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Iceland GeoSurvey

**Where energy production
is not a problem
- it's a solution**

Iceland is the planet's most perfect geological laboratory. Here the earth's inner workings are revealed, accessible for study and experimentation. Here generations of scientists have observed and trained. This is a place where accumulated scientific knowledge has been applied to harnessing the earth's power. Iceland GeoSurvey is an active participant in the development and evolution of that endeavour. Our experience and know-how are our most valuable assets, and have practical application throughout the world.

Iceland GeoSurvey

Geothermal

Harnessing geothermal resources is a complicated process. It requires a combination of technical and scientific expertise, highly specialised equipment, sophisticated computer systems, and practical know-how. This is where Iceland GeoSurvey excels. Teams of scientists, engineers, and technicians work on every aspect of geoscientific investigations and the development of sophisticated systems to understand and utilise the earth's heat energy.



Beneath the earth's crust are vast reserves of heat energy. Heat is transported to the surface in volcanic eruptions, via hot springs, geysers, and by heat convection. Harnessing this heat is economically viable and environmentally benign, and it represents a vast worldwide energy resource that has hardly been tapped.

Meteoric water (rain) makes this heat accessible for use. Groundwater seeping deep into the earth's crust through fissures and faults comes into contact with the hot rock below. Brought to the surface from considerable depths through boreholes as water or steam, the heat energy can be applied to many uses.

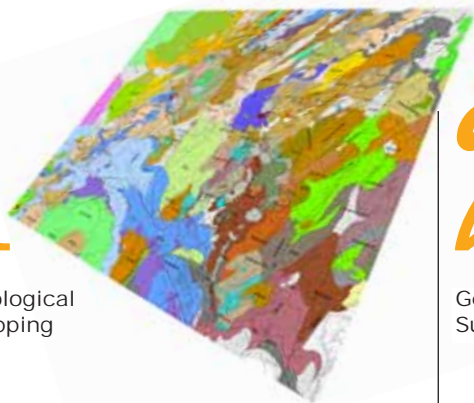
Only a small fraction of the worldwide geothermal potential has been developed so far. There is ample opportunity for an increased use of geothermal energy both for direct applications and electricity production.

Iceland GeoSurvey is committed to the promotion of geothermal energy, both as a viable solution to the world's energy needs and as a contribution to its environmental well-being. Our company actively participates in the dissemination of knowledge about geothermal systems, and in the training of scientists and technicians from around the world, with emphasis on assisting developing nations.

Exploration and Field Assessment

1

Geological Mapping



For Iceland GeoSurvey, the development of a geothermal resource for electric power and hot water production comprises in principle three phases:

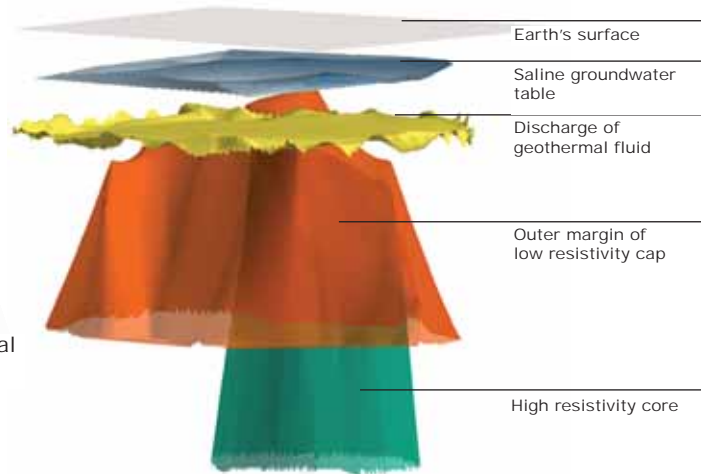
- Resource identification, surface exploration, and assessment
- Siting and drilling of wells, and resource evaluation
- Monitoring of reservoir and environment

The hallmark of Iceland GeoSurvey is to develop technologies that combine relatively low cost and high effectiveness.

- Our geologists produce detailed maps of potential geothermal resource areas, covering tectonic and stratigraphic features, surface petrology, mineralogy, and lithology of the resource area. Features of particular interest are fracture zones, which may provide flow paths for the geothermal fluid.

2

Geophysical Surveys



- Resistivity surveys as carried out by Iceland GeoSurvey yield important information about the subsurface structure of geothermal systems. Transient electromagnetic (TEM) soundings are used to map temperature distribution in the uppermost 1 km of the crust, and magneto-telluric (MT) methods are applied to detect up-flow of thermal fluid into the reservoir. Monitoring of seismic activity shows fracture zones at depth. Gravity surveys may reveal tectonic features in the reservoir.

3

Geochemical Studies

Sulphur crystals are deposited around fumaroles when hydrogen sulphide in geothermal steam is oxidised by the atmosphere.



- Chemical analysis of surface geothermal fluids yields an estimate of the likely temperature of the reservoir, and provides insights into boiling processes, fluid flow paths, and fluid origins.



4

Exploration Drilling and Coring



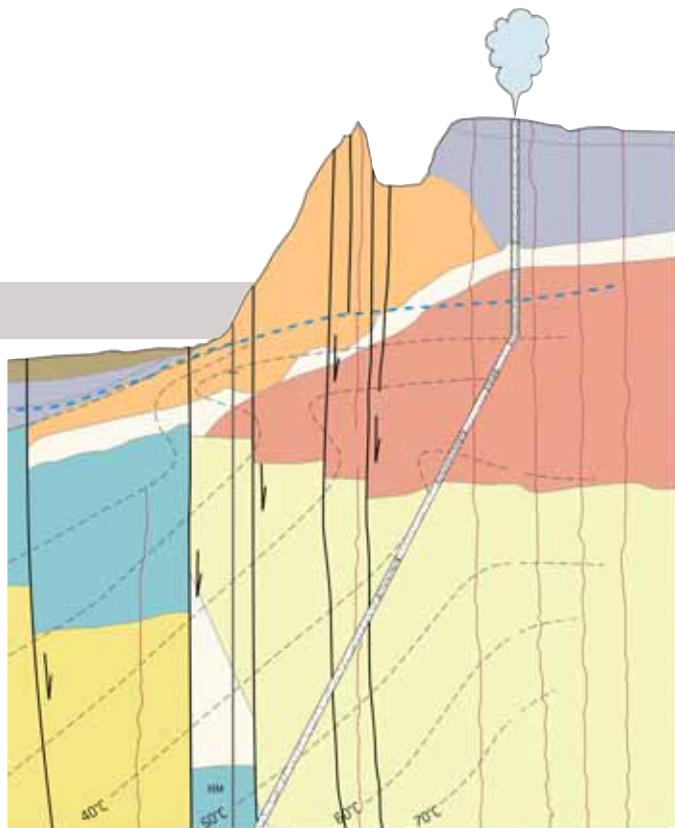
Information about subsurface geology and the inner structure of the reservoir is obtained by drilling exploration wells, which yield data on the potential temperature and pressure of the reservoir; the chemical composition of the fluid is established by sampling.

Field Development: Drilling and Reservoir Evaluation

5

Siting and Design of Wells and Drilling Services

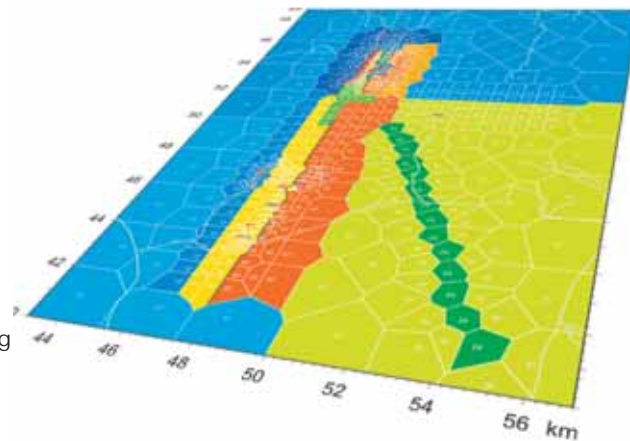
Cross-interpretation of data obtained from surface study and exploratory drilling is used to site and design the first two to four production/injection wells. Iceland GeoSurvey scientists carry out geophysical logging and geological monitoring throughout the drilling phase. Testing upon completion of the well includes measurements of reservoir pressure and temperature and determination of fluid chemical composition. The results are used to construct a natural-state reservoir model.



6

Evaluation and Modelling of Reservoir

Based on surface exploration and drilling, an estimate is made of the reservoir's area, depth, and potential capacity. The geothermal reservoir's response to fluid production is assessed by mathematical modelling of its properties.



Such models help predict the geothermal reservoir's short and long-term behaviour, and the level of reinjection necessary to sustain its pressure and yield. Chemical analysis of the fluid is used to assess its corrosion and scaling potential.

7

Long-term Reservoir and Environmental Monitoring

A geothermal reservoir in production requires continuous and careful monitoring. This involves metering net mass extraction, reservoir pressure and temperature, and chemical analyses to detect possible intrusion of cold fluid and changes in properties of reservoir fluid. Iceland GeoSurvey is committed to environmental standards, entailing systematic assessment of environmental parameters such as liquid and gaseous emissions, subsidence, and near-surface boiling.

With laboratories, highly specialised equipment, powerful computers, and sixty years of experience in Iceland's geothermal fields, Iceland GeoSurvey's scientific and engineering personnel are uniquely well-equipped to carry out every step of this development process for their clients, either in its entirety or as separate tasks or evaluations.



USA, Alaska

Evaluation of geothermal data from the Makusin geothermal field in the Aleutian Islands.

USA, California

Evaluation of geothermal data from the Truck-haven geothermal field. Consulting on well location and design.

El Salvador

Geothermal services involving drilling, reservoir modelling, tracer tests, and resource management in the Ahuachapan and Berlin geothermal fields. Training courses and workshops on different aspects of geothermal development.

Nicaragua

Consulting on siting new wells and reservoir re-assessment. Review of and recommendation on energy conversion equipment for the new San Jacinto Development. Evaluation of possible development cooperation between Iceland and Nicaragua. Geothermal workshops and training.

Costa Rica

Training and consulting services on geothermal development and resource management. Advice on tracer testing.

Guadeloupe

Stimulation and testing of geothermal wells connected to power plants in operation. Monitoring of the Bouillante geothermal field's response to power production.

Germany

Data evaluation and consulting on deep geothermal drilling for combined heat and electrical power generation in Molassenbecken and upper Rhine Valley.

Uganda

Geothermal exploration and exploratory drilling.

Hungary

Data evaluation and consulting on development of geothermal resources for combined heat and electrical power generation, using dry oil exploration wells.

Djibouti

Long-term geothermal well testing to determine chemical properties of brine with high dissolved-solids content in the Assal field. Geothermal surveying as prelude to production/injection well siting.

Kenya

Resource assessment of the Olkaria II geothermal field. Workshops and lecture courses for geothermal decision makers and specialists from countries in the East African Rift Valley.

Iceland GeoSurvey's teams of scientists and technicians travel around the globe, focusing on a broad range of projects related to geothermal development, monitoring, and consulting.

China

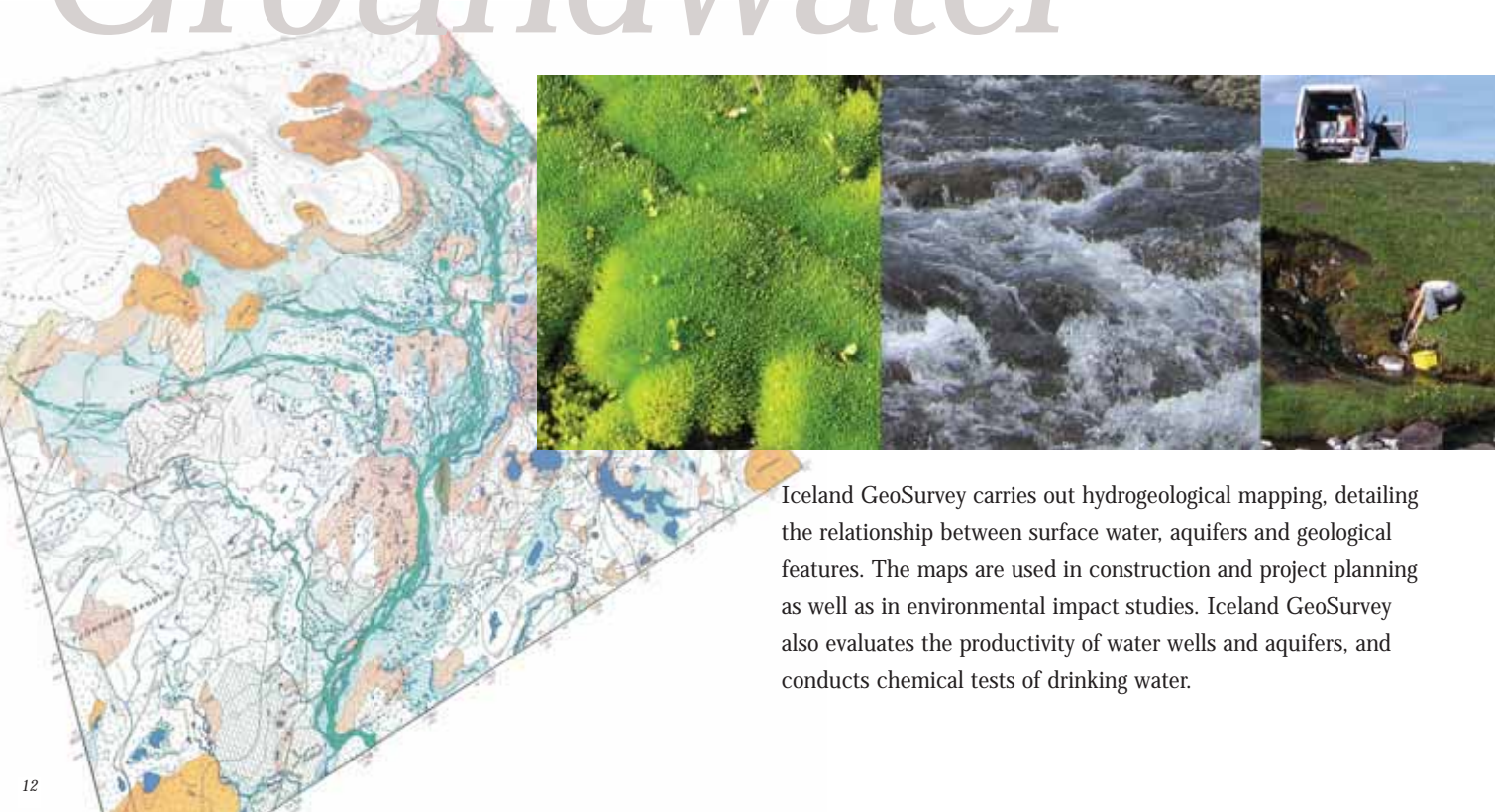
Consulting services and resource assessment training, reservoir modelling, and management of geothermal resources in Tanggu, Beijing, and Xianyang.

Russia, Chukotka

Geothermal exploration and drilling consulting services.

Groundwater

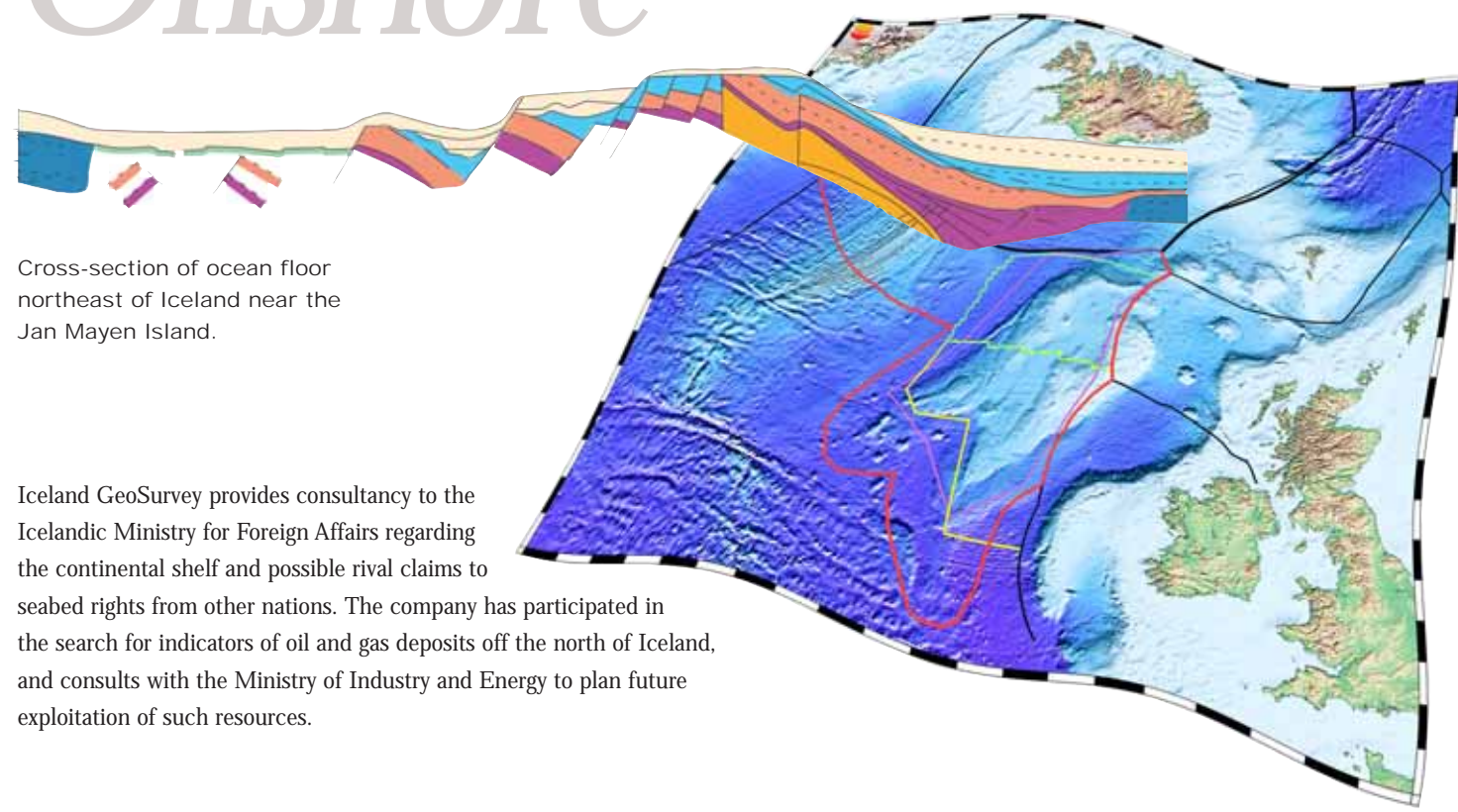
Iceland GeoSurvey offers services related to groundwater issues. These include advising municipal waterworks, fish farmers, and the bottled-water industry, defining water protection areas, and monitoring groundwater pollution.



Iceland GeoSurvey carries out hydrogeological mapping, detailing the relationship between surface water, aquifers and geological features. The maps are used in construction and project planning as well as in environmental impact studies. Iceland GeoSurvey also evaluates the productivity of water wells and aquifers, and conducts chemical tests of drinking water.

Offshore

Iceland GeoSurvey's project list includes a marine survey of the ocean floor, interpreting geophysical data of the sea bottom to define the extent of Iceland's continental shelf. The results of such surveys are an important tool in international discussions vis-à-vis national claims on gas and oil drilling rights.



Cross-section of ocean floor northeast of Iceland near the Jan Mayen Island.

Iceland GeoSurvey provides consultancy to the Icelandic Ministry for Foreign Affairs regarding the continental shelf and possible rival claims to seabed rights from other nations. The company has participated in the search for indicators of oil and gas deposits off the north of Iceland, and consults with the Ministry of Industry and Energy to plan future exploitation of such resources.

Environment

Environmental Impact Assessments (EIAs) are an important aspect of any geothermal project, from the earliest planning stages through to post-project analysis. Iceland GeoSurvey offers complete EIA services at every juncture of the process, as well as studies conducted for municipal, construction, and public works projects.



What sorts of environmental assessments are conducted in relation to any given geothermal development project?

Before any project commences, various options are considered to determine maximum energy production with minimum impact on the environment.

Once the suitability of geothermal development has been confirmed, studies must be conducted to determine the effect of mass removal of fluids on subsidence and erosion in the area, the effect on groundwater of the discharge of geothermal fluids, the emission of gases such as H₂S and CO₂, and the potential of mineral deposition in the wells or nearby geological formations.

During the project's construction phase, constant monitoring and testing guide the placement and drilling of wells.

After an area has been developed, on-going testing is necessary to understand and mitigate the long-term effects of the project, both to protect the environment and to keep the wells efficient and reliable.

International Cooperation and Membership

Iceland GeoSurvey is active worldwide in the promotion and advancement of geothermal energy production.

- EuroGeoSurvey *Member*
- Global Roundtable on Climate Change *Participant*
- European Geothermal Energy Council *Member*
- International Geothermal Association *Representative*
- International Energy Association *Icelandic representative for the National Energy Authority*
- Association of Regional Geothermal Energy Organization *Consultancy in East African project*
- European Union Energy Committee *Iceland representative*

Education



Scientists employed by Iceland GeoSurvey conduct about 60% of the teaching at the United Nations University Geothermal Training Programme (UNU-GTP). Established in 1978 by the United Nations University and the government of Iceland, the UNU-GTP is administered by the National Energy Authority of Iceland with facilities located at Iceland GeoSurvey's headquarters in Reykjavik.

Iceland GeoSurvey meets its commitment to the development of geothermal energy worldwide to a considerable degree through geothermal training at all levels. Iceland GeoSurvey's scientists comprise the majority of the specialist staff of the United Nations University Geothermal Training Programme. In addition, training courses and workshops are conducted all over the world, teaching local scientists geothermal science and techniques.

Each year over 20 geothermal professionals from developing countries around the world are enrolled for six months' intensive training in geothermal science and engineering. Annually five or six individuals complete a two-year Masters of Science degree in geothermal studies in cooperation with the University of Iceland.

Iceland GeoSurvey has co-operated in organising tailor-made international workshops, lectures, and training courses in geothermal development, with special emphasis on developing nations in Africa, Central America, and Asia.

Iceland GeoSurvey is committed to

- 1** ...being in the forefront of geoscientific research, development, and service.
- 2** ...finding ways to enhance and augment geothermal resources and participating in the Iceland Deep Drilling Project.
- 3** ...enhancing the environment and contributing to the debate on environmental issues.
- 4** ...actively promoting geothermal development by increasing public and political awareness and understanding.
- 5** ...training scientists throughout the world in geothermal science and development.
- 6** ...participating in international geothermal development projects.

Iceland GeoSurvey

Iceland GeoSurvey is a 100% self-financed, non-profit governmental institution which operates on the free market like a private company. It receives no direct funding from the government, and operates on a project and contract basis.

Iceland GeoSurvey, established in July 2003, is a service and research institute providing specialist services to the Icelandic power sector, the Icelandic government and foreign companies, in particular in the field of geothermal sciences and utilisation. Iceland GeoSurvey took over all responsibilities of the former GeoScience Division of Orkustofnun, the National Energy Authority of Iceland.



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