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DECEMBER 1980

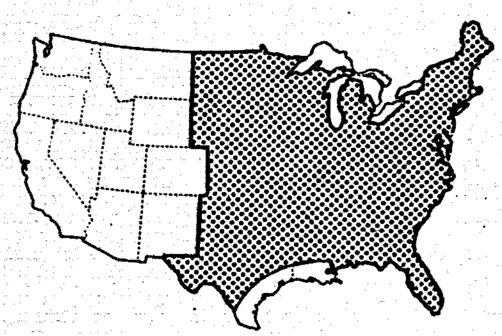
Geothermal Energy and the Eastern U.S.

Fifth Technical Information Interchange Meeting

MINUTES

Prepared by: THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY

For the: DIVISION OF GEOTHERMAL ENERGY
RESOURCE APPLICATIONS
U.S. DEPARTMENT OF ENERGY



THE JOHNS HOPKINS UNIVERSITY ■ APPLIED PHYSICS LABORATORY

This work is supported by the Department of Energy under Interagency Agreements
No. EX-76-A-36-1008 and DE-ALOL-ET27025.

DISCLAIMER

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Johns Hopkins Road, Laurel, Maryland 20810

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PREFACE

The technical interchange meeting documented here is the fifth such meeting where people interested in geothermal energy in the Eastern U.S. have met to exchange technical information. These meetings are intended to assist all in the difficult task of balancing time and effort in doing their assigned jobs and keeping track of what others are doing in similar or related tasks. All of these meetings have served their intended purpose, and the steadily growing response to them is taken to be one sure indication that they fulfill a need in the geothermal community.

We thank those who attended the meeting and presented summaries of their work. Particular recognition is due Dr. David B. Lombard and Mr. Randall C. Stephens of the Department of Energy who assisted in the organization of the meeting and contributed to its success. Session chairmen who were instrumental in the success of the meeting were: Dr. Charles Bufe, U.S. Geological Survey; Dr. David B. Lombard; and Dr. A. M. Stone of The Johns Hopkins University Applied Physics Laboratory.

The Coolfont Convention Center in Berkeley Springs, W. Virginia, provided a pleasant setting and very suitable facilities for the meeting. The able assistance of Mrs. Sharon Ryan is acknowledged for those arrangements. The very capable receptionist at the meeting was Mrs. Barbara Klaess of The Johns Hopkins University Applied Physics Laboratory.

On the evening of November 6th, after dinner, Mr. Paul Rodzianko, president of the Geothermal Energy Co., provided us with a fascinating discussion on the mechanics of starting and operating a geothermal enterprise.

Finally, Mrs. Margaret Sexton, Mrs. Barbara Klaess, Mrs. Carolyn Silas, and Mr. William B. Chapman of The Johns Hopkins University Applied Physics Laboratory very capably took care of the myriad of items required to hold the meeting and to issue these Minutes in a minimum of time.

INTRODUCTION

The Technical Information Interchange Meeting, held at Berkeley Springs, West Virginia, on November 6-7, 1980, was the fifth in a series, each previously under separate auspices.

The first information interchange meeting on Eastern geothermal programs, the Near-Normal Gradient Workshop, was held in March 1975 under the aegis of the Energy Research and Development Administration. The second Technical Information Meeting was held at the Applied Physics Laboratory in September 1978 under the auspices of the Division of Geothermal Energy, Department of Energy (DOE). A symposium on Geothermal Energy and Its Direct Use in the Eastern United States was sponsored by the Geothermal Resources Council in Roanoke, Virginia in April 1979. The fourth such meeting was sponsored by the Division of Geothermal Resource Management, DOE. This, the fifth, was again sponsored by the Division of Geothermal Energy, DOE.

The seventy-four attendees represented DOE/RA, U. S. Geologic Survey, NOAA, state geologic offices, state energy offices, DOE Regional Offices, Program Research and Development Announcement (PRDA) recipients, industrial representatives, the national laboratories, a financial analyst, and interested county officials (see Section XXXX for the list of attendees). Virtually all attendees participated in the program, summarizing their efforts in promoting the use of geothermal energy in the East. By all accounts this was an enthusiastic and successful interchange meeting, with most participants expressing a desire for additional meetings in this format.

In the evening of the first day, an informal talk was given by Mr. Paul Rodzianko, president of the Geothermal Energy Co., who is both a skilled lecturer and writer as well as a practioner in the art of organizing, financing and operating a direct-use geothermal project.

The agenda for the meeting are presented in Section

During the first morning, an overview of the current programs of DGE/DOE was presented by the keynote speaker, as well as a review of the Eastern geothermal resource assessment program by the DGE contractors, Gruy Federal and Virginia Polytechnic Institute and State University. The Eastern Hot Dry Rock program was reported by the Los Alamos Scientific Laboratory (LASL) and its contractors. Included here were a detailed study of the area between Crisfield, MD and Wallops Island, VA by D'Applonia, Inc., Florida and the eastern Gulf coastal plains by the University of Florida, potential hot dry rock sites mid-continent and northeastern New England by LASL, and Ohio and western Pennsylvania state resources by Kent State University, and, finally, the extensive geothermal resource assessment program funded by DGE and New York State Energy Research Administration (NYSERDA). The final talk in this series consisted of a resume' of the User-Coupled Resource Confirmation program by the DOE Idaho Operations Office. Other Eastern programs were presented, notably that of the Oak Ridge Energy Analysis Institute for the Tennessee Valley Authority (TVA) region, and the Nebraska resources by the University of Nebraska.

The first day concluded with a number of applications papers, notably one on geothermal vaporization of liquified natural gas (LNG) at Cove Point, Maryland, by the Columbia Gas Company, and one on the results of the Eastern PRDAs and PONs by EG&G. Other reports discussed the forthcoming geothermal drilling programs at Lewes, DE and at Montezuma, NY. This session included papers on legislative issues, economic analyses and concluded with a discussion of the USGC geothermal and regional aquifer programs.

The second day was devoted to reports on geothermal commercialization in the Eastern states, giving particular emphasis to market penetration and to technical assistance programs. A final report on failure analysis in direct utilization of geothermal energy for space heating in central Texas by the Radian Corp. and an outline of a service they supply free of charge in analyzing material compatibility with hydrothermal water concluded the meeting.

These Minutes of the Technical Interchange Meeting consist of the textual and illustrative material as furnished by each speaker*. No attempt has been made by the editor to do more than ensure legibility and therefore the responsibility for the content lies entirely with the individual authors. Furthermore, correspondence with regard to any paper should be addressed to each author, respectively. The primary distribution of these Minutes is being made to the list of invitees to the meeting. Additional copies may be had on application to the Applied Physics Laboratory, Attn: Mr. William E. Chapman.

*In one or two cases, as indicated in the appropriate text, the material was assembled by APL/JHI from the author's notes or telephoned information.

TABLE OF CONTENTS

Keynote Address

by

D. Lombard
Department of Energy
Division of Geothermal Energy

GEOTHERMAL ENERGY IN THE NATIONAL ENERGY PICTURE

EASTERN GEOTHERMAL TECHNICAL
INFORMATION INTERCHANGE MEETING

BERKELEY SPRINGS, W. VA.

by

DAVID B. LOMBARD

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We are meeting today because, for the immediate future, the energy outlook is not bright. World energy demand will exceed world energy production within the next couple of years, if it has not done so already. What was a buyer's market has become a seller's market.

For the people of the United States, there are two messages in this:

- The day of the free energy lunch is gone.
- At times in the next few years, the energy lunch pickings at any price may be lean indeed.

The prospects for future decades are brighter. Beyond the year 2000, we can expect to have ample quantities of energy from alternative resources: oil shale, nuclear breeders, fusion, and advanced solar and geothermal technologies, to name a few. The problem for the short and mid-terms is thornier. The question is, how can we as a nation move from today's dependence on imported fuel, to the future independence we expect to achieve, without being subjected to the severe social and economic stress that could accompany major supply interruptions and/or a continued steep rise in oil prices?

This is one of the most serious questions facing the United States today, because it involves not only money, politics, and people's lifestyles, but because basic national security is at risk as well. During the next several years, while our consumption of energy still exceeds our ability to supply it from within, we are extremely vulnerable to externally imposed interruptions of supply.

The problem is real. It has spawned so many studies in the past decade that I suspect we could satisfy our national energy demand for a considerable time by burning the paper on which they are printed. A consensus of their conclusions seems to be that no single regulation, no individual course of action, no one energy source, can be relied upon to pick up all of the slack. There is a possibility, however, that we can convert potential disaster into mere discomfort by applying a <u>combination</u> of solutions to the problem.

Conservation is our first line of defense in the energy wars. It has the twin advantages of being immediate and relatively cheap. The potential for conservation is great because the economics of energy in the U.S. heretofore have encouraged profligacy. We can save a lot because we have been wasting a lot.

As a nation, we have made measurable progress in conservation over the past few years. Individuals have insulated their homes and tuned their thermostats with a moderate hand. Automobiles that guzzle gas are a drug on the market, and fuel efficient models are hot sellers. Communities and private industries have achieved impressive energy savings by applying simple management techniques. The rate at which we import oil has peaked and begun to fall -- at first gradually, more recently at a faster rate.

Despite their encouraging signs, we are not yet out of the woods. While conservation may be necessary, it certainly is not sufficient. The reduction of our national energy consumption to a level commensurate with present domestic energy production would exact an enormous toll on our economic, social and political systems. Few of us would be willing to pay such a price.

Consequently we must identify -- and tap on a commercial scale -- in the near to mid-term -- substantial new domestic energy sources. That is the second leg of the national energy strategy. And that brings us to the reason we are meeting here today. Geothermal energy, heat from beneath the earth's surface, can contribute significantly to our domestic energy supply in the closing decades of this millennium. It is your responsibility -- and mine -- to make that happen.

Geothermal heat is an attractive alternative to imported oil or gas; it satisfies the requirements for being a key domestic energy contributor: it is available within the United States, and it is environmentally benign. The production technology for hydrothermal electric power and direct heat systems is known and easily available to U.S. industry.

The generation of electric power from high temperature hydrothermal resources is currently economical, with the cost per KW being roughly comparable to that of electric power from coal -- and certainly less than oil. Unfortunately, high temperature of resources are found principally in the western third of the country, while the largest power markets are in the east.

Geothermal resources at temperatures below 300F are not currently economical for electric power generation, but they are ideal for nearby direct use applications, and they are widely distributed throughout the United States.

Technically, hydrothermal systems for electric power and for direct heat applications are ready for industrial development. Both are economically competitive with imported oil. Together with other near term supplies such as coal-oil mixtures, oil and gas from the outer continental shelf, and alcohol fuels, hydrothermal resources can help bridge the gap while advanced technologies are being developed for synfuels, geopressured, and hot dry rock resources, all expected to come on line in the 1990's.

Federal interest in geothermal resources is not new. In the last 1960's, the U.S. Geological Survey conducted a preliminary assessment of the nation's geothermal resources, (this work has been updated twice since that time). In 1970, the Congress authorized the Secretary of the Interior to issue geothermal leases for certain federal lands.

Early in the 1970's, as concern about future energy supplies began to mount, geothermal resource programs were begun in the Atomic Energy Commission and the National Science Foundation. In 1975 the Congress formed ERDA, the Energy Research and Development Administration. The AEC and NSF geothermal programs were moved into ERDA and consolidated. Two years later the entire ERDA structure became part of the Department of Energy. Since that time the program focus has broadened to include a major effort aimed at industrial and commercial development of geothermal resources.

The DOE is not the only federal agency with an interest in geothermal energy. The Departments of Agriculture and the Interior, for example, have responsibility for millions of acres of federally owned lands, much of which has geothermal potential. The Defense Department has many military installations that might be heated by geothermal energy. The Treasury Department regulates the collection of taxes that have been adjusted for geothermal credits allowed by law. Housing and urban development is deeply concerned with alternative energy sources for heating new and rehabilitated dwelling units and commercial space.

The responsibility for welding these diverse federal interests into a coherent geothermal energy program has been assigned by Congress to the Interagency Geothermal Coordinating Council. The Council is chaired by the DOE Assistant Secretary for Resource Applications, and other agencies are represented at the Assistant Secretary level. The Council establishes national geothermal policy in the context of the overall national energy strategy, and plans the federal geothermal energy program. The Council also develops recommendations for Congressional action to alleviate barriers to geothermal resource development, and submits a consolidated federal geothermal budget to the President's Office of Management and Budget each year.

The IGCC produces an annual report to the Congress, presenting the progress, status and plans of the federal geothermal program. If any of you want copies of the latest annual report, please speak to Mr. Paddison and he will see that you get them.

The U.S. presently generates 900 megawatts of electric power from geothermal energy, and produces an additional 11 trillion BTU's for space heating and for industrial and agricultural purposes every year. This is equivalent to an annual savings of about 10 million barrels of oil. With the cooperation of all levels of government and private industry -- together we could generate up to 6,000 MW of electric power and produce up to 300 trillion BTU's of direct heat by 1990 -- saving over 100 million barrels of oil per year.

The direct heat goals, of course, are of primary interest to those of us in the east because hydrothermal resources here are not hot enough to generate economical electric power. But we are fortunate because much of the identified eastern resource is located close to existing and potential markets for direct heat. Many of these markets are now served by gas and oil or by electric power generated by burning natural gas or oil.

How can these resources be tapped to serve these markets quickly enough and in sufficient quantity to achieve our goals for direct thermal uses? The Congress has given DOE the responsibility for making it happen -- not as a massive federal program imposed upon the states, cities and industries, but rather as a commercial market activity.

In formulating a strategy for our hydrothermal industrialization program, we have kept in mind from the start that the desired end will be accomplished by literally tens of thousands of independent decisions to commit community, corporate, and individual resources of money and manpower to geothermal development. We in the federal program can provide information, assistance, guidance, and sometimes a modicum of fiscal lubricant for the geothermal gears. We can make it possible for the industrialization process to occur, but we cannot force it. The ultimate outcome is truly your challenge and the challenge of thousands of others like you.

Our strategy, basically, is to focus government efforts upon barriers to geothermal development, including:

- Lack of resource knowledge,
- Lack of direct technical, economic, and institutional experience with geothermal systems,
- The perception of high economic risk, common to the initial commercial stages of any new technology,
- Lack of tax parity with other renewable and alternative energy sources,
- Lack of appropriate legislation and regulatory apparatus at the state level,
- Lack of an industrial infrastructure to service user needs,
- Lack of communication among a highly diverse community of geothermal interest.

Although particulars will vary with time, place, and local requirements, our basic program approach involves the following elements:

- Resource definition (cooperation with states)
- Reservoir confirmation (user-coupled; alters risk)
- Energy market analysis (localized by resource definition results)
- Assistance to state legislatures (NCSL)
- State commercialization teams - state focus, info center, prospectus, brokering
- Technical assistance to would-be developers and users
  - Geologic/hydrologic
  - Engineering/economic
- Feasibility study loans
- Pioneer projects
- Develop advanced technology to reduce costs

- Cooperative projects with OFA's
  (HUD-direct heat)
  (DOD-studies)

- Reservoir confirmation loans

- Tax incentives

- Loan guaranties

In all this we are moving toward the creation of the industrial infrastructure that will be needed: future "geothermal" listings in the yellow pages. We are doing this in part by engaging industrial firms to provide our free technical assistance, and by competing much of our study and drilling and construction business to the private sector to provide "hands-on" geothermal experience.

Finally, we are working with other federal agencies and the Congress to adjust laws, rules, and regulations that impede industrial development of geothermal resources, and to provide incentives to spur that development.

You will learn much more in detail about this program effort during this meeting, and I would like to give you something of a preview by highlighting some of the more significant achievements of this program.

- In the past two years we have confirmed the presence of extensive moderate temperature hydrothermal reservoirs beneath the Atlantic coastal plain, and identified substantial markets for low grade heat co-located with these resources.

- We have identified areas of high promise for moderate temperature hydrothermal resources in upper and western New York State.

- We have defined a major moderate temperature hydrothermal zone across much of central Texas.

- We have started resource evaluation projects in several other eastern states.

- We have initiated a program of free (but limited) technical assistance for potential developers and users of geothermal resources in the east.

- We have signed contracts for cost shared geothermal wells adjacent to potential industrial users in Delaware and New York State, and have begun exploratory drilling on the site of a potential industrial user in Virginia.

- In July 1980 we began a cost-shared user-coupled drilling program to identify resources for direct heat applications. Contract awards will be announced shortly.

- We are supporting the first state geothermal industrialization team on the east coast in Delaware.

- We have provided legal/technical staff help to several eastern State Legislatures that wish to review the legal status of geothermal development in their respective states.

- We have supported the construction of hydrothermal direct heat projects in Texas and the Dakotas.

- We have supported the construction and testing of a prototype pilot plant of revolutionary design to investigate the production of electrical power from moderate to low temperature brines in Arkansas.

- And finally, as a result of a cooperative DOE/Navy engineering analysis, the Navy has planned to use geothermal resources to heat a large hangar-like building at the Naval Air Rework Facility in Norfolk, Virginia.

- Throughout the country, DOE is currently funding 33 technical/economical feasibility studies for specific applications. We are also cost-sharing over 20 direct heat demonstration projects, including district heating projects and space heating installations in hospitals and schools. Two of these are in Texas, and two in South Dakota.

- A DOE appropriate technology grant has been awarded for using geothermal energy to preheat feedwater for a gas fired plant that supplies electric power and space heat to the University of South Carolina Medical Center.

As these accomplishments show, eastern geothermal resources are ready for commercial development as alternatives to natural gas and oil for many applications.

We in the Department of Energy are providing support and assistance, but you are the bottom line. Your decisions and actions, not ours, will put geothermal power to work in homes, farms and factories. Your efforts, not ours, will cut directly into imports of foreign oil and you, not we, will reach the goals.

NOAA's Geothermal
Mapping Program

by

D. Clark
National Oceanographic and Atmospheric
Administration

TIMETABLE:

Already published:

Geothermal Resources of the Western United States 1977

Three maps for USGS Circular 790, 1978-1979

Geothermal Resources of Colorado 1980

Geothermal Resources of Idaho 1980

Geothermal Resources of New Mexico 1980

Geothermal Resources of Utah 1980

Thermal Springs List for the United States 1980

Maps in Production

Geothermal Resources of California to be printed by January 15, 1981

Geothermal Resources of Montana to be printed by March 1, 1981

Geothermal Resources of North Dakota to be printed by March 1, 1981

Geothermal Resources of Washington to be printed by March 15,1981

Geothermal Resources of Texas to be printed by May 15, 1981

Additional maps on the drawing board for FY81 include Geothermal Resources of the following: Alaska, Arizona, Kansas, Nebraska, Oregon, Virginia, and Wyoming. A technical map of New Mexico will also be worked on during FY81. On the far horizon are public maps of Hawaii, Missouri, Oklahoma and numerous technical maps.

PHILOSOPHY OF MAPPING PROGRAM

The maps NOAA produces are designed for two audiences, the general public and the earth science community. To this end two maps will be produced for each state, a "public usage" map and a "geotechnical" map for which New Mexico will be the prototype. The "public usage" map has been designed to be of use to the entrepreneur, land planner, legal community, and environmentalist as well as the explorationist. This genre of map has been designed also to be a tool for education of the general public concerning the magnitude of the geothermal resource within a given state. As such, it is hoped that the public map will also serve as a promotional tool and encourage the expanded usage of the geothermal resource. The geotechnical maps, to which DOE has given secondary priority, will emphasize tectonic, geophysical, and geochemical information as related to the geothermal resources of a given state.

DATA PRESENTED ON STATE "PUBLIC USAGE" MAPS:

Geothermal Data: Springs, wells, temperature, flow, TDS, depth, areas considered to have a high value for finding additional geothermal resources, gradient ranges. Various maps have combinations of the above data sets.

Cultural and geographic data displayed on the map include urban areas, roads, railroads, airports, drainage, off-limits areas such as parks, monuments, and wilderness areas, national forests, Indian reservations, military lands, DOE reservations, and KGRA's.

PLAYERS IN THE GEOTHERMAL MAPPING PROGRAM:

DOE --- funding and policy formulation

STATE TEAMS --- either state geologic agencies or university teams responsible for data collection and interpretation

NOAA --- cartographic expertise, design of maps, and data quality control

USGS --- base map negatives, GEOTHERM FILE, upcoming update of low-temperature portion of Circular 790

University of Utah Research Institute and Los Alamos Scientific Laboratory --- liaison between NOAA and state teams as well as map editorial function

Government Printing Office --- arranges contracts for printing of maps and contracts

Private contractors in Denver Metro Area --- cartographic services, photographic services, typesetting, supplies, etc.

METHOD OF MAP PRODUCTION:

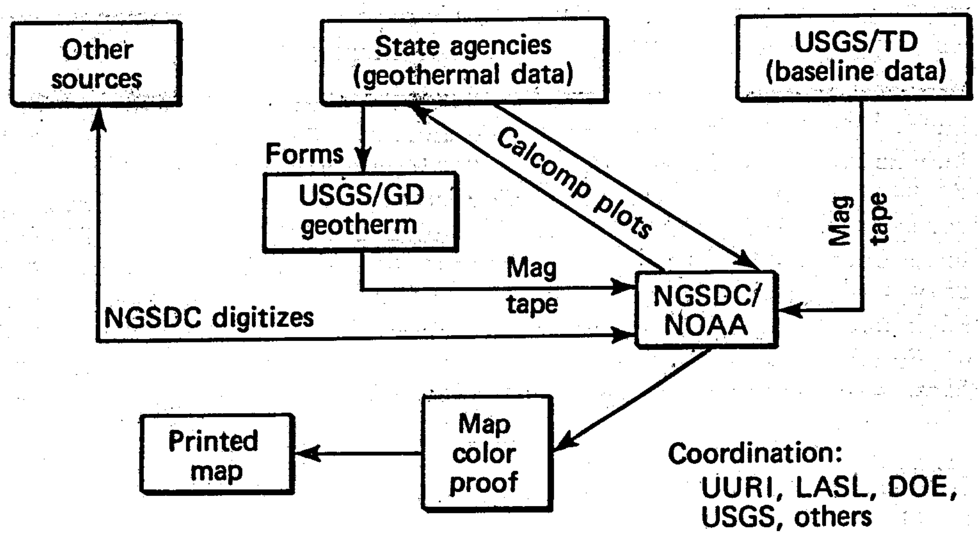
The original plan was to contract to the USGS Topo Division to provide NOAA with digitized base map data so as to be able to custom design each map using a machine plotter. Because of technical problems and personnel problems, the USGS was unable to provide NOAA with timely, accurate digitized data. Thus we went to obtaining base map negatives through USGS NCIC's for all information that one would see on a USGS 1:500,000 topo base map. Geothermal information is usually machine scribed from state provided digital data or from NOAA digitizing of state provided hand plots. Cultural information such as military reservations, DOE reservations, wilderness areas, etc. are normally hand scribed from source documents such as BLM maps. Then the scribed boundary plates are either photographically exposed to photo-sensitive peel coat material or overlayed with CUT'n'PEEL to hand make our tint coats. All information in lists, title blocks, squibs, temperatures, flow rates, etc. is photo-typeset and made into either thinfilm positives or stripfilm stickyback for stickup to positives. These positives are then made into negatives for manufacture of color proofs.

Between USGS provided negatives (at a cost of approximately $1200 per state) and NOAA manufactured negatives, approximately 30 negatives go into the production of each colorproof. The color proofs allow us to edit negatives and arrive at the final format of the maps. After the final version is agreed upon we composite our thirty negatives down to about 15 negatives based on color and percent screen of color for each negative. These fifteen negatives are then forwarded to GPO for delivery to a printer. The printer in turn composites the fifteen negatives to six aluminum plates which encompass the six basic colors with screens for final printing.

WHAT IS NOAA AND WHY IS NOAA MAKING GEOTHERMAL MAPS?

NOAA is the National Oceanic and Atmospheric Administration which falls under the U.S. Department of Commerce. Major functions of NOAA include the National Weather Service, National Ocean Survey, National Marine Fisheries Service, National Environmental Satellite Service, and Environmental Data and Information Service (EDIS). Under EDIS falls numerous Data Centers including the National Geophysical and Solar-Terrestrial Data Center in Boulder, Colorado. In 1977, Paul Grim, a geophysicist with NGSDC in Boulder obtained a copy of USGS Circular 726 (Assessment of Geothermal Resources of the United States-1975) and, as he was a heat flow specialist, felt that this was good material for a multicolored map. The resulting map, Geothermal Energy Resources of the Western United States 1977, was produced largely by computer graphical methods and was funded by DOE. Since that time the Datamapping Group has produced nine geothermal maps and one publication.

David M. Clark
Datamapping Group



Data flow for state geothermal maps.

Gruy Federal Work Plans
for FY 1981

by

J. Renner
Gruy Federal, Incorporated

III

Gruy Federal Work Plans for FY 1981

Gruy Federal, Inc. will provide technical and administrative support to DOE for the Hydrothermal Resources Program. The work will include tasks in the resource definition and technical assistance areas.

The resource definition task will include geothermal definition efforts where state coupled teams are not presently active, provide liaison and information dissemination activities among state coupled activities in the east, and assist the U. S. Geological Survey in its ongoing assessment of low temperature resources in the United States.

The technical assistance task shall provide assistance to prospective geothermal users through liaison, information dissemination, reservoir analyses and engineering and economic studies. The Gruy staff will also be available to make presentations of geotechnical information concerning geothermal resources to state, county, and local governments, and others interested in the development of eastern geothermal resources.

During FY-1980 several reports were prepared which are available to the public:

Renner, J.L., and Vaught, Tracy L., 1979, Geothermal resources of the eastern United States: Houston, Gruy Federal, Inc., Report DOE/ET/28373-T2. Available from NTIS. (Stapled copies available from R. A. Gray, Division of Geothermal Energy, DOE, Washington, D. C.)

Vaught, Tracy L., 1980, Temperature gradients in a portion of Michigan: A review of the usefulness of data from the AAPG geothermal survey of North America: Houston, Gruy Federal, Inc., Report DOE/NV/10072-1 available from NTIS.

Reports on the preliminary definition of geothermal resources in the states of Illinois and Indiana have been transmitted to DOE for release and will be available through NTIS in several months.

Atlantic Coastal Plain
Geological Targeting and Evaluation
Progress Report

by

J. Lambiase
Virginia Polytechnic Institute and
State University

IV

Atlantic Coastal Plain Geological Targeting and Evaluation: Progress Report

Joseph J. Lambiase
Virginia Polytechnic Institute
and State University

Our exploration model for geothermal resources beneath the Atlantic Coastal Plain requires four criteria for a resource. These are: 1. a source of radiogenic heat in the crystalline basement complex underlying the Coastal Plain sediments; 2. a relatively thick sedimentary insulator; 3. relatively low thermal conductivity of that insulator; and 4. favorable reservoir conditions in the basal sedimentary units.

During the past year, we have drilled several test holes that were located to improve our knowledge of the crystalline basement, and to determine geothermal gradients and heat flow in previously unexplored areas; some of these holes constitute the first geothermal exploration in South Carolina and Georgia. Table 1 summarizes the depth, purpose for drilling, and geothermal gradient for each hole; all locations are identified in Figure 1. In the upcoming year, an additional basement hole will be drilled at the location indicated in Figure 1. Also, two geothermal gradient holes will be drilled at as yet undetermined locations.

Of the four criteria for a geothermal resource listed above, reservoir conditions in the basal sedimentary units is the least understood. Laczniak (1980) recently completed a mathematical modelling study of Atlantic Coastal Plain geothermal resources. He assumed a doublet system with a production well and a reinjection well in a semi-confined aquifer. Reservoir temperature was modelled through time assuming different values for permeability, well spacing and well production. The results indicate that Atlantic Coastal Plain resources can be viable for at least fifteen years of continuous pumping with adequate well spacing. Some of Laczniak's results are summarized in Figure 2 and 3.

Evaluation of reservoir potential must consider the size and geographic distribution of aquifers within the basal units of the Atlantic Coastal Plain. Generally, the basal units are wedge-shaped, and thicken from west to east. Also, the depth to the top of these units increases from west to east. The geographic distribution and size of sand bodies that are potential aquifers within these formations is controlled by the depositional system in which the sediments were deposited.

There are three general depositional systems that can be recognized in the basal Atlantic Coastal Plain sediments: non-marine, marginal marine and shallow marine. Non-marine deposits are characterized by relatively high sand/clay ratios and comparatively small sand bodies which tend to be physically adjacent so that they often form large, composite aquifer systems. Marginal marine deposits have relatively less sand, but tend to form large sand bodies that are more isolated from each other by clay deposits than are non-marine sand bodies. Shallow marine deposits have even lower sand/clay ratios but larger and more isolated sand bodies than marginal marine deposits. Generally, the basal Coastal Plain units tend to be more non-marine at the north and west, and more shallow marine at the east and south. Also, depositional system often changes vertically in the sedimentary section. Figure 4 depicts a hypothetical cross-section of a basal sedimentary unit showing its thickness and depth as well as the distribution of sand bodies within it assuming a non-marine to marine transition from west to east.

We are investigating the distribution of sand bodies within the Atlantic Coastal Plain sediments using drill hole and seismic data. There are few drill holes that penetrate the basal units, and electric logs from these holes indicate that there are several potential aquifers in these units (Figure 5). We are using VIBROSEIS reflection seismic data to determine the areal extent of potential aquifers, and to explore for potential aquifers in areas where there is no drill hole data.

In summary, much of our past year's effort has been aimed at locating and evaluating potential geothermal reservoirs. Also, several new drill holes have improved our knowledge of the crystalline basement, and initiated exploration in South Carolina and Georgia. In the coming year, we will continue to determine geothermal gradients and to explore for potential geothermal reservoirs.

Reference

Laczniak, R. J., 1980. Analysis of the relationship between output and well spacing in a typical Atlantic Coastal Plain geothermal doublet system. Unpub., M.Sc. thesis, Virginia Polytechnic Institute and State University.

Table 1

Drill Hole Data

Hole #	Location	Total Depth (m)	Geothermal Gradient ($^{o}c/km$)	Purpose for Drilling
26	Isle of Wight, VA	500	25	basement data
16A	Kinston, NC	219	23	basement data
13A	Myrtle Beach, SC	448	30	basement data
10	Charleston, SC	283	34	geothermal gradien
9	Salley, SC	353	18	basement data
7A	Savannah, GA	300	*3 —	geothermal gradien
KB	Kings Bay, GA	298	22	geothermal gradien
CP	Cove Point, MD	*1 1100	—	geothermal gradien basement data
59	Smith Point, VA	*2 1100	—	geothermal gradien basement data

*1 - In progress; estimated total depth
*2 - Estimated total depth
*3 - Gradient not yet determined

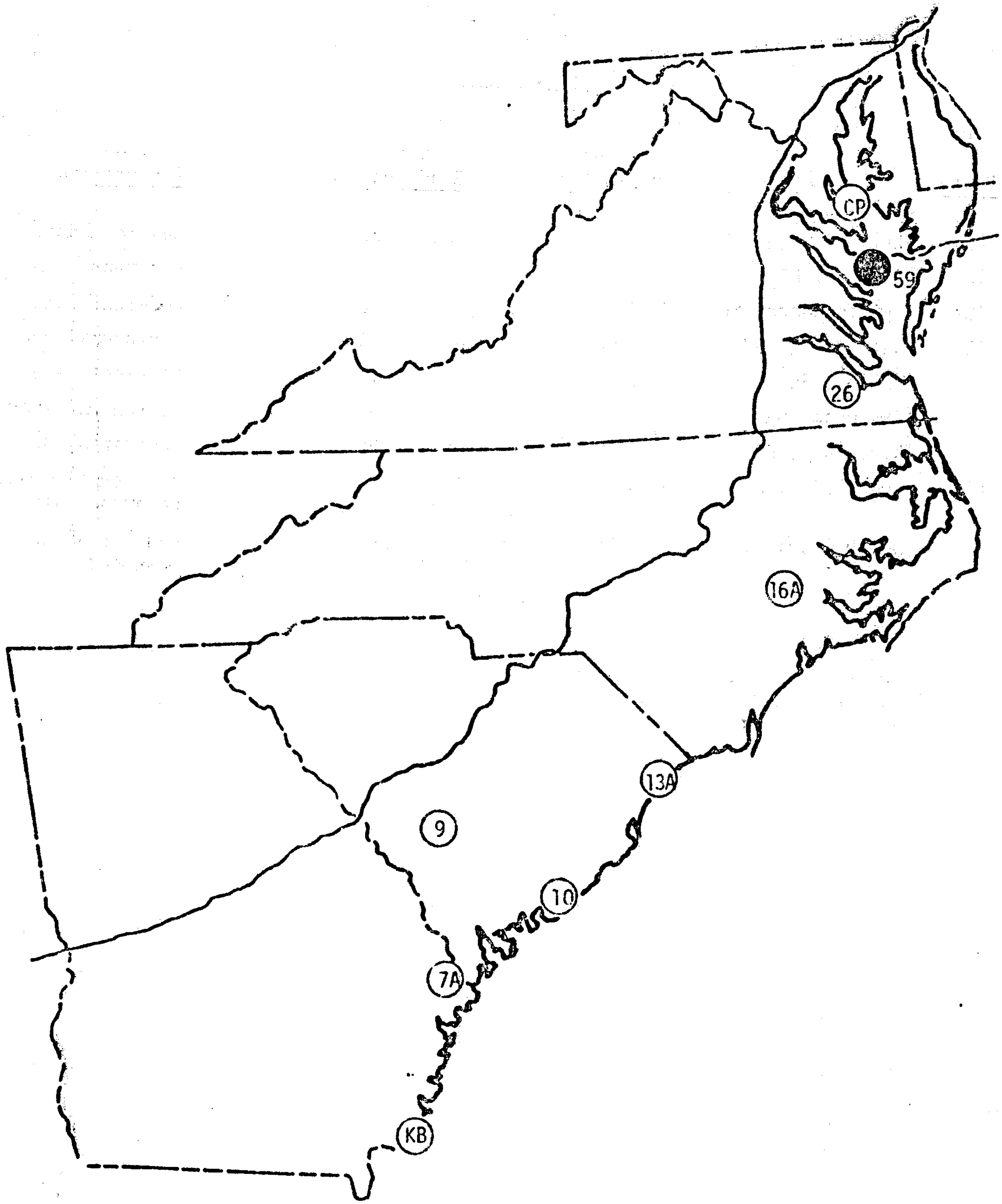


Figure 1. Locations of test holes drilled during the past year. The basement hole to be drilled next year is a filled circle.

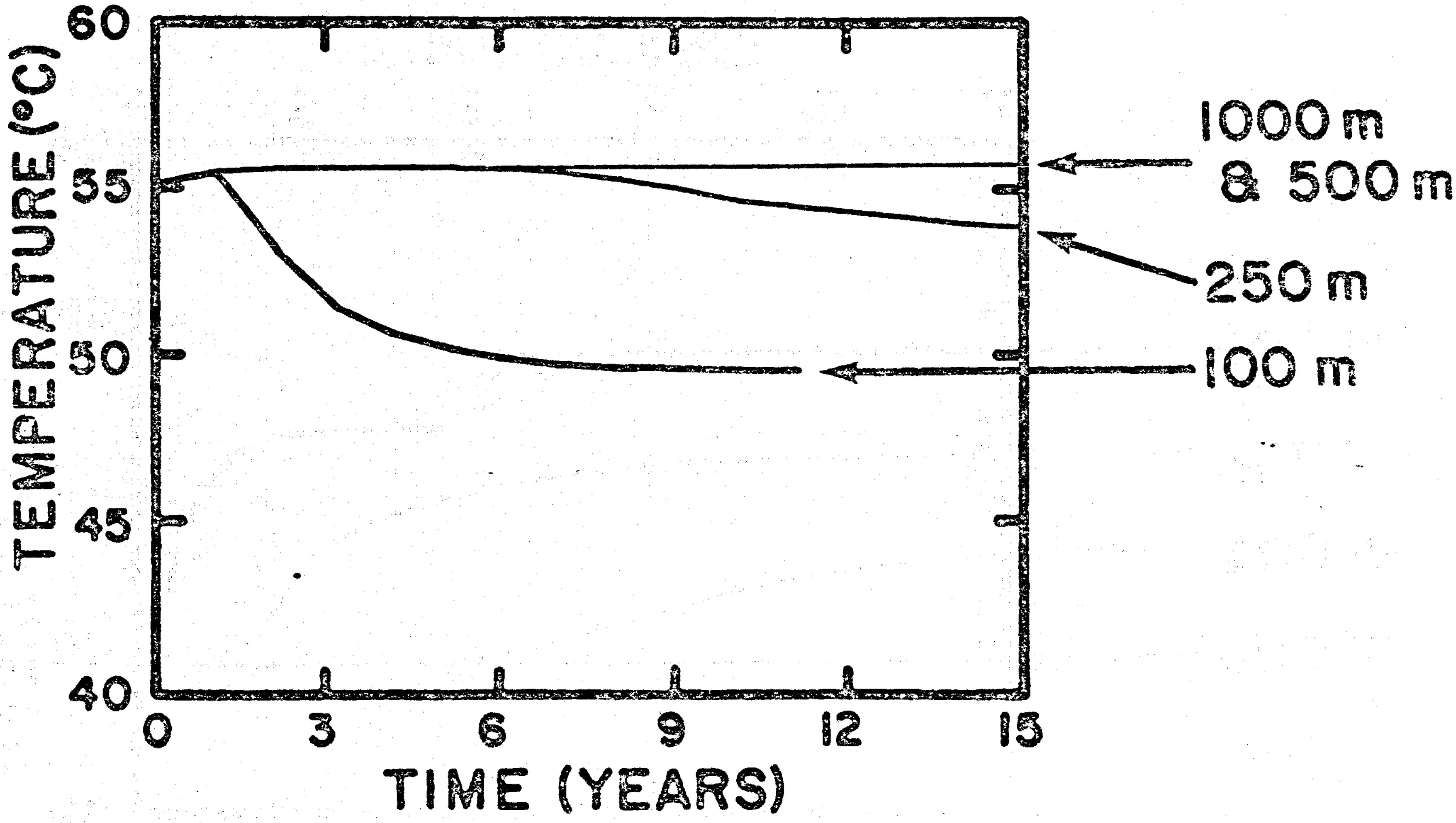


Figure 2. Production temperature versus time at the four specified well spacings assuming a pumping rate of 100 gpm and a permeability of 100 md.

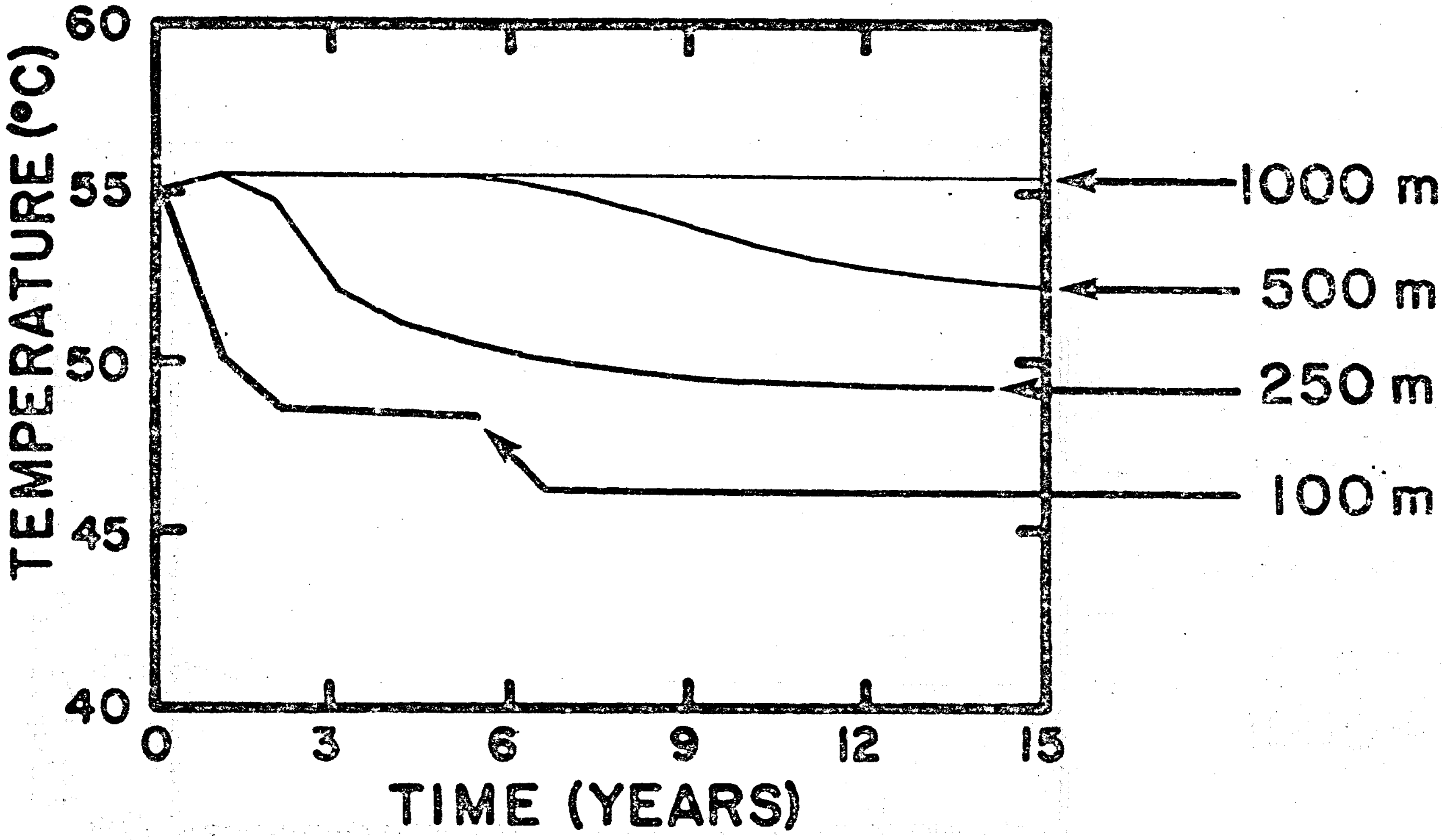


Figure 3. Production temperature versus time with the same conditions as in Figure 2 except that pumping rate is 500 gpm.

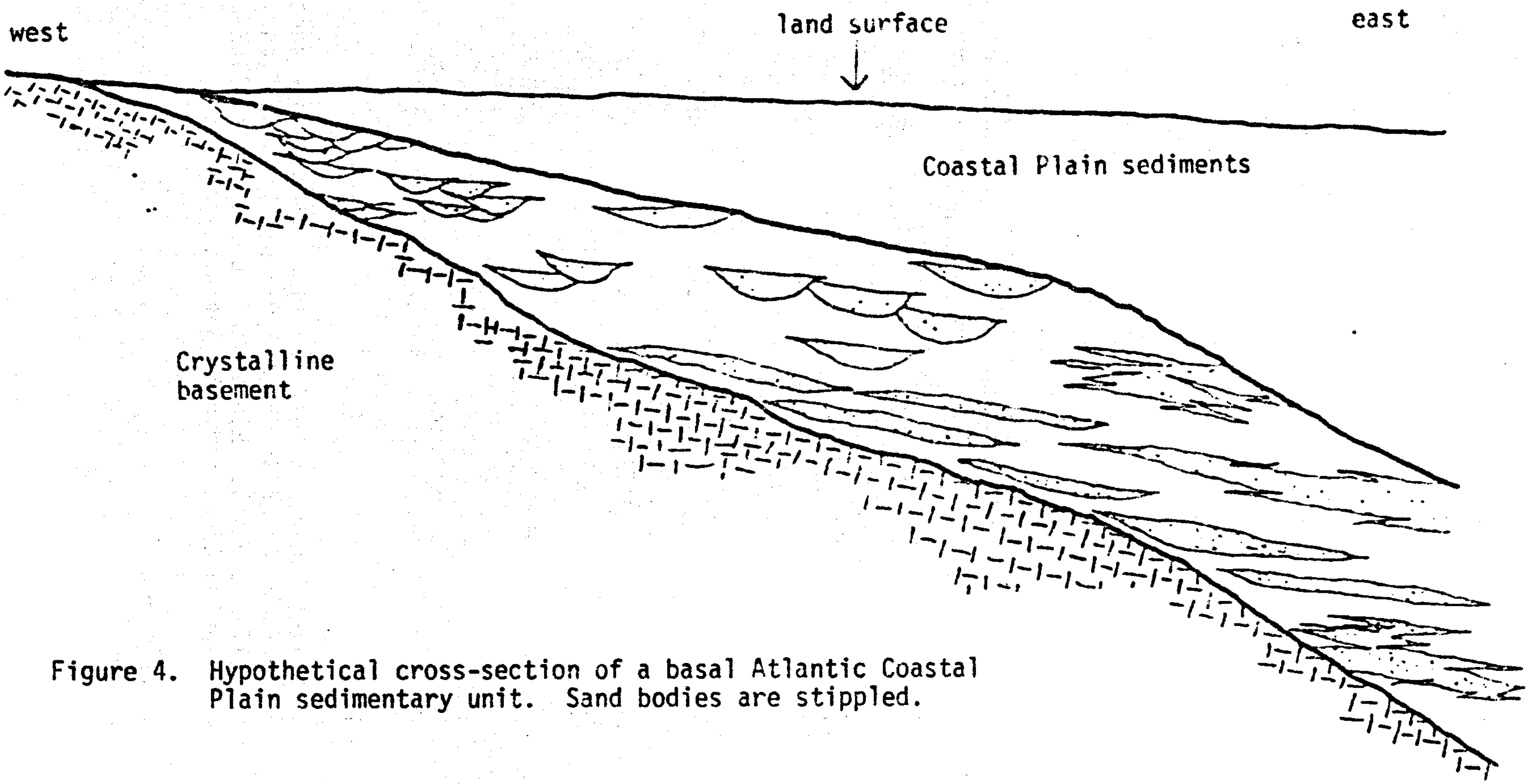


Figure 4. Hypothetical cross-section of a basal Atlantic Coastal Plain sedimentary unit. Sand bodies are stippled.

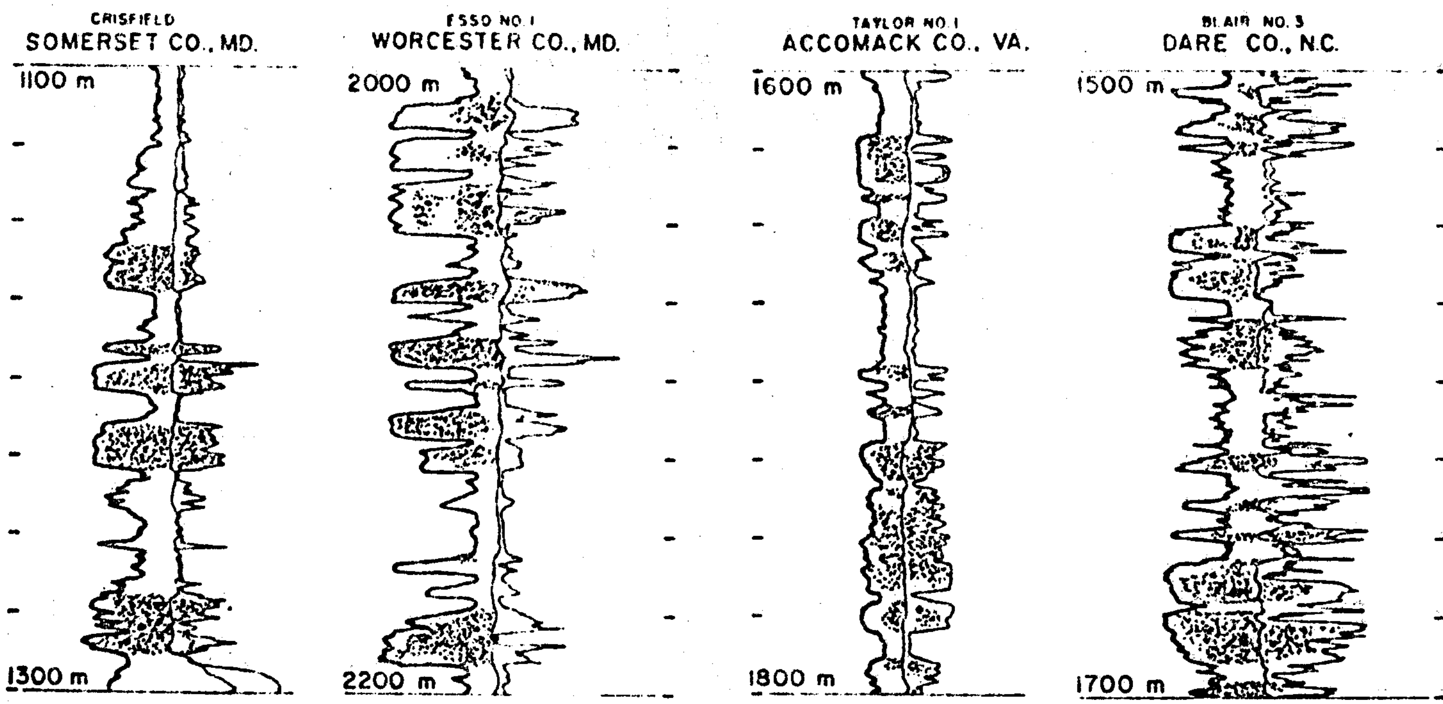


Figure 5. Selected parts of electric logs from deeper sections of four holes in Northern Atlantic Coastal Plain. Left-hand curve in each figure is self-potential. Right-hand curves are shallow and deep induction logs. Stippled areas indicate potential aquifers.

Nebraska Geothermal Resources

by

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NEBRASKA GEOTHERMAL RESOURCES

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Abstract

Analyses of existing data indicate that potential low-temperature geothermal resources are accessible to about two-thirds of Nebraska. This conclusion is supported by the results of temperature gradient measurements in shallow holes (60 m to 570 m) and bottom hole temperatures from deep oil and gas exploration wells which indicate that the subsurface temperatures in north-central and western Nebraska are significantly higher than would be expected for the continental platform. Geothermal gradients greater than 40 K/km are common for bottom hole temperature data from holes with depths of 1 km or greater. Preliminary results of 27 new heat flow measurements provide a means for understanding the thermal structure of Nebraska and lead to the conclusion that the high subsurface temperatures are due to large scale flow of warm waters from the Kennedy Basin in South Dakota and the Denver Basin in Colorado. Comparisons between shallow gradient measurements and the deep bottom hole temperatures are proving to be valuable as an assessment procedure. The bottom hole temperature data do identify areas with anomalous subsurface temperatures, and the heat flow data provide a means for interpreting the overall geothermal picture.

Introduction

The geothermal resource assessment of Nebraska includes the compilation of existing data, analyses of bottom hole temperatures logged in exploration wells, and surface heat flow measurements. The assimilation and interpretation of these data is in an advanced stage and it is expected that the ultimate goal of the project, i.e., the production of a user-oriented geothermal resource map, will be attained by mid-1981.

Existing Data

The assimilation of existing data is summarized by Gosnold (1979, 1980 a) and is shown as a composite map in Figure 1. An interpretation of the geothermal resource potential of Nebraska based on these data is depicted in Figure 2 from Gosnold (1980 a). Figure 2 is a temperature contour map for a depth of one kilometer with the constraint that the isotherms are drawn only where they lie within sedimentary formations that could potentially produce large amounts of water. Some of the sedimentary units of interest are the Dakota Group of Cretaceous age, the Lansing Group and Kansas City Group of Pennsylvanian age, the Hunton Formation of Silurian-Devonian age, and the St. Peter Sandstone of Ordovician age. The data indicate that about 67 % of Nebraska overlies a potential geothermal resource with temperatures greater than 40 °C at a depth of one kilometer. The 50 °C isotherm lies at depths ranging from 1.0 to 1.4 km within the potential resource area. Some local areas are evidently warmer because temperatures ranging from 70 °C to 105 °C have been recorded in wells ranging in depth from 1.3 km to 1.5 km in western Nebraska. An important feature of Figure 2 is that all temperature data used are from depths of one kilometer or greater and there is no extrapolation of shallow gradient data. The result is a reliable representation of the potential geothermal resource.

Bottom Hole Temperature Data

Compilation of bottom hole termperatures and stratigraphic data recorded for about 13,000 exploration wells is 60 % completed. These data will be used in several ways in the resource assessment. One of the products of this phase of the study will be a geothermal gradient contour map of Nebraska. The combination of this new map with the stratigraphic data will yield a refined version of the map shown in Figure 2. The bottom hole temperatures will also be compared to the shallow gradients measured in heat flow holes and in holes of opportunity, e.g., water wells. Comparisons of this type have been made for several areas in Nebraska and have produced interesting results, some of which are discussed later in this paper. The bottom hole temperatures and stratigraphic data will also be combined to produce temperature contour maps of those formations which have potential for producing large quantities of water.

Heat Flow Data

Twenty-seven new heat flow determinations are in progress (Gosnold, 1980 b) and the preliminary results are given in Figure 3. Some of the values are preliminary because thermal conductivities have not yet been determined and estimated conductivities are used. The estimated conductivities are the actual conductivities determined for other wells that penetrate the rocks in question. The drill holes used range in depth from 150 m to 570 m and all but one were completed for heat flow measurements. The one exception is a mining test hole that has a total depth of 570 m and penetrates about 420 m of Precambrian crystalline rocks on the Nemaha Ridge in southeastern Nebraska.

Sixteen of the heat flow values are greater than 84 mW/ m^2 (2 H.F.U.) and eight of the values are greater than 125 mW/ m^2 (3 H.F.U.). These values are markedly greater than expected for the Great Plains on the basis of previous conventional heat flow studies (Roy, Blackwell, and Decker, 1972; Combs and Simmons, 1973; Lachenbruch and Sass, 1977). However the values are consistent with the heat flow map of the United States produced by Swanberg and Morgan (1979) on the basis of geochemical data. An analysis of the heat flow data may be obtained by use of the continental heat flow model of Vitorello and Pollack (1980) to predict a hypothetical heat flow value for the Great Plains. According to Vitorello and Pollack (1980) the heat flow components for a continental platform should be 27 mW/ m^2 from the mantle, 18 to 36 mW/ m^2 from the radioactive crust, and a zero tectonic component. This gives a range of hypothetical heat flow values of 45 mW/ m^2 to 63 mW/ m^2. These hypothetical values are useful in interpreting the measured heat flow values because they provide a reasonable estimate of the magnitude of any additional heat sources. In this case the additional heat sources are on the order of 40 mW/ m^2 to 130 mW/ m^2. These values for additional sources are far greater than could be reasonably expected for additional crustal radioactivity or mantle sources and are interpreted to be due to convective heat transport in the upper crust.

The existence of a large convective heat flow component in Nebraska is consistent with the heat flow map of Swanberg and Morgan (1980) and it could not have been anticipated by the previous conventional heat flow studies because they included no data from Nebraska. Two separate convective systems could account for the high heat flow values in Nebraska. One system underlies the north-central part of Nebraska and the south-central part of South Dakota. In this region, which includes the Kennedy Basin, warm water from the Madison formation may enter the Dakota Group through a subcrop connection beneath South Dakota and flow within the Dakota Group through parts of South Dakota and Nebraska. Warm waters are encountered in numerous wells penetrating the Madison and the Dakota in South Dakota (Schoon and McGregor, 1974) and 12 water wells in north-central Nebraska produce warm water from the Dakota Group. Four of the 12 Nebraska wells reach the Dakota at depths ranging from 260 m to 296 m and flow at rates ranging from 4 gpm to 150 gpm with water temperatures averaging about 28 ^{o}C (Souders, 1976). A temperature of about 30 ^{o}C in the Dakota Group would cause temperature gradients of about 75 K/ km in the regions overlying the Dakota Group. This value generally agrees with the least-squares gradients determined for near by heat flow holes. Figure 4 is a hypothetical gradient curve and heat flow model for north-central Nebraska showing the effect of the shallow heat source. It is important to note that the high surface-gradients do not continue below the heat source.

A different convective system is postulated to account for the high heat flow in western Nebraska. Figure 5-a is a structure-coutour map of the top of the Dakota Group from Volk (1972) and Figure 5-b is a cross section along the line A-A' in Figure 5-a. It is proposed that meteoric water enters the Dakota along its outcrops at the western margin of the Great Plains and flows within the formation through Colorado and Wyoming into Kansas and Nebraska. The flowing water would be heated significantly at depths of $2\frac{1}{2}$ km in the

Denver basin and would carry a large amount of heat into Nebraska and Kansas as depicted in Figure 5-b. It is important to note that the large scale water flow system is not known from other geological studies and is merely inferred from the heat flow data collected in this study. However it is considered that such a system is the most reasonable explanation for the high heat flow values in western Nebraska.

Comparisons between shallow gradient data from the heat flow holes and the bottom hole temperature data are shown in Figures 6, 7, and 8. In general the bottom hole temperatures are lower than would be predicted by extrapolation of the shallow gradients. A good example of the differences between the two data sets is seen in Figure 8. There the temperatures from the heat flow holes are plotted at 10 m intervals and the bottom hole temperatures are plotted as single points indicated by letters A, B, & C and numbers 1 thru 12. Figure 9 is a map showing the relative locations of the wells. The heat flow holes in Figures 8 & 9 are gas exploration wells that were completed for heat flow and the original bottom hole temperatures are indicated by the letters. Well "C" has not yet been logged and no bottom hole temperature is available for well "B". The wells were cemented from their bottoms up to the top of the Niobrara Formation about one year before the temperature gradients were measured. Extrapolation of the equilibrium gradients to the maximum depths of the holes, indicated by A & C, shows that the original bottom hole temperatures are about 10 °C to 15 °C low. In general, the comparisons between the two data sets show good agreement and lead to two conclusions: 1) The bottom hole temperature data set does identify areas of anomalous subsurface temperatures. 2) The bottom hole temperature data set probably represents the minimum temperatures to be expected at a given depth.

Concluding Remarks

The existing data indicate some potential for low temperature geothermal resources in Nebraska, and this is borne out by heat flow determinations and by analyses of bottom hole temperature data. The bottom hole temperature data are useful as a large data set for identifying potential resource areas. The heat flow values are extremely useful in the interpretation of subsurface temperatures in sediment covered areas like the Great Plains.

Acknowledgements

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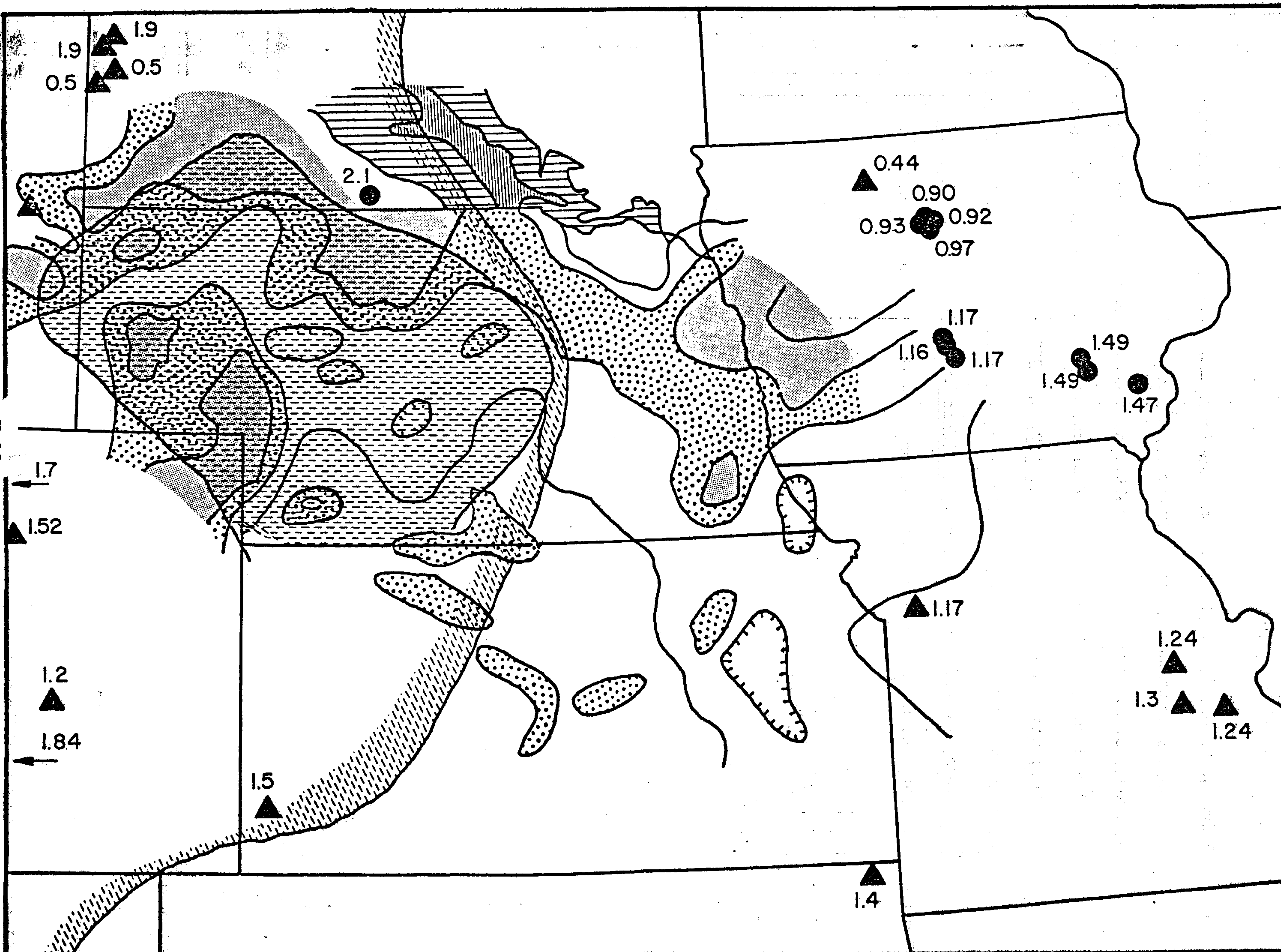
1.9
1.9
0.5
0.5
2.1
0.44
0.90
0.93
0.92
0.97
1.17
1.16
1.17
1.49
1.49
1.47
1.7
1.52
1.17
1.24
1.3
1.24
1.2
1.84
1.5
1.4

Figure 1.

Summary of existing data on the geothermal regime of Nebraska (from Gosnold, 1980 a).

LEGEND

		Ref.
	1.9 Heat flow in HFU (1 HFU = 41.8 mw/m^2)	(1)
	1.5 HFU contour line	(2)
	$\Delta T/\Delta X$ 33°C/km	(3)
	$\Delta T/\Delta X$ 36°C/km	(3)
	$\Delta T/\Delta X$ 54°C/km	(4)
	$\Delta T/\Delta X$ 91°C/km	(4)
	Silica geothermometry anomaly	(5)

References: (1) Combs and Simmons, 1973, (2) Sass et al., 1976, (3) AAPG Geothermal Gradient Map of North America, 1976, (4) Schoon and McGregor, 1974, (5) Swanberg and Morgan, 1979.

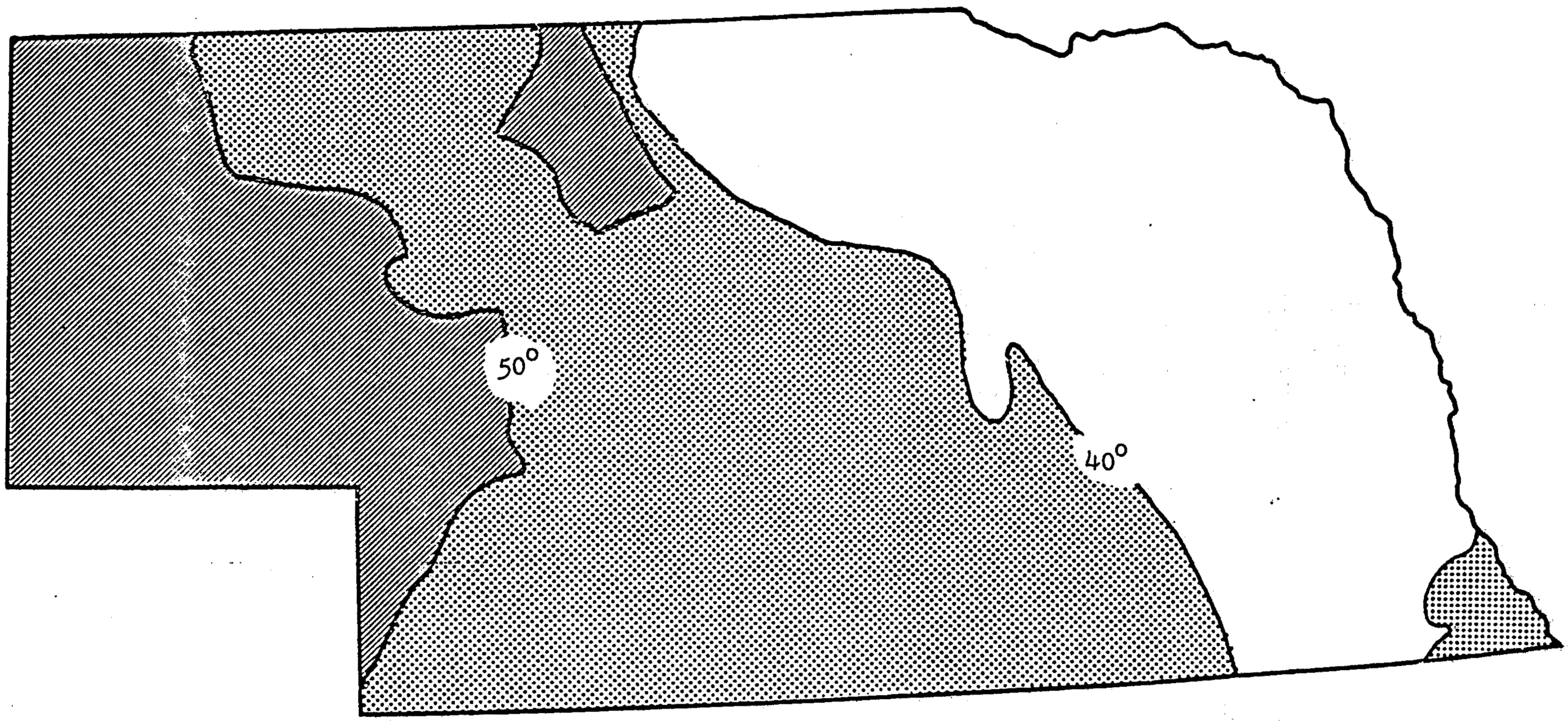

Figure 2. Temperature contours at a depth of one kilometer as inferred from existing data. See text for explanation.

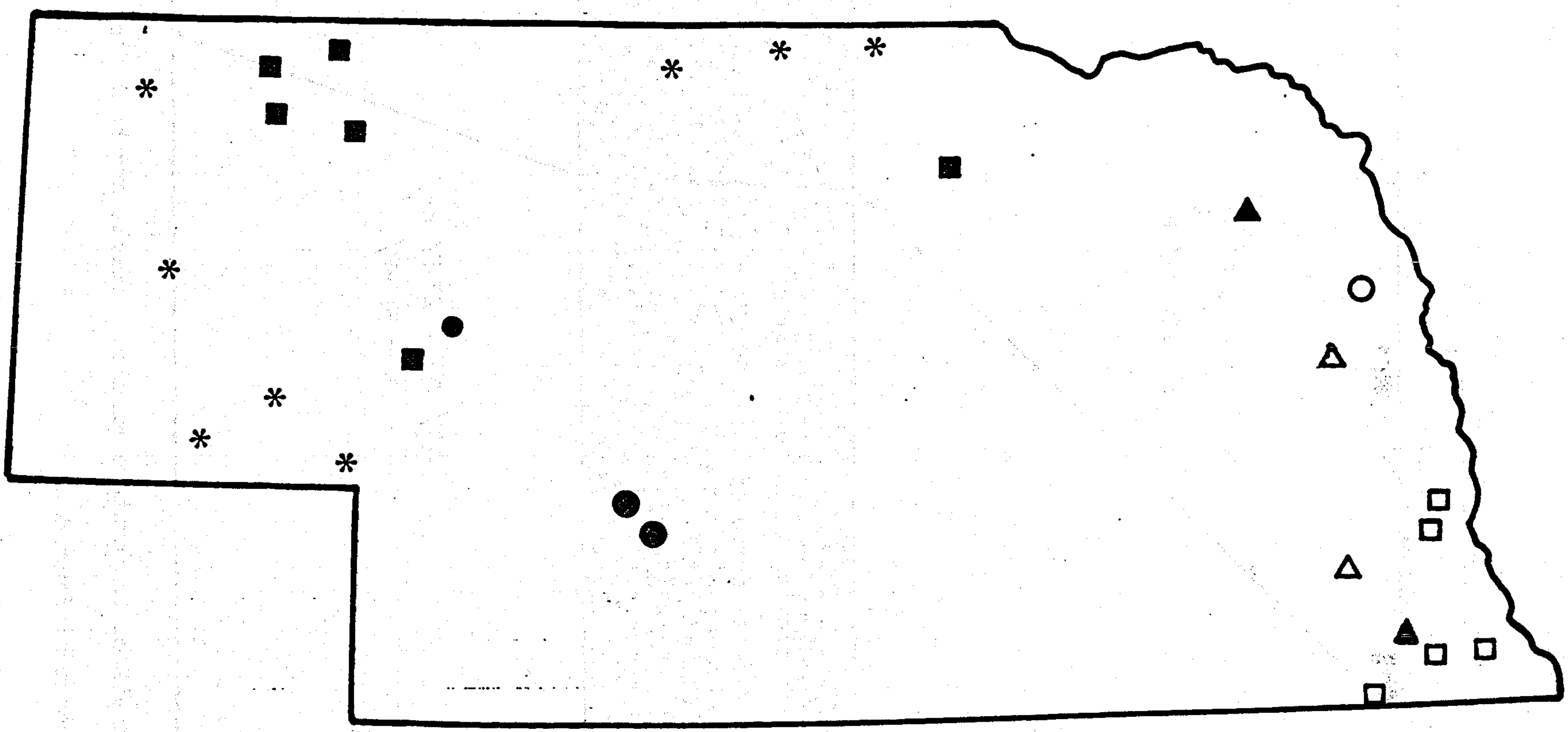

Figure 3. Preliminary heat flow map of Nebraska.

Key: (Units are mW/ m^2) ○ = 30-50; □ = 50-60; △ = 60-70; ● = 70-80; ■ = 80-100; ▲ = 100-120; ✱ > 120.

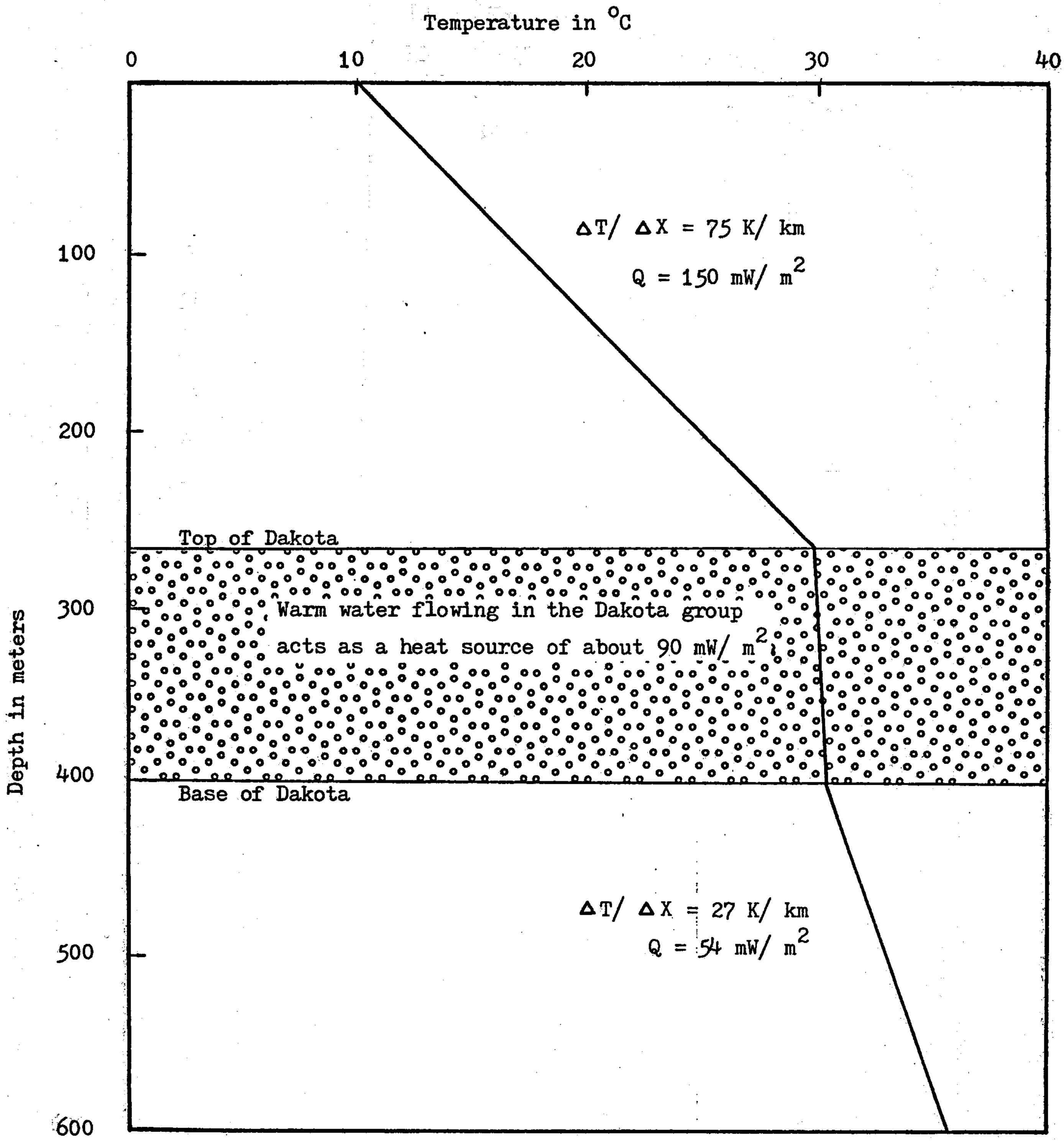

Figure 4. Hypothetical temperature gradient profile and heat flow model for north-central Nebraska.

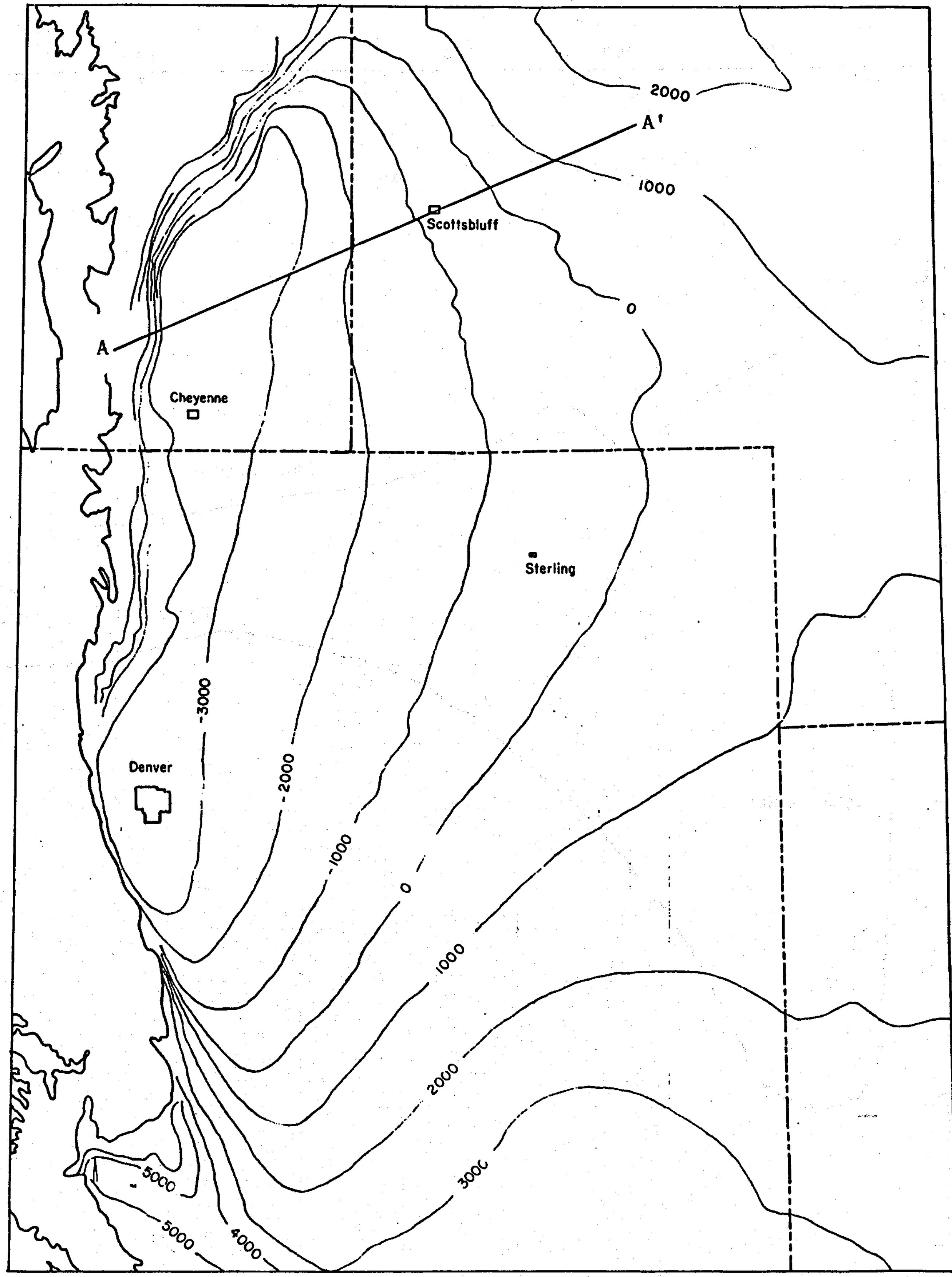

Figure 5 a. Structure contour map of the Dakota group from Volk,(1972).

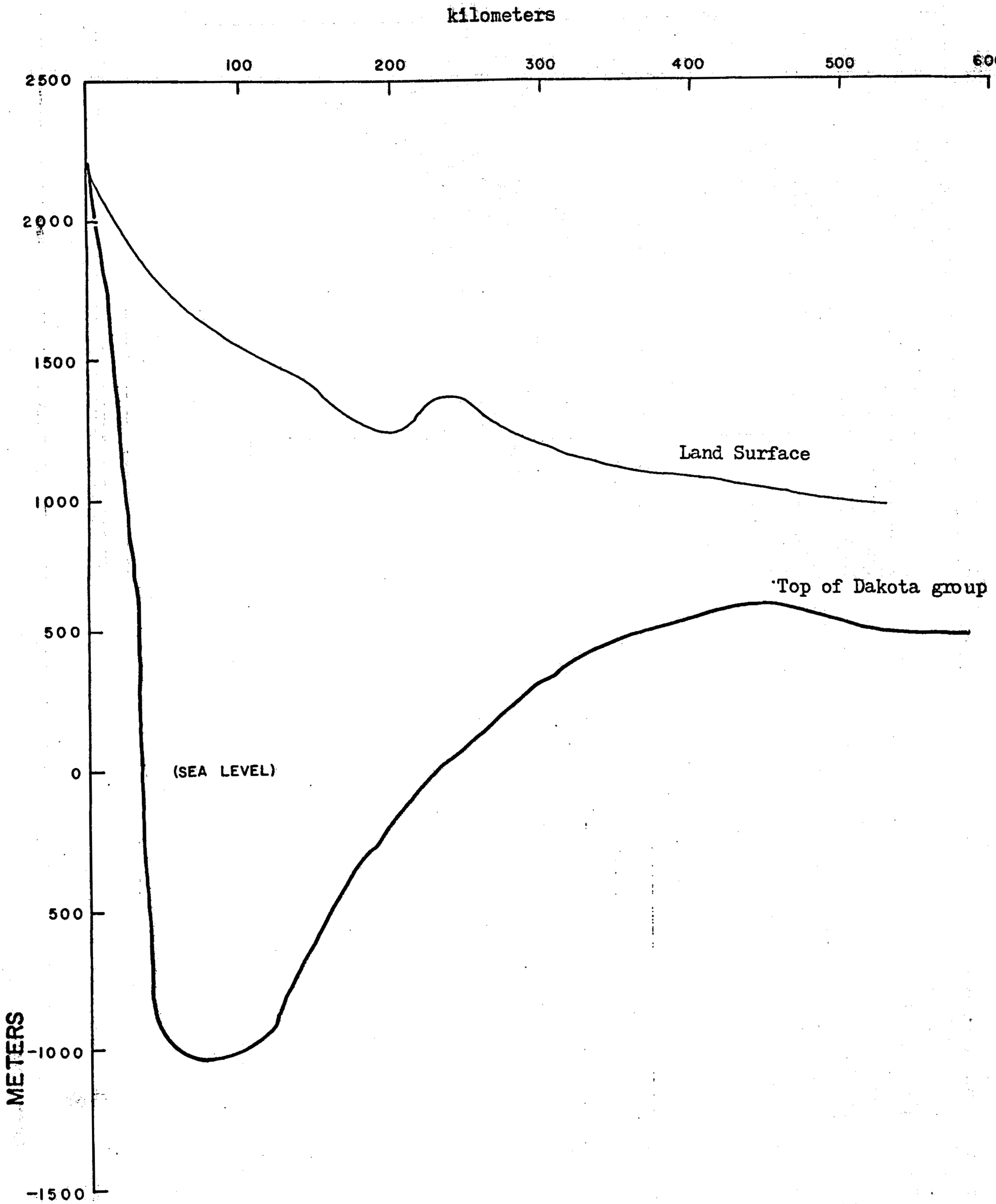

Figure 5 b. Structure cross section along line A A' in Figure 5 a. Note the elevation for the Dakota along the outcrop compared to its elevation beneath Nebraska.

V-17

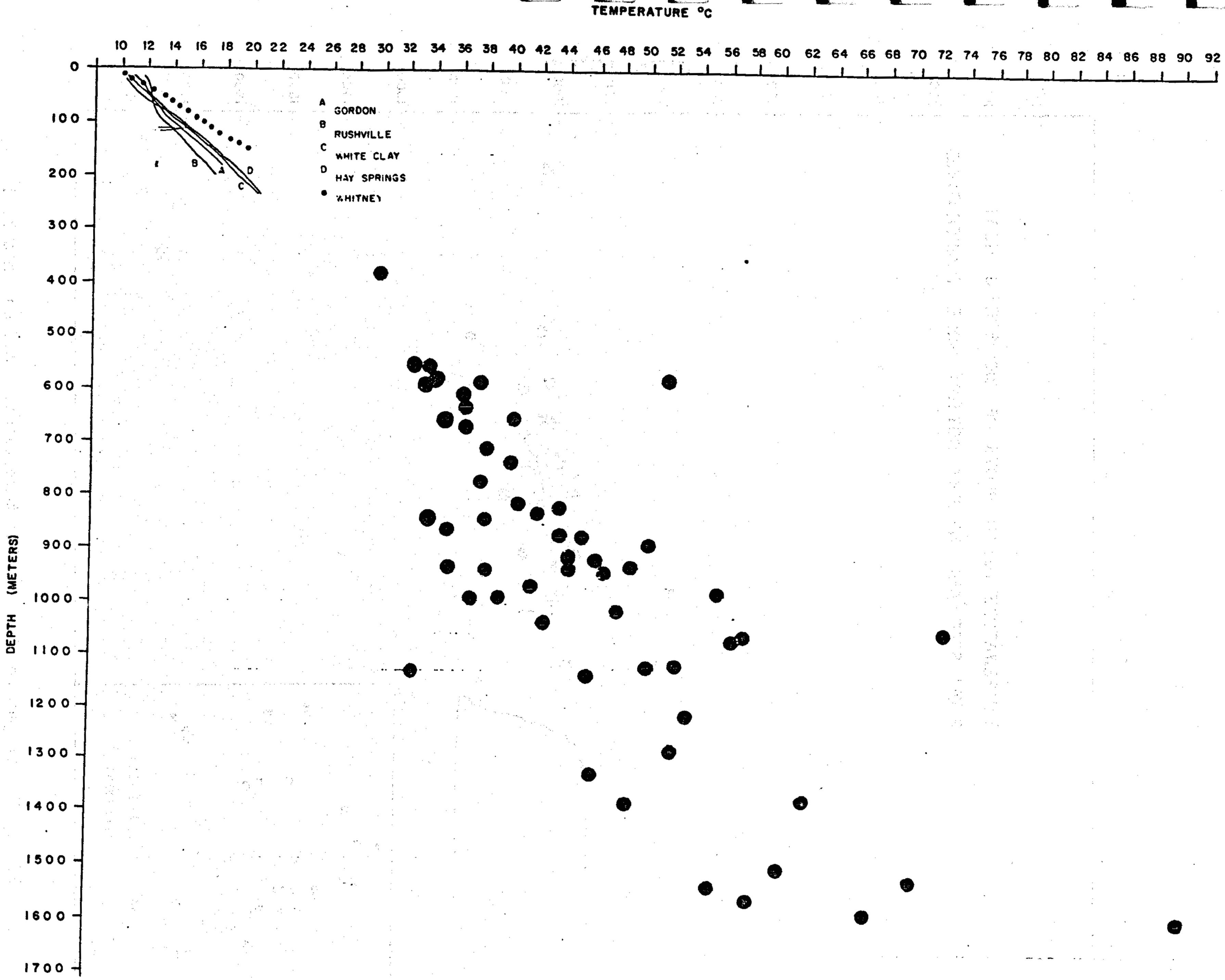

Figure 6. Comparison between gradients in heat flow holes and bottom hole temperatures in western Nebraska.

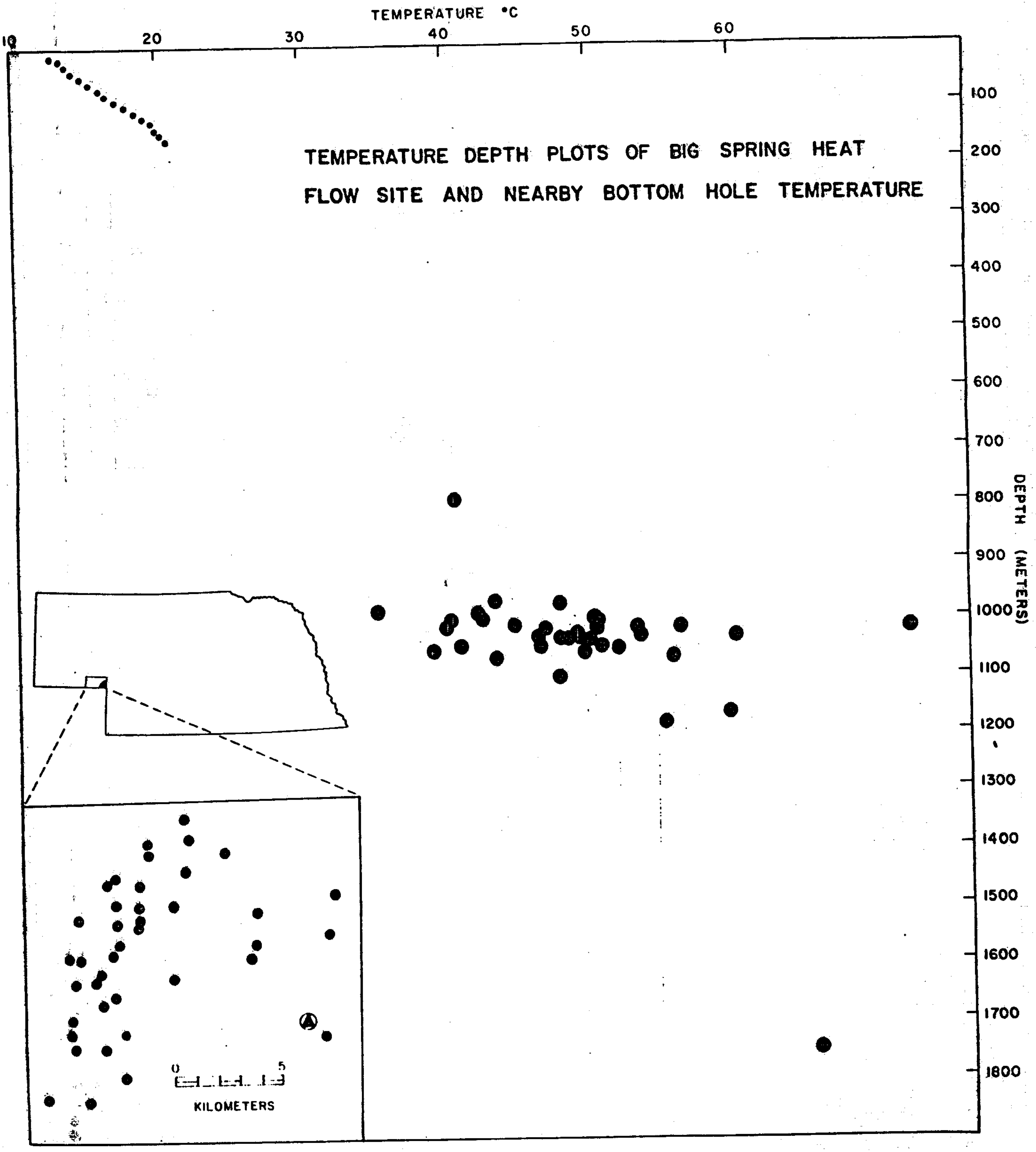

Figure 7. Comparison between the temperature gradient in a heat flow hole and bottom hole temperatures in Deuel County.

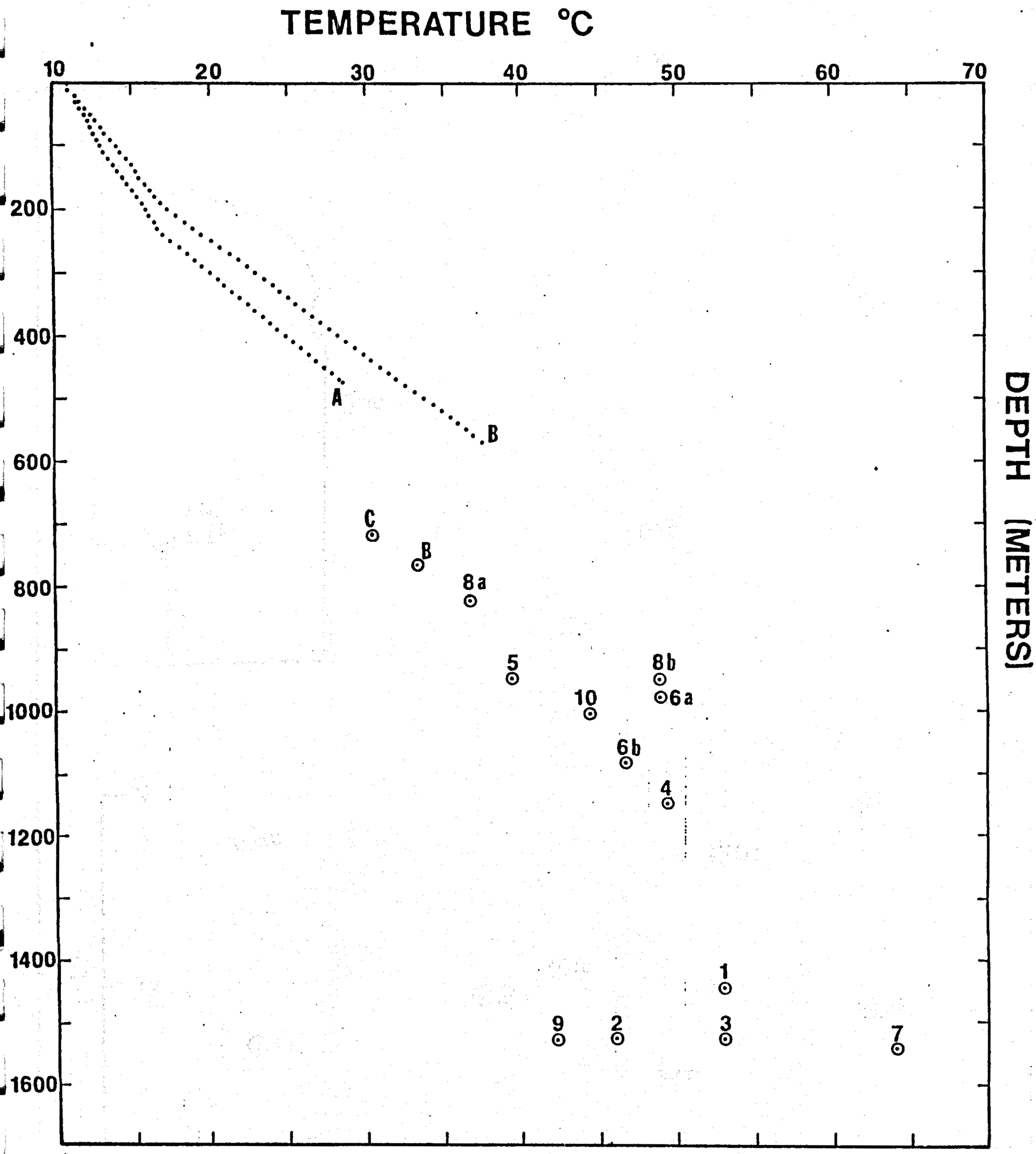

Figure 8. Temperature-depth plot of two heat flow holes and 12 bottom hole temperatures. See text for explanation.

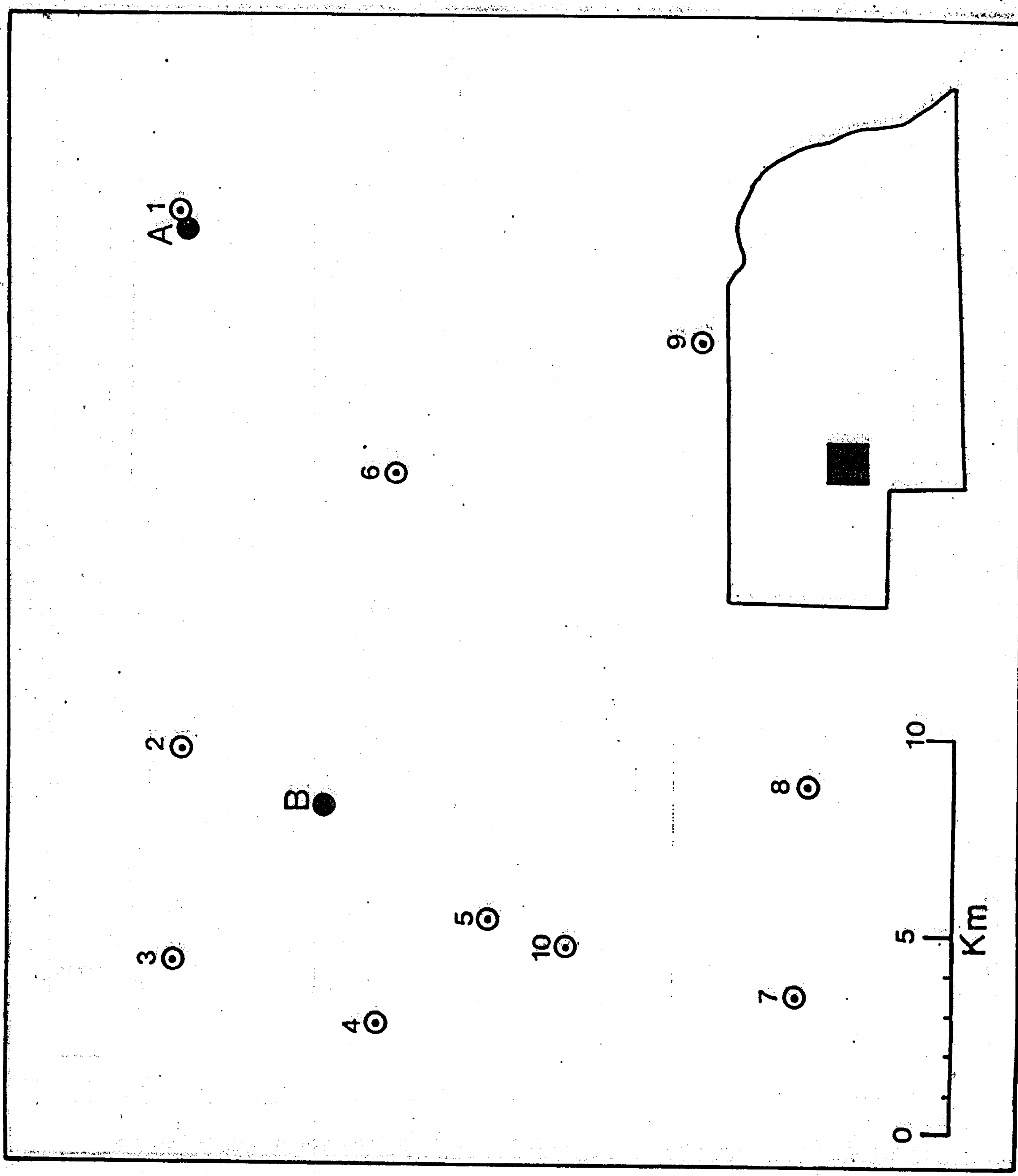

Figure 9. Location map for well data plotted in Figure 8.

Ohio Geothermal Resources
(HDR Program)

by

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VI

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A LOW ENTHALPY CONVECTIVE SYSTEM IN WESTERN OHIO

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ABSTRACT

A distinct positive anomaly in the temperatures of the shallow (Pleistocene) aquifers along the Cincinnati-Findlay Arch in Western Ohio coincides with a low geothermal gradient. A conceptual model of convective currents associated with a tensional fault and/or fracture system along the crest of the Arch is suggested as an explanation of the anomaly. Hydrochemical information indicates that various quantities of warmer ground water, with the composition characteristics of deep bedrock aquifers, is present as an admixture in the shallow aquifers. This confirms the conceptual model of convection in fractures.

INTRODUCTION

An analysis of a network of 370 bottom hole temperature readings recorded in various oil and gas boreholes throughout Ohio indicates rather low to moderate increases in temperature with depth. The range is between 15^{o} and 25^{o}C per kilometer. The lowest values for the geothermal gradient coincide with the area of the Cincinnati-Findlay Arch. Remarkably, the analysis of ground water temperatures at depths of 50 to 150 feet shows a prominent positive anomaly, which coincides with the Arch. The inverse correlation between the geothermal gradient and temperatures in the shallow aquifers is of particular interest, as it signals a deep convective system.

BASEMENT SURFACE

The Precambrian basement rocks in Ohio, none of which are exposed at the surface, are known from cores and cuttings obtained from wells drilled for oil and gas. Figure 1a shows the shape of the Precambrian basement surface which defines a broad plateau-like structure in western Ohio, identified by Green (1957) as the Indiana-Ohio platform. This feature relates very generally to the Cincinnati Arch. Eastward of the Arch, the basement slopes down at an accelerated rate, increasing from an approximate 40 feet per mile to more than 100 feet per mile, delineating the western margin of the Appalachian basin.

Cores and cuttings from eastern and central Ohio indicate that the basement consists of a metamorphic complex dominated by quartzo-feldspathic gneiss and smaller amounts of quartz-mica schist, amphibolite, marble, and associated calc-silica rocks (Figure 1b). It appears that the western one-third of Ohio is underlain by Precambrian quartzo-feldspathic rocks, including gneiss as well as more massive rocks classified as granite. Additionally, several fine-grained igneous rocks have been classified as rhyolite and trachyte (McCormick, 1961).

Sr-Rb and K-Ar age determinations on biotite and muscovite from the basement rocks in Ohio, fall in the range 870-940 m.y., with the exceptions of Sr-Rb ages of two trachyte and rhyolite samples. These two samples yielded ages which average 1260 m.y. (Lidiak et al., 1966).

No rocks younger than Precambrian have been identified in the buried basement complex in Ohio.

GRAVITY DATA

Figure 1c represents a compilation of various regional and detailed gravity surveys carried out by Heiskanen and Uotila (1956), Woolard and Joesting (1964), Pincus (1960), Newhart (1975), Haidarian (1976), Williams (1976), and Quick (1976).

Most of the major anomalies shown in Figure 3 represent density contrasts within the Precambrian basement complex. The greater wavelength and smaller amplitude anomalies of eastern Ohio may be due to both increasing depth to the basement complex and decreasing heterogeneity of the complex. The higher magnitude and more complex anomalies of western Ohio are probably due to greater heterogeneity of the basement.

Four major anomalies in northwestern Ohio were interpreted in detail (Pincus, 1960). Three of these were positive and are related to gabbroic or amphibolitic masses, and one large negative anomaly is related to deep granitic bodies.

GEOTHERMAL REGIME

Preliminary evaluation of the geothermal potential in Ohio was initiated with special interest directed primarily towards the areas defined by the negative Bouguer anomalies associated with the quartzo-feldspathic rock masses in

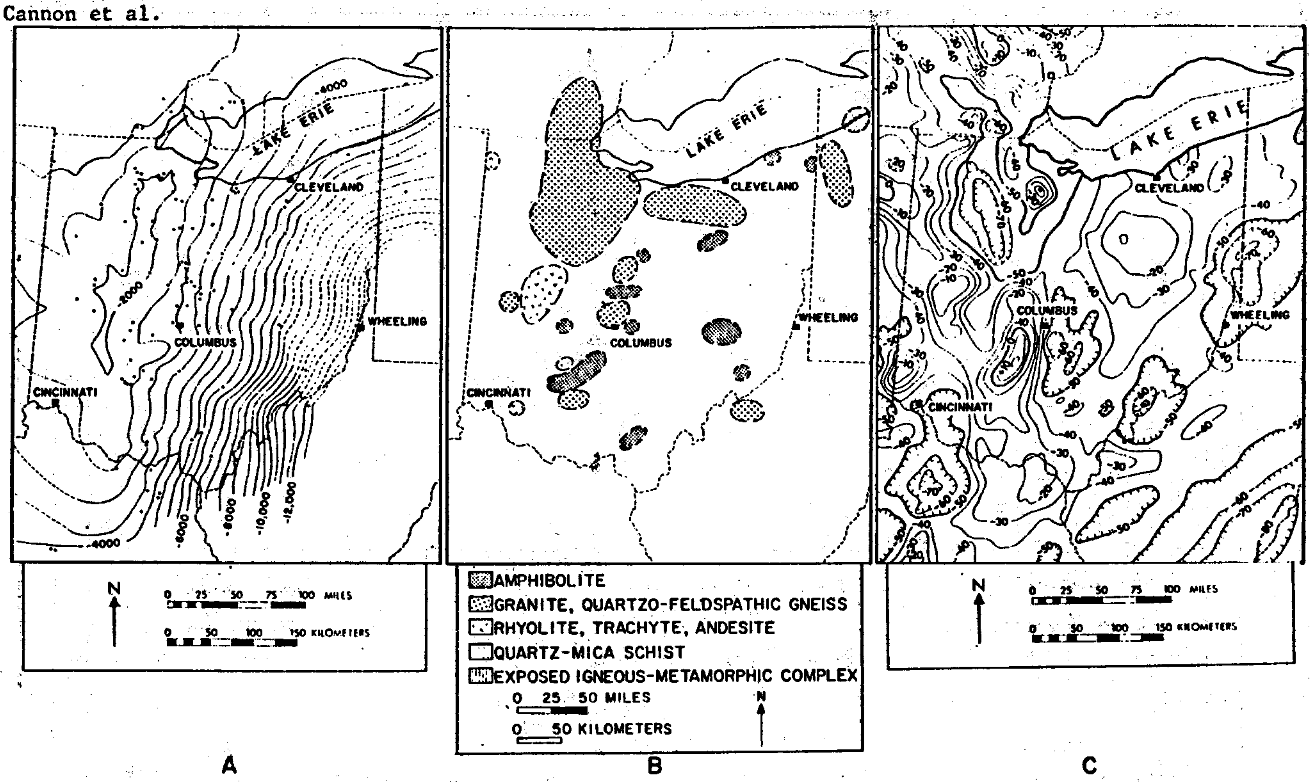

Fig. 1. a - Precambrian basement surface; b - Basement lithology; c - Bouguer anomaly.

the western part of the state. It was assumed that the body of the quartzo-feldspathic rocks, buried under more than 2000 feet of the sedimentary blanket, may generate enough radiogenic heat to maintain an anomalous geothermal gradient in the region. A map of the geothermal gradient in Ohio, prepared on the basis of a network of 370 bottom hole temperature readings in oil and gas boreholes

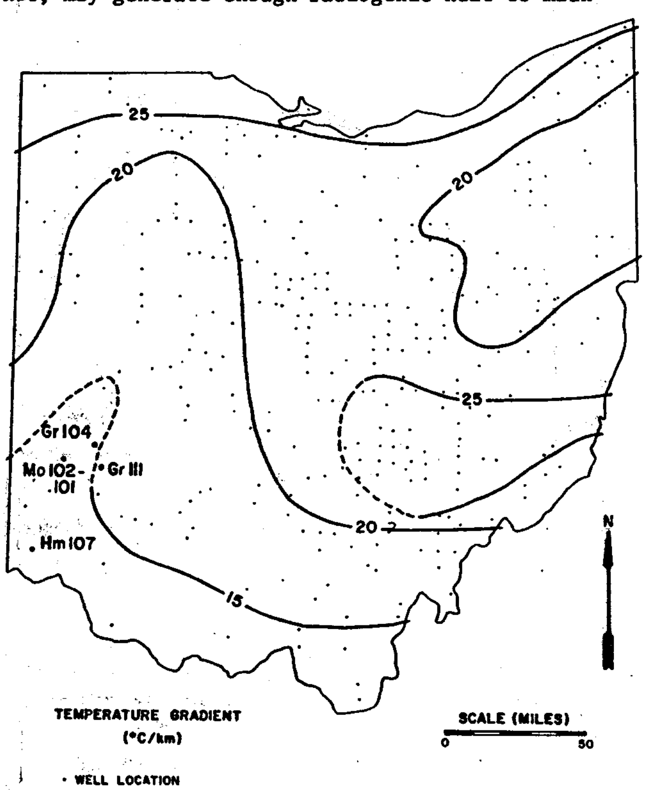

Fig. 2. Geothermal gradient in Ohio.

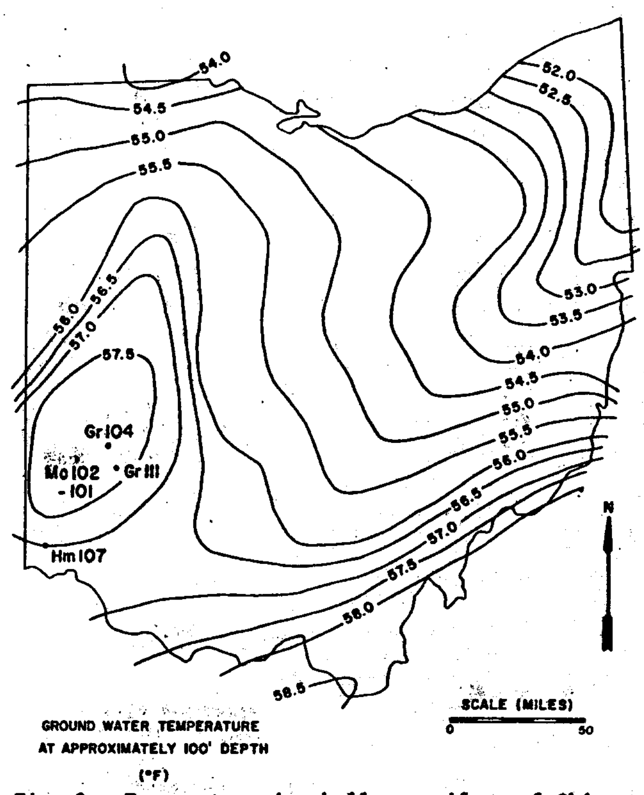

Fig. 3. Temperature in shallow aquifers of Ohio.

(Fig. 2), did not reveal, however, any distinct positive anomaly. One remarkable feature was the close association of the Cincinnati Arch with a mildly low geothermal gradient, ranging from less than 15° up to 20°c/km (Fig. 2). Comparison of the geothermal gradient map with the shallow (50-150 feet) ground water temperature map (Fig. 3), revealed a surprising inverse correlation between the two maps. The most distinct feature on the ground water temperature map is the prominent high, striking roughly in the northward direction along the Cincinnati-Findlay Arch in the western part of the state. This feature is associated with the low geothermal gradient on Figure 2. The topography of the region is fairly flat. Therefore,

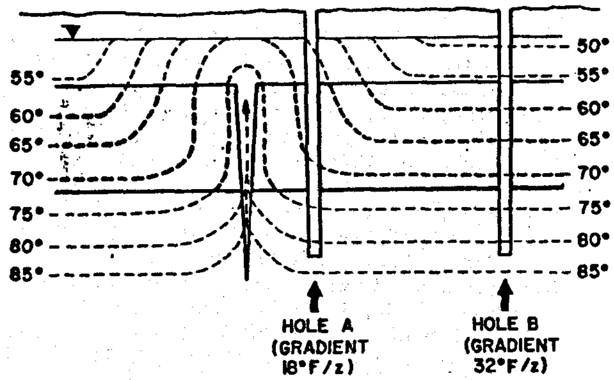

Fig. 4. Three-layer (aquifer/aquiclude/aquifer) conceptual model of the temperature field around a fracture-convecting system.

it has to be concluded that the higher temperature of the ground water along the ridge of the Cincinnati Arch is a result of a deeper convective ground water movement, probably along a system of faults and vertical fractures. A conceptual model of the system is shown in Figure 4.

HYDROGEOLOGIC SETTING

The stratigraphic and structural setting of the model is depicted on Figure 5.

The ground water potential in western Ohio is dependent on recharge to the carbonate aquifers.

The permeability of the aquifers is generally derived from secondary porosity including joints, fractures, and solution channels. The carbonate aquifers are confined beneath a layer of glacial till ranging in thickness from 20-40 feet throughout most of the area, except where closely associated with buried valleys. Much of the recharge to the aquifers is derived from vertical leakage through the confining layer.

The mechanism of differentiation between negative (downwards) and positive (upwards) convection in the fractures and its distribution relative to the structure is not apparent at this stage. Both negative and positive convection may produce low geothermal gradient, but only positive anomaly in the temperatures of shallow ground water (Figures 3&4).

HYDROCHEMICAL EVIDENCE

Based on the assumption that a positive convective flow would bring into the shallow aquifer not only warmer water, but also some anomalous chemical concentrations of dissolved solids, an extensive compilation of the chemical data from wells located along the Arch was carried out. An early confirmation of the model by hydrochemical data was found in wells from Greene, Montgomery and Hamilton counties. Wells Mo. 102 and Gr. 104 are both shallow, penetrating Pleistocene sediments, whereas Gr. 111 is deeper, drilled into the Trenton formation (Fig. 5). Water from Mo. 101 & 102 has the highest concentration in dissolved solids, and is warmest compared to all the wells drilled in the Pleistocene aquifer in the study area (Fig. 6).

Graphical representation of the analysis, following Piper method (Piper 1953), indicates

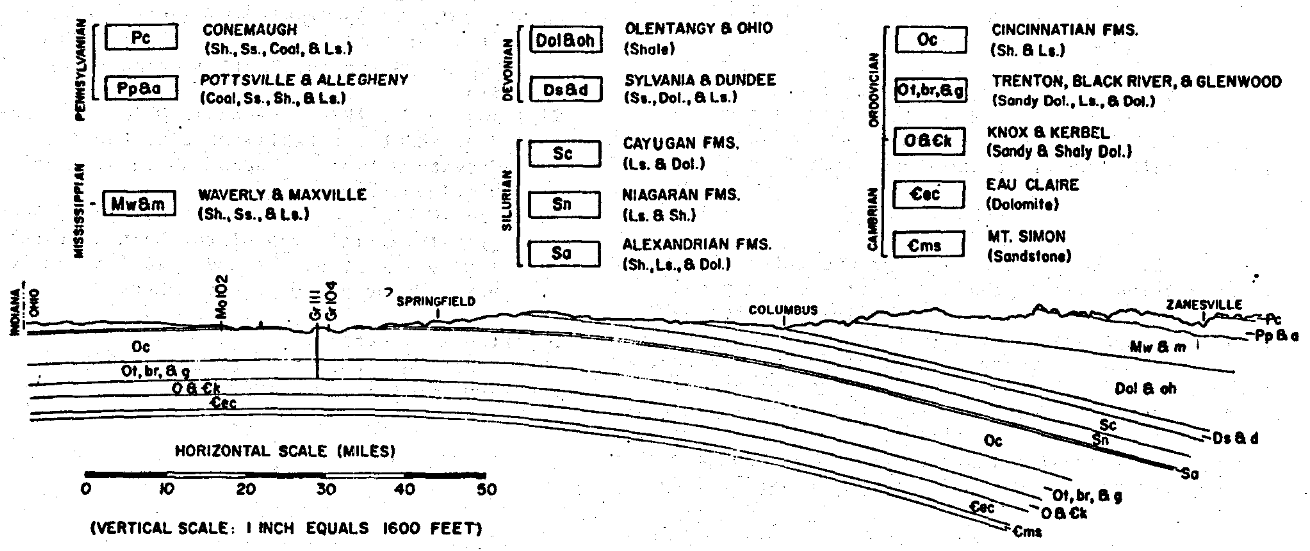

Fig. 5. Generalized stratigraphic and structural section across Ohio.

that the composition of Mo. 102 can be obtained by mixing 98% of the water from Gr. 104, and 2% of the water from Gr. 111 (Fig. 7). A similar mixing pattern may be recognized in the water from Mo. 101.

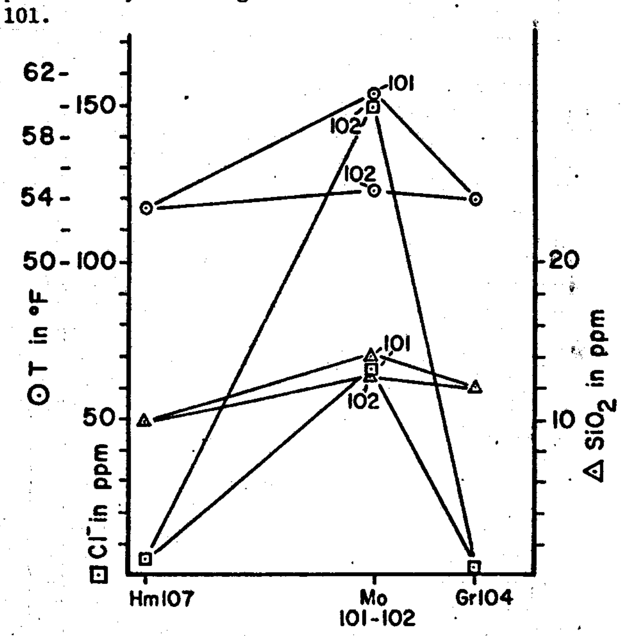

Fig. 6. Chloride and silica concentrations and temperatures in shallow aquifers on Cincinnati Arch

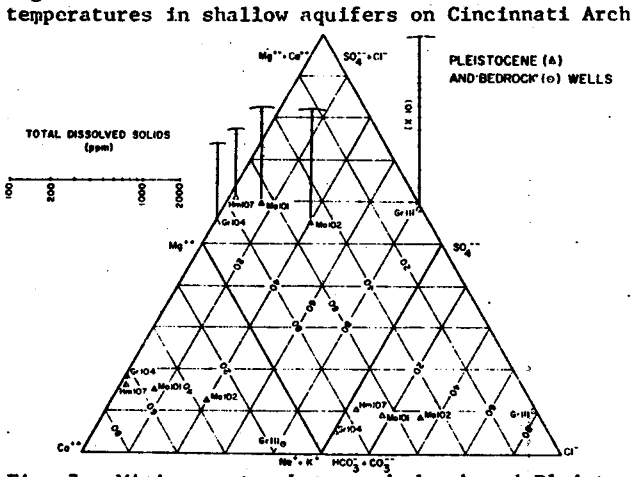

Fig. 7. Mixing system between bedrock and Pleistocene aquifer water of the Cincinnati Arch.

CONCLUSIONS

A distinct admixture of ground water with the composition that is characteristic for deep bedrock formations, found in a shallow Pleistocene aquifer represents sufficient confirmation for the proposed model. Consequently, it is implied that a geothermal potential, obviously at low enthalpy level, is available in western Ohio. It is associated with a convective flow of ground water, along a system of tensional fractures and/or faults, developed at the crest of the Cincinnati-Findlay Arch.

ACKNOWLEDGMENTS

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R. A. Heimlich and D. F. Palmer, both of the Geology Department at Kent State University, respectively compiled the basement and Bouguer anomaly information summarized here.

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Heat Generation and Heat Flow in Western Pennsylvania

by

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(from thesis by G. Maurath, 1980)

Excerpts from: Maurath, Garry, 1980 - Heat Generation and Terrestrial Heat Flow in Northwestern Pennsylvania; M.S. Thesis, Department of Geology, Kent State University, Kent, Ohio 44242; 156 pp.

ABSTRACT.

A steady-state divided bar and a thermistor probe has been used to obtain thermal conductivity measurements of rock-core samples from six boreholes and temperature gradient measurements from two boreholes in northwestern Pennsylvania. When combined, these measurements yield uncorrected heat flow values for Clarion and Venango Counties of 1.73 HFU (72.42 mW/m^2) and 1.44 HFU (60.28 mW/m^2) respectively. Fully corrected for the effects of a secondary recovery experiment, the Allegheny river, Pleistocene climatic variations, and the effects of topography the heat flows are 1.84 HFU (77.02 mW/m^2) and 2.00 HFU (83.72 mW/m^2). These values are highest among the heat flow measurements reported to this date for the Allegheny Plateau.

A temperature gradient map constructed on the basis of over 380 reported bottom-hole-temperature measurements of deep oil and gas wells in conjunction with measurements of the temperature in shallow aquifers in Pennsylvania, indicates that the high heat flow values in Clarion and Venango Counties coincide with a local, relatively high geothermal gradient.

Study of the radiogenic heat production based on analyses of 64 samples of basement material suggests that the heat flow and geothermal gradient anomaly in Clarion and Venango Counties are apparently associated with a shallow crustal heat source.

Table 1. Basic information on boreholes used in core and heat flow survey.

Location (Fig. 1)	Well Name	Permit No.	North Lat. DEG	North Lat. MIN	East Long. DEG	East Long. MIN	Elevation (m)	Depth (m)	Remarks
E	Bowser	CLA-165	41°	13.98'	79°	31.87'	402.3	749.2	Gradient and core well
F	Wile	CLA-173	41°	13.49'	79°	33.25'	373.1	646.2	Core well
A	Bankson	VEN-169-P	41°	27.61'	79°	41.14'	459.3	362.7	Core well
C	Hazlett	VEN-172-P	41°	21.49'	79°	48.07'	410.0	365.8	Core well
B	Marsh	VEN-174-P	41°	23.77'	79°	43.43'	443.5	363.3	Core well
D	Reed	VEN-160	41°	20.39'	79°	48.00'	430.7	760.2	Core well
G	Ignition	VEN-154	41°	24.93'	79°	44.19'	426.7	172.2	Ignition well for secondary recovery experiment
H	Morrison	None	41°	23.87'	79°	43.41'	443.5	323.1	Gradient well

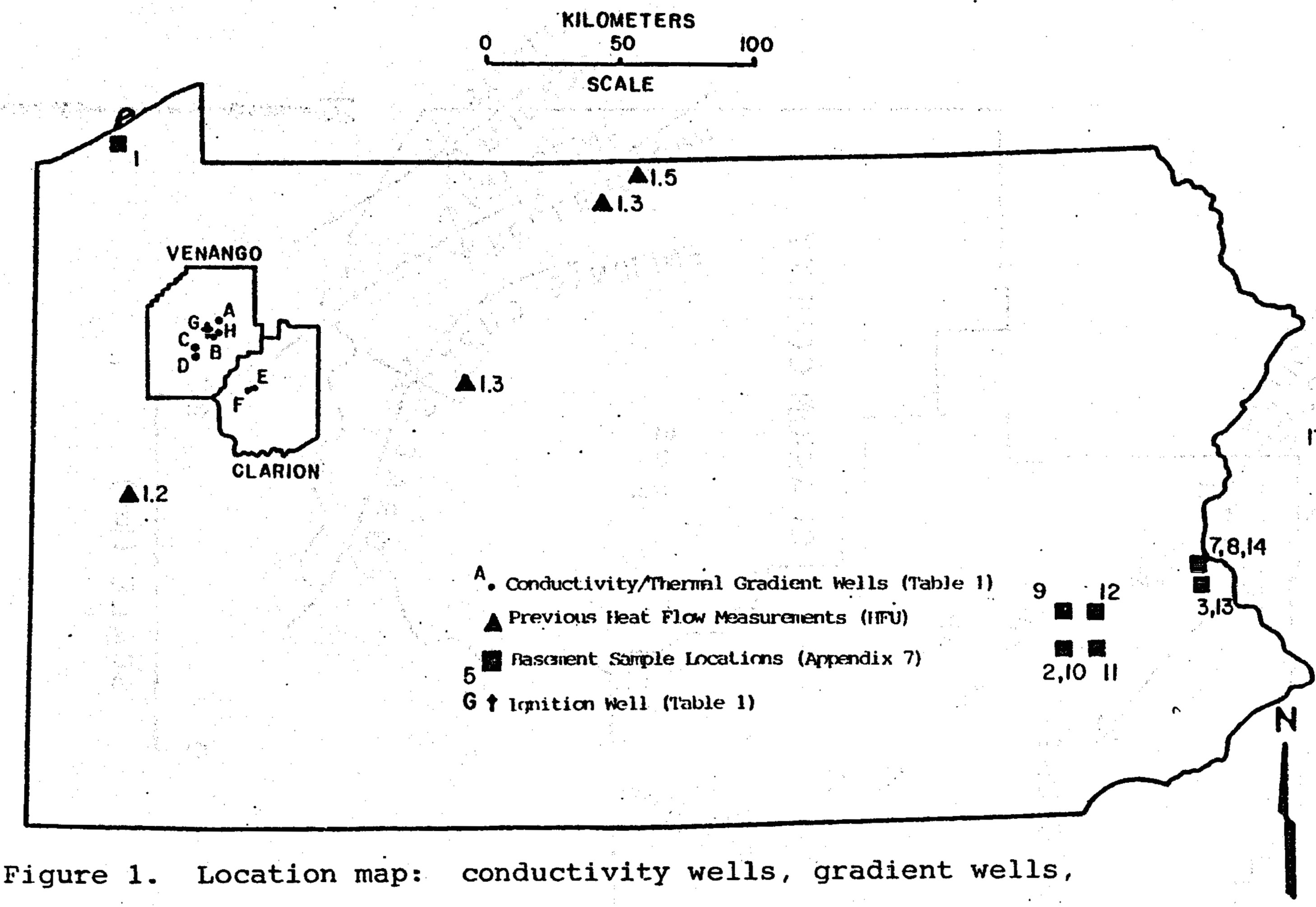

Figure 1. Location map: conductivity wells, gradient wells, basement sample locations , previously reported (measured/estimated) heat flow values, and ignition well.

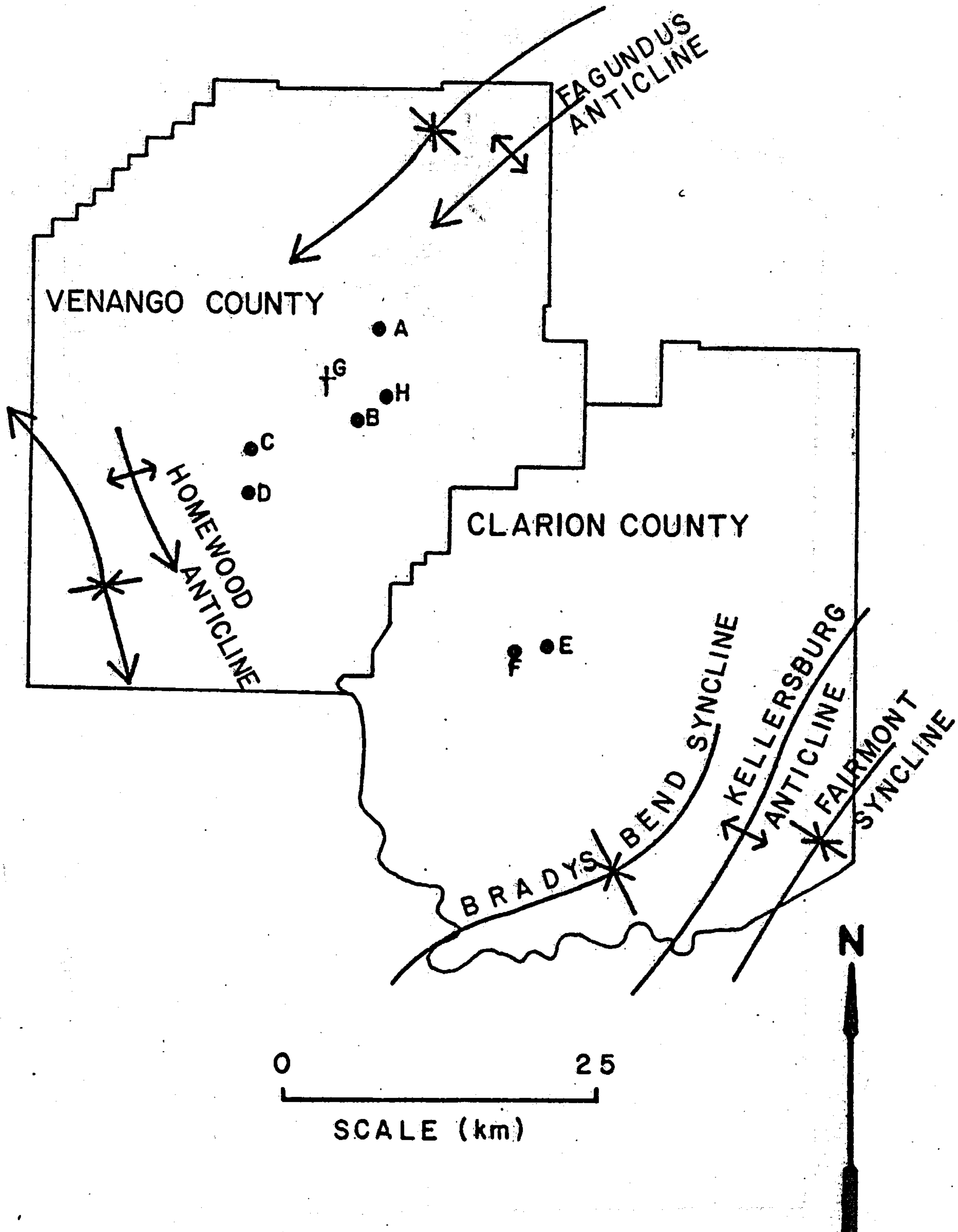

Figure 2. Tectonic map of Venango and Clarion counties (Leggette, 1936 and Newport, 1973).

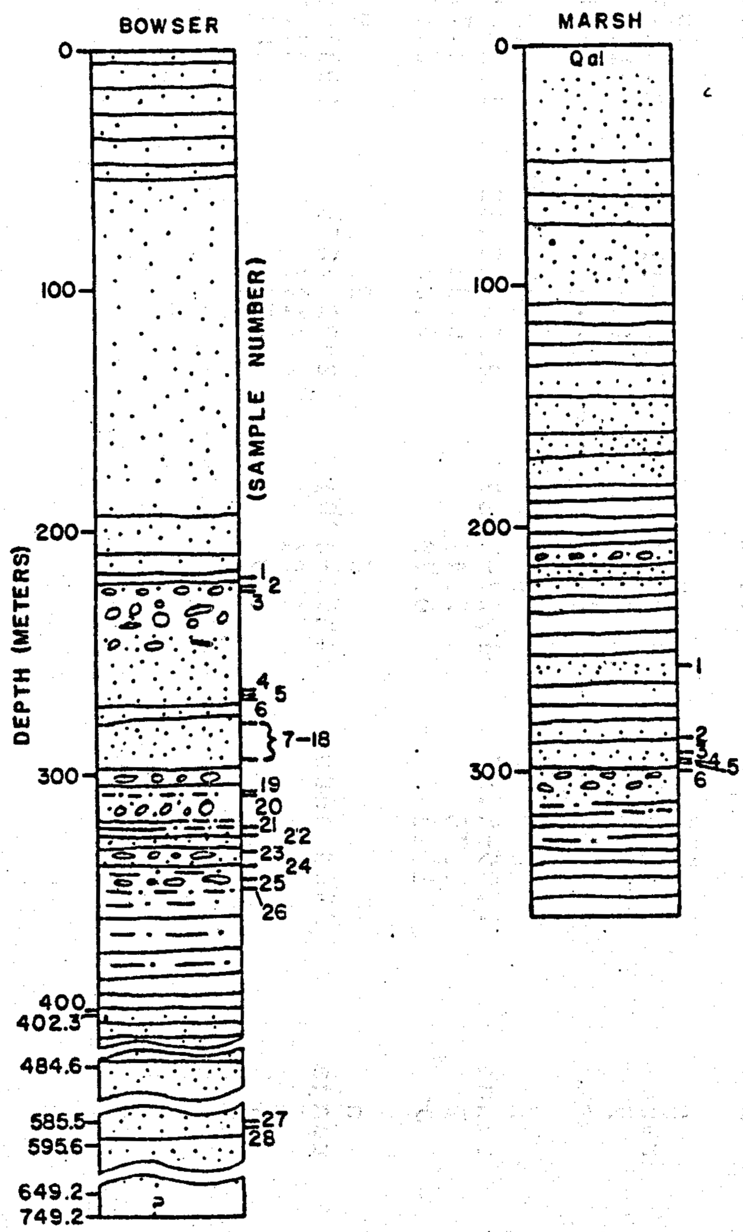

Figure 3. Sample locations and lithology of Clarion and Venango County gradient wells.

Table 2. Summary of thermal conductivity, porosity, and sonic velocity measurements.

		LITHOLOGY			
		Shale	Siltstone	Sandstone	Conglomerate
k (dry) $\left(\frac{mcal}{cm\ sec^{\circ}C}\right)$	n	13	7	34	10
	range	3.33-5.43	5.36-8.28	5.32-9.92	7.62-12.69
	$\bar{x}$	4.13	7.51	7.64	10.15
	σ	0.70	1.02	1.30	1.57
k (wet) $\left(\frac{mcal}{cm\ sec^{\circ}C}\right)$	n	6	6	34	10
	range	3.52-5.71	7.91-8.99	5.88-11.63	8.35-12.99
	$\bar{x}$	4.79	8.40	8.86	11.26
	σ	0.73	0.39	1.48	1.51
Porosity (%)	n	6	6	34	10
	range	1.99-5.55	1.27-3.39	2.26-15.32	1.20-10.65
	$\bar{x}$	3.75	2.47	6.33	4.72
	σ	1.23	0.79	3.63	2.84
Sonic Velocity (mps)	n	6	6	29	9
	range	3908-4800	4293-4701	2903-4665	2931-5278
	$\bar{x}$	4421	4504	4197	4577
	σ	303	159	434	687

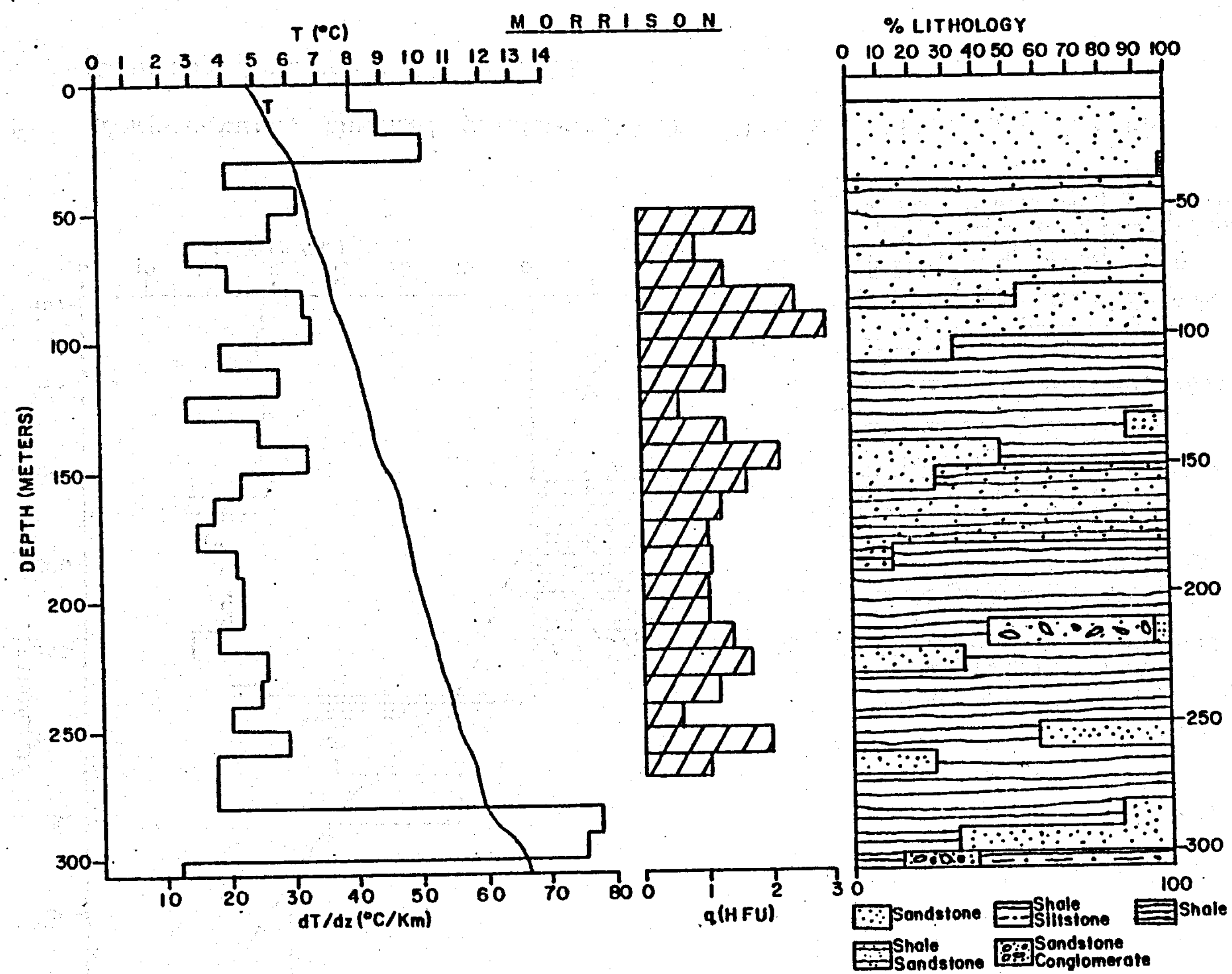

Figure 4. Temperature, thermal gradient, heat flow, and lithology for the Venango County gradient well.

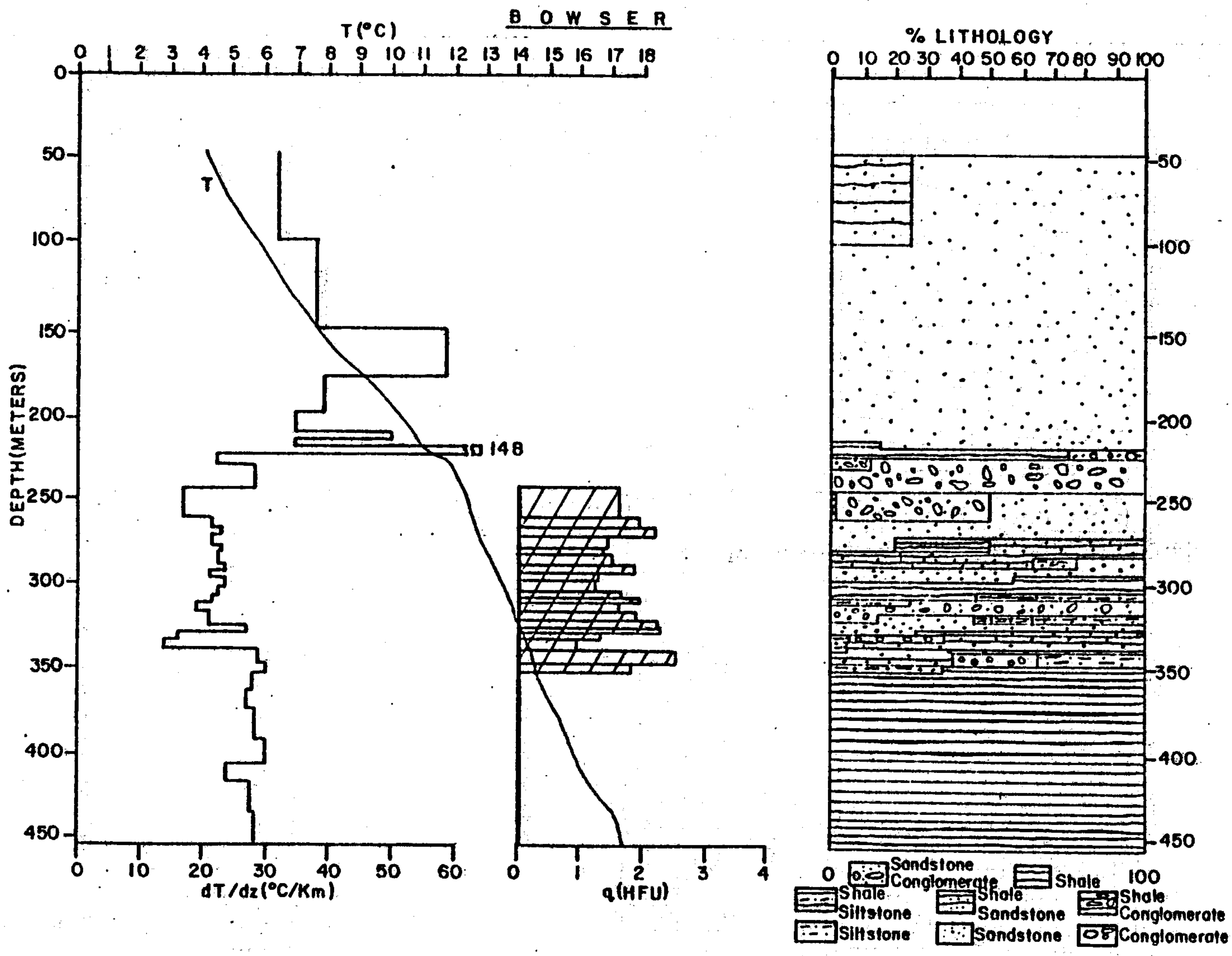

Figure 5 . Temperature, thermal gradient, heat flow and lithology for the Clarion County gradient well.

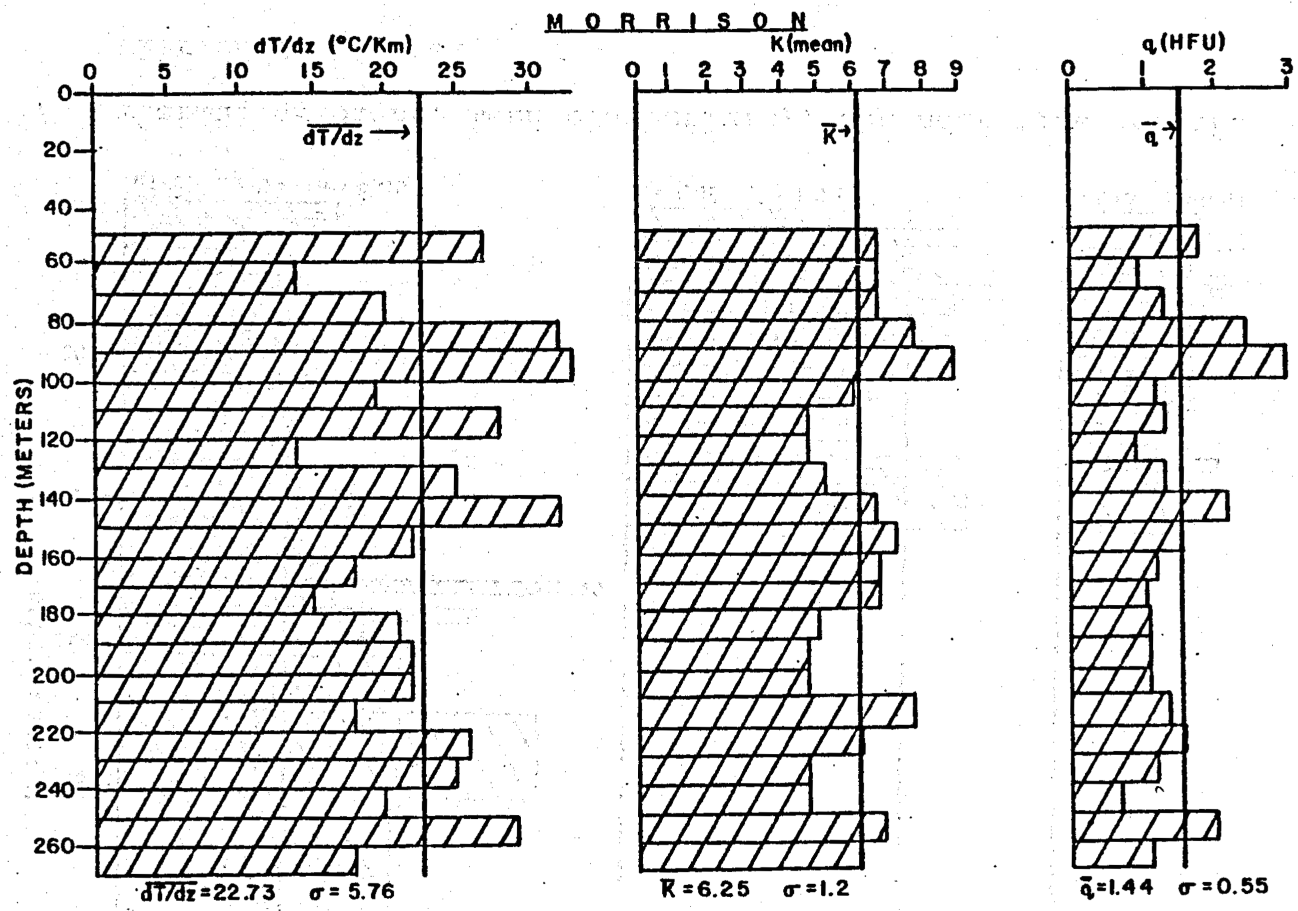

Figure 6. Thermal gradient, mean conductivity, and heat flow for the Venango County well.

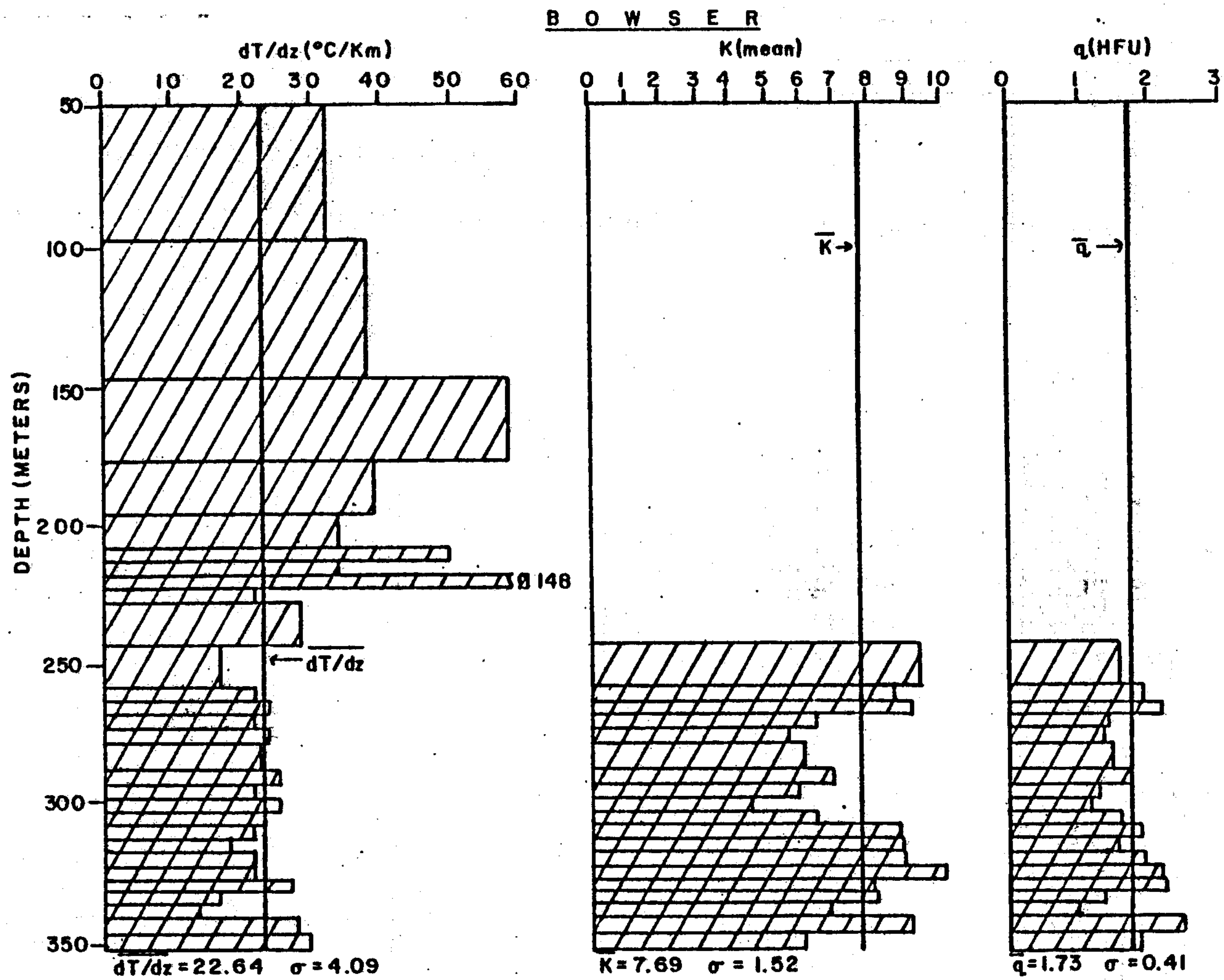

Figure 7. Thermal gradient, mean conductivity, and heat flow for the Clarion County well.

Table 3. Uncorrected and corrected heat flow values.

	q (HFU)(mW/m^2)	range (HFU)(mW/m^2)	(°C/km)	r	T(°C)[1]
Uncorrected					
Morrison	1.44+0.55(60.28+23.02)	0.67-2.92(28.05-122.23)	22.63	-0.99	6.30
Bowser	1.73+0.41(72.42+17.16)	0.97-2.55(40.60-106.74)	22.53	-0.99	7.36
Uncorrected + River Correction					
Morrison	1.49+0.56(62.37+23.44)	0.72-3.01(30.14-126.00)	23.57	-0.99	6.29
Bowser	No river correction was applied.				
Uncorrected + River + Pleistocene Corrections					
Morrison	1.92+0.75(80.37+31.40)	1.15-4.08(48.14-170.79)	30.51	-0.99	5.71
Bowser	1.97+0.47(82.46+19.67)	1.11-2.92(46.46-122.23)	25.60	-0.99	7.50
Uncorrected + River + Pleistocene + Topographic Corrections					
Morrison	2.00+0.72(83.72+30.14)	1.08-3.35(45.21-140.23)	31.95	-0.99	6.10
Bowser	1.84+0.36(77.02+15.07)	1.19-2.56(49.81-107.16)	24.99	-0.99	7.44

Note: 1. Extrapolated temperature at a depth of 30.5 meters.

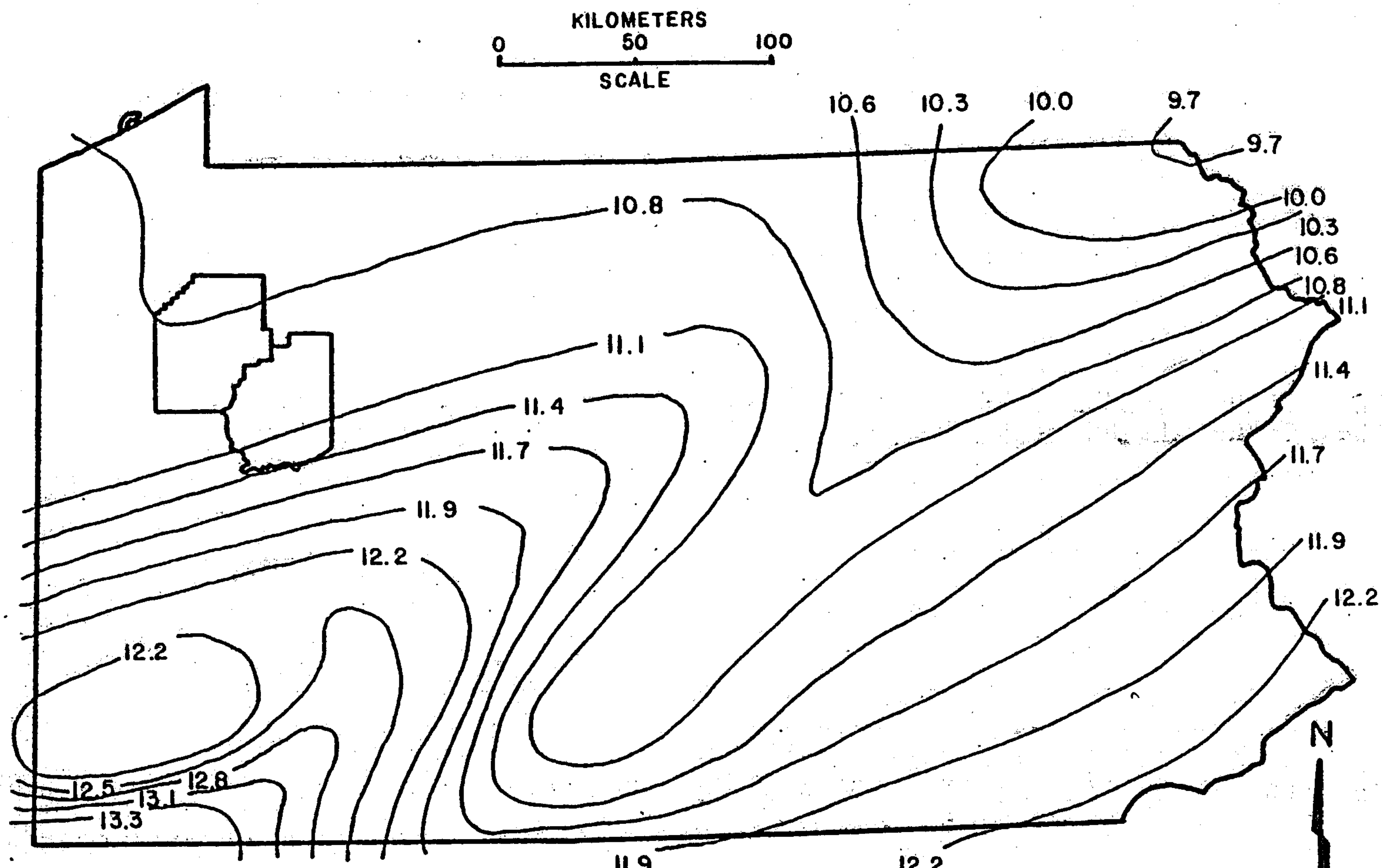

Figure 8 . Temperature of ground-water in Pennsylvania at a mean depth of 30.5 meters (Water Well Journal, 1979).

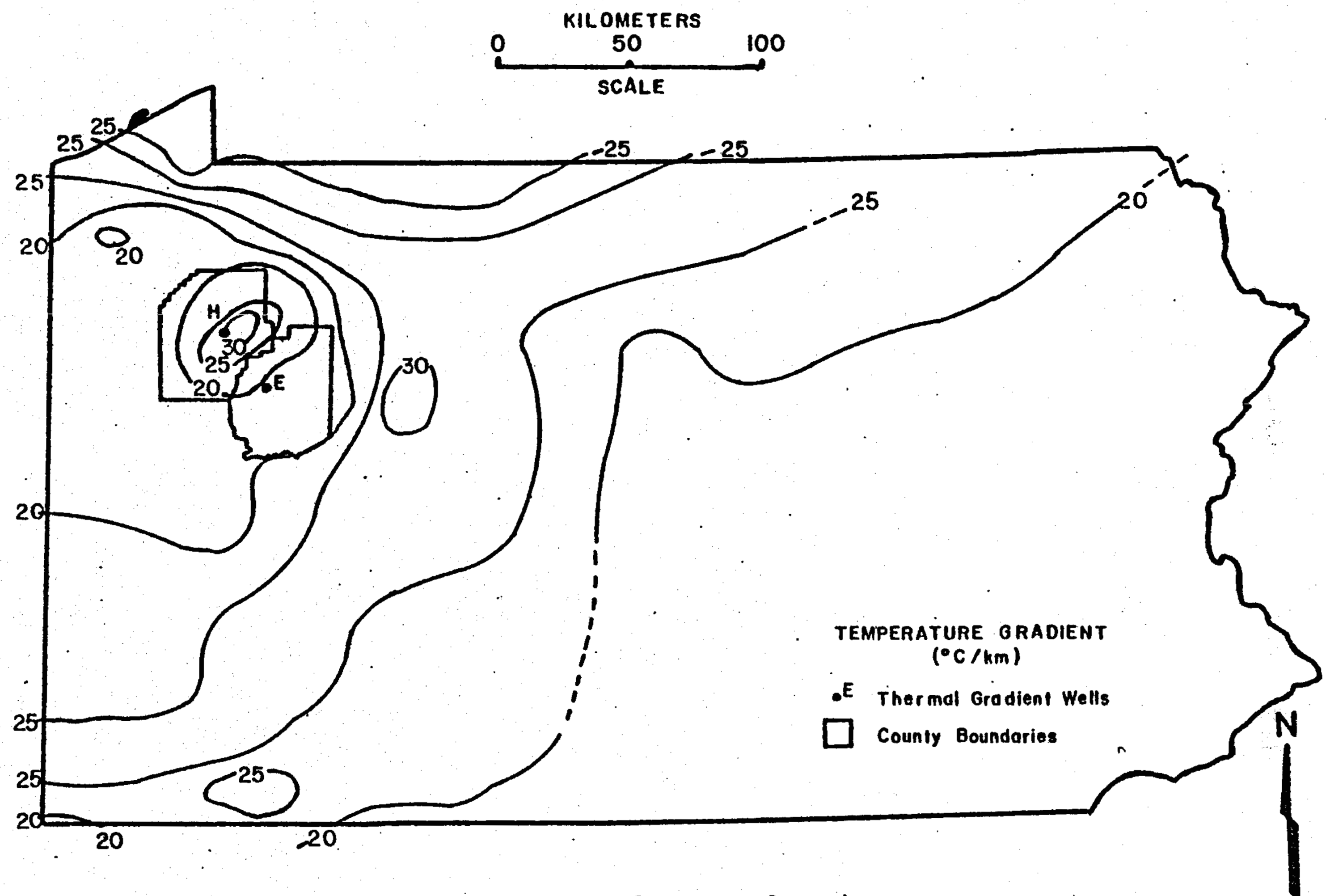

Figure 9. Temperature gradient map of Pennsylvania.

Mid-Continent HDR Program

by

R. R. B. von Frese, et al.
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—

given by

J. Maxwell
Los Alamos Scientific Laboratory

An Integrated Geophysical-Geological Study of Potential Hot Dry Rock Sites in the Midcontinent

by

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Exploration for Hot Dry Rock (HDR) as a potential energy resource in the midcontinent of the United States is of considerable interest because of the large population density of the region and the increasing demand on conventional energy sources. Available geological and geophysical data indicate the widespread distribution of potentially favorable conditions for HDR geothermal sites including radiogenic plutons, residual intrusive heat, anomalous upper mantle heat, thermal conductivity anomalies, geohydrology, and sedimentary rock blanketing.

Accordingly, a cooperative effort among several major universities has been funded by DOE through LASL to develop a HDR site exploration strategy for the region from the Rocky to Appalachian Mountains excluding the Gulf Coast geopressured region and the Madison aquifer of North and South Dakota, and to initiate a test of this strategy by applying it to selected favorable areas. In addition, the status of pertinent available regional geologic and geophysical data will be ascertained and the data evaluated. These data will be collated and synthesized and initial steps will be taken to analyze these data and to delimit areas in which regional data are insufficient for locating broad areas favorable for HDR site development.

Three areas have been identified and are being investigated for developing and testing a midcontinental HDR exploration strategy. The test areas are indicated by the shaded regions of Figure 1 and include the western Nebraska site being studied by the University of Texas-Dallas and New Mexico State University groups, the northern Mississippi Embayment site being investigated by the University of Texas-El Paso group, and the eastern Michigan site being considered by the Purdue University group. Integral parts of these studies include the compilation of basement drill hole data by the University of Pittsburgh group (Lidiak & Denison) and the geochemical and in-situ temperatures by the New Mexico State University group.

The panhandle of western Nebraska, $(41.0 - 43.0)^{\circ}$N, $(104.0 - 102.0)^{\circ}$W shown in Figure 2, recommended for study as a HDR test site is characterized by a prominent, broadly defined negative Bouguer gravity anomaly (see Figure 3). The basement geology generalized for the area by Lidiak (1972) is included in Figure 3 as well as the location of LASL's proposed MT traverse. The results of the MT study will be incorporated in the HDR evaluation of the test site as they become available. Magnetic anomaly data at a 6 mile flight line spacing also have been made available recently by the NURE magnetic study.

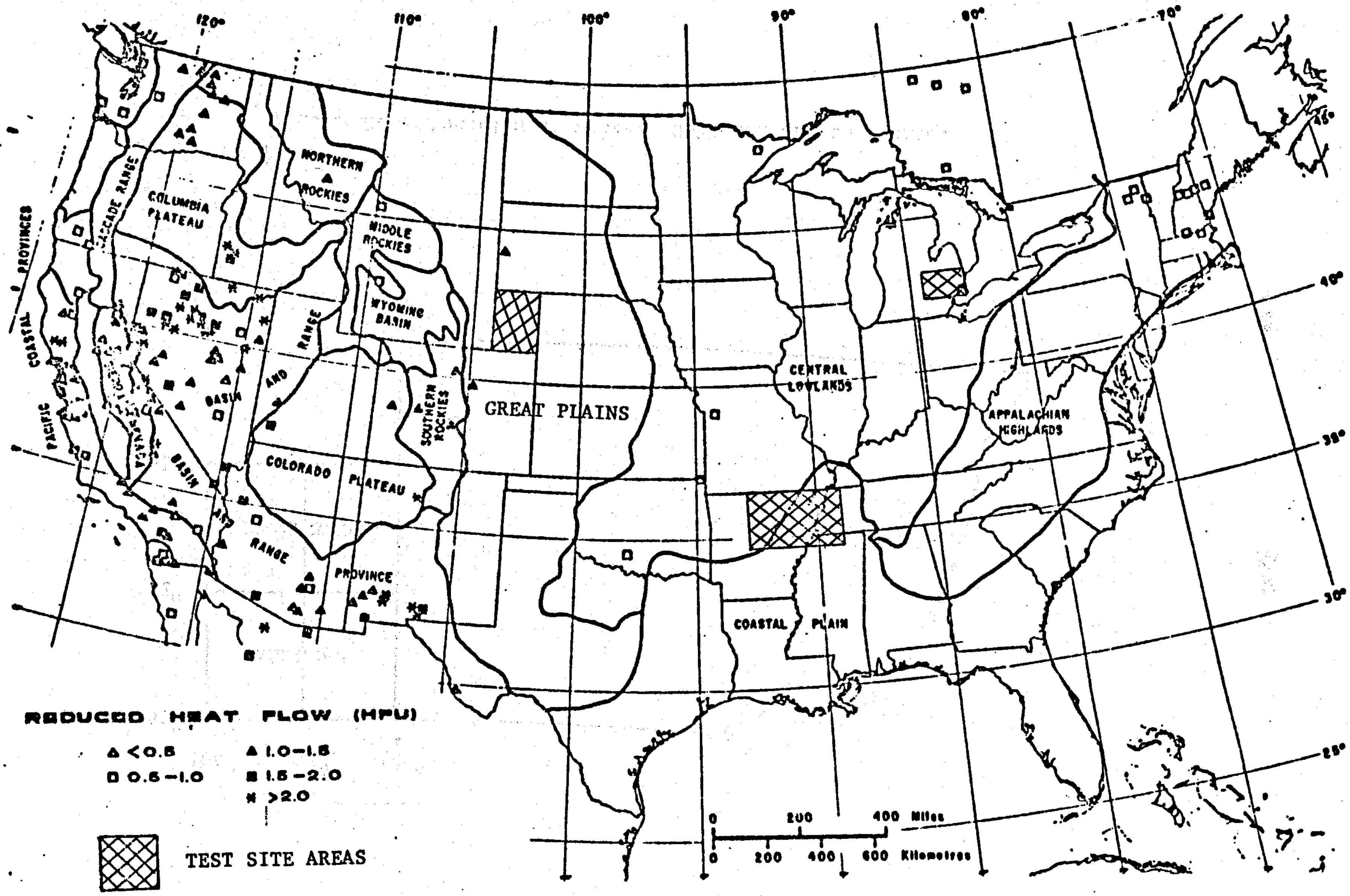

Figure 1. Location of midcontinent HDR test site areas.

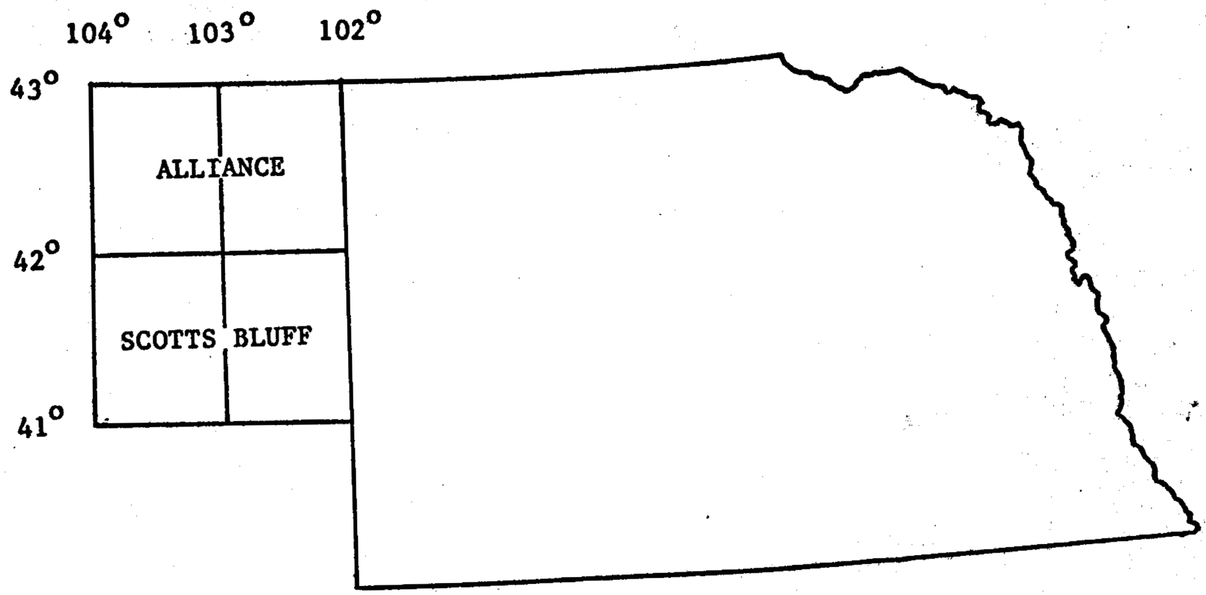

Figure 2. Location of western Nebraska HDR test site.

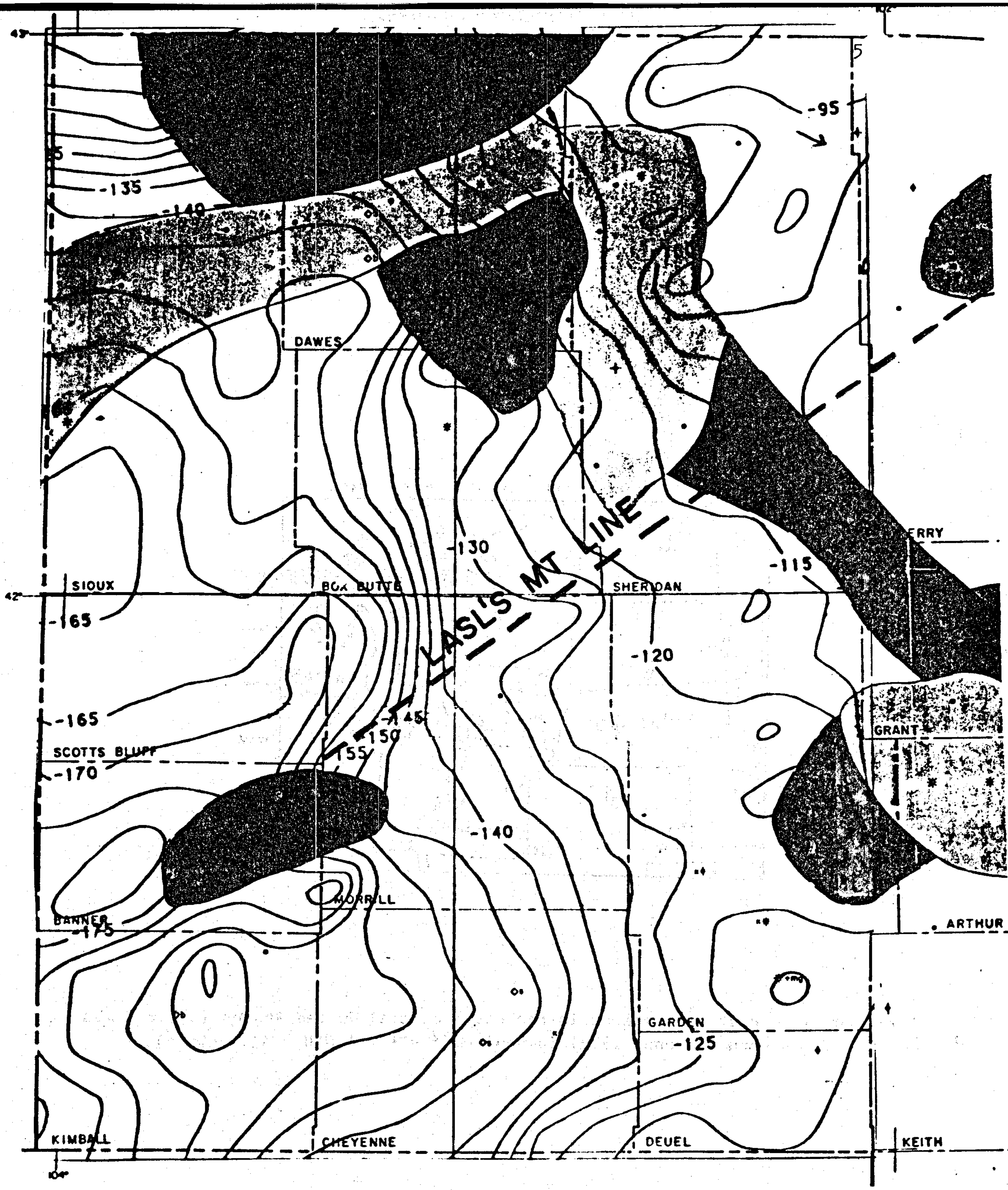

Figure 3. Preliminary Bouguer gravity anomaly map, and basement geology from Lidiak (1972), for the western Nebraska test site area. Light shaded areas correspond to granitic basement rocks and dark shaded regions to schists and granofels. LASL'S proposed MT line also is shown.

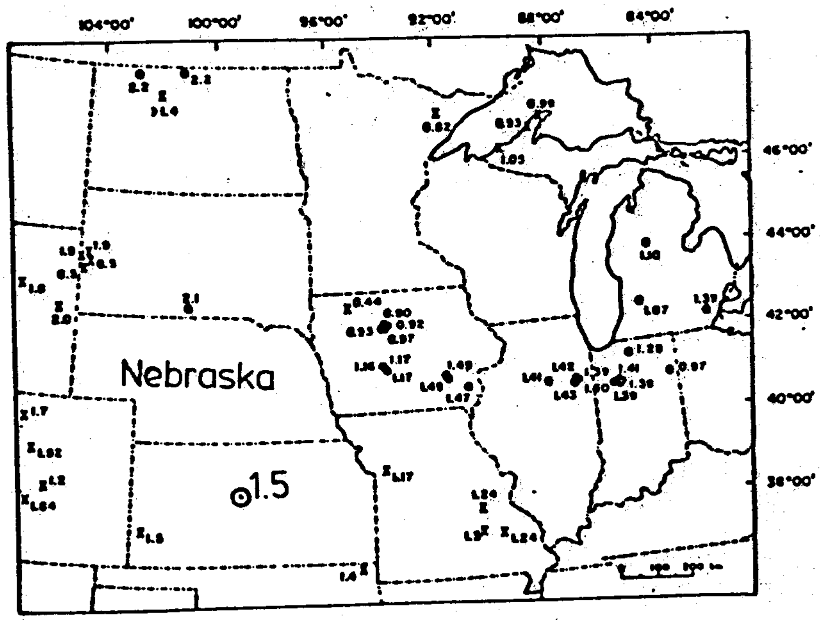

Figure 4. Heat flow values in the north central United States (after Combs and Simmons, 1973) in μcal cm^{-2} s^{-1} = 1 HFU = 41.8 mWm^{-2}).

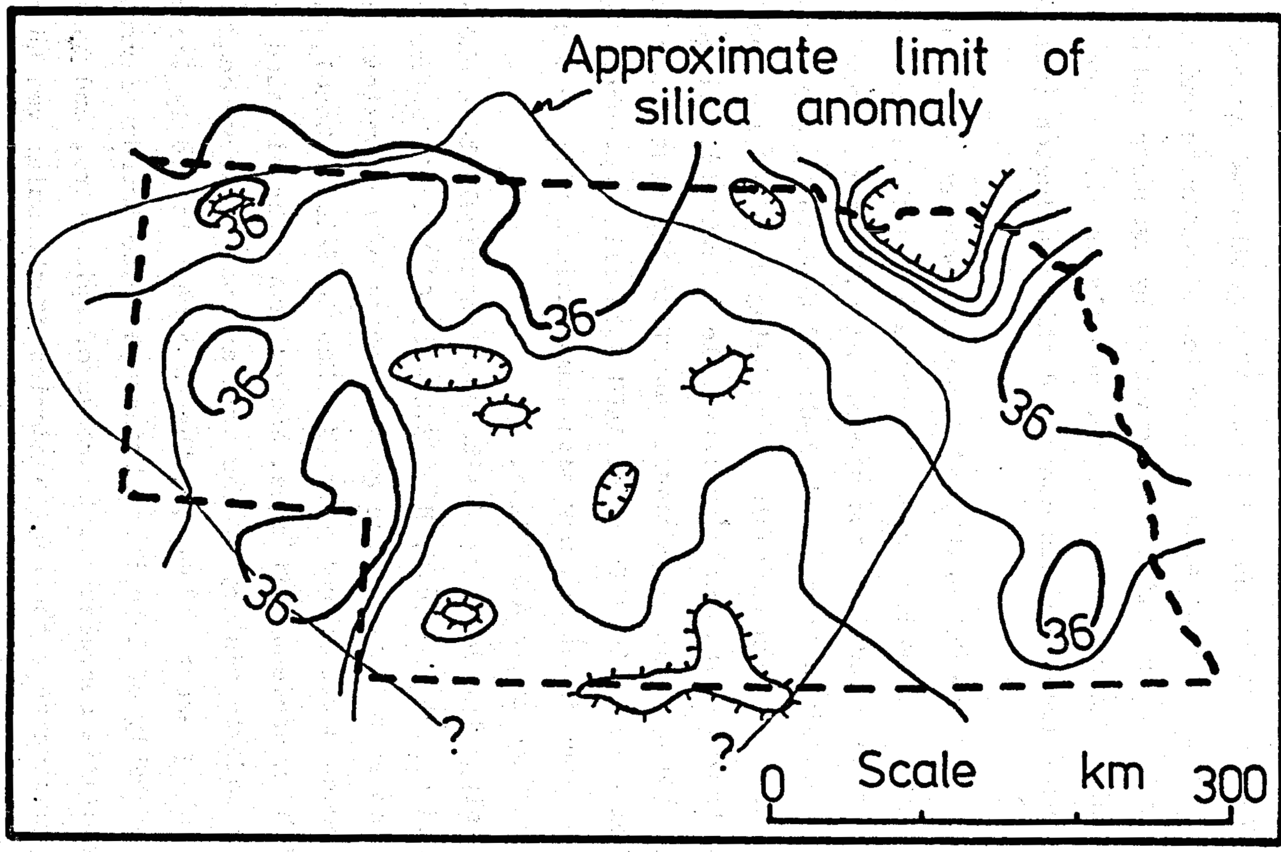

Figure 5. Bottom hole temperature gradients for Nebraska (after AAPG-USGS, 1976). Contours are at 3.7° c/km (0.2°F/100ft) intervals. The 36° c/km contour corresponds to the 2.0°F/100ft contour on the AAPG-USGS map. Limit of silica anomaly taken from Swanberg and Morgan (1978).

The existence of a prominent thermal anomaly (≈ 2HFU) in western Nebraska can be postulated from the heat flow data given in Figure 4 which has been generalized from Combs and Simmons (1973) and Sass et al. (1976). The temperature gradient contour map of the United States, generated basically from oil and gas well bottom hole temperature data for the Geothermal Survey of North America (AAPG-USGS, 1976), confirms the existence of a geothermal anomaly in western Nebraska, although it is contoured as a series of separate anomalies, as shown in Figure 5. Groundwater silica data compiled by Swanberg and Morgan (1978) indicate that this is a single continuous anomaly as also shown on Figure 5. A reanalysis of the silica data has confirmed this conclusion (Swanberg and Morgan, 1980).

W.D. Gosnold of the University of Nebraska-Omaha has been making temperature gradient measurements in wells across Nebraska and with his cooperation these results will be integrated into the study. Also, in-situ groundwater temperatures, and temperatures obtained from Si, Na-K-Ca and Na-K-Ca-Mg geothermometry as well as groundwater fluoride concentrations are being compiled for the western Nebraska test site from the U.S.G.S. water quality file (WATSTORE). To complement the Nebraska study, bottom hole temperature data from the states surrounding western Nebraska are being reexamined from the AAPG data file and, where appropriate, new data will be sought out and new data compilations will be made and integrated with the Nebraska and other AAPG data.

The Mississippi Embayment test site has tentatively been chosen to include the area bounded by $(34.5 - 36.5)^{\circ}N$, $(93.0 - 89.0)^{\circ}W$ as illustrated in Figure 6. This area was chosen because of the good coverage of geophysical data, the evidence for recent tectonic activity (New Madrid Seismic Zone), the possible association with an ancient rift zone, and evidence for elevated heat flow. The details of the geologic history of the area are poorly known because of the thick Cenozoic sediments present. However, the embayment is widely accepted as being an aulacogen, probably of late Precambrian age. The trends of gravity and magnetic anomalies in the area correlate with trends of epicenters, and this correlation led to the suggestion that the old boundaries of the aulacogen have been reactivated. The many correlative gravity and magnetic anomalies suggest widespread plutonism, probably of pre-Cenozoic age. Also, the deep fracturing of the crust suggested by the formation of an aulacogen is of interest.

Gravity and magnetic data coverage for the site is considerable. Current gravity coverage is illustrated in Figure 7 as the number of stations per $1^{\circ}x1^{\circ}$ quadrilateral. Magnetic data coverage is shown in Figure 8 where the flight line

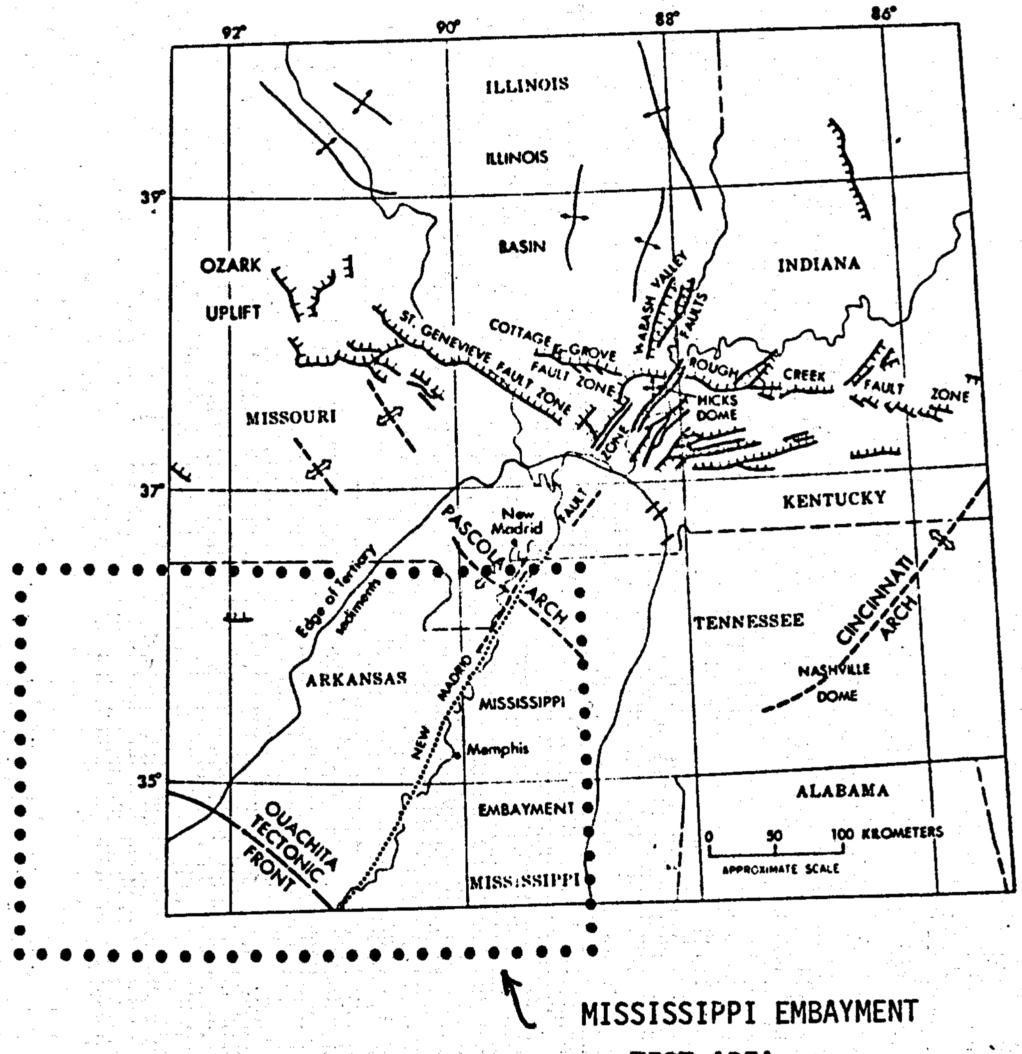

Figure 6. Location of Mississippi Embayment HDR test site.

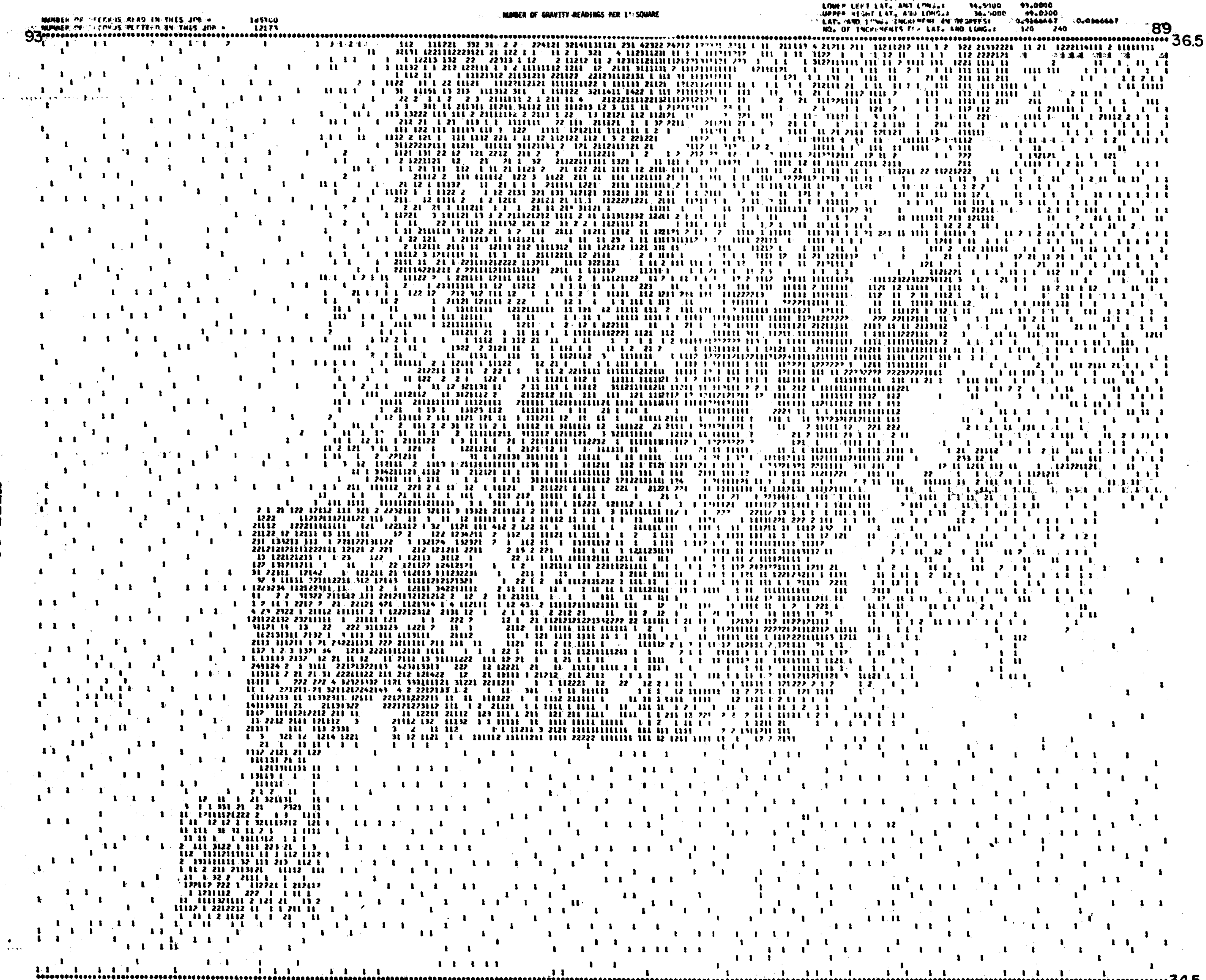

Figure 7. Gravity data per 1^{o} x 1^{o} quadrilateral currently available for the Mississippi Embayment HDR test site.

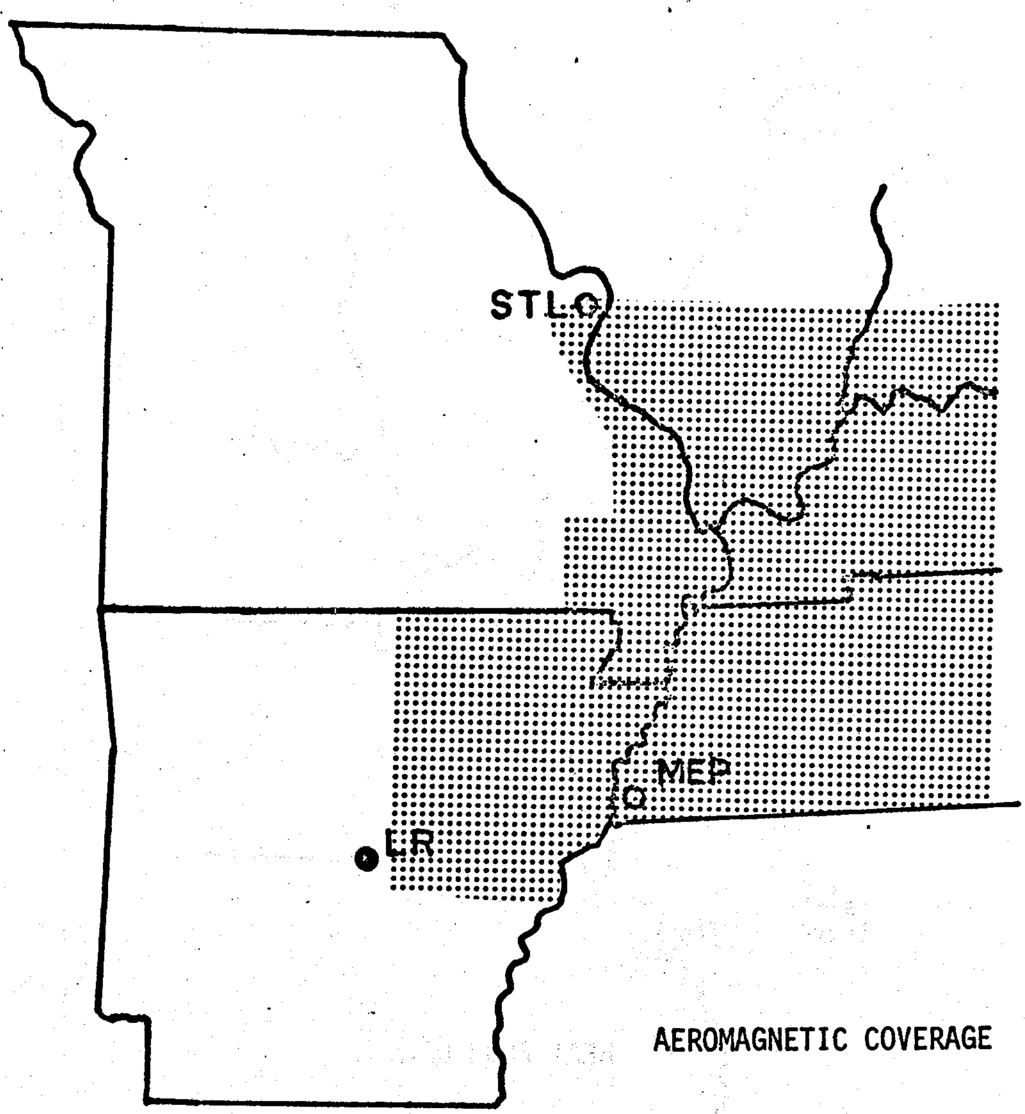

Figure 8. Current aeromagnetic coverage for the Mississippi Embayment HDR test site. These data are available at 1 mile flight line intervals.

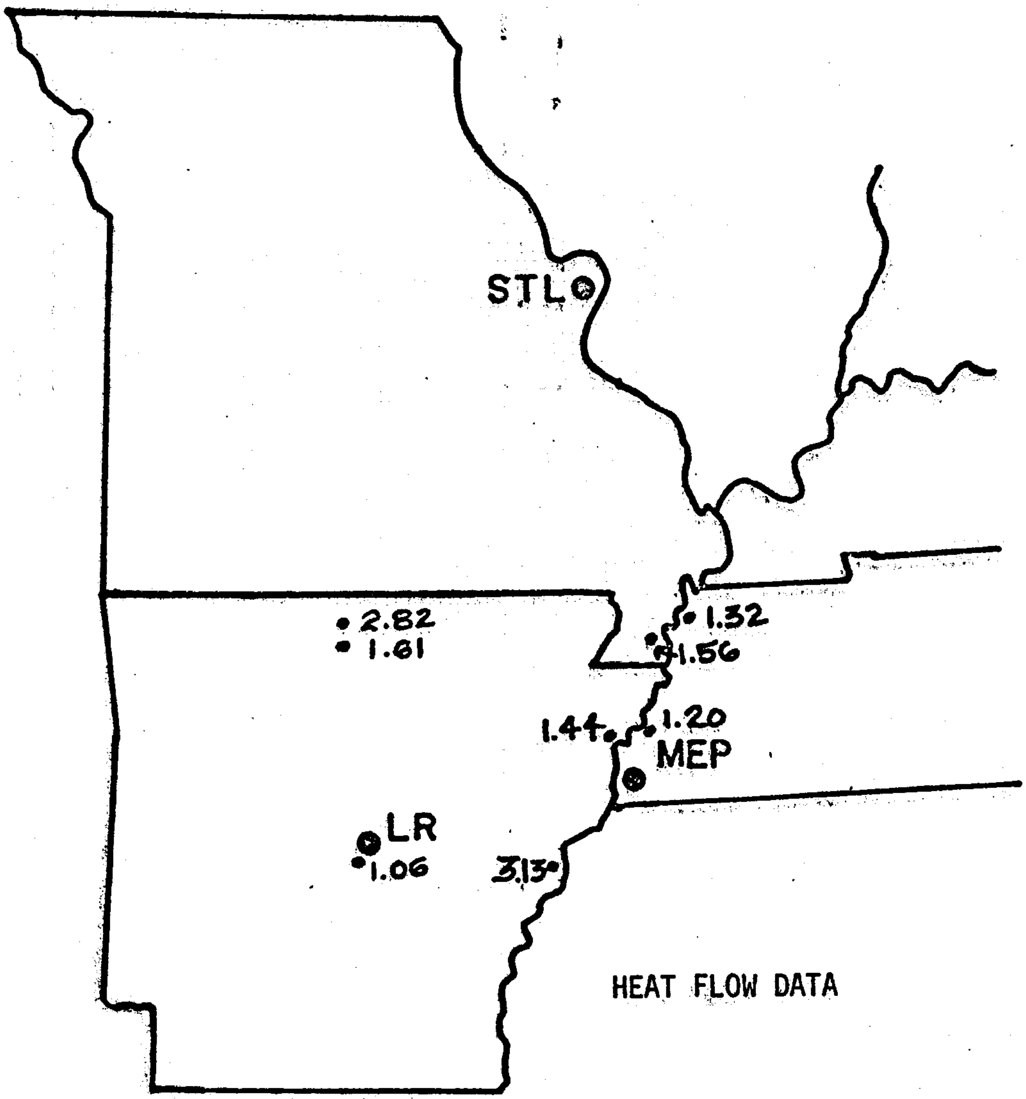

Figure 9. Heat flow data (in HFU) available for the Mississippi Embayment HDR test site.

spacing for these data is roughly 1 mile. As illustrated in Figure 9, available heat flow data obtained from recent studies by the University of Texas-El Paso and New Mexico State University indicate some high values for the test site. The occurrence of elevated temperatures in the test site area also is being investigated by studying the in-situ groundwater temperatures, as well as temperatures derived from Si, Na-K-Ca and Na-K-Ca-Mg geothermometers, and groundwater fluoride concentrations, which are being synthesized from the U.S.G.S. water quality file (WATSTORE).

Considerable geological and geophysical data are available to recommend the region $(42.25 - 43.25)^{o}$N, $(84.50 - 82.50)^{o}$W in eastern Michigan as a potential HDR site. As shown in Figure 10 (Hinze et al., 1975) gravity anomaly data, which are available at a 6 mile grid interval, characterize the area as a pronounced negative gravity anomaly (≈ -30 mgal). The anomaly source probably is a basement granitic intrusive associated with the Grenville Front. Basement lithologies for the study region are generalized from geophysical and limited drilling information in Figure 11 (Hinze et al., 1975). To date, at least, there is no evidence to suggest the anomaly source is due to a thickening of Devonian or Silurian evaporites (Hinze et al., 1975; Chandler, 1977). Further evidence indicating the anomaly source is an intrabasement lithological variation is given by the magnetic data in Figure 12 (Hinze et al., 1975) which are available on a 3 mile flight line interval. The data generally characterize the study region as a negative magnetic anomaly.

Accordingly, these results suggest the gravity anomaly source is within some of the youngest basement rocks in the midcontinent, near a major tectonic break (Grenville Front) and in the vicinity of a Precambrian rift that has undergone Proterozoic diastrophism. Furthermore, the probable basement source is within a basin that is covered by a thick blanket of low conductivity sediments. Limited heat flow data (Figure 10) also are available for the study region (Combs and Simmons, 1973; Judge and Beck, 1973). The geochemical data from the U.S.G.S. water quality file (WATSTORE) also are being assembled to provide fundamental information regarding the HDR potential for the Michigan site.

The three pilot areas described above were selected on the basis of available data as possible HDR sites of widely varying geologic conditions. These test site investigations are directed toward synthesizing available geophysical, geochemical and geological data into a generalized exploration strategy, as well as an evaluation of the HDR resource potential of each of the sites. An example of this investigative procedure is given for the eastern Michigan test site by the preliminary flow chart illustrated in Figure 13.

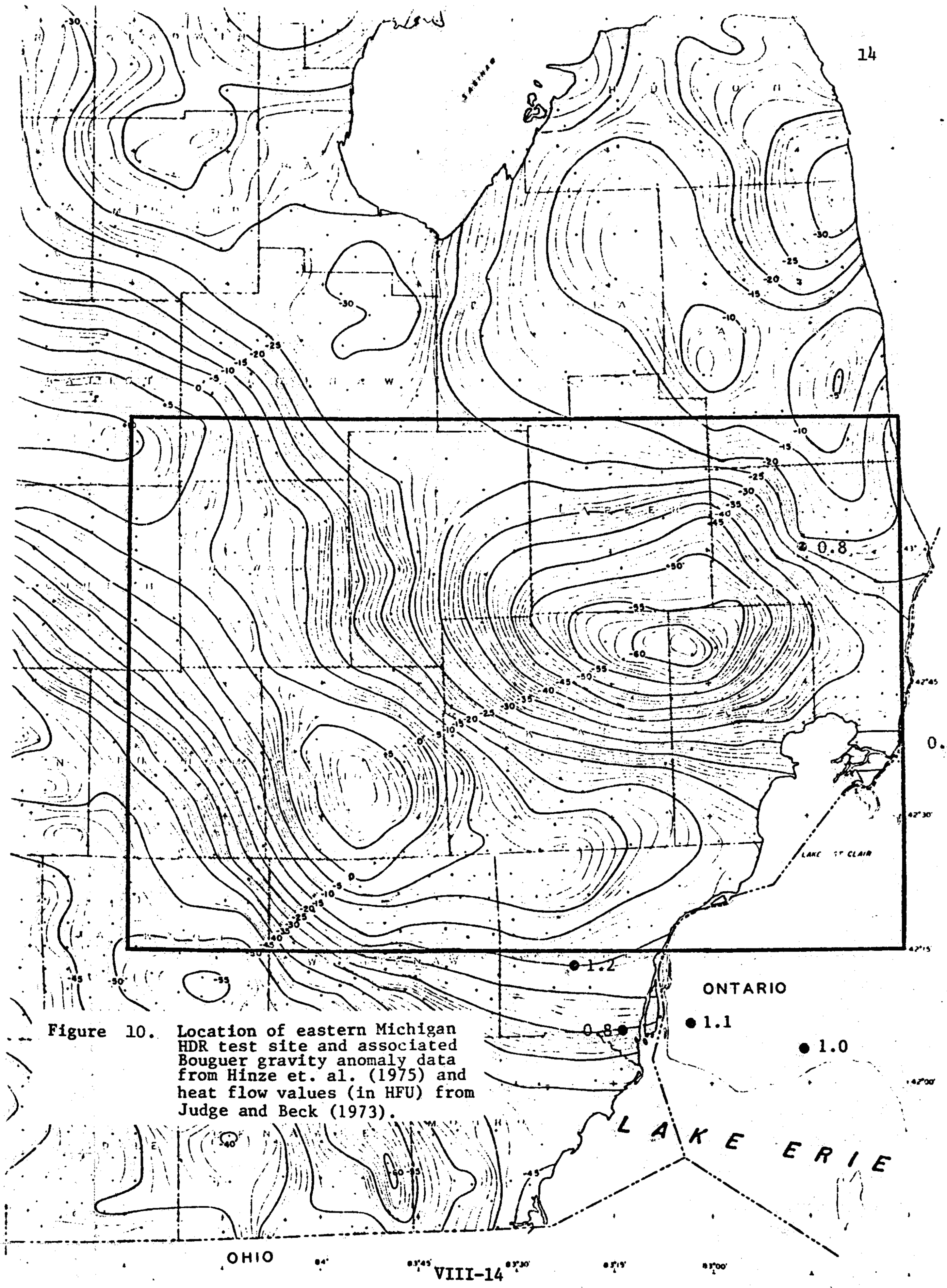

Figure 10. Location of eastern Michigan HDR test site and associated Bouguer gravity anomaly data from Hinze et. al. (1975) and heat flow values (in HFU) from Judge and Beck (1973).

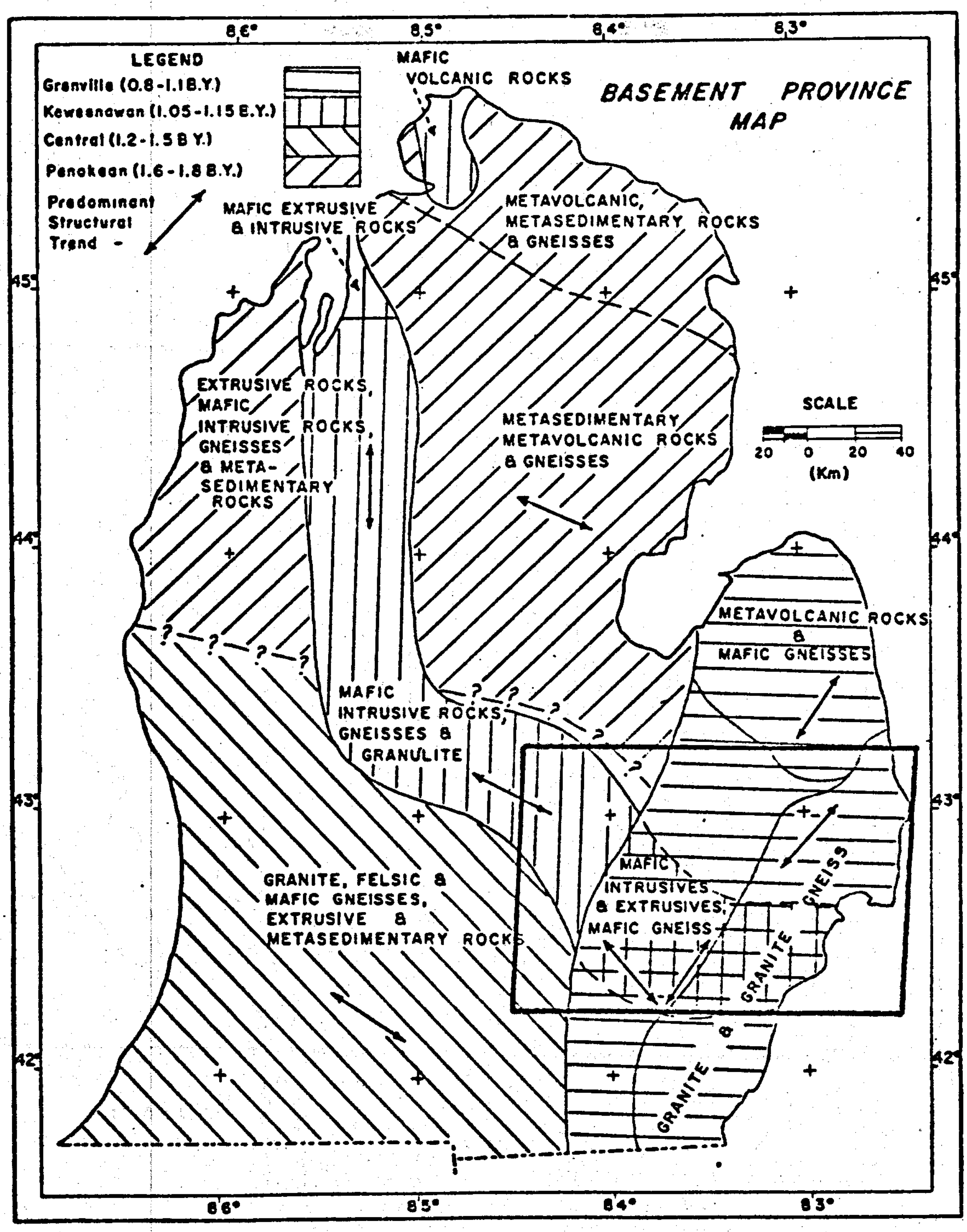

Figure 11. Basement province map (Hinze et. al., 1975) for the eastern Michigan HDR test site.

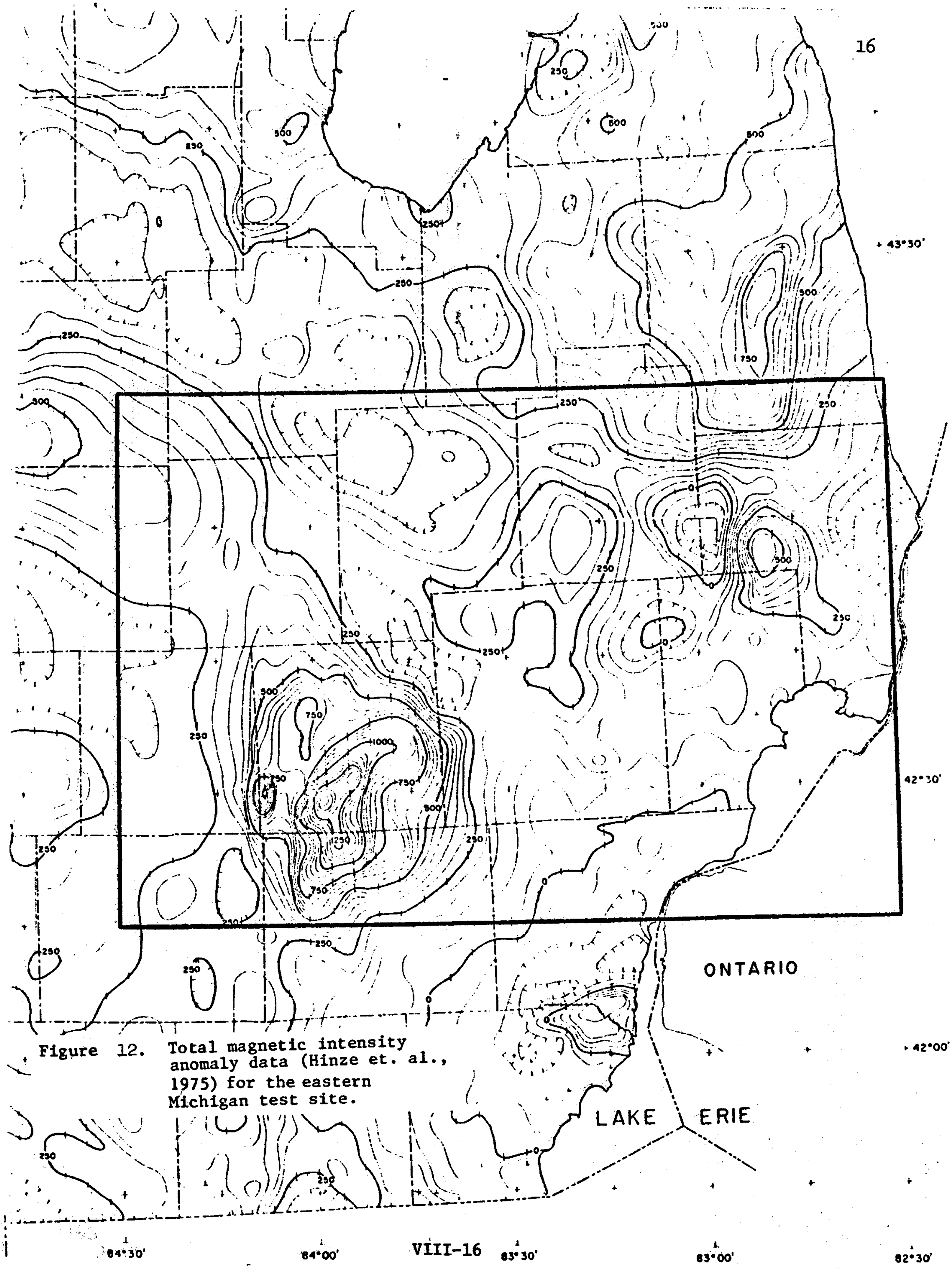

Figure 12. Total magnetic intensity anomaly data (Hinze et. al., 1975) for the eastern Michigan test site.

EASTERN MICHIGAN HDR TEST SITE INVESTIGATION

(Preliminary Flow Chart)

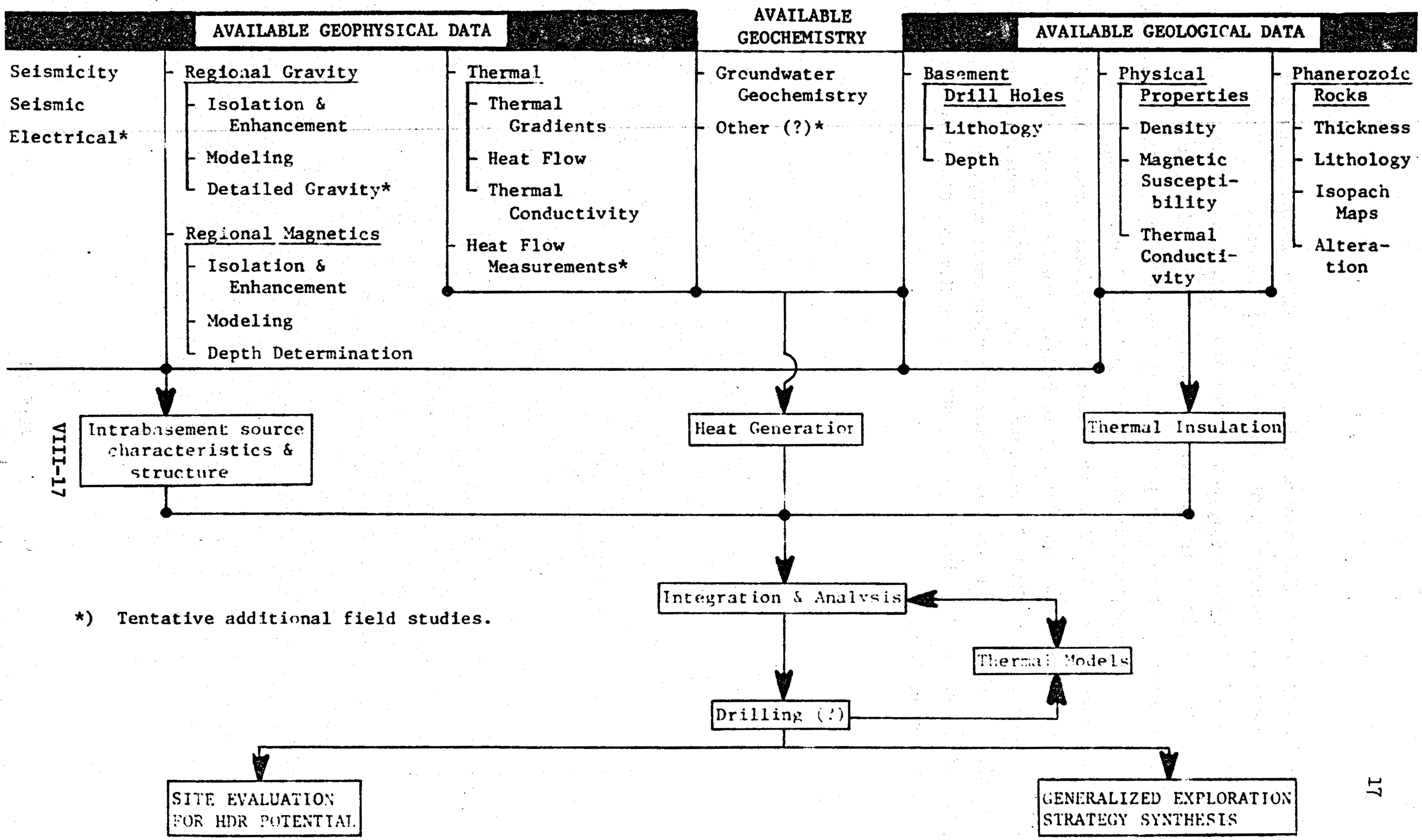

Figure 13. Preliminary flow chart for eastern Michigan HDR test site investigation.

The Midcontinent HDR Group also has been active in preparing the scientific plan for conducting studies on the core from the Illinois Deep Drill Holes and performing surface and in-hole geophysical investigations. Arrangements have been made for obtaining core samples for thermal conductivity and heat generation measurements which will be performed by the UTEP group. The University of Pittsburgh group inspected the core from UPH-1 and 2 and arranged for 48 samples from these cores to be obtained for detailed petrologic study. Additional core samples will be obtained from drill hole UPH-3. A wide variety of geophysical logs were observed by the U.S. Geological Survey in UPH-3 subsequent to its completion at 1200 hrs on May 20. These included three temperature logs with observations at 0.5 foot intervals at 1400 hrs on May 22, 0545 hrs on May 25, and 0845 hrs on May 26.

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Southeastern Gulf Coast
Heat Flow Program

by

D. L. Smith
University of Florida

IX

SOUTHEASTERN GULF COAST HEAT FLOW PROGRAM

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ABSTRACT

Thirty-nine new heat flow values from western Florida, Alabama, Mississippi, and Louisiana range from $<$ 1.0 heat flow unit (microcalorie/cm^{2}sec) to 2.1 hfu. In general, heat flow values for the Gulf Coastal Plains are low to normal. Anomalously low values (0.4 - 0.7 hfu) in north-central Florida and northern Alabama appear to corroborate previous measurements in those areas. Positive thermal conditions are observed in extreme western Florida (30-34°C/km gradients; 1.1 - 1.3 hfu) and throughout much of northern Louisiana (35-44°C/km gradients; $>$ 2.0 hfu). Conditions in these areas indicate possibilities of potential geothermal exploitation. Relatively high heat flow values in southwestern Mississippi suggest a continuous zone of mild thermal anomalies from northern Louisiana to the Florida panhandle.

INTRODUCTION

The current program of near-surface geothermal research conducted by the University of Florida Geophysical Laboratory in the Gulf Coastal Plains is an outgrowth of an earlier project in the southern Appalachians and southeastern Coastal Plains. Those initial reconnaissance surveys of heat flow (Smith et al., 1977, 1981) suggested relatively high values of heat flow ($\sim$1.4 - 1.6 heat flow units) and high geothermal gradients along the Atlantic Coastal Plains (figure 1). These initial results were confirmed with the expansive and continuing program underway at Virginia Polytechnic Institute (Costain et al., 1980).

Other indications (figure 1) were noted: the relatively high geothermal conditions do not appear to continue southward beyond the region of Brunswick, Georgia, where incidentally, the East Coast Magnetic Anomaly turns inland. Throughout the Florida peninsula heat flow values were anomalously low, but the total effect of hydrologic influences remains unresolved. An area of exceptionally low heat flux was identified with four measurements in the Appalachian Plateau - Valley and Ridge region of extreme northeastern Alabama and northwestern Georgia. Finally, measurements in the Gulf Coastal Plains near Pensacola, Florida, and Mobile, Alabama, suggested the existance of "normal" or above-normal thermal conditions and justified expectations of thermal anomalies in the Gulf Coastal region similar to those in the Middle Atlantic Coastal Plains.

Accordingly, the Gulf Coastal Plain area of panhandle Florida, southern Alabama, southwestern Georgia, Mississippi, and Louisiana was considered for continued investigation. Despite a large number of shallow ($<$ 1000 meter) depth water monitor wells and numerous oil and gas test wells, the area was devoid of heat flow measurements. The paucity of seismicity and tectonic activity in this area and the abundance of geologic descriptions for the subsurface rocks contributed to the decision to proceed. This investigation was limited

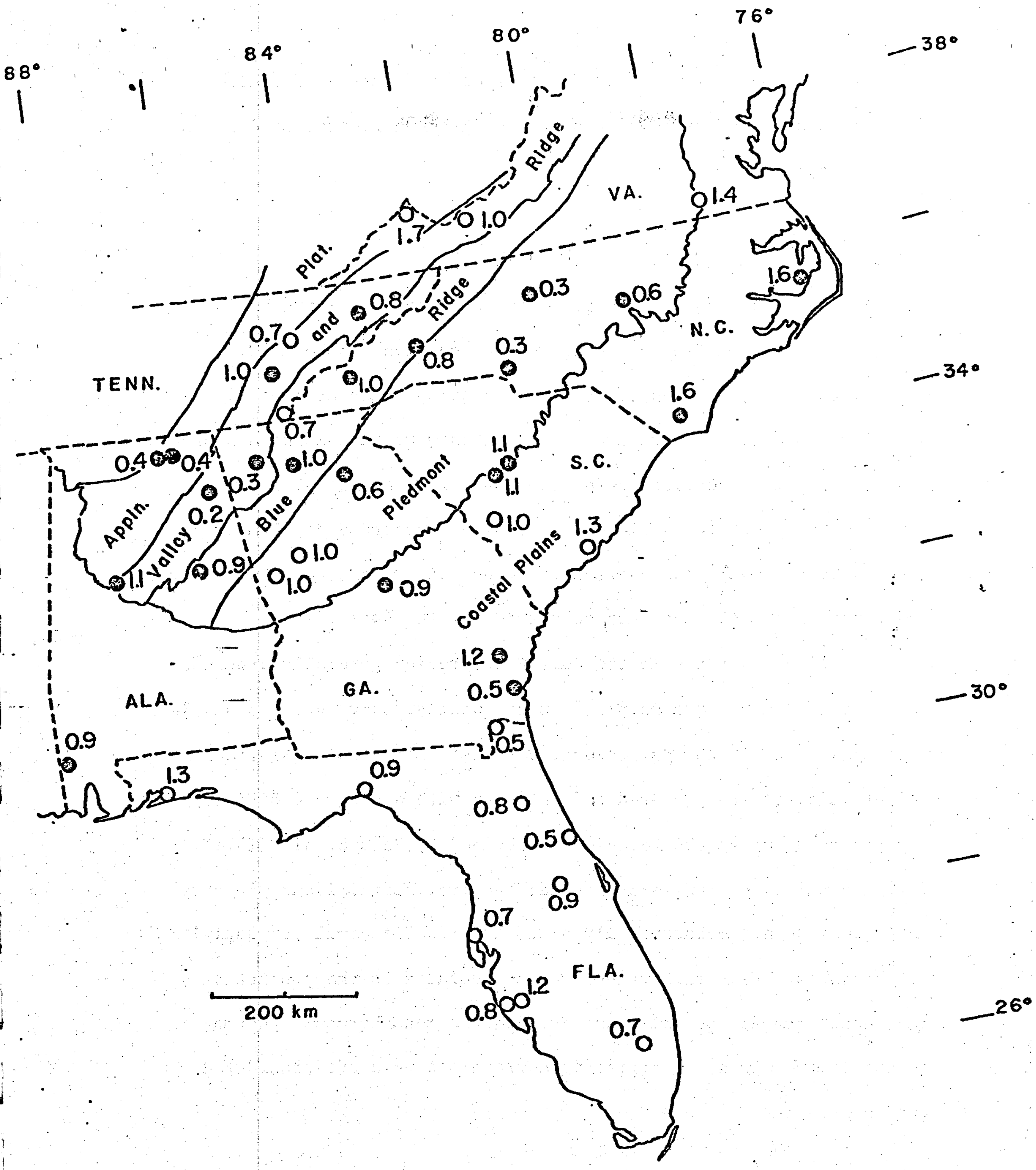

Figure 1. Initial heat flow values (in heat flow units) for the southeastern United States as depicted by Smith et al. (1977, 1981).

to a study of heat flow values, geothermal gradients, and their distributions; no examination of the well-known geopressured zones was contemplated.

PROCEDURES

Available boreholes were selected on an opportunistic basis through cooperation from state geological surveys and local U. S. Geological Survey offices. Cased, non-flowing holes at least 150 m deep were sought. Temperature measurements were made using a standard thermistor probe, four-conductor cable and reel assembly, and a Mueller-type Wheatstone bridge. Values were recorded at 10 m or 20 m intervals and least square gradients were determined, where necessary, for separate lithologic zones penetrated by the boreholes.

Drilling practices in the Gulf Coast region generally preclude the acquisition of core samples. Consequently, only cuttings samples were available for thermal conductivity determinations. Representative samples were procured and analyzed with a standard divided-bar apparatus using the technique described by Sass et al. (1971). Porosity values of 30% were assumed; however, significant porosity variations do not substantially alter the final thermal conductivity computations. Heat flow values were calculated as the product of the least squares thermal gradients and the mean harmonic thermal conductivity values. Topographic corrections were not considered necessary.

RESULTS

All results to date are summarized in table 1. Figure 2 depicts computed heat flow values at sites where measurements are complete. During the first year of the program, twenty-one new heat flow values ranging from < 1.0 heat flow unit to 1.7 hfu were determined in western Florida, Alabama, Mississippi, and Louisiana. In general, the values suggested a low to average heat flux for most of the eastern Gulf Coastal Plain. Anomalously low values of 0.4 hfu determined in northern peninsular Florida and northern Alabama tend to corroborate previously-determined values (figure 1) in those regions.

Measurements at two sites in southwestern Mississippi (Natchez and Utica) yielded thermal gradients as high as 46°C/km (over 180-340 m depth at Utica) and heat flux values of 1.4 hfu and 1.5 hfu (figure 2). Utica is located in Hines County overlying the Jackson Dome, a major subsurface feature associated with temperature elevations as observed from petroleum exploration efforts.

Higher geothermal gradients were also observed in northern Louisiana (i.e. 37°C/km at Bastrop) where two heat flow values of 1.7 and 1.3 hfu were recorded. Similarly, several deep boreholes in the western Florida panhandle displayed gradients of approximately 30-34°C/km and temperatures as high as 35°C at 500 m depth. Confident temperature extrapolations of 50°C at 1 km depth can be made and are significant because an extensive consumer market for geothermal energy is co-located in the Pensacola - Mobile region.

During the 1980 field season, eighteen new heat flow values from Mississippi and northern Louisiana were determined. Other

Table 1. Preliminary list of new geothermal gradient values, thermal conductivity values, and heat flow determinations for the southeastern Gulf Coast plains. (*) weighted average including other zones in borehole.

Location	Depth (M)	Gradient °C/km	Conductivity mcal/cmsec°C	Heat Flow (hfu)
Florida:				
Gainesville	500	12.04	3.11	0.37
Ft. Walton Bch.	500	31.54 (340m)	3.29	1.03
Navarre	280	34.13 (140-280)	3.29	0.98*
St. George Is.	273	21.18	2.77	0.58
Gretna	280	24.82	3.40	0.84
Wellborn	300	19.71	3.15	0.62
Whiting Field	360	27.81	3.52	1.03*
Camp Henderson	148	12.49	3.34	0.4
Alabama:				
Guin	155	11.28	3.50	0.39
Union Springs	267	23.84	3.10	0.74
Thomaston	340	37.07 (140-280)	2.38	0.74*
Mississippi:				
Natchez	260	27.96	5.07	1.42
Senatobia	340	19.94	5.10	1.01
Utica	340	45.98	3.09	1.48*

Table 1, cont.

Location	Depth (m)	Gradient °C/km	Conductivity mcal/cmsec°C	Heat Flow (hfu)
Brooklyn	220	20.08	5.06	1.06
Cary	190	17.11	4.68	0.8
Shelby	500	23.97	4.86	1.2
Pace	280	16.23	5.55	0.9
Forest	380	27.73	3.77	0.9*
Columbus	306	15.70	3.55	0.6
Louisiana:				
Simpson	380	26.82	4.78	1.28
Scotlandville	500	19.57	6.10	1.24*
Bogalusa	440	17.71	5.90	1.04
Baton Rouge N.	500	22.06	5.07	1.21*
Baton Rouge S.	500	23.64	4.42 4.42	1.10*
Vernon	220	29.11	4.92	1.26*
Bastrop	260	37.45	4.92	1.72*
Calhoun	260	31.08	5.12	1.6
Sikes	200	10.37	5.93	0.6
Haile	236	34.98	6.46	2.1

Table 1. Cont'd

Location	Depth	Gradient °C/km	Conductivity mcal/cm sec°C	Heat Flow (hfu)
Junction City	230	24.94	6.02	1.5
Bernice	220	32.17	6.17	2.0
Marsalis	258	27.48	6.50	1.8
Winnfield	215	27.65	5.73	1.6
North Hodge	200	23.74	5.4	1.3
Bosco	236	29.00	4.07	1.2
Kelly	172	44.23	5.72	2.0*
Deville	250	24.94	4.51	1.1
Truxno	215	33.13	6.42	2.1

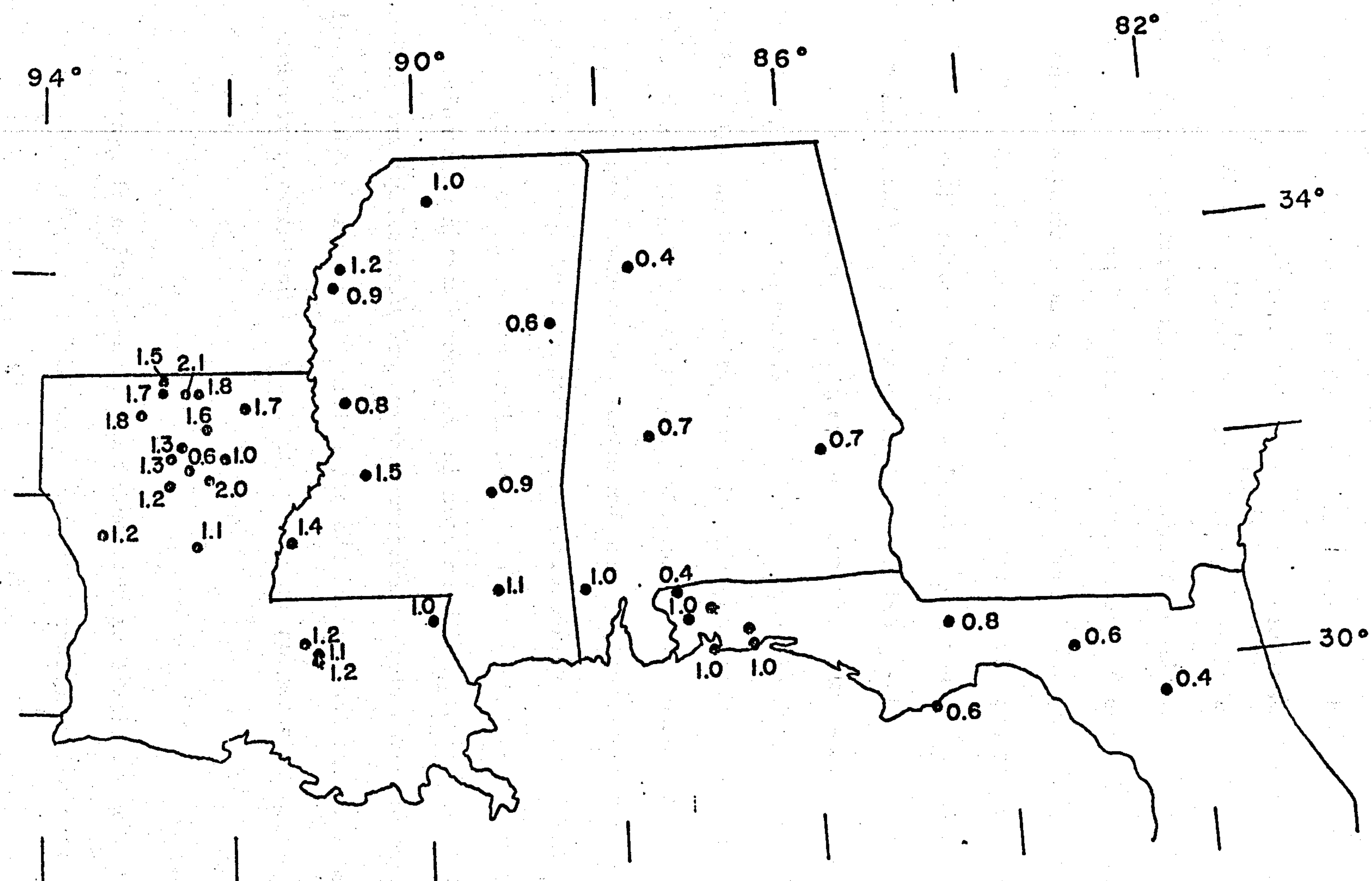

Figure 2. New (unpublished) heat flow values (in heat flow units) obtained in the current program for the Gulf Coastal Plains.

additional determinations in western Florida and Alabama are incomplete. Measurements in southwestern Georgia are planned for early 1981. The new values indicate that a three-parish area (Ouachita, Union, and Claiborne) in northern Louisiana is characterized by higher heat flow values (six sites average 1.75 hfu; maximum 2.1 hfu). Geothermal gradients of 35-44°C/km were recorded in this region, and temperatures as high as 85°C can be extrapolate to depths of 2 km.

New values in Mississippi fail to suggest an extension of the limited zone of positive anomalies revealed in the first year of investigations. Values from a total of nine sites in Mississippi average 1.1 hfu and approximate typical Gulf Coastal Plain values.

Based on the presently available data and contingent on the pending cultivation of models, it is interesting to note, without speculative interpretation, that the zone of elevated thermal gradients and heat flow values can be correlated with reported patterns of salt-dome intrusions across northern Louisiana and southwestern Mississippi. Within the area under investigation, a wedge-shaped zone of apparent and inferred positive geothermal conditions can be tentatively proposed (figure 3). With an apex in the west Florida panhandle, this zone broadens across southern Alabama and Mississippi and includes most of northern Louisiana. The potentiality for exploitable thermal resources in this region is encouraging, but is not clearly resolved.

SUMMARY

Initial results from the continuing investigation of heat flow and temperature gradients in the eastern Gulf Coastal Plains suggest

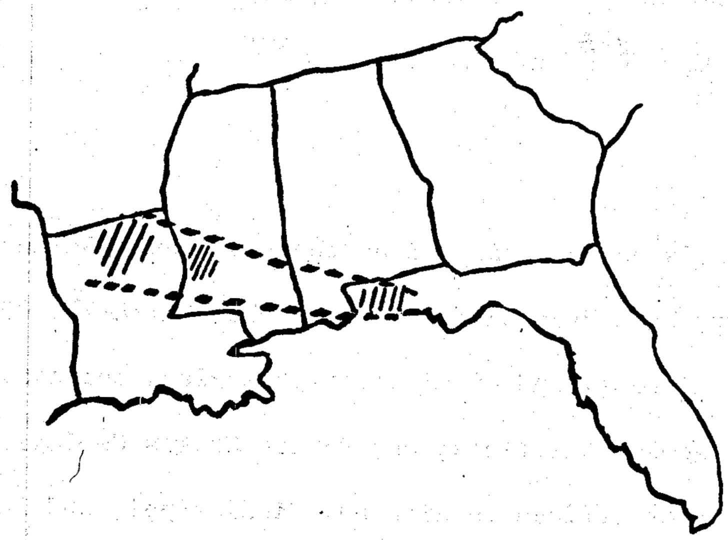

Figure 3. Areas of possible interest for potential geothermal energy exploitation (shaded). Dotted line suggests inferred zone of possible positive thermal anomalies.

at least two distinct areas and a possible zone of interest amid general conditions of low to normal heat flow values. In extreme western Florida, thermal gradients to 500 m depth are approximately 30-34°C/km, and temperatures of 50°C can be extrapolated to 1 km depth. Continued evaluation of conditions in this area appear warrented in view of the substantial population and industrial complex in the Pensacola-Mobile area.

In northern Louisiana (and a small, but undetermined portion of southern Mississippi), thermal gradients of 35-46°C/km and heat flow values up to 2.1 hfu are observed. A broad area of relatively high heat flow is identified, and a three-parish area of particular interest can be recognized. Temperatures as high as 85°C can be extrapolated to 2 km depth.

The near-surface thermal conditions observed to date in the Gulf Coastal Plain do not display an overwhelming lure for immediate development, but conditions in specific regions are such to suggest eventual consideration for exploitation.

ACKNOWLEDGEMENTS

This research is being sponsored by the Los Alamos Scientific Laboratory, Hot Dry Rock Program (Contract #4-L60-2178K-1). Principals from the Florida, Alabama, and Mississippi geological surveys, the Florida Water Management Districts, and United States Geological Survey water resources offices in Alabama, Mississippi, and Louisiana contributed significantly to this project with their courteous cooperation. William Dees and Eric Medlin from the University of Florida assisted immeasurably in field and laboratory efforts.

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The Eastern Hot Dry Rock Target Prospect Evaluation

by

C. E. Schubert
D'Appolonia Consulting Engineers, Incorporated

X

THE EASTERN HOT DRY ROCK TARGET PROSPECT EVALUATION

Carl E. Schubert

D'Appolonia Consulting Engineers, Inc.

ABSTRACT

The Eastern Hot Dry Rock Target Prospect is located in a corridor between Smith Island, Maryland on Chesapeake Bay and the southern tip of Assateague Island, Virginia on the Atlantic Ocean. The prospect was selected for investigation based on heat flow values and thermal gradients relatively higher than other areas in the coastal plain. The exploration program was aimed at locating the most favorable location within the site area for the targeting of a deep test borehole for HDR heat extraction. The program consisted of an aeromagnetic survey, gravity/magnetic analysis, time-domain electromagnetic (TDEM) survey, Vibroseis seismic reflection profiling, drilling and logging of four 300-meter borings, and the reopening and logging of an abandoned oil exploration hole. The results of this study indicate that the area has potential for the extraction of heat using the Hot Dry Rock concept.

INTRODUCTION

The Eastern Hot Dry Rock (HDR) Target Prospect (Figure 1) was previously determined to have geothermal potential based on the regional studies by VPI & SU (Costain, et al., 1980). This study was sponsored by the Los Alamos Scientific Laboratory (LASL), and executed by D'Appolonia Consulting Engineers, Inc. (D'Appolonia), with the purpose of supplementing and interpreting the previous work by VPI & SU, which was oriented to wet geothermal systems, and evaluating and targeting a deep test boring for HDR extraction experiments.

The previous work by VPI & SU included a number of short seismic reflection lines and several shallow (300 meter) borings where thermal gradient and conductivity measurements were taken. These studies indicated heat flow values up to 1.9 HFU across the site area, which are among the highest recorded in the coastal plain. The model proposed by VPI & SU (Costain, et al., 1980), and used as the preconceived basis for exploration in this study, is that of a granitic pluton, which may, if sufficiently insulated by sediments of low thermal conductivity without convection systems, retain sufficient radiogenic heat to exist as a resource.

INVESTIGATIONS PERFORMED

Investigations included an aeromagnetic survey, gravity/magnetic analysis, time-domain electromagnetic (TDEM) survey, Vibroseis seismic reflection profiling, drilling and logging of four 300-meter borings, and the reopening and logging of an abandoned oil exploration well found open to a depth of 462 meters. The gravity, magnetic, and TDEM methods had the purpose of defining the nature of the basement rocks while the seismic reflection profiles provided information on the sedimentary cover and also provided constraints on the potential field models of the basement. The borings provided additional information on the sedimentary cover and data for the thermal analyses. The individual methods are discussed separately below, and the locations of individual measurement points are shown in Figure 1.

Drilling Program/Analysis of Thermal Data

Four holes to 300 meters were bored by drilling a three-inch casing and abandoning the bit at total depth, without cementing. Thermal gradient and natural gamma measurements were made. No cores were attempted as it was known from previous work that recovery in the unconsolidated sediments was difficult and feasible only in clay-rich horizons. In addition to the borings drilled for this study, the E. G. Taylor No. 1 abandoned oil exploration well was located and found to be open to a depth of 462 meters and was also logged.

The exceptional consistency of the gamma log signatures between borings (Figure 2) enabled a reliable correlation of shallow formations across the site area. The thermal gradients in clays proved to be relatively high, as was the natural gamma response to the same clay units, producing a great similarity in overall response between the gamma and thermal gradient logs (Figure 3). Individual sedimentary formations proved to have consistent lithologic and thermal properties across the site area (Figure 4), leading to the conclusion that limited conductivity data can be reasonably extrapolated to interpret variations in thermal data across the site.

The range and mean of the observed gradients are:

FORMATION		GRADIENT	MEAN $\pm$/s.d.
St. Marys	(n = 12)	30.9 - 40.8	34.4 $\pm$ 2.9
Choptank	(n = 12)	25.4 - 35.5	28.8 $\pm$ 2.7
Calvert	(n = 11)	47.0 - 55.5	51.3 $\pm$ 2.8
Piney Point/ Nanjemoy	(n = 4)	37.3 - 52.1	44.4 $\pm$ 5.4

The higher gradients in any particular formation generally lie in the eastern part of the site. Some gradients persist over fairly large depth intervals. For example, in the E. G. Taylor 1-G well, the gradient over a 500-meter interval averages 45 degrees Centigrade per kilometer, or about 50 percent more than the 30 degrees Centigrade per kilometer customarily assumed as an average crustal gradient. It is estimated that the gradients will fall to the crustal average with deeper depths, as was observed by VPI & SU at the Crisfield well, in response to changes in thermal conductivity with depth.

Magnetic/Gravity Analysis

An aeromagnetic survey covering in excess of 1,300 line miles was flown over the site area (Figure 5) and was analyzed in conjunction with existing gravity coverage of over 200 stations to estimate bedrock lithology and structure. Three granite plutons (low gravity, low to intermediate magnetization) were interpreted as well as three mafic (high magnetization, high gravity). The magnetic data have been analyzed to interpret a depth to basement rock over the site area, which shows an increase in basement dip in the eastern third of the site as well as several local anomalies. This dip is such that the crystalline basement exceeds in depth the seismic basement by over two kilometers in places. Accordingly, seismic mapping using present techniques cannot be relied on to always record top of crystalline basement.

Time-Domain Electromagnetic (TDEM) Analysis

The controlled source TDEM method, as well as two deep DC electrical soundings, were used to determine spatial resistivity variations. Approximately 85 square miles in the eastern part of the site were investigated using six transmitter sites with an output of up to about 200 kilowatts and 42 receiver locations. This method encountered large variations of resistivity in the upper sedimentary section, probably due to the presence of saline aquifers. This somewhat limited the effectiveness of determining the electrical properties of the basement rocks. The electric structure is a five layer, QH type section ($\rho_1>\rho_2>\rho_3>\rho_4>\rho_5$) with the conducting layer above crystalline basement having a resistivity of less than 2.0 ohm-meters. The lateral variation of resistivity noted in the deep conducting layer could be due to a 9.3 degree Centigrade change if all the resistivity changes were due to temperature, i.e., porosity, salinity, etc., were constant.

The variance of electrical properties of the sedimentary cover may limit the effectiveness of electrical methods in the Atlantic Coastal Plain.

Seismic Reflection

Twenty-five miles of a Vibroseis seismic reflection survey were performed to connect existing seismic lines and provide an interpretation of the depth to bedrock and to establish the disposition of sedimentary horizons deeper than the units penetrated by the shallow borings. The use of this technique to provide depth control on deep high thermal conductivity formations such as the Patuxent Formation is critical in estimating the temperature at the basement rock surface. In addition, the depth control obtained from this survey provided a model constraint for the potential field analysis.

CONCLUDING DISCUSSION

The use of shallow borings for measuring the geothermal gradient provides a valuable tool for assessing the geothermal potential in the Atlantic Coastal Plain, but the information should be assessed with caution. Variations in lithology between formations in this site area cause a lagre change in geothermal gradients. Thus, stratigraphic correlations should be carefully established so that gradients can be assessed in context of the formations penetrated. Sediments on the coastal plain are not flat, but can be modeled as a wedge thickening to the east, and borings of equal depth parallel to the dip will penetrate formations of very different thermal conductivities. To estimate the basement and deep sedimentary horizon temperatures, thermal conductivity data are required. Only one deep boring to basement with such data, the Crisfield well, exists. Data from the Crisfield deep well can be extrapolated within the adjacent area using existing conventional well logs from the Taylor deep well for guidance.

Drilling with casing is a practical and efficient way to make a stable hole to determine thermal gradient data in areas of largely unconsolidated sediments to depths of at least 300 meters. Repeated thermal logs have shown excellent correspondence, and the short drilling time and absence of heat produced by cementing allows the well to arrive at a relatively rapid thermal equilibrium.

The assessment of basement lithology in the absence of expensive deep borings can be accomplished by analyzing gravity and magnetic data. Anomalies found are interpreted as due both to lithologic changes in the basement and variations in the depth to bedrock. Seismic reflection studies provide control on the model, as well as determining the disposition of deep sedimentary horizons, important to the assessment of the variation of temperature with depth. In the coastal plain however, seismic basement is usually not the true crystalline basement, but indurated sediments resting unconformably over the igneous/metamorphic basement. In the coastal plain, electrical methods appear to have limited usefulness in determining gross basement characteristics. However, although none was found, the technique is capable of locating major fluid filled fractures or fault zones which could be detrimental to HDR extraction technology.

The site basement was mapped as shown in Figure 6, showing a complex of faulted lithologic units. The Crisfield well was drilled with anticipation that it might lie on or at least close to the eastern margin of a granitic pluton lying to the west under Chesapeake Bay. Our analysis confirms that the pluton exists and that the well lay off the pluton. Figures 7 and 8 illustrate our estimates of the temperatures with depth. A number of potential drilling targets, where temperatures at the top of basement in excess of 80 degrees Centigrade are reasonable and where temperatures over 100 degrees Centigrade could be found, have been identified.

The future of HDR in the Delmarve area hinges on a number of potential developments. The second HDR site is anticipated to be selected by late 1982. A number of other sites are under investigation presently; only one in detail approaching this study. Part of the decision process will be whether or not the second HDR site should be amenable to electricity generation or to direct use. A commercial venture, entirely separate from this project, has been looking at a number of targets in the east for pursuit of HDR energy extraction to produce electricity.

Our overall results indicate that potential does exist in the Eastern Hot Dry Rock Target Prospect for the development of an HDR geothermal resource to supply hot water for direct use. Consideration of the site for production of electricity appears unreasonable in light of the present status of technology and firm knowledge of the basement rock characterics. The eastern part of the site area appears to have the greatest potential for development, primarily to higher predicted temperatures.

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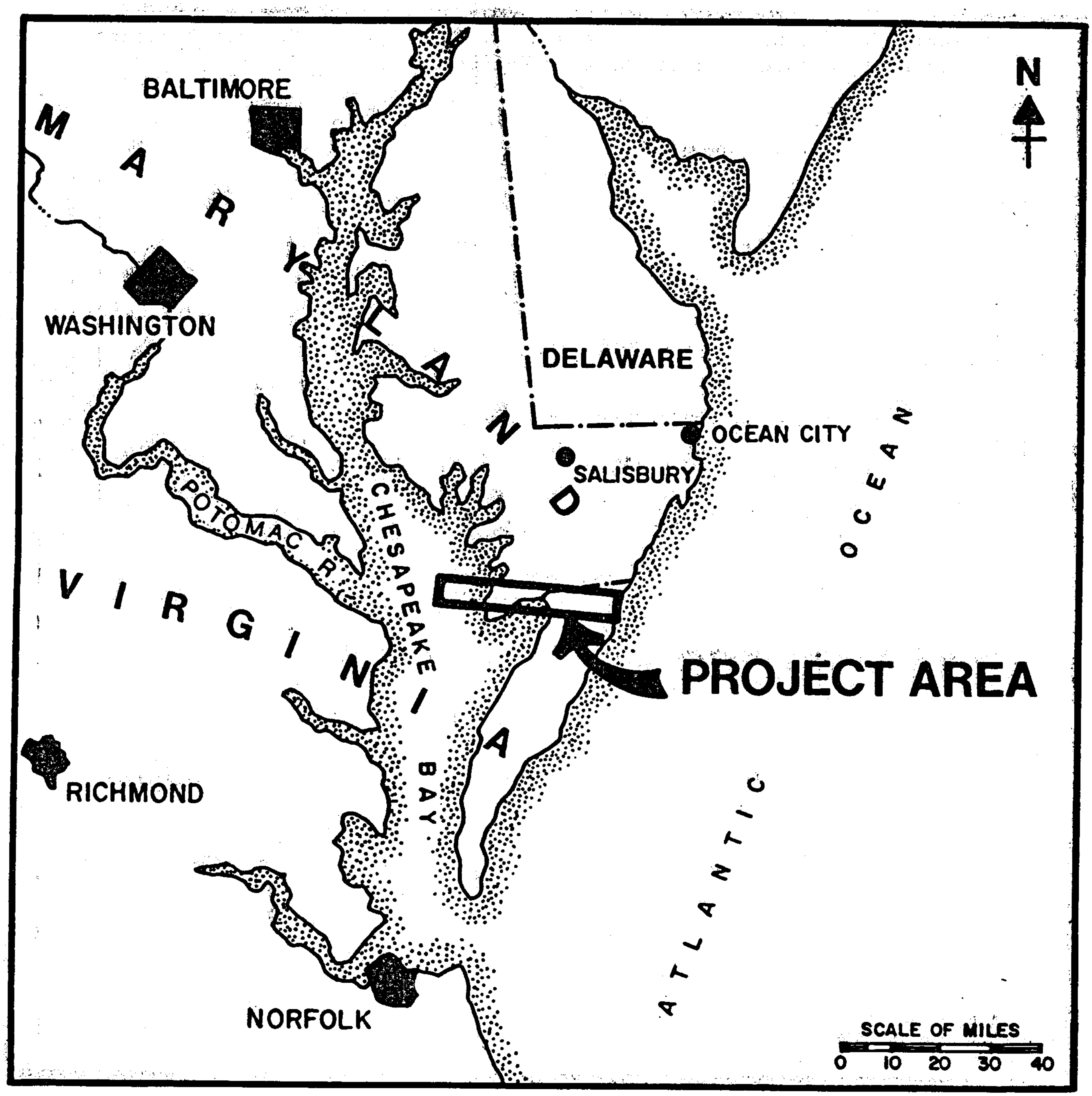


FIGURE 1
LOCATION MAP

D'APPOLONIA

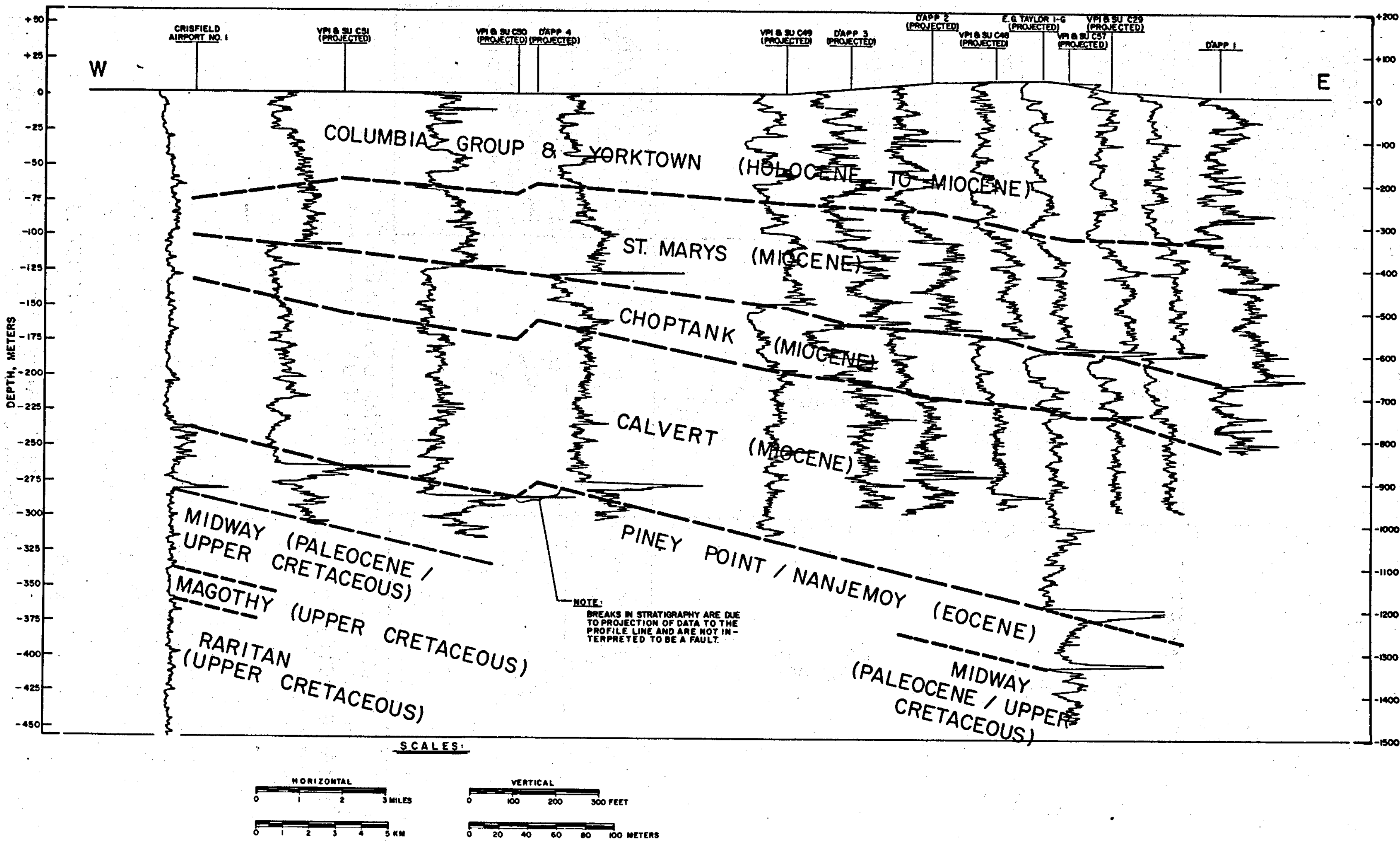


FIGURE 2

GAMMA LOG INTERPRETATION
OF SURFACE STRATIGRAPHY IN AN EAST-WEST PROFILE
THROUGH THE HDR SITE

D'APPOLONIA

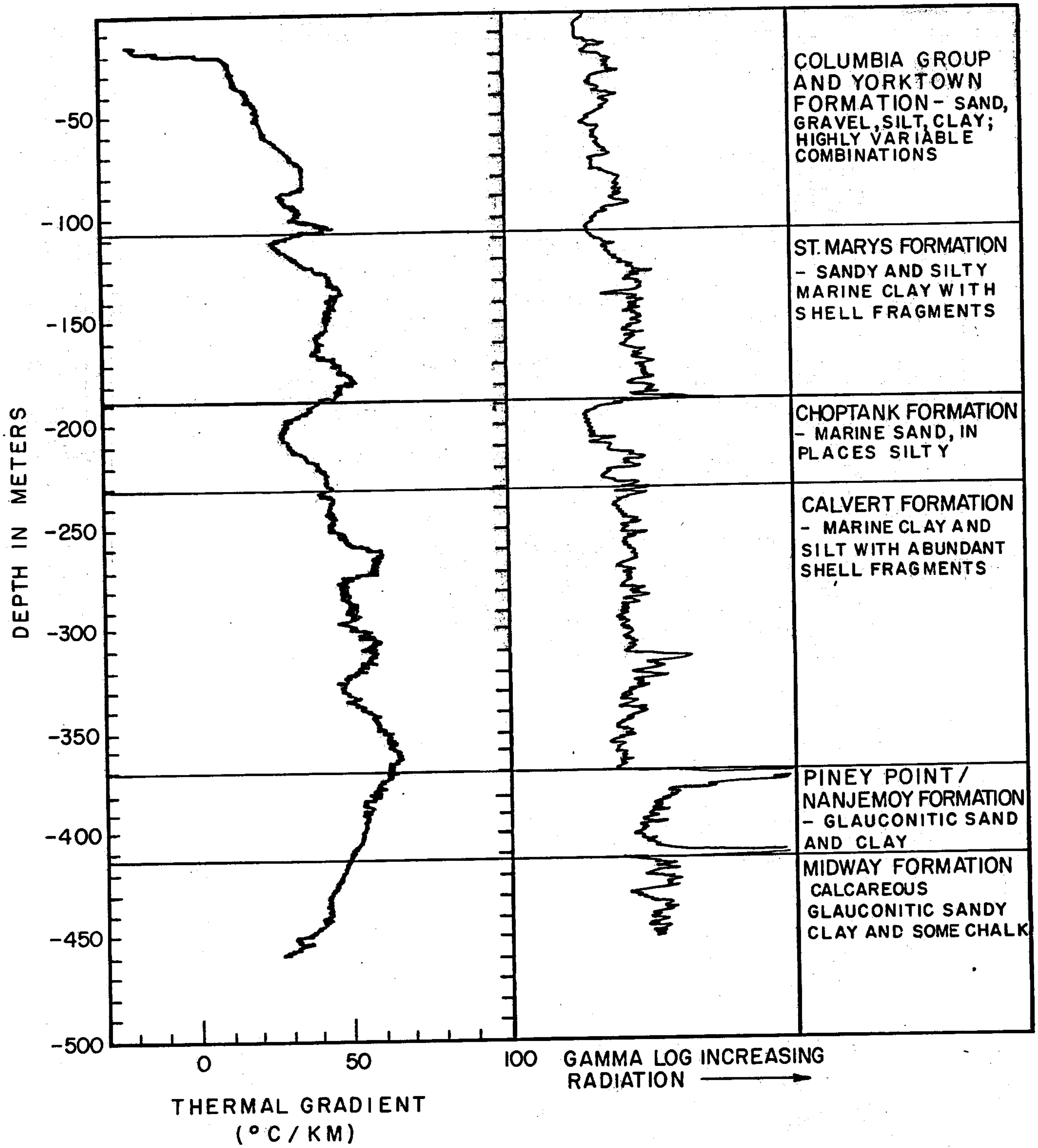


FIGURE 3

COMPARISON OF THERMAL GRADIENT AND GAMMA LOGS FOR THE E. G. TAYLOR 1-G WELL

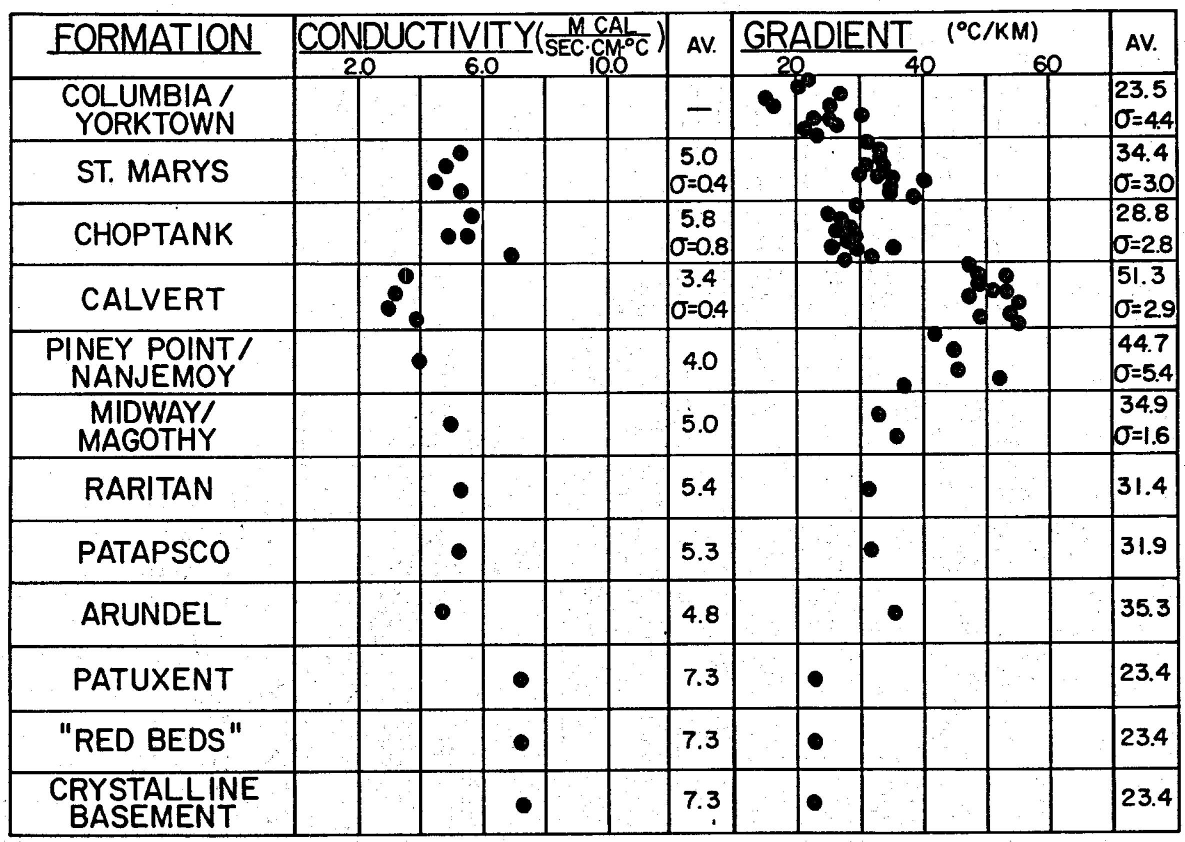


FIGURE 4

MEASURED GRADIENT AND CONDUCTIVITY VALUES
FOR INDIVIDUAL GEOLOGIC FORMATIONS

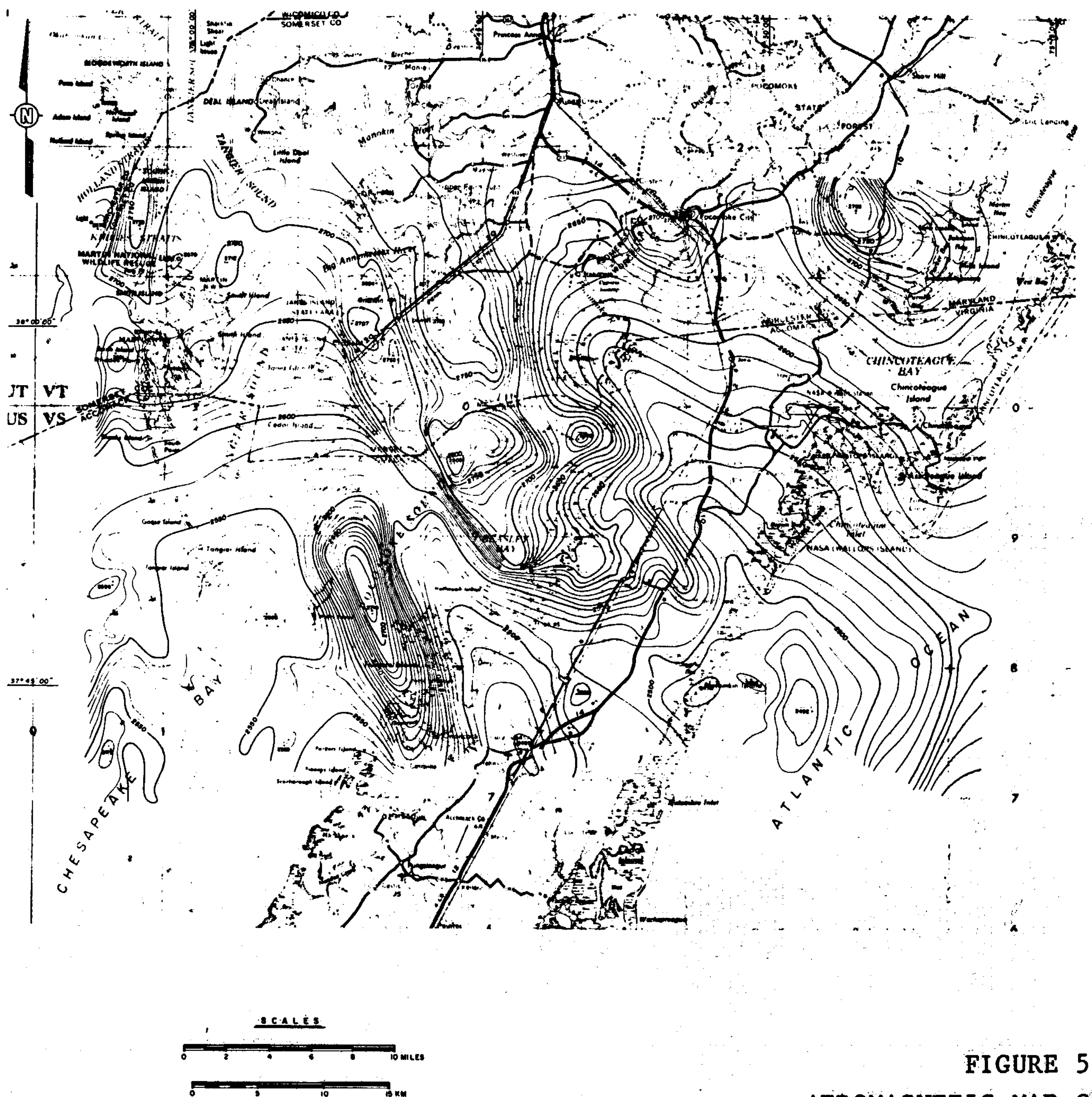


FIGURE 5

AEROMAGNETIC MAP OF HDR SITE

D'APPOLONIA

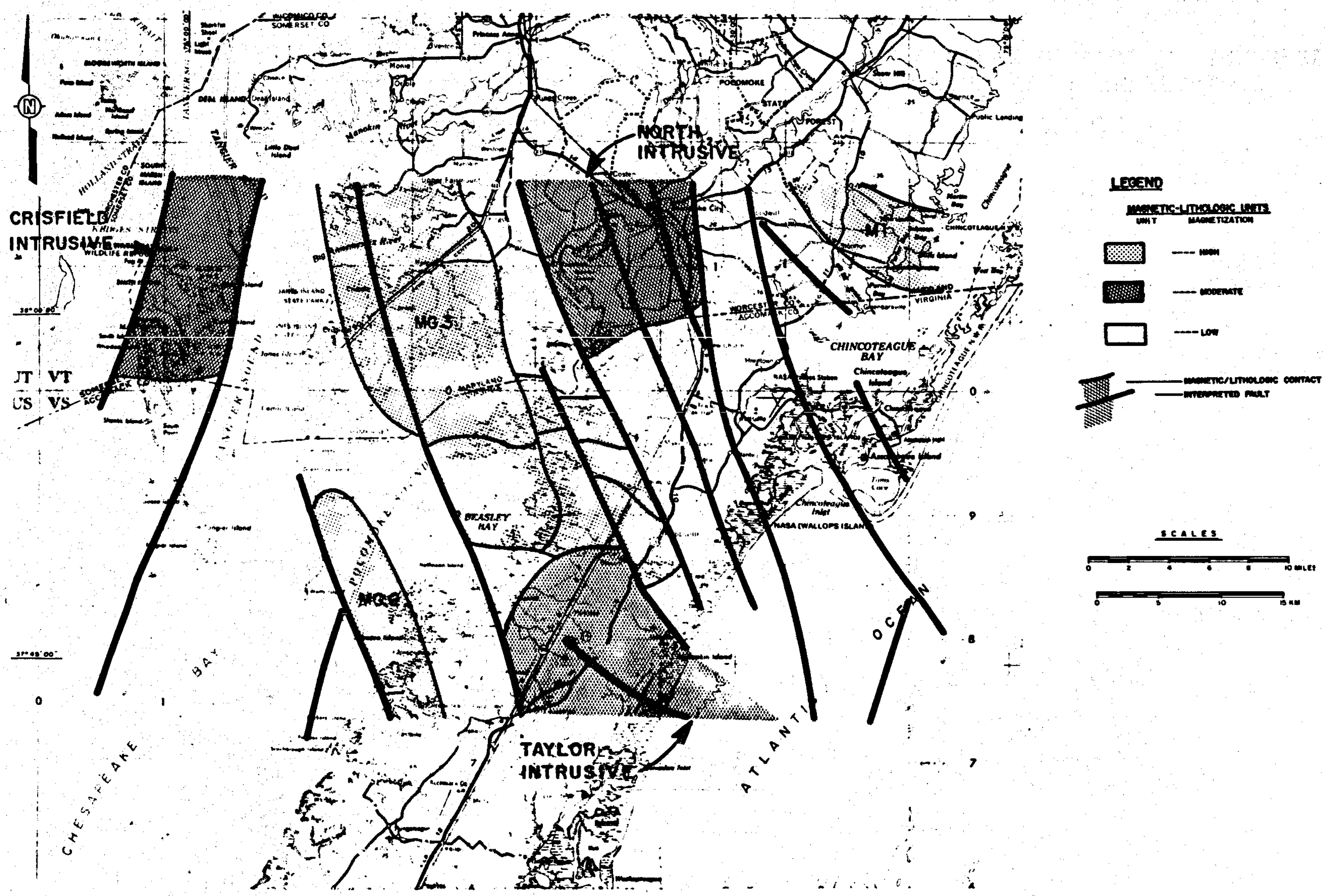
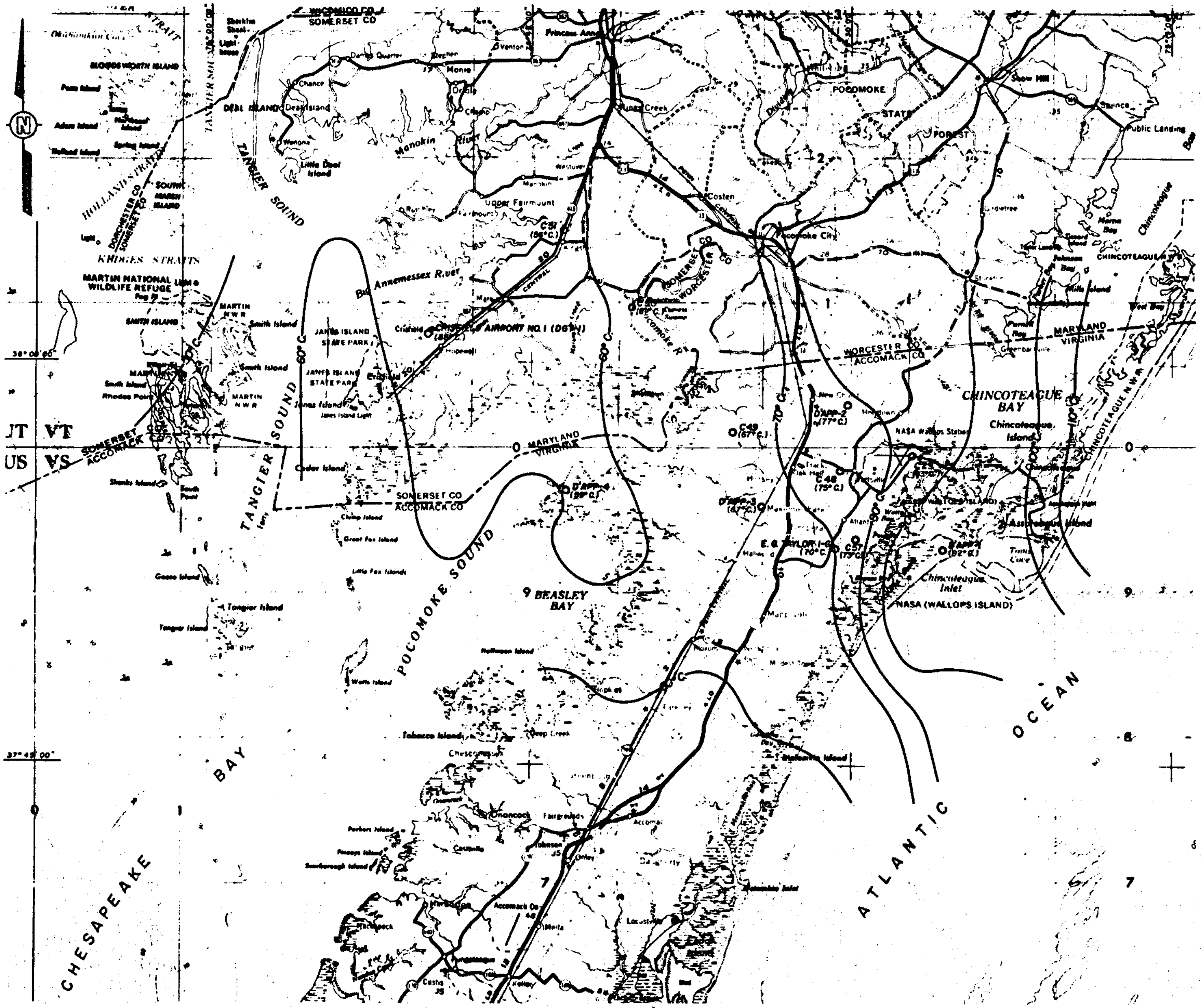


FIGURE 6

BASEMENT GEOLOGICAL MAP
BASED ON A COMBINED GRAVITY MAGNETIC INTERPRETATION

D'APPOLONIA



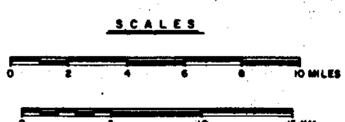


FIGURE 7

ESTIMATED TEMPERATURE
AT THE SURFACE OF CRYSTALLINE BASEMENT

D'APPOLONIA

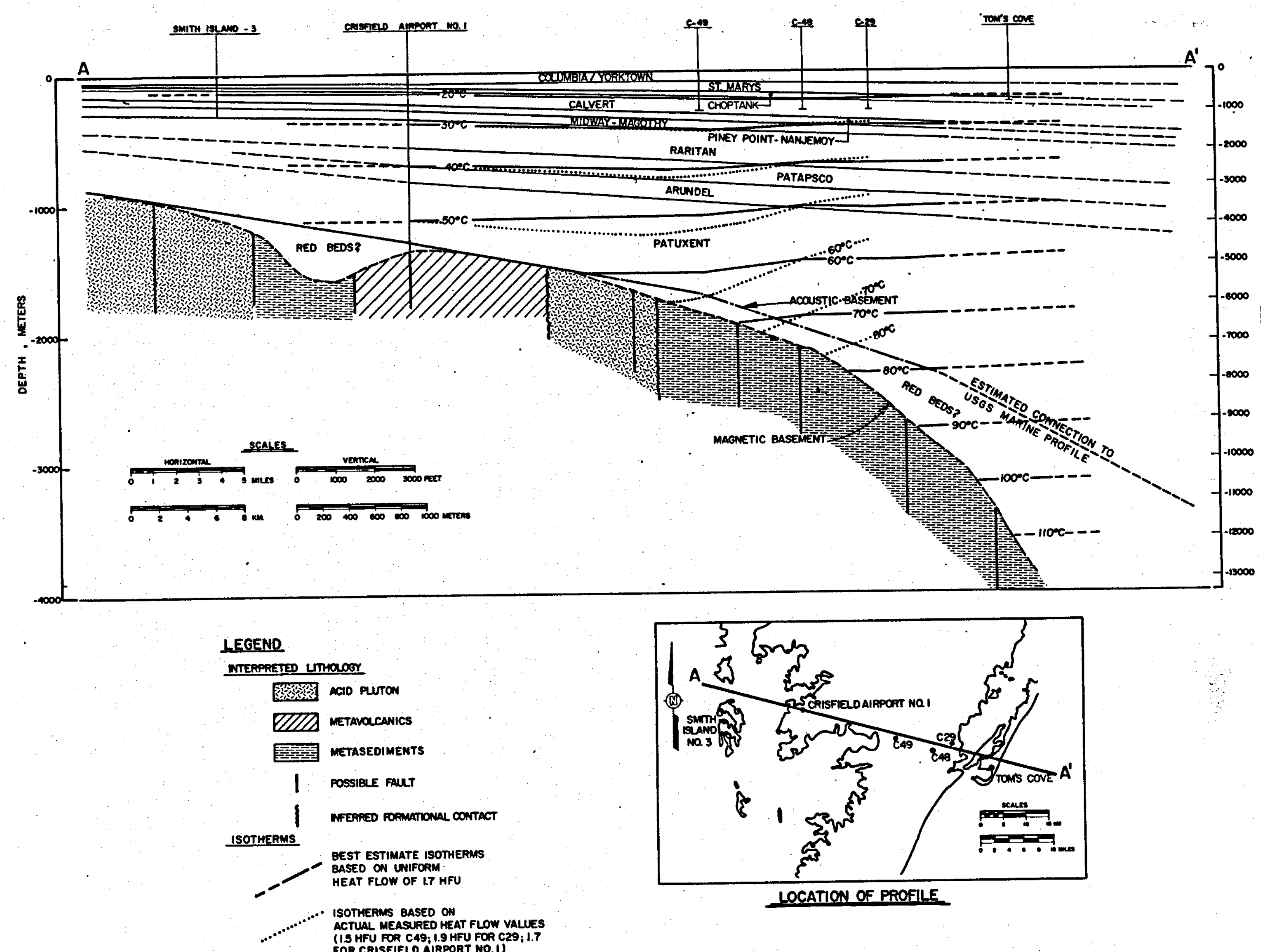


FIGURE 8

GEOLOGIC CROSS-SECTION
WITH ESTIMATED ISOTHERMS THROUGH THE HDR SITE

D'APPOLONIA

Lebanon Springs (NY)
Progress Report

by

J. R. Dunn
Dunn Geoscience Corporation

XI

LEBANON SPRINGS
PROGRESS REPORT

1.0 INTRODUCTION

1.1 Warm water with a temperature of about 72° F has long been known to occur at Lebanon Springs, New York. In addition, warm water with a temperature of about 74° F has been tapped at the Sand Springs area, approximately 20 miles north, at the northeastern edge of Williamstown, Massachusetts. In 1979 the New York State Energy Research and Development Agency (NYSERDA) agreed to support a program to determine the feasibility of developing the Lebanon Springs waters or, alternatively, of developing potentially similar waters in the vicinity of Lebanon Springs.

1.2 The waters at Lebanon Springs are used by some 40 households for ordinary domestic purposes. The owner of the spring has the right to all water not used by other homeowners. The sign on the springs indicates that the flow is 500 gallons per minute. Before the proposal was made to NYSERDA, Dunn Geoscience Corporation (DGC) had obtained the right to test the spring to determine flow but had no assurance of rights to set up a facility to use any excess warm waters. Because of legal uncertainties, an alternate research path was to explore in the region to determine why Lebanon Springs was warm and if other springs might exist or be developed through drilling.

1.3 Although it was geologically feasible and probably legal to develop water by drilling up the mountain from Lebanon Springs, reducing the flow of the springs was considered probable; and, hence, the decision was made to look elsewhere for warm water. The alternate research path of trying to find warm water away from the Lebanon Springs area was ultimately followed.

1.4 The possibility of locating the developable warm water did not appear to be too remote because: (1) the warm waters at Williamstown were in the same general belt; (2) a deep gravity low occurred with its axis parallel to the possible warm water trends; and, (3) the research on the carbonated waters of the Saratoga area indicated abnormal heat occurred at several areas in the general capital district.

2.0 EXPLORATION PROGRAM

2.1 Temperature Gradients

A search for abandoned water wells into rock in the general area of western Rensselaer County was instituted to determine if any abnormally high temperature gradients occurred in the area.

2.2 Active Domestic Wells

Meanwhile, a program was started to measure the silica content and temperatures of active domestic wells which obtained water from bedrock.

2.3 Geologic Mapping

A program of geologic outcrop mapping of the belt between Lebanon Springs and Williamstown was started which had the multiple purposes of: (1) trying to see why the warm springs occurred; (2) trying to determine if structural conditions could exist where other warm water might be located; and, (3) trying to see if any other warm seeps or springs existed.

3.0 RESULTS

3.1 In a sense, all three research programs were successful in that they yielded positive results. All showed that additional warm waters almost certainly exist in the region. The programs failed, however, in that they did not result in locating one or more specific sites in New York State where warm water could be developed in the immediate future.

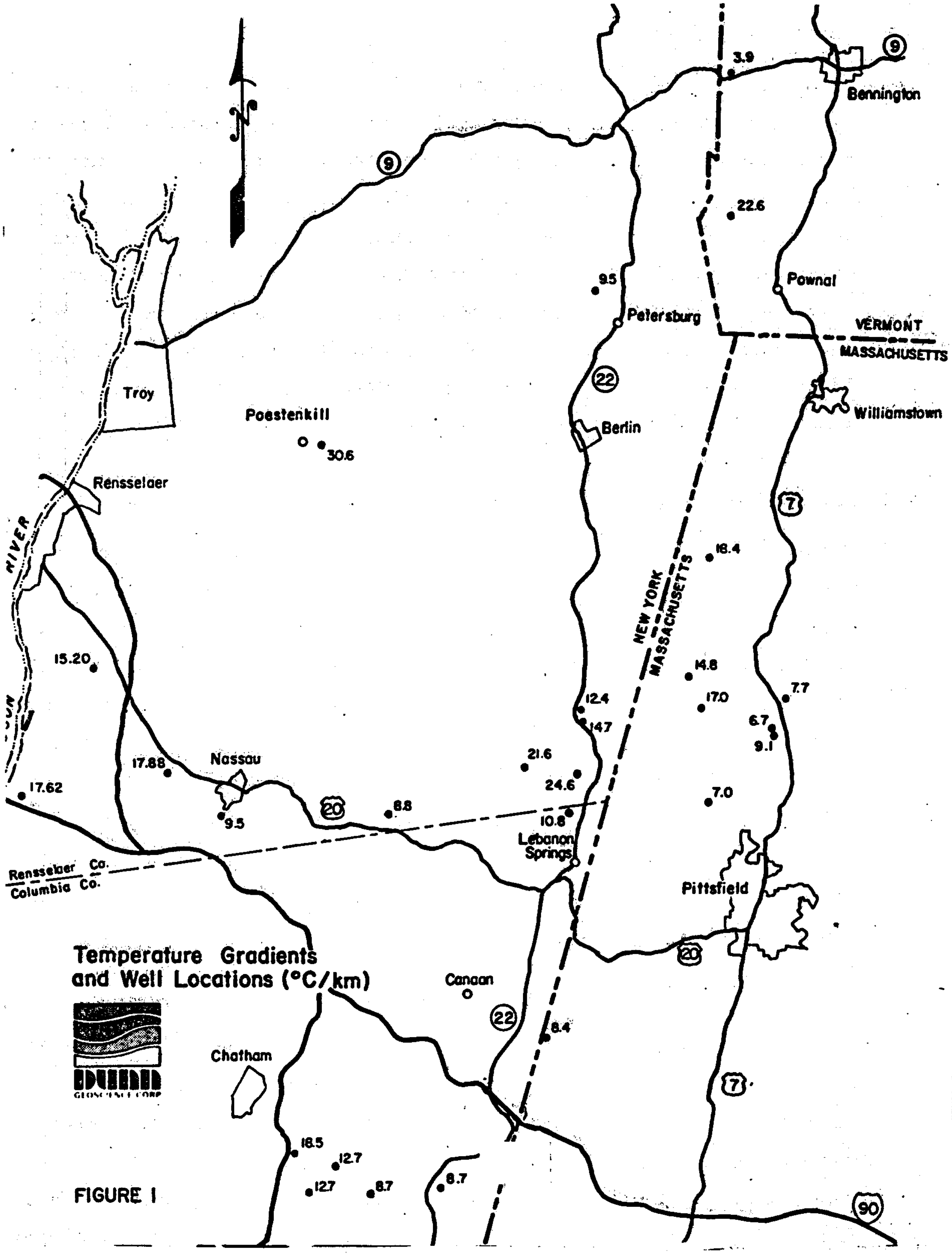
3.2 Temperature Gradients

Twenty-eight abandoned wells were located and temperatures measured every five meters using a thermister probe and recorder. Figure 1 shows the location of these wells and the temperature gradients in $^{o}C/km$. The regional background gradient to the east, north, and south appeared to average about $8^{o}C/km$, i.e., gradients are abnormally low relative to apparent worldwide averages. To the north, northwest, and west of Lebanon Springs, some gradients were located which were from two to nearly four times the background gradient of $8^{o}C/km$. The highest gradient was $30^{o}C/km$ at Poestenkill and was somewhat higher than worldwide norms.

3.3 Silica-Temperatures of Active Domestic Wells

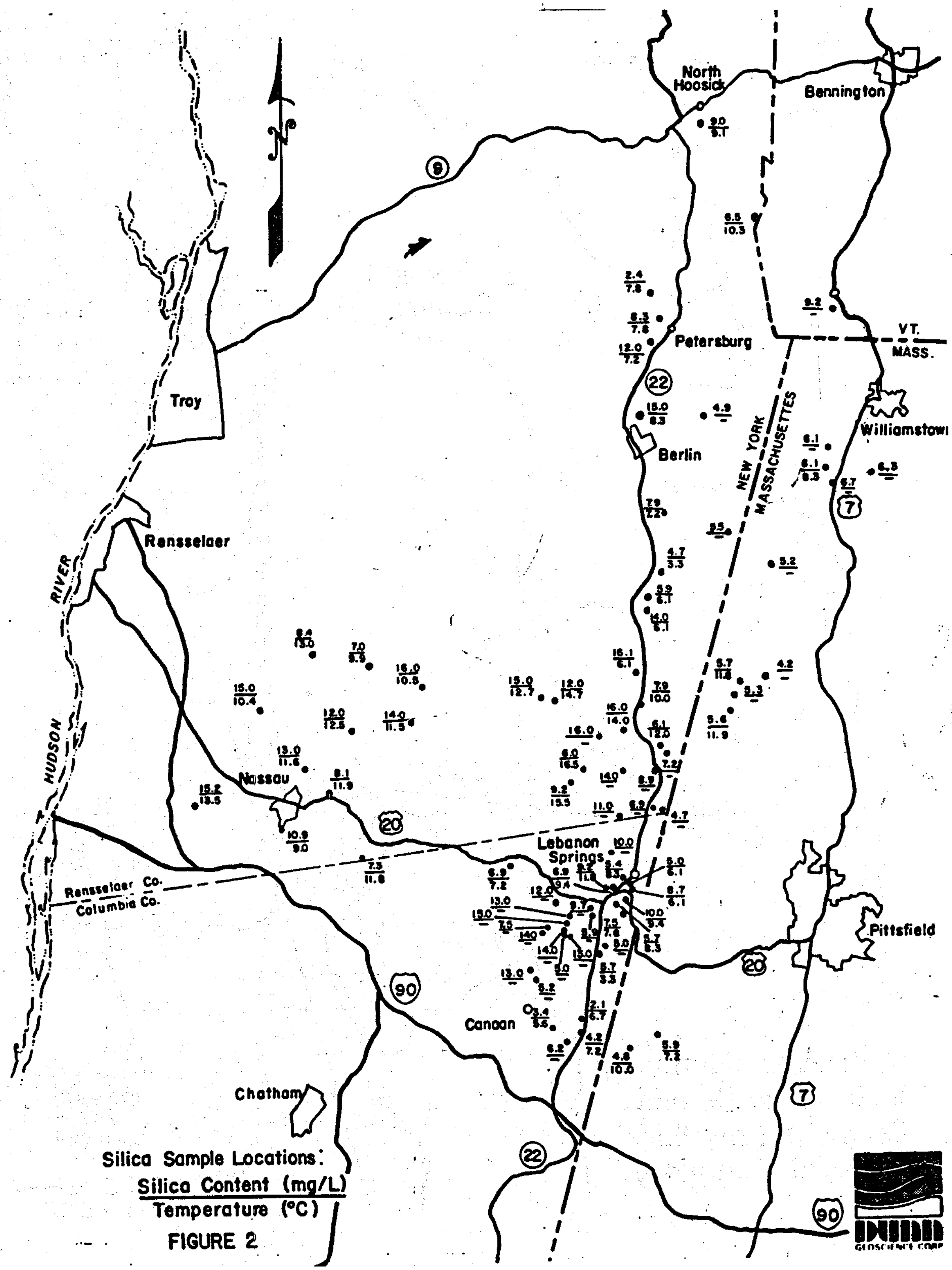
Figure 2 summarizes the results of silica and temperature measurements of active domestic wells which penetrated rock. Most wells were from 100 to 500 feet deep. The SiO_2 content in ppm is the upper number and the temperature in degrees centigrade is the lower. Although no high values were observed, the values did appear to show a pattern. Generally, the high silica values were with higher well temperatures and, conversely, for the lower silica values. Further, a line can be drawn around most wells which had water silicas of over 12 ppm and/or temperature of $10.3^{o}C$ or higher. Note that many of these wells with the higher SiO_2 are also those with the higher temperatures. The dashed sections of line indicate alternate interpretations.

Figure 3 shows the same line superimposed on the temperature gradients of Figure 1. We see that the higher gradients fall into the same zone. We believe that these correlations indicate the methods used are promising research tools for this part of the United States, just as somewhat deeper wells were found to be in the Central United States. The tool may be refined by determining such additional parameters as pH, lithology and well depths.

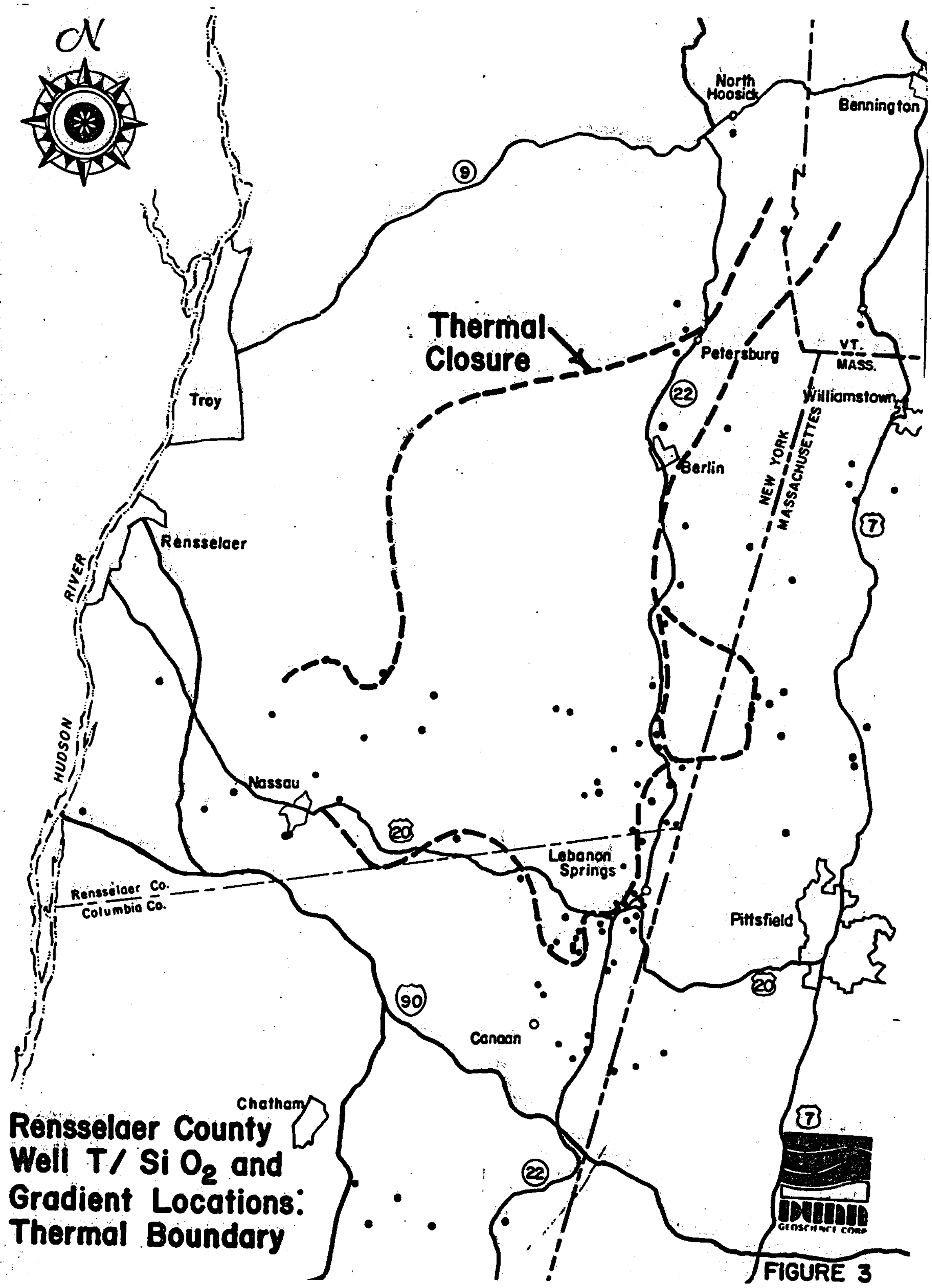


Temperature Gradients and Well Locations (°C/km)

FIGURE I



Silica Sample Locations:
Silica Content (mg/L) / Temperature (°C)
FIGURE 2



Rensselaer County Well T/ Si O$_2$ and Gradient Locations: Thermal Boundary

3.4 Geologic Mapping

Figure 4 shows the area where geologic mapping was done. It also shows the location of two additional warm springs. The geologic mapping showed that all warm springs and wells were along or near major faults. Two additional warm springs were located about one mile west of Williamstown, but unfortunately, in Massachusetts. The warm springs and well locations were compatible with the warmth of the water being the result of deeply circulating ground-water along major zones of permeability.

3.5 Integration of Data

Figure 5 shows the location of the CO_2-rich brine area of the Capital District, the major negative gravity anomaly of the area, the termination of a magnetic high against the axis of the gravity low, along with the warm area line as indicated by the data from wells and well waters. Note that almost all of the warm area falls within the gravity low. Note also that the boundary of the gravity low to the south and east coincides with the boundary of the warm area. Note also that the southern boundary of the thermal area and the gravity low coincide with the only east-west displacement that we know of along Logan's line.

Currently we can only guess about the nature of these correlations and do not feel we should speculate further at this time.

4.0 CONVECTIVE SYSTEMS

4.1 One final consideration which must be evaluated is the movement of heat in the area. The east-west fault block which shows as an offset of Logan's line appears to bound the gravity low and the thermal low. Heat in the Schenectady-Albany-Saratoga area appears to concentrate along fault zones in that the highest thermal gradients seen are along the Saratoga and MacGregor faults. We feel that the evidence now favors the hypothesis that heat is brought up from depth in aqueous convective systems.

AREA OF GEOLOGIC MAPPING (QUADRANGLES SHOWN) AND LOCATIONS OF WARM SPRINGS (o)

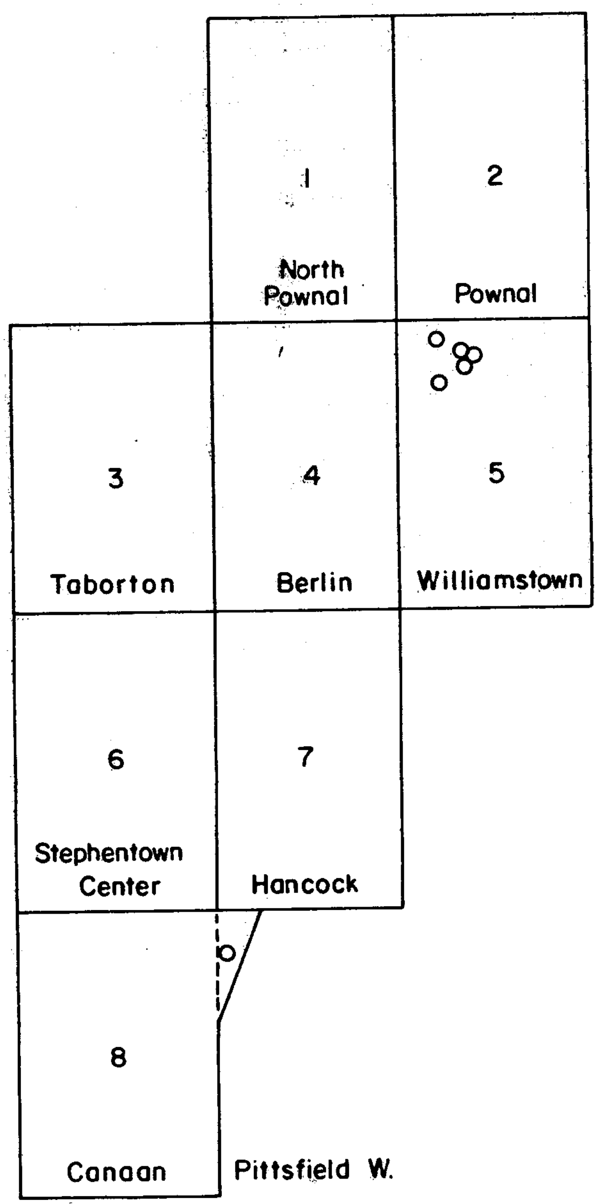
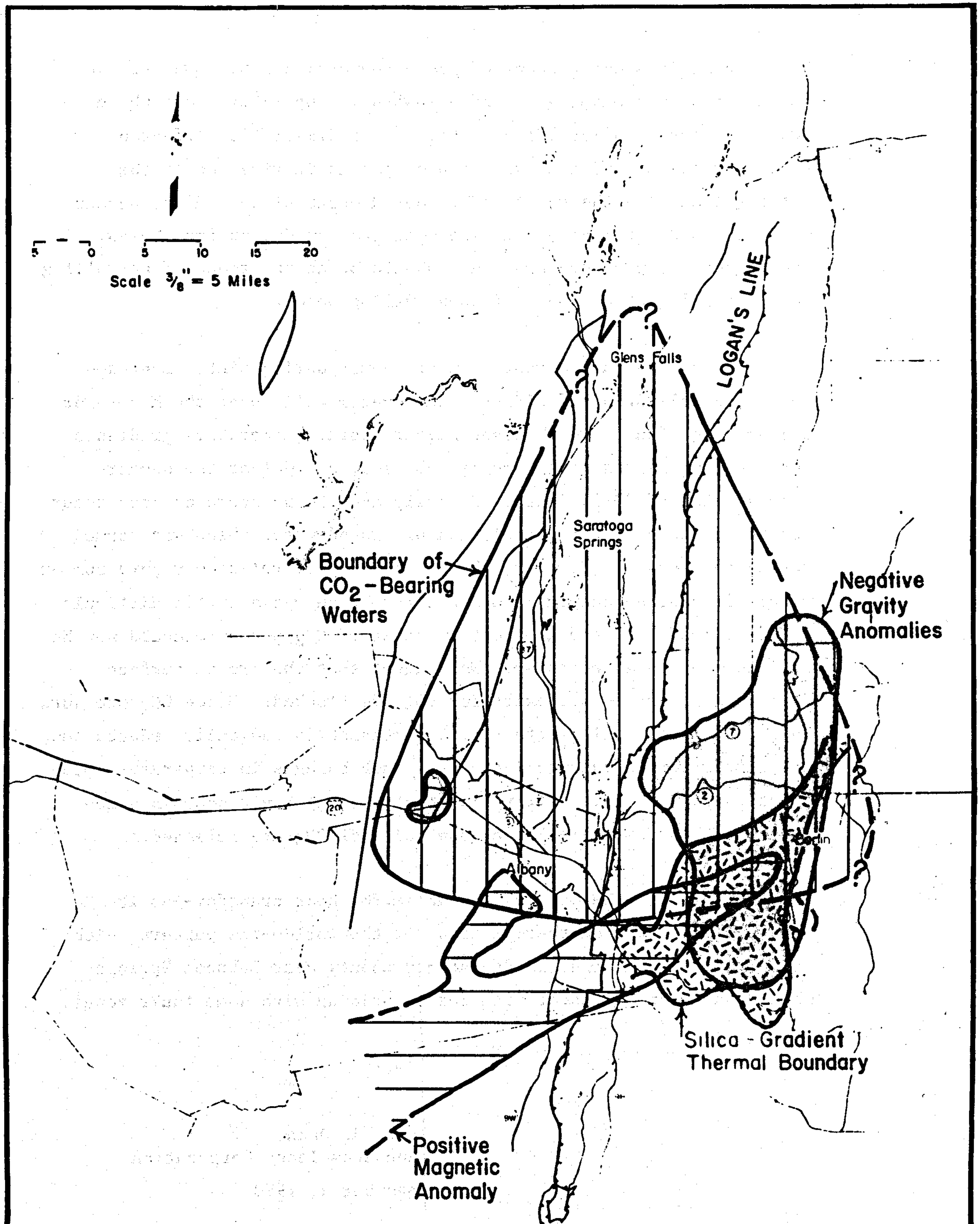


FIGURE 4



Relative Locations of Area of CO_2-Bearing Waters, Negative Gravity Anomolies, Positive Magnetic Anomaly, and the Silica-Gradient Thermal Boundary.

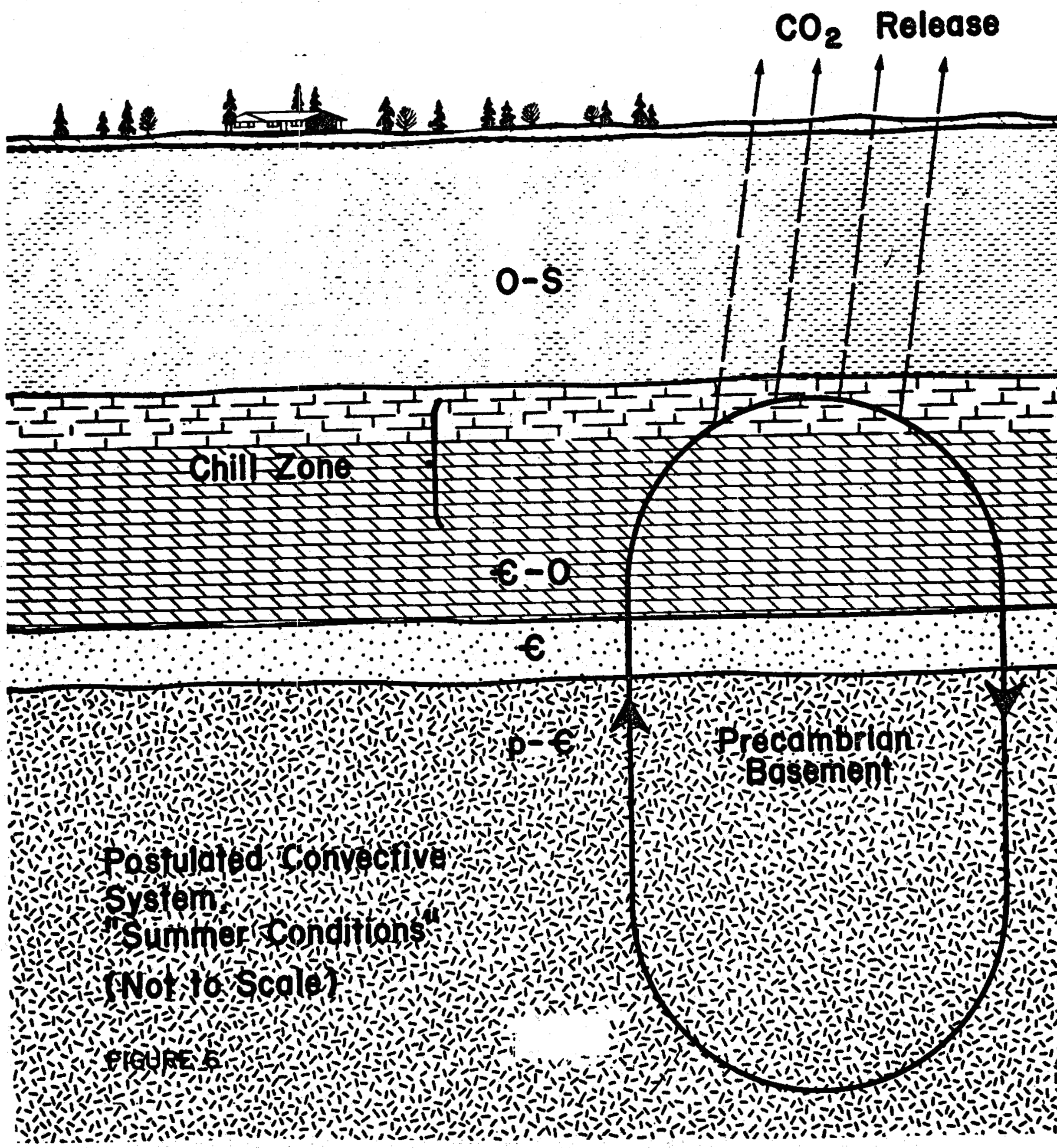
FIGURE 5

4.2 Figure 6 depicts our concept of how a convective system works. We suggest that the major areas of downward moving water occur where CO_2 is released in largest amounts. The refrigeration effect of exsolving of CO_2 and the expansion of gas as it rises cools the water (along with the rock). The cooled water sinks and the warmer water rises convectively bringing heat and new CO_2 up from below. The highest temperature gradients should be at the zones of up-welling water, the lowest at zones of down-welling water.

4.3 Figure 7 depicts our concept of what occurs during winter months--called "bottle stopper" effect. In several wells near the MacGregor and Saratoga faults we observed higher winter temperature gradients and deep CO_2 release (as deep as 250 feet, as against the summer release zone of 20-30 feet). Normally such temperature changes occur because of deep winter circulation of ground water which was warmed during the summer. However, the possibility of relatively pure summer water circulating deeply into a heavier brine was a little difficult to visualize. And the apparent increase of CO_2 pressure could not be explained by this mechanism. We suggest that the ground surface freezes and most normal exits for CO_2 are blocked. Hence CO_2 pressure builds up; the cooling effect of CO_2 release is radically reduced and the temperature gradients increase. Such changes in temperature gradients should be irregularly distributed along fault zones and coincide with areas where large quantities of CO_2 are released.

4.4 If convection is the primary mechanism for heat transfer--as it apparently is in most thermal areas of the world--the pattern which we will ultimately find in Rensselaer County near Lebanon Springs should have strong linear features coinciding with some fault zones.

James R. Dunn
Dunn Geoscience Corporation
November 4, 1980



CO_2 Release
O-S
Chill Zone
Є-O
Є
p-Є
Precambrian Basement
Postulated Convective System, "Summer Conditions"
(Not to Scale)

FIGURE 6

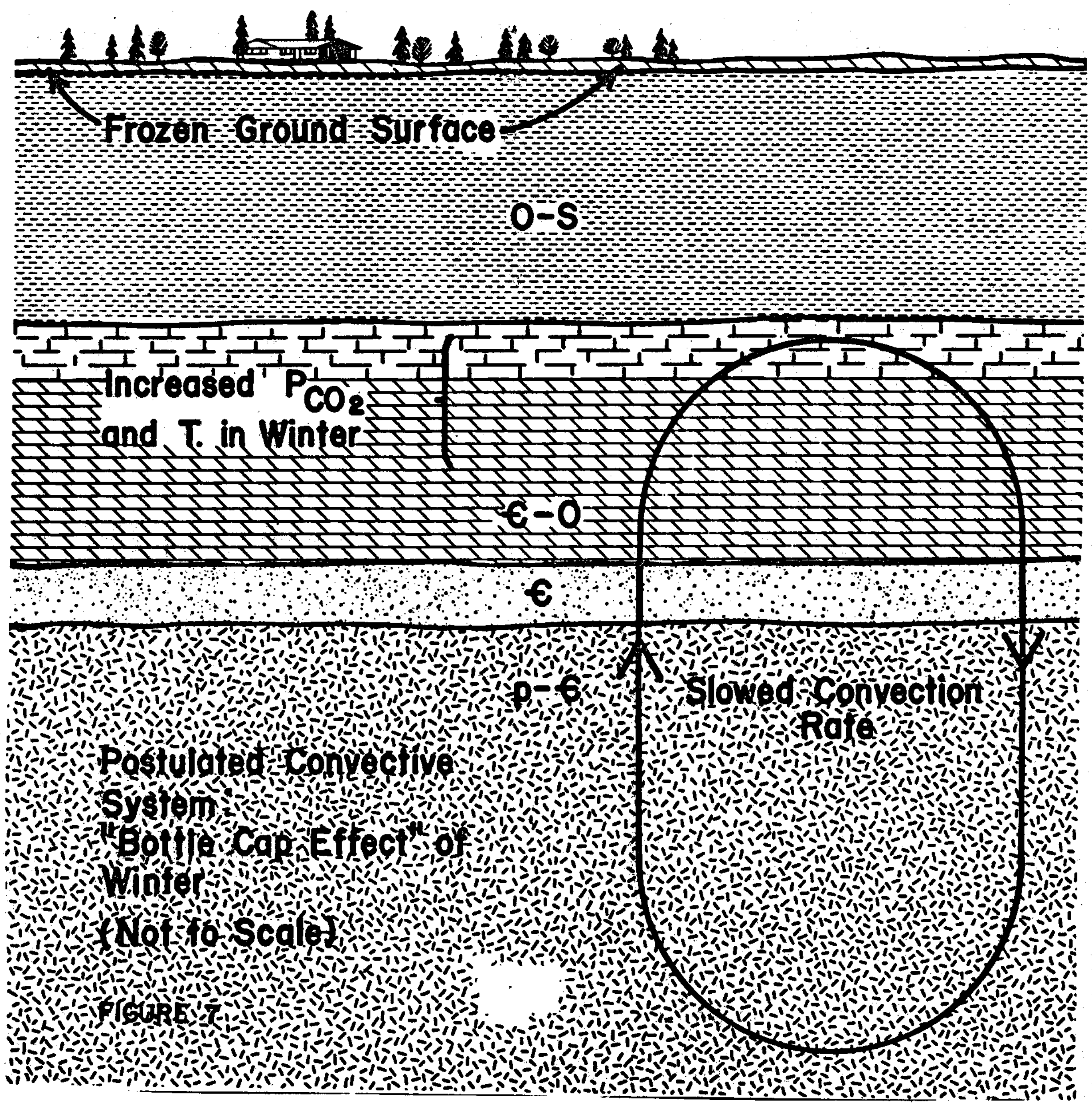

Frozen Ground Surface
O-S
Increased P_{CO_2}
and T. in Winter
€-O
€
p-€
Slowed Convection
Rate
Postulated Convective
System:
"Bottle Cap Effect" of
Winter
(Not to Scale)

FIGURE 7

Progress of New York
Capital District Geothermal Exploration

by

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XII

Progress of New York Capital District Geothermal Exploration

1.0 INTRODUCTION

1.1 Saline and carbonated saline waters occur in the Capital District of New York, most notably in the Saratoga Springs vicinity. The springs are not thermal, their temperatures being generally the same or slightly cooler than normal ground water; but they do have an unusual chemistry with up to 20,000 ppm total solids and large volumes of carbon dioxide. There are fresh water thermal springs occurring in nearby Lebanon Springs, New York, and in Williamstown, Massachusetts. The presence of these thermal springs and the unusual chemistry of the Saratoga waters have led to further exploration of a possible geothermal system in the Capital District area. The program is funded by the New York State Energy Research and Development Authority (NYSERDA) and the U. S. Department of Energy.

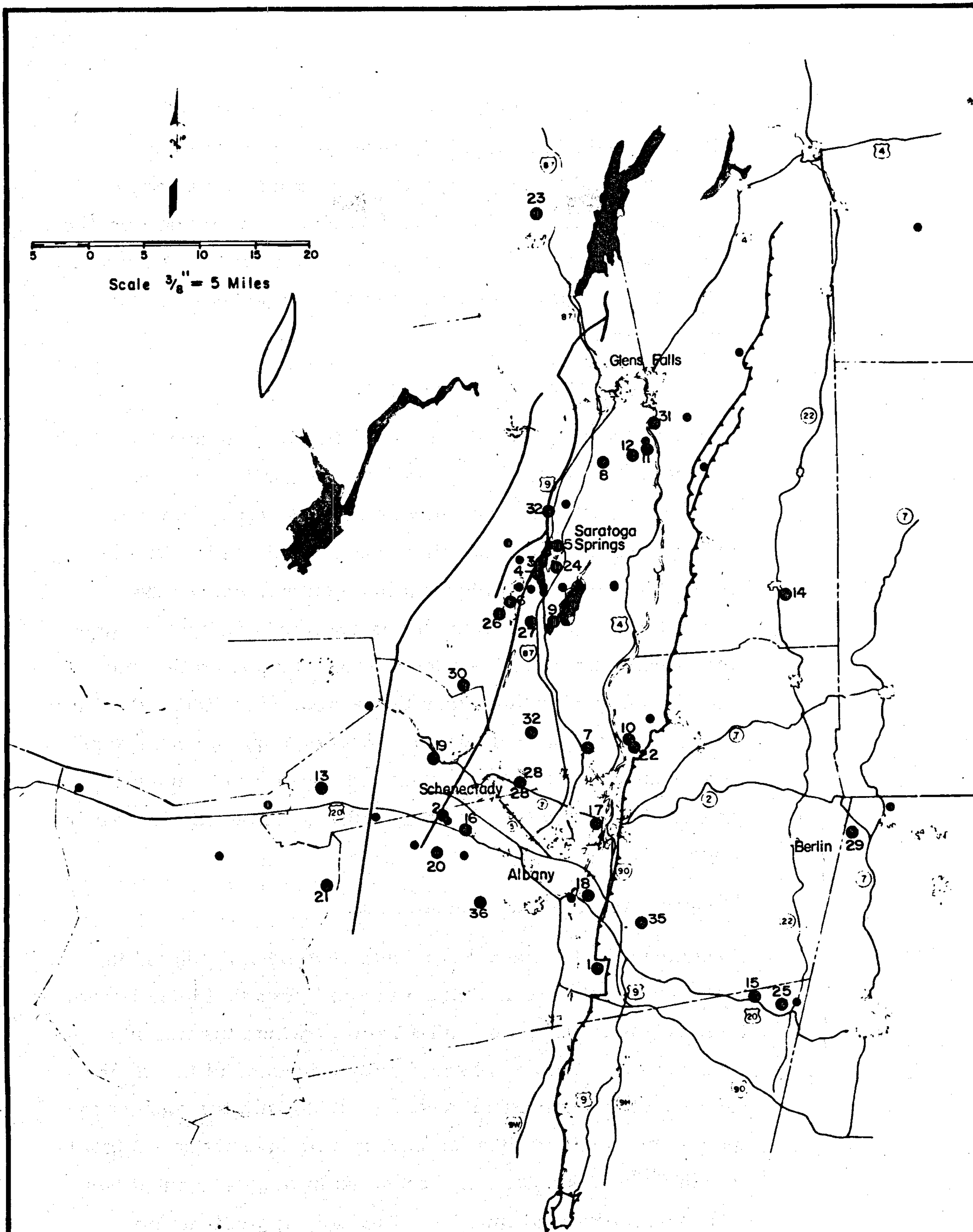
1.2 The presence of a convective geothermal system in the Capital District area is suggested indirectly from geochemical data and more directly from thermal gradient measurements. Exploration techniques have included detailed water chemistry, free and dissolved gas analysis, a silica-water temperature survey, the thermal gradient measurement program, a small scale gravity survey coupled with recalculation of existing data, and a passive seismic survey. The thermal gradient measurement program has produced the most direct evidence of subsurface heat; and that data is supported by the geochemical and gravity data showing a coincidence of the apparent thermal area, the locations of saline and carbonated wells, waters within the latter group showing unusual trace element compositions, and the locations of possibly related gravity structures. Further exploration is intended to improve our understanding of the thermal system and to aid in the selection of one or more sites for deeper drilling.

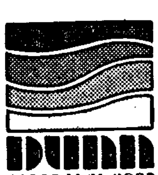
2.0 EXPLORATION PROGRAM AND RESULTS

2.1 Water Chemistry and Gas Chemistry

Water and gas samples were collected from abandoned and operating wells producing saline and carbonated waters in a nine-county area surrounding the Capital District (see Figure 1). The samples were analyzed for a complex suite of elements and several gases including carbon dioxide, oxygen and argon, nitrogen, helium, and light hydrocarbons. Water temperature, pH, and alkalinity were measured at the time of sampling.

Results of these analyses were difficult to interpret because of a complex mixing problem of the saline and carbon dioxide-rich components with the surface waters and an apparent ionic filtration of the waters away from assumed zones of issuance. The most concentrated solutions, however, and those producing the more unusual trace element compositions did tend to be associated with major fault zones, particularly in the Saratoga Springs vicinity. Perhaps the most notable trace indicator present in high concentrations was silica, occurring in concentrations up to 70 ppm in Saratoga Springs itself. Gas analyses indicated that the largest quantities of carbon dioxide released were also associated with the major fault zones but also that significant amounts of natural gas are being carried in waters in the area. Helium was present in some gas samples in quantities exceeding 4,000 ppm; but, although the area over which the helium is being released overlaps the apparent area of interest indicated by other





Location Map for Standard Geochemical Samples.
Phase II Samples numbered.

FIGURE I

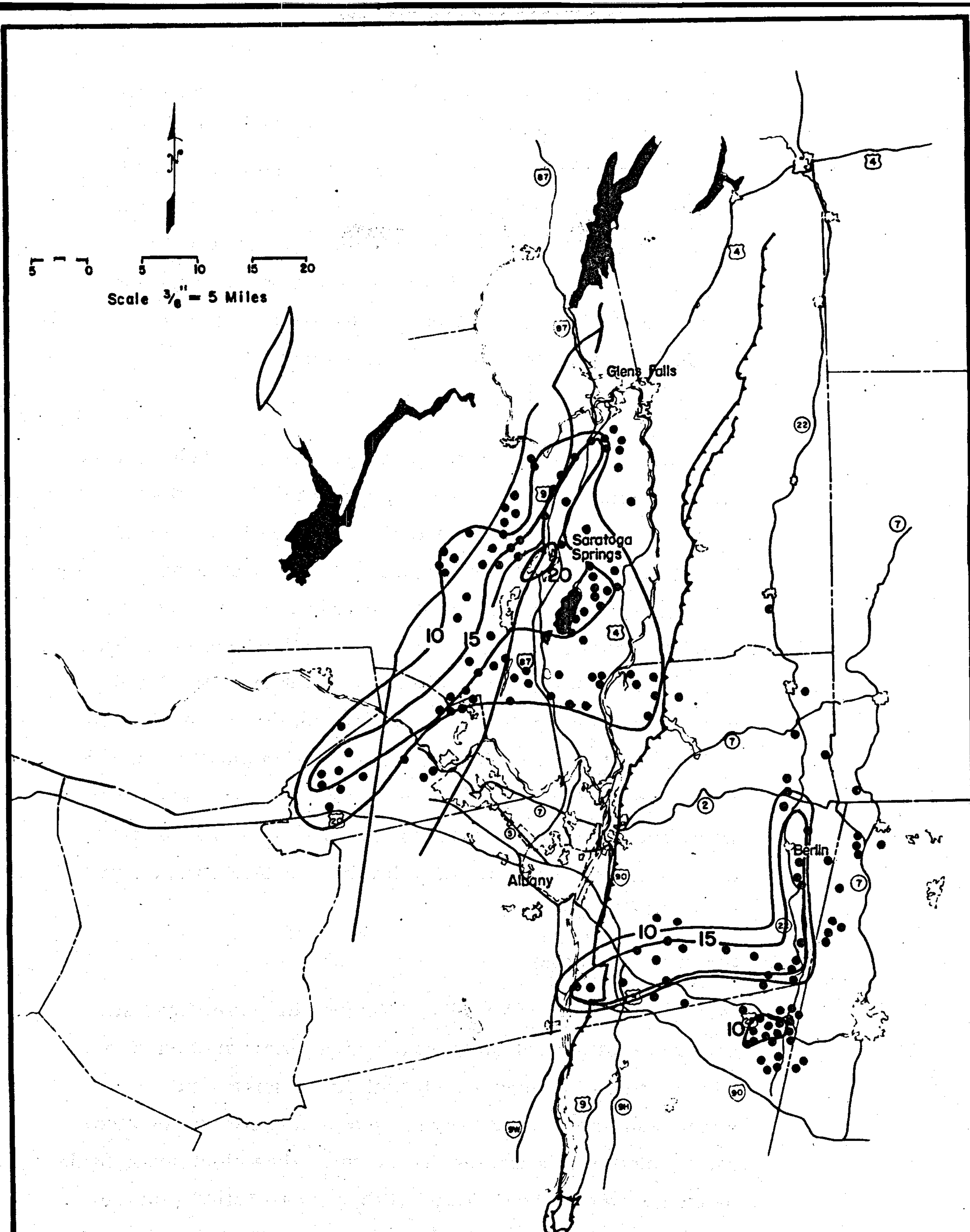
chemical parameters, it is clearly offset from it. The significance and relationship of the helium to the area is not clear at this time. Oxygen and carbon isotopes were previously measured on carbon dioxide gas exsolving from the Saratoga waters, and the pertinent ratios indicated a thermal origin for the gas. Another series of isotope analyses are currently underway.

2.2 Silica-Water Temperature Analysis

Consequent to finding high silica contents in some waters in Saratoga Springs, water samples were collected from wells penetrating bedrock in a broad area around Saratoga Springs and analyzed for silica content and water temperature. A correlation of higher silica contents and warmer temperatures was noted and a general trend of slightly higher silica contents around Saratoga Springs and along the fault zones, decreasing away from these areas (see Figure 2). No values of the magnitude noted in Saratoga Springs were found elsewhere, but the pattern observed appears to be useful in exploration and the data base will be increased and further analyzed.

2.3 Temperature Gradient Measurements

Approximately 80 thermal gradients have been measured in abandoned water wells ranging in depth from 80 to 605 meters using a thermistor probe and a Yellow Springs Instruments thermometer. This has been the most successful indicator of a possible geothermal system to date, with the highest reproducible gradient thus far measured of 44.3^{o}C/km. A gradient of 64.5^{o}C/km has been measured in the area, but it has not been reproduced thus far. The highest gradients observed are in the area between Saratoga Springs and Schenectady and appear to be strongly related to the Saratoga and



Rough Contouring of Silica Data Showing Areas of Slightly Anomalous Silica Content.

Contour Interval ≈ 5ppm SiO_2

FIGURE 2

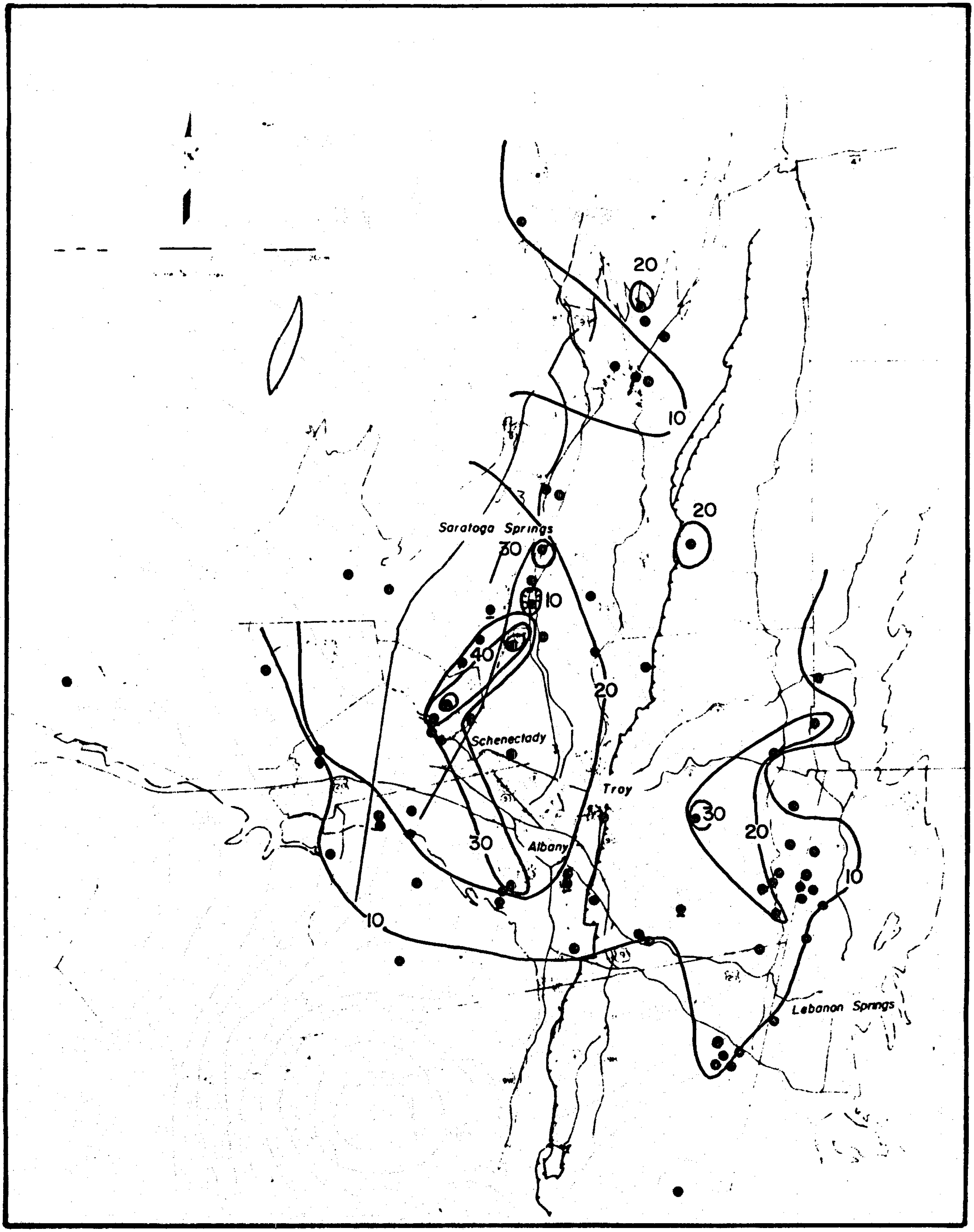
McGregor Faults (see Figure 3). The regional background appears to be on the order of 8°C/km to 10°C/km based on gradients measured around the area. Bearing this in mind, we have a system apparently producing gradients from two to four times background and even up to almost two times the worldwide average gradient. It is extremely important to determine if these gradients can be extended to depth, and future efforts will be in that direction.

2.4 Gravity Survey

The gravity data base for the Saratoga Springs to Schenectady area was expanded, and existing data was recalculated and contoured to show more clearly the configurations of gravity anomalies in the area (see Figure 4). Negative bouguer gravity anomalies were emphasized in the areas west and south of Saratoga Springs and also just to the south of Schenectady. There is a slight gravity disturbance which may be related to the east-dipping Saratoga Fault and an interesting feature between Melrose and Mechanicville. These gravity features cannot be directly related to the thermal system we are dealing with, but there is a general correlation of high thermal gradients and carbonated waters with them. Further work may be merited in this area.

2.5 Seismic Monitoring

Members of the New York State Geological Survey have set up a five-station seismic network in an effort to determine whether there is unusual fault activity or seismic noise which might be geothermally related. The network operated for a period of four months during which time eight minor earthquakes were recorded. Three of these were actually in the area of interest, but their significance is not clear. The network will be reactivated in the near future, and that monitoring

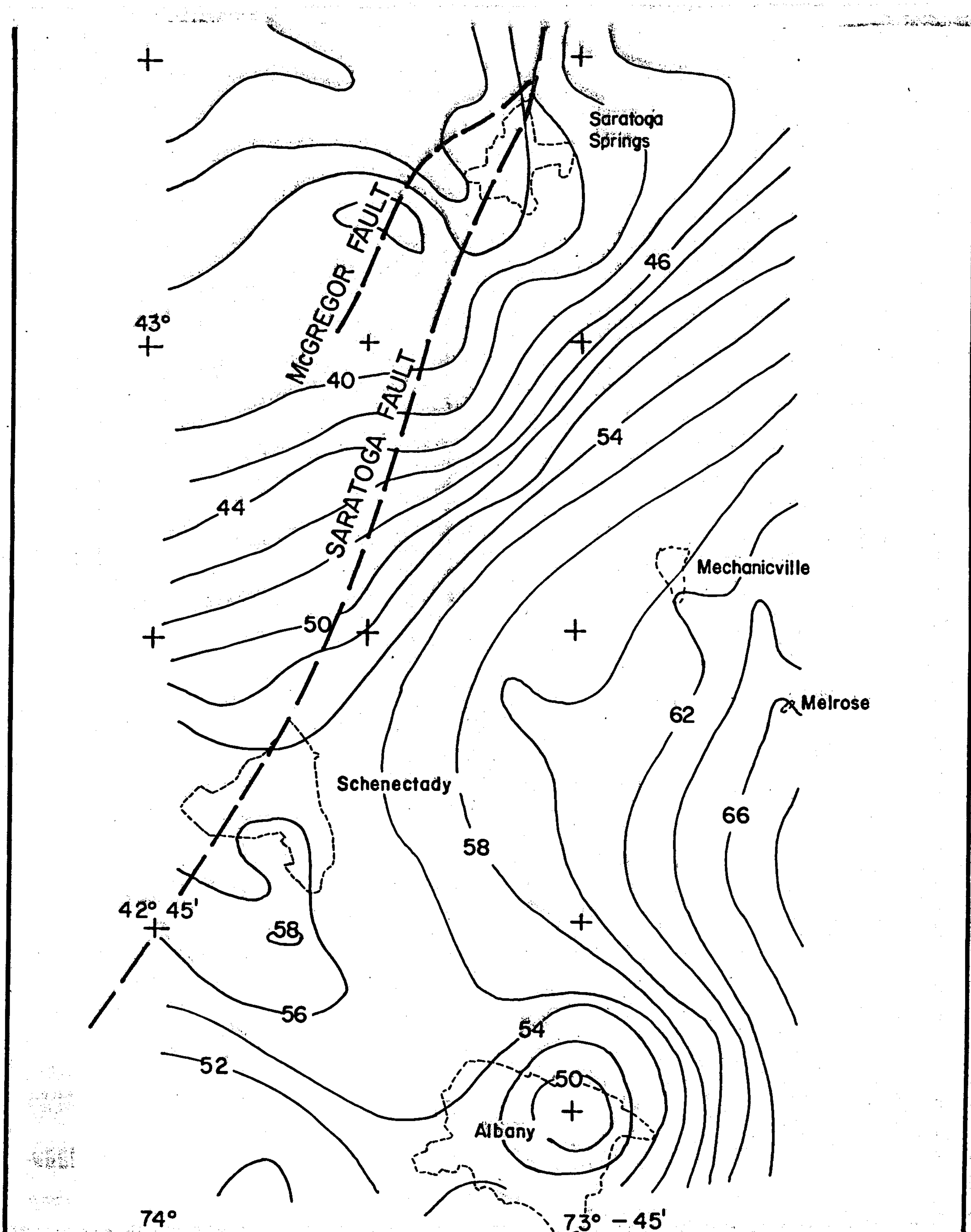


DUNN GEOSCIENCE CORP

Contour Map of Temperature Gradients

Contour Interval 10° C/Km.

FIGURE 3



Detailed Simple Bouguer Gravity Anomaly Map
of the Schenectady — Saratoga Springs (from Porter, 1980)

Values in Negative Milligals
Scale: 1: 250,000

FIGURE 4

will continue over the course of the next year (see Figure 5).

3.0 CONCLUSIONS AND PROJECTIONS

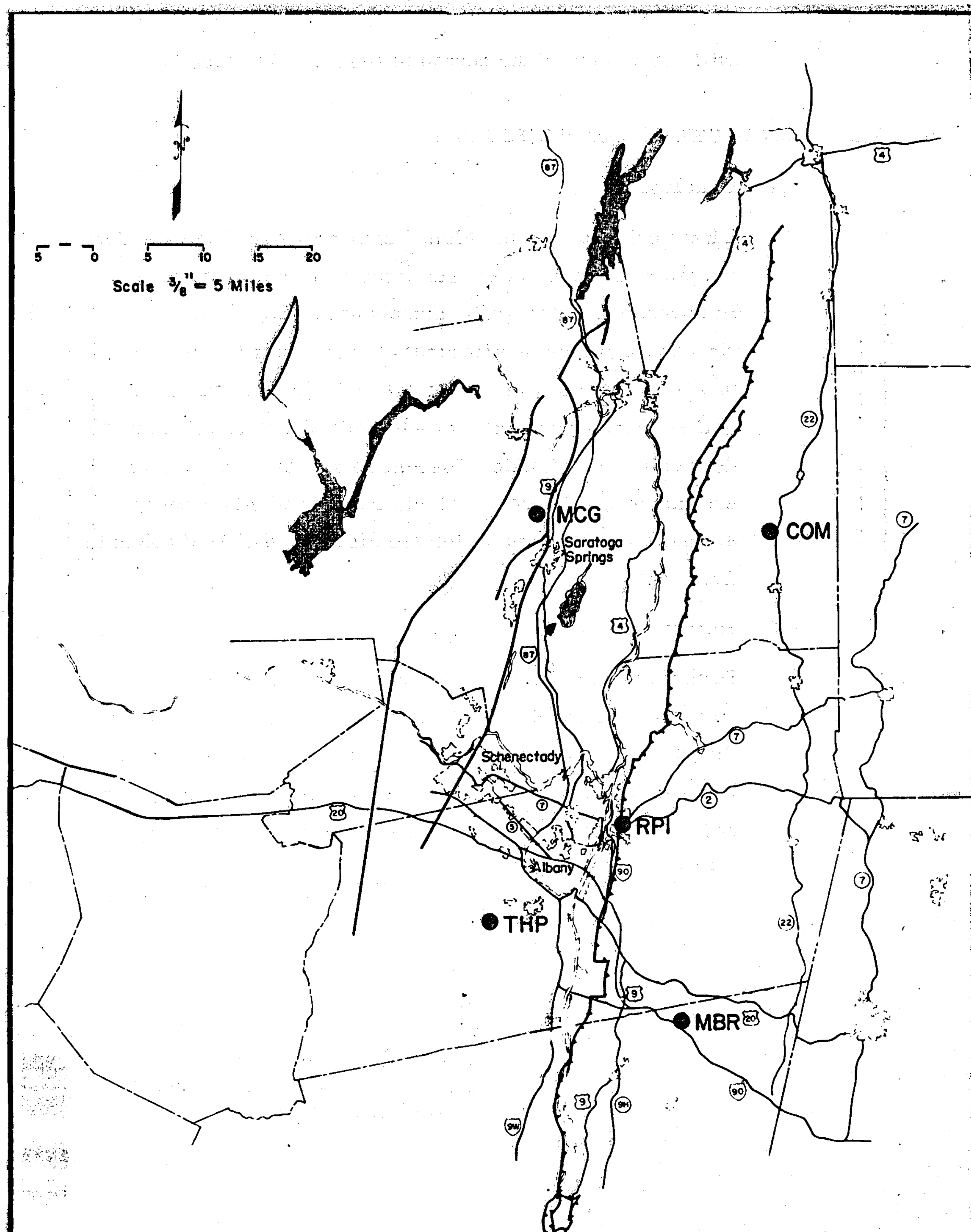
3.1 Conclusions

Direct evidence of anomalous geothermal heat has been demonstrated through the measurement of temperature gradients in abandoned water wells throughout the Capital District. New and previous geochemical data supports these results and indicates that the Saratoga and McGregor Faults are acting as major conduits for mineralized waters and thermally derived carbon dioxide. Issuant points for these waters and higher geothermal gradients correspond with gravity anomalies in the area which are also suggestive of conduits from depth.

3.2 Projections

Further exploration will involve an expanded silica sampling program, continued seismic monitoring of the area, continued thermal gradient measurements in abandoned wells, and a drilling program designed to confirm some of the higher gradients and to aid in the selection of one or more sites for deeper drilling.

Margaret R. Sneeringer
Dunn Geoscience Corporation
November 6, 1980



Seismic Monitoring Network — Station Locations

DUNN GEOSCIENCE CORP

FIGURE 5

Mid and Western New York Geothermal Resources

by

D. S. Hodge

and

K. G. Hilfiker
State University of New York
at Buffalo

Mid and Western New York Geothermal Resources;
Heat Flow, Gravity and Gradient Program

Dennis S. Hodge

and

Kenneth G. Hilfiker

SUNY AT BUFFALO*

Eastern Geothermal Technical
Information Interchange Meeting

Berkeley Springs, WV
November 6, 1980

*Work performed for the Hot Dry Rock Program under the direction of James Maxwell

Introduction

Inspection of the A.A.P.G. temperature gradient map for the United States (A.A.P.G., 1976, Figure 1) reveals that two of the most prominent anomalies in the eastern United States are located near Cayuga Lake and East Aurora, New York. Since these two areas are located near large population centers, considerable potential exists for the use of geothermal energy and this report evaluates the subsurface temperatures, heat flow, and source of the anomalies.

Diment, et al. (1972) present the only published heat flow data for central and western New York (Figure 2). Four heat flow values of about 50 mW/m^2 are given for areas near Buffalo, New York, and from southeast of Syracuse values of 60 and 70 mW/m^2 were obtained. These heat flow values are significantly above the norm for the eastern United States, although Diment, et al. (1972) question the reliability of some of the data. The values indicate, however, that anomalously high heat flow may exist within the region in restricted areas.

Hodge, et al. (1979,1980) have completed detailed temperature gradient analysis in New York. Consistent patterns of temperature gradients have been shown for the area using a large sampling of bottom-hole temperatures.

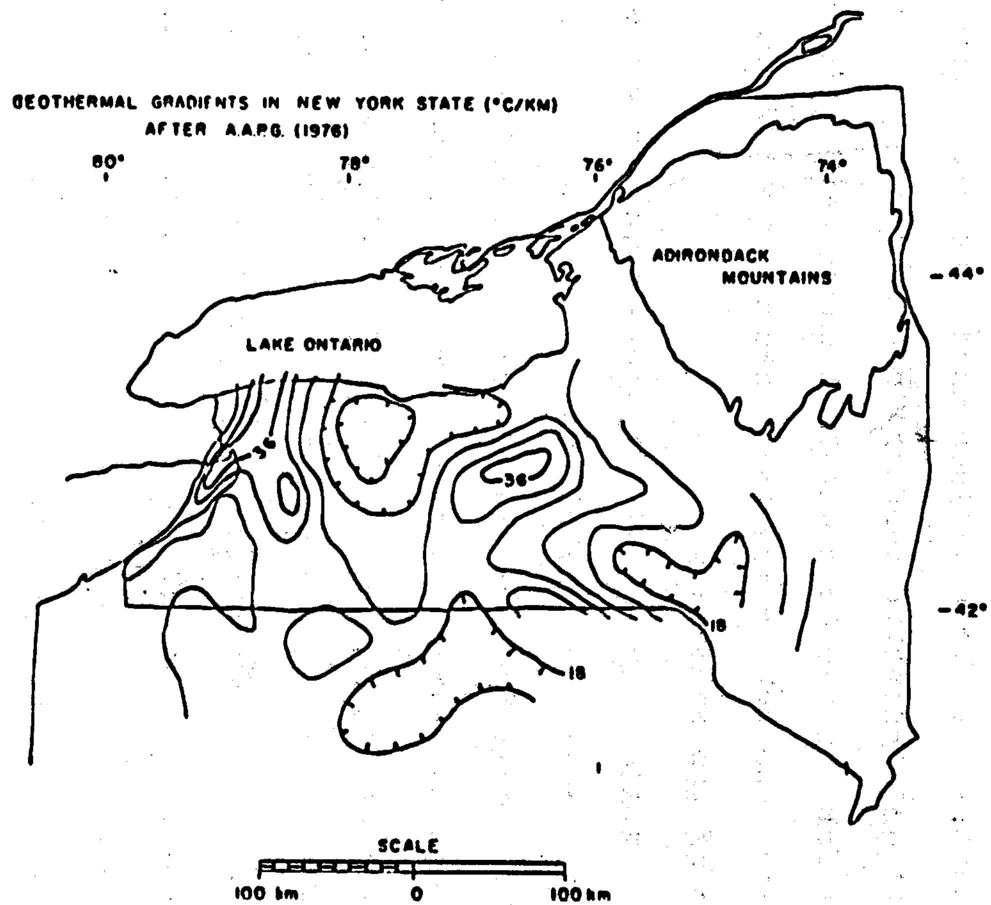


Figure 1 - 1976 A.A.P.G. Temperature Gradient Map (°C/Km) for New York State.

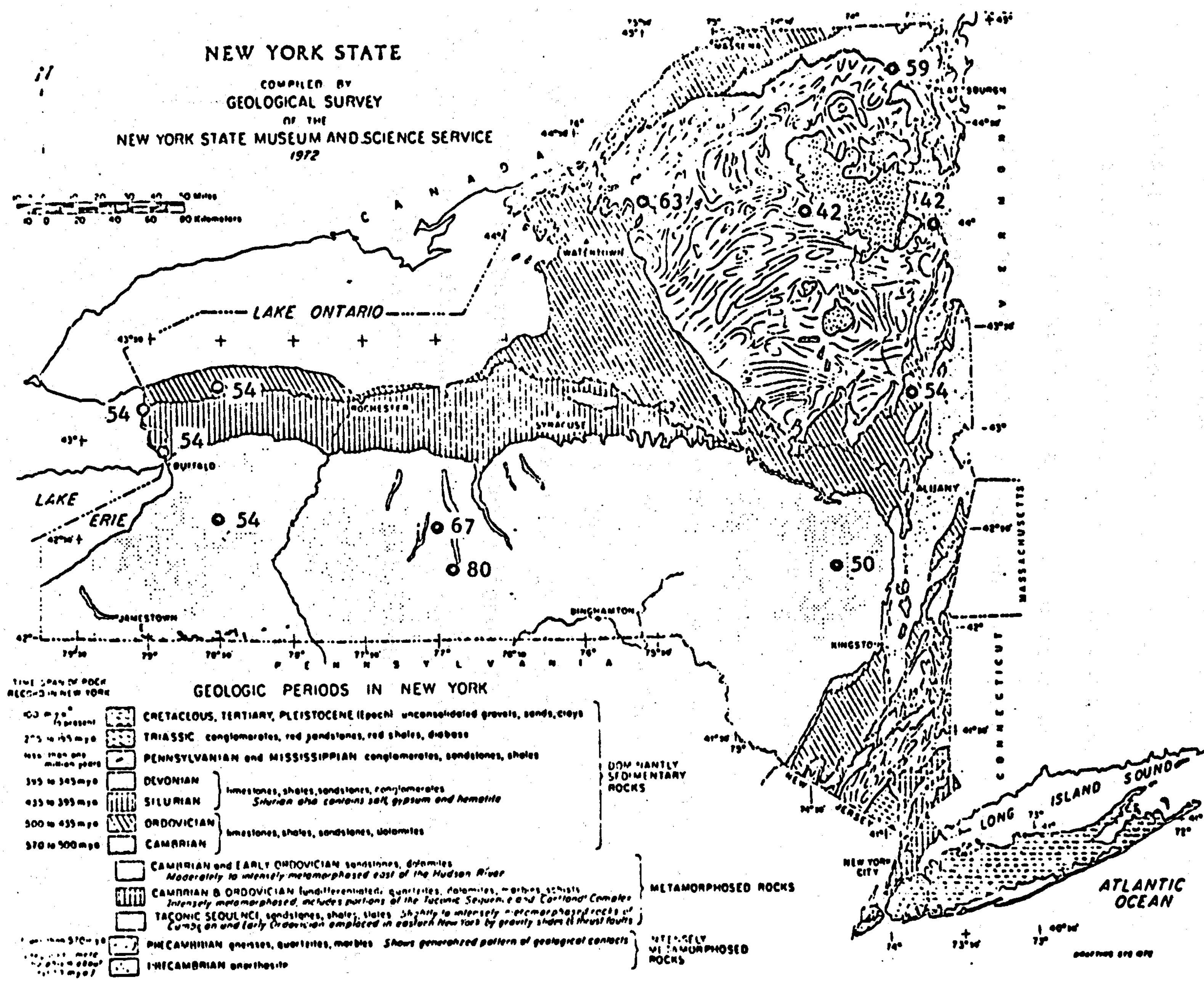


Figure 2 - Diment, et al. (1972) Heat Flow Values (mW/m^2)

The regional and local variations in temperature gradients are thought to be related to heat generation in granitic plutons in the basement (Hodge, et al., 1979); this preliminary conclusion is consistent with the interpretation of heat flow on the Atlantic coastal plain (Costain, et al., 1980). Due to the relatively simple geology, New York State is an ideal location for the analysis of heat flow variation and relationship of this variation to basement lithology.

In order to determine the souce of heat flow variation, this study focuses on (1) geothermal gradient calculations using a data set of 971 bottom-hole temperatures recorded during routine electric logging for the area of central and western New York State; (2) temperature-depth logging for detail geothermal gradient and conductivity analysis; and (3) analysis of gravity and magnetic data to determine the subsurface geology.

REGIONAL GEOLOGY

Within the central and western portion of New York State the geologic structure is relatively simple. Cambrian through Devonian shales and limestones dip gently to the south and the thickness of this sedimentary sequence is about 3,000' at the shore of Lake Ontario and thickens to the south to over 10,000' in some areas. Precambrian crystalline basement rocks underlie these Paleozoic sediments. The Paleozoic rock section also contains some evaporites but is composed principally of shales and sandstones. A thin veneer of glacial debris covers most of the area and may reach thickness as great as 600 feet in some valleys.

Geothermal Gradients from Electric Log Temperatures

The temperature gradient map prepared by the A.A.P.G. (1976) for the geothermal survey of North America made use of bottom-hole temperatures from approximately 125 wells in New York State. A data file of 971 new bottom-hole temperature records is now available (see Hodge, et al., 1980 for data listing), and the gradients from central and western portions of the state have been reevaluated.

Surface temperatures for the gradient calculation in this study were estimated from mean annual temperatures compiled at 73 NOAA recording stations located throughout the state. The temperatures were corrected to sea level using a lapse rate of 9.8°C/km (Jaeger, 1965) and a second order trend surface was calculated. The trend surface equation corrected to borehole collar elevation was then used to calculate the surface temperature at each well location.

The majority of wells in New York are gas wells drilled using air percussion methods and the results from measurements taken immediately after cessation of drilling indicate that a correction for a thermal disturbance must be made.

A correction factor was adapted from the 1971 A.A.P.G. study and applied to all the bottom-hole temperatures in New York State. The correction factor equation for bottom-hole temperature is:

$$BHTCOR = \frac{DEPTH\ (ft) - 500\ (ft)}{260.8696\ (ft/°F) \times 1.8\ (°F/°C)}$$

Where BHTCOR is the amount of correction to the temperature at logging point DEPTH. This linear equation simulates the A.A.P.G. non-linear emperical correction to a depth of 1830 meters. Below 1830 meters, the correction is slightly higher than the A.A.P.G. factor with the maximum difference being less than 5°C. The correction factor increases temperatures in bottom-holes with depths greater than 150 meters (where the correction is 0°C) and at a depth of 1830 meters the correction factor would add 11.7°C.

The geothermal gradient corrected for drilling disturbances is calculated using the "A.A.P.G. Corrected" bottom-hole temperature minus the calculated surface temperature divided by the borehole depth. Figure 3 is a gradient contour map using 789 well records with depths greater than 500 meters. The geothermal gradients in the data set range from 15.5°C/km to 47.3°C/km and gradient values in the computed grid matrix range from 22.3°C/km to 37.6°/km.

Contoured gradients (Figure 3) show values for the East Aurora and Cayuga and Elmira anomalies to be 32 and 36°C/km, respectively. Figure 4 shows a perspective diagram of the elevated temperatures highlighting the relative magnitude of the gradients. The corrected gradients are considered a maximum.

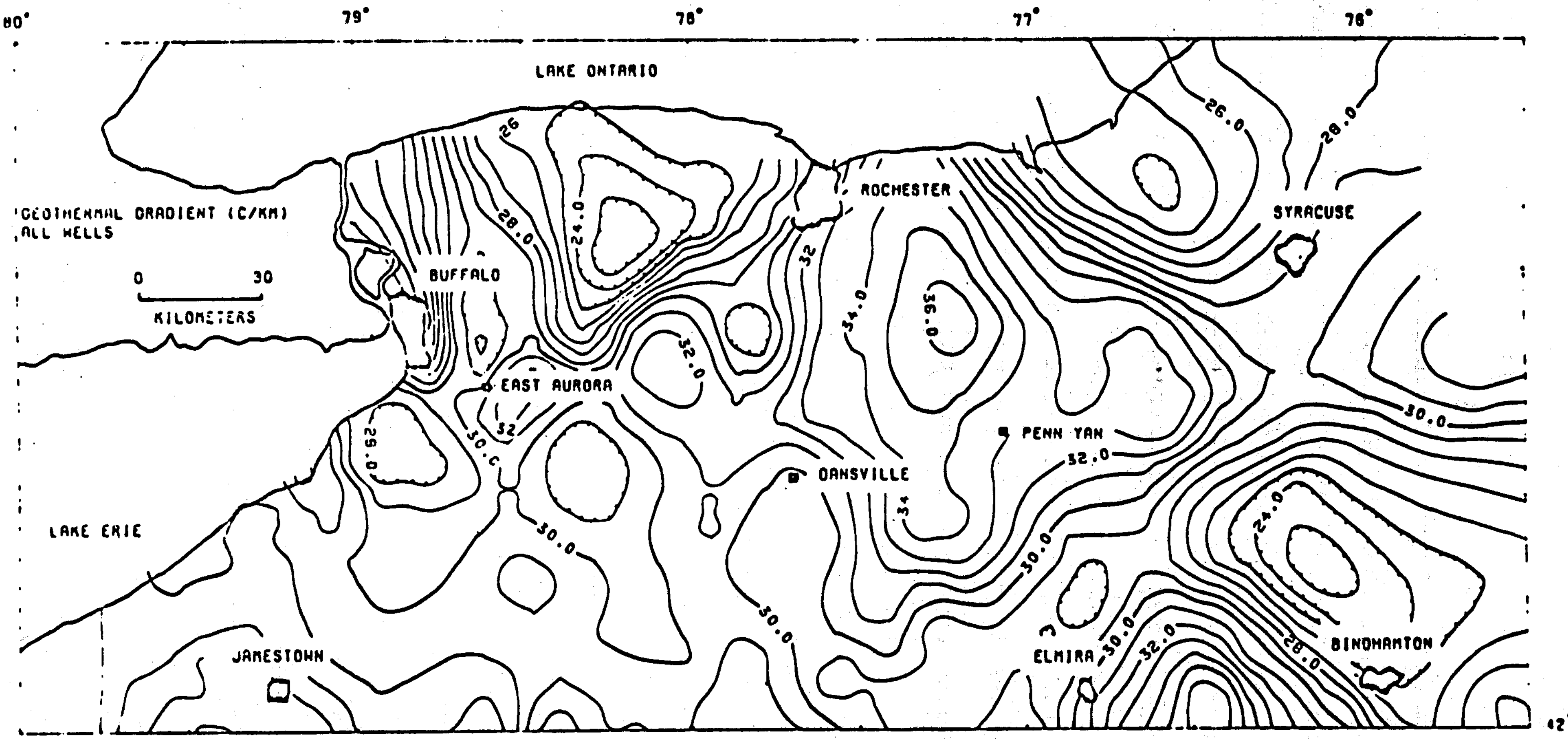


Figure 3 - Contoured temperature gradients (°C/Km) for wells with depth greater than 500 meters assuming a drilling disturbance correction similar to the correction used by the A.A.P.G. (1971).

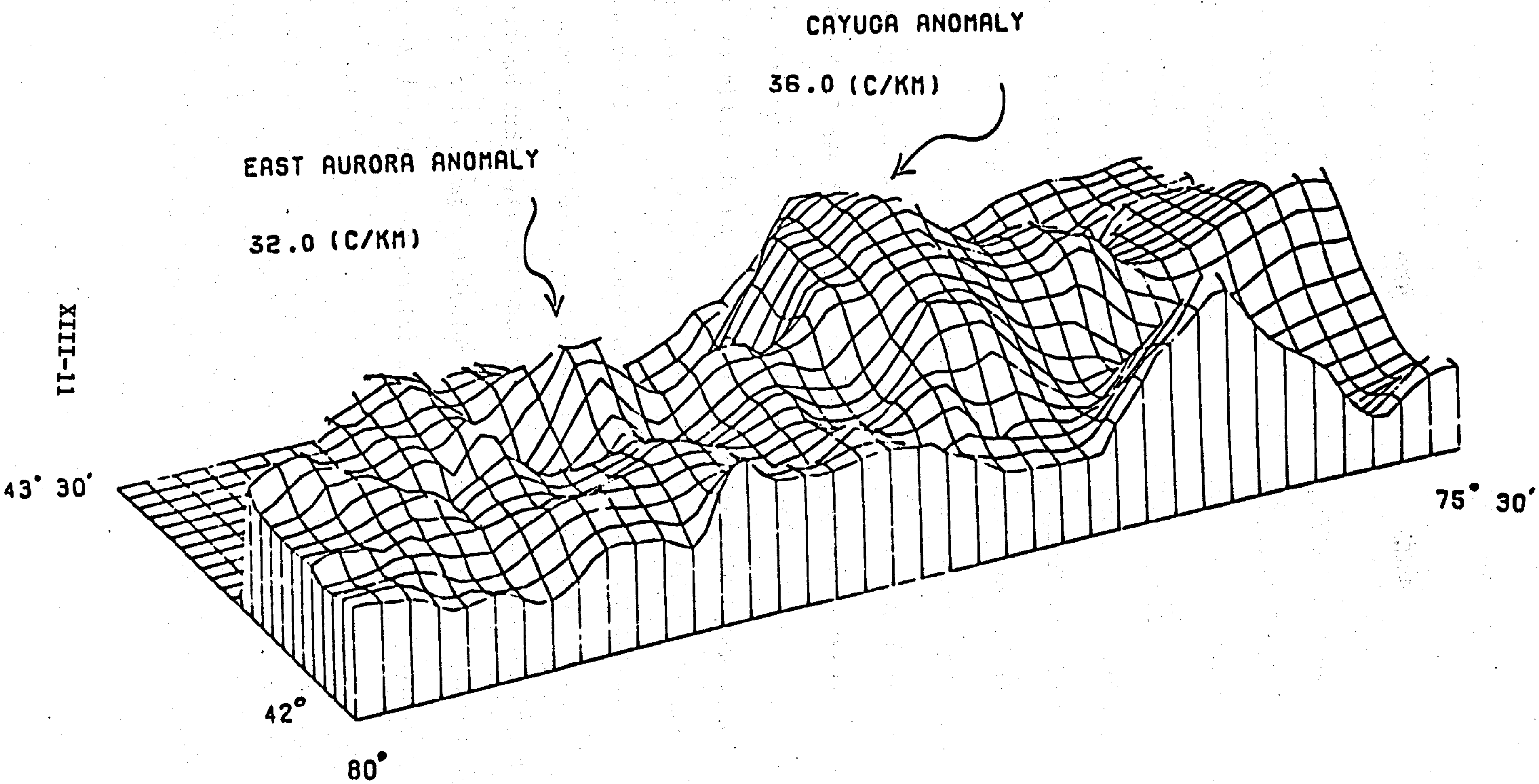


Figure 4 - Perspective diagram of temperature gradients in New York State showing relative magnitudes of the anomalies.

GEOTHERMAL GRADIENTS FROM DETAILED TEMPERATURE LOGS

Equilibrium temperature logs were obtained on a number of gas wells. These wells were drilled principally by air percussion drills and electric logs with bottom-hole temperatures were recorded within 4-12 hours of completion. Normally, the wells are cased and a cement "plug" inserted at the bottom of the hole with no water or gas circulation possible at this time. Depending upon scheduling, the wells may remain in this status for a week to several weeks prior to perforation, stimulation, and final completion. It is during this interval in which the well is cased but not perforated that temperatures are measured.

One well logged near Auburn (13689, Fig. 5) shows relatively linear temperature gradient segments. The calculated gradient in the upper section of the well is 36.3^{o}C/km and a gradient of 17.3^{o}C/km is calculated for the lower half; the average geothermal gradient is 27.5^{o}C/km. The temperature log (Fig. 5) shows an apparent change in the geothermal gradient at a depth that corresponds to the top of the Queenston. The ratio of gradients in the Queenston to gradients above the Queenston in this well is 0.47 and the ratio of the conductivities in and above the Queeston must be equal to the ratio of the gradients. Joyner (1960) indicates that shales and older sandstones and limestones from Pennsylvania have a similar measured conductivity ratio. These detailed temperature logs indicate that the shales have low conductivity, thus producing higher geothermal gradients. Because these shales blanket a large area of New York State, they effectively provide a thermal insulator for the heat derived from below.

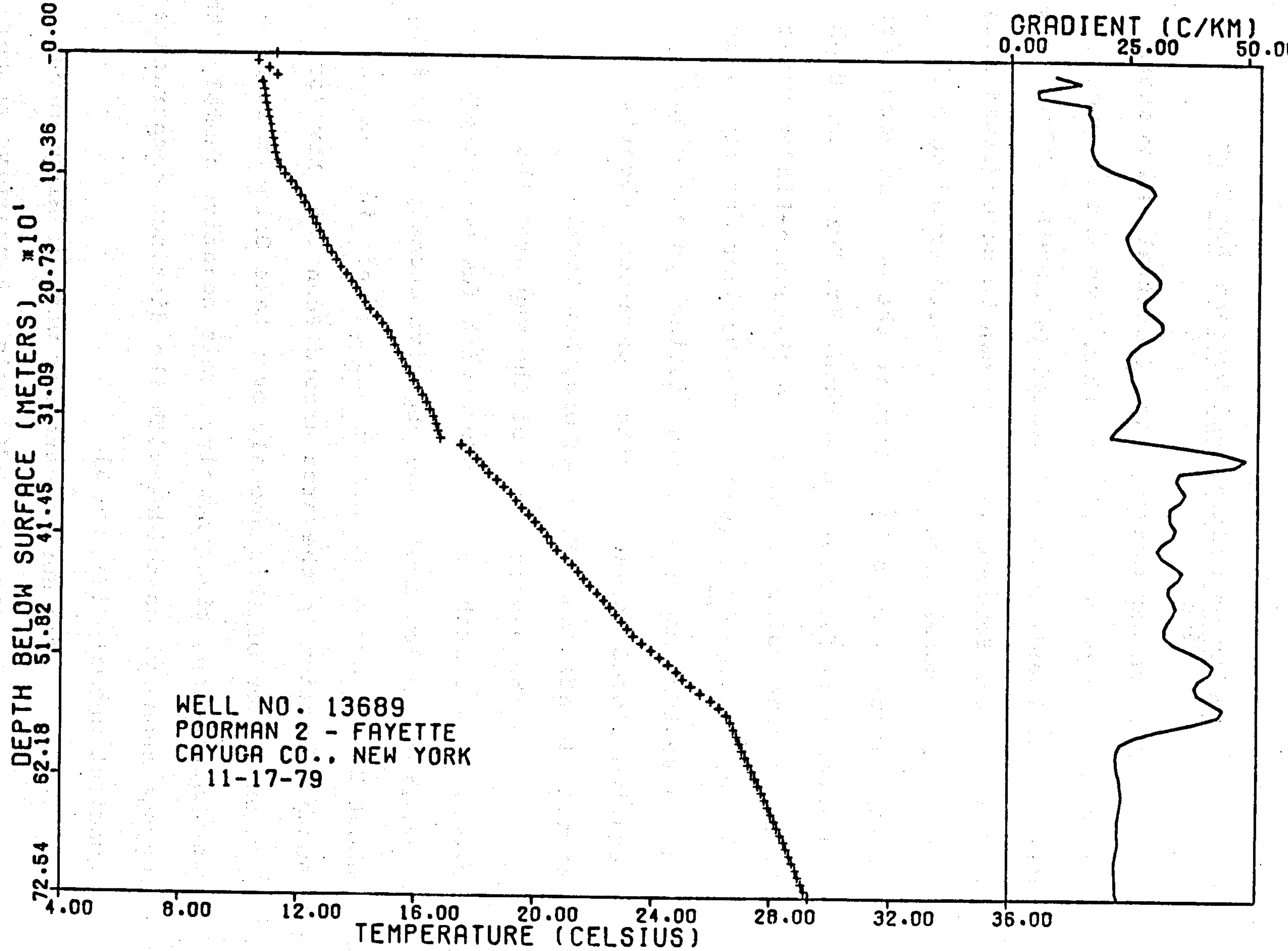


Figure 5 - Detailed Temperature log illustrating the variation of geothermal gradients with depth and lithology.

Gravity of Central and Western New York

The Bouguer Gravity Map of central and western New York (Figure 6) has been taken from the Bouguer Map of Northeastern United States (Hildreth, 1979). The pattern of the Bouguer anomalies can be categorized into two distinct zones separated by a north trending high gravity gradient area that lies to the west of Rochester and extends as far south as Arcade, New York. The high gradient zone coincides with the Clarendon-Linden Fault Zone (Diment, et al., 1972). The Bouguer anomaly field in the western map area shows distinct positive and negative closed anomalies with a prominent negative anomaly located near East Aurora, New York.

In the eastern part of the map area the anomalies are much more subdued with few positive anomalies. A low amplitude negative anomaly is located about 20 km east of Rochester and extends in a north-south direction to the area around Penn Yan, New York. The extension of this anomaly over Lake Ontario shows a very strong negative anomaly. This negative anomaly (the Cayuga anomaly) coincides with the distinct temperature gradient anomaly (Figure 3).

The Bouguer anomaly west of Binghamton (Figure 6) decreases to -76 mgals. A positive temperature gradient and heat flow anomaly are also located over this negative Bouguer anomaly.

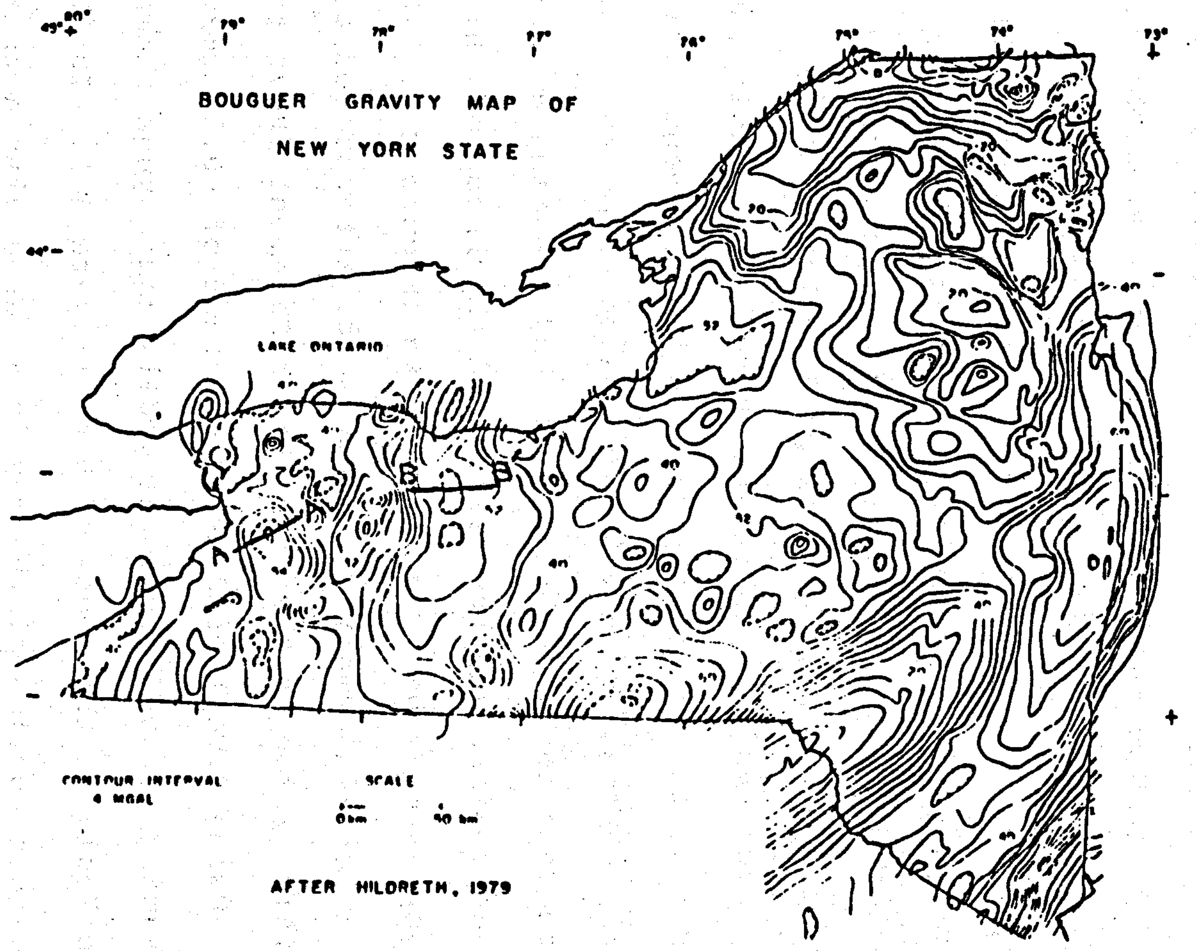


Figure 6 - Bouguer Gravity map of New York State.

Because undeformed near-horizontal sedimentary rocks are found to depths in excess of 1060 meters, the character of the Bouguer field generally reflects the density differences in the Precambrian Basement. Similar Precambrian Basement rocks outcrop in southern Ontario (Petraske, et al., 1978) and the Bouguer gravity over this area shows a strong correlation with Precambrian geology; the Bouguer fields over granitic rocks typically display negative anomalies and gabbroic igneous rocks show strong positive anomalies. These plutonic rocks are enclosed in metamorphic schists and gneisses. Using this relationship as a general guide, the negative anomaly over East Aurora is attributed to a granitic pluton located near the top of the Precambrian Basement. Selecting a density contrast of -0.09 gm/cc based on measurements on southern Ontario Precambrian rocks and assuming a two-dimensional approximation, the calculated thickness of this density contrast may be as great as 5 km (Figure 7). The Cayuga negative anomaly may likewise be interpreted as a granitic pluton in the Precambrian Basement (Revetta, 1970). Using Revetta's density contrast of -0.12 gm/cc and assuming a two-dimenisonal model, the Cayuga anomaly has a calculated thickness of 6 km (Figure 8). In the southwestern portion of the map is an area with a thick sedimentary sequence; the low gravity in this area may in part reflect this sequence, although the character

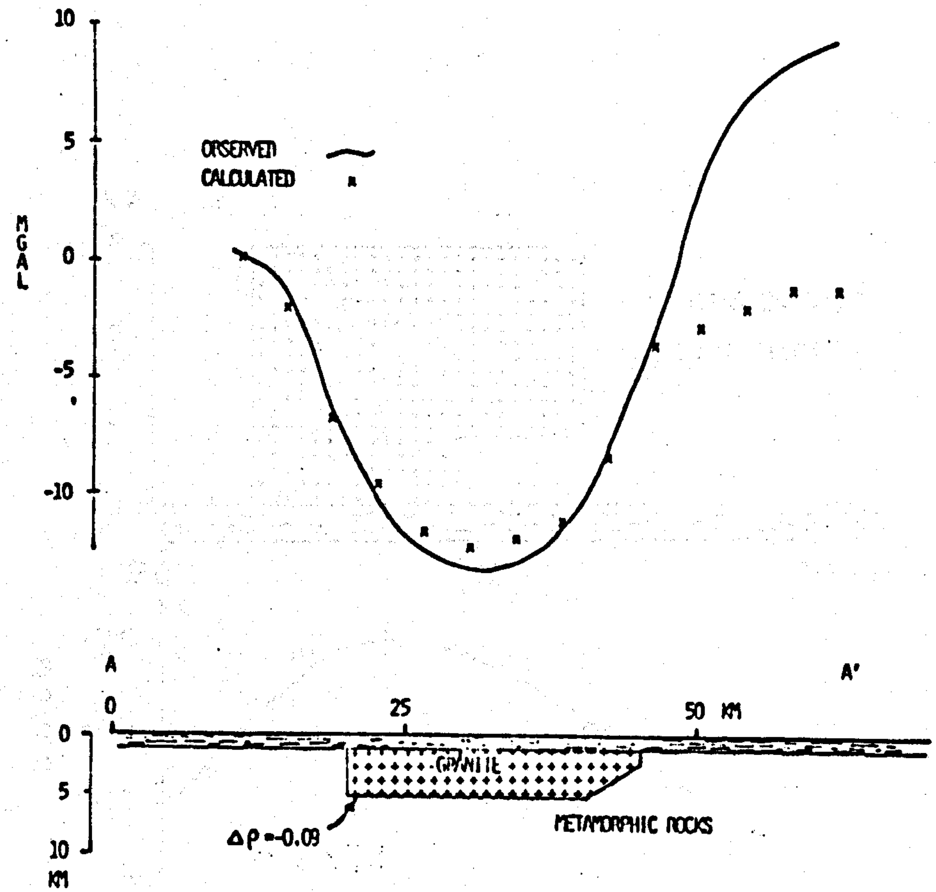


Figure 7 - Residual gravity profile of the East Aurora gravity anomaly.

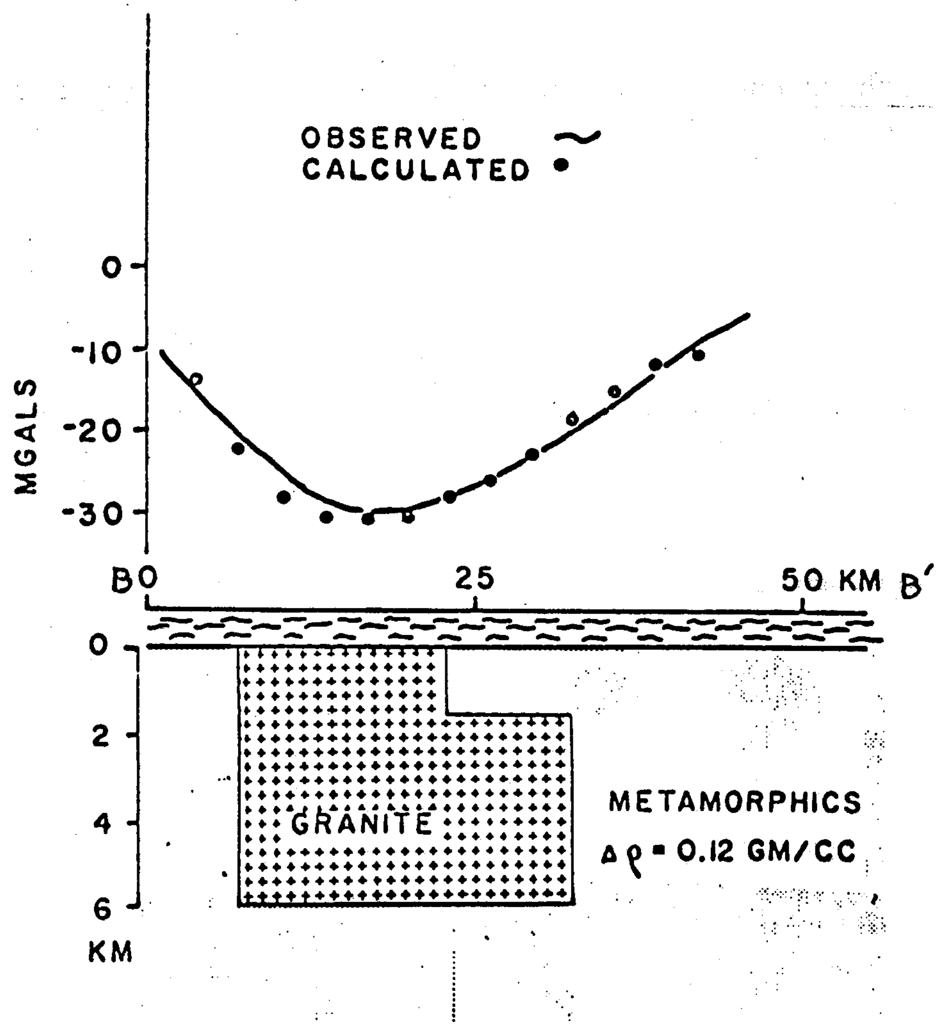


Figure 8 - Residual gravity profile of the Cayuga gravity anomaly.

of the gravity low which reaches -76 mgals is similar in extent to other gravity lows delineating granites.

A distinct correlation between the temperature gradient gradient map and gravity map is apparent (Figures 3 and 6). The East Aurora negative gravity anomaly coincides spatially with a positive temperature gradient anomaly. The Cayuga temperature anomaly trends in a north-south direction with the highest gradients delineated by the 36°C/km contour with a smaller anomaly following an east-west trend. This north-south trend correlated again with a negative Bouguer gravity anomaly. The Elmira temperature anomaly (36°C/km) corresponds exactly with the gravity low located between Elmira and Binghamton, New York.

Source of Heat Flow Anomalies

A distinct correlation between the temperature gradient, heat flow, and Bouguer gravity maps suggest that the source of the thermal anomalies may be due to radioactive heat produced by granitic rocks in the Precambrian Basement. It has been demonstrated (Simmons, 1967; Costain, 1980; Birch, et al., 1968) that heat flow near the Earth's surface is influenced by contrasts of heat production in the Earth's interior.

There are two major components of heat flow that contribute to surface heat flux (Birch, et al., 1968): (1) heat flow from the lower crust and mantle and (2) the heat generated by radioactive decay within the crust. Therefore, surface heat flow (q_0) can be expressed:

$$q_0 = q^* + DA$$

where A is the near surface heat generation due to uranium, thorium, and potassium, q^* is the amount of heat flux contributed from the lower crust and mantle which varies with different provinces (Lachenbruch and Sass, 1977), and D is the depth of constant concentrations of radioactive elements as observed near the Earth's surface.

Birch, et al. (1968) showed a strong linear correlation between heat flow and local bedrock radioactivity in New England and New York. Work by Costain, et al., (1980) confirms this linear relationship between heat flow and heat production in granitic plutons in the southeastern portion of the United States.
Rybach (1976) reports that U, Th, and K become increasingly concentrated in residual liquid during progressive differentiation and granites are found to be relatively enriched with the radioactive elements in comparison to gabbros. Therefore, increased radioactive heat generation in basement rocks (i.e., granites) may be causing elevated

temperatures and heat flow in the East Aurora, Cayuga and Elmira anomalies. Figure 9 illustrates the effect of heat production as well as the sediment blanket effect on subsurface temperatures and geothermal gradients. Contrasts in thermal conductivity and/or radioactive heat generation can explain local geothermal anomalies in purely conductive heat flow environments.

Conclusion

There is remarkable correlation between the spatial distribution of the high temperature gradient, high heat flow anomalies, and the negative Bouguer gravity anomalies. Comparison of the temperature gradient and heat flow maps with the Bouguer map suggests that the causative heat source may be the same that is reflected in the gravity field. From a few basement samples, and by extrapolation from the gravity field in exposed areas in the Precambrian shield of Canada, there is strong evidence that the negative gravity anomalies are due to granite bodies in the basement. Since heat production studies show that granites contain higher amounts of U, Th and K than most other crystalline rocks, the anomalous temperature gradients and heat flow are likely due to the greater amounts of heat conducted into the sedimentary rocks overlying radioactive granites in the Precambrian Basement rock. This process has been more or less undisturbed for about 500 million years and a distinct temperature signature has been developed. Results of this study indicate that this region has significant temperature gradients and heat flow anomalies as high as any observed in the eastern United States.

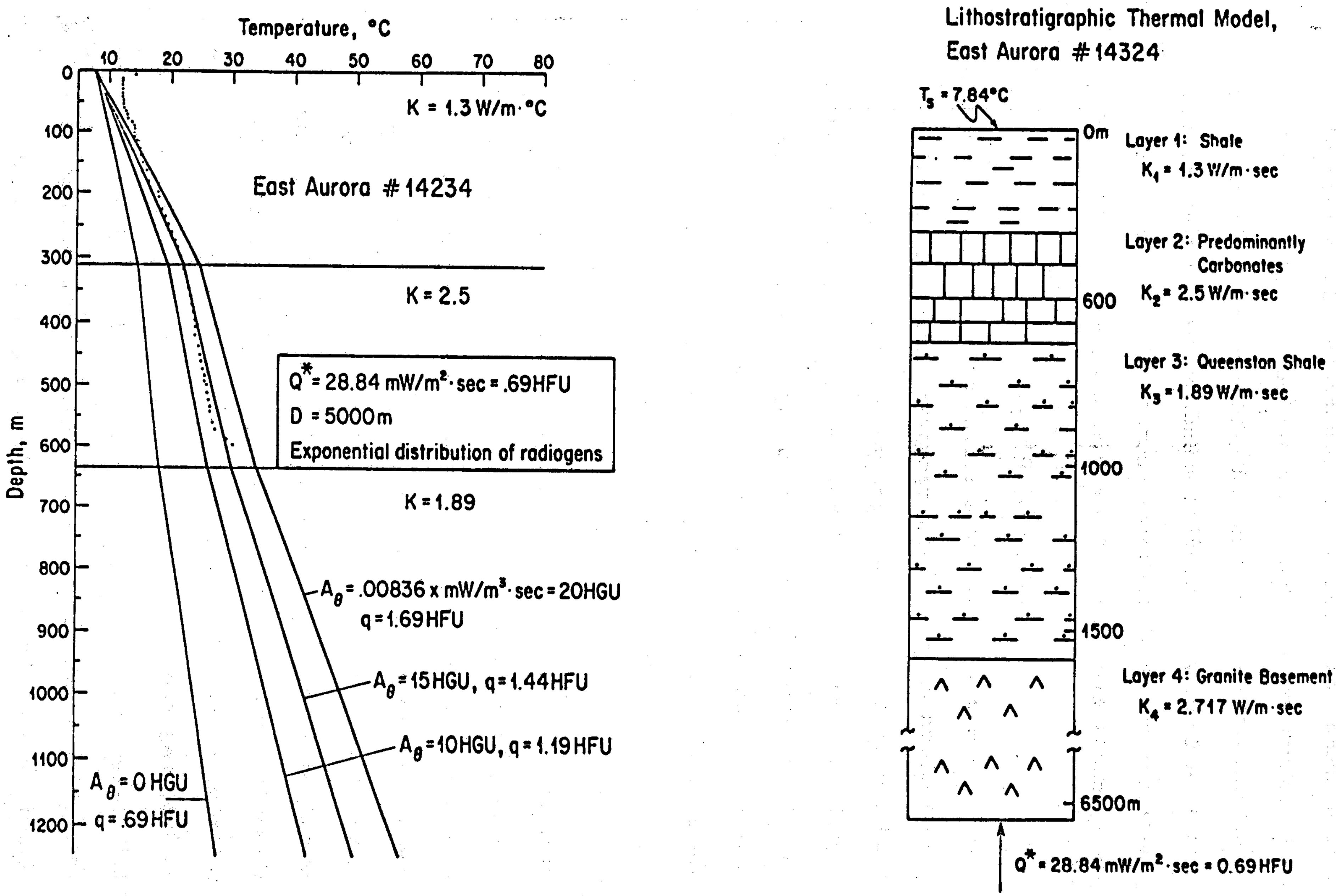


Figure 9 - Effect of conductivity and heat production on temperature gradients in a well logged in East Aurora.

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Overview
Northeastern Geothermal Program

by

J. Maxwell
Los Alamos Scientific Laboratory

Geothermal Resource Potential in New Hampshire and Vermont

James C. Maxwell

Some of the earliest exploration for geothermal energy in the United States was done in New England during the 1960's. By 1968, Birch, Roy and Decker[1] had published 22 values of heat flow for New England and adjacent New York. Of these, 8 were from New Hampshire and 3 from Vermont. The highest uncorrected value was 2.53 microcalories per cm^2 sec from a 320 m deep hole near Waterville, NH. After correction for topography, the highest value was found to be 2.27 μcal cm^{-2} sec^{-1} from a 305 m deep hole in Conway granite near the Kancamagus Highway. The Conway granite was known to have higher concentrations of heat-producing potassium, thorium and uranium than most other granites. The concentrations of these elements and their distributions with depth have been topics of dispute from 1945[2] to the present.

In 1976, under the direction of Hoag and Stewart[3], an overall gradient and heat flux of 29°C/km and 1.9 μcal cm^{-2} sec^{-1} were measured in a 915 m deep hole near the margin of a Conway granite pluton near Redstone, NH. Hoag and Stewart estimate that the heat flow for this hole would have been 2.7 μcal cm^{-2} sec^{-1} if it had been entirely in the red phase of the Conway granite. The same data used by Hoag and Stewart have recently been reinterpreted by Foster[4] to show a gradient of 40.56°C/km in the deepest 150 m interval of this hole.

Many new gradient measurements have recently been added by Simmons[5] and coworkers at M.I.T. Table 1 shows how data density has improved from 1968 to the present. At least three substantial conclusions have resulted from these new data. First, confirmation of above average gradients and heat flow in the vicinity of Conway and North Conway, NH, by locating in this area 10 more wells with gradients ranging from 22 to 29°C/km heat flow was determinable for 8 of these, ranging from 1.49 to 2.26 μcal cm^{-2} sec^{-1} with the higher values closer to North Conway. Second, discovery of two more areas of above average gradient. One of these, near Manchester and Concord, NH, has gradients of 20 to 26 °C/km and heat flow of 1.5 to 1.8 μcal cm^{-2} sec^{-1}. The other straddles the Vermont-New Hampshire state boundary near Brattleboro and Bellows Falls, VT. Third, the new data show that, regionally, gradients and heat flow decline southwestward in southern Vermont to values less than 15°C/km and 1.0 μcal cm^{-2} sec^{-1} and decline northward to northern Vermont and New Hampshire to values less than 10°C/km and 1.0 μcal cm^{-2} sec^{-1}. Although density of measurements, except in the Conway area, is still so low that additional local areas of above average values may be found, these regional trends are not expected to be changed much by future measurements.

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TABLE 1

HEAT FLOW IN NEW ENGLAND

(microcals/cm^2 sec)

From Birch and Others, 1968

Maine	2 Measurements		
		Range 1.3 - 1.6	Average 1.5
New Hampshire	8 Measurements		
		Range 1.0 - 2.2	Average 1.7
Vermont	3 Measurements		
		Range 1.1 - 1.2	Average 1.1
Massachusetts	4 Measurements		
		Range 1.2 - 1.5	Average 1.4
Rhode Island	No Measurements		

From Simmons and Others, 1980

New Hampshire	57 New Measurements		
		Range 0.76 - 2.26	Average 1.4
Vermont	59 New Measurements		
		Range 0.10 - 2.57	Average 1.2

A Preliminary Geothermal Resource Appraisal of the Tennessee Valley Region

by

W. P. Staub
Institute for Energy Analysis
Oak Ridge Associated Universities

November 6, 1980

A PRELIMINARY GEOTHERMAL RESOURCE APPRAISAL OF THE TENNESSEE VALLEY REGION*

by

W. P. Staub**

Institute for Energy Analysis
Oak Ridge Associated Universities
Oak Ridge, Tennessee 37830

As part of a study of the potential for commercialization of geothermal energy in the Tennessee Valley region, a preliminary appraisal of geothermal energy resources of Kentucky and Tennessee has been completed. An assessment of resources in other parts of the region will be carried out in the second phase of this study.

Shallow, intermediate and deep aquifers were selected for study. Shallow groundwater temperatures were compiled from data supplied by the National Water Well Association and shallow aquifer characteristics were provided by staff of the Tennessee Valley Authority (TVA). Maps were compiled for the basement and Top-of-Knox structure and temperature using oil and gas well data on file at various state geological survey offices.

Results of this study indicate that the Mississippi Embayment (extreme western Kentucky and Tennessee) is the most likely area within Kentucky and Tennessee to possess potential for direct heat utilization, but that several engineering problems may be encountered in attempting to use low-grade geothermal energy from deep wells in this region. Drilling conditions are

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* This report is based on work performed by contract No. DE-AC05-760R0003 between the U.S. Department of Energy and Oak Ridge Associated Universities.

** W. P. Staub is a geologist with Oak Ridge National Laboratory operated by Union Carbide Corporation under contract W-7405-eng-26 for the U.S. Department of Energy, currently working under contract for the Institute for Energy Analysis, Oak Ridge Associated Universities.

likely to be difficult beneath the top of the Paleozoic, and geothermal fluid from the deeper horizons may contain in excess of 100,000 MG/l total dissolved solids, requiring elaborate heat exchanger and disposal design features. Furthermore, it is uncertain whether the high geothermal gradient encountered in shallow wells persists at depth.

On the other hand, shallow (less than a depth of one Km) aquifers in the Mississippi Embayment are nearly ideal for groundwater heat pump augmented direct heat applications. Few groundwater wells have been drilled to depths greater than 500 m in this region because adequate municipal and industrial supplies are available at much shallower depths. Flowing artesian wells are the rule rather than the exception in the few places where deeper aquifers are developed. These artesian aquifers yield excellent quality water at high flow rates. Individual wells produce 15 l/s (250 gpm) or more under artesian pressure heads between 5 and 20 m above ground surface. The water chemistry is described as (1) mainly sodium bicarbonate, (2) generally low to moderate hardness (10 to 120 mg/l), (3) fresh to slightly brackish (300 to 1700 mg/l), (4) moderately alkaline [$8 < pH < 9$], and (5) very low iron, manganese and sulfate content. Thus scaling and corrosion are not expected to be severe. Groundwater temperature is expected to be about 35°C (95°F) and 40°C (104°F) for wells drilled to 500 and 1000 m, respectively. In theory it should be possible to develop a groundwater heat pump with a coefficient of performance (ratio of energy output to input) approaching 6 for the above geothermal resource. The temperature of the output fluid from a heat exchanger may exceed 70°C (158°F) which would be high enough for many space heating and some process heating requirements. Once the heat is extracted the cooled groundwater would be suitable for a municipal or agricultural water supply or for surface discharge.

In areas other than the Mississippi Embayment, geothermal energy is either too deep for economical extraction or it will not be able to compete with other local but underutilized fossil energy resources. The only anomalously high temperature wells outside the Mississippi Embayment were located in the Rome Trough near the central part of the eastern Kentucky coal basin and in the Moorman Syncline of the western Kentucky coal basin.

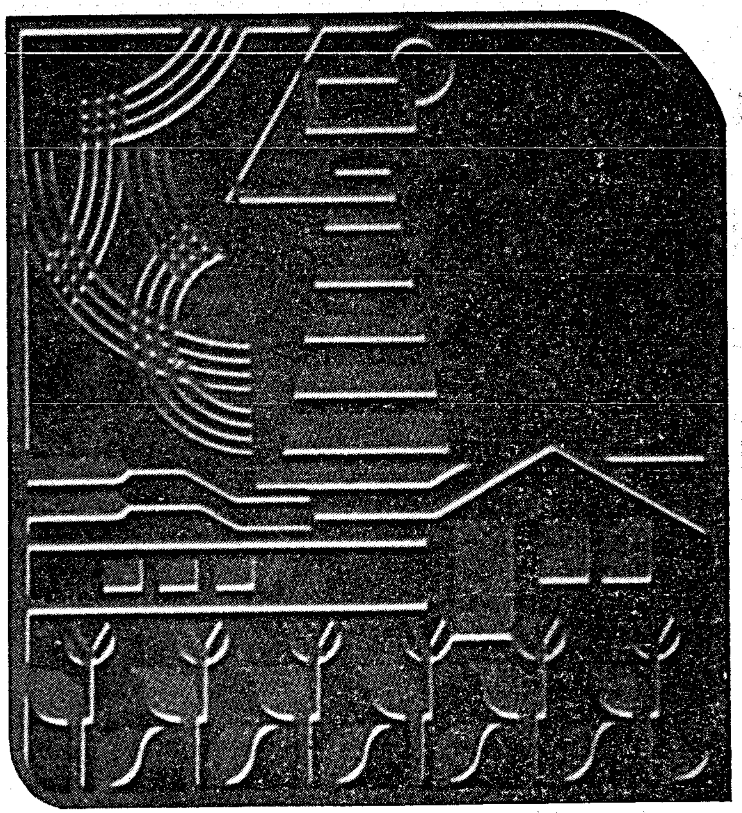
Geothermal energy in these coal basins would face especially strong competition from natural gas. Marginal gas wells (shut-in or abandoned) are common to an area stretching from north central Tennessee through eastern Kentucky and beyond the Tennessee Valley region to southern New York. In Clay County, Kentucky several marginal gas wells (production rates too low to justify laying a long pipeline) have already been brought into production for on site utilization. This is precisely the manner in which geothermal energy would be exploited (long pipelines are not a viable option for geothermal energy because of heat loss). Wherever shut-in wells are already available natural gas could be cheaper to produce and less likely to have environmental restraints placed upon it.

User Coupled
Resource Confirmation

by

S. Prestwich
Department of Energy
Idaho Operations Office

Overview of User Coupled Confirmation Drilling Program



Idaho Operations Office

INEL-S-25 258

Reservoir Confirmation Lags

Because of:

- Inability of many users to spread high risks and costs
- Inability of some users to get risk money
- Lack of experienced infrastructure
- Lack of economic data

INEL-S-25 2

Project Objectives

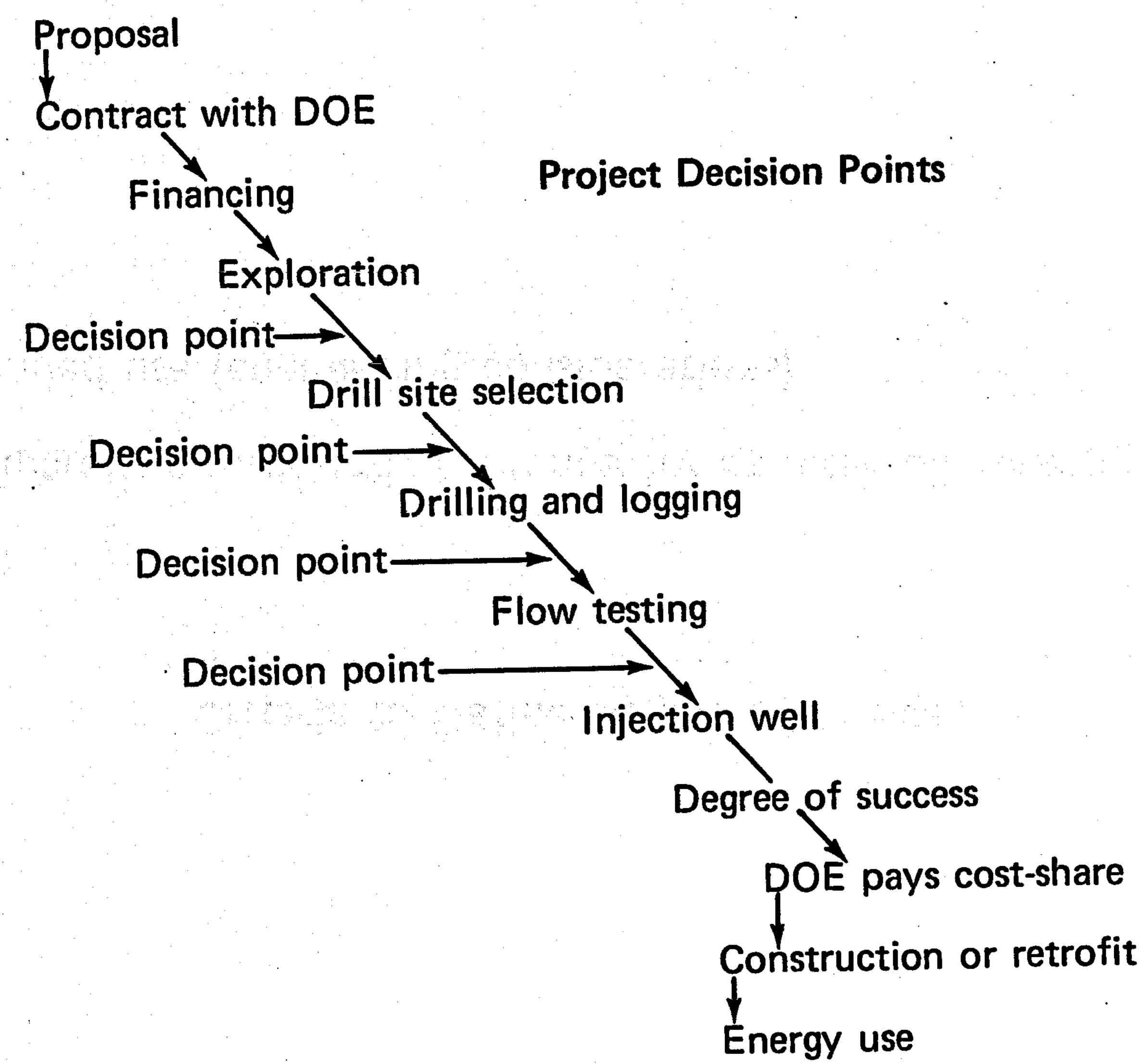
- Confirm usable hydrothermal reservoirs
- Reduce exploration risks by cost-sharing
- Promote expertise for geothermal exploration and development
- Power on-line

Proposals Must Contain

(Key Features)

- Project description — Plans for reservoir confirmation using new or existing well
- Variable cost-share plan
- Statement of intent to use resource if confirmed
- Evidence that land and geothermal use rights can be obtained

Project Decision Points



Criteria to Define Degree of Success

Based On

- Temperature, productivity, longevity of reservoir (energy available)
- Intended use (engineering considerations)

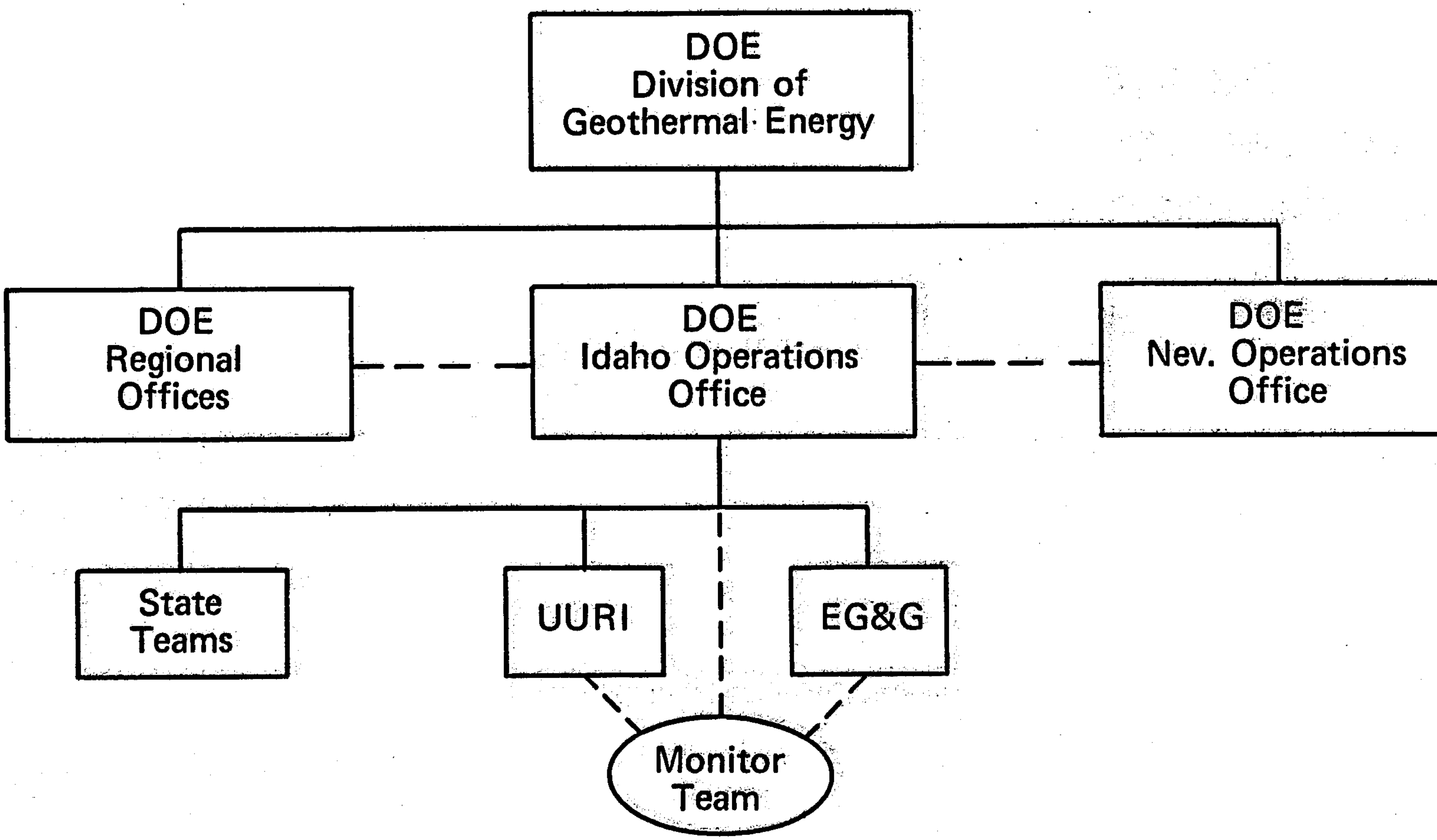
Simplified Cost-Share

Successful well
80% developer
20% DOE

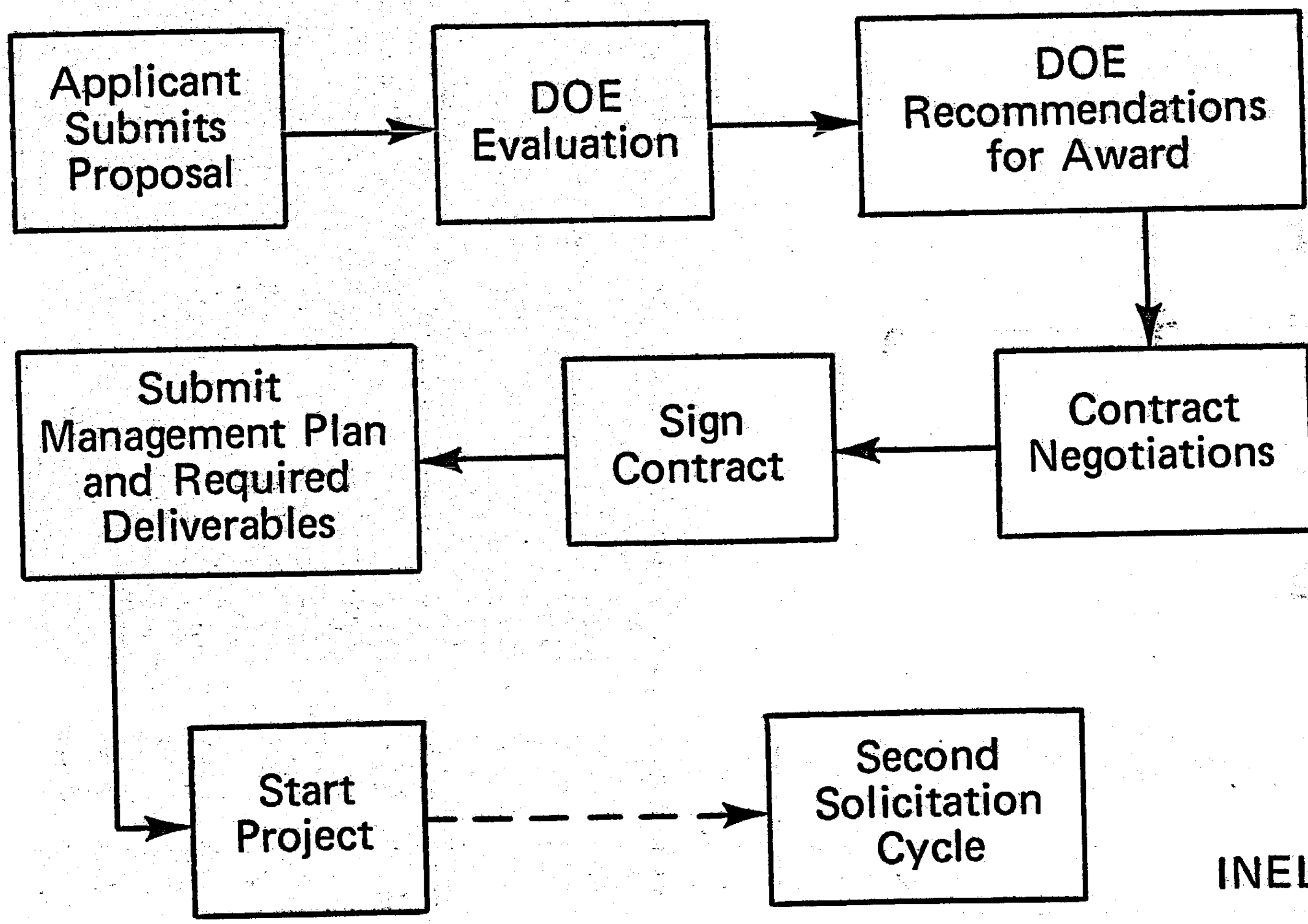
Negotiation

Unsuccessful well
10% developer
90% DOE

Management


DOE
Division of
Geothermal Energy
DOE
Regional
Offices
DOE
Idaho Operations
Office
DOE
Nev. Operations
Office
State
Teams
UURI
EG&G
Monitor
Team

Procurement Process



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Energy Security Act
Title VI Geothermal Energy Loans

XVI-10

Idaho Operations Office

INEL-S-29 066

Energy Security Act Loans

- Non-competitive
- Interest rate = effective rate Sec 80 Water Resources Development Act of 1974
- Forgivable
- Loan program termination Sept. 30, 1986

INEL-S-29 069

Resource Confirmation Loan

- Loans for projects:
  - To determine economic viability of geothermal reservoir
  - Consist of surface exploration and drilling of exploratory wells
- Loan amount
  - Direct space, cooling, or process heat 90%
  - All other geothermal projects 50%

  $3 M maximum

INEL-S-29 067

Resource Confirmation Loan (cont'd)

- Loans repayable from resource confirmation
  - Start 3 yrs (revenues)
  - Start 5 yrs (without revenues)
  - Fully repaid within 20 yrs
- Funding

  FY 81 - $ 5 M

  FY 82–86 - $20 M
- Regulations required in 6 months

INEL-S-29 068

Feasibility Studies Loan Authorizing Legislation

- Loans for nonelectric applications
  - Geothermal utility districts
  - Geothermal industrial development districts
  - Other "persons"
- Loan amount

– Feasibility studies, Permitting	90% loans
– Construction (nonelectric)	75% loans

- Loan repayable

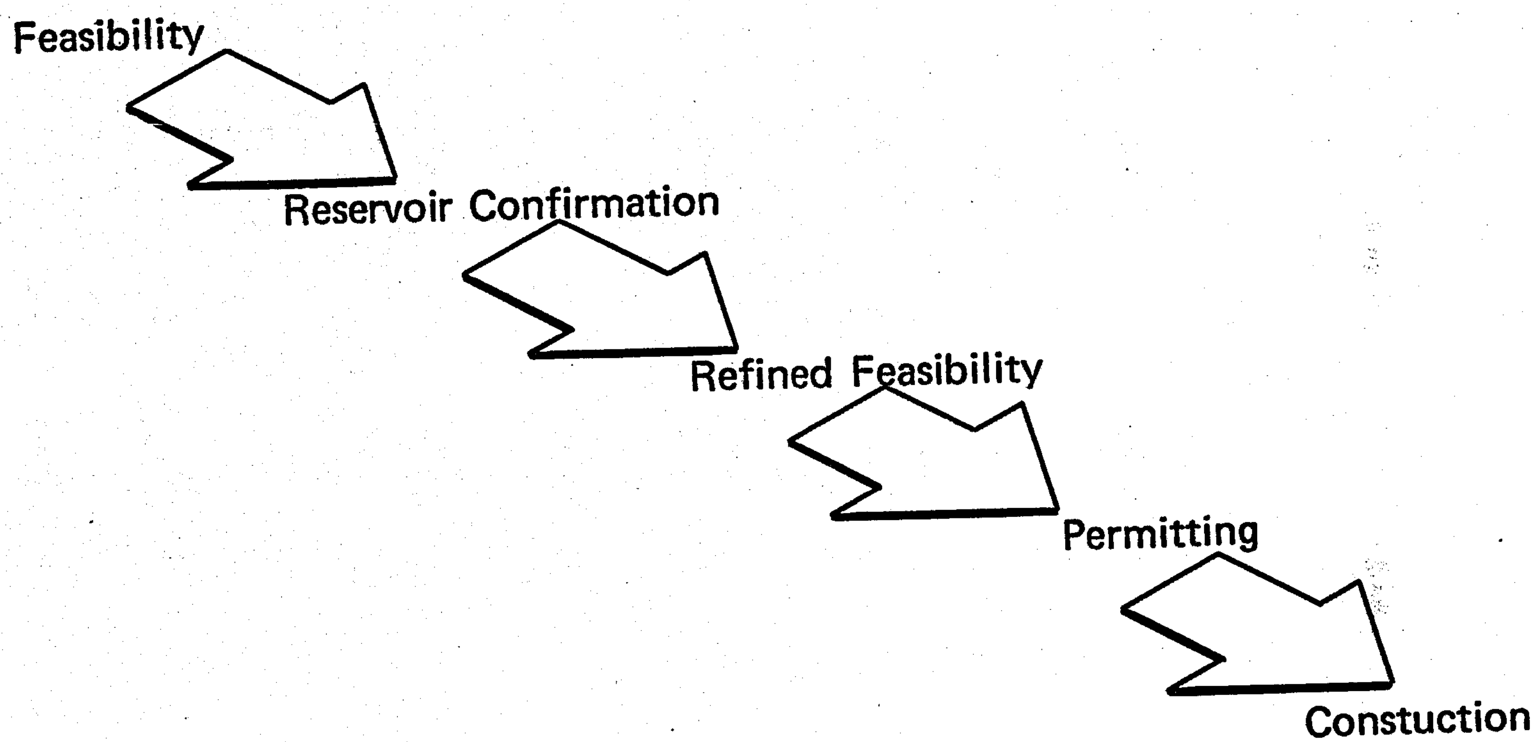
– Feasibility and permitting	10 yrs.
– Construction	30 yrs.

- Funding

  FY 81 - $5 M (feasibility only)

  FY 82–86 - subject to authorizing legislation

Flow of Loans



INEL-S-29 070

The DOE/DGE
State Coupled Program

by

M. Wright
Earth Sciences Laboratory
University of Utah Research Institute

XVII

U. S.

DEPARTMENT OF ENERGY

DIVISION OF GEOTHERMAL ENERGY

STATE COUPLED PROGRAM

SC/MW-001

STATE COUPLED PROGRAM

A GOAL-ORIENTED PROGRAM TO COLLECT AND PUBLISH REGIONAL AND AREAL GEOTHERMAL DATA

- **TO ENCOURAGE DEVELOPMENT BY PROSPECTIVE USERS**

- **TO ASSIST USGS IN RESOURCE INVENTORY (Circular 790 Update)**

SC/MW-020

COMPANION PROGRAMS

- COMMERCIALIZATION PLANNING
- USER COUPLED DRILLING
- PONs AND PRDAs
- USER ASSISTANCE
- USGS REGIONAL ASSESSMENT

MAJOR BARRIERS TO COMMERCIALIZATION

- Lack of defined resources
- Lack of an established industry
- Limited technical and economic data
- Policy and regulatory confusion
- Environmental impact uncertainties

SC/MW-014

STATE COUPLED PROGRAM

PURPOSE

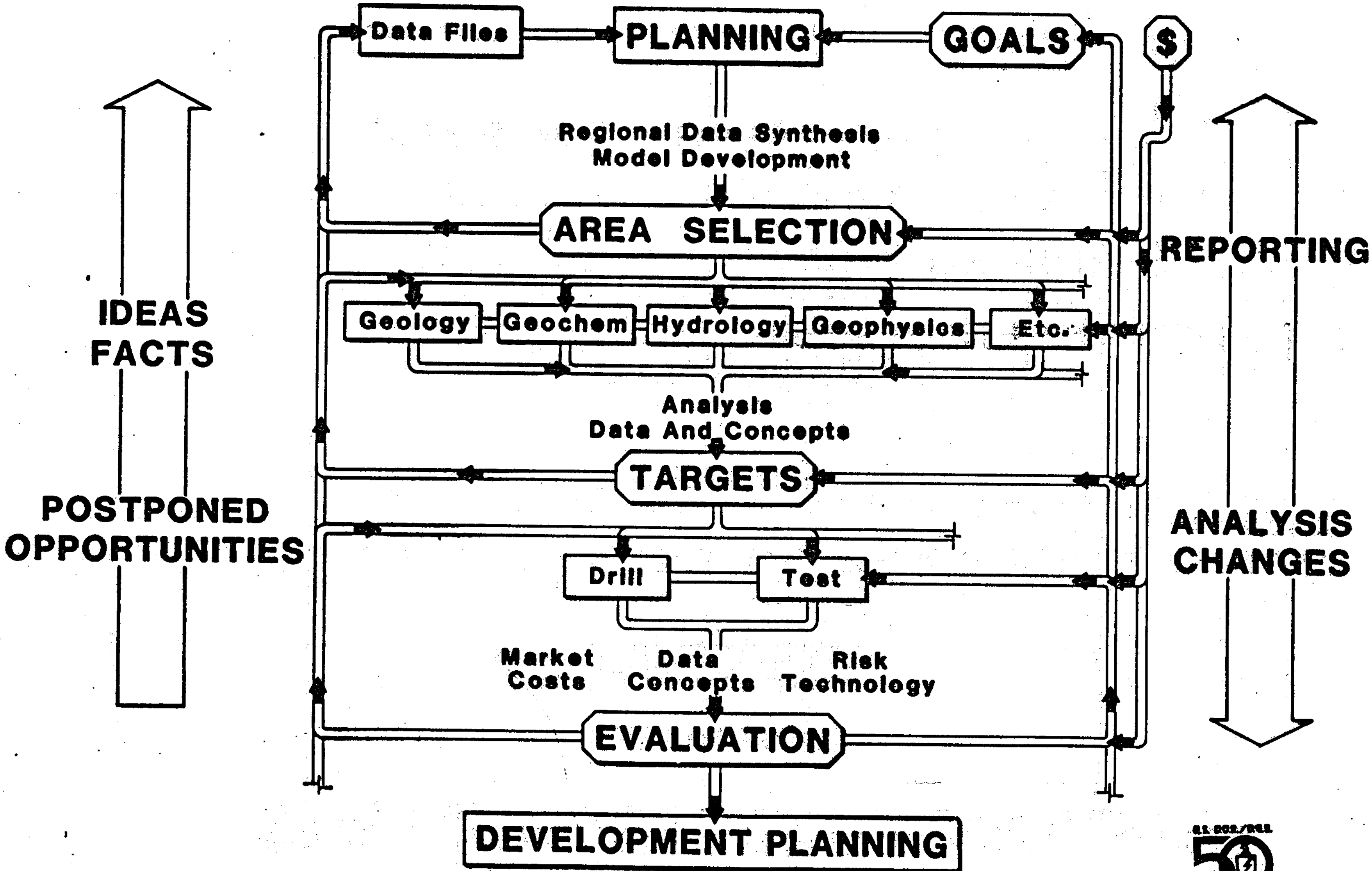
- TO COLLECT AND PUBLISH REGIONAL AND AREAL GEOTHERMAL RESOURCE DATA

JUSTIFICATION

- TO FACILITATE SELECTION OF HIGH-QUALITY SITES FOR FURTHER EXPLORATION BY USERS AND DEVELOPERS

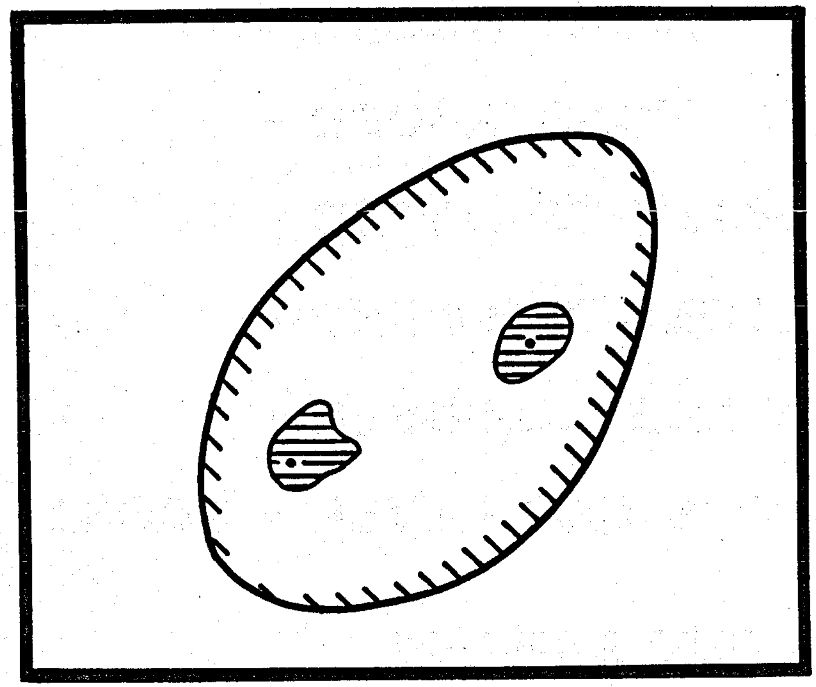
SC/MW-019

EXPLORATION



8C/MW-022

EXPLORATION STAGES



STATEWIDE INVENTORY

REGIONAL RECONNAISSANCE

AREA EXPLORATION

• SITE SPECIFIC ANALYSES

SC/MW-029

DIRECT VS INDIRECT DETECTION

DIRECT METHOD - TEMPERATURE MEASUREMENT SPRINGS AND DRILL HOLES

INDIRECT METHODS
- HEAT FLOW STUDIES
- GRADIENT EXTRAPOLATION
- CHEMICAL GEOTHERMOMETRY
- GEOLOGIC MAPPING
- GEOPHYSICAL SURVEYS
- GEOCHEMICAL SURVEYS
- HYDROLOGIC STUDIES

GEOTHERMAL MODEL DEVELOPMENT

PURPOSE - TO DEVELOP AND TEST NEW GEOTHERMAL TARGET MODELS

METHODS - GEOLOGICAL AND HYDROLOGICAL REASONING, DRILL TESTING

PRODUCTS - PROVEN TARGET CONCEPTS

EXAMPLE - MODEL FOR EAST COAST GEOTHERMAL RESOURCES DEVELOPED AT VPI

REPORTS

NEEDS OF PROSPECTIVE USERS ARE PARAMOUNT

- **RESOURCE DESCRIPTION**

  LOCATION, TEMPERATURE, DEPTH, WATER QUALITY, PRODUCTIVITY

- **GEOLOGIC CHARACTERIZATION**
- **DISCOVERY POTENTIAL**
- **SOURCES OF FURTHER INFORMATION**
- **SUPPORTING SCIENTIFIC DATA**

PERIODIC REPORTS ALSO REQUIRED BY DOE

EXPLORATION STAGES

• STATEWIDE INVENTORY		STATE COUPLED PROGRAM
• RECONNAISSANCE LARGE REGIONS	1,000– 10,000 Sq. mi.	STATE COUPLED PROGRAM
• AREA EXPLORATION SELECTED AREAS	100– 1,000 Sq. mi.	STATE COUPLED PROGRAM
• SITE EXPLORATION SELECTED SITES	less than 10 Sq. mi.	USER COUPLED DRILLING PROGRAM
• TEST AND PRODUCTION WELL DRILLING		USER COUPLED DRILLING PROGRAM

SC/MW-028

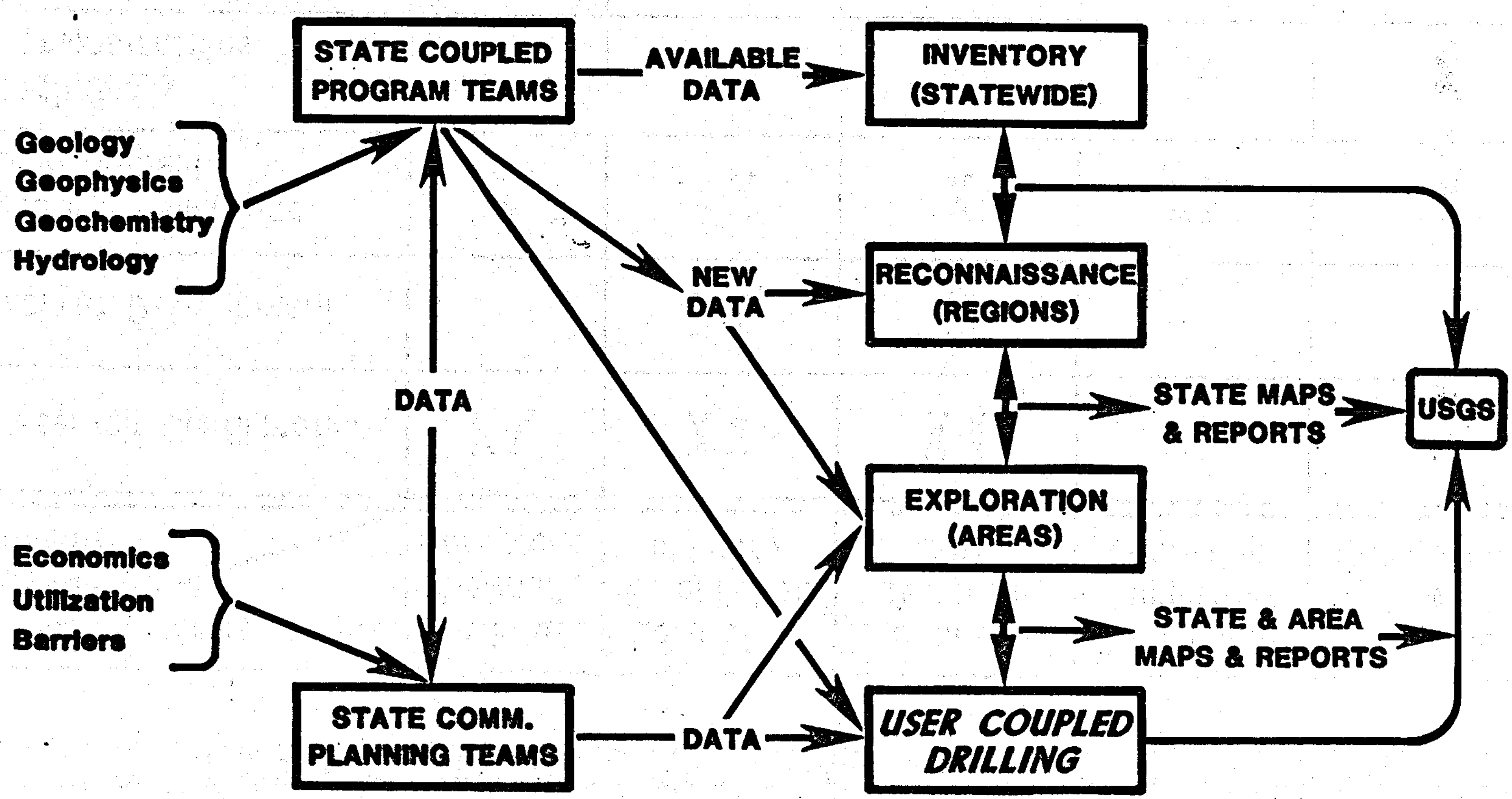
PROPOSALS

(TAILORED TO EACH STATE'S NEEDS)

SUGGESTED % EFFORT

	YEAR 1	YEAR 2	YEAR 3	OUT-YEARS
STATEWIDE INVENTORY	30	10	5	5
REGIONAL RECONNAISSANCE	25	25	10	5
AREA EXPLORATION AND MODEL DEVELOPMENT	5	15	20	25
MAP PRODUCTION	10	10	10	5
REPORTING	5	5	10	5
USER ASSISTANCE	5	10	25	35
USGS INTERFACE	10	10	5	5
COMMERCIALIZATION PLANNING SUPPORT	5	10	10	10
DOE REQUESTS FOR DATA	5	5	5	5

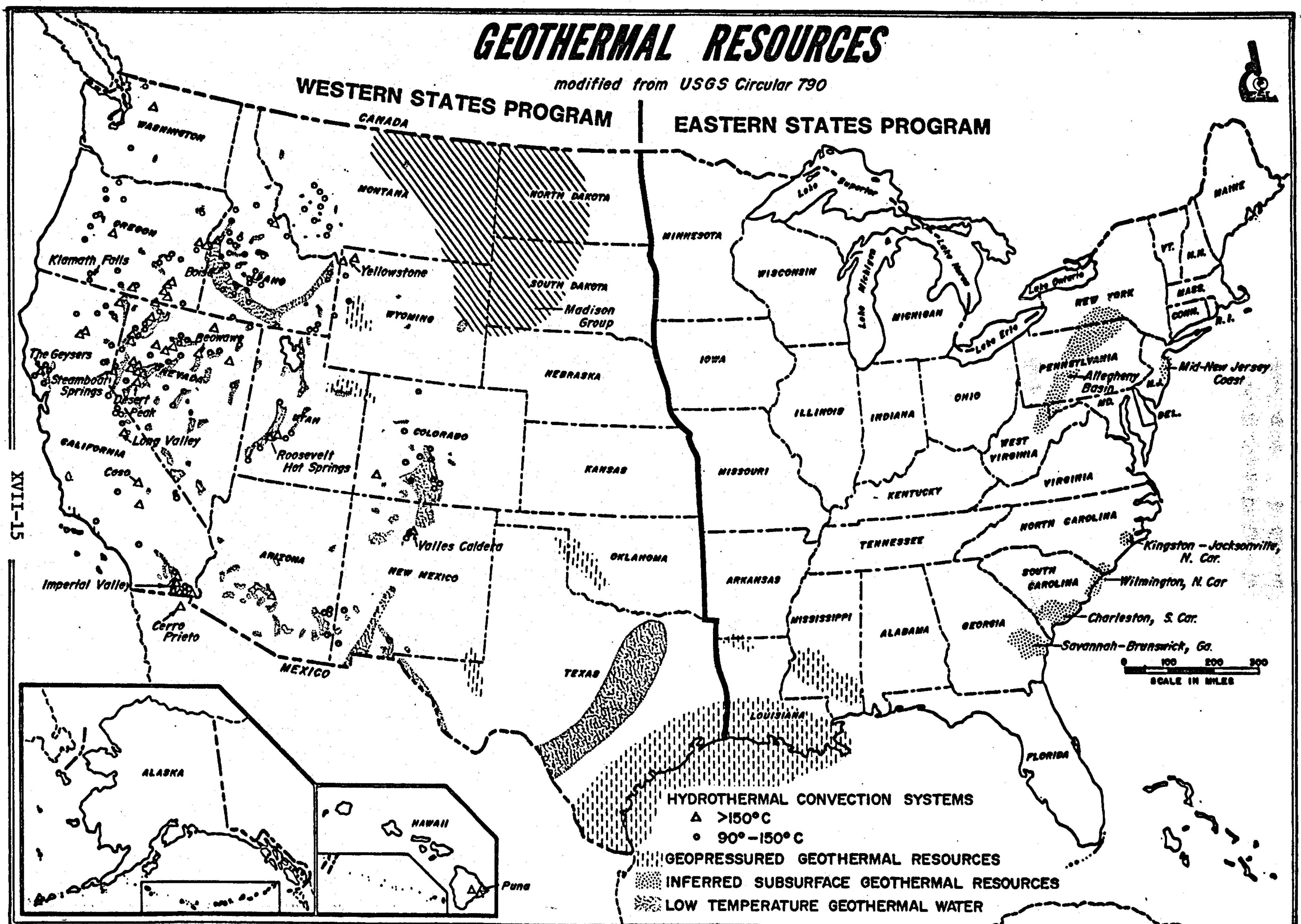
STATE COUPLED PROGRAM



PROGRAM DEVELOPMENT MATRIX

Program Elements / Barriers →	Lack of Defined Resources	Lack of an Established Industry	Limited Technical Data	Policy and Regulatory Confusion	Environmental Impact Uncertainties
• Reservoir Confirmation	XX	XX	XX	X	X
• Market Development		XX	X		
• State Planning and Development	X	XX	X	XX	X
• Technology Demonstrations		XX	XX	X	X
• Environmental Assessment		X	X	XX	XX
• Policy and Regulatory Issues Assessment		X	X	XX	X
• Progress Monitoring	X	X	X	X	X

XX Primary Impact X Secondary Impact


GEOTHERMAL RESOURCES
modified from USGS Circular 790
WESTERN STATES PROGRAM
EASTERN STATES PROGRAM
CANADA
WASHINGTON
OREGON
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
WISCONSIN
MICHIGAN
MAINE
VT.
N.H.
MASS.
CONN.
R.I.
NEW YORK
Lake Superior
Lake Michigan
Lake Huron
Lake Ontario
Lake Erie
Klamath Falls
Boise
IDAHO
Yellowstone
WYOMING
Madison Group
The Geysers
Beowawe
NEVADA
Steamboat Springs
Desert Peak
Long Valley
CALIFORNIA
UTAH
Roosevelt Hot Springs
COLORADO
NEBRASKA
IOWA
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
Allegheny Basin
MD.
N.J.
DEL.
Mid-New Jersey Coast
WEST VIRGINIA
VIRGINIA
KANSAS
MISSOURI
KENTUCKY
Coso
Valles Caldera
ARIZONA
NEW MEXICO
OKLAHOMA
ARKANSAS
TENNESSEE
NORTH CAROLINA
Kingston – Jacksonville, N. Car.
SOUTH CAROLINA
Wilmington, N. Car
Charleston, S. Car.
Savannah-Brunswick, Ga.
Imperial Valley
Cerro Prieto
MEXICO
TEXAS
MISSISSIPPI
ALABAMA
GEORGIA
LOUISIANA
FLORIDA
0 100 200 300
SCALE IN MILES
ALASKA
HAWAII
Puna
HYDROTHERMAL CONVECTION SYSTEMS
Δ >150°C
○ 90°–150°C
GEOPRESSURED GEOTHERMAL RESOURCES
INFERRED SUBSURFACE GEOTHERMAL RESOURCES
LOW TEMPERATURE GEOTHERMAL WATER

Geo/RM-003

Utilization of Geothermal Energy at the Cove Point (Md.) LNG Receiving Terminal*

by

A. Litchfield
Columbia LNG Corporation

*An appendix concerning the test well drilling at Cove Point was not presented at the conference but is included — submitted by R. J. Gleason, V.P.I. & S.U.

UTILIZATION OF GEOTHERMAL ENERGY
AT THE COVE POINT LNG RECEIVING TERMINAL

Presentation to the Eastern Geothermal Efforts -
Technical Information Interchange Meeting
November 1980

. . . (SLIDE 1-LOGO). . . I certainly want to thank all of you for giving me the opportunity to discuss with you what we feel is a very exciting and economic use for low temperature east coast geothermal energy. The Cove Point receiving terminal, which is jointly owned by Columbia LNG Corporation and Consolidated System LNG Company, is located. . .(Slide 2-Map). . .in an area which has recently been postulated to contain significant amounts of geothermal energy. Last year at Coolfont we discussed some of these reasons and the subject was again covered in this mornings sessions, so, I won't go over them. I'd like to point out, however, the close proximity of Cove Point to Crisfield and Lakesville.

This year, however, I'd like to show you just how we intend to use the Geothermal water at the Cove Point terminal.

. . . (Slide 3-Old Faithful). . . No this isn't Cove Point, it's "Old Faithful" as I'm sure you know. While the temperature of east coast geothermal water is expected to be quite a bit lower than that of our western counterparts, the Cove Point terminal . . . (Slide 4-Aerial). . . is in a very unique position of being able to utilize large quantities of warm water in the vaporization of LNG. As mentioned it is expected that the temperature of the geothermal water at Cove Point will be about 115°F. Our engineers at Columbia LNG have devised a method using present day technology for utilizing up to 8000 gpm of this geothermal water to save nearly 1.9 Bcf per year of natural gas currently being burned as fuel at the terminal. To give you an idea of how much energy this is; it is sufficient to heat all the homes in a city of 40,000 people and is equivalent to approximately 400,000 barrels of oil per year in heating value, which if valued at $4.00 per million Btu's, will save our customers nearly $8 million a year in energy costs.

This aerial view of our terminal shows most of the 1023 acres within our property line; 325 of which is reserved for operations and 700 of which is kept as an undeveloped buffer zone. It is in this area that we expect to develop the geothermal resource.

I need to point out here that our site at Cove Point is somewhat encumbered by an agreement we reached in 1973 with the Sierra Club and the Maryland Conservation Council. The agreement would not allow any industrial activity to take place, including well drilling, on the 700 acres that more or less surrounds the 325 acres that have been rezoned for industrial use. While wells and connecting pipelines would create only minimal disturbance to the property, we must nonetheless obtain concurrence from the Maryland Conservation Council and Sierra Club if this project proves feasible.

. . . (Slide 5-Plant). . . In order for you to understand how we intend to use Geothermal Energy at Cove Point, I think a brief review of the basic plant operations is in order. The terminal has a capacity of 1000 MMcfd of sendout. However, at the present time we are, as you know, currently operating under a temporarily suspended contract with the Algerians for 650 MMcfd. The terminal is basically divided into two areas--storage and sendout facilities. In the sendout operation, LNG is withdrawn from the storage tanks and pumped to two different areas in the plant, both of which vaporize LNG. One is the primary vaporization facility shown here in this building, and the other is the waste heat recovery area shown by these two black shell and tube heat exchangers. The vaporized LNG from both these areas is then combined and sent out as natural gas through the distribution system.

. . . (SLIDE 6). . . This is a simplified flow diagram of these two vaporization systems--primary and waste heat recovery areas. LNG is withdrawn from storage, pumped up to 1250 psig and sent to the respective areas. This block represents the vaporizer building where 75% of the vaporization occurs. In this building there are ten gas fired submerged exhaust vaporizers. Here natural gas is burned as a source of heat to vaporize LNG utilizing approximately 1.2% of the terminal throughput. It is in this area that geothermal energy can be best utilized.

The lower section of the diagram represents the waste heat recovery vaporization. This system picks up heat from the turbines used for on site electrical generation and vaporizes LNG. Approximately 25% of the LNG is vaporized in this way.

. . . (SLIDE 7). . . Let me show you how the main vaporization system works. Pictured here is one of the ten submerged exhaust vaporizers, each capable of 100 MMcfd of LNG. You will note that each vaporizer has six burners. Here is a cross section representing one of these burners.

. . . (SLIDE 8). . . Here is a better view of the cross section. As the name implies, they are submerged exhaust units. Each burner's exhaust is forced down into a bath of water and is bubbled up through the bath heating the water to 100^{o}F. This 100^{o} water contacts these tubes which contain LNG at 1250 psig and vaporizes it. This is a very efficient system, but the burners do consume a lot of gas, as mentioned earlier, approximately 1.9 Bcf per year.

Because the LNG is vaporized and sent out as a gas at only 40^{o}F, you can now begin to see how tremendously valuable a source of warm water could be in accomplishing this vaporization, even 100^{o} water. It is these submerged exhaust units which we would replace with a geothermal energy system.

. . . (SLIDE 9). . . Now let's look at the waste heat recovery vaporizers. You are looking at a cross section of one of the shell and tube heat exchangers used for heat recovery. It consists of two tube bundles in a shell with the lower bundle immersed in iso-butane. The waste heat is transferred from the lower bundle to the top one by boiling the iso-butane which condenses on the top bundle and vaporizes the LNG in the tubes. It is this type of system which we believe holds the greatest promise for utilizing geothermal energy. Hot geothermal water could be pumped into the lower tube bundle,

. . . (Slide 10) . . . and the system would be set up like this. Similar to the heat recovery system, but with hot water from a geothermal reservoir, the system is very simple and highly reliable.

In order to supply the amount of geothermal energy we need for the terminal, it may be necessary to drill perhaps as many as 20 to 30 production wells. The 8000 gpm is a lot of water and to eliminate any possibility of subsidence, the geothermal energy system will consist of both production wells and reinjection wells so that all the water which is withdrawn from the aquifer will be replaced. I should point out here that the success of the system does not necessarily depend on getting this much water. There may be not be that much available. However, we have determined that we could economically use any rate between 1000 and 8000 gpm with corresponding gas savings.

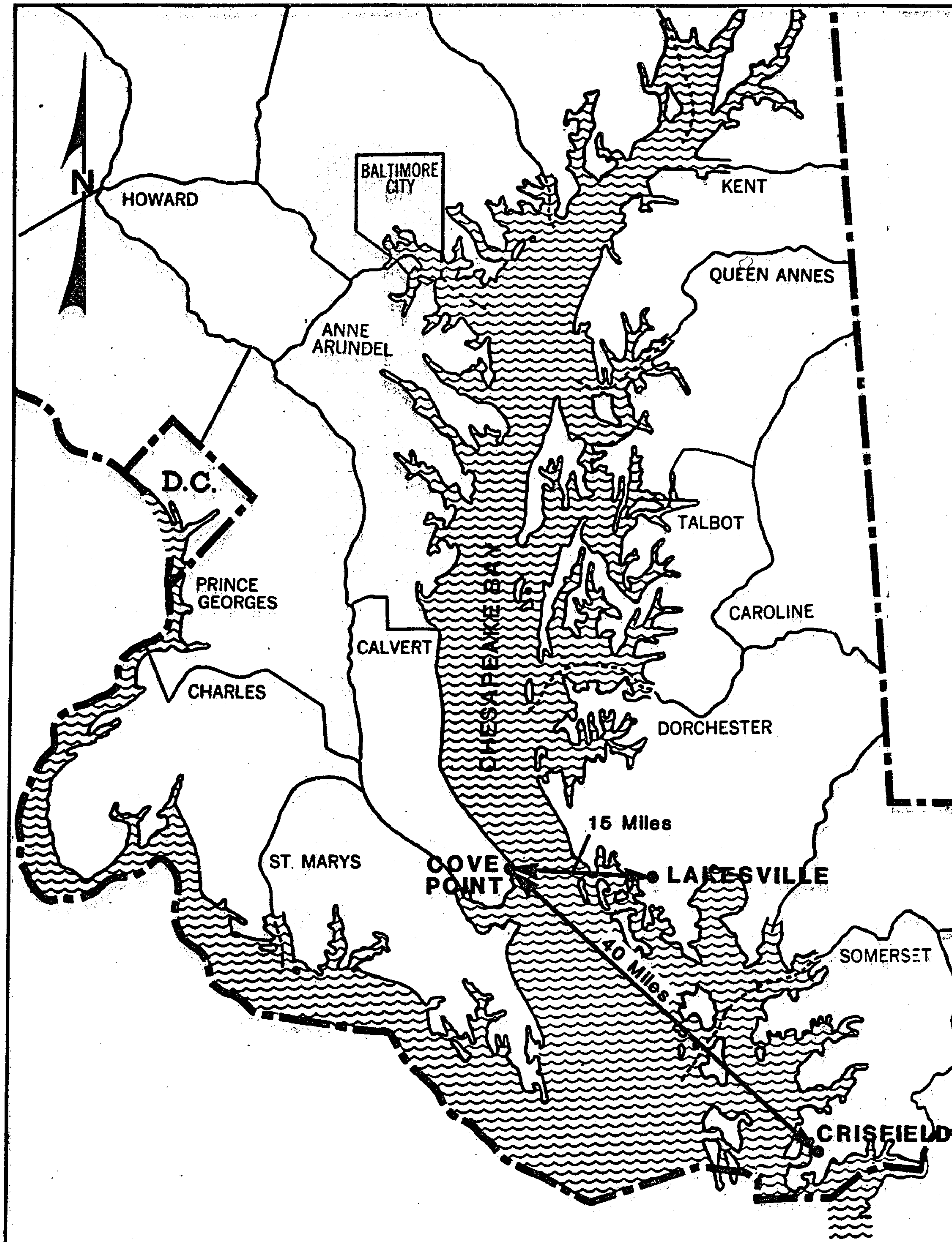
. . . (Slide 11-Logo). . . So where do we stand at this point in time in developing the goethermal energy resource? Last March we approached the DOE for exploratory funds to be used in determining the extent of geothermal energy at the Cove Point site. They have since agreed to fund the initial exploratory effort at Cove Point, which is slated to begin sometime in early November. (In fact they started yesterday). This effort will consist of drilling a slim hole test well on the Cove Point terminal property drilled to a depth of about 3000 feet. Electronic, sonic and resistivity logs will be run along with numerous core samples. The thermal gradient or temperature profile of the well will be measured, but no flow tests will actually be run. This test well will only verify the existence of geothermal energy; i.e., the presence of water and its temperature, but will provide little information into its producibility. However, if this initial test well proves successful then Columbia LNG will propose that additional wells be drilled in which flow tests can be made to confirm the geothermal resource. Confirmation of the resource would ultimately lead to Columbia LNG making application to the Federal Energy Regulatory Commission (FERC) for a full scale production facility.

Thank you, and at this time I'll answer any questions you may have.

COLUMBIA LNG CORPORATION

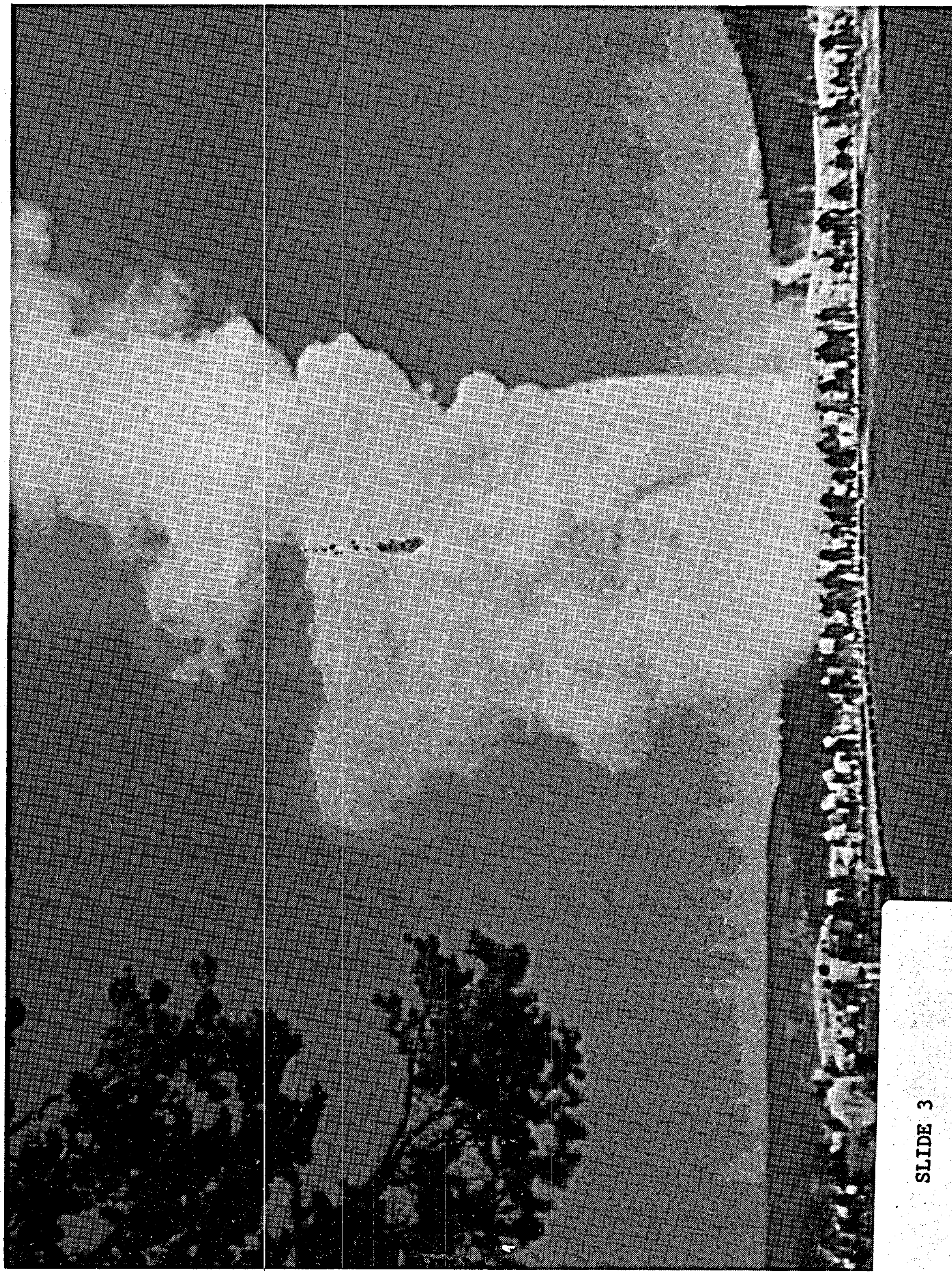
COLUMBIA GAS SYSTEM

SLIDE 1

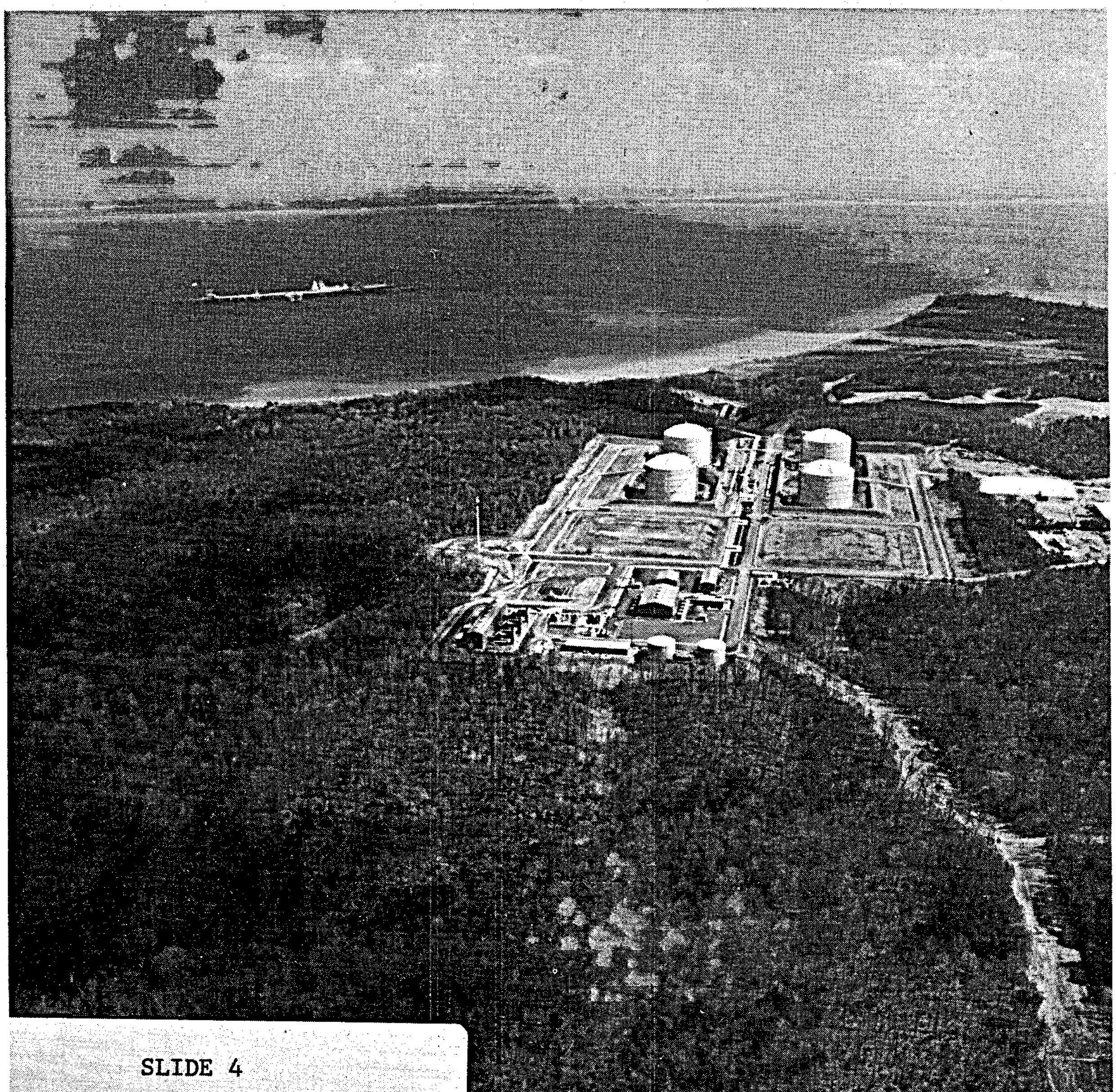


CRISFIELD TEST WELL LOCATION

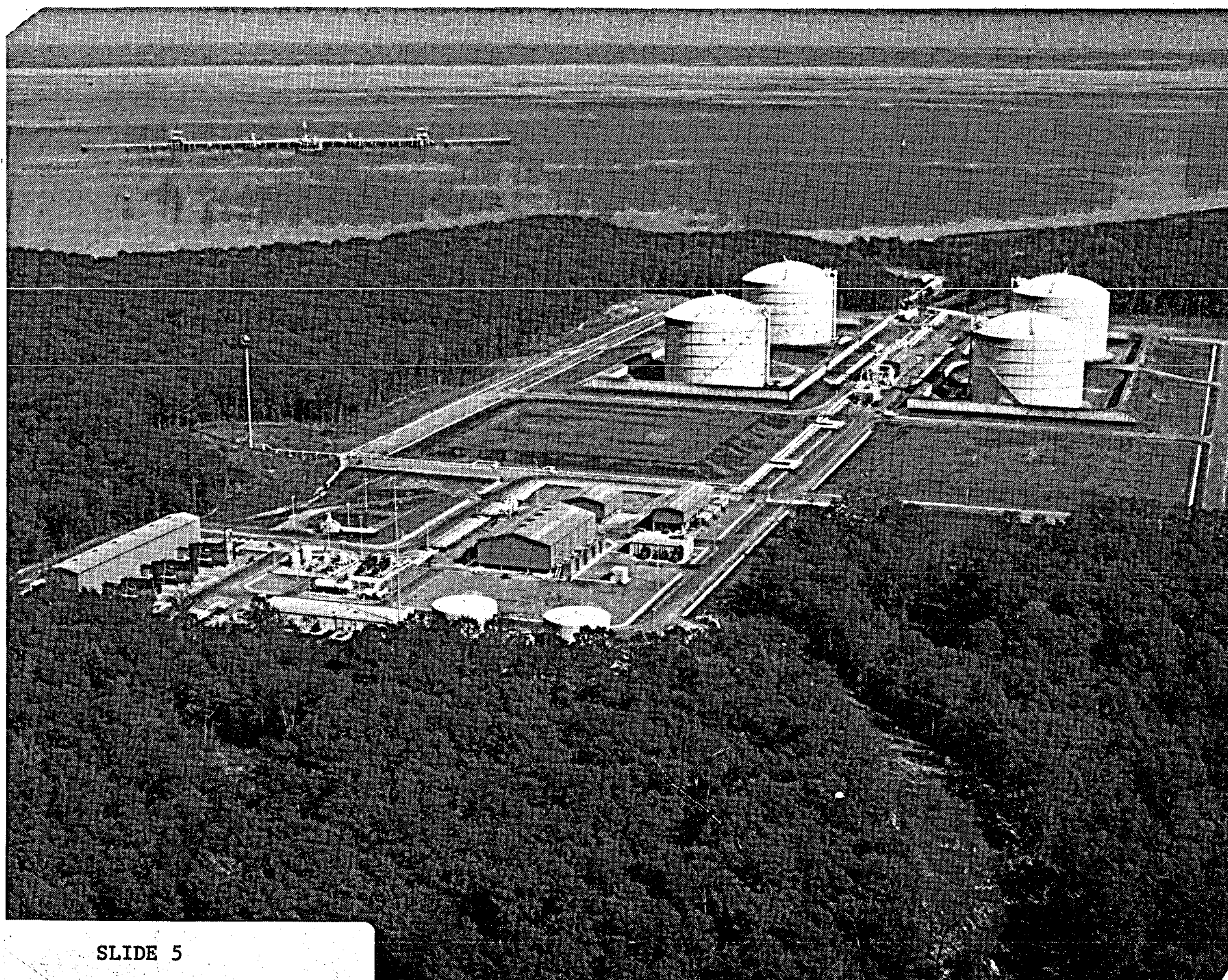
SLIDE 2



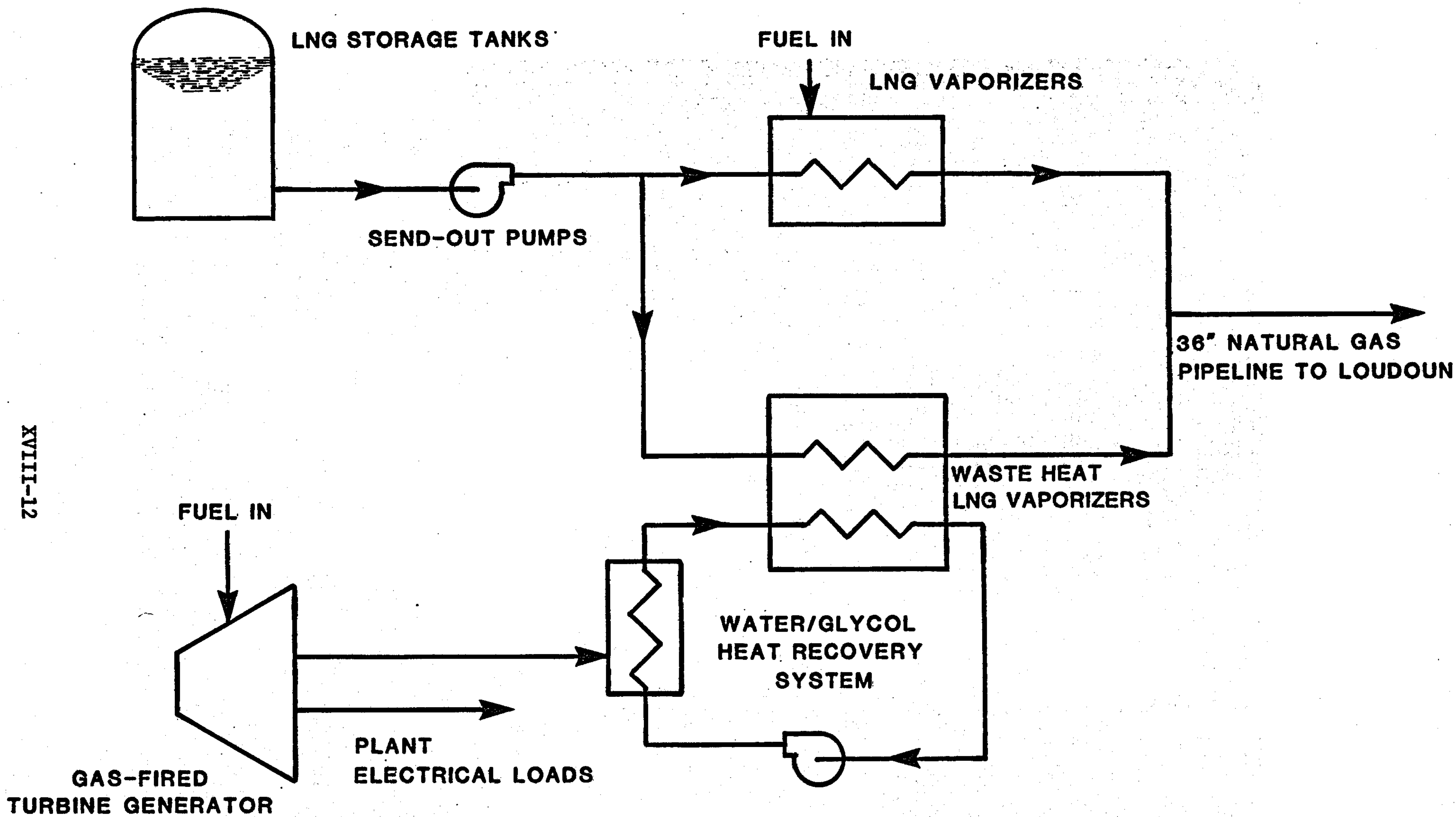
SLIDE 3



SLIDE 4

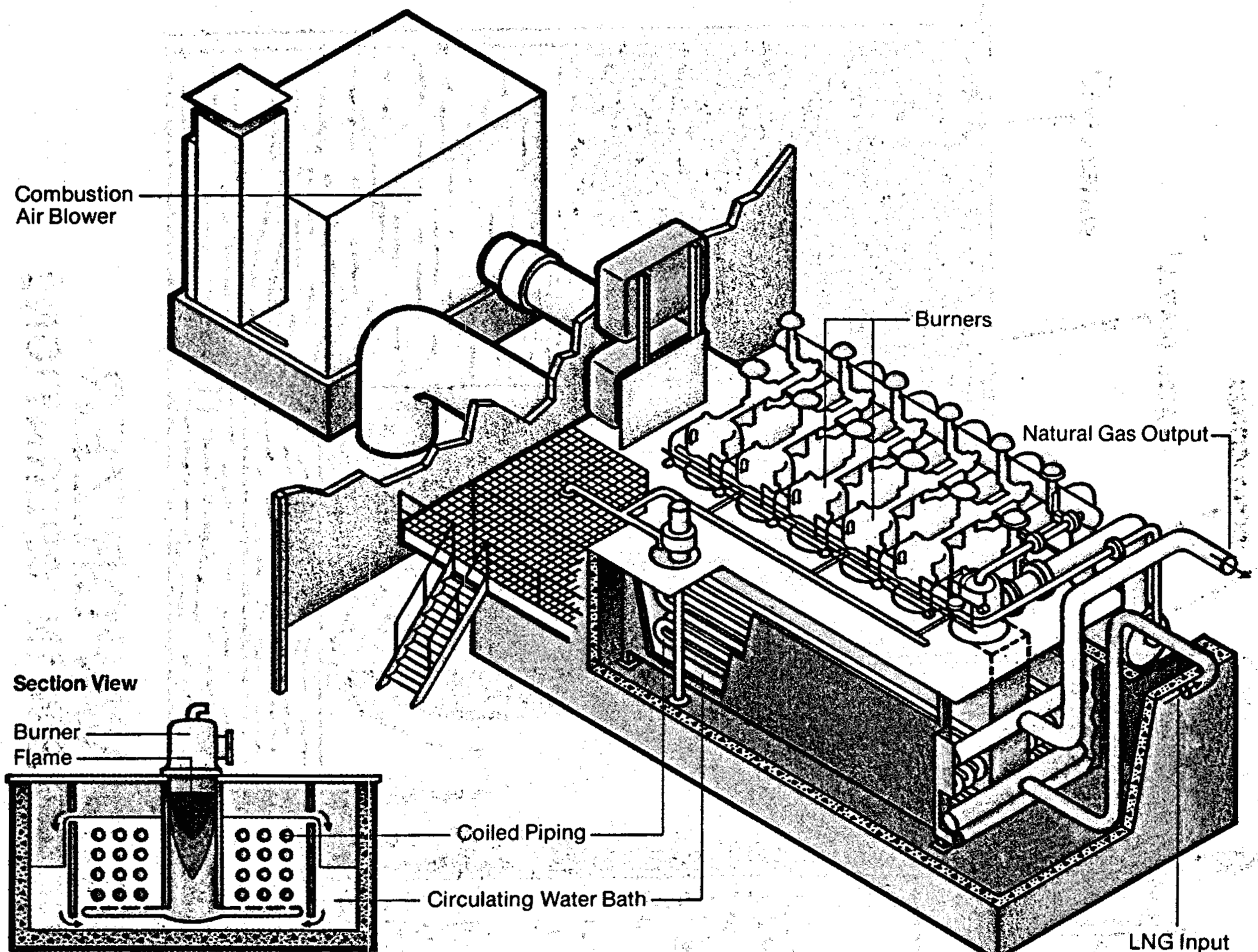


SLIDE 5



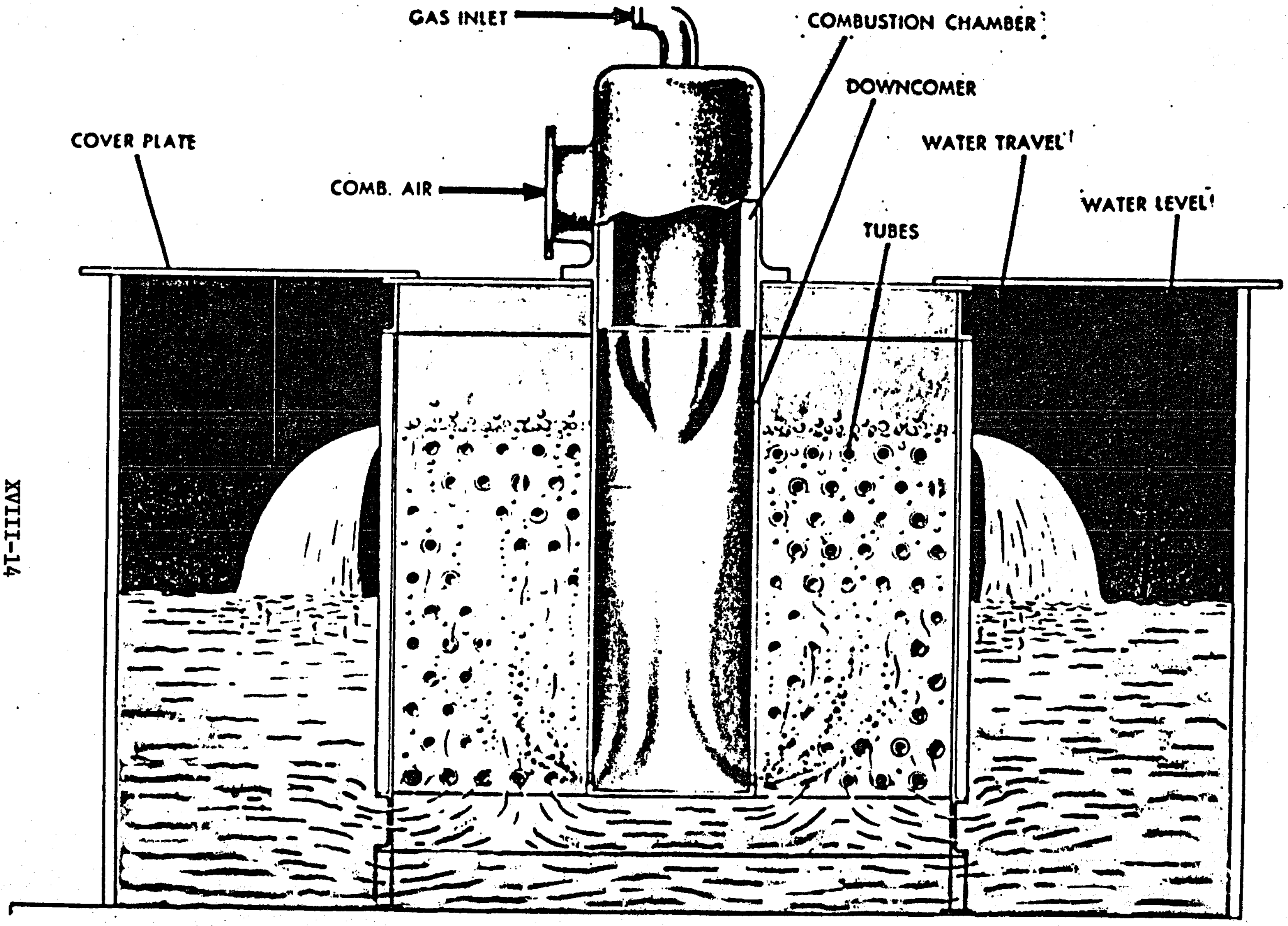
EXISTING VAPORIZATION SYSTEM WITH SUBMERGED COMBUSTION VAPORIZERS
AND WASTE HEAT RECOVERY

SLIDE 6



TYPICAL SUBMERGED EXHAUST VAPORIZER

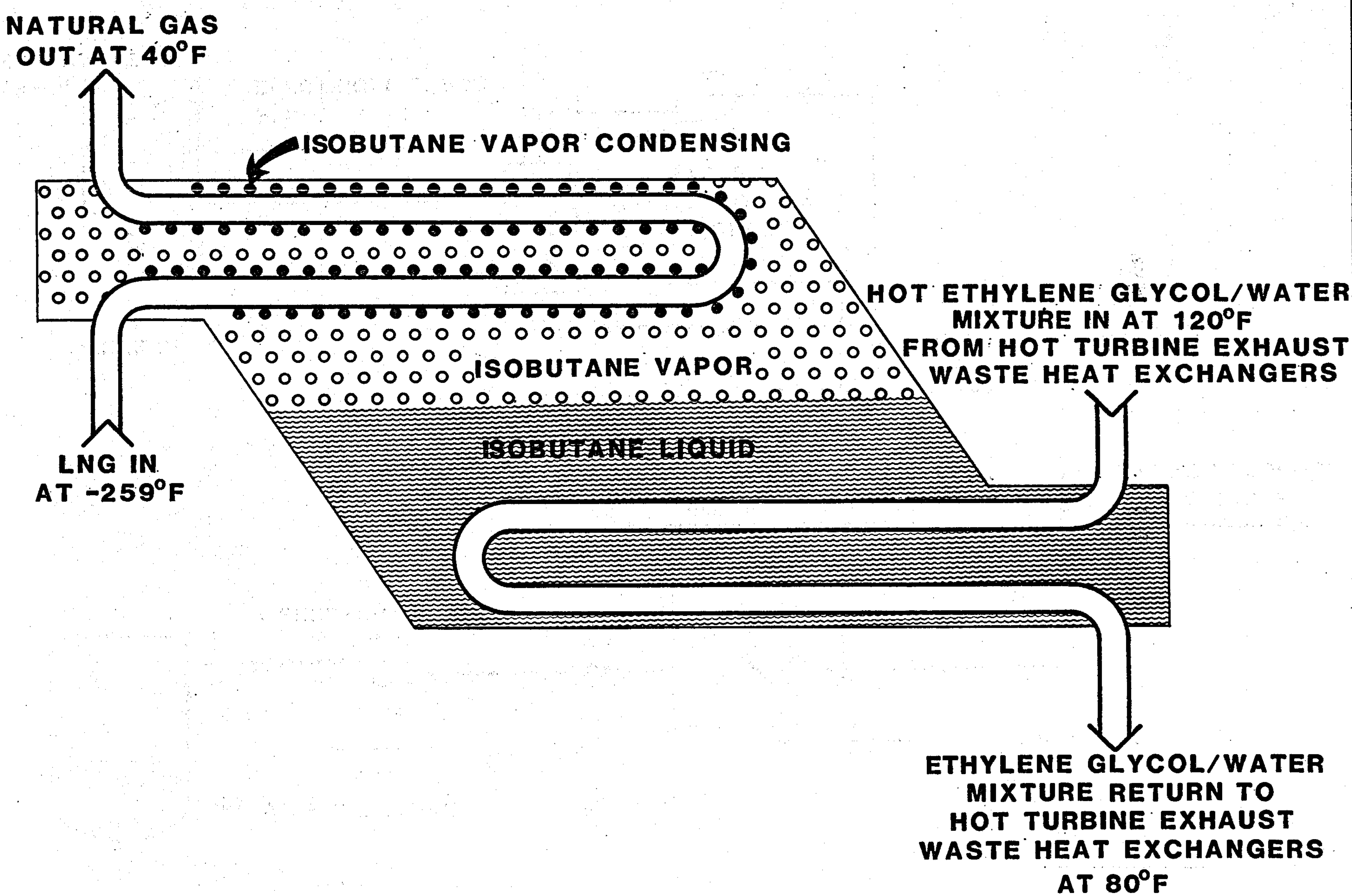
SLIDE 7



SUB-X LNG VAPORIZER
(CROSS SECTION VIEW IN OPERATION)

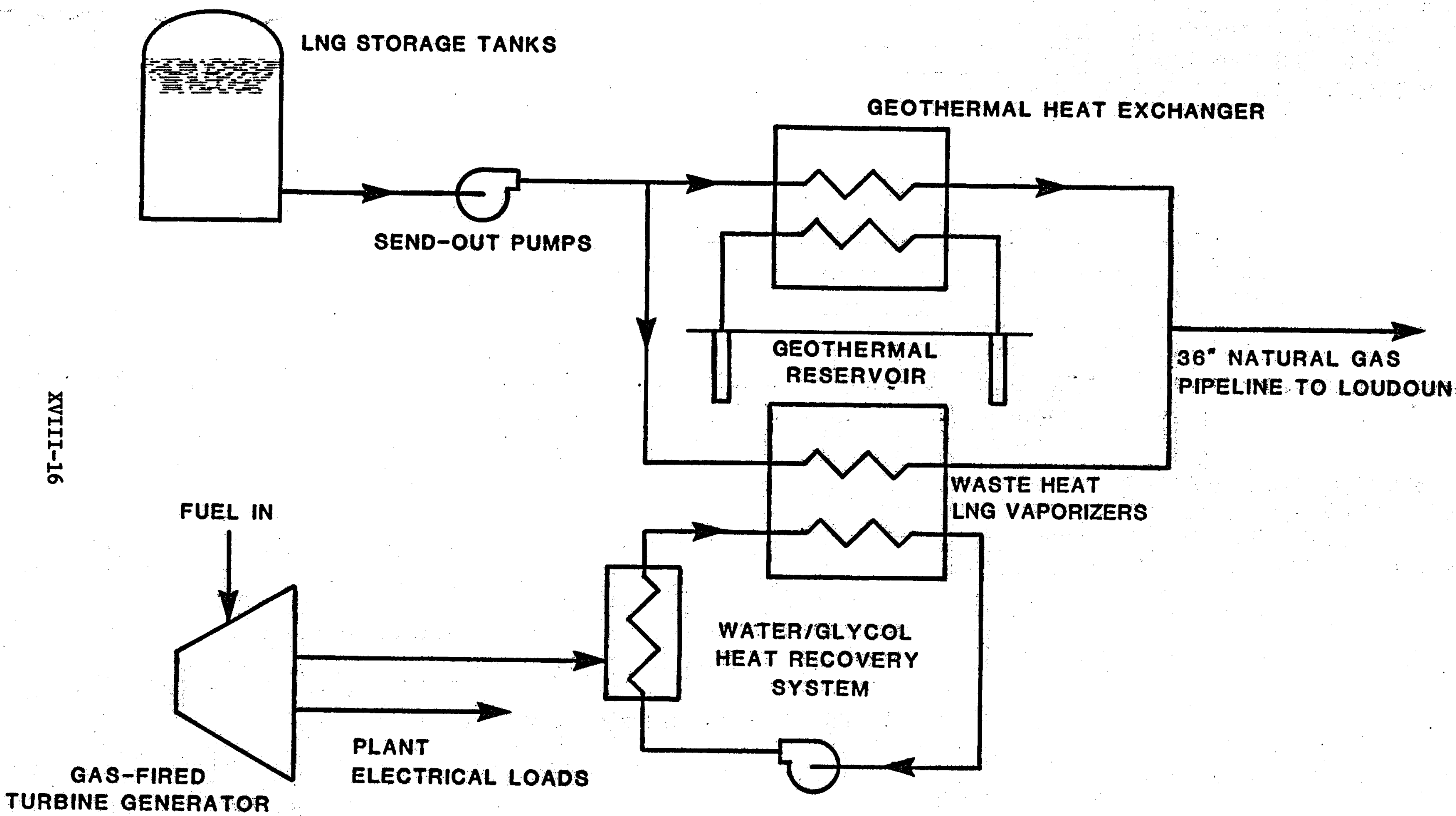
SLIDE 8

WASTE HEAT RECOVERY VAPORIZER



XVIII-15

SLIDE 9



- PROPOSED VAPORIZATION SYSTEM WITH GEOTHERMAL WELLS AND WASTE HEAT RECOVERY

Test Drilling at Cove Point LNG Terminal; Cove Point, Maryland

Richard J. Gleason
Geothermal Program
V.P.I. & S.U.

As part of a D.O.E - funded program to evaluate low- to moderate temperature geothermal resource potential in the Atlantic Coastal Plain, VPI & SU is in the process of drilling a test hole at the Cove Point LNG terminal. It is hoped that geothermal gradient data, aquifer data, and perhaps basement geology, heat production, and heat flow data will be obtained from this test.

Rig mobilization and set-up were completed during the week of October 19-25, 1980. Drilling began during the week of November 2-8, 1980, and is expected to continue through December, 1980. Estimated depth to basement is 3050'. It is hoped that the entire coastal plain sequence can be penetrated during this drilling.

It is presently projected that drilling will be completed in two stages. The initial drilling from the surface to between 400 and 1000' will produce a boring of approximately 11 1/2 " diameter. Surface casing of 8 5/8 " outside diameter will be grouted into the ground over this interval. Drilling will proceed using a 6 1/4" tricone bit inserted inside the surface casing. Second stage casing will be J-55 steel tubing with 2 3/8" outside diameter. These drilling plans are subject to change as need arises with drilling progress.

Scientific investigations will include sediment sampling, electrical and geophysical logging, including temperature logging. These logs will delineate potential aquifers as well as attainable temperatures at depth. If drilling is completed to crystalline basement, basement core will be obtained for petrologic study and heat flow/ heat production measurements.

Data obtained from VPI & SU test drilling at Cove Point, Md. should provide a sound base of information for the evaluation of a potential resource at the LNG terminal. The initial data base will be a framework from which to plan further geothermal testing.

Two Direct Applications of Geothermal Energy in New York

by

B. Krakow
NYSERDA

XIX

Two Direct Applications of Geothermal Energy in New York

Jim Dunn, Maggie Sneeringer, and Denis Hodge have discussed their exploratory work to define the geothermal potential in New York. As this definition comes into focus, we are fitting applications to it. I am going to discuss two projects in which studies are being made for site specific verification of the resource and of applicability of the resource to satisfaction of process heat needs. Both projects have just started. We have no results yet so I will just discuss their motivations and scopes.

Slide #1 is a temperature gradient contour map of western and central New York similar to the one Denis Hodge showed you earlier. One of our applications is at the Friendship Dairies in Allegany county in the southwestern part of the State. It is at a location where the temperature gradient reads about 30°C/km. The other application is at the Clinton Corn Processing Co. plant near Montezuma, Cayuga County, in the North Central part of the State. There the temperature gradient reads about 38°C/km.

The Friendship Dairy project is being done as a result of the recent DOE PRDA for "Resource, Engineering, and Economic Studies for Direct Applications of Geothermal Energy." The plant manufactures cottage cheese and applications for geothermal heat are listed on Slide #2.

During the 6 month period from January to June, 1980, this plant used 468,125 gallons of fuel oil and it is estimated that about 80% of it was used to supply process heat for these low to medium temperature processes. Some was also used for space heating.

As you will see, the applications we are aiming to satisfy in this project require somewhat higher temperatures than those being considered at the Corn Processing Plant. This is feasible despite the apparently lower geothermal temperature gradient at Friendship because the site is further south where the target geologic formations are much deeper.

These target formations are the Cambrian, Potsdam and Galway (or Theresa) formations for which Kreidler reported the presence of high permeability in his analysis of structures suitable for underground disposal of liquid waste. In the Friendship area these formations run from about 7,500 to about 9,000 feet below sea level. With a surface elevation of about 1,500 feet, the target depth is in the vicinity of 3 km. A geothermal temperature gradient of 30°C/km would give a target temperature of over 200°F at this depth.

We are hoping for 190°F. If the permeability is adequate to supply enough water, this would serve nicely to satisfy the highest temperature application being considered; namely, heating the milk to 162°F for pasteurization. Kreidler suggests that the Galway and Potsdam are generally good prospects for permeability but, from this standpoint, Friendship has a particularly interesting location in alignment with the Clarendon-Linden Fault System, as shown in Slide #3.

This is by far the most prominent fault system in the area. Its surface manifestations end in the northern part of Allegany county. However, there is suspicion that deep faulting extends considerably south of that with Friendship in that zone of deep faulting. Of course, this would enhance the prospect for finding high permeability in the Galway and Potsdam formations at Friendship.

We have found well records of 4 wells in that area that have penetrated the Galway. Two were in Allegany County, a little north of Friendship. Two others were in adjacent Cattaraugas County. All four reported encountering water in the Cambrian - but we don't know how much.

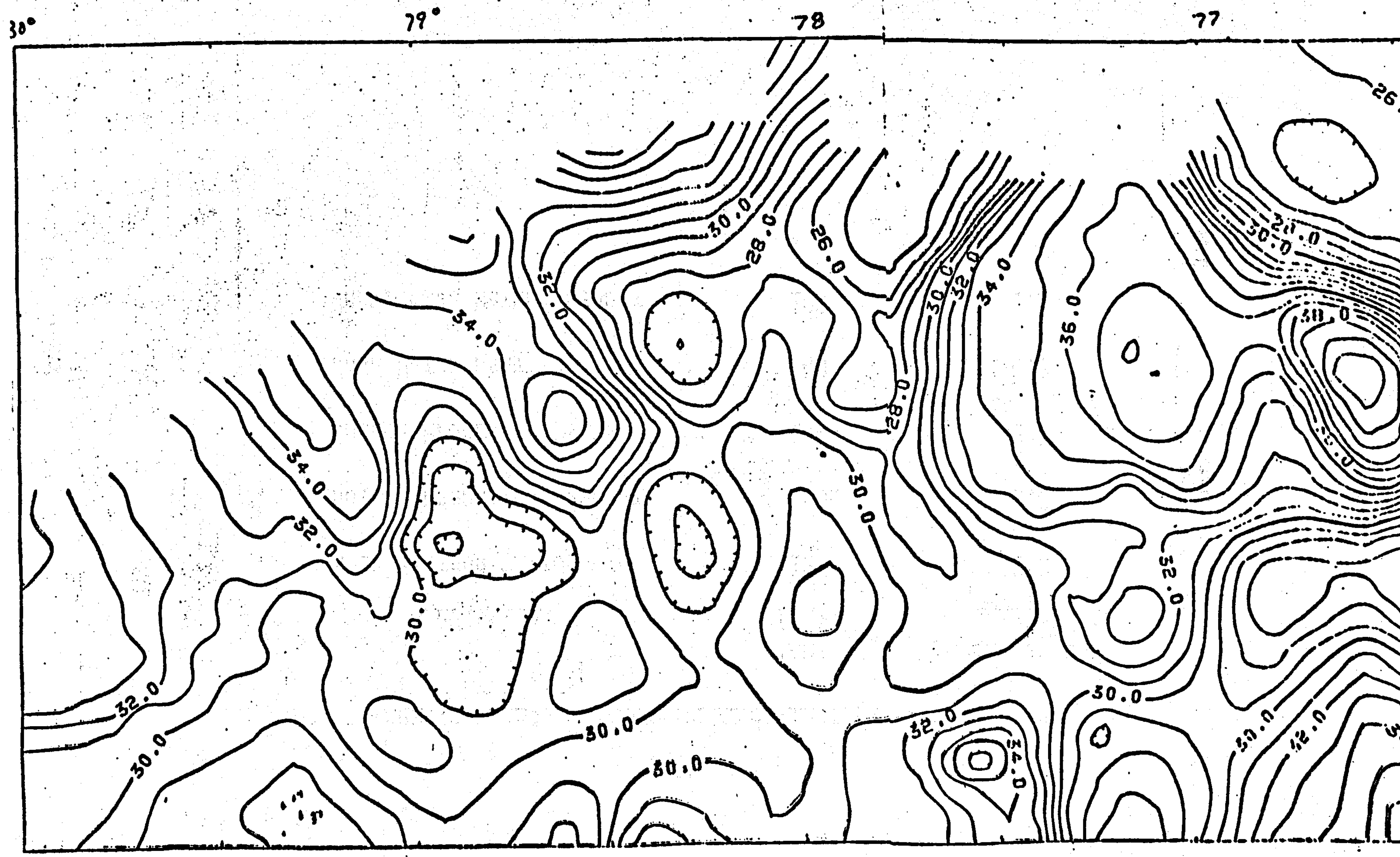
The Friendship project is primarily a study of engineering, economics, environmental impact, institutional factors, and financing problems. Resource assessment will be of a preliminary nature. There will be no drilling.

In contrast, the project at Montezuma in Cayuga County is primarily resource assessment and consists largely of drilling and testing a deep hole. What can be anticipated is indicated in Slide #4 which shows data from the Record of the Alnutt well which was drilled in 1965, in Cayuga county, about 10 miles from Montezuma. Our target formation is the Cambrian Theresa which corresponds to the Galway. Salt water was encountered at 3 levels within the Theresa, two giving a moderate flow and one giving a low flow. However, we don't know what "moderate" means. A target that is 1 1/2 km deep where the geothermal temperatures gradient is $38^{o}C/km$ would have a temperature of over $150^{o}F$. There are many process heat requirements at the Clinton Corn Processing Plant that require temperatures below this. A few illustrations are noted in Slide #5. These illustrations represent a potential oil saving of between 1/2 and 1 million gallons of oil a year and could use up the output of a good geothermal well but are not an exhaustive list. This plant uses 13 million gallons of oil a year and there are other low temperature applications.

The goal of the project is to drill a deep hole for exploration purposes. The hole will be tested to verify the geothermal temperature profile and heat flow, determine the horizons of deep aquifers as well as their flow capacity and response to stimulation and to obtain an unweathered core sample of basement rock to help evaluate the suitability of the basement for heat extraction by the hot dry rock method.

Slide #1

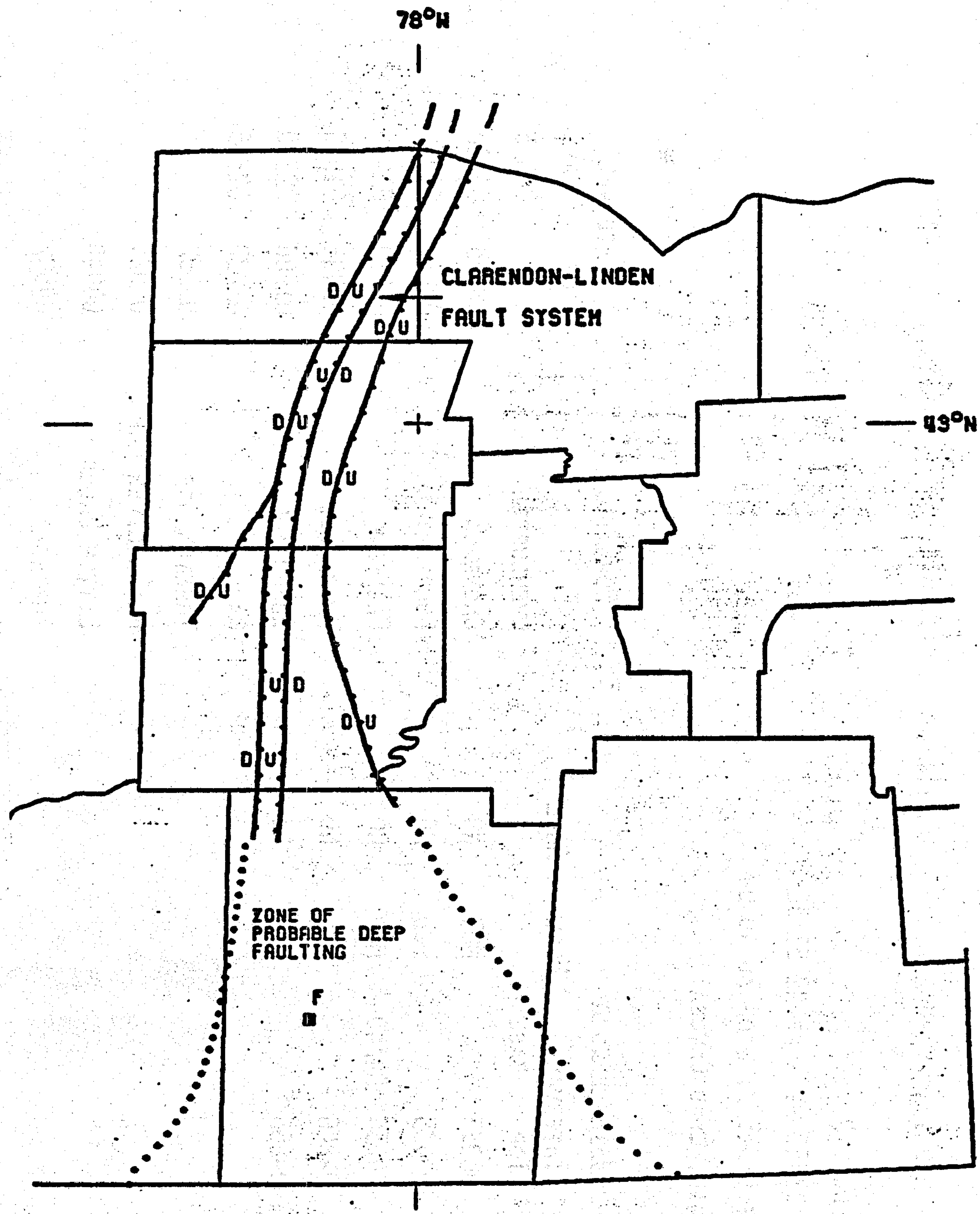
Geothermal Temperature Gradients in Western New York



Slide #2

APPLICATIONS FOR GEOTHERMAL HEAT AT FRIENDSHIP DAIRY

APPLICATION	TEMP (°F)	ENERGY USE (10^6 BTU/HR)
MILK PASTEURIZATION	162	2.0
BOILER FEEDWATER PREHEAT	150	1.8
CHEESE PROCESSING VATS	140	2.7
WASH WATER HEATING	140	0.2
WHEY, WASH WATER PREHEAT	105	1.2



Slide #3

EXTENSION OF THE ZONE OF PROBABLE DEEP FAULTING

Slide #4

WELL DATA

COUNTY - CAYUGA TOWNSHIP - AURELIUS STATE - NEW YORK

FARM - ALNUTT R

LATITUDE 13350 FT S OF 42 57 30

LONGITUDE 01325 FT W OF 76 40 00

7 - 1/2 MIN. QUAD CAYUGA

WATER RECORD

TYPE	INTERVAL TOP	INTERVAL BASE	FLOW	ANAL
FRSH	00035		MOD	NO
FRSH	00435		MOD	NO
SALT	04735	04740	MOD	NO
SALT	04840		LOW	NO
SALT	04853		MOD	NO

FORMATIONS

FORMATIONS	INTERVAL TOP	INTERVAL BASE
OVERBURDEN		00033
ONONDAGA	00033	00300
LOCKPORT GRP	00937	01064
GRIMSBY	01410	01496
WHIRLPOOL	01496	01506
QUEENSTON	01506	02220
OSWEGO	02220	02665
TRENTON GRP	03252	
BLACK RIVER GRP	04023	
LITTLE FALLS	04444	
THERESA	04502	
TOTAL DEPTH		04853

Slide #5

APPLICATIONS FOR GEOTHERMAL HEAT
AT CLINTON CORN PROCESSING CO.

APPLICATION	TEMPERATURE (F^{O})	ENERGY USE (10^6 BTU/HR)
STARCH WASH WATER	120	10
REACTOR PREHEATER	120	2.8
REACTOR TRIM HEATER	120	.23
ION EXCHANGE RINSE WATER	120	5.6 (3 HR/DAY)
ION EXCHANGE DILUTION WATER	110	4.5 (2 HR/DAY)

<u>NOTE</u>: COMPONENTS OPERATE 24 HOURS/DAY UNLESS OTHERWISE NOTED.

Eastern Geothermal Drilling Project
Lewes, Delaware

by

Z. A. Saleem

and

W. S. Mott
Ebasco Services, Inc.

Presented by

N. Tilford
Ebasco Services, Inc.

EASTERN GEOTHERMAL DRILLING PROJECT, LEWES, DELAWARE

Dr. Zubair A. Saleem and Willard S. Mott
Ebasco Services Incorporated

Introduction

Low to moderate temperature (85°F to 300°F or 30°C to 150°C) hydrothermal resources are much more widespread than high-temperature (greater than 300°F or 150°C) hydrothermal resources. Although the developmental potential of the low and moderate temperature resources is high, very little use is being made of these resources. The proposed Delaware Geothermal Drilling Project is part of the U.S. Department of Energy's Division of Geothermal Energy Program to encourage the direct use of low to moderate temperature hydrothermal sources.

The project includes drilling a well about 8,000 feet deep or to the crystalline basement in Lewes, Delaware (Figure 1), and tapping a highly mineralized aquifer whose temperature is expected to be approximately 150°F. A brief statement of the scope of the project is shown in Figure 2. The well site is located next to the Barcroft Corporation which will be the principal user of the hydrothermal resource. The heat from the ground water will be utilized and minerals will be extracted for the manufacture of antacid pharmaceuticals. The process water, reduced in temperature, will be mixed with an available source of brackish water to further lower its temperature and mineral content to seawater levels and will be discharged into Delaware Bay, if this proves to be environmentally acceptable.

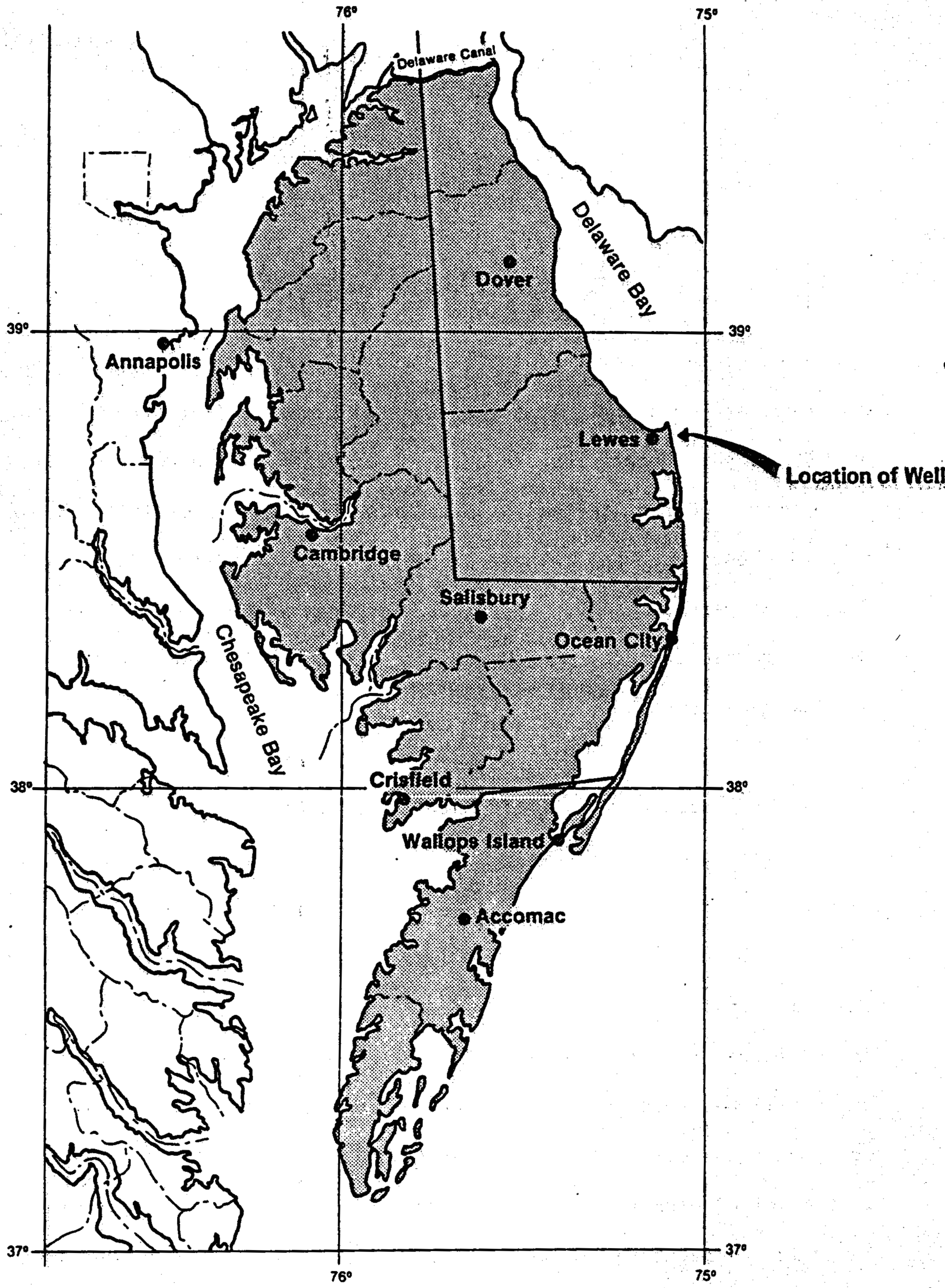


Figure 1. LOCATION OF PROPOSED WELL IN DELMARVA PENINSULA.

STATEMENT OF WORK

- Prepare a Project Management Plan
- Select the exact drill site in conjunction with the other key participants
- Prepare an Environmental Report for site preparation, drilling, and abandonment
- Prepare the site
- Prepare a final reference drilling plan
- Engage one or more drilling contractors depending on the drilling plan
- Drill and complete the well, take the required samples and tests, to a depth to be determined by test results, economics, and funding limits
- Test the completed well for flow, temperature, draw down, and mineralization
- Analyze all test data for its contribution to understanding of the hydrology and stratigraphy of the Atlantic Coastal Plain
- Prepare reports on well drilling, testing, and completion
- Drill and complete the reinjection well if required

Figure 2. STATEMENT OF WORK FOR THE EASTERN GEOTHERMAL PROJECT, LEWES, DELAWARE.

PROJECT ORGANIZATION

Proposing Entity:	State of Delaware
Purveyor of Resource:	Not yet selected from a number of possibilities
Initial User:	Barcroft Corporation, manufacturers of magnesium salts for pharmaceutical use, uses heat and expected high mineral content
Project Director:	Ebasco Services Incorporated, a major engineer/constructor with 75 years experience in the energy field, an Enserch company
Well Director:	Frank Pool – Founder and General Manager – The Pool Company, an Enserch company
Drilling Manager:	Grace, Shursen, Moore and Associates

Figure 3. PROJECT ORGANIZATION FOR EASTERN GEOTHERMAL PROJECT, LEWES, DELAWARE.

The use of this geothermal resource will replace approximately 500,000 gallons of No. 2 fuel oil or its equivalent in propane per year. The fuel saving will be realized in a combination of space heat, domestic hot water, and process heat.

Overall project organization is shown in Figure 3. The project will be managed by the Energy Office of the State of Delaware with day-to-day direction by Ebasco Services Incorporated. An entrepreneurial entity not yet selected will purvey the resource to users. The well has been designed around the requirements of a sole private user, the Barcroft Corp., which will use most of the projected thermal and mineral content of the well waters. The volume of water required is kept to a minimum, resulting in low drilling costs.

Figure 4 indicates the location of the well with respect to Barcroft (location 10). The hot water can be piped directly across the fence to a heat exchanger which will be sized to raise the temperature of 250 gpm of fresh water from 55° to 90°F 24 hours per day every day of the year. The heat exchanger design will be dependent upon the temperature and mineralization of the resource and could be limited by results of the draw-down tests. If we produce 350 gpm at 140°F, Barcroft will be utilizing less than 30% of the heat, and other potential users are being considered.

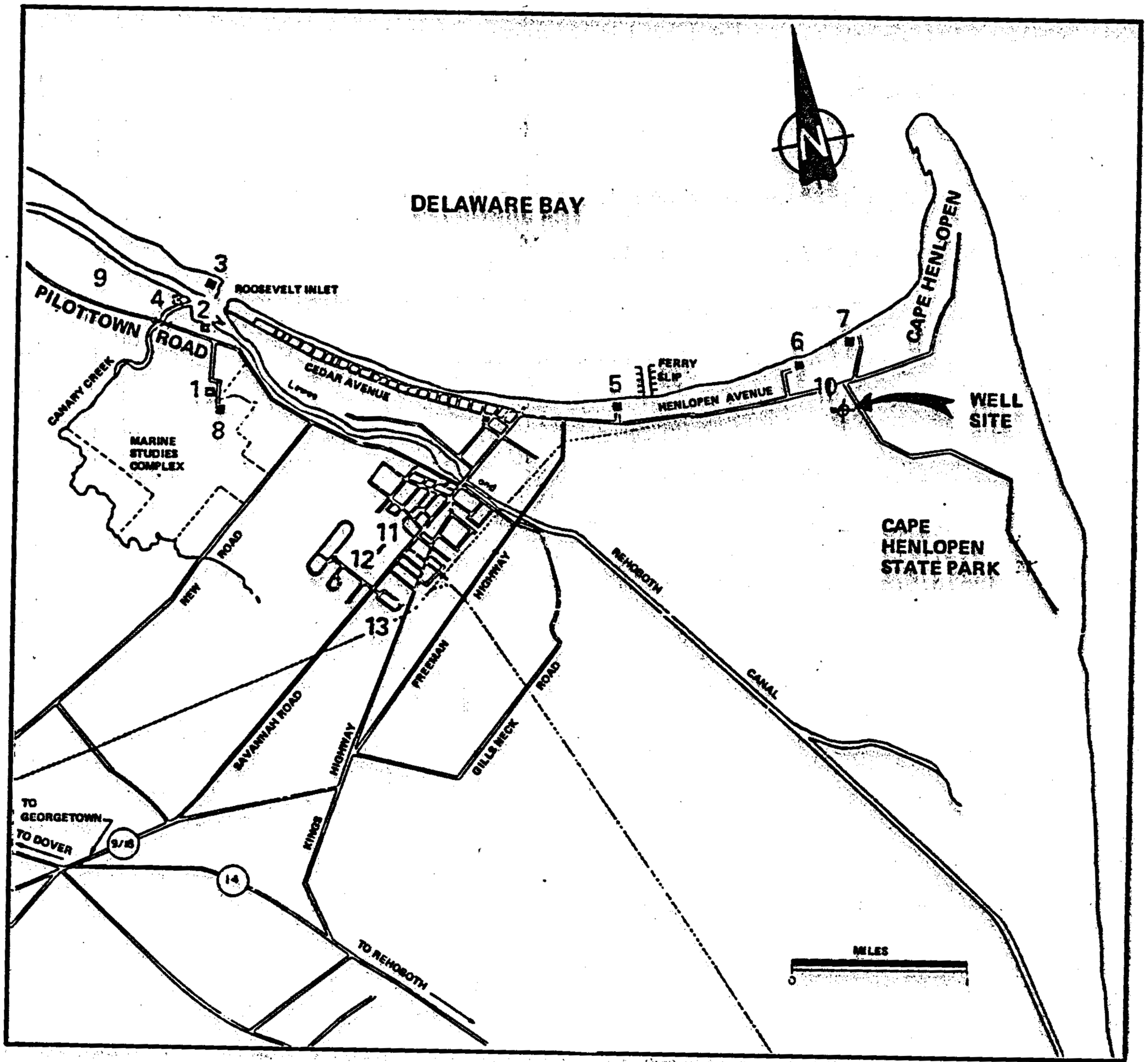


Figure 4. PROPOSED LOCATION OF WELL IN LEWES, DELAWARE.

Geologic Setting

The proposed well site is located on the Atlantic Coastal Plain near the western margin of the Baltimore Canyon Trough (Figure 5), a large sedimentary basin lying offshore from the States of Delaware, Maryland, New York, and Virginia. The general stratigraphic framework of the project area is described by, among others, Maher (1971), Brown et al. (1972), Cushing et al (1973), and Woodruff (1979). The basin has been under exploration for oil and gas since 1959, however, information about the geologic nature of the landward portion of the Trough is not available.

A total of 41 statute miles of marine seismic reflection profiles were run in 1976 for the Delaware Geological Survey (DGS) and provide useful stratigraphic information in the Delaware Bay area. Figure 6 shows the thickness of Coastal Plain sediments or depths to pre-Jurassic basement based on data from holes drilled to basement rocks and on analysis of magnetic and offshore seismic reflection profiles by the DGS (Benson, 1979; and Woodruff, 1979). The exact nature of both the basement rocks and those sediments which rest directly upon basement is not fully known.

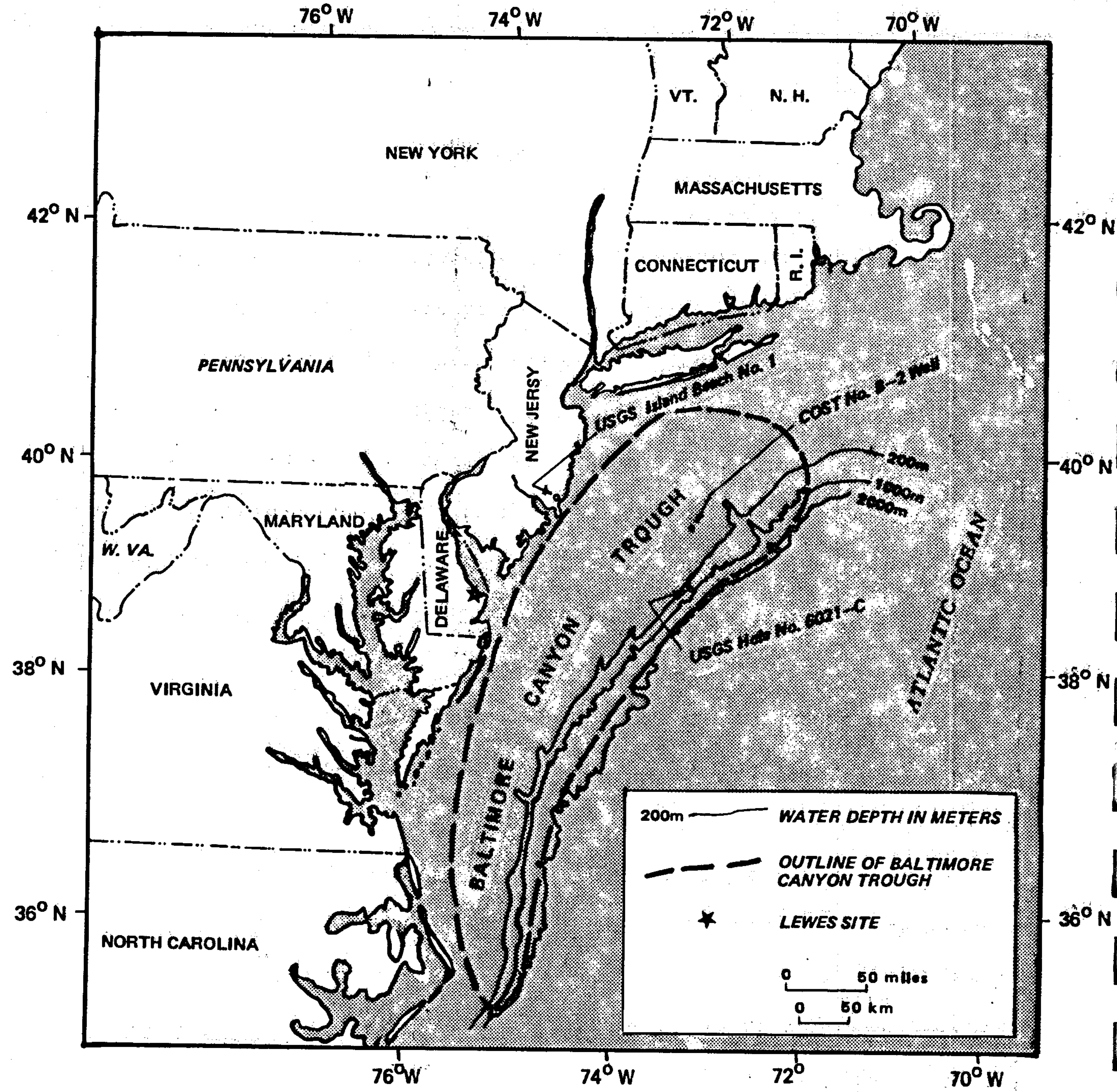


Figure 5. LOCALITY MAP SHOWING THE PROJECT AREA IN RELATION TO THE BALTIMORE CANYON TROUGH AND THE COASTAL STATES.

The Coastal Plain sediments immediately overlying the crystalline basement rocks beneath Delaware generally are considered to be part of the Potomac Formation and are assigned a Cretaceous age. Recent unpublished work by R. V. Smith of the DGS (personal communication, 1980) indicates that Jurassic age sediments datable in offshore wells can be traced by means of seismic reflectors into the mouth of Delaware Bay. Jurassic sediments may, therefore, constitute a significant portion of the bottom half of the Coastal Plain rocks above crystalline basement. In addition, a number of authors have postulated the presence of Triassic rocks buried beneath the Coastal Plain sediments. If this is the case in the Delmarva Peninsula, then the nature of the magnetic or seismic basement is not clear.

A basement hole at Cape May, New Jersey (Anchor Gas Dickinson No. 1), immediately across Delaware Bay, encountered gneiss at about 6,400 feet. Rocks immediately above basement were identified as sands and shales and tentatively assigned a Cretaceous and Late Jurassic(?) age (Brown et al., 1972). The Dickinson well is the closest basement control to the proposed Delaware site.

Woodruff (1977) indicated that an acoustic boundary exists at about 6000 feet at the mouth of Delaware Bay as determined from the seismic lines run for the DGS. However, no clear crystalline basement reflections can be seen on this line within the three seconds of record. Velocities calculated for this layer average about 3.5 km/sec and are not indicative of crystalline rocks. Analysis of interval velocities by R. V. Smith of the DGS (personal communications, 1980) indicates velocities of about 2.9

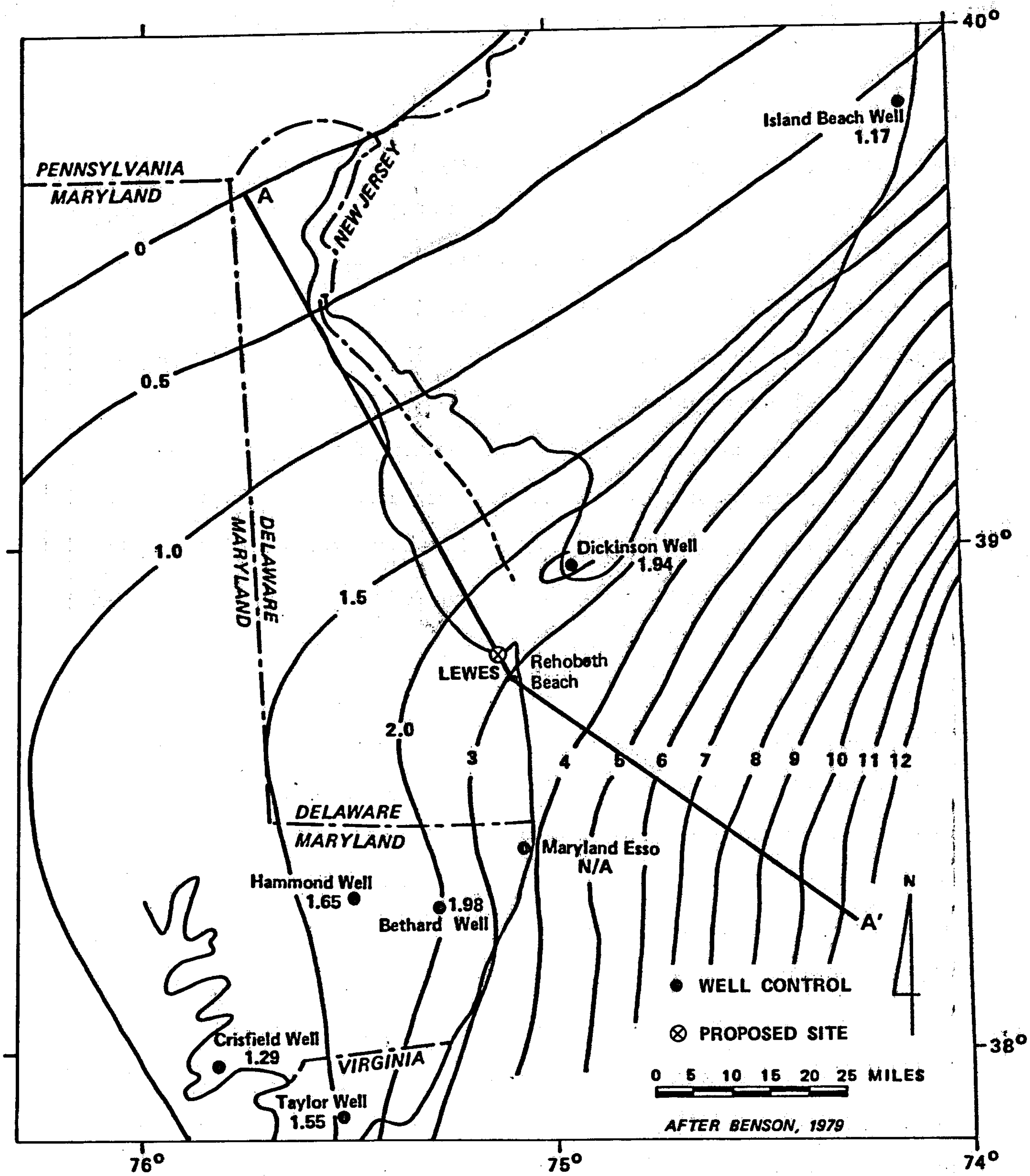


Figure 6. DEPTH TO PRE-JURASSIC "BASEMENT" (BASE OF POTOMAC) IN KILOMETERS

km/sec between depths of 4000 and 5500 feet. Calculations based on aeromagnetic surveys indicate that to the south at Rehoboth Bay magnetic basement may be as deep as 13,000 feet (Woodruff, 1977). Specifically, because of the lack of other basement well control and deep seismic reflection profiles, the depth to crystalline basement at Lewes is estimated by the DGS as about 9,500 to 10,000 feet (Woodruff, 1979; and Benson, 1979). In summary, sedimentary rocks of the Potomac Group (permeable section of interest) may occur as deep as 9,500 feet. A diagrammatic geologic section through the vicinity of Lewes is shown in Figure 7.

Wells drilled to the basement near the coast in the Delmarva area have encountered a thick sequence of Coastal Plain sediments comprising mostly clays, silts, and sands. Layers comprising coarser more permeable sands are commonly encountered just above the basement. It is anticipated that similar conditions will be encountered at the Lewes site. The Crisfield well encountered a hydrothermal source with about 70 percent salinity. The expected salinity of the hydrothermal source at Lewes is expected to be at least 70 percent. A least-squares gradient of 28°C/km was measured in the DOE 1000 feet deep geothermal test hole at Lewes and is higher than the normal geothermal gradient (Woodruff, 1979). The primary heat source is probably granite-like rocks bearing significant quantities of radioactive elements. An alternative heat source related to deep-seated fracture zones has also been suggested (unpublished DGS report, 1977). The expected heat from the hydrothermal resource along with the expected high mineral content makes the Lewes Project a profitable long-term combination.

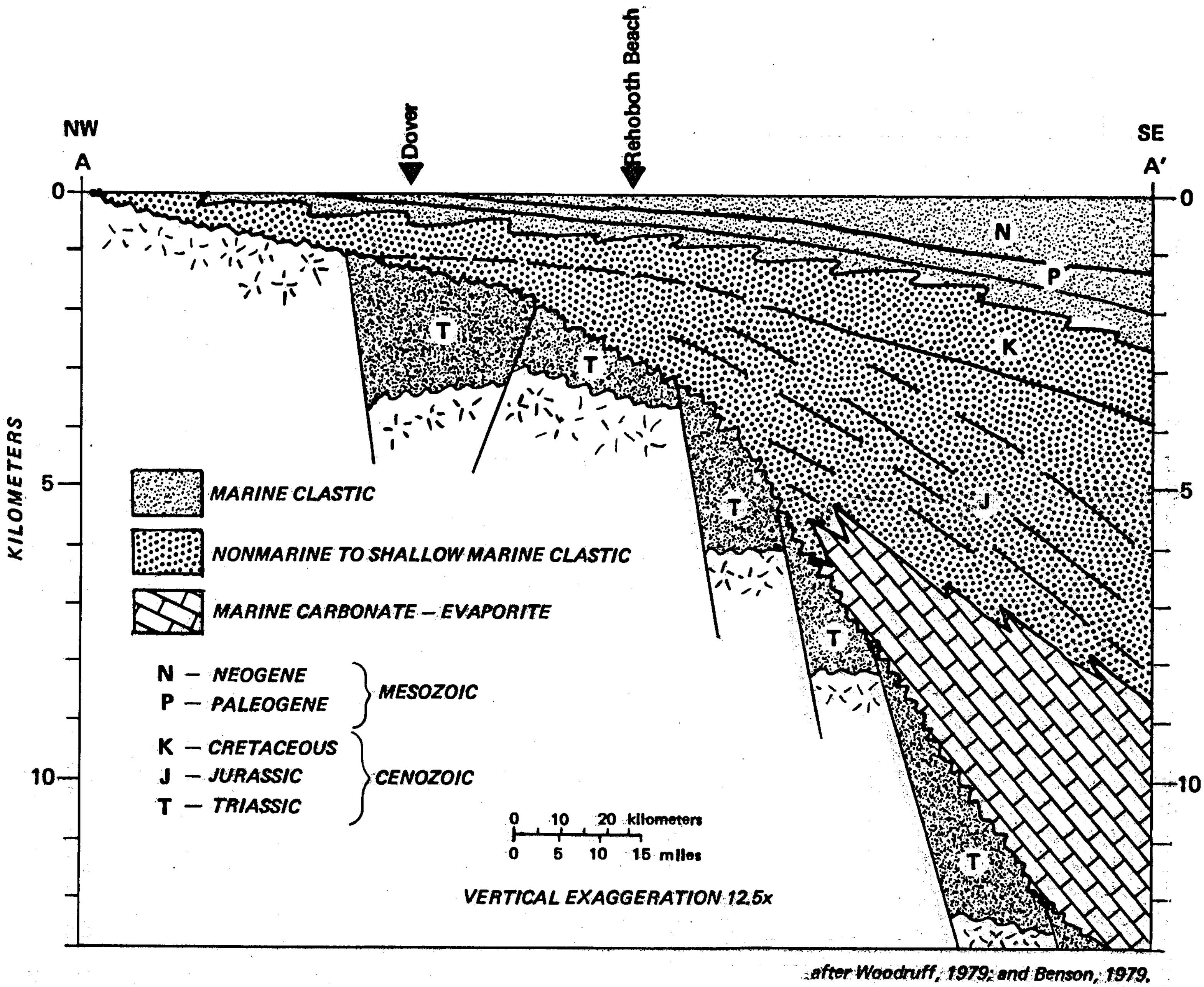


Figure 7. DIAGRAMMATIC CROSS SECTION THROUGH THE HINGE ZONE OF THE BALTIMORE CANYON TROUGH, DELAWARE.

Anticipated Geologic and Hydrologic Information

A well to the crystalline basement or up to about 8000 feet deep will be drilled at the Lewes site in Delaware. In case the crystalline basement is deeper than 8000 feet, the decision to extend the well to the basement will be based on the availability of funds. Several oil companies have expressed interest in the project and in possibly providing financial support for extending the well to the basement for the purpose of obtaining geologic information (Woodruff, personal communication, 1980). The well will provide information related to area stratigraphy, deep saline aquifers, regional tectonics, and hydrocarbon deposits.

Stratigraphic Information

The deep hole at Lewes will be a key (control) well in assessing the stratigraphy of the Coastal Plain in the Delmarva Peninsula. There is no well control in southern Delaware below about 1,000 feet and the stratigraphic section can only be postulated by projecting the control from known updip sections in Delaware or from deep holes drilled in Maryland or New Jersey.

Both the age and lithology of sediments below about 5,000 feet are poorly known. Present analysis of offshore drilling and geophysical data by the DGS staff indicates that sediments older than Cretaceous may be present in the subsurface as far inshore as the mouth of Delaware Bay. If this is correct, then some revisions in local stratigraphic correlations and nomenclature may be necessary. More importantly, firmer correlations with offshore data might be possible which would aid in better understanding the regional stratigraphic framework. The proposed hole would also provide badly needed control for marine seismic reflection profiles run in 1976 for the DGS. The line of one profile passed into the mouth of Delaware Bay about one mile east of the Lewes area and the crystalline basement could not be clearly identified on the seismic record.

Hydrologic Information

Little is known about the groundwater hydrology in the Delmarva Coastal Plain below about 1,000 feet. The fresh-salt water interface appears to occur at about 500 feet below land surface, disregarding local intrusion of salt water into shallower aquifers. However, sediment permeability and total dissolved solids of interstitial waters at depths are largely unknown. The U. S. Geological Survey Water Resources Division has indicated a need for deep subsurface data as part of the regional aquifer program for the Atlantic Coastal Plain. Data from the Lewes well can satisfy an immediate data need for this particular program. Conventional geophysical logs run in the hole would assist in defining not only the location of potential aquifers but the general quality of the water in these aquifers as well.

Information about Regional Tectonics and Hydrocarbon Deposits

Acquisition of data at the proposed depths would do much to test the validity of current ideas concerning the regional tectonics. Basement depths indicated by geophysical data infer a steeply dipping crystalline basement, possibly due to block faulting. Such faulting would be consistent with theories proposed by Brown et al. (1972) to explain observed sedimentation patterns in the Atlantic Coastal Plain. The testing of these ideas might provide guidance on sediment thickness and on possible fracture zones as these parameters would influence the siting of future geothermal holes.

Current interest in hydrocarbon exploration has been centered on the continental shelf where the sediment thickness has generally been great and known structures are present. Nearshore exploration has been mainly ignored due to apparent lack of sufficient sediment thickness. However, this assumption too would at least be partially tested by a hole at Lewes. It is also possible that pinch-outs of individual beds landward could provide hydrocarbon traps given initial generation of hydrocarbons.

Drilling Plan

The Lewes geothermal well will be drilled to a depth of about 8000 feet. The site will be carefully prepared before moving in the drilling rig. The site preparation will include covering the access path, connecting the paved road to the drilling site with crushed stone for the drilling-related traffic, covering the area around the hole with a polyproplene typar liner which in turn will be topped with crushed stone, and the excavation and lining of pits.

A 12¼ inch hole will be drilled to about 150 feet and opened to about 20 inches. A 16-inch OD casing string will be run, set in hard clay at about 140 feet, and cemented to the surface (Figure 8). The clay layer was indicated by the 1000 feet DOE geothermal test hole at Lewes. A local

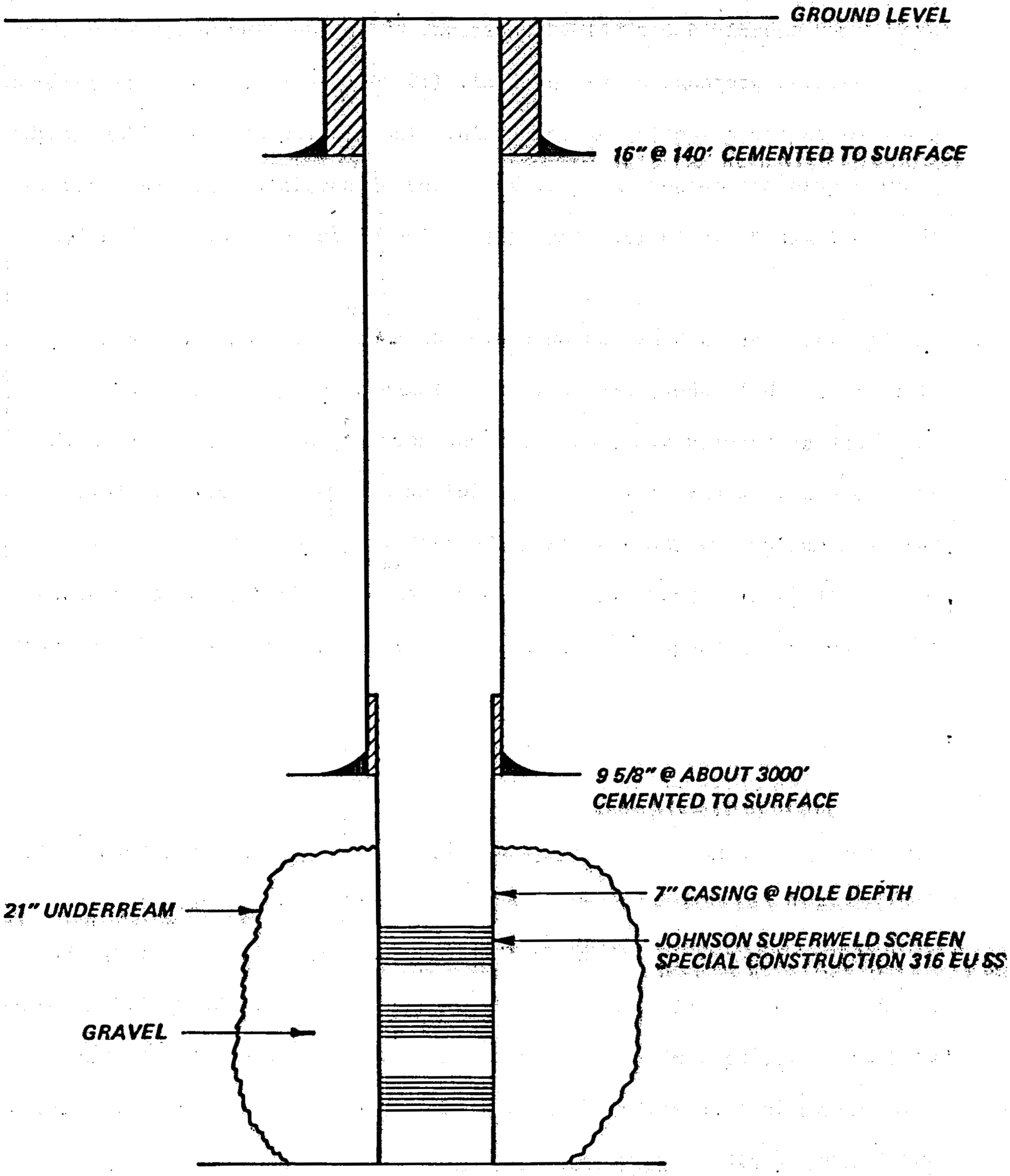


Figure 8. SCHEMATIC OF THE LEWES GEOTHERMAL WELL

water well contractor will be utilized to prepare the site and to drill the shallow hole if it is more economical than having all work performed by the deep drilling contractor.

Following the completion of the shallow hole, a 12¼ inch hole will be drilled to about 3000 feet and a 9-5/8 inch casing will be cemented to the surface. An 8-3/4 inch hole will then be drilled to about 8000 feet and a 7 inch casing will be set and cemented to about 2700 feet. In the lowest 5000 feet of the hole, a total of about 200 feet of 7 inch Superweld Johnson screen sections will be installed against permeable horizons. If necessary, the bottom portion of the hole will be opened to 21 inches using an underreamer and will be gravel packed as shown in Figure 5 before installing the screens. The well will be extended to the crystalline basement depending upon the availability of other financial support and on the information derived from the 8000 feet section of the hole.

An application form for a permit to drill the well, according to Delaware's law and regulations, will be submitted to the Water Resources Section of the Delaware Department of Natural Resources and Environmental Control. In case the well is unsuccessful, the State of Delaware's well abandonment procedures will be followed. In any case, all necessary steps will be taken to protect the shallow fresh water aquifers from potential contamination by the brines which would be encountered in the geothermal well.

Test Plan

Well cuttings will be collected at 20 ft intervals and examined concurrently with the drilling operation. Samples will be logged and apparent changes in lithology will be recorded by a qualified geologist. Multiple samples will be collected for distribution to DOE and the Delaware Geological Survey. Based on predetermined criteria (well cutting analysis, drilling rate, mud loss, major water producing horizons, etc.),30 foot cores will be extracted to characterize major lithologic units with increased emphasis placed upon units at levels of water extraction and those underlying and overlying these horizons. A complete record of cores will be maintained.

A preliminary lithologic log of the well will be prepared concurrently with the drilling operation based on the examination of well cuttings and cores. During the drilling operation, periodic temperature measurements will be made to compare the observed and the predicted geothermal gradient and to determine if water producing layers of interest might have been reached at depths above those predicted based on the thermal gradient observed in the 1000 ft Lewes test hole.

After the completion of each major drilling phase, except for the first 100 feet, a comprehensive suite of downhole geophysical logs will be obtained. These logs will include electrical survey, 3-D velocity, borehole compensated density, borehole compensated neutron, nuclear cement-top locator, spectral gamma ray, natural gamma ray, and temperature. A cement bond log will be run after the well is constructed.

Temperature logs will be obtained for each drilling phase primarily to determine if it is worthwhile to proceed further with the drilling. However, a temperature log of the well will also be run after completion of the well under stable conditions. The Virginia Polytechnic Institute and State University (VPI & SU) will run temperature logs to about 8000 feet depth. After all the necessary down-hole logs have been obtained, side-wall cores of selected layers will be obtained before installation of casing. Deviational surveys of the well will also be conducted at various depths and any deviational problems will be appropriately controlled.

During drilling, special drill stem tests (DST) will be conducted of selected horizons of interests. These tests will provide information regarding the formation fluid quality and quantity. After the drilling is completed and before the rig is demobilized, all major production zones will be pump tested. Each zone will be isolated by setting packers. The bottom-most zone will be pump tested first and then isolated with a packer and the next higher zone will then be pump tested and so on. Before the start of the test, static water levels (pressures) in each zone will be carefully monitored and then the zone will be tested by pumping it at a constant rate. Water levels will be recorded during the pumping and the recovery stages.

Each pumping test will be at least of 24-hours duration depending upon the response of the production zone. One test of the major producing zone will be designed to be of at least 48-hours duration. A composite test of the major zones of interest will also be conducted, if necessary. These tests will be analyzed to determine the hydraulic characteristics of the production zones, evaluate the degree of well success, and determine the long-term yield of the well.

Well cuttings and cores will be examined and a micropaleontological analysis will be conducted by the DGS. The DGS will also carry out a detailed geological correlation of the strata penetrated by the well. VPI&SU will determine thermal conductivities of the materials based on the core samples. Water samples from each production zone will be analyzed for the major and minor chemical constituents.

Interpretation of the geophysical logs will be carried out by a team consisting of a geophysicist and the well geologist with input and review from the logging specialist. Emphasis will be placed on reconstructing a lithologic section of the entire well. Analyses of the logs will also provide data on the characteristics of the production zones which will be used in conjunction with the analyses of pumping tests to determine the success of the well.

Information from other wells drilled to the bedrock will be carefully reviewed and considered in the interpretation of data from the Lewes well. Special consideration will be given to the methods used and results obtained from the DOE Crisfield well. The drilling and testing procedures employed for the Crisfield well will be modified to meet the site specific conditions that will be encountered at Lewes, if necessary, to accomplish the objectives of the project in an optimum manner.

Acknowledgements

The generous cooperation of the Delaware Geological Survey in providing useful published and unpublished geological information is greatly appreciated. The geological sections of this paper are mostly based on the works of K. Woodruff and R. Benson of the DGS. The project is funded by the U.S. Department of Energy through the Delaware Energy Office. The work statement is after the DOE Solicitation for Cooperative Agreement Number DE-RP07-80ID12132, Eastern Geothermal Drilling Project.

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Department of Defense
East Coast Geothermal Program

by

T. A. Ladd
Department of Defense
Geothermal Program Coordinator

Department of Defense
East Coast
Geothermal Program
by
Thomas A. Ladd
DOD Geothermal Program Coordinator

I. Approach. It is strictly up to the prerogatives of the three services as to their level of funding and involvement in geothermal resource development. Army for example has elected to do little or nothing while both the Department of the Navy and the Air Force have their own geothermal programs. These programs are not centrally funded or controlled by the Office of the Secretary of Defense (OSD). The major problem with the current DOD geothermal program is the low level of funding given it. However, this is an entirely defensible position in that the true mission of DOD is not to develop new energy sources but rather to prepare for the defense of our Nation. Also, to the greatest extent possible DOD must and does use the DOE geothermal program to eliminate duplication of staff and efforts. This is often accomplished by DOE actually performing work on military bases such as exploratory well drilling. The work effort may be either entirely funded by DOE or split funded by the two Departments.

II. Economics. The time honored approach to economics from the OSD viewpoint has been the least first cost approach. This was to enhance the acquisition of the greatest amount of facilities within the limited funding available. Today the approach is shifting over to the traditional life cycle costing methodology. This combined with, for energy projects, the requirement that the project save a certain level of energy per thousand dollars invested (FY-82 - 19MBTU/$1000) forms the basis for project selection.

III. Development. There are three possible methodologies for the development of a DOD geothermal resource. These are: (1) the Energy Conservation Investment Program (ECIP); (2) the Military Construction Program (MCON); and (3) through third part investment.

As regards ECIP, the program is funded at approximately $150 million per year and a project must be both life cycle cost effective and save a sufficient amount of energy to investment. The risk involved in the geothermal development, such as unproven resource, as well as capital intensity makes the funding of a project under ECIP unlikely.

MCON is a much larger program than ECIP running on the order of $2.5 to $3.0 billion annually. For a project to be funded under this program it must simply be life cycle cost effective. However, due to the risks of geothermal development and the need to provide more mission essential facilities only one project (Naval Station, Keflavik, Iceland) has been funded using MCON appropriations to date and no others are immediately anticipated in the future.

Perhaps the most viable opportunity to DOD is that of a third party operation. Under this concept the resource would be made available to the developer as well as his plant site, without charge. Under a long term contract of up to 30 years the resource would be developed and the energy sold to DOD to amortize the investment required. To date this approach has been used at one site (Naval Weapons Center, China Lake, CA) and is being considered for two others (Williams Air Force Base, Arizona and Naval Air Station, Fallon, NV).

IV. Sites. At present the majority of DOD geothermal efforts involve sites in the western states. This is where the greatest and easiest attainable resource benefits are perceived to be. However, on the East Coast DOD is currently looking at seven sites (Table 1). Geothermal gradient wells have been drilled on or near all of these sites by DOE and preliminary studies as to the economic feasibility of using the resources are in various stages of preparation and review by either DOE or DOD. Project development does look promising and to whatever level feasible these will be funded.

Sites (Table 1)

I. Air Force

a. Dover, Delaware

b. Charleston, S.C.

c. Myrtle Beach, N.C.

II. Navy

a. Norfolk, VA

b. Parris Island, S.C.

c. Kings Bay, GA

III. Army

a. None

IV. Army/Air Force Exchange Service

a. Fort Dix/McGuire, N.J.

Geothermal Energy —
Naval Air Rework Facility (NARF)

by

F. K. Hill
The Johns Hopkins University
Applied Physics Laboratory

XXII

GEOTHERMAL ENERGY NAVAL AIR REWORK FACILITY (NARF)

F. K. Hill

Our objective in this technical assistance work was to see how geothermal energy could be used to reduce the use of fuel oil at NARF. The electronic integration aircraft hangar (LP-167) was chosen for specific application. It is a one story building (640' x 225' x 30') and uses oil-fired burners for hot water heating rates of 14 M BTU/hr. The problem was, therefore, to see if a use of geothermal energy could be suggested which would be economic and would significantly reduce the amount of oil consumed. Our estimate of the geothermal potential was that a well, 2500 ft. deep at the site would yield about 225 GPM of 107°F water (with a reinject temp. of 85°F this produced 2.5 M BTU/hr). So the heat supplied would A) have to be used in a floor, ceiling or wall radiation system directly or B) would have to be raised in temperature (∿ 180°F) to be useful in the existing heat convection system. In addition C) a reservoir to store heat during non-working hours provided the reserve for cold weather operation.

Several combinations of equipments were selected and the operating conditions optimized. When this was done the operating costs were found and the time required to amortize the capital costs computed. The simplest and most cost effective option, (A), is shown schematically in Fig. 1 (A-1). Since the well output rate was only ∿ 1/5th of maximum demand heating rate it was necessary to include a reservoir to store heat from the well during non-working hours. The result was that 85% of the heat load of the building could be supplied by geothermal: as much as 15% of peak load would have to continue to be supplied by the existing oil fired system.

The economics are indicated in Fig. 2 (A-2). In computing these curves, an inflation rate of 9%/annum and escalation rates of 3-1/2% for oil, 1-1/2% for electricity were assumed. The capital appreciation rate of 10% was used. Fig. 2 (A-2) shows about 11-1/2 years required to amortize the capital costs.

Table I is a cost summary of four options. Option B interposes a heat pump between the well water and the convective heat system in the building. 73% of the yearly heat load can be supplied by the geothermal system in this case with 27% remaining to be supplied by the existing oil fired system. Options C and D make use of heat pumps and a reservoir for storing heat. Option C also takes heat from the 85°F reinject water to feed into the reservoir storage. These options are more expensive -- involving higher capital cost -- but provide enough energy in the storage tank to heat a second building with little additional capital cost.

Probably "the bottom line" is shown in Table II. Here the net saving to the nation in oil used is shown in the last column to the right. The advantage of option A is seen in payout time, and in oil saved; not to be ignored is the potential additional heat which can be obtained from the 85° reinject water.

The detailed report documenting this limited feasibility study is as follows.

JHU/APL QM-80-102, June 1980, "TECHNICAL ASSISTANCE REPORT NO. 5 GEOTHERMAL SPACE HEATING - NAVAL AIR REWORK FACILITY, NORFOLK, VA., by F. K. Hill and R. W. Henderson

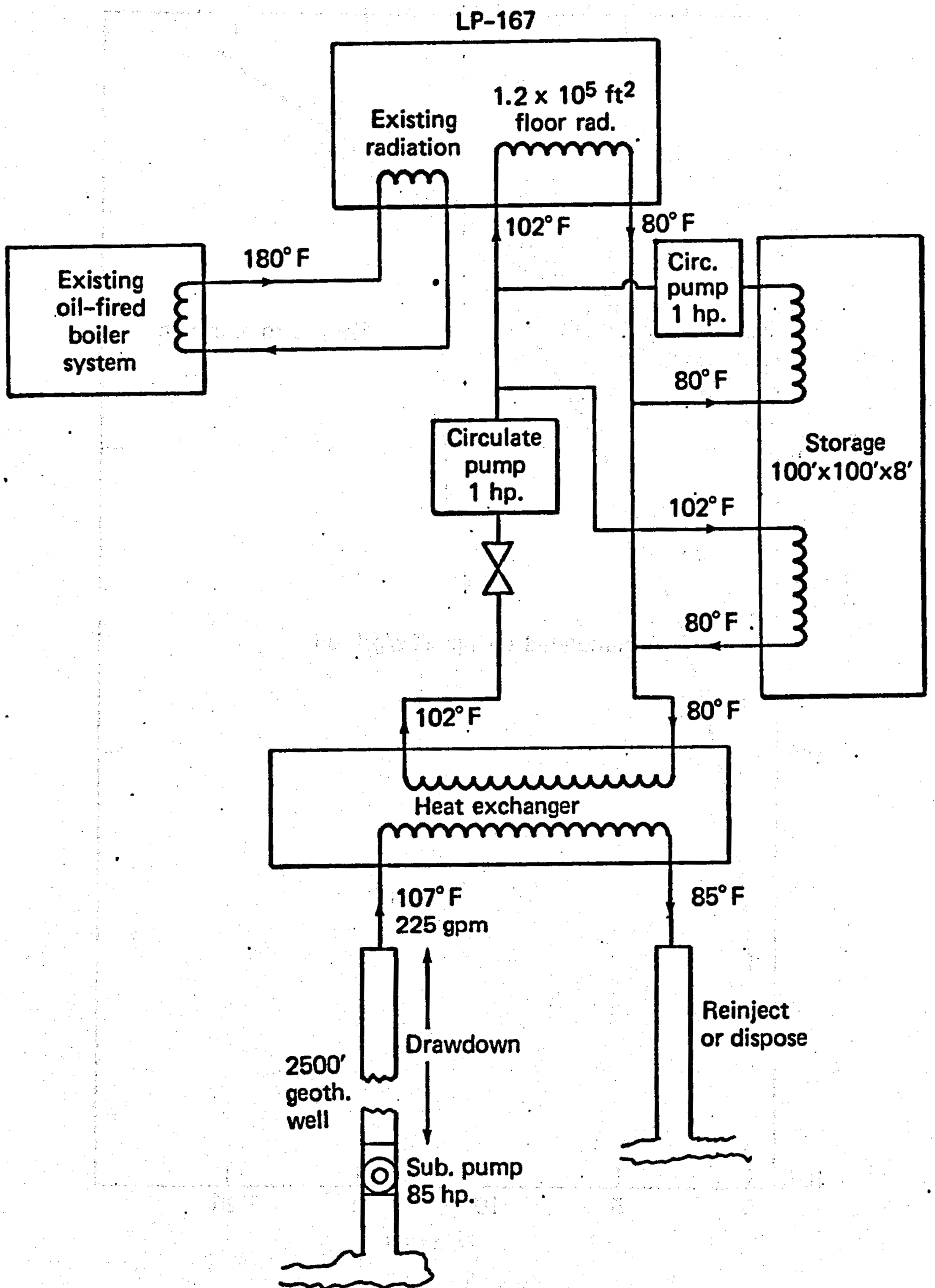

Fig. A-1 Option A. - Geothermal energy used directly, radiant/convective space heat.

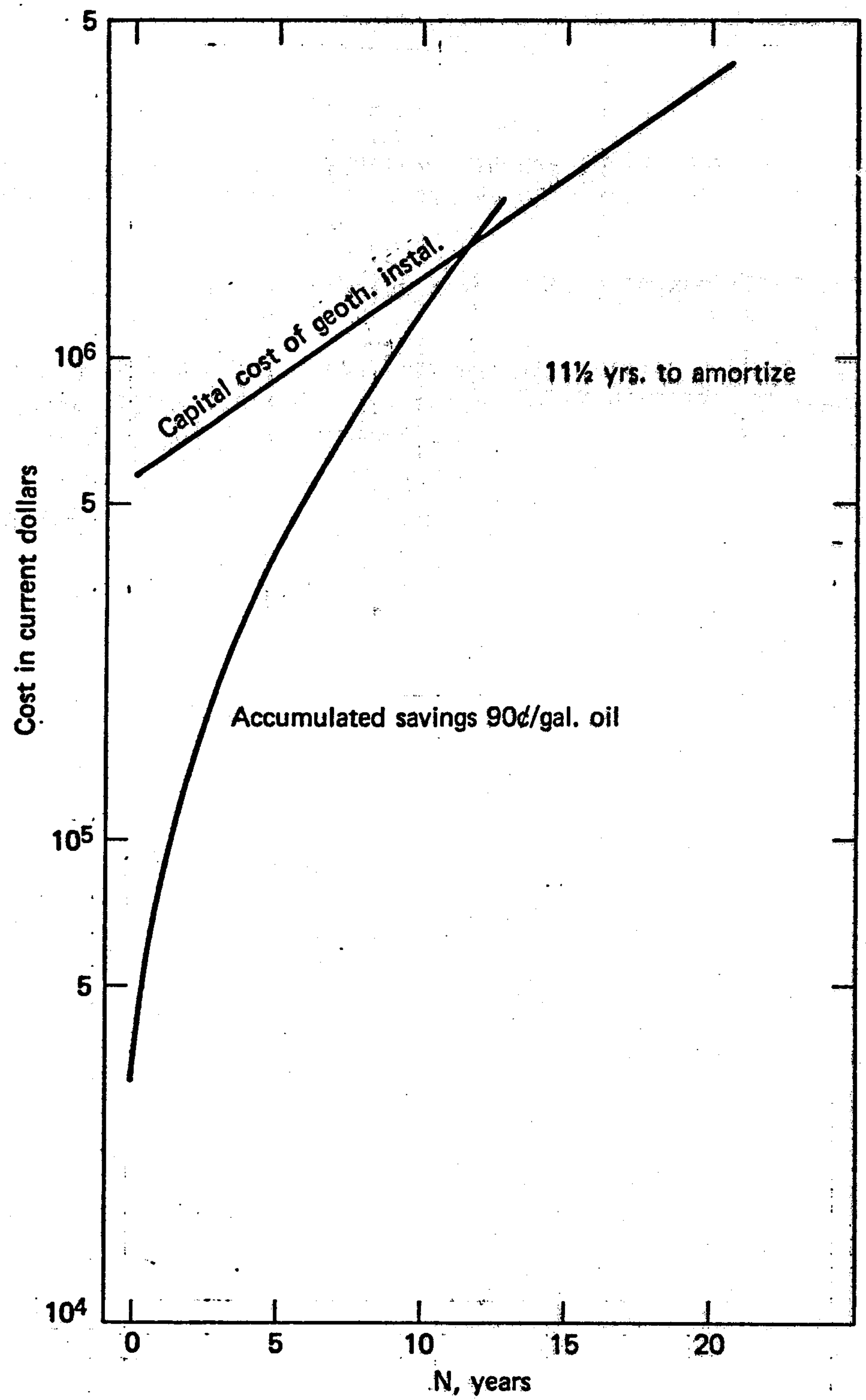

Fig. A-2 Option A – Pay back period.

Table I. COST SUMMARY

Costs	A	B	C	D
Capital	\$560.2K	\$501.1K	\$914K	\$829.1K
Operating	Geo. $17.9K(1.105)^n + 9.87K(1.125)^n$ 100% Oil $65.79K(1.125)^n + 4K(1.09)^n$	Geo. $39.32K(1.105)^n + 17.76K(1.125)^n$ 100% Oil $65.79K(1.125)^n + 4K(1.09)^n$	Geo. $49.68K(1.105)^n + 6.8K(1.09)^n$ 100% Oil $65.79K(1.125)^n + 4K(1.09)^n$	Geo. $74.4K(1.105)^n + 5.96(1.09)^n$ 100% Oil $65.79K(1.125)^n + 4K(1.09)^n$
Net	$55.92K(1.125)^n - 17.9K(1.105)^n$	$55.13K(1.125)^n - 39.32K(1.105)^n$	$65.79K(1.125)^n - 49.68K(1.105)^n - 2.8K(1.09)^n$	$65.79K(1.125)^n - 74.4K(1.105)^n - 1.96K(1.09)^n$
Amortization	11.5 yrs	22.5 yrs	26 yrs	< 40 yrs
Equipment	Geothermal well source Reinject well Heat exchanger Floor rad. system Use existing oil-fired boiler system for 15% heat Storage reservoir (100' x 100' x 8')	Geothermal well source Reinject well Heat exchanger Heat pump (391 hp) Use oil-fired system for 27% heat load	Geothermal well source Reinject well Heat exchanger 3 heat pumps 391 hp, 327 hp, 756 hp Storage reservoir (100' x 50' x 6')	Geothermal well source Reinject well Heat exchanger 2heat pumps 195 hp, 1004 hp Storage reservoir (100' x 50' x 6')

Table II. OIL USE

Option	Capital	Amortization	Oil used at NARF(LP-167)	Oil at Power Plant*	Net Saving
Oil-Fired System now existing	--	--	73,100 gal. (avg.)	0	0
A	$560.2K	11.5 yrs	10,965 gal.	12,058 gal	50,077 gal
B	501.1	22 1/2	19,737	33,000	20,363
C	914	26	0	41,694	31,406
D	829.1	< 40	0	62,441	10,659

*Coal or nuclear would zero this item.

Notes:

1) Both A and B retain use of the existing oil-fired hot water system for peak heating, needed only in the coldest weather.

2) C uses the waste heat from the Geothermal Well, thus doubling its useful output, and also provides a large reservoir of heat available for heating a similar building in the area. If additional use is made of this heat the savings in oil burned could increase significantly and the amortization time decrease as well.

3) D is less desirable and more expensive, although this system also makes available the 24-hr output of the well which is twice the total annual demand of Bldg. LP-167.

South Dakota Demonstration Projects

by

E. G. DiBello
EG&G Idaho, Incorporated

SOUTH DAKOTA DEMONSTRATION PROJECTS

Edward G. DiBello
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The application of hydrothermal energy for direct use by the private sector in the United States has been quite limited to date. The reasons most commonly given for the limited development of this alternative energy source are the lack of: (a) inexpensive and reliable exploration and drilling techniques, (b) knowledge of the resource base, (c) established geothermal laws and regulations, and (d) technical and economic data. Therefore, baseline information regarding direct applications is needed to assist prospective users in defining the engineering and economic requirements of direct use projects.

To stimulate development and build the necessary data base, the U.S. Department of Energy, Division of Geothermal Energy, in 1977 and 1978 issued two Program Opportunity Notices for cost-shared direct use projects, and 22 projects were initiated as a result.

Three projects located in South Dakota are summarized below:

District Heating in Philip, South Dakota

The geothermal well for this project was drilled in February 1979, to a total depth of 4266 feet. The well flows 300 gpm artesian at a temperature of 157°F (69°C). The system will heat five Haakon School District buildings and eight business buildings in downtown Philip. The system effluent is surface discharged into the Bad River after being treated to remove the naturally occuring Radium 226. The total cost of the project is $1,205,804, with DOE funding set at $936,199 (78%). The system is operational for the 1980-81 heating season, and will save 9.53×10^9 Btu/yr (.32 MW-yr).

Heating St. Mary's Hospital, Pierre, South Dakota

The geothermal well for this project was drilled in April 1979, to a total depth of 2176 feet. The well flows 375 gpm artesian at a temperature of 106°F (41°C). The geothermal water will be used for space heating and domestic hot water heating in the existing hospital. The effluent from this heating system will be used for a heat pump application in the new hospital annex. The water is then surface discharged into the Missouri River. The total cost of the project is $718,000, with DOE funding set at $538,500 (75%). The system is operational for the 1980-81 heating season. The project will save 11.44×10^9 Btu/yr (.38 MW-yr).

Heating and Grain Drying at Diamond Ring Ranch, Midland, South Dakota

The Diamond Ring Ranch well was drilled in 1959 to a total depth of 4112 feet and flows 170 gpm artesian at a temperature of 152°F (67°C). The geothermal water is being used to heat six ranch buildings and a 700 bushel/hr. grain dryer. The water is then surface discharged into an existing ranch reservoir. The system is operational, and final check-out and instrumentation installation is being completed for the 1980-81 heating season. The total cost of the project will be $403,908, with DOE's share being $250,725 (62%). The project will save 7.87 x 109 Btu/yr (.26 MW-yr).

As a result of these and similar projects, institutional barriers are being tested, private firms and organizations are gaining experience, and public awareness of hydrothermal energy is being increased. In addition, valuable environmental, technical, operational, and economic data are being generated. This information will be available in final reports to be issued upon project completion. The Department of Energy is also preparing a generic analysis on the overall program that will be available to those interested in hydrothermal direct use development.

Reference

Geothermal Direct Heat Applications Program Summary, Semi-Annual Review Meeting, El Centro, California, April 1980.

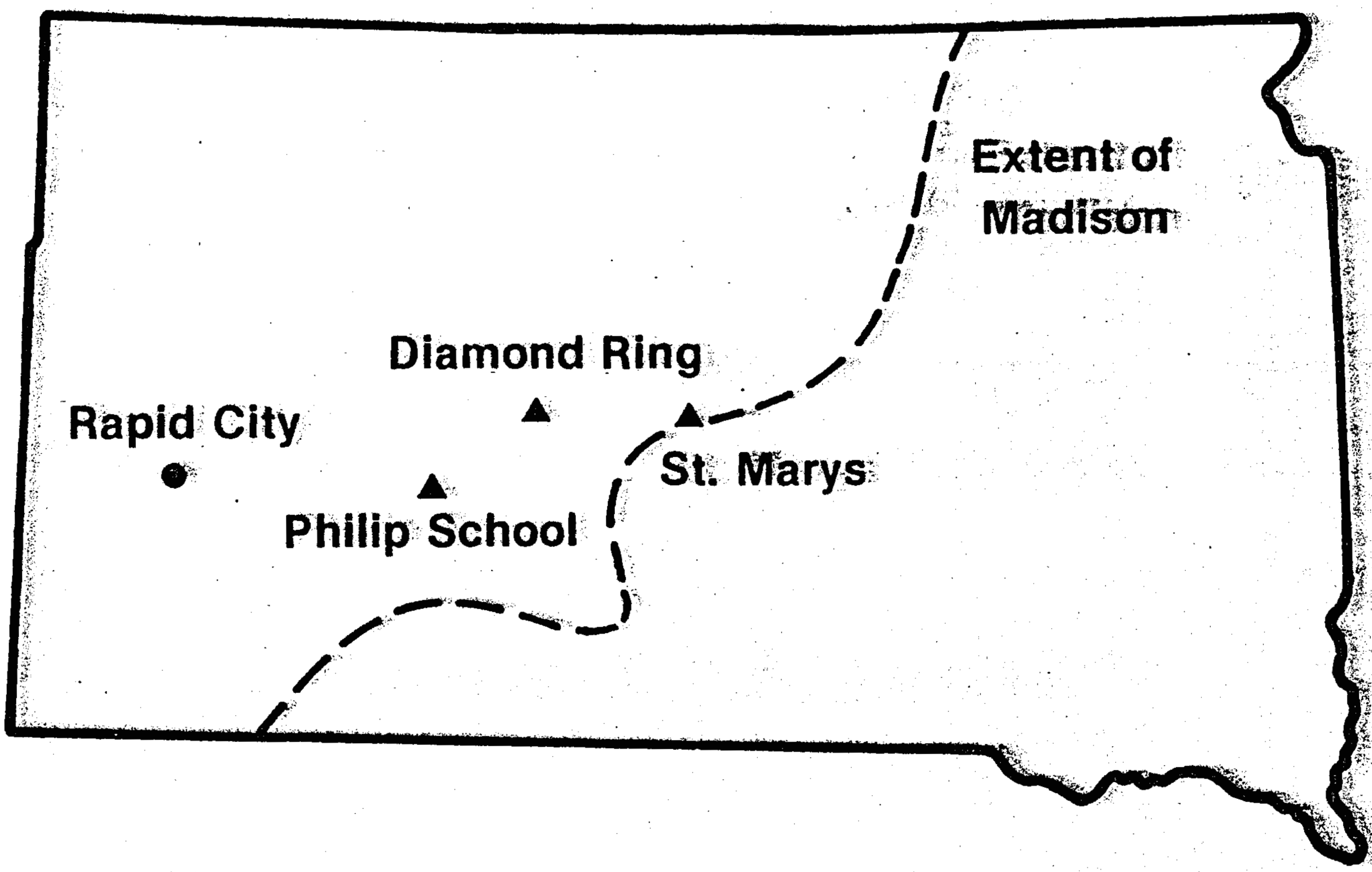
Project Overview

Philip School -	Space and water heating Business district heating
Diamond Ring Ranch-	Space and water heating Grain drying
St. Marys Hospital-	Space and water heating Heat pump application

XXIII-3

INEL-S-29 134

South Dakota



INEL-S-29 142

Resource Data

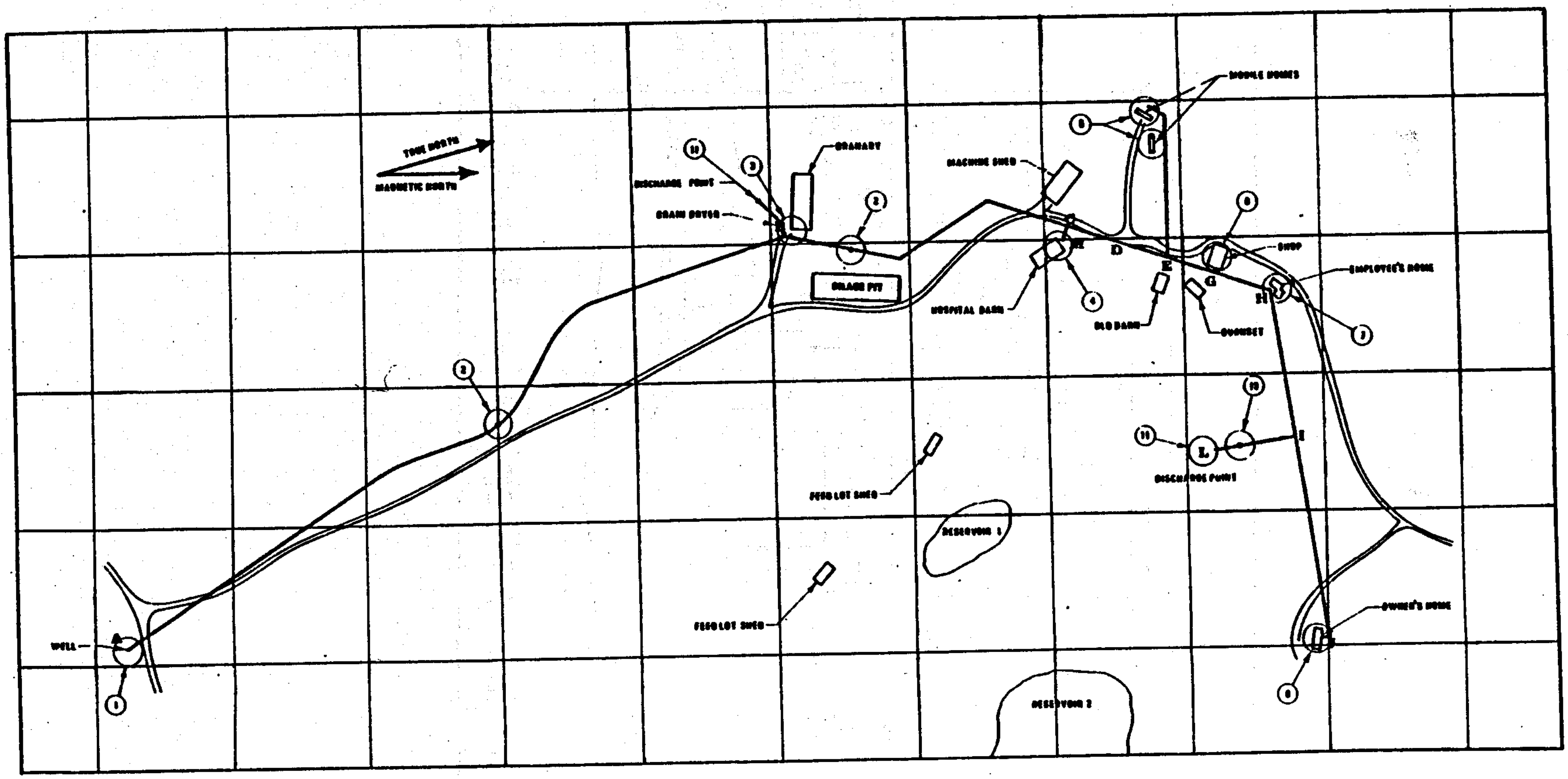
	Philip	Diamond Ring	St Marys
Well depth (Ft)	4266	4112	2176
Date complete	2/79	1959	4/79
Completion	OH	OH	PC
Temperature (°F)	157	152	106
Flowrate (gpm)	300	170	375
Cost ($\$ \times 10^3$)	317	N/A	320

Design Features

	Philip	Diamond Ring	St Marys
Design BTU/Hr ($x10^6$)	5.5	3.35	5.55
Maximum BTU/Hr ($x10^9$)	9.53	7.87	11.44
Heat exchangers	All flat plate SS 316		
Pipe material	FRP	Reinforced PVC	Insulated FRP
Facilities	5 school bldgs. 8 businesses	6 ranch bldgs. 1 grain dryer	2 hosp. bldgs.
Disposal	Bad R.*	Stock ponds	Missouri R.

* with treatment

INEL-S-29 136



TRUE NORTH
MAGNETIC NORTH
WELL
FEED LOT SHED
FEED LOT SHED
RESERVOIR 1
RESERVOIR 2
GRANARY
DISCHARGE POINT
GRAIN DRYER
SILAGE PIT
MACHINE SHED
HOSPITAL BARN
OLD BARN
QUONSET
MOBILE HOMES
SHOP
EMPLOYEE'S HOME
OWNER'S HOME
DISCHARGE POINT
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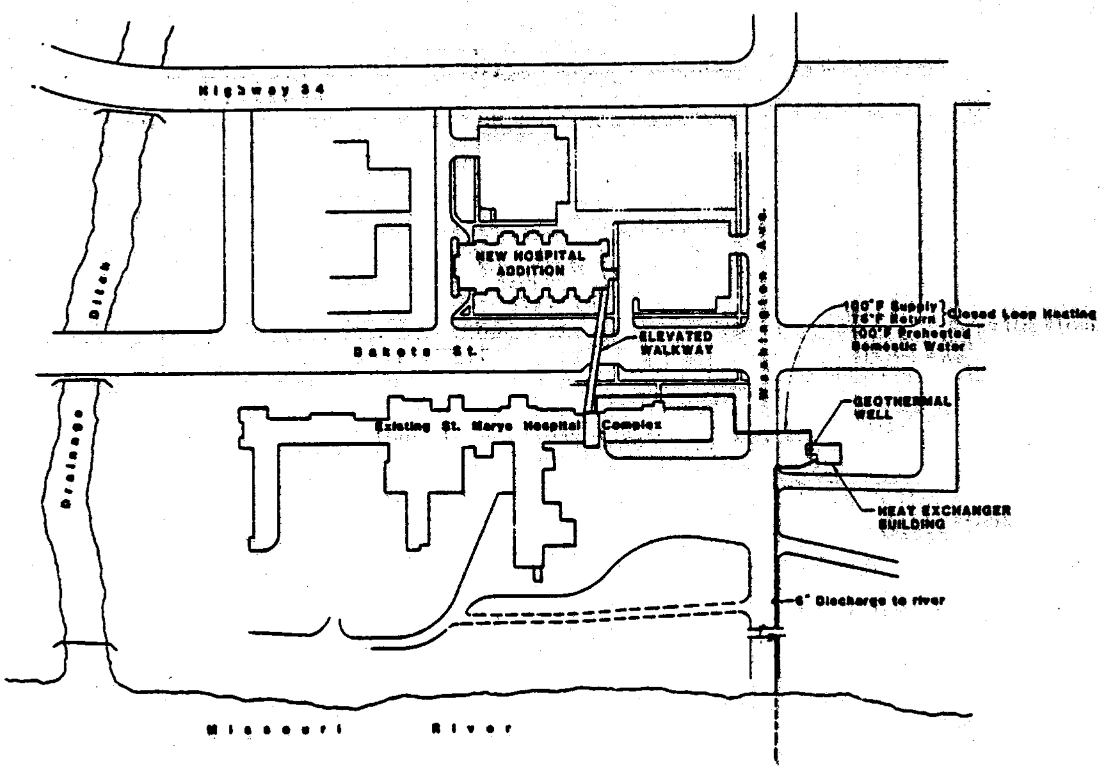
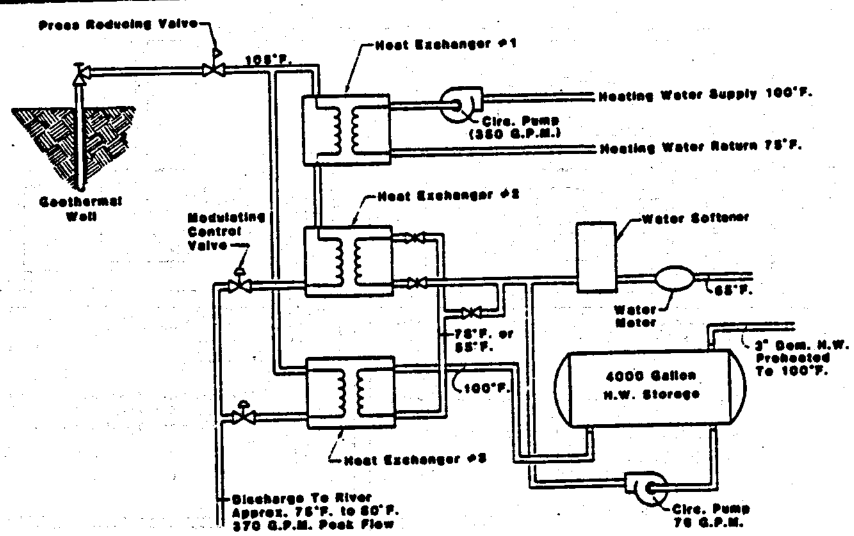
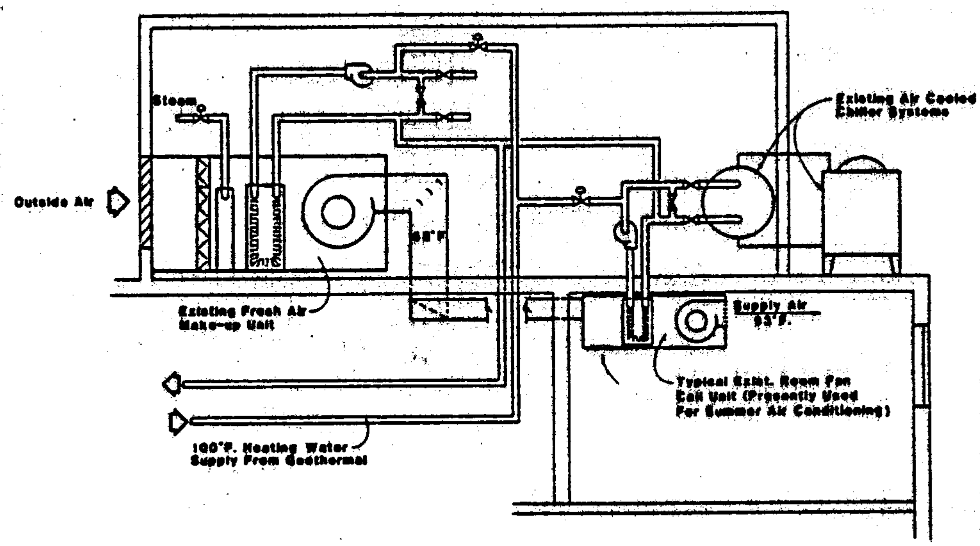


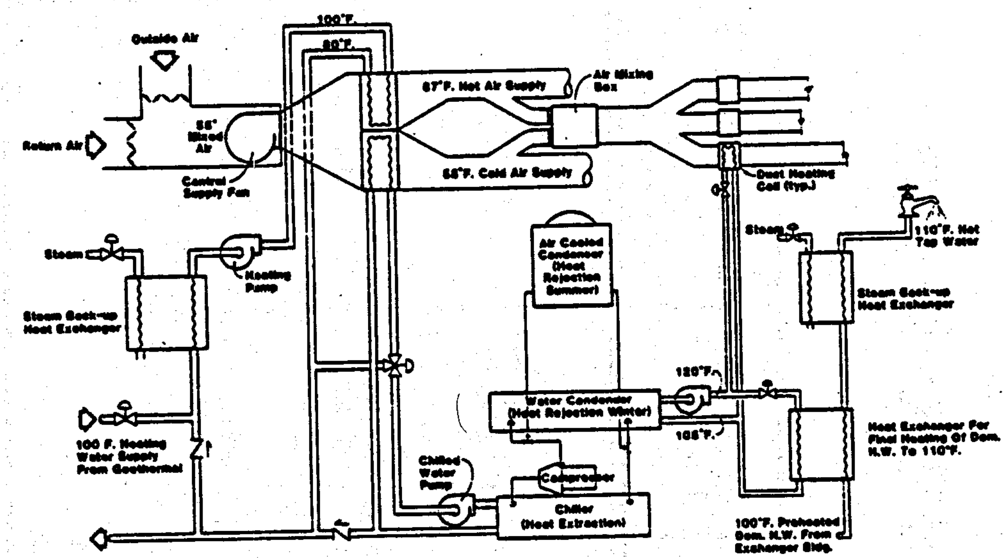
St. Mary's Hospital Pierre, South Dakota



WELL HOUSE AND EXCHANGER BUILDING SCHEMATIC



EXISTING HOSPITAL DIRECT HEAT APPLICATIONS



NEW BUILDING HEATING SYSTEM SCHEMATIC

Economic Data

	Philip	Diamond Ring	St. Marys
Total cost ($ x 10^3)	1,205	403	718
Participant share (%)	22	38	25
Estimated Operating Cost ($ x 10^3)	22	12	31

INEL-S-29 137

XXIII-12

Economic Data

	Philip	Diamond Ring	St. Marys
$ / MBTU	15.42	8.65	9.07
Interest Rate (%)	9.5	13.25	9.0
$ / installed Kw	748	411	440
Simple payback (yrs.)	20	8	9

Lessons Learned

- Regulatory delays
- Well driller availability
- Well construction
- Flow testing
- Radium 226
- Injection
- Disposal permits
- Temperature and flows - less than expected

INEL-S-29 141

Review of Technical Assistance
In the Eastern United States

by

F. C. Paddison
The Johns Hopkins University
Applied Physics Laboratory

REVIEW OF TECHNICAL ASSISTANCE IN THE EASTERN UNITED STATES

F. C. Paddison, APL/JHU

The Applied Physics Laboratory of The Johns Hopkins University is one of four institutions supported by the Department of Energy to provide technical assistance on request for the application of geothermal energy. The type of assistance may fall into any or all of the following categories.

1. The identification of available data on geothermal resource in the area, or upon the application of the resource to a specific use.
2. The estimates of hydrologic properties of resource as function of usage and time.
3. The engineering mechanics of heat recovery and hydrothermal water handling.
4. Estimates of geothermal system life-cycle costs.
5. The federal and state legal and institutional requirements for use of geothermal fluids.
6. Availability of federal, state, or other programs to assist or that relate to use of geothermal energy.
7. Availability of and mechanics of applying for federal geothermal loan guarantee.

Technical Assistance in East - Completed or Still in Process

The following Table I lists individuals of groups who have received, or are still receiving, technical assistance. The scope of effort varies from a few to many hours of effort. Those assistance efforts that are marked by an asterisk are documented in formal reports, Refs. 1 through 5.

TABLE I

TECHNICAL ASSISTANCE IN EAST - COMPLETED OR STILL IN PROCESS

Space Heating

Crisfield, MD High School*
Crisfield, MD Hospital
Pittsville, MD Middle School*
Hot Springs, AR
Town of Newport News, VA
Naval Air Rework Facility, Norfolk, VA*
NASA-Wallops Flight Test Center, VA
Kings Bay, GA

Geothermal Industrial or Agricultural Process Heat

Standard Brands Fructose Plant, Montezuma, NY
Mariculture, Chesapeake Bay*
Wet Corn Mill Alabama - Ethanol
Wed Corn Mill North Carolina - Ethanol
Seafood Terminal, Newport News, VA
Liquefied Natural Gas Terminal, Cove Point, MD*
Showell Farms - Poultry Industry

Combinations of Above

Industrial Park - Melfa, VA
Lewes, DE

Heat Pumps

Bellows Falls, VT
Lebanon Springs, NY
Individuals (3)
Energy Concepts Corp., MD
New Hope, PA
McGuire AFB, NJ

Technical Assistance in East - Requested

The above list is substantially in excess of APL's and DOE/DGE's original expectations. In FY 1981 this trend is apparently going to continue. The following Table II lists current requests for technical assistance.

TABLE II

TECHNICAL ASSISTANCE IN EAST - REQUESTED

Geothermal Space Heating

Senior Citizens Center, Ocean City, MD

Dover AFB, Dover, DE

Charleston AFB, Charleston, SC

Auburn, NY

Industrial Process on Agricultural Treatment

Bristol Meyers, Syracuse, NY

Federal Fish Hatcheries, PA

Burlington Industries, NC

Combinations

Town of Salisbury, MD

Heat Pumps

Borough of Forty Fort, PA

Harlan, KY

Richmond, IN

Indianapolis, IN

Summary Paper on Technical Assistance

A paper summarizing parts of the Eastern Technical Assistance Program was presented at the Geothermal Resources Council 1980 Annual Meeting in Salt Lake City and is published in their proceedings. The heating of a high school at

Crisfield, Maryland, with 133° F water, the vaporization of liquefied natural gas with geothermal water at Cove Point, and the mixing of geothermal water with Chesapeake Bay water to control salinity and temperature to grow clams and oysters are all summarized in that paper (Ref. 6). The latter proposed use to culture oysters and clams is repeated here as typical of technical assistance.

Geothermal and Mariculture in Chesapeake Bay

The Ceda Corporation, now named The Brand Corporation of Annapolis, Maryland, is interested in growing seed and full-term meat oysters and hard shell clams. The process can be accelerated if nutrient-rich Bay water is mixed with geothermal water so that salinity and temperature are controlled and held nearly uniform year-round. The plant is located in the upper region of the Chesapeake Bay where there is no MSX disease. The area selected by The Brand Corporation is Talbot County. See Fig. 1.

The Geothermal Resource

It was assumed that the hydrothermal water chemistry and the aquifer characteristics were similar to those found at the Crisfield well (Refs. 7 and 8). These are tabulated in Fig. 2. The depth to basement was assumed to be 3000 ft and the temperature of the geothermal water was assumed to be 116° F.

The System Block Diagram

The Ceda Corporation desired a flow of 200 gallons of water per minute at the controlled temperature and salinity. Further, they wished to provide space heat for the building housing the growing tank. Figure 3 shows the system block diagram. The mixed Bay and geothermal water is released to the Bay. Figure 3 shows the variation in pumping rates of geothermal water and Bay water. A flow of six gallons per minute is shown to provide space heating for the building.

Salinity and Temperature

Table III shows the temperature and salinity of of mixed culture water.

TABLE III

BAY WATER TEMPERATURE AND SALINITY

	Av. Temp. (°C)	Av. Sal. (PPT)
Spring	10	7.0
Summer	26.5	13
Fall	11	13
Winter	1	7.0

The recommended parameters are shown in Table IV.

TABLE IV

RECOMMENDED PARAMETERS

	Pumping* Rate (GPM)	Mixture** Ratio	Mixture Temp (°C)	Mixture Sal. (PPT)
Spring	66.7	2.0	22	28
Summer	12.5	15	28	17
Fall	57.1	2.5	21	29
Winter	80.0	1.5	19	32

* For the geothermal well
**Vol. ratio bay water/GT water

The geothermal water pumping schedule is shown in Fig. 4. This should produce a drawdown in the well not in excess of 600 feet, which will allow the use of submerged vertical turbine pump with motor and variable speed control at the surface.

System Costs

The capital costs ($132K) of the geothermal system are greater than a system where Bay water is heated with fossil fuel ($95K). However, the annual operating costs are substantially lower - $6.4K vs. $19K and accordingly in 15 years they are equal and thereafter the geothermal system suffers approximately one-third the operating cost of fossil fired system. See. Ref. 2 for further discussion.

Status

The Brand Corporation is interested and is in the process of acquiring capital and property.

Concluding Comments

Institutional and other considerations apparent from Technical Assistance Program are as follows:

1. It is most desirable to have Eastern States with known hydrothermal resources enact laws and put in place rules and regulations implementing the laws in a timely fashion to facilitate geothermal development. The status of legislation in Delmarva is as follows:

   a) Both houses of the Delaware legislature passed a geothermal act in 1980 which the Governor vetoed.

   b) The Virginia Commission of Coal and Energy is in the process of considering legislation during the 1981 Legislative Session.

   c) Maryland has law on its books since 1978 and is considering a revision to clarify in the 1981 Legislative Session. There are no rules and regulations to date.

2. Some form of well insurance is necessary to minimize risk.

3. A method of borrowing construction funds is necessary.

4. The transfer of complete geologic, hydrologic and and other data to local bodies, i.e., state geologic surveys, is most necessary.

5. Formation of state teams to layout how to apply and use geothermal in respective state is desirable. The State of Delaware is the only state with a team.

6. Extended Federal Resource Assessment effort in the East is desirable. Small user cannot afford resource assessment effort to minimize risk.

7. Space cooling by modest temperature geothermal is a most necessary and possible technical development for the southeastern U.S.

8. Reliable cost estimates for future geothermal production and reinjection wells are not in hand.

References

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3. APL/JHU CQO-2850, "Report on Technical Assistance for Columbia LNG Corporation," March 28, 1980.

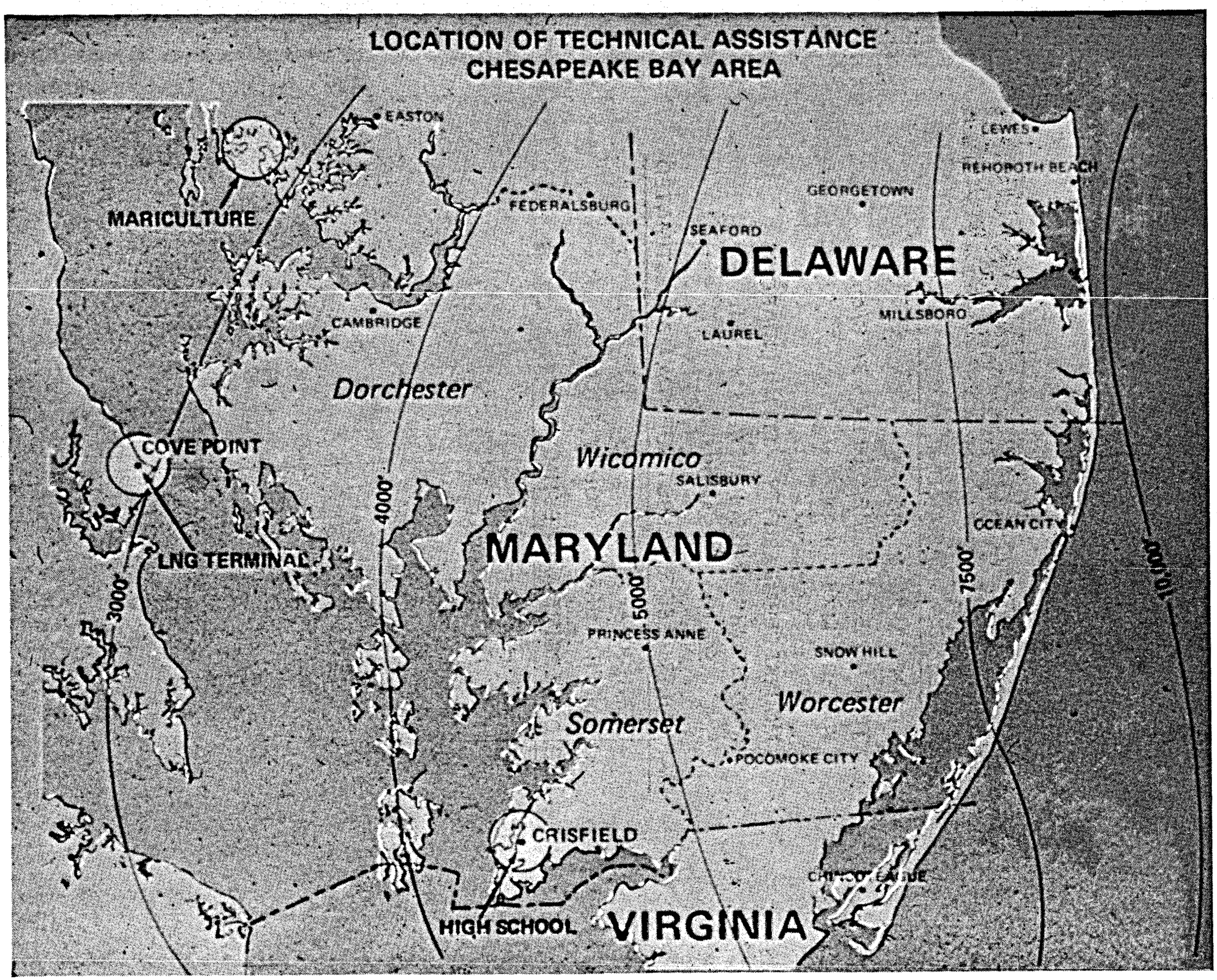
4. APL/JHU QM-80-101, "Geothermal Energy Development in the Eastern United States, Technical Assistance Report No. 4 Geothermal Space Heating - Pittsville Middle/Elementary School, Pittsville, Maryland," June 1980.

5. APL/JHU QM-80-102, "Geothermal Energy Development in the Eastern United States, Technical Assistance Report No. 5 Geothermal Space Heating - Naval Air Rework Facility, Norfolk, Virginia," June 1980.

6. K. Yu and F. C. Paddison, "Technical Assistance - Hydrothermal Resource Application in the Eastern U.S.," Geothermal Resources Council Transactions Vol. 4, pp 629-632, September 1980.

7. Completion Report, Department of Energy, DOE/Crisfield Airport No. 1 Well, Somerset County, Maryland, Part I: Drilling and Completion, and Part II: Well Test Analysis, Gruy Federal, Inc., October 1979.

8. APL/JHU QM-79-261, "Geothermal Energy and the Eastern U.S., Technical Information Interchange Meeting, Minutes," December 1979.


LOCATION OF TECHNICAL ASSISTANCE
CHESAPEAKE BAY AREA
EASTON
LEWES
REHOBOTH BEACH
GEORGETOWN
MARICULTURE
FEDERALSBURG
SEAFORD
DELAWARE
CAMBRIDGE
MILLSBORO
LAUREL
Dorchester
COVE POINT
Wicomico
SALISBURY
OCEAN CITY
LNG TERMINAL
MARYLAND
3000
4000
5000
7500
10,000
PRINCESS ANNE
SNOW HILL
Worcester
Somerset
POCOMOKE CITY
CRISFIELD
HIGH SCHOOL
VIRGINIA

GEOTHERMAL RESOURCES

CRISFIELD, MD – MEASURED

- DEPTH – APPROX. 4000 FT
- TEMP – 135° F OR 20° F/1000 FT ~ 37° C/km
- WATER – LIKE OCEAN
  7% SALINITY
- MODEST PERMEABILITY – 110 MILLIDARCIES
- MODEST TRANSMISSIBILITY – 348 gpd/ft
- UNCONSOLIDATED SANDS

MARICULTURE SITE, TALBOT COUNTY, MD – ESTIMATED

- DEPTH 3000 FT
- TEMPERATURE 116° F OR 17° F/1000 FT

LNG, COVE POINT, MD – ESTIMATED

- DEPTH – 3000 FT
- TEMP – 110° F – 135° F

Figure 2

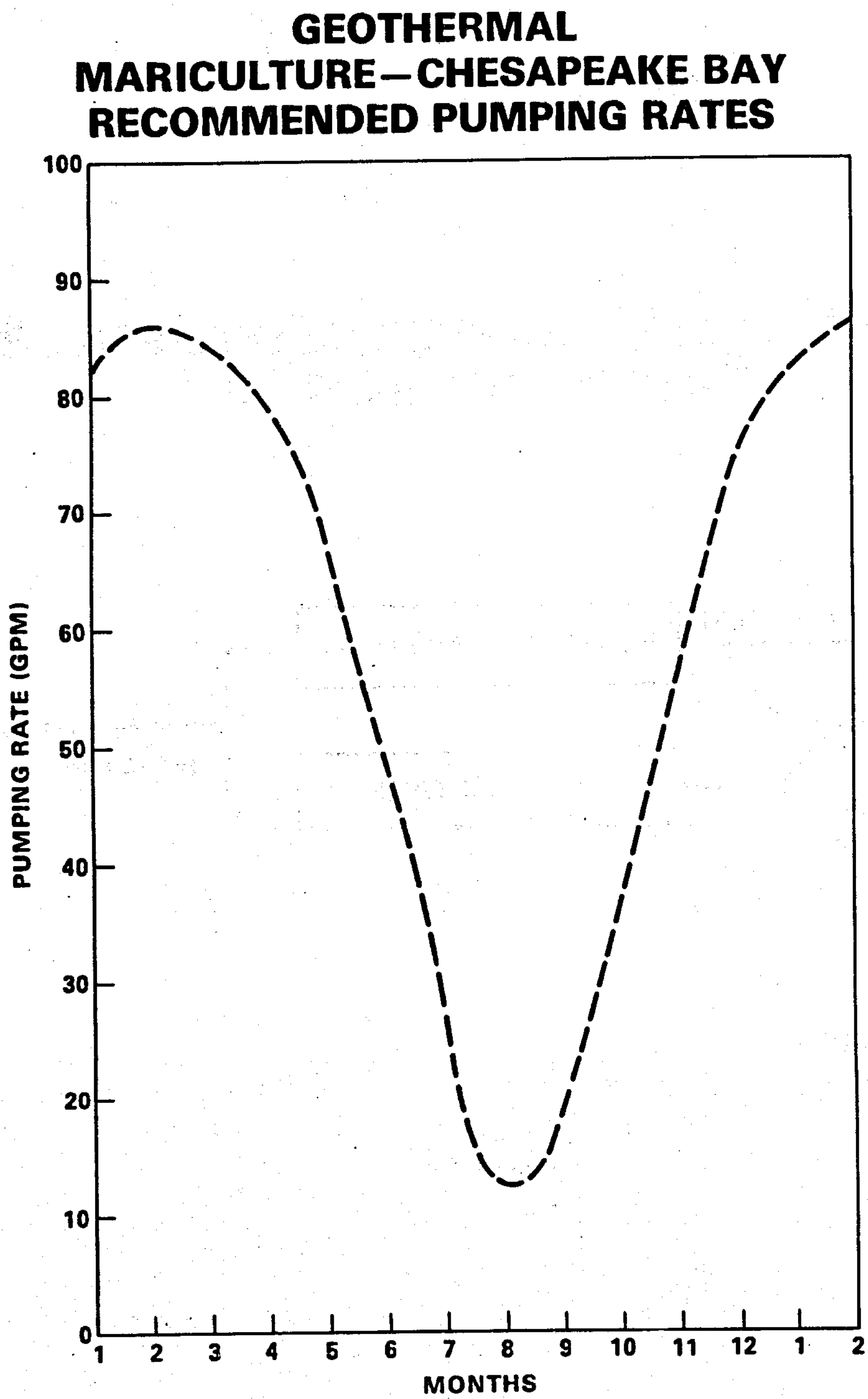

GEOTHERMAL
MARICULTURE—CHESAPEAKE BAY
RECOMMENDED PUMPING RATES
PUMPING RATE (GPM)
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
1
2
MONTHS

Figure 3

GEOTHERMAL MARICULTURE CHESAPEAKE BAY BLOCK DIAGRAM

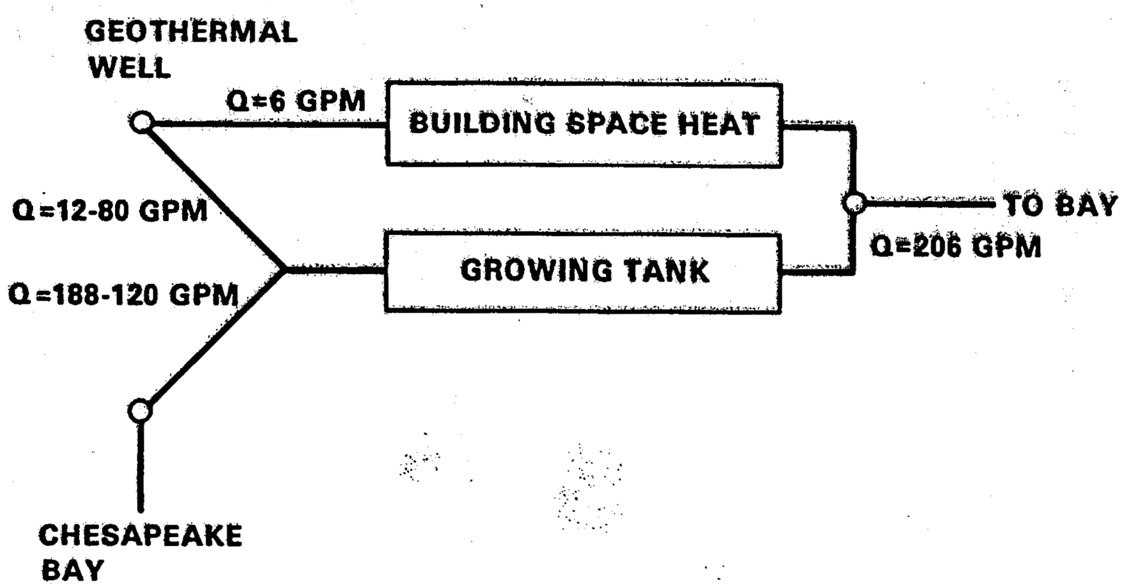


Figure 4

Hydrothermal Geothermal
in Texas

by

M. F. Conover
Radian Corporation

HYDROTHERMAL GEOTHERMAL IN TEXAS

- DOMESTIC WATER AND SPACE HEATING PROJECTS
- COMPONENT FAILURE ANALYSIS SERVICES

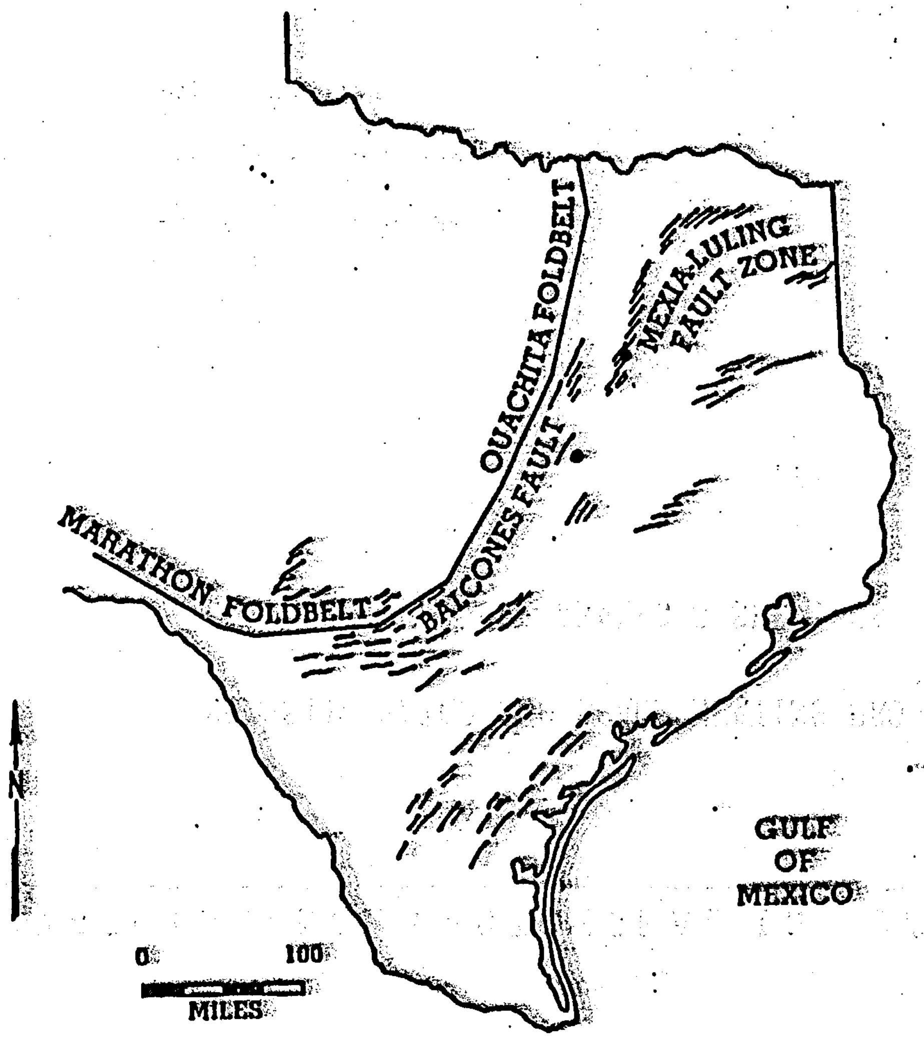
MARSHALL F. CONOVER

GEOTHERMAL PROGRAMS MANAGER

512 - 454-4797

RADIAN
CORPORATION

CENTRAL TEXAS FAULT ZONES



DIRECT UTILIZATION GEOTHERMAL PROJECTS IN TEXAS

Location:	Marlin	Marlin	Corsicana
User:	Hospital	Ch. of Comm.	College & Hospital
Funding:	DOE/State/IKS	DOE/IKS	DOE/IKS
Use:	DWH & SH	SH	DWH & SH
Well Data:			
- Temp (°F)	153	118	125
- Depth (Ft)	3885	3360	2664
- Flow (gpm)	315 (p)	15 (art.)	315 (p)
- TDS (mg/l)	4,000	10,000	5860
Disposal:	Surface	Surface	Injection

RADIAN CORPORATION

GEOTHERMAL COMPONENT FAILURE ANALYSIS SERVICES

- AVAILABLE TO ALL GEOTHERMAL ACTIVITIES
- NO CHARGE TO THE REQUESTOR
- INVESTIGATOR WILL SURVEY COMPONENT'S PHYSICAL AND CHEMICAL ENVIRONMENT
- COMPLETED FAILURE ANALYSIS REPORT ADDRESSES:
  - Failure Background
  - Visual Examination
  - Examination Procedure
  - Examination Results
  - Discussion
  - Conclusions
  - Recommendations (Alternate materials)

RADIAN CORPORATION

Recent Federal District Heating Initiatives

by

E. Peterson
Department of Energy
Division of Geothermal Energy

given by

R. Stephens
Department of Energy
Division of Geothermal Energy

RECENT FEDERAL DISTRICT HEATING INITIATIVES

by Eric Peterson

A Proposed National District Heating and Cooling Program Strategy has been prepared by DOE and HUD with input from several other federal agencies. The draft strategy was to be published in The Federal Register this Fall but will likely be delayed for consideration by the new administration. Several aspects of the strategy however are being activated including The Interagency District Heating Coordinating Group and the HUD/DOE cooperative solicitations for district heating and cooling feasibility assessments.

The Interagency District Heating Coordinating Group (IDHCG) composed of 12 agencies of the federal government was established to promote the implementation of district heating on a wide scale as rapidly as possible. the IDHCG is chaired by The Deputy Secretary, U. S. Department of Energy. Membership in the IDHCG is at the Assistant-Secretary or Assistant Administrator level as appropriate from the following agencies:

Department of Energy

Department of Housing and Urban Development

Department of Commerce

Department of Defense

Department of the Treasury

Department of Health & Human Resources

Environmental Protection Agency

General Services Administration

Veterans Administration

In addition appropriate-level representation from the following organizations:

Council of Environmental Quality

President's Domestic Policy Advisor

Office of Management and Budget

The IDHCG will operate as an independent organization but will keep the Assistant Secretaries' Coordinating Committee appraised of program activities being recommended. Policy issues will be referred to the Energy Coordinating Committee (ECC) for resolution.

Functions of IDHCG include:

- establish an overall policy for Federal efforts to have district heating and cooling systems implemented on a wide scale in the U. S.
- establish the requirements for formal interagency agreements
- serve as a focal point for review of existing regulations and programs within the Federal establishment which can be used or possibly modified to assist in meeting the goals of the district heating and cooling (HDC) effort
- develop a unified approach to supporting agency request for appropriations in furtherance of the DHC program
- report to the President in Spring 1981 on the status and needs of a national district heating program.

The first HUD/DOE cooperative solicitation (Technical Assistance Potential District Heating and Cooling Projects) was published in the Oct. 17 Federal Register and Oct. 14 Commerce Business Daily. The objectives of this solicitation are to assist communities in

- identifying DGC projects
- organizing team to carry through project
- educate community (public hearings)
- develop an implementation plan.

The funding for the solicitation is $1.5 million with awards in the 20 to 30 thousand dollar range. Extensive technical assistance will be provided to the communities to help them during the study. The proposals are due Jan. 15, 1981.

A second solicitation scheduled to be published in Feb. 1981 by DOE in cooperation with HUD will be directed at communities that have their DHC project feasibility identified and a team organized to carry through the project. The objectives include:

- complete conceptual design
- identify financial arrangements/options
- clarify institutional arrangements
- obtain user commitments.

The geothermal resource if not already confirmed must be confirmed during this phase.

The funding anticipated for this solicitation is $2.8 million with individual awards in the $50 thousand range. Proposals would be due in April with awards announced in July.

In order to coordinate our geothermal activities with the HUD/DOE initiatives and to place focus on our district heating activities DGE has formed a Geothermal District Heating Team. The initial activities of the DH Team include:

- establishing a bibliography of DH reports
- summary of DH activities
- coordinator for HUD Team activities
- analysis of DH program models
- organize DH Technical Blue Ribbon Panel
- organize DH User Panel.

The chief coordinator is:

George Budney
Energy Technology Engineering Center
P. O. Box 1449
Canota Park, Ca. 91304
Tele. (213) 341-1000 ext. 6474

If you have information that may be of use to the team, please contact him directly.

Geothermal Awareness Program

by

T. J. Duesterberg
J. C. Engle
International Business Services, Inc.

GEOTHERMAL AWARENESS PROGRAM

Presented to:

Geothermal Technical Interchange Meeting
Berkeley Springs, West Virginia

November 6-7, 1980

Thomas J. Duesterberg
John C. Engle

International Business Services, Inc.
1424 K Street, N.W.
Washington, D.C. 20005

(202) 789-5350

GEOTHERMAL AWARENESS PROGRAM

IBS has been working under contract to DOE for more than a year to promote public understanding and interest in geothermal energy and in the DOE geothermal program. Our primary goal during this time has been to inform the general public and potential end-users about research and commercial development of this energy resource. To accomplish this goal we have worked closely with editors and writers of newspapers, magazines, trade association journals, and the broadcast media which serve a national audience. We send these editors and writers a general packet of information which gives general background information on geothermal energy, descriptions of specific projects, and summaries of government programs. (I have a sample copy of this packet which I would be happy to show you.) In the past six months we have assisted editors of the following publications with articles on geothermal: Nation's Cities Weekly, Banking, American City and County, Popular Mechanics, Fortune, Electric Light & Power, Aquaculture, Energy Management, Science & Mechanics, and National Geographic. A Sunday syndicate carried in newspapers with over 20 million in readership also ran a geothermal special based on one of our fact sheets.

IBS has also furnished general outreach materials such as fact sheets and brochures to energy information centers and trade associations. We've distributed geothermal brochures and fact sheets on specific aspects of the geothermal development program to the President's Clearinghouse on Community Energy Efficiency, the Energy Extension Service, to the energy education community, and to trade associations such as the National Rural Electric Cooperative Association.

Much of our work with the national media is aimed at reaching specifically targeted audiences. The targeted audiences are those such as the food processing and electric utility industries which are likely to be important users of geothermal energy. We have also attempted to reach groups such as bankers and local government officials which can affect the pace of geothermal development. Thus our work with national trade association and professional journals such as Energy Management, Nation's Cities Weekly, and Banking are intended to inform those who will determine the pace of commercial development of geothermal energy.

I wanted to emphasize that we focus our efforts primarily on the national media and on information centers serving national audiences. It has been difficult to interest either the East Coast or the national press in geothermal energy, for the obvious reason that most developments considered newsworthy are in the states west of the Rockies. For instance, Fortune wanted to do a piece on geothermal in the East and ended up by writing mostly about ground water heat pumps. Additionally, there have been some less than enthusiastic pieces carried in the New York Times and the Washington Post which tend to corroborate the scepticism of many easterners with regard to geothermal energy. Even though it is desirable to have more in the press about geothermal in the East, I think we should be cautious and emphasize only clear successes. More articles on unsuccessful or unproductive wells would only reinforce some of the early impressions.

The point I'm making is only that we should exercise care in trying to publicize geothermal projects in the East. Articles which give a general overview of geothermal development are always useful to inform and build a base of understanding of geothermal energy.

I know many of you have cooperated with APL to develop active outreach campaigns which inform both the general public and stimulate interest among potential users of geothermal energy. IBS may be able to provide you with some assistance in some of your outreach efforts. For instance, we have prepared a number of fact sheets, bibliographies, and have multiple copies of several geothermal brochures and articles. These might be useful to you as background material when working with the local press or community organizations. Secondly, we have in the past assisted in direct mailings to potential industrial, commercial, and institutional users of geothermal resources and would be anxious to do more of these. We worked with Fletcher Paddison to send a background release to potential users on the Delmarva Peninsula. This release announced the Delmarva solicitation for cooperative agreement. Third, if you wish to give broad exposure to a specific event, we can circulate your press release or an article in a local newspaper to the national media with whom we work. I might also add that we are constantly looking for specific events (such as ground-breaking ceremonies or successful start-up of geothermal systems) which could be used as the basis for an article on geothermal in the East.

As a final note, I wanted to tell you that IBS is now preparing a poster-map on geothermal energy which will be available in about six to eight weeks. The color map will show the location of geothermal resources in the U.S. and have photographs of about ten existing sites. A text will describe a sample of electric and direct use demonstration projects as well as the DGE program. We should be able to send you a limited number of copies toward the end of the year. I've also brought along copies of some of our recent fact sheets which you can review at this meeting.

Status of Geothermal Legislation

by

R. Stephens
Department of Energy
Division of Geothermal Energy

STATUS OF GEOTHERMAL LEGISLATION

During 1980, two of three major geothermal legislative initiatives were enacted, and the third still has some chance of final passage. In April 1980, the Crude Oil Windfall Profits Tax Act (PL 96-223) was signed by the President. The law provides tax credit increases over those provided by the National Energy Act. The investment tax credit for geothermal equipment is increased to 15% in excess of the normal 10% and extended through 1985. The residential credit is increased to 40% of the first $10,000 in expenditures for geothermal equipment, for a maximum of $4,000. Finally, a tax credit is provided equal to 10% of the cost of cogeneration equipment. Geothermal systems designed to tap waste heat or steam would qualify. IRS final regulations on the residential credit and draft regulations, (dated September 19, 1980) on the business credit have been objected to by DOE. DOE's objections are to (1) a minimum temperature limit of 50°C in both regulations, (2) a requirement that equipment be specially adapted or modified to qualify for the business investment credit, (3) disallowance of the credit if both geothermal energy and another source is used, and (4) disallowance of the credit for exploration and development expenses.

The Energy Security Act (PL 96-294) was enacted in June 1980. Title VI, the Geothermal Energy Act of 1979, contains the following major provisions:

(1) An $85 million five-year program under which the Federal government government will share the risks of drilling for commercially viable geothermal resources. Loans will cover 50% of the cost of surface exploration and drilling and 90% of the cost of a project to use geothermal for space conditioning or process heat. The loans will be repayable out of project revenues and will be wholly or partially forgivable if a project is unsuccessful. Because the high economic risk perceived by drillers and developers is considered to be one of the major forces slowing development, the reservoir confirmation loan program is expected to accelerate the rate of exploration for and confirmation of geothermal reservoirs. Authorization is $5 million for FY 1981 and $20 million for each of fiscal years 1981 through 1985. Regulations are being prepared, but no moneys have been appropriated.

(2) A program authorizing DOE to grant low-interest forgivable loans to cover up to 90% of the cost of feasibility studies and regulatory applications and up to 75% of the construction costs of nonelectric systems. $5 million is authorized for feasibility studies for FY 1981. Regulations are being prepared but no moneys have been appropriated yet.

(3) A DOE study and report to Congress by June 1981, to examine the need for and feasibility of a Federal reservoir insurance and reinsurance program. On the basis of the report, Congress will determine whether to authorize a program of insurance or reinsurance against the risk of reservoir failure after investment of at least $1 million has been made in reservoir development and use. The direct insurance would be provided only where the developer could not obtain private insurance at reasonable premiums.

(4) Modification of Geothermal Loan Guaranty Program (GLGP). The law extends the life of the GLGP from 1984 to 1989 and provides an increased level of assistance under the program. Loan guarantees for loans to municipalities and public cooperatives will be increased from 75% to 90% of project costs. PL 96-294 also includes provisions to expedite processing of loan guarantees; such reforms include a four-month deadline for processing applications, requirements to give faster consideration to applicants for non-electric projects, and a requirement to eliminate duplicative Environmental Impact Statements under NEPA for loan guaranty applications.

(5) A provision requiring consideration of the use of geothermal energy in new Federal buildings or facilities in areas designated by DOE.

(6) New authorities under PURPA. The law explicitly includes geothermal facilities of 80 MWe or less in the small power producer category under the Public Utility Regulatory Policies Act (PURPA). Geothermal facilities qualifying as small power producers are eligible for interconnection, wheeling of power through grid transmission lines, exemption from The Federal Power Act and the Public Utility Holding Company Act and other utility orders as determined by FERC. The law also allows utility owned plants to qualify for these exemptions and for wheeling and interconnection. FERC has issued draft regulations (Nov. 6, 1980) which appear to fully implement this authority.

The latest considerations by the Federal government include federal leasing and permitting reforms, and several Federal geothermal leasing bills are under consideration by the Congress. They would increase acreage limitations, redefine KGRA's, require expedited leasing procedures, and require geothermal production goals for Federal lands. Bills passed both the House (HR6080) and the Senate (S1388) during 1980. Final passage during the lame duck session is possible but not very likely.

National Conference of State Legislatures
Geothermal Project Overview

by

K. Wonstolen
National Conference of State Legislatures

THE NATIONAL CONFERENCE OF STATE LEGISLATURES

Geothermal Project Overview

The principal objective of the NCSL Geothermal Project is to stimulate and assist state legislative action to encourage the efficient development of geothermal resources, including the use of groundwater heat pumps. The project has the following work tasks:

- Initiate state geothermal policy reviews
  --select target states
  --solicit legislative participation
  --arrange committee structure

- Provide technical assistance to state geothermal reviews
  --prepare background materials
  --analyze issues and options
  --prepare legislative proposals
  --conduct workshops/conferences
  --interact with executive agencies

- Liaison with geothermal community
  --assist other DOE geothermal contractors
  --interact with geothermal organizations/developers
  --publicize activities

- Project evaluation
  --monthly, quarterly and final reports
  --annual summary of state actions

Project states to which technical assistance has been provided are as follows:

DOE Region I	New Hampshire
DOE Region II	(none)
DOE Region III	Delaware Maryland Pennsylvania Virginia
DOE Region IV	South Carolina
DOE Region V	Wisconsin Minnesota
DOE Region VI	New Mexico
DOE Region VII	(none)
DOE Region VIII	Utah Wyoming
DOE Region IX	Hawaii Nevada
DOE Region X	Alaska Oregon Washington

For further information contact:

Ken Wonstolen
Senior Project Manager

National Conference of State Legislatures
1125 Seventeenth Street, Suite 1500
Denver, Colorado 80202
303/623-6600

Brookhaven
Geothermal District Heating Model

by

R. Leigh
A. Reisman
Brookhaven National Laboratory

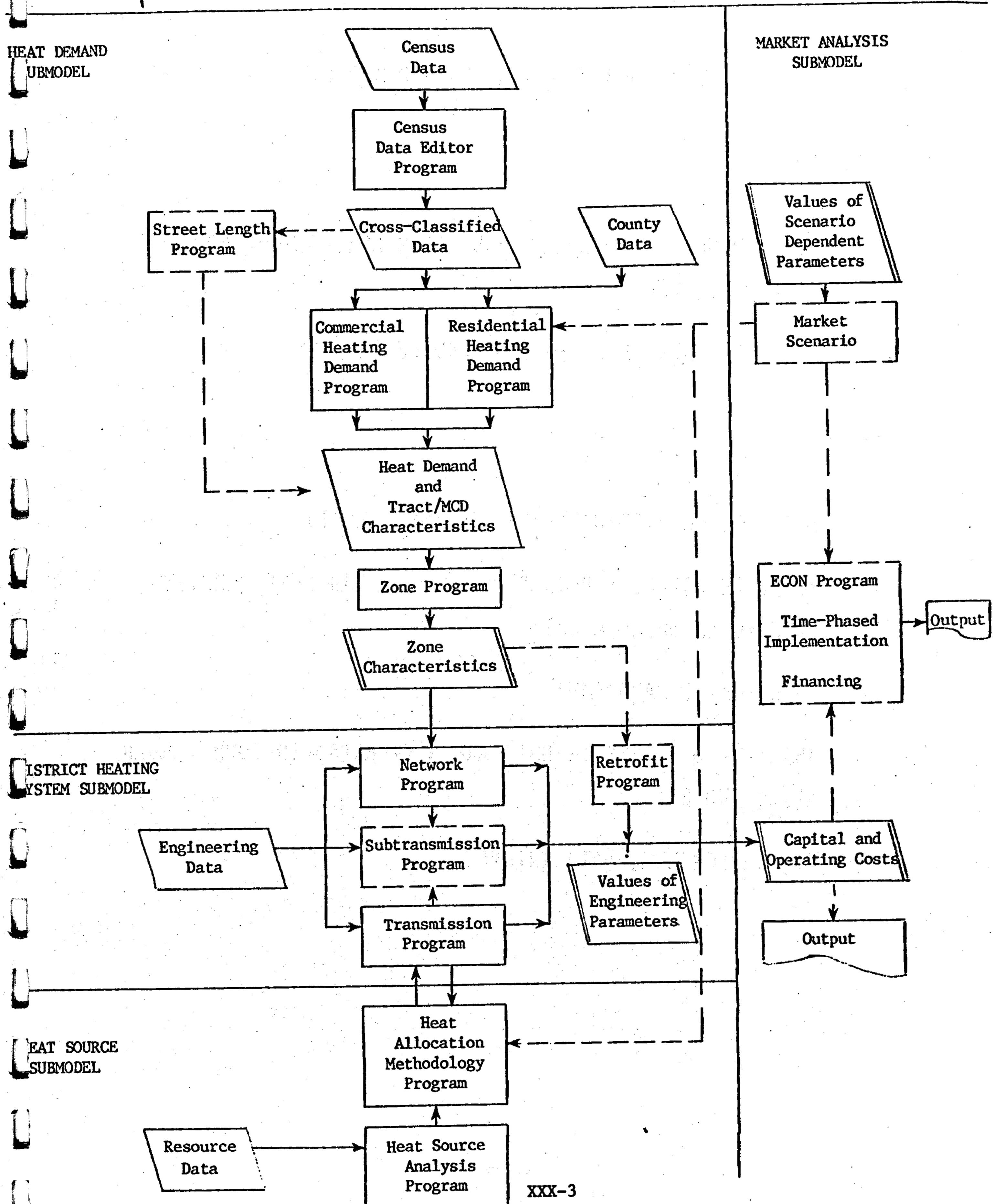
BROOKHAVEN GEOTHERMAL DISTRICT HEATING MODEL

RICHARD LEIGH
ANN REISMAN

November 6, 1980

Technology and Data Division
National Center for Analysis of Energy Systems
Department of Energy and Environment

DISTRICT HEATING MODEL



HEAT DEMAND SUBMODEL

PURPOSE:

- TO ESTIMATE ANNUAL SPACE AND WATER HEAT DEMAND FOR ANY U.S. COMMUNITY
- TO DEFINE DISTRICT HEATING SERVICE "ZONES"

REQUIREMENTS:

- SMALL GEOGRAPHIC UNIT AREA (CENSUS TRACT)
- TOTAL ANNUAL HEAT DEMAND (BTU/YEAR) AND HEAT DENSITY (BTU/YEAR/SQUARE MILE)
- PEAK HEAT DEMAND (MW)
- ABILITY TO AGGREGATE UNIT AREAS (TRACTS) TO FORM LARGER AREAS (ZONES)
- FAST, FLEXIBLE, DATA INTENSE

HEAT DEMAND METHODOLOGY

1. ESTIMATE LOCATION, NUMBER, AND TYPE OF BUILDINGS AT THE CENSUS TRACT LEVEL

RESIDENTIAL SECTOR
CLASSIFICATION (TRACT)

BUILDING SIZE HOUSEHOLDS/ STRUCTURE	ROOMS/ HOUSEHOLD	FUEL	HEATING EQUIPMENT
SINGLE FAMILY 1 - 4 FAMILY ATTACHED	1-4 5-6 7-8 9+	UTIL GAS L.P. GAS OIL ELECTRIC COAL, WOOD NONE	STEAM, HOT WATER HOT AIR ELECTRIC BASEBOARD OTHER
5-19 20 + MH TR	1-2 3-4 5-6 7+		

SOURCE: UNITED STATES 1970 CENSUS DATA.

2. APPLY HEAT DEMAND COEFFICIENTS

RESIDENTIAL SECTOR - SPACE HEAT DEMAND

A. SPACE HEAT FOR EACH RESIDENTIAL CATEGORY

$$HH \times SHDC \times HDD \times \frac{1}{BE} = SHD$$

B. TOTAL SPACE HEAT OVER ALL CATEGORIES

$$\sum SHD = TSHD$$

C. PEAK SPACE HEAT DEMAND

$$TSHD \times \frac{65 - DT}{HDD} = PSHD$$

D. SPACE FUEL DEMAND FOR EACH FUEL TYPE

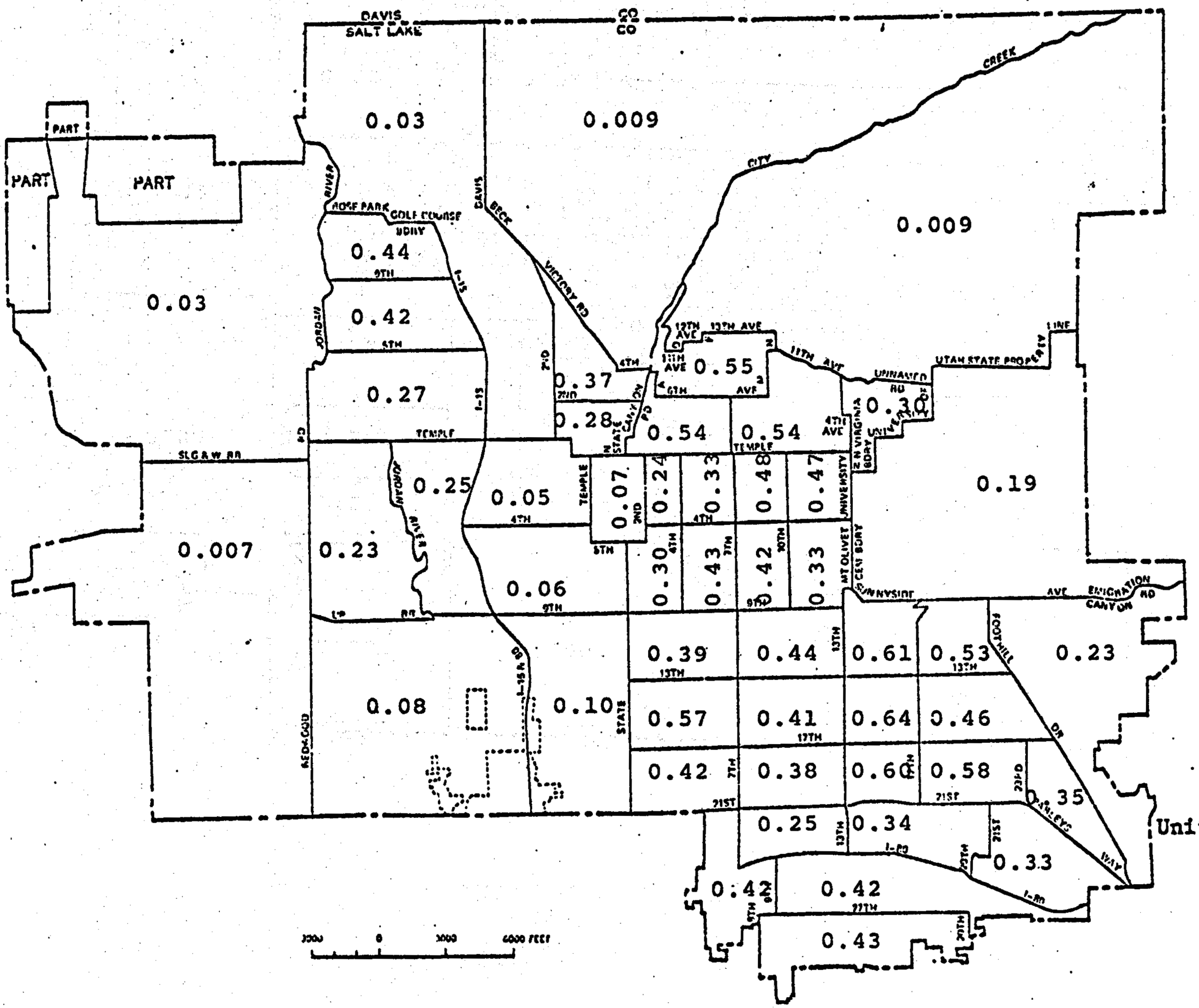
$$SHD \times \frac{1}{SFE} = SHFD$$

E. SPACE HEAT DEMAND DENSITY

$$TSHD \times \frac{1}{LA} = SHDD$$

SALT LAKE CITY, UTAH

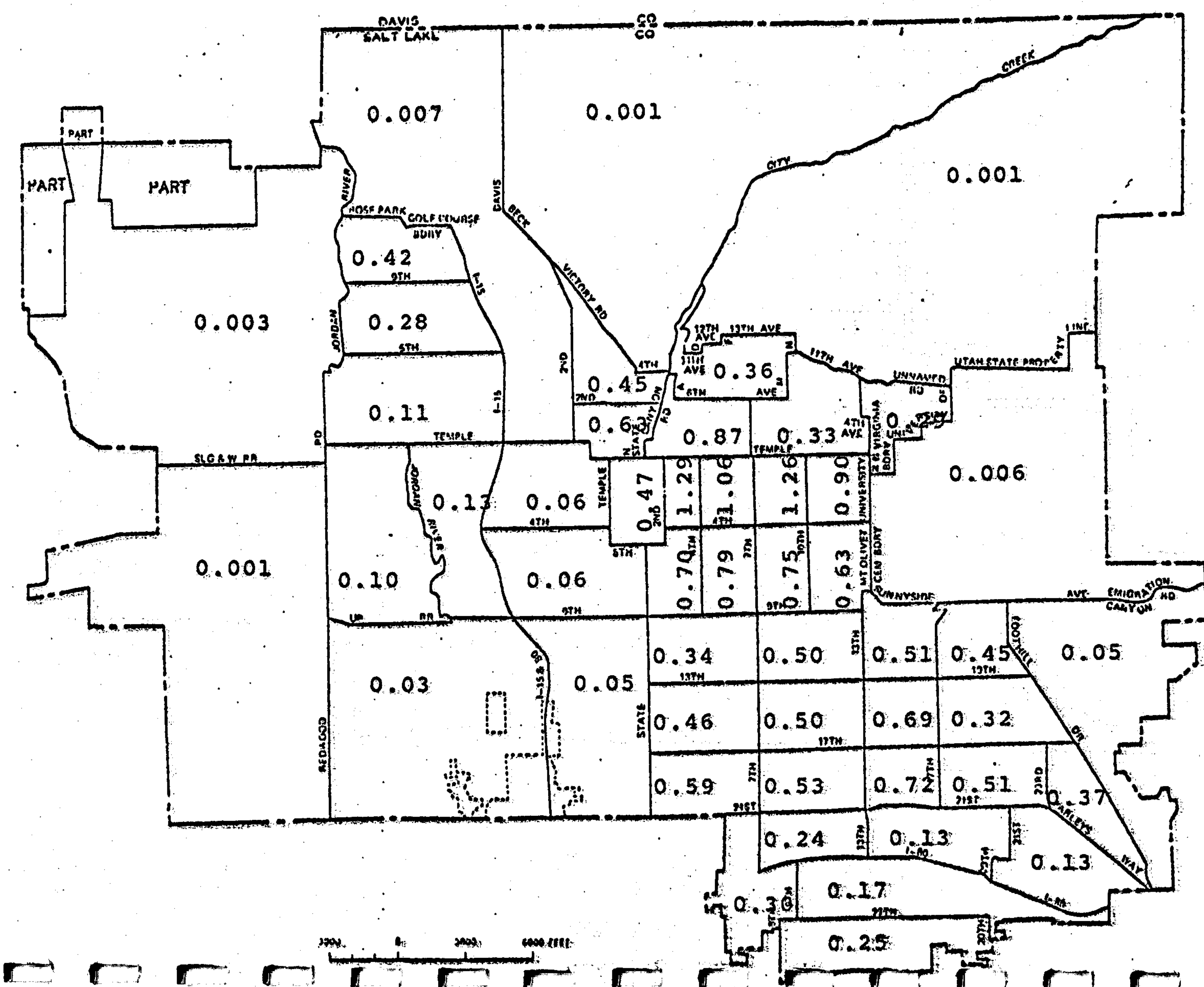
CENSUS TRACTS
RESIDENTIAL HEAT DEMAND DENSITY



Units: 10^{12} Btu/sq. mi.

SALT LAKE CITY, UTAH

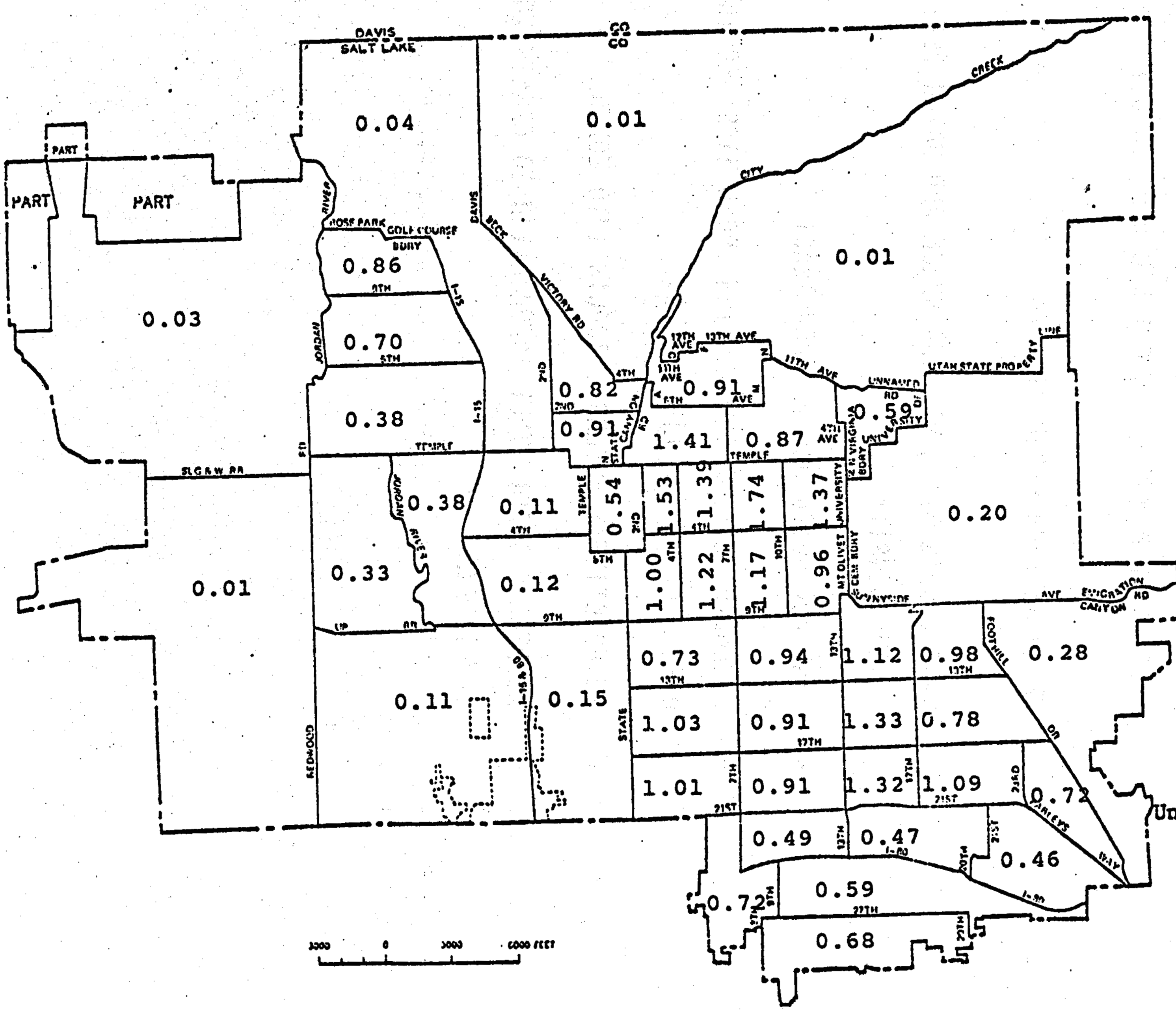
CENSUS TRACTS
COMMERCIAL HEAT DEMAND DENSITY



Units: 10^{12} Btu/sq. mi.

SALT LAKE CITY, UTAH

CENSUS TRACTS
TOTAL HEAT DEMAND DENSITY



Units: 10^{12} Btu/sq. mi.

6-XXX

HEAT DEMAND METHODOLOGY

3. DEFINE ZONES FROM CENSUS TRACTS

- RANK TRACTS BY DECREASING SPACE AND WATER HEAT DEMAND DENSITY
- LIST ALL NEIGHBORS OF EACH TRACT
- ASSEMBLE OUTSIDE INFORMATION (ROAD MAPS, ZONING MAPS, COLD WATER LINES, ETC.)
- INTERACTIVELY ASSEMBLE TRACTS INTO ZONES
- AGGREGATE TRACT LEVEL INFORMATION TO CREATE ZONE LEVEL DATA

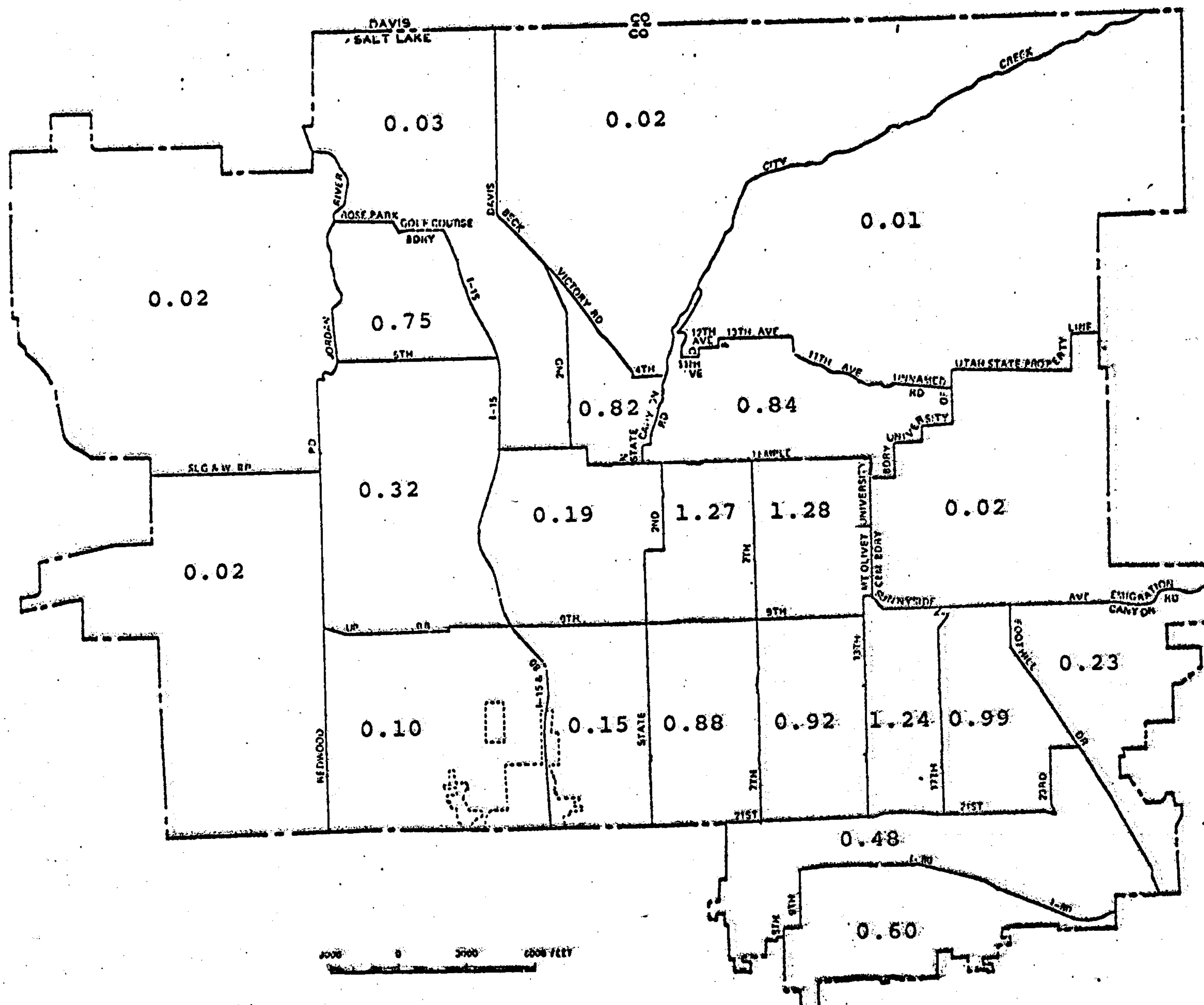
H E A T   D E M A N D   M E T H O D O L O G Y

OUTPUT:

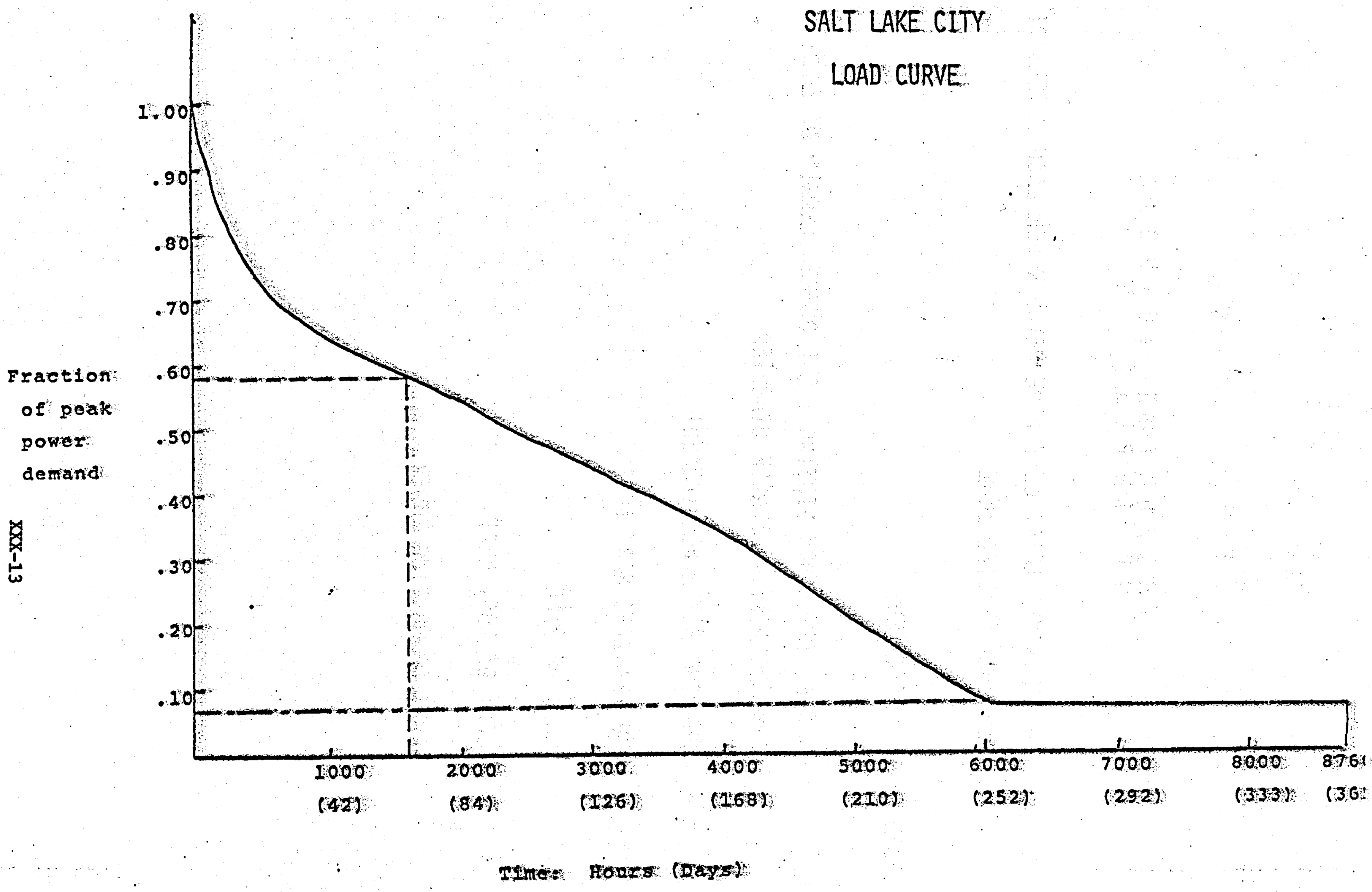
- CANDIDATE DISTRICT HEATING ZONES DEFINED AT A SMALL AREA BASIS
- ZONE CHARACTERISTICS SUMMED FROM CENSUS DATA
- ANNUAL SPACE AND WATER HEAT DEMAND BY ZONE (REQUIRED BY HEAT SOURCE SUBMODEL)
- PEAK SPACE AND WATER HEAT DEMAND BY ZONE (REQUIRED BY DISTRICT HEATING SYSTEM SUBMODEL)

SALT LAKE CITY, UTAH

HEATING ZONES
TOTAL HEAT DEMAND DENSITY



Units: 10^{12} Btu/sq. mi.


SALT LAKE CITY
LOAD CURVE
Fraction of peak power demand
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
1000 (42)
2000 (84)
3000 (126)
4000 (168)
5000 (210)
6000 (252)
7000 (292)
8000 (333)
Time: Hours (Days)

DISTRIBUTION NETWORK OPTIMIZATION

PURPOSE: TO SPECIFY A LEAST COST PIPE NETWORK FOR EACH POTENTIAL DISTRICT HEATING ZONE

QUANTITIES ESTIMATED:

- A PIPE INVENTORY LISTING THE REQUIRED LENGTH AT EACH COMMERCIALLY AVAILABLE DIAMETER
- PUMPING POWER REQUIREMENT
- SUPPLY LINE HEAT LOSS
- COST OF PIPE
- COST OF LOST HEAT
- COST OF PUMPING POWER

COST OF PIPE DISTRIBUTION SYSTEM

APPROACH:

$$COST_{PIPE} = COST_{MATERIALS} \cdot \alpha_M + COST_{LABOR} \cdot \alpha_L \cdot \beta$$

α_M = MATERIALS SCALE FACTOR

α_L = LABOR SCALE FACTOR

β = LAND USE INTENSITY FACTOR

METHODOLOGY:

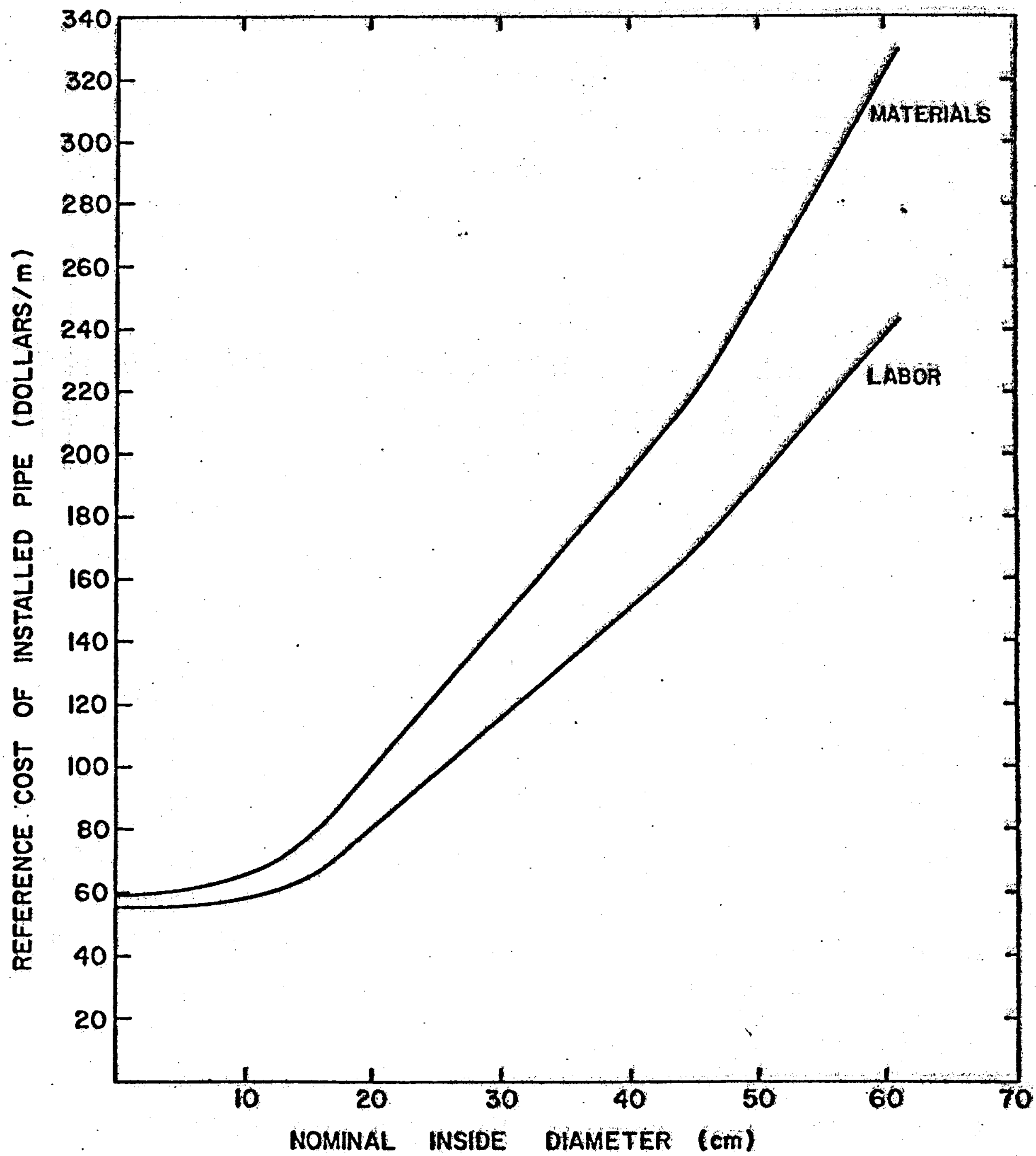
1. SURVEY MADE OF ACTUAL INSTALLATION OF COLD WATER OR GAS MAINS IN A LARGE NUMBER OF CITIES.

2. COSTS DISAGGREGATED INTO MATERIALS AND LABOR, THEN FURTHER BROKEN INTO ITEMS RELATED TO PIPE OR TO LAND-USE INTENSITY.

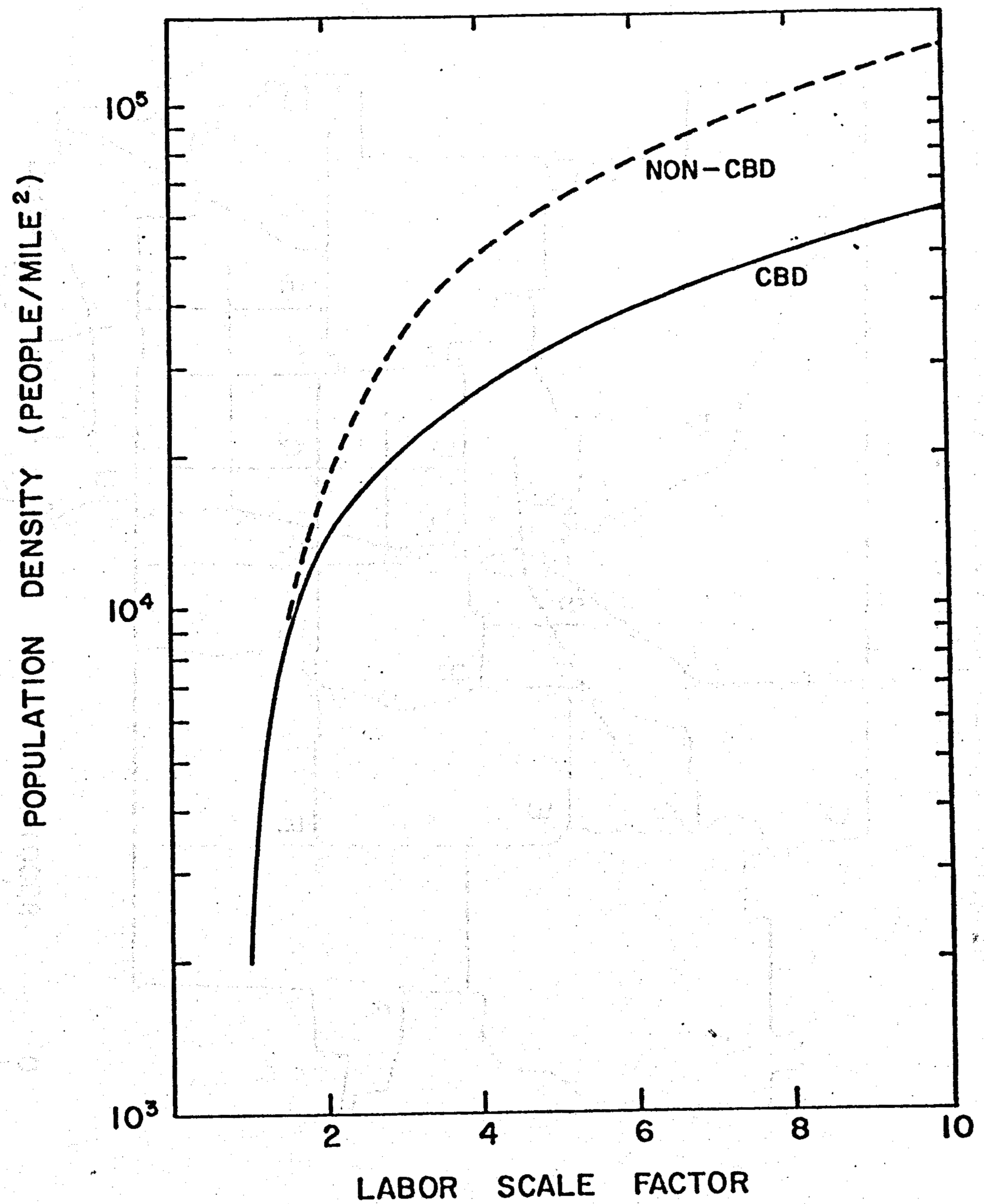
3. COST NORMALIZED TO 1978 BOSTON RATES. BY EXAMINATION OF LABOR COSTS VS. POPULATION DENSITY A LAND USE INTENSITY FACTOR IS DETERMINED ($1 \leq \beta$) FOR ANY POPULATION DENSITY AND LAND USE TYPE, I.E, CBD, NON-CBD.

4. A REFERENCE PIPE DESIGN IS COSTED AT BOSTON RATES. THIS DESIGN REPRESENTS THE LOWEST COST TO INSTALL THE REFERENCE PIPE SYSTEM.

5. FOR A SPECIFIC SITE, MATERIALS AND LABOR COSTS ARE ADJUSTED BY SCALE FACTORS. LAND USE INTENSITY FACTOR IS APPLIED TO LABOR. ADJUSTED COSTS ARE SUMMED.

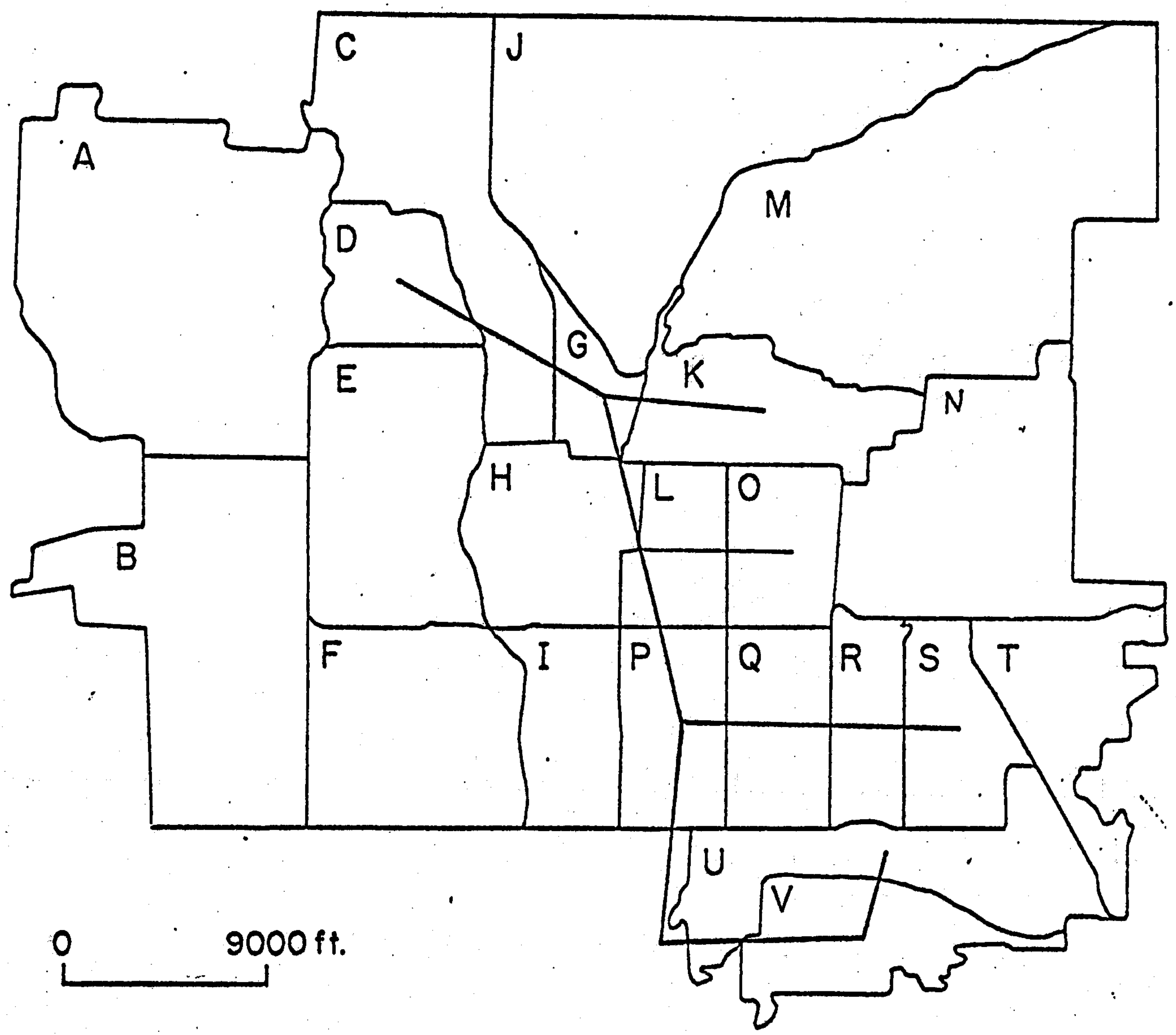


340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
10
20
30
40
50
60
70
MATERIALS
LABOR
REFERENCE COST OF INSTALLED PIPE (DOLLARS/m)
NOMINAL INSIDE DIAMETER (cm)



10⁵
10⁴
10³
POPULATION DENSITY (PEOPLE/MILE²)
NON-CBD
CBD
2
4
6
8
10
LABOR SCALE FACTOR

HEATING ZONES AND SUBTRANSMISSION LAYOUT
FOR SALT LAKE CITY



GEOTHERMAL HEAT DELIVERY OPTIMIZATION

PURPOSE: TO CALCULATE THE OPTIMAL NUMBER OF WELLS AND THE TRANSMISSION PIPE CHARACTERISTICS WHICH WILL MINIMIZE THE COST OF DELIVERED HEAT

QUANTITIES ESTIMATED:

GEOTHERMAL HEAT SOURCE ANALYSIS

- WELL DEPTH
- EXPECTED FIELD LIFETIME
- MAXIMUM NUMBER OF WELLS
- TRANSMISSION PIPE LENGTH
- OPTIMUM HEAT EXCHANGER ΔT
- HEAT EXCHANGER AREA

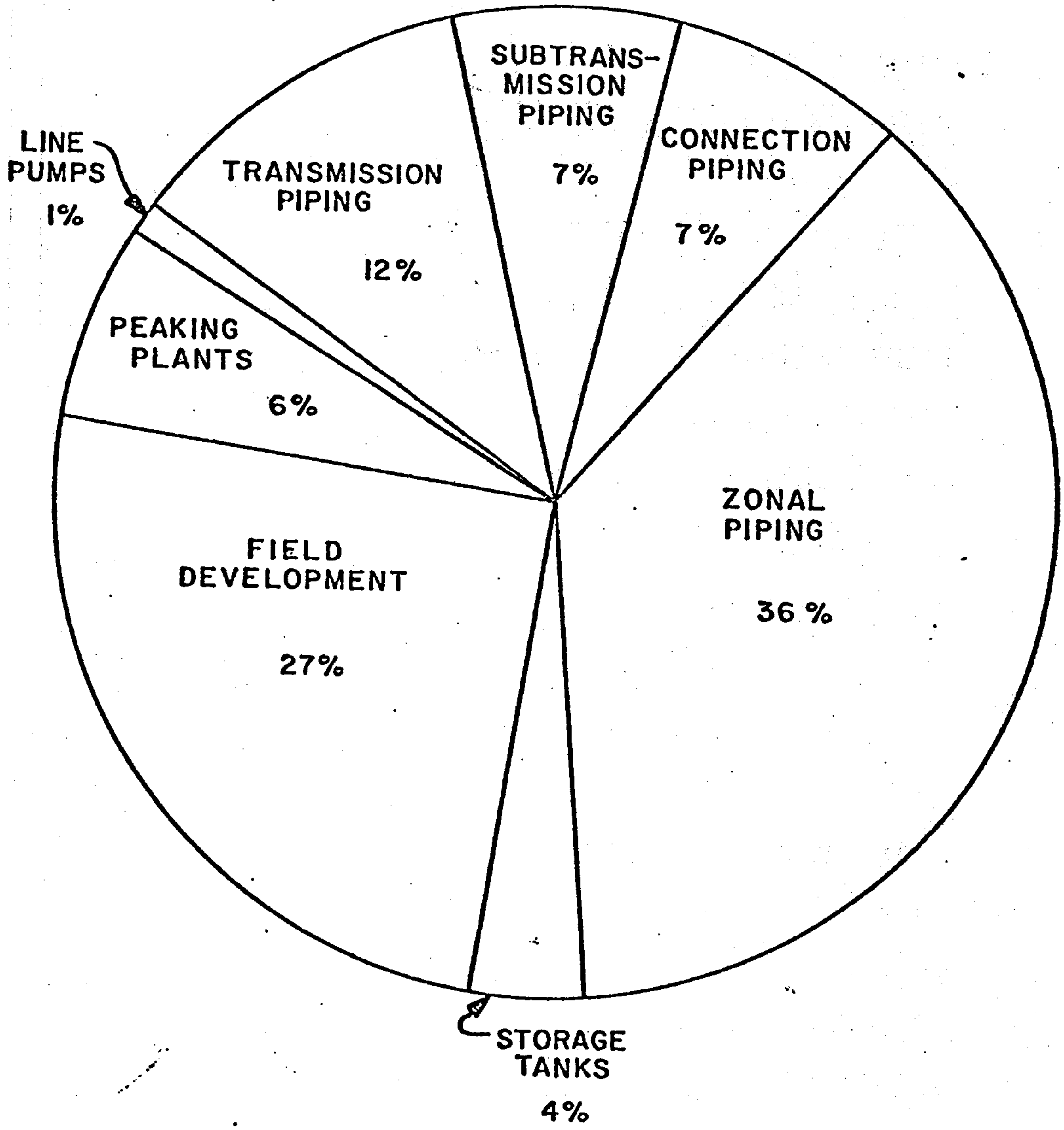
HEAT ALLOCATION

- OPTIMUM NUMBER OF WELLS
- HEAT SALES FROM THE FIELD
- PEAK HEAT RATE FROM THE FIELD
- PEAKER CAPACITY
- HEAT PRODUCTION COST

TRANSMISSION

- OPTIMUM TRANSMISSION DIAMETER
- OPTIMUM TRANSMISSION FLOW VELOCITY
- TRANSMISSION LINE PUMPING POWER
- TRANSMISSION LINE HEAT LOSS
- HEAT DELIVERY COST

CAPITAL COST BREAKDOWN
SALT LAKE CITY



TYPICAL ESTIMATED HEAT COST COMPONENTS FOR LARGE GEOTHERMAL DISTRICT HEATING SYSTEMS (1978 DOLLARS PER GIGAJOULE)	
CAPITAL	
PIPING (30 YEAR AMORTIZATION)	1.63
PUMPS (20 YEAR AMORTIZATION)	.02
PEAKERS AND STORAGE (30 YEAR AMORTIZATION)	.20
FIELD DEVELOPMENT (20 YEAR AMORTIZATION)	.73
OPERATING	
PUMPING ENERGY	.35
PEAKER FUEL (OIL)	.19
MISCELLANEOUS	
ENGINEERING AND CONTINGENCY	.62
ADMINISTRATION AND MAINTENANCE	.26
TOTAL	$4.00

TYPICAL ESTIMATED CAPITAL COSTS FOR LARGE GEOTHERMAL DISTRICT HEATING SYSTEMS (1978 DOLLARS PER THERMAL KILOWATT)		
PIPING		
DISTRIBUTION	139.0	
SUBTRANSMISSION	19.2	
TRANSMISSION	30.7	
CONNECTION	19.7	
	SUBTOTAL	208.6
LINE PUMPS		
DISTRIBUTION	1.7	
TRANSMISSION	0.44	
	SUBTOTAL	2.14
HEAT PRODUCTION		
FIELD DEVELOPMENT	79.4	
PEAKERS	17.1	
STORAGE	9.1	
	SUBTOTAL	105.6
BUILDING RETROFIT	57.0	
	TOTAL	373.34

The Geothermal Progress Monitor Project

by

D. J. Entingh
B. Walker
The MITRE Corporation

XXXI

The Geothermal Progress Monitor Project
Status and Directions

Daniel J. Entingh
Beth Walker
The MITRE Corporation
McLean, VA 22102

10 October 1980

ABSTRACT

The Geothermal Progress Monitor (GPM) project exists to inform government and industry officials about the general pace of geothermal development. Starting in July 1979, the project has developed a network of information sources and analysts that cover a variety of topics related to industrialization of the U.S. hydrothermal resources. A good base of information has been developed for some major topics and four reports have been published. Future reports will focus on greater depth about individual projects and more analysis of the pace and problems of geothermal developments in general.

The purpose of the Geothermal Progress Monitor (GPM) project is to assemble and analyze the major facts about U.S. geothermal development in order to provide government and industry officials within the useful overview. The project is funded by the Division of Geothermal Energy, DOE.

The GPM project has been active at MITRE since July 1979. The effort includes coordination with existing DOE contact points with the geothermal industry (e.g., Applied Physics Laboratory; EG&G, Idaho Falls; Oregon Institute of Technology; and the University of Utah Research Institute), State Resource Teams, State Industrialization Teams, and member federal agencies of the Interagency Geothermal Coordinating Council. Much of the initial work has focused on obtaining information from existing government databases and commercial information services.

During the first year of the GPM project, we have identified many of the major information sources and have established good information files on the following topics: (1) Deep geothermal wells, (2) Existing and planned electric plants, (3) Locations of existing and planned direct heat projects, (4) Details of government-aided direct heat projects and feasibility studies, (5) Status of federal geothermal loan guaranties, and (6) Leasing of federal lands for geothermal production. We have published an analysis of the amount of federal land that needs to be leased to support the attainment of the Interagency Geothermal Coordinating Council goals for geothermal energy production. We have begun a detailed analysis of the status of development at all of the high temperature Known Geothermal Resource Areas.

In a number of topical areas our early hopes for rapid analyses have been thwarted. In these areas we have found the available information to be either sparse or unevaluated to a degree that precludes drawing useful inferences. Geothermal thermal gradient holes are one example. We had hoped in mid-1979 that reports of the drilling of these holes would be a useful indicator of the pace and location of geothermal exploratory work. We have found records of about 300 thermal gradient holes drilled over the past five years, compared to about 300 deep production-oriented geothermal wells drilled in the same period. We are sure, for a number of reasons, that our 300 gradient hole records represent but a limited fraction of all such wells drilled in the period. While our records do indicate exploratory or step-out interest in certain geographical areas, we are unable to conclude anything about the general pace of such drilling.

Similar situations pertain with respect to details about many existing and announced direct heat projects, preleasing environmental assessments for federal lands, the status of state geothermal laws, and patterns of investment in geothermal energy development. Enough information has surfaced to suggest important developments, but there is not enough information readily available to draw useful conclusions.

During the next year we will attempt to make the GPM effort more analytical and investigative. We believe that one of the most important needs is more detail about private sector direct heat projects. Another is to determine what can be done with the information that arises from environmental assessments.

We believe that the next three to five years is a very important period for both geothermal electric and direct heat growth. Industry will watch the current projects closely to determine the conditions that make geothermal systems good investments. Governments will be evaluating the pace of development to ascertain whether the current mix of incentives is appropriate for geothermal growth. We believe and hope that the Geothermal Progress Monitor effort will help both of these groups of decision makers gain a clearer picture of the major facts and issues of geothermal development.

EXPLANATIONS OF PRESENTED SLIDES

FIGURE 1. The Geothermal Progress Monitor effort involves many contributors, most of whom have substantive roles in geothermal energy development.

FIGURE 2. This diagram shows major routes for tasking and information flow in the GPM system.

FIGURE 3. This diagram amplifies Figure 2.

FIGURE 4. The technical areas that form the "Table of Contents" of the GPM Reports.

FIGURE 5. This diagram shows MITRE's estimate of the amount and general validity of the information on hand after about one year of operation. Indicators of exploration activity constitute the largest gap in the current data base.

FIGURE 6. To amplify the baseline data about direct heat commercialization, we would like to assemble these items for each major active and proposed direct heat project in the U.S.

FIGURE 7. Information sources for direct heat projects are shown here. Projects with DOE involvement are covered pretty well. The information about other projects is less adequate, and will require significant new data collection efforts during the next few months.

XXXI-5

GEOTHERMAL PROGRESS

MONITOR

MITRE - OCTOBER 1980

CURRENT IMPLEMENTATION OF GEOTHERMAL PROGRESS MONITOR

DGE HEADQUARTERS

- System Requirements
- Supply Information
- Validate Information
- Official Channel for Acquiring Information
- Review and Publish Reports
- Request and Use Trend Analyses

MITRE

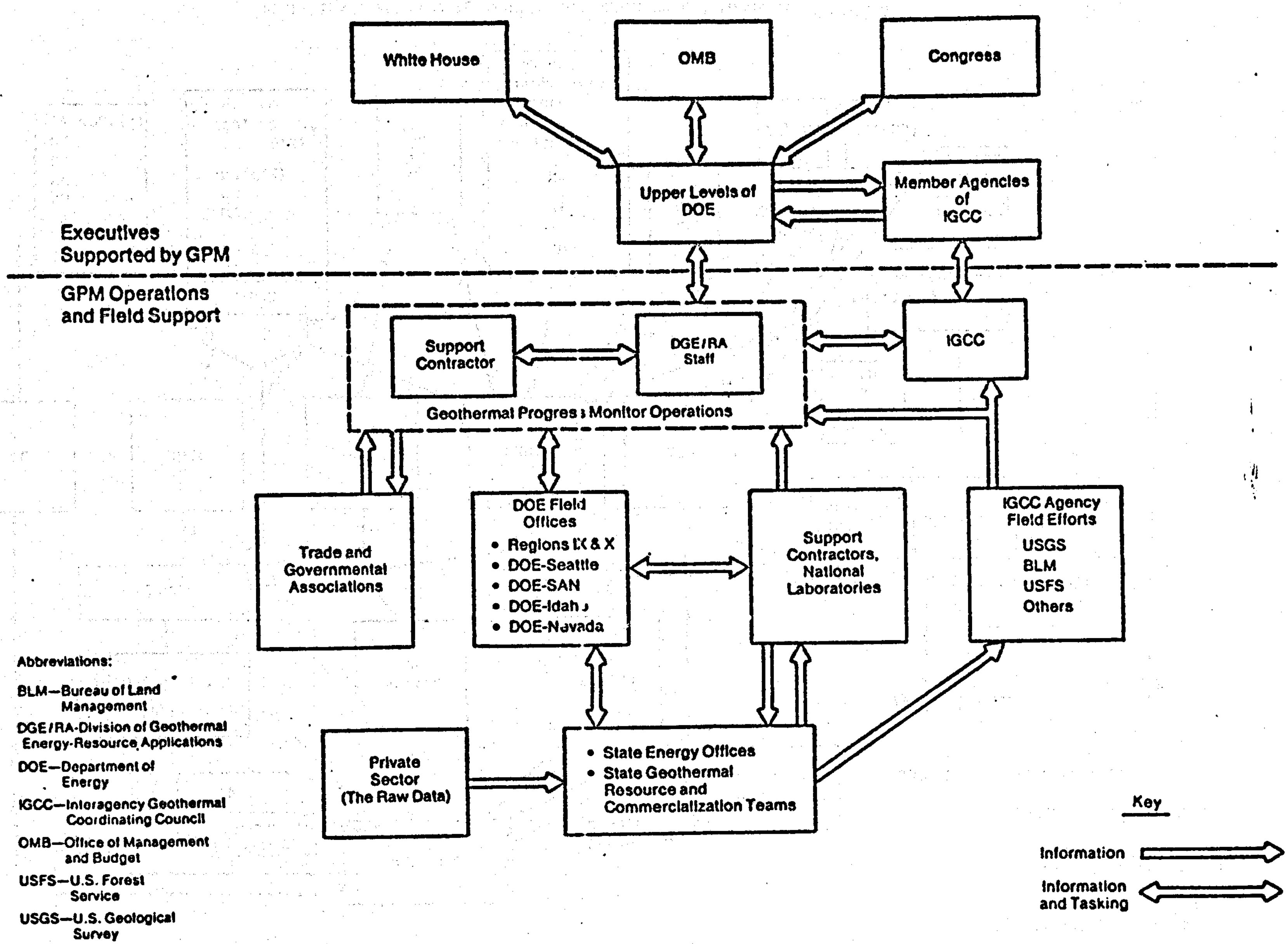
- System Design and Documentation
- Collect Information
- Validate Information
- Establish Manual and Automated Files
- Organize and Prepare Reports
- Suggest and Perform Trend Analyses

DOE REGIONAL OFFICES AND STATE TEAMS

- Monitor the Field
- Maintain Deep/Detailed Knowledge of Field Activities
- Report Events
- Update Status Information
- Help Analyze Significance of Trends

OTHER AGENCIES

- USGS - Report Site Physical Data
  - Report Leasing Events and Status (BLM, USGS)
- EPA - Report Environmental Assessment Results
- NCSL - Report State Legislative Status and Events
- DOD - Progress at Coso, Ca. Site



GEOTHERMAL PROGRESS MONITOR SYSTEM

KEY

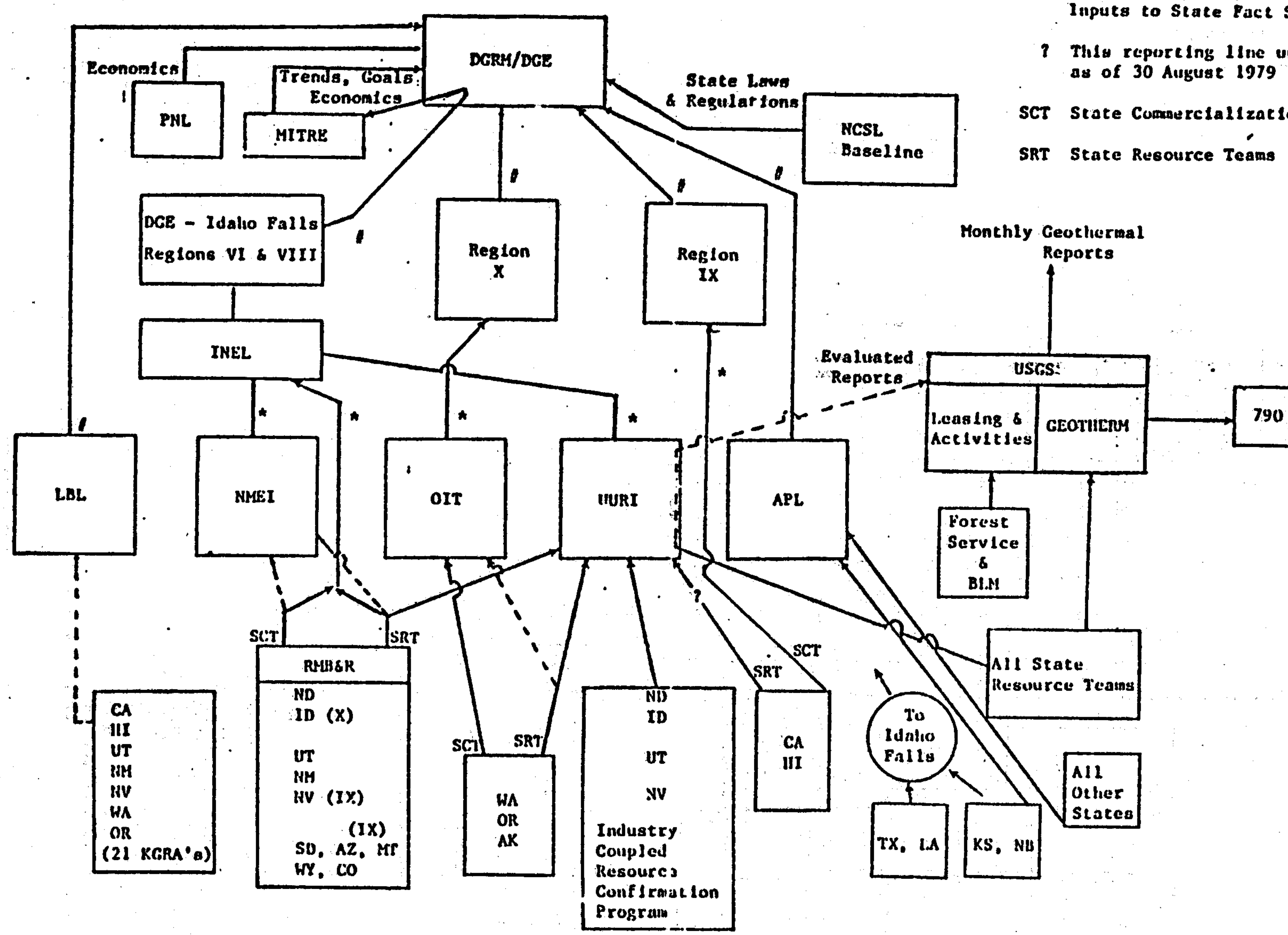
Activity Reports, State Fact Summaries (Books or Sheets)

* Activity Reports, Status Reports, Inputs to State Fact Summaries

? This reporting line uncertain as of 30 August 1979

SCT State Commercialization Teams

SRT State Resource Teams

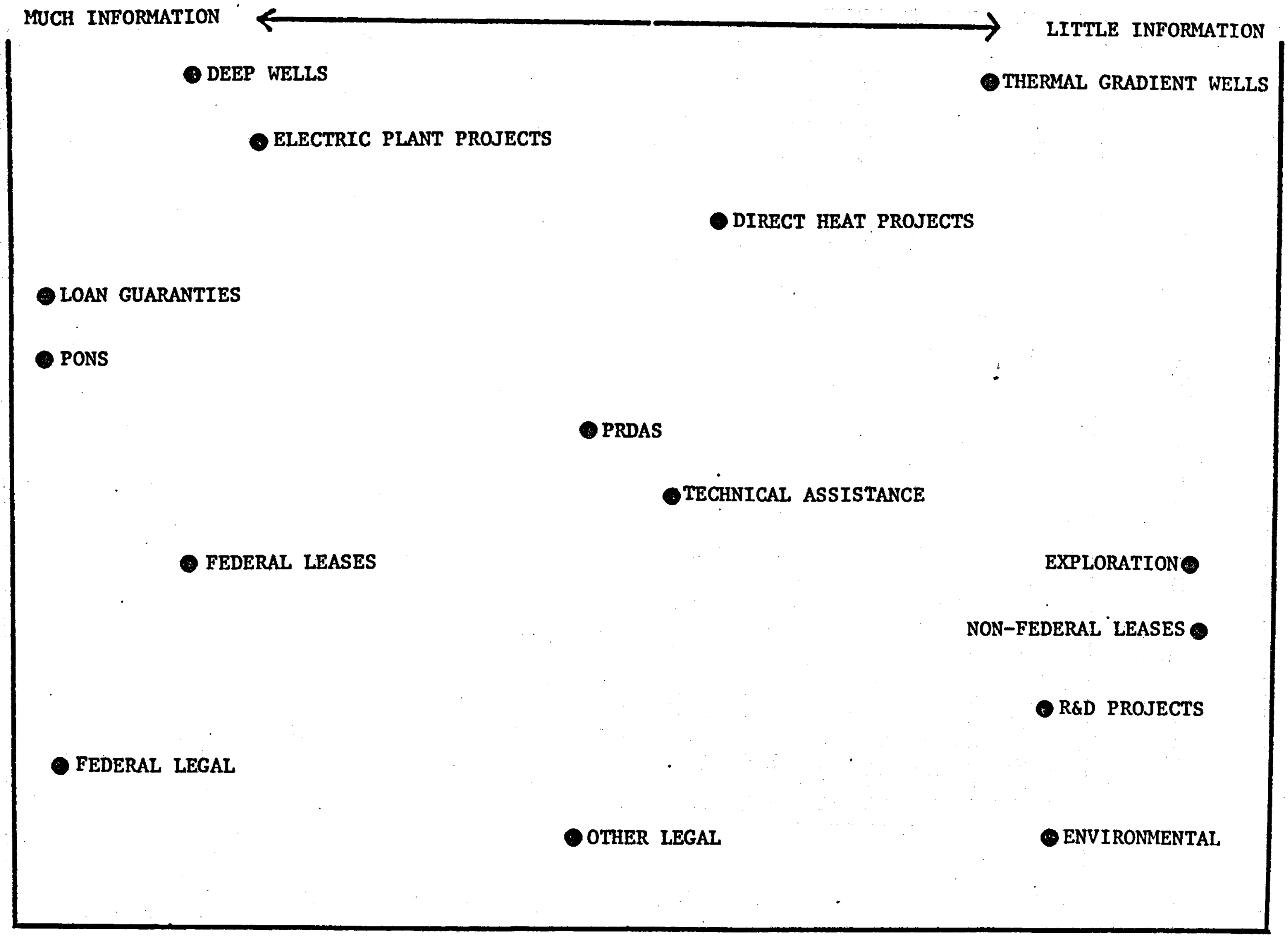


PRELIMINARY FLOW CHART OF EXISTING GEOTHERMAL INFORMATION NETWORKS

GEOTHERMAL PROGRESS MONITOR: TECHNICAL AREAS COVERED

- Electrical Uses
- Direct Heat Uses
- Drilling Activities
- Exploration
- Leases
- Outreach and Technical Assistance
- Feasibility Studies and Application Demonstrations
- Geothermal Loan Guarantee Program (GLGP)
- General Activities
- R&D Activities
- Legal, Institutional and Regulatory Activities
- Environmental Activities
- State, Local and Private Sector Activities
- Reports and Publications
- Directory

GEOTHERMAL PROGRESS MONITOR
TECHNICAL AREAS COVERED



DIRECT HEAT PROJECTS

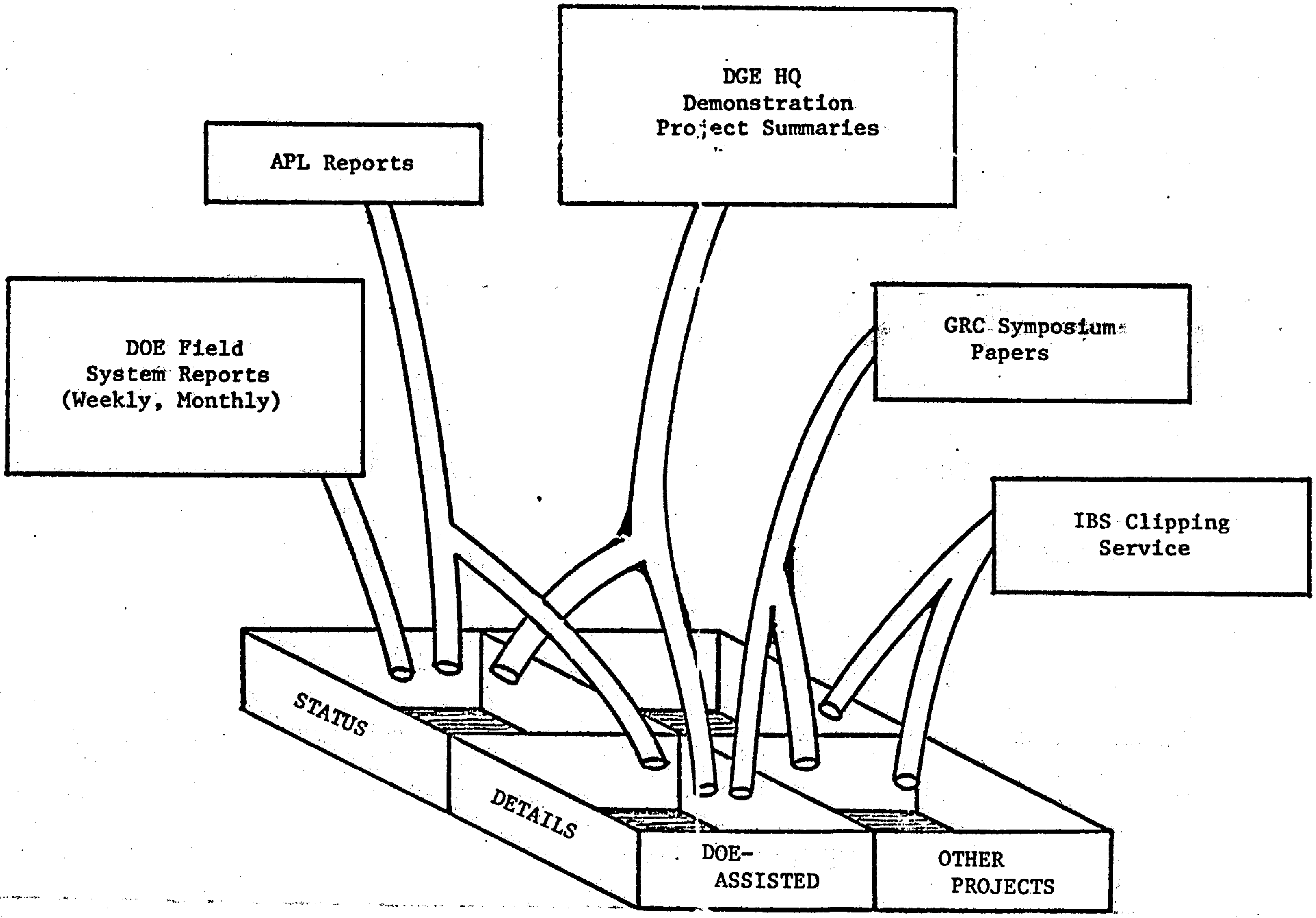
STATUS

- Initial Interest
- Feasibility Study
- Financing
- Design
- Drilling
- Construction
- Operation

DETAILS

- Participants
- Location
- Costs
- Temperature
- Depth, Flow
- Annual Energy (BTU)
- Utilization Factor

FLOW OF DIRECT HEAT INFORMATION
INTO GEOTHERMAL PROGRESS MONITOR SYSTEM



USGS Low-Temperature Geothermal Resource Assessment of the United States

by

Marshall Reed
U. S. Geological Survey, Menlow Park, CA

and

Charles Bufe
U. S. Geological Survey, Reston, VA

USGS Low-Temperature Geothermal Resource Assessment of the United States

by Marshall Reed[1/] and Charles Bufe[2/]

Abstract

The U.S. Geological Survey (USGS) is the lead agency for national assessment of geothermal resources. Despite a massive (25 percent) reduction in its geothermal program in FY (fiscal year) 1981, the USGS has made a major commitment to provide the Federal Geothermal Program with a national assessment of low-temperature geothermal resources. The assessment probably will be completed in FY 1981, and the report should be compiled in FY 1982. The assessment effort will be facilitated by DOE (U.S. Department of Energy) support in FY 1981 and will draw heavily on the data base provided by the State teams through the DOE Division of Geothermal Energy's State-Coupled Program.

[1/] U.S. Geological Survey, Menlo Park, CA
[2/] U.S. Geological Survey, Reston, VA

USGS Geothermal Research Program

A description of the USGS Geothermal Research Program was provided by Kover (1979) at the 1979 Conference on Geothermal Energy and the Eastern U.S., Berkeley Springs, West Virginia. The program is continuing in FY 1981 at a reduced level (see Figure 1). The reduction in program funding is especially apparent when it is expressed in 1972 dollars (see lower curves in Figure 1). As a result of the 25-percent budget cut, the extramural part of the USGS Geothermal Research Program has been terminated. In-house research has also been cut back along a broad front. Despite the reduced FY 1981 geothermal research budget, the USGS, with support from Division of Geothermal Energy (DGE), U.S. Department of Energy, is embarking on a major effort to assess the Nation's low-temperature geothermal resources.

National Low-Temperature Geothermal Resource Assessment

The U.S. Geological Survey is presently conducting a Low-Temperature Geothermal Resource Assessment of the United States, including Alaska and Hawaii. The assessment is a Survey-wide effort.

The Low-Temperature Geothermal Resource Assessment of the United States will present an estimate of the energy available from hot water resources between 10^{o}C above ambient temperature and 100^{o}C. The objective is to assess the amount of energy recoverable at the surface of the earth, considering such factors as reinjection and natural recharge. In USGS high-temperature geothermal resource assessments by Nathenson and Muffler (1975 in USGS Circular 726) and Brook and others (1979 in USGS Circular 790) a recovery factor of about 25 percent was used to estimate the geothermal energy producible at the well head in a hot water system. However, Sammell (1979, in Circular 790) did not attempt to quantify the recoverable energy for low-temperature waters.

The assessment is limited to a depth of 2 km by economic and observational limitations - extrapolation is required to assess conditions even at this depth in most regions.

The approach will be site specific, and a multivariant analysis incorporating geologic characteristics will be used to estimate the undiscovered resource. The discovered (or identified) resource is that for which characteristics such as temperature or permeability are determined from well or spring data. Data on temperature, flow rate (of wells and springs), water chemistry, and rock permeability are analyzed to determine the energy recoverable at the surface. Geologic models are being prepared for several types of low-temperature geothermal systems and will be applied in the assessment of each known system. The GEOTHERM data file (Swanson, 1977) is the repository for pertinent information from the DGE State Coupled-Program (Brophy, 1979) and from the USGS Regional Aquifer Program (Bennett, 1979) and will provide the basis for analysis of geothermal sites. An advisory panel has been established to provide independent review of the methodology devised for this assessment.

The schedule provides for completion of the assessment late in FY 1981, and publication in FY 1982.

References

Bennett, G. D., 1979, The Regional Aquifer System Analysis Program in Geothermal Energy and the Eastern U.S., Applied Physics Laboratory Report QM-79-261, p. XXIX1-2.

Brook, C. A., Mariner, R. H., Mabey, D. R., Swanson, J. R., Guffanti, M., and Muffler, L. J. P., 1979, Hydrothermal convection systems with reservoir temperatures $\geq 90^{\circ}C$, in Muffler, L. J. P., ed., Assessment of geothermal resources of the United States -- 1978: U.S. Geological Survey Circular 790, p. 18-85.

Brophy, J., 1979, Summary description of the DOE/DGE State Coupled Program, in Geothermal Energy and the Eastern U.S., Applied Physics Laboratory Report QM-79-261, p. III1-9.

Kover, A. N., 1979, The U.S. Geological Survey's Geothermal Research Program, in Geothermal Energy and the Eastern U.S., Applied Physics Laboratory Report QM-79-261, p. XI1-5.

Nathenson, Manuel, and Muffler, L. J. P., 1975, Geothermal resources in hydrothermal convection systems and conduction-dominated areas, in White, D. E., and Williams, D. L., eds., Assessment of geothermal resources of the United States -- 1975: U.S. Geological Survey Circular 726, p. 104-121.

Sammell, E. A., 1979, Occurrence of low-temperature geothermal waters in the United States, in Muffler, L. J. P., ed., Assessment of geothermal resources of the United States -- 1978: U.S. Geological Survey Circular 790, p. 86-131.

Swanson, J. R., 1977, GEOTHERM data file, in Geothermal -- State of the art: Geothermal Resources Council Transactions, v. 1, p. 285-286.

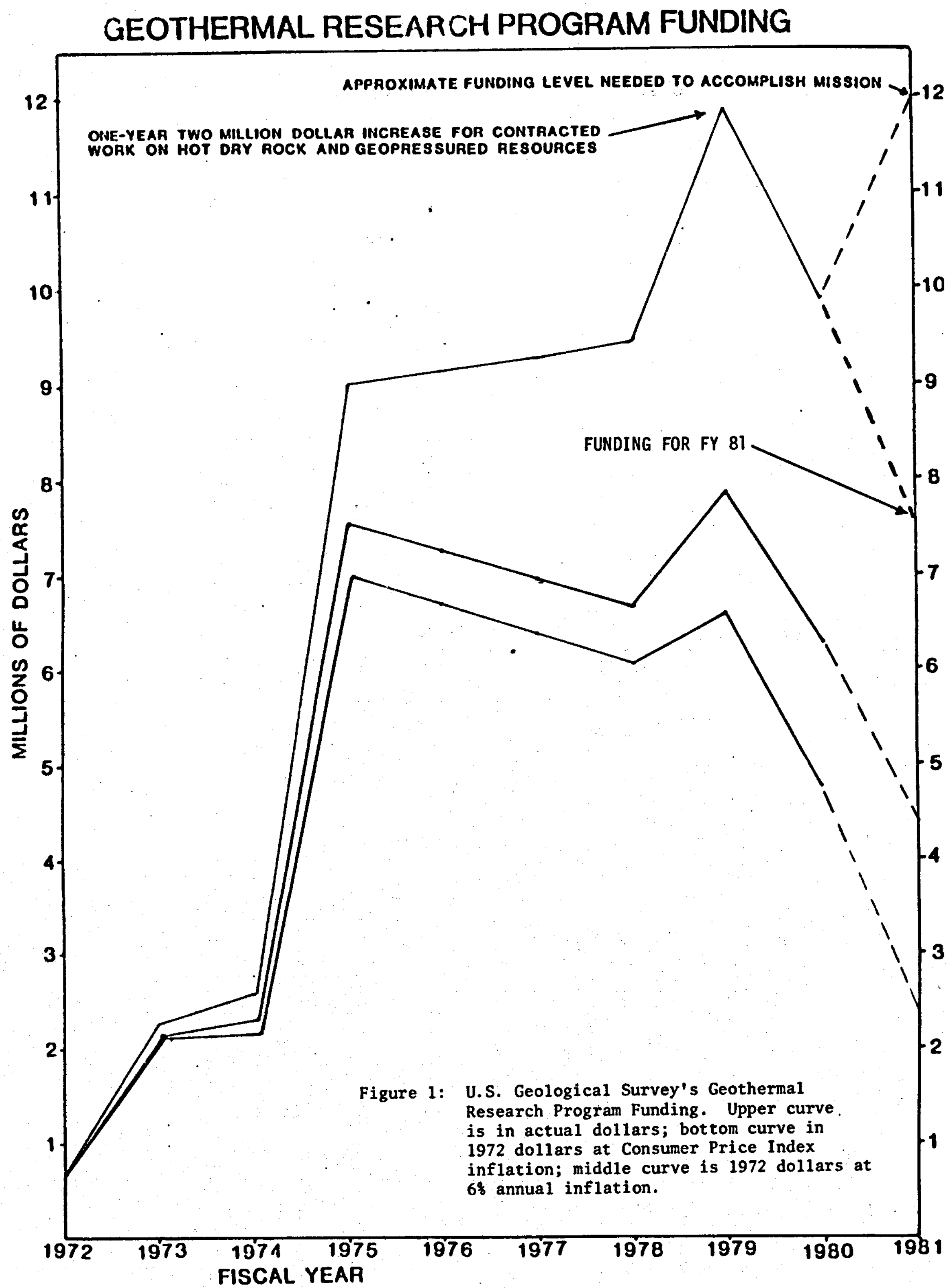


Figure 1: U.S. Geological Survey's Geothermal Research Program Funding. Upper curve is in actual dollars; bottom curve in 1972 dollars at Consumer Price Index inflation; middle curve is 1972 dollars at 6% annual inflation.

U.S. Geological Survey
Regional Aquifer Program*

by

G. Bennett
U.S. Geological Survey

*Mr. Bennett presented material that restated and updated material given at the 1979 meeting. That presentation was printed in the minutes of the Technical Information Interchange Meeting, Berkeley Springs, W. Va., JHU/APL QM-79-261, Dec 1979.

National Geothermal District Heat Market Penetration Estimate

by

D. J. Entingh
The MITRE Corporation

XXXIV

NATIONAL GEOTHERMAL DIRECT HEAT MARKET PENETRATION ESTIMATE

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15 October 1980

ABSTRACT

Market size and market penetration of hydrothermal direct heat use in three regions was estimated. The results suggest that year-2000 direct heat use will be small, about 0.04 quads/year, unless significant new initiatives occur in the 1981-1985 period.

We have made an analysis and forecast of hydrothermal moderate temperature (50°C - 150°C) direct heat market size and market penetration for the U.S. in the period 1980-2020. The purpose of the study was to estimate a reasonable upper bound for hydrothermal direct heat market penetration, assuming generally favorable industrialization conditions.

The analysis is disaggregated into three regions: Pacific, Rocky Mountain Basin and Range (RMB&R), and Eastern. Texas and Louisiana were omitted because we expect their contribution will be dominated by the development of geopressured resources, which fall outside of the scope of this study.

The results suggest that hydrothermal direct heat market penetration will be relatively small (about 0.2 to 0.4 quads/year end use in 2020) unless new large-scale stimulatory actions are undertaken. Installation of additional projects totalling an end use of 0.010 quads/year by 1985 would elevate the year 2020 end use to about 0.4 to 0.10 quads/year. Such an initiative would entail a government cost of about $95 million To $130 million (1980$).

The maximum resource-colocated market is about 1.5 quads/year in 2020. The maximum resource-noncolocated market is about 2.2 quads/year, assuming that all firms in six major industries would relocate to use hydrothermal industry.

The approach was based on a number of primary analytical distinctions and assumptions.

(1) The analysis differentiated between resource-colocated markets and resource-noncolocated markets. Colocated markets were defined to be relatively densely populated centers within 50 miles of an economically useful hydrothermal resource. Noncolocated markets were defined as six major industries whose process heat needs are especially well matched to hydrothermal energy use (food and kindred products, tobacco, textiles, lumber and wood, paper and pulp, chemicals).

(2) All technico/economic criteria examined in this study are incorporated into the estimates of market size (quads/year demand), rather than into the market penetration algorithm. This was necessary because of the relatively great disparity in knowledge concerning resource characteristics across the three regions.

(3) The rate of market penetration was modeled using Blackman's technology substitution (diffusion) model. This model reproduces the typical behavior of early, middle, and late adopters of successful

new technologies. The model has a principal rate parameter, which is a characteristic takeover time (the time between capture of 10% and 90% of the market).

The takeover time was assumed to be 60 years for the colocated markets, by analogy with the historical market penetration for natural gas. For the noncolocated markets the takeover time was assumed to be 120 years. This latter assumption was based on the concept that if one had to relocate a factory in order to adopt hydrothermal energy, the propensity to adopt hydrothermal would be at most 50% of the propensity to adopt if one did not have to relocate.

(4) Effects of varying levels of government stimulation were studied. In the Base Case, only the current (F.Y. 1980) incentives and projects are assumed to be in place. Under accelerated cases, effects of different levels of incremental stimulation were examined, each expressed as an "Incremental Government Buy" or "IGB" of additional hydrothermal installations by the end of 1985.

Results for the colocated markets, summed across the three regions, are shown in Table 1. The regional distribution of the colocated market for identified resources in the 50°C - 150°C range is: Pacific - 12%, RMB&R - 31%, Eastern - 57%. Market penetration is forecast to be low in the base case, about 0.3 quads/year in 2020, because the existing incentives and cost-shared projects are not sufficient to push hydrothermal market penetration into the rapid growth phase. Additional stimulation by 1985 is projected to have pronounced effects.

Results for the noncolocated markets are shown in Table 2. Announced plans by industry to relocate to use moderate temperature hydrothermal energy by 1985 are almost nil. The model therefore predicts zero penetration in the base case. However, if government were to stimulate this market by investing enough to install 0.010 quads/year end use in each of the three regions by the end of 1985, the model forecasts gradual but self-sustained growth in hydrothermal use. However, we believe that this latter forecast is somwehat speculative. Much more extensive analysis of the conditions and tradeoffs associated with such relocations of plants needs to be done before any reasonable prediction of industry behavior can be made.

TABLE 1

ESTIMATES OF RESOURCE-COLOCATED HYDROTHERMAL MARKET SIZE AND MARKET PENETRATION[1,2]

Year	Total[1] Colocated Demand (quad/yr)	Suitable[1] Colocated Demand (quad/yr)	Estimated Penetration (quad/yr)			
			Base Case IGB = 0.09 q/y	Case 1 IGB = 0.01 q/y	Case 2 IGB = 0.4 q/y	Case 3 IGB = 0.09 q/y
1985	1.63	0.27	0.01	0.02	0.05	0.10
1990	2.12	0.35	0.02	0.03	0.08	0.16
2000	3.50	0.58	0.04	0.10	0.22	0.36
2020	9.24	1.53	0.27	0.66	1.11	1.34

(1) U.S., exclusive of Texas and Louisiana.

(2) Takeover time = 60 years.

TABLE 2

ESTIMATES OF RESOURCE-NONCOLOCATED HYDROTHERMAL MARKET SIZE AND MARKET PENETRATION[1,2]

Year	Total[1] Noncoloc. Demand (quad/yr)	Suitable[1] Noncoloc. Demand (quad/yr)	Estimated Penetration (quad/year) if IGB = 0.010 q/y in each region.			
			Pacific	RMB&R	Eastern	Total[1]
1985	6.8	1.09	0.010	0.010	0.010	0.03
1990	7.5	1.20	0.013	0.013	0.014	0.04
2000	9.2	1.47	0.022	0.022	0.024	0.07
2020	13.6	2.18	0.070	0.050	0.080	0.20

(1) U.S., exclusive of Texas and Louisiana.

(2) Takeover time = 120 years.

NATIONAL HYDROTHERMAL

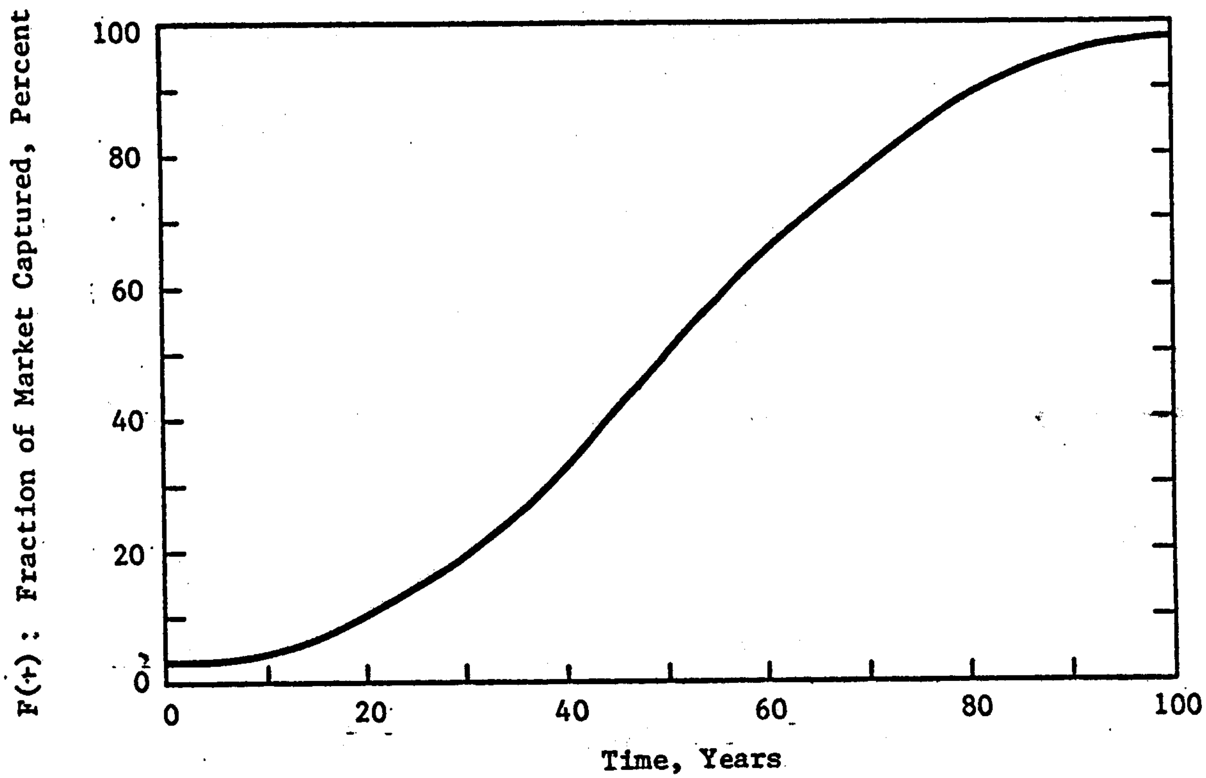
MARKET AND PENETRATION

ESTIMATES

MITRE - September 1980

FACTORS IN ANALYSIS

- THREE REGIONS - 90°C TO 150°C
- RESOURCE - MARKET COLOCATION CRITERIA
  - 50 MILES
  - 3600 PEOPLE/MI^2
- NONCOLOCATED MARKET - SIX INDUSTRIES
- SUITABILITY INDEXES - THERMO, SOCIAL
- MARKET GROWTH RATES - REGIONAL TRENDS
- PENETRATION RATES - SUBSTITUTION
- GOVERNMENT IMPACTS - SHARE GROWTH



HYDROTHERMAL MARKET PENETRATION FUNCTION,
TAKEOVER TIME = 60 YEARS

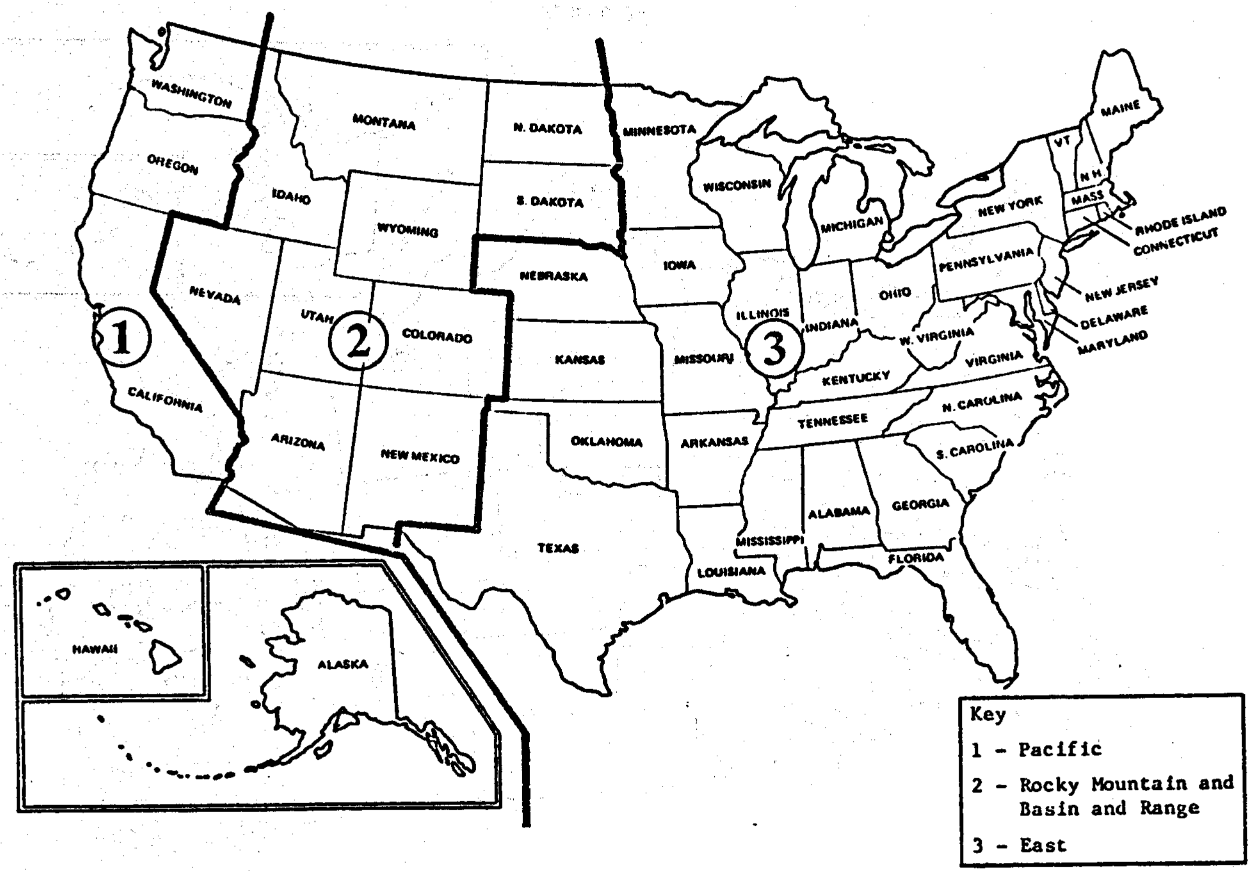


FIGURE 1-2

GEOGRAPHIC BOUNDARIES FOR STUDY REGIONS

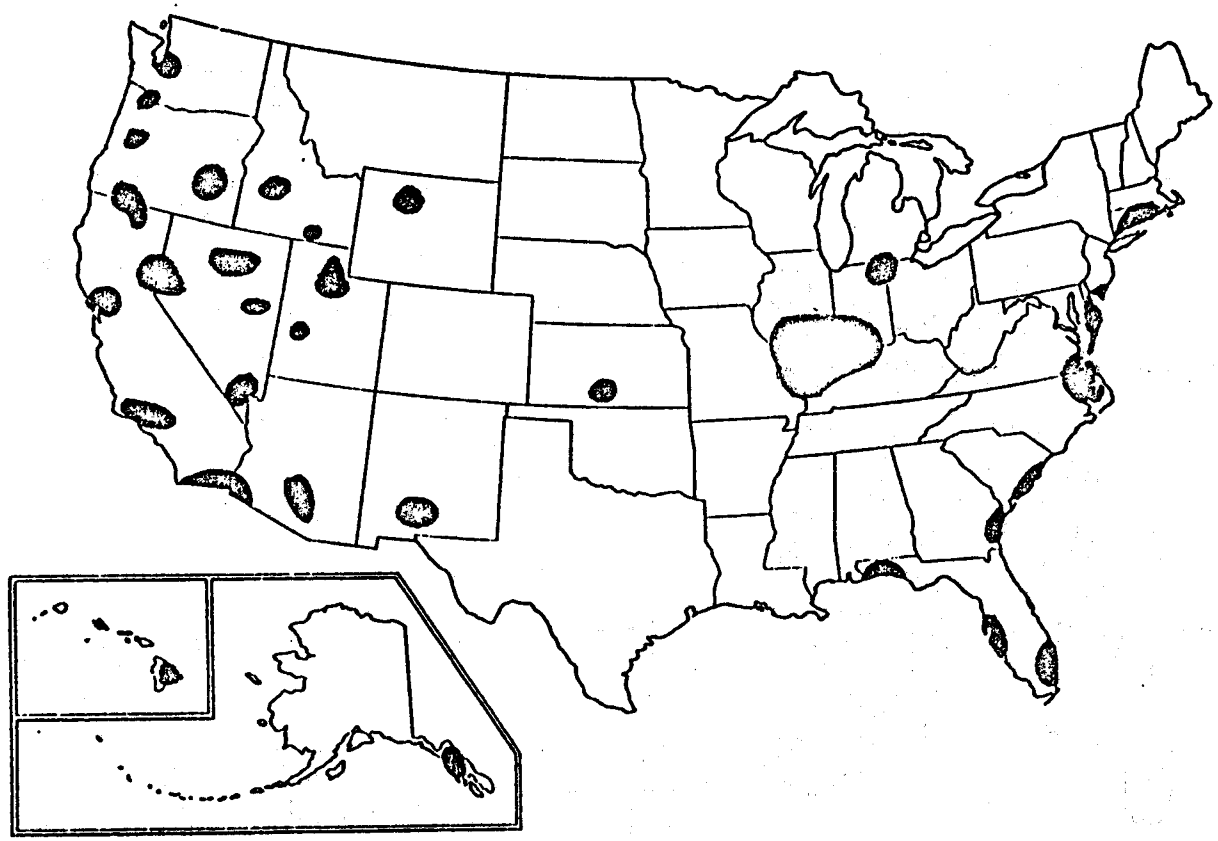


FIGURE 3-2

TENTATIVE LOCATIONS OF MARKET COLOCATED LOW TEMPERATURE (50°-150°C) HYDROTHERMAL RESOURCES IN THE UNITED STATES

SUITABILITY INDEX
OR
POTENTIAL OF DIRECT HEAT APPLICATIONS

TYPE OF APPLICATION	MAXIMUM FRACTIONAL DEMAND SUITABLE FOR HYDROTHERMAL ENERGY (SUITABILITY INDEX)
Space Heating	0.35
Water Heating	0.16
Refrigeration	0.24
Air Conditioning	0.09
Process Heating	0.09
Other (e.g. Agricultural Uses)	0.11

- Average Suitability Index for Residential/Commercial = 0.22
- Average Suitability Index for Industrial Usage = 0.09

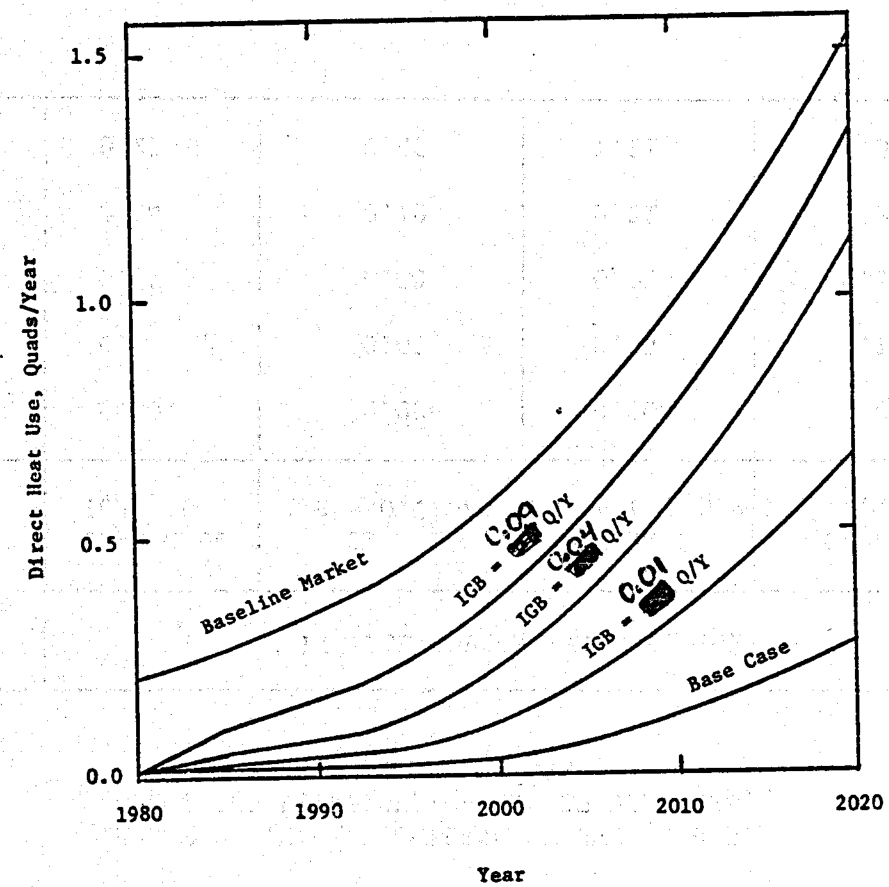
HYDROTHERMAL BASELINE COLOCATED
MARKET-SIZE ESTIMATION FACTORS
(for 1985)

REGION	RESOURCE-COLOCATED POPULATION (Millions)	RESOURCE-COLOCATED DIRECT HEAT DEMAND (Quads/Year)			
		RESIDENTIAL	COMMERCIAL	INDUSTRIAL	TOTAL
Pacific	5.03	0.068	0.034	0.107	0.21
RMB&R	2.14	0.129	0.193	0.138	0.46
Eastern	4.27	0.316	0.221	0.422	0.9
Total U.S.[1]	11.44	0.51	0.45	0.67	1.63

REGION	TOTAL COLOCATED DEMAND (Q/Yr.)	WEIGHTED HYDROTHERMAL SUITABILITY INDEX	BASELINE COLOCATED HYDROTHERMAL MARKET (Q/Yr)	AVERAGE EXPECTED MARKET GROWTH RATE (%/Yr)
Pacific	0.21	0.15	0.032	5.4
RMB&R	0.46	0.18	0.083	3.8
Eastern	0.90	0.16	0.153	5.6
Total U.S.[(1)]	1.63	0.17	0.27	5.1

ESTIMATION OF NON-COLOCATED BASELINE MARKET
FOR HYDROTHERMAL DIRECT HEAT APPLICATIONS

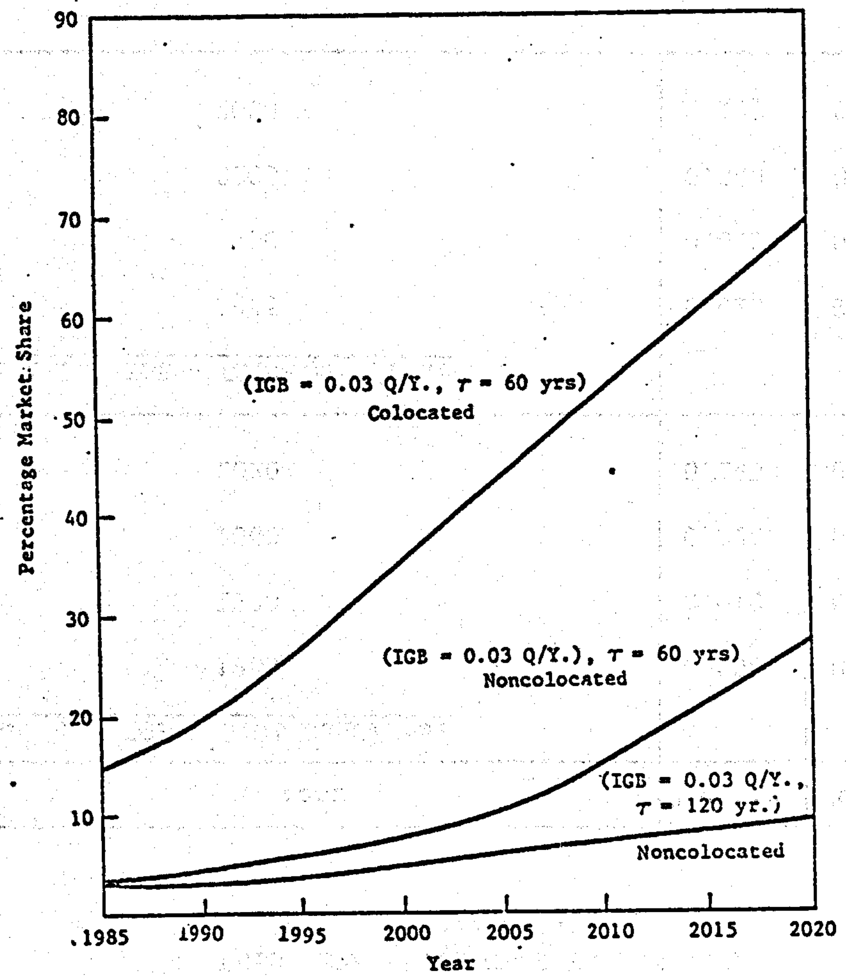
Selected Industry	1985 U.S. Total Direct Heat Demand Q/Yr	Suitability Index	1985 U.S. Direct Head Demand Suitable for Hydrothermal Q/Yr	Regional Distribution of Total (Colocated & Non-colocated) Suitable Demand for Hydro-thermal Energy Usage (Q/Yr)		
				Pacific Region	RMB&R Region	Eastern Region
Food & Kindred	1.17	0.36	0.42	0.16	0.08	0.18
Tobacco	0.03	0.5	0.02	-	-	0.02
Textile	0.39	0.39	0.15	0.01	-	0.14
Lumber & Wood	0.38	0.33	0.13	0.07	0.01	0.05
Paper & Pulp	1.42	0.05	0.07	0.02	-	0.05
Chemicals	4.04	0.10	0.40	0.03	-	0.37
Total (i.e., colocated + Non-colocated)	7.43	Weighted Average = 0.16	1.19	0.29	0.09	0.81
Suitable Industrial Colocated Demand Q/Yr			0.10	0.016	0.018	0.067
Noncolocated Baseline Market Demand Q/Yr			1.09	0.274	0.072	0.743



HYDROTHERMAL MARKET PENETRATION
UNDER DIFFERENT LEVELS OF
GOVERNMENT STIMULATION TO 1985

IMPACT OF INITIAL GOVERNMENT BUY ON U.S. COLOCATED HYDROTHERMAL DIRECT HEAT USE, QUADS/YEAR END USE

Year	INITIAL GOVERNMENT BUY, IGB			
	Base Case IGB = 0	Case 1 IGB = 0.01Q/Y	Case 2 IGB = 0.04Q/Y	Case 3 IGB = 0.09Q/Y
1980	0.004	0.004	0.004	0.004
1985	0.01	0.02	0.05	0.10
1990	0.02	0.03	0.08	0.16
2000	0.04	0.10	0.22	0.36
2020	0.27	0.66	1.11	1.34



COMPARATIVE IMPACT OF SAME INITIAL GOVERNMENT BUY
ON COLOCATED VS NONCOLOCATED MARKET SHARE PERCENTAGES

IMPACTS PREDICTED IF INITIAL GOVERNMENT BUYS WERE RESTRICTED TO THE WEST
(quads/year)

Year	Pacific	RMB&R	Total
Case 1. IGB = 0.01 Quad/Year			
1985	0.006	0.015	0.021
1990	0.010	0.023	0.033
2000	0.026	0.056	0.082
2020	0.145	0.229	0.374
Case 2. IGB = 0.04 Quad/Year			
1985	0.015	~~0.36~~ 0.036	0.051
1990	0.023	0.052	0.075
2000	0.048	0.098	0.146
2020	0.183	0.282	0.465

HYDROTHERMAL SUPPLY/DEMAND BALANCE

Region	Colocated Demand		Noncolocated Demand		Total Colocated and Noncolocated Demand (Q/Yr)		Known Colocated Suitable Supply (Q/Yr.)
	1985	2000	1985	2000	1985	2000	1985
Pacific	0.0042	0.021	0.01	0.022	0.014	0.043	0.15
RMB&R	0.01	0.041	0.01	0.022	0.02	0.063	0.12
Eastern	0.0058	0.038	0.01	0.024	0.016	0.062	0.10

Market Penetration of
Geothermal Community Heating Systems

by

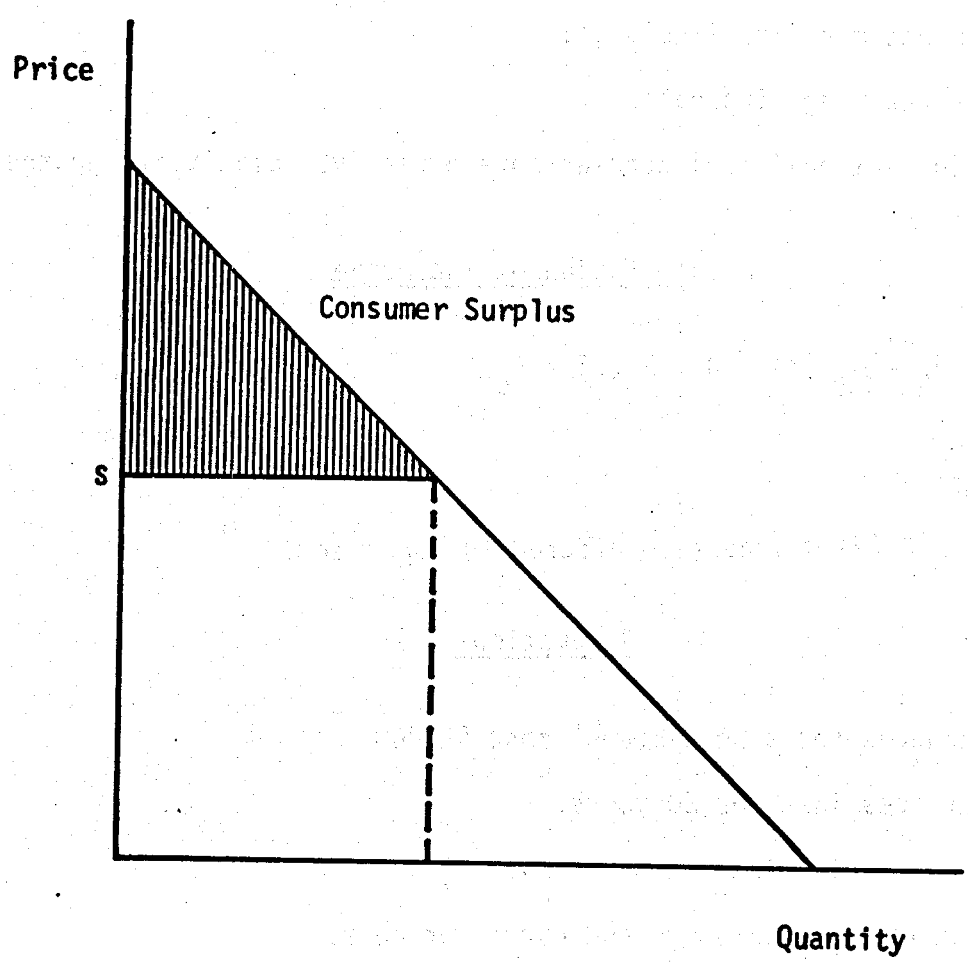
R. Dubin
The Johns Hopkins University
Center for Metropolitan Planning and Research

Market Penetration of Geothermal
of Community Heating Systems: Micro Approach

An obstacle to rapid consumer conversion to a community heating system is the value remaining in the consumer's current heating system. In the following illustrations a model of the consumer's decision to convert to the community heating system is presented. The utility can influence the rate at which consumers convert through the use of incentive schemes.

The results of the research indicate that, in the absence of large price differentials between geothermal and conventional fuels, consumers will not convert naturally at high rates. Further, rapid market penetration is desirable to the utilities, even if achieved at the cost of an incentive scheme.

Illustration of Consumer Surplus



Consumer's Conversion Decision

$$F_G - M_C(z) - H \geq F_C$$

where:

H = hook-up costs

$M_C(z)$ = value of service remaining in current conventional heating system

z = furnace age

$F_{G\ (C)}$ = consumer surplus in new geothermal (conventional) heating system

= furnace service life x (annual value of heat - annual fuel costs) - cost of new heating systems

Conversion becomes more likely as:

A. Furnace age increases.

B. Conventional fuel becomes more expensive relative to geothermal fuel.

Computation of Incentive

$$F_A - M_C(z) - H + B(z) = F_C$$

where:

$B(z)$ = incentive offered to consumer

Assumptions

1. Furnaces (heating systems) cost $2,000.
2. Furnaces last for 20 years.
3. Uniform distribution of furnace ages.
4. Linear compensated demand curve for heat.
5. Elasticity of demand for heat equals -.5.
6. Utility pays all hook-up costs.

Value of Current Heating System to Consumer

		Percent Geothermal Price Advantage	
		0	20
Furnace Age	1	1,940	1,540
	2	1,878	1,478
	3	1,812	1,412
	4	1,742	1,342
	5	1,669	1,269
	6	1,593	1,193
	7	1,512	1,112
	8	1,428	1,028
	9	1,339	939
	10	1,245	845
	11	1,147	747
	12	1,043	643
	13	934	534
	14	820	420
	15	700	300
	16	574	174
	17	441	41
	18	301	0
	19	154	0
	20	0	0

Incentive Schemes

Incentive Scheme One:

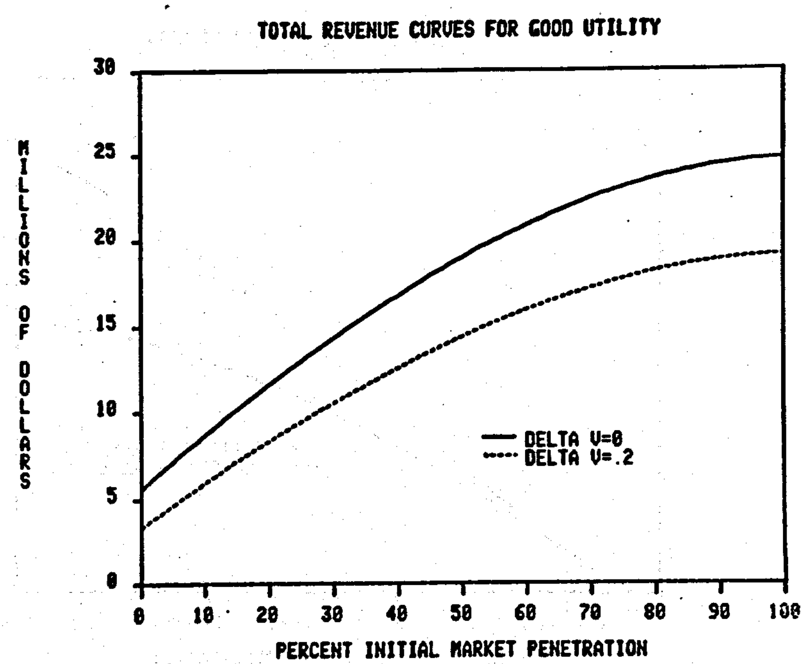
The utility offers each cohort an incentive which is exactly equal to the value of the consumer's current heating system.

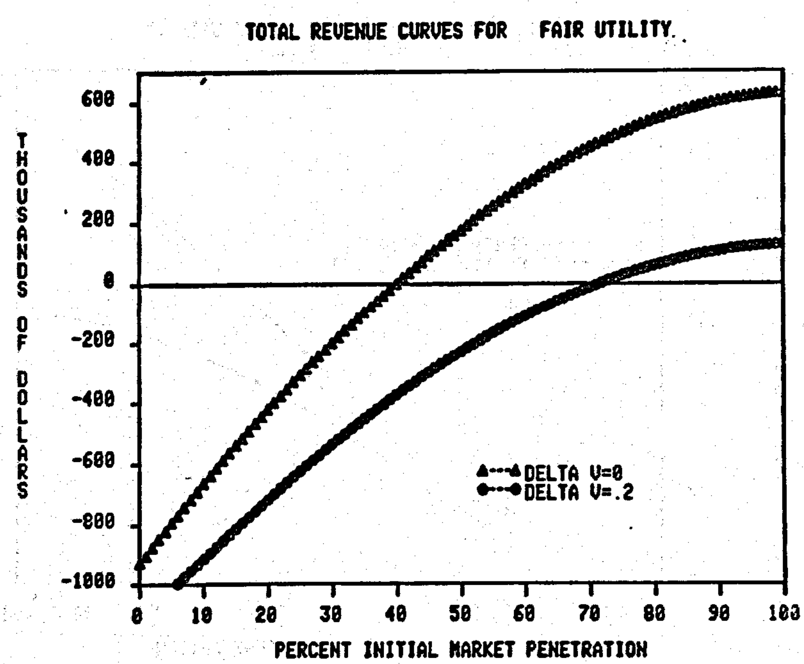
Incentive Scheme Two:

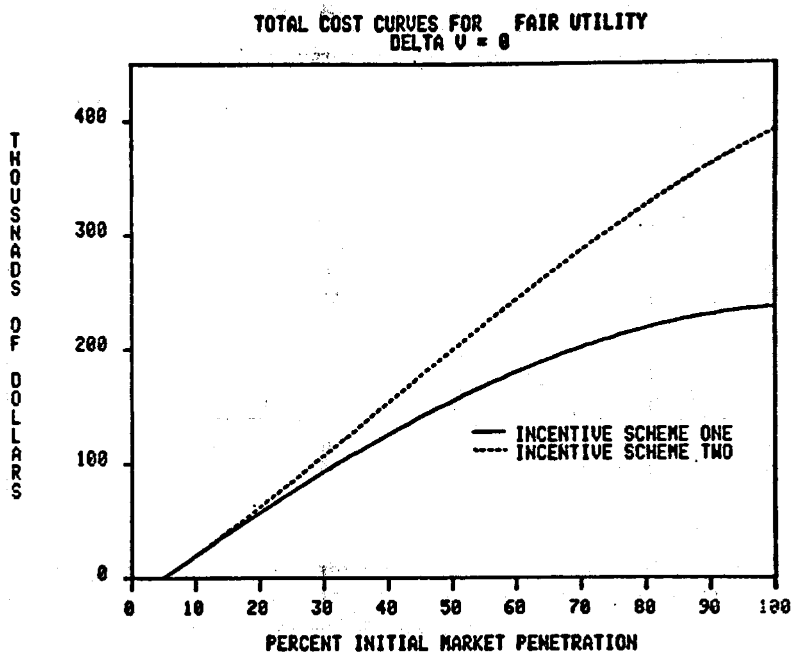
The utility offers a fixed sum to all persons willing to convert.

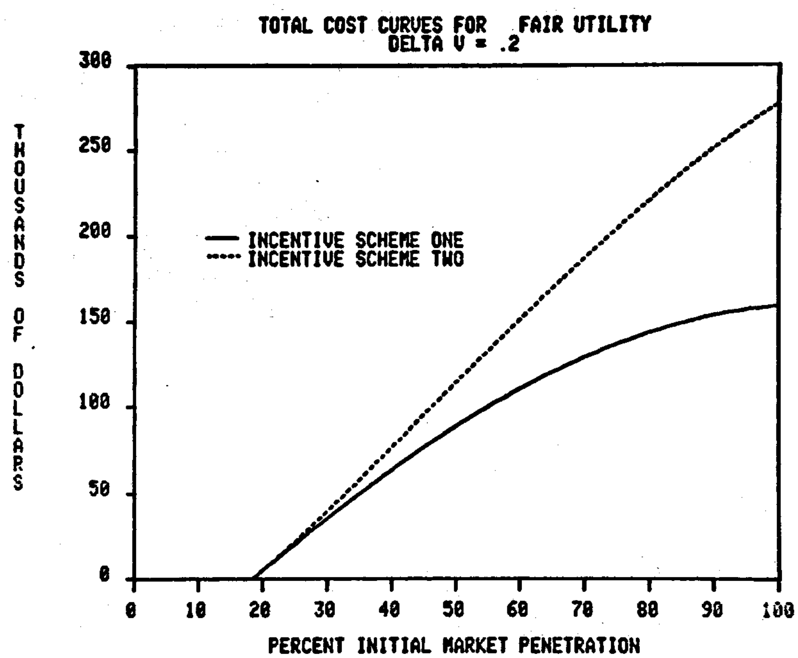
Scenarios

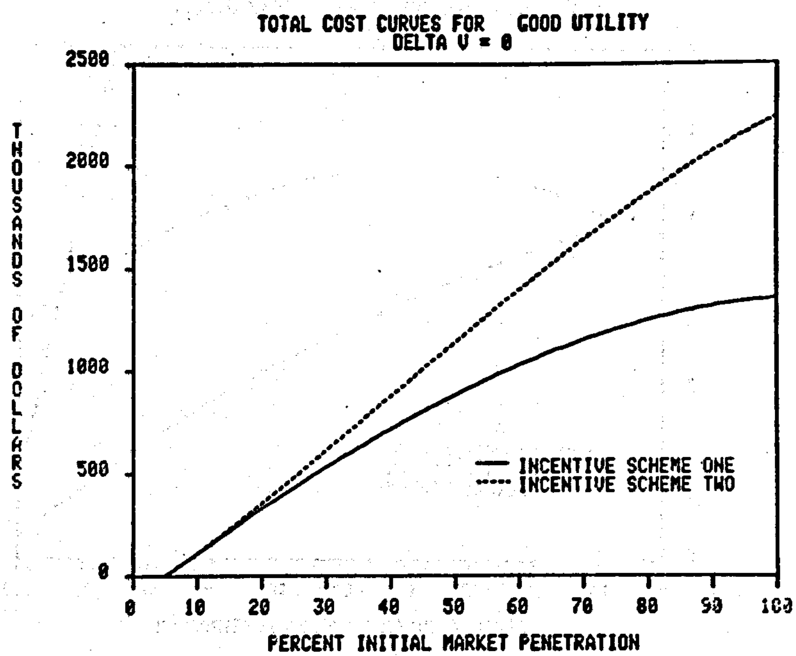
	Good	Fair
Number of production wells	1	1
Depth of upwell	500	5,000
Wellhead water temperature	195°F	150°F
Reject temperature	95°F	85°F
Number of reinjection wells	1	1
Depth of reinjection wells	500	5,000
Drawdown	5%	
Flow	1,000 GPM	200 GPM
Transport distance	3.3 Mi.	.6 Mi.
Design temperature	30°F	30°F
Number of households	1,216	212

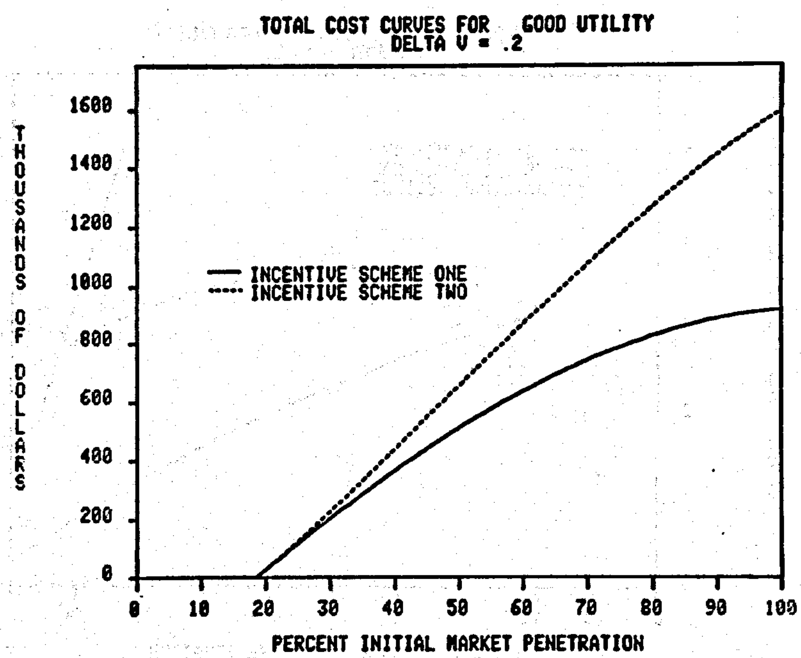

TOTAL REVENUE CURVES FOR GOOD UTILITY
MILLIONS OF DOLLARS
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
PERCENT INITIAL MARKET PENETRATION
DELTA V=0
DELTA V=.2

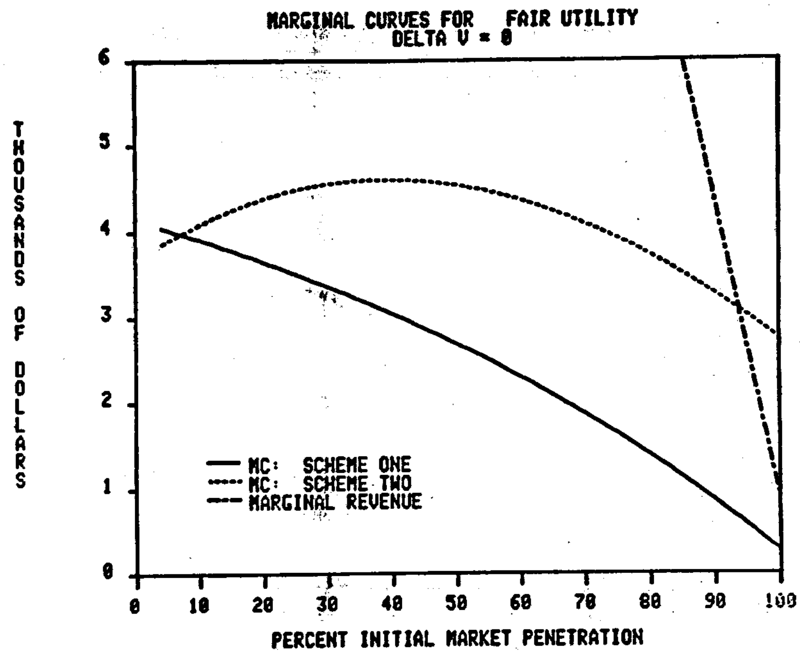

TOTAL REVENUE CURVES FOR FAIR UTILITY
THOUSANDS OF DOLLARS
600
400
200
0
-200
-400
-600
-800
-1000
0
10
20
30
40
50
60
70
80
90
100
PERCENT INITIAL MARKET PENETRATION
DELTA V=0
DELTA V=.2

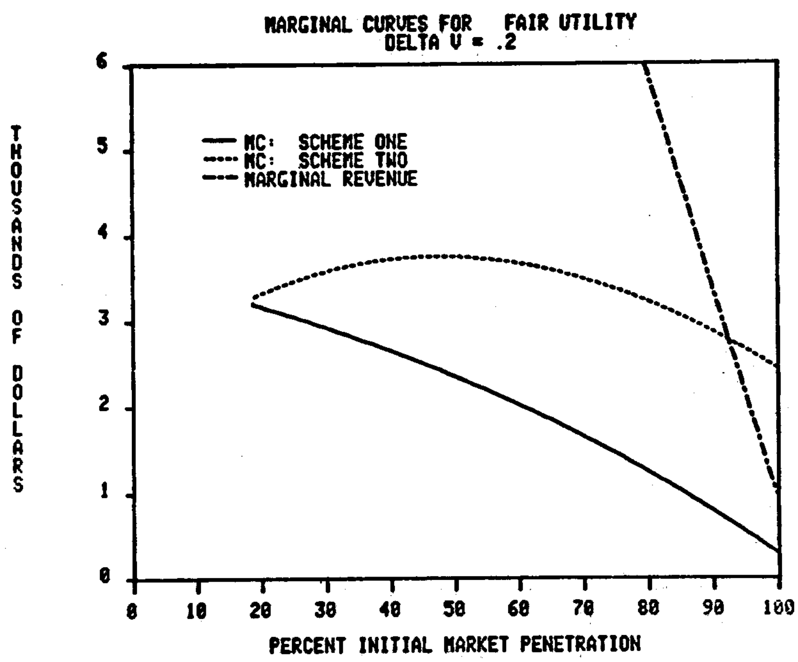

TOTAL COST CURVES FOR FAIR UTILITY
DELTA V = 0
THOUSANDS OF DOLLARS
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
PERCENT INITIAL MARKET PENETRATION
INCENTIVE SCHEME ONE
INCENTIVE SCHEME TWO

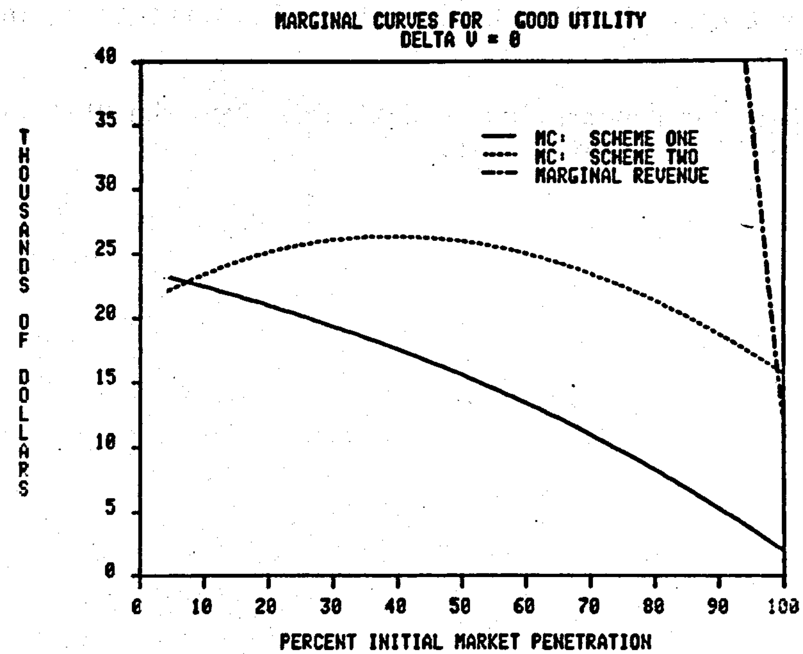

TOTAL COST CURVES FOR FAIR UTILITY
DELTA V = .2
THOUSANDS OF DOLLARS
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
100
PERCENT INITIAL MARKET PENETRATION
INCENTIVE SCHEME ONE
INCENTIVE SCHEME TWO

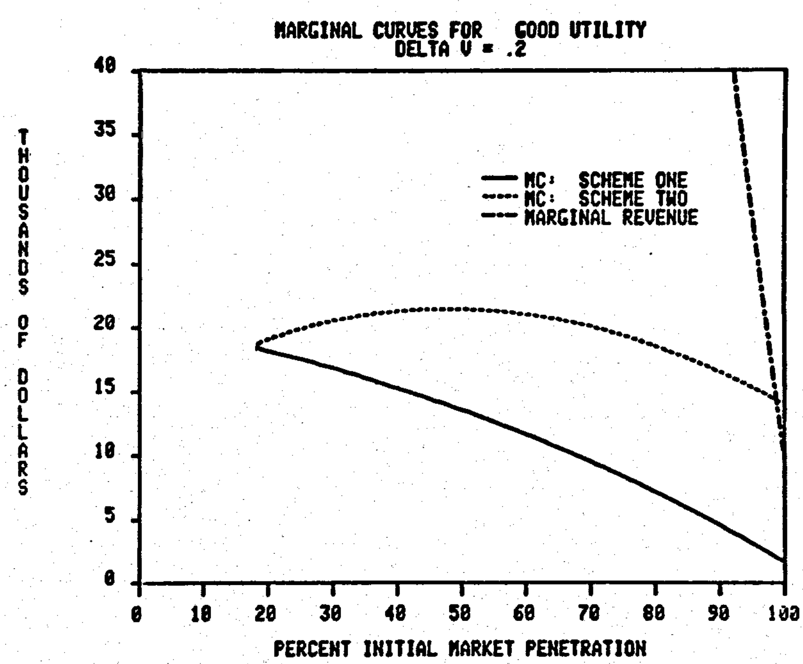

TOTAL COST CURVES FOR GOOD UTILITY
DELTA V = 0
THOUSANDS OF DOLLARS
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
90
100
PERCENT INITIAL MARKET PENETRATION
INCENTIVE SCHEME ONE
INCENTIVE SCHEME TWO


TOTAL COST CURVES FOR GOOD UTILITY
DELTA V = .2
THOUSANDS OF DOLLARS
1600
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
80
90
100
PERCENT INITIAL MARKET PENETRATION
INCENTIVE SCHEME ONE
INCENTIVE SCHEME TWO


MARGINAL CURVES FOR FAIR UTILITY
DELTA V = 0
THOUSANDS OF DOLLARS
0
1
2
3
4
5
6
MC: SCHEME ONE
MC: SCHEME TWO
MARGINAL REVENUE
0 10 20 30 40 50 60 70 80 90 100
PERCENT INITIAL MARKET PENETRATION


MARGINAL CURVES FOR FAIR UTILITY
DELTA V = .2
THOUSANDS OF DOLLARS
0
1
2
3
4
5
6
MC: SCHEME ONE
MC: SCHEME TWO
MARGINAL REVENUE
0 10 20 30 40 50 60 70 80 90 100
PERCENT INITIAL MARKET PENETRATION


MARGINAL CURVES FOR GOOD UTILITY
DELTA V = 0
MC: SCHEME ONE
MC: SCHEME TWO
MARGINAL REVENUE
THOUSANDS OF DOLLARS
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
80
90
100
PERCENT INITIAL MARKET PENETRATION


MARGINAL CURVES FOR GOOD UTILITY
DELTA V = .2
MC: SCHEME ONE
MC: SCHEME TWO
MARGINAL REVENUE
THOUSANDS OF DOLLARS
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
80
90
100
PERCENT INITIAL MARKET PENETRATION

Conclusions

I. Except in cases of large geothermal price advantages, consumers will not convert at high rates in the absence of an incentive scheme.

II. Rapid market penetration is desirable from the utilities standpoint, even at a cost.

Market Penetration of Geothermal Energy for Industrial and Residential Applications

by

R. J. Thomas

and

R. A. Nelson
Technical Research Analysis Company

MARKET PENETRATION OF GEOTHERMAL ENERGY FOR INDUSTRIAL AND RESIDENTIAL APPLICATIONS

PREPARED BY:
RONALD J. THOMAS
AND
RICHARD A. NELSON
TECHNICAL RESEARCH ANALYSIS COMPANY

XXXVI-1

PURPOSE OF ANALYSIS

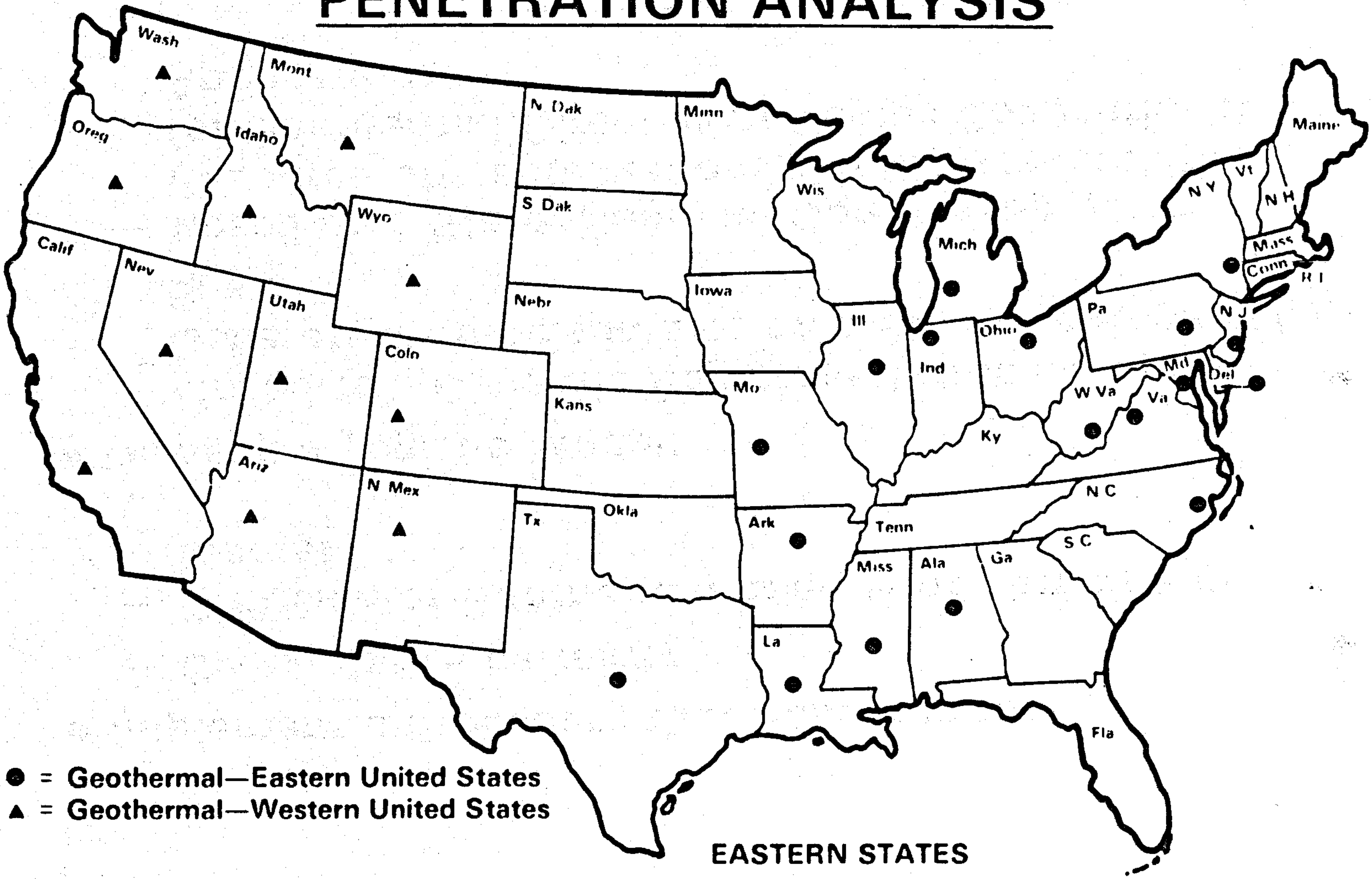
- Investigate the Feasibility of Applying a General Market Penetration Procedure to Residential and Industrial Direct Heat Geothermal Applications in the United States

- Provide the Division of Geothermal Energy (DGE) with a Policy Planning Tool Based on:

  — Market Penetration Estimates for Mid- and Long-Term Time Periods (1985-2010)

  — Method for Assessing Market Impacts Resulting from Changes in Energy and Economic Variables

STATES CONSIDERED FOR MARKET PENETRATION ANALYSIS



● = Geothermal—Eastern United States
▲ = Geothermal—Western United States

EASTERN STATES

Alabama	Maryland	North Carolina
Arkansas	Michigan	Ohio
Delaware	Mississippi	Pennsylvania
Illinois	Missouri	Texas
Indiana	New Jersey	Virginia
Louisiana	New York	West Virginia

ASSESSMENT METHODOLOGY

- Implement a Procedure that Accounts for:
  - Consumer Uncertainty
  - Diffusion of Geothermal Energy into the Energy Market
- Develop a Logistic Model:
  - Linked to a Dynamic Adjustment Process to Generate Model Estimates on a State and Regional Basis
  - Based on a State/Regional Comparison of Resource Characterizations and Market Conditions for Geothermal Direct Heat Versus Conventional Applications

FOCUS OF THE MARKET PENETRATION ANALYSIS

- Compare the Attractiveness of Geothermal Energy Relative to Conventional Energy Sources for Particular Market Applications.

- Determine the Rate of Penetration of Geothermal Systems into the Residential Space and Water Heating Market and the Industrial Low Temperature Process Heat Market

COMPARATIVE STATIC MODEL ASSUMPTIONS

- Consumers are Fully Informed about the Relative Costs of Geothermal and Conventional Energy Sources
- Consumers Will Seek Out Sources of Energy Which Have Lower Costs
- Market Conditions Would not Impede Instant and Total Conversion to the Lowest-Cost Source of Heating
- Eventual Equilibrium Market Share for Geothermal Energy Will be that Share of the Market for which Geothermal Provides the Lowest Cost Alternative

DYNAMIC PROCESS CONDITIONS

- Consumer Uncertainty Exists for a New Unproved Technology
- Large Initial Capital Investment Implies a Greater Risk Factor
- Consumer Confidence in Geothermal Energy Applications Will Increase Over Time
- Learning Process Will Generate an Accelerating Market Penetration Rate
- Market Saturation Will Occur when the New Installation Market is Greater than the Replacement Installation Market

GENERALIZED MODEL FORMAT

- $$MSE = \frac{1}{1 + [ACG_{i,t} / ACC_{i,t}]^a}$$

WHERE:

MSE	=	Equilibrium Market Share
$ACG_{i,t}$	=	Annualized Cost of Geothermal Energy (ACG) for a Particular State (i) Over a Given Time Period (t)
$ACC_{i,t}$	=	Annualized Cost of Conventional Energy (ACC) for a Particular State (i) Over a Given Time Period (t)
a	=	Response Parameter (Elasticity of Substitution Between Geothermal and Conventional Energy Sources)

GENERALIZED MODEL FORMAT

- $dy/dt = A\ [(P_t\ (1 - P_t)]$

WHERE:

dy/dt = Rate of Conversion to Geothermal Energy

A = Market Adjustment Coefficient

P_t = Proportion of the Market Already Converted to Geothermal at Time t

COMPILATION OF GEOTHERMAL ENERGY COSTS

- $ACG_j = \frac{1}{EG_j} [KG_j \bullet CRF \bullet (OM - TC + D_j)]$

WHERE:

KG_j = Capital Cost of the Geothermal System for State j

EG_j = Energy Output of the Generic System for State j

CRF = Capital Recovery Factor

OM = Operation and Maintenance Costs

TC = Investment Tax Credit

D = Combined Effect on the Amount of Revenue of Interest Payments on the Debt, Depreciation, and Cost of Capital for State j

CONCLUDING REMARKS

- Generalized Market Penetration Approach is Feasible
- Specific Results will be Generated in Phase II of the Project
- Model Significance for Policy Planning Purposes is Based on the Relative Values and Sensitivities as Opposed to the Absolute Values of the Forecast Data
- Approach Provides a Low Cost Procedure to Test Significance of Key Market Variables
- Improved Data and Information from State Geothermal Participants will Enhance the Market Penetration Effort, and Aid DGE in Commercialization Efforts

Geothermal Industrial Utilization
Plan Overview

by

J. Markiewicz

and

M. Iriarte
Engineering and Economics Research, Inc.

INDUSTRIALIZATION PLAN

PURPOSE:

- DOCUMENT CURRENT STATUS
- SET ATTAINABLE GOALS
- DEVELOP PLANS FOR REACHING STATED GOALS
- DEVELOP JUSTIFICATION FOR DOE/FEDERAL PROGRAMS
- MONITOR EFFECTIVENESS OF THE PLAN

APPROACH:

- Determine the Size of the Resource Base
- Estimate Potential Market Share
- Determine Current Status
- Prepare Development Scenarios
- Develop Site Specific Plans
- Identify Barriers and Corrective Actions
- Monitor Activity
- DOE/Federal Programs

PROGRAM ELEMENTS AND SUBELEMENTS OF THE INDUSTRIALIZATION PLAN

PROGRAM ELEMENT	SUBELEMENTS
A. Planning and Coordination	(1) Site-Specific Development Plans (2) Utility and Industry Working Groups (3) Progress Monitoring
B. Regulatory Streamlining and Administration	(1) Federal Streamlining Plan (2) State Law Project (3) Leasing and Land Use Coordination
C. Resource Assessment/ Confirmation	(1) Removal of Tax Disincentives (2) User Coupled Drilling
D. Power Plant Incentives	(1) Utility Outreach Effort (2) Rural Energy Initiative (a) Feasibility Studies (b) REA Financing for Projects (3) Loan Guarantee Program (a) Streamlining (b) Time Extension (c) 90% Guarantees for Cooperatives and Municipalities (4) Fuel Use Act/Oil Backout Program (5) Non-utility Owner Producer Initiatives (a) Tax Credit (b) Regulatory Exemption (c) Interconnection Authority (6) Wheeling Authority (7) Reservoir Insurance
E. Technology Development	(1) Geosciences Program (2) Geochemical Engineering and Materials (3) Energy Extraction and Conversion Technology (4) Environmental Control
F. Technology Demonstration	(1) Flash Steam Power Plant Demonstration (2) Binary Power Plan Demonstration (3) Well Head Generator Demonstration (4) Moderate Temperature Power Plant Demonstration (5) Reservoir Demonstration Plants

OVERVIEW OF PLAN (ELECTRIC)

- OBJECTIVES
- RESOURCE DESCRIPTION
- WORLD-WIDE STATUS
- CURRENT STATUS
- MARKET POTENTIAL
- STATE OF READINESS
- COMMERCIALIZATION SEQUENCE
- INDUSTRIALIZATION PLAN
- STRATEGY
- BARRIERS TO DEVELOPMENT
- LEGISLATIVE ACTION
- INDUSTRIALIZATION ACTIVITIES
- SITE SPECIFIC INFORMATION

FIGURE 8

EXAMPLE OF SITE SPECIFIC DATA FORMAT

1. SITE: EAST MESA
2. STATE: CALIFORNIA
3. COUNTY: IMPERIAL
4. SITE AND RESOURCE CHARACTERIZATION:

CHARACTERISTICS	VALUE
TOTAL AREA	38,365 ACRES
FEDERAL AREA	32,725 ACRES
STATE AND PRIVATE AREA	4,840 ACRES
DEPTH TO RESERVOIR TOP	6,560 FEET
RESERVOIR MEAN TEMPERATURE	182 ± 7 °C
TOTAL DISSOLVED SOLIDS	2,500 PPM
TYPE OF ROCK	DELTAIC RIVER SEDIMENTS

5. LEASING DATA:

FEDERAL LAND				NON-FEDERAL LAND			
LEASEHOLDER	DATE OF LEASE	AREA LEASED (ACRES)		LEASEHOLDER	DATE OF LEASE	AREA LEASED (ACRES)	
		COMPETITIVE	NON-COMPETITIVE			COMPETITIVE	NON-COMPETITIVE
Republic Geothermal	08-01-74	4145					
Magma Power Co.	09-01-74	5064					
Union Oil	05-10-79	1920					

6. DRILLING STATUS:

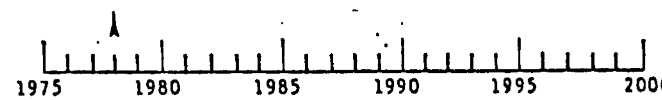
SITE NAME OR UNIT #	LEASEHOLDER	EXPLORATORY DRILLING				PRODUCTION WELLS			INJECTION WELLS	
		STARTED	COMPLETED	# DRILLED	# PRODUC.	# DRILLED	WELL HEAD TEMP (O_C) MAX	MIN	# DRILLED	DEPTH
EM 6, 5, 4	REPUBLIC GEOTHERMAL			3	0					
56-19, 16-30, 74-30, 56-30, 58-30, 78-30	REPUBLIC GEOTHERMAL			6	0					
WW-I	REPUBLIC GEOTHERMAL								2	
-	MAGMA					9	259			
MESA 6-1			8-72			1				
MESA 6-2			8-73			1				
MESA 5-1			5-74						1	6016
MESA 8-1			6-74							
MESA-31-1			6-74							

7. REGULATORY ACTIVITY:

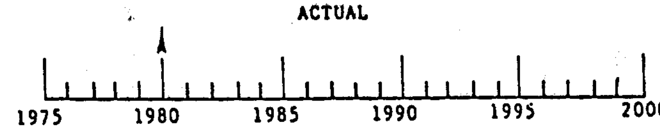
ACTIVITY	AGENCIES INVOLVED
Background Data Collection	BLM, USGS, USFWS
EAR/EIS Process	BLM, USGS, USFWS
Lease Sales	BLM, USFS, USGS, USFWS
Exploratory Operation Review	BLM, USFS, USGS, USFWS
Exploratory Operations	BLM, USFS, USGS, USFWS
Reservoir Evaluation Plan Review	BLM, USFS, USGS, USFWS
Characterization Operation	BLM, USFS, USGS, USFWS
NOI Review	BLM, USFS, USGS, USFWS
Certification & Production Plan Review	BLM, USFS, USGS, USFWS
Drilling Operations & Plant Construction	BLM, USFS, USGS

8. DEVELOPMENT SCHEDULE:

PROJECTED - POWER ON LINE



ACTUAL



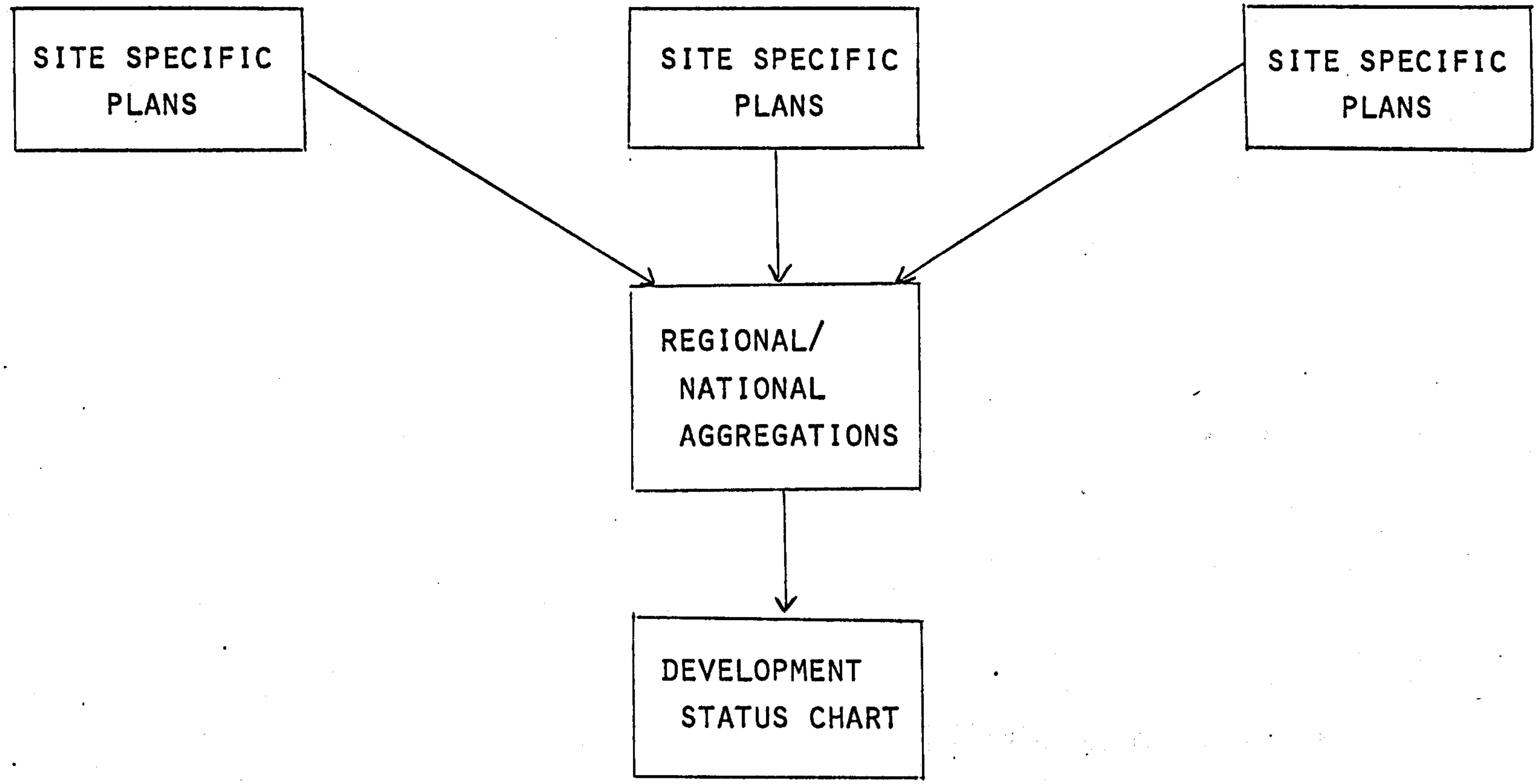
- Arrow indicates year of power on line
- 10 MWe on line with 50 MWe planned for 1982
- Major barriers are down hole pump failures, cooling water availability, and numerous state and local regulations

9. GENERAL COMMENTS:

Magma and RGI testing, 9 wells with temperature of 500°F. Developer is Magma. Utility is SDG&E.

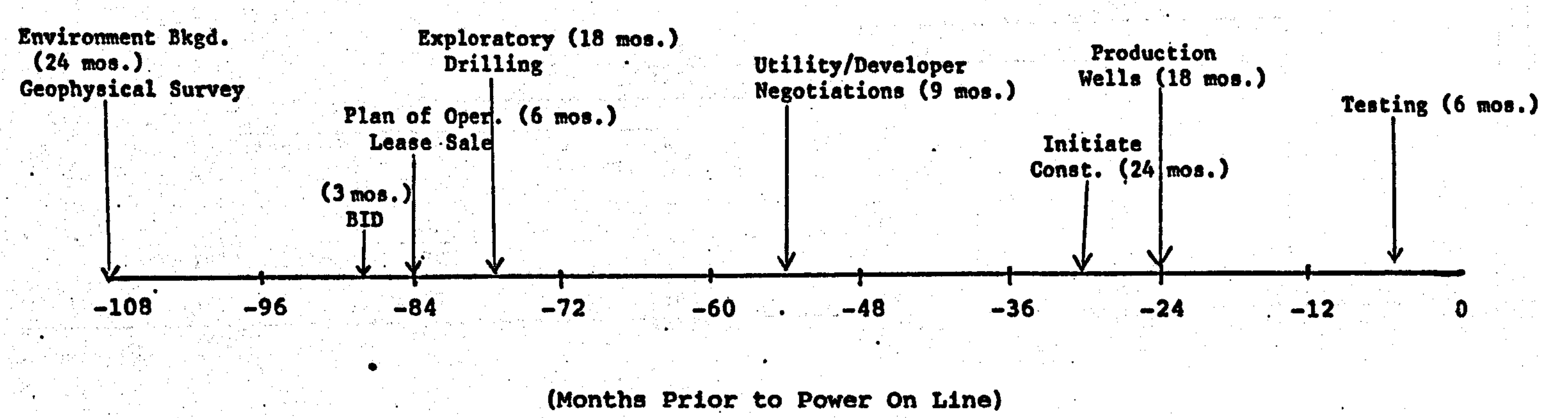
DEVELOPMENT MONITORING

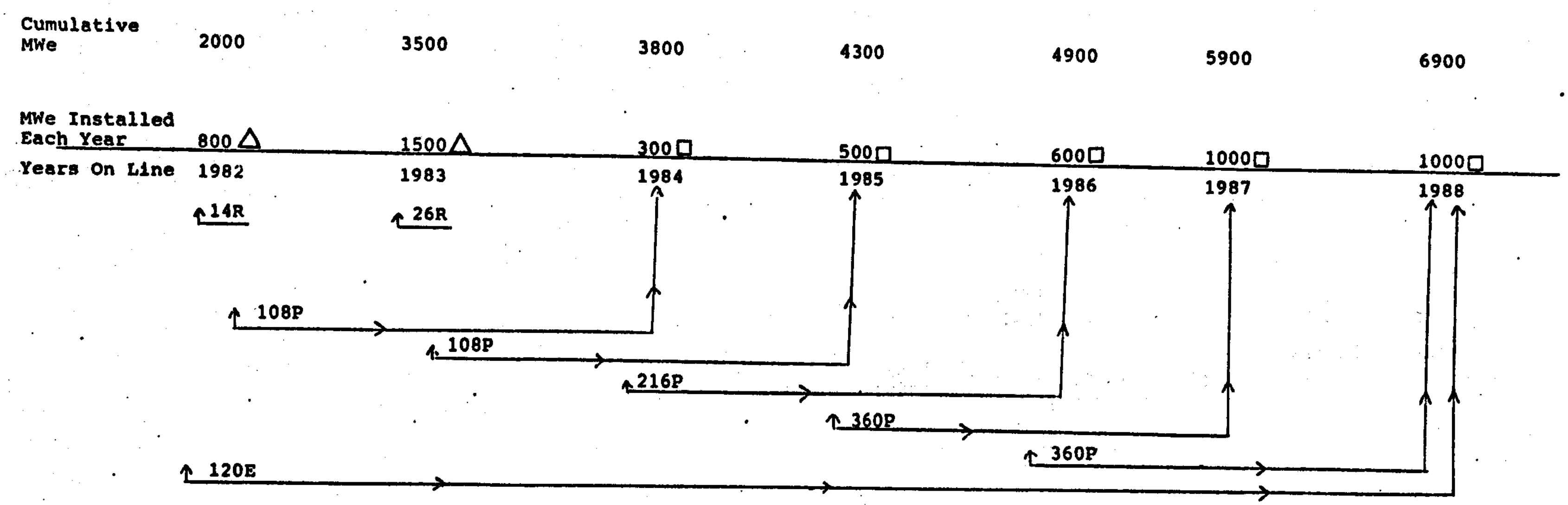
- DETERMINE THE LEVEL OF ACTIVITY (LEASING, EXPLORATION, WELL DRILLINGS) THAT IS NEEDED TO ACHIEVE STATED GOALS
- DETERMINE THE LEVEL OF ACTIVITY THAT HAS BEEN ACCOMPLISHED
- COMPARE THESE LEVELS OF ACTIVITY TO DETERMINE WHAT IS NEEDED TO REACH GOALS
- MONITOR AND MAKE THE NEEDED ADJUSTMENTS IN PROGRAMS



REQUIRED STEPS TO ASSESS CURRENT STATUS

DEVELOPMENT SEQUENCE





WELL DRILLINGS NECESSARY TO ACHIEVE STATED GOALS
(Figures are Hypothetical and for Illustration Only)

△ - On Line
□ - Planned
P - Production Wells
E - Exploratory Wells
R - Replacement Wells

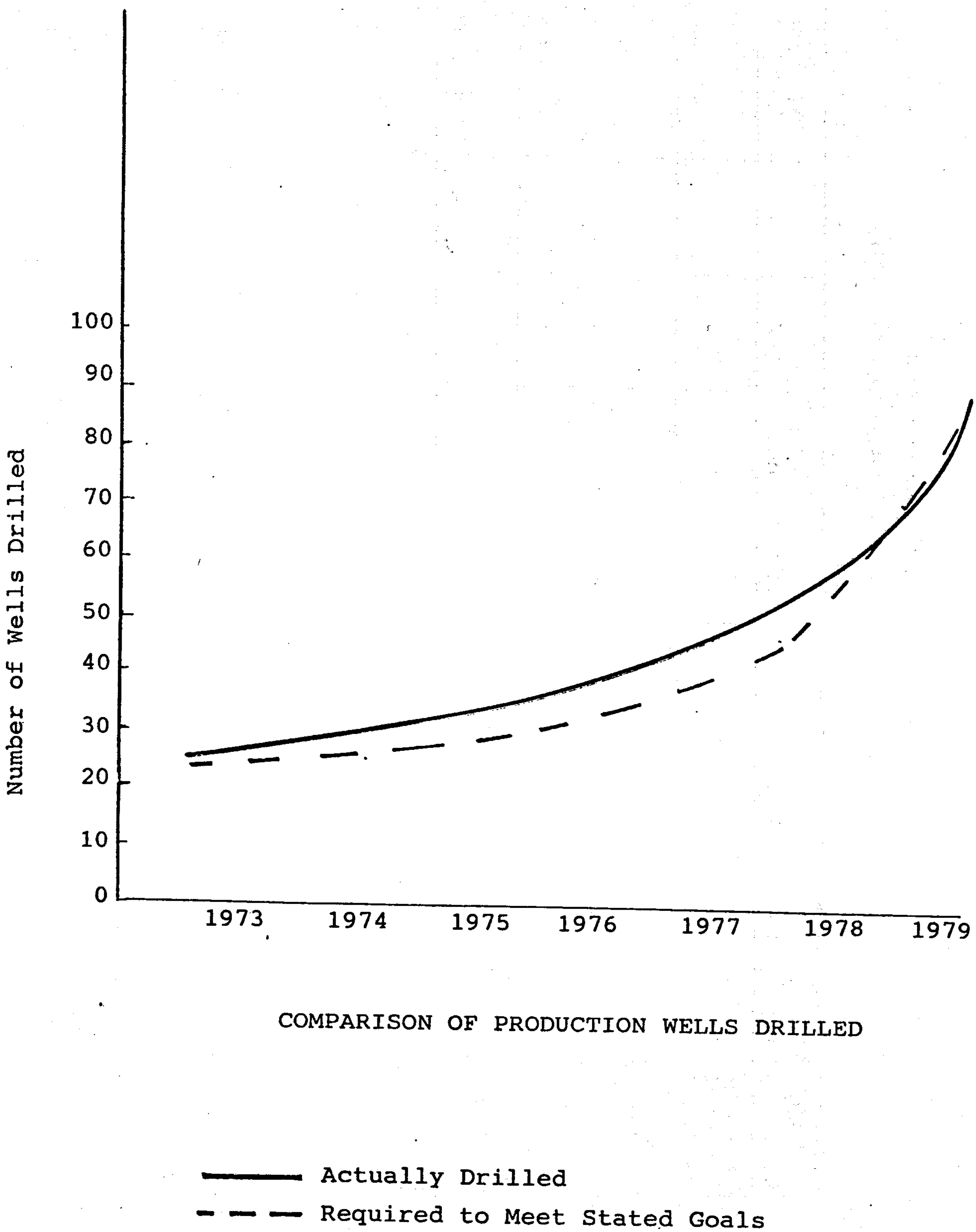
WELL DRILLINGS REQUIRED TO MEET GOALS

(Figures are Hypothetical and for Illustration Only)

WELLS \ START YEAR	1982	1983	1984	1985	1986	1987	1988	MW_e on Line Each Year
Production Exploratory Replacement	14							1982 800 △
Production Exploratory Replacement		26						1983 1500 △
Production Exploratory Replacement	108							1984 300 □
Production Exploratory Replacement		180						1985 500 □
Production Exploratory Replacement			216					1986 600 □
Production Exploratory Replacement				360				1987 1000 □
Production Exploratory Replacement	120				360			1988 1000 □

△ - Operational

□ - Planned



COMPARISON OF PRODUCTION WELLS DRILLED

MONITOR OF DEVELOPMENT STEPS - STATUS

		Required For Achieving Goals For			
	Actual On	1985	1990	2000	Comments
Acres of Land Leased	2,000,000	2,200,000	2,200,000	2,400,000	
Exploratory Wells	420	440	440	460	
Production Wells	1,200	1,210	1,280	1,300	
Reinjection Wells					
Plants On Line					
Plants Under Construction					
Permits Issued					
Developer/Utility Agreements					
Drilling Rigs					

APPROACH:

- DETERMINE THE SIZE OF THE RESOURCE BASE
- ESTIMATE POTENTIAL MARKET SHARE
- DETERMINE CURRENT STATUS
- PREPARE DEVELOPMENT SCENARIOS
- DEVELOP STATE PLANS
- IDENTIFY BARRIERS AND CORRECTIVE ACTIONS
- MONITOR ACTIVITY
- DOE/FEDERAL PROGRAMS

TABLE 7

PROGRAM ELEMENTS AND SUBELEMENTS OF THE INDUSTRIALIZATION PLAN

PROGRAM ELEMENT	SUBELEMENTS
A. Resource and Market Definition	(1) USGS Resource Assessment (2) State Resource Teams (3) State Commercialization Planning Teams (4) Market Assessment (5) Industry/Utility/Municipality Working Groups
B. Market Development	(1) National Media Program (2) Trade, Professional and Municipal Association Liaison (3) State Law Project (4) Regulatory Barrier Mitigation
C. Technology Development	
D. Technology Demonstration	
E. Feasibility Assessment Support	(1) Technical Assistance (2) Engineering and Economic Study Grants/Loans (3) User-coupled Reservoir Confirmation Grants/Loans
F. Implementation Assistance and Incentives	(1) Utility Systems (a) Loan Guaranty Program.Reservoir Insurance (b) Public Works Grants/Loans (2) Industrial Users (a) Business Tax Credits (b) Loan Guaranty Program/Reservoir Insurance (c) Fuel Use Act (ERA) - Exemption Procedure (d) Economic Development Assistance (3) Residential Users (a) Residential Tax Credits (b) Loan Guaranty Program (c) Federal Housing Programs (4) Federal Buildings/Facilities (a) Resource Assistance (b) Identification of Suitable Areas

OVERVIEW OF PLAN (DIRECT)

- OBJECTIVES
- RESOURCE DESCRIPTION
- WORLD-WIDE STATUS
- CURRENT STATUS
- MARKET POTENTIAL
- STATE OF READINESS
- COMMERCIALIZATION SEQUENCE
- INDUSTRIALIZATION PLAN
- STRATEGY
- BARRIERS TO DEVELOPMENT
- LEGISLATIVE ACTION
- INDUSTRIALIZATION ACTIVITIES
- STATE INFORMATION

1. STATE: Colorado

	10^{12} BTU/YR			
	1975	1985	2000	2020
Total Energy Use	839.20	1177.63	1957.60	3854.88
Geothermal Potential for Direct Use	20.01	34.68	81.77	204.71
Forecast Geothermal Direct Use	--	6.72	43.79	134.72

2. LEASING

Federal Leases	Number	Acreage
Competitive	3	5037
Non-Competitive	43	50245
State Leases	27	83192
Total	73	138474

3. RESOURCES

Location	Mean Reservoir Temperature (°C)
Wagon Wheel Gap	105±9
Sand Dunes Swimming Pool Well	141±7
Mapco State Well 1-32	118±10
Splashland Hot Water Well	141±10
Routt Hot Springs	130±11
Penny (Avalanche) Hot Springs	105±8
Mt. Princeton Hot Springs Area	112±10
Poncha Hot Springs	109±7
Waunita Hot Springs	141±10
Cebolla (Powderhorn) Hot Springs	95±19

4. POTENTIAL USERS

HIGH INTENSITY USERS

USER	POTENTIAL/ INFERRED	YEAR ON LINE	GEOTHERMAL PRICE PER MILLION BTU ($)	ALTERNATIVE FUEL PRICE PER MILLION BTU ($)
Applewood	P	1988	5.76	3.94
Golden	P	1988	5.43	3.94
Lakewood	P	1991	6.76	3.94
Wheat Ridge	P	1991	6.91	3.94
Canon City	P	1986	4.76	3.91
Industrial Park	P	1983	2.83	4.25
Montrose	P	1994	9.11	4.42
Durango	P	1989	4.59	3.00
Colorado Springs	I	2000	10.71	3.91
Stratten Meadows	I	1999	10.00	3.91

4. POTENTIAL USERS

LOW INTENSITY USERS

SITE NAME	USER NAME	POPULATION	ANNHD (1E9 BTU)
Potential			
Craig Wrm Water Well	Craig	7613	591
Steamboat Springs	Steamboat Springs	5012	533
Hot Sulphur Springs	Granby	819	127
Hot Sulphur Springs	Kremmling	1207	185
Hot Sulphur Springs	Hot Sulphur Springs	220	22
Idaho Hot Springs	Evergreen	2321	277
Idaho Hot Springs	Georgetown	1027	114
Idaho Hot Springs	Idaho Springs	2169	192
Glenwood Hot Springs	Glenwood Springs	5351	561
South Canyon Hot Springs	Rifle	2422	123
South Canyon Hot Springs	New Castle	447	29
Penny Avalanche HS	Carbondale	2203	317
Ctnwood Crk Jump HS	Leadville	4506	494
Chlk Crk Mt. Princton	Buena Vista	2979	248
Poncha Hot Springs	Salida	5455	421
Poncha Hot Springs	Poncha Springs	428	34
Canon City HS	Lincoln Park	2984	214
Splashland Hot Water	Alamosa	8948	953
Pagosa Springs	Pagosa Springs	1371	113
Wagon Wheel Gap HS	Creede	676	240
Wuanita Hot Springs	Gunnison	6075	541
Orvis Hot Spring	Ridgway	262	21
Ouray Hot Springs	Ouray	899	59
Ouray Hot Springs	Silverton	863	65
Ouray Hot Springs	Telluride	982	123
Rico	Rico	298	24

4. POTENTIAL USERS (continued)

LOW INTENSITY USERS

SITE NAME	USER NAME	POPULATION	ANNHD (1E9 BTU)
Inferred			
Brands Ranch Art Well	Walden	1034	86
Col Chinn Hot Well	Hotchkiss	869	28
Col Chinn Hot Well	Paonia	1390	86
Conundrum Hot Spring	Aspen	4010	518
Ranger Warm Spring	Crested Butte	1090	26
Wuanita Hot Springs	New Town	3000	716

5. OPERATIONAL SYSTEMS

LOCATION	USE	COMMENTS
Alamosa	Residential Heating, Aquaculture	Fish Farm
Archuleta	Agricultural	Irrigation
Boulder	Swimming Pool	
Chafee	Space Heating, Aquaculture	Residences, Fish Farming
Clear Creek	Space Heating	Two Story Building
Grand	Industrial	Laundry
Ouray	Space Heating	2 Motels

6. DEVELOPMENT PLANS

LOCATION	USE	COMMENTS
Canon City	Space Heating	
Pagosa Springs	District Heating	Initial well completed in July PON project

7. ENERGY USE & PROJECTIONS

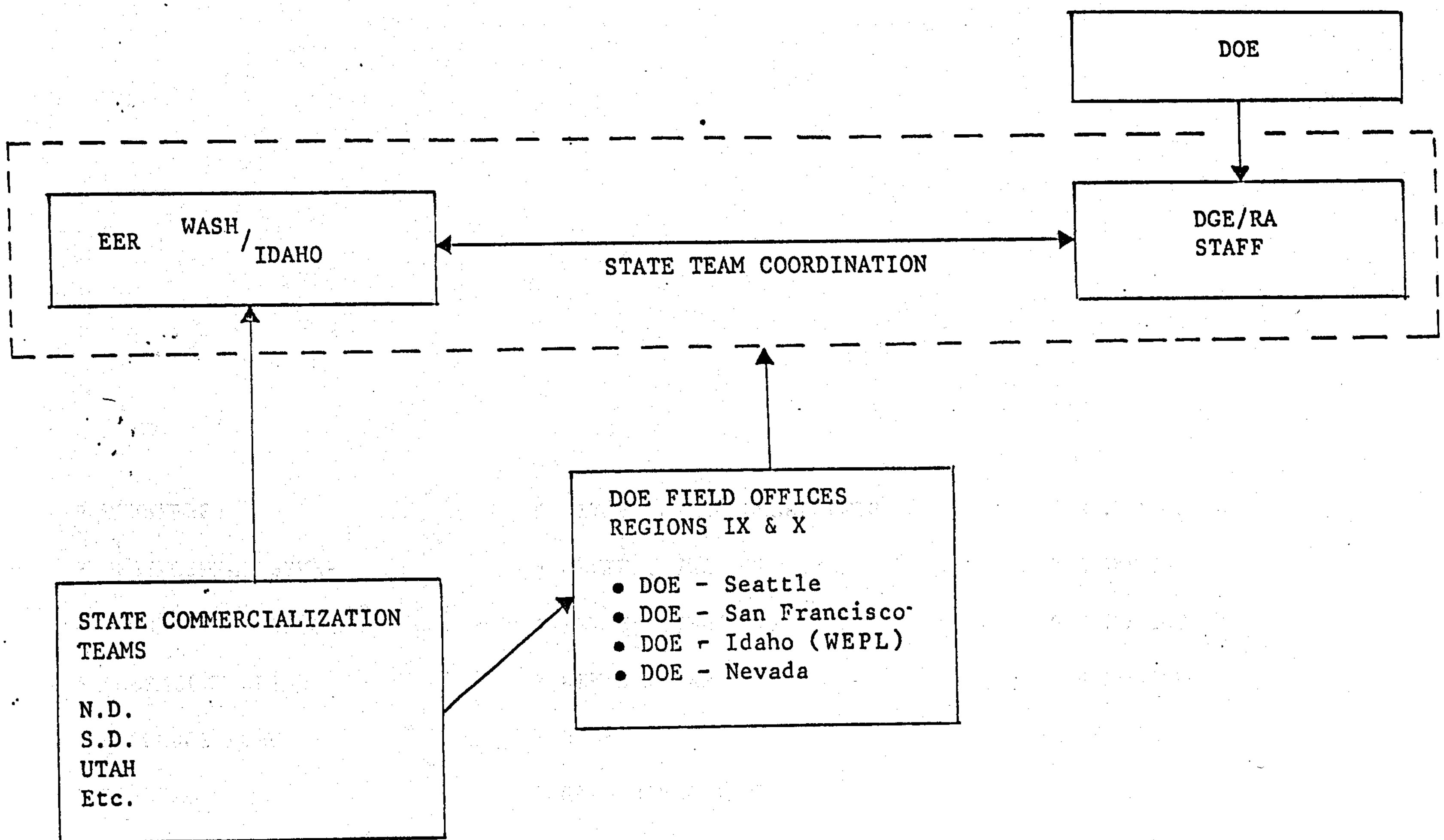
INDUSTRIAL PROCESS HEAT

	1975 ENERGY USE BTU X 10^{12}/YR.	1985 ENERGY USE BTU X 10^{12}/YR.	2000 ENERGY USE BTU X 10^{12}/YR.	2020 ENERGY USE BTU X 10^{12}/YR.
<u>POTENTIAL GEOTHERMAL USE</u>				
17 counties evaluated (of 59 counties total)	2.211	2.794	4.778	6.675
9 counties considered (factor 9/17 x .5)	0.585	0.740	1.265	1.767
3% per capita increase	0	0.962	2.634	12.765
5% growth stimulation	0	0.225	5.094	26.179
15% new discoveries	0	0	2.066	7.108
Total	2.796	4.721	15.837	54.494
<u>FORECAST GEOTHERMAL CAPTURE</u>				
Retrofit	0	0.140	0.559	0.699
New Growth Capture	0	0.911	9.804	40.730
Total	0	1.051	10.363	41.429

7. ENERGY USE & PROJECTIONS (continued)

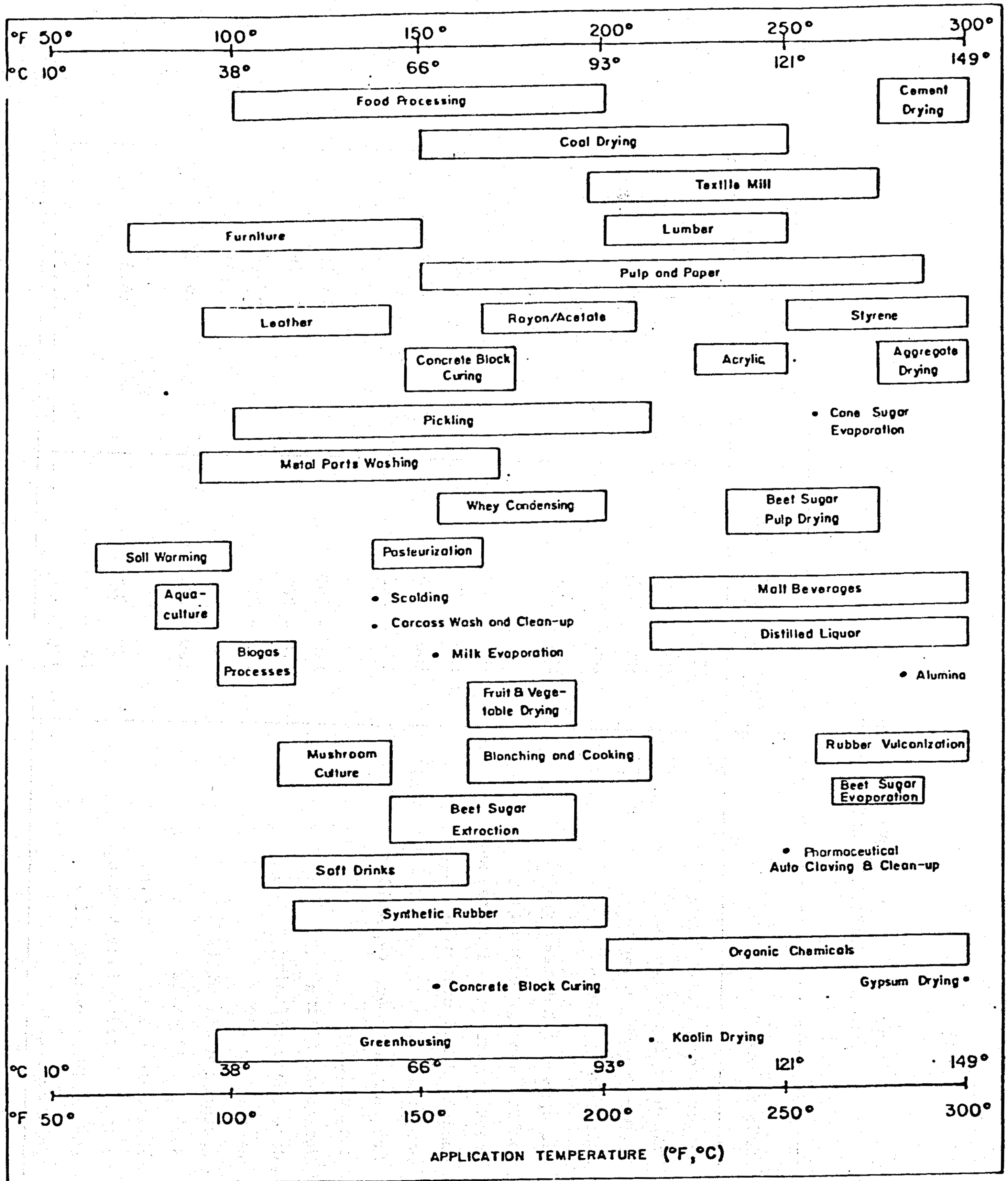
RESIDENTIAL/COMMERCIAL SPACE CONDITIONING

	1975 ENERGY USE BTU X 10^{12}/YR.	1985 ENERGY USE BTU X 10^{12}/YR.	2000 ENERGY USE BTU X 10^{12}/YR.	2020 ENERGY USE BTU X 10^{12}/YR.
POTENTIAL GEOTHERMAL USE				
17 counties evaluated (of 59 counties total)	13.61	19.01	31.40	61.27
9 counties considered (factor 9/17 x .5)	3.60	5.03	8.31	16.22
3% per capita increase	0	5.92	17.62	53.14
15% new discoveries	0	0	8.60	19.59
Total	17.21	29.96	65.93	150.22
FORECAST GEOTHERMAL CAPTURE				
Retrofit	0	0.86	3.44	4.30
New Growth Capture	0	4.81	29.99	88.99
Total	0	5.67	33.43	93.29



DATA COLLECTION & MONITORING NETWORK

ITEM	SOURCE	UPDATE FREQUENCY
• TOTAL ENERGY USE	• STATE TEAMS	• YEARLY
• LEASING	• BLM, STATE TEAMS	• 6 MONTHS
• RESOURCE BASE	• USGS	• YEARLY
• POTENTIAL USERS	• STATE TEAMS	• 6 MONTHS
• OPERATIONAL SYSTEMS	• STATE TEAMS, GPM	• 3 MONTHS
• DEVELOPMENT PLANS	• STATE TEAMS, GPM	• 3 MONTHS
• BARRIERS	• STATE TEAMS, DEVELOPERS	• 3 MONTHS



SOURCE: Direct Utilization of Geothermal Energy: A Technical Handbook, Special Report No. 7.

Figure 4-5. Application temperature range for selected industrial processes and agricultural applications

TABLE 6

PARTIAL LIST OF INDUSTRIES WITH SUBSTANTIAL REQUIREMENT
OF LOW TEMPERATURE ENERGY (PROCESS HEAT) BELOW 400°F

SIC	INDUSTRY GROUP	PROCESS TEMPERATURE (°F)	ESTIMATED PROCESS HEAT DEMAND 10^{12} BTU/YEAR
1021	Copper concentrate drying	250	1.7
1474	Potash drying filter cake	250	1.03
1477	Sulfur Frasch mining	325 - 240	60
2011	Meatpacking plants	140 - 200	45.28 (2011 and 2013 combined)
2013	Sausages & other prepared meats	140 - 200	
2017	Poultry and egg processing		1.54
2022	Cheese, natural and processed	100 - 200	15.00
2023	Condensed and evaporated milk	160 - 400	12.25
2034	Dehydrated fruits, vegetables & soups	160 - 350	8.20
2037	Frozen fruits and vegetables	170 - 212	5.21
2044	Rice milling		1.02
2046	Wet corn milling	120 - 350	15.49
2062	Cane sugar refining	110 - 265	31.16
2063	Beet sugar	140 - 280	61.84
2074	Cottonseed oil mills		2.56
2075	Soybean oil mills	160 - 340	16.31
2076	Vegetable oil mills, n.e.c.		1.37
2077	Animal & marine fats & oils	330 - 350	16.5
2079	Shortening & cooking oils	160 - 400	2.48
2082	Malt Beverages	170 - 400	15.82

TABLE 6

PARTIAL LIST OF INDUSTRIES WITH SUBSTANTIAL REQUIREMENT
OF LOW TEMPERATURE ENERGY (PROCESS HEAT) BELOW 400°F
(CONTINUED)

SIC	INDUSTRY GROUP	PROCESS TEMPERATURE (°F)	ESTIMATED PROCESS HEAT DEMAND 10^{12} BTU/YEAR
2083	Malt		4.27
2085	Distilled liquor, except brandy	212 - 400	21.38
2111	Cigarettes	220	0.86
2254	Knit underwear mills		1.19
2257	Circular knit fabric mills		8.87
2258	Warp knit fabric mills		3.92
2261	Finishing plants, cotton	200 - 275	42.1
2262	Finishing plants, synthetics	200 - 275	74.3
2269	Finishing plants, n.e.c.		3.24
2272	Tufted carpets and rugs		10.41
2282	Throwing & winding mills		2.73
2284	Thread mills		1.37
2296	Tire cord and fabric		1.19
2435	Hardwood veneer & plywood	250	50.6
2436	Softwood veneer & plywood	212	57.8
2611	Pulpmills }		
2631	Paperboard mills }	150 - 370	975.0
2641	Paper coating & glazing }		
2661	Building paper and board mills }		
2653	Corrugated & solid fiber boxes	300 - 350	21.6

TABLE 6

PARTIAL LIST OF INDUSTRIES WITH SUBSTANTIAL REQUIREMENT OF LOW TEMPERATURE ENERGY (PROCESS HEAT) BELOW 400°F (CONTINUED)

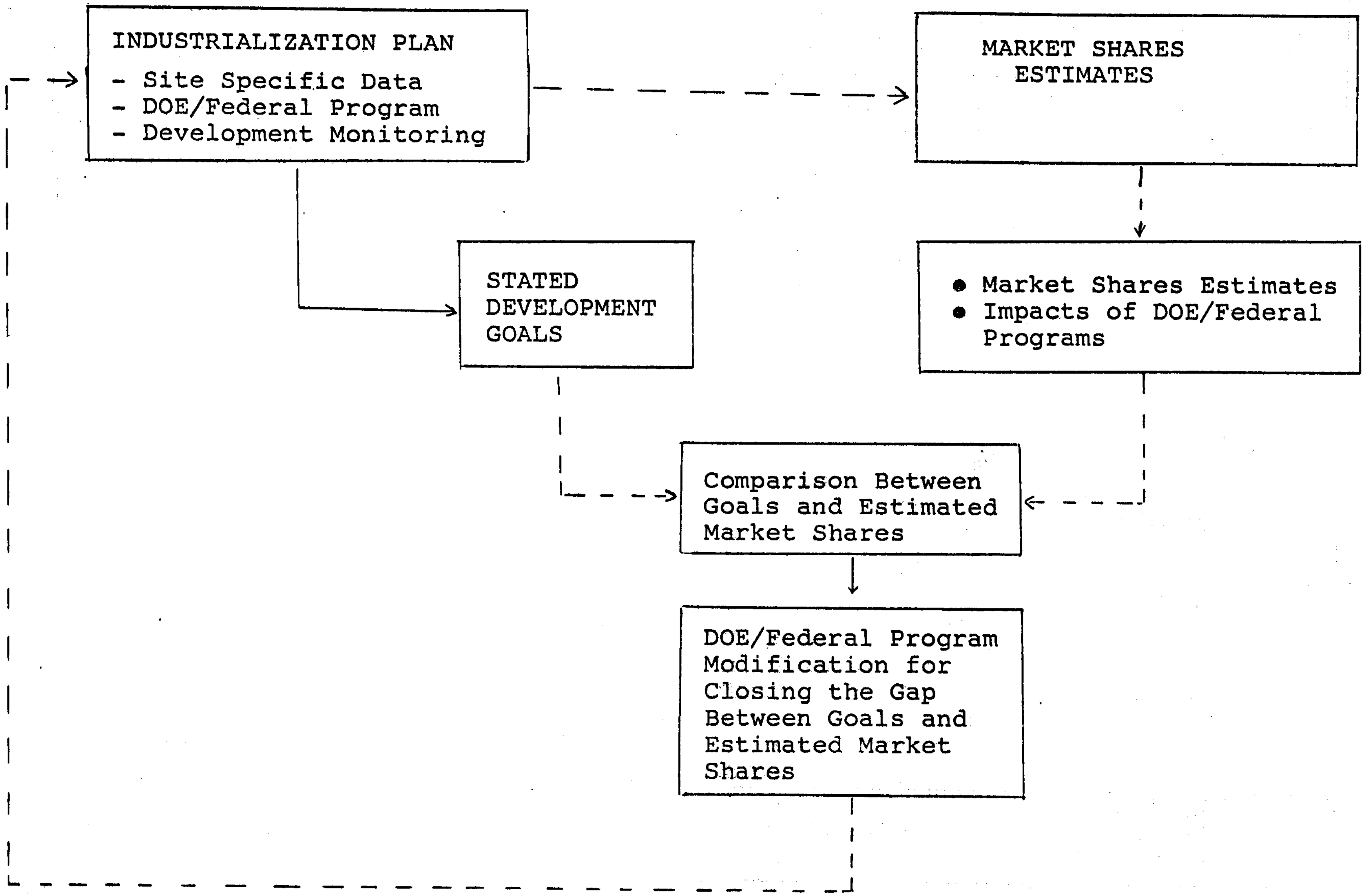
SIC	INDUSTRY GROUP	PROCESS TEMPERATURE (°F)	ESTIMATED PROCESS HEAT DEMAND 10^{12} BTU/YEAR
2812	Alkalies and chlorine	350	88.5
2819	Industrial inorganic chemicals, n.e.c.	280	113.2
2822	Synthetic rubber	80 - 200	10.60
2823	Cellulosic manmade fibers	250	23.5
2824	Organic fibers, noncellulosic	212	75.4
2833	Medicinals and botanicals		10.41
2834	Pharmaceutical preparations	150 - 250	19.90
2844	Toilet preparations		2.05
2861	Gum and wood chemicals		4.10
2865	Cyclic crudes and intermediates	250 - 350	38.45
2869	Industrial organic chemicals, n.e.c.	200 - 350	27
2873	Nitrogenous fertilizers	290 - 375	5.96
2911	Petroleum refining	45 - 350	119
2951	Paving mixtures and blocks	275 - 325	93.03
2952	Asphalt felts and coatings	300 - 400	5.12
3011	Tires and i-ner tubes	250 - 340	6.18
3241	Cement, hydraulic	275 - 325	8.0
3271	Concrete block and brick	165 - 360	17.67
3275	Gypsum products	300 - 330	21.18
3295	Minerals, ground or treated	160 - 230	13.26

TABLE 6

PARTIAL LIST OF INDUSTRIES WITH SUBSTANTIAL REQUIREMENT OF LOW TEMPERATURE ENERGY (PROCESS HEAT) BELOW 400°F

(CONCLUDED)

SIC	INDUSTRY GROUP	PROCESS TEMPERATURE (°F)	ESTIMATED PROCESS HEAT DEMAND 10^{12} BTU/YEAR
3321	Gray iron foundries		
3322	Malleable iron foundries	100 - 475	268.7
3324	Steel investment foundries		
3325	Steel foundries, n.e.c.		
3996	Hard surface floor coverings		1.19
	TOTAL		2568.19



RELATIONSHIP BETWEEN MARKET SHARE ESTIMATION
AND INDUSTRIALIZATION PLAN

Market Penetration of Hydrothermal Energy for Non-Electric Uses

by

T. A. V. Cassel
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Technecon Analytic Research, Inc.

MARKET PENETRATION OF HYDROTHERMAL ENERGY FOR NON-ELECTRIC USES

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Technecon Analytic Research, Inc.
Philadelphia, PA

1. SUMMARY

A Task Force was organized by the U.S. Department of Energy/Division of Geothermal Energy (DGE) in early 1980 to estimate the likely market *penetration* of hydrothermal energy through the year 2000. Whereas past efforts have provided estimates of the market *potential* of hydrothermal energy, the Task Force was directed to study the rate of realization of this potential. Both electric and non-electric uses were examined. The sensitivity of these estimates to various Federal program elements was also evaluated.

The Task Force is comprised of: Engineering and Economics Research, Inc. (EER) of Falls Church, VA; E G & G Idaho, Inc. of Idaho Falls; New Mexico Energy Institute (NMEI) of Las Cruces; University of Utah Research Institute, Earth Science Laboratory (UURI/ESL) of Salt Lake City; Western Energy Planners, Ltd. (WEPL) of Denver; and Technecon. An Industry Review Panel was also organized to provide periodic critiques of the methods and assumptions used by the Task Force. The Review Panel is comprised of representatives from the financial community, resource companies, public utilities, non-electric users and governmental agencies.

This paper addresses the methodology applied by the Task Force to estimate market penetration for *non-electric* uses. Results from the parallel effort on electric market penetration indicate no appreciable power generation east of Colorado during the next twenty years. Electric usage is, therefore, not presented here to this conference concerning eastern geothermal efforts.

Figure 1 illustrates the structure of the computerized analysis for non-electric users. In summary, the analysis is initiated by the specification of a projected hydrothermal resource discovery. Potential

colocated and relocatable users are identified at the projected discovery and a discounted cash flow (DCF) analysis is performed for each user/resource pair. The likelihood of a positive decision to use the resource is then estimated for each potential user, taking into account alternative energy forms available to each. If a positive user decision is indicated, then the rate of resource development is estimated to accommodate implementation lags. Resource development is constrained by saturation of the available resource as a last step in the analysis.

2. RESOURCE PROJECTIONS

Hydrothermal resource discoveries are specified by UURI/ESL in terms of a 6-digit generic classification and the projected year and region of discovery. The 6-digit code specifies: (i) well-head temperature, (ii) unpumped well flow rate, (iii) dissolved solids content of the brine, (iv) completed well cost, (v) pumped well flow rate and (vi) size of the resource. Results of sensitivity tests conducted early in the Task Force effort indicate that these six site-specific variables are of primary significance to project feasibility. Other resource-related parameters (e.g., well spacing, dry well fraction, redrill frequencies, etc.) are fixed across all resources in the analysis.

Table 1 defines the 6-digit generic resource code. For example, a discovery which is projected to have 275F fluid temperature, an unpumped well flow rate of 150,000 lb/hr, 2000ppm total dissolved solids, completed wells costing $400,000 each, a pumped well flow rate of 300,000 lb/hr and 6000 producible acres would be characterized by the code "4-3-3-4-4-7". A similar resource having 175F fluid would be coded "2-3-3-4-4-7", etc.

3. CANDIDATE USERS

Non-electric market penetration is estimated by performing a computerized decision analysis of the 25 categories of users listed in Table 2. Potential users outside of the 25 listed categories enter into the estimate by applying a multiplier to results from this decision analysis. It is important to note that although there are roughly 10 times as many potential user establishments in categories outside of the 25 modeled categories, the total potential sub-400F process heat demand of all these establishments is estimated to be less than 18% of that of establishments within the 25 modeled categories. Therefore, the selection of a limited number of energy intense user categories as a modeling base greatly enhances modeling efficiency with minimal effect upon resulting market estimates.

Selection of the 25 user categories listed in Table 2 was accomplished by a sequential screening process as indicated in Figure 2. Potential industrial and agricultural users were first screened for process temperature. Users with temperature requirements in excess of 400F were eliminated from the sample. User categories having a total annual process heat demand of less than 5×10^{12} BTU/yr for *all* establishments within the category were eliminated next. User categories having an average annual process heat demand of less than 0.01×10^{12} BTU/yr for *each* establishment within the category were eliminated in the third screen. The final screen eliminated user categories which, for reasons of practicality or logistics, are unlikely hydrothermal candidates (e.g. steel mills with excess internal process waste heat). It should be reiterated that the purpose of the screening is only to enhance interviewing and modeling efficiency. The heat demand of likely but screened-out users *is included* in estimate results via the 18% factor discussed in the previous paragraph.

For each projected hydrothermal resource discovery, the number of colocated establishments from the 25 user categories -- including colocated district heat demand -- is provided by NMEI from their computerized user data base. Regional energy intensity per establishment (BTU/yr/Establishment) is provided from data developed by EER. Demand growth over time is introduced on a regional and user-specific basis by growth rates derived by Technecon from the Wharton Annual and Industry Forecasting Model and from DOE/EIA's Regional Shares Model (REGSHARE).

The percentage of potential relocators within each user category is estimated by an analysis of interviews conducted by the Task Force with management representatives of 270 companies in the 25 user categories. This analysis revealed the potential fraction of relocators and the preferred regions of relocation of each.

4. PROJECT ANALYSIS

For each potential user/resource pair, a DCF analysis provides the estimated delivered energy price of hydrothermal energy and capital investment requirements for utilizing this energy. Project capital costs, recurrent costs and utilization factors are based upon figures provided by E G & G. The DCF analysis incorporates various component escalation rates derived from the Wharton Annual Model and incorporates estimated Federal, state and local tax liabilities and credits. Table 3 summarizes the several input parameters which are used in the analysis. Bulleted (•) items are site-specific and vary from resource to resource and/or user to user. Non-bulleted items are fixed in the model.

For the purposes of this analysis, district heat distribution systems are assumed to be financed and owned by regulated, tax-exempt municipalities. Hydrothermal fluid suppliers to all users are assumed to be non-regulated and able to take advantage of tax incentives.

5. USER DECISIONS

Included in the 270 industry interviews conducted by the Task Force were questions pertaining to a firm's preference for (or aversion to) utilizing hydrothermal energy under various combinations of: (a) delivered energy cost relative to that of their alternative fuel; (b) capital investment requirements; (c) energy supply reliability; and (d) project risk. Binary (yes/no) responses were tabulated by user category. Response data were then processed with a multiple regression analysis of a multivariate logit model. Statistical tests of confidence indicate that the resulting logit decision models provide acceptable goodness-of-fit to the industry supplied behavioral data.

The logit model estimates the fraction of firms within a given user category which are likely to respond positively to a hydrothermal utilization decision. The decision is characterized by four project attributes, a thru d, listed in the preceding paragraph.

The logit model represents one part of the overall user decision model illustrated in Figure 3. Also included in the complete model are: (i) an exclusion factor, (ii) a learning curve, and (iii) an implementation rate curve. The exclusion factor is estimated for each user category from industry interviews and represents the fraction of firms that would not consider utilizing hydrothermal energy regardless of incentives. The shape of the learning curve for each user category is determined from an analysis of interview responses together with published data on industrial innovation characteristics. As shown in the lower left hand corner of Figure 3, learning curves provide the fraction of firms which are informed and in a position to make a hydrothermal decision.

As shown in the center of Figure 3, the asymptote of the S-shaped logit model is defined by the combined influences of the exclusion factor and the learning curve. N* represents the logit estimate of positive response fraction as a function of the multivariate stimulus S*. The rate at which N* firms are expected to put hydrothermal energy into use is estimated by the curve shown in the lower right hand corner of Figure 3. This curve accounts for decision and construction lags and the retirement of existing process heat equipment. The curve is constructed from data compiled from the industry interviews conducted by the Task Force.

6. CONCLUSION

This paper has presented the methodology applied by DGE's Task Force to estimate the likely national market penetration of hydrothermal energy for non-electric uses. To date preliminary estimates have been provided to DGE. The effectiveness of various Federal incentives and research program elements are currently being evaluated by performing sensitivity tests with these methods. A technical report is, at present, being prepared by the Task Force which will fully document the methods and results discussed above. This report is scheduled to be published by the end of the calendar year.

November, 1980

FIGURE 1
NON-ELECTRIC HYDROTHERMAL MARKET ANALYSIS

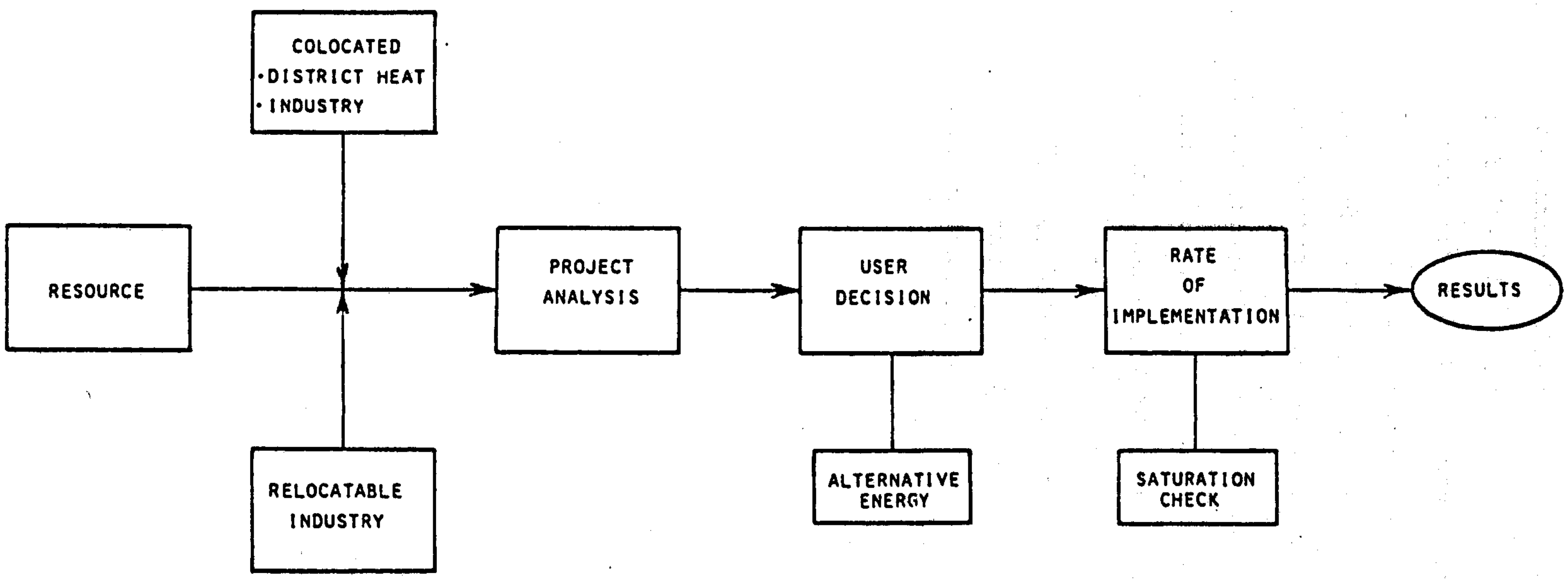


TABLE 1
GENERIC HYDROTHERMAL RESOURCE QUALITIES

	1	2	3	4	5	6	7	8
WELL-HEAD TEMPERATURE (F)	125	175	225	275	325	375	425	475
UN-PUMPED WELL FLOW (10^6 LB/HR)	50	75	150	300	500	700	800	--
BRINE CONTAMINATION (PPM TDS)	100000	2000-100000	2000	--	--	--	--	--
WELL COST (1980 $ Thousands)	2000	1500	750	400	200	75	--	--
PUMPED WELL FLOW (10^6 LB/HR)	50	75	150	300	500	700	800	--
PRODUCIBLE ACREAGE	1500	2000	3000	3500	4000	5000	6000	10000

TABLE 2
SURVEYED INDUSTRIES

	SIC CODE	INDUSTRY CATEGORY
1.	018	GREENHOUSES
2.	024	DAIRY FARMS
3.	025	POULTRY & EGGS
4.	0279	FISH FARMS
5.	1311	TERTIARY OIL RECOVERY
6.	201	MEAT PRODUCTS
7.	202	DAIRY PRODUCTS
8.	203	FRUITS & VEGETABLES
9.	2046	WET CORN MILLING
10.	206	SUGAR REFINING
11.	207	FATS & OILS
12.	208	ALCOHOLIC BEVERAGES
13.	2436	SOFTWOOD VENEER & PLYWOOD
14.	26	PULP & PAPER PRODUCTS
15.	281,2	CHEMICAL PRODUCTS
16.	283	MEDICINES
17.	2865	CYCLIC CRUDES & INTERMEDIATES
18.	2869	INDUSTRIAL ORGANIC CHEMICALS
19.	2873	NITROGENOUS FERTILIZERS
20.	3011	TIRES & INNER TUBES
21.	3241	CEMENT PRODUCTS
22.	3271	CONCRETE BLOCK & BRICK
23.	3275	GYPSUM PRODUCTS
24.	3295	MINERALS, GROUND & TREATED
25.	--	DISTRICT HEATING SYSTEMS

** NON-SURVEYED INDUSTRIES ACCOMMODATED VIA REGIONAL ENERGY USE MULTIPLIERS **

FIGURE 2
INDUSTRIAL SCREENING FOR SAMPLE SURVEY

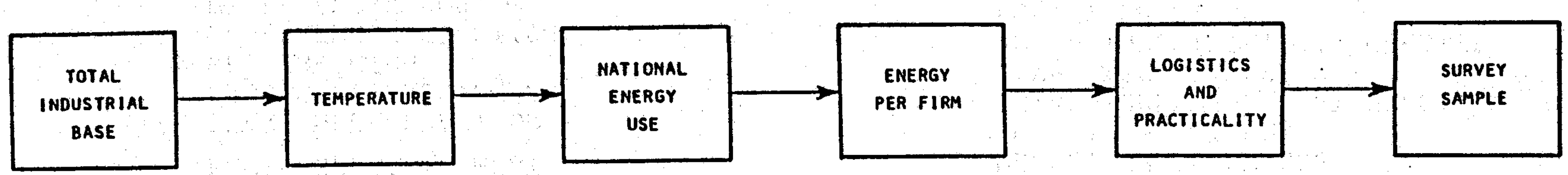


TABLE 3
NON-ELECTRIC ECONOMIC MODEL PARAMETERS

RESOURCE PARAMETERS

- WELL-HEAD TEMPERATURE
- CONTAMINATION INDEX
- WELL FLOW UNPUMPED
- WELL FLOW PUMPED
- WELL COST
- PRODUCIBLE ACREAGE
- FLUID SPECIFIC HEAT

SPARE WELL FRACTION
PRODUCER/INJECTOR RATIO
WELL SPACING
WELL REWORK FRACTION
WELL REWORK COST
WELL REDRILL FRACTION
WELL REDRILL COST
DRY WELL FRACTION
DRY WELL COST

USER PARAMETERS

- ANNUAL HEAT REQUIREMENT
- TEMPERATURE REQUIREMENT
- ANNUAL USE FACTOR
- ALTERNATIVE FUEL TYPE

TEMPERATURE LOSS AND PINCH

ECONOMIC & TAX PARAMETERS

- INFLATION RATES: ENERGY
- ENERGY PRICES
- ENERGY USE EFFICIENCIES

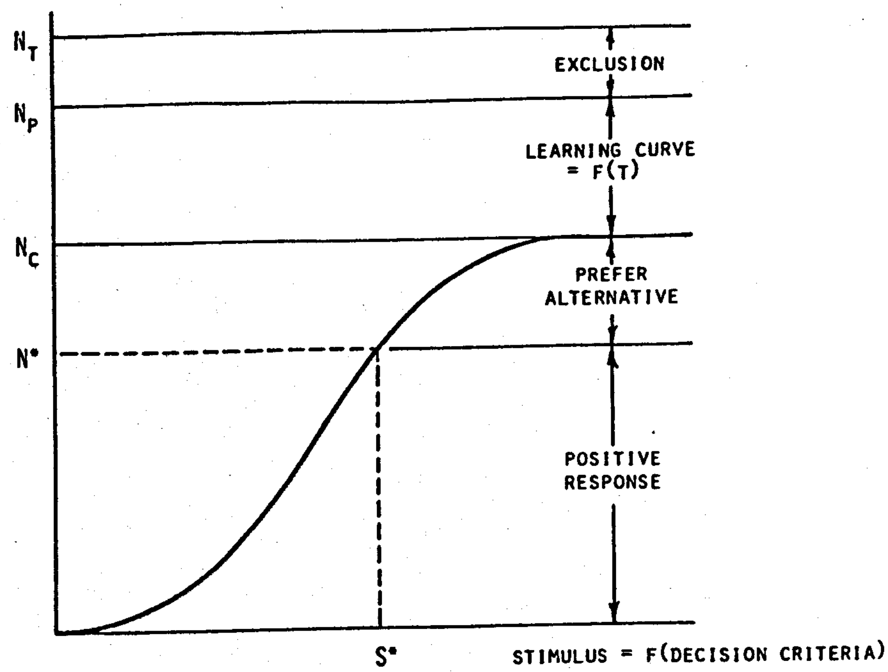
PROJECT BOOK LIFE
PROJECT TAX LIFE
DEPLETION ALLOWANCE
ROYALTY FRACTION
INTANGIBLE WELL COST FRACTION
INVESTMENT TAX CREDIT
ADD'L INVESTMENT TAX CREDITS
EQUITY FRACTION
EQUITY RETURN
LONG TERM DEBT COST
LOCAL TAX RATES
STATE TAX RATE
FEDERAL TAX RATE
USER'S DISCOUNT RATE
GNP DEFLATOR
INFLATION RATE: MAINTENANCE
INFLATION RATE: CONSTRUCTION

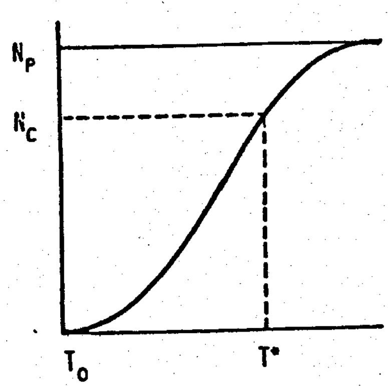
COMPUTED OUTPUT

▼ CAPITAL REQUIREMENTS
▼ ENERGY COST RATIO
▼ FRACTION OF RESOURCE UTILIZED

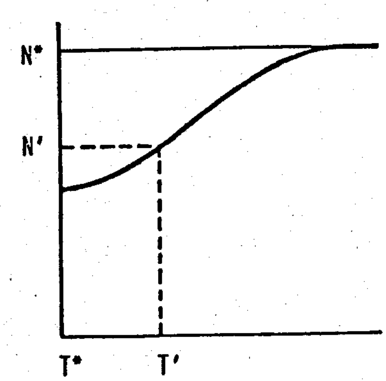
FIGURE 3

NON-ELECTRIC HYDROTHERMAL USER DECISION MODEL





LEARNING CURVE



IMPLEMENTATION RATE

Past, Present, Future
The Hot Springs of Arkansas*

by

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U.S. Department of Interior
National Park Service

*This material was not presented but was sent for inclusion in the published minutes.

PAST, PRESENT, FUTURE
The Hot Springs of Arkansas

I believe it is appropriate to introduce this presentation with a brief history lesson, to give the reader an understanding of Hot Springs National Park and the use of the park's prime resource, a collection of 47 hot springs. It will explain why things are the way they are in respect to the use or lack of use of the thermal water for energy-saving purposes.

In 1895, an unidentified writer of the period noted that, "The 'Luxury of the Bath' is realized beyond compare at Hot Springs..." He was referring to the baths offered by the numerous bathhouses at Hot Springs, Arkansas. There were at that time, 21 bathhouses drawing water from the 47 thermal springs, owned and controlled by the U.S. Government, and known as the Hot Springs Reservation.

A later writer, touching upon the history of the Hot Springs Reservation, attached something more than luxury to the thermal waters. He reported that,

> "In 1832, our government, believing that the all-wise Architect of the Universe had a purpose in creating those fountains of health almost midway between our ocean boundaries, and that such a priceless gift should be free from monopoly and exploitation, set aside ... the Hot Springs and four sections of land surrounding them."

It is difficult to attach such lofty motives to the United States Congress for setting aside the 47 hot springs of Arkansas. As though an afterthought to an act authorizing the Governor of the Arkansas Territory to lease the salt springs in the territory, the act stated,

> "and be it further enacted that the hot springs in said territory, together with four sections of land including such springs, as near the centre thereof as may be, shall be reserved for the future disposal of the United States, and shall not be entered, located, or appropriated for any other purpose whatever."

There is nothing in the act about the all-wise Architect of the Universe nor about preserving the waters forever for the use by all.

But for whatever reason, the act was a significant one, for here was Congress reserving for the future four sections of land containing 47 thermal springs.

Long before Congress took an interest in the hot springs, people had been traveling to Hot Springs to bathe in the hot waters and to find relief and cure from a variety of diseases and illnesses. Legend has it that the locality of the hot springs was held as neutral territory by various hostile Indian tribes who gathered here to enjoy the benefits of the hot waters. The first white men to visit the Hot Springs region were Hernando DeSoto and his followers in September, 1541, when they set up winter camp in the vicinity of the hot springs, although it is doubtful that they entered the so-called Valley of the Vapors and actually saw the springs. After that visit, it was over 250 years before white men again visited the region and recorded their visit. In 1804, following the Louisiana Purchase, William Dunbar and Dr. George Hunter headed an official expedition into the area.

They found that white men were already visiting the springs, for they reported that they had found "an open log cabin with a few huts of split boards all of which had been calculated for summer encampment for the recovery of their health." Two years after the Hunter-Dunbar expedition, the first white resident settled in the Hot Springs area. From this time forward, Hot Springs was to be a health spa to which people with all manner of afflictions would visit for cures or relief.

After enacting the 1832 law, the Congress appears to have forgotten the 47 springs and four sections of land. The act did not define specific policies governing the use of the land or the springs nor did it appoint any government agency to administer them or look after them. This inattention continued for almost forty years, giving rise to numerous unattractive settlements of squatters around the springs. Eventually, in 1870, Congress did enact a law to settle the matter of ownership, following which several claimants brought suit in the Court of Claims. The claims were denied by the court and the decree was affirmed by the United States Supreme Court in a decision delivered on April 24, 1876. With this, the passive role of the Federal government was ended.

An act of March 8, 1877, dealing with land issues also provided that Hot Springs Reservation was thereafter to be under the charge of a superintendent appointed by the Secretary of the Interior.

With the arrival of the superintendent and an increased interest in the hot springs, Congress henceforth more than made up for the forty years of neglect. During the 23 years between 1877-1900, the Congress passed sixteen pieces of legislation relative to the use of the land and the waters of the Hot Springs Reservaiton. Several dealt with land titles, others were grants of land or rights-of-way to a variety of organizations and public agencies for a variety of purposes.

As the fame of the Hot Springs Reservation continued to grow, the importance of additional regulation or control became manifest. An Act of Congress, approved March 3, 1891, authorized the Secretary of the Interior to prescribe rules and regulations for the conduct of all the houses receiving hot water from the government. The regulations thus issued dealt with such matters as sanitation, wasting water, rates charged, issuance and redemption of bath tickets, salaries paid bathhouse attendants, drumming up business, lawn maintenance, use of the free bathhouse, and more.

At the turn of the century, the Hot Springs Reservation was a bustling health resort, with thermal waters of the Reservation being the central attraction. According to the superintendent, it was seen as a great national sanitarium. It was also being recognized as one of the most attractive parks controlled by the government. The picturesque scenery of the Ouachita Mountains, the foliage, the sight and aroma of natural and cultivated flowers, the winding carriage roads, bridle paths, and walking trails, scenic overlooks, and landscaped parks, combined to make Hot Springs Reservation a beautiful and enjoyable place to visit aside from the benefits derived from the thermal water.

Hot Springs had become "...a comfortable gathering place where old friends came year after year to enjoy the sunshine, the leisurely life and the gay society of the hotels, much as had been previously found only in the spas and resorts of Europe."

The development of the park, the city, and the resort resulted, of course, from the water of the 47 springs; it is clear, tasteless, odorless, and hot -- 143 degrees F. The tritium and carbon 14 analyses of the water indicate that the water is a mixture of a very small amount of water less than twenty years old and a preponderance of water about 4,400 years old. The springs are charged by local rainfall that precipitates very slowly to unknown depths, from 4,000 to 8,000 feet, where it obtains its heat from an unknown source, then travels to the surface where it discharges on the western slope of Hot Springs Mountain.

The springs produce about three quarters of a million gallons of water per day. In the early days of the Hot Springs Reservation, the bathhouses drew water from individual springs. During the 1800s, the government began enclosing the springs, and in 1888, Congress appropriated funds for providing a system of reservoirs, pumps, and piping for the collection and distribution of the hot water. These actions supported the philosophy that the first great object was the preservation and the free and absolute control of all the hot springs by the government.

The act of March 1, 1872, establishing Yellowstone National Park, was to have an effect upon the history of the Hot Springs Reservation. It presented the concept of public parks in Federal ownership set apart "...for the benefit and enjoyment of the people." Thereafter, the Secretary of the Interior in his annual reports included entries on the Hot Springs Reservation and Yellowstone National Park. Until 1916, the national parks and monuments under control of the Secretary of the Interior were administered by a small force in the Secretary's office. Then, in 1916, the National Park Service was established by Congress as an agency in the Department of the Interior to be responsible for the "supervision, management, and control of the several national parks and national monuments which are now under the jurisdiction of the Department of the Interior, and of the Hot Springs Reservation in the State of Arkansas..."

The Hot Springs Reservation thus continued to be closely affiliated with the national parks and national monuments. But the change in designation from reservation to national park did not come until 1921.

So, although Hot Springs National Park is the oldest of all national park areas and was included in all lists of national parks from 1872 on, it was not designated a national park until 1921.

Throughout the 1920s and 30s, the bathing industry flourished. Some refer to these decades as the "Golden Age of Bathing." During the Second World War, the nearby Army-Navy hospital made heavy use of the hot water for treatment of its patients. But shortly after World War II, the bathing industry in Hot Springs began to decline. In 1946, the peak year, there were 649,269 baths given in the bathhouses on Bathhouse Row. Last year, 1979, there were 100,000. There are now four vacant bathhouses on the Row. And a large surplus of hot water.

So, in 1973, following the Arab oil embargo, when the President ordered all Federal agencies to reduce their energy consumption, the superintendent of Hot Springs National Park had not far to go to find an alternate heat source for the park's visitor center/administration building.

The conversion to geothermal heat in the Visitor Center/Administration building at Hot Springs National Park was not costly nor complex. Engineering plans cost $675; coils, valves and other supplies cost $1,567.40; park labor to put it all together cost $804.85. Thus, the conversion of the heating system in this 7,700 square foot building was done at a cost of $3,047.25.

The system it replaced was a gas fired boiler rated at 630,000 BTUs. Air delivered throughout the building was heated by a steam radiator located in the basement ductwork.

The new system consists of a copper coil located in the plenum above the blower. The thermal water comes into the coil at about 138° F; it leaves the coil at about 128°. Obviously, the system can be improved. It is planned to modify it, making it a closed circulation system with temperature probes to keep the water in the system until it reaches about 110° F. It is also planned to make additional use of this cooled water, as will be described below.

Water coming from the springs at 143° F is too hot for bathing. So a portion of that water is pumped through heat exchangers to bring the temperature down to 90° F. The exchangers are expensive to operate and consume considerable amounts of electrical energy. When the existing geothermal heating system in the Visitor Center/Administration building is modified, it is planned to pipe the "used" 110° F water into the cool water system so that the heat exchangers will be needed to extract only fifteen to twenty degrees from the water instead of the fifty-three degrees now required. Thus, an additional savings of energy.

In 1978, the National Park Service conducted a feasibility study on the conversion of bathhouse heating systems from gas fired to geothermal water, looking to the possibility of requiring all of the bathhouses to make the conversion. Because of the conversion costs and the very low margin on which the bathhouses operate, it was decided that the conversions would not be required, but that the bathhouses could convert at their option. One, the Buckstaff Bathhouse, has selected the option.

The Buckstaff is a three story masonry building with approximately 18,200 square feet, excluding the basement. The existing heating system is a low pressure steam system utilizing two boilers. The heat distribution system is a combination of 26 cast iron radiators and a makeup air system consisting of multiple zones. The system was designed to change the air in the building six times per hour, in order to remove humidity and odors.

The conversion to thermal water will be in the makeup air system only. The modification includes installation of cleanable thermal water heating coils in the existing air handling system and replacement of the multizone temperature control system. There will be two air exchanges per hour.

Replacement of heated air two to four times per hour is an acknowledged waste. An alternative is to recirculate the air through dehumidifiers. However, this option was rejected by the Buckstaff Bathhouse Company because of the significantly higher cost of installation.

The Buckstaff conversion is being designed so that the 110° F return water may be piped into the cool water distribution system, as discussed earlier.

The next conversion will probably be the Libbey Memorial Physical Medicine Center, a government-owned bathhouse in the national park. Depending upon the availability of funds, this conversion may be made in 1981. Engineering and cost studies are underway.

Additional conversions are expected to be made in the future, as adaptive uses are found for the four vacant bathhouses. One, the Fordyce Bathhouse, is to be converted into a visitor center/museum. It is expected that this 28,000 square foot building will be heated by the thermal water from the springs.

Other energy uses are being made of the thermal water at the present time, Two public comfort stations on Bathhouse Row are heated by the springs water. Two more are being planned for conversion, replacing two 5,000 watt heaters.

The domestic hot water used in the park's administration building is heated by the hot springs water. A copper coil carrying domestic (city) water is submerged in the hot water reservoirs under the administration building. It provides tap water at approximately 130° F.

It is estimated that present use of the hot water may double within the next two years, which still will leave a surplus of approximately 350,000 to 400,000 gallons per day.

The National Park is presently preparing criteria for making the springs water available to users outside of the national park. It will be the superintendent's recommendation that first consideration will be given other federal agencies, then local government. It is not expected that sufficient water will be available for private users. Before doing any of the above, present laws relating to the use of the thermal water may need to be amended.

There is a possibility for using the surplus hot spring water for purposes other than heating. It may be that today's technology makes it possible to convert the energy contained in the hot water from the springs into shaft power which could be utilized in a refrigeration system. Quantitative information on the potential capacity of this system is needed along with some economic evaluations.

It needs to be emphasized that the first use of the thermal water is and always will be viewing, bathing, and similar public uses.

The collection of forty-seven springs is the prime resource of Hot Springs National Park. The National Park Service is charged with the responsibility of preserving these springs for the benefit and enjoyment of the people.

Many visitors to the national park complain that they are able to view only two of the springs, the other forty-five being encased in spring enclosures. The Park Service plans to open another one for public viewing in 1981, giving the park visitor an even greater understanding and appreciation of the resource that is of such significance that years ago the U.S. Congress set the area aside as Hot Springs National Park.

List of Attendees and Initial Distribution

ATTENDEES

EASTERN GEOTHERMAL TECHNICAL INFORMATION INTERCHANGE MEETING

November 6-7, 1980

Beebee, John Energy Systems, Inc.	Box 6065 Anchorage, AK 99507	907-243-1942
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Brown, Mitchell R. NASA/Wallops	Flight Center Bldg. F160 Wallops Is., VA 23337	807-827-3411
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Cassel, Tom Technecon Analytic Research, Inc.	2400 Chestnut Philadelphia PA 19103	215-561-5462
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Fukundiny, Robert H. New York State Geol. Soc.	CEC 3136 ESP Albany, NY 12230	518-474-5816
Giles, Harry N. U. S. Department of Energy Division of Geothermal Energy	RA-342.5 12th & Pennsylvania Ave., NW Washington, DC 20461	202-633-8820
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