GEOTHERMAL TRAINING IN ICELAND

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ABSTRACT

An international training programme in geothermal *energy* research and technology has been operated in Iceland under the auspices of the Government of Iceland and the UN University since 1979. Twenty two participants from leading energy agencies in Africa, Asia and Central America have received 6–8 months specialized training and eight scientists and engineers have come for shorter study tours. Specialized training is offered in geological exploration, borehole geology, geophysical exploration, borehole geophysics, chemistry of thermal fluids, reservoir engineering, geothermal utilization and drilling technology. A summary is given in the paper of the conclusions of an international committee which reviewed training needs in geothermal energy in developing countries in 1989.

INTRODUCTION

The development of geothermal resources requires a dedicated *group* of highly skilled specialists from many scientific disciplines. 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 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 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 scientists from 12 countries, including scientists from Italy and Japan where international geothermal training courses have been organized since 1970, and from New Zealand where a post-graduate diploma course was due to start in 1979. Present at the meting were also representatives from UN agencies that have sponsored geotheml work in developing countries (UNESCO and UNDP). 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 born *by* the Government of Iceland and the UNU, with the latter providing grants (UNU Fellowships) for the travel and living allowances of the participants. Priority for Fellowships is given to candidates fran developing countries where geothermal exploration and development is already *under* way.

Twentytwo UNU Fellows from leading energy agencies in China (5), El Salvador (1), Honduras (1), Indonesia (2), Kenya (3), Mexico (1), Nicaragua (1) and the Philippines (8) have come for 6–8 months training. One UNDP Fellow from India has come for 3 mnths training and seven UNU Special Fellows from China (5), Indonesia (1) and the Philippines (1) for shorter study trips.

GEOTHERMAL TRAINING PROGRAMME

The UNU Geothermal Training Programme is executed by the Geothermal Division of the National Energy Authority of Iceland, but is also linked with the University of Iceland. Supervisors and instructors are drawn from the staffs of both institutions, and in some cases from other specialized 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 fran geothermal projects in their home countries and work on the data under the supervision of specialists.

The aim is to provide practical training that will enable successful participants to return to their countries and work independently in their chosen fields. Participants *are expected* to have a university degree in science or engineering and preferably some practical experience in geothermal work in their home countries. The training is conducted in English, which the participants must speak fluently. The curriculum of the training programme is shown on the next page. In general, all participants are expected to attend an introductory lecture course (exemptions *can* be given to those participants who have already participated

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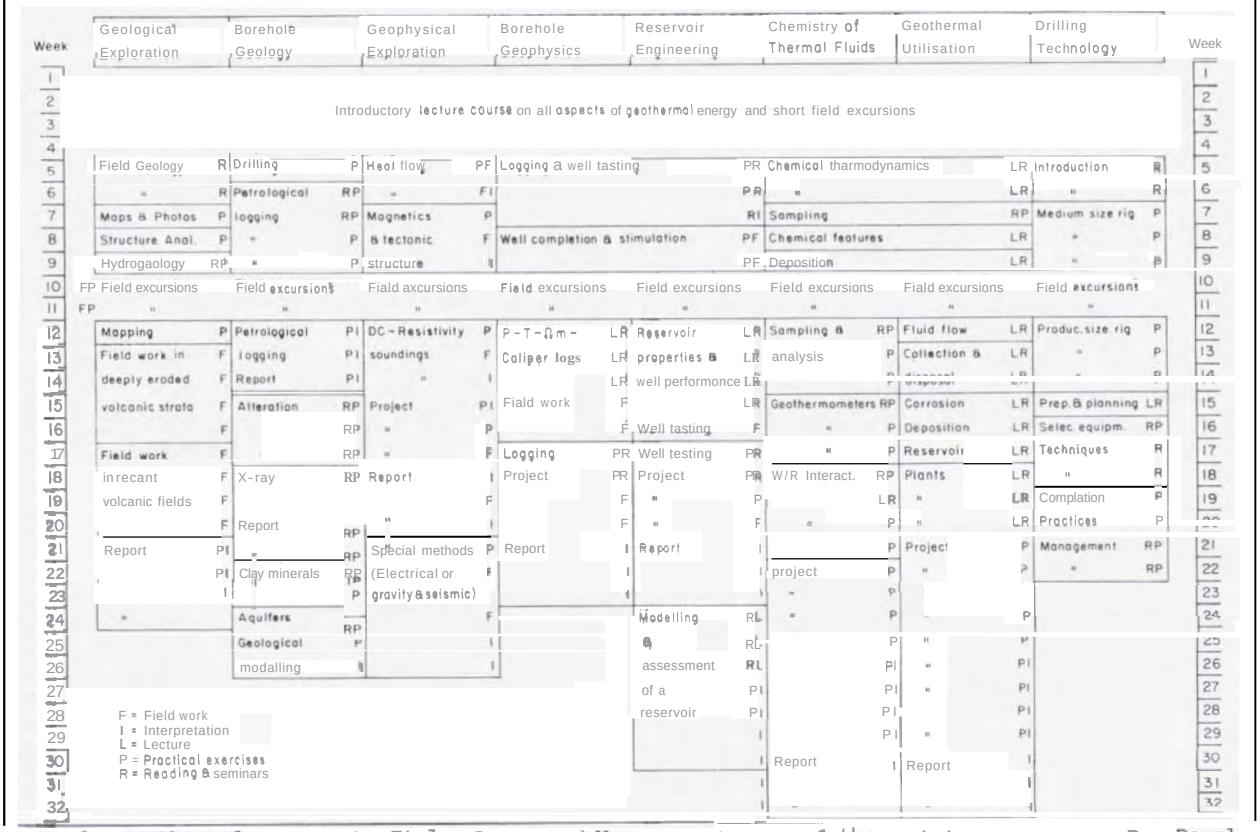

in the geothermal courses in Italy, Japan and New Zealand). The lecture aurse is followed by practical training under close supervision in a specialized field. During the training, study tours are arranged to all the main geothermal fields in Iceland.

The introductory lecture course is composed of lectures on awide range of topics related to geothermal energy, including geothermal energy around the world; geology, geophysics, and chemistry of thermal fluids in geothermal exploration; drilling borehole geology and geophysics; safety aspects of geothermal drilling, well testing and reservoir engineering; utilization of geothermal resources, environmental factors; planning and execution of geothermal projects, and case histories of selected geotheml projects around the world. The purpose of this lecture course is to provide a general background knowledge concerning most aspects of geotheml energy and to generate an appreciation of the interrelationship between the various disciplines necessary in geothermal projects from the first to the last stages. In addition to the formal lecture course carried out by 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 two weeks to two mnths. The following have been visiting lecturers of the training programme: Dr. Donal 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 in 1981 and Prof. Stanley H. Ward of the University of Utah Research Institute is expected in September 1982.

An essential feature of the training program 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 six mnths, including the introductory lecture course and field excursions. If a participant follows more than one specialized aurse, the training period becomes correspondingly longer. UNU Certificates are awarded to participants who complete the training satisfactorily.

Short descriptions are given of the specialized training courses in the following section. As the number of participants is limited to 5–10 each year, only two or three 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 training programme normally starts in mid April and ends in mid October each year. On their way home from training in Iceland the participants have gone on study tours to geothermal fields and/or research organizations in Italy, Denmark, France or the USA.

SPECIALIZED COURSES

The curriculum is divided into eight specialized courses and each participant normally receives training in one such course. Attempts are made to suit the training to the background of the individual participants and the needs of his organization, so the following description of the specialized courses serves only as a guideline.

a. 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 manifestations. 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 frm countries where geothermal fields are associated with active volcanoes can receive special training in volcanic surveillance methods applied in Iceland. One participant from Mexico has been trained in this course. He specialized in the application of paleomagnetic mapping and tephrochronology in geothermal exploration in volcanic regions (Flores, 1981). A geologist from India was trained for three months in siting geothermal wells.

b. 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 regarding production drilling, in recording of aquifers with tenperatwe logs and hydrological methods, and in making geological models of geothermal reservoirs from their own data and data fran other disciplines. Three participants have been trained in this course and the fourth (from Indonesia) is presently receiving training. Two participants from the Philippines specialized in analysing rock cuttings from their own country (Bagamasbad, 1979; Reyes, 1979), but a participant from Honduras worked on the borehole geology of an Icelandic geothermal field (Flores, 1980).

c. Geophysical exploration

This course requires a solid prior knowledge of geology, geophysics, physics or engineering. Emphasis is placed on practical training in how to conduct geophysical surveys of geothermal fields and in interpretation of geophysical data. The essentials of heat-flow studies, ground magnetic surveys and their relation to tectonic structure, DC-resistivity depth soundings and profiling are covered. During the last six weeks a selection can be made among (a) further training in electrical survey methods such as dipole, MT, EN, AMT and SP, (b) training in gravity and magnetic surveys and (c) training in seismology with emphasis on microearthquakes and ground noise studies. One participant from the Philippines has been trained in this course specializing in the application of computer programmes for the interpretation of resistivity data and for one- and two-dimensional resistivity modelling of geothermal fields (Layugan, 1981). Three participants from Indonesia, Kenya and the Philippines are receiving training in 1982.

d. Borehole geophysics

The training mvers 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 cbtain adequate informtion on: geological structure, the location of aquifers, hydrological characteristics, chemical composition of deep water, well performance and modelling of geothermal systems. The course is in two main parts; practical and theoretical instructions in the various methods are followed by the design, execution and interpretation of the results of a logging project under the supervision of an instructor. Three participants from China, El Salvador and the Philippines have participated in the course. Two of them specialized in the interpretation of various types of logs from single wells (Sarmiento, 1980; Zuniga, 1980), and one interpreted temperature data from typical high and low temperature geothermal fields (Zhou, 1980).

e. Reservoir engineering

The purpose of this course is to provide practical training in the reservoir engineering methods required to obtain informtion on the hydrological characteristics of a geothermal reservoir. The course covers both surface and downhole measurements and the interpretation of well tests. This course requires a sound background in mathematics. One participant from the Philippines has been trained in this course. He specialized in mathematical modelling of geothermal reservoirs and in methods to predict the response of a geothermal field to long term exploitation (Regolado, 1981). Another Philippino received two mnths training in the theoretical part of the course.

f. Chemistry of thermal fluids

The objective is to provide 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. Participants can also bring chemical data from their home countries and interpret these data under the supervision of a specialist. Three participants from China, Nicaragua and the Philippines have been trained in this course and two from Kenya and the Philippines are receiving training in 1982. They have all specialized in the interpretation of geochemical data from geothermal fields in their home countries (Baltasar, 1980; Martinez, 1981; Yao, 1980).

g. 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. Two engineers from China have participated in this course. One specialized in the application of a computer in solving geothermal utilisation problem such as the selection of well pumps, heat and pressure losses in geothermal transmission pipes and for evaluating design features for district heating systems (Shen, 1981). The other specialized in the design and feasibility studies of district heating systems and made suggestions for future development of the geothermal heating system in Tianjin in China based on systems he studied in operation in Iceland (Sun, 1981).

h. 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. One engineer from china has participated in the course. He was trained in general aspects of drilling in high tenperatwe geothermal fields (Tang, 1981). An engineer from Kenya is receiving training in 1982. He specializes in cementing techniques for long production casings.

SELECTION OF PARTICIPANTS

To harness geothermal energy a team of highly specialized experts is needed in the fields of geology, chemistry, physics and engineering. With this in mind the participants with UNU Fellowships have been selected from leading energy organizations in a few countries or regions which are closely tied geographically and culturally, so as to assist these countries/regions in building up their own cadre of specialists. One can foresee these organizations in the near future providing regional geothermal training facilities for their own nationals or neighbours in the various continents. The participants have come from China, Indonesia, Kenya, Philippines and Central America. All of the recipient countries are deeply involved in geothermal work, and are generally highly dependent on foreign consultants, who mainly come from France, Iceland, Italy, Japan, New Zealand and the USA.

Much care has been taken in selecting the participants. Site visits have been made by staff members of the training programme to 11 developing countries which have started geothermal work and an assessment made 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 that 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 some 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 have obtained UNU Fellowships that mer international travel and living cost in Iceland. In the future qualified candidates sponsored by equivalent grants from their own institutions or international organizations can also be accepted. The training is financed by the Government of Iceland as a contribution to development aid and no fees have been requested of participants. 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.

REPORTS OF THE TRAINING PROGRAMME

For many of the specialized courses no textbooks are 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 or are in the process of being published (Stefansson and Steingrimsson, 1980; Eliasson, 1980; Karlsson, 1982; Kjaran and al———, 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). Papers on the status of geothermal development in various countries of the world presented at a meting of the UNU sponsored Standing Advisory Committee on Geothermal Training held in Italy 1980 have also been published by the training program~(Fridleifsson, 1982).

The participants in the training spend a few weeks writing their project reports all of which are published in 100-200 copies. 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. The subjects of the reports by trainees were referred to in a previous chapter. Copies are available of most of the reports of the training programme and these can be mailed upon request.

TRAINING NEEDS IN DEVELOPING COUNTRIES

At the recommendation of the international workshop an training needs in geothermal energy held in Iceland in 1978 (United Nations University, 1979) the UNU Geothermal Training Programme has established an international Standing Advisory Committee on Geothermal Training (SACGT) that has the role of co-ordinating all geothermal training sponsored by the UN system. The statues for this committee were constructed at the 1978 workshop. This committee is the only forum that has been established within the UN system for the co-ordination of geothermal energy training and dissemination Of geothermal information. Three UN agencies presently sponsor geothermal energy training. UNESCO has since 1970 sponsored yearly group-oriented courses at Pisa in Italy (9 months) and Kyushu in Japan (3 months). UNDP has since 1979 spansored an academic course at Auckland University in New Zealand (9 months) and several. short (few weeks) regional seminars in Central America, china and the Philippines. UNU has since 1979 spansored the project-oriented specialized training in Iceland (6 months).

At a meeting of the SACGT held in Italy in November 1980 a group 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 haw best to train their students in teaching their own nationals; more stimulus be given to local training of high quality teahnicians; suitable training texts and possibly audio-visual aids be prepared for use in regional seminars; geothermal institutions should be encouraged and helped in establishing basic libraries related to geothermal work.

The SACGT meting estimated the training needs of geothermal personnel in the developing countries to be about 250 per year for the next 10 years. This is far beyond the capacity of the existing international geothermal courses, and most of the people will have to receive on the job training in their home countries. Similarly language difficulties and the finances involved in international travel make national and regional training centres highly desirable. The most severe limiting factor in setting up national and regional training centres is, however, the lack of qualified instructors locally. This cannot be solved quickly. Experience has shown that once national geothermal programmes have started the urgency of the energy demand causes all qualified personnel to be absorbed in activities leading to quick energy production, and little time is left for scholarly activities or training. It is, however, essential to have a cadre of specialists in each country that is seriously developing its geothermal resources. Initially these have to be trained abroad. These people commonly start working in geothermal as counterparts with foreign consultants, then go for specialized training to gain wider experience and confidence to gradualllly take over from the foreign consultants. At the international geothermal training centres they obtain training material and learn how to train their colleagues at home. Experience in several countries has shown that the best way to secure that technological knowhow of foreign consultants is left in a country is to send counterpart scientists and engineers to training centres abroad. The SACGT meeting stressed that more specialized courses are needed than presently available for countries with established capacities for geothermics. These courses should be of short duration and co-ordination between training centres would be required to avoid needless duplication.

An increased effort should be made to assist the recipient countries in establishing training courses on the national level for technicians and specialists. This is already being done to some extent by UNDP and UNESCO. These courses are presently in the form of seminars lasting fran a few days to a few weeks. These courses are most

useful in countries where a group of geothermal specialists has already been established by training at international courses and by working side by side with foreign consultants. The value of such courses is, however, very limited in countries where only one or two people have a sound background knowledge of the subject. People who attend short crash courses can even gain a false sense of security and competence which can be very costly to their countries. It should be kept in mind that an average geothermal production well costs approximately 1 million US$. Geothermal is a field of energy technology where gains can be high but mistakes are expensive. A high priority should be given to promote co-operation between geothermal training centres operated under the auspices of UN agencies, regional and national organizations in various parts of the world. The training task is so large that significant results can only be obtained through a dynamic international co-operation.

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