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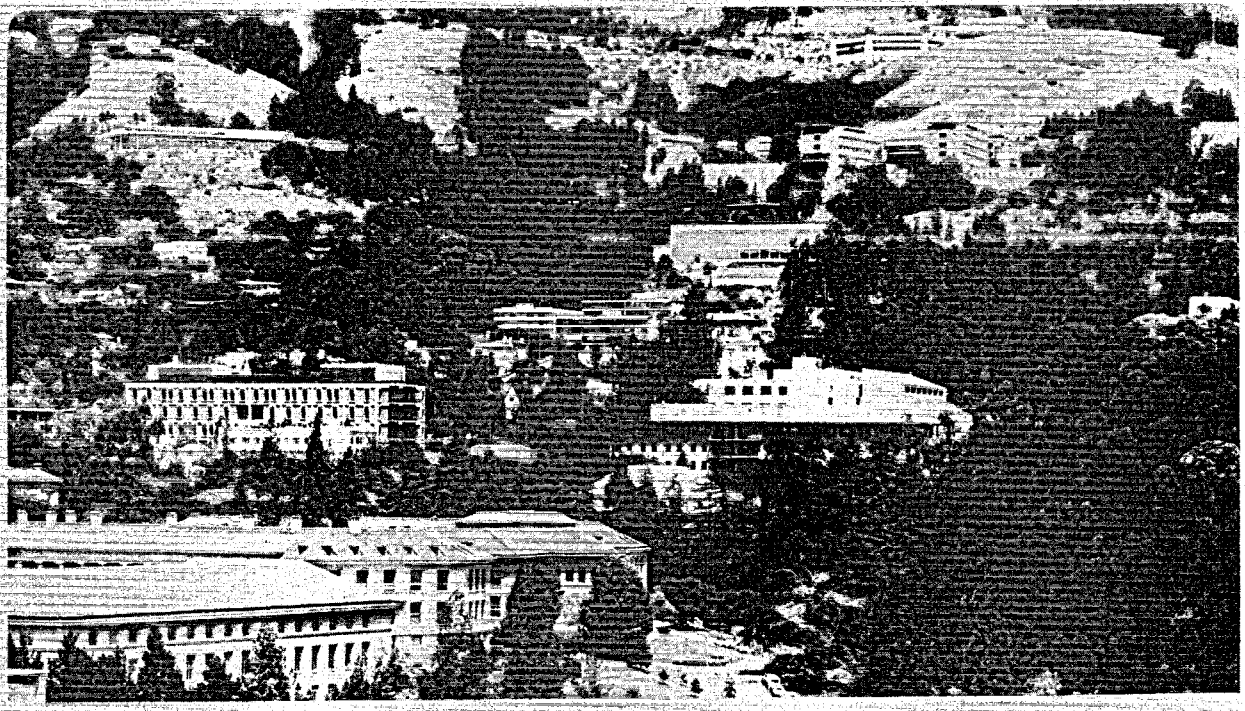

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Computerized International Geothermal Information Systems

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ABSTRACT

The computerized international geothermal energy information system is reviewed. The review covers establishment of the Italy - United States linked data centers by the NATO Committee on Challenges of Modern Society, through a bilateral agreement, and up to the present time. The result of the information exchange project is given as the bibliographic and numerical data available from the data centers. Recommendations for the exchange of computerized geothermal information at the international level are discussed.

A key to the development and utilization of geothermal energy is readily accessable reliable data. Based on data, areas are selected as likely sites for drilling, brine treatment processes are modified, plants are designed for power production or direct use, and financial assistance is made available. A small error on the negative side may dissuade development of new domestic sources such as geothermal energy and thereby continue our reliance on imported but expensive petroleum sources, while an error on the positive side can lead to financial disaster. The need for sound exploration and plant data is obvious.

Reliable geothermal energy data are needed for decision-making in a number of areas; (1) policy planning, which requires broad scale assessment of plant construction to measure the effectiveness of the National effort, and to identify inhibiting regulations; (2) program planning, which requires information on significant gaps in the research and development needed to accelerate plant construction; (3) general assessment of resources including the availability of resources such as hot brines as a national resource for power production; (4) compliance with existing environmental quality standards such as those for ambient air; and (5) data on the basic properties of brines and aqueous solutions such as sodium chloride which are so important in modelling heat flow from the production wells, through the plant, and thence to the injection well system.

The utilization of worldwide geothermal resources has a long history of careful measurements. Most of this work was done for other applications such as the recovery of chemicals from steam or hot water, or to examine the resource as a potential addition to an existing water supply. While these data were satisfactory for this limited purpose, the present needs are for greatly increased quantities of data and this added data has made mandatory the use of computer-assisted methods for storing, manipulating, retrieving and transmitting data.

The availability of computers for handling large amounts of data, as well as for modelling and mathematical calculations has made it possible to examine increasingly complex problems. The computer systems used are based on data acquisition, processing, storage media, display and printout capabilities designed for interactive data retrieval with quick response time. They also include means to query the stored data with very specific requests, the ability to construct a large variety of report formats, and a wide selection for disposing the output in a form suitable for the user.

Information for geothermal energy applications can be classified in many ways; the following is convenient: (1) basic or site-independent, (2) site-specific, and (3) bibliographic. Basic data include the properties of solutions, rocks and gases. These thermodynamic and transport measurements are made on thoroughly characterized samples, and under carefully controlled laboratory conditions. Site-specific data are measurements generally obtained in the field as for example at a geothermal site. The properties measured apply only to that site. Bibliographic information is in the form of indexed and annotated references to important publications and reports. Table 1 lists these three classes of computerized information generally used to evaluate the geothermal energy resource.

In this summary of the pilot study, the following topics are discussed: (1) objectives of the program; (2) the computerized geothermal data bases involved in the exchange program; (3) results of the CCMS phase of the program; (4) current status of geothermal data exchange with traceability to CCMS; and (5) recommendations for future work involving international cooperation for the exchange of geothermal information.

The material contained in this summary is drawn mainly from correspondence and reports that are directly related to the program; some are not widely circulated. In those cases where reports are related to the pilot study, the NATO/CCMS traceability is indicated by an appropriate reference.

Table 1. Classes of computerized information listing the form of storage and typical output for geothermal energy data.

Storage Form	Data Output
Basic	
Theoretical correlation equation	Graphs; tables of smoothed values-interpolated and extrapolated (enthalpy, viscosity, solubility)
Empirical correlation equation	Graphs; tables of smoothed values-interpolated (enthalpy, viscosity, solubility)
Code consisting of a number of equations	Graphs; tables; modelling (scaling, corrosion, brine treatment, heat flow through a power plant)
Site-Specific	
Data base management system	Geology: rock types, depth to reservoir Geochemistry: geothermometry, pH, thermal spring flow rate, TDS Geophysics: gravity, electrical, temperature and seismic surveys Reservoir properties: temperature, permeability, porosity Wells: depth, flow rate, temperature Well logs: caliper, acoustic, temperature, dipmeter Plants: scaling, capacity, downtime
Text editing systems	
Bibliographic	
Data base management system	Listing of references Indexes: author, affiliation, journal, subject Frequency of occurrence: author, subject, affiliation, journal, CODEN, year of publication Specific retrieval: boolean

Objectives of the Information Exchange Pilot Study

The initial goal of the program was a one-year test of linked data centers designed to facilitate the exchange of new geothermal information at the international level. Three linked principal world centers were originally suggested, as described in the Summary Records of the First Geothermal Implementation Conference (Ref. 1):

> Three equivalent regional information centers should be established to promote international exchange of information and data concerning the utilization of geothermal resources. Suggested locations for the centers are Italy, New Zealand, and the United States. The centers would be linked in the sense that all information generated in one center would be transmitted to the other centers and each would have a complete data file of all available information.

and

> Individual requests for specific information could be made to any of the regional centers. Each center would provide information in appropriate tabular, graphic or computer-readable formats.

(See Ref. 6 also).

The final form of the information pilot study involved computerized data centers in Italy and the United States, with active participation by New Zealand in development of formats and in providing data.

In summary, the Information Exchange Pilot Study was a one-year study, using two linked computerized data centers supplemented by assistance from a third. Its aim was to develop common formats and utilize computer methods for the prompt exchange and dissemination of new information and data related to geothermal energy. The information exchange depended on computer assistance to provide the most rapid, efficient and economic means of handling large quantities of data.

Implementation of the Information Exchange Pilot Study

Implementation of the expanded program involves the following participating data centers: (1) Centro Nazionale Universitario di Calcolo Electtronico (CNUCE), Pisa, Italy; (2) The National Geothermal Information Resource

(GRID), Berkeley, California, and (3) GEOTHERM, Reston, Virginia (now at Menlo Park, California). A description of these data centers is contained in References 8 and 9.

The idea was to include both bibliographic and numerical data in the exchange on a trial basis to assess the time, cost, and usefulness of the work (Ref. 1). Objectives and data collection for the one-year pilot study included the following:

1. Bibliographic data compiled by GRID on the following aspects of development and use of geothermal energy, including information from other fields with relevance to geothermal energy: (1) Subsidence; (2) Hydrogen Sulfide; (3) Geothermal Resources; and (4) Non-Electrical Applications. Indexed and annotated bibliographic listings were made available either as computer print-outs or magnetic tapes.
2. Tape of site-dependent numerical data by GEOTHERM to include the following subject areas: Geothermal Field/Area; Chemical Analysis; Geothermal Well/Drillhole.
3. Development of formats using internationally accepted standards by CNUCE, GEOTHERM and GRID. See, for example, Ref. 2.

Implementation of the work plan outlined by these tasks, which involved worldwide participation, required communication among the participants. With this in mind, meetings were held in 1974 and 1975 at Menlo Park, Berkeley, Reston, Pisa, Wellington and San Francisco. Participants at one or more of the meetings included representatives from Italy, Mexico, New Zealand and the United States. Generally, in addition to those directly involved with the project, other staff personnel from DOE and USGS were also present. Because of geographical distances and consequent travel involved, it was not possible for all committee members to meet at each location as frequently as

might be desired. To coordinate and facilitate obtaining worldwide data on-site, visits were made to Pisa and Wellington by Clark and Phillips, and by Stefanelli to Washington and San Francisco.

The Second U.N. Conference was held in San Francisco, May 26, 1975. The results of the "Pilot Study" were reported at a special afternoon session. These included the following: (1) Development of a common format for recording bibliographic information. The format had as its basis the International Nuclear Information System (INIS) descriptive cataloging procedures, indexing rules and authority lists. (2) Development of a format for site-dependent numerical data for fields, drillholes, and chemical analysis. The format was based in part on the system used by the U.S. Geological Survey Office of Resource Analysis CRIB file; it had been reviewed by the New Zealand Department of Scientific and Industrial Research staff. (3) A pilot bibliographic file by GRID and a pilot numerical file by GEOTHERM. (4) Identification by the three data centers (GRID, GEOTHERM, CNUCE) of problem areas in the international exchange of geothermal energy data.

All participants agreed that the data exchange programs should continue. James Bresee, described the CCMS pilot study concept and asked for suggestions for an international organization to sponsor the information exchange. There were no suggestions from the floor. Following the report session, four members of the committee (Barbier, Stefanelli, Calkins, and Phillips) continued the business portion of the meeting. A draft document was prepared to help define the scope of follow-up activities to continue the worldwide data collection and exchange (Ref. 4). A bilateral exchange agreement was signed by Italian and U.S. representatives in 1976.

GRID informally provided Pisa a file on subsidence in July 1975; in 1976 more extensive computer tapes were sent to Pisa under the bilateral exchange

agreement. These included the GRID hydrogen sulfide file; a tape from TIC, Oak Ridge containing their geothermal bibliographic file; the GRID geothermal thesaurus; the EDB magnetic tape description; and, a description of the GRID document file structure. In June 1977 the following additional computer tapes were transmitted to Italy under the bilateral agreement: (1) GRID geothermal hot water reservoir data; (2) the current TIC bibliographic file; (3) a composite file of geothermal energy abstracts from 1967 to 1977 from TIC. This information exchange also included the sending of a tape and printout from the Pisa geothermal bibliographic file to TIC and GRID. In 1979 and 1980, GRID and Banco Geotermica (Pisa) exchanged additional information to include the Pisa printout and tape on well temperatures in Italy.

Under the bilateral agreement the United States was responsible for data collection in the following geographic areas: Iceland, North America, Central America, South America, Australia, Asia (but not the USSR). Italy was responsible for data collection in Europe, Africa and the USSR (Ref. 7).

Contacts were established with Central and South American geothermal specialists in October of 1976 by GRID via the Department of State under the auspices of CCMS during a geothermal conference in Guatemala (Ref. 5). In 1977, this effort was continued by working with the relevant U.S. Embassy Science Counselor through the Department of State to establish a mechanism for the exchange of geothermal data between the U.S., Central America, and South America. GRID sent a printout of data on geothermal reservoir chemistry to Central and South American specialists in 1977, and information to India and Israel in 1978. See Table 2.

Conclusion

The results of the CCMS pilot study and the follow-up work demonstrate the effectiveness of the pilot study concept as applied to the exchange of

Table 2. Typical information provided by GRID and received from others under NATO/CCMS, or successor international exchange programs

Information Type	Form/Year	Recipient
Well data from Banca Dati Geotermici	Tape/1979	GRID (from CNUCE)
Bibliographic Standards	Report/1978	Geological Survey of Japan
	Report/1978	Geological Survey of India
	Reports/1978	Instituto de Geología y Minería, Peru
Description of GRID	Report/1978	Israel, National Center of Scientific and Technological Information
Description of GRID	Reports/1978	Geothermal Energy Research & Development Co., Ltd., Japan
Thesaurus, GEODOC	Report/1978	DSIR, New Zealand
Reservoir, fluids file	Computer tapes/ 1977	CNUCE, Italy
To GRID: Copies of publications	Xerox/1977	GRID (from CNUCE)
Bibliographic (TIC)	Tapes/1977	CNUCE
Thesaurus, H_2S file, Bibliography (TIC), GEDOC	Tapes, Reports/ 1976	CNUCE
Reservoir fluids file and establishment of contacts	Printout/1977	Costa Rica, Guatemala, Haiti, Chile, Bolivia, Mexico, Argentina, El Salvador, Canada, United Nations, Nicaragua, Ecuador, Columbia, Panama
Description of GRID	Report/1977	OLADE, Ecuador
Description of GRID	Report/1977	Empresa Nacional de Electricidad, Bolivia
Brine treatment	Report/, Printout/1978	Instituto Costarricense de Electricidad, Costa Rica
Guanacaste Project	Report/1977	To GRID From Costa Rica
Requested plant data	1977	Empresa Nacional de Electricidad, Chile
--	1977	Prospec Ecuador
Information on GRID	1977	Central American Common Market Economic Research Unit, Guatemala
Description of Banca Dati Geotermici (CNUCE)	Report/1977	GRID (from CNUCE)
Subsidence	Microfiche and Report/1975	CNUCE
Forms to input data	Xerox/1974	CNUCE

geothermal information on a worldwide basis, and the advantages of computerized information systems for this kind of operation. The success of the work requires the cooperation and coordination of many agencies and laboratories in each participating nation. In the U.S., for example, the agencies involved in coordinating the project were the Department of Energy, Department of State, Environmental Protection Agency, Geological Survey, and Lawrence Berkeley Laboratory of the University of California.

The past five years have seen a substantial growth in the availability of data. Only a brief survey is needed to identify the many databases currently available in the United States: See Table 3. Unfortunately, the vast majority of the data are neither readily available, nor in computerized form; they are therefore of limited use.

Recommendations for Future Work on International Information Exchange

The primary objective of the CCMS Pilot Study on data exchange was to create an international geothermal information resource, a pool of information from which all countries may draw. The difficulty does not lie with designing the data system but rather with the mechanics of securing and coding the information. Most participants are eager to contribute to the file but balk at the tedious and sometimes formidable task of coding forms for the computer. This is understandable because such coding could create a drain on manpower and funds. Future work in data exchange must face the reality that responsibility for coding lies with the data center. In this context, an ideal international computerized geothermal information system would include the following:

1. Collection and transmittal of internal reports and manually logged data by the participating country to the center in either Italy or the United States. This is especially important for work that is otherwise not widely circulated. The computer center will code and input the data, and disseminate the data to the users.
2. Costs for access to the Italy-United States information system which is borne by the users. This could be done on a graduated

Table 3. Selected geothermal information databases in the United States.

Type of Data	Availability	Computerized
Bibliographic	DOE Technical Information Center	Yes
Specific bibliographies	Lawrence Berkeley Laboratory	Yes
	U.S.Geological Survey (Basic)	No
	Sandia (Magma)	No
Environmental bibliography	Lawrence Livermore Laboratory	No
	Lawrence Berkeley Laboratory	Yes
Basic Numerical Data	Lawrence Berkeley Laboratory	Yes
	U.S.Geological Survey	Yes
Brine Treatment	Lawrence Berkeley Laboratory	Yes
	Lawrence Livermore Laboratory	No
Subsidence	Lawrence Berkeley Laboratory	No
Reservoir Engineering	Terra Tek (bibliography)	No
Reservoir Chemistry	Lawrence Berkeley Laboratory	Yes
	Battelle Pacific Northwest	No
Geology	U.S.Geological Survey	Yes
Geochemistry	U.S.Geological Survey	Yes
Drillhole	Lawrence Livermore Laboratory	No
Wairakei report	Systems, Science and Software	No
Cerro Prieto report	Lawrence Berkeley Laboratory	No
Hot Dry Rock	Los Alamos Scientific Laboratory	No
Geopressured	University of Texas	Yes
Nevada	Nevada Bureau of Mines	No
Central United States	University of Utah	No
Thesaurus	Lawrence Berkeley Laboratory	Yes
	Technical Information Center	Yes
Well Log, Cerro Prieto	Los Alamos Scientific Laboratory	No
Drilling	Lawrence Berkeley Laboratory	No
	Munger Oilogram	No
	Petroleum Information's National Geothermal Service	No
	U.S.Geological Survey	No
Progress Monitoring	Lawrence Berkeley Laboratory	No

Table 3, continued

Type of Data	Availability	Computerized
Southwest United States	Western Energy Planners, Ltd.	No
Washington, Wyoming	OIT Geo-Heat Utilization Center	No

scale which depends on the ability of the subscriber to pay the cost. See for example Reference 10.

3. A monthly newsletter that describes information available from the linked data centers. The person interested in obtaining selected information need only query the system, e.g., by filling out a card, letter, or directly accessing the computer.
4. Information supplied to the data centers in either the Italian or English languages. The data centers would provide the user with printouts in either language. It is difficult to translate material which is in diverse languages, and much valuable data is lost in untranslated publications.
5. Numerical values which are in a consistent set of scientific units. Much time and expense is expended in converting the different units to one set of units so that the data may be properly compared. The Standard International units are recommended.
6. Designation of a person who will be responsible for collecting and transmitting the information from each nation to the Italy or United States computer center.
7. A cost to the user that is defensible. It is imperative that the international geothermal information system be supported almost entirely by the users. Thereby, the information provided must be timely, accurate, current and in a thoroughly understandable format.
8. Expand the geothermal energy coverage to include geosciences data such as nuclear waste isolation and deep drilling.

Dissemination of the collected data to users is via printed reports, magnetic tapes, or computer-connected communication lines. Printed reports are produced by a computer system in a variety of formats (including graphs), to meet a variety of user requirements. They are most appropriate for those without computer facilities, and for the person who wishes to make direct use of the data without any additional manipulations.

Magnetic tapes allow data to be sent to users in standard computer accessible formats, and are most appropriate to those who wish to make use of the data in their own computer systems. The development of international computer networks such as EURONET and ARPANET raises the possibility of direct access to a data center, either by the person querying the system or by their computers. This would allow very rapid dissemination of data, particularly compared to trans-oceanic surface mail. Direct interrogation of computerized data bases, via interactive exchanges between a user at a terminal and a computer at a data center, can enable the user to rapidly obtain current data that closely fits his needs. The refinement of queries based on partial results, the ability to manipulate data to show relationships in new forms, and the production of printed reports and graphs that satisfy ad-hoc changing needs are additional benefits of direct interaction between a user and the computer. Computer-assisted connections allowing files to be transmitted from one to the other offer additional benefits. One example is the transmission of a file of current data from a data center to a user's computer to be used by a forecasting program owned by the user.

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