GEOTHERMAL TRAINING IN ICELAND 1979-1996

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INTRODUCTION

The Geothermal Training Programme of the United Nations University (UNU) was established in Iceland in 1979. Since then, a group of scientists and engineers from energy agencies and research organizations, and in a few instances, universities in the developing countries, have come to Iceland every spring to spend six months in high-specialized studies and on-the-job training in geothermal science and engineering. All of them are university graduates with practical experience in geothermal work in their home countries. The training is tailor-made to the individual and the needs of his institution/country. In all, 181 participants from 33 countries completed the six-month course during 1979-1996. Table 1 shows the number of participants per country and the specialized courses they have taken during 1979-1996.

The Training Programme operates within the Geothermal Division of Orkustofnun, the National Energy Authority (NEA) of Iceland. It is academically governed by a Studies Board, which is composed of experts responsible for each of the eight specialized courses that are offered, and a chairman who is the director of the Training Programme. The present members of the Studies Board are Kristjan Saemundsson (Geological Exploration), Hjalti Franzson (Borehole Geology), Olafur Flovenz (Geophysical Exploration), Benedikt Steingrimsson (Borehole Geophysics), and Sverrir Thorhallssson (Drilling Technology) from the NEA; Stefan Armorsson (Chemistry of Thermal Fluids) and Valdimar K. Jonsson (Geothermal Utilization) from the University of Iceland, and Snorri Pall Kjaran (Reservoir Engineering) from the Vatnaskil Consulting Engineers Ltd. Ingvar Birgir Fridleifsson has been the director of the Training Programme from the beginning except for one training season in 1981 when Hjalti Franzson served as director, and three training sessions in 1986-1988 when Jon Steinar Gudmundsson served as director. Ludvik S. Georgsson has been the deputy-director since 1990.

The NEA became an Associated Institution of the UNU in 1979. It is the only Associated Institution of the UNU offering training in geothermal energy science and technology. The cost of the operations of the Training Programme in Reykjavik is shared by the Government of Iceland (80%) and the United Nations University (20%). The Icelandic contribution is a part of the development aid of the Government of Iceland. There is a great demand for the type of specialized training offered. It is, therefore, planned to continue with the same type of training in the near future.

THE TRAINING

The approximate time schedule of the Training Programme is shown in Table 2. The duration is 6 months. In general, all participants are expected to attend an introductory lecture course that last 4-5 weeks (three lectures and a practical each day). The aim of the lecture course is to provide a background knowledge on most aspects of geothermal energy resources and technology, and to generate an appreciation for the inter-relationship between the various disciplines necessary in geothermal projects from the initial exploration to the stages of implementation and utilization. Participants have to take two written tests during the introductory lecture course. The lecture course is followed by practical training in a specialized field and the execution of a research project that is concluded with an extensive project report. Study tours are arranged to all the main geothermal fields under exploration and utilization in Iceland.

All participants receive training in using PC-computers for word processing and interpretation of data. Experience has shown that most trainees have access to PC-computers at home, and they can take their diskettes home and continue to work there. Thus, there has been a considerable transfer of computer technology from Reykjavik to geothermal institutions in the developing countries. Participants having access to large computers at home are allowed to work on the main frame computer at the NEA.

The main emphasis of the training is to provide the participants with sufficient understanding and practical experience to permit the independent execution of projects within a selected discipline in their home countries. Eight specialized lines of training are offered (Table 2). Each participant is meant to follow only one line of training; but within each line, there is considerable flexibility. A significant part of the practical training is done in connection with the research projects of the Fellows. In many cases, the participants bring with them data from geothermal projects in their home countries; but sometimes, the research projects are integrated with geothermal exploration or utilization projects that are in progress in Iceland at the time of training. The project topic is always selected with respect to the conditions of the home country of the participant. Many of the project reports are written in such a way that they serve as manuals for performing certain measurements or interpretations dealt with in respective reports. All the project reports are published by the Training Programme. Copies can be obtained upon request. The reports are mailed regularly to many of the

Table 1. Participation in the UNU Geothermal Training Programme in Iceland, 1979-1996

Country	Geological Exploration	Borehole Geology	Geophysical Exploration	Borehole Geophysics	Reservoir Engineering	Chemistry of Thermal Fluids	Geothermal Utilization	Drilling Technology	Total
Algeria	1					1	1		3
Bulgaria				1	2	2			5
Burundi	1								1
Costa Rica	1	1	2		1		1		6
China		3	1	2	10	6	9	1	32
Djbouti		1							1
Egypt		1			1	1			3
El Salvador	1	1	1	2	3			2	10
Ethiopia		1	2	1	2	2	1	1	10
Greece			1				2		3
Guatemala			1				1		2
Honduras		1	1						2
Indonesia		3	3	2	2			1	11
Iran	1								1
Jordan				1	1				2
Kenya	1	4	7		3	4	1	2	22
Lithuania							1		1
Macedonia						1			1
Mexico	1		1		2				4
Nepal						1	1		2
Nicaragua					3	1			4
Pakistan	1								1
Philippines		3	3	4	7	5	3		25
Poland		1			2				3
Romania							4		4
Russia				1					1
Serbia				1	1	1			3
Slovakia				1	1				2
Tanzania	1								1
Thailand		1		2		1	1		5
Turkey		1			1		1		3
Uganda	2	1	1			1			5
Viet Nam					1	1			2
Total	11	23	24	18	42	29	26	7	181

Table 2. UNU Geothermal Training Programme in Iceland

Week	Geological Exploration	Borehole Geology	Geophysical Exploration	Borehole Geophysics	Reservoir Engineering	Chemistry of Thermal Fluids	Geothermal Utilization	Drilling Technology	Week
1 2 3 4 5	Lecture course on all main aspects of goethermal energy exploration and utilization, practicals and short field excursions								1 2 3 4 5
6 7 8 9 10	Field Geology Maps and Photos Structure analysis Hydrogeology	Drilling Petrological logging	Theoretical studies Field Work	Course on well logging and reservoir engineering Logging and well test practises Data analysis Reservoir properties Well performance Reservoir simulation		Sampling of fluids and gas Scaling and corrosion Analytical methods Thermdynamics	Course on heat transfer and fluid flow	Drilling equipment Drilling procedures Safety Well design Management	6 7 8 9 10
11 12	Excursion to the main geothermal fields of Iceland								11 12
13 14 15 16	Field work in deeply eroded strata and recent volcanic fields	Alteration mineralogy Aquifers Modeling	Data processing techniques and tools	Logging methods Data evaluation	Well testing Reservoir simulation Responses to exploitation	Chemical geothermometers Water rock interaction	Design of plants systems	Rig operations Cementing Completion	13 14 15 16
17 18 19 20 21 22 23 24 25 26	Project and Report	Project and Report	Project and Report	Project and Report	Project and Report	Project and Report	Project and Report	Project and Report	17 18 19 20 21 22 23 24 25 26

leading geothermal institutions in the developing countries. The titles of the reports from 1979-1984, 1985-1989, and 1990-1994 are listed by author in Fridleifsson (1985), Fridleifsson (1990) and Fridleifsson (1995) respectively. These lists also give the names of all participants who have completed the six-month course during 1979-1989.

THE SPECIALIZED COURSES

The geological exploration course offers practical training in basic geological mapping, which is commonly the first step in the geothermal exploration of an area. Participants analyze the geological structure of an area with regard to siting drill holes, both thermal gradient and production wells. Many of the participants have also been trained in mapping surface geothermal manifestations, including shallow temperature surveys and measurement of flow rates of springs. The field work is commonly conducted both in active geothermal and volcanic areas and in deeply eroded areas where the roots of extinct volcanoes and hydrothermal systems can be inspected. Participants should have a degree in geology.

The **borehole geology** course gives training in making geological logs, analyses of drill cuttings and cores, and in some cases, fluid inclusions. The identification of alteration minerals (microscope and x-ray diffraction) and the interpretation of the alteration mineralogy forms an integral part of the course. Many of the participants receive training in collecting and interpreting data on aquifers and in making geological models of geothermal reservoirs based on their own data and data from other disciplines. Participants should have a degree in geology.

The **geophysical exploration** course is for practical training in conducting geophysical surveys of geothermal areas and/or interpretation of such data. The essentials of heat flow surveys, magnetic and gravity surveys, as well as resistivity depth soundings and profiling are covered. During the latter half of the training, a selection can be made between further specialization in electric survey (Schlumberger, dipole, head-on profiling, TEM, MT, AMT, SP), magnetic surveys and gravity surveys. Emphasis is laid on the application of computers in the interpretation of geophysical data. Participants should have a degree in physics, geophysics or engineering.

The course in **borehole geophysics** covers the essentials of geophysical measurements in boreholes used for geothermal investigations, with the main emphasis on temperature and pressure measurements, but including lithology logs such as electrical resistivity, caliper, porosity and density logs, and well completion logs such as CCL, CBL, inclination and spinner logs. The participants undertake well measurements; but, most of the time is devoted to the interpretation of logging data. Participants should have a degree in physics, geophysics or engineering.

The **reservoir engineering** course covers the methodology needed to obtain information on the hydrological characteristics of geothermal reservoirs and to forecast the long-term response of the reservoirs to exploitation. Both surface and downhole measurements are considered and the interpretation of flow tests of wells, injection tests and interference tests. It is also possible to specialize in production engineering of geothermal fields. The course requires a sound background in mathematics. Participants should have a degree in engineering, physics, geophysics, mathematics or hydrogeology.

The course on **chemistry of thermal fluids** gives an insight into the role of thermal fluid chemistry in geothermal exploration and exploitation, including sampling, analysis of

major constituents and the interpretation of results. Much emphasis is placed on the application of chemical thermometers and the calculation of mixing models. Environmental aspects of the thermal fluids are also considered. The participants need a solid background in chemistry. They should have a degree in chemistry, geochemistry or chemical engineering.

The course in **geothermal utilization** deals with the civil, mechanical and chemical engineering aspects of geothermal fluids in pipes, equipment and plants. The feasibility of projects and environmental factors are also considered. Due to the wide spectrum covered by geothermal engineering, the participants have to be very selective in their specialization. Most of the participants specialize in the design and/or feasibility studies of district heating systems and/or in the application of geothermal steam and water in industry. One specialization is the selection, installment and operation of downhole pumps in geothermal wells. Participants should have a degree in engineering.

The course in **drilling technology** provides engineers with the information and on-site training necessary to prepare them for the work of drilling engineers or supervisors. The course is thus, training in the planning and supervision of drilling and not in the task of drilling itself. The course deals with the selection of drilling equipment, the design of wells and casing programs, as well as cementing techniques. The cleaning and repairs of production wells is also covered. Participants should have a degree in engineering.

TEACHING MATERIAL

Most the teaching is done by tutorials and practical work where the teacher works with two or three trainees, and use is made of available textbooks and articles in journals as appropriate. In some instances, however, a special effort has been required to compile text material and manuals as teaching material for the training. Most of this work has been done by the regular teachers of the Training Programme, who are mostly staff members of the National Energy Authority and the University of Iceland. Some texts have also been written by visiting scholars from other countries. Some of the teaching material has been published in reports, and is available from the Training Programme. Examples include the texts on hydrogeology (Sigurdsson, 1987), geophysical exploration (Hersir and Bjornsson, 1991), geothermal logging (Kjaran and Eliasson, 1983), geothermal reservoir physics (Bodvarsson, 1987), geothermal district heating (Karlsson, 1982), direct use of geothermal energy (Lund, 1987 and 1996), and one dimensional inversion of Schlumberger resistivity soundings (Arnason and Hersir, 1988). This last report contains the description of a computer program, user's guide and a diskette for a PC-computer. A few of the teaching texts are already into their second and third edition.

One guest lecturer with an international reputation is invited every year as a UNU Visiting Lecturer to give a lecture series and to lead discussions with the trainees. The UNU Visiting Lecturers have stayed from about two weeks to two months in Reykjavik. The following have been UNU Visiting Lecturers:

1979	Donald E. White	USA
1980	Christopher Armstead	UK
1981	Derek H. Freeston	New Zealand
1982	Stanley H. Ward	USA
1983	Patrick Browne	New Zealand
1984	Enrico Barbier	Italy
1985	Bernardo Tolentino	Philippines
1986	Russel James	New Zealand
1987	Robert Harrison	UK
1988	Robert O. Fournier	USA
1989	Peter Ottlik	Hungary
1990	Andre Menjoz	France
1991	Wang Ji-yang	P.R. China
1992	Patrick Muffler	USA
1993	Zosimo F. Sarmiento	Philippines
1994	Ladislaus Rybach	Switzerland
1995	Gudmundur Bodvarsson	USA
1996	John W. Lund	USA

Most of the lecturers of the UNU Visiting Lecturers have been published by the Training Programme and are listed by author in Fridleifsson (1995). Some of these have served as important teaching material. Copies of the publications are available on request.

BUILDING OF SPECIALIST GROUPS AND EVALUATION

Table 1 lists the countries of origin of the participants during 1979-1996 and their specialized courses. The largest groups have come from three countries: China (32), Kenya (22), and the Philippines (25). Ten other countries have sent 4-10 participants. The aim of the UNU Geothermal Training Programme is to concentrate its training efforts so as to assist in building up groups of specialists in the geothermal departments of selected countries with significant geothermal potential. Priority for training is given to candidates from carefully selected institutions from developing countries where geothermal exploration and development is already underway. The limiting factor is, in some cases, the availability of sufficiently qualified staff in the recipient institutions. The fact that participants must speak English fluently has, for example, hampered participation from certain parts of the world such as Latin America.

Assessment of the training has mainly taken the form of interviews with former trainees and their directors. A representative of the Training Programme visits the main recipient countries every few years, and meetings are also arranged in connection with international geothermal conferences. Some changes have been made in the detailed contents of some of the specialized courses based on the feedback from the trainees and their institutions. But generally speaking, the fact that the training is tailor-made to the abilities of the individual and the needs of the recipient country/institution seems to have been very successful. The number of fully-qualified applicants each year is normally much greater than the number of scholarships available. All the participants are selected after private interviews with staff

members of the Training Programme and on the recommendation of the recipient institutions. It is, therefore, not surprising that many of the former trainees have become the leading specialists in their countries in their given fields. Our records indicate that about 85% of all our trainees are still working in the geothermal sector.

SELECTION OF PARTICIPANTS

Specialized practical training is considerably more expensive than group training because of the high teacher-to-student ratio. On average, a full-time teacher takes care of three students during the intensive training. The total cost of training per student in Reykjavik (including international travel and per diem) is over US$ 30,000. Much care is, therefore, taken in selecting the participants. The selection procedures of the UNU are adhered to, which involve site visits by representatives of the Training Programme to the countries of potential candidates and personal interviews with all candidates. The potential role of geothermal energy, within the energy plans of the respective country is assessed, and an evaluation made of the institutional capacities in the field of geothermal research and utilization. Based on this, the training needs of the country are assessed and recipient institutions selected.

The candidates must have a university degree in science or engineering, a minimum of one-year practical experience in geothermal work, speak English fluently, and have a permanent position at a government energy company, research institution, or university. The directors of such institutions are invited to nominate candidates for training in the specialized fields that are considered most relevant to promote geothermal development in the respective country. Nominations, including the curriculum vitae of the candidates, should be sent to the Training Programme in Iceland. Training starts in late-April and ends in late-October each year. Nominations must be received in Reykjavik before 1st August each year for participation in the training staring the following year. Due to the high cost of international travel, site visits for interviewing candidates cannot be held in all requesting countries every year. Therefore, interviews are held in aheld in a given country for candidates for two or three years at a time. Participants from developing countries normally receive scholarships financed by the Government of Iceland and the UNU or UNDP that cover international travel, tuition fees and per diem in Iceland. The participants, therefore, do not need other funds for their training. Qualified participants from industrialized countries can also be accepted on condition that they obtain similar scholarships from their own institutions/countries.

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