



## **ANNEX I**

### **Project Plan**

### **HYDRORIFT**

Project ID: 09-01-007

Coordinator: Ólafur G. Flóvenz , ISOR

Start date: 05/2009

Duration: 3 years/36 months

Partners: Kristján Ágústsson/ISOR.

Guðmundur Ómar Friðleifsson / HS-orka.

Laurent Geoffrey/University of Le-Mans-Nantes, France.

Catherine Dorbath/EOST - Ecole et Observatoire des Sciences de la  
Terra, France.

## 1 Project description

The proposed project will include a new highly detailed seismic tomography (P, S and  $V_p/V_s$ ) of the Kleifarvatn-Fagradalsfjall area of the Reykjanes peninsula and a joint interpretation with the recently collected TEM/MT data supported by information from boreholes.

The Hydrorift seismic experiment involves 19 seismic stations from the French GEOSTAR network and 13 Reftek stations from the Icelandic Rannis-supported seismic instrument pool Loki, including three broad band stations. Data from the Icelandic regional seismic network, the SIL-network, will be available. The network was fully deployed on May 27<sup>st</sup> 2009 and will run until the end of first week of October 2009. Two days after the deployment was finished, a large earthquake swarm started in the area with thousands of earthquakes recorded in a few days. This meant that already when this proposal was finalised a huge amount of data had been successfully acquired, securing the necessary material for the project.

The Krísuvík-Fagradalsfjall area, located on the plate boundary between the North American and Euro-Asian plates, is seismically very active with frequent microearthquakes and earthquake swarms. Surface manifestations of geothermal activity are widespread. Significant geological and geophysical investigations have been carried out in the area. It is monitored by the regional seismic network operated by the Icelandic Meteorological Office. Dense network of MT and TEM measurements has already been made by ISOR on behalf of HS-orka. Several deep boreholes (up to 3 km) are in the area and temperature profiles and other logs from the wells will be used for the interpretation of the seismic data. HS-orka has been granted a research permit for geothermal exploration in the area and this project will add supplementary data and create synergies with the ongoing exploration.

The collection of the data was a joint effort by the French group and ISOR with managerial participation from HS-orka. Scientists from France and Iceland operated the network under the supervision of Kristján Ágústsson at ÍSOR and performed quality analysis and preliminary processing of the data. After the completion of the data acquisition the actual processing of the data starts. A French PhD student has already been attached to the project and the an Icelandic young scientist (post-doc) will be hired on the project. The processing of the data and their interpretation will include or give:

1. Location of seismic events.
2. Analysis of focal mechanisms and stress fields.
3. Analysis of active faults, their strike and dip.
4. Tomographic imaging of the research area using both P and S waves.
5. Estimate the velocity anisotropy by using S-wave splitting.
6. Special analysis of the maximum depth of earthquakes and how it varies over the area in order to estimate the brittle-ductile transition.
7. Near-source attenuation patterns for large magnitude events.

8. Evaluate the temperature at the brittle/ductile transition and use it to put constraint on the temperature distribution in the area with special respect to the geothermal systems. Compare with earlier results (Ágústsson & Flóvenz, 2005).
9. Use jointly TEM/MT resistivity data, seismic and temperature data as well as other available geophysical data to interpret the anomalies observed in all datasets.
10. Make special effort to explain the anomaly Vp/Vs ratio in the area (Lauernt & Dorbath, 2008), with emphasis of the hypothesis of supercritical fluids (Tryggvason et al, 2002).

All the above items will be carried out in close co-operation between the Icelandic and the French parties. The French party will mainly concentrate on items 1-4 while the main contribution from the Icelandic side will be on items 5-10.

### 1.1 Objectives and GEORG WP relevance

In the Grant Submission Document the main objectives of the project are:

- 1) To understand better the mechanical significance of a velocity anomaly known to be in the Kleifarvatn-Fagradalsfjall area. The experiment is a more extended and focused continuation of a seismic experiment carried out in Krísuvík 2005 (Geoffroy & Dorbath 2008).
- 2) To improve the understanding and knowledge of hydrothermal processes in the crust, especially the processes of heat extraction from hot or even partially molten intrusions at crustal levels.

| WP Number: | Project relevance %  |
|------------|----------------------|
| WP 2       | 30 (tasks 2.1 & 2.2) |
| WP 3       |                      |
| WP 4       | 50 (tasks 4.1 – 4.4) |
| WP 5       |                      |
| WP 6       |                      |
| WP 7       |                      |
| WP 8       | 20 (tasks 8.2 – 8.4) |

The objectives according to the WPs of GEORG in the table above will be achieved in the following way:

**WP2:** Research activity and training of a young scientist (**Task 2.1**) with involvement of local and foreign experts (**Task 2.2**).

**WP4:** The project touches upon several tasks in this work package. In particular **Task 4.1(c)** (Surveys to reveal the deep structure of active geothermal fields), **Task 4.2(a)** (Detailed analysis of focal mechanisms of earthquakes), **Task 4.3(c)** (Microseismic data collection and detailed analysis of seismic activity in geothermal systems) and **Task 4.4.(a)** (The development of the magneto-telluric and passive seismic methods to create high resolution 3D resistivity and seismic velocity images of the reservoir).

**WP8:** Presentation of results and progress will be through standard methods of publications and presentations in conferences with emphasis on mini-conferences to strengthen relationships with Energy Authorities (**Tasks 8.2, 8.3 and 8.4**)

## 2 Work plan and time schedule:

The project consisted of two main parts. First, there was a deployment of 32 seismic stations and its operation over five months period (May-Oct 2009). Included in that was quality control and preliminary analysis. Secondly is detailed analysis of the data and interpretation integrated with MT/TEM measurements.

### Time schedule:

| Subtask                                     | Start      | Finish     | Deliverable/Milestone               |
|---|------------|------------|-------------------------------------|
| Data collection                             | 22-05-2009 | 15-11-2009 | Collection of Data, Data report     |
| Processing of data                          | 01-07-2009 | 31-05-2010 | Reports with results                |
| Interpretation of data & modeling           | 01-06-2010 | 31-12-2011 | Preliminary reports                 |
| Comparison with other data (res, temp etc.) | 01-07-2010 | 31-12-2011 | Preliminary reports                 |
| Paper for publication                       | 31-10-2011 | 30-04-2012 | Manuscript submitted, PhD completed |

| Timeline for Hydrorift         | 2009 |   |   |   | 2010 |    |    |    | 2011 |   |   |   | 2012 |   |   |   |   |    |    |    |   |   |   |   |
|--------------------------------|------|---|---|---|------|----|----|----|------|---|---|---|------|---|---|---|---|----|----|----|---|---|---|---|
|                                | 5    | 6 | 7 | 8 | 9    | 10 | 11 | 12 | 1    | 2 | 3 | 4 | 5    | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
| Network installation/demobil.  | ■    |   |   |   |      |    |    |    |      |   |   |   |      |   |   |   |   |    |    |    |   |   |   |   |
| Seismic data collection        | ■    | ■ | ■ | ■ |      |    |    |    |      |   |   |   |      |   |   |   |   |    |    |    |   |   |   |   |
| Seismic data collection report |      |   |   |   |      |    |    | ■  |      |   |   |   |      |   |   |   |   |    |    |    |   |   |   |   |
| Seismic data processing        |      | ■ | ■ | ■ | ■    | ■  | ■  | ■  |      |   |   |   |      |   |   |   |   |    |    |    |   |   |   |   |
| Seismic data processing report |      |   |   |   |      |    |    | ■  |      |   |   |   |      |   |   |   |   |    |    |    |   |   |   |   |
| Seismic data interpretation    |      |   |   |   |      |    |    |    | ■    | ■ | ■ | ■ | ■    | ■ | ■ | ■ | ■ | ■  | ■  | ■  |   |   |   |   |
| Preliminary data int. Report   |      |   |   |   |      |    |    |    |      |   |   |   | ■    |   |   |   |   |    |    | ■  |   |   |   |   |
| Comparison with resistivity    |      |   |   |   |      |    |    |    |      |   |   |   |      |   |   |   |   |    |    |    |   |   |   |   |
| Comparison with other data     |      |   |   |   |      |    |    |    |      |   |   |   |      |   |   |   |   |    |    |    |   |   |   |   |
| Papers for publication         |      |   |   |   |      |    |    |    |      |   |   |   |      |   |   |   |   |    |    |    |   |   |   |   |
| Submission of papers/Thesis    |      |   |   |   |      |    |    |    |      |   |   |   |      |   |   |   |   |    |    |    |   |   |   | ■ |

### 3 Project Management

The project extends over three years. It is managed by the three applicants: Dr. Ólafur G. Flóvenz on behalf of ISOR, Dr. Guðmundur Ómar Friðleifsson on behalf of HS-orka and Laurent Geoffrey on behalf of the CNRS. The specialists involved are on ISOR's part: Kristján Ágústsson (seismology), Arnar Már Vilhjálmsson (MT expert), Gylfi Páll Hersir (MT expert) and Ragna Karlsdóttir (geothermal expert). On the French part: Dr. Catherine Dorbath (EOST, seismology responsible) Dr. Cécile Doubre (EOST, seismology), Dr. Ludovic Bodet (UMR CNRS 6112 Le Mans-Nantes), Dr. Alexandre Scubnel (ENS Paris), Dr. Jérôme Fortin (ENS Paris), Mathilde Adelinet (PhD student, UMR CNRS 6112 Le Mans-Nantes) and Aurore Franco (Post-doc, UMR CNRS 6112 Le Mans-Nantes).

All resources of the project are already secured. It includes close co-operation of Icelandic and French and provides large financial and scientific contribution from international (French) sources where the project has already passed the review process.

## 4 Budget overview

Consortium: ISOR, HS-orka, CNRS,EOST - Ecole et Observatoire des Sciences de la Terre  
 Name of Project: HYDRORIFT

| ISK '000  |           | 2009       |        | Year 1 2009/2010 |        | Year 2 2010/2011 |        | Year 3 2011/2012 |  | Grand Total |
|---|-----------|------------|--------|------------------|--------|------------------|--------|------------------|--|-------------|
|   | Unit cost | Man-months | Total  | Man-months       | Total  | Man-months       | Total  |                  |  |             |
| <b>Salaries including overhead</b>                      |           |            |        |                  |        |                  |        |                  |  |             |
| Senior experts  | ISOR      | 1.200      | 2,0    | 2.400            | 2,0    | 2.400            | 2      | 2.400            |  | 7.200       |
| Young scientist (PhD)                                   | ISOR      | 900        | 4,0    | 3.600            | 12,0   | 10.800           | 12     | 10.800           |  | 25.200      |
| Junior scientist  | ISOR      | 600        | 3      | 1.800            |        | 0                |        | 0                |  | 1.800       |
| Co-ordinator  | HS-orka   | 1.200      | 0,5    | 600              | 0,5    | 600              | 0,5    | 600              |  | 1.800       |
| France scientist  | CNRS/EOST |            |        | 17.000           |        | 11.500           |        | 11.500           |  | 40.000      |
| <participant>   | NN        |            |        | 0                |        | 0                |        | 0                |  | 0           |
| <participant>   | NN        |            |        | 0                |        | 0                |        | 0                |  | 0           |
| <b>Total</b>  |           |            | 10     | 25.400           | 15     | 25.300           | 15     | 25.300           |  | 76.000      |
| <b>Operational exp.</b>                                 |           |            |        |                  |        |                  |        |                  |  |             |
| Seismic stations rental from LOKI instrument pool       |           |            | 900    |                  |        |                  |        |                  |  | 900         |
| Batteries   |           |            | 160    |                  |        |                  |        |                  |  | 160         |
| 4WD cars  |           |            | 600    |                  |        |                  |        |                  |  | 600         |
| Sustenance  |           |            | 240    |                  |        |                  |        |                  |  | 240         |
| The cost of the France stations, transport and logistic |           |            | 8.500  |                  |        |                  |        |                  |  | 8.500       |
| <b>Total</b>  |           |            | 10.400 |                  | 0      |                  | 0      |                  |  | 10.400      |
| <b>Travel expenses</b>                                  |           |            |        |                  |        |                  |        |                  |  |             |
| Travel for Icelandic PhD student to France              |           |            |        |                  | 400    |                  |        |                  |  | 400         |
| b   |           |            |        |                  |        |                  |        |                  |  | 0           |
| c   |           |            |        |                  |        |                  |        |                  |  | 0           |
| <b>Total</b>  |           |            | 0      |                  | 400    |                  | 0      |                  |  | 400         |
| <b>Total cost</b>                                       |           |            | 35.800 |                  | 25.700 |                  | 25.300 |                  |  | 86.800      |
| <b>Financing</b>  |           |            |        |                  |        |                  |        |                  |  |             |
| ISOR  |           |            | 5.200  |                  | 5.000  |                  | 8.300  |                  |  | 18.500      |
| HS-orka   |           |            | 600    |                  | 5.300  |                  | 2.500  |                  |  | 8.400       |
| Franch partners and foundations                         |           |            | 25.500 |                  | 11.500 |                  | 11.500 |                  |  | 48.500      |
| <b>Total other financing</b>                            |           |            | 31.300 | 87%              | 21.800 | 85%              | 22.300 | 88%              |  | 75.400      |
| <b>Requested funding from GEORG</b>                     |           |            | 4.500  | 13%              | 3.900  | 15%              | 3.000  | 12%              |  | 11.400      |
| <b>Total financing</b>                                  |           |            | 35.800 |                  | 25.700 |                  | 25.300 |                  |  | 86.800      |