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GEOTHERMAL TRAINING IN ICELAND 1979-1999

WGCUNUrev

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ABSTRACT
The Geothermal Training Programme of the United Nations University (UNU) has operated in Iceland since 1979 with six months annual courses for professionals from developing countries. Candidates must have a minimum of one year practical experience in geothermal work in their home countries prior to the training. Specialized training is offered in geological exploration, borehole geology, geophysical exploration, borehole geophysics, reservoir engineering, chemistry of thermal fluids, environmental studies, geothermal utilization, and drilling technology. Each trainee attends only one specialized course. The training is conducted in English. The trademark of the training is to give university graduates engaged in geothermal work very intensive on-the-job training in their chosen fields of specialization. The trainees work side by side with professionals of Orkustofnun, an agency actively working on most aspects of geothermal research, exploration, and development. The training is tailor-made for the individual and the needs of his institution/country. The aim is to assist developing countries with significant geothermal potential to build up groups of specialists that cover most aspects of geothermal exploration and development. Priority is given to candidates from institutions where geothermal work is already under way. All candidates are selected by private interviews. Candidates from developing countries and most Central and Eastern European countries receive scholarships (covering tuition fees, per diem and international travel) financed by the Government of Iceland and the UNU. Upon completion of their training the participants receive a UNU Certificate. During 1979-1999, 227 scientists and engineers from 35 countries have completed the six month courses, and over 70 have received shorter training (2 weeks t o 4 months).

1. INTRODUCTION

The Geothermal Training Programme of the United Nations University (UNU/GTP) was established in Iceland in 1979, when Orkustofnun (the National Energy Authority) became an Associated Institution of the UNU. Since then, a group of scientists and engineers from the developing countries have come to Iceland every spring to spend six months in highly specialized studies, research, 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. They come from energy agencies and research organizations and in a few instances universities.

During 1979-1999, a total of 227 Fellows have completed the six months specialized courses in Reykjavik. They have come from 35 countries: 45% from Asia, 26% from Africa, 15% from Latin America, and 14% from Central and Eastern Europe. During 1979-1999, there have been 30 ladies (13%). Table 1 shows the nationalities and the specialized courses completed by the Fellows trained during 1979-1999.

The Training Programme is operated at Orkustofnun (website: http://www.os.is). It is academically governed by a Studies Board, which is composed of experts responsible for each of the nine specialized courses that are offered, and a chairman who is the director of the Training Programme. The present members of the Studies Board are Dr. Kristjan Saemundsson (Geological Exploration), Dr. Hjalti Franzson (Borehole Geology), Dr. Knutur Arnason (Geophysical Exploration), Dr. Benedikt Steingrimsson (Borehole Geophysics), Dr. Gudni Axelsson (Reservoir Engineering) Dr. Halldor Armannsson (Environmental Studies) and Mr. Sverrir Thorhallsson (Drilling Technology) from Orkustofnun, Prof. Stefan Arnorsson (Chemistry of Thermal Fluids) and Prof. Valdimar K. Jonsson (Geothermal Utilization) from the University of Iceland. Dr. Ingvar Birgir Fridleifsson has been the director of the Training Programme from the beginning except for one training season in 1981 when Dr. Hjalti Franzson served as director, and three training seasons in 1986-1988 when Dr. Jon Steinar Gudmundsson served as director. Mr. Ludvik S. Georgsson has been the deputy-director since 1990.

2. INSTITUTIONAL ENVIRONMENT

Most of the training and research of the UNU/GTP takes place at Orkustofnun, which is a government agency under the Ministry of Industry and Commerce. Its main responsibilities are to advise the Government of Iceland on energy issues and related topics, and to carry out energy research and provide consulting services relating to energy development and utilization. Orkustofnun has an excellent library specialized on energy research and development (in particular geothermal and hydropower), with some 12.000 titles and subscription to 140 journals. Orkustofnun has a chemical laboratory, geophysical laboratory, petrological laboratory, and three logging trucks for geothermal wells. The UNU Fellows also have the full rights and privileges to use the facilities of the University of Iceland as registered students.

Orkustofnun is now divided into four independent units: Energy Management Division (energy resources, statistics and analyses), the UNU Geothermal Training Programme, the Geoscience Division, and the Hydrological Service Division. The total staff is about 100, whereof 74% are university graduates. The UNU/GTP has a permanent staff of three, but most of the teaching and research supervision is conducted by geothermal specialists of the Geoscience Division. Of the 45 staff members of the Geoscience Division, 37 have university degrees, and of these 19 have Ph.D. qualifications. The disciplines are represented as follows: 14 geologists, 15 geophysicists, 5 chemists, and 3 engineers. The turnover of Orkustofnun in 1998 was USD 7.6 million. In 1998, Orkustofnun published 82 research reports, and 66 scientific papers by staff members were

published in journals. UNU funds are, of course, not used for Orkustofnun research. The UNU Fellows, however, have full access to the research facilities and the multidisciplinary research environment of Orkustofnun, which is one of the leading geothermal energy research institutions in the world.

Some of the teaching and supervision of UNU Fellows is conducted by professors of the University of Iceland and specialists at government agencies, consulting engineering companies and drilling contractors, depending on the specialized training required for the individual Fellows. The share of each institution varies from year to year. In 1998, 62% of the supervision was in the hands of specialists at Orkustofnun, 12% at the University of Iceland, and 26% at other agencies.

3. 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 lasts 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 interrelationship 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 research 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, interpretation of data as well as in using the Internet. Each of them is provided with a personal PC during their training in Iceland. Experience has shown that most trainees have access to PC-computers at home, and they can take their diskettes home and continue the 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 network workstations at Orkustofnun. All the participants are trained in using the Internet and encouraged to do so. In December 1999, about 120 former U NU Fellows are listed in the e-mail directory of the Geotherma l Training Programme. An updated directory is sent out twice per year to all alumni of the Programme.

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. Nine 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. Since 1994, the reports have been published in the annual book "Geothermal Training in Iceland" which has an international publishing code (ISBN 9979). Copies can be obtained upon request. The reports are mailed regularly to former UNU Fellows and many of the leading geothermal institutions in the developing countries. The titles of the reports from 1979-1999 and the abstracts from 1988-1999 can be found on the home page of the Geothermal Training Programme (www/ os.is/unugtp/).

4. 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 electrical surveys (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. T

he course requires a sound background in mathematics. Partici pants should have a degree in engineering, physics, geophysics, mathematics or hydrogeology.

The **environmental studies** course covers environmental impact assessments (EIA), laws and policies, the planning and executi on of EIA projects and environmental auditing. Aspects of reservoir engineering and geothermal chemistry are treated, including sampling and analytical methods, injection and tracer studies, scaling and corrosion along with methods of interpretation. Physical methods of monitoring geothermal areas such as mapping of surficial thermal features, aerial thermography, refraction measurements, seismic monitoring and gravity and levelling methods for subsidence are studied. Biological impact is considered in some detail as well as the management of wastes, toxic chemicals, air pollution and noise. Occupational health and safety are introduced and abatement methods (e.g. for H_2S) and ground revegetation feature too. As a background, energy statistics and forecasts are considered and case histories of exploration and environmental impact studies introduced. The projects are from wide-ranging disciplines as are the Fellows themselves who are required to have a degree in science or engineering. This course was officially opened in 1998.

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, geochemis try 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, instalment 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.

5. TEACHING MATERIAL

Most of 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 st aff members of Orkustofnun and the University of Iceland. So me texts have also been written by visiting scholars from other countries. Some of the teaching material has been published in reports. These include texts on hydrogeology (Sigurdsson, 198 7), geophysical exploration (Hersir and Björnsson, 1991), geot hermal logging (Stefansson and Steingrimsson, 1981), reservoi r engineering (Kjaran and Eliasson, 1983), geothermal reservoi r physics (Bödvarsson, 1987), geothermal district heating (Karl sson, 1982), direct use of geothermal energy (Lund, 1987; Lun d, 1996), and one dimensional inversion of Schlumberger resist ivity soundings (Arnason and Hersir, 1988). This last report co ntains the description of a computer program, user's guide and a diskette for a PC-computer. A few of the teaching texts are al ready into their second and third editions.

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 Zeal.
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 Lund	USA
1997	Toshihiro Uchida	Japan
1998	Agnes Reyes	Philippines/New Zealand
1999	P. Michael Wright	USA

Many of the lectures of the UNU Visiting Lecturers have been published and are listed by author in the reference list. Some of these have served as important teaching material. Copies of the publications of the UNU/GTP are available on request (www/ os.is/unugtp/).

6. BUILDING OF SPECIALIST GROUPS AND EVALUATION

Table 1 lists the countries of origin of the participants during 1979-1999 and their specialized courses. The largest groups have come from China (39), Kenya (26), and the Philippines (27). Twelve other countries have sent 5-16 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 under way. 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.

Changes have been made in the detailed contents of the specialized courses based on the feedback from the trainees an d their institutions. Generally speaking, the effort to have the training 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 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.

Many of our alumni have been active internationally. At the World Geothermal Congress in Italy in 1995, which had about 1300 participants, there were 35 former UNU Fellows giving papers and representing their countries. Over 70 abstracts by 50 former UNU Fellows were submitted to the WGC2000 secretariat. A good opportunity for assessment was the 20th Anniversary Workshop of the Geothermal Training Programme held in Reykjavik in October 1998. The proceedings of the workshop with 20 papers have been published (Georgsson, 1999).

Our records indicate that about 80% of all our trainees have continued working in the geothermal sector. A few from the fi rst years of training, however, have gone into retirement.

7. 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 USD 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. The candidates should normally be under 40 years in age. 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 training starting 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 a given country for candidates for two or three years at a time.

Participants from developing countries and most Central and Eastern European countries normally receive scholarships financed by the Government of Iceland and the UNU that cover international travel, tuition fees and per diem in Iceland. The participants therefore do not need other funds for their training. The UNDP and the Inetrnational Atomic Energy Agency (IAE A) as well as the European Union have also financed fellowshi ps for several trainees. Qualified participants from industrialize d countries can also be accepted on condition that they obtain s imilar scholarships from their own countries.

8. FINANCES AND THE FUTURE

Figure 1 shows the number of Fellows completing the six months specialized training per year during 1979-1998. In the last five years there have been 14-18 Fellows per year. There is a steady flow of requests for training from all over the world, only a portion of which can be met. In view of this, it is planned to continue with the six months specialized research and training as the main activity of the UNU/GTP.

As from year 2000 we expect, however, to admit two outstanding UNU Fellows per year to continue their studies and study for M.Sc. degrees in geothermal science or engineering in co-oper ation with the University of Iceland. Many of our trainees hav e already completed their M. Sc. or Ph.D. degrees when they come to Iceland, but several excellent students who have only B. Sc. degrees have requested to come again to Iceland for a higher academic degree. Their six months studies in Iceland will form a part of their graduate programme. The first UNU Fellow (from Jordania) enrolled at the University of Iceland for a masters degree in the fall semester of 1999.

During 1979-1982, the financing of the UNU/GTP was shared equally by the UNU and the Government of Iceland. Since then, the Government of Iceland has carried the lions share (about 80%) of the annual financing. Through the years, international agencies such as UNDP, the IAEA, and EFTA /EU (Brussels) have financed one to three Fellowships per year. These have both been for six months and shorter periods of time. Fellowships awarded by UNU/Iceland have been restricted to six months training. Over seventy people have come for short training and study visits (2 weeks to 4 months) during 1979-1999 in addition to the 227 who have completed the six months training.

The UNU Fisheries Training Programme (UNU/FTP) started operating in Iceland in 1998 on the basis of an Agreement on Cooperation betweeen the UNU, the Government of Iceland, and the Marine Research Institute in Reykjavik. The training methods and mode of selection of participants is based on the experience of the UNU/GTP. Th UNU/FTP is expected to grow in size similar to the UNU/GTP. The demand for training in fisheries studies is expected to be much larger than in geothermal energy since so many more countries are higly dependant on fisheries than geothermal energy. Five specialized courses are offered: Fisheries Policy and Planning; Marine Resources, Assessment and Monitoring; Fishing Technology and Fleet Operations, Fish Handling, Processing and Quality Management; and Managem ent of Fisheries Copmanies and Marketing.

The Icelandic State Budget for 2000 includes a contribution of

over 1 million USD to the training activities of the UNU in Iceland in these two subjects where Iceland is amongst world leaders in expertice. Both of these specialities are of national importance in Iceland, since approximately 70% of the export earnings of Iceland come from fish products, and about 48% of the total primary energy of Iceland is provided by geothermal energy. With a total population of 277,000, Iceland is contributing about USD 3.60 per capita to the training and research activities under the name of the United Nations University. The Government of Iceland considers the UNU a most suitable venue for channelling a part of its multilateral development aid. The feedback from the recipient countries has been very favourable with regard to the geothermal energy trai ning. It is commonly stated in public debate in Iceland that the research and training activities in cooperation with the UNU a re the most effective development aid undertaken by Iceland.

The Foreign Minister of Iceland, Mr. Halldor Asgrimsson, said in his opening speech at the 20th Anniversary Workshop of the UNU Geothermal Training Programme in October 1998, that a significant portion of Iceland's aid for international development will continue to be channeled for supporting the development of high-level manpower in the fields of geothermal energy and fisheries, as well as in other areas for which Iceland has comparative advantage to make significant contribution to international development.

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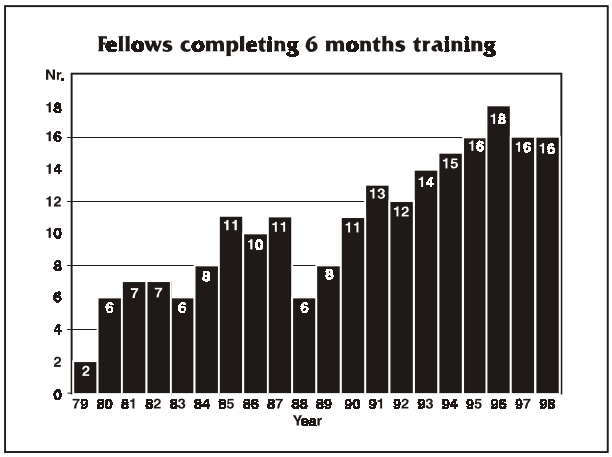

Figure 1. Fellows completing 6 months training by year

Table 1. Fellows of the UNU Geothermal Training Programme 1979-1999

Country	Geological exploration	Borehole geology	Geophysic. exploration	Borehole geophys.	Reservoir engineer.	Chemistry of therm. fluids	Environm. studies	Geotherm. utilization	Drilling technology	Total
Algeria	1					1		1		3
Bulgaria				1	2	2				5
Burundi	1									1
China		3	1	2	13	10		9	1	39
Costa Rica	1	1	2		1		1	1		7
Djibouti		1								1
Egypt		1			1	1				3
El Salvad.	1	1	1	2	4	2	1	1	3	16
Eritrea			1							1
Ethiopia		2	1	1	3	3		1	2	13
Greece			1					2		3
Guatemala		1				1				2
Honduras		1	1							2
Indonesia		3	3	2	3					11
Iran	1	1	1	1			1	1		6
Jordan				1	1	1		1		4
Kenya	1	4	7		4	4	3	1	2	26
Lithuania								1		1
Macedonia						1				1
Mexico	1		1		2					4
Nepal						1		1		2
Nicaragua					3	1				4
Pakistan	1	1			1	1				4
Philippines		3	5	4	7	5		3		27
Poland		1			3			1		5
Romania								5		5
Russia				1						1
Serbia				1	1	1				3
Slovakia				1	1					2
Tanzania	1									1
Thailand		1		2		1		1		5
Tunisia								5		5
Turkey		1			1	2		1		5
Uganda	2	1	1			1				5
Vietnam			1		1	1			1	4
Total	11	27	27	19	52	40	6	36	9	227

Table 2. The approximate time schedule for the UNU Geothermal Training Programme

UNU GEOTHERMAL TRAINING PROGRAMME IN ICELAND

Week	Geological Exploration	Borehole Geology	Geophysical Exploration	Borehole Geophysics	Reservoir Engineering	Environmental Studies	Chemistry of Thermal Fluids	Geothermal Utilization	Drilling Technology
1 2 3 4 5	Lecture course on all main aspects of geothermal energy exploration and utilization, practicals and short field excursions								
6	Field geology	Drilling	Resistivity methods	Course on well logging and reservoir		EIA Project planning	Sampling of fluids and gas		Drilling equipment
7	Maps and photos	Petrological logging	Thermal methods	engineering including:		Chemistry Physics	Scaling and corrosion		Drilling procedures
8	Structure analysis	Alteration	Magnetics	Logging and well testing practises		Biology Monitoring	Analytical methods	Heat transfer and	Well design Safety
9	Hydrogeology	Mineralogy	Gravity	Reservoir physics Reservoir simulation		Revegetation	Thermodynamics	fluid flow	Management
10				Tracer tests Computer programs		Health and safety	Geothermometers	Control systems	Rig operations
11 12	Excursion to the main geothermal fields of Iceland								
13	Field work in deeply	Aquifers	Data processing	Logging methods	Responses to	Gas dispersion	Water rock	Design of plants	Cementing
14	eroded strata	Modelling	techniques	Data evaluation	exploitation	and abatement	interaction	and systems	Completion
15									
16	Project	Project	Project	Project	Project	Project	Project	Project	Project
17	and	and	and	and	and	and	and	and	and
18	report	report	report	report	report	report	report	report	report
19									
20									
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