

Technology Transfer from Iceland to Kenya During Green Field Study

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ABSTRACT

ÍSOR has been working with a privately-owned energy company Olsuswa Energy (OEL) in Kenya in a green field development at the Barrier Volcanic Center in Kenya. ÍSOR has also assisted OEL in the surface exploration studies as a subcontractor, and in choosing the equipment and techniques to be used. During this process, two specialists from the OEL, Francis Njino Kimani, Geologist and Kevin Njau, Volcanologist were trained by ÍSOR's specialists both in Kenya and Iceland. The OEL experts worked side by side with the Icelandic experts on data collection, data quality evaluation, interpretation, conceptual modelling and resource assessment. The field work, performed by KenGen and supervised by ÍSOR was realized in March 2019 and the final resource report was delivered in July 2019.

ÍSOR's experts participating in the training were; Gylfi Páll Hersir, Finnbogi Óskarsson, Sigurður G. Kristinnsson and Helga Tulinius. The duration of the training was with gaps from beginning of March to end of June 2019.

1. INTRODUCTION

The capacity building was one of the key components of the project. Thus, transfer of knowledge and capacity building was emphasized throughout the consultation and collaboration with experts from the OEL. Technical Review Meetings (TRM) were used to evaluate the status of knowledge within the OEL.

As a provider of advisory services, ÍSOR worked with the OEL's experts on overseeing the process and interpretation of the surface exploration data. The collaboration between ÍSOR and the experts improved overall skills in data interpretation and conceptual modelling.

The experts were involved in all work at site and in ÍSOR's office and in the workshops. The training in the use of geoscientific software was made during the visit of the experts to Iceland.

OEL's experts worked with ÍSOR's experts during site visits and participated in the TRMs. In addition, OEL's experts visited ÍSOR's headquarters for further training for two weeks in May 2019. The visit was used to work on the conceptual model of the geothermal prospect, based on the results of the field work in March and previous studies. The composition of OEL's team visiting Iceland for training purposes was decided in cooperation between ÍSOR and the OEL. As the capacity building program was tailor-made to meet the requirements of OEL, the program was re-evaluated throughout the project.

The training program was divided into two sections: Field section and interpretation section. The field section did focus on field activities and professional data acquisition. The interpretation section focused on interpretation of each data set and integrated interpretation of all available data. "Brain storming" workshops were arranged with participation of key experts at ÍSOR from the different geoscientific disciplines during the conceptual model development. During the workshops, the data interpretation and integrated conceptual model were discussed with input from geochemists, geologists and geophysicists. Several workshops were arranged during the visit of OEL's experts to Iceland, prior to the delivery of the Draft Resource Report. The visit of OEL's experts to Iceland was also used to introduce to OEL experts' various types of geoscientific software used at ÍSOR.

Every member of the ÍSOR team was responsible for the on-the-job training activities and acted as a mentor to the assigned OEL experts. Working alongside ÍSOR experts provided opportunity to extend and develop skills in geological, geophysical and geochemical surface exploration studies. The fieldwork at the early stages of the project did establish a contact that was maintained throughout the project. This contact opened doors for mutual discussion throughout the project.

2. TRAINING IN THE FIELD

In addition to the surface exploration workshop, the capacity building goals of the project were met mainly with *on-the-job training*. ÍSOR proposed direct participation of experts in data collection, data review and interpretation. The OEL experts worked alongside ÍSOR and KenGen experts during the fieldwork. Data review and interpretation were mainly carried out during the visit of OEL experts to Iceland. Each expert had a corresponding key expert at ÍSOR to work with. Two ÍSOR experts were designated to each discipline (geology, geochemistry and geophysics), one responsible and the other to step in when the first was absent for some reason.

The ÍSOR field team included Gylfi Páll Hersir (geophysicist), Finnbogi Óskarsson (geochemist), Sigurdur G. Kristinnsson (geologist) and Martin Mwangi (geophysicist and local contact). Meetings were held in the Barrier-camp all evenings on what had been achieved during the day and to plan the next day with the participation of ÍSOR, OEL and KenGen.

In the first Technical Review Meeting (TRM) it was presented how the field surveys in geology, geochemistry and geophysics should be performed. ÍSOR's experts commented on the plans and pointed out what should be done differently. The OEL participated actively in the discussion.



Figure 1. The ÍSOR team in Barrier (Martin is not present, photo: Brynja Jónsdóttir, ÍSOR).

The scope, main goals and nature of the field campaign to be performed was addressed in lectures before the fieldwork began. The lectures did address technical specifications of the equipment to be used in the surface exploration survey, data acquisition, quality control, data management and interpretation. The lectures were held in the field at the beginning of the field work.

Gylfi and Martin went in the field with the geophysical team, for the MT, TEM, gravity and seismic surveys, and made sure the procedure and locations were correct. OEL's experts participated in those discussions.

While in the field, Finnbogi accompanied the geochemistry team in sampling. Different aspects of sampling were discussed in the field and a few changes were made in order to improve the procedure and thereby the quality of the resulting samples. The mapping of the geology group, previous work and local knowledge were used to identify sampling points.

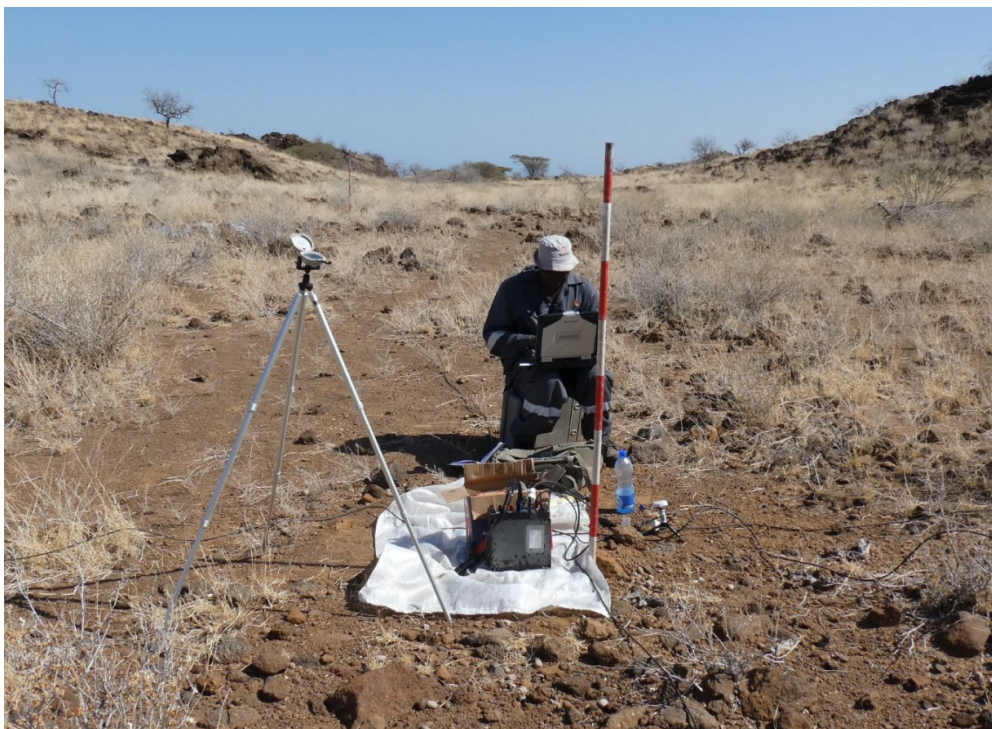


Figure 2. MT data acquisition (photo: Brynja Jónsdóttir, ÍSOR).



Figure 3. Learning how to collect a sample (photo: Brynja Jónsdóttir, ÍSOR).



Figure 4. Evening meeting in the field (photo: Brynja Jónsdóttir, ÍSOR).

Sigurdur went with to the field the geological team for three days and followed up on the methods for the structural and geothermal mapping.

Another TRM was held after two weeks of fieldwork. Martin attended that meeting for ÍSOR. Discussions took place with the participations of ÍSOR, OEL's experts and the subcontractors (KenGen). At the end of the fieldwork the OEL's experts participated with the subcontractor in analyzing the data. When the individual reports were ready they were sent to ÍSOR for review. Shortly after that two experts from OEL arrived in Iceland for two weeks of training.



Figure 5. Gylfi teaching in the field (photo: Brynja Jónsdóttir, ÍSOR).

3. TRAINING IN ICELAND

The training in Iceland was threefold, most mornings were lectures or work with individual ÍSOR expert and group work in the afternoon. Many of the morning lectures were a part of the United Nations Geothermal Programme (UNU), specialized course. Below is the agenda for the two weeks course. All experts worked on the conceptual model of the geothermal area together and selected locations for the first boreholes.

Monday

9:00-12:00 - Geophysical exploration

Gylfi Páll Hersir

The role of geophysical methods in geothermal exploration; its task and primary aim. On geophysical anomalies; what they are and how to interpret them qualitatively and quantitatively. An overview of geophysical methods: Heat transfer and thermal methods, electrical methods (DC-methods, MT and TEM) and the resistivity of rocks, gravity, magnetics, and seismic methods (both active and passive).

The basic theory of these methods was covered plus examples of application from different areas. Also, instrumentation and measurement techniques; model calculations; interpretation in geothermal terms. Finally, fundamentals in presenting data and results will be discussed.

13:00-16:00 – Barrier conceptual model geophysics

Leader: Gylfi, other participants as needed

Tuesday

9:00-12:00 – Chemistry of thermal fluids

Finnbogi Óskarsson

The role of geochemical investigations in geothermal exploration, development and utilization. The application of chemical geothermometers; use of gas chemistry to evaluate boiling processes; deduction of underground movement of water; location of upflow zones. Calculations of composition and chemistry of reservoir fluids. Chemical factors affecting the operation of a geothermal plant. Scaling and corrosion chemistry.

13:00-16:00 – Barrier conceptual model geophysics

Leader: Gylfi, other participants as needed

Wednesday

9:00-16:00 – Barrier conceptual model geology

Leading: Sigurdur, other participants as needed



Figure 6. Training in Iceland (photo: Brynja Jónsdóttir, ÍSOR).

Thursday

9:00-12:00 – Hydrology and hydrogeology

Dadi Thorbjörnsson

Basic concepts in hydrology and hydrogeology along with the history of the science and relations with geothermal sciences: Hydrologic cycle. Hydrogeological parameters (yield – storage – supply – porosity). Permeability and transmissivity. Darcy's Law. Viscosity of liquids and its relations to temperature. Groundwater flow. Aquifers and aquicludes. Intrusions, tectonics, fissures. Hydrogeological maps. Environmental impact. Geothermal pollution in groundwater.

13:00-16:00 – Barrier conceptual model geology

Leader: Sigurdur, other participate as needed. First conceptual model meeting with all experts from both OEL and ÍSOR

Friday

9:00-12:00 – Environmental and sustainability aspects of geothermal development

Marta Rós Karlsdóttir og Hildigunnur Thorsteinsson

Sustainable energy development with a focus on environmental concerns. Sustainability impacts of geothermal development. Air pollution and gas emission control. Liquid and solid disposal. Brine treatment and re-injection. Monitoring methods. Environmental Impact Assessment (EIA), environmental laws and policies.

13:00-16:00 – Barrier conceptual model geophysics

Leader: Gylfi, other participate as needed. Second conceptual model meeting with all experts from both OEL and ÍSOR.

Gylfi: Late afternoon – evening: Visiting and inspecting high-temperature areas on the Reykjanes peninsula: Reykjanes proper, Svartsengi and Krýsuvík.

Monday

9:00-12:00 – Drilling

Sverrir Thorhallsson

13:00-16:00 – Barrier conceptual model geochemistry

Leader: Finnbogi, others participate as needed

16:00 -18:00– Drilling cont. (Sverrir Thorhallsson)

Tuesday

9:00-12:00 - Borehole geophysics (logging)

Benedikt Steingrímsson

Types of geophysical logging in drillholes for the determination of geophysical properties. The main emphasis will be on temperature and pressure measurements: equipment, procedures, interpretation.

Other logs: caliper, electrical, nuclear.

13:00-16:00 – Barrier conceptual model geochemistry

Leader: Finnbogi, Auður. Others participate as needed

Wednesday

9:00-12:00 - Testing of wells

Benedikt Steingrímsson

Flowrate and enthalpy measurement methods in high- and low-temperature fields. Production characteristics of geothermal wells; steam tables; instrumentation; initiation of flow. Well tests and their analysis.

13:00-16:00 – Barrier conceptual model

Leader: Helga, all available ÍSOR experts

Thursday

9:00-12:00 - Geothermal reservoir physics, resource assessment/management and modelling

Gudni Axelsson

Basics/purpose of geothermal reservoir physics/engineering, classification of geothermal systems, conceptual models of geothermal systems, rock and fluid properties, physical processes in geothermal systems, basics of reservoir management, monitoring and reinjection.

13:00-16:00 – Barrier conceptual model and siting of wells

Leader: Helga, all available ÍSOR experts

Friday

9:00-16:00 – Wells siting

Leader: Helga, all available ÍSOR experts

4. DISCUSSION

The OEL experts received all the reports on Barrier from both ÍSOR and KenGen and gave their comments and participated in discussion throughout the project. A final resource report was then delivered to the OEL and the last TRM was held in Nairobi where both ÍSOR and KenGen gave lectures on their interpretation and conclusions.

The training was held both in the field at the Barrier Volcanic Complex (BVC) and at the offices of ÍSOR in Iceland. OEL's experts were trained in geophysics (MT, TEM, gravity and micro-seismic monitoring), geology with emphasis on structural geology and geothermal mapping, and in geochemistry, both in soil gas surveys, sampling and interpretation. The training consisted of hands-on training in the field and two weeks training in Iceland where they had lectures on the above-mentioned topics and hands-on training with the experts from ÍSOR. They also participated while in Iceland in several working meetings with ÍSOR's experts on a conceptual model of BVC based on previous and the new geoscientific results. The final product was a conceptual model of the geothermal field at Barrier. During the course of the training ÍSOR's experts and OEL's experts communicated via email and Skype meetings.

The training was very effective and ÍSOR can state that the training was successful in making both Kevin Njau and Francis Kimani qualified geothermal experts.

Besides the training these two OEL experts received from ÍSOR, they were also trained by KenGen's staff in field data collection, interpretation and analysis and laboratory work which was successfully carried out at KenGen's facilities at Olkaria.