SAGA REPORT No. 10

24 June 2016

Introduction

An IDDP-2 Kick-Off Meeting (KOM), a joint effort of the IDDP-Consortium and DEEPEGS, was held 23th June 2016. The meeting agenda is shown in Appendix 1, and a list of the 62 participants is shown in Appendix 2. The meeting was opened by the IDDP-Principal Investigator (PI) and the DEEPEGS-Coordinator, Guðmundur Ó. Friðleifsson, who began by briefing the participants on the meeting agenda, its purpose, and on the IDDP history, which extends for more than 16 years. In 2005 the IDDP plan was to deepen to 5 km depth well RN-17 in the Reykjanes field operated by HS Orka. However, prior to IDDP deepening, this 3.1 km deep drill hole collapsed during a flow test and the well could not be reconditioned. The IDDP activity thus moved to the Krafla field, operated by Landsvirkjun, and well IDDP-1 was drilled there in 2009. That well was terminated at only 2.1 km depth as it penetrated into 900°C magma, and so further drilling could not be attempted. The IDDP-1 well however was extensively tested and became the world's hottest production well for a while, yielding 452°C hot superheated steam at 140 bar pressure with production potential of up to 36 MWe. The lesson learned was most valuable and will be used for further development of the Krafla field, while in January 2014 a Special Issue of the journal Geothermics was devoted to the engineering and scientific results of the IDDP-1 well.

The IDDP-2 KOM meeting is the tenth in a series of international IDDP workshops (see table below), all of which are reported in SAGA reports and published at www.iddp.is website.

Four of these workshops were supported by the International Continental Scientific Drilling Program (ICDP), which additionally has provided substantial funds to obtain drill cores for scientific purposes. Funds for coring and their scientific study have also been augmented by the US National Science Foundation (NSF) – award EAR 05076725 to Wilfred A. Elders and co-workers in USA.

Background

The Iceland Deep Drilling Project (IDDP) was initiated at the World Geothermal Congress held in Japan in 2000, with an invitation for international collaboration. Its basic aim is to investigate the feasibility and economics of deep, high-enthalpy geothermal resources, and especially supercritical hydrothermal fluids, as possible energy sources. Given the pressure-temperature conditions required this involves drilling wells >4 km deep, to reach temperatures >450^{o}C. From the outset IDDP planned to drill three deep wells, one in a geothermal field operated by each of three Icelandic energy companies in the consortium and sharing the cost of drilling these wells by the field operator concerned and by the IDDP consortium. The IDDP is organized and funded by an Icelandic energy consortium (HS Orka, Landsvirkjun, Orkuveita Reykjavíkur, and Orkustofnun (The National Energy Authority) with additional support from Alcoa (2007-2013) and Statoil (2007-2011). In 2015 Statoil renewed its commitment until 2020. In December 2015 the IDDP-2 became part of the European Union supported project DEEPEGS (Deployment of Deep Enhanced Geothermal Systems for Sustainable Energy Business), a major effort to speed development of EGS within Europe and worldwide, both for high- and low-enthalpy systems. DEEPEGS will test stimulation technologies for EGS in deep wells in three different geological settings, to create sufficient permeability to deliver significant amounts of geothermal power. The first of these sites is the IDDP-2 (www.deepegs.eu).

After Krafla the IDDP consortium shifted its activities back to the Reykjanes geothermal system Peninsula in SW Iceland. The plan is to take over an existing well, RN-15, which is 2.5 km deep, deepen it to 3.0 km, set casing, and then continue drilling to 5.0 km depth to continue exploring for a supercritical geothermal resource. Drilling this IDDP-2 well will begin at the end of July 2016 and was the main topic of the Kick-off meeting. Preparations for deepening it to 5 km are at an advanced stage with the drilling pad prepared and the drilling rig Thor, due to move on site before the end of July. All the necessary materials, service contracts and personnel are ready. Some 34 wells have already been drilled in the Reykjanes geothermal field so the geology, geophysics and geochemistry of the system to <3 km depth is well known. The results of comprehensive seismic and MT investigations of the Reykjanes Peninsula (Project IMAGE) will be released shortly.

IDDP-2 Kick off Meeting

The meeting began with a review of the genesis, history, and progress of IDDP and a presentation of the Drilling Plan and time line for the IDDP-2. Jardboranir, the Iceland Drilling Company (IDC) has been contracted for drilling the well on a day rate basis using a Bentec 350 ton rig with an electrical top drive. All participants must take a safety briefing and follow the health and safety protocols of HS Orka and IDC. A schematic of the well design is shown in Figure 1.

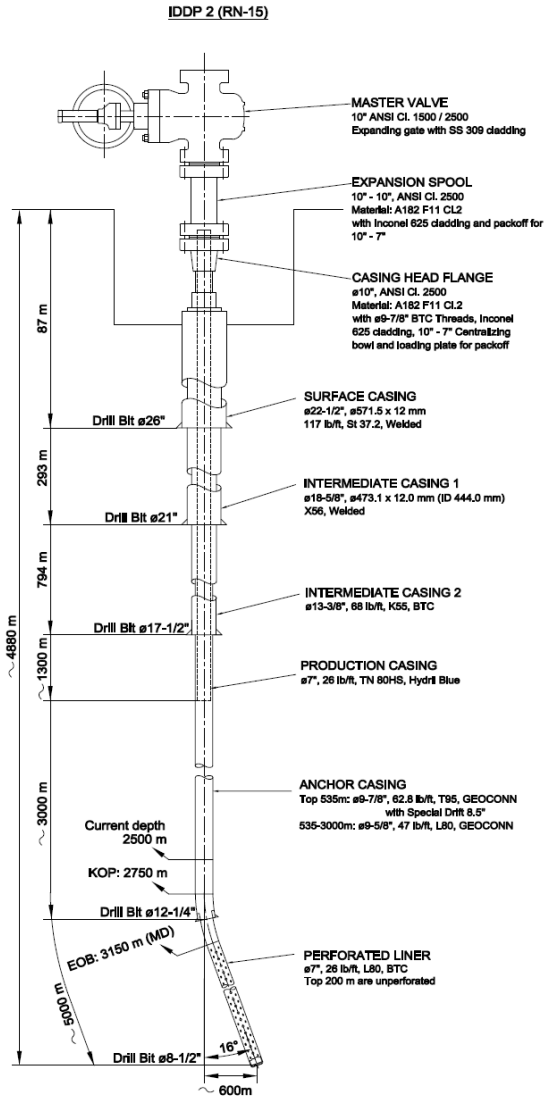

Figure 1: *Schematic of the IDDP-2 well casing and well-head design (from Mannvit). The RN-15 has an existing production casing of 13 3/8" cemented from 0-794 m and a 12 ¼" open hole to 2507 m. After deepening to 3000 m a 9 7/8" and a 9 5/8"casing will be reverse cemented to 3000 m. Drilling will then proceed at 8 1/2" from 3000 to 5000 m open hole. The hole will be deviated at 16° with a kick-off point at 2750 m, direction 210°. A 7" perforated liner will then be inserted before flow testing. A sacrificial 7 " casing will be hung from 0-1300 m and cemented to top.*

Completing the well to 5000 m is estimated to take about 150 days and of this time approximately 30 days are assigned for 10 m coring runs (Figure 2). The available funding should allow 20-25 core runs to be attempted using equipment, techniques, and personnel that have already cored successfully in geothermal wells at Reykjanes. The well will be deviated 16° SW with a kick-off point at 2750 m to intersect the deep target zone. Conventional down-hole motors and gyros will be used from the kickoff point to 3150 m. Then high-temperature down-hole directional drilling equipment recently developed by Baker Hughes will also be employed. Lithological logging of drill cuttings samples taken at 2 m intervals will be carried out by ISOR and both cores and cuttings will be scanned and the core descriptions and lithological logs will be entered into an ICDP Drilling Information System (DIS) to disseminate the data expeditiously.

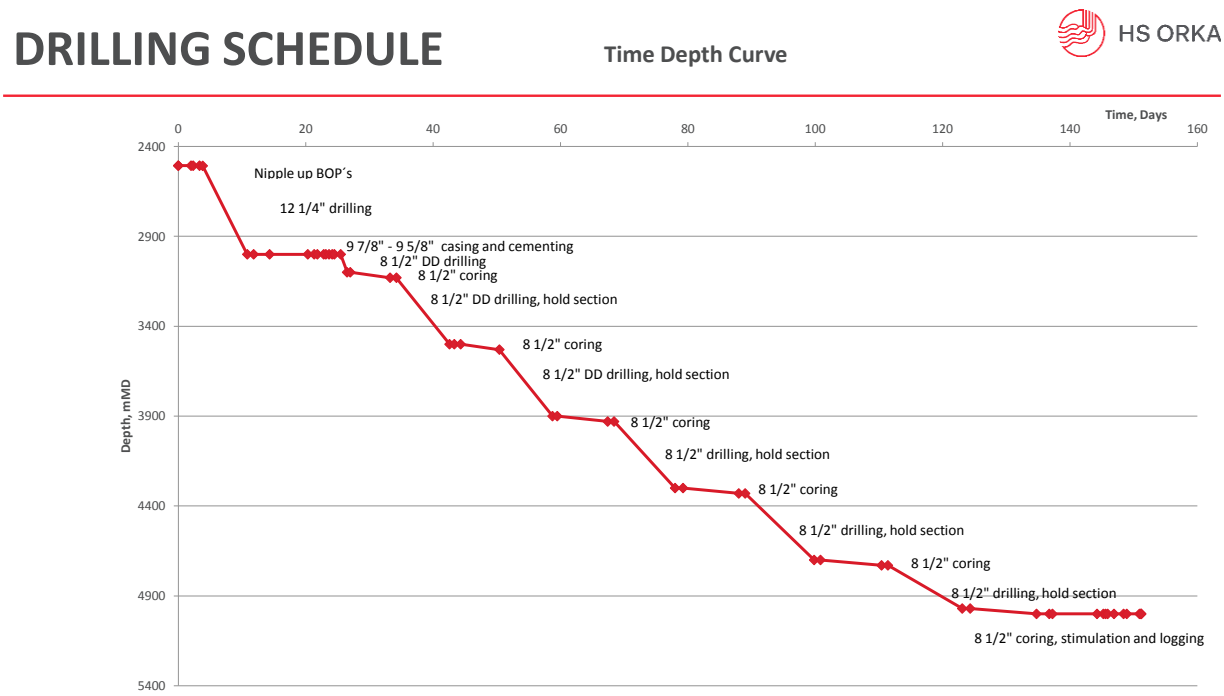

Figure 2. *The estimated time/depth curve for the IDDP-2.*

A comprehensive geophysical logging program will be carried out by ISOR to the limit of the temperature tolerance of the logging tools and cables. The wireline tools normally used in high-temperature wells in Iceland are: CBL, Temperature, Pressure, Caliper, NN-porosity, Natural - gamma, and Normal Resistivity. Optional tools include Televiewer Imaging, Density or Acoustic Velocity, and Spinner. The temperature limits of these tools are likely to be reached below 3500 m depth, so deployment of logging while drilling or logging while tripping are being considered

for the hotter parts of the well. ICDP will provide equipment for on-line monitoring and sampling of drilling mud gas , with a gas chromatograph, a gas mass spectrometer, and an alpha detector, to continuously monitor Ar, He, CO_2, H_2, CH_4, N, Cl, Rn, etc., information useful in identifying zones of fluid inflow and fluid sources.

If the IDDP-2 encounters suitable zones of low permeability, as part of the DEEPEGS study, attempts will be made to stimulate permeabilty. Because suitable packers that function at the high temperatures expected are not available, soft stimulation will be attempted by pumping cold water through a 3 1/2'' tubing at up to 450 bars for 6-12 months if needed, creating fractures by thermal shock. In addition tracer tests will be attempted by injection. The proposal is to inject three tracers, one liquid only – ^{125}I, one vapor only – Inert gases, and one liquid + vapor – ^{3}H. However the tracers are still under discussion.

A preliminary report on passive seismicity of the Reykjanes Peninsula between January 2013 and November 2015 indicates that the depth of earthquakes suggests that the brittle-ductile transition below Reykjanes is generally at 5.5 – 6 km depth. However a seismic gap appears beneath the core of the production field below 3 km depth. This could be due to the lower the pressure in the production field that has reduced the pore pressure at depth resulting in increased rock strength. Alternatively it could be due to the temperature being high enough within this aseismic body to prevent stress accumulation that results in fracturing. That would mean the brittle-ductile boundary would be close to 3 km depth below the production field. Laboratory studies indicate that the brittle ductile transition in basalts occurs at temperatures >600^{o}C. This indication is of concern although the time series monitored is relatively short, geologically speaking. High resolution seismic structure beneath Reykjanes is currently being evaluated by the EU funded IMAGE project and the result expected to be available this autumn.

Flow testing is unlikely to take place until at least a year after well completion, but the time will depend on the extent of needed stimulation effort. Well head conditions of temperatures >345°C to <500°C and pressures of 155 to 250 bar are likely, judging from several thermal gradient estimates. The well head master valves that failed on the IDDP-1 at Krafla have been improved and refabricated and a new expansion spool with a range of 1 m has been developed.

Following the practice of Statoil, a Drilling a Well on Paper (DWOP) meeting will be held on the 27th of July, 2016 involving the drilling and engineering teams and others concerned with down hole operations such as logging and coring. The objective is to avoid surprises during drilling and make explicit the coordination between those responsible for the various aspects of the onsite operations during drilling, to assign responsibilities, and to consider contingency plans.

An important aspect of DEEPEGS projects is community outreach, involving both the public and the geothermal industry. This can be achieved by press releases and open access days, as well as publications and presentations at suitable forums.

SAGA/ Deep Vision Meeting

On June 24th 2016 the Science Applications Group of Advisors (SAGA) met to discuss the Kick-off meeting and later met with DEEPVISION, the coordinating committee of the IDDP, to report on the status of the IDDP-2 and to make recommendations. The mood of these meetings was very optimistic as no "show-stoppers" to moving forward as proposed have been identified. All necessary materials will be on site by July 20th, e.g. new drill pipe, casing, fishing tools, and expendables, etc. The IDC drilling rig will be mobilized and set up during the last two weeks of July.

Among the issues discussed were the philosophy of quality rather than speed of drilling, the petrophysical program, the availability in Iceland of a 300°C televiewer, simplifying the tracer program, collecting cuttings while coring, and adding a logging tool (gyro?) and a data logger to the core barrel.

Recommendations

The DWOP meeting on July 27th is an important step in coordination and communication of the IDDP-2. In addition, daily morning meetings of representative of the drilling, engineering, and management teams should continue as was done during drilling IDDP-1.

Contingency plans should be prepared ahead of time. For example, what geological conditions would indicate that drilling should be terminated? What mineralogical changes would indicate that we could have reached into supercritical environment?

In case of drilling problems we should have problem solvers on call and these experts should be identified before they are need.

The public relations and outreach issue was also discussed and the need for designated spokespersons. IDDP should plan on producing a documentary film and assign the necessary budget.

Significance of the IDDP

The IDDP-2 is significant not only for the development of new geothermal resources in Iceland but internationally. Not only do aqueous geo-fluids at supercritical condition have more than five times the power producing potential than hydrothermal liquid water 225^{o}C, but there is a singularity in the transport properties of water at the critical point. Thus modeling indicates that a supercritical well could have ten times the power output of a conventional geothermal well. Potential sites for supercritical geothermal resources occur worldwide, both on and offshore, wherever young volcanoes occur. These are large and attractive targets, but require big

investments to develop (especially offshore). The IDDP model (a consortium of government, industry, and academia) could be a way to develop them.

The IDDP-2 will investigate the interactions of high-temperature (400-500^{o}C) hydrothermal fluids with the basaltic crust in Iceland on the Reykjanes Peninsula, the landward extension of the Mid-Atlantic Ridge. The Reykjanes geothermal system is unique in that its geothermal fluids are modified sea water so that the IDDP-2 well will provide the first opportunity worldwide to investigate the deep, high temperature reaction zone of mid-ocean ridge hydrothermal environment, an issue that has been a long-term goal of the Integrated Ocean Drilling Program, the IODP, and its predecessors.

SAGA report compiled by the PI's: Guðmundur Ó. Friðleifsson and Wilfred A. Elders

Attachments

1) IDDP-2 Kick off meeting AGENDA
2) List of Participants.

DEEPEGS - *"Deployment of deep enhanced geothermal systems for sustainable energy business"* is a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690771

The DEEPEGS project is providing complimentary research support to the IDDP-2 well development at Reykjanes in Iceland

IDDP-2 KICK OFF MEETING

23 JUNE 2016

AGENDA

9:00-9:20	Welcome – Introduction – Project overview Guðmundur Ómar Friðleifsson, HS Orka
9:20-10:00	Drilling plan 1 – Drilling overview and discussion Ari Stefánsson and Þór Gíslason, HS Orka
10:00-10:20	Drilling plan 2 – Casing and cementing Ari Stefánsson and Þór Gíslason, HS Orka
10:20-10:35	Coffee break
10:35-11:00	Risk Assessment, mitigation, HSE Þorgrímur St. Árnason and Kristín B. Ingadóttir, HS Orka
11:00-11:30	Drilling plan 3 – Coring procedure Alister C. Skinner. ACS Services, Scotland
11:30-11:50	Drilling plan 4 – Geological logging/ÍSOR & ICDP-DIS Tobias Weisenberger, ISOR
11:50-12:10	Drilling plan 5 – Core logging and science team Robert Zierenberg, UC Davis, USA
12:10-12:30	Drilling plan 6 – Geochemical logging Thomas Wiersberg, GFZ, Potsdam, Germany
12:30-13:10	LUNCH
13:10-13:25	Drilling plan 7 – Geophysical logging during drilling Ómar Sigurdsson, HS Orka
13:25-13:40	Drilling plan 8 – DEEPEGS Stimulation plan Ómar Sigurdsson, HS Orka

13:40-14:00	Drilling plan 9 – DEEPEGS Tracer test
	Kristín V. Matthíasdóttir, HS Orka
14:00-14:30	Conceptual model, Seismic-MT monitoring
	Gunnlaugur M. Einarsson and Egill Á. Gudnason, ISOR
14:30-15:00	IDDP-2 – Heat up, flow test, pilot test overview
	Geir Þórólfsson and Albert Albertsson, HS Orka
15:00-15:30	Coffee
15:30-15:45	Drilling plan 10 – Drill Well on Paper / HSE
	Carsten Sörlie, Statoil, Norway
15:45-16:00	High-Temperature prototype downhole motor
	Thor Jan Erikssen, Baker Hughes, Norway
16:00-16:15	DEEPEGS – interaction and public outreach
	Sigurdur G. Bogason, Markmar
16:15-17:30	Summary and Conclusion - Science Plan
	Wilfred A. Elders, UC Riverside, USA and
	Gudmudur Ó. Fridleifsson, HS Orka
18:30-20:00	DINNER

IDDP-2 KICK OFF MEETING

24 JUNE 2016

SAGA MEETING

9:00-12:00	SAGA REPORT – SUMMARY DISCUSSION
11:00-13:00	136-DEEP VISION Meeting - with SAGA - Lunch
13:00-17:00	SAGA REPORT – CONCLUSION

IDDP-2 Kick-Off Meeting – 23 June 2016

List of Participants

Albert Albertsson	HS Orka	Deep Vision
Alicja Wiktoria Stoklosa	GEORG	DEEPEGS organizer
Alister Skinner	ACS Coring, Scotland	SAGA
Ari Stefánsson	HS Orka	
Ásgrímur Guðmundsson	Landsvirkjun	
Bastien Romain Poux	ÍSOR	
Birgir Þ. Birgisson	Jardboranir - IDC	
Bjarni Guðmundsson	Jardboranir - IDC	
Bjarni Steinar Gunnarsson	ÍSOR	
Björn Sverrir Harðarson	ÍSOR	
Bruce Gatherer	Jardboranir - IDC	
Carsten F Sørlie	Statoil, Norway	Deep Vision deputy
Dennis Nielson	DOSECC, USA	SAGA
Egill Árni Guðnason	ÍSOR	
Emmanuel Gaucher	KIT, Germany	
Eva Schill	KIT, Germany	
Finbogi Óskarsson	ÍSOR	
Geir Þórólfsson	HS Orka	
Grímur Björnsson	Warm Artic ehf	DEEPEGS EAP
Guðmundur Ómar Friðleifsson	HS Orka - IDDP-PI	SAGA-DEEPEGS Coordinator
Gunnar Skúlason Kaldal	ÍSOR	
Gunnlaugur M. Einarsson	ÍSOR	
Hafþór Ægir Sigurjónsson	University of Iceland	
Hanne Wigum	Statoil, Norway	
Hildigunnur H Thorsteinsson	Reykjavik Energy	Deep Vision deputy
Hjalti Páll Ingólfsson	GEORG	DEEPEGS organizer
Hörður Halldórsson	ÍSOR	
Ingelinn Aarnes	Baker Hughes, Norway	
Ingólfur Örn Þorbjörnsson	ÍSOR	
Iwona Monika Galeczka	ÍSOR	
Jóhann Lindal Jóhannsson	HS Orka	
Jón Örn Bjarnason	ISOR	SAGA

IDDP-2 Kick-Off Meeting – 23 June 2016

List of Participants (continued)

Kristín Birna Ingadóttir	HS Orka	
Kristín Vala Matthíasdóttir	HS Orka	
Kristján Ágústsson	ÍSOR	
Kristján Einarsson	Landsvirkjun	
Kristján Geirsson	Orkustofnun	Deep Vision deputy
Knútur Árnason	ÍSOR	
Léa Lévy	ÍSOR	
Mariane Peter-Borie	BRGM, France	
Marín Ó. Hafnadóttir	HS Orka	
Mathieu Darnet	BRGM, France	
Ólafur G. Flóvenz	ÍSOR	
Ólafur Sverrisson	Landsvirkjun	
Ómar Sigurðsson	HS Orka	
Paul Rabb	Alterra, Canada	
Pálmar Sigurðsson	ÍSOR	
Rike Köpke	KIT, Germany	
Robert Zierenberg	UC – Davis, USA	
Sigurður G. Bogason	GEORG	DEEPEGS Coordinator deputy
Sigrún B. Sverrisdóttir	HS Orka	
Steinþór Nielsson	ÍSOR	
Sveinbjörn Hólmgeirsson	GeoEnergy Consulting	
Sverrir Þórhallsson	ÍSOR	
Thomas Wiersberg	GFZ Potsdam, Germany	
Thor Jan Eriksen	Baker Hughes, Norway	
Tobias Weisenberger	ISOR	
Wilfred A. Elders	UC – Riverside - USA	IDDP-co-PI and SAGA
Yodha Nusiaputra	KIT, Germany	
Þorgrímur S. Árnason	HS Orka	
Þórir Sveinbjörnsson	Jardboranir - IDC	
Þór Gíslason	HS Orka	