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TWO-WAY GEOTHERMAL TECHNOLOGY TRANSFER VIA UNU-GTP TRAINING

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ABSTRACT

Ever since the foundation of the United Nations University Geothermal Training Programme (UNU-GTP) in Iceland in 1979 the Geothermal Division of Orkustofnun (OS, the National Energy Authority of Iceland), along with its successors the GeoScience Division of OS and the recently founded Iceland GeoSurvey (ISOR), have provided the bulk of the teaching and supervision at the UNU-GTP. About 72% of the 380 Fellows who have completed six months training at the programme during the 29 years up to 2007 have e.g. been supervised by OS, and later ISOR, scientific staff. In addition, six members of a ten member Studies Board are at present ISOR senior scientists. ISOR scientists also play a role in an MSc/PhD-programme, recently established by the UNU-GTP and the University of Iceland, and in a programme of annual workshops and short courses being held by the UNU-GTP in Africa, Central-America and Asia. But this activity has not only benefitted the UNU Fellows on the receiving end, and their home countries. It has actually resulted in very efficient and productive two-way geothermal technology transfer with the benefactors being OS, ISOR, the geothermal industry in Iceland as well as the worldwide geothermal community.

1. INTRODUCTION

The United Nations University Geothermal Training Programme (UNU-GTP) in Iceland started operations in 1979. The aim of the programme is to assist developing and transitional countries with significant geothermal potential to build up groups of specialists that cover most aspects of geothermal exploration and development (Fridleifsson, 2008). This is done by six month training through nine specialized lines. During the first 29 years of operation 380 scientists and engineers from 41 countries in Asia, Africa, Central America and Central and Eastern Europe have completed the six month training in addition to about 80 specialists who have received shorter training. In addition, the UNU-GTP started an MSc-programme in cooperation with the University of Iceland in 2000. Fifteen students have graduated from this new programme to date.

The host institution for the UNU-GTP is the National Energy Authority of Iceland, or Orkustofnun (OS). The main reason for choosing OS was the ability of the institute to provide a large part of the training required as well as research facilities and institutional support. At the time of the foundation of the UNU-GTP, Iceland was already one of the world leaders in the development of geothermal resources and OS was the main geothermal research institute in the country, with ample expertise and knowhow. The history of geothermal research in Iceland is directly linked with the history of OS dating back to 1956, when a Geothermal Division was established at the Electricity Administration Office, which was transformed into OS in 1967. Since then, some institutional changes have affected

OS. Firstly, the establishment of the partly independent GeoScience Division in 1997, which manly focused on geothermal research and, secondly, the foundation of Iceland GeoSurvey (ISOR) in 2003, which took over all the responsibilities of the GeoScience Division of OS.

ISOR is a government owned service and research institute providing specialist services to the Icelandic power industry, the Icelandic government, individuals and foreign institutes and companies, in particular geothermal research and development (see *www.isor.is*). At present ISOR employs more than 90 permanent staff members, a majority of which have academic degrees. This number has doubled since the foundation of the institute because of rapidly growing project load, mostly in Iceland but also abroad. ISOR has entirely taken over the role of OS in providing teaching and supervision services to the UNU-GTP. In recent years this has amounted to about 60% of all teaching and training at the programme.

Since its foundation ISOR has been committed to providing geothermal education and to promoting and advancing the development of geothermal resources, both in Iceland and worldwide, as were its predecessors (Jonsdottir, 2008). This has included teaching at Icelandic universities, supervision of MSc and PhD candidates, as well as teaching at training courses and workshops the world over. Therefore, continuing to service the UNU-GTP fits this commitment perfectly.

On the occasion of the 30 year anniversary of the UNU-GTP, it is appropriate to look back and review the contribution of ISOR and its predecessors to the goals of the UNU-GTP during these three decades, as this paper does. But this has not only benefitted the Fellows on the receiving end, and their home countries. This has actually resulted in very efficient and productive two-way geothermal technology transfer, also discussed in the paper, with the benefactors being OS, ISOR, the geothermal industry in Iceland as well as the worldwide geothermal community.

2. UNU-GTP TRAINING BY ORKUSTOFNUN AND ISOR

The six-month specialized training is organized such that all participants first attend a five week intensive introductory lecture course. During the spring of 2008 more than 50% of the introductory lectures were given by ISOR specialists and close to 30% by UNU-GTP and OS staff. Following this the training is continued along nine specialized lines of training (Fridleifsson, 2005):

- Geological exploration
- Borehole geology
- Geophysical exploration
- Borehole geophysics
- Reservoir engineering
- Environmental studies
- Chemistry of thermal fluids
- Geothermal utilization
- Drilling technology

A ten member studies board administers the UNU-GTP academically. The board is chaired by the Director of the programme and the nine additional members are responsible for the specialized lines. Of these, six are presently ISOR senior scientists. The geological exploration, chemistry and utilization lines are in the hands of professors from the University of Iceland and a senior geologist from Hitaveita Sudurnesja Ltd.

The first half of the specialized training varies somewhat between individual lines. It consists mostly of lectures, reading, solving homework problems, hands-on training in laboratory and field techniques as well as training in utilizing appropriate computer software. Again, the bulk of this training has been

provided by ISOR and its predecessors, with the remainder being provided by different engineering firms, universities and research institutions.

The second half of the specialized training involves individual project work, under the supervision of different scientists, through which the Fellows put the methods and techniques studied into practical use. This has of course been a key element of the training. Figure 1 shows the number of UNU-GTP Fellows supervised by OS and ISOR scientists during the last 29 years compared with the total number of Fellows each year. About 72% of the 380 Fellows who have graduated up to 2007 have been supervised by OS and ISOR staff. This percentage was about 68% during the first decade of the programme, about 80% during the second decade, and about 67% during the third decade.

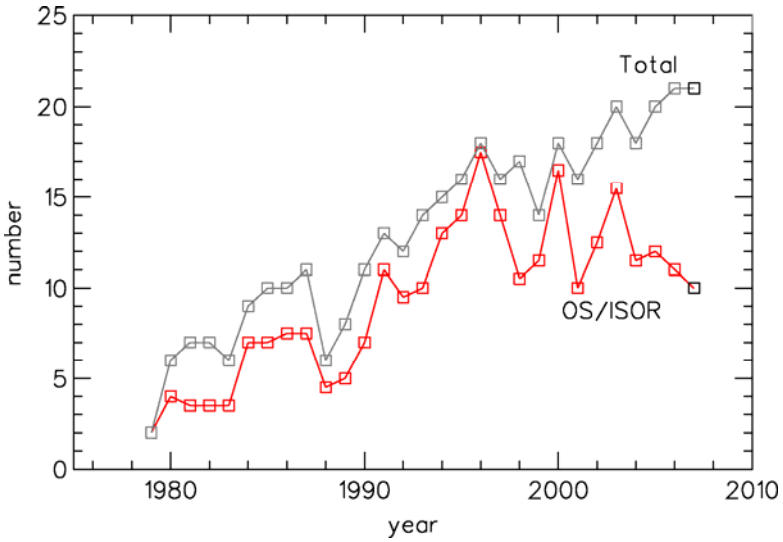

FIGURE 1: The number of UNU-GTP Fellows supervised by OS and ISOR scientist 1979-2007, compared with the total number of Fellows

The figure shows that the number of Fellows has been steadily increasing. This has been followed by a comparable increase in the OS/ISOR contribution up to the beginning of the present century. Since then the number of Fellows supervised by OS/ISOR has levelled off at 10-15 Fellows. The reasons for this are an increasing number of Fellows taking the environmental and utilization lines, which are not the core specialities of ISOR, in addition to the continuously increasing workload at ISOR, both in Iceland and abroad.

In many cases the projects are based on data from geothermal projects in the participant's home countries, while in other cases projects are based on Icelandic geothermal research and utilization projects. The open information and research policy of the Icelandic geothermal power companies, both those involved in electricity production and in space-heating and other direct uses, has made the latter option possible and greatly benefitted the UNU-GTP, as well as the power companies. The degree of supervision needed is of course variable, all depending on the project selected and the capabilities of the Fellow involved, but emphasis has always been placed on direct access between Fellow and supervisor. In recent years, two supervisors have sometime been assigned to a single Fellow to secure this direct access. The project work is concluded by the writing of a report with editing assistance from the supervisor(s). All the project reports are published by the UNU-GTP. In some instances results of the work is eventually published in scientific journals and conference proceedings.

The Fellows for the six month UNU-GTP training are all selected on basis of personal interviews mostly conducted by the staff of the UNU-GTP. Most years, however, some of the candidates are interviewed by ISOR scientists, often in conjunction with project missions to the candidate's home-countries or neighbouring countries.

In 2000, the UNU-GTP established an MSc programme in geothermal science and engineering in cooperation with the University of Iceland. OS and later ISOR scientists have been actively involved in that; as supervisors, committee-members and defence moderators. Fifteen former six-month

Fellows have completed their masters at present. This year the programme was extended to PhD-studies. The capacity-building activity of the UNU-GTP was expanded even further in 2005 when it started operating annual workshops / short courses in selected countries in Africa (since 2005), Central America (since 2006) and Asia (since 2008) in cooperation with local geothermal institutions (Fridleifsson, 2008). These are financed by the Government of Iceland as its contribution to the Millennium Development Goals of the United Nations. ISOR has provided lecturers for all these events in addition to local lecturers and other international speakers.

We do not have to dwell on the great success of the 30 years capacity building of the UNU-GTP, which is well known (Fridleifsson, 2005). Many of the UNU-GTP graduates are among the leading specialists in geothermal research and development in their home countries and the UNU-GTP training has clearly advanced and accelerated geothermal development in the respective countries. Good examples are large and capable groups of former Fellows in El Salvador, Kenya, the Philippines and China.

The activity of the UNU-GTP has not only benefitted the UNU-GTP Fellows, MSc-students and work-shop participants on the receiving end, and their home countries. Less obvious are considerable benefits to OS, and later ISOR, and other indirect benefits reviewed in the next chapter. The main benefits for OS/ISOR have been:

(i) Maintaining a high standard in scientific work.
(ii) Keeping up with advances in geothermal research and development.
(iii) Maintaining a beneficial academic research edge.
(iv) Establishing contact with institutes involved in geothermal research and development all over the world.
(v) Collecting general and detailed information on geothermal conditions, research and development the world over.

This is in addition to the associated revenues received by OS/ISOR.

3. TRAINING AND TECHNOLOGY TRANSFER BEYOND UNU-GTP

The UNU-GTP activity has actually resulted in further two-way geothermal technology transfer outside the realm of the UNU-GTP. The benefactors have been OS/ISOR, the geothermal industry in Iceland, including engineering firms, and the worldwide geothermal community. This includes scientific cooperation, specialized training as well as small and large scale spin-off projects. The following are some examples:

(A) Scientific cooperation on specific research projects. Results often presented in scientific journals and conference proceedings.
(B) Smaller consultancy missions and individual, on location, training arranged directly by local institutes or companies.
(C) Specialized training courses in different countries lasting 1-2 weeks, at the request of local institutes or companies. Often 10-20 participants from the country involved and sometimes also from neighbouring countries.
(D) Work for international agencies such as the International Atomic Energy Agency (IAEA), both consultancy and training missions.
(E) Major consultancy jobs involving institutes and/or engineering firms in Iceland, and local counterparts, with research activity on location and in offices in Iceland.
(F) Major geothermal development jobs, involving institutes and engineering firms in Iceland, and local counterparts, with research, design and construction activity on location and in offices in Iceland.

Many such projects have come about through direct links between former UNU Fellows and Icelandic scientists and engineers. Former UNU Fellows are often involved in planning various geothermal projects, small or large, and they have a tendency to turn to their old teachers and advisors if possible. Many other projects have come about more indirectly because of the reputation of Icelandic scientists and engineers spread by former UNU-GTP Fellows.

Good examples of (A) are presented in papers such as the ones by Zhao and Ármannsson (1996) and Tole et al. (1993), to name two examples. Quite a number of smaller missions (B) have been undertaken by Icelandic scientists and engineers during the last thirty years, mostly to UNU-GTP affiliated countries in Central America, Eastern Africa and Asia. Specialized training courses (C) have been conducted in El Salvador, Nicaragua and Greece to name a few countries. The results of work for international agencies (D), such as the IAEA, can be partly found in handbooks, reports and scientific papers (see e.g. International Atomic Energy Agency, 2004). A good example of a major consultancy job (E) is the development of a numerical geothermal reservoir model for the geothermal resource under Beijing, China, undertaken in conjunction with a geothermal development project in the city (see e.g. Hjartarson et al., 2005). A good example of a major development project is a project undertaken in Tanggu, China, in cooperation between Icelandic engineering firms, OS and Chinese counterparts, part of which is described by Axelsson and Dong (1998).

More recently the projects of Enex (*www.enex.is*) and Geyser Green Energy (*www.gge.is*), such as in El Salvador and Xianyang in China, can often be attributed to direct or indirect UNU-GTP influence. Geothermal projects of the Icelandic International Development Agency (ICEIDA, *www.iceida.is*) in Nicaragua and Eastern Africa should also be mentioned.

4. CONCLUSIONS

This paper has reviewed the contribution of ISOR, and its predecessors the Geothermal and Geo-Science Divisions of OS, to the thirty year success of the UNU-GTP, as well as direct and indirect benefits of the association with the programme, both for ISOR and the geothermal industry in Iceland. The benefits to UNU-GTP Fellows and other participants, as well as their respective home-countries, are well known. The main direct benefits for OS/ISOR include the drive to maintain high academic and scientific standards as well as establishing contacts and collecting geothermal information worldwide. The main indirect benefits for OS/ISOR and the geothermal industry in Iceland, as well as the worldwide geothermal community, include scientific cooperation, small and large training missions, work for international agencies, consultancy jobs and larger scale development projects, that have come about through direct links with former UNU-GTP Fellows or because of the reputation of Icelandic specialists spread by UNU-GTP alumni.

ISOR's contribution to the work of the UNU-GTP has not entirely kept pace with the rapid growth and expansion of the programme, but it has nonetheless been growing in recent years. A continued commitment of the institute and its scientists is certainly expected in coming years, in accordance with their overall dedication to providing geothermal education and to promoting and advancing the development of geothermal resources worldwide.

ACKNOWLEDGEMENTS

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