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27th GEOTHERMAL COORDINATING GROUP
MEETING Oct. 3-5, 1979
SALT LAKE CITY, UTAH

Washington Scene, Reviewed by Bill Ogle

It seems likely that the halves of DGE will be re-united in a couple of weeks, under Under Secretary Ruth Davies. Director is unknown. Rudy Black believes the commercialization effort benefitted from the split. Its most viable part is the loan guarantee program. Bennie Dibona may be promoted to handle the national petroleum reserve.

Rudy Black received a separate 1980 budget, apparently just in time for the new fusion.

Bennie Dibona is optimistic about the future use of geothermal energy for generating electricity, particularly after 1986.

Other than geopressure and hot dry rock, neither Rudy Black or Bennie Dibona has a clear idea about what the laboratories should be doing. In fact, the Department of Energy has no consistent attitude toward the national laboratories. Both think applications are the future effort of the geothermal energy divisions. The Division of Geothermal Energy needs to see that research and development necessary for applications is being done. The government's role in pursuing thousands of small uses is not clear, though Rudy Black is pushing direct use. The problem is one-of-a-kind projects. Regionalization seemed to be working, better at INEL than at SAN.

The government is considering guaranteeing in some way the longevity of the reservoir, like they have guaranteed the uranium supply to U.S.-made reactors. There is going to be a lot more consideration, however.

San Diego Gas and Electric has put their last nickel in geothermal energy without Department of Energy help.

Lawrence Berkeley Laboratory's director resigned over the point that the Department of Energy would not support LBL initiatives.

The Treasury Department and the Office of Management and Budget argue for using grants, not tax credits, to stimulate geothermal development, because neither like programs that go on forever. Congress likes tax credits.

United States Geological Survey - Bob Christiansen and Wendell Duffield

There will be a cut in the 1980 USGS geothermal effort to the 1979 level ($11,363,000 to $9,941,000). The program will be similar to what it has been. Emphasis on the Cascade Mountains region will be increased and the Coso-Long Valley effort will be wound down. There will be more work on the low temperature systems to narrow some of the existing data gaps. The USGS is committed to continue some of the extramural work (managed by Don Click).

The USGS program is complimentary to the commercialization effort, since the USGS is characterizing the commercial geothermal systems.

Using the laboratories to do any portion of the USGS program is difficult because of a bureaucratic problem. The USGS can deal with the Department of Energy, but not the laboratories.

EG&G - Joe Hanny

EG&G is doing the following hydrothermal planning and analyses:

National planning assistence.
State baseline document preparation.
Energy technology requirements planning.
Activities reporting and progress monitoring.
Commercialization studies:
- Market penetration
- Capital planning requirements
- Direct heat infrastructure

The state baseline documents include the following information:
- Basic state data.
- Hydrothermal resources.
- Commercialization activities.
- Development plans.
- Government assisted programs.
- Energy use patterns.
- Leasing and permitting policies.
- Bibliography.

The documents do not discuss auxilliary requirements such as for cooling water. They are primarily for the Resource Applications branch of DGE but copies go the governor and state energy offices. Documents have been completed for Nevada and Arizona.

The energy technology requirements planning has the following purposes:

1. To be sure the Energy Technology Division of DGE is supporting projects helping commercialization, not just projects Bennie can't stop.
2. To prepare a technology problem list, with advice from industry, advisory committees, etc.
3. Obtain industry prioritization of energy technology problems.
4. Recommend a technology development program.

(Joe had the group fill out the technology development prioritization matrix, Figure 1.)

Discussion

Well costs seem to rise exponentially with depth, and are higher than estimates by AAPG.

In pricing geothermal energy it must be assumed that the price of geothermal will rise with the price of the alternatives. It can't be assumed geothermal rises 5% less steeply. After all, the principal product of a steel mill is money, not steel.

Rudy Black seems to think we will have 3000mw of geothermal electricity by 1986, but the non-electric goal will fall short by a factor of 5.

Applied Physics Laboratory - Al Stone

The Crissfield, Maryland well has been drilled, tested, and abandoned, prematurely. The bottomhole temperature was 133°F for the best aquifer. Water contained 90,000 ppm contaminants, twice seawater. Permeability was 70md using the

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TECHNOLOGY REQUIREMENTS TO ACCELERATE COMMERCIALIZATION OF HYDROTHERMAL ENERGY

1. Improve reliability of down hole pumps
2. Reduce cost of heat exchangers
3. Reduce corrosion and erosion
4. Improve injection capability
5. Develop 10-20 MWe power systems
6. Reduce cost of component testing in hydrothermal environment
7. Improve the technology for power plant cooling systems
8. Improve non-metallic materials (seals, coatings, tools, cables)
9. Improve system modeling capability (reservoirs thru power cycles & injections)
10. Improve capability for determining reservoir recharge
11. Reduce effluent pollution (H_2S, mercury, radium, arsenic)
12. Improve capability to predict or control induced seismicity and subsidence
13. Develop low temperature refrigeration and air conditioning equipment
14. Improve capability of downhole instruments and log interpretation (geophysical & geochemical)
15. Establish confidence in the economics and reliability of direct heat systems
16. Determine economics and reliability of a commercial size binary plant (50 MWe)
17. Reduce the risk & cost of exploration
18. Improve the availability of existing geoscience and resource data (low, moderate & high temp.)
19. Control scaling
20. Reduce hydrothermal field development costs and improve well flow rates
21. Reduce cost of and improve technology for drilling (fluids, motors, bits, cements & packers)
22. Develop 1-5 MWe wellhead generators
23. Increase reservoir confidence (reservoir engineering & assessment techniques)
24. Improve understanding of reservoir chemistry (rock and fluid)
25. Increase electrical power cycle efficiency
26. Reduce cost of hardware for direct heat applications

Figure 1

ATTACHMENT TO THE PRIORITIZATION MATRIX

1. Do you believe the major barriers to accelerated commercialization are:

   ◯ Technical

   ◯ Non-Technical

2. If you consider the major barriers to be non-technical, please list the most important issues to be solved.

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. Are there any major technical barriers that you feel were not covered by the prioritization matrix?

   Please list: ______________________________

   ____

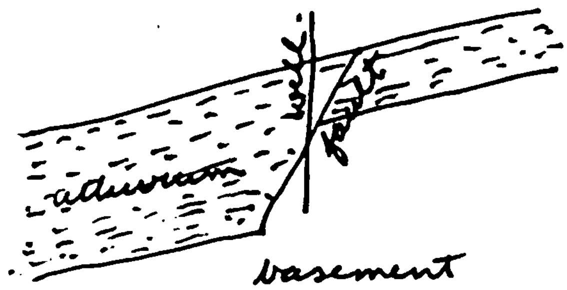
   ____

Name ______________________ Company ______________________

Figure 1 (cont.)

last 6 minutes of pumping, but reanalysis shows 130md, indicating the well might have been useful. The well was filled with concrete, cut 20 ft. below the surface, and abandoned.

Monroe Hot Springs Project - Roger Harrison



The production well drilled for the project may dry up Monroe Hot Springs. Water from the well shows 2700ppm dissolved solids, with considerable CO_2. The well temperature is 75°C. It is almost isothermal below 400'. The cost of geothermal energy to the city is $.008/kwh, which is lower than fuel oil.

The questions concerning direct use are: where is the water, what does it cost, how long will it last? Even on the East Coast, for a co-located user of geothermal energy the cost is $1-2/MBtu. District heat is not necessarily competitive, but is in the ball park.

The whole subject of heat pumps and use of low temperature water is of relevance to direct use. Oak Ridge National Laboratory is looking at ground water referenced heat pumps.

Los Alamos Scientific Laboratory - Mort Smith

The new hot dry rock system is supposed to yield 50mw (35mw±15), with lower thermal drawdown than the present system.

The present system was adequately modeled (at least the temperature drawdown) by a disk shaped fracture system of 8000m^2 area. The chemistry suggests the system was being continually expanded. Water temperature didn't vary greatly with flow.

New experiments have provided a 1000 ft. long fracture, but experiments using packers to produce parallel fractures resulted in sticking the packers in the hole.

The drilling for the new hot dry rock system used downhole drill motors for directional drilling. There were problems with the seals on the motor, which can't stand up to the temperature. The Maurer turbodrill works but it is hard to keep it going in the right direction.

The 13-14000' holes are costing $3 million each.

International arrangements for foreign participation in the project have proven to be hard to make.

The heat exchange surface of the new system will be determined by modeling, dye injection, acoustic ranging, and microseismic mapping.

At 275°C, there are cable and measuring tool problems.

Plains Electric is looking at the problems of building a Fenton Hill hot dry rock power plant, and the Forest Service is serious about an 8700 ft. altitude greenhouse.

Drilling for hot water to heat the laboratory was unsuccessful, though there is a basin structure in the graben beneath the laboratory which may be hot and wet. The problem was drilling in porous, volcanic rock, causing lost circulation, a simple common problem which has not been solved. The money for the project came from Bennie Dibona, who reprogrammed it from the hot dry rock project.

The federal hot dry rock program is making contracts to recon for hot dry rock everywhere. There is about $2 million in this program and $10x10^6 at Fenton Hill.

Union Oil has found a good hydrothermal system in Valles Caldera, with 8 or 9 productive holes. The plan is to construct a $120 million, 50mw power plant; of which $60 million will come from the Division of Geothermal Energy. Environmental problems are tying up the project. Indian pueblos have water rights to potential cooling water. All three power line routes have problems.

Los Alamos Scientific Laboratory - Lee Aamodt

People who have an applied problem requiring basic energy research do not rely on the Office of Basic Energy Sciences to solve it for them; they do it themselves.

The most interesting basic science problem, related to geothermal energy, seems to be the possibility of getting a deep temperature measurement by using the depth to the Curie point. This might be possible by using aeromagnetics.

Oak Ridge National Laboratory - John Michel

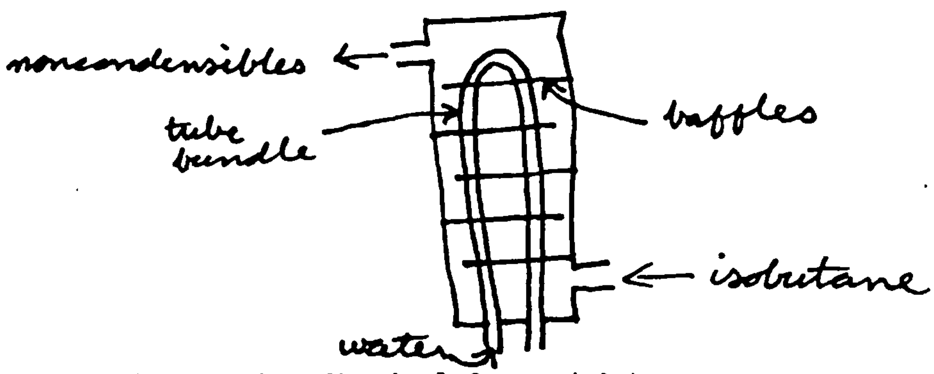
The Baca project has the environmental impact statement writers pinned down.

The heat exchanger work for the 500kw LBL binary turbine generator and the Arkansas Power & Light direct contact evaporator, is done.

The 40 tube enhanced exchange condenser has been tested at East Mesa. When coupled with the direct contact boiler the 40 tube condenser had heat exchange coefficients way under predictions. This may be due to water vapor and non-condensible gases in the pentane. Apparently the non-condensibles concentrate around the heat exchange surface. Also, the isobutane vented with the non-condensibles must be recovered.

Considering these and other problems, is the direct contact heat exchanger really any better than a shell and tube exchanger?

The vertical tube bundle in the enhanced exchange condenser appears to be best. Better performance might be achieved with more closely spaced baffles.



The Great Lakes Chemical Co. and Arkansas Power & Light isopentane machine hasn't yet worked because of brine ph problems (the pump impellers dissolved). The net output of the system (using a direct contact atmospheric pressure condenser) is quite sensitive to the wet bulb temperature. The cooling water pump power load goes way up at high environmental temperatures.

Oak Ridge has a third program, which is to study the effect of water availability on geothermal electric development. Water requirements for resources that can supply 150mw for 30 years are being examined.

Lawrence Berkeley Laboratory - Jack Howard

Lawrence Berkeley Laboratory's geothermal research is divided into the following topics: utilization technology, exploration technology, reservoir engineering, reservoir case studies, and geothermal environmental research.

"SHAFT 78" is a 3 dimensional, 2 phase large mass chemical and heat flow code. Numerical models are being tested on a rock filled tea pot. Other aspects of the GREMP (geothermal reservoir engineering management plan) are outlined in the attached article (Figure 2).

LBL has been trying to maintain a geothermal resource information data base (GRID). Its principle purpose is to be the basis for national progress monitoring. Data is maintained for 21 sites in the country. The data shows past and current development status. A text edit file has been developed for the above data sets, and an interactive program is being developed for use with the above data. A second purpose of GRID is to maintain bibliographic information.

At one time GRID was to be a national system for information, and was to include the United States Geological Survey system. Now there seem to be several such systems, and the original purpose has been lost. Further, if the cost to users is ever determined it may be decided that the whole thing costs more than it is worth.

Is it more important to have information useful for geothermal development or to answer Congress questions? At one time the key to survival of the geothermal program was satisfying Congress' quad fetish.

Since 1976 mitre has been the key actor in geothermal information gathering.

Lawrence Berkeley Laboratory - Ernie Majer

This is a report on studies of wave propagation in geothermal reservoirs and microseism analysis. We tried to find out if these seismic methods would be useful in geothermal exploration.

The work was done in Northern Nevada, including Dixie Valley, Buffalo Valley, Grass Valley, and Kyle Hot Springs. (At Dixie Valley there may be a steam reservoir, though AMEX thinks it is hot water.)

Can geothermal earthquakes be characterized? They may be caused by hot water or rising magma. There may also be geothermally caused quiet zones.

The only anomaly observed in numerous Northern Nevada earthquakes, in the geothermal area, was the shallow depth. We never saw one deeper than 6km, whereas 15km would be the deepest elsewhere. There seems to be a lack of seismic activity in the vicinity of hot springs. Otherwise, the rate of occurrence was normal, and there was nothing unusual about the earthquakes.

In another survey, the seismic signals from Nevada Test Site nuclear tests were observed. The hot areas seemed to speed up the wave, or advance the time of P-wave arrival. This may be due to mineralization by the hot springs.

In all of the hydrothermally altered areas there was a lack of definition in the vibroseismic picture.

There is no evidence for thinning of the earth's crust under Nevada, where there is a higher than average heat flow.

The Geysers region was abnormally active seismically, but there seemed to be fewer than expected events at reservoir depth, 2-3km. As production has gone up, so has the seismicity, possibly due to subsidence.

At Cerro Prieto, very few seismic events occurred in the reservoir region.

Lawrence Berkeley Laboratory developed a machine to evaluate the arrival times, magnitudes, locations of seismic events in the field.

STATUS OF GEOTHERMAL RESERVOIR ENGINEERING RESEARCH PROJECTS
SUPPORTED BY USDOE/DIVISION OF GEOTHERMAL ENERGY *

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ABSTRACT

In the fall of 1977, the U. S. Department of Energy (DOE), Division of Geothermal Energy (DGE) proposed that Lawrence Berkeley Laboratory (LBL) assume lead responsibility, on DGE's behalf, for geothermal reservoir engineering. This summary discusses briefly the DOE/DGE-sponsored geothermal reservoir engineering research program which includes LBL in-house research and research done by others through LBL. LBL in-house research has emphasized improvement of well test analysis methods and the development of geothermal reservoir performance simulators. Work by others has included 18 separate contracts on a variety of technical and scientific projects. Altogether, 29 distinguishable research topics have been addressed. Fourteen institutions, including eight private companies, have interacted with the program. Table 1, along with figures 2 and 3 summarizes the status of the work.

INTRODUCTION

The purpose of this paper is to review the program of geothermal reservoir engineering related research that has been supported by the U. S. Department of Energy, Division of Geothermal Energy, through Lawrence Berkeley Laboratory. Administratively, the program consists of two parts: (1) Work done at LBL, (2) work contracted for by LBL and done by a variety of organizations other than LBL. The primary responsibility assigned to LBL was (1) to define and resolve technical and scientific problems related to successful exploitation of geothermal reservoirs. In addition, implicit in the assignment was the desire that the program (2) help promote the establishment of an industry-wide geothermal reservoir engineering community and (3) help assure the education of personnel who would staff this community in the future. The document, LBL-7000 (Lawrence Berkeley Laboratory, 1978) explains details of the process that lead to the broad outline for research shown in Figure 1. This outline addresses all conceivable activities that relate to successful exploitation of a geothermal resource and goes beyond reservoir engineering in a restricted sense. Those activities in the top third of the figure (e.g., well logging) pertain to the acquisition, synthesis, and interpretation of information related to a working description of the reservoir, in particular to estimates of its size, and to a description of the distribution of temperature, porosity, pressure, and permeability within it. Those activities in the central third of the figure pertain to the development of the capability to reproduce and forecast reservoir performance. The two activities in the bottom third of the diagram, namely economics and exploitation strategies, must be factored into good planning for successful exploitation of a geothermal reservoir, which is the ultimate goal of the effort.

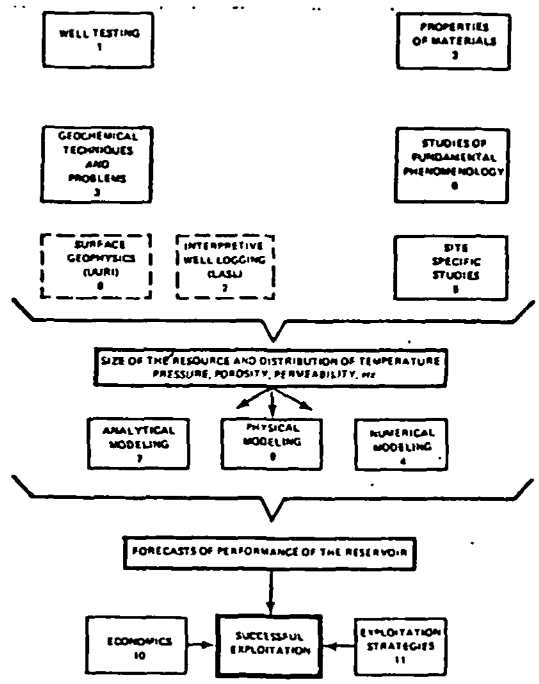

Fig. 1 Broad outline of geothermal reservoir engineering related research activities.

The program has been executed in a way consistent with the priorities laid down by the industry advisory group which helped draft the planning document. The priorities assigned are shown by numerals in the box for the activity (Fig. 1). Implementation of the program as originally defined (LBL-7000) has been carried out mainly by LBL. However, the University of Utah Research Institute has had the lead role for research on surface geophysics, and Los Alamos Scientific Laboratory has had the lead role for well logging.

Figure 2

WORK ON TECHNICAL AND SCIENTIFIC PROJECTS RELATED TO SUCCESSFUL EXPLOITATION OF GEOTHERMAL RESERVOIRS

Although Fig. 1 provides a broad view of the various research areas considered when the program began, Figs. 2 and 3 are more useful in explaining the many projects that have been considered. Furthermore, these figures can be related to Table 1, wherein certain details on the work are given. The projects can be grouped as follows:

A. The synthesis of available sets of data and other information related to geothermal reservoir engineering: Items 1, 10, 11, 12, 14, 105, 106 (Table 1). For example, item 12 is a summary of all available data on the Wairakei, New Zealand, geothermal field.

B. The establishment of techniques of measurements of interest to geothermal reservoir engineers: Items 3, 4 (Table 1). For example, item 4 concerns measurements at the wellhead of noncondensibles in the flow-stream.

C. The analysis of measurements in order to define the characteristics of a geothermal reservoir: Items 2, 6, 15, 16, 17, 18, 101, 104 (Table 1). For example, item 2 is concerned with evaluating the theoretical basis of the James method.

D. The generation of new data important to geothermal reservoir engineering practice: Items 5, 7, 8, 9, 21, 22, 23 (Table 1). For example, item 7 is concerned with procedures to mitigate mud damage.

E. The establishment, improvement, or application of simulators that describe and forecast geothermal reservoir performance: Items 13, 20, 102, 103 (Table 1). Item 103 is the LBL-developed simulator "SHAFT 78," that models heat and fluid transport in porous media.

It is subjective and also difficult to measure the value of the overall program in terms of projects under way or completed since the beginning of the program. However, the following should be noted:

1. All identified major concerns have been addressed by qualified groups whose abilities to work on the project has been favorably reviewed by selection committees made up mainly of non-LBL personnel.

2. A steady stream of publications, including both volumes in the GREMP (Geothermal Reservoir Engineering Management Program) series and in the quarterly Newsletter from GREMP, has been established.

CREATION OF AN INDUSTRY-WIDE GEOTHERMAL RESERVOIR ENGINEERING COMMUNITY AND THE EDUCATION OF PERSONNEL

Support provided by USDOE/DGE for research has had a positive effect on creating a geothermal reservoir engineering community and on the education of personnel. This conclusion is supported by several lines of reasoning. Forty organizations have submitted proposals to the program, and 14 have been supported. Contractor organizations, including LBL, have participated actively in professional society meetings (e.g., Pruess et al. 1978).

Altogether, more than two dozen students have been recognized to be part of the program through reference to them in contracts. Also, in particular, Stanford University has reported employment of eight students by geothermal companies subsequent of their graduation; they constitute a highly significant group to the future of geothermal resource development.

CONCLUDING REMARKS

Our own judgment of the program is that it is progressing well. However, two aspects that need more attention are as follows:

1. Relating the results of research to identified technical problems at specific geothermal sites. As an example, it would be useful to know from industry how critical are concerns over mud damage at their specific development sites, how important are readings on wellhead enthalpy, and so on. Cooperation from industry in providing such feedback is vital.

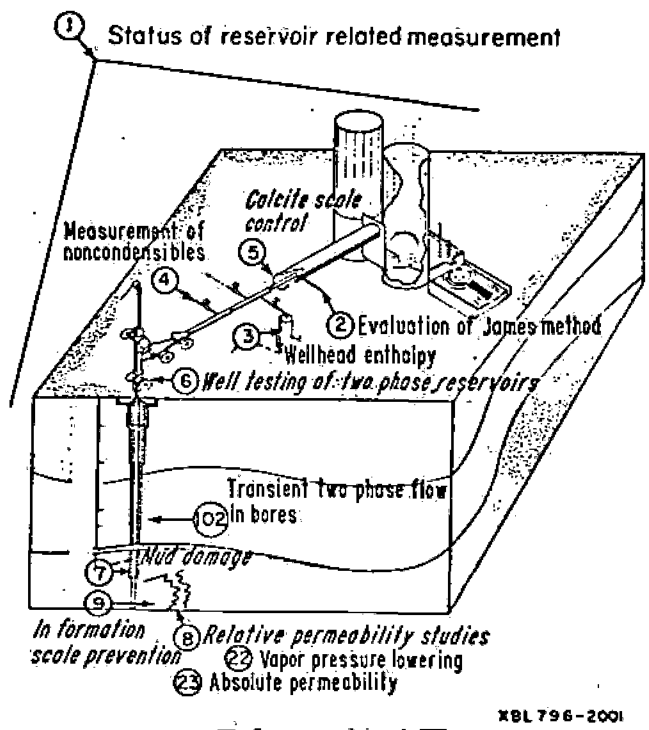

Fig. 2 Summary diagram of well system and near-bore research projects.

2. Economics. Although conceived as an area of work in the original program plan, no effort has been put on this topic in keeping with the recommendation of the advisory group to GREMP. It is very difficult, therefore, to place other research in an economic framework and judge its importance with respect to the crucial questions of economics and geothermal resource development.

Figure 2 (cont.)

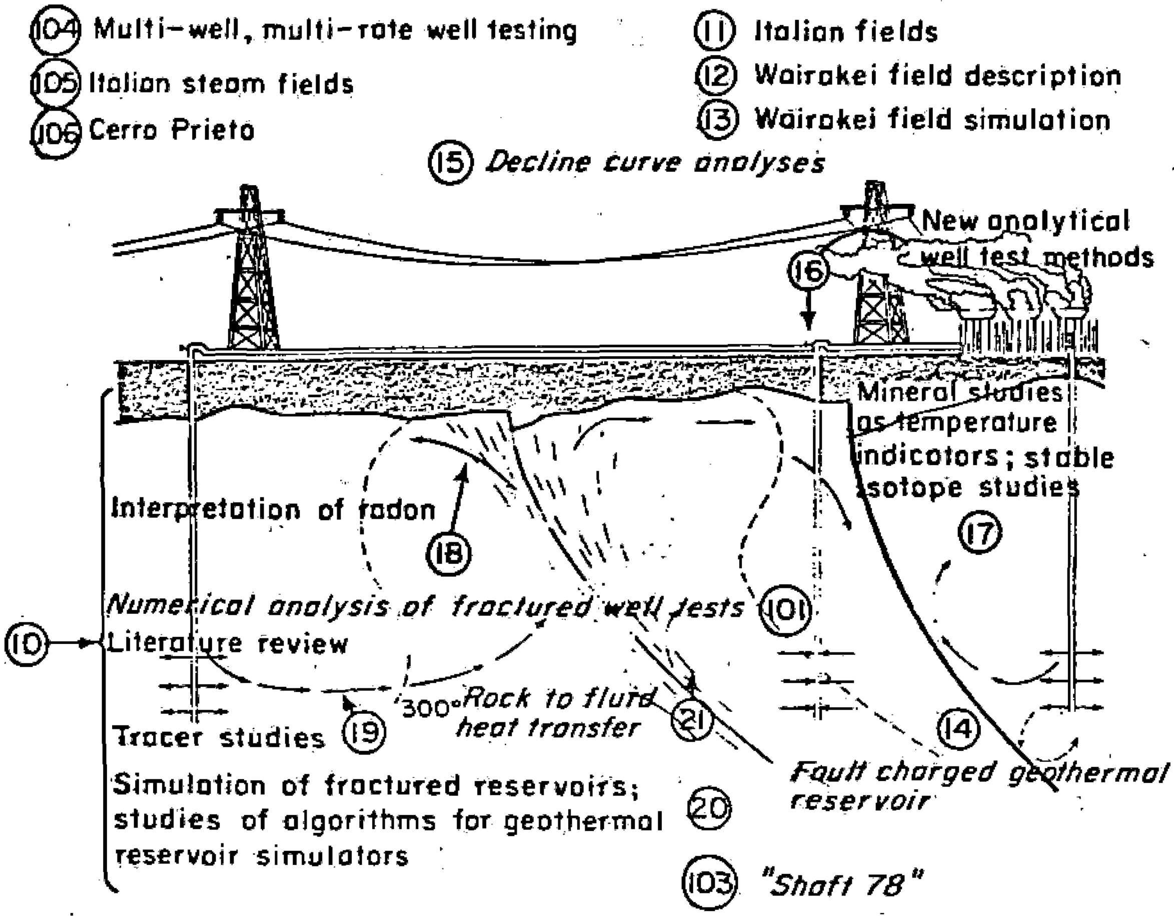

Fig. 3 Summary diagram of mainly field-wide research projects. XBL 795-7435

Future work of the program should emphasize the application of research and heavier support to problems of major economic consequence.

ACKNOWLEDGMENTS

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Figure 2 (cont.)

Table 1. Summary of Geothermal Reservoir Engineering projects supported by USDOE/DGE through Lawrence Berkeley Laboratory.

ID #	Brief project name	Contractor	Brief summary of work
1.	Status of reservoir related measurements *	Measurement Analysis Corp.	A comprehensive appraisal of measurement needs and instrumentation for geothermal applications has been completed, indicating that commercially available technology and instrumentation exists in principle for all wellhead and process plant measurement requirements, except two-phase flow (Lamers, 1979).
2.	Theoretical basis for James method	University of Hawaii	This project has just been started. Its purpose is to understand the theoretical basis of James empirical method for estimating mass flow and enthalpy (Cheng, 1979).
3.	Measurement of enthalpy at wellhead	Battelle Pacific Northwest Laboratory	Several calorimetry methods for measuring geothermal wellhead enthalpies were evaluated. A mixing tee condenser was recommended when cooling water is available. When not, a multiphase tank was recommended. Work has started on engineering drawings of a sampling system and mixing tee condenser (Cliff et al., 1979).
4.	Measurements of noncondensible gases at wellhead	TerraTek	Engineering design of a device with the capability to monitor noncondensible gas concentrations continuously in geothermal discharges has been completed (Harrison et al., 1979).
5.	Control of calcite precipitation by additives *	Vetter Research	Scale inhibitor tests performed at Republic Geothermal Inc. East Mesa wells have shown that Dequest can economically eliminate calcite precipitation in the discharge flow stream (Vetter, 1979).
6.	Analysis of well tests of two-phase reservoir	Intercomp	Comparison of Intercomp's proprietary geothermal well bore and reservoir simulators with the experimental and numerical results from three other models has been completed. Data on two-phase well tests are currently being assembled for analysis (Aydelotte and Taylor, 1979).
7.	Formation damage of drilling mud	TerraTek	Laboratory simulation of drilling mud damage to geothermal reservoir rocks has been initiated. Parameters to be considered are pressure, temperature, reservoir fluid chemistry, mud composition, and time (Butters, 1979).
8.	Relative permeability of steam and water	Stanford University	Relative permeability data have been collected by Counsil (1978).
9.	Calcite formation by inappropriate production practices	Republic Geothermal Inc.	Carbonate rich geothermal brine is being passed through containers of granular materials in order to evaluate the mechanism and rate of calcite precipitation within the pore space. The ultimate practical purpose of the activity is to plan remedial "acid jobs" on calcite-fouled geothermal wells (Michaels, 1979).
10.	Literature review of reservoir exploitation *	TerraTek	An annotated bibliography covering reservoir modeling, exploitation strategies, and interpretation of production trends has been prepared (Harrison and Randall, 1979).
11.	Study of the Travali Radicondoli geothermal areas in Italy	Stanford University	Geology and pressure-production history of Serrazzano reservoir have been reviewed. Bottomhole temperatures and pressures have been calculated from wellhead measurements. Areal distribution of pressure has been mapped for seven different times spanning the last 15 years. A conceptual model of Travali Radicondoli geothermal field was developed on the basis of the available field data (Miller et al., 1978).
12.	Data collection for the Wairakei field, New Zealand *	Systems, Science and Software	All geological, geochemical, geophysical, and wellbore data from January, 1953 to December 1976 has been collected and synthesized (Pritchett et al., 1978).
13.	Simulation of past and future performance at Wairakei, New Zealand	Systems, Science and Software	With the data collected and synthesized (#12 above), an attempt is under way to match the pressure and enthalpy history during past production of the Wairakei field (Pritchett et al., 1979).
14.	Prototype of a fault-charged geothermal reservoir *	University of Colorado	A physical, viable mathematical model of an unexploited geothermal system has been constructed in terms of a fault zone controlled charging of a reservoir (Kassoy and Goyal, 1979).
15.	Review of decline curves appropriate to geothermal reservoirs	E. Zais and Associates	This project is to review decline curve procedures used in the petroleum industry, determine which procedures are applicable to geothermal systems, and establish a theoretical basis for applicability. Project has just started.
16.	New analytical well test methods for geothermal engineering	Stanford University	The utility of parallelepiped models has been investigated (Ramey et al., 1978).
17.	Studies of mineral facies and stable isotopes and their relations to geothermal reservoirs	University of California, Riverside	Cuttings and core samples, obtained from the six wells drilled during the year 1977 were studied and interpreted to define the current temperatures in the field (Elders et al., 1978).
18.	Understanding the significance of radon in geothermal reservoirs	Stanford University	The variation of radon associated with geothermal reservoir production has been analyzed and interpreted for several reservoirs throughout the world (Kruger et al., 1978).
19.	Studies of the use of tracers in geothermal reservoirs	(under negotiation)	
20.	Study of basic formulation of simulators of geothermal reservoirs	Princeton University	Multiphase flow equations have been derived for a deformable porous medium. Equations for heat and mass transfer in a fractured reservoir have also been formulated. A computer code BIFEPS (Block Interactive Finite Element Processed Scheme) has been developed to solve nonlinear transient problems with one or two governing equations in two or three dimensions. (Pinder et al., 1978).
21.	Studies of heat transfer from rock to fluid	Stanford University	Heat flow from rock to water has been studied as a function of a number of parameters including the size of rock fragments (Kruger et al., 1979).
22.	Vapor pressure lowering phenomena of geothermal fluids	Stanford University	The project demonstrated that vapor pressure may be lowered as a consequence of a number of chemical and petrophysical parameters (Miller et al., 1979).
23.	Absolute permeability of geothermal fluids	Stanford University	The effects of temperature and chemical composition of the rock types on relative permeability has been investigated (Miller, et al., 1978)
101.	Numerical analysis of well tests of fractured reservations	LBL	Analysis of fractured well response during testing using numerical models has been studied. Results compare favorably with analytical solutions (Narasimhan and Palen, 1979).
102.	Transient two-phase flow in geothermal bores	LBL	A code simulating transient two-phase flow in bores has been written and compared against limited field data (C. W. Miller, 1979).
103.	Geothermal reservoir simulator SHAFT 78	LBL	A code to simulate mass and heat transport in porous media has been written and applied to hypothetical and real examples (Pruess et al., 1979).
104.	Multiple well, variable rate well test analysis	LBL	The ANALYZE code has been proven capable of this kind of analysis (McEdwards, 1979).
105.	Study of Serrazzano Castelnuevo geothermal area, Italy	LBL	SHAFT 78 is being used to reproduce past performance and forecast reinjection of liquid (Schroeder et al., 1979).
106.	Study of the Cerro Prieto area, Mexico	LBL	A very comprehensive case study at Cerro Prieto is being carried out cooperatively with the Mexican government (Lippmann et al., 1978).

* Project completed.

Figure 2 (cont.)

This study found that several claims for passive seismic techniques made in AEC times were unfounded (there seems to be no such thing as a geothermal earthquake), clarified what microseismics could do, and clarified the economic and instrumental requirements.

University Of Utah Research Institute - Mike Wright

The University of Utah Research Institute has a $5.5 million annual budget, 90% of which is spent for Department of Energy work, almost all in geothermal energy. A lot of the personnel are from the mining industry. The major programs are: the industry coupled program, state coupled program, geothermal sample library, user assistance program, exploration assessment technology program, and the induced seismicity program.

The industry coupled program provides cost sharing with industry for exploration, reservoir assessment, and reservoir confirmation. Provisions are made for the release of geological data, evaluation of techniques and methods, etc.

The University of Utah monitors the contract, sees that what was proposed to be done is done, collects the geological data to be released, and puts it in the public domain. The earth science laboratory analyzes and resifts the data. In some cases, industry releases their own data. That is, they want to publish it before UURI does. When UURI published data from Roosevelt Hot Springs it increased industry's land aquisition cost. The Roosevelt field is to be unitized. The city of Bountiful bought part of the Roosevelt field.

A problem in geothermal work generally is re-educating petroleum geologists and drillers. Petroleum geologists look at fossils, not faults. Petroleum geologists did not recognize the flat faulting at Roosevelt.

The national energy act tax incentives are supposed to supplant the industry coupled program in 1980.

The state coupled program provides assistance to states for low temperature resource assessment. The money, about $100,000 per state per year, goes to a state agency, the state geologist or energy office. The state agency provides management, data compilation, and site specific reservoir confirmation. The Earth Science Laboratory of the University of Utah Research Institute provides technical management, technical help to the states, and coordinates between the states. The Division of Geothermal Energy provides funding and business management. The United States Geological Survey provides base data at 1:500,000 scale, assists in geoscience data interpretation, and transfers data to the USGS data file (GEOTHERM). The National Oceanic and Atmospheric Administration publishes state resource maps.

The tasks that the state coupled program tries to accomplish are to collect geothermal data (T>20°C), relevant geoscience data, and base data; to interpret the data, investigate specific sites, publish a map for users; and in some cases to provide reservoir confirmation drilling. Jerry Brophy shepherds the program in Washington.

The user assistance program tries to give up to 100 hours of assistance to people in need. The 3 people assigned to it are swamped. As part of the job, a list of local geothermal contractors has been compiled.

The exploration and assessment technology program sponsors technical review committees and other activities to review the state of the art in exploration and to recommend any improvements. The goal is to reduce the risk and cost of exploration.

Lawrence Livermore Laboratory - Jack Harrar

Larry Owen is now the geothermal program leader, Roland Quong will be deputy. The program will be funded for $900,000 this year, vs. $3 million last year. The 1980 program is as follows:

Scale control additives:	$180,000
Alternate well casing materials:	124,000
Localized corrosion studies:	70,000
Geopressured fluid R & D: (methane extraction & fluid injectivity)	352,000
Advanced reservoir assessment:	140,000
United States-New Zealand cooperative project	68,000
Low salinity fluid treatment:	?

For extracting methane from geopressured brine merely reducing the pressure won't work because of the small quantities.

The results of the silica scale control project are as follows: acidification was the only effective method, but it was cost prohibitive. The economics of other additives (for Salton Sea brines) is that power costs $.033/kw-hr, corresponding to 100lbs of brine yielding one kw-hr. The required additive concentration to control silica scaling is 20ppm, and the cost is $1.00/lb. The chemical cost adds 6% to the cost of power. A 50mw plant would require 1 ton per day of additive, which is injected with the spent brine. No really good organics were found, though some that worked were identified. The optimum compound has not yet been found. With time the organic polymers decompose, and are probably not toxic.

Acidification uses hydrocloric acid, which costs only a third as much, $.33/lb, but 15 times as much must be used.

ATTENDEES

NAME	ORGANIZATION
A.M. Stone	John Hopkins Applied Physics Laboratory
John Beebee	Energy Systems, Inc.
Lee Aaamodt	Los Alamos Scientific Laboratory
Mike Wright	University of Utah Research Institute
Morton C. Smith	Los Alamos Scientific Laboratory
Jackson E. Harrar	Lawrence Livermore Laboratory
John W. Michel	Oak Ridge National Laboratory
Fred Holzer	Lawrence Livermore Laboratory
William Ogle	Energy Systems, Inc.
Wendell Duffield	U.S. Geological Survey
Robert L. Christiansen	U.S. Geological Survey, Menlo Park
Joe Hanny	EG&G Idaho (INEL)
John Griffith	DOE-ID
Bill Rice	DOE/RA
Roger Harrison	Terra Tek
Norman Goldstein	Lawrence Berkeley Laboratory
Jack Howard	Lawrence Berkeley Laboratory
Ernie Majer	Lawrence Berkeley Laboratory

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PEARL, R.H. (ED.) [COLORADO GEOLOGICAL SURVEY, DENVER, COLO. (USA). DEPT. OF NATURAL RESOURCES].

REFERENCE- ECONOMIC CONSIDERATIONS FOR GEOTHERMAL EXPLORATION IN THE WESTERN UNITED STATES. BULLETIN NO. 35, COLORADO GEOLOGICAL SURVEY, DENVER, COLO., 1974, P. 45-60.

DESCRIPTORS- ECONOMICS; CAPITAL REQUIREMENTS; BUDGETING; COSTS; RETURN ON INVESTMENT; TABLES.

MEIDAV 75B
EXPLORATION/EVALUATION

X

TITLE- COSTS OF GEOTHERMAL STEAM CAPACITY.

AUTHOR- MEIDAV, T. [GEONOMICS, INC., BERKELEY, CALIF. (USA)].

REFERENCE- OIL GAS J., UNPAGINATED(1975).

DESCRIPTORS- ASSESSMENT; COSTS; GEOTHERMAL FIELDS; INVESTMENTS; ECONOMICS; ITALY; LARDELLO GEOTHERMAL FIELD; CALIFORNIA; GEYSERS GEOTHERMAL FIELD; MEXICO; CERRO PRIETO GEOTHERMAL FIELD; DIAGRAMS.

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EXPLORATION/EVALUATICN

H

TITLE- GEOTHERMICS.

AUTHOR- RINEHART, J.S. [COLORADO UNIV., BOULDER (USA)].

REFERENCE- APPL. MECH. REV., V. 28 (8), P. 1081-1084(1975).

DESCRIPTORS- VAPOR DOMINATED SYSTEMS; HOT WATER SYSTEMS; GEOPRESSURED SYSTEMS; HOT DRY ROCK SYSTEMS; GEOTHERMAL RESOURCE SYSTEMS; TEMPERATURE GRADIENTS; COSTS; UNITED STATES; POWER POTENTIAL; NEW ZEALAND; MEXICO.

SHUPE 76B
EXPLORATION/DRILLING
WELL COMPLETION DATA
TEMPERATURE GRADIENT
ENVIRONMENTAL EFFECTS
ECONOMICS
DIAGRAMS
SLOTTED LINER

H

TITLE- THE HAWAII GEOTHERMAL PROJECT. PROGRESS REPORT ON THE DRILLING PROGRAM, MAY 5, 1976.

AUTHOR- SHUPE, J.W. [HAWAII UNIV., HONOLULU (USA)].

REFERENCE- THE HAWAII GEOTHERMAL PROJECT. PROGRESS REPORT ON THE DRILLING PROGRAM, MAY 5, 1976. UNIV. OF HAWAII, HONOLULU, HAWAII, 1976, P. 1-10.

DESCRIPTORS- DEPTHS; COSTS.

GREIDER 74
EXPLORATION/EVALUATION

DH

TITLE- ECONOMIC CONSIDERATIONS FOR GEOTHERMAL EXPLORATION IN THE WESTERN UNITED STATES.

AUTHOR- GREIDER, R. [CHEVRON OIL CO., SAN FRANCISCO, CALIF. (USA)].

DESCRIPTORS- CAPITAL; DRILLING; ECONOMICS; ENGINEERING; ENVIRONMENTAL EFFECTS; AIR QUALITY; LAND USE; LEASES; LEGAL ASPECTS; FORECASTING; COSTS; ENVIRONMENTAL IMPACT STATEMENTS; POWER TRANSMISSION; TAXES; GEOTHERMAL DEVELOPMENT; GEOTHERMAL POTENTIAL; GEOTHERMAL RESOURCES; GEOTHERMAL RESERVES; GEOTHERMAL WELLS; DRILLING TECHNOLOGY; POWER GENERATION; REGULATIONS; WASTE DISPOSAL; DISCUSSION; EVALUATION; FIELD DATA; CALIFORNIA; GLASS MOUNTAIN KGRA; LAKE CITY-SURPRISE VALLEY KGRA; WENDEL AMACEE KGRA; BODIE KGRA; SALINE VALLEY KGRA; COSO HOT SPRINGS KGRA; BECKWOURTH PEAK KGRA; IMPERIAL VALLEY; CENTRAL VALLEY; SALTON SEA; KGRA'S; GOVERNMENT POLICIES; FORD DRY-LAKE KGRA; GEYSERS GEOTHERMAL FIELD; LASSEN KGRA; MONO-LONG VALLEY KGRA; RANDSBURG KGRA; SESPE HOT SPRINGS KGRA; MAPS; DIAGRAMS.

PEARSON 76
EXPLORATION/EVALUATION

DH

TITLE- PLANNING AND DESIGN OF ADDITIONAL EAST MESA GEOTHERMAL TEST FACILITIES (PHASE 1B). VOLUME 1. FINAL REPORT.

AUTHOR- PEARSON, R.O. [TRW SYSTEMS GROUP, REDONDO BEACH, CALIF. (USA)].

REFERENCE- PLANNING AND DESIGN OF ADDITIONAL EAST MESA GEOTHERMAL TEST FACILITIES (PHASE 1B). VOLUME 1. FINAL REPORT. SAN/1140-1/1, TRW, INC., REDONDO BEACH, CALIF., 1976, 1-1 - 5-7.

DESCRIPTORS- PETROLOGY; POROSITY; PERMEABILITY; TEMPERATURE MEASUREMENT; CHEMICAL COMPOSITION; PIPELINES; DOWNHOLE PUMPS; DRILLING; ECONOMICS; MATHEMATICAL MODEL; THEORETICAL TREATMENTS; COMPUTER CALCULATIONS; FORECASTING; WELLS; DEPTHS; COSTS; HOT WATER SYSTEMS; FLOW RATES; INJECTION WELLS; WELL COMPLETION DATA; ENERGY RESERVES; DISCUSSION; EXPERIMENTAL DATA; CALIFORNIA; IMPERIAL VALLEY; EAST MESA GEOTHERMAL FIELD; MAPS; TABLES; DIAGRAMS.

RINEHART 75

MEIDAV 76
EXPLORATION/EVALUATICN

DH
TITLE- A COMPARISON OF HYDROTHERMAL RESERVOIRS OF THE WESTERN UNITED STATES. TOPICAL REPORT 3.

AUTHOR- MEIDAV, H.T. [GEONOMICS, INC., BERKELEY, CALIF. (USA)].

SANYAL, S.

REFERENCE- A COMPARISON OF HYDROTHERMAL RESERVOIRS OF THE WESTERN UNITED STATES. TOPICAL REPORT 3. ERRI ER-364, GEONOMICS, INC., BERKELEY, CALIF., 1976, 170 P..

DESCRIPTORS- GEOLOGIC SETTING; LITHOLOGY; ROCKS; SEDIMENTATION; VOLCANISM; TEMPERATURE MEASUREMENTS; FLUID FLOW; DRAWDOWN; WATER LEVELS; DRILLING; MATHEMATICAL MODEL; THEORETICAL TREATMENTS; COMPUTER CALCULATIONS; FORECASTING; SITE SELECTION; COSTS; DEPTH; WELL SPACING; EFFECTIVE PRESSURE; FLUID PRESSURE; GEOTHERMAL RESERVES; VAPOR-DOMINATED SYSTEMS; HOT WATER SYSTEMS; GEOTHERMAL WELLS; FLOW RATES; INJECTION WELLS; CHEMICAL ANALYSIS; POWER POTENTIAL; DISCUSSION; EVALUATION; FIELD DATA; UNITED STATES; CALIFORNIA; IDAHO; NEW MEXICO; NEVADA; WYOMING; MEXICO; YELLOWSTONE KGRA; HEBER KGRA; EAST MESA KGRA; RAFT RIVER KGRA; MONO-LONG VALLEY KGRA; BRUNCA KGRA; BRADY-HAZEN KGRA; ROOSEVELT HOT SPRINGS KGRA; BRAWLEY KGRA; DUNES KGRA; LAKE CITY-SURPRISE VALLEY KGRA; BEOWAWE KGRA.

SCHULLER 76
EXPLORATION/EVALUATION

DH
TITLE- LEGAL.
PT=LEGAL,
INSTITUTIONAL AND POLITICAL PROBLEMS IN PRODUCING ELECTRIC POWER FROM GEOTHERMAL RESOURCES IN CALIFORNIA.

AUTHOR- SCHULLER, C.R.;SCHILLING, A.H.;COLE, R.J.;SIMON, G.D. [BATTELLE (USA)].

REFERENCE- LEGAL.
PT=LEGAL,
INSTITUTIONAL AND POLITICAL PROBLEMS IN PRODUCING ELECTRIC POWER FROM GEOTHERMAL RESOURCES IN CALIFORNIA. BATTELLE, SEATTLE, WASH., 1976, 390 P..

AUTHOR- STARLING, K.E.;FISH, L.W.;WEST, H.;JOHNSON, D.W.;IQBAL, K.Z.;LEE, C.O. [OKLAHOMA UNIV., NORMAN (USA). SCHOOL OF CHEMICAL ENGINEERING AND MATERIALS SCIENCE].

REFERENCE- RESOURCE UTILIZATION EFFICIENCY IMPROVEMENT OF GEOTHERMAL BINARY CYCLES - PHASE II. SEMIANNUAL REPORT, JUNE 15, 1976 - DECEMBER 15, 1976. ORO-4944-5, OKLAHOMA UNIV., NORMAN, OKLA., 1976, 42 P..

DESCRIPTORS- POWER GENERATION; BINARY-FLUID SYSTEMS; ECONOMICS; THEORETICAL TREATMENTS; COMPUTER CALCULATIONS; FORECASTING; COSTS; HEAT EXCHANGERS; COOLING; GEOTHERMAL FLUIDS; GEOTHERMAL POTENTIAL; FLOW RATES; COMPUTER CODES; UNITED STATES; TABLES; DIAGRAMS.

BECHTEL 76
EXPLORATION/EVALUATION

DH

TITLE- CONCEPTUAL DESIGN OF COMMERCIAL 50 MWE (NET) GEOTHERMAL POWER PLANTS AT HEBERAND NILAND, CALIFORNIA. FINAL REPORT.

AUTHOR- BECHTEL CORP., SAN FRANCISCO, CALIF. (USA).

REFERENCE- CONCEPTUAL DESIGN OF COMMERCIAL 50 MWE (NET) GEOTHERMAL POWER PLANTS AT HEBERAND NILAND, CALIFORNIA. FINAL REPORT. SAN-1124-1, BECHTEL CORP., SAN FRANCISCO, CALIF., 1976, 1-1 - 10-6.

DESCRIPTORS- GEOLOGIC SETTING; POWER GENERATION; TEMPERATURE MEASURMENT; ECONOMICS; ENVIRONMENTAL EFFECTS; SITE SELECTION; TEST FACILITIES; GEOTHERMAL WELLS; INJECTION WELLS; AIR QUALITY; WATER QUALITY; CHEMICAL COMPOSITION; CLIMATE; EVALUATION; CALIFORNIA; IMPERIAL VALLEY; SALTON SEA; NILAND; HEBER; MAPS; TABLES; DIAGRAMS; SILICA; CORROSION; HYDROGEN SULFIDE; FLOW RATES; GOVERNMENT REGULATIONS; THERMODYNAMIC CYCLES; THEORETICAL TREATMENT; COSTS.

GENERATION; RESISTIVITY SURVEYS; MAPS; PHOTOGRAPHS.

SANDIA 75
EXPLORATION/DRILLING

DH TITLE- DRILLING RESEARCH-NEW BIT DESIGNS PROMISE LOWER DRILLING COSTS.

AUTHOR- SANDIA LABS., ALBUQUERQUE, N. MEX. (USA)

REFERENCE- MIN. ENG. N.Y., P. 38-40(1975).

DESCRIPTORS- RESEARCH PROGRAMS; DRILL BITS; PENETRATION RATE; COSTS; DESIGN; EQUIPMENT; ROCK DRILLING; WELL DRILLING.

STOREY 74
EXPLORATION/DRILLING

DH TITLE- GEOTHERMAL DRILLING IN KLAMATH FALLS, OREGON.

AUTHOR- STOREY, D.M.

REFERENCE- GEOTHERM. ENERGY, MAG., V. 2 (11), P. 61-63(1974).

DESCRIPTORS- DRILL RIGS; AIR ROTARY RIGS; CABLE RIGS; SPACE HEATING; COMMERCIAL WELLS; RESIDENTIAL WELLS; COSTS.

STARLING 76
EXPLORATION/EVALUATION

DH TITLE- RESOURCE UTILIZATION EFFICIENCY IMPROVEMENT OF GEOTHERMAL BINARY CYCLES - PHASE II. SEMIANNUAL REPORT, JUNE 15, 1976 - DECEMBER 15, 1976.

1975, 92 P..

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; GEOTHERMOMETRY; SEISMIC SURVEYS; HEAT FLOW; RESISTIVITY SURVEYS; SELF POTENTIAL SURVEYS; HOT SPRINGS; CHEMISTRY; DRILLING; FLOW RATES; GRAVITY SURVEYS; LOGGING; RADIOACTIVITY SURVEYS; NEVADA; WHIRLWIND VALLEY; BUFFALO VALLEY; GRASS VALLEY; BUENA VISTA VALLEY; LEACH HOT SPRINGS; MAPS; DIAGRAMS; PHOTOGRAPHS; KYLE HOT SPRINGS KGRA.

BARR 75
EXPLORATION/EVALUATION

DA TITLE- GEOTHERMAL EXPLORATION-STRATEGY AND BUDGETING.

AUTHOR- BARR, R.C. [EARTH POWER CORPORATION, TULSA, OKLA. (USA)].

REFERENCE- GEOTHERM. ENERGY MAG., V. 3 (5), P. 39-41(1975).

DESCRIPTORS- GEOTHERMAL EXPLORATION; EXPLORATION PROGRAMS; PLATE TECTONICS; ECONOMICS; DRILLING; EVALUATION; LAND-USE FACTORS; CALIFORNIA; THE GEYSERS; TABLES.

FUCHS 75B
EXPLORATION/EVALUATION

DH TITLE- GEOTHERMAL ENERGY--THE CHALLENGES THAT LIE AHEAD. PART 2.

AUTHOR- FUCHS, R.L. [GEOSYSTEMS CORP., NEW YORK, N.Y. (USA)].

HUTTRER, G.W. [THERMEX CO., DENVER, COLO. (USA)].

REFERENCE- ENG. MIN. J., V. 176 (2), P. 78-82(1975).

DESCRIPTORS- GEOTHERMAL WELLS; CALIFORNIA; THE GEYSERS; IMPERIAL VALLEY; LEGAL ASPECTS; LEASING; NEW ZEALAND; DRILLING; POWER

DEPTHS; COSTS; HOT WATER SYSTEMS; FLOW RATES; INJECTION WELLS; WELL COMPLETION DATA; ENERGY RESERVES; DISCUSSION; EXPERIMENTAL DATA; CALIFORNIA; IMPERIAL VALLEY; EAST MESA GEOTHERMAL FIELD; MAPS; TABLES; DIAGRAMS.

FUCHS 75

DA TITLE- GEOTHERMAL ENERGY--SLOW-GROWING INDUSTRY FINALLY HEATS UP. PART 1.

AUTHOR- FUCHS, R.L. [GEOSYSTEMS CORP., NEW YORK, N.Y. (USA)].

HUTTRER, G.W. [THERMEX CO., DENVER, COLO. (USA)].

REFERENCE- ENG. MIN. J., V. 176 (1), P. 89-93(1975).

DESCRIPTORS- LEGAL ASPECTS; CALIFORNIA; POWER GENERATION; IDAHO; NEVADA; ECONOMICS; LEASES; TABLES; GEOTHERMAL WELLS; DRILLING; OREGON; ID
ELES;
GEOTHERMAL WELLS; DRILLING; OREGON; DIAGRAMS; NEW MEXICO; MONTANA; COLORADO; IMPERIAL VALLEY; MENDOCINO COUNTY; LAKE COUNTY; STEAMBOAT SPRINGS; SURPRISE VALLEY; SONOMA COUNTY; HONEY LAKE; LAKEVIEW; CHANDLER; CHOCOLATE MTNS.; PLUMAS COUNTY; VALLES; CALDERA; BRADY; INDIAN HOT SPRINGS; PINE FARMS; OREANA; RAFT RIVER; BEOWAWE; BRIGHAM CITY; CANBY; MARYSVILLE; SAN LUIS VALLEY; HOT LAKE; HEAT FLOW; PHOTOGRAPHS; FORECASTING.

WOLLENBERG 75
EXPLORATION/EVALUATION

DA TITLE- GEOTHERMAL ENERGY RESOURCE ASSESSMENT.

AUTHOR- WOLLENBERG, H.A.;ASARO, F.;BOWMAN, T.;MC EVILLY, T.;MORRISON, F.;WITHERSPOON, P. [CALIFORNIA UNIV., BERKELEY (USA). LAWRENCE BERKELEY LAB.].

REFERENCE- GEOTHERMAL ENERGY RESOURCE ASSESSMENT. UCID-3762, CALIF. UNIV., BERKELEY, CALIF.,

SHUPE 76
EXPLORATION/EVALUATION

DH

TITLE- THE HAWAII GEOTHERMAL PROJECT. INITIAL PHASE II PROGRESS REPORT.

AUTHOR- SHUPE, J.W. [HAWAII UNIV., HONOLULU (USA)].

REFERENCE- THE HAWAII GEOTHERMAL PROJECT. INITIAL PHASE II PROGRESS REPORT. UNIV. OF HAWAII, HONOLULU, HAWAII, 1976, P. 1-148.

DESCRIPTORS- HAWAII GEOTHERMAL PROJECT; PUNA; GEOPHYSICAL SURVEYS; ENVIRONMENTAL EFFECTS; DRILLING; RESERVOIR ENGINEERING; HAWAII; RESISTIVITY SURVEYS; MAPS; MICROSEISMICITY; ECONOMICS; DIAGRAMS; SEISMIC REFRACTION; TEMPERATURE GRADIENTS; GRAVITY SURVEYS; MAGNETIC SURVEYS; SEISMOLOGY; ROCKS; ROCK-FLUID INTERACTIONS; THEORETICAL TREATMENT; RAYLEIGH NUMBER; MATHEMATICAL MODEL; COMPUTER CALCULATIONS; POWER GENERATION; BINARY FLUID SYSTEMS; HEAT EXCHANGERS; LEGAL ASPECTS; WELL COMPLETION DATA.

PEARSON 76
EXPLORATION/EVALUATION

DH

TITLE- PLANNING AND DESIGN OF ADDITIONAL EAST MESA GEOTHERMAL TEST FACILITIES (PHASE 1B). VOLUME 1. FINAL REPORT.

AUTHOR- PEARSON, R.O. [TRW SYSTEMS GROUP, REDONDO BEACH, CALIF. (USA)].

REFERENCE- PLANNING AND DESIGN OF ADDITIONAL EAST MESA GEOTHERMAL TEST FACILITIES (PHASE 1B). VOLUME 1. FINAL REPORT. SAN/1140-1/1, TRW, INC., REDONDO BEACH, CALIF., 1976, 1-1 - 5-7.

DESCRIPTORS- PETROLOGY; POROSITY; PERMEABILITY; TEMPERATURE MEASUREMENT; CHEMICAL COMPOSITION; PIPELINES; DOWNHOLE PUMPS; DRILLING; ECONOMICS; MATHEMATICAL MODEL; THEORETICAL TREATMENTS; COMPUTER CALCULATIONS; FORECASTING; WELLS;

MEASUREMENTS; FLUID FLOW; DRAWDOWN; WATER LEVELS; DRILLING; MATHEMATICAL MODEL; THEORETICAL TREATMENTS; COMPUTER CALCULATIONS; FORECASTING; SITE SELECTION; COSTS; DEPTH; WELL SPACING; EFFECTIVE PRESSURE; FLUID PRESSURE; GEOTHERMAL RESERVES; VAPOR-DOMINATED SYSTEMS; HOT WATER SYSTEMS; GEOTHERMAL WELLS; FLOW RATES; INJECTION WELLS; CHEMICAL ANALYSIS; POWER POTENTIAL; DISCUSSION; EVALUATION; FIELD DATA; UNITED STATES; CALIFORNIA; IDAHO; NEW MEXICO; NEVADA; WYOMING; MEXICO; YELLOWSTONE KGRA; HEBER KGRA; EAST MESA KGRA; RAFT RIVER KGRA; MONO-LONG VALLEY KGRA; BRUNCA KGRA; BRADY-HAZEN KGRA; ROOSEVELT HOT SPRINGS KGRA; BRAWLEY KGRA; DUNES KGRA; LAKE CITY-SURPRISE VALLEY KGRA; BEOWAWE KGRA.

SCHULLER 76
EXPLORATION/EVALUATION

DH

TITLE- LEGAL.

PT=LEGAL,

INSTITUTIONAL AND POLITICAL PROBLEMS IN PRODUCING ELECTRIC POWER FROM GEOTHERMAL RESOURCES IN CALIFORNIA.

AUTHOR- SCHULLER, C.R.;SCHILLING, A.H.;COLE, R.J.;SIMON, G.D. [BATTELLE (USA)].

REFERENCE- LEGAL.

PT=LEGAL,

INSTITUTIONAL AND POLITICAL PROBLEMS IN PRODUCING ELECTRIC POWER FROM GEOTHERMAL RESOURCES IN CALIFORNIA. BATTELLE, SEATTLE, WASH., 1976, 390 P..

DESCRIPTORS- CAPITAL; DRILLING; ECONOMICS; ENGINEERING; ENVIRONMENTAL EFFECTS; AIR QUALITY; LAND USE; LEASES; LEGAL ASPECTS; FORECASTING; COSTS; ENVIRONMENTAL IMPACT STATEMENTS; POWER TRANSMISSION; TAXES; GEOTHERMAL DEVELOPMENT; GEOTHERMAL POTENTIAL; GEOTHERMAL RESOURCES; GEOTHERMAL RESERVES; GEOTHERMAL WELLS; DRILLING TECHNOLOGY; POWER GENERATION; REGULATIONS; WASTE DISPOSAL; DISCUSSION; EVALUATION; FIELD DATA; CALIFORNIA; GLASS MOUNTAIN KGRA; LAKE CITY-SURPRISE VALLEY KGRA; WENDEL AMADEE KGRA; BODIE KGRA; SALINE VALLEY KGRA; COSO HOT SPRINGS KGRA; BECKWOURTH PEAK KGRA; IMPERIAL VALLEY; CENTRAL VALLEY; SALTON SEA; KGRA'S; GOVERNMENT POLICIES; FORD DRY-LAKE KGRA; GEYSERS GEOTHERMAL FIELD; LASSEN KGRA; MONO-LONG VALLEY KGRA; RANDSBURG KGRA; SESPE HOT SPRINGS KGRA; MAPS; DIAGRAMS.

KGRA; HEBER; THE GEYSERS; MAPS; TABLES;

COSTAIN 76
EXPLORATION/EVALUATION

TITLE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, MAY 1, 1976 - OCTOBER 31, 1976.

AUTHOR- COSTAIN, J.K.;GLOVER, L., III;SINHA, A.K. [VIRGINIA POLYTECHNIC INST. AND STATE UNIV., BLACKSBURG (USA)].

REFERENCE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, MAY 1, 1976 - OCTOBER 31, 1976. VPI-SU-5103-2, VIRGINIA POLYTECHNIC INST., BLACKSBURG, VA., 1976, 170 P..

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; SEDIMENTARY ROCKS; HEAT FLOW; TEMPERATURE MEASUREMENTS; THERMAL CONDUCTIVITY; GEOTHERMAL WELLS; DRILLING; GRAVITY SURVEYS; MAGNETIC SURVEYS; HOT SPRINGS; CHEMICAL COMPOSITION; SOUTH CAROLINA; VIRGINIA; NORTH CAROLINA; MAPS; TABLES; DIAGRAMS.

MEIDAV 76
EXPLORATION/EVALUATION

TITLE- A COMPARISON OF HYDROTHERMAL RESERVOIRS OF THE WESTERN UNITED STATES. TOPICAL REPORT 3.

AUTHOR- MEIDAV, H.T. [GEONOMICS, INC., BERKELEY, CALIF. (USA)].

SANYAL, S.

REFERENCE- A COMPARISON OF HYDROTHERMAL RESERVOIRS OF THE WESTERN UNITED STATES. TOPICAL REPORT 3. ERRI ER-364, GEONOMICS, INC., BERKELEY, CALIF., 1976, 170 P..

DESCRIPTORS- GEOLOGIC SETTING; LITHOLOGY; ROCKS; SEDIMENTATION; VOLCANISM; TEMPERATURE

COSTAIN 77
EXPLORATION/EVALUATION

TITLE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, NOVEMBER 1, 1976 - MARCH 31, 1977.

AUTHOR- COSTAIN, J.K.;GLOVER, L., III;SINHA, A.K. [VIRGINIA POLYTECHNIC INST. AND STATE UNIV., BLACKSBURG (USA)].

REFERENCE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, NOVEMBER 1, 1976 - MARCH 31, 1977. VPI-SU-5103-3, VIRGINIA POLYTECHNIC INST. AND STATE UNIV., BA

PUP=BLACKSBURG, VA., 1977, A-1 - C-31.

DESCRIPTORS- GEOLOGIC SETTING; ROCKS; MINERALOGY; VOLCANISM; PLUTONS; GRANITES; METAMORPHIC ROCKS; HEAT FLOW; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; MOLYBDENUN; MAGNETIC SURVEYS; GEOCHEMISTRY; DRILLING; THEORETICAL TREATMENTS; COMPUTER CALCULATIONS; STRUCTURAL MODEL; POTASSIUM; URANIUM; GRAVITY SURVEY; VIRGINIA; NORTH CAROLINA; SOUTH CAROLINA; MAPS; TABLES; DIAGRAMS.

ERMAK 77
EXPLORATION/LAND-USE FACTORS

TITLE- A SCENARIO FOR GEOTHERMAL ELECTRIC POWER DEVELOPMENT IN IMPERIAL VALLEY.

AUTHOR- ERMAK, D.L. [CALIFORNIA UNIV., LIVERMORE (USA). LAWRENCE LIVERMORE LAB.].

REFERENCE- A SCENARIO FOR GEOTHERMAL ELECTRIC POWER DEVELOPMENT IN IMPERIAL VALLEY. CALIFORNIA UNIV., LIVERMORE, CALIF., 1977, 58 P..

DESCRIPTORS- TEMPERATURE MEASUREMENTS; POWER GENERATION; CHEMICAL COMPOSITION; AIR QUALITY; HYDROGEN SULFIDES; FLUID FLOW; ENVIRONMENTAL EFFECTS; LAND USE; FORECASTING; GEOTHERMAL WELLS; DRILLING; INJECTION WELLS; CALIFORNIA; BRAWLEY; IMPERIAL VALLEY; SALTON SEA; EAST MESA

BUREC 73
EXPLORATION/EVALUATION

DK TITLE- GEOTHERMAL RESOURCE INVESTIGATIONS, IMPERIAL VALLEY, CALIFORNIA. TEST WELL MESA 6-1.

AUTHOR- BUREAU OF RECLAMATION, BOULDER CITY, NEV. (USA).

REFERENCE- GEOTHERMAL RESOURCE INVESTIGATIONS, IMPERIAL VALLEY, CALIFORNIA. TEST WELL MESA 6-1. SPECIAL REPORT, BUREAU OF RECLAMATION, BOULDER CITY, NEV., 1973, 44 P..

DESCRIPTORS- LITHOLOGY WELL LOGS; ROCKS; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; PRESSURE MEASUREMENTS; CORING; PERMEABILITY; POROSITY; FLUID FLOW; ECONOMICS; PRESSURE GRADIENTS; GEOTHERMAL WELLS; DRILLING; DRILL STEM TESTS; CHEMICAL COMPOSITION; CALIFORNIA; IMPERIAL VALLEY; EAST MESA KGRA; MAPS; PHOTOGRAPHS; TABLES; DIAGRAMS.

ANDERSON 72
EXPLORATION/EVALUATION

K TITLE- GEOTHERMAL OVERVIEWS OF THE WESTERN UNITED STATES, 1972.

AUTHOR- ANDERSON, D.N.;AXTELL, L.H. [CALIFORNIA STATE DIV. OF OIL AND GAS, SACRAMENTO (USA)].

REFERENCE- GEOTHERMAL OVERVIEWS OF THE WESTERN UNITED STATES, 1972. CALIF. STATE DIV. OF OIL AND GAS, SACRAMENTO, CALIF., 1972,

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; VOLCANOES; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; HOT SPRINGS; HYDROLOGY; LAND USE; LEGAL ASPECTS; FORECASTING; POWER GENERATION; GEOTHERMAL WELLS; DRILLING; CHEMICAL COMPOSITION; HOT SPRINGS; GRAVITY SURVEYS; ARIZONA; CALIFORNIA; IDAHO; NEW MEXICO; NEVADA; COLORADO; HAWAII; MONTANA; OREGON; UTAH; WASHINGTON; WYOMING; IMPERIAL VALLEY; SALTON SEA; MAPS; TABLES; DIAGRAMS; COSO HOT SPRINGS; GEYSERS; GLASS MOUNTAIN; LAKE CITY; LASSEN; MONO-LONG VALLEY; SESPE HOT SPRINGS; WENDEL-AMEDEE.

1976, P. A1 - E3.

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; VOLCANOES; TEMPERATURE MEASUREMENTS; HOT SPRINGS; AIR QUALITY; LAND USE; LEASES; LEGAL ASPECTS; GEOTHERMAL WELLS; DRILLING; MAGNETIC SURVEYS; GEOTHERMOMETRY; CALIFORNIA; OREGON; GLOSSARY; TABLES; THE GEYSER; CALISTOGA KGRA; KNOXVILLE KGRA; LITTLE HORSE MOUNTAIN KGRA; LOVELADY RIDGE KGRA; WITTER SPRINGS KGRA; IMPERIAL VALLEY; BRAWLEY KGRA; DUNES KGRA; EAST MESA KGRA; FORD DRY LAKE KGRA; GLAMIS KGRA; HEBER KGRA; SALTON SEA KGRA; BODIE KGRA; COSO HOT SPRINGS KGRA; MONO-LONG VALLEY KGRA; RANDSBURG KGRA; SALINE VALLEY KGRA; BECKWOURTH PEAK KGRA; GLASS MOUNTAIN KGRA; LAKE CITY-SURPRISE VALLEY KGRA; LASSEN KGRA; WENDEL-AMEDEE; SESPE HOT SPRINGS KGRA.

BUREC 74
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL RESOURCE INVESTIGATIONS, EAST MESA TEST SITE, IMPERIAL VALLEY, CALIFORNIA. STATUS REPORT.

AUTHOR- BUREAU OF RECLAMATION, BOULDER CITY, NEV. (USA).

REFERENCE- GEOTHERMAL RESOURCE INVESTIGATIONS, EAST MESA TEST SITE, IMPERIAL VALLEY, CALIFORNIA. STATUS REPORT. BUREAU OF RECLAMATION, BOULDER CITY, NEV., 1974, 64 P..

DESCRIPTORS- LITHOLOGY; SEISMIC SURVEYS; EARTHQUAKES; HEAT FLOW; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; CHEMICAL COMPOSITION; RESISTIVITY SURVEYS; SUBSIDENCE; POWER GENERATION; PRESSURE SURVEYS; FLUID FLOW; FLUID DISPOSAL; CHEMICAL COMPOSITION; ENVIRONMENTAL EFFECTS; LEASES; THEORETICAL TREATMENTS; GEOTHERMAL WELLS; DRILLING; INJECTION WELLS; CASING; PERMEABILITY; GRAVITY SURVEYS; DRILL STEM TESTS; CALIFORNIA; IMPERIAL VALLEY; EAST MESA KGRA; MAPS; PHOTOGRAPHS; TABLES; DIAGRAMS.

DESCRIPTORS- TEMPERATURE MEASUREMENTS; NONCONDENSIBLE GASES; BINARY CYCLE; FLUID FLOW; ECONOMICS; THEORETICAL TREATMENTS; DRILLING; COMPUTER CODES; TABLES; DIAGRAMS.

JET PROPULSION LAB 76B
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA. STATUS REPORT.

AUTHOR- CALIFORNIA INST. OF TECH., PASADENA (USA). JET PROPULSION LAB..

REFERENCE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA. STATUS REPORT. JPL DOCUMENT 5040-25, CALIF. INST. OF TECH., PASADENA, CALIF., 1976, P. 1-1 - 6-13.

DESCRIPTORS- GEOLOGIC SETTING; DRILLING; ECONOMICS; LEASES; LEGAL ASPECTS; GEOTHERMAL POTENTIAL; GEOTHERMAL RESOURCES; GEOTHERMAL WELLS; POWER GENERATION; NON-ELECTRICAL; BECKWOURTH KGRA; SALINE VALLEY KGRA; GLASS MOUNTAIN KGRA; WENDEL-AMEDEE KGRA; GLAMIS KGRA; BODIE KGRA; FORD DRY LAKE KGRA; RANDSBURG KGRA; SESPE HOT SPRINGS; CALIFORNIA; MONO-LONG VALLEY; COSO HOT SPRINGS; LAKE CITY; IMPERIAL VALLEY; SURPRISE VALLEY; HEBER; EAST MESA KGRA; LASSEN; SALTON SEA; BRAWLEY; LITTLE HORSE MOUNTAIN; LOVELADY RIDGE; WITTER SPRINGS; THE GEYSERS; KNOXVILLE KGRA; DUNES KGRA; MAPS; TABLES; DIAGRAMS.

JET PROPULSION LAB 76C
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA, STATUS REPORT. APPENDIX.

AUTHOR- CALIFORNIA INST. OF TECH., PASADENA (USA). JET PROPULSION LAB..

REFERENCE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA, STATUS REPORT. APPENDIX. JPL DOCUMENT 5040-25, ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION, SACRAMENTO, CALIF.,

AUTHOR- REYNEOLDS ELECTRICAL AND ENGINEERING CO., INC., LAS VEGAS, NEV. (USA).

REFERENCE- COMPLETION REPORT-RAFT RIVER GEOTHERMAL EXPLORATORY HOLE NO. 1. IDO-10062 (NVO-410-30), REYNOLDS ELEC. AND ENGR. CO., LAS VEGAS, NEV., 1975, 42 P..

DESCRIPTORS- DRILL BITS; WELL CASINGS; LOGGING; CEMENT BOND LOG; RADIOACTIVITY LOG; CALIPER LOG; DRILL CORES; IDAHO; RAFT RIVER KGRA; PHOTOGRAPHS; DIAGRAMS; LITHOLOGY WELL LOGS; ACOUSTIC LOG; TEMPERATURE MEASUREMENT; FLUID FLOW; DRILLING.

BAKER 75B
EXPLORATION/DRILLING

OK

TITLE- REPORT OF THE GEOPHYSICAL MEASUREMENTS IN GEOTHERMAL WELLS WORKSHOP.

AUTHOR- BAKER, LE

AU=BAKER, L.E.;BAKER, R.P.;HUGHEN, R.L. [SANDIA LABS., ALBUQUERQUE, N. MEX. (USA)].

REFERENCE- REPORT OF THE GEOPHYSICAL MEASUREMENTS IN GEOTHERMAL WELLS WORKSHOP. SAND75-0608, DECEMBER 1975, 70 P..

DESCRIPTORS- WELL LOGS; DRILLING; PLANNING.

BLOOMSTER 76B
EXPLORATION/EVALUATION

OK

TITLE- THE ECONOMICS OF GEOTHERMAL ELECTRICITY GENERATION FROM HYDROTHERMAL RESOURCES.

AUTHOR- BLOOMSTER, C.H.;KNUTSEN, C.A. [BATTELLE PACIFIC NORTHWEST LABS., RICHLAND, WASH. (USA)].

REFERENCE- THE ECONOMICS OF GEOTHERMAL ELECTRICITY GENERATION FROM HYDROTHERMAL RESOURCES. BNWL-1989, BATTELLE, PACIFIC NORTHWEST LABS., RICHLAND, WASHINGTON, 43 P..

LAUGHLIN 75
EXPLORATION/GEOPHYSICS

TITLE- HOT DRY ROCK TESTED FOR GEOTHERMAL ENERGY.

AUTHOR- LAUGHLIN, A.W. [LOS ALAMOS SCIENTIFIC LAB., N. MEX. (USA)].

REFERENCE- GEOTIMES, V. 20 (3), P. 20-21(1975).

DESCRIPTORS- NEW MEXICO; JEMEZ MOUNTAINS GEOTHERMAL AREA; VALLES CALDERA; SANDOVAL CO.; HOT DRY ROCK SYSTEMS; DRILLING; HYDRAULIC FRACTURING; GEOTHERMAL GRADIENTS; BOTTOM HOLE TEMPERATURES; REGIONAL GEOLOGY; WELL LOGGING; GEOPHYSICAL SURVEYS.

SASS 76
EXPLORATION/DRILLING

TITLE- GEOTHERMAL DATA FROM TEST WELLS DRILLED IN GRASS VALLEY AND BUFFALO VALLEY, NEVADA.

AUTHOR- SASS, J.H.;OLMSTEAD, F.H.;SOREY, M.L.;LACHENBRUCH, A.H.;MUNROE, R.J.;GALANIS, S.P., JR.;WOLLENBERG, H.A. [CALIFORNIA UNIV., BERKELEY (USA). LAWRENCE BERKELEY LAB.].

REFERENCE- GEOTHERMAL DATA FROM TEST WELLS DRILLED IN GRASS VALLEY AND BUFFALO VALLEY, NEVADA. LBL-4489, CALIF. UNIV., BERKELEY, CALIF., 1976, 43 P..

DESCRIPTORS- LITHOLOGY; THERMAL CONDUCTIVITY; HEAT FLOW; TEMPERATURE GRADIENTS; DRILLING; DRILLCORES; NEVADA; GRASS VALLEY; BUFFALO VALLEY; MAPS; TABLES; DIAGRAMS.

REYNOLDS ELEC. AND ENG. CO. 75
EXPLORATION/DRILLING

TITLE- COMPLETION REPORT-RAFT RIVER GEOTHERMAL EXPLORATORY HOLE NO. 1.

ITALY-ALFINA.

AUTHOR- CATALDI, R.;RENDINA, M. [ENTE NAZIONALE PER L'ENERGIA ELECTTRICA, PIZA (ITALY)].

REFERENCE- GEOTHERMICS, V. 2 (3-4) P. 106-116(1974).

DESCRIPTORS- ITALY; ALFINA GEOTHERMAL AREA; DRILLING.

SNYDER 75
EXPLORATION/DRILLING

A

TITLE- HOW STEAM IS PRODUCED AND HANDLED AT THE GEYSERS.

AUTHOR- SNYDER, R.E.

REFERENCE- WORLD OIL, V. 180 (7), P. 43-48(1975).

DESCRIPTORS- CALIFORNIA; THE GEYSERS KGRA; DEVELOPMENT HISTORY; GEOLOGY; PRODUCTION; WELL SITING; DRILLING.

WARREN 75
EXPLORATION/DRILLING

DH

TITLE- DESIGN OF AN INSULATED COAXIAL PIPE ASSEMBLY FOR A DRILLED GEOTHERMAL WELL.

AUTHOR- WARREN, J.H.;WHITELAW, R.L. [VIRGINIA POLYTECHNIC INST. AND STATE UNIV., BLACKSBURG (USA)].

REFERENCE- DESIGN OF AN INSULATED COAXIAL PIPE ASSEMBLY FOR A DRILLED GEOTHERMAL WELL. 75-HT-56, AM. SOC. MECH. ENG. PAP., 1975, 7 P..

DESCRIPTORS- DRILLING; HYDROSTATIC PRESSURE; DRILL PIPE; INSULATION; RESEARCH; DEEP DRILLING.

FUCHS 758
EXPLORATION/EVALUATION

DA
TITLE- GEOTHERMAL ENERGY--THE CHALLENGES THAT LIE AHEAD. PART 2.

AUTHOR- FUCHS, R.L. [GEOSYSTEMS CORP., NEW YORK, N.Y. (USA)].

HUTTRER, G.W. [THERMEX CO., DENVER, COLO. (USA)].

REFERENCE- ENG. MIN. J., V. 176 (2), P. 78-82(1975).

DESCRIPTORS- GEOTHERMAL WELLS; CALIFORNIA; THE GEYSERS; IMPERIAL VALLEY; LEGAL ASPECTS; LEASING; NEW ZEALAND; DRILLING; POWER GENERATION; RESISTIVITY SURVEYS; MAPS; PHOTOGRAPHS.

COLLI 75
EXPLORATION/EVALUATION

DA
TITLE- GEOTHERMAL ENERGY IN FRANCE. (IN FRENCH). LA GEOTHERMIE EN FRANCE.

AUTHOR- COLLI, J.C.

REFERENCE- BULL. BUR. RECH. GEOL. MINIERES (FR), SECT. 2, NO. 1, 24 P.(1975).

DESCRIPTORS- FRANCE; RESERVOIRS; DRILLING.

CATALDI 73
EXPLORATION/DRILLING

DA
TITLE- RECENT DISCOVERY OF A NEW GEOTHERMAL FIELD IN

AUTHOR- OKI, Y.;HIRANO, T. [SANDIA LABS., ALBUQUERQUE, N. MEX. (USA)].

COLP, J.L.;FURUMOTO, A.S. (EDS.)

REFERENCE- HYDROTHERMAL SYSTEM AND SEISMIC ACTIVITY OF HAKONE VOLCANC.

DESCRIPTORS- JAPAN; CHEMICAL PROPERTIES; EARTHQUAKES; GEOCHEMISTRY; HYDROTHERMAL SYSTEMS; PROPERTIES; SEISMOLOGY; SODIUM CHLORIDES; SULFATES; THERMAL WATERS; VOLCANOES; MAPS; FIGURES; GEOLOGIC SETTING; SUBSURFACE TEMPERATURES; FLUID FLOW; ENERGY YIELD; GEOTHERMAL WELLS.

BARR 75B
EXPLORATION/EVALUATION

H TITLE- WHAT IS THE OUTLOOK FOR GECTHERMAL POWER .

AUTHOR- BARR, R.C. [EARTH POWER CORPORATION, TULSA, OKLA. (USA)].

REFERENCE- OIL GAS J., V. 73 (19), P. 148-151(1975).

DESCRIPTORS- ECONOMICS; POWER PRODUCTION; GEOTHERMAL WELLS; GAS; OIL; COAL; NUCLEAR; THE GEYSERS; MEXICO; JAPAN; TABLES.

BOLDIZSAR 75
EXPLORATION/EVALUATION

H TITLE- GEOTHERMAL ENERGY USE IN HUNGARY.

AUTHOR- BOLDIZSAR, T. [TECH. UNIV., MISKOLC-EGYETEMVAROS (HUNGARY)].

REFERENCE- GEOTHERM. ENERGY MAG, V. 3 (4), P. 5-13(1975).

DESCRIPTORS- HUNGARY; CARPATHIAN BASIN; HEAT FLOW; GEOTHERMAL WELLS; DIRECT ENERGY UTILIZATION; TEMPERATURE MEASUREMENTS; WELL COMPLETION DATA; FLOW RATES; CHEMICAL ANALYSIS; DISCUSSION; MAPS.

REFERENCE- ENG. MIN. J., V. 176 (1), P. 89-93(1975).

DESCRIPTORS- LEGAL ASPECTS; CALIFORNIA; POWER GENERATION; IDAHO; NEVADA; ECONOMICS; LEASES; TABLES; GEOTHERMAL WELLS; DRILLING; OREGON; ID
BLES;
GEOTHERMAL WELLS; DRILLING; OREGON; DIAGRAMS; NEW MEXICO; MONTANA; COLORADO; IMPERIAL VALLEY; MENDOCINO COUNTY; LAKE COUNTY; STEAMBOAT SPRINGS; SURPRISE VALLEY; SONOMA COUNTY; HONEY LAKE; LAKEVIEW; CHANDLER; CHOCOLATE MTNS.; PLUMAS COUNTY; VALLES; CALDERA; BRADY; INDIAN HOT SPRINGS; PINE FARMS; OREANA; RAFT RIVER; BEOWAWE; BRIGHAM CITY; CANBY; MARYSVILLE; SAN LUIS VALLEY; HOT LAKE; HEAT FLOW; PHOTOGRAPHS; FORECASTING.

HOUSE 75
EXPLORATION/EVALUATION

DH

TITLE- POTENTIAL POWER GENERATION AND GAS PRODUCTION FROM GULF COAST GEOPRESSURE RESERVOIRS.

AUTHOR- HOUSE, P.A.;JOHNSON, P.M.;TOWSE, D.F. [CALIFORNIA UNIV., LIVERMORE (USA). LAWRENCE LIVERMORE LAB.].

REFERENCE- POTENTIAL POWER GENERATION AND GAS PRODUCTION FROM GULF COAST GEOPRESSURE RESERVOIRS. UCRL-51813, CALIFORNIA UNIV., LIVERMORE, CALIF., 1975, 40 P..

DESCRIPTORS- GEOLOGIC SETTING; TEMPERATURE MEASUREMENTS; BINARY CYCLE; PRESSURE MEASUREMENTS; CHEMICAL COMPOSITION; SCALING; FLUID FLOW; HYDRAULICS; ECONOMICS; THEORETICAL TREATMENTS; GEOTHERMAL WELLS; INJECTION WELLS; POWER GENERATION; GAS PRODUCTION; TEXAS; GEOPRESSURED SYSTEMS; MAPS; TABLES; DIAGRAMS.

OKI 74
EXPLORATION/GEOCHEMISTRY

DH

TITLE- HYDROTHERMAL SYSTEM AND SEISMIC ACTIVITY OF HAKONE VOLCANO.

SCHULLER 76
EXPLORATION/EVALUATION

DH

TITLE- LEGAL.

PT=LEGAL,

INSTITUTIONAL ANC POLITICAL PROBLEMS IN PRODUCING ELECTRIC POWER FROM GEOTHERMAL RESOURCES IN CALIFORNIA.

AUTHOR- SCHULLER, C.R.;SCHILLING, A.H.;COLE, R.J.;SIMON, G.D. [BATTELLE (USA)].

REFERENCE- LEGAL.

PT=LEGAL,

INSTITUTIONAL ANC POLITICAL PROBLEMS IN PRODUCING ELECTRIC POWER FROM GEOTHERMAL RESOURCES IN CALIFORNIA. BATTELLE, SEATTLE, WASH., 1976, 390 P..

DESCRIPTORS- CAPITAL; DRILLING; ECONOMICS; ENGINEERING; ENVIRONMENTAL EFFECTS; AIR QUALITY; LANC USE; LEASES; LEGAL ASPECTS; FORECASTING; COSTS; ENVIRONMENTAL IMPACT STATEMENTS; POWER TRANSMISSION; TAXES; GEOTHERMAL DEVELOPMENT; GEOTHERMAL POTENTIAL; GEOTHERMAL RESOURCES; GEOTHERMAL RESERVES; GEOTHERMAL WELLS; DRILLING TECHNOLOGY; POWER GENERATION; REGULATIONS; WASTE DISPOSAL; DISCUSSION; EVALUATION; FIELC DATA; CALIFORNIA; GLASS MOUNTAIN KGRA; LAKE CITY-SURPRISE VALLEY KGRA; WENDEL AMACEE KGRA; BODIE KGRA; SALINE VALLEY KGRA; COSO HOT SPRINGS KGRA; BECKWOURTH PEAK KGRA; IMPERIAL VALLEY; CENTRAL VALLEY; SALTON SEA; KGRA'S; GOVERNMENT POLICIES; FORD DRY-LAKE KGRA; GEYSERS GEOTHERMAL FIELD; LASSEN KGRA; MONO-LONG VALLEY KGRA; RANDSBURG KGRA; SESPE HOT SPRINGS KGRA; MAPS; DIAGRAMS.

FUCHS 75

DH

TITLE- GEOTHERMAL ENERGY--SLOW-GROWING INDUSTRY FINALLY HEATS UP. PART 1.

AUTHOR- FUCHS, R.L. [GEOSYSTEMS CORP., NEW YORK, N.Y. (USA)].

HUTTRER, G.W. [THERMEX CO., DENVER, COLO. (USA)].

[VIRGINIA POLYTECHNIC INST. AND STATE UNIV., BLACKSBURG (USA)].

REFERENCE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, MAY 1, 1976 - OCTOBER 31, 1976. VPI-SU-5103-2, VIRGINIA POLYTECHNIC INST., BLACKSBURG, VA., 1976, 170 P..

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; SEDIMENTARY ROCKS; HEAT FLOW; TEMPERATURE MEASUREMENTS; THERMAL CONDUCTIVITY; GEOTHERMAL WELLS; DRILLING; GRAVITY SURVEYS; MAGNETIC SURVEYS; HOT SPRINGS; CHEMICAL COMPOSITION; SOUTH CAROLINA; VIRGINIA; NORTH CAROLINA; MAPS; TABLES; DIAGRAMS.

MEIDAV 76
EXPLORATION/EVALUATION

DH

TITLE- A COMPARISON OF HYDROTHERMAL RESERVOIRS OF THE WESTERN UNITED STATES. TOPICAL REPORT 3.

AUTHOR- MEIDAV, H.T. [GEONOMICS, INC., BERKELEY, CALIF. (USA)].

SANYAL, S.

REFERENCE- A COMPARISON OF HYDROTHERMAL RESERVOIRS OF THE WESTERN UNITED STATES. TOPICAL REPORT 3. ERRI ER-364, GEONOMICS, INC., BERKELEY, CALIF., 1976, 170 P..

DESCRIPTORS- GEOLOGIC SETTING; LITHOLOGY; ROCKS; SEDIMENTATION; VOLCANISM; TEMPERATURE MEASUREMENTS; FLUID FLOW; DRAWDOWN; WATER LEVELS; DRILLING; MATHEMATICAL MODEL; THEORETICAL TREATMENTS; COMPUTER CALCULATIONS; FORECASTING; SITE SELECTION; COSTS; DEPTH; WELL SPACING; EFFECTIVE PRESSURE; FLUID PRESSURE; GEOTHERMAL RESERVES; VAPOR-DOMINATED SYSTEMS; HOT WATER SYSTEMS; GEOTHERMAL WELLS; FLOW RATES; INJECTION WELLS; CHEMICAL ANALYSIS; POWER POTENTIAL; DISCUSSION; EVALUATION; FIELD DATA; UNITED STATES; CALIFORNIA; IDAHO; NEW MEXICO; NEVADA; WYOMING; MEXICO; YELLOWSTONE KGRA; HEBER KGRA; EAST MESA KGRA; RAFT RIVER KGRA; MONO-LONG VALLEY KGRA; BRUNCA KGRA; BRADY-HAZEN KGRA; ROOSEVELT HOT SPRINGS KGRA; BRAWLEY KGRA; DUNES KGRA; LAKE CITY-SURPRISE VALLEY KGRA; BEOWAWE KGRA.

DEVELOPMENT IN THE IMPERIAL VALLEY. EQL MEMO NO. 20, CALIF. INST. OF TECH., PASADENA, CALIF., 1976, 52 P..

DESCRIPTORS- TEMPERATURE MEASUREMENTS; POWER GENERATION; POWER PLANTS; COOLING TOWERS; TRANSMISSION PIPES; SURFACE WATERS; WATER ANALYSIS; ECONOMICS; ENVIRONMENTAL EFFECTS; ARTIFICIAL RECHARGE; LAND USE; THEORETICAL TREATMENTS; FORECASTING; CHEMICAL COMPOSITION; GEOTHERMAL WELLS; DRILLING TECHNOLOGY; NON-ELECTRICAL; DISCUSSION; EVALUATION; EXPERIMENTAL DATA; FIELD DATA; CALIFORNIA; IMPERIAL VALLEY; SALTON SEA; TABLES; DIAGRAMS.

REITZEL 76
EXPLORATION/EVALUATION

DA

TITLE- UTILIZATION OF U.S. GEOTHERMAL RESOURCES. FINAL REPORT.

AUTHOR- REITZEL, J. (TRW, INC., REDONDO BEACH, CALIF. (USA)].

REFERENCE- UTILIZATION OF U.S. GEOTHERMAL RESOURCES. FINAL REPORT. ER-382, SYSTEMS AND ENERGY GROUP OF TRW INC., REDONDO BEACH, CALIF., 1976, P. 1-1 - D-2.

DESCRIPTORS- TECTONICS; TEMPERATURE MEASUREMENTS; POWER GENERATION; ECONOMICS; LEASES; THEORETICAL TREATMENTS; FORECASTING; GEOTHERMAL WELLS; GEOTHERMOMETERS; HOT SPRINGS; CALIFORNIA; IDAHO; LOUISIANA; NEW MEXICO; NEVADA; TEXAS; WYOMING; UTAH; OREGON; GEOPRESSURED SYSTEMS; MAPS; TABLES; DIAGRAMS.

COSTAIN 76
EXPLORATION/EVALUATION

DA

TITLE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, MAY 1, 1976 - OCTOBER 31, 1976.

AUTHOR- COSTAIN, J.K.;GLOVER, L., III;SINHA, A.K.

DESCRIPTORS- TEMPERATURE MEASUREMENTS; POWER GENERATION; CHEMICAL COMPOSITION; AIR QUALITY; HYDROGEN SULFIDES; FLUID FLOW; ENVIRONMENTAL EFFECTS; LAND USE; FORECASTING; GEOTHERMAL WELLS; DRILLING; INJECTION WELLS; CALIFORNIA; BRAWLEY; IMPERIAL VALLEY; SALTON SEA; EAST MESA KGRA; HEBER; THE GEYSERS; MAPS; TABLES;

NARASIMHAN 77
EXPLORATION/GEOLOGY

TITLE- RESERVOIR EVALUATION TESTS ON RRGE 1 AND RRGE 2, RAFT RIVER GEOTHERMAL PROJECT, IDAHO.

AUTHOR- NARASIMHAN, T.N.;WITHERSPOON, P.A. [CALIFORNIA UNIV., BERKELEY (USA). LAWRENCE BERKELEY LAB.].

REFERENCE- RESERVOIR EVALUATION TESTS ON RRGE 1 AND RRGE 2, RAFT RIVER GEOTHERMAL PROJECT, IDAHO. LBL-5958, CALIFORNIA UNIV., BERKELEY, CALIF., 1977, 50 P..

DESCRIPTORS- FAULTS; SUBSURFACE FAULTING; GEOLOGIC SETTING; LITHOLOGY; LITHOLOGY WELL LOGS; SEDIMENTATION; SEDIMENTARY ROCKS; POROSITY; PERMEABILITY; TEMPERATURE MEASUREMENTS; PRESSURE MEASUREMENTS; PERMEABILITY; FLUID FLOW; DRAWDOWN; STORAGE COEFFICIENT; THEORETICAL TREATMENTS; GEOTHERMAL DEVELOPMENT; GEOTHERMAL POTENTIAL; GEOTHERMAL WELLS; DISCUSSION; EVALUATION; FIELD DATA; TESTING; UNITED STATES; IDAHO; RAFT RIVER KGRA; MAPS; TABLES; DIAGRAMS.

GOLDSMITH 76
EXPLORATION/EVALUATION

TITLE- ENGINEERING ASPECTS OF GEOTHERMAL DEVELOPMENT IN THE IMPERIAL VALLEY.

AUTHOR- GOLDSMITH, M. [CALIFORNIA INST. OF TECH., PASADENA (USA). ENVIRONMENTAL QUALITY LAB.].

REFERENCE- ENGINEERING ASPECTS OF GEOTHERMAL

FRANCISCO, CALIF., 1975,

DESCRIPTORS- FAULTS; THRUST FAULTS; GEOLOGIC STRUCTURES; LITHOLOGY; ROCKS; TECTONISM; GEOTHERMAL WELLS; THERMAL SPRINGS; VOLCANOES; CALIFORNIA; MAPS.

BECHTEL 76
EXPLORATION/EVALUATION

DH

TITLE- CONCEPTUAL DESIGN OF COMMERCIAL 50 MWE (NET) GEOTHERMAL POWER PLANTS AT HEBERAND NILAND, CALIFORNIA. FINAL REPORT.

AUTHOR- BECHTEL CORP., SAN FRANCISCO, CALIF. (USA).

REFERENCE- CONCEPTUAL DESIGN OF COMMERCIAL 50 MWE (NET) GEOTHERMAL POWER PLANTS AT HEBERAND NILAND, CALIFORNIA. FINAL REPORT. SAN-1124-1, BECHTEL CORP., SAN FRANCISCO, CALIF., 1976, 1-1 - 10-6.

DESCRIPTORS- GEOLOGIC SETTING; POWER GENERATION; TEMPERATURE MEASURMENT; ECONOMICS; ENVIRONMENTAL EFFECTS; SITE SELECTION; TEST FACILITIES; GEOTHERMAL WELLS; INJECTION WELLS; AIR QUALITY; WATER QUALITY; CHEMICAL COMPOSITION; CLIMATE; EVALUATION; CALIFORNIA; IMPERIAL VALLEY; SALTON SEA; NILAND; HEBER; MAPS; TABLES; DIAGRAMS; SILICA; CORROSION; HYDROGEN SULFIDE; FLOW RATES; GOVERNMENT REGULATIONS; THERMODYNAMIC CYCLES; THEORETICAL TREATMENT; COSTS.

ERMAK 77
EXPLORATION/LAND-USE FACTORS

DK

TITLE- A SCENARIO FOR GEOTHERMAL ELECTRIC POWER DEVELOPMENT IN IMPERIAL VALLEY.

AUTHOR- ERMAK, D.L. [CALIFORNIA UNIV., LIVERMORE (USA). LAWRENCE LIVERMORE LAB.].

REFERENCE- A SCENARIO FOR GEOTHERMAL ELECTRIC POWER DEVELOPMENT IN IMPERIAL VALLEY. CALIFORNIA UNIV., LIVERMORE, CALIF., 1977, 58 P..

STATE DIV. OF OIL AND GAS, SACRAMENTO (USA)].

REFERENCE- GEOTHERMAL OVERVIEWS OF THE WESTERN UNITED STATES, 1972. CALIF. STATE DIV. OF OIL AND GAS, SACRAMENTO, CALIF., 1972,

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; VOLCANOES; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; HOT SPRINGS; HYDROLOGY; LAND USE; LEGAL ASPECTS; FORECASTING; POWER GENERATION; GEOTHERMAL WELLS; DRILLING; CHEMICAL COMPOSITION; HOT SPRINGS; GRAVITY SURVEYS; ARIZONA; CALIFORNIA; IDAHO; NEW MEXICO; NEVADA; COLORADO; HAWAII; MONTANA; OREGON; UTAH; WASHINGTON; WYOMING; IMPERIAL VALLEY; SALTON SEA; MAPS; TABLES; DIAGRAMS; COSO HOT SPRINGS; GEYSERS; GLASS MOUNTAIN; LAKE CITY; LASSEN; MONO-LONG VALLEY; SESPE HOT SPRINGS; WENDEL-AMEDEE.

AXTELL 72
EXPLORATION/DRILLING

H

TITLE- MONO LAKE GEOTHERMAL WELLS ABANDONED.

AUTHOR- AXTELL, L.H.

REFERENCE- CALIF. GEOL., V. 25 (3), P. 66(1972).

DESCRIPTORS- MONO-LONG VALLEY; CALIFORNIA; GEOTHERMAL WELLS; TEMPERATURE GRADIENTS; LITHOLOGY; DIAGRAMS; PHOTOGRAPHS.

JENNINGS 75
EXPLORATION/GEOLOGY

DH

TITLE- FAULT MAP OF CALIFORNIA WITH LOCATIONS OF VOLCANOES, THERMAL SPRINGS AND THERMAL WELLS.

AUTHOR- JENNINGS, C.W.;STRAND, R.G.;ROGERS, T.H.;STINSON, M.C.;BURNETT, J.L.;KAHLE, J.E.;STREITZ, R.;SWITZER, R.A.

REFERENCE- FAULT MAP OF CALIFORNIA WITH LOCATIONS OF VOLCANOES, THERMAL SPRINGS AND THERMAL WELLS. MAP NO. 1, CALIF. DIV. MINES AND GEOLOGY, SAN

TITLE- EVALUATION OF GEOTHERMAL ACTIVITY IN THE TRUCKEE MEADOWS, WASHOE COUNTY, NEVADA.

AUTHOR- BATEMAN, R.L.;SCHEIBACH, R.B. [NEVADA UNIV., RENO (USA). MACKAY SCHOOL OF MINES].

REFERENCE- EVALUATION OF GEOTHERMAL ACTIVITY IN THE TRUCKEE MEADOWS, WASHOE COUNTY, NEVADA. NBMG REPORT 25, NEVADA UNIV., RENO, NEV., 1975, 38 P..

DESCRIPTORS- GEOLOGIC SETTING; HEAT FLOW; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; HOT SPRINGS; CLIMATE; FLUID FLOW; HYDROLOGY; ECONOMICS; THEORETICAL TREATMENTS; GEOTHERMAL WELLS; WELLS; NON-ELECTRICAL; CHEMICAL COMPOSITION; SPACE HEATING; NEVADA; WASHOE COUNTY; STEAMBOAT SPRINGS; MOANA SPRINGS; MAPS; TABLES; DIAGRAMS.

BLACK 75
EXPLORATION/EVALUATION

TITLE- A SUBSURFACE STUDY OF THE MESA GEOTHERMAL ANOMALY, IMPERIAL VALLEY, CALIFORNIA.

AUTHOR- BLACK, H.T. [COLORADO UNIV., BOULDER (USA)].

REFERENCE- A SUBSURFACE STUDY OF THE MESA GEOTHERMAL ANOMALY, IMPERIAL VALLEY, CALIFORNIA. PB-247082, NTIS, SPRINGFIELD, VA., 1975, 58 P..

DESCRIPTORS- GEOLOGIC SETTING; LITHOLOGY LOGS; TEMPERATURE GRADIENTS; POROSITY; PERMEABILITY; GEOTHERMOMETRY; HYDRAULICS; HYDROLOGY; GEOTHERMAL WELLS; SALINITY LOGS; CALIFORNIA; IMPERIAL VALLEY; SALTON SEA; EAST MESA KGRA; MAPS; TABLES; DIAGRAMS.

ANDERSON 72
EXPLORATION/EVALUATION

TITLE- GEOTHERMAL OVERVIEWS OF THE WESTERN UNITED STATES, 1972.

AUTHOR- ANDERSON, D.N.;AXTELL, L.H. [CALIFORNIA

AUTHOR- BUREAU OF RECLAMATION, BOULDER CITY, NEV. (USA).

REFERENCE- GEOTHERMAL RESOURCE INVESTIGATIONS, EAST MESA TEST SITE, IMPERIAL VALLEY, CALIFORNIA. STATUS REPORT. BUREAU OF RECLAMATION, BOULDER CITY, NEV., 1974, 64 P..

DESCRIPTORS- LITHOLOGY; SEISMIC SURVEYS; EARTHQUAKES; HEAT FLOW; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; CHEMICAL COMPOSITION; RESISTIVITY SURVEYS; SUBSIDENCE; POWER GENERATION; PRESSURE SURVEYS; FLUID FLOW; FLUID DISPOSAL; CHEMICAL COMPOSITION; ENVIRONMENTAL EFFECTS; LEASES; THEORETICAL TREATMENTS; GEOTHERMAL WELLS; DRILLING; INJECTION WELLS; CASING; PERMEABILITY; GRAVITY SURVEYS; DRILL STEM TESTS; CALIFORNIA; IMPERIAL VALLEY; EAST MESA KGRA; MAPS; PHOTOGRAPHS; TABLES; DIAGRAMS.

BUREC 73
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL RESOURCE INVESTIGATIONS, IMPERIAL VALLEY, CALIFORNIA. TEST WELL MESA 6-1.

AUTHOR- BUREAU OF RECLAMATION, BOULDER CITY, NEV. (USA).

REFERENCE- GEOTHERMAL RESOURCE INVESTIGATIONS, IMPERIAL VALLEY, CALIFORNIA. TEST WELL MESA 6-1. SPECIAL REPORT, BUREAU OF RECLAMATION, BOULDER CITY, NEV., 1973, 44 P..

DESCRIPTORS- LITHOLOGY WELL LOGS; ROCKS; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; PRESSURE MEASUREMENTS; CASING; PERMEABILITY; POROSITY; FLUID FLOW; ECONOMICS; PRESSURE GRADIENTS; GEOTHERMAL WELLS; DRILLING; DRILL STEM TESTS; CHEMICAL COMPOSITION; CALIFORNIA; IMPERIAL VALLEY; EAST MESA KGRA; MAPS; PHOTOGRAPHS; TABLES; DIAGRAMS.

BATEMAN 75
EXPLORATION/EVALUATION

SPRINGS; CALIFORNIA; MONO-LONG VALLEY; COSO HOT SPRINGS; LAKE CITY; IMPERIAL VALLEY; SURPRISE VALLEY; HEBER; EAST MESA KGRA; LASSEN; SALTON SEA; BRAWLEY; LITTLE HORSE MOUNTAIN; LOVELADY RIDGE; WITTER SPRINGS; THE GEYSERS; KNOXVILLE KGRA; DUNES KGRA; MAPS; TABLES; DIAGRAMS.

JET PROPULSION LAB 76C
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA, STATUS REPORT. APPENDIX.

AUTHOR- CALIFORNIA INST. OF TECH., PASADENA (USA). JET PROPULSION LAB..

REFERENCE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA, STATUS REPORT. APPENDIX. JPL DOCUMENT 5040-25, ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION, SACRAMENTO, CALIF., 1976, P. A1 - E3.

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; VOLCANOES; TEMPERATURE MEASUREMENTS; HOT SPRINGS; AIR QUALITY; LAND USE; LEASES; LEGAL ASPECTS; GEOTHERMAL WELLS; DRILLING; MAGNETIC SURVEYS; GEOTHERMOMETRY; CALIFORNIA; OREGON; GLOSSARY; TABLES; THE GEYSER; CALISTOGA KGRA; KNOXVILLE KGRA; LITTLE HORSE MOUNTAIN KGRA; LOVELADY RIDGE KGRA; WITTER SPRINGS KGRA; IMPERIAL VALLEY; BRAWLEY KGRA; DUNES KGRA; EAST MESA KGRA; FORD DRY LAKE KGRA; GLAMIS KGRA; HEBER KGRA; SALTON SEA KGRA; BODIE KGRA; COSO HOT SPRINGS KGRA; MONO-LONG VALLEY KGRA; RANDSBURG KGRA; SALINE VALLEY KGRA; BECKWOURTH PEAK KGRA; GLASS MOUNTAIN KGRA; LAKE CITY-SURPRISE VALLEY KGRA; LASSEN KGRA; WENDEL-AMEDEE; SESPE HOT SPRINGS KGRA.

BUREC 74
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL RESOURCE INVESTIGATIONS, EAST MESA TEST SITE, IMPERIAL VALLEY, CALIFORNIA. STATUS REPORT.

MEASUREMENT; SURFACE WATERS; ECONOMICS; LEGAL ASPECTS; GEOTHERMAL WELLS; SPACE HEATING; IDAHO; SUGAR CITY; MAPS; TABLES; DIAGRAMS.

BLOOMSTER 76
EXPLORATION/EVALUATION

DH

TITLE- THE POTENTIAL BENEFITS OF GEOTHERMAL ELECTRICAL PRODUCTION FROM HYDROGHERMAL RESOURCES.

AUTHOR- BLOOMSTER, C.H.;ENGEL, R.L. [BATTELLE PACIFIC NORTHWEST LABS., RICHLAND, WASH. (USA)].

REFERENCE- THE POTENTIAL BENEFITS OF GEOTHERMAL ELECTRICAL PRODUCTION FROM HYDROGHERMAL RESOURCES. BNWL-2001, BATTELLE PACIFIC NORTHWEST LABS., RICHLAND, WASH., 1976, 33 P..

DESCRIPTORS- ECONOMICS; MATHEMATICAL MODEL; FORECASTING; COST COMPARISONS; GEOTHERMAL RESOURCES; HYDROTHERMAL CONVECTION SYSTEMS; GEOTHERMAL WELLS; POWER GENERATION; MAPS; TABLES; DIAGRAMS.

JET PROPULSION LAB 76B
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA. STATUS REPORT.

AUTHOR- CALIFORNIA INST. OF TECH., PASADENA (USA). JET PROPULSION LAB..

REFERENCE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA. STATUS REPORT. JPL DOCUMENT 5040-25, CALIF. INST. OF TECH., PASADENA, CALIF., 1976, P. 1-1 - 6-13.

DESCRIPTORS- GEOLOGIC SETTING; DRILLING; ECONOMICS; LEASES; LEGAL ASPECTS; GEOTHERMAL POTENTIAL; GEOTHERMAL RESOURCES; GEOTHERMAL WELLS; POWER GENERATION; NON-ELECTRICAL; BECKWOURTH KGRA; SALINE VALLEY KGRA; GLASS MOUNTAIN KGRA; WENDEL-AMEDEE KGRA; GLAMIS KGRA; BODIE KGRA; FORD DRY LAKE KGRA; RANDSBURG KGRA; SESPE HOT

LIVERMORE, CALIF., 1976, 33 P..

DESCRIPTORS- TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; PRESSURE MEASUREMENTS; CHEMICAL COMPOSITION; GEOTHERMAL WELLS; FLOW RATES; BRINES; SCALING; BINARY CYCLE; POWER GENERATION; CALIFORNIA; IMPERIAL VALLEY; NIALAND; MAPS; PHOTOGRAPHS; TABLES.

WEST 75
EXPLORATION/GEOPHYSICS

OH

TITLE- GEOPHYSICAL LOGGING IN LOS ALAMOS SCIENTIFIC LABORATORY GEOTHERMAL TEST HOLE NO. 2.

AUTHOR- WEST, F.G.;KINTZINGER, P.R.;LAUGHLIN, A.W. [LOS ALAMOS SCIENTIFIC LAB., N. MEX. (USA)].

REFERENCE- GEOPHYSICAL LOGGING IN LOS ALAMOS SCIENTIFIC LABORATORY GEOTHERMAL TEST HOLE NO. 2. LA-6112 MS, LOS ALAMOS SCIENTIFIC LAB., LOS ALAMOS, N. MEX., 1975, 12 P..

DESCRIPTORS- GEOLOGIC SETTING; ACOUSTIC LOGS; TEMPERATURE LOGS; SEDIMENTARY-SECTION LOGS; DRILL-RATE LOGS; HOT-DRY-ROCK SYSTEMS; GEOTHERMAL WELLS; LOGGING; RADIOACTIVITY LOGS; SELF-POTENTIAL LOGS; SEISVIEWER LOGS; DIAGRAMS.

KUNZE 77
EXPLORATION/EVALUATION

OH

TITLE- THE POTENTIAL FOR UTILIZING GEOTHERMAL ENERGY FOR SPACE HEATING IN RE-CONSTRUCTED SUGAR CITY, IDAHO.

AUTHOR- KUNZE, J.F.;LOFTHOUSE, J.H.;STOKER, R.C. [IDAHO NATIONAL ENGINEERING LAB., IDAHO FALLS (USA)].

REFERENCE- THE POTENTIAL FOR UTILIZING GEOTHERMAL ENERGY FOR SPACE HEATING IN RE-CONSTRUCTED SUGAR CITY, IDAHO. TREE-1016, EG AND G IDAHO, INC., IDAHO FALLS, IDAHO, 1977, 30 P..

DESCRIPTORS- GEOLOGIC SETTING; TEMPERATURE

RESERVOIR ENGINEERING PROGRESS REPORT FOR JANUARY 1977.

AUTHOR- YUEN, P.C. [HAWAII UNIV., HONOLULU (USA)].

REFERENCE- THE HAWAII GEOTHERMAL PROJECT. WELL TEST AND RESERVOIR ENGINEERING PROGRESS REPORT FOR JANUARY 1977. UNIV. OF HAWAII, HONOLULU, HAWAII, 1977, P. 1-19.

DESCRIPTORS- HAWAII; MAPS; MAGMAS; GEOTHERMAL WELLS; RESERVOIR ENGINEERING; DIAGRAMS; TEMPERATURE GRADIENTS; TABLES; WELL COMPLETION DATA; FLUID FLOW.

AAMODT 77
EXPLORATION/EVALUATION

DH
TITLE- HYDRAULIC FRACTURE EXPERIMENTS IN GT-1 AND GT-2.

AUTHOR- AAMODT, R.L. [LOS ALAMOS SCIENTIFIC LAB., N. MEX. (USA)].

REFERENCE- HYDRAULIC FRACTURE EXPERIMENTS IN GT-1 AND GT-2. LA-6712, LOS ALAMOS SCIENTIFIC LAB., LOS ALAMOS, N. MEX., 1977, 19 P..

DESCRIPTORS- FRACTURES; HYDRAULIC FRACTURING; HOT-DRY-ROCK SYSTEMS; HEAT FLOW; TEMPERATURE MEASUREMENT; THEORETICAL TREATMENTS; GEOTHERMAL WELLS; EXPERIMENTAL DATA; NEW MEXICO; TABLES; DIAGRAMS.

QUONG 76

DH
TITLE- SCALING CHARACTERISTICS IN THE GEOTHERMAL LOOP EXPERIMENTAL FACILITY AT NILAND, CALIFORNIA.

AUTHOR- QUONG, R. [CALIFORNIA UNIV., LIVERMORE (USA). LAWRENCE LIVERMORE LAB.].

REFERENCE- SCALING CHARACTERISTICS IN THE GEOTHERMAL LOOP EXPERIMENTAL FACILITY AT NILAND, CALIFORNIA. UCRL-52162, CALIF. UNIV.,

MILLER 77
EXPLORATION/EVALUATION

OK TITLE- THE USE OF GEOCHEMICAL-EQUILIBRIUM COMPUTER CALCULATIONS TO ESTIMATE PRECIPITATION FROM GEOTHERMAL BRINES.

AUTHOR- MILLER, D.G.;PIWINSKII, A.J.;YAMAUCHI, R. [CALIFORNIA UNIV., LIVERMORE (USA). LAWRENCE LIVERMORE LAB.].

REFERENCE- THE USE OF GEOCHEMICAL-EQUILIBRIUM COMPUTER CALCULATIONS TO ESTIMATE PRECIPITATION FROM GEOTHERMAL BRINES. UCRL-52197, CALIF. UNIV., LIVERMORE, CALIF., 1977, 35 P..

DESCRIPTORS- GEOTHERMAL WELLS; INJECTION WELLS; BRINES; SCALES; CHEMICAL COMPOSITION; MINERALS; SOLUBILITY; COMPUTER CODES; CALIFORNIA; IMPERIAL VALLEY; TABLES; DIAGRAMS.

WHITE 75
EXPLORATION/EVALUATION

H TITLE- ASSESSMENT OF GEOTHERMAL RESOURCES OF THE UNITED STATES-1975.

AUTHOR- WHITE, D.E.;WILLIAMS, D.L. (EDS.)

REFERENCE- ASSESSMENT OF GEOTHERMAL RESOURCES OF THE UNITED STATES-1975. CIRC. 726, U.S. GEOLOGICAL SURVEY, RESTON, VA., 1975, 155 P..

DESCRIPTORS- GEOTHERMAL RESOURCES; HYDROTHERMAL CONVECTION SYSTEMS; GEOPRESSURED SYSTEMS; GEOTHERMAL WELLS; HOT-DRY-ROCK SYSTEMS; GEOTHERMOMETRY; EVALUATION; UNITED STATES; ARIZONA; CALIFORNIA; IDAHO; LOUISIANA; NEW MEXICO; NEVADA; TEXAS; OREGON; WASHINGTON; IMPERIAL VALLEY; MAPS; TABLES; DIAGRAMS.

YUEN 77
EXPLORATION/DRILLING

OK TITLE- THE HAWAII GEOTHERMAL PROJECT. WELL TEST AND

PHOTOGRAPHS.

BAKER 75
EXPLORATION/DRILLING

TITLE- WELL-LOGGING TECHNOLOGY AND GEOTHERMAL APPLICATIONS--A SURVEY AND ASSESSMENT WITH RECOMMENDATIONS.

AUTHOR- BAKER, L.E.;CAMPBELL, A.B.;HUGHEN, R.L. [SANDIA LABS., ALBUQUERQUE, N. MEX. (USA)].

REFERENCE- WELL-LOGGING TECHNOLOGY AND GEOTHERMAL APPLICATIONS--A SURVEY AND ASSESSMENT WITH RECOMMENDATIONS. SAND75-0275, 1975, 75 P..

DESCRIPTORS- ACOUSTIC TESTING; ELECTRIC MEASURING INSTRUMENTS; GEOTHERMAL WELLS; MEASURING INSTRUMENTS; MEASURING METHODS; RADIATION DETECTORS; SAMPLERS; TEMPERATURE MEASUREMENT; WELL LOGGING.

ONODERA 74
EXPLORATION/GEOPHYSICS

TITLE- GEO-ELECTRICAL INDICATIONS AT THE OTAKE GEOTHERMAL FIELD IN THE WESTERN PART OF THE KUJYU VOLCANO GROUP, KYUSHU, JAPAN.

AUTHOR- ONODERA, S. [KYUSHU UNIV., FUKUOKA (JAPAN)].

REFERENCE- GEO-ELECTRICAL INDICATIONS AT THE OTAKE GEOTHERMAL FIELD IN THE WESTERN PART OF THE KUJYU VOLCANO GROUP, KYUSHU, JAPAN. 1974,

DESCRIPTORS- ELECTRICAL SURVEYS; FLUID FLOW; GEOTHERMAL FLUIDS; GEOTHERMAL WELLS; JAPAN; OTAKE GEOTHERMAL FIELD; ZONES.

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; GEOTHERMOMETRY; SEISMIC SURVEYS; HEAT FLOW; RESISTIVITY SURVEYS; SELF POTENTIAL SURVEYS; HOT SPRINGS; CHEMISTRY; DRILLING; FLOW RATES; GRAVITY SURVEYS; LOGGING; RADIOACTIVITY SURVEYS; NEVADA; WHIRLWIND VALLEY; BUFFALO VALLEY; GRASS VALLEY; BUENA VISTA VALLEY; LEACH HOT SPRINGS; MAPS; DIAGRAMS; PHOTOGRAPHS; KYLE HOT SPRINGS KGRA.

BARR 75
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL EXPLORATION-STRATEGY AND BUDGETING.

AUTHOR- BARR, R.C. [EARTH POWER CORPORATION, TULSA, OKLA. (USA)].

REFERENCE- GEOTHERM. ENERGY MAG., V. 3 (5), P. 39-41(1975).

DESCRIPTORS- GEOTHERMAL EXPLORATION; EXPLORATION PROGRAMS; PLATE TECTONICS; ECONOMICS; DRILLING; EVALUATION; LAND-USE FACTORS; CALIFORNIA; THE GEYSERS; TABLES.

FUCHS 75B
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL ENERGY--THE CHALLENGES THAT LIE AHEAD. PART 2.

AUTHOR- FUCHS, R.L. [GEOSYSTEMS CORP., NEW YORK, N.Y. (USA)].

HUTTRER, G.W. [THERMEX CO., DENVER, COLO. (USA)].

REFERENCE- ENG. MIN. J., V. 176 (2), P. 78-82(1975).

DESCRIPTORS- GEOTHERMAL WELLS; CALIFORNIA; THE GEYSERS; IMPERIAL VALLEY; LEGAL ASPECTS; LEASING; NEW ZEALAND; DRILLING; POWER GENERATION; RESISTIVITY SURVEYS; MAPS;

INJECTION WELLS; WELL COMPLETION DATA; ENERGY RESERVES; DISCUSSION; EXPERIMENTAL DATA; CALIFORNIA; IMPERIAL VALLEY; EAST MESA GEOTHERMAL FIELD; MAPS; TABLES; DIAGRAMS.

FUCHS 75

DH

TITLE- GEOTHERMAL ENERGY--SLOW-GROWING INDUSTRY FINALLY HEATS UP. PART 1.

AUTHOR- FUCHS, R.L. [GEOSYSTEMS CORP., NEW YORK, N.Y. (USA)].

HUTTRER, G.W. [THERMEX CO., DENVER, COLO. (USA)].

REFERENCE- ENG. MIN. J., V. 176 (1), P. 89-93(1975).

DESCRIPTORS- LEGAL ASPECTS; CALIFORNIA; POWER GENERATION; IDAHO; NEVADA; ECONOMICS; LEASES; TABLES; GEOTHERMAL WELLS; DRILLING; OREGON; ID
BLES;
GEOTHERMAL WELLS; DRILLING; OREGON; DIAGRAMS; NEW MEXICO; MONTANA; COLORADO; IMPERIAL VALLEY; MENDOCINO COUNTY; LAKE COUNTY; STEAMBOAT SPRINGS; SURPRISE VALLEY; SONOMA COUNTY; HONEY LAKE; LAKEVIEW; CHANDLER; CHOCOLATE MTNS.; PLUMAS COUNTY; VALLES; CALDERA; BRADY; INDIAN HOT SPRINGS; PINE FARMS; OREANA; RAFT RIVER; BEOWAWE; BRIGHAM CITY; CANBY; MARYSVILLE; SAN LUIS VALLEY; HOT LAKE; HEAT FLOW; PHOTOGRAPHS; FORECASTING.

WOLLENBERG 75
EXPLORATION/EVALUATION

H

TITLE- GEOTHERMAL ENERGY RESOURCE ASSESSMENT.

AUTHOR- WOLLENBERG, H.A.;ASARO, F.;BOWMAN, T.;MC EVILLY, T.;MORRISON, F.;WITHERSPOON, P. [CALIFORNIA UNIV., BERKELEY (USA). LAWRENCE BERKELEY LAB.].

REFERENCE- GEOTHERMAL ENERGY RESOURCE ASSESSMENT. UCID-3762, CALIF. UNIV., BERKELEY, CALIF., 1975, 92 P..

SHUPE 76
EXPLORATION/EVALUATION

DH

TITLE- THE HAWAII GEOTHERMAL PROJECT. INITIAL PHASE II PROGRESS REPORT.

AUTHOR- SHUPE, J.W. [HAWAII UNIV., HONOLULU (USA)].

REFERENCE- THE HAWAII GEOTHERMAL PROJECT. INITIAL PHASE II PROGRESS REPORT. UNIV. OF HAWAII, HONOLULU, HAWAII, 1976, P. 1-148.

DESCRIPTORS- HAWAII GEOTHERMAL PROJECT; PUNA; GEOPHYSICAL SURVEYS; ENVIRONMENTAL EFFECTS; DRILLING; RESERVOIR ENGINEERING; HAWAII; RESISTIVITY SURVEYS; MAPS; MICROSEISMICITY; ECONOMICS; DIAGRAMS; SEISMIC REFRACTION; TEMPERATURE GRADIENTS; GRAVITY SURVEYS; MAGNETIC SURVEYS; SEISMOLOGY; ROCKS; ROCK-FLUID INTERACTIONS; THEORETICAL TREATMENT; RAYLEIGH NUMBER; MATHEMATICAL MODEL; COMPUTER CALCULATIONS; POWER GENERATION; BINARY FLUID SYSTEMS; HEAT EXCHANGERS; LEGAL ASPECTS; WELL COMPLETION DATA.

PEARSON 76
EXPLORATION/EVALUATION

DH

TITLE- PLANNING AND DESIGN OF ADDITIONAL EAST MESA GEOTHERMAL TEST FACILITIES (PHASE 1B). VOLUME 1. FINAL REPORT.

AUTHOR- PEARSON, R.O. [TRW SYSTEMS GROUP, REDONDO BEACH, CALIF. (USA)].

REFERENCE- PLANNING AND DESIGN OF ADDITIONAL EAST MESA GEOTHERMAL TEST FACILITIES (PHASE 1B). VOLUME 1. FINAL REPORT. SAN/1140-1/1, TRW, INC., REDONDO BEACH, CALIF., 1976, 1-1 - 5-7.

DESCRIPTORS- PETROLOGY; POROSITY; PERMEABILITY; TEMPERATURE MEASUREMENT; CHEMICAL COMPOSITION; PIPELINES; DOWNHOLE PUMPS; DRILLING; ECONOMICS; MATHEMATICAL MODEL; THEORETICAL TREATMENTS; COMPUTER CALCULATIONS; FORECASTING; WELLS; DEPTHS; COSTS; HOT WATER SYSTEMS; FLOW RATES;

LEVELS; DRILLING; MATHEMATICAL MODEL; THEORETICAL TREATMENTS; COMPUTER CALCULATIONS; FORECASTING; SITE SELECTION; COSTS; DEPTH; WELL SPACING; EFFECTIVE PRESSURE; FLUID PRESSURE; GEOTHERMAL RESERVES; VAPOR-DOMINATED SYSTEMS; HOT WATER SYSTEMS; GEOTHERMAL WELLS; FLOW RATES; INJECTION WELLS; CHEMICAL ANALYSIS; POWER POTENTIAL; DISCUSSION; EVALUATION; FIELD DATA; UNITED STATES; CALIFORNIA; IDAHO; NEW MEXICO; NEVADA; WYOMING; MEXICO; YELLOWSTONE KGRA; HEBER KGRA; EAST MESA KGRA; RAFT RIVER KGRA; MONO-LONG VALLEY KGRA; BRUNCA KGRA; BRADY-HAZEN KGRA; ROOSEVELT HOT SPRINGS KGRA; BRAWLEY KGRA; DUNES KGRA; LAKE CITY-SURPRISE VALLEY KGRA; BEOWAWE KGRA.

SCHULLER 76
EXPLORATION/EVALUATION

DH

TITLE- LEGAL.

PT=LEGAL,

INSTITUTIONAL AND POLITICAL PROBLEMS IN PRODUCING ELECTRIC POWER FROM GEOTHERMAL RESOURCES IN CALIFORNIA.

AUTHOR- SCHULLER, C.R.;SCHILLING, A.H.;COLE, R.J.;SIMON, G.D. [BATTELLE (USA)].

REFERENCE- LEGAL.

PT=LEGAL,

INSTITUTIONAL AND POLITICAL PROBLEMS IN PRODUCING ELECTRIC POWER FROM GEOTHERMAL RESOURCES IN CALIFORNIA. BATTELLE, SEATTLE, WASH., 1976, 390 P..

DESCRIPTORS- CAPITAL; DRILLING; ECONOMICS; ENGINEERING; ENVIRONMENTAL EFFECTS; AIR QUALITY; LAND USE; LEASES; LEGAL ASPECTS; FORECASTING; COSTS; ENVIRONMENTAL IMPACT STATEMENTS; POWER TRANSMISSION; TAXES; GEOTHERMAL DEVELOPMENT; GEOTHERMAL POTENTIAL; GEOTHERMAL RESOURCES; GEOTHERMAL RESERVES; GEOTHERMAL WELLS; DRILLING TECHNOLOGY; POWER GENERATION; REGULATIONS; WASTE DISPOSAL; DISCUSSION; EVALUATION; FIELD DATA; CALIFORNIA; GLASS MOUNTAIN KGRA; LAKE CITY-SURPRISE VALLEY KGRA; WENDEL AMACEE KGRA; BODIE KGRA; SALINE VALLEY KGRA; COSO HOT SPRINGS KGRA; BECKWOURTH PEAK KGRA; IMPERIAL VALLEY; CENTRAL VALLEY; SALTON SEA; KGRA'S; GOVERNMENT POLICIES; FORD DRY-LAKE KGRA; GEYSERS GEOTHERMAL FIELD; LASSEN KGRA; MONO-LONG VALLEY KGRA; RANDSBURG KGRA; SESPE HOT SPRINGS KGRA; MAPS; DIAGRAMS.

COSTAIN 76
EXPLORATION/EVALUATION

DH

TITLE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, MAY 1, 1976 - OCTOBER 31, 1976.

AUTHOR- COSTAIN, J.K.;GLOVER, L., III;SINHA, A.K. [VIRGINIA POLYTECHNIC INST. AND STATE UNIV., BLACKSBURG (USA)].

REFERENCE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, MAY 1, 1976 - OCTOBER 31, 1976. VPI-SU-5103-2, VIRGINIA POLYTECHNIC INST., BLACKSBURG, VA., 1976, 170 P..

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; SEDIMENTARY ROCKS; HEAT FLOW; TEMPERATURE MEASUREMENTS; THERMAL CONDUCTIVITY; GEOTHERMAL WELLS; DRILLING; GRAVITY SURVEYS; MAGNETIC SURVEYS; HOT SPRINGS; CHEMICAL COMPOSITION; SOUTH CAROLINA; VIRGINIA; NORTH CAROLINA; MAPS; TABLES; DIAGRAMS.

MEIDAV 76
EXPLORATION/EVALUATION

DH

TITLE- A COMPARISON OF HYDROTHERMAL RESERVOIRS OF THE WESTERN UNITED STATES. TOPICAL REPORT 3.

AUTHOR- MEIDAV, H.T. [GEONOMICS, INC., BERKELEY, CALIF. (USA)].

SANYAL, S.

REFERENCE- A COMPARISON OF HYDROTHERMAL RESERVOIRS OF THE WESTERN UNITED STATES. TOPICAL REPORT 3. ERRI ER-364, GEONOMICS, INC., BERKELEY, CALIF., 1976, 170 P..

DESCRIPTORS- GEOLOGIC SETTING; LITHOLOGY; ROCKS; SEDIMENTATION; VOLCANISM; TEMPERATURE MEASUREMENTS; FLUID FLOW; DRAWDOWN; WATER

COSTAIN 77
EXPLORATION/EVALUATION

TITLE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, NOVEMBER 1, 1976 - MARCH 31, 1977.

AUTHOR- COSTAIN, J.K.;GLOVER, L., III;SINHA, A.K. [VIRGINIA POLYTECHNIC INST. AND STATE UNIV., BLACKSBURG (USA)].

REFERENCE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, NOVEMBER 1, 1976 - MARCH 31, 1977. VPI-SU-5103-3, VIRGINIA POLYTECHNIC INST. AND STATE UNIV., BA

PUP=BLACKSBURG, VA., 1977, A-1 - C-31.

DESCRIPTORS- GEOLOGIC SETTING; ROCKS; MINERALOGY; VOLCANISM; PLUTONS; GRANITES; METAMORPHIC ROCKS; HEAT FLOW; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; MOLYBDENUN; MAGNETIC SURVEYS; GEOCHEMISTRY; DRILLING; THEORETICAL TREATMENTS; COMPUTER CALCULATIONS; STRUCTURAL MODEL; POTASSIUM; URANIUM; GRAVITY SURVEY; VIRGINIA; NORTH CAROLINA; SOUTH CAROLINA; MAPS; TABLES; DIAGRAMS.

ERMAK 77
EXPLORATION/LAND-USE FACTORS

TITLE- A SCENARIO FOR GEOTHERMAL ELECTRIC POWER DEVELOPMENT IN IMPERIAL VALLEY.

AUTHOR- ERMAK, D.L. [CALIFORNIA UNIV., LIVERMORE (USA). LAWRENCE LIVERMORE LAB.].

REFERENCE- A SCENARIO FOR GEOTHERMAL ELECTRIC POWER DEVELOPMENT IN IMPERIAL VALLEY. CALIFORNIA UNIV., LIVERMORE, CALIF., 1977, 58 P..

DESCRIPTORS- TEMPERATURE MEASUREMENTS; POWER GENERATION; CHEMICAL COMPOSITION; AIR QUALITY; HYDROGEN SULFIDES; FLUID FLOW; ENVIRONMENTAL EFFECTS; LAND USE; FORECASTING; GEOTHERMAL WELLS; DRILLING; INJECTION WELLS; CALIFORNIA; BRAWLEY; IMPERIAL VALLEY; SALTON SEA; EAST MESA KGRA; HEBER; THE GEYSERS; MAPS; TABLES;

EXFLORATION/EVALUATION

DH

TITLE- GEOTHERMAL RESOURCE INVESTIGATIONS, IMPERIAL VALLEY, CALIFORNIA. TEST WELL MESA 6-1.

AUTHOR- BUREAU OF RECLAMATION, BOULDER CITY, NEV. (USA).

REFERENCE- GEOTHERMAL RESOURCE INVESTIGATIONS, IMPERIAL VALLEY, CALIFORNIA. TEST WELL MESA 6-1. SPECIAL REFORT, BUREAU OF RECLAMATION, BOULDER CITY, NEV., 1973, 44 P..

DESCRIPTORS- LITHOLCGY WELL LOGS; RCCKS; TEMFERATURE GRADIENTS; TEMPEFATURE MEASUREMENTS; PRESSURE MEASUREMENTS; CCFING; PERMEABILITY; POROSITY; FLUID FLOW; ECONOMICS; PRESSURE GRADIENTS; GEOTHERMAL WELLS; DRILLING; CRILL STEM TESTS; CHEMICAL COMPOSITION; CALIFORNIA; IMPERIAL VALLEY; EAST MESA KGRA; MAPS; PHOTOGRAPHS; TABLES; DIAGRAMS.

ANDERSON 72
EXFLORATION/EVALUATION

H

TITLE- GEOTHERMAL OVERVIEWS OF THE WESTERN UNITED STATES, 1972.

AUTHOR- ANDERSON, D.N.:AXTELL, L.H. [CALIFORNIA STATE DIV. OF OIL AND GAS, SACRAMENTO (USA)].

REFERENCE- GEOTHERMAL OVERVIEWS OF THE WESTERN UNITED STATES, 1972. CALIF. STATE DIV. OF OIL AND GAS, SACRAMENTO, CALIF., 1972,

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; VOLCANOES; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; HOT SPRINGS; HYDROLOGY; LAND USE; LEGAL ASPECTS; FORECASTING; POWER GENERATION; GEOTHERMAL WELLS; DRILLING; CHEMICAL COMPOSITION; HOT SPRINGS; GRAVITY SURVEYS; ARIZONA; CALIFORNIA; IDAHO; NEW MEXICO; NEVADA; COLORADO; HAWAII; MONTANA; OREGON; UTAH; WASHINGTON; WYOMING; IMPERIAL VALLEY; SALTON SEA; MAPS; TABLES; DIAGRAMS; COSO HOT SPRINGS; GEYSERS; GLASS MOUNTAIN; LAKE CITY; LASSEN; MONO-LONG VALLEY; SESPE HOT SPRINGS; WENDEL-AMEDEE.

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; VOLCANOES; TEMPERATURE MEASUREMENTS; HOT SPRINGS; AIR QUALITY; LAND USE; LEASES; LEGAL ASPECTS; GEOTHERMAL WELLS; DRILLING; MAGNETIC SURVEYS; GEOTHERMOMETRY; CALIFORNIA; OREGON; GLOSSARY; TABLES; THE GEYSER; CALISTOGA KGRA; KNOXVILLE KGRA; LITTLE HORSE MOUNTAIN KGRA; LOVELADY RIDGE KGRA; WITTER SPRINGS KGRA; IMPERIAL VALLEY; BRAWLEY KGRA; DUNES KGRA; EAST MESA KGRA; FORD DRY LAKE KGRA; GLAMIS KGRA; HEBER KGRA; SALTON SEA KGRA; BODIE KGRA; COSO HOT SPRINGS KGRA; MONO-LONG VALLEY KGRA; RANDSBURG KGRA; SALINE VALLEY KGRA; BECKWOURTH PEAK KGRA; GLASS MOUNTAIN KGRA; LAKE CITY-SURPRISE VALLEY KGRA; LASSEN KGRA; WENDEL-AMEDEE; SESPE HOT SPRINGS KGRA.

BUREC 74
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL RESOURCE INVESTIGATIONS, EAST MESA TEST SITE, IMPERIAL VALLEY, CALIFORNIA. STATUS REPORT.

AUTHOR- BUREAU OF RECLAMATION, BOULDER CITY, NEV. (USA).

REFERENCE- GEOTHERMAL RESOURCE INVESTIGATIONS, EAST MESA TEST SITE, IMPERIAL VALLEY, CALIFORNIA. STATUS REPORT. BUREAU OF RECLAMATION, BOULDER CITY, NEV., 1974, 64 P..

DESCRIPTORS- LITHOLOGY; SEISMIC SURVEYS; EARTHQUAKES; HEAT FLOW; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; CHEMICAL COMPOSITION; RESISTIVITY SURVEYS; SUBSIDENCE; POWER GENERATION; PRESSURE SURVEYS; FLUID FLOW; FLUID DISPOSAL; CHEMICAL COMPOSITION; ENVIRONMENTAL EFFECTS; LEASES; THEORETICAL TREATMENTS; GEOTHERMAL WELLS; DRILLING; INJECTION WELLS; CASING; PERMEABILITY; GRAVITY SURVEYS; DRILL STEM TESTS; CALIFORNIA; IMPERIAL VALLEY; EAST MESA KGRA; MAPS; PHOTOGRAPHS; TABLES; DIAGRAMS.

BUREC 73

NONCONDENSIBLE GASES; BINARY CYCLE; FLUID FLOW; ECONOMICS; THEORETICAL TREATMENTS; DRILLING; COMPUTER CODES; TABLES; DIAGRAMS.

JET PROPULSION LAB 76B
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA. STATUS REPORT.

AUTHOR- CALIFORNIA INST. OF TECH., PASADENA (USA). JET PROPULSION LAB..

REFERENCE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA. STATUS REPORT. JPL DOCUMENT 5040-25, CALIF. INST. OF TECH., PASADENA, CALIF., 1976, P. 1-1 - 6-13.

DESCRIPTORS- GEOLOGIC SETTING; DRILLING; ECONOMICS; LEASES; LEGAL ASPECTS; GEOTHERMAL POTENTIAL; GEOTHERMAL RESOURCES; GEOTHERMAL WELLS; POWER GENERATION; NON-ELECTRICAL; BECKWOURTH KGRA; SALINE VALLEY KGRA; GLASS MOUNTAIN KGRA; WENDEL-AMEDEE KGRA; GLAMIS KGRA; BODIE KGRA; FORD DRY LAKE KGRA; RANDSBURG KGRA; SESPE HOT SPRINGS; CALIFORNIA; MONO-LONG VALLEY; COSO HOT SPRINGS; LAKE CITY; IMPERIAL VALLEY; SURPRISE VALLEY; HEBER; EAST MESA KGRA; LASSEN; SALTON SEA; BRAWLEY; LITTLE HORSE MOUNTAIN; LOVELADY RIDGE; WITTER SPRINGS; THE GEYSERS; KNOXVILLE KGRA; DUNES KGRA; MAPS; TABLES; DIAGRAMS.

JET PROPULSION LAB 76C
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA, STATUS REPORT. APPENDIX.

AUTHOR- CALIFORNIA INST. OF TECH., PASADENA (USA). JET PROPULSION LAB..

REFERENCE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA, STATUS REPORT. APPENDIX. JPL DOCUMENT 5040-25, ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION, SACRAMENTO, CALIF., 1976, P. A1 - E3.

INC., LAS VEGAS, NEV. (USA).

REFERENCE- COMPLETION REPORT-RAFT RIVER GEOTHERMAL EXPLORATORY HOLE NO. 1. IDO-10062 (NVO-410-30), REYNOLDS ELEC. AND ENGR. CO., LAS VEGAS, NEV., 1975, 42 P..

DESCRIPTORS- DRILL BITS; WELL CASINGS; LOGGING; CEMENT BOND LOG; RADIOACTIVITY LOG; CALIPER LOG; DRILL CORES; IDAHO; RAFT RIVER KGRA; PHOTOGRAPHS; DIAGRAMS; LITHOLOGY WELL LOGS; ACOUSTIC LOG; TEMPERATURE MEASUREMENT; FLUID FLOW; DRILLING.

BAKER 75B
EXPLORATION/DRILLING

H TITLE- REPORT OF THE GEOPHYSICAL MEASUREMENTS IN GEOTHERMAL WELLS WORKSHOP.

AUTHOR- BAKER, LE
AU=BAKER, L.E.;BAKER, R.P.;HUGHEN, R.L. [SANDIA LABS., ALBUQUERQUE, N. MEX. (USA)].

REFERENCE- REPORT OF THE GEOPHYSICAL MEASUREMENTS IN GEOTHERMAL WELLS WORKSHOP. SAND75-0608, DECEMBER 1975, 70 P..

DESCRIPTORS- WELL LOGS; DRILLING; PLANNING.

BLOOMSTER 76B
EXPLORATION/EVALUATION

DH TITLE- THE ECONOMICS OF GEOTHERMAL ELECTRICITY GENERATION FROM HYDROTHERMAL RESOURCES.

AUTHOR- BLOOMSTER, C.H.;KNUTSEN, C.A. [BATTELLE PACIFIC NORTHWEST LABS., RICHLAND, WASH. (USA)].

REFERENCE- THE ECONOMICS OF GEOTHERMAL ELECTRICITY GENERATION FROM HYDROTHERMAL RESOURCES. BNWL-1989, BATTELLE, PACIFIC NORTHWEST LABS., RICHLAND, WASHINGTON, 43 P..

DESCRIPTORS- TEMPERATURE MEASUREMENTS;

LAUGHLIN 75
EXPLORATION/GEOPHYSICS

H

TITLE- HOT DRY ROCK TESTED FOR GEOTHERMAL ENERGY.

AUTHOR- LAUGHLIN, A.W. [LOS ALAMOS SCIENTIFIC LAB., N. MEX. (USA)].

REFERENCE- GEOTIMES, V. 20 (3), P. 20-21(1975).

DESCRIPTORS- NEW MEXICO; JEMEZ MOUNTAINS GEOTHERMAL AREA; VALLES CALDERA; SANDOVAL CO.; HOT DRY ROCK SYSTEMS; DRILLING; HYDRAULIC FRACTURING; GEOTHERMAL GRADIENTS; BOTTOM HOLE TEMPERATURES; REGIONAL GEOLOGY; WELL LOGGING; GEOPHYSICAL SURVEYS.

SASS 76
EXPLORATION/DRILLING

H

TITLE- GEOTHERMAL DATA FROM TEST WELLS DRILLED IN GRASS VALLEY AND BUFFALO VALLEY, NEVADA.

AUTHOR- SASS, J.H.;OLMSTEAD, F.H.;SOREY, M.L.;LACHENBRUCH, A.H.;MUNROE, R.J.;GALANIS, S.P., JR.;WOLLENBERG, H.A. [CALIFORNIA UNIV., BERKELEY (USA). LAWRENCE BERKELEY LAB.].

REFERENCE- GEOTHERMAL DATA FROM TEST WELLS DRILLED IN GRASS VALLEY AND BUFFALO VALLEY, NEVADA. LBL-4489, CALIF. UNIV., BERKELEY, CALIF., 1976, 43 P..

DESCRIPTORS- LITHOLOGY; THERMAL CONDUCTIVITY; HEAT FLOW; TEMPERATURE GRADIENTS; DRILLING; DRILLCORES; NEVADA; GRASS VALLEY; BUFFALO VALLEY; MAPS; TABLES; DIAGRAMS.

REYNOLDS ELEC. AND ENG. CO. 75
EXPLORATION/DRILLING

H

TITLE- COMPLETION REPORT-RAFT RIVER GEOTHERMAL EXPLORATORY HOLE NO. 1.

AUTHOR- REYNEOLDS ELECTRICAL AND ENGINEERING CO.,

AUTHOR- CATALDI, R.;RENDINA, M. [ENTE NAZIONALE PER L'ENERGIA ELECTTRICA, PIZA (ITALY)].

REFERENCE- GEOTHERMICS, V. 2 (3-4) P. 106-116(1974).

DESCRIPTORS- ITALY; ALFINA GEOTHERMAL AREA; DRILLING.

SNYDER 75
EXPLORATION/DRILLING

H TITLE- HOW STEAM IS PRODUCED AND HANDLED AT THE GEYSERS.

AUTHOR- SNYDER, R.E.

REFERENCE- WORLD OIL, V. 180 (7), P. 43-48(1975).

DESCRIPTORS- CALIFORNIA; THE GEYSERS KGRA; DEVELOPMENT HISTORY; GEOLOGY; PRODUCTION; WELL SITING; DRILLING.

WARREN 75
EXPLORATION/DRILLING

DH TITLE- DESIGN OF AN INSULATED COAXIAL PIPE ASSEMBLY FOR A DRILLED GEOTHERMAL WELL.

AUTHOR- WARREN, J.H.;WHITELAW, R.L. [VIRGINIA POLYTECHNIC INST. AND STATE UNIV., BLACKSBURG (USA)].

REFERENCE- DESIGN OF AN INSULATED COAXIAL PIPE ASSEMBLY FOR A DRILLED GEOTHERMAL WELL. 75-HT-56, AM. SOC. MECH. ENG. PAP., 1975, 7 P..

DESCRIPTORS- DRILLING; HYDROSTATIC PRESSURE; DRILL PIPE; INSULATION; RESEARCH; DEEP DRILLING.

FUCHS 758
EXFLORATION/EVALUATION

DH

TITLE- GEOTHERMAL ENERGY--THE CHALLENGES THAT LIE AHEAD. PART 2.

AUTHOR- FUCHS, R.L. [GEOSYSTEMS CORP., NEW YORK, N.Y. (USA)].

HUTTRER, G.W. [THERMEX CO., DENVER, COLO. (USA)].

REFERENCE- ENG. MIN. J., V. 176 (2), P. 78-82(1975).

DESCRIPTORS- GECTHERMAL WELLS; CALIFORNIA; THE GEYSERS; IMPERIAL VALLEY; LEGAL ASPECTS; LEASING; NEW ZEALAND; DRILLING; POWER GENERATION; RESISTIVITY SURVEYS; MAPS; PHOTOGRAPHS.

COLLI 75
EXFLORATION/EVALUATION

DH

TITLE- GEOTHERMAL ENERGY IN FRANCE. (IN FRENCH). LA GEOTHERMIE EN FRANCE.

AUTHOR- COLLI, J.C.

REFERENCE- BULL. BUR. RECH. GEOL. MINIERES (FR), SECT. 2, NC. 1, 24 P.(1975).

DESCRIPTORS- FRANCE; FESERVOIRS; DRILLING.

CATALDI 73
EXPLORATION/DRILLING

DH

TITLE- RECENT DISCOVERY OF A NEW GEOTHERMAL FIELD IN ITALY-ALFINA.

AUTHOR- OKI, Y.;HIRANO, T. [SANDIA LABS., ALBUQUERQUE, N. MEX. (USA)].

COLP, J.L.;FURUMOTO, A.S. (EDS.)

REFERENCE- HYDROTHERMAL SYSTEM AND SEISMIC ACTIVITY OF HAKONE VOLCANO.

DESCRIPTORS- JAPAN; CHEMICAL PROPERTIES; EARTHQUAKES; GEOCHEMISTRY; HYDROTHERMAL SYSTEMS; PROPERTIES; SEISMOLOGY; SODIUM CHLORIDES; SULFATES; THERMAL WATERS; VOLCANOES; MAPS; FIGURES; GEOLOGIC SETTING; SUBSURFACE TEMPERATURES; FLUID FLOW; ENERGY YIELD; GEOTHERMAL WELLS.

BARR 75B
EXPLORATION/EVALUATION

TITLE- WHAT IS THE OUTLOOK FOR GEOTHERMAL POWER .

AUTHOR- BARR, R.C. [EARTH POWER CORPORATION, TULSA, OKLA. (USA)].

REFERENCE- OIL GAS J., V. 73 (19), P. 148-151(1975).

DESCRIPTORS- ECONOMICS; POWER PRODUCTION; GEOTHERMAL WELLS; GAS; OIL; COAL; NUCLEAR; THE GEYSERS; MEXICO; JAPAN; TABLES.

BOLDIZSAR 75
EXPLORATION/EVALUATION

TITLE- GEOTHERMAL ENERGY USE IN HUNGARY.

AUTHOR- BOLDIZSAR, T. [TECH. UNIV., MISKOLC-EGYETEMVAROS (HUNGARY)].

REFERENCE- GEOTHERM. ENERGY MAG, V. 3 (4), P. 5-13(1975).

DESCRIPTORS- HUNGARY; CARPATHIAN BASIN; HEAT FLOW; GEOTHERMAL WELLS; DIRECT ENERGY UTILIZATION; TEMPERATURE MEASUREMENTS; WELL COMPLETION DATA; FLOW RATES; CHEMICAL ANALYSIS; DISCUSSION; MAPS.

REFERENCE- ENG. MIN. J., V. 176 (1), P. 89-93(1975).

DESCRIPTORS- LEGAL ASPECTS; CALIFORNIA; POWER GENERATION; IDAHO; NEVADA; ECONOMICS; LEASES; TABLES; GEOTHERMAL WELLS; DRILLING; OREGON; ID ELES; GEOTHERMAL WELLS; DRILLING; OREGON; DIAGRAMS; NEW MEXICO; MONTANA; COLORADO; IMPERIAL VALLEY; MENDOCINO COUNTY; LAKE COUNTY; STEAMBOAT SPRINGS; SURPRISE VALLEY; SONOMA COUNTY; HONEY LAKE; LAKEVIEW; CHANDLER; CHOCOLATE MTNS.; PLUMAS COUNTY; VALLES; CALDERA; BRADY; INDIAN HOT SPRINGS; PINE FARMS; OREANA; RAFT RIVER; BEOWAWE; BRIGHAM CITY; CANBY; MARYSVILLE; SAN LUIS VALLEY; HOT LAKE; HEAT FLOW; PHOTOGRAPHS; FORECASTING.

HOUSE 75
EXPLORATION/EVALUATION

DH

TITLE- POTENTIAL POWER GENERATION AND GAS PRODUCTION FROM GULF COAST GEOPRESSURE RESERVOIRS.

AUTHOR- HOUSE, P.A.;JOHNSON, P.M.;TOWSE, D.F. [CALIFORNIA UNIV., LIVERMORE (USA). LAWRENCE LIVERMORE LAB.].

REFERENCE- POTENTIAL POWER GENERATION AND GAS PRODUCTION FROM GULF COAST GEOPRESSURE RESERVOIRS. UCRL-51813, CALIFORNIA UNIV., LIVERMORE, CALIF., 1975, 40 P..

DESCRIPTORS- GEOLOGIC SETTING; TEMPERATURE MEASUREMENTS; BINARY CYCLE; PRESSURE MEASUREMENTS; CHEMICAL COMPOSITION; SCALING; FLUID FLOW; HYDRAULICS; ECONOMICS; THEORETICAL TREATMENTS; GEOTHERMAL WELLS; INJECTION WELLS; POWER GENERATION; GAS PRODUCTION; TEXAS; GEOPRESSURED SYSTEMS; MAPS; TABLES; DIAGRAMS.

OKI 74
EXPLORATION/GEOCHEMISTRY

DH

TITLE- HYDROTHERMAL SYSTEM AND SEISMIC ACTIVITY OF HAKONE VOLCANO.

SCHULLER 76
EXPLORATION/EVALUATICN

OH

TITLE- LEGAL.

PT=LEGAL,

INSTITUTIONAL ANC POLITICAL PROBLEMS IN PRODUCING ELECTRIC POWER FROM GEOTHERMAL RESOURCES IN CALIFORNIA.

AUTHOR- SCHULLER, C.R.;SCHILLING, A.H.;COLE, R.J.;SIMON, G.D. [BATTELLE (USA)].

REFERENCE- LEGAL.

PT=LEGAL,

INSTITUTIONAL ANC POLITICAL PROBLEMS IN PRODUCING ELECTRIC POWER FROM GEOTHERMAL RESOURCES IN CALIFORNIA. BATTELLE, SEATTLE, WASH., 1976, 390 P..

DESCRIPTORS- CAPITAL; DRILLING; ECONOMICS; ENGINEERING; ENVIRONMENTAL EFFECTS; AIR QUALITY; LAND USE; LEASES; LEGAL ASPECTS; FORECASTING; C(STS; ENVIRONMENTAL IMPACT STATEMENTS; POWER TRANSMISSION; TAXES; GEOTHERMAL DEVELCPMENT; GEOTHERMAL POTENTIAL; GEOTHERMAL RESOURCES; GEOTHERMAL RESERVES; GEOTHERMAL WELLS; DRILLING TECHNOLOGY; POWER GENERATION; REGULATIONS; WASTE DISPOSAL; DISCUSSION; EVALUATION; FIELD DATA; CALIFORNIA; GLASS MOUNTAIN KGRA; LAKE CITY-SURPRISE VALLEY KGRA; WENDEL AMACEE KGRA; BOCIE KGRA; SALINE VALLEY KGRA; CCSO HOT SPRINGS KGRA; BECKWOURTH PEAK KGRA; IMPERIAL VALLEY; CENTRAL VALLEY; SALTON SEA; KGRA'S; GOVERNMENT POLICIES; FORD DRY-LAKE KGRA; GEYSERS GEOTHERMAL FIELD; LASSEN KGRA; MONO-LONG VALLEY KGRA; RANDSBURG KGRA; SESPE HOT SPRINGS KGRA; MAPS; DIAGRAMS.

FUCHS 75

OH

TITLE- GEOTHERMAL ENERGY--SLOW-GROWING INDUSTRY FINALLY HEATS UP. PART 1.

AUTHOR- FUCHS, R.L. [GEOSYSTEMS CORP., NEW YORK, N.Y. (USA)].

HUTTRER, G.W. [THERMEX CO., DENVER, COLO. (USA)].

BLACKSBURG (USA)].

REFERENCE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, MAY 1, 1976 - OCTOBER 31, 1976. VPI-SU-5103-2, VIRGINIA POLYTECHNIC INST., BLACKSBURG, VA., 1976, 170 P..

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; SEDIMENTARY ROCKS; HEAT FLOW; TEMPERATURE MEASUREMENTS; THERMAL CONDUCTIVITY; GEOTHERMAL WELLS; DRILLING; GRAVITY SURVEYS; MAGNETIC SURVEYS; HOT SPRINGS; CHEMICAL COMPOSITION; SOUTH CAROLINA; VIRGINIA; NORTH CAROLINA; MAPS; TABLES; DIAGRAMS.

MEIDAV 76
EXPLORATION/EVALUATION

DH

TITLE- A COMPARISON OF HYDROTHERMAL RESERVOIRS OF THE WESTERN UNITED STATES. TOPICAL REPORT 3.

AUTHOR- MEIDAV, H.T. [GEONOMICS, INC., BERKELEY, CALIF. (USA)].

SANYAL, S.

REFERENCE- A COMPARISON OF HYDROTHERMAL RESERVOIRS OF THE WESTERN UNITED STATES. TOPICAL REPORT 3. ERRI ER-364, GEONOMICS, INC., BERKELEY, CALIF., 1976, 170 P..

DESCRIPTORS- GEOLOGIC SETTING; LITHOLOGY; ROCKS; SEDIMENTATION; VOLCANISM; TEMPERATURE MEASUREMENTS; FLUID FLOW; DRAWDOWN; WATER LEVELS; DRILLING; MATHEMATICAL MODEL; THEORETICAL TREATMENTS; COMPUTER CALCULATIONS; FORECASTING; SITE SELECTION; COSTS; DEPTH; WELL SPACING; EFFECTIVE PRESSURE; FLUID PRESSURE; GEOTHERMAL RESERVES; VAPOR-DOMINATED SYSTEMS; HOT WATER SYSTEMS; GEOTHERMAL WELLS; FLOW RATES; INJECTION WELLS; CHEMICAL ANALYSIS; POWER POTENTIAL; DISCUSSION; EVALUATION; FIELD DATA; UNITED STATES; CALIFORNIA; IDAHO; NEW MEXICO; NEVADA; WYOMING; MEXICO; YELLOWSTONE KGRA; HEBER KGRA; EAST MESA KGRA; RAFT RIVER KGRA; MONO-LONG VALLEY KGRA; BRUNCA KGRA; BRADY-HAZEN KGRA; ROOSEVELT HOT SPRINGS KGRA; BRAWLEY KGRA; DUNES KGRA; LAKE CITY-SURPRISE VALLEY KGRA; BEOWAWE KGRA.

NO. 20, CALIF. INST. OF TECH., PASADENA, CALIF., 1976, 52 P..

DESCRIPTORS- TEMPERATURE MEASUREMENTS; POWER GENERATION; POWER PLANTS; COOLING TOWERS; TRANSMISSION PIPES; SURFACE WATERS; WATER ANALYSIS; ECONOMICS; ENVIRONMENTAL EFFECTS; ARTIFICIAL RECHARGE; LAND USE; THEORETICAL TREATMENTS; FORECASTING; CHEMICAL COMPOSITION; GEOTHERMAL WELLS; DRILLING TECHNOLOGY; NON-ELECTRICAL; DISCUSSION; EVALUATION; EXPERIMENTAL DATA; FIELD DATA; CALIFORNIA; IMPERIAL VALLEY; SALTON SEA; TABLES; DIAGRAMS.

REITZEL 76
EXPLORATION/EVALUATION

OH

TITLE- UTILIZATION OF U.S. GEOTHERMAL RESOURCES. FINAL REPORT.

AUTHOR- REITZEL, J. [TRW, INC., REDONDO BEACH, CALIF. (USA)].

REFERENCE- UTILIZATION OF U.S. GEOTHERMAL RESOURCES. FINAL REPORT. ER-382, SYSTEMS AND ENERGY GROUP OF TRW INC., REDONDO BEACH, CALIF., 1976, P. 1-1 - D-2.

DESCRIPTORS- TECTONICS; TEMPERATURE MEASUREMENTS; POWER GENERATION; ECONOMICS; LEASES; THEORETICAL TREATMENTS; FORECASTING; GEOTHERMAL WELLS; GEOTHERMOMETERS; HOT SPRINGS; CALIFORNIA; IDAHO; LOUISIANA; NEW MEXICO; NEVADA; TEXAS; WYOMING; UTAH; OREGON; GEOPRESSURED SYSTEMS; MAPS; TABLES; DIAGRAMS.

COSTAIN 76
EXPLORATION/EVALUATION

H

TITLE- EVALUATION AND TARGETING OF GEOTHERMAL ENERGY RESOURCES IN THE SOUTHEASTERN UNITED STATES. PROGRESS REPORT, MAY 1, 1976 - OCTOBER 31, 1976.

AUTHOR- COSTAIN, J.K.;GLOVER, L., III;SINHA, A.K. [VIRGINIA POLYTECHNIC INST. AND STATE UNIV.,

DESCRIPTORS- TEMPERATURE MEASUREMENTS; POWER GENERATION; CHEMICAL COMPOSITION; AIR QUALITY; HYDROGEN SULFIDES; FLUID FLOW; ENVIRONMENTAL EFFECTS; LAND USE; FORECASTING; GEOTHERMAL WELLS; DRILLING; INJECTION WELLS; CALIFORNIA; BRAWLEY; IMPERIAL VALLEY; SALTON SEA; EAST MESA KGRA; HEBER; THE GEYSERS; MAPS; TABLES;

NARASIMHAN 77
EXPLORATION/GEOLOGY

H

TITLE- RESERVOIR EVALUATION TESTS ON RRGE 1 AND RRGE 2, RAFT RIVER GEOTHERMAL PROJECT, IDAHO.

AUTHOR- NARASIMHAN, T.N.;WITHERSPOON, P.A. [CALIFORNIA UNIV., BERKELEY (USA). LAWRENCE BERKELEY LAB.].

REFERENCE- RESERVOIR EVALUATION TESTS ON RRGE 1 AND RRGE 2, RAFT RIVER GEOTHERMAL PROJECT, IDAHO. LBL-5958, CALIFORNIA UNIV., BERKELEY, CALIF., 1977, 50 P..

DESCRIPTORS- FAULTS; SUBSURFACE FAULTING; GEOLOGIC SETTING; LITHOLOGY; LITHOLOGY WELL LOGS; SEDIMENTATION; SEDIMENTARY ROCKS; POROSITY; PERMEABILITY; TEMPERATURE MEASUREMENTS; PRESSURE MEASUREMENTS; PERMEABILITY; FLUID FLOW; DRAWDOWN; STORAGE COEFFICIENT; THEORETICAL TREATMENTS; GEOTHERMAL DEVELOPMENT; GEOTHERMAL POTENTIAL; GEOTHERMAL WELLS; DISCUSSION; EVALUATION; FIELD DATA; TESTING; UNITED STATES; IDAHO; RAFT RIVER KGRA; MAPS; TABLES; DIAGRAMS.

GOLDSMITH 76
EXPLORATION/EVALUATION

H

TITLE- ENGINEERING ASPECTS OF GEOTHERMAL DEVELOPMENT IN THE IMPERIAL VALLEY.

AUTHOR- GOLDSMITH, M. [CALIFORNIA INST. OF TECH., PASADENA (USA). ENVIRONMENTAL QUALITY LAB.].

REFERENCE- ENGINEERING ASPECTS OF GEOTHERMAL DEVELOPMENT IN THE IMPERIAL VALLEY. EQL MEMO

DESCRIPTORS- FAULTS; THRUST FAULTS; GEOLOGIC STRUCTURES; LITHOLOGY; ROCKS; TECTONISM; GEOTHERMAL WELLS; THERMAL SPRINGS; VOLCANOES; CALIFORNIA; MAPS.

BECHTEL 76
EXPLORATION/EVALUATION

OH TITLE- CONCEPTUAL DESIGN OF COMMERCIAL 50 MWE (NET) GEOTHERMAL POWER PLANTS AT HEBERAND NILAND, CALIFORNIA. FINAL REPORT.

AUTHOR- BECHTEL CORP., SAN FRANCISCO, CALIF. (USA).

REFERENCE- CONCEPTUAL DESIGN OF COMMERCIAL 50 MWE (NET) GEOTHERMAL POWER PLANTS AT HEBERAND NILAND, CALIFORNIA. FINAL REPORT. SAN-1124-1, BECHTEL CORP., SAN FRANCISCO, CALIF., 1976, 1-1 - 10-6.

DESCRIPTORS- GEOLOGIC SETTING; POWER GENERATION; TEMPERATURE MEASURMENT; ECONOMICS; ENVIRONMENTAL EFFECTS; SITE SELECTION; TEST FACILITIES; GEOTHERMAL WELLS; INJECTION WELLS; AIR QUALITY; WATER QUALITY; CHEMICAL COMPOSITION; CLIMATE; EVALUATION; CALIFORNIA; IMPERIAL VALLEY; SALTON SEA; NILAND; HEBER; MAPS; TABLES; DIAGRAMS; SILICA; CORROSION; HYDROGEN SULFIDE; FLOW RATES; GOVERNMENT REGULATIONS; THERMODYNAMIC CYCLES; THEORETICAL TREATMENT; COSTS.

ERMAK 77
EXPLORATION/LAND-USE FACTORS

OH TITLE- A SCENARIO FOR GEOTHERMAL ELECTRIC POWER DEVELOPMENT IN IMPERIAL VALLEY.

AUTHOR- ERMAK, D.L. [CALIFORNIA UNIV., LIVERMORE (USA). LAWRENCE LIVERMORE LAB.].

REFERENCE- A SCENARIO FOR GEOTHERMAL ELECTRIC POWER DEVELOPMENT IN IMPERIAL VALLEY. CALIFORNIA UNIV., LIVERMORE, CALIF., 1977, 58 P..

REFERENCE- GEOTHERMAL OVERVIEWS OF THE WESTERN UNITED STATES, 1972. CALIF. STATE DIV. OF OIL AND GAS, SACRAMINTO, CALIF., 1972,

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; VOLCANOES; TEMPEFATURE GRADIENTS; TEMPERATURE MEASUREMEITS; HCT SPRINGS; HYDROLOGY; LAND USE; LEGAL ASPECTS; FCRECASTING; POWER GENERATICN; GEOTHERMAL WELLS; DRILLING; CHEMICAL COMPOSITION; HOT SPRINGS; GRAVITY SURVEYS; ARIZONA; CALIFCRNIA; IDAHO; NEW MEXICO; NEVADA; COLORADO; HAWAII; MONTANA; OREGON; UTAH; WASHINGTON; WYOMING; IMPERIAL VALLEY; SALTON SEA; MAPS; TABLES; DIAGRAMS; COSO HOT SPRINGS; GEYSERS; GLASS MOUNTAIN; LAKE CITY; LASSEN; MONO-LONG VALLEY; SESPE HOT SPRINGS; WENDEL-AMEDEE.

AXTELL 72
EXPLORATION/DRILLING

TITLE- MONO LAKE GECTHERMAL WELLS ABANDONED.

AUTHOR- AXTELL, L.H.

REFERENCE- CALIF. GEGL., V. 25 (3), P. 66(1972).

DESCRIPTORS- MONO-LCNG VALLEY; CALIFORNIA; GEOTHERMAL WELLS; TEMPERATURE GRADIENTS; LITHOLOGY; DIAGRAMS; PHOTOGRAPHS.

JENNINGS 75
EXPLORATION/GEOLOGY

TITLE- FAULT MAP OF CALIFORNIA WITH LOCATIONS OF VOLCANOES, THERMAL SPRINGS AND THERMAL WELLS.

AUTHOR- JENNINGS, C.W.;STRAND, R.G.;ROGERS, T.H.;STINSON, M.C.;BURNETT, J.L.;KAHLE, J.E.;STREITZ, R.;SWITZER, R.A.

REFERENCE- FAULT MAF CF CALIFORNIA WITH LOCATIONS OF VOLCANOES, THERMAL SPRINGS AND THERMAL WELLS. MAP NO. 1, CALIF. DIV. MINES AND GEOLOGY, SAN FRANCISCO, CALIF., 1975,

TRUCKEE MEADOWS, WASHOE COUNTY, NEVADA.

AUTHOR- BATEMAN, R.L.;SCHEIBACH, R.B. [NEVADA UNIV., RENO (USA). MACKAY SCHOOL OF MINES].

REFERENCE- EVALUATION OF GEOTHERMAL ACTIVITY IN THE TRUCKEE MEADOWS, WASHOE COUNTY, NEVADA. NBMG REPORT 25, NEVADA UNIV., RENO, NEV., 1975, 38 P..

DESCRIPTORS- GEOLOGIC SETTING; HEAT FLOW; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; HOT SPRINGS; CLIMATE; FLUID FLOW; HYDROLOGY; ECONOMICS; THEORETICAL TREATMENTS; GEOTHERMAL WELLS; WELLS; NON-ELECTRICAL; CHEMICAL COMPOSITION; SPACE HEATING; NEVADA; WASHOE COUNTY; STEAMBOAT SPRINGS; MOANA SPRINGS; MAPS; TABLES; DIAGRAMS.

BLACK 75
EXPLORATION/EVALUATION

TITLE- A SUBSURFACE STUDY OF THE MESA GEOTHERMAL ANOMALY, IMPERIAL VALLEY, CALIFORNIA.

AUTHOR- BLACK, H.T. [COLORADO UNIV., BOULDER (USA)].

REFERENCE- A SUBSURFACE STUDY OF THE MESA GEOTHERMAL ANOMALY, IMPERIAL VALLEY, CALIFORNIA. PB-247082, NTIS, SPRINGFIELD, VA., 1975, 58 P..

DESCRIPTORS- GEOLOGIC SETTING; LITHOLOGY LOGS; TEMPERATURE GRADIENTS; POROSITY; PERMEABILITY; GEOTHERMOMETRY; HYDRAULICS; HYDROLOGY; GEOTHERMAL WELLS; SALINITY LOGS; CALIFORNIA; IMPERIAL VALLEY; SALTON SEA; EAST MESA KGRA; MAPS; TABLES; DIAGRAMS.

ANDERSON 72
EXPLORATION/EVALUATION

TITLE- GEOTHERMAL OVERVIEWS OF THE WESTERN UNITED STATES, 1972.

AUTHOR- ANDERSON, D.N.;AXTELL, L.H. [CALIFORNIA STATE DIV. OF OIL AND GAS, SACRAMENTO (USA)].

(USA).

REFERENCE- GEOTHERMAL RESOURCE INVESTIGATIONS, EAST MESA TEST SITE, IMPERIAL VALLEY, CALIFORNIA. STATUS REPORT. BUREAU OF RECLAMATION, BOULDER CITY, NEV., 1974, 64 P..

DESCRIPTORS- LITHOLOGY; SEISMIC SURVEYS; EARTHQUAKES; HEAT FLOW; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; CHEMICAL COMPOSITION; RESISTIVITY SURVEYS; SUBSIDENCE; POWER GENERATION; PRESSURE SURVEYS; FLUID FLOW; FLUID DISPOSAL; CHEMICAL COMPOSITION; ENVIRONMENTAL EFFECTS; LEASES; THEORETICAL TREATMENTS; GEOTHERMAL WELLS; DRILLING; INJECTION WELLS; CASING; PERMEABILITY; GRAVITY SURVEYS; DRILL STEM TESTS; CALIFORNIA; IMPERIAL VALLEY; EAST MESA KGRA; MAPS; PHOTOGRAPHS; TABLES; DIAGRAMS.

BUREC 73
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL RESOURCE INVESTIGATIONS, IMPERIAL VALLEY, CALIFORNIA. TEST WELL MESA 6-1.

AUTHOR- BUREAU OF RECLAMATION, BOULDER CITY, NEV. (USA).

REFERENCE- GEOTHERMAL RESOURCE INVESTIGATIONS, IMPERIAL VALLEY, CALIFORNIA. TEST WELL MESA 6-1. SPECIAL REPORT, BUREAU OF RECLAMATION, BOULDER CITY, NEV., 1973, 44 P..

DESCRIPTORS- LITHOLOGY WELL LOGS; ROCKS; TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; PRESSURE MEASUREMENTS; CORING; PERMEABILITY; POROSITY; FLUID FLOW; ECONOMICS; PRESSURE GRADIENTS; GEOTHERMAL WELLS; DRILLING; DRILL STEM TESTS; CHEMICAL COMPOSITION; CALIFORNIA; IMPERIAL VALLEY; EAST MESA KGRA; MAPS; PHOTOGRAPHS; TABLES; DIAGRAMS.

BATEMAN 75
EXPLORATION/EVALUATION

A

TITLE- EVALUATION OF GEOTHERMAL ACTIVITY IN THE

SPRINGS; LAKE CITY; IMPERIAL VALLEY; SURPRISE VALLEY; HEBER; EAST MESA KGRA; LASSEN; SALTON SEA; BRAWLEY; LITTLE HORSE MOUNTAIN; LOVELADY RIDGE; WITTER SPRINGS; THE GEYSERS; KNOXVILLE KGRA; DUNES KGRA; MAPS; TABLES; DIAGRAMS.

JET PROPULSION LAB 76C
EXPLORATION/EVALUATION

DA

TITLE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA, STATUS REPORT. APPENDIX.

AUTHOR- CALIFORNIA INST. OF TECH., PASADENA (USA). JET PROPULSION LAB..

REFERENCE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA, STATUS REPORT. APPENDIX. JPL DOCUMENT 5040-25, ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION, SACRAMENTO, CALIF., 1976, P. A1 - E3.

DESCRIPTORS- FAULTS; GEOLOGIC SETTING; ROCKS; VOLCANOES; TEMPERATURE MEASUREMENTS; HOT SPRINGS; AIR QUALITY; LAND USE; LEASES; LEGAL ASPECTS; GEOTHERMAL WELLS; DRILLING; MAGNETIC SURVEYS; GEOTHERMOMETRY; CALIFORNIA; OREGON; GLOSSARY; TABLES; THE GEYSER; CALISTOGA KGRA; KNOXVILLE KGRA; LITTLE HORSE MOUNTAIN KGRA; LOVELADY RIDGE KGRA; WITTER SPRINGS KGRA; IMPERIAL VALLEY; BRAWLEY KGRA; DUNES KGRA; EAST MESA KGRA; FORD DRY LAKE KGRA; GLAMIS KGRA; HEBER KGRA; SALTON SEA KGRA; BODIE KGRA; COSO HOT SPRINGS KGRA; MONO-LONG VALLEY KGRA; RANDSBURG KGRA; SALINE VALLEY KGRA; BECKWOURTH PEAK KGRA; GLASS MOUNTAIN KGRA; LAKE CITY-SURPRISE VALLEY KGRA; LASSEN KGRA; WENDEL-AMEDEE; SESPE HOT SPRINGS KGRA.

BUREC 74
EXPLORATION/EVALUATION

DH

TITLE- GEOTHERMAL RESOURCE INVESTIGATIONS, EAST MESA TEST SITE, IMPERIAL VALLEY, CALIFORNIA. STATUS REPORT.

AUTHOR- BUREAU OF RECLAMATION, BOULDER CITY, NEV.

ASPECTS; GEOTHERMAL WELLS; SPACE HEATING; IDAHO; SUGAR CITY; MAPS; TABLES; DIAGRAMS.

BLOOMSTER 76
EXPLORATION/EVALUATION

OH

TITLE- THE POTENTIAL BENEFITS OF GEOTHERMAL ELECTRICAL PRODUCTION FROM HYDROGHERMAL RESOURCES.

AUTHOR- BLOOMSTER, C.H.;ENGEL, R.L. [BATTELLE PACIFIC NORTHWEST LABS., RICHLAND, WASH. (USA)].

REFERENCE- THE POTENTIAL BENEFITS OF GEOTHERMAL ELECTRICAL PRODUCTION FROM HYDROGHERMAL RESOURCES. BNWL-2001, BATTELLE PACIFIC NORTHWEST LABS., RICHLAND, WASH., 1976, 33 P..

DESCRIPTORS- ECONOMICS; MATHEMATICAL MODEL; FORECASTING; COST COMPARISONS; GEOTHERMAL RESOURCES; HYDROTHERMAL CONVECTION SYSTEMS; GEOTHERMAL WELLS; POWER GENERATION; MAPS; TABLES; DIAGRAMS.

JET PROPULSION LAB 76B
EXPLORATION/EVALUATION

OH

TITLE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA. STATUS REPORT.

AUTHOR- CALIFORNIA INST. OF TECH., PASADENA (USA). JET PROPULSION LAB..

REFERENCE- GEOTHERMAL ENERGY RESOURCES IN CALIFORNIA. STATUS REPORT. JPL DOCUMENT 5040-25, CALIF. INST. OF TECH., PASADENA, CALIF., 1976, P. 1-1 - 6-13.

DESCRIPTORS- GEOLOGIC SETTING; DRILLING; ECONOMICS; LEASES; LEGAL ASPECTS; GEOTHERMAL POTENTIAL; GEOTHERMAL RESOURCES; GEOTHERMAL WELLS; POWER GENERATION; NON-ELECTRICAL; BECKWOURTH KGRA; SALINE VALLEY KGRA; GLASS MOUNTAIN KGRA; WENDEL-AMEDEE KGRA; GLAMIS KGRA; BODIE KGRA; FORD DRY LAKE KGRA; RANDSBURG KGRA; SESPE HOT SPRINGS; CALIFORNIA; MONO-LONG VALLEY; COSO HOT

DESCRIPTORS- TEMPERATURE GRADIENTS; TEMPERATURE MEASUREMENTS; PRESSURE MEASUREMENTS; CHEMICAL COMPOSITION; GEOTHERMAL WELLS; FLOW RATES; BRINES; SCALING; BINARY CYCLE; POWER GENERATION; CALIFORNIA; IMPERIAL VALLEY; NIALAND; MAPS; PHOTOGRAPHS; TABLES.

WEST 75
EXPLORATION/GEOPHYSICS

DH

TITLE- GEOPHYSICAL LOGGING IN LOS ALAMOS SCIENTIFIC LABORATORY GEOTHERMAL TEST HOLE NO. 2.

AUTHOR- WEST, F.G.;KINTZINGER, P.R.;LAUGHLIN, A.W. [LOS ALAMOS SCIENTIFIC LAB., N. MEX. (USA)].

REFERENCE- GEOPHYSICAL LOGGING IN LOS ALAMOS SCIENTIFIC LABORATORY GEOTHERMAL TEST HOLE NO. 2. LA-6112 MS, LOS ALAMOS SCIENTIFIC LAB., LOS ALAMOS, N. MEX., 1975, 12 P..

DESCRIPTORS- GEOLOGIC SETTING; ACOUSTIC LOGS; TEMPERATURE LOGS; SEDIMENTARY-SECTION LOGS; DRILL-RATE LOGS; HOT-DRY-ROCK SYSTEMS; GEOTHERMAL WELLS; LOGGING; RADIOACTIVITY LOGS; SELF-POTENTIAL LOGS; SEISVIEWER LOGS; DIAGRAMS.

KUNZE 77
EXPLORATION/EVALUATION

DH

TITLE- THE POTENTIAL FOR UTILIZING GEOTHERMAL ENERGY FOR SPACE HEATING IN RE-CONSTRUCTED SUGAR CITY, IDAHO.

AUTHOR- KUNZE, J.F.;LOFTHOUSE, J.H.;STOKER, R.C. [IDAHO NATIONAL ENGINEERING LAB., IDAHO FALLS (USA)].

REFERENCE- THE POTENTIAL FOR UTILIZING GEOTHERMAL ENERGY FOR SPACE HEATING IN RE-CONSTRUCTED SUGAR CITY, IDAHO. TREE-1016, EG AND G IDAHO, INC., IDAHO FALLS, IDAHO, 1977, 30 P..

DESCRIPTORS- GEOLOGIC SETTING; TEMPERATURE MEASUREMENT; SURFACE WATERS; ECONOMICS; LEGAL

JANUARY 1977.

AUTHOR- YUEN, P.C. [HAWAII UNIV., HONOLULU (USA)].

REFERENCE- THE HAWAII GEOTHERMAL PROJECT. WELL TEST AND RESERVOIR ENGINEERING PROGRESS REPORT FOR JANUARY 1977. UNIV. OF HAWAII, HONOLULU, HAWAII, 1977, P. 1-19.

DESCRIPTORS- HAWAII; MAPS; MAGMAS; GEOTHERMAL WELLS; RESERVOIR ENGINEERING; DIAGRAMS; TEMPERATURE GRADIENTS; TABLES; WELL COMPLETION DATA; FLUID FLOW.

AAMODT 77
EXPLORATION/EVALUATION

DH

TITLE- HYDRAULIC FRACTURE EXPERIMENTS IN GT-1 AND GT-2.

AUTHOR- AAMODT, R.L. [LOS ALAMOS SCIENTIFIC LAB., N. MEX. (USA)].

REFERENCE- HYDRAULIC FRACTURE EXPERIMENTS IN GT-1 AND GT-2. LA-6712, LOS ALAMOS SCIENTIFIC LAB., LOS ALAMOS, N. MEX., 1977, 19 P..

DESCRIPTORS- FRACTURES; HYDRAULIC FRACTURING; HOT-DRY-ROCK SYSTEMS; HEAT FLOW; TEMPERATURE MEASUREMENT; THEORETICAL TREATMENTS; GEOTHERMAL WELLS; EXPERIMENTAL DATA; NEW MEXICO; TABLES; DIAGRAMS.

QUONG 76

DH

TITLE- SCALING CHARACTERISTICS IN THE GEOTHERMAL LOOP EXPERIMENTAL FACILITY AT NILAND, CALIFORNIA.

AUTHOR- QUONG, R. [CALIFORNIA UNIV., LIVERMORE (USA). LAWRENCE LIVERMORE LAB.].

REFERENCE- SCALING CHARACTERISTICS IN THE GEOTHERMAL LOOP EXPERIMENTAL FACILITY AT NILAND, CALIFORNIA. UCRL-52162, CALIF. UNIV., LIVERMORE, CALIF., 1976, 33 P..

MILLER 77
EXPLORATION/EVALUATION

DH TITLE- THE USE OF GEOCHEMICAL-EQUILIBRIUM COMPUTER CALCULATIONS TO ESTIMATE PRECIPITATION FROM GEOTHERMAL BRINES.

AUTHOR- MILLER, D.G.;PIWINSKII, A.J.;YAMAUCHI, R. (CALIFORNIA UNIV., LIVERMORE (USA). LAWRENCE LIVERMORE LAB.).

REFERENCE- THE USE OF GEOCHEMICAL-EQUILIBRIUM COMPUTER CALCULATIONS TO ESTIMATE PRECIPITATION FROM GEOTHERMAL BRINES. UCRL-52197, CALIF. UNIV., LIVERMORE, CALIF., 1977, 35 P..

DESCRIPTORS- GEOTHERMAL WELLS; INJECTION WELLS; BRINES; SCALES; CHEMICAL COMPOSITION; MINERALS; SOLUBILITY; COMPUTER CODES; CALIFORNIA; IMPERIAL VALLEY; TABLES; DIAGRAMS.

WHITE 75
EXPLORATION/EVALUATION

H TITLE- ASSESSMENT OF GEOTHERMAL RESOURCES OF THE UNITED STATES-1975.

AUTHOR- WHITE, D.E.;WILLIAMS, D.L. (EDS.)

REFERENCE- ASSESSMENT OF GEOTHERMAL RESOURCES OF THE UNITED STATES-1975. CIRC. 726, U.S. GEOLOGICAL SURVEY, RESTON, VA., 1975, 155 P..

DESCRIPTORS- GEOTHERMAL RESOURCES; HYDROTHERMAL CONVECTION SYSTEMS; GEOPRESSURED SYSTEMS; GEOTHERMAL WELLS; HOT-DRY-ROCK SYSTEMS; GEOTHERMOMETRY; EVALUATION; UNITED STATES; ARIZONA; CALIFORNIA; IDAHO; LOUISIANA; NEW MEXICO; NEVADA; TEXAS; OREGON; WASHINGTON; IMPERIAL VALLEY; MAPS; TABLES; DIAGRAMS.

YUEN 77
EXPLORATION/DRILLING

DH TITLE- THE HAWAII GEOTHERMAL PROJECT. WELL TEST AND RESERVOIR ENGINEERING PROGRESS REPORT FOR

BAKER 75
EXPLORATION/DRILLING

TITLE- WELL-LOGGING TECHNOLOGY AND GEOTHERMAL APPLICATIONS--A SURVEY AND ASSESSMENT WITH RECOMMENDATIONS.

AUTHOR- BAKER, L.E.;CAMPBELL, A.B.;HUGHEN, R.L. [SANDIA LABS., ALBUQUERQUE, N. MEX. (USA)].

REFERENCE- WELL-LOGGING TECHNOLOGY AND GEOTHERMAL APPLICATIONS--A SURVEY AND ASSESSMENT WITH RECOMMENDATIONS. SAND75-0275, 1975, 75 P..

DESCRIPTORS- ACOUSTIC TESTING; ELECTRIC MEASURING INSTRUMENTS; GEOTHERMAL WELLS; MEASURING INSTRUMENTS; MEASURING METHODS; RADIATION DETECTORS; SAMPLERS; TEMPERATURE MEASUREMENT; WELL LOGGING.

ONODERA 74
EXPLORATION/GEOPHYSICS

TITLE- GEO-ELECTRICAL INDICATIONS AT THE OTAKE GEOTHERMAL FIELD IN THE WESTERN PART OF THE KUJYU VOLCANO GROUP, KYUSHU, JAPAN.

AUTHOR- ONODERA, S. [KYUSHU UNIV., FUKUOKA (JAPAN)].

REFERENCE- GEO-ELECTRICAL INDICATIONS AT THE OTAKE GEOTHERMAL FIELD IN THE WESTERN PART OF THE KUJYU VOLCANO GROUP, KYUSHU, JAPAN. 1974,

DESCRIPTORS- ELECTRICAL SURVEYS; FLUID FLOW; GEOTHERMAL FLUIDS; GEOTHERMAL WELLS; JAPAN; OTAKE GEOTHERMAL FIELD; ZONES.

Letter written to CBL for information on obtaining articles we dont have. 1-5-78

Lawrence Berkeley Laboratory.

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A Critique of Geothermal Exploration Techniques

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ABSTRACT

The purpose of this paper is to provide a general critique of individual geophysical or geochemical techniques and to indicate how interpretation may be improved through the correlation of geophysical-geophysical, geophysical-geochemical, and geochemical-geochemical techniques.

Pitfalls in the interpretation of temperature-gradient data, resistivity, gravity, and microearthquake seismology are briefly discussed. Geochemical techniques (chemical geothermometry) result in erroneous inferences when the assumptions underlying the different thermometric techniques are not fulfilled, due to dilution, exchange reactions, or others. The importance of steam leakage manifestations as a geothermal reservoir indicator is stressed. The Phlegrean field example, near Naples, Italy, shows that silica thermometry is not valid in that case, and that a plot of Na vs K is a superior method of analyzing what is happening in the reservoir than a Na:K plot vs thermal spring temperature. Isoresistivity data from the area and isovolatile contour maps reinforce the conclusion that a high-temperature reservoir underlies the area.

INTRODUCTION

The technical literature is replete with case histories extolling the salutary virtues of individual geophysical or geochemical techniques. The rife examples given seldom report the pitfalls associated with any one approach. Costly failures of geothermal exploration efforts in a number of projects around the world may be directly attributed to an undue faith in the uniqueness of interpretation of technical data of a specific type, geophysical or geochemical. An analysis of those failures suggests that the inherent ambiguities in any one geophysical or geochemical technique were not fully appreciated. The success of such techniques as temperature-gradient measurements, heat flow, resistivity, or chemical thermometry, for example, when applied to the investigation of outstanding geothermal systems (where most techniques work, by themselves or in any combination) does not provide useful guides for the investigation of complex geothermal systems or deeply buried ones.

In this paper, we wish to discuss some of the pitfalls associated with the geothermally related interpretation of data from a variety of geophysical and geochemical techniques. We then wish to demonstrate how ambiguities related to specific techniques may be reduced either by separating the geothermally related 'signal' from background 'noise', or by interrelating data from a number of different sources. Specifically, we wish to examine cursorily the joint interpretation of geophysical-geophysical, geochemical-geochemical, and geophysical-geochemical data.

No single technique, or specific suite of techniques, may be taken as a panacea for the explorer's dilemma of minimizing the drilling risk. The optimal exploration strategy is an iterative one, where different suites of techniques are employed in a manner that would reduce the drilling risk to an acceptable level.

GEOPHYSICAL TECHNIQUES

Temperature Gradients and Heat Flow

Temperature-gradient measurements and their dependent parameter, conductive heat flow, have often been employed as a primary criterion for selection of a drilling target. The implicit assumption is that temperature gradients measured in shallow holes may be linearly extrapolated to a great depth. However, such an assumption would hold true only in a perfectly impermeable medium, where no water flows. In a fractured rock system, convection of hot water may be the dominant heat transfer mechanism, where the quantity of heat flowing convectively may be a thousand times or more that of the conductive heat flow (White, 1965). In any geologic environment where the temperature gradient is greater than 6.5°C/km, the specific volume of water increases with depth at a rate greater than the rate of volume reduction of water due to hydrostatic pressure (Nagara, 1974). This results in a net buoyancy of deeper water and upward migration, wherever channels of communication, such as faults, are open and wherever salinity stratification does not occur. The upward-flowing water would cause a flattening of the thermal gradient for the zone where vertical flow is possible. Conversely, should an impermeable zone occur at a shallow depth, a steeper temperature gradient and a higher conductive heat flow would be created in the area, due to the presence of the shallow warm water body just below the impermeable cap.

This situation is demonstrated in Figure 1. Here, a well drilled in the East Mesa geothermal field of the Imperial Valley, California, indicates that a freely convective system

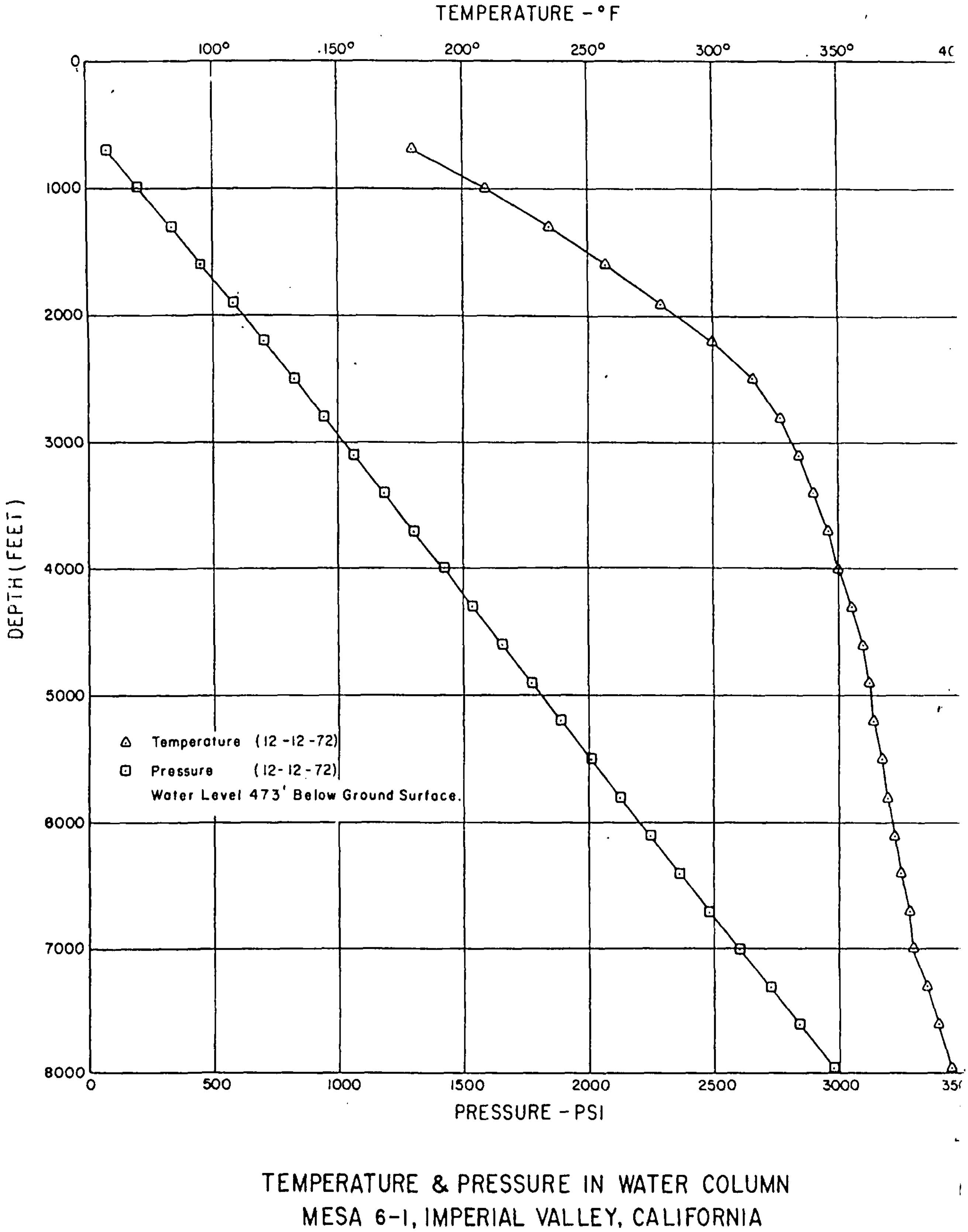

Figure 1. Temperature gradient data, East Mesa borehole.

occurs at a depth below about 600 m, characterized by a rather flat temperature gradient. Above the 600-m-deep cap layer, conductive heat flow predominates. The temperature gradient measurements (Meidav and Rex, 1970) and the ensuing conductive heat-flow measurements (Combs, 1971) were most useful in defining the limits of the geotherm field (Fig. 2). However, neither one of them could be reli upon to predict the actual reservoir temperature, determin subsequently by drilling.

A more dramatic example of the potential pitfall th

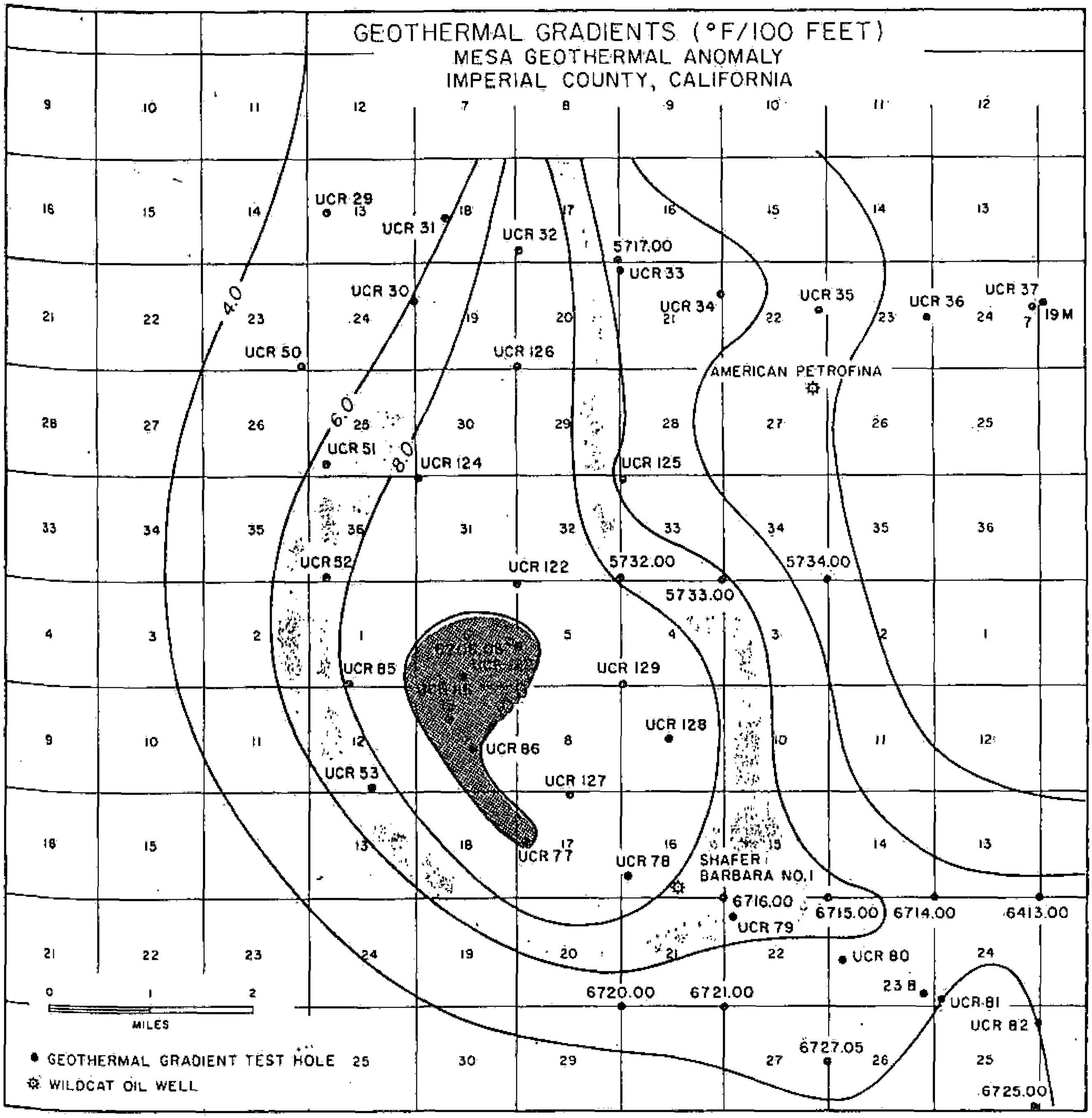

Figure 2. Temperature gradient map, East Mesa, California (from Combs, 1971).

could result from extrapolating either temperature gradient or conductive heat flow may be shown by recourse to the Dunes anomaly, Imperial Valley, case history (Combs, in 1973). Here, a shallow temperature gradient and conductive heat-flow measurements (shown by x marks in Fig. 3) suggested a most positive geothermal potential for the area, if the steep temperature gradient extended to any great depth. Subsequent drilling and temperature-gradient measurements to a depth of 600 m showed that the bottom of the previously drilled temperature-gradient hole was also the top of a quartzitic cap layer. Below that depth, the temperature gradient reversed itself (solid line in Fig. 3). The negative gradient is caused by the presence of a hot-water cap layer which flows laterally across the borehole.

Figure 4 is a schematic representation of a conceivable thermal-water flow regime in a complexly faulted area, which could explain the negative temperature gradient in the Dunes anomaly. It further demonstrates the dangers associated in neglecting the vagaries of vertical and lateral thermal-water flow. A steep, shallow-temperature gradient is a condition which could manifest the existence of an economic geothermal reservoir in the area, but could also indicate rapid upward flow due to the buoyancy of water in a normal-gradient area. Conversely, in an area of high infiltration rates of rainwater or strong lateral ground-water flow, the absence of a significant temperature gradient does not necessarily rule out the existence of a geothermal reservoir below. This is of special importance in grabens, where strong lateral flows could take place, but where geothermal reservoirs may occur. Finally, heat-flow measurements in a mountain-

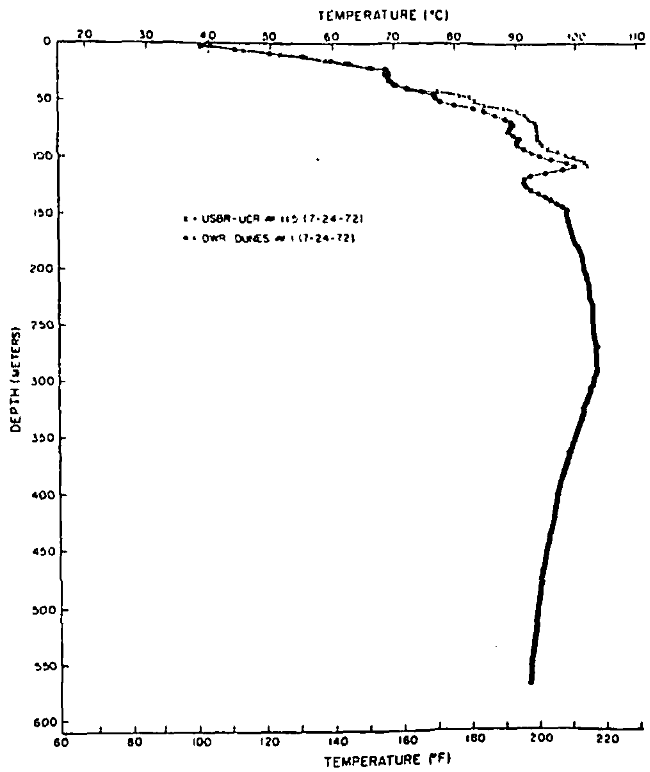

Figure 3. Temperature gradient profiles, Dunes anomaly, California. The x marks designate data gathered in a shallow temperature-gradient survey of the area. The solid line represents subsequent temperature gradients measured in the exploration hole which was drilled subsequently (data by Combs in 1973).

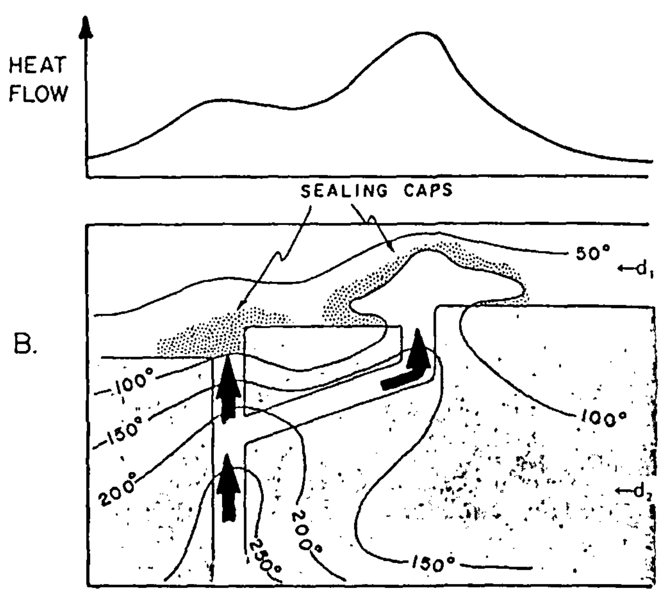

Figure 4. A model of hot-water flow in a faulted geothermal system which could result in the highest heat flows and steepest temperature gradients in shallow holes (drilled to a depth d_1) being associated with the coldest reservoir temperature (drilled to a depth d_2).

ous terrain must be compensated for terrain effects. Otherwise, genuine temperature anomalies may be masked by terrain effects, and false anomalies created in places.

Electrical Resistivity

The applicability of electrical resistivity to geothermal exploration is by now well known. Many case histories describing the usefulness of the technique have been described in the literature (Keller, 1970; Meidav, 1970; Zohdy, Anderson, and Muffler, 1973; Banwell and Macdonald, 1965; Risk, Macdonald, and Dawson, 1970). As a general rule, the electrical conductivity of electrolytes increases at the rate of 2.5% for every degree centigrade increase in temperature. Additionally, hot water has a greater dissolving power, and is therefore usually more saline and hence more conductive electrically. Moreover, because of the greater dissolving power of hot water, the pore space in the central portion of a geothermal field is likely to be increased, further decreasing the electrical resistivity of the rock. Finally, hydrothermally altered rock is characterized by lower resistivity than the surrounding fresh rock. We thus find that all of the above factors will combine to amplify the electrical resistivity contrast between a geothermal system and the surrounding rocks. Thus, the electrical resistivity of many of the classical geothermal systems is typically less than 5 ohm·m, while that of the surrounding rocks is in many cases greater than 100 ohm·m (Meidav, 1972).

Three bothersome flies ruin the resistivity ointment, preventing it from being a perfect geothermal exploration tool. These adverse factors which introduce ambiguity into some resistivity surveys include (1) the effect of dry steam; (2) brine; and (3) presence of clay, shale, or other highly porous but nonpermeable rocks.

While the resistivity of a liquid-dominated system is expected to decrease with temperature, this is not necessarily the case for a dry-steam system. It is worthwhile noting that resistivity studies in Larderello, Italy (Battini and Menut, 1961), Matsukawa, Japan (Hayakawa, 1966), and The Geysers, California (Stanley, Jackson, and Hearn, 1973), all of which are vapor-dominated systems, have failed to show consistent low-resistivity zones in the areas known to be producing dry steam. Dry steam, like any gas, would be characterized by a very high resistivity.

Therefore, perfectly dry-steam or gas reservoirs would be expected to be characterized by resistivity which is higher than that of the surrounding rocks. Thus, in a situation where a noncondensable gas cap or a dry-steam layer overlies a boiling water table, resistivity depth soundings are expected to show a high-resistivity zone sandwiched between lower-resistivity zones. Such situations were verbally reported from Iceland, and probably occur in portions of the Olkaria geothermal field in Kenya.

Figure 5 presents a model of the types of resistivity depth sounding that are expected to occur in an area where a dry-steam layer exists (curve a), in comparison with an area where temperature increases more moderately with depth (curve b). It is seen that the resistivity of the dry-steam zone is, paradoxically enough, greater than that of the liquid-dominated case. Under such conditions, however, it is anticipated that a resistivity map of the area would display a doughnut effect. The center of the doughnut, above the highest temperature zone, would be characterized by high resistivities, surrounded by a zone of low resistivities, which in turn grades into a zone of moderate resistivities.

In this case, a comparison of temperature-gradient measurements with resistivity should serve as a useful filter to separate the hot dry-steam zone from cold, dense igneous rocks.

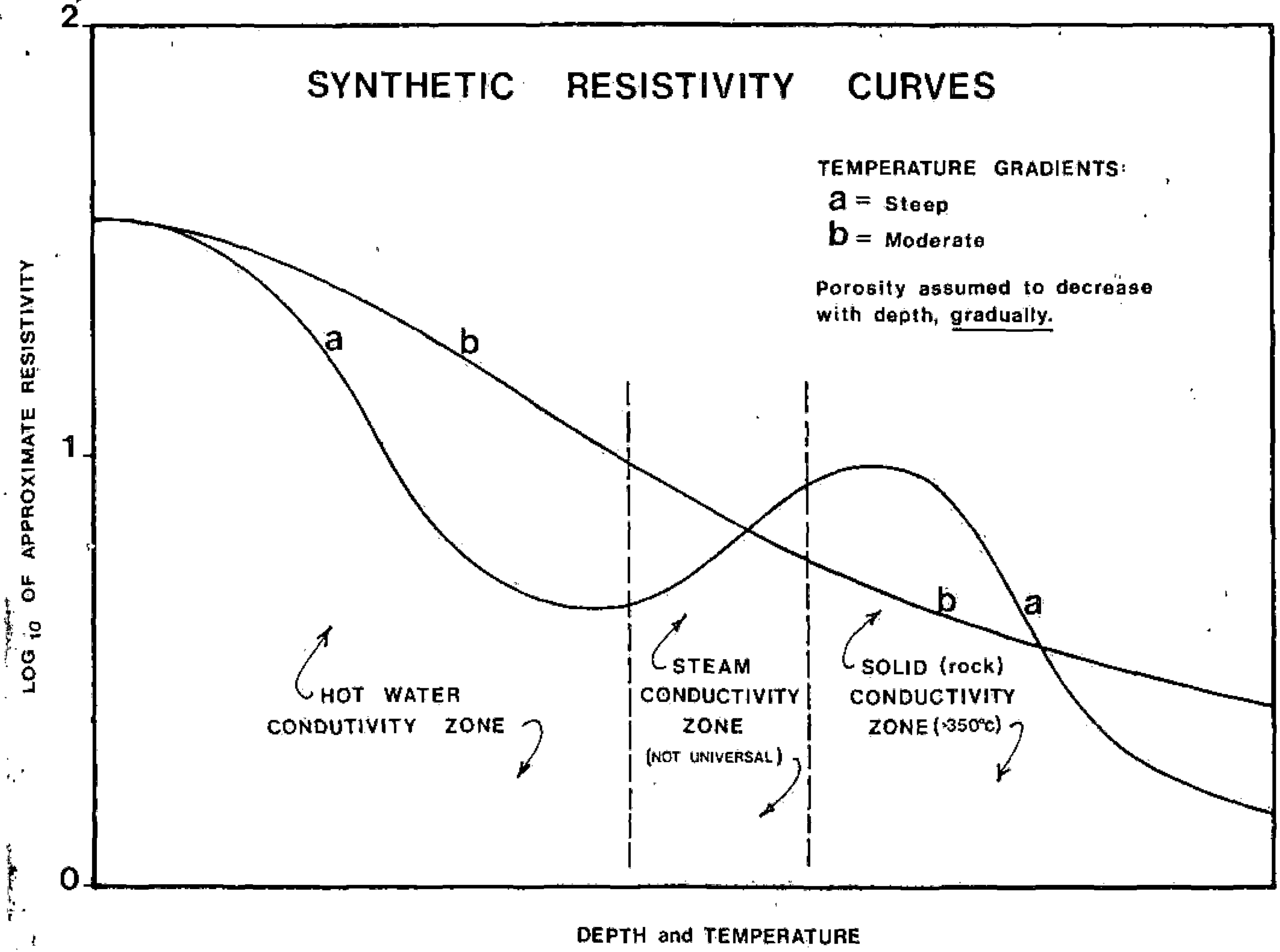

Figure 5. A schematic representation of resistivity depth graphs in areas of moderate increase in temperature with depth (curve b) and areas of rapid increase in temperature with depth (a), where a gas or dry steam layer might occur.

Sea water or cold brine possesses an electrical resistivity of less than 1 ohm·m. Since electrical conductivity increases linearly with salinity, the latter could be the dominant factor in the regional resistivity. Thus, many of the basins of the Basin and Range of Nevada have typically a lower resistivity along their axis, due to the accumulation of brine. These low-resistivity belts have no direct relationship to the potential geothermal reservoirs which may or may not occur in the area. A characteristic example of this type was previously reported for the Imperial Valley, where the resistivity values decrease regionally from 30 ohm·m at the Colorado River near Yuma, Arizona, to 1 ohm·m near the Salton Sea, representing an increase in ground-water salinity in a northwestward direction (Meidav and Furgerson, 1972).

Finally, all large sedimentary basins, such as the Gulf Coast of Mexico and areas of Texas and Louisiana, which are rich in clay-sand sequences, are characterized by varying, but generally low resistivities. Since resistivity decreases with the increase in clay or shale content, low-resistivity zones in sedimentary basins cannot be adjudged to represent geothermal conditions without some independent evidence.

One approach to the minimization of ambiguity associated with the interpretation of either temperature-gradient (or heat-flow) data on the one hand and electrical resistivity data on the other hand is to correlate the data from both

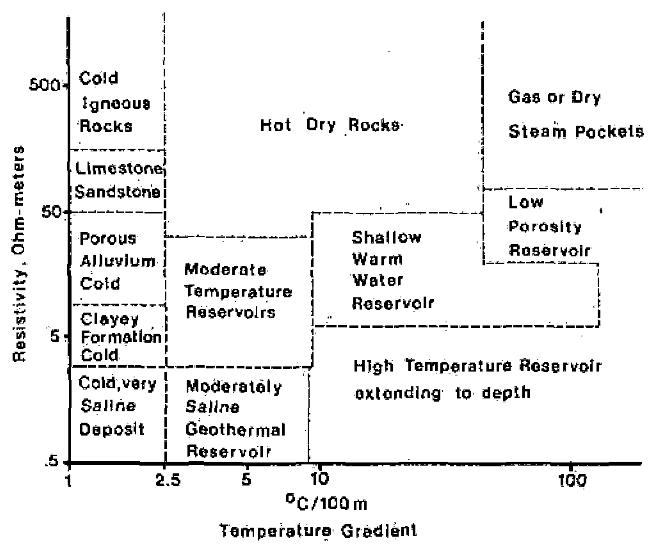

Figure 6. A schematic plot of resistivity versus temperature gradient, which may permit diagnosis of the nature of the subsurface rocks in terms of their geothermal energy potential.

techniques, as shown in Figure 6. The graph shows that only some combinations of high temperature gradient and resistivity are indicative of favorable geothermal conditions.

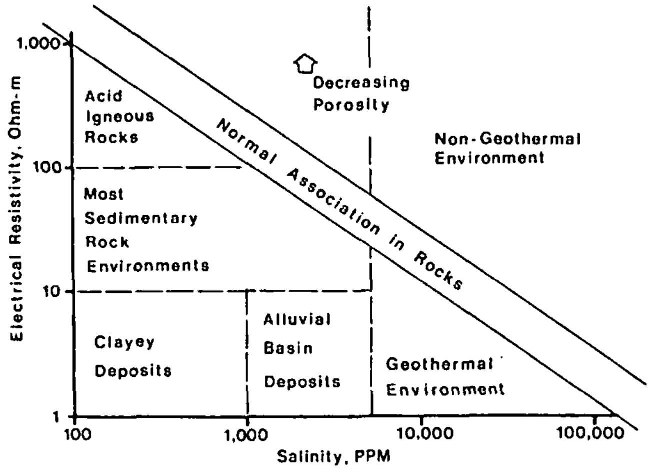

Figure 7. Relationship of resistivity to salinity, lithology, and temperature.

High temperature gradient or low resistivity by themselves are not necessarily indicative of the existence of an economic geothermal reservoir at depth.

Another approach to the minimization of ambiguity of electrical resistivity data may be achieved by relating the resistivity data to local lithologic conditions and salinity of the ground water, as shown in Figure 7. As can be seen from the plot in Figure 7, knowledge of local geological-hydrologeological components of the area under investigation could be useful.

Correlation of geophysical data with independent geochemical data has proven to be most useful, as shown in the case history of the Phlegrean geothermal field, further discussed below.

Gravimetry

A number of other geophysical techniques may prove useful in many cases. Gravimetry has proven to be an important auxiliary exploration tool in many cases. In the Imperial Valley of California, for example, every known geothermal field is associated with a measurable residual gravity anomaly, varying from 2 to 22 mgal (Meidav and Rex, 1970). There, local gravity anomalies are generally associated with metamorphism or densification of the sediments due to deposition of minerals from the rising plumes of thermal water. It is evident, however, that some of the Imperial Valley gravity anomalies have a compound origin, due to both structural-intrusive bodies, which may have been the primary source of anomalous heat flow in the area, as well as precipitation of minerals out of the thermal water at a shallower depth.

In the Basin and Range of Nevada it may be observed that both microearthquake activity and thermal spring occurrence are more commonly associated with that side of the basin which has the steeper gravity gradient. This may be explained in terms of the active tectonics of the region. A steep gravity gradient usually denotes absence of isostatic equilibrium. Hence, when local readjustment of strain takes place, due to the extensive, dynamic regional stress, it is likelier to take place in areas which are already being stressed by isostatic imbalance. The observed correlation between microearthquake activity frequency and steepness of regional gravity gradients lends support to the above hypothesis.

Thus, in regions where geological considerations suggest that economic geothermal reservoirs may be encountered, gravimetry may provide a useful clue to localized subareas where geothermally related processes may have taken place. The reverse may not be true, that is, the existence of gravity anomalies of any type is not necessarily indicative of geothermal conditions in the area, if they occur in a geological environment which is not associated with young volcanism or tectonism. Again, independent evidence is required to verify that the geophysical anomaly is geothermally related.

Microearthquake Seismology

Ward (1972) has summarized the evidence that microearthquake seismology in a geothermal area is useful in determining the gross limits of the geothermal area, as well as in defining the active fault planes, along which thermal water may flow more readily. Again, the occurrence of high microearthquake activity in itself, without independent geological or geophysical evidence, is no proof of the occurrence of an abnormal temperature regime in the subsurface.

Empirical correlations have been noted between the level of ground noise in a geothermal area and the location of the geothermal system (Iyer and Hitchcock, 1974). These correlations are best demonstrated for surface or near-surface manifestations of geothermal activity. However, variations in ground-noise amplitude are most commonly related to variations in the acoustic impedance of rocks and the thickness of alluvial-sedimentary fill in large structural basins. Geothermal ground-noise signal must be carefully separated from unrelated noise factors, if that technique is to be employed.

Self-potential (SP) is being increasingly employed in geothermal exploration. SP anomalies may be caused by streaming potential, temperature differences, pressure differences, and salinity differences. Most of the reported geothermally related SP anomalies (Zohdy, Anderson, and Muffler, 1973, for example) are positive above the center of the geothermal cell, although some have been reported to be negative above the geothermal anomaly (McEuen, personal commun., 1974). Self-potential is largely an electrochemical phenomenon due to a number of causes, some of which may be totally unrelated to the convection of hot, geothermal fluids. These other causes could include shale-sandstone contacts and reduction-oxidation processes, especially in the presence of sulfide minerals.

GEOCHEMICAL TECHNIQUES

Geochemistry, as applied to geothermal exploration, may cover a broad spectrum of techniques that can be employed in a number of ways to reduce the ambiguity inherent in any single approach. In the following we shall attempt to analyze some of the pitfalls associated with a number of specific techniques.

In the early stages of geochemical exploration for geothermal energy, which is still prevalent in many quarters, the tendency was to search for a 'geothermal indicator'. That 'indicator', if present in a quantity above some threshold, would prove the existence of a geothermal field. However, experience suggests that the occurrence of commercial geothermal reservoirs cannot be related in a simple fashion to any unique condition. For example, knowledge of the original temperature of a fluid emanating at the surface is not truly significant from an economic point of view, if depth-related information is totally lacking.

Specifically, we wish to re-examine a number of approaches to the determination of reservoir temperature and to the identification of leakage manifestations from a boiling liquid reservoir or a vapor-dominated one.

Some comprehensive reviews of techniques for chemical geothermometry have been published by Ellis (1970), White (1970), and Fournier and Truesdell (1973). The basic facts are well documented in the above papers as well as in some other works. The usual chemical geothermometers are based upon the measurable change in silica content of the fluid, the change in ratios of some metals (such as Na:K), and other indicators as a function of temperature. Detection of leakage manifestations from a deeper boiling reservoir was discussed by Tonani (1970). Those studies related the occurrence of carbon dioxide, ammonia, boric acid, and other substances to the buildup of free energy, volcanic explosions, and fumarolic activity in the area. White (1970) has summarized the various manifestations of the occurrence of vapor-dominated reservoirs, as expressed by leakage manifestations to the surface.

The release of a steady supply of steam strongly enhances circulation because of the large density difference between steam and water. It is likely to occur wherever reservoir temperature and pressure are near the boiling curve. Under such conditions, leakage manifestations from the boiling water table or steam reservoir can be expected, due to the compositional differences between steam and most natural water systems (Facca and Tonani, 1967). The utilization of that concept by Facca in the early 1960's was instrumental in the revision of the potential of The Geysers geothermal field.

Neither technique, chemical thermometry or identification of leakage manifestations, is absolutely valid in itself. A number of geological, hydrogeological, thermodynamic, and time-related factors can smudge or completely obliterate the geothermally related signal. Simplistic references to temperature-solubility graphs or to metal-ratio graphs can be totally misleading and therefore quite dangerous, as will be shown below. Likewise, a high rate of evolution of noncondensable gases or a superabundance of volatile elements in a warm spring is not necessarily related to inordinately high reservoir temperatures.

Chemically derived temperature requires hydrogeological correction to compensate for dilution, cooling, and exchange reactions (Tonani, 1970; Fournier and Truesdell, 1973). At the very least, it is necessary to be able to establish whether the different chemical geothermometers are in balance with each other. In most cases, a regional hydrogeochemical survey is required, in order to be able to postulate meaningful models of the potential geothermal systems under consideration. Independent evidence will then be required to establish which of these models is likely to be valid. The geochemical examination of isolated thermal springs alone can be considered almost as invalid as the measurement of gravity on top of the gravity anomaly, without taking regional measurements to establish the 'normal' gravity of the region. In some cases, for example, the shallow wells of the Phlegrean field, no chemical temperature can be reliably established even though the samples were collected over a wide region, probably because the assumptions underlying geothermometry—such as attainment of equilibrium with the appropriate mineral assemblage, or that dilution does not involve contamination—are not fulfilled in that case (Fig. 8).

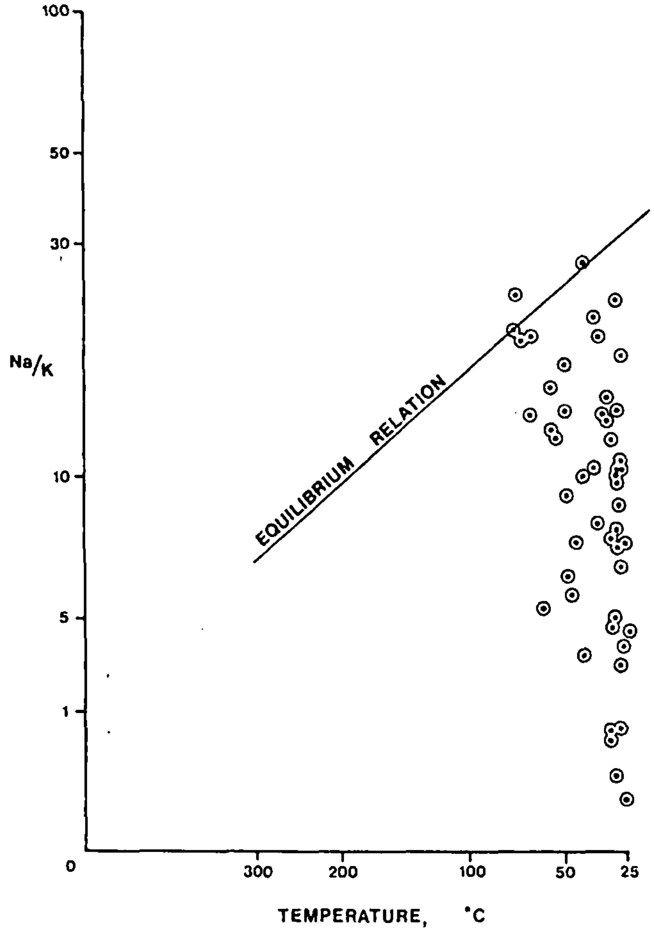

Figure 8. Na:K ratios for the Pozzuoli wells, Phlegrean fields, Italy, as a function of observed well temperature, compared with the Na:K-T° graph (straight line). The lack of correlation of Na:K to observed temperature indicates that the geothermometer may not be used without additional analysis.

Using alternative estimates of temperature to cross-check the geothermometers does not always lead to certainty in the quality of those estimates. Likewise, selective filtering of samples, rejecting one sample and accepting another, without careful analysis other than seeming 'reasonableness' of the values of temperature obtained, might lead to circular reasoning. Such reasoning might be employed to prove what was previously known or assumed. On the other hand, including all samples—unreliable ones as well as those which are reliable—in any analysis might create a large scatter in the data. Broader geochemical data can be used to a large extent to determine which conditions control sample composition in order to single out samples whose composition is likely to be controlled by chemical exchange equilibria.

Surface water, for example, is definitely out of equilibrium. Chemical geothermometry based upon Na:K ratio would suggest at first examination that the 'base temperature' of most rivers is at boiling or even higher. Silica-based geothermometry is usually much less distorted in surface water.

It has been suggested that the potential loss of equilibrium during the passage of the water from the reservoir to the surface could be overcome by selecting the largest output springs in the area; with a shorter transit time to the surface, equilibrium readjustment is less likely to take place. While this reasoning is probably correct, it may be argued that the water in high-output springs may not have cooled much in its upward passage; and hence the observed temperature at the surface may not be much different in that case from the temperature observed in a hole drilled into the source reservoir in the area. In actuality, chemical thermometry would be of greater importance in the opposite case, that of very slow flow to the surface, where considerable cooling in the course of upward passage might have taken place. Under such conditions, however, we must be able to separate the effect of 'noise,' due to mixing with shallower water, or to exchange reactions with the wallrock and thus, from the 'signal'—the original temperature signature, blurred as it might be.

Two chemical geothermometers received the greatest attention, the silica and the Na:K ratio. In the following discussion, we shall recapitulate some well-known facts about the limitations and advantages of these geothermometers, as well as indicate some other approaches to their application.

Silica Geothermometry

The solubility of different forms of silica (that is, quartz, cristobalite, amorphous silica) is so great that assumptions about the mineral assemblage are quite critical. The silica content of water in many volcanic regions is typically quite high, resulting in high apparent geochemical temperatures if the quartz-solubility curve is employed. This high apparent temperature is probably due to the high content of amorphous silica in waters of volcanic regions. The data from the Phlegrean field (Fig. 9) demonstrate the pitfall that may present itself if a temperature is calculated based upon the assumption that quartz solubility controls the content of silica in the water. A statistical analysis relating hot-spring composition or that of local ground water would establish the empirical relationship between temperature and the silica content in the area. Such a correlation would make individual estimates in the higher temperature range less dependent on unproven assumptions and would also provide a factor for correcting for the effect of admixture with surface water. Fournier and Truesdell (1973) have proposed a numerical and a graphical scheme to accomplish this task. The graphic version provides a clearer assessment of the effect of data scatter. Corrections are likely to be effective for limited mixing only. Furthermore, the indeterminacy of the problem increases rapidly with increasing dilution and with scatter in the chemical composition of the diluting surface water.

Na:K Geothermometry

A number of papers have been written on the Na:K geothermometer (for example, Ellis, 1970; Fournier and Truesdell, 1970), and graphs relating equilibrium to temperature to Na:K ratio have been provided. Three distinct geochemical processes may affect Na:K vs temperature ratios, resulting in three distinct Na:K temperature graphs (Fig. 10). Only one of these graphs applies directly to hydrothermal conditions. The other two refer to the Na:K distribution in surface water and to Na:K distribution in a magmatic environment. In a magmatic environment, the sodium and potassium distribution between solids and the liquid favors the accumulation of potassium in the residual liquids.

The opposite is known to be true in the low-temperature environment near the surface of the earth, where potassium is captured on absorbing surfaces more readily than sodium. As for hydrothermal systems, where geothermometry is widely applied, the evidence suggests that potassium is captured also in this case, in preference to sodium, in the

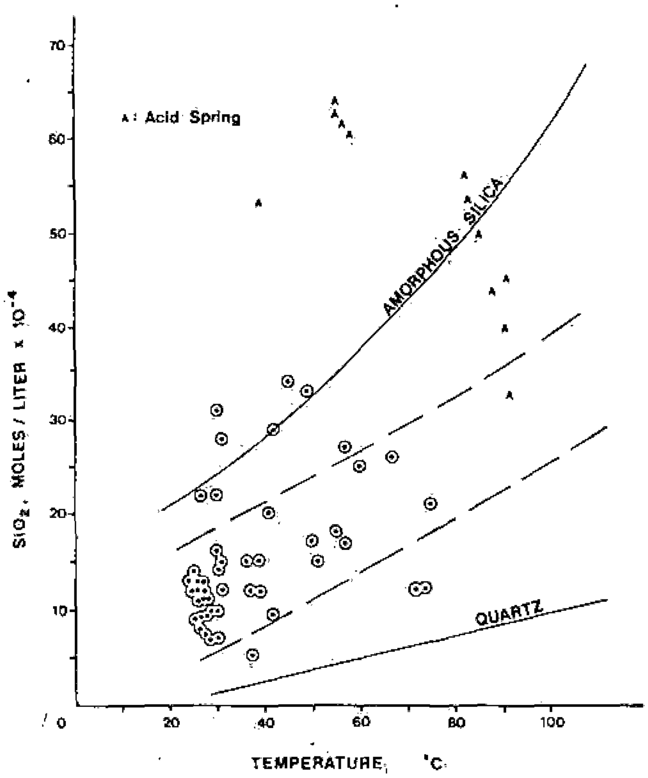

Figure 9. Silica-temperature graph, Phlegrean fields, Italy.

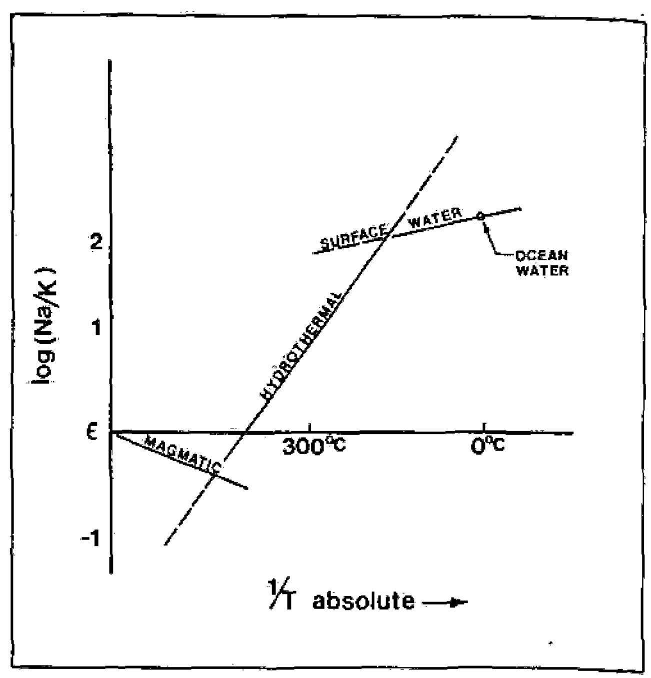

Figure 10. Generalized Na:K ratios as a function of temperature in three different environments: magmatic, hydrothermal, and surface water.

crystal lattices of minerals. Thus, absorption plays a greater role in low-temperature equilibria, while incorporation into crystal lattices is the dominant one for hydrothermal equilibria.

Hence, three different Na:K temperature relationships could control the equilibrium composition of the fluids. Here as in other cases, the correlation of geochemical-hydrogeological, geochemical-geochemical, or geochemical-geophysical data could provide the clue as to which environment is likely to dominate the hydrochemistry of the area, leading to the acceptance or rejection of the hydrothermal metal-ratio thermometer in that area. Fournier and Truesdell (1973) have pointed out that $\sqrt{Ca}$:K and $\sqrt{Ca}$:Na ratios are correlatable with temperature, and may be employed as a geochemical thermometer, except for cases where calcite solubility controls the calcium concentration at depth. In those cases where calcite solubility is the dominant factor in calcium solubility, calcite can serve as an effective geothermometer (Tonani, 1970).

Leakage Manifestations

The second group of geochemical techniques which is applicable to the exploration of geothermal manifestations can be broadly described as that associated with leakage manifestations from a boiling water table (Tonani, 1970; White, 1970).

In reservoirs which are sufficiently close to the boiling point, steam will flash off as a consequence of a comparatively small decrease in reservoir pressure. A steady flow of steam can be triggered either naturally, along fractures or joints, or can be artificially induced by drilling. Such a flow will be naturally sustained as long as the density of the water-steam mixture in the joint or borehole is lower than that of the formation water. Surrounding conditions will affect the characteristics of the discharge in both natural and artificial thermal fluid flows. For example, infiltration of cooler water into the hydrothermal system may change it from a steady-state steam flow to a geyser-like action or to complete quenching. The outlet of the steam discharge can also be variable: it can vent itself to the atmosphere, it can be released at the bottom of a water pool, or it can be discharged into the saturated or unsaturated groundwater zone beneath the surface. A great variation in the nature of leakage, from the visually obvious to the barely discernible, can occur in different settings. It is the latter that is the object of exploration, since the former does not require much sophistication for its discovery. The real exploration problem is that of detecting minute traces of steam leakage in large bodies of water, and the regional assessment of such leakage manifestations.

Pitfalls in the Analysis of Leakage Data

The mere identification of a steam leakage manifestation is no proof that an economic geothermal reservoir does occur in the area. Unsuccessful exploration drilling into fumaroles and into some volcanic areas attests to the veracity of the above statement. Independent geological and geophysical data are required to corroborate that an adequate-size reservoir exists at an acceptable depth below the surface for the prospect to be considered economical.

Allen and Day (1927) have understood the leakage manifestations of The Geysers essentially correctly, except that the view of the magmatists prevailed at the time, identifying the reservoir with 'magma'. Similar views were held at the time with regard to the origin of the Larderello steam field. Subsequent geochemical and isotopic data were instrumental in the evolution and conceptual understanding of relations between hydrogeology, thermodynamics, and the nature of surficial geothermal manifestations.

One element that has been somewhat neglected in previously published studies of both The Geysers and Larderello is an assessment of the difference in distribution of volatile substances in the productive areas as compared with their distribution in the surrounding 'normal' environment. Achieving the capability of separating residual geochemical anomalies of volatile elements from the regional background required that a higher level of sensitivity of analytical chemical techniques be available at a reasonable cost, so that systematic large-scale surveys, similar in scope to those conducted in mineral surveys, are available. In our opinion, mapping of leakage manifestations offers a powerful geothermal exploration tool, which in some cases would be more diagnostic than the now-accepted chemical geothermometry, as the Phlegrean field case history below demonstrates.

The Phlegrean Fields, Italy: Case History

An assessment of hydrothermal activity was carried out over the Phlegrean field, over an area of some 50 sq km (Dall'Aglio, Martini, and Tonani, 1972). Fumaroles, hot springs, cold springs, and wells were repeatedly sampled to evaluate the possibility of volcanic explosions, following a dramatic uplift in the area. In the process, the existence of a high-temperature reservoir at depth was clearly demonstrated through analysis of steam leakage manifestations into the local ground water, utilizing techniques similar to those which were described by one of us (Tonani, 1970). Based upon the geochemical data the convective heat flow through the sea floor of the adjoining bay was estimated to be as much as several thousand hfu, over an area of over 25 km^2 (Tonani, 1972). Independent geophysical studies were carried out at about the same time (Carrara and Rapolla, 1972). The isoresistivity map (Fig. 11) is that of the calculated 'true' resistivity of the water table, at a variable depth below surface, depending upon the depth of the water table below the surface (typically of the order of 100 m). Iso-CO_2 and iso-NH_4 maps of the area, prepared by Geotecneco, a consulting company, on behalf of AGIP, indicate that the maps of noncondensable gases and volatile elements more or less duplicate the electrical resistivity map by Carrara and Rapolla.

This correlation, among others, indicates that the geophysical and geochemical evidence reflects a higher temperature of the water table in the central area, and that the heat is probably due to steam-heating. The steam-heating in turn is manifested by the leakage of volatile elements and noncondensable gases. Geochemical evaluation of underground temperatures was also carried out in the course of the investigations outlined above. The relevant geochemical framework is as follows.

Extensive mixing between sea water and inland ground water occurs throughout the area. Nevertheless, chloride content is correlated with water temperature, though weakly. This could be explained by occurrences of more saline water at greater depth and temperature that would contribute water

Figure 11. Isoresistivity map of the resistivity of the unconfined aquifer (≈100 m depth, based upon Carrara and Rapolla, 1972).

with both higher chloride and temperature to the ground water, as well as by emergence of hot chloride water in springs fed by deep-seated aquifers. Abundant 'leakages' of geothermal steam into the ground water were positively and independently proved by geochemical methods based on the boron, ammonia, and mercury distribution (Dall'Aglio, Martini, and Tonani, 1972).

A plot of sodium vs potassium data confirmed that sample points lie not far from a mixing curve of surface and sea water. However, deviation from the actual mixing curve is significant (see graph of Fig. 12). The end members, surface and sea water, obviously lie on the curve. Except for a few chloride water samples, intermediate samples deviate from a mere mixing curve and cluster more or less around the 100°C isotherm. The isotherms are plotted as continuous straight lines in the logarithmic graph of Figure 12, while the mixing curve is reported as a dashed line. The clear shift in Na:K ratios that occurs for samples whose overall composition fits in with mere mixing can be reasonably interpreted as the result of exchange of sodium for potassium. The effect of this exchange on the location of individual points on the graph of Figure 12 is shown by the arrow. In interpreting these results, attention must be paid to the fact that the country rocks are especially rich in potassium. As a consequence, the actual location of equilibrium isotherms in a Na-K plane might be shifted towards lower Na:K values than usually assumed. This could easily account for the difference between actually observed temperatures in ground water proper and the estimated 100°C.

A cluster of points at extremely low Na:K ratios shows up at the left of the graph, Figure 12. All of these points refer to a group of acid springs. The observed behavior is characteristic for acid springs all over the world. As a consequence of intense leaching of bases and of the resulting depletion, Na:K ratios in waters approach Na:K ratios in

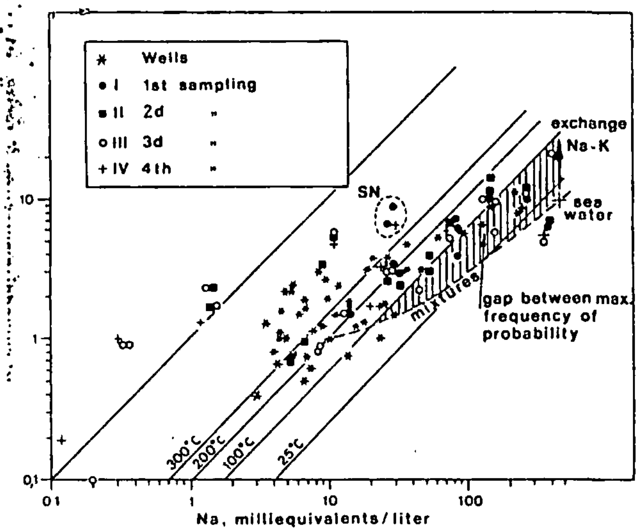

Figure 12. Spring and well samples, Phlegrean fields, Italy.

the country rock and are not related to any equilibrium, and even less to temperature. It may be worth noting that many occurrences of low Na:K ratios in hot-spring waters do in fact result from acid leaching.

Surface waters for the area are not reported on the graph of Figure 12. They are known, however, to have average Na:K ratios in the low range of values between 1 and 10. Well samples are the closest to surface waters appearing in the graph of Figure 12. Surface waters, if plotted, would fill the gap between well samples and acid springs.

In the example described above, geochemical temperatures are absolutely misleading unless the share of surface water in individual samples can be assessed.

Although high geochemical temperatures must be greeted with extreme caution under the circumstances outlined above, the apparent temperature in excess of 300°C obtained for the thermal springs called La Salute deserves some consideration. The Na:K ratio in this chloride water is hardly consistent with anything but exchange of sodium for potassium (see the set of points indicated by SN on the graph of Fig. 12). Actual estimates should allow for a shift of isotherms depending on rock composition. To the best of our knowledge, exchange experiments have not been published for rocks from this area.

Tentatively, a shift of the isotherms that would account for ground-water temperature can be assumed. This would supply an estimate of geochemical temperature for the La Salute water of 200 to 300°C. This seems consistent with the proved existence of boiling hot aquifers at depth in precisely that area and with their capability to produce boron anomalies.

The correspondence of three types of data, that of electrical resistivity, Na-K thermometry (corrected for exchange effects), and leakage effects (unpublished as yet, but quite similar in anomaly shape to the resistivity data), all reinforce each other to suggest that an extensive geothermal anomaly associated with a deeper boiling water table does exist in the area and that probable reservoir temperatures are higher than 200°C.

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29 January 1979

SUMMARY: USGS-DOE Cooperation in Geothermal Petrophysics

In July, 1975, the USGS Geothermal Program started to develop a Petrophysics Laboratory to investigate the physical properties of materials under laboratory simulated geothermal environmental conditions. In July, 1976, the Department of Energy (then ERDA) joined in a cooperative effort by funding and supporting the operation of the laboratory's specialised high temperature and high pressure equipment.

The Geothermal Petrophysics Project is investigating the electrical and textural properties of geothermal materials to: 1) support the interpretation of field geophysical data, 2) identify the important mechanisms behind the observed properties, and 3) develop models to describe the behavior of the physical properties as functions of temperature, pressure, water content, and so forth.

The project is interfaced with USGS and DOE funded programs in other government agencies and at universities. Currently, there are active cooperative efforts with the DOE funded project of Prof. Ershaghi at the University of Southern California and the USGS funded project of Prof. Manghnani at the University of Hawaii. The project is also operating in conjunction with the USGS Uranium and Waste Isolation Programs and the NASA Planetary Geology and Lunar Supporting Research and Technology Programs.

The Geothermal Petrophysics Project is also providing partial support to the development of a computer bibliographic and data base on electrical properties for the book, "Electrical Properties of Rocks and Minerals" by Gary R. Olhoeft (to be published by Elsevier), and for two chapters in the "Handbook on Physical Properties" being assembled by CINDAS at Purdue University under DOE contract.

Accomplishments to date include:

1) Development of the Petrophysics Laboratory facilities to measure grain density, dry bulk density, helium accessible porosity, water accessible porosity, total (including occluded) porosity, pore size distribution, mercury accessible specific surface area, hydraulic conductivity, and all electrical properties. Electrical properties are measured as functions of frequency (10^{-6} to 4×10^{10} Hz), current density (10^{-9} A/cm^2 and up), temperature (-60 to +1700°C), pressure (10^{-9} to 10^9 Pa), and water chemistry (water content and state, salt concentration, pH, Eh, etc.).

2) Measurements to date include:

a) Electrical resistivity of potassium, sodium, and calcium brines to 375°C under hydrostatic pressure as a function of concentration to 25 wt%. The measurements show that the standard log interpretation charts are accurate only for NaCl salt solutions below 200°C. For other salts and at higher temperatures, the published log interpretation charts are in error by over 25%. Three-dimensional regression analysis of the data produced new formulas that fit all three salts to 25 wt% concentration and 375°C accurate to ±2%.

b) Electrical resistivity of brine saturated sandstone and basalt as a function of temperature to over 300°C under hydrostatic pressure. The assumption of volume conduction dominance in Archie's Law relating rock resistivity to pore fluid resistivity is accurate for shale and clay-free sandstones to over 300°C. However, in samples containing alteration products lining pore walls, the surface conduction dominates the volume conduction above 80°C and Archie's Law falls apart.

c) In conjunction with the USGS Uranium Program, a nonlinear complex resistivity technique was developed which has demonstrated the capability of identifying the presence or absence of clay minerals and related alteration products. Borehole tests with a standard logging tool and the Petrophysics Laboratory instrumentation has demonstrated that the technique works in real boreholes.

3) Modelling to date has shown that alteration products and hydrous minerals at depth in the earth may explain some existing magnetotelluric anomalies without having to invoke anomalous near-surface magma chambers in areas of otherwise normal heat flow.

In the coming year, all of these investigations and tasks will continue with the following projected accomplishments:
1) completion of the book, "Electrical Properties of Rocks and Minerals",
2) completion of two chapters for the CINDAS book, "Handbook of Physical Properties",
3) extension of brine-saturated electrical rock measurements to 400°C,
4) extension of partially saturated electrical rock measurements to 1200°C,
5) addition of the capability to measure seismic velocity and attenuation,
and 6) publication of the preliminary geothermal models for electrical properties.

Gary R. Olhoeft

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Carbon Isotopic Composition of CO_2 from Springs, Fumaroles, Mofettes, and Travertines of Central and Southern Italy: A Preliminary Prospection Method of Geothermal Area

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ABSTRACT

The CO_2 from thermal springs and natural gas emanations was sampled, and its ^{13}C:^{12}C ratio was measured by mass-spectrometry. At the same time samples of fossil and modern travertines were collected. The isotopic composition of the travertine, being related to that of the evolved CO_2, has been used to evaluate the isotopic composition of the CO_2 emitted in the past by thermal springs which are now extinct.

The total range of $\delta^{13}C$ observed in the manifestations of central and south Italy is from +1.8 to −21.3‰. Samples from areas with different geological features show different ^{13}C contents. The more negative δ values were found where the geological conditions could justify an inorganic origin for CO_2. On the contrary, CO_2 from geothermal areas and CO_2 connected with recent volcanic activity is characterized by a relative enrichment in ^{13}C ($\delta^{13}C$ ranging from +2 to −6‰), when compared to the CO_2 from other areas. Hydrolysis of carbonates in the temperature range from 100 to 300°C has been emphasized as the main source of CO_2 with relatively higher ^{13}C contents rather than magmatic or juvenile ones.

On this basis, isotopic analyses of CO_2 (and travertines) are proposed as a useful tool in the preliminary prospection of the anomalous thermality of a certain area.

INTRODUCTION

The recent increased interest in geothermal energy has given incentive to widespread exploration for this source. Until now, the areas receiving the most attention have been those with fumaroles and hot springs. From the geochemist's viewpoint some of the major problems associated with geothermal manifestations are the source of the volatiles emitted in these areas, and how this knowledge can be used in the exploration of new zones.

The origin of geothermal steam has been clarified by stable isotopic studies, which have also shown that it can be labelled in respect to its isotopic composition ("oxygen shift") as a consequence of the high temperature conditions to which it has been subjected during deep circulation in areas with high thermal gradient (Craig, 1963; White, 1970; Panichi et al., 1974).

Many studies of hydrothermal gases have been carried out in an attempt to evaluate the composition of the volatiles associated with a magma. The interpretation of these studies has been complicated by the addition of nonmagmatic components to the gas phase, the evaporation of ground water, the decomposition and alteration of the country rocks through which these solutions rise, and by the dissolution of some volatile components in the aqueous phase.

Mazor and Wasserburg (1965) and Gunter and Musgrave (1971) have confirmed earlier theories that the greatest part of the nitrogen, oxygen, and inert gases found in these systems is of atmospheric origin. Other volatiles, such as hydrogen, are more frequently assigned a magmatic source.

Chemical and isotopic analyses of CO_2 and CH_4 have been used in evaluating the temperatures of the geothermal reservoir, but their application is always questionable. The chemical reaction of carbon dioxide and molecular hydrogen to form methane is thermodynamically possible (Ellis, 1957; Krauskopf, 1959), and the observed fractionation factors are in good agreement with the theoretical values for geothermal temperatures (Craig, 1963; Hulston and McCabe, 1962; Panichi et al., 1975). However, there is evidence to support the organic origin of methane (Gunter and Musgrave, 1971).

The carbon dioxide may originate from magma, decarbonation, organic matter, or dissolved CO_2 in meteoric waters. Many papers have been published on carbon dioxide; however, most have been concerned with one particular local mode of occurrence.

The present study was undertaken in an attempt to summarize the available data on the problem of origin and to clarify the possibility of using the isotopic content of ^{13}C in hydrothermal CO_2 and in other carbon components, such as travertine, in the preliminary prospecting of geothermal areas.

CARBON DIOXIDE PROBLEM

Theories on the origin of the carbon dioxide in natural manifestations may most conveniently be divided into two general groups: organic and inorganic.

Considering the organic source first of all, CO_2 can be

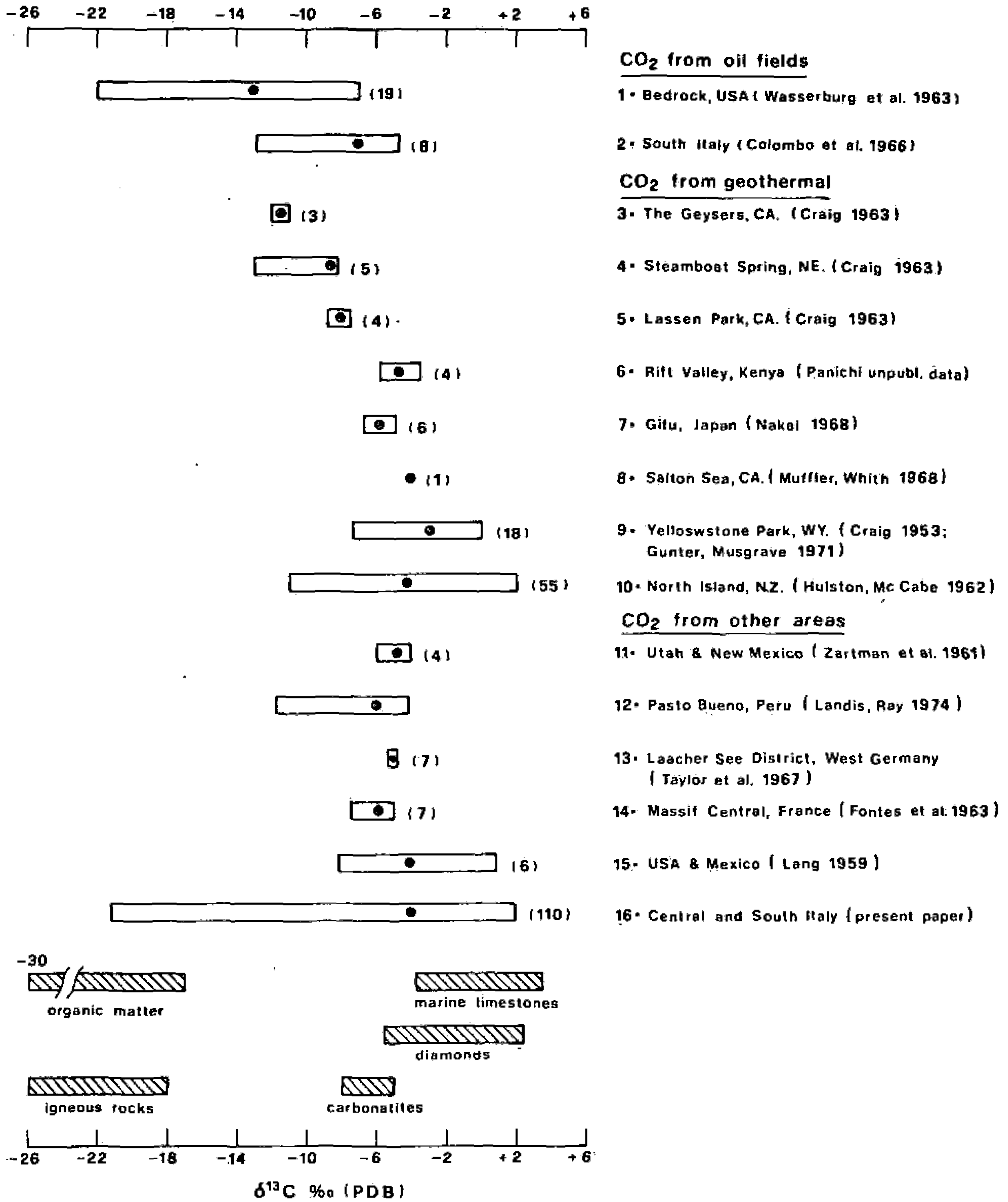

Figure 1. Carbon isotopic composition of CO_2 samples from different areas throughout the world. Black points represent the average values in each area. The number of samples analyzed is given in parentheses. The $\delta^{13}C$ values for organic matter, marine limestone, diamonds, igneous rocks, and carbonatites, as derived from Craig (1963) and Taylor, Frencen, and Degens (1967), are also included for comparison.

produced both from decay of organic matter and from oxidation of hydrocarbons by mineralized waters. In the former case the anaerobic bacteria are the effective agents in oxidizing organic material (ZoBell, 1952), while in the latter case it has been suggested that calcium or sodium sulfate are effective in the oxidation of hydrocarbons through the following reactions:

$$C_nH_m + M_eSO_4 \rightarrow M_eSO_4 + CO_2 + H_2O \rightarrow M_eCO_3 + H_2S(+CO_2 + H_2O)$$

Several isotopic analyses of the CO_2 associated with oil fields in North America and southern Italy have been performed by Wasserburg, Mazor, and Zartman (1963) and Colombo et al. (1966) respectively, and the $\delta^{13}C$ ranges are reported in Figure 1. Carbon dioxide samples are always lighter than the carbonate rocks, and the more negative values fall in the range of the isotopic composition of organic matter. On the contrary, the heavier CO_2 samples are genetically related either to intense volcanic activity (Quaternary period) in sedimentary sequences including large volumes of carbonate rocks, as in the case of Italian fields, or to large amounts of methane, as in the case of glacial drift gases from Illinois, USA. In both cases CO_2 is produced with an isotopic composition affected by different processes other than the oxidation of hydrocarbons. In the Italian zones CO_2 is certainly a mixture of organic and inorganic CO_2 derived from the metamorphosis of limestones, and in the glacial drift gases the CO_2 samples have their isotopic composition regulated by an isotopic exchange at low temperature with an excess of methane which is characterized by a very strong depletion of ^{13}C content (Wasserburg, Mazor, and Zartman, 1963). It must be noted that biochemically derived CO_2 is confined to zones of comparatively low temperature (less than 60 or 70°C).

Among the inorganic theories, igneous emanations, metamorphism of carbonates, and solution of limestones by ground waters represent the main mechanisms of CO_2 production.

High percentages of carbon dioxide have been measured in gases collected from seeps in many areas where recent volcanism is known. This compound is a common accessory of igneous activity, and, according to Clarke (1924), the end product (with steam) of the gases evolved. Subsurface accumulation of carbon dioxide occurs commonly in these areas and its presence has been ascribed by many authors to a magmatic origin (primary CO_2) in some cases only, and in others has been coupled with an origin by metamorphism of country rocks.

Generation of carbon dioxide by contact metamorphism of intruded carbonate rocks is a well-documentated phenomenon (Germann and Ayres, 1941). The formation of forsterite and wollastonite at intrusive dolomite-limestone contacts is evidence of a carbon dioxide production by the formulae:

$$2CaMg(CO_3)_2 + SiO_2 \rightarrow Mg_2SiO_4\text{(forsterite)} + 2CaCO_3 + 2CO_2$$

or

$$CaCO_3 + SiO_2 \rightarrow CaSiO_3\text{(wollastonite)} + CO_2$$

Other similar reactions are proposed for the production of CO_2 in the Salton Sea geothermal system by Muffler and White (1968), who infer that dolomite and calcite react with kaolinite and K-mica respectively to form chlorite and epidote, perhaps according to the following reactions:

$$7MgCa(CO_3)_2 + 2.5Al_2Si_2O_5(OH)_4 + 3H_2O + 3Fe^{+2} + 3.5O^{-2} \rightarrow Mg_7Al_2Fe_3Si_5Al_3O_{20}(OH)_{16} + 7CaCO_3 + 7CO_2$$

$$4CaCO_3 + K_2Al_4Si_6Al_2O_{20}(OH)_4 + 6SiO_2 + 2Fe^{+2} + O^{-2} \rightarrow 2Ca_2Al_2FeSi_3O_{12}(OH) + 2KAlSi_3O_8 + 4CO_2 + H_2O$$

Temperature conditions both for reaction of carbonates with silica or silicates generally exceed 200°C. On the other hand, the emission of CO_2 as a result of thermal metamorphism, with no water involved, occurs at much higher temperatures (600 to 700°C or more).

In areas where temperatures of 100 to 200°C prevail, both biochemical and thermometamorphic processes are prohibited. Kissin and Pakhomov (1967) suggest that in these cases CO_2 can originate in situ through hydrolysis of carbonates affected by ground water at temperatures as low as 100°C. This process appears to be common in nature, for at moderately high temperature it merely requires such extremely common compounds as water and carbonate rocks. The same authors have also tested carbonate-bearing clay, showing that CO_2 is evolved when waters reacted both with prevalently carbonate rocks and with those that have been carbonatized. They thus conclude that the hydrolysis of carbonate may well play a definite part in volcanic processes.

Carbon isotope data on "inorganic" CO_2 gas samples analyzed by previous studies are reported in Figure 1 and compared with Italian CO_2 manifestations data. Also included are analyses of ^{13}C:^{12}C ratios in marine limestones, organic matter, diamonds, and igneous rocks by Craig (1963), and in carbonatites as reported by Taylor, Frencen, and Degens (1967).

Apart from the dispersion of $\delta^{13}C$ values in each area, the average values fall in a very narrow range (from −3 to −6‰), except for the CO_2 samples from The Geysers, Steamboat Springs, and Lassen Park. In these cases the CO_2 is lighter and the average values reach −11.5‰.

This observation is quite interesting and suggests the possibility that almost all the more important CO_2 manifestations could have derived from the same source, despite the fact that the studied areas present different geological conditions. In this respect Taylor, Frencen, and Degens (1967) reported that primary carbonatite calcite has a $\delta^{13}C$ of −8.0 to −5.0 values, very similar to the diamond compositions which are presumed to originate in the mantle, and they conclude that CO_2 gas samples having similar δ values could be of magmatic origin.

On the other hand, several authors suggest that the only ubiquitous alliance between carbon dioxide and a particular rock type is with calcite and/or dolomite, both of which seem invariably to be present in the stratigraphic section where significant amounts of carbon dioxide are present.

Although it is impossible for us to review all geological details of all the areas shown in Figure 1, it is quite indicative that volcanic rocks in the areas studied in New Zealand, the Salton Sea, and Japan contain significant amounts of calcite as reported by Browne and Ellis (1970), Muffler and White (1968), and Nakamura et al. (1970) respectively, from which CO_2 could be derived.

If this is a general situation, it appears that it is not possible at present to give one single explanation of the genesis of the carbon dioxide found in the areas associated with anomalous temperatures.

The following section gives arguments in support of the prominent role played by the limestones in the genesis of CO_2.

CO_2 FROM CENTRAL AND SOUTH ITALY

One hundred ten CO_2 samples from geothermal areas, cold and thermal springs, mofettes, and fumaroles were collected in central and southern Italy on the Tyrrhenian side.

The total observed range of $\delta^{13}C$ values is +1.8 to −21.3‰ versus the PDB standard, and the average value is −4.1, as indicated in Figure 1. Practically the same value is obtained if we consider the thermal springs only, as only a few carbon dioxide samples have $\delta^{13}C$ less than −11‰, which represents the minimum value observed in thermal manifestations (see Appendix 1).

A $\delta^{13}C$ value of about −4‰ is very similar to those observed in the other areas discussed previously and the interpretation of this figure is, once again, submitted to the uncertainty discussed before.

Table 1. Carbon isotopic composition CO_2 samples from geothermal and recent volcanic areas in central and southern Italy.

Location	$\delta^{13}C$‰ from	(PDB) to
Geothermal areas:		
Larderello	−1.7	−6.5
Travale	−1.5	−3.5
Mt. Amiata	0	−3.2
Volcanic areas:		
Lake Bolsena	+1.7	−2.8
Lake Bracciano	−1.3	−3.5
M. Albani	+1.8	−2.2
Roccamonfina	+1.0	−2.1
Campi Flegrei	−0.8	−3.1

However, if we examine in detail the isotopic composition of CO_2 emerging in some specific areas such as the geothermal or volcanic ones, some more definite conclusions can be made on the main source of the CO_2.

Table 1 summarizes the observed variations in the ^{13}C contents in the CO_2 of these areas. Except for Larderello geothermal area, the $\delta^{13}C$ values fall between +1.8 and −3.5‰, that is, practically in the same interval as the marine limestones. These rocks always occur in the geological columns of the studied volcanic areas, either as the basement or as interbedded formations of volcanites, and may reasonably represent the carbon dioxide source. The probable mechanism of the production of CO_2 is the above-mentioned hydrolysis of carbonates at temperatures greater than 100°C, rather than the decarbonation at 600 to 700°C. In fact, despite the obvious aspects of differences and probabilities of the thermalism required in the two different processes, decarbonation will produce CO_2 which is enriched by 2 to 3‰ in ^{13}C compared to the parent limestone.

Most of the CO_2 samples analyzed are equal to, or appreciably lower than, the marine limestones, which have in these regions $\delta^{13}C$ values ranging from −1 to +3‰.

On the contrary the observed values can be due to different fractionations occurring at different temperatures between calcite and carbon dioxide. Data from Bottinga (1969) show that CO_2 is depleted compared to the calcite by about 4 and 0‰ when the equilibrium temperature increases from 100 to 200°C.

In this respect the $\delta^{13}C$ values which are more negative by −5 to −6‰ can be considered as a result of some

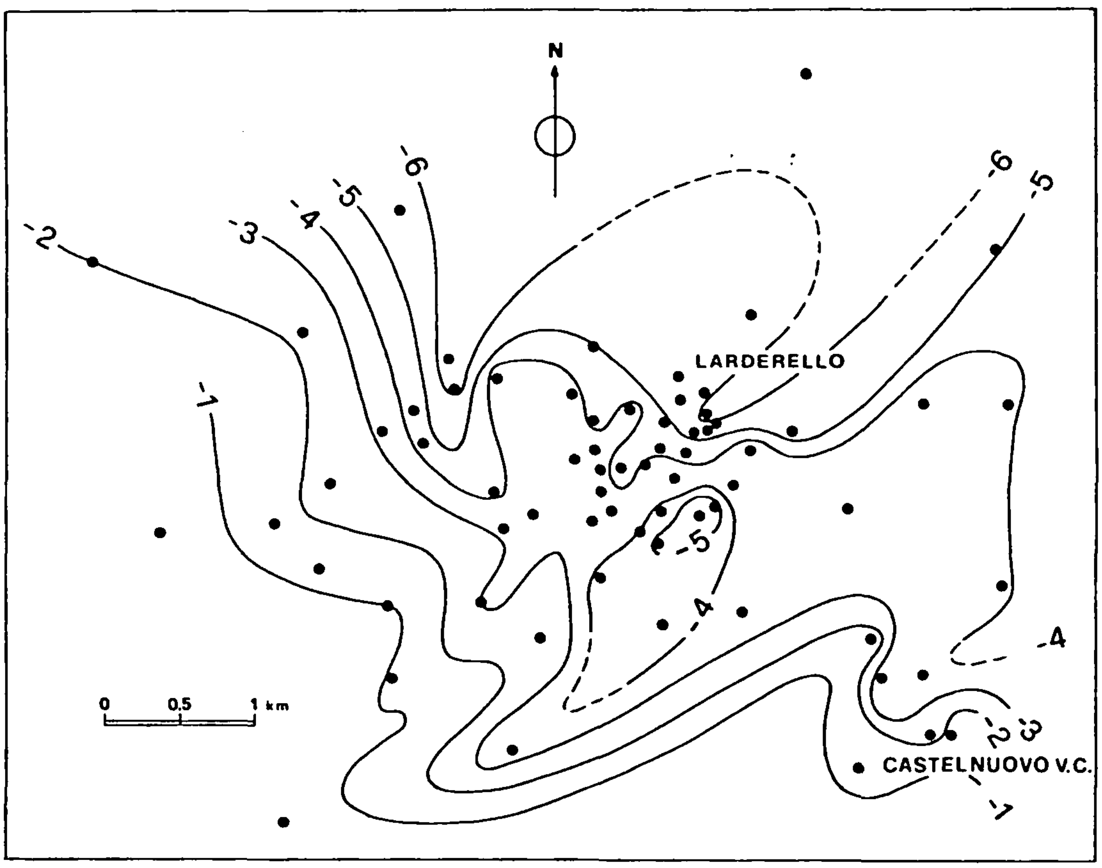

Figure 2. The $\delta^{13}C$ distribution of CO_2 samples from steam wells of the Larderello and Castelnuovo V.C. geothermal fields. The δ values are expressed versus PDB standard. The maximum and minimum values are −0.5 and −6.5‰ respectively.

mixing with organic CO_2 dissolved in shallow waters and produced by sediments rich in organic matter.

The CO_2 produced in steam wells in Larderello geothermal area shows quite large variations, in relation to the other thermal areas. Taking into account the two main possible sources (magmatic or limestones), the more negative values (about −6‰) could be interpreted in terms of primary CO_2, while the more positive ones could be interpreted as a result of a successive reequilibration of the deeper CO_2 with carbonate rocks, which would determine an enrichment in ^{13}C of CO_2. However, this hypothesis is not confirmed by the observed trend of the $\delta^{13}C$ variations in the geothermal CO_2 samples in relation to the isotopic composition of the CO_2 observed outside the geothermal field.

Figure 2 shows that CO_2 is strongly depleted moving from south to north in the geothermal field, and the variations are very regular except for the central intensively exploited area where a lot of drilling has determined the conditions for a quite homogeneous fluid reservoir. At the same time, Figure 3, where the distribution of ^{13}C contents in the majority of Tuscany's CO_2 manifestation is reported, shows what kind of interferences occur, in particular, between "geothermal" CO_2 and the "organic" CO_2 produced by Pliocene and Quaternary sedimentary rocks occurring north-northwest of the Larderello region.

It must be noted from Figure 3 that similar conditions occur in Mt. Amiata field, where geothermal CO_2 tends to assume progressively more negative values on the field boundaries.

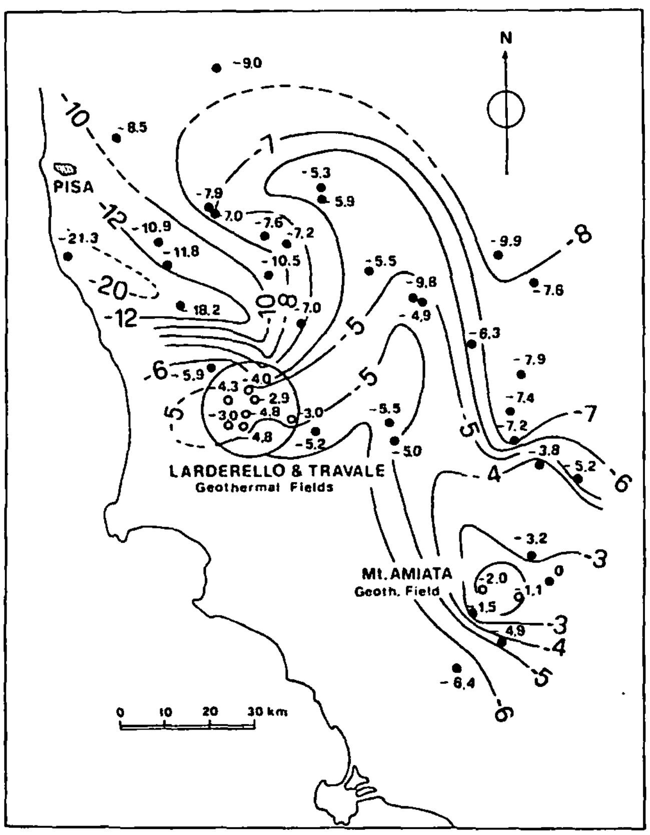

Figure 3. Geographycal distribution of $\delta^{13}C$ values of CO_2 gas samples in Tuscany. Isotopic compositions of CO_2 from mofettes and both cold and thermal springs (black circles) are compared with those of CO_2 emerging with steam in geothermal areas (open circles) in which only the average values are shown.

In conclusion, although the magmatic hypothesis is very attractive as a possible general mechanism of the production of CO_2, excluding any important role played by the carbonates, this statement can be reversed on the basis of the previous observations. The hydrolysis of carbonate rocks at a relatively lower temperature could also be a very common process in volcanic areas where limestones are present in small amounts.

If the latter hypothesis were proved, it could have important implications. For example, it could serve as a valuable criterion in preliminary prospecting of new geothermal areas. Any carbon dioxide sample which has a $\delta^{13}C$ inside the range of local limestones would be automatically suspect as being derived from hydrothermal reactions at relatively shallow depths and at temperatures as high as 100 to 150°C.

TRAVERTINES

Before presenting the results obtained in the application of this "working hypothesis" to manifestations in central and south Italy, we must deal with the possibility of using the ^{13}C of travertines as an integration of ^{13}C of CO_2 gas samples.

Ground water charged with CO_2 can precipitate travertine at the surface where the CO_2 bubbles out due to release of pressure. Before precipitation the solution contains HCO_3 and CO_3, as well as H_2CO_3 app [that is, $CO_2(aq) + H_2CO_3$] carbon species which are in isotopic equilibrium with respect to the carbon isotopes.

The knowledge of the fractionation factors at the deposition temperature between CO_2 and $CaCO_3$ could permit the evaluation of the $\delta^{13}C$ of CO_2 from the analytical data on the travertine samples where fossil deposits occur without any CO_2 emanations.

However, Gonfiantini, Panichi, and Tongiorgi (1968) and Friedman (1970) have independently shown that the outgassing process of CO_2 determines deposition of $CaCO_3$ at disequilibrium with respect to both carbon and oxygen isotopes.

Figure 4 shows some examples of departure from equilibrium conditions for the carbon isotopes observed in thermal springs of Tuscany, where deposition of travertine occurs at present.

In addition a positive correlation generally exists between ^{18}O and ^{13}C contents in travertine samples deposited at increasing distances from the orifice of the spring (Gonfiantini, Panichi, and Tongiorgi, 1968), because of the progressive ^{13}C enrichment of the dissolved bicarbonate due to the preferential escape of isotopically light CO_2.

However $\delta^{13}C$ values of CO_2 and $CaCO_3$ show a quite good correlation (Fig. 5) which can be used in practice in evaluating the isotopic composition of CO_2 from the analyzed values of "fossil" intravertine samples. In order to avoid the uncertainty as to the original spring orifice which has formed the studied deposit, several samples must be collected from all over the selected formation and the lighter one for calculating the isotopic composition of the associated CO_2.

Using this criterion and the formula given in Figure 5, travertine samples were collected in the some areas where CO_2 was studied and 110 additional $\delta^{13}C$ values of CO_2 were obtained. As expected the total variations range from

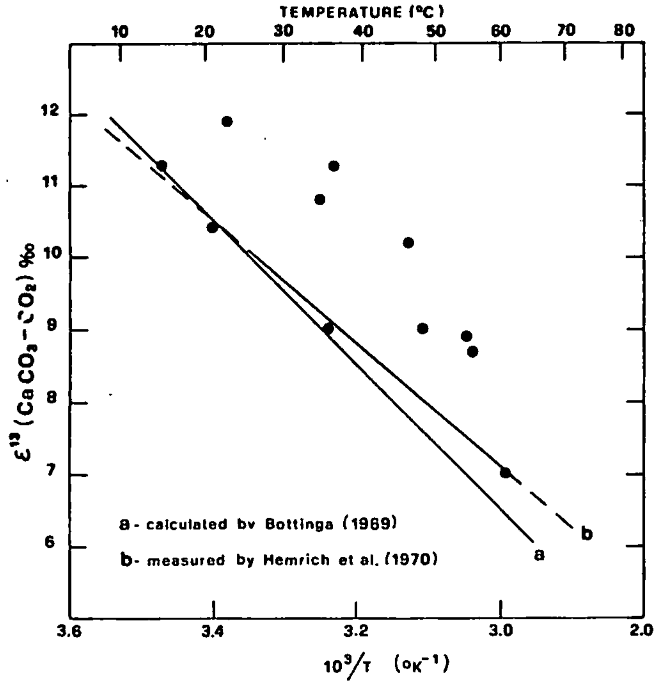

Figure 4. Comparison between the carbon fractionation factors in the system $CaCO_3$-CO_2 observed in springs which actually form travertine, and the theoretical values for the equilibrium precipitation (modified from Gonfiantini, Panichi, and Tongiorgi, 1968). The enrichment factor is defined by: $\epsilon = (R_A/R_B - 1) \times 10^3$ where R_A and R_B are the ^{13}C:^{12}C ratios of the $CaCO_3$ and CO_2 respectively.

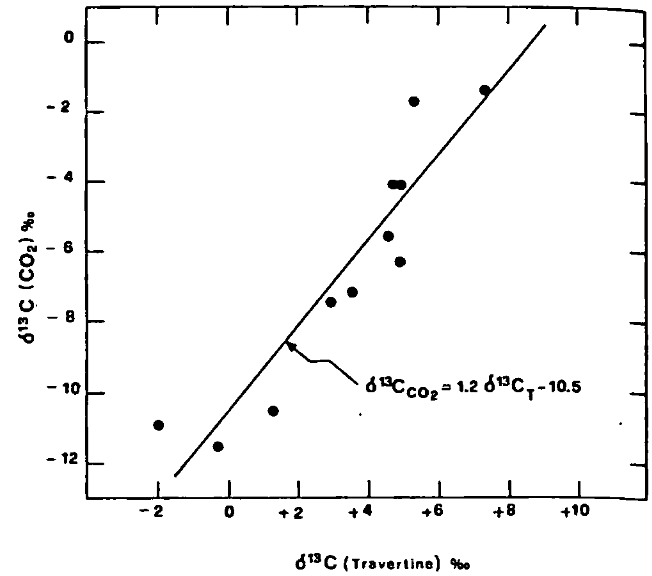

Figure 5. Relationship between the carbon isotopic compositions of CO_2 and travertine samples collected at the orifices of the 11 springs of Figure 4. The equation obtained by the least-squares fitting is used for calculation of ^{13}C values of CO_2 from ^{13}C values of fossil travertines (see Appendix 2).

+1.8 to −19.4‰, that is, practically the same as the CO_2 gas samples (see Appendix 2).

$\delta^{13}C$ AS INDICATOR OF ANOMALIES

Figures 6 and 7 show the geographical distribution of the $\delta^{13}C$ values of the studied CO_2 gas samples together with those calculated from fossil travertine analyses. Assuming that CO_2 samples having $\delta^{13}C$ values more positive than −3‰ (black points) are derived from effective hydrothermal processes at depth without any significant mixing with the CO_2 produced from different sources (for example, an organic source), almost eight zones are individuated for their anomalous hydrothermalism. They include the well-known steam fields of Larderello, Travale, and Mt. Amiata, and five of the six zones in which Pliocene or Pleistocene volcanic activity has occurred.

In the volcanic areas near Frosinone the isotopic analyses do not reveal any indication of active thermalism.

During the past few years ENEL, in collaboration with CNR, began geothermal exploration of the more promising volcanic areas located south of Tuscany. Detailed results are given elsewhere, but some information on the maximum temperatures, maximum depth, and type of fluid recovered in this research is summarized in Table 2. Except for the Mt. Albani and Roccamonfina areas, in which exploration has not quite started, the results obtained strongly support our working hypotheses and lead us to suggest that the carbon isotopic composition of CO_2 of natural manifestations may be a useful tool in preliminary geothermal prospecting.

Table 2. Some characteristics of the fluid recovered during early or recent geothermal exploration in central and southern Italy.

Name	Type of fluid	Max temp. (°C)	Max depth (m)	Remarks
Larderello	superheated steam	300	2003	(Ferrara et al. in 1967)
Travale	superheated steam	277	1841	(Burgassi et al., 1975)
M. Amiata	steam and/or hot water	177	1475	(Cataldi, 1967)
Alfina (Lake Bracciano)	hot water	148	1040	TDS = 6 g/liter, (Cataldi and Rendina, 1973)
Cesano (Lake Bolsena)	hot brine	210–250	1435	TDS >300 g/liter, 210°C is not stabilized, 250°C is evaluated (Calamai et al., 1975).
Mt. Albani	—	—	—	Chemical analyses of surface water were carried out by ENEL with no significant information of the condition at depth.
Roccamonfina	cold water	—	300	(Barbier et al., 1970) Geothermal measurements are affected by an active circulation of cold water in the volcanic cover. Investigations of carbonatic basement (below 2000 m) are needed.
Campi Flegrei	hot water	300	1800	TDS >26 g/l; these figures are relative to the volcanic cover, investigations are begun of the carbonate basement (Cameli et al., 1975).

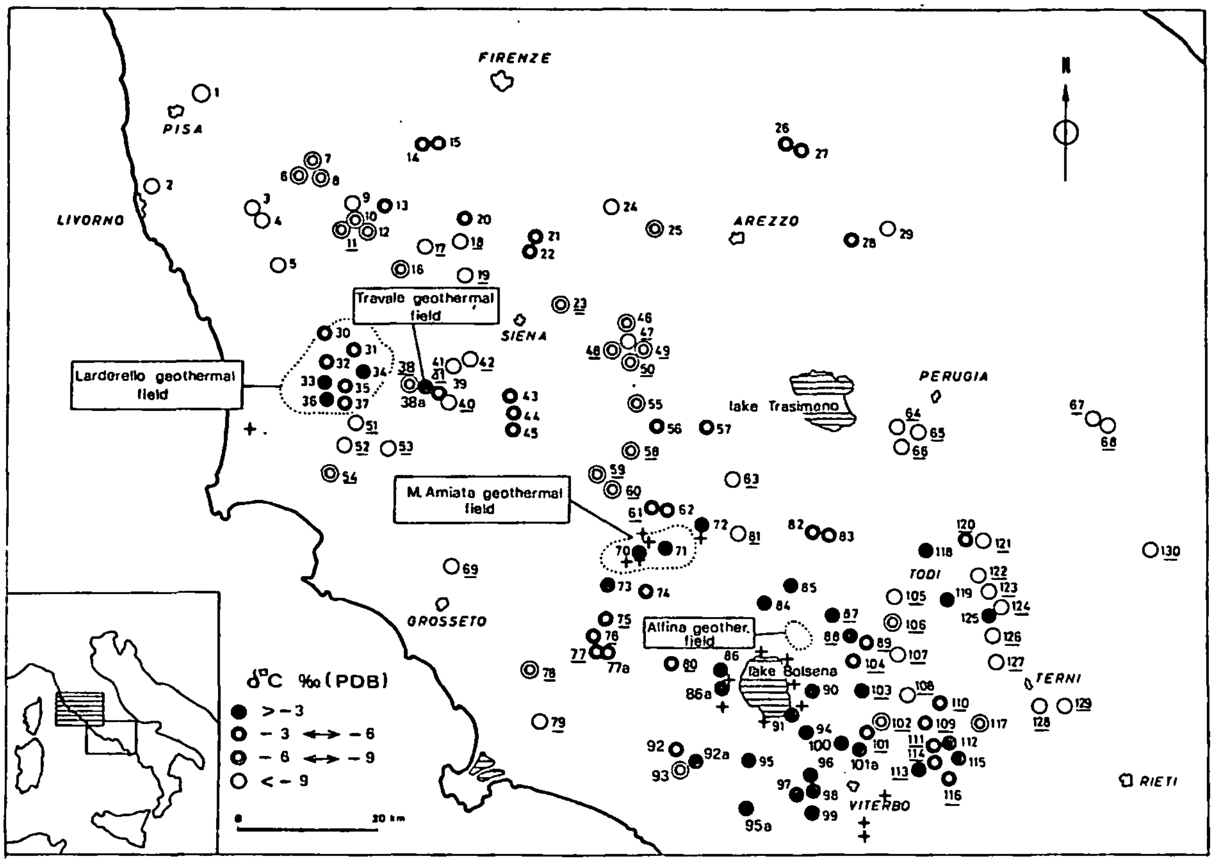

Figure 6. Geographical distribution of $\delta^{13}C$ values of CO_2 samples from practically all gas manifestations of central Italy (Tyrrhenian side). The numeration refers to the samples listed in Appendixes 1 and 2. The underlined numbers represent CO_2 calculated in travertines. The main areas where geothermal exploration had given positive results or is still in progress are also shown.

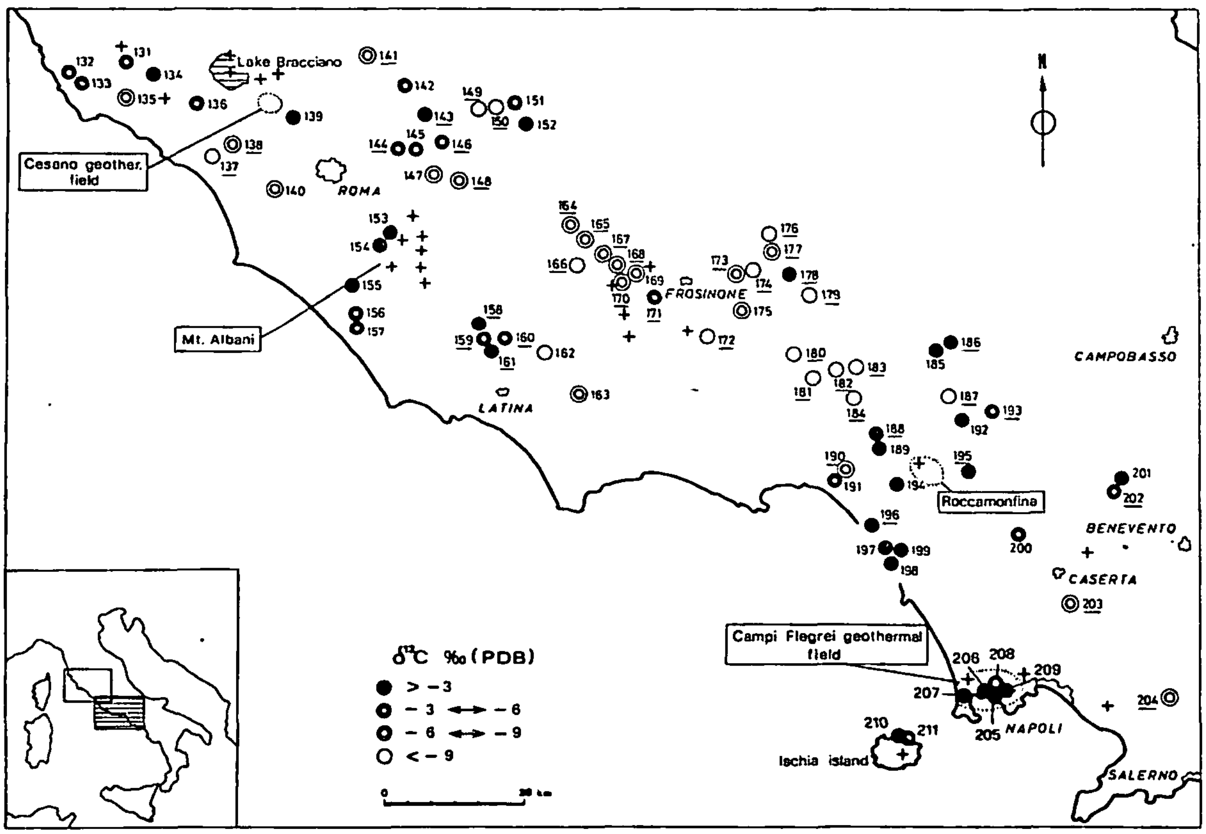

Figure 7. Geographical distribution of $\delta^{13}C$ values of CO_2 samples from practically all gas manifestations of southern Italy (Tyrrhenian side), up to the Neapolitan region. The numeration refers to the samples in Appendixes 1 and 2. The underlined numbers represent CO_2 calculated in travertines. The main areas where geothermal exploration is in progress are also shown.

APPENDIX 1

Offered here are data on carbon-isotopic composition of CO_2 samples from mofettes, fumaroles, cold and thermal springs, and geothermal wells of central and southern Italy. Samples were collected by a water-displacement technique, using one-liter glass bulbs. Analysis of duplicate field samples taken from several different sites yielded essentially identical results, so air contamination was not a problem.

No.	Location	$\delta^{13}C$‰ (PDB)	Temperature of spring waters (°C)
1	Bagnetti–Agnano, PI	−8.5	20–27
2	La Puzzolente, LI	−21.3	15
3	Acqua delle Terme–Casciana T., PI	−10.9	36
4	Acq. S. Leopoldo–Casciana T., PI	−11.8	15
5	Miemo–Castelnuovo Val di Cecina, PI	−18.2	22
6	Baccanella–Palaia, PI	−8.0	15
7	Bagni di Chiecinella–Palaia, PI	−7.9	15
8	Rio Chiecinella–Palaia, PI	−7.0	15
9	Iano–Volterra, PI	−10.5	dry gas
10	Torricchi–Gambassi, FI	−7.6	dry gas
12	Bagni di Mommialla–Gambassi, FI	−7.2	15
13	Bollore–Gambassi, FI	−3.1	32
14	Acqua Bolle–Montespertoli, FI	−5.3	16
15	Le Mandrie–Montespertoli, FI	−5.9	16
16	Montemiccioli–Volterra, PI	−7.0	dry gas
20	Le Fonti–Poggibonsi, SI	−5.5	17.5
21	S. Fedele–Radda in Chianti, FI	−4.8	16
22	Bagni S. Fedele–Radda in Chianti, FI	−4.9	10
23	Acqua Borra–Castelnuovo Berardenga, SI	−6.3	37
24	Levane-Monetvarchi, AR	−9.9	18
25	Pergine, AR	−7.6	dry gas
26	Poggio Morelle–Sigliano, AR	−4.3	25
27	Cura di Sigliano–Sigliano, AR	−4.6	17
28	Acqua del Buon Riposo–Città di Castello, PG	−9.6	16
30	Libbiano–Pomarance, PI	−5.9	gas + steam
31	Larderello–Pomarance, PI	−4.1*	gas + steam
32	Serrazzano, PI	−4.5*	gas + steam
33	Lustignano, PI	−1.7*	gas + steam
34	Castelnuovo Val di Cecina, PI	−2.9*	gas + steam
35	Sasso Pisano, PI	−4.7*	gas + steam
36	Lago, PI	−2.8*	gas + steam
37	Monterotondo, PI	−4.7*	gas + steam
39	Castelletto Mascagni–Chiusdino, SI	−5.2	16.3
43	Doccio di Macereto–Murlo, SI	−5.0	48
38a	Travale, SI	−3.0*	gas +steam
44	Potatine–Murlo, SI	−5.0	15
45	Bagni di Petriolo–Monticiano, SI	−5.5	44
46	Bagni di S. Giovanni–Rapolano, SI	−7.9	36-40
50	Acqua Passante–Asciano, PI	−7.4	21
55	Bagnaccio–S. Giovanni d'Asso, SI	−7.2	35
56	Acqua Puzzola–Pienza, SI	−3.8	15
57	S. Albino–Montepulciano, SI	−5.2	35
62	Acqua Solfurea di Bagni di S. Filippo–Castiglione d'Orcia, SI	−3.2	43.7
70	Bagnore, GR	−2.0*	gas + steam
71	Piancastagnaio, GR	−1.1*	gas + steam
72	Radicofani, GR	0	dry gas
73	Triana–Roccalbegna, SI	−1.5	15
74	Acqua del Colle di Selvena–Castell'Azzara, GR	−4.9	15
77a	Terme di Saturnia, GR	−6.4	37
82	Sorgente Solfurea–Parrano, TR	−5.7	26
83	Acqua Ferruginosa–Parrano, TR	−5.2	22
84	Torre Alfina–Acquapendente, VT	+0.4	14
85	Monterubiaglio–Castelviscardo, TR	+1.7	23
86	Làtera–Poggio Montione, VT	+1.4	19.5
86a	Valentano, GR	−0.5	19
90	Ferentino–Montefiascone, VT	+0.4	13
91	Montefiascone, VT	+1.6	18
92a	Musignano, GR	−3.0	dry gas
94	Bagnaccio, VT	−1.7	60
95	Acqua Forte–Tuscania, VT	−0.6	22
95a	Tuscania, GR	+0.1	dry gas
96	Bullicame, VT	−1.4	56
97	S. Cristoforo–Castel d'Asso, VT	−2.5	38
98	Podere Ospedali–Castel d'Asso, VT	−2.8	51
99	S. Sisto, VT	−1.6	dry gas
100	Società SAMAC, VT	−0.2	dry gas
101a	Grotte di S. Stefano, VT	−0.1	18
112	Varie Sorgenti–Orte, VT	−0.8	19-27
115	Fiuggi–Orte, VT	−0.6	19
117	Lecinetto–Narni, TR	−6.5	18
118	Acqua Forte–Montecastello di Vibio, PG	−1.4	18
119	Vasciano–Todi, PG	−1.8	12.4
125	Terme di S. Faustino–Massa Martana, PG	−0.3	22
131	Bagnarello–Tolfa, Roma	−5.5	46.5
132	Ficoncella–Civitavecchia, Roma	−4.1	55.5
133	Terme Taurine–Civitavecchia, Roma	−5.4	46
134	Terme di Stigliano–Bracciano, Roma	−1.3	50
135	Fosso del Marchese–S. Severa, Roma	−6.3	37
136	Acqua Acetosa–Cerveteri, Roma	−3.4	19
139	Vaschetta–Isola Farnese, Roma	−2.1	19
142	Acqua di Cretone–Palombara Sabina, Roma	−3.5	22
145	Acque Albule–Tivoli, Roma	−3.5	70
147	Passerano–Gallicano nel Lazio, Roma	−7.8	15
151	Sorgente Solfurea–Anticoli Corrado, Roma	−5.0	15
152	Sorgente Solfurea–Marano Equo, Roma	−1.4	19
153	Acqua Acetosa–Marino, Roma	−2.2	16
154	Le Frattocchie–Marino, Roma	+1.2	23
155	Località Solfarata–Pomezia, Roma	+1.8	31
156	Olimpia–Pomezia, Roma	−5.5	18
157	Ardea–Pomezia, Roma	−3.5	18
162	Acqua Puzza–Borgo Tufette, LT	−9.5	16
163	Crecigli–Pontinia, LT	−8.5	20
169	Terme Pompeiane–Ferentino, FR	−6.7	19
175	Lago di Plinio–Fontana Liri, FR	−8.7	16
185	Sorgente Solfurea–Terme Agrippa Pozzilli, CB	+0.6	17
189	Duratore–Suio Terme, LT	+0.5	42
191	S. Marco–Minturno, LT	−5.4	16
192	Acqua Solfurea–Sesto Campana, CB	+0.3	20
194	Sorgente della Rogna–Sessa Aurunca, CE	+1.0	25
197	Sinuessa I–Mondragone, CE	−2.1	52
198	Sinuessa II–Mondragone, CE	−0.8	30
200	Triflisco del Salvatore–Bellona, CE	−6.1	16
201	Gocciolon–Telese, BN	−1.8	21
205	Pisciarelli–Pozzuoli, NA	−1.4	90
206	Solfatara–Pozzuoli, NA	−1.8	65
207	Grotte dell'acqua–Pozzuoli, NA	−0.8	36
208	Sprudel–Agnano, NA	−3.1	28
209	Scassone–Pozzuoli, NA	−1.9	dry gas
210	Lacco Ameno–Ischia Island	−2.8	54
211	Lacco Ameno–Ischia Island	−4.6	35

*These values are averages for many CO_2 samples taken from different productive wells in the geothermal areas.

APPENDIX 2

Tabulated below are the carbon-isotopic compositions of travertine samples from "fossil" deposits in central and southern Italy, and $\delta^{13}C$ values calculated from "associated" CO_2. The travertine samples were all analyzed for ^{18}O and ^{13}C by treating the solid with 100% phosphoric acid and analyzing the liberated CO_2. Many samples contained organic matter: these samples were heated to 450°C in a stream of helium before the CO_2 was liberated by phosphoric acid. Only the minimum $\delta^{13}C$ values of the travertine samples were used for calculation of $\delta^{13}C$ of the CO_2 for each area (see text).

No.	Location	Travertine samples $\delta^{13}C$‰	(PDB)	Analyzed samples	$\delta^{13}C$‰ (PDB) of associated CO_2 calculated by $\delta^{13}C_{CO_2} = 1.2\,\delta^{13}C_T - 10.45$
11	Torricchi–Vicarello, FI	+2.5	+6.6	10	−7.45
17	Santa Lucia, SI	−3.5	−1.4	3	−14.65
18	Romituzzo, SI	−3.8	−0.2	3	−15.01
19	Bagnoli in Piano, SI	−1.4	+2.2	4	−12.13
38	Galleraie, PI	+2.1	+4.3	4	−7.93
40	Palazzetto–Chiusdino, SI	−3.4	+1.3	5	−14.53
41	Frosini, SI	−2.0	+0.3	11	−12.85
42	Cave Villanova–Frosini, SI	−2.4	+1.1	11	−13.33
47	Serre Rapolano, SI	−0.8	+3.4	9	−11.41
48	Asciano, SI	+2.9	+3.3	3	−6.97
49	Cave Villa Oliviera, SI	+2.0	+5.5	6	−8.05
51	Campo Agnelli–M. Marittima, GR	−1.0	+1.6	11	−11.65
52	Monte Arsenti–M. Marittima, GR	−1.3	+2.9	11	−12.01
53	Fiume Pecora–M. Marittima, GR	−4.5	+0.3	9	−15.85
58	Bagno Vignoni, SI	+3.4	+3.9	4	−6.37
59	Castelnuovo dell'Abate, GR	+1.0	+4.2	7	−9.25
60	St. Monte Amiata, GR	+2.1	+5.7	12	−7.93
61	Castiglione d'Orcia, SI	+5.0	+6.7	6	−4.45
63	Sarteano–Cetona, SI	−2.5	+1.6	8	−13.45
64	Strozzacapponi, PG	−2.2	+2.0	5	−13.09
65	S. Andrea di Fratte, PG	−3.4	+1.0	4	−14.53
66	Castel del Piano, PG	−7.5	−1.5	8	−19.45
67	Stravignano I–Nocera Umbra, PG	−9.1	−4.6	8	−21.37
68	Stravignano II–Nocera Umbra, PG	−9.4	−8.7	5	−21.73
69	Terme Roselle, GR	−2.3	−0.9	8	−13.21
75	Samprugnano, GR	+6.2	+7.9	4	−3.01
76	Poggio Castellina, GR	+4.0	+7.6	9	−5.65
77	Terme Saturnia, GR	+4.1	+5.0	4	−5.53
78	Poggio Banditaccia, GR	+1.0	+3.3	9	−9.25
79	Fosso Camerone, GR	−1.2	0	8	−11.89
80	Pitigliano, GR	+3.5	+5.4	5	−6.25
81	S. Casciano dei Bagni	+0.1	+1.8	8	−10.33
87	Orvieto I, TR	+7.2	+8.9	5	−1.81
88	Orvieto II, TR	+11.2	+12.2	6	+2.99
89	S. Egidio–Orvieto, TR	+4.0	+8.3	5	−5.65
92	Musignano, VT	+4.6	+6.5	7	−4.93
93	Canino, VT	+1.1	—	1	−9.13
101	Grotta S. Stefano, VT	+5.5	+9.5	7	−3.85
102	Attigliano, TR	+3.4	+7.3	9	−6.37
103	Graffignano, VT	+9.0	+10.4	5	+0.35
104	Vaiano–Castiglione in Teverina, VT	+4.2	+7.0	8	−5.41
105	Titignano–Orvieto, TR	−0.6	+5.4	5	−11.17
106	Civitella dei Pazzi-Boschi, TR	+1.0	+3.1	5	−9.25
107	Montecchio, TR	−3.0	+2.0	5	−14.05
108	Lugnano in Teverina, TR	+0.8	—	1	−9.49
109	Parchiano–Aurelia, TR	+4.1	+5.4	5	−5.53
110	Aurelia, TR	+6.2	+7.5	5	−3.01
111	Orte–Penna in Teverina, VT	+4.6	+9.0	10	−4.93
113	Vasanello, VT	+8.1	+10.1	5	−0.73
114	Orte, VT	+5.1	—	1	−4.33
116	Bagnolo–Amatrice, RI	+4.6	+7.9	10	−4.93
120	S. Terenziano–M. Martana, PG	+4.0	+5.7	5	−5.65
121	Le Torri–Gualdo Cattaneo, PG	−1.3	+4.6	4	−12.01
122	Massa Martana III, PG	−7.7	−0.3	9	−19.69
123	Massa Martana II, PG	−6.8	−0.5	8	−18.61
124	Massa Martana I, PG	−7.3	−4.7	5	−19.21
126	Acquasparta, TR	−4.8	−2.3	6	−16.21
127	Montecastrilli, TR	−5.6	+1.5	6	−17.17
128	Papigno, TR	−1.9	−1.0	5	−12.73
129	Marmore, TR	−0.8	+0.5	4	−11.41
130	Triponzo–Cerreto di Spoleto, PG	−5.7	−4.2	6	−17.29
137	Palidoro, Roma	0	+2.5	6	−10.45
138	Castellombardo, Roma	+2.0	+6.1	1	−8.05
140	Malagrotta, Roma	+2.7	+5.5	5	−7.21

APPENDIX 2 *continued*

No.	Location	Travertine samples $\delta^{13}C‰$	(PDB)	Analyzed samples	$\delta^{13}C‰$ (PDB) of associated CO_2 calculated by $\delta^{13}C_{CO_2} - 1.2\delta^{13}C_T - 10.45$
141	Fiano Romano, Roma	+2.0	+3.4	6	−8.05
143	Giudonia–Monticelio, Roma	+7.0	+10.1	6	−2.05
144	Bagni di Tivoli, Roma	+5.7	+9.6	5	−3.61
146	Tivoli, Roma	+5.8	+6.1	6	−3.49
148	Gallicano, Roma	+1.8	+3.3	6	−8.29
149	Palombara Sabina I, Roma	+0.6	+2.4	5	−9.73
150	Palombara Sabina II, Roma	+0.3	+2.8	5	−10.09
158	Cisterna di Latina, LT	+8.5	+9.3	5	−0.25
159	Ponte della Regina, LT	+2.0	+3.0	5	−8.05
160	Campo di Sermoneta, LT	+6.5	+8.0	5	−2.65
161	Borgo Carso, LT	+7.0	+8.8	6	−2.05
164	Gloria–Alatri, FR	+3.7	+7.1	7	−6.01
165	Abbadia della Gloria–Alatri, FR	+2.2	+3.1	6	−7.81
166	Masseria S. Maria–Alatri, FR	−0.4	+1.2	7	−10.93
167	Anagni, FR	+3.0	+5.0	5	−6.85
168	Casa delle Monache, FR	+1.7	+2.1	7	−8.41
170	Ferentino, FR	+2.0	+3.9	3	−8.05
171	Le Cinque Vie, FR	+5.1	+5.8	5	−4.33
172	Contrada Roana, FR	−0.1	+0.9	4	−10.57
173	Castelliri, FR	+1.4	+2.3	6	−8.77
174	Isola Liri, FR	−1.7	−1.0	4	−12.49
176	Forcella-Sora, FR	−0.8	+1.2	4	−11.41
177	Sora, FR	+1.5	+2.2	5	−8.65
178	Fontechiari, FR	+7.2	+8.7	4	−1.81
179	Casalvieri–Cassino, FR	+1.0	+1.5	5	−9.25
180	Aquino, FR	−2.0	−0.1	7	−12.85
181	Ponte di Castelluccio–Cassino, FR	−7.6	−4.4	6	−19.57
182	Masseria Romito–Cassino, FR	−2.1	+1.0	4	−12.97
183	Cassino, FR	−5.0	−4.0	5	−16.45
184	Panaccioni–Cassino, FR	−4.8	−3.3	5	−16.21
186	Pozzilli, CB	+11.8	+12.5	6	+3.71
187	Sesto Campano, CB	−2.4	−0.8	6	−13.33
188	S. Egidio di Suio Terme, LT	+9.7	+11.0	7	+1.19
190	Minturno, LT	+3.1	+8.7	8	−6.73
193	Pratella, CE	+4.2	+7.9	11	−5.53
195	Masseria Montanari–Riardo, CE	+10.1	+13.1	10	+1.67
196	Mondragone, CE	+9.9	+11.5	10	+1.43
202	Telese, BN	+4.0	+8.9	8	−5.65
203	Bellona, CE	+2.4	+3.4	10	−7.57
204	S. Valentino Torio, SA	+1.8	+2.6	6	−8.29
212	Filetta, SA	+3.6	+6.0	7	−6.13
213	Faiano, SA	+1.5	+7.7	10	−8.65
214	Contursi, SA	+9.6	+11.2	7	+1.07

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