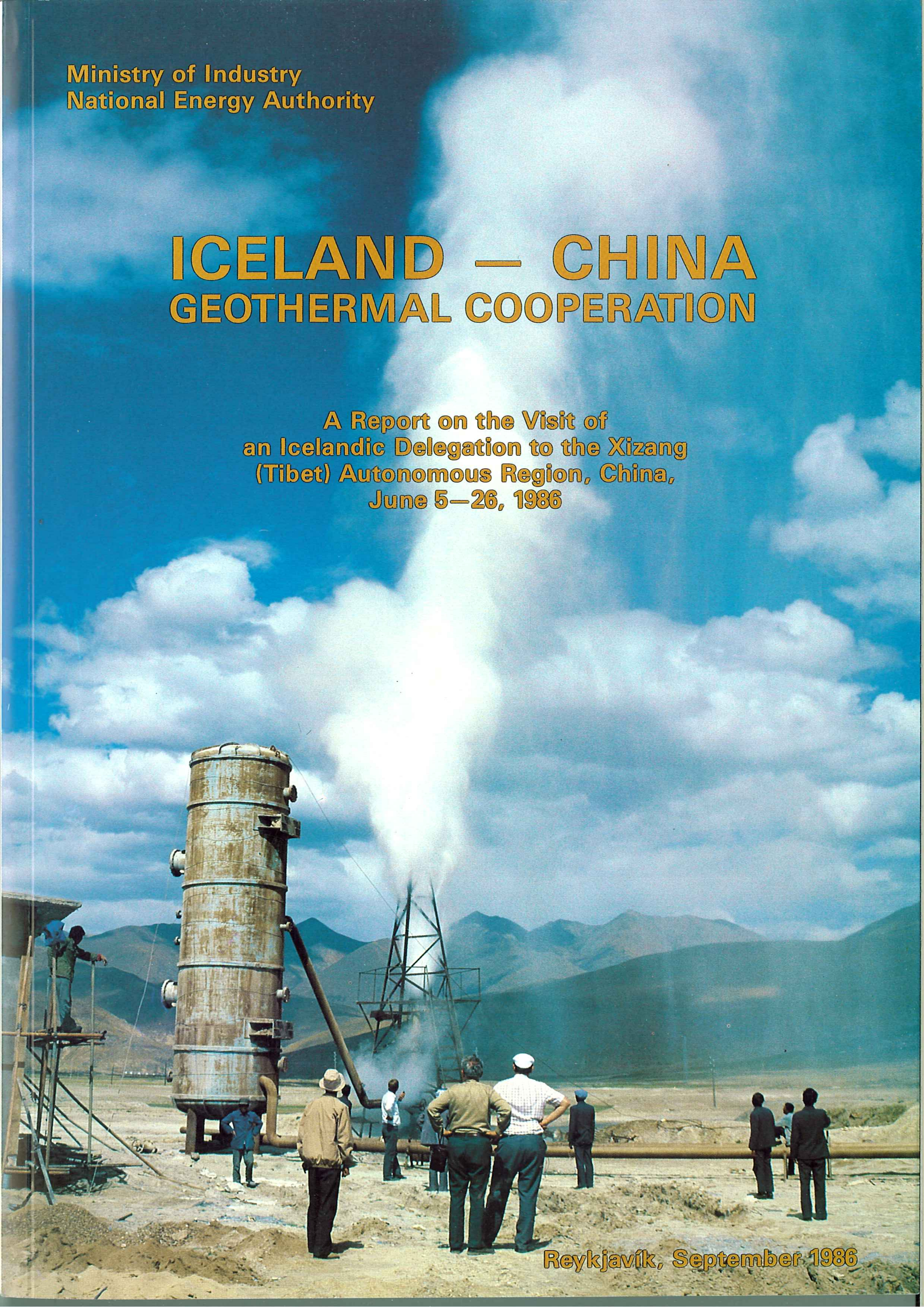
Ministry of Industry
National Energy Authority

ICELAND — CHINA
GEOTHERMAL COOPERATION

A Report on the Visit of
an Icelandic Delegation to the Xizang
(Tibet) Autonomous Region, China,
June 5—26, 1986



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1 INTRODUCTION AND MAIN CONCLUSIONS AND RECOMMENDATIONS

1.1 Introduction and Background

In June 1986 an Icelandic Delegation of geothermal experts visited the People`s Republic of China at the invitation of the Authorities of the Xizang (Tibet) Autonomous Region. The purpose was to acquaint Chinese geothermal experts with the techniques used to develop geothermal energy in Iceland and to discuss possible modes of cooperation between the two countries. At the request of the Icelandic side, visits were also paid to geothermal establishments in Tianjin and Beijing. This report summarizes the main observations of the Delegation and makes some suggestions as to continued cooperation between the two countries.

Cooperation between Iceland and the People`s Republic of China in geothermal research and development dates back to the year 1978, when the Director of the Geothermal Division of the National Energy Authority (NEA) in Reykjavík, Iceland, visited the Ministry of Geology in Beijing and gave lectures on geothermal research and development in Iceland.

In 1979 an International Geothermal Training Programme was established at the National Energy Authority, which is an advisory and research organization under the Icelandic Ministry of Industry and Energy. This Programme was a joint undertaking of the United Nations University (UNU) in Tokyo and the NEA, established in accordance with a special agreement between the NEA and the UNU, and is financed jointly by the UNU and the Icelandic Government. The Training Programme is run by the Geothermal Division of the NEA, under the directorship of a Resident Programme Coordinator, a post held by a senior staff member of the Geothermal Division.

Since 1979, altogether 17 scientists and engineers from the People`s Republic of China have participated in the Geothermal Training Programme. Of these, 12 have received six months` specialized training, and five senior members of the Chinese geothermal community have come for shorter study visits.

Icelandic geothermal experts made brief visits to China on behalf of the United Nations University in 1979, 1980, 1981, 1983 and 1984 to interview candidates for training in Iceland. In 1982, four Icelandic geothermal experts went on separate missions to China on behalf of the United Nations Department of Technical Cooperation for Development (UN/DTCD) to advise on certain aspects of geothermal development in Beijing and Tianjin and to give lectures to Chinese colleagues. One went on a similar mission to Tianjin in November 1985, and finally, an Icelandic professor and geothermal expert gave a series of lectures on geothermal engineering in Tianjin in early 1986.

1.2 Invitation

During previous years, the desirability of more extensive Icelandic-Chinese geothermal cooperation was frequently mentioned in informal discussions between Icelandic and Chinese geothermal experts. In November 1985, the Office of Foreign Affairs and Bureau of Water Conservancy and Electricity of the Xizang Autonomous Region of China sent, through the Chinese Embassy in Reykjavík, a formal letter of invitation to Mr. Jakob Björnsson, the Director General of the NEA, inviting the NEA to send a group of geothermal experts to the Xizang Autonomous Region to study geothermal resources there, especially in the Yangbajain geothermal area. The invitation letter is reproduced as Exhibit 1 at the end of this report.

The Director General notified the Minister for Industry and Energy, Mr. Albert Gudmundsson, of the content of the invitation letter. The Minister decided that the Icelandic mission should be headed by his Special Assistant in the Ministry and Chairman of the Board of NEA and ORKINT (Orkustofnun International Ltd.), Mr. Jónas Elíasson. The National Energy Authority was assigned the task of detailed preparation of the mission. The Minister accepted the invitation in a letter forwarded to the XAR Authorities through the Reykjavík Embassy of the People`s Republic of China. The Minister`s letter of response is reproduced as Exhibit 2 at the end of this report.

1.3 Itinerary

The Delegation stayed 11 days in Xizang according to a programme prepared by the hosts, and 8 days in Tianjin and Beijing. The detailed itinerary of the Delegation within the People`s Republic of China was as follows:

June 5, 1986	Arrival in Beijing.
June 6	Sight-seeing in Beijing in the morning. Meeting in the Beijing Office of the Xizang Autonomous Region in the afternoon.
June 7	Visit to the Great Wall in the morning. Flight from Beijing to Chengdu in the afternoon. Overnight stay in Chengdu.

June 8	Flight from Chengdu to Lhasa Airport at Gonggar in the morning. Travel to Lhasa by jeeps and coach. Rest and brief meetings of welcome in the afternoon.
June 9	Formal presentation on the state of geothermal development in Xizang given by staff members of Bureau of Water Resources and Electricity and Bureau of Geology and Mineral Resources. An introductory meeting with Vice-Chairman Mao in the afternoon.
June 10	Travel by jeep and coach from Lhasa to Yangbajain in the morning. Visit to the power plants, greenhouses and the geothermal field in the afternoon. Overnight stay at Yangbajain.
June 11	Technical discussions in the morning in three separate groups, viz. (1) corrosion and scaling problems; (2) district heating systems and greenhouse installations and (3) reservoir engineering and geothermal training. In the afternoon travel by jeep and coach from Yangbajain to Nagqu. Overnight stay at Nagqu.
June 12	Introductory discussion, followed by a visit to the Nagqu geothermal field, where the district heating pumping station and a drilling site is located, in the morning. Visit to a geothermally-heated hospital and a Scientific and Technical Forum in the afternoon. Overnight stay in Nagqu.
June 13	Travel by jeep and coach from Nagqu to Lhasa. Overnight stay in Lhasa.
June 14	Technical discussions in Lhasa the whole day. In the afternoon, the discussions proceeded in two separate groups, (1) a geological and geophysical group and (2) a utilization group.
June 15	Technical discussions in Lhasa the whole day on cooperation between Iceland and XAR in the field of geothermal energy.

June 16	Technical discussions in Lhasa the whole day on cooperation between Iceland and XAR in the field of geothermal energy. Drafting of the Letter of Intent. Vice-Chairman Mao participated in the afternoon discussions.
June 17	Sight-seeing in Lhasa.
June 18	Discussions and re-drafting of the Letter of Intent. Final text prepared in the evening and the Letter of Intent signed by midnight.
June 19	In the morning travel by coach from Lhasa to Lhasa Airport. In the afternoon flight to Chengdu. Sightseeing in Chengdu and overnight stay.
June 20	Morning flight from Chengdu to Beijing. Travel by coach to Tianjin in the afternoon. Overnight stay in Tianjin.
June 21	A morning meeting at the Bureau of Geology in Tianjin to discuss geothermal developments in the Tianjin area and possible cooperation with Icelandic firms and institutions. In the afternoon a visit to the Aquatic Research Institute some 60 km from Tianjin. Overnight stay in Tianjin.
June 22	In the morning a visit to the Agricultural Research Institute in Tianjin, which among other things, operates experimental greenhouses which were visited. Also in the morning, a visit to the Tianjin District Heating System, where a borehole and a heat-exchanger installation as well as some newly-built houses with heating installations were inspected. In the afternoon travel by coach to Beijing. Overnight stay in Beijing.
June 23	In the morning sightseeing in Beijing. In the afternoon a meeting at the Beijing Tibet Office to discuss our findings in Tibet; the Tibetan energy situation and the role of geothermal in future energy developments in Tibet and possible Icelandic-Chinese cooperation in geothermal developments in Tibet.

June 24 In the morning a visit to the Institute of Geology of the Chinese Academy of Sciences.

The work of the Institute was described to the Delegation; a visit was made to a geothermal laboratory under the Institute, and possible Icelandic - Chinese cooperation discussed, including geothermal training in Iceland of Chinese students.

Sightseeing in Beijing in the afternoon, with Peking Opera in the evening.

June 25 The whole day: Meeting in Beijing at the Ministry of Geology and Mineral Resources.

Icelandic-Chinese cooperation, especially in the field of geothermal training was discussed, as well as funding of geothermal projects in Tibet. Finally, the works of the Ministry were explained to the Icelandic Delegation.

June 26 Departure for Iceland.

1.4 Members of the Delegation

The Icelandic Delegation was composed of the following members:

Mr. Jónas Elíasson, Special Assistant to the Minister for Industry and Energy, Chairman of the Board of NEA and ORKINT Ltd., Reykjavík. Head of Delegation.

Mr. Jakob Björnsson, Director General, National Energy Authority, Reykjavík.

Mr. Gudmundur Pálmason, Director, Geothermal Division, National Energy Authority, Reykjavík.

Mr. Hjalti Franzson, Geologist, United Nations University Geothermal Training Programme, Geothermal Division, National Energy Authority, Reykjavík.

Mr. Sverrir Thórhallsson, Head of the Geothermal Engineering Section, Geothermal Division, National Energy Authority, Reykjavík.

Mr. Karl Ómar Jónsson, Managing Director, Fjarhitun h.f., Consulting Engineers, Reykjavík.

1.5 Acknowledgements

The Icelandic Delegation wishes to express its sincere thanks to the numerous persons who contributed to the success of their visit to the People`s Republic of China.

First of all the Delegation expresses its deep-felt thanks and appreciation to the Government of the Xizang Autonomous Region of the People`s Republic of China for their invitation, and to the Chargés d`Affaires in the Embassy of People`s Republic of China in Reykjavík, Messrs Li Qinping and Zhai Shixiong, who acted as intermediaries and were instrumental in bringing about the visit. In particular Mr. Li Qinping, who left his post at the Reykjavík Embassy a few days after the Delegation departed for China, and was succeeded by Mr. Zhai Shixiong. The Delegation also extends its warm thanks to our guides, Mr. Wu Fangzhi and Mrs Lu Run, who spared no effort to make the tour within China both successful and pleasant. Thanks are also due to the numerous officials and scientists both in the XAR and elsewhere in China, with whom we had fruitful and stimulating discussions and who received us with such great hospitality. They are too numerous all to be named here, but most of them appear on the list in Appendix 4.

Last, but not least, the Delegation wishes to express its sincere thanks to the Icelandic Minister for Industry and Energy for entrusting it with the task of comprising the first delegation of Icelandic geothermal experts to visit the People`s Republic of China.

1.6 Summary of Conclusions and Recommendations

Important results have been achieved in the geothermal development in Yangbajain. It is recommended that Yangbajain be given the opportunity and financial means to aquire the special equipment and upgrade its technologies so a complete transfer from the experimental stage, to the professional stage with adequate stability of energy delivery, can be achieved.

Deep-penetrating exploration, followed by a new resource assessment is necessary before the final design of the power stations to be built according to the new five year plan can be decided.

Utilization of the effluent water from the power stations in Yangbajain could sustain a district heating service for the greenhouse complex, the station village and Yangbajain town, soil heating of outdoor vegetable fields, and a tourist hotel with health spa and recreational facilities connected to the build up of tourist industry in Lhasa.

In Nagqu a new design of the district heating system is recommended together with a study of electricity production with binary system technology.

The following technologies already in use in Yangbajain should be upgraded with new equipment and training of personnel:

House insulation.
District Heating System (DHS) pipeline insulation and plumbing.
DHS system pressure and flow control equipment.
Wellhead design and anti-corrosion measures.
Steam-collector pressure and flow control.
On-site chemical sampling and analysing.
Greenhouse ventilation and temperature control.
Greenhouse heating arrangement.
Well-pump design and installation.
Field monitoring.
Computer analysis.

There exists a vast potential for fruitful cooperation between the geothermal communities of Iceland and Tibet. This matter was extensively discussed during a series of meetings (Appendix 4) in Lhasa, Yangbajain, Nagqu and in the Tibet Office in Beijing, and with Mr. Wang Hai, Director of the Office of the Advisory Group of the State Council on Economic Affairs of Tibet. The Icelandic Delegation and the officials of the Bureau of Water Resources and Electricity of XAR have already agreed upon the projects of future cooperation in a Letter of Intent (Appendix 1). This document has already been ratified by the Government of Iceland (Appendix 2). The ratification of the Government of XAR has also been communicated to Iceland by the Chargé d`Affaires of the People`s Republic of China in Reykjavik. By the ratification of both governments, the articles of the Letter of Intent have been effectuated. Special attention should be drawn to Art. 1, 2, and 3, which contain invitations to Chinese officials, geothermal scholars and trainees to come to Iceland.

The climatic conditions in Tibet are such, that there is great need for thermal energy to heat houses and provide process heating for agricultural product industries (wool washing, tanning, dairy products etc.). More than 20 towns in Tibet have potential sources of geothermal energy nearby.

It is recommended that the making of a countrywide plan for utilization of geothermal energy in Tibet be entrusted to a special adviser, and a job description for this task is included according to request (Appendix 3).

In Tianjin the geothermal reservoirs in use are slowly decaying. All possible measures should be taken to stop further deterioration of the geothermal resources of Tianjin, with utilization of new resources and reservoir engineering countermeasures.

Hydraulic fracturing methods for well improvement and stimulation can be recommended.

A special reservoir engineering programme including:

- the design and performance of well tests,
- a field monitoring programme,
- reservoir simulation, matched to production history, and
- reinjection studies

is highly recommended as a follow up to the latest U.N. activities in this field.

Through the UNU Geothermal Training Programme, the independent business company ORKINT Ltd and various private companies, Iceland has ways and means of contributing to China technologies and experience in direct utilization of geothermal energy.

China on the other hand, has educated scientists and development potential that makes it possible for the country to gain from such cooperation.

In this connection the Icelandic delegation has noted with interest the contents of the speech given by His Exellency Duoji Cairang, Acting Chairman of the People`s Government of XAR, in Hong Kong on 14th January 1986.

Utilizing the opportunities set forth in this speech, the possibility exists for a joint Chinese-Icelandic undertaking in the form of a joint venture Geothermal Company, owned in majority by the Chinese and in minority by the Icelanders. This company could undertake geothermal projects for the government of XAR, and in the process ensure the complete transfer of necessary technologies and the training of key personnel.

2 AN OUTLINE OF GEOTHERMAL ENERGY IN THE PEOPLE'S REPUBLIC OF CHINA

2.1 General

China is relatively rich in geothermal resources, with more than 2,500 natural springs distributed all over the country. They are mainly of the low- to medium-temperature type (lower than 150°C). The low-temperature resources, which are by far the largest, occur mainly in sedimentary basins in the eastern part of the country. Low-temperature resources related to volcanism occur in the southeastern coastal provinces. The medium- to high-temperature resources occur mainly in southern Tibet and western Yunnan, where the Indian and the Eurasian Plates collide. High-temperature resources occur also in Taiwan, in the Datun volcanic region, where the Pacific and the Eurasian Plates meet.

Geothermal energy has been used for centuries in China for irrigation, washing, salt extraction, and medical purposes. In the last 10-15 years an increased emphasis has been placed on space heating and generation of electricity. In the Tianjin-Beijing area geothermal space heating is being developed in order to diminish air pollution due to heating by coal. The Yangbajain geothermal field in Xizang (Tibet) has been developed since 1977 to provide electricity for the city of Lhasa. Small experimental power stations to produce electricity from low-temperature water have been built in several places in China.

2.2 Principal Geothermal Zones

The Xizang-Yunnan Geothermal Zone (or the Himalayan Geothermal Belt) is the most active geothermal zone in China with over 700 sites of hydrothermal activity (Fig.2.1). It runs along southern Tibet north of the Himalayan Range, and into the Tengchong volcanic zone in western Yunnan. Due to continual uplifting of the earth's crust, volcanic activity and earthquakes are frequent and violent. The Zone is characterized by many types of geothermal activity including geysers, hydrothermal explosions, fumaroles, boiling springs, and mud pools. The geothermal areas along this zone are in varying stages of exploration and utilization. The best known is the Yangbajain field, about 90 km northwest of Lhasa at an elevation of about 4,300 m, where 13 MWe of electrical generating capacity have been installed. In the Langjiou field of western Tibet 1 MWe has been installed. The Nagqu geothermal field is about 300 km north of Lhasa. It is being explored for possible use for space heating and agricultural uses in the adjacent town of Nagqu. In western Yunnan the geothermal resources, some of them larger than Yangbajain, are being considered for electricity generation as well as for multipurpose utilization.

The Southeast Coast Geothermal Zone has about 600 hot springs concentrated in the coastal regions of the Fujian and Guangdong provinces. The thermal springs seem to be controlled by NE-trending tectonic fractures. Their temperature ranges from about 80° to 100°C, with a maximum bottom-hole temperature of 120°C found so far. Exploration is being carried out in some of the fields of this zone.

The Beijing, Tianjin and north Hebei areas are parts of a vast sedimentary basin (the North China Plain), where until now 34 geothermal anomalies have been found with a total area of 6,400 km^2. The temperature of shallow Tertiary sandstone reservoirs ranges from 40°C to 70°C, while the temperature of the deeper reservoirs is somewhat higher. Considerable progress has been made in utilizing the hot water in this region for large-scale district heating, industrial processing, greenhouse cultivation, agriculture and aquaculture.

The above areas are the priority areas for geothermal development in China. They have been selected on the basis of potentially favorable reservoir characteristics, proximity to industrial and agricultural centers, and possible beneficial effects on economy, environment and society. In addition to these areas there are many others, which at the present time are considered of less interest for immediate development.

2.3 The Xizang-Yunnan Geothermal Zone

The Xizang-Yunnan Geothermal Zone extends for about 2,000 km from east to west (Fig.2.1). It is a part of a still larger geothermal zone which extends westward through Kashmir and Iran into the Mediterranean Zone, including Turkey, Greece and Italy.

The hydrothermal activity is concentrated mainly in southern Tibet, between the Himalayas in the south and the Gangdise-Nyainqentanglha Mountain Ranges to the north (Fig 2.2). Based on surveys that have been carried out in the last ten years it is estimated that more than 700 hydrothermal areas exist in this zone, many of them high-temperature areas with an estimated reservoir temperature of over 200°C. Some of these areas are within a few tens of kilometers of the main centers of population. The Yangbajain field, has been developed since 1977 to provide electricity for Lhasa. The second largest city in Xizang is Xigaze about 250 km west of Lhasa. In the vicinity of Xigaze there are three high-temperature geothermal fields, which may be developed to provide electricity and heat for that city.

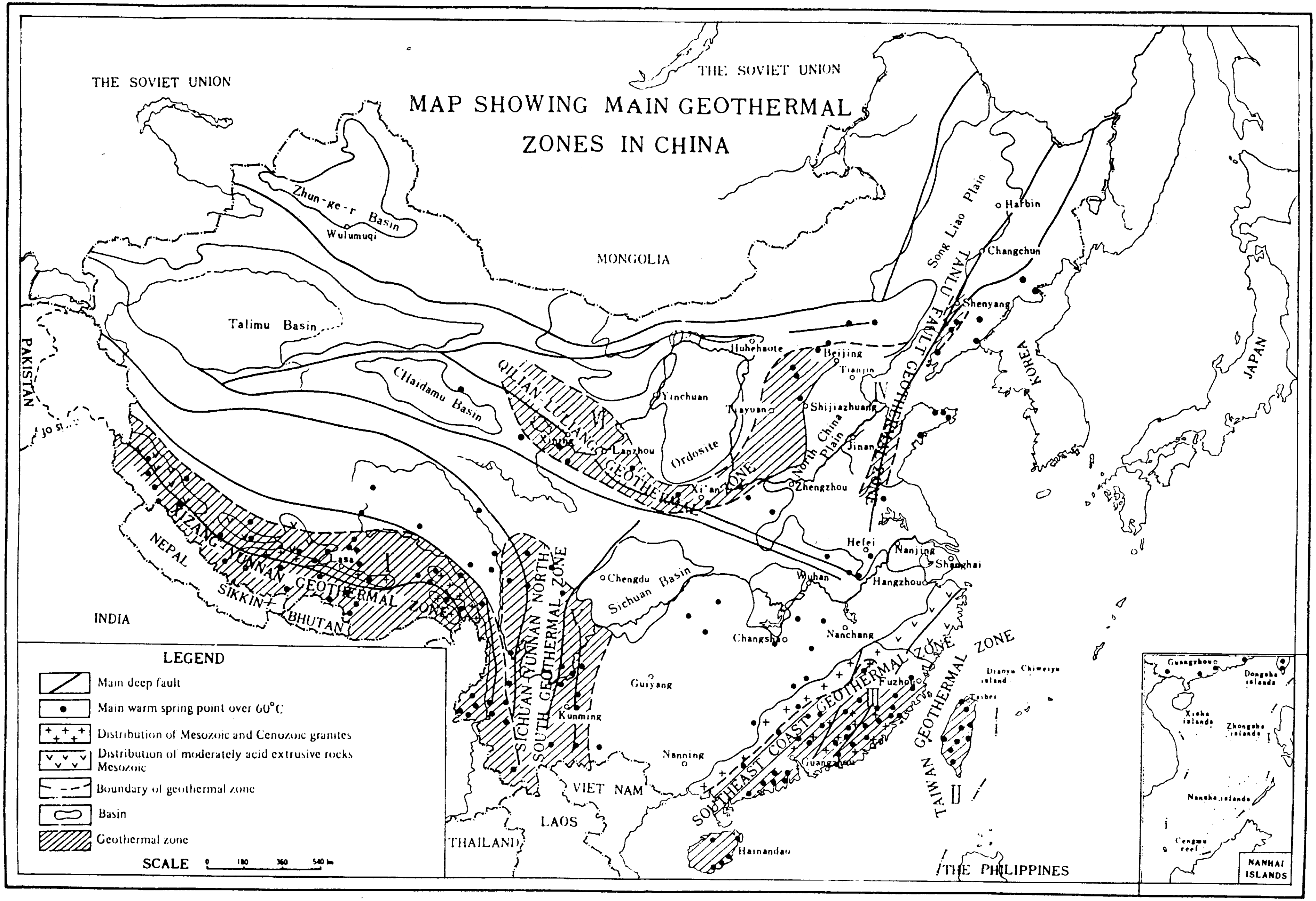

Fig. 2.1. The main geothermal zones in China, excluding sedimentary basins (Geothermics, v.11,1982).

Attempts have been made to find usable geothermal resources closer to Lhasa than Yangbajain. A hot spring area is being explored about 18 km from Lhasa in the direction of Yangbajain. The surface temperature is 30°C. This thermal area was discovered about 10 years ago. In Lhasa a 900-m hole has been drilled. No aquifers were found and the geothermal gradient was found to be less than 30°C/km, which is low.

2.4 Geothermal utilization in the Xizang Autonomous Region (XAR) and elsewhere in the People's Republic of China

The first experimental production of electricity from geothermal resources in Xizang began in Yangbajain in 1975. At the present time 13 MWe of generating capacity have been installed. The field now produces about one-third of the power load of Lhasa. The only other geothermal power station in Xizang is in Langjiou in west Xizang, where 1 MWe has been installed.

Greenhouses have been built in Yangbajain to utilize the waste water from the power plants, which otherwise is discharged at 80°C to the river. Their total area is 25,000 square meters. Tomatoes, cucumbers, eggplants and green pepper are grown. The greenhouses are owned and operated by the Geothermal Science Institute, the Geothermal Geology Section, the Geothermal Engineering Section, and the Army.

The town of Nagqu about 300 km north of Yangbajain has about 12,000 inhabitants. A geothermal field is located just outside the town. It is being explored with a view to a possible use for space heating, wool washing and hide processing. At present a hotel and a hospital are geothermally heated.

The development of the geothermal resources of Tibet is mainly in the hands of two organizations. The Bureau of Water Resources and Electric Power (BWRE) is responsible for the construction and operation of power plants, while the Bureau of Geology and Mineral Resources (BGMR) has responsibility for the exploration and drilling for the steam. The reservoir engineering aspects seem to be in the hands of BGMR, but the division is not clear-cut. In Nagqu the local government is responsible for financing the district heating system, but the technical work is carried out by the BWRE.

The geothermal team and a geothermal research center of the Bureau of Geology and Mineral Resources of Tibet is housed in quarters about 18 km from Lhasa. The total number of people employed by the Bureau is about 3,800, of which about 700 are engaged in geothermal work.

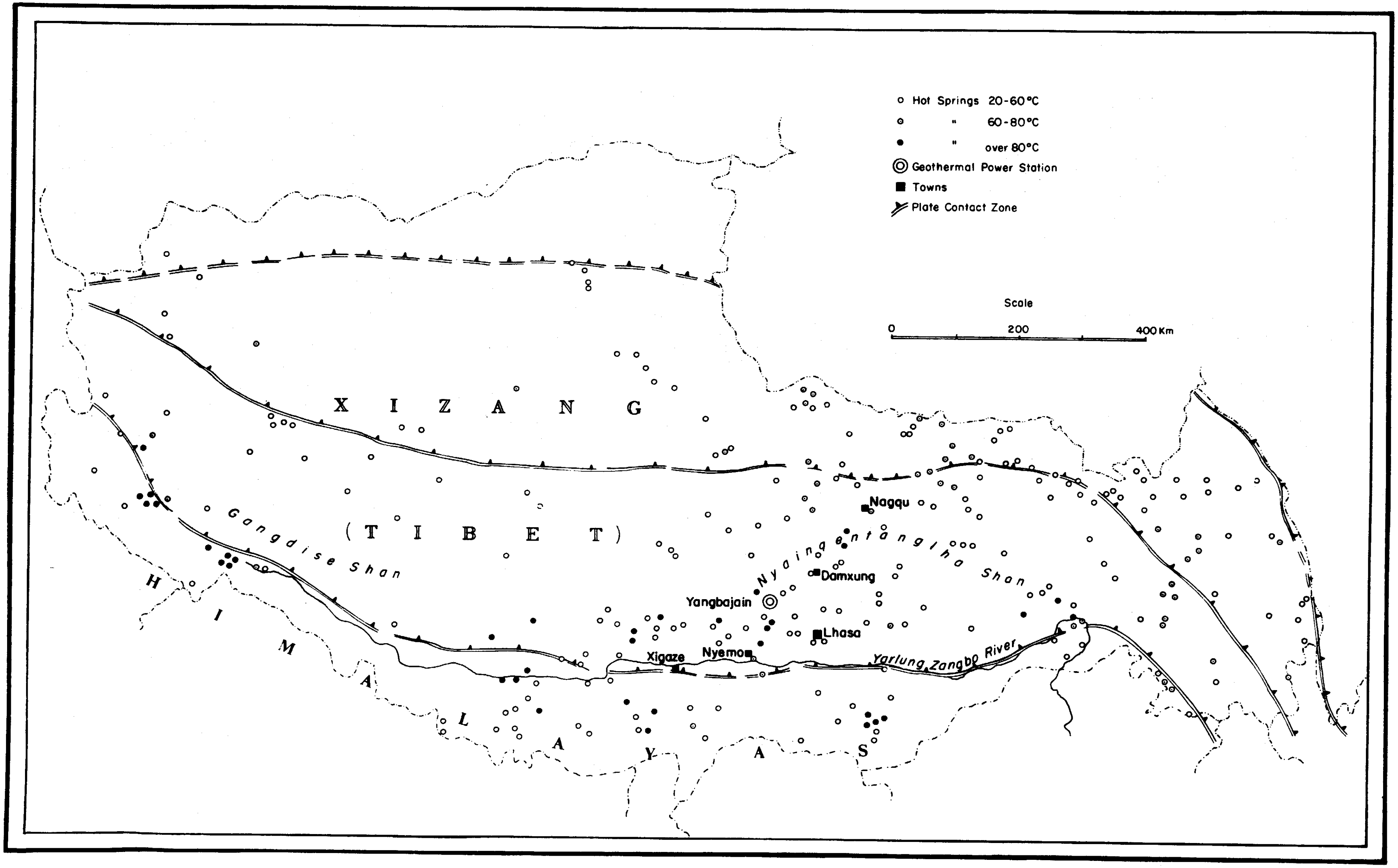

Fig. 2.2 The main geothermal areas in the Xizang Autonomous Region, China. Based on information supplied by the Bureau of Geology and Mineral Resources, Lhasa. Boundaries are inaccurate.

In addition to Yangbajain there are small experimental geothermal power stations in at least six locations in the P.R. of China. Direct use of geothermal energy is being developed in the Southeast Coast Geothermal Zone as well as in the Tianjin - Beijing area. At the present time about 30,000 square meters of apartment houses are heated with geothermal water in the city of Tianjin.

2.5 Discussion of Potential Uses in the XAR

The area of the XAR is about 1.2 million square kilometers and the population about 2 million. It is thus a very sparsely populated region, and this makes distribution of electricity in many areas uneconomical, despite an abundance of potential hydropower sites. The total installed hydroelectric capacity in Tibet is about 100 MW. Sunshine is abundant, with more than 3,000 hours of sunshine per year in Lhasa. The use of solar energy may thus be a promising possibility for the future. No hydrocarbons or coal have been found in the XAR and oil is transported to Lhasa (pop. 60,000) via a more than 1,000-km long pipeline from the Qinghai Province north of the XAR.

Geothermal energy offers promising possibilities where the geothermal resources are located close to centers of population. Most of the high-temperature fields are along the Yarlong Tsangpo junction zone north of the Himalayas, and this is also where the main centers of population are. Heating of houses is required for 5 months a year in Lhasa, 6 months in Yangbajain, and 8 months in Nagqu. In Nagqu the temperature in winter may get as low as -30°C. Comprehensive uses for power generation, industrial processing, space heating, and greenhouses may be possible in many places and can make such projects more economical than would be the case for individual sectors of utilization.

A feasibility study has been made of hot-water transportation from Yangbajain to Lhasa. The outcome was negative, due to difficult terrain and the very high investment needed. This study should be reconsidered in the light of Icelandic experience in long distance piping of geothermal water.

3 VISITS TO THE YANGBAJAIN AND NAGQU GEOTHERMAL FIELDS, XAR

3.1 General

In Yangbajain and Nagqu modern scientific methods and technologies are used in producing geothermal energy. Projects are staffed with well--educated and skilled people.

The energy production is in an experimental stage but is very close to a transfer to the full professional stage.

According to Icelandic experience under similar circumstances, increased cooperation and communication with fellow experts, and also the import of additional specialized equipment and technologies from other parts of China and abroad, will pay off almost immediately. Important fields such as computerization and automation will have important consequences far outside the geothermal industry.

The geothermal developments in Yangbajain and Nagqu are a very important contribution to the XAR energy industry as a whole, as they make possible new industries and district heating services that provide space heating and new quality of life to the people. And they also show the way for development of other hitherto unexploited geothermal areas in XAR.

3.2 The Yangbajain Geothermal Field

3.2.1 Location and Short Description

The Yangbajain geothermal field is located in the Damxung-Yangbajain--Nyemo basin which is a NE-SW graben believed to have formed during the Quaternary period.

The rock formations at Yangbajain are chiefly of three types: Lower-Palaeozoic gneisses in the northern part of the Yangbajain basin (Nyainqentanglha Mountains). In the central and southern part of the valley rocks of volcanic and intrusive origin are found, the youngest of which are approx. 7-8 m.y. Quaternary sediments up to 300 m thick overlie the basement rocks on the valley floor. The geothermal fluid which feeds the geothermal power plant at Yangbajain is derived from this sedimentary layer. The permeability in the reservoir is controlled mainly by the sedimentary structures as well as sinter-cemented deposits that form the cap rock of the reservoir.

The chemical components being discharged from the Yangbajain field are near neutral (pH 6-8) sodium chloride-bicarbonate water, rich in boron and bicarbonate (400ppm) as the major anions, and sodium (310ppm) as the major cation. Chemical and isotopic data indicate waters of meteoric origin.

The stable isotopes of Deuterium and O-18 indicate that some shallow springs are recharged from local meteoric water, whereas well water and boiling springs represent recharge of meteoric water from higher elevation.

Resistivity survey shows a low resitivity layer which compares relatively well with the maximum temperatures measured in the wells. In the granitic basement below the Quaternary deposits resistivity is believed to increase rapidly. Some magneto-telluric measurements in the area suggest a low resistivity at 10-20 km depth which may correspond to a rock melting zone; a possible heatsource for the geothermal fields.

Perhaps the most important data is the temperature information from wells which conclusively deliniates the explored field. It shows that the upflow zone most likely underlies the Sulphur Mine locality to the NW where water of estimated temperature 170°C flows laterally towards SE along permeable zones in the Quaternary sedimentary layer flooring the valley. Along the way the temperature of the water decreases due to conductive heat loss and mixing with colder ground water. Well-temperature data shows very clearly a temperature reversal at about 100-150 m depth. A deep well (ZK-308) which reaches down to about 1,500 m indicates that the thermal gradient in the basement underlying the geothermal reservoir may be of the order of about 40°C/km. Figures 3.1 and 3.2 show the extent of the field through temperature data.

During the visit we were shown and told about the main features of the Yangbajain field. The impression that we gained was that while information on the structure of the hydrothermal system in the Quaternary basement was displayed very conclusively, comparable data on the structure and the exact location of the upflow zone within the underlying basement was lacking. The upflow zone is, however, expected to be situated somewhere below the Sulphur Mine deposits. It seems logical to proceed with the investigation by:

a) Careful mapping of all steam vents in the Sulphur Mine area and location of all fractures,

b) Careful geochemical sampling of the steam vents and analysis with respect to chemical geothermometers,

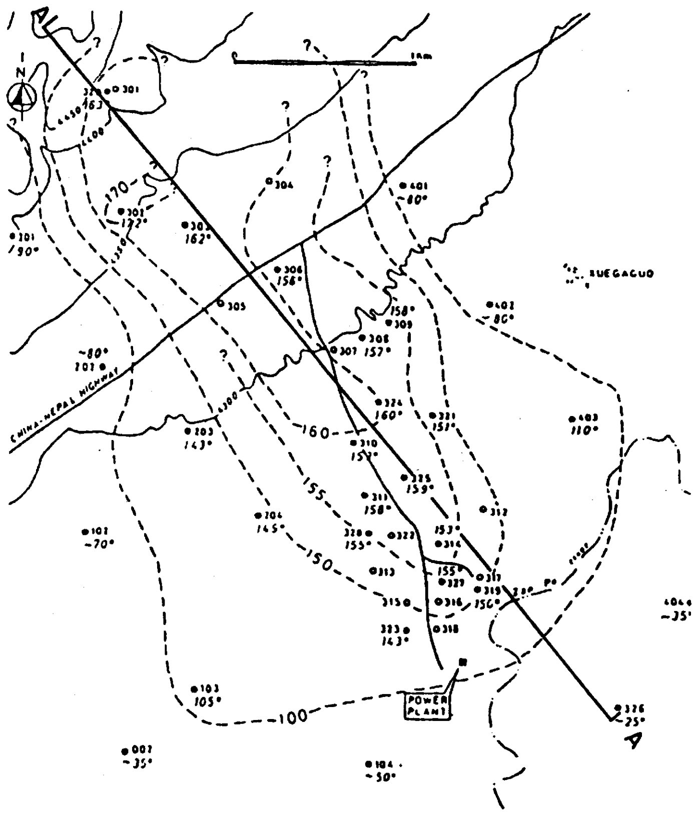

Fig. 3.1 Map of the maximum recorded temperatures in Yangbajain geothermal field.

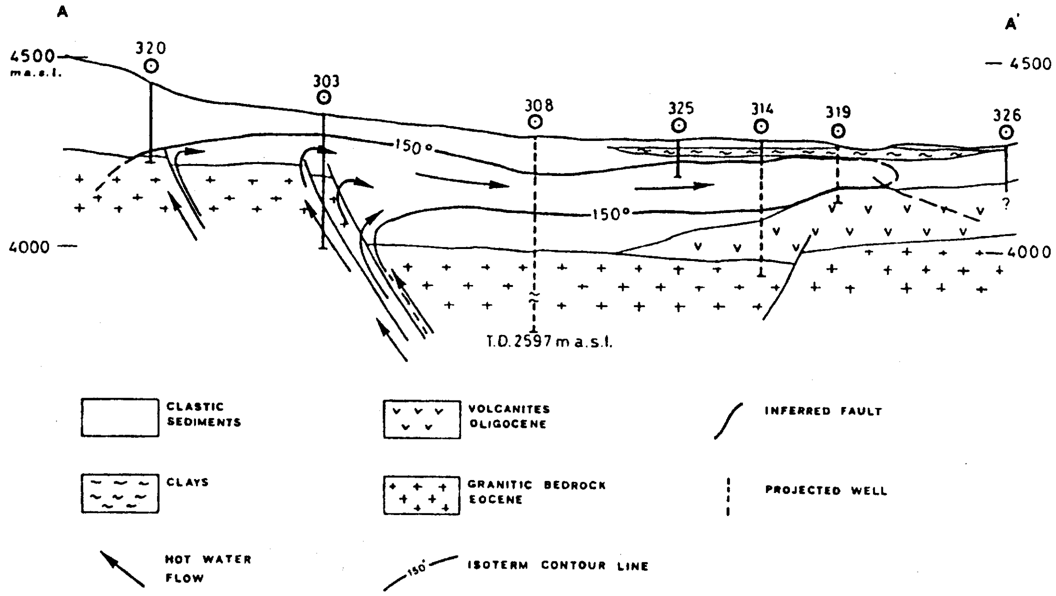

Fig. 3.2 Cross section through Yangbajain geothermal field. Line of section shown in figure 3.1. (Ref: Cappetti and Wu Fangzhi, 1985: Present Status and Prospect of Yangbajain Geothermal Field. In; GRC, Intern. vol., p 563-568)

c) Deep resistivity soundings with vertical resolution well into the underlying granite in order to locate eventual low resistivity channels equivalent to the upflow zone(s). The terrain around the Sulphur Mine appears not to be too rugged for an extensive survey of that kind.

From discussions with the Chinese geothermal specialists it appears that the surface thermal manifestations are undergoing a cooling especially in the marginal areas of the field. It is of paramount importance to monitor these changes, as they may indicate a depletion of the reservoir.

It must also be kept in mind that if and when the upflow zone of the geothermal system is found and utilized, it is likely to result in a more rapid depletion of the Quaternary reservoir.

3.2.2 Developments to Date

Geothermal investigation in the Yangbajain area started in 1974 when geological, geochemical and geophysical surveys were able to identify a promising geothermal site some 15 km^2 in extent. To date, 49 wells have been completed with depths ranging from 43-603 m and one well reaching down to 1,726 m.

The first 1 MW power unit was put into operation in 1977 and its purpose, besides generating electricity, was to proceed with comprehensive testing of design for future turbines.

The second turbine was put into operation in 1981, the third in 1982 and the fourth in 1984. Each of these are 3 MW. All are of double-flash design except the first one which was a single-flash turbine. At the time of the Icelandic Delegation`s visit, the final preparations for starting the fifth turbine, also of 3 MW capacity, were under way. Including it, the total installed power in the Yangbajain field is about 13 MW. At the time of the visit, the power plant was producing 5-6 MW electricity.

3.2.3 Planned and Potential Future Developments

The planned and proposed geothermal development at Yangbajain, in addition to the present 13 MW power generation there, may usefully be divided into two categories, viz.:

being mined there now, i.e. for district heating, greenhouse heating, wool-washing and hide-processing, in addition to the present power generation.

(2) Extended power generation, with or without comprehensive use of the additional fluid.

This categorization of future developments at Yangbajain is important in that category (1) does not impose any additional load on the geothermal reservoir over and above the one existing today, whereas category (2) does.

The developments in category (1) were extensively discussed during the Delegation's stay in Tibet, and are dealt with elsewhere in this report and in the Letter of Intent (Appendix 1).

As to category (2), the Delegation was informed that in the present five-year plan, substantial additional generation was contemplated at Yangbajain, to be commissioned by or before 1990. This development touches directly upon the question of the ultimate potential of the Yangbajain geothermal field; a question that was considerably discussed with Tibetan geologists and engineers during the stay in Tibet, and was also mentioned at a meeting with Mr. Wang Hai in Beijing after the trip to Tibet. It is also dealt with elsewhere in this report; in the Letter of Intent (Appendix 1, Document C1) and in Appendix 3. Here, the conclusion of the Delegation is that a cautious and systematic procedure should be followed in future planning, using the most advanced reservoir data collection and evaluation procedures, including computer model simulations. Emphasis should be placed on comprehensive and systematic data collection from existing boreholes at Yangbajain, to serve as the basis for such simulations.

3.2.4 Reservoir Evaluation in Relation to Present and Future Developments.

Extensive surface exploration work has been carried out in Yangbajain. The geothermal reservoir is identified as being in two parts, a NW (north-west) part and a SE (south east) part. Geological data show that both these reservoirs are in formations of relatively thin layers of sedimentary deposits storing medium- to low-temperature geothermal fluid that is almost saturated with calcite. The horizontal extent of both reservoirs is well mapped by temperature, pressure and resistivity data. Formation permeability is presumably granular and the storage is elastic, or elasto-plastic.

Deep reservoir conditions are more uncertain. An underlying formation is feeding the upper formations. The permeability of the granite is presumably fracture permeability only, and storage coefficient may be very low. The feed fractures are not identified, there may exist separate feed fractures for the NW and the SE reservoir and shallow interconnecting fractures between the reservoirs. The state of the deep reservoir is not properly known. Further exploration such as a deep-penetrating resistivity sounding, followed by drilling, logging and pressure transient testing of deep wells is necessary to retrieve the state parameters of the deep reservoir. This should be followed by a program for identification of the feed fractures and interconnecting fractures, if any.

There have been several attempts to build a conceptual model of the upper reservoir. By analytical heat-flow calculations based on these models, estimates of the reservoir capacity have been obtained. By using these conceptual models it is possible to build computer models of pressure transient drawdown of the water level in the wells and convection between the upper reservoir and the baserock reservoir and also to build forecast models to predict production, provided that adequate hardware and software computer facilities are available to the production engineering staff.

Field monitoring is by individual measurements only. It is possible to install automatic water level gauges in several wells where pressure transient drawdown is known to take place. It is also valuable to keep records of the elevation of the calcite plugs that are regularly cleaned out of the production casings.

It would also be valuable to take regular measurements at the wellheads of reservoir fluid parameters, especially enthalphy and chemical composition to detect any change that might occur in the reservoir state parameters. It would be necessary for the production chemist to have special sampling equipment for this purpose.

Steady production is maintained in the 3x3 MW station, with double-flash system. Some production history data from this production is available. The new station is having difficulties with the deep well pumping scheme. A new pump-shaft type with special bearings adapted to geothermal water is necessary.

The reservoir has responded to production in two ways. Firstly the wells show significant drawdown, and secondly calcite plugs are deposited in the production casing. Present calculations of reservoir performance are based on thermodynamic heat-flow calculations only. As these calculations result in a reservoir capacity of around 20 MWe, it will be necessary to consider possible deviation due to the effect of storage and pressure decay (drawdown).

The drawdown of the reservoir pressure level will make the calcite plugs move deeper into the wells. When the plugs come too close to the less permeable baserock granite formations, the inflow to the wells will decay. In order to evaluate the feasibility of future enlargement schemes, it will be necessary to build a computer drawdown model, and compare its result to production history until a proper match is obtained. This model can then be used to forecast future drawdown and see if the calcite plugs are creeping too far down into the wells. When the feed zones from the deeper reservoir to the upper are identified, it may be possible to introduce remedies against more drawdown and maintain the pressure level of the upper aquifer.

3.2.5 Specific Problems at Yangbajain

During our stay in Yangbajain (el. 4,230 m), we had the opportunity to visit the main power station which has an installed capacity of 9 MW, and a new one (3 MW) that has been undergoing trial operation since March of this year. In discussions with the resident engineers and accompanying experts we had the opportunity to learn about some of the problems and solutions that have been identified, and discussed others that could be the source of future Icelandic-Chinese cooperation. The problems that were discussed had to do with the following:

- Deposition of calcite scaling in the wells and equipment.
- Scaling of turbine blades.
- Corrosion of wellhead parts, pipes, pumps and ejectors.
- Breakdown of the first deep well pump.
- Field monitoring of drawdown, and well-production data.
- Logging and sampling of the wells.

Questions were raised whether the geothermal field at Yangbajain could support the forecast increase in power generation, under the new five-year plan ending 1990. The subject of geothermal utilization was also discussed, especially the use of spent geothermal water for district heating for housing the 400 employees of the power station, the town of Yangbajain, and for greenhouses. The possibility of long-distance transmission (90 km) of hot water to Lhasa was discussed where the present heating load is estimated at 20 MW and load duration 3,000 hours a year.

Calcite deposition. The problem of calcite deposition in geothermal wells is a serious one at Yangbajain. This is a rather common problem of geothermal utilization, and different approaches have been used around the world to tackle it. In Yangbajain a novel method of cleaning the wells has been invented. The wells are cleaned several times a week by lowering a special clean-out device down the wellbore on a steel cable. The hollow sleeve that is lowered down the well is approximately 80 kg in weight and scrapes the deposits, and the debris is subsequently carried by the wellflow out of the well (Fig. 3.3) This method has enabled the plant to keep the wells producing, in spite of the heavy scaling. The scaling starts at a depth of 40-70 m below the wellhead and is still present at the wellhead and into the pipeline leading to the steam separator. The scaling of the surface pipeline is, however, not as easily cleaned, and requires removal of the pipe-section for cleaning once a month. The original design of the steam-collection system was for the steam and water to be separated at the well, and transported in separate pipelines to the power plant. A centrifugal pump was to boost the water pressure to take care of pressure losses. It was later found out that the flow could be transferred to the plant without pumping, and now the steam and water is transferred to the two-stage separators at the plant (Fig. 3.4).

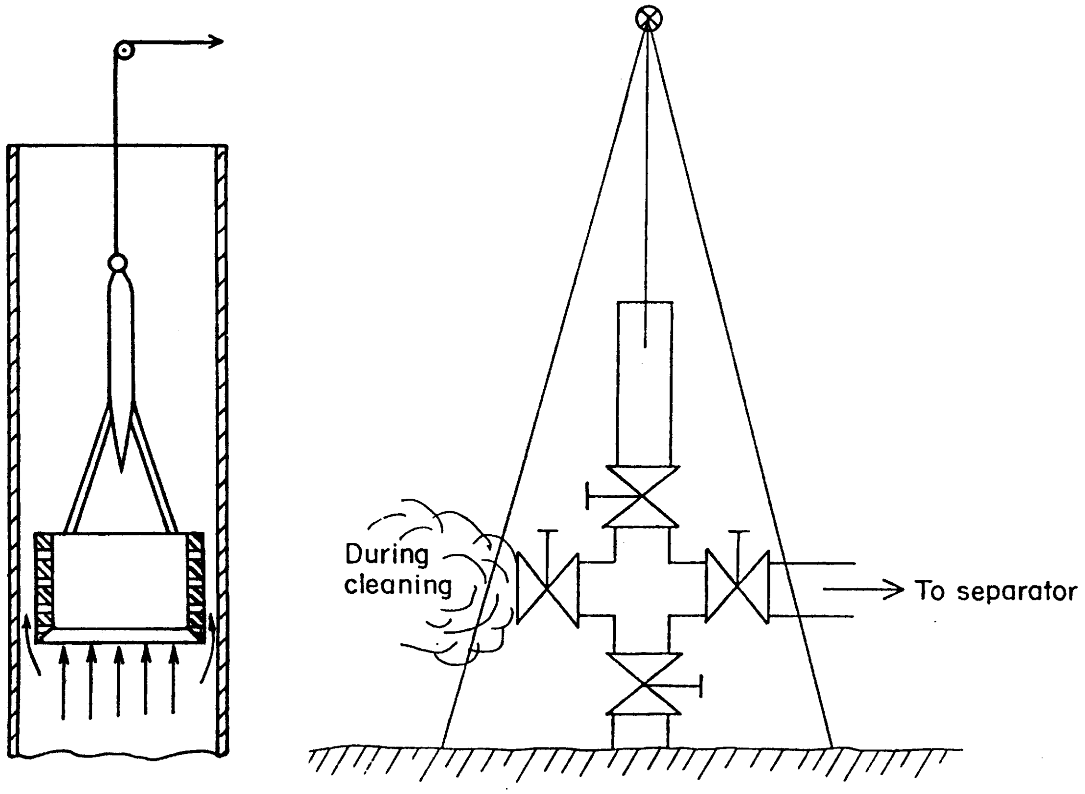

Fig. 3.3 A sketch of the Chinese cleaning device for removing calcite from wells. (Ref.: Research on the Yangbajain Geothermal Power Station 1985).

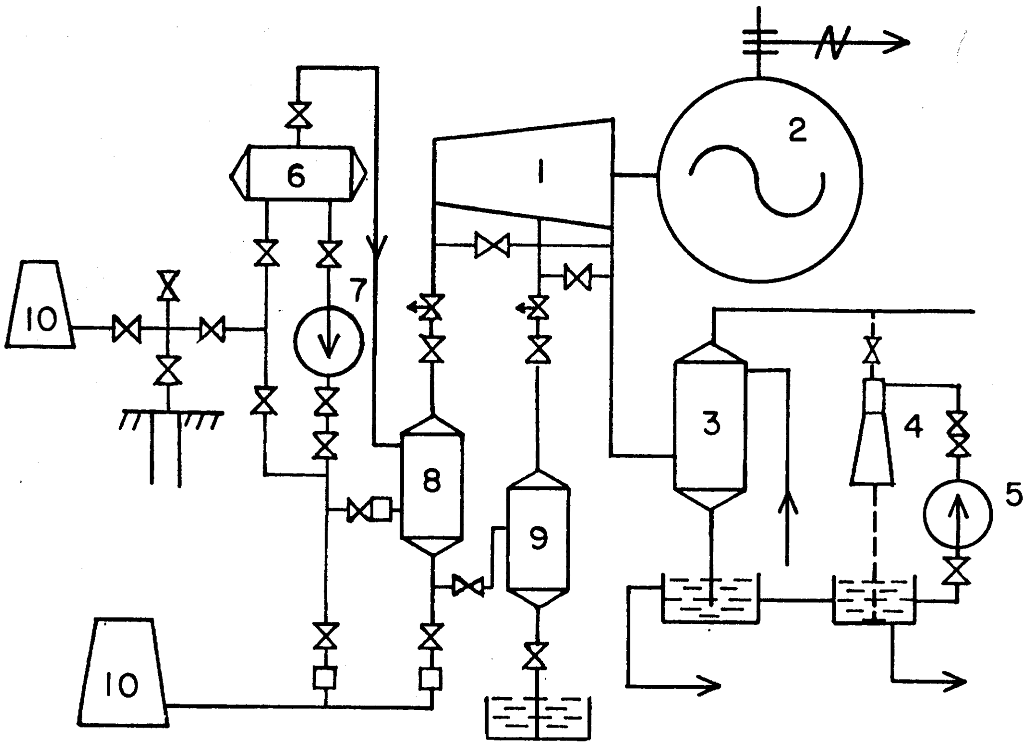

Fig. 3.4 A flow diagram of the power station at Yangbajain. Equipment marked 1 to 5 shows the generating equipment and 6-10 the steam supply system. (Ref.: see Fig. 3.3).

After 6 years of operation the pipeline from the separator to the plant has some 1-3 cm of scaling deposits. It is conceivable that by lowering the wellhead pressure further, the calcite scaling could be controlled to take place in the well only. There the cleaning could be done with existing technology. It was explained to us that the present wellhead pressure is 4.1 ata, and the pressure is lowered to approx. 3.0 ata by a manually-adjusted valve located just after the wellhead separators. The flow is controlled by automatic valves at the plant site where the pressure is reduced to 1.7 ata (118°C), which is the separation pressure. The second stage separators have a pressure of 0.5 ata. In spite of the unusually low separation pressures the steam fraction is only 5% by weight, because of the low temperature of the produced fluid (160°-170°C). The use of such low temperature (enthalpy) fluid makes the water requirements of the plant high. During our visit to the field the geothermal stations of Yangbajain produced in total only 5.5 MW in two units.

The cleaning method developed in Iceland, using a small drilling rig to clean the wells with a conventional bit was explained. This method allows the well to flow during the cleaning operation, and takes only 1-2 days to complete. This method may have some use in the Tibetan fields if scales become too hard for the method used at present.

The turbines have to be overhauled once a year to clean out scale deposits on both rows of blades in the high and low pressure stages. This is probably due to inadequate separation efficiency of the steam separators. This problem is commonly solved either by locating the separators some 200-300 m away from the power station and having the pipework collect the droplets carried over, or by installing wire-mesh mist-eliminators either in the separators or in a separate tank.

The most recent 3 MW unit (unit nr. 5) is supplied under a contract with a firm in the USA, and a different method of dealing with the calcite deposition is used. The turbine is Japanese (Fuji Electric), but the design and a good share of the equipment comes from the USA. One feature of the design is to use down-hole pumps to keep the water from flashing and thus from precipitating calcite in the wells. This is a trick which sometiemes has worked, but results in high pump maintenance in most cases. A large 22-stage shaft-driven deep-well pump (160 t/h) from Johnson Pumps had just been tested when we arrived, but had broken down after only 3 hours of operation. The shaft broke in two pieces inside the bowl assembly, between the pump stages. We did not have an opportunity to inspect the pump, but the design of this system seems flawed. The pumped water is to be transferred several hundred meters to a flasher located in front of the two-stage separators at the station. An automatic control valve is located in front of the flasher, where the water will be degassed and rapid calcite deposition can be expected to take place. So even if the pump operated without problems, the scaling problem would simply be transfered from the well to the separators. Cleaning of the flashers and connected pipework will not be easy, and in fact few provisions seem to have been made for clean-outs. This raises the question whether this design will result in better operation than is experienced today with the daily cleaning with the special well cleaning device.

<u>Utilization of effluent water from the power station</u>. Indications from the greenhouse operations are that the effluent water can be used without the use of heat exchangers or chemical treatment in the hot-water distribution network for the greenhouses and district heating system. No scaling was observed in an open conduit at the power station in the 80°C hot water. We were told that corrosion of the pipe close to the plant was a problem, but not further down-stream. We suggested that oxygen take-up in the hot water collecting system

may be the problem, and recommended that measurements be made with highly accurate ampoules to confirm that. Chemical analysis of the effluent water was not available. A recent paper published in English by Mr. Capetti of ENEL of Italy and Mr. Wu Fangzi of the Chinese Academy of Electric Power gives the average down-hole composition as: pH 6.00, Na 450 ppm, K 50 ppm, Ca 15 ppm, Mg 0.25 ppm, Cl 500 ppm, HCO_3 420 ppm, SO_4 40 ppm, SiO_2 220 ppm, H_3BO_3 320 ppm, F 11 ppm, Li 10 ppm, Rb 1.1 ppm, Cs 5.5 ppm, Br 1.6 ppm, TDS 2100 ppm.

Areas of future cooperation between Iceland and China for the design of the hot water distribution system were identified: the district heating system and the greenhouse complex.

Geothermal field development. From discussions with the Chinese experts it was clear that the subject of reservoir development is of great concern, both as regards the effects of production on the reservoir and the subject of reinjection. There is lack of information on the drawdown in the field, as no records are kept of fluid withdrawal, depth of calcite deposits, or the change in chemical composition with time. Two scientific studies have been made that indicate that the field cannot support much greater production. These studies, one made by a Chinese expert and the other by ENEL of Italy, should be followed up with more extensive monitoring and reservoir modelling. There are few down-hole logging instruments in the field, except what was left by a United Nations team.

Most of the drilling sites have been limited to the floor of the valley, as overpressure in wells on the south side of the field made drilling difficult. Uncontrolled blow-outs occurred in four wells. In total, some 49 geothermal wells have been drilled to date, of which only eight supply steam to the 9 MW plant. Several wells are yet to be utilized. The large number of wells drilled suggest that siting of the wells and exploration strategy could be improved.

Several wells we observed suffered leakage on the wellhead. Although the exact cause could not be identified during our brief visit of only 3 hours to the field, the most likely cause is outside corrosion on the casing. The most susceptable part of the wellhead is the area just below the casing flange where water from leaks and soil moisture provides the corrosive environment. Proper wellhead design and good maintenance can reduce this problem. The general appearance and maintenance of the steam collection system in general was poor.

The subject of reinjection was discussed at some length, especially the siting of reinjection wells. Plans are under way to drill reinjecetion wells, but for the time being the effluent water flow (600-900 l/s) is disposed of to the Zangbo river. Careful chemical monitoring of the receiving river system has been in effect. To find aquifers for reinjection that do not adversely affect the production wells may be difficult.

During the discussions between the Chinese and Icelandic experts it was concluded that far greater emphasis should be placed on the reservoir engineering aspects of the geothermal field of Yangbajain, and that future cooperation between the parties should include projects in this field.

3.2.6 Conclusions and Recommendations

The scientific staff responsible for the research of the Yangbajain geothermal field have achieved results of great importance to their country and geothermal science. Up to now the development of Yangbajain has been at an experimental stage, but a transfer is recommended, from the experimental stage where minor disturbances in the production are tolerated, to the professional stage where steady energy production is demanded. We conclude that the building of the new power plant (unit 5) is the first step in that direction.

More communication between the Yangbajain geothermal staff experts and their collegues elsewhere in China and abroad is recommended. First priority should be given to the build-up of deep-penetrating exploration and logging techniques together with computer facilities and field monitoring equipment.

The electricity generation produces effluent water with usable thermal energy several times that of the electrical energy produced. The following extensions of the experimental downstream utilization already in progress can be concluded:

A DHS (District Heating Service) for the greenhouse complex, the station village and Yangbajain town. The DHS would be both for space heating and industry.

Outdoor fields with soil heating to lengthen the growing season for the growing of storable vegetables.

A tourist hotel with health spa and recreational facilities. This project should be connected to the planned increase in tourist traffic to Lasha from the 20,000 level to the 100,000 level.

When the increase of electricity production commissioned in the next five year plan has been put into effect, the feasibility of a DHS pipeline to Lasha may be studied once more.

The Yangbajain project is suffering from a series of special problems. These are technical problems well known to Icelandic geothermal experts. All geothermal developments throughout the world have experienced scaling and corrosion problems of their own special kind. Proper technical research utilizing the right kind of equipment will, given time and financial means, minimize the problems, so that steady production and reliable energy delivery is ensured.

As the upper Quaternary reservoir is showing signs of decay, an increased reservoir engineering effort is highly recommended. A new resource assessment, including the deep resource and new production technologies, should be made prior to the final design of new power stations.

The following technologies already in use in Yangbajain should be upgraded with new equipment and training of personnel:

House insulation.
DHS pipeline insulation and plumbing work.
DHS system pressure and flow control equipment.
Wellhead design and anti-corrosion measures.
Steam collector pressure and flow control.
On-site chemical sampling and analysing.
Greenhouse ventilation and temperature control.
Greenhouse heating arrangement.
Well-pump design and installation.
Field monitoring.
Computer analysis.

All these technologies are in steady progress in China and elsewhere in the world, so increased cooperation and communication between Yangbajain staff and fellow experts will be very valuable for both parties.

3.3 The Naqqu Geothermal Field

3.3.1 Location and Geothermal Developments

The Naqqu area is located at a distance of about 300 km from Lhasa and about 200 km WNW from Yangbajain. The location is at an altitude of about 4,500 m. The Nagqu area is a part of the pronounced fault structure that is believed to be closely related to much of the high temperature activity in Tibet. The town of Nagqu, which is situated 2-3 km from the geothermal area, has about 12,000 inhabitants. At present the town utilizes the geothermal field for space heating in the main hotel and hospital. There is a very strong desire on the part of the authorities to harness the geothermal energy for the benefit of the people in the town; e.g. to reduce oil consumption, reduce air pollution from yak manure burning, create greenhouse industry and hopefully to generate electicity.

3.3.2 Geothermal Research

At the time of the visit of the Icelandic Delegation, intense geothermal prospecting was taking place in the Nagqu field. The state of investigation appeared to be exploration and production drilling.

We were being told that surface geological mapping in the scale of 1:10,000 was being done.

Geochemistry has shown that the main chemical components of the hydrothermal fluids sampled at surface manifestations were HCO_3-Na, HCO_3-Ca, HCO_3-Mg-Ca, HCO_3-SO_4-Ca, the pH about 7-8, and the salinity 2.7 - 3.2 g/l. The well samples at wellhead were taken through a separator where the sample is taken of the water but the steam is discarded.

A resistivity survey (a derivative of a Schlumberger array configuration) has delineated nicely the horizontal extent of the low resistivity anomaly irrespective of depth. Thus the area inside the 15 ohmm line is about 1 km^2 and about 1.8 km^2 within the 20 ohmm line. The shape of the resistivity anomaly appears to relate to tectonic features, and we were shown traces of faults which very nicely could be superimposed on the anomaly. The resistivity map was extensively used to site exploration wells.

Last year 3 wells were sunk and this year (1986) 6-7 wells are expected to be completed. The depth of the wells is generally 50-150 m with the exception of a well that is expected to reach to 500 m depth when finished. The temperatures found in the wells reach a maximum of 112°C measured at wellhead and a pressure of 1-2 bar. Three drill-rigs were at the site during our visit, the largest one having a maximum depth capacity of 1,200 m. Mud is used as a drilling fluid due to the weakness of the strata.

The rock succession in which the geothermal system is thriving consists of Quaternary sediments some tens of meters thick, underlain by partly consolidated sediments of sandstone some 60 m thick. Below that rocks of Jurassic age were dissected. We were told that granite underlies the geothermal area.

Cores appear to be the main source of information in borehole geology and cutting samples are only looked at in a superficial way. We were not aware of the use of alteration data in the borehole studies.

Borehole geophysical logging, especially measuring temperature, appeared not to be functioning well as all the data that we were shown were temperatures measured at well head.

It must be emphasized that accurate temperature logging in the wells gives very important information regarding temperature variation in the reservoir especially when the exploration should be focussed upon finding the upflow zone.

Reservoir engineering studies appear not to be in the picture at the present moment in the investigation.

3.3.3 Planned and Potential Future Developments

In Nagqu, there are plans to extend the present district heating system, which serves the hospital and the new hotel, to other buildings.

It is also planned to use the hot water, in addition to district heating, for such purposes as greenhouse heating, wool-washing and hide-processing. Of these, greenhouses would constitute a more comprehensive use of the district heating water, whereas the other uses would be in parallel to that use and thus require increased pumping from the geothermal field.

These planned geothermal applications at Nagqu were all discussed during the stay of the Delegation and are treated elsewhere in this report and in the Letter of Intent (Appendix 1). The question of the ultimate potential of the Nagqu geothermal field is referred to in the Letter of Intent; Document C1. Emphasis should be placed on a systematic field monitoring of the Nagqu geothermal field and data collection. Any future extension of utilization of the field should be planned on the basis of an evaluation of its potential based on these data, using the most advanced evaluation methods.

3.3.4 Reservoir Evaluation in Relation to Present and Future Developments

Surface exploration work in Nagqu consists mainly of shallow resistivity soundings. Geological data shows that the reservoir is in formations of relatively thin layers of sedimentary deposits storing geothermal fluid similar to Yangbajain, but of lower temperature. Drilling is in progress so further reservoir data will be coming in soon. Formation permeability is presumably granular and the storage is elastic, or elasto-plastic.

Subsurface conditions and feed zone identification are presumably subject to the same problems as in Yangbajain. The state of the deep reservoir is entirely unknown. A deep penetrating resistivity sounding, followed by drilling, logging and pressure transient testing of deep wells will be necessary in the future. In due time this should be followed up by a programme for identification of the feed fractures and interconnecting fractures if any.

A conceptual model of the Nagqu reservoir should be built. It would be used to estimate the reservoir capacity by analytical heat flow calculations based on the model. Later this conceptual model would be the basis of a computer model of pressure transient drawdown of the water level in the wells and downward movement of the calcite plugs into the wells. It would also be used as forecast model to monitor production, provided that adequate hardware and software computer facilities are available to the production engineering staff.

Automatic water level gauges should be installed in two wells to monitor pressure transient drawdown and pressure gradient build-up. It is also valuable to keep records of the elevation of the calcite plugs that are regularly cleaned out of the production casings. A special programme for observing and mapping the undisturbed reservoir state (pressure, temperature and fluid chemistry) should be initiated as soon as possible, so this valuable information is not lost for good.

It would also be valuable to take regular measurements at the wellheads of reservoir fluid parameters especially enthalphy and chemical composition as to uncover any change that might occur in the reservoir state parameters. For this it is necessary for the production chemist to have special sampling equipment.

Feasibility studies of production of electricity should include binary systems. Further scaling and corrosion studies will have to be made and an interesting possibility would be the operation of a skid-mounted binary cycle 500-1,000 kW turbine-generator unit. The potential for direct use of the geothermal energy from the Nagqu field is considerable and the cooling provided by the binary system would help to eliminate the problem of calcite precipitation in the direct use systems (pipeline distibution network of the district heating service).

Calcite problems are similar to Yangbajain. The drawdown of the reservoir pressure level will make the calcite plugs move deeper into the wells. When the plugs come too close to the less permeable base-rock granite formations the inflow to the wells will decay. It will be necessary to build a computer drawdown model, and compare its result to production history as obtained by the automatic water level recordings until a proper match is obtained. This model can then be used to forecast future drawdown and give advance warning, if the calcite plugs are creeping too far down into the wells.

3.3.5 Specific Problems at Nagqu

The geothermal field at Nagqu (elevation 4,450 m) has been under investigation and exploitation much shorter than the Yangbajain field, as the first production well was drilled in 1984. The wells are relatively shallow, less than 200 m deep. Two wells have been connected to a district heating system commissioned in 1985, serving the new hotel and hospital. After a short period of operation several problems have appeared. The main problem is calcite scaling in the wells and in the surface piping close to the well, but problems in the distribution system have also been observed. Improvements in the radiator systems inside the buildings are also required. The City Council is interested in expanding the district heating system to include most of the official and commercial buildings, and also local industry. At the present time no plans have been made to heat other houses in this town of 12,000 inhabitants, in spite of the obvious need in this harsh climate where the average annual temperature is -1.9°C, the range being -37.6°C to +20.5°C.

The single geothermal well, 200 m deep, now serving the system has a scaling rate of 1.5 cm in 24 hours. The scaling which starts at 20 m depth in the well when it is operated at 2 ata wellhead pressure, is cleaned every day with the same method as used in Yangbajain; lowering a hollow sleeve down the well. Deposition inside the pipeline also creates a problem, because rapid scaling occurs in the pipe to the separator and from there some 30 m into the distribution system. The pipe had just before our arrival been cut open at the inlet to the main pipeline leading to the town, some 50 m away from the well.

Visual inspection of the pipes was thus possible (Fig. 6.14, chapter 6). The pipe contained calcite deposits approximately 3 cm thick. From this description it is obvious that the design has to be changed. Interestingly, the main pipe was free of all scaling, and corrosion seemed to be minor where it could be inspected (Fig. 6.15). This sharp transition from scaling to non-scaling conditions is a well-known behaviour of calcite, because of the retrograde solubility (more soluble at lower temperatures). This, it seems, makes it possible to transfer the geothermal water directly to the town without any serious deposits. Improvements are required in the pipe system from the well to the main pipeline, to enable cleaning of the pipes, and consideration should be given to installing down-hole pumps to keep the 112°C water from boiling in the well. If the water can be cooled while still under pressure, scaling may be avoided.

The house installations were inspected, and the following problems discussed:

- The cast iron radiators used in the hotel show heavy scale accumulation on the outside at the joint between each rib, as is shown in Fig. 6.21. This is simply due to poor sealing between the cast iron elements, something which should be easy to correct in the manufacturing. In Naqqu the cast iron radiators are considered inferior to the welded ones, something which is contrary to experience in Iceland where cast iron radiators are preferred where there is corrosion or scaling.

- Valves show scale accumulation at the spindle, and become difficult to operate. The reason for this is the same as for the previous item; simply due to evaporation from the highly mineralized geothermal water, which leaves the dissolved solids behind.

- The radiators in the hospital were not designed for the lower temperature of the geothermal distribution system. The design engineer informed us that the heating system was changed from steam over to the much colder geothermal water at the last minute without design modifications. The radiators are therefore only half as large as they need to be for efficient utilization of the hot water.

- Gas has to be bled from the radiators to keep them hot. Installing tanks to remove entrained gas before it enters the system would solve this problem.

- It has proved difficult to keep all of the radiators in the hospital warm. It was suggested that proper control valves could balance the system.

- Chemical samples have to be taken of the water and steam phase, to analyse the problem of calcite scaling. As the fluid is to be produced from deeper wells to be drilled in the future, such information has to be collected and analysed before the wells are put to use. It is quite common for wells within the same field to display different scaling behaviour.

- Coupons for measuring scaling rates, and corrosion rates should be placed inside the pipes at several locations for monitoring.

3.3.6 Conclusions and Recommendations

The energy production from the Nagqu geothermal field is at an experimental stage and will probably stay that way for the next few years.

The plans for direct utilization of the energy of the Nagqu field for space heating and industry are very promising and suitable for this kind of resource. The temperature is too low to sustain large scale production of electric energy, but plans for electricity generation should, however, not be abandoned altogether.

Instead, a new design, based on a pressurized system with electricity production in a binary system station on-line with the DHS should be studied. This could eliminate calcite problems and provide electricity as an extra benefit.

A temperature, pressure and chemical sampling field survey should be initiated as soon as possible in order to obtain undisturbed state reservoir data as reference level for later reservoir engineering work.

Specialized equipment and upgrading of technologies are more needed in Nagqu than in Yangbajain. Priority fields are insulation, plumbing, DHS pressure and flow control.

4 VISITS TO THE TIANJIN GEOTHERMAL UTILITIES

4.1 General

There has been considerable communication between scientists in Tianjin and the geothermal community in Iceland. Many of the trainees of the Geothermal Training Programme in Iceland have come from Tianjin, and Icelandic geothermal experts have been on missions in Tianjin. The Icelandic Delegation had therefore asked for the opportunity to pay a courtesy visit to Tianjin.

After a meeting in the Bureau of Geology and Mineral Resources in Tianjin, there followed a visit to a fish farm and a greenhouse farm, also to the Tianjin District Heating Co. and to a carpet factory.

The geothermal industry in Tianjin is well established and can contribute a considerable technological input to other areas in China. But on the other hand the geothermal experts of Tianjin are fighting an uphill battle against the effects of decaying resources. The dwindling of resources is a considerable threat, not only to the geothermal industry of Tianjin but the manufacturing industry as well.

4.2 The Tianjin Geothermal Fields

The Tianjin geothermal anomalies are situated within the subsidence zone of the North China plain at the northern end of the subsidiary structure of the Canxian uplift. The Neotectonic features in eastern China appear to be related to the movement along the crustal boundary of the Asian and the Pacific plates, and these undoubtingly are providing the conditions for the hydrothermal activity evident in the Tianjin area as well as at other localities within the subsidence zone of the North China plain.

Three geothermal anomalies have so far been identified within the Tianjin region; the Shanlingzi field, the Wang-lan Zhuang field and the Wanjiamatou field.

The geological succession is made up of a crystalline basement of an age older than ca 300 m.y. and overlain unconformably by Tertiary to Quaternary sediments of up to 2,000 m thickness. The geothermal anomalies are related to the uplift and subsidence of the basement. Available data show that shallow thermal anomalies are distributed mainly in and above the uplifted part of the basement.

Two types of geothermal systems are present in the Tianjin area. One is a pore water layer which is confined to the Tertiary silt and fine grained sand, and the other is a fracture carst water within the basement, confined mainly to the limestone of Ordovician and Sinian age.

Hydrochemically the porous water of the Tertiary system is characterized by high alkalinity and low hardness and salinity, while that of the fracture carst water of the basement by the relatively high salinity, alkalinity and fluorine content, and low hardness.

The geothermal anomalies are generally best defined by their thermal gradient. The normal gradient within the North China basin ranges from about 10-40°C/km while the gradient within the thermal anomalies is 40-50°C/km.

The temperature of the water in the upper system ranges from about 30°-63.5°C whereas the temperatures in the lower system ranges from 50°-98°C.

The extensive withdrawal of water from the upper system has resulted in a drawdown amounting to about 3 m/year. So far no temperature changes have been observed. The extraction of water from the lower geothermal system is as yet relatively small, but expectations of high productivity are high in the lower system.

4.3 Geothermal Utilization in Tianjin

4.3.1 District Heating

Our visit to The Tianjin Municipal District Heating Co. was only short, but the engineers who showed us around gave us an informative account of the installation and its operation.

The district heating system is located north of the Sport College and serves now about 33,000 m^2 of residential building floor space. Three boreholes are at present utilized, borehole no. 1 (1,500 m deep, flow 95 t/h, temperature 57°C) and 2 boreholes, 9 km away from no. 1 (temperature 85°C, flow 80 t/h each).

There has been good cooperation between Icelandic and Chinese engineers concerning district heating in Tianjin. Engineers from Tianjin have studied in the UNU Geothermal Training Programme in Iceland and some Icelandic experts have visited Tianjin.

We were shown the headquarters of the system, where office premises were under construction, and where there is a also a borehole (no. 1), and a heat-exchanger unit. The borehole water is corrosive, and its effects could be seen on the pump. We were also shown insulated hot-water pipes of the type that has been used in the distribution system. They were not of very high quality, but this is likely to be remedied, since according to the engineers a new factory is being built to produce insulated piping.

The surrounding area is densely populated and highly suitable for a district heating distribution system. Many of the buildings are blocks of flats of 3-4 storeys. We were shown the flats on the ground floor of one of them. The radiators were small compared to what we are used to, and they were all situated against internal walls, not under the windows as is desirable. We were surprised to note that each flat, or pair of flats, had a separate water meter: in Iceland it is normal to have only one meter for the flats served by each staircase, or even only one for a whole block.

At the end of the block that we looked at there was a connection chamber for the heating system. It was half-full of water, indicating that the water-table is extremely high.

If a distribution system is frequently exposed to groundwater there is a danger of corrosion and failures. It can prove necessary to lay special drainage pipes in order to keep the pipes of the heating system dry and in that way prevent corrosion.

4.3.2 Greenhouses

The greenhouses in the Vegetable Research Institute in Tianjin were attractive and sturdily built. Heat is derived from a borehole yielding water at 59°C, but as it is corrosive, fresh water is heated in heat-exchangers and circulated in a closed double-pipe system in the greenhouses.

Geothermal heating is used in the greenhouses only in winter, and when we arrived, the pump had been lifted out of the borehole and a heat-exchanger had been opened for inspection. The effects of corrosion could be seen clearly on both.

The heating system seemed to be well designed. There were plenty of windows that could be opened by electric controls and also electric fans to ensure air circulation.

An automatic watering system was installed in the greenhouses, and experiments were being conducted with cultivation in artificial soil.

The area of the greenhouses is 3,300 m^2. The main types of vegetable being grown, depending on the season, are watermelons, tomatoes, cucumbers and lettuce.

There are three harvests each year and the total crop is 55,000 kg.

4.3.3 Fish Farming

We visited an experimental fish farm, Wanchamato, in the outskirts of Tianjin. Nile perch are bred there, most of the young fish being sold to farmers for further rearing, though some are reared on the farm. Nile perch were chosen for rearing because they grow quickly, need little oxygen and have a very good flavour. The staff said that the project was highly successful and that the perch are easy to farm. The fish are bred in ponds in the ground. Over some of them a plastic film could be spread on iron frames. The yearly production is 20,000 kg.

A borehole yielding an ample supply of 97°C water supplied the whole farm through a distribution pipe with a single feed-pipe with a tap for each pond. There was no automatic temperature control and no mixing of the water-supply, but the staff said that manual control proved highly satisfactory.

4.4 Potential Future Developments

In 4.2 above it is mentioned that there is large drawdown in the upper geothermal system in Tianjin but that there are high expectations of high productivity in the lower system.

The utilization of geothermal energy is part of the planned expansion of energy sources to meet the growing needs of the city. The role of geothermal energy will therefore increase in industry, fish farming and greenhouse cultivation in the future. It is planned to increase the area of premises using geothermal energy for space heating.

There is serious air pollution in Tianjin because of the use of large amounts of coal in both houses and industry, and the increased use of geothermal energy is part of the authorities' attempts to deal with the pollution problem.

Without more extensive familiarity with the use of geothermal energy in China it is difficult to give a detailed picture of the lines future developments will take. Nevertheless, the following points may be mentioned:

- It should be possible to improve the bearings in the pumps and pump-shafts.
- Plates of stainless steel are at present used in the heat-exchangers. These are affected by corrosion. The use of other materials, such as titanium, should be investigated.
- The preinsulated steel pipes which are at present in use are not of high quality. The quality of production will presumably improve with the coming of the new factory. Insulated pipes and fittings must be of high quality, and particular attention must be given to the joints, which must be watertight.
- Because of the high water-table, it is particularly important not to lay the pipes deep in the ground, and drainage pipes for groundwater should be dug wherever possible to minimize the problem of corrosion.

Methods of improving energy utilization and energy saving in homes must be investigated. Larger radiators must be used in central heating systems so as to exploit the energy content of the water better, and with better house insulation and double glazing it would be possible to reduce the total energy requirement considerably. If these methods are applied, the same hot water supply can be used to heat three times the housing volume it now serves. Although the installation of larger radiators and the improved insulation of houses are costly, the heating costs themselves need not rise, because the pipes used in the distribution system could be of smaller diameter. The outlay on the distribution system and the cost of boreholes and heating plants would be borne by far more consumers, with the result that the cost of heating per square metre would be reduced.

4.5 Specific Problems

The delegation did not study the specific problems of the Tianjin geothermal industry in the field.

On the other hand, Icelandic geothermal experts are well aware of the problems facing the geothermal industry in Tianjin because of over-exploitation of the resource and diminishing production. This problem is steadily getting worse due to the transient spreading of local drawdown anomalies.

Tianjin geothermal authorities are trying hard to utilize new resources by drilling deeper wells. The deep aquifers have relatively low permeability. A major reinjection operation is necessary in order to maintain water levels in existing production wells.

4.6 Conclusions and Recommendations

Local industry and agriculture use the geothermal energy for a variety of purposes. All possible measures should be taken as to stop further deterioration of the geothermal resources of Tianjin.

Careful siting of new wells, using deep penetrating exploration techniques may help in sinking the new wells in fault zones with local permeability anomaly.

Hydraulic fracturing methods for well improvement can be recommended.

A special reservoir engineering programme including:

- the design and performance of well tests,
- a field monitoring programme,
- reservoir simulation, matched to production history, and
- reinjection studies

is highly recommended as a follow-up to the latest U.N. activities in this field.

5 ICELANDIC-CHINESE GEOTHERMAL COOPERATION

5.1 General Impressions from the Visit

During its visits to Tibet, Tianjin and Beijing, the Icelandic Delegation had a number of meetings with geothermal experts and government officials. Appendix 4 gives a list of the meetings and the names of the people the Delegation met and who attended the meetings.

The Delegation`s impressions from these meetings and from its tour in general may be summarized as follows:

- Several regions of the People`s Republic of China, in particular the Xizang Autonomous Region (Tibet), are rich in geothermal resources, which may play an important role in the country`s economic development. They may be particularly important in Tibet due to its size, their widespread occurrence and the scarcity of other energy sources in the region.

- The P.R. of China has available a number of highly qualified geothermal scientists and engineers. However, it is very important that these experts be provided with increased opportunities for exchange of views and experience with their collegues in the international geothermal community, and that they have at their disposal at all times equipment and facilities that represent the latest state of the art. This may greatly enhance the value of these experts to the country and speed up geothermal development in Tibet and other regions of China endowed with this source of energy.

- There is therefore a pronounced need for training and transfer of methods and technology in geothermal exploration and exploitation.

- There appears to be ample room for an increase in cooperation between Iceland and the P.R. of China in the field of geothermal energy. The Icelandic Delegation considers the Letter of Intent signed in Lhasa on the eve of the delegation`s departure from Tibet an important first step in this direction.

5.2 The Need for Transfer of Technology and Know-how

5.2.1 Geothermal Training

On grounds of a need for a geothermal training scheme, the Government of Iceland and the United Nations University decided in 1978 to operate a UNU-Geothermal Training Programme in Iceland. Since commencing in 1979 it has been financed by these two bodies.

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 geothermal institutions and firms in Iceland as required. A studies board is responsible for the academic content 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 or in their home countries.

Fig. 5.1 shows a simplified course programme of the UNU-Training Programme. An essential feature of the Training Programme is to provide participants with sufficient understanding and practical experience to permit the the independent execution of projects within a selected dicipline in their home country. Therefore each participant is required to follow mainly one of the eight courses, and furthermore, the training in that respective field is aimed at bringing the maximum benefit to the geothermal research in the Fellow`s country.

Priority as Fellows is given to candidates from developing countries where geothermal exploration and development is already under way. An attempt has been made to assist individual countries in building up a cadre af specialists representing the various disciplines.

The participants must have a university degree in science or engineering and a minimum of one year`s practical experience in geothermal work. The training is conducted in English, which the participants must speak fluently.

Since the initiation of the UNU-Geothermal Programme an emphasis has been on training geothermal scientists from China. This is evidenced by the fact that of the 44 Fellows that have received 6-8 months` training, 12 have come from China, or more than 25%. Further to that 5 Chinese have come for shorter stays as Special Fellows.

The Icelandic Delegation was able to view the state of art in geothermal research in the Xizang Autonomous Region. Its conclusions are that geothermal training as exemplified in the UNU-Geothermal Training Programme could greatly benefit the urgent geothermal effort that is presently in progress in XAR.

In Xizang special visits were made to the officies of the Bureau of Water Resources and Electricity (BWRE), Bureau of Geology and Mineral Resources (BGMR), and the Yangbajain and the Nagqu geothermal fields. In Beijing visits were made to the Institute of Geology of the Academia Sinica, and the Beijing Office of the Xizang Autonomous Region. In Tianjin the Bureau of Geology and Mineral Resources and the District Heating Service were visited.

One of the purposes of the visits in the Beijing and Tianjin areas was to meet former UNU-Fellows and assess how the training had benefitted geothermal progress. We met seven of the 12 Fellows. Through discussion with them we are happy to report that we believe that the training has in most cases been highly successful. One of the former UNU-fellows, Mrs. Lu Run from the Bureau of Geology and Mineral Resources in Tianjin, was selected to act as an interpreter and guide for the Icelandic Delegation throughout the visit in China. This she did in a very satisfactory manner.

Interviews were held with 6 prospective candidates for future UNU-courses. Of these 4 were from BWRE in Xizang, one from the Bureau of Geology and Mineral Resources in Xizang, and one from Academia Sinica, Department of Geology in Beijing.

According to the Letter of Intent it is the intention of the governments of Iceland and XAR on cost-sharing basis to provide two grants for Fellowships, each of the years 1987, 1988 and 1989, six fellowships altogether, for studies at the UNU-Geothermal Training Programme in Iceland. Further to that the UNU-programme looks favourably on offering UNU-grants for training scientists and engineers of XAR in geothermal work.

5.2.2 Research Methodology and Equipment

One of the factors that has determined the competitiveness of geothermal in Iceland to other energy resources is the cost of exploration. Exploration experience has been accumulated both through international cooperation and through experience.

GEOLOGICAL EXPLORATION	GEOPHYSICAL EXPLORATION	DRILLING TECHNOLOGY	BOREHOLE GEOLOGY	BOREHOLE GEOPHYSICS	RESERVOIR ENGINEERING	FLUID CHEMISTRY	GEOTHERMAL UTILISATION
Lecture Course (4 Weeks) – Exploration – Geosciences – Engineering – Development – Computers	Lecture Course (4 Weeks) – Exploration – Geosciences – Engineering – Development – Computers	Lecture Course (4 Weeks) – Exploration – Geosciences – Engineering – Development – Computers	Lecture Course (4 Weeks) – Exploration – Geosciences – Engineering – Development – Computers	Lecture Course (4 Weeks) – Exploration – Geosciences – Engineering – Development – Computers	Lecture Course (4 Weeks) – Exploration – Geosciences – Engineering – Development – Computers	Lecture Course (4 Weeks) – Exploration – Geosciences – Engineering – Development – Computers	Lecture Course (4 Weeks) – Exploration – Geosciences – Engineering – Development – Computers
Seminars and Field Excursion (2 Weeks)	Seminars and Field Excursion (2 Weeks)	Seminars and Field Excursion (2 Weeks)	Seminars and Field Excursion (2 Weeks)	Seminars and Field Excursion (2 Weeks)	Seminars and Field Excursion (2 Weeks)	Seminars and Field Excursion (2 Weeks)	Seminars and Field Excursion (2 Weeks)
Specialized Training (8-12 Weeks) – Field geology – Maps and photos – Structure – Hydrogeology – Mapping – Eroded volcanics – Recent volcanics	Specialized Training (8-12 Weeks) – Heat flow – Magnetics – Tectonics – Resistivity – Gravity – Seismic – Modeling	Specialized Training (8-12 Weeks) – Rig operations – Cementing – Wellhead design – Site preparation – Completion – Management	Specialized Training (8-12 Weeks) – Drilling – Petrological logs – Alteration – X-Ray – Clay minerals – Aquifers – Modeling	Specialized Training (8-12 Weeks) – Well testing – Logging – Flow testing – Injection – Mathematics – Modeling – Simulation	Specialized Training (8-12 Weeks) – Well testing – Logging – Flow testing – Injection – Mathematics – Modeling – Simulation	Specialized Training (8-12 Weeks) – Sampling – Thermodynamics – Deposition – Analysis – Geothermometers – W/R interaction	Specialized Training (8-12 Weeks) – Pipeline – Deposition – Corrosion – Downhole pumps – Power plants – Separators – Feasibility – Management
Project Work (8–12 Weeks) – Selected topic	Project Work (8–12 Weeks) – Selected topic	Project Work (8–12 Weeks) – Selected topic	Project Work (8–12 Weeks) – Selected topic	Project Work (8–12 Weeks) – Selected topic	Project Work (8–12 Weeks) – Selected topic	Project Work (8–12 Weeks) – Selected topic	Project Work (8–12 Weeks) – Selected topic
Report Writing (4–8 Weeks)	Report Writing (4–8 Weeks)	Report Writing (4–8 Weeks)	Report Writing (4–8 Weeks)	Report Writing (4–8 Weeks)	Report Writing (4–8 Weeks)	Report Writing (4–8 Weeks)	Report Writing (4–8 Weeks)

Fig. 5.1 A simplified course programme of the UNU-Geothermal Training Programme in Iceland.

As is well known the two main exploration phases, i.e. the surface and subsurface exploration vary a great deal in cost, where the latter is many times as expensive as the surface exploration. This difference in cost has led to the increased emphasis on surface exploration prior (and to some extent concurrant) to drilling. This emphasis has in many cases led to the decrease or even elimination of wells designed as exploration wells, and where conclusive surface data is available wells have been sited and drilled as production wells, thus combining the well as both an exploration and a production well.

During our visit to Yangbajain it was quite evident that the reservoir within the Quaternary sediments is well defined. However, the upflow zone which is expected to be situated below the Sulphur Mine has not been accurately located, but is expected to be confined to fractures in the underlying granite. Before attempting to reach deeper parts of the upflow zone by drilling it is advisable rigorously to use surface exploration methods, such as resistivity surveys (Head-on, Schlumberger etc.) which can delineate thermal structures down to 500-700 m. Furthermore it may be advisable to make a detailed tectonic map of the Sulphur Mine area in order to locate possible fractures that may relate to recent fracture pattern.

In the Nagqu area geothermal exploration is at a very active phase. In the review of the exploration data with the Chinese scientists, we would have liked to see depth-controlled resistivity surveys, more data on the chemistry of surface manifestations, e.g. in order to demarcate the locations of the highest temperatures according to chemical geothermometers. Borehole data such as distribution and interpretation of geological structures and alteration was limited, and, even more importantly, temperature log data within the wells were apparently not available (we were told that the borehole logging equipment which dates back to 1958 was not giving reliable results). It is very important to know the temperature distribution in the wells as one can in some cases (as is so very clear in the case of Yangbajain) recognize the flow direction from the shape of the temperature curves.

In Iceland mud is sparingly used in drilling, at least in the production part of wells. This is mainly because mud is prone to seal off aquifers. Instead water circulation is used as much as possible. This would however result in having to use bigger pumps on the drillrigs.

It was obvious to the Icelandic Delegation that the Chinese scientists we met in the field were highly motivated and resourceful in their search for harnessable geothermal energy. However, we believe that the exploration strategy can be improved in two ways:

a) By importing more advanced exploration knowhow; by training abroad, by inviting consultancy from abroad including on-the-spot training, and by greater interaction with the international geothermal community (e.g. through conferences).
b) By a renewal of the exploration equipment that is now in use. Examples would be borehole logging equipment that would be able to measure accurately temperature variations, resistivity equipment and computer facilities (software, hardware) for the interpretation of the geoscientific data. Methods in the sampling technique of geothermal fluids both from surface manifestations and wells may have to be modernized.

5.2.3 Utilization Technology

Geothermal energy has been used in Iceland for over 50 years for space heating and greenhouse cultivation, and in the last few decades there has been a steady increase in the harnessing of geothermal energy for industrial purposes and electrical generation. Wide experience has been gained over the years, and considerable technical innovations have been made in Iceland. There are therefore ample grounds for fruitful cooperation between Chinese and Icelandic specialists in a number of fields.

According to the Letter of Intent (Appendix 1), Orkint of Iceland is to undertake a prefeasibility study of the utilization of the energy of the Nagqu geothermal field, including:

- a district heating supply system for 180,000 m^2 heated area,
- a heating system for 5,000 m^2 of greenhouses,
- a wool-washing plant with a capacity of 1,000 tons of wool per year, and
- a hide-processing plant, processing 50,000 hides per year.

Orkint is also to send a specialist to Nagqu to provide the critical equipment required to sample the wells and evaluate the scaling potential.

Orkint is to undertake a feasibility study of the use of geothermal water for space heating and greenhouses in Yangbajain and forward a proposal for the sale of a geothermal deep-well pump.

Further details of the planned cooperation can be found in the Letter of Intent.

In section 4.4 above mention is made of some technical features which could be improved in the district heating system in Tianjin, such as deep-well pumps, heat-exchangers and preinsulated steel pipes. Improvements in the heating systems and house insulation are also touched on. When planning a heating system, i.e. the power plant, pipelines and distribution system, it is necessary to examine the total cost of the system and also the cost of thorough insulation of the houses to be heated by the system, and to choose the alternative which will give the lowest heating cost and also the best utilization of the energy source.

5.3 Possible Forms of Icelandic-Chinese Geothermal Cooperation in the Future

The Letter of Intent signed in Lhasa, has been ratified by both the Government of Iceland and the Government of the Autonomous Region of Xizang. It will therefore be necessary to find the most appropriate form for the cooperation between Iceland and China in the future, especially how to implement the intentions set forth in the Letter of Intent.

In this connection the Icelandic delegation has noted with interest the contents of the speech given by His Exellency Duoji Cairang, Acting Chairman of the People's Government of XAR in Hong Kong on 14th January 1986. The text was provided to us by XAR government officials. The text of this speech is arranged around five main topics.

1. Extended scope for investments
2. Granting foreign enterprises and joint ventures more decision-making power
3. Tax reduction or exemption
4. Offering preferential loans
5. Allowing investors to establish agencies

On this basis the possibility exists for a joint Chinese-Icelandic undertaking in the form of a joint venture Geothermal Company, owned in majority by Chinese and in minority by Icelanders. This company could undertake geothermal projects for the government of XAR, and in the process ensure the complete transfer of necessary technologies and the training of key personnel.

Today a U.S. company is completing a new geothermal station. Icelandic companies, both private and state companies, can perform such tasks in China and are certainly willing to do so. On the other hand, the direct utilization technologies to be put into effect according to the Letter of Intent will always be in majority Chinese, and in minority foreign.

5.4 Conclusions and Recommendations

The development of geothermal resources is well under way in Tibet and utilization of geothermal energy will play an important role in the ecomomy of the Region.

Most of the resources are medium to low temperature and are best suited for development by direct use technologies with electricity production confined to the energy that can be harnessed from the temperatures above approximately 90°C.

The climatic conditions in Tibet are such, that there is great need for thermal energy to heat houses and provide process heating for agricultural product industries. (Wool-washing, tanning, dairy products etc.). More than 20 towns in Tibet are located near potential sources of geothermal energy.

The geothermal specialists have already pinpointed target areas of utilization and started development on an experimental scale.

Iceland has technologies and trained personnel, with years of experience in maintaining a steady production of energy and coping with the problems in exploration, drilling, scaling and corrosion that always come up each time a new geothermal field is developed.

The Icelanders have taken the step to make their experience and technologies available to other nations through their UNU Geothermal Training Programme. An independent business company ORKINT Ltd, has recently been established for the export of Icelandic geothermal technology.

Thus Iceland is able to provide China, and especially XAR, with special technologies and training of personnel. Tibet has the resources in geothermal energy and market potential to establish a professional geothermal industry of nationwide economic importance and will undoubtably do so.

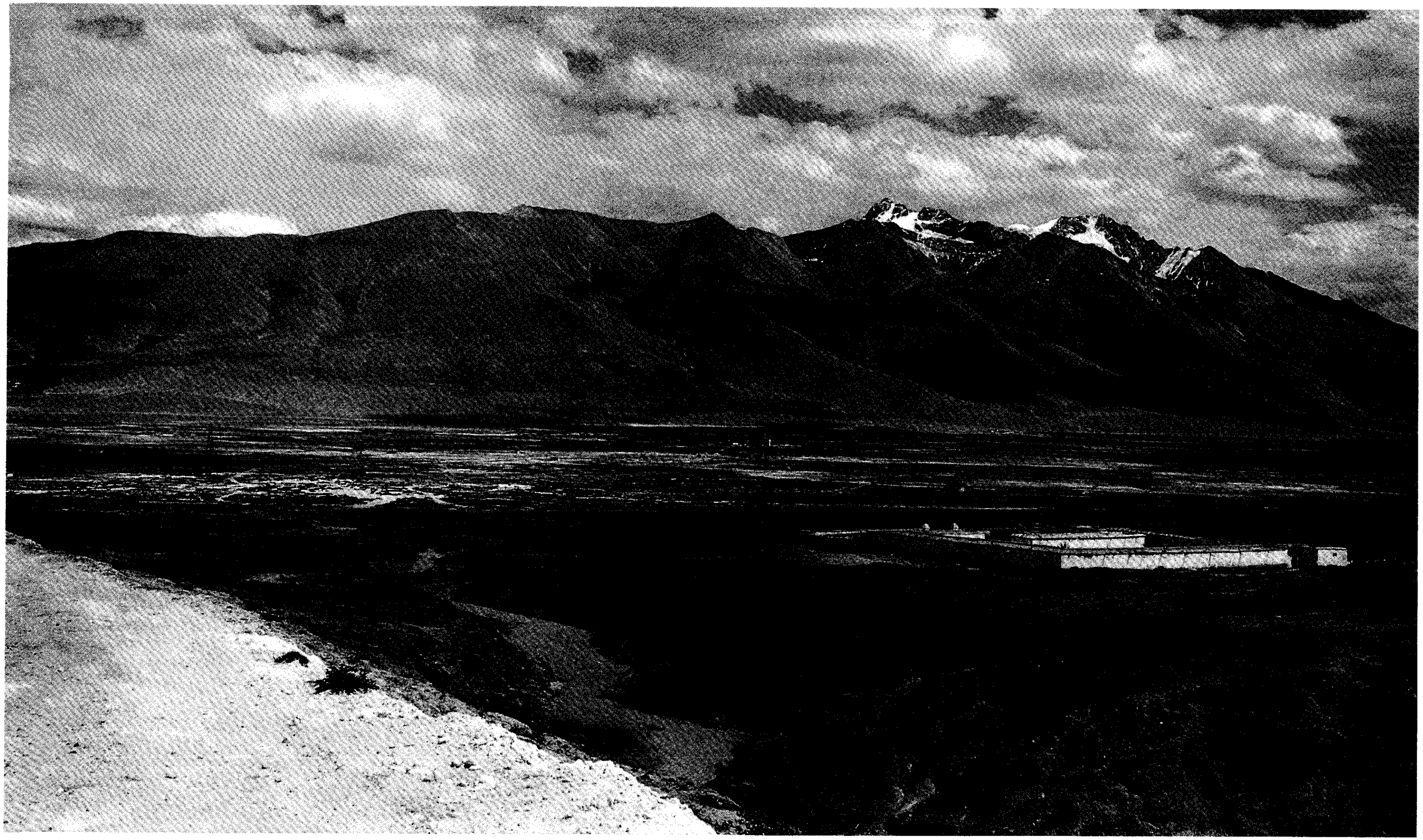

Fig. 6.1 A view of the geothermal field presently being exploited at Yangbajain, seen from the Sulfur Mines where the center of upflow is believed to be. The 9 MW power station in the center, greenhouses to the right, and Tang mountains in the background.

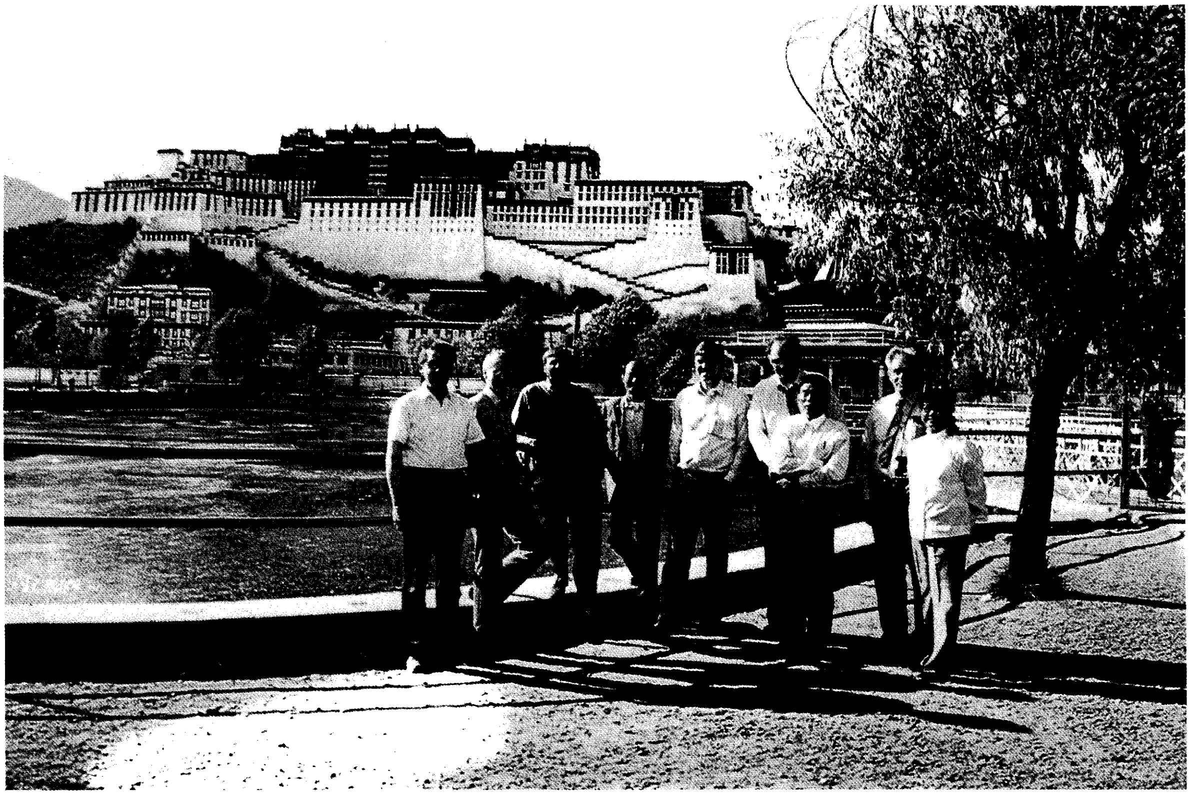

Fig. 6.2 The Icelandic Delegation and Chinese hosts in front of the Potala Palace, Lhasa.
From left: G. Pálmason, K.Ó. Jónsson, H. Franzson, Fan Yuan-Xian, S. Thorhallsson, J. Elíasson, Wu Fangzhi, J. Björnsson, and Lu Run.

Fig. 6.3 The town of Yangbajain and the Nyainqentanglha Mts.

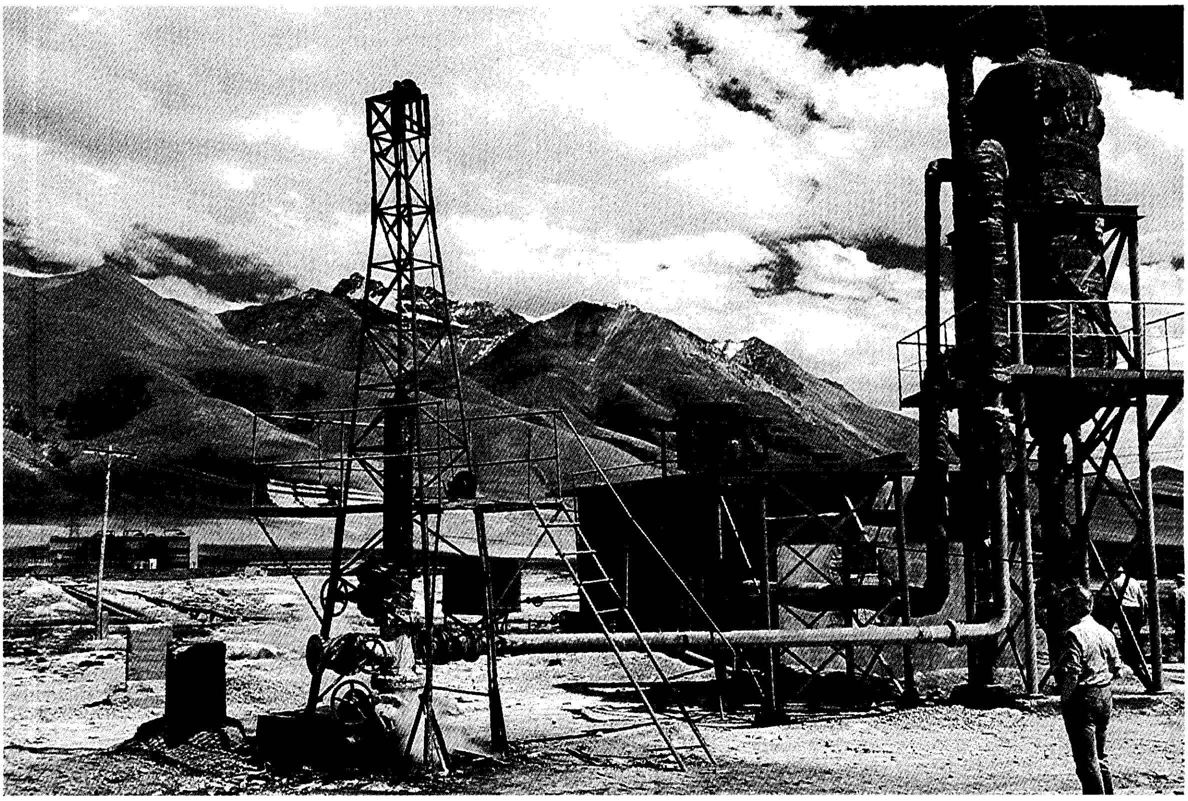

Fig. 6.4 Well ZK-313 at Yangbajain, showing the wellhead with a vertical steam separator.

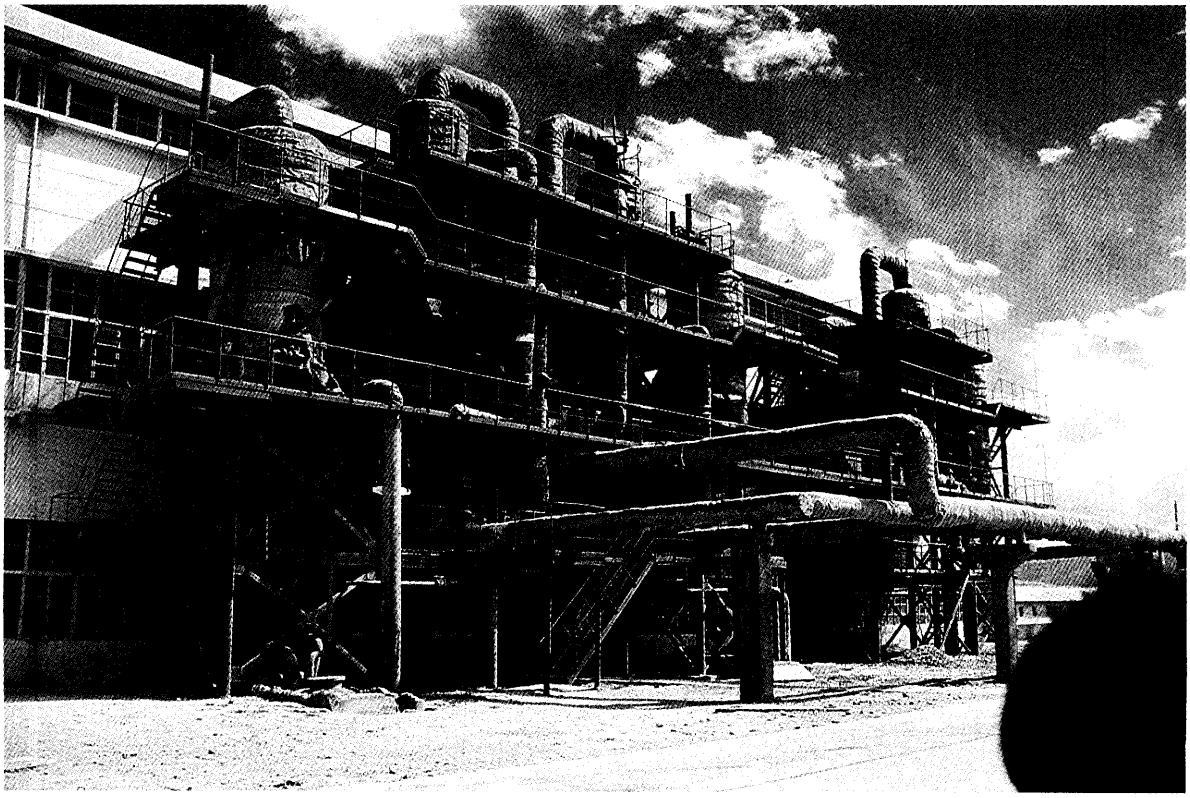

Fig. 6.5 The Yangbajain Geothermal Power Station (9 MW).

Fig. 6.6 Surplus 80°C effluent water being discharged to the Zhangbu river. The first geothermal power station (1977) in background.

Fig. 6.7 Inside one of the greenhouses at Yangbajain. Large diameter heating pipes suspended from the roof.

Fig. 6.8 Discussions with engineers on district heating.

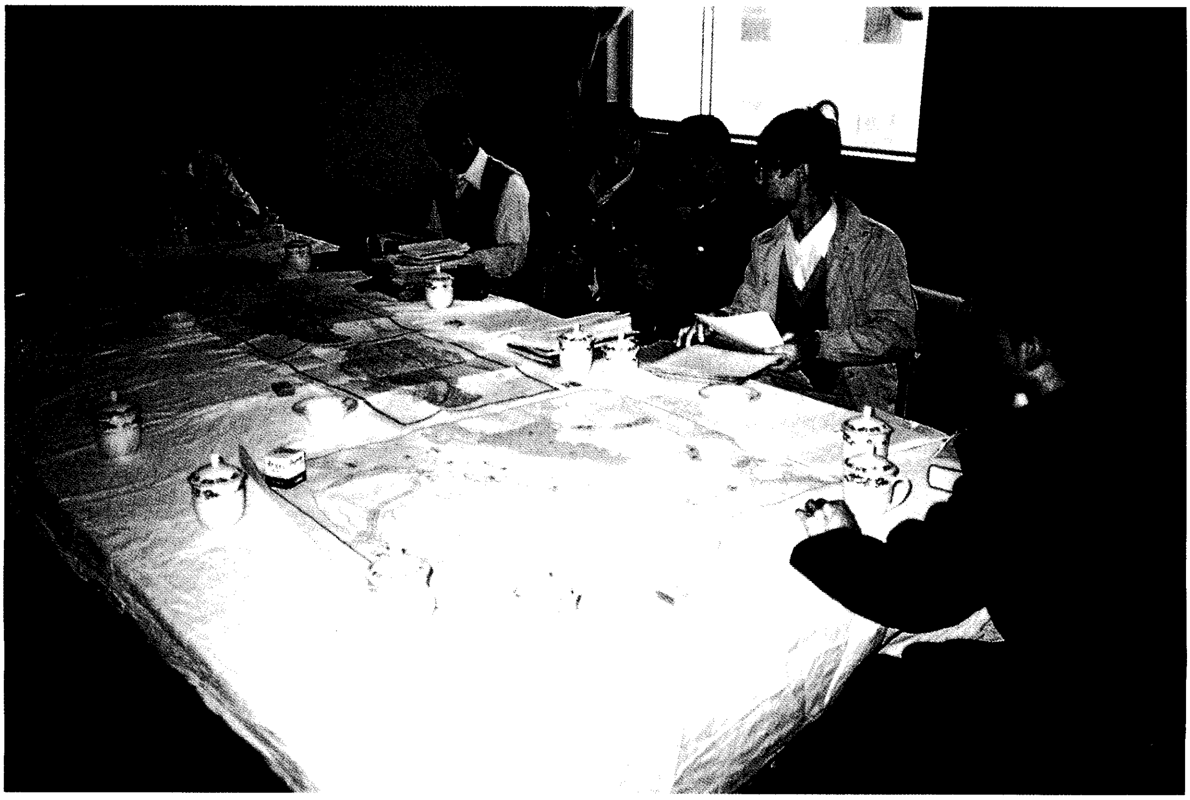

Fig. 6.9 Chinese scientists present their findings on the Tibetan geothermal areas, at a meeting in the Lasa Hotel.

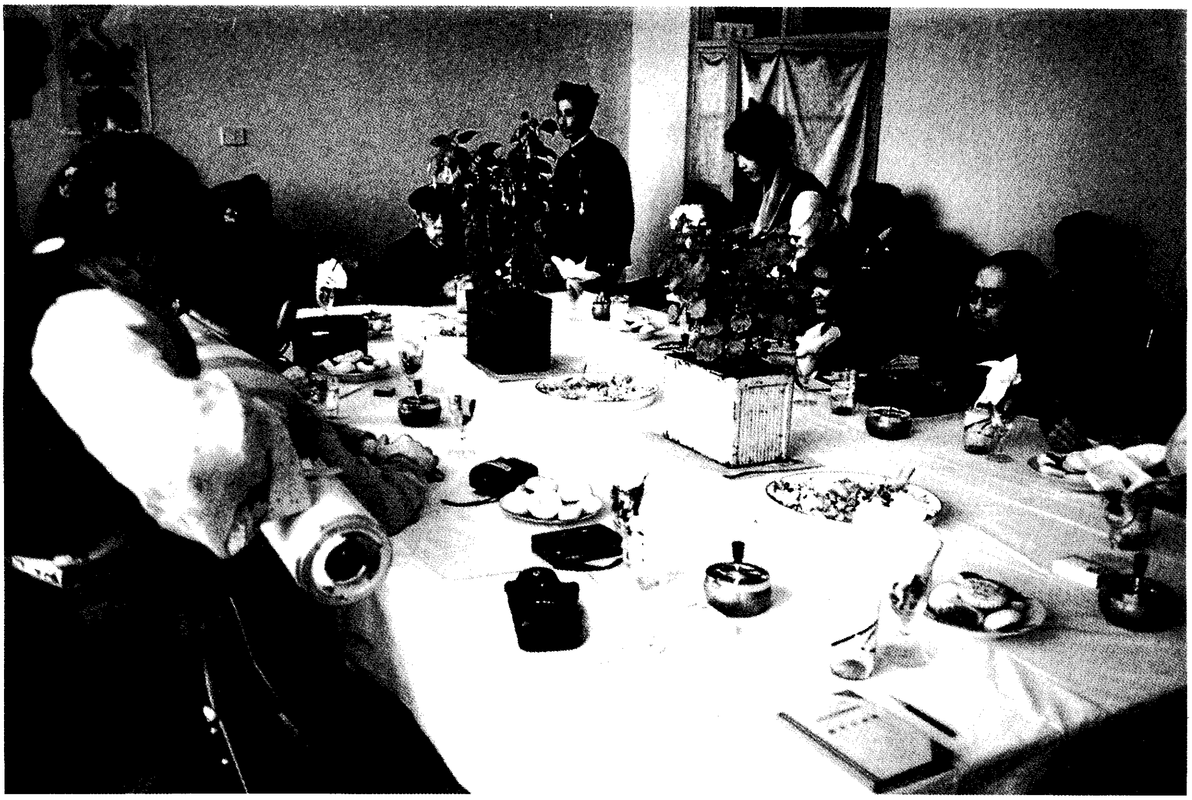

Fig. 6.10 Nagqu Local Government in discussions with the Icelandic Delegation.

Fig. 6.11 A banquet held in Lhasa by Mr. Mao Ru Buo (center), Vice-Chairman of the Xizang Autonomous Region.

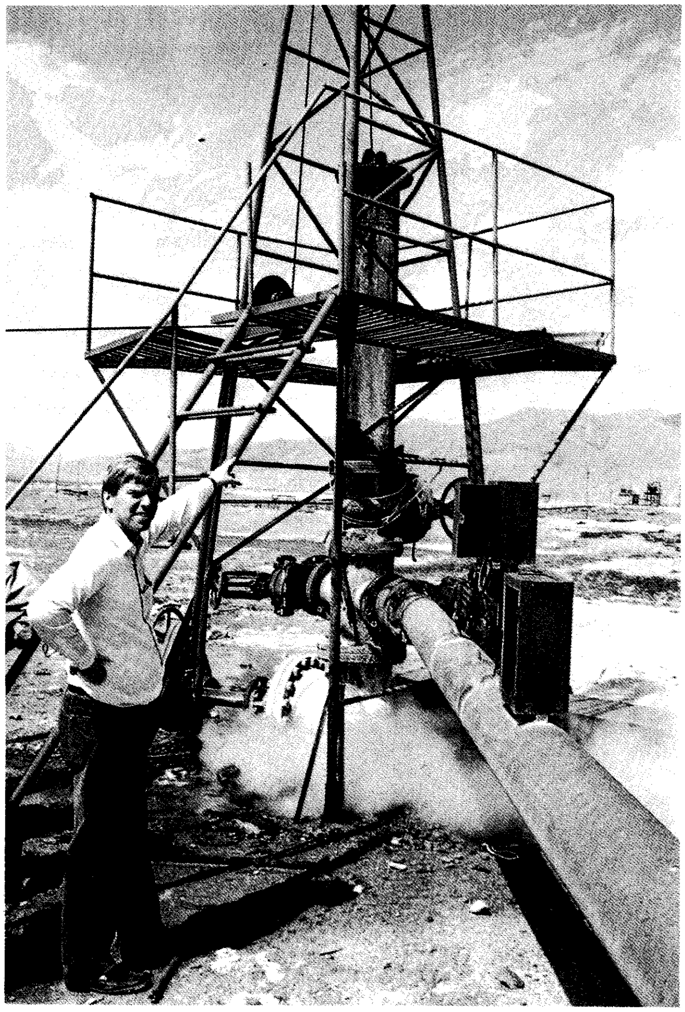

Fig. 6.12 A Chinese device for cleaning calcite scales from inside the wells. When the tool is not in use it is stored in the chamber being pointed at. A steam leak is also visible.

Fig. 6.13 A valve on a pipeline from a well to a separator at Yangbajain partly clogged by calcite scaling.

Fig. 6.14 A pipe section at the pumping station at the Nagqu geothermal district heating system, partly clogged by calcite.

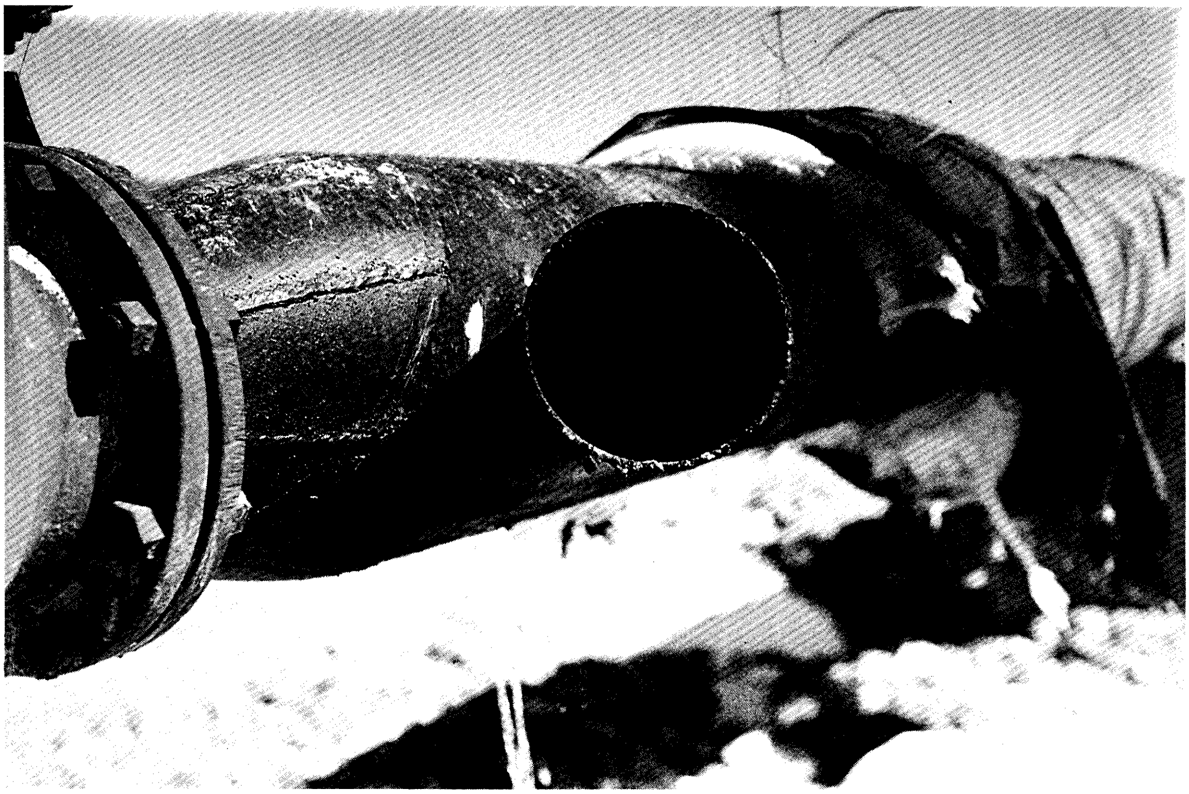

Fig. 6.15 The inlet to the main pipeline to Nagqu. At this point, some 50 m away from the well, no scaling is visible.

Fig. 6.16 A view of the geothermal field at Nagqu. The present wells and pumping station are on the left, and drilling is under way at the foot of the hill.

Fig. 6.17 A small coring rig at Nagqu geothermal field. The logging trucks are at the site.

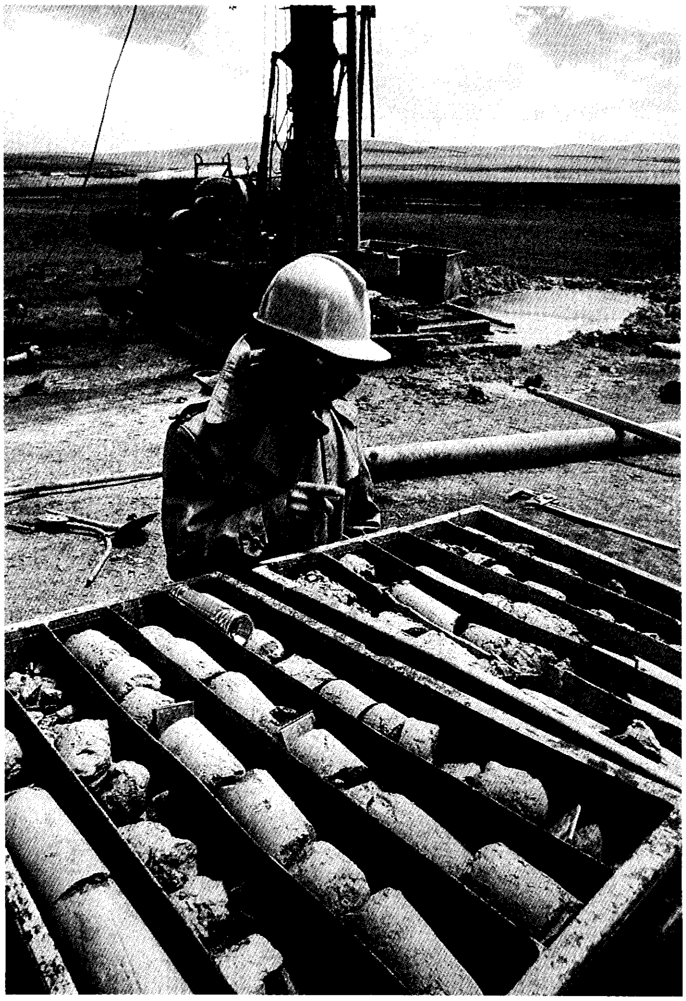

Fig. 6.18 Cores collected from an exploration well.

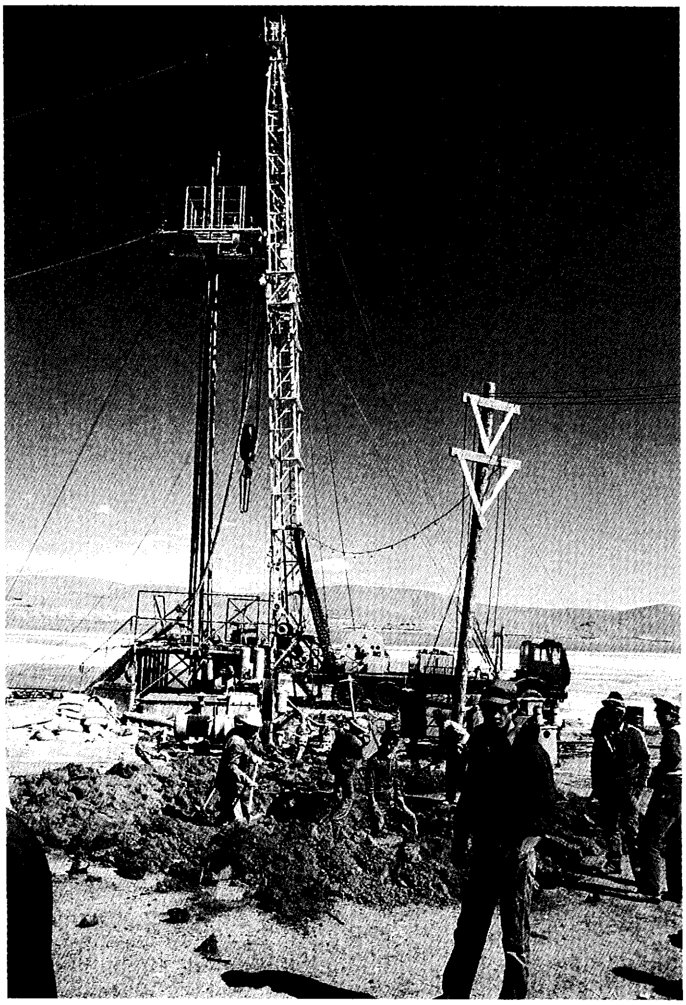

Fig. 6.19 Drilling of a 500 m deep production well at Nagqu.

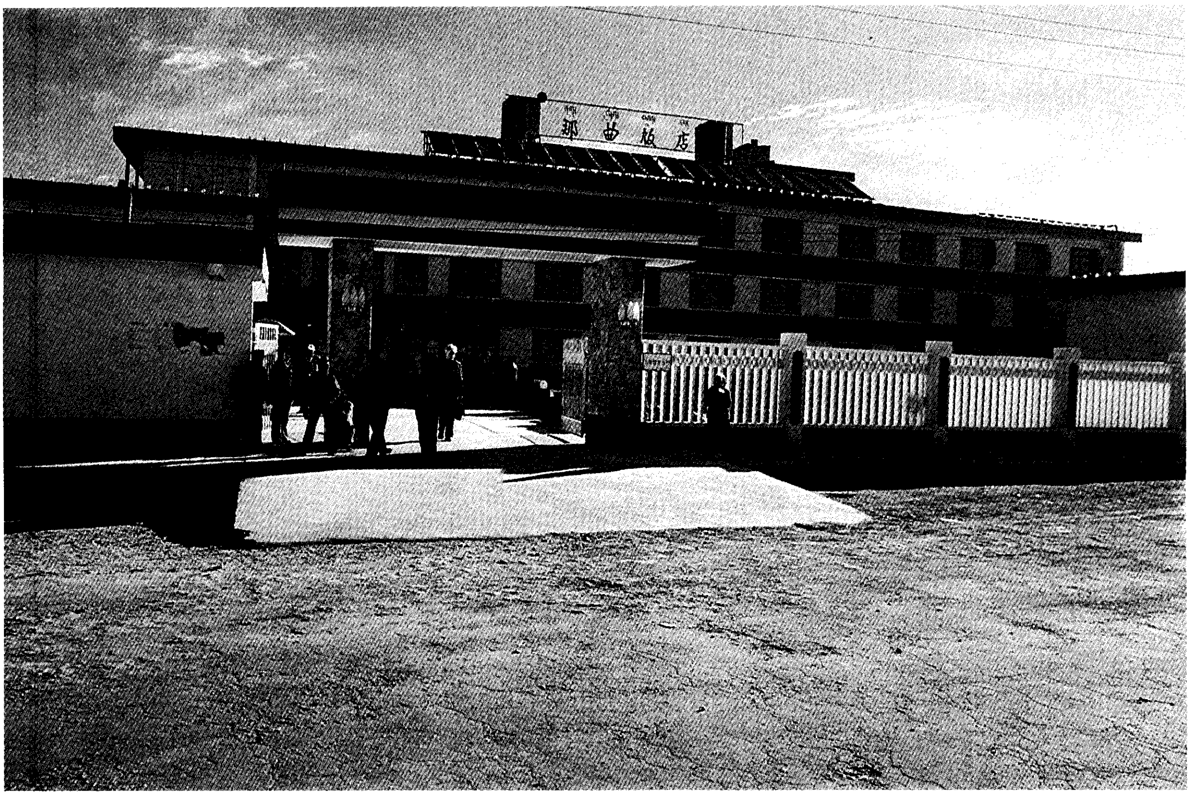

Fig. 6.20 The geothermally-heated hotel at Nagqu. Solar collectors are on the roof, and below the windows.

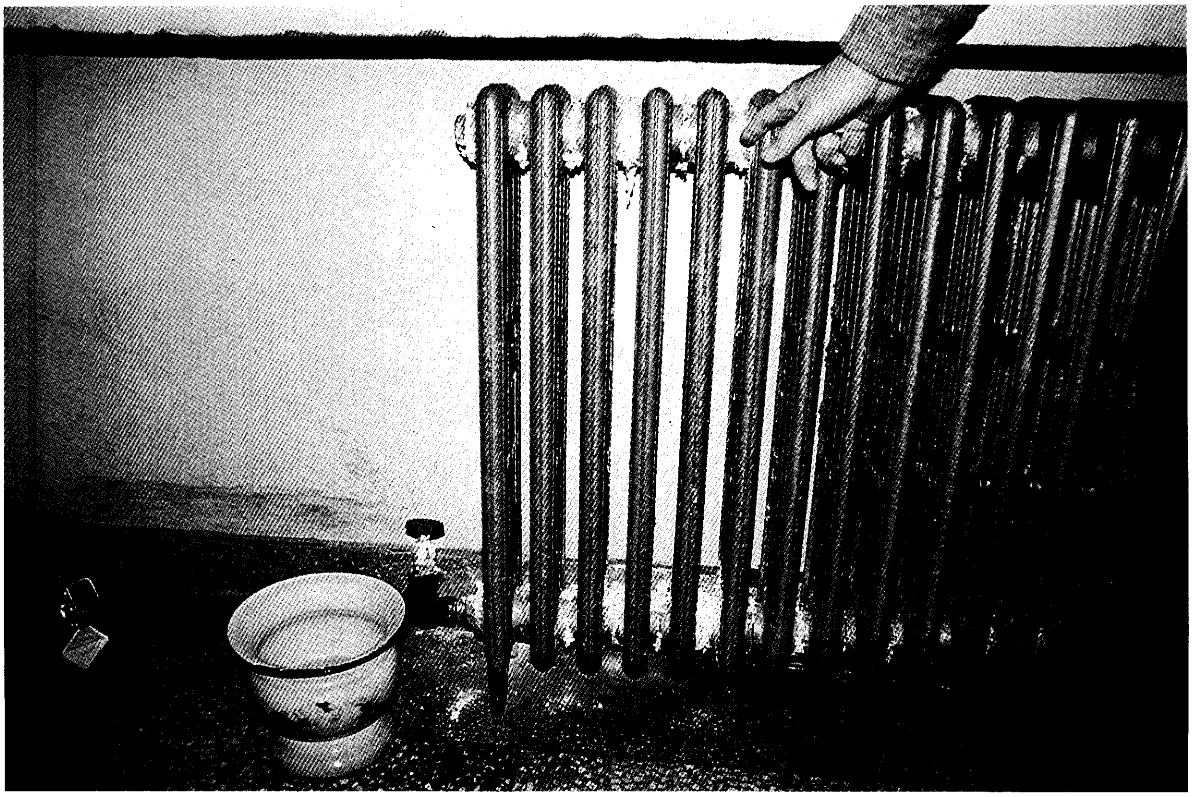

Fig. 6.21 Incrustations on a radiator at the hotel. The deposits consists of salts which are left when the water that has leaked past the threaded joints is evaporated.

Fig. 6.22 A scenic view on the road from Nagqu to Yangbajain.

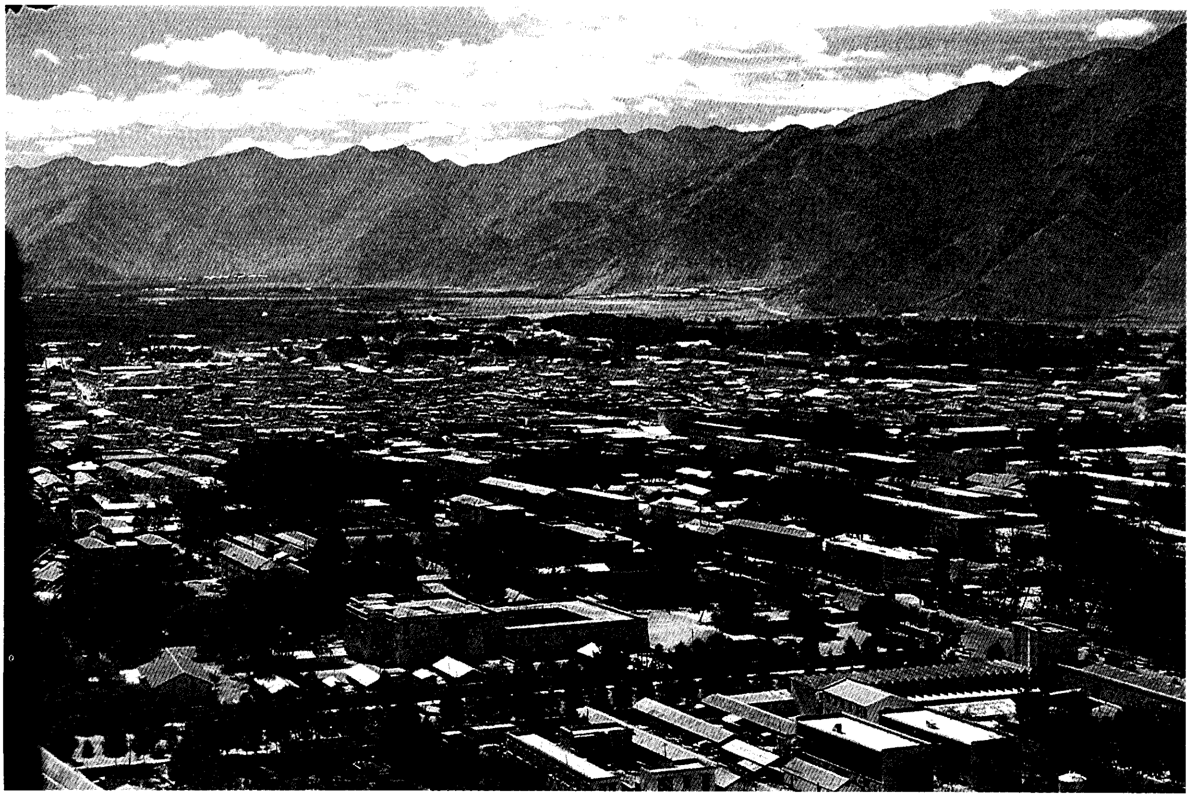

Fig. 6.23 A view from the Potala Palace overlooking Lhasa.

Fig. 6.24 The new Headquarters of the Tianjin Municipal District Heating Co.

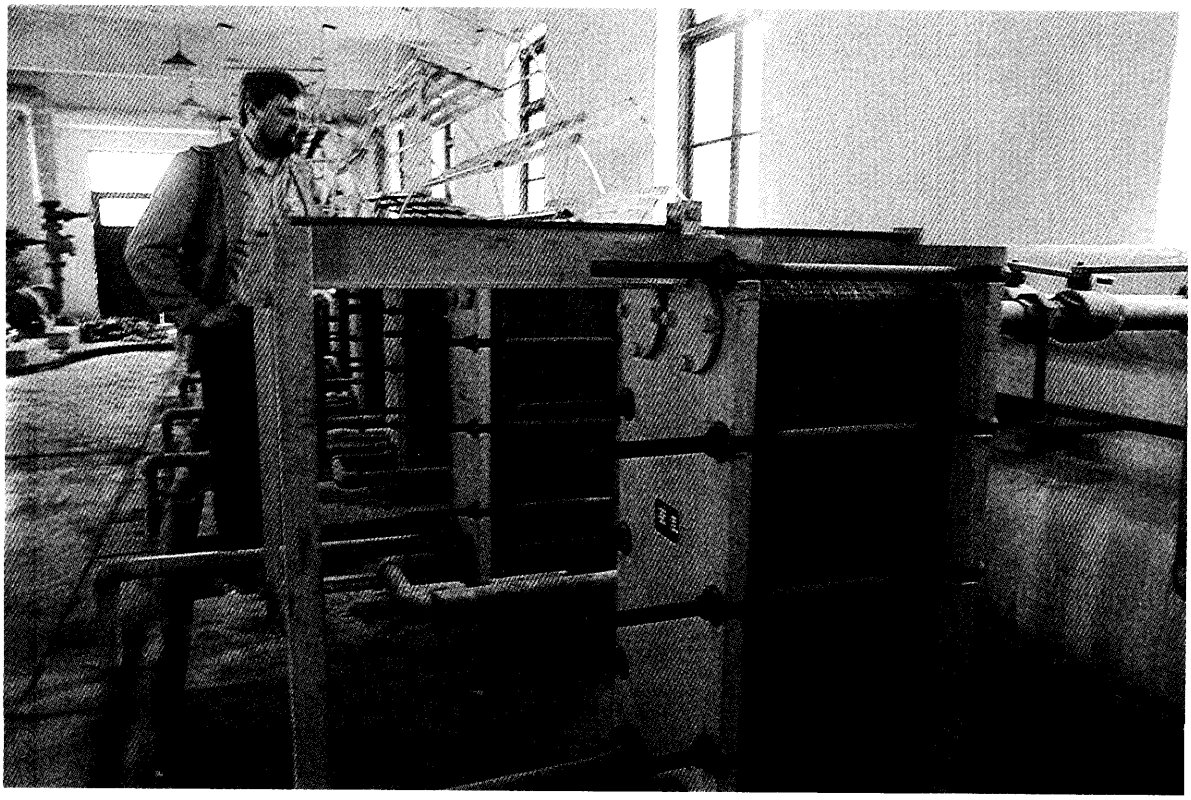

Fig. 6.25 Plate-type heat exchangers used in Tianjin.

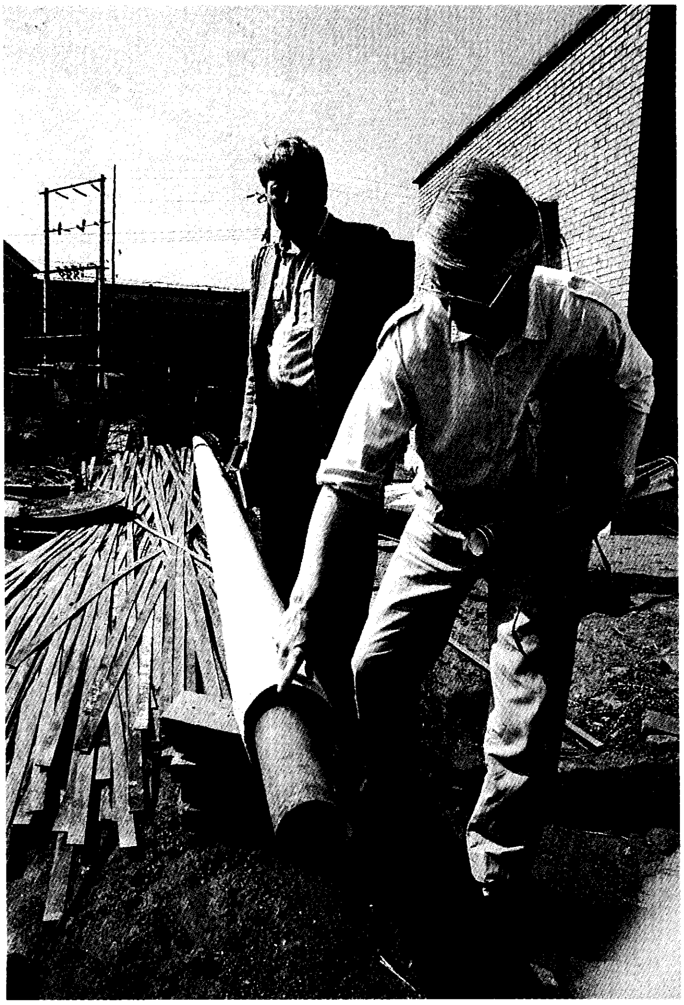

Fig. 6.26 Pre-insulated steel pipes in Tianjin.

Fig. 6.27 The delegation visiting a geothermally heated district at North of Sports College Area, Tianjin.

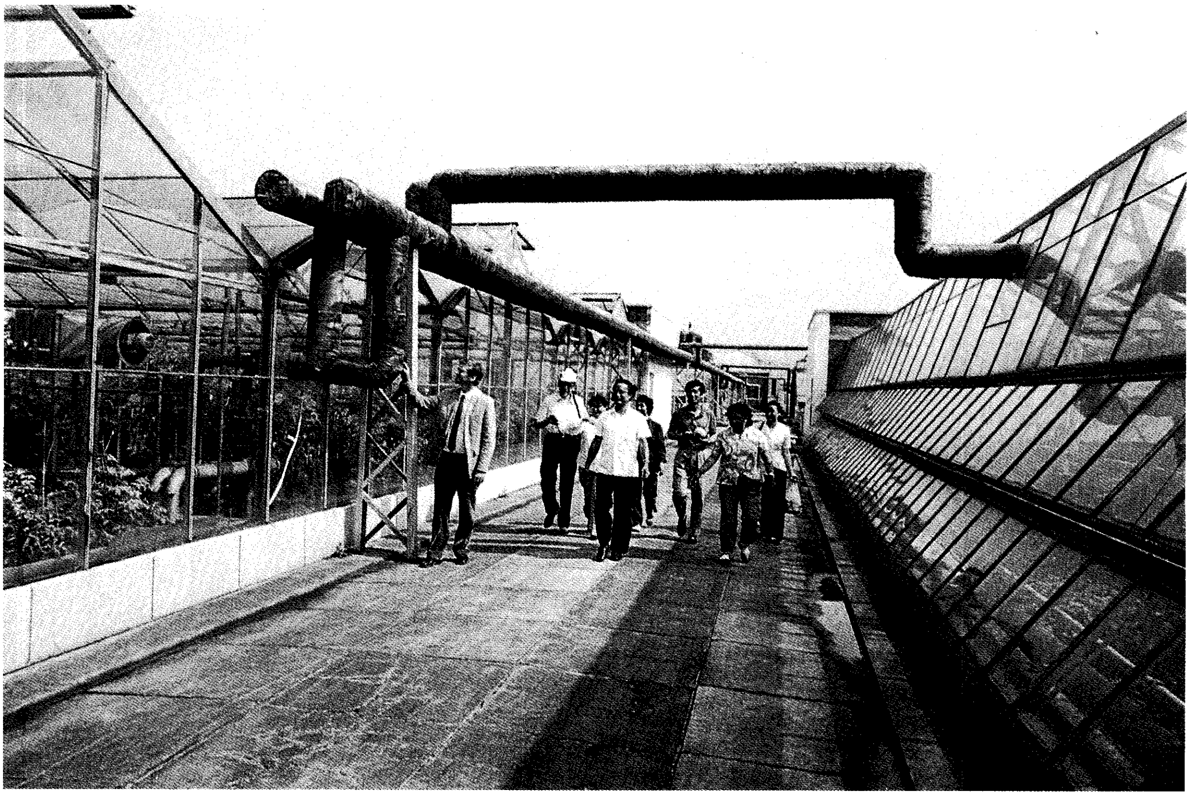

Fig. 6.28 An Agricultural Research Institute in Tianjin.

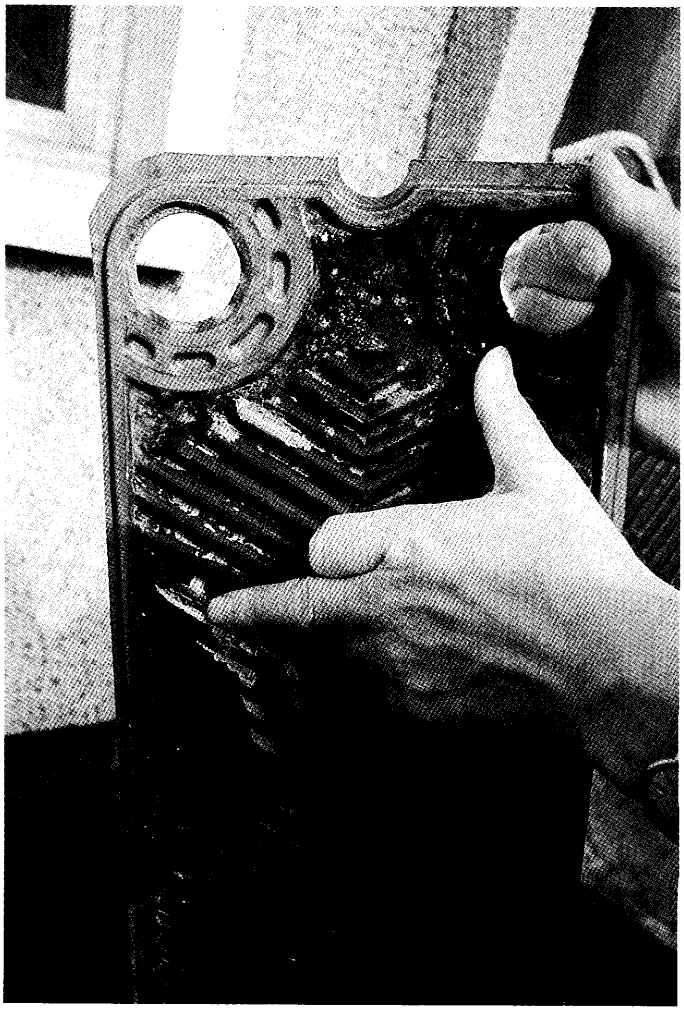

Fig. 6.29 Heat exchangers used for the greenhouses, showing holes in the stainless steel plate due to corrosion.

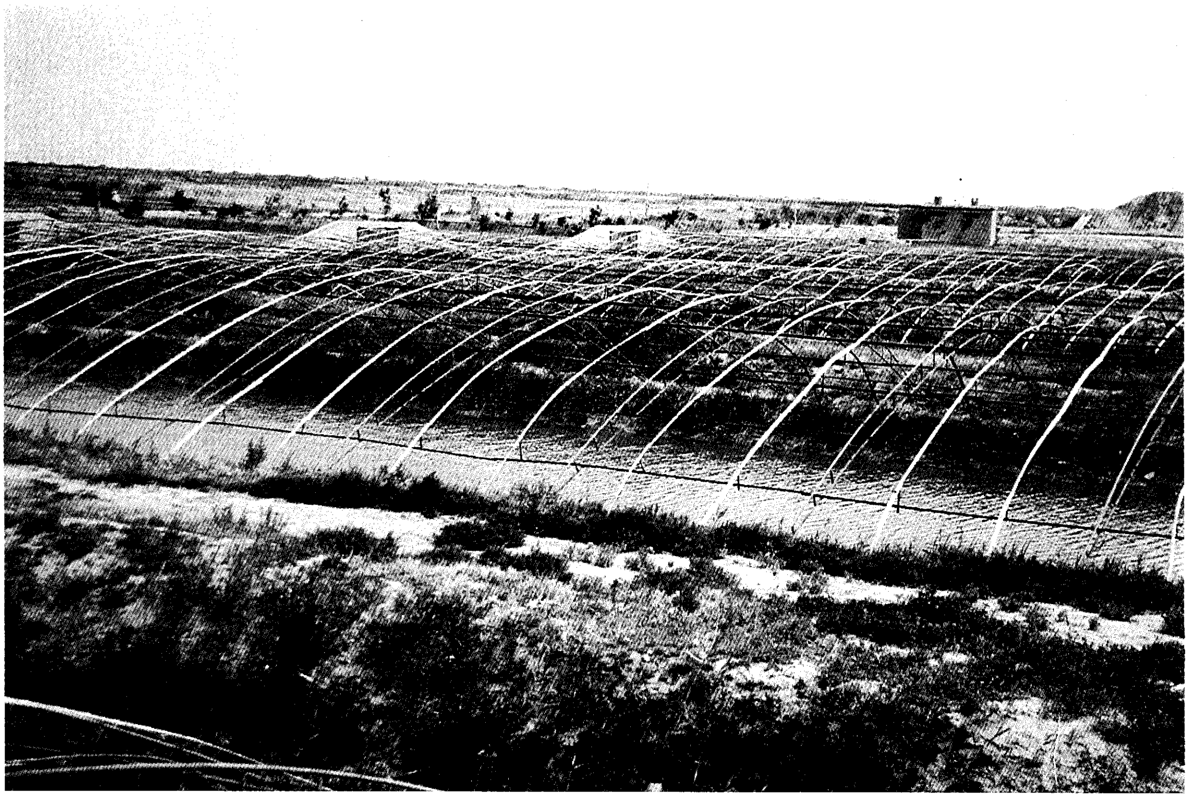

Fig. 6.30 Aquatic Research Institute (Wanchamoto) outside Tianjin, where Nile perch and shrimp are raised in ponds.

Fig. 6.31 A valve being opened at a fish pond to show how geothermal water is used during the winter.

EXHIBITS

Exhibit 1: Invitation to the National Energy Authority of Iceland (NEA).

Exhibit 2: Reply by the Minister of Industry and Energy.

(Translation)

EXHIBIT 1

Mr. Jakob Björnsson,

Director of the National
Energy Authority of Iceland,
R E Y K J A V I K

Dear Sir,

Nov. 23, 1985

The Office of the Foreign Affairs and the Bureau of Water Conservancy and Electricity of the Xizhang (Tibet) Autonomous Region of the People's Republic of China present the compliments to you.

The Xizhang (Tibet) Autonomous Region of China is rich in geothermal resources and has broad prospects in this fields. Now the Yang Ba Jin geothermal electricity power station has installed equipments with a total capacity of 10,000 kw. The other two geothermal fields are under full exploitation. And at the same time, the research work for comprehensive utilization of geothermal resources is now in progress actively.

We greatly appreciate the achievements you have gained in comprehensive utilization of geothermal fields, and we are informed that the National Energy Authority is willing to dispatch some geothermal people to make an on-the-spot investigation in Tibet.

We, the Office of Foreign Affairs and The Bureau of Water Conservancy and Electricity of the Xizhang (Tibet) Autonomous Region, are entrusted by the People's Government of the Xizhang Autonomous Region to invite five or six geothermal experts of Iceland to visit Tibet and discuss the possibility of applying your technique and equipments of comprehensive utilization of geothermal resources to Yang Ba Jin geothermal fields. The main contents of discussions are as follows:

1. The drilling technology;
2. Evaluation of geothermal resources;
3. Comprehensive utilization of electricity, space-heating, green houses ect;
4. Training of technicians;
5. Suggestions for economical and technical co-operation.

We hope that through this on-the-spot investigation, your people will put forward feasible proposals for comprehensive utilization and economical analysis of the Yang Ba Jin geothermal fields. And the two sides will also discuss the way, the scope, the schedule and the co-operation of comprehensive utilization of geothermal resources.

We suggest that your geothermal people will arrive Tibet in June, 1986 and stay for 7-10 days there. The accomodations, meals and travel costs in China will be borne by us.

We expect your reply at your earliest convenience.
We remain,

(seal)

Office of Foreign Affairs and
Bureau of Water Conservancy and
Electricity of the Xizhang
Autonomous Region of China

EXHIBIT 2

IÐNAÐARRÁÐUNEYTIÐ
MINISTRY FOR INDUSTRY
ARNARHVOLI
REYKJAVÍK - ICELAND

Embassy of the
People's republic of China
c/o Mr. Li Qinping,
Chargé d'Affaires
Víðimelur 29,

107 Reykjavík

OUR. REF. DATE

I/510.0 January 15, 1986

Re: <u>Invitation for visit of Icelandic geothermal experts to Xizhang (Tibet), China.</u>

Dear Sir,

The Ministry of Industry of the Republic of Iceland has received a letter, dated November 23, 1985, from the Office of Foreign Affairs and the Bureau of Water Conservancy and Electricity of the Xizhang Autonomous Region of the People's Republic of China, with an invitation for five or six geothermal experts from Iceland to visit Xizhang (Tibet) in June 1986. We have followed with pleasure the good co-operation that has been established between geothermal experts in Iceland and the People's Republic of China during the last decade. Twelve geothermal experts from China have received six months specialized training in Iceland and five senior members of the Chinese geothermal community have come to Iceland for shorter study visits. We consider a visit of Icelandic geothermal experts to Xizhang may serve a good purpose in strengthening further the co-operation between our two countries in the field of geothermal energy. We, therefore, accept the invitation with pleasure.

We regard 10 days as a suitable length of time for the group to stay in Xizhang, in order to secure as good results as possible from discussions of the five items mentioned in the letter of November 23, 1985. It has been decided that the leader of the Icelandic delegation will be professor Jónas Elíasson, special assistant to the Minister of Industry and Chairman of the Board of the Directors of the National Energy Authority. There will be four members of the National Energy Authority (NEA) in the delegation. Their names are as follows:

/...

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- 2 -

Mr. Jakob Bjornsson, Director General of the NEA,
Dr. Guðmundur Palmason, geophysicist and Director of the Geothermal Division of NEA,
Dr. Hjalti Franzon, Geologist and Deputy Director of the Geothermal Training Program of the United Nations University,
Mr. Sverrir Thorhallsson, Chemical Engineer and Chief of the Geothermal Engineering Section of the Geothermal Division of the NEA.

In addition there will be one specialist in the design of district heating systems, Mr. Karl Ómar Jónson, Director of Fjarhitun Consulting Engineers. A more detailed Curriculum Vitae of the six members of the delegation will be forwarded to your embassy at a later stage.

Please convey the sincere regards of the Ministry of Industry of the Republic of Iceland to the Office of Foreign Affairs and the Bureau of Water Conservancy and Electricity of the Xizhang Autonomous Region.

With respect,

(sign)

Albert Guðmundsson,
Minister of Industry and Energy

APPENDICES

Appendix 1: Letter of Intent of June 18, 1986

Appendix 2: Resolution of the Icelandic Government of July 1986 concerning the Letter of Intent.

Appendix 3: Proposed Job Description for a Special Adviser to the XAR Government on Geothermal Energy in Relation to General Energy Planning in the XAR.

Appendix 4: List of Meetings and Participants.

LETTER OF INTENT

concerning cooperation between Iceland and the Xizang Autonomous Region of the People's Republic of China in the field of geothermal exploration and comprehensive utilization.

The Iceland delegation to Tibet in June 1986 and representatives of the Government of the Autonomous Region of Xizang hereby declare the intention of their respective Governments to cooperate in the development of the geothermal resources in Tibet according to the following plan that is set forth to faciliate the transfer of Icelandic technologies and geothermal sciences, in order to support the successful completion of the 5-year plan for utilization of geothermal energy, already decided by the Government of the Autonomous Region of Xizang. Therefore, the parties agree on the following:

1. An invitation from the Government of Iceland to the Government of the Autonomous Region of Xizang to send a delegation of 7 to Reykjavík in 1987 and stay as guests of the Icelandic Government for approximately 3 weeks to study geothermal energy in Iceland.

2. An invitation to geothermal scientists and scholars to come to Reykjavík and stay as visiting scholars at the National Energy Authority to do independent studies of sciences and technologies invested in the NEA. Their costs of living in Reykjavík shall be on a cost-share basis for 2 scholars in 19987 and 2 in 1988. The Government of Iceland will provide office facilities and services as well as computer service free of charge.

3. An invitation to geothermal specialists to study at the United Nations Geothermal Training Program at NEA in Reykjavík. For this purpose China and Iceland will on a cost-sharing basis provide two grants for fellowships in each of the years 1987, 1988 and 1989, 6 fellowships altogether on the same terms as the UNU fellowships are, but independent of these.

   The United Nations University Geothermal Training Program in Iceland looks favourably on offering UNU-grants for training scientists and engineersof Tibet in geothermal work. These grants include tuition fees and per diem while in Iceland, but travel cost to and from Iceland would be paid by the trainee or his country.

4. The Icelandic delegation visisted Yangbajain geothermal field on June 10 and NAQU geothermal field on June 12 and 13.

   During these visits the Icelandic geothermal specialists discussed together with their Chinese colleagues the following items:
   * Scaling and scaling control.
   * Reservoir engineering aspects, including deep well pump operations.

* Greenhouse construction and operation with geothermal heating.
* Utilization of geothermal water and geothermal electric plant waste water for district heating systems.

The Parties have agreed upon the following cooperation projects in the future:

A. Prefeasibility study of a comprehensive utilitization of the NAQU geothermal field.

Document A1 contains a summary of the project.
Document A2 contains the technical scope of the work, and document A3 a scaling control investigation and training program to be performed prior to the prefeasibility study in order to ensure that effective scaling control is possible.

The Government of XAR, will contractually agree with ORKINT of Iceland that the said company shall undertake and perform the scaling control and investigation programme document A3 for the price of

30,000 U.S.$

exclusive of airfaires and expenses within China, but inclusive of sampling equipment left in Tibet, worth 20,000 U.S.$

Providing a positive result of the scaling investigation, the Government of XAR shall, after the investigation, receive from Iceland a detailed proposal for:

* How to perform the prefeasibility study.
* Chinese part of work and the Icelandic part of work.
* Funding of the projects.

Meanwhile, the Bureau of Water Resources and Electricity (BWRE) and NEA will stay in contact and BWRE will send to Iceland the technical data mentioned in document A2.

B. Prefeasibility study of the utilization of geothermal water for space heating and greenhouses at Yangbajing.

Document B1 contains summary of the project. Document B2 contains the technical scope of the work, and document B3 contains specifications for a proposal of a deep well pump for Yangbajin geothermal field.

The Government of XAR will receive from Iceland a detailed proposal for:

* How to perform the prefeasibility study.
* Chinese part of work and Icelandic part of work.
* Funding of the projects.

Meanwhile BWRE and NEA will stay in contact and BWRE will send to Iceland the technical data mentioned in document B2.

C. Both sides consider that a reservoir engineering study of the geothermal field of Yangbajin is very important. The Icelandic delegation has proposed a reservoir engineering study of NAQU and Yangbajin C1. Now the BWRE is studying the Yangbajin reservoir. When these studies are completed BWRE will consider the Icelandic proposal.

5. Indentification of geothermal reservoirs for space heating of Tibetian towns.

The National Energy Authority of Iceland will assist the Government of the Autonomous Region of Xizang to file an application with the UNDP for economic assistance to identify those geothermal reservoirs in Tibet that can economically be developed to provide energy for district heating systems to nearby towns. NEA shall work out the application in cooperation with the Geological and Mineralogical Bureau in Tibet.

In agreement to this letter of intent we sign with our names

June 18th 1986

For Icelandic Delegation

Jónas Elíasson (sgd)
Jónas Elíasson
Chairman of NEA

Jakob Björnsson (sdg)
Jakob Björnsson
Director General of NEA

Liu Dian-Gong (sgd)
Liu Dian-Gong
Director General of BWRE

Fan Yuan Xian (sgd)
Fan Yuan Xian
Chief Engineer of BWRE

Gu Qingge (sgd)
Engineer and Chief of the Geological and Mineral Section of the BGM.

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Document A[1]
NAQU PROJECT
Liol/Fan/JE/JB
June 15, 1986

Iceland/XAR Letter of Intent

ORKINT of Iceland will undertake a prefeasibility study of a

Comprehensive Utilization of the Energy of Naqu Geothermal Field.

The project includes the following items:

1. A district heating supply system for 180,000 m^2 heated area in buildings in Naqu.

2. A two-temperature heating system; a ventilation system and an irrigation system for 500 m^2 of greenhouses.

3. A woolwashing plant with a capacity of 1000 tons of wool each year.

4. A hides-processing plant capable of processing 50,000 hides each year, of which 80% will be yak hides to be fully processed into shoe leather, and 20% sheepskins to be fully processed into cloathing leather.

Iceland/XAR Letter of Intent

Document A2
Naqu Project
Liao/Fan/JE/JB/KOJ

GENERAL SPECIFICATIONS FOR A PREFEASIBILITY STUDY OF A COMPREHENSIVE UTILIZATION OF THE ENERGY OF THE NAQU GEOTHERMAL FIELD.

1. District Heating System.

1.1 The district heating system is intended to serve the following:

The hospital, the hotel, schools, offices, commercial buildings, cinema and theater, a swimmingpool and a sports centre.

Living houses built according to a rehousing programme will be connected to the system, but not the existing stock of living houses.

1.2 The designed indoor temperature shall be 18 degrees Centigrade.

1.3 Street mains shall be laid in concrete ducts and insulated with glass fiber.

1.4. The return water from the district heating system shall be returned to the geothermal field.

1.5 The wall construction of the houses mentioned above is either (A) concrete blocks, solid or with air spaces, or (B) solid clay blocks.

1.6 The existing pipeline from the geothermal field to the town of Naqu has a diameter of 325 mm, and is insulated with a 60 mm thick blanket of glass fibre.

2. GREENHOUSES.

2.1 The greenhouses shall be designed for the growing of vegetables like tomatoes, cabbage, cucumber etc.

2.2 The design of the greenhouse construction, and the automatic systems for heating, ventilation and irrigation shall be in accordance with best Icelandic practice, with due regard to Naqu weather conditions.

3. Woolwashing plant.

The woolwashing plant shall comprise the following functions:

* Receiving and sorting.
* Continuous washing and rinsing.
* Drying.
* Bailing.

4. Hides processing plant.

No specifications are needed.

DATA TO BE SUPPLIED BY BWRE.

1. District heating system.

1.1 Location and size (in m^2 or m^3) of buildings to be heated. The location shall be shown on a map to scale 1:2000 and the building sizes shall be listed in a table, with the buildings enumerated, with their numbers shown on the map.

1.2 Meterological data, including daily means of temperature for the length of available records.

1.3 Chemical analysis of water.

1.4 Corrosion rate and scaling rate, as measured in coupons.

1.5 Standards for steel pipes and other materials available in China.

1.6 A detailed list of materials for the district heating system that are available in China, together with a correspondingly detailed list of unit prices of materials, including transport to Naqu.

1.7 Labour costs applicable to Naqu conditions, inclusive of fringe benefits, subsistence costs, transport costs etc., as appropriate.

1.8 A topographic map of Naqu area, to a scale of 1:10,000 with 2,5 m contours.

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2. Greenhouses.

2.1 Location of greenhouses, shown on a map to scale 1:10,000

3. Woolwashing plant.

3.1 Location of woolwashing plant, shown on a map to scale 1:10,000.

4. Hides-processing plant.

4.1 Location of hides processing plant, shown on a map to scale 1: 10,000

IÐNAÐARRÁÐUNEYTIÐ

Iceland/XAR Letter of Intent

DOCUMENT A3
June 18, 1986

ANALYSIS OF THE SCALING PROBLEM AT NAQU.

ORKINT of Iceland will send a specialist to Naqu and provide critical equipment to evaluate the scaling potential at Naqu. An important part of the project is the transfer of equipment and field procedures required for proper sampling and field chemical analysis.

1. A chemical and a wellbore simulator model will be made. This requires chemical analysis and well measurements. To insure proper sampling new sampling equipment will be brought in, and a specialist sent with the equipment to Naqu to instruct a BWRE counterpart in the data collection.

2. Equipment for sampling of water and steam under pressure will be provided. A detailed list of analytical apparatus required for field determination of selected elements will also be provided. If BWRE can not provide the items on the list ORKINT will provide these items upon request from BWRE at cost.

3. A report on the findings will be made.

4. For the above services BWER will pay;
   30,000 U.S. $
   The payment is with an irrevocable letter of credit in Landsbanki Íslands in Reykjavík, through Bank of China London Branch, made out in the name of ORKINT Ltd. Reykjavík.

IÐNAÐARRÁÐUNEYTIÐ

Iceland/XAR Letter of Intent

Document B1
June 18, 1986

PROJECT YANBAJIN.

ORKINT of Iceland will undertake a feasibility study of the following project:

Utilization of geothermal water for space heating and greenhouses at Yangvajin

The project includes the following items:

1. A prefeasibility study for a geothermal district heating system for two communities to be supplied bg waste water from unit 5.
   Houses with a total floor area of 20,000 m will be heated, where of Yangbajn town with 5,000 m and living area of power plant village 12,000 m

2. A redesign of the heating system of the existing green houses at Yangbajin, and design systems for ventilation and irrigation for the same green houses.

IÐNAÐARRÁÐUNEYTIÐ

Iceland/Xar Letter of Intent

Document B2,
June 18, 1986

SPECIFICATIONS RELATING TO PROJECT SPACE HEATING AND GREEN-HOUSES AT YANGBAJIN.

1. Spaceheating
   1.1 Water temperature from unit 5 will be 80°C and the water is considered non-scaling. The distance to the living area of power plant village is 5 km and additional 4 km to the Yangbajin town.

   1.2 The spent water with a temperature of approximately 40°C will be piped 3-4 km to the border of the geothermal field and reinjected to the geothermal field.

   1.3 Water meters are to be placed at each branch.

   1.4 Design proposal of a heating system for a typical house will be made.

   1.5 Tap water use shall be used in each kitchen and for taking bath in the hotel.

   1.6 A bath house and a swimmingpool will be added at a later date. That will use the return water (40°C).

   1.7 The transmission pipeline will be above ground, insulated with glass fiber. The distribution pipes will be pre-insulated and cased in a plastic jacket.

   1.8 Indoor designed temerature is 20°C.

2. A redesign of the heating system of the existing green-houses at Yangbajin and designed systems for ventilation and irrigation for the same greenhouses.

3. Information to be supplied by BWRE:

   3.1 Topographic map covering the towns and pipe route from unit 5.

   3.2 Map showing location of houses and floor area of each.

   3.3 Climate data.

   3.4 Architectural drawing of a typical living house.

   3.5 Chemical composition of geothermal effluent water from unit 5.

3.6 Corrosion date for carbon steel and scaling rate for effluent water measured on cupons.
3.7 Drawings of existing greenhouses at Yangbajin, showing their present heating systems.

IÐNAÐARRÁÐUNEYTIÐ

Iceland/XAR Letter of Intent

Document B3,
June 19, 1986

ORKINT of Iceland will forward to the Bureau of Water Resources and Electricity, a proposal for the sale of Icelandic geothermal deep well pump with following specifications:

* Casing diameter 95/8 inches.
* Output at wellhead above saturation pressure.
* The pump shall withstand a 70°C working temperature of the pumping skeid.

IÐNAÐARRÁÐUNEYTIÐ

Iceland/XAR Letter of Intent

Document C1
June 19, 1986

After discussions with geothermal experts from the Bureau of Geology and the Bureau of Water Resources and Electricity, and after having visited the Yangbajin and Naqu geothermal fields, the Icelandic delegation is of the opinion that a greatly increased effort should be made to improve reservoir engineering studies at both Yangbajin and Naqu geothermal fields. More specifically, this effort should be aimed at:

1. Field monitoring, which includes long-term collection of data on borehole characteristics such as production characteristics of the holes.

2. Mathematical modelling of the geothermal field, based on data collected under 1 above. The purpose of the modelling is to predict the long-term behaviour of the field under production, and to optimize its energy output.

The Icelandic delegation wishes to propose as a first step towards achieving the goals described above to send an Icelandic expert in reservoir engineering to Tibet to train local experts and to give advice on procedures to be followed. The ultimate objective is to build up the necessary local know-how, instrumentation and computer facilities, so that these studies can in the future be undertaken by local geothermal experts. The duration of the first visit would be about 1-2 months.

意向书

关于中华人民共和国西藏自治区和冰岛共和国在地热开发和综合利用方面的合作。

一九八六年六月冰岛赴西藏代表团和西藏自治区政府代表在此表明各自政府根据下述计划在开发地热资源方面进行合作的意向，即促进冰岛地热科学和技术的转让，以支持西藏自治区政府已经决定的五

年地热能利用计划的顺利完成。因此，双方就如下各项达成协议：

1. 冰岛政府发出邀请书，请西藏自治区政府派遣一行七人代表团于一九八七年赴雷克雅未克作为冰岛政府的客人在冰岛作为期约三周的地热能利用的考察。

2. 邀请中国西藏地热科学工作者和学者作为访问学者去雷克雅未克在冰岛国家能源局(NEA)独立进行

该局投资的科学和技术研究工作。

双方共同负担一九八七年和一九八八年度各两名这样的学者在雷克雅未克的生活费用，冰岛政府将免费提供办公室设备和服务以及计算机服务。

3. 邀请地热专家去雷克雅未克在NEA的联合国大学地热培训项目学习。为此目的，中国和冰岛将共同提供一九八七、一九八八和一九

第 4 页

八九年度各两名受训者的助学金。一共六名受训者与联合国大学(UNU)受训者学期相同，但不属此列之类。

在冰岛的联合国大学培训项目非常愿意用UNU助学金为西藏培训从事地热工作的科学工作者和工程师。这些助学金包括在冰岛期间的学费和每日的花费，但去冰岛的往返旅行费应由受训者或其国家支出。

4. 冰岛代表团于六月十日和六

第 5 页

月十二日、十三日分别参观了羊八井地热田和那曲地热田。

在参观过程中，冰岛地热专家和他们的中国同事们一起讨论了下列各项：

* 结垢和结垢控制；
* 热储工程方面，包括深井泵运行；
* 地热供热的温室结构和运行；
* 利用地热水和地热电厂发电后

的弃水进行区域供热。

双方同意在将来进行如下合作项目：

A. 那曲地区综合利用的预可行性研究

附件A1：包括项目概况；

附件A2：包括工作的技术范围；

附件A3：在预可行性研究之前进行结垢控制调查研究和培训，以保证有效的结垢控制是可靠的。西藏

刘

杨辉 JB

第 7 页

自治区政府将契约性地同意冰岛的ORKINT接受和执行附件A3中的结垢控制调查研究项目，并付款30000美元。此款不包括在中国境内的费用和机票，但包括留在西藏的价值为20000美元的取样设备和仪器。

提供一个结垢调查研究的明确结果，在调查研究之后，西藏自治区政府将收到冰岛一个详细的大纲，其内容为：

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横 J.S. JB

第 8 页

* 如何执行预可行性研究；

* 中方的工作和冰方的工作；

* 项目资金

同时，水利电力厅(BWRE)和NEA将保持接触，並将附件A_2所提及的技术资料寄往冰岛。

B. 关于利用地热水于空间供热和温室的预可行性研究。

附件B_1：包括项目概要；

附件B_2：包括工作的技术范围；

15×10=150

刘

樊 J.S. JB

第 9 页

附件B_3：包括建议在羊八井地热田应用深井泵的技术规范。

西藏自治区政府将收到冰岛一详细工作大纲，内容为：

* 如何进行预可行性研究；
* 中方工作和冰方工作；
* 项目资金。

西藏水利电力厅和NEA将保持联系和西藏水利电力厅将在附件B_2中所提及的技术资料寄往冰岛。

第 10 页

c. 双方都认为羊八井热田的热储工程研究是非常重要的。在附件C1中冰岛代表团已提出那曲和羊八井的热储工程研究。现在水利电力厅正在研究羊八井热储，当这些研究完成后，水利电力厅将考虑冰岛的提议。

5. 为寻找地热资源用于西藏城镇空间供热：冰岛国家能源局将协助西藏自治区政府向联合国开发计

15×10=150

刘

樊 J.E. JB

划署提出申请书以获得经济资助，在西藏寻找地热资源并进行经济开发，以向附近的城镇进行区域供暖。NEA将和西藏人民政府合作共同进行该项工作。

因同意此意向书，我们在此签下我们的名字。

1986年6月18日.

代 表 签 名

刘

樊 J. E. JB

第 12 页

中华人民共和国 西藏自治区人民政府 代表	冰岛共和国 代表
西藏水利电力厅厅长	NEA主席
刘殿功	Jónas Elíasson
西藏水利电力厅 总工程师	NEA局长
樊之邦	Jakob Björnsson
西藏地质矿产局 地矿处处长 [signature]	

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第 1 页

西藏自治区／冰島　　　附件 A 1

那曲項目

廖／樊／JE／JB

一九八六年六月十五日

关於冰島 ORKINT 将承担综合利用那曲地热水預可行性研究项目包括如下条款

1．那曲地区一供热面积为 180,000 米^{2}的区域供暖系统。

2．一双温供热系统用于 5000 平方

1 5 × 1 0 = 1 5 0

刘 樊 JE．JB

第 2 页

求溫室的空调系统。

3．年生产能力为1000吨的洗毛工厂。

4．年处理能力为50,000張皮革的皮革加工厂，其中80%为牦牛皮用於制鞋；20%为羊皮，用於制作服装。

15×10=150

刘 斌 十三JB

ORKINT

ORKUSTOFNUN INTERNATIONAL LTD

GRENSÁSVEGUR 9 MAIL
108 REYKJAVÍK
ICELAND
(354-1) 83600 PHONE
ORKUSTOFNUN CABLES
(0501) 2339 ORKUST IS TELEX

第 1 页

西藏自治区/冰岛

意向书

1986年6月19日 附件 A2

罗/樊/JE/JB/KOJ

综合利用那曲地热流体的能量的预可行研究的一般技术规范

1 区域供热系统

1.1 区域供热系统服务于下列各项：那曲医院、那曲饭店、学校、

15×10=150

刘 樊 J.S. JB

办公室、商业建筑、电影院和剧院，一座游泳池和一座运动中心。

根据房屋改造计划修造的居民住宅将与系统连接，但不包括现存的居民住宅区。

1.2. 设计室内温度为18°C。

1.3. 街道主管线设置在水泥槽中，使用玻璃纤维保温。

1.4 区域供热系统的回水将返回地热田。

15×10=150

刘樊 Liu Fan [signature]

3

1.5 上面所提及的房屋墙结构 A) 水泥予制实心砖或空心砖，B) 粘土砖。

1.6 现有从地热田到那曲镇的管道直径为325mm，用60mm厚的玻璃纤维保温。

2 温室

2.1 温室设计适应于生长西红柿、洋白菜、黄瓜等蔬菜。

2.2 根据最好的冰岛实践同时考

虑那曲的气候条件设计温室的结构和供热、通风及调节自动化系统。

3 洗毛厂

洗毛厂将包括如下功能：

· 进料和分类

· 连续洗涤和漂洗

· 干燥

4 皮加工厂

无需技术规范。

15×10=150

刘 樊 J.E.JB

第 5 页

水电厂提供的资料：

1 区域供热系统

1.1 供热建筑物的位置和尺寸（m^2 或 m^3）。建筑物将标在比例尺为 1:2000 的地图上并编号，建筑物的大小对应于编号列于一张表中。

1.2 气象资料。包括长期气象观测累记的日平均温度。

1.3 水的化学分析。

1.4 用试验测定的腐蚀率和结垢

15×10=150

刘樵 4.5.88

第 6 页

速率。

1.5 钢管和在中国通用的其它材料标准。

1.6 在中国通用的用于区域供热系统的材料的详细清册。同时附上相应的详细的当地价格表。

1.7 适合于那曲情况的合适人力费用。包括小额优惠、津贴费、运输费等。

2 温室

刘樊 J. E. JB

第 7 页

2.1 在1:10,000比例尺地图上标出温室位置。

3 洗羊厂

3.1 在1:10,000比例尺地图上标出洗毛厂的位置。

4 皮加工厂

4.1 在1:10,000比例尺地图上标出皮革厂位置。

刘慧 十五 JB

西藏自治区／冰岛

意向书

1986年6月18日　　　　　　附件　A3

那曲热田结垢问题的分析

冰岛ORKINT公司将派遣一名专家来那曲和根据那曲热田结垢情况提供所需要的关键设备并作出结垢评价。此工程一个重要的部分是辨认和正确的取样，并对化验结果作出现场分析解释。

刘　樊　J.E. JB

第 2 页

1. 制作了水化学和井下模拟装置。此需要化学分析和测井。为保证正确的取样，将购进新的取样设备，同时派遣一名专家携带设备前往那曲，并在资料收集过程中培养一名同专业人员。

2. 提供在压力下取水样和汽样的设备，并提供野外鉴定对选择的元素所需要的详细分析装置清册。如果水电厅不能提供清册中的各项，

15×16 150

刘樹 [illegible] JB

ORKINT公司将根据水电厅的要求应传送些图。

3 编写调查结果报告。

4 水电厅将支付上述服务费30,000美元。此款通过中国银行汇款支付给雷克雅未克的Landsbank Islands。开户名为ORKINT Ltd. Reykjavik。

158107150

刘楚 J.E. JB

第 1 页

西北利治巴/冰岛

意向书 1986. 6. 18

羊巴井项目 附件 B1

冰岛ORKINT将进行下列可行性

研究

项目名称：

利用地下热水进行房屋供暖和

温室培育。

該项目包括以下各条款

1. 进行应用5号机组发电后放弃

15×20=150

刘 想 I.E JB

第 2

术及两个居民住宅区供暖的可行性研究。需供暖的房屋总面积为20000平方米，其中平巴井镇为8000平方米，平巴井电站生活区为12000平方米。

2、对现有平八井供暖系统重新设计，并且对原有的温室通风和降温系统进行设计。

1 5 5 1 0 7 1 5 0

刘楷 6.5. JB

西班牙自治区/冰岛

意向书

1986年6月18日　　附件 B2

在羊八井地区地热供暖

和温室的说明

1 室内供暖

1.1 由第5发电机组排出的发电弃水为80℃，水中是无垢的，从羊八井发电厂居民区至发电厂距离为5公里，离镇距羊八井镇4公里。

1.2 居民区供暖后的水温为40°C，这种废水再通过管线输至地热田的边界并再回到地热田中。

1.3 在每一个网线上都要有测试装置。

1.4 对于房屋供暖系统要进行典型的房屋供暖需求设计。

1.5 热水不仅用于房屋供暖还用于厨房和洗浴。

1.6 随后将进行浴室和游泳池的

第 3 页

设计，说两地采用40°C供热用的热水。

1.7 输水管线沿地表铺设，用玻璃纤维包装保温，分布管线要事先安装好，然后将其放入保温系统中。

1.8 室内温度设计为20°C。

2. 对华八井现有的温室进行设计，并对同一温室进行空调和灌溉的设计。

3. 水电厅需要提供如下资料：

15×16=240

3.1 第五发电机组附近的布线和附近地形图。

3.2 图件附有破房位置和两个房间的平面图。

3.3 气象资料。

3.4 房屋的典型单元设计图。

3.5 5号机组排出的化学成分。

3.6 用锈蚀挂片对碳钢的腐蚀和结垢速率进行测试。

3.7 划出第八号温室的现状图，并标出现有供热系统。

第 1 页

西藏自治区/冰岛

意向书

1986年6月19日　　　　附件　B3

冰岛ORKINT公司向西藏自治区水利电力厅转交冰岛的地热深井泵，该泵具有如下的规格：

1. 泵径为9 5/8英吋；
2. 最大抽水量200吨/时；
3. 压力高于饱和压力；
4. 泵可在170℃高温下正常运行。

15810150

刘樊　J.E.　JB

第 1 页

西藏自治区／冰島

意向書

附件 C1

在与地矿局和水利电力厅的地热专家討论及考察羊八井，那曲地热田之后，冰島代表团意見是应在羊八井和那曲兩地热田的热储工程研究作出大量的努力。进一步地说此努力品在于：

1 热田监测，包括长期收集热

15×10=150

刘楷

井特征资料例如温度、压力、地热流体力学以及热井的生产特性。

2. 根据上述第1项所收集的资料对热田进行数学模拟。此模拟的目的在于预测在生产条件下热田的长期行为和优化其能源输出量。

冰岛代表团希望派一名冰岛在热储工程方面的专家到西藏训练当地专家以及在随后的资料处理方面进行指导并以此作为达到上述目的

刘 楚

L.E. JB

第一步。最终目标在于增加当地科学家的技术、仪器和计算机设备，以便当地地热专家能进行这些研究。第一次来访持续时间约为1-2个月。

15×10=150

刘 琪

J.E. JB

IÐNAÐARRÁÐUNEYTIÐ

Appendix 2

People's Government of
Tibet Autonomous Region
Lasha
People's Republic of China

I/510.0 July 8, 1986

On November 30, 1985, we received an invitation from the Government of the Autonomous Region of Xizang to visit China and make on-the-spot studies of the geothermal resources of this region of the People's Republic of China. This offer we accepted in our letter to the Chargé d'affaires His Excellency Mr. Li Qinping, dated January 15, 1986.

Our delegation of geothermal experts stayed in China June 5.-26. We want to convey to all Chinese authorities concerned our warmest thanks for the splendid reception and great hospitality that our delegation received everywhere.

The Letter of Intent, negotiated between our experts and the experts of the Bureau of Water Resources and Electricity in Lasha is enclosed herewith in its Chinese version.

By this letter we want to inform you that the Government of Iceland has in its meeting on July 3 confirmed this document. We are looking forward to receiving a similar confirmation from the Government of the People's Republic of China at the earliest convenience.

Awaiting your distinguished reply, we remain,

Yours respectfully,

Albert Guðmundsson
Minister of Industry and Energy

INNFÆRT 9 JUL 1986

Copy:

Mr. Liu Dian-Gong, Director
Bureau of Water Resources and Electricity

Mr. Fan Yuan-Xiang, Chief Engineer,
Bureau of Water Resources and Electricity

Mr. Gu Qinge, Chief Engineer,
Bureau of Geology and Mineral Resources

Appendix 3: Proposed Job Description for a Special Adviser to the XAR Government on Geothermal Energy in Relation to General Energy Planning in the XAR

The Adviser shall provide the Government of the Xizang (Tibet) Autonomous Region of the People`s Republic of China with expert advice, based on the most advanced state of the art in geothermal research and exploration, as to the necessary and appropriate steps and measures to be followed in the inclusion of geothermal energy developments into overall, countrywide energy planning. More specifically, in his work the Special Adviser shall inter alia address the following questions:

- Field monitoring of the Yangbajain geothermal field, including long-term collection of borehole data from existing boreholes.

- Mathematical modelling of the Yangbajain geothermal field on the basis of the collected data, in order to predict the long-term response of the reservoir to various levels of development.

- Definition and timing of suitable stages of further development at Yangbajain on the basis of the model studies.

- Study of available data on geothermal occurrences in Tibet other than Yangbajain and Nagqu, that are located within a reasonable distance from centres of population, and identification of those sites that, on the basis of this study, appear most suitable for development.

- Drawing up of a research and exploration programme for these sites.

- Establishment of a least-cost analysis methodology for energy planning in those regions of Tibet, especially the Lhasa and Nagqu regions, where geothermal may play an important role, as an energy planning tool that will allow geothermal to be inserted in the overall energy development in the most economical way, consistent with the results of the model studies.

The Special Adviser shall carry out his duties in close cooperation with the Tibetan Bureau of Geology and Mineral Resources as far as the subsurface aspects of his work are concerned, and with the Bureau of Water Resources and Electricity concerning other aspects. He shall also advise the XAR Government as to coordination of the work of these two Bureaus in the field of geothermal energy so as to ensure smooth cooperation between them in order to secure the most effective course of geothermal developments consistent with the overall objectives in energy planning decided by the XAR Government.

Appendix 4: List of Meetings and Participants

List of Meetings

Date	Place
June 6, 1986	Beijing Office of the Xizang Autonomous Region, Beijing
June 8	Lasa Hotel, Lhasa
June 9	Lasa Hotel, Lhasa
June 11	Yangbajain
June 12, morning	Nagqu Hotel, Nagqu
June 12, afternoon	Premises of the Nagqu local government, Nagqu
June 14	Lasa Hotel, Lhasa
June 15	Lasa Hotel, Lhasa
June 16	Lasa Hotel, Lhasa
June 18	Lasa Hotel, Lhasa
June 21	Tianjin Bureau of Geology, Tianjin
June 23	Beijing Office of the Xizang Autonomous Region, Beijing
June 24	Institute of Geology of the Academia Sinica, Beijing
June 25	Ministry of Geology and Mineral Resources, Beijing

In addition to these formal meetings, the Icelandic Delegation, as a whole or individual members of it, made visits to the headquarters and laboratories of the Tibetan Bureau of Geology and Mineral Resources, Lhasa; the head office of the Tibetan Bureau of Water Resources and Electricity, Lhasa; the Tianjin Agricultural Research Institute; the Tianjin District Heating Service as well as field visits to the Yangbajain geothermal power plants; the Nagqu geothermal field and drilling sites; a geothermally heated hospital in Nagqu and to a geothermal experimental fish farm near Tianjin.

List of Participants in Meetings and other Discussions with the Icelandic Delegation during its Tour of Tibet, Tianjin and Beijing.

Mr. An Ru Yu
Vice Director, Engineer
Xizang Autonomous Region Science and Technology Committee
Lhasa

Mr. Cai Degen
Deputy Chief Engineer
Geothermal and Geological Group
Administrative Office
Nagqu

Mr. Ci Ren Duo Ji
Chief
Economic and Planning Department
Nagqu

Mr. Chen Xian Xu
Vice Director
Industrial and Electrical Bureau
Nagqu

Mr Chen Xinmin
Responsible position
New Energy Section
Bureau of Water Conservancy and Electricity
Lhasa

Mr. Dan Zhen Wang Dui
Chief
Scientific Research Department
Nagqu

Mr. Diao Yan Feng
Vice Director of Prospecting
Geological and Mineral Bureau
Lhasa

Mr. Dun Zhu Jia Can
Director
Department of Geothermal Engineering of Tibet Autonomous Region
Yangbajain (Lhasa)

Mr. Ea Kou
Vice General Secretary
Nagqu

Mr. Fan Yuan-Xiang
Chief Engineer
Bureau of Water Resources and Electric Power of Tibet Auton. Region
Lhasa

Mr. Fu Shao-Hua
Deputy Chief
Tianjin Geological and Mineral Resources Bureau
261 Yingou Road
Tianjin

Mr. Gong Zhan O
Chief Engineer of Prospecting
Geological and Mineral Bureau
Lhasa

Mr. Gu Qing Ge
Engineer in geology. Chief of Geological and Mineral Department
Geological and Mineral Bureau, Tibet
Lhasa

Mr. Hou Hong Xi
Assistant Engineer
Geophysical Team
Geological and Mineral Bureau
Lhasa

Mr. Hsiao Gong-Ren
Senior Engineer
Dept. Sci. & Technol.,
Ministry of Water Resources and Electric Power
P.O. Box 2905
Beijing

Mr. Lang Jia Wang Zhi
Vice General Secretary
Administrative Office
Nagqu

Mr. Li Zhi Da
Vice Chief Engineer
Geophysical Team
Geological and Mineral Bureau
Lhasa

Mr. Jiang Xuen Lie
Chief Engineer
Yangbajain Geothermal Engineering Department
Yangbajain

Mr. Jiang Zhen
Chief Engineer
Yangbajain Power Station
Yangbajain

Mr. Li Zhi
Chief Engineer
Planning and Design Section
Tianjin District Heating Service
Tianjin

Mr. Liao Ximing
Deputy Director
Bureau of Water Resources and Electric Power of Tibet Auton. Region
Lhasa

Mr. Liu Dian-Gong
Director
Bureau of Water Resources and Electric Power of Tibet Auton. Region
Lhasa

Mr. Liu Shang Xian
Senior Engineer
The Institute of Electric Power Test and Research of SW China
Chengdu

Mrs. Lu Run
Engineer
Bureau of Geology and Mineral Resources of Tianjin
No. 261 Yingkou Road
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Mr. Luo Jiasheng
Engineer
Inst. of Test and Research of SW China Electric Power Administration
QingYnag Gong
Chengdu

Mr. Lou Sang Dan Zhen
General Secretary
Nagqu

Mr. Pu Bu Duen Duo
Vice Director
Administrative Office
Nagqu

Mr. Ma Bao Ha
Engineer, Geothermal team
Geological and Mineral Bureau
Lhasa

Mr. Mao Ru Buo
Vice-Chairman
Xizang Autonomous Region
Lhasa

Mr. Nian Zha
Staff of Handicraft Industry Bureau
Nagqu

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261 Yingkou Road
Tianjin

Mr. Quiang Ba Qu Sang
Technician
Yangbajain Power Plant
Yangbajain

Mr. Qin Chang Long
Engineer
Geothermal Team
Geological and Mineral Bureau
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Vice Chairman
Beijing Association for Science and Technology
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Mr. Su Jialin
Deputy Chief of Section,
Planning and Design Section
Tianjin District Heating Service
Tianjin

Mr. Tang Min
Vice director, Administrative Office
Nagqu

Mr. Tang Ning Hua
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Beijing Association for Science and Technology
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140 Xi Wai Street
Beijing

Mr. Tang Zhi Li
Vice Director
Industrial and Electrical Bureau
Nagqu

Mr. Tong Wei
Associate Professor
Director of Geothermal Research Section
Peking University, Geology Department
Beijing

Mr. Tu Deng Qu Zha
Vice Chairman
Political Consultative Conference
Nagqu

Mr. Wang Daxiong
Division Chief
Bureau of Foreign Affairs
Ministry of Geology
Xisi, Beijing

Mr. Wang Hai
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149 West Street Gulou
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Mr. Wang Heng-Zhou
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Foreign Affairs and Management Section
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Mr. Wang Ji-yang
Professor, Director, Council Member Chinese Geophysical Society
Geoth. Res. Division, Institute of Geology, Academia Sinica
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Mr. Wu Fangzhi
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Mr. Xin Kuide
Chief Engineer
Bur. Hydrogeol. Eng. Geol.
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China Geo-Engineering Corporation, Business Department
20 Dahuisi, Haidian District, P.O. Box 1072
Beijing

Mr. Yang Shu Chuen
Section Chief
Department of Scientific Research
Nagqu

Mr. Yao Zujin
Senior Geologist
Inst. Hydrogeol. Eng. Geol., Ministry of Geol. & Mineral Resources
Zhengding, Hebei

Mr. Ye Jian Zhong
Geophysicist. Chief engineer, geophysical research team
Geological and Mineral Bureau
Lhasa,

Mr. Yiang Xan Dong
Secretary
Party Committee of People`s Hospital
Nagqu

Mr. Yin Jin Ping
Vice Section Chief
Department of Exonomics and Planning
Nagqu

Mr. Yu Wuzhen
Deputy Director
Foreign Affairs Office
Peoples Government of Tibet Autonomous Region
Lhasa

Mr. Yueng Zhueng Jia Wa
Vice Chairman
Political Consultative Conference
Nagqu

Mr. Zhang Zhenguo
Chief of Geothermal and Mine Hydrogeology Division
Dept. Hydrogeology & Eng. Geol.
Min. of Geol. Mineral Resources
Xizi, Beijing

Mr. Zhong Ming
Director
Bureau of Handicraft Industry
Nagqu

Mr. Zhou Cheng You
Engineer
Yangbajain Geothermal
Engineering Department
Yangbajain

Mr. Zhou Xixiang
Professor, Dean of Applied Geophysics Department
Chengdu College of Geology
Chengdu, Sichuan

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