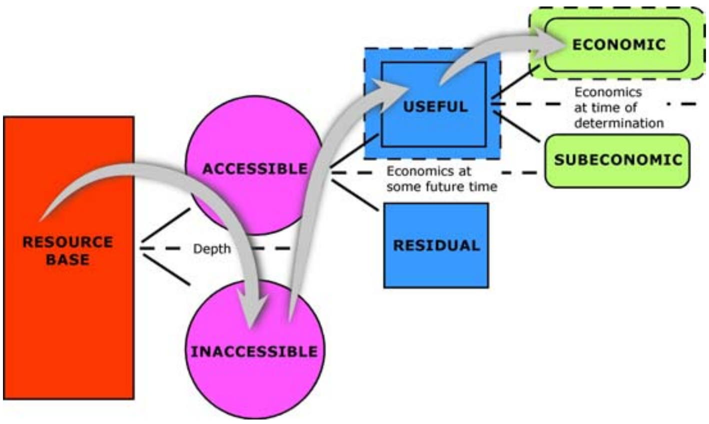


Figure 1: A slightly modified McKelvey diagram. The arrows are meant to indicate that the IDDP deep drilling could result in an increase of the *accessible* portion of the *resource base* at the expense of the *inaccessible* portion. And an increase in the *useful* and *economic* portions as well (also indicated by the dotted frames around the two boxes).

Therefore, the principal target of IDDP is to test the concept that producing supercritical high-enthalpy hydrous fluids in natural settings has economic benefits over producing conventional geothermal fluids, which are two-phase mixtures of liquid and steam. Modelling indicates that under favourable conditions, a 4-5 km deep well producing supercritical fluids at temperatures significantly greater than 450°C could yield sufficient high-enthalpy steam to generate 40-50 MW_e (Albertsson et al., op cit.). That is an order of magnitude greater electrical power output than is usual from a conventional 2 km deep well producing from a subcritical, liquid-dominated geothermal reservoir in Iceland. A five to tenfold mean increase in power output per well would be a substantial success.

Clearly, 4-5 km deep wells are more expensive than 2 km deep conventional wells. For IDDP to be successful a positive balance between increased drilling cost and increased power output needs to be realized. Irrespective of the outcome of IDDP, however, important by-products of IDDP should also be considered. Very important new knowledge of the exploited high-temperature systems will be added by the deep drilling. The benefit of drilling deeper for more energy within exploited fields, making use of the entire infrastructure within the geothermal fields, is an obvious advantage to IDDP. The environmental advantage of drilling deep instead of covering a wide area need also be mentioned. At present, knowledge on the permeability conditions below 2,5 km depth in drilled fields in Iceland is nonexistent. New knowledge of the permeability in the 2,5-5 km depth range becomes one of the by-products of IDDP. For the first stage the IDDP wells are cased off, but sidetracking out of a cemented casing at 2-4 km depth is not a complicated operation, if the need arise to produce a permeable target known to exist outside the casing. In such a case, most of the high cost of the IDDP well could possibly be recovered later on by the energy company exploiting the drill field.

Although the super deep IDDP wells are designed to investigate the economics of producing supercritical fluids they will also provide an unparalleled opportunity to experiment with deep reinjection of water in order to enhance the performance of the overlying hydrothermal systems. The wells will be drilled through fractured rocks, towards the heat sources of vigorously active high-temperature hydrothermal systems, within an active spreading zone. This should be an ideal environment for reinjection, and if it works here, it should work in similar kinds of geologic settings elsewhere. The IDDP well completion process, as recommended in the Feasibility Report (op. cit), from Phase 1 testing, to Phase 2, followed by flow testing with or without the "pipe" (op. cit), may extend for some years. Injection tests, e.g. with the aid of tracers, should become a part of that well testing process, and can be designed once more is known about the composition and properties of the deep fluids and the characteristics of the deep reservoirs.

The potential benefits of the IDDP project are listed below:

1. Increased power output per well, perhaps by an order of magnitude, and production of higher-value, high-pressure, high-temperature steam.
2. Development of an environmentally benign, high-enthalpy energy source below currently producing geothermal fields.
3. Extended lifetime of the exploited geothermal reservoirs and power generation facilities.
4. Re-evaluation of the geothermal resource base.
5. Industrial, educational, and economic spin-off.
6. Knowledge of permeabilities within drillfields below 2 km depth.
7. Knowledge of heat transfer from magma to water.
8. Heat sweeping by injection of water into hot, deep wells.
9. Possible extraction of valuable chemical products?
10. Advances in research on ocean floor hydrothermal systems.

3 The chief recommendations of the Feasibility study and potential risks

The chief recommendations of the IDDP feasibility study (op.cit.) were the following:

1) A full-size vertical well should be drilled with a two-stage coring program. Phase 1 should involve the drilling to 2,400 m, cementing an appropriate casing, and then continuous core drilling to 3.5-4 km depth. Phase 2 would involve reaming the well to insert the appropriate production casing to 3,500+ m, and coring to the target depth.
2) As an alternative, the deepening of existing "wells of opportunity" by core drilling should be considered seriously at this time. The options for wells of opportunity should to be identified before a selection of the most suitable wellsite for such a pilot hole was to be made.

The main concerns about potential risks involve the exceptionally high temperatures and pressures at depths, and uncertainties about the fluid composition. Experience in deep drilling and coring under such hostile conditions is very limited, but in order to minimize the risk due to this lack of direct experience, the concept of core drilling from an existing well, or a phased programme of a core drilling project was considered sensible at the beginning.

During flow testing and fluid sampling, the production casing would be protected by an instrumented and retrievable, 4″ diameter, solid liner, referred to as "the pipe". When this preliminary testing phase is completed, and more is known about the physics and chemistry of the produced fluid, a suitable pilot plant would be designed and constructed. The "pipe" is meant to mitigate the potential risks from hostile chemical compositions. Model calculations indicated that the fluid at surface will be superheated steam. if the reservoir temperature were above 450°C, hotter than 350°C, and at a pressure approximately 90 bars lower than the reservoir pressure. The role of the "pipe" during flow tests is to minimize the risk of losing the well due to rapid corrosion or scaling. Because the existing casing is too narrow in some existing "wells of opportunity", like wells KJ-18 and NJ-12, those wells could not be completed with the "pipe", nor deepened to greater depths than 3.5-4 km. Other existing wells, such as RN-12 at Reykjanes, are wide enough to be cored and completed according to the proposed IDDP plan.

4 Costs

The IDDP is an expensive undertaking. A 5 km deep well with 9 ⅝″ casing to 3.5 km is estimated to take up to 270 days to drill, and cost US$ 14.4-15.5 million. Furthermore, the cost of deploying "the pipe" and carrying out the fluid sampling program is estimated to be about US$ 5.5 million. Several less expensive options were also considered in the feasibility report. Depending on the specific design and depth, the costs of the alternatives for such "wells of opportunity" range from US$ 6-9 million. These considerations are dealt with in more detail in two papers within this conference volume (Thórhallsson et al., 2003b, Albertsson et al., 2003b).

5 The Future

If the Iceland Deep Drilling Project meets the goal of drilling up to 3 deep drillholes during the next decade or so, and a significant increase in power output per well is realised, e.g. by an order of magnitude, a new principal question arises. Can the total power output per geothermal field be significantly increased, say by a factor of 3 or 5?

Most scientists would expect that there is a limit to maximum output from a geothermal field, and that it would vary between fields. However, we do not know the real limiting factor. Today, the electric power output of each of the three drillfields being considered is estimated to be close to 100 MW_e. Increasing this by a factor of 3 to 5 would have a favourable impact on the economy and the environment for those fields. The estimated cost of a conventional 5 km deep hole drilled by a conventional rotary rig, without coring, is US$ 8-9 million, or about 3 times more expensive than a conventional production drillhole to 2 km depth.

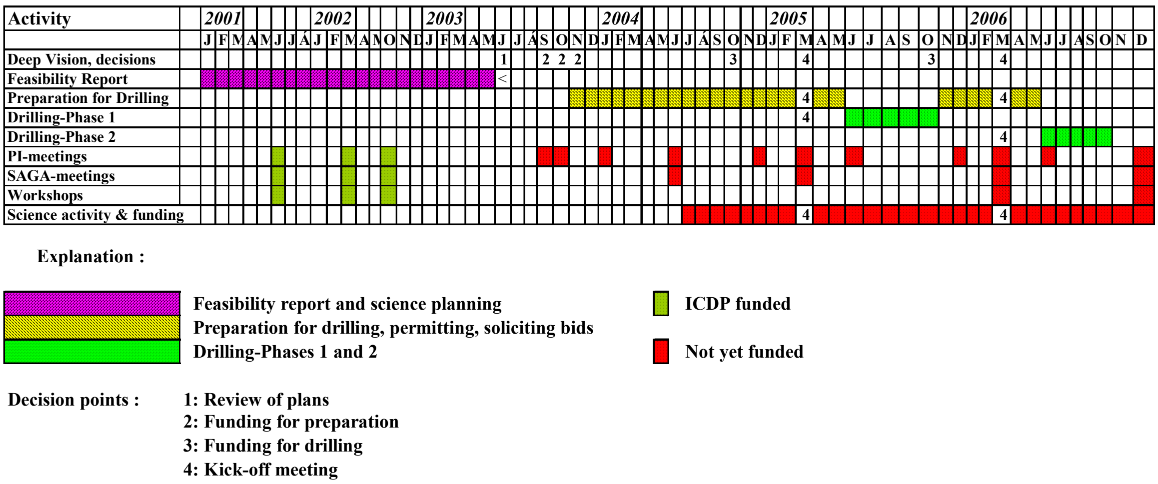
In addition to the potential economic benefits, there is worldwide scientific interest in the IDDP, as drilling into supercritical conditions will permit studies of a broad range of important scientific issues. The range covers investigation of the development of a large, igneous province, and the on-land magmatic and fluid circulation character of the Mid-Atlantic Ridge, to investigations and sampling of fluids at supercritical conditions - aspects of high-temperature hydrothermal systems that have rarely been available for direct observation. In addition, the IDDP will require the use of techniques for high-temperature drilling, well completion, logging, and sampling. These techniques will have the potential for widespread applications in drilling into both oceanic and continental high-temperature hydrothermal systems. The IDDP project opens up the opportunity for a very comprehensive scientific program investigating the anatomy of a mid-ocean rift zone, by tying together land–based and ocean-based deep borehole studies with complementary geological, geophysical, and seismic imaging studies - putting the drilling activities into a broad regional, geological context.

6 The recommended Work Plan

A work plan for the continuation of IDDP was presented in the feasibility report (op cit.) shown in Table 1. This plan should be implemented if the decision of the energy companies, backed up by Icelandic energy- and research authorities, were to proceed. Depending on funding, the time interval between Phase 1 coring and Phase 2 coring, as shown in the work plan, could be made shorter or longer. It should also pointed out that coring a well of opportunity would, in some cases, only involve Phase 1 coring.

To this Deep Vision only needs to add, that a decision is awaited when this paper was prepared. Hopefully, a decision on behalf of the energy companies may be announced at the IGC-2003 conference in September.

Table 1: IDDP Work Plan – Scenario 2001-2007.



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