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THE GEOTHERMAL TRAINING PROGRAMME OF THE UNITED NATIONS UNIVERSITY IN ICELAND

Ingvar Birgir Fridleifsson

UNU Geothermal Training Programme
National Energy Authority
Grensasvegur 9, 108 Reykjavik, Iceland

ABSTRACT

An international post-graduate training programme in geothermal energy research and technology has been operated in Iceland since 1979 under the auspices of the government of Iceland and the United Nations University. Forty seven participants from leading energy agencies in 15 developing countries have received 6 months specialized training, and 19 scientists and engineers have come for shorter study tours. The training programme is designed for professionals with a minimum of 1 year practical experience in geothermal work in their home countries. Specialized training is offered in geological exploration, borehole geology, geophysical exploration, borehole geophysics, chemistry of thermal fluids, reservoir engineering, geothermal utilization, and drilling technology. Each trainee participates in only one of the specialized courses. Upon satisfactory completion of course work and an extensive project thesis, participants are awarded a UNU Certificate.

INTRODUCTION

The development of geothermal resources requires a dedicated group of highly skilled specialists from many disciplines of science and engineering. Because of its diversity, geothermal energy research is not taught as a separate subject at universities, but is a field where practical training is required at the post-graduate level. This was the guideline in the proposal of the Icelandic government to the United Nations University (UNU) in 1978 to establish jointly a training programme in geothermal energy research and technology in Iceland for scientists and engineers from the developing countries.

Prior to the establishment of the training programme, the UNU sponsored an international workshop in Iceland in 1978 (United Nations University, 1979). The workshop was attended by geothermal specialists from 12 countries, including scientists from Italy and Japan where international geothermal training courses have been operated since 1970, and from New Zealand where a post-graduate diploma course was due to start in 1979. Present at the meeting were also representatives from UN agencies that have sponsored geothermal work in developing countries (UNESCO and the UN Department of Technical Co-operation for Development). The workshop concluded, after consideration of the existing courses in the world, that the training programme proposed in Iceland was an important addition to existing training courses.

The UNU Geothermal Training Programme in Iceland was formally started on 1 March 1979. The cost of the training programme is shared mainly by the government of Iceland and the UNU. Priority for fellowships is given to candidates from developing countries where geothermal exploration and development are already under way. An attempt has been made to assist individual countries in building up a cadre of specialists representing the various disciplines. There have been 44 UNU Fellows and three UNDP Fellows have come for 6 to 8 months training. They have come from leading energy agencies in Burundi (1), China (12), Costa Rica (1), El Salvador (1), Ethiopia (7), Honduras (1), Indonesia (2), Kenya (6), Mexico (1), Nicaragua (1), Philippines (11), Thailand (2), and Turkey (1). For 3 months training have come 2 UNDP Fellows from India as well as participants from the Netherlands (2), Portugal (1), Sweden (1), and West Germany (1). There have been 11 UNU Special Fellows and 1 UNDP Fellow on shorter study trips.

PLANNING OF THE GEOTHERMAL TRAINING

The UNU Geothermal Training Programme is executed by the Geothermal Division of the National Energy Authority of Iceland, but is also linked with the

TABLE 1

U.N.U. TRAINING PROGRAMME IN GEOTHERMAL ENERGY IN ICELAND

Week	Geological Exploration	Borehole Geology	Geophysical Exploration	Borehole Geophysics	Reservoir Engineering	Chemistry of Thermal Fluids	Geothermal Utilisation	Drilling Technology	Week
1	Introductory lecture course on all aspects of geothermal energy and short field excursions								1
2									2
3									3
4									4
5	Field Geology R	Drilling P	Heat flow PF	Logging & well testing PR		Chemistry & LR		Introduction R	5
6	" R	Petrological RP	" FI			PR chemical thermodynamics LR		" R	6
7	Maps & Photos P	logging RP	Magnetics P			RI " LR		Medium size rig P	7
8	Structure Anal. P	" P	& tectonic F	Well completion & stimulation PF		Sampling RP		" P	8
9	Hydrogeology RP	" P	structure I			PF Deposition LR		" P	9
10	FP Field excursions	Field excursions	Field excursions	Field excursions	Field excursions	Field excursions	Field excursions	Field excursions	10
11	FP "	"	"	"	"	"	"	"	11
12	Mapping P	Petrological PI	DC-Resistivity P	P-T-Ωm- LR	Reservoir LR	Sampling & RP	Fluid flow LR	Produc. size rig P	12
13	Field work in F	logging PI	soundings F	Caliper logs LR	properties & LR	analysis P	Collection & LR	" P	13
14	deeply eroded F	Report PI	" I	LR	well performance LR	P	disposal LR	" P	14
15	volcanic strata F	Alteration RP	Project PI	Field work F	LR	Geothermometers RP	Corrosion LR	Prep.& planning LR	15
16	F	" RP	" P	F	Well testing F	" P	Deposition LR	Selec. equipm. RP	16
17	Field work F	" RP	" F	Logging PR	Well testing PR	" P	Reservoir LR	Techniques R	17
18	in recent F	X-ray RP	Report I	Project PR	Project PR	W/R Interact. RP	Plants LR	" R	18
19	volcanic fields F	" RP	" F	" F	" P	" LR	" LR	Completion P	19
20	F	Report IP	" I	" F	" F	" P	" LR	Practices P	20
21	Report PI	"	Special methods P	Report I	Report I	" P	Project P	Management RP	21
22	" PI	Clay minerals RP	(Electrical or F	I	I	Project P	" P	" RP	22
23	" I	P	gravity & seismic)	I	I	" P	"		23
24	"	Aquifers F			Modelling RL	" P	" P		24
25		Geological P	I		& RL	" P	" P		25
26		modelling I	I		assessment RL	" PI	" PI		26
27					of a PI	" PI	" PI		27
28	F = Field work				reservoir PI	" PI	" PI		28
29	I = Interpretation				I	" PI	" PI		29
30	L = Lecture				I	Report I	Report I		30
31	P = Practical exercises				I	"	" I		31
32	R = Reading & seminars				I	"	" I		32

University of Iceland. Supervisors and instructors are drawn from the staffs of both institutions, and in some cases from other specialized geothermal institutions in Iceland as required. A studies board is responsible for the academic contents of the training. An attempt is made to integrate the training of participants into the geothermal exploration and utilization projects that are in progress in Iceland at the time of training. In some cases, however, participants bring with them data from geothermal projects in their home countries and work on the data under the supervision of specialists.

Participants are expected to have a university degree in science or engineering and a minimum of one year practical experience in geothermal work. The training is conducted in English, which the participants must speak fluently. The curriculum of the training programme is shown in Table 1. In general, all participants are expected to attend an introductory lecture course that lasts 4 to 5 weeks, but exemptions can be given to those participants who have already participated in the international geothermal courses in Italy, Japan or New Zealand. The lecture course is followed by practical training in a specialized field. Study tours are arranged to all the main geothermal fields in Iceland. The introductory lecture course is composed of lectures on a wide range of topics such as geology, geophysics, and chemistry of thermal fluids in geothermal exploration; borehole geology and geophysics; drilling technology, well testing and reservoir engineering; utilization of geothermal resources, environmental factors; planning and execution of geothermal projects, and case histories of selected geothermal projects around the world. The purpose of this lecture course is to provide a general background knowledge concerning most aspects of geothermal energy and to generate an appreciation of the interrelationship between the various disciplines necessary in geothermal projects from the first to the last stages. Participants are required to take two written tests in the material presented during this introductory course.

In addition to the lectures of Icelandic specialists, a guest lecturer with international reputation is invited every year to give a lecture series related to his speciality and to lead discussion sessions with the trainees. The visiting lecturers have stayed from about 2 weeks to 2 months. The following have been visiting lecturers of the training programme: Dr. Donald E. White of the US Geological Survey in 1979, Mr. Christopher Armstead, geothermal engineering consultant from England in 1980, Prof. Derek Freeston of the Geothermal Institute, Auckland University (New Zealand) in 1981, Prof. Stanley H. Ward of the University of Utah Research Institute (USA) in 1982, Dr. Patrick Browne of the Geothermal Institute, Auckland University (New Zealand) in 1983, and Dr. Enrico Barbier of the

International Institute for Geothermal Research in Pisa (Italy) in 1984. The visits of the lecturers from Auckland and Pisa have particularly helped in strengthening the co-operation between the international geothermal courses in Italy, New Zealand, and Iceland.

An essential feature of the training programme is to provide participants with sufficient understanding and practical experience to permit the independent execution of projects within a selected discipline in their home countries. This is an ambitious goal and requires dividing the training into several courses. Each participant is expected to follow mainly one of the eight courses. The training takes approximately 6 months, including the introductory lecture course and field excursions. If a participant follows more than one specialized course, the training period becomes correspondingly longer. UNU Certificates are awarded to participants who complete the training and research project reports satisfactorily. Short descriptions are given of the specialized training courses in the following section. As the number of participants is limited to 8 to 10 each year, only two to four courses may be offered in any given year. The selection of the courses that are run depends on the demand shown by the recipient countries for the various courses and to some extent on the availability of supervisors in the specialized fields. The specialized training is very intensive, and an average one full time teacher trains three Fellows.

For many of the specialized courses no textbooks have been available and a large amount of text material and manuals have been collected or written by the supervisors of the individual specialized courses for the benefit of the trainees. Some of the training texts have been published (Stefansson and Steingrimsson, 1980; Karlsson, 1982; Kjaran and Eliasson, 1982). These are used by the participants both as working manuals and to train their colleagues back home. Similarly some of the lectures of the visiting lecturers have been published (Armstead, 1981; Freeston, 1982; Ward, 1983; Ward and Sill, 1983; Ward and Wannamaker, 1983; Browne, 1984; Barbier, 1985). Copies of the publications are available on request.

SPECIALIZED COURSES

Attempts are made to adjust the training to the background of the individual participant and the needs of his organization, so the following description of the specialized courses serves only as a guideline. In order to demonstrate how the practical training is tailored to suit the needs of the recipient countries, a brief mention is made of the projects of some of the Fellows. Many of the project reports are written in such a way that they can serve as manuals for performing certain measurements or interpretations dealt with in the respective reports. All the project reports are published, and copies can be obtained upon request.

Geological Exploration

This course offers practical training in basic geological mapping, which is commonly the first step in the geothermal exploration of an area. Participants analyse the geological structure of an area with regard to siting drill holes and can be trained in mapping surface geothermal mainfestations. The fieldwork is conducted partly in deeply dissected strata, where the roots of extinct volcanoes and geothermal systems can be inspected, and partly in active geothermal fields. Participants from countries where geothermal fields are associated with active volcanoes can receive special training in volcanic surveillance methods applied in Iceland. One participant from Mexico and one from Burundi have been trained in this course. The Mexican specialized in the application of paleomagnetic mapping and tephrochronology in geothermal exploration in volcanic regions (Flores, 1981). The geologist from Burundi was trained in geological mapping of a geothermal prospect area and in the tasks of geological logging of the first exploration wells in an area (Muhagaze, 1984). A UNDP Fellow from India was also trained for 3 months in siting geothermal wells.

Borehole Geology

In this course participants are trained in making geological logs from drill cuttings. They are introduced to alteration studies and their use in geothermal exploration. They may receive practical training in the application of x-ray diffraction and other methods for mineral identification. They can also be trained in providing geological advice during production drilling, in recording of aquifers with temperature logs and hydrological methods, and in making geological models of geothermal reservoirs from their own data and data from other disciplines. Six participants have been trained in this course and three (from China, Ethiopia and Kenya) are receiving training in 1985. Most participants in this course have specialized in analysing rock cuttings from their own countries, such as China (Zhang, 1984), Indonesia (Soemodipoero, 1982), Philippines (Bagamasbad, 1979; Reyes, 1979), and Thailand (Yaowanoiyothin, 1984), but a participant from Honduras worked on the borehole geology of an Icelandic geothermal field (Flores, 1980).

Geophysical Exploration

This course requires a degree in geophysics, physics or engineering. Emphasis is placed on practical training in how to conduct geophysical surveys of geothermal fields and in interpretation of data. The essentials of heat-flow studies, ground magnetic surveys and their relation to tectonic structure, and DC-resistivity depth soundings and profiling are covered. During the last 6 weeks a selection can be made among (a) further training in electrical survey methods such as dipole, MT, EM, AMT and SP, (b) training in gravity and magnetic surveys, and (c) training in seismology with emphasis on microearthquakes and ground noise studies. Six participants from Costa Rica (Lezama, 1984), Ethiopia (Abdulkadir, 1984; Tadesse, 1984), Indonesia (Alhamid, 1982), Kenya (Mwangi, 1982), and the Philippines (Layugan, 1981) have been trained in this course specializing in electrical resistivity surveys and the interpretation of resistivity data with one- and two-dimensional resistivity modelling of geothermal fields. Most of them have interpreted data from their home countries but also worked extensively on high quality data collected during field work in Iceland. One participant from the Philippines has specialized in ground magnetic surveys (Ignacio, 1982). One participant from China is being trained in 1985.

Borehole Geophysics

The training covers the essentials of geophysical measurements in boreholes used for geothermal investigations, with the main emphasis on pressure and temperature measurements, but including resistivity, SP, caliper, porosity and density logs. The purpose is to provide practical experience for the planning and execution of the measurements necessary to obtain adequate information on: geological structure, the location of aquifers, hydrological characteristics, chemical composition of deep water, well performance and modelling of geothermal systems. Participants must have a degree in physics or electrical engineering. A participant from China specialized in the interpretation of temperature logs (Zhou, 1980), an Ethiopian specialized in temperature and pressure logs (Gebreigziabhier, 1983), and participants from El Salvador (Zuniga, 1980) and the Philippines (Sarmiento, 1980; Paete, 1983) specialized in the interpretation of the various types of logs listed above. All of these participants worked on logging data from Icelandic wells. One participant from the Philippines (Maceda, 1983) specialized in the application and adaptation of digital computers to conventional analog well logging equipment and worked on the design of equipment for transferring data from a logging truck to a central computer in the office.

Reservoir Engineering

The purpose of this course is to provide practical training in the reservoir engineering methods required to obtain information on the hydrological characteristics of a geothermal reservoir and to forecast the long term responses of the reservoirs to exploitation. The course covers both surface and downhole measurements and the interpretation of well tests. This course requires a sound background in mathematics. Two participants from the Philippines have specialized in mathematical modelling of high-temperature geothermal reservoirs, one using data from Iceland (Regalado, 1981) and the other data from the Philippines (Catigtig, 1983). A reservoir engineer from China (Lu Run, 1983) was trained in the mathematical simulation of a low-temperature field within a Chinese city and in forecasting the long term drawdown of the water level in response to different pumping rates. Four UNU Fellows are being trained in this course in 1985. Two come from Kenya, one from Ethiopia, and one from Turkey.

Chemistry of Thermal Fluids

The objective of this course is to give an insight into the role of thermal fluid chemistry in geothermal exploration and exploitation, including sampling, analysis of major constituents and interpretation of the results. Towards the end of the training period a special exercise on a geochemical problem is undertaken and a final report prepared. Much emphasis is placed on the application of chemical geothermometers and the calculation of mixing models. Participants are encouraged to bring chemical data from their home countries and interpret these data under the supervision of a specialist. Five participants have been trained in this course, and all of them have specialized in the interpretation of geochemical data from geothermal fields in their home countries, namely China (Yao, 1980), Kenya (Muna, 1982), Nicaragua (Martinez, 1981), and the Philippines (Baltasar, 1980; Jordan, 1982). Two UNU Fellows are being trained in this course in 1985. They come from Ethiopia and Thailand.

Geothermal Utilization

The purpose of this course is to give advanced training in the use of geothermal resources. The course deals with the mechanical and chemical engineering aspects of geothermal fluids in pipes, equipment and plants. The feasibility of projects and environmental factors are also considered. The training aims at providing sufficient experience and knowledge to understand the engineering required in geothermal utilization projects and in carrying out some of the tasks independently. A university degree in engineering is a prerequisite. Four engineers from China have participated in this course. Two have specialized in the design and feasibility studies of district heating systems; Sun (1981) made suggestions for future development of the geothermal heating system in the city of Tianjin based on systems he studied in operation in Iceland; and Wu (1984) made a district heating energy analysis of using geothermal energy for district heating with or without the combination of a fossil fuel peak load station. (Shen, 1981) specialized in the application of a computer in solving geothermal utilization problems such as the selection of well pumps, heat and pressure losses in geothermal transmission pipes and for evaluating design temperatures for district heating systems. Li (1984) specialized in the design criteria for automatic supervisory control and data aquisition systems for a geothermal district heating system.

Drilling Technology

The aim is to provide engineers with the information and on-site training necessary to prepare them for work as drilling supervisors. The course begins with seminars on the techniques and equipment used in drilling for hot water and steam, followed by practical training on the drill site to provide a feeling for the real work involved in geothermal drilling. Participants have an opportunity to observe equipment of different sizes in operation. Seminars are held on the criteria for the selection of equipment and methods appropriate for each task. The course is not training for the task of drilling itself but the planning and supervision of geothermal drilling. Three UNU Fellows have participated in the full course. Engineers from China and Ethiopia were trained in the general aspects of planning and drilling in high-temperature geothermal fields (Tang, 1981; Abera, 1983), and an engineer from Kenya specialized in cementing techniques for long production casings (Nganga, 1982). He further compared drilling practices in high-temperature fields in Kenya and Iceland. A UNDP Fellow from India received 3 months training in the safety aspects of drilling in a high-temperature field.

SELECTION OF PARTICIPANTS

Specialized practical training of the type described in the previous chapter is more expensive than group training because of the high teacher to student ratio. Much care is taken in selecting the participants for the training, and the selection procedures of the UN University are adhered to.

Site visits have been made by staff members of the training programme to 15 developing countries that have started geothermal work and an assessment of their energy policy, geothermal potential and institutional capacities in the field of geothermal research and development. By interviews and visits to laboratories as well as geothermal fields the training needs of the countries have been assessed. On this basis directors of energy institutions have been invited to nominate candidates for training in the specialized fields that are considered most relevant to promote geothermal development in the respective countries. All candidates are interviewed personally by a representative of the training programme. Attempts have been made to identify and train persons who are both capable of working independently as specialists and of responding to the multidisciplinary nature of their responsibilities as leaders within their organizations. The participants must have at least one year practical experience in geothermal work prior to training and most of them have assumed leading roles within their organizations upon conclusion of training. In many instances they are the only moderately qualified people in their specialized fields in their countries. They bring a lot of geothermal literature and training texts home and this material is used by their organizations for training of new recruits.

Since 1979, all the participants from the developing countries have held UNU or UNDP Fellowships that cover tuition fees and living cost in Iceland and in most cases also international travel. In the future, qualified candidates sponsored by equivalent grants from their own institutions or international organizations can also be accepted. Nominations for participation in the training programme should be sent by managers of institutions to the office of the training programme at the National Energy Authority in Iceland. The curriculum vitae of candidates must be sent with the nominations. Nominations must be received in Iceland at the latest on 1 August each year for participation in training commencing in April of the following year. The training programme starts in mid April and ends in mid October each year.

FUTURE DEVELOPMENTS

At the recommendation of the 1978 UNU workshop in Iceland, the UNU organized a second international workshop in November 1980 in Italy, to review geothermal energy training facilities and training needs in developing countries (Fridleifsson, 1983). This meeting of international geothermal experts concluded that: the geothermal industry in the world needs more of specialized courses than presently available and the speciality options of the existing courses should be increased; to meet the growing demand of the developing countries, training opportunities within regions should be strengthened and, where necessary, established; present training centres should consider how best to train their students in teaching their own nationals; more stimulus should be given to local training of high quality technicians; suitable training texts and possibly audio-visual aids should be prepared for use in regional seminars; geothermal institutions should be encouraged and helped in establishing basic libraries related to geothermal work.

The UNU Geothermal Training Programme has been operated as much as possible in accordance with the conclusions of the UNU workshop. The results of the training have been evaluated by interviews with former trainees and their directors, and some modifications made to the training methods. No significant changes are planned in the operation of the training programme in the near future. The agreement on the training programme between Icelandic authorities and the United Nations University has recently been renewed until 1988. All the UNU Fellows and UNDP Fellows who have received training in Iceland are working in geothermal in their home countries. Many of them are the leading specialists of the countries in their respective fields.

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